THE SOLAR ATLAS OF
EGYPT

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THE GEO-CRADLE PROJECT RECEIVED FUNDING FROM THE EUROPEAN UNION’S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 690133.

GEO-CRADLE

THE GEO-CRADLE TEAM

LIST OF INVOLVED INSTITUTIONS

CHAPMAN UNIVERSITY, USA

FACULTY OF SCIENCE,
ALEXANDRIA UNIVERSITY

WORLD RADIATION CENTER,
DAVOS, SWITZERLAND

NATIONAL OBSERVATORY
OF ATHENS, GREECE

CEDARE

CENTRE FOR ENVIRONMENT AND DEVELOPMENT
FOR THE ARAB REGION AND EUROPE

MINISTRY OF STATE FOR IMMIGRATION
AND EGYPTIAN EXPATRIATES' AFFAIRS

MINISTRY OF ELECTRICITY
AND RENEWABLE ENERGY

MINISTRY OF ELECTRICITY
AND RENEWABLE ENERGY

NEW AND RENEWABLE
ENERGY AUTHORITY

IN THE SOLAR ATLAS OF EGYPT

PANAGIOTIS KOSMOPOULOS

ATL

Panagiotis Kosmopoulos has a BSc in Geology and Geo-Environment, a MSc in Environmental Physics (both from the National and Kapodistrian University of Athens), and today, is a PhD candidate in Physics at the Aristotle University of Thessaloniki. His PhD thesis is in the field of Solar Energy forecasting and applications. He has more than 80 publications and 800 third-party citations in international journals and conferences (h-index 16), and is reviewer of 10 highly ranked scientific journals. He is a research fellow at the National Observatory of Athens with professional experience in national and regional competitive project (Horizon's 2020 Geo-Cradle, FP7's ACI-UV, NSRF's Kripis-Thespia, Siemens'sAristotelis). His research interests include environmental physics with emphasis on solar energy and applications, radiative transfer modeling, satellite and ground-based observations, aerosol and cloud physics, and physical climatology. Finally, he deals with the exploitation of EO, CAMS and modeled data for a variety of solar energy applications (http://solea.gr/).

AUTH

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Hesham El-Askary received his Ph.D. in Computational Sciences and Informatics from George Mason University along with his two MS degrees in Computational sciences and Earth Systems Sciences. His research interests include dust storms monitoring and detection using satellite observations, marine environment, coral reefs, solar energy as well as studying other extreme events. He is particularly interested in events that have a global impact (going from global to local) and mixing scenarios between natural and anthropogen-

AS

STELIOS KAZADZIS

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SteliosKazadzis has studied (BSc in Physics, MSc in Environmental Physics and PhD in Atmospheric Physics) at the Physics Department, Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki (LAP-AUTH), Greece. In 2009 he received the position of the Associate Researcher at the Institute of Environmental Research and Sustainable Development of the National Observatory of Athens, and in 2014 he has promoted at the position of the Senior Researcher at the same Institute (NOA). Today, is a Senior Researcher, Leader of the World aerosol Optical depth Research and Calibration Center at the PhysicalischMeteorologischesObservatorium Davos, World Radiation Center. He is member of the Scientific Advisory Group of WMO for Aerosols. He has 76 accepted publications in peer reviewed scientific journals and more than 110 accepted publications in conference proceedings. Since 2000, he has participated (under contract) in 25 European funded and 7 national (Greek) projects. He is a member of the editorial board of the Atmospheric Chemistry and Physics journal and has been an active reviewer in more than 15 scientific Journals.

ORS

HESHAM EL-ASKARY

ic generated aerosols.He has published over a 100 refereed research publications, conferences full paper and book chapters in these research areas. Dr. El-Askary's research has been supported by NSF, NASA, USDA and EU. He is a member of the IEEE, AGU, EGU, COSPAR, and Phi Beta Delta Honor Society.He is the 2015 recipient of the Chapman University's elite Senior Wang-Fradkin Professorship award.He is also the 2006 recipient of the Saudi Arabia Prize for best published article in environmental management hosted by Arab Administrative Development Organization(ARADO), affiliated with the League of Arab States. He currently serves as the program director for computational and data sciences (CADS) at Chapman University, USA. He has been an active reviewer in many scientific Journals and funding agencies.

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ACKNOWLEDGEMENTS

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The authors would like to extend their thanks and appreciation to the following individuals who provided a lot of help and support at different stages and in different capacities during the accomplishment of this Solar Atlas.

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{PREF

This document was written within the framework of the GEO-CRADLE (Coordinating and integRating state-of-the-art Earth Observation Activities in the regions of North Africa, Middle East, and Balkans and Developing Links with GEO-related initiatives towards GEOSS) Coordination and Support Action funded under the H2020`s Framework Program-Climate action, environment, resource, efficiency and raw materials. The activity is to develop comprehensive and sustained global environmental observation and information systems project (http://geocradle.eu/) under the grant agreement No 690133 (HORIZON 2020). The contracting authority is the European Commission, Executive Agency for Small and Medium-sized Enterprises (EASME) H2020 Environment & Resources.

ACE

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REGIONAL COORDINATOR FOR
NORTH AFRICA AND MIDDLE EAST

Prof. Hesham El-Askary

The objective of this official document is the application of the EUMETSAT (European Organization for the Exploitation of Meteorological Satellites) based Solar Radiation Atlas for the Egyptian Ministry of Electricity and Renewable Energy.

NADIA MAKRAM EBEID

As always, it is a special pleasure and privilege to partner with the highly respected Ministry of Electricity and Renewable Energy and the Renewable Energy Authority of Egypt, as well as other prominent institutions in advancing the country's pioneering solar energy programme. This is part of galvanizing action for the implementation of Egypt's 2030 vision, which has synergies with the Global 2030 Agenda for Sustainable Development, its goals and targets; the "World's Global Charter for People and Planet".

We are proud that this deserving sustainable path is being charted through the EU-supported GEO-CRADLE Project, under the Horizon 2020 Framework, in which Cedare is a member. We greatly value our deeply-rooted cooperation with the EU, a towering European institution. The widely-acclaimed Analytical Solar Energy Atlas of Egypt is a notable product of this cooperation and the cutting-edge professional efforts of leading experts, particularly the very able Dr. Hesham El–Askary, and institutions. Thankfully, Egypt is at the heart of the global solar belt and is blessed with abundant solar energy! Equally important, Egypt is also blessed with world-class leaders, scientists and forward-thinking disruptive innovators who are staunchly committed to reaping the massive benefits of its rapidly-evolving solar energy initiative, as part of its renewable and energy-efficiency programme.

The Atlas is a key catalyst to support the development of progressive policies, new profitable investments, markets, "green" jobs and technological innovations. Happily, it will also contribute to the preservation of nature's wonders and gifts, Egypt's precious ecological capital and life support system.

When all is said and done, these tireless efforts can advance a climate-resilient, prosperous and sustainable future for Egypt, the land of the Nile, as old as time; an inspiring story that continues to be written with renewed passion and commitment. And the continuity is there past, present and future.

Nadia Makram Ebeid

Nadia MakramEbeid
Executive Director
Center for Environment and Development
for the Arab Region and Europe (CEDARE)
(Former Minister of the Environment)

THE ATLAS IS A KEY CATALYST TO SUPPORT THE DEVELOPMENT OF PROGRESSIVE POLICIES, NEW PROFITABLE INVESTMENTS, MARKETS, “GREEN” JOBS AND TECHNOLOGICAL INNOVATIONS.

WE FACILITATE
MEETINGS WITH
GOVERNMENT OFFICIALS,
ORGANIZE CONFERENCES
AND FUNDRAISERS TO
INCREASE THEIR PRESENCE
AND CONNECTION
WITH EGYPT

LAMIA MEKHEMAR

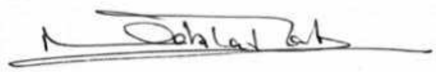
A proud nation is a nation inspired by the strive for excellence of its people. Egypt has always been proud of its sons and daughters who, despite living far away from their homeland, have always been strongly tied to their origins, cherishing their culture and longing to serve their country. It is the role of the Egyptian consulates abroad not only to keep this bond alive, but more so to encourage their Egyptians living within their jurisdictions to interact with their mother land and to participate in bringing about the wellbeing of their brothers and sisters back home. Accordingly, we constantly communicate with our community in the Western states. We share with them ways and means through which they can be a valuable asset helping in the advancement of our country. In fulfilling this endeavor, we develop strategies to utilize their amazing diverse skill base. We facilitate meetings with government officials, organize conferences and fundraisers to increase their presence and connection with Egypt. A perfect example of an Egyptian who wanted to give back to his country is Prof. Hesham El-Askary of Chapman University. Through his work as the Regional Coordinator for North Africa and Gulf region on the Geo-CRADLE project funded under the H2020's Framework, he with his colleagues from the National Observatory of Athens and World Radiation Center, Davos, Switzerland, were able to provide Egypt with its First Solar Atlas, a much needed deliverable to address the increasing demand for energy through the use of renewable sources, thus; achieving Egypt's goals in economic growth, while preserving the environment. Dr. El-Askary's work with the Geo-CRADLE team is a witness on the effectiveness of partnership between the Consulate in LA, the Egyptian Scholars and the Government in catering to the prosperity of our beloved Egypt.

Lamia Mekhemar

Consul General of Egypt in Los Angeles

NABILA MAKRAM ABDEL SHAHID

In our goal to contribute to Egypt's development, the Ministry of Immigration and Egyptian Expatriates Affairs acts as a bridge and link between Egyptians abroad and their country. We are committed to reinforce communication with Egyptian emigrants to strengthen their ties to their homeland as well as utilize their experiences and competencies in various fields and specialties. For that reason the Ministry organized and hosted the first National Conference of Scholars and Egyptian Experts Abroad "Egypt Can 2016" that was held in December 2016 in Hurghada, Egypt, where Dr. Hesham El-Askary of Chapman University (USA); presented the dynamical Solar Atlas of Egypt. The Solar Atlas is a result of Dr. El-Askary's efforts with his colleagues from the National Observatory of Athens and World Radiation Center, Davos, Switzerland through the GEO-CRADLE project funded under the H2020's Framework. The Solar Atlas is one of the most important and early results of "Egypt Can 2016" and has been commended and currently being utilized by the Ministry of Electricity and Renewable Energy (MOEE). This deliverable is a continuation of efforts that started by a meeting arranged by H.E. Ambassador Lamia Mekhemar, Consul General of Egypt in Los Angeles with Dr. El-Askary and being in direct and constant communication with him since then. I would also like to encourage all Egyptians abroad to follow this modelof giving back to their motherland Egypt. As they always say, it is the three Ts, Treasure, Talent and Time. Give back what you can, when you can.



Nabila Makram Abdel Shahid

Minister of Immigration and Egyptian Expatriate Affairs

THE SOLAR ATLAS
IS ONE OF THE MOST
IMPORTANT & EARLY
RESULTS OF “EGYPT CAN 2016”
& HAS BEEN COMMENDED
& CURRENTLY BEING UTILIZED
BY THE MINISTERY OF
ELECTRICITY & RENEWABLE
ENERGY(MOEE)

THE IDEA
OF DEVELOPING THE
ANALYTICAL SOLAR ENERGY
ATLAS OF EGYPT IS A MUCH
NEEDED PRODUCT AND OF
GREAT AND ABSOLUTE
IMPORTANCE.

MOHAMED SAID EL-ASSAR

The Ministry of Military Production gives priority for military products while working on other projects that may result in surplus capacity in production which contributes to these projects for the interest of the Egyptian state. Military Production has distinctive potentials in solar power production as we witness around twenty four projects of electrical power plant production through solar power all over Egypt's governorates. As such, the idea of developing the analytical Solar Energy Atlas of Egypt is a much needed product and of great and absolute importance. It will help in the efficient solar energy exploitation to support the Egyptian energy authorities to better plan solar energy demands. The Ministry of Military Production will be willing to adopt this technology while being engaged in solar-related projects in Egypt.

The availability of such analytical information will help establish a high-return on possible investment projects that will make use of Egypt Silica Sand in the manufacturing of photovoltaic panels that are used in electricity generation from solar power. Therefore, the Ministry of Military Production believes that this developed Solar Atlas is an excellent addition, complementing the Government's efforts in finding other venues for electricity production.

We commend Prof. El-Askary's work with the GEO-CRADLE team on their efforts and direct collaboration with the renewable authorities, to deliver the Solar Atlas that will support better schemes of energy production and investments.

Mohamed Said El-Assar

Minister of State for Military Production

MOHAMED SHAKER EL MARKABI

In the light of the efforts exerted by the Government of the Arab Republic of Egypt to achieve the desired economic growth while preserving the environment, the government tries to address the demand for Energy efficiency through the use of renewable energy sources. We find that the idea of the Solar Energy Nowcasting SystEm (SENSE) pilot in order to produce (i) the analytical solar energy Atlas of Egypt mainly for the efficient solar energy exploitation and (ii) the nowcasting of the solar energy potential in real time in order to support the Egyptian energy authorities to better plan solar energy demands, is of great and absolute importance. The Ministry of Electricity and Renewable Energy (MOEE) together with the New and Renewable Energy Authority of Egypt (NREA) considers this developed Solar Atlas as an excellent addition, complementing the Government's efforts in finding other venues of electricity production. Moreover, the nowcasting product running on the official ministry website, as well as on NREA website adds an expediting element to realize efficient operational solar -based projects. This project straddles the intersection of the Earth System Science and Computational Science disciplines, demanding high-resolution numerical model data, sensitive remote sensing observational data, data mining and machine learning techniques. It is also a clear example of successfully building a value chain through a partnership between innovation and capacity building provider, Geo-CRADLE team, working with the ministry and associated renewable authority, to deliver the Solar Atlas and the dynamical output, hopefully to meet the mandate of the investors and fund providers resulting in better schemes of energy production and hence in customer satisfaction.

ElMak

Mohamed Shaker El-Markabi

Minister of Electricity and Renewable Energy

THE NOWCASTING PRODUCT RUNNING ON THE OFFICIAL MINISTRY WEBSITE AS WELL AS ON NREA WEBSITE ADDS AN EXPEDITING ELEMENT TO REALIZE EFFICIENT OPERATIONAL SOLAR BASED PROJECTS

CONT

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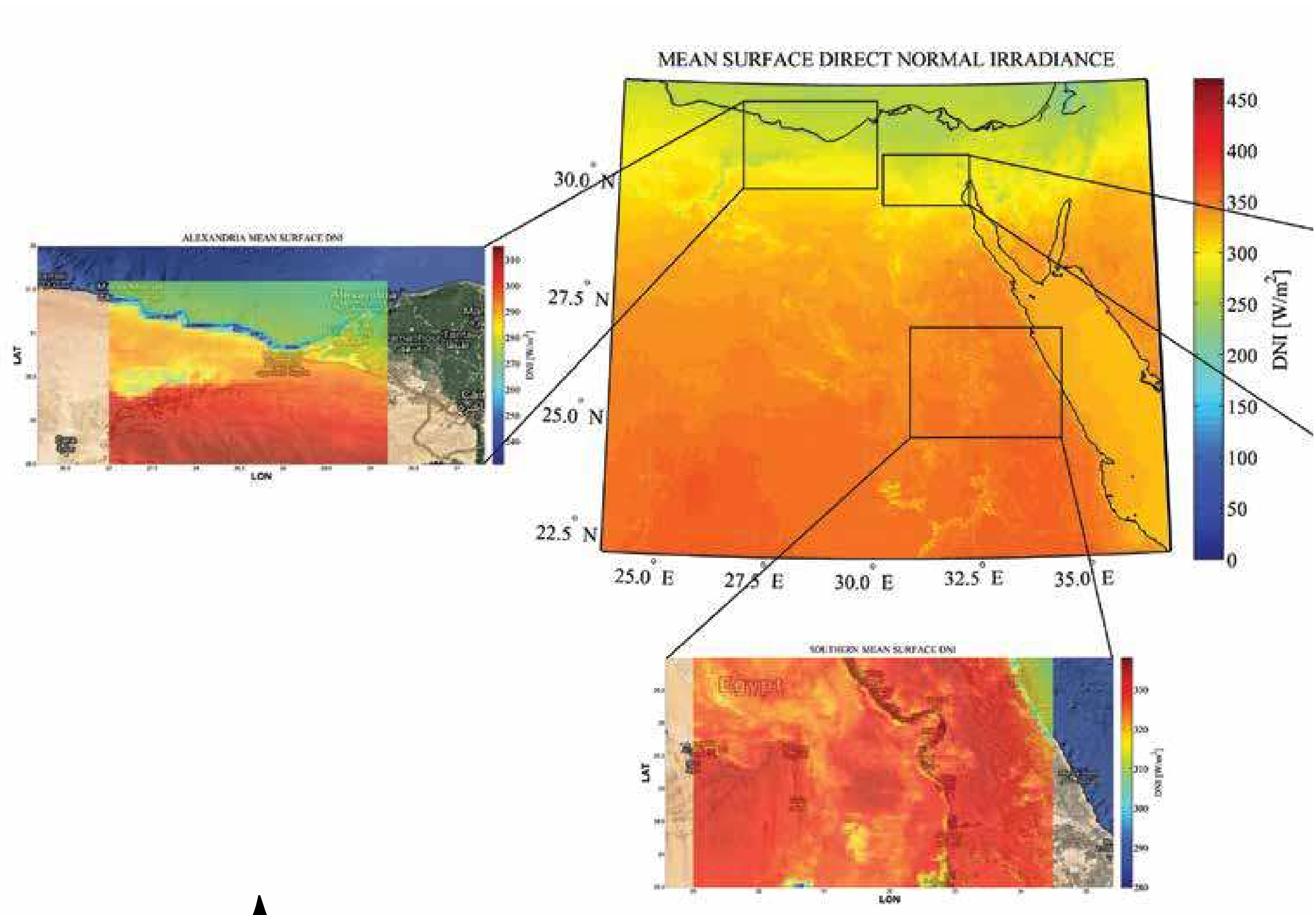
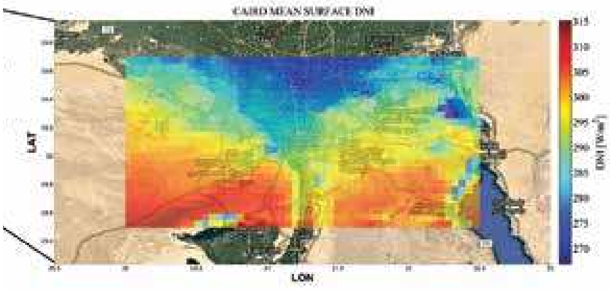
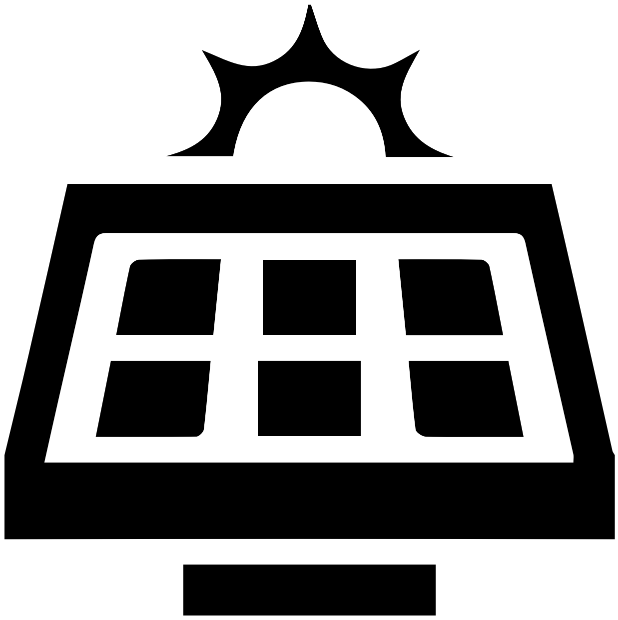


EXECUTIVE SUMMARY



Egypt is a country with high solar energy potential and its exploitation is critical for national sustainable development through efficient energy planning and a gradual independence from fossil fuels. Equitable access to energy is a basic requisite for economic development and an important condition to galvanize economic growth. Demographic trends in Egypt require informed long-term planning of the energy sector investments on the national level to expand existing electricity production capacities and meet growing demand. Egypt has one of the most favorable environments for the largest production of renewable energy in the world. As a result there has been demonstrated market traction for the region's solar power in a growing export market for clean energy. This Solar Atlas comes to meet these regional needs for optimum solar energy exploitation and for active and effective integration and mainstreaming of these technologies into the national sustainable development economies and strategies. The quantification of the clouds' and aerosols' impact on the solar energy potential guarantees the reliability of the Atlas.

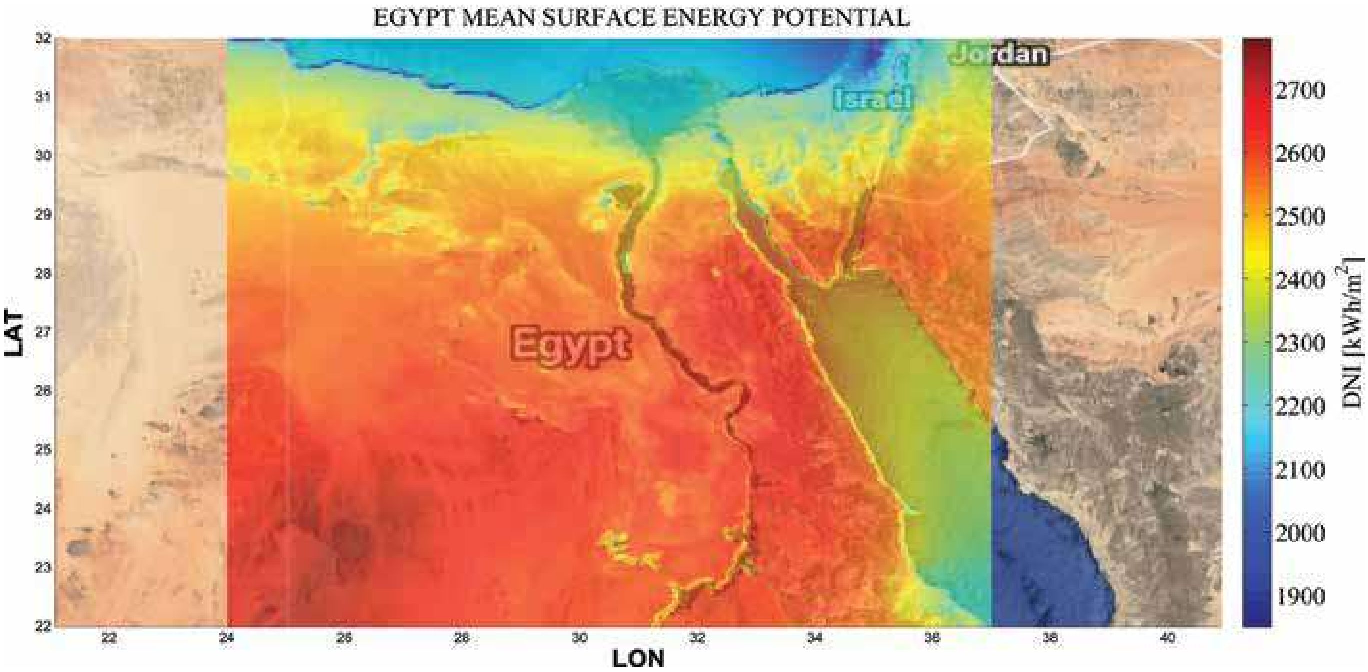
Several actions point to the fact that a more climate-resilient economy and society must be built in Egypt, such as measures aimed at reducing fuel consumption for energy production, emphasis on energy efficiency and conservation as well as on power generation from renewable sources such as the Sun. Egypt is one of the



few worldwide countries endowed with potential for electricity production from renewable sources because of its climate and with short-term objectives an increase in the production from renewable energy sources to at least 50% of the total national energy production may be achieved. To manage the electricity grid with high amount of solar energy will require high-quality information on everyaspect of solar power generation, and in particular, solar radiation and energy atlas. Solar yield climatology is still in an early state in terms of accuracy and coverage. With this Atlas based on EUMETSAT data, the climatology of the solar resources and its application for management of solar-based electricity power plants and grid integration strategies are dealt with.

Solar energy is the most abundant renewable resource and therefore much of the focus on sustainable energy is targeting the optimum solar energy. By 2050, the MENA Energy Policy Plan aims to limit climate change by capping the global temperature rise to no more than 2°C. For this reason, there is a possibility for a reduction of Green House Gas (GHG) emissions in Egypt by 80 - 95%, hence establishing a goal of 50% of primary energy from renewable origin by 2020. In order to achieve this goal, the MENA countries have developed specific technology-roadmaps that will lead to the integration of low carbon energy technologies, and in particular the deployment of Concentrated Solar Power (CSP) plants and Concentrated Photovoltaic (CPV) installations in the energy economy.

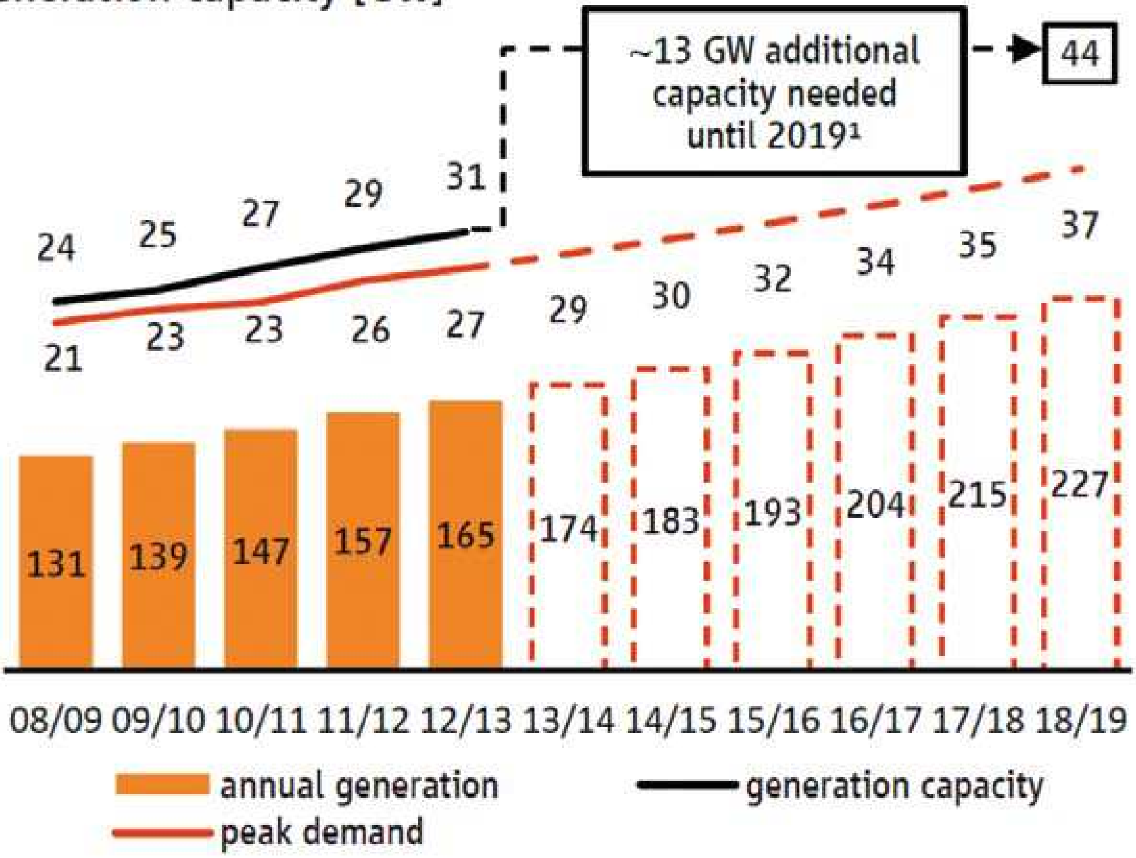
Mean solar energy potential for CSP in Egypt



The mean monthly solar energy maps are based on a 15-year climatology of the Direct Normal and Global Horizontal Irradiances (DNI and GHI respectively) in W/m2. The climatological radiation data have been downloaded from the EUMETSAT's (http://www.eumetsat.int/website/home/index.html) Satellite Application Facility on Climate Monitoring (http://www.cmsaf.eu/EN/Home/home_node.html) Surface Solar Radiation Data Set - Heliosat (SARAH) which is a satellite-based climatology of the solar surface irradiance and the surface direct normalized irradiance, derived from satellite observations of the MVIRI and SEVIRI instruments onboard the geostationary Meteosat satellites. The data cover the region ±65° longitude and ±65° latitude. The products are available with a spatial resolution of 0.05° x 0.05°. The solar atlas maps shown here were produced for Egypt and they cover the mean monthly DNI and GHI from January of 1999 to December of 2013, as well as the climatological monthly means and the solar radiation atlas total means.

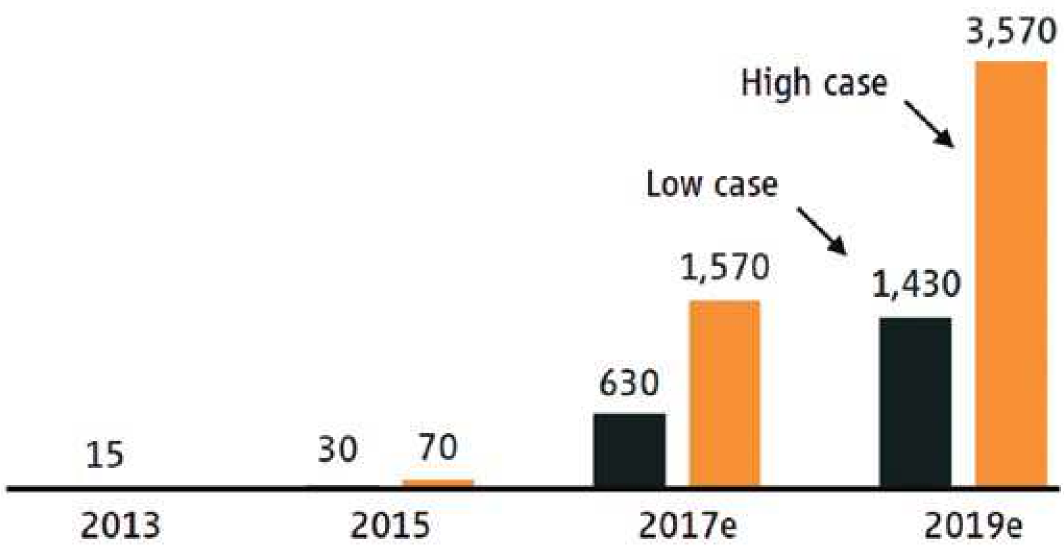
Electricity producing systems use different quantities of solar radiation: The Direct Normal Irradiance (DNI) is applicable in Solar Thermal Power Plants while the Global Horizontal Irradiance (GHI) in Photovoltaic systems. The energy source for any stand-alone photovoltaic (PV) system or Concentrated Solar Power (CSP) plant is the solar insolation available at the location of the installation.

Annual power generation [TWh], peak demand [GW] and generation capacity [GW]

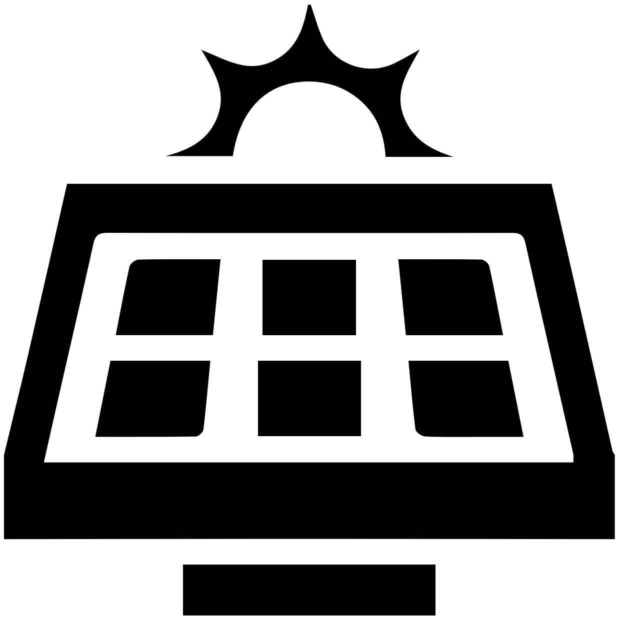


Sources: EEHC, Apricum research

PV market forecast Egypt (cumulative installations) [MW]



Source: Apricum market model Q4/2015



The performance of such systems is directly affected by the amount of insolation available to the system. PV systems enable direct conversion of global horizontal irradiance (GHI) into electricity through semi-conductor devices, while CSP systems generate solar power by using mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electricity is generated when the concentrated light is converted to heat, which drives a heat engine connected to an electrical power generator or powers a thermo-chemical reaction. Heat storage in molten salts allows some solar thermal plants to continue to generate after sunset and adds value to such systems when compared to photovoltaic panels. For the design, implementation and efficient operation of these systems, the weather-dependent production plays a key role and determines the balance between production and demand.

To enhance their efficient control and improve the accuracy of information on the availability of solar radiation, quality solar radiation data and validated forecasts are essential for planning and deployment purposes. Photovoltaic technology (PV) has prevailed as the preferred solution across the board, while the uptake of concentrated solar power (CSP) systems has been limited in geographical scope due to their higher insolation requirements. Nevertheless, CSP adoption is expected to continue to rise in areas which benefit from high levels of long-term yearly Direct Normal Irradiance (DNI), such as the Middle East and North Africa (MENA) region.

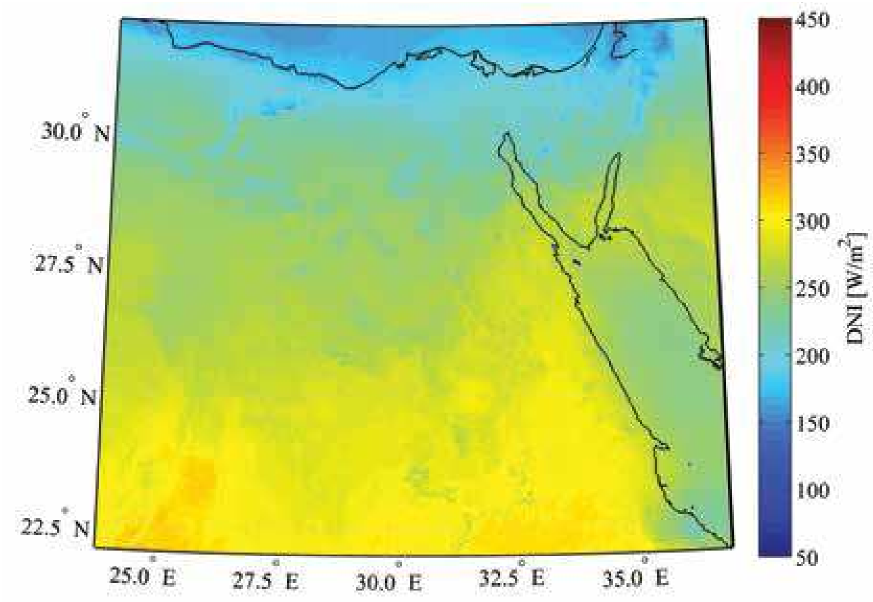
01

SOLAR ATLAS CLIMATOLOGY OF EGYPT (1999-2013)

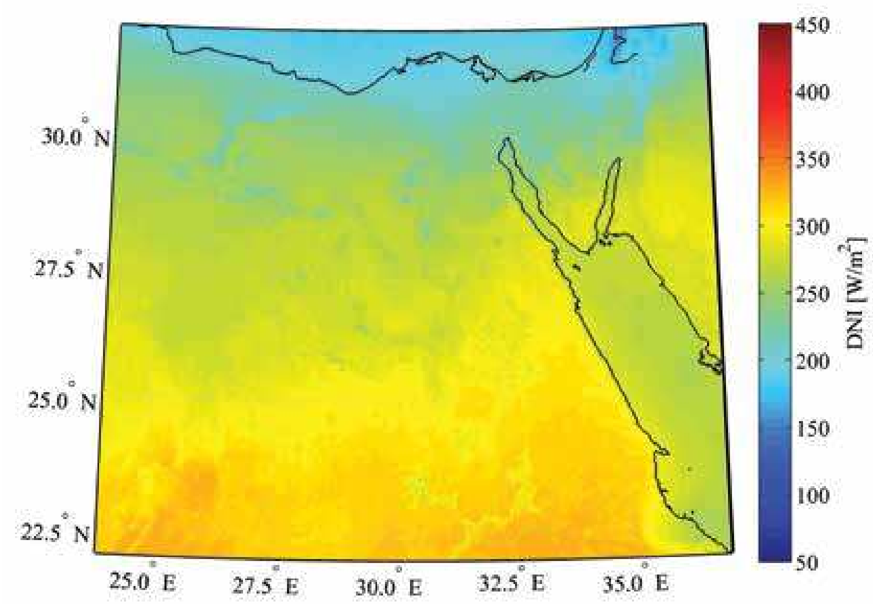
This Section presents an analysis of the solar power potential in Egypt with specific reference to solar power plants for electricity production. In the analysis provided, the mapping of solar radiation components is calculated from long-term monthly EUMETSAT data of DNI and GHI over a period of 15 years (Jan. 1999 to Dec. 2013). The climatological solar power results of this Section are in W/m2. These data enable the modeling of PV and CSP production for several sunshine-privileged locations where solar power plants exist, are under construction, or being planned by NREA. This analysis helps establish the solar potential for electricity generation in Egypt, and can support the design and decision-making process for solar energy systems in the country.

The 15-year mean monthly DNI and GHI reveals a clear seasonal variability with the maximum solar inputs in summer months and the minimum in winter months. In all months the distinct anthropogenic impact in large cities is highlighted mainly in northern Egypt, along the Nile and in the Nile Delta. In April, May and September the impact of dust is intense in the southern part of Egypt, while the cloud presence can be extended in October in addition to the spring season as a result of the synoptic climatological conditions. The impact of dust aerosols and clouds on DNI is much stronger than on GHI, an effect that is clearly reflected in the following solar atlas maps and in the mean monthly curves in the following Sections.

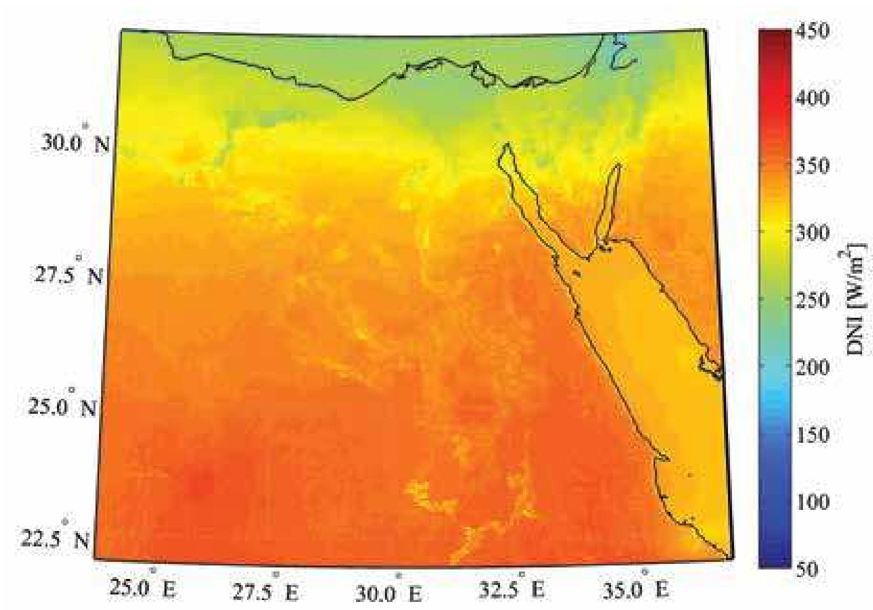
MEAN SURFACE DIRECT NORMAL IRRADIANCE



JANUARY



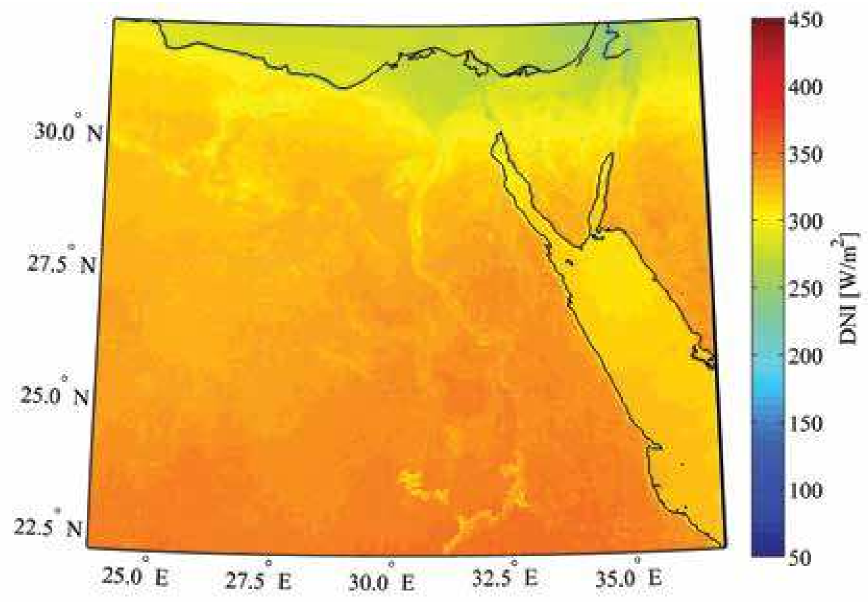
FEBRUARY



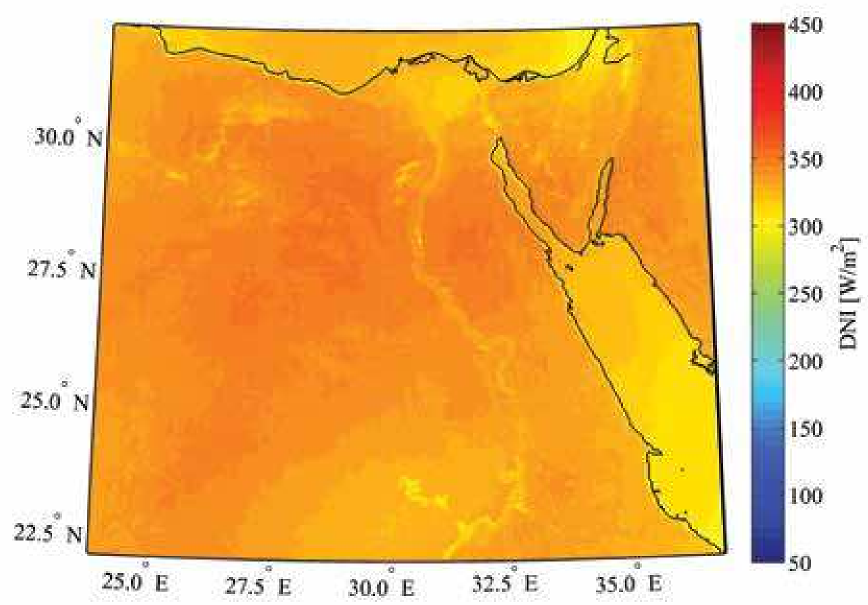
MARCH

MEAN SURFACE DIRECT NORMAL IRRADIANCE

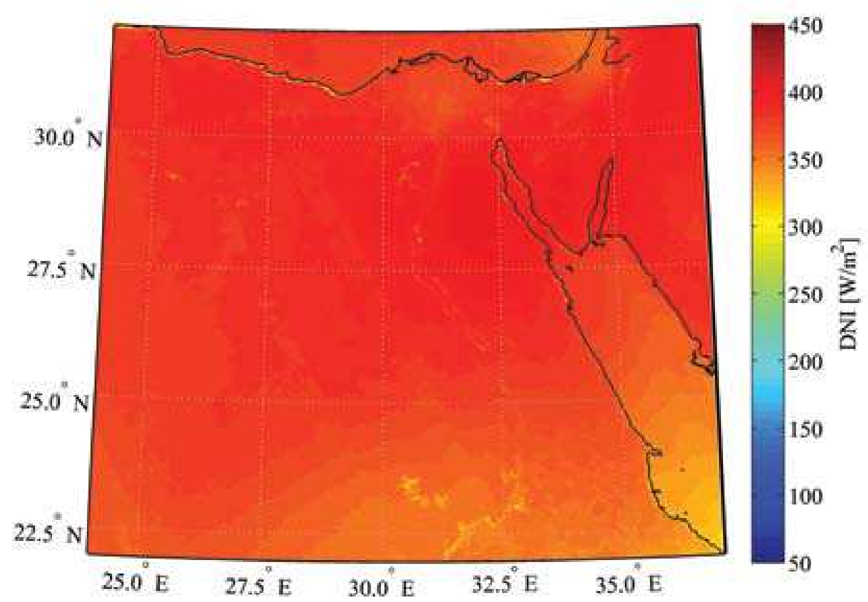
Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. Typically, the amount of irradiance annually received by a surface can be maximized by keeping it normal to the incoming radiation. This quantity is of particular interest to concentrating solar thermal installations and installations that track the position of the sun.



APRIL



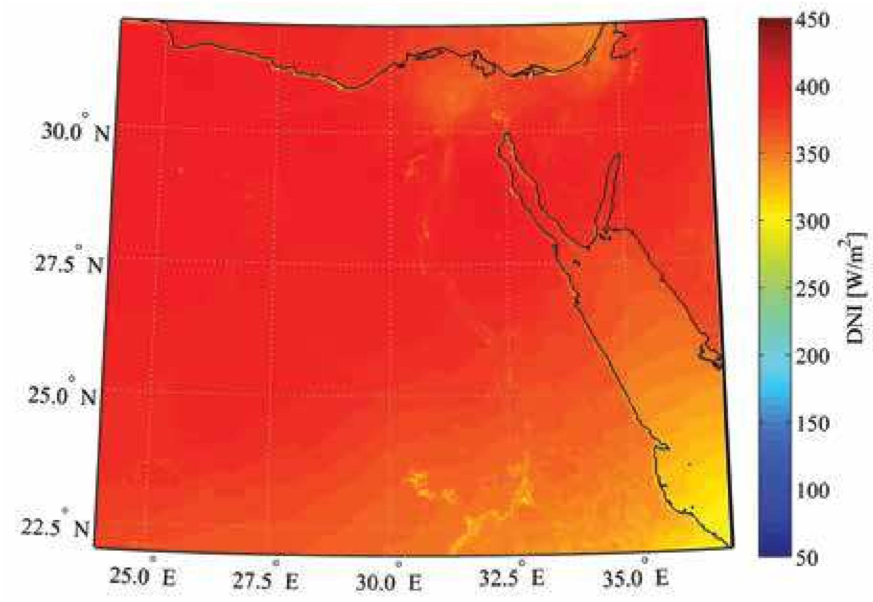
MAY



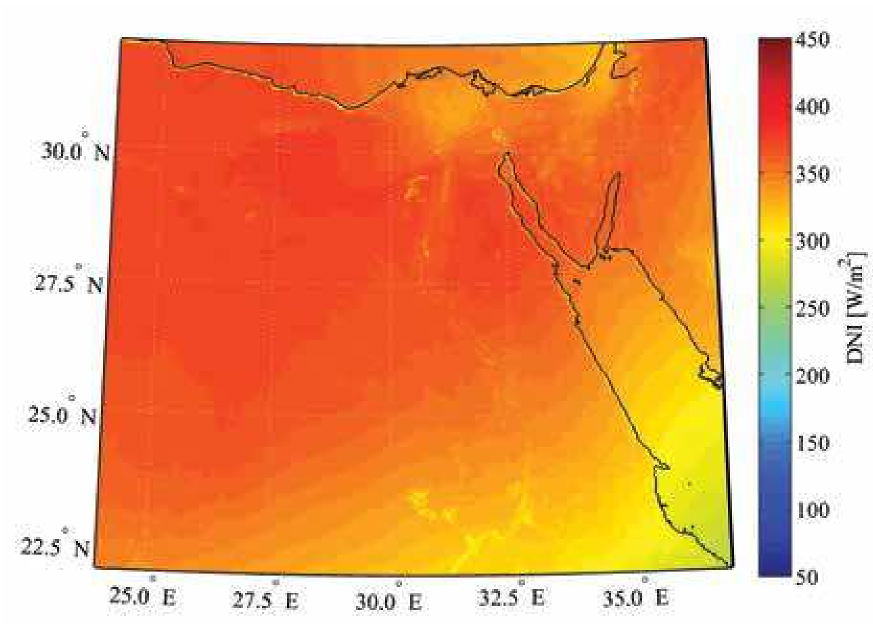
JUNE

MEAN SURFACE DIRECT NORMAL IRRADIANCE

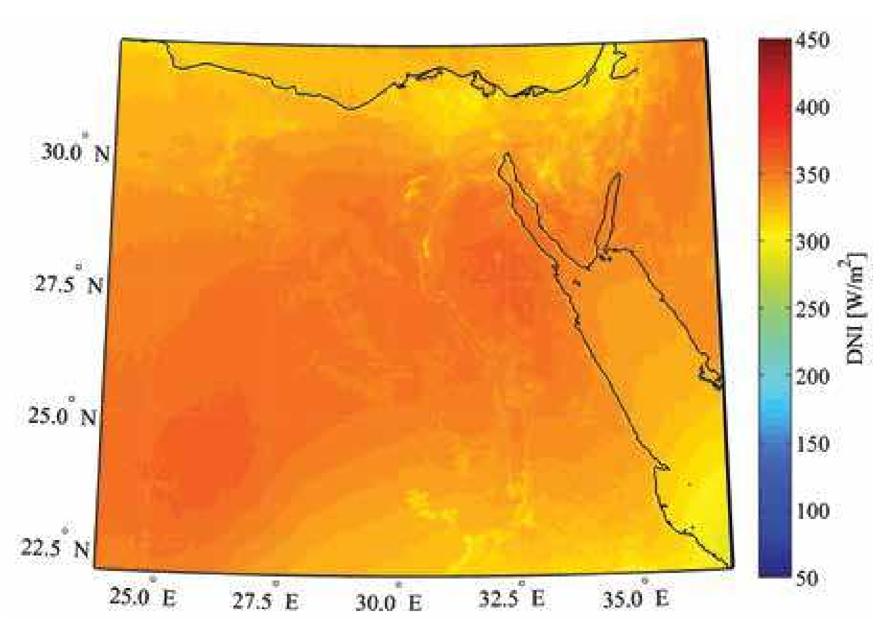
JULY



AUGUST

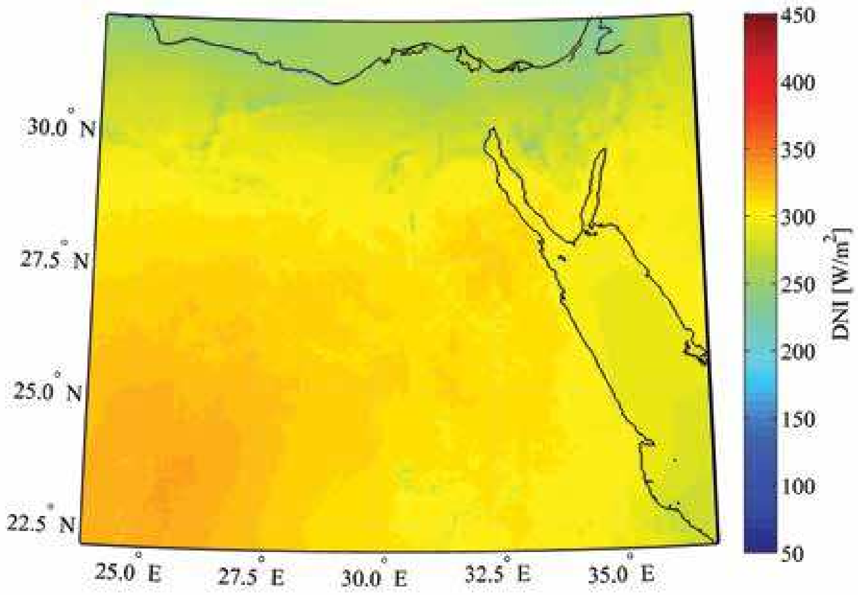


SEPTEMBER



MEAN SURFACE DIRECT NORMAL IRRADIANCE

OCTOBER



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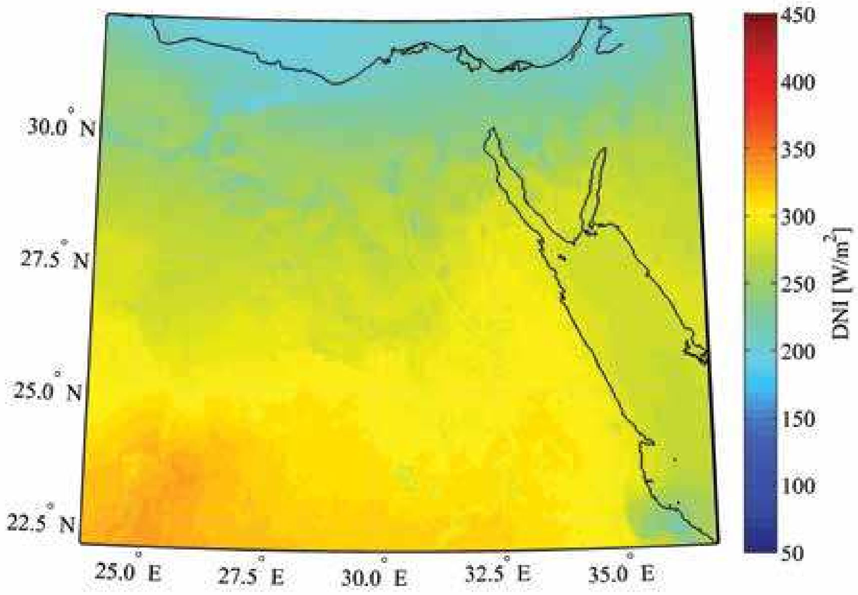
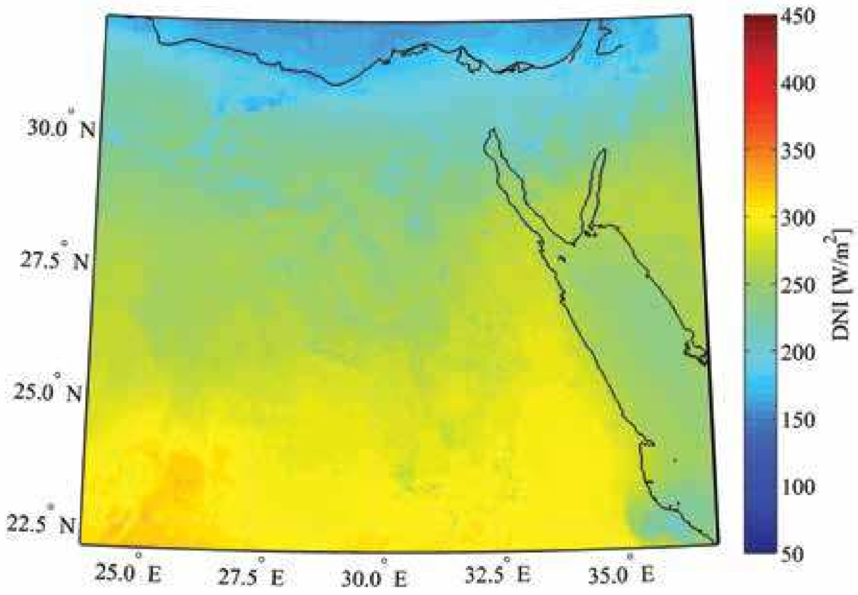
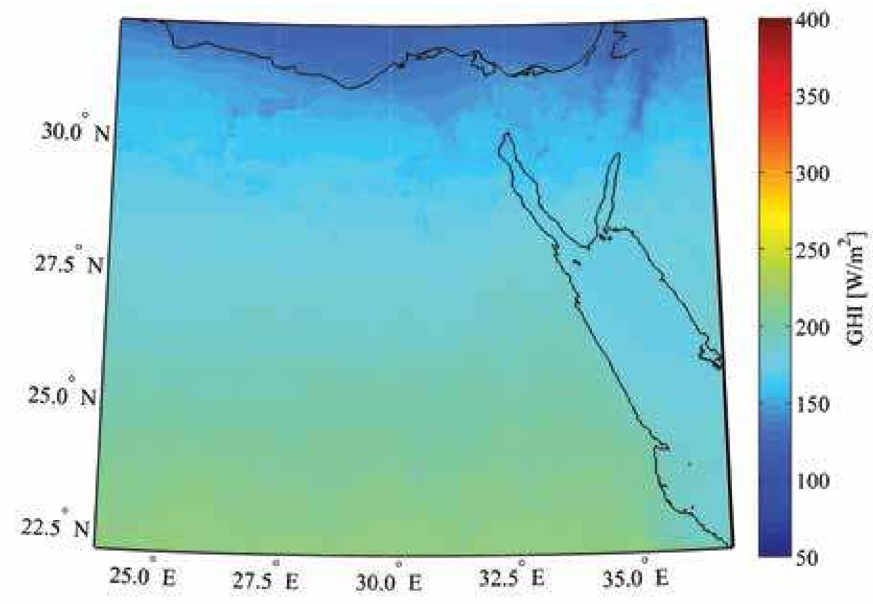


DECEMBER

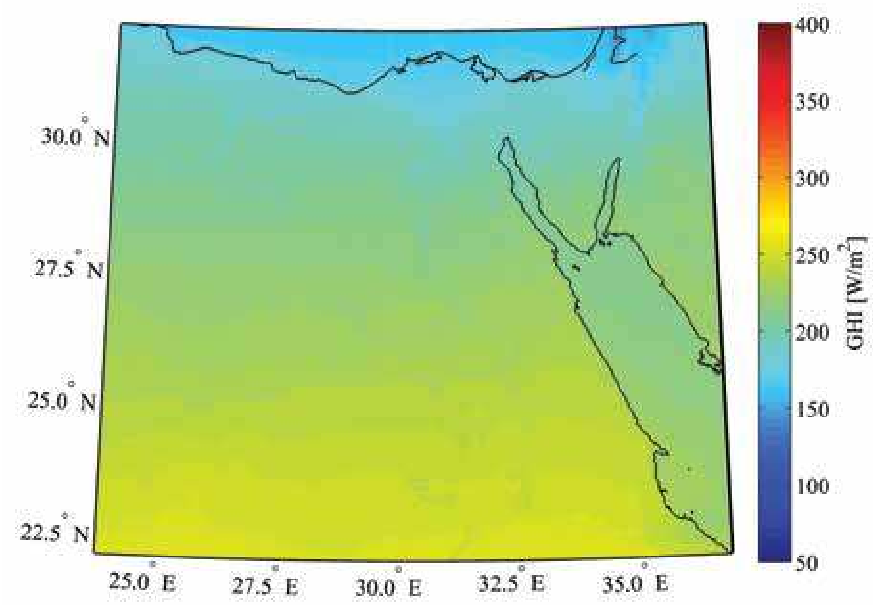


GLOBAL HORIZONTAL IRRADIANCE (GHI A&B)

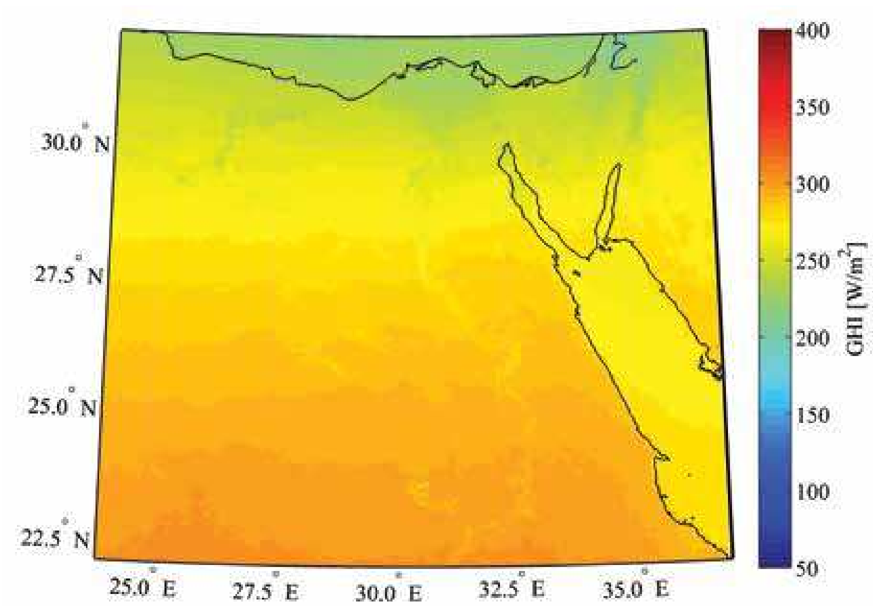
MEAN SURFACE DIRECT NORMAL IRRADIANCE



JANUARY



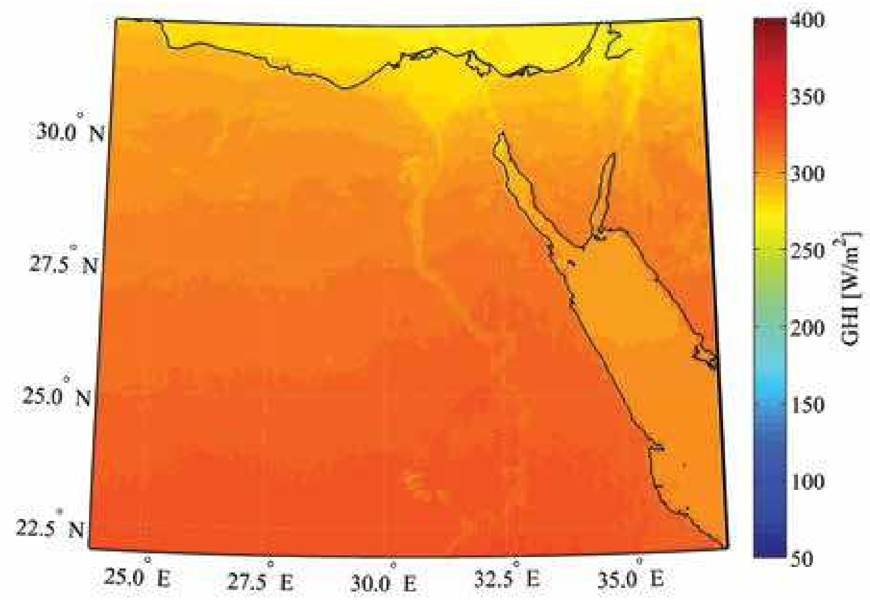
FEBRUARY



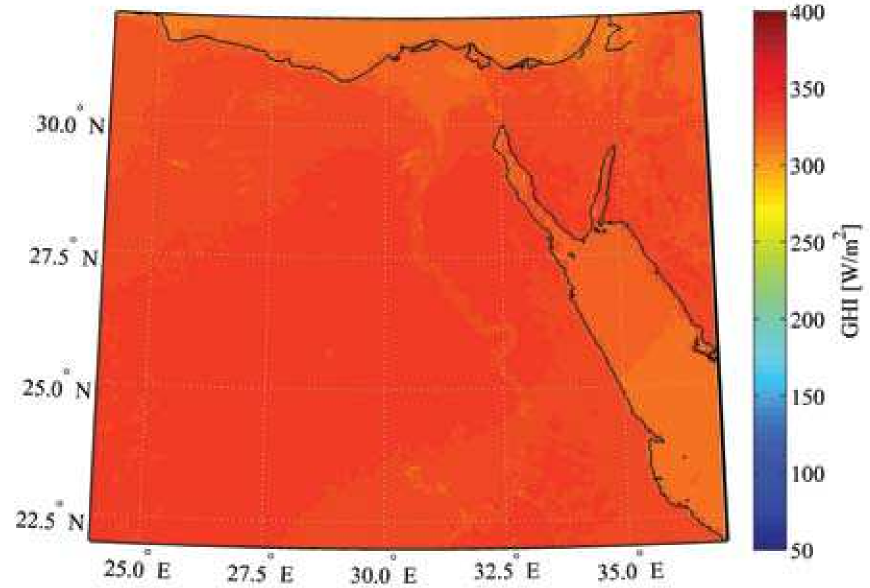
MARCH

MEAN SURFACE DIRECT NORMAL IRRADIANCE

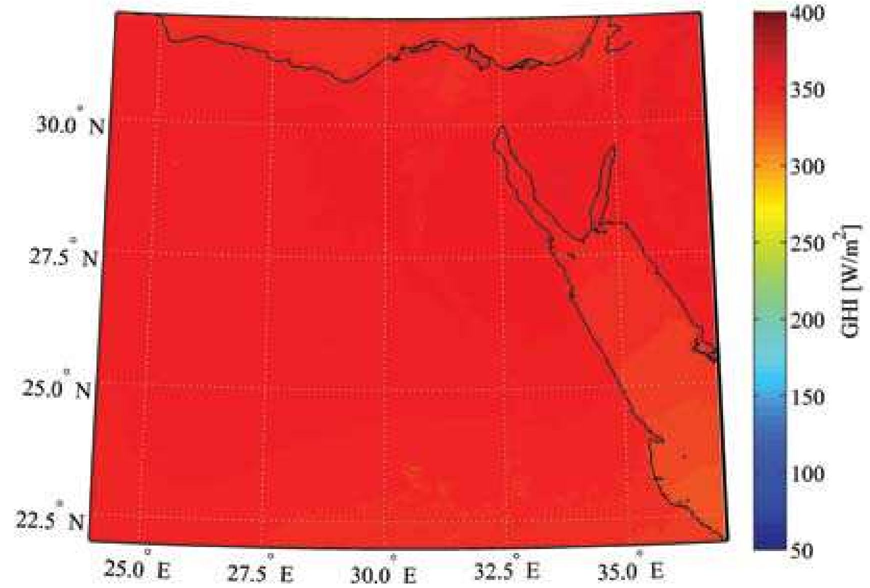
Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF).



APRIL



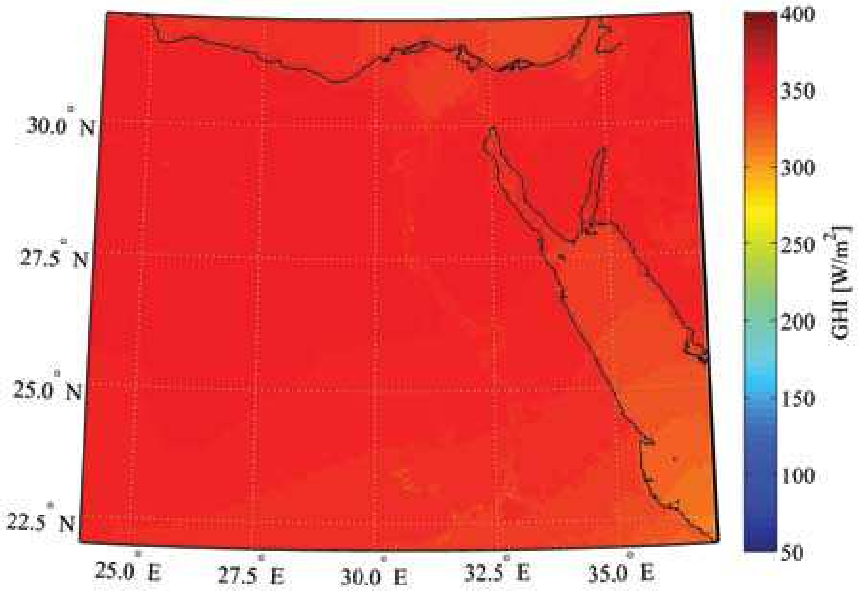
MAY



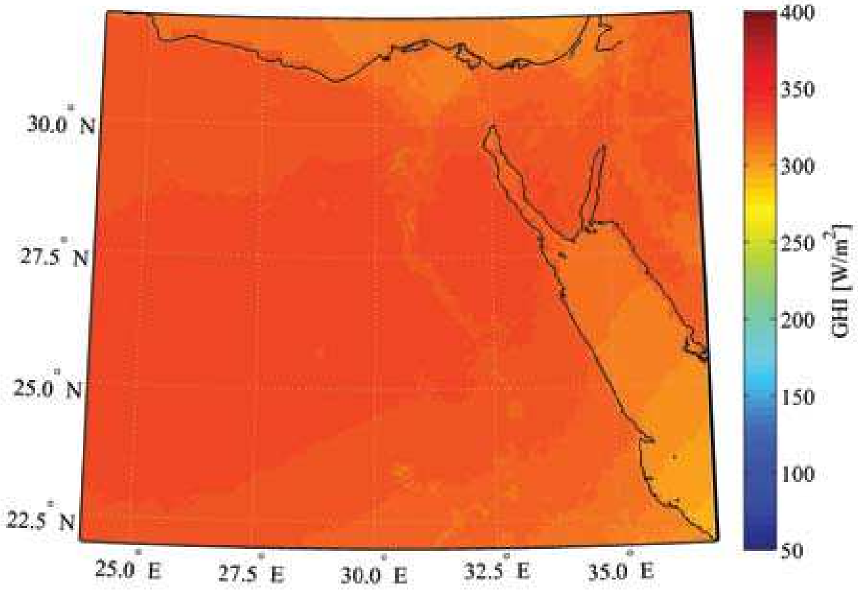
JUNE

GLOBAL HORIZONTAL IRRADIANCE (GHI C&D)

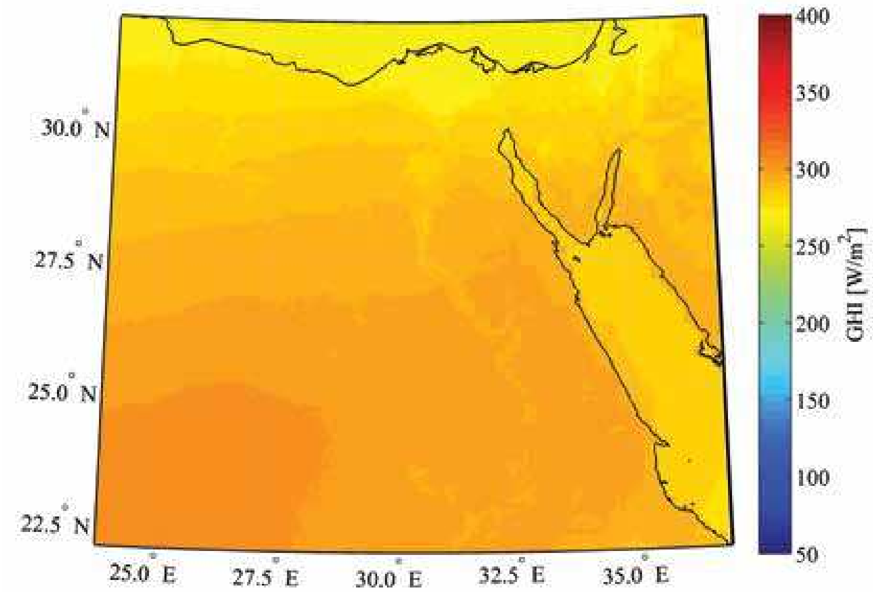
MEAN SURFACE DIRECT NORMAL IRRADIANCE



JULY



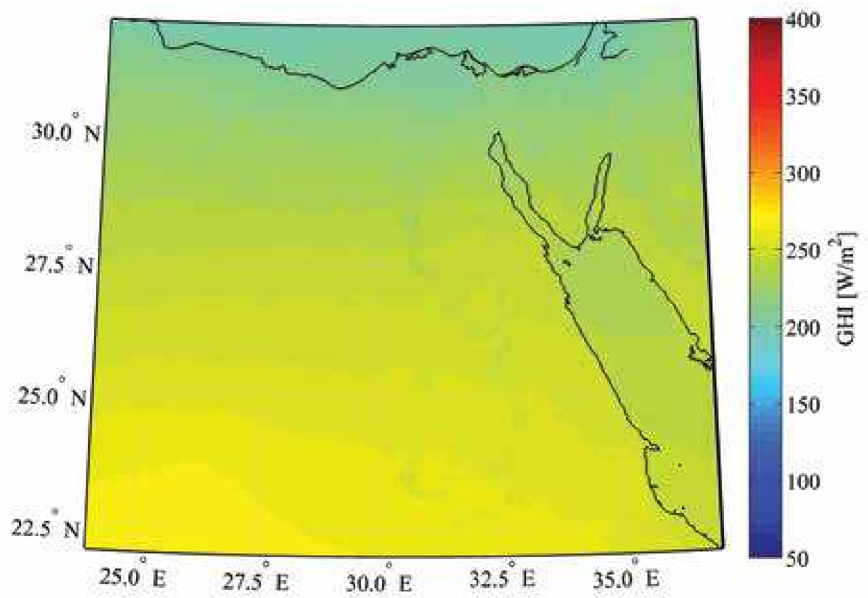
AUGUST



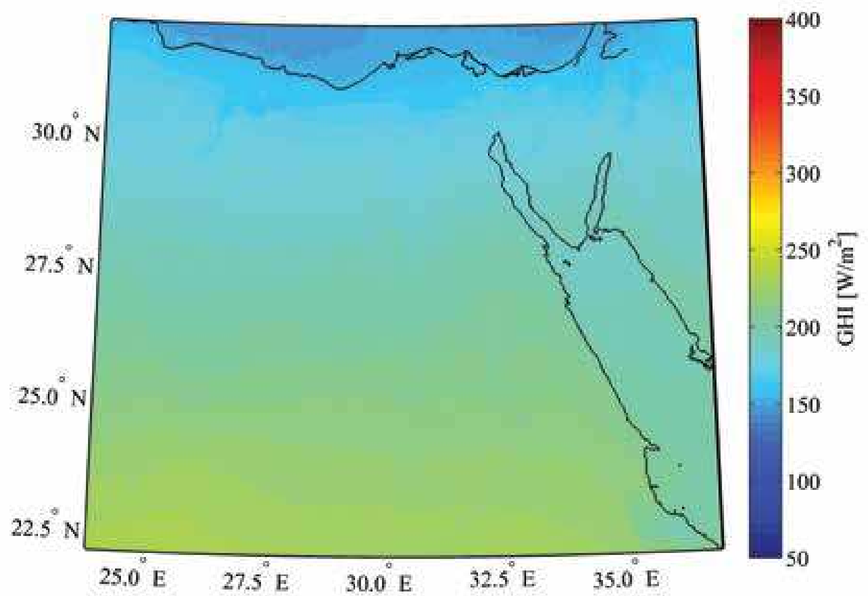
SEPTEMBER

MEAN SURFACE DIRECT NORMAL IRRADIANCE

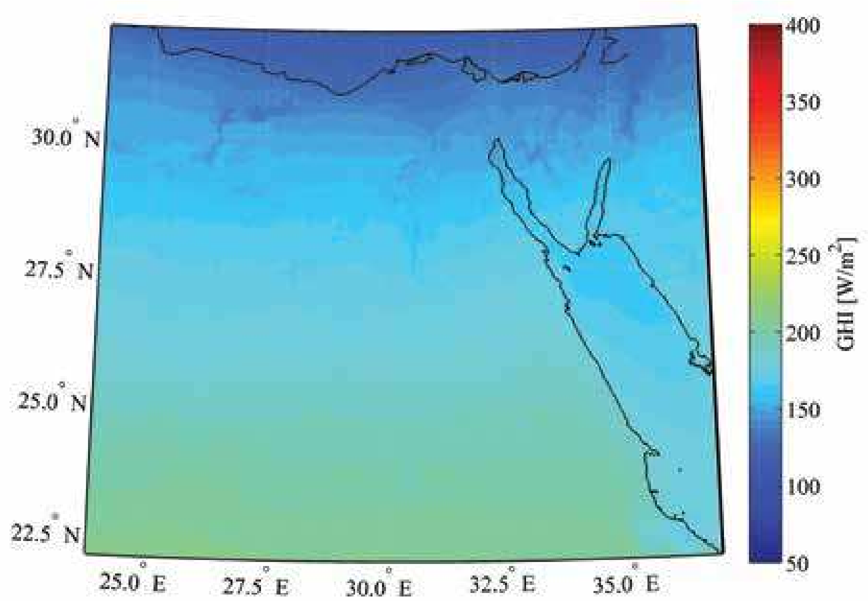
OCTOBER



NOVEMBER



DECEMBER



02

SOLAR ATLAS CLIMATOLOGY OF NORTHERN, CENTERAL AND SOUTHERN EGYPT (1999-2013)

In this Section, the mean monthly GHI and DNI for three specific locations covering various geographical and climatological conditions are presented. From the northern part of Egypt, the greater area of Alexandria was covered; in the center of Egypt, the greater area of Cairo covering the southern part of the Nile Delta was covered, and finally, in the southern part of Egypt the greater region of Luxor and Aswan was selected.

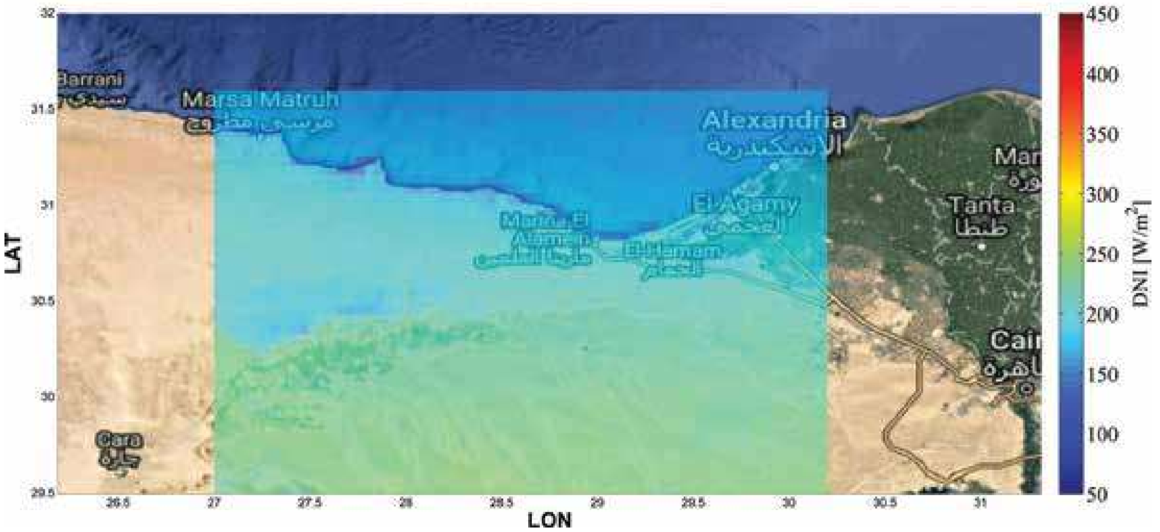
The analysis is based on the same EUMETSAT radiation database of the DNI and GHI for the period Jan. 1999 - Dec. 2013.

ALEXANDRIA

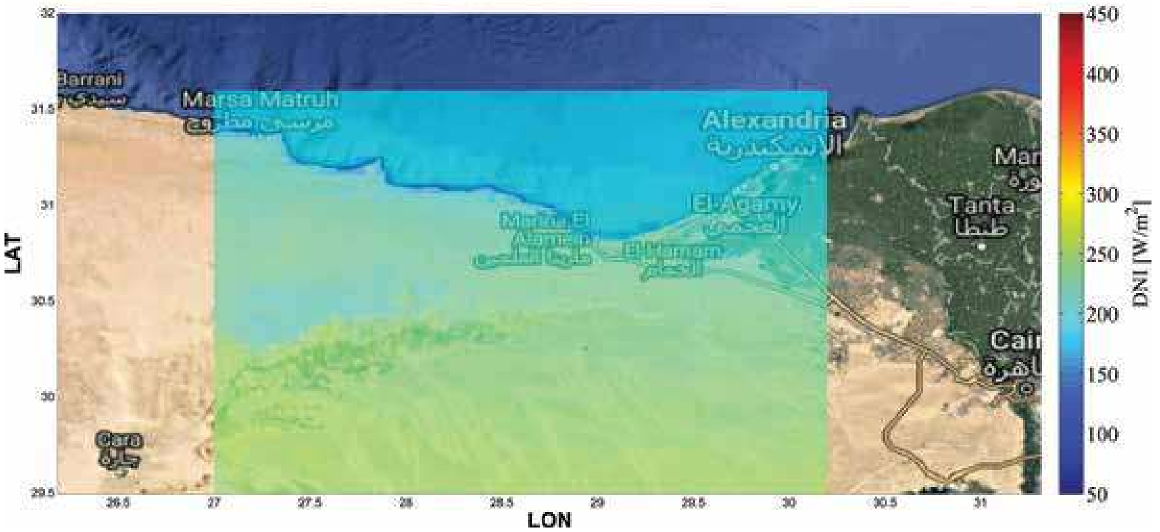
DNI
GHI

ALEXANDRIA

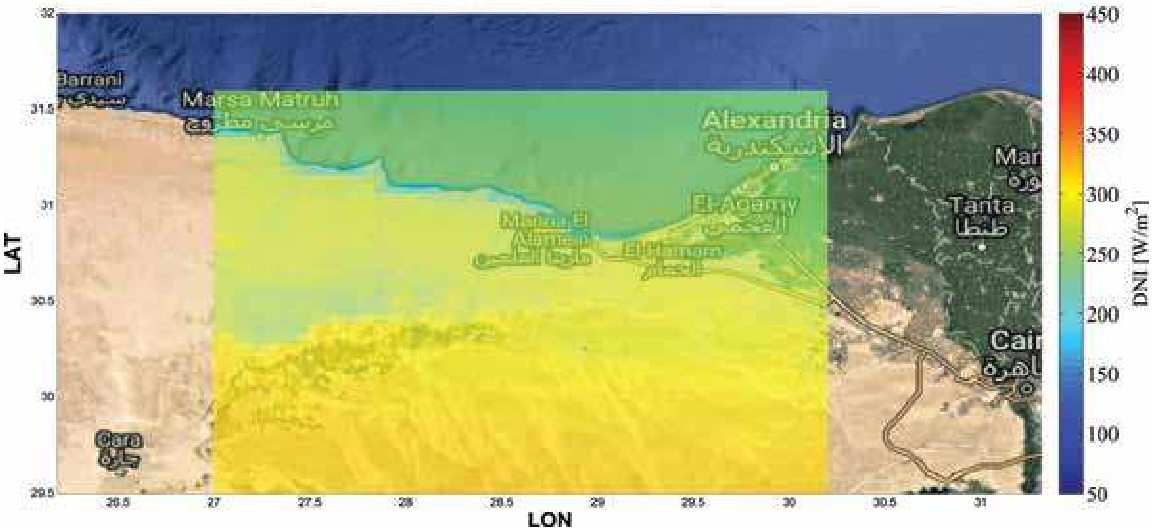
ALEXANDRIA MEAN SURFACE DNI



JANUARY



FEBRUARY

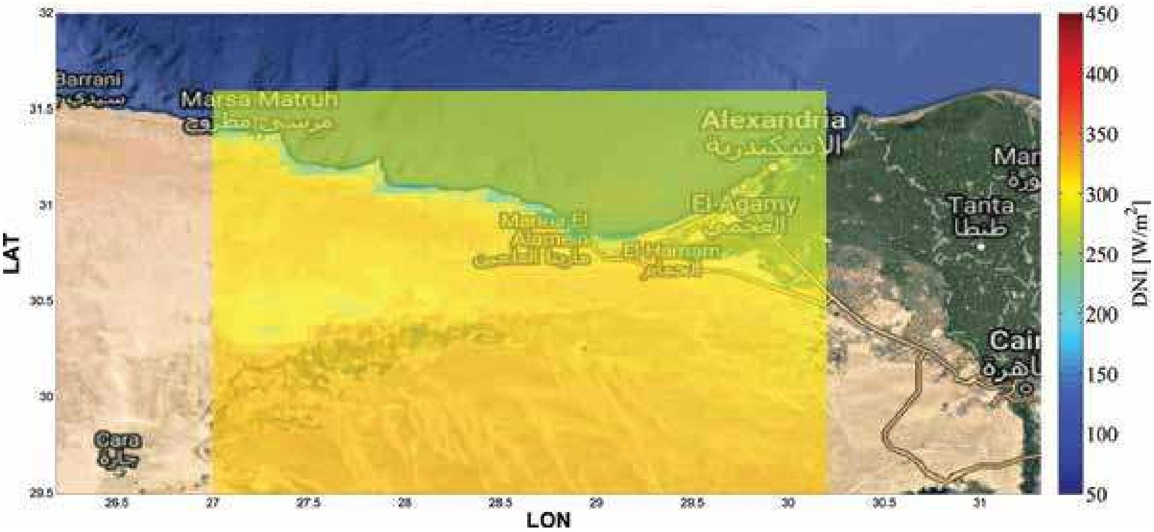


MARCH

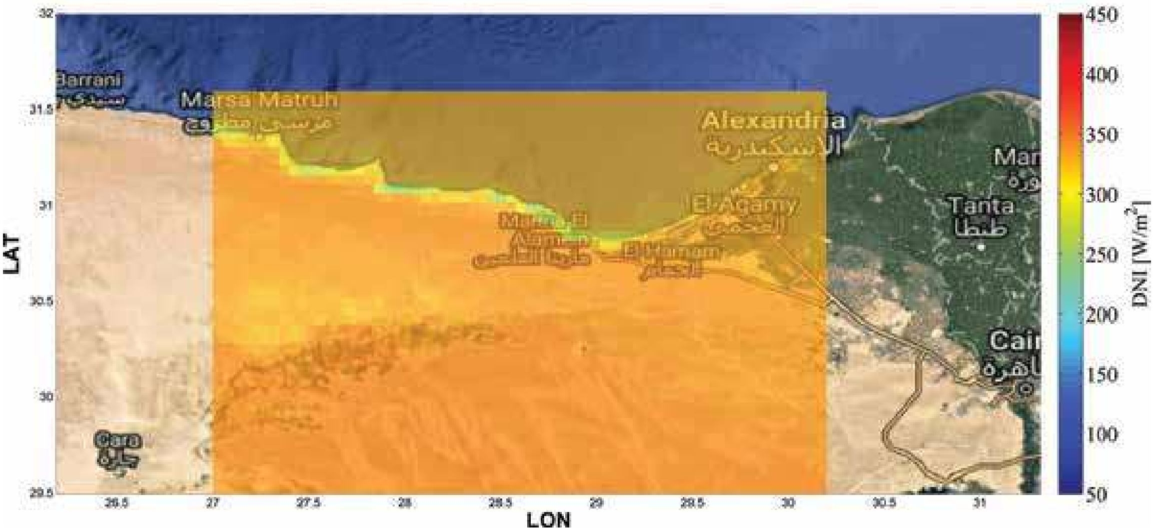
DNI (A&B)

ALEXANDRIA MEAN SURFACE DNI

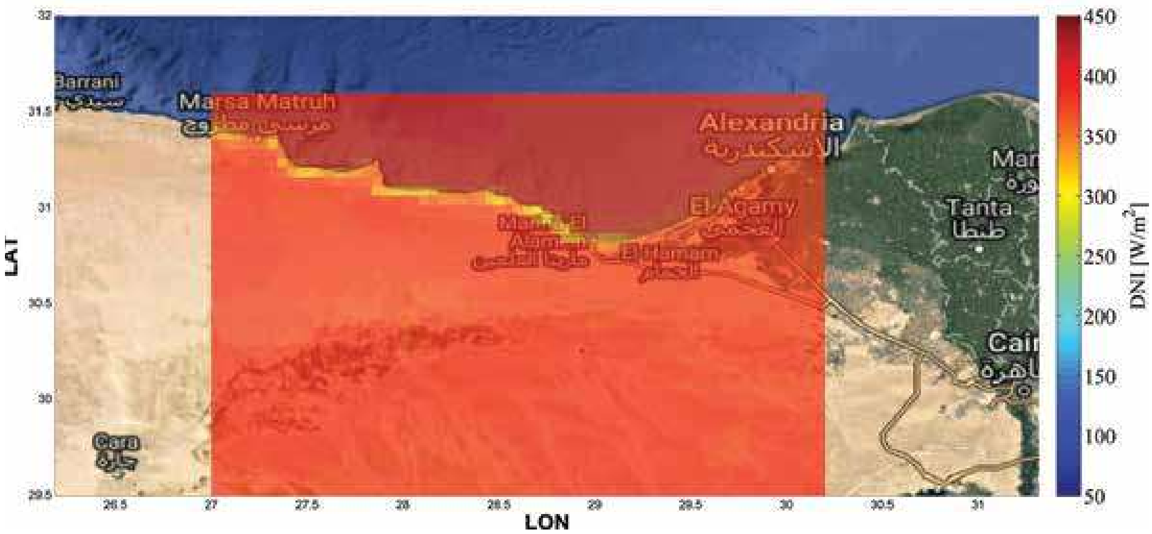
APRIL



MAY

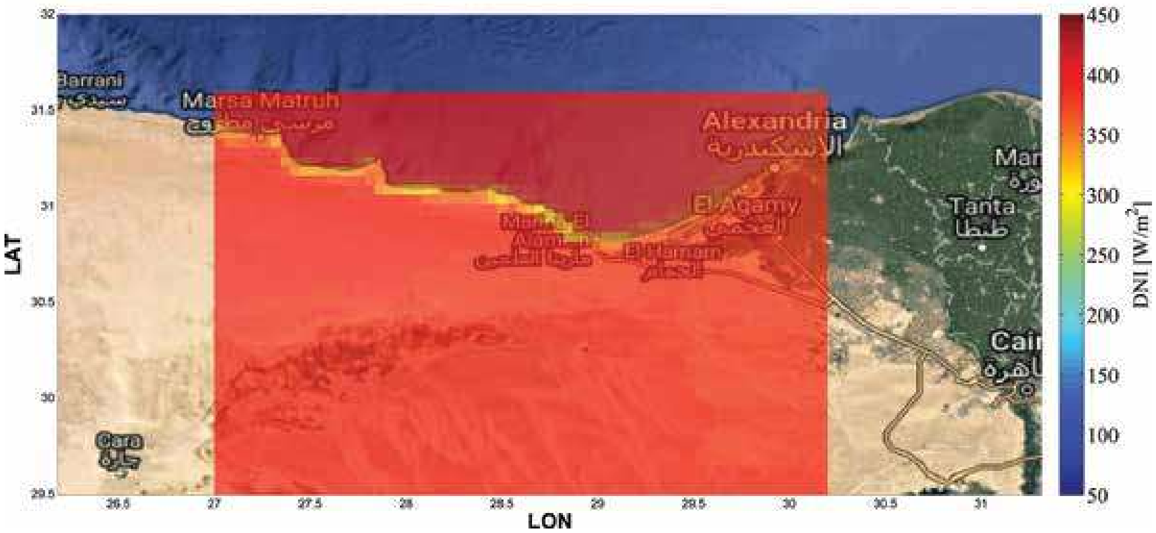


JUNE

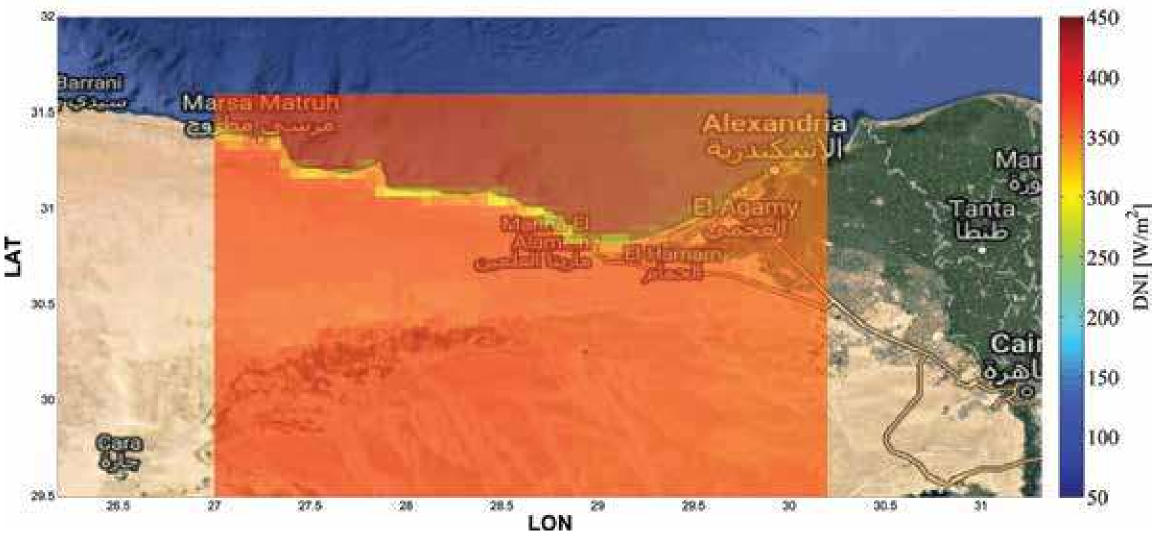


ALEXANDRIA

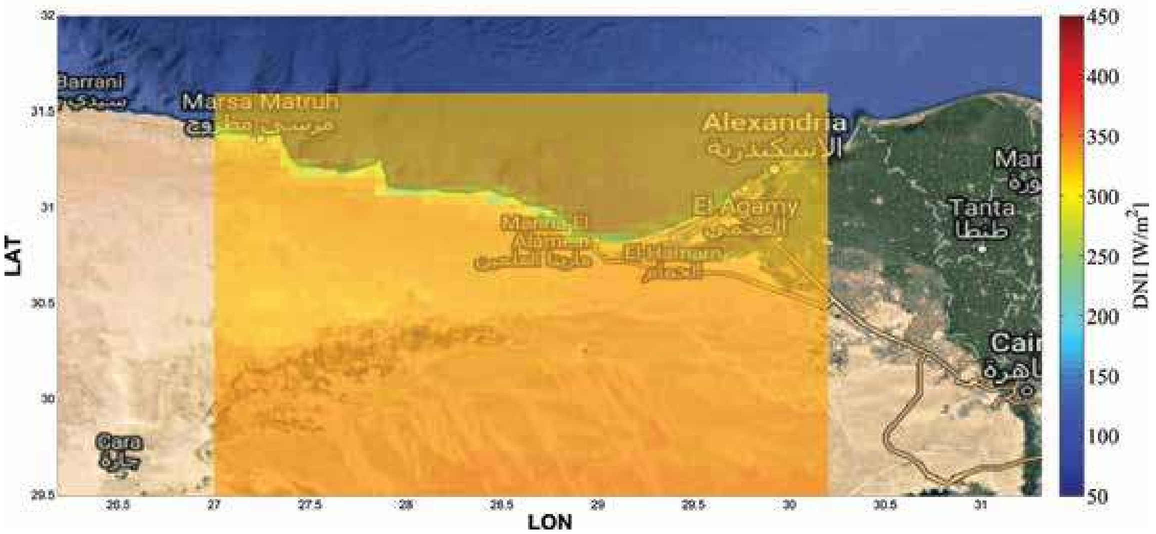
ALEXANDRIA MEAN SURFACE DNI



JULY



AUGUST

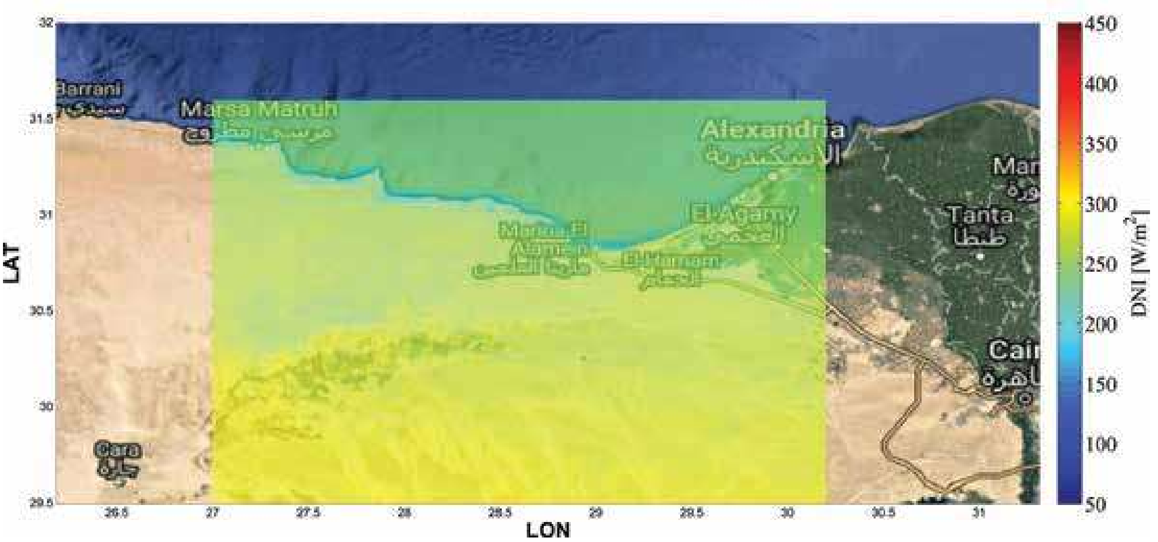


SEPTEMBER

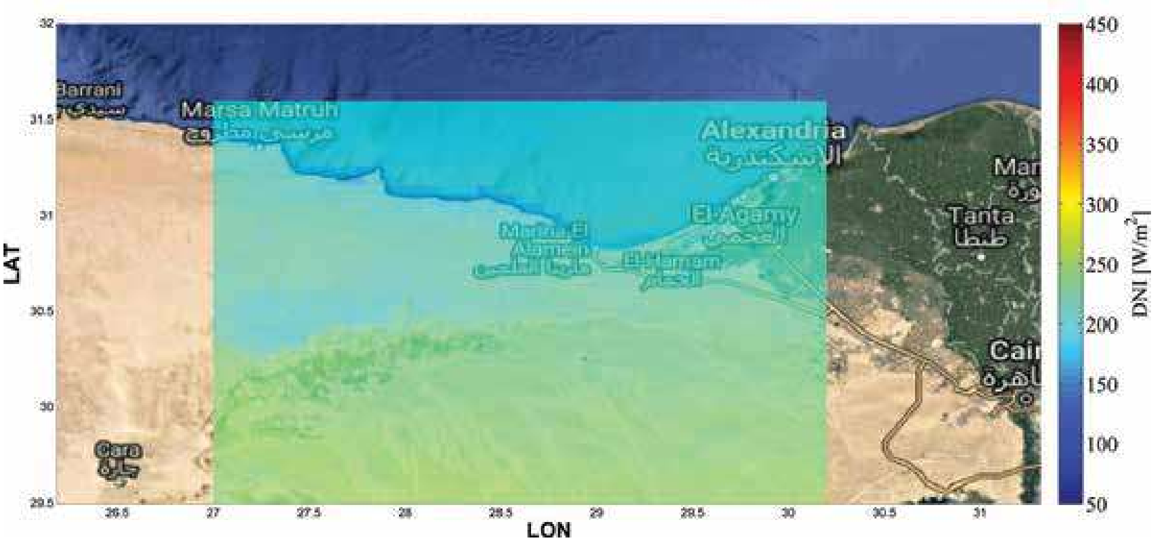
DNI (C&D)

ALEXANDRIA MEAN SURFACE DNI

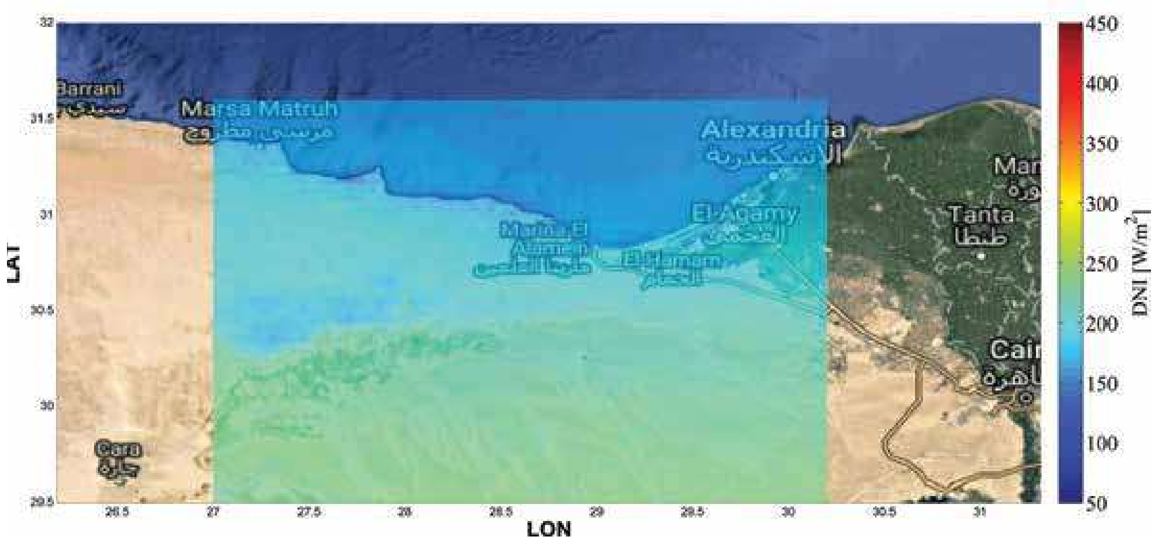
OCTOBER



NOVEMBER

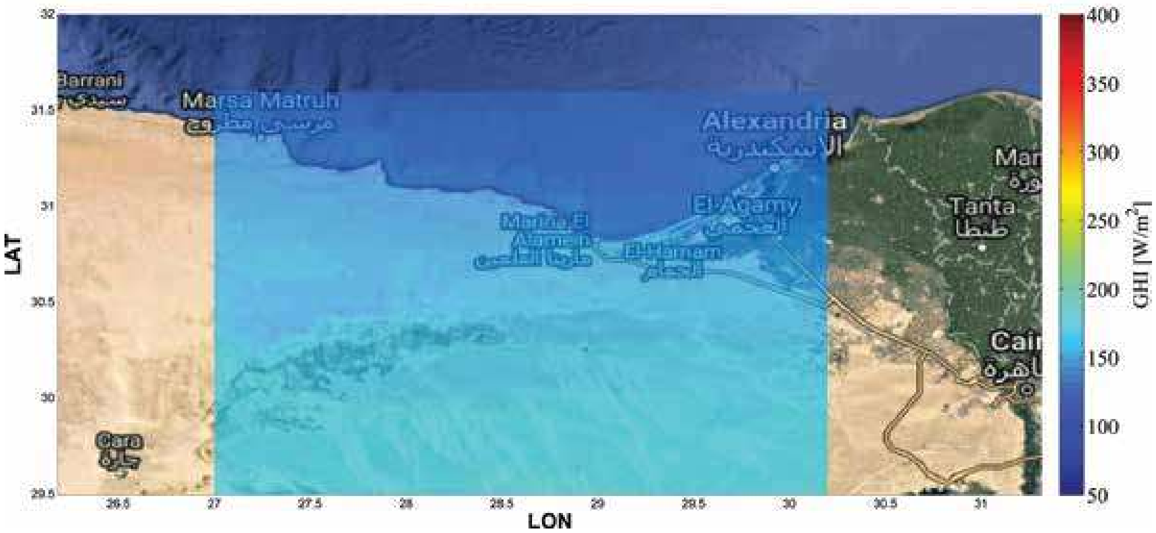


DECEMBER

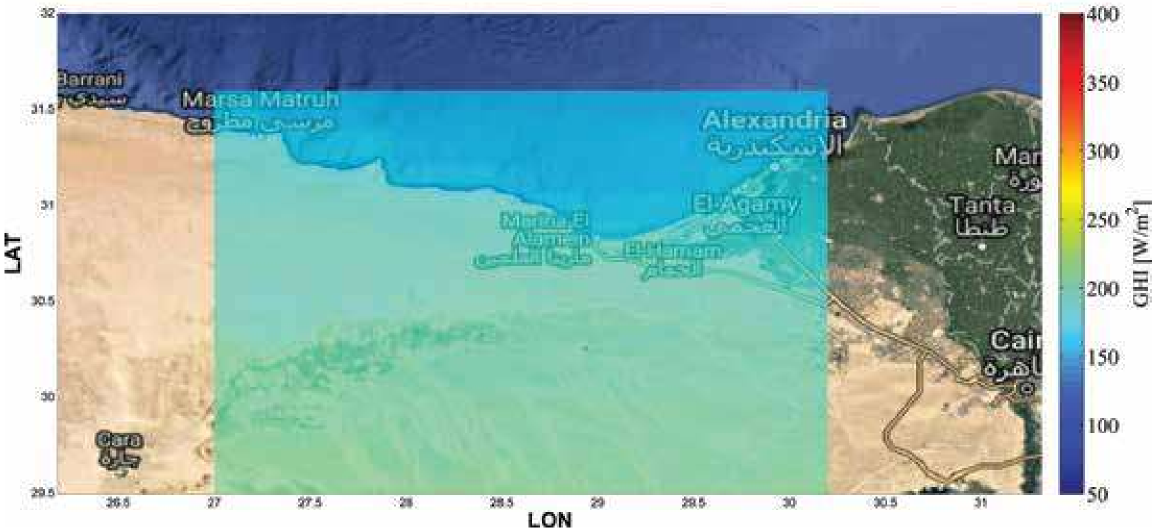


ALEXANDRIA

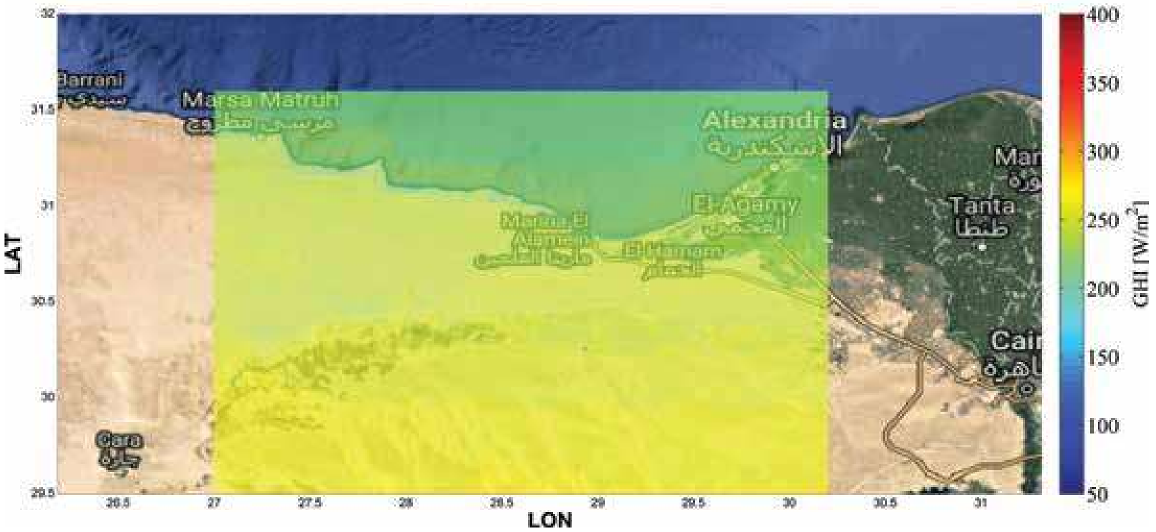
ALEXANDRIA MEAN SURFACE DNI



JANUARY



FEBRUARY

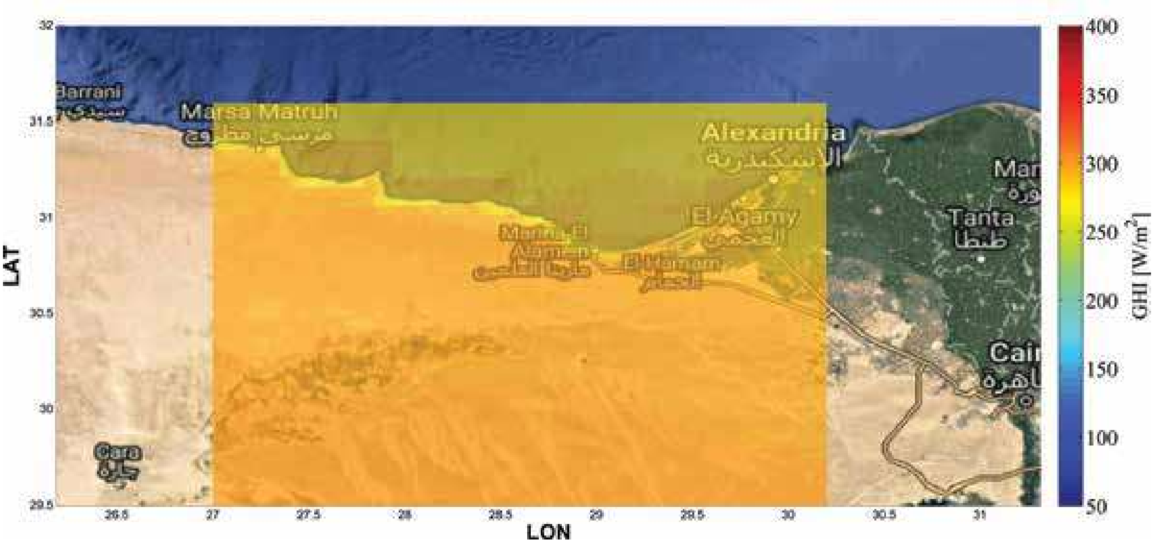


MARCH

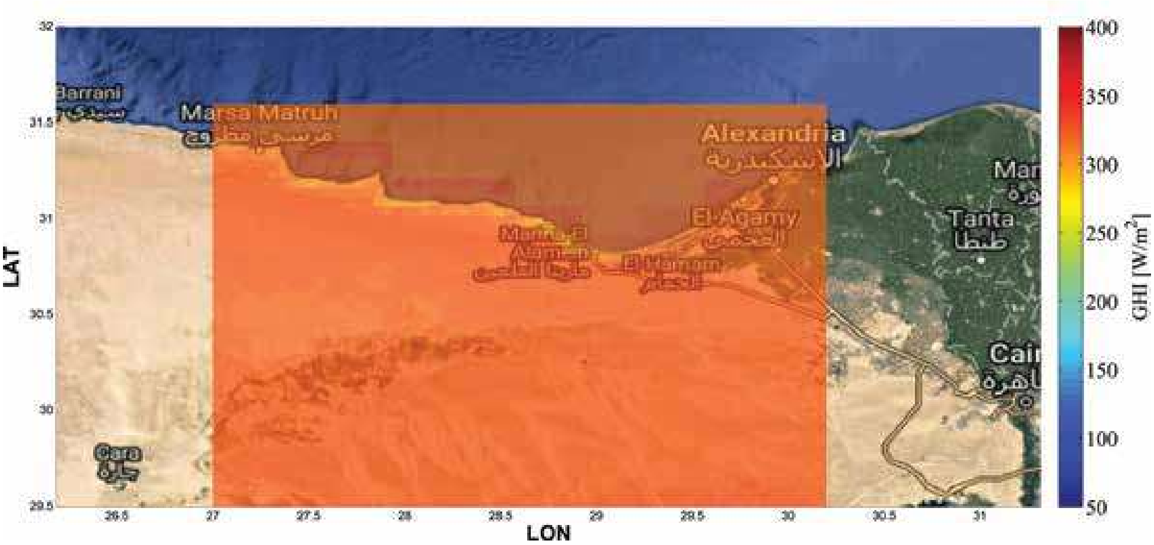
GHI (A&B)

ALEXANDRIA MEAN SURFACE DNI

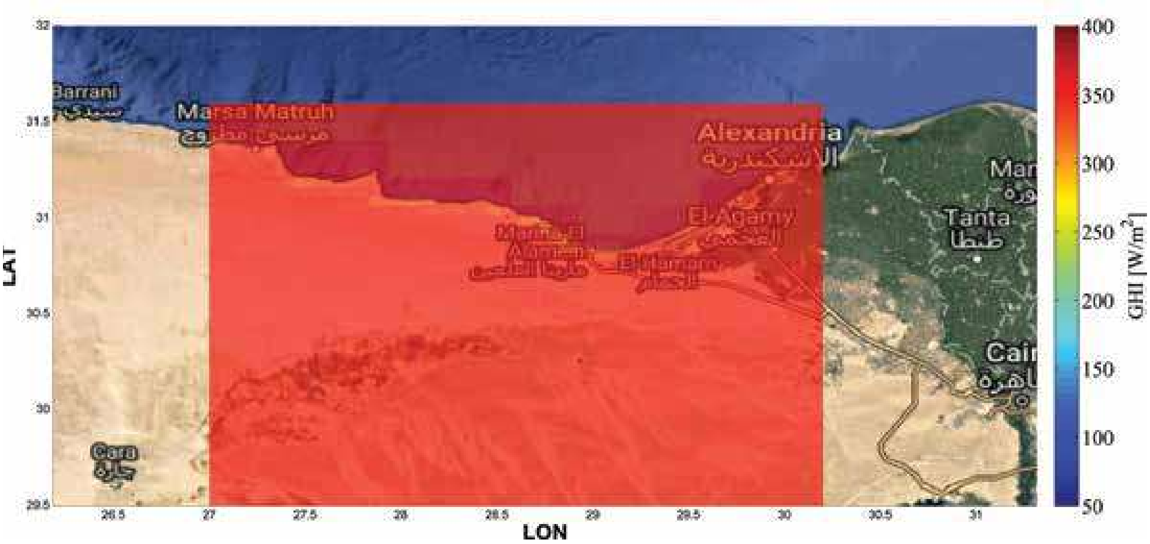
APRIL



MAY

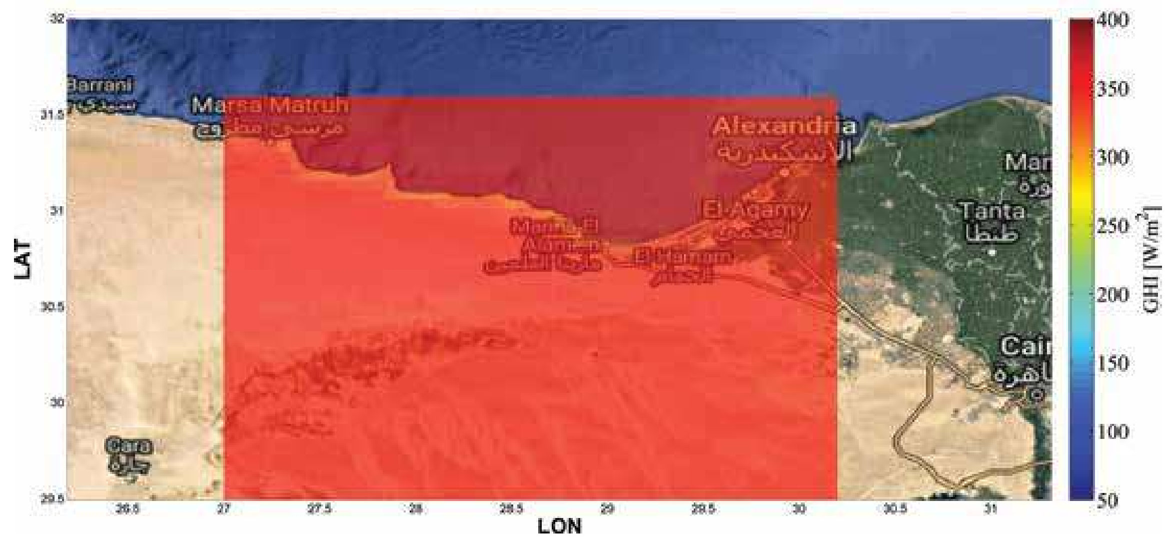


JUNE

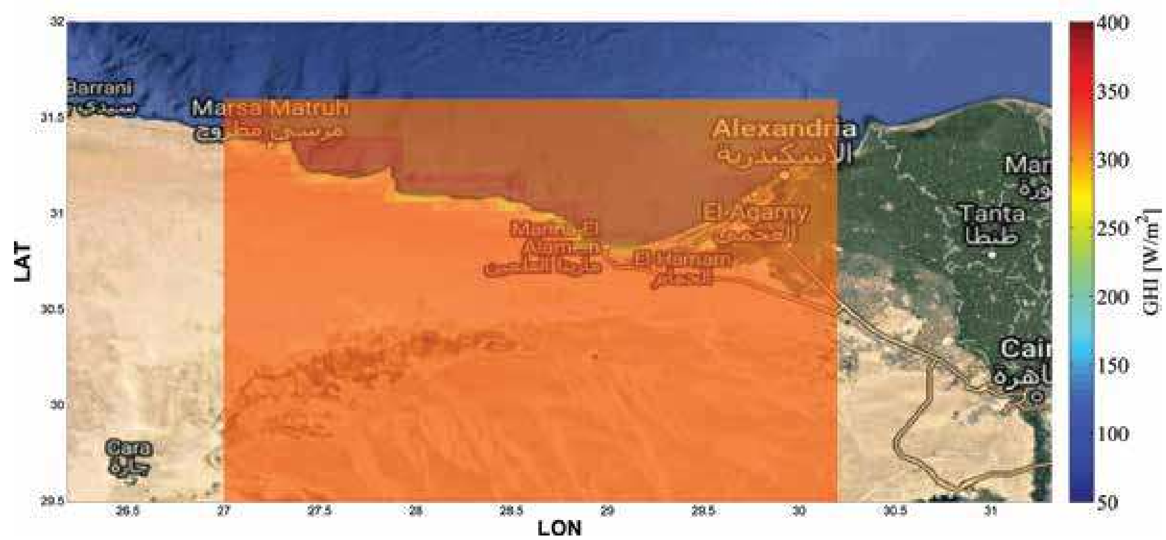


ALEXANDRIA

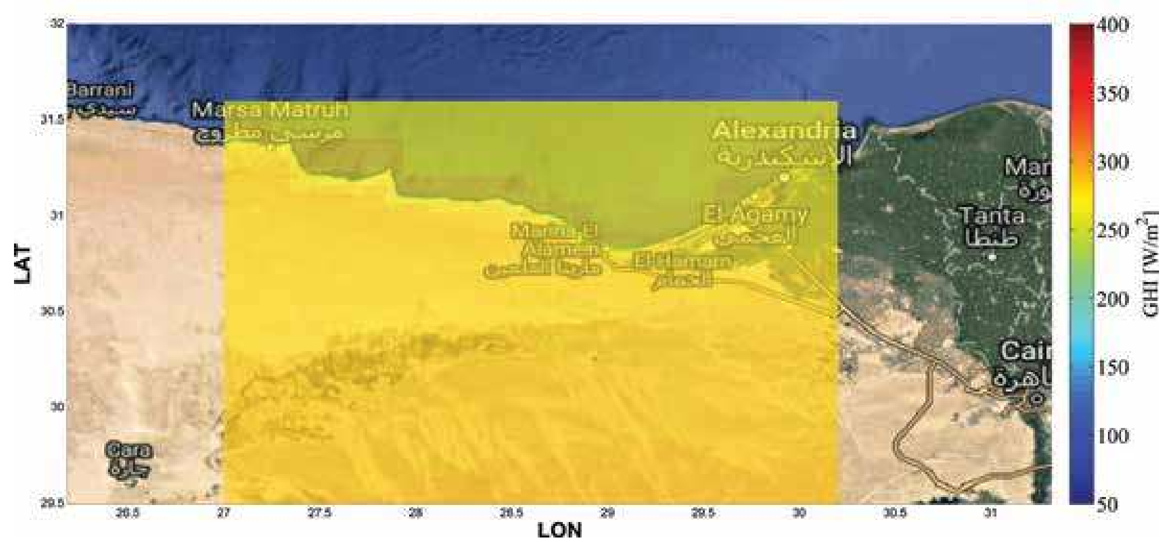
ALEXANDRIA MEAN SURFACE DNI



JULY



AUGUST

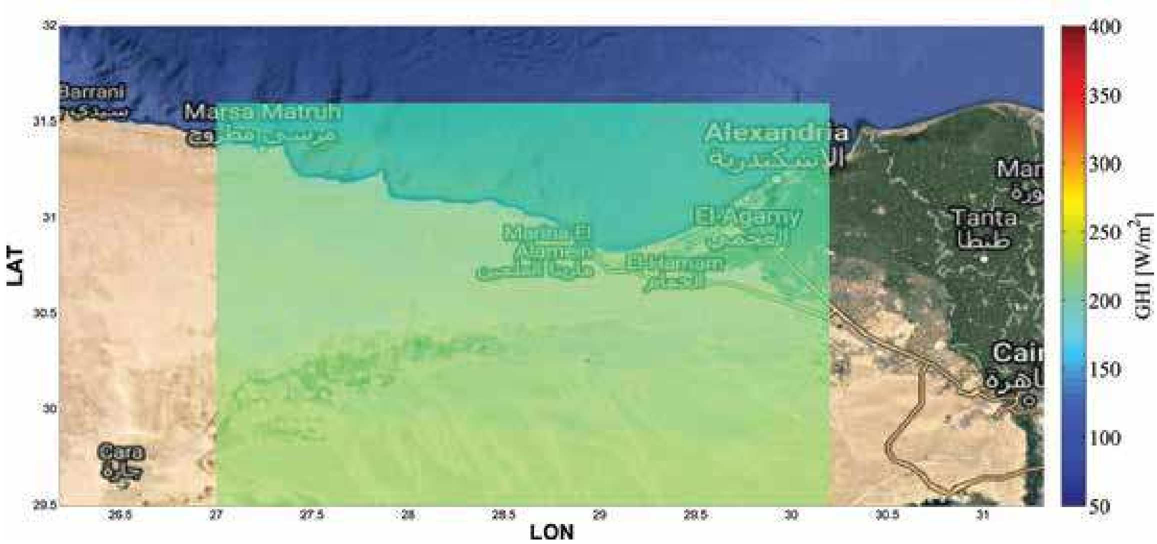


SEPTEMBER

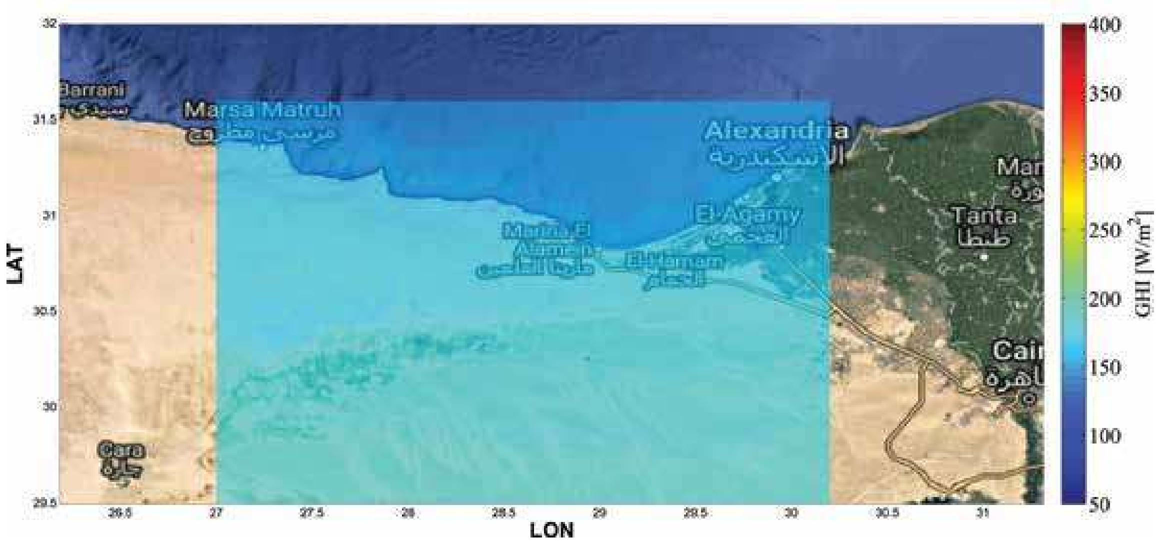
GHI (C&D)

ALEXANDRIA MEAN SURFACE DNI

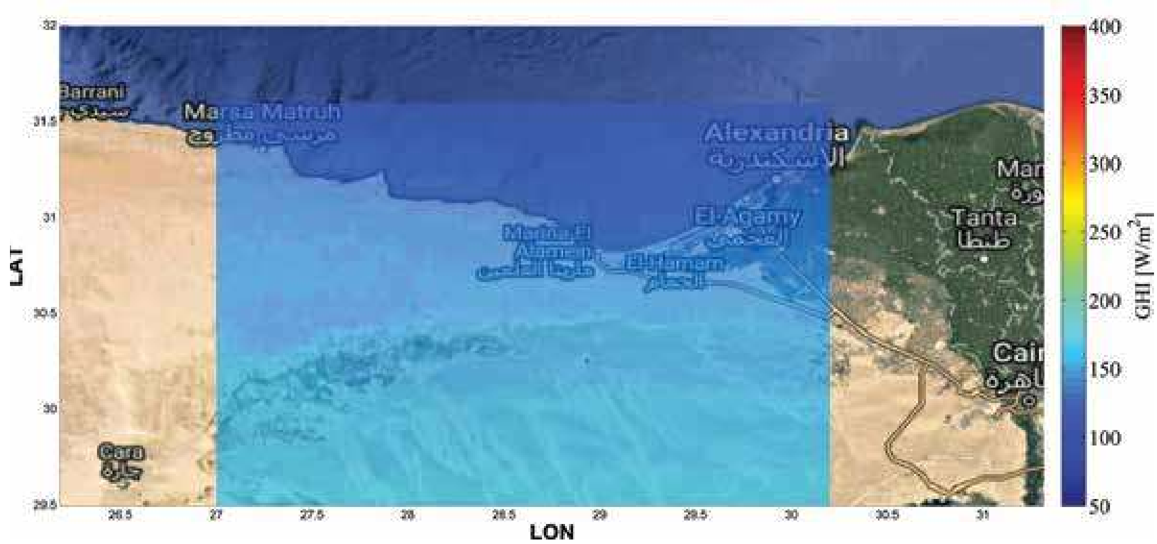
OCTOBER



NOVEMBER



DECEMBER



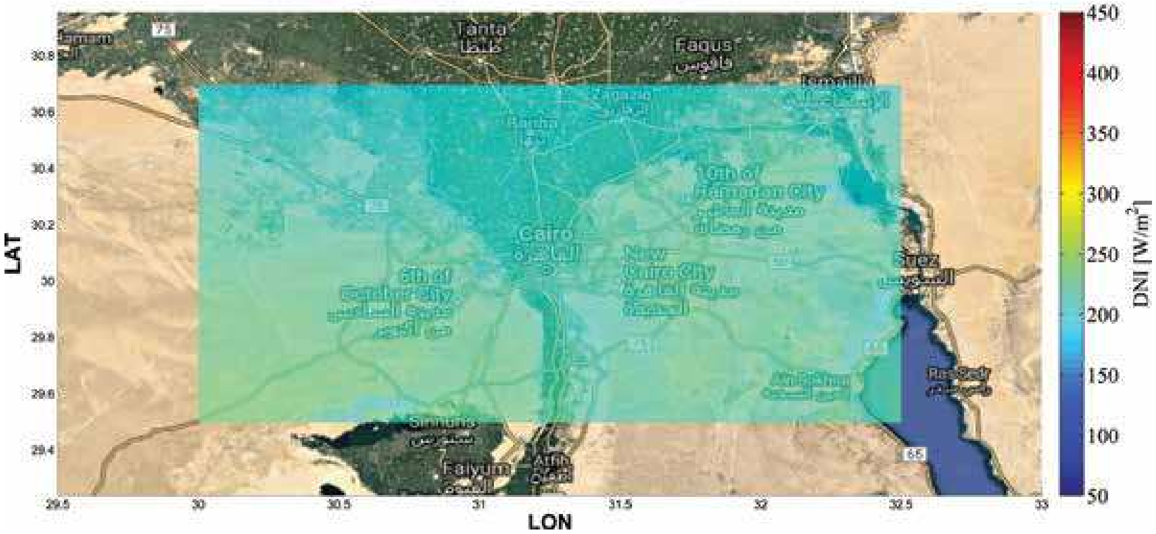
CAIRO

DNI

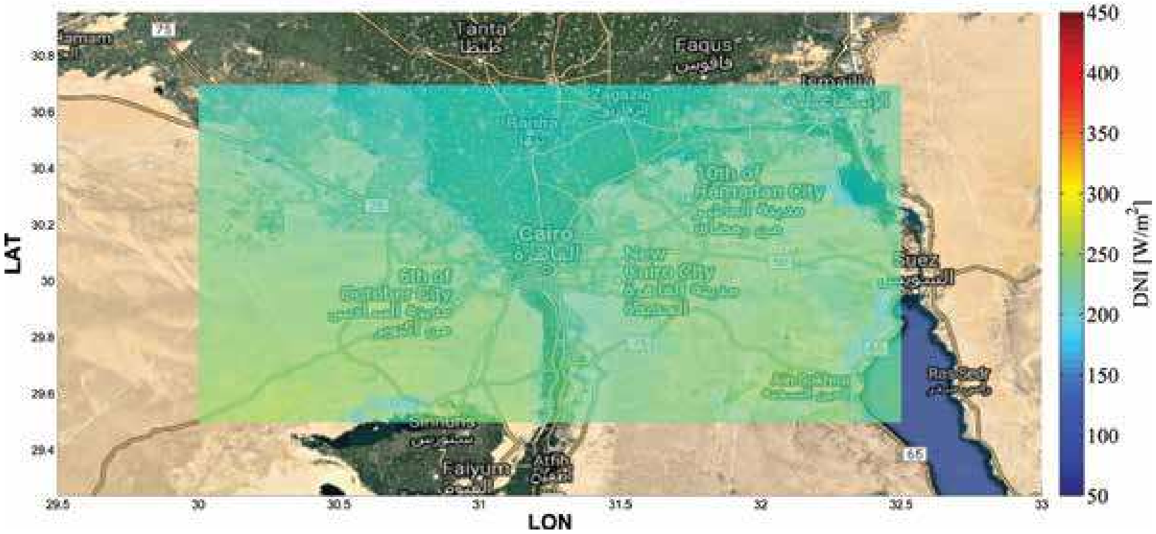
GHI

CAIRO

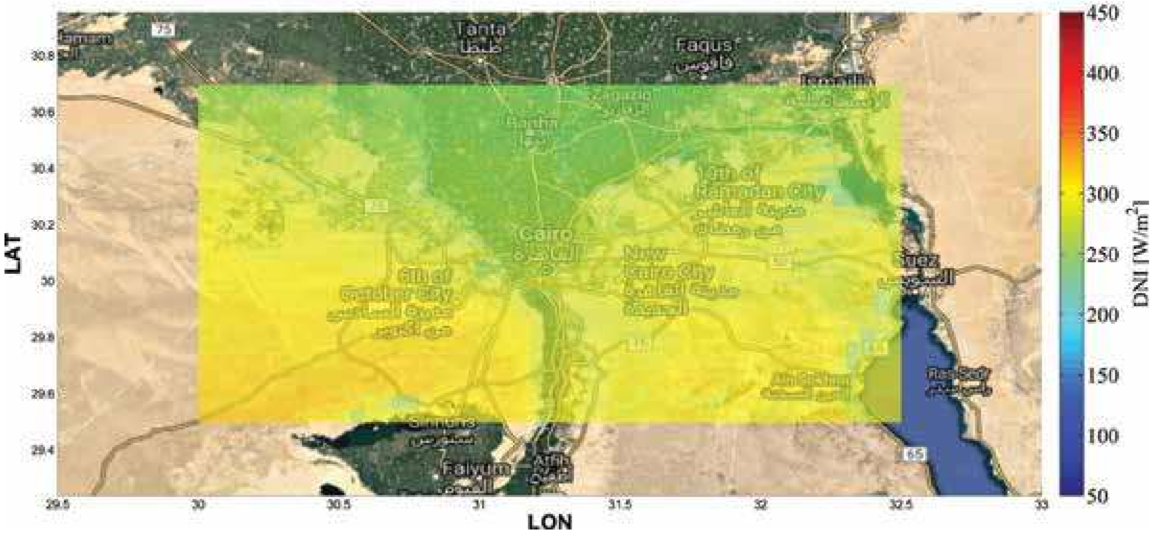
CAIRO MEAN SURFACE DNI



JANUARY



FEBRUARY

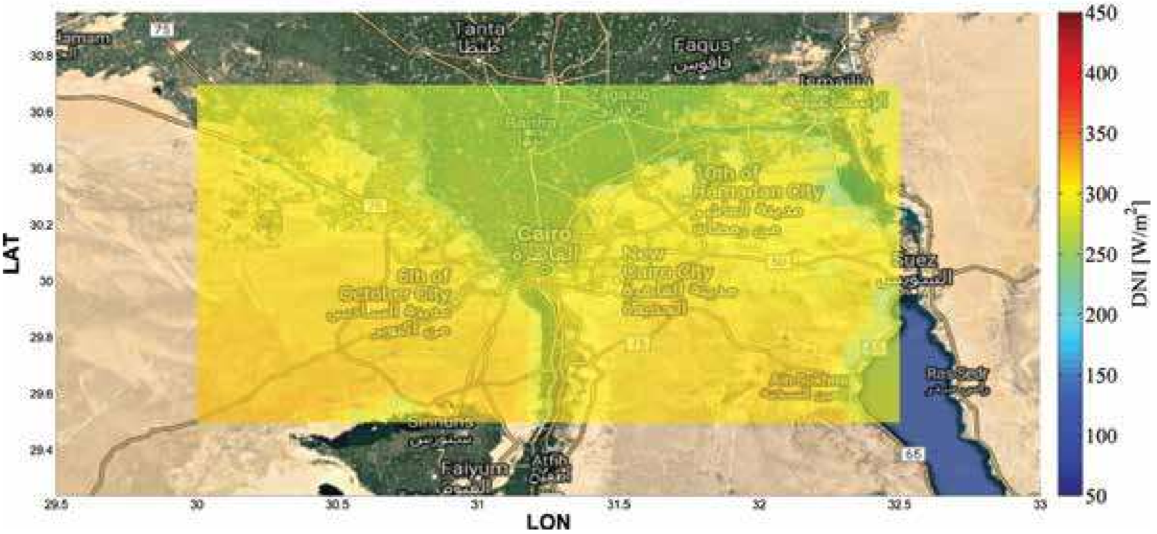


MARCH

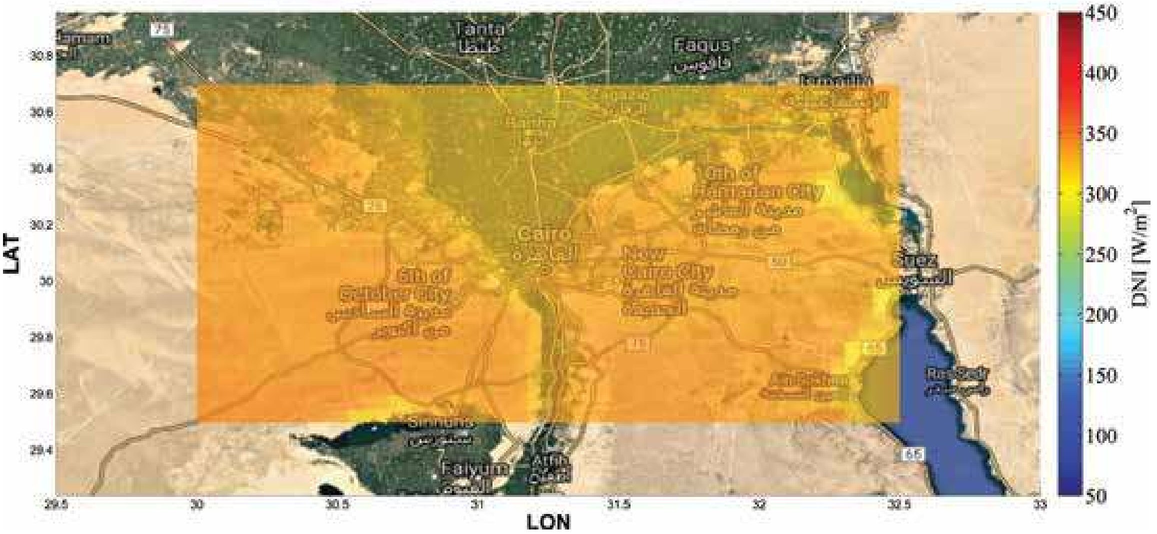
DNI (A&B)

CAIRO MEAN SURFACE DNI

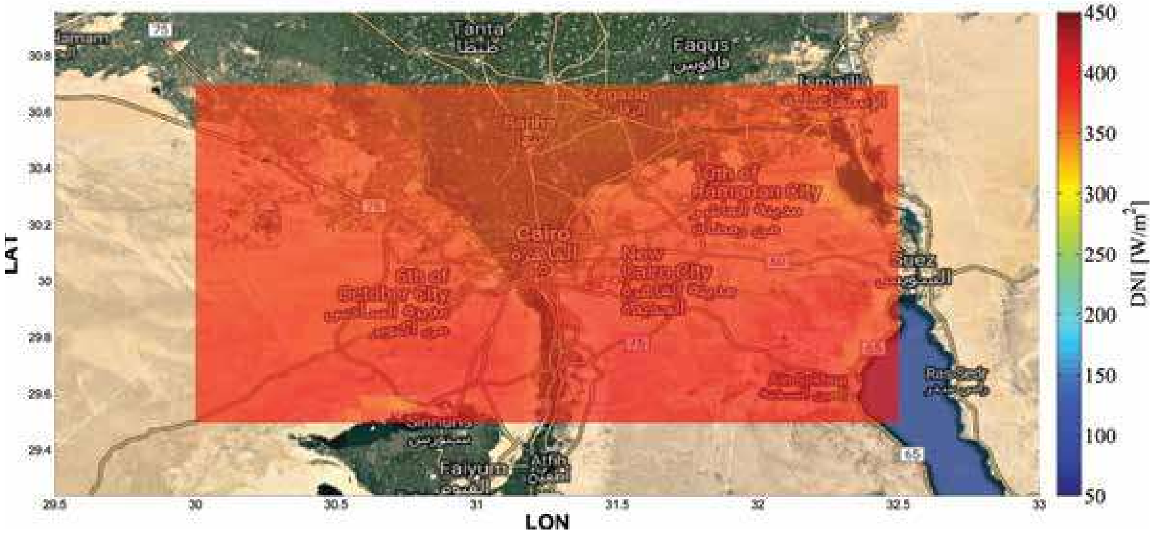
APRIL



MAY

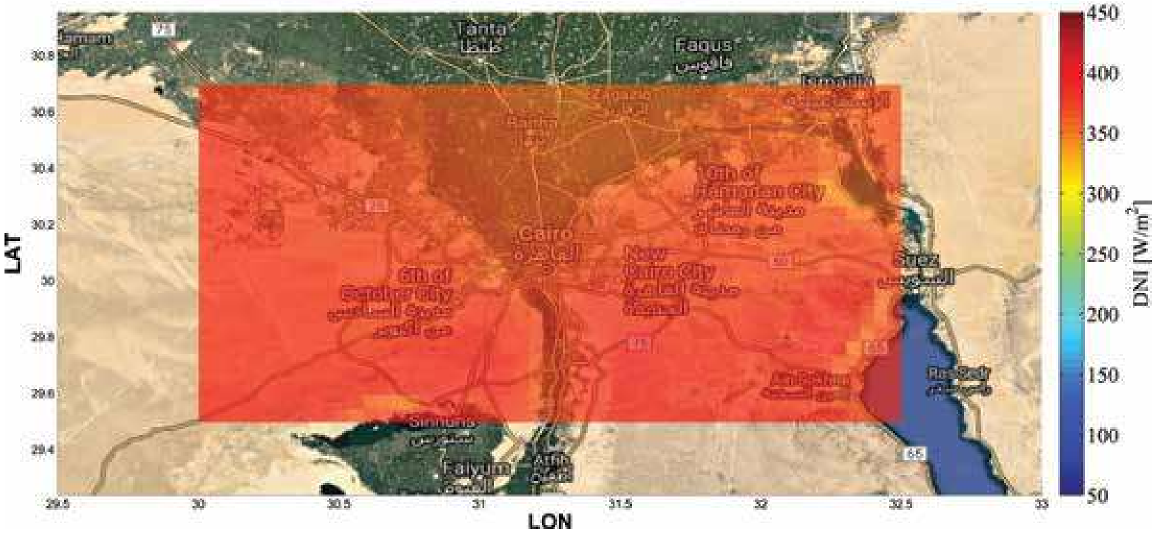


JUNE

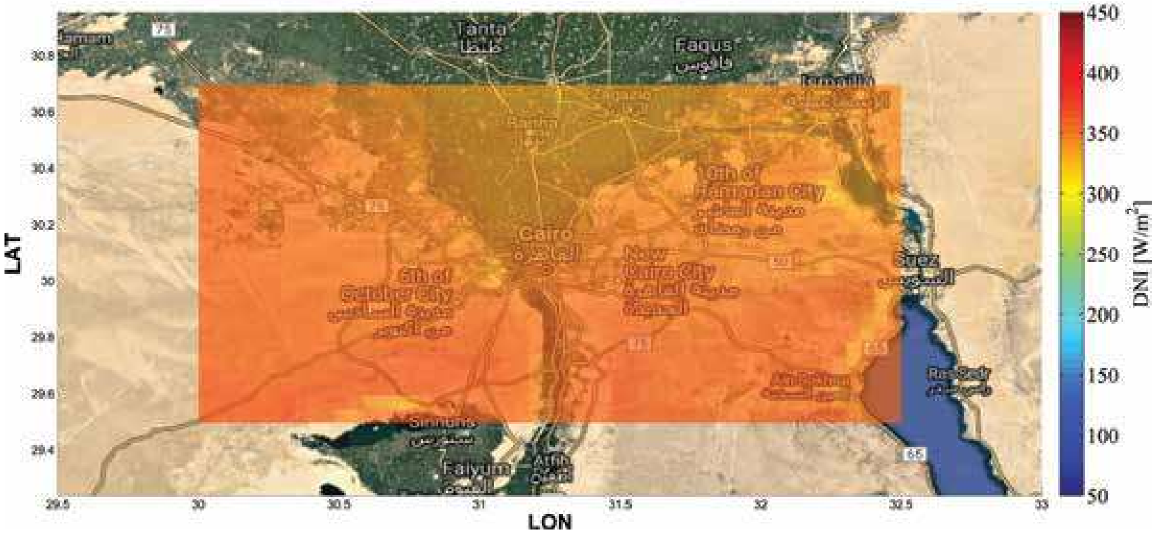


CAIRO

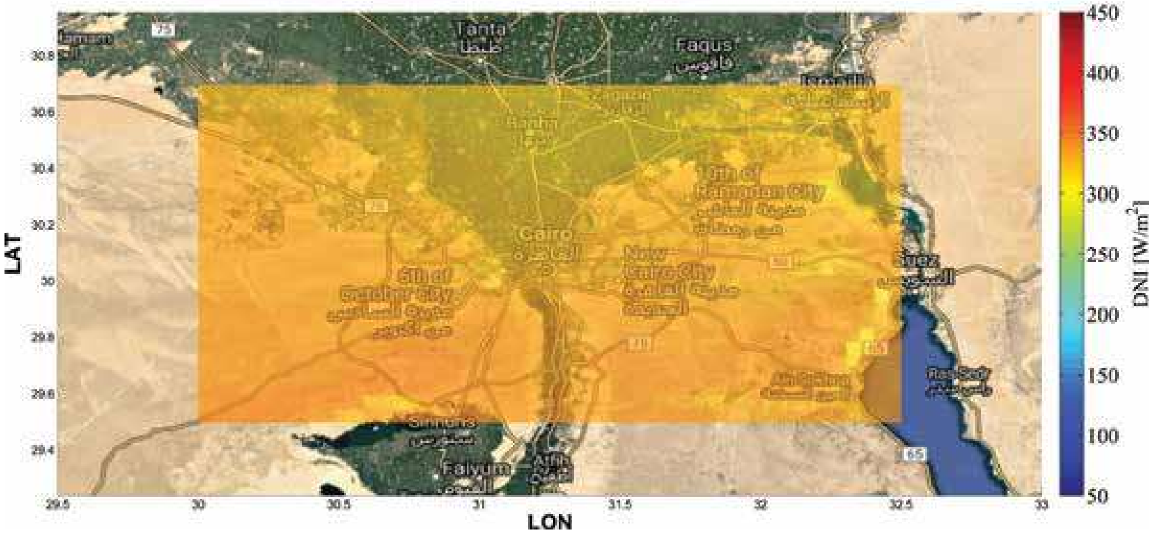
CAIRO MEAN SURFACE DNI



JULY



AUGUST

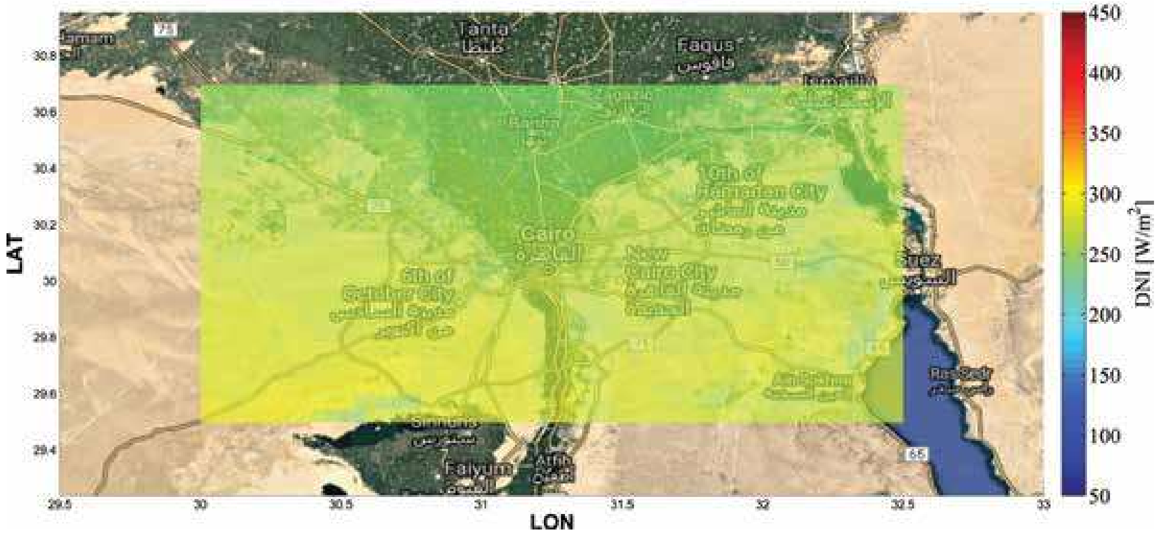


SEPTEMBER

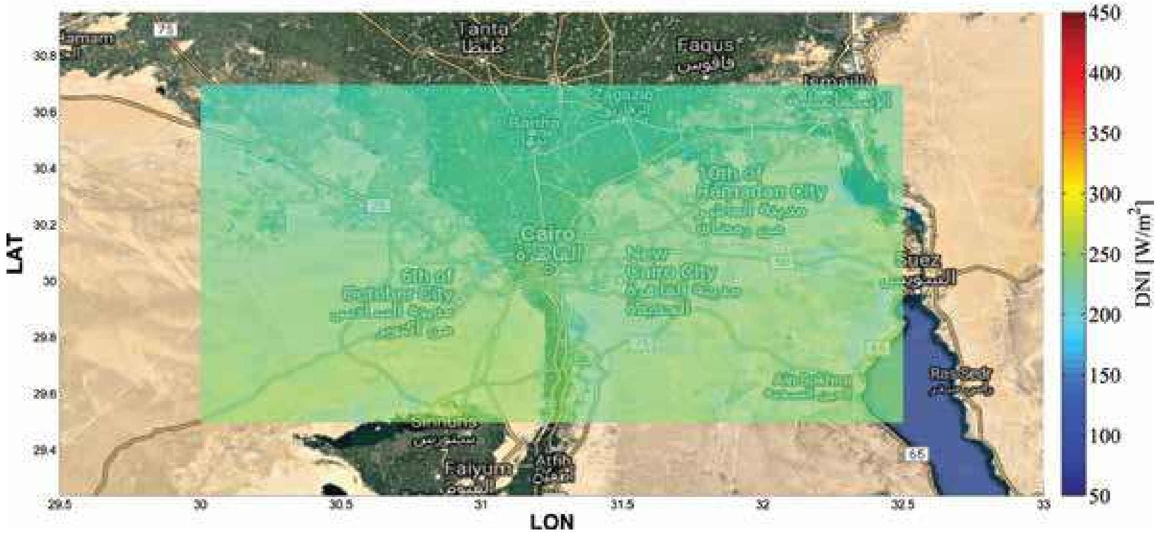
DNI (C&D)

CAIRO MEAN SURFACE DNI

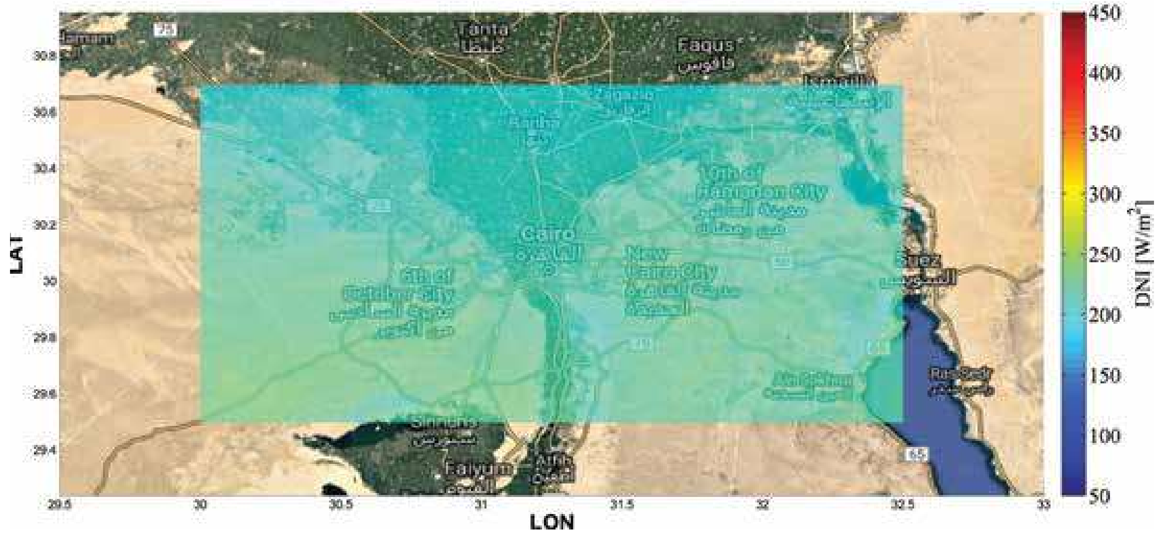
OCTOBER



NOVEMBER

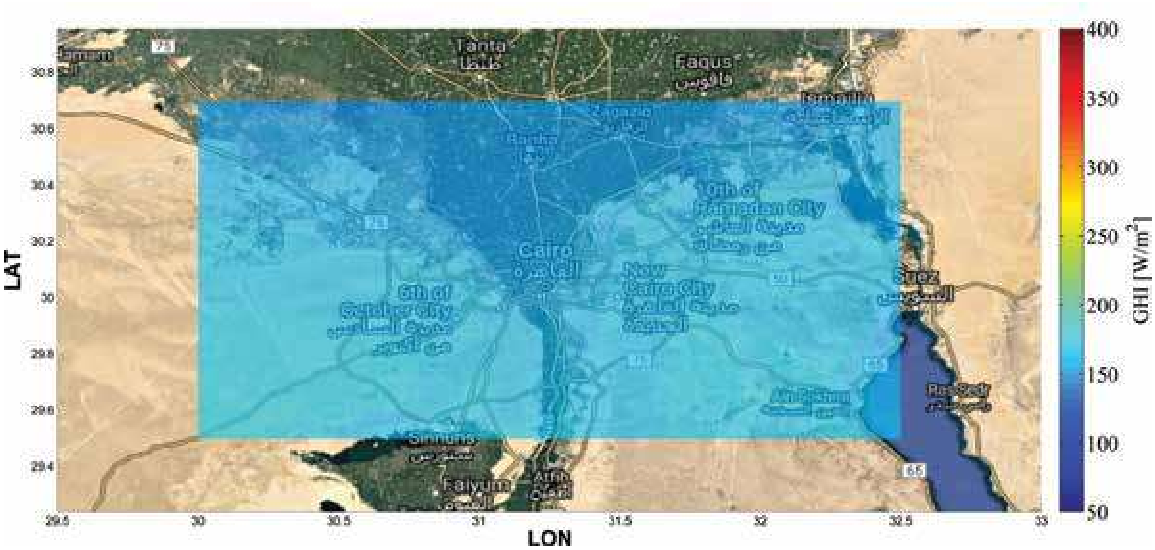


DECEMBER

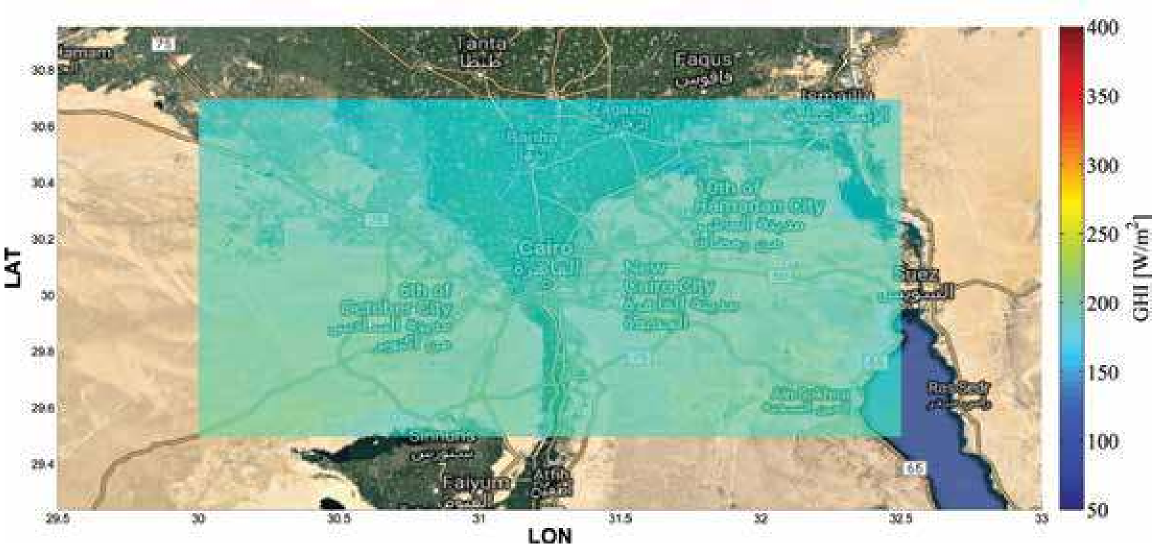


CAIRO

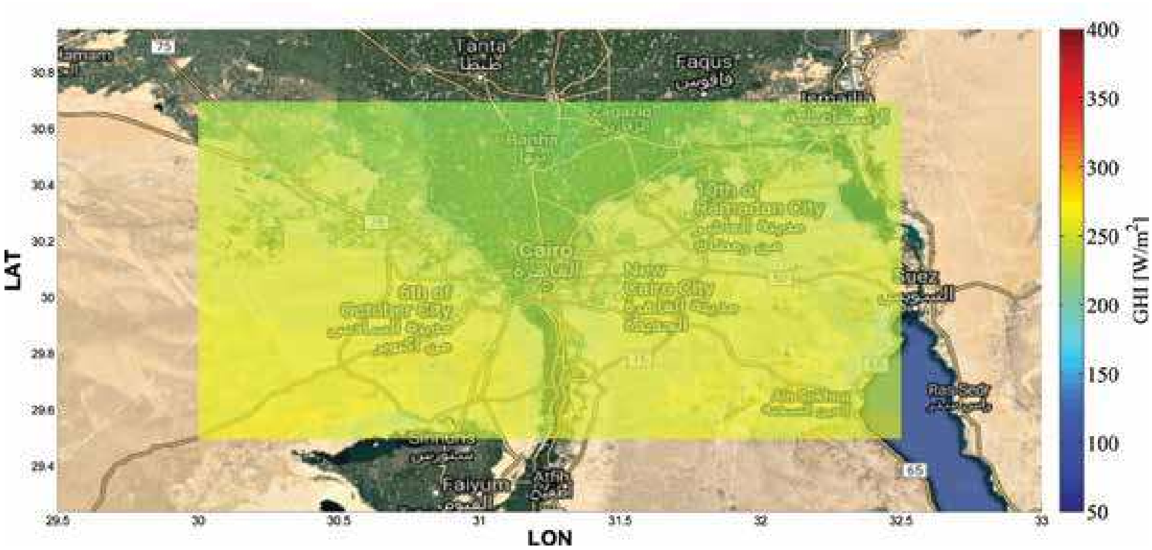
CAIRO MEAN SURFACE DNI



JANUARY



FEBRUARY

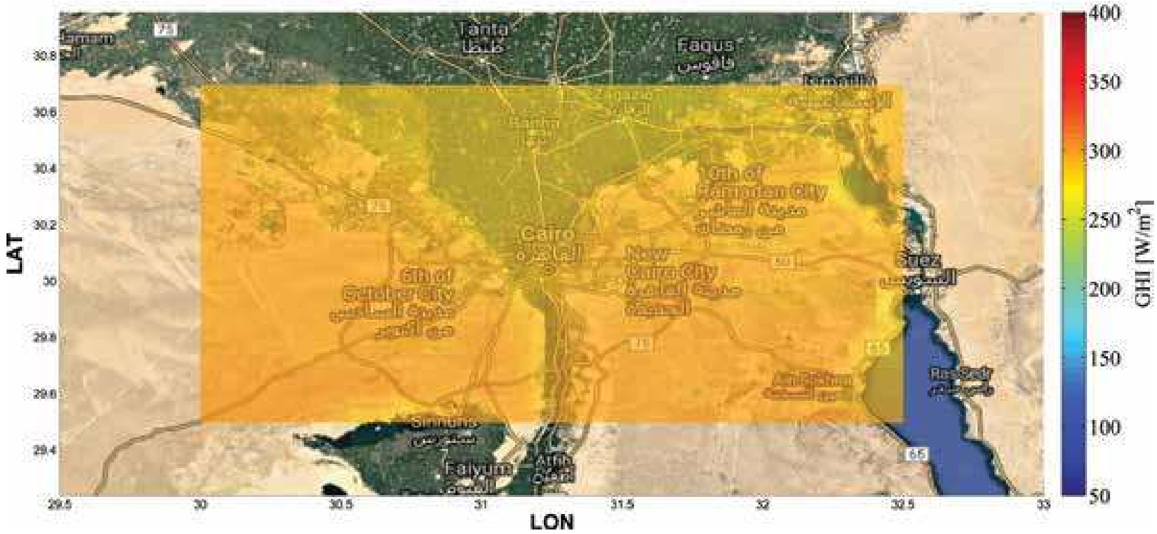


MARCH

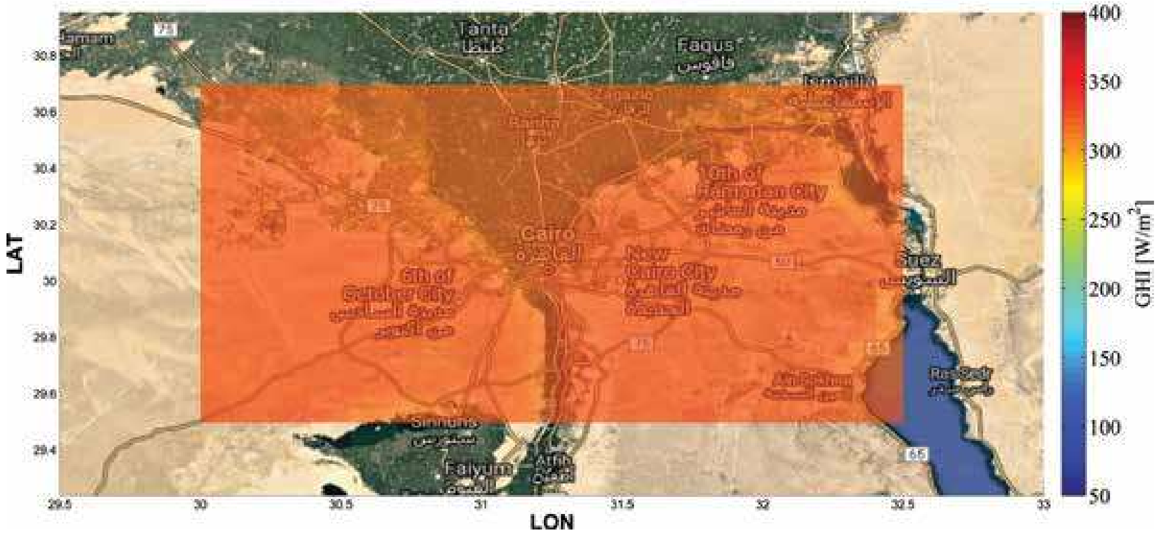
GHI (A&B)

CAIRO MEAN SURFACE DNI

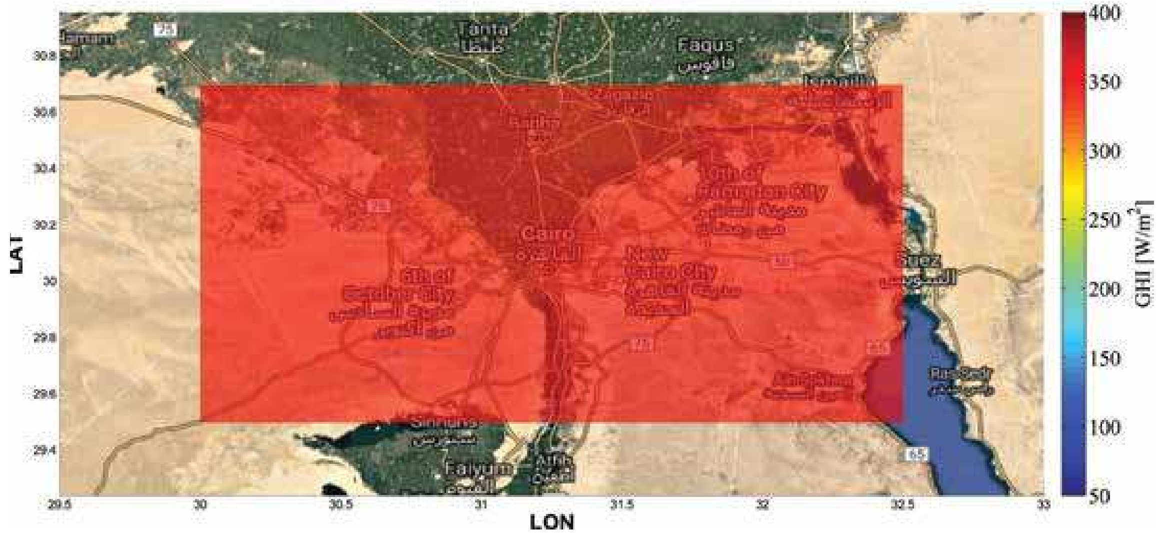
APRIL



MAY

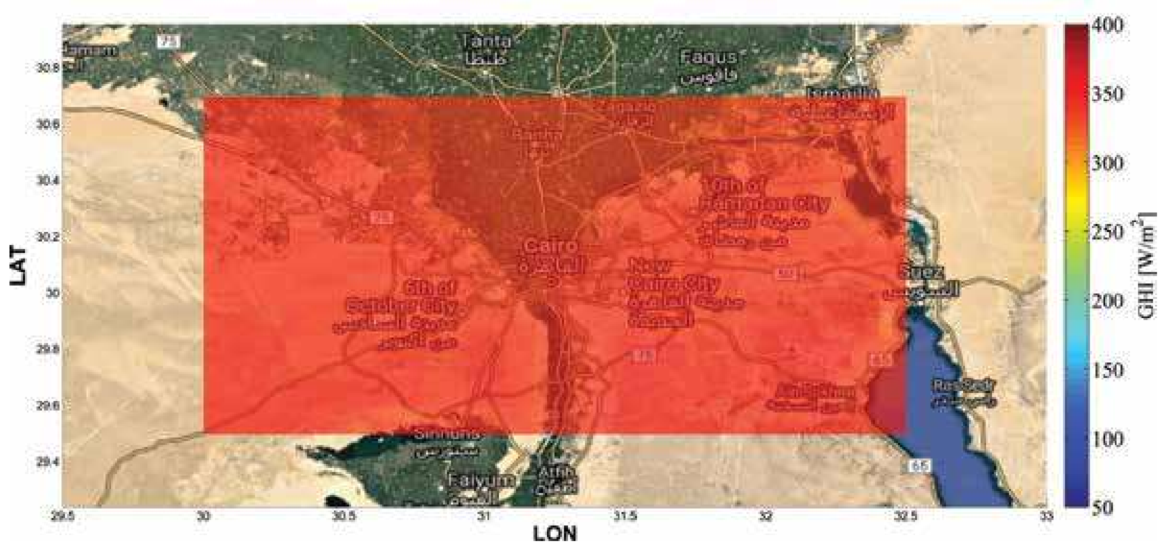


JUNE

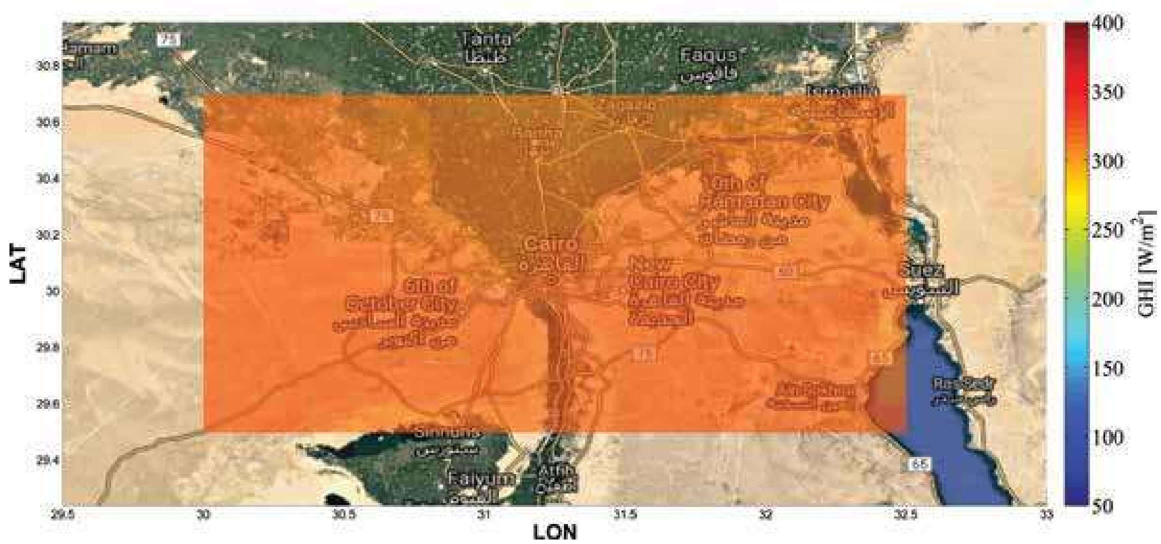


CAIRO

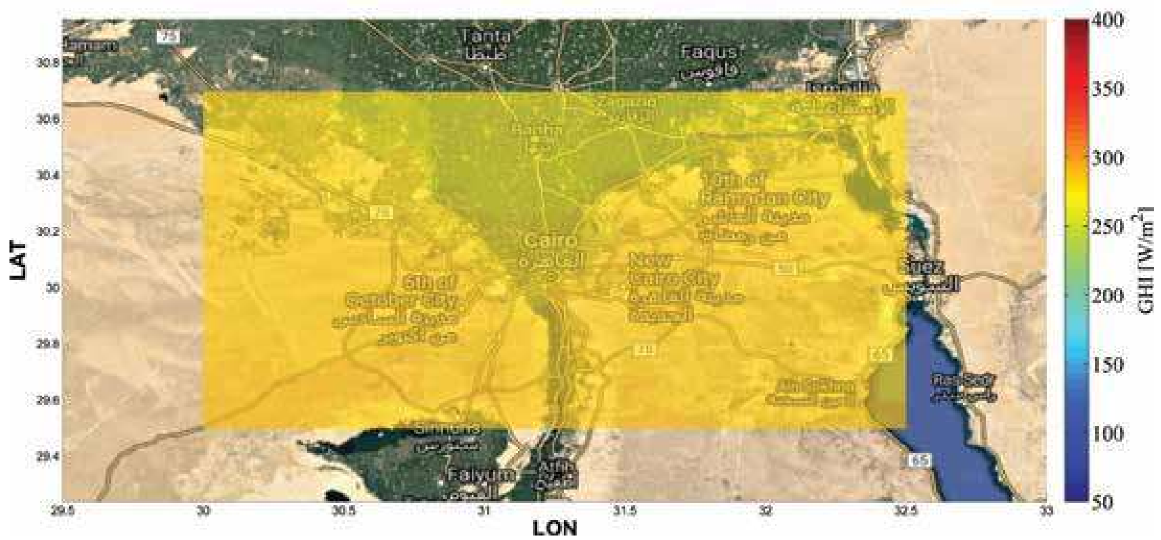
CAIRO MEAN SURFACE DNI



JULY



AUGUST

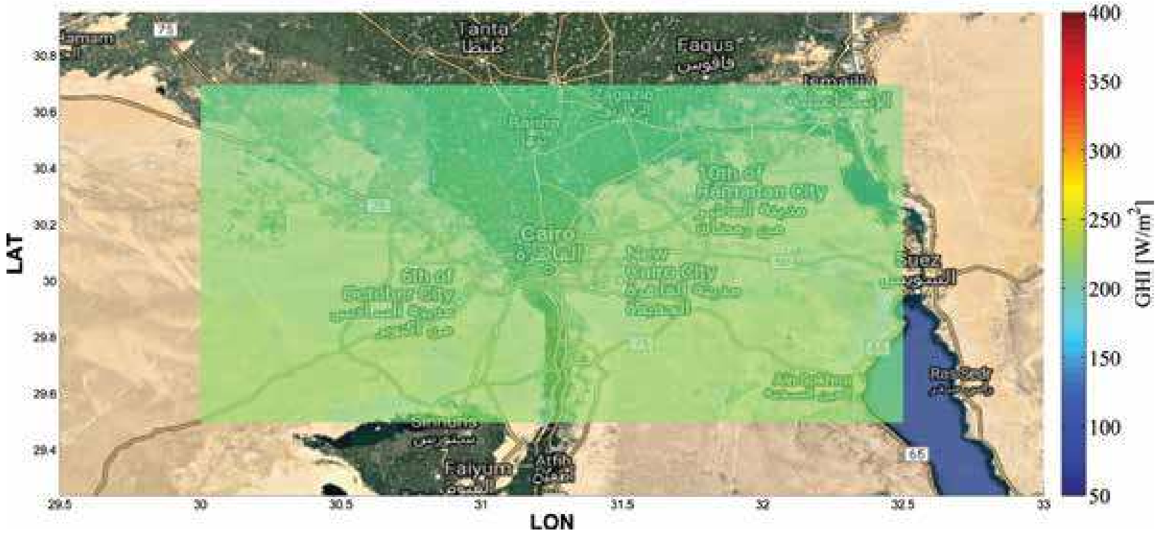


SEPTEMBER

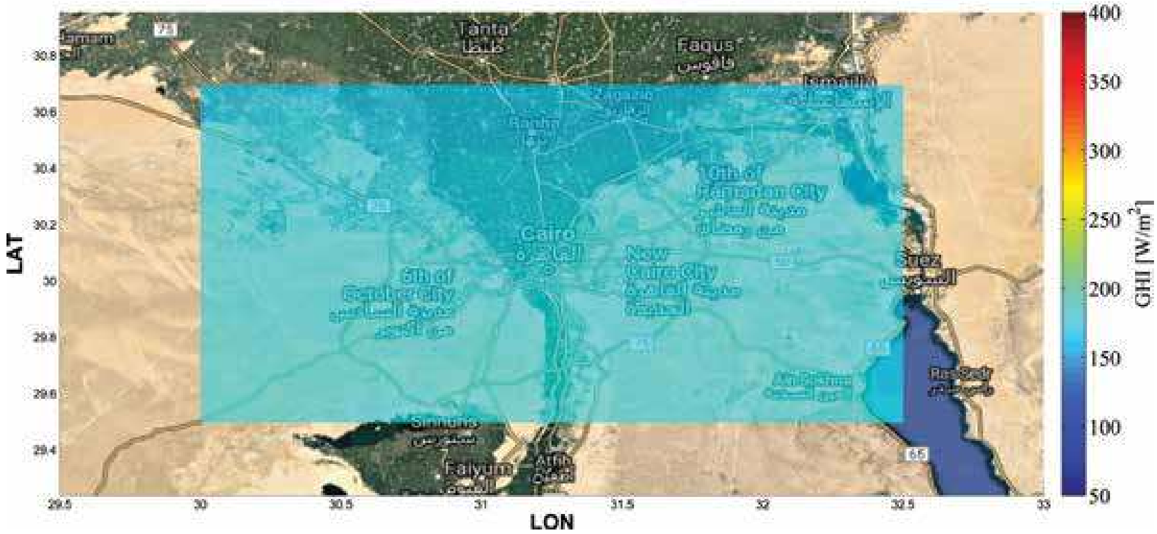
GHI (C&D)

CAIRO MEAN SURFACE DNI

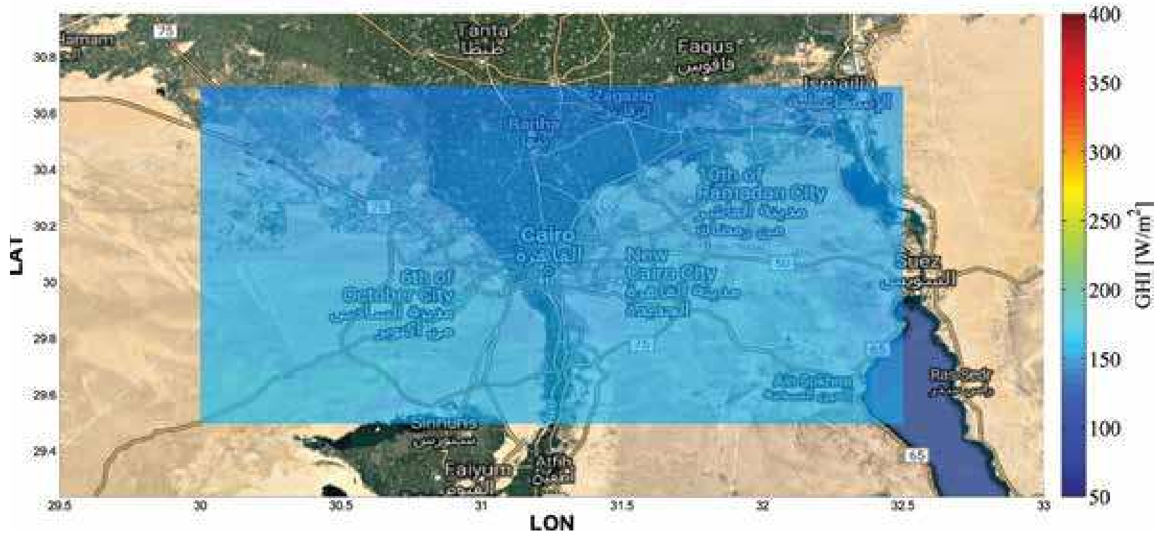
OCTOBER



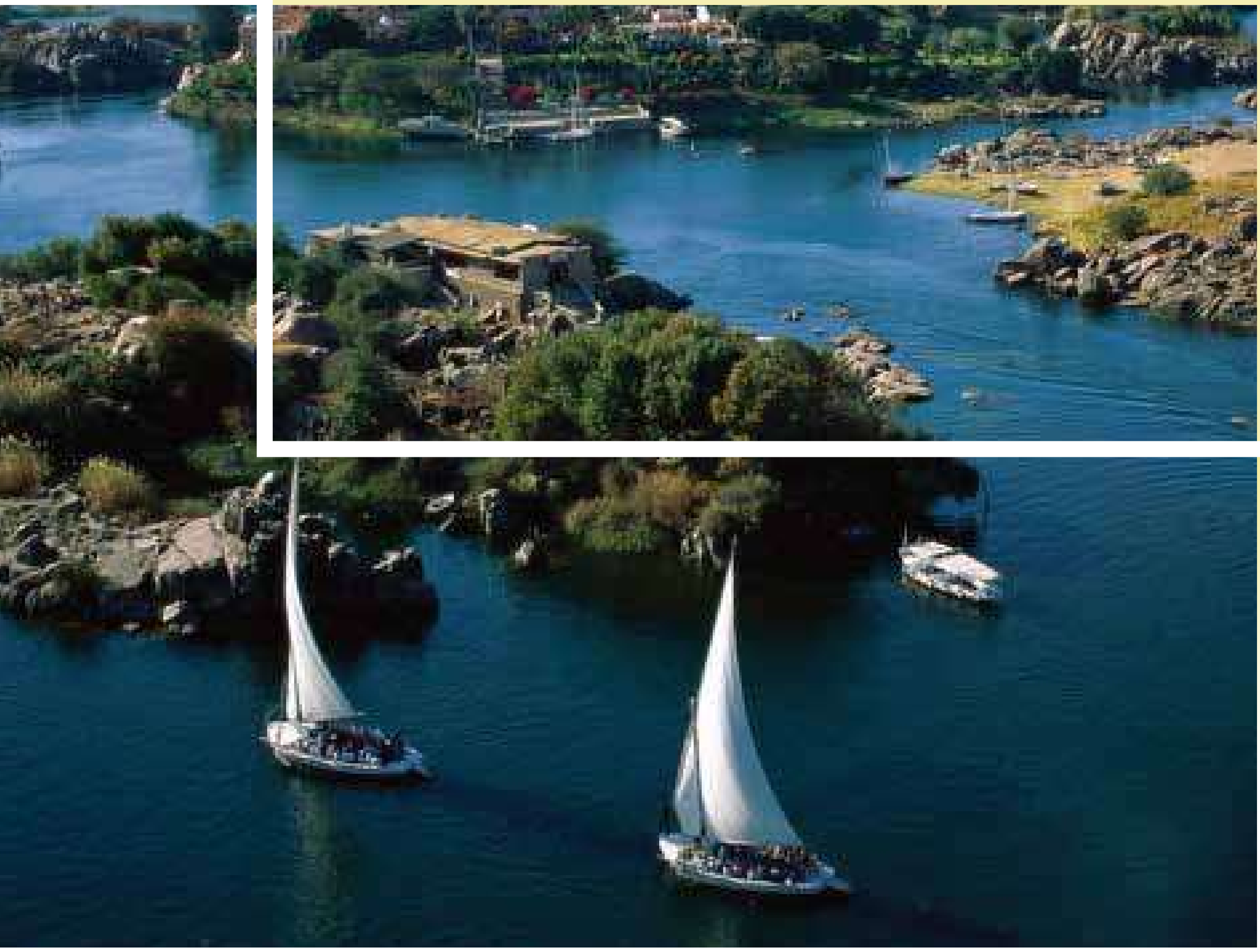
NOVEMBER



DECEMBER



SOUTHERN EGYPT

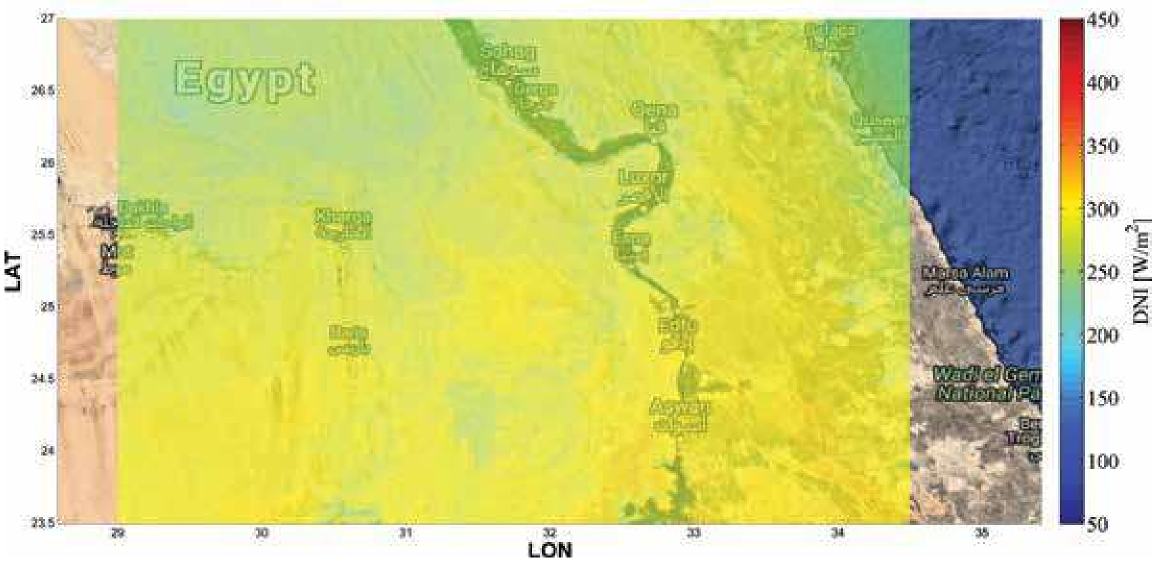


DNI

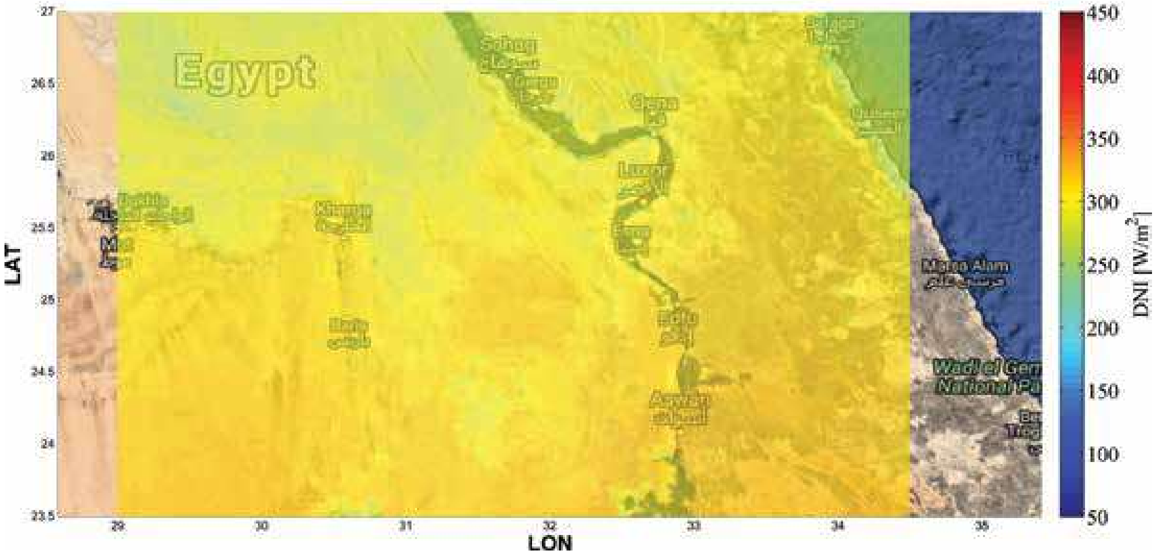
GHI

SOUTHERN EGYPT

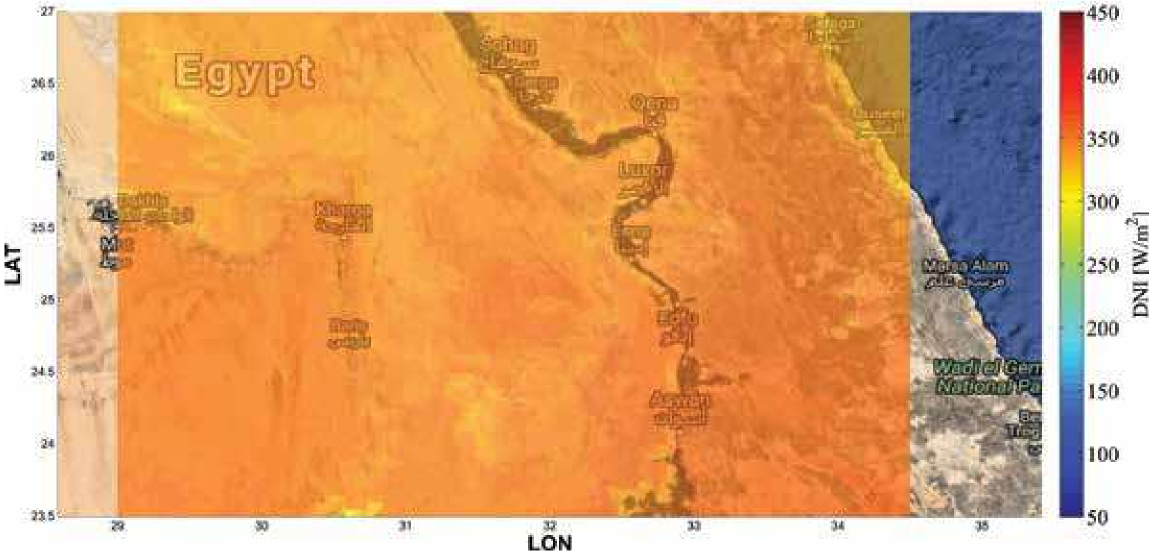
SOUTHERN MEAN SURFACE DNI



JANUARY



FEBRUARY

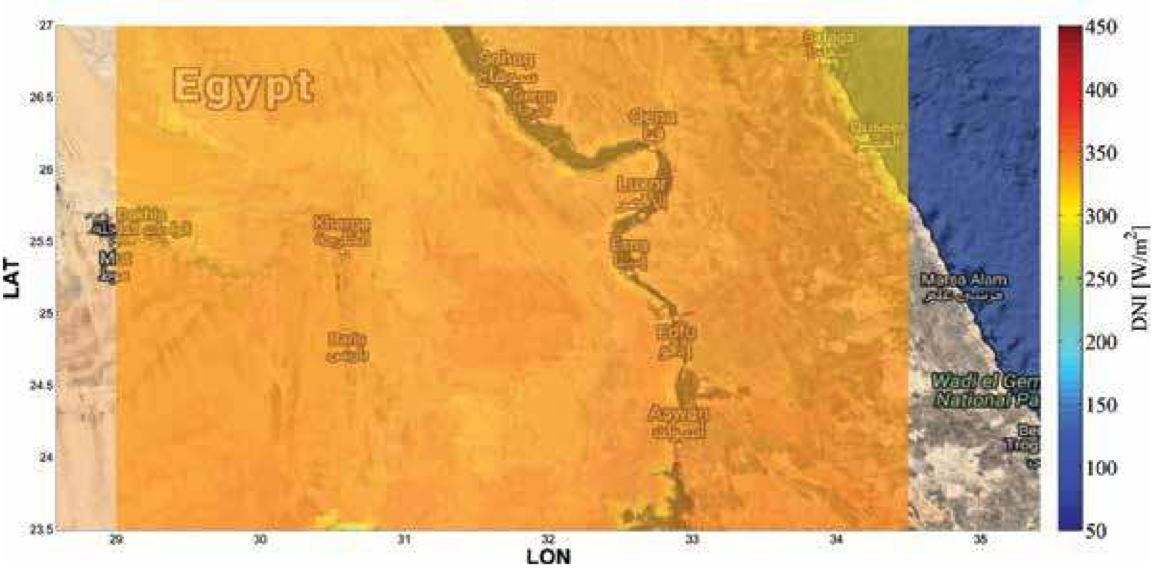


MARCH

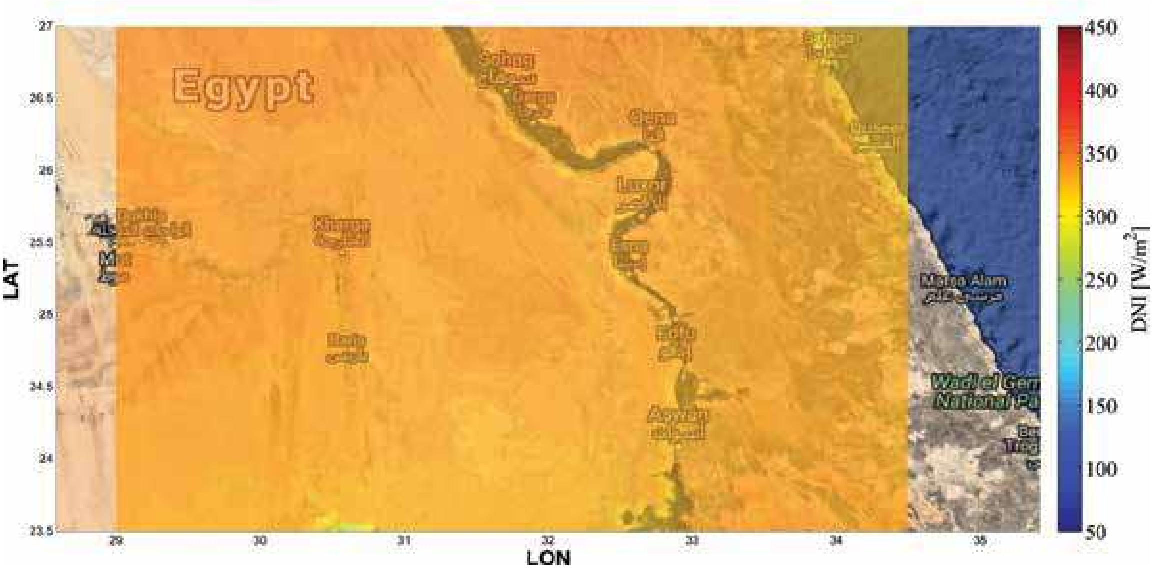
DNI (A&B)

SOUTHERN MEAN SURFACE DNI

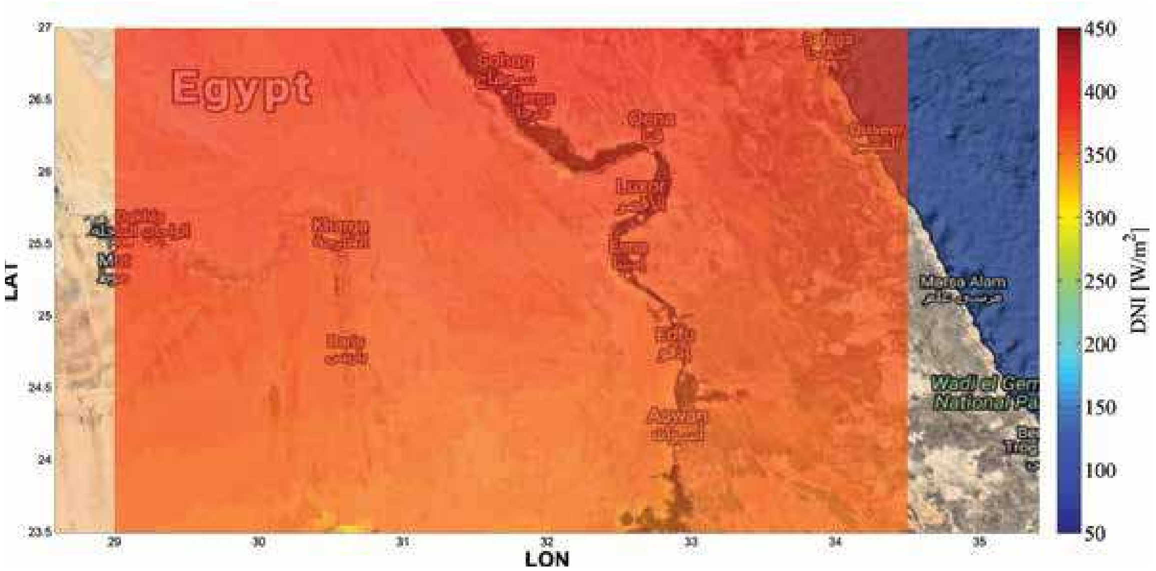
APRIL



MAY

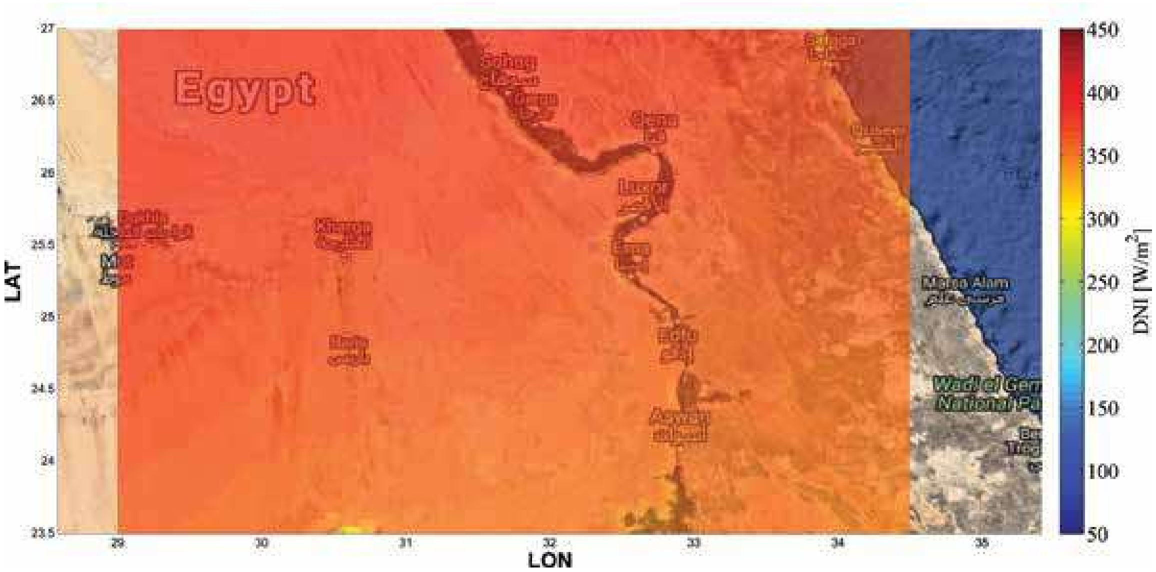


JUNE

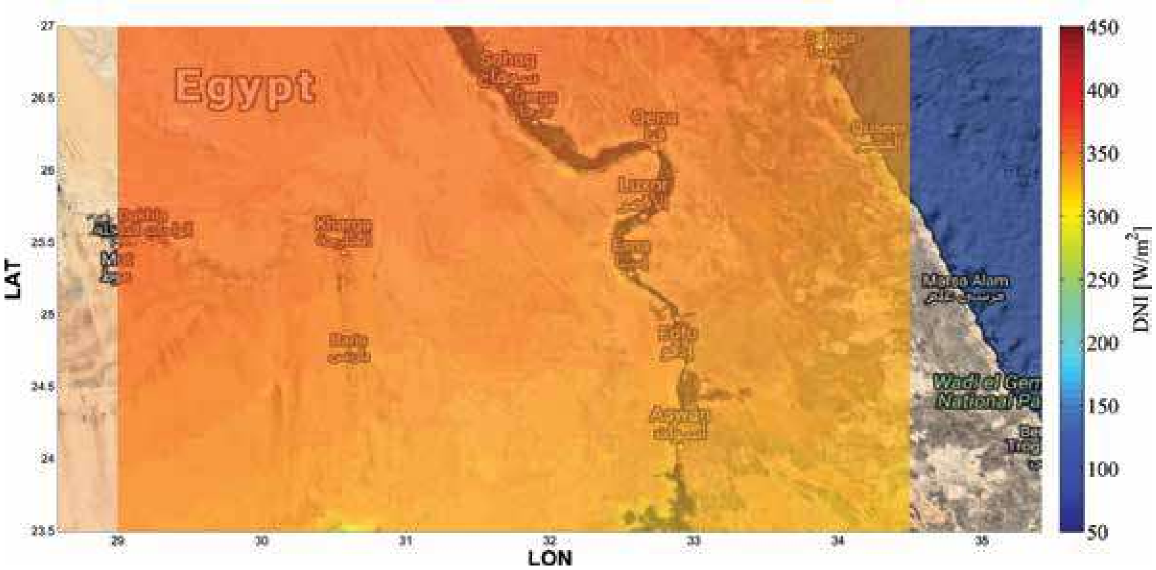


SOUTHERN EGYPT

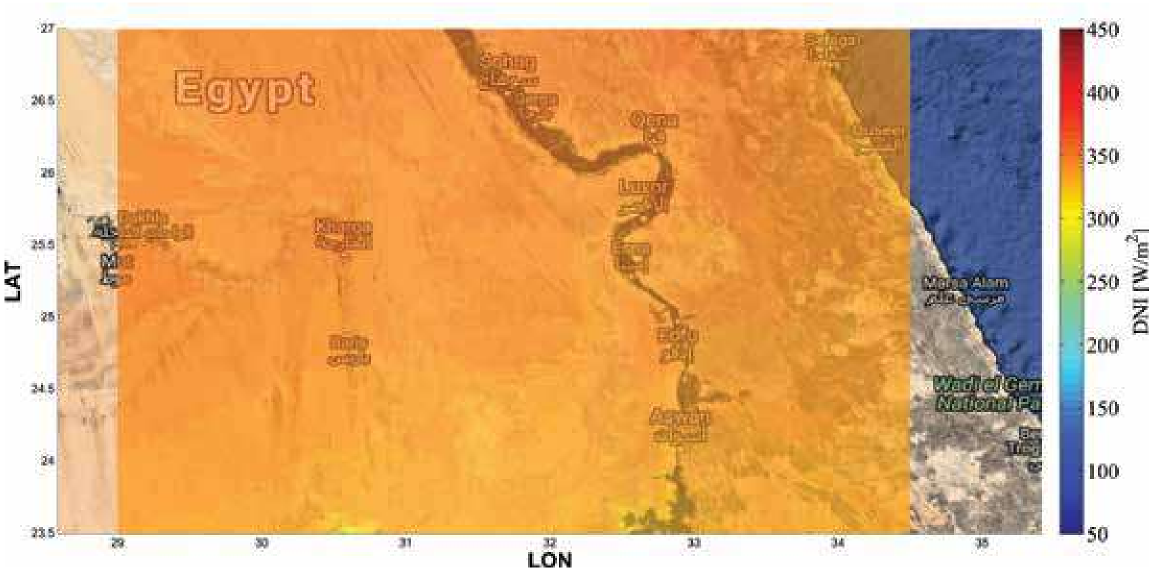
SOUTHERN MEAN SURFACE DNI



JULY



AUGUST

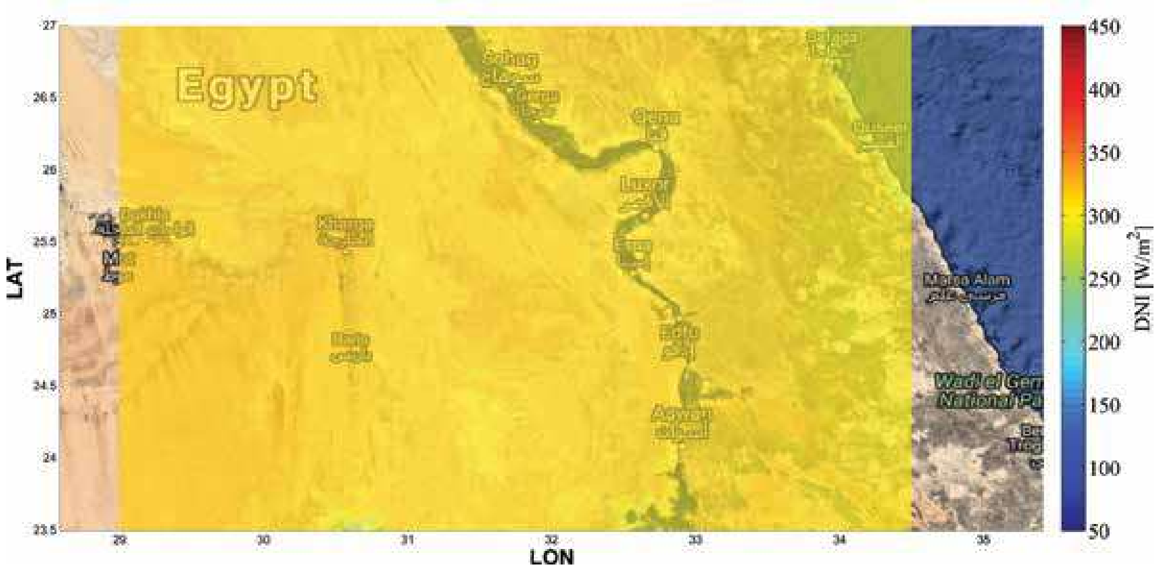


SEPTEMBER

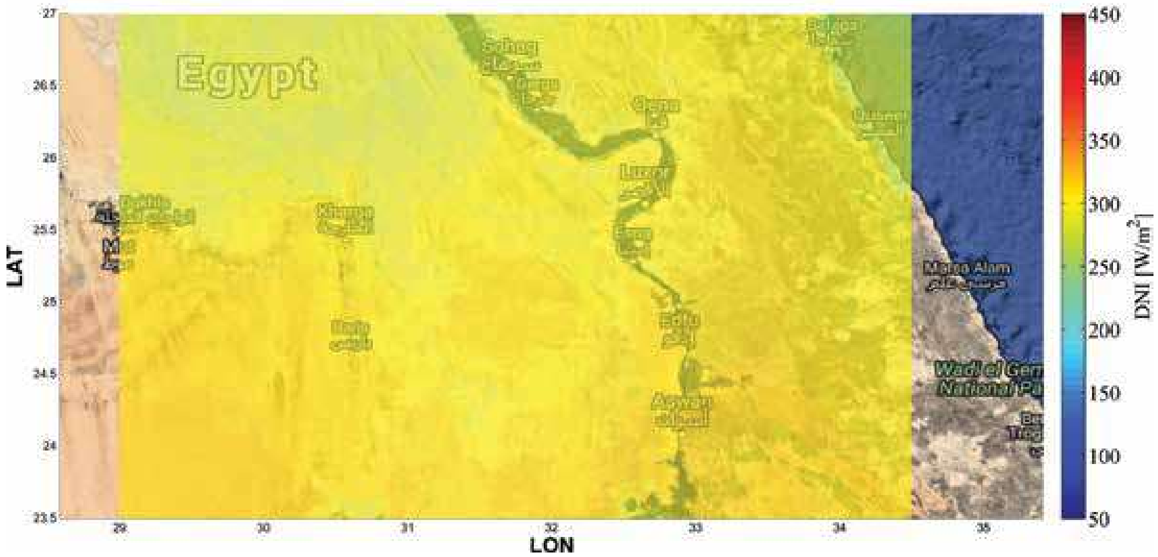
DNI (C&D)

SOUTHERN MEAN SURFACE DNI

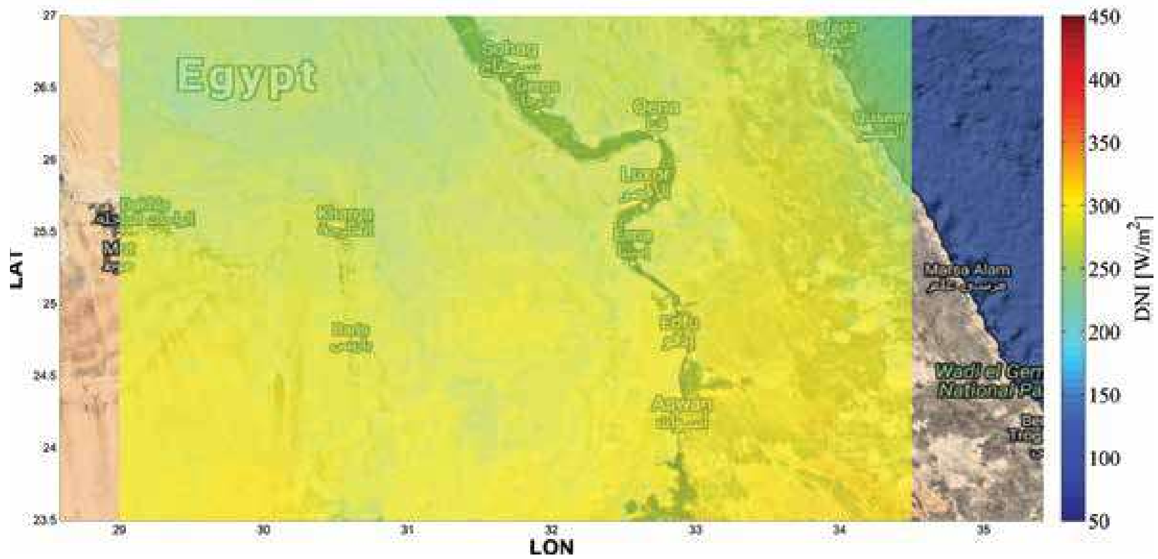
OCTOBER



NOVEMBER

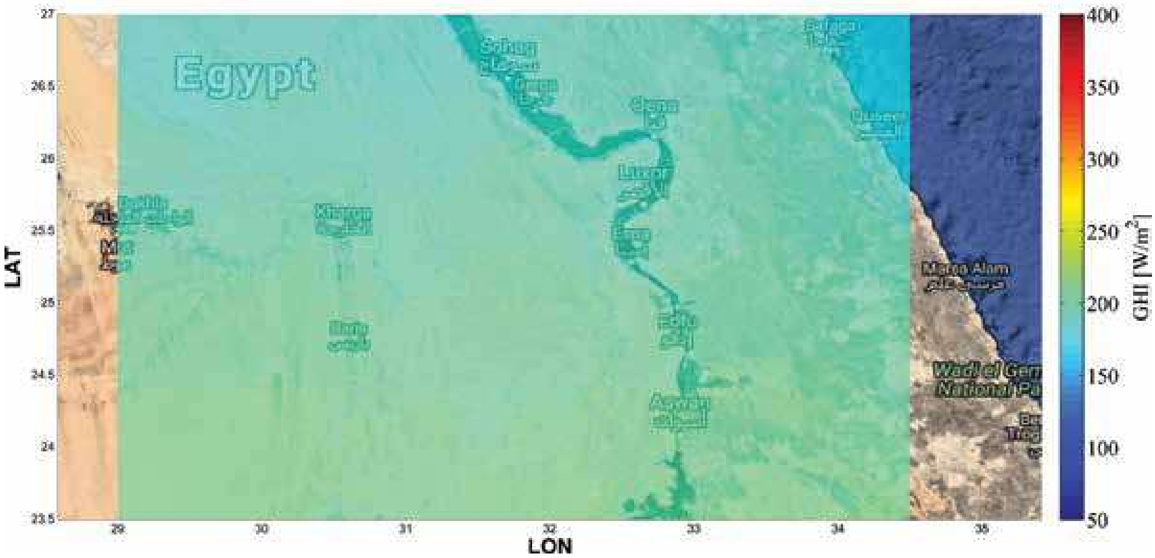


DECEMBER

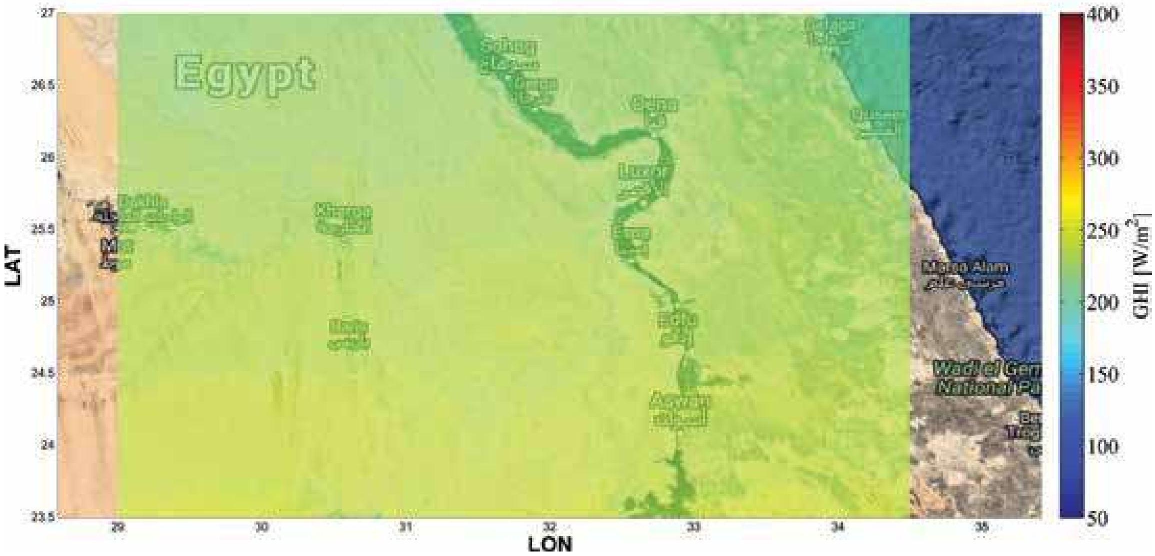


SOUTHERN EGYPT

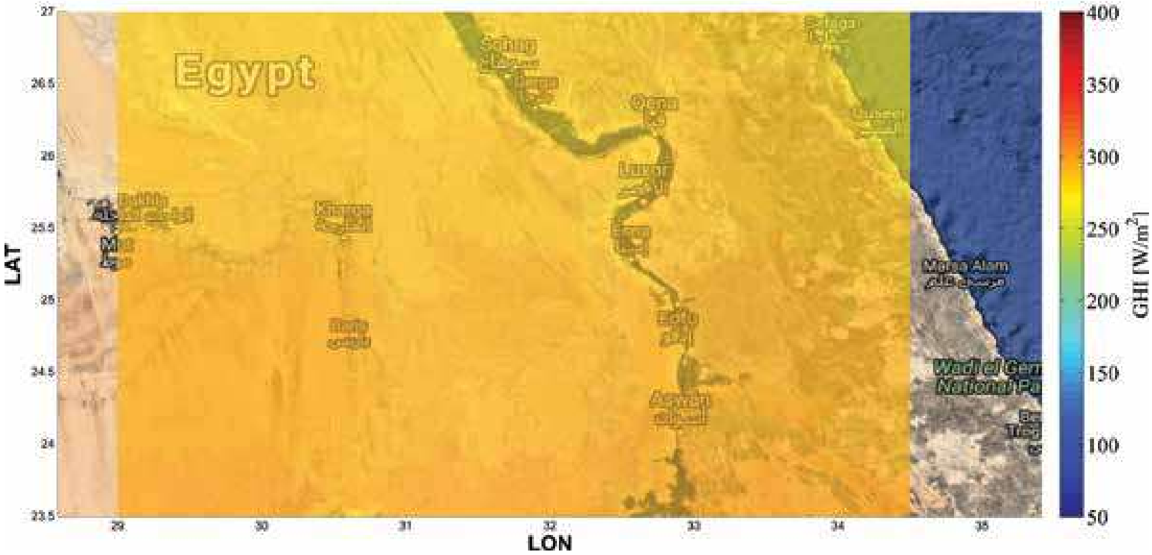
SOUTHERN MEAN SURFACE DNI



JANUARY



FEBRUARY

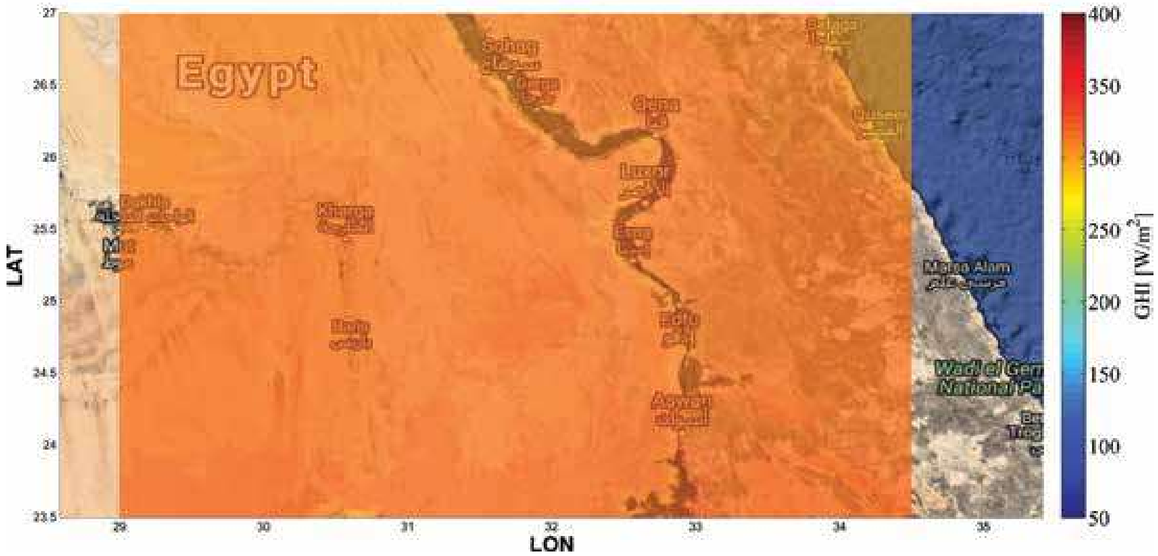


MARCH

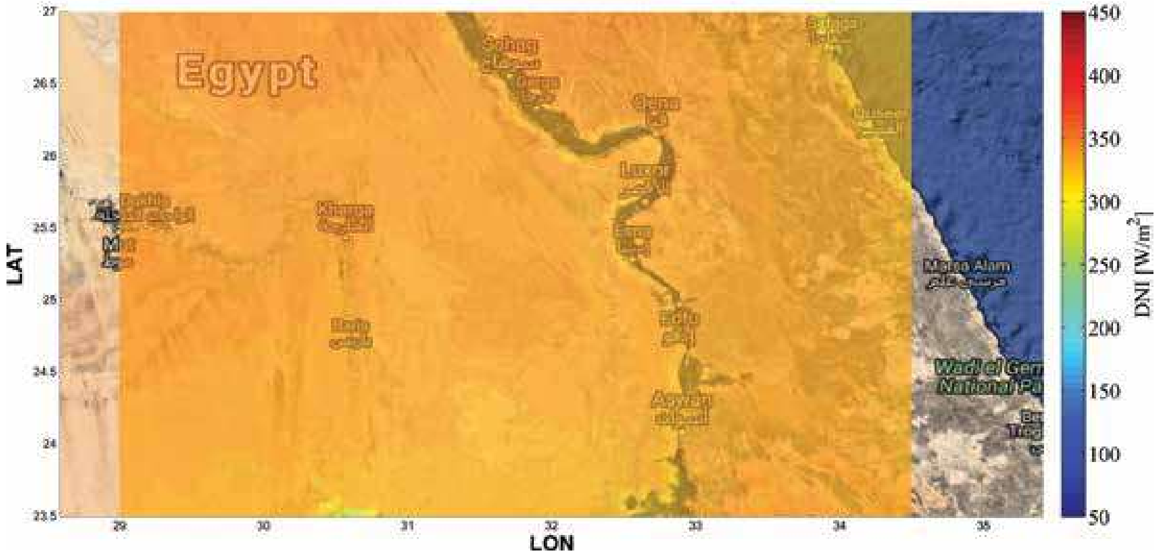
GHI (A&B)

SOUTHERN MEAN SURFACE DNI

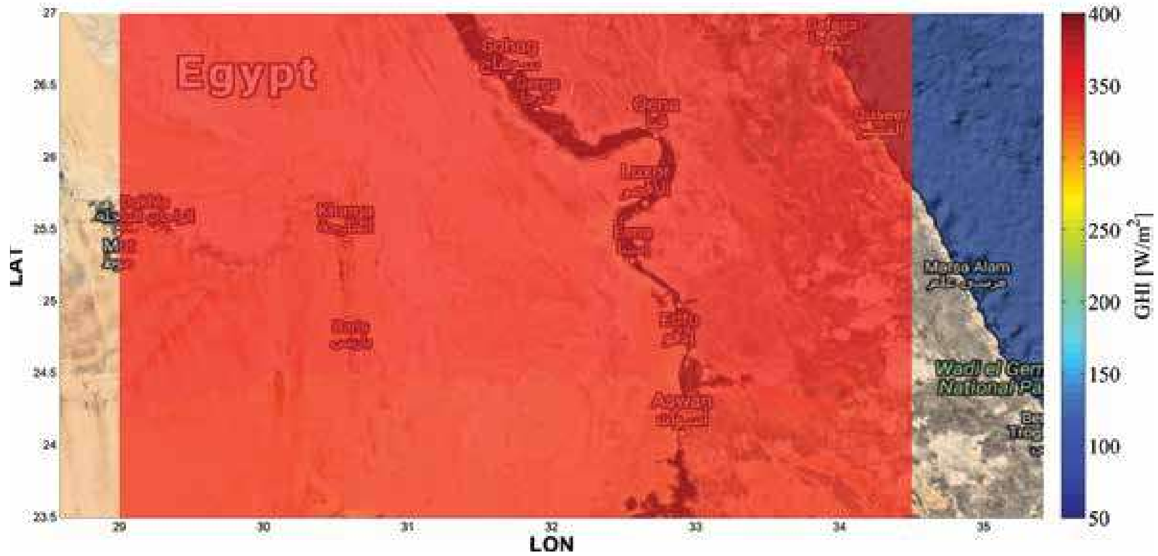
APRIL



MAY

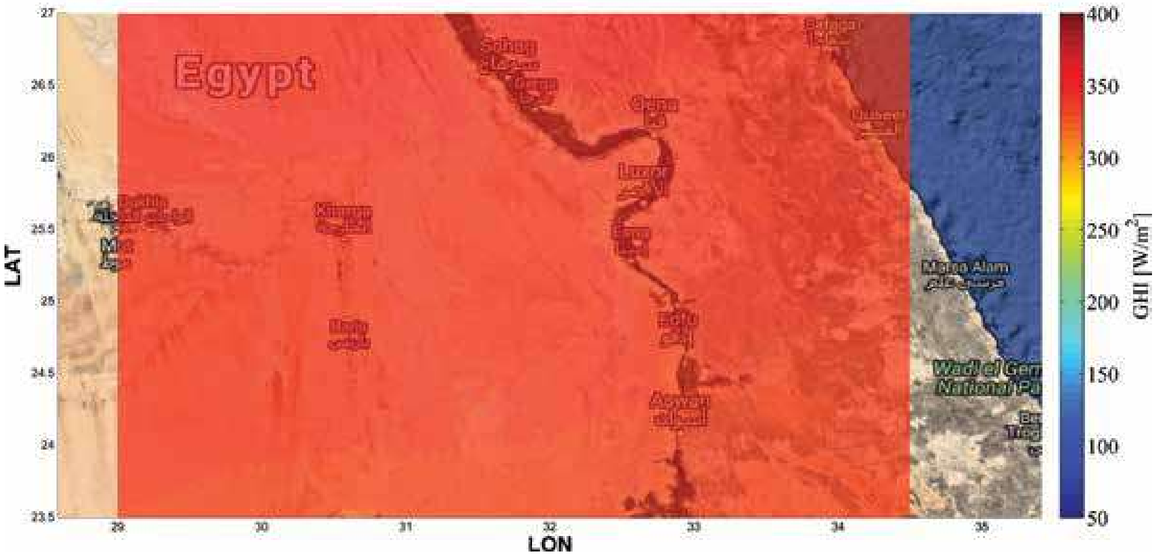


JUNE

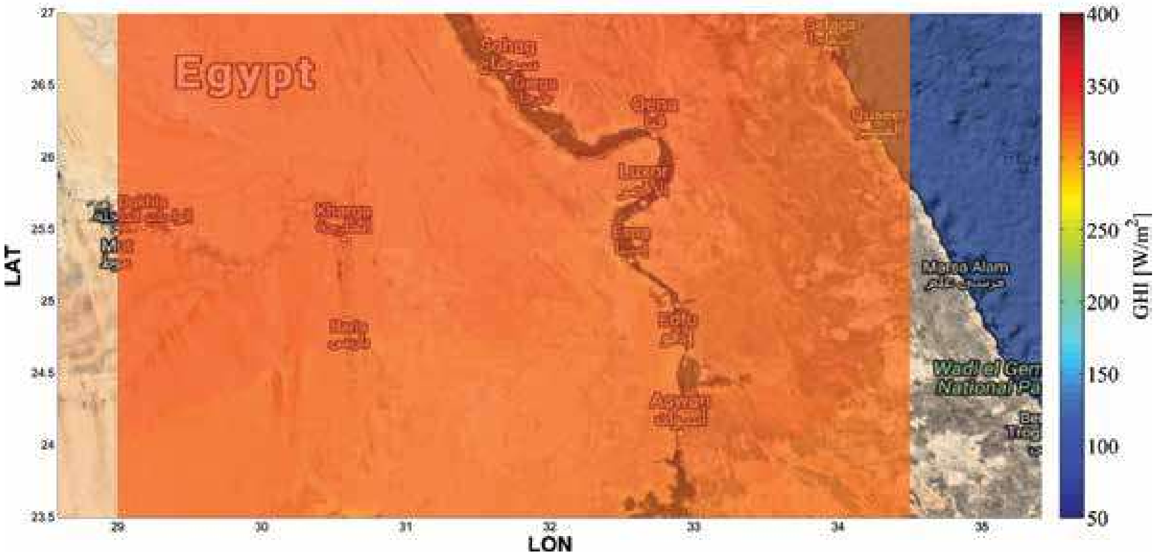


SOUTHERN EGYPT

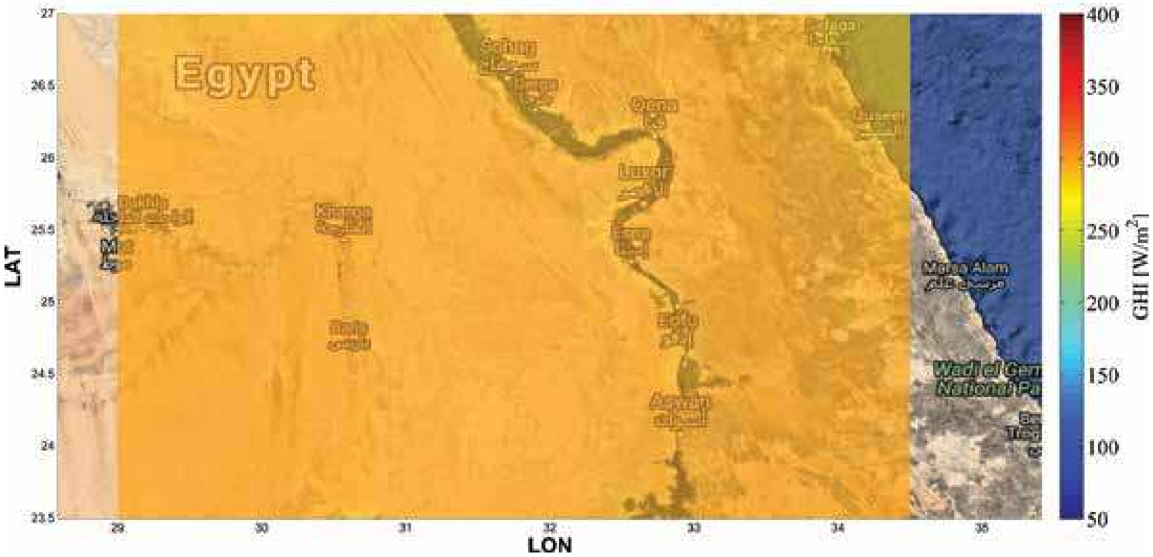
SOUTHERN MEAN SURFACE DNI



JULY



AUGUST

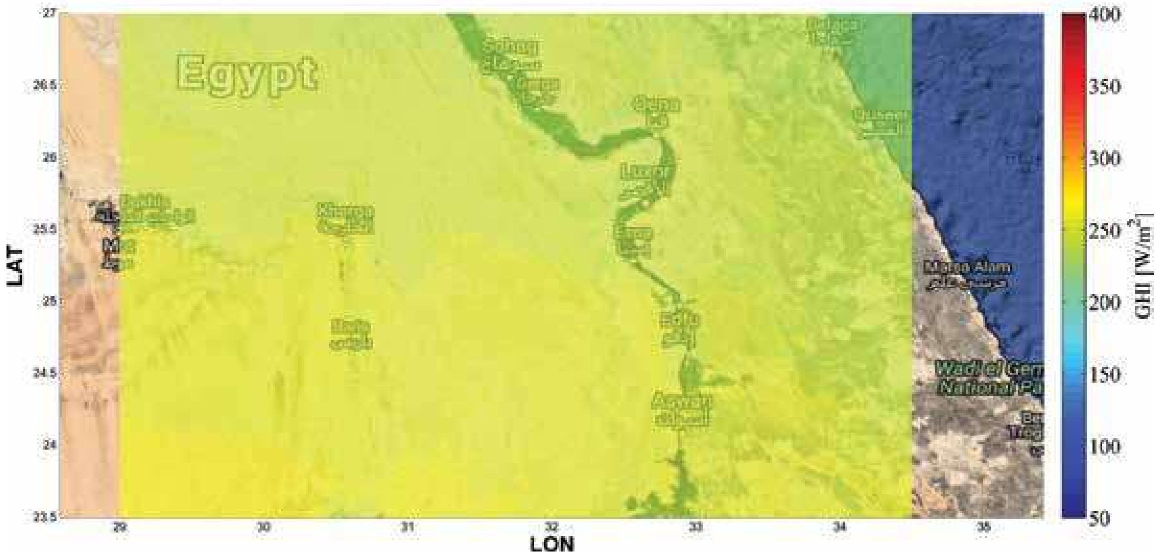


SEPTEMBER

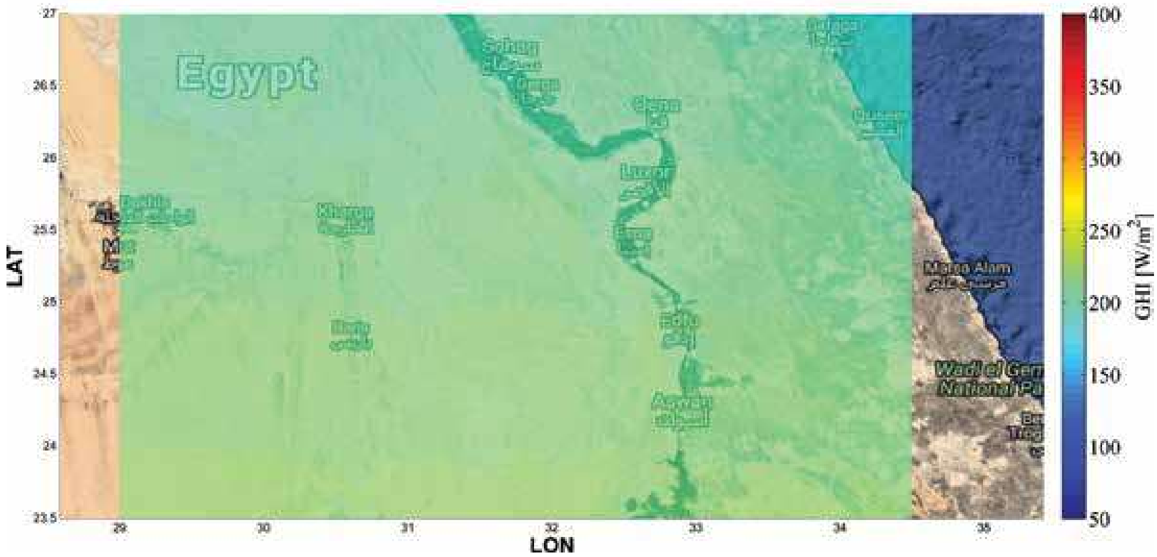
GHI (C&D)

SOUTHERN MEAN SURFACE DNI

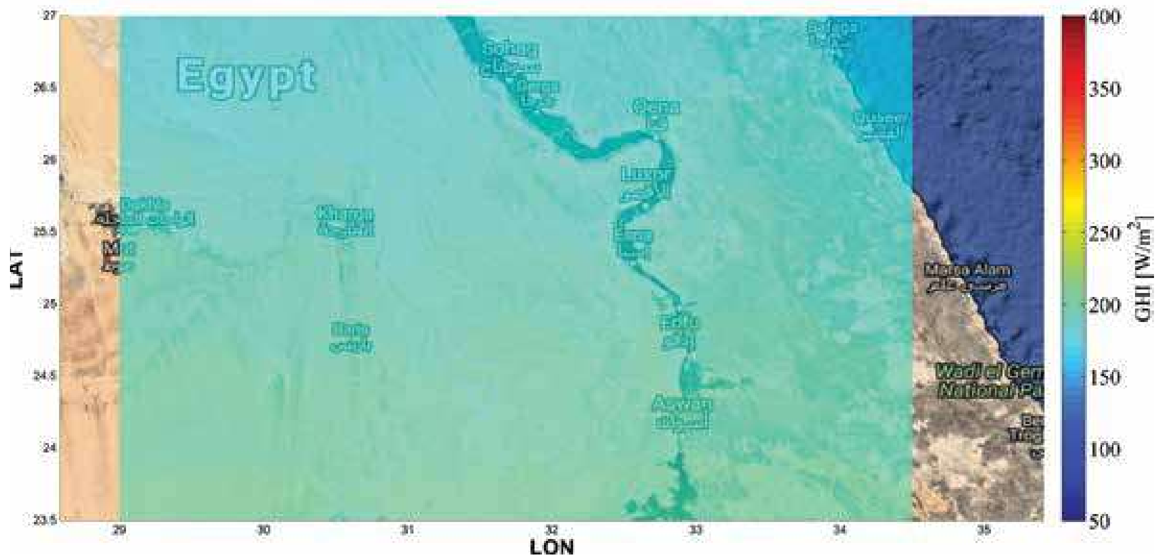
OCTOBER



NOVEMBER



DECEMBER



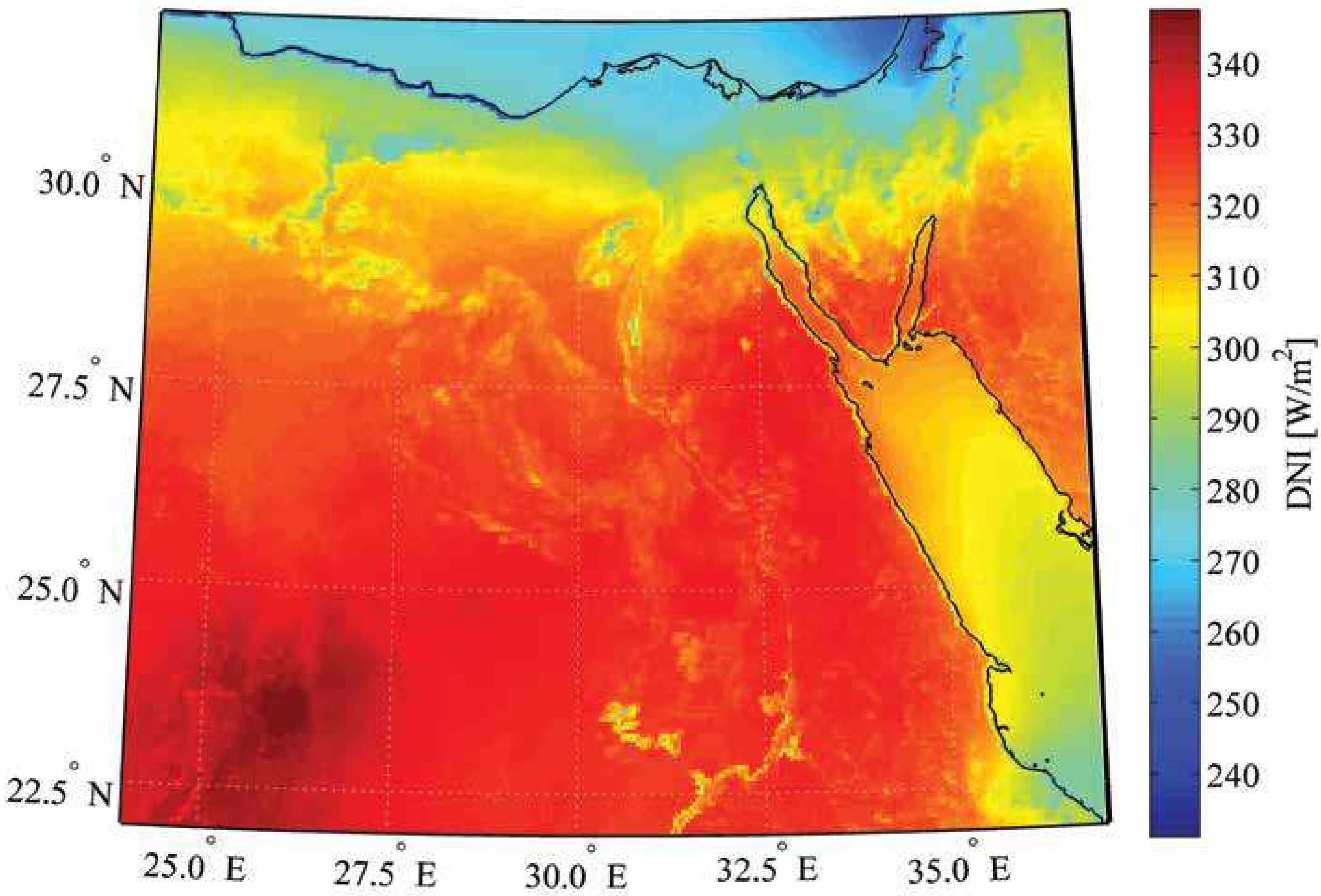
03

SOLAR ATLAS OF TOTAL DNI AND GHI

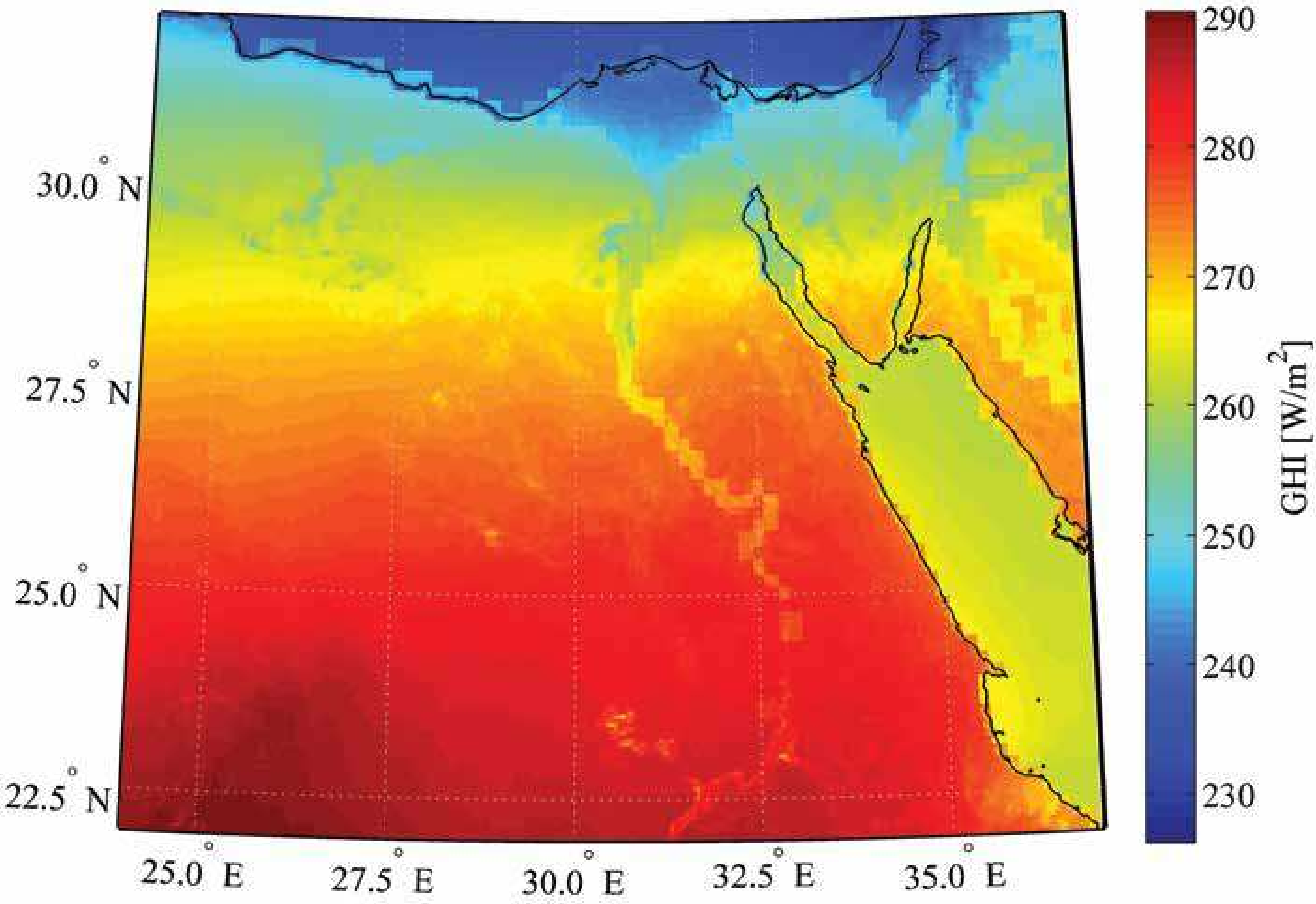
The mean surface DNI was calculated by using the mean monthly DNI values from Jan. 1999 to Dec. 2013. This 15-year climatology of DNI allows us to quantify the solar power and energy potential in Egypt for efficient exploitation in CSP installation.

For the mean surface GHI, the mean monthly GHI values for the same 15-year period was used which can potentially support the local authorities to identify the optimum locations for PV installations.

DNI SOLAR ATLAS 1999-2013

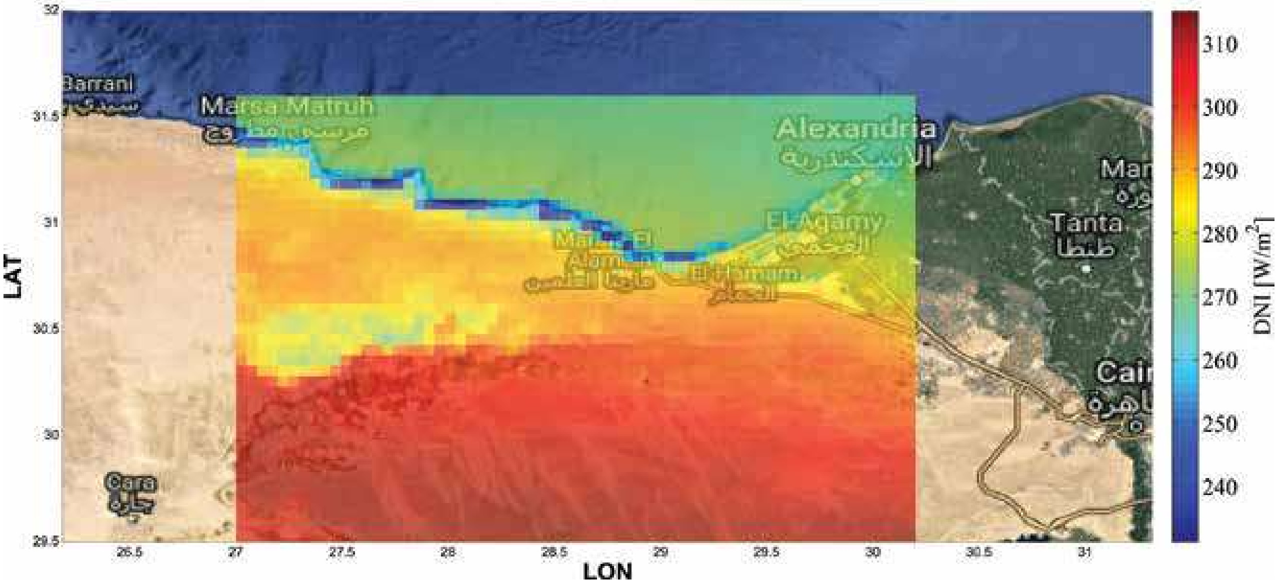


GHI SOLAR ATLAS 1999-2013

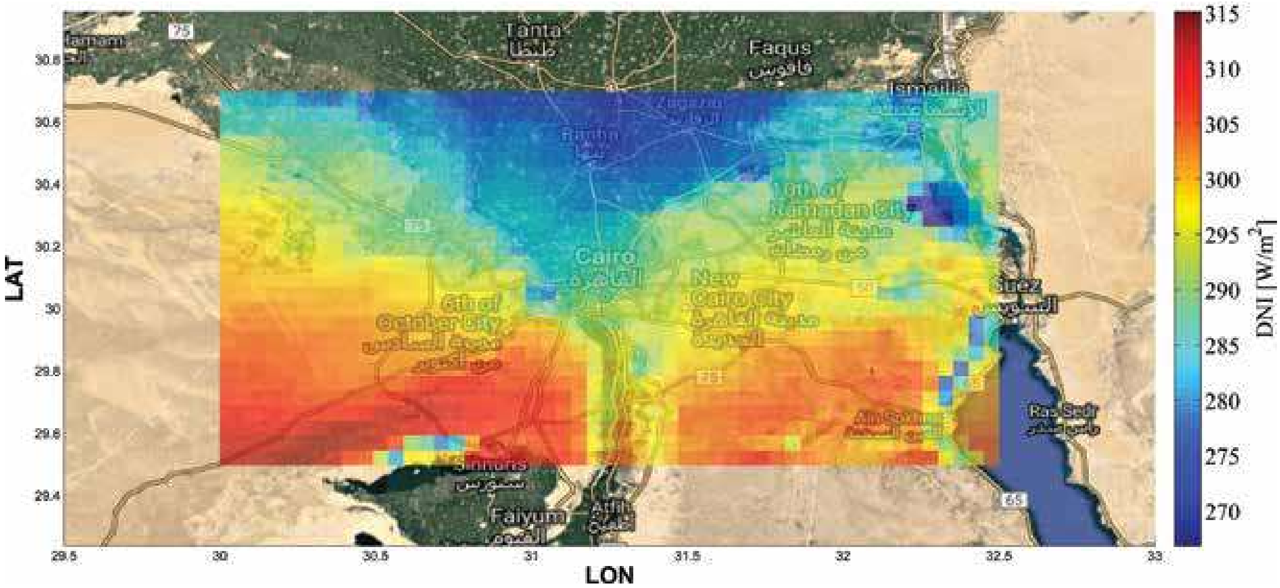


The same EUMETSAT dataset was implemented for the specific greater region of Alexandria (Northern Egypt), Cairo (Center Egypt, greater Nile Delta region) and Southern Egypt (greater area of Luxor and Aswan). In both DNI and GHI maps, a comprehensive view of the climatological surface irradiance conditions was provided, as to compare in general the potential solar power and energy conditions at places with different geographical and climatological background.

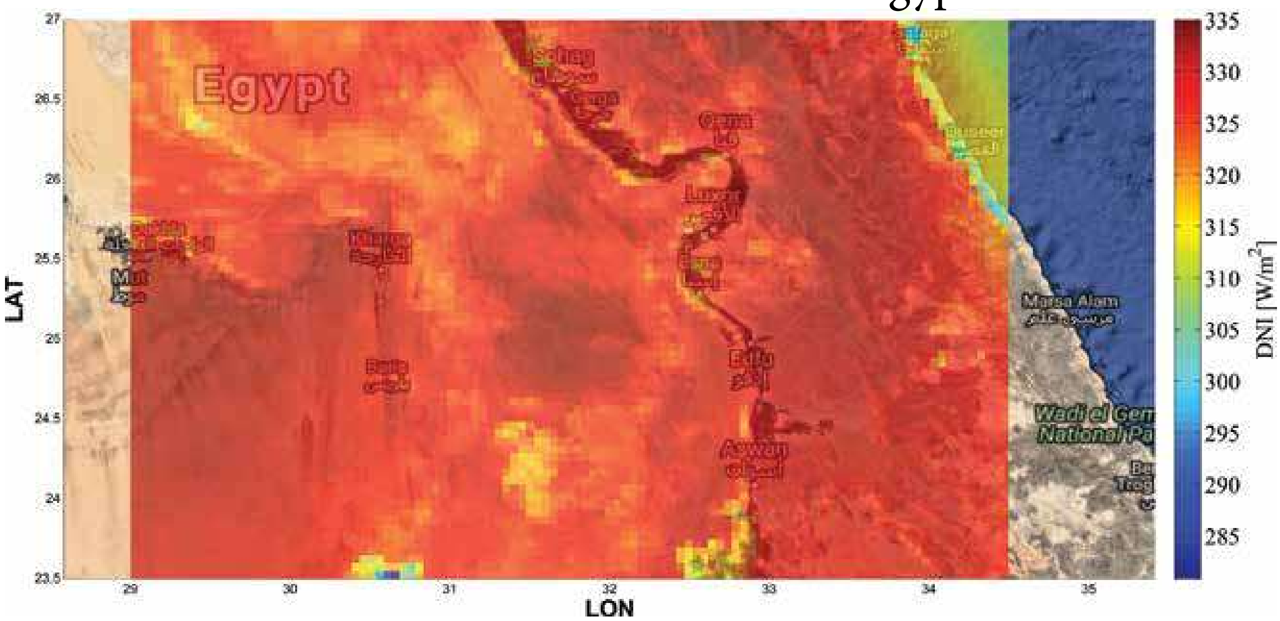
DNI Solar Atlas of Alexandria



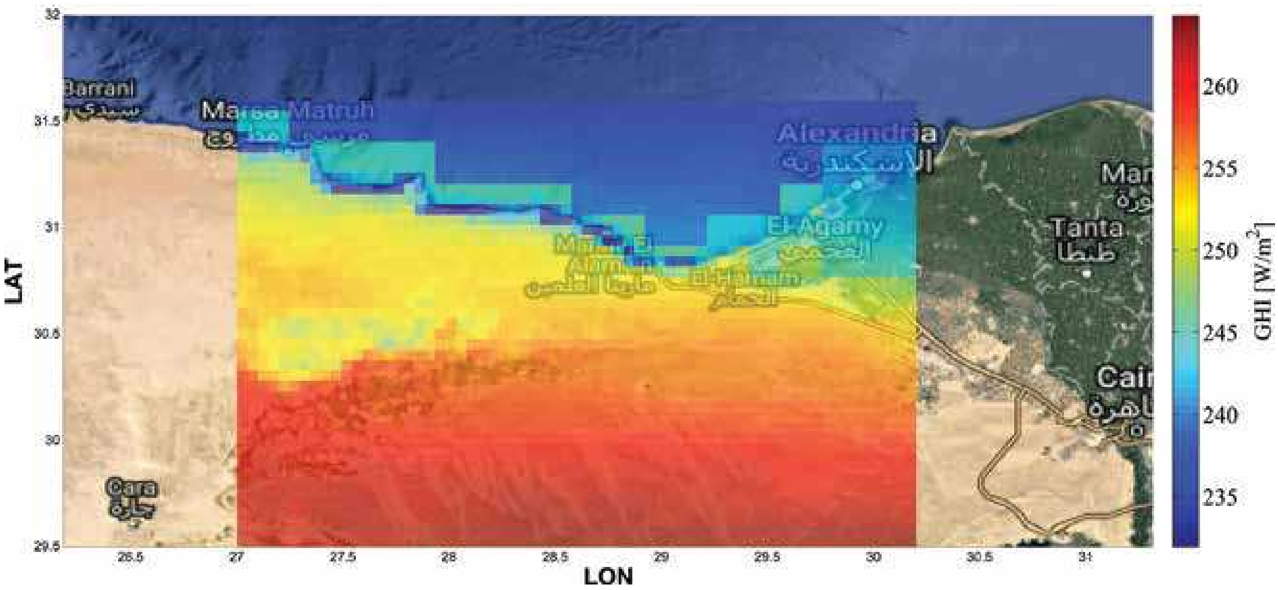
DNI Solar Atlas of Cairo



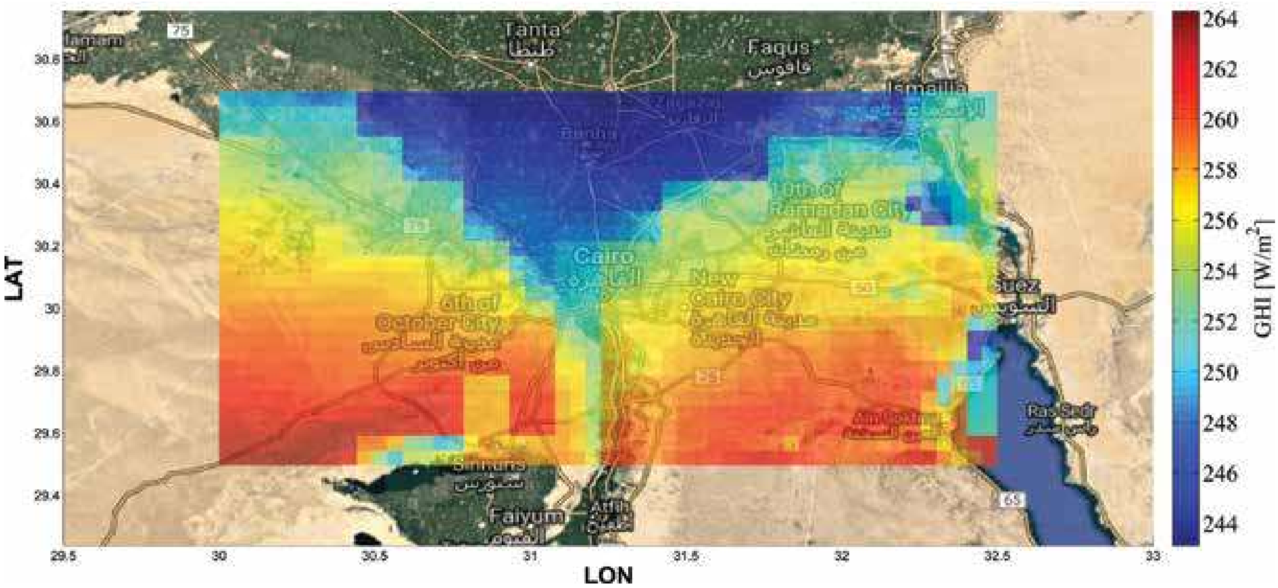
DNI Solar Atlas of Southern Egypt



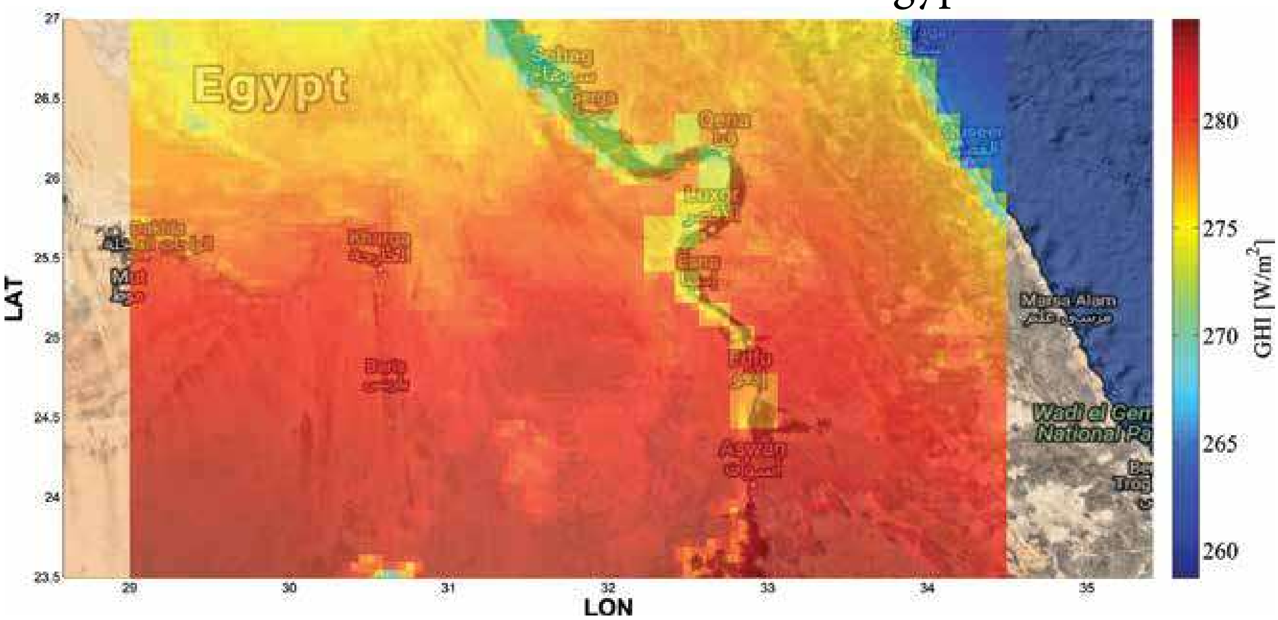
GHI Solar Atlas of Alexandria



GHI Solar Atlas of Cairo



GHI Solar Atlas of Southern Egypt

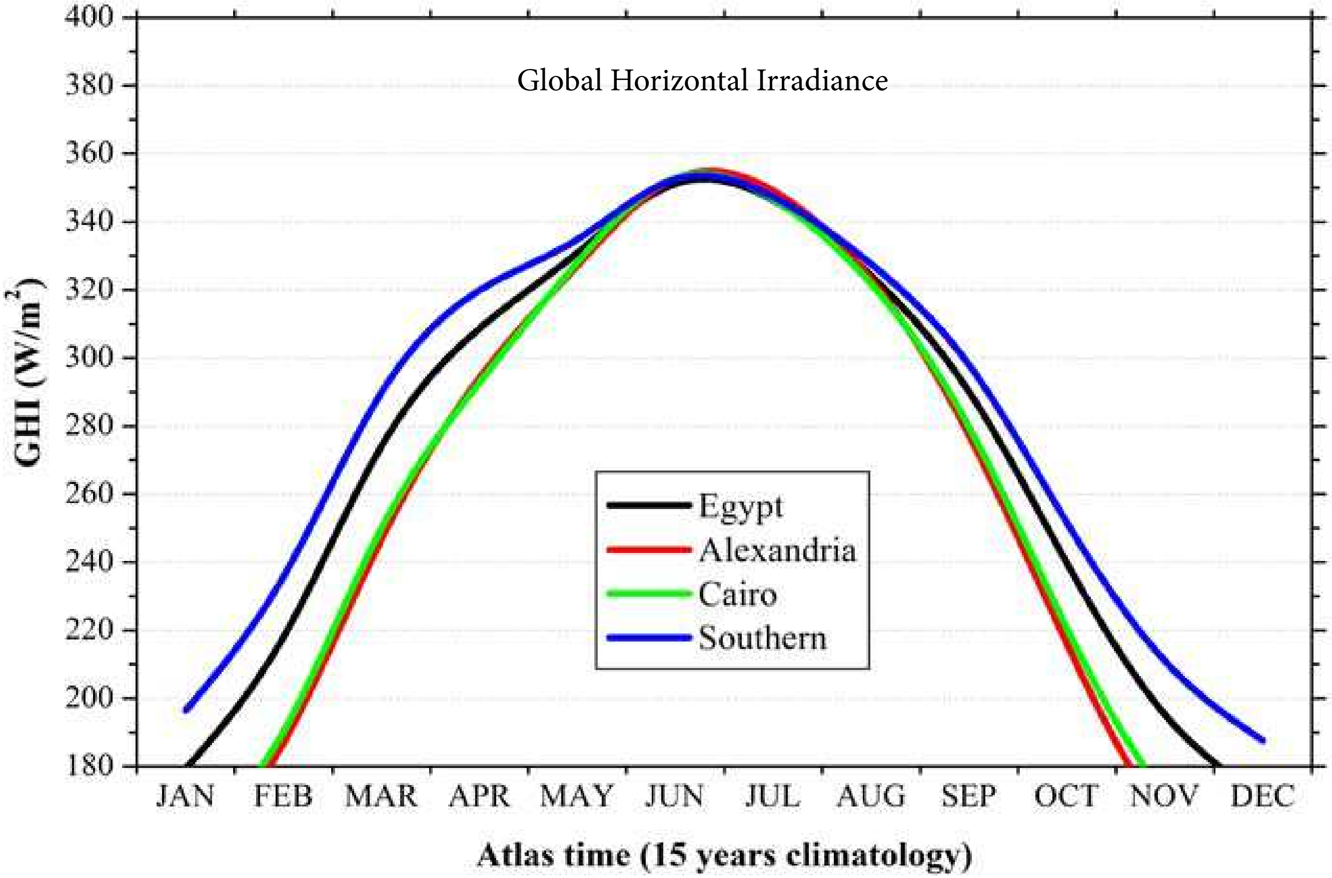


The figures below represent the mean inter annual GHI and DNI curves by calculating the mean of means for the 15-years period (Jan 1999 - Dec 2013) for the whole Egypt region as compared with the three sub-locations. The GHI shows a typical summer maximum in all cases reaching means values around 350 W/m2, while in winter months the lowest GHI is about 180 to 190 W/m2. Southern Egypt has the largest values in all months and the lowest are in northern Egypt (greater region of Alexandria).

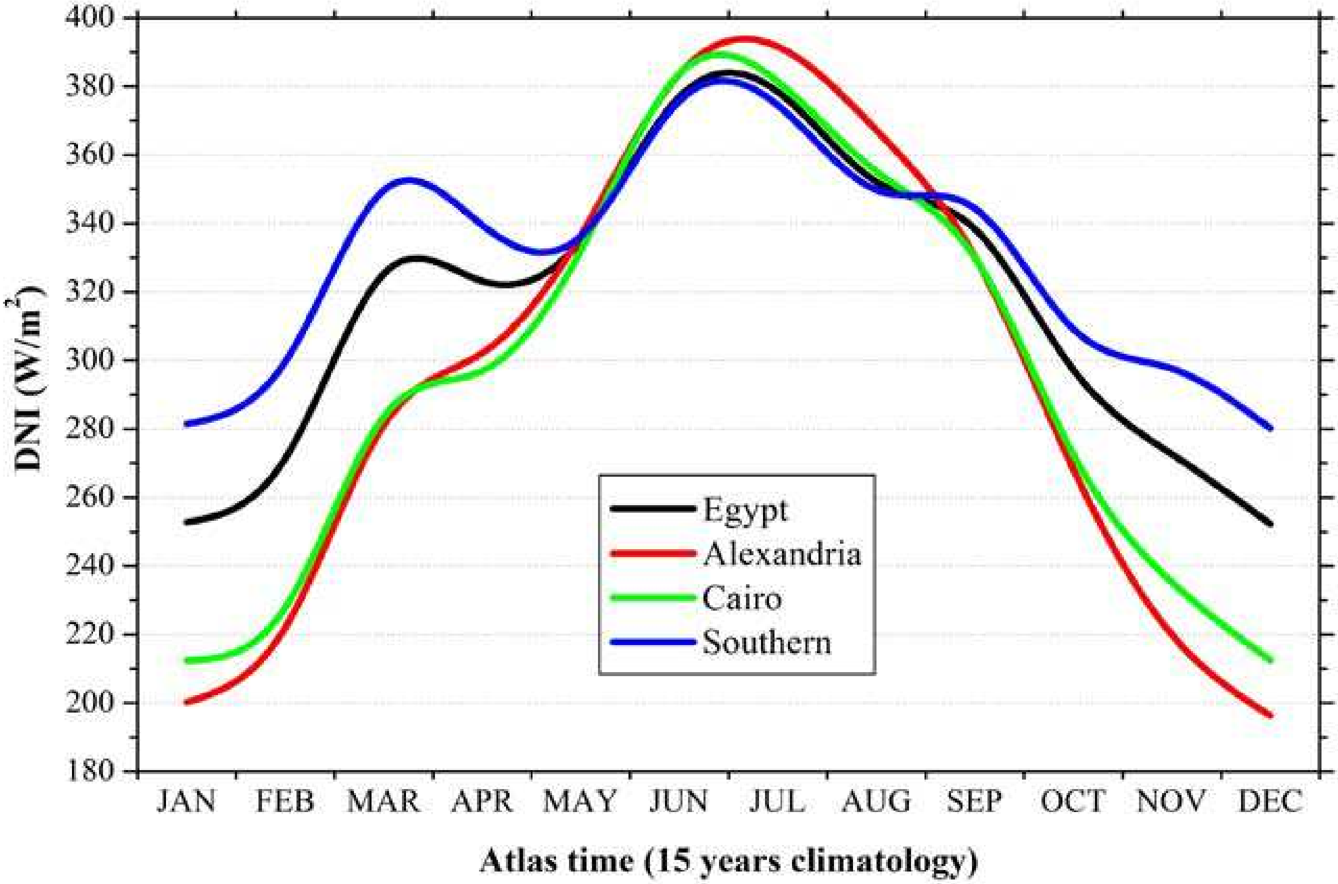
The DNI presents the maximum mean values in summer months as well starting from March with DNI of about 330 W/m2 (Egypt) to 380 W/m2 in July. A local reduction in April and May for the southern Egypt region and the mean values of Egypt was found and has to do with the relatively increased cloud coverage and frequent dust storms in the late spring (mean DNI in the period April-May is 325-350 W/m2). Southern Egypt has the highest mean DNI values in winter and autumn, while in summer the highest power values are in Delta of Nile and northern Egypt regions reaching 390 W/m2.

MEAN SOLAR POWER AND ENERGY FOR EGYPT AND THE THREE SUB-REGIONS.

ATLAS 15 YEARS CLIMATOLOGY	SOLAR POWER (W/M2)		SOLAR ENERGY (KWH/M2)	
	DNI	GHI	CSP	PV
EGYPT	292	252	2554	2208
ALEXANDRIA	294	255	2572	2230
CAIRO	328	279	2875	2447
SOUTHERN	315	269	2756	2357



DIRECT NORMAL IRRADIANCE



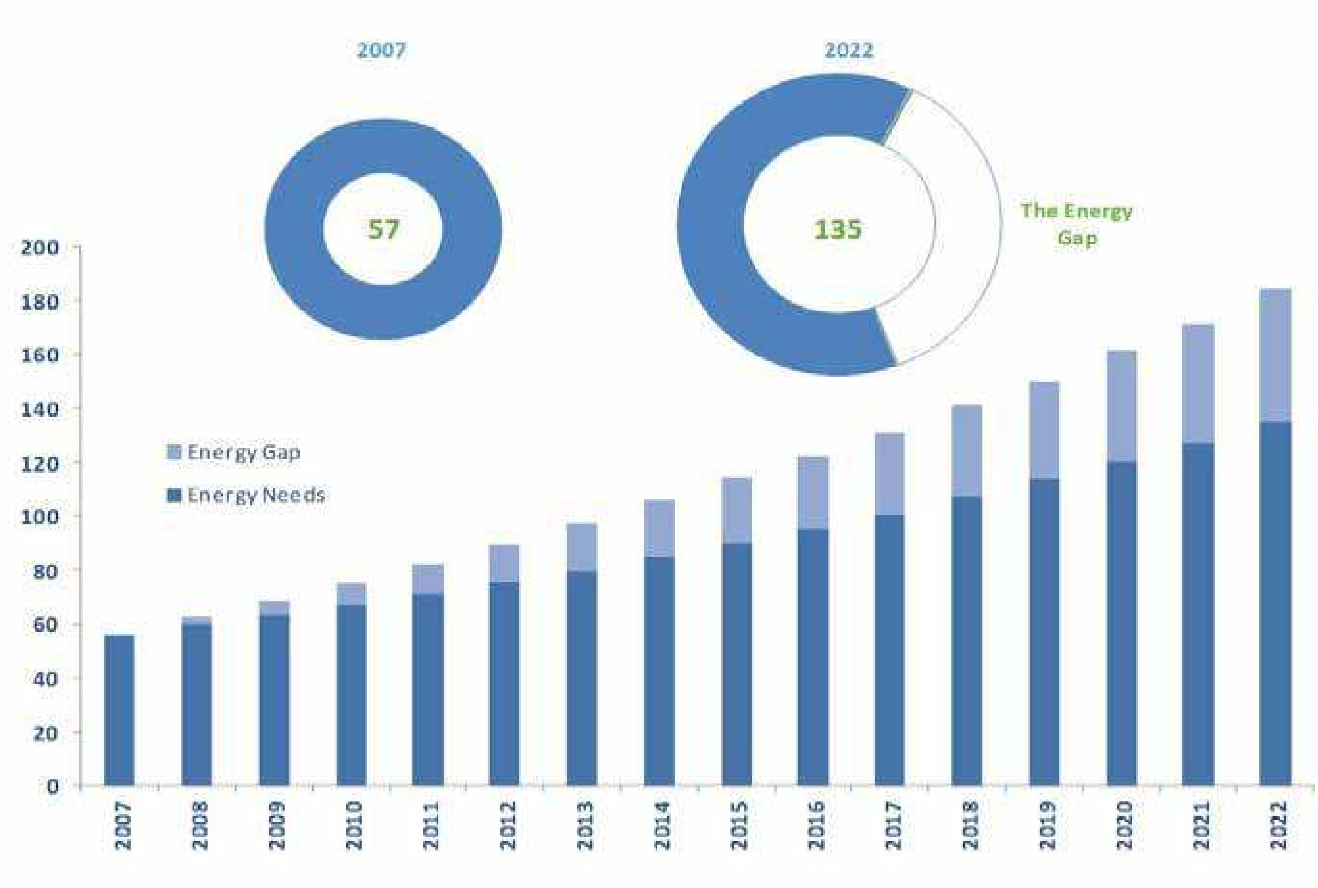
04

LANDS DEVOTED TO DEVELOPMENT THAT ARE ASSIGNED TO NREA THROUGH A PRESIDENTIAL DECREE

Once an exporter of oil and gas, Egypt is now struggling to meet its own energy needs. Whilst Egypt has proven oil reserves of 4.4 billion barrels and proven natural gas reserves of 78 trillion cubic feet, an ever-increasing percentage of its daily production is being used to meet the country's growing energy needs.

Egypt's demand for electricity is growing rapidly and the need to develop alternative power resources is becoming ever more urgent. It is estimated that demand is increasing at a rate of 1,500 to 2,000MW a year, because of rapid urbanization and economic growth.

Development of the renewable energy industry has become a priority over recent years for the Egyptian government. Egypt's present energy strategy aims at increasing the share of renewable energy, a target expected to be met largely by scaling-up of renewable energy projects.



“EGYPT IS RECOGNIZED AS HAVING VAST POTENTIAL FOR SOLAR AND WIND ENERGY APPLICATION.”

D

Due to its location, topography and climate, Egypt has an average level of solar radiation between 2,000 to 3,200 kWh per square meter a year, giving it significant potential for utilizing this form of renewable energy. Egypt is recognized as having vast potential for solar and wind energy application.

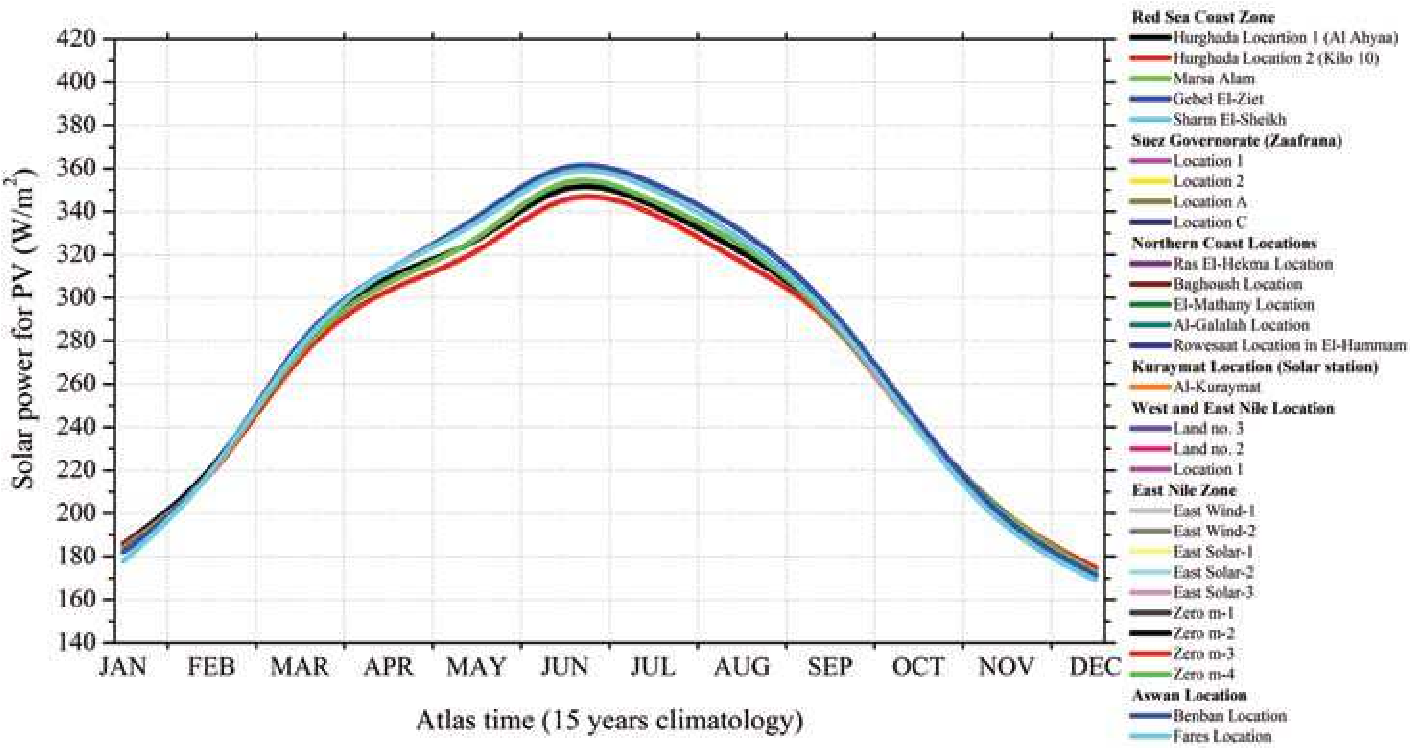
The Egyptian government is making extensive progress towards becoming a significant player in the renewable energy industry; it has since long recognized the need for reform of the electricity sector in order to attract private sector investment in power generation, as it is believed that the private sector will be instrumental to Egypt's ability to deliver its renewable energy targets. One of the key models that the decision-makers in Egypt are pursuing is the presidential decree of devoting a number of lands for those renewable energy projects, in addition to encouraging scientists to work on all tools and facilities that improve those proposed projects.

One of the major steps is the presidential decrees (ex. No. 116 for the year 2016) for devoting a number of Egyptian zones (including sub-zones) to be developed and used by the New and Renewable Energy Authority and Ministry of Electricity and Renewable Energy, to use it in electricity generation stations from wind, solar energy, and photovoltaic cells.

1st RED SEA

ONE	TWO
Hurghada location 1 (Al Ahyaa sector)	Hurghada location 2 (Kilo 10 sector)

RED SEA COAST ZONE

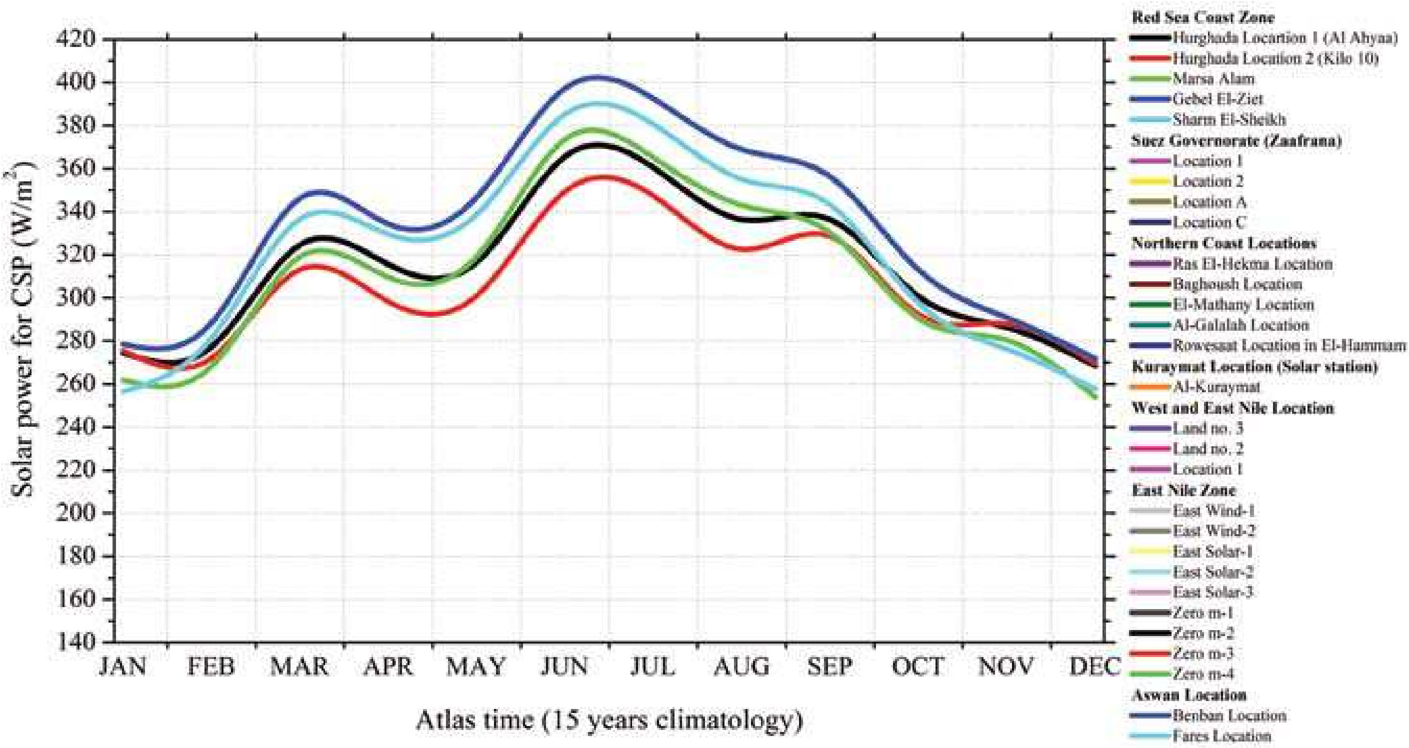


The interannual variability for PV exploitation in the Red Sea Coast Zone presents incoming solar power values from 180 W/m2 in winter to 360 W/m2 in summer (land range 345-365 W/m2).

COAST ZONE

THREE	FOUR	FIVE
Marsa Alam location	Gebel El-Ziet location	Sharm El-Sheikh

RED SEA COAST ZONE

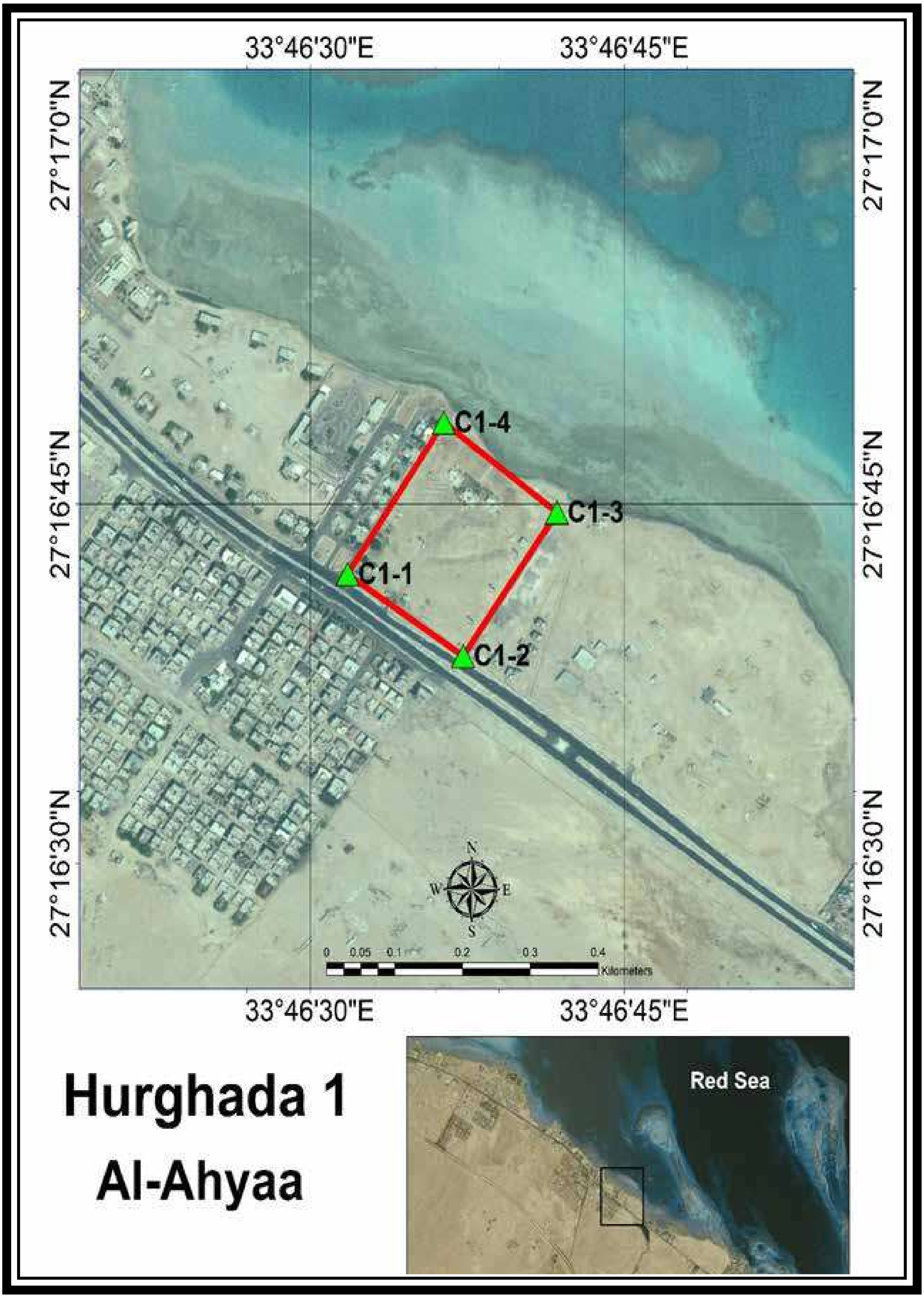


For CSP, the corresponding values and ranges are 260-400 W/m2 for winter and summer months, respectively, while based on the specific lands in summer, the range is 340 - 400 W/m2.

1

HURGHADA LOCATION 1 (AL AHYAA)

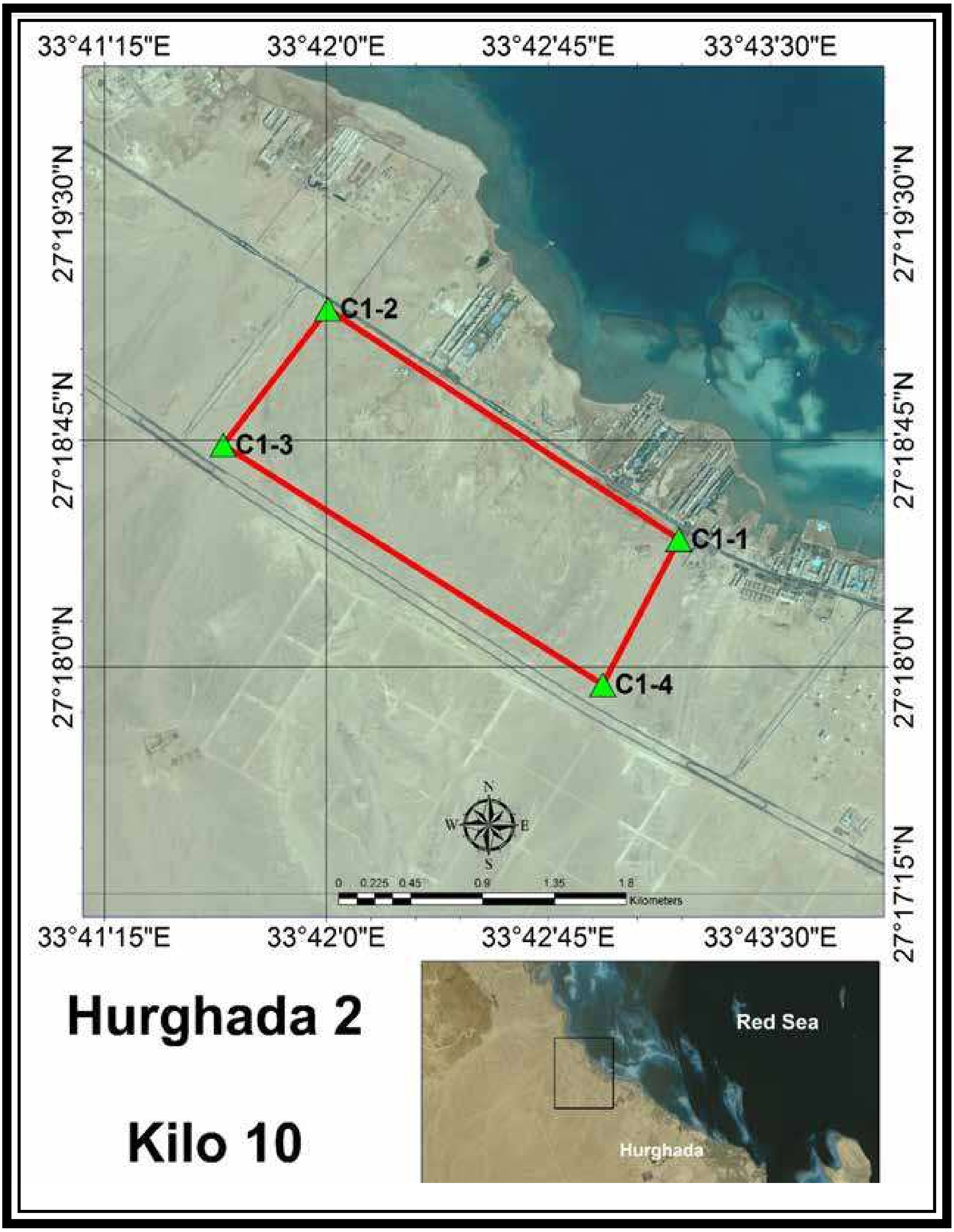
Land area 200m x 170m devoted by Red Sea Governor decree No. 64 year 1986 (Dated 16/7/1986). Its coordinates are as follows:



HURGHADA LOCATION 2 (KILO 10)

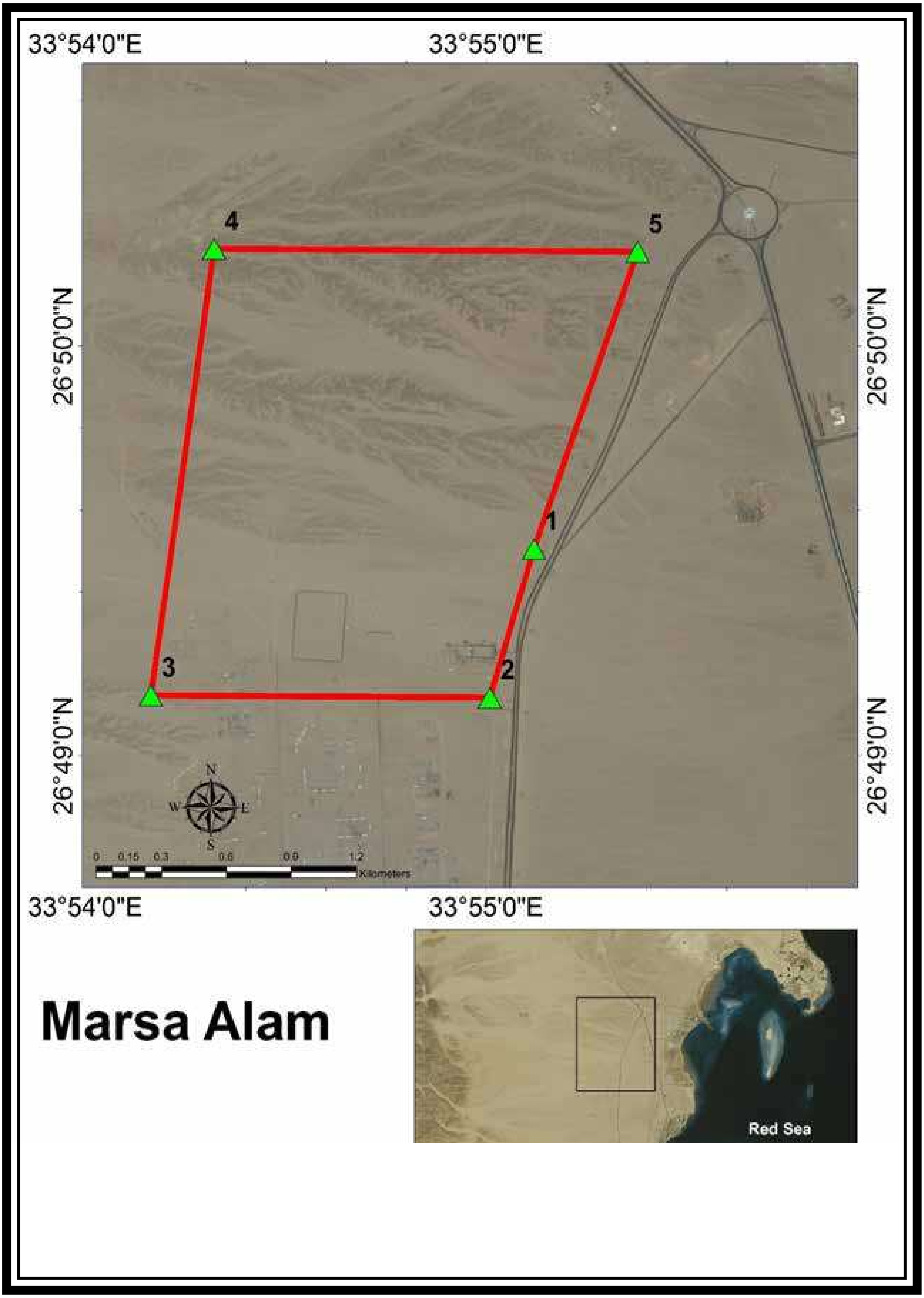
2

Land of 2500m x 1000m devoted by Red Sea Governor decree No. 112 year 1993 (Dated 20/6/1993). Its coordinates are as follow:



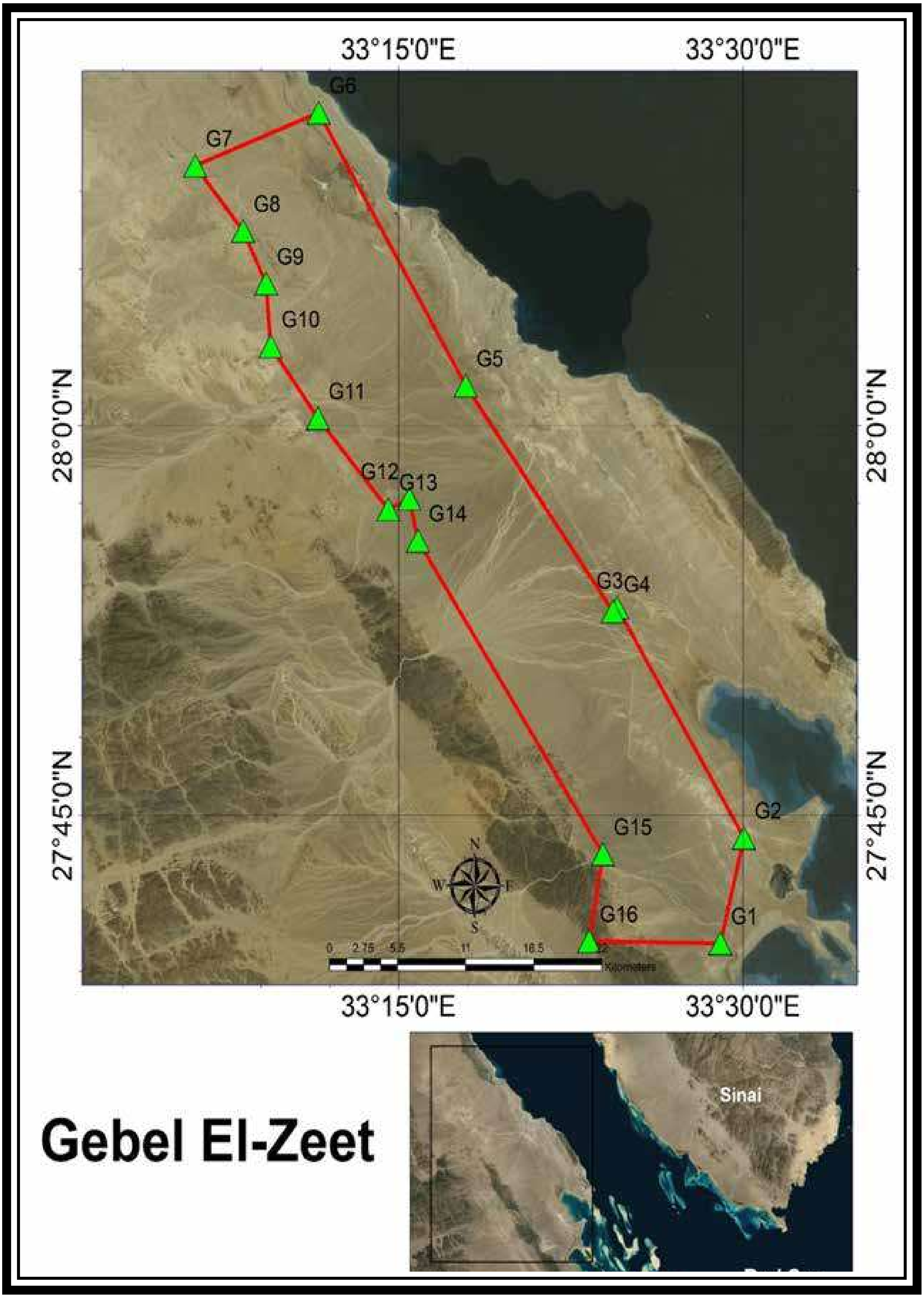
3 MARSA ALAM

Land of area 629.38 Feddan (2.547 km2). It coordinates are as follows



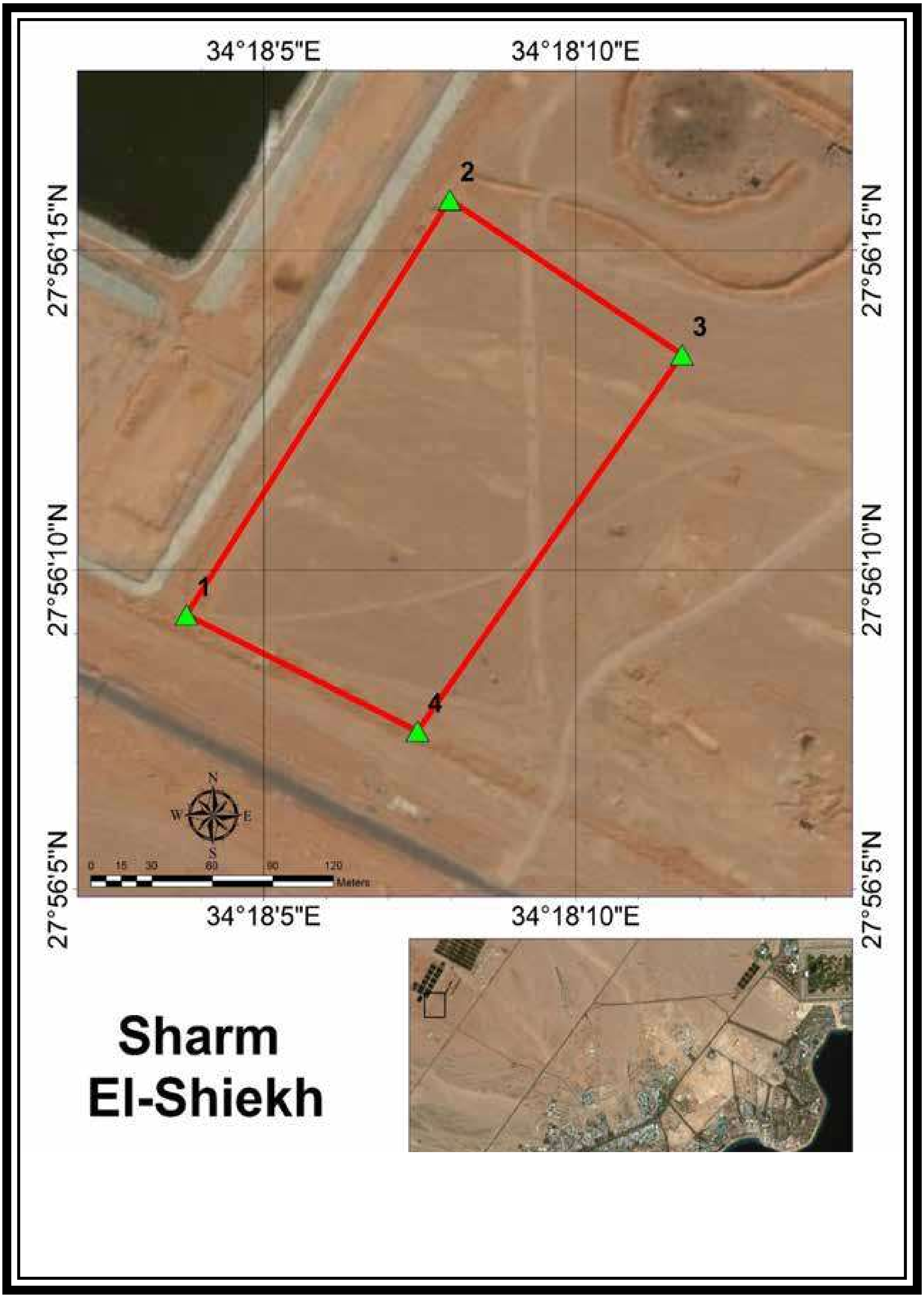
4 GEBEL EL-ZIET

Land of area 656.4 km2 devoted by Red Sea Governor decree No. 91 year 2006 (Dated 27/3/2006). Its coordinates are as follows:



5 SHARM EL-SHEIKH

Land of area 25337 m2 (about 6.26 Feddans) devoted by Prime Minister Decree No. 1478 year 2015. Its coordinates are as follows:



Monthly mean solar energy in kWh/m2 for PV systems for the 5 lands of the Red Sea Coast Zone.

SOLAR ENERGY PV (KWH/M2)

LOCATION	1	2	3	4	5
JAN	138	138	136	136	132
FEB	149	147	148	148	148
MAR	205	202	205	207	206
APR	223	218	221	225	225
MAY	243	239	244	251	249
JUN	252	249	254	259	258
JUL	255	252	257	263	260
AUG	239	236	241	246	243
SEP	209	208	209	212	210
OCT	179	177	179	180	177
NOV	144	143	143	142	140
DEC	130	130	128	128	126
TOTAL	2365	2338	2363	2395	2372

Monthly mean solar energy in kWh/m2 for CSP systems for the 5 lands of the Red Sea Coast Zone.

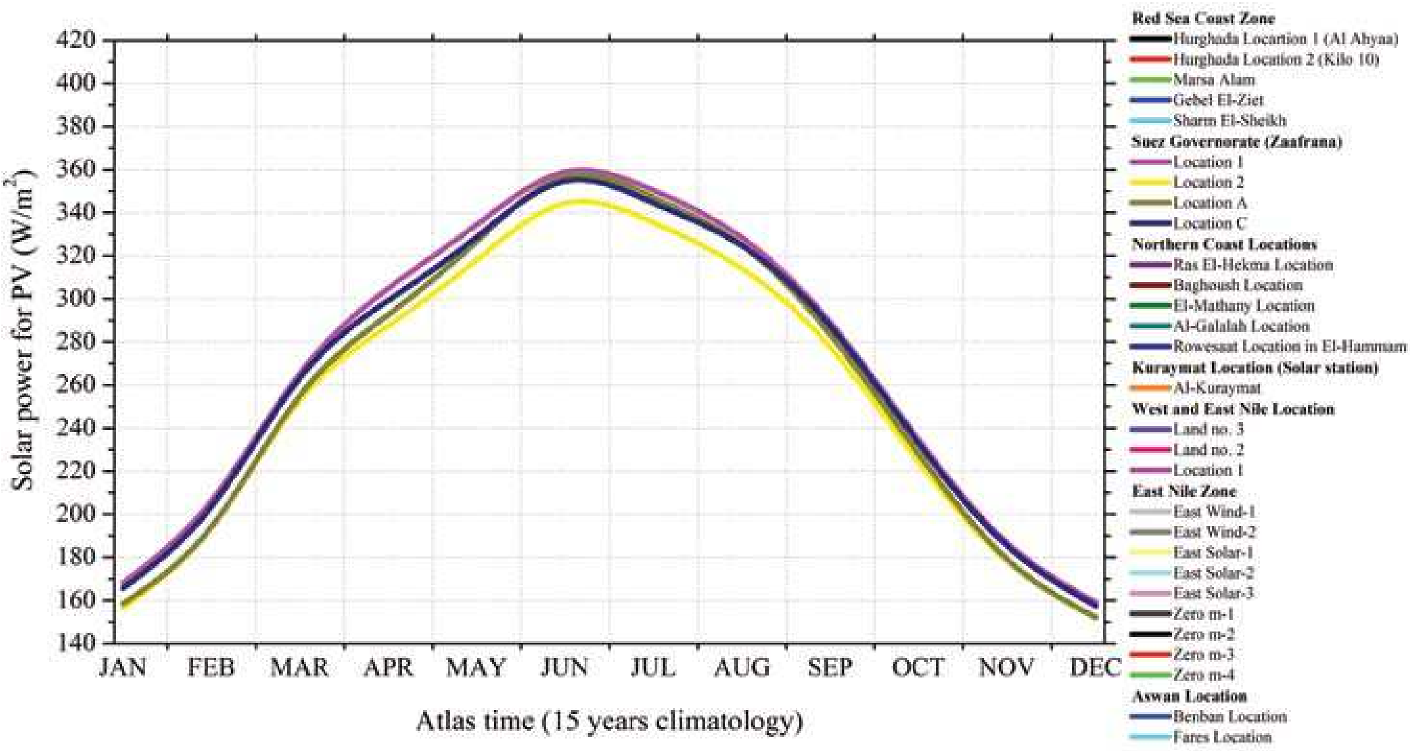
SOLAR ENERGY CSP (KWH/M2)

LOCATION	1	2	3	4	5
JAN	204	205	195	207	191
FEB	186	183	180	194	189
MAR	241	233	237	258	250
APR	227	215	223	241	237
MAY	236	224	237	258	252
JUN	263	252	269	286	277
JUL	268	258	272	292	283
AUG	250	240	255	274	264
SEP	242	237	238	257	247
OCT	224	217	216	233	221
NOV	206	207	202	209	199
DEC	200	201	189	202	192
TOTAL	2747	2670	2712	2909	2802

2nd SUEZ GOVER

ONE	TWO
Location 1	Location 2

SUEZ GOVERNORATE (ZAAFRANA ZONE)

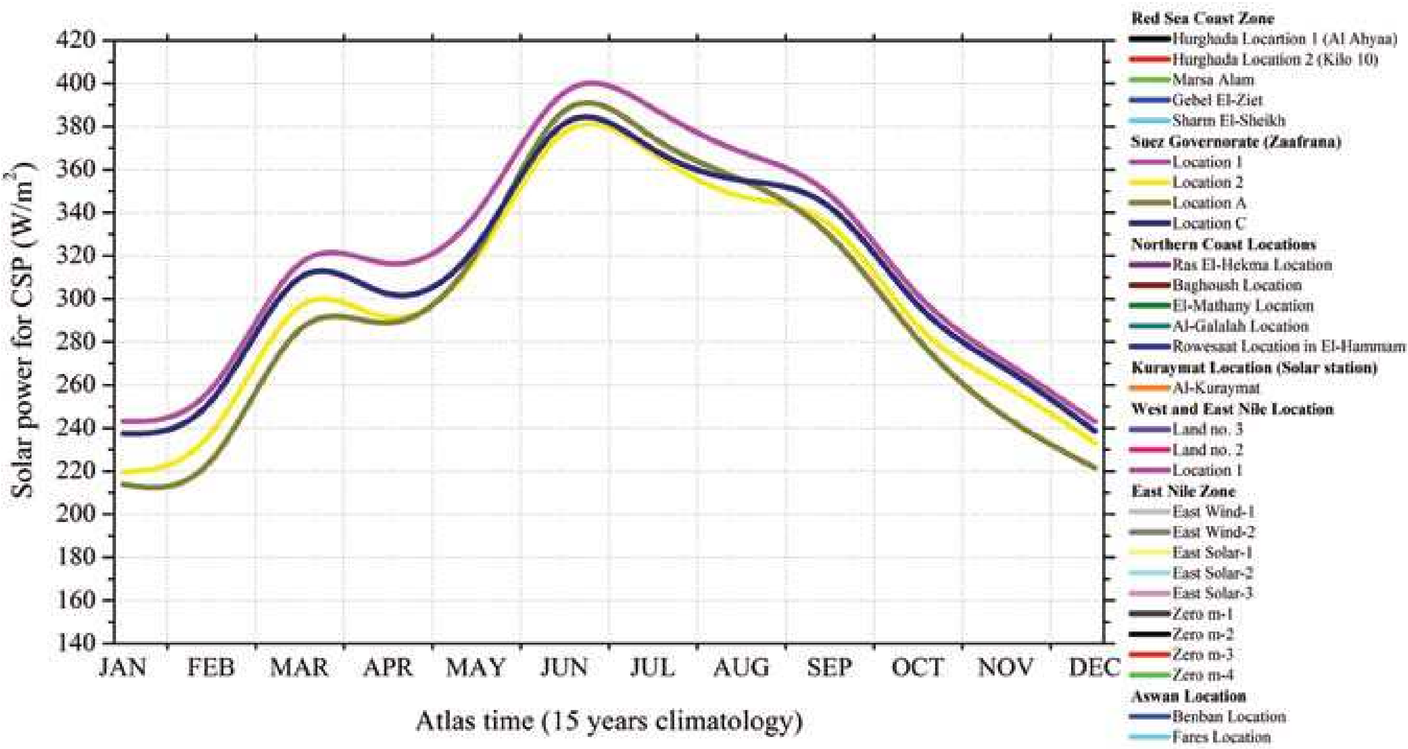


Figures show the interannual variability for PV and CSP systems in the Suez Governorate (Zaafrana) lands. The GHI values range from 160 W/m2 in winter to 360 W/m2 in summer.

NORATE (ZAAFRANA)

THREE	FOUR
Location A	Location C

SUEZ GOVERNORATE (ZAAFRANA ZONE)

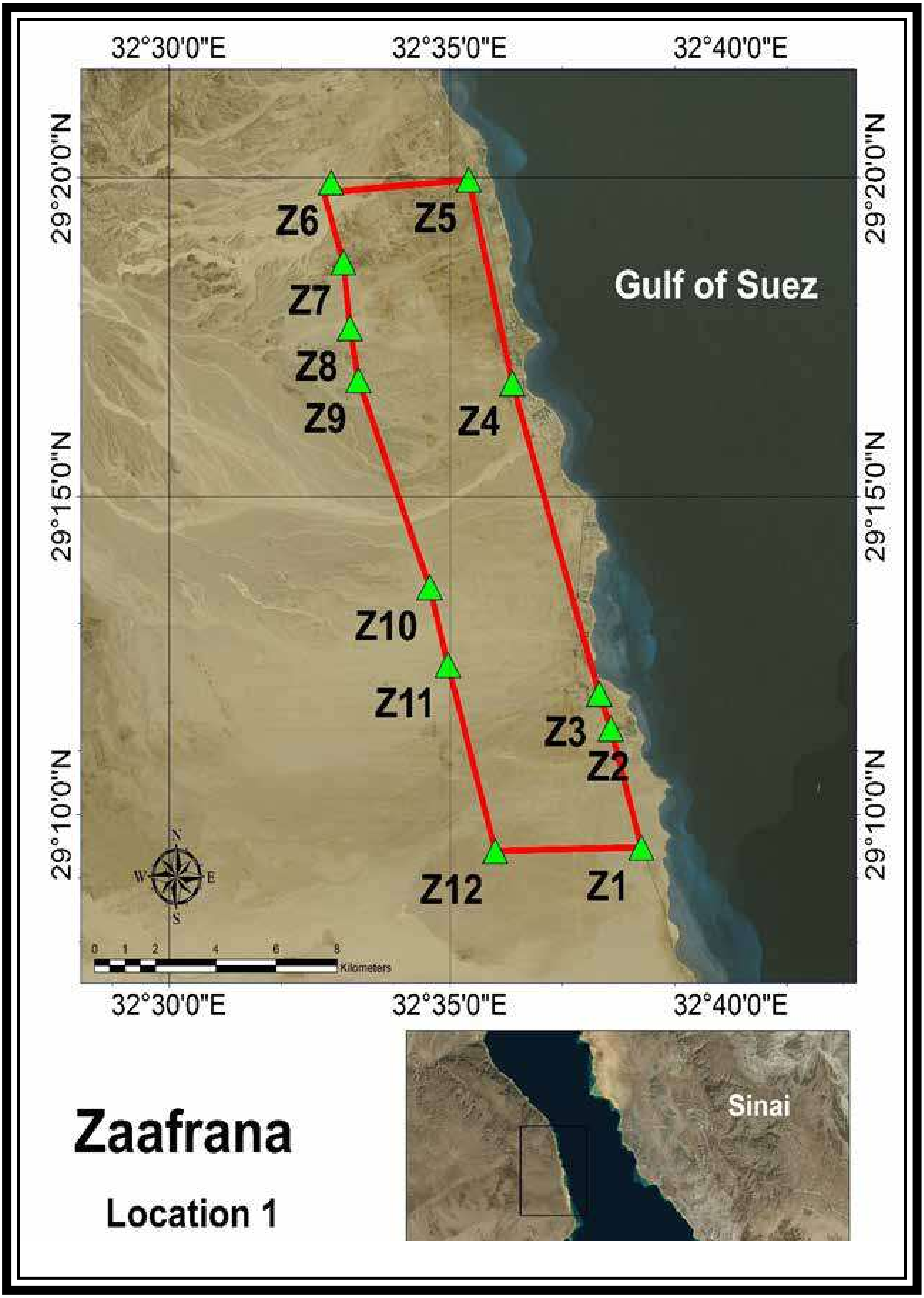


For CSP the corresponding values are 220-240 W/m2 and 380-400 W/m2 for winter and summer months.

1

LOCATION 1

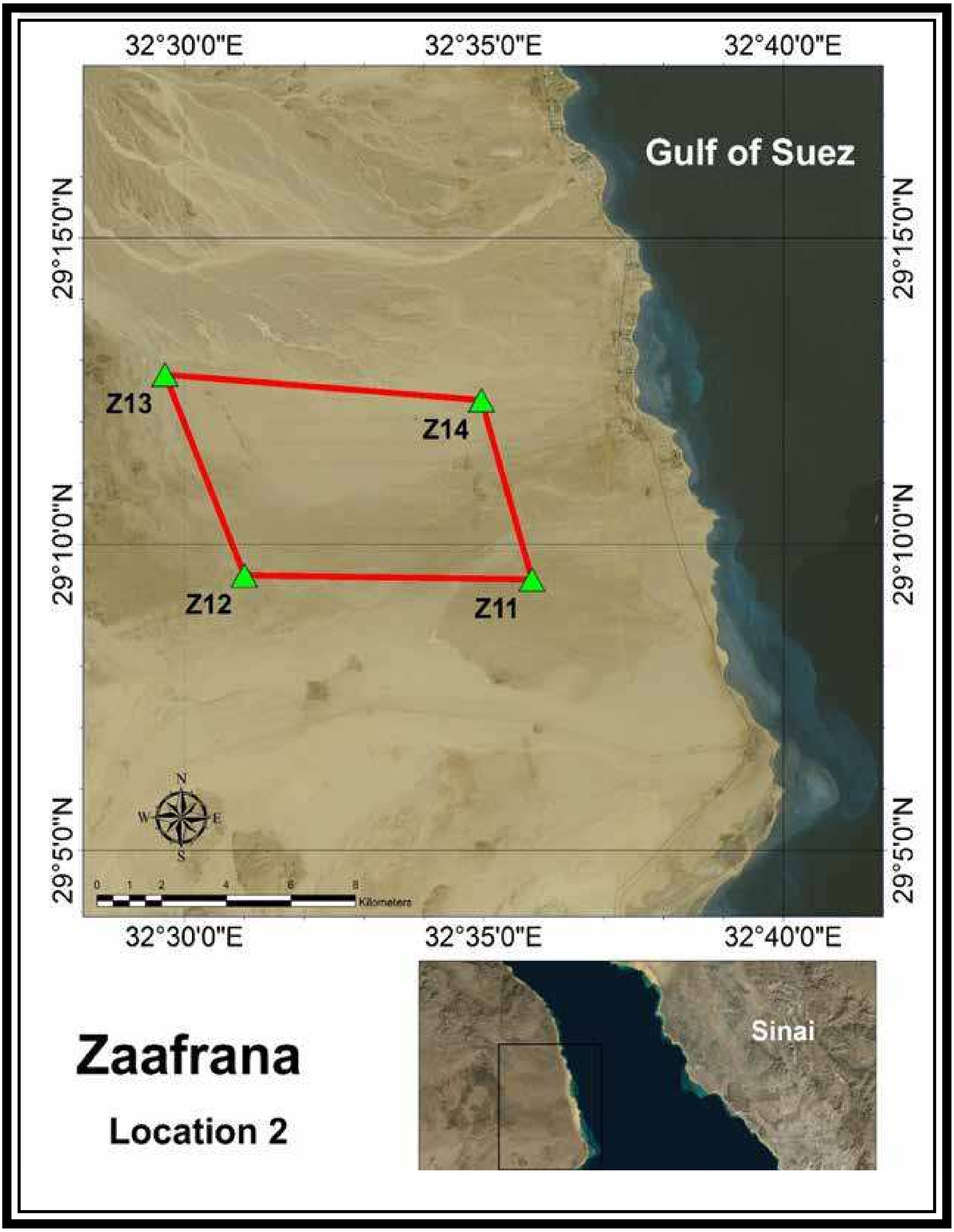
Land of area 80 km2 devoted by Presidential decree No. 400 year 1995 (Dated 13/12/1995). Its coordinates are as follows



2

LOCATION 2

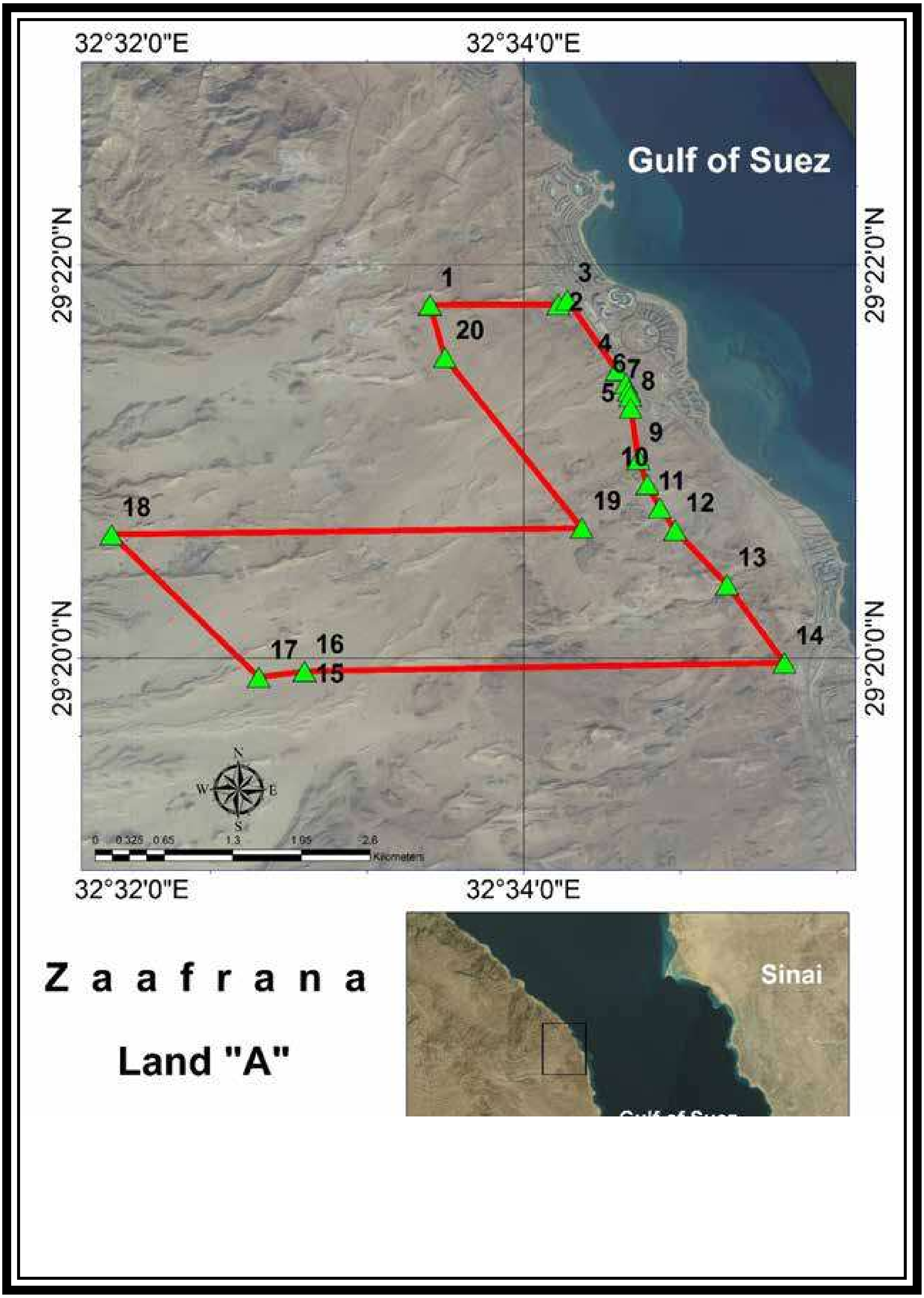
Land of 9500m x 8000m devoted by Red Sea Governor decree No. 107 year 2002 (Dated 30/7/2002). Its coordinates are as follows:



3

LOCATION A

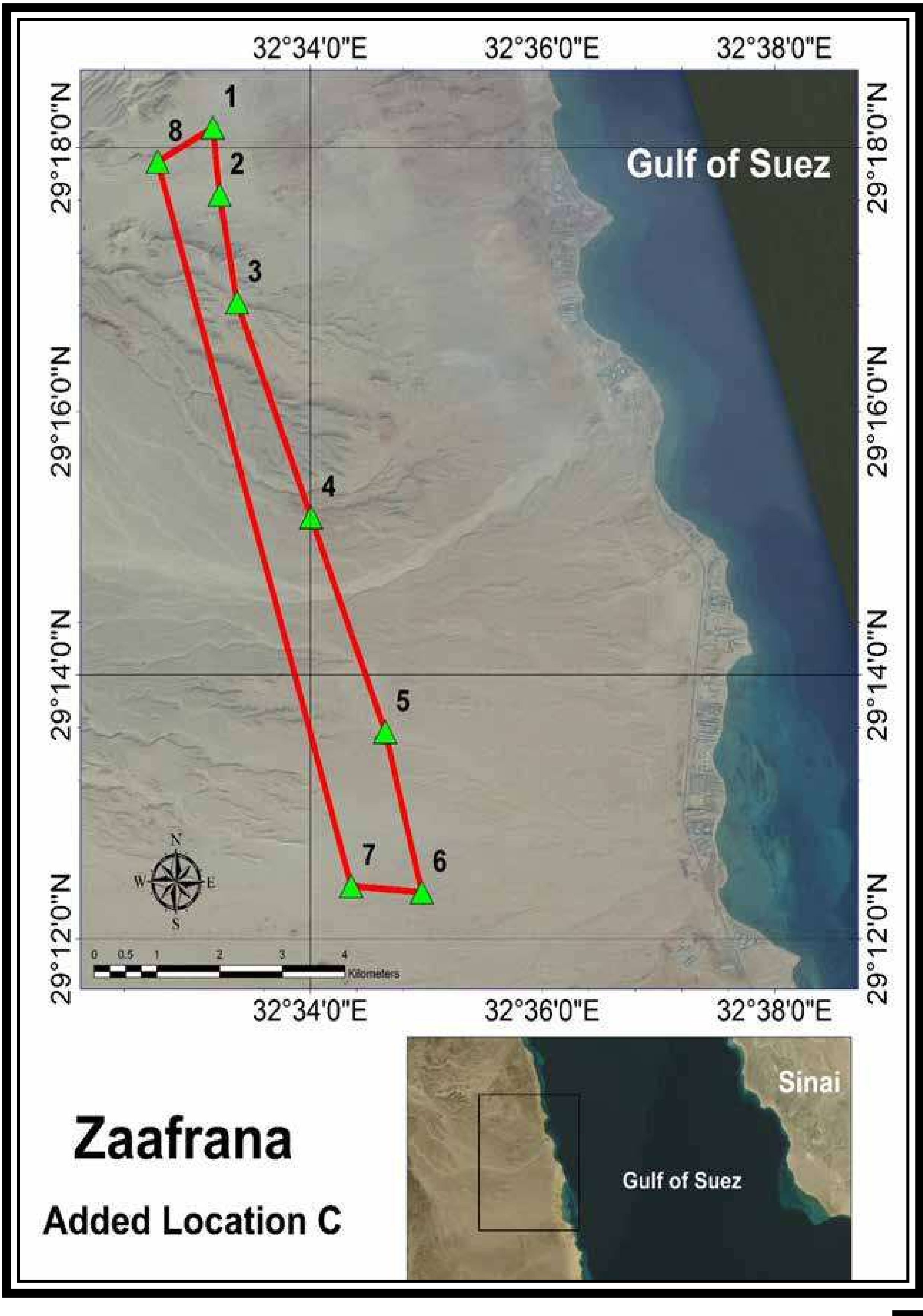
Land of area 8192415 m2 (about 8.19 km2) devoted by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates are as follows:



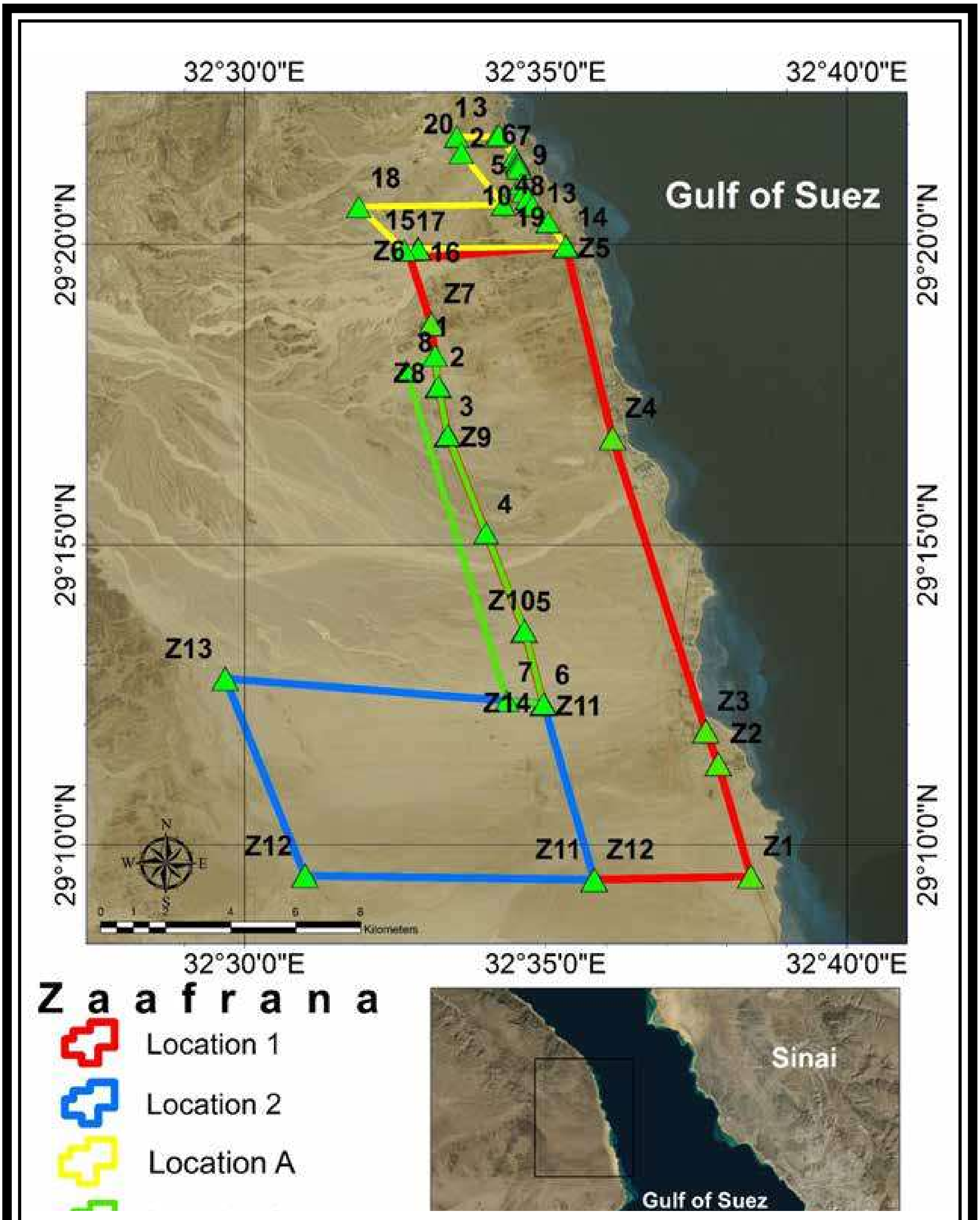
4

LOCATION C

Land of area 8664830 m2 (about 8.66 km2) devoted by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates are as follows:



MAP OF THE FOUR LOCATIONS OF ZAAFRANA AREA



Monthly mean solar energy in kWh/m2 for PV systems for the 5 lands of the Suez Governorate (Zaafrana Zone).

SOLAR ENERGY PV (KWH/M2)				
LOCATION	1	2	3	4
JAN	125	116	118	123
FEB	139	131	131	137
MAR	197	188	190	196
APR	220	207	211	216
MAY	249	237	243	245
JUN	258	248	257	255
JUL	261	250	258	256
AUG	244	234	242	242
SEP	208	200	204	207
OCT	174	167	170	173
NOV	134	128	129	133
DEC	118	113	113	117
TOTAL	2326	2216	2262	2298

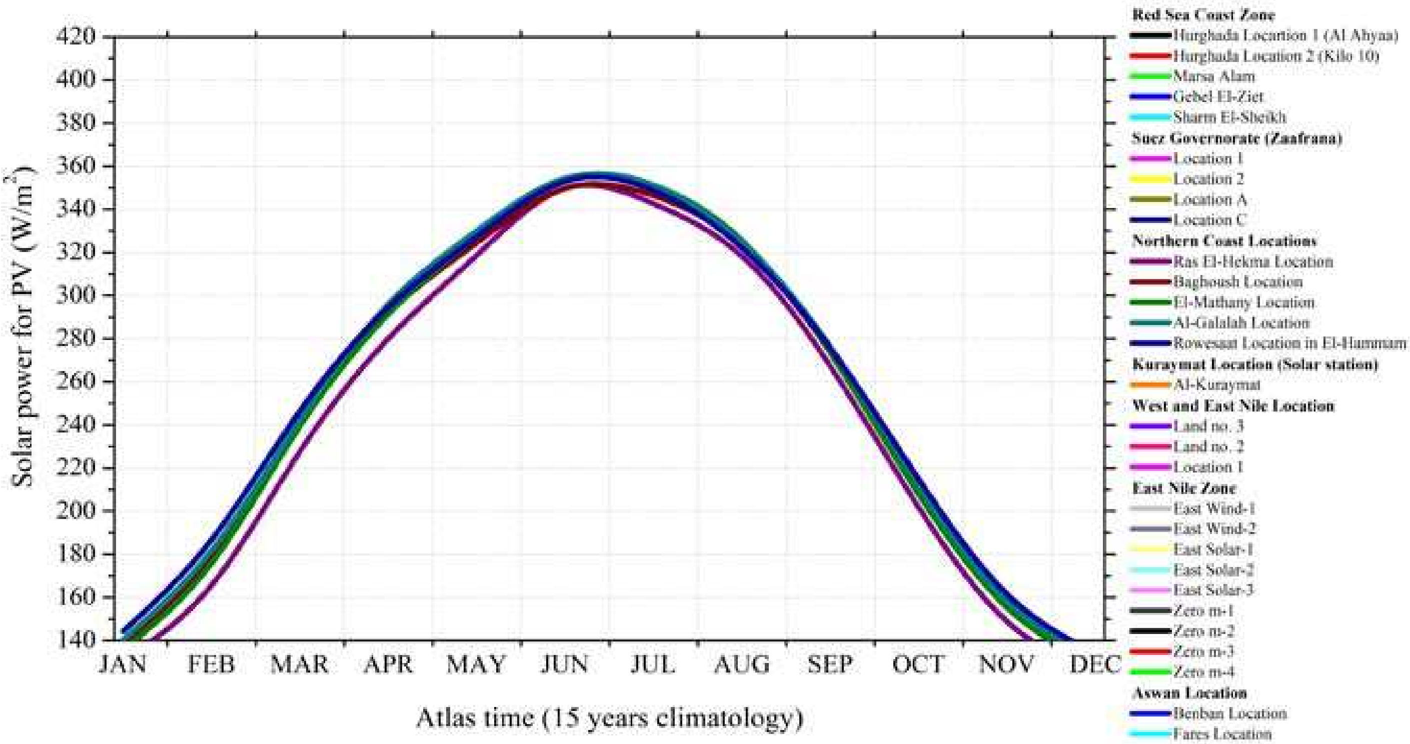
Monthly mean solar energy in kWh/m2 for CSP systems for the 5 lands of Suez Governorate (Zaafrana Zone).

SOLAR ENERGY CSP (KWH/M2)				
LOCATION	1	2	3	4
JAN	181	163	159	177
FEB	174	160	151	170
MAR	235	221	213	230
APR	228	210	208	218
MAY	253	237	239	242
JUN	285	272	279	275
JUL	289	273	279	275
AUG	274	259	264	264
SEP	251	241	237	247
OCT	224	214	209	221
NOV	195	187	176	192
DEC	181	174	165	178
TOTAL	2767	2607	2577	2685

3rd NORTHERN

ONE	TWO	THREE
Ras El-Hekma Location	Baghoush Location	El-Mathany Location

NORTHERN COAST ZONE

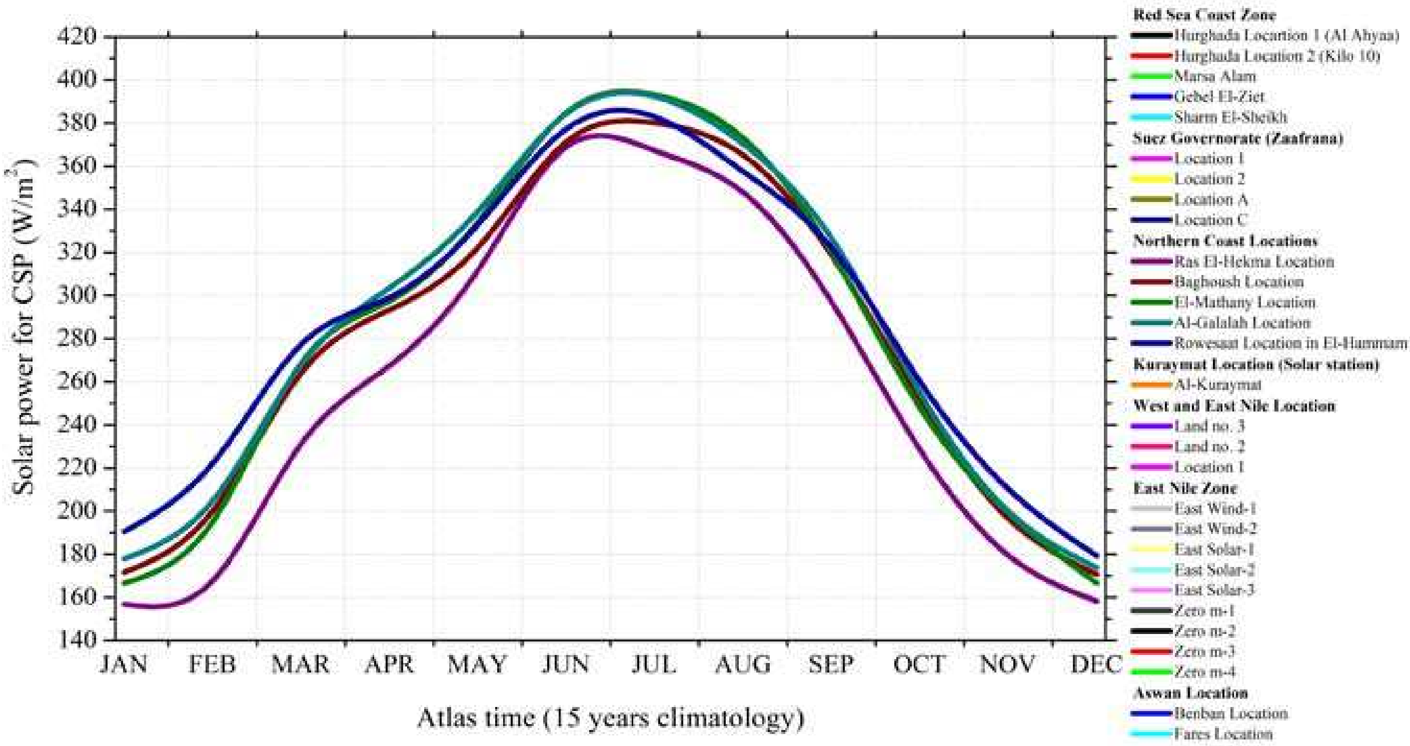


In the Northern Coast locations, the available solar power for PV is in the range 140-360 W/m2 (winter and summer months respectively).

COAST LOCATIONS

FOUR	FIVE
Al-Galalah Location	Rowesaat Location in El-Hammam City

NORTHERN COAST ZONE

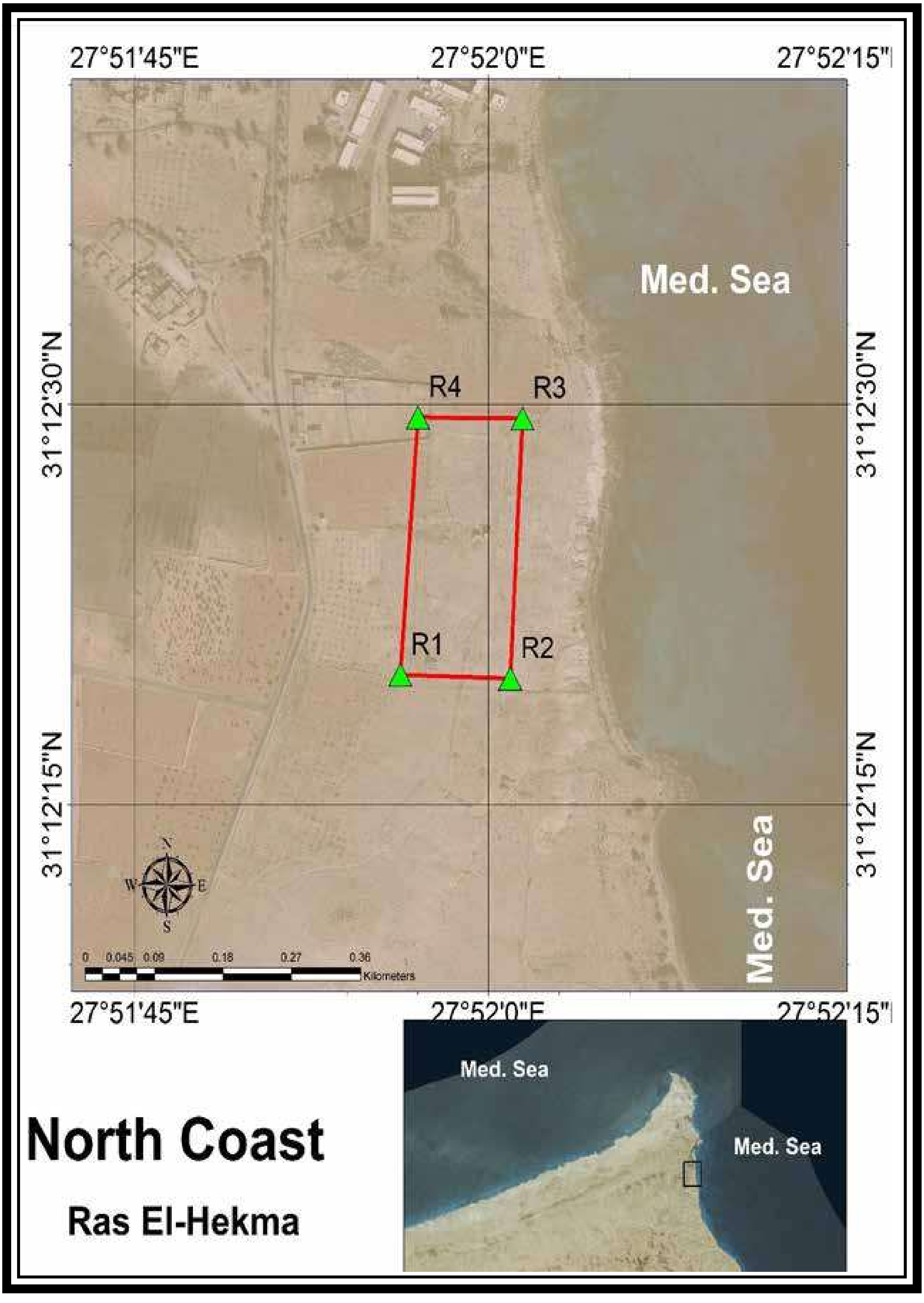


For CSP the corresponding values are 220-240 W/m2 and 380-400 W/m2 for winter and summer months.

1

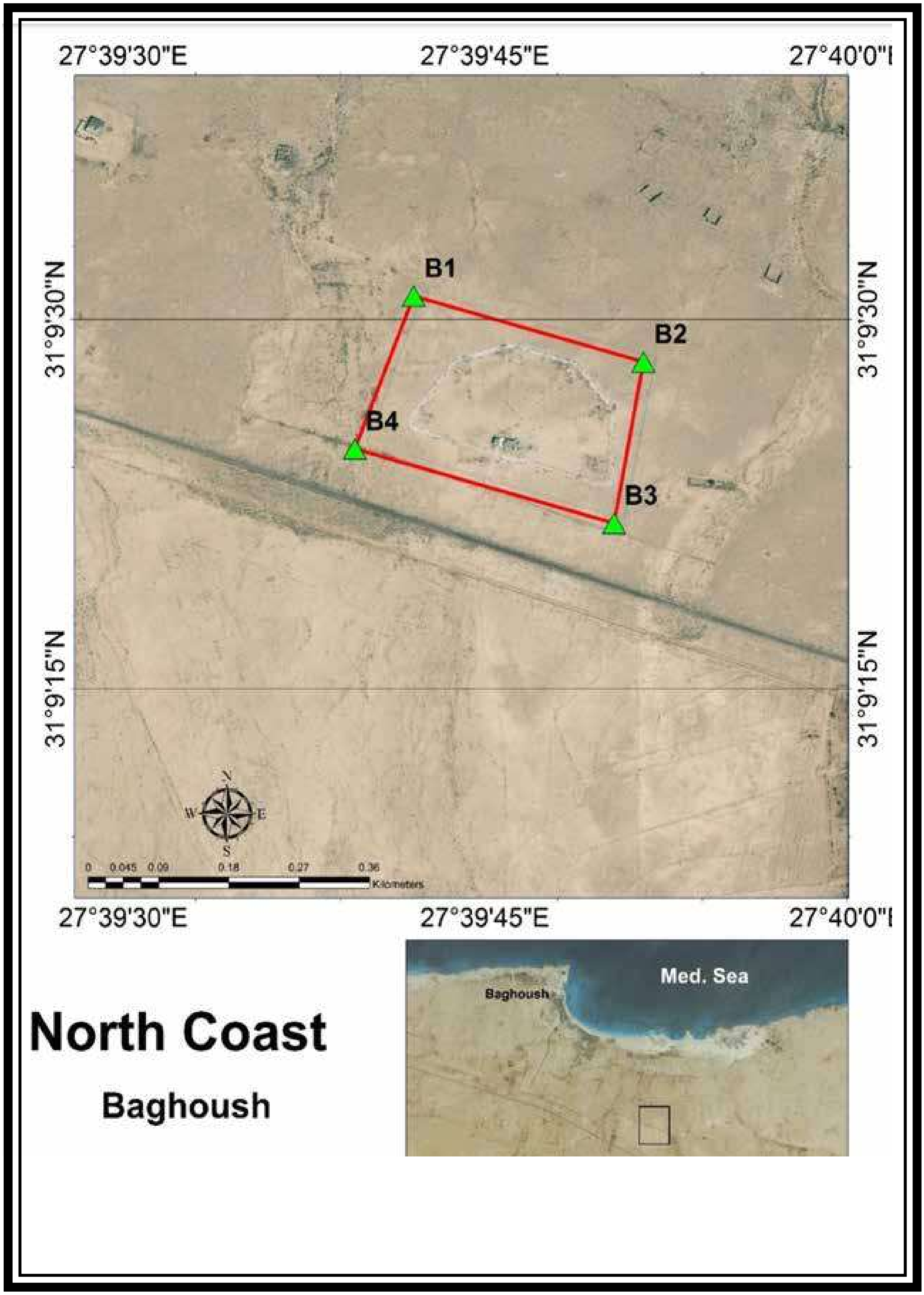
RAS EL-HEKMA LOCATION

Land of area 300m x 150m devoted by Matrouh Governor Decree No. 154 year 1995. Its coordinates are as follows:



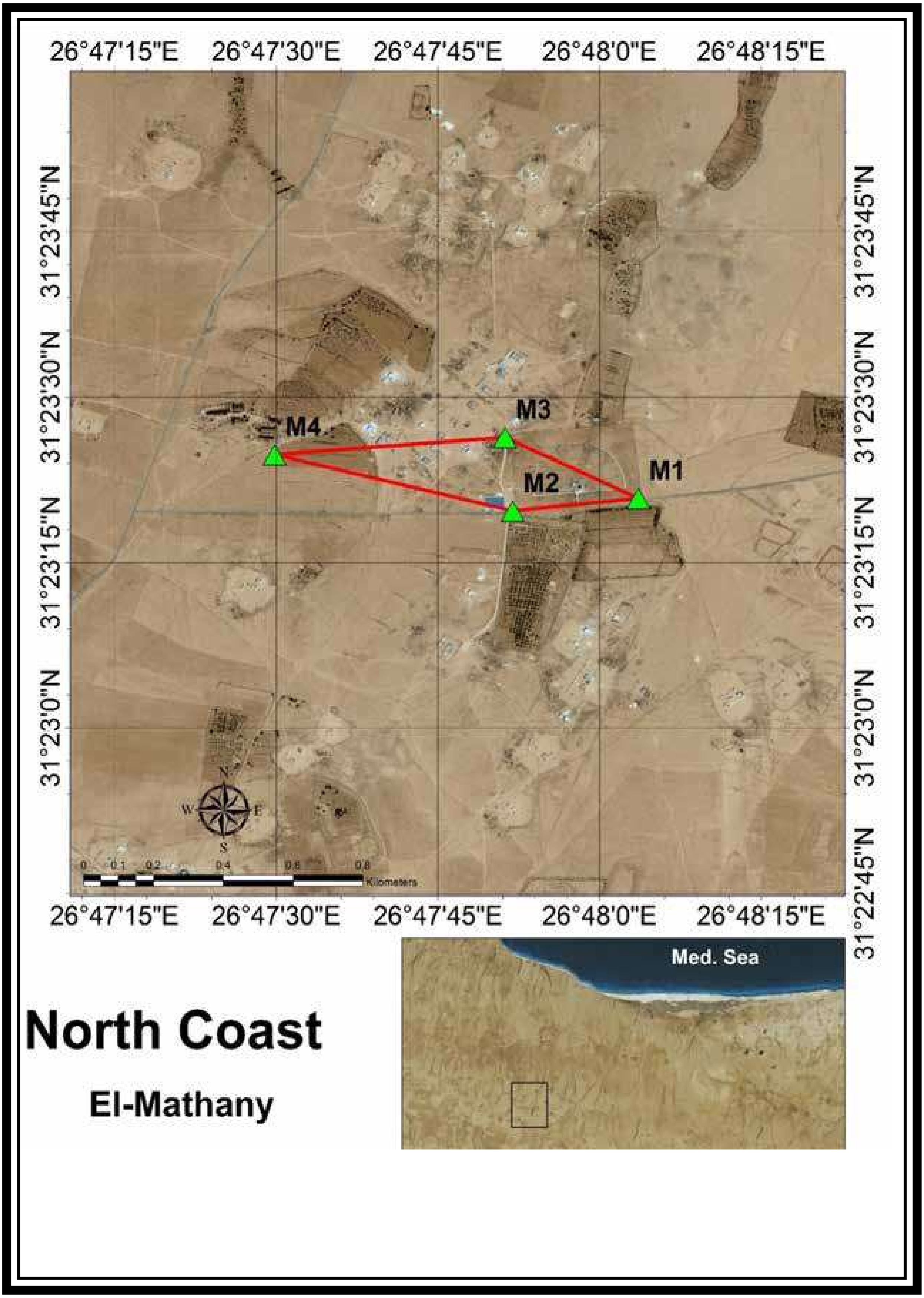
2 BAGHOUSH LOCATION

Land of area 300m x 200m devoted by Matrouh Governor Decree No. 100 year 1995. Its coordinates are as follows:



3 EL-MATHANY LOCATION

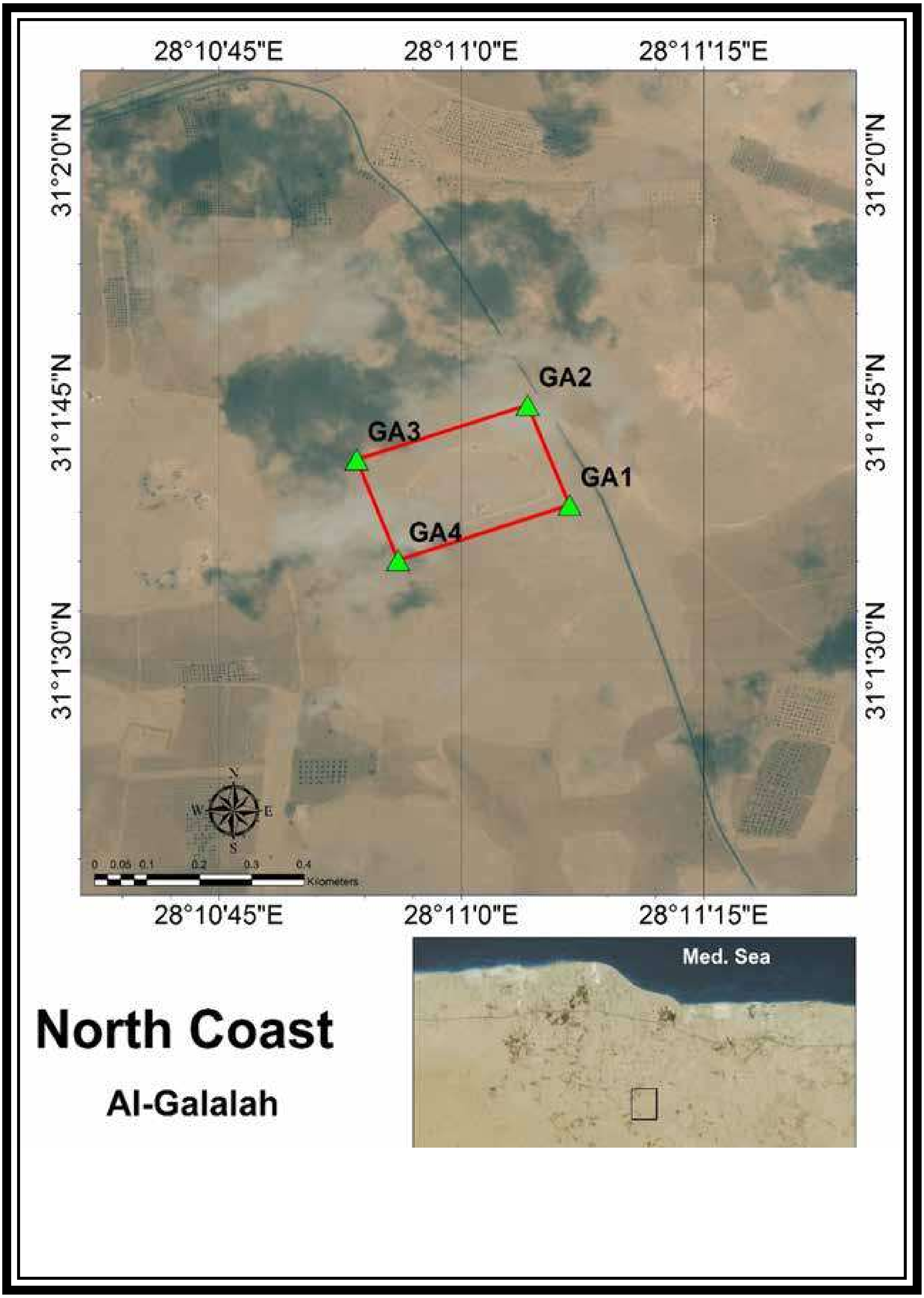
Land of area 200m x 200m devoted by Matrouh Governor Decree No. 100 year 1995. Its coordinates are as follows:



4

AL-GALALAH LOCATION

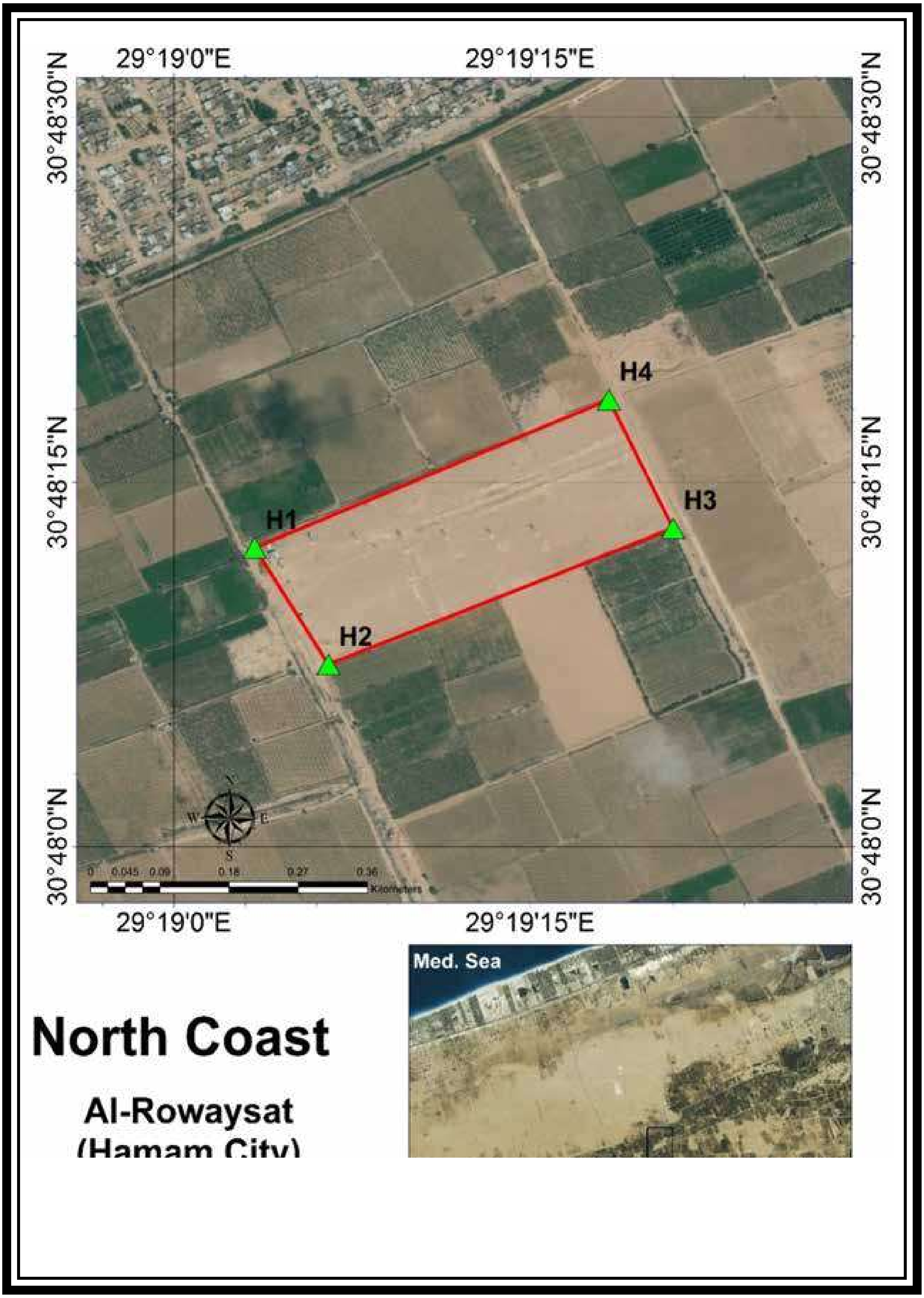
Land of area 300m x 200m devoted by Matrouh Governor Decree No. 100 year 1995. Its coordinates are as follows:



5

ROWESAAT LOCATION IN EL-HAMMAM CITY

Land of area (19 1 16) devoted by Presidential Decree No. 399 year 2006, date 20/11/2006. Its coordinates are as follows:



Monthly mean solar energy in kWh/m2 for PV systems for the 5 lands of the northern coast zone.

SOLAR ENERGY PV (KWH/M2)

LOCATION	1	2	3	4	5
JAN	97	103	101	104	107
FEB	111	120	118	122	126
MAR	169	179	178	180	183
APR	202	210	210	213	212
MAY	237	241	244	246	244
JUN	252	252	255	255	254
JUL	255	258	261	261	260
AUG	237	241	242	242	240
SEP	192	197	197	199	198
OCT	150	156	155	158	160
NOV	107	112	112	114	116
DEC	93	97	95	98	100
TOTAL	2100	2162	2164	2190	2197

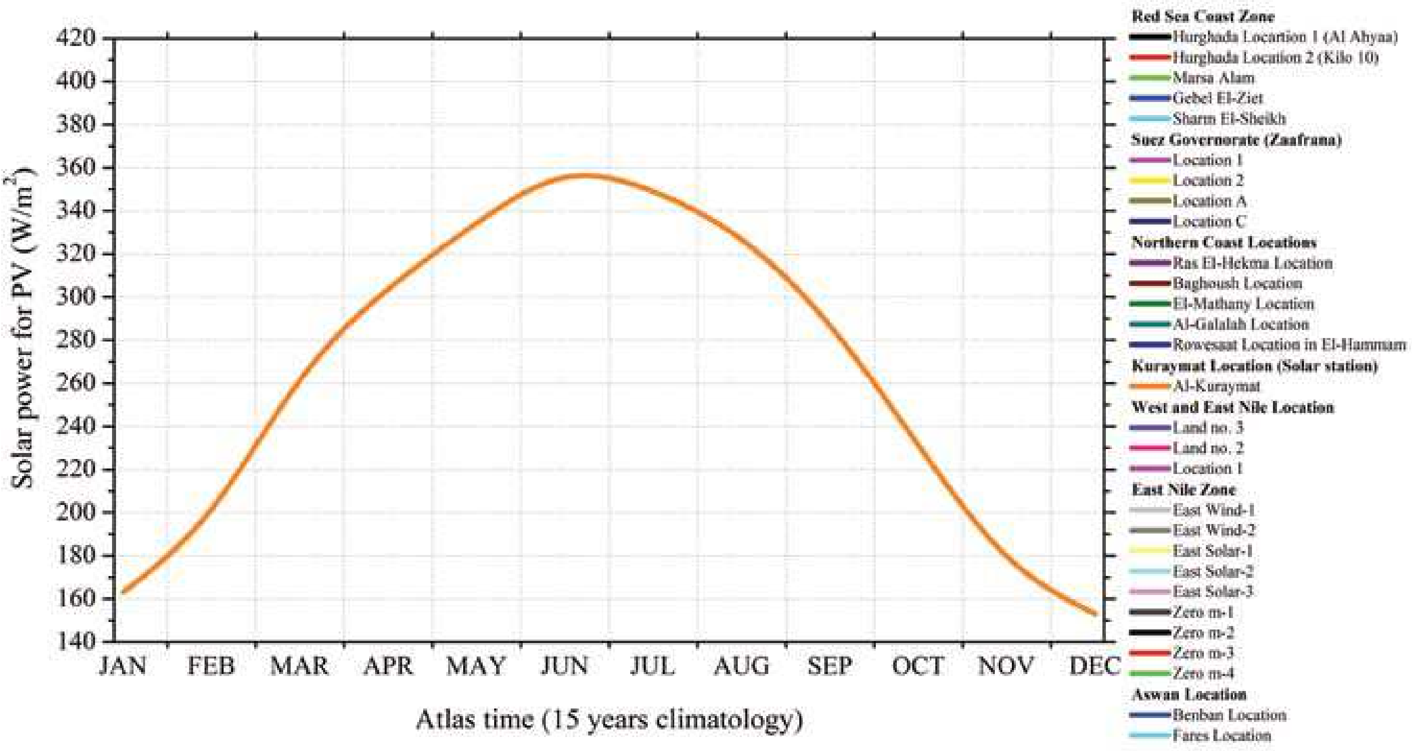
Monthly mean solar energy in kWh/m2 for CSP systems for the 5 lands of northern coast zone.

SOLAR ENERGY CSP (KWH/M2)

LOCATION	1	2	3	4	5
JAN	117	128	124	132	142
FEB	113	134	131	138	149
MAR	172	196	200	199	206
APR	193	211	214	219	215
MAY	232	240	248	252	248
JUN	266	267	277	277	272
JUL	273	283	293	292	285
AUG	259	272	278	276	266
SEP	214	230	230	235	232
OCT	170	187	184	190	194
NOV	129	142	143	144	151
DEC	118	127	124	129	133
TOTAL	2250	2413	2443	2479	2491

4th KURAYMAT

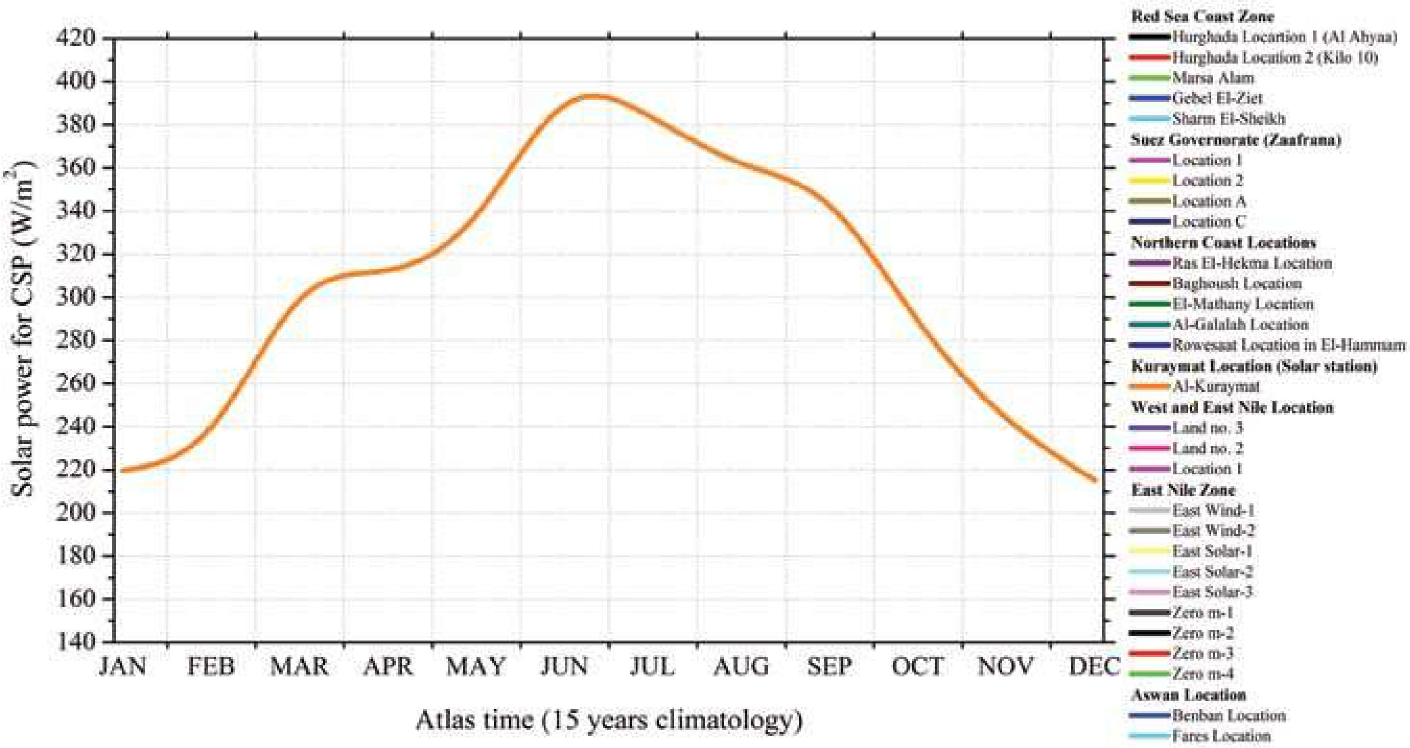
KURAYMAT LOCATION (SOLAR STATION)



At Kuraymat location PV technologies are able to exploit a power potential of 160 to 350 W/m2.

LOCATION (SOLAR STATION)

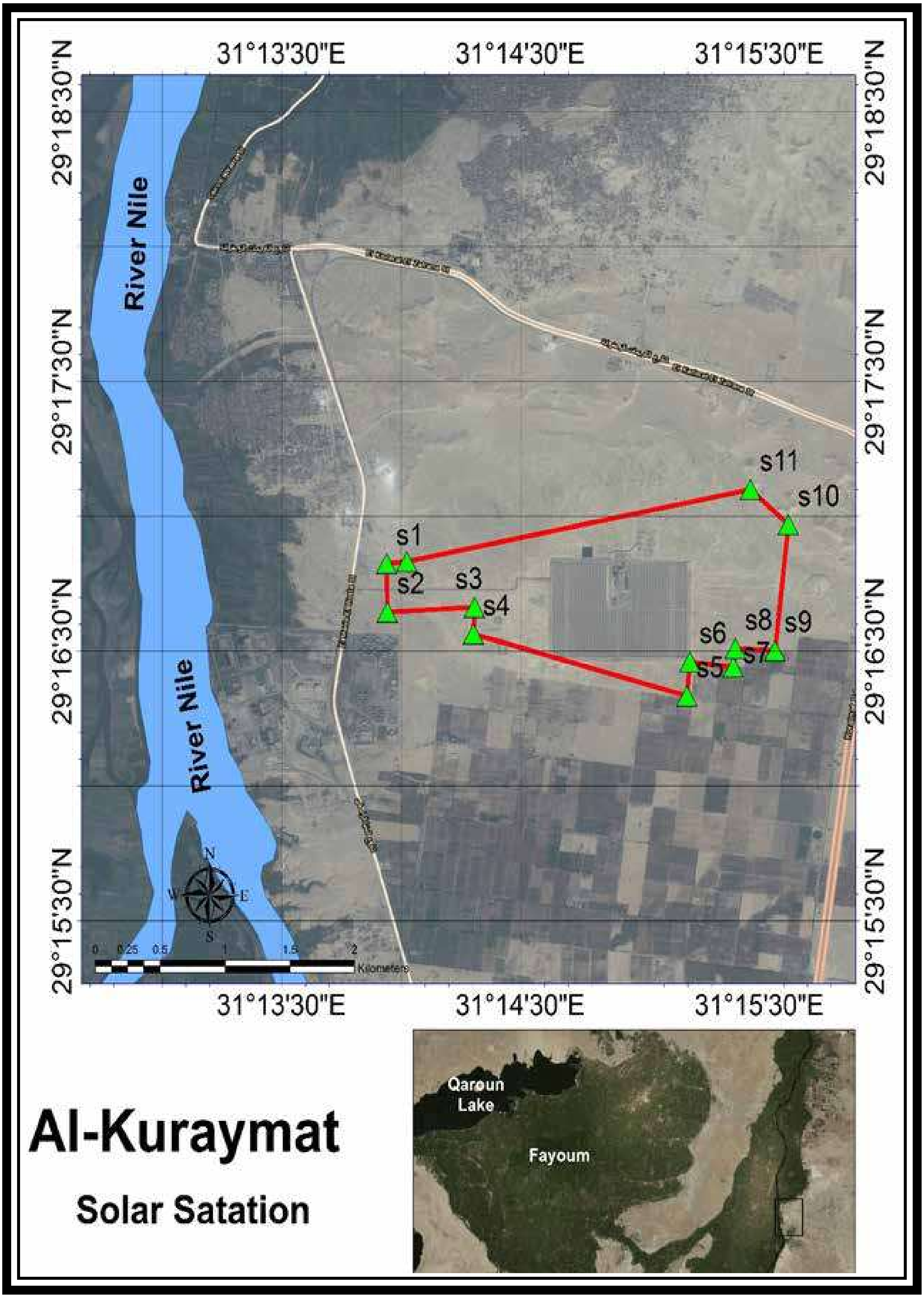
KURAYMAT LOCATION (SOLAR STATION)



CSP technologies exploit at Kuraymat 220 to 390 W/m2 with the dust storms causing during April a consequent energy reduction.

KURAYMAT LOCATION (SOLAR STATION)

Land area 660 Feddan devoted by Presidential Decree No 212 of year 2003, Date 11/8/2003, its coordinates are as follows:



KURAYMAT LOCATION (SOLAR STATION)

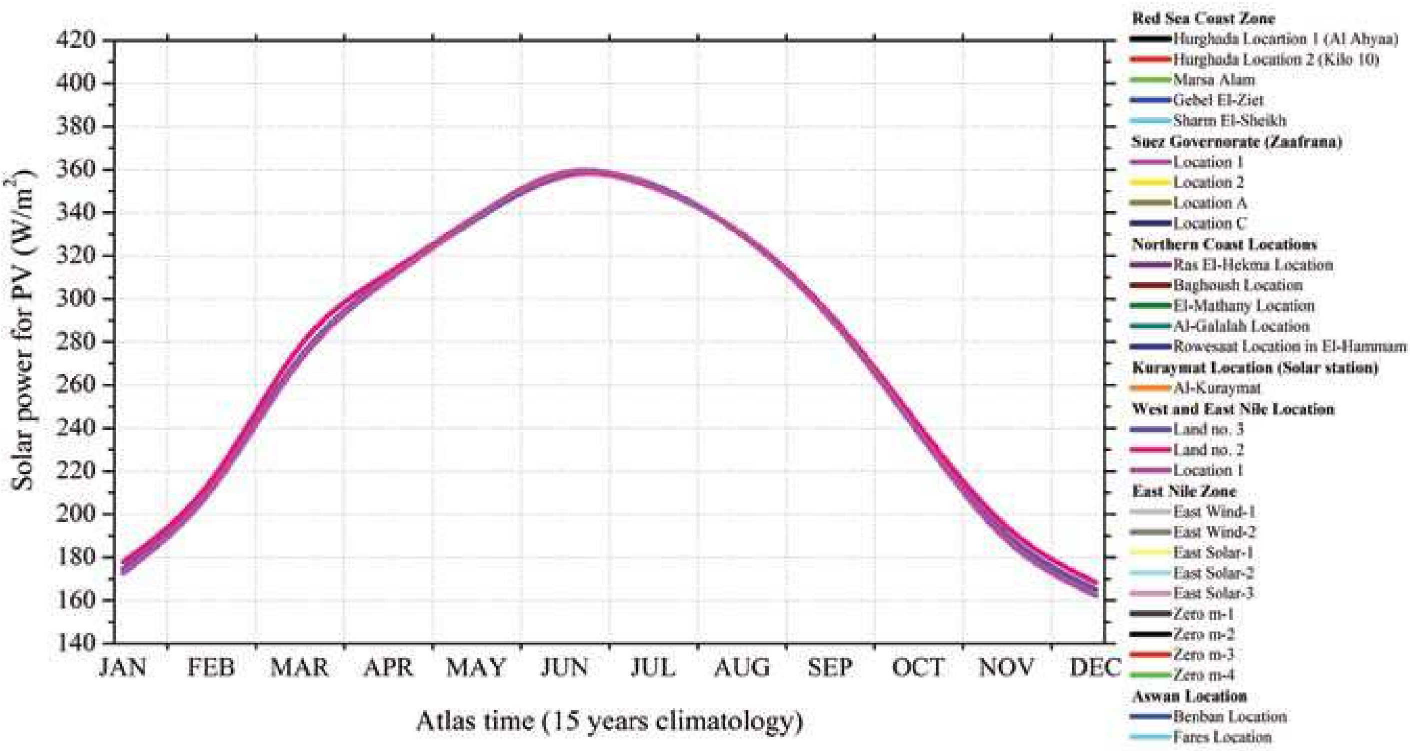
Monthly mean solar energy in kWh/m2 for PV & CSP systems for the lands of Kuraymat Location (Solar Station).

	SOLAR ENERGY (KWH/M2)	
	CSP	PV
JAN	121	164
FEB	136	161
MAR	194	222
APR	219	225
MAY	249	252
JUN	256	280
JUL	260	285
AUG	243	269
SEP	206	246
OCT	172	215
NOV	129	176
DEC	114	160
TOTAL	2296	2653

5th WEST AND

ONE	TWO
Land no. 3	Land no. 2

WEST AND EAST NILE LOCATION



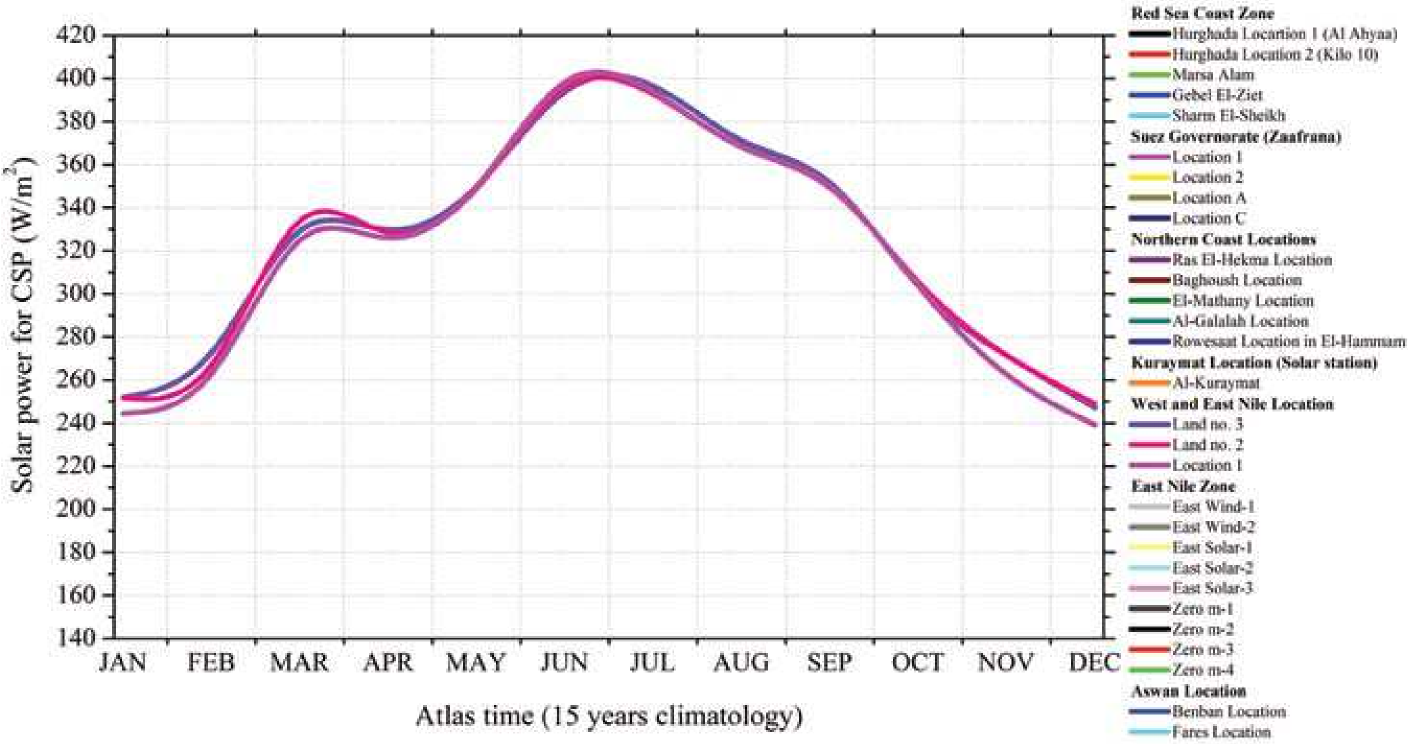
West and East Nile location offers solar power conditions of 180 to 360 W/m2 for the PV solar farms.

EAST NILE LOCATION

THREE

Land no. 1

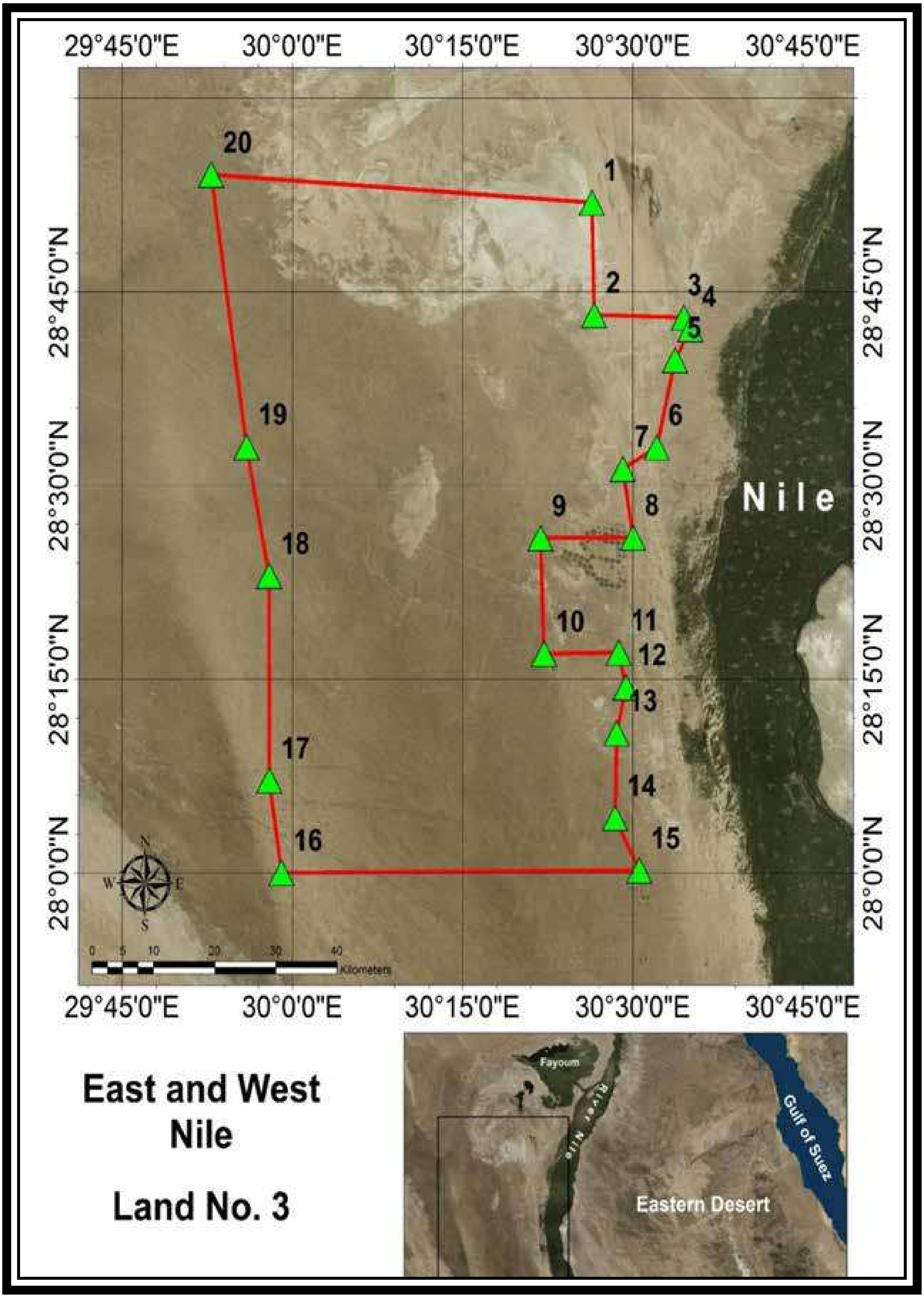
WEST AND EAST NILE LOCATION



At the same time CSP benefits from the DNI which is from 250 W/m2 during January to 400 W/m2 in June-July months.

1 LAND NO. 3

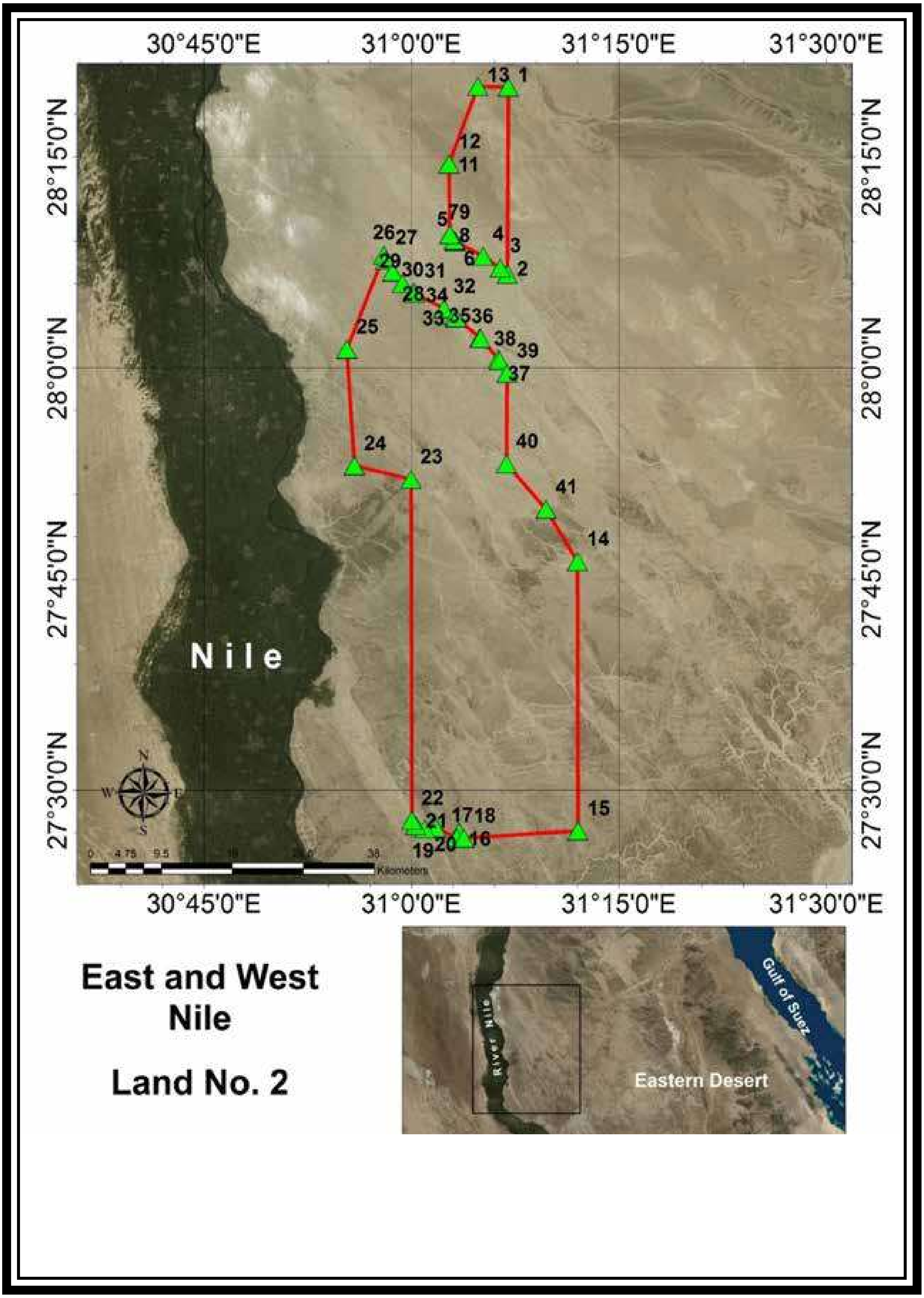
Land area 109897.11 Feddan devoted by Presidential Decree No. 116 of year 2016, date 21/3/2016. Its coordinates are as follows:



2

LAND NO. 2

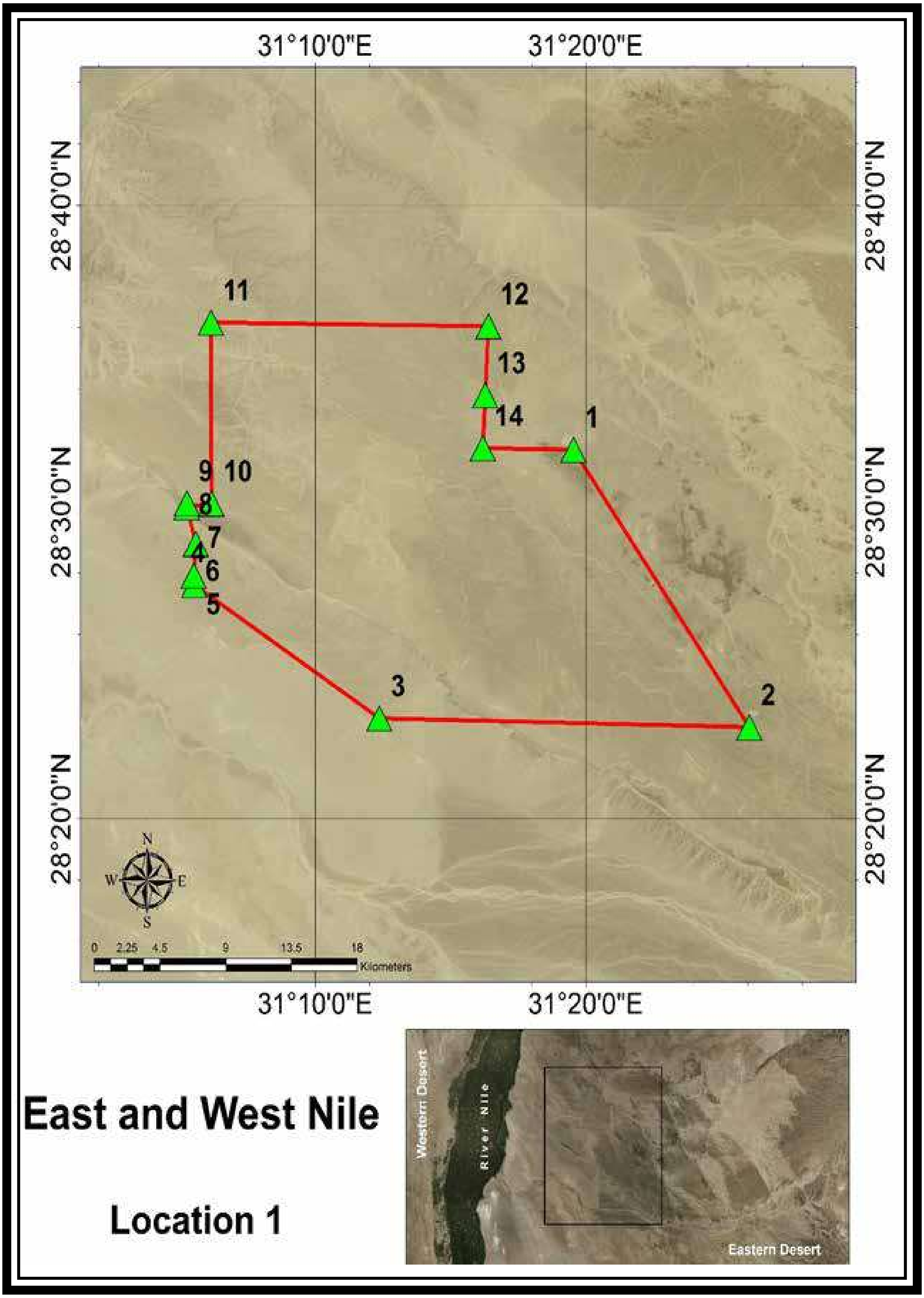
Land area 338325.49 Feddan devoted by Presidential Decree No. 116 of year 2016, date 21/3/2016. Its coordinates are as follows:



3

LOCATION 1

Land area 127790.54 Feddan devoted by Presidential Decree No. 116 of year 2016, date 21/3/2016. Its coordinates are as follows:



Monthly mean solar energy in kWh/m2 for PV systems for the lands of West and East Nile Location.

SOLAR ENERGY PV (KWH/M2)			
LOCATION	1	2	3
JAN	130	132	128
FEB	144	145	142
MAR	203	207	202
APR	223	225	223
MAY	251	252	252
JUN	257	258	258
JUL	263	262	262
AUG	245	246	245
SEP	210	211	209
OCT	177	179	177
NOV	137	140	135
DEC	123	125	121
TOTAL	2360	2379	2352

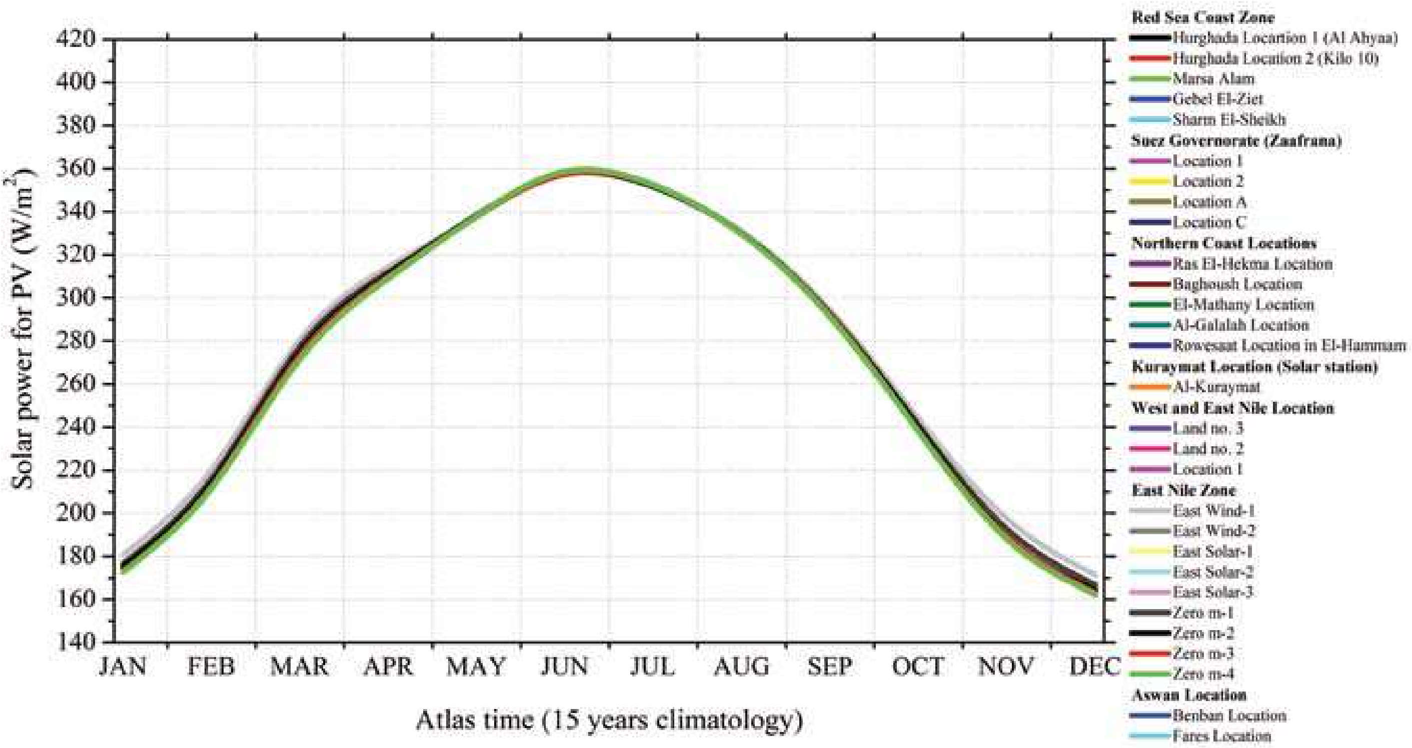
Monthly mean solar energy in kWh/m2 for CSP systems for the lands of the West and East Nile Location.

SOLAR ENERGY CSP (KWH/M2)			
LOCATION	1	2	3
JAN	187	187	182
FEB	183	179	177
MAR	245	248	242
APR	237	236	235
MAY	260	260	260
JUN	284	285	287
JUL	295	292	293
AUG	276	274	274
SEP	253	252	252
OCT	226	227	226
NOV	195	196	189
DEC	184	185	178
TOTAL	2824	2819	2791

5th EAST

ONE	TWO	THREE	FOUR
East Wind-1	East Wind-2	East Solar-1	East Solar-2

EAST NILE ZONE

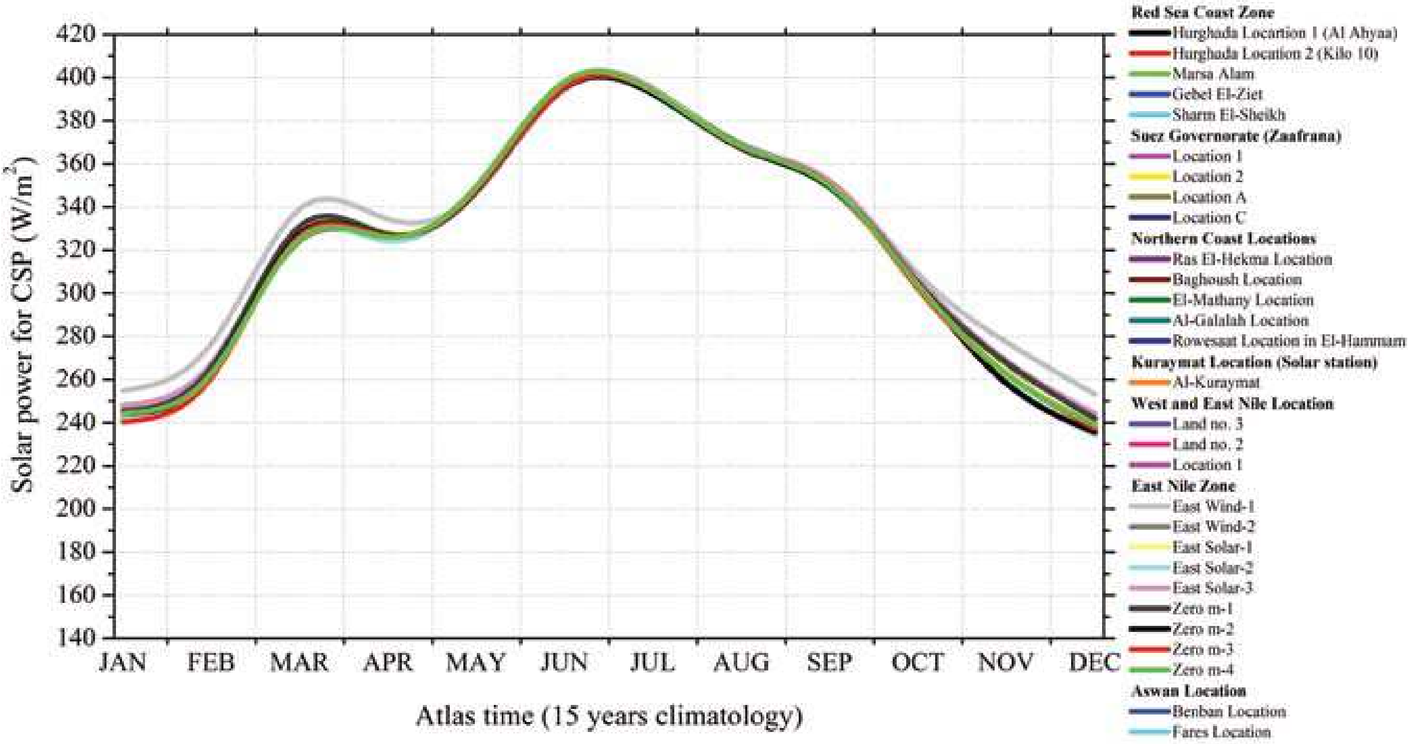


The interannual variability for PV exploitation in the East Nile zone presents incoming solar power values from 160 W/m2 in winter to 260 W/m2 in summer.

NILE ZONE

FIVE	SIX	SEVEN	EIGHT	NINE
East Solar-3	Zero m-1	Zero m-2	Zero m-3	Zero m-4

EAST NILE ZONE

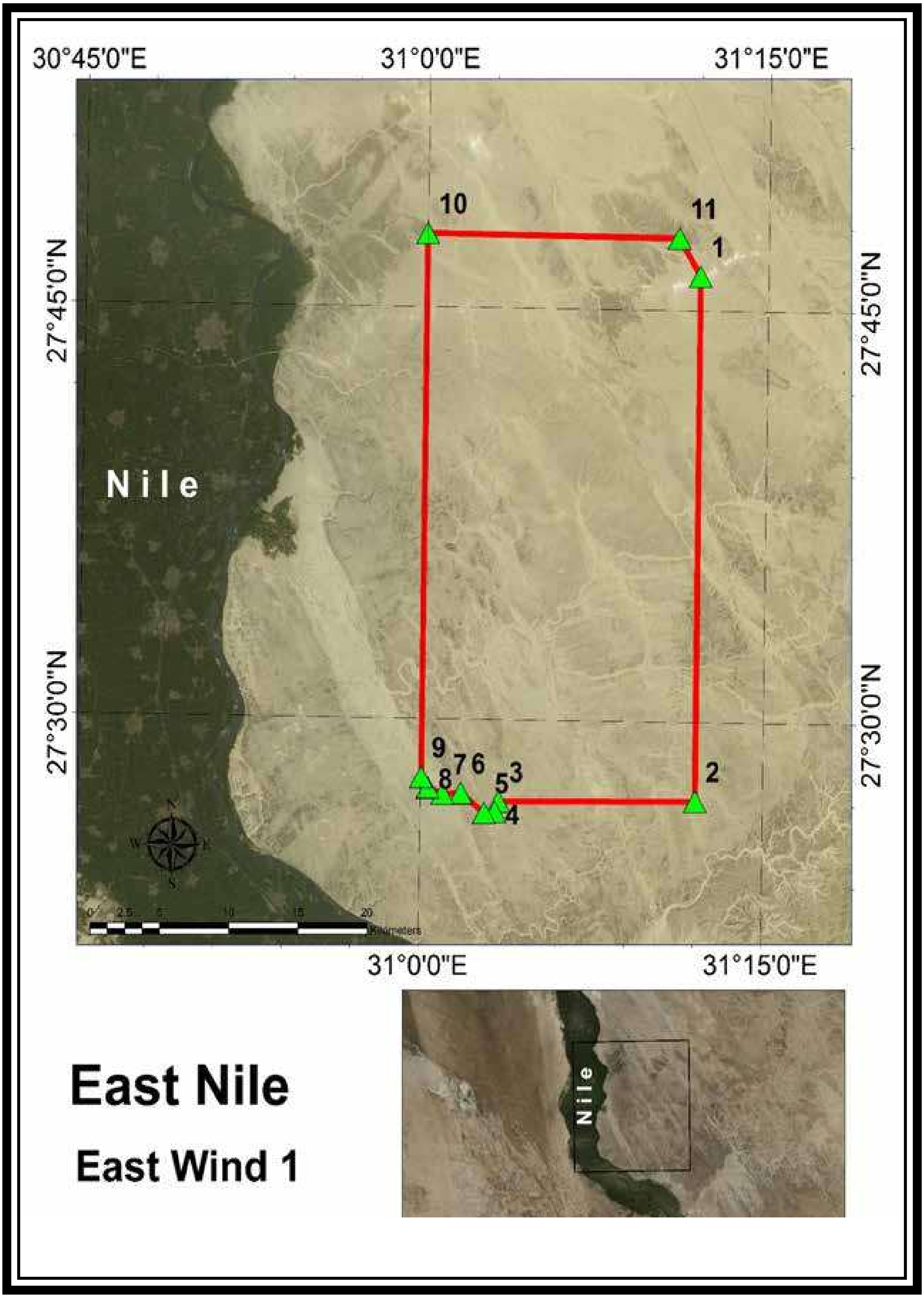


For CSP the corresponding values are 240-260 for winter to 400 W/2 for summer months.

1

EAST WIND-1

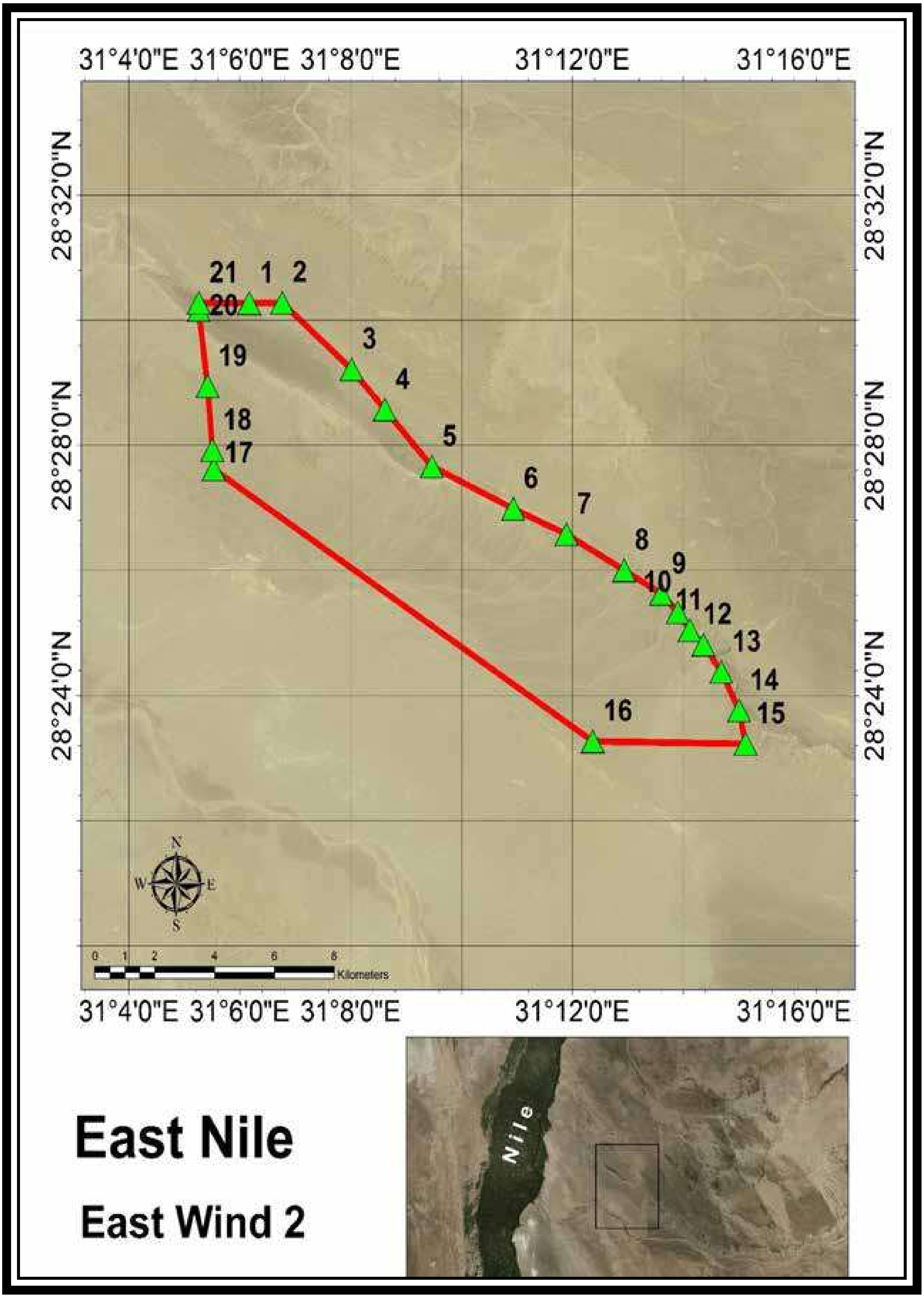
Land of area 748.3510132 km2 (Elevation is 150 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



2

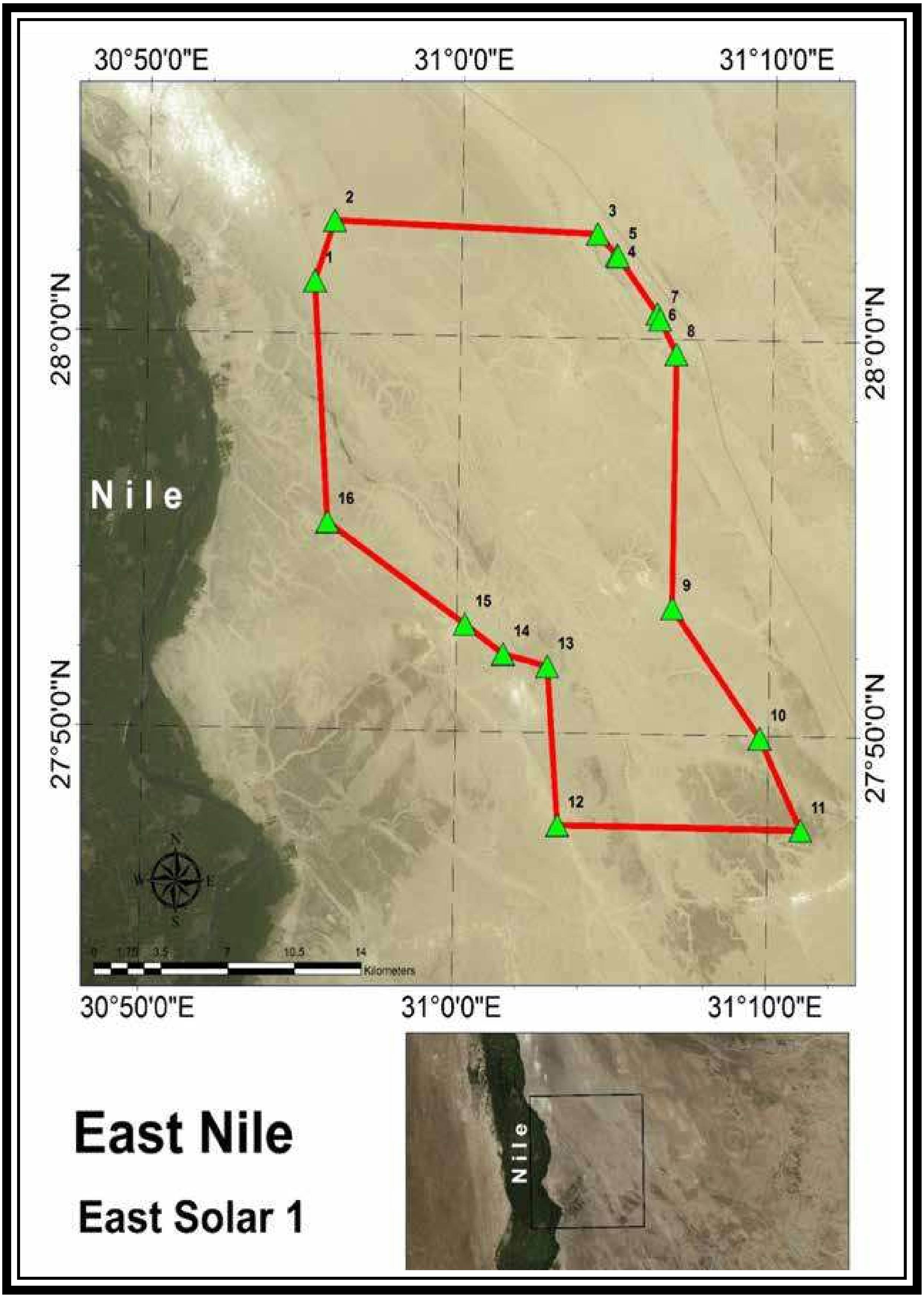
EAST WIND-2

Land of area 78.9180984 km2 (Elevation is 150 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



3 EAST SOLAR-1

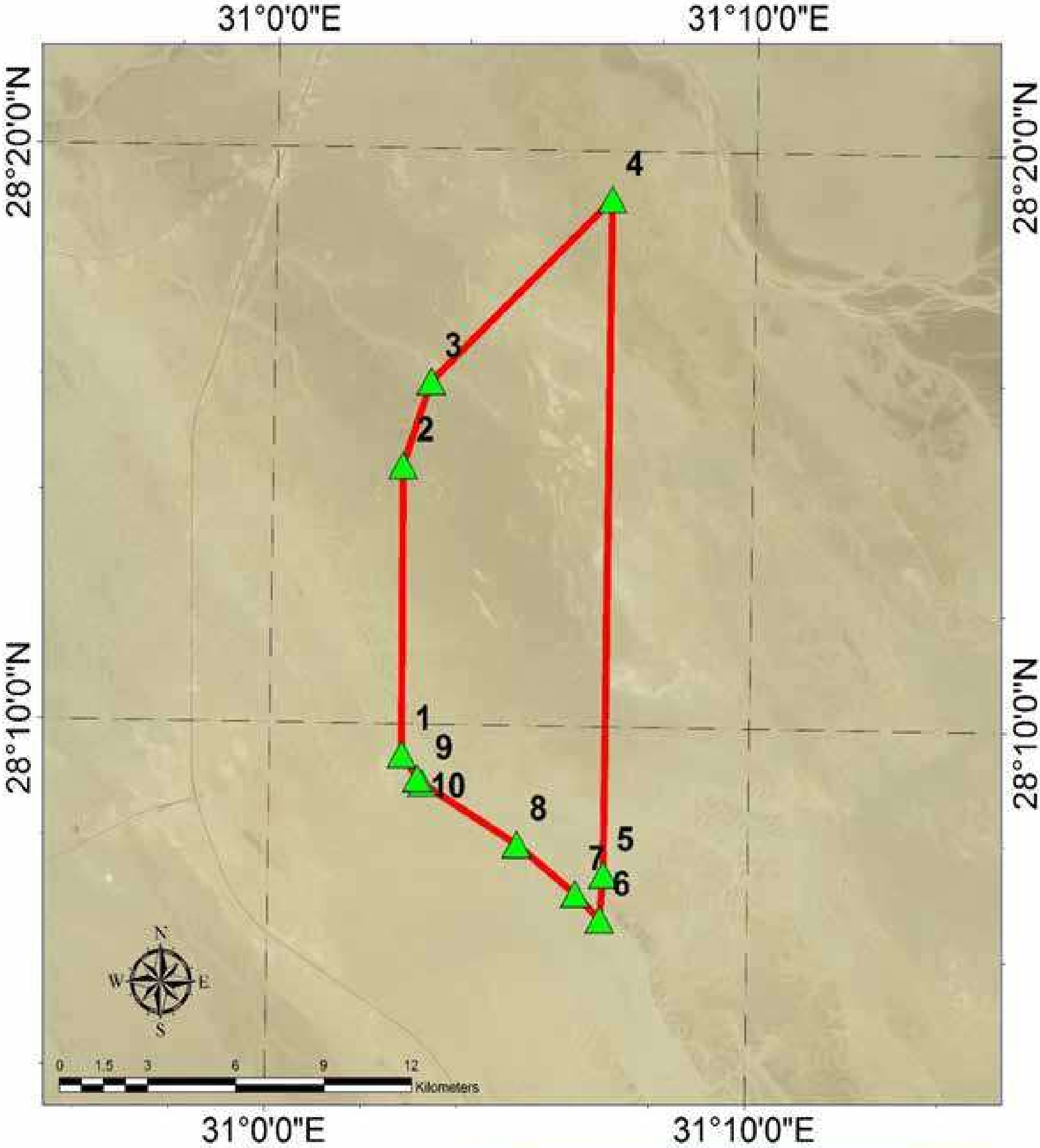
Land of area 416.0840149 km2 (Elevation is 5 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



4

EAST SOLAR-2

Land of area 118.6579971 km2 (Elevation is 5 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



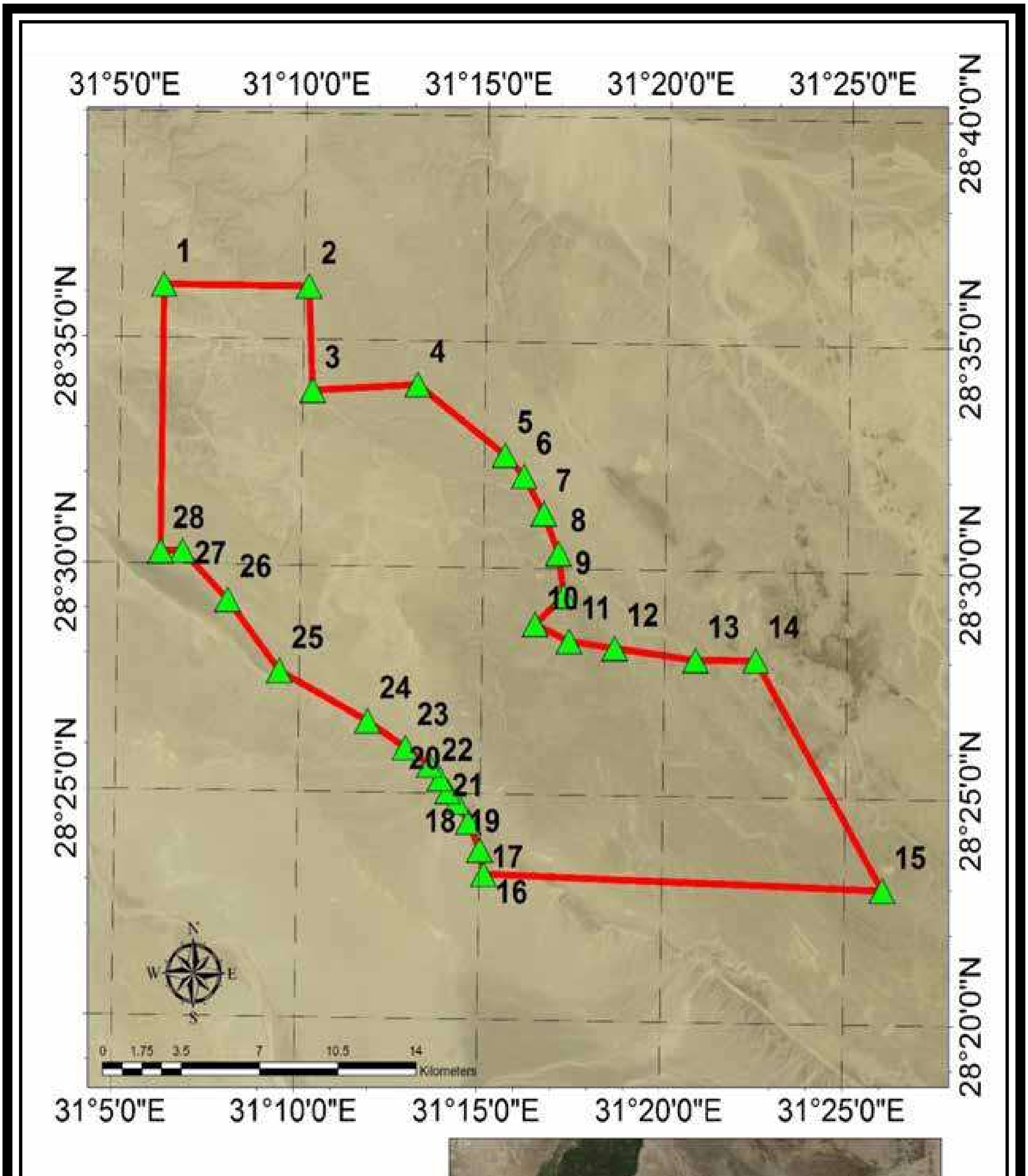
East Nile

East Solar 2

5

EAST SOLAR-3

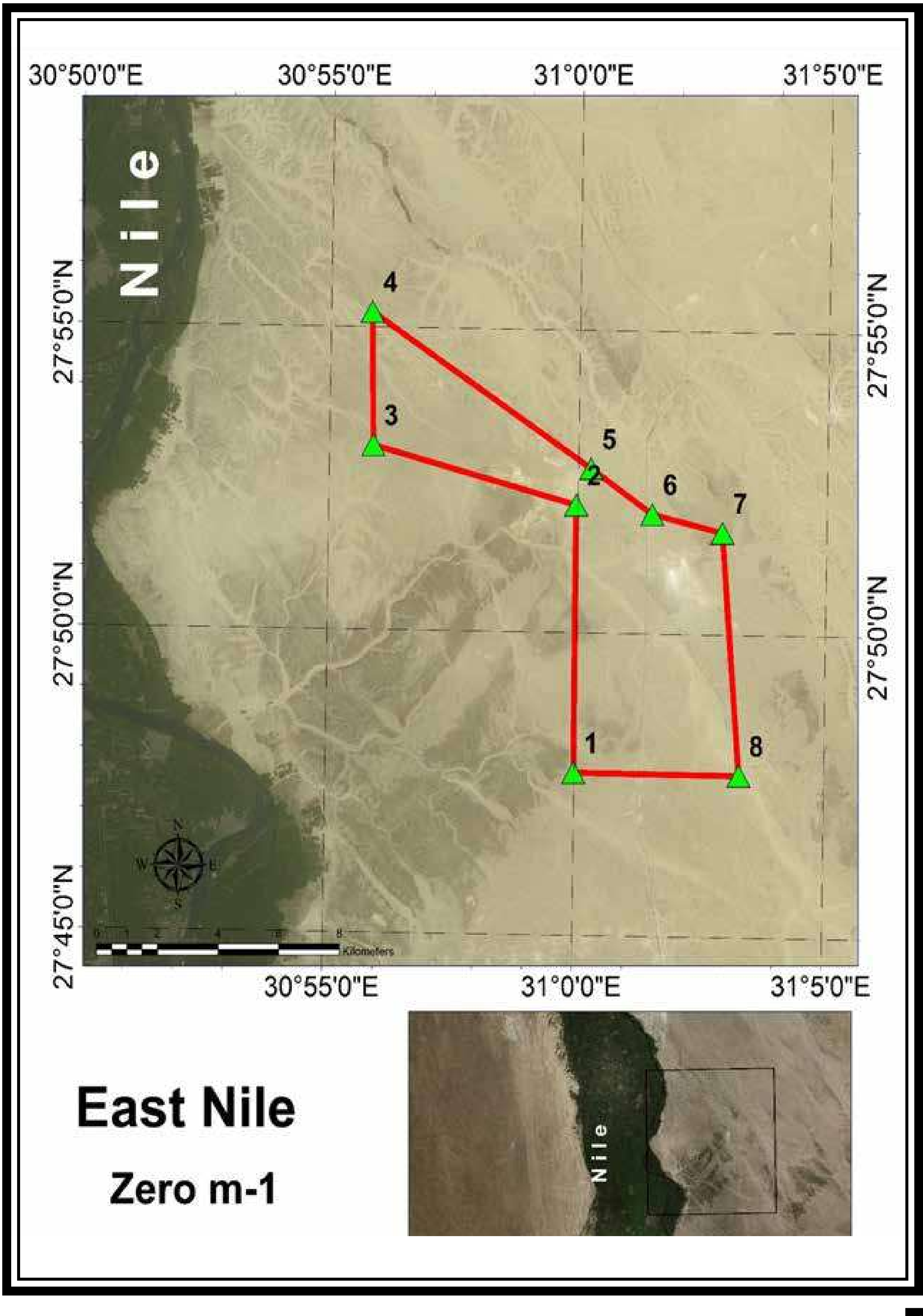
Land of area 363.0570068 km2 (Elevation is 5 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



6

ZERO M-1

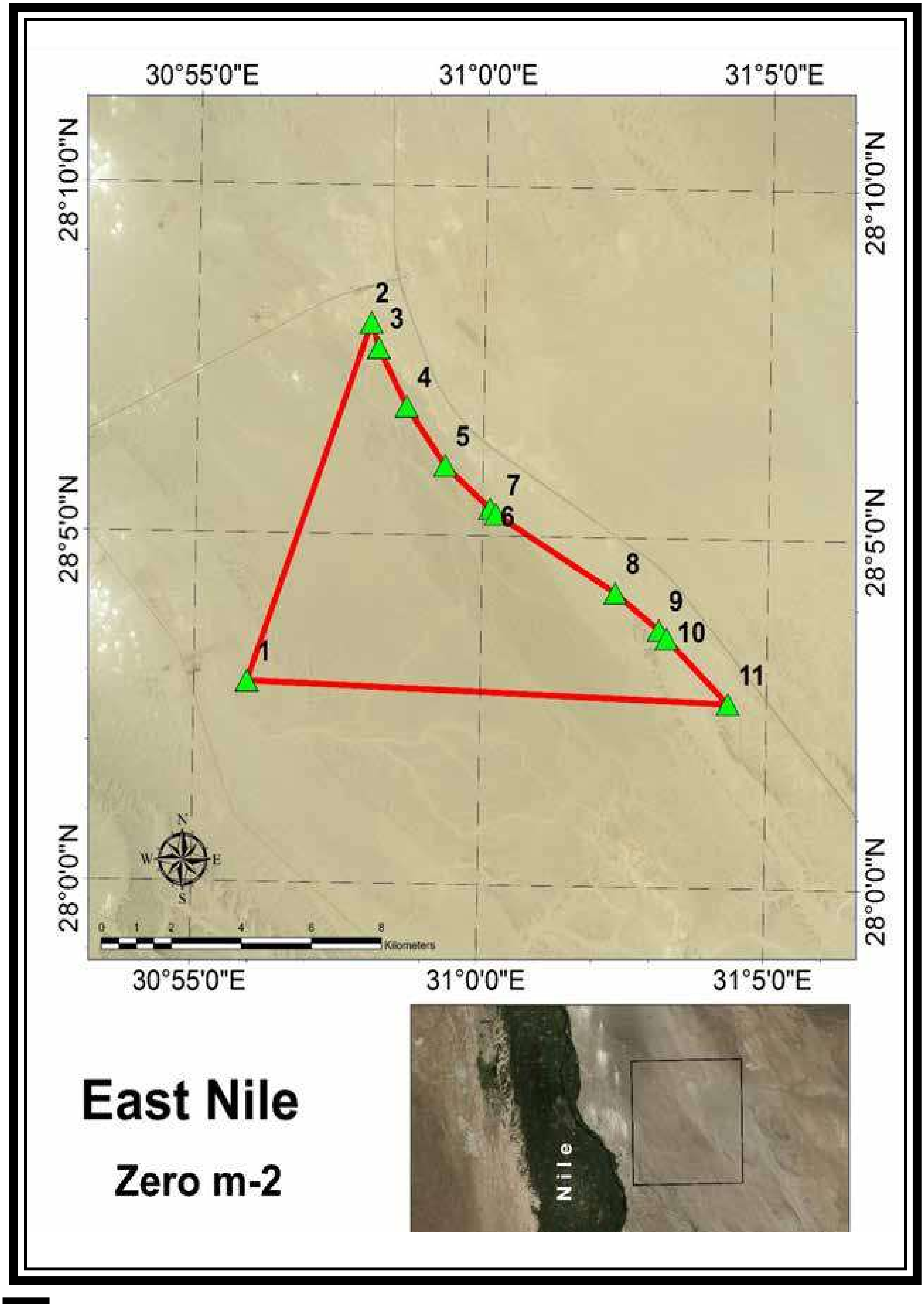
Land of area 60.4500999 km2 (Elevation is 0 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



7

ZERO M-2

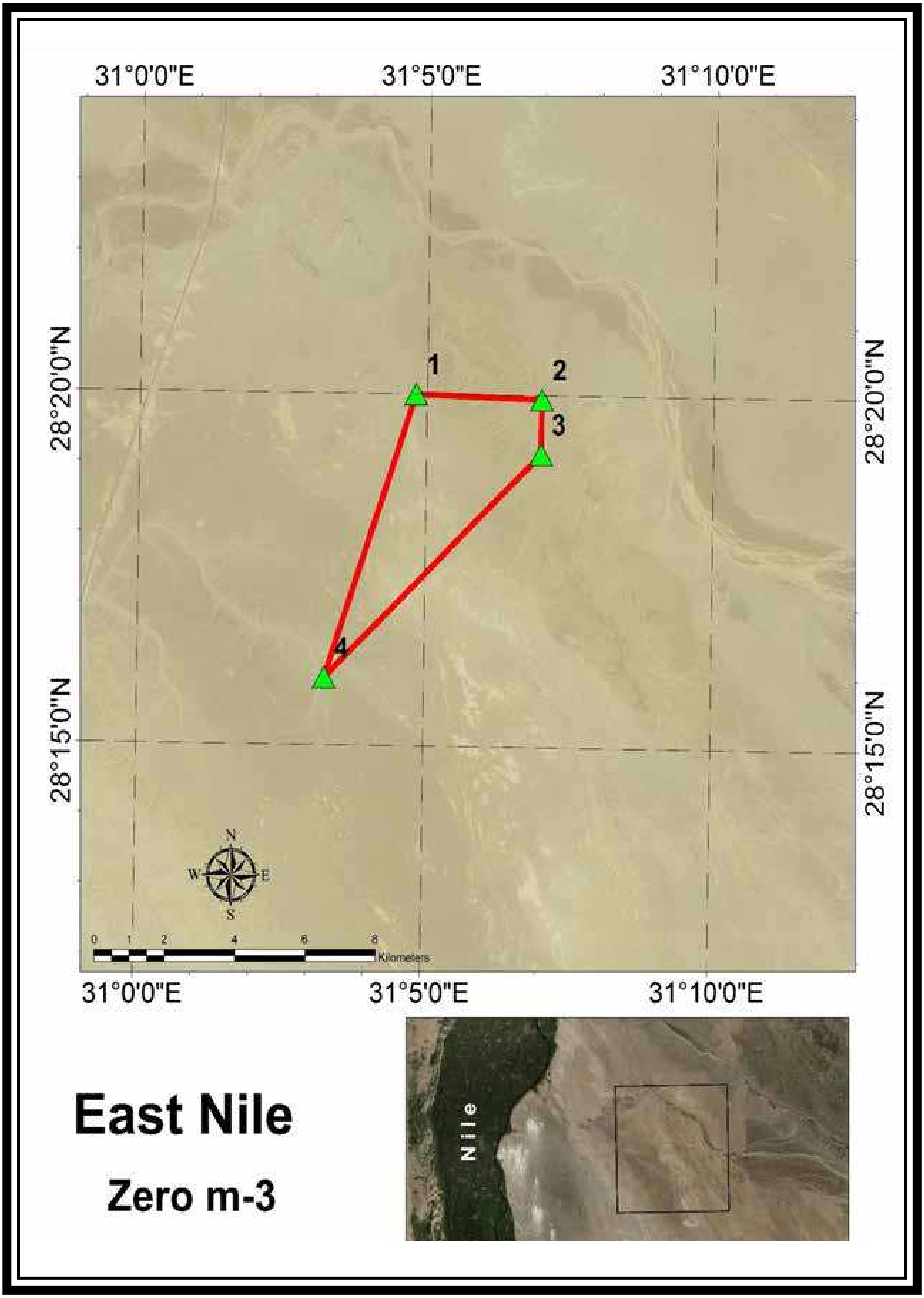
Land of area 58.3455009 km2 (Elevation is 0 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:



8

ZERO M-3

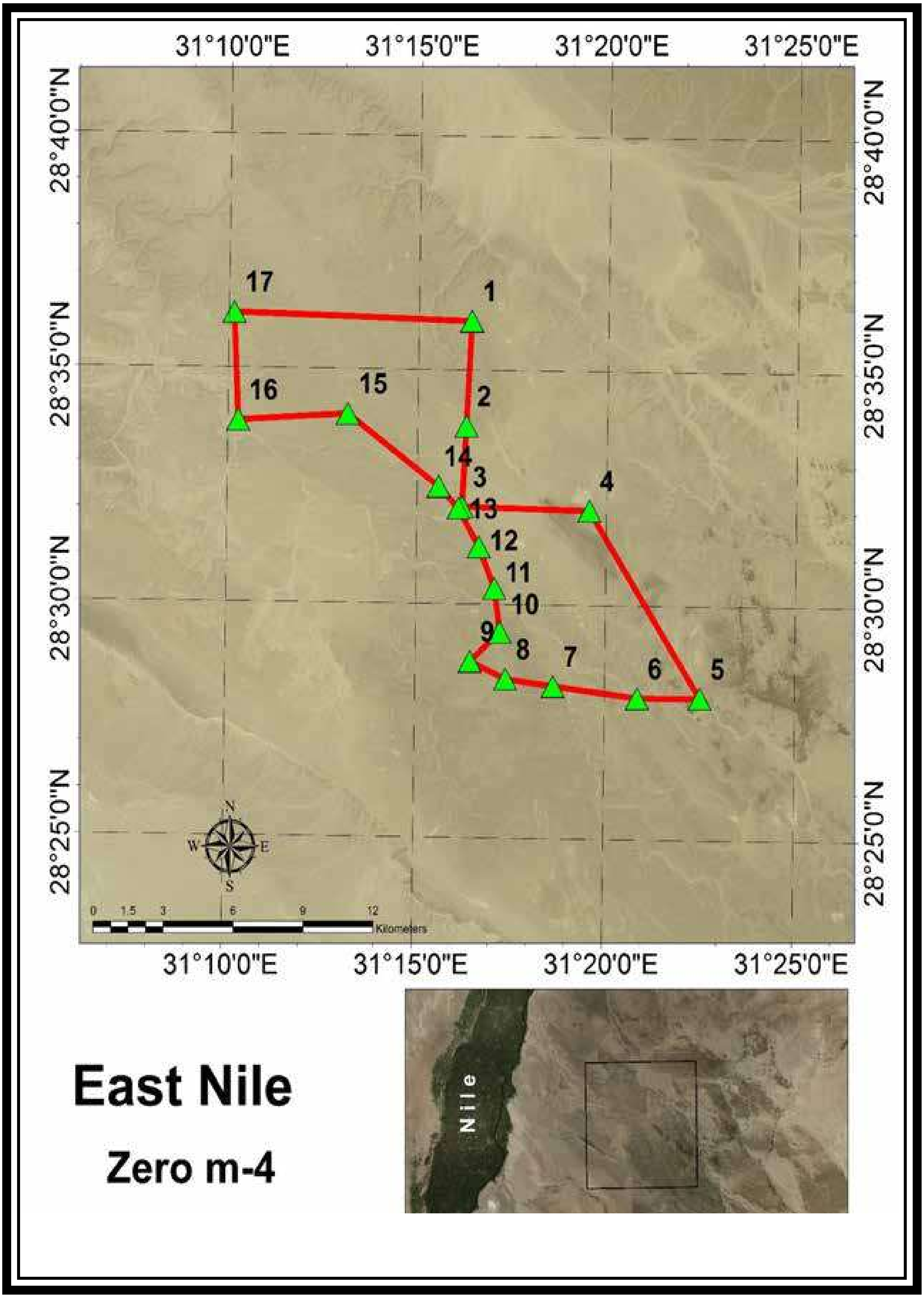
Land of area 17.8666 km2 (Elevation is 0 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:

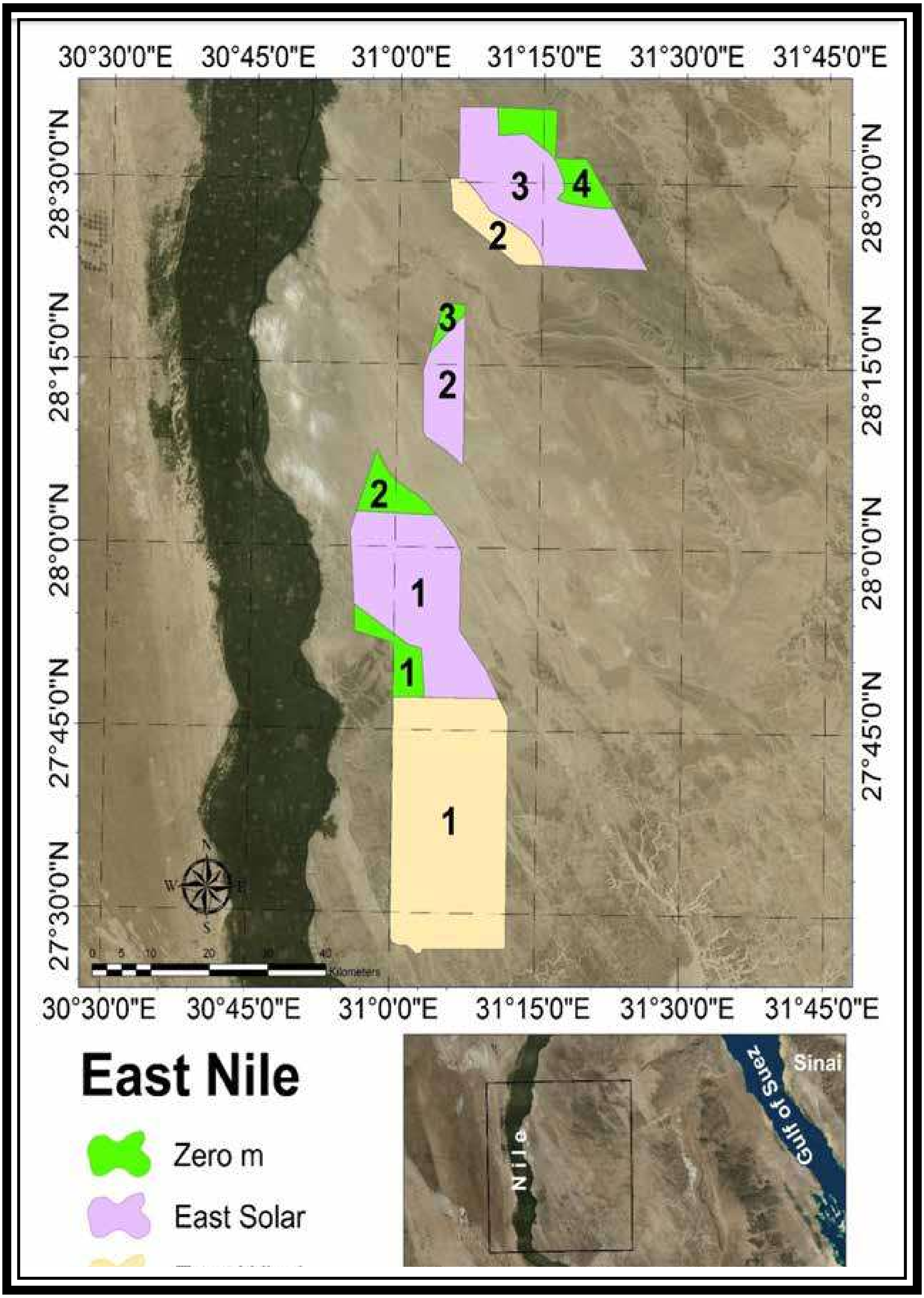


9

ZERO M-4

Land of area 96.6465988 km2 (Elevation is 0 m), devoted to the Authority of Development and Using New and Renewable Energy, by Presidential decree No. 572 year 2016 (Dated 17/12/2016). Its coordinates (UTM, WGS84, Zone 36N) are as follows:




30°30'0"E
30°45'0"E
31°0'0"E
31°15'0"E
31°30'0"E
31°45'0"E
28°30'0"N
28°15'0"N
28°0'0"N
27°45'0"N
27°30'0"N
3
4
2
3
2
2
1
1
1
Kilometers
East Nile
Zero m
East Solar
Nile
Gulf of Suez
Sinai

EAST NILE ZONE

Monthly mean solar energy in kWh/m2 for PV systems for the lands of East Nile Zone.

SOLAR ENERGY PV (KWH/M2)

LOCATION	1	2	3	4	5	6	7	8	9
JAN	134	128	132	130	129	131	130	129	128
FEB	148	143	145	143	143	145	144	143	142
MAR	209	202	206	204	203	206	205	203	202
APR	226	223	225	223	222	225	224	223	223
MAY	251	251	252	252	251	251	252	251	252
JUN	258	258	258	257	258	257	257	258	258
JUL	262	262	262	262	262	262	262	262	262
AUG	246	245	245	245	245	245	245	245	245
SEP	212	210	211	210	210	211	210	210	209
OCT	181	177	179	178	178	179	178	177	177
NOV	142	136	138	136	137	139	136	136	135
DEC	128	121	124	122	122	124	122	121	121
TOTAL	2396	2355	2373	2361	2358	2374	2363	2356	2352

Monthly mean solar energy in kWh/m2 for CSP systems for the lands of the East Nile Zone.

SOLAR ENERGY CSP (KWH/M2)

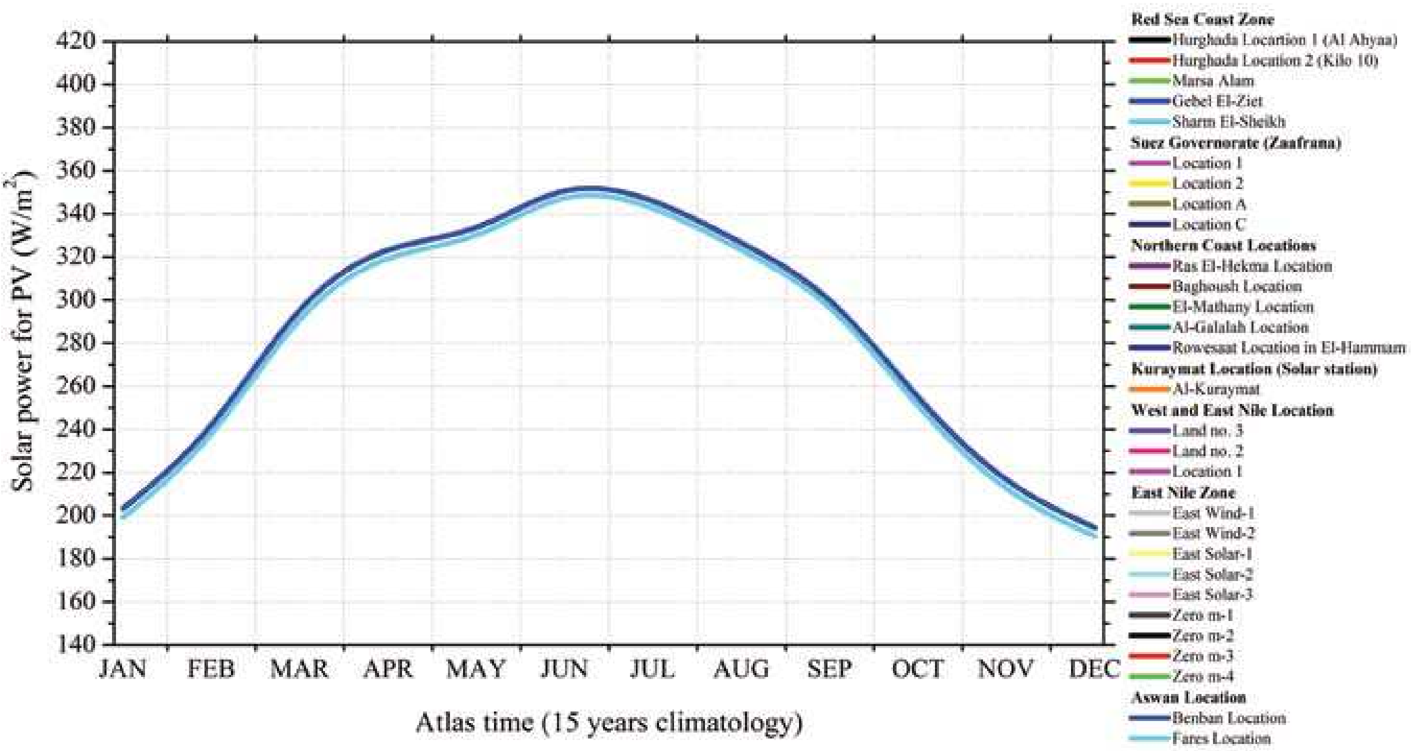
LOCATION	1	2	3	4	5	6	7	8	9
JAN	190	180	184	181	185	183	182	179	182
FEB	186	178	178	176	180	179	177	175	177
MAR	252	241	246	242	244	246	244	243	242
APR	241	234	236	233	235	236	235	235	235
MAY	258	258	259	259	260	258	259	259	260
JUN	284	286	285	285	287	285	285	285	287
JUL	293	294	293	292	293	292	292	293	293
AUG	275	275	274	274	274	273	273	274	274
SEP	253	252	252	252	253	251	252	252	252
OCT	230	226	228	226	228	227	226	225	226
NOV	200	191	190	187	193	193	186	189	189
DEC	188	176	178	174	182	180	175	177	178
TOTAL	2847	2788	2799	2778	2811	2800	2782	2782	2791

6th ASWAN

ONE

Benban Location

ASWAN LOCATION



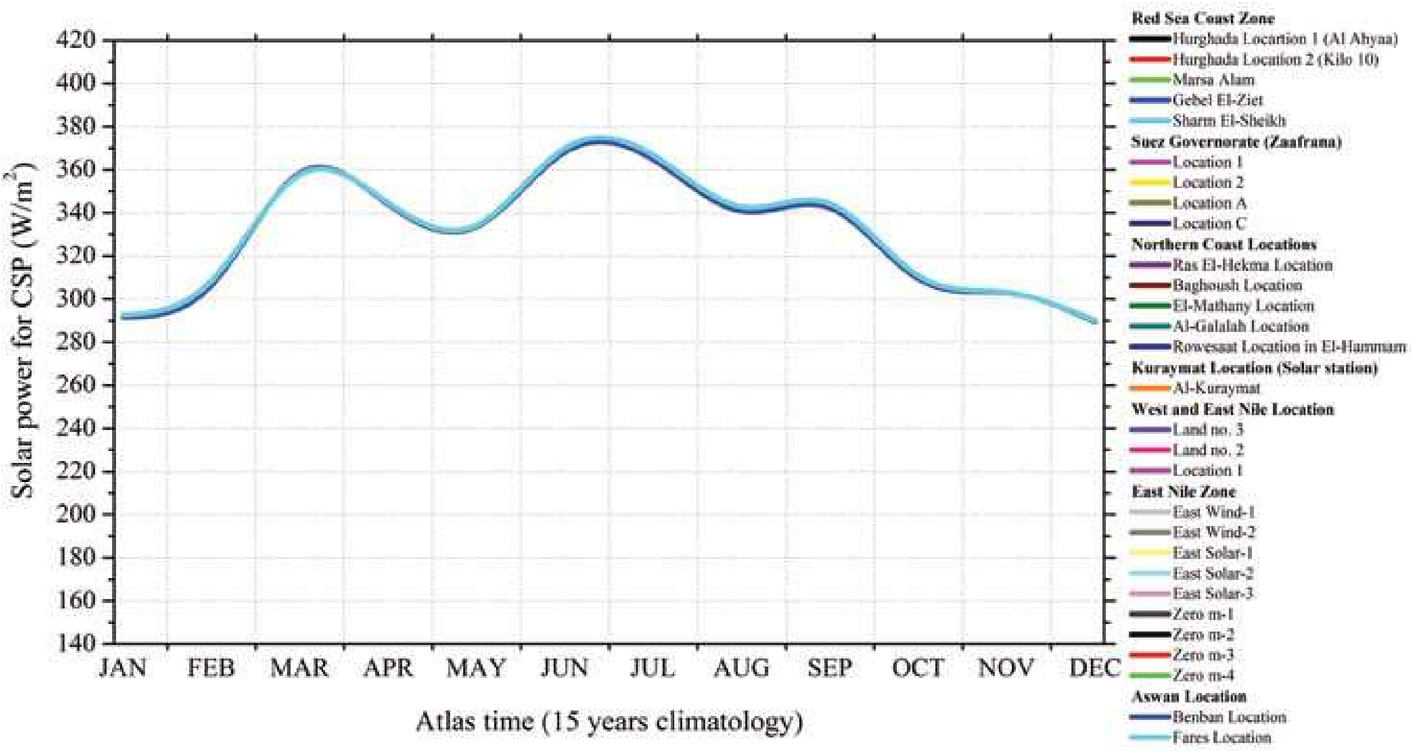
Aswan is a location where the available solar power for PV technologies is in the range 200 and 250 W/m2 and this indicates the appropriateness of Aswan and the surroundings for efficient energy exploitation almost all year.

LOCATION

TWO

Fares Location

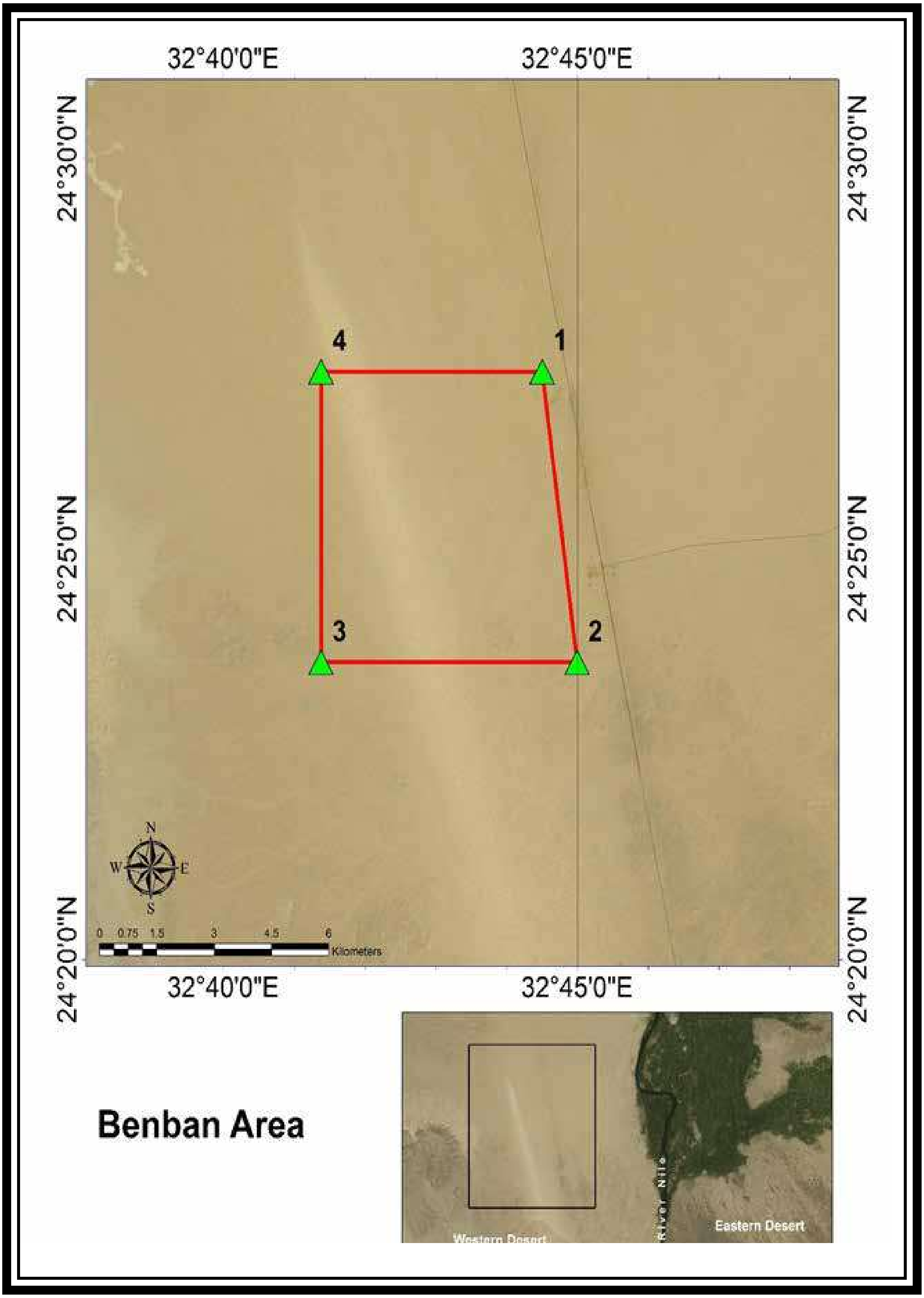
ASWAN LOCATION



Under DNI, the CSP technologies are able to exploit a high solar power of more than 290 W/m2 for the largest part of the year with maximum mean DNI values of about 370 W/m2.

1 BENBAN LOCATION

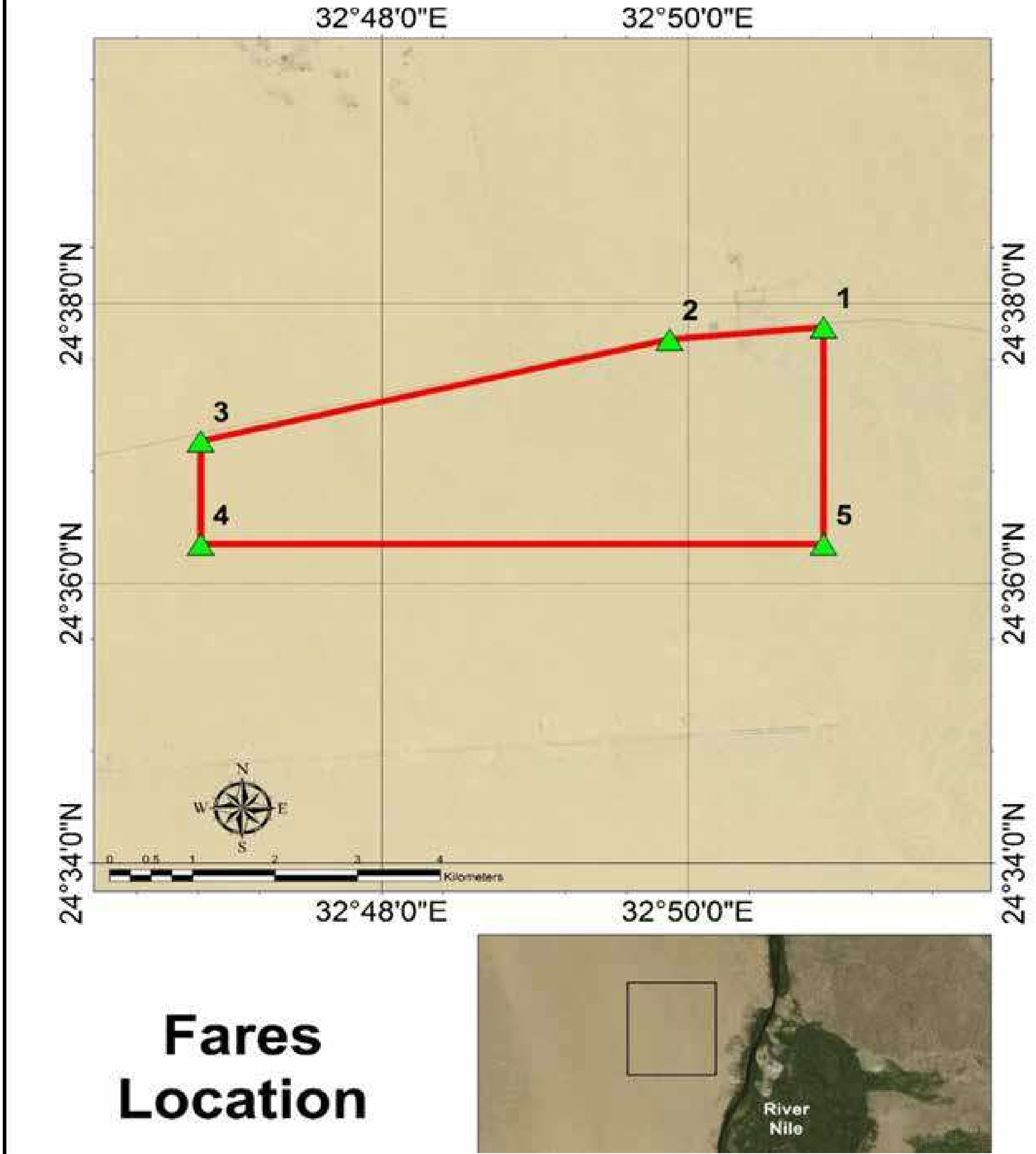
Land area 8843.28 Feddan devoted by Presidential Decree No 116 of year 2016, Date 21/3/2016, its coordinates as the follow:



2

FARES LOCATION

Land area 3621.2 Feddan (15.212 km2) devoted by Presidential Decree No 116 of year 2016, Date 21/3/2016, Its coordinates are as follows:



ASWAN LOCATION

Monthly mean solar energy in kWh/m2 for PV systems for the lands of Aswan Location.

LOCATION	SOLAR ENERGY PV (KWH/M2) 1	2
JAN	151	148
FEB	163	160
MAR	220	216
APR	233	230
MAY	248	246
JUN	252	250
JUL	257	255
AUG	243	240
SEP	216	213
OCT	190	187
NOV	156	153
DEC	145	142
TOTAL	2472	2439

Monthly mean solar energy in kWh/m2 for CSP systems for the lands of Aswan Location.

SOLAR ENERGY CSP (KWH/M2)		
2	1	LOCATION
218	217	JAN
207	206	FEB
266	267	MAR
248	248	APR
249	248	MAY
266	265	JUN
273	271	JUL
255	254	AUG
248	246	SEP
231	230	OCT
218	218	NOV
216	215	DEC
2895	2885	TOTAL

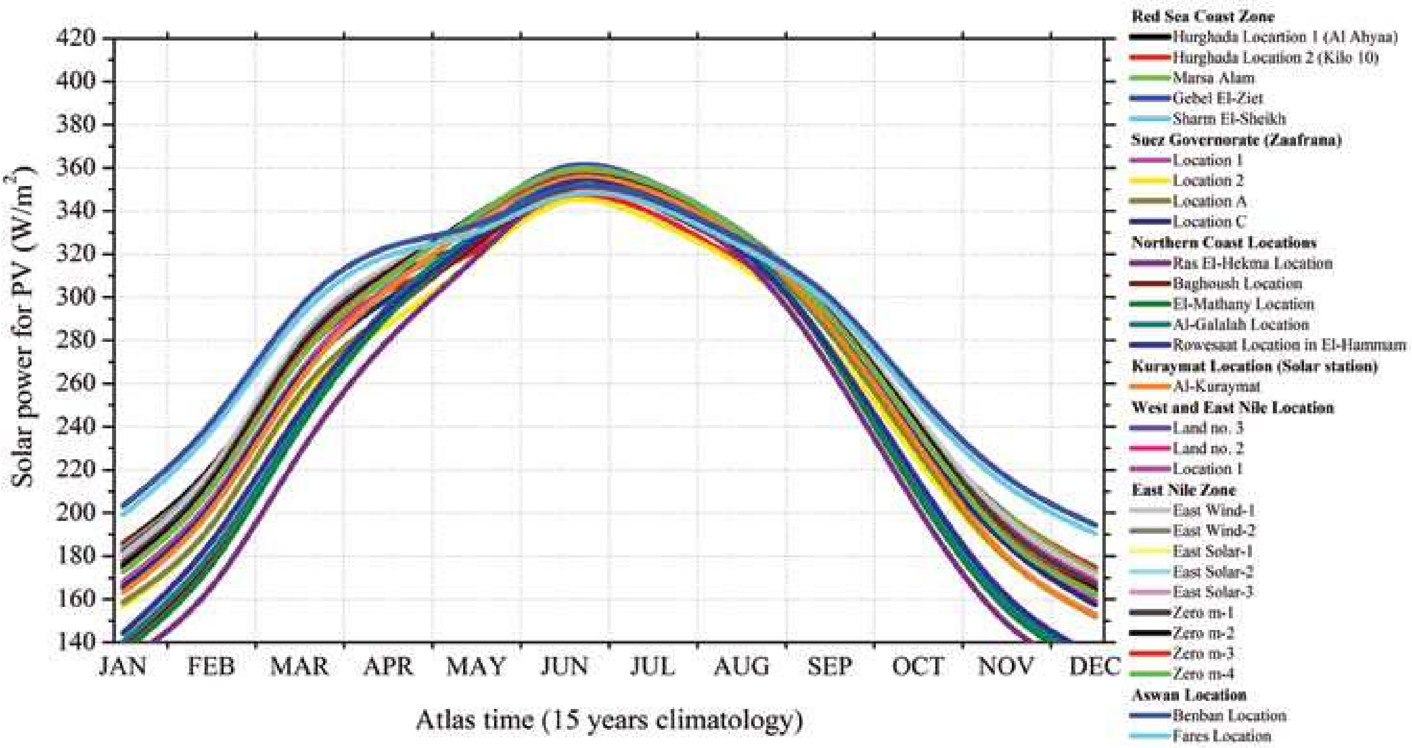
05

NREA LANDS SOLAR POWER AND ENERGY POTENTIAL FOR PV AND CSP INSTALLATIONS

In this Section, the solar power and energy results of Section IV is concluded in order to present all together the 29 NREA locations for comparison reasons, and the analysis for specific exploitation areas is extended as to quantify the potential energy outputs for PV and CSP installations.

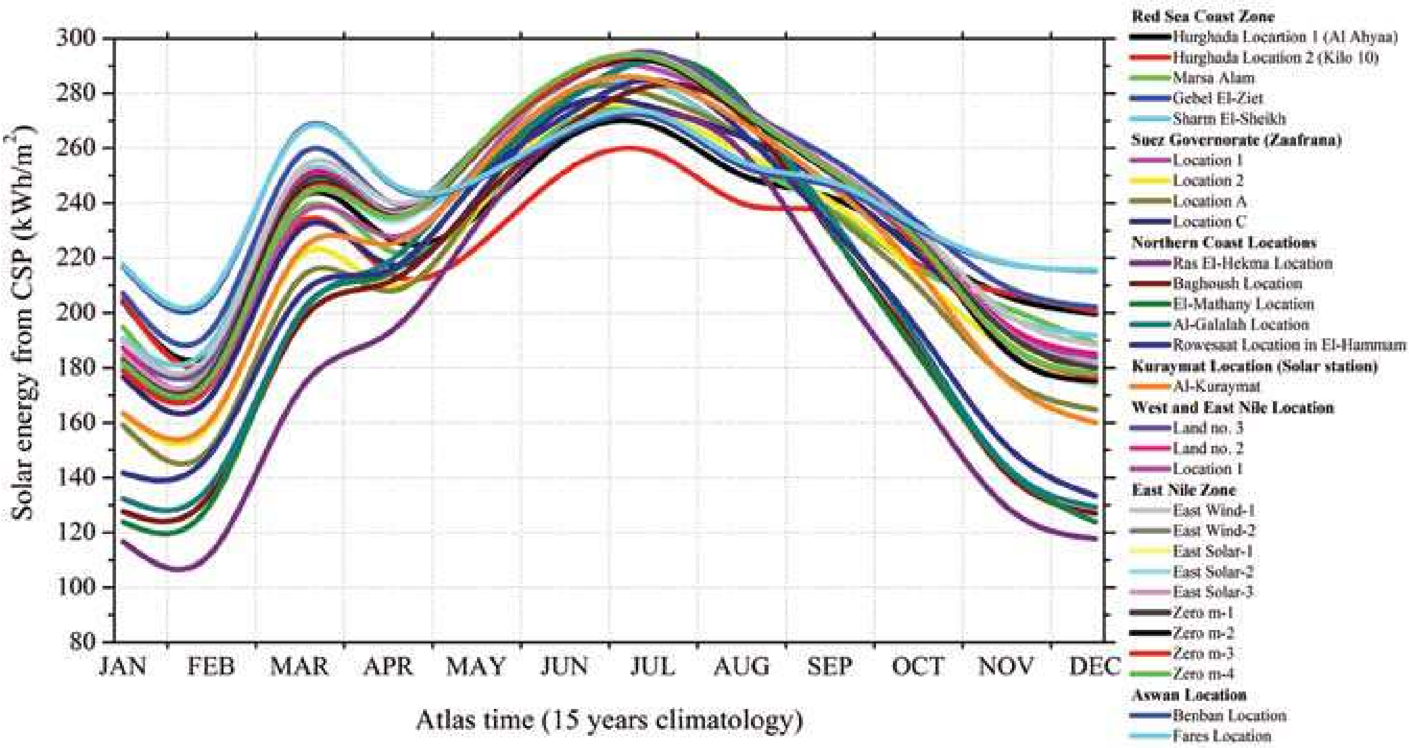
EAST NILE ZONE

EAST NILE ZONE



The proposed by NREA lands showed that the majority of the locations in Egypt are favorable for PV exploitation since the mean winter GHI values range from 140 to 200 W/m2 and during summer are 340-360 W/m2.

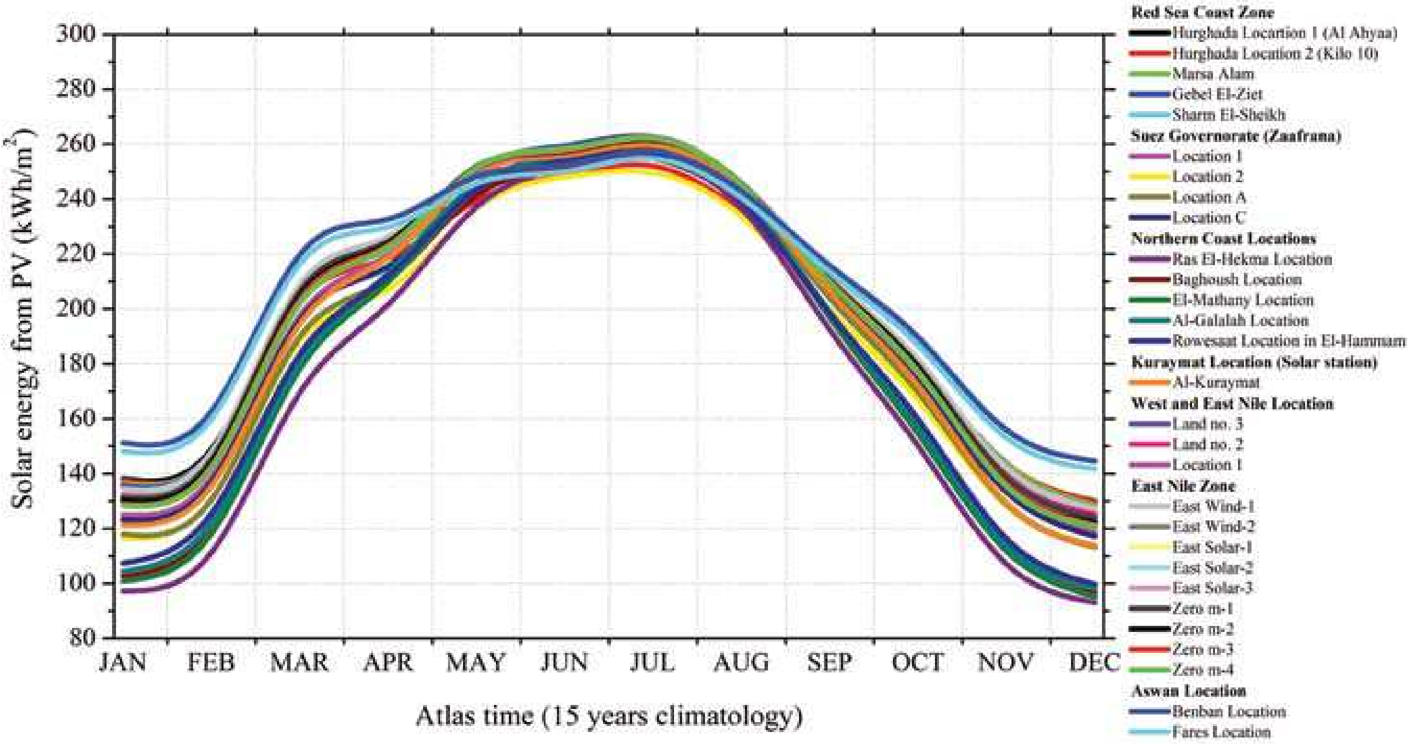
EAST NILE ZONE



CSPs are ideal for the Egyptian climatological conditions in terms of high mean DNI values which are from 160 to 300 in winter and reach 400 W/m2 in summer.

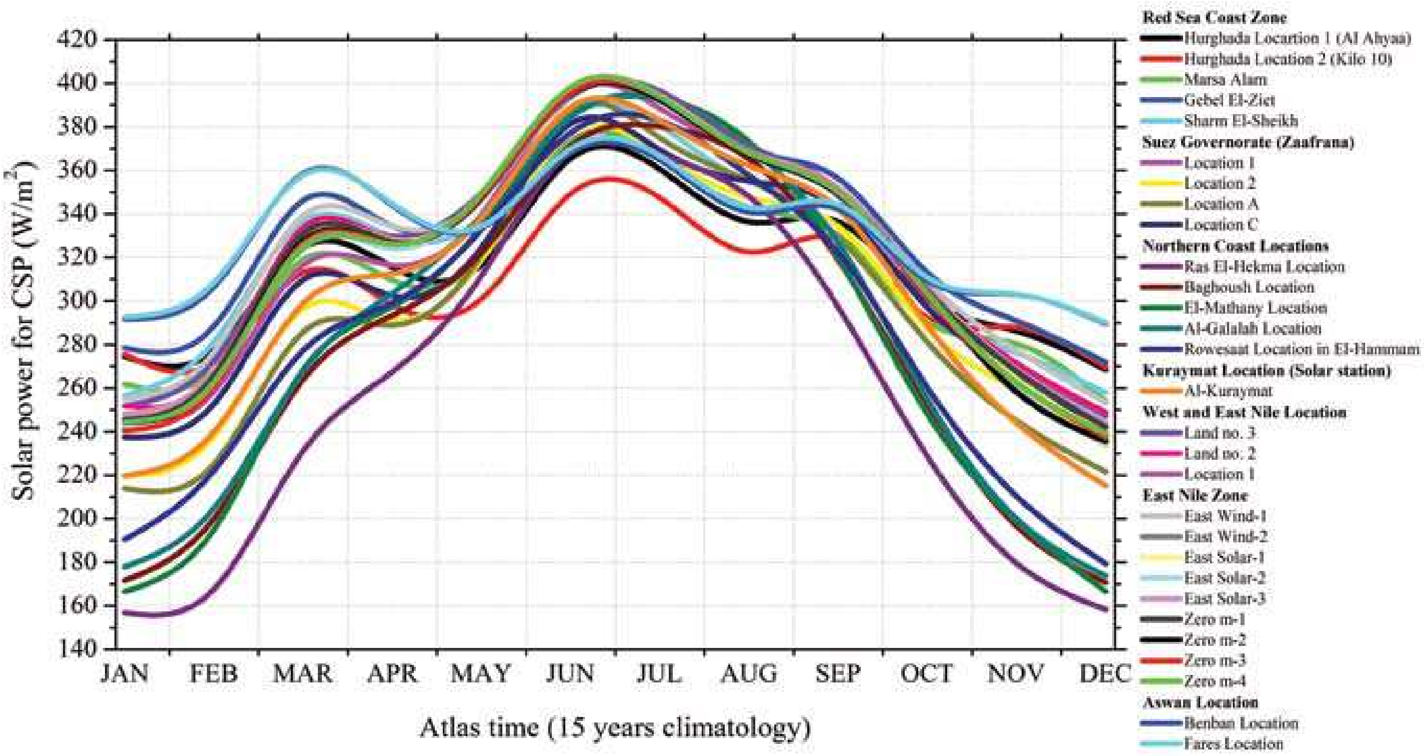
EAST NILE ZONE

EAST NILE ZONE



The sums of the monthly mean solar energy potential values suggest that the proposed locations have energy potential for PV exploitation starting from 2100 kWh/m2 at the Northern Coast locations to more than 2450 at Aswan location. East Nile zone reaches annual energy potential of 2400 kWh/m2, while the Red Sea Coast Zone, the Suez Governorate, the Kuraymat and the West and East Nike locations have mean energy potential of more than 2300 kWh/m2.

EAST NILE ZONE



CSPs benefit from the cloudless conditions but at the same time have to deal with the dust storms which are favorable during spring and in particular in April. However, the range of the solar energy potential is from 2250 kWh/m2 at the Northern Coast locations to almost 2900 kWh/m2 at the Southern locations including the greater region of Aswan and the southeast Nile zone.

SOLAR ENERGY POTENTIAL IN EGYPT

LOCATION	PV KWH/M2	PV TWH/YEAR
RED SEA COAST ZONE		
HURGHADA LOCATION 1 (AL AHYAA)	2365	0.08
HURGHADA LOCATION 2 (KILO 10)	2338	5.84
MARSA ALAM	2363	6.02
GEBEL EL-ZIET	2395	1572.13
SHARM EL-SHEIKH	2372	0.06
SUEZ GOVERNORATE (ZAAFRANA)		
LOCATION 1	2326	186.08
LOCATION 2	2216	168.39
LOCATION A	2262	18.53
LOCATION C	2298	19.91
NORTHERN COAST LOCATIONS		
RAS EL-HEKMA LOCATION	2100	0.09
BAGHOUSH LOCATION	2162	0.13
EL-MATHANY LOCATION	2164	0.09
AL-GALALAH LOCATION	2190	0.13
ROWESAAT LOCATION IN EL-HAMMAM CITY	2197	0.04
KURAYMAT LOCATION (SOLAR STATION)		
AL-KURAYMAT	2296	6.37
WEST AND EAST NILE LOCATION		
LAND NO. 3	2360	1089.37
LAND NO. 2	2379	3379.97
LOCATION 1	2352	1262.74
EAST NILE ZONE		
EAST WIND-1	2396	1792.83
EAST WIND-2	2355	185.82
EAST SOLAR-1	2373	987.44
EAST SOLAR-2	2361	280.18
EAST SOLAR-3	2358	856.25
ZERO M-1	2374	143.52
ZERO M-2	2363	137.89
ZERO M-3	2356	42.10
ZERO M-4	2352	227.35
ASWAN LOCATION		
BENBAN LOCATION	2472	91.81
FARES LOCATION	2439	37.10

SOLAR ENERGY POTENTIAL IN EGYPT

LOCATION	CSP KWH/M2	CSP TWH/YEAR
RED SEA COAST ZONE		
HURGHADA LOCATION 1 (AL AHYAA)	2747	0.09
HURGHADA LOCATION 2 (KILO 10)	2670	6.68
MARSA ALAM	2712	6.91
GEBEL EL-ZIET	2909	1909.37
SHARM EL-SHEIKH	2802	0.07
SUEZ GOVERNORATE (ZAAFRANA)		
LOCATION 1	2767	221.34
LOCATION 2	2607	198.10
LOCATION A	2577	21.11
LOCATION C	2685	23.27
NORTHERN COAST LOCATIONS		
RAS EL-HEKMA LOCATION	2250	0.10
BAGHOUSH LOCATION	2413	0.14
EL-MATHANY LOCATION	2443	0.10
AL-GALALAH LOCATION	2479	0.15
ROWESAAT LOCATION IN EL-HAMMAM CITY	2491	0.05
KURAYMAT LOCATION (SOLAR STATION)		
AL-KURAYMAT	2653	7.35
WEST AND EAST NILE LOCATION		
LAND NO. 3	2824	1303.64
LAND NO. 2	2819	4005.96
LOCATION 1	2791	1498.33
EAST NILE ZONE		
EAST WIND-1	2847	2130.77
EAST WIND-2	2788	220.06
EAST SOLAR-1	2799	1164.67
EAST SOLAR-2	2778	329.65
EAST SOLAR-3	2811	1020.65
ZERO M-1	2800	169.28
ZERO M-2	2782	162.33
ZERO M-3	2782	49.71
ZERO M-4	2791	269.76
ASWAN LOCATION		
BENBAN LOCATION	2885	107.16
FARES LOCATION	2895	44.03

06

ANALYTICAL CLIMATOLOGY OF THE DIRECT NORMAL IRRADIANCE

The last two Sections VI and VII present the analytical monthly climatology of DNI and GHI for the period Jan. 1999 to Dec. 2013. It is based on the EUMETSAT radiation database, while this 15 years of data provide the capability and knowledge needed in order to better understand the atmospheric and climatological processes from year to year and from month to month that determine and specify the surface solar power.

1999

2000

2001

1999 2000 2001 2002 2003

2002

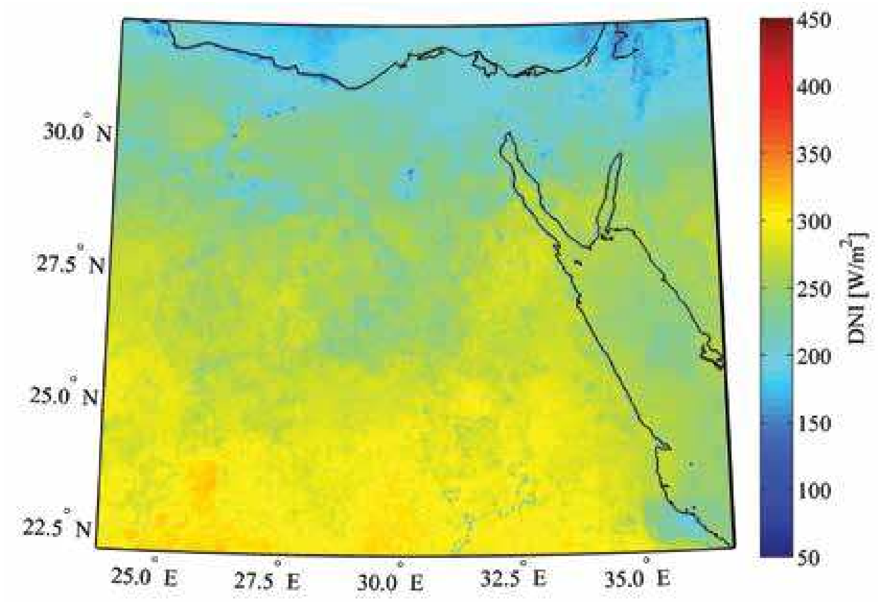
2003

2004

2004 2005 2006 2007 2008
2009 2010 2011 2012 2013

DIRECT NORMAL IRRADIANCE

JAN
1999



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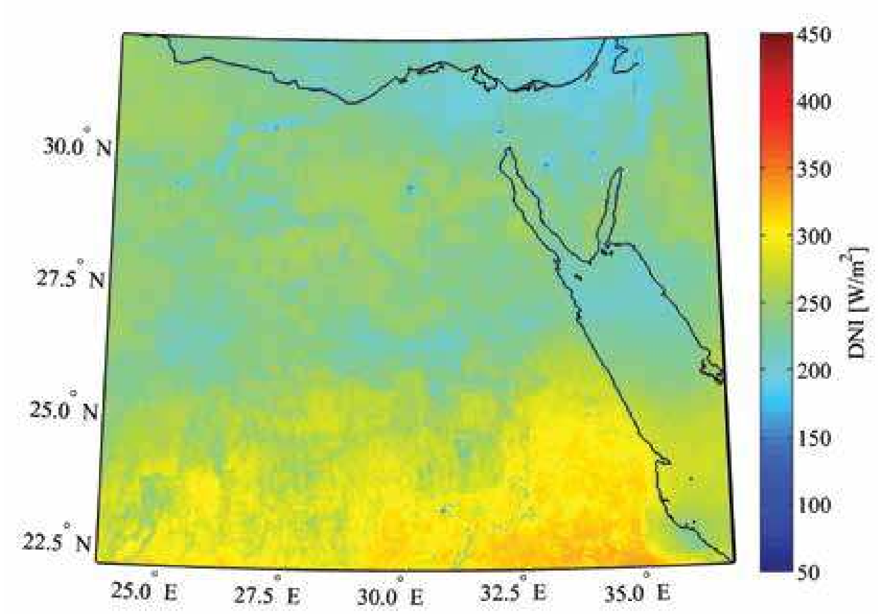
1999



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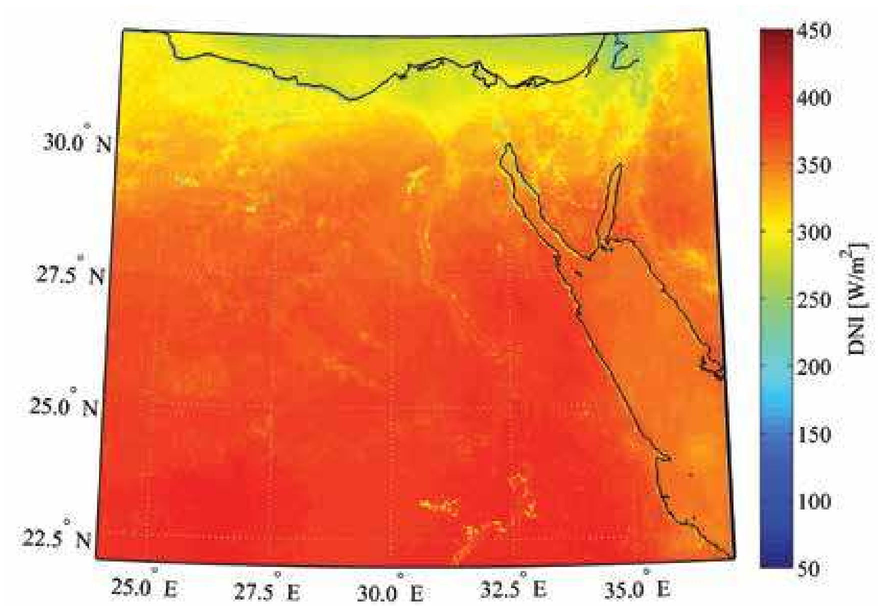

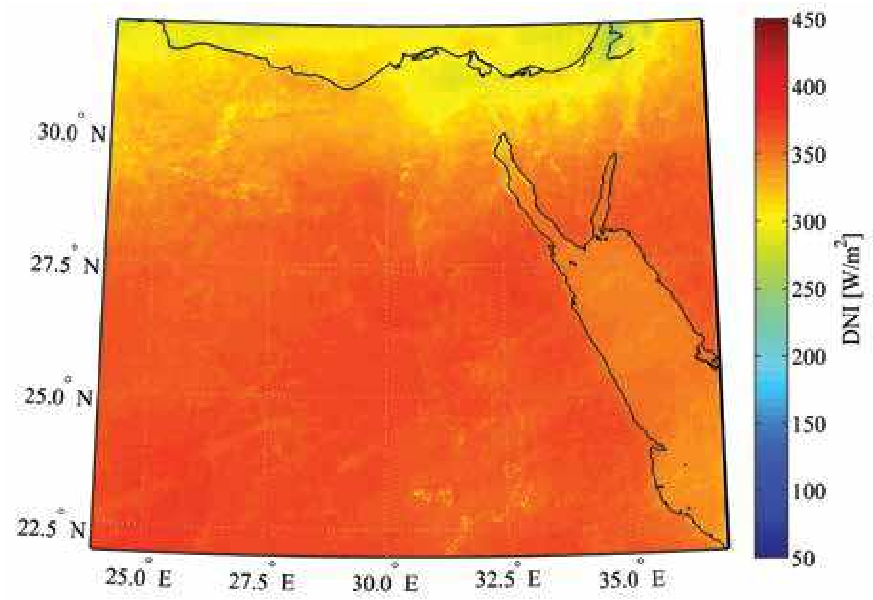

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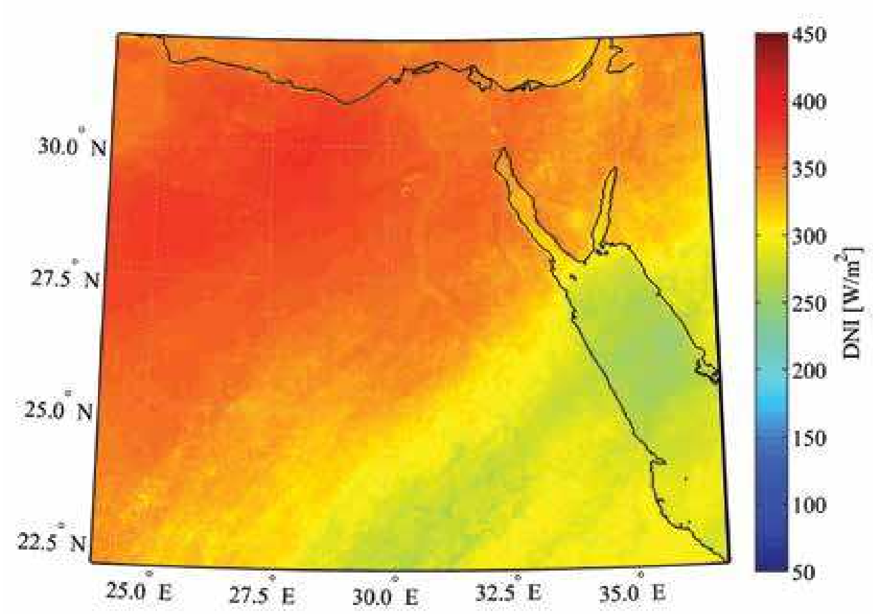

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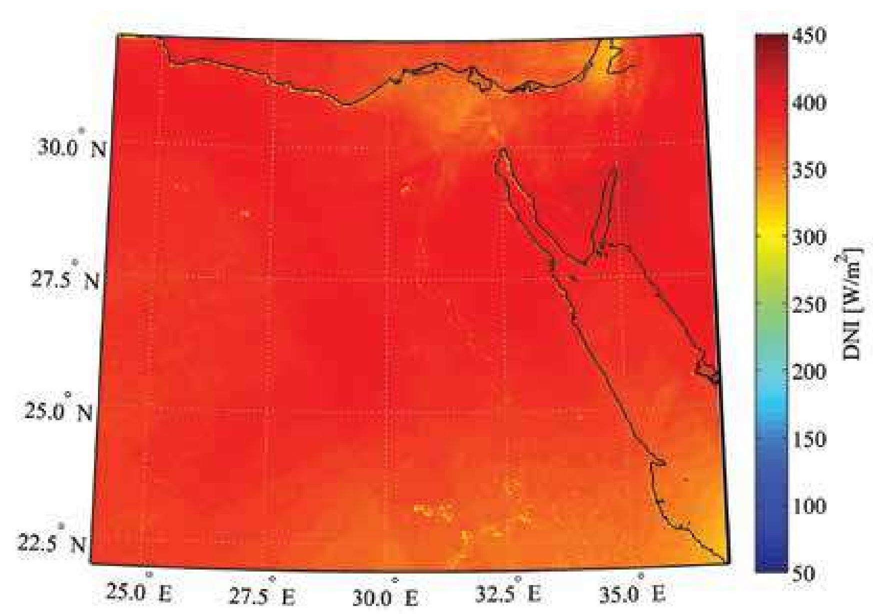
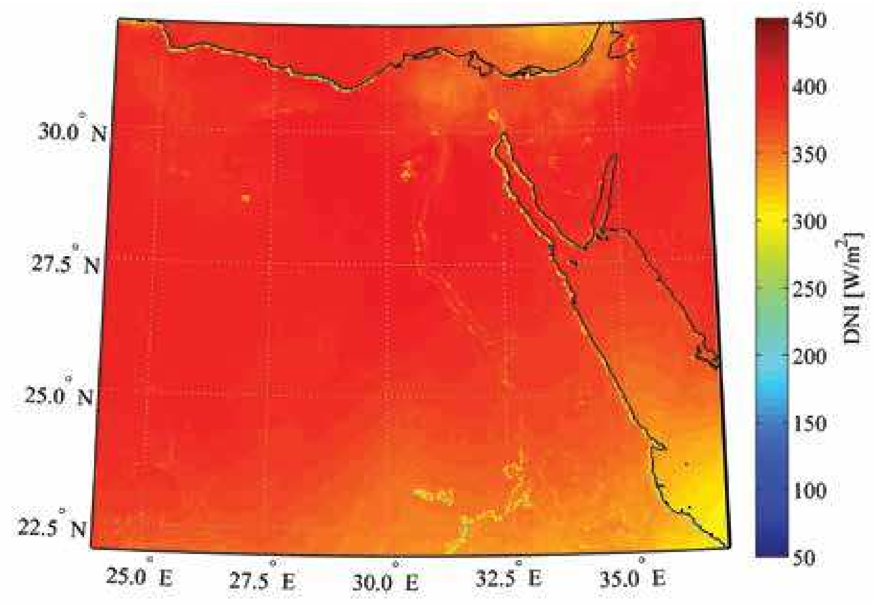


JUNE
1999

JULY
1999



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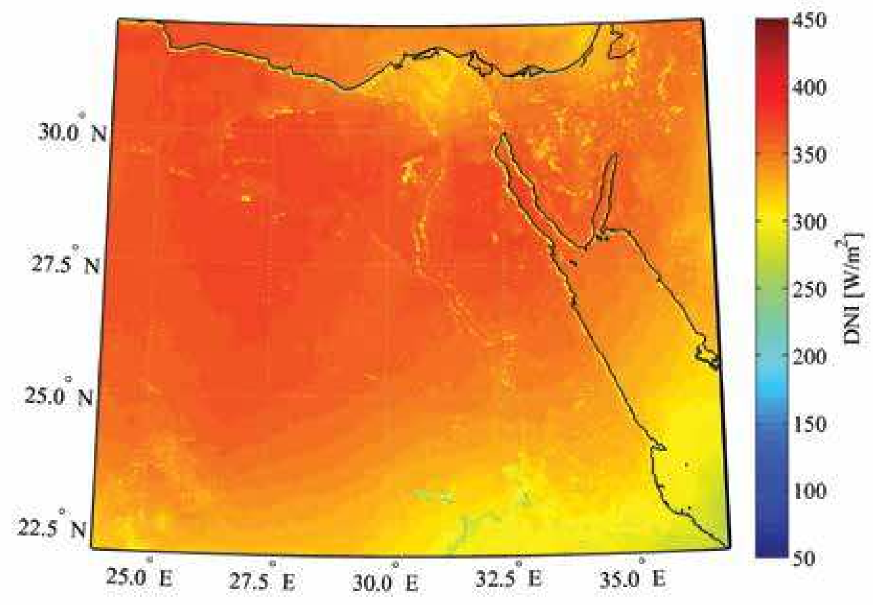

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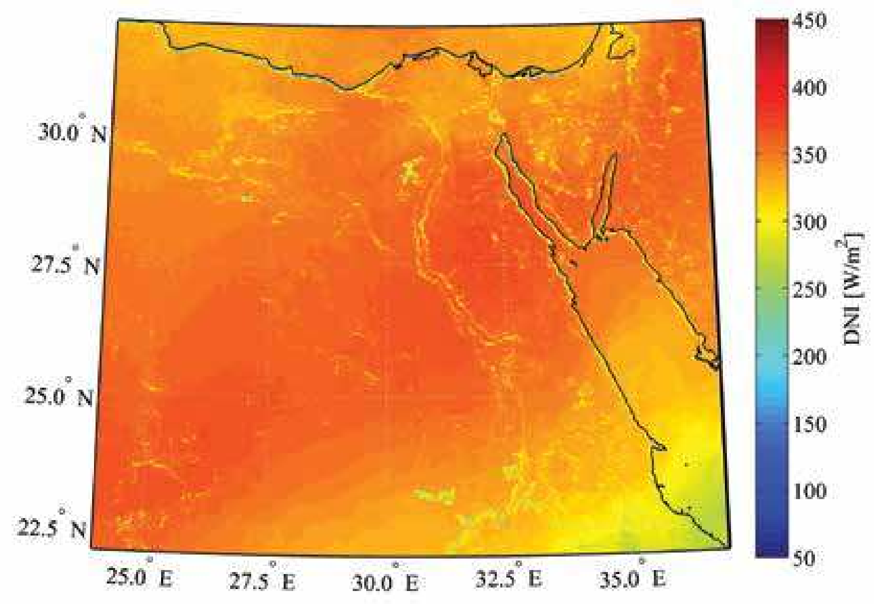

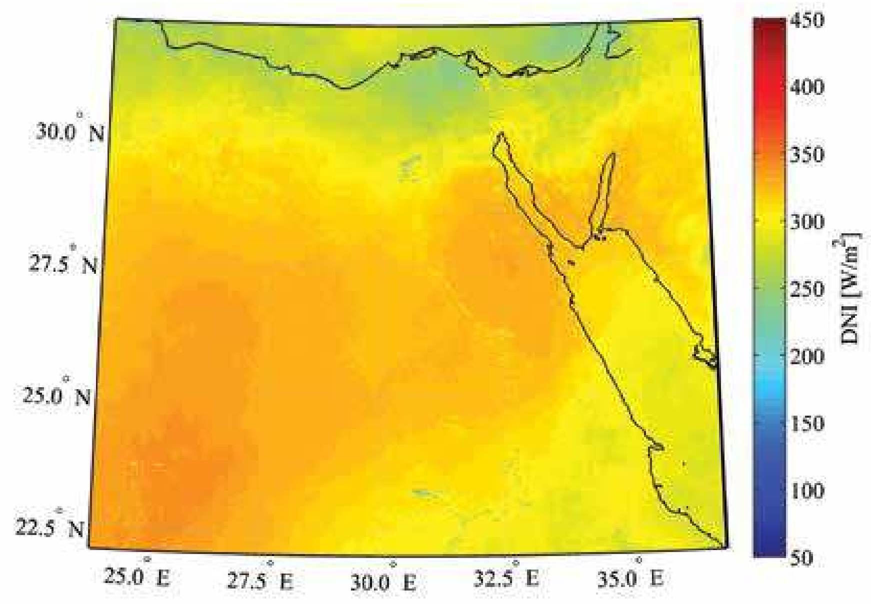

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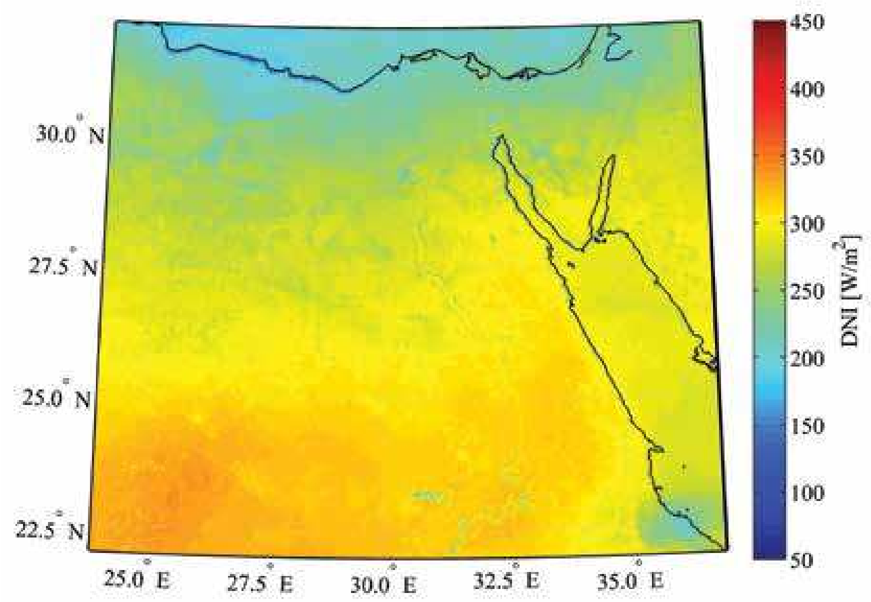

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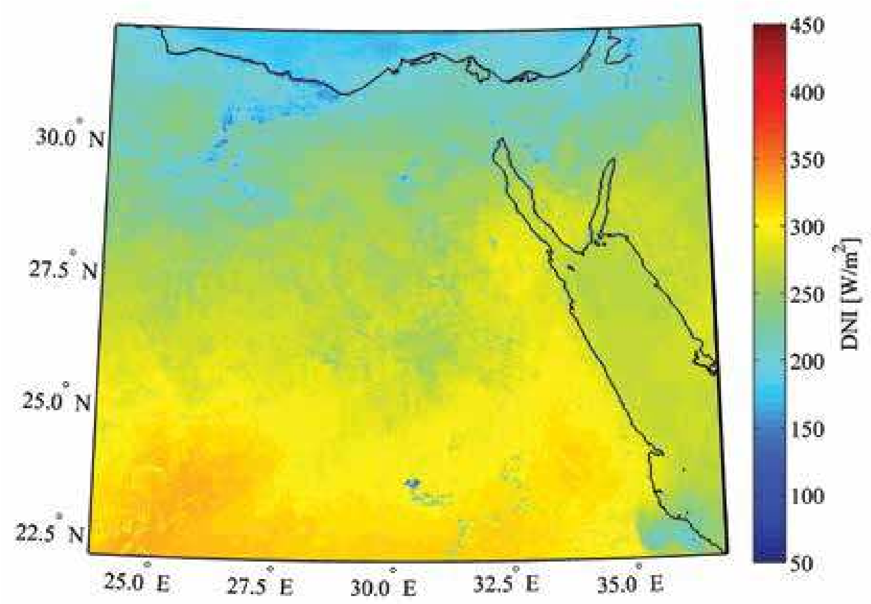

DEC
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JAN
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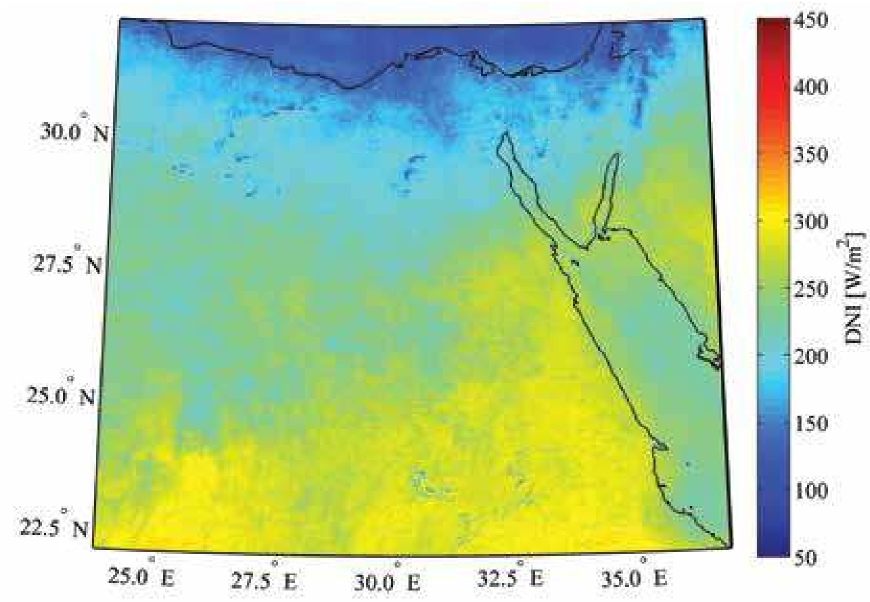

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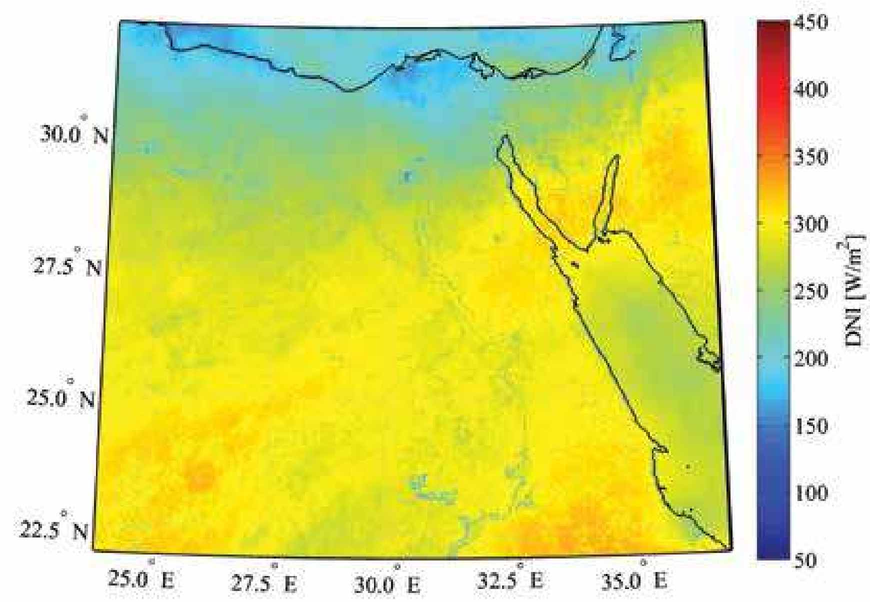

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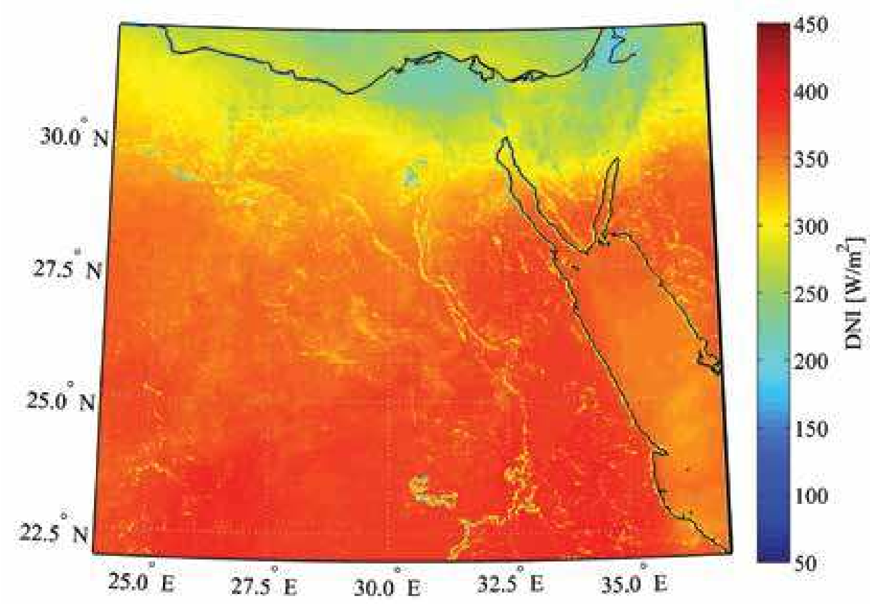

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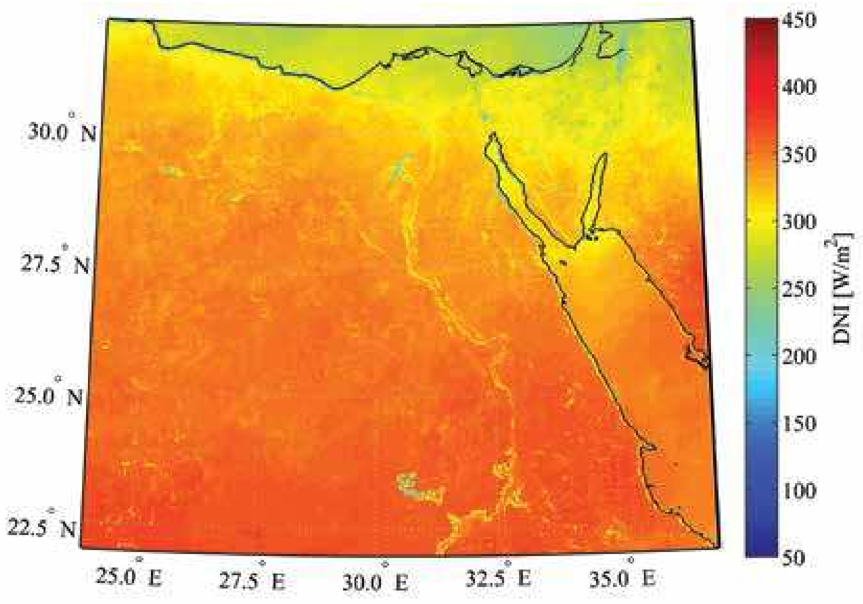

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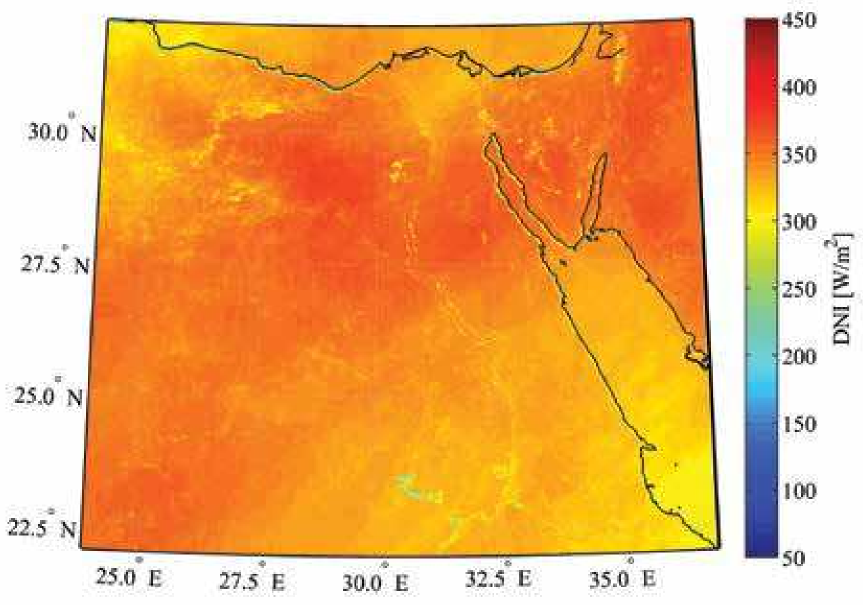

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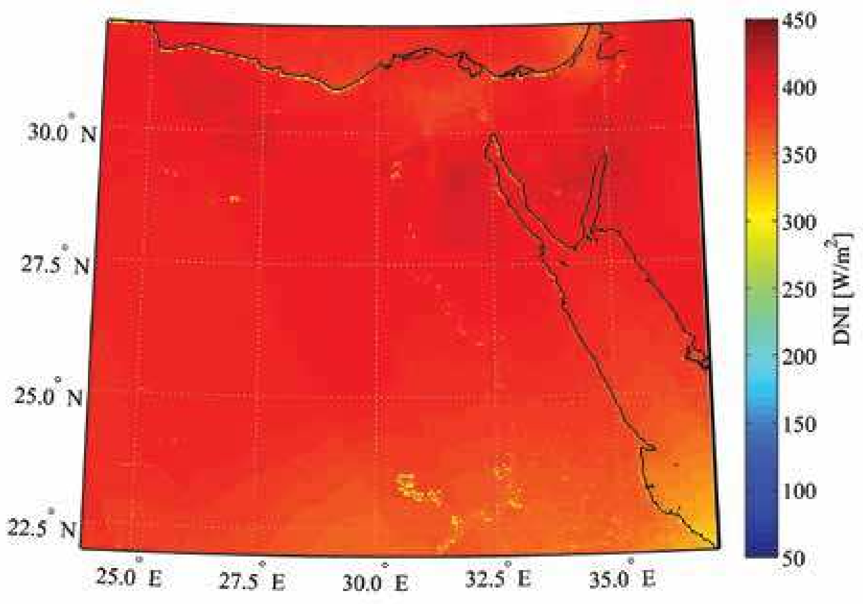

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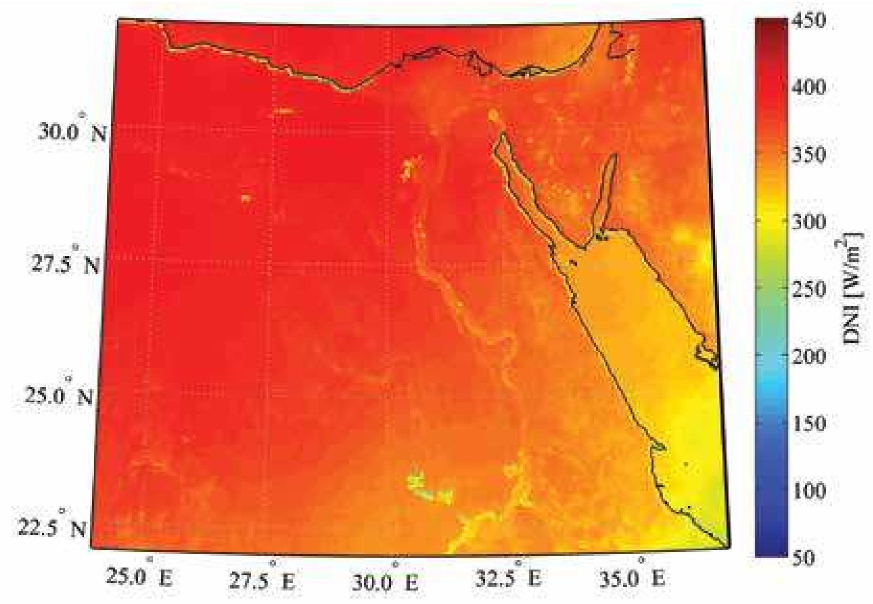

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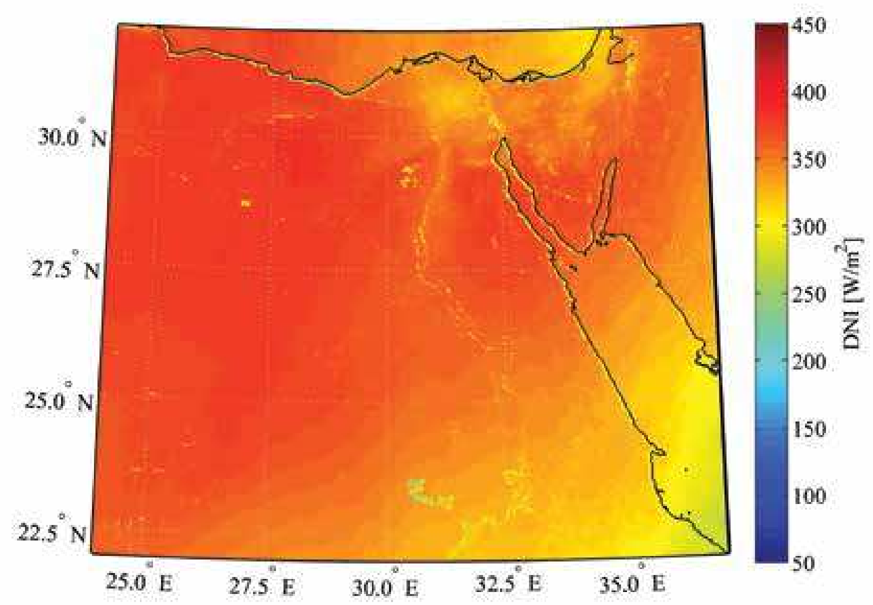

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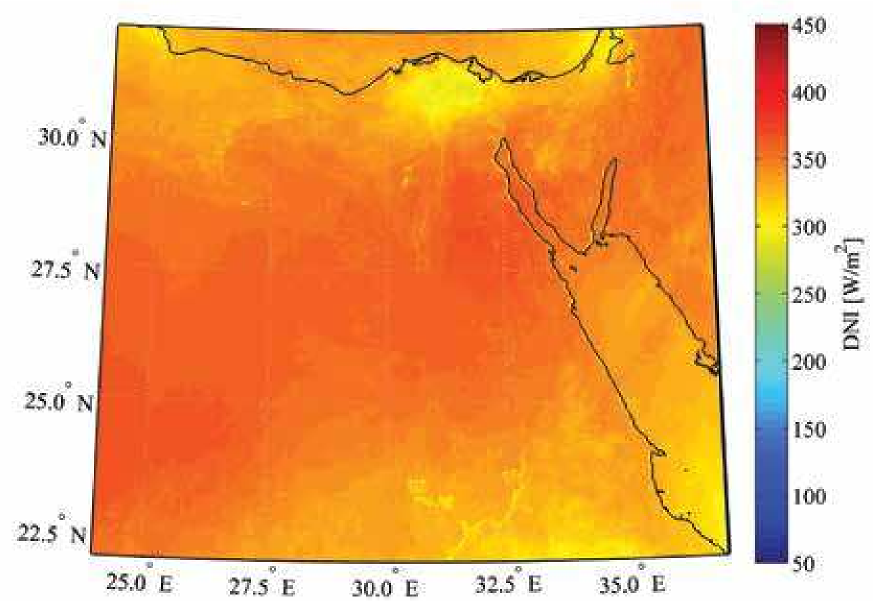

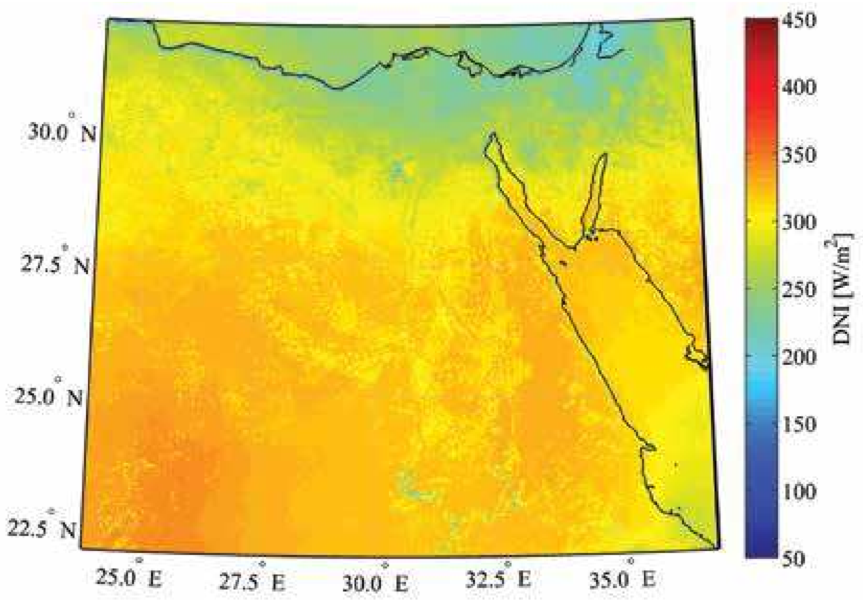

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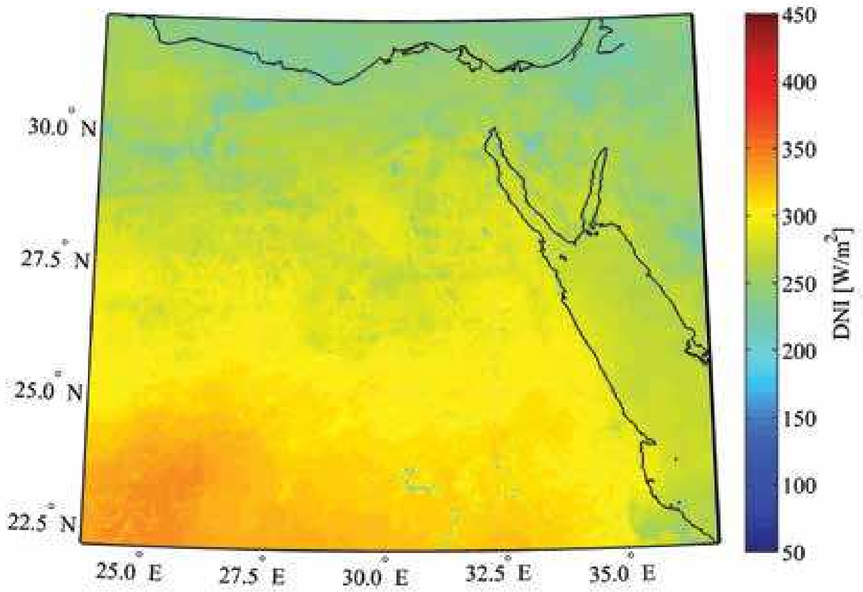

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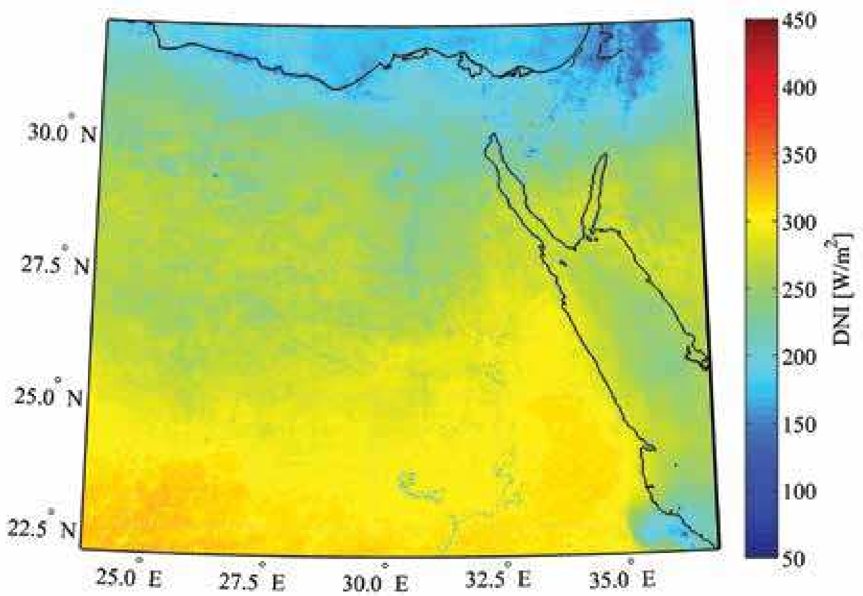

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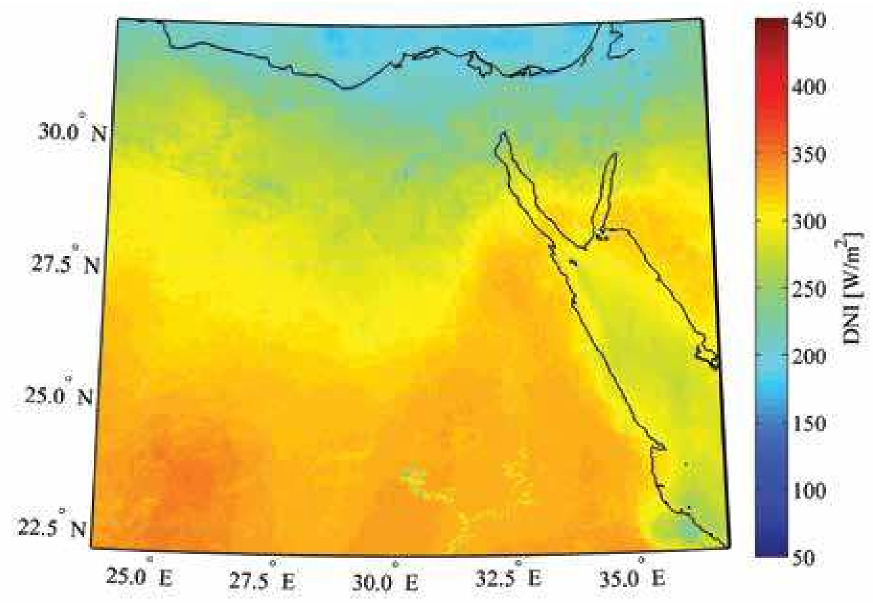

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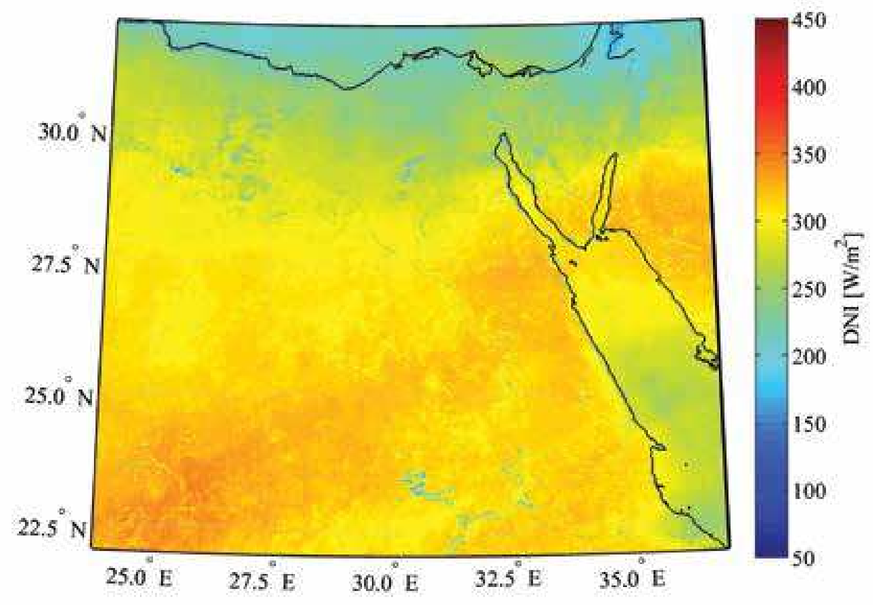

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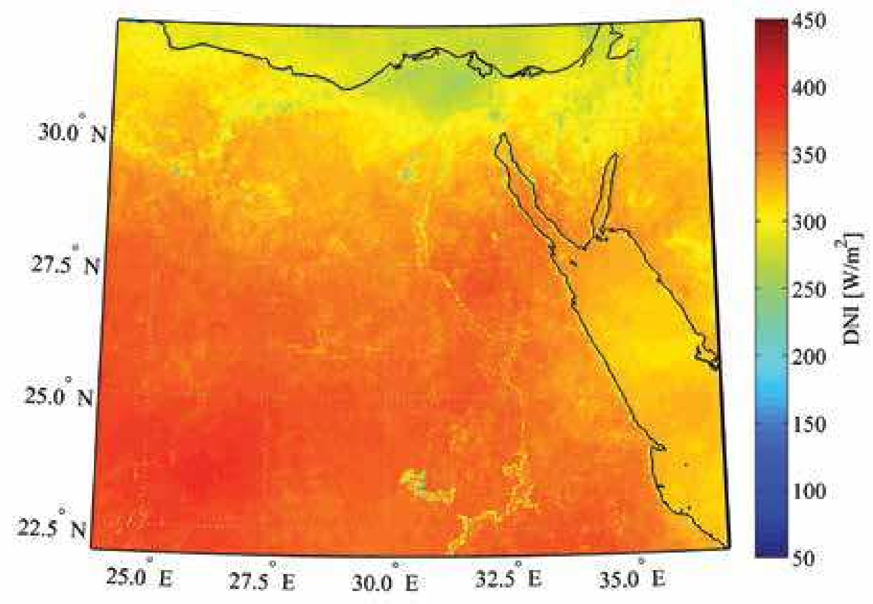

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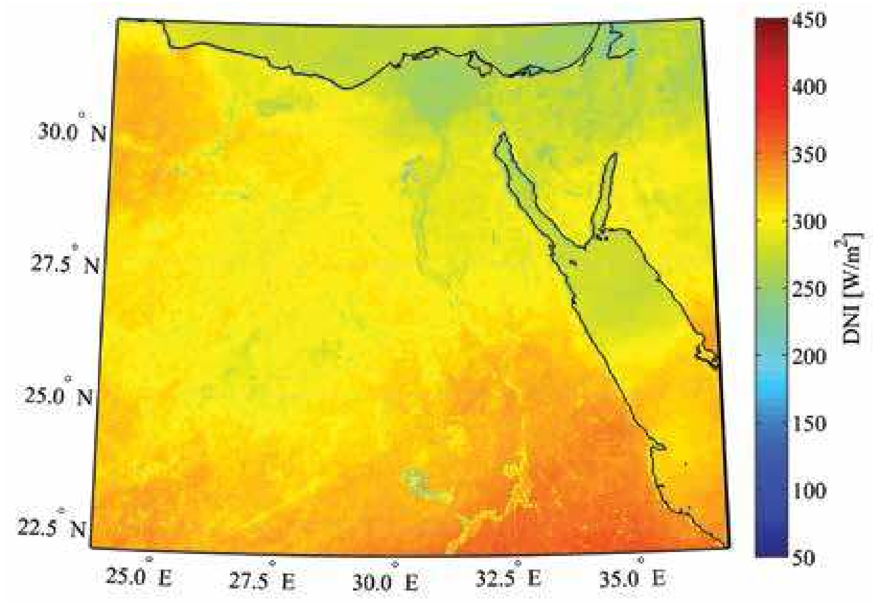

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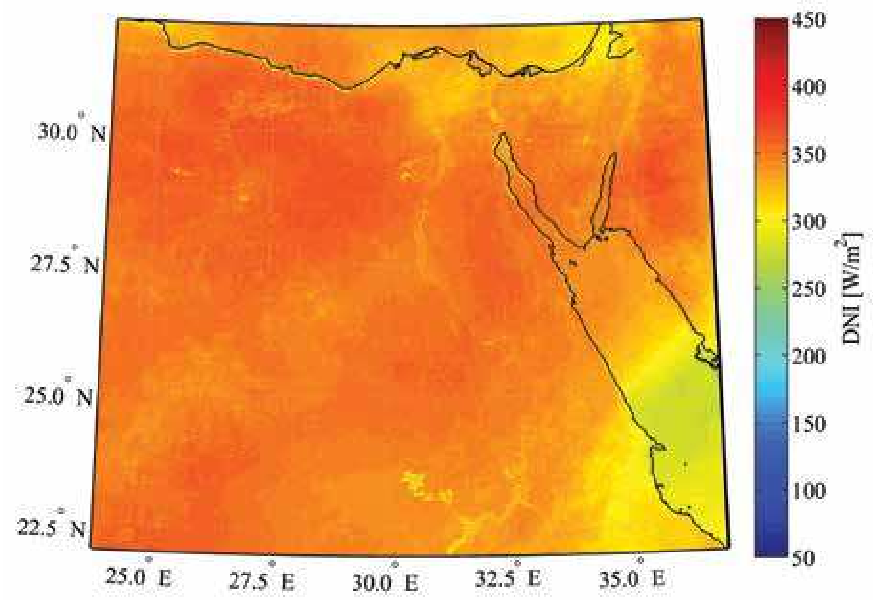

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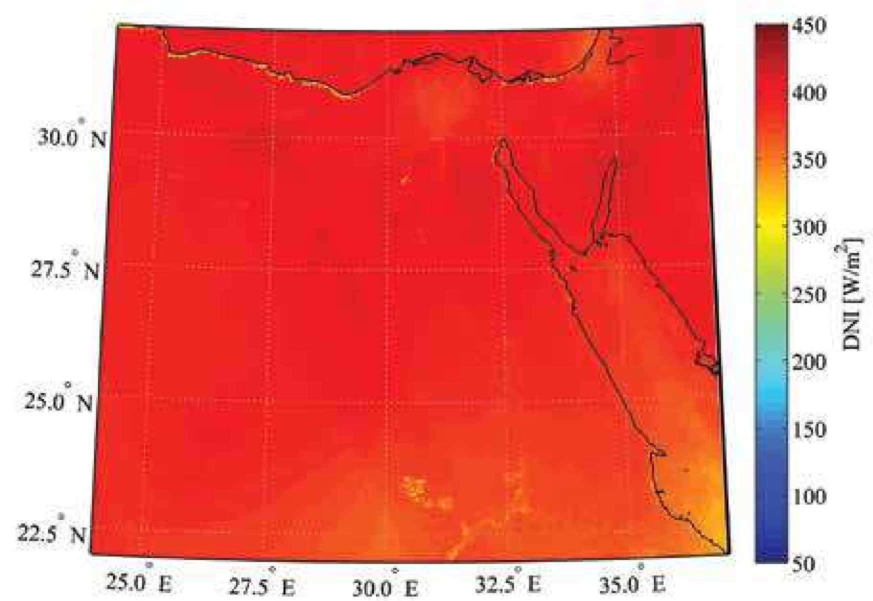

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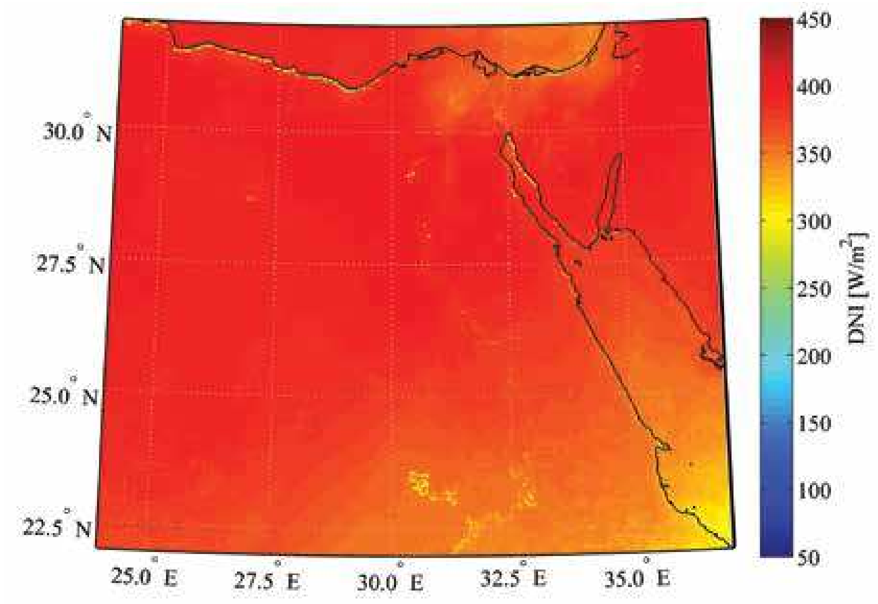

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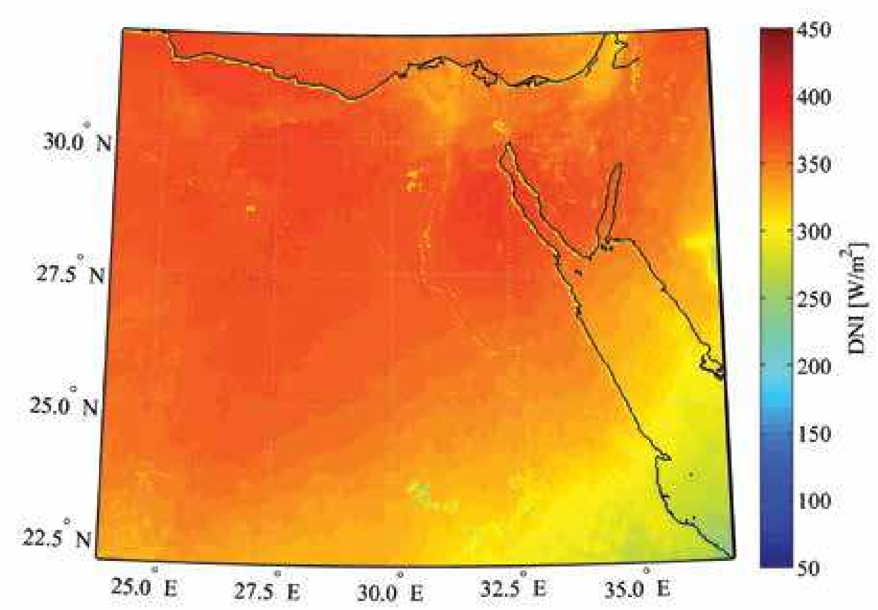

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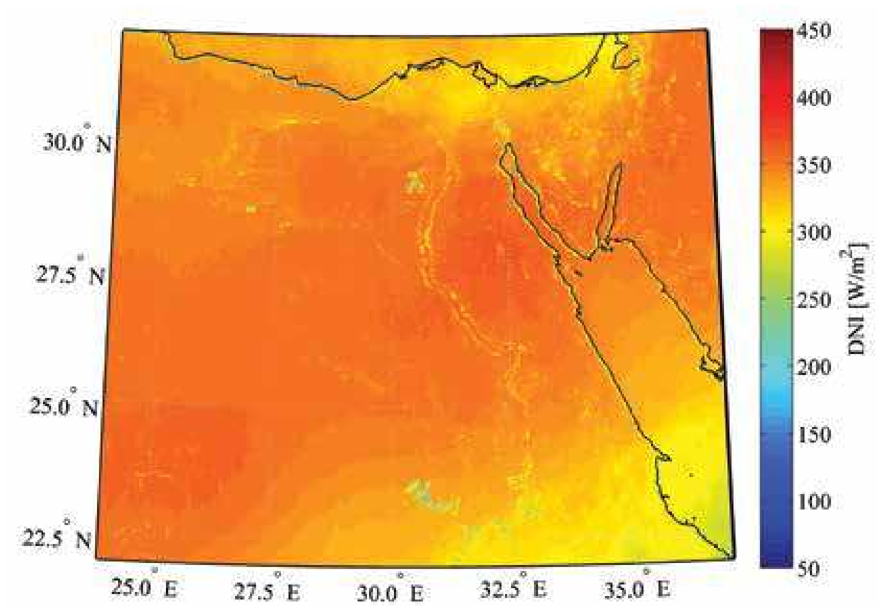

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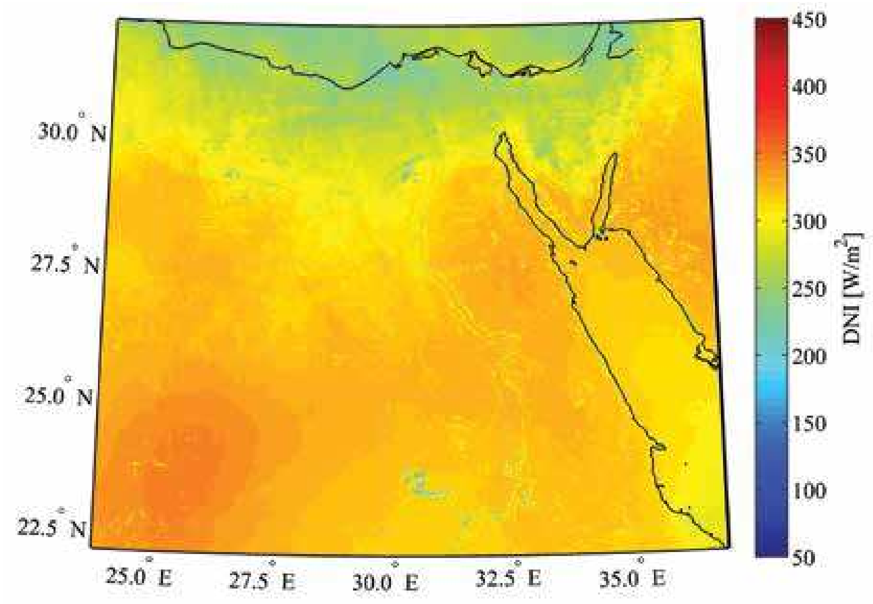

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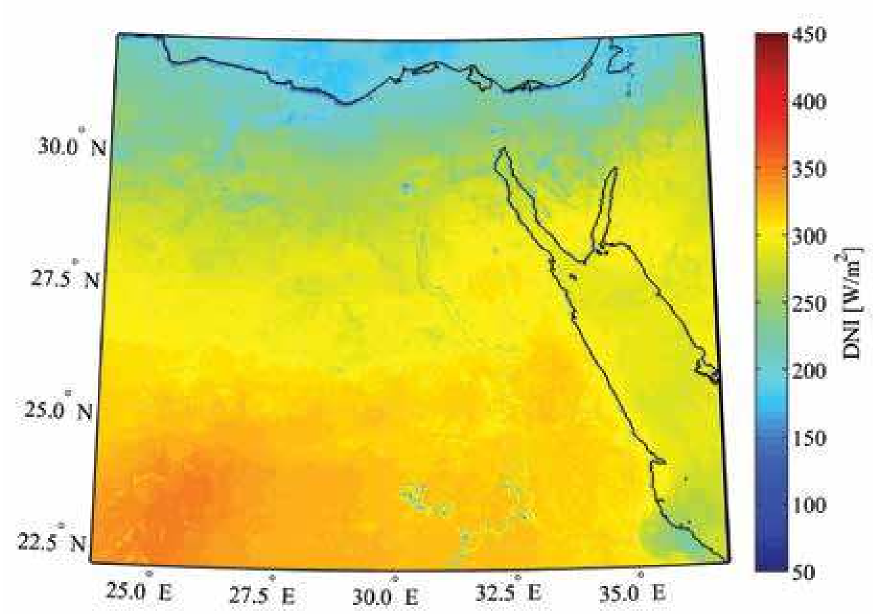

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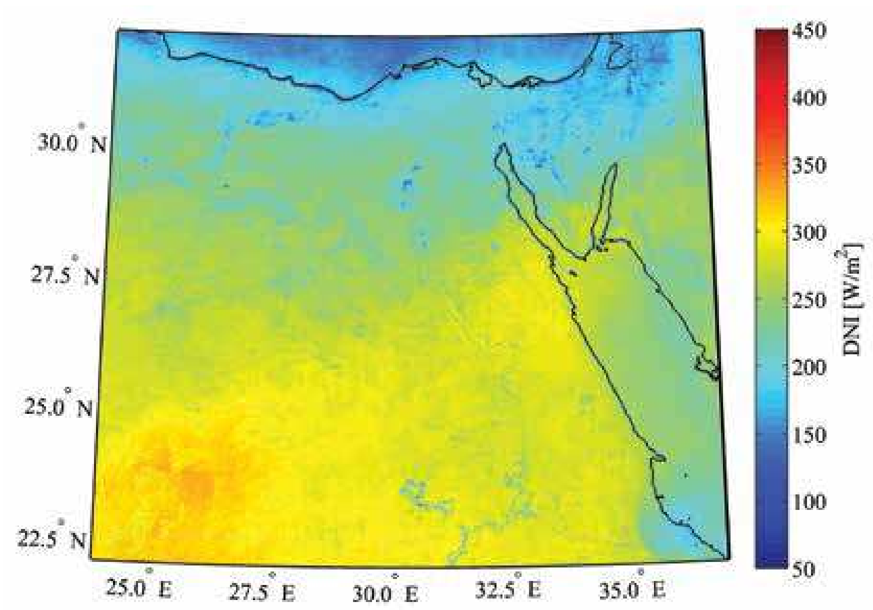

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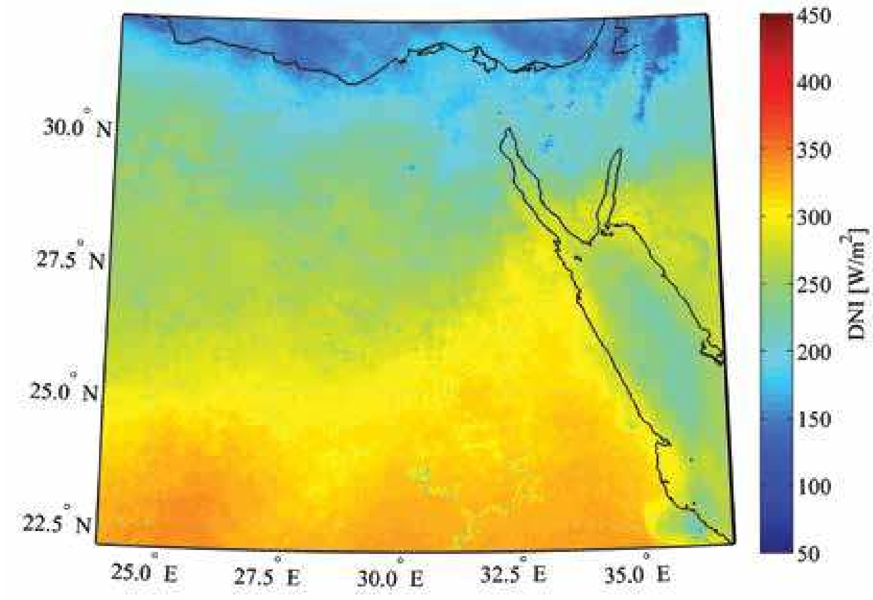

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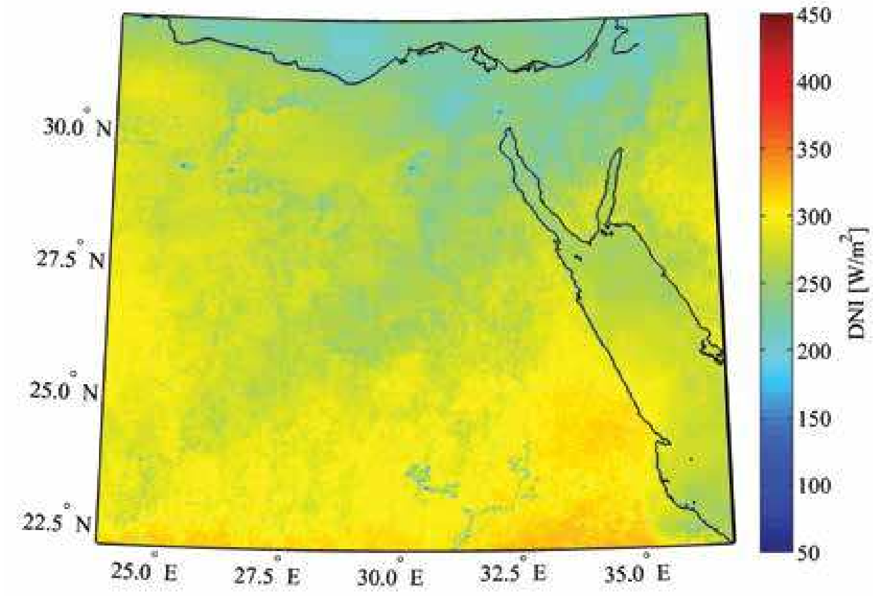

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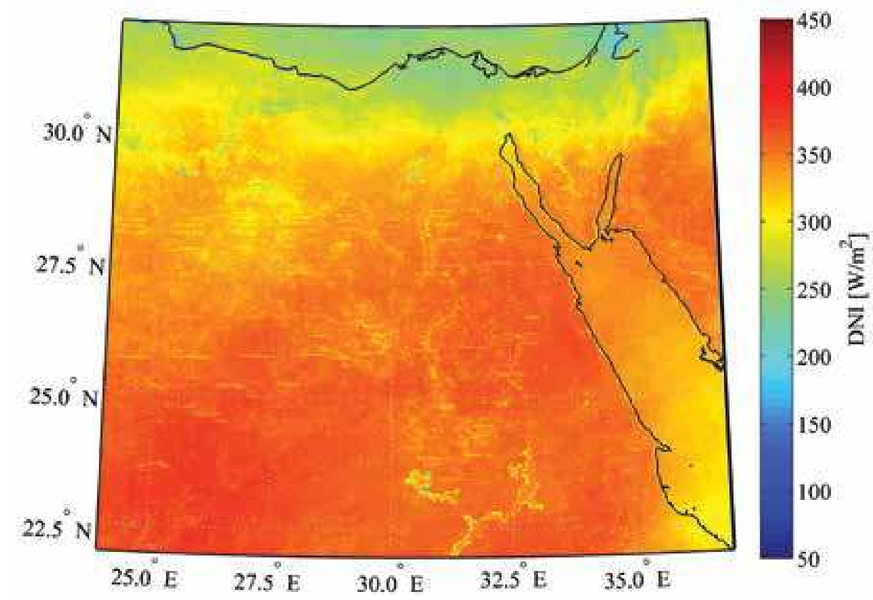

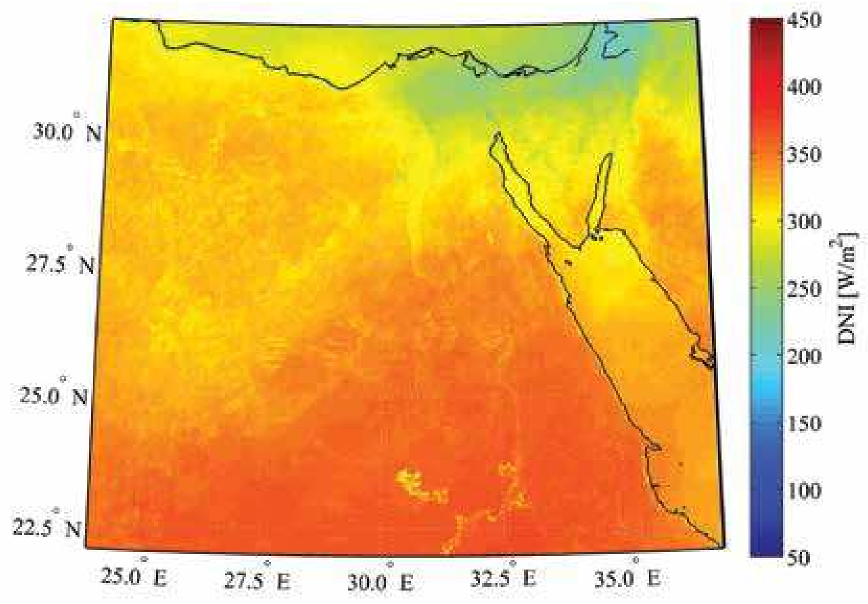

APR
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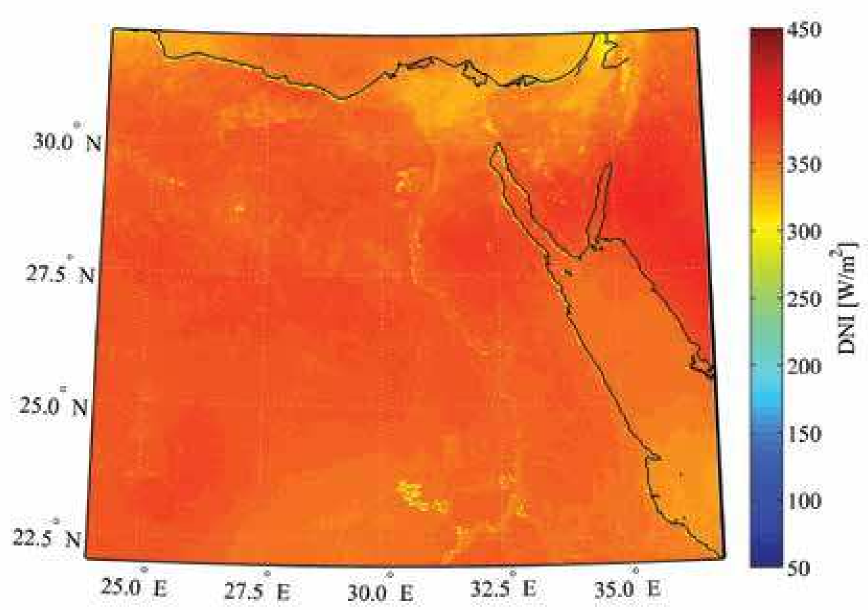

MAY
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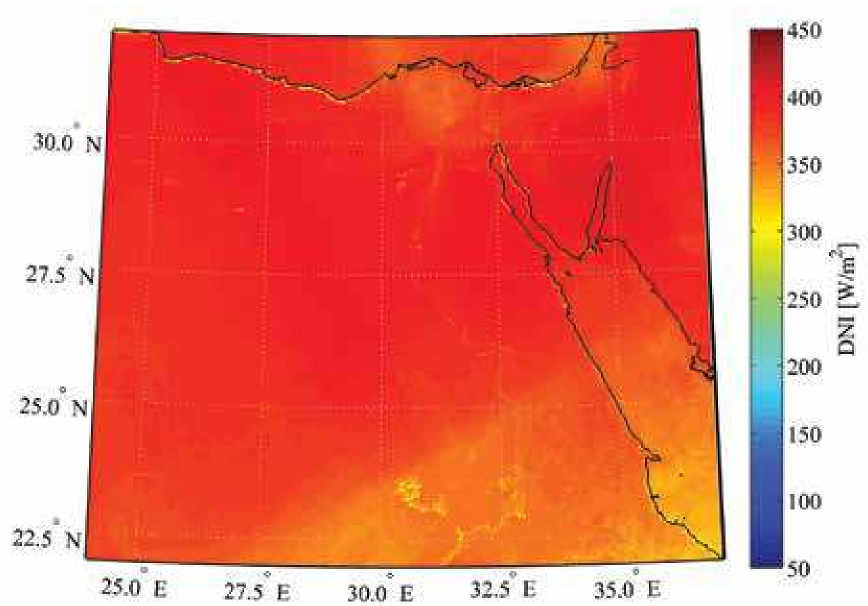

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2002

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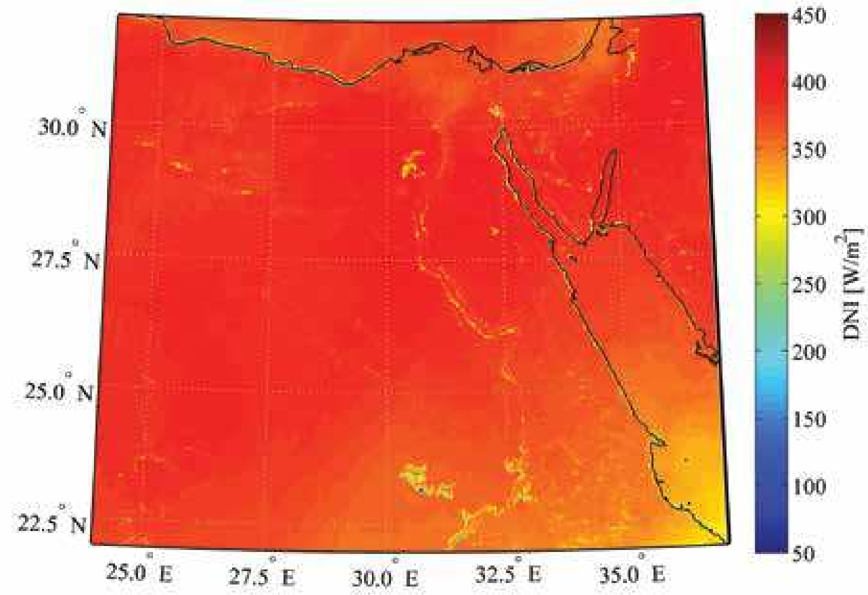

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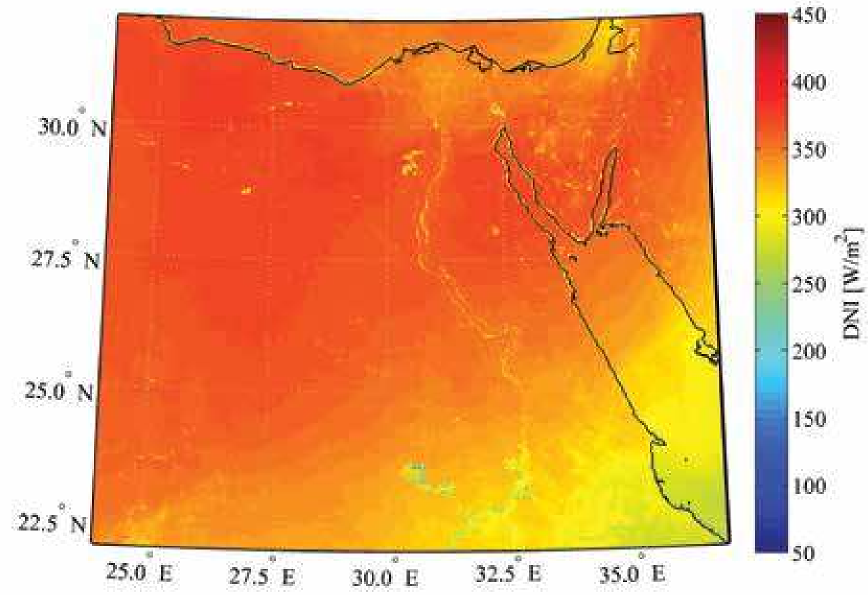

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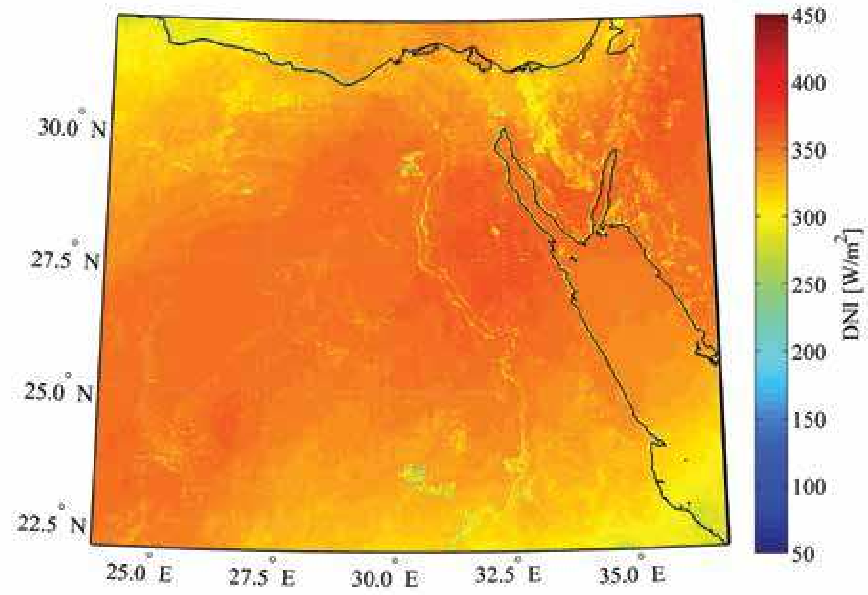

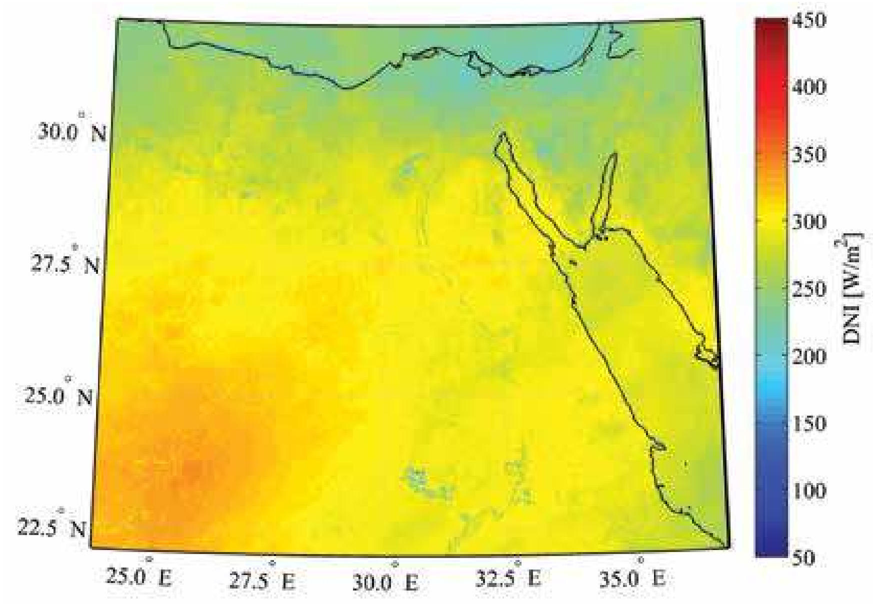

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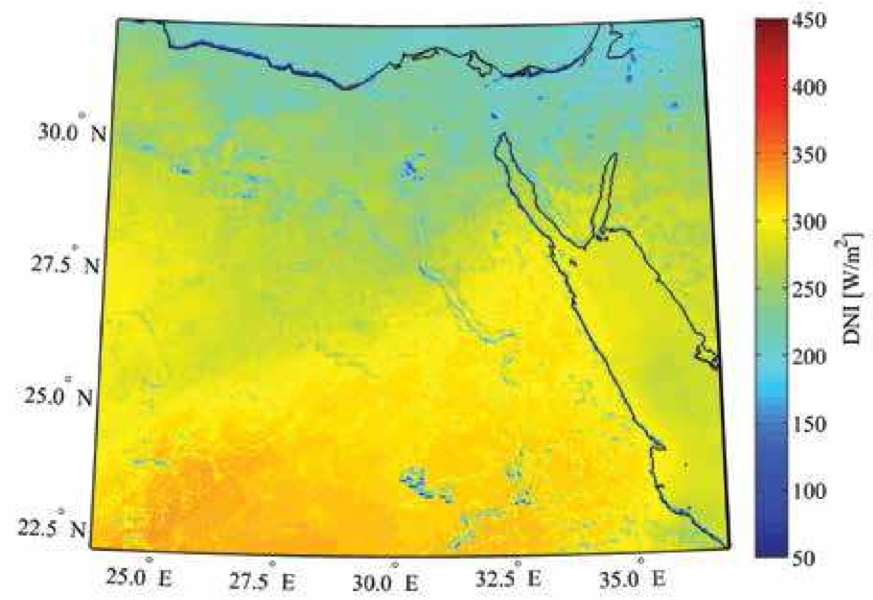

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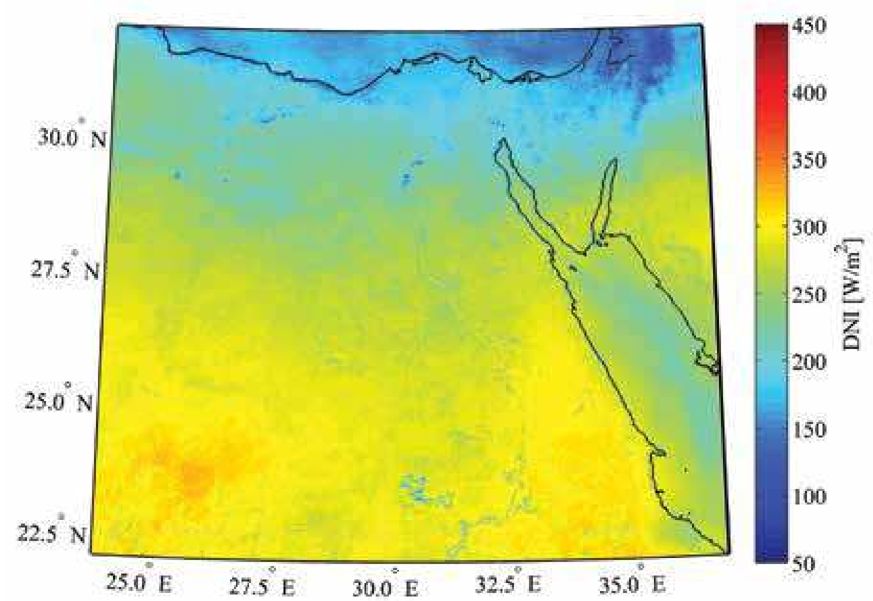

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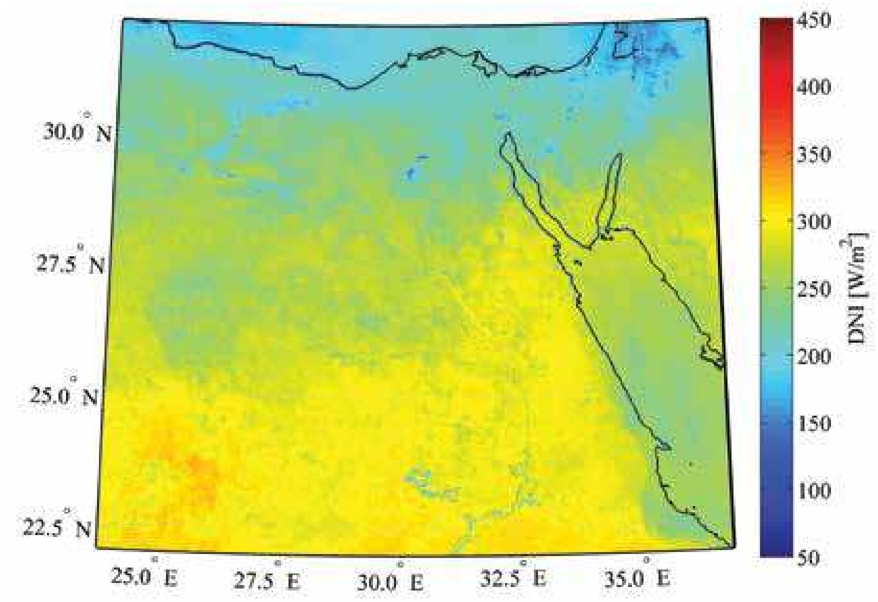

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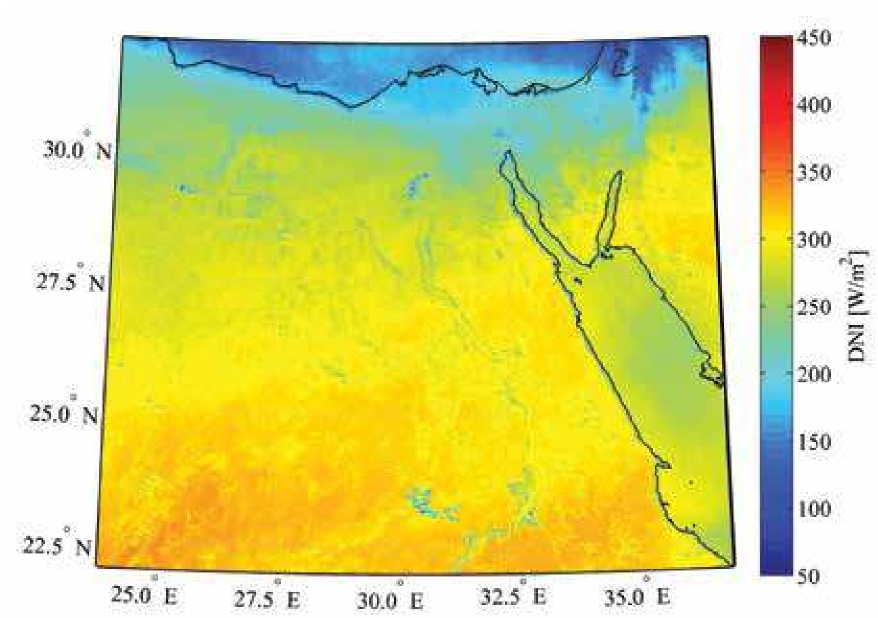

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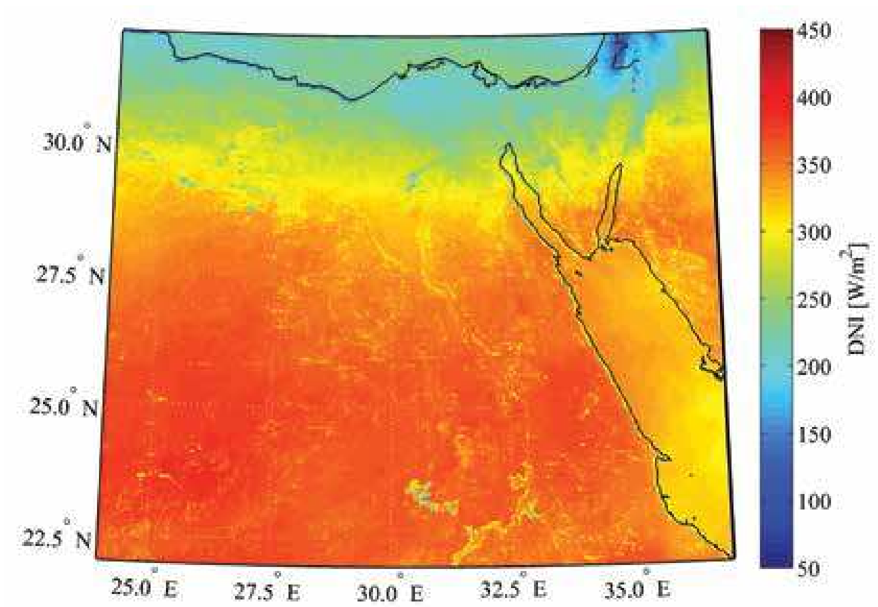

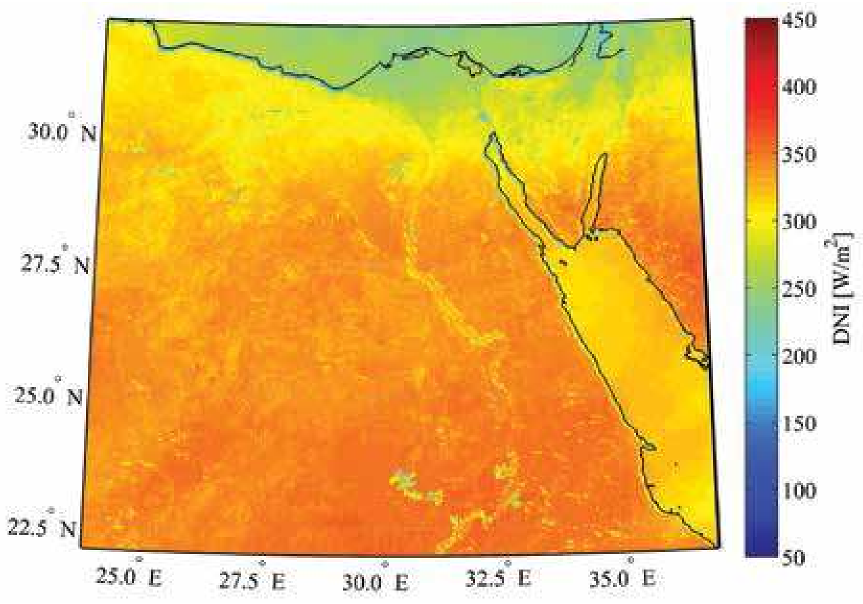

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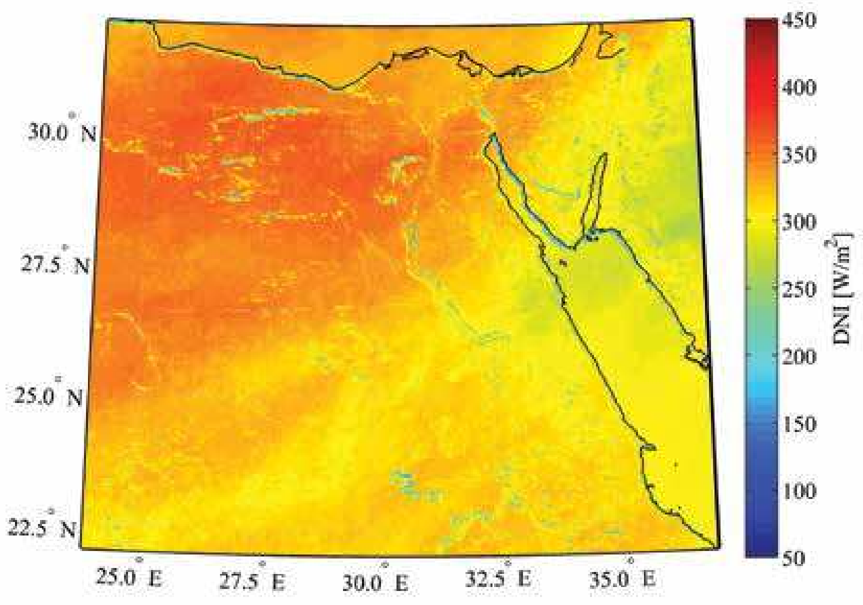

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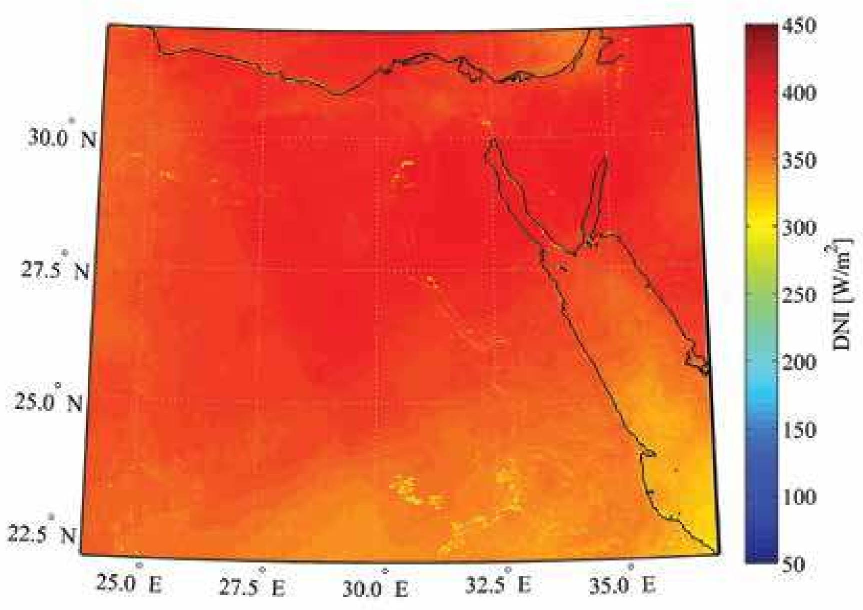
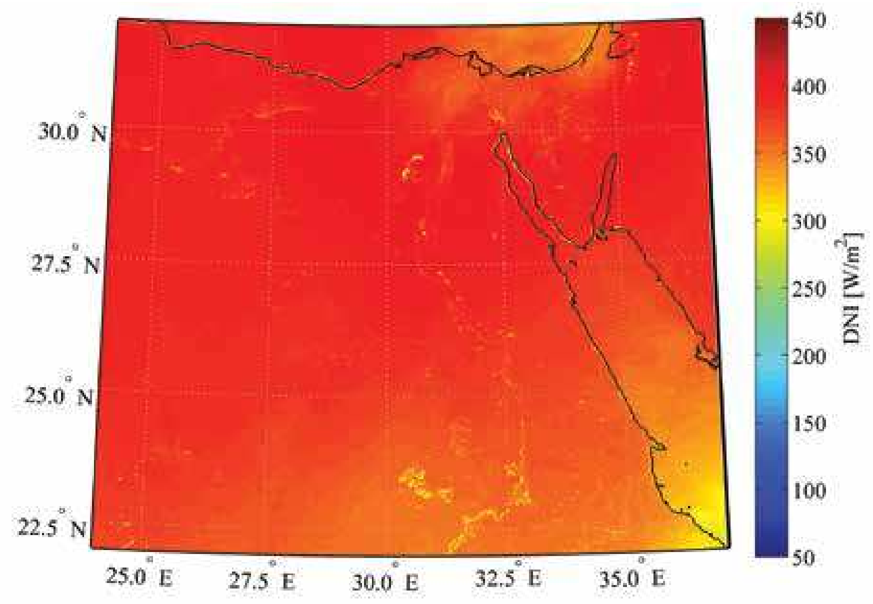
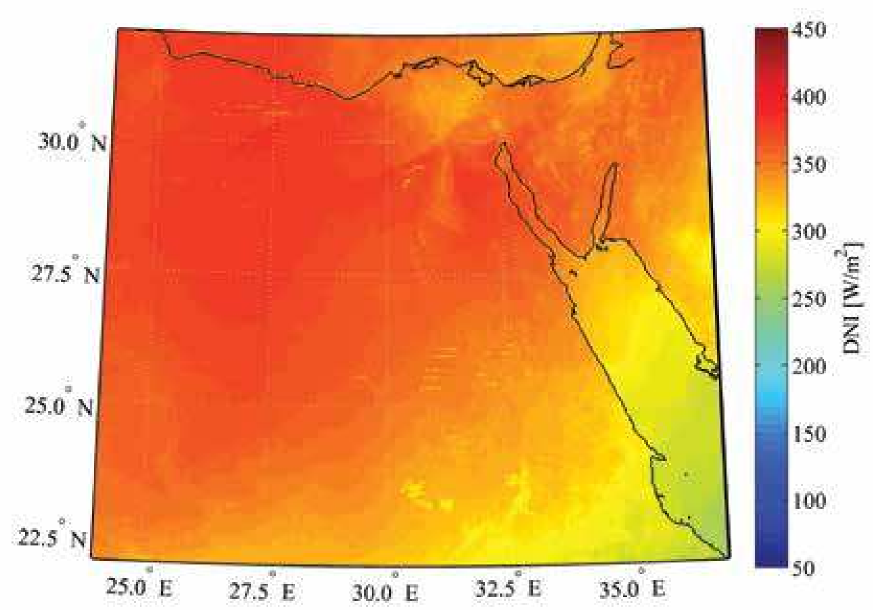


JUNE
2003

JULY
2003



AUG
2003



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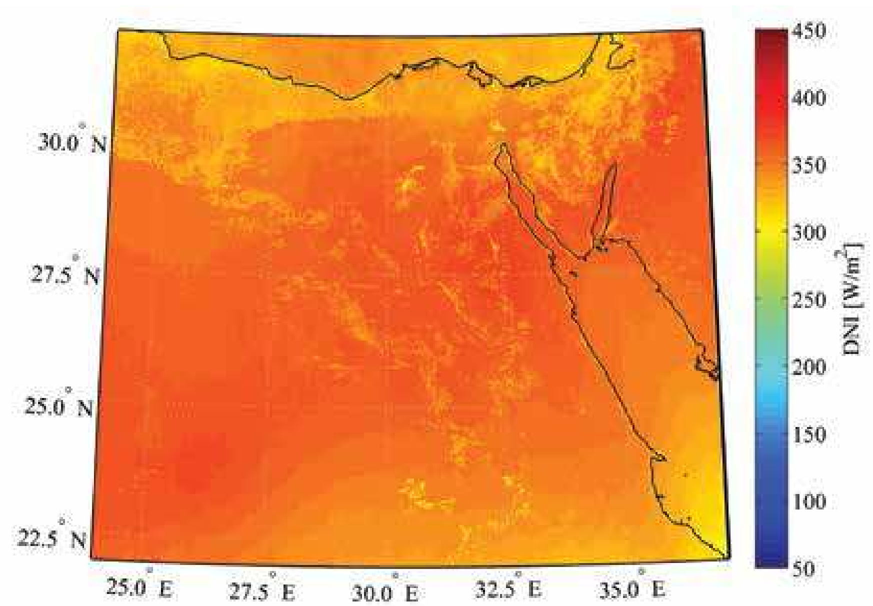

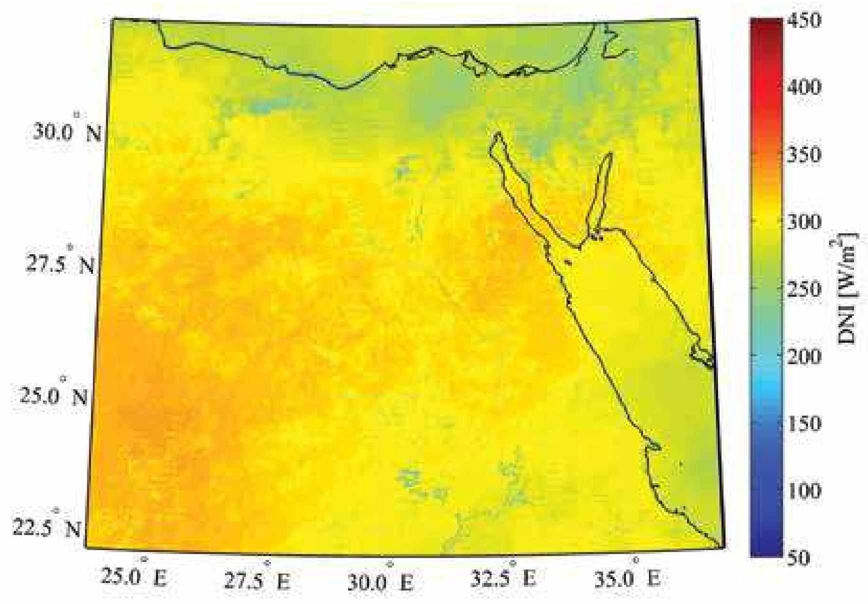

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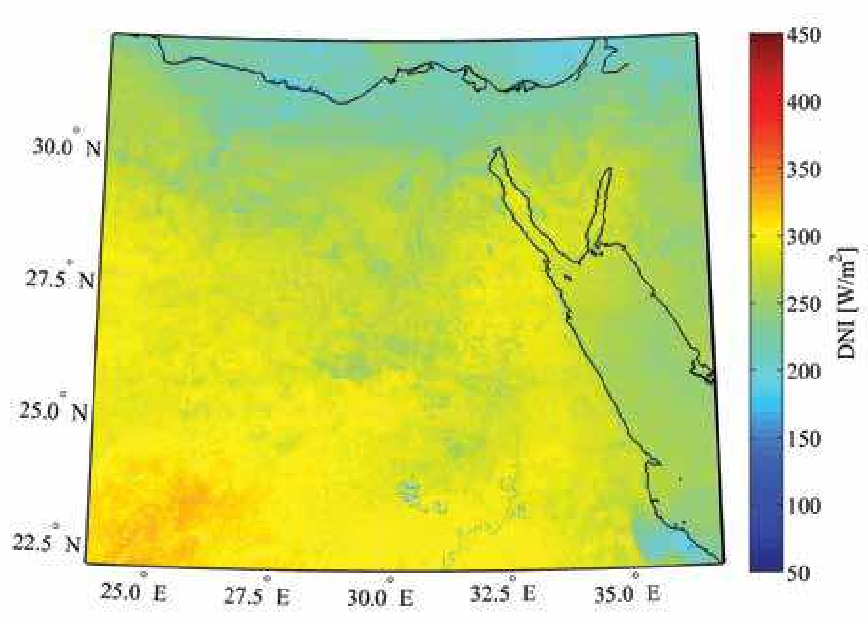

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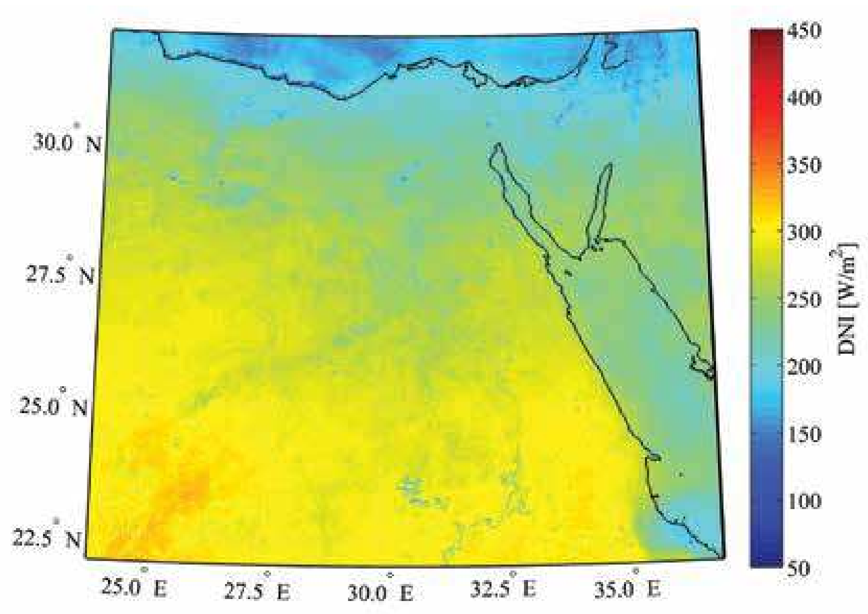
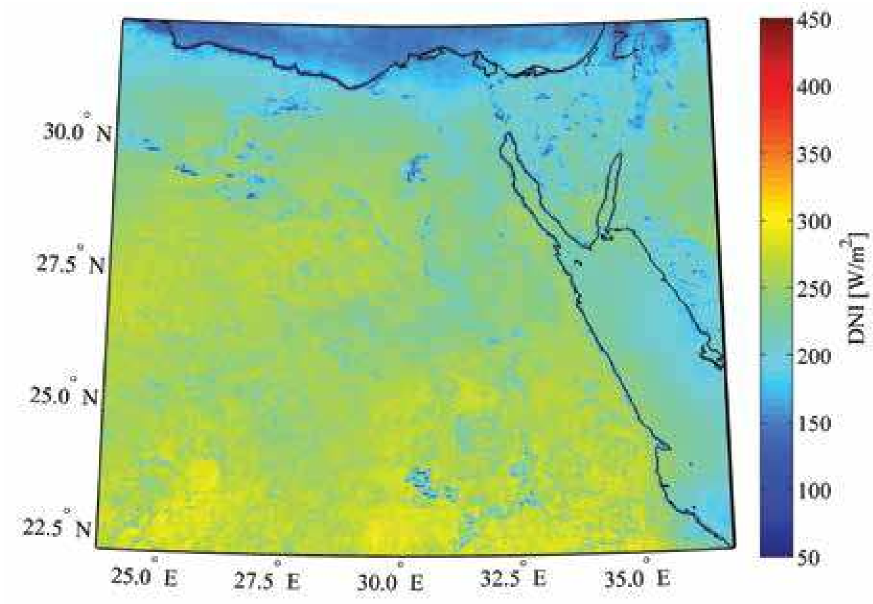


DEC
2003

JAN
2004



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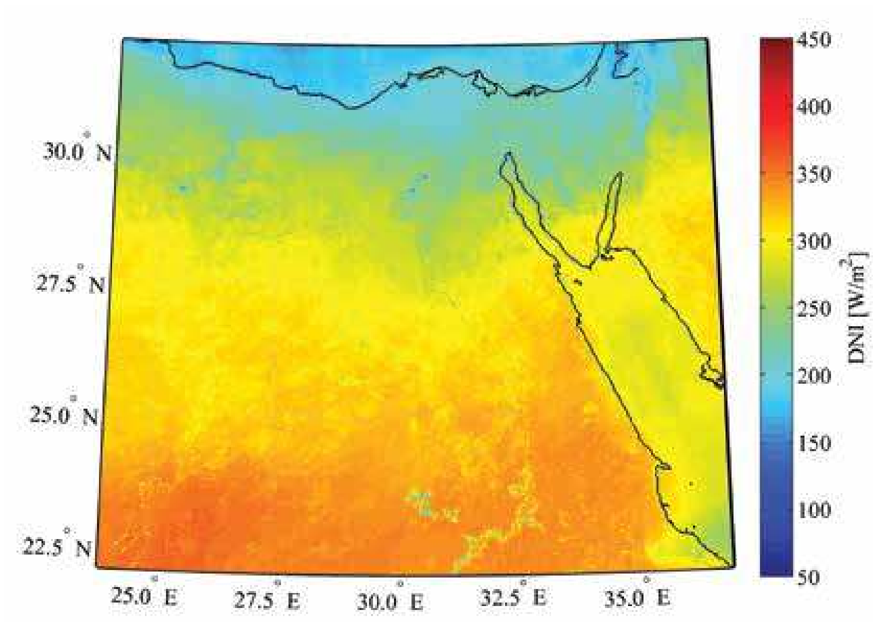

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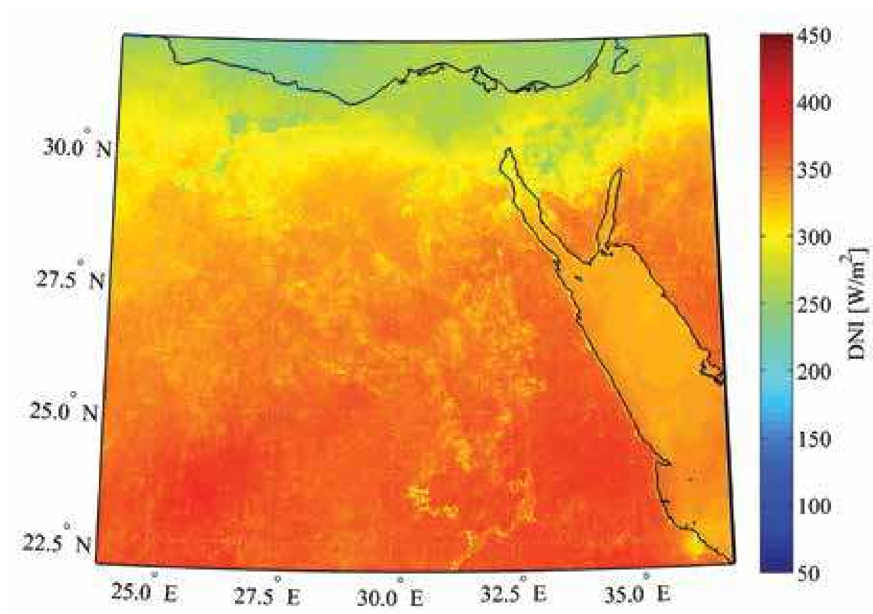

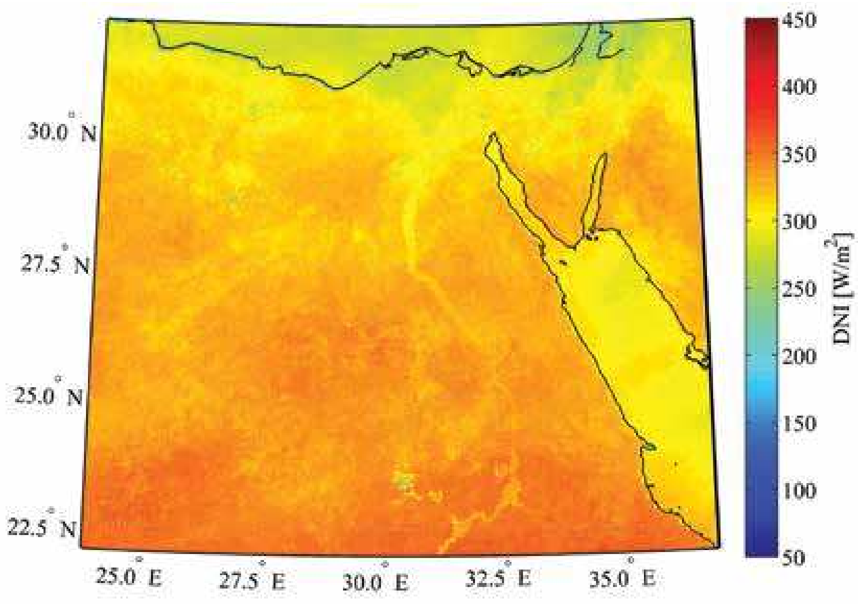

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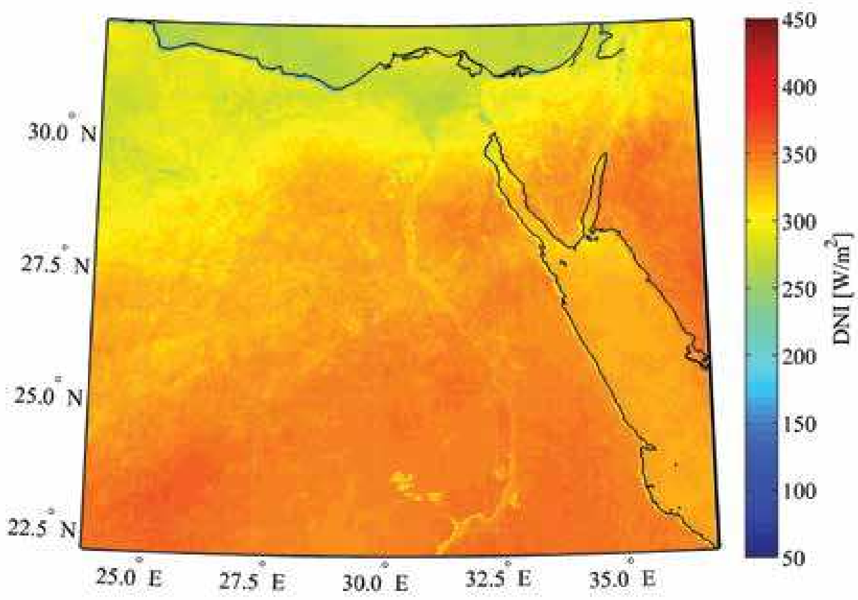

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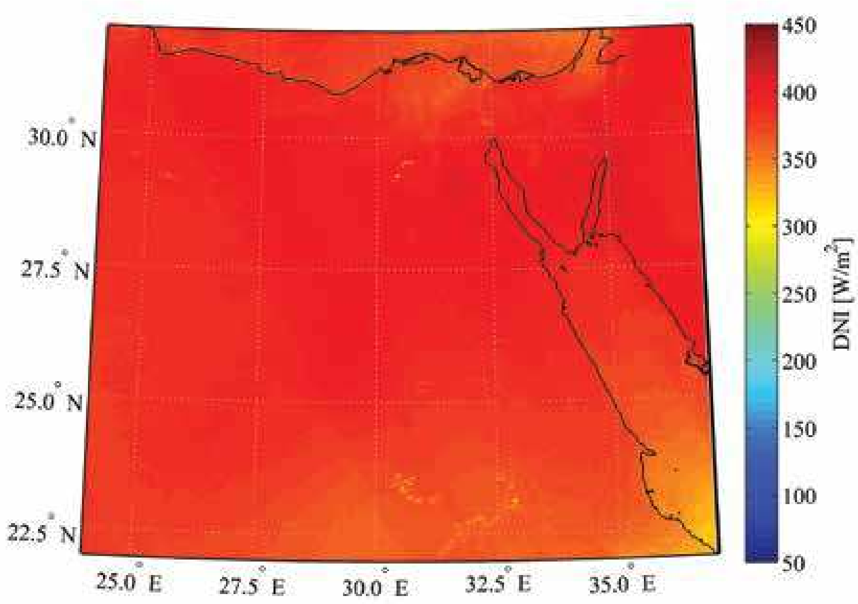
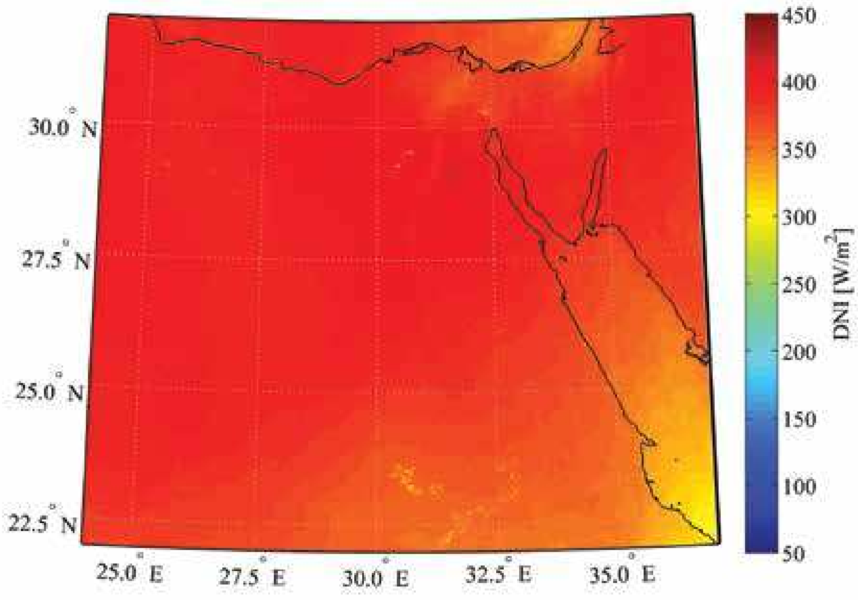


JUNE
2004

JULY
2004



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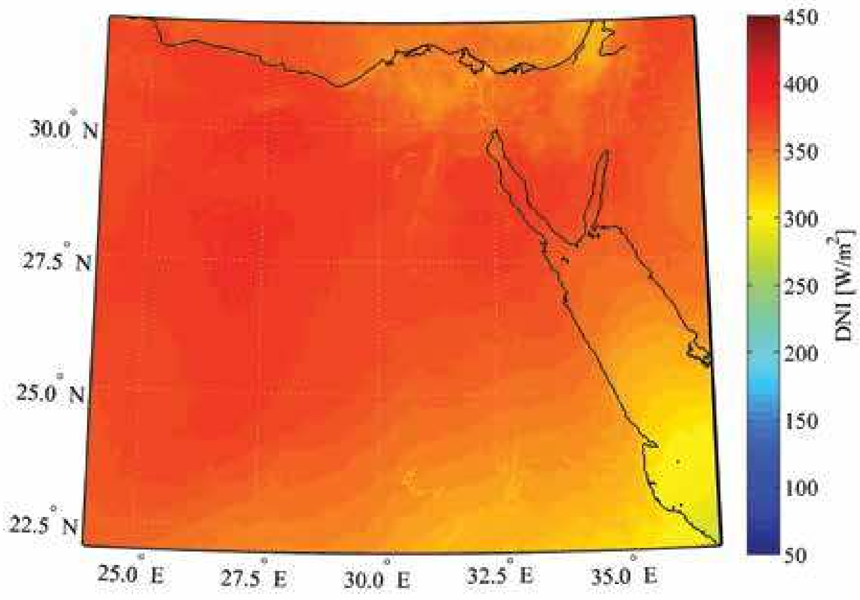

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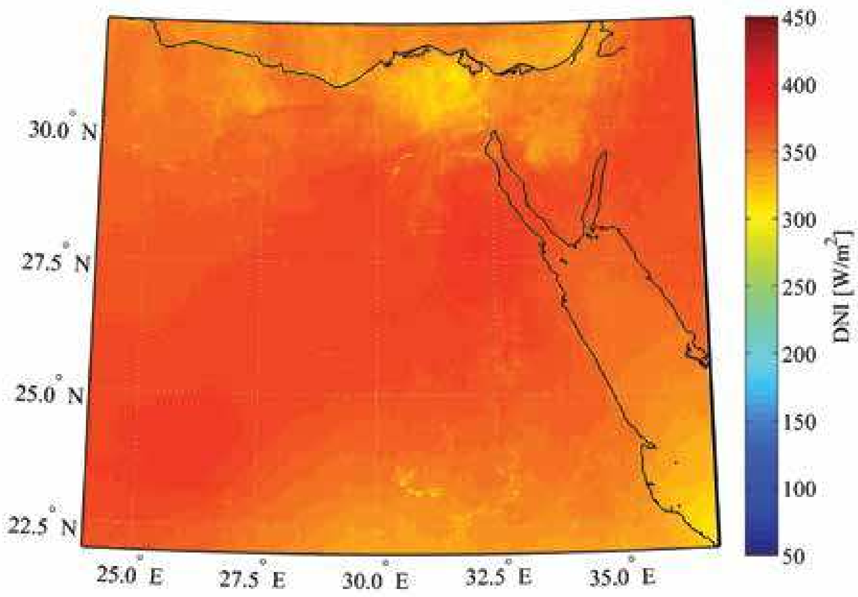

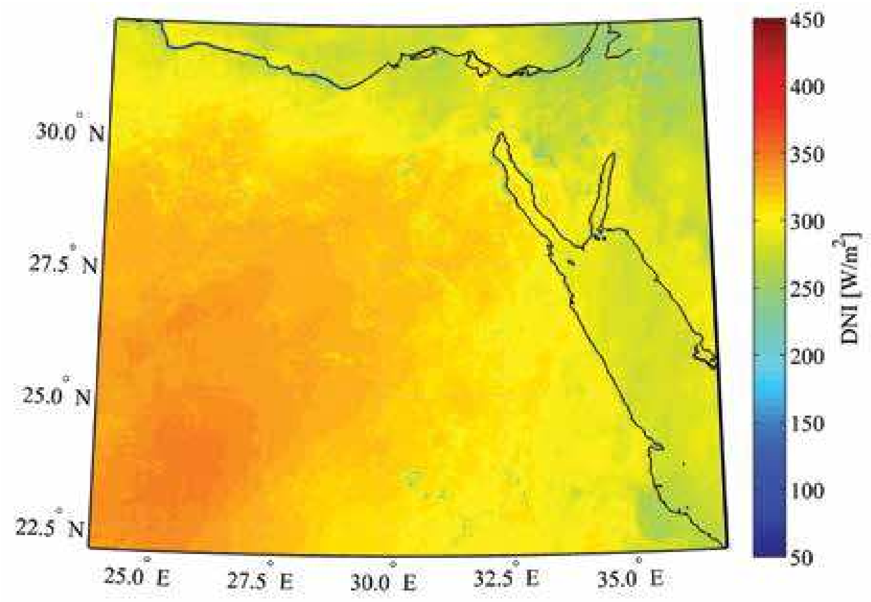

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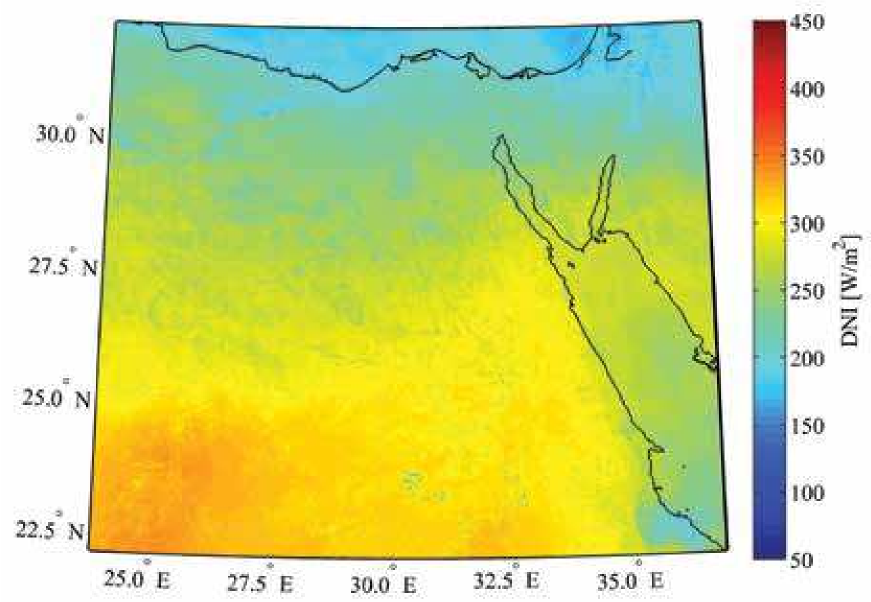

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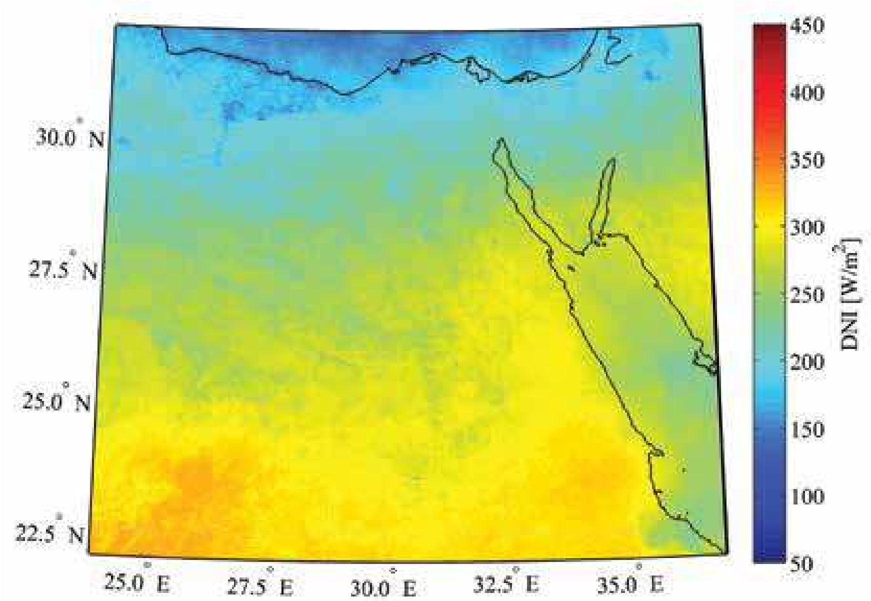

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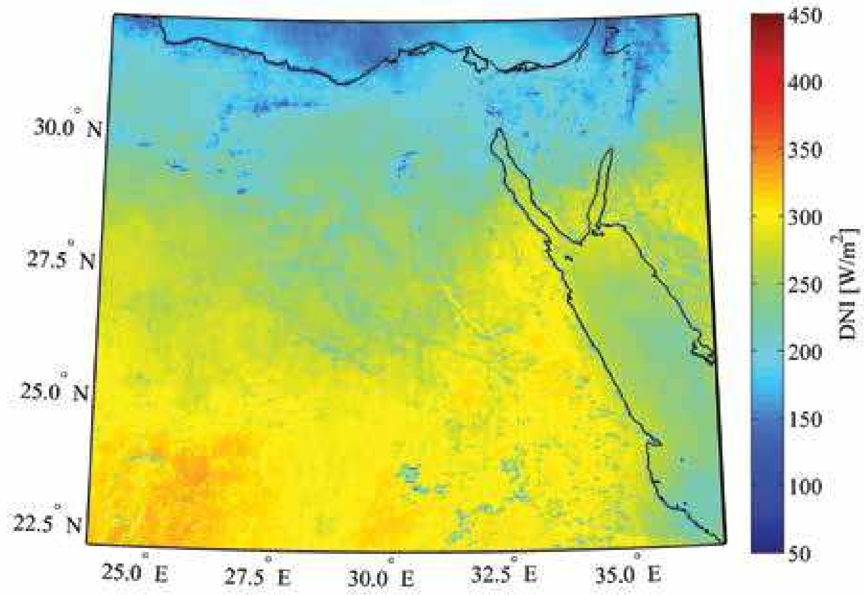

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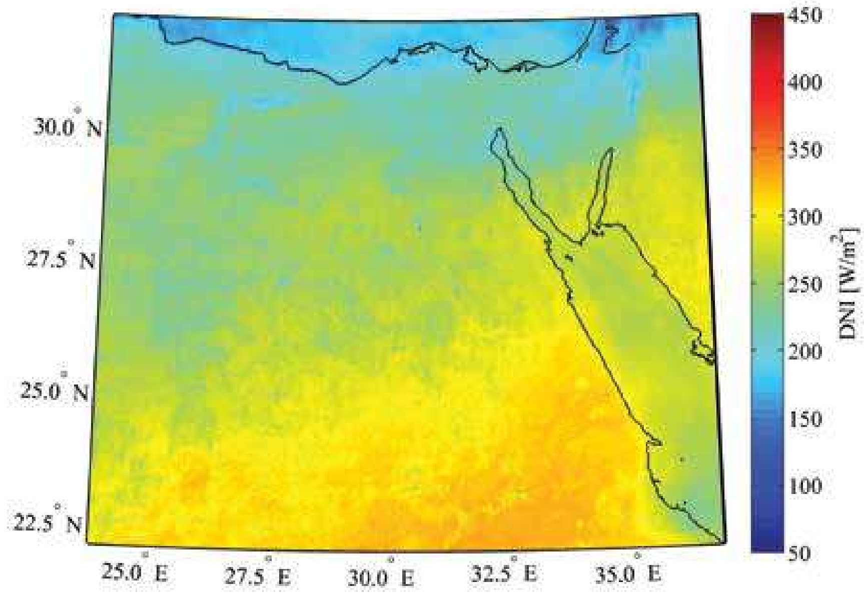

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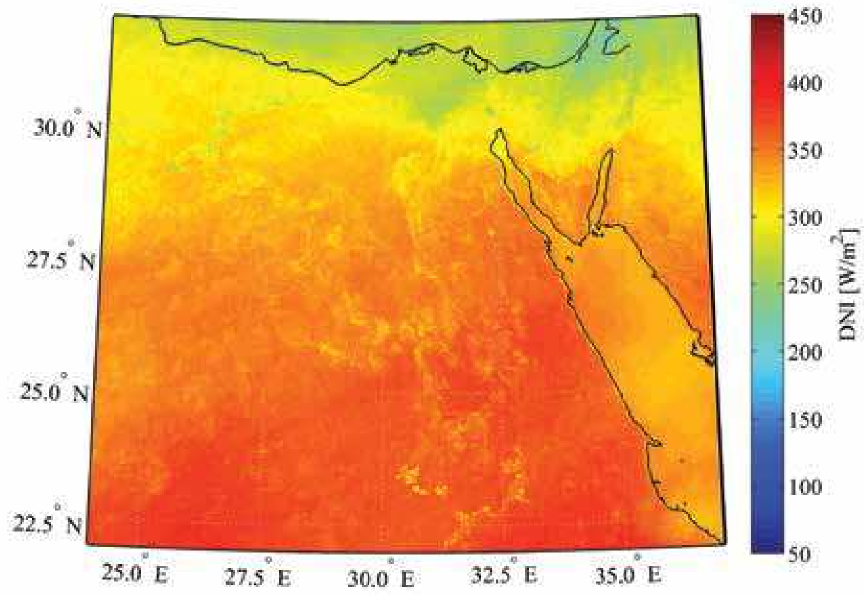

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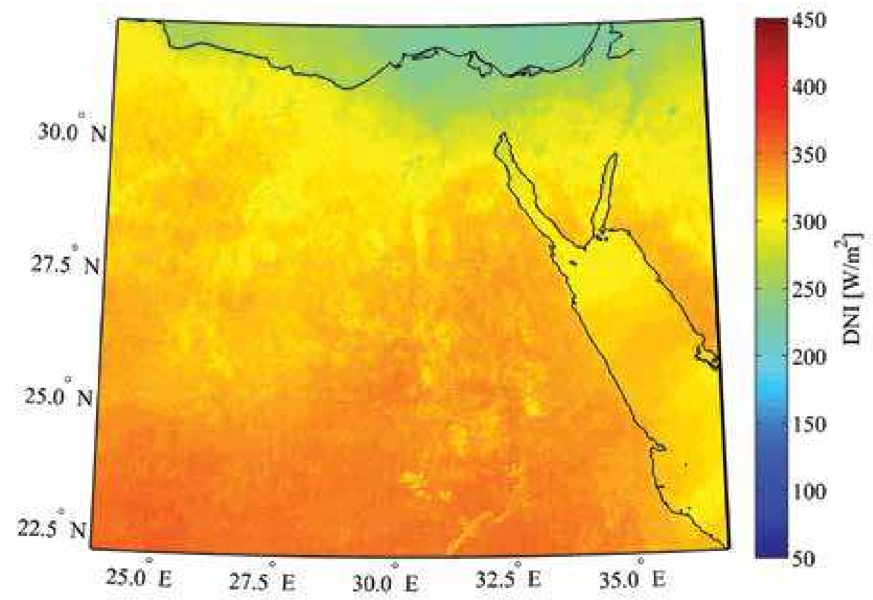

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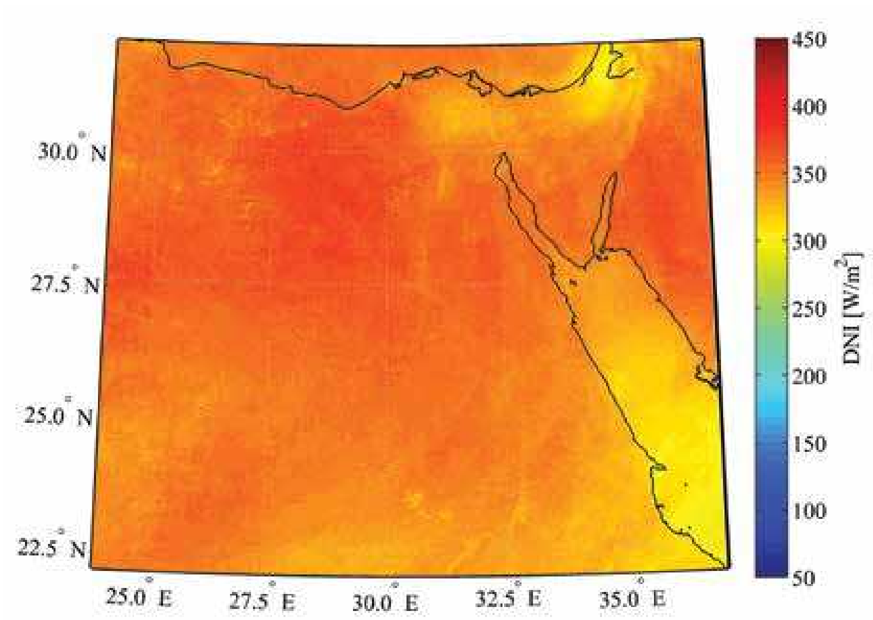

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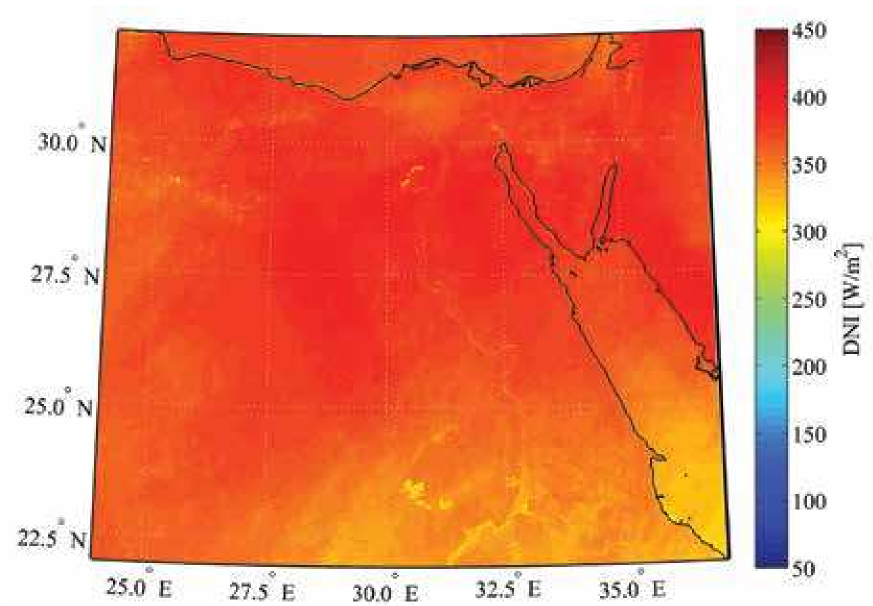

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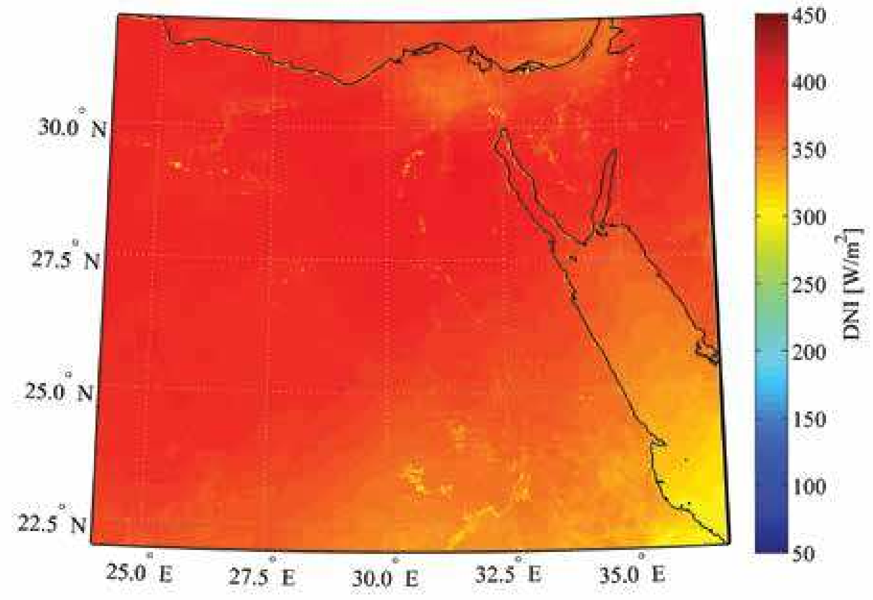

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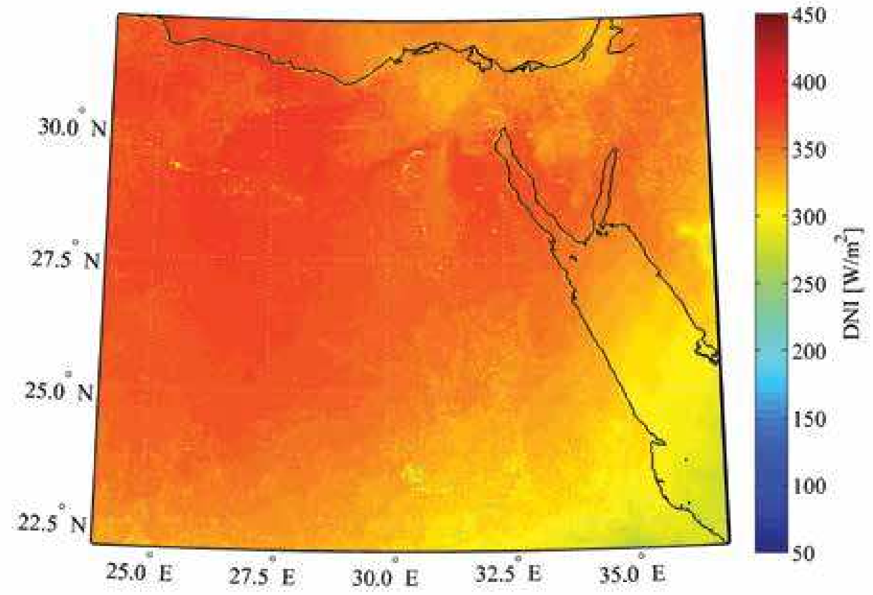

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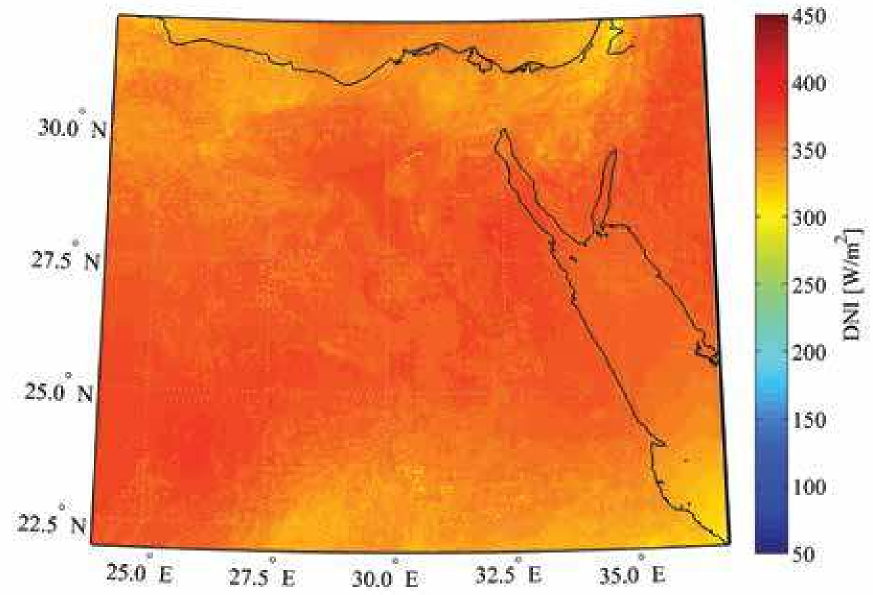

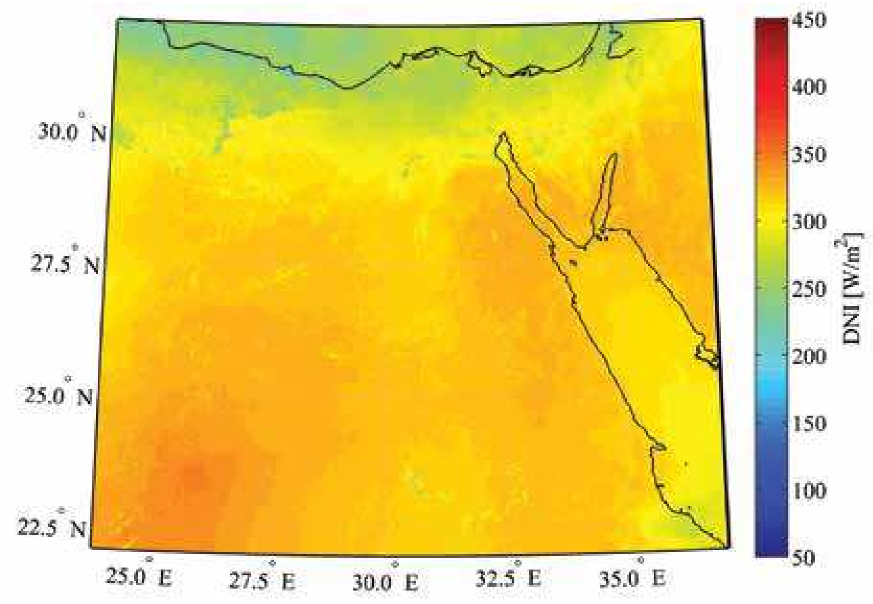

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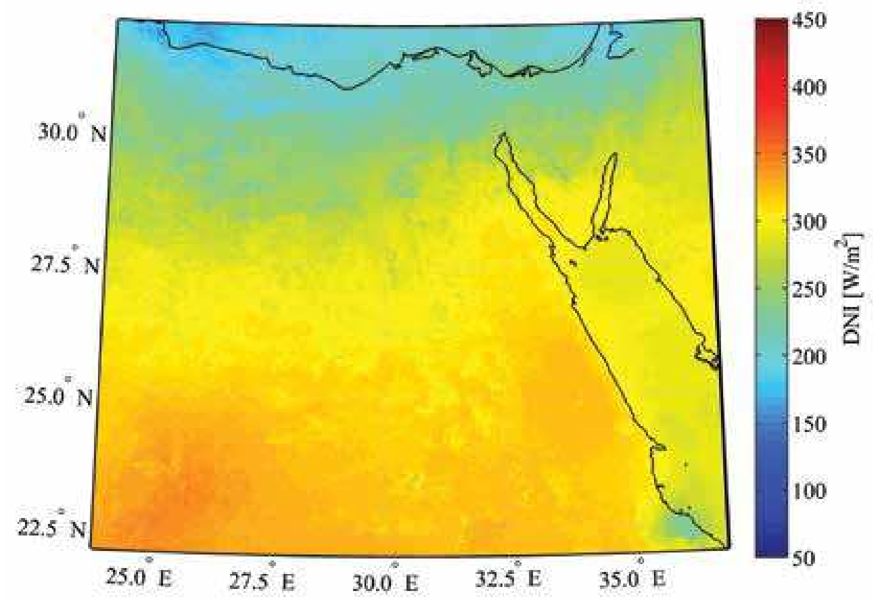

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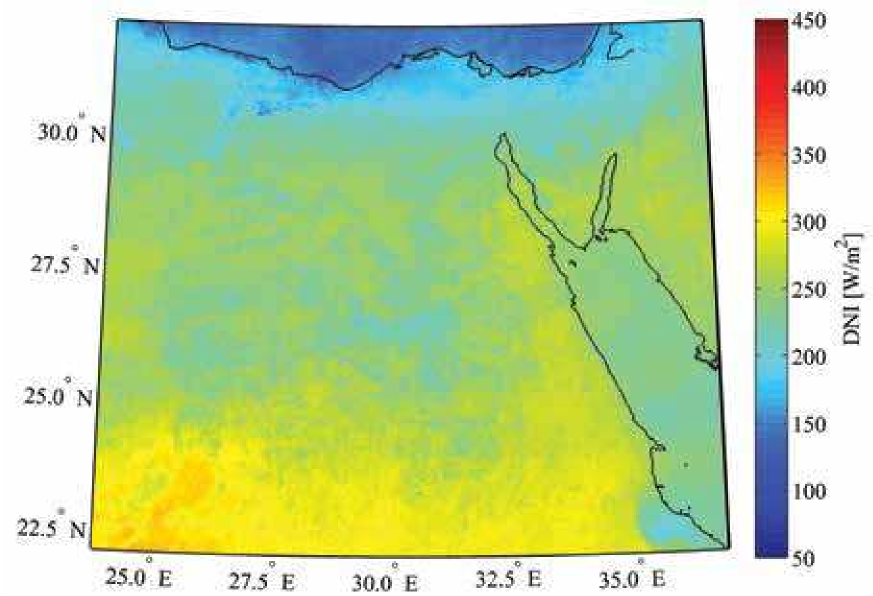

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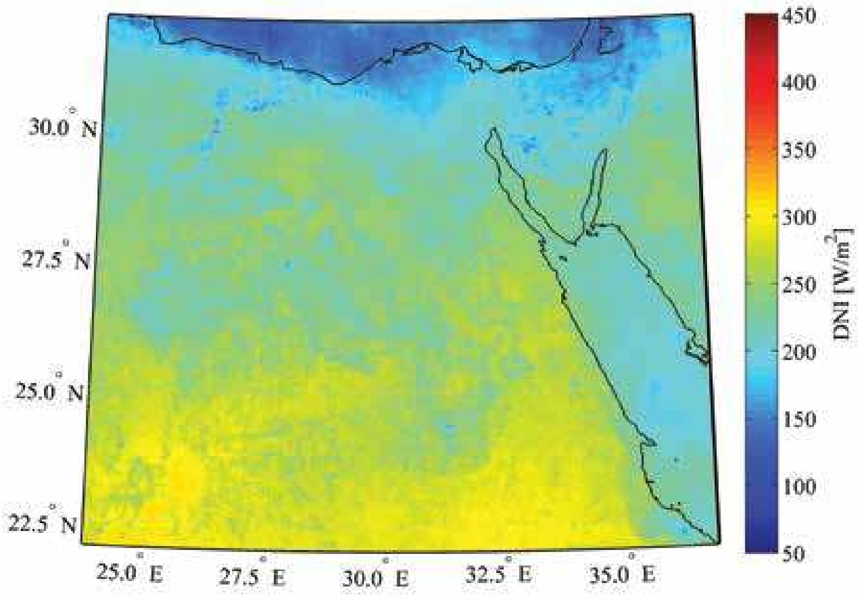

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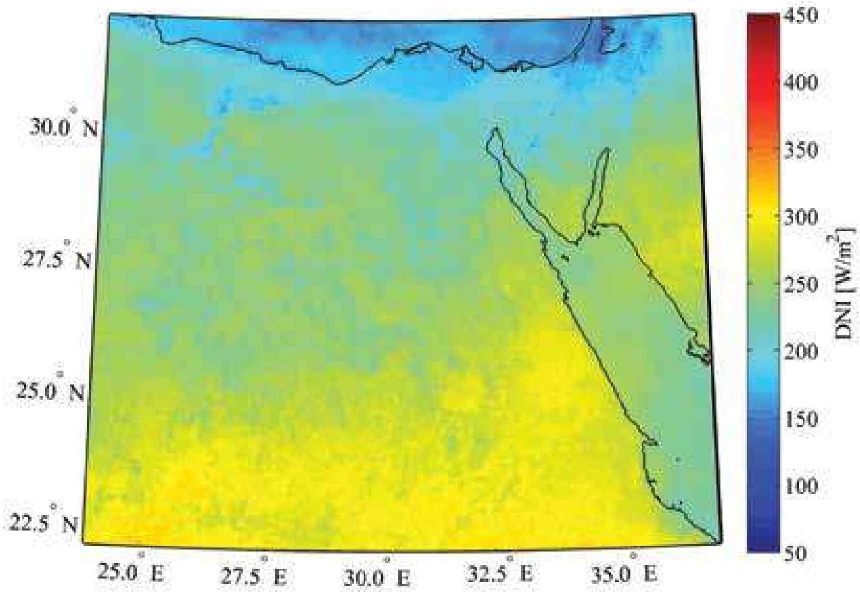

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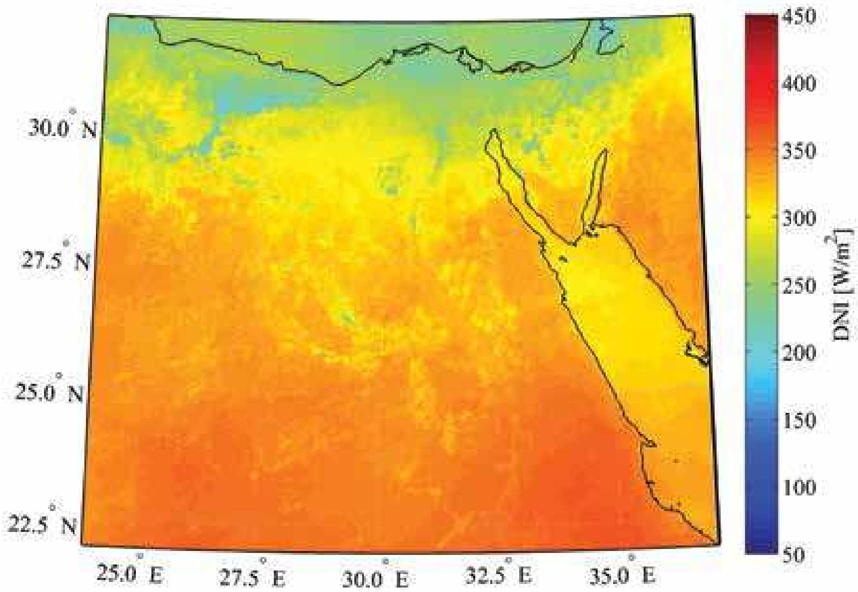

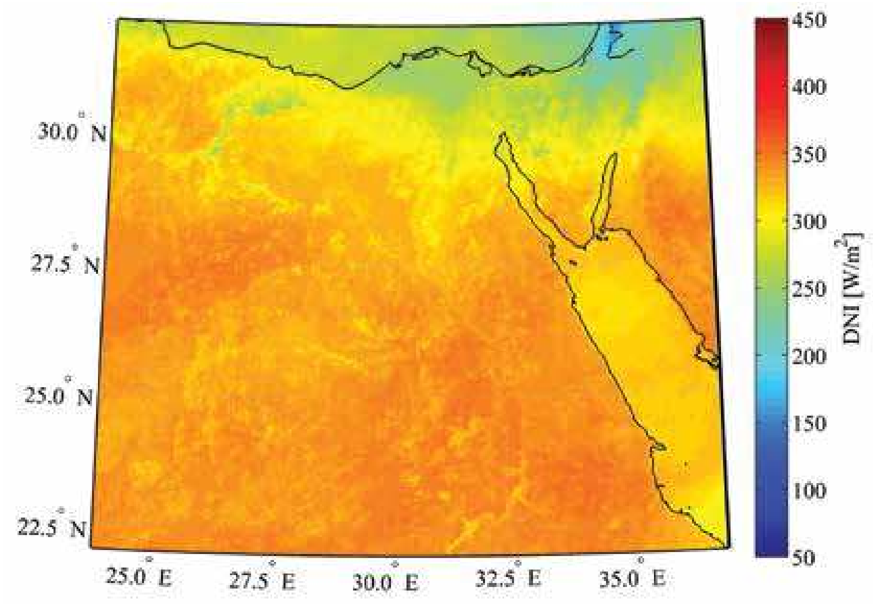

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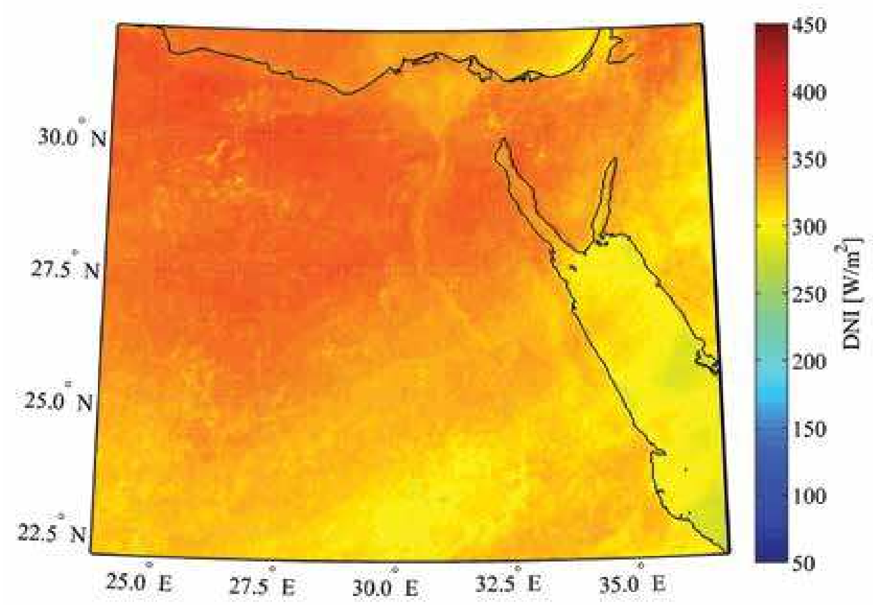

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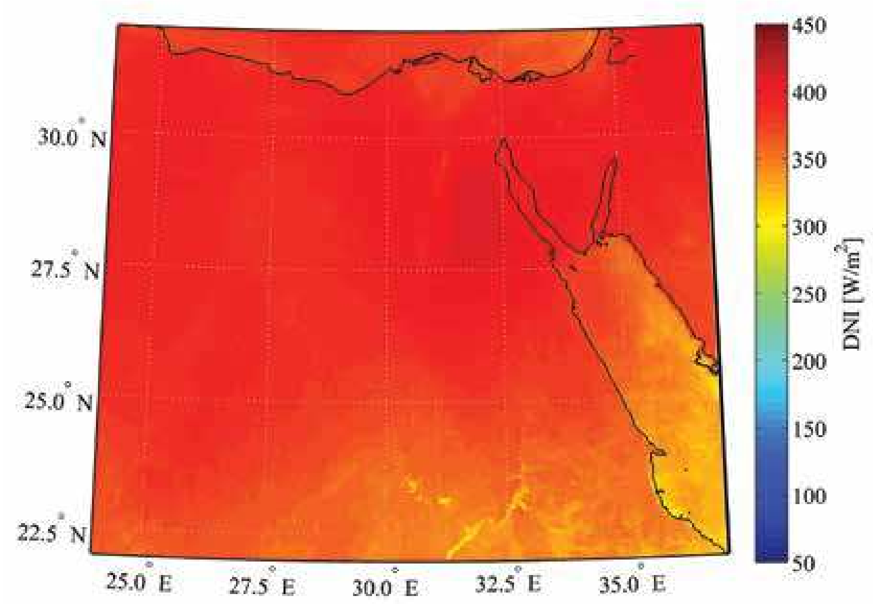

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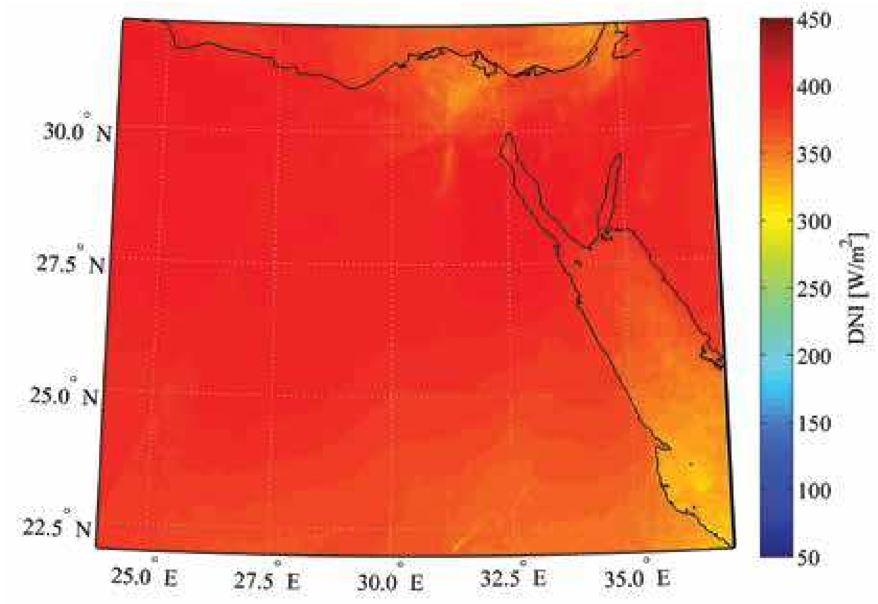

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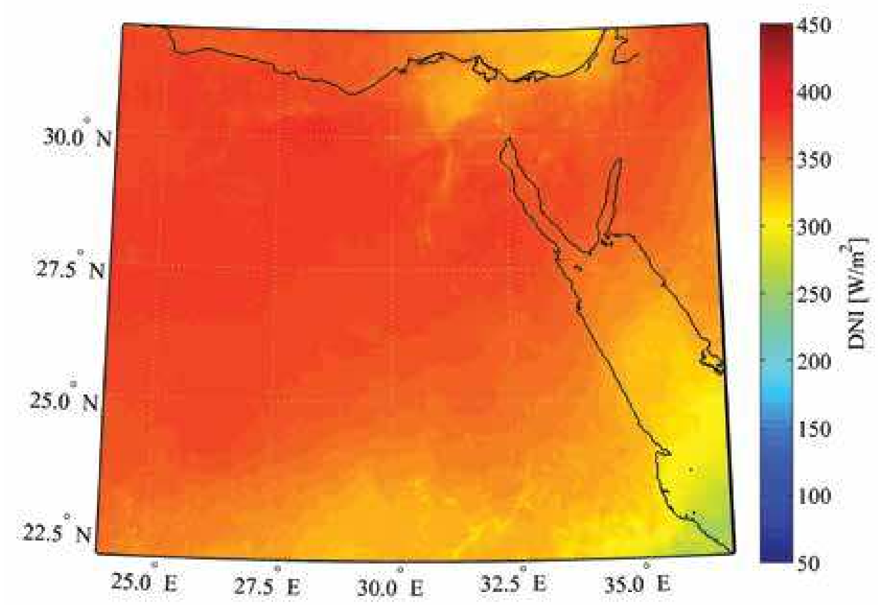

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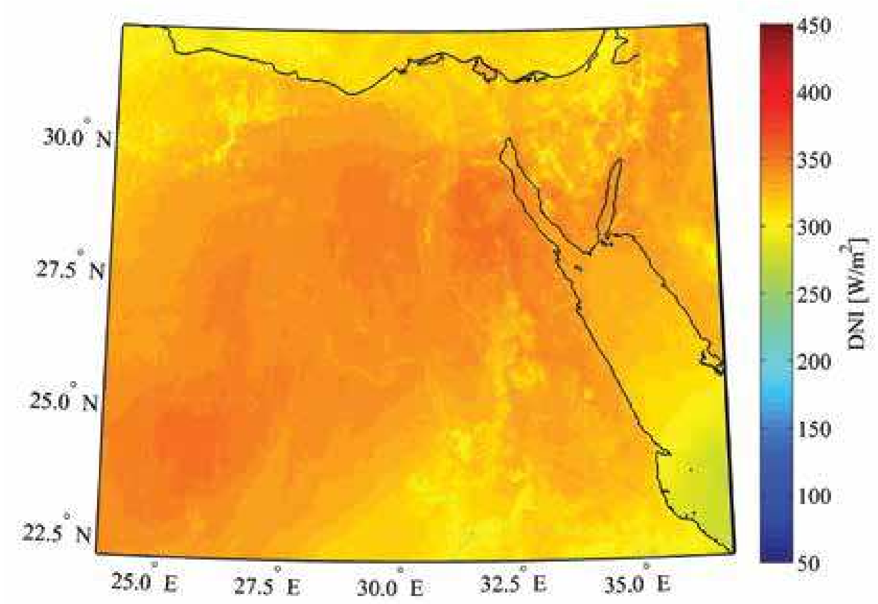

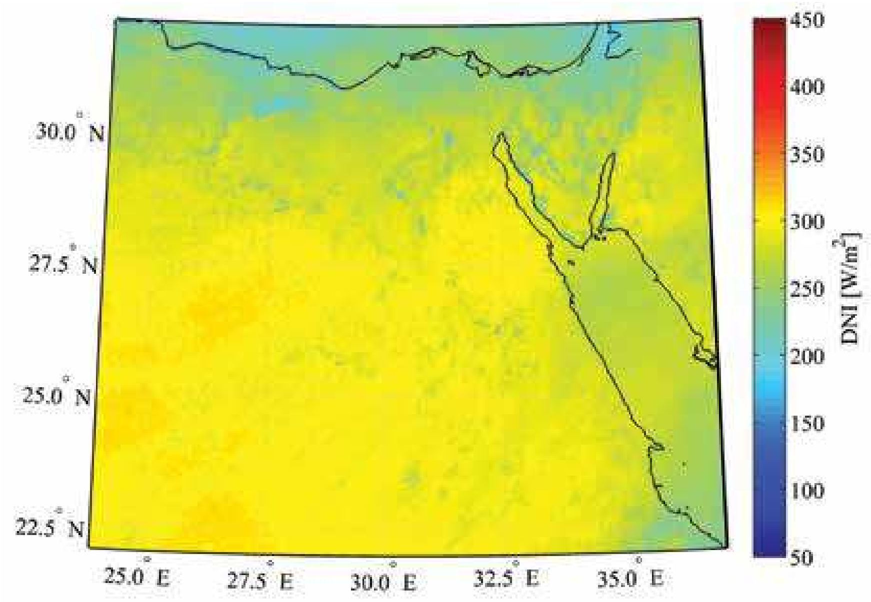

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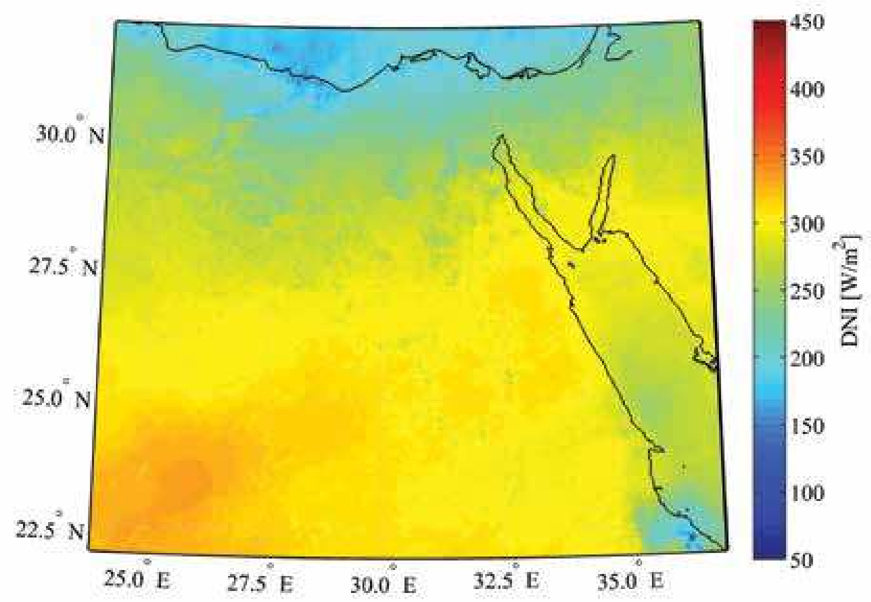

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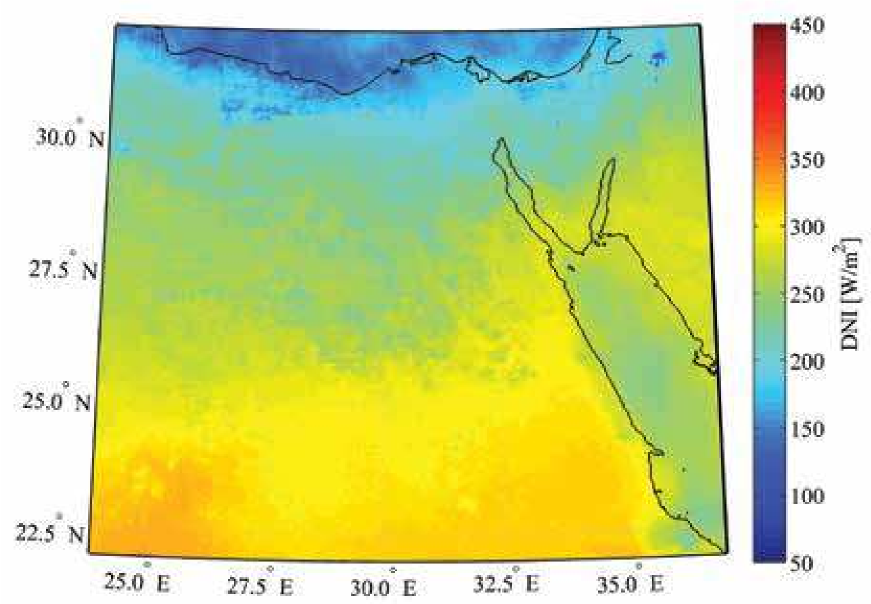

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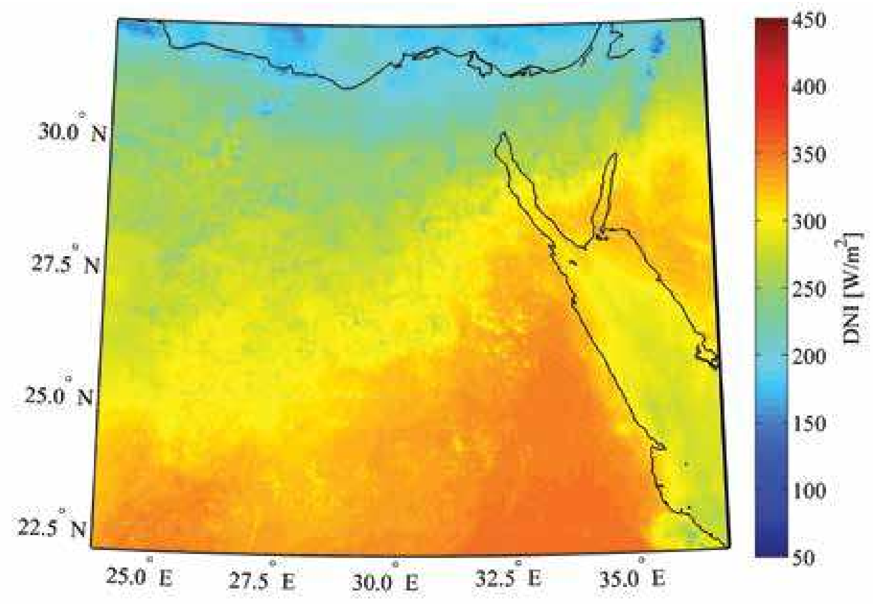

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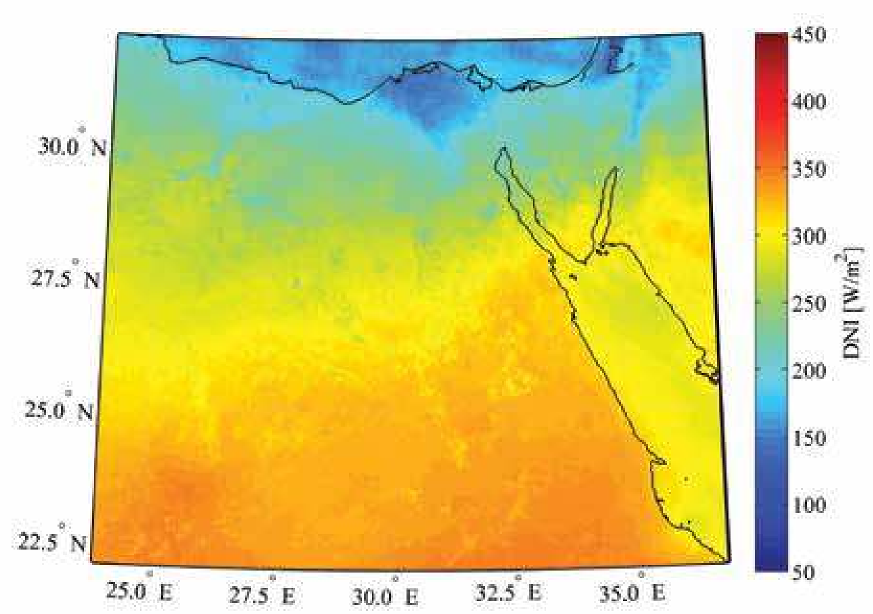

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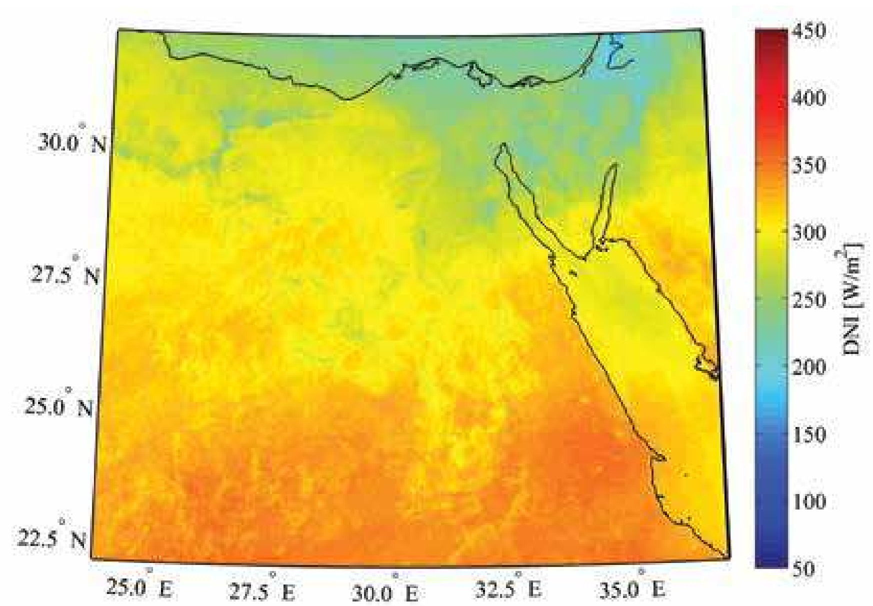

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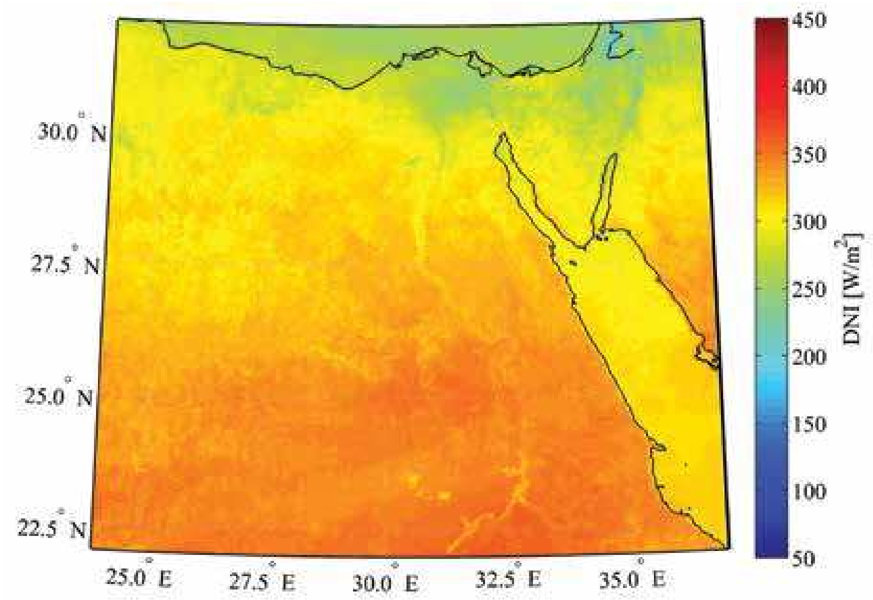

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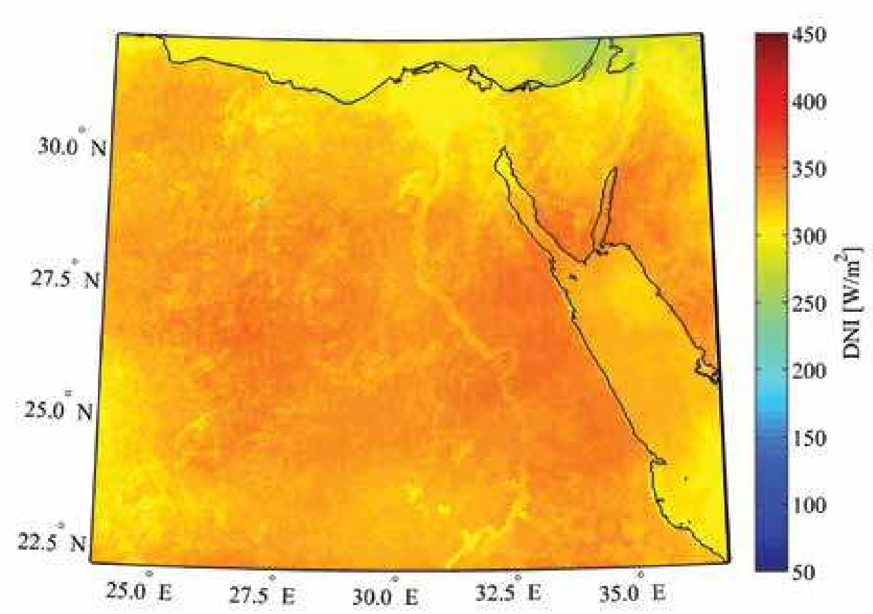

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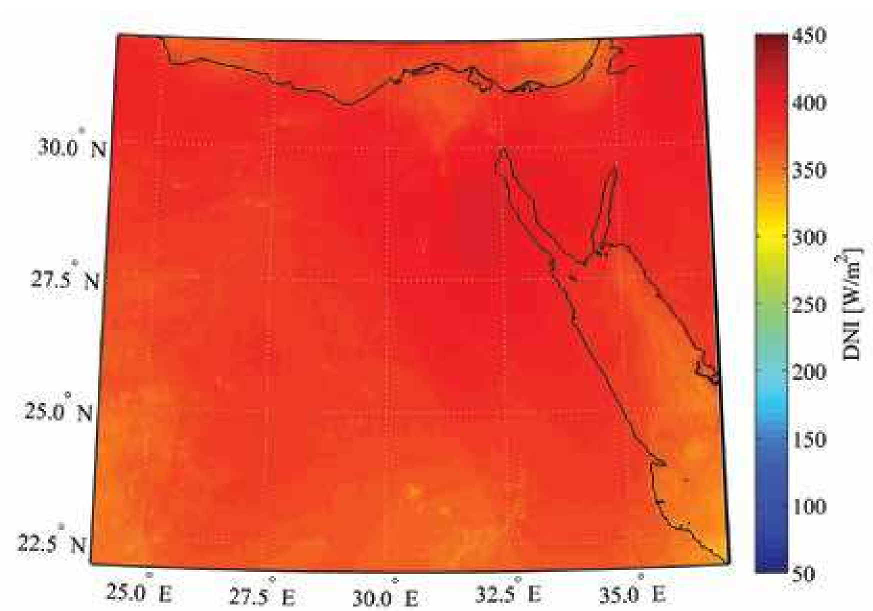

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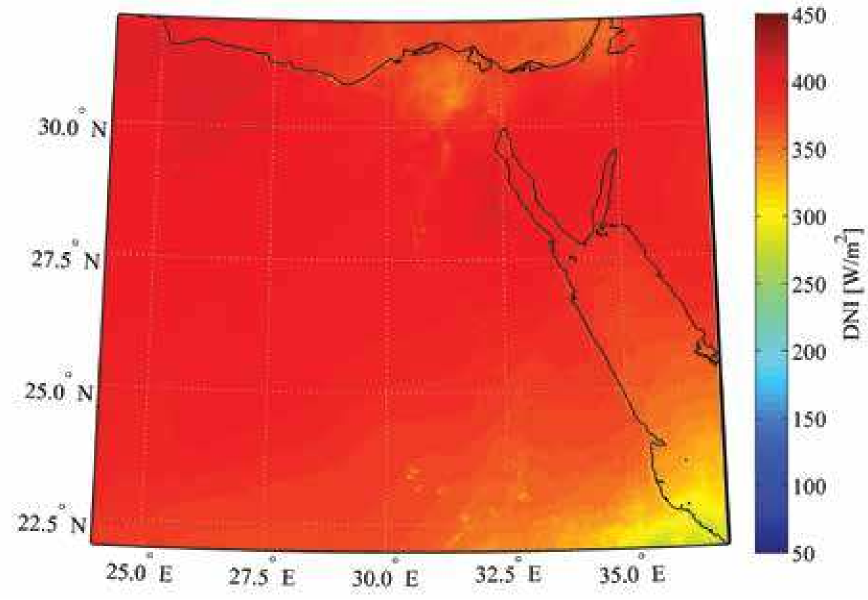

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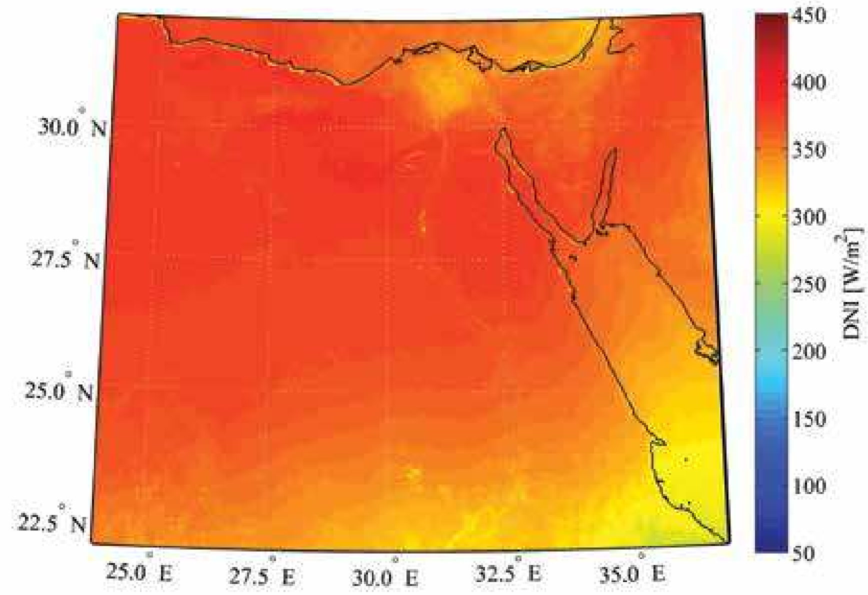

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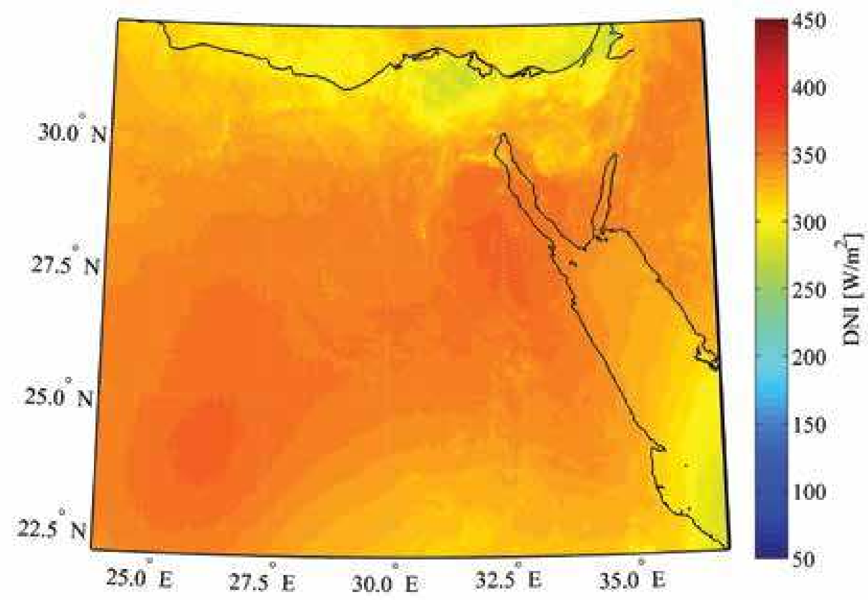

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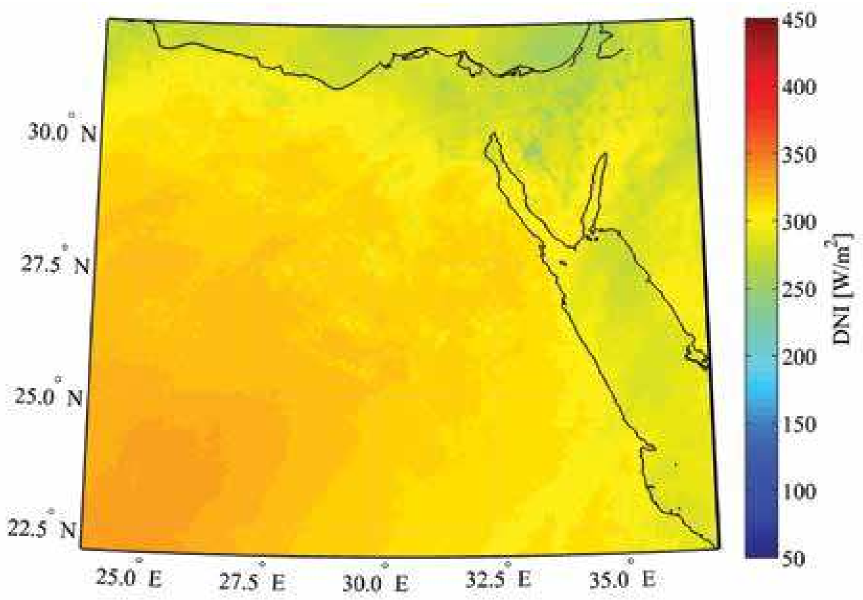

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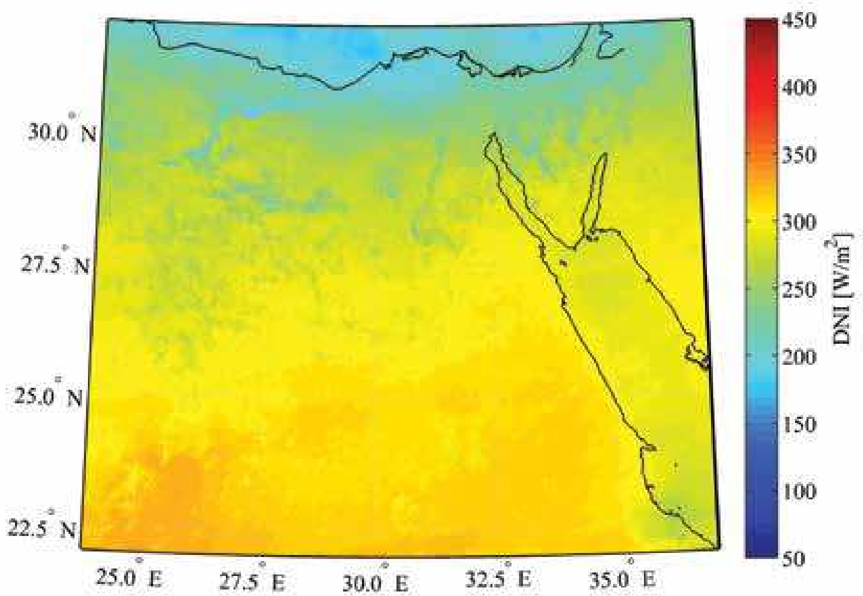

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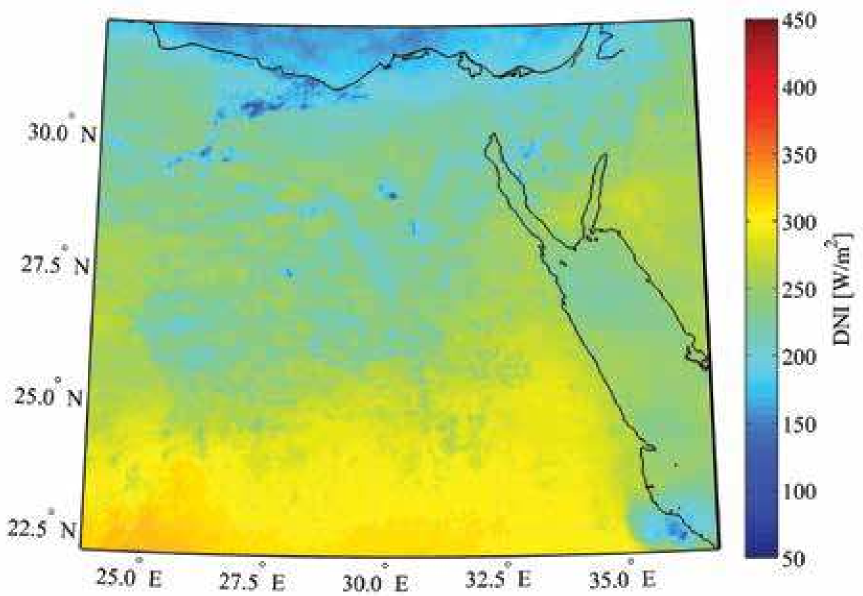

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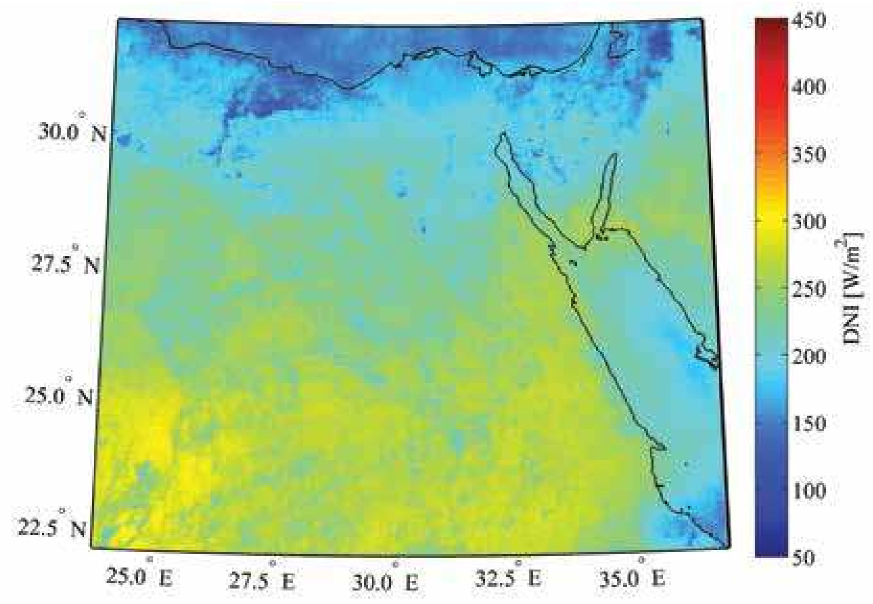

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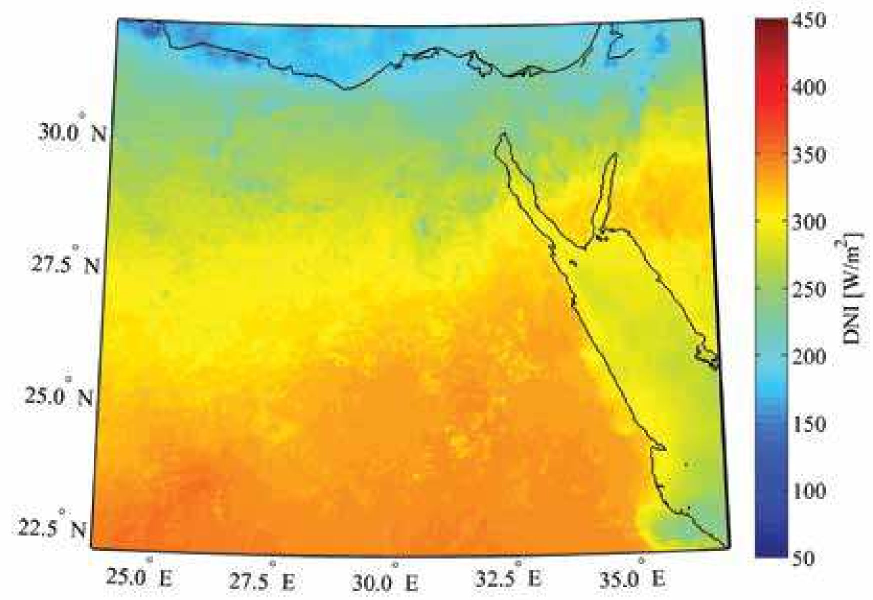

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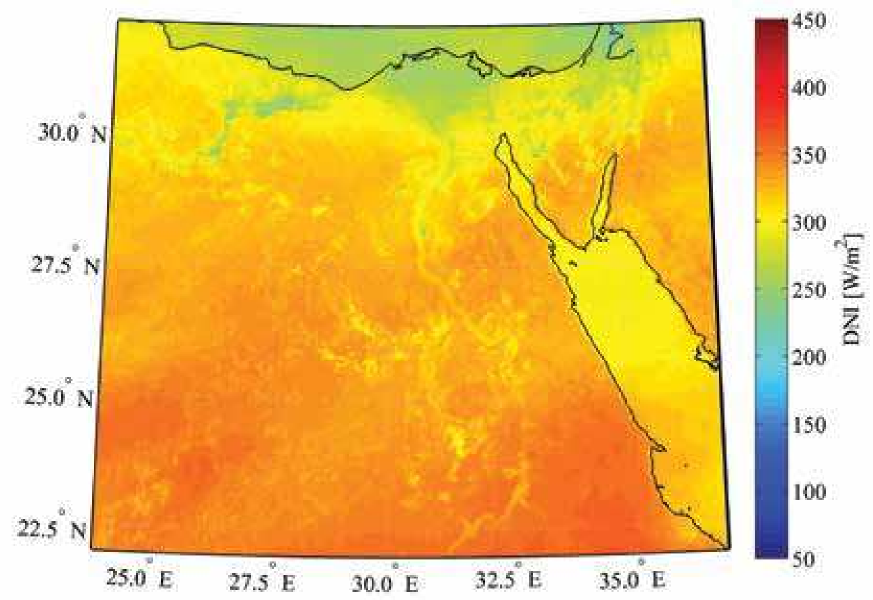

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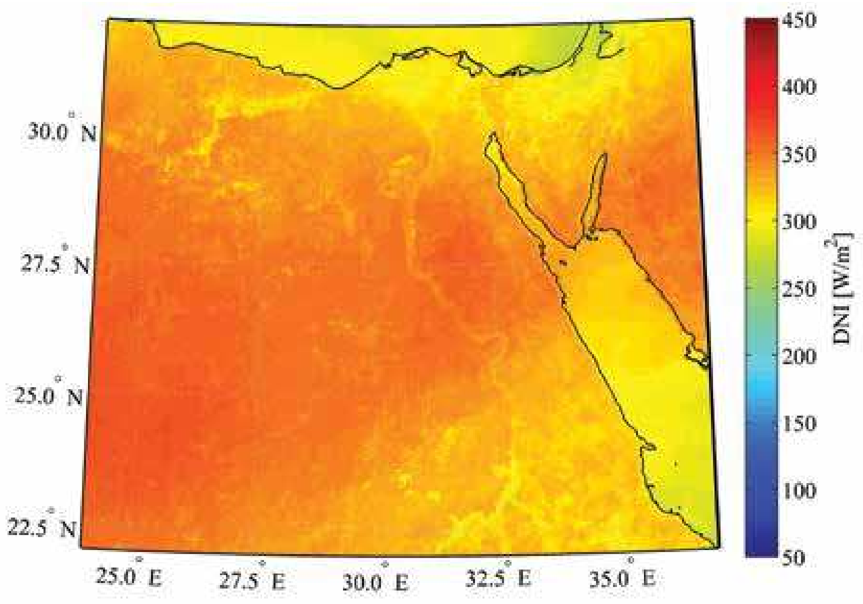

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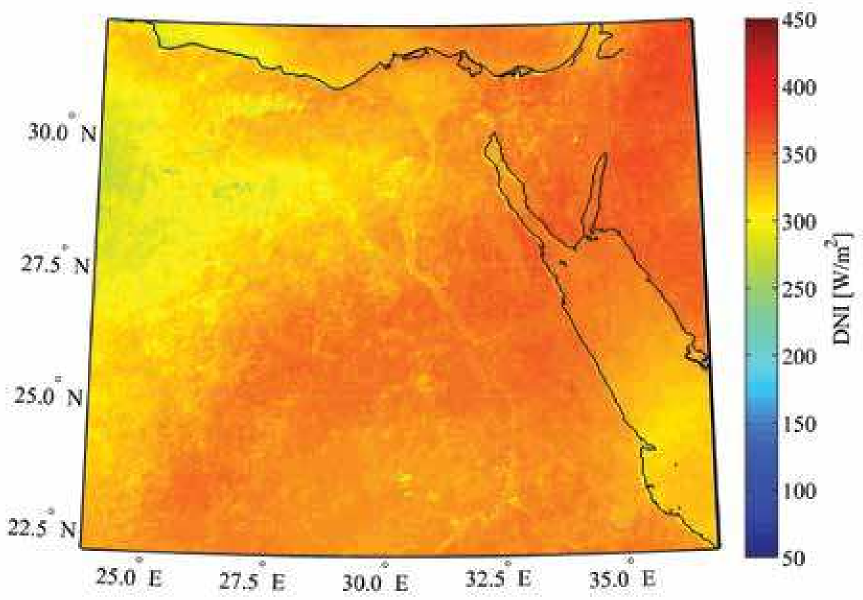

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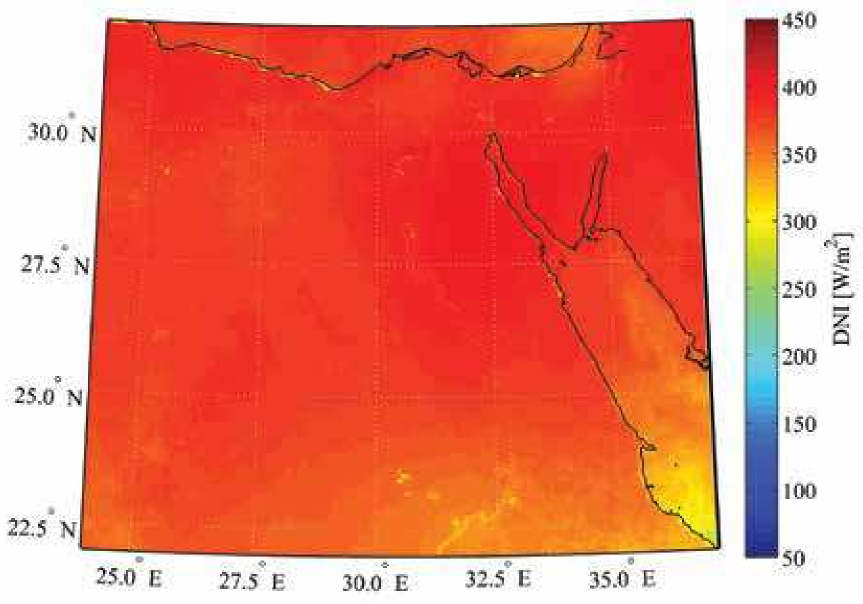

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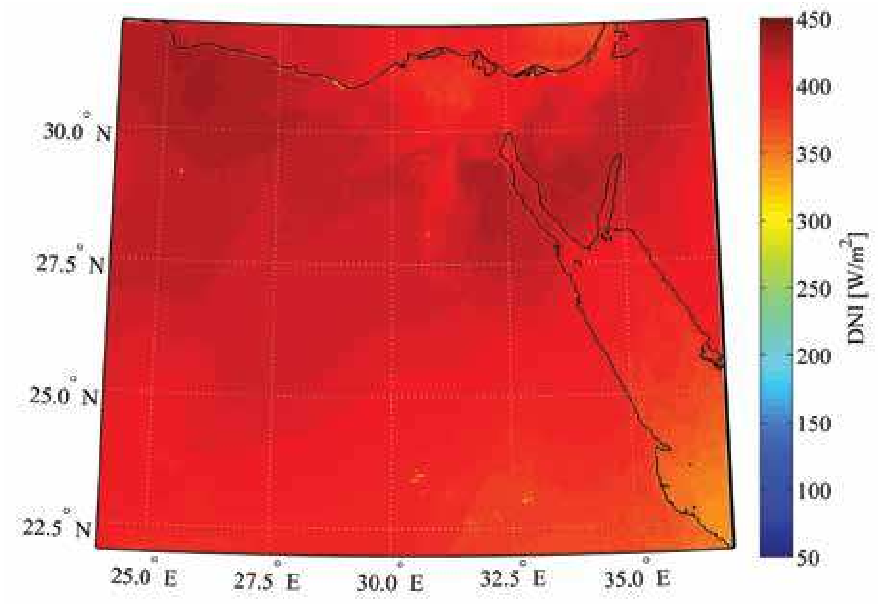

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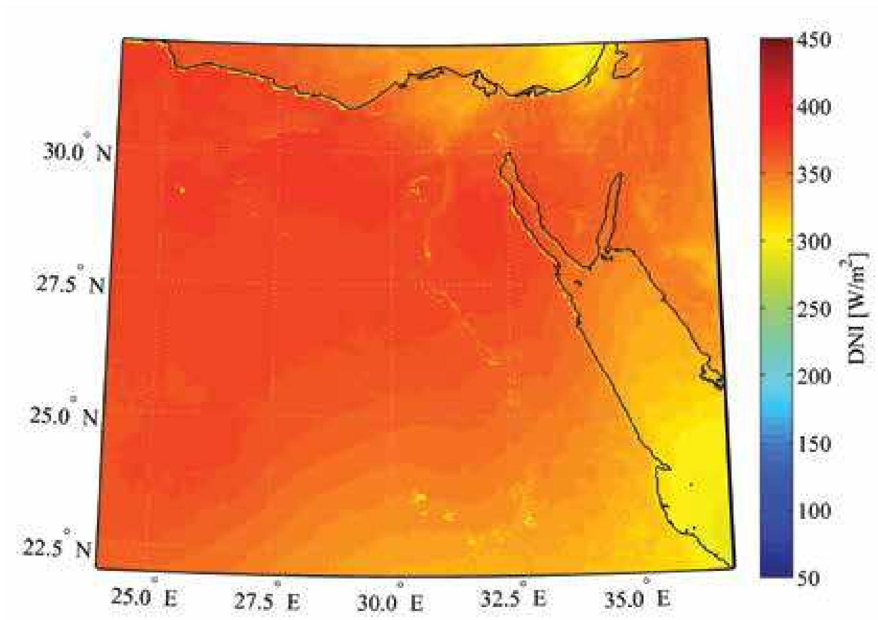

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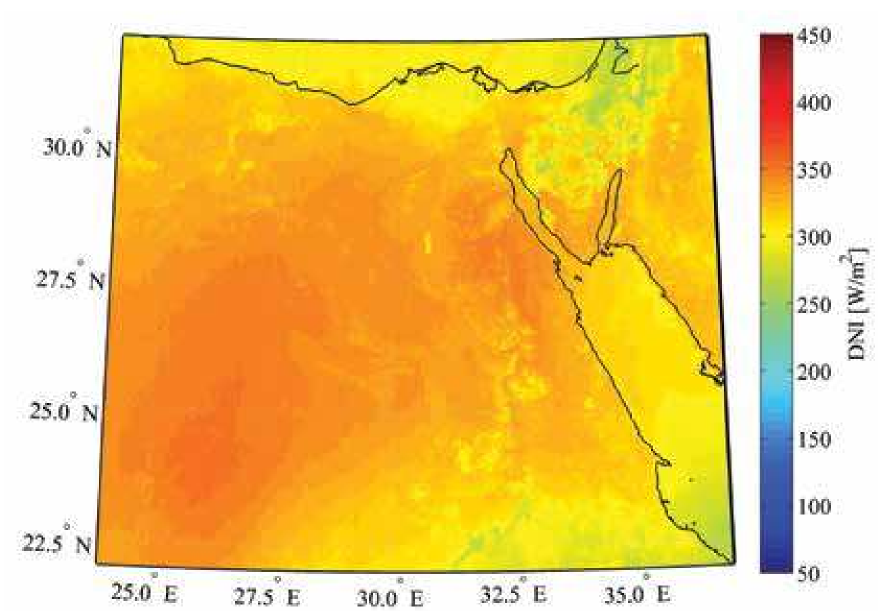

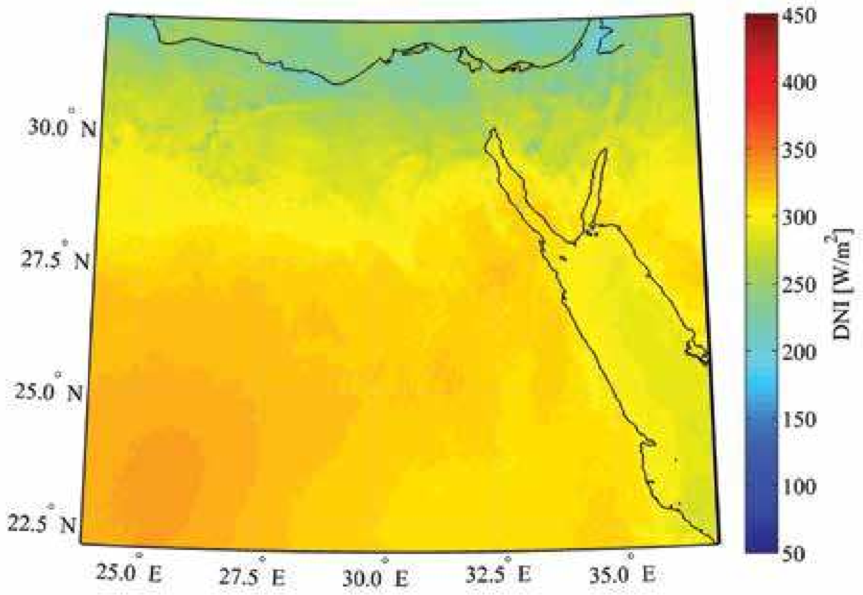

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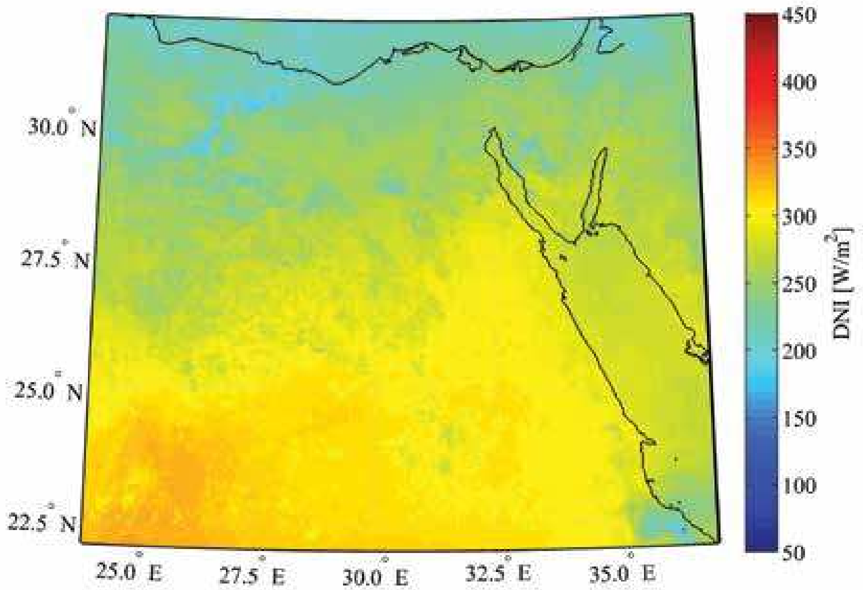

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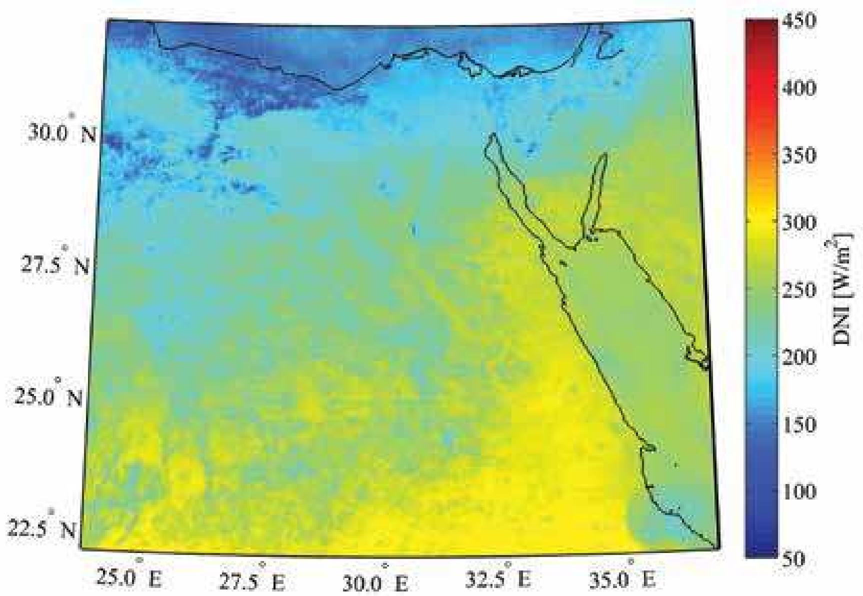

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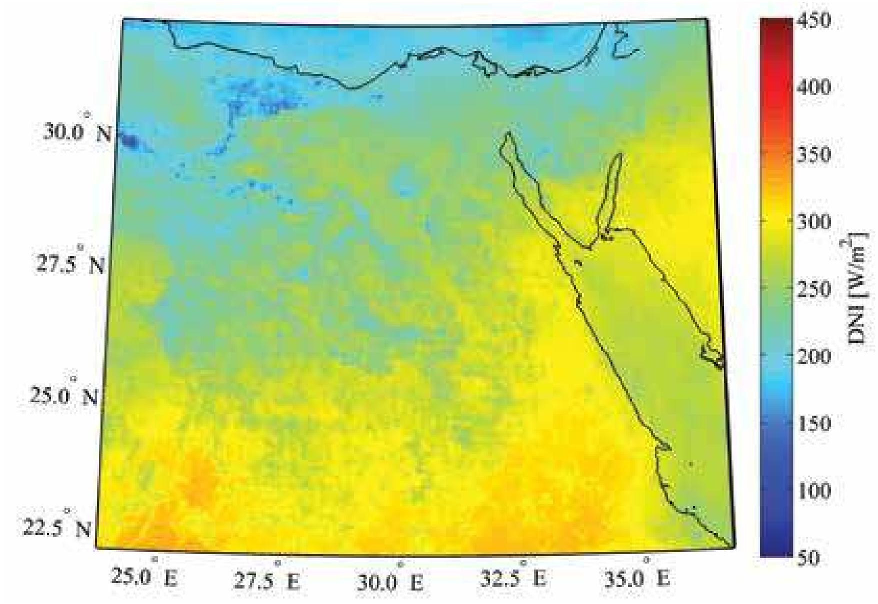

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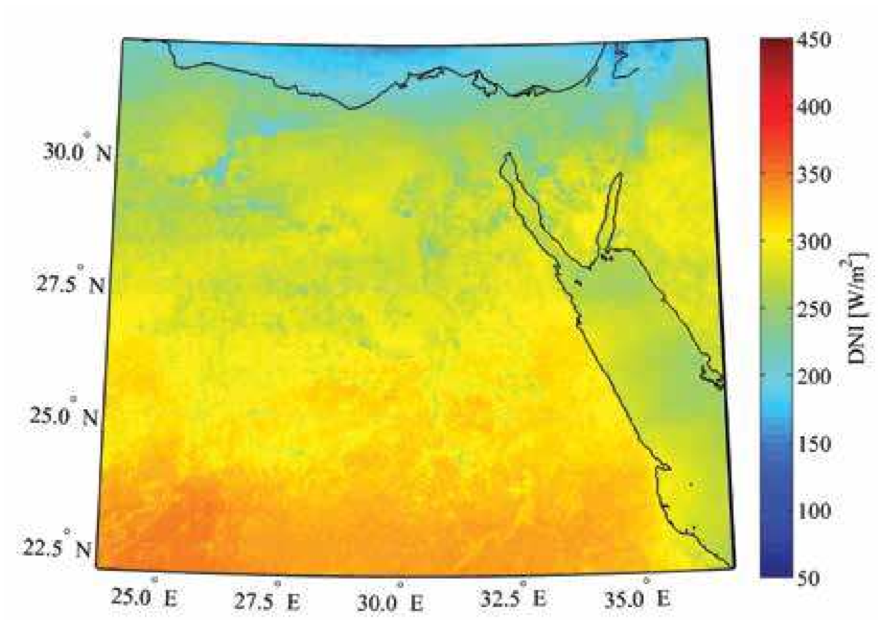

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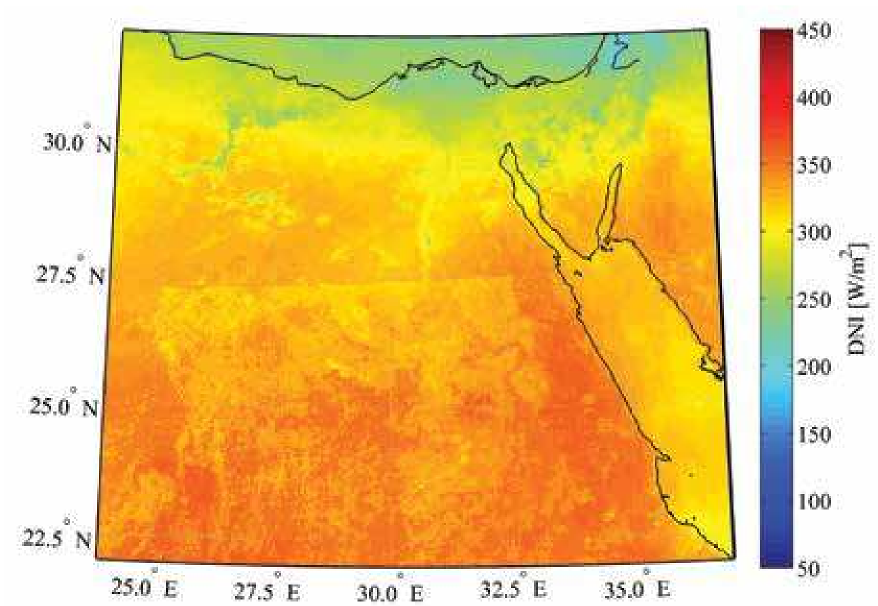

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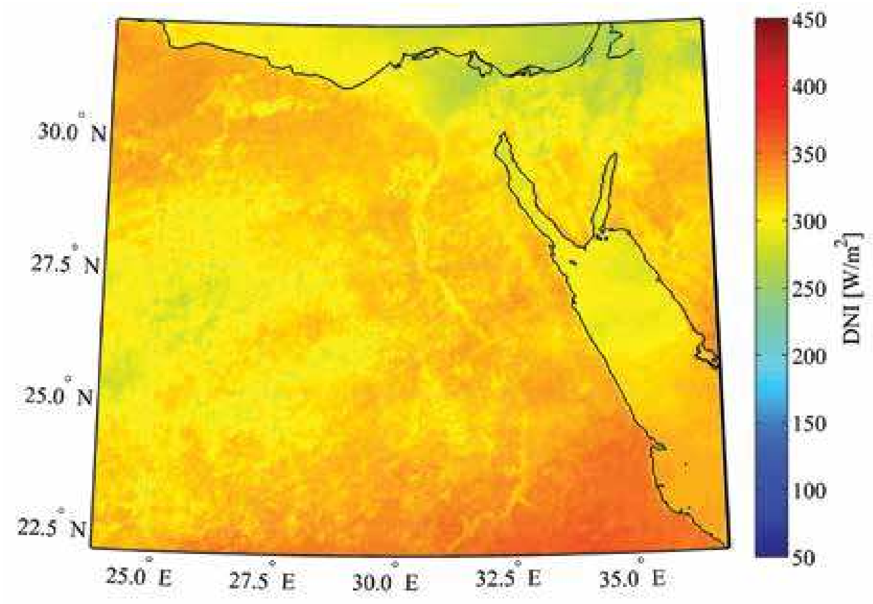

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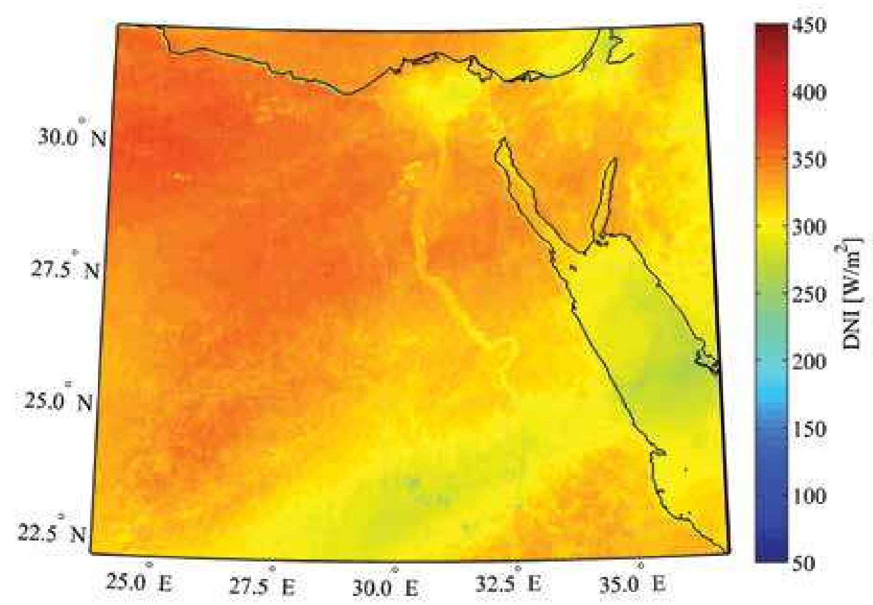

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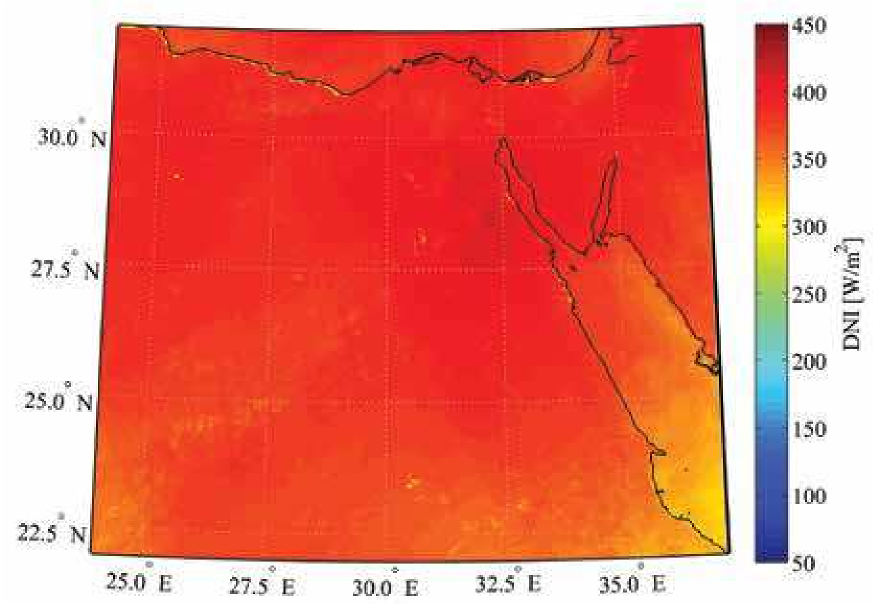

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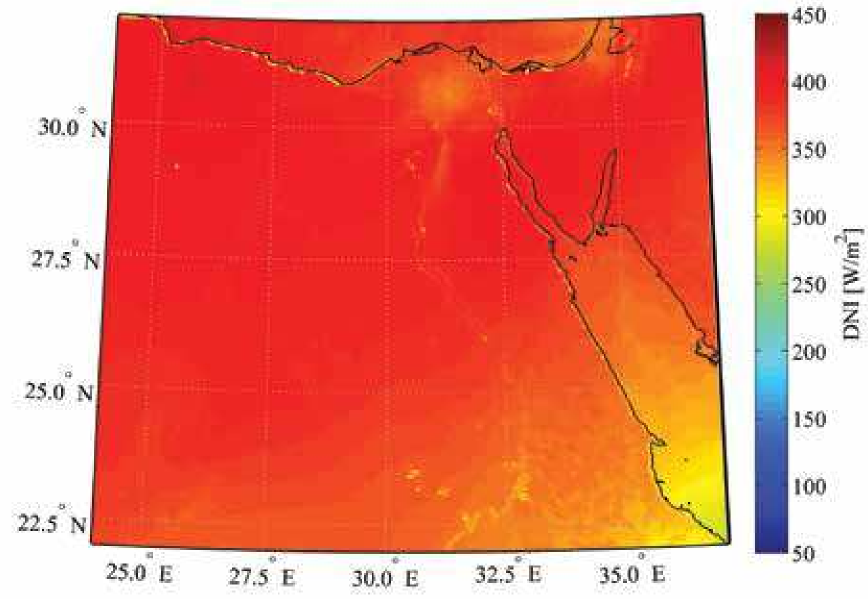

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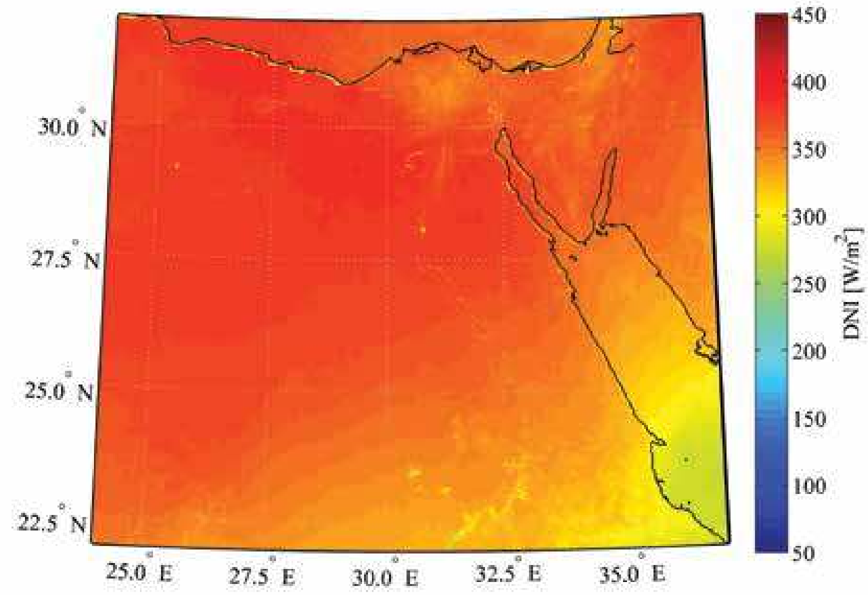

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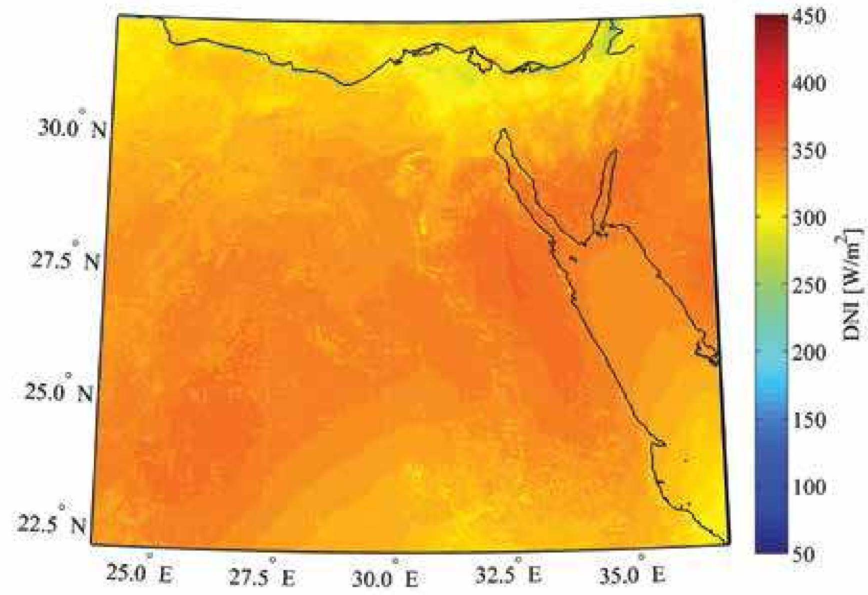

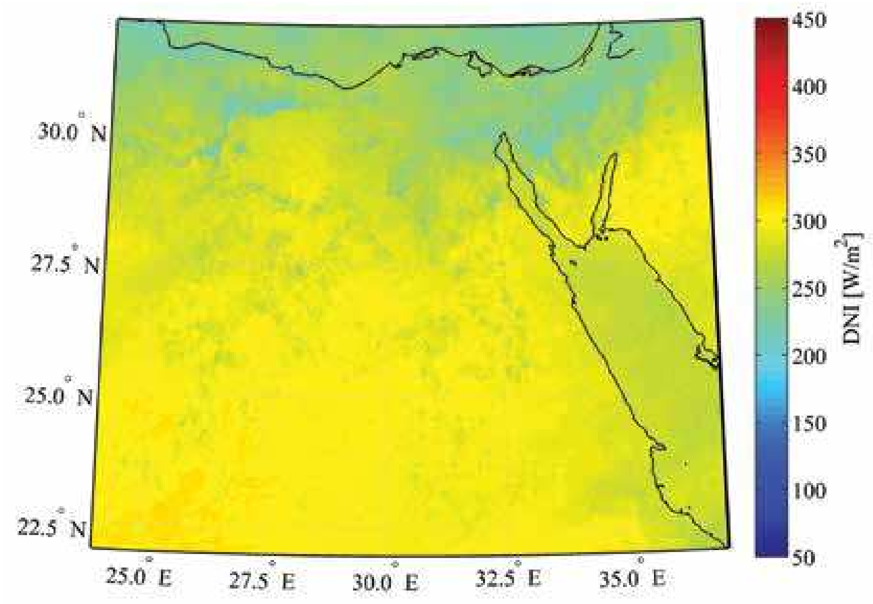

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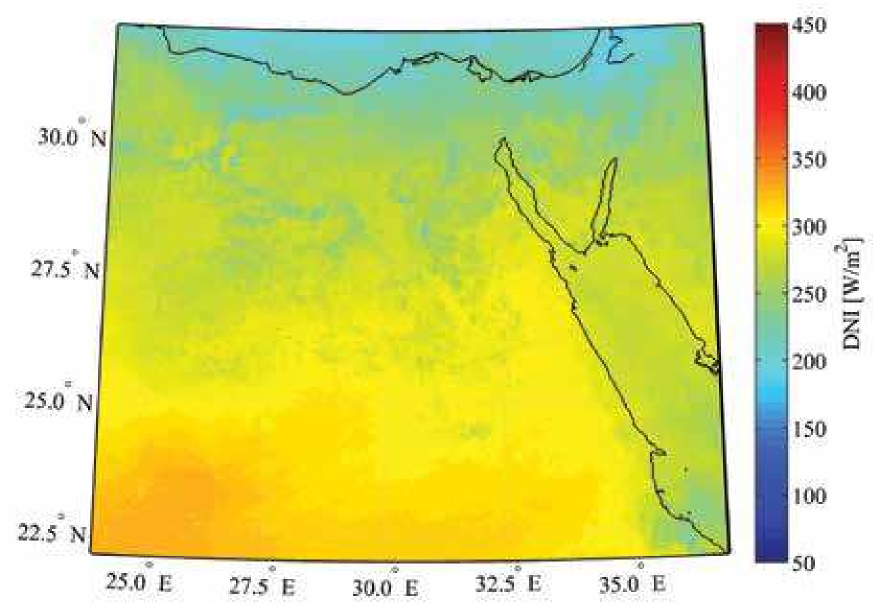

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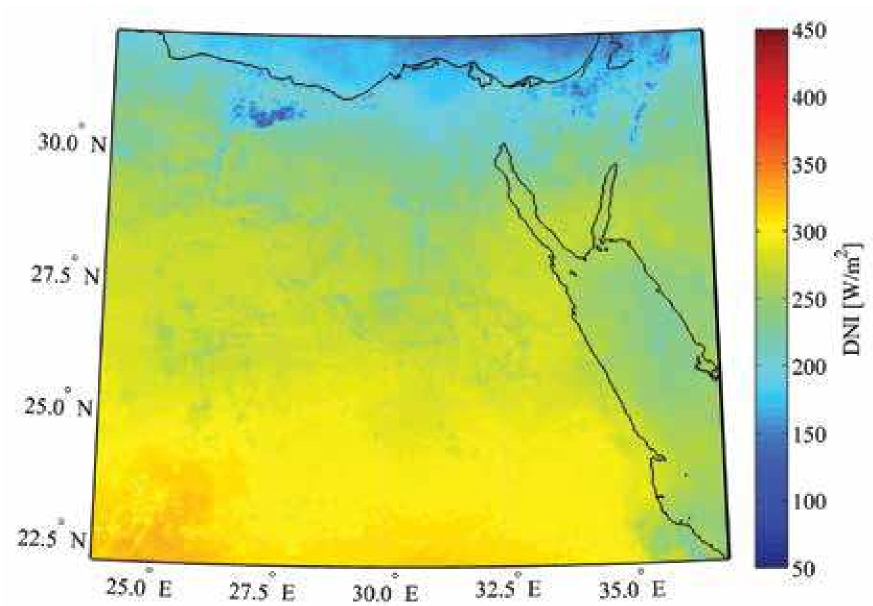

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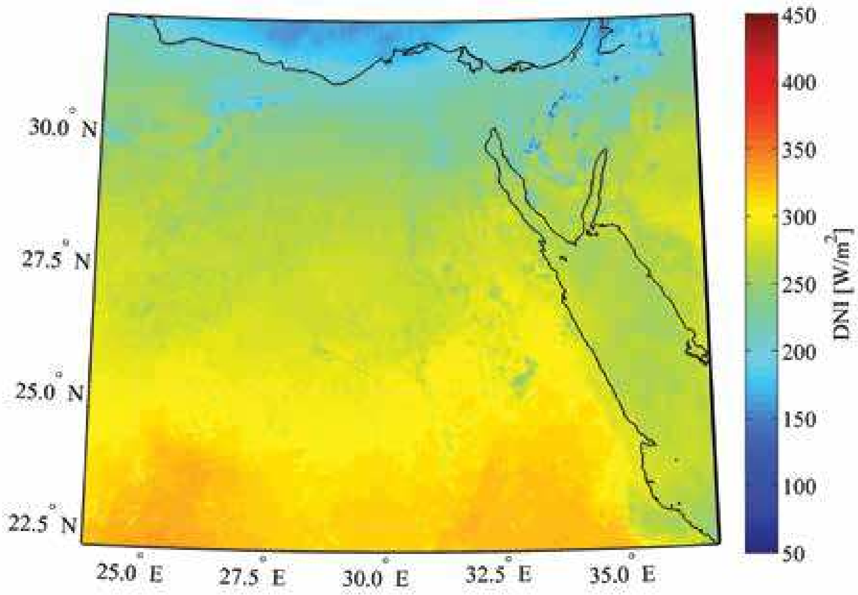

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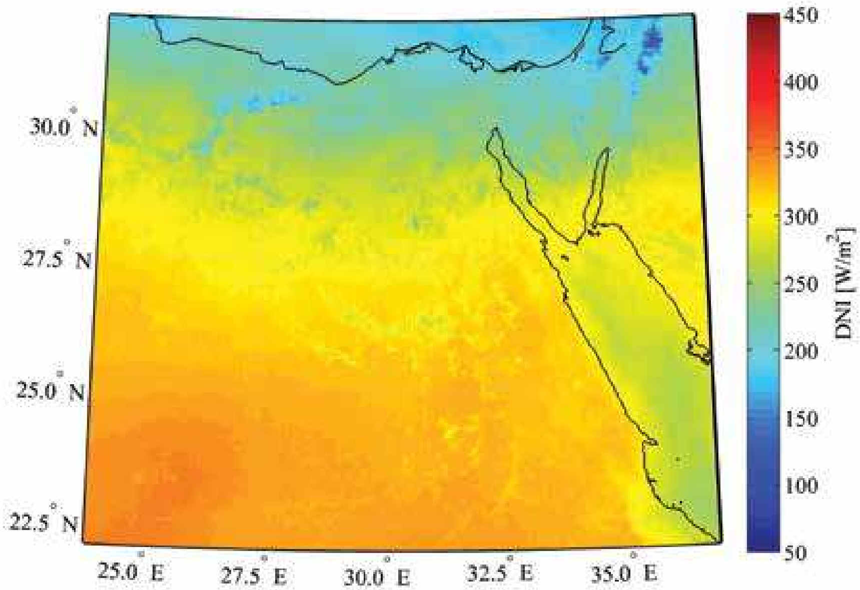

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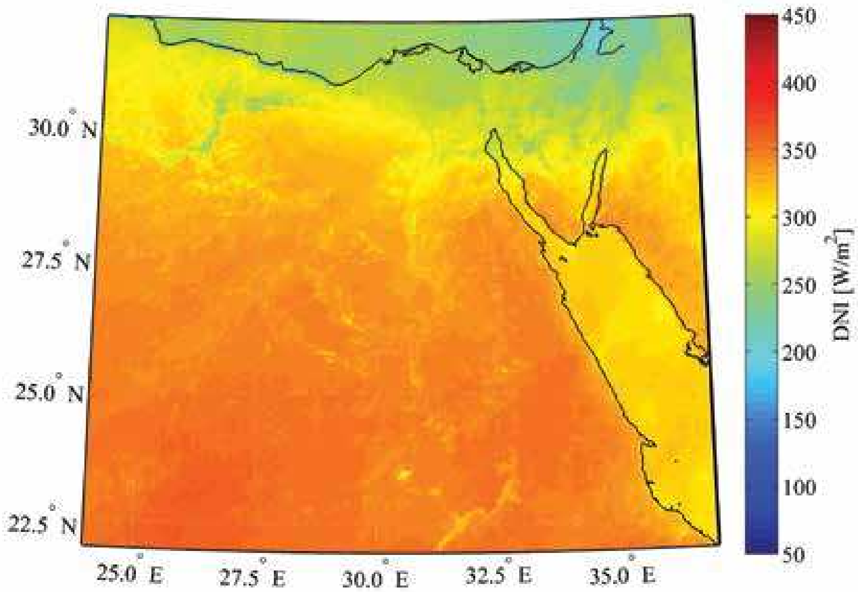

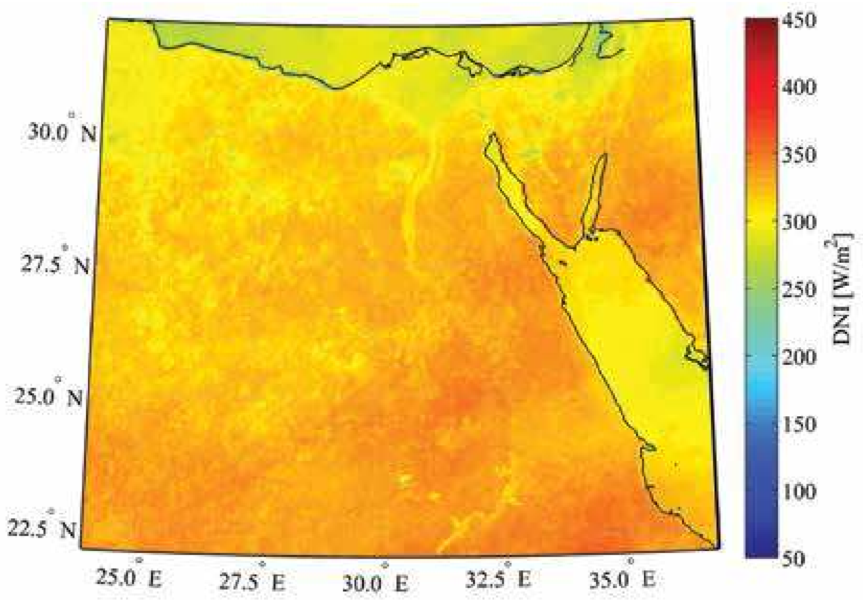

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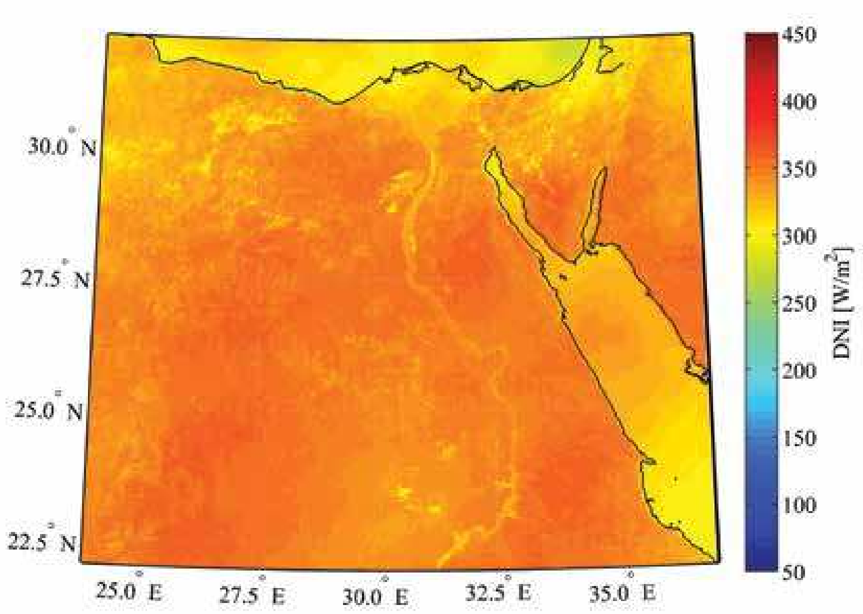

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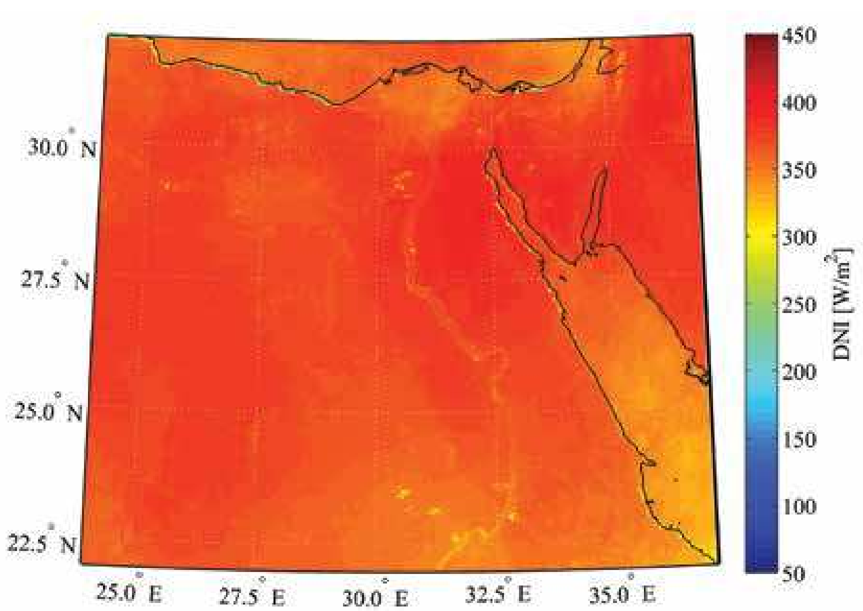

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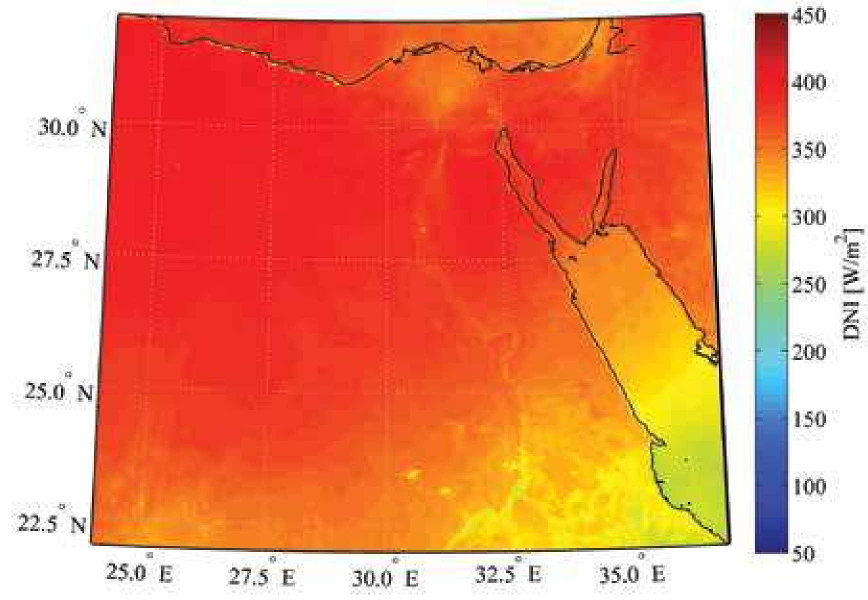

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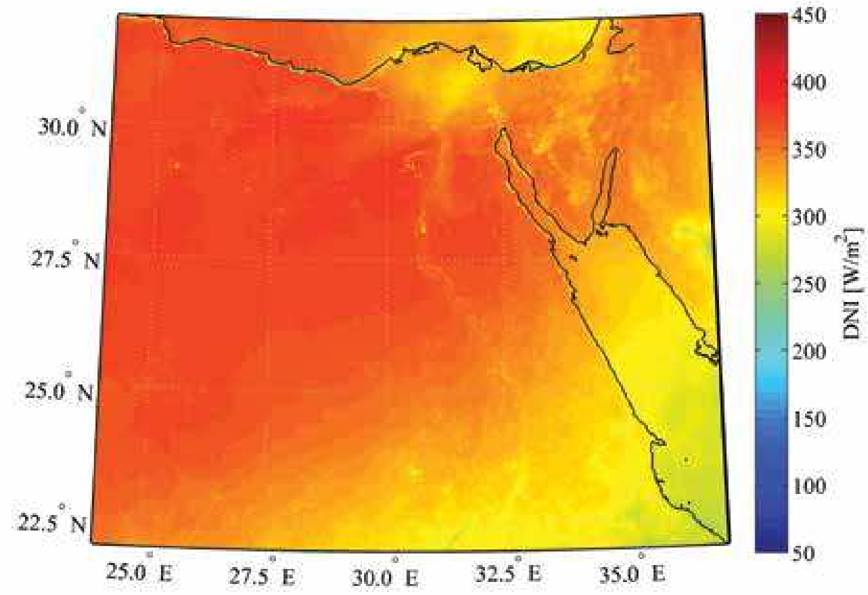

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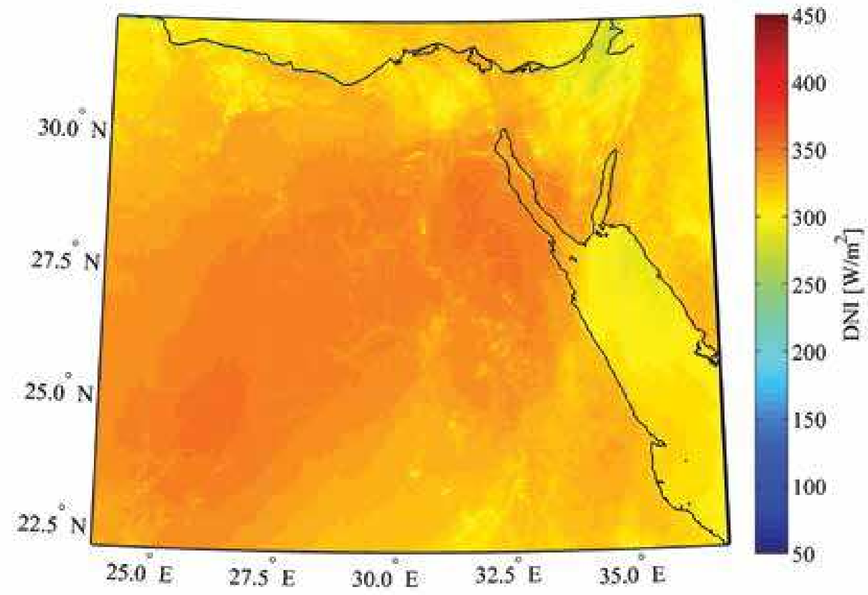

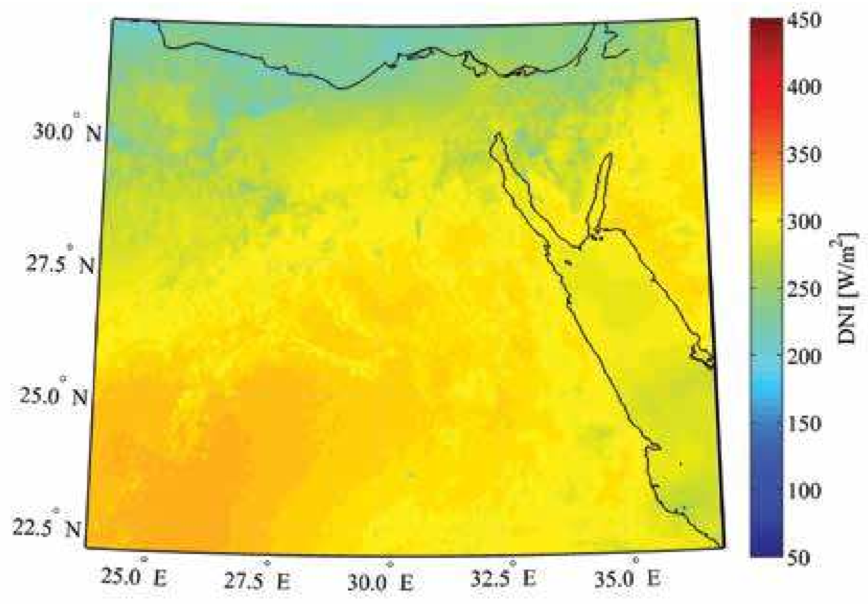

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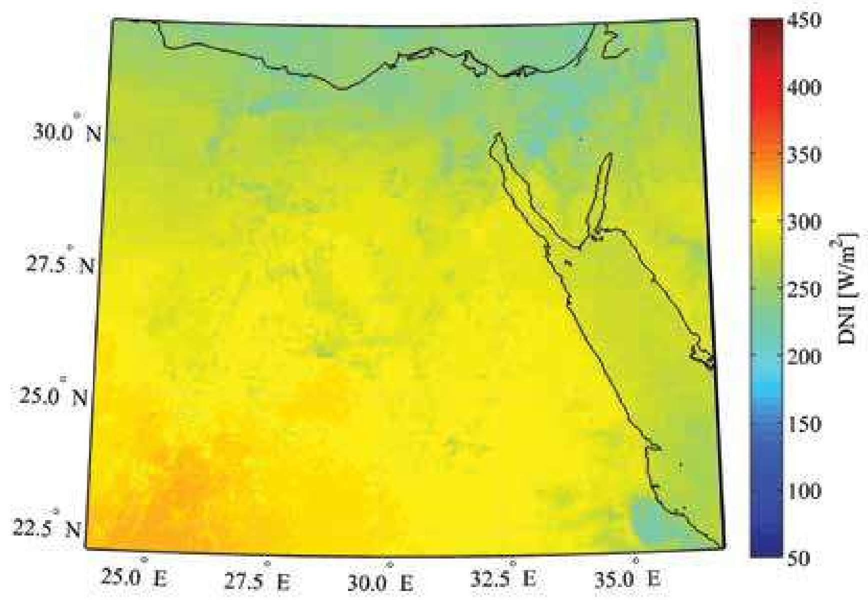

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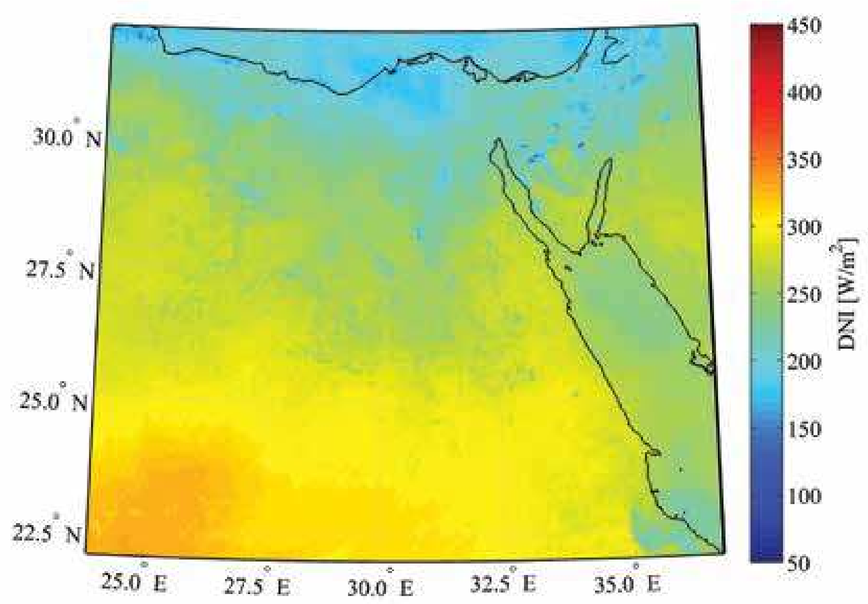

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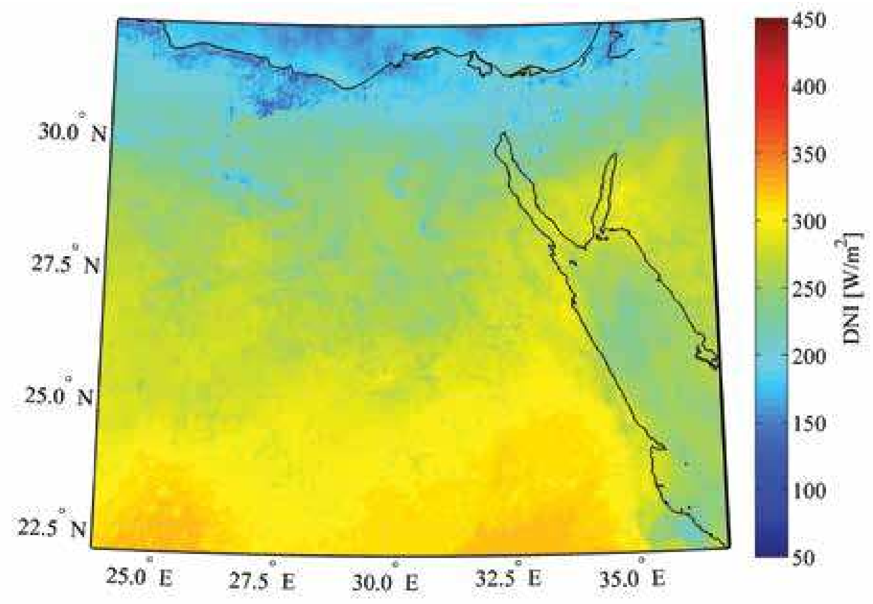

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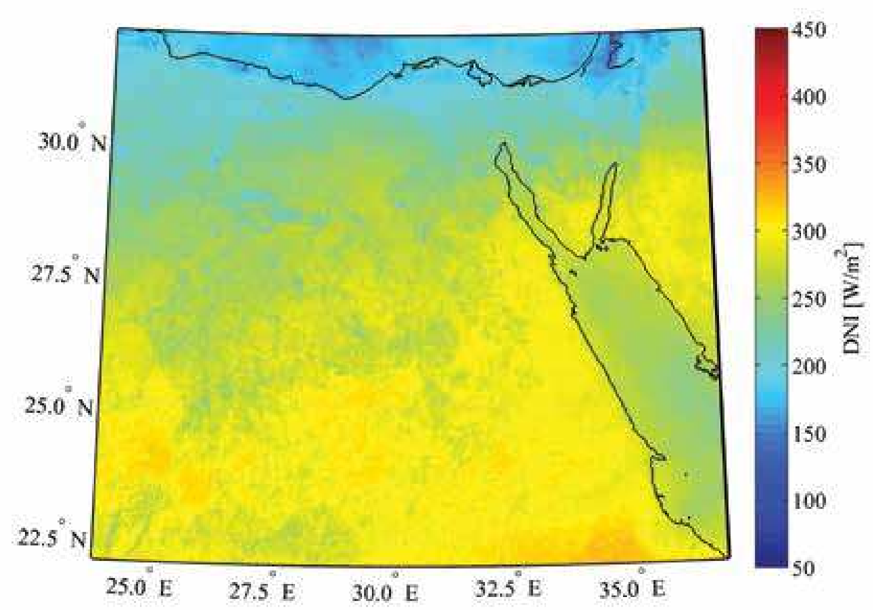

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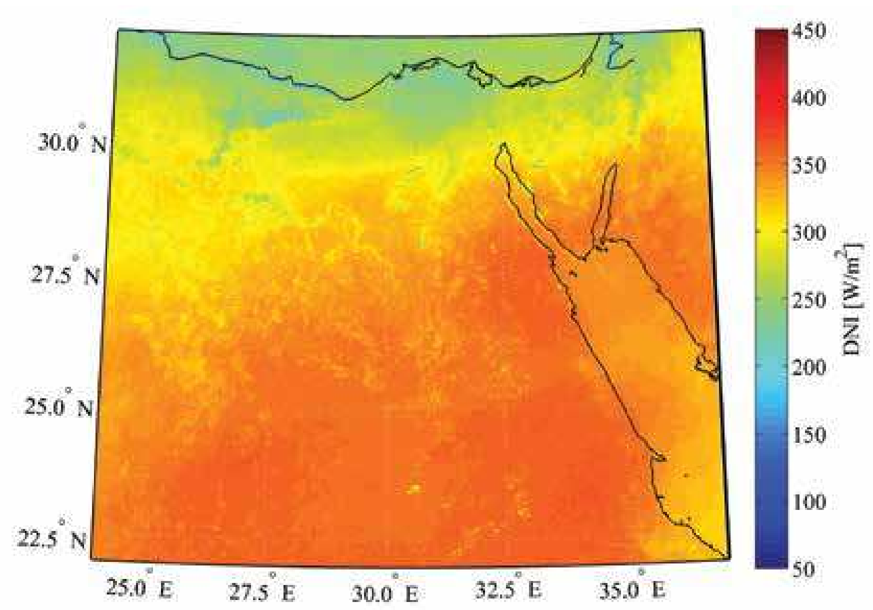

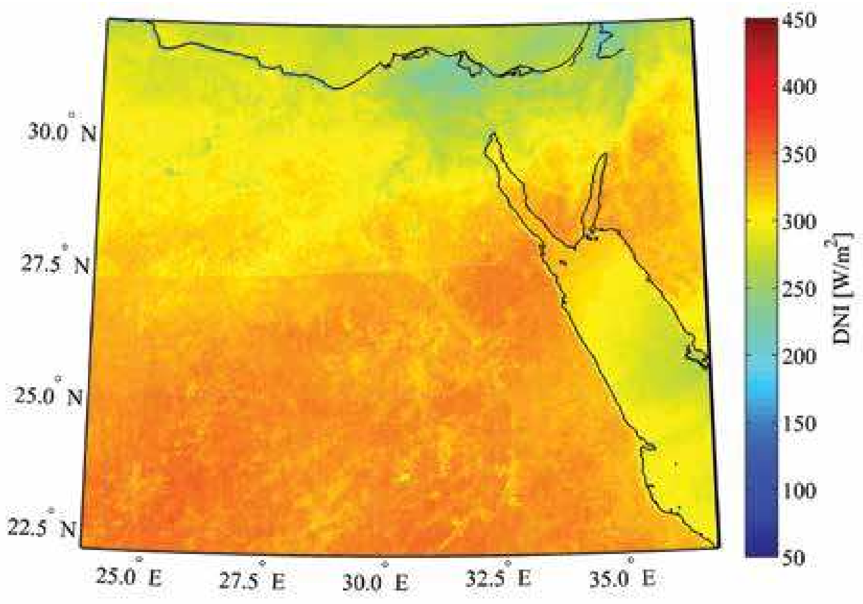

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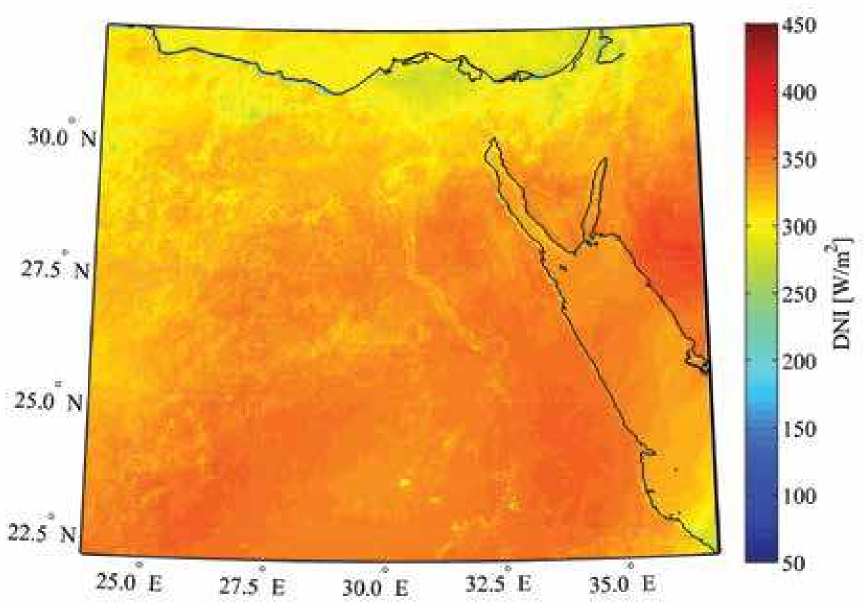

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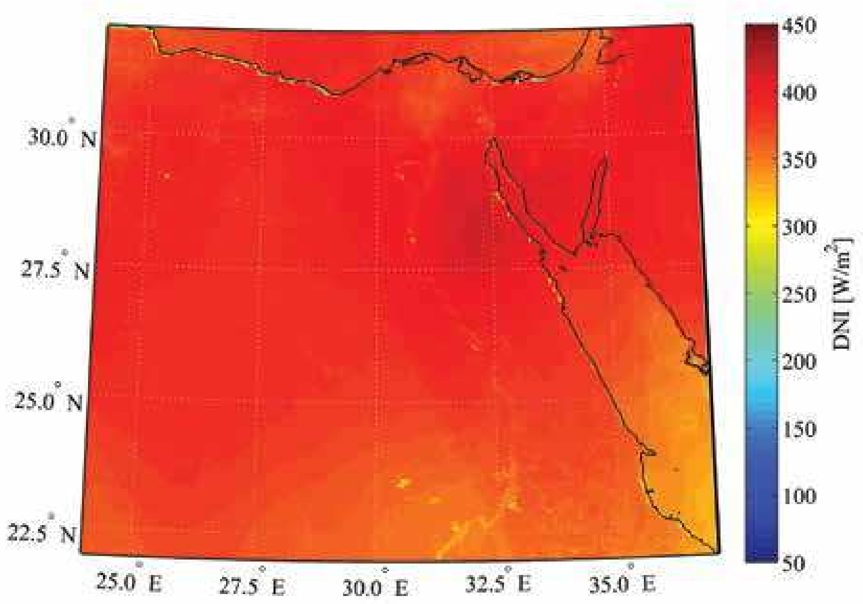

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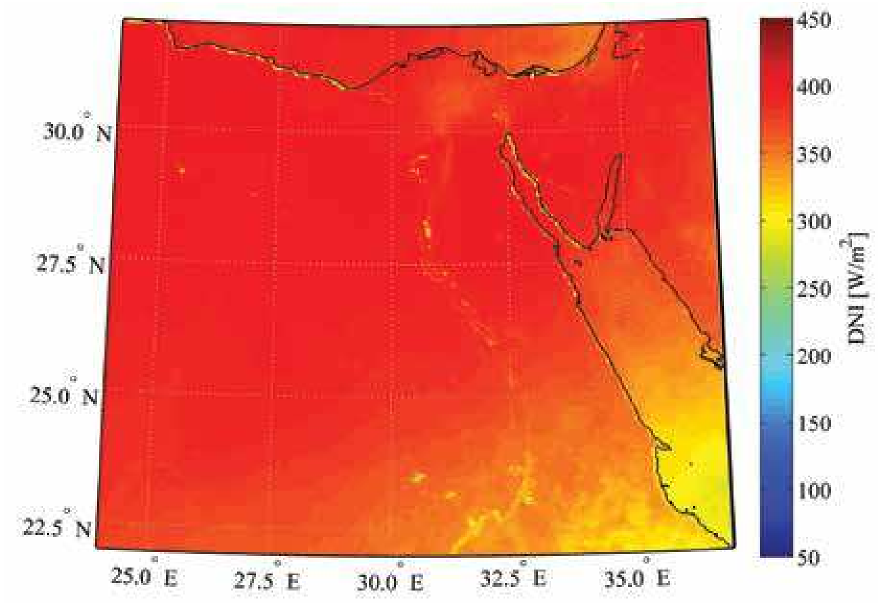

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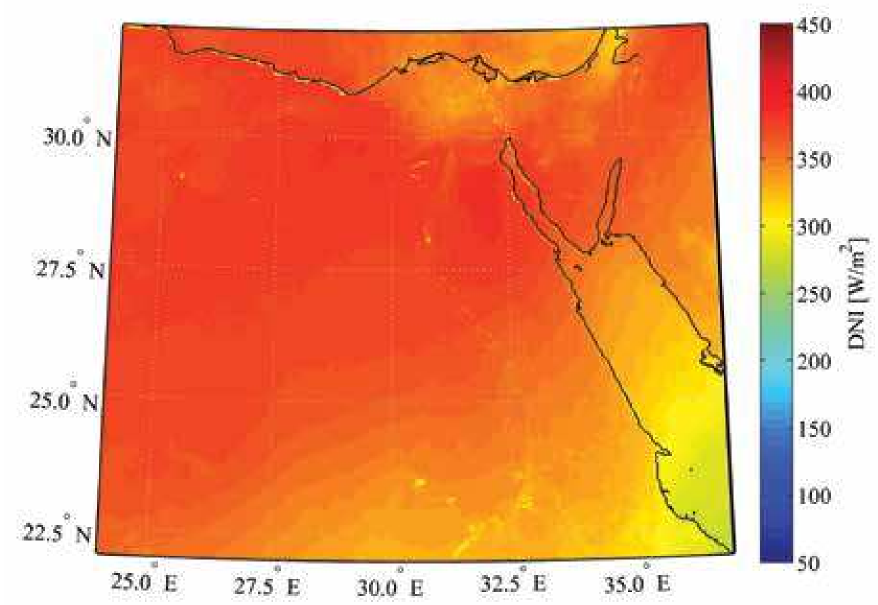

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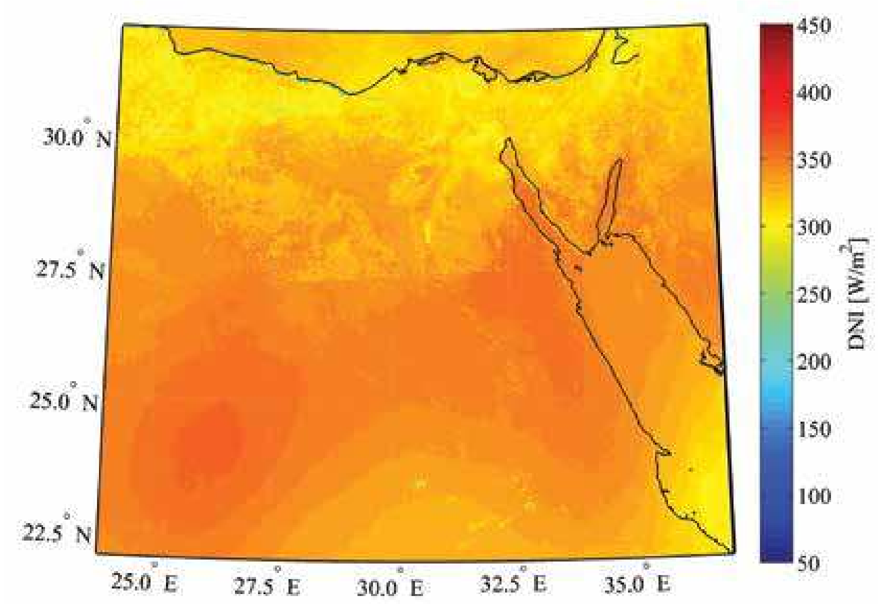

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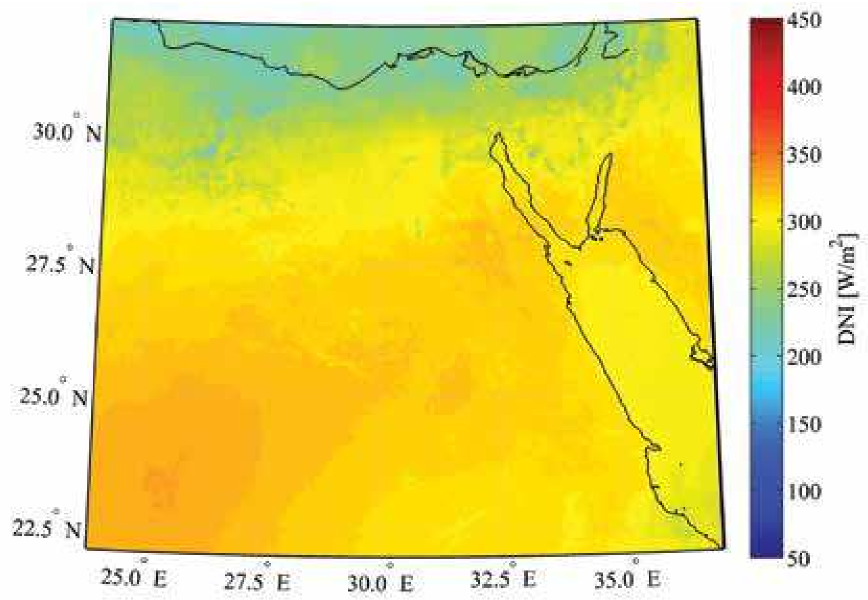

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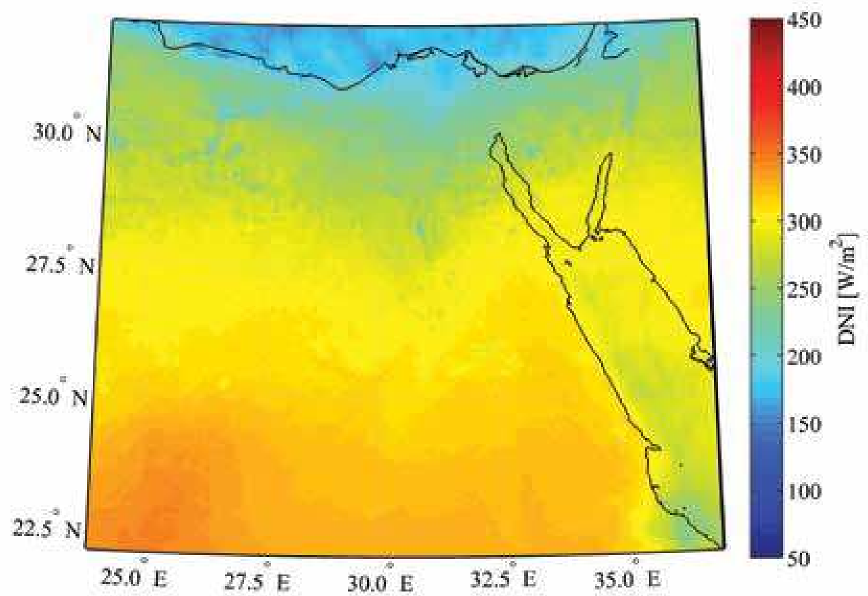

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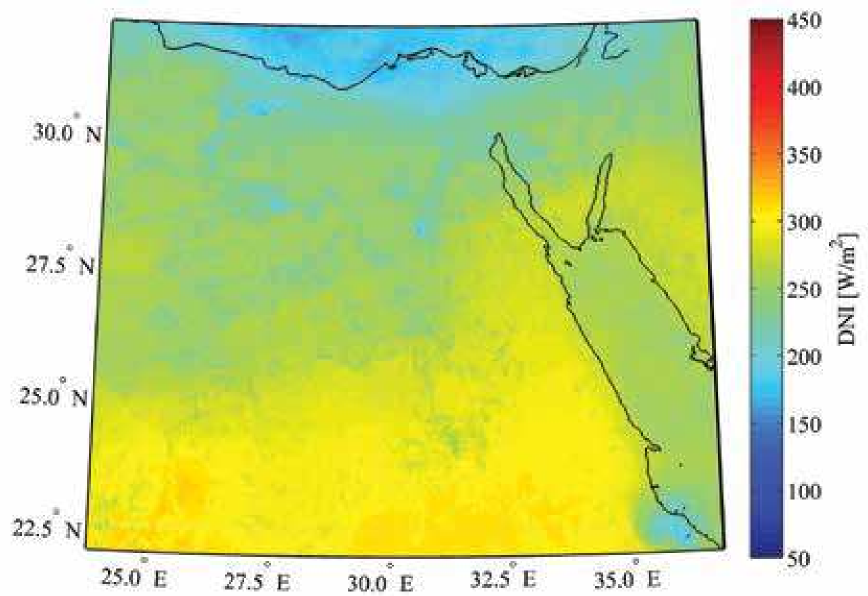

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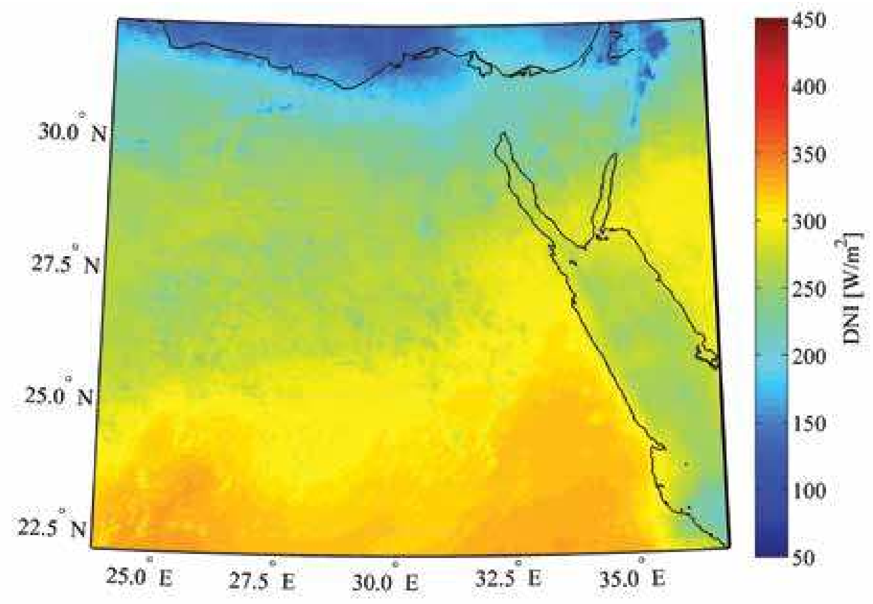

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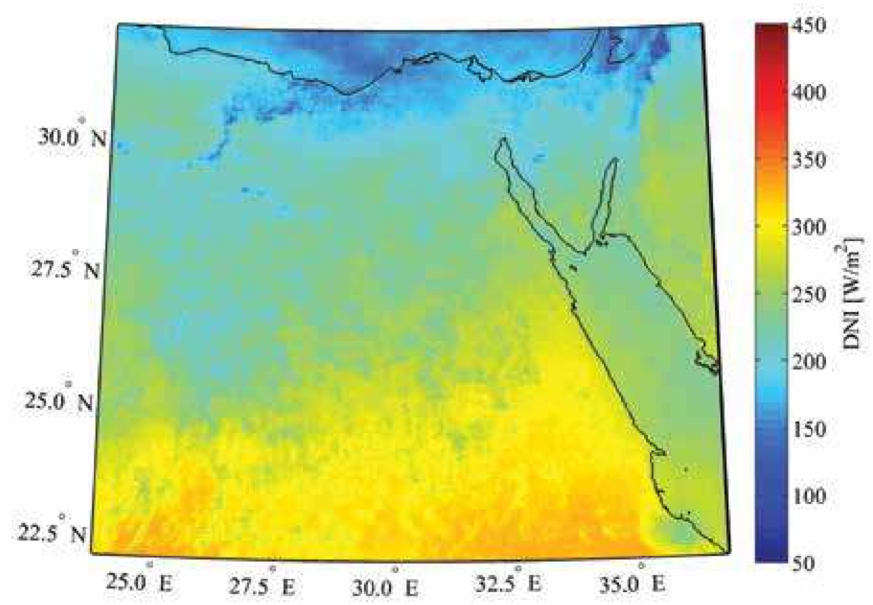

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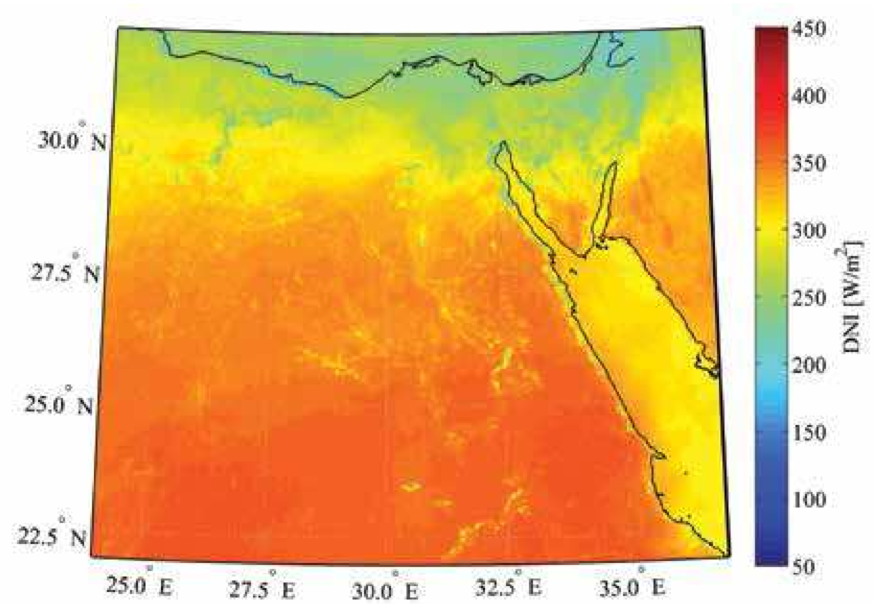

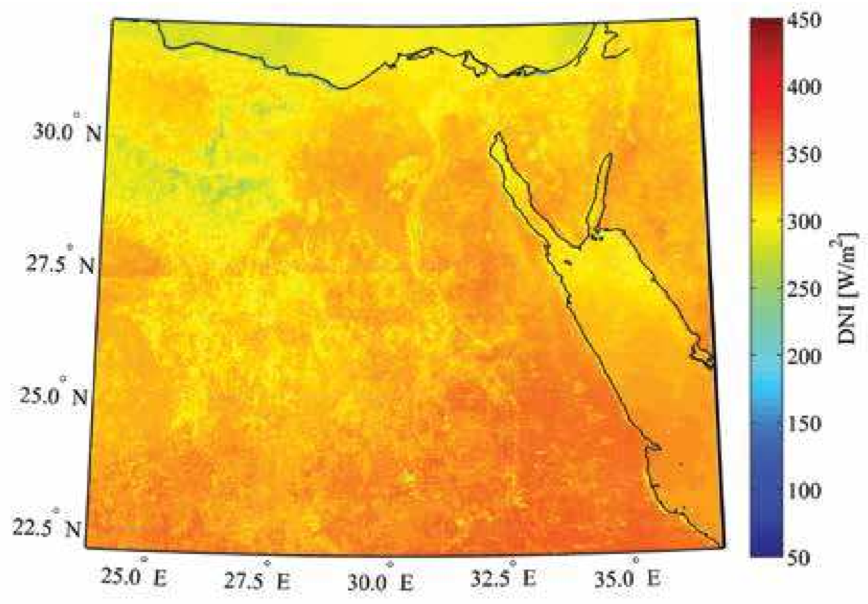

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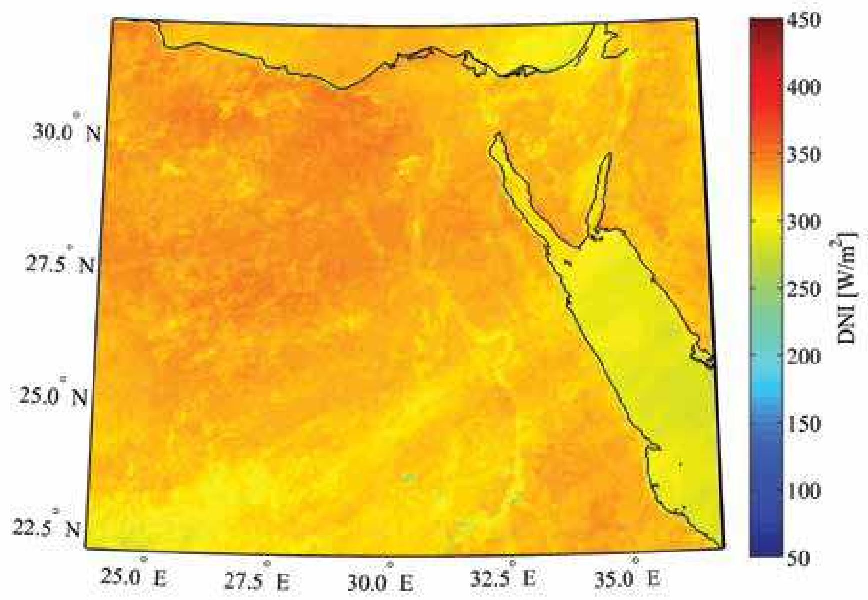

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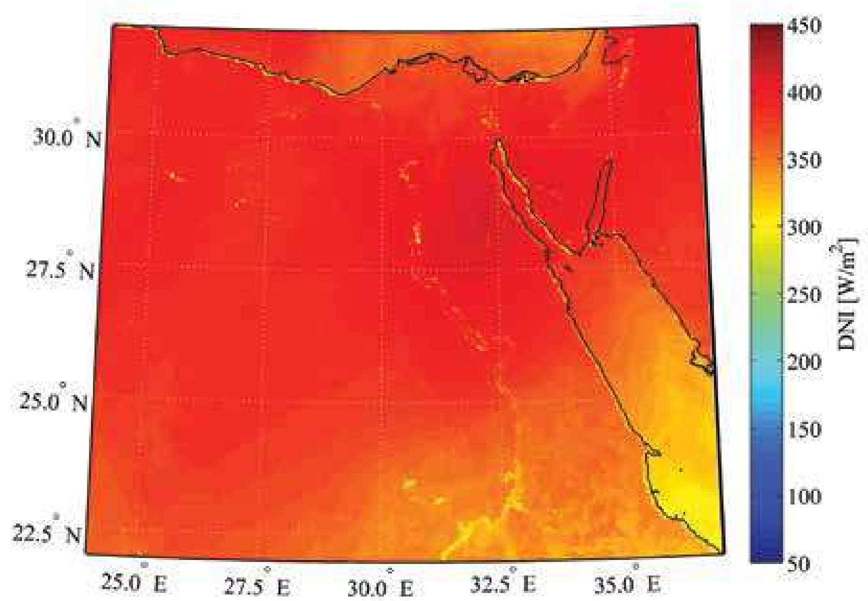

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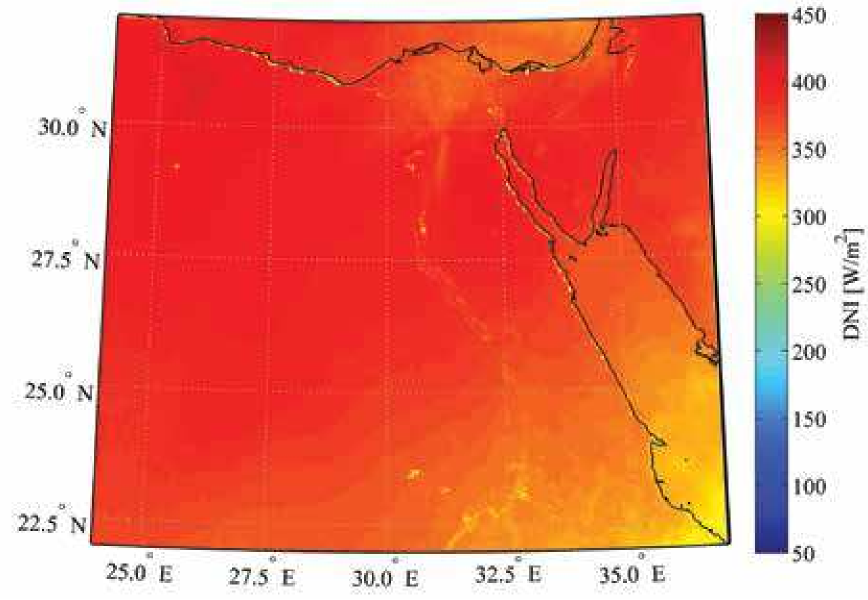

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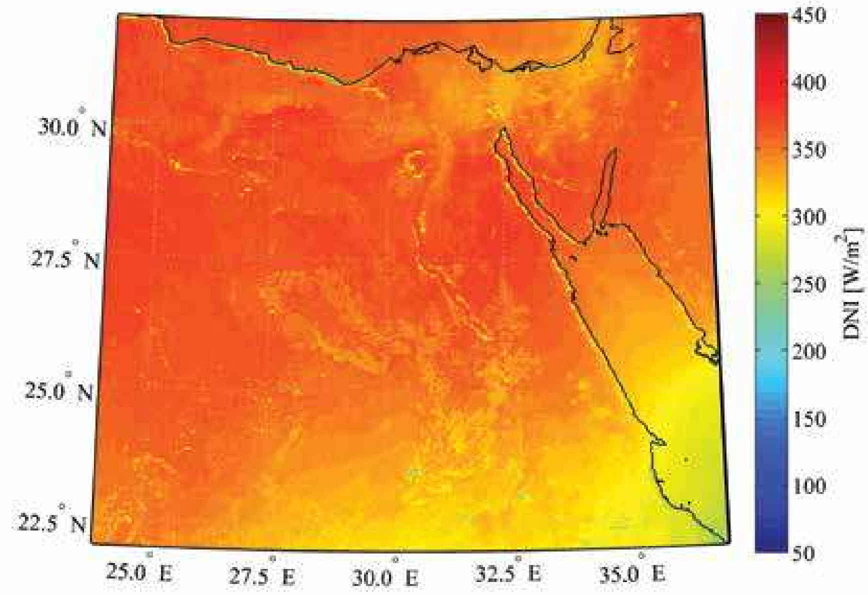

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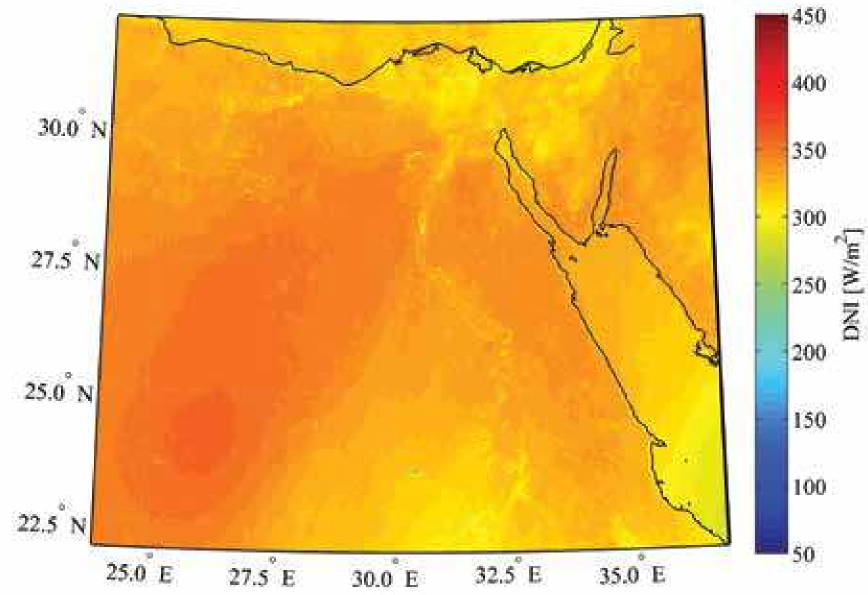

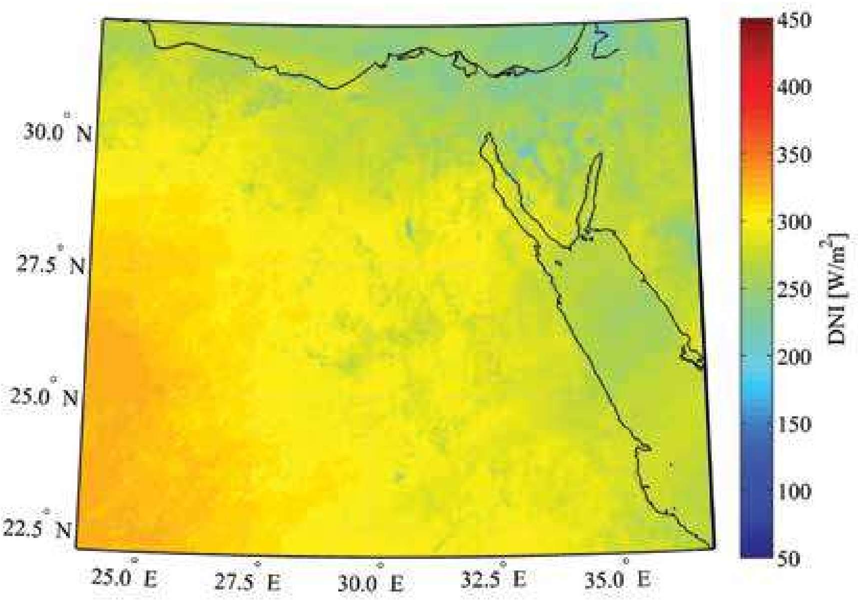

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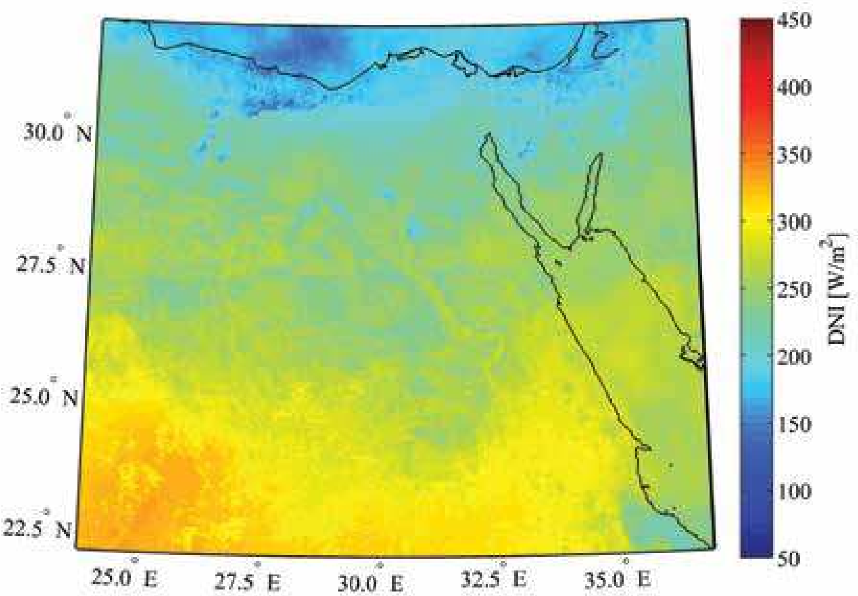

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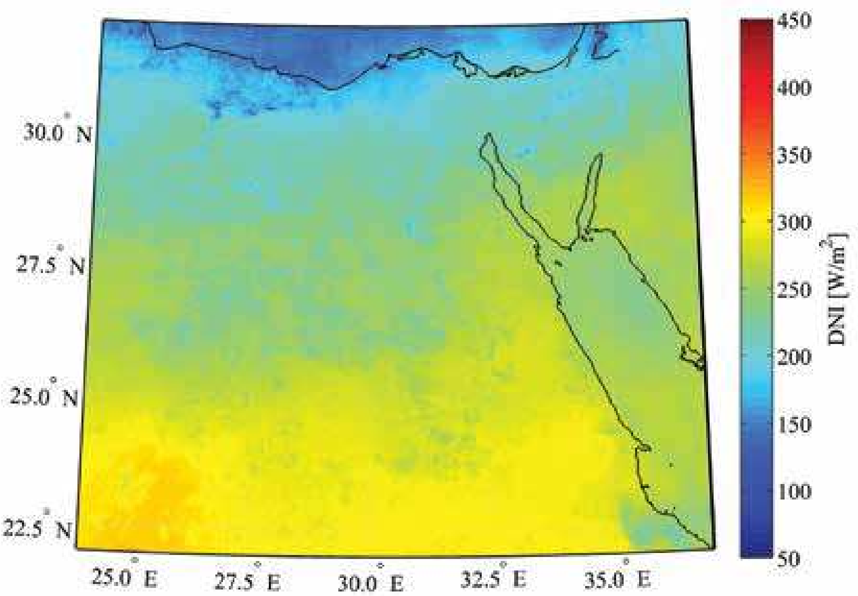

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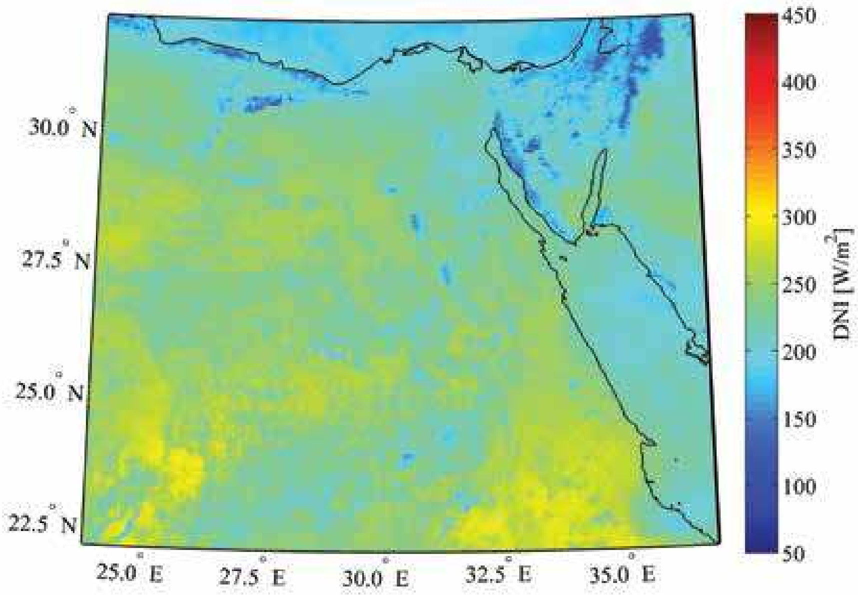

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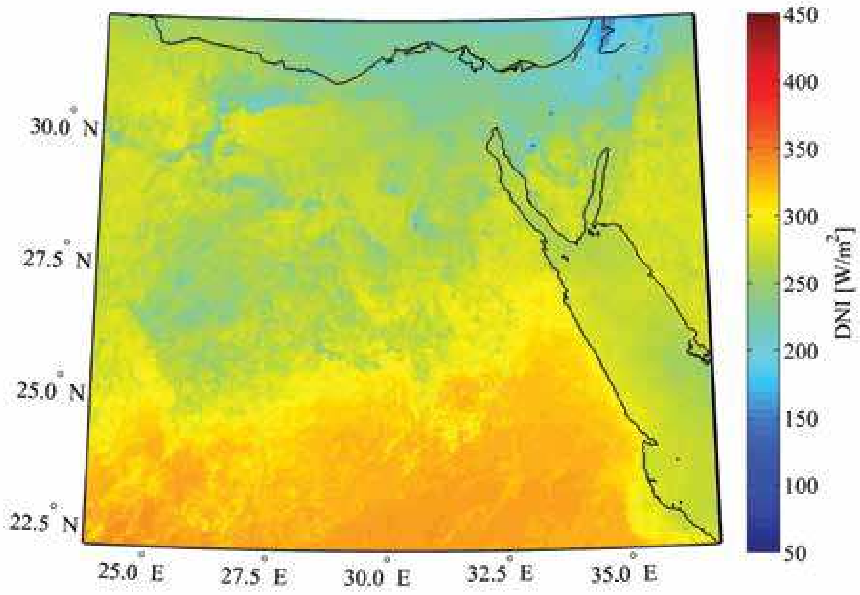

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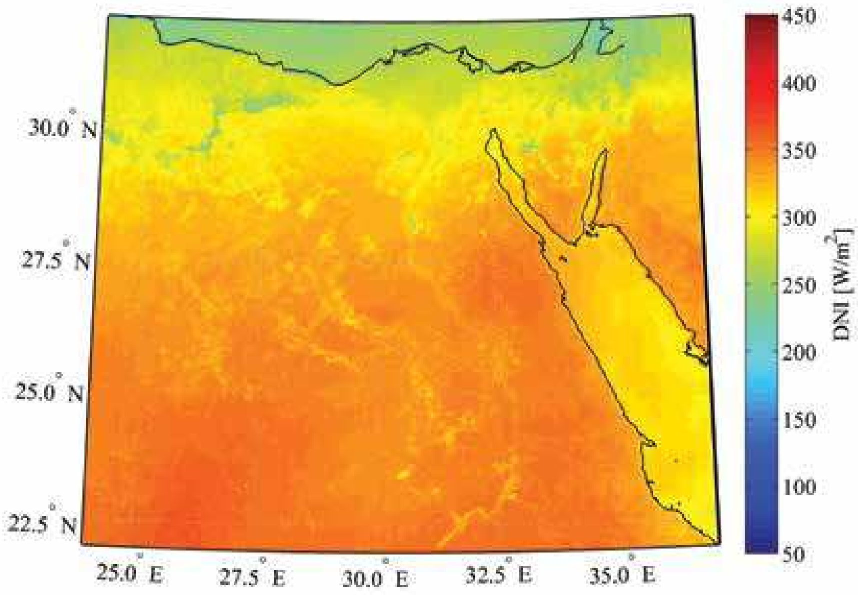

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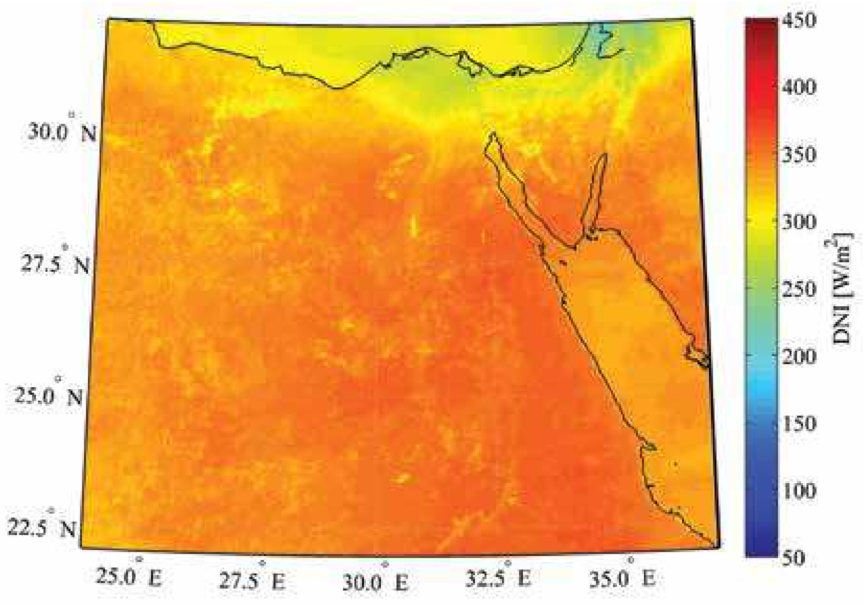

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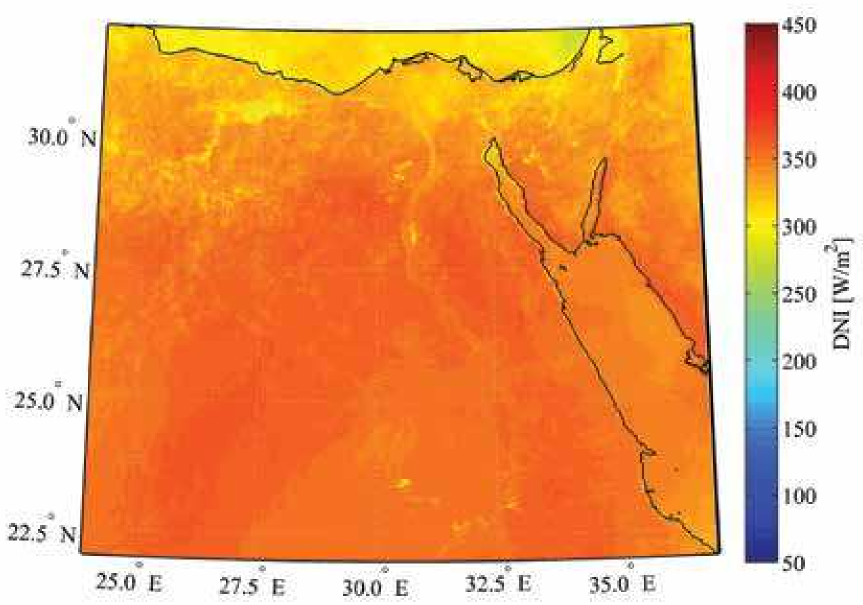

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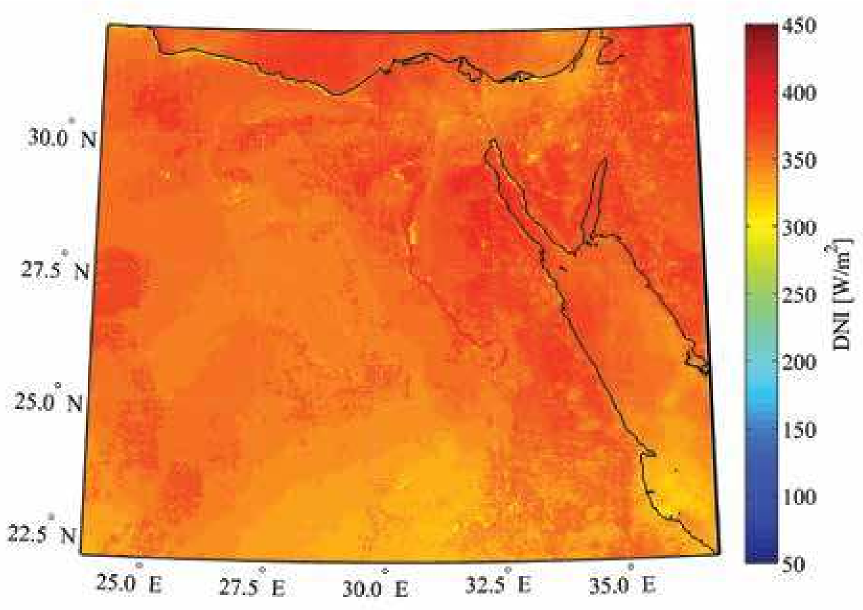

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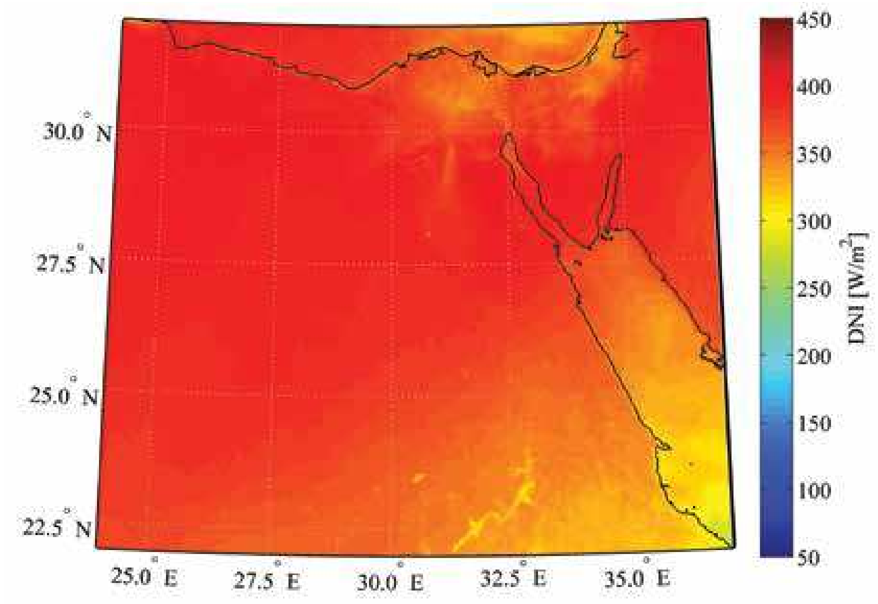

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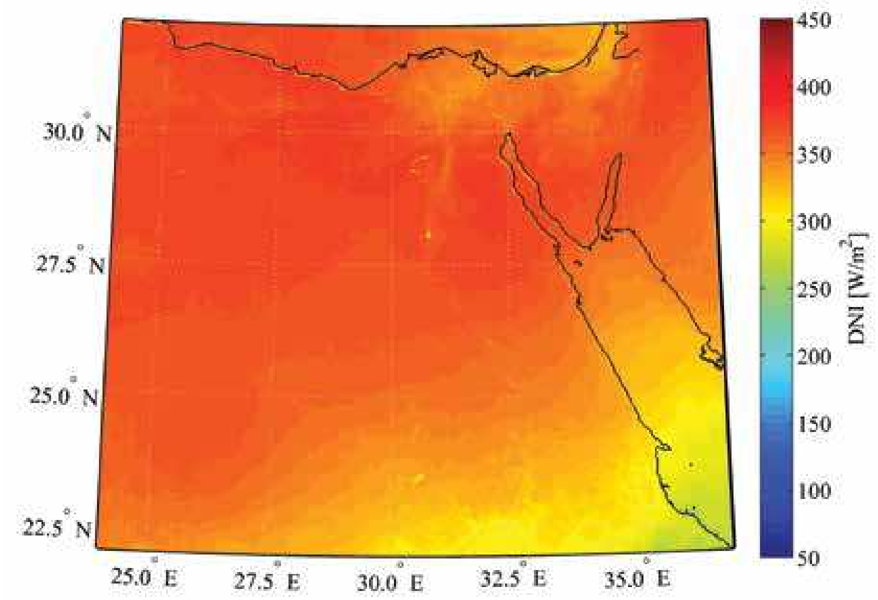

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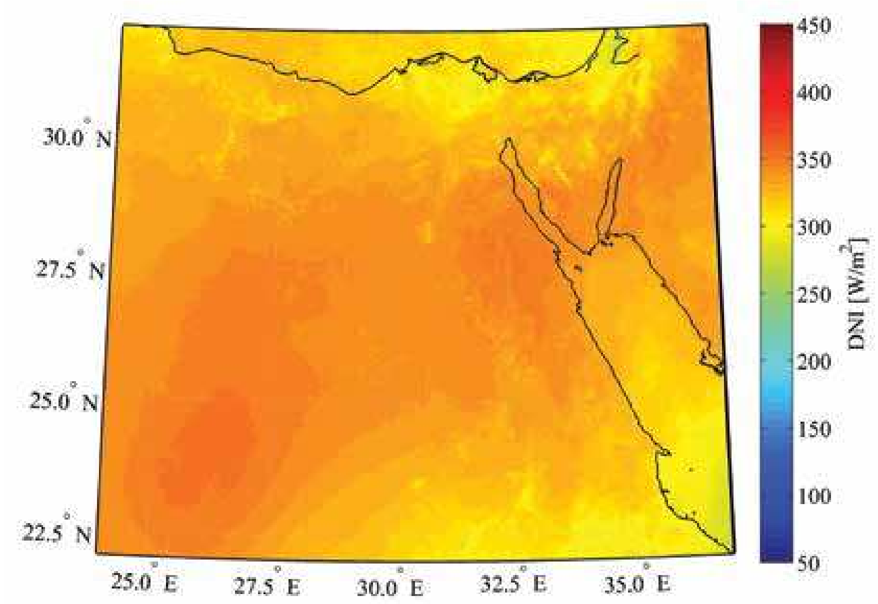

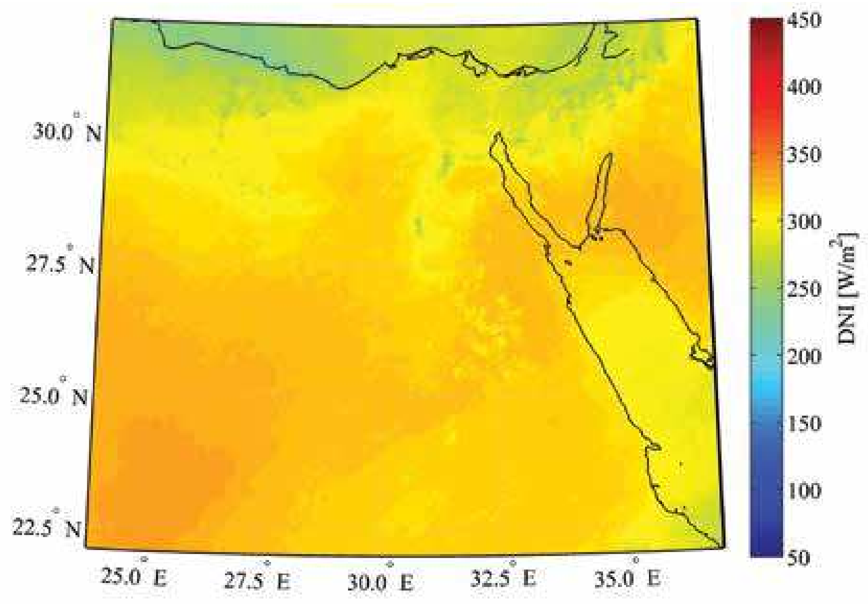

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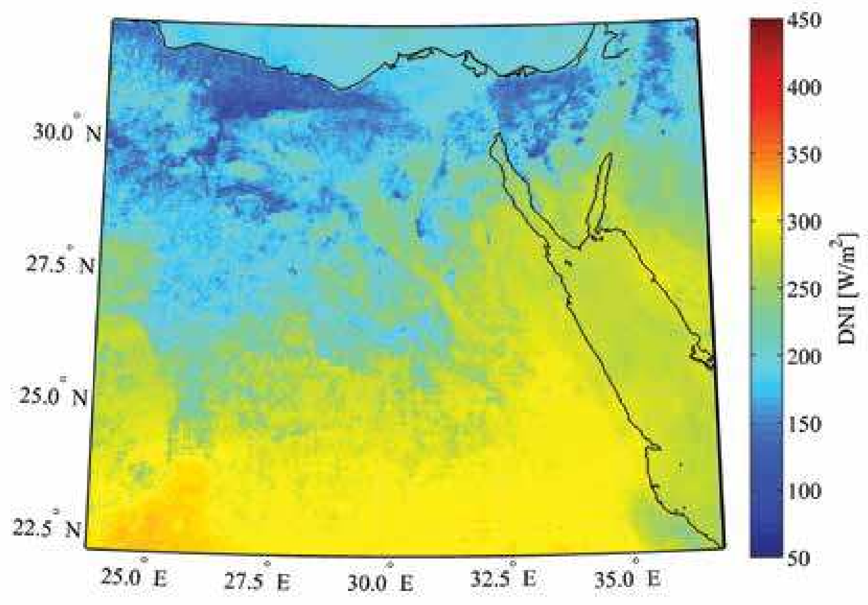

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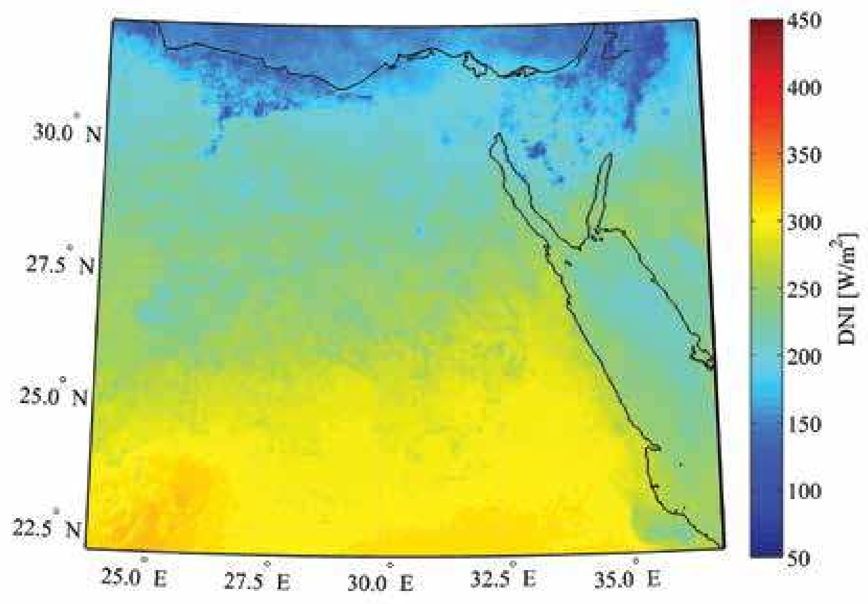

DEC
2013

07

ANALYTICAL CLIMATOLOGY OF THE GLOBAL HORIZONTAL IRRADIANCE

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GLOBAL HORIZONTAL IRRADIANCE

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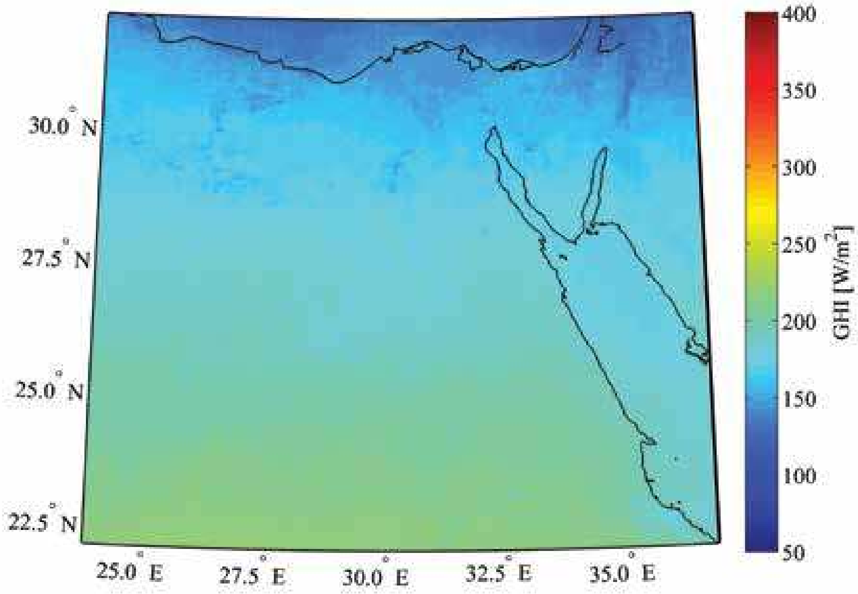

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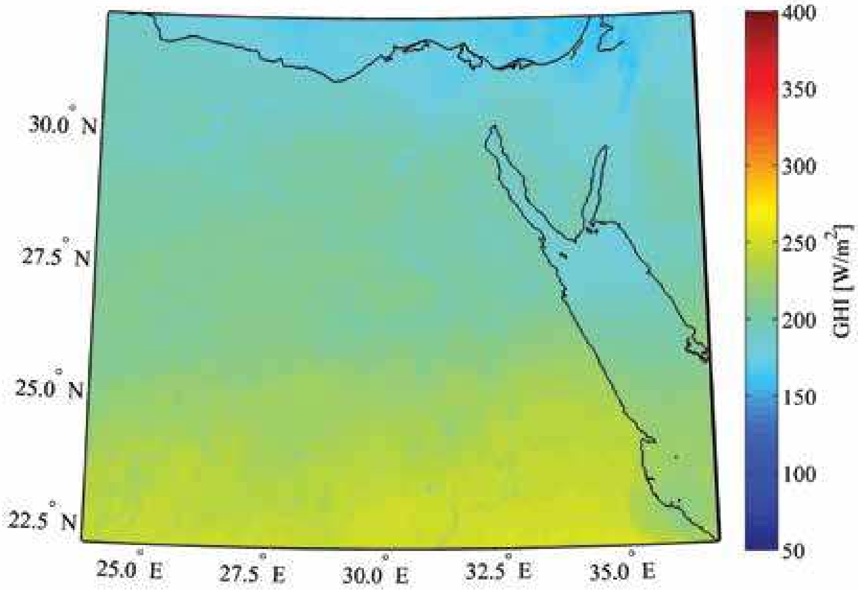

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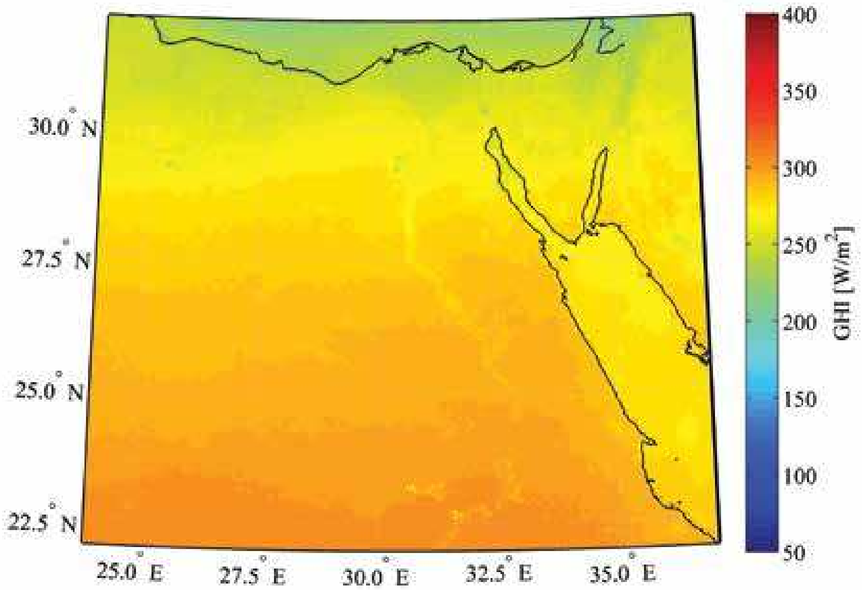

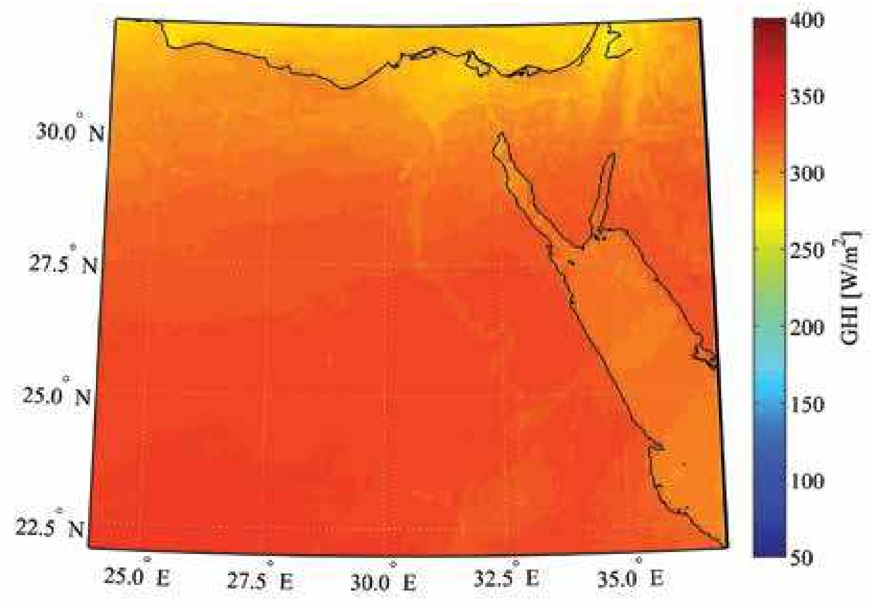

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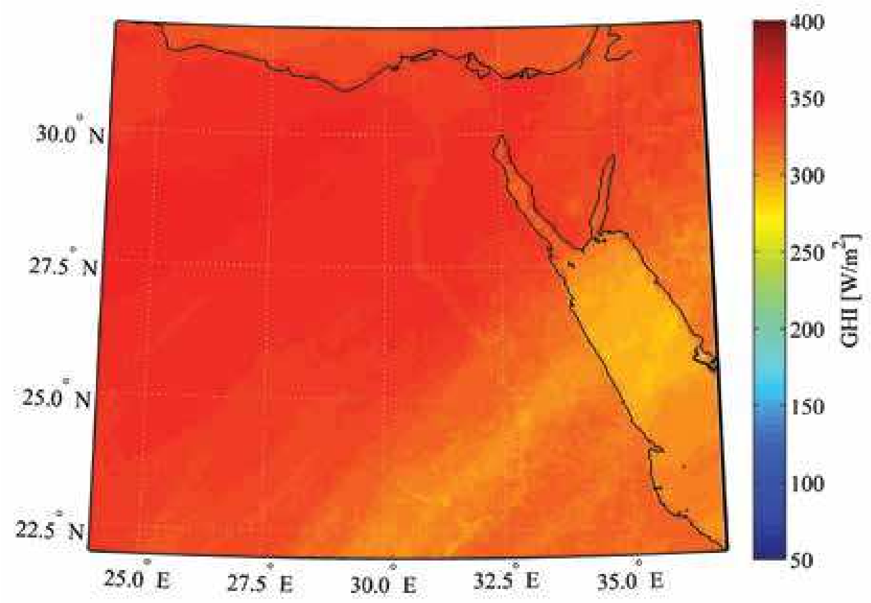

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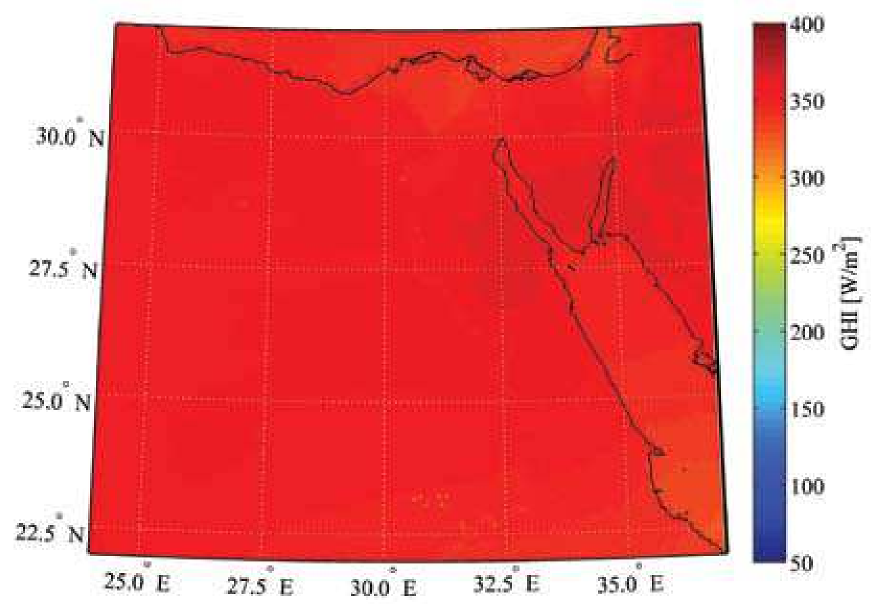

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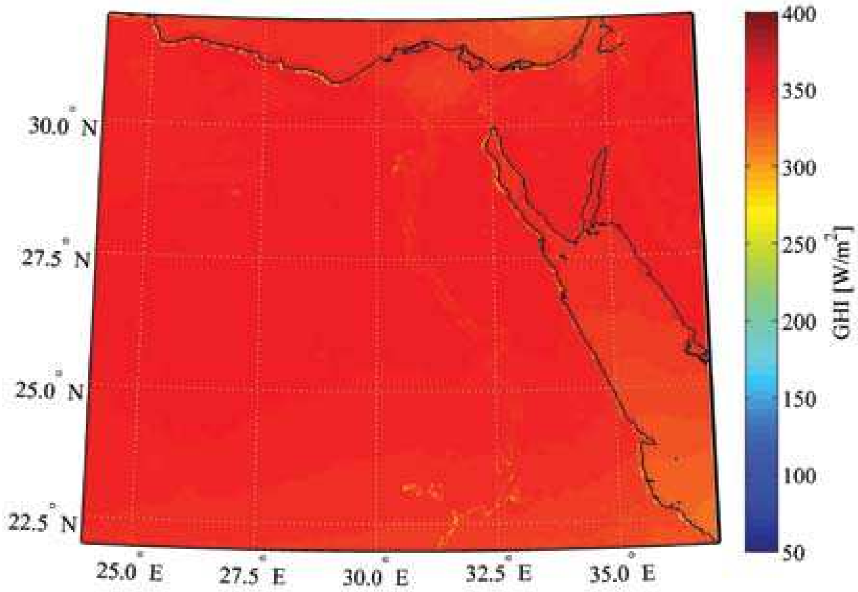

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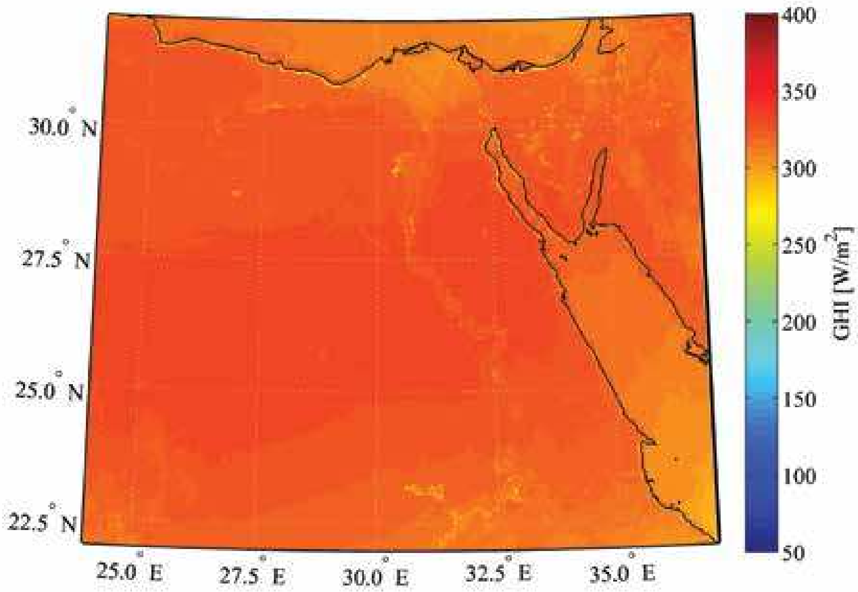

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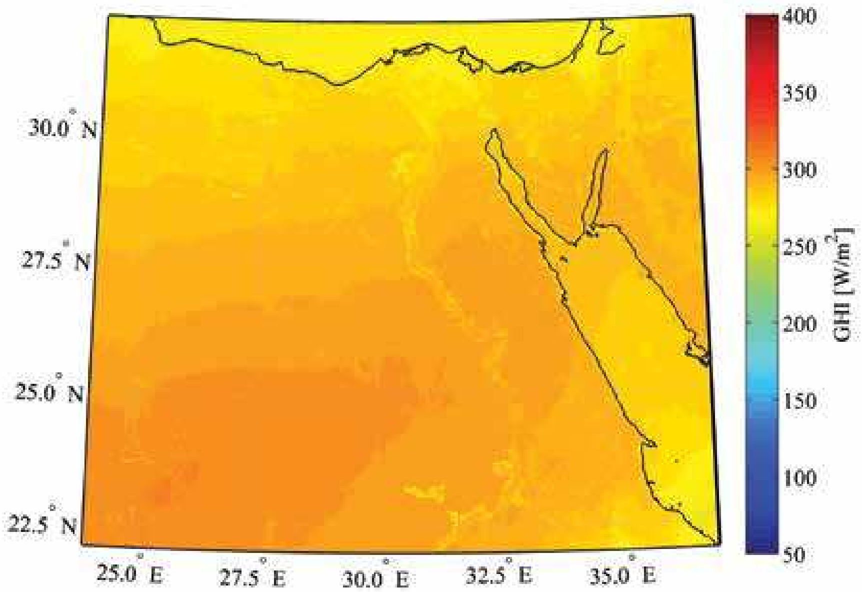

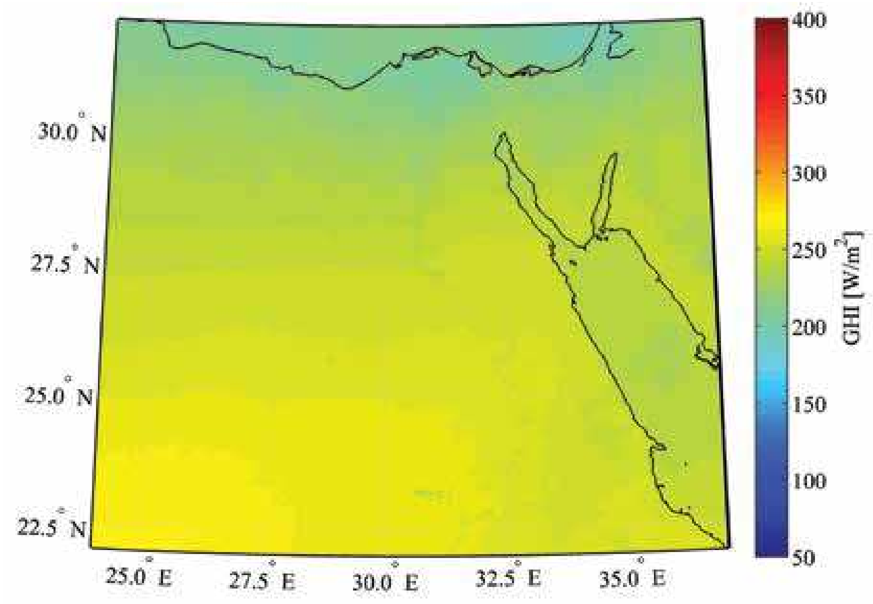

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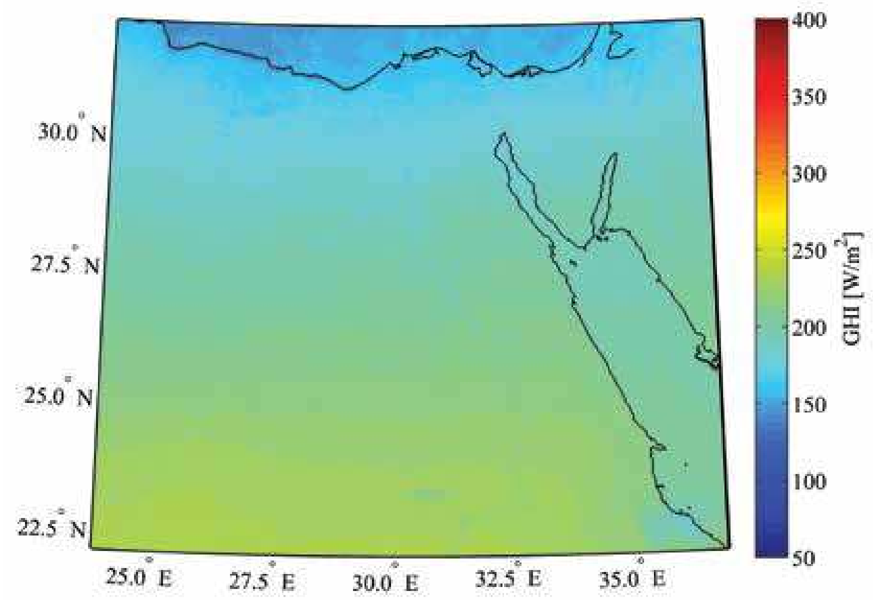

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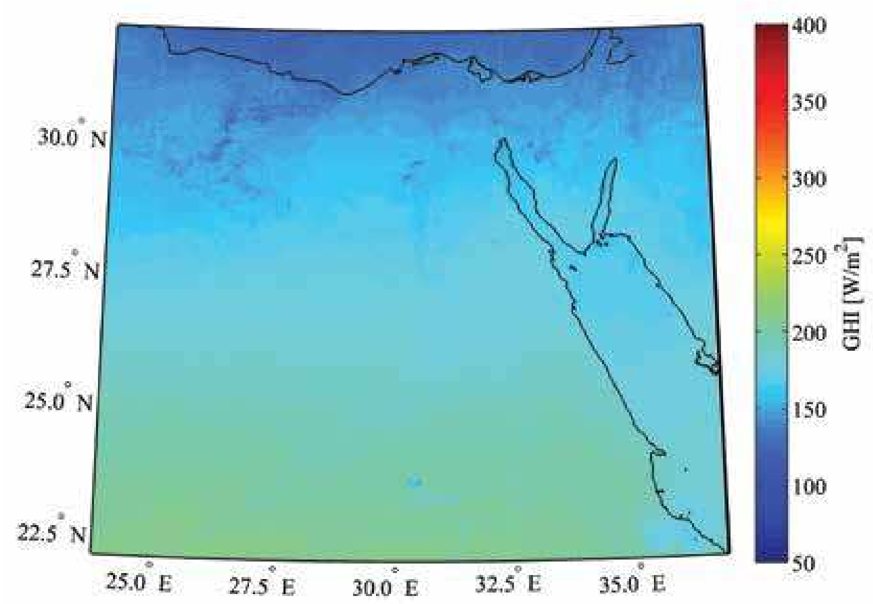

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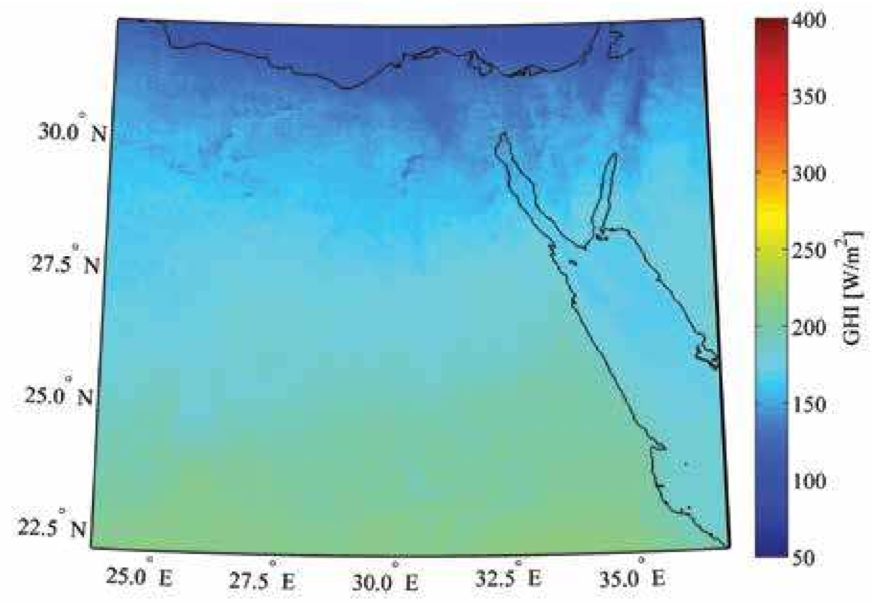

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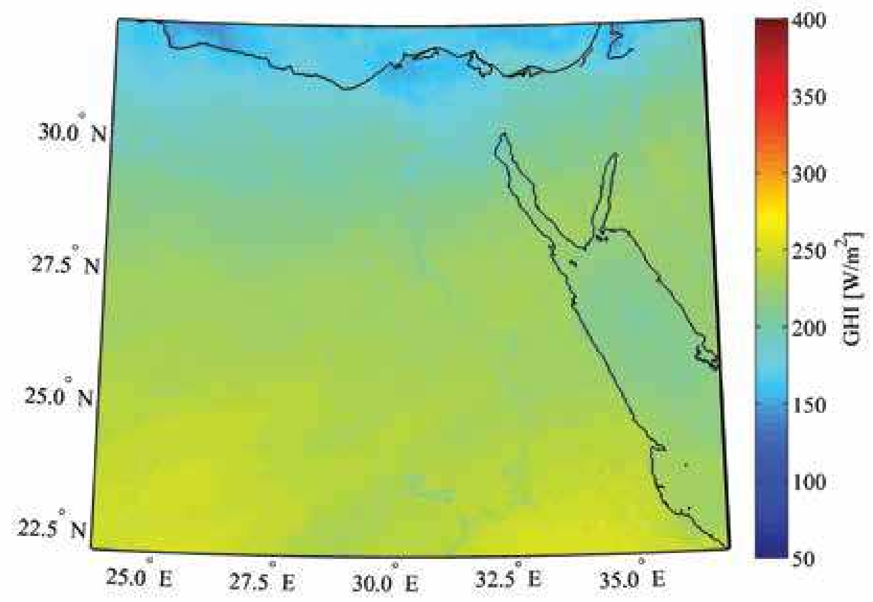

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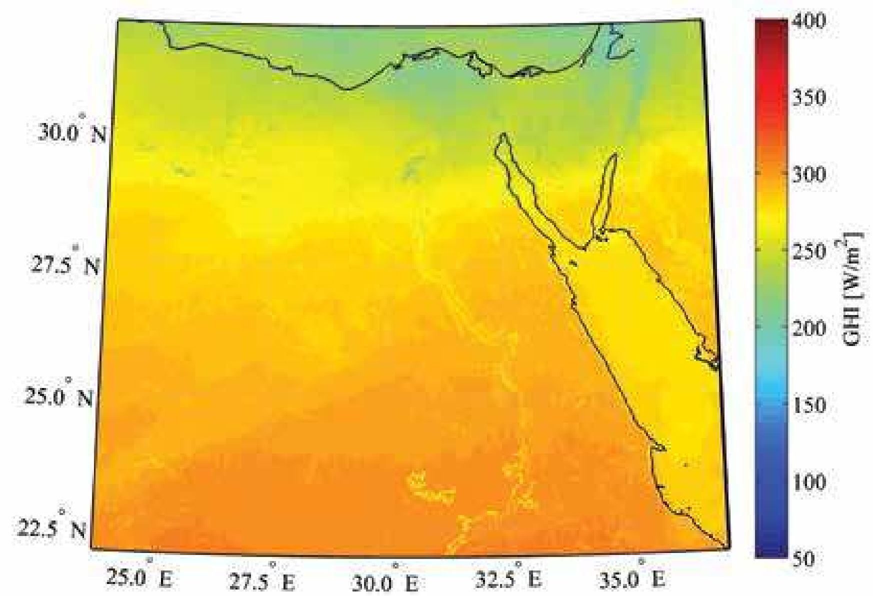

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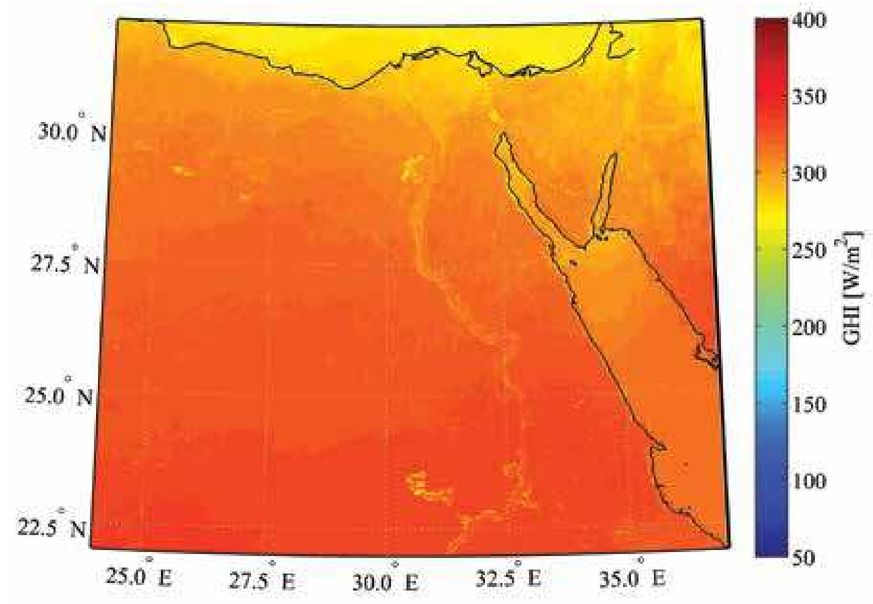

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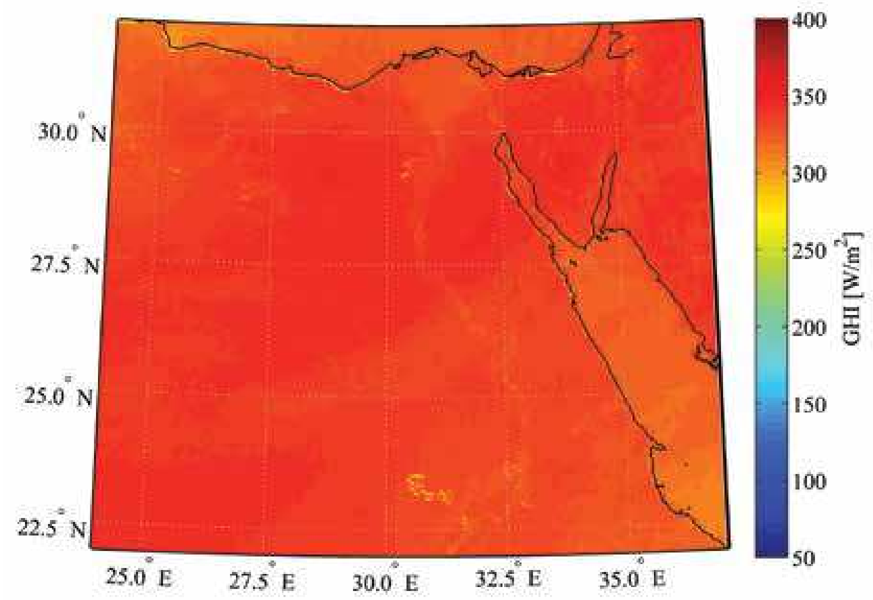

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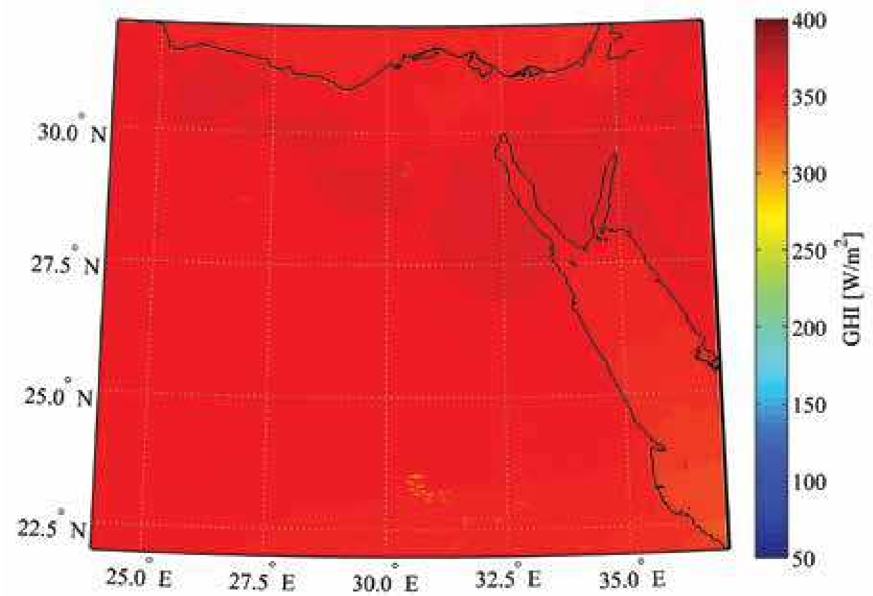

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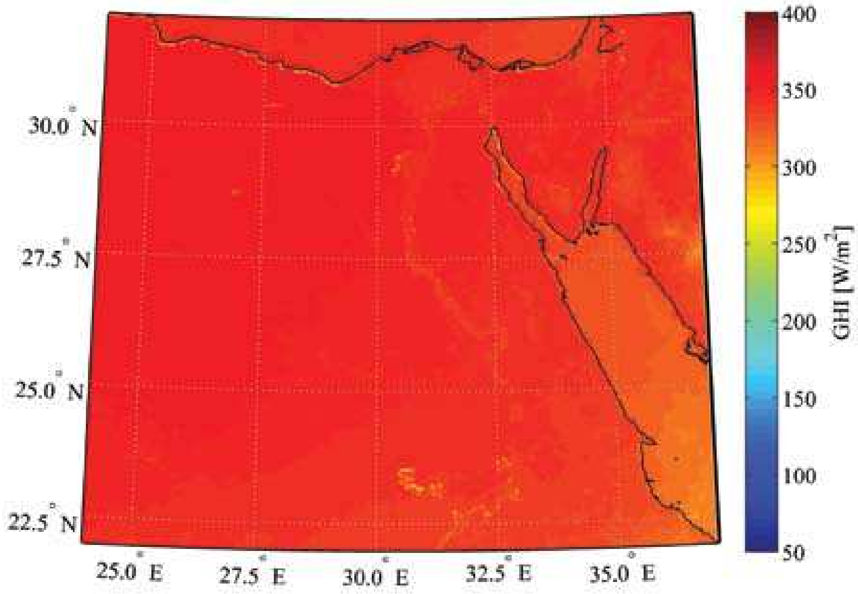

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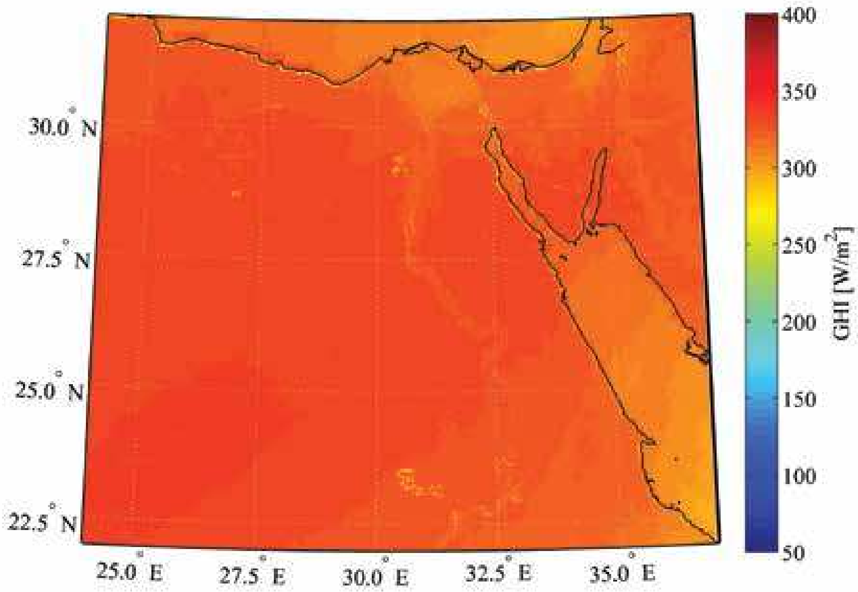

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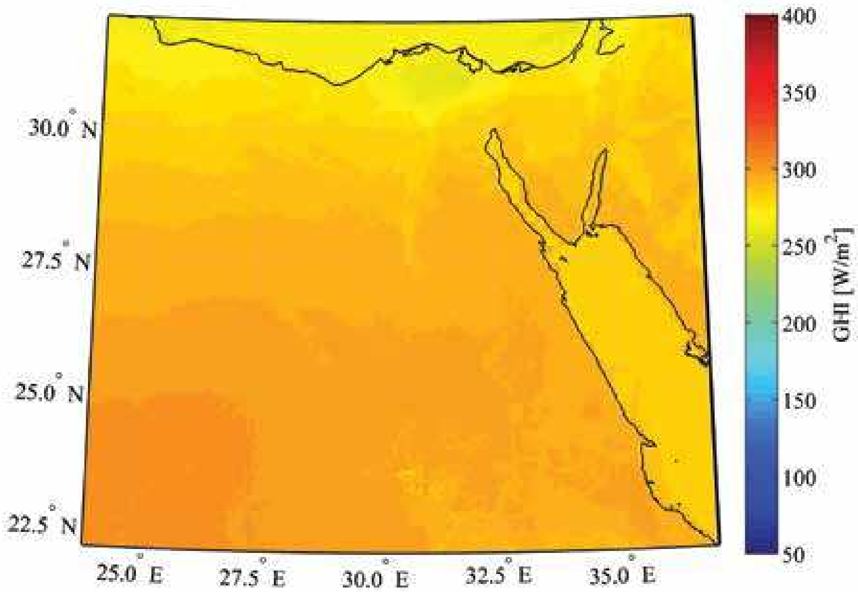

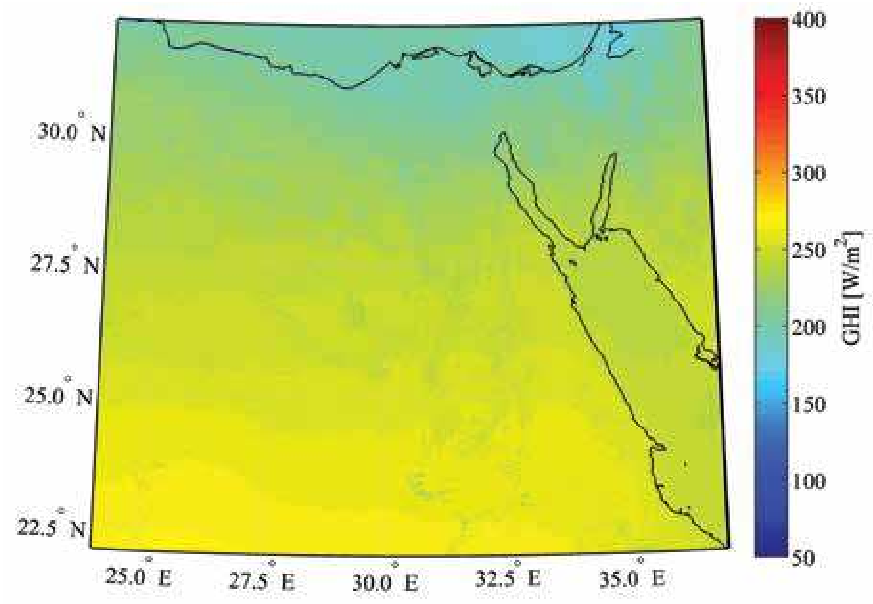

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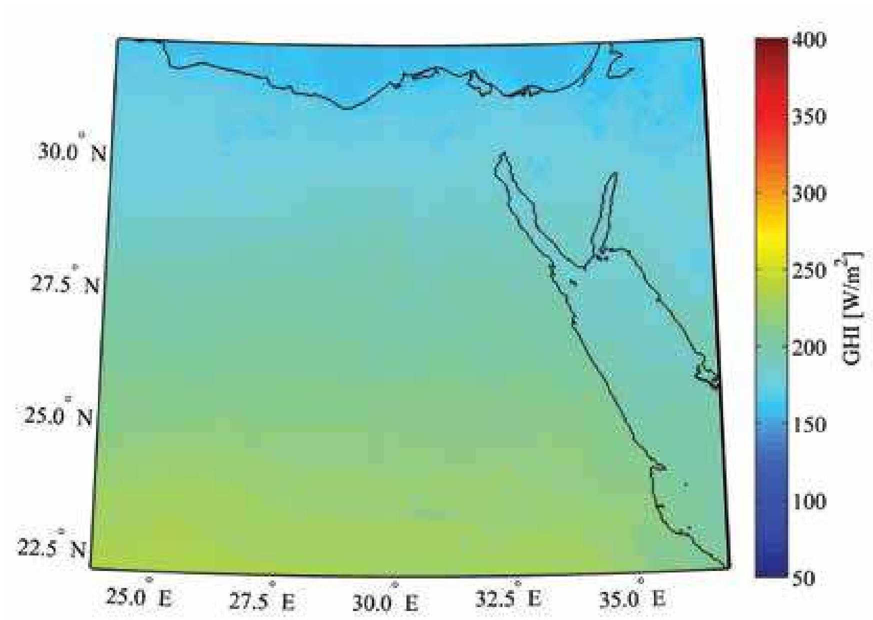

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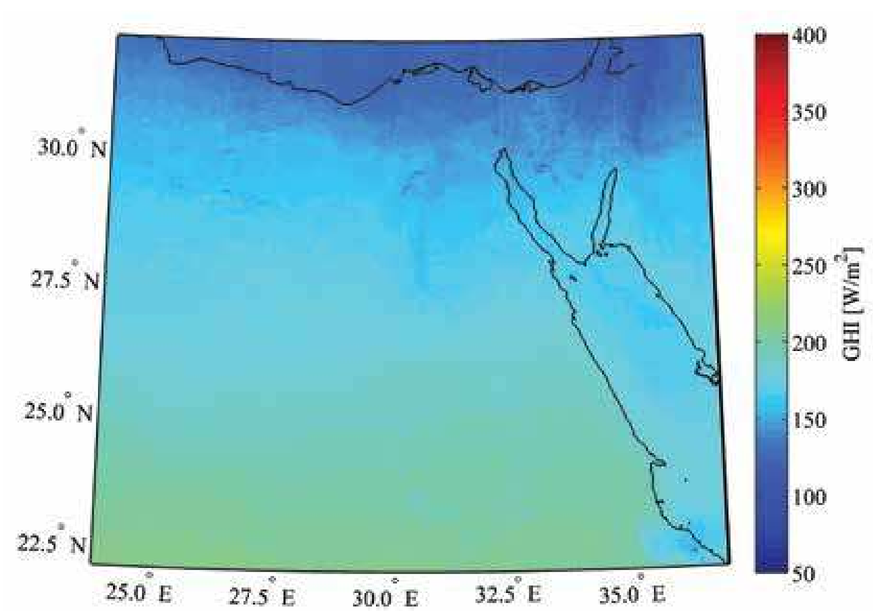

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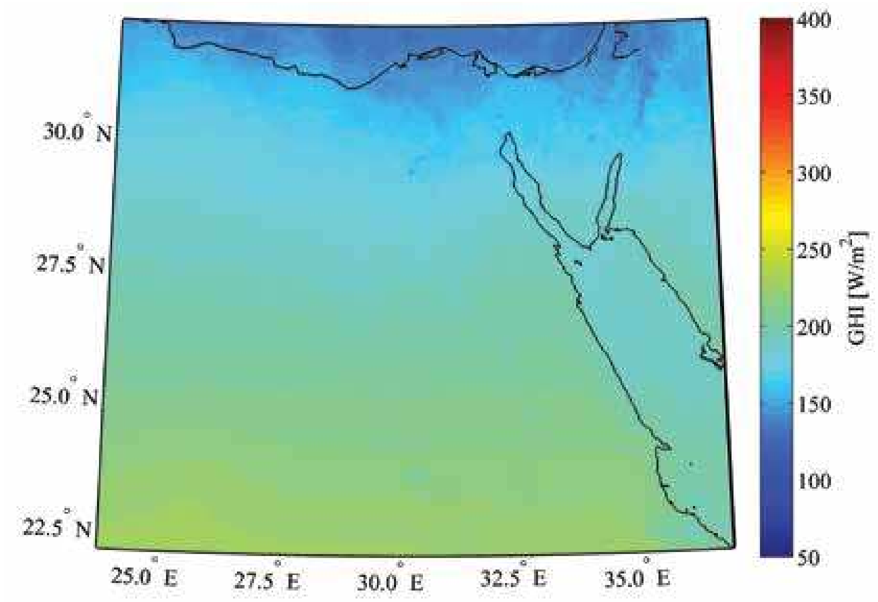

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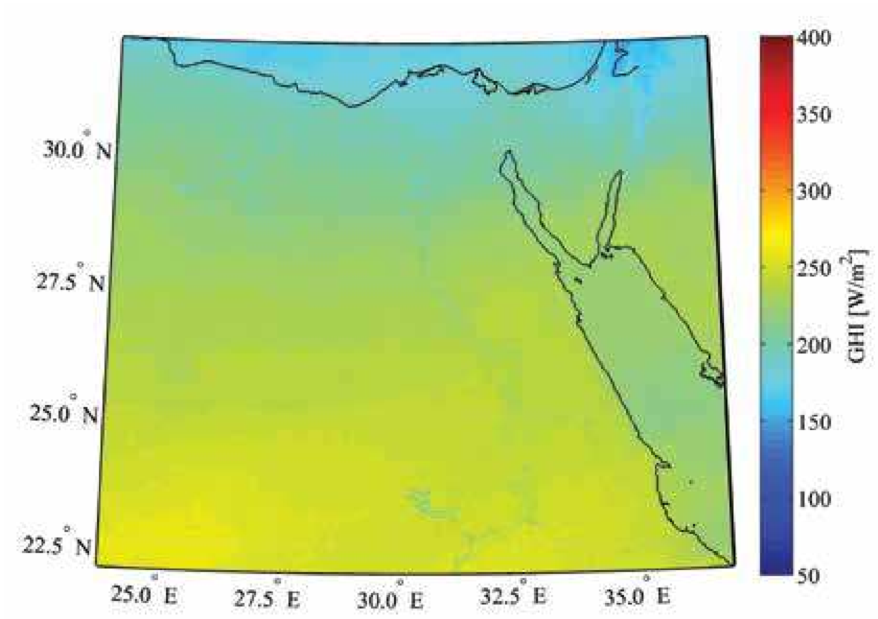

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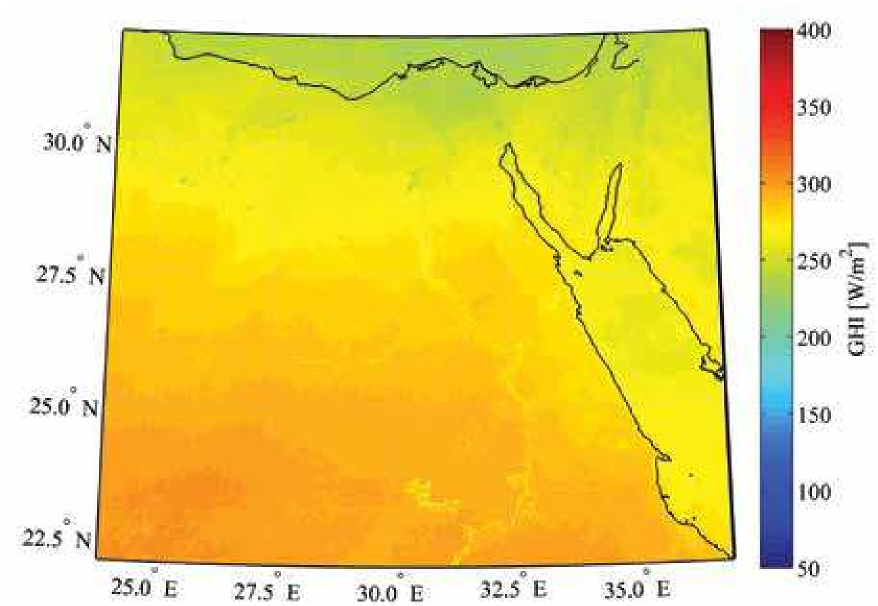

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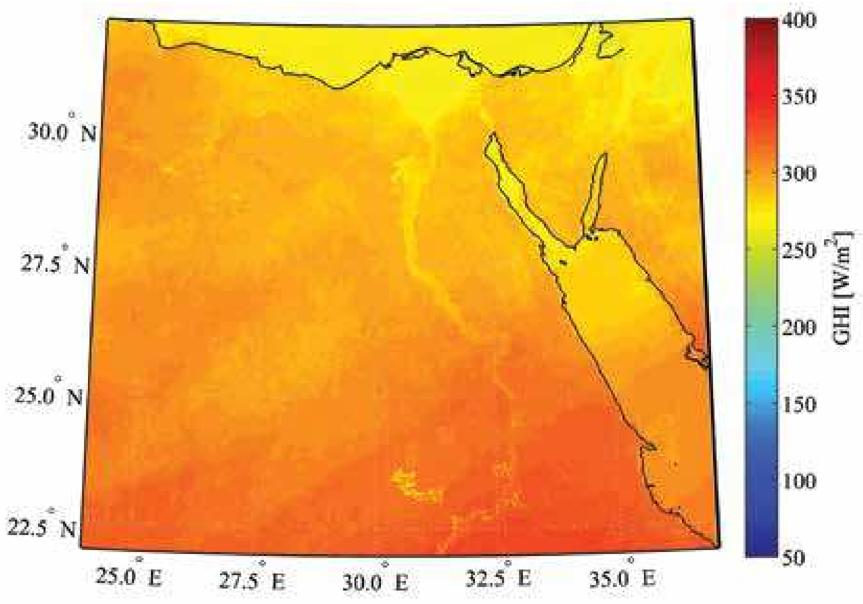

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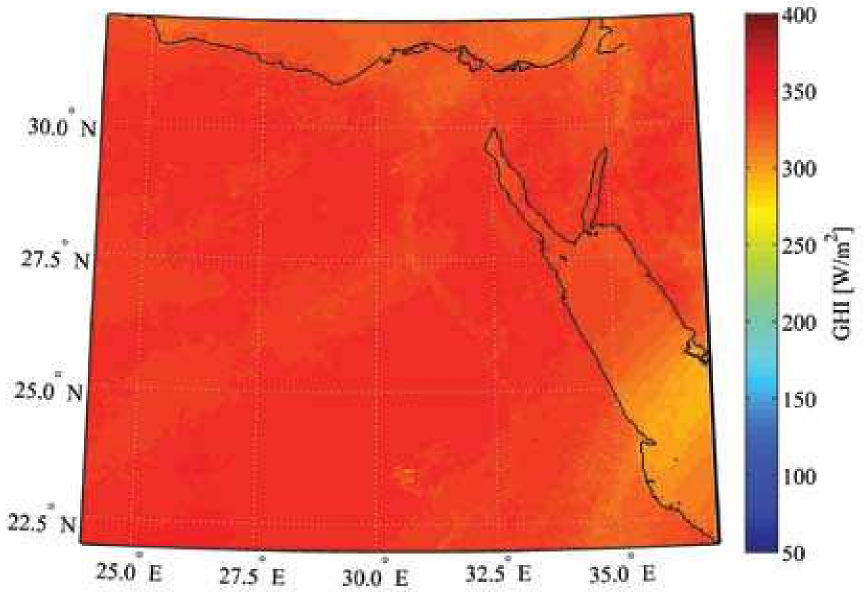

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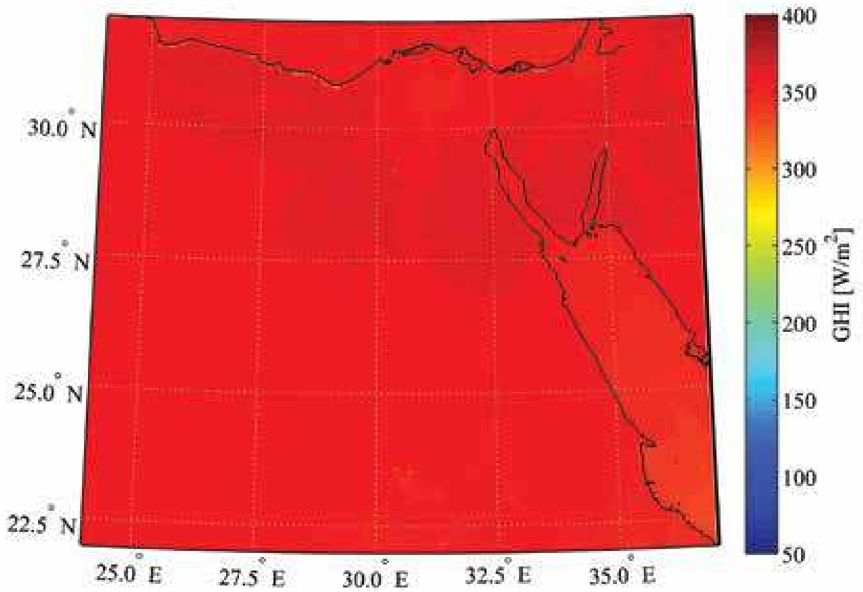

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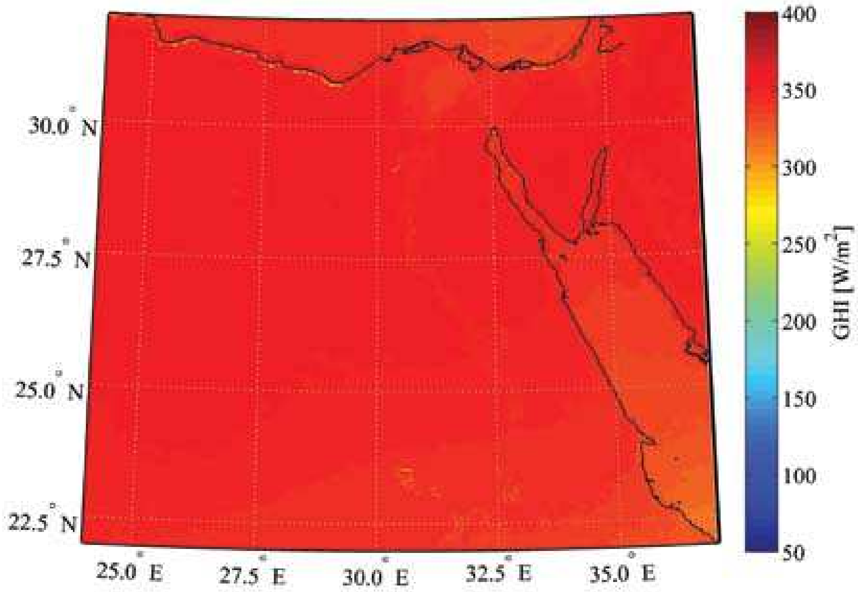

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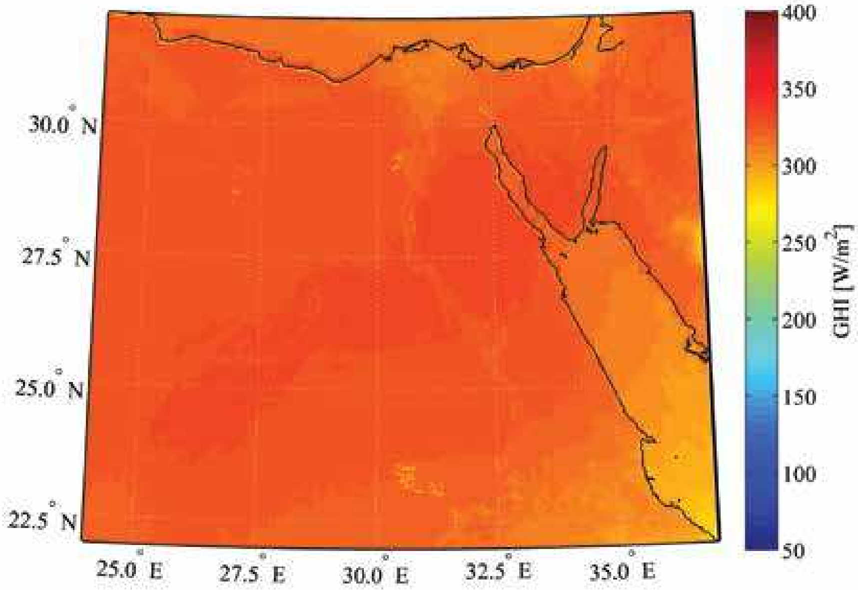

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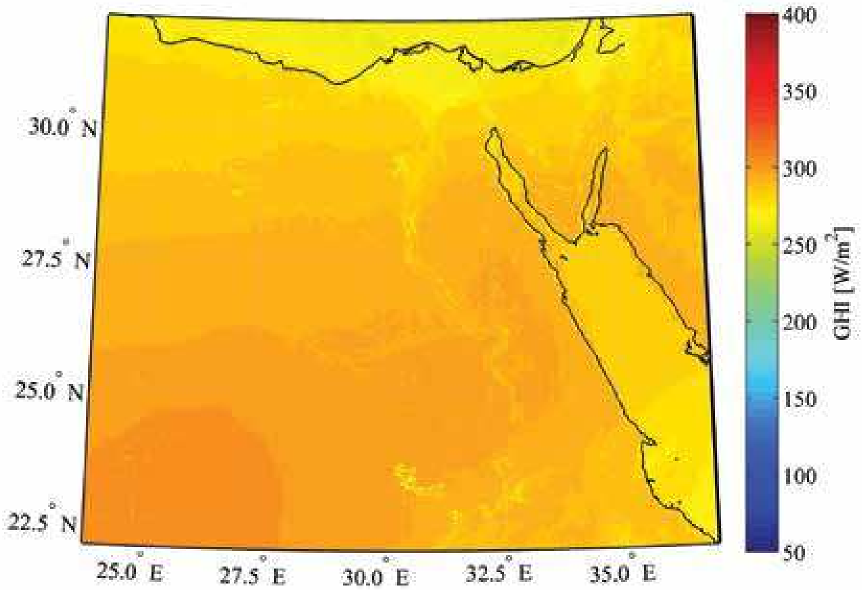

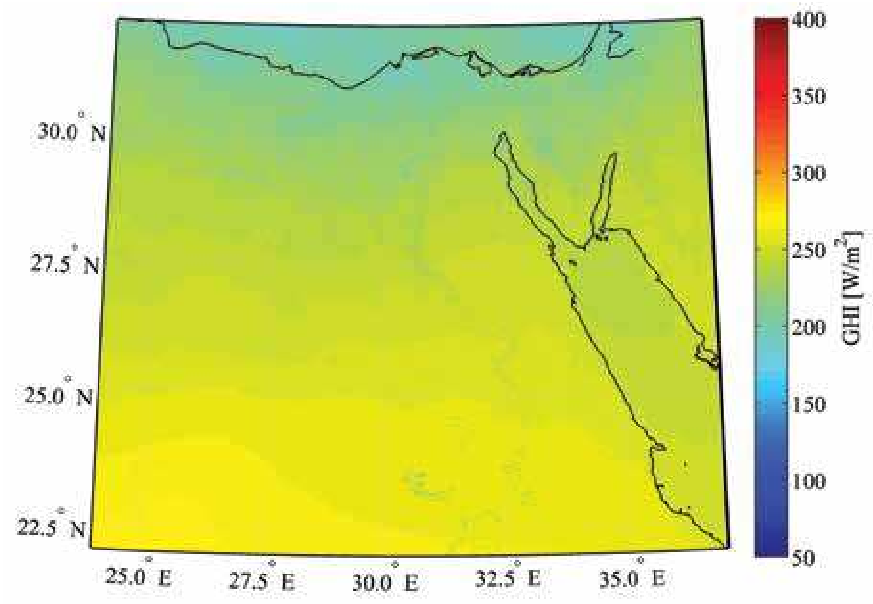

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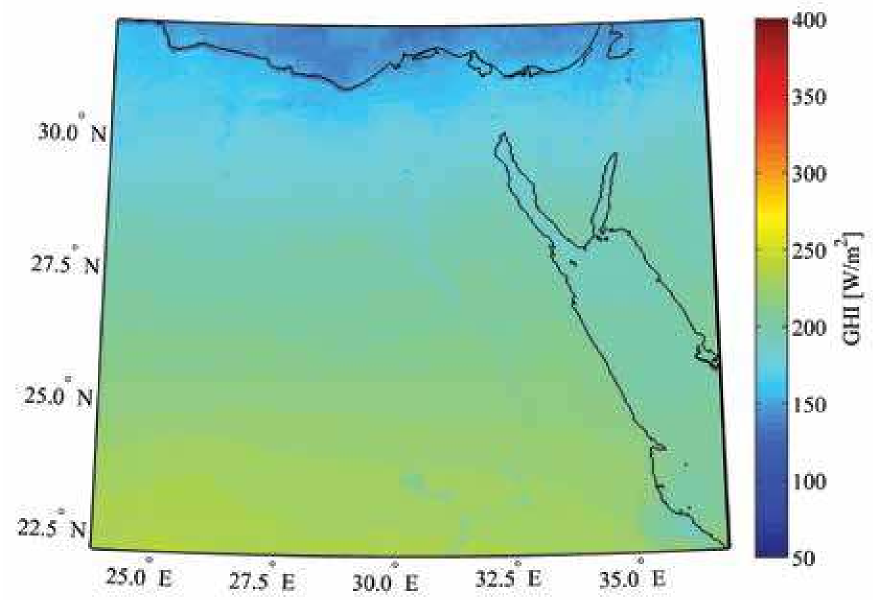

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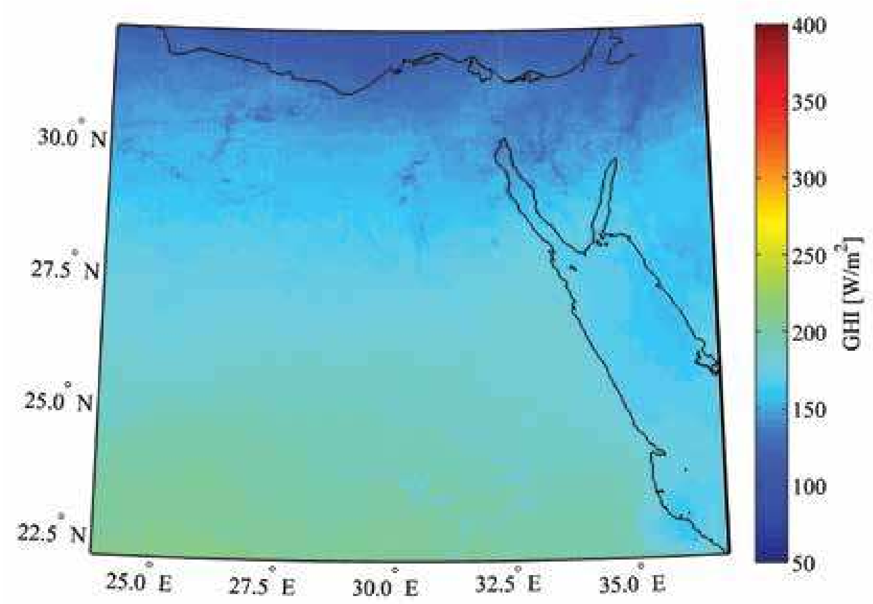

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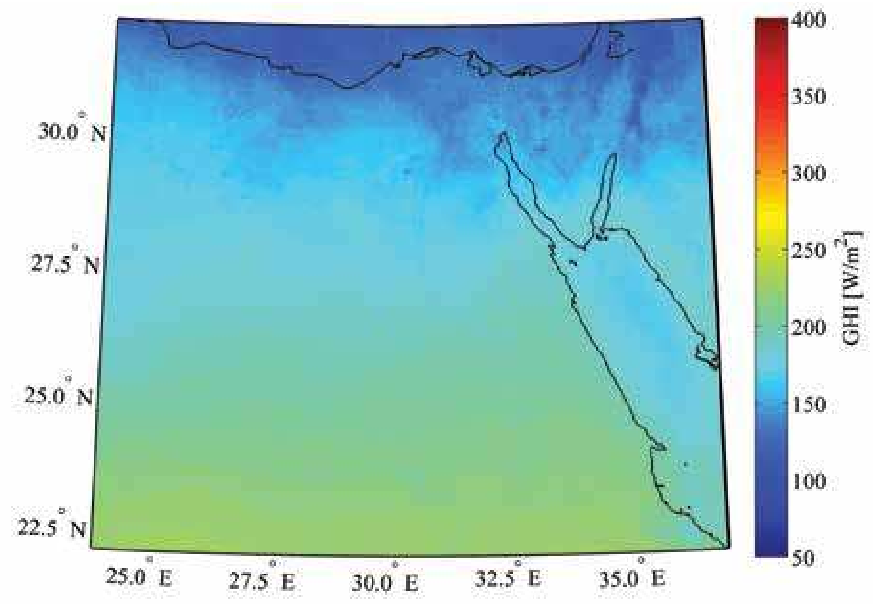

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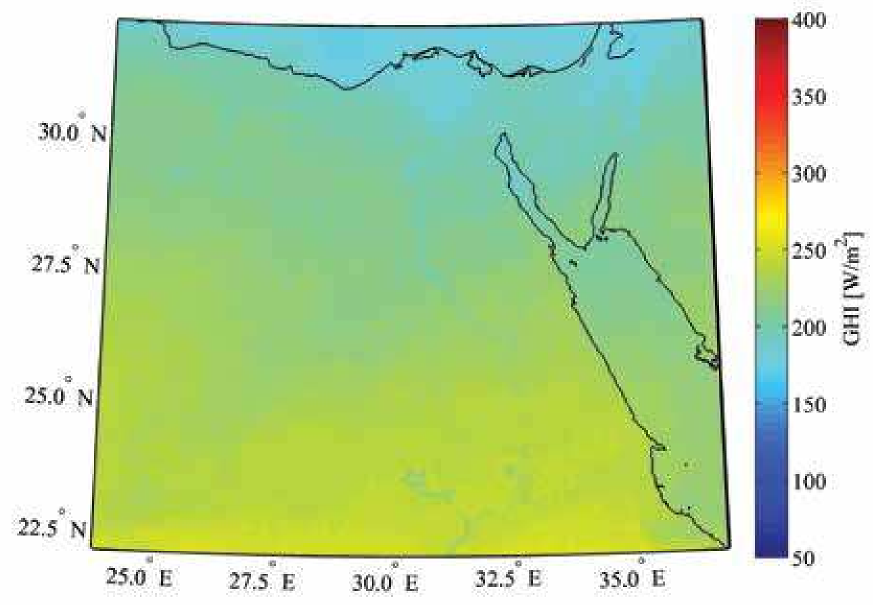

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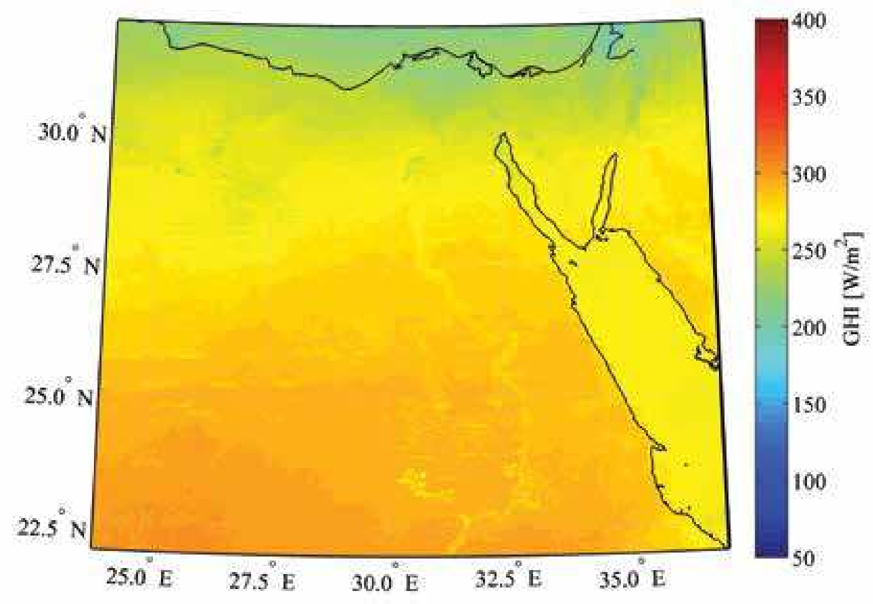

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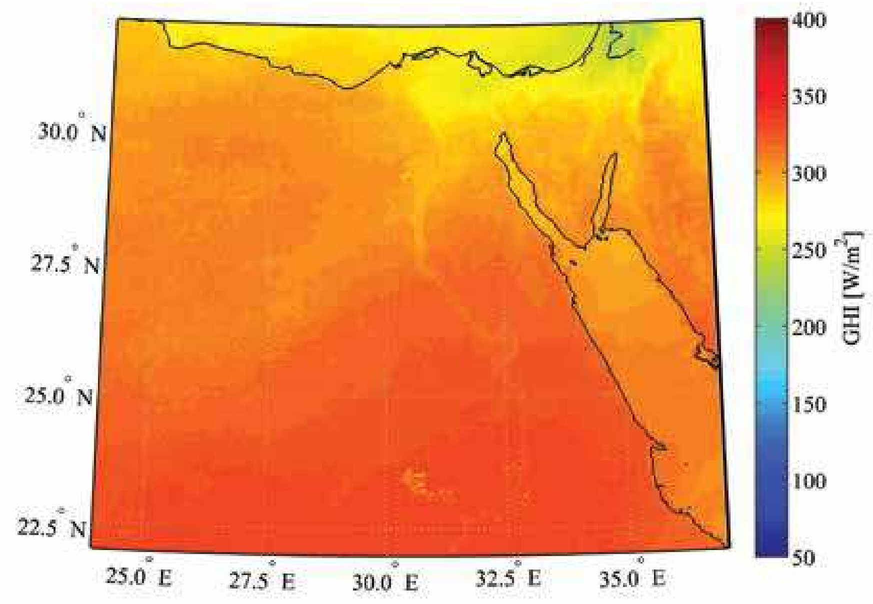

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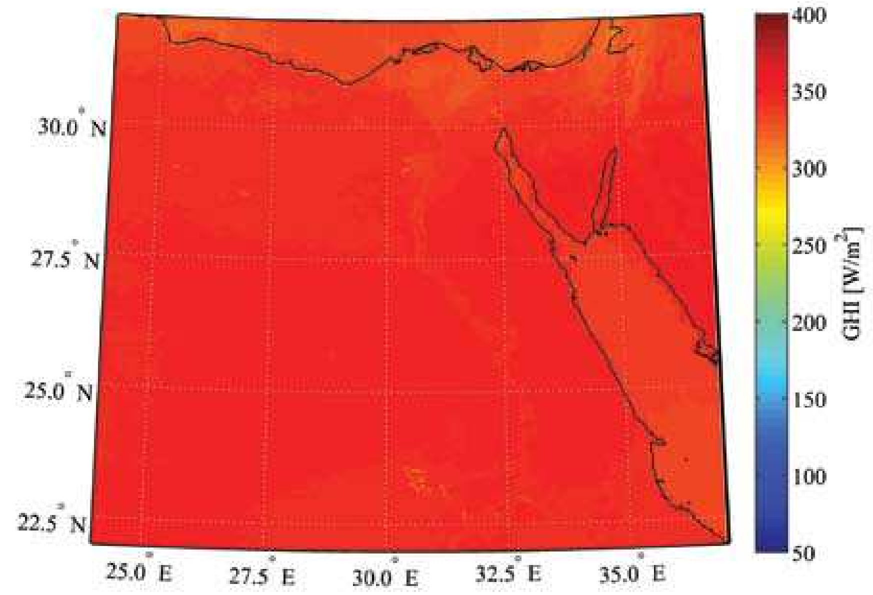

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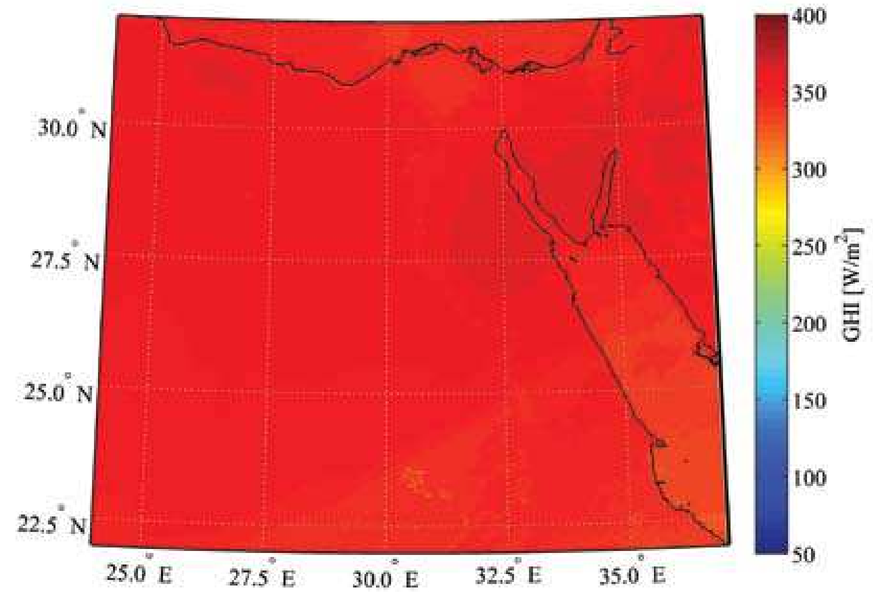

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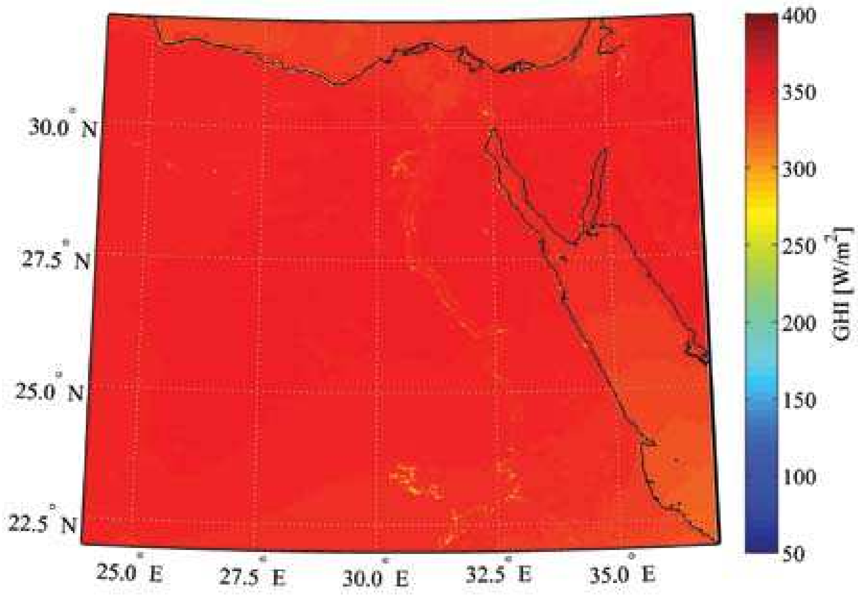

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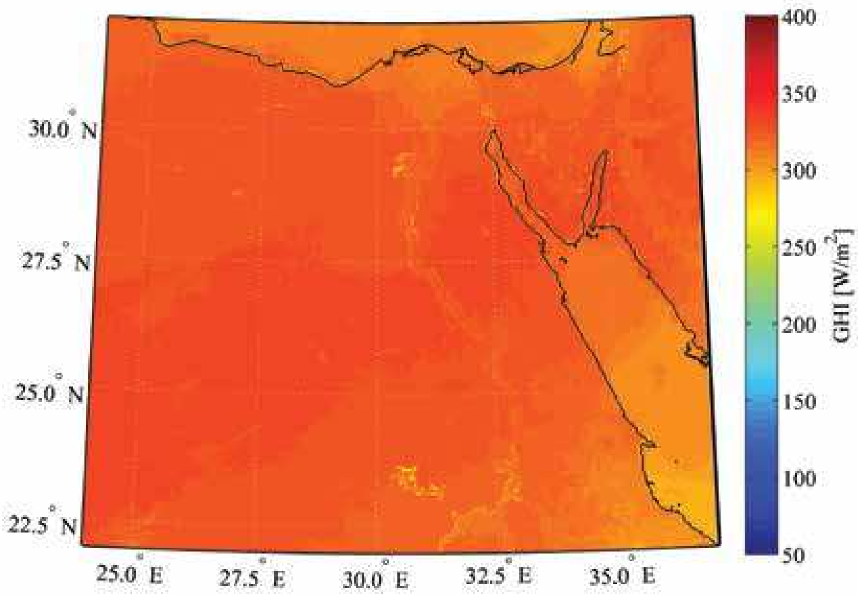

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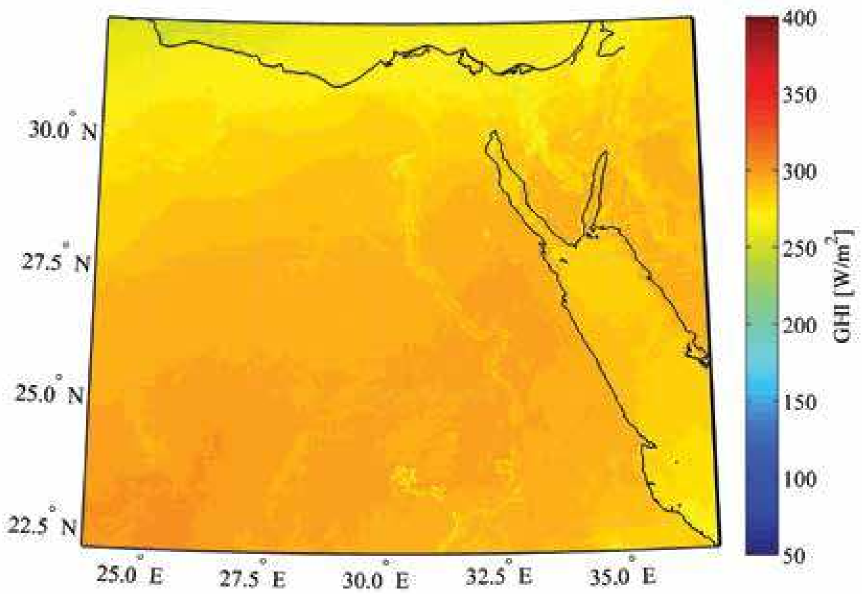

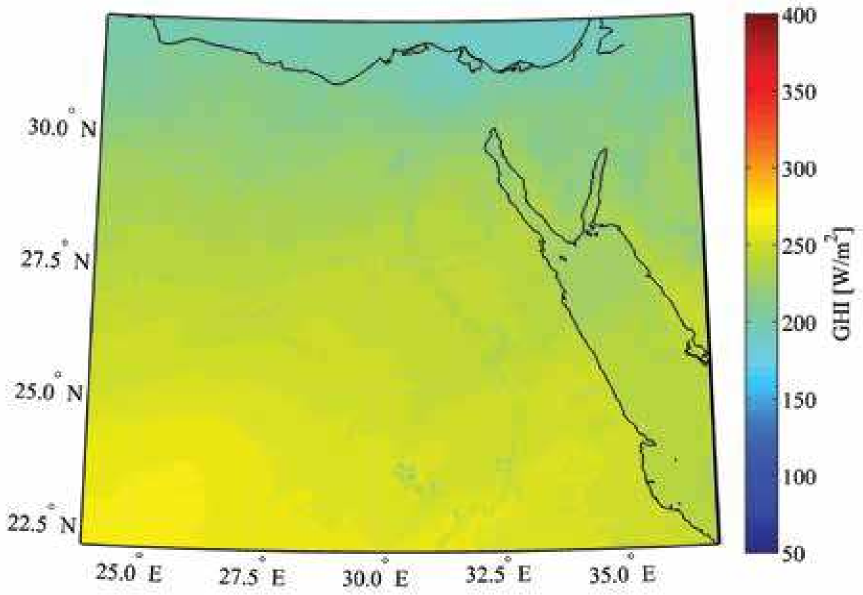

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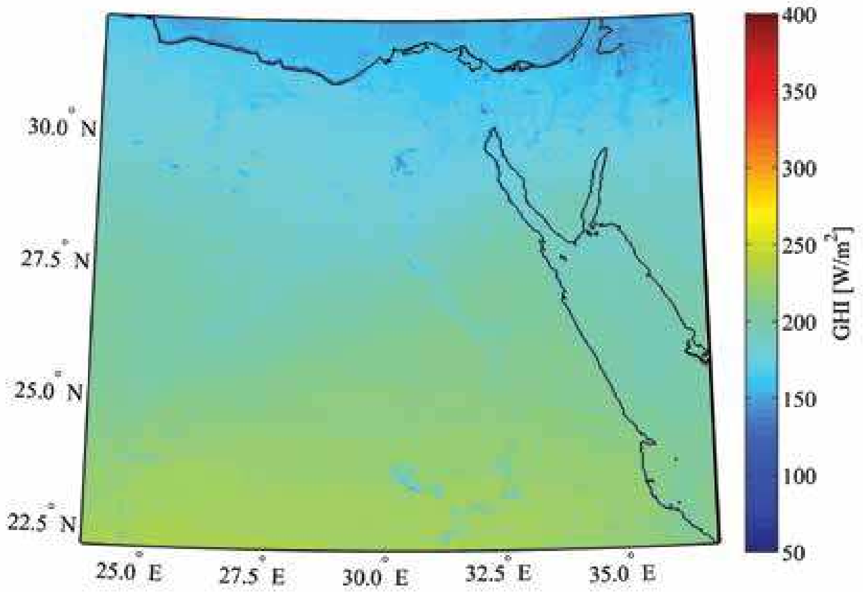

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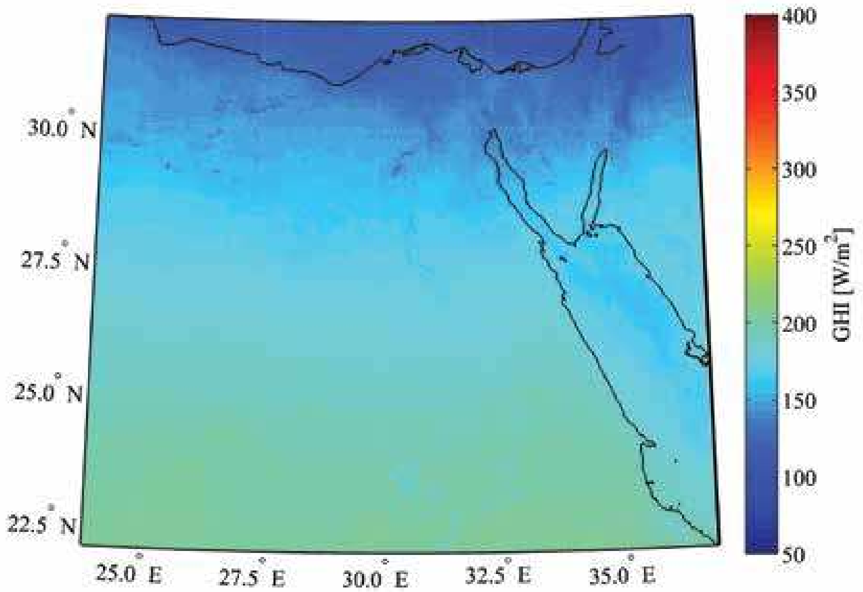

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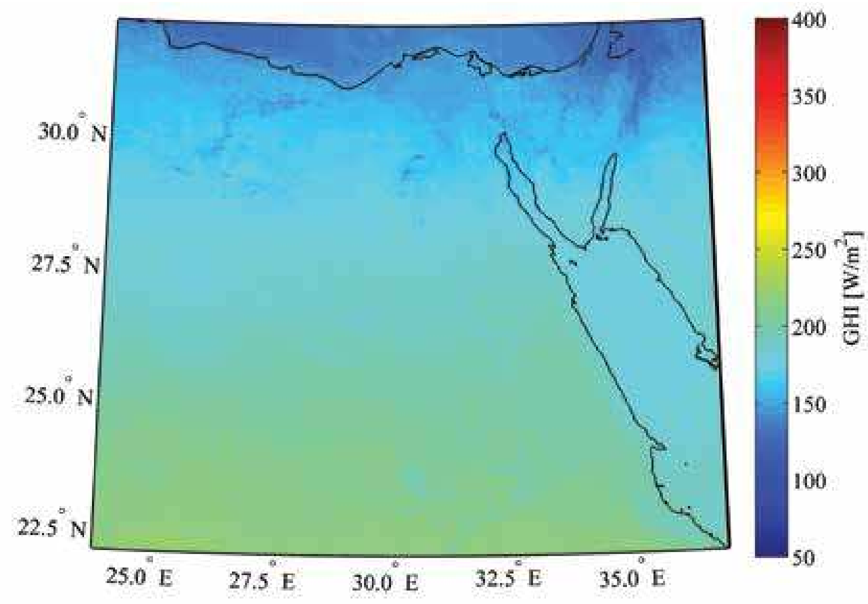

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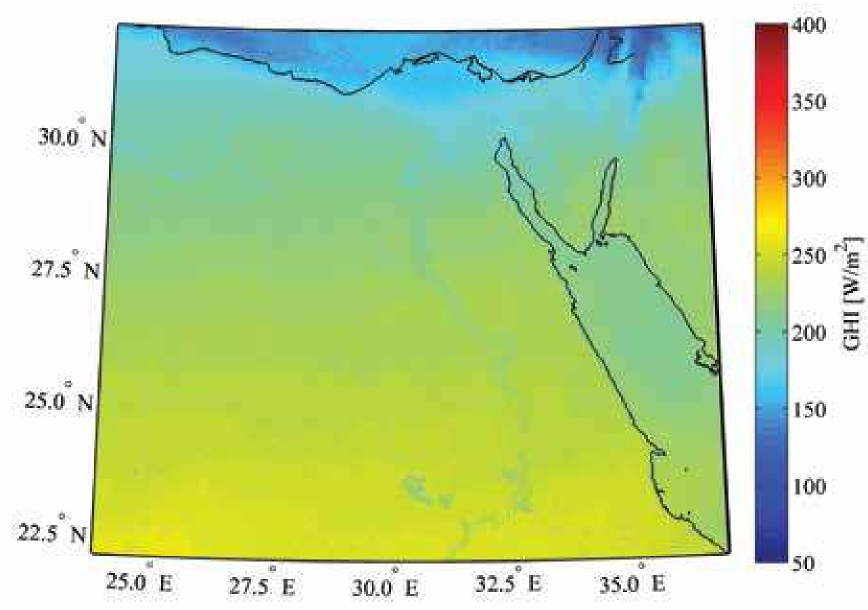

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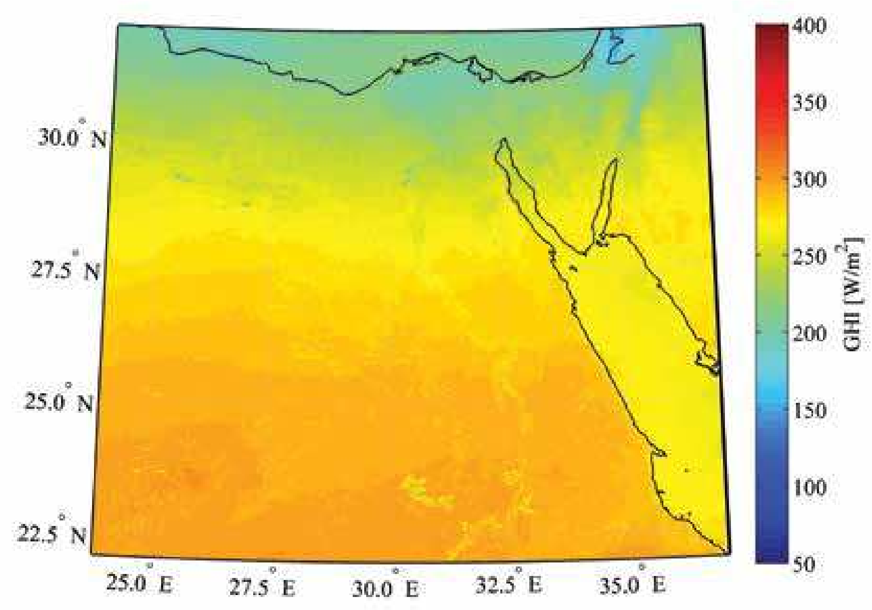

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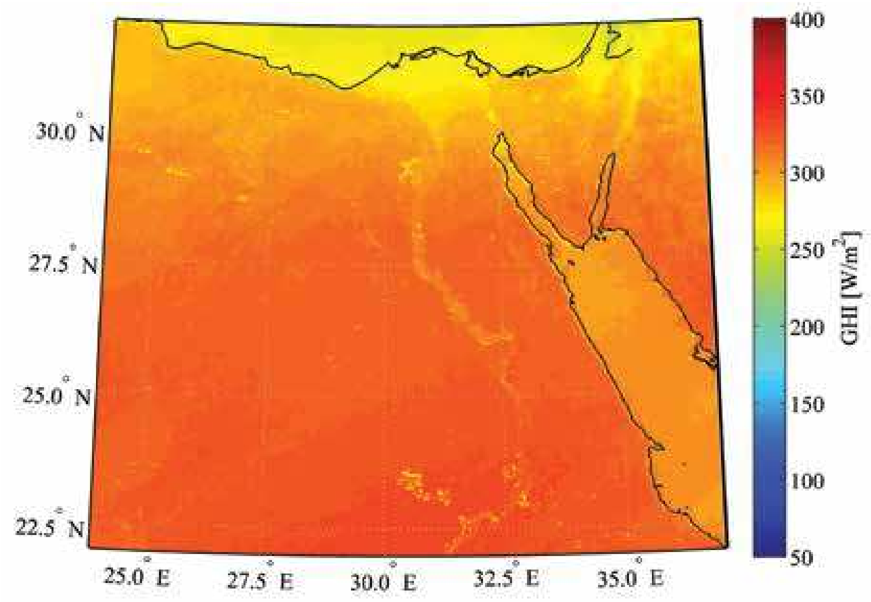

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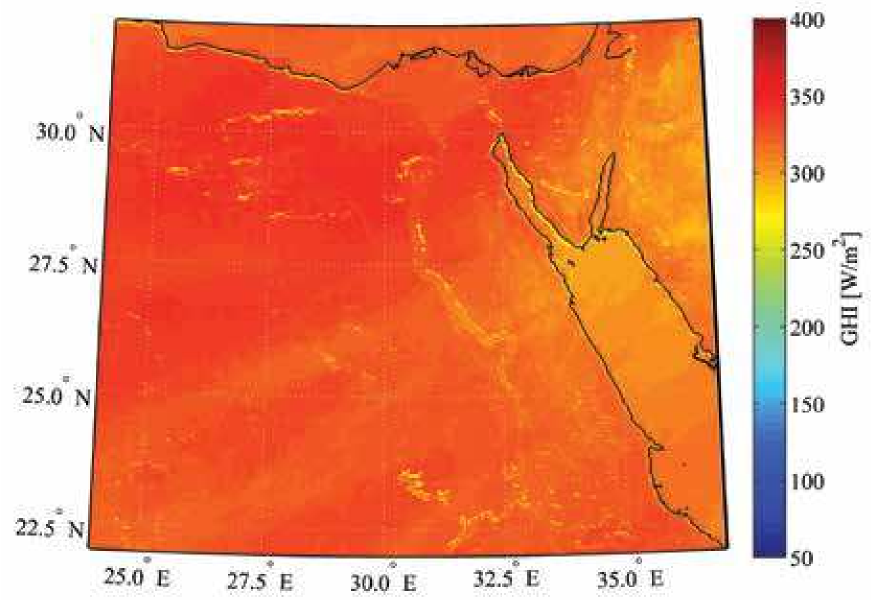

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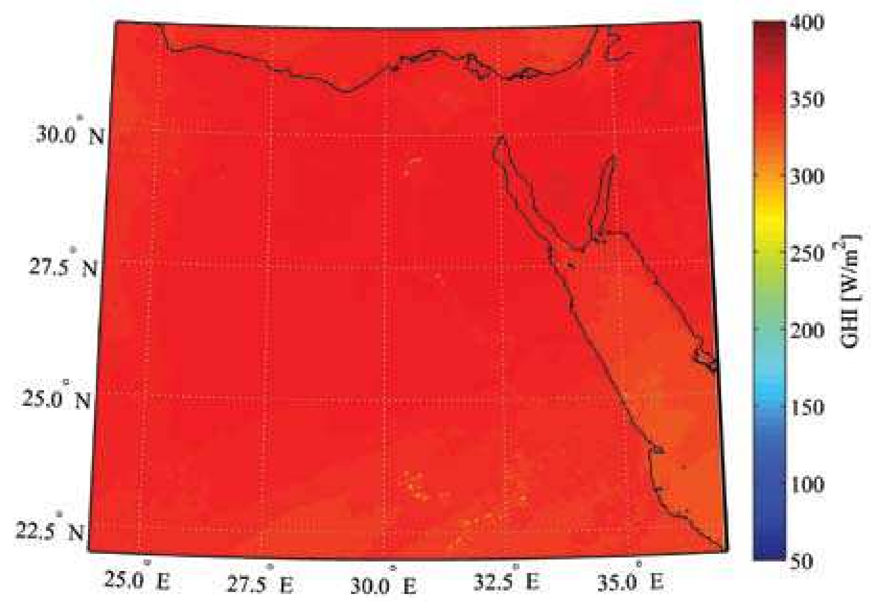

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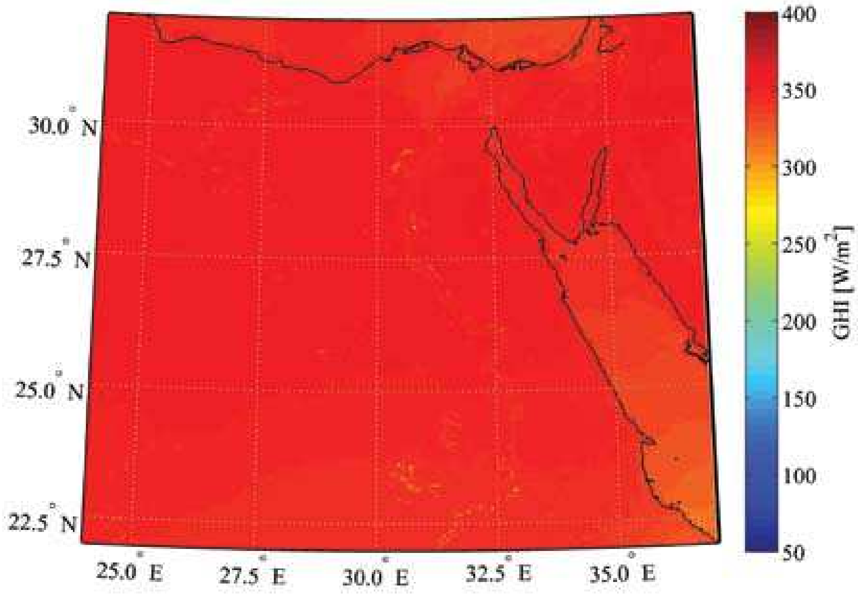

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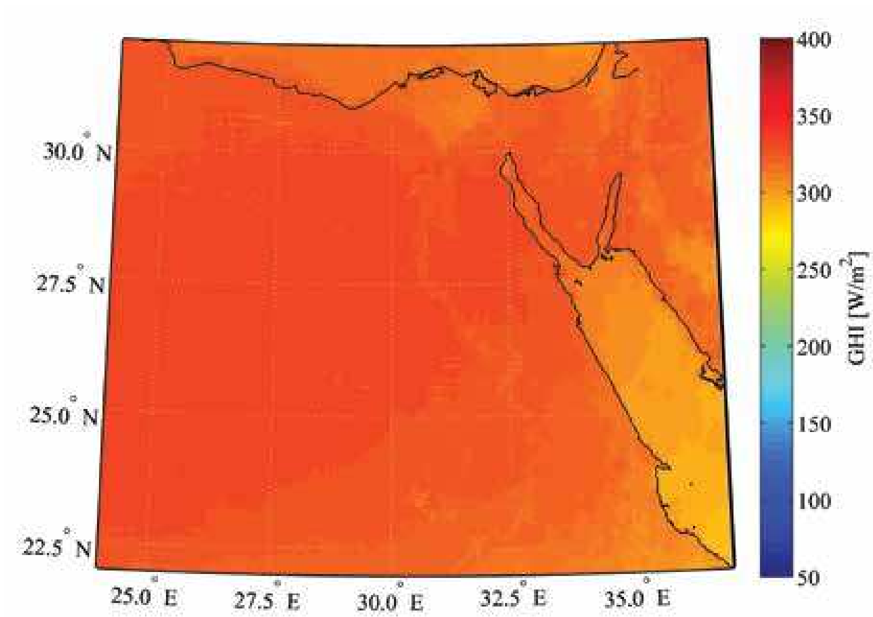

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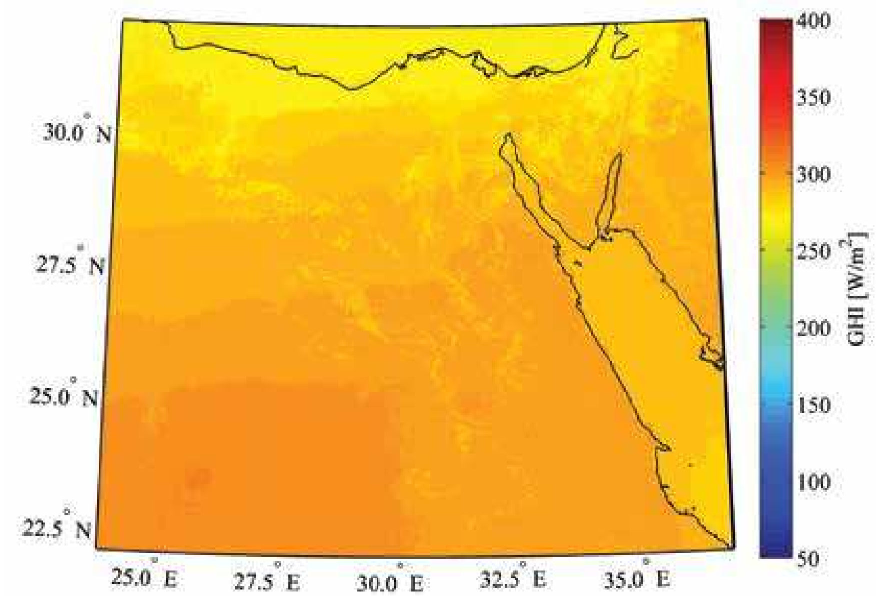

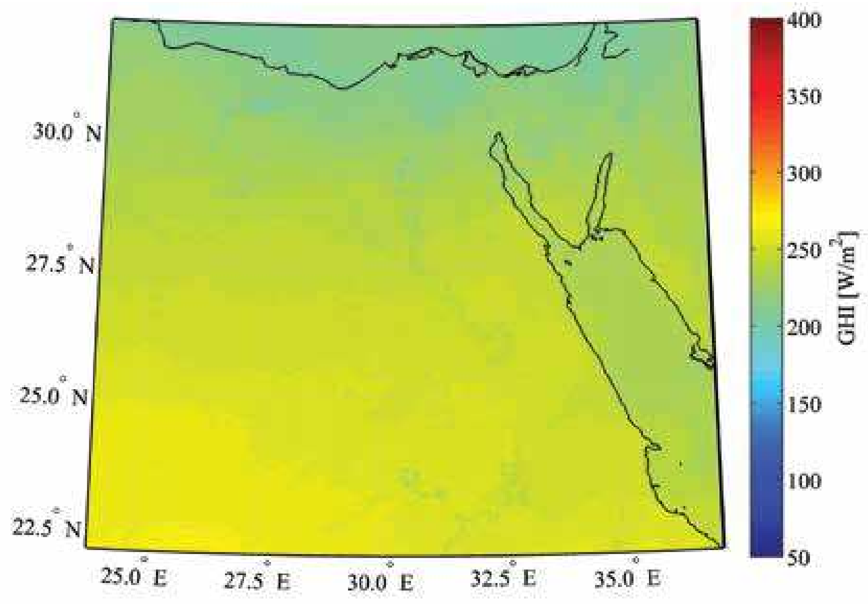

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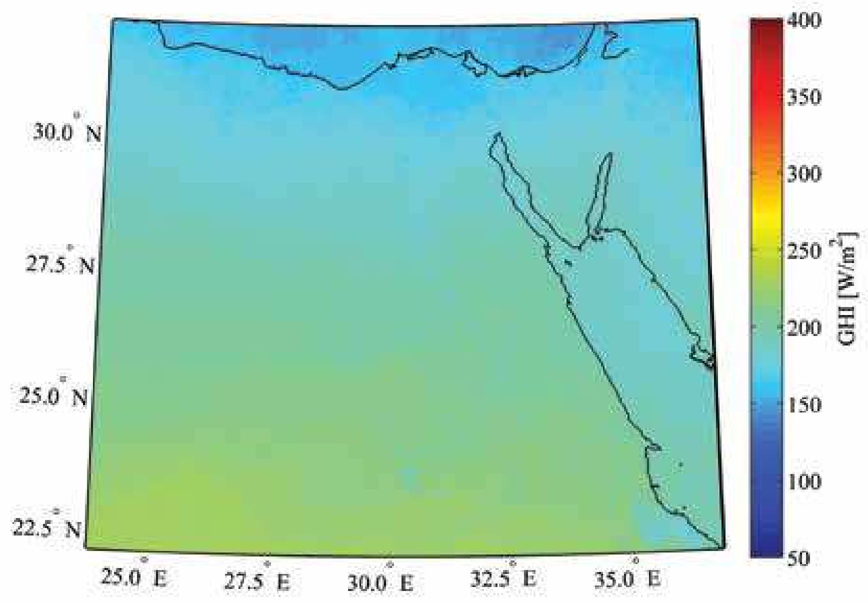

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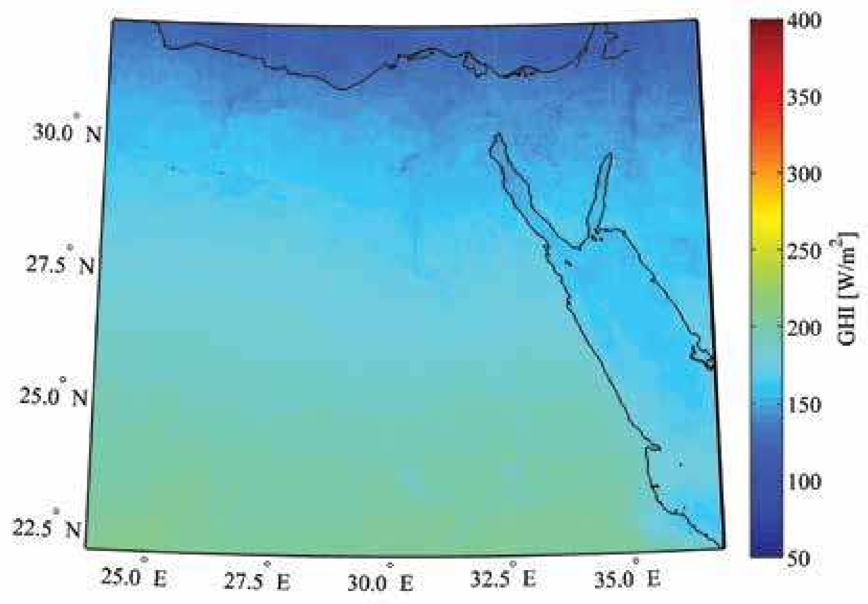

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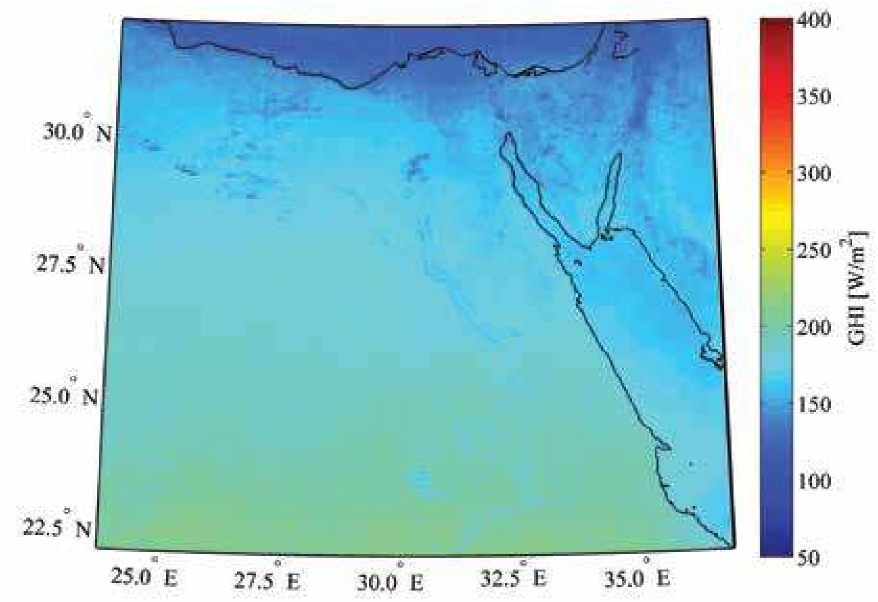

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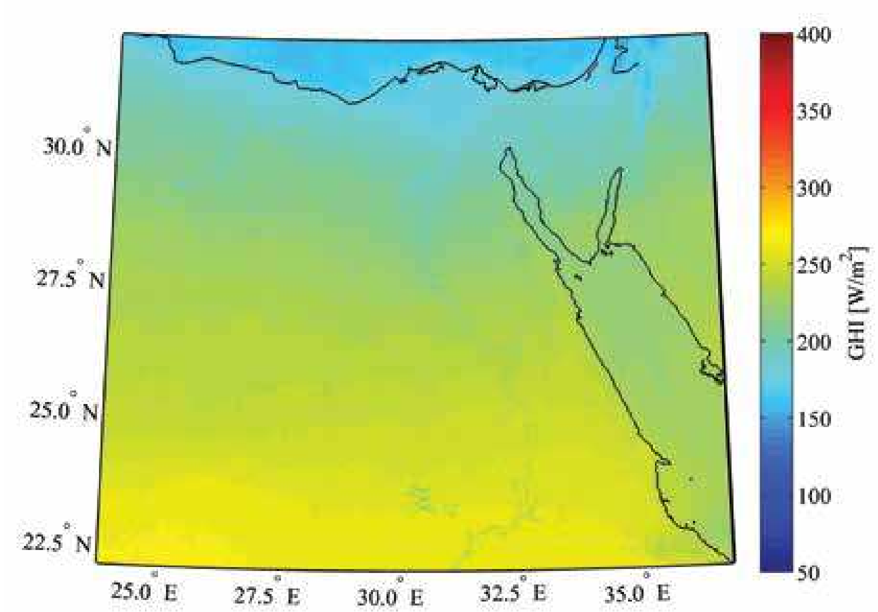

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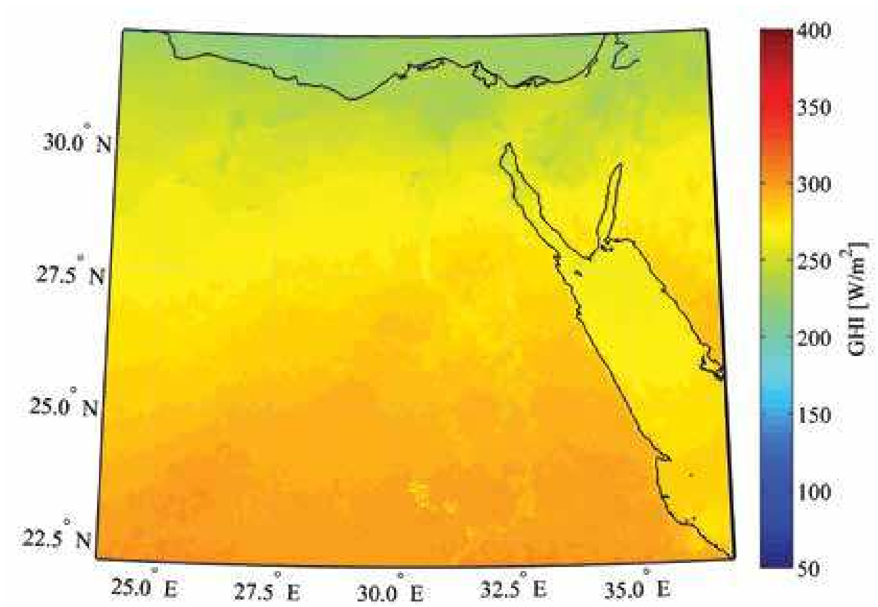

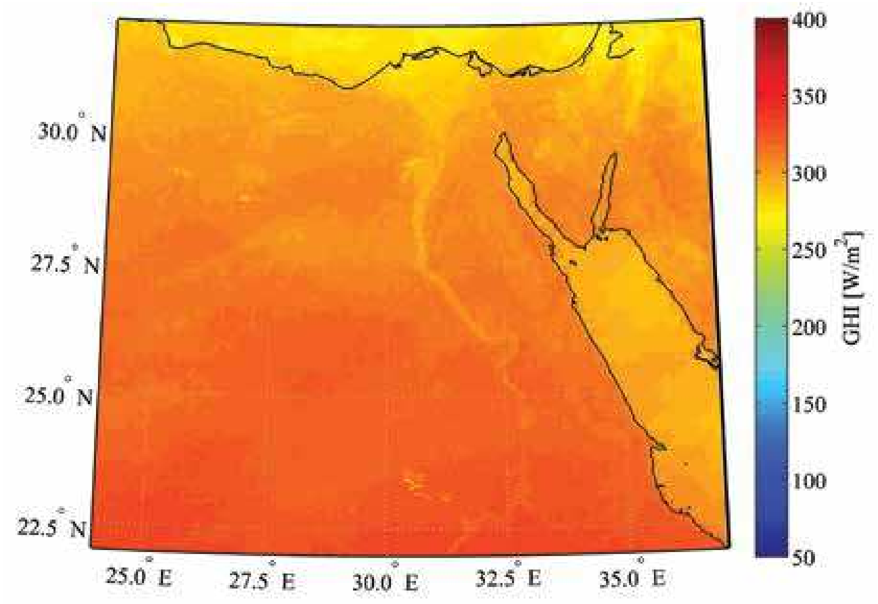

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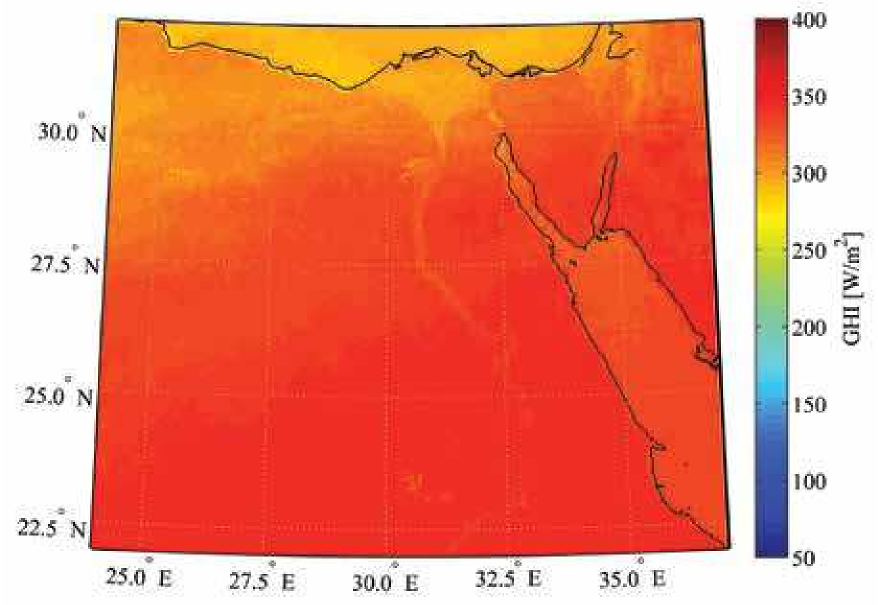

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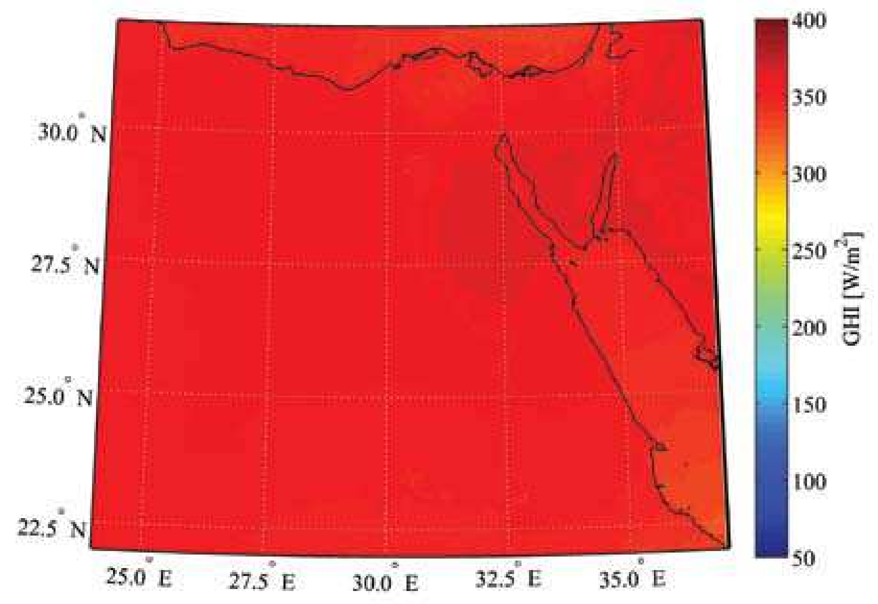

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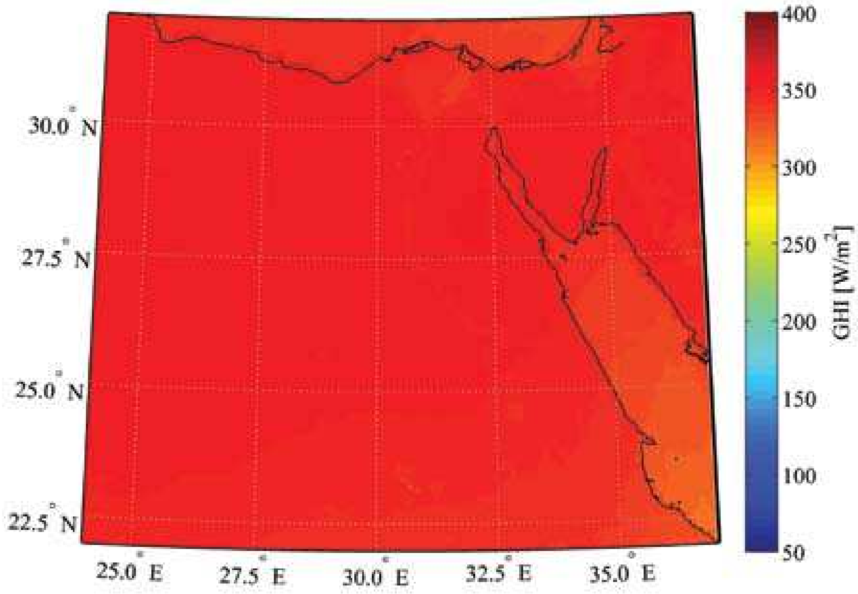

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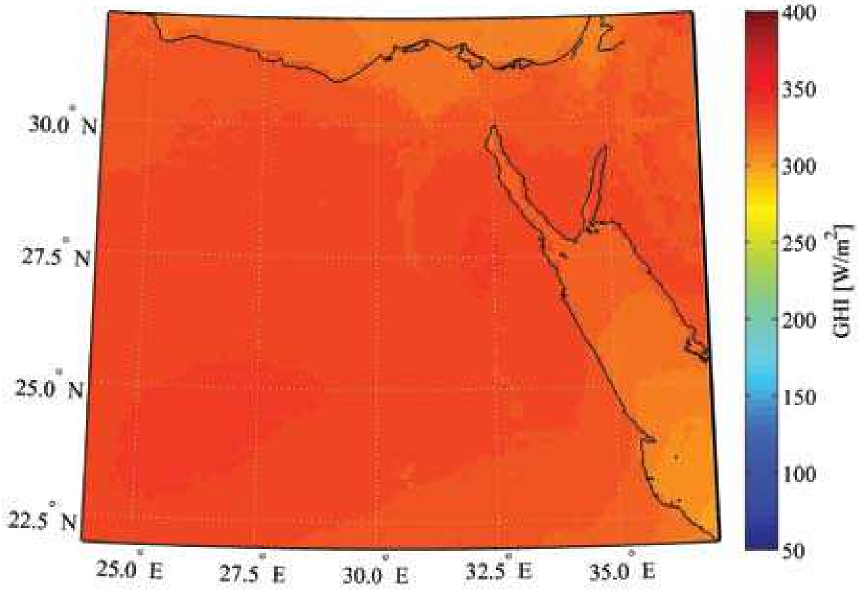

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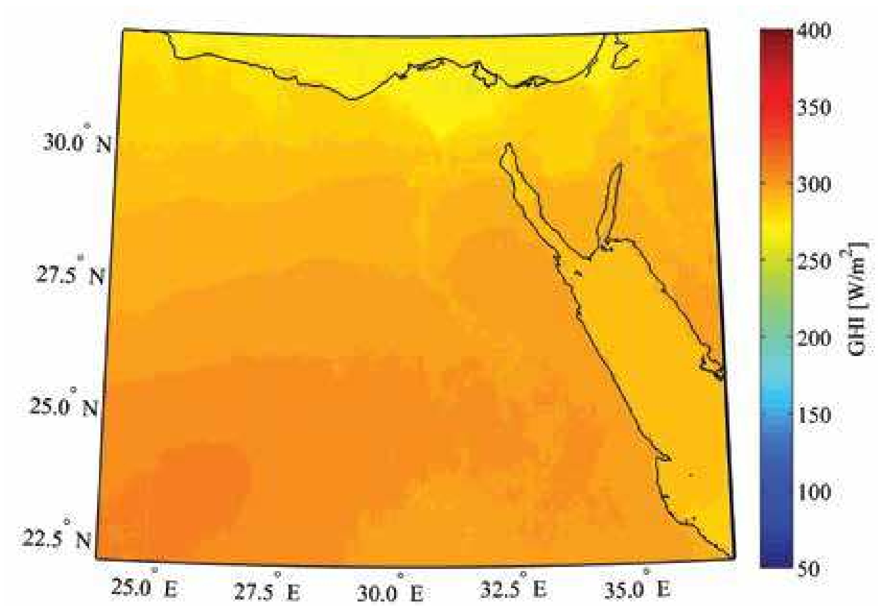

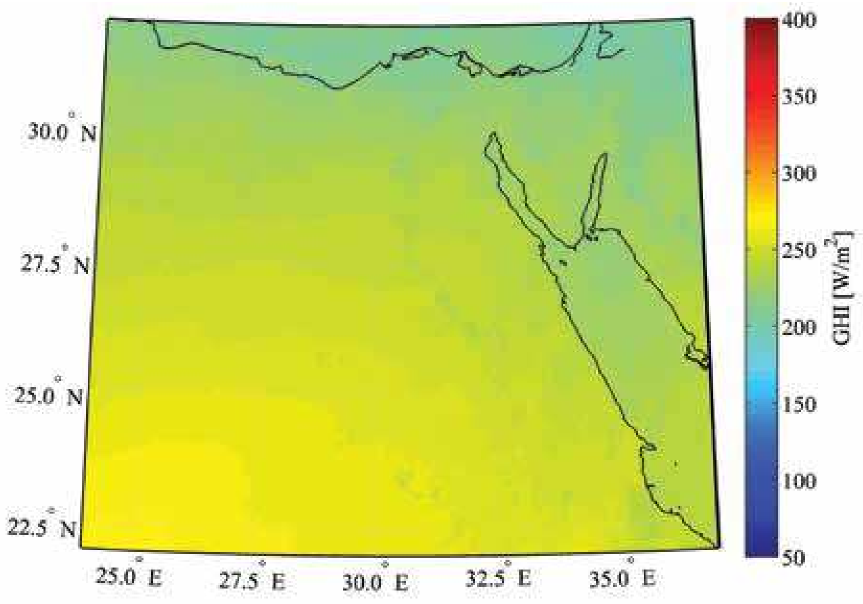

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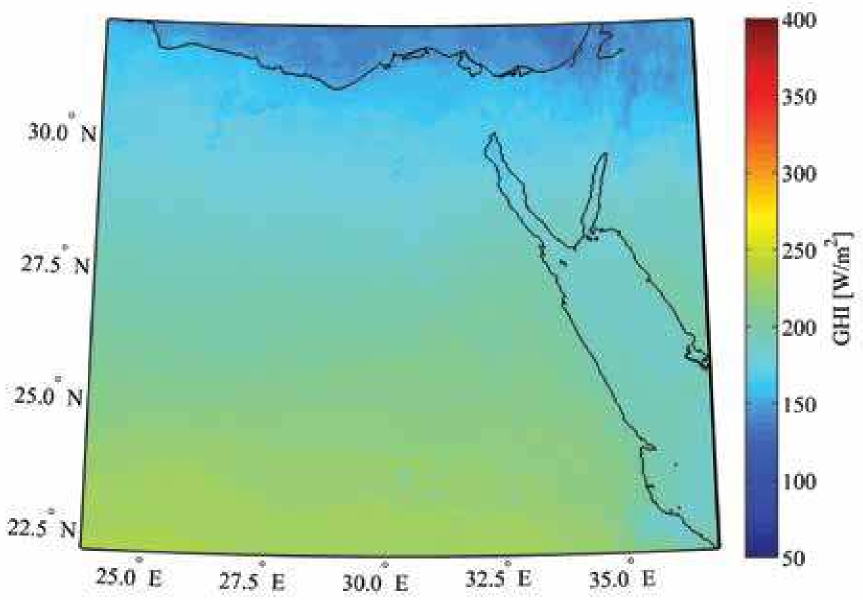

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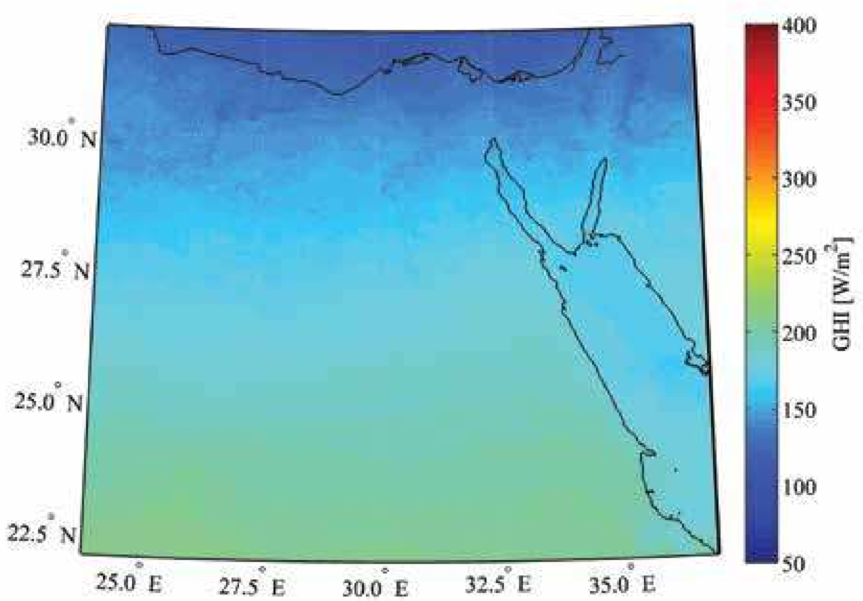

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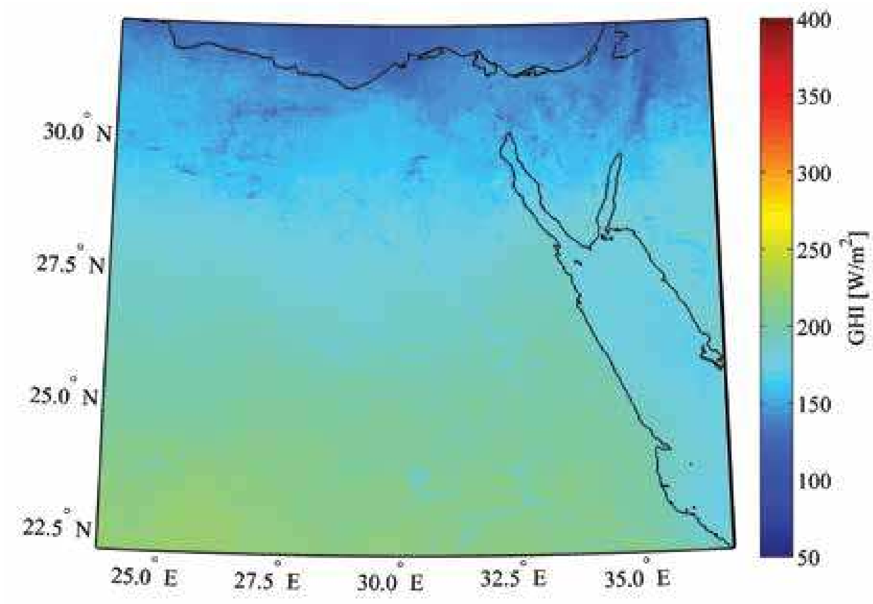

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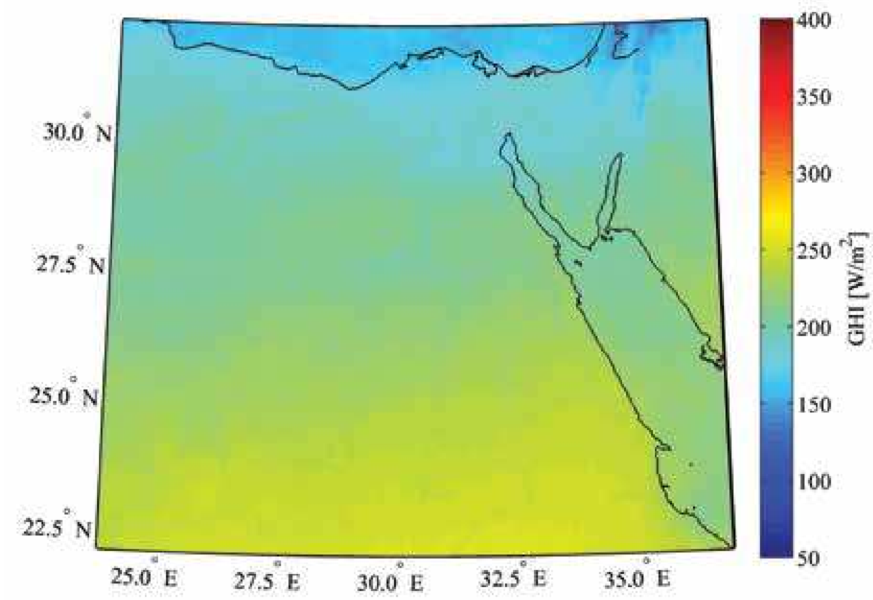

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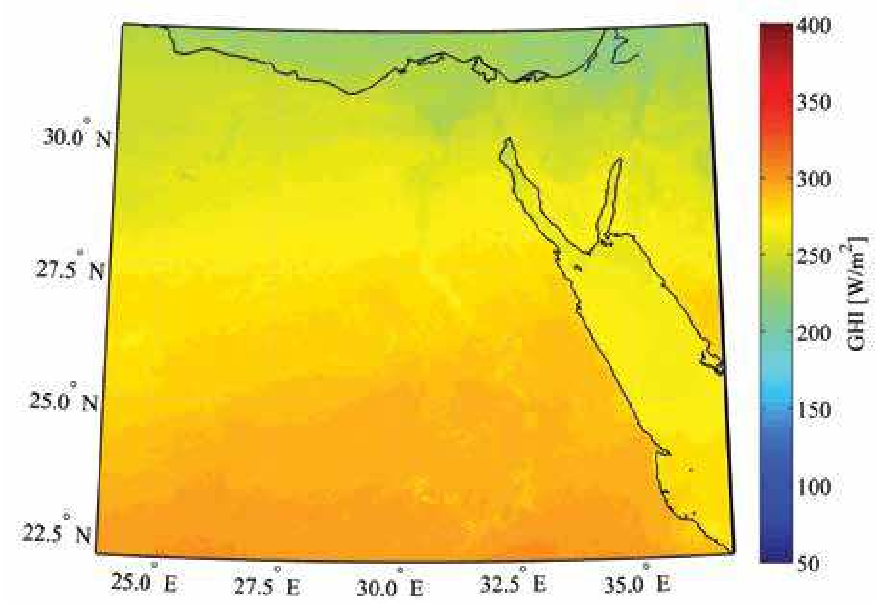

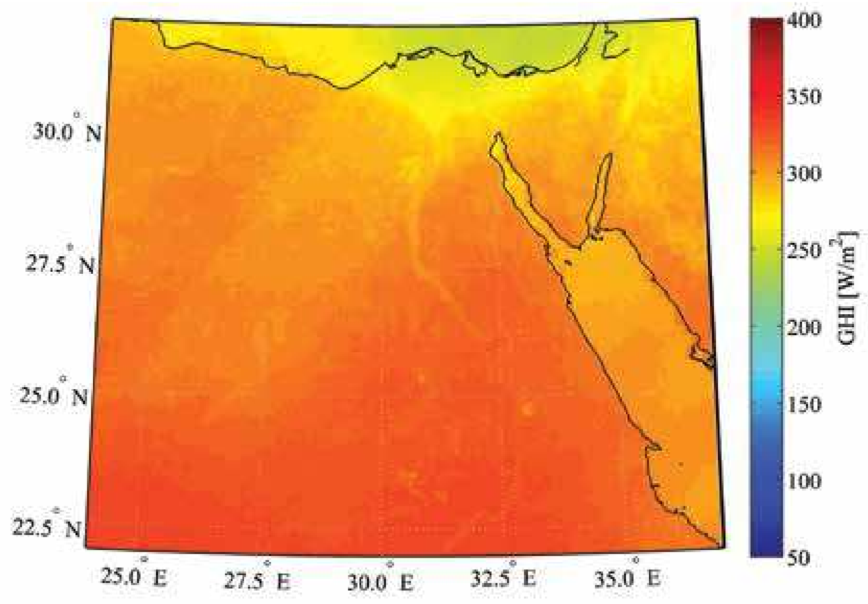

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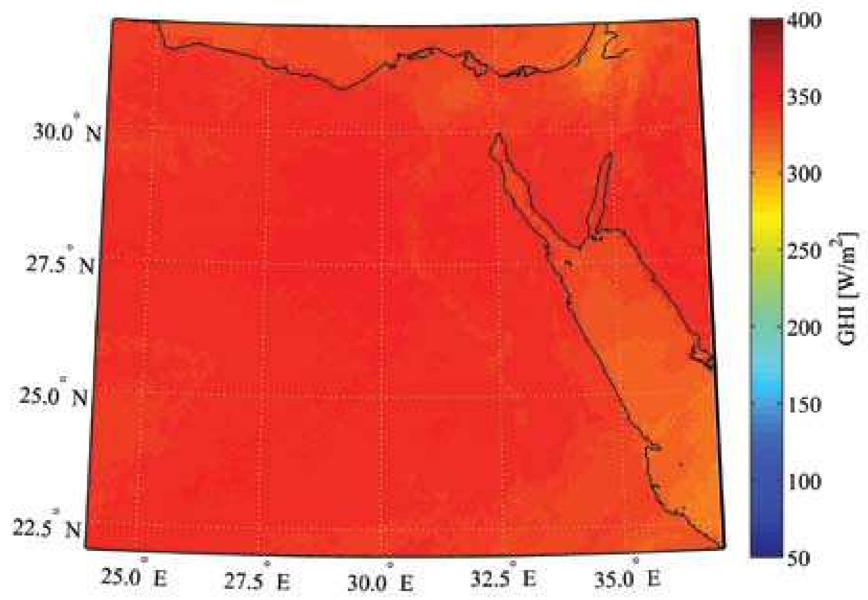

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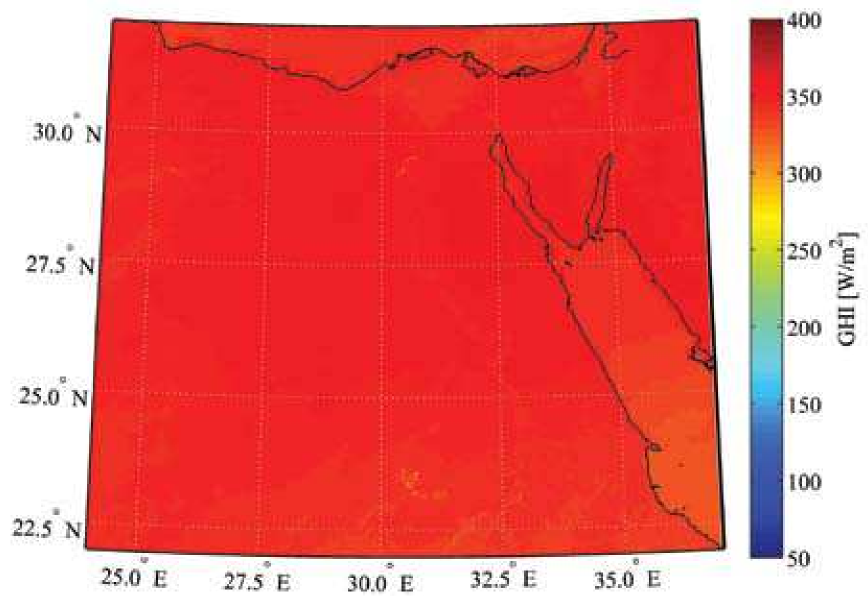

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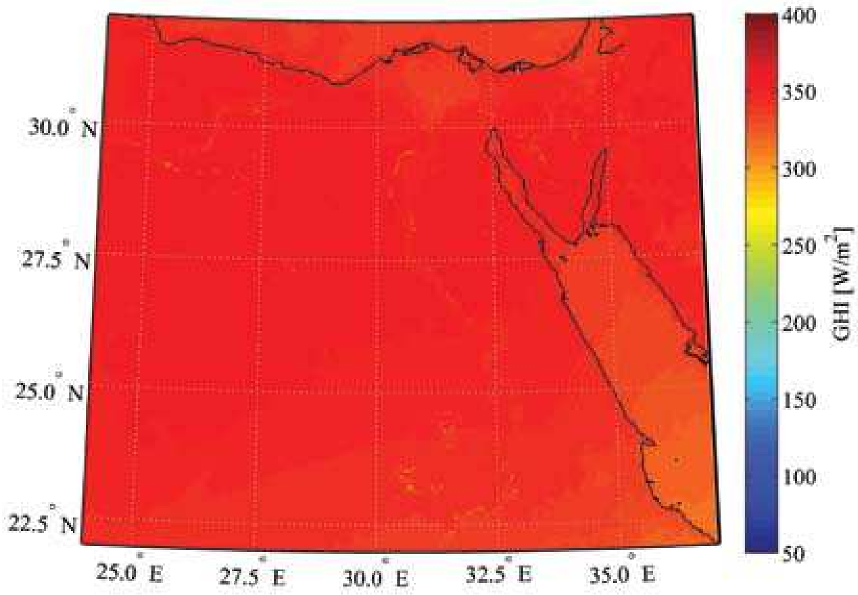

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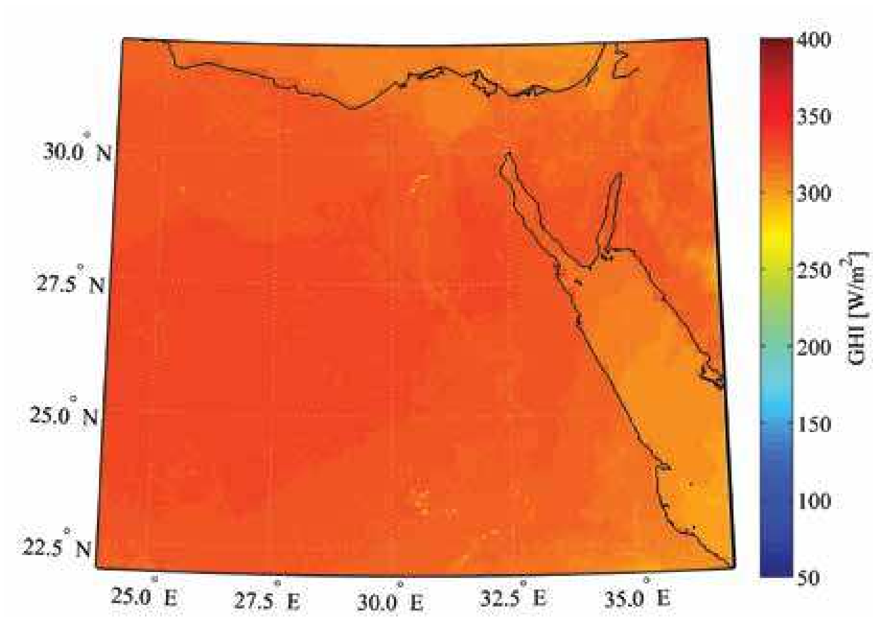

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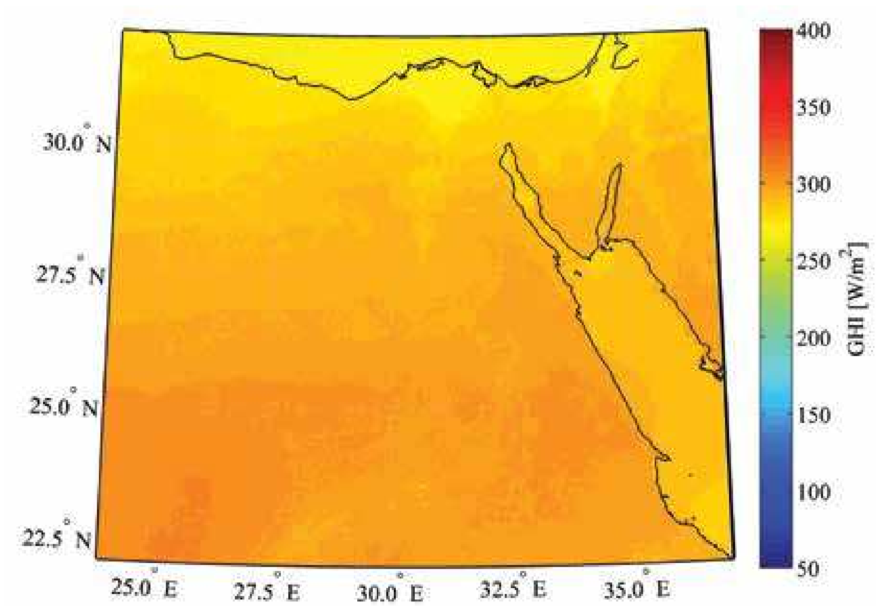

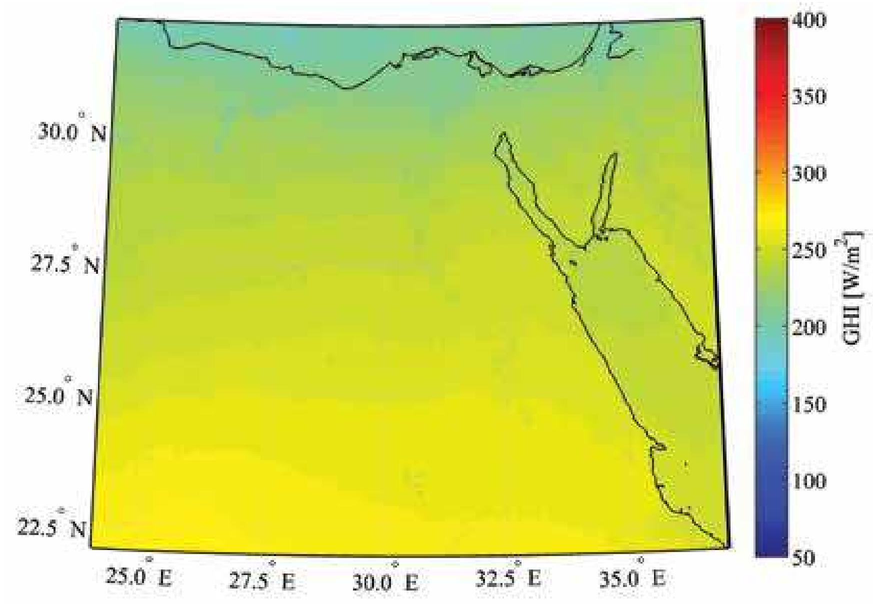

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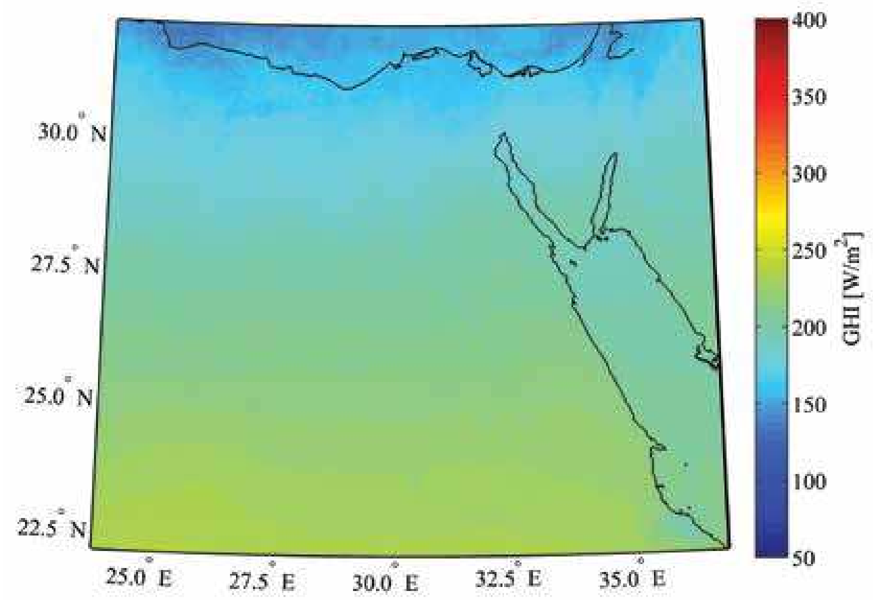

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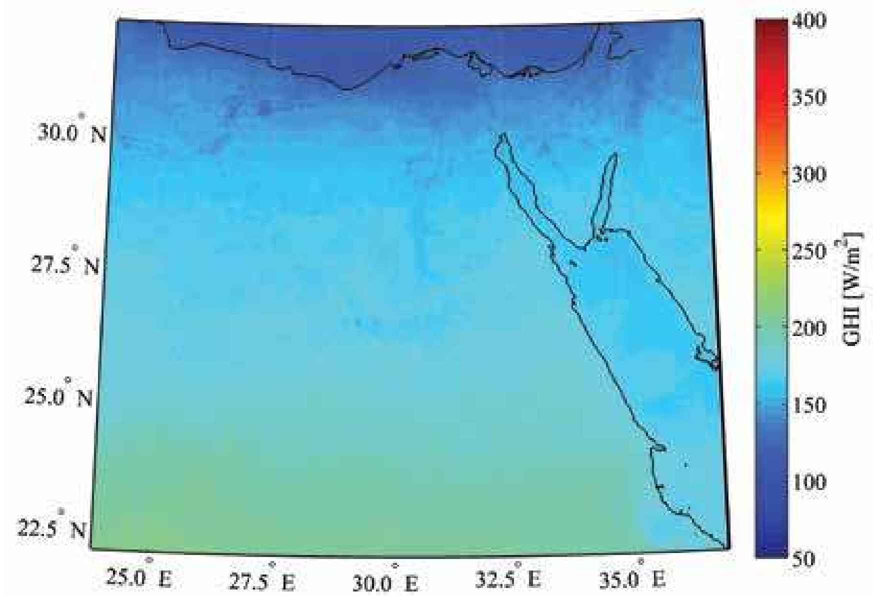

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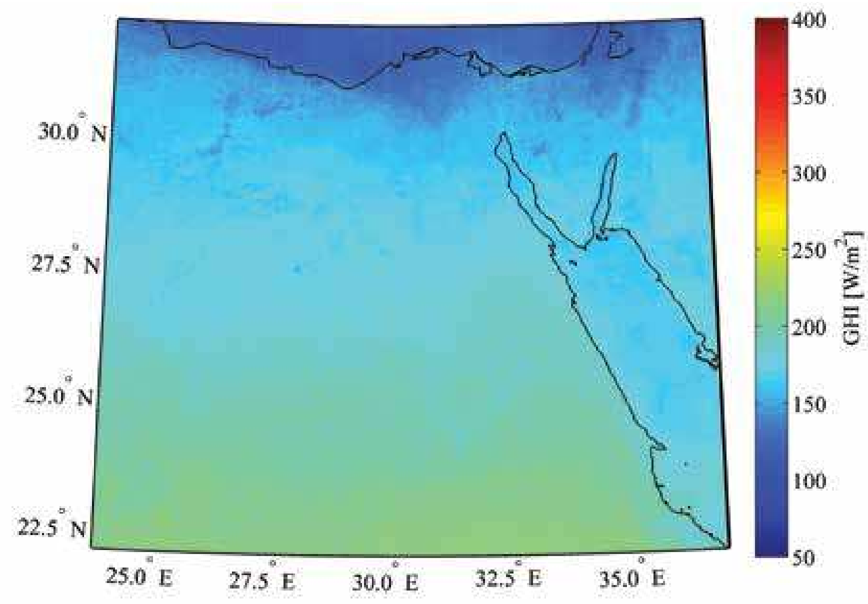

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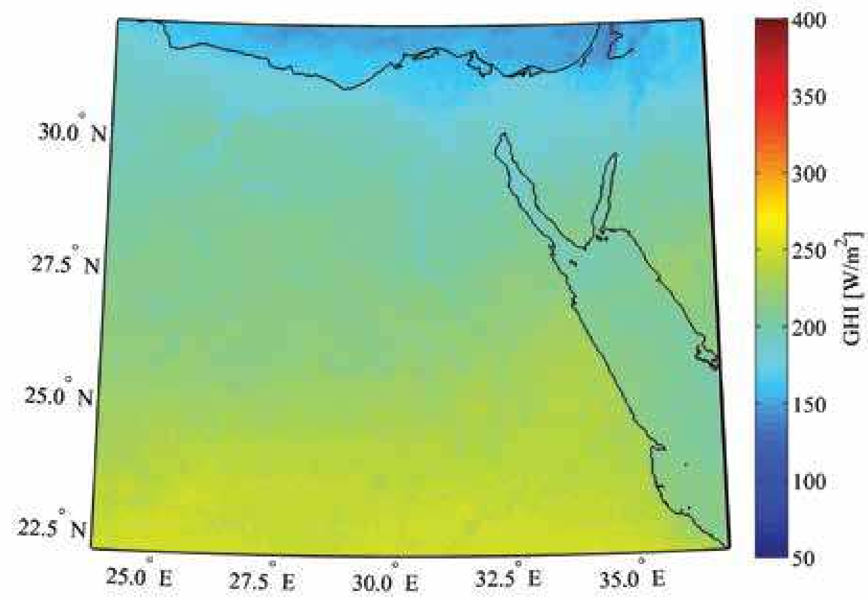

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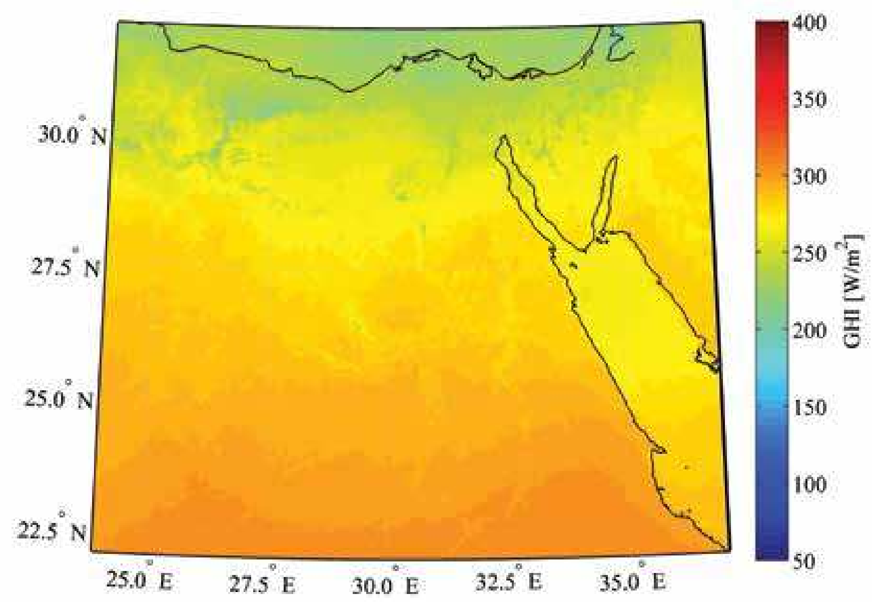

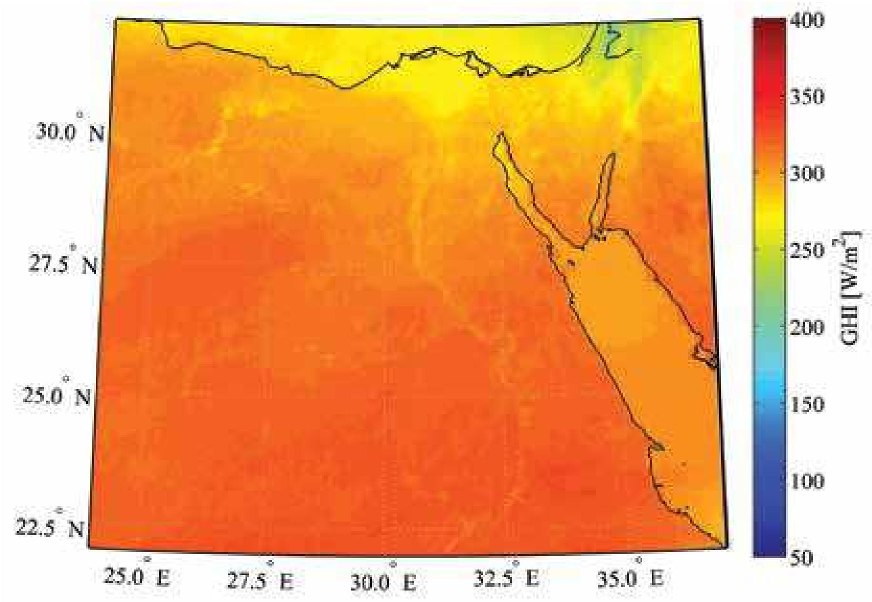

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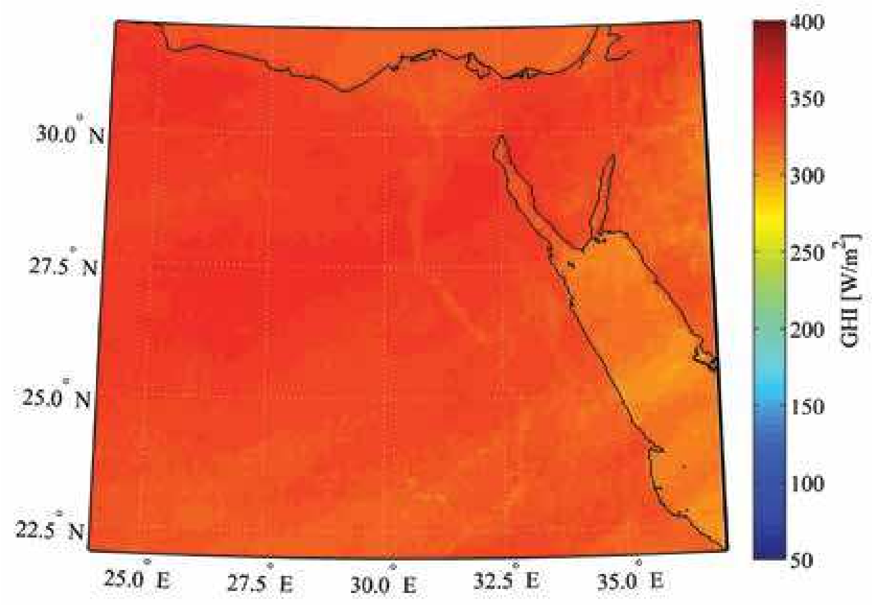

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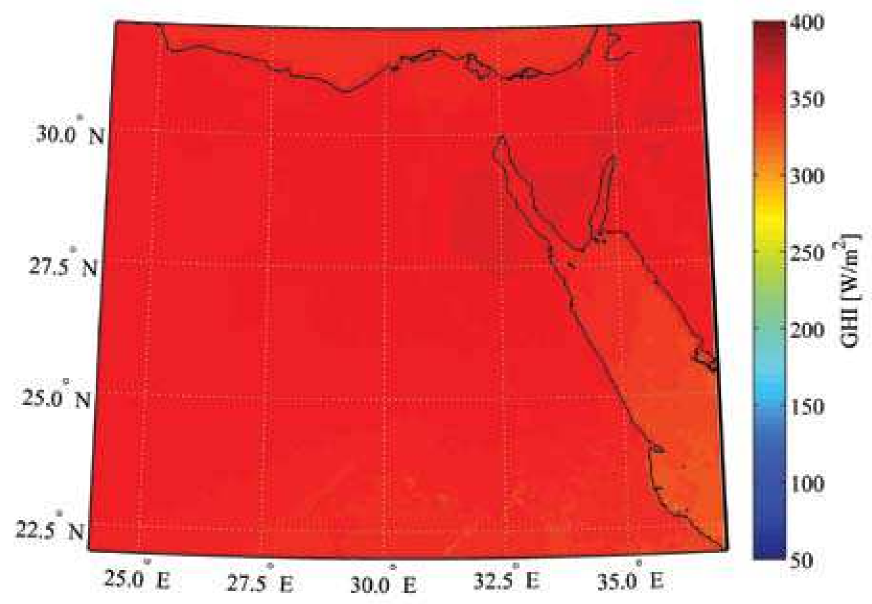

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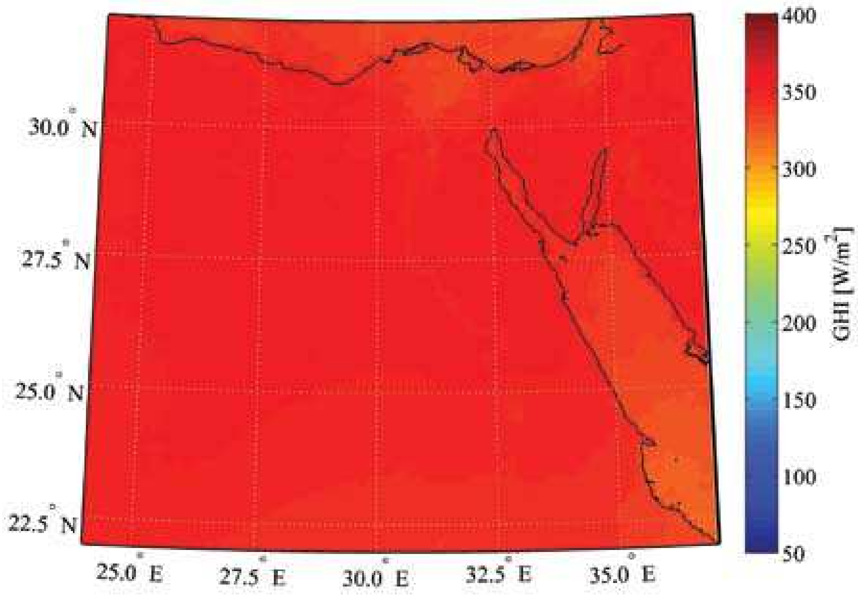

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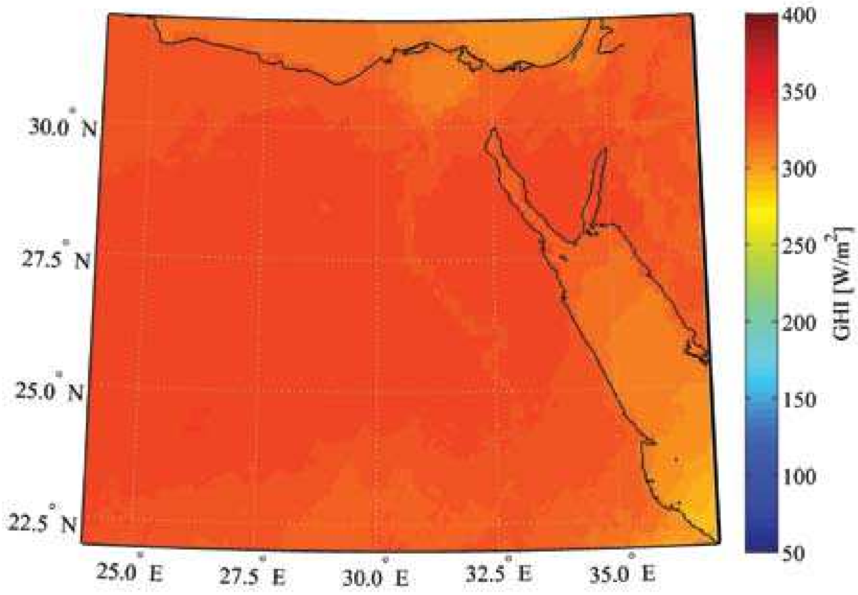

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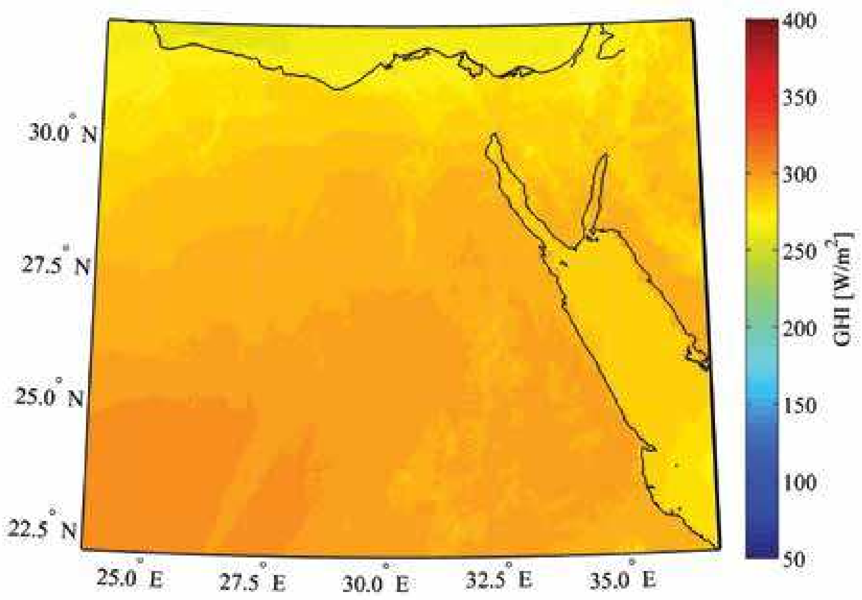

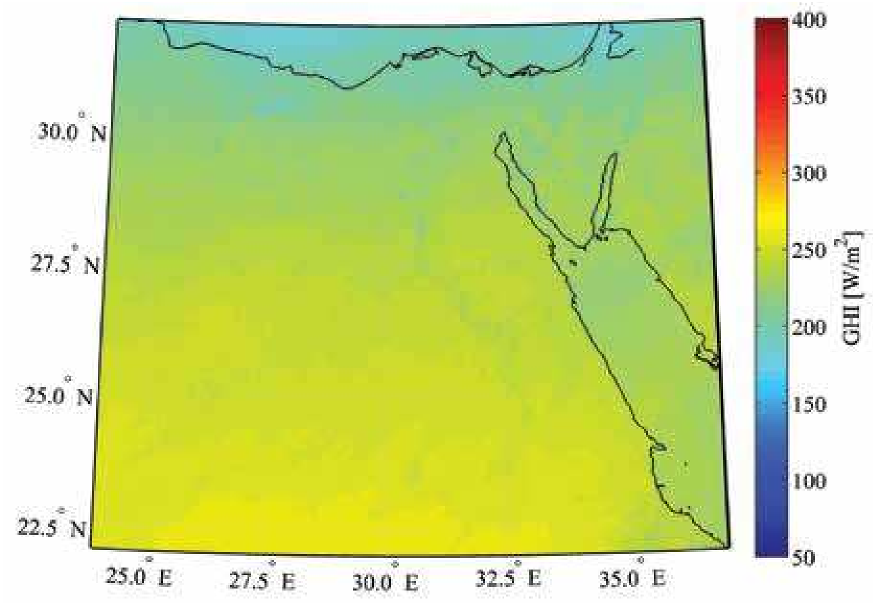

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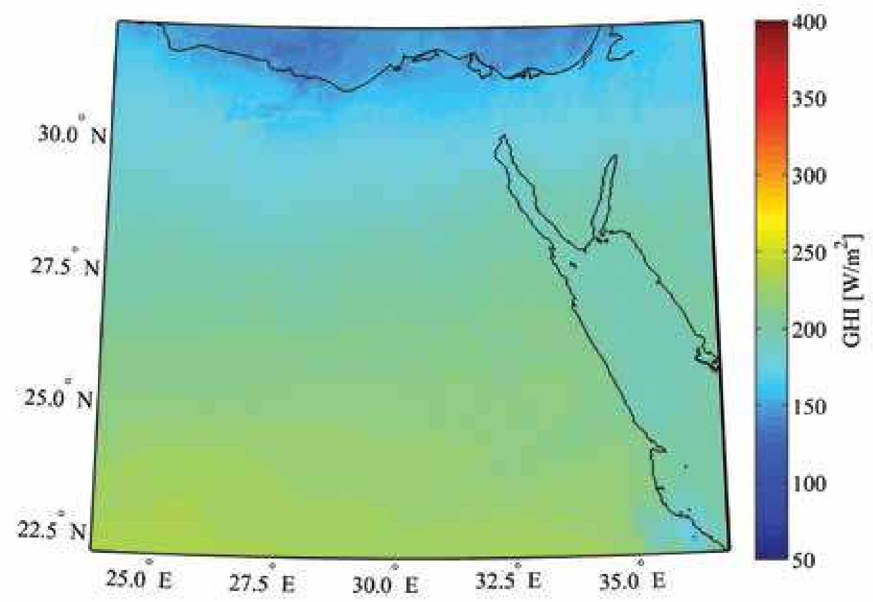

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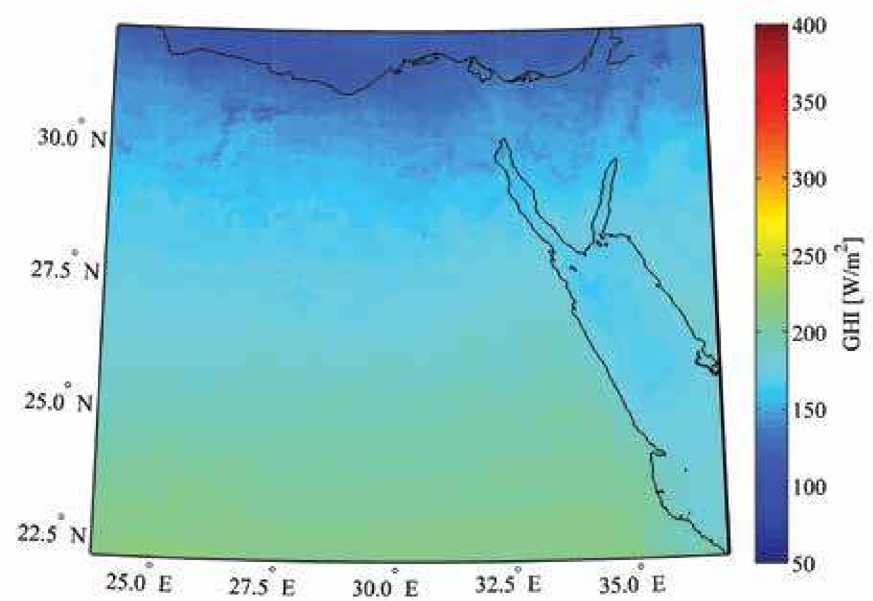

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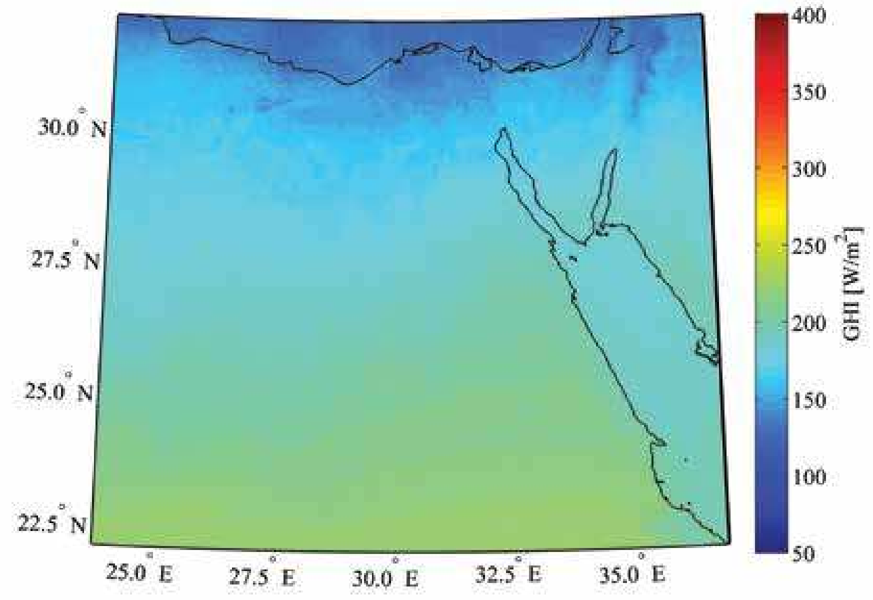

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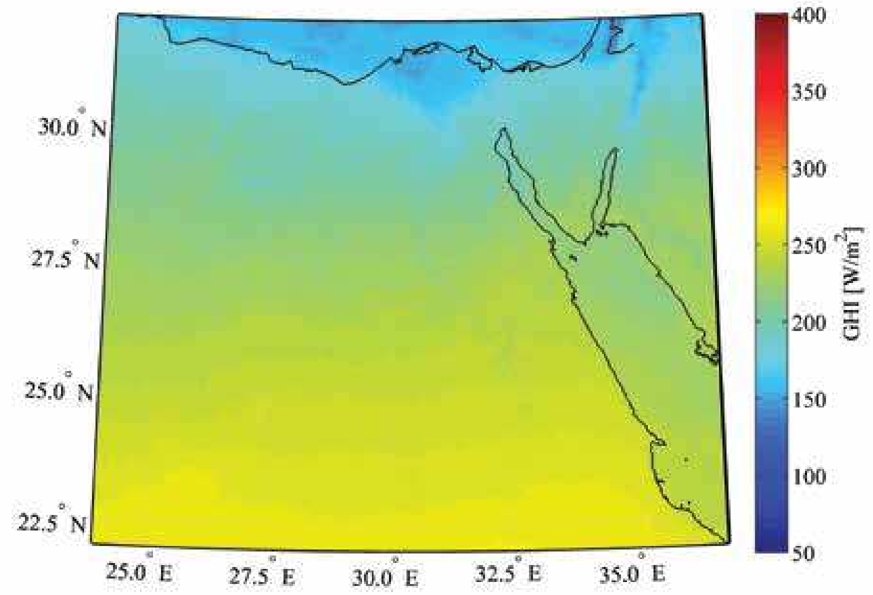

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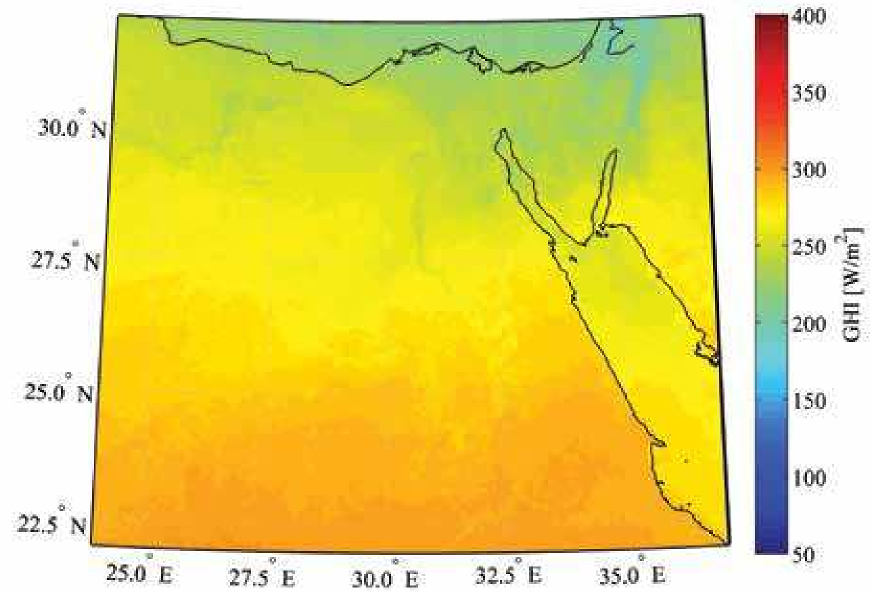

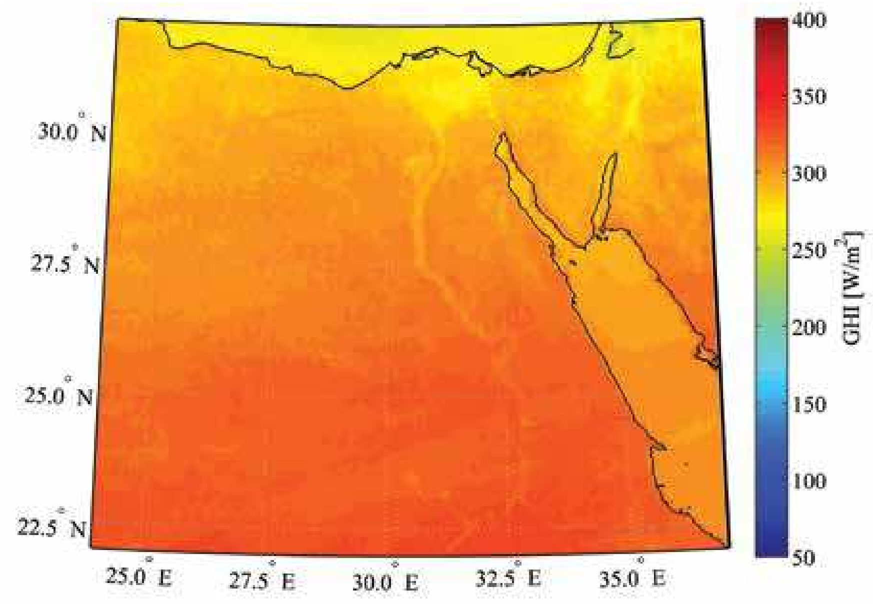

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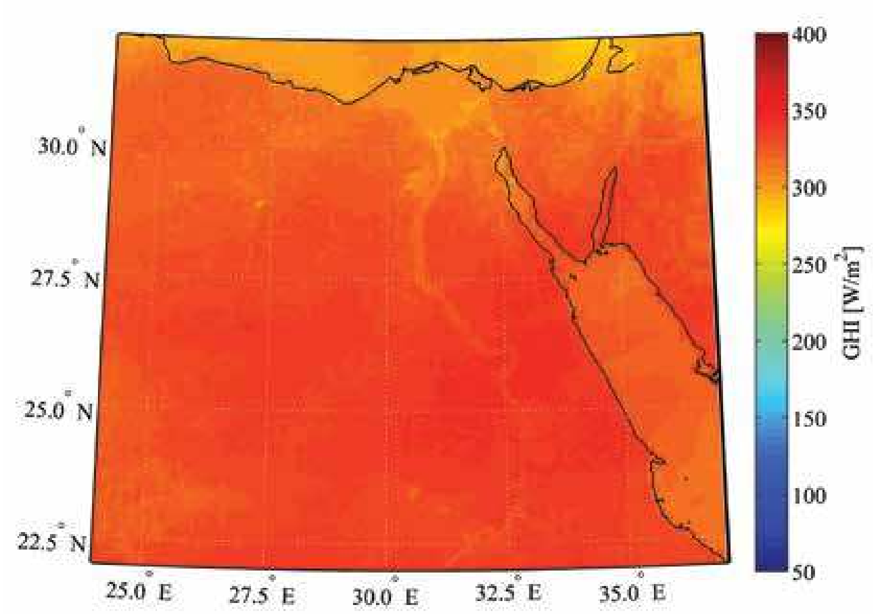

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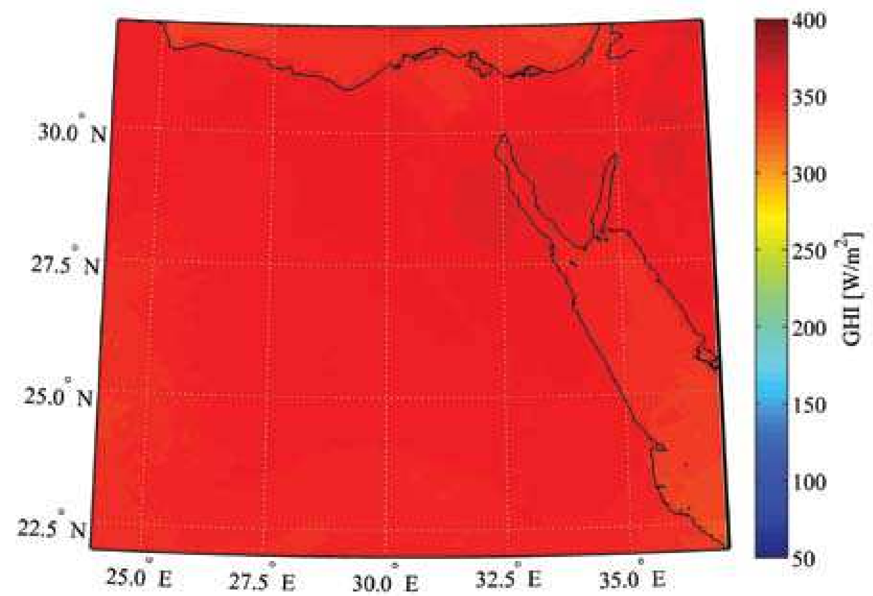

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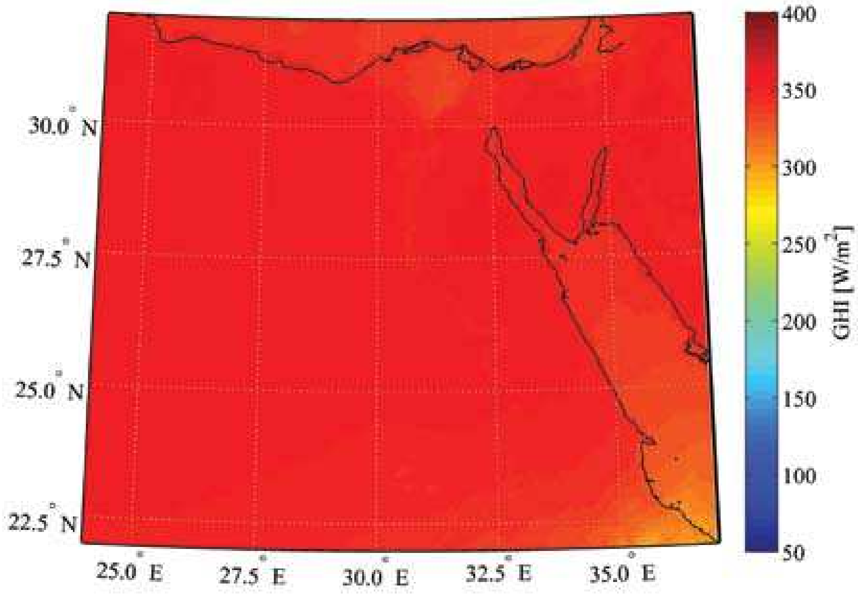

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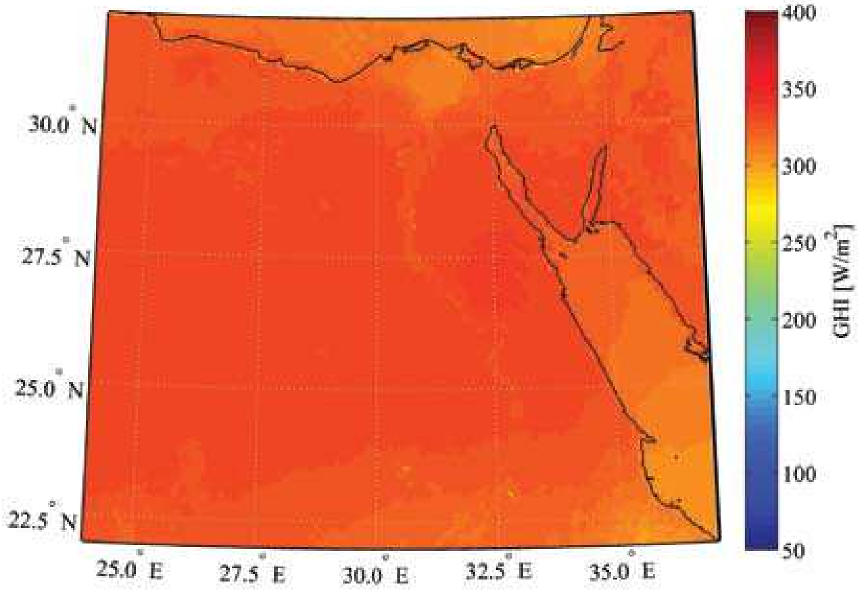

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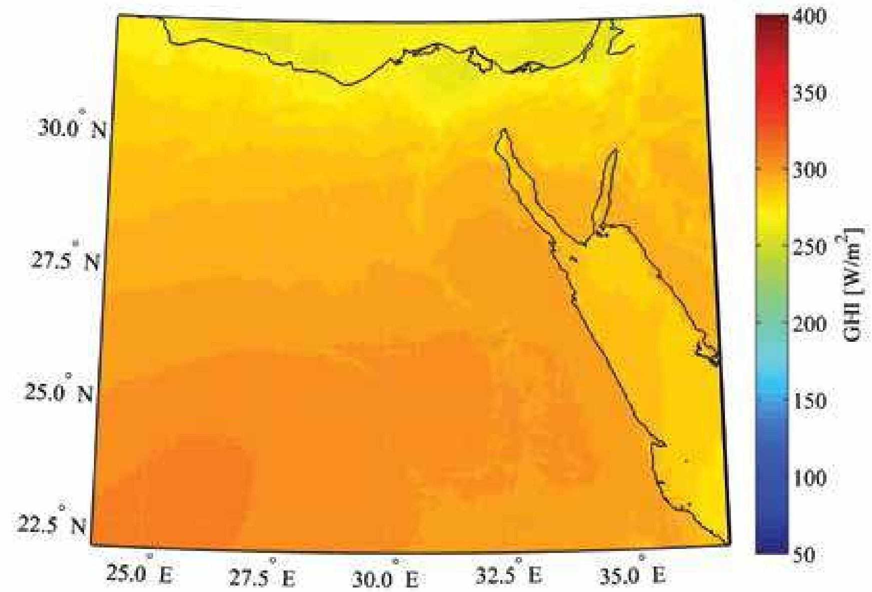

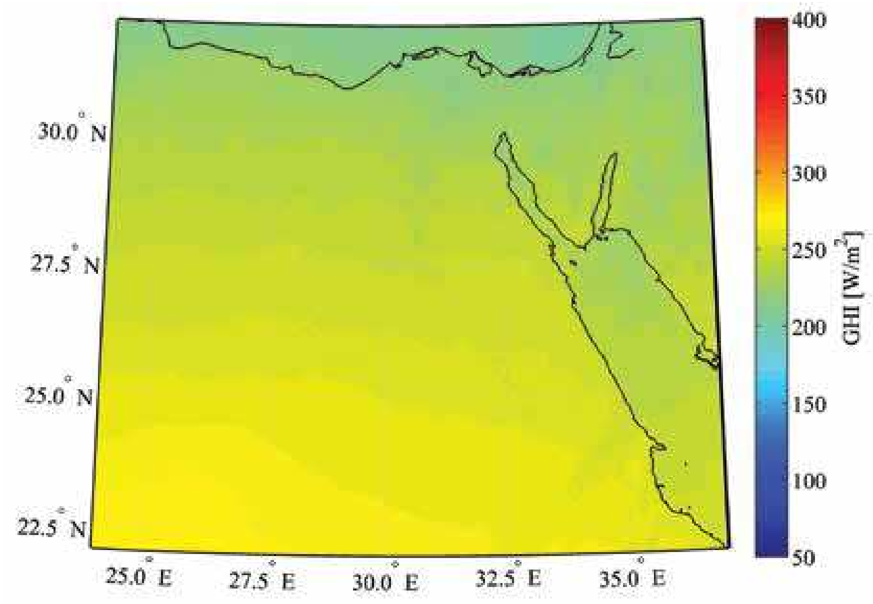

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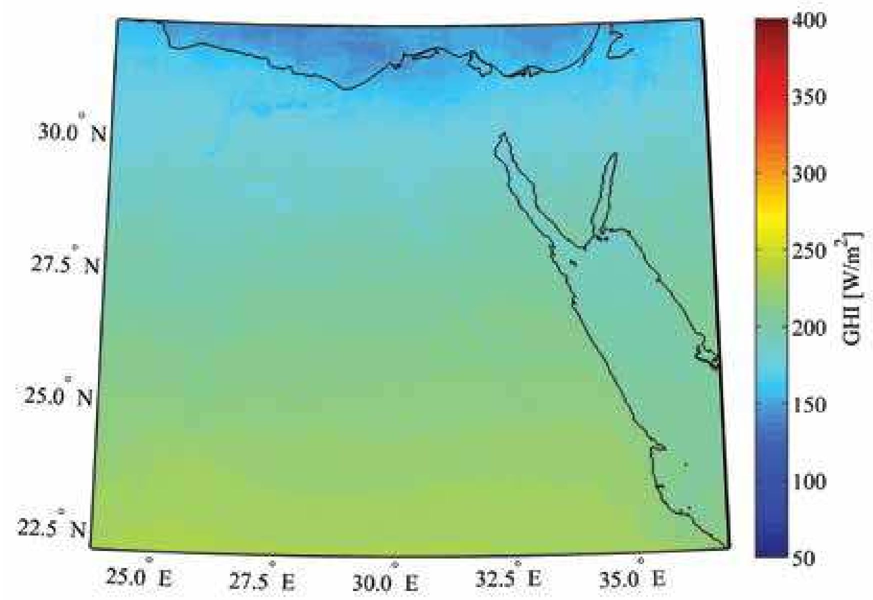

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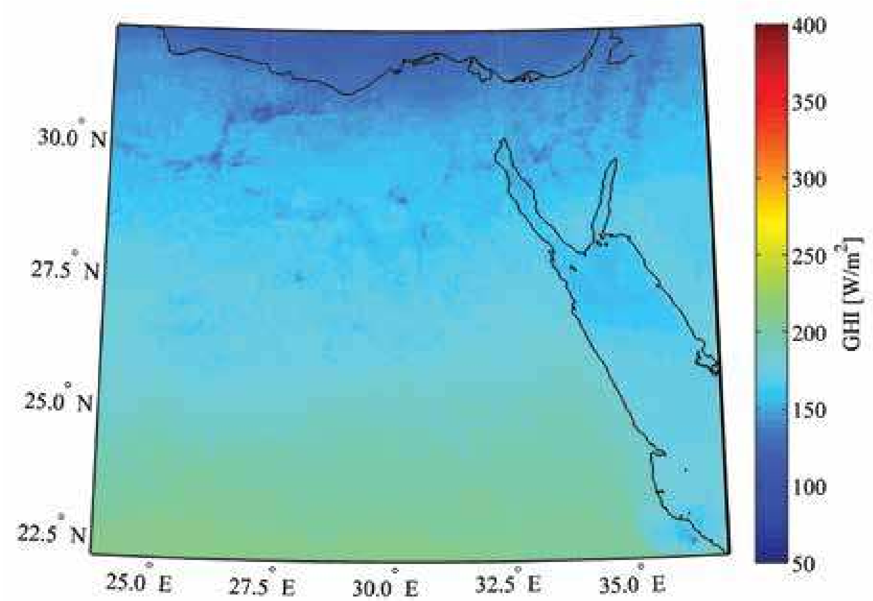

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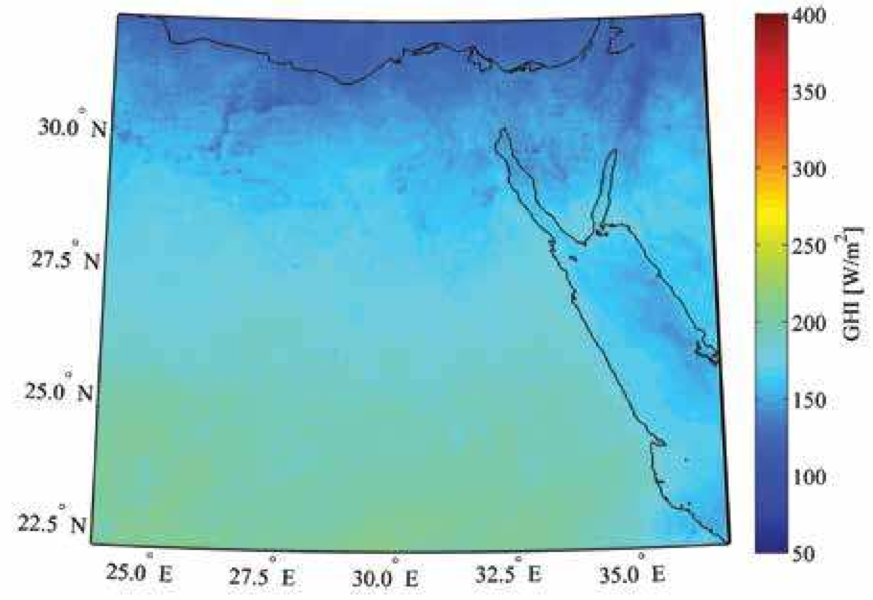

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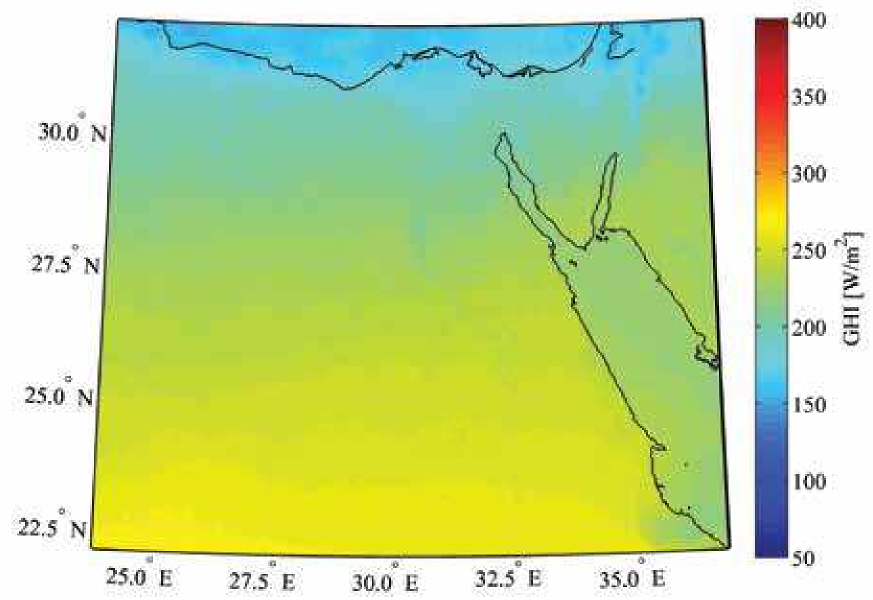

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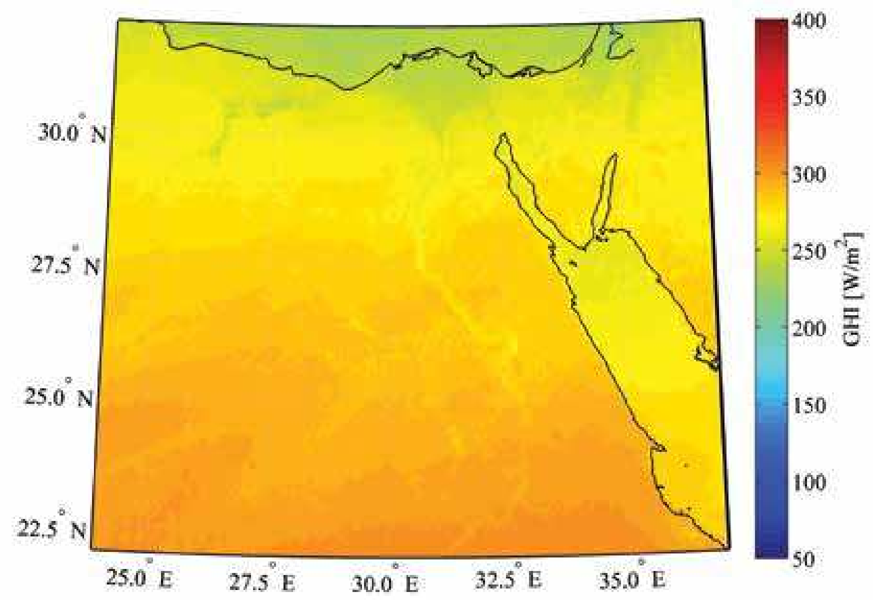

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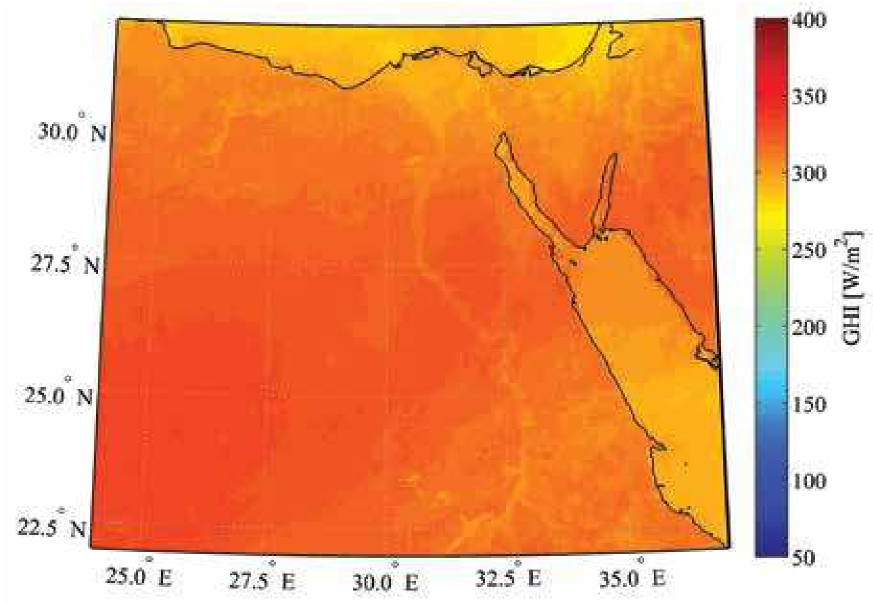

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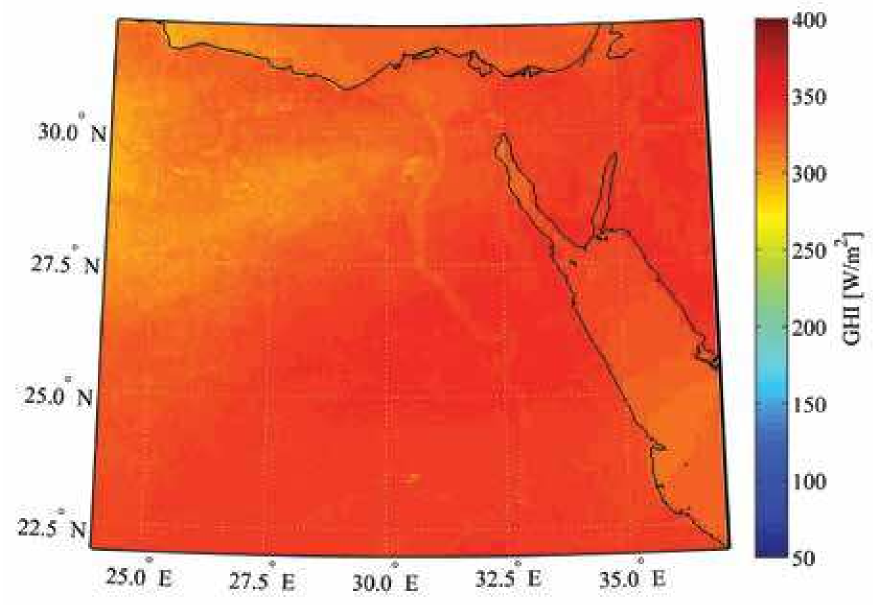

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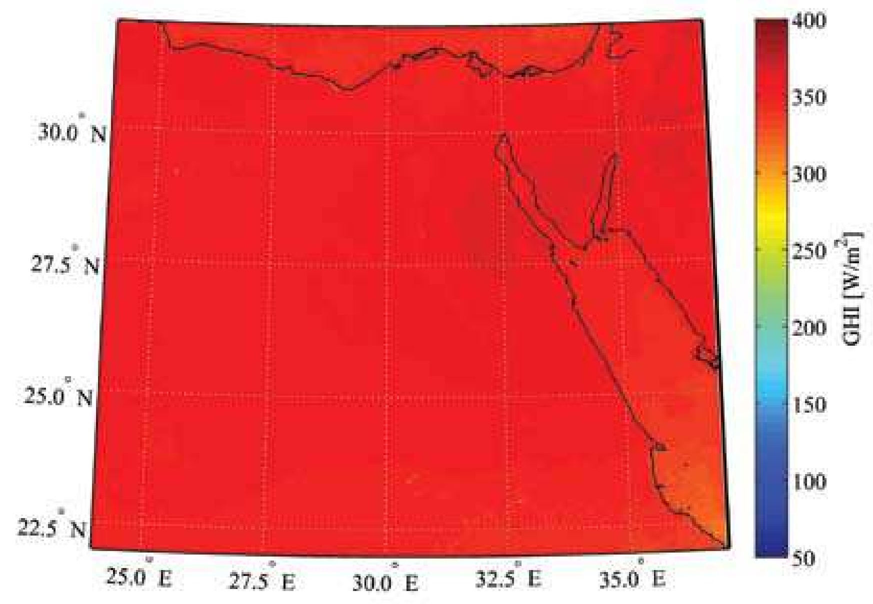

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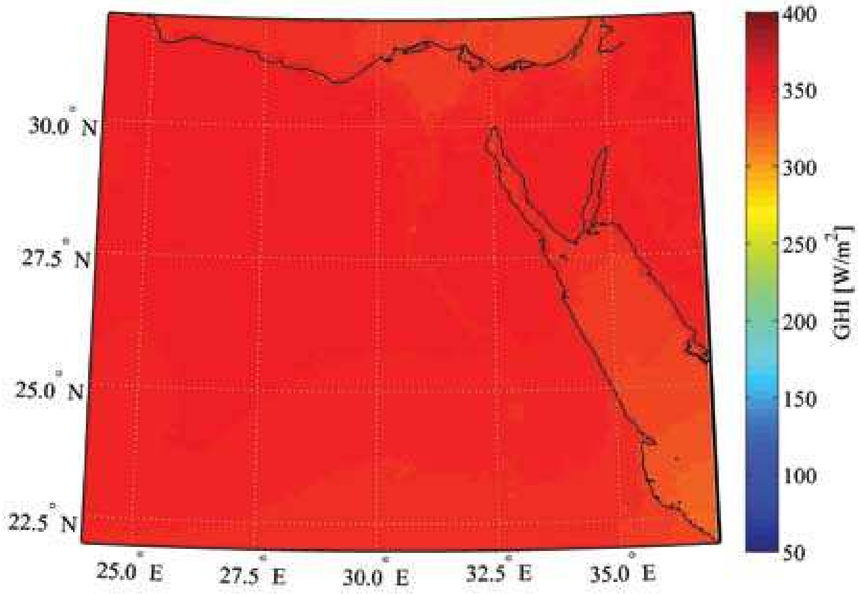

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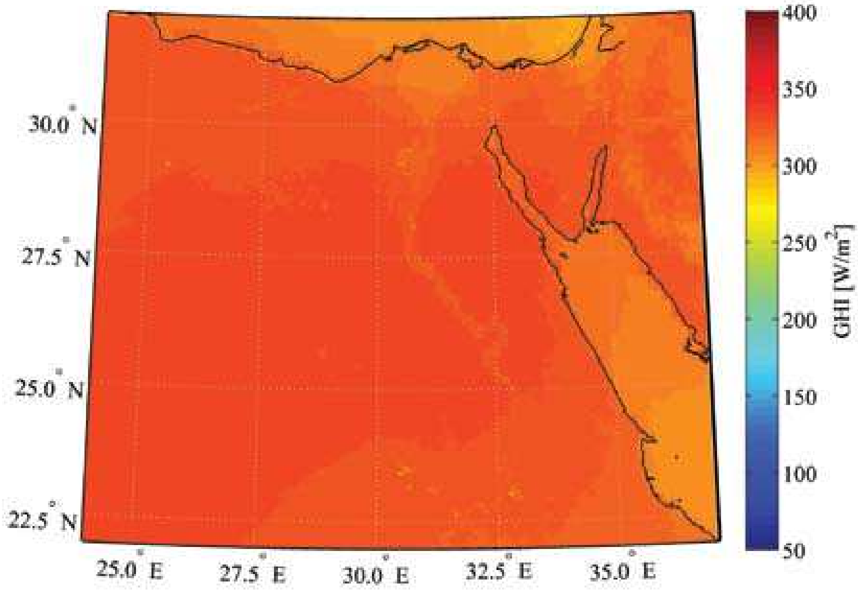

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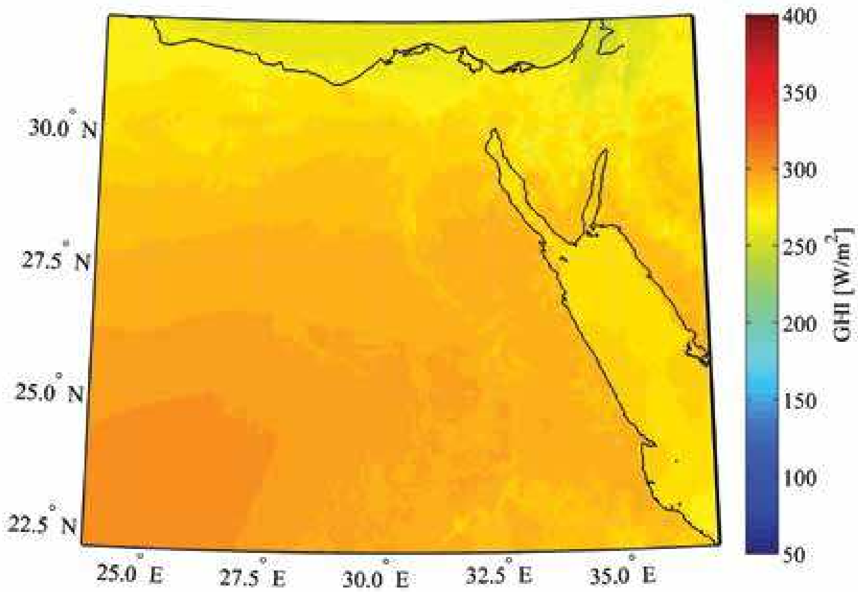

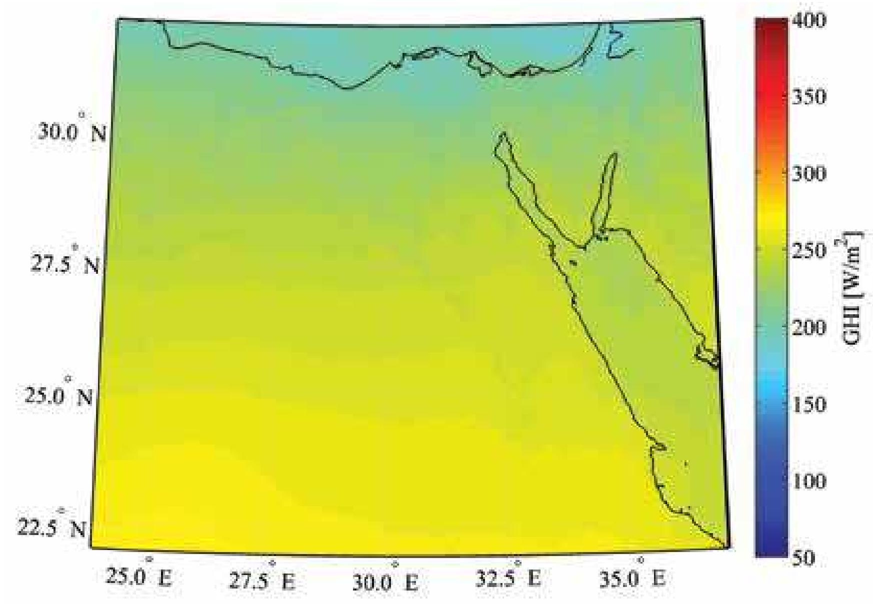

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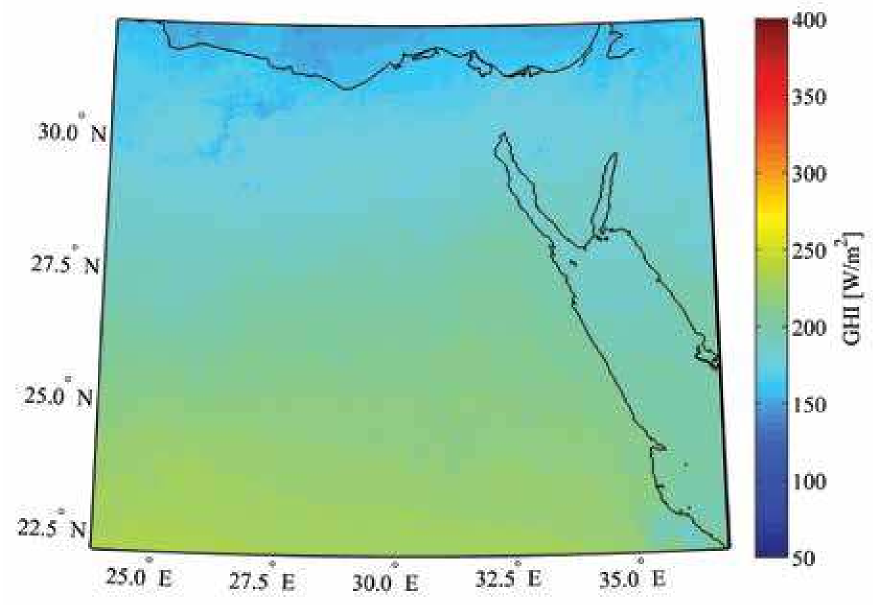

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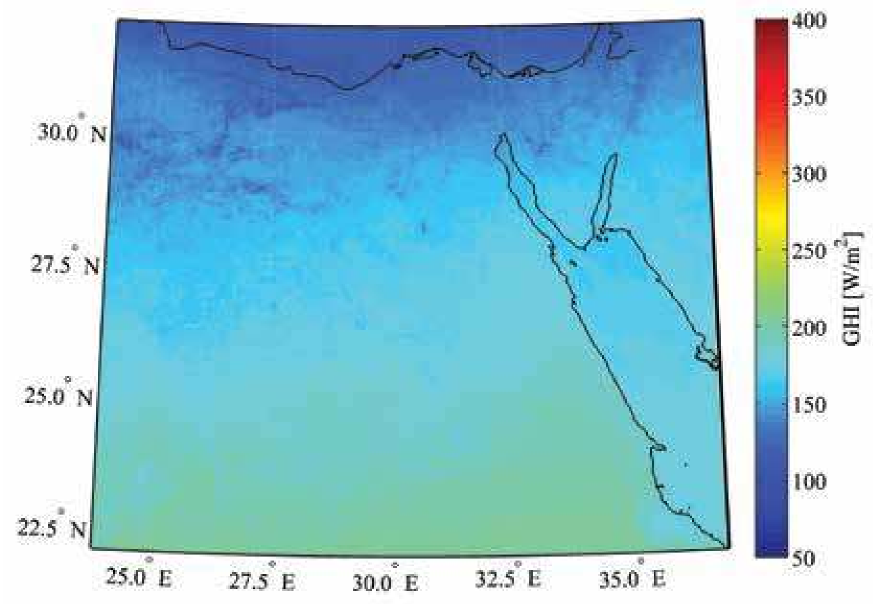

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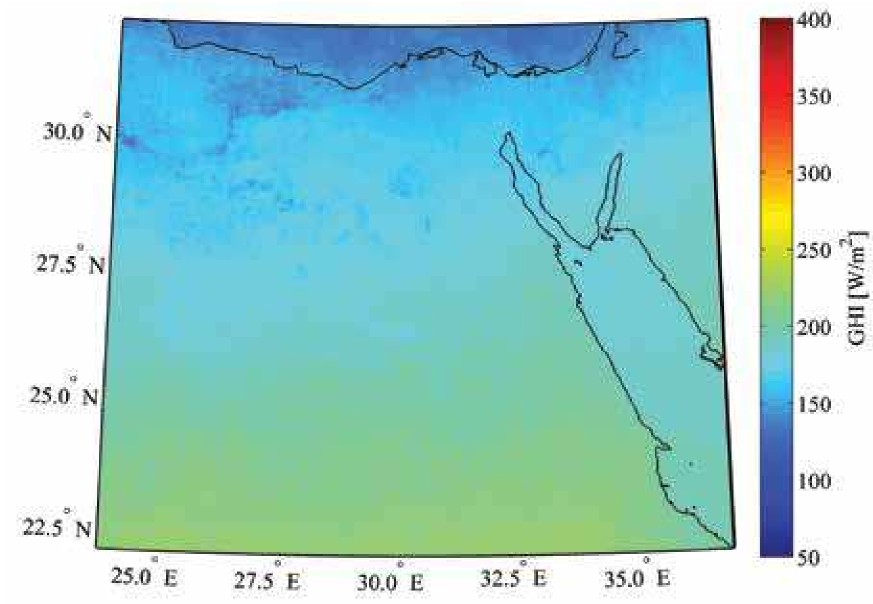

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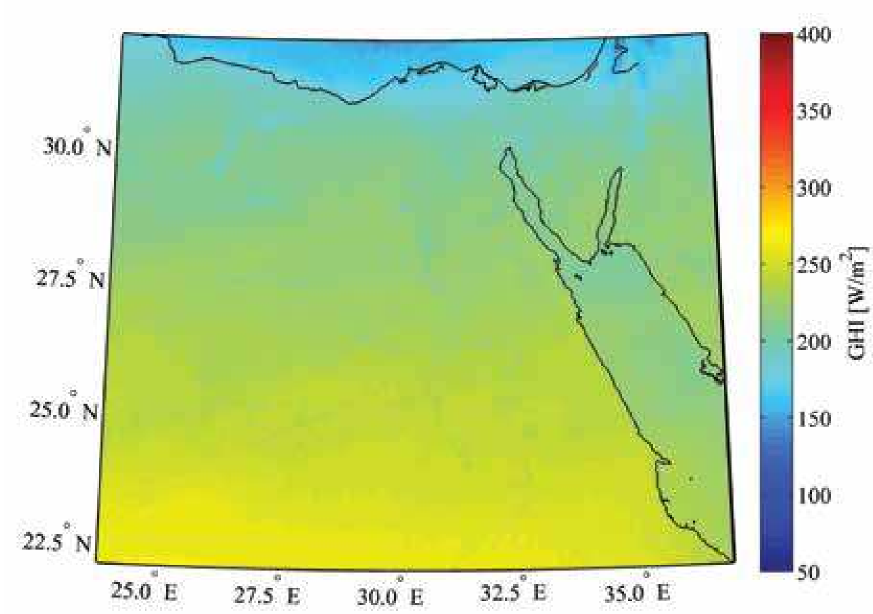

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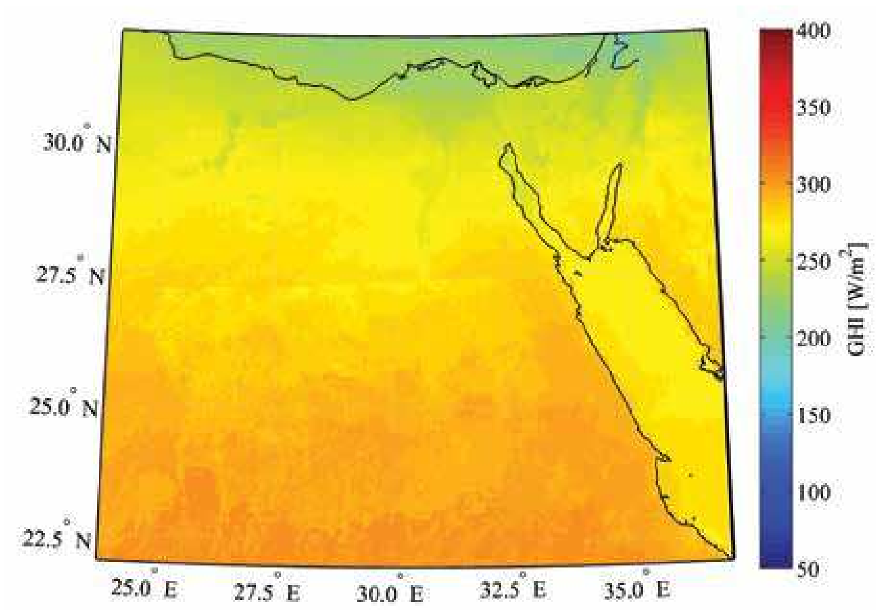

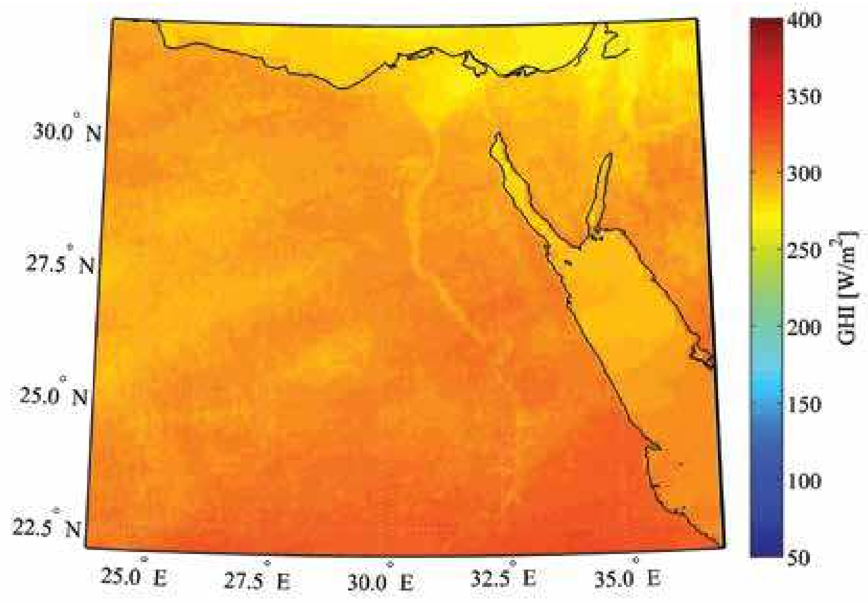

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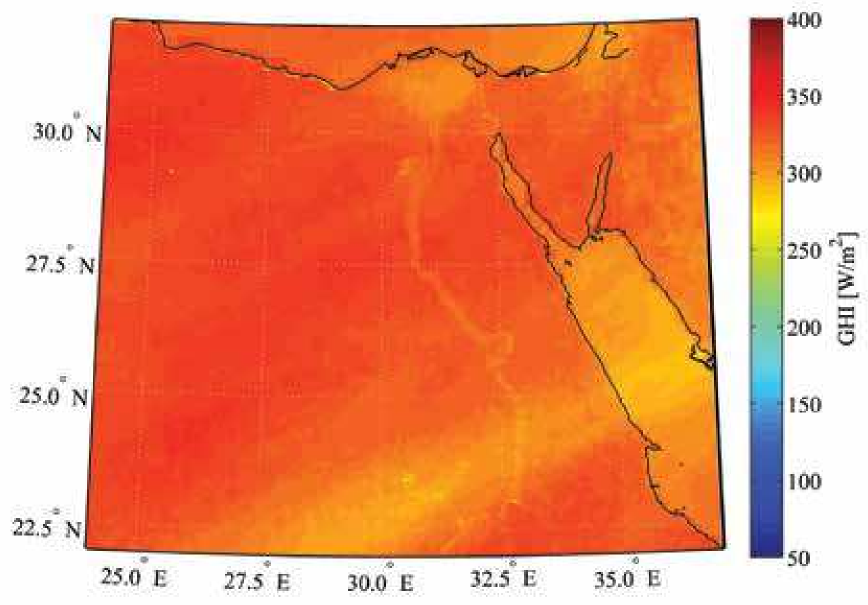

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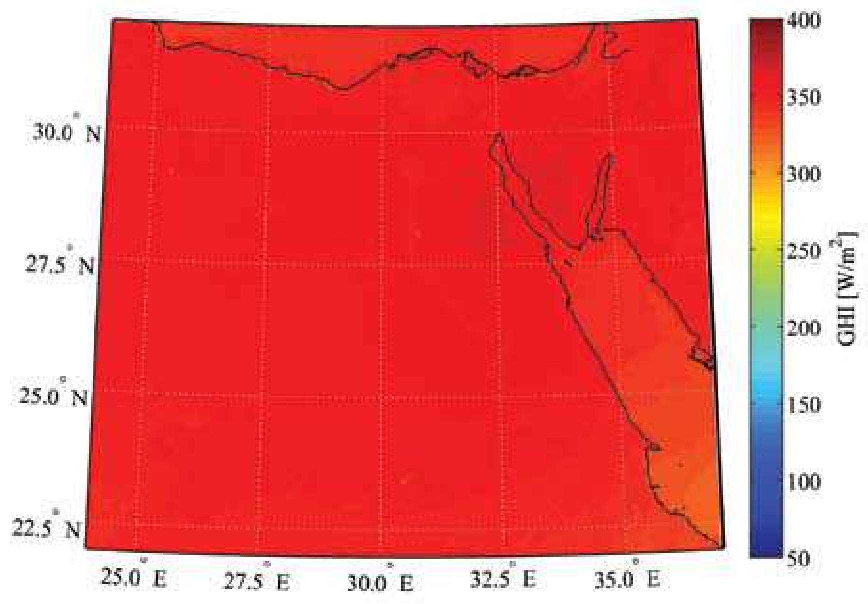

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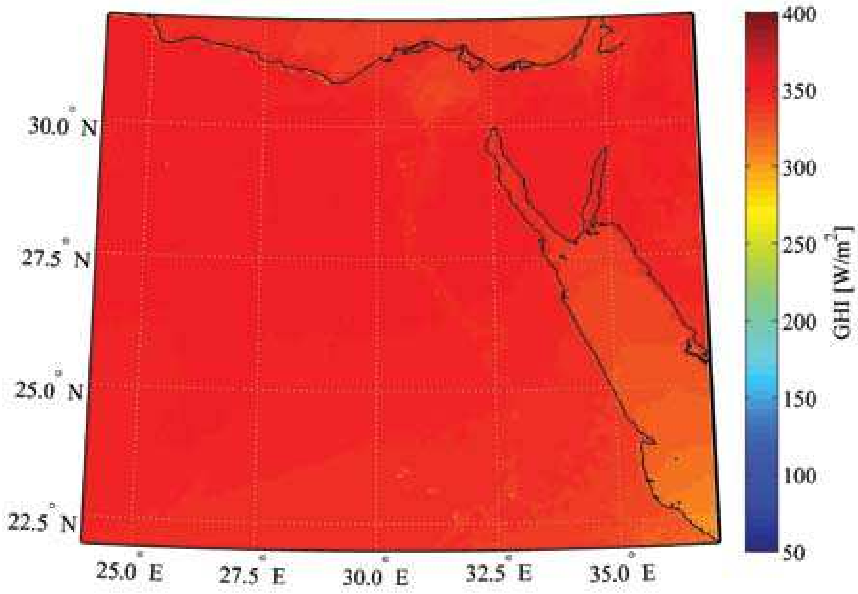

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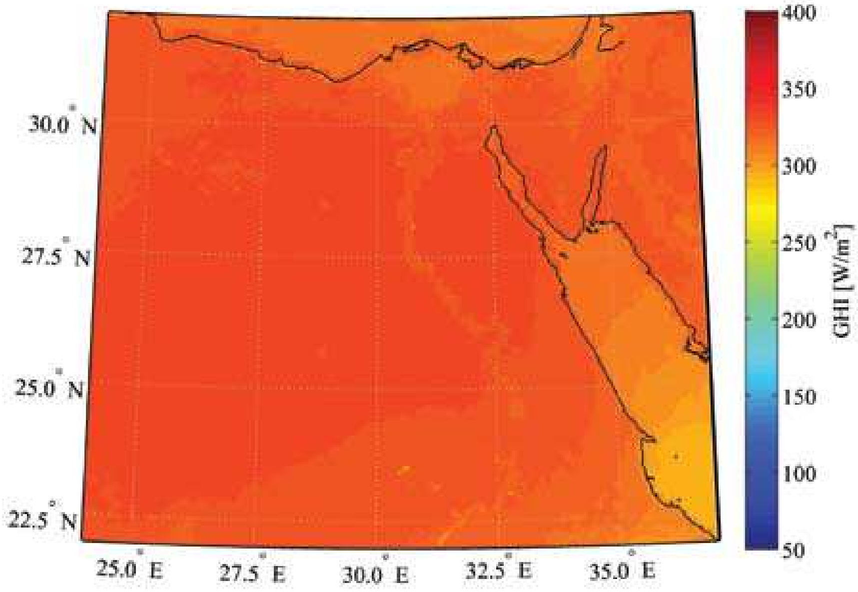

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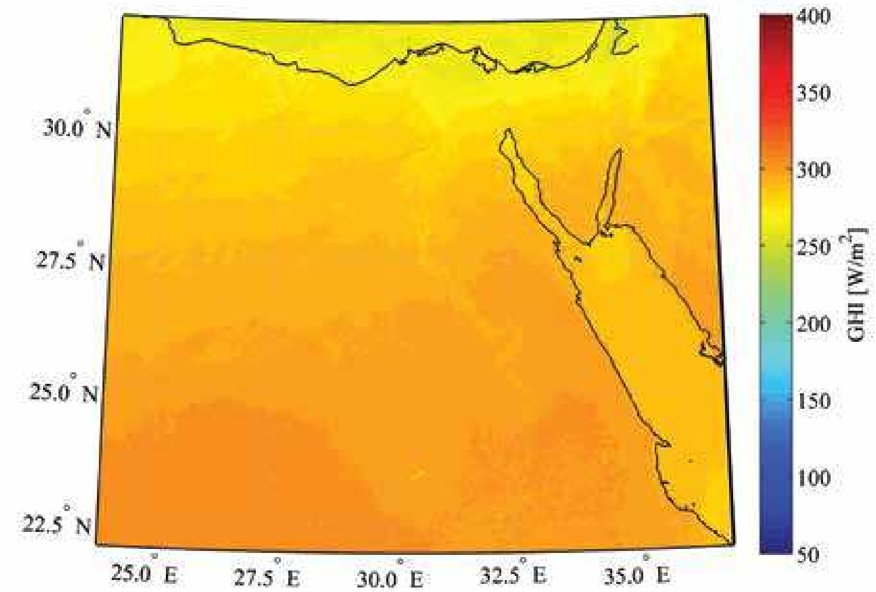

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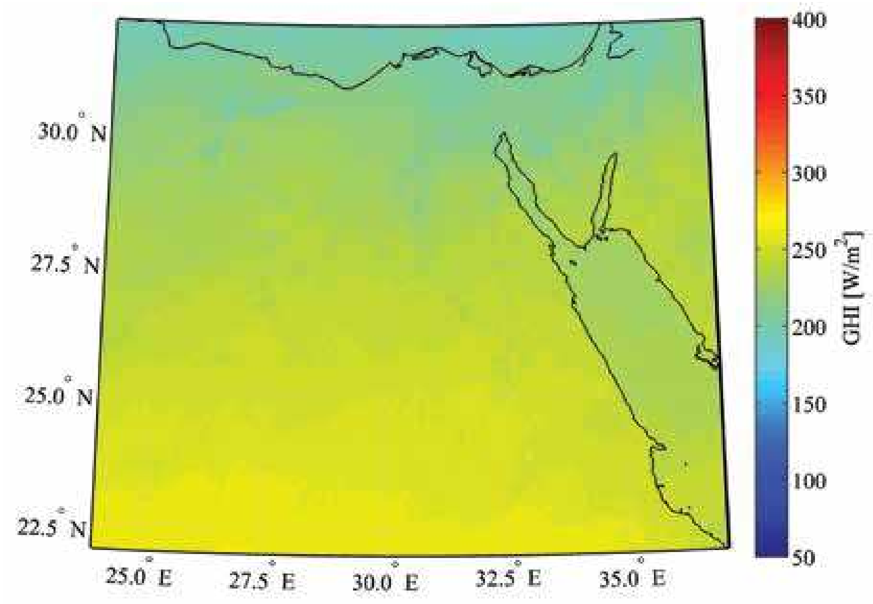

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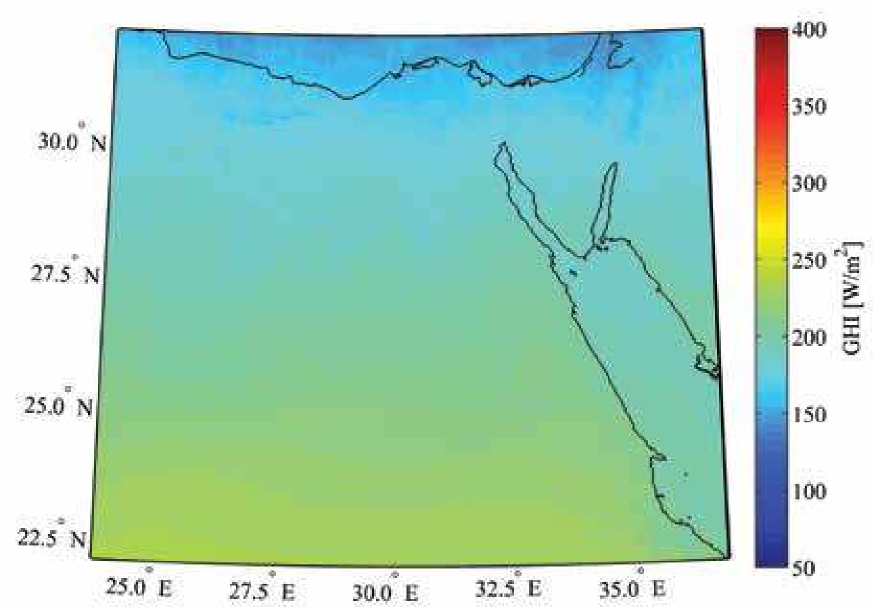

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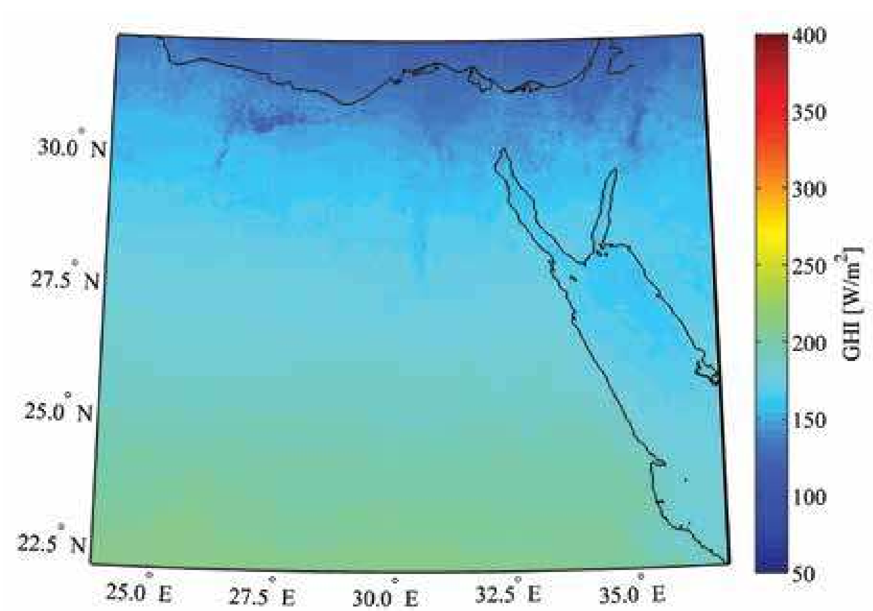

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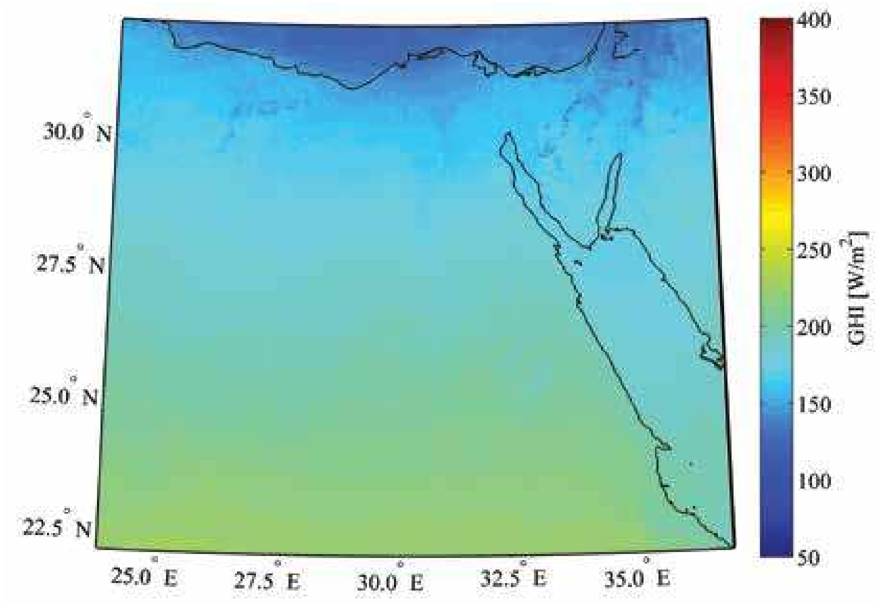

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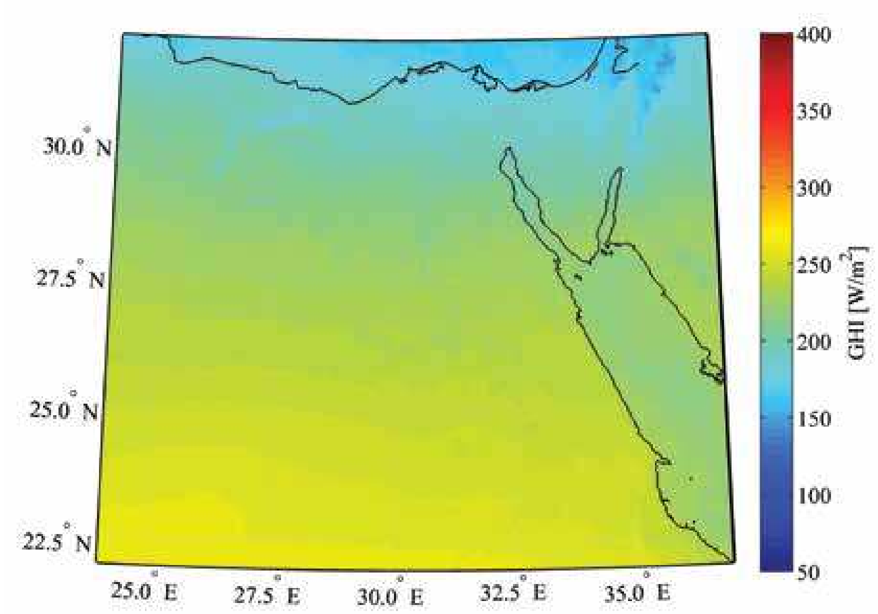

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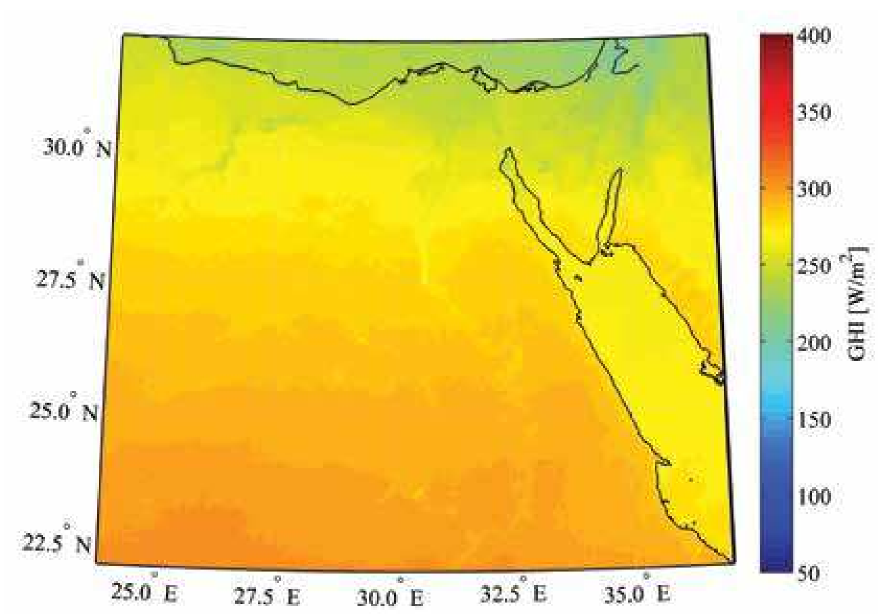

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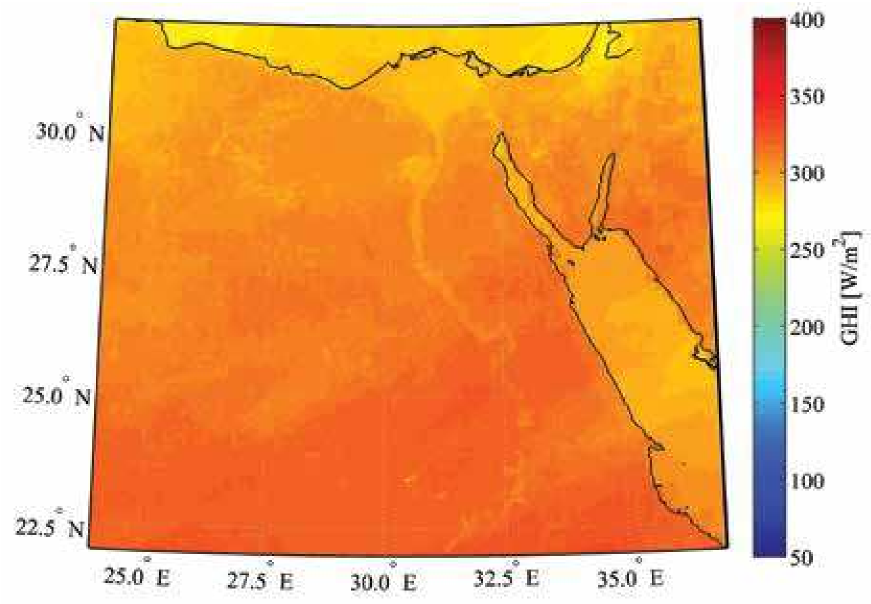

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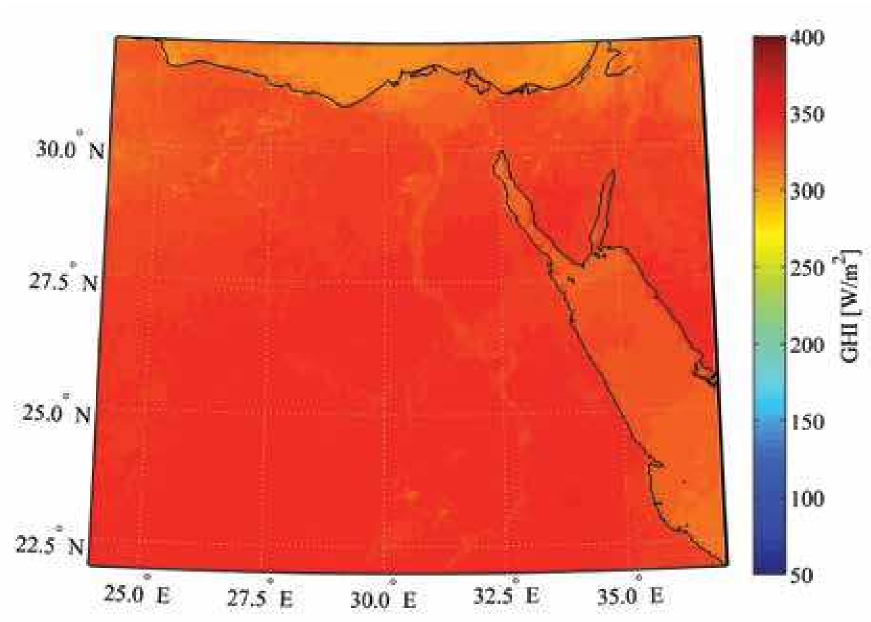

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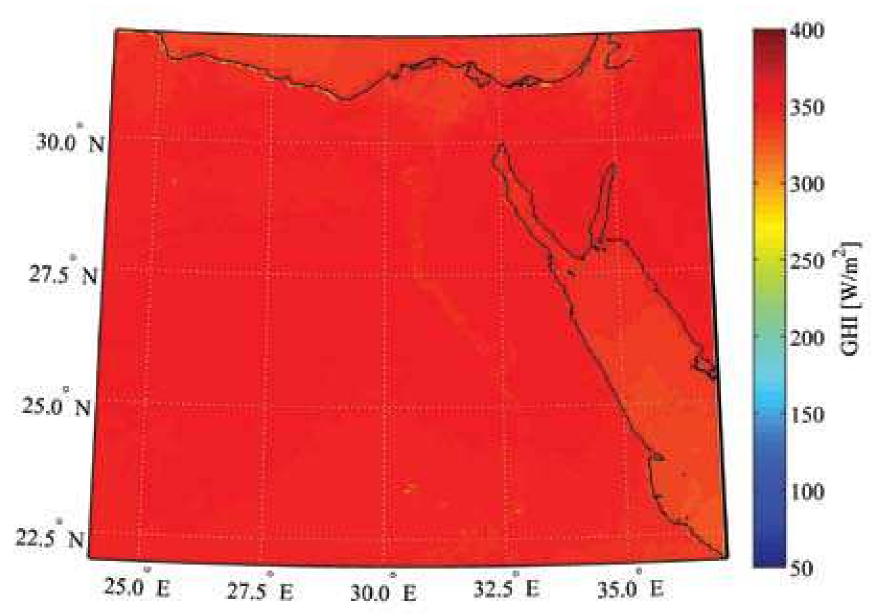

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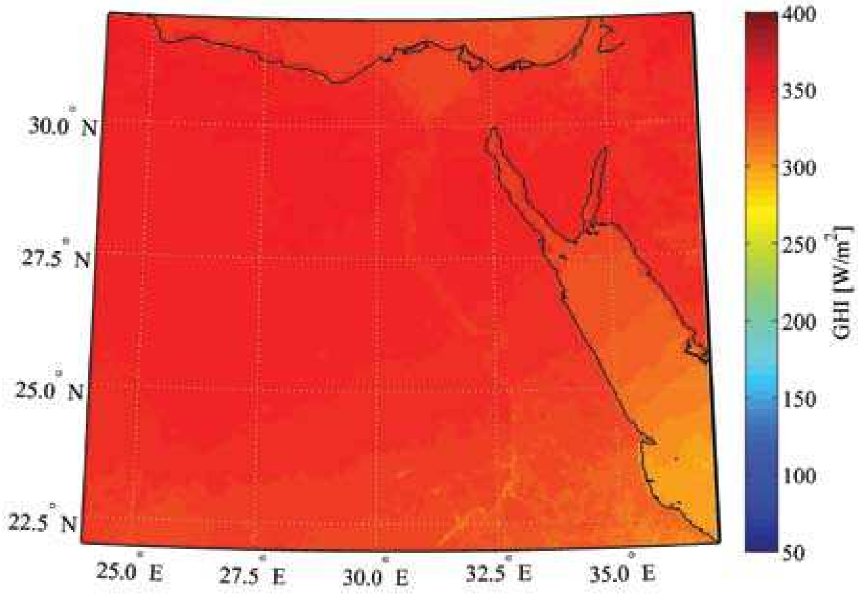

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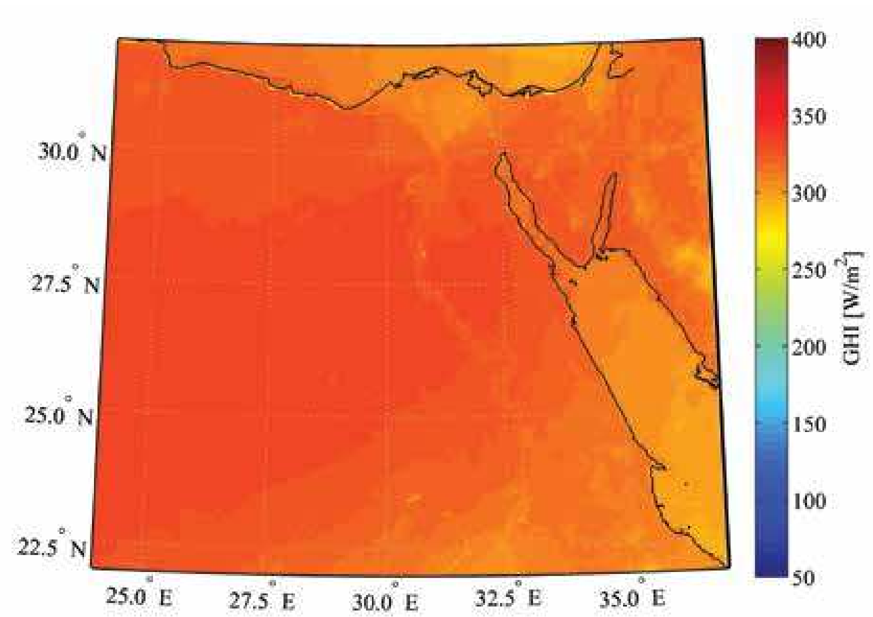

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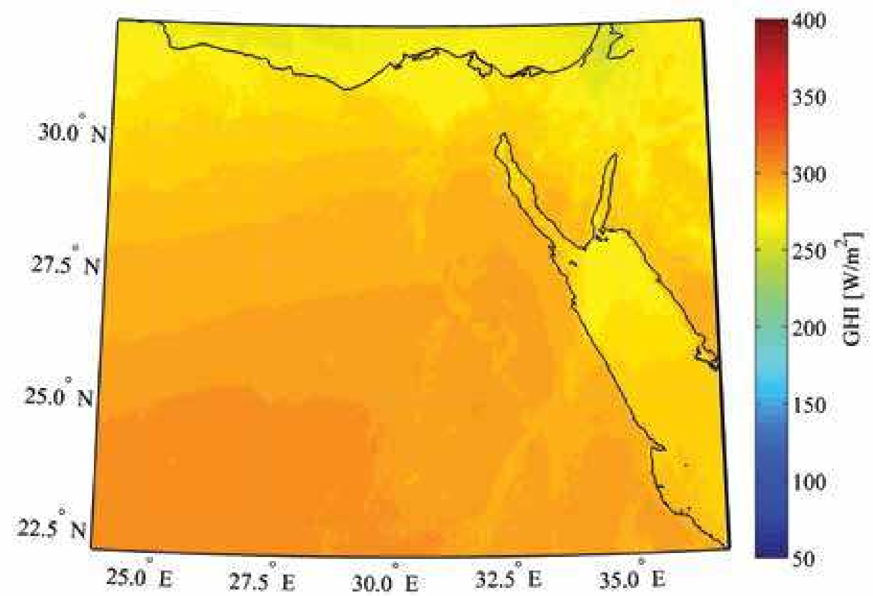

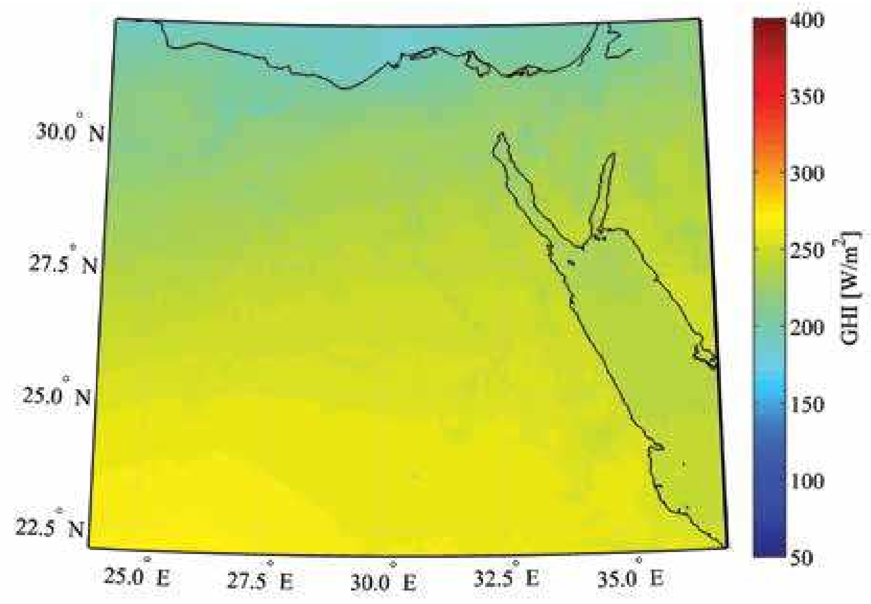

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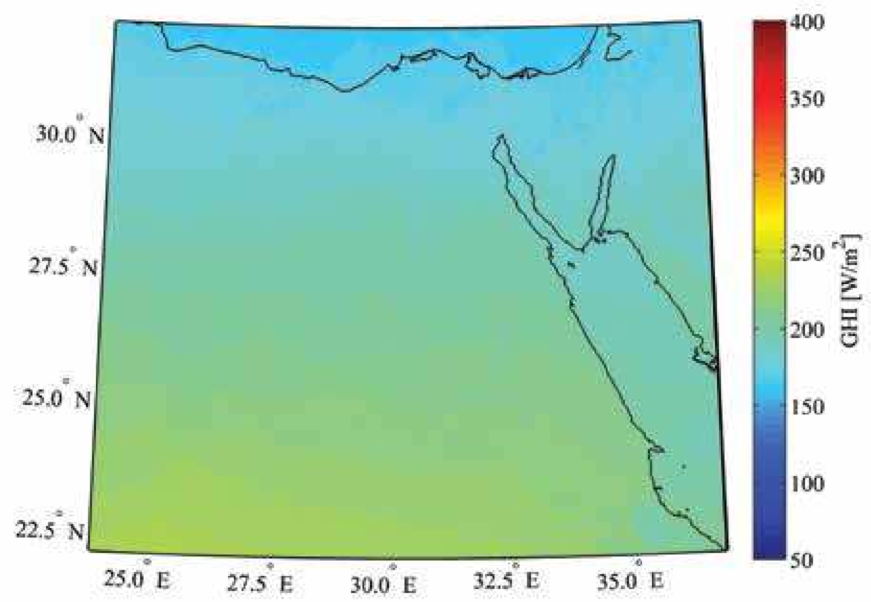

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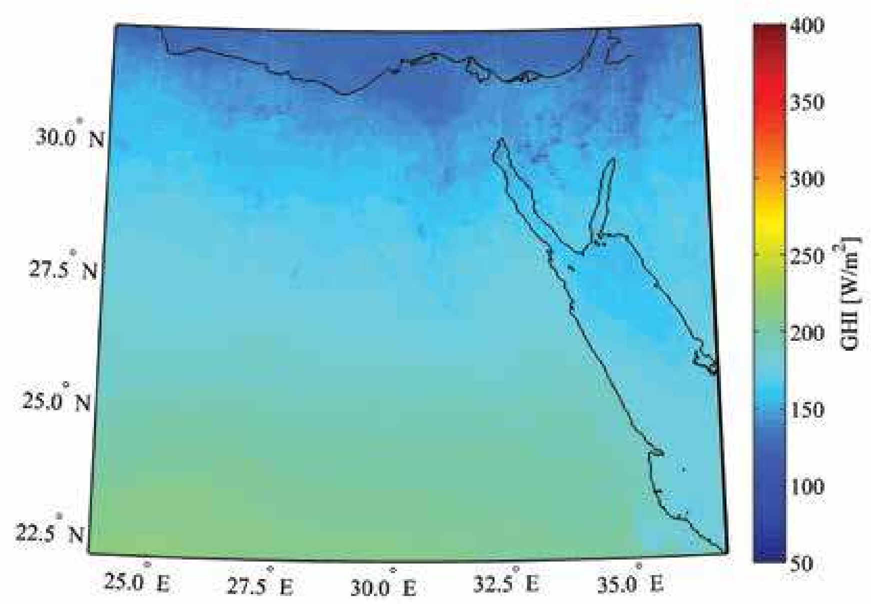

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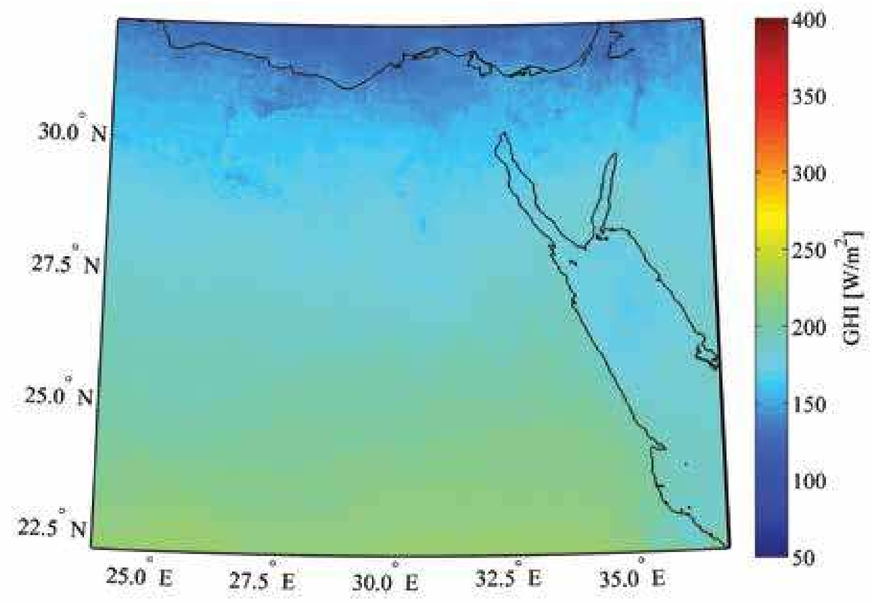

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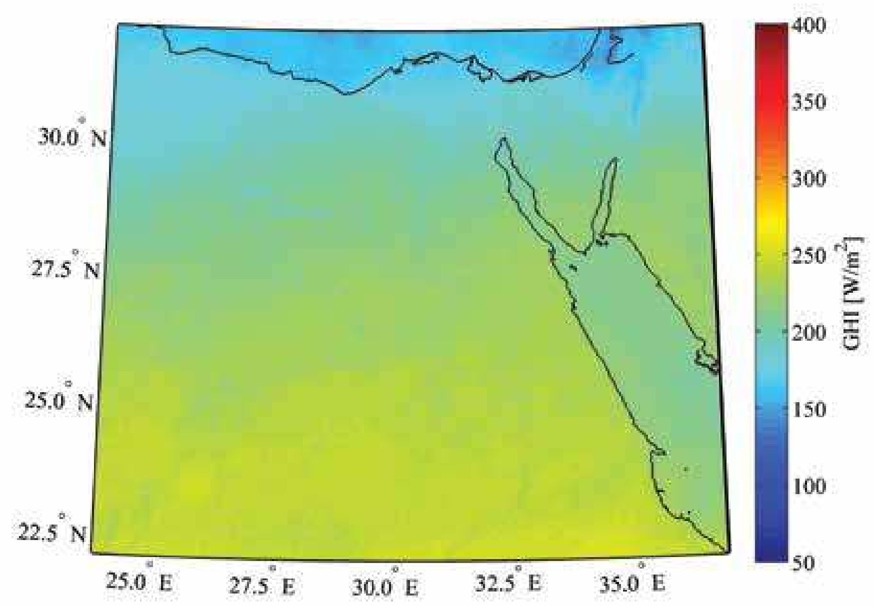

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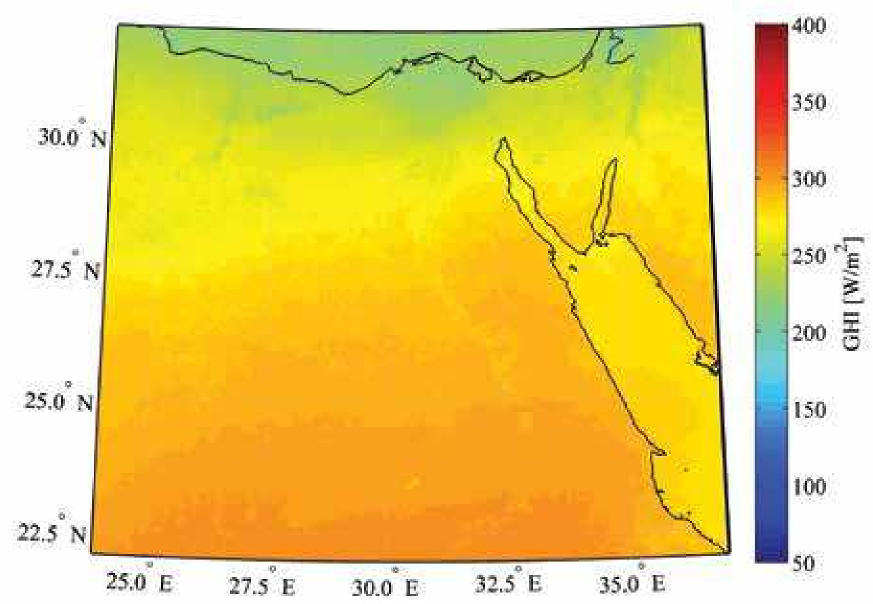

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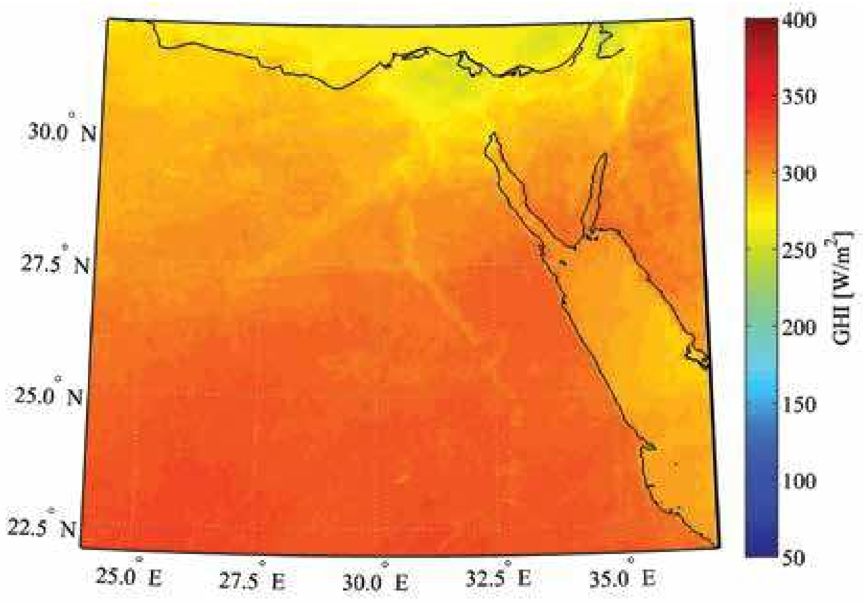

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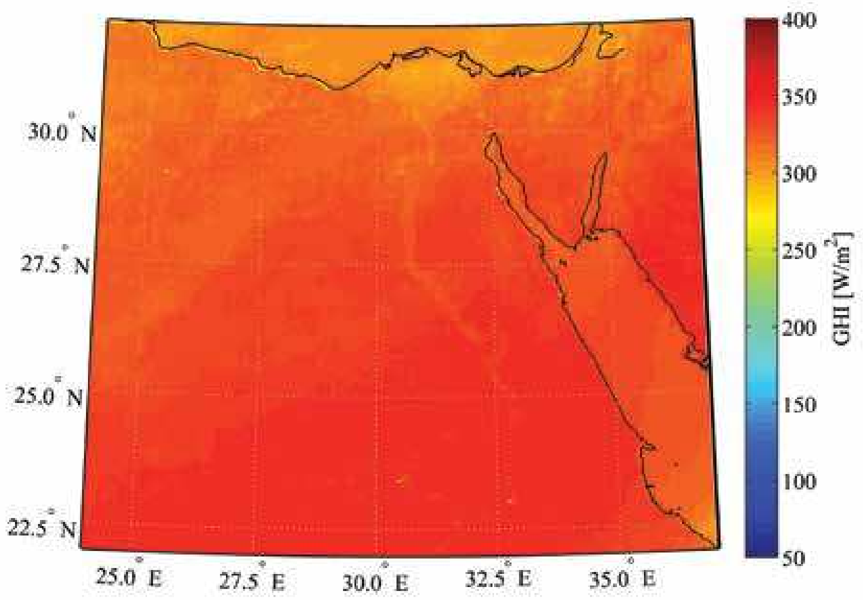

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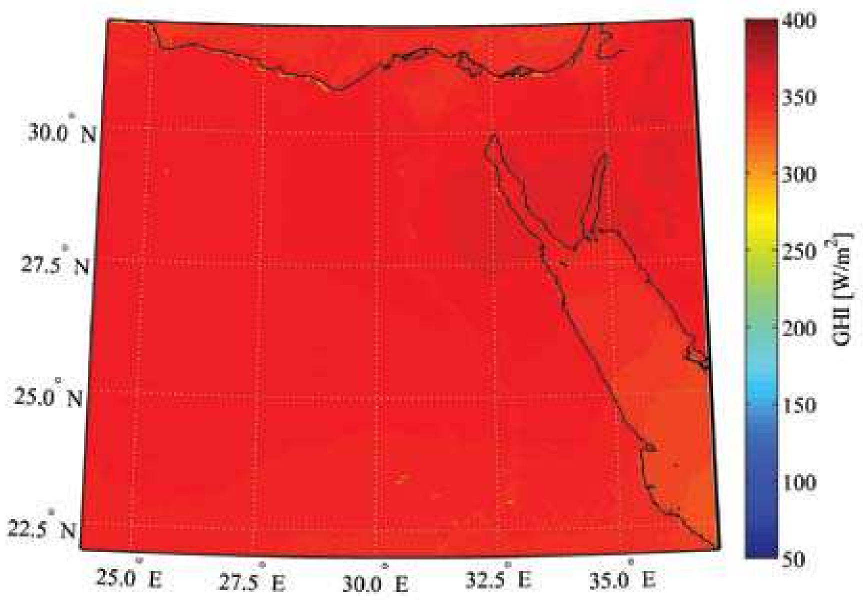

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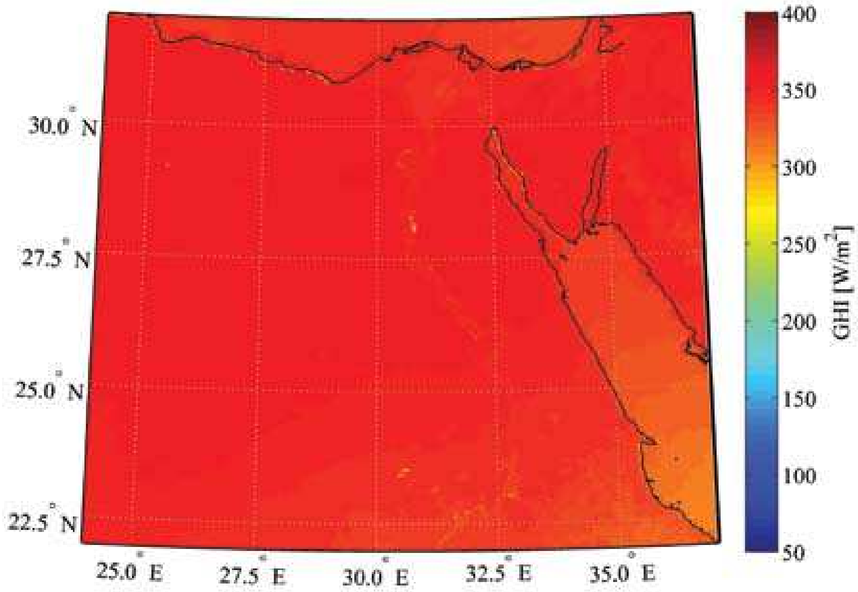

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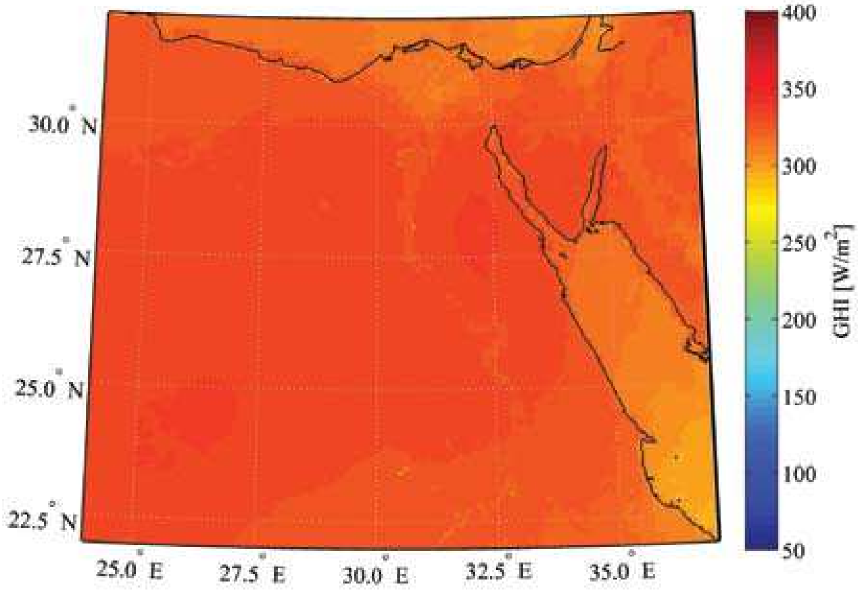

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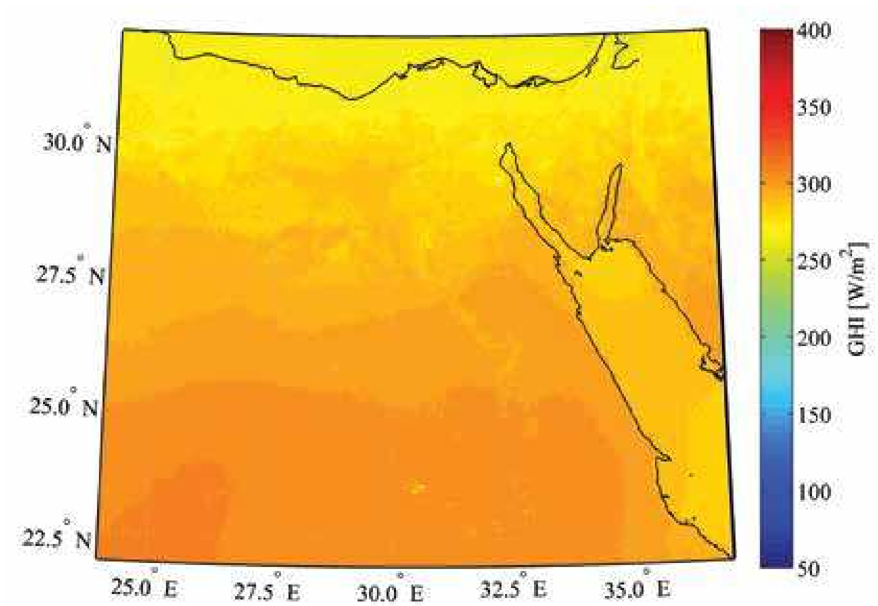

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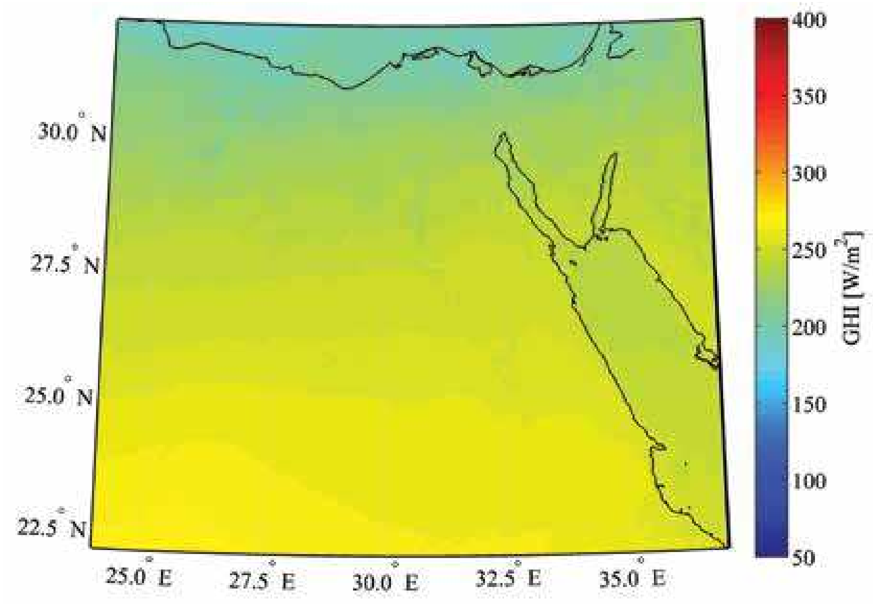

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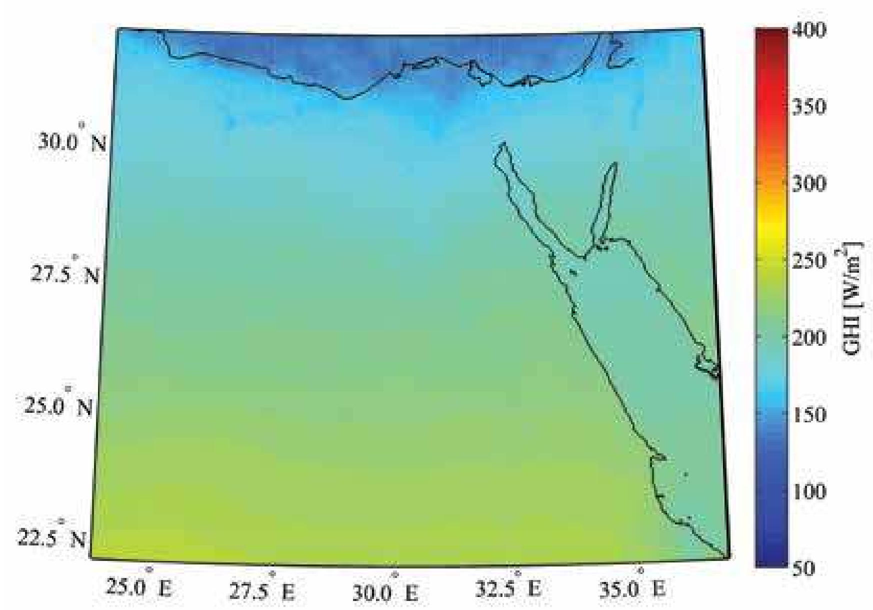

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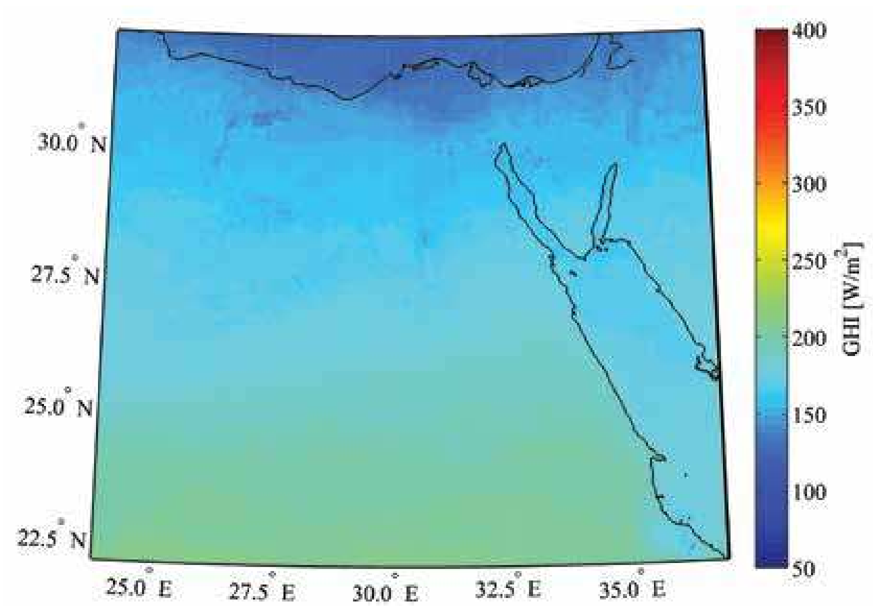

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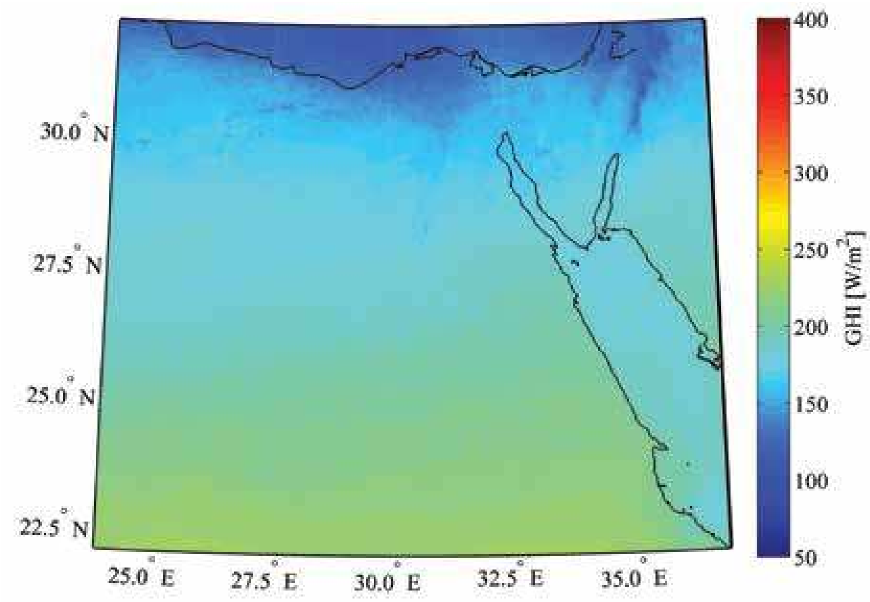

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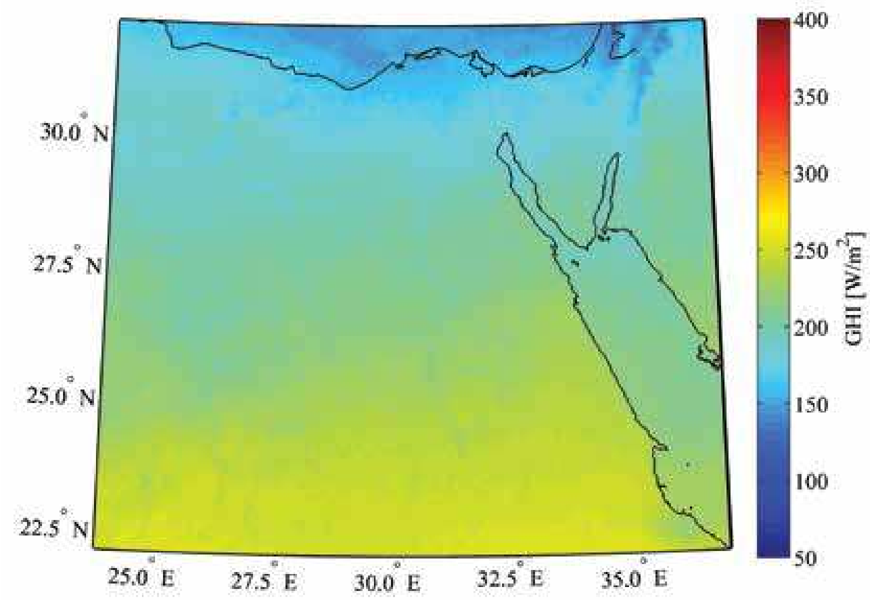

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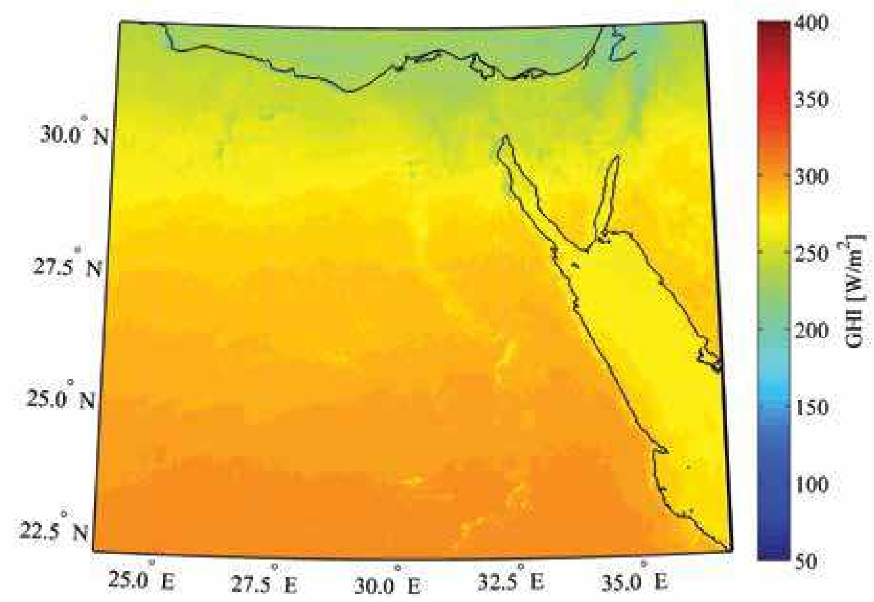

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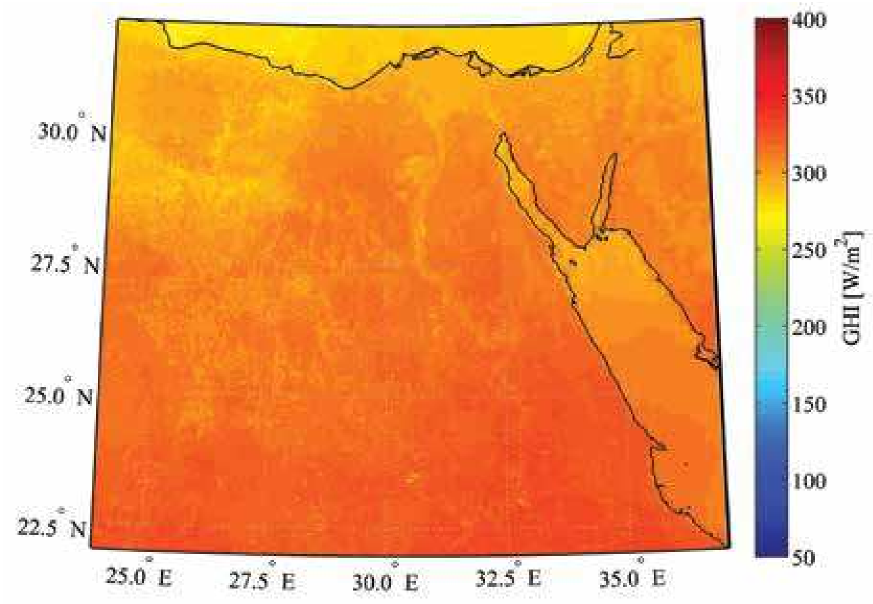

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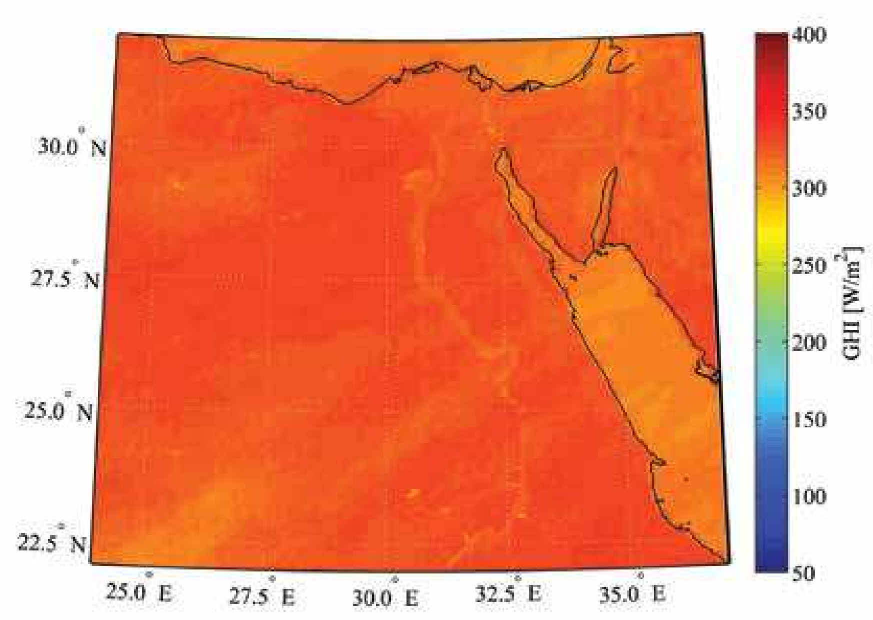

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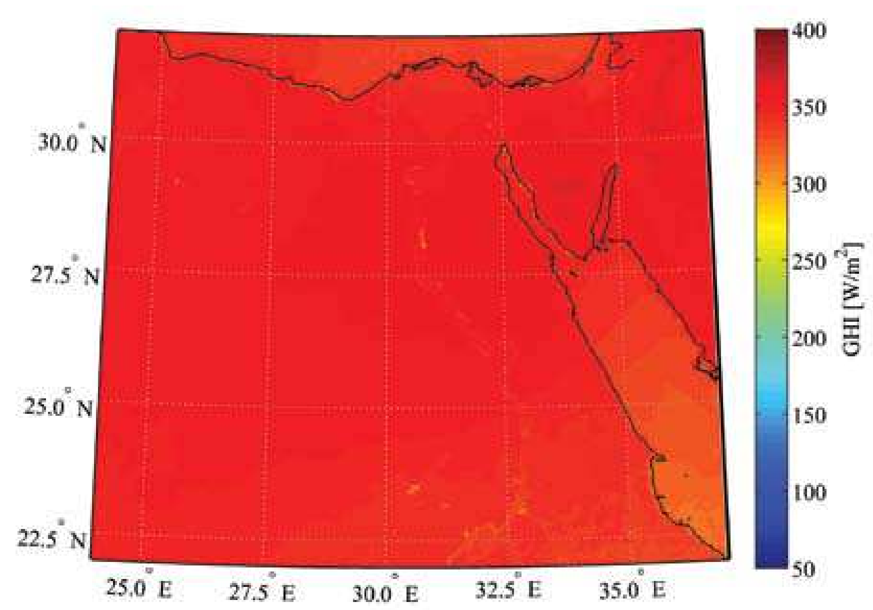

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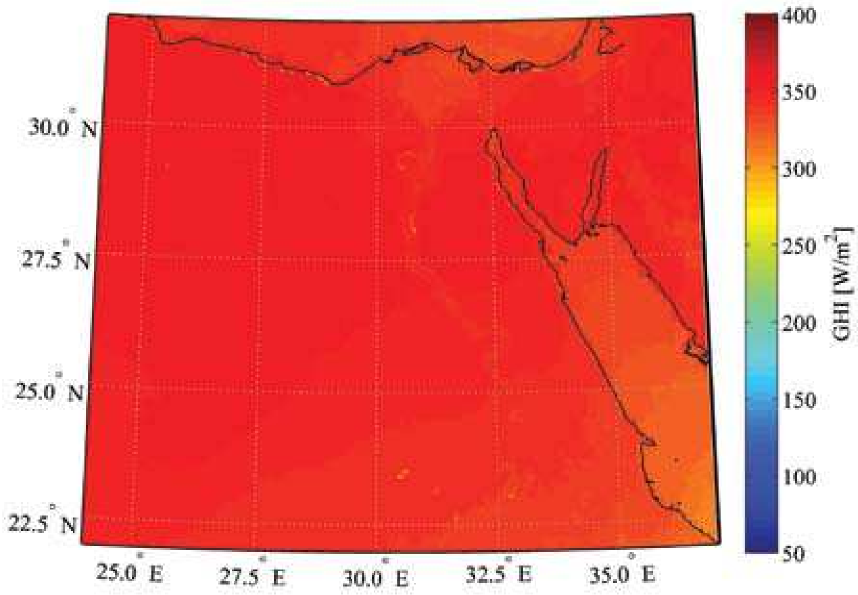

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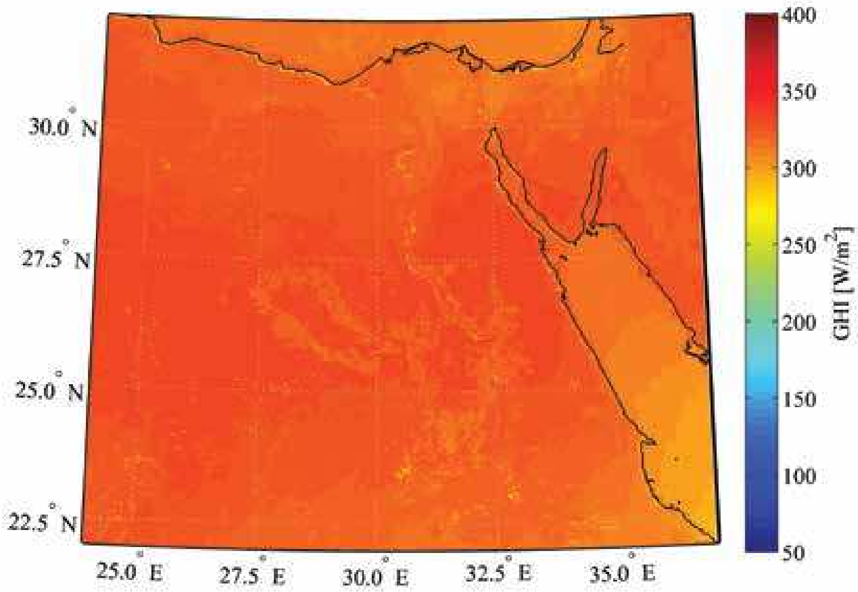

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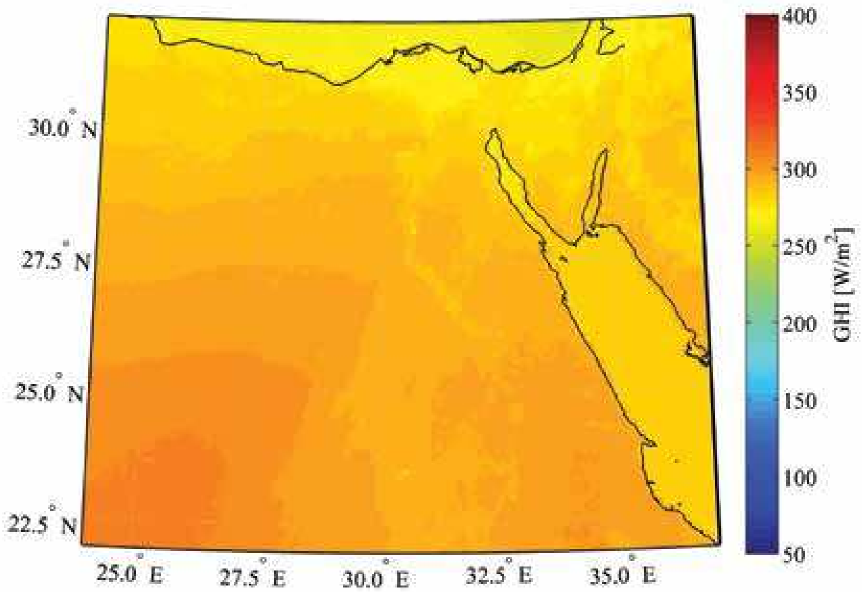

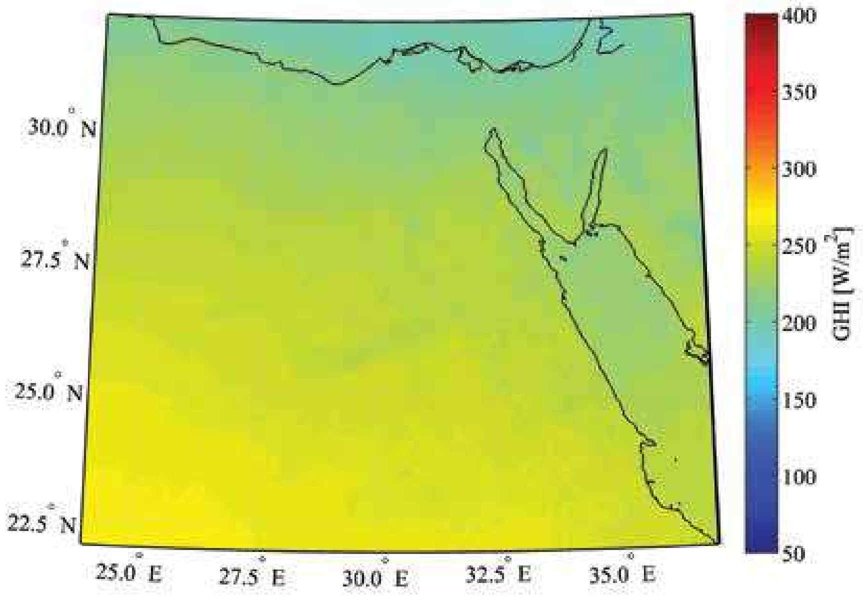

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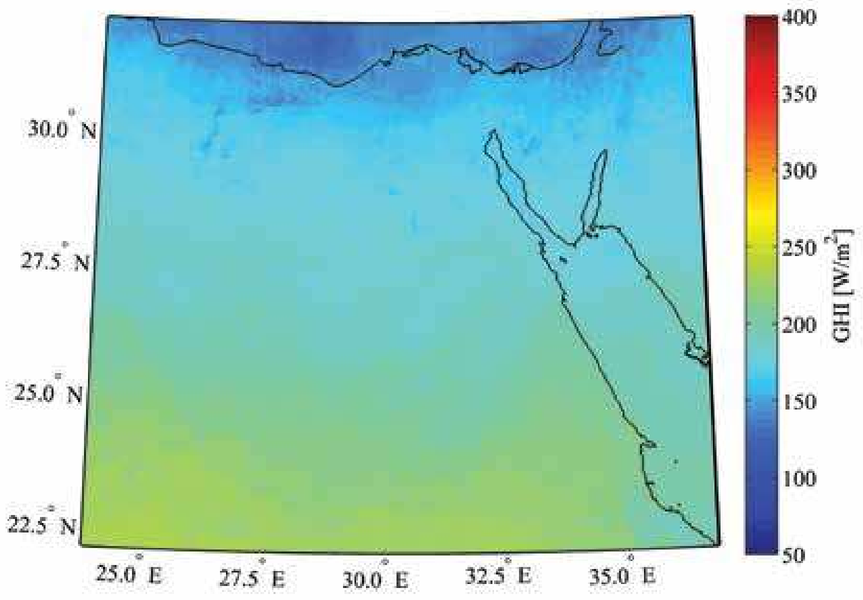

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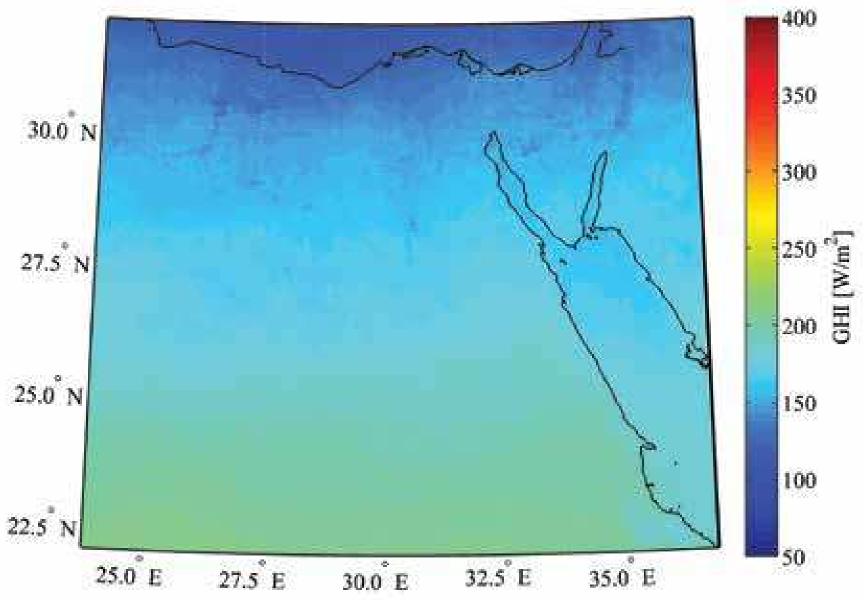

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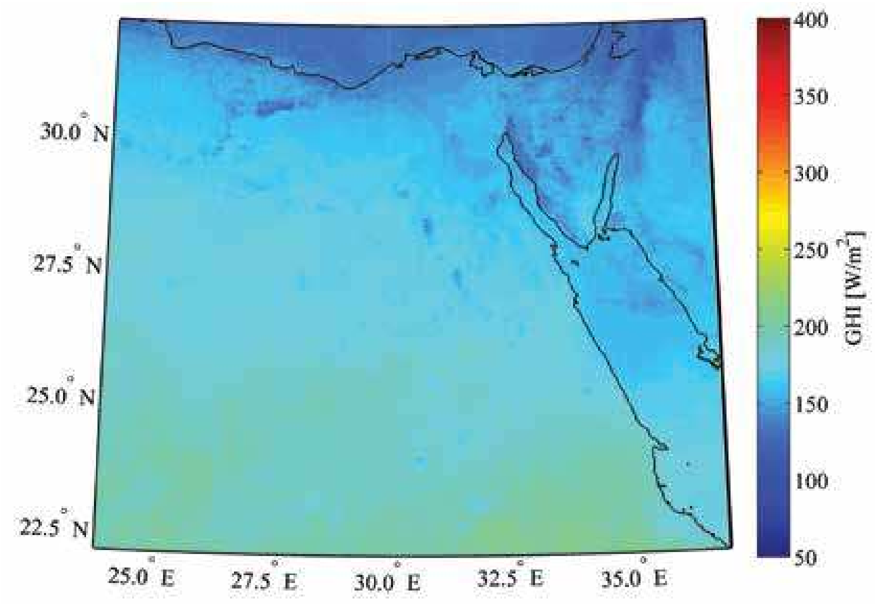

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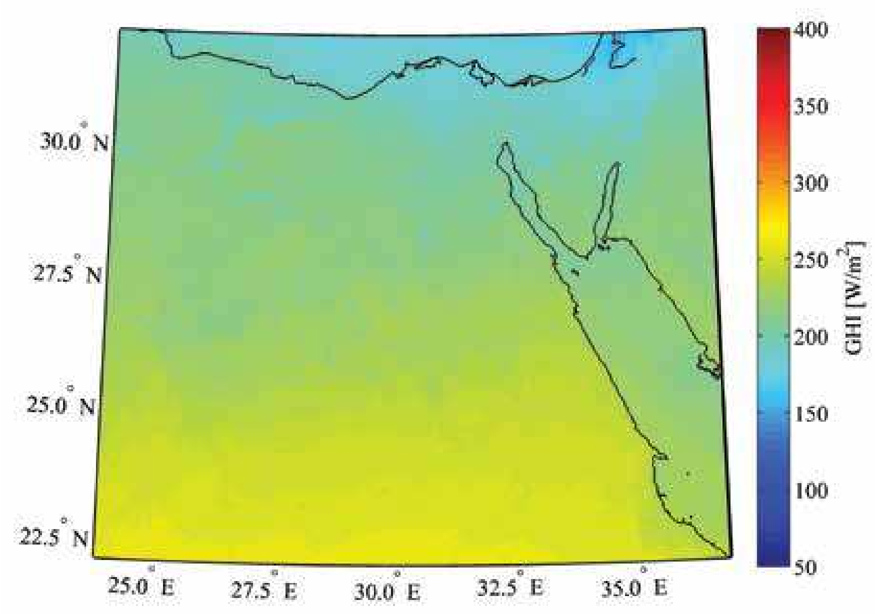

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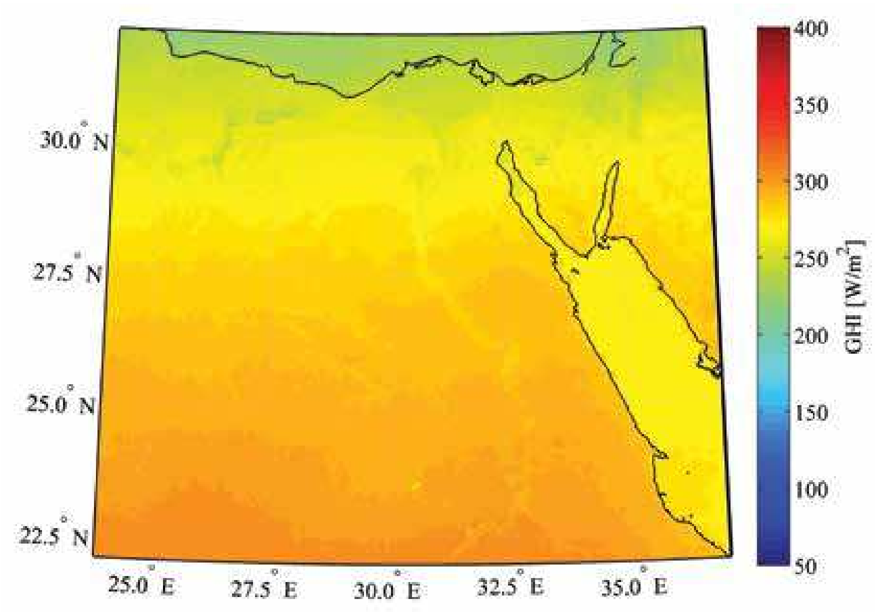

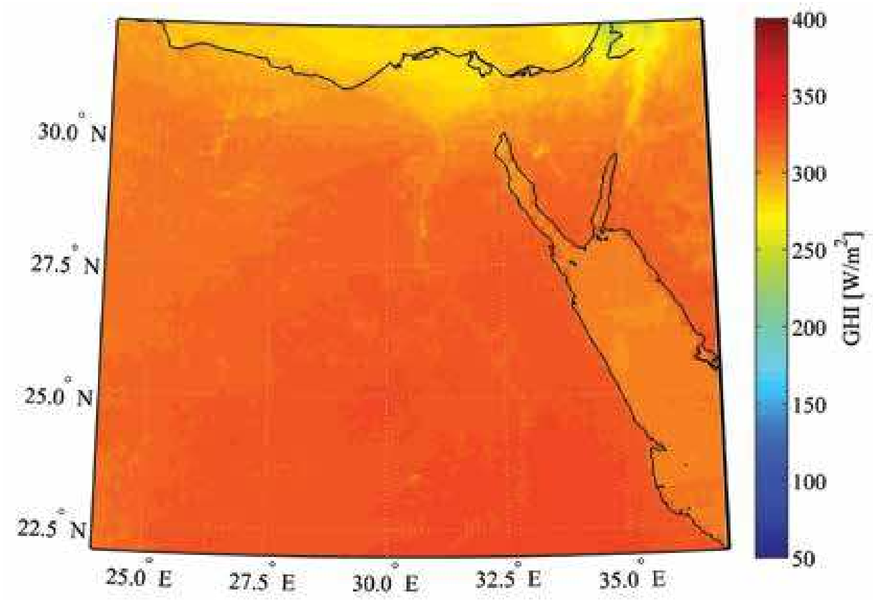

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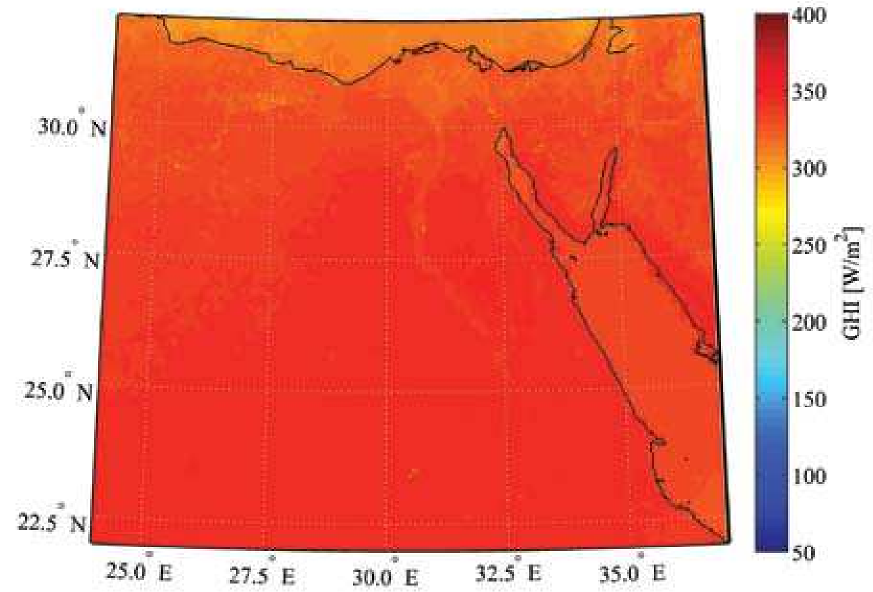

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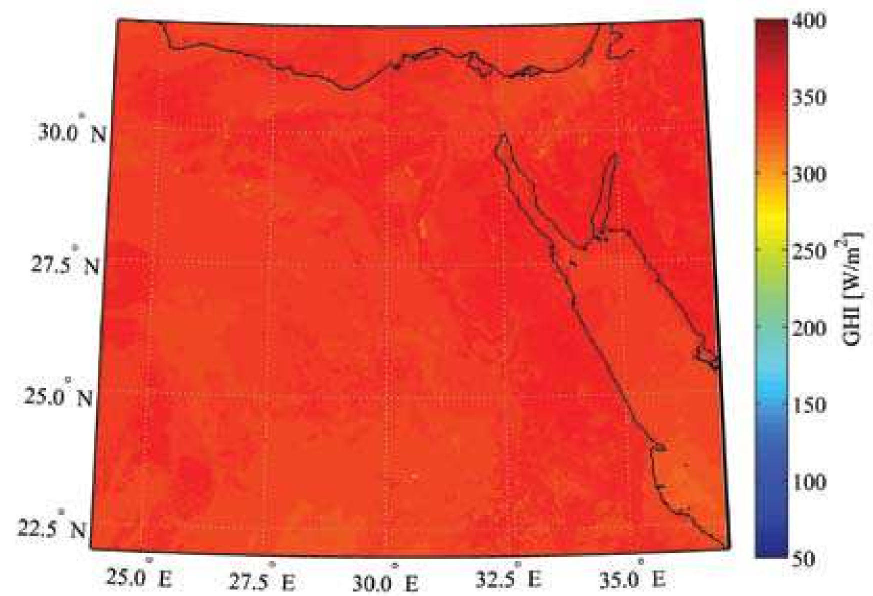

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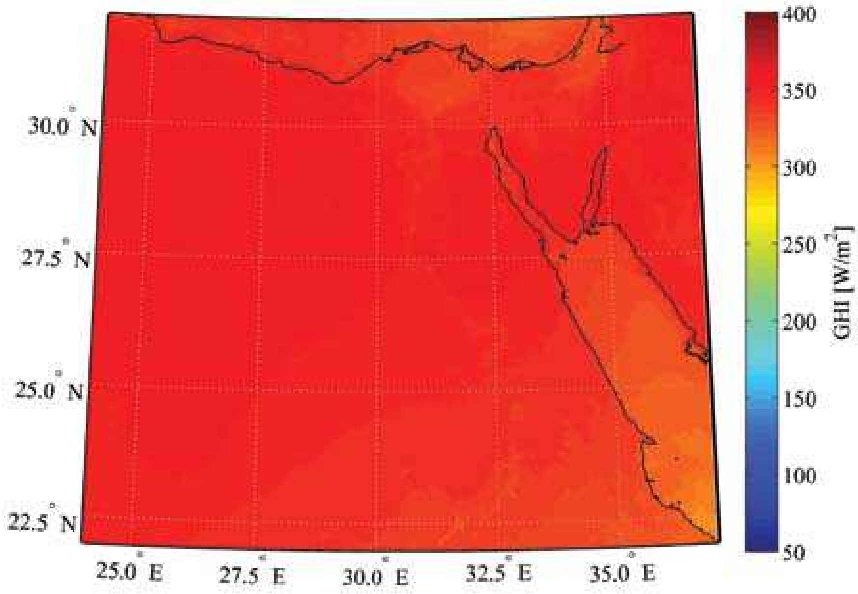

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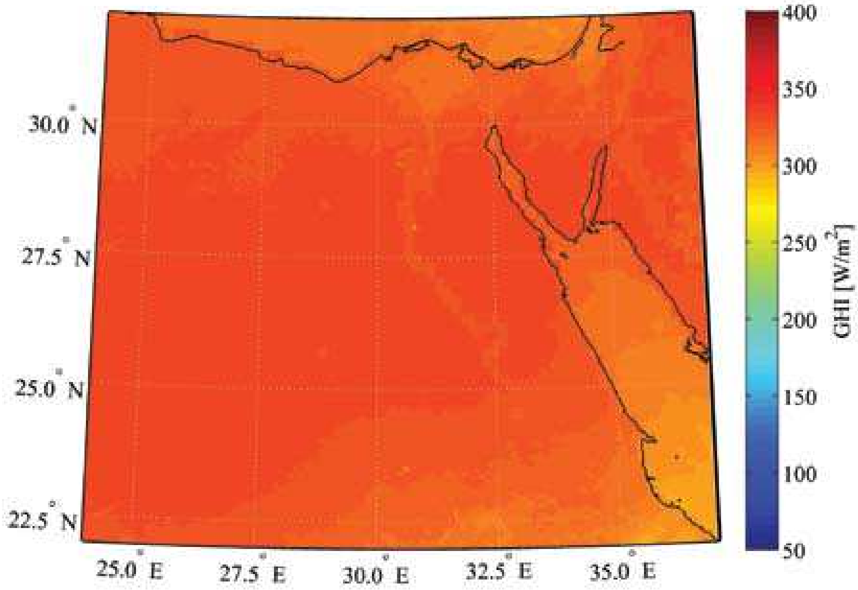

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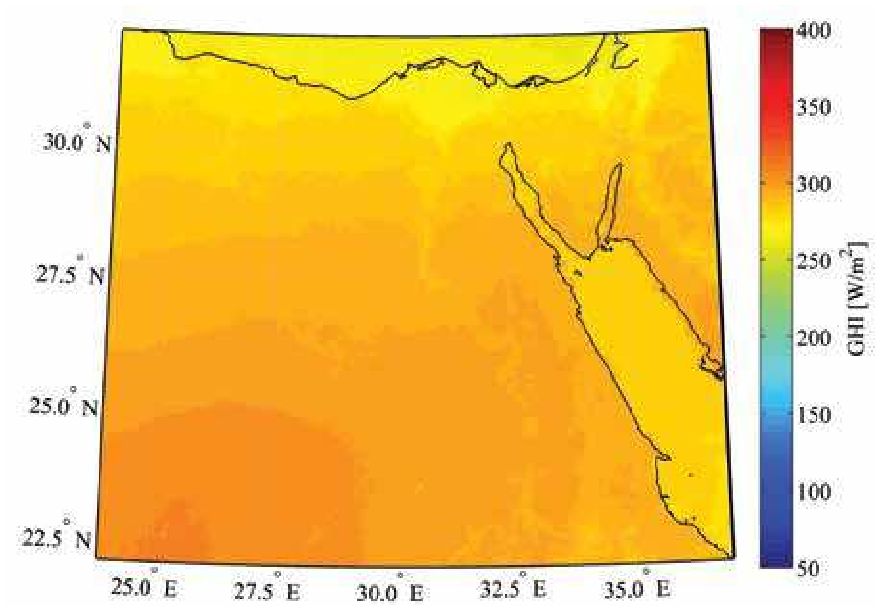

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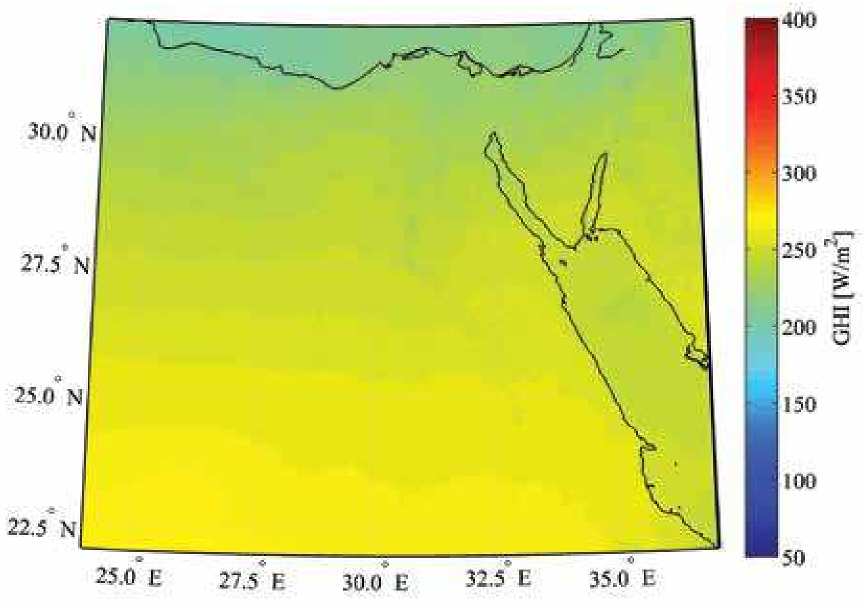

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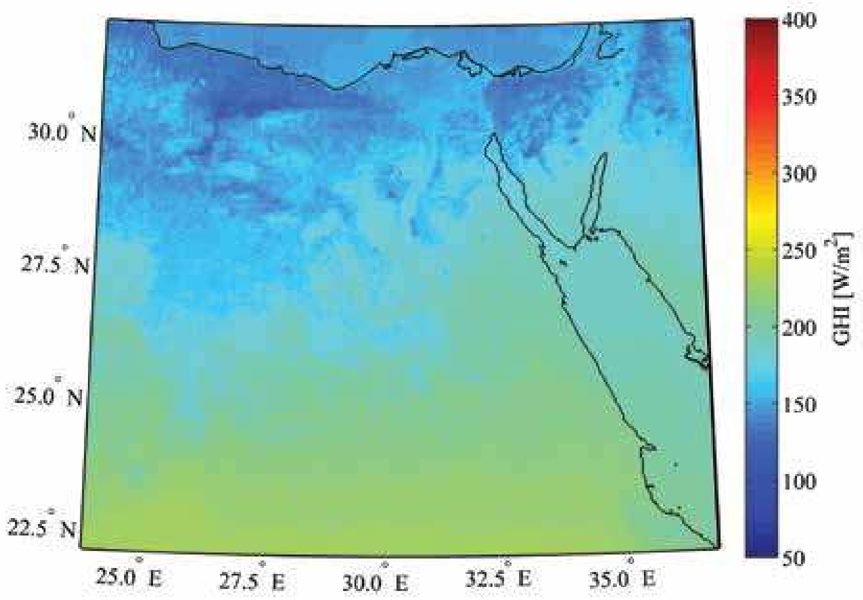

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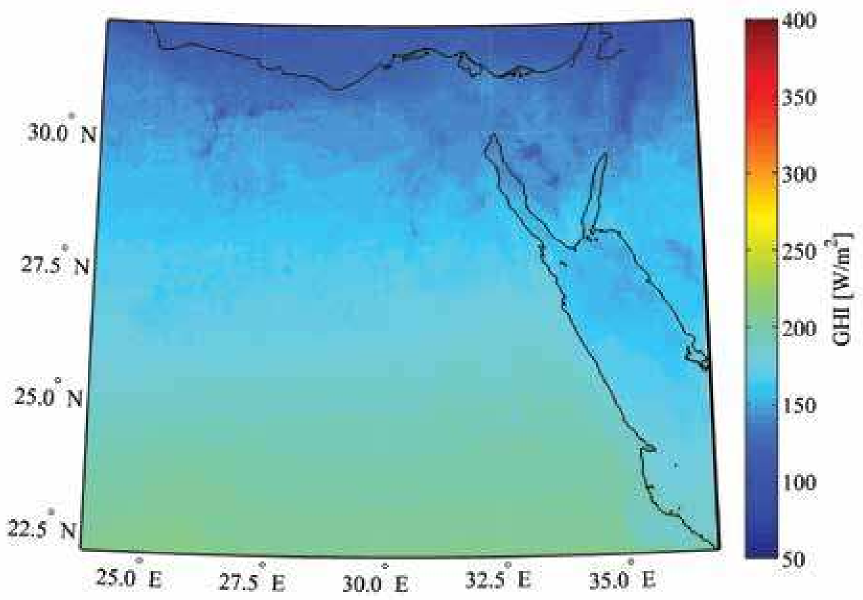

The GEO-CRALDE's regional coordinator for North Africa and Middle East Hesham El-Askary with her Excellency Mrs. Nabila Makram, Minister of Immigration and Egyptian Expatriates' Affairs as well as His Excellency Dr. Mohamed Shaker El-Markabi, Minister of Electricity and Renewable Energy while presenting the Solar Atlas concept

THE SOLAR ATLAS PHOTOGALLERY

THE GEO-CRADLE TEAM

THE GEO-CRADLE REGIONAL WORKSHOP

The authors of this Solar Radiation Atlas (in a workshop of the GEO-CRADLE project in Cyprus). From left to right: Panagiotis Kosmopoulos from the National Observatory of Athens (NOA, Greece), Hesham El-Askary from the Centre for Environment and Development for the Arab Region and Europe (CEDARE, Egypt) and Stelios Kazadzis from the World Radiation Center (PMOD/WRC, Switzerland).

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GEO-CRADLE

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