GERMAN EGYPTIAN YEAR OF SCIENCE AND TECHNOLOGY 2007

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Weather Modeling for Wind and Solar Energy in Egypt

Meso-scale Meteorological (Weather Forecast) Modeling

Presented By;

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Solar power

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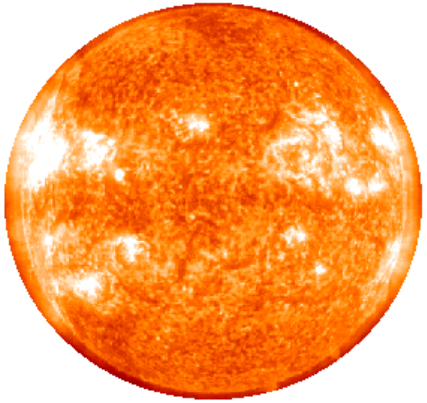
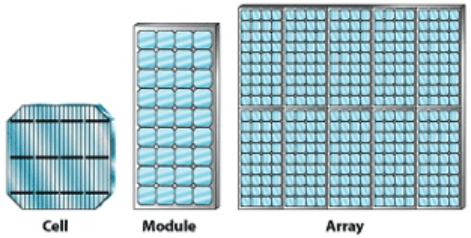
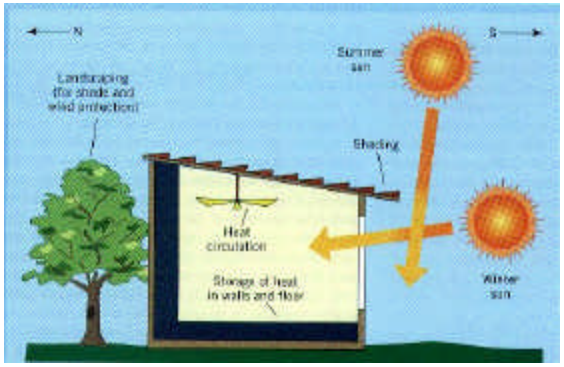
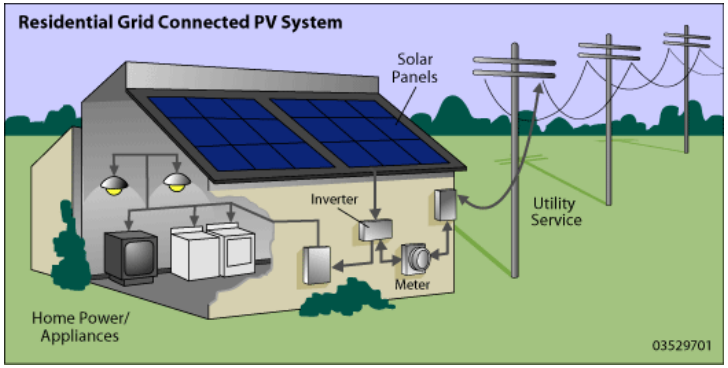
- As far back as more than 5,000 years ago, Egyptians considered the sun as a Deity. Ra, the sun-god, who was considered the first king of Egypt.
- Solar Energy is a clean environmentally friendly source of power.
  - All the energy stored in Earth's reserves of coal, oil, and natural gas is matched by the energy from just 20 days of sunshine.
  - In *40* minutes of daylight The SUN releases upon The Earth the amount of energy that is consumed by the entire population of the planet in ONE YEAR
  - Each day more solar energy falls to the Earth than the total amount of energy the planet's 6 billion inhabitants would consume in 27 years.
  - Currently we harness about 1% of this energy



SOHO EIT(Extreme ultraviolet Imaging Telescope) Image







Photovoltaic Panels

Presentation layout

- General Overview
- The Numerical Weather Forecast Model
- Model validation and enhancement
  - Four dimensional data assimilation
- Preliminary Considerations for Solar Energy
- Conclusions

General Overview 1/2

- Numerical meteorological models are used to asses air pollution, temperature inversion phenomenon, transport of pollutants/dust (sand storms), micro-climate change due to natural causes like formation of lakes, desertification, etc…, man made causes: different land use categories and Assessment and utilization of Wind and Solar energy potentials.
- Computational models are enhanced with remotely sensed observations for improvement of land surface modeling and accuracy and assimilation of meteorological satellite data.
- Recent numerical experiments suggests that severe deforestation around the Mediterranean in the last 2000 years was a major factor in current dry conditions and Attributed to change in albedo, and increased evapo-transpiration.
- Statistical trends from observations (over past 50 years) in the Eastern Mediterranean point to increased summer temperatures, decreased winter temperatures and reduced annual precipitation. *However*, recent observations suggest that atmospheric sensitivity to land use change occurs locally may be due to intensive irrigation and changed albedo.

General overview 2/2

- Meso-scale meteorology studies atmospheric phenomena with typical spatial scales between 10 and 1000 km. Examples of meso-scale phenomena include thunderstorms, gap winds, down slope windstorms, land-sea breezes, etc …
- Most weather phenomena that impacts human activity occur on the meso-scale

Scale	Length	Area	Locale
Micro	1 m - 1 km	1 m^2 - 1 km^2	local
Meso	1 km - 100 km	1 km^2 - 100 km^2	regional
Macro (Synoptic)	100 km - 10 000 km	100 km^2 - 10 000 km^2	continental
Mega	> 10 000 km	>10 000 km^2	global

Weather Prediction Players

- The Egyptian Meteorological Authority, EMA, Ministry of Aviation,
- The National Authority of Remote Sensing and Space Sciences, NARSS, and The National Research Center, NRC, State Ministry of Scientific Research Affairs,
- The Egyptian Environmental Affairs Agency, EEAA, State Ministry of Environmental Affairs,
- The Agricultural Research Center- Climate Research Unit, and the Desert Research Center, DRC, Ministry of Agriculture,
- The Water Resources Research Center, WRC, Weather and Climate research Unit, Ministry of Irrigation and Water Resources,
- New and Renewable Energy Authority, NREA, Ministry of Electricity and Energy.
- Universities, Ministry of Higher Education
  - Flow Visualization laboratory, FVLab, Aerospace department, Cairo University
  - Space Science and Technology Research and Studies Center, Cairo University
  - Center of Environmental Studies, Cairo university
  - Institute of Environmental Studies, Ain Shams University
  - Institute of Postgraduate Studies, Alexandria University

FVLab: Long Term Objectives

- Aerodynamic modeling of Weather and Climate related issues for Egypt
  - Boundary layer corrections for urban cities and local land use
  - Assimilation of remotely sensed satellite data to provide physically consistent estimates of the meteorological conditions.
  - Modeling relevant physical process related to weather modeling
- Meteorological assessment of air pollution
  - Extreme air pollution events
  - Atmospheric dispersion and transport of gases and particles
- Modeling long term local meteorological climate changes
  - Due to aggressive land use/land cover change
  - Due to formation of artificial water bodies
- Investigation of Wind and Solar Energy Potentials in Egypt
  - Wind Farm Site Operation Planning and Performance Assessment.
  - Study Effects of Dusty Weather on Wind Mill Performance
  - Site Selection and proper Wind Mill Sizing Related Studies

Weather & Wind Modeling:

The State of the Art

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NASA Research Strategy: Prediction Goals

	TODAY	Goals for 2010
Weather	3-Day forecast at 93%* 7 Day forecast at 62%* 3 day rainfall forecast not achievable Hurricane landfall +/-400Km at 2-3 days Air quality day by day	5-Day forecast at >90%* 7-10 Day forecast at 75%* 3 day rainfall forecast routine Hurricane landfall +/-100Km at 2-3 days Air quality forecast at 2 days
Climate	6-12 month seasonal prediction experimental; achieved an understanding of El Nino mechanics Decadal climate prediction with coarse models and significant uncertainties in forcing and response factors	6-12 month seasonal prediction routine; 12-24 months experimental 10 year climate forecasts experimental; moderate to high confidence in forcing & response factors
Natural Hazards	Demonstrate centimeter-level measurement of land deformation Accurate characterization of long-term tectonic motions, but no short-term earthquake forecast capability Accurate characterization of volcanic activity, but no long-term prediction accuracy	Continuous monitoring of surface deformation in vulnerable regions with millimeter accuracy Improved temporal dimension of earthquake & volcanic eruption forecasts Improve post-eruption hazard assessment

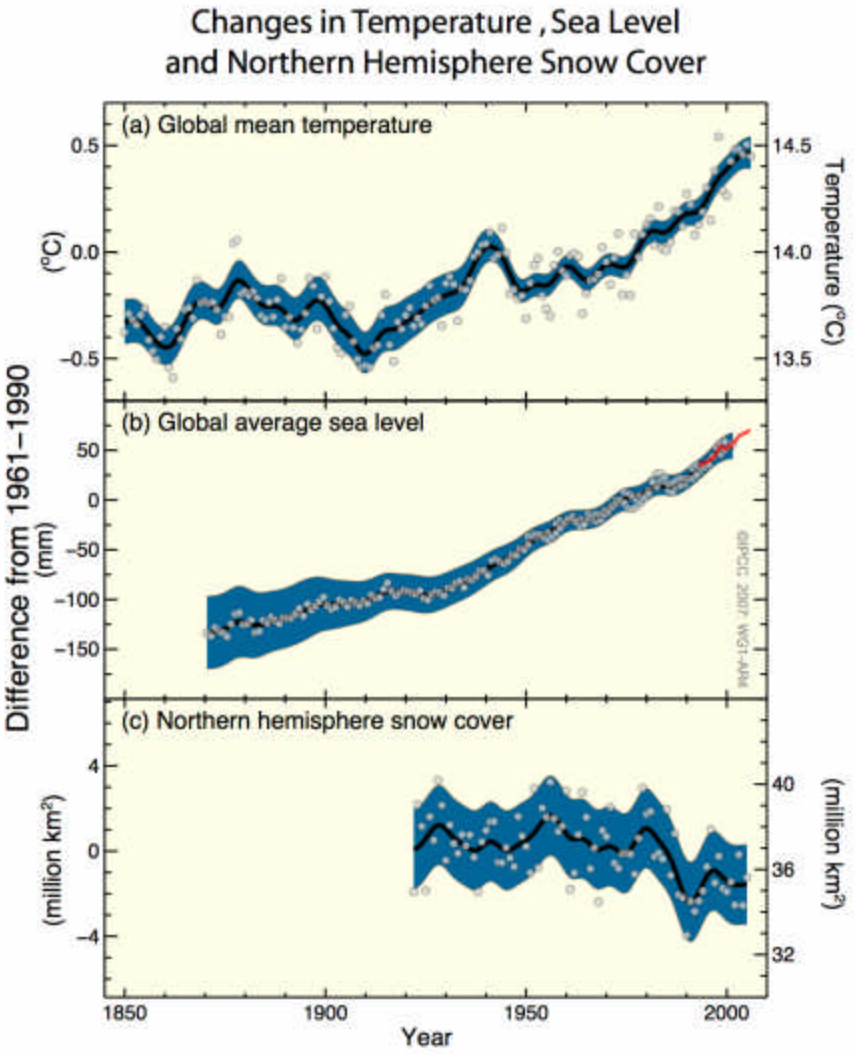
** Accuracy refers to sea level pressure forecasts over Northern Hemisphere during winter.*

Improved weather prediction tools will help enhance day to day operations of wind related activities. Improved Climate predictions will help enhance medium and long term planning and economic/policy/strategic related studies

Direct Observations of Recent Climate Change

IPCC Climate Change 2007 Workgroup I

- Gobal mean temperature
- Global average
- sea level
- Northern hemisphere
- Snow cover



The Numerical Weather Models: MM5 & WRF

- The Developed "Weather Model for Egypt" was first based on the 5th generation NCAR/Penn state meso-scale model (MM5) and later upgraded to use The Weather Research and Forecast Model, WRF.
- Both are open source models, Continuously being improved by contributions from users worldwide
- The two models are designed to simulate and predict meso-scale and regional scale atmospheric circulations.

FVLab-NARSS Meteorological Modeling System

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Gridded Data obtained from the global solvers to provide **Initial** and **Boundary** conditions with resolution up to 1 degree (**111** km^2)

Global Meteorological Data

Ground observations

Assimilated in Model

MM5 Model

Updating The Model

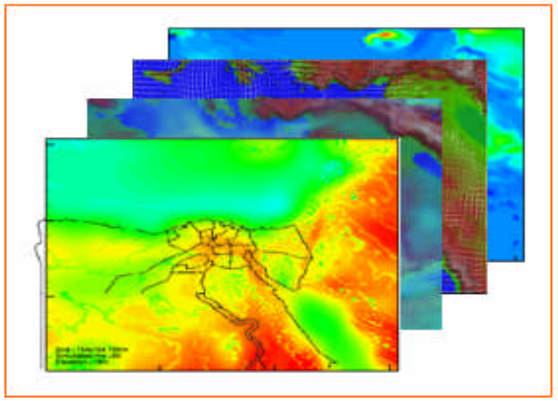
Boundary Conditions

High Resolution Data

(One km or Less)

Frequently updated (4-6 times daily)

Post Processing

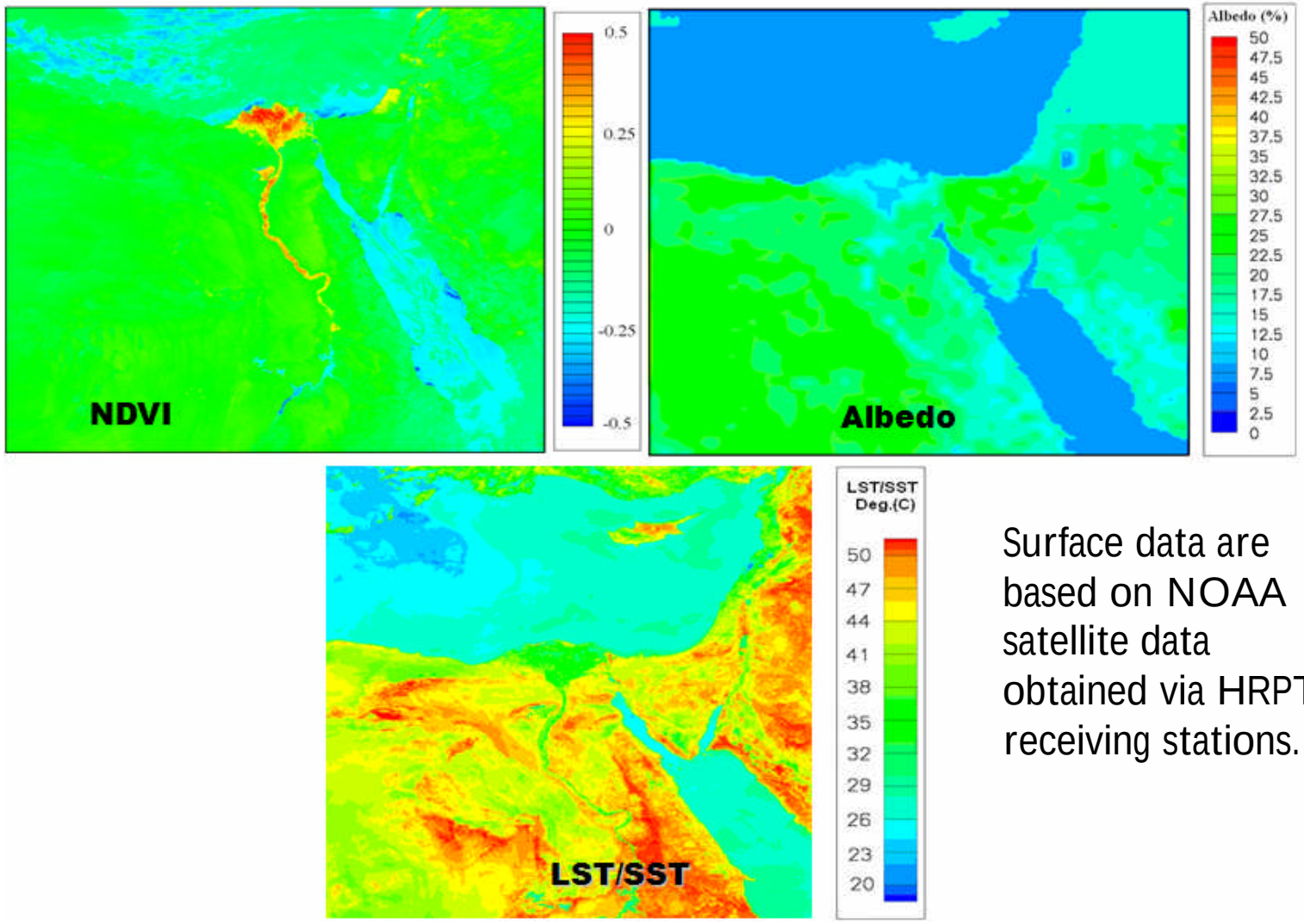


Terrestrial Data & Global Topology

- **Land use / Land Cover**
- **Vegetation Fraction**
- **Terrain Elevation**
- **Soil Type**

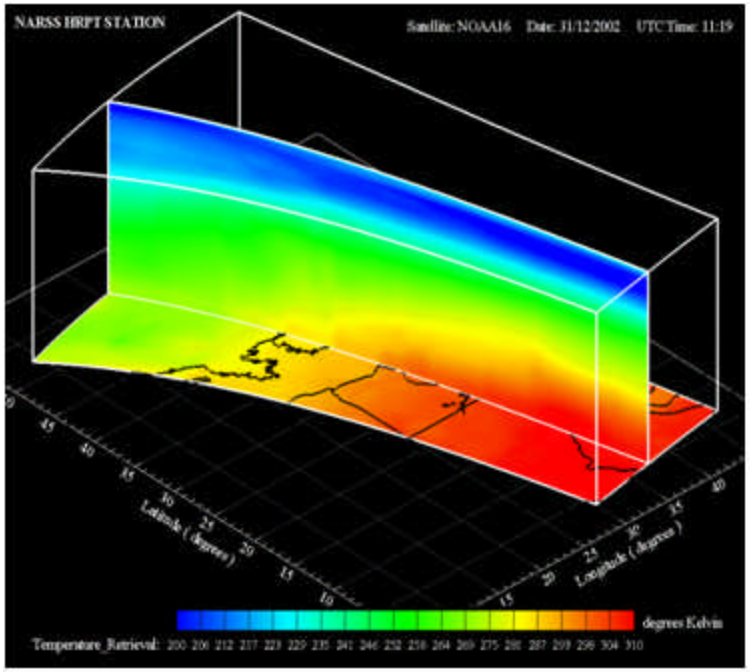
Initial version of the Model was first established in 2000 at FVLab-CU in cooperation with EEAA, extended to use satellite data at NARSS in 2002-2006 and Further Enhanced with pre and post processing and WRF at FVLab-CU 2006 to present

Model Enhancement & Validation:
Assimilation of Satellite based Surface Data

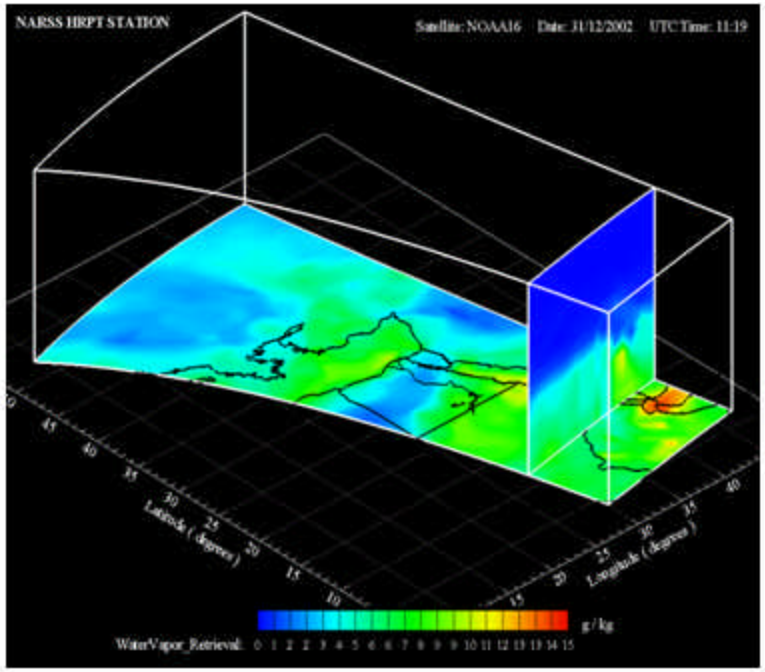


Surface data are based on NOAA satellite data obtained via HRPT receiving stations.

Model Enhancements:
Assimilation of 4 Dimensional Satellite Data



ATOVS Temperature Retrieval

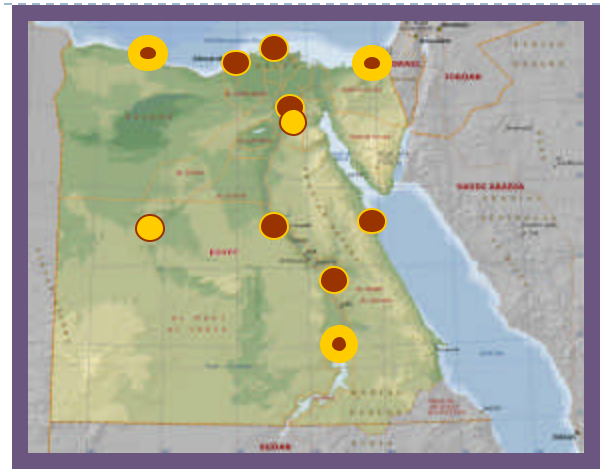


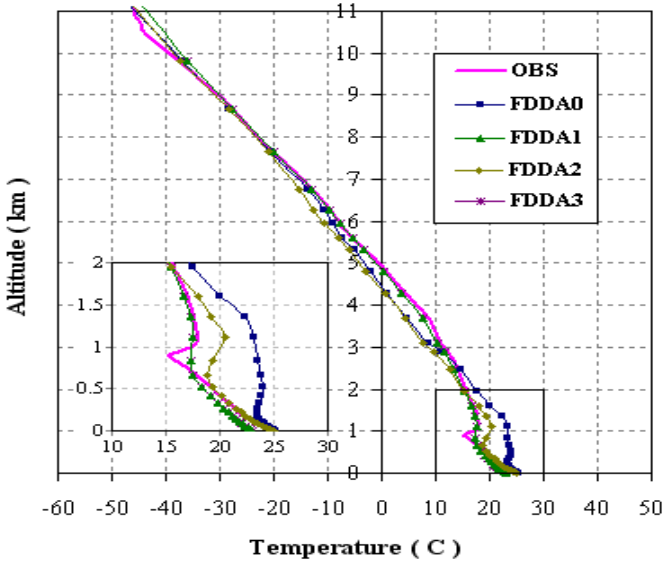
ATOVS Water-Vapor Retrieval

Satellite data is continuously received at NARSS using HRPT receiving station. Four receiving stations are available in Egypt at NARSS, EMA, DRC and ARC

Model Validation &Testing 1/2

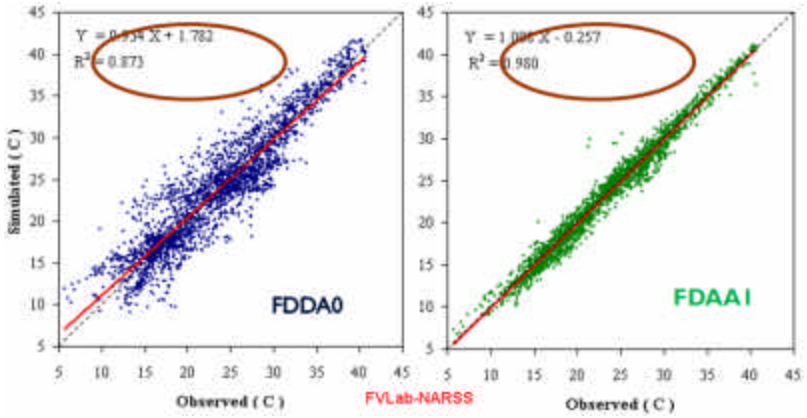
- Several sets of simulations were performed; using FDDA0: as a reference case, FDDA1: Grid FDDA from FNL., FDDA2: Grid FDDA from ATOVS, FDDA3: Grid FDDA from FNL + ATOVS.
- Comparison of simulations results with surface observations at nine monitoring locations and soundings at five monitoring locations.
- Validation results in FDDA1 is more efficient for research where FNL datasets are available



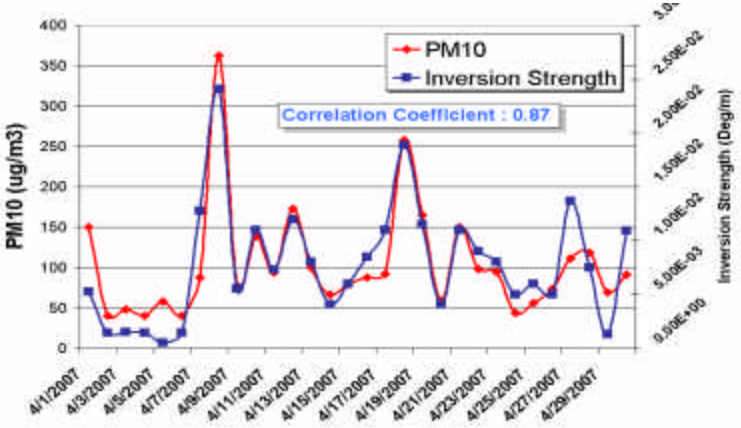


Vertical temperature profile for the different FDDA Techniques: at Helwan Station

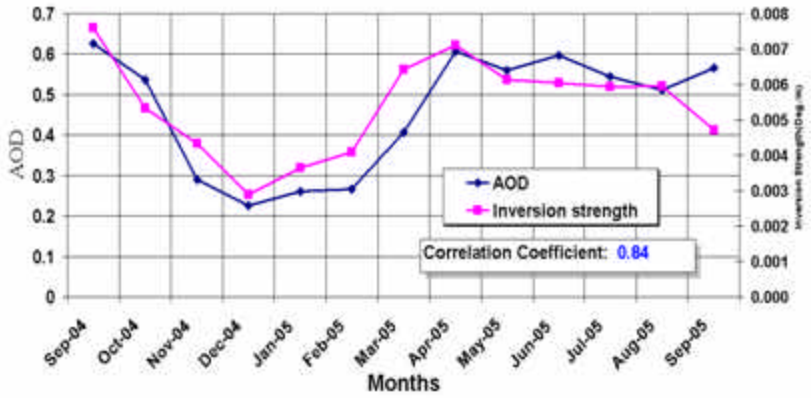
Model Validation & Testing 2/2



FDDA1 was better correlated and more efficient for research where FNL datasets are available



Ground temperature inversion, GTI, and Particulate matter Measurements, PM10 over Greater Cairo



Subsidence Temperature Inversion, SDI, over Cairo vs satellite based Aerosol Optical Depth AOD

Weather Modeling and wind Forecast:
Preliminary Environmental Considerations for Solar Energy

Satellite Data 1/2

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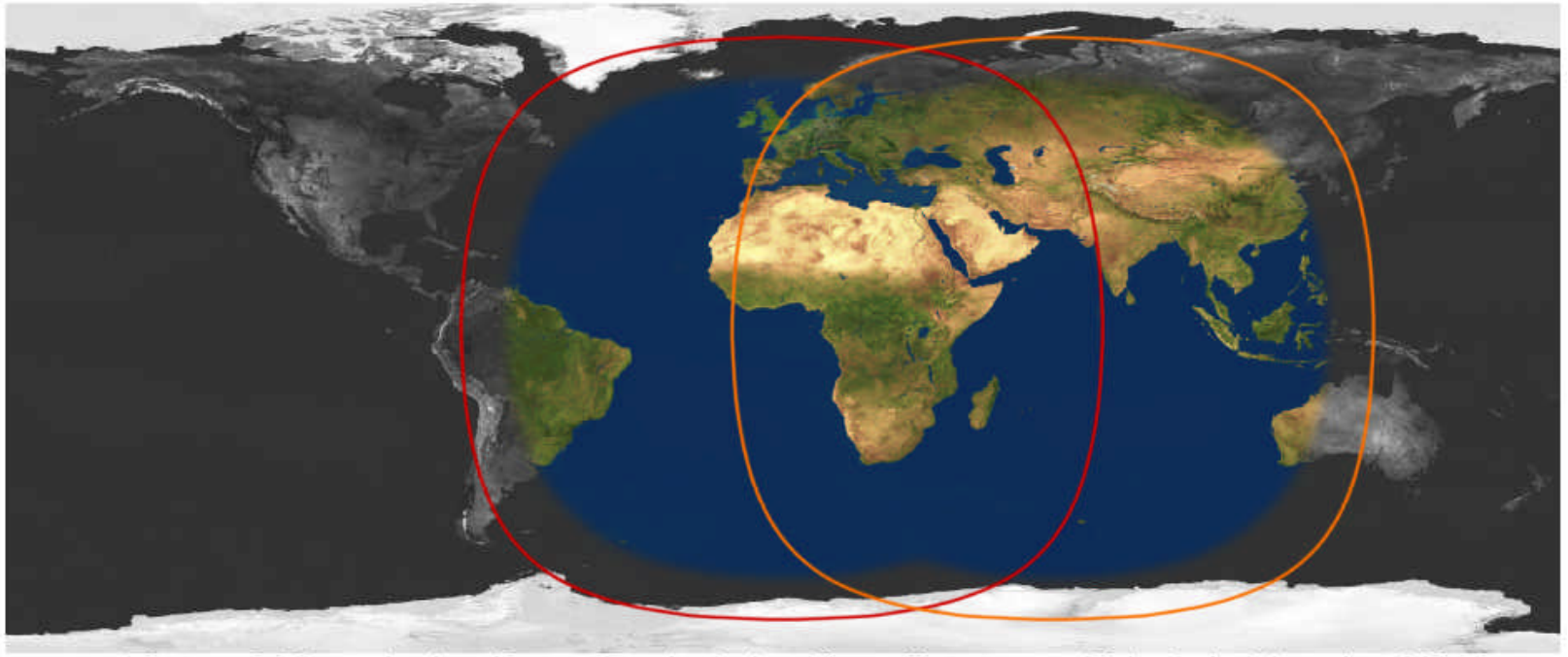

The solar irradiance data is derived from Meteosat a 0° (red circle) and at 63° East (orange circle). The brightened area marks the quantitatively analyzable region. (Meyer et al.,2004).

- The high resolution solar radiation assessment is based on data of the geostationary satellite
- Meteosat. Due to the location of the participating SWERA countries, data of Meteosat 7
- (M-7) for the years 2000, 2001 and 2002 (for Ghana, Kenya and Ethiopia) and data of
- Meteosat 5 (M-5) for the years 2000, 2002 and 2003 (for Bangladesh, West-China, Nepal
- and Sri Lanka) are used. M-5 has its position at 0° latitude and 63° East longitude, M-7 is
- located at an orbit at 0° latitude and 0° longitude. Figure 1 gives the field of view of both
- satellites which scans the specific area every 30 minutes with a spatial resolution of 5x5 km².

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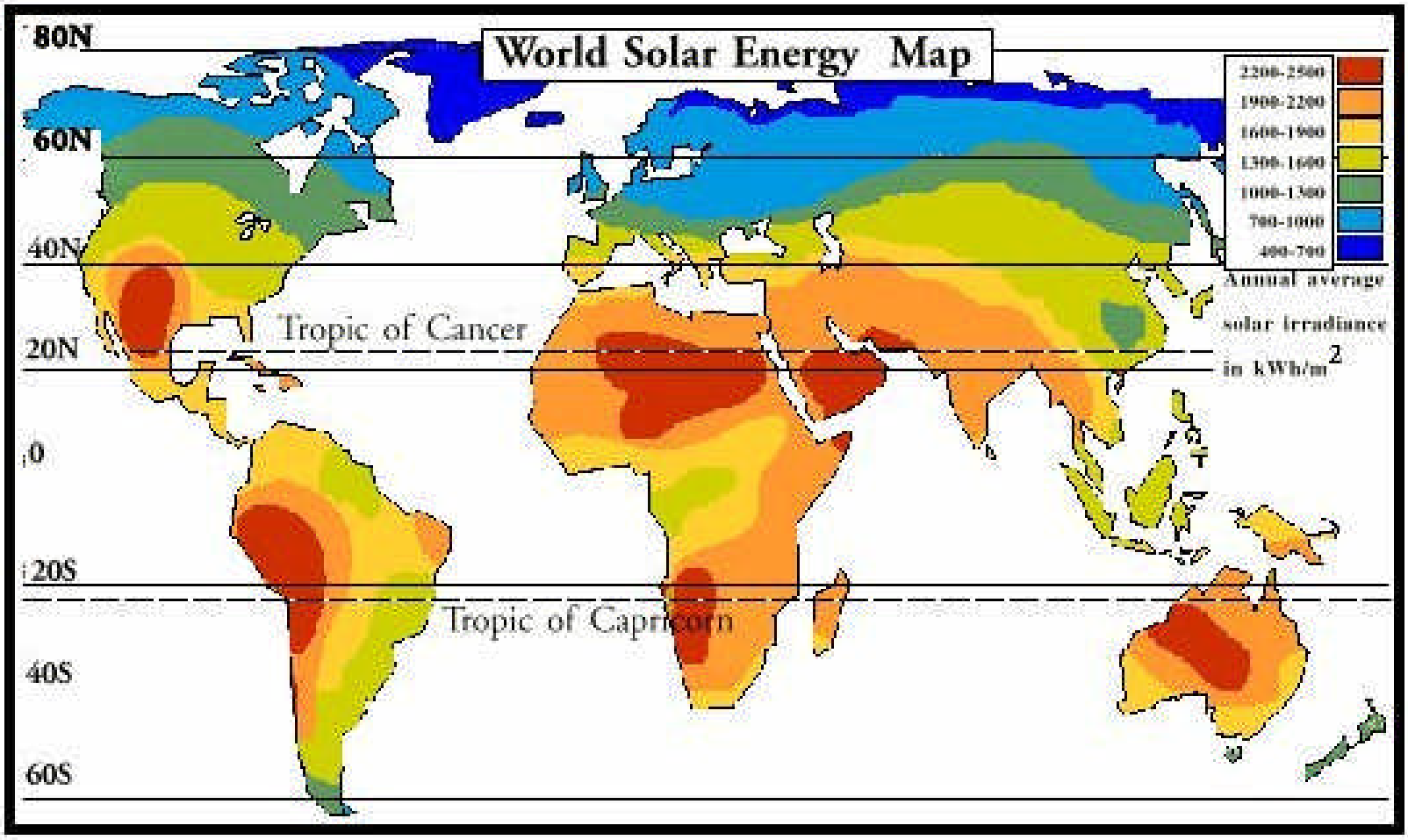
Satellite Data 2/2

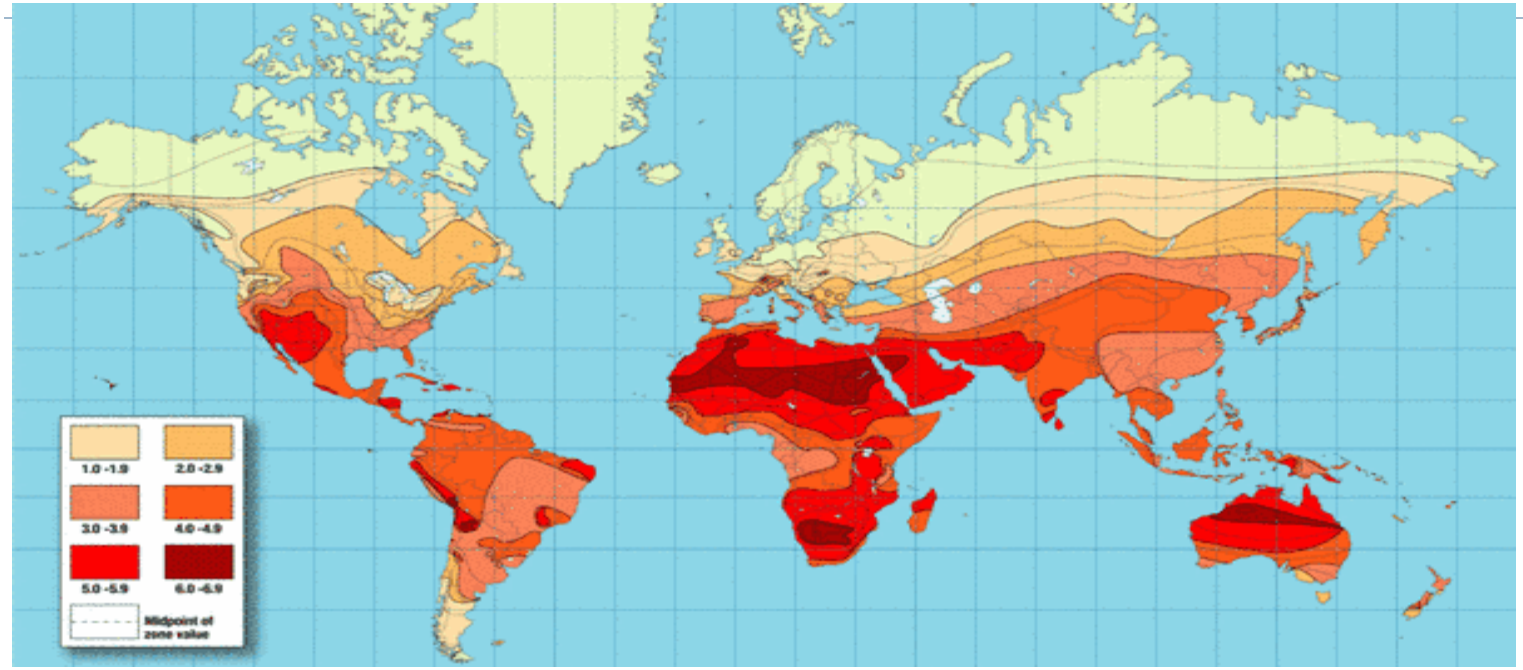
- Data of the visible (VIS) channel, which gives the reflection of the system earth/atmosphere (including clouds) and data of the infrared (IR) channel, which represents the temperature ofthe surface and atmosphere, are used for gathering information about the clouds.
- Both areused in a different way to assess the global horizontal (*GHI*) and the direct normal radiation (*DNI*) at ground.
- Additionally, data of the most important atmospheric components that attenuate the radiation, namely ozone, water vapor and aerosols, are used to take into account the clear-sky conditions of the atmosphere.
- In the following, the method for deriving *DNI* based on the DLR method and the method for deriving *GHI*, based on a combined method of DLR and SUNY, is described.

World Solar Energy Map



The solar irradiance figures indicate the average annual energy available per square meter

Solar Energy Potential In the Mediterranean



- Photovoltaic energy has large potential in the Southern and Eastern Mediterranean Countries, especially where the electricity network covers only part of the country.
- Morocco is an example of such countries, as its electrification rate is very low and nearly 10.000 villages – with an average of 300.000 households still need electrification. The estimated potential of Morocco and Tunisia is respectively of 200.000 PV systems and 14.000 PV systems. Also Turkey has a high interest in the development of PV, with a special focus on water pumping, electric signals and telecommunications.
- Such a high potential is not reflected in the market development, which remains small and underexploited. Its growth will strongly depend on the implementation of more ambitious national programmes and the creation of a specific industry to manufacture solar silicon.
- The 2nd PV-Med will emphasize the potential of the Mediterranean market and involve the key actors in order to discuss market opportunities and barriers and propose policies and actions to give feasibility to the development of the market.