Weather Modeling for Wind and Solar Energy in Egypt

Meso-scale Meteorological (Weather Forecast) Modeling

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12 November 2007
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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
General Overview

The Numerical Weather Forecast Model

Model validation and enhancement

Four dimensional data assimilation

Preliminary Considerations for Solar Energy

Conclusions
Numerical meteorological models are used to assess 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 evapotranspiration.

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.
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

<table>
<thead>
<tr>
<th>Scale</th>
<th>Length</th>
<th>Area</th>
<th>Locale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>1 m - 1 km</td>
<td>1 m² - 1 km²</td>
<td>local</td>
</tr>
<tr>
<td>Meso</td>
<td>1 km - 100 km</td>
<td>1 km² - 100 km²</td>
<td>regional</td>
</tr>
<tr>
<td>Macro (Synoptic)</td>
<td>100 km - 10 000 km</td>
<td>100 km² - 10 000 km²</td>
<td>continental</td>
</tr>
<tr>
<td>Mega</td>
<td>&gt; 10 000 km</td>
<td>&gt;10 000 km²</td>
<td>global</td>
</tr>
</tbody>
</table>
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, Water 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

### NASA Research Strategy: Prediction Goals

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

- Global mean temperature
- Global average sea level
- Northern hemisphere snow cover

Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover

(a) Global mean temperature
(b) Global average sea level
(c) Northern hemisphere snow cover
The Developed “Weather Model for Egypt” was first based on the 5th generation N CAR/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.
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

Satellite data is continuously received at NARSS using HRPT receiving station. Four receiving stations are available in Egypt at NARSS, EMA, DRC and ARC.
Several sets of simulations were performed; using FDDA0: as a reference case, FDDA1: Grid FDDA from FN L., FDDA2: Grid FDDA from ATOVS, FDDA3: Grid FDDA from FN L + 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 FN L datasets are available.
FDAA1 was better correlated and more efficient for research where FN L 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
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 SW ERA 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.
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 of the surface and atmosphere, are used for gathering information about the clouds.

Both are used 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.
The solar irradiance figures indicate the average annual energy available per square meter.
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.