Atmospheric dust transport models and usage

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inDust COST Action: The Effect of Soiling on Solar Energy, Munich, Germany
Dust cycle and its extension

Organic Carbon + Elemental carbon
Dust
Sulfate
Sea salt

NASA | GEOS-5 Aerosols
Motivation – Dust impacts

- Ecosystems, meteorology and climate
- Air Quality and Human Health
- Aviation and Ground Transportation
- Energy and industry
- Agriculture and fishing
- Astrophysics

Image from WMO website (http://www.wmo.int/pages/prog/arep/wwrp/new/hurricanes.html)
Dust forecasting models

Dust models are a mathematical representation of atmospheric dust cycle.
NMNM-MONARCH: Atmospheric Composition and Air Quality

- The main system is build on the meteorological driver NMNNMB
- *Multiscale*: global to regional scales allowed (nesting capabilities)
- *Nonhydrostatic* dynamical core: single digit kilometre resolution allowed
- Fully *on-line* coupling: weather-chemistry feedback processes allowed
- Enhancement with a *data assimilation* system

Known as NMNNMB/BSC-Dust
Mineral Dust Services

• BSC dust operational forecast (global and regional domains)
  • Contribution to the SDS-WAS (regional) and ICAP (global) multi-model ensembles

• WMO Dust Regional Centers
  • Barcelona Dust Forecast Center. First specialized WMO Center for mineral dust prediction. Started in 2014 – Operational
    • http://dust.aemet.es
    • @Dust_Barcelona
  • SDS-WAS Regional Center. Sand and Dust Storm Warning Advisory and Assessment System. Started in 2010 – Research
    • http://sds-was.aemet.es
Barcelona Dust Forecasting Center

Barcelona Dust Forecast Center starts operations

The Center will release operational dust forecasts for Northern Africa, Middle East and Europe

Read More

Dust forecast

Latest dust forecast for Northern Africa, Middle East and Europe

Check it here

@Dust_Barcelona

http://dust.aemet.es/
Barcelona Dust Forecasting Center

72-hours forecasts of:

- Dust Optical Depth at 550nm
- Dust Dry and Wet Deposition
- Dust Load
- Dust Surface Concentration
- Dust Surface Extinction at 550nm

@Dust_Barcelona
http://dust.aemet.es/
SDS-WAS and the NAMEE Regional Center

http://sds-was.aemet.es/
SDS-WAS and the NAMEE Regional Center

Model intercomparison

- Products: **surface concentration** and **DOD maps**, the SDS-WAS multi-model product.

12 Global – Regional models from ~ 100 to 10 km

http://sds-was.aemet.es/
Applications in Solar Energy

- Solar irradiance
  - The presence of dust reduce the incoming solar irradiance through direct radiative effect
  - but also indirectly, through favouring cloud formation

\[(\text{Soret et al., 2016})\]
Applications in Solar Energy

- Soiling
  - panels efficiency and water management
SOLWATT project

Provide near to market solutions for reducing the water consumption of CSP

The solutions will be implemented at two CSP operational sites:

- La Africana, Site location: Posadas, Córdoba, Spain
- SEDC plant, Site Location: Rotem, Israel

H2020SOLWATT project targets a significant reduction in the water used by CSP plants (by 35% for wet cooled & by 90% for dry cooled). In this way more of 0.5 M€/year of operational cost for a 50 MW CSP plant will be saved in the future.
SOLWATT project

→ O&M optimizer supported by soiling forecasts assures that innovative water-saving technologies are used in the best way.
Soiling-Downscaling

Biggest solar plant in EU in Hungary is 300,000m$^2$ → This is 0.3km$^2$ vs 100km$^2$ from the model.

Operational forecasts

Prediction over specific locations
The DLR Institute of Solar Research (SF) is the largest research entity in Germany investigating and developing concentrating solar technologies to provide heat, electricity and fuel.

DLR has developed a soiling model that has been validated for two sites during WASCOP – Water Saving for Concentrated Solar Power (H2020 project).

Next presentation: Soiling modelling with ground data (Fabian Wolfertstetter)
Operational dust atmospheric forecast

BSC model is going to be run for the years selected from DLR in order to provide inputs for the soiling model.

Its evaluations until now for various AERONET stations are satisfactory.
Model evaluation results

Malaga AERONET

- AOD500 onell_v3-lev15
- AOD500 Coarse onell_v3-lev15
  - DOD550 3DS+WAS
  - DOD550 MONARCH-GLob
  - DOD550 MONARCH-REG-033
  - DOD550 MONARCH-REG-010

NDATA = 351/351/35/1333
MEAN_obs = 0.08/0.08/0.08/0.08
MEAN_model = 0.09/0.11/0.09/0.08
COR = 0.77/0.58/0.6/0.64
RMSE = 0.07/0.13/0.13/0.11
MB = 0.01/0.03/0.01/0
Model evaluation results
Summary

❑ SOLWATT will provide:
   ➢ Operational soiling forecasts: up to 5-days soiling forecasts based on the daily operational dust NMMB-MONARCH system.

❑ To achieve this objective, the dust atmospheric NMMB-MONARCH model will be coupled with a soiling model.
   ❑ The evaluation of NMMB-MONARCH (the inputs used by the soiling model) shows that the model can predict the desert dust cycle over North Africa, Middle East and Europe.
     • Over the Mediterranean, the model is capturing the timing and the magnitude of the dust events. The model can not reproduce the haboobs (associated to convective events) in the current operational configurations.
     • In middle east the model is overestimating the summer events.

❑ Ongoing improvements in the description of the desert sources in the Middle east and Africa. Next, evaluation of the deposition fields.
Thank you

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Backup slides
Aim: predict soiling rate on solar mirrors from other weather data. Test and validate with measurement data.

- **Sedimentation**
  - Gravitation
  - \[ v_{S,p} = \frac{g d_p^2 (\rho_{Aerosol} - \rho_{Luft})}{18 \eta_{Luft}} \]

- **Brownian motion**
  - Thermal motion
  - \[ v_B = a_{Brown} u_{Wind} \left( \frac{\nu_{Luft}}{D_B} \right)^{-\gamma} \]

- **Impaction**
  - Air stream/wind
  - \[ v_{Im} = a_{Im} \cdot \frac{\sigma_{Ausrichtung} u_{Wind}}{1 + \exp(-f_{Im} \cdot (St - 1))} \]

Also considered:
- Rebound, resuspension, rain washing, cementation, mirror/panel orientation
• Model validated for two sites
• RMSE = 2 x soiling rate measurement accuracy
• Bias = 0.5 x soiling rate measurement accuracy

<table>
<thead>
<tr>
<th></th>
<th>Bias (%/d)</th>
<th>RMSE (%/d)</th>
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<tbody>
<tr>
<td>PSA Training Set</td>
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<tr>
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<td>Missouri</td>
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</table>
• Trade-off between **cleaning cost** minimization and **revenue** maximization
• **Time resolved soiling rate** information improves cleaning scheduling
• Adaptation of cleaning intensity on cleanliness **increases profit** significantly
• **Soiling forecast** could further increase profit during operation: planned within recently started SOLWATT H2020 project in collaboration with BSC
Dust cycle and associated processes

Dust transport is a global phenomenon. However, dust emission is a threshold phenomenon, sporadic and spatially heterogeneous, that is locally controlled on small spatial and temporal scales.