Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Improving Solar Radiation in NWP Models

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EWeLiNE

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

50hertz

TenneT Taking power further

amprion

Fraunhofer IWES

Outline

1. EWeLiNE Project

2. Modeling Errors

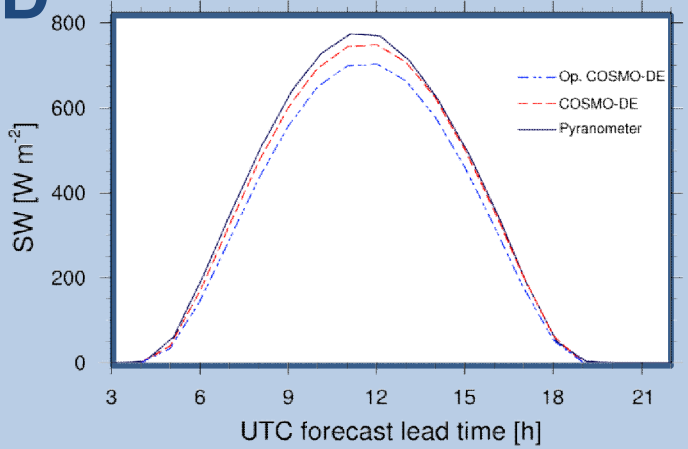
3. Data Assimilation

4. Clouds and Other Uncertainties

5. Conclusion

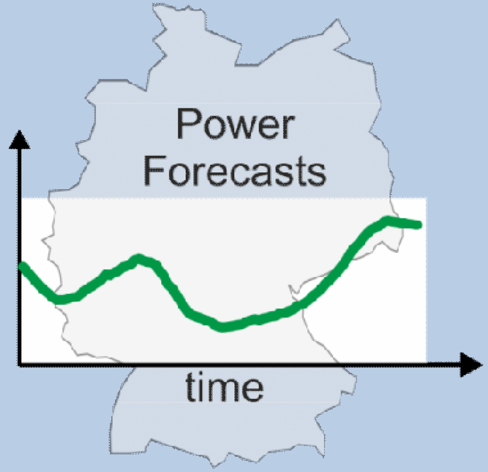
EWeLiNE

DWD

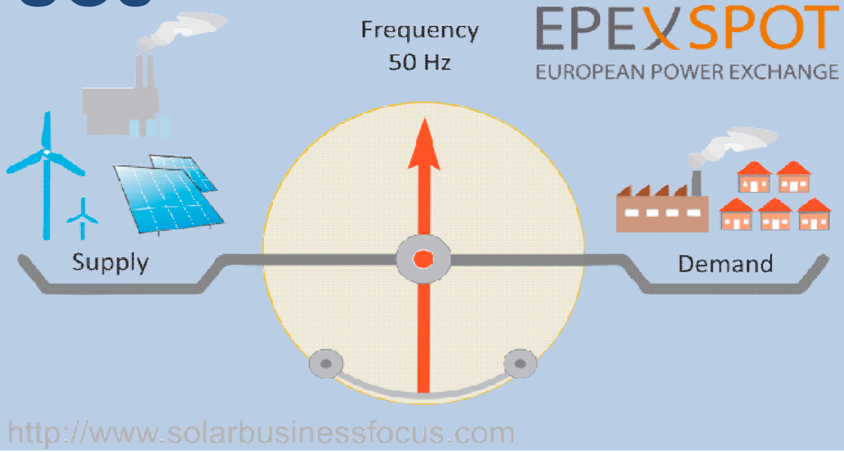


Weather-forecast

IWES



TSOs



Feedback

Power-forecast

PV Modeling Errors

Photovoltaik:

→ Shallow convection after cold frontal passage

→ Spatial and temporal resolution of convection

→ Low stratus/ fog

→ Snow cover on solar panels

Satellite cloud product information

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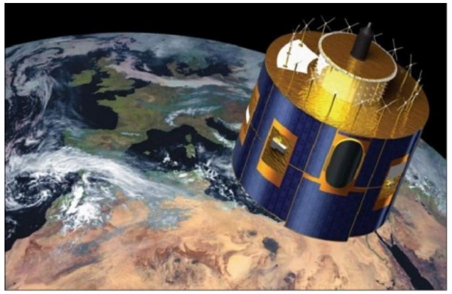
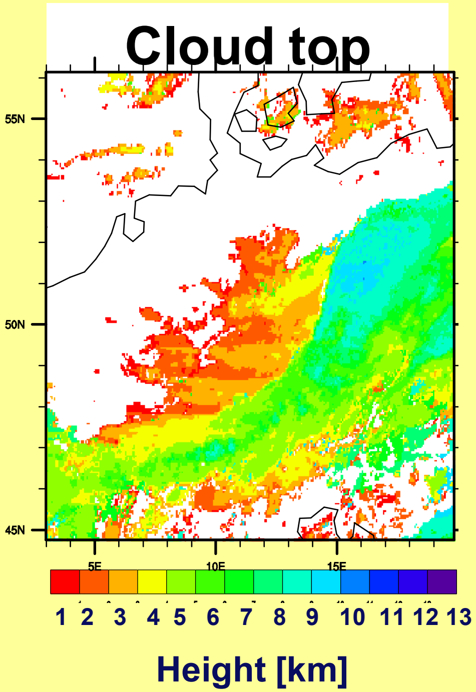
- Geostationary satellite data: **Meteosat-SEVIRI**
  (Δx ~ 5km over central Europe, Δt=15 min)



Source: EUMETSAT

Satellite product: cloud top height

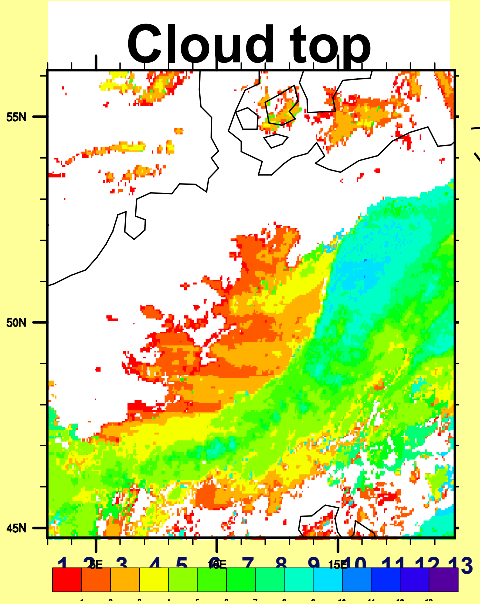


→ contains information on horizontal and vertical distributions of clouds

Method

- Extract information if a pixel is observed as **cloudy:**

OBSERVATION:
Satellite product: cloud top height



Height [km]

Assimilated variables:

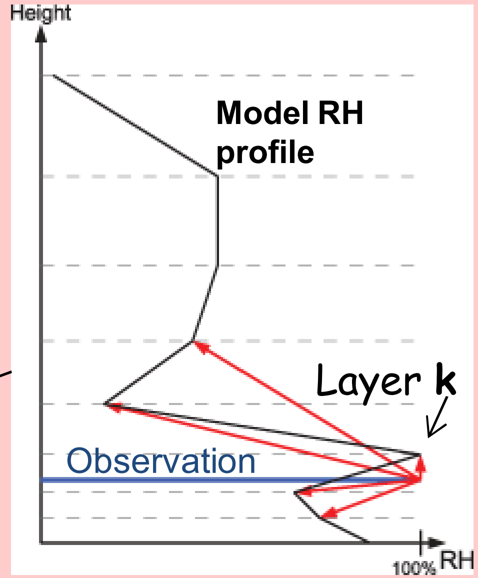
Cloud top height

100% Relative humidity at cloud top height

MODEL EQUIVALENT:
Determine cloud top model equivalent: top of most humid layer **k** close to observation

Height (k)

RH(k)



see Schomburg et al., QJRMS, 2014

Ex.: Single-observation experiments

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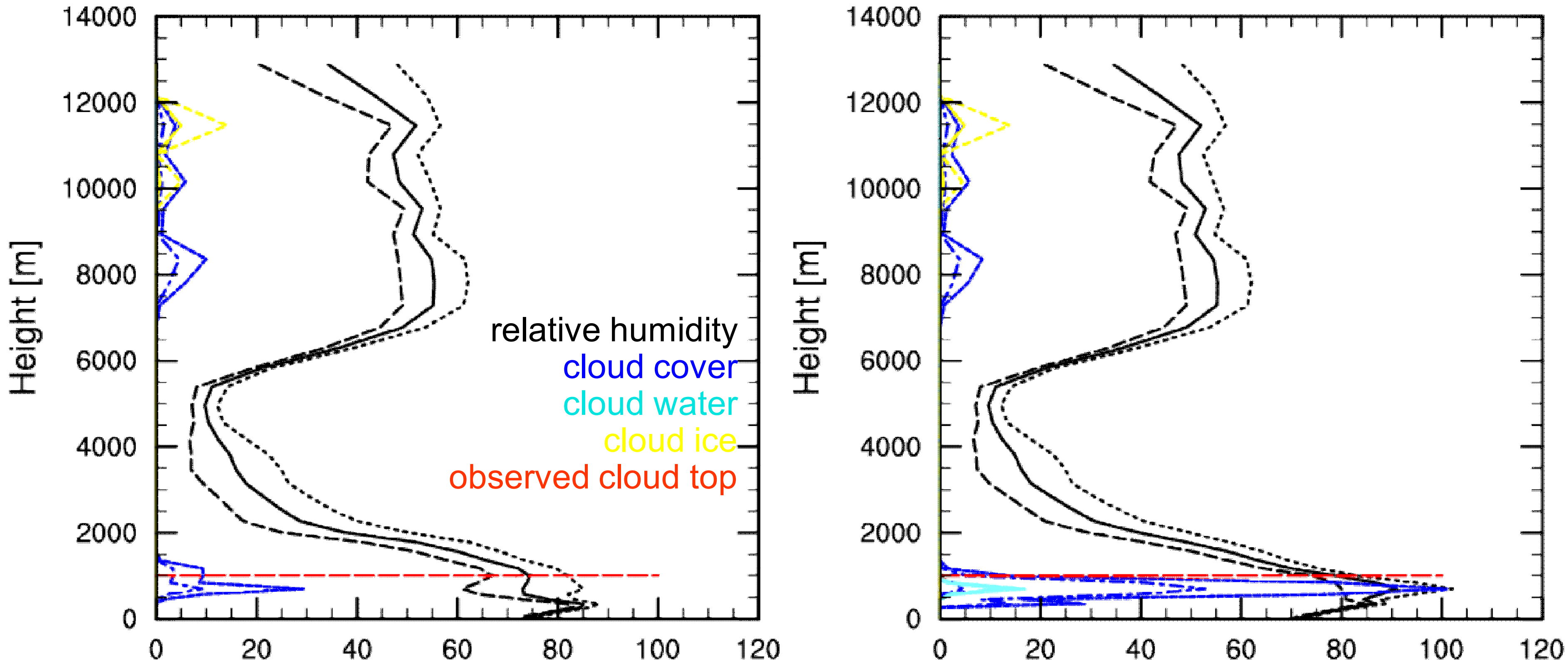
- missed low stratus cloud
- 1 analysis step, 17 Nov. 2011, 6 UTC (wintertime low stratus)

First guess vertical profiles **Analysis**



3 lines in one colour indicate ensemble mean and mean +/- spread

EWeLiNE

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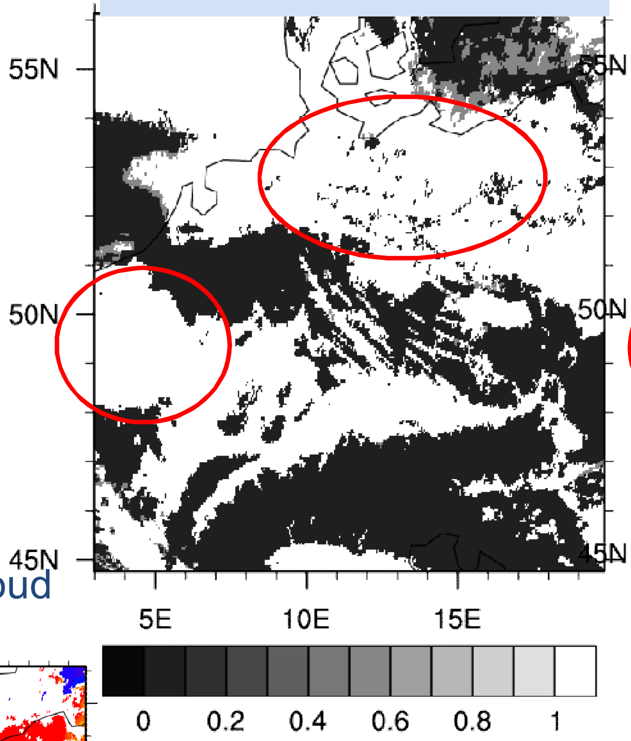
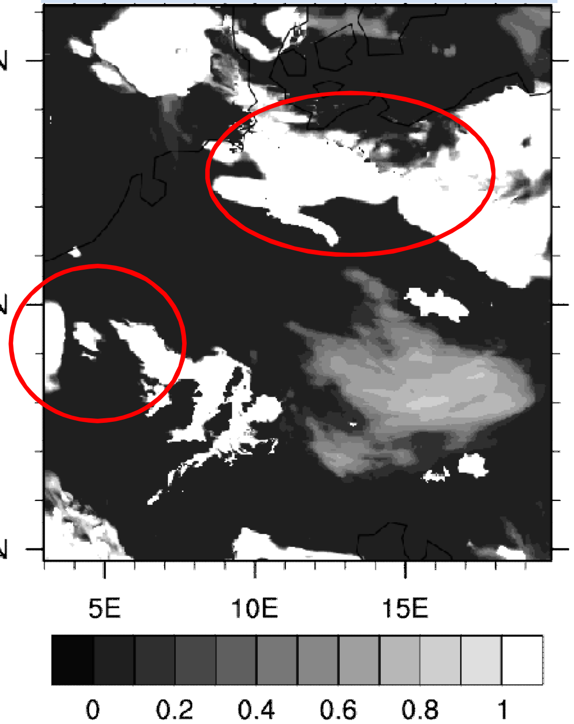
Comparison of free forecast results

Total cloud cover after 12 h free forecast

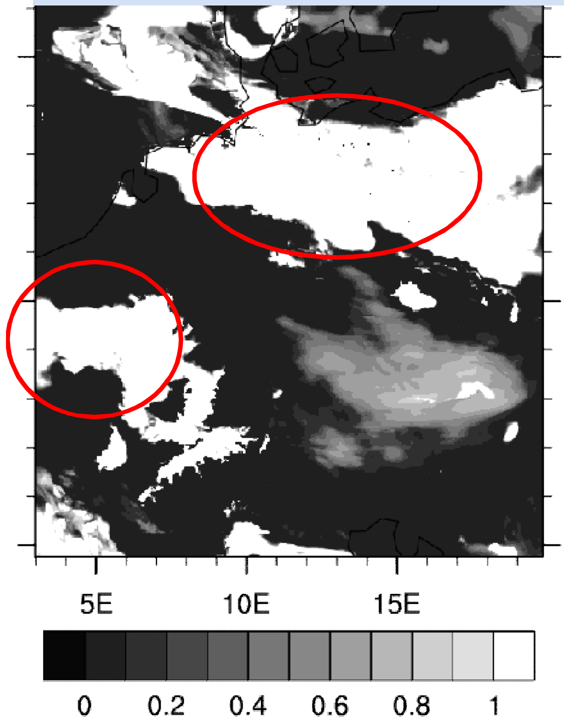
satellite obs



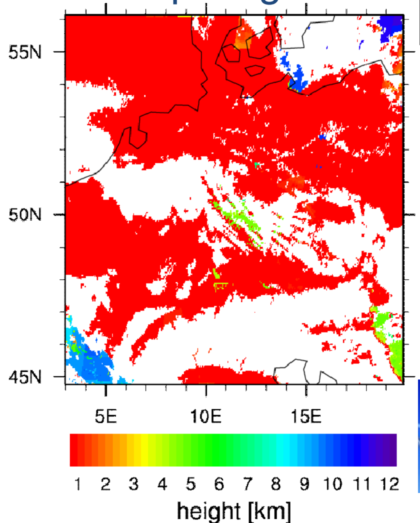
conventional only



conventional + cloud assimilation



Observed cloud top height



15. Nov 2011, 6:00 UTC

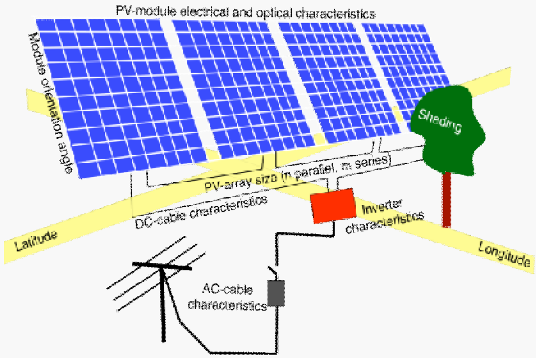
Assimilation of photovoltaic power

Forward operator:

Model variables:
- surface irradiance
- 2m temperature
- albedo

→

Forward operator for PV module



Source: Yves-Marie Saint-Drenan, IWES

→

Synthetic PV power (clouds main forcing factor)

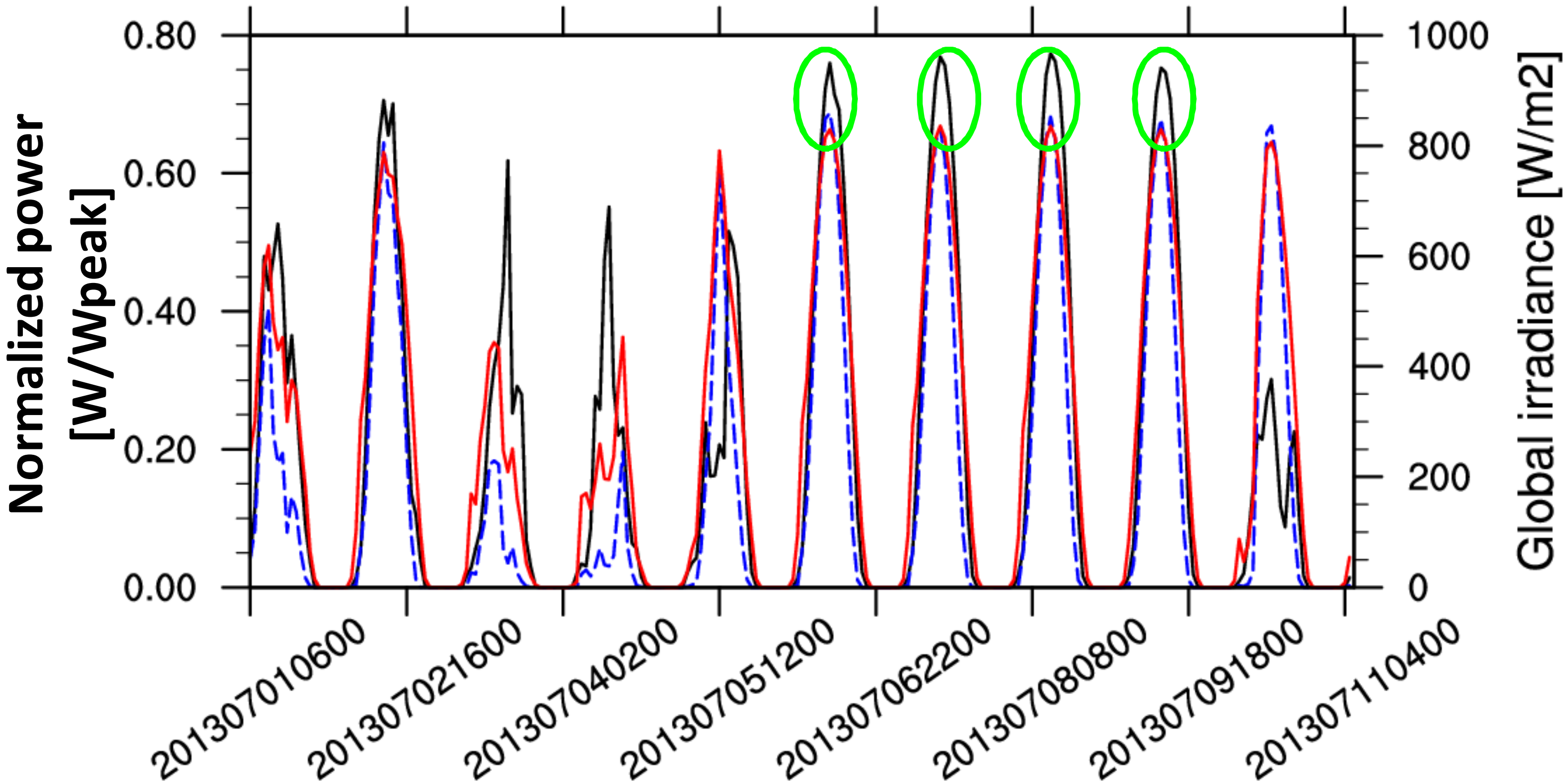
Challenge:

- Data availability
- meta-data availability and quality

  Shading by trees, string failures, soiling…

Example of simulated and observed photovoltaic power

Model forecast solar insolation at surface
Observed photovoltaic power
Simulated photovoltaic power (based on model forecast radiation)



PV Modeling Errors

From a modelers perspective:

→ Cloud-free days

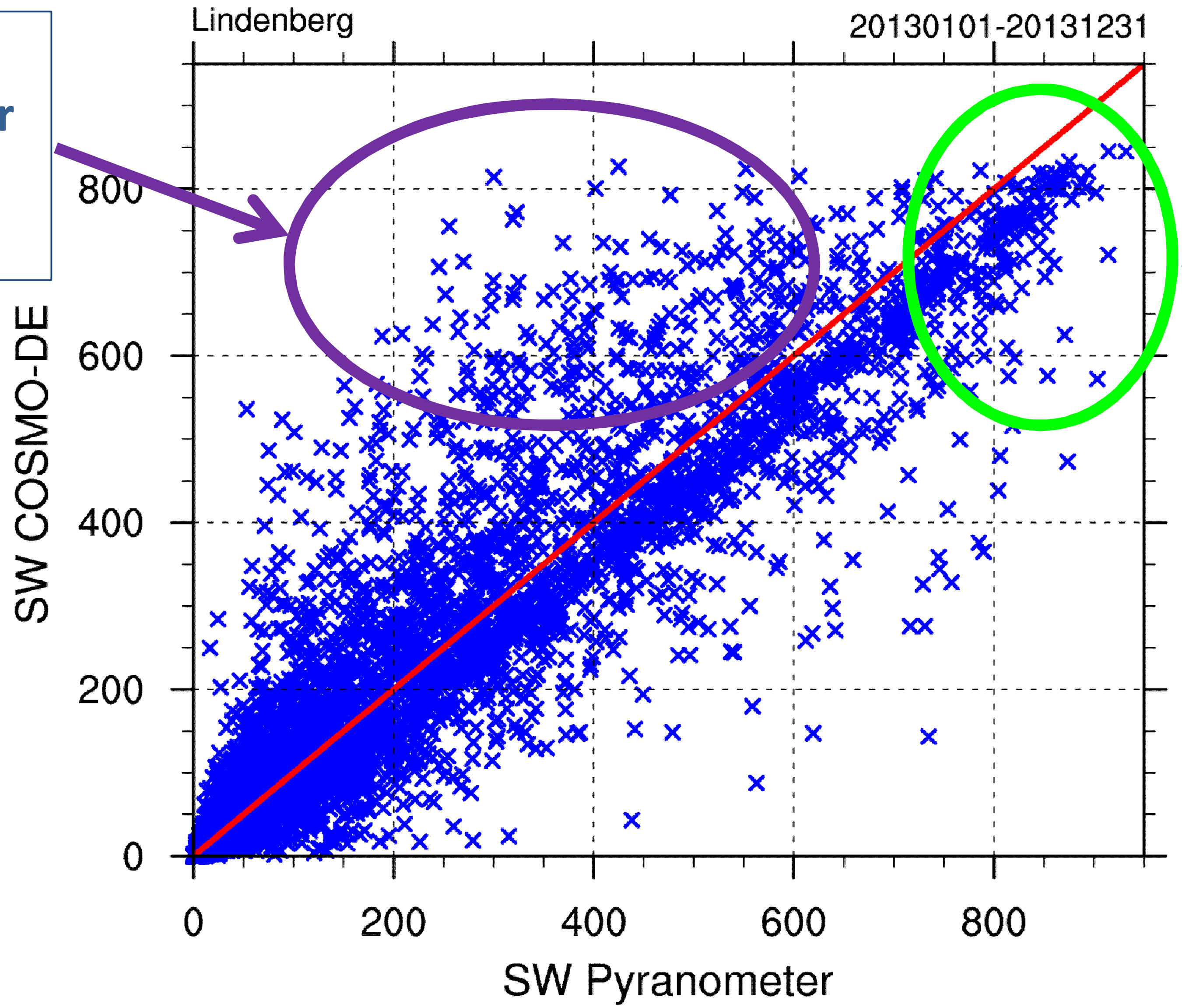
→ Optical thickness of clouds

→ Aerosol interactions

http://www.photocase.de/stock-fotos/33254-stock-photo-himmel-sonne-wolken-kalt-strahlung.jpg

PV Modeling Errors

Too much radiation for cloudy conditions



Insufficient radiation for clear sky conditions

PV Modeling Errors

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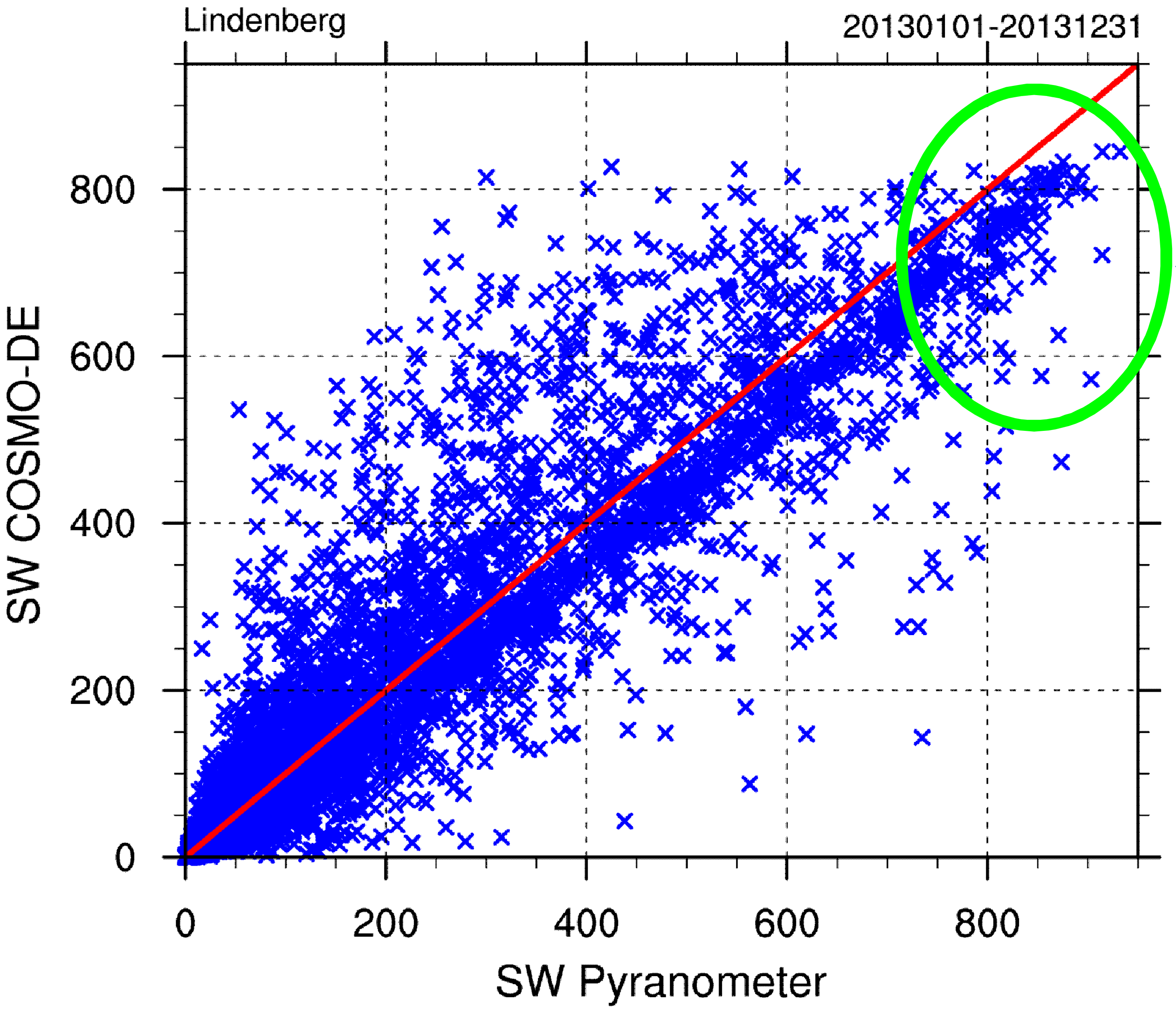
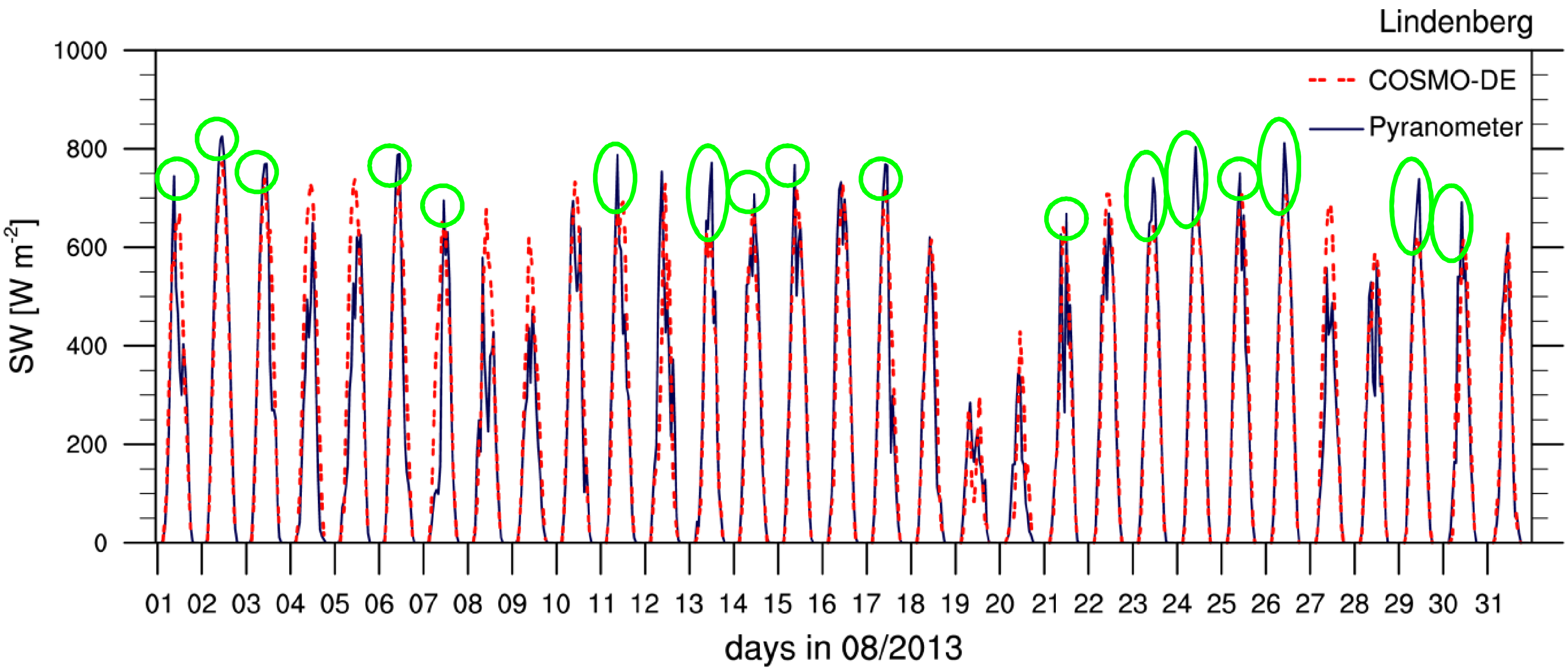


Insufficient radiation for clear sky conditions

Cloud-free Days



Aerosols from Tanré et al. 1984 are operational

- Constant in time
- On cloud free days the shortwave radiation forecast of the COSMO-DE model is underpredicted

Cloud-free Days

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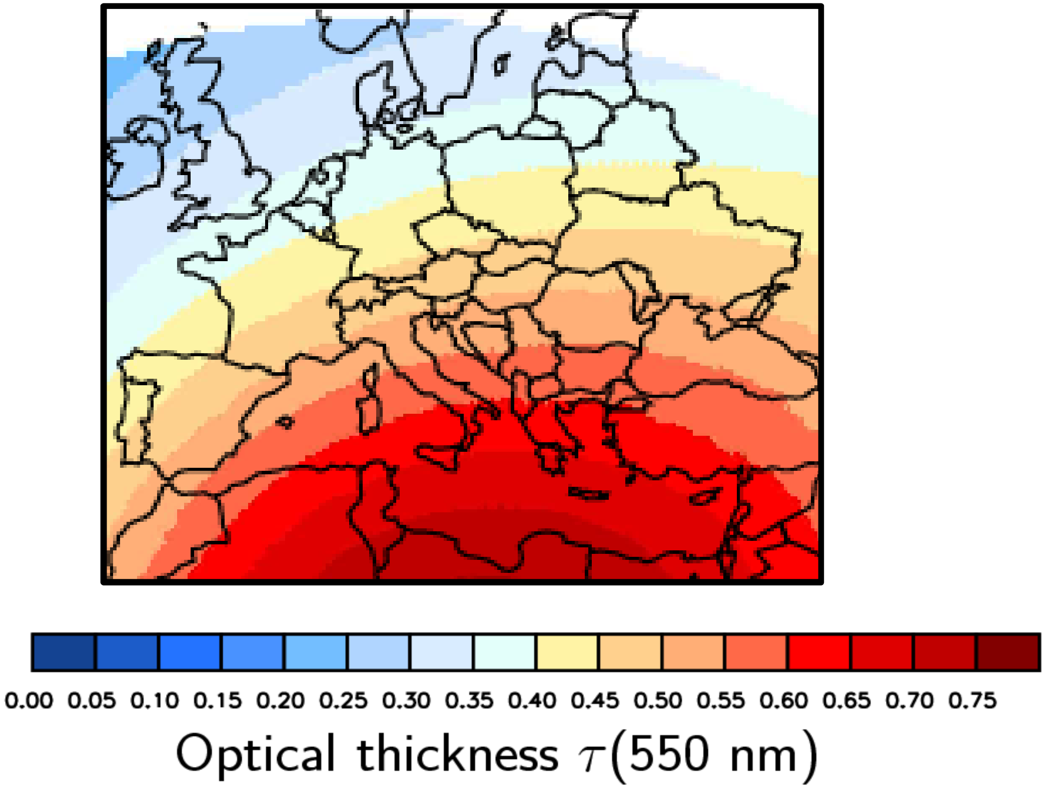
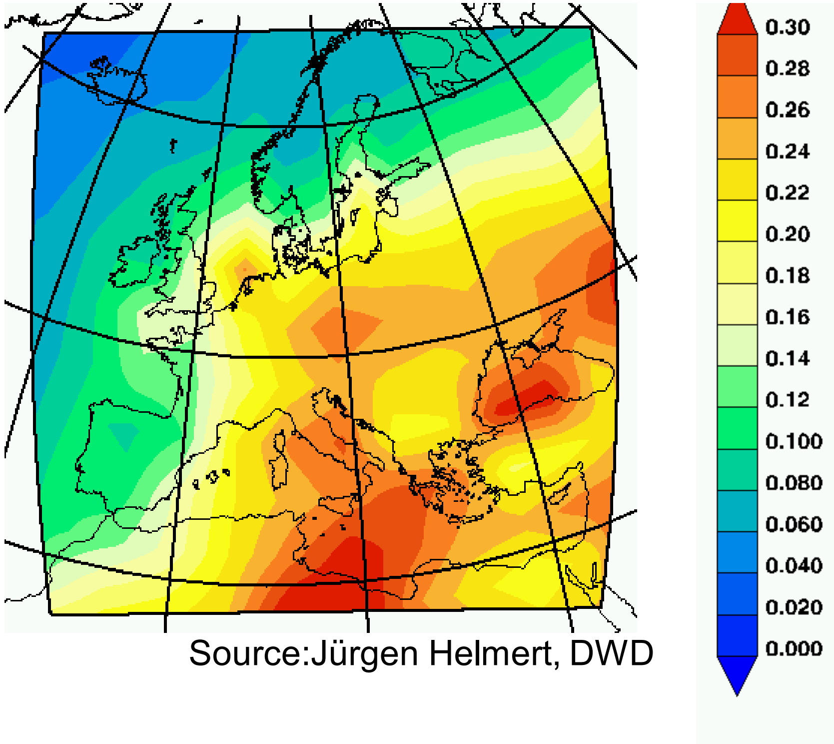
Aerosols based on Tanré, 1984 (operationel)



Source: Helmert et al. (2007)

Aerosol climatology from Tegen, 1997

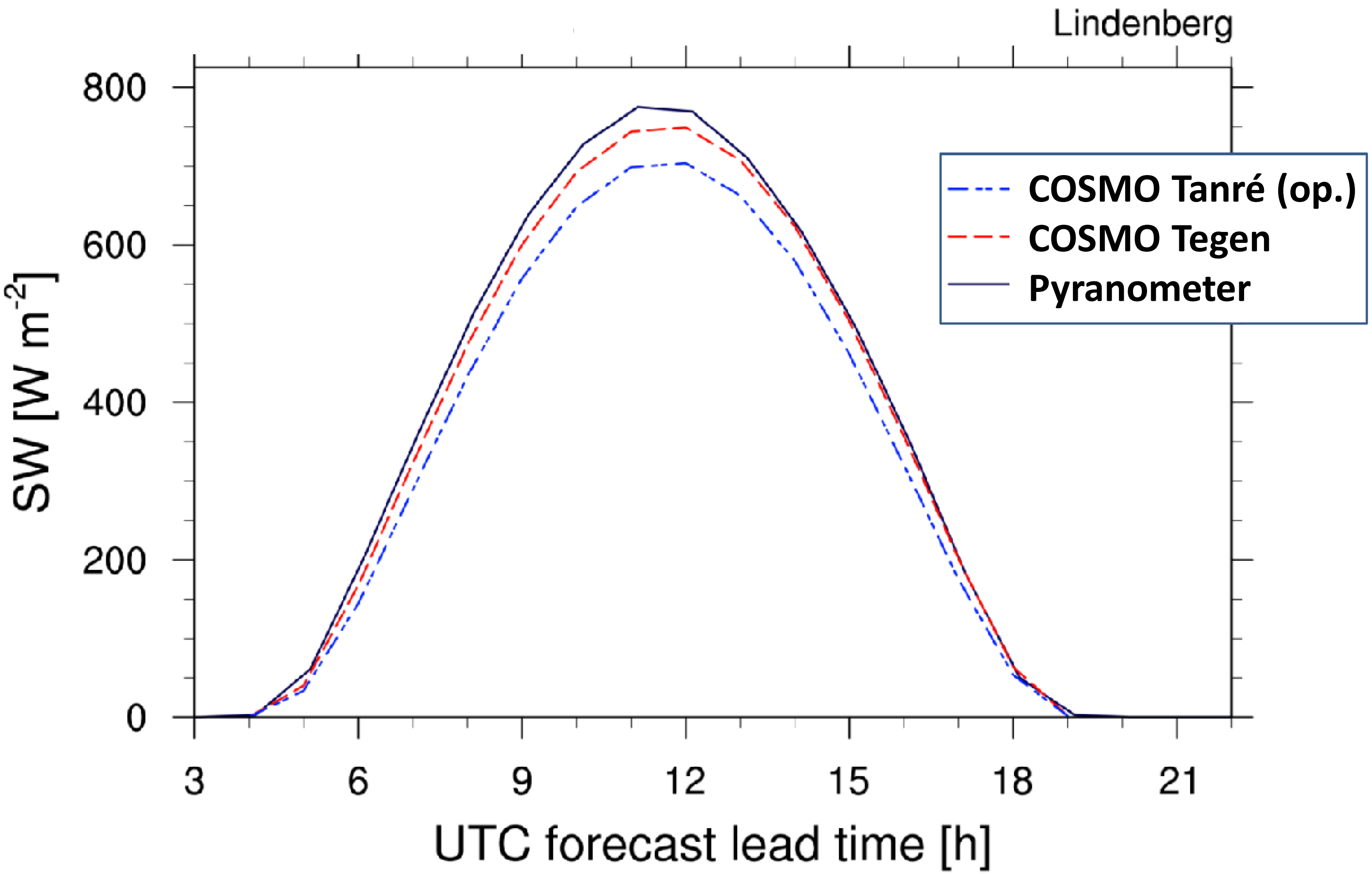


Source:Jürgen Helmert, DWD

$$\tau(\lambda) = \int_0^{z_{TOA}} \sigma_{ext(z,\lambda)} dz$$

τ – optical thickness
σ_{ext} – extinction coefficient
λ – wave length

Clear Sky Day- 18.08.2012



- Hourly averages of the surface shortwave irradiance
- Using the Tegen aerosol climatology shows an improvement due to reduced optical thickness of the atmosphere

PV Modeling Errors

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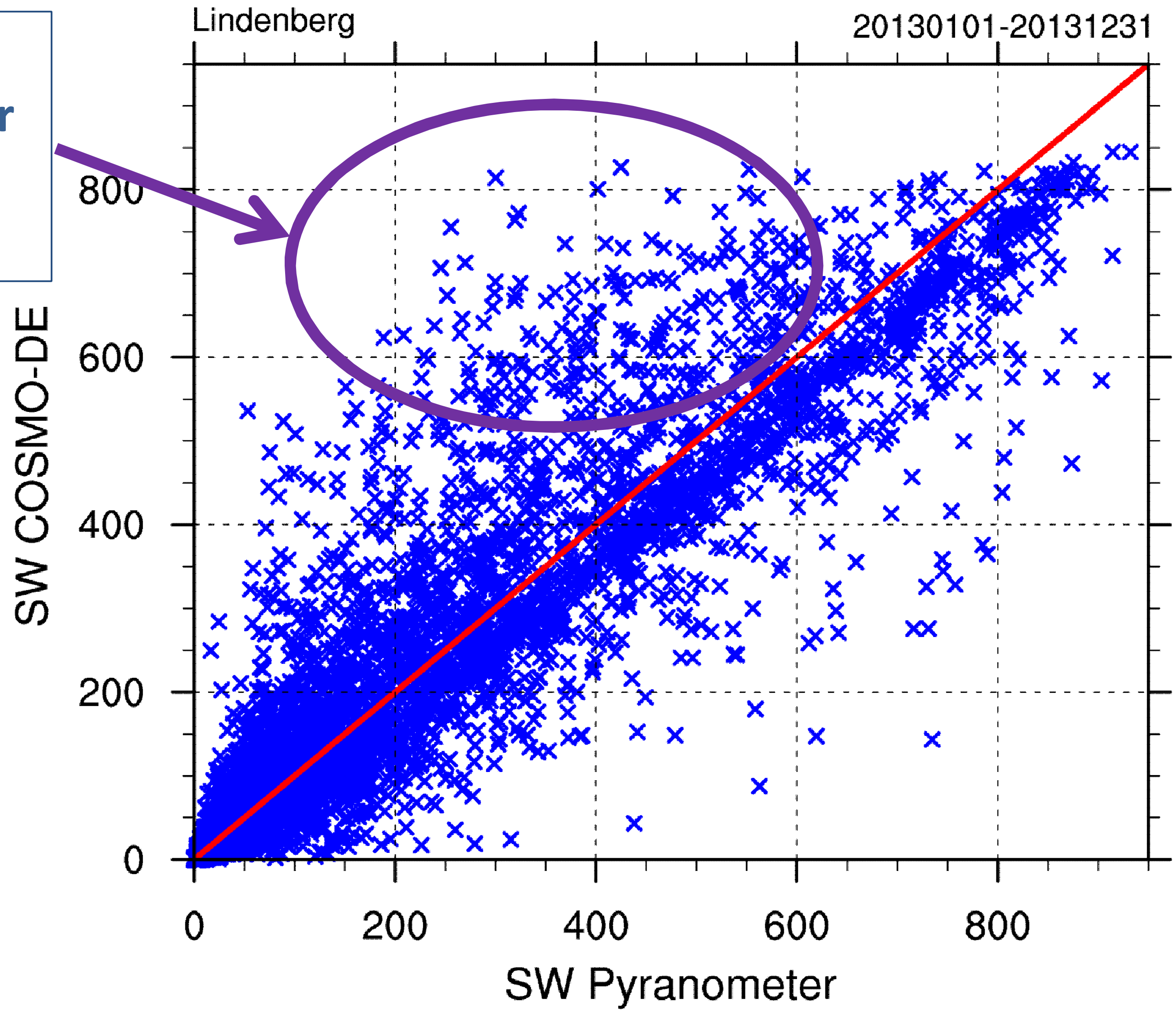
Too much radiation for cloudy conditions



PV Modeling Errors

- Radiation scheme based on Ritter und Geleyn 1992 only includes cloud ice and cloud water
- Rain, snow and graupel are neglected

→ Clouds optically too thin

→ Optical properties are being revised and rain, snow and graupel accounted for in te radiation scheme (Uli Blahak, DWD)

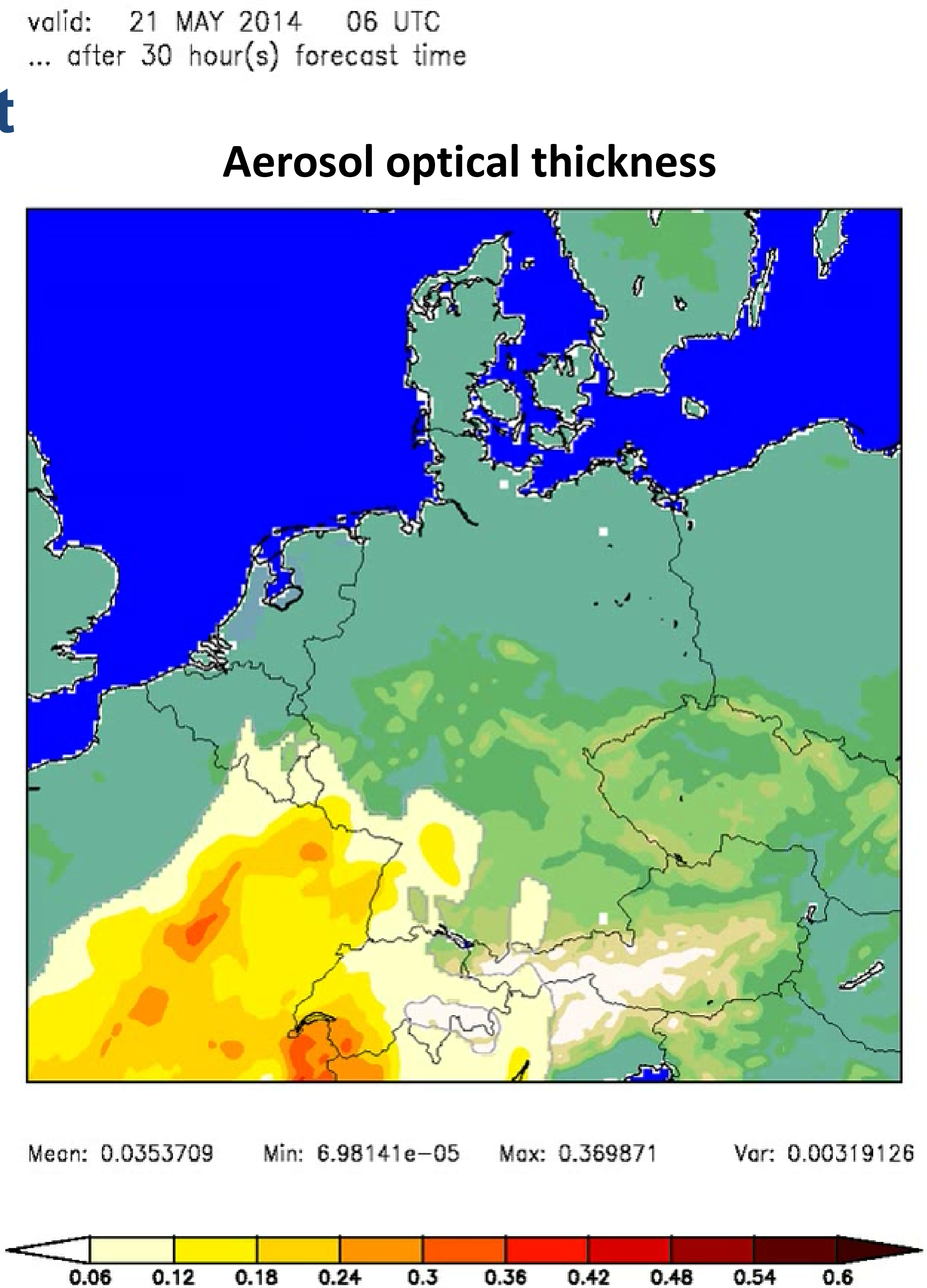

Other Challenges

External factors important for PV power forecast which are currently not included in the operational model:

- Sahara dust events
- Solar eclipse

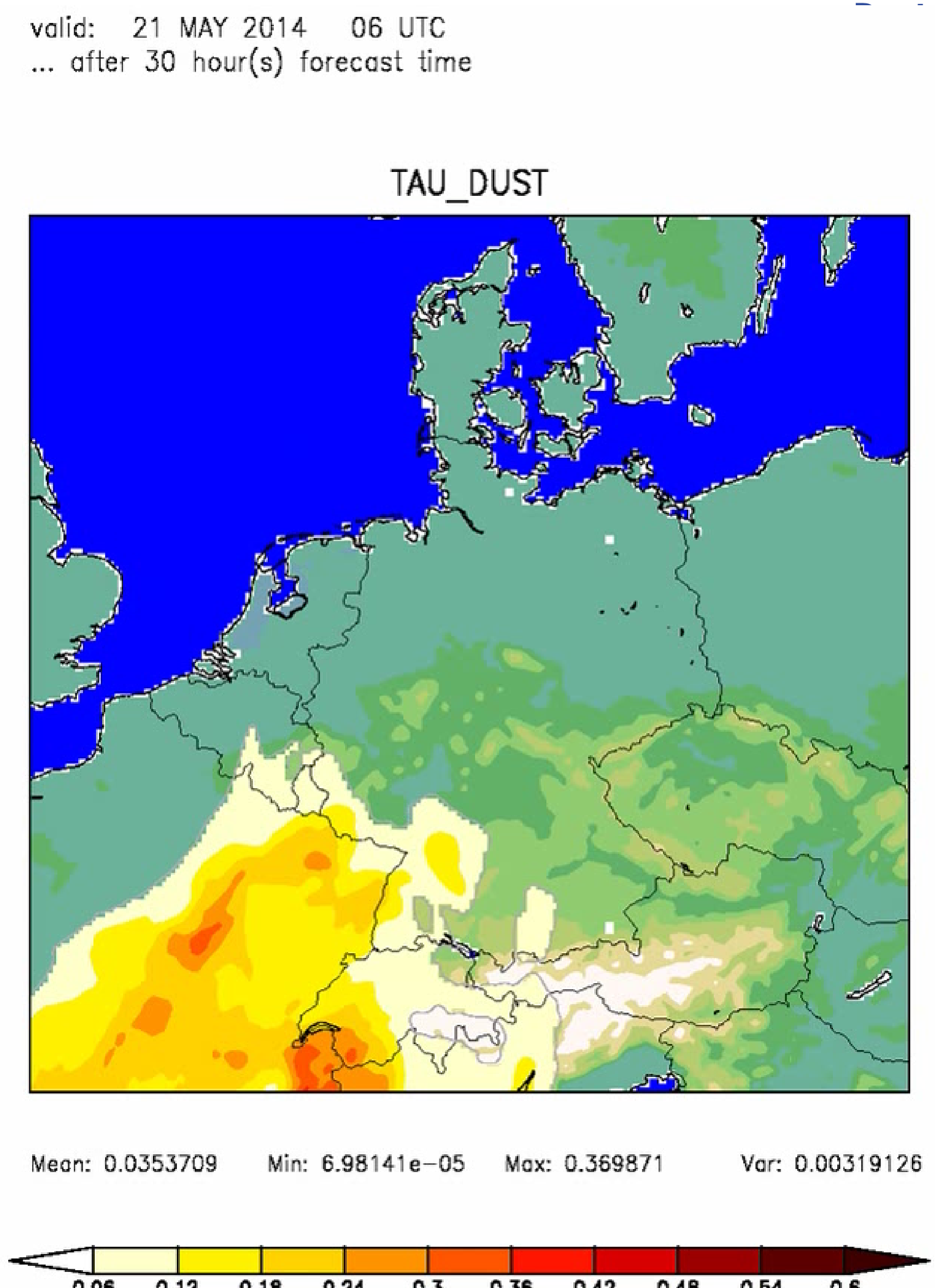
Sahara Dust

Aerosol optical thickness

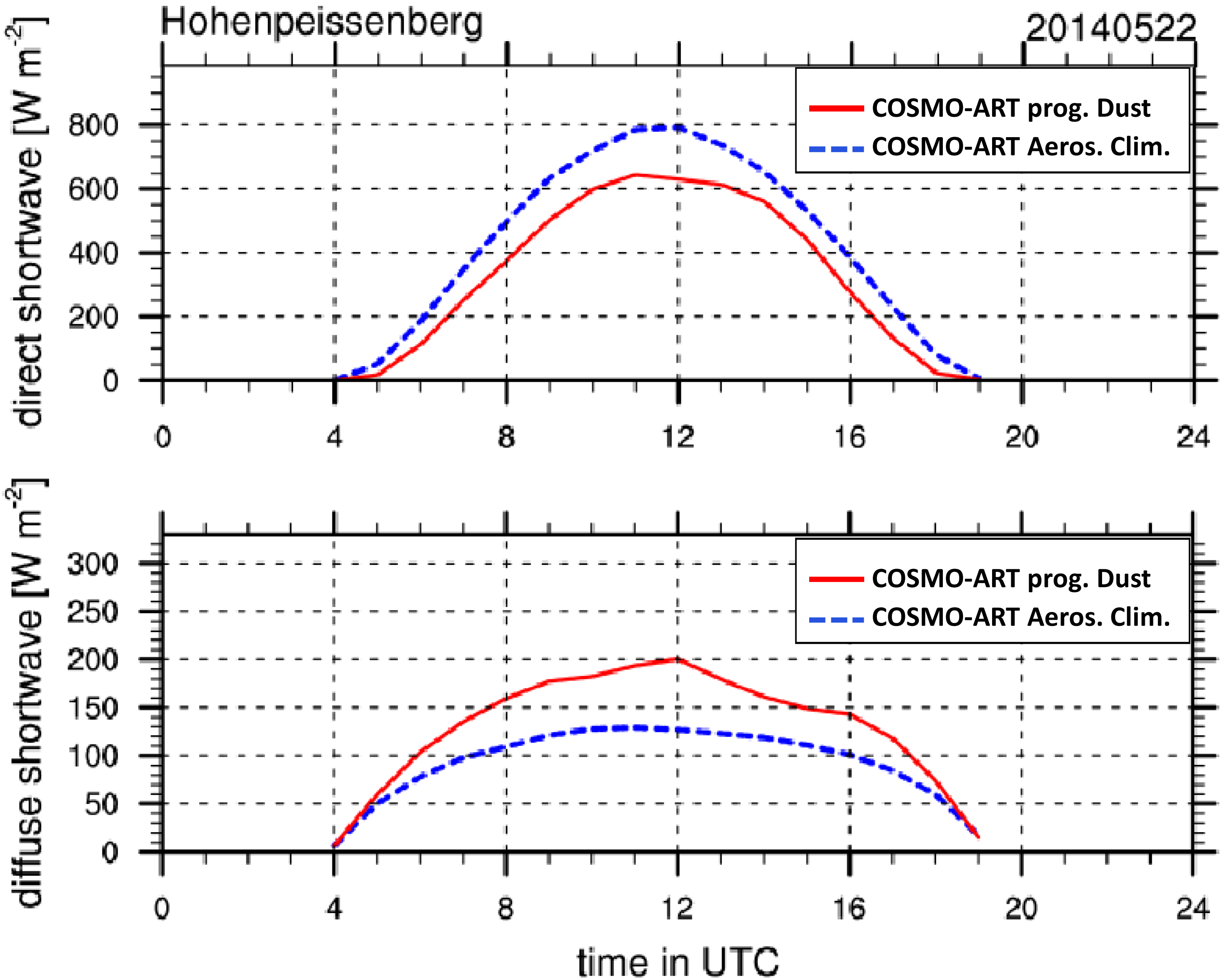


Source: B. Vogel (KIT), J. Förstner (DWD)

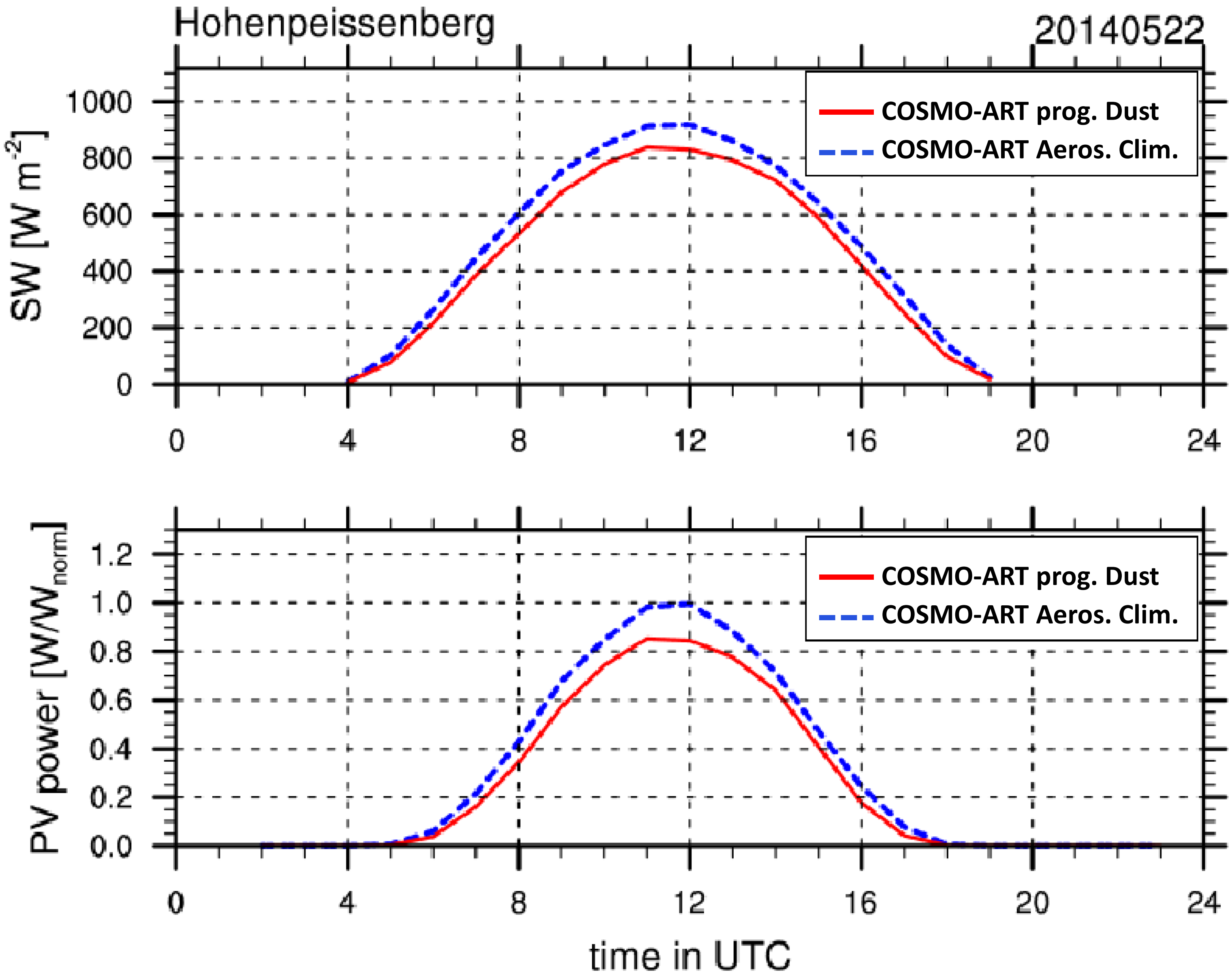
Sahara Dust


valid: 21 MAY 2014 06 UTC
... after 30 hour(s) forecast time
TAU_DUST
Mean: 0.0353709
Min: 6.98141e-05
Max: 0.369871
Var: 0.00319126

Sahara Dust

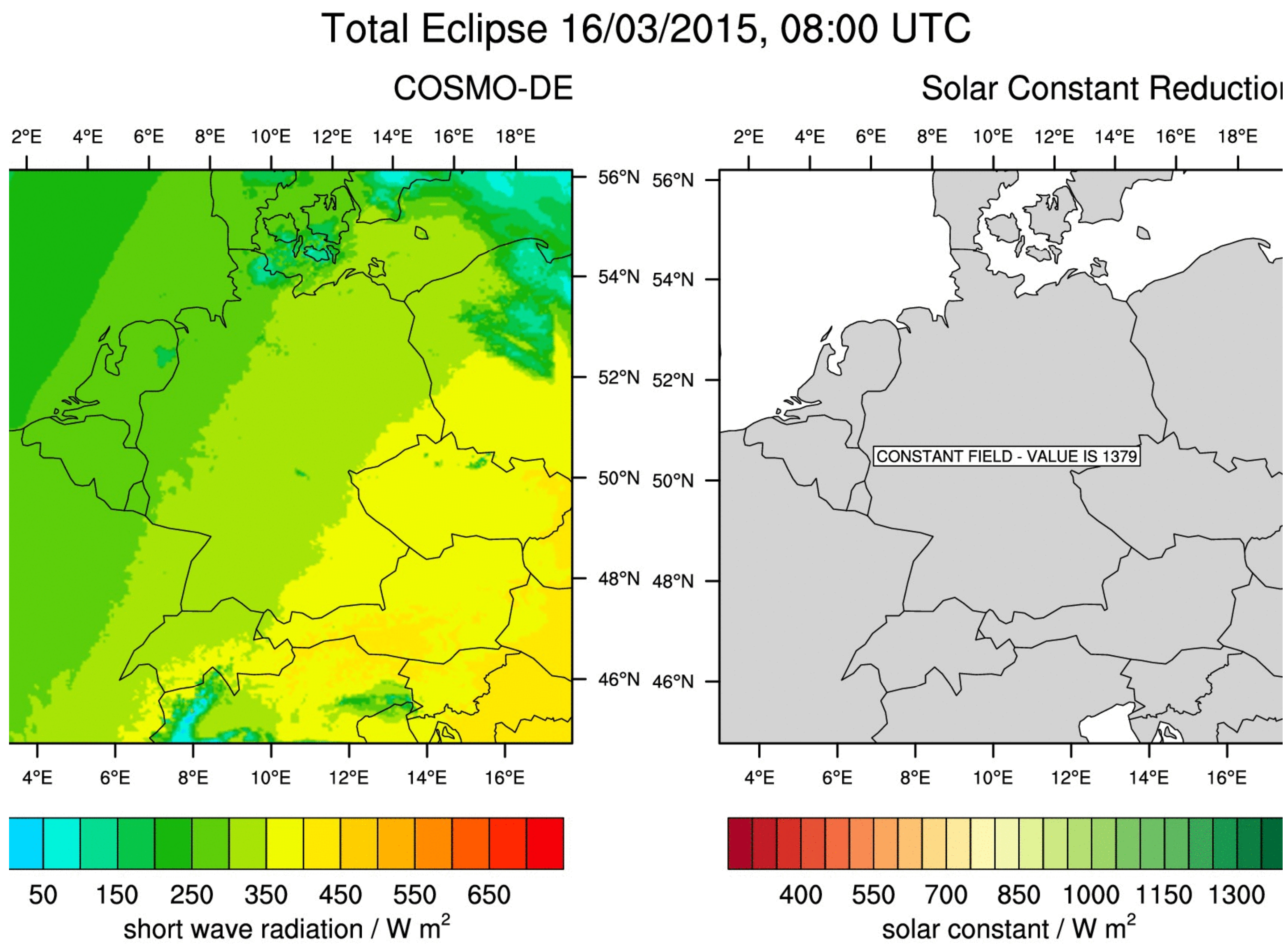

Hohenpeissenberg
20140522
direct shortwave [W m^-2]
800
600
400
200
0
0
4
8
12
16
20
24
COSMO-ART prog. Dust
COSMO-ART Aeros. Clim.
diffuse shortwave [W m^-2]
300
250
200
150
100
50
0
0
4
8
12
16
20
24
COSMO-ART prog. Dust
COSMO-ART Aeros. Clim.
time in UTC

Sahara Dust


Hohenpeissenberg
20140522
SW [W m-2]
1000
800
600
400
200
0
COSMO-ART prog. Dust
COSMO-ART Aeros. Clim.
0
4
8
12
16
20
24
PV power [W/Wnorm]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
COSMO-ART prog. Dust
COSMO-ART Aeros. Clim.
0
4
8
12
16
20
24
time in UTC

Solar Eclipse

March 20th 2015, 08:20-11.05h



Summary

Data Assimilation:

- Work on **assimilating cloud information** from various sources at the convective scale in a LETKF system ongoing:
  Satellite products, satellite radiances, PV power
- **Challenges**: Presentation of clouds in the model, Forward modelling, PV data

Model physics:

- Revision of optical cloud particle properties
- Change aerosol climatology
- Quantify effects of sahara dust and solar eclipse


Thank you!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Questions?