Modelling Beam Attenuation in Solar Tower Plants Using Common DNI Measurements

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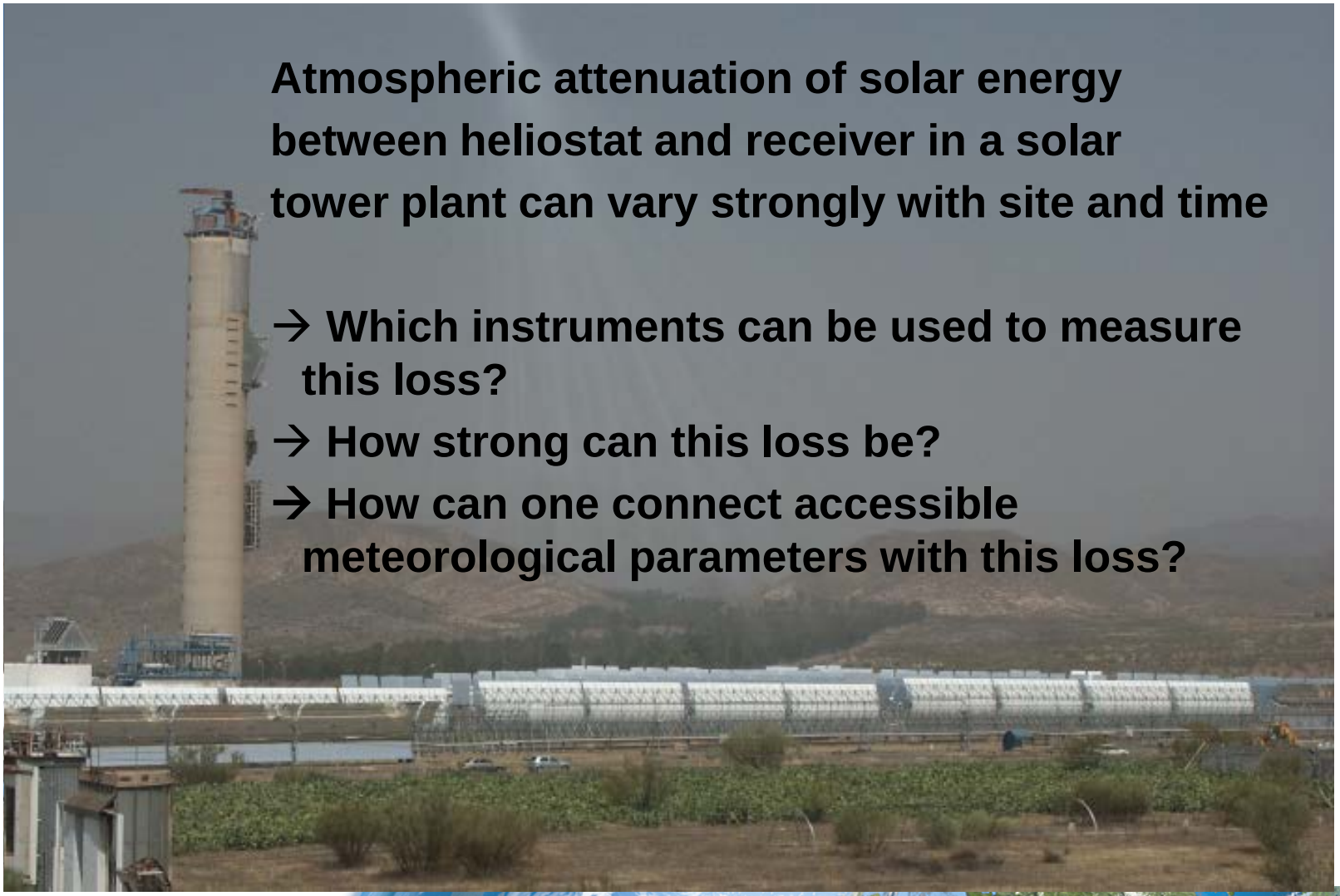
Motivation



Atmospheric attenuation of solar energy between heliostat and receiver in a solar tower plant can vary strongly with site and time

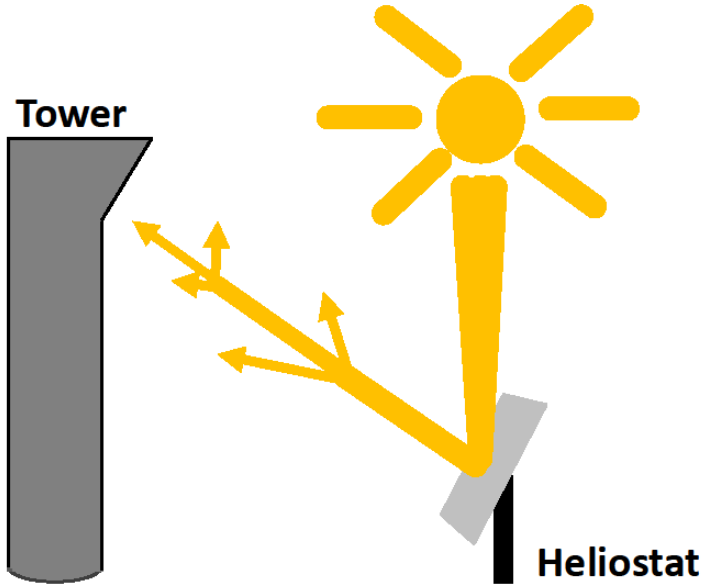
→ **Which instruments can be used to measure this loss?**

→ **How strong can this loss be?**

→ **How can one connect accessible meteorological parameters with this loss?**

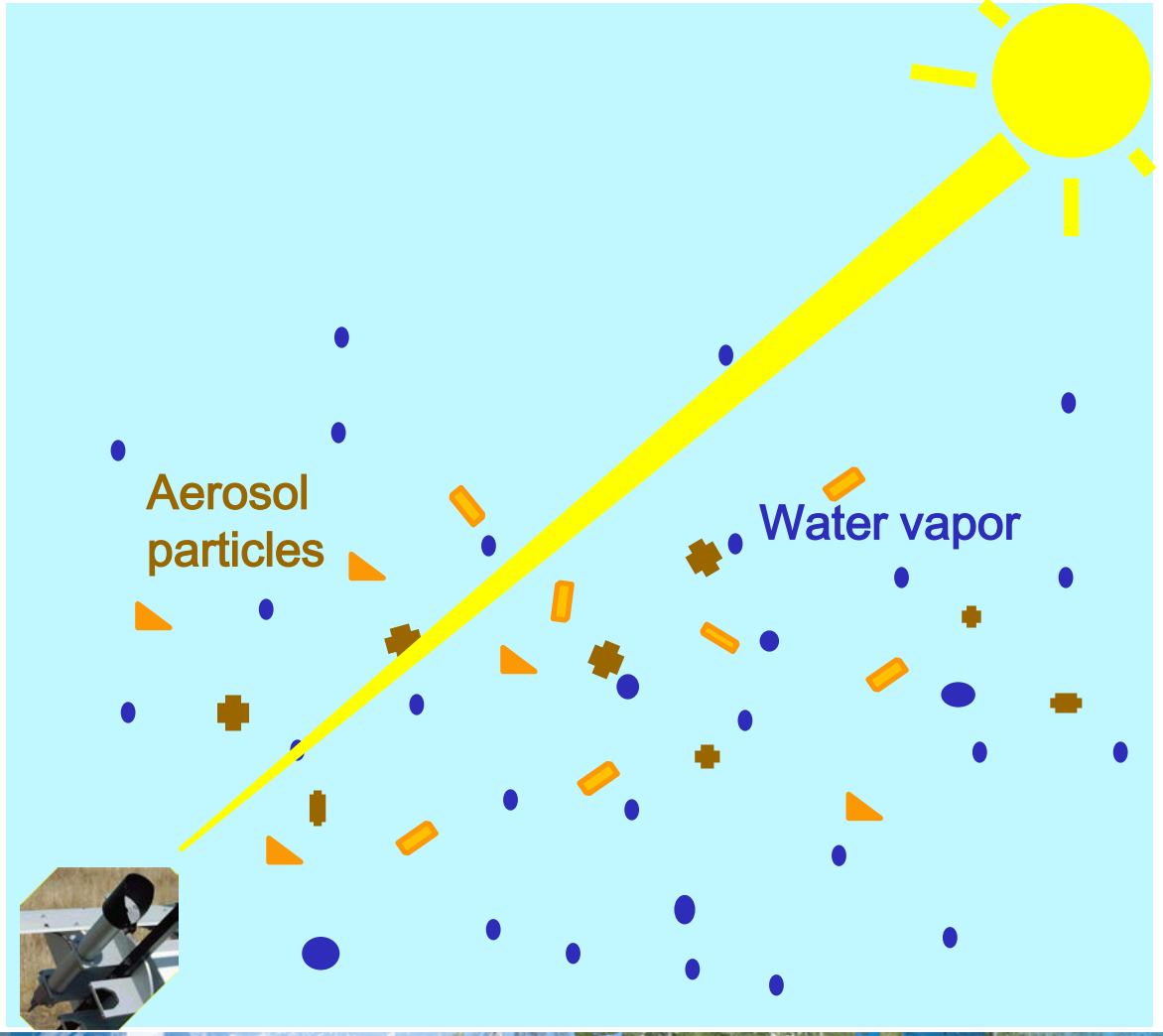
Measure atmospheric extinction?

Common DNI measurements available on every plant site



State of the Art: SolarPACES 2011 → Sengupta & Wagner Model

Transmittance model based only on DNI measurements



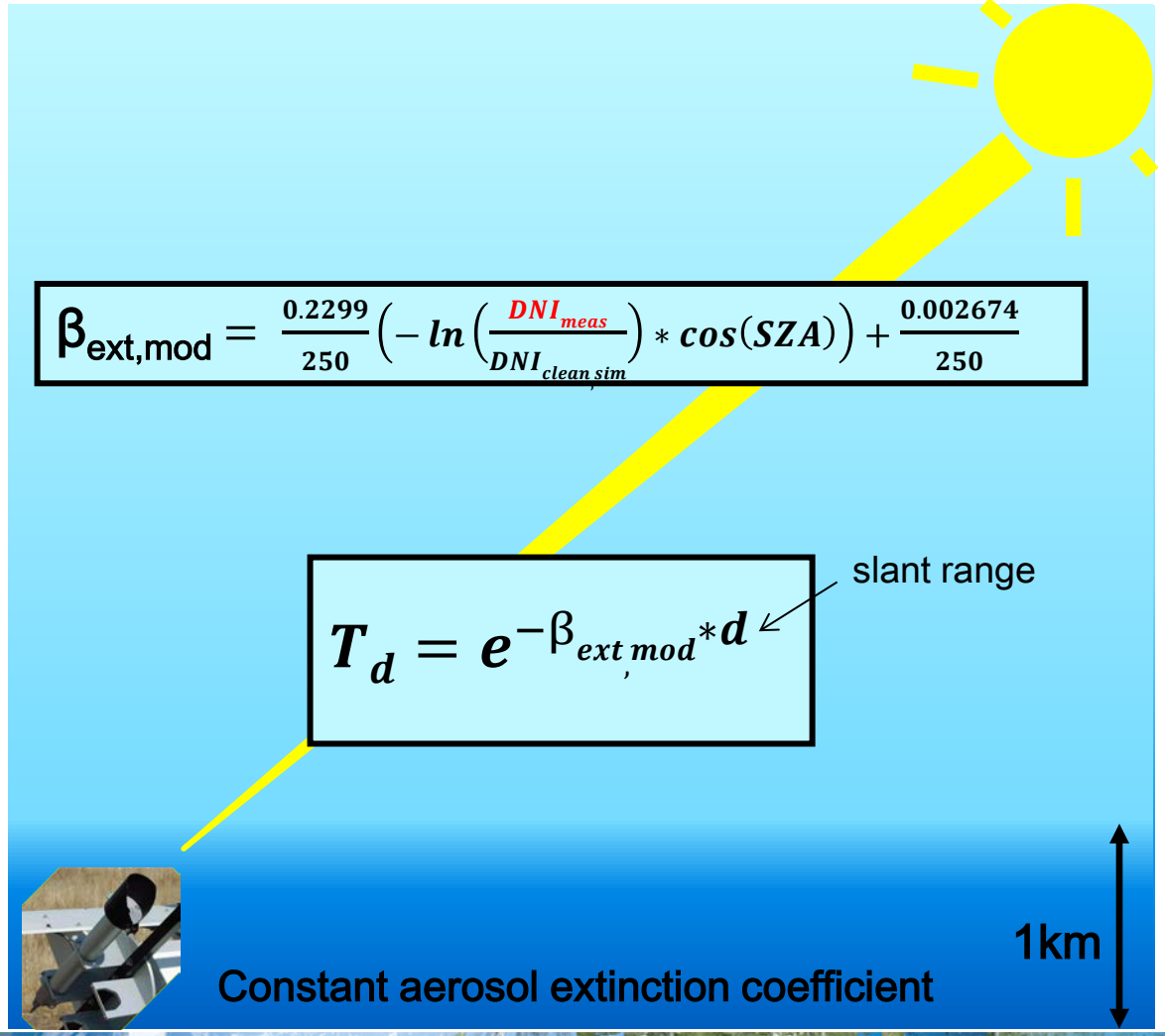
Sengupta et al., 2011: “Impact of aerosols on atmospheric attenuation loss in central receiver systems”

State of the Art: SolarPACES 2011 → Sengupta & Wagner Model

Most aerosol particles + water vapor located in lower troposphere

Assumption about aerosol height profile
+
theoretical clear sky DNI for atmosphere without aerosol
+
DNI measurement

→ Calculate extinction coefficient close to ground

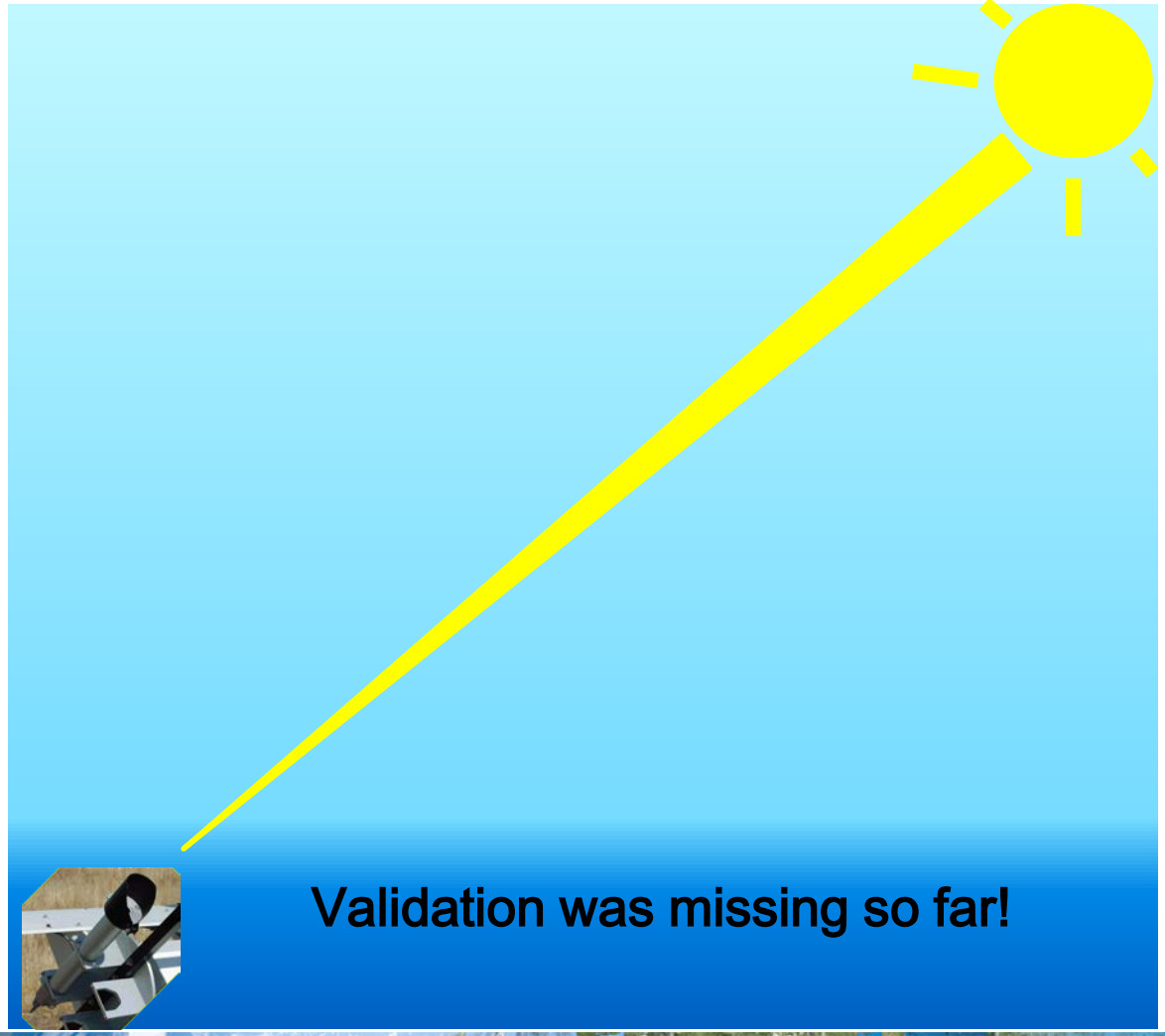


Sengupta et al., 2011: “Impact of aerosols on atmospheric attenuation loss in central receiver systems”

State of the Art: SolarPACES 2011 → Sengupta & Wagner Model

Drawbacks:
Model developed for only one

- water vapor content
- aerosol type
- aerosol height distribution
- site altitude



Sengupta et al., 2011: “Impact of aerosols on atmospheric attenuation loss in central receiver systems”

Validation of Model 2011

Reference data set:

- 1km realistic slant range distance in tower plant → T_{1km} for May 2013 - May 2014
- Scatterometer Vaisala FS11
- Pulses monocromatic NIR (875nm) light beam through volume of air
  → measures forward scattering of beam
- T_{1km} measurement range: 0 – 0.961
- Absorption and broadband corrected

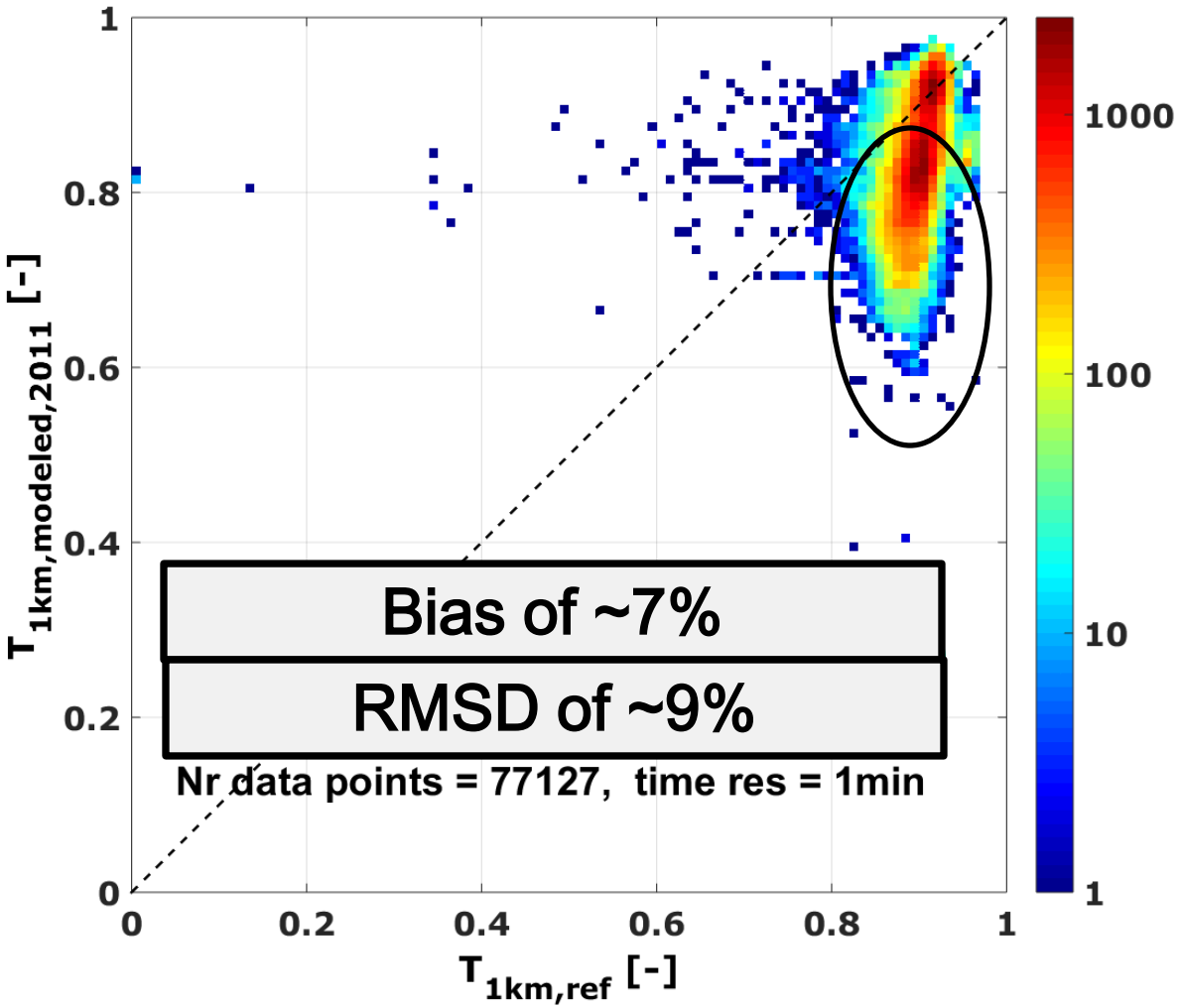
Hanrieder et al. 2015:“Atmospheric extinction in solar tower plants: the Absorption and Broadband Correction for MOR measurements“,AMTD 8,4737-4768

Validation of Model 2011

Implementation model 2011 for PSA

only **clear sky** DNI measurements

Cloud detection: thresholds for Ineichen Linke turbidity (TL) and DNI, temporal variability criteria



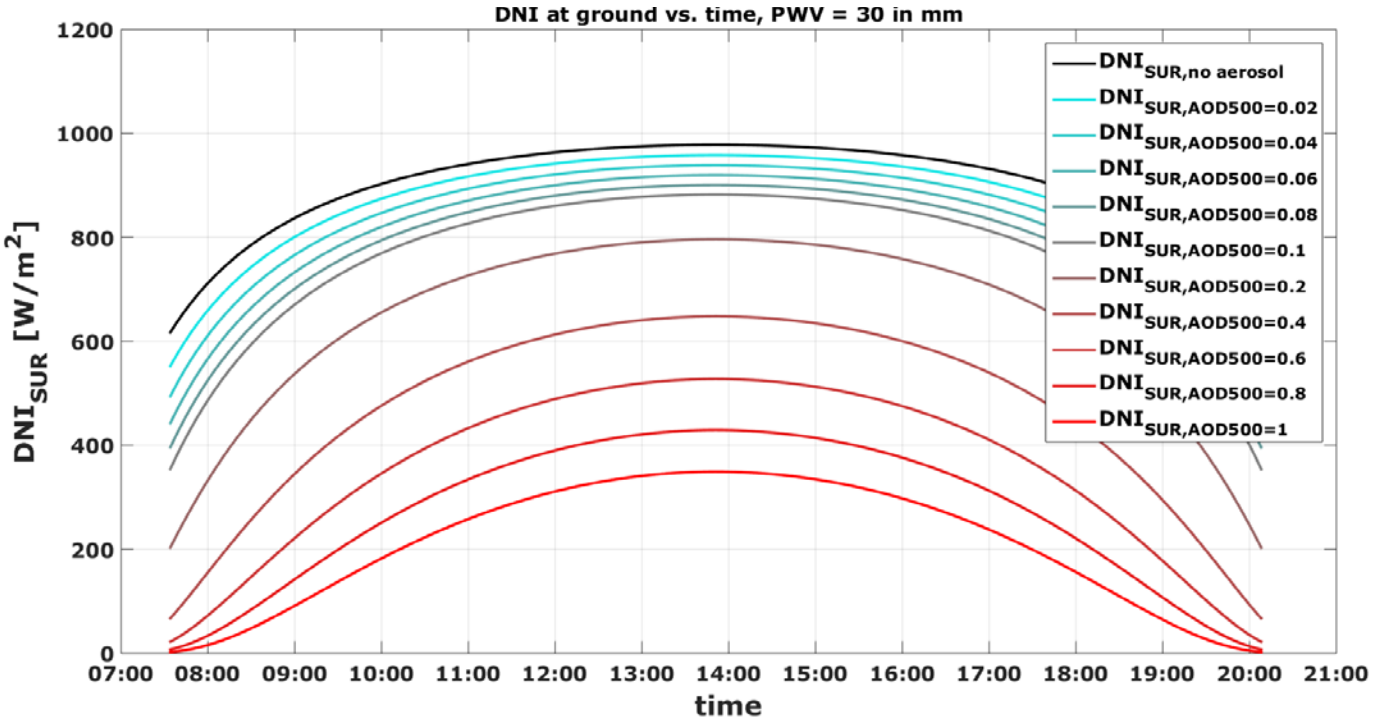
Ineichen, P., and Perez, R., 2002: “A new airmass independend formulation for the Linke turbidity coefficient”, Solar Energy, 73, 151-157

Developement of Model 2015

Approach 2015: Develop model for

- elevation adjusted to validation site
- flexible precipitable water vapor content (timeseries of PWV, derived from RH with approach of Gueymard 1993/1994)

Gueymard, C.: Assessment of the Accuracy and Cumputing Speed of Simplified Saturation Vapor Equations Using a New Reference Dataset, Journal of Applied Meteorology, 32, 1294-1300, 1993



libRadtran radiative transfer calculations for PSA and 21st of June

Mayer and Kylling, 2005: "Technical note: The libRadtran software package for radiative transfer calculations - description and examples of use"

Developement of Model 2015

DNI measurement +
theoretical clear sky DNI for atmosphere without aerosol

DNI loss between 250m height and surface

↓

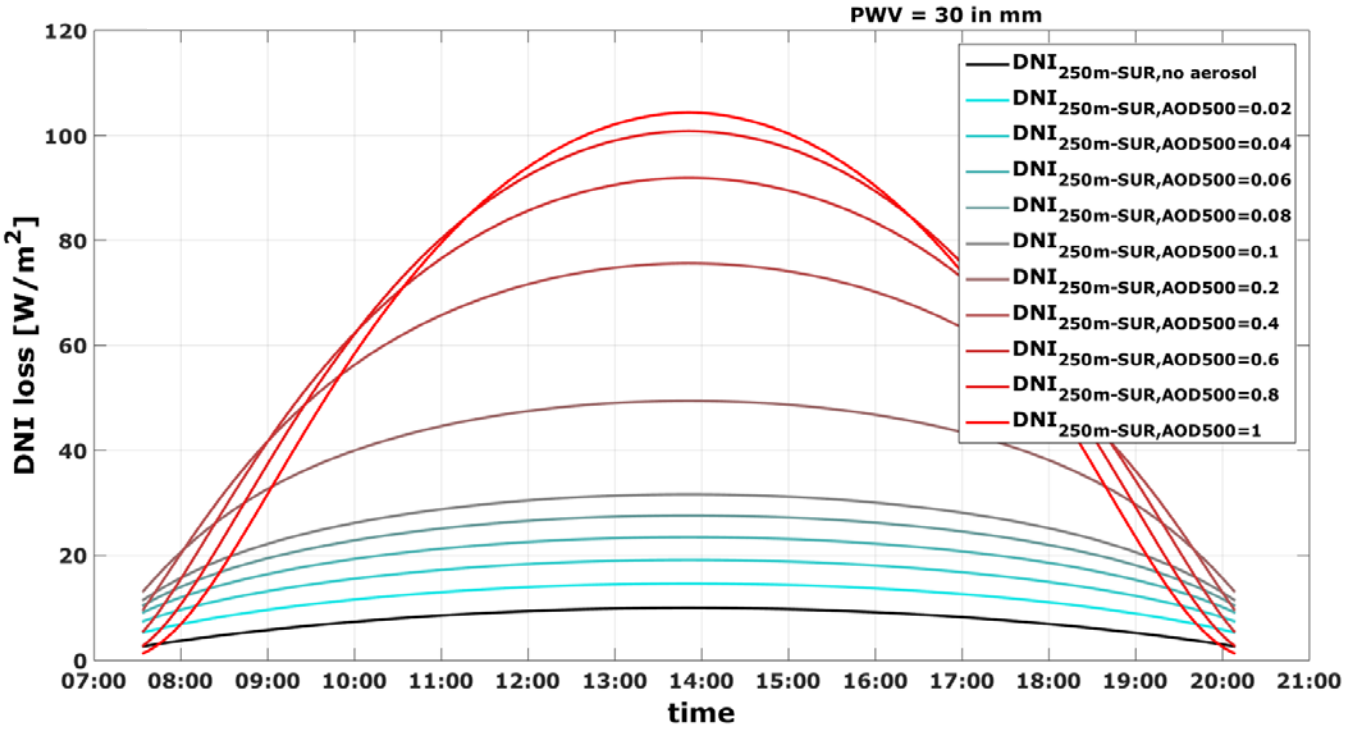
OD of 250m layer over ground

↓

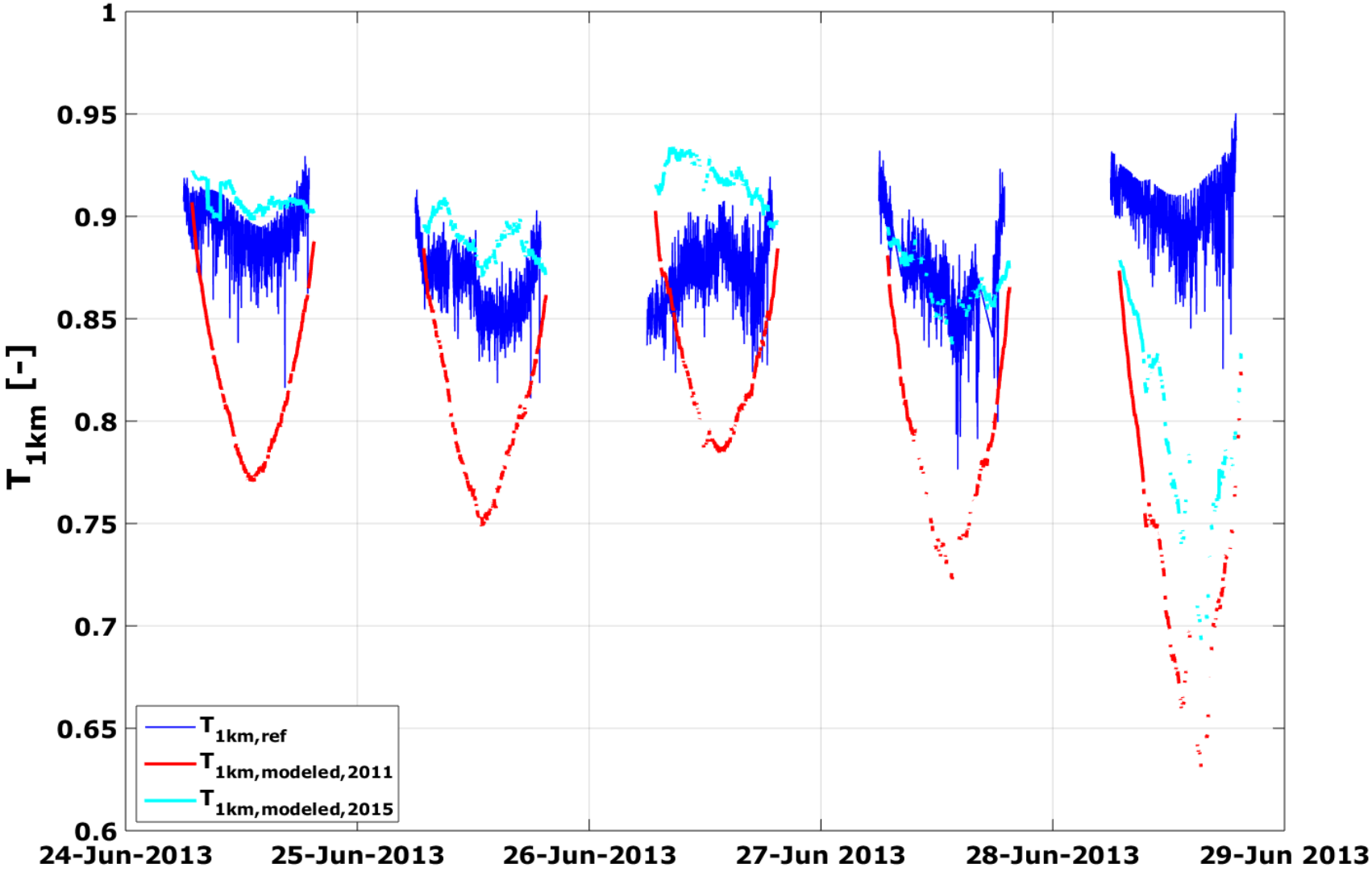
β_{ext} close to ground

↓

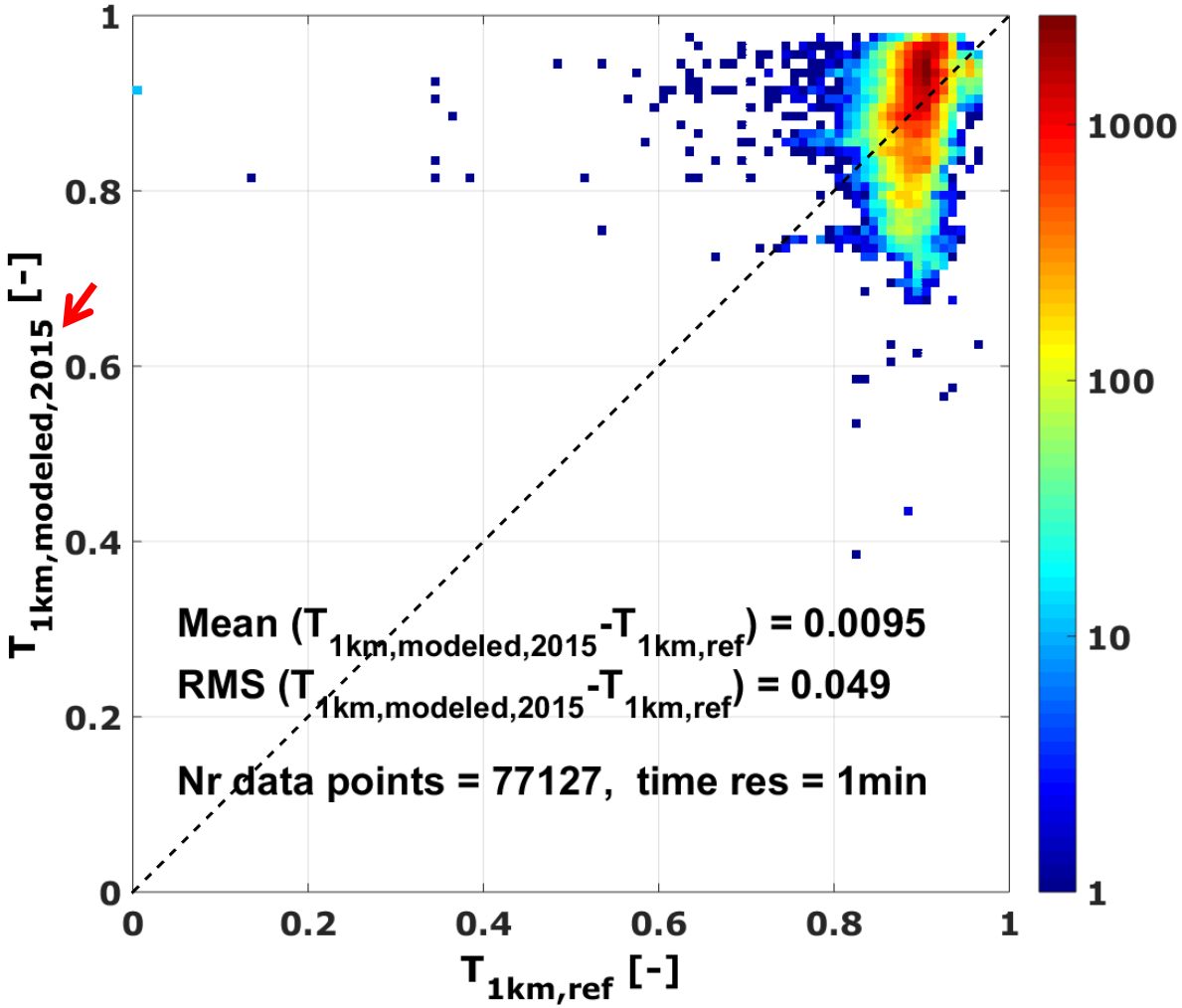
T_{1km} at ground



Validation of Model 2015



Validation of Model 2015



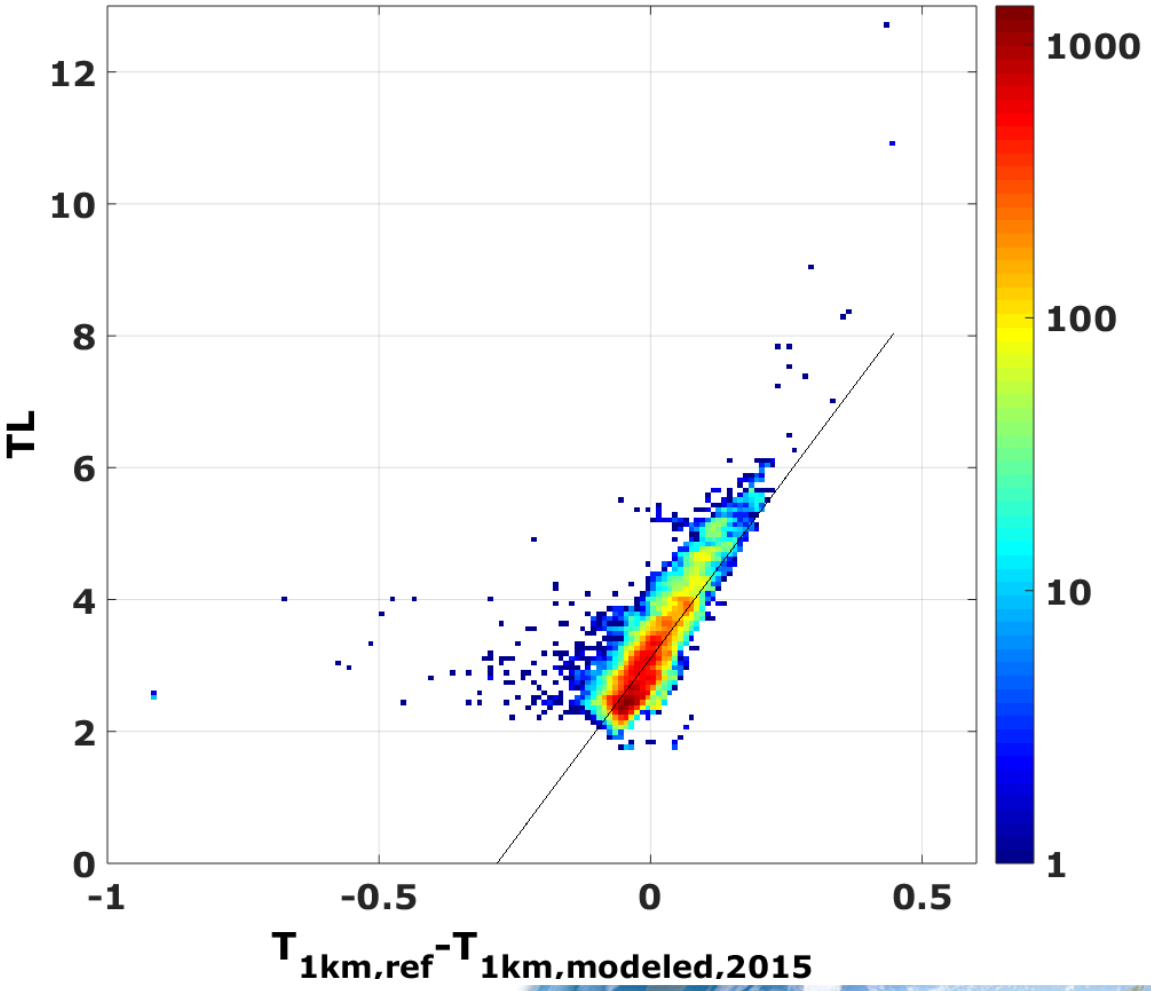
↘ **Bias**

1% (instead of 7%)

↘ **RMSD**

5% (instead of 9%)

Further improvements of Model 2015



Still dependency on Linke turbidity

→ can be corrected

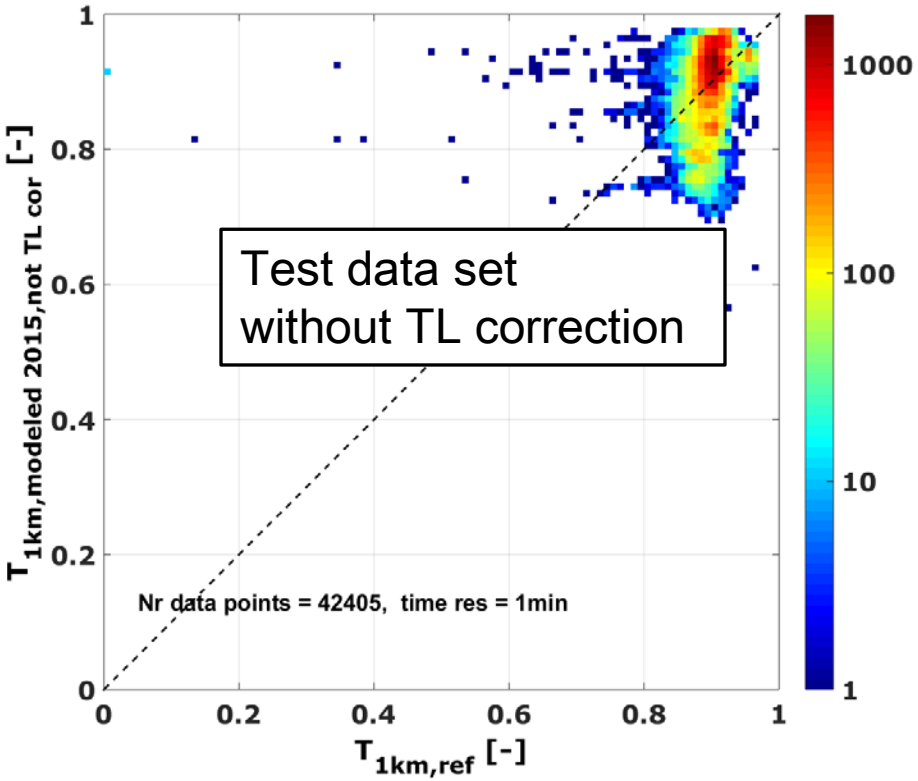
→ linear correction for Linke turbidity!

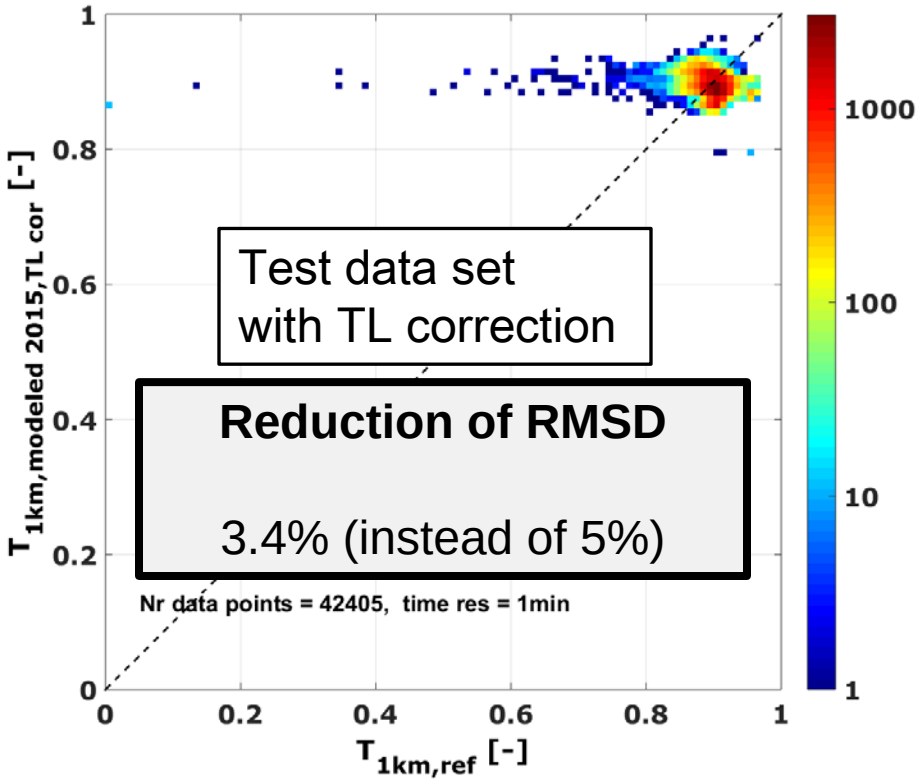
Further improvements of Model 2015

Development of linear correction function from half of the data (every second months of data set)

→

Application of correction function to other half of data





Further improvements of Model 2015

Main assumption of model is aerosol height profile

For PSA bias < 1%

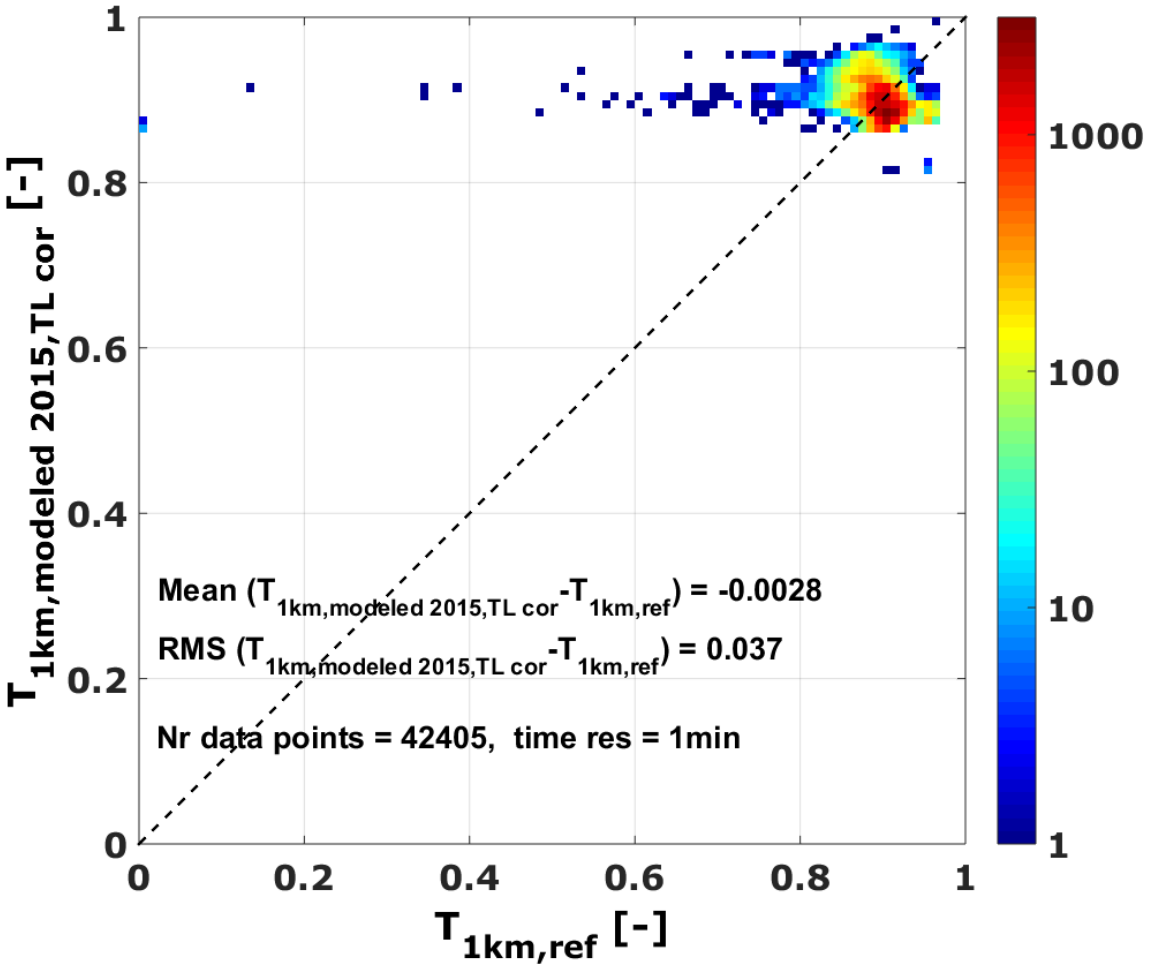
For other sites?

→ ESA project LIVAS: global 3D aerosol and cloud optical climatology (CALIPSO+EARLINET)

→ Test of LIVAS extinction height profile for PSA

Amiridis et al. 2015:" LIVAS: a 3-D multi wavelength aerosol/cloud climatology based on CALIPSO and EARLINET"

Further improvements of Model 2015



Test of LIVAS extinction height profile for PSA

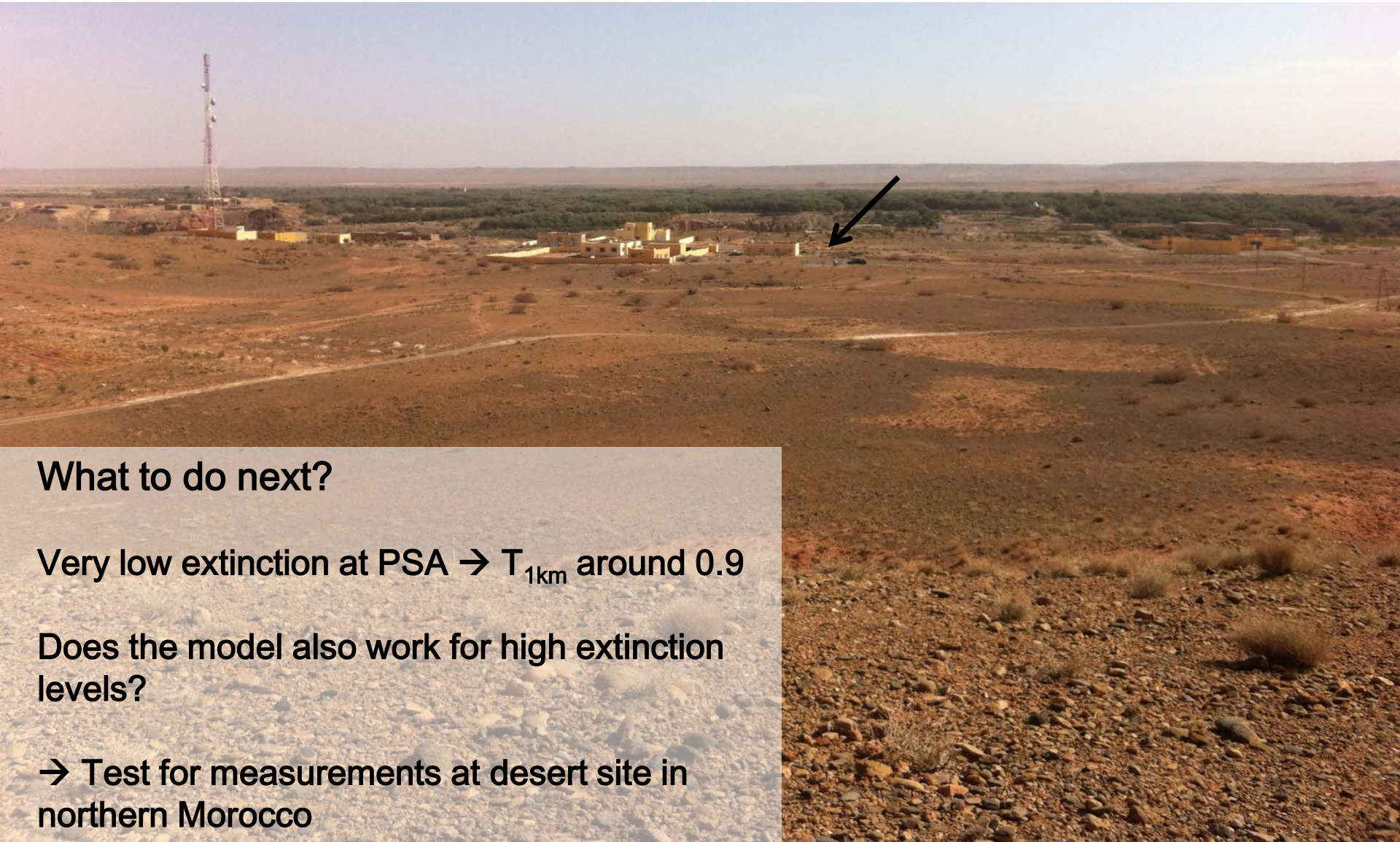
Transmittance model 2015
+
TL correction

RMSD = 3.7%

Summary

- Modeling beam attenuation in solar tower plants using DNI measurements possible
- Model of 2011 tested with corrected scatterometer data for PSA → bias of 7%, RMSD 9%
- Development of new model 2015 for elevation of PSA including flexible water vapor content
- Validation of new model 2015 shows bias of less than 1% and a RMSD of 5%
- Further correction for TL possible → reduction of RMSD to 3.4%
- Adapting LIVAS aerosol extinction height profile possible (RMSD 3.7%) → Opportunity to apply method for different sites

Outlook



What to do next?

Very low extinction at PSA → T_{1km} around 0.9

Does the model also work for high extinction levels?

→ Test for measurements at desert site in northern Morocco

Thank you for your attention!

For more details please contact:
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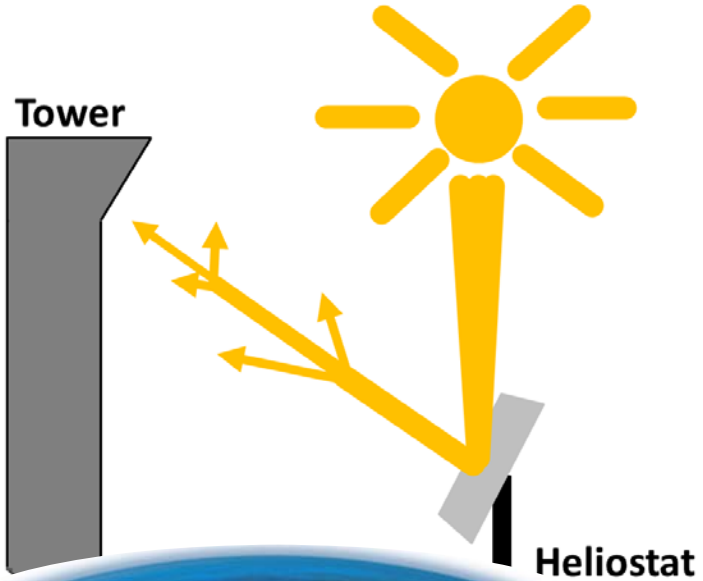

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