The uncertainties of shortwave radiation computations in COSMO-Ru due to the radiative transfer code and the application of different aerosol climatologies

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COSMO / CLM / ICON / ART User Seminar 2017

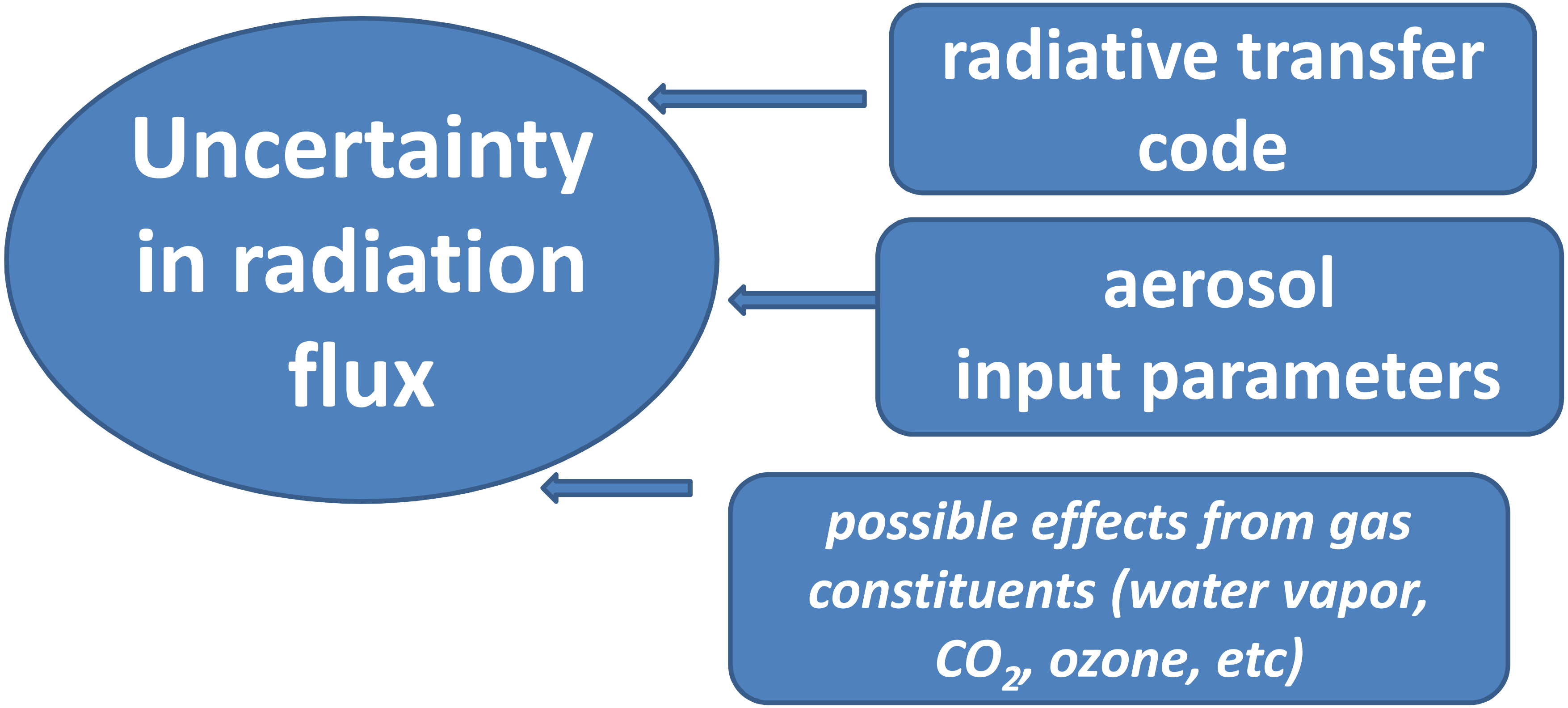
The objectives:

- **To test radiative computations with different aerosol datasets against the accurate RT simulations and ground-based radiative measurements in cloudless conditions.**

- **This includes:**
- ***Verification of different aerosol climatologies and MACC (CAMS) ECMWF aerosol input data against observations.***

- ***Testing radiative transfer algorithm (Ritter and Geleyn, 1992)* implemented in COSMO model *against accurate model simulations with the same aerosol optical parameters within their large range.***

- Radiative effects of COSMO-ART aerosol implementation – case study.


Uncertainty in radiation flux
radiative transfer code
aerosol input parameters
possible effects from gas constituents (water vapor, CO_2, ozone, etc)

Testing the radiative effects of aerosol input parameters against experimental ground-based radiative observations

Two datasets applied:

Falkenberg/Lindenberg site (Meteorologisches Observatorium Lindenberg, Germany.

Moscow State University Meteorological Observatory (MSU MO, Russia), Russia

Measurements at the MSU Meteorological Observatory, 55.7N, 37.5E

www.momsu.ru

Radiative measurements:

- net radiometer Kipp&Zonen CNR-4, (downward shortwave and longwave radiation, upward shortwave and longwave radiation)

Data on aerosols and atmospheric water vapor content :

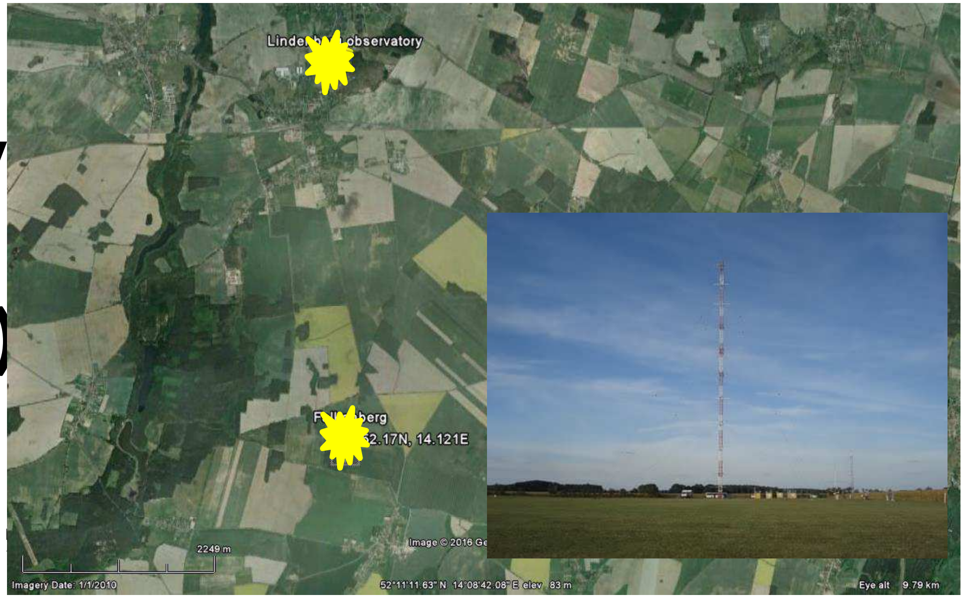
- sun sky photometer AERONET CIMEL dataset from AERONET version 2.0, level 2.0

Meteorological observations:

- Hourly cloud observations,
- The air temperature at a height of 2m (T2m).

Measurements at the Lindenberg observatory

(Falkenberg/Lindenberg) sites 52.17N, 14,12E / 52.209N, 14.121E



At Falkenberg site (6 km to the south from Lindenberg) BSRN–like radiative measurements are available: all components of shortwave radiation (direct, diffuse, global, reflected shortwave irradiance)

Automatic weather station data. Visual cloud observations;

•Directly at the Lindenberg observatory the data on aerosols and atmospheric water vapor content are available from sun sky photometer AERONET CIMEL dataset , version 2.0; as well as upper –air soundings (temperature, water vapor) , ozonezondes dataset.

COSMO Radiative Code

Solar spectral intervals

Interval number	1	2	3
Limits (μm)	1.53–4.64	0.70–1.53	0.25–0.70
Gaseous absorption, No. of k_i for H_2O, CO_2 and O_3	H_2O, CO_2 CH_4, N_2O (7, 6, 0)	H_2O, CO_2, O_2 (7, 3, 0)	O_3, H_2O O_2 (3, 2, 5)
Droplet			
scattering	yes	yes	yes
absorption	yes	yes	yes
Rayleigh scattering	yes	yes	yes
Aeorsol			
scattering	yes	yes	yes
absorption	yes	yes	yes

from Ritter, Geleyn, 1992

1982 AFGL spectroscopic database for optical properties of gases for gaseous transmission function .

Delta two stream parameterization of radiative transfer.

Main equations:

$$\frac{dF_1}{d\delta'} = \alpha'_1 F_1 - \alpha'_2 F_2 - \alpha'_3 J$$

$$\frac{dF_2}{d\delta'} = \alpha'_2 F_1 - \alpha'_1 F_2 + \alpha'_4 J$$

$$\frac{dS}{d\delta'} = -\frac{S}{\mu_0}$$

$$\delta' = (1 - \tilde{\omega} f)\delta$$

$$\tilde{\omega}' = \frac{\tilde{\omega}(1 - f)}{1 - \tilde{\omega} f},$$

CLIRAD(FC05)-SW Radiative Code.

(for solar shortwave irradiance accurate computations)

8 intervals (μm):

0.200 - 0.303; 0.303 - 0.323; 0.323 - 0.70;
0.323 - 1.220; 0.700 - 1.220; 1.220 - 10.0;
1.220 - 2.270; 2.270 - 10.0;

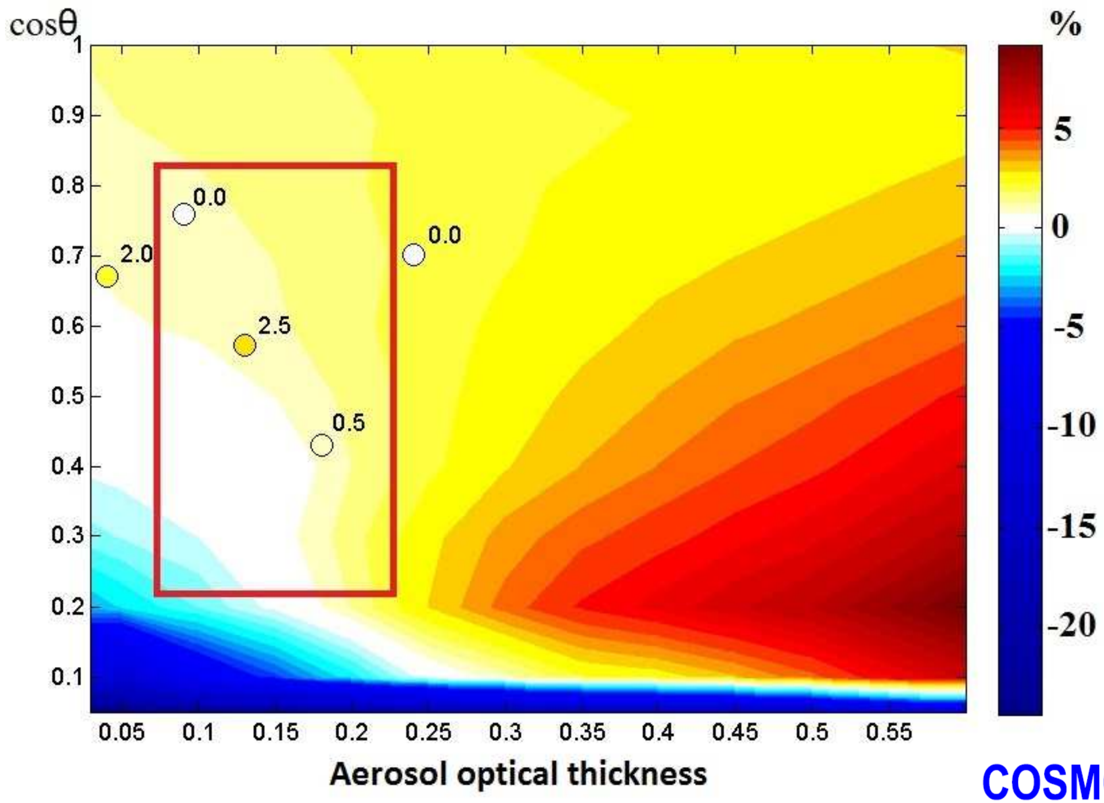
Gases: H_2O, O_2, O_3, CO_2;

The absorption bands: HITRAN-12v (2004);

Two-stream adding method (*Chou, 1992*).

Relative errors of global solar irradiance calculated using the CLIRAD(FC05)-SW model against benchmark Monte-Carlo model as a function of cos SZA and AOT at 550nm

Testing was performed against benchmark calculations by the application of Kurchatov Center radiation Monte-Carlo model (*Rublev A.N., 2001*).
The conditions of "midlatitude summer", and continental aerosol properties (*WCP-112, 1986*) were used in simulations.



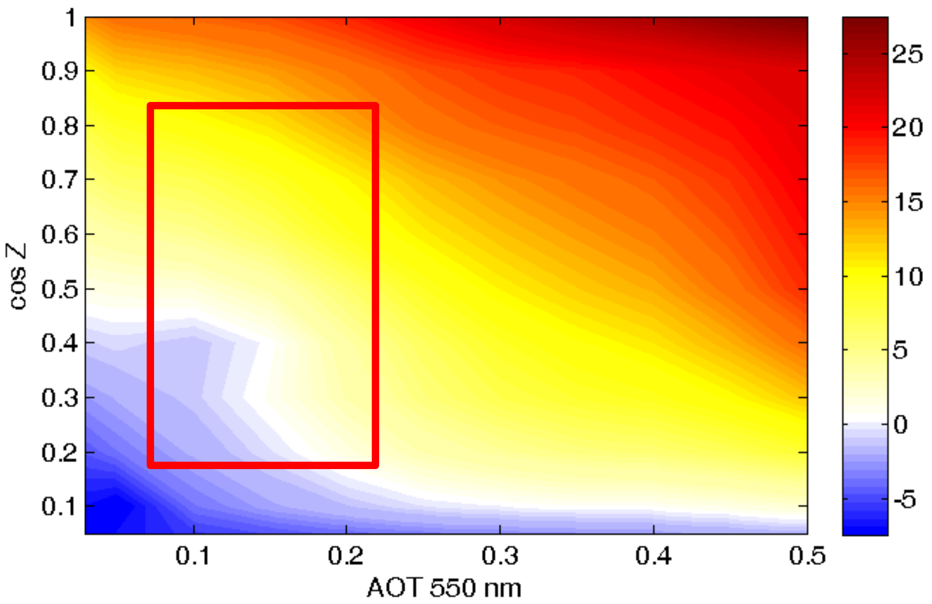
Red frame restricts the typical aerosol/solar zenith angle conditions in Moscow.

Points depict the results from the CIRC Phase 1 model intercomparisons (*Oreopoulos L. et al., 2012*).

Absolute difference between global solar irradiance calculated using the CLIRAD(FC05)-SW model and benchmark Monte-Carlo model as a function of cos SZA and AOT at 550nm

Testing was performed against benchmark calculations by the application of Kurchatov Center radiation Monte-Carlo model (*Rublev A.N., 2001*).

The conditions of "midlatitude summer", and continental aerosol properties (*WCP-112, 1986*) were used in simulations.

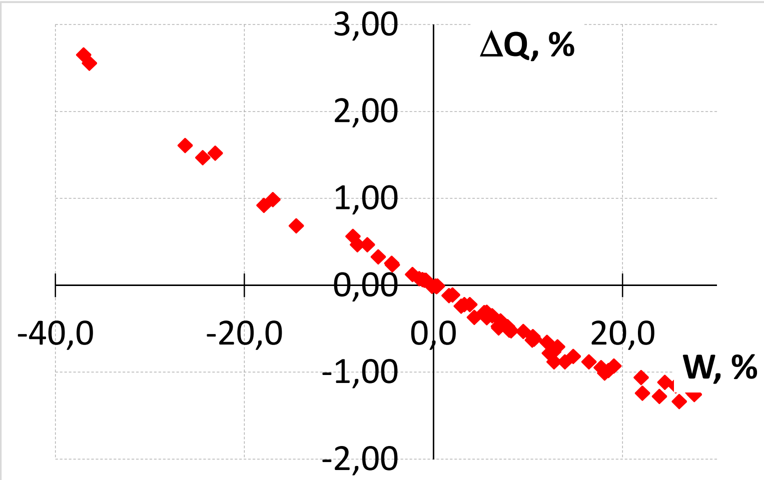


Red frame restricts the typical aerosol/solar zenith angle conditions in Moscow.

Shortwave irradiance sensitivity to variation in gas content

Water vapor, H_20:

$\Delta Q = Q(W_{COSMO}) - Q(W_{AERONET}) / Q(W_{AERONET})$,%



Uncertainty in solar irradiance due to water vapor <u>profile is less than 0.2%</u>

Carbon dioxide, CO_2:

Uncertainty in solar irradiance due to C02 is less 0.1%

Ozone, 0_3:

Uncertainty in solar irradiance due to variation in ozone is less 0.2%

Different aerosol datasets used in the comparisons:

- Tegen climatology (Tegen et al., 1997)

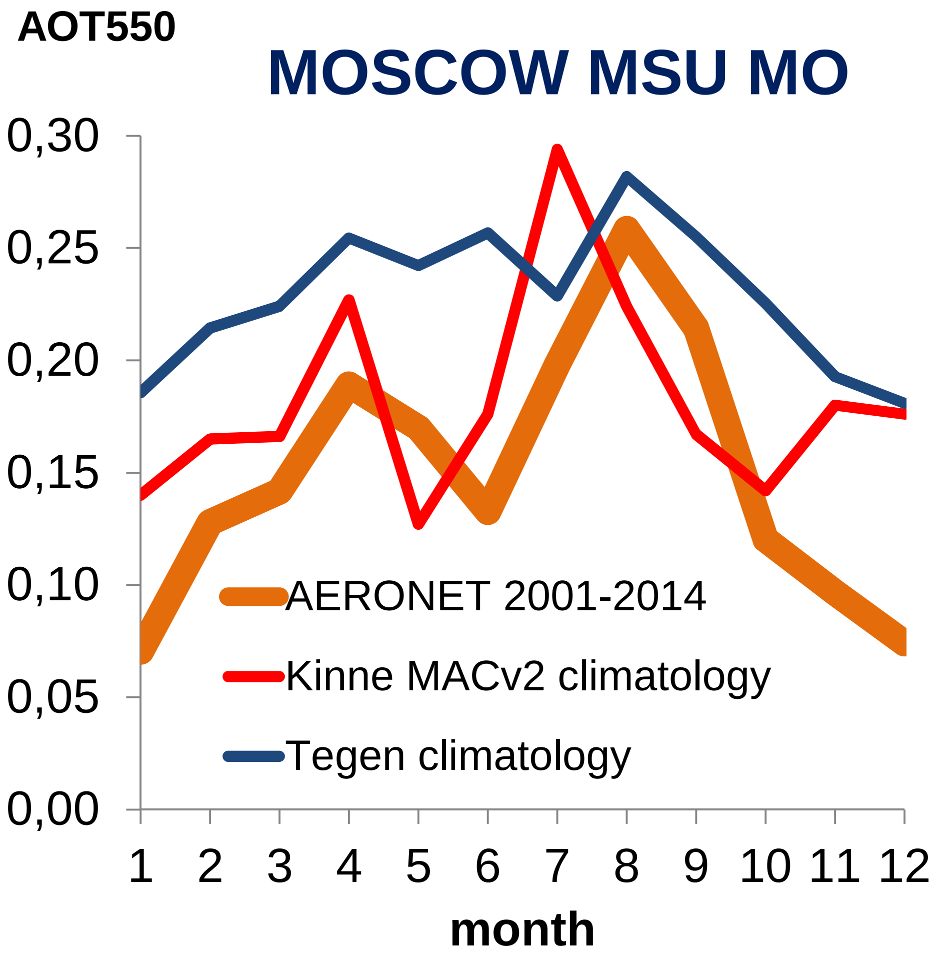
(AOT550 from Tegen climatology used in COSMO model is 0.04-0.05 higher than initial Tegen dataset due to old stratospheric and tropospheric simulated AOT in the profile subroutine),

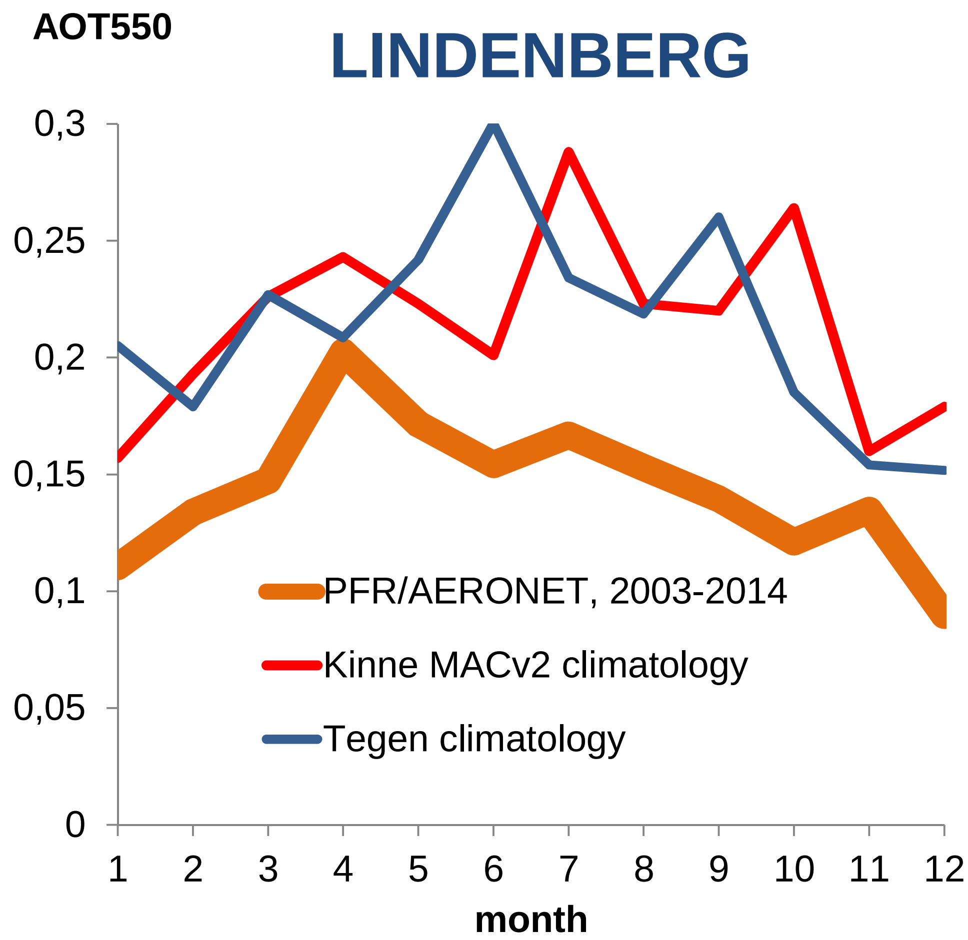
- Tanre climatology (Tanre et al., 1984),
- MACC (CAMS ECMWF) aerosol dataset,
- AERONET datasets: Moscow since 2001, and Lindenberg (PFR+AERONET) since 2003,
- COSMO_ART aerosol (case study for Moscow conditions),
- Macv2 climatology (Kinne et al., 2013).

The implementation of MACv2 aerosol climatology in COSMO

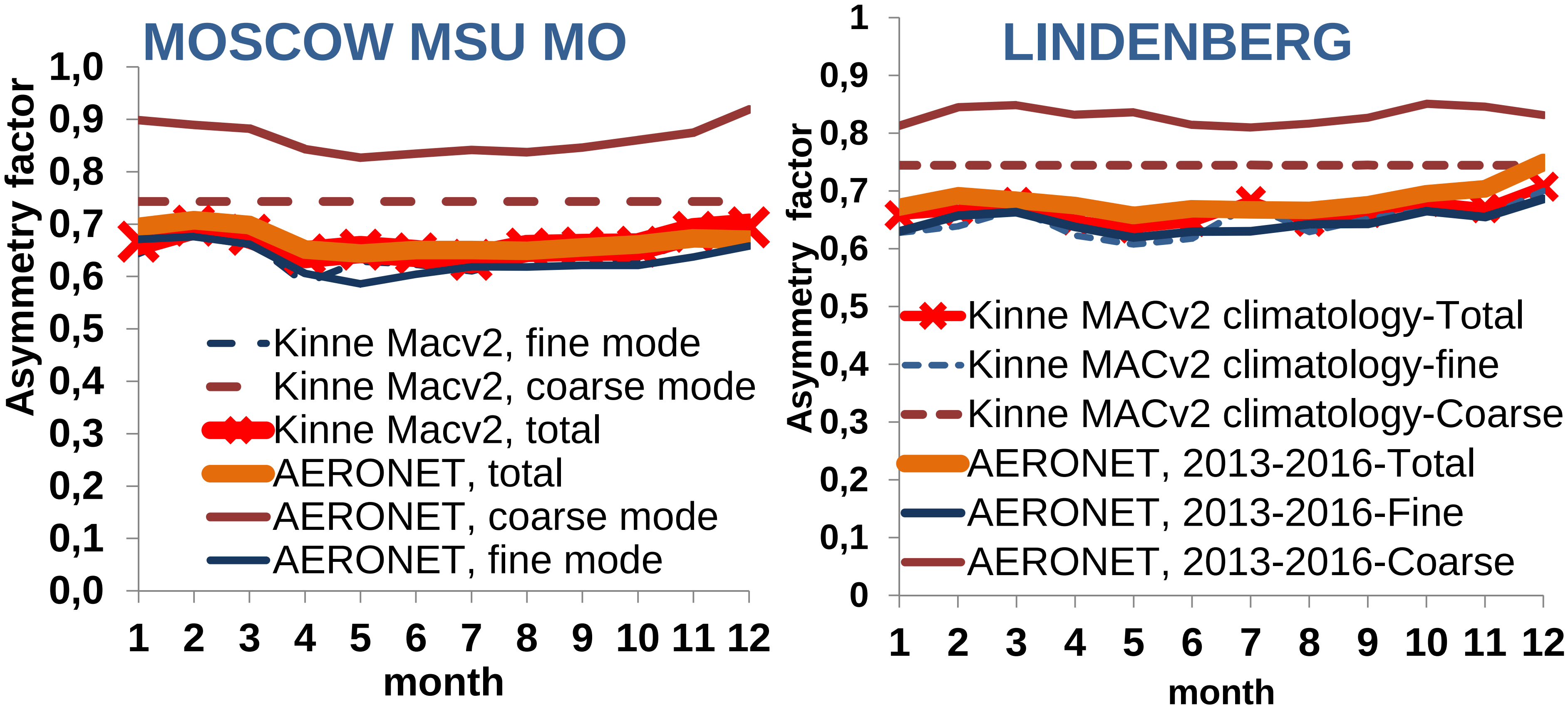
- The Macv2 data (Kinne et al. 2013) were added to EXTPAR. *Many thanks to Daniel Lüthi !* (These data will be available after release of EXTPAR, version 4.)
- Test version of int2lm is ready and provides the ability to account for this new aerosol climatology (itype_aerosol=3).
- The necessary changes in radiative code have been implemented. New version is being under final stage of testing.

Seasonal changes in aerosol optical thickness at 550 nm (AOT550) according to different aerosol climatologies.

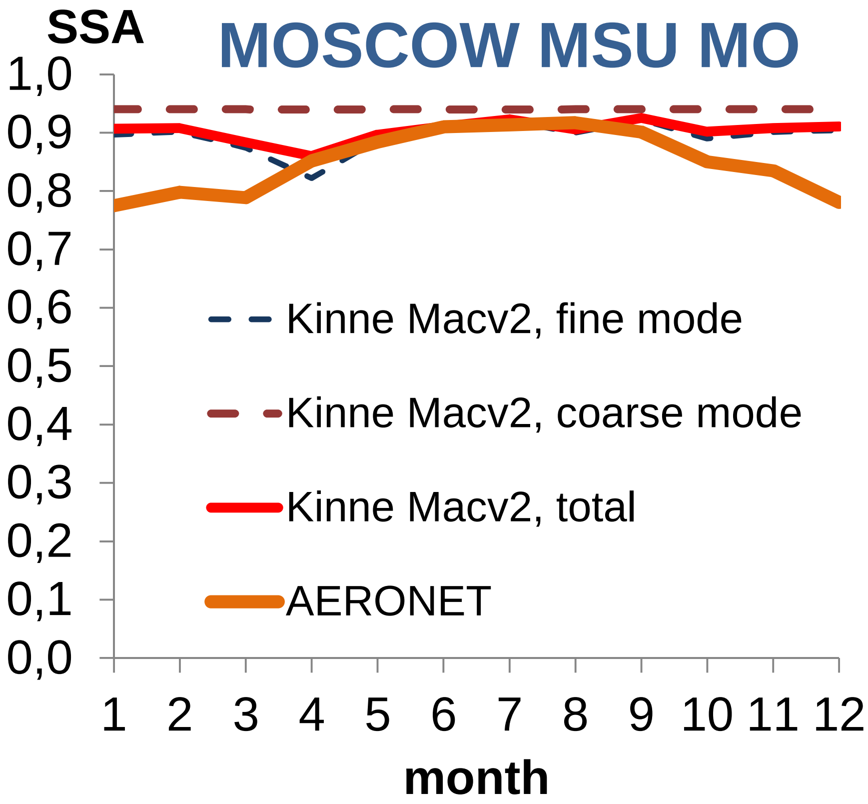


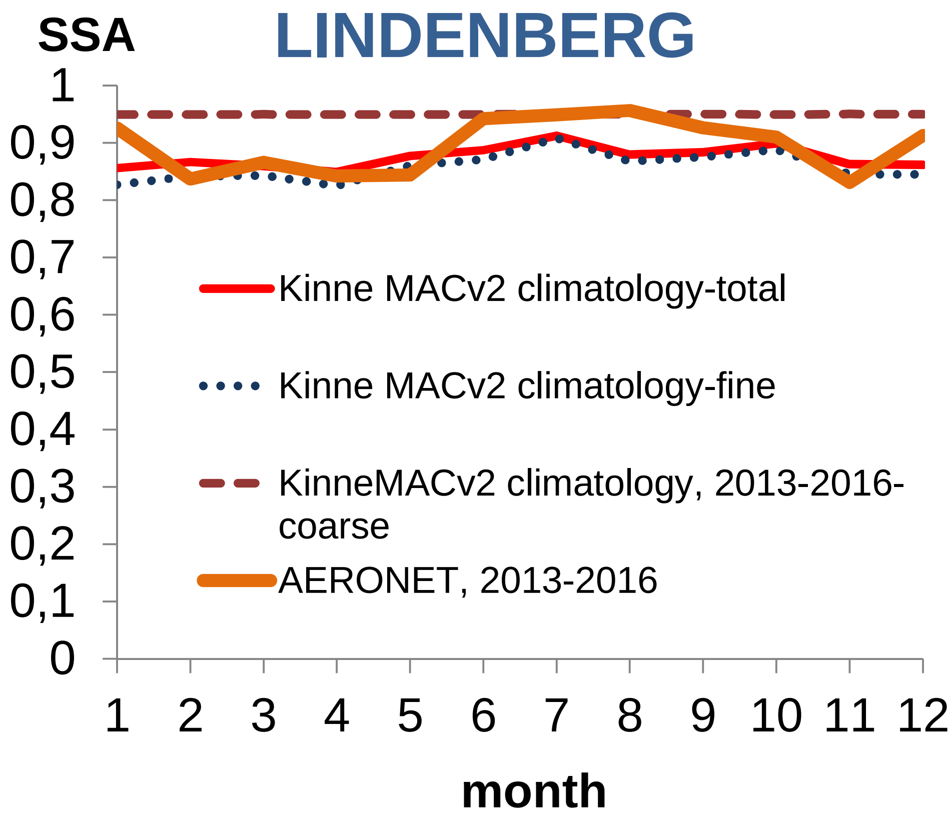


Asymmetry factor for different aerosol modes according to the Kinne MACv2 and AERONET datasets.



Single scattering albedo according to the Kinne MACv2 different modes and AERONET* datasets.





- With special cloud filtering for Moscow AERONET data.*(Chubarova et al., AMT, 2016)

The list of model runs with different aerosol and water vapor options

COSMO-radiative scheme

1. No aerosols, water vapor – COSMO **(COSMO_no aerosol);**
2. Aerosol climatology - Tanre (1984), water vapor – COSMO (**COSMO_Tanre);**
3. Aerosol climatology - Tegen (1997), water vapor – COSMO **(COSMO_Tegen).**

CLIRAD(FC05)-SW radiative code

1. No aerosols, water vapor – COSMO **(CLIRAD, no aerosol);**
2. AOD and SSA – Tegen (1997) ,surface albedo - COSMO, water vapor-COSMO **(CLIRAD_Tegen);**
3. AOD and SSA - Kinne Macv2 (2015), surface albedo - COSMO, water vapor - COSMO (**CLIRAD_Kinne**);
4. AOD – from MACC(CAMS);, surface albedo - COSMO, water vapor - COSMO (**CLIRAD_MACC);**
5. Aerosol, water vapor content, surface albedo according to the measurements (**CLIRAD_real**).

The days for the analysis:

- *Clear sky conditions were chosen when both COSMO-Ru model and observations at the MSU MO record the absence of clouds.*

MOSCOW MSU MO

- ✓ **August 22, 2012 (6-12 UTC);**
- ✓ **March 29, 2014 (6-14 UTC);**
- ✓ **July 27, 2014 (5-15 UTC);**
- ✓ **September 16, 2014 (6-13 UTC);**
- ✓ **November 18 (typical) and November 20 (polluted), 2014 (8-10 UTC)**
- ✓ **May 27, 2015 (3-11 UTC);**
- ✓ **July 4, 2015 (3-16 UTC);**
- ✓ **August 12, 2015 (5-14 UTC);**
- ✓ **August 20, 2015 (5-13 UTC);**
- ✓ **August 22, 2015 (3-13 UTC);**
- ✓ **August 25, 2015 (5-12 UTC);**

N days = 11

The days for the analysis:

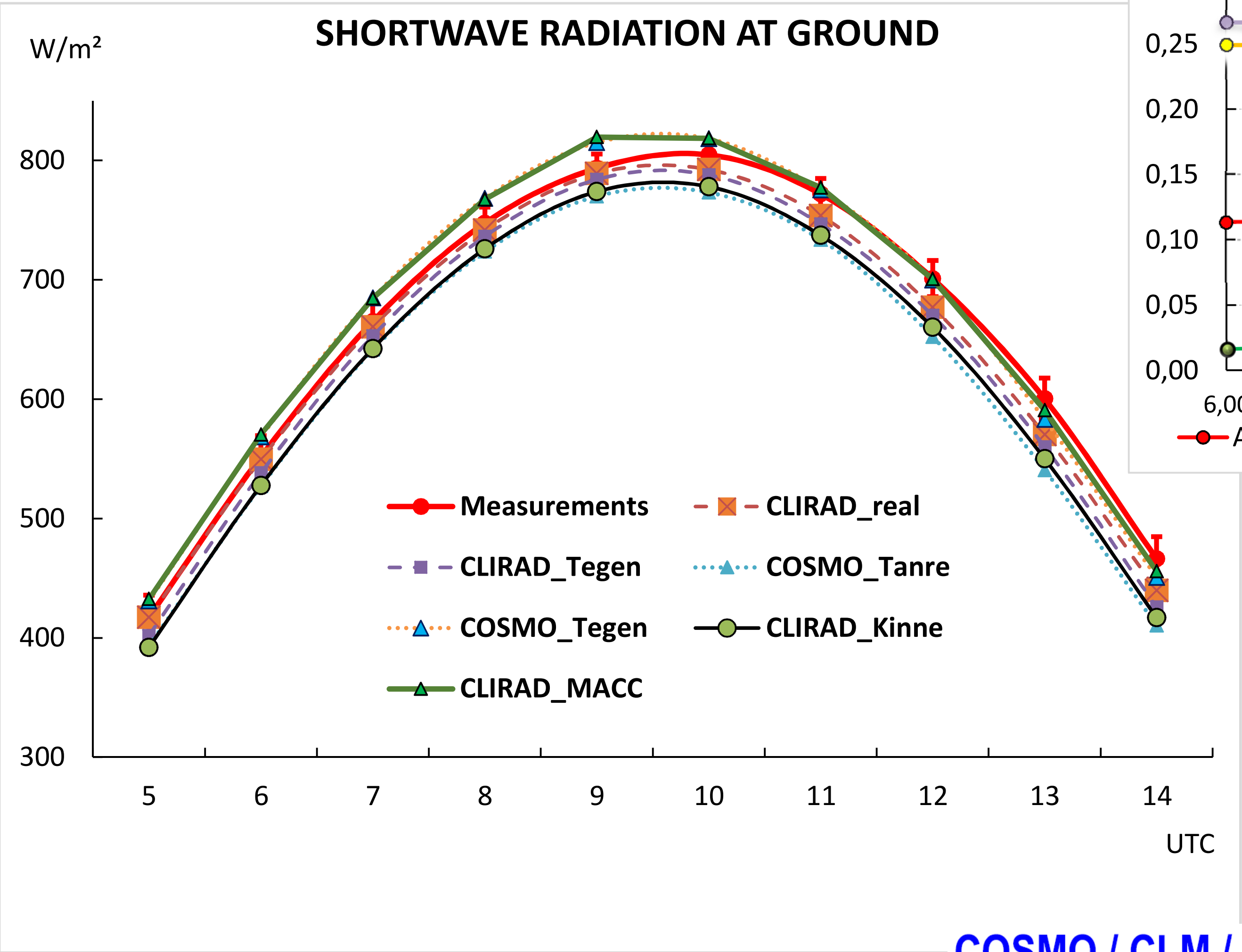
- *Clear sky conditions were chosen when both COSMO-Ru model and observations at the Lindenberg record the absence of clouds.*

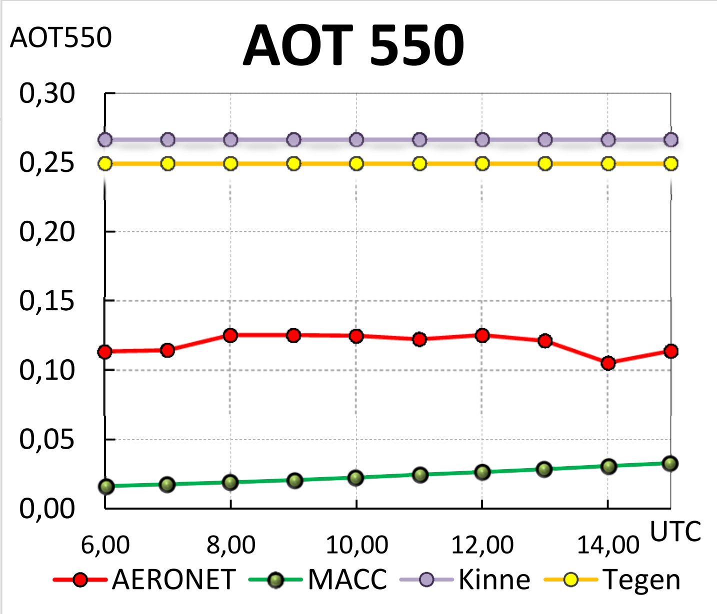
Falkenberg/Lindenberg

- ✓ February 26, 2015;
- ✓ March 19, 2015;
- ✓ April 20, 2015;
- ✓ June 5, 2015;
- ✓ July 2, 2015;
- ✓ October 12, 2015.

Global shortwave radiation from the experimental data and modelling with different aerosol datasets.

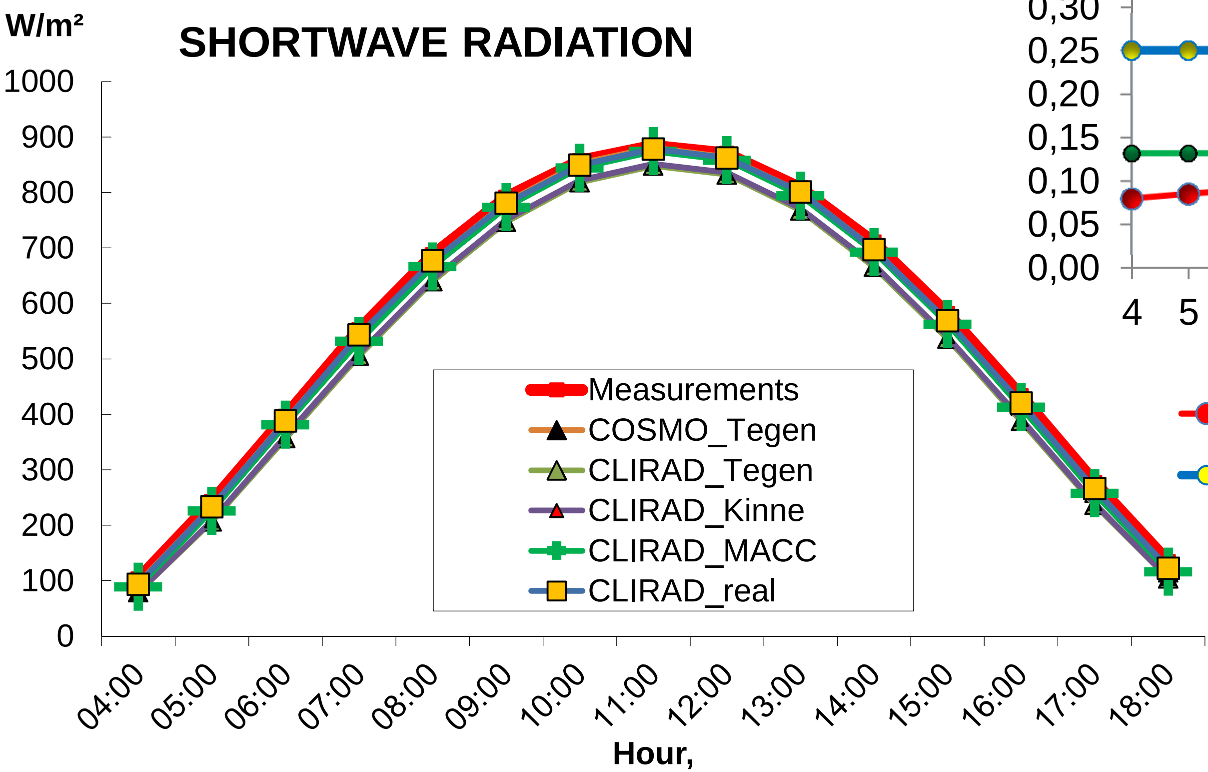
27.07.2014, Moscow.

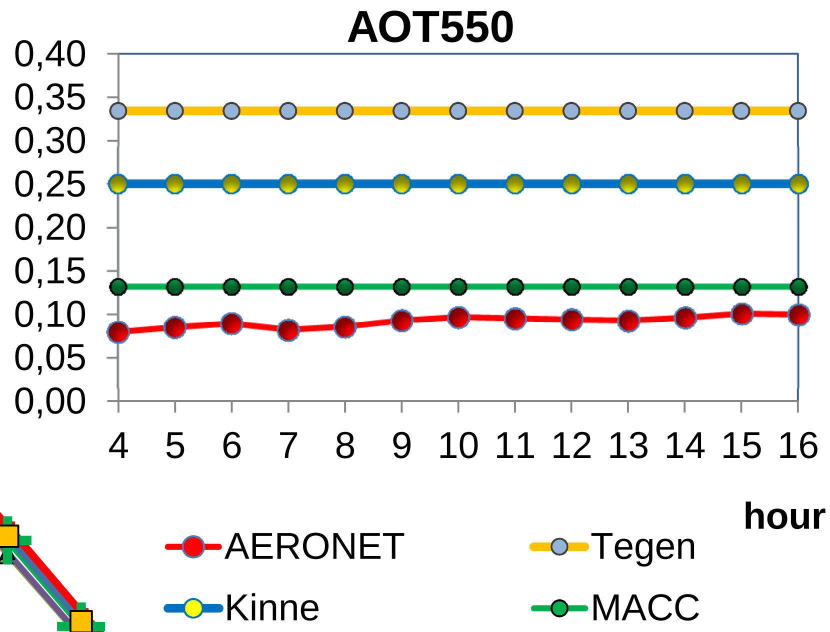




Global shortwave radiation from the experimental data and modelling with different aerosol datasets

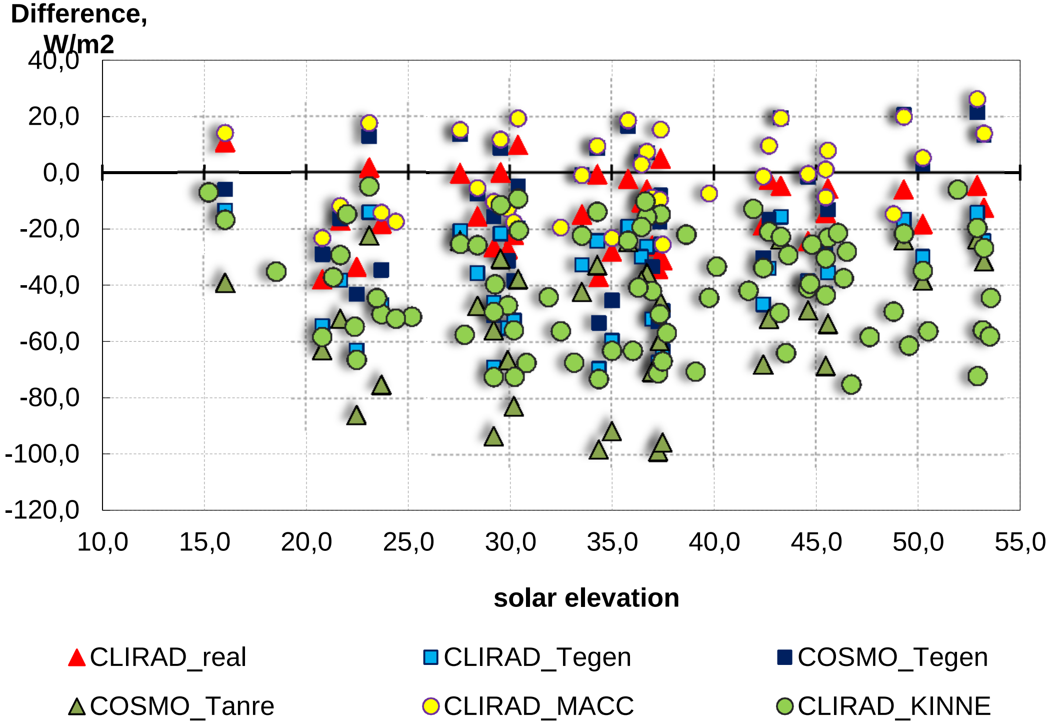
02.07, 2015, LINDENBERG

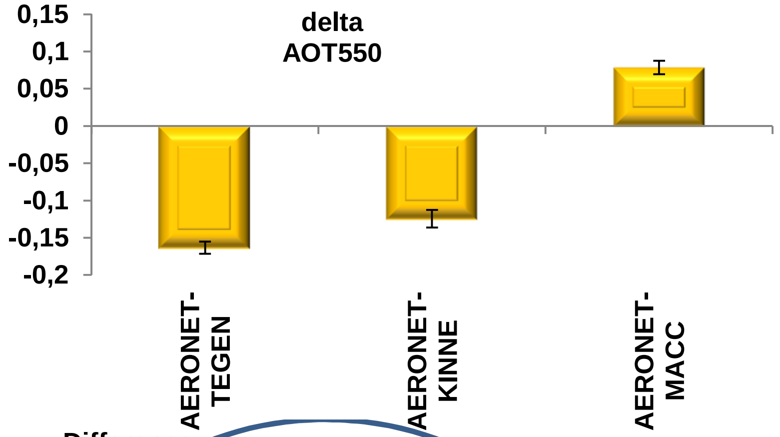


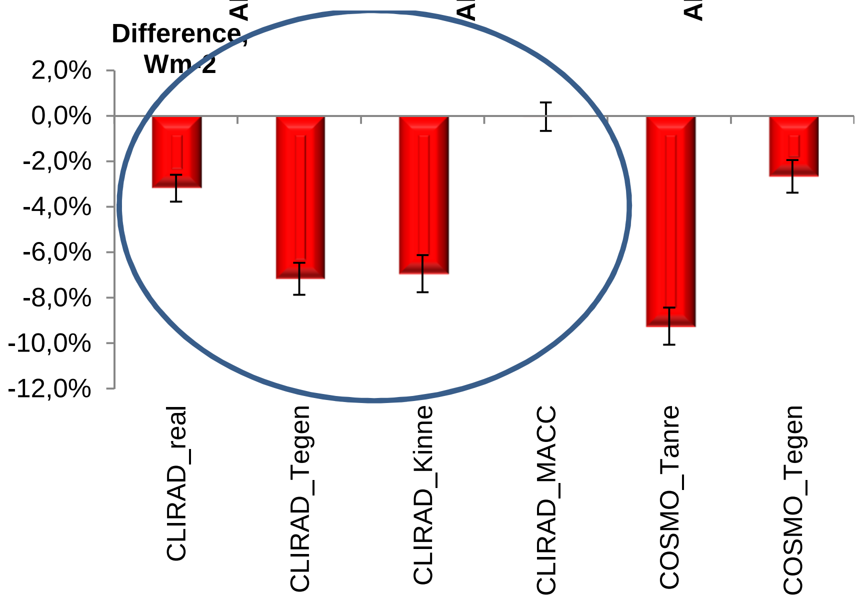


Global irradiance difference between model and observations as a function of solar elevation.

❑ Moscow MSU MO



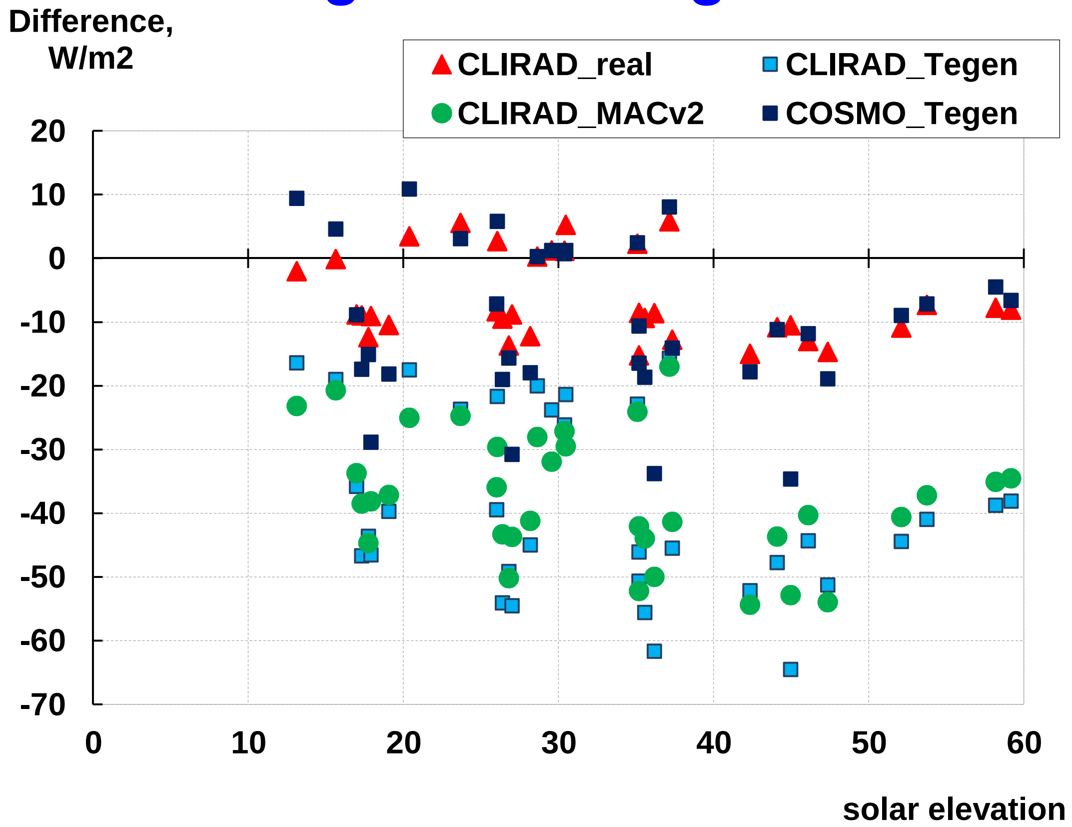


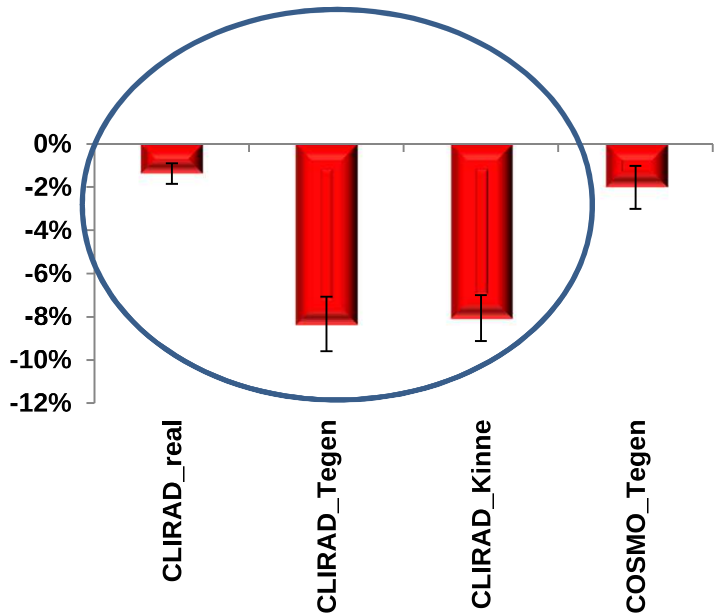


$$\text{Difference}=Q_{measurements} - Q_{model}$$

Global irradiance difference between model and observations as a function of solar elevation.

❑ Falkenberg/Lindenberg

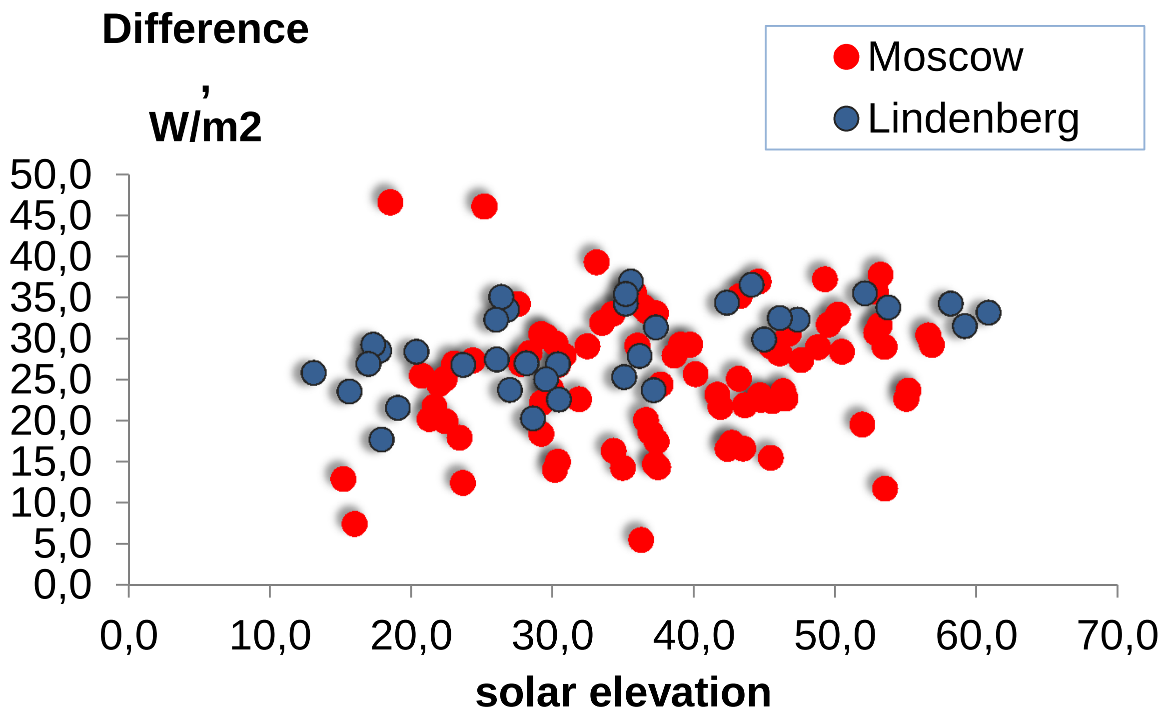




Difference=$Q_{measurements}$ - Q_{model}

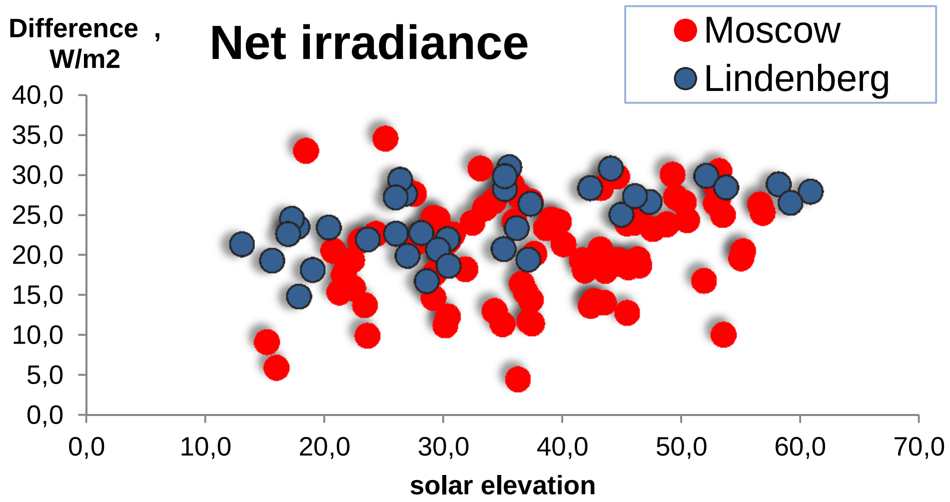
Shortwave global irradiance difference between COSMO and CLIRAD model simulations with the same input parameters as a function of solar elevation.

$$\text{Difference} = Q_{COSMO} - Q_{CLIRAD}$$

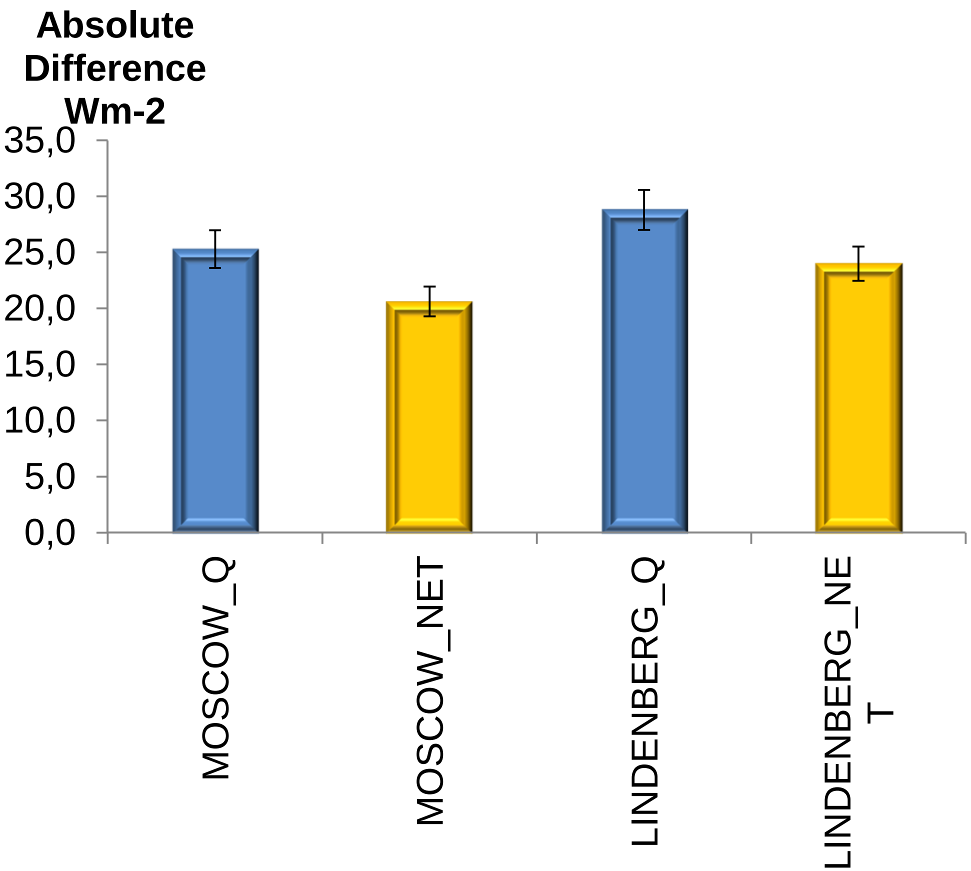


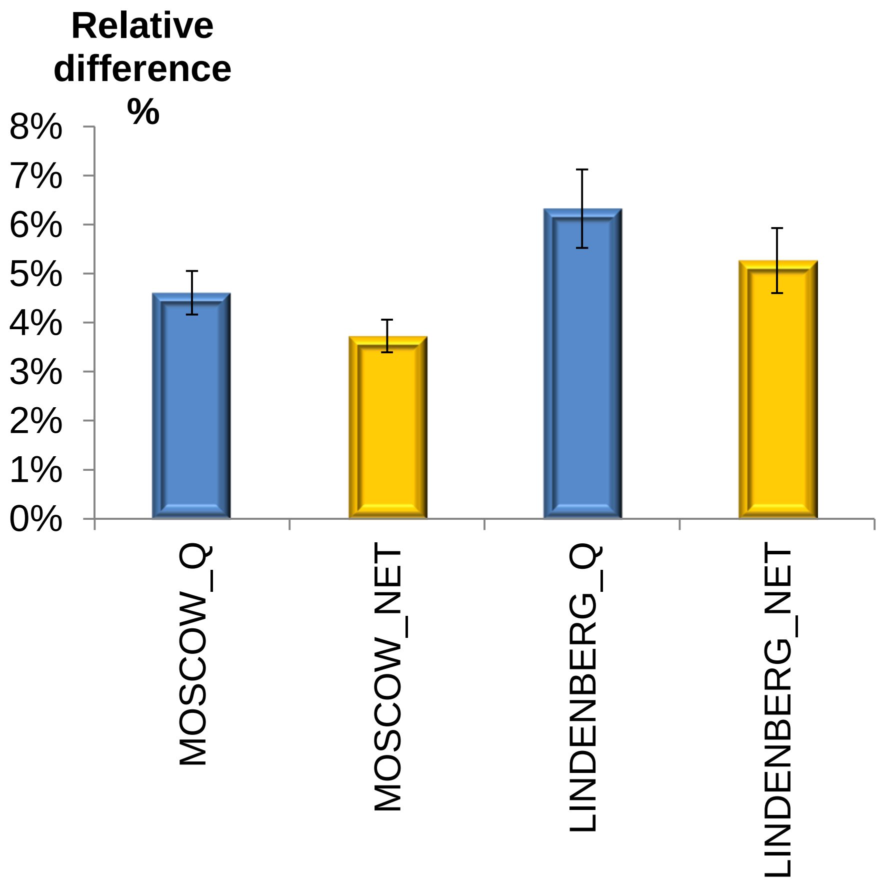
Shortwave NET irradiance difference between COSMO and CLIRAD model simulations with the same input parameters as a function of solar elevation.

$$\text{Difference} = NET_{COSMO} - NET_{CLIRAD}$$



Statistics of absolute and relative differences between the COSMO and CLIRAD radiative codes.

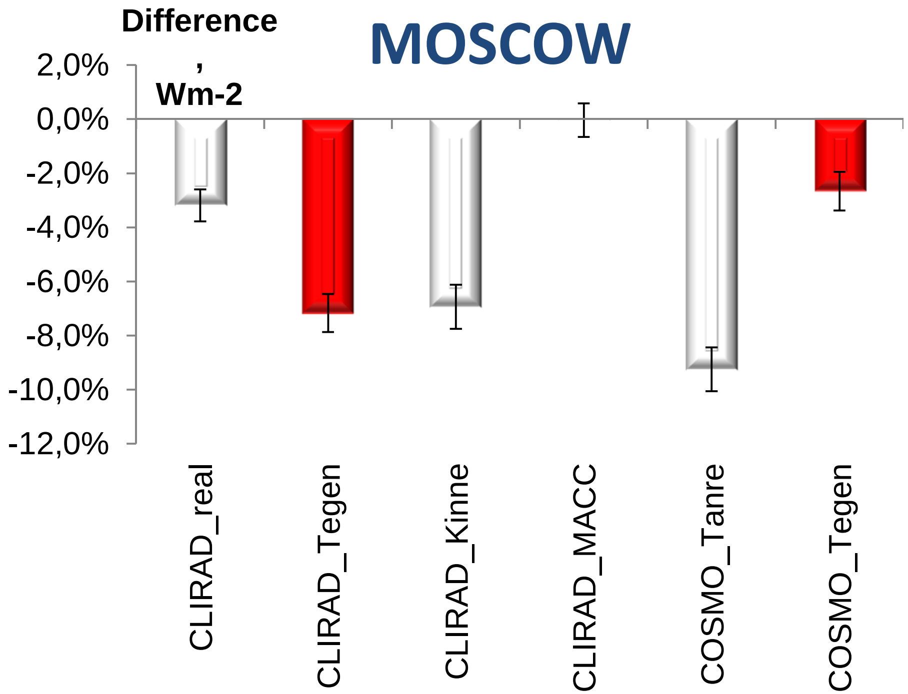


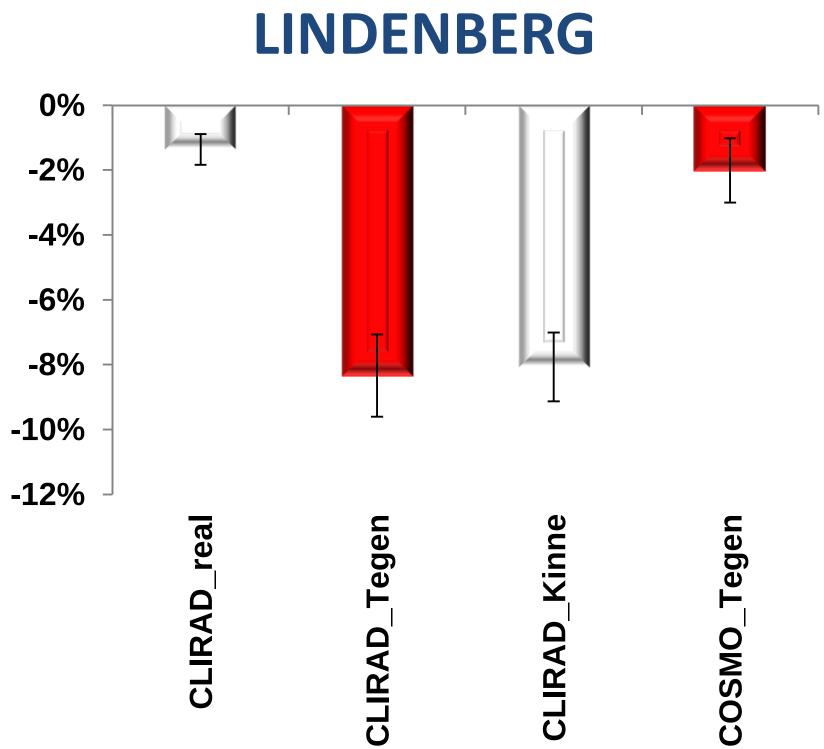


$$\text{Difference}=Q(\text{Net})_{\text{COSMO}} - Q(\text{NET})_{\text{CLIRAD}}$$

Global irradiance difference between model and observations.

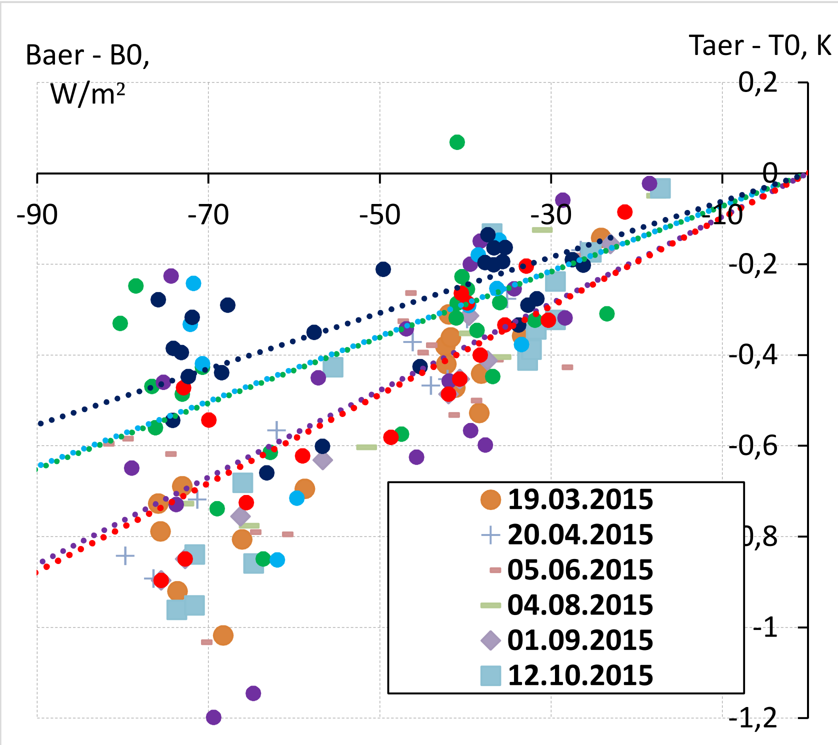
$$\text{Difference} = Q_{measurements} - Q_{model}$$



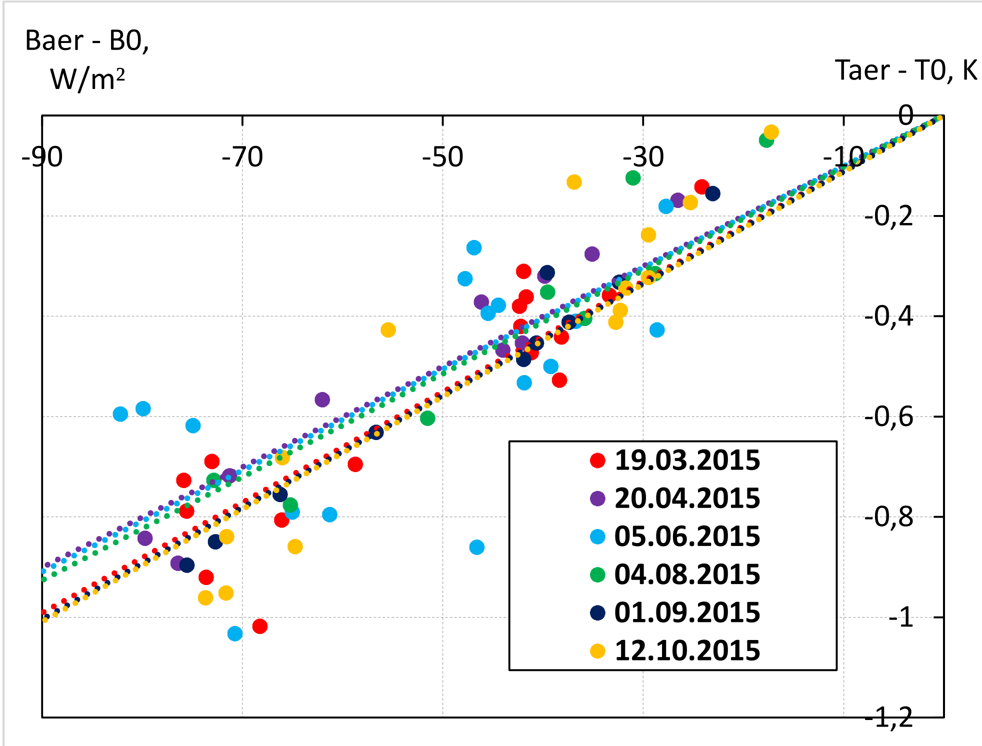


T2M sensitivity to changes in net radiation at ground

MOSCOW MSU MO



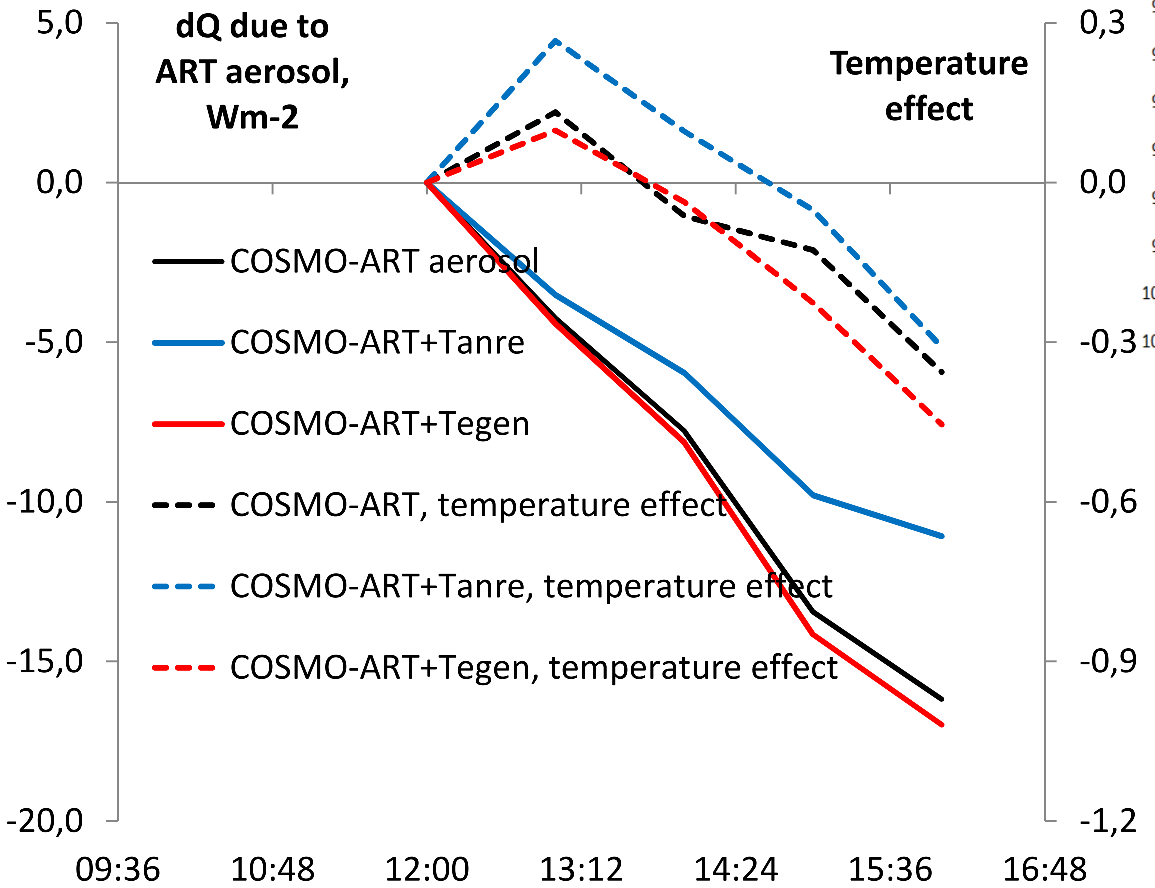
FALKENBERG/LINDENBERG

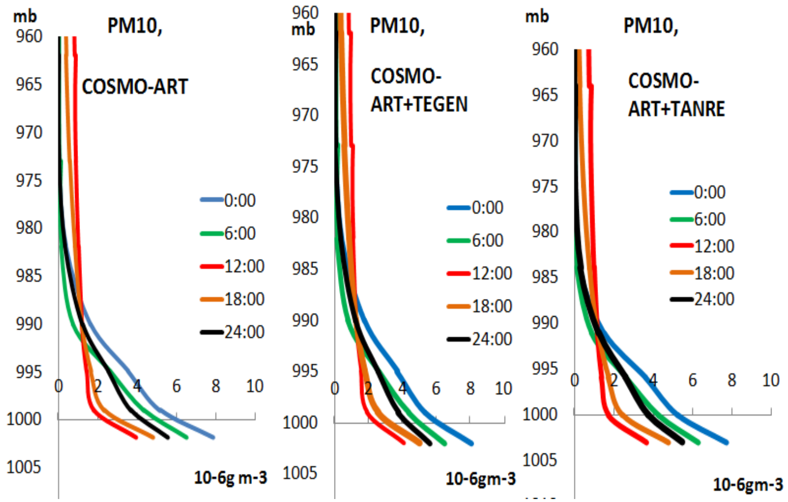


T2M gradient of about 0.7- 1 °C per 100 Wm-2

Radiative and temperature effects of the COSMO-ART aerosol application compared with COSMO—Ru outputs

Moscow, clear sky conditions





Case study, 04.07.2015

Simulations were fulfilled by Alexander Kirsanov.

CONCLUSIONS

- The results obtained for both sites (Moscow and Lindenberg) demonstrate the same tendency in comparisons with model simulations.
- Aerosol climatologies provide the AOT overestimation (Tanre>Tegen>Kinne), while MACC (CAMS) aerosol is lower than the observed data.
- Using the dataset obtained from accurate model simulations we evaluated the uncertainty of RT code in the COSMO model. According to the RT simulations with the same Tegen climatology and similar other atmospheric parameters the COSMO algorithm provides <u>higher shortwave irradiance</u> estimates of about 5-6% for both Moscow and Lindenberg locations.
- The overestimation of solar irradiance in the COSMO algorithm is compensated by the higher AOT in all climatologies compared with real data. For example, for Lindenberg the application of the too high aerosol content from Tegen climatology provides the global irradiance underestimation of about 8% in the accurate RT code, and only 2% - in the COSMO RT algorithm.

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- **Alexander Kirsanov and Denis Blinov, Hydrometeorological Centre of Russia,**

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