The accuracy assessment of the COSMO-Ru radiative calculations using different aerosol climatologies and their influence on temperature forecast

N.Ye. Chubarova[1,2], A.A. Poliukhov[1,2], G.S.Rivin[1,2], M.V.Shatunova[2]

1- Lomonosov Moscow State University, Faculty of Geography, Moscow, Russia

2 - Hydrometeorological Centre of Russia, Moscow, Russia

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THE OBJECTIVE

Testing the radiative scheme of the operational Russian COSMO-Ru weather forecast model with different aerosol climatologies in cloudless conditions according to

- **the accurate model simulations;**
- **the ground-based radiative measurements of the Moscow State University Meteorological Observatory (MSU MO);**

and

- **evaluating aerosol radiative effect on temperature forecast.**

For testing the radiative block of COSMO-Ru model we used :

1. **CLIRAD(FC05)-SW model**
   (*Tarasova T.A., Fomin B.A., 2007***);**

2. **Benchmark Monte-Carlo RT model**
   (*Rublev et al., 2001***);**

3. **Different kind of measurements at the MSU MO**
   (Meteorological Observatory of Moscow State University
   (*Chubarova et al., 2014***).**

Overview

- CLIRAD, MC model, observations – main features and quality
- Aerosol climatology in NWP
- Simulation results
- Conclusions

Brief description of the CLIRAD-SW model

(for solar radiation only)

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*).

Monte-Carlo model

- $\Delta\lambda$=0.2 - 5.0 μm, initially with 99 spectral interval with 0.005 - 0.02 μm resolution;
- Spectral resolution - $\Delta\nu$=10 cm^{-1} in the near infrared region. Line-by-line evaluation of absorption coefficients with line-by-line 0.005 cm^{-1} resolution, HITRAN96, H_2O, N_2O, CH_4, CO, CO_2, O_2, O_3, SO_2 и N_2. Account for N_2 continuum, ozone absorption bands;
- account for sphericity;
- Lambert reflection;
- Total error - less than 2 W/m^2.

Observations
at the Meteorological Observatory MSU

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 moisture content :

- sun sky photometer **AERONET CIMEL** dataset from AERONET version 2.0

Meteorological observations:

- Hourly cloud observations,
- The air temperature at a height of 2m (T2m) every 3 h.

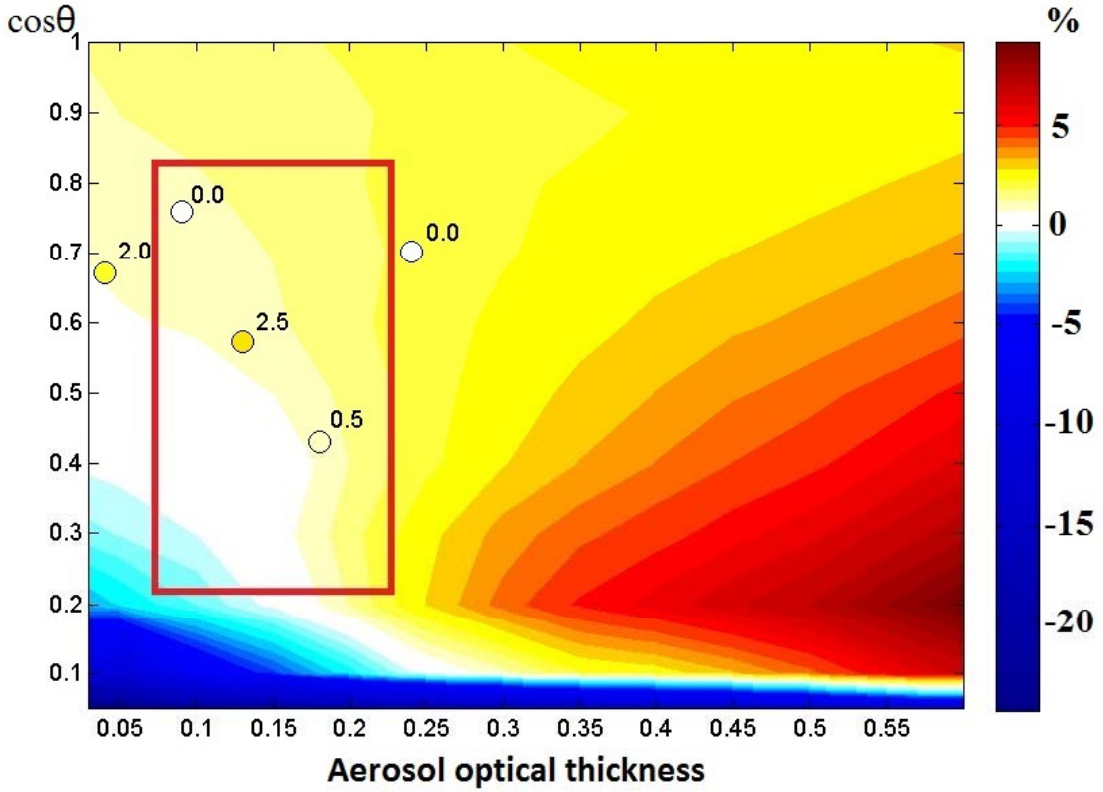
website: www.momsu.ru

“DOMAIN” (location of Kipp&Zonen CNR-4 at the MSU MO and the nearest COSMO-Ru1 grid node)

~120 meters

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 AOT550

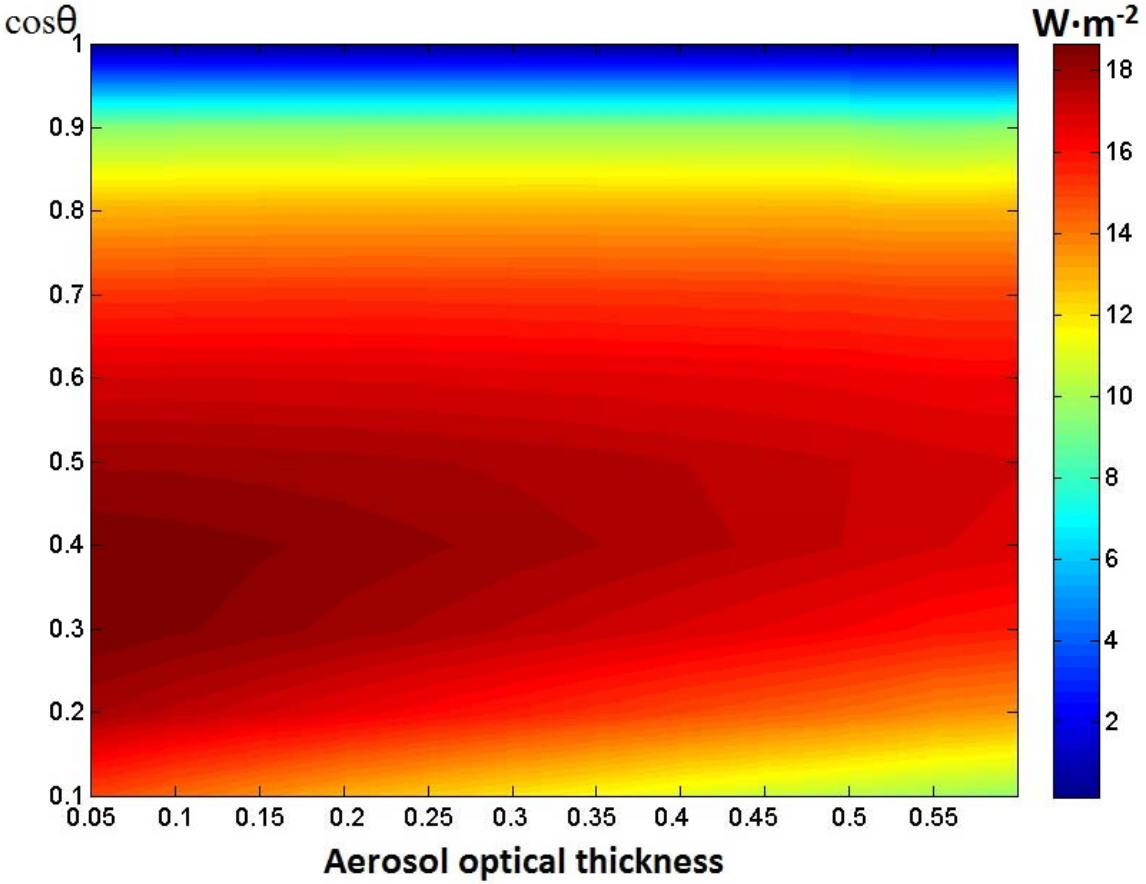
Testing was performed against benchmark calculations by the application of Kurchatov Center radiation Monte-Carlo model (*Rublev A.N., 2001*). The conditions of "midlatitude summer", and continental aerosol properties (*WCP-112, 1986*) were used in simulations.



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*).

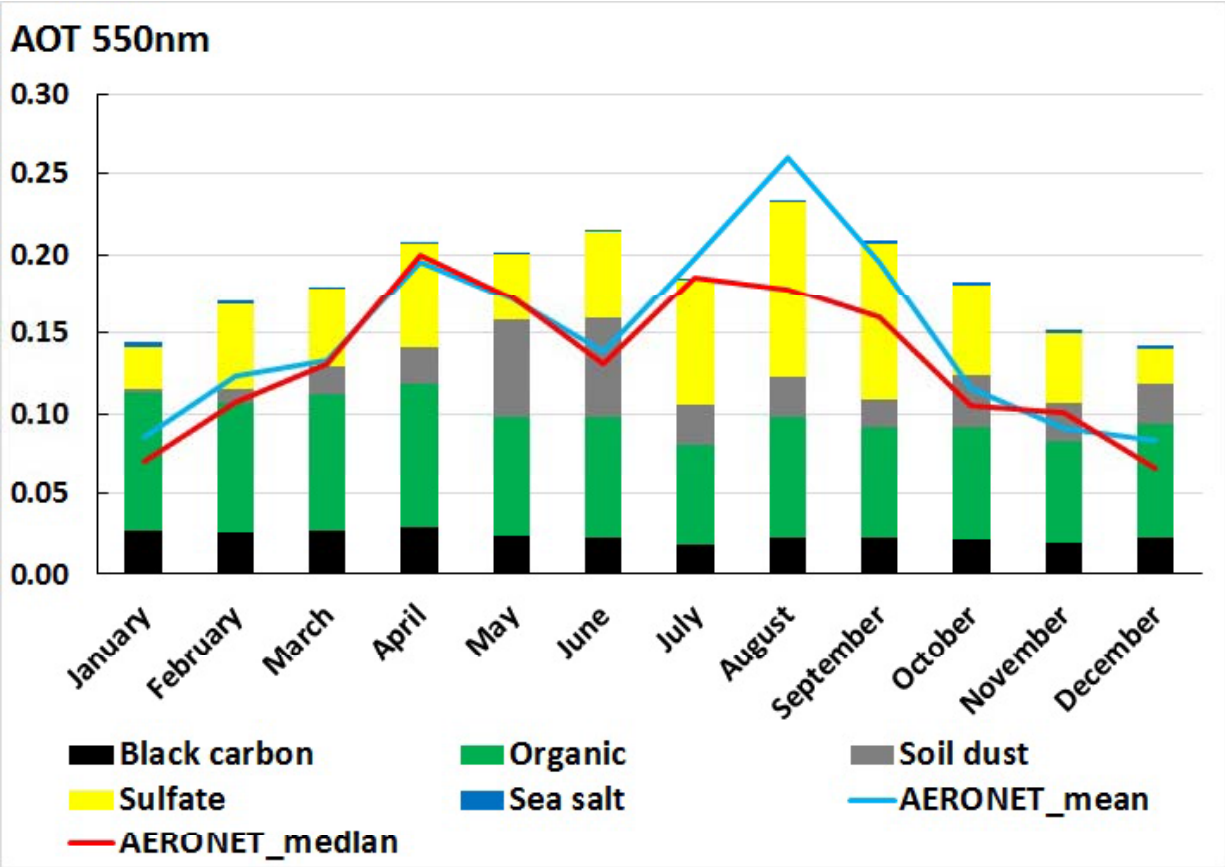
Possible uncertainties in radiation measurements as a function of cos SZA and AOT550



- The error in global shortwave radiation due to the possible deviation of receiving surface of about ±1° from the horizontal plane lies within 10 to 18 W/m^2
- The error due to the negative offset of shortwave sensors at night is about ± 1-2 W/m^2

Aerosol climatology in NWP

Seasonal variation of aerosol optical thickness at 550nm

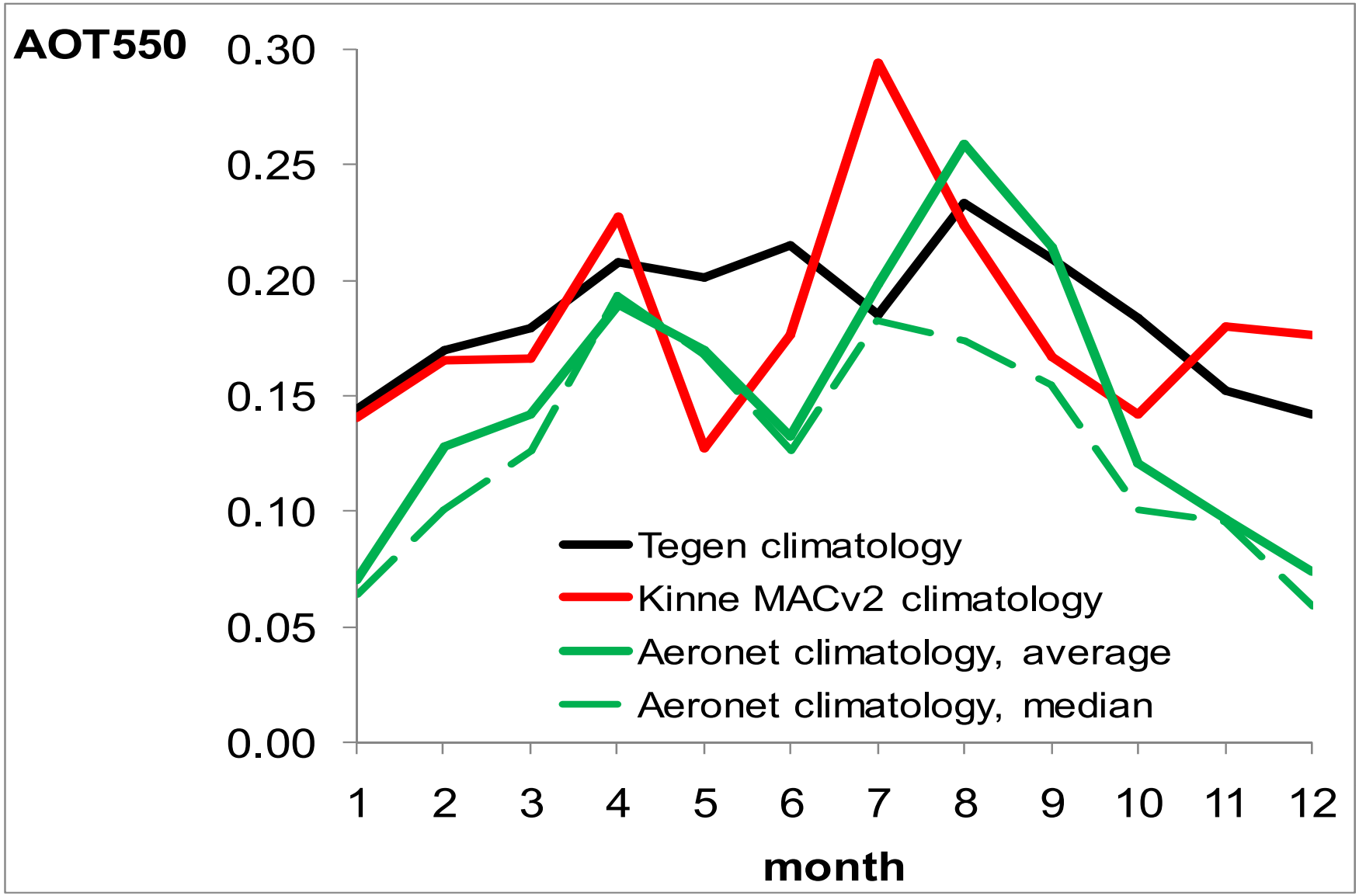


- **Tegen climatology, currently used in COSMO model (*Tegen et al.,1997*)**
- **long-term AERONET dataset in Moscow (2001-2014, level 2.0) with additional cloud and NO_2 correction (*Chubarova et al., 2016*)**

The annual AOT550 = 0.185 – from (Tegen,1997);
AOT550 = 0.150 – Moscow AERONET data from (Chubarova et al., 2016)

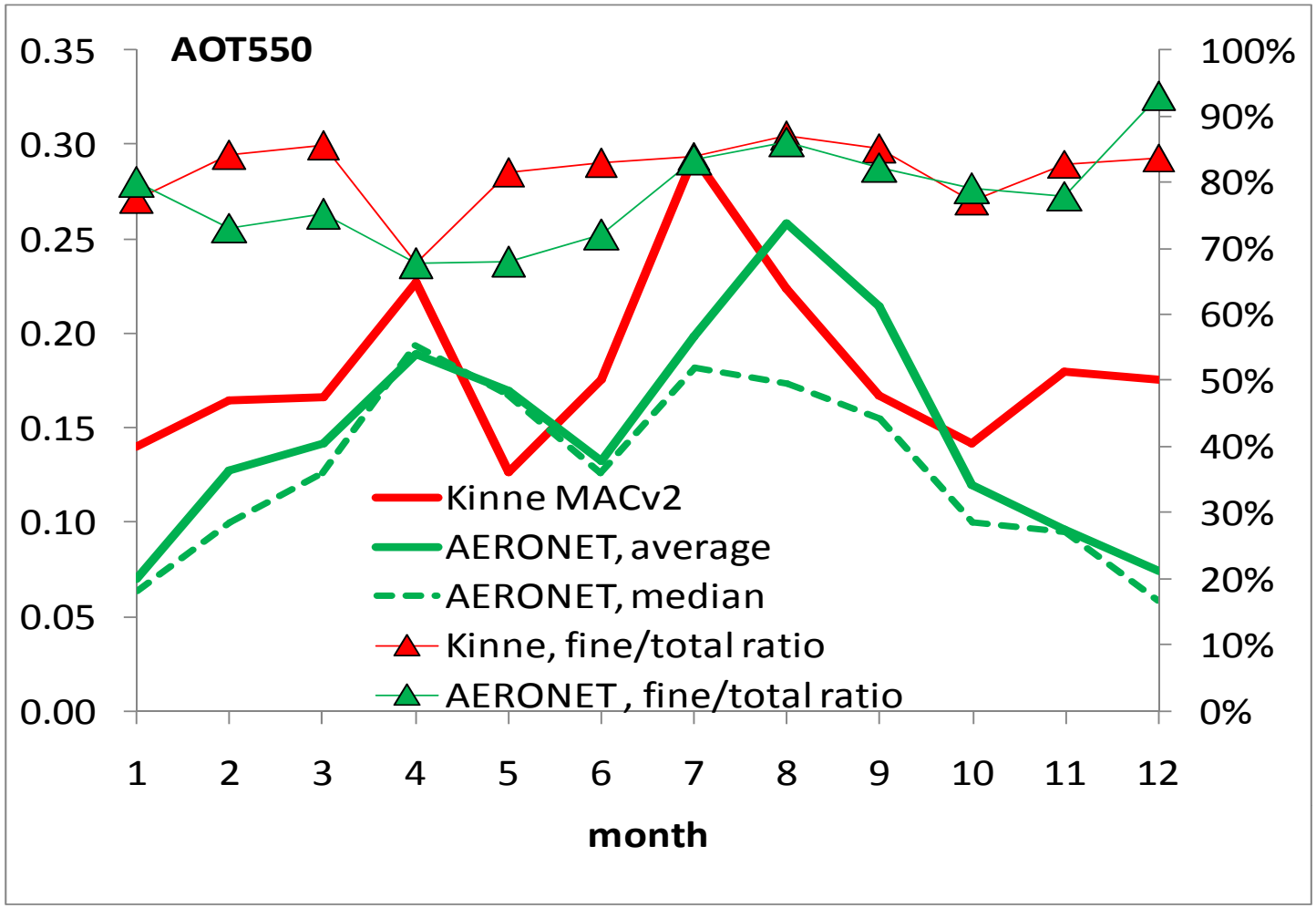
Aerosol climatology in NWP

Seasonal changes in aerosol optical thickness at 550 nm (AOT550) in Moscow according to different datasets



Aerosol climatology in NWP

Seasonal changes of AOT550 (left axis) and fine/total AOT ratio (%, right axis) according to the Kinne MACv2 climatology and observation datasets. Moscow.



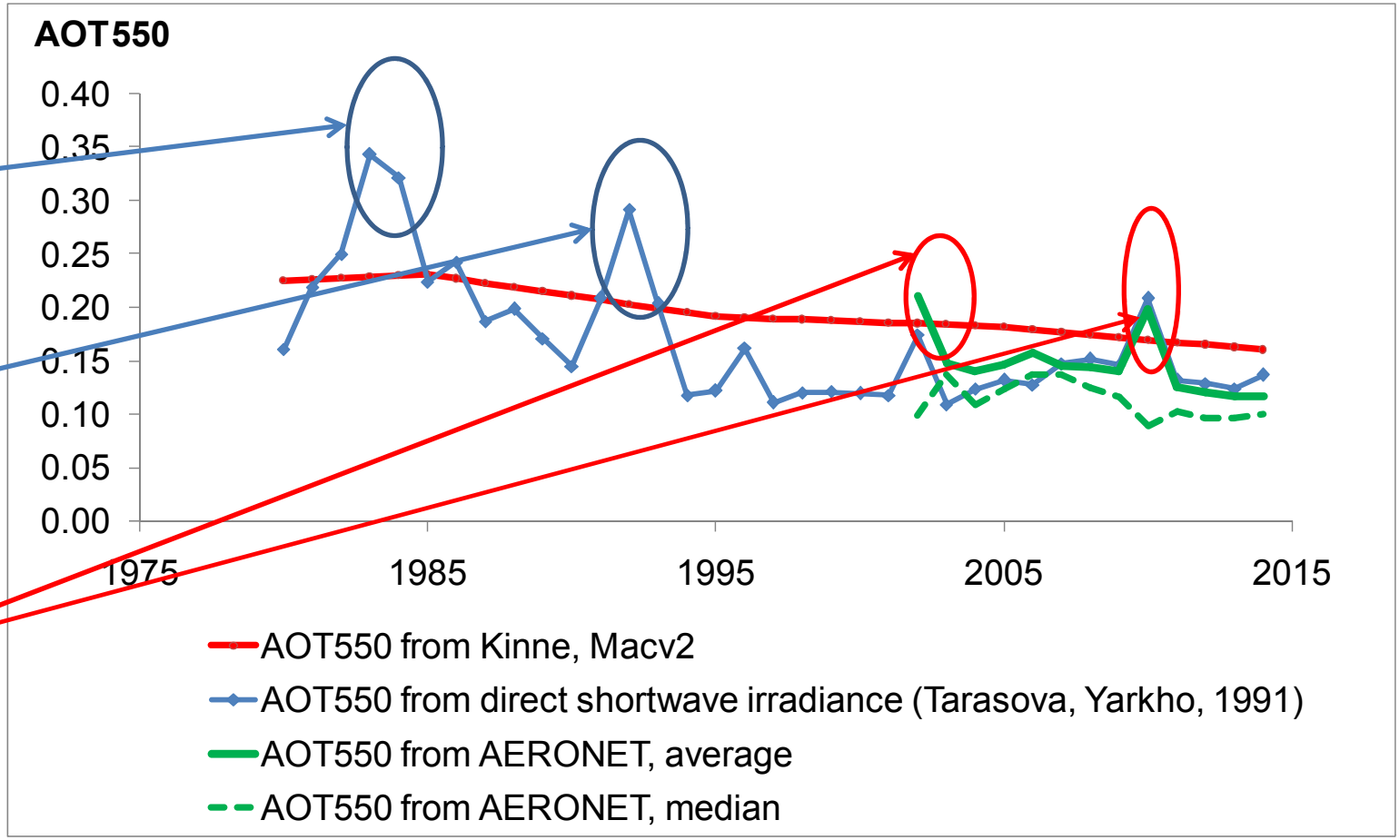
Aerosol climatology in NWP

AOT550 time series according to long-term measurements at the MSU MO (*Abakumova et al., 2008, Chubarova et al., 2016*) and Kinne MACv2 dataset (*Kinne , 2015*). Moscow.

El-Chichon volcano influence

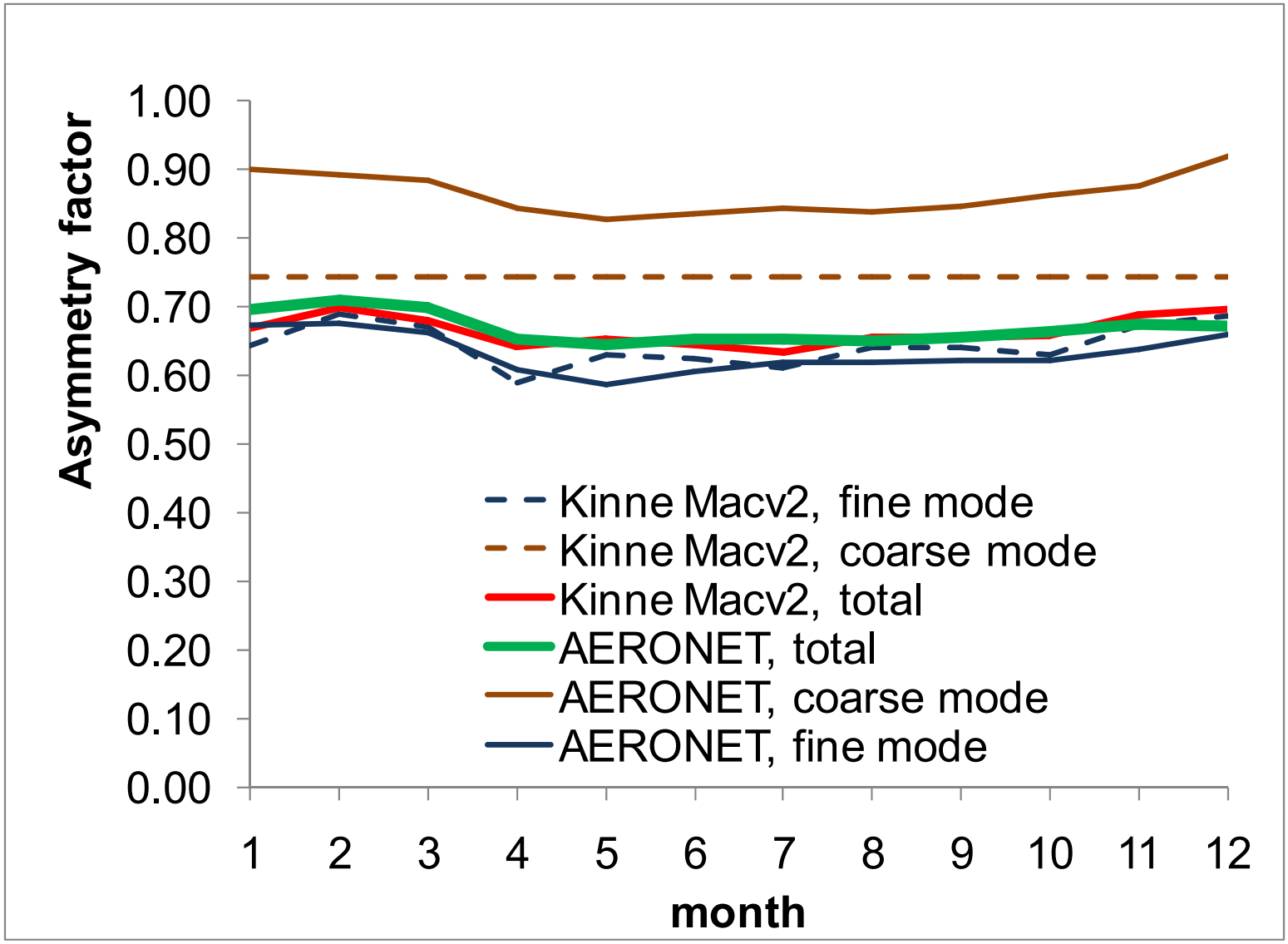
Pinatubo volcano influence

Forest fires, 2002 and 2010



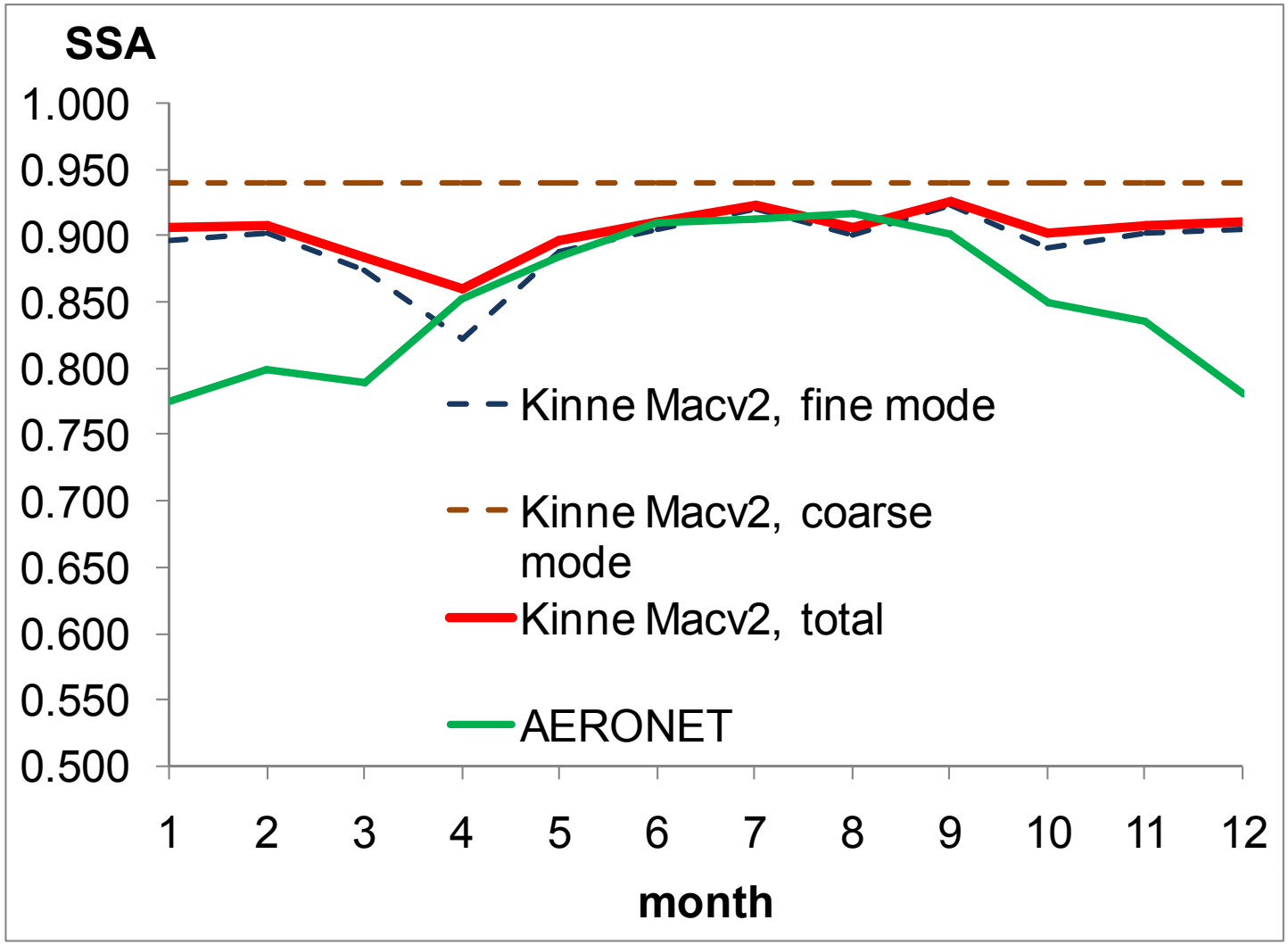
Aerosol climatology in NWP

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



Aerosol climatology in NWP

Single scattering albedo
according to the Kinne MACv2 and AERONET datasets



Aerosol climatology in NWP

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).**

Model CLIRAD(FC05)-SW

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. Aerosol, water vapor content, surface albedo according to the measurements (**CLIRAD_real**).

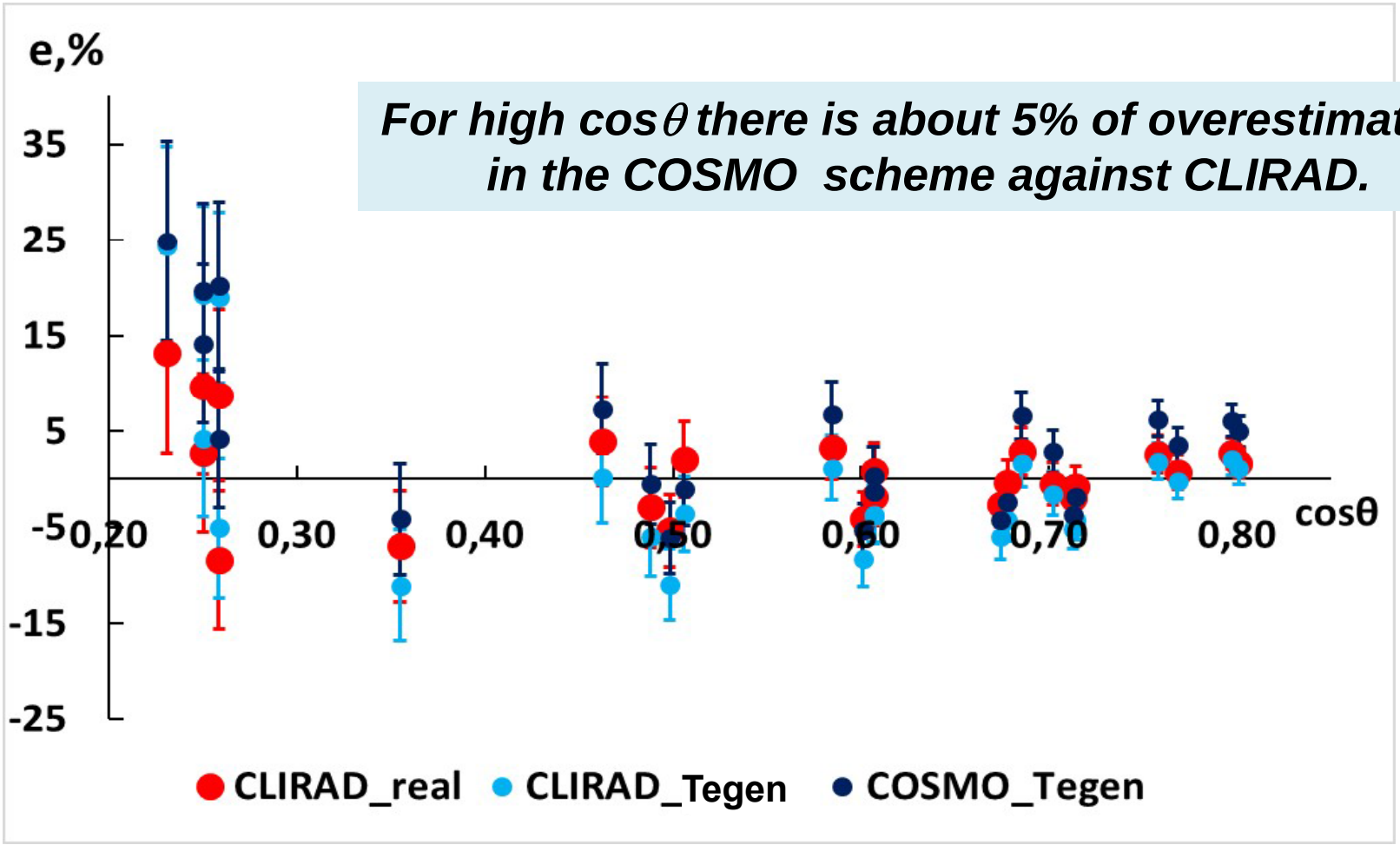
Aerosol climatology in NWP

- ***The dates with clear sky conditions when model testing was made against observations.***
- ***Clear sky conditions were chosen when both COSMO-Ru model and observations at the MSU MO provide cloudless situations.***

  - ✓ **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 (clear) and November 20 (polluted), 2014 (8-10 UTC)**
  - ✓ **August 12, 2015**
  - ✓ **August 20, 2015**
  - ✓ **August 22, 2015**

Aerosol climatology in NWP

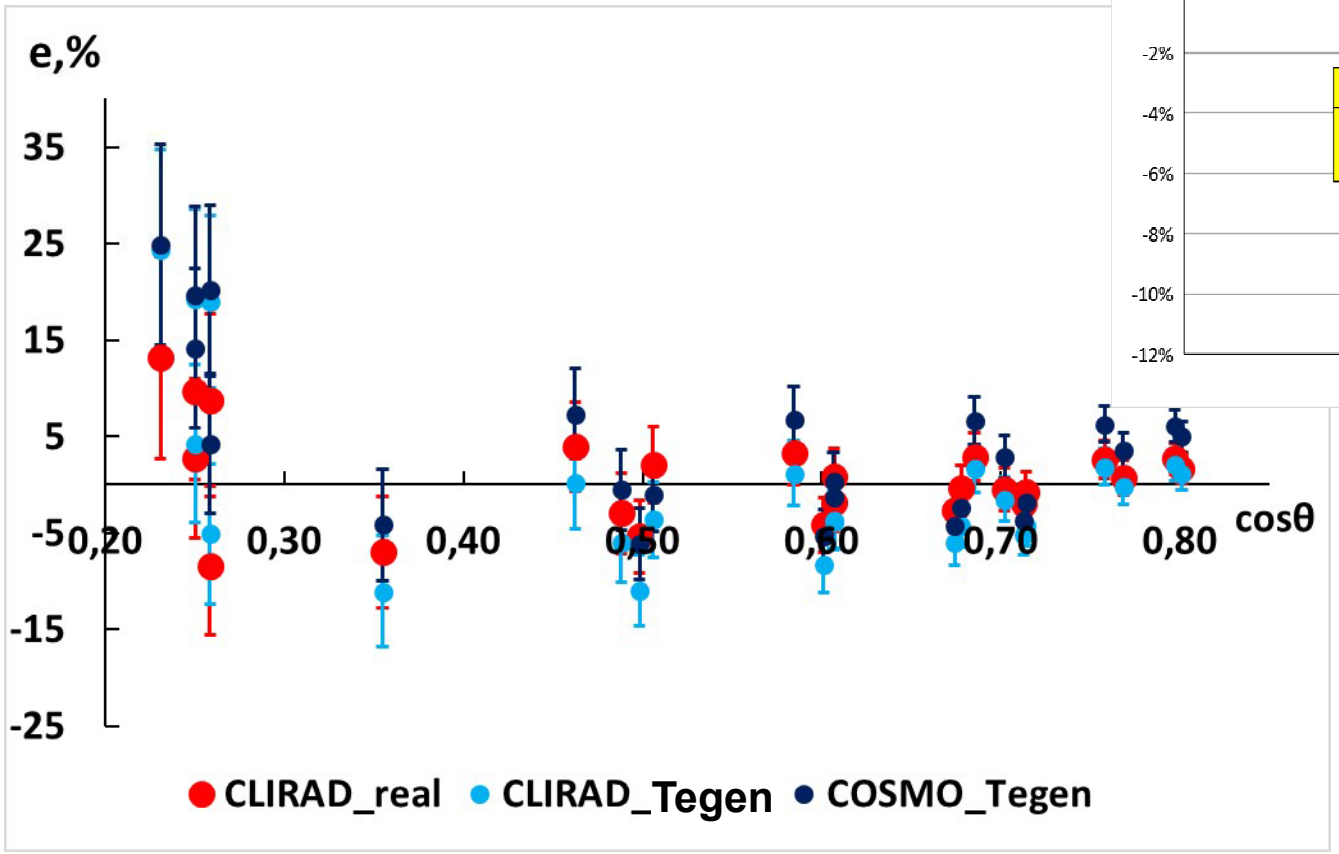
Relative difference between model and observed global total irradiance as a function of cosine SZA

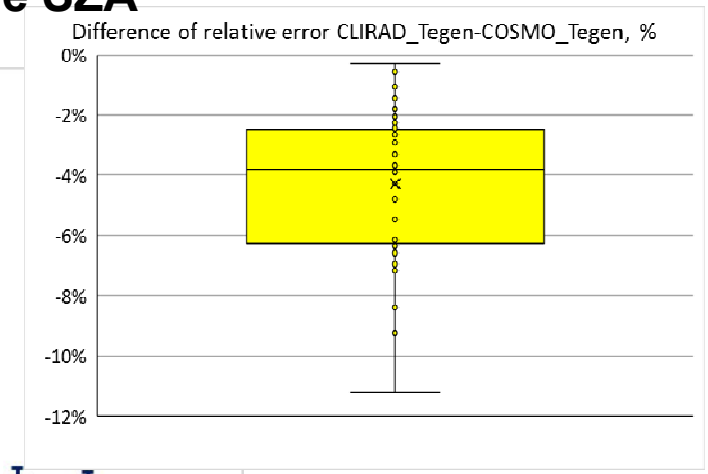


For high cosθ there is about 5% of overestimation in the COSMO scheme against CLIRAD.

Aerosol climatology in NWP

Relative difference between model and observed global total irradiance as a function of cosine SZA

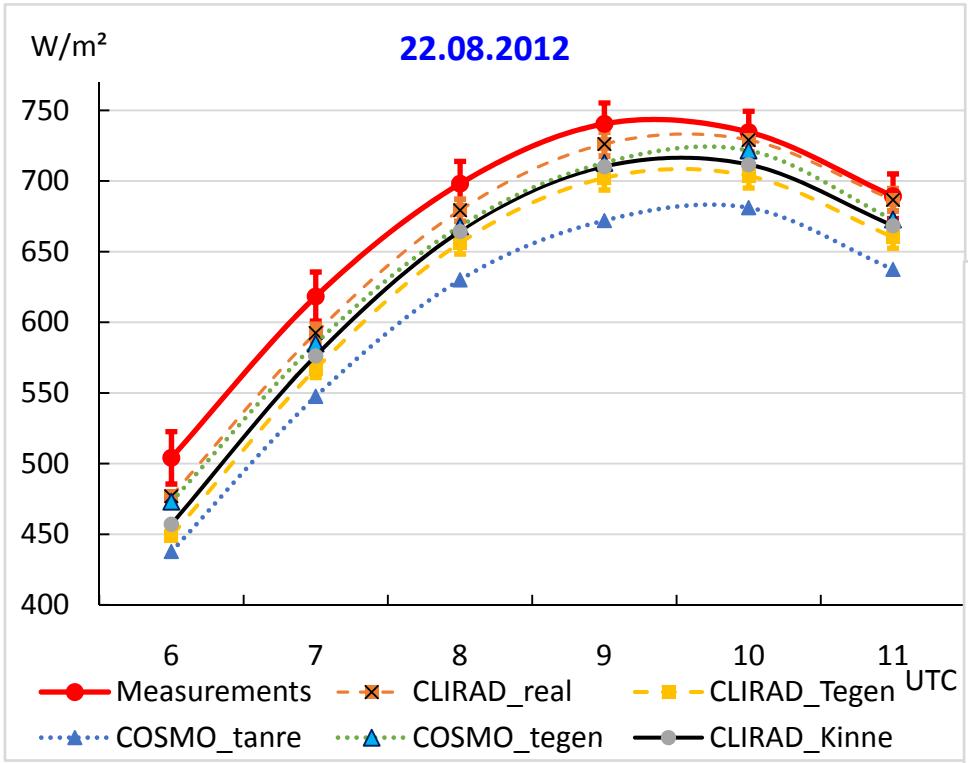


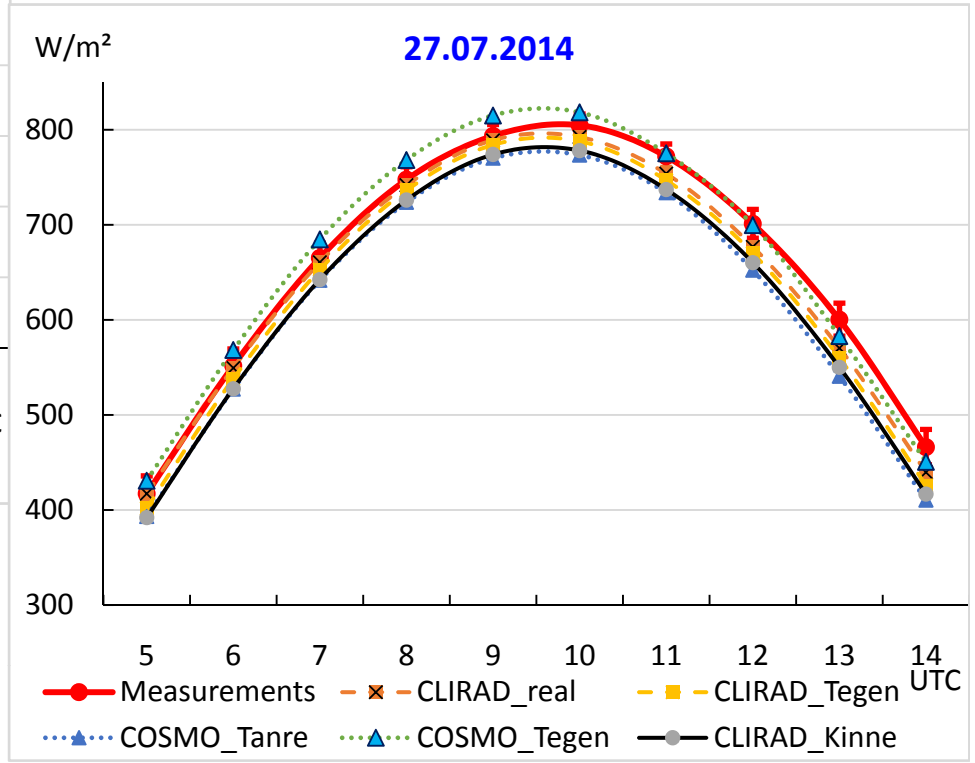


For high cosθ there is about 5% of overestimation in the COSMO scheme against CLIRAD.

Aerosol climatology in NWP

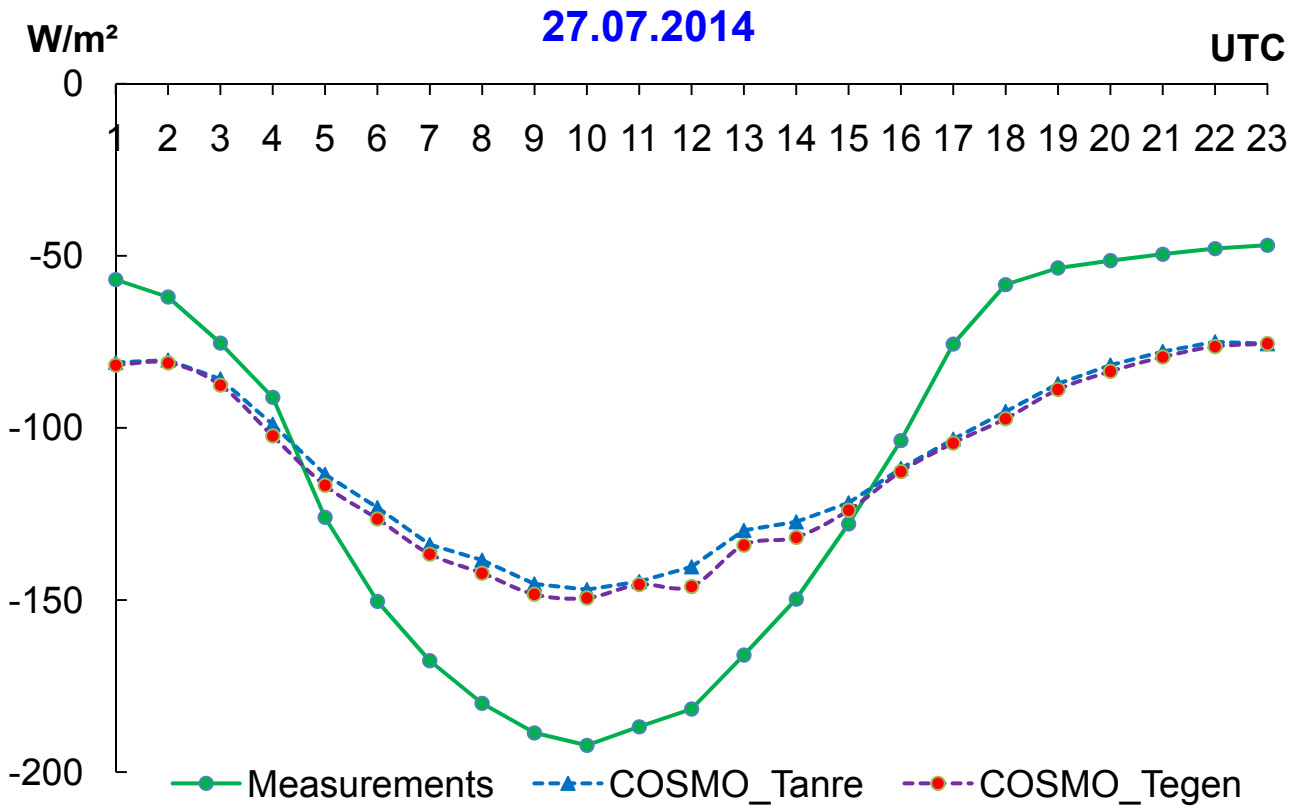
Global shortwave radiation from the experimental data and modelling with different aerosol datasets





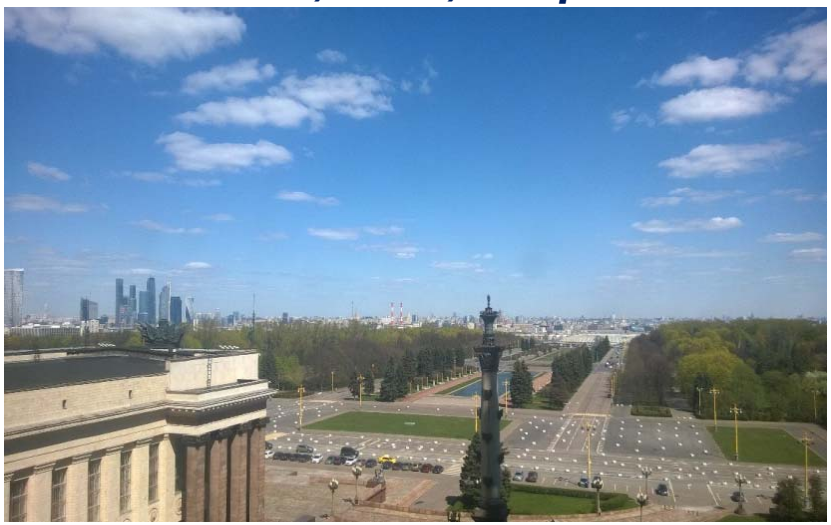
Aerosol climatology in NWP

Net longwave irradiance from the experimental data and modelling with different aerosol datasets

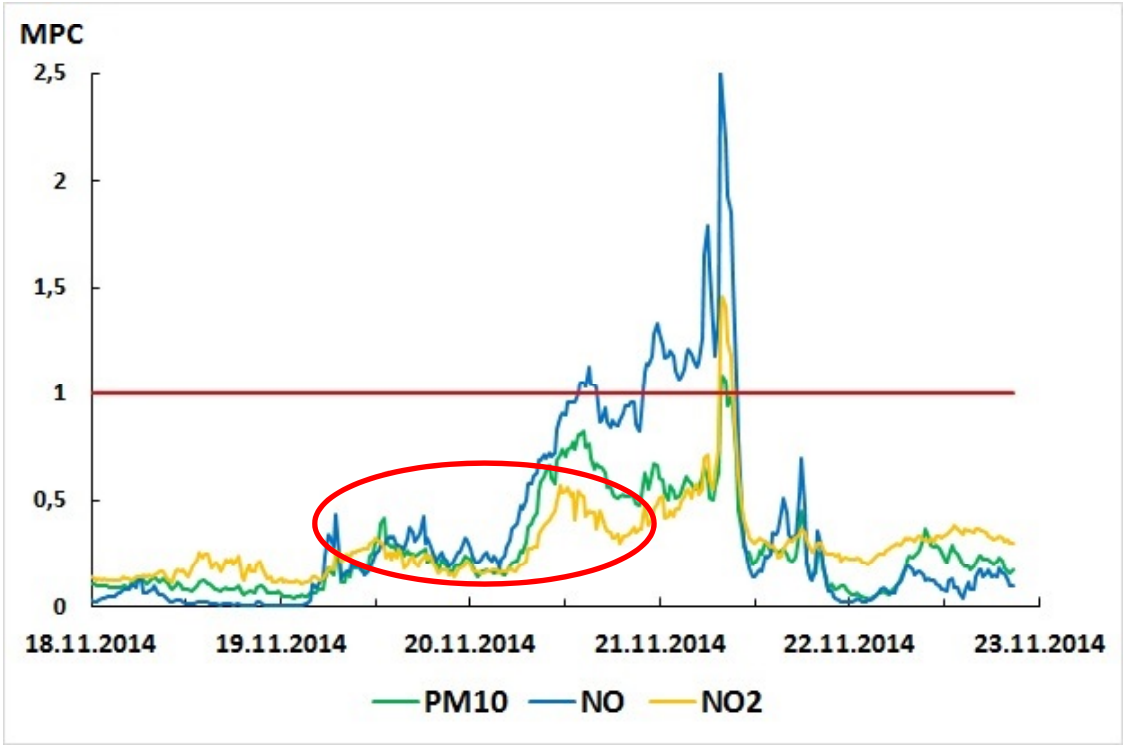


Aerosol climatology in NWP

November 17, 2014, no pollution



November 21, 2014, polluted case

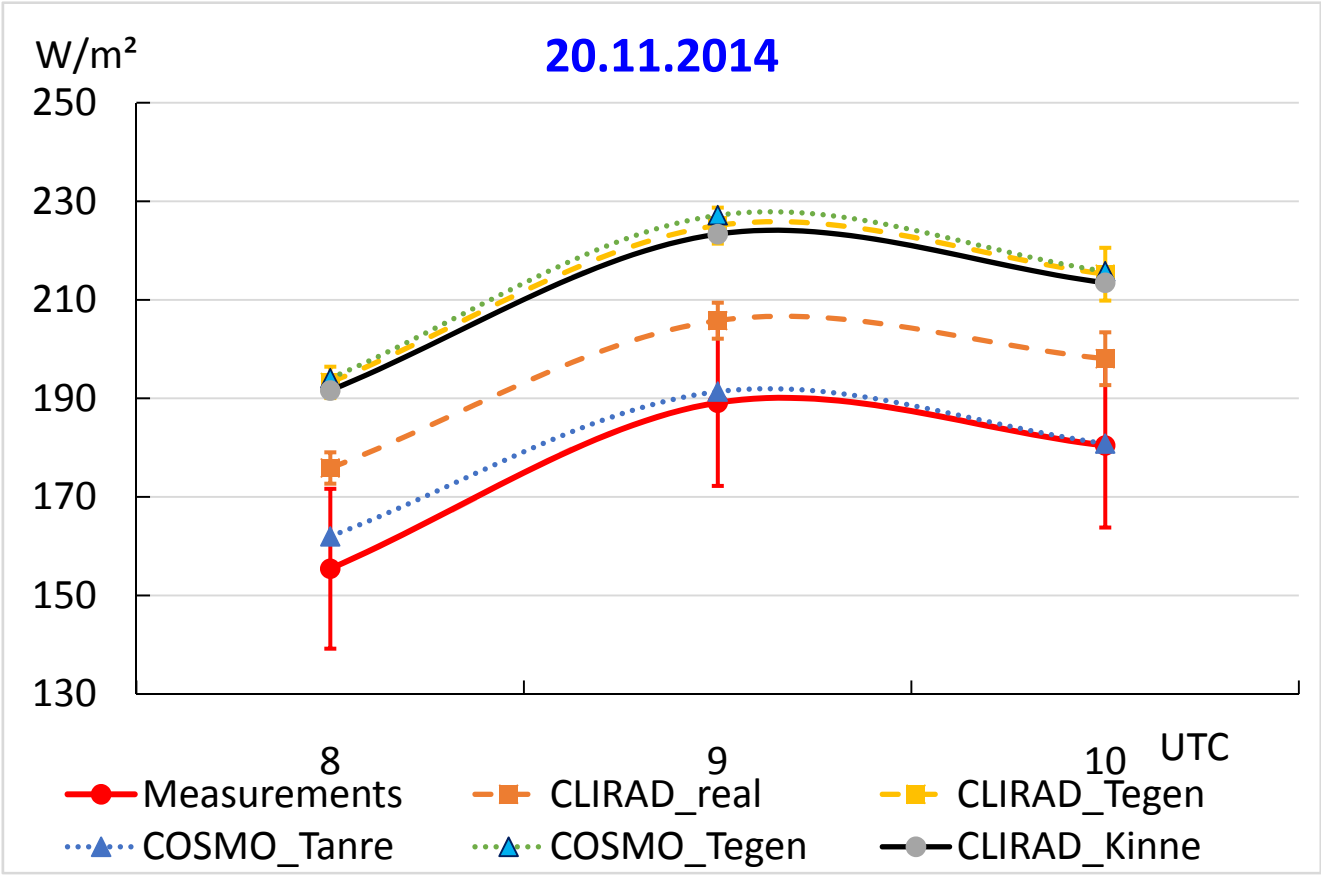


Aerosol climatology in NWP

The results of the comparison with measured data (November 20, 2014, polluted case)

AOT550

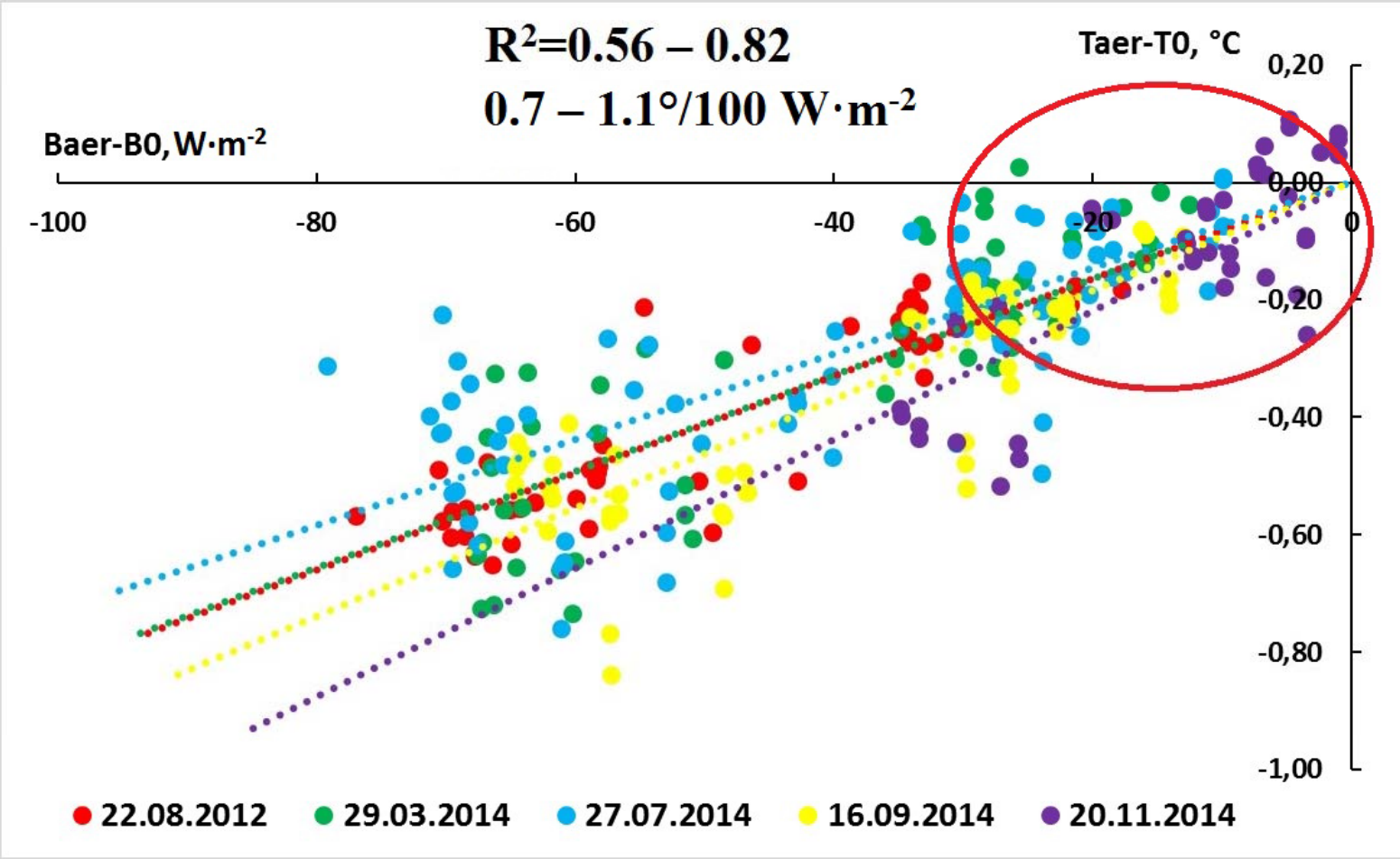
- **Tegen,1997 – 0.17,**
- **AERONET – 0.17 - 0.20**



However, there was a high concentration of NO_2 and possible additional absorption in visible region of spectrum due to this gas.

Aerosol climatology in NWP

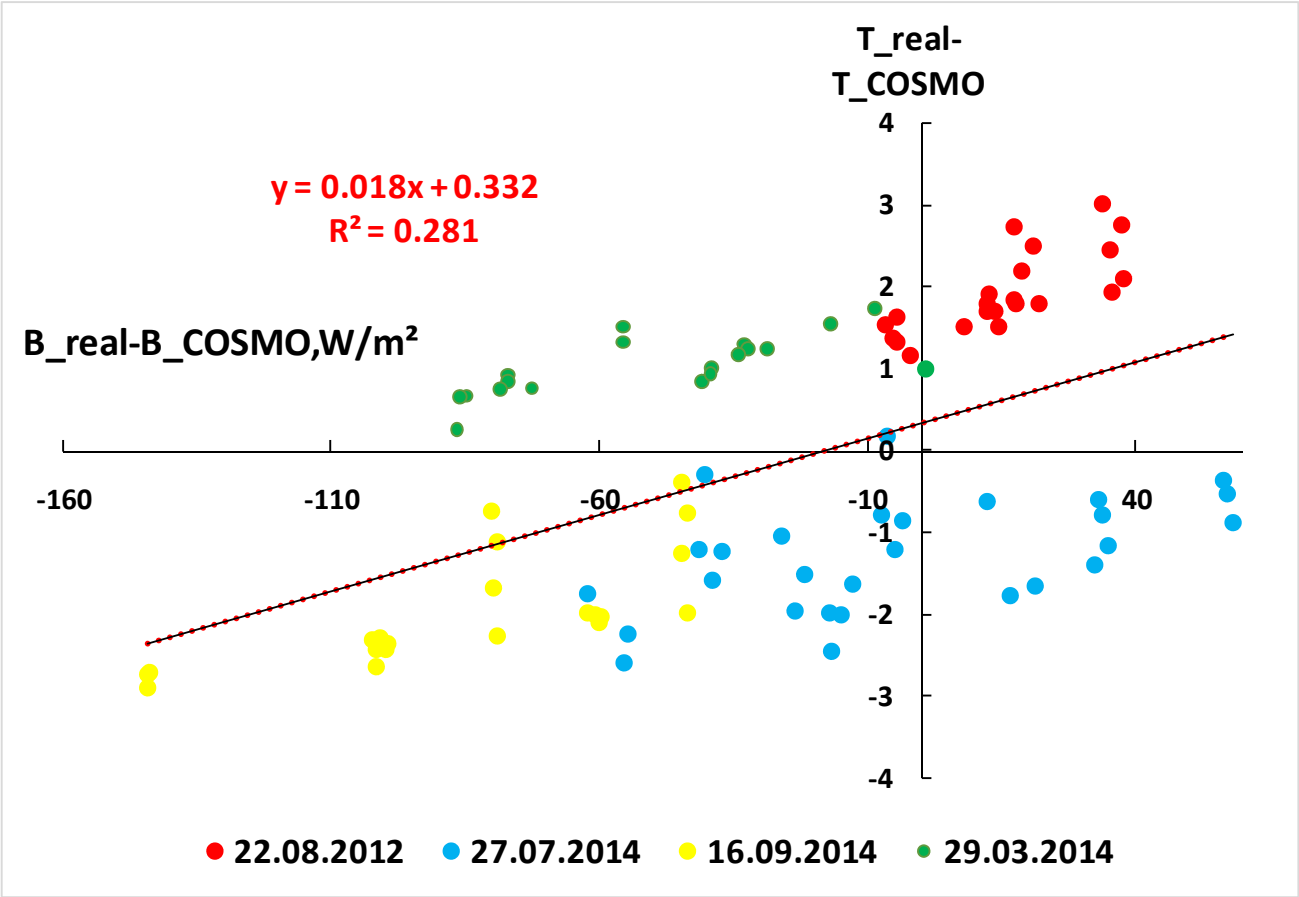
The sensitivity of the air temperature T2m forecast to the shortwave net radiation changes due to aerosol. Simulated by COSMO-Ru.



Axis X – the difference between shortwave net radiation with and without aerosol,
Axis Y – the difference between T2m forecast with and without aerosol.

Aerosol climatology in NWP

The difference between the observed and forecasted by COSMO-Ru model T2m as a function of the difference in observed and forecasted shortwave net radiation due to aerosol

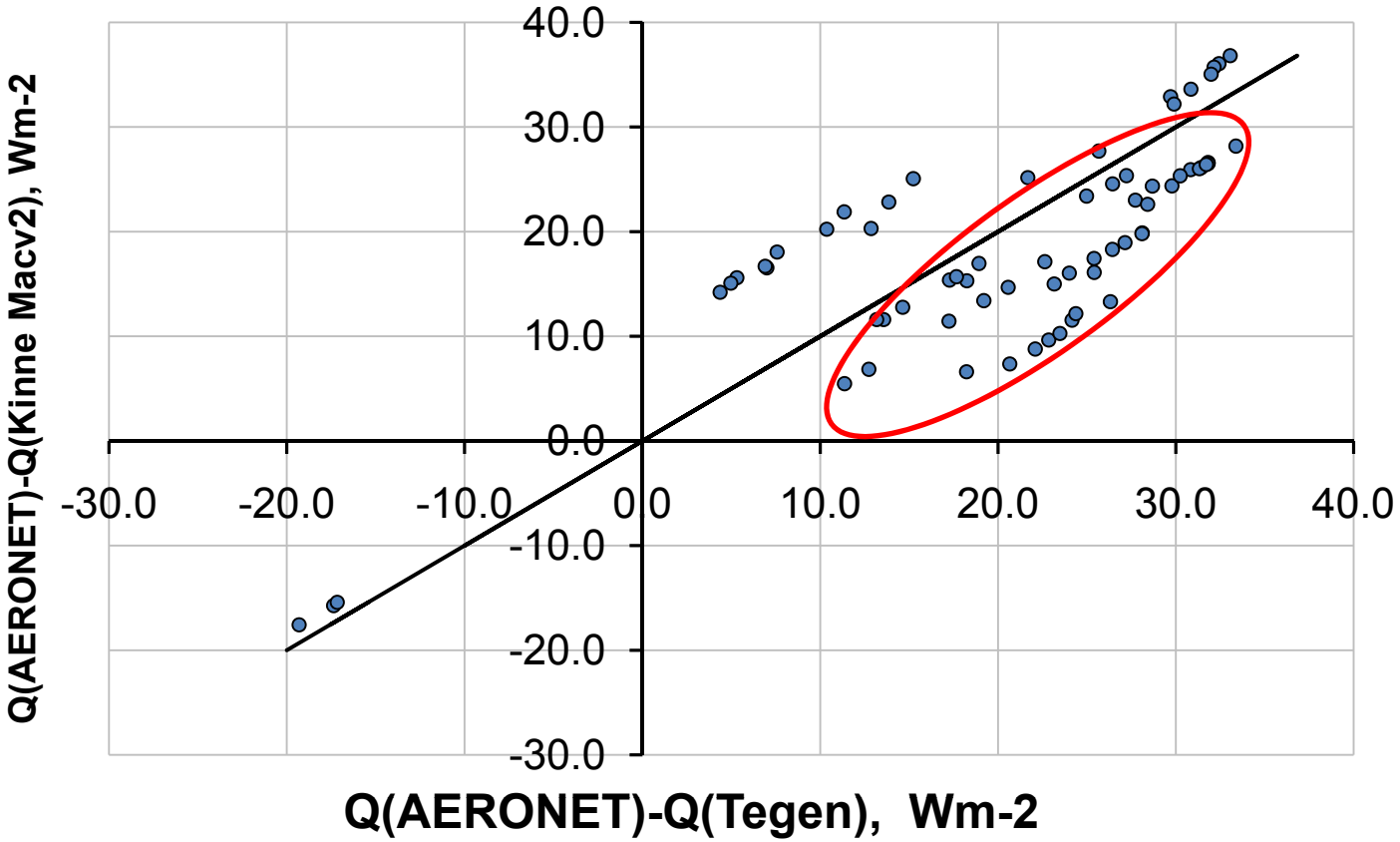


Axis X – shortwave net radiation difference (observations – model)
Axis Y – T2m difference (observations – model)

Aerosol climatology in NWP

Differences (ΔQ, Wm-2) in global shortwave irradiance:
Q(AERONET)-Q(Kinne Macv2) versus Q(AERONET)-Q(Tegen).

CLIRAD model simulations. Clear sky.



Conclusions

- **CLIRAD-SW model demonstrates 0-2% uncertainty within the typical AOT and high cos SZA against benchmark simulations;**
- **The COSMO algorithm provides systematically 4% higher simulation of global shortwave irradiance against the reference model;**
- **The Kinne Macv2 aerosol climatology provide better agreement with measurements, however it is necessary to study it for a variety of conditions;**
- **There is a pronounced T2m sensitivity to the aerosol loading of about 0.7-1.1°C per 100 W/m^2.**

Thanks for your attention

- Questions?