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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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

<u>Radiative measurements:</u>

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

<u>Data on aerosols and atmospheric water vapor content :</u>

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

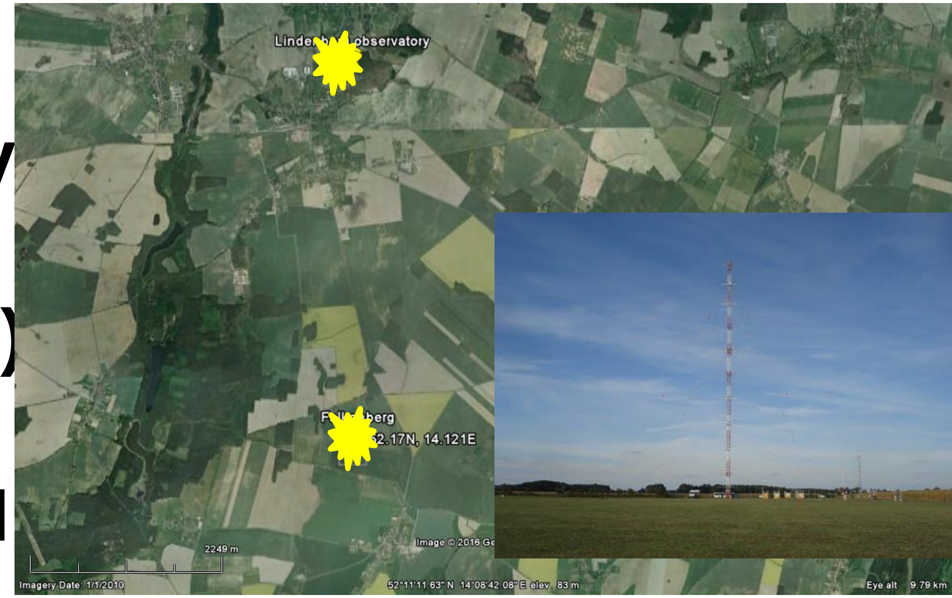
<u>Meteorological observations:</u>

- **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 (<u>6 km </u>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
Aerosol			
scattering	yes	yes	yes
absorption	yes	yes	yes

from Ritter, Geleyn, 1992

Delta two stream parameterization of radiative transfer.

Main equations:

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

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

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

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

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

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

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;

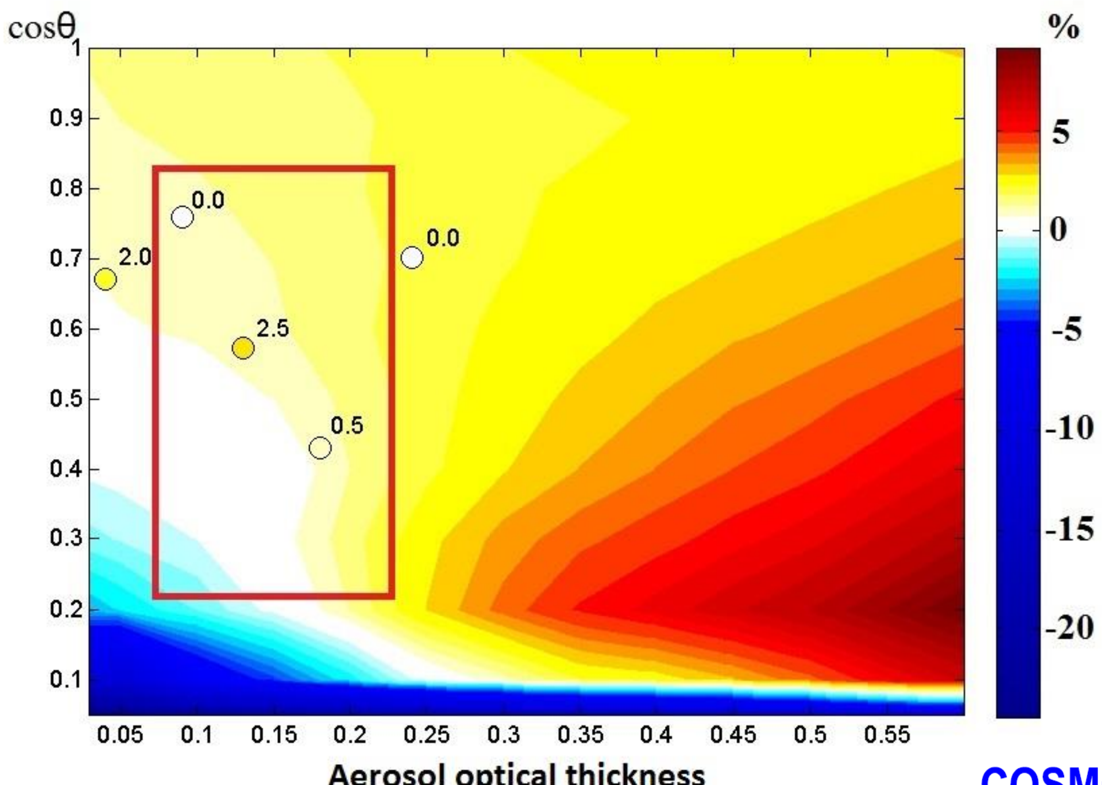
Gases: H_2O, O_2, O_3, CO_2;

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.



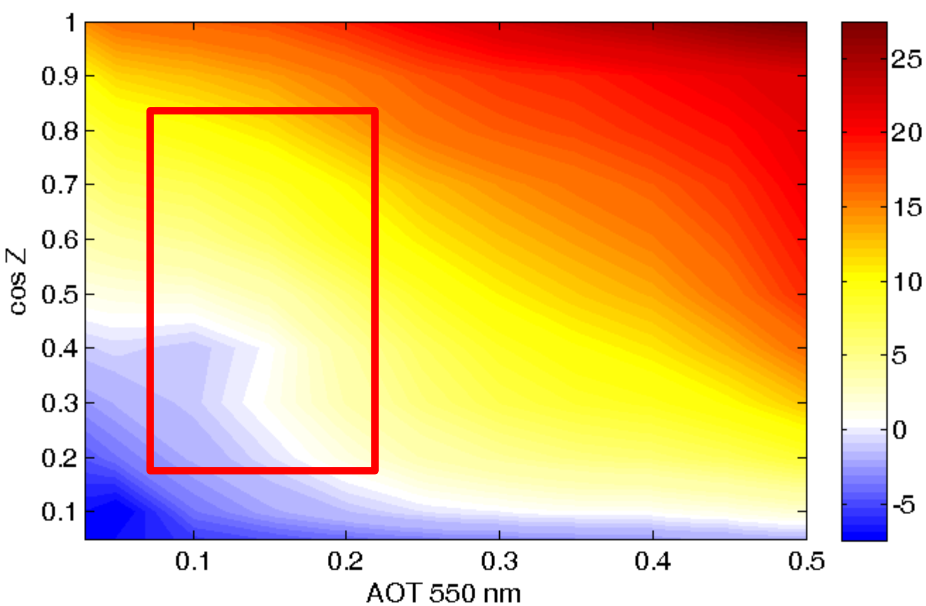
Red frame restricts the typical aerosol/solar zenith angle conditions in Moscow.

<u>Points depict the results from the CIRC Phase 1 model intercomparisons</u> (*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.

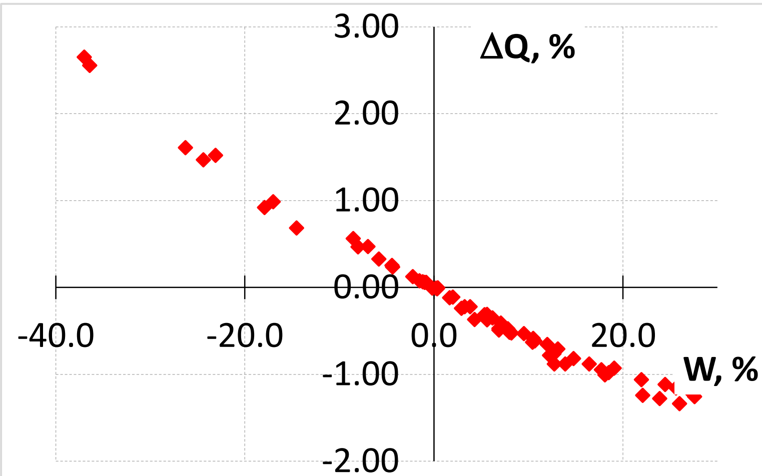


Red frame restricts the typical aerosol/solar zenith angle conditions in Moscow.

Shortwave irradiance sensitivity to variation in gas content

Water vapor, H_20:

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



Uncertainty in solar irradiance due to water vapor profile is less than 0.2%

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)**

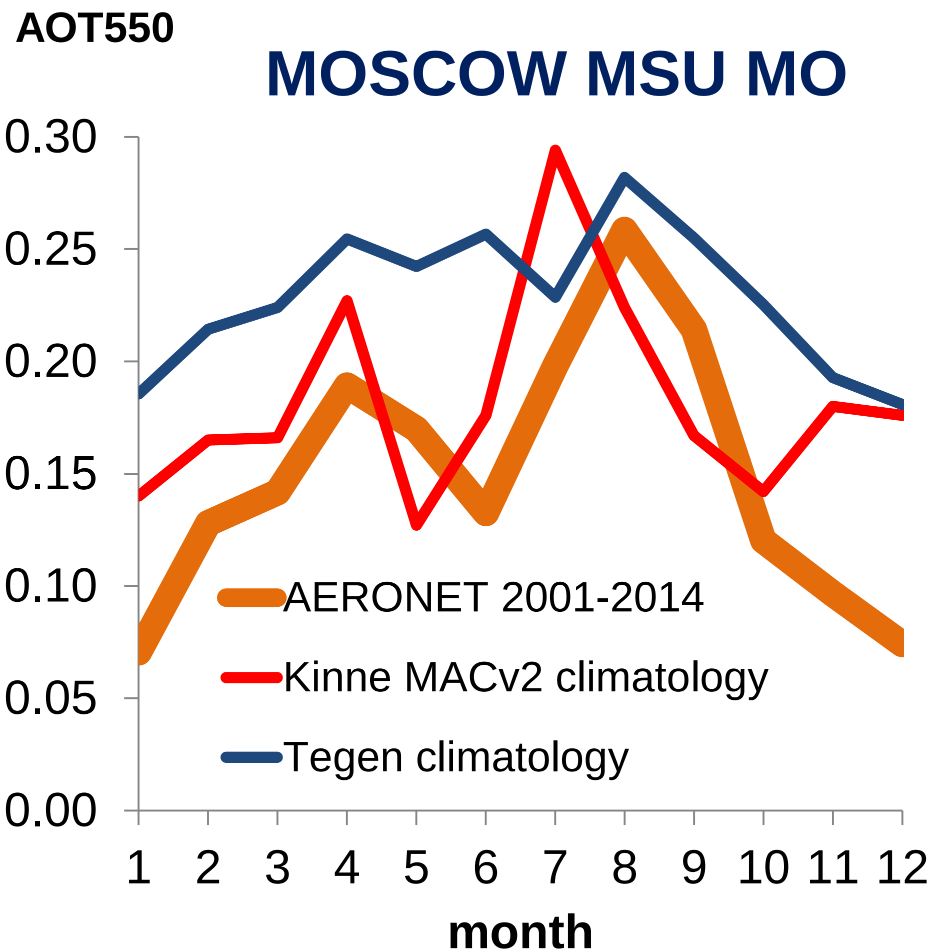
(AOT550 from Tegen climatology used in COSMO model is 0.04-0.05 higher than initial Tegen dataset due to old stratospheric and tropospheric simulated AOT in the profile subroutine),

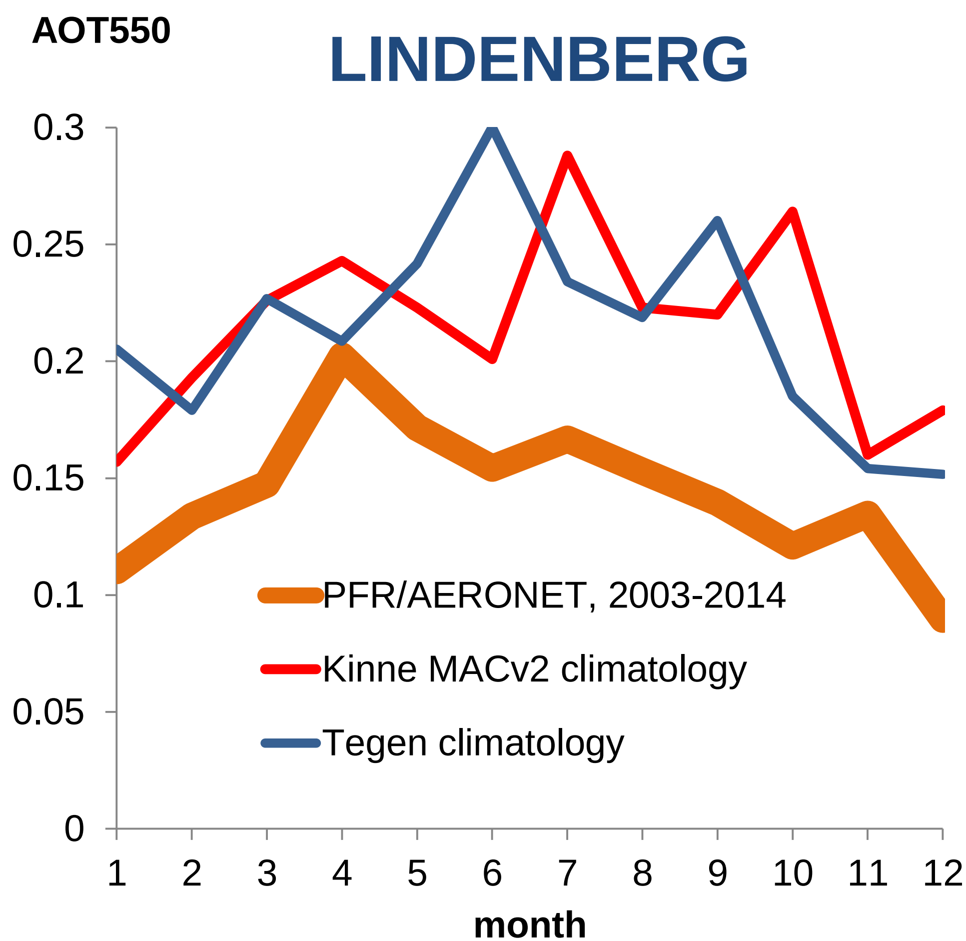
- **Tanre climatology (Tanre et al., 1984),**
- **MACC (CAMS ECMWF) aerosol dataset,**
- **AERONET datasets: Moscow since 2001, and Lindenberg (PFR+AERONET) since 2003,**
- **COSMO_ART aerosol (case study for Moscow conditions),**
- **Macv2 climatology (Kinne et al., 2013).**

The implementation of MACv2 aerosol climatology in COSMO

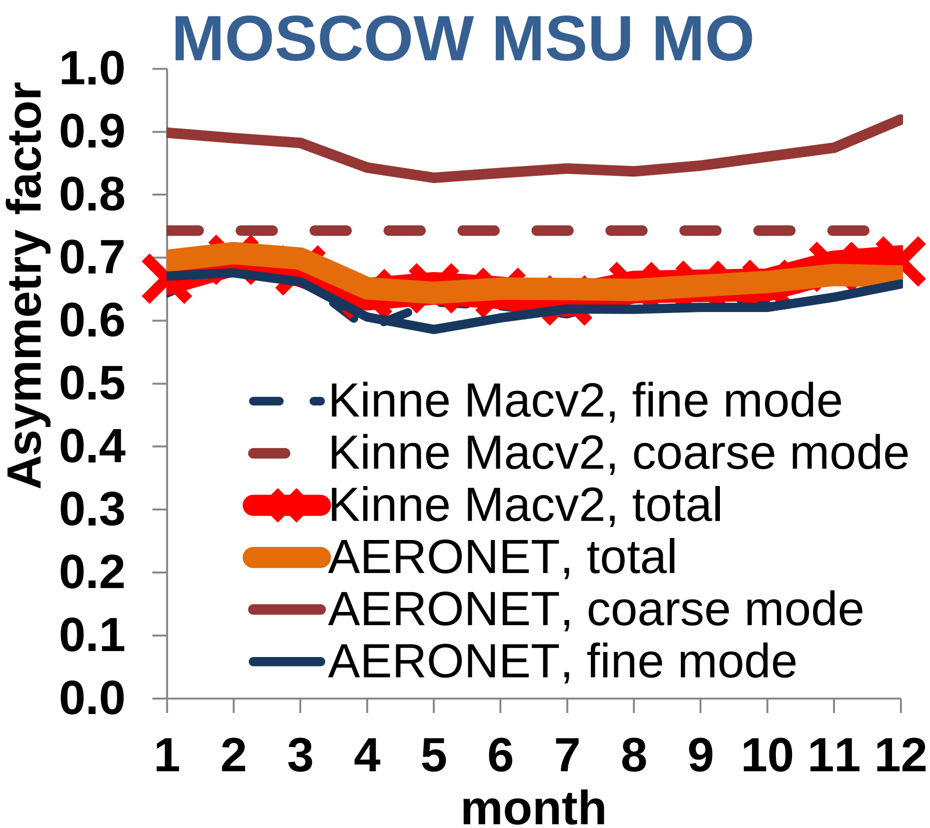
- The Macv2 data (Kinne et al. 2013) were added to EXTPAR. *Many thanks to Daniel Lüthi !* (These data will be available after release of EXTPAR, version 4.)
- Test version of int2lm is ready and provides the ability to account for this new aerosol climatology (itype_aerosol=3).
- The necessary changes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

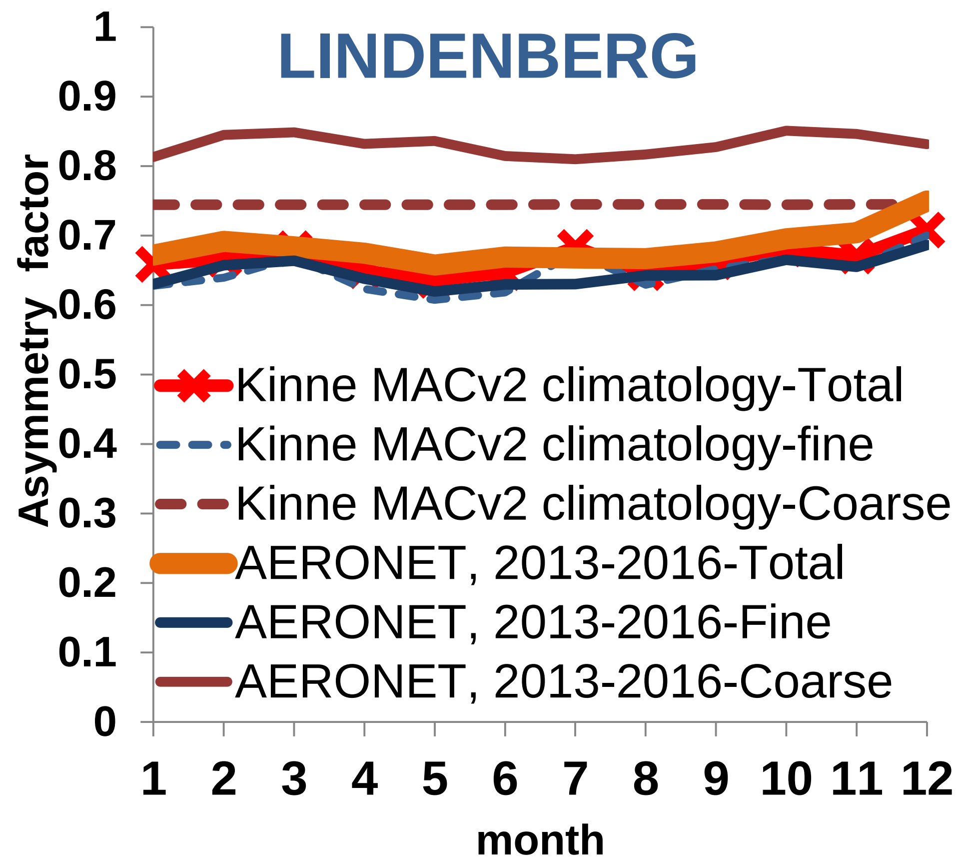
Seasonal changes in aerosol optical thickness at 550 nm (AOT550) according to different aerosol climatologies.



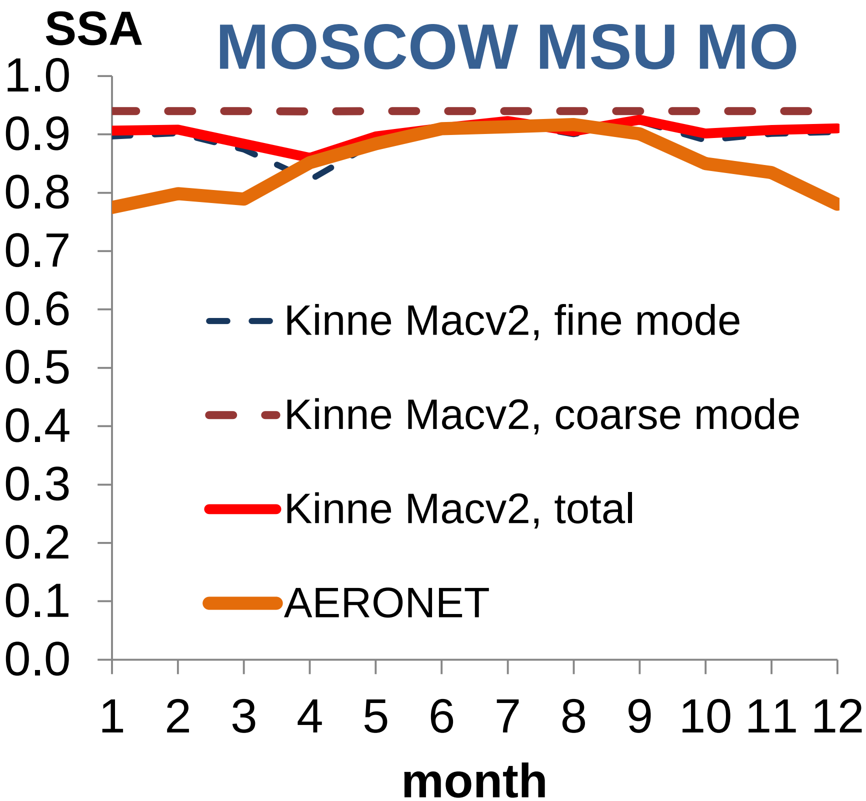


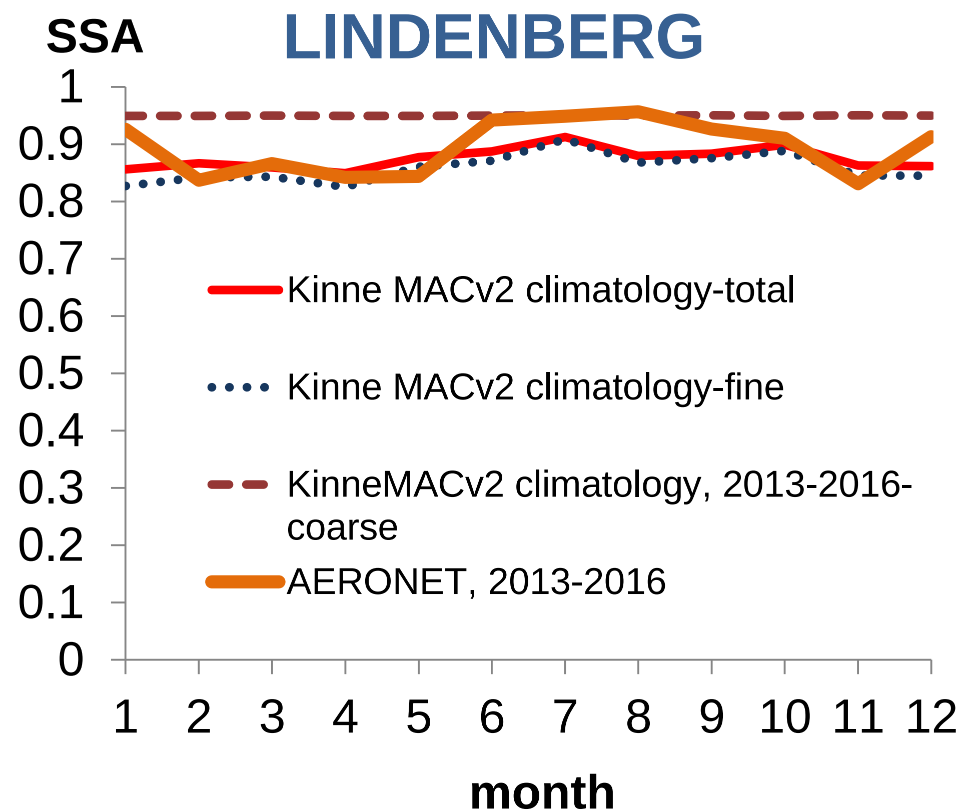
Asymmetry factor for different aerosol modes according to the Kinne MACv2 and AERONET datasets.





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:

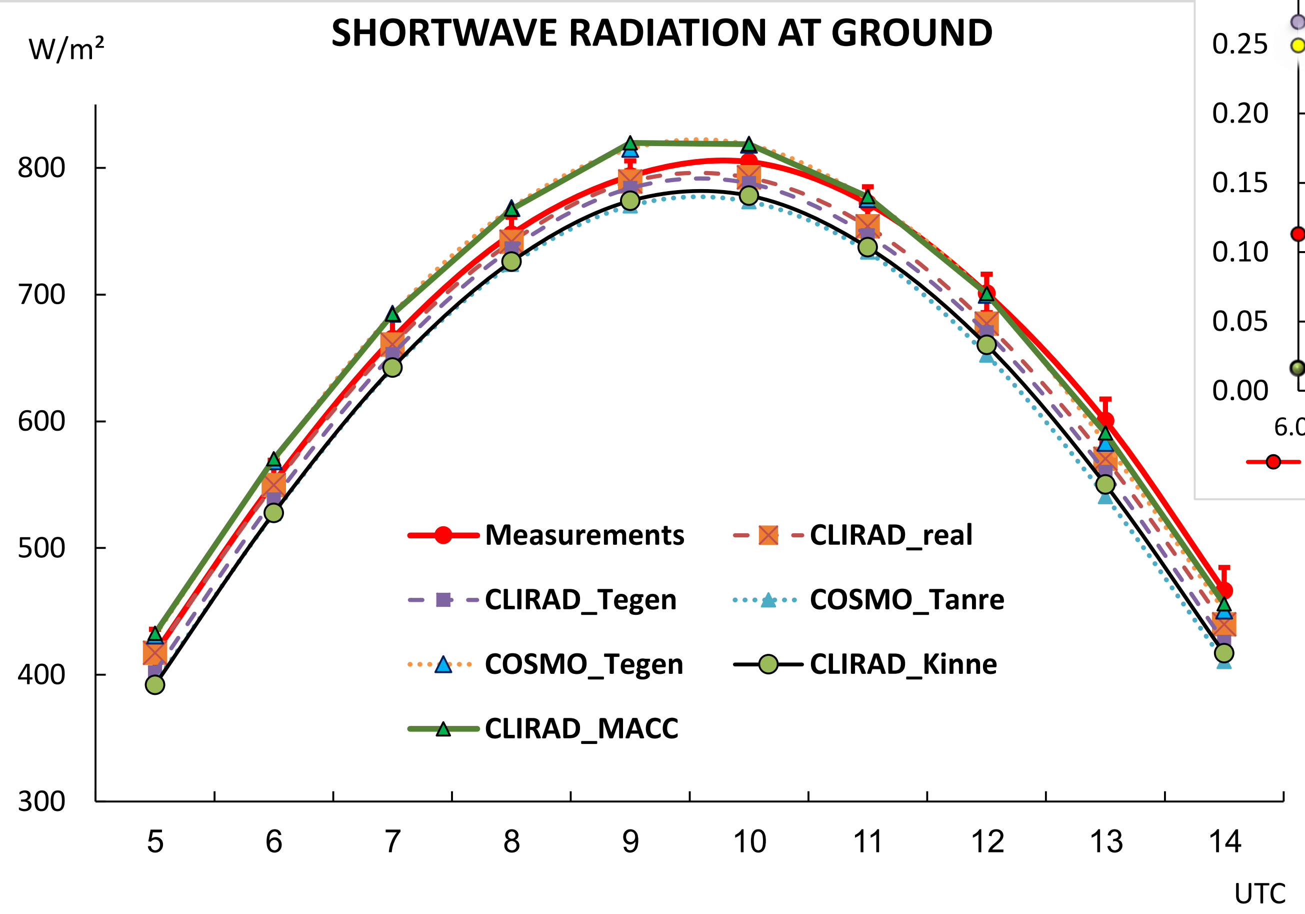
- *Clear sky conditions were chosen when both COSMO-Ru model and observations at the Lindenberg record the absence of clouds.*

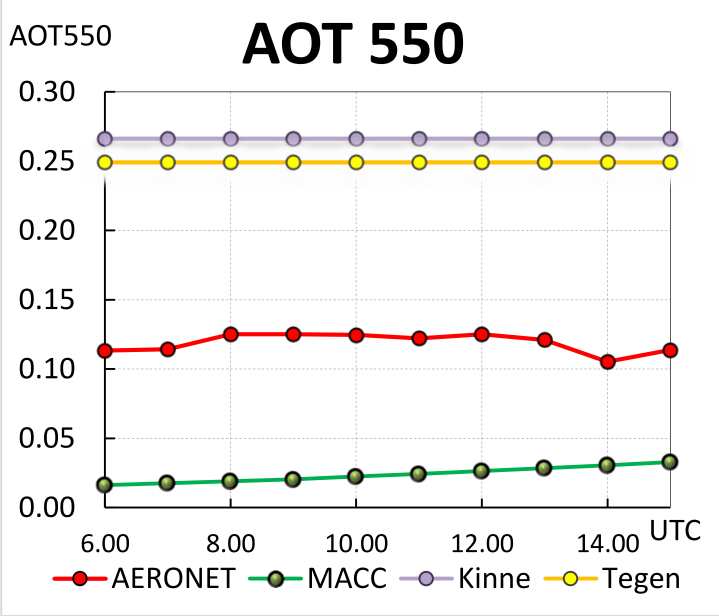
Falkenberg/Lindenberg

- ✓ 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.

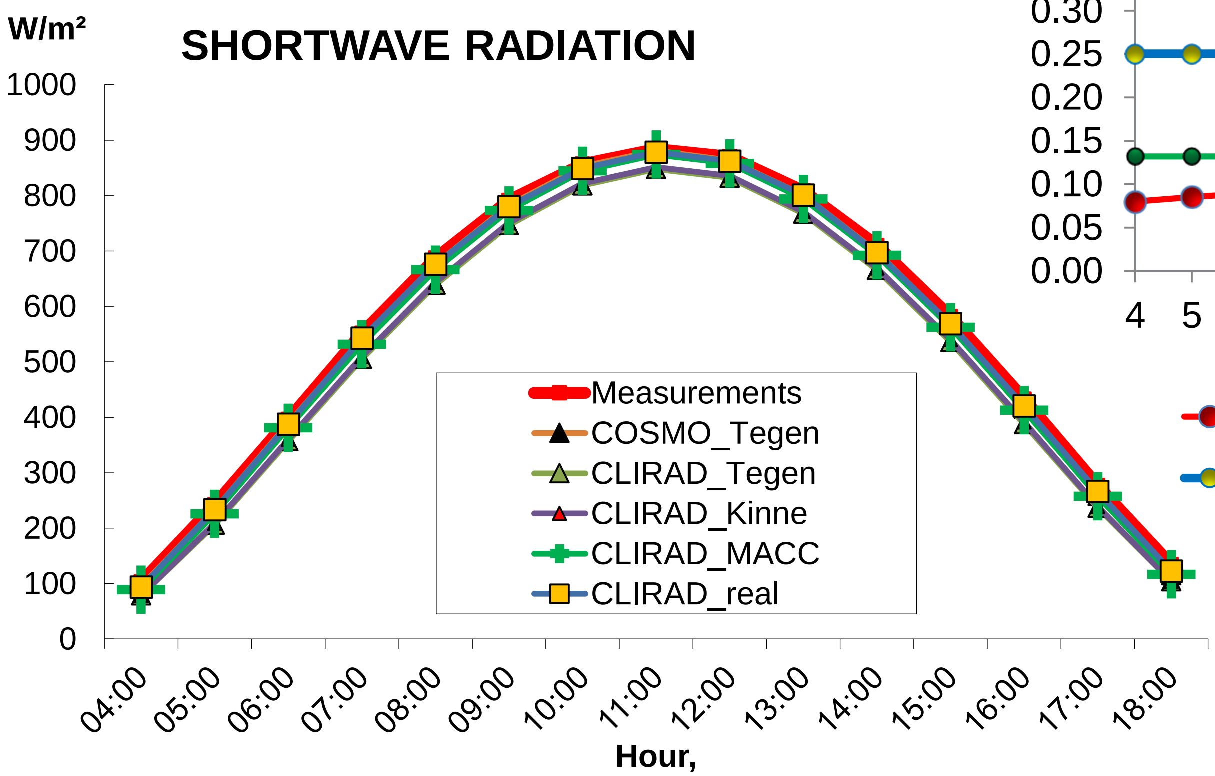
27.07.2014, Moscow.

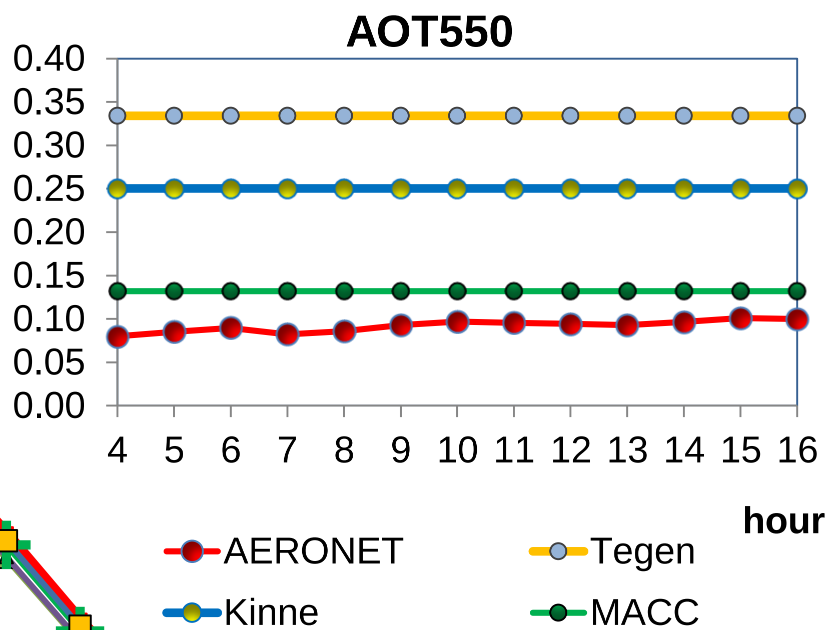




Global shortwave radiation from the experimental data and modelling with different aerosol datasets

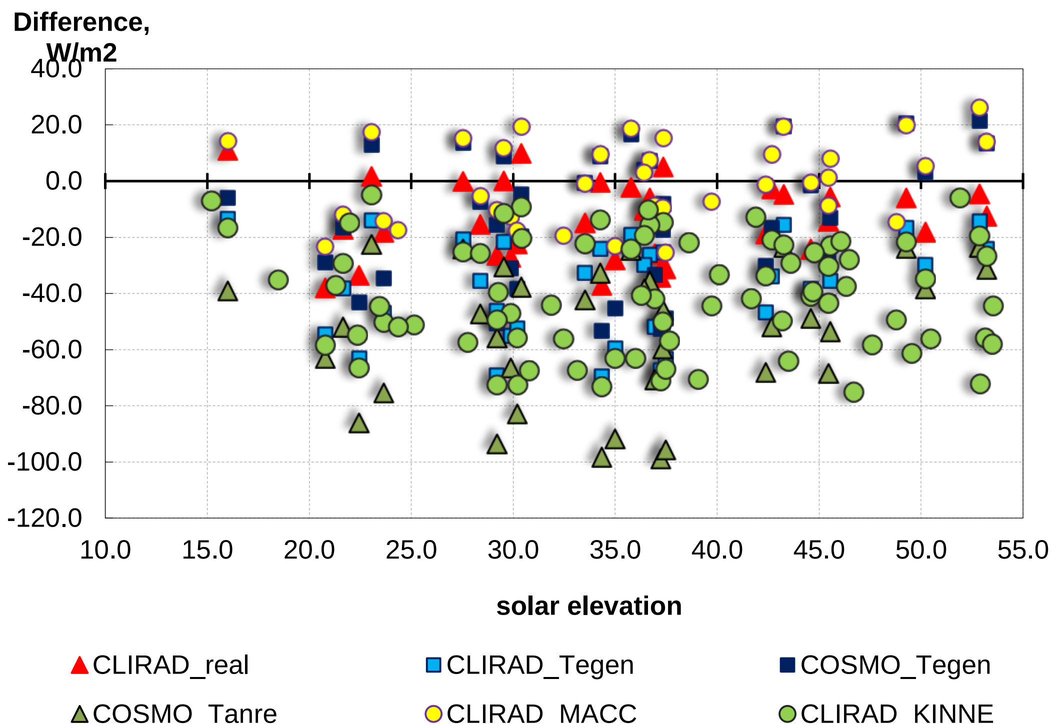
02.07, 2015, LINDENBERG

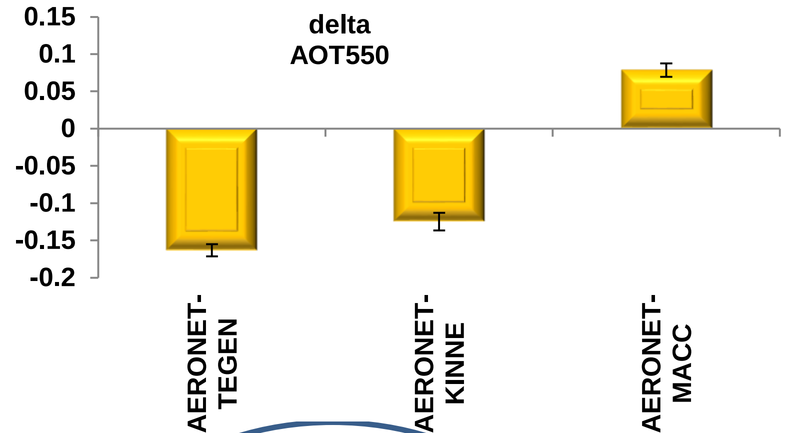


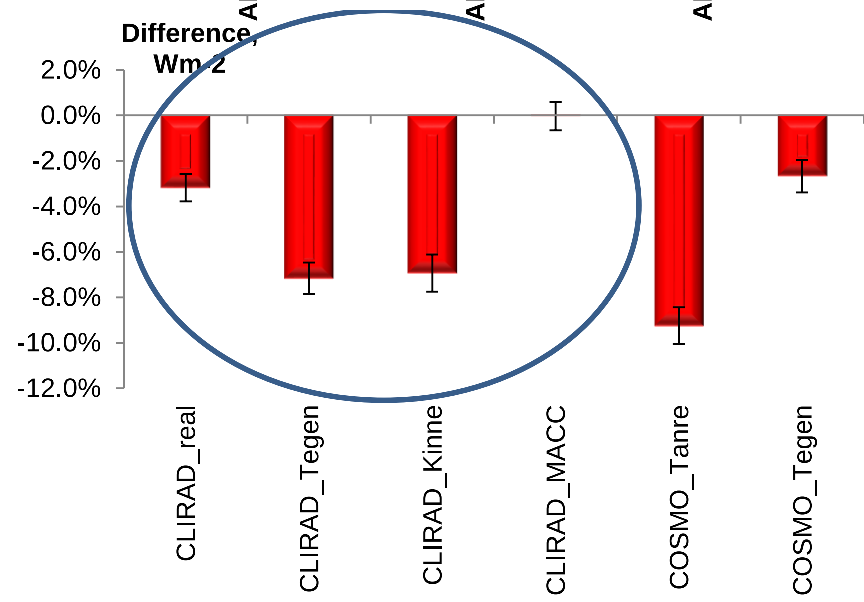


Global irradiance difference between model and observations as a function of solar elevation.

❑ Moscow MSU MO



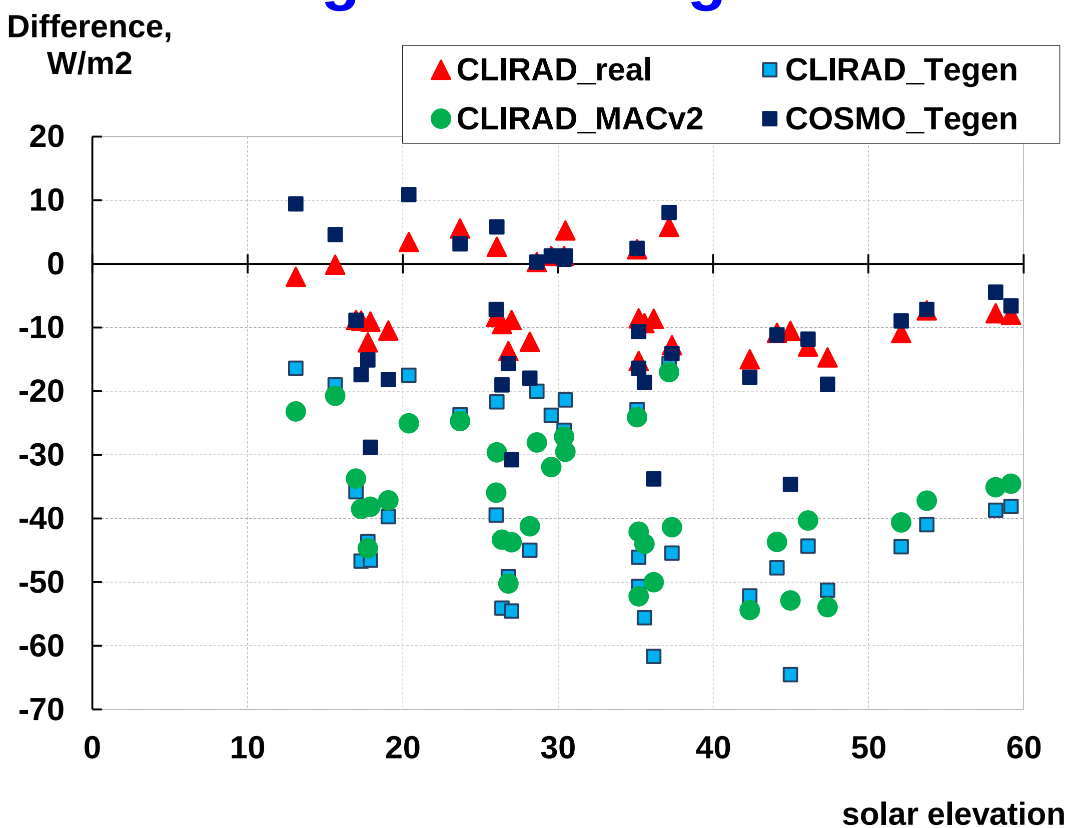


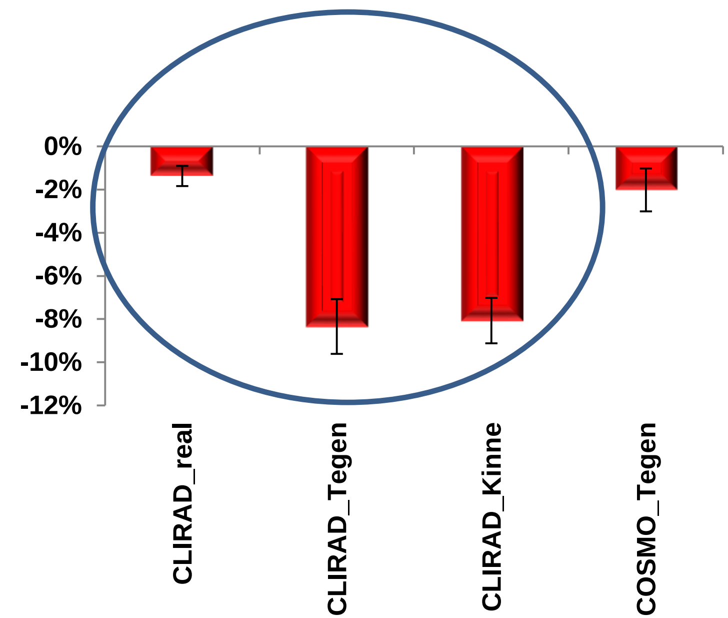


$$\text{Difference}=Q_{\text{measurements}} - Q_{\text{model}}$$

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

❑ Falkenberg/Lindenberg

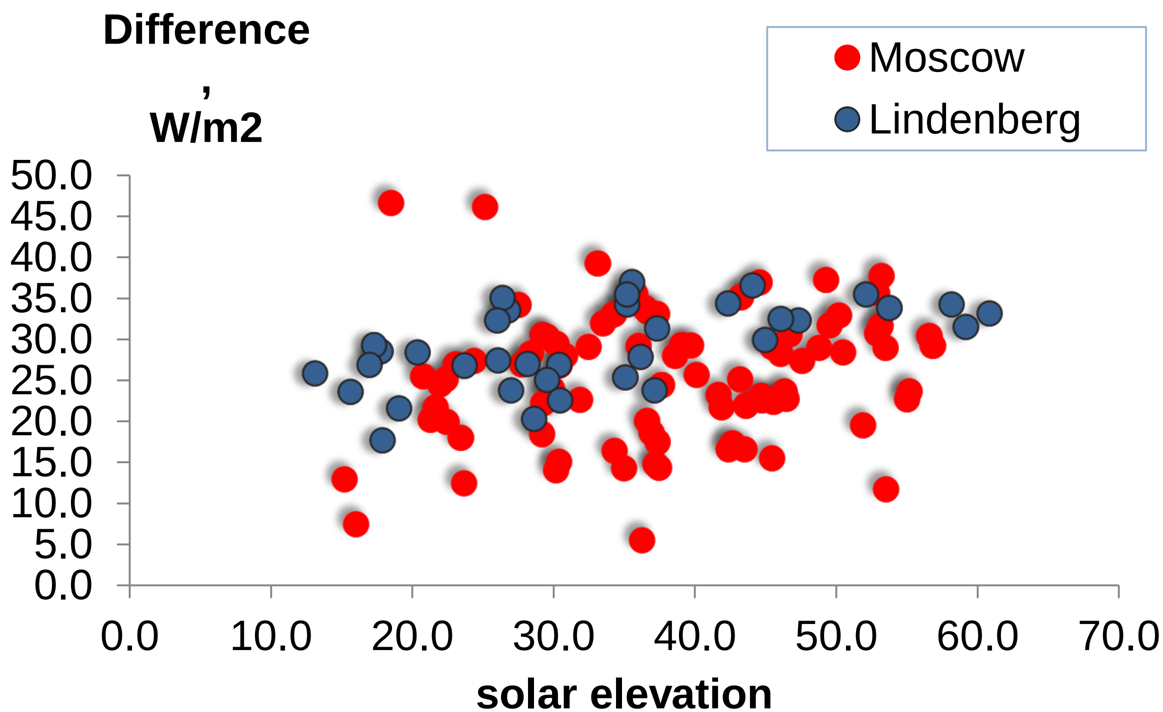




Difference=$Q_{measurements}$ - Q_{model}

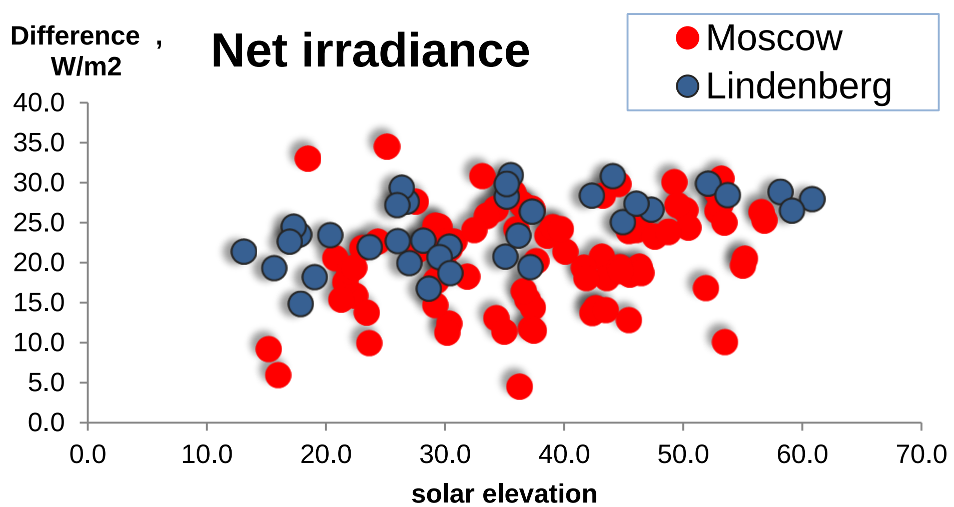
Shortwave global irradiance difference between COSMO and CLIRAD model simulations with the same input parameters as a function of solar elevation.

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

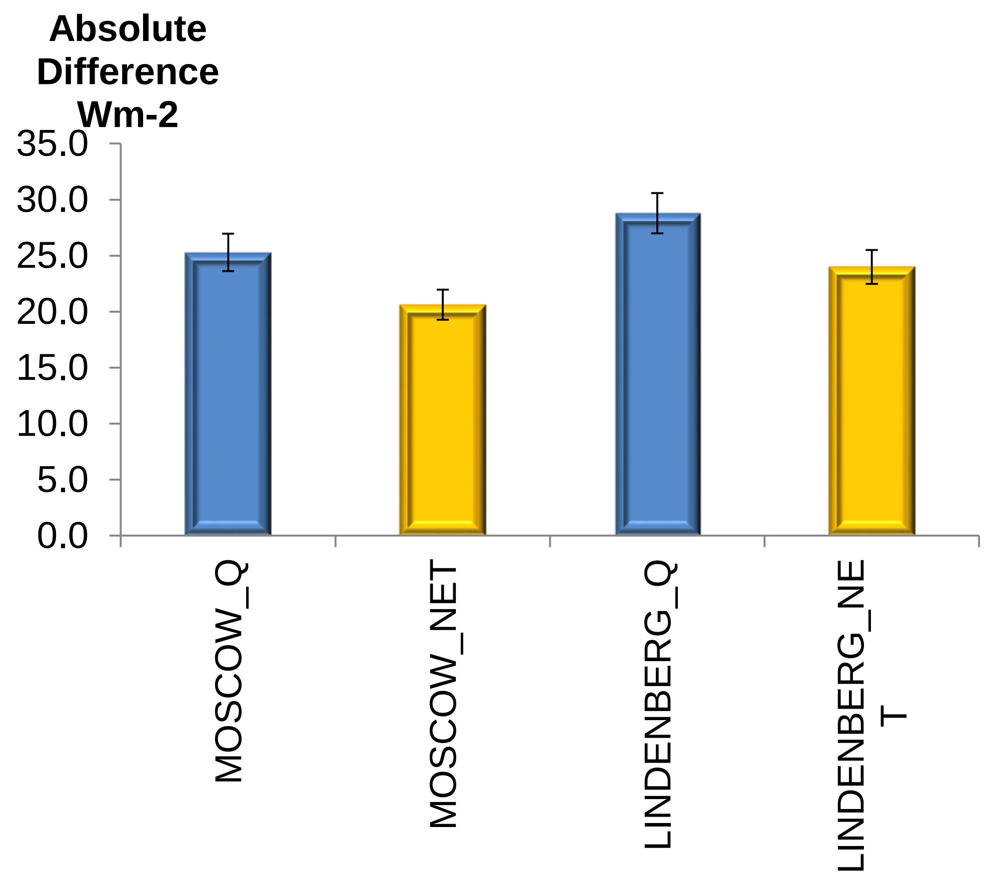


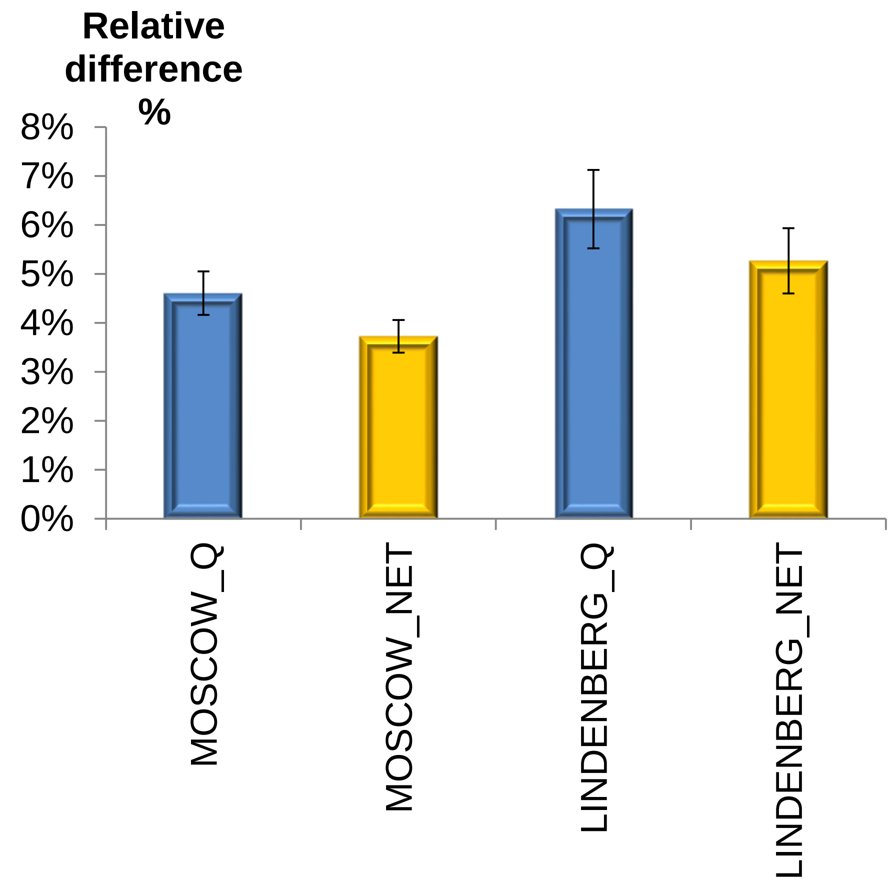
Shortwave NET irradiance difference between COSMO and CLIRAD model simulations with the same input parameters as a function of solar elevation.

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



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

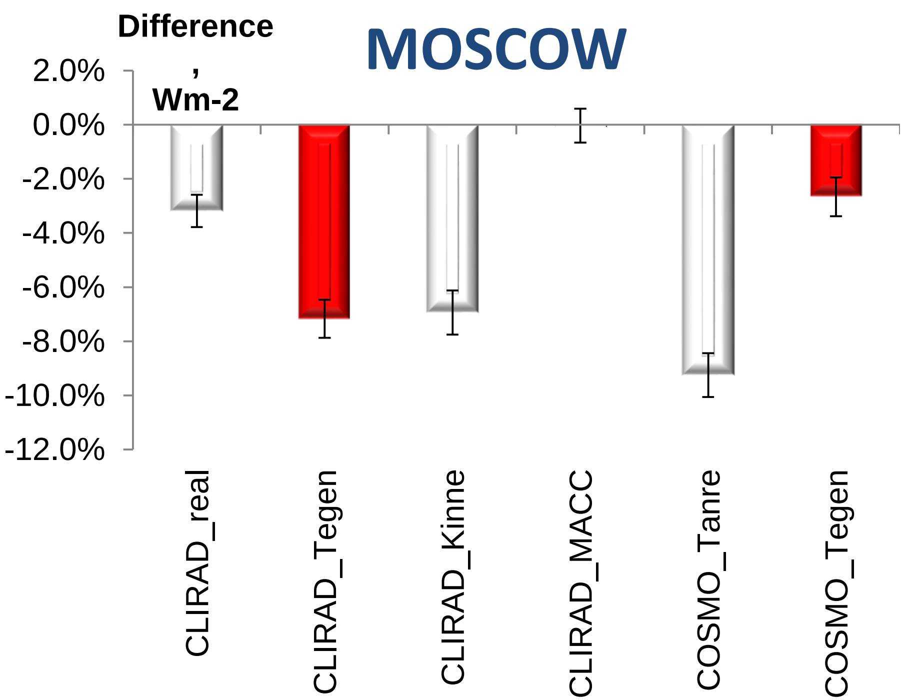


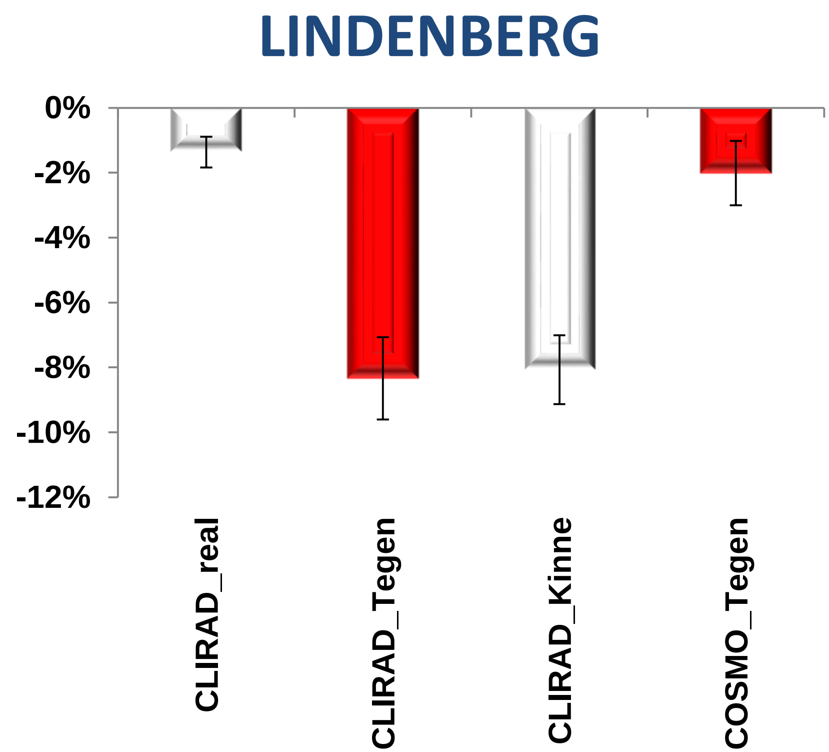


$$\text{Difference}=Q(\text{Net})_{\text{COSMO}} - Q(\text{NET})_{\text{CLIRAD}}$$

Global irradiance difference between model and observations.

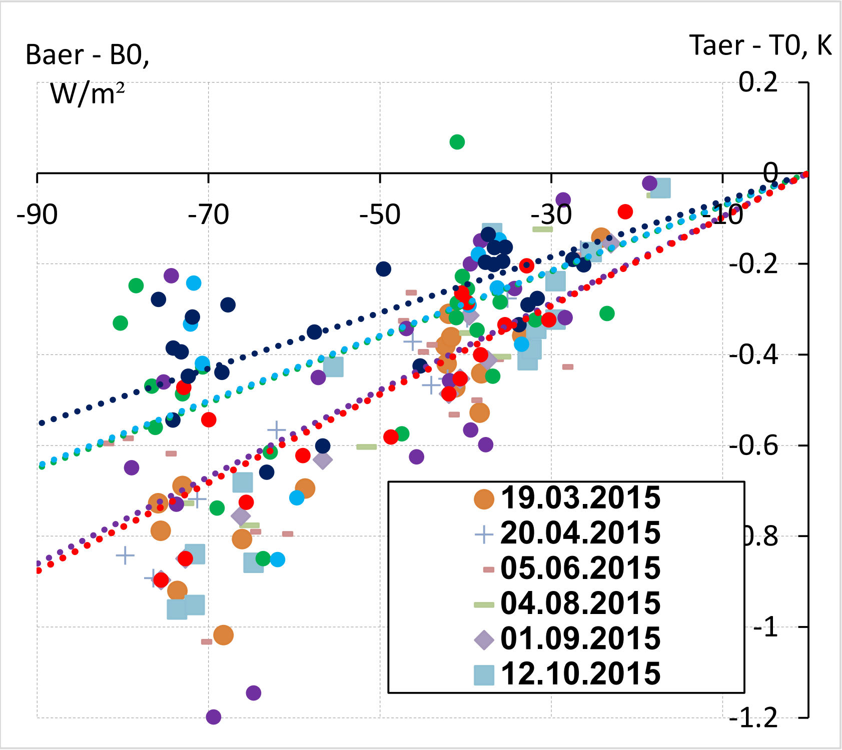
Difference=$Q_{measurements}$ - Q_{model}



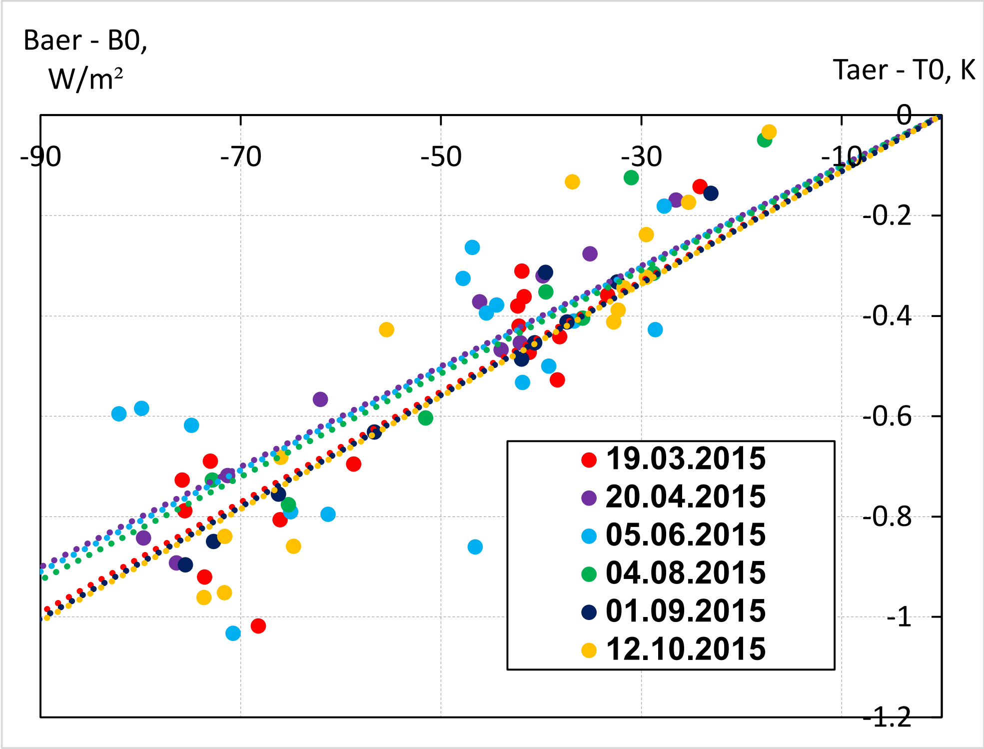


T2M sensitivity to changes in net radiation at ground

MOSCOW MSU MO



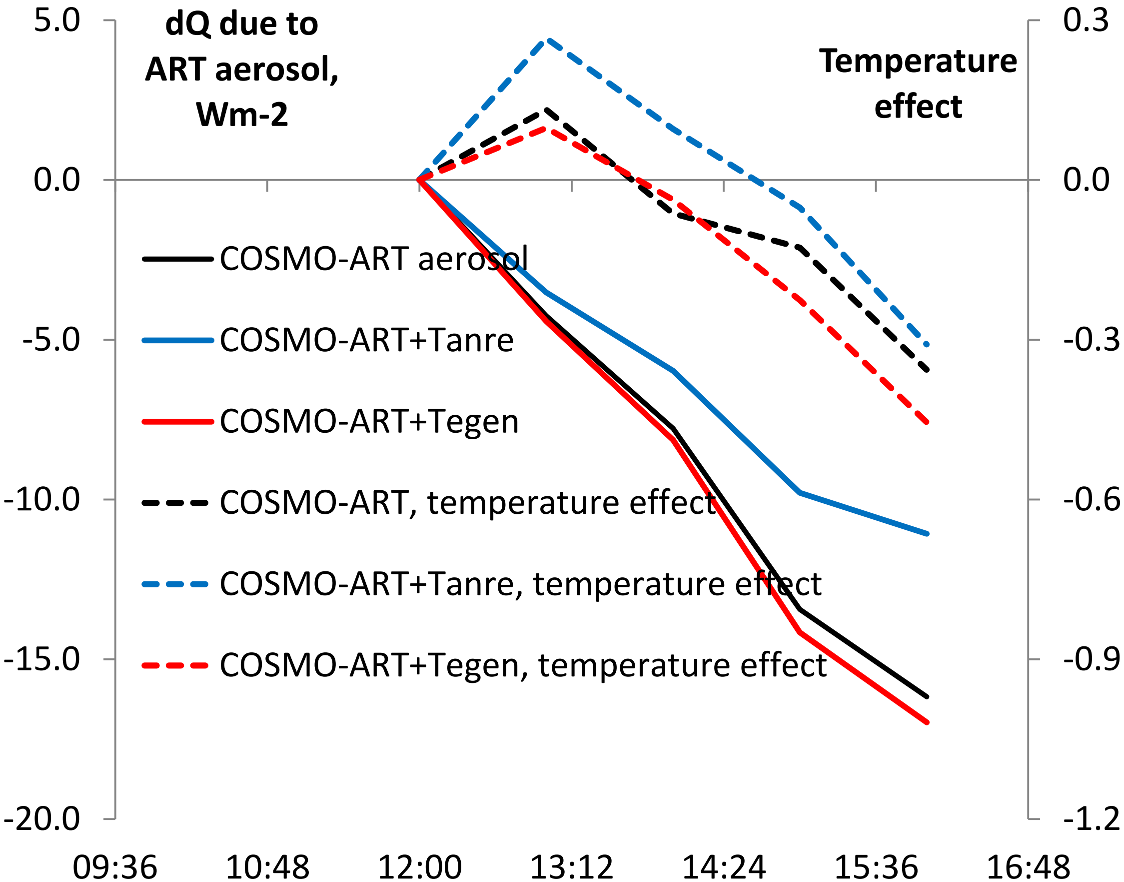
FALKENBERG/LINDENBERG

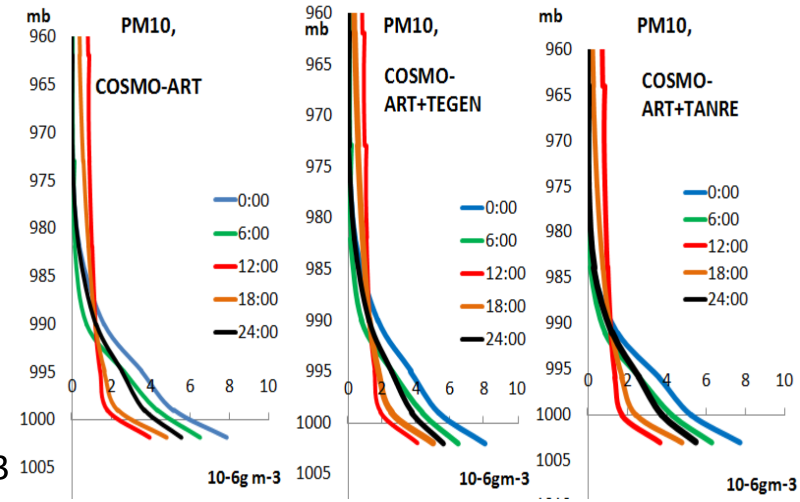


T2M gradient of about 0.7- 1 °C per 100 Wm-2

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.

Acknowledgements:

We would like to thank very much:

- **Daniel Lüthi, Institute for Atmospheric and Climate Science ETH Zürich,**
- **Alexander Kirsanov and Denis Blinov, Hydrometeorological Centre of Russia,**

This work is being fulfilled within the framework of the COSMO Priority Project - T2(RC)2 - Testing & Tuning of Revised Cloud Radiation Coupling.

Radiative and temperature effects of different aerosol types according to COSMO-Ru model in clear sky and cloudy conditions

Natalia Chubarova[1,2], Julia Khlestova[1,2], Marina Shatunova[1], Alexei Poliukhov[1,2], Gdali Rivin[1,2], Ulrich Görsdorf[3], Ralf Becker[3], Harel Muskatel[4], Ulrich Blahak[5]

1 - Hydrometeorological Centre of Russia, 11-13, B. Predtechensky per., Moscow, 123242, Russia
2 –Faculty of Geography, Moscow State University, 119991, Moscow, Russia
3 - Deutscher Wetterdienst, Meteorologisches Observatorium Lindenberg, Am Observatorium 12, D-15848 Tauche, Germany
4 - Israel Meteorological Service, P.O box 25, Bet-Dagan, 5025001, Israel
5 - German Weather Service, Research and Development, Numerical Models Division, Deutscher Wetterdienst Frankfurter Str. 135, 63067 Offenbach, Germany

ICCARUS , Offenbach, Germany, *26.02 – 28/02/2018*

Outline:

1. Radiation in clear sky conditions over various geographical areas

1.1. Different geographical aerosol properties effects on radiation using different aerosol climatologies over Tiksi (Russia), Moscow(Russia), Lindenberg (Germany), Eilat-Yotvata (Israel), Bet-Dagan (Israel).

1.2. Comparisons with observations and COSMO model simulations for the particular clear sky cases.

1.3. Aerosol temperature effects.

2. Radiation in cloudy atmosphere

2.1 Comparisons of different COSMO cloud parameters and irradiance with Lindenberg datasets

2.2 Comparisons for 2 different cloud-radiation interaction schemes with observations.

Tiksi
Lindenberg
Moscow
Bet-Dagan- Nes_Ziona
Eilat-Yotvata

Meteorological Observatory of Moscow State University, 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 :

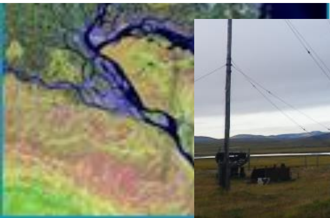
- sun sky photometer **AERONET CIMEL** dataset from AERONET version 2.0, level 2.0

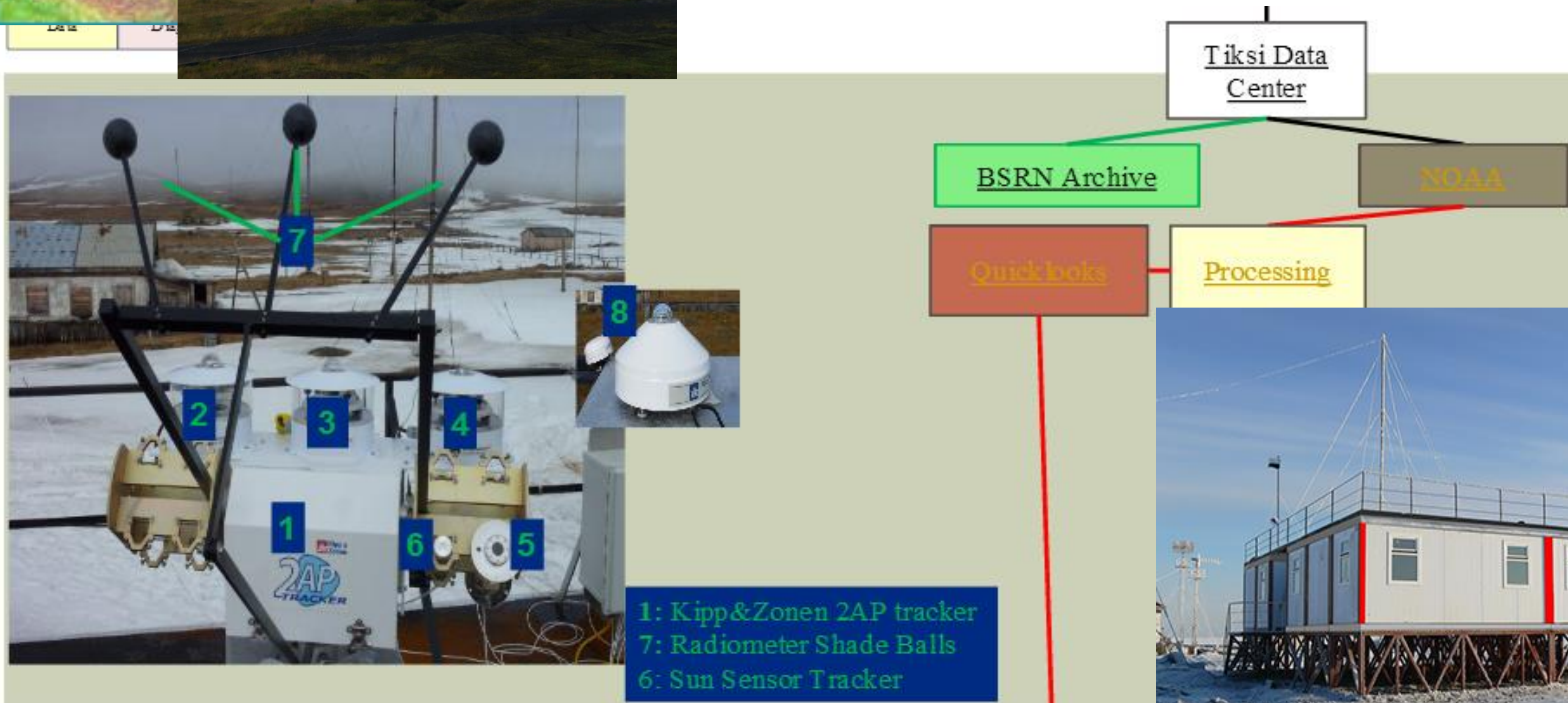
Meteorological observations:

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

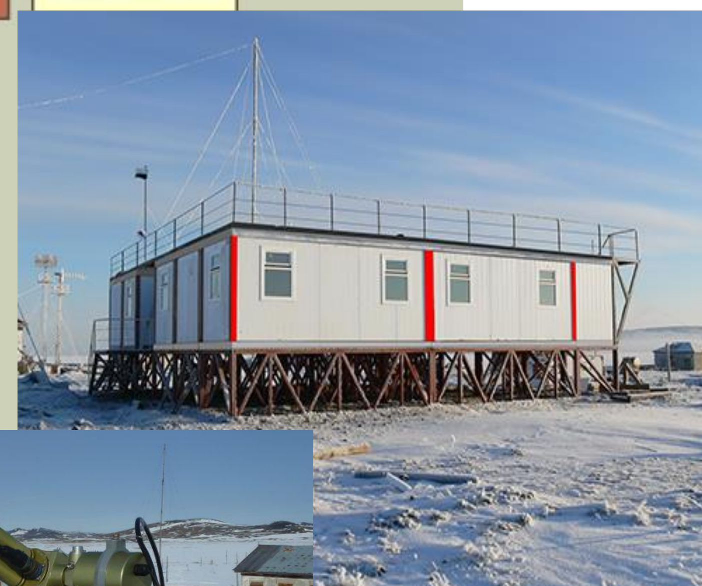
Hydrometeorological Observatory of Tiksi, Russia

Location: 71.596 N 128.889 E





Instrument Details					
Specifications	2	3	4	5	
Measurement	Downwelling Shortwave Diffuse	Downwelling Shortwave Diffuse	Downwelling Longwave Total	Downwelling Shortwave Direct	Dow… Short…



Responsible: Dr. Alexander Makshtas (Russia) ,
NOAA personnel (USA)

Israel sites

Nes-Ziona(AERONET)
Bet-Dagan

31.9°N, 34.8 °E (9km)

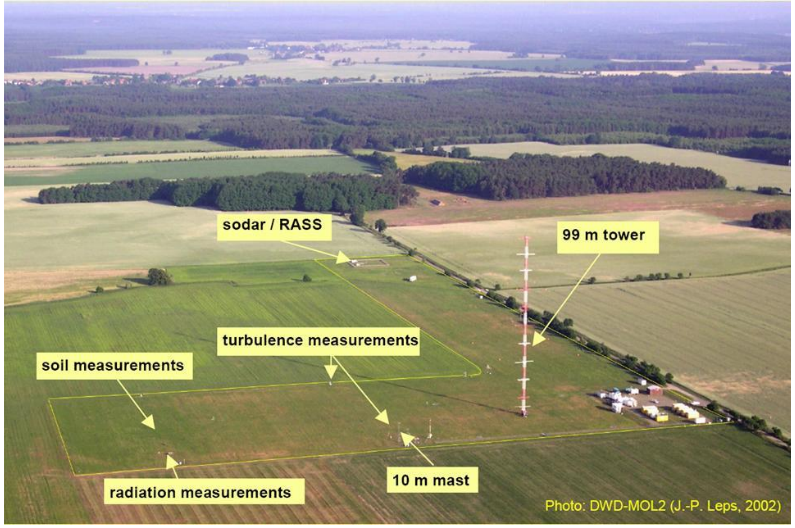
Global radiation - Kipp&Zonen CMP11
Direct radiation - Eppley NIP
Diffuse radiation - Eppley PSP

Eilat (AERONET)-Yotvata

29.5N 34.9 E (45 km)

Global radiation - Kipp&Zonen CMP11
Direct radiation - Eppley NIP
Diffuse radiation - Eppley PSP

Lindenberg observatory 52.17N, 14,12E (Falkenberg/Lindenberg) site



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.

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;

Different aerosol datasets used in the comparisons:

- AERONET datasets: Moscow since 2001, and Lindenberg (PFR+AERONET) since 2003, Tiksi – since 2010, Israel sites – Nes-Ziona since 2000, Eilat – since 2007.
- Tegen* climatology (Tegen et al., 1997)
-
- Macv2 or so-called Kinne climatology (updated from Kinne et al., 2013)

Comment:

Tegen* :

ALL simulations with Tegen aerosol (CLIRAD and COSMO algorithms were made with the additional aerosol used in the COSMO model in vertical profile for tropospheric and stratospheric components)

AOT Tegen*=AOT550 Tegen +0.02 (up to 0.04) - in the stratosphere

AOT Tegen*=AOT550 Tegen +0.03 – in the troposphere

depending on temperature profile (i.e. location of the tropopause)

Modified CLIRAD(FC05)-SW Radiative Code (*Tarasova, Fomin, 2006)*.

(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*).

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

Delta two stream parameterization of radiative transfer.

Main equations:

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

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

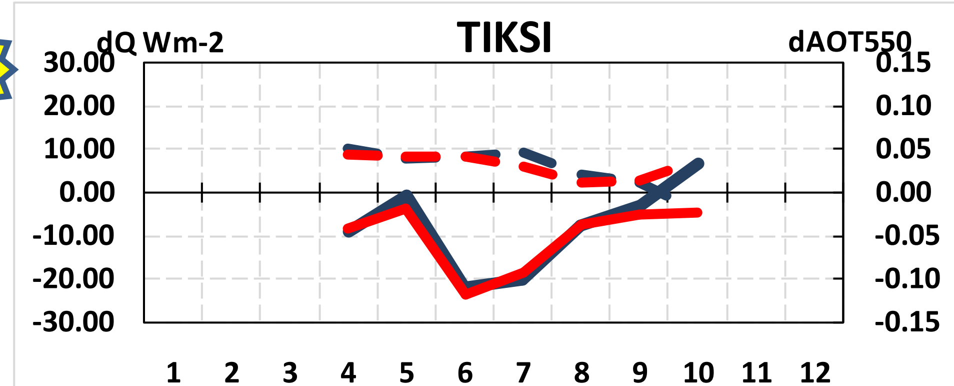
$$\frac{dS}{d\delta'} = -\frac{S}{\mu_0}$$

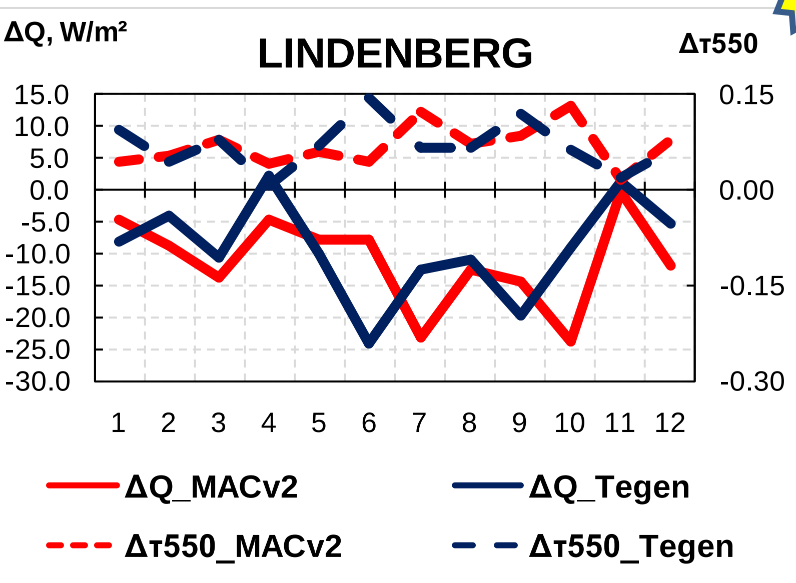
$$\delta' = (1 - \tilde{\omega} f)\delta$$

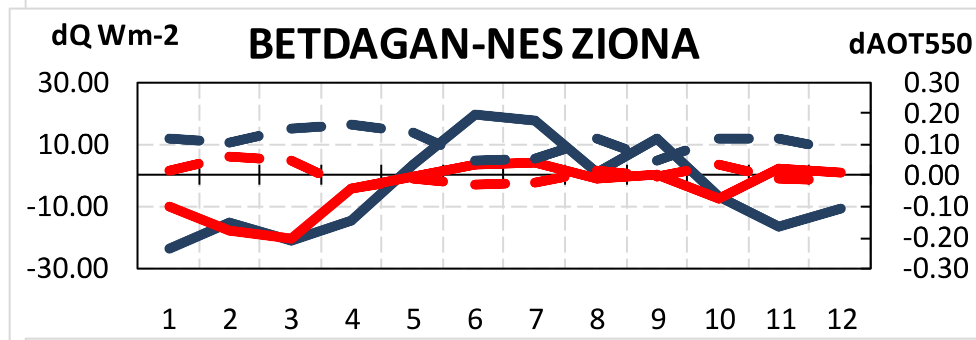
$$\tilde{\omega}' = \frac{\tilde{\omega}(1 - f)}{1 - \tilde{\omega} f},$$

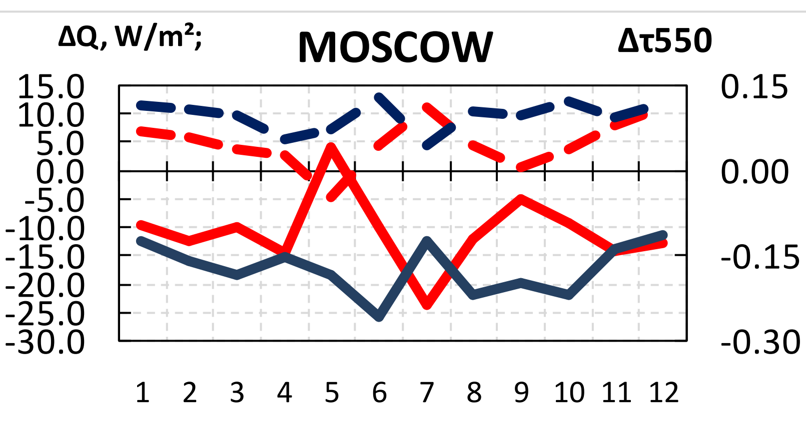
1982 AFGL spectroscopic database for optical properties of gases for gaseous transmission function .

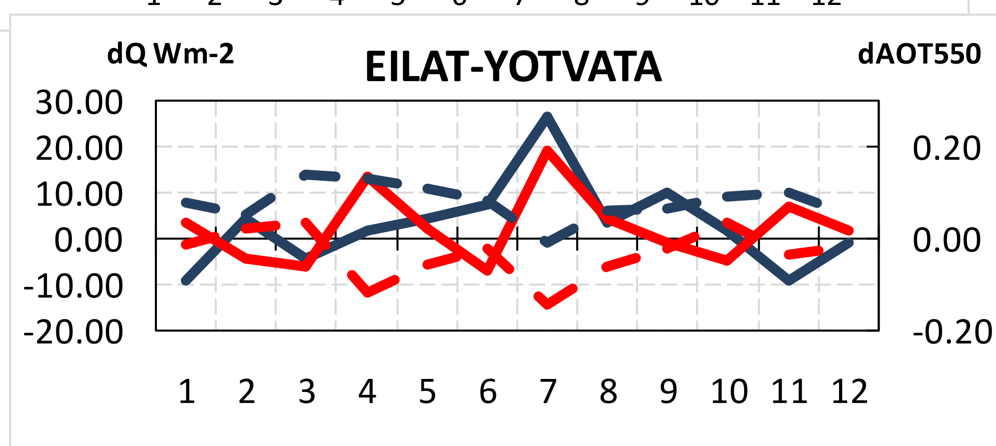
Difference in AOT and in shortwave irradiance for Tegen* and Macv2 climatologies versus AERONET AOT and radiative simulations with AERONET characteristics for noon. CLIRAD



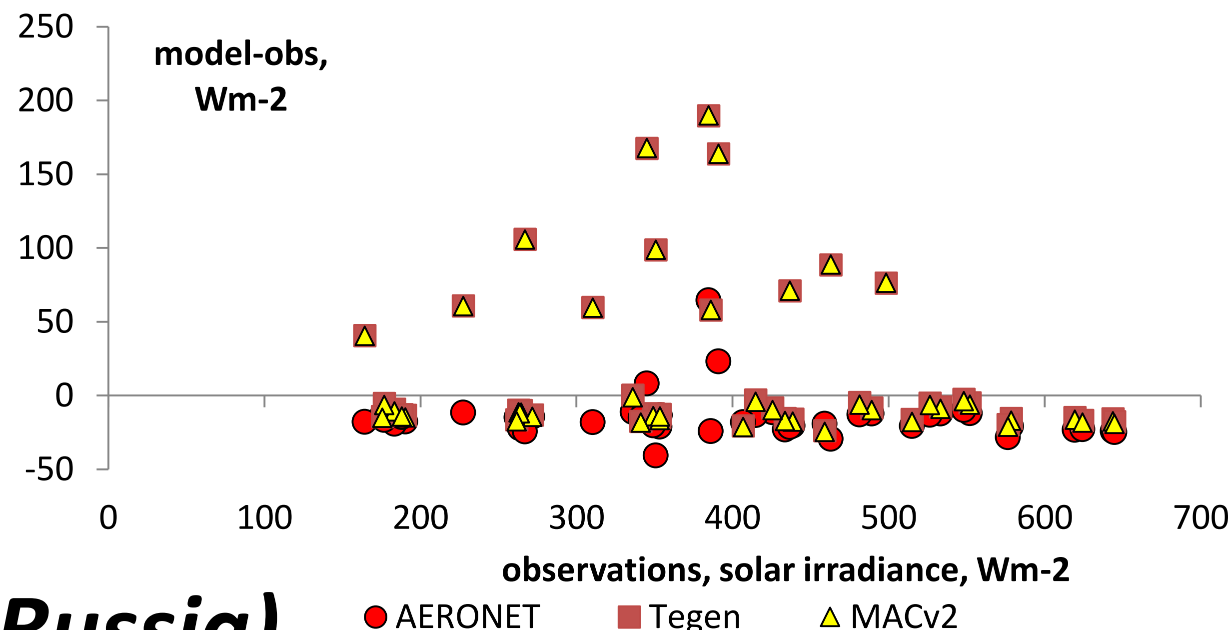




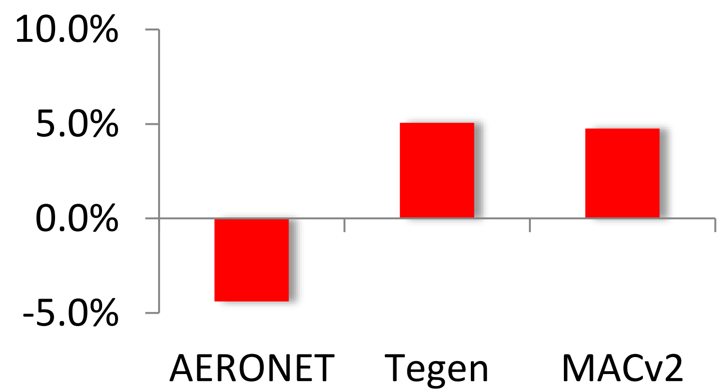




Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



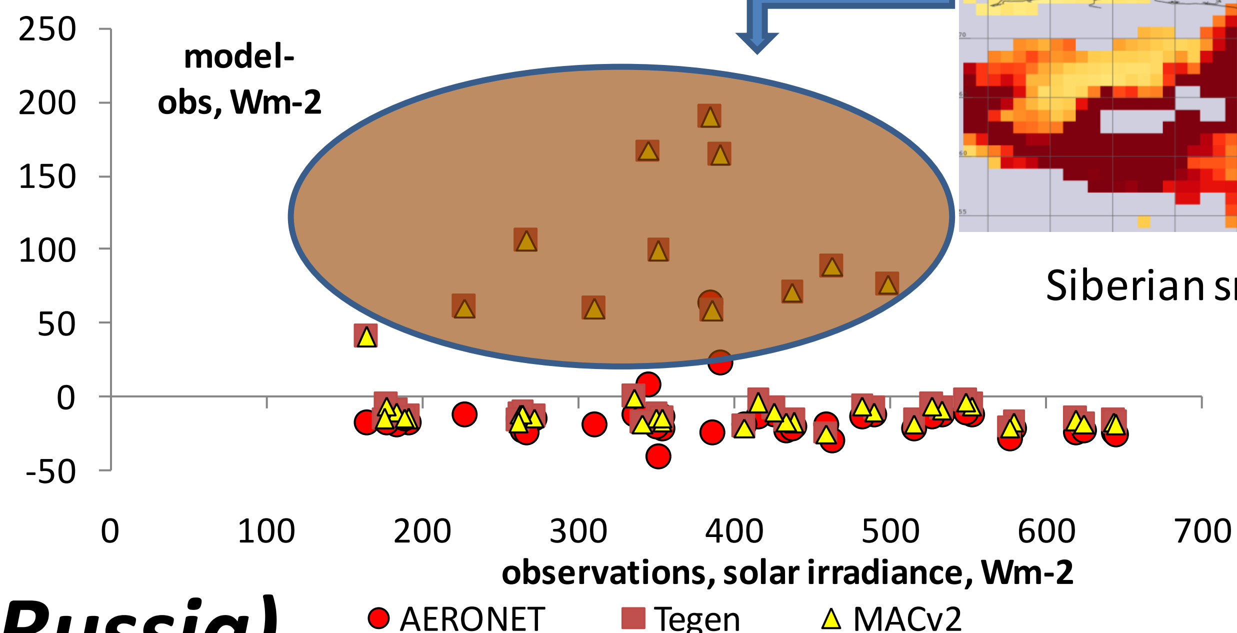
Tiksi (Russia)

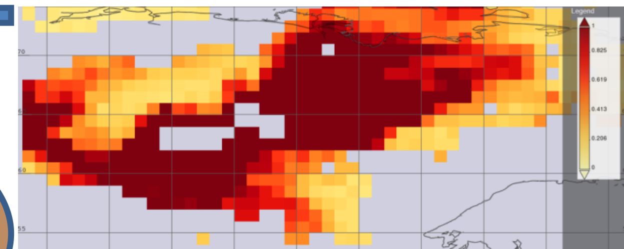


Tiksi, standard deviation for absolute difference

AERONET – 18 Wm-2 ,
Macv2 – 55 Wm-2,
Tegen* – 54 Wm-2,

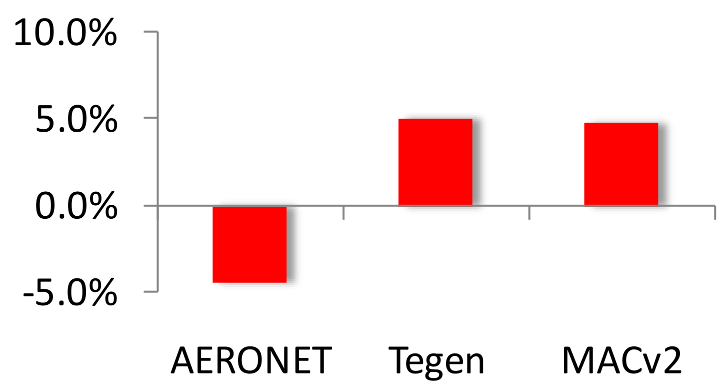
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets





Siberian smoke aerosol

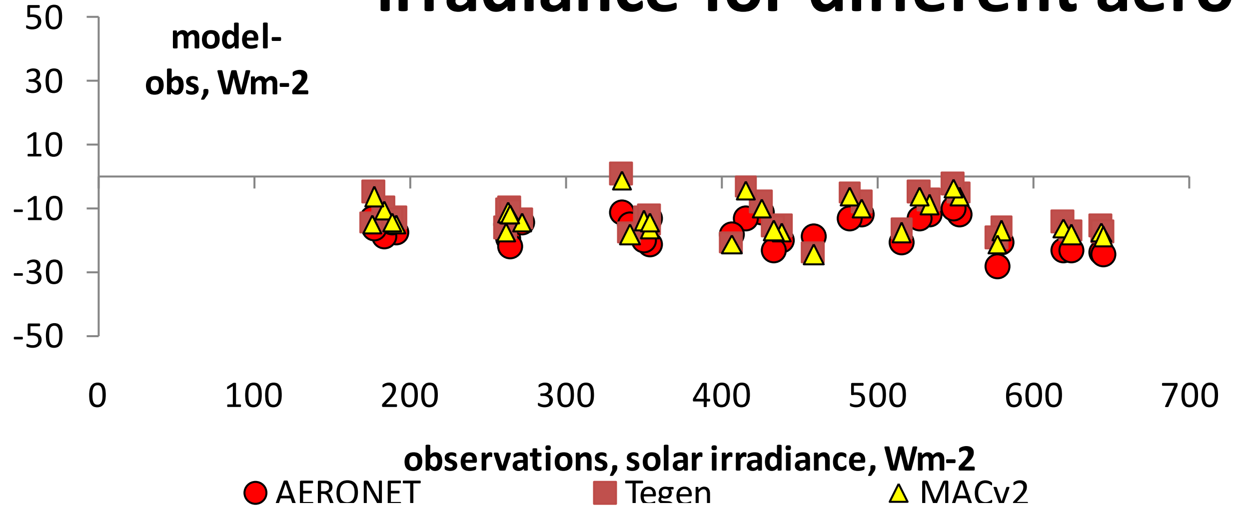
Tiksi (Russia)



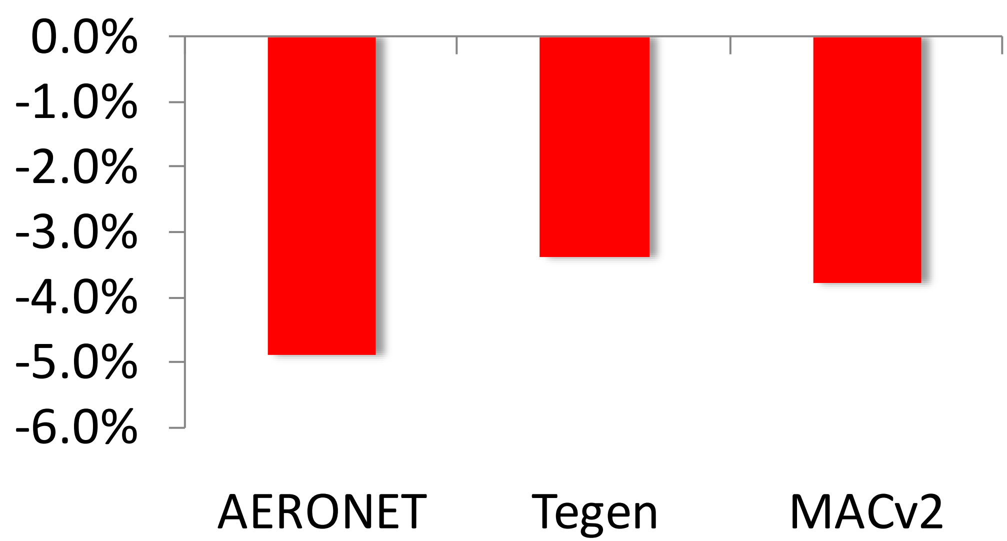
Tiksi, standard deviation for absolute difference

AERONET – 18 Wm-2 ,
Macv2 – 55 Wm-2,
Tegen* – 54 Wm-2,

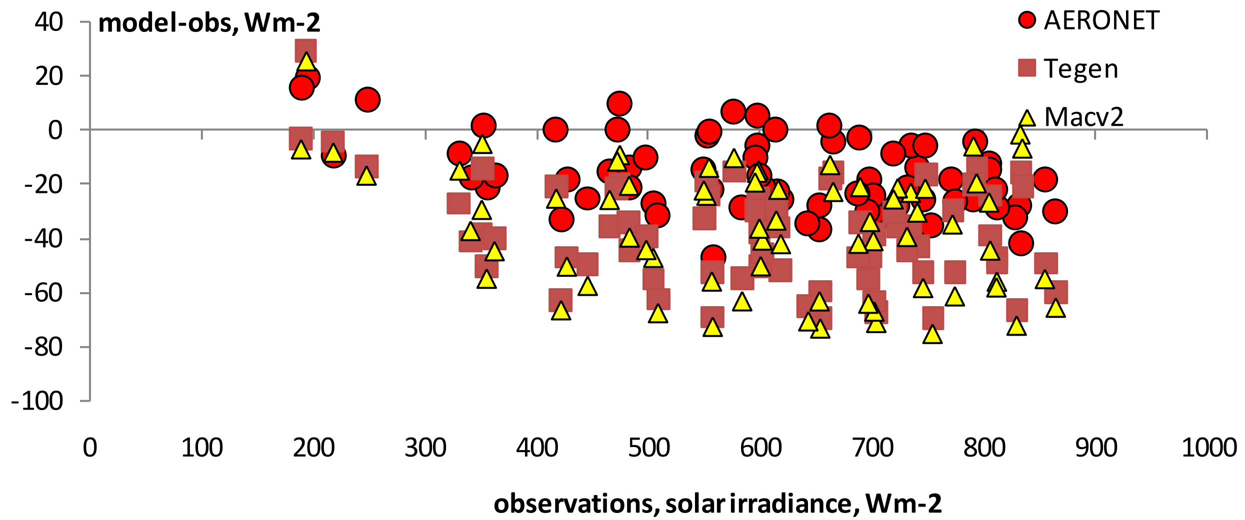
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



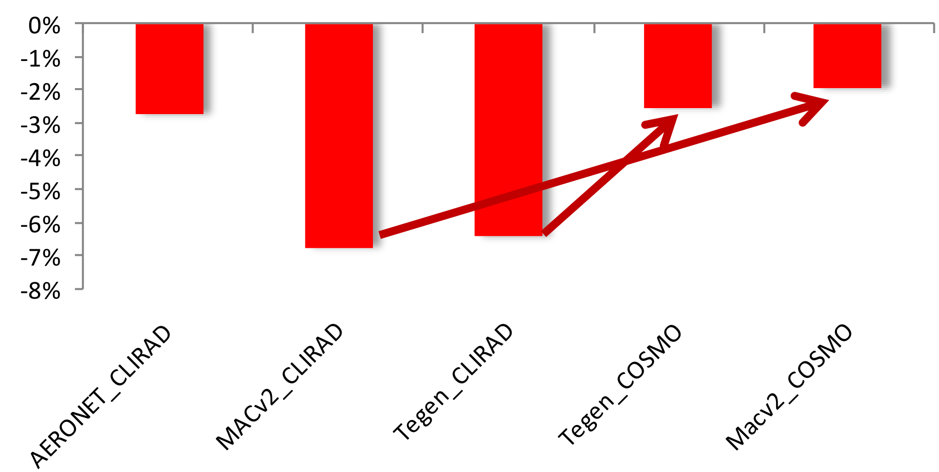
Tiksi (Russia)



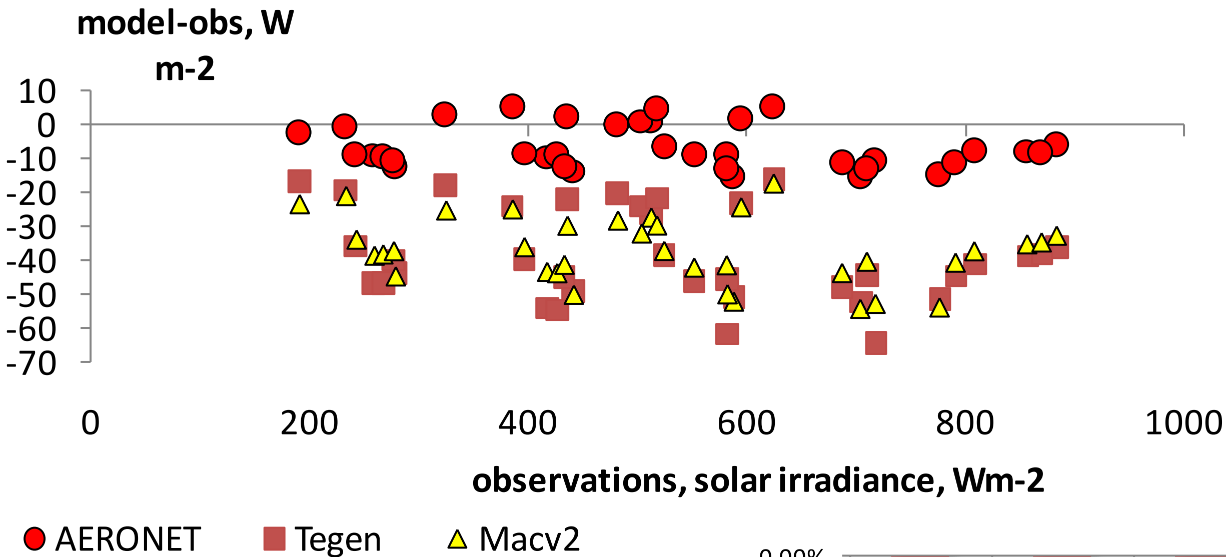
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



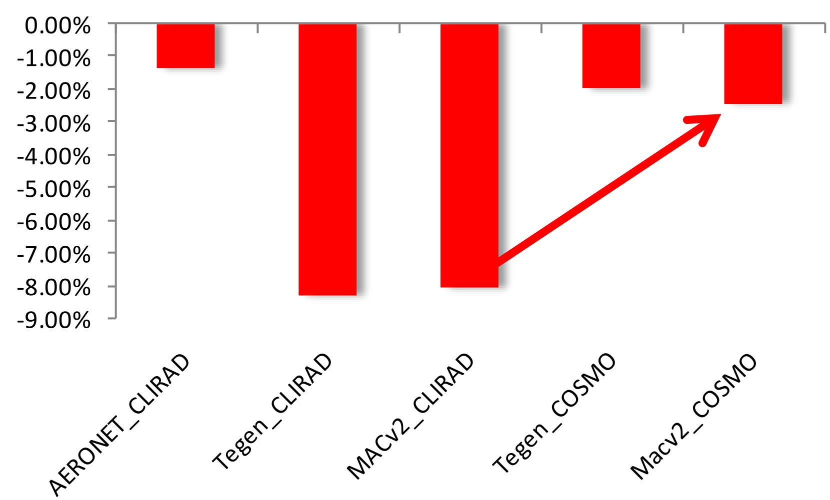
Moscow (Russia)



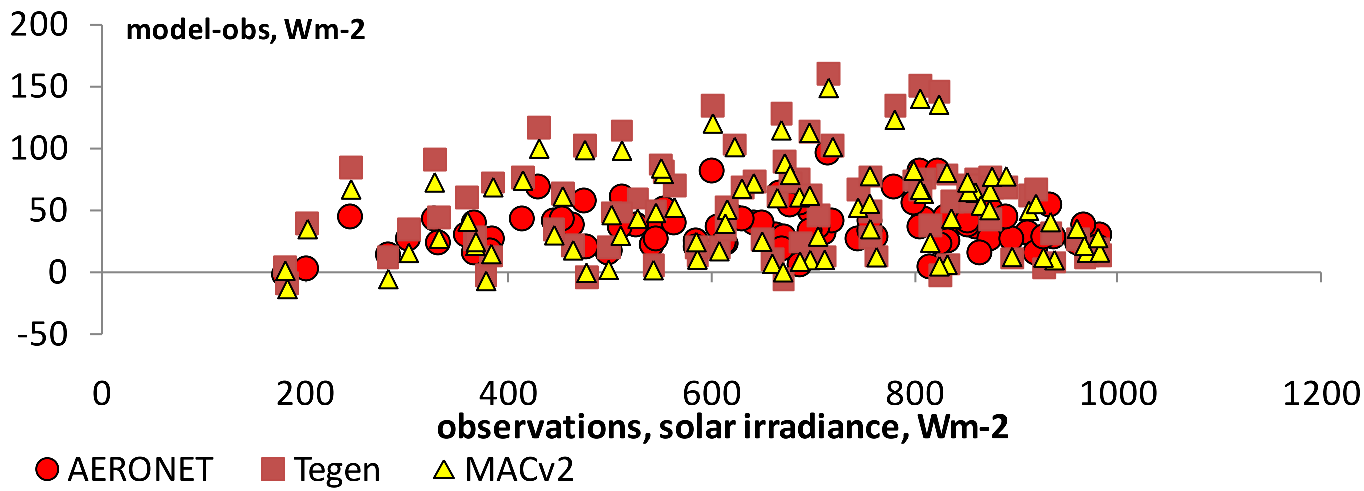
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



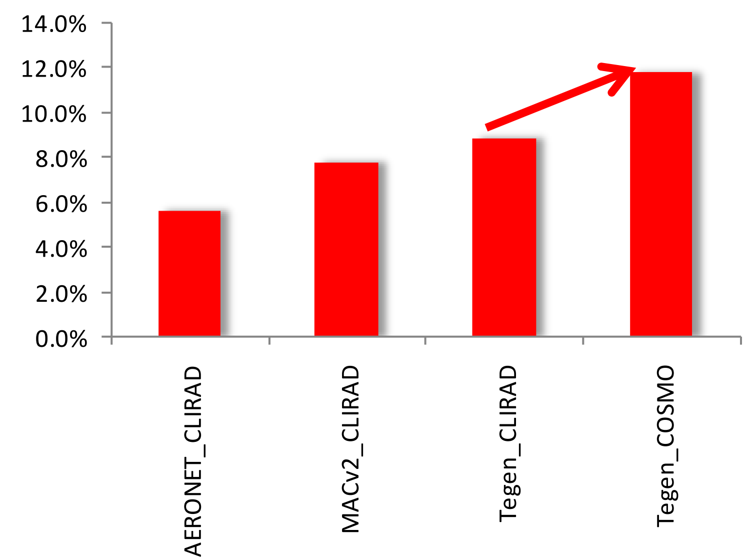
Lindenberg (Germany)



Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



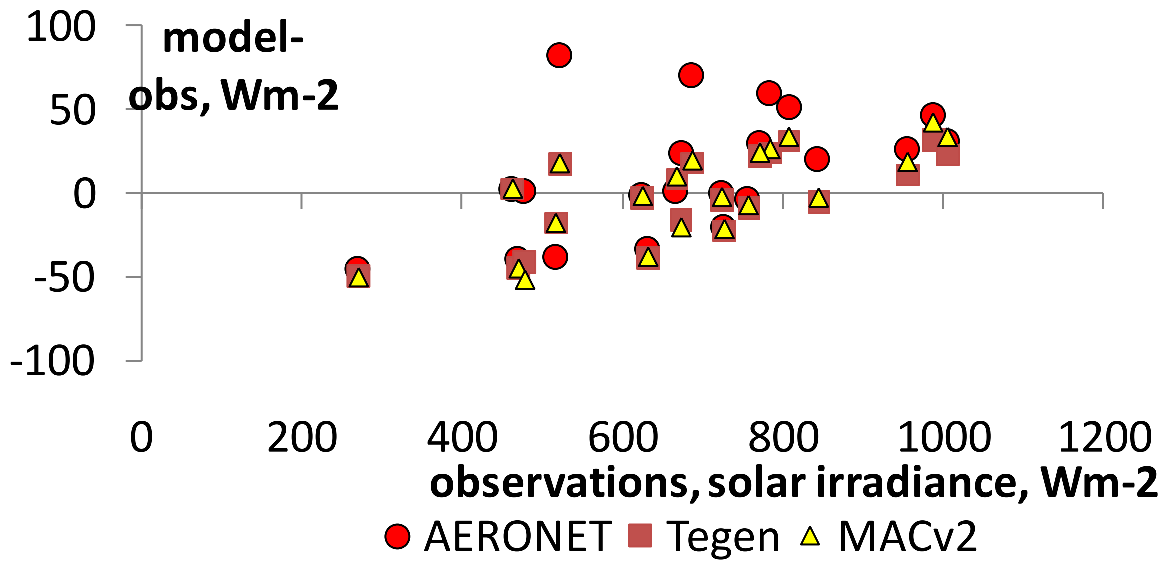
Bet-Dagan - Nes-Ziona, (dS=9km):



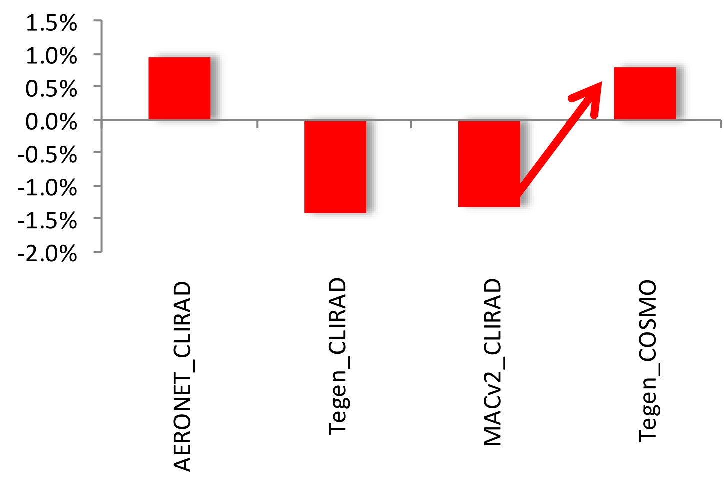
Bet-Dagan, standard deviation for absolute difference:

AERONET – 18 Wm-2
Macv2 – 37 Wm-2,
Tegen* – 40 Wm-2,

Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



Eilat- Yotvata (dS=45 km)



Eilat, standard deviation for absolute difference:

AERONET – 37 Wm-2

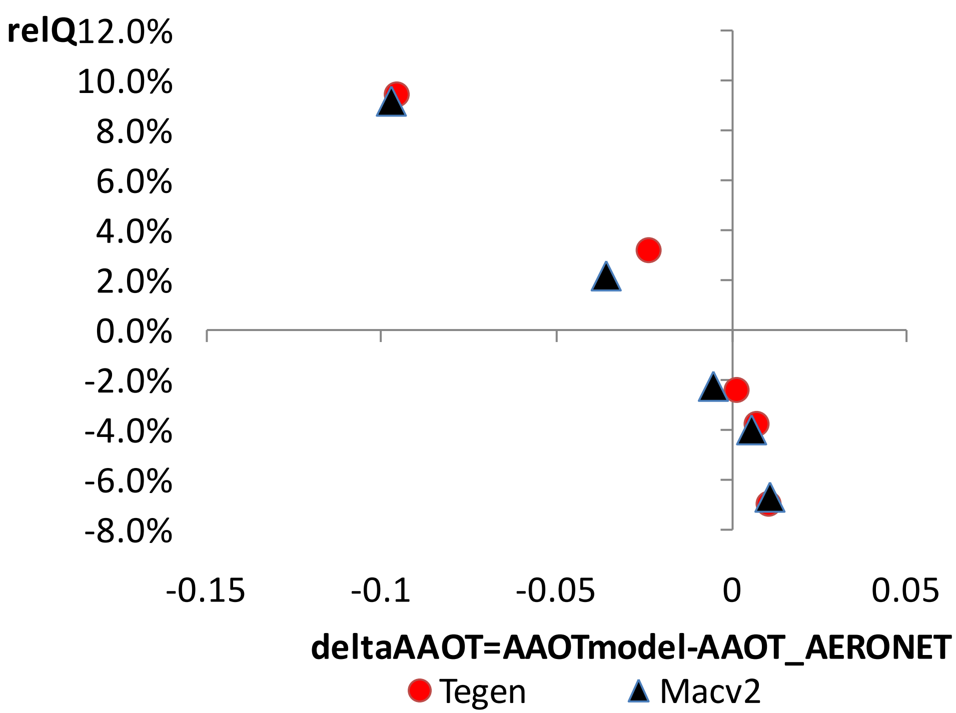
Macv2 – 26 Wm-2,

Tegen* – 29 Wm-2,

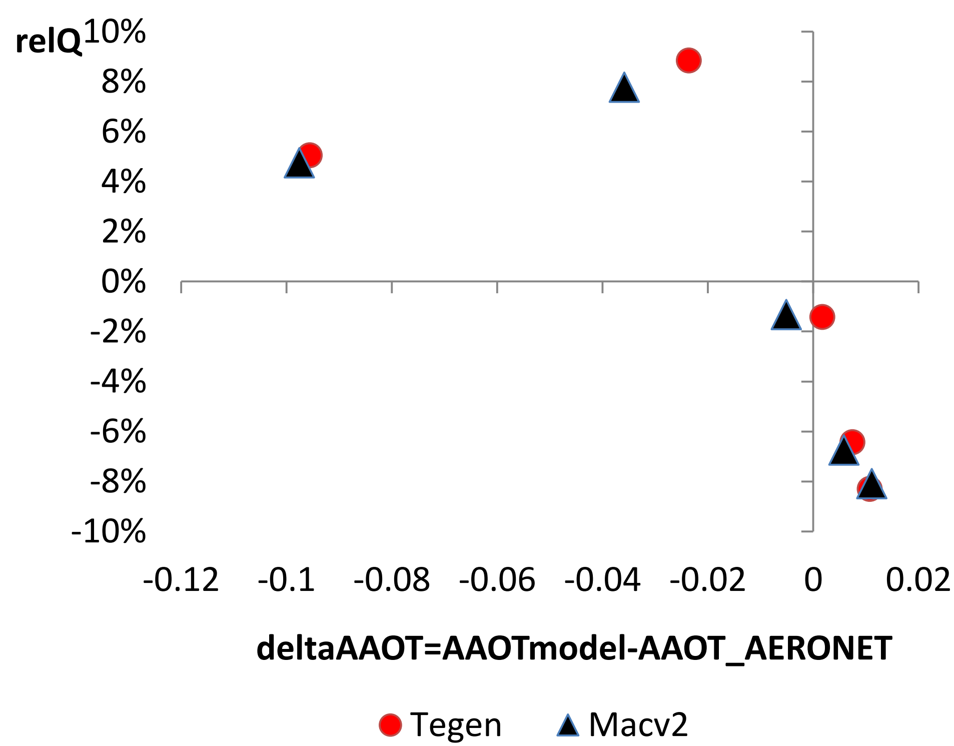
Relative difference in Q against difference in <u>absorbing</u> aerosol optical thickness (*dAAOT*). *All sites*

AAOT=AOT (1-SSA) at 550nm

Q model /Qmodel (AERONET),%

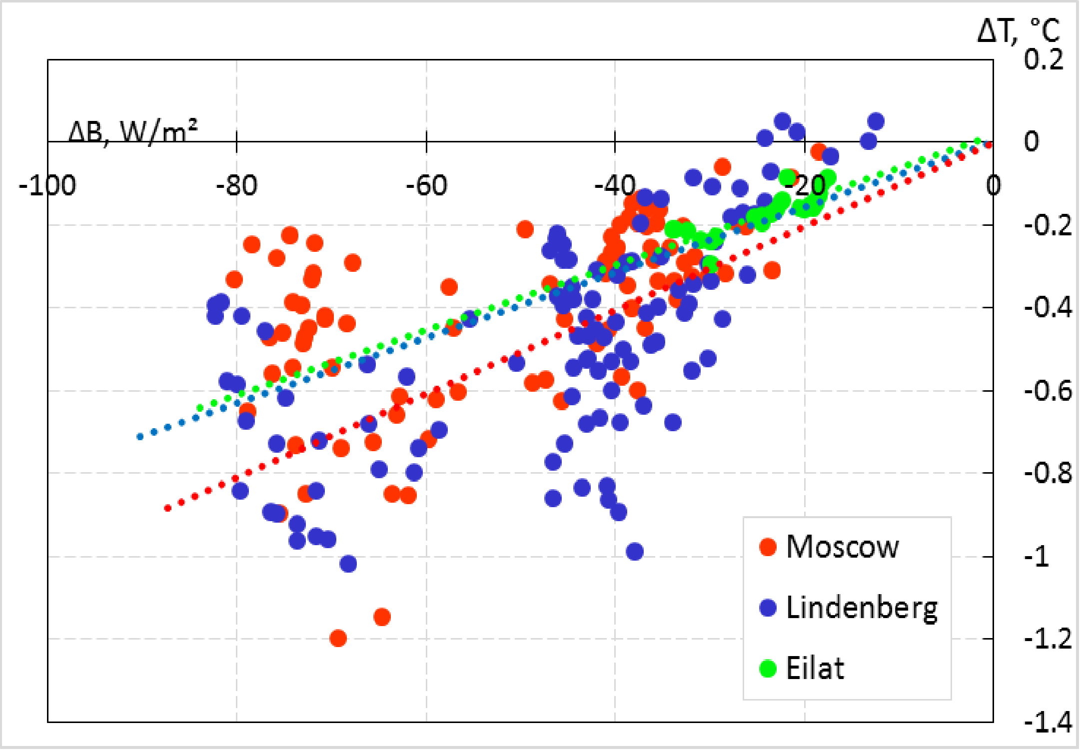


Q model /Q observations,%

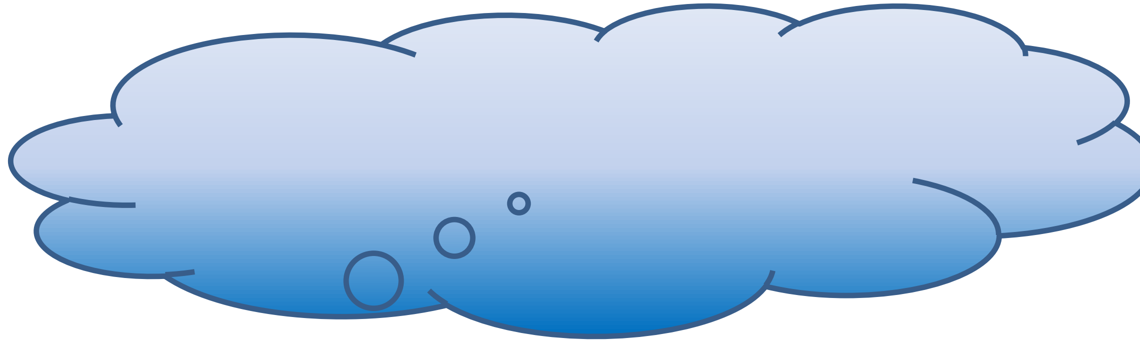


Temperature effects of aerosol

The dependence of difference in shortwave net radiation with and without aerosol as a function of difference in corresponding T2M s



Gradient is about 0,7-0.9° per dB=100 Wm^{-2}



2. Radiation <u>in cloudy atmosphere</u>

2.1 Comparisons of different COSMO cloud parameters over Lindenberg observatory supersite.

SAMD - Standardized Atmospheric Measurement Data (HD(CP)² project)

Welcome at SAMD

The new archive for Standardized Atmospheric Measurement Data.

Standardized Atmospheric Measurement Data

one of the most
loud and
ldwide. Unifying
an "easy-to-use"
astructure to
to the climate
AD. Therefore
data have to be
nultivariate, long-
d super sites, through short-term area-wide remote sensing
n satellite data.

ure of distributed data servers with a common web portal hosted by
ntry point. The central administration of these servers is based on a
system called Thematic Realtime Environmental Distributed Data
ata, which is also used by the ESGF and the ARM program.

'High Definition of Clouds and Precipitation in advancing Climate
the the German Federal Ministry of Education and Research.

Region (use map to select a region) or Supersite:

Region: Germany | Supersite: JOYCE (JOY) | Campaign: HOPE

No selection
JOYCE (JOY)
CESAR (CES)
LINDENBERG (RAO)
LACROS (LAC)

Time period:

All data (since 01.01.2007)

from: Jan 1 2007 to: Feb 23 2018

https://icdc.cen.uni-hamburg.de/projekte/samd.html

Data description

A network of stations for the continuous evaluation of cloud and aerosol profiles in operational NWP models

Europa

Lindenberg observatory provides the cloud products with CLOUDNET algorithms (Illingworth et al, 2007).

The instrumentation used:

Doppler Cloud radar (for ice clouds up to 9 km)

A low power lidar ceilometer – for indication of the altitude of the base of liquid water cloud and location of supercooled water layers

Dual-frequency microwave radiometers - for revealing liquid water path and water vapor path from several brightness temperatures

in combination of these measurements

Instrumentation at Lindenberg:

Metek MIRA36 cloud radar (35 GHz) ref. M. Bauer-Pfundstein and U. Goersdorf, Target separation and classification using cloud radar Doppler-spectra, Extended abstract of 33rd Int. Conference on Radar Meteorology, 6-10 August 2007, Cairns, Australia)

Jenoptik CHM15k ceilometer: ID CHM100110, serlom TUB120001, software version 12.03.1 2.13 0.559 (ref. Cloud Height Meter CHM 15k - Manual, 2009)

Microwave multichannel radiometer (Radiometric Profiler) TP/WVP-3000 ID:3001 (Ware et al. (2003), A multi-channel radiometric profiler of temperature, humidity and cloud liquid., *Radio Sci.,*38(4), 8079, doi: 10.1029/2002RS002856; Gueldner, J. and Spaenkuch, D. (2001), Remote sensing of the thermodynamic state of the atmospheric boundary layer by ground-based microwave radiometry. *J. Atmos. Ocean. Technol*., 18, 925–933; Gueldner, J. (2013), A model-based approach to adjust microwave observations for operational applications: results of a campaign at Munich Airport in winter 2011/2012. *Atmos. Meas. Tech.*, 6, 2879-2891, doi:10.5194/amt-6-2879-2013

The description of the data used for the intercomparisons in cloudy conditions for the March-October 2016 period and special cases in 2014

For 2016 period:

- Liquid water content (LWC);
- Ice water content (IWC);
- Water vapor content in the cloudy atmosphere (TQV);
- Solar radiation (global, diffuse and direct components).
- SYNOP data .

For 2014 period (will be described further):

(availability of R_{eff} data)

COSMO model setting

Version: COSMO-Ru2 v5.1

Domain: 250 x 300 grid points

Grid step: 2.2 km

Number of vertical level: 50

Lateral boundary condition: ICON

Aerosol climatology: Tegen

Radiation timestep: 15 min

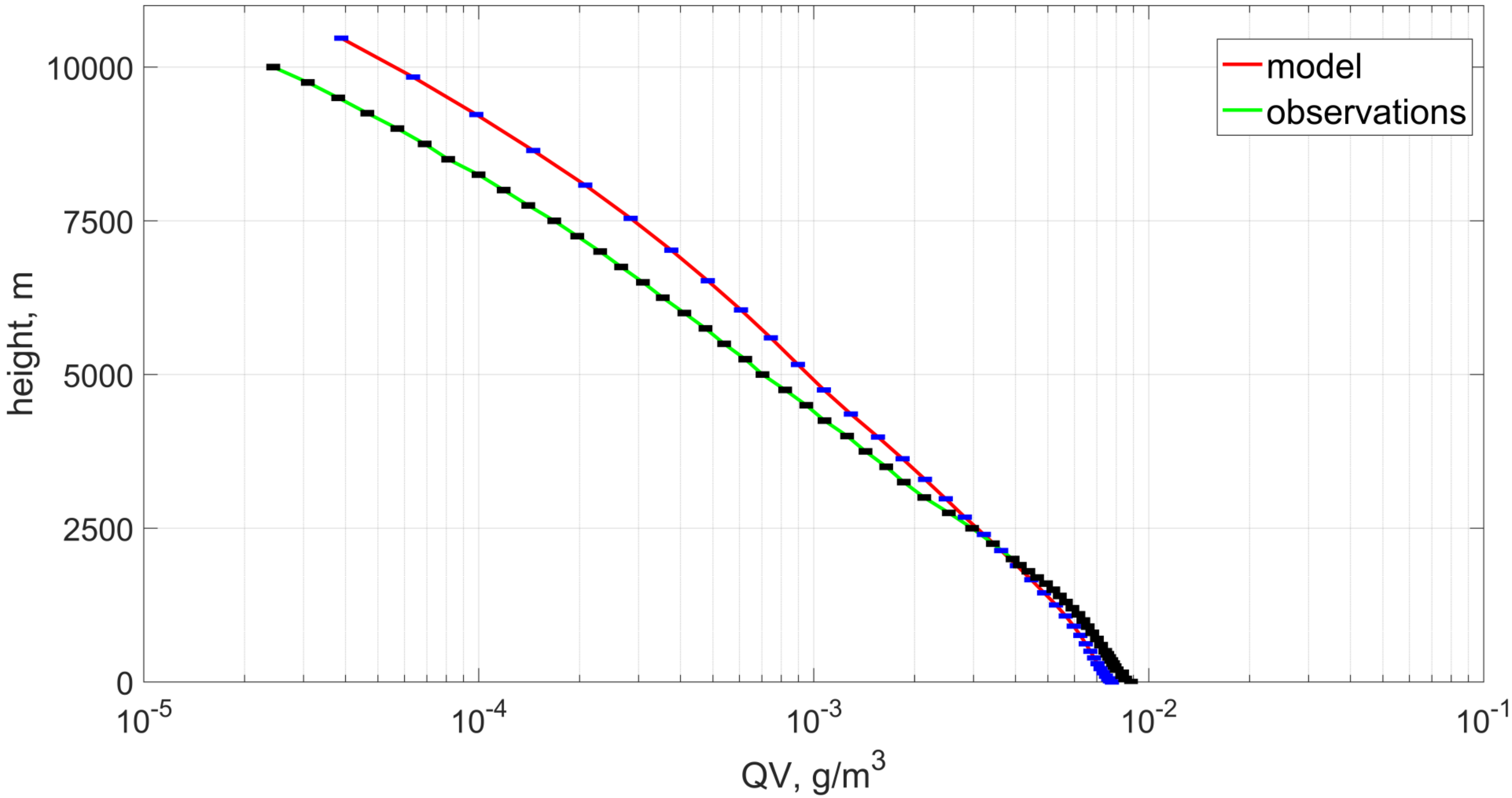
Period of analysis: March-October 2016

Several overcast days – during warm period in 2014 (Reff information)

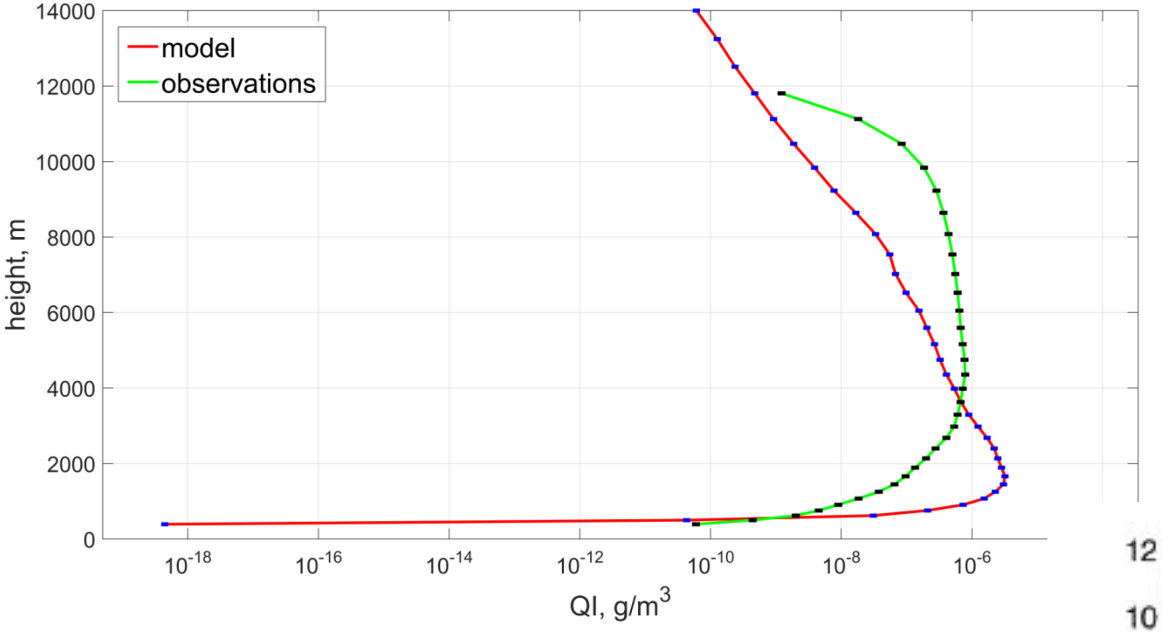
Observations point: Lindenberg

Simulation domain. Red dot indicates Lindenberg.

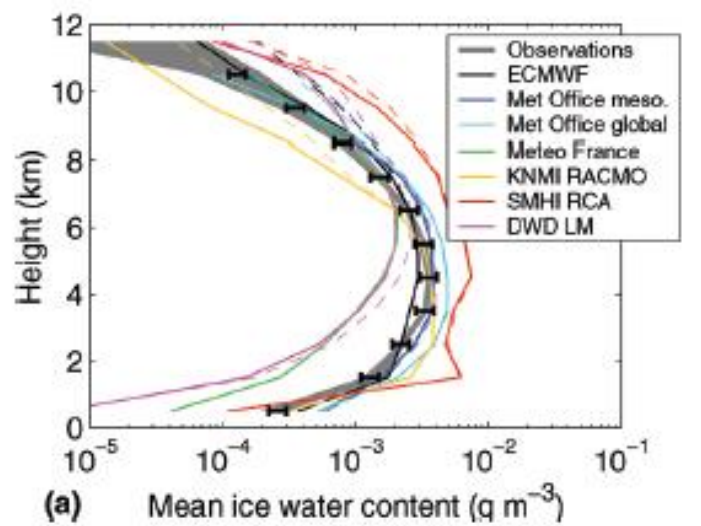
Water vapor profile from model and observations (N=19051). 2016. Error bars for observations in addition consider the 15% uncertainty of the method.



Profiles of mean ice content (gm-3) obtained from observations and model, 2016. The error bars for observations accounts for the 35% uncertainty of the method. N_{model}= 21600, N_{obs}=18768.

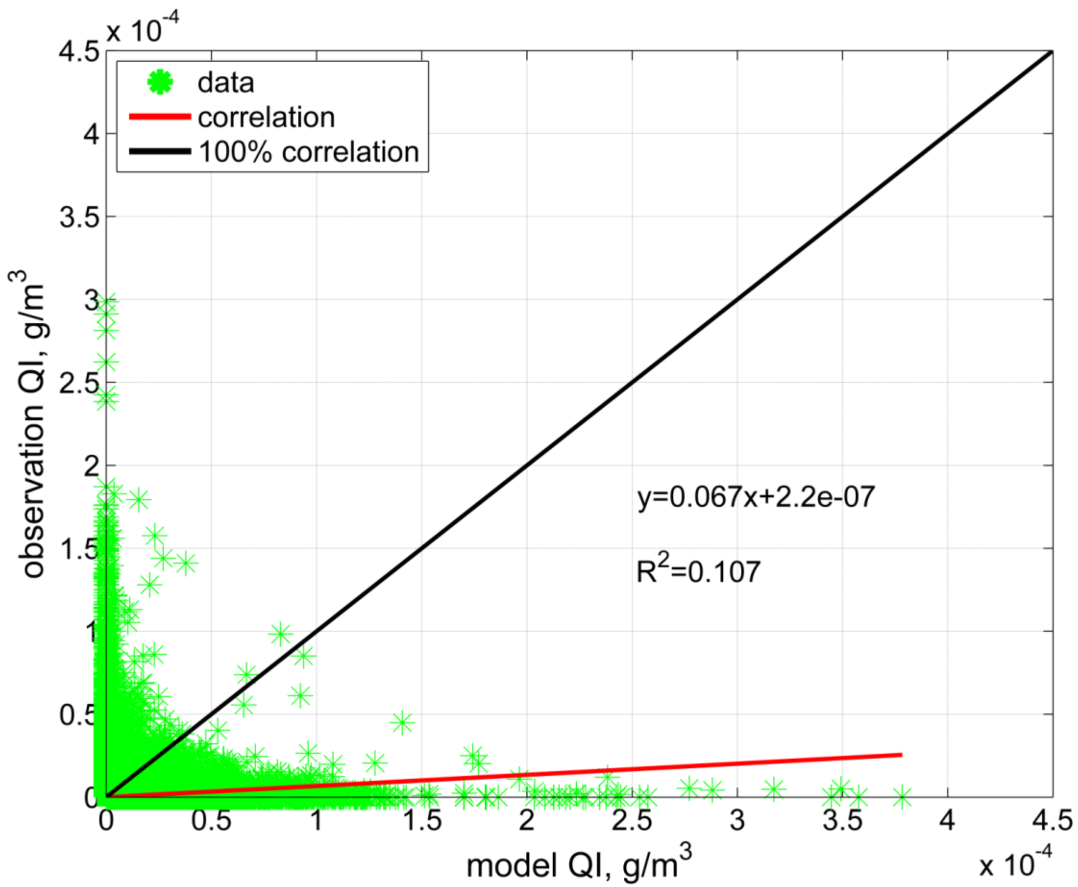


From Illingworth, 2007

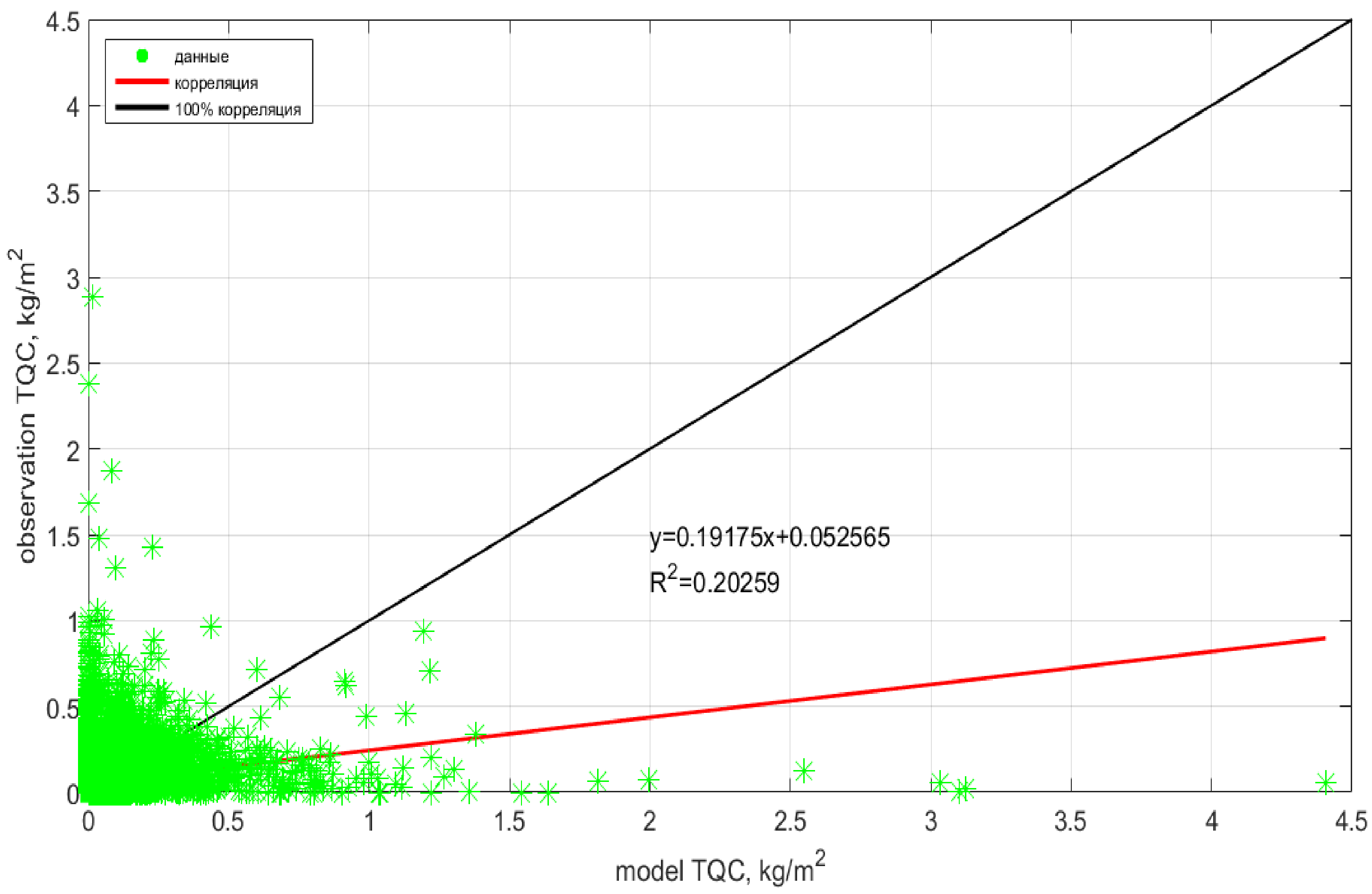


Observed versus modeled ice water content IWC in each layer. 2016. Lindenberg.

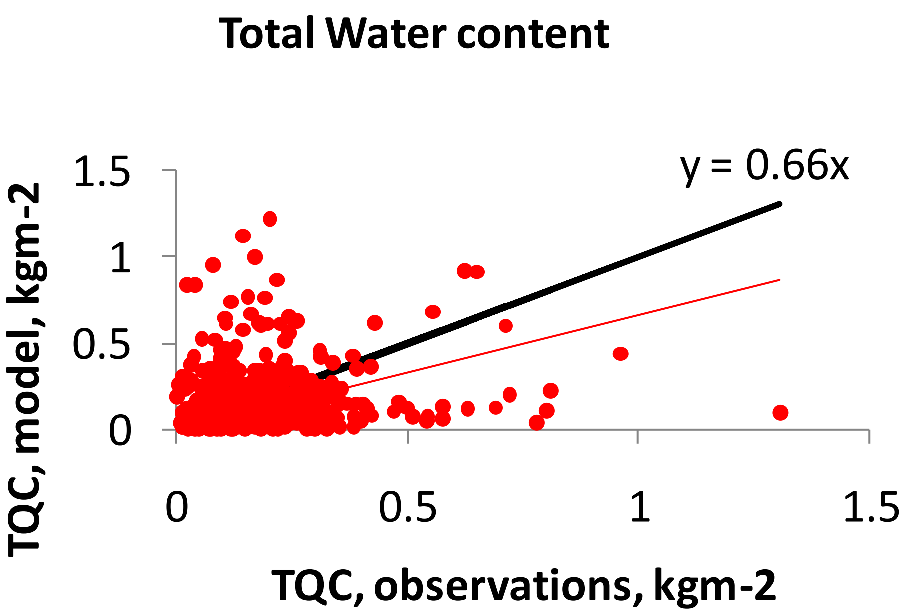
(N= 703676)

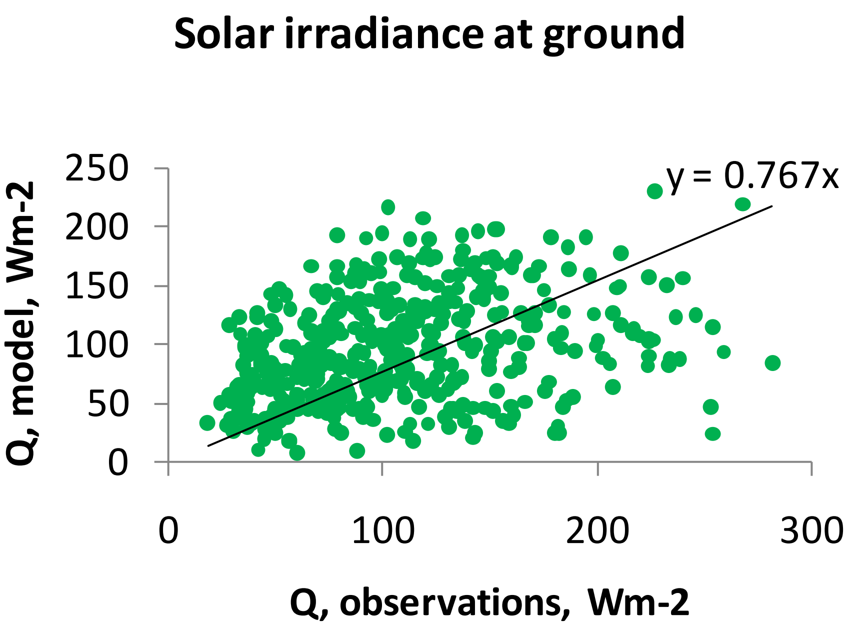


Observed versus modeled total water content integrated over th column (LWP) (kgm^{-2}). (n=19121). 2016. Lindenberg.

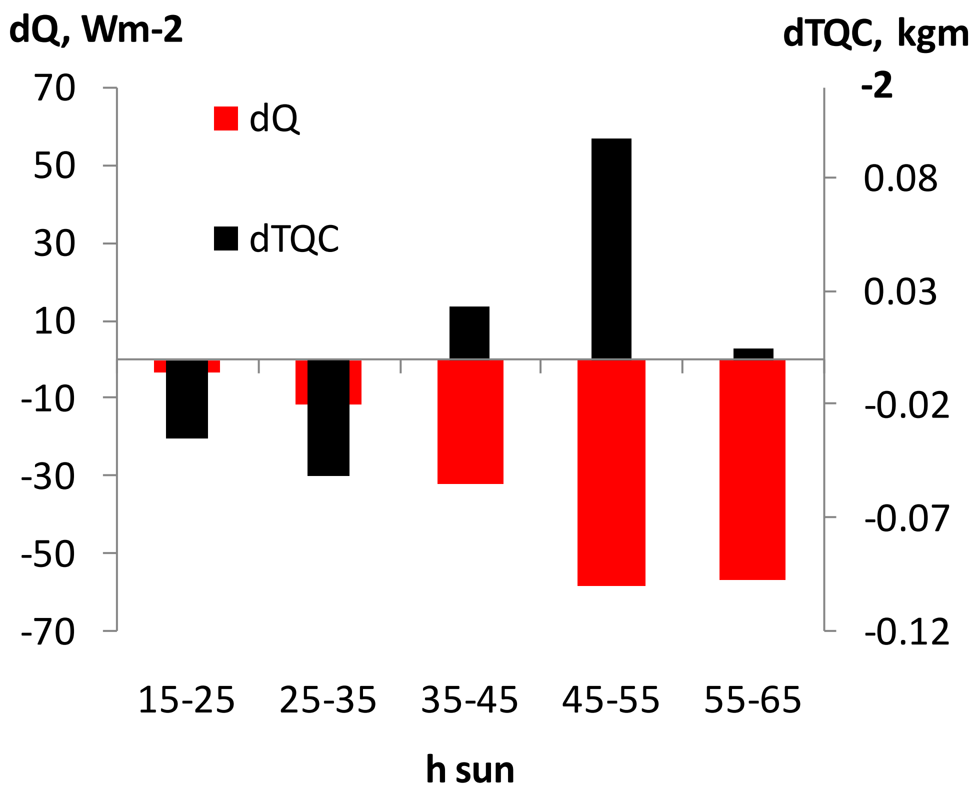


The comparisons between model versus observed total water content and model versus observed solar irradiance. All cases with non-zero data and additional threshold – no direct irradiance (S<1 Wm^{-2}) . 2016. hsun>15°. N=452.



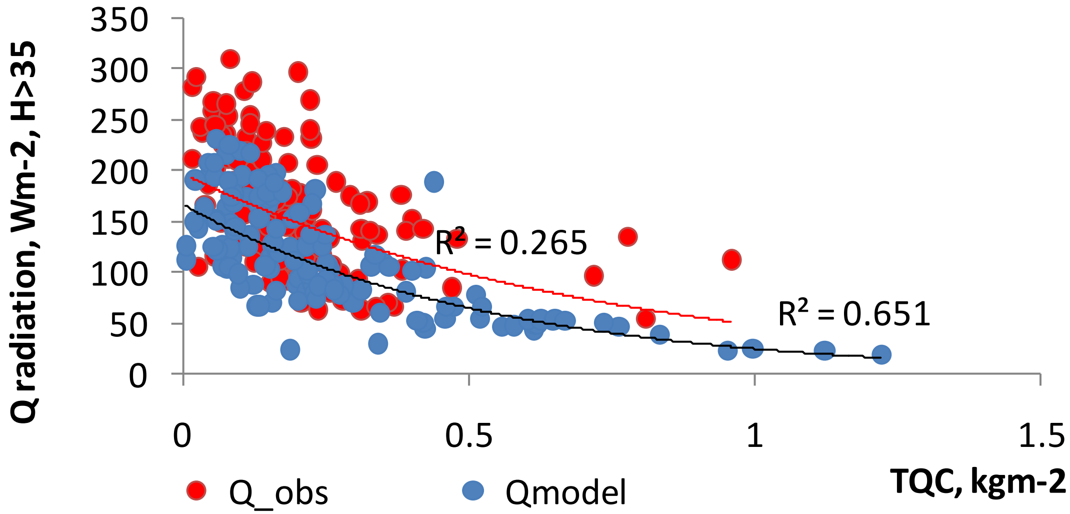


The same but for different solar elevation bins.

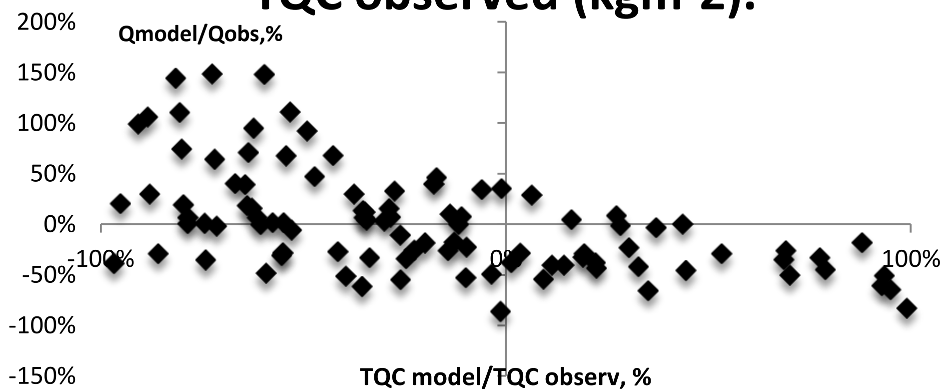


model minus observations

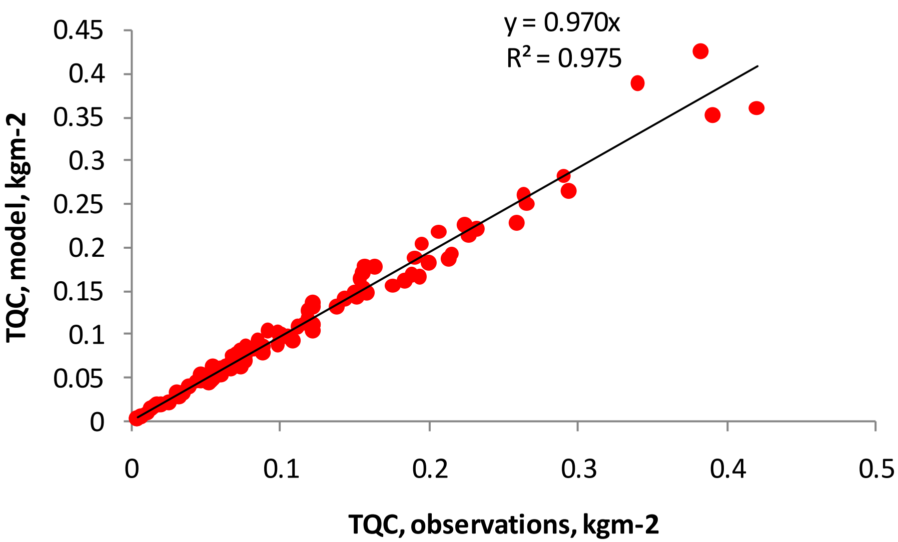
The dependence of shortwave irradiance Q at ground on Total Water Content (TQC) in the column (kgm^{-2}). Solar elevation>35°. N=145.

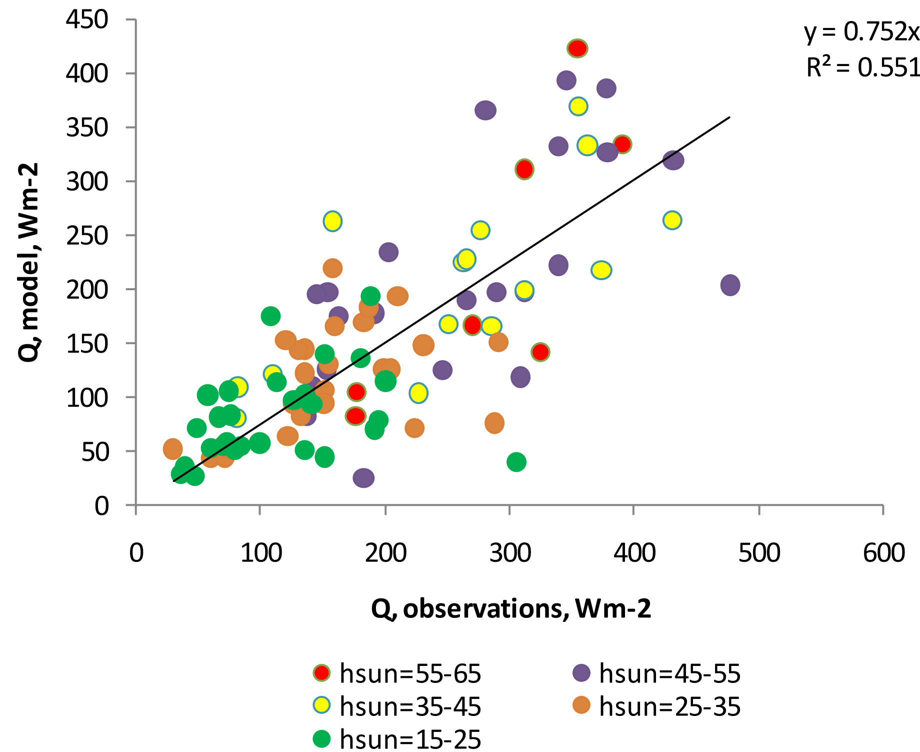


Ratio Qmodel /Qobserved as a function of ratio of TQC model / TQC observed (kgm-2).

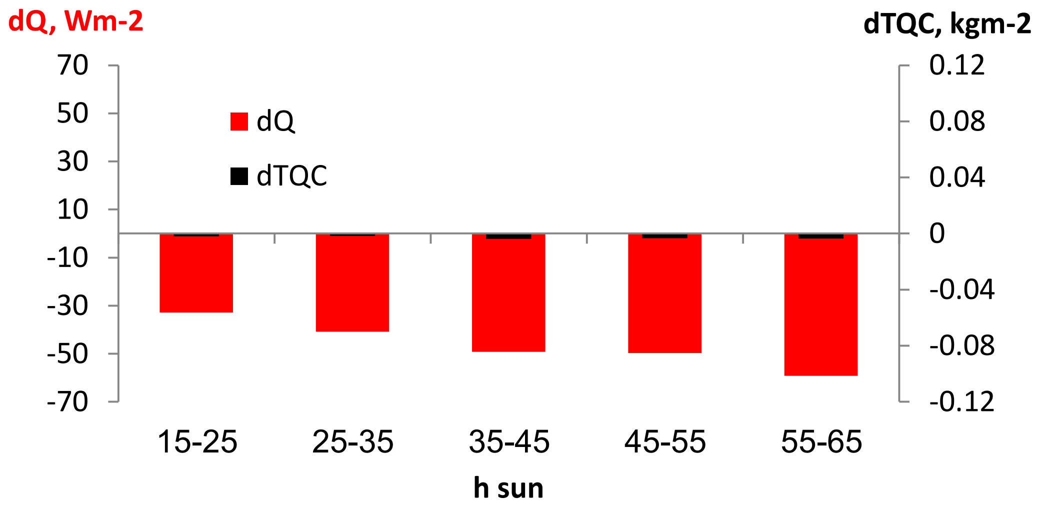


The comparisons between model versus observed total water content and solar irradiance with GOOD (±15%) agreement in water content (TQC). 2016. hsun>15°. N=99.





Comparisons between observed and modeled shortwave irradiance when there were no gaps in the observed cloud cover, (Sdirect<1 Wm^{-2}) hsun>15°, TQC model agrees within 15% with observations, N=99, 2016.



Comparison of two cloud-radiation interaction schemes :

- Old scheme (original Ritter and Geleyn, 1992):
  - Direct fit of cloud optical thickness as function of cloud water content qc based on few old measurements
  - Dependence of opt. thickn. on eff. Radius R_{eff} implicitly hidden in this relation

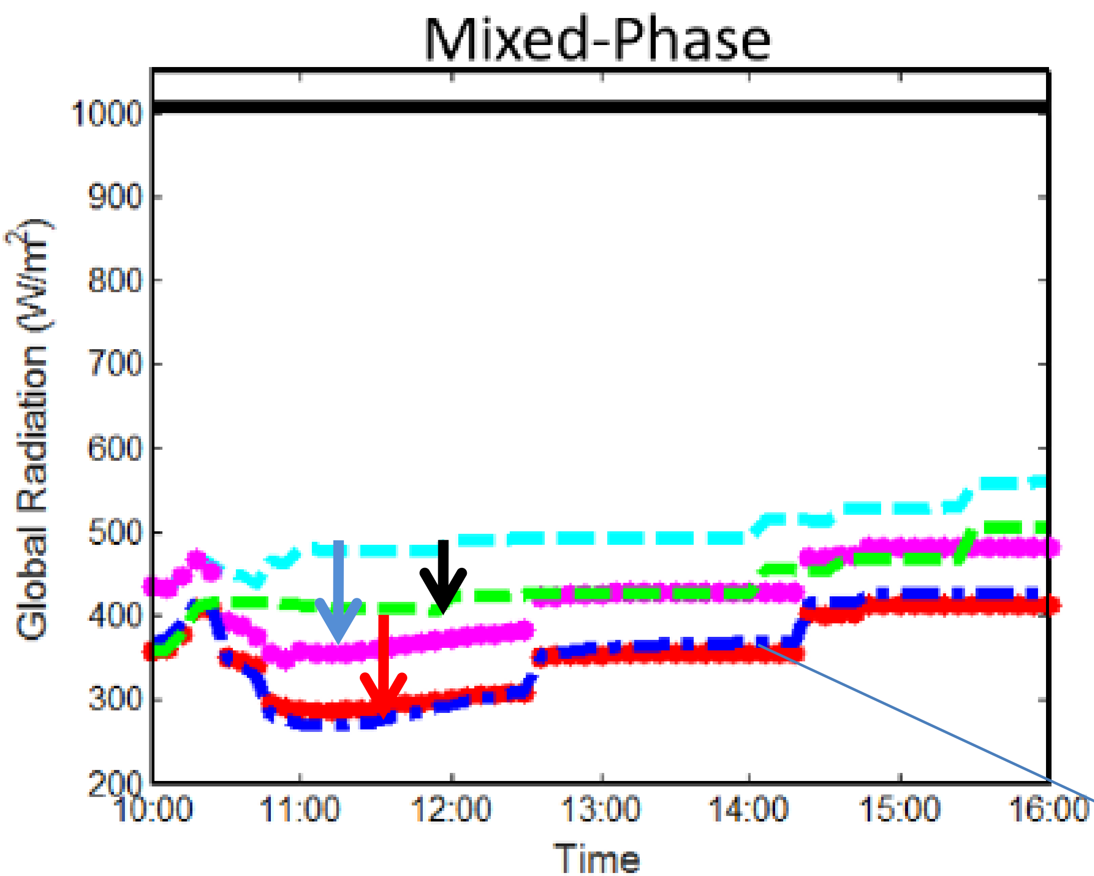
- New scheme from $T^2(RC)^2$:
  - Expl. Dependence of opt. thickn. on R_{eff} based on Hu and Stamnes (1993), spectrally remapped to RG92
  - R_{eff} is a function of qc and cloud number concentration nc and is computed as follows:
    - Grid scale clouds: qc from microphysics, nc = constant tuning parameter, assuming generalized gamma distribution with assumed fixed shape parameters
    - Subgrid scale clouds: qc from original COSMO parameterization; two options for R_{eff}:

      a. $R_{eff,sgs}$ directly given as constant tuning parameter **(not used in the following)**

      b. nc from Tegen aerosols and updraft-based cloud activation parameterization from Segal and Khain (2006). **(used in the following)**

      Updraft = $W_{grid} + W_{turb} + W_{radiative\text{-}cooling} + W_{convective}$

Model simulation of solar irradiance with different methods.



Blakhak, Muskatel, Khain, "Documentation Documentation of the new optical properties of hydrometeors as function of effective size (radius or diameter) or mean axis ratio ".2016

change in radiation due to adding large hydrometeors and high particle number concentration N=500cm-3

change in radiation due to adding large hydrometeors and low particle number concentration N=50cm-3

Change due to increase in particle number concentration

in blue color - standard RG algorithm

Observations: Data sources.
For the cases - 2014

Standardized Atmospheric Measurement Data

- Water vapor vertical profile (Microwave radiometer TP/WVP-3000, IPT)
- Integral liquid and ice water content (Microwave radiometer TP/WVP-3000)
- Effective radius of cloud particles (IPT)
- PMSL, T2m, RH2m

IPT – Integrated Profile Technique combines measurements of a microwave profiler, a cloud radar and a lidar ceilometer

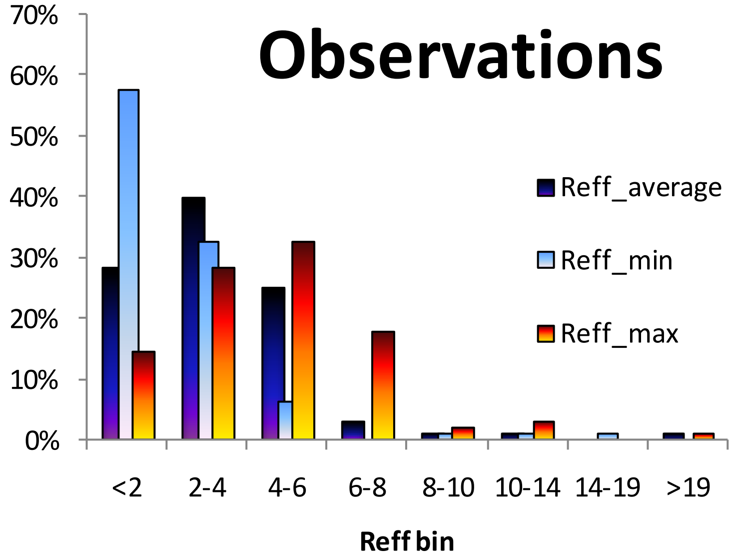
HMC Data Base

- SYNOP (PMSL, T2m, cloud cover, cloud type, cloud low boundary height, precipitation)
- Weather charts with frontal analysis

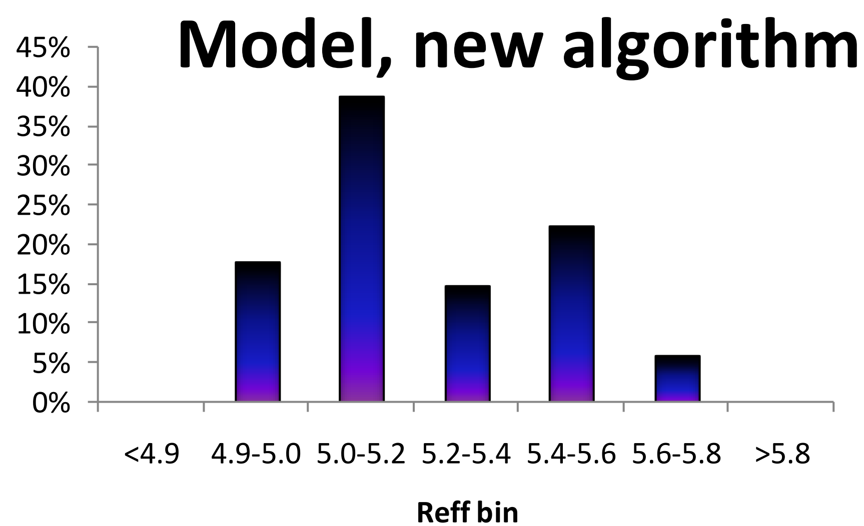
Selection criteria

- Cloudy day, preferable overcast conditions, without precipitation
- Observation data availability
- 15 minute averages

Frequency distribution of effective cloud radius from observations (left) and modelling (right) using the new algorithm.



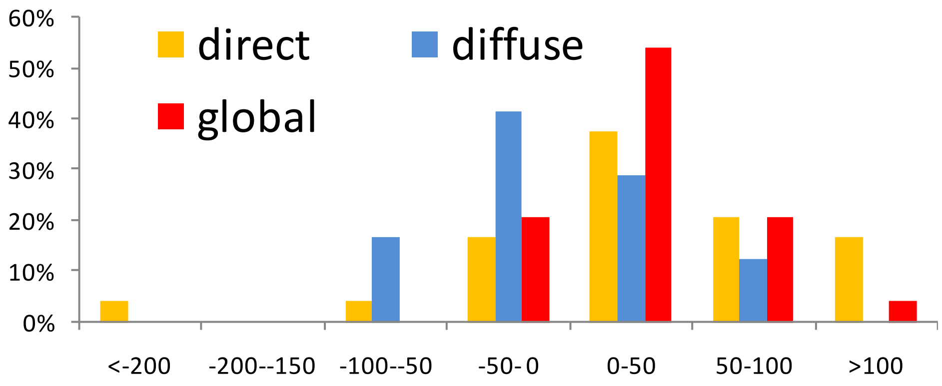
N=95



N=67

<u>Direct</u> comparisons between observations and model :
2 cases only with R_{eff}(obs)=2.3mkm and R_{eff}(mod)=5.3 mkm

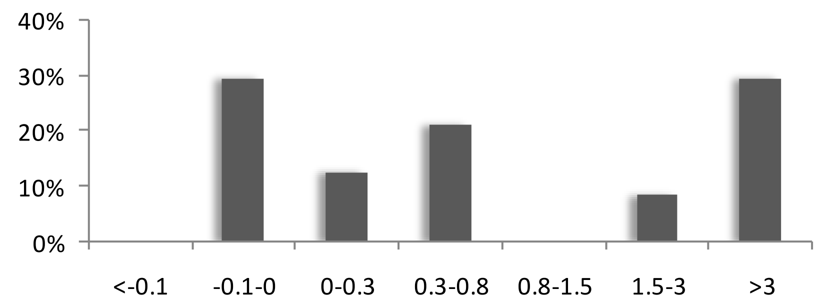
Frequency distribution of the differences between the new and old algorithm for direct, diffuse, global solar irradiance and temperature. 2014.



new minus old , solar irradiance bins, Wm-2

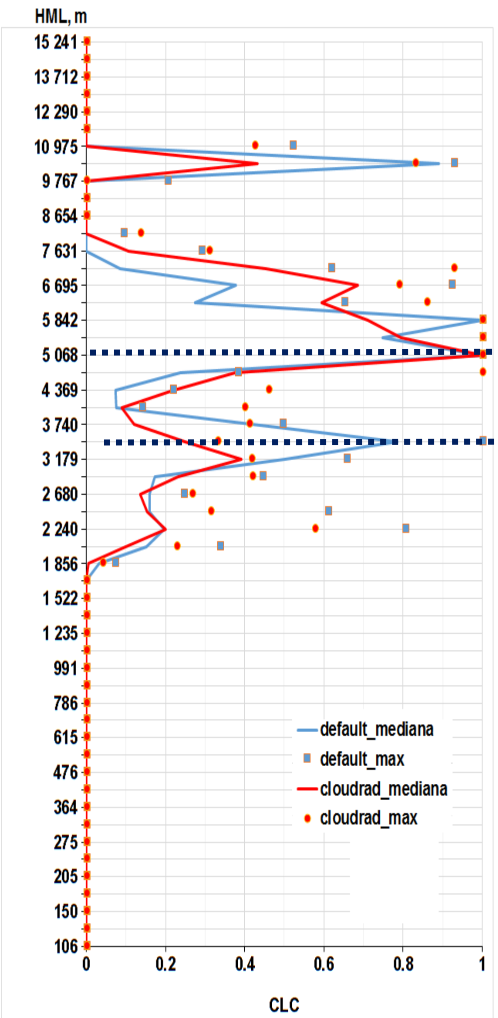
RESULTS ARE SHOWN AS NEW MINUS OLD

Temperature changes due to the new algorithm



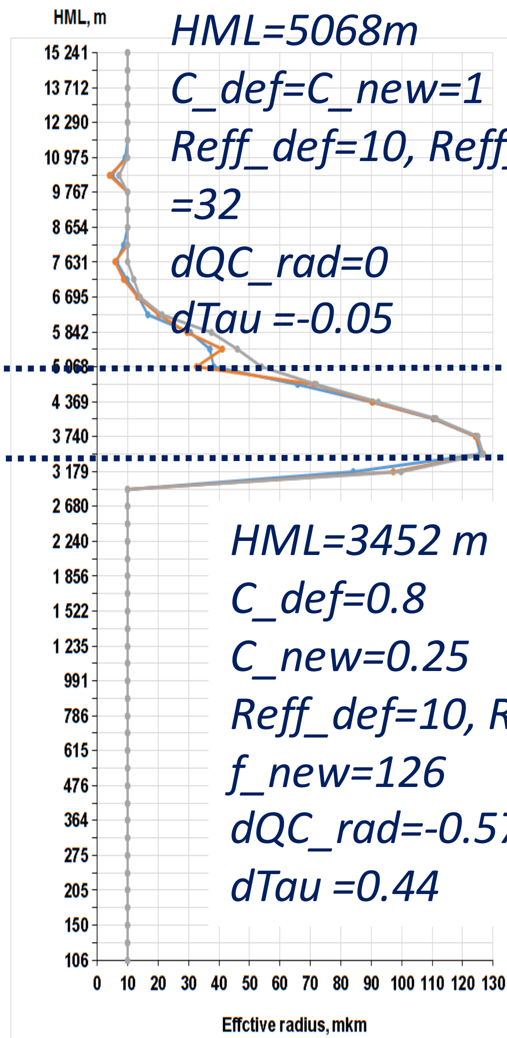
Comparison of the two cloud-radiation interaction schemes. Case study 05/04/2014.

Cloud cover



Effective radius

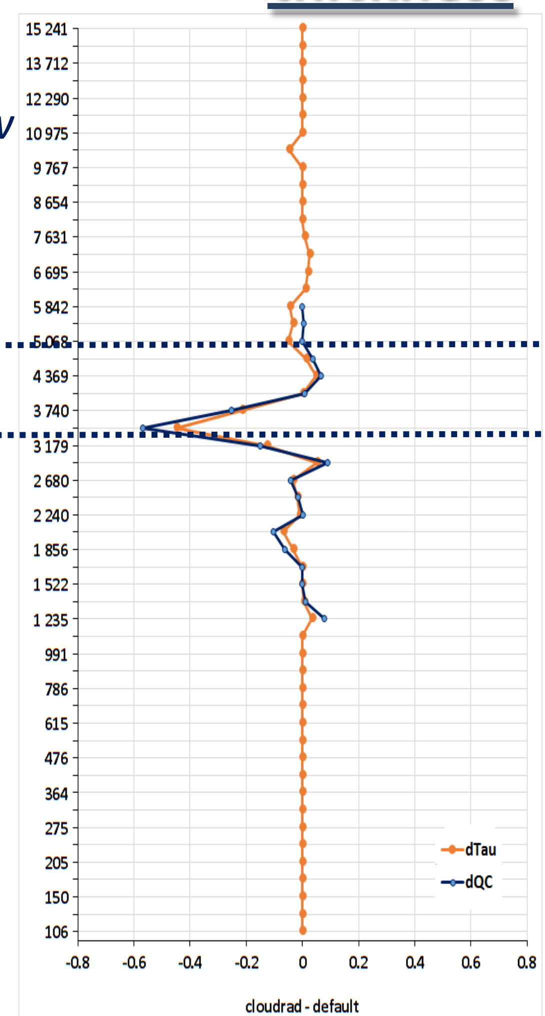
(new scheme only)



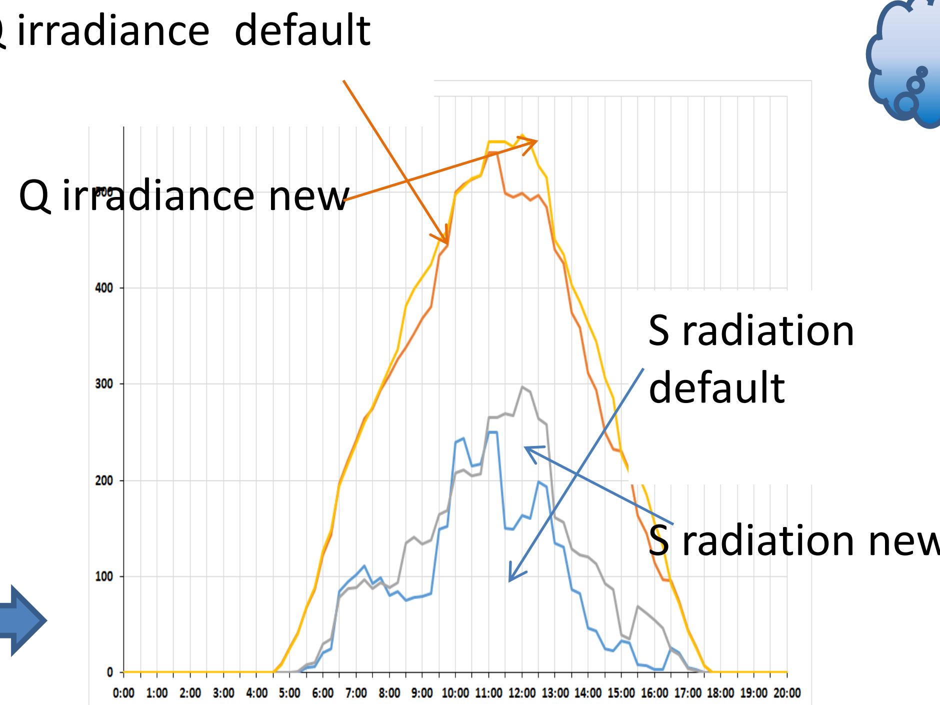
HML=5068m
C_def=C_new=1
Reff_def=10, Reff_new =32
dQC_rad=0
dTau =-0.05

HML=3452 m
C_def=0.8
C_new=0.25
Reff_def=10, Ref f_new=126
dQC_rad=-0.570
dTau =0.44

Water content and cloud optical thickness



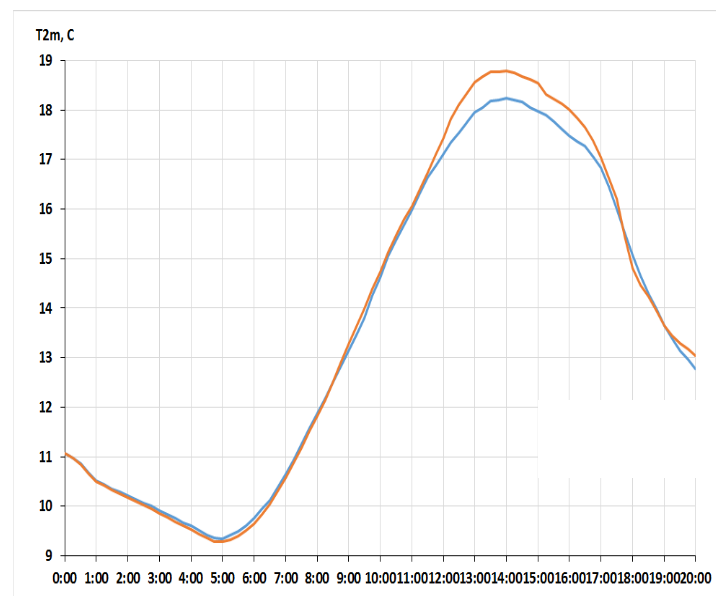
Solar irradiance and temperature in the new and old cloud-radiation interaction schemes. Case study 05/04/2014.



2M temperature effect:

Blue is default scheme

Orange is the new cloud radiation interaction scheme



CONCLUSIONS

For clear sky conditions:

- The new Macv2 climatology has similar features to Tegen for far northern area (Tiksi), but better agrees with the observations over Israel (mineral dust) sites.
- The irradiance difference model minus observation fluxes depends on AAOT difference.
- For mineral dust there COSMO algorithm overestimation works not for compensating the negative difference with aerosol climatology but for increasing the difference with observations.

CONCLUSIONS

For cloudy conditions :

- Weak correlation in model/observed TQC (r=0.11 even in case $dS<1Wm^{-1}$);
- A noticeable difference between model/observed vertical profiles of water vapor content and ice water content;
- There is a pronounced dependence of solar irradiance attenuation with the increase in TQC in both model and observations;
- There is a constant underestimation of model irradiance in overcast cloudy conditions which is also observed case when TQC (LWP) values are in agreement.
- The comparisons between new and operational cloud radiation interaction algorithm (with accounting for non-direct links) reveals *a tendency* of mainly increasing Reff which is in agreement with *a tendency* of increasing global irradiance and large temperature effect (indirect influence) and *disagreement* in observed and model Reff. *Strongly need in increasing the statistics.*

Acknowledgements

We are very grateful to Dr. Alexander Makshats and his colleages from AANII and NOAA for providing consultiations and data on Tiksi Observatory.

This work is being fulfilled within the framework of the COSMO Priority Project - T2(RC)2 - Testing & Tuning of Revised Cloud Radiation Coupling.

Institutes:

DWD (Germany), IMS (Israel), RHMC (Russia) and MCH (Switzerland).

Cloud and aerosol effects on radiative fluxes and meteorological characteristics at ground according to measurements and modelling

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1 - Hydrometeorological Centre of Russia, 11-13, B. Predtechensky per., Moscow, 123242, Russia
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3 - Deutscher Wetterdienst, Meteorologisches Observatorium Lindenberg, Am Observatorium 12, D-15848 Tauche, Germany
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5 - German Weather Service, Research and Development, Numerical Models Division, Deutscher Wetterdienst Frankfurter Str. 135, 63067 Offenbach, Germany
6. – Arctic and Antarctic Research Institute, Bering str, 38, 199397, St. Petersburg, Russia

ICCARUS2019, Offenbach, March 18 – 20, 201

OUTLINE:

CLEAR SKY CONDITIONS: AEROSOL RADIATIVE EFFECTS

1. Testing different kinds of aerosol climatologies in various optical conditions.
2. Radiative effects of aerosol over COSMO ENA domain
3. Implementation of the ICON-ART dust aerosol. Aerosol and radiative effects.
4. Case studies of urban aerosol from COSMO-ART model over Moscow. Discussion

Verification of Macv2 aerosol climatology in COSMO model over ENA domain in all conditions.

CLOUDY CONDITIONS: CLOUD-AEROSOL-RADIATIVE EFFECTS

1. Operational scheme: analysis of cloud characteristics from surface observations (CLOUDNET standard retrieval algorithm) over Lindenberg and their radiative effects.
2. New model experiments with the experimental cloud-aerosol scheme over Moscow. Radiative effects.
3. New model experiments with the experimental cloud-aerosol scheme on cloudiness and precipitation over Pyeongchang area (South Korea) .

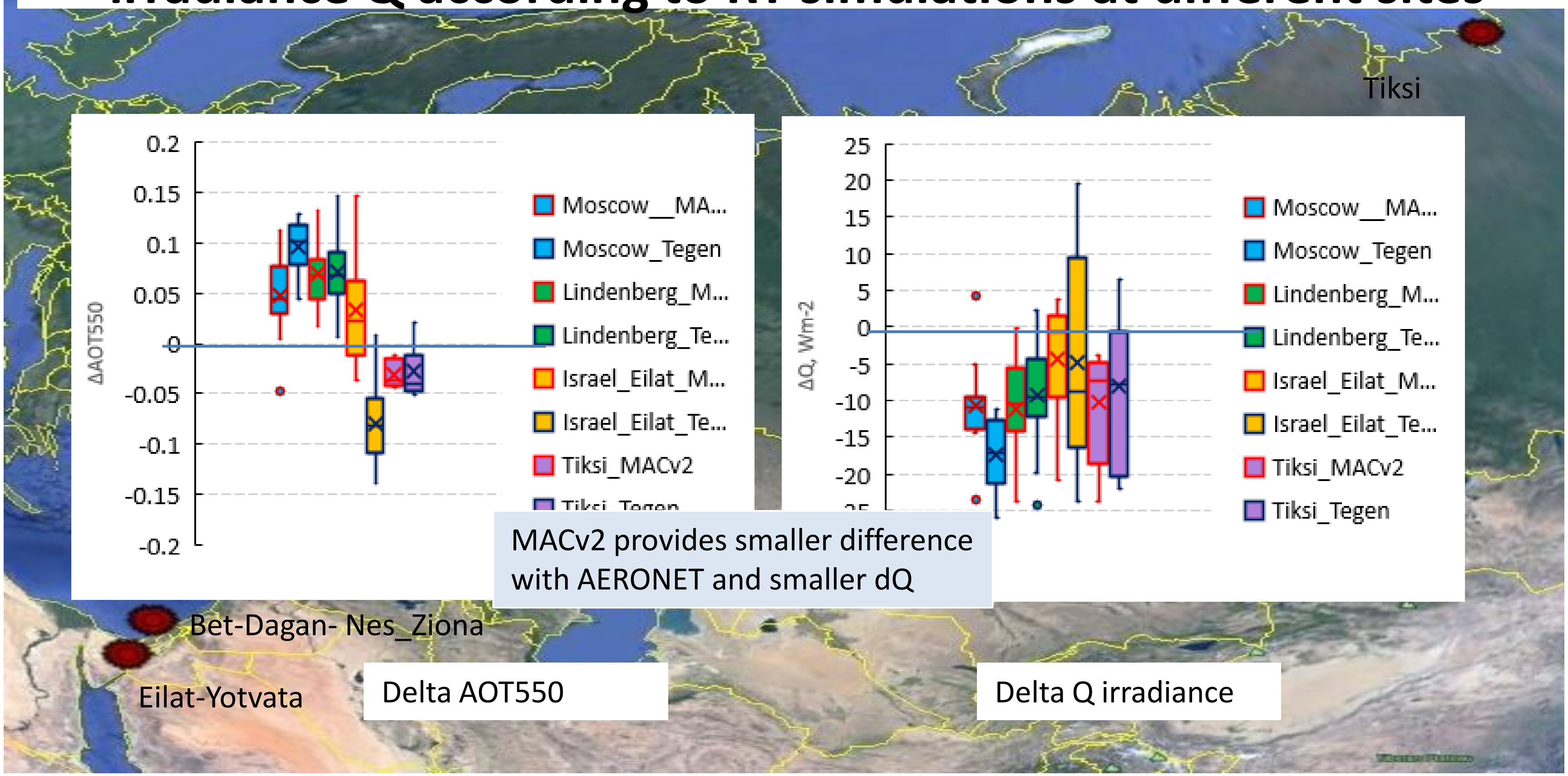
Clear sky conditions

What are the approaches of aerosol accounting in the COSMO model?

AEROSOL DATASETS	COMPUTER TIME	ACCURACY
AEROSOL CLIMATOLOGIES: TANRE TEGEN **MACv2 (or Kinne or AEROCOM)**	EFFICIENT	LARGER UNCERTAINTY FOR PARTICULAR CONDITIONS EVEN FOR THE BEST CLIMATOLOGIES
DIRECT AEROSOL SIMULATIONS (COSMO-ART /ICON_ART)	TIME CONSUMING	GOOD BUT DEPENDS ON OUR KNOWLEDGE ON PRECURSORS
AEROSOL FORECAST DATA FROM OTHER SOURCES: (CAMS, FOR EXAMPLE)	EFFICIENT	GOOD BUT ALSO MAY DEPENDS ON OUR KNOWLEDGE ON PRECURSORS

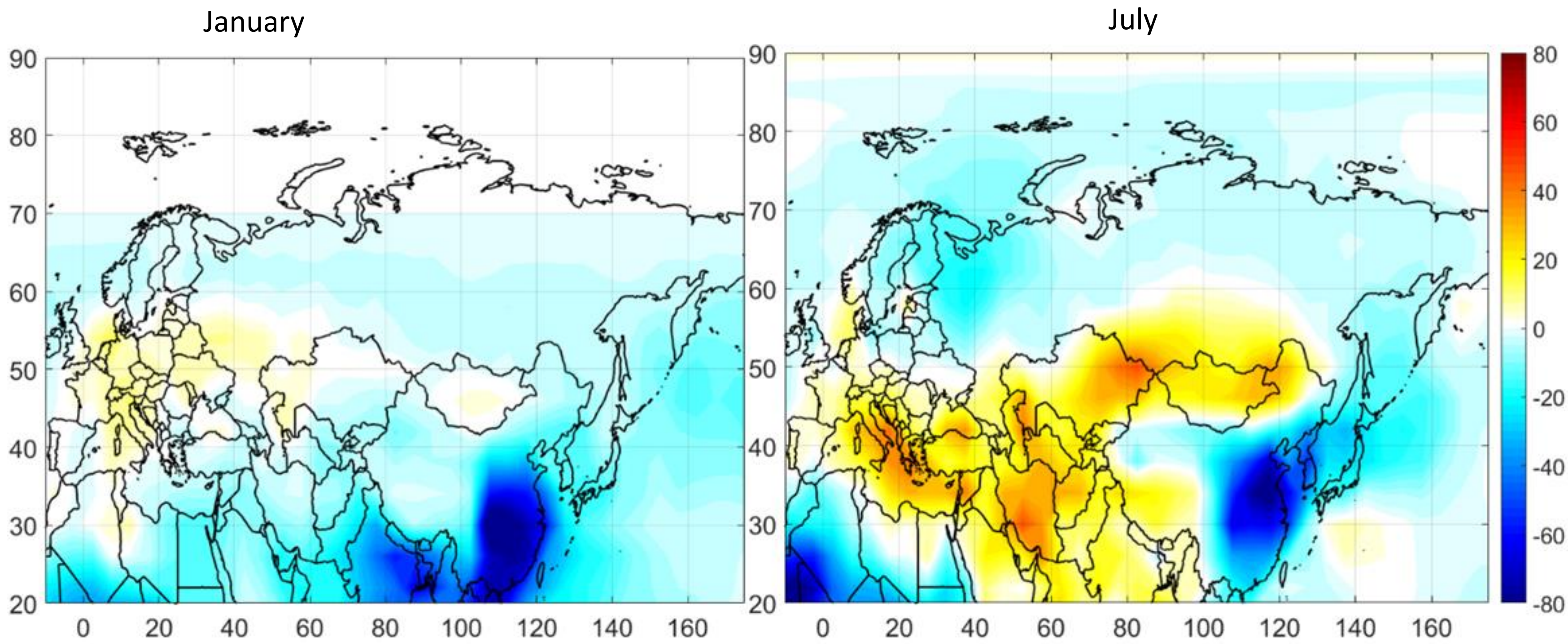
TESTING AEROSOL AND RADIATION:

Differences between AOT from aerosol climatologies (Macv2, Tegen) and AERONET, and their effects on global shortwave irradiance Q according to RT simulations at different sites



Noon difference in solar irradiance (Wm^{-2}) due to different aerosol climatologies. RT model simulations.

$\Delta Q = Q_{MAcv2} - Q_{Tegen}$



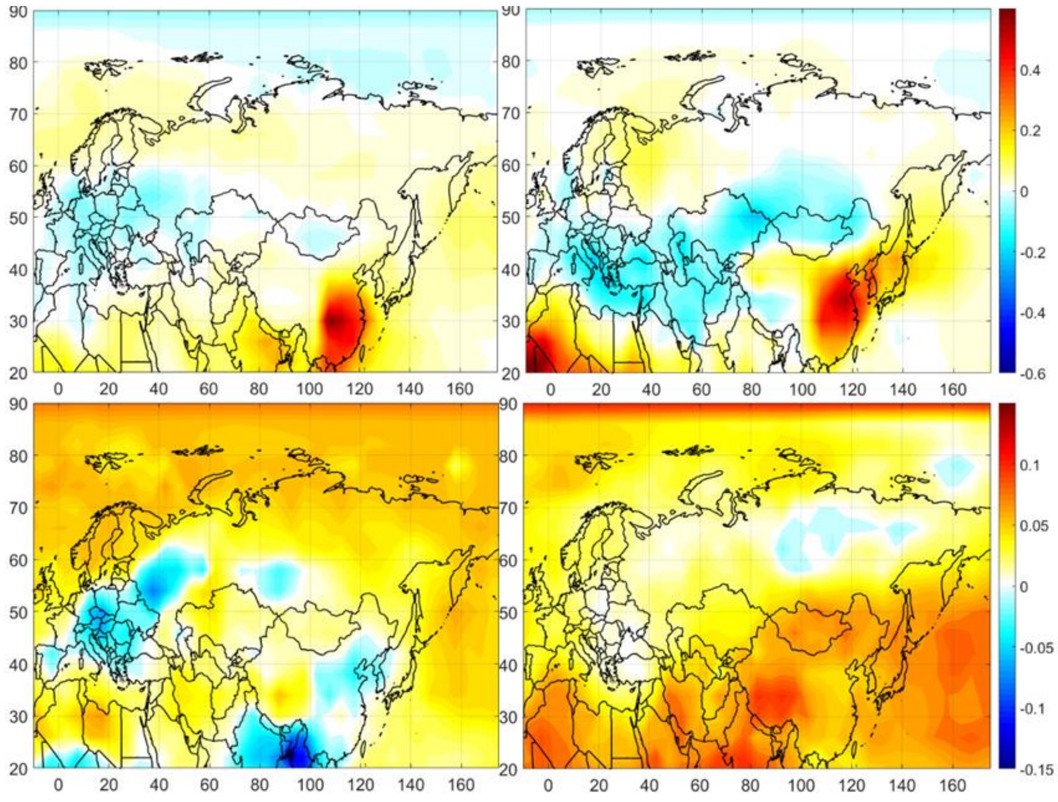
Poliukhov et al., 2019

Difference in AOT and SSA between MACv2 and Tegen aerosol climatologies

JANUARY | JULY

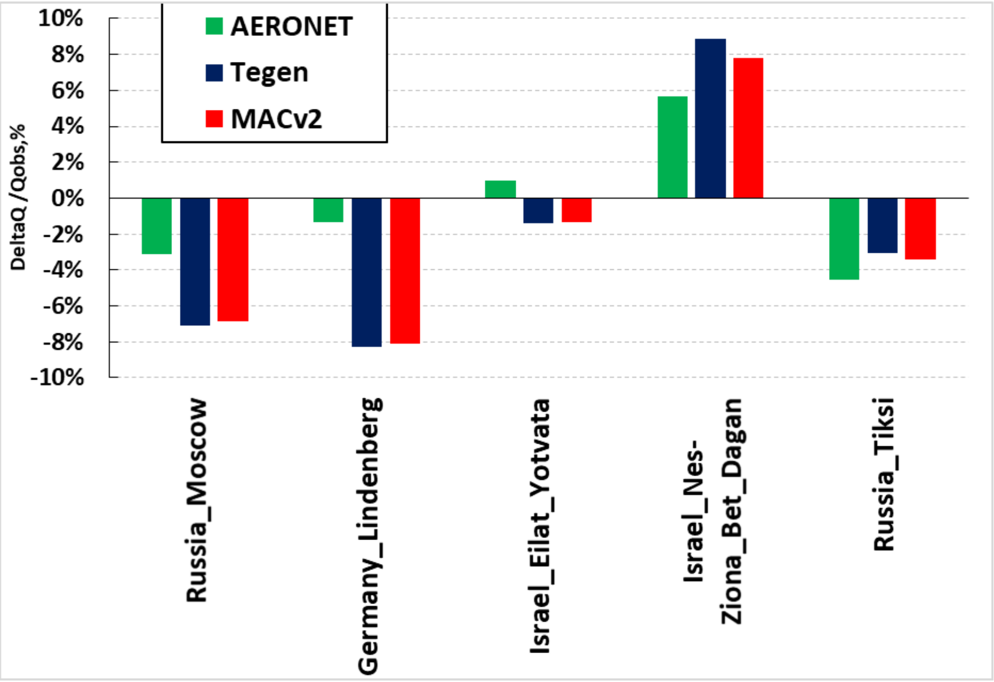
DIFFERENCE IN AOT

DIFFERENCE IN SSA

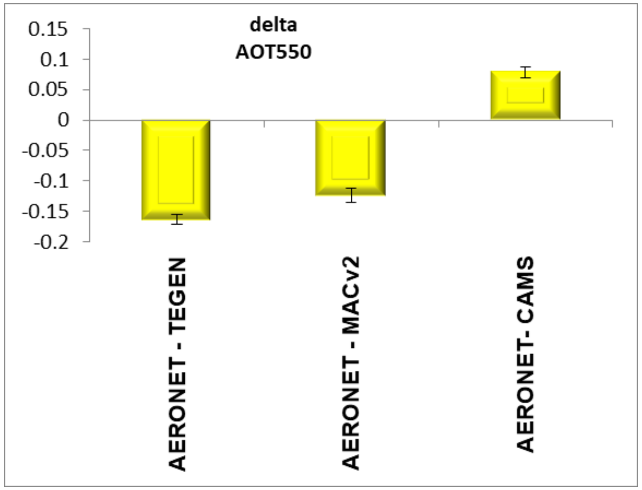


Poliukhov et al., 2019

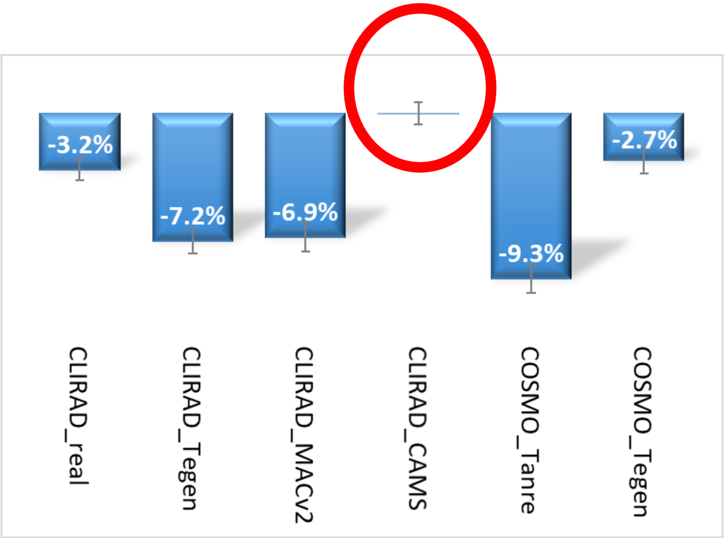
Relative difference between RT modelling (CLIRAD(FC05)-SW) with different aerosol climatologies and shortwave irradiance measurements.



Difference between AERONET AOT observations and Tegen (Macv2, CAMS*) AOT climatologies. Moscow

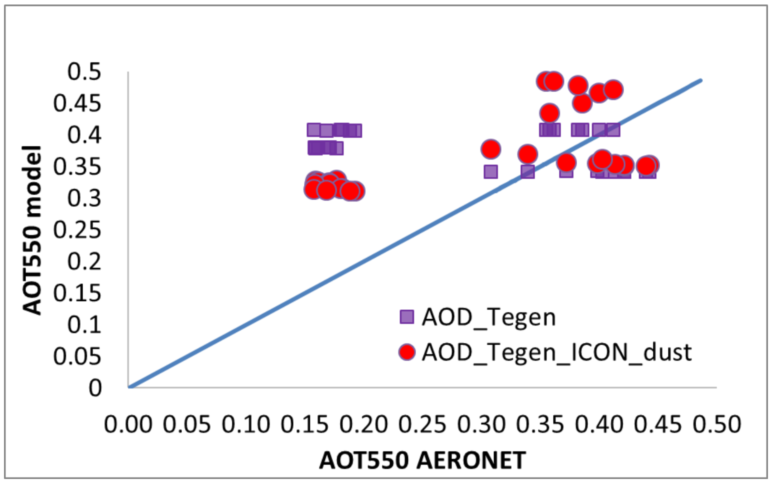


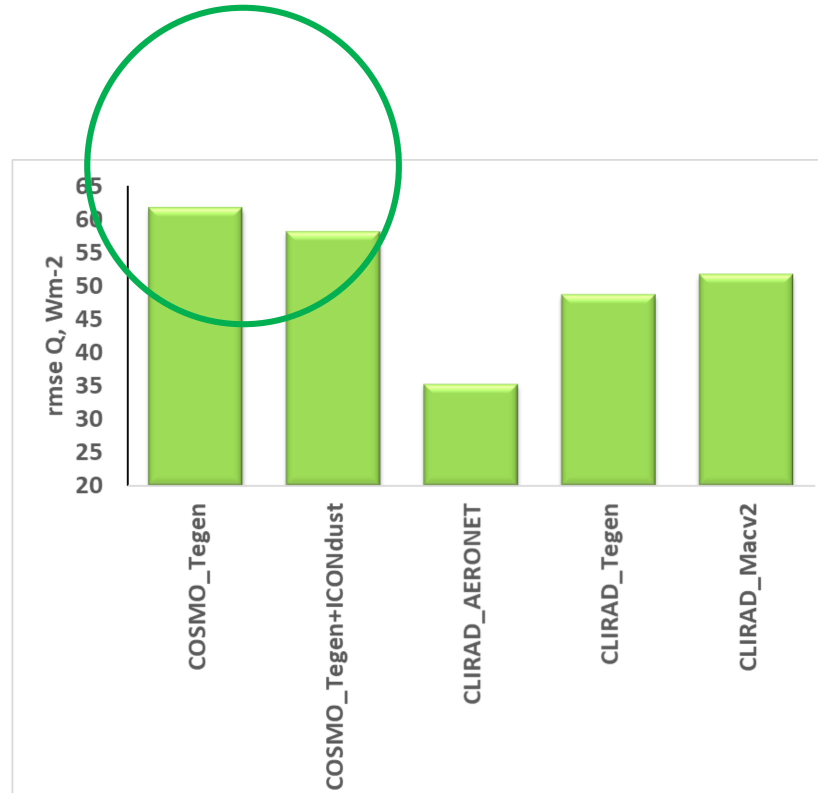
Relative difference between RT modelling (CLIRAD(FC05)-SW) with different aerosol climatologies and aerosol CAMS dataset with shortwave irradiance measurements. Moscow

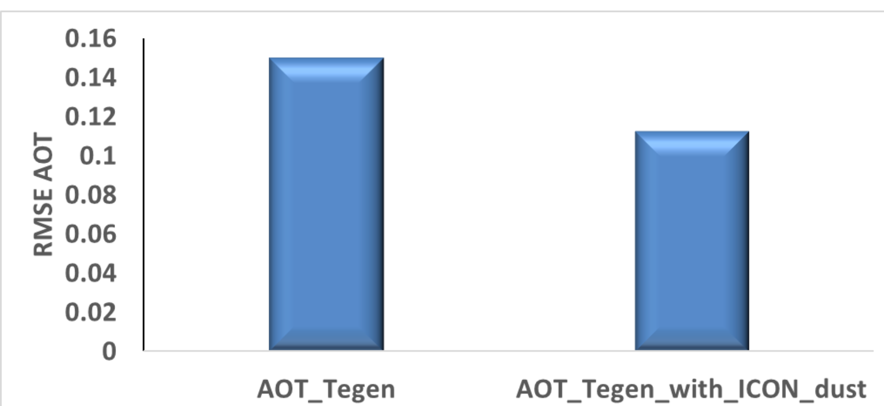


***-CAMS** - Copernicus Atmosphere Monitoring Service aerosol

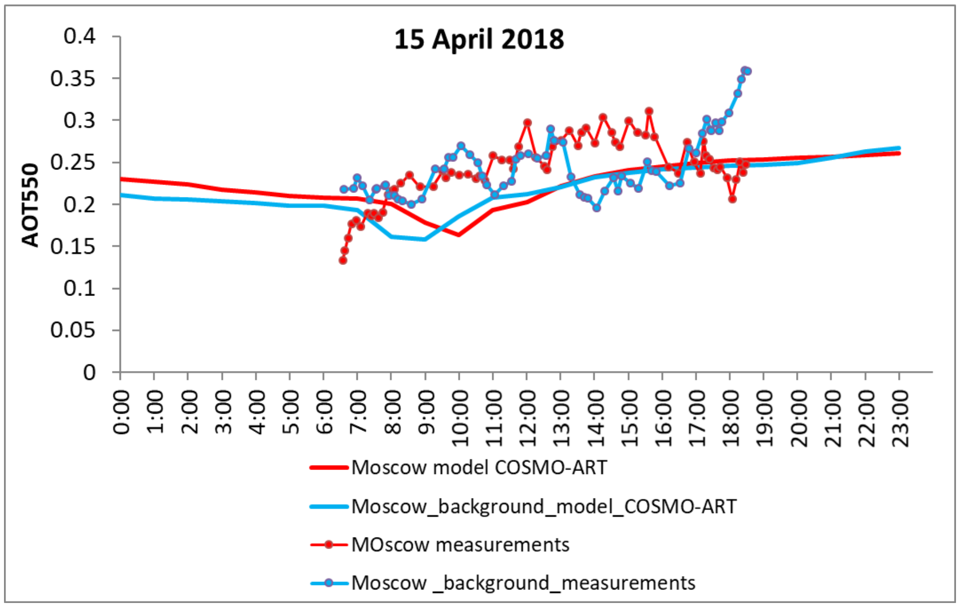
ICON DUST EXPERIMENTS OVER NES-ZIONA (Israel)

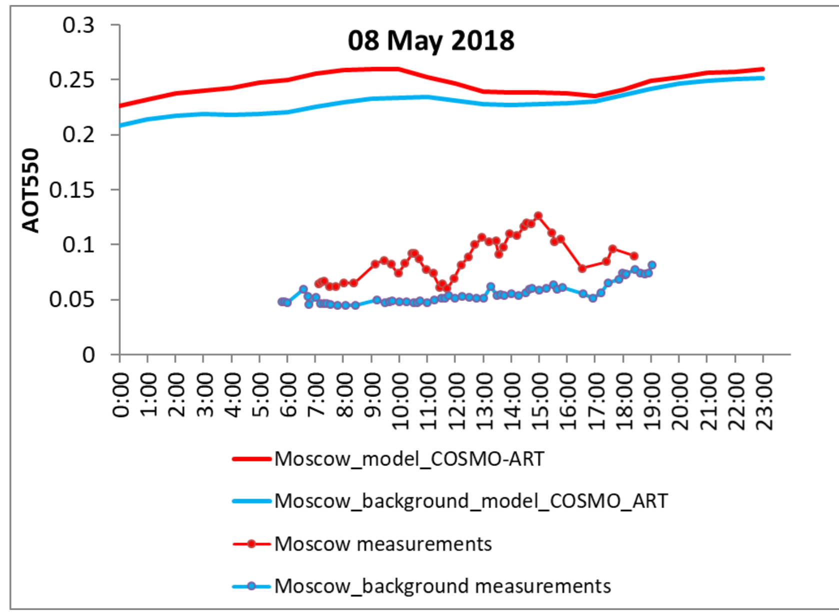






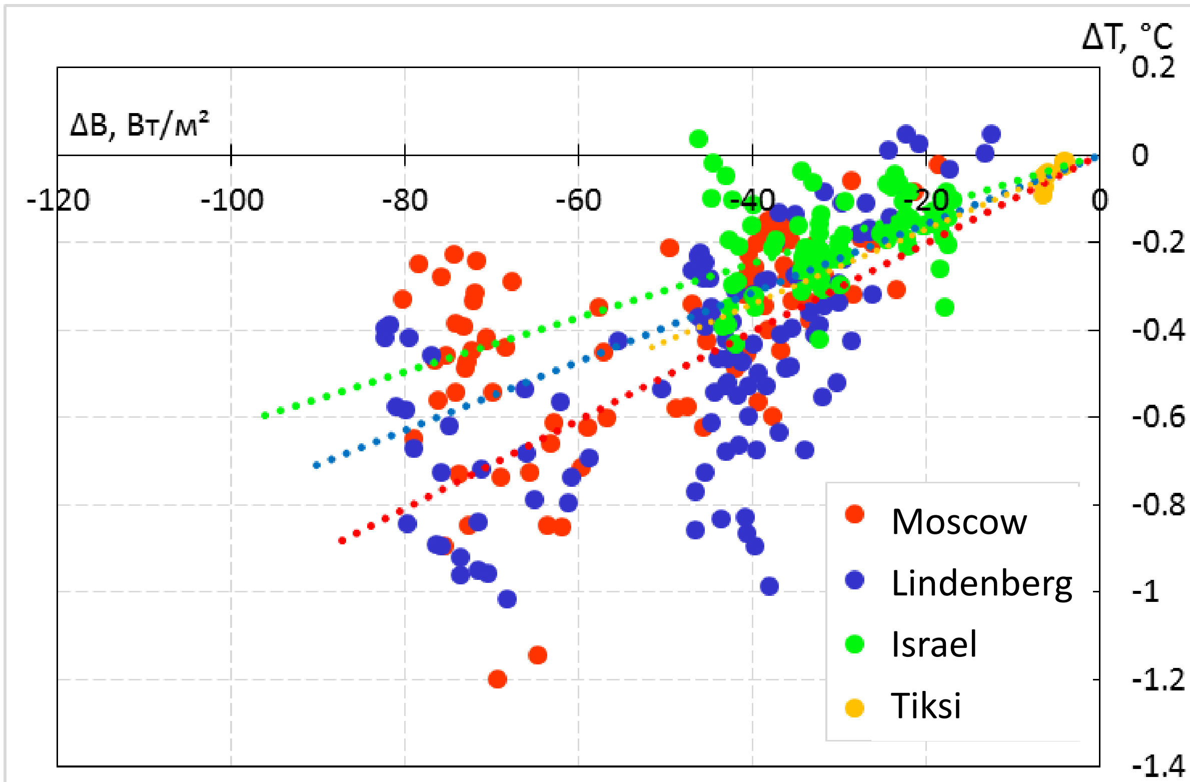
COSMO-ART simulations (*lines*) for urban (red color) and background conditions (blue color) and comparisons with AOT observations (*dots*) from the two AERONET sites (MSU Moscow and Zvenigorod (background)). 2018. TNO 2010





Credits: Alexander Kirsanov for COSMO-ART simulations

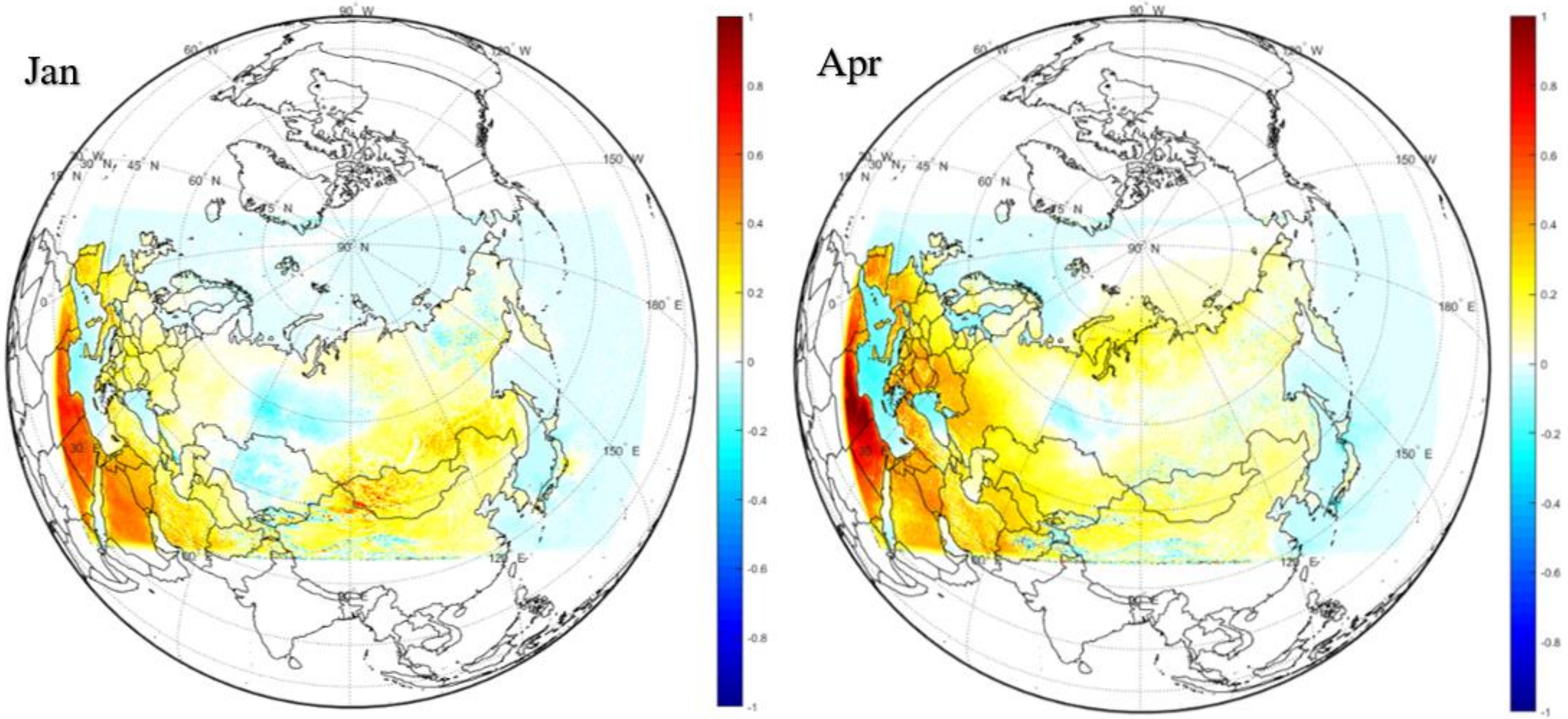
Temperature sensitivity to the aerosol radiative effects at ground for different aerosol types



Poliukhov et al., 2019

Verification of Macv2 aerosol climatology

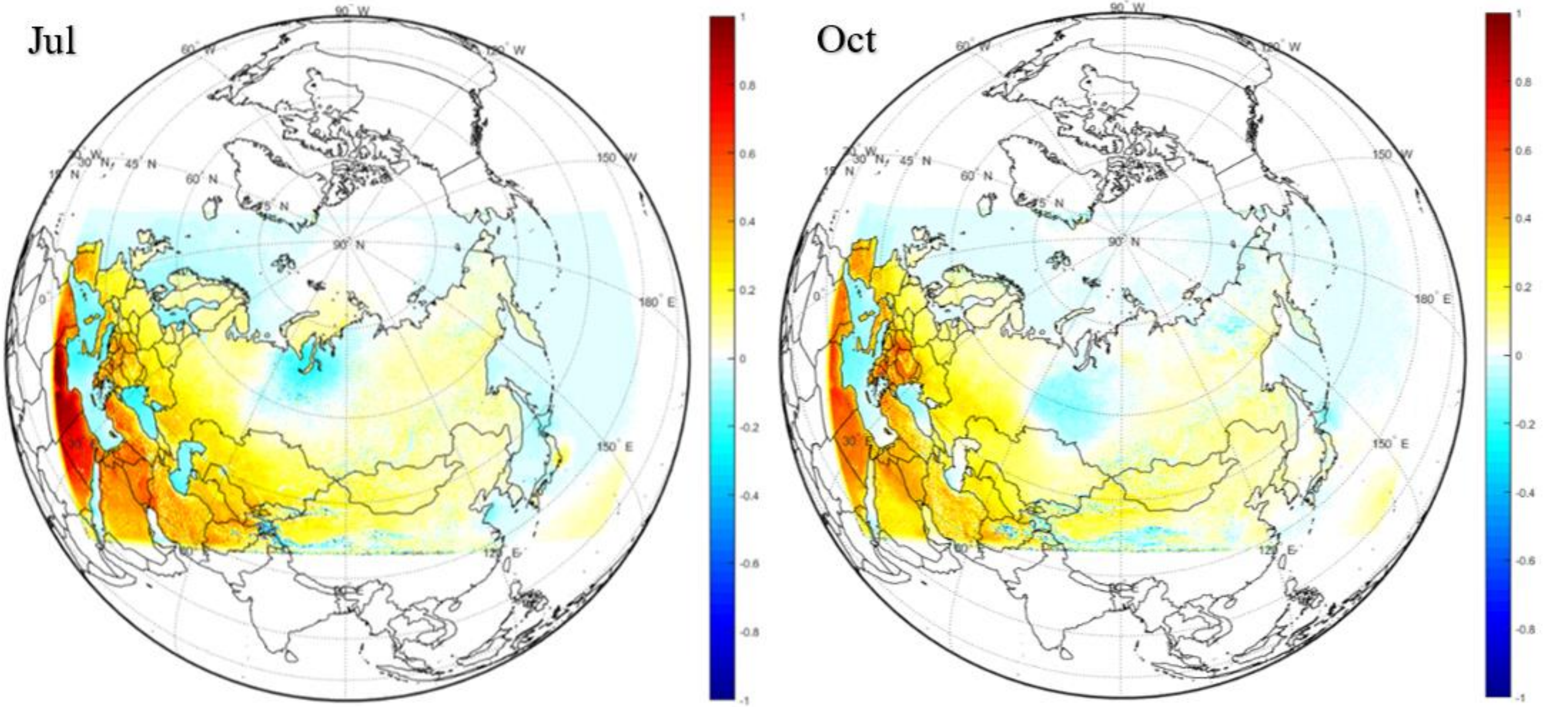
All sky conditions, temperature at 2 m (T2M):
delta T2M=T2M(MACv2)-T2M(Tanre)



ENA region with 13 km step, COSMO version 5.05, for 2017

Verification of Macv2 aerosol climatology

All sky conditions, temperature at 2 m (T2M):
delta T2M=T2M(MACv2)-T2M(Tanre)



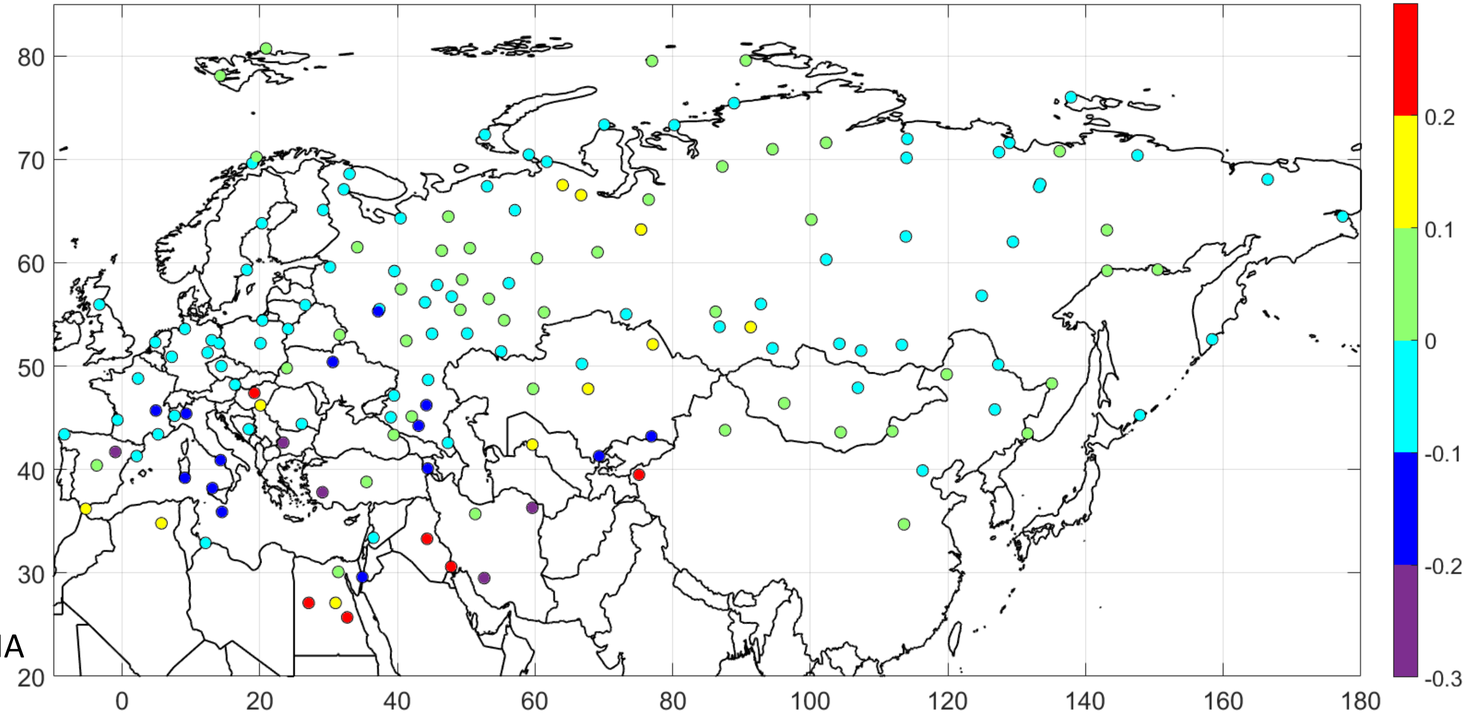
ENA region with 13 km step, COSMO version 5.05 for 2017

Verification for temperature T2M:

Blue points mean better results for Macv2 aerosol climatology compared with Tanre

$$\mathrm{Delta}RMSE = \sqrt{\Sigma\,(T_{Macv2} - T_{obs})^2} - \sqrt{\Sigma\,(T_{Tanre} - T_{obs})^2}$$

Comparisons with Tanre aerosol climatology



For 163 stations over ENA

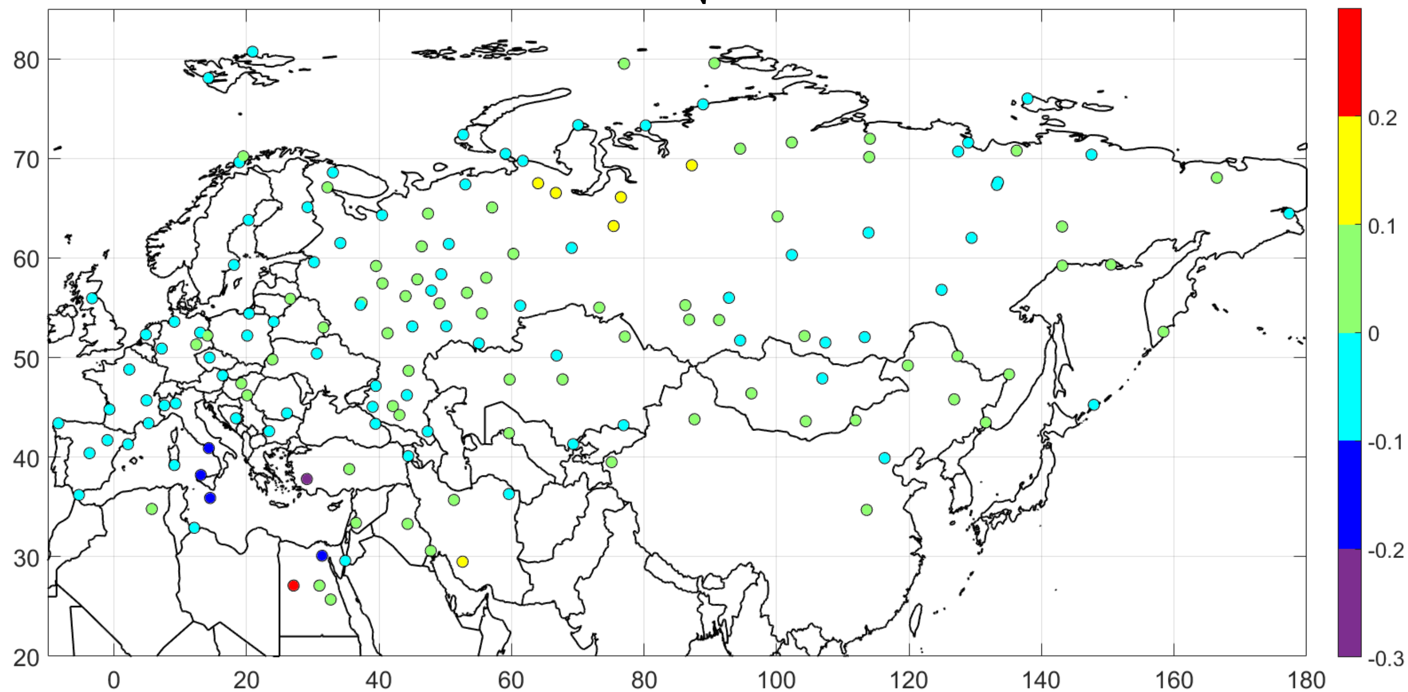
Nodes from the model were selected by the neighborhood method

Verification for temperature T2M:

Blue points mean better results for Macv2 aerosol climatology compared with Tegen

$$\text{Delta}RMSE = \sqrt{\Sigma\,(T_{Macv2} - T_{obs})^2} - \sqrt{\Sigma\,(T_{Tegen} - T_{obs})^2}$$

Comparisons with Tegen aerosol climatology



July

For 163 stations over ENA

CONCLUSIONS FOR THE PART DESCRIBING AEROSOL DIRECT EFFECT:

- Macv2 aerosol climatology provides better agreement with AOT and radiative observations.
- The application of ICON-DUST aerosol provides smaller RMSE. But better agreement is observed not always.
- The best agreement with radiative observations was obtained with prognostic CAMS aerosol dataset.
- COSMO-ART has a good ability in modelling urban columnar AOT with TNO2010 emissions.
- Temperature (T2M) verification with Macv2 climatology provides better agreement with observations over Europe, large territory of Russia.

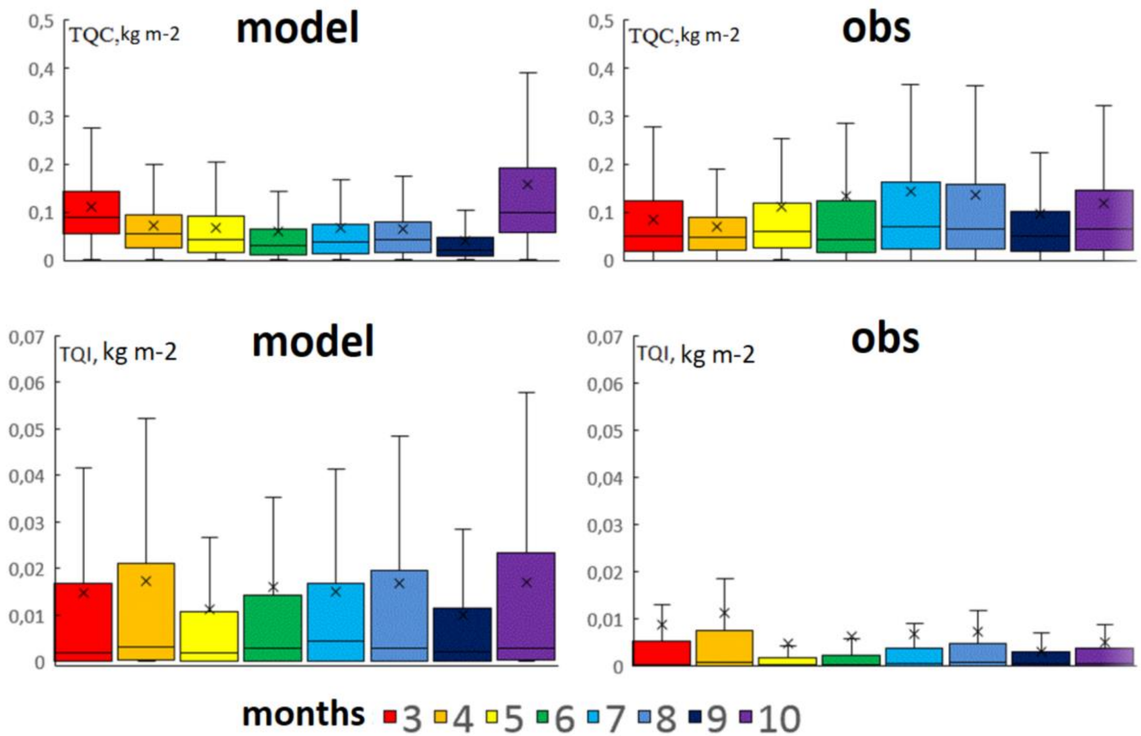
CLOUDY CONDITIONS:

Lindenberg, 2016

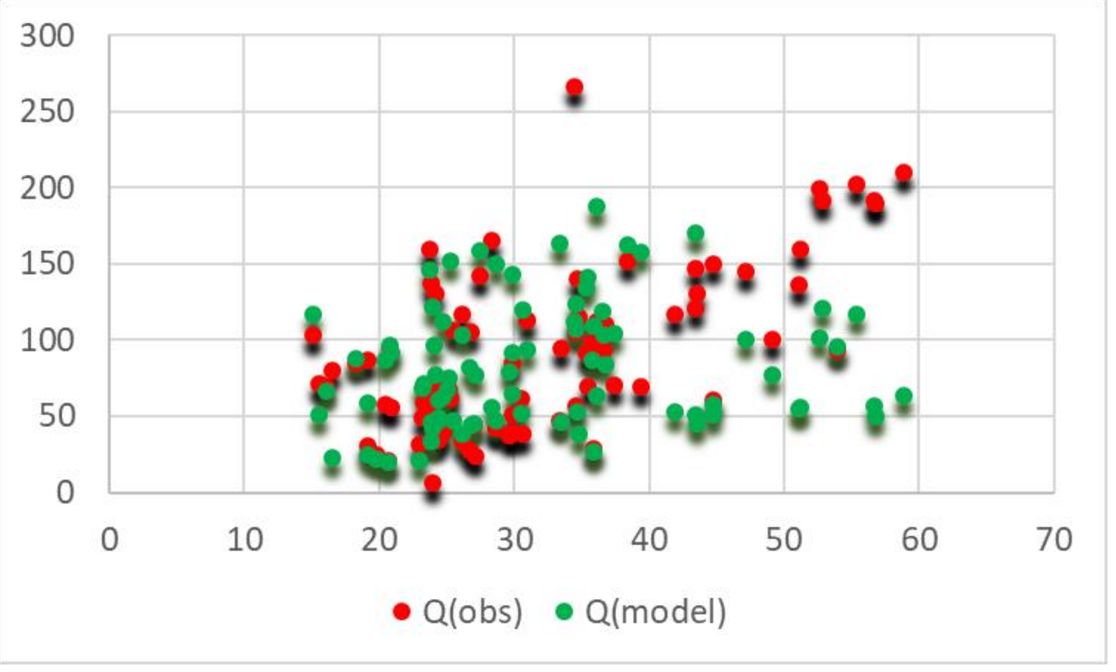
OBSERVATIONS – CLOUDNET ALGORITHM

TOTAL WATER CONTENT

TOTAL ICE CONTENT



The comparisons of model and observed shortwave irradiance (Wm^{-2}) in overcast conditions as a function of solar elevation. Lindenberg.



1-hour averages.

Evaluation of the non direct cloud-aerosol effect

Moscow experiment – April 2018

Measurements:

MSU Meteorological Observatory, Kipp&Zonen CNR4

Model experiments:

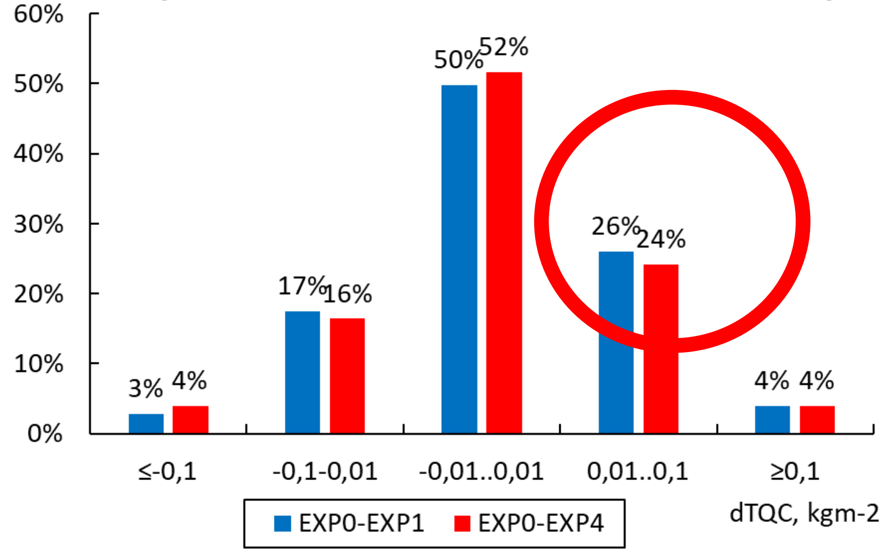
E0 – standard scheme

E1 – new cloud-radiation scheme with Tegen

E4 – new cloud-radiation scheme with $N_0=5*10^8\ m^{-3}$.

Frequency distribution of total water content (TQC) differences:

TQC(Exp0-standard) – TQC(Exp1)
TQC(Exp0-standard) – TQC(Exp4)

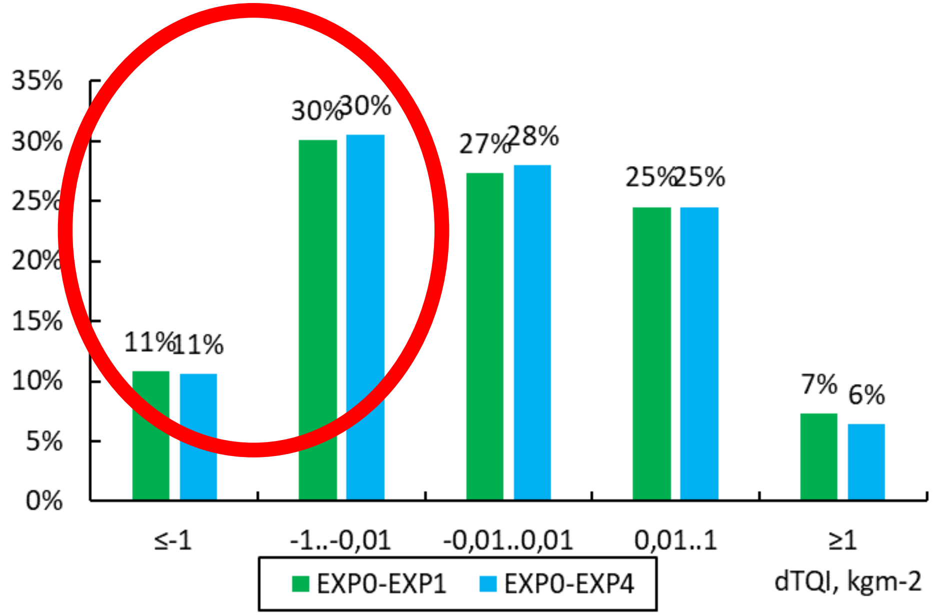


Mean difference:
-0.0054 kgm-2 for EXP1;
-0.0029 kgm-2 for EXP4.

Model experiments:
E0 – standard
E1 – new cloud-radiation scheme with Tegen
E4 – new cloud-radiation scheme with $N_0=5*10^8$ m-3

Smaller TQC with new scheme.

Frequency distribution of total ice content (TQI) differences: *TQI=TQI(Exp0-standard) – TQI(Exp1)* *TQI=TQI(Exp0-standard) – TQI(Exp4)*



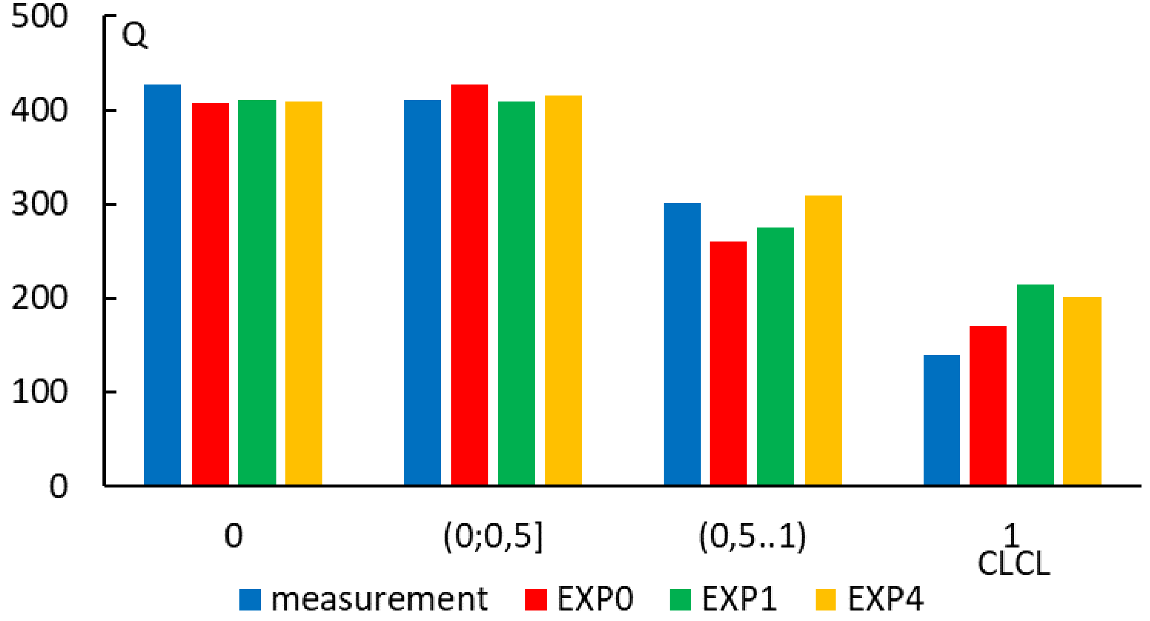
Model experiments:

E0 – standard

E1 – new cloud-radiation scheme with Tegen

E4 – new cloud-radiation scheme with N_0=5*10^8 m-3

Shortwave irradiance for different low layer cloud amount bins according to observations and different model experiments. Moscow.



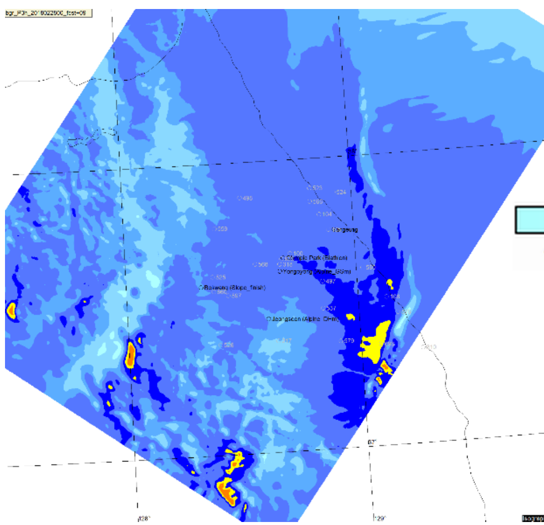
Impact on precipitation forecast:
the experiments over Pyeongchang area (KOREA)

COSMO-ICE005, 28.02.20180, 00UTC

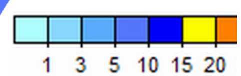
- **Precipitation localization and amount**
  3h accumulated precipitation, fcst+09

Standard scheme–EXP0

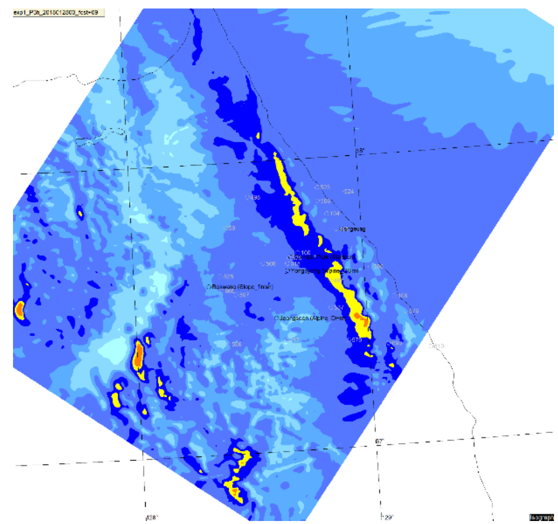
FSS=0.73



mm/3h



New scheme_EXP1(Tegen)



FSS=0.83

Experiments were made within the framework of T2(RC)2 and ICE-POP2018 projects.

Impact on precipitation forecast

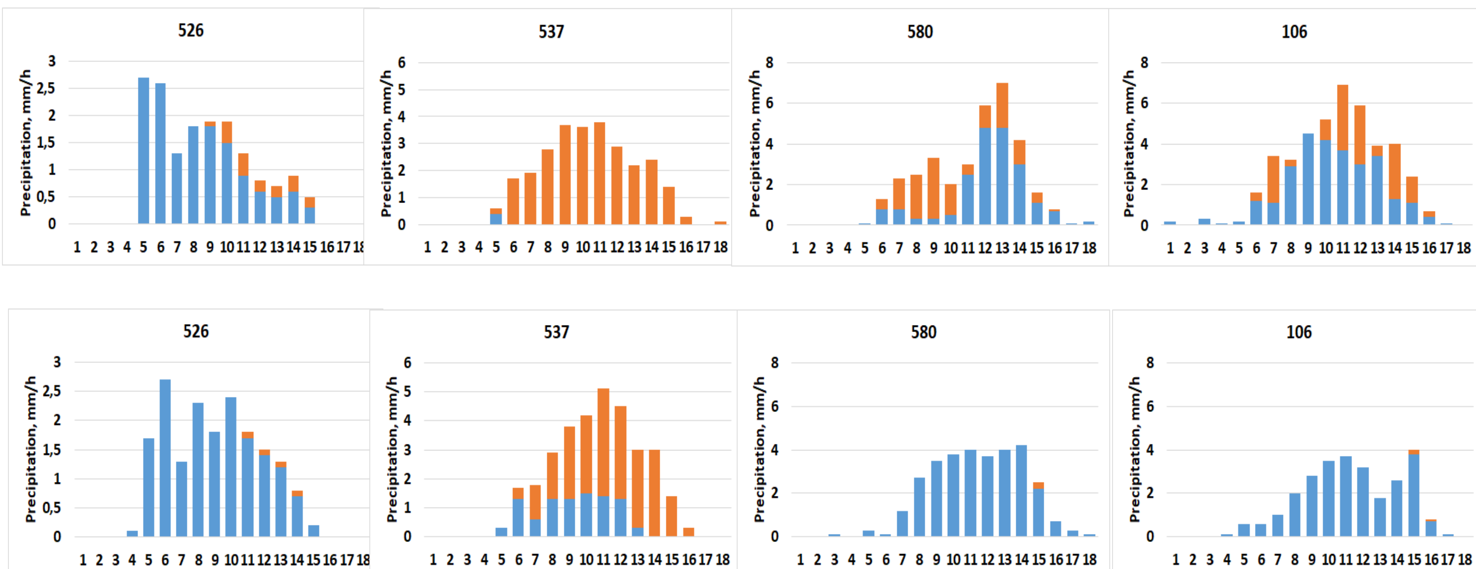
Pyeongchang area, COSMO-ICE005, 28.02.20180, 00UTC

- ❑ Precipitation rate (mm/h) and phase

Mountain cluster → *Coastline*

Exp0-STANDARD

Exp1_Tegen



rain snow

More details on these experiments can be found at the POSTER20 (Shatunova et al., P20: COSMO for ICE-POP2018: status, verification results and future plans)

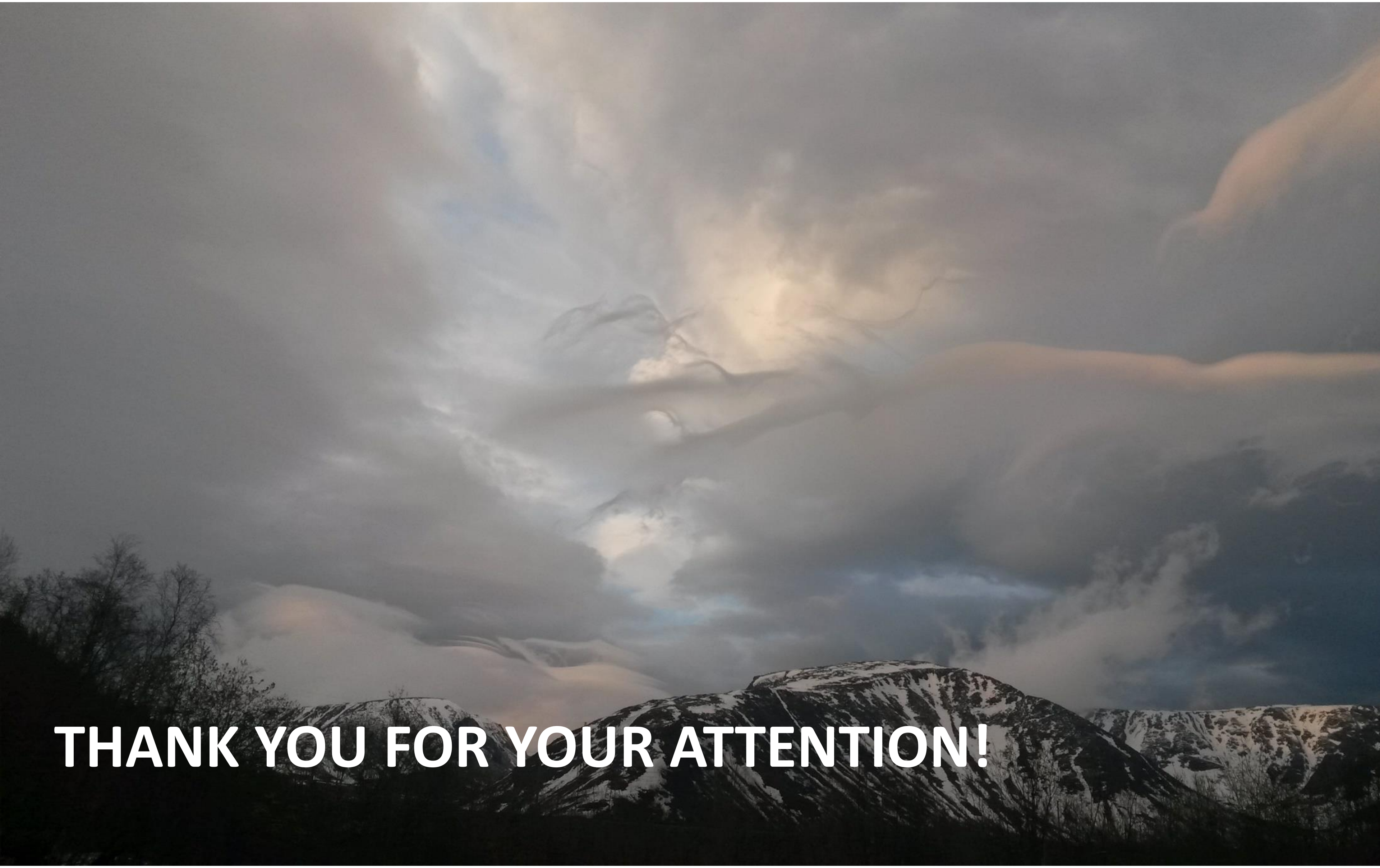
CONCLUSIONS for CLOUD PART:

Evaluation of cloud parameters in standard COSMO algorithm has some biases compared with observations especially TCI (total ice content).

New scheme provides mainly the increase in global shortwave irradiance due to smaller TQC.

Korean experiment has revealed an increase in proportion of liquid precipitation.

NEED MORE EXPERIMENTS AND TESTS !


THANK YOU FOR YOUR ATTENTION!