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

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4 - Israel Meteorological Service, P.O box 25, Bet-Dagan, 5025001, Israel
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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 :

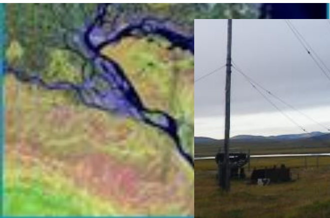
- sun sky photometer **AERONET CIMEL** dataset from AERONET version 2.0, level 2.0

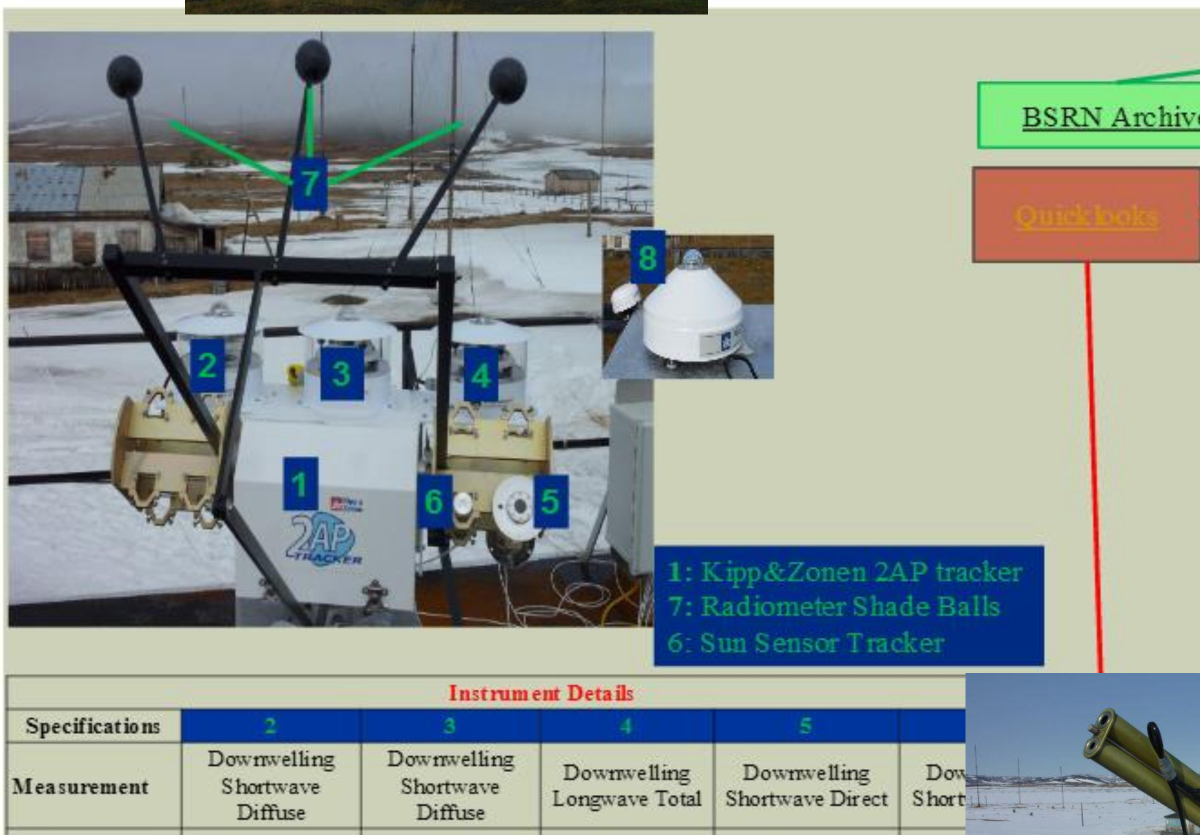
Meteorological observations:

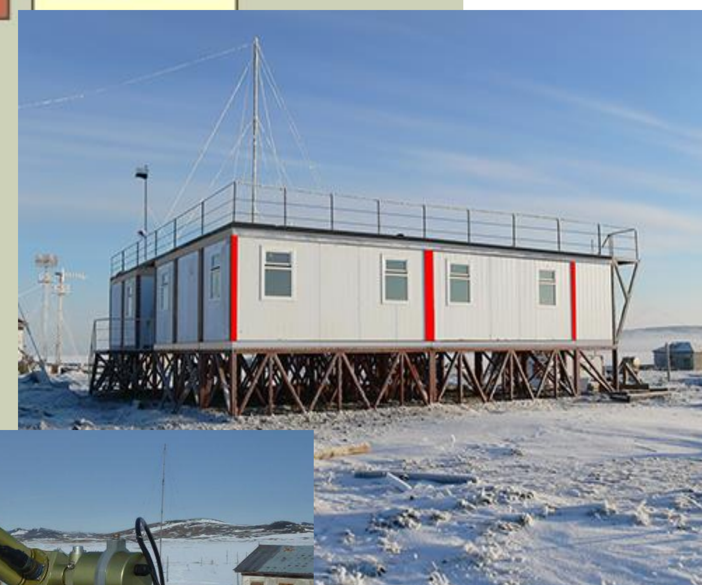
- Hourly cloud observations,
- The air temperature at a **height of 2m (T2m).**

Hydrometeorological Observatory of Tiksi, Russia

Location: 71.596 N 128.889 E







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

Israel sites

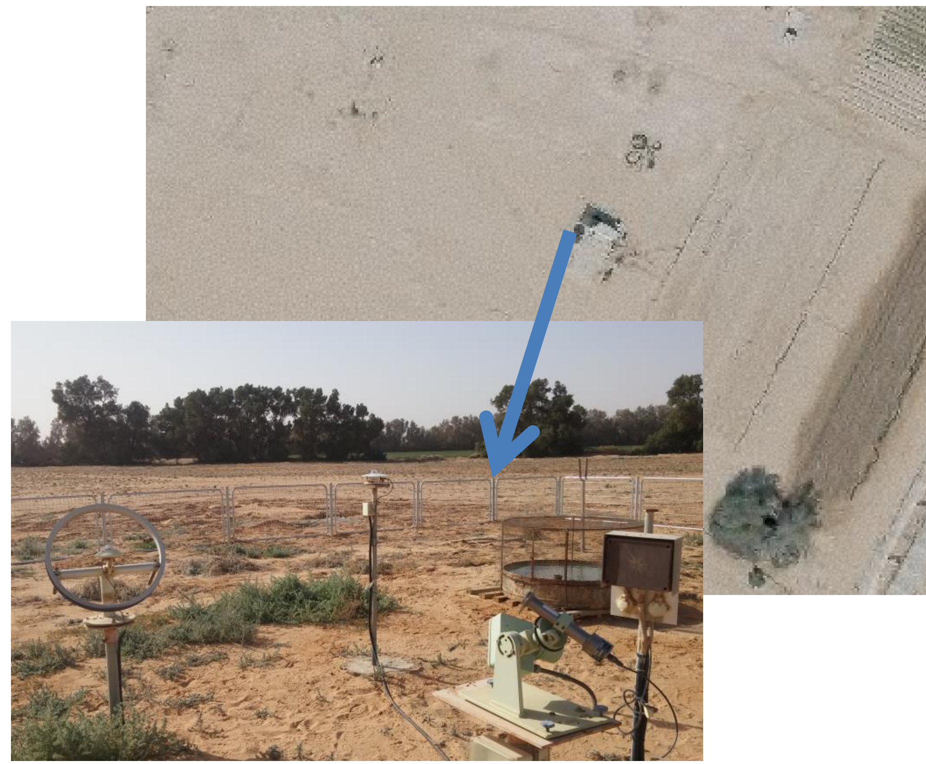
Nes-Ziona(AERONET) Bet-Dagan

31.9°N, 34.8 °E (9km)

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

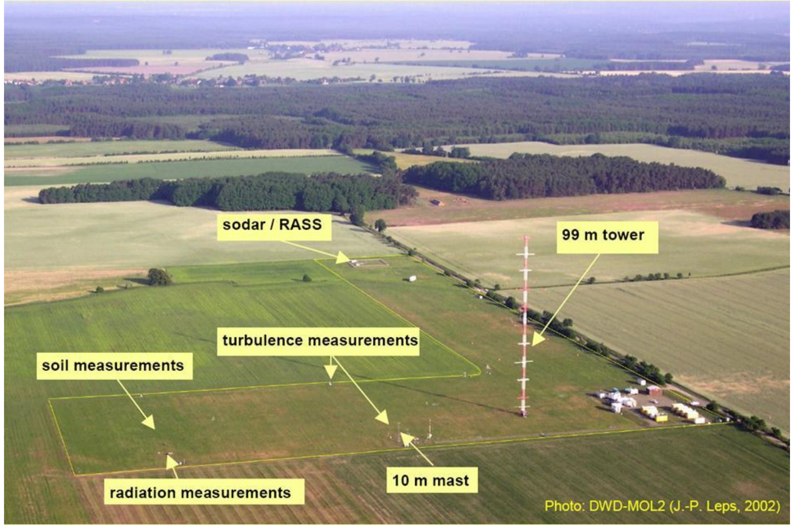
Eilat (AERONET)-Yotvata

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 climatology (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:

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

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

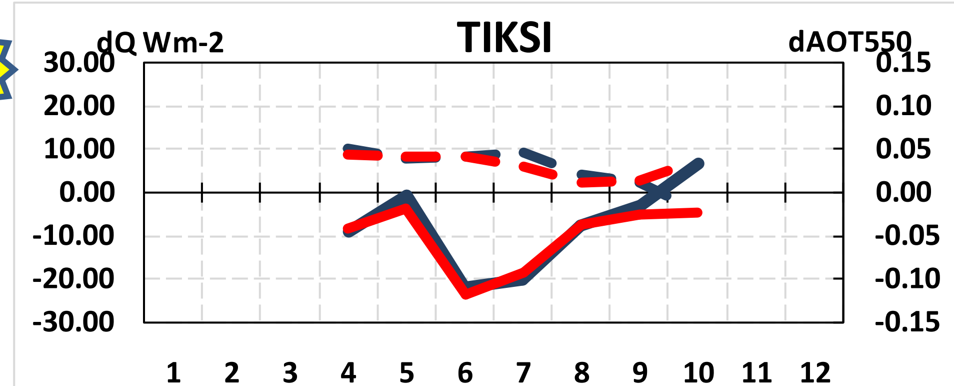
$$\frac{dS}{d\delta'} = -\frac{S}{\mu_0}$$

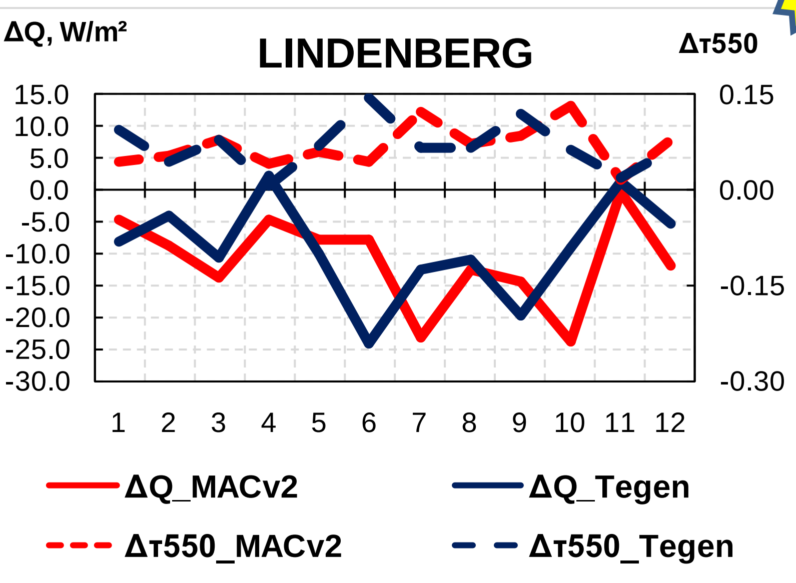
$$\delta' = (1 - \tilde{\omega} f)\delta$$

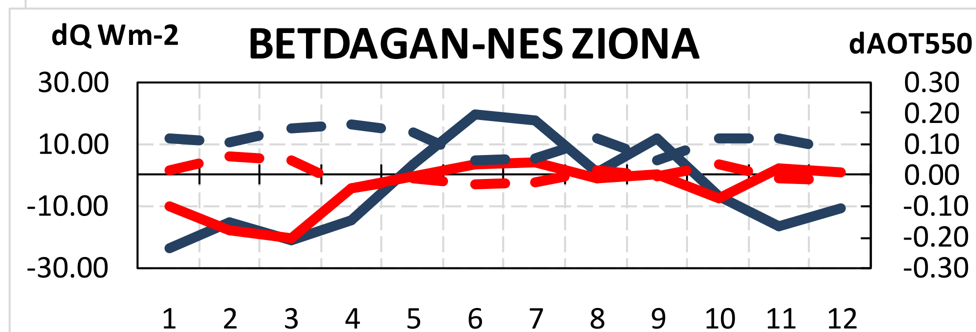
$$\tilde{\omega}' = \frac{\tilde{\omega}(1-f)}{1-\tilde{\omega} f},$$

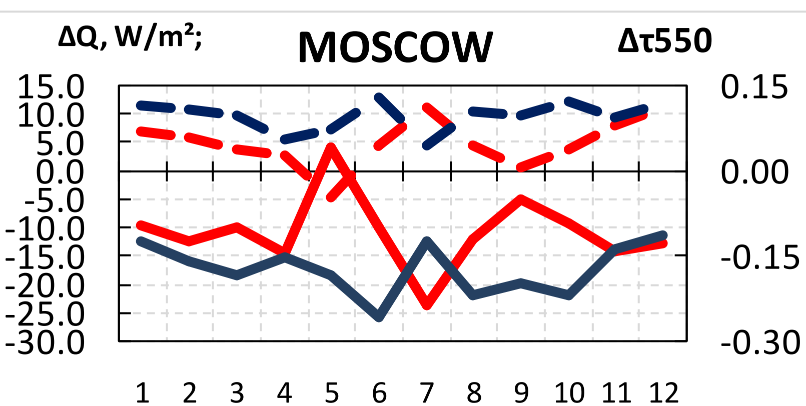
1982 AFGL spectroscopic database for optical properties of gases for gaseous transmission function .

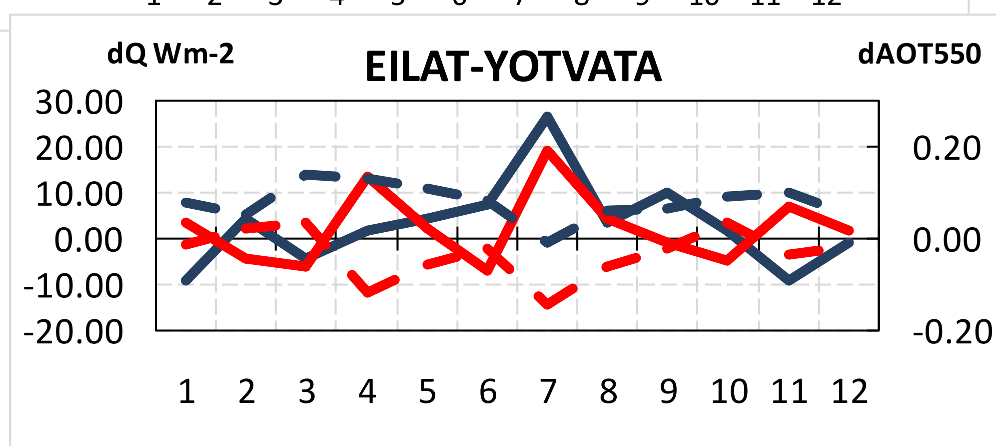
Difference in AOT and in shortwave irradiance for Tegen* and Macv2 climatologies versus AERONET AOT and radiative simulations with AERONET characteristics for noon. CLIRAD



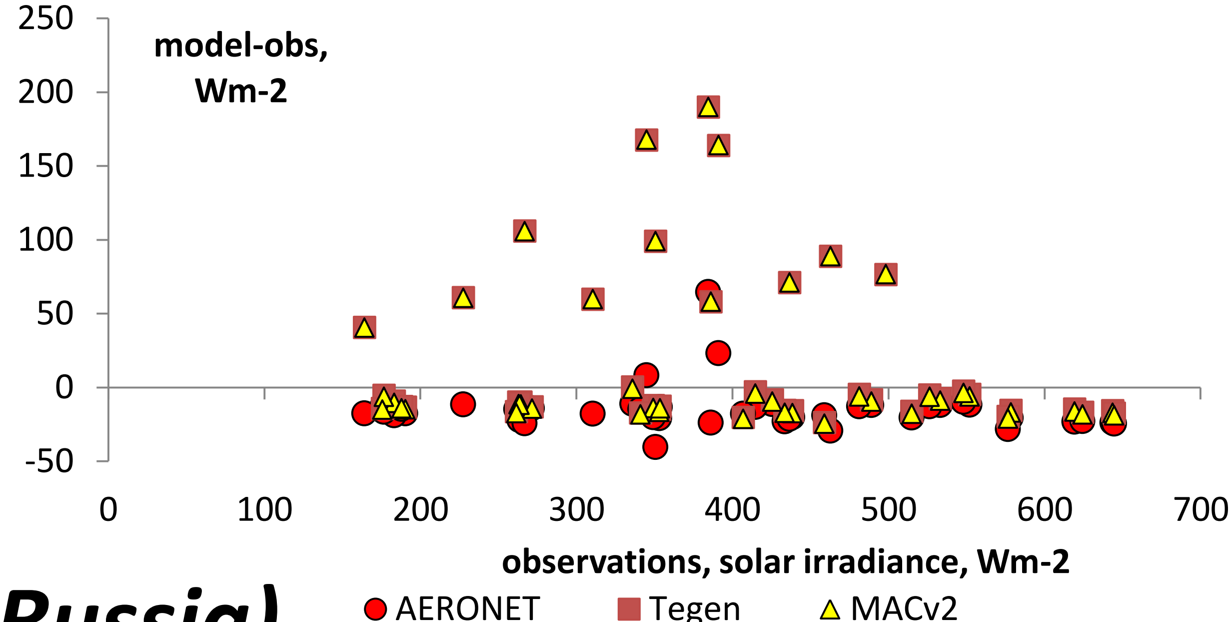




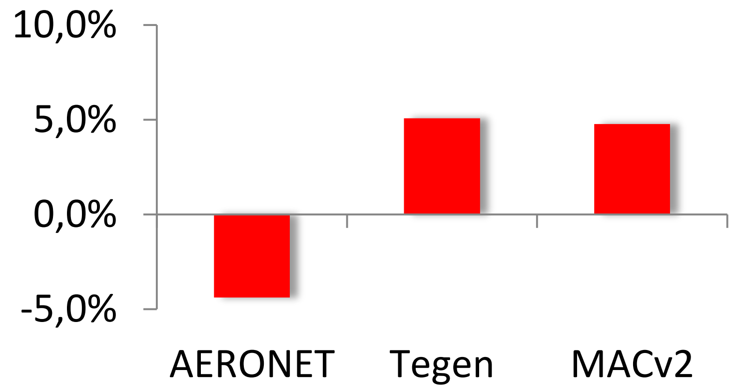




Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



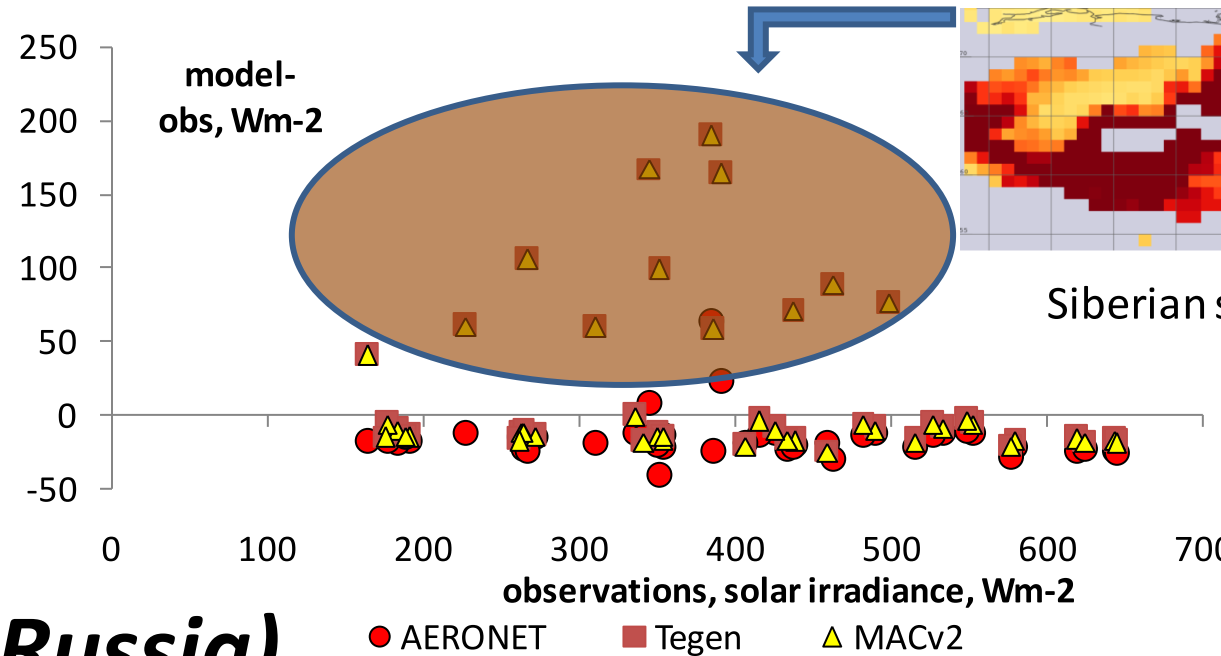
Tiksi (Russia)

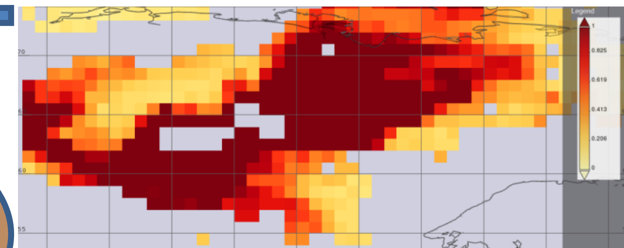


Tiksi, standard deviation for absolute difference

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

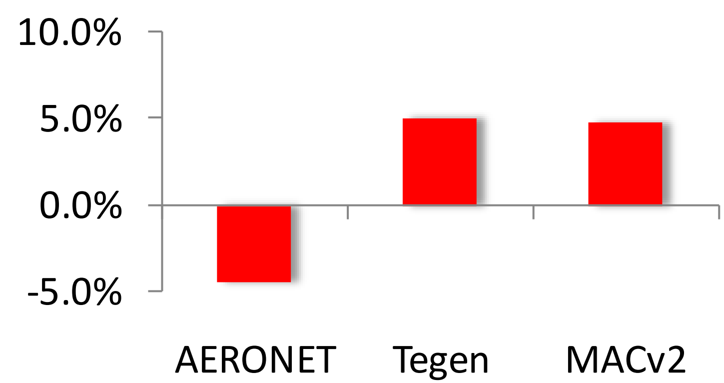




Siberian smoke aerosol

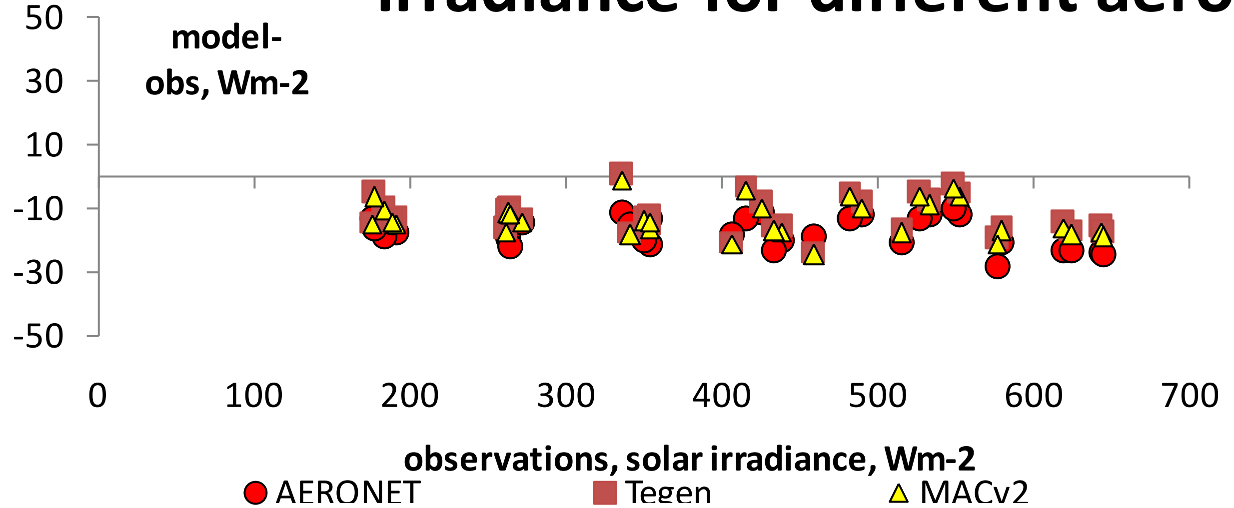
Tiksi (Russia)

Tiksi, standard deviation for absolute difference

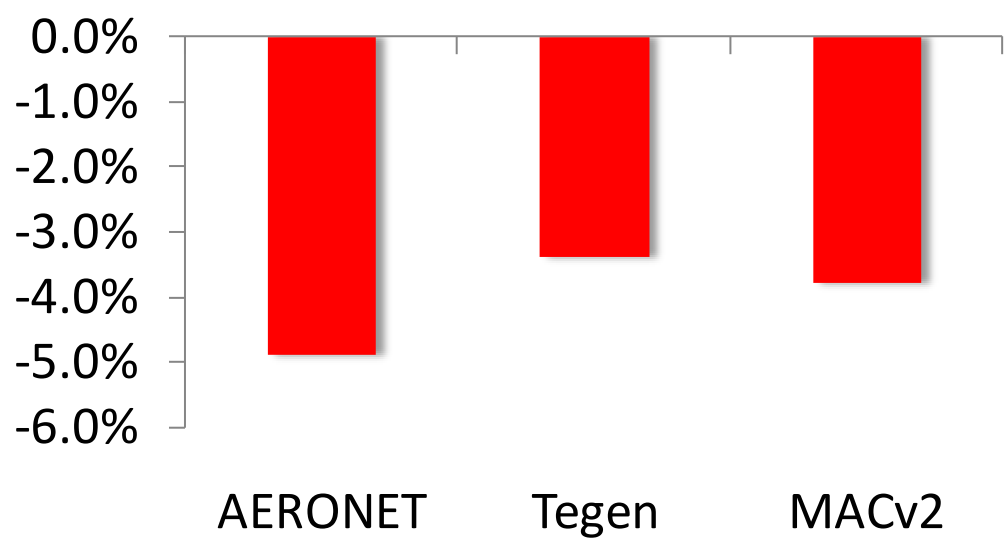


AERONET – 18 Wm-2 ,
Macv2 – 55 Wm-2,
Tegen* – 54 Wm-2,

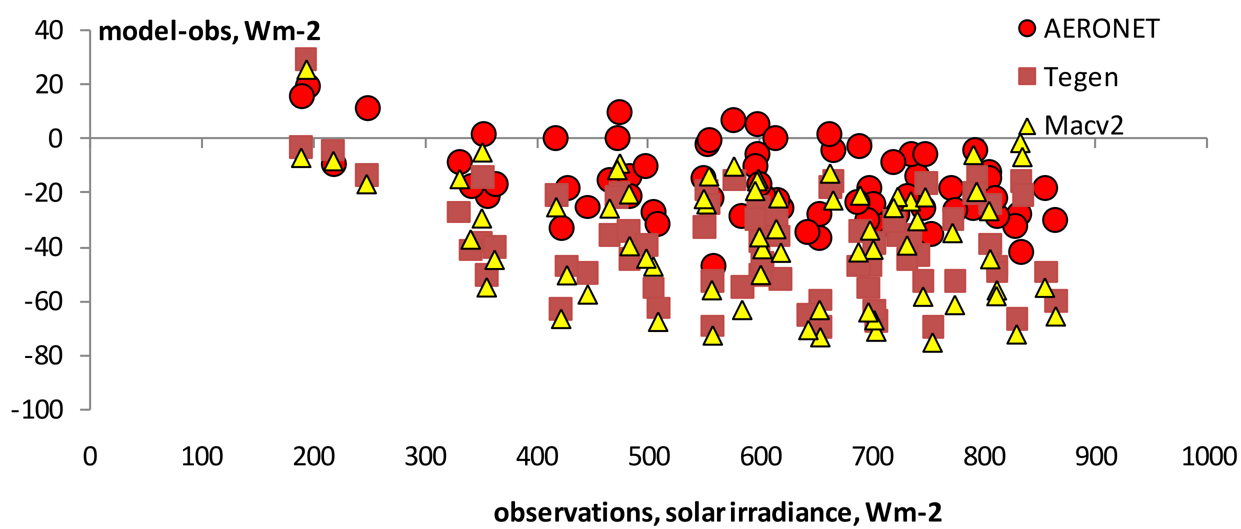
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



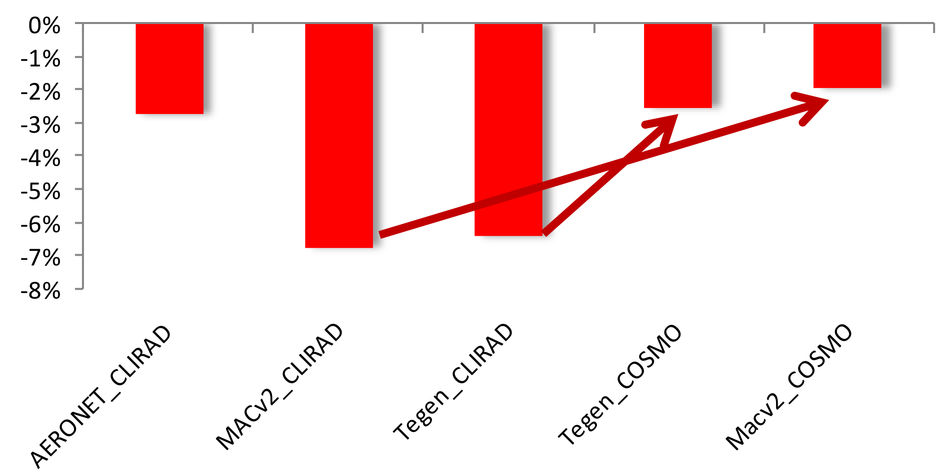
Tiksi (Russia)



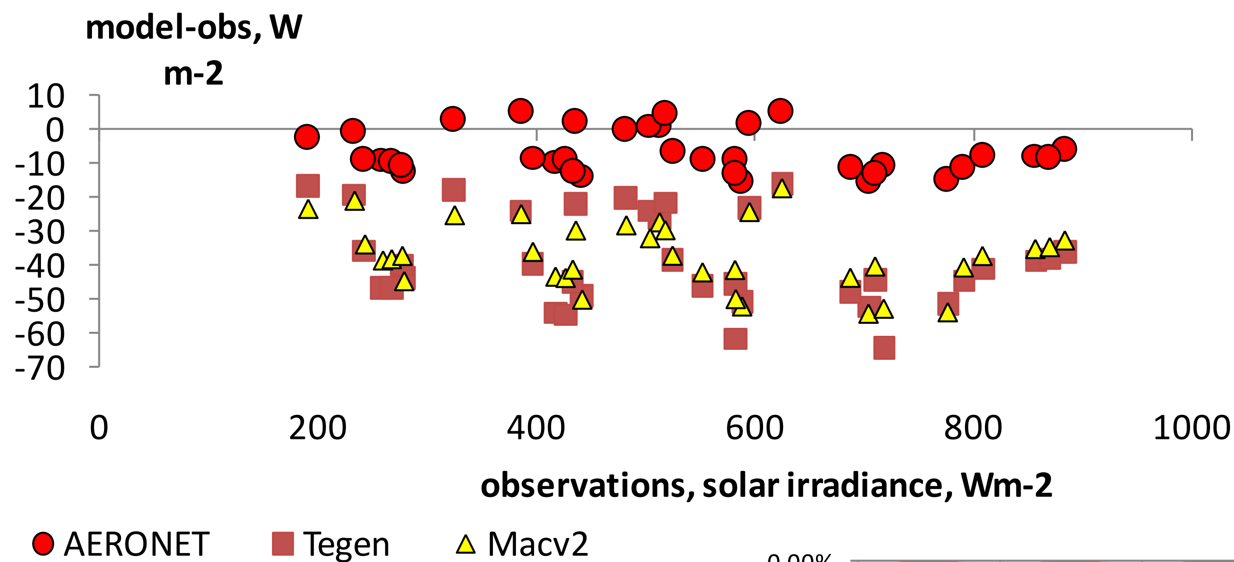
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



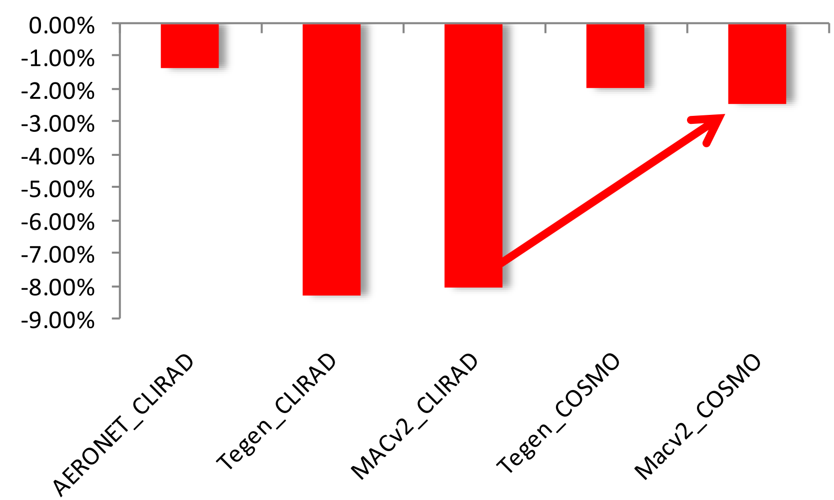
Moscow (Russia)



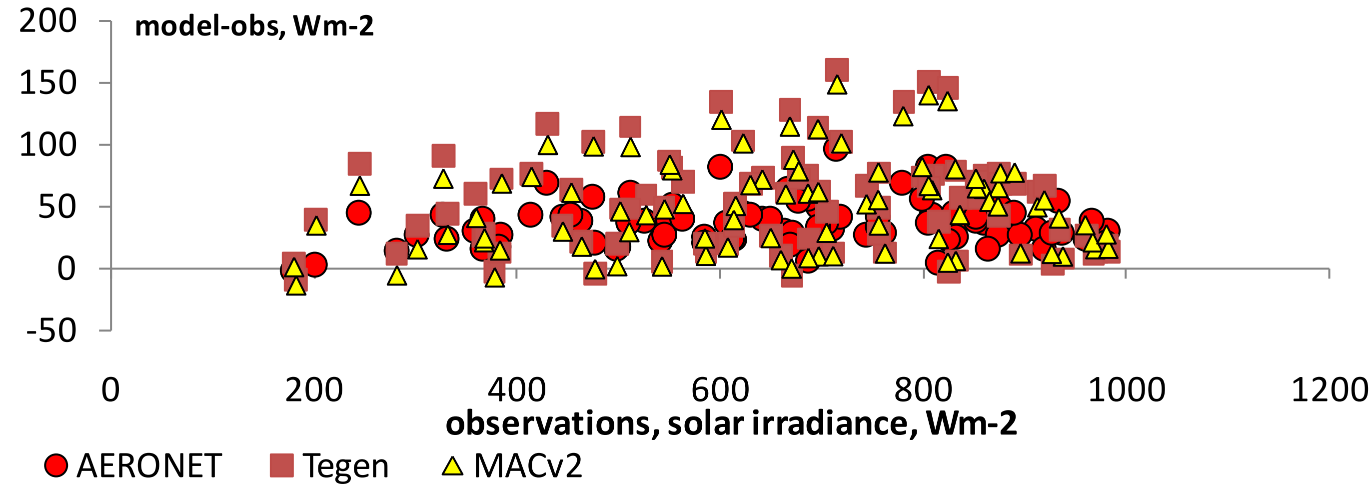
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



Lindenberg (Germany)



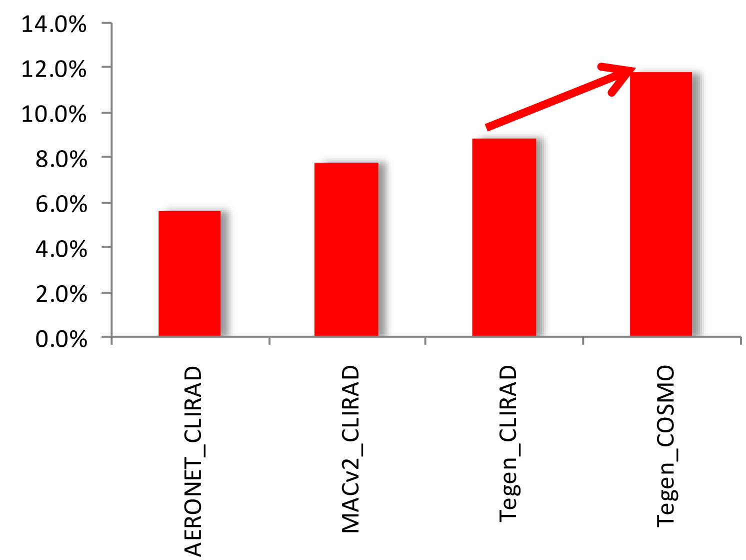
Difference in solar irradiance (model minus observations) as a function of the observed solar irradiance for different aerosol datasets



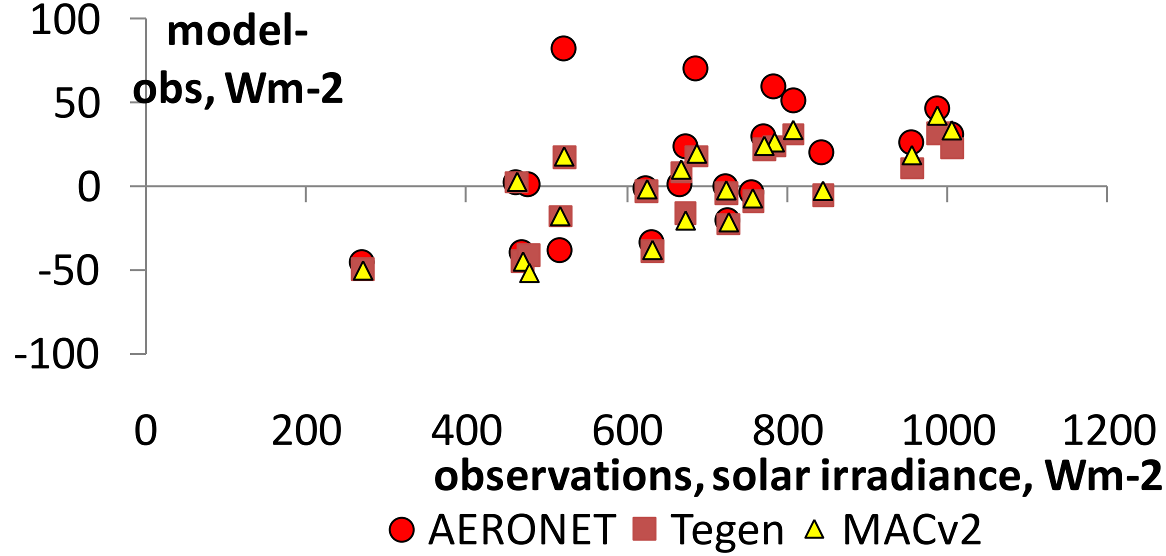
Bet-Dagan - Nes-Ziona, (dS=9km):

Bet-Dagan, standard deviation for absolute difference:

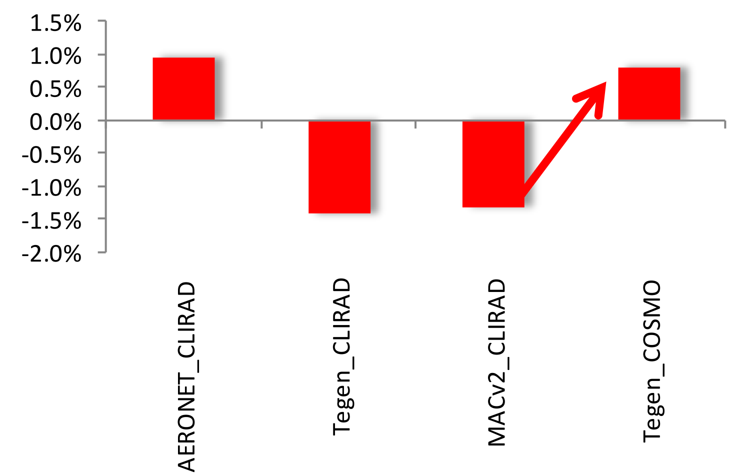
AERONET – 18 Wm-2
Macv2 – 37 Wm-2,
Tegen* – 40 Wm-2,



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

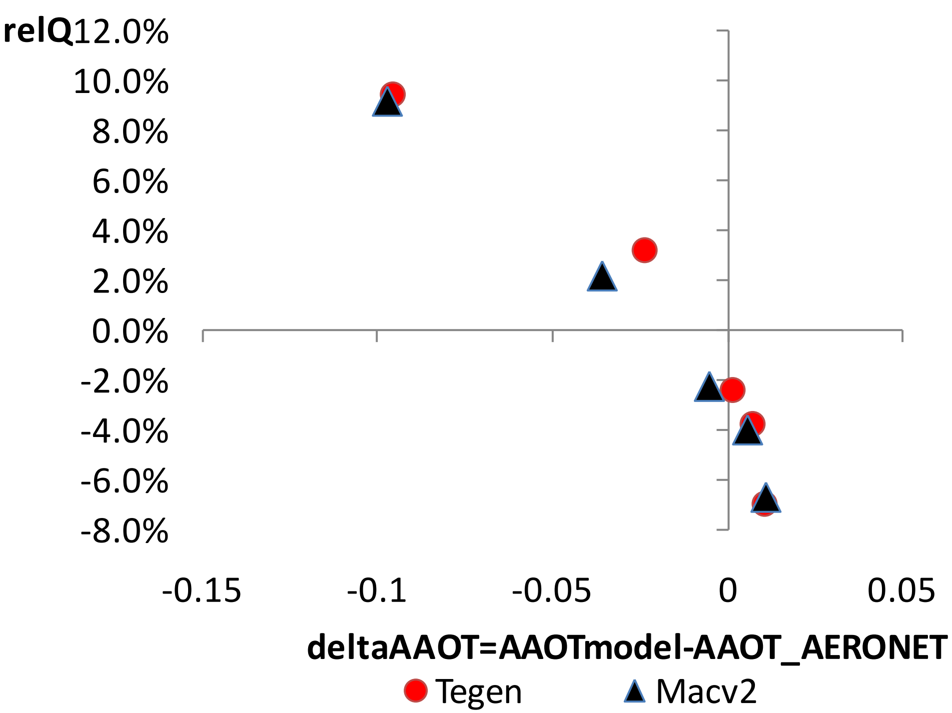
Macv2 – 26 Wm-2,

Tegen* – 29 Wm-2,

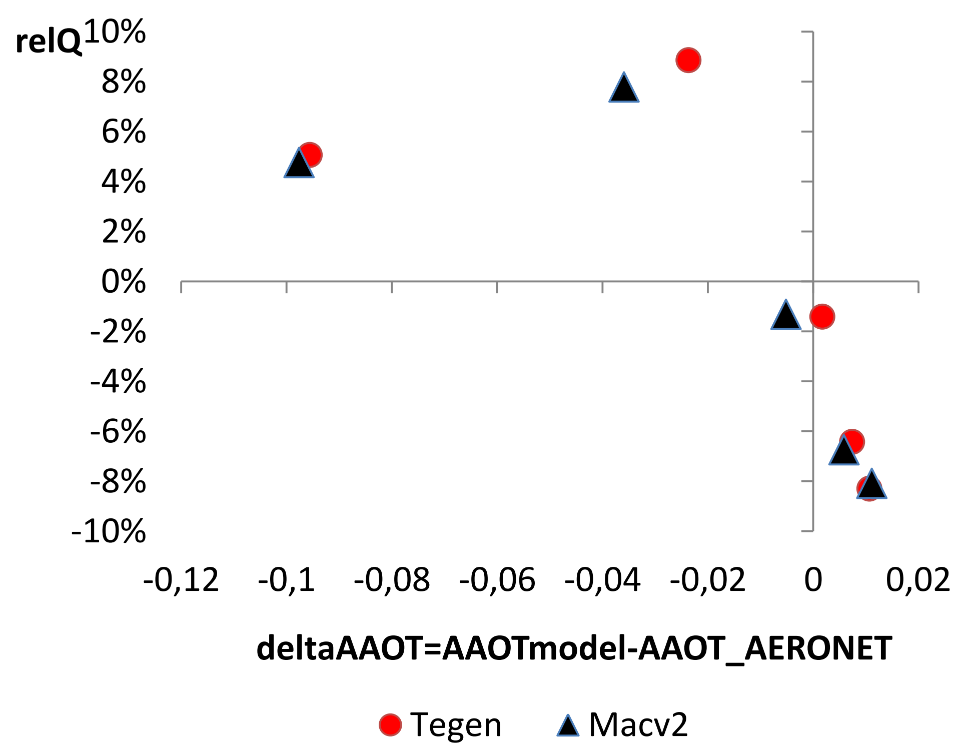
Relative difference in Q against difference in <u>absorbing</u> aerosol optical thickness (*dAAOT). All sites*

AAOT=AOT (1-SSA) at 550nm

Q model /Qmodel (AERONET),%

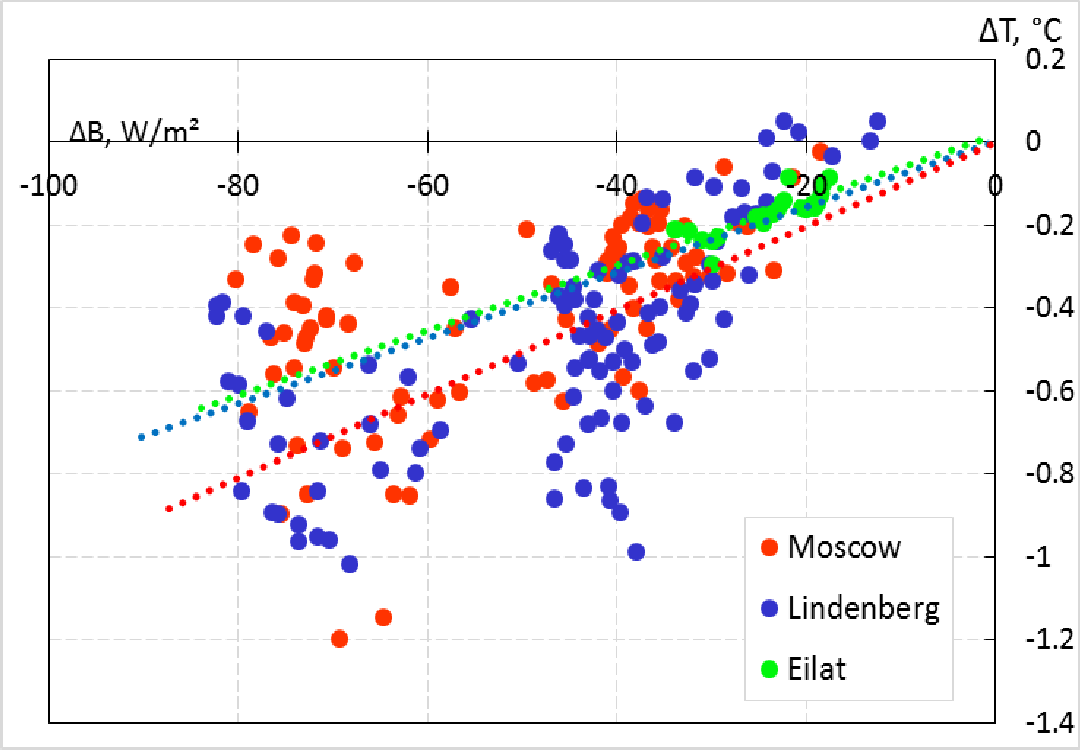


Q model /Q observations,%



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 in cloudy atmosphere

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

ı one of the most
loud and
ldwide. Unifying
an "easy-to-use"
astructure to
to the climate
ΛD. Therefore
l data have to be
ıultivariate, 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
ıtry 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 Eduction 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

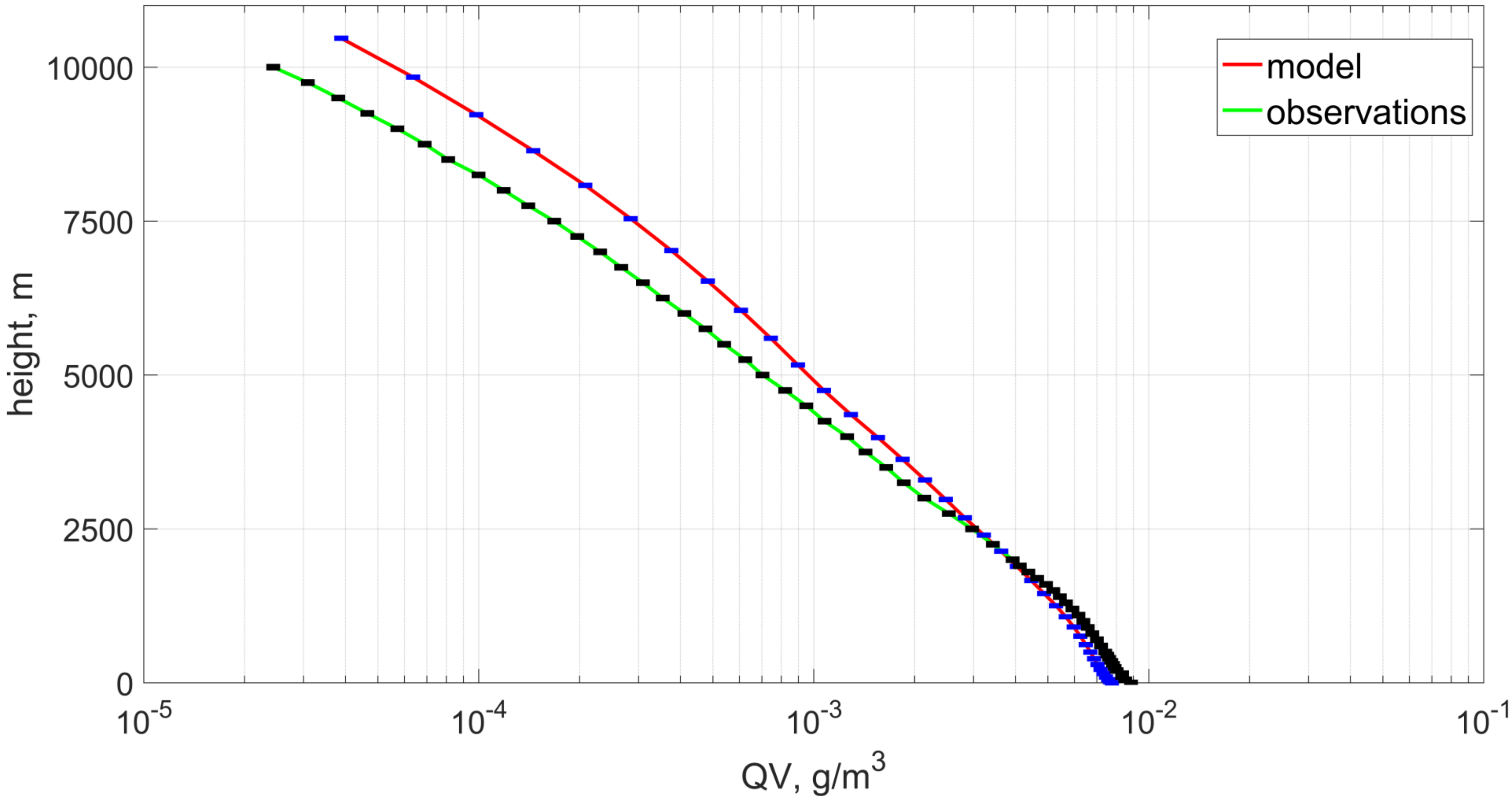
Period of analysis: March-October 2016

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

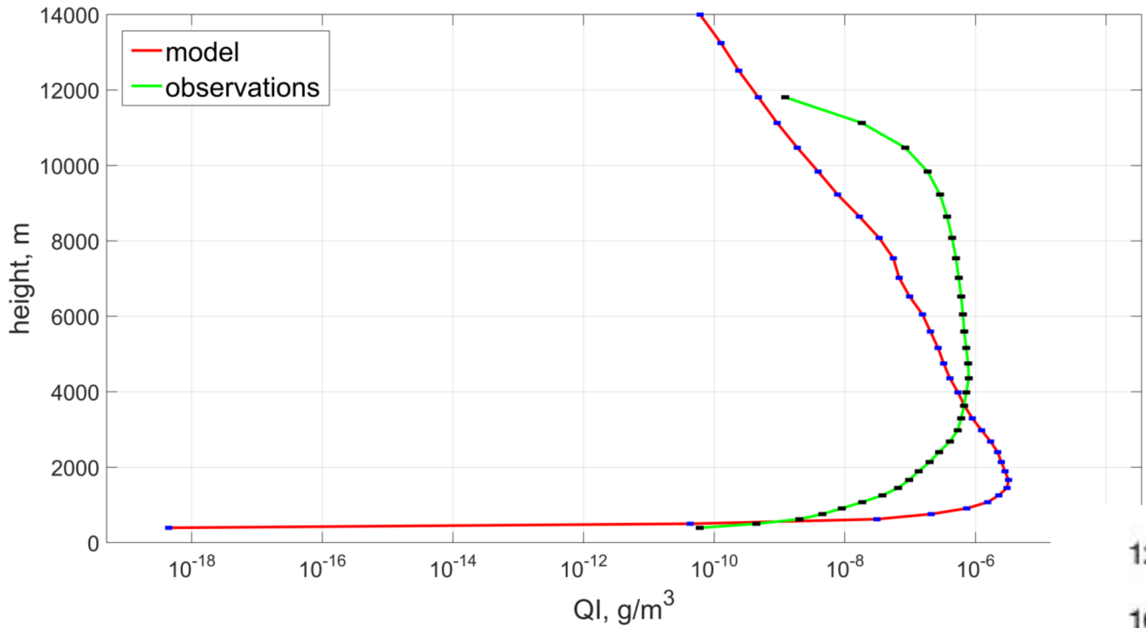
Observations point: Lindenberg

Simulation domain. Red dot indicates Lindenberg.

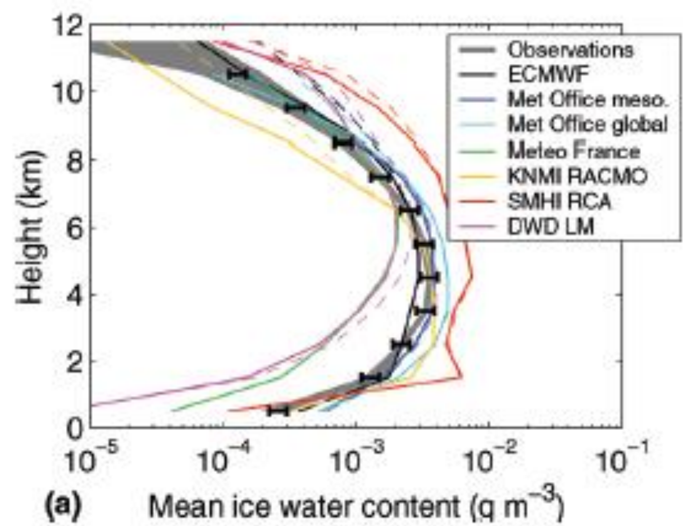
Water vapor profile from model and observations (N=19051). 2016. Error bars for observations in addition consider the 15% uncertainty of the method.



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.

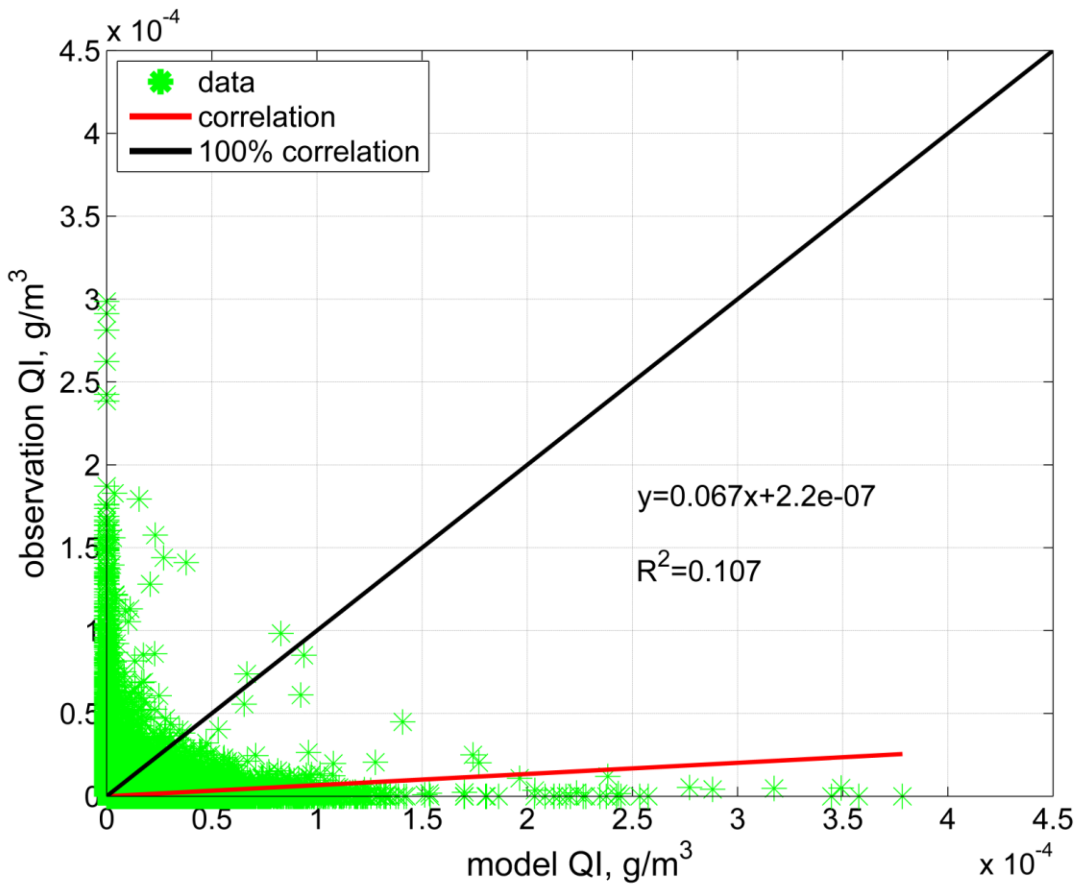


From Illingworth, 2007

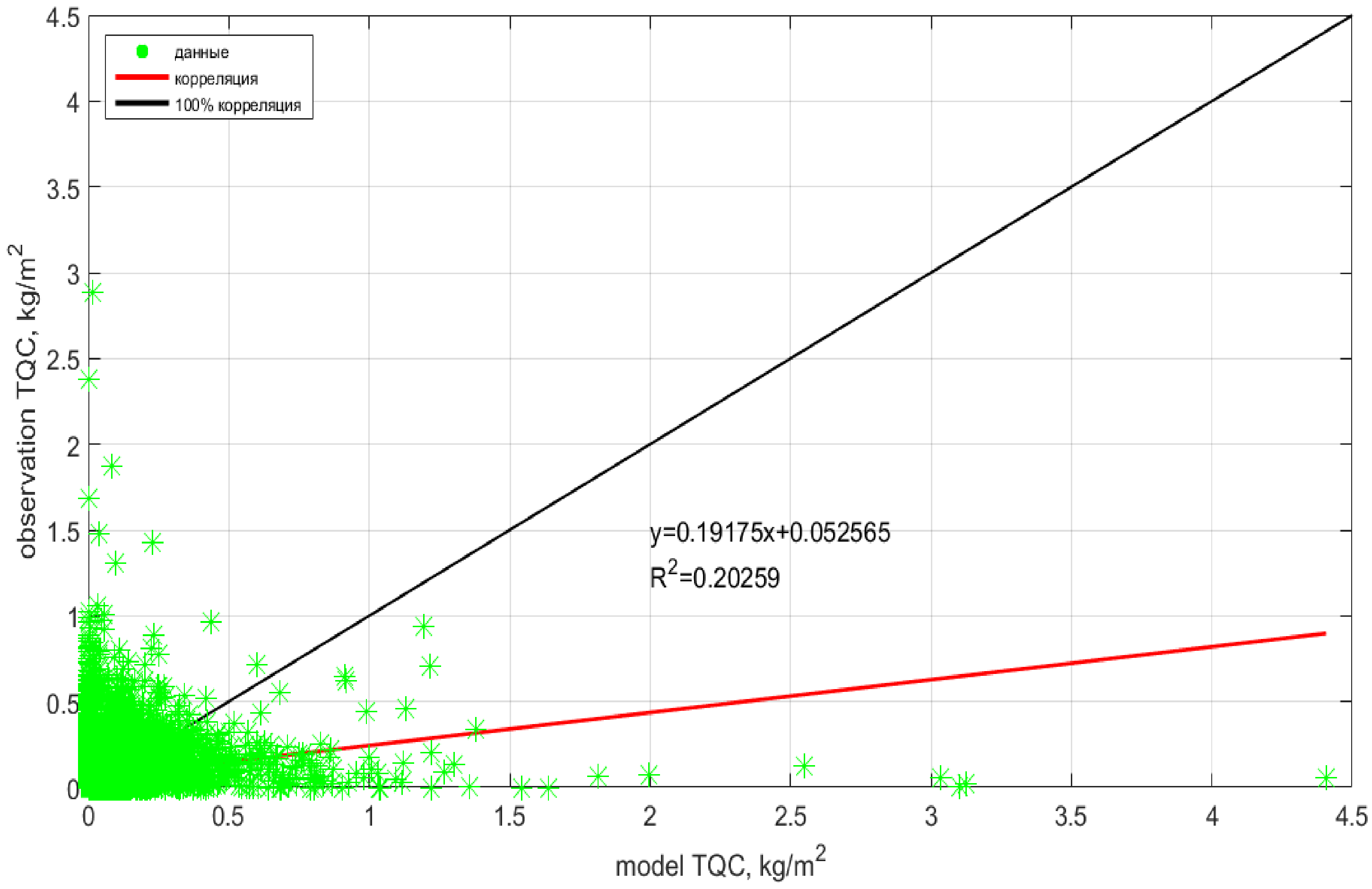


Observed versus modeled ice water content IWC in each layer. 2016. Lindenberg.

(N= 703676)

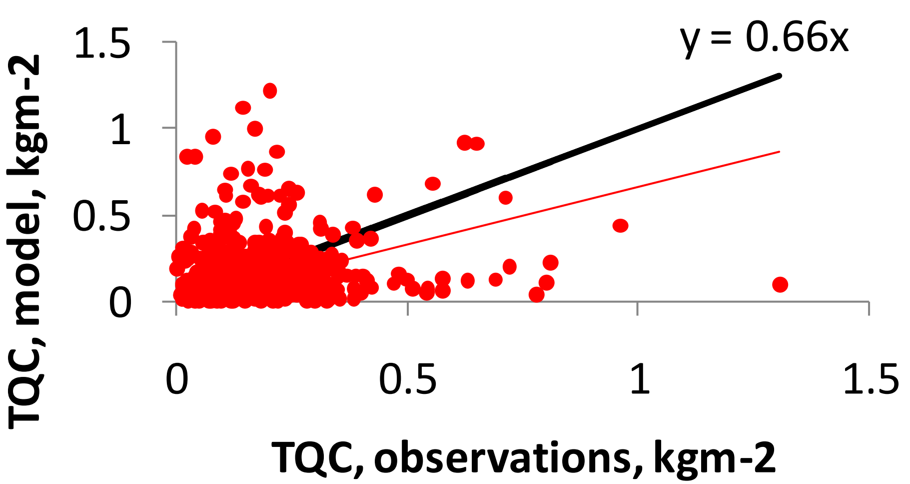


Observed versus modeled total water content integrated over th column (LWP) (kgm^{-2}). (n=19121). 2016. Lindenberg.

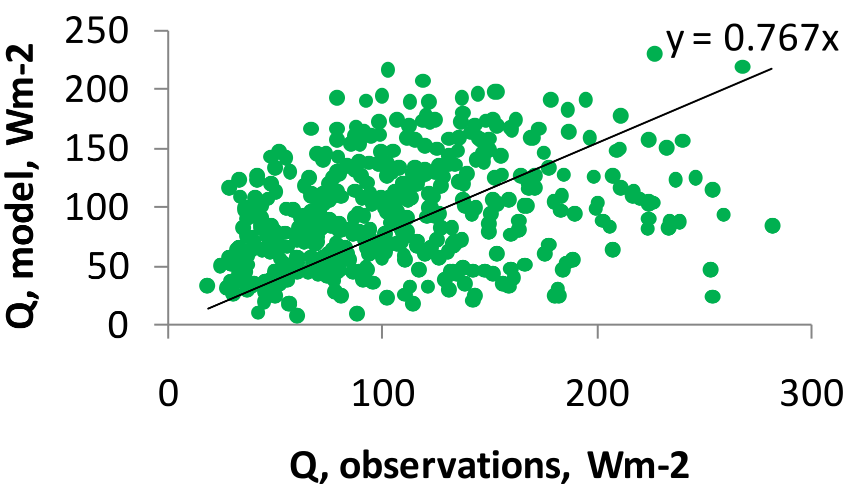


The comparisons between model versus observed total water content and model versus observed solar irradiance. All cases with non-zero data and additional threshold – no direct irradiance (S<1 Wm^{-2}) . 2016. hsun>15°. N=452.

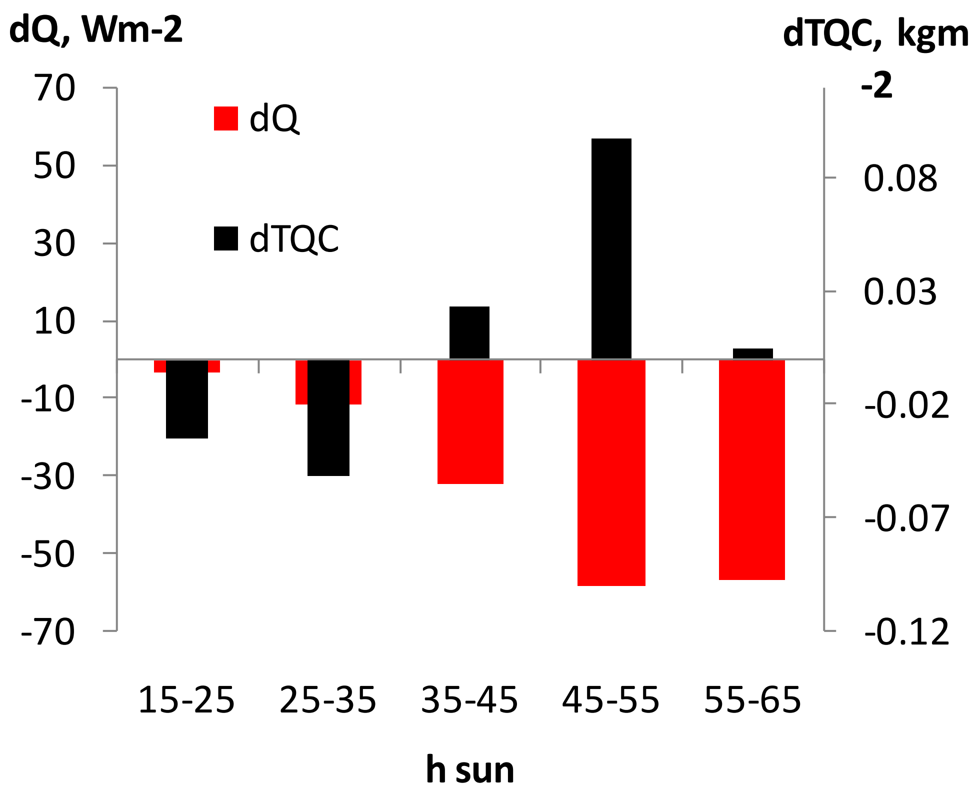
Total Water content



Solar irradiance at ground

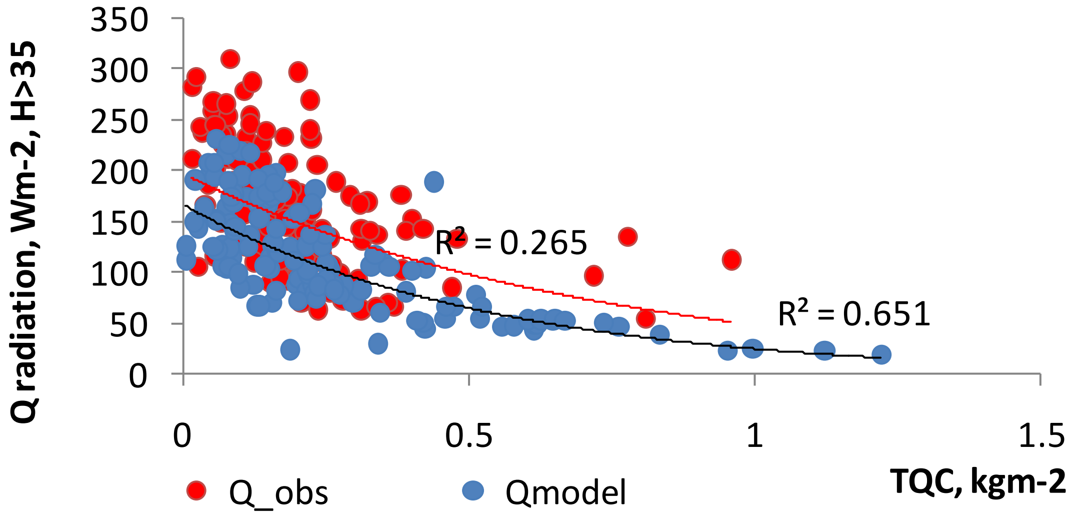


The same but for different solar elevation bins.

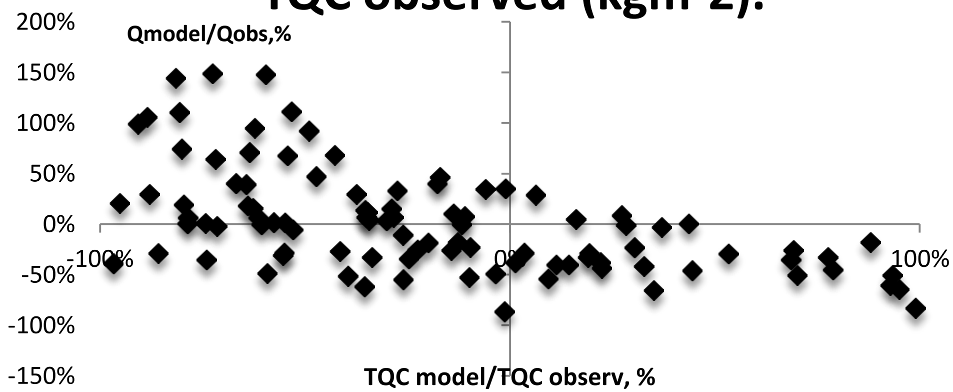


model minus observations

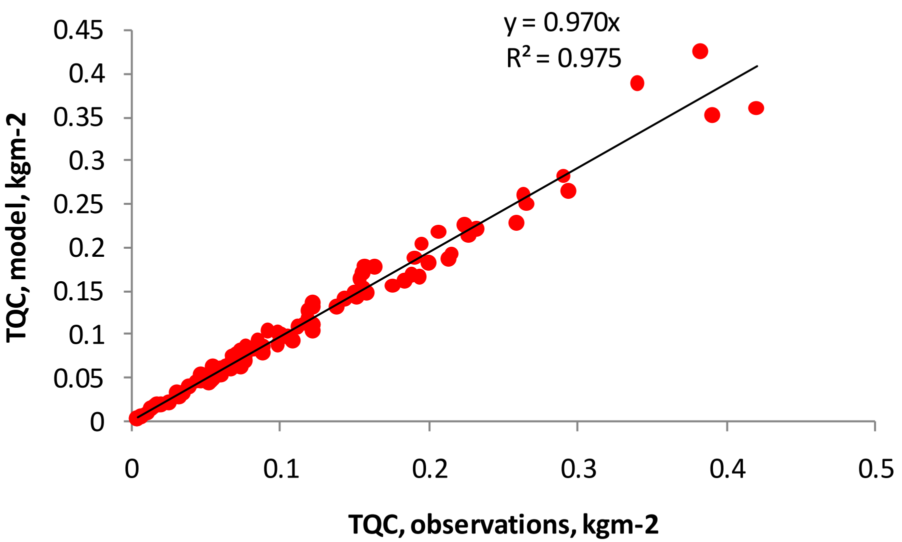
The dependence of shortwave irradiance Q at ground on Total Water Content (TQC) in the column (kgm^{-2}). Solar elevation>35°. N=145.

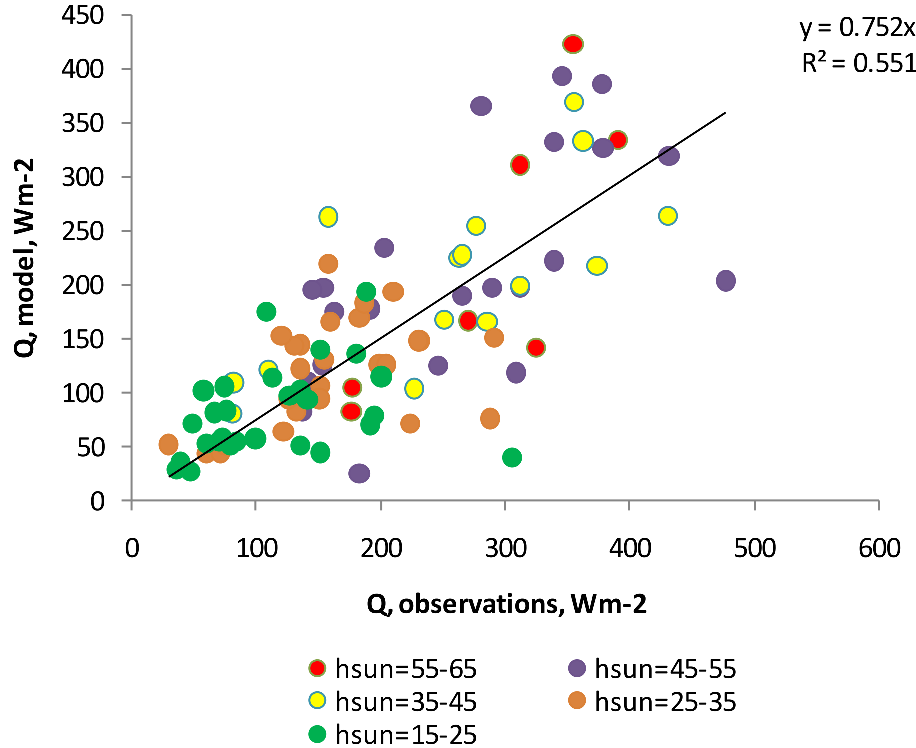


Ratio Qmodel /Qobserved as a function of ratio of TQC model / TQC observed (kgm-2).

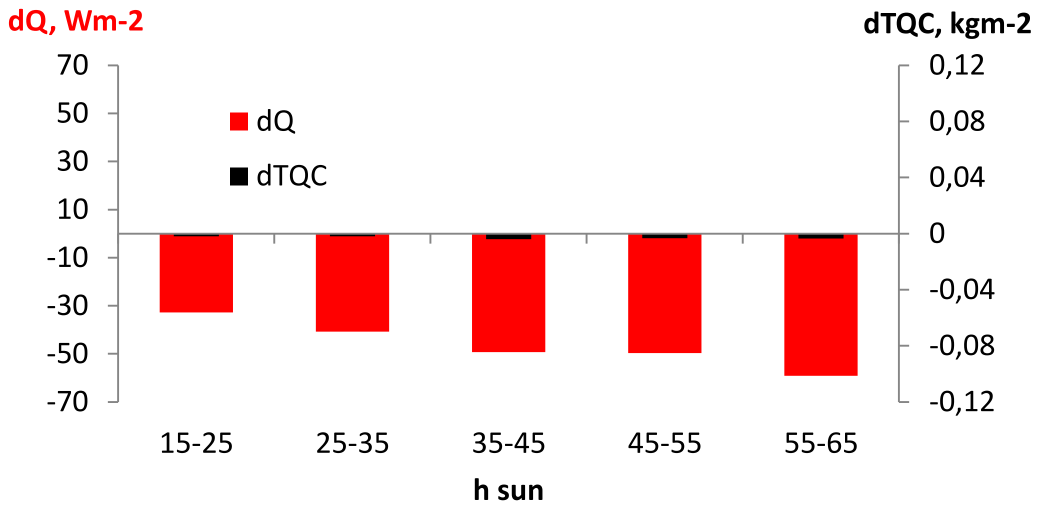


The comparisons between model versus observed total water content and solar irradiance with GOOD (±15%) agreement in water content (TQC). 2016. hsun>15°. N=99.





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

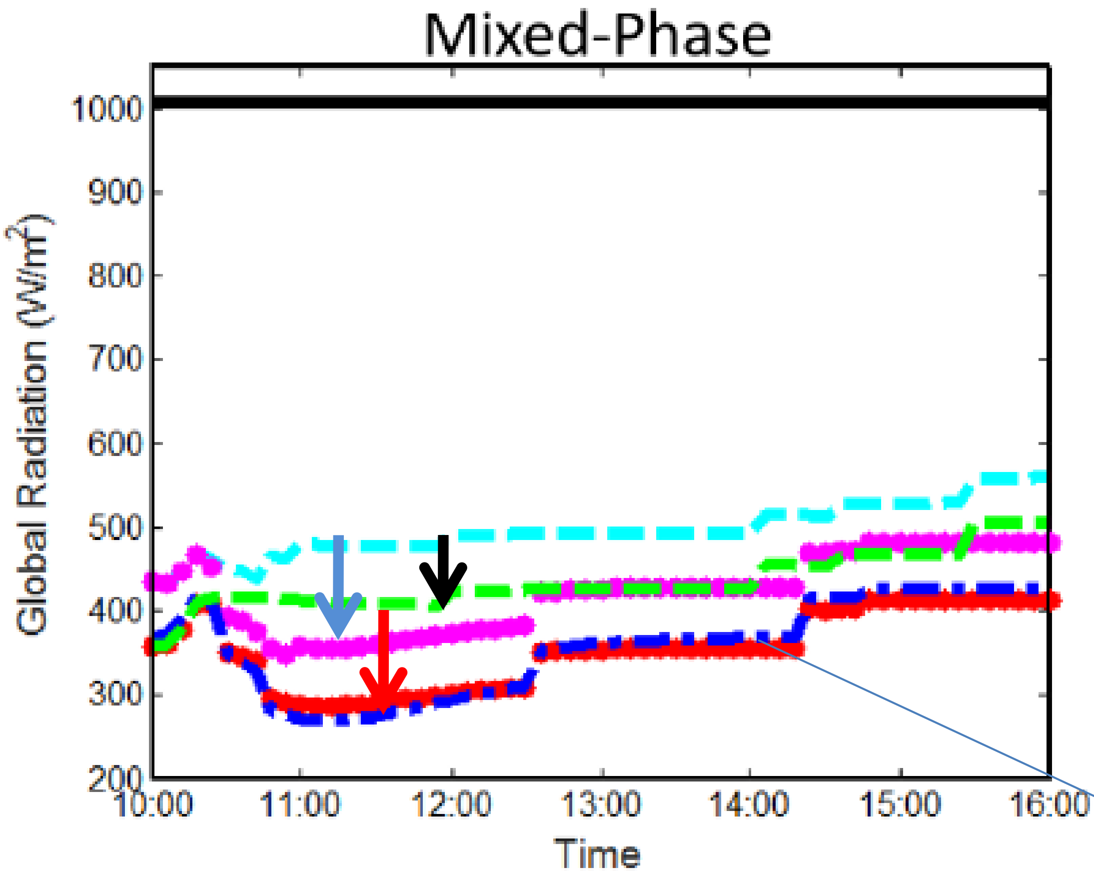
- New scheme from $T^2(RC)^2$:
  - Expl. Dependence of opt. thickn. on R_{eff} based on Hu and Stamnes (1993), spectrally remapped to RG92
  - R_{eff} is a function of qc and cloud number concentration nc and is computed as follows:
    - Grid scale clouds: qc from microphysics, nc = constant tuning 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)**

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

Model simulation of solar irradiance with different methods.



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

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

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

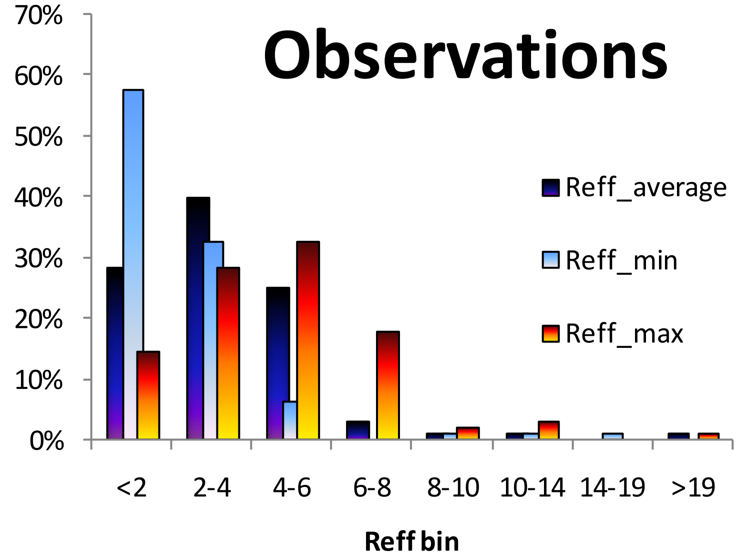
HMC Data Base

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

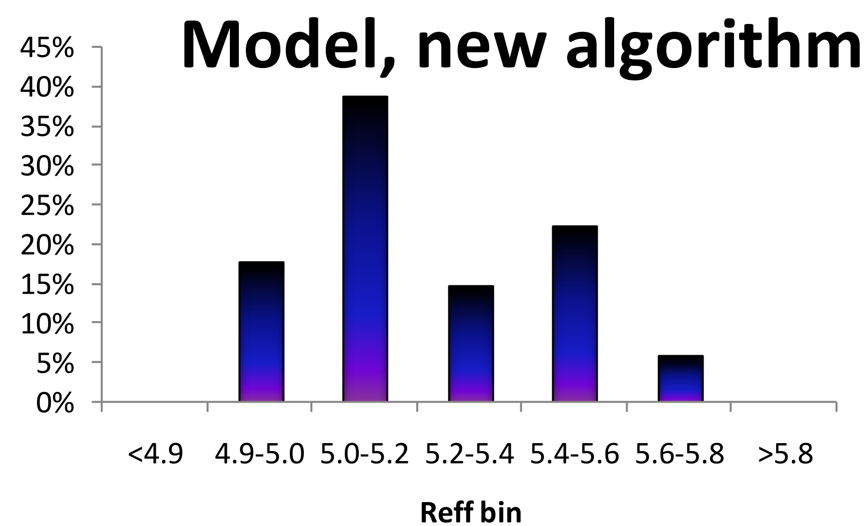
Selection criteria

- 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

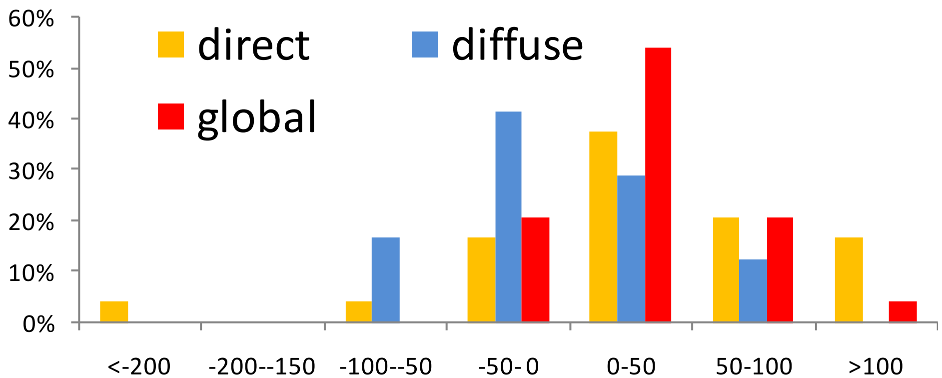


N=67

<u>Direct</u> comparisons between observations and model :

2 cases only with R_{eff}(obs)=2.3mkm and R_{eff}(mod)=5.3 mkm

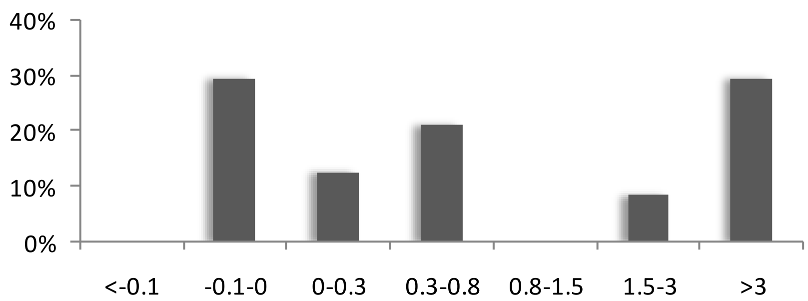
Frequency distribution of the differences between the new and old algorithm for direct, diffuse, global solar irradiance and temperature. 2014.



new minus old , solar irradiance bins, Wm-2

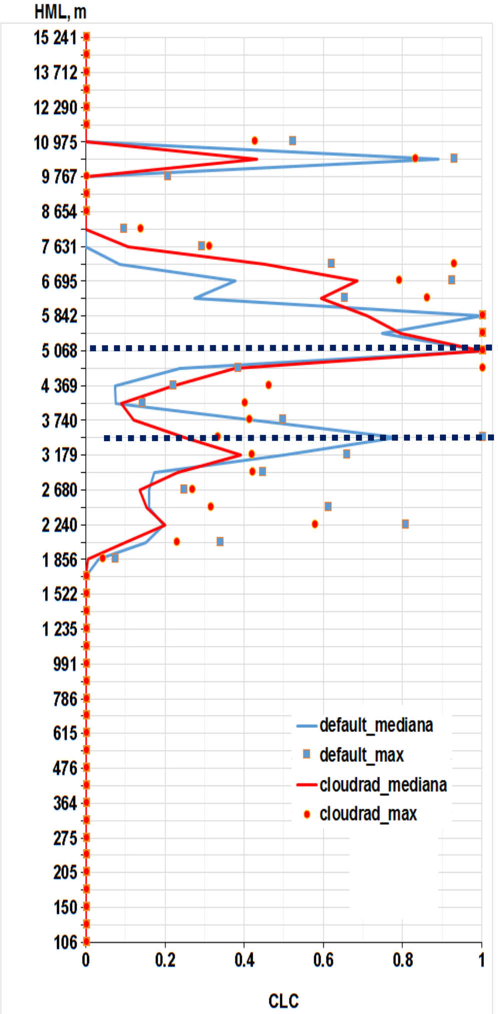
RESULTS ARE SHOWN AS NEW MINUS OLD

Temperature changes due to the new algorithm

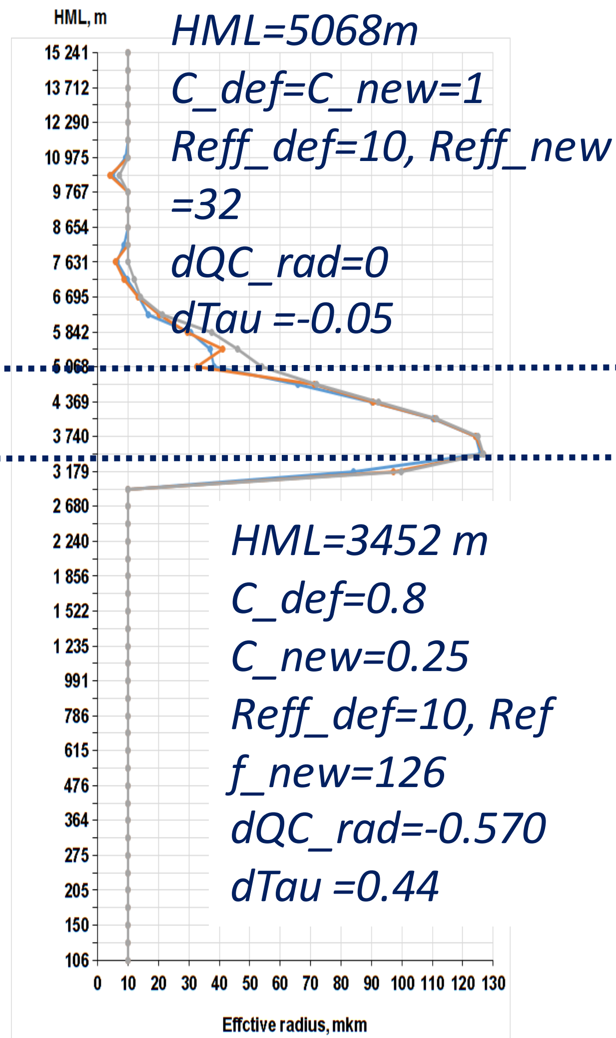


Comparison of the two cloud-radiation interaction schemes. Case study 05/04/2014.

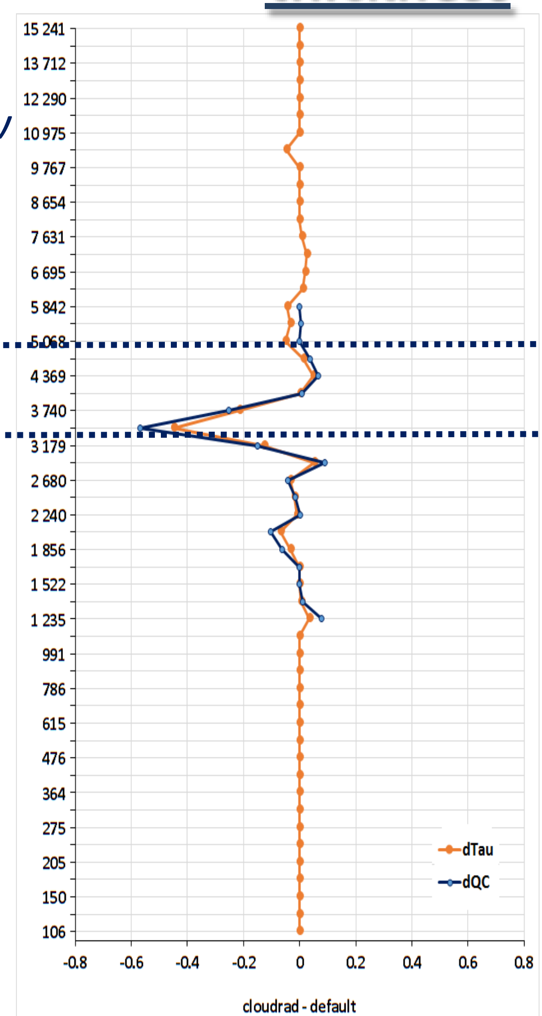
Cloud cover



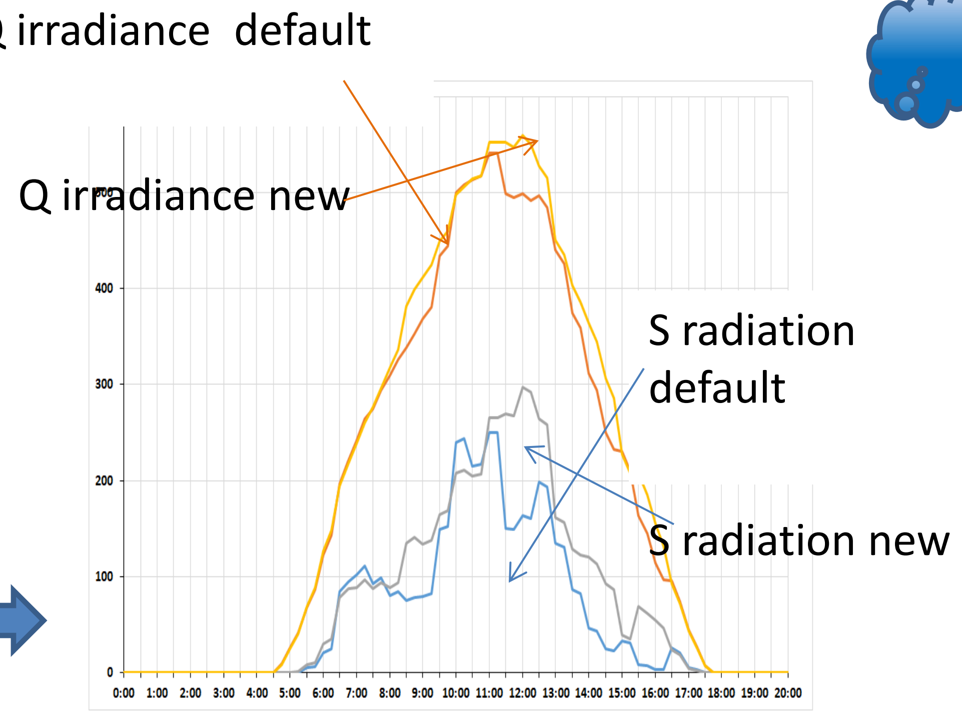
Effective radius
(new scheme only)



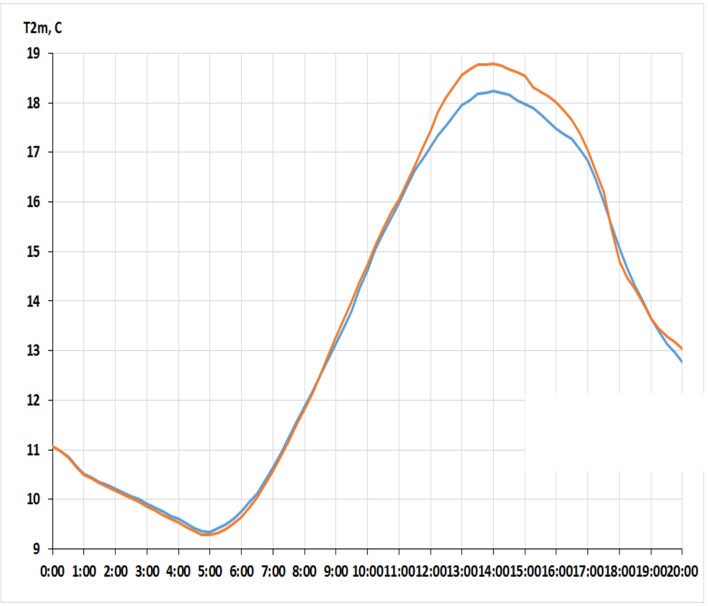
Water content and cloud optical thickness



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.

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Institutes:

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