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Aerosol direct radiative effect efficiency, aerosol optical properties and surface albedo - comparison between simulations and observations

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Aim of the study

Comparison between model simulations and observations at the surface:

- **The main parameter: the Aerosol Direct Radiative Effect Efficiency (ADREE)**
  - Attenuation of solar flux due to aerosol scattering and absorption normalized by the AOD in clear sky
  - In some publications ADREE:=N(ormalized)DRE (also other acronyms are used)
- **In addition:**
- **Aerosol optical properties**
  - Absorption AOD (AAOD) at 550 nm (and AOD 440 nm and 870 nm). SSA=1-AAOD/AOD.
- **Surface albedo**

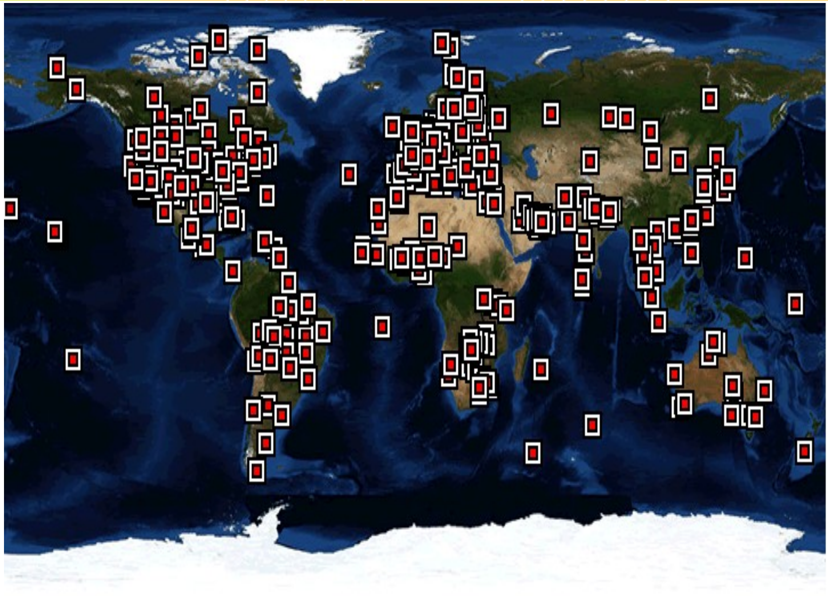
AERONET

Observations: AOD

•The AODs are collected from the Aerosol Robotic Network (AERONET) sun measurements (level 2.0)

•The AERONET also provides other aerosol optical properties, retrieved by a inversion algorithm and sun/sky measurements

- e.g. aerosol size distribution, AAOD, SSA, Asymmetry, Ångström parameter and surface albedo (albedo relies on MODIS measurements and BRDF)



Sun photometer (Cimel) measuring in Kuopio site Finland June 2008

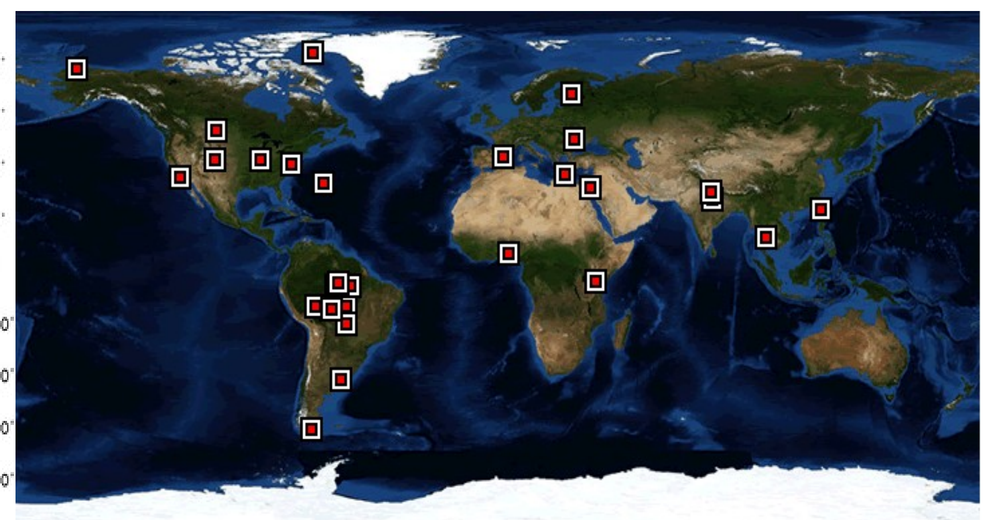
Observations: solar flux

•Solar fluxes are from Solar Radiation Network (SolRadNet) and Baseline Surface Radiation Network (BSRN)

•Solar fluxes are measured by pyranometers (broadband flux 310 – 2800 nm) with an accuracy of ±2%

Pyranometer (Kipp & Zonen, CMP-21)

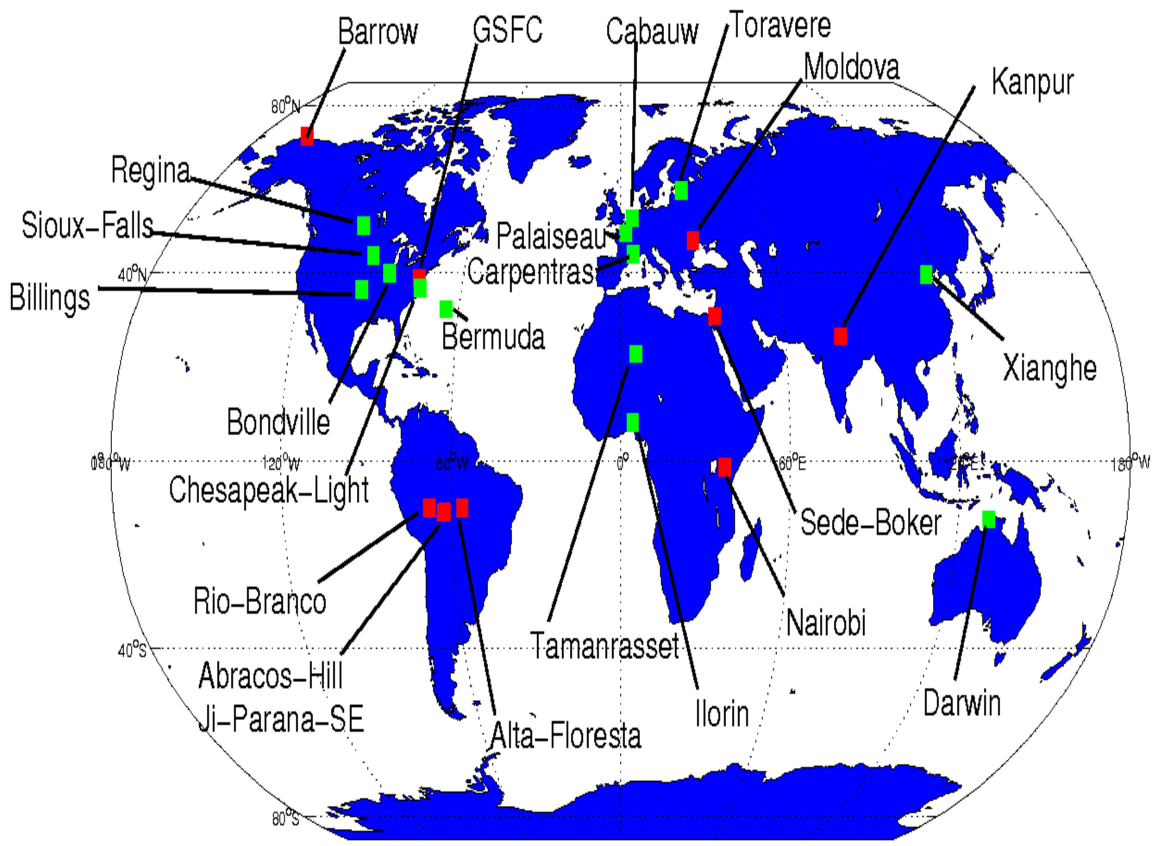
BSRN



SolRadNet

Stations of the study

- Totally over 20 surface sites where the AOD (AERONET level 2.0 sun) and solar flux observations are available
- A good coverage of different regions (different aerosol particles and also surface properties)
- Red squares are indicating SolRadNet and green squares BSRN stations



Observation based method

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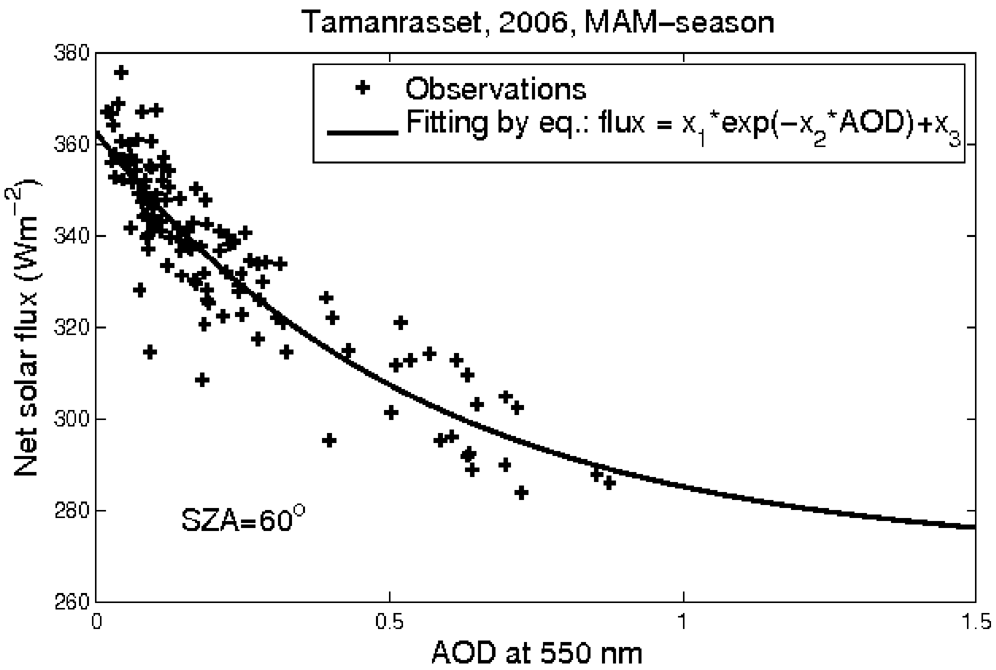
- The observation based ADREE is calculated with regressions using solar flux and the AOD observations (***figure***)
- Regression is a function of the AOD
- Accuracy of the method is ±5% (e.g. [Satheesh and Ramanathan, 2000])
- The observation based results are divided into two quality classes (1,2*) using using statistical parameters as thresholds
- ***-** A change of AOD observations is large enough [below 0.1 to over 0.3] **(1, 2)** and - coefficient of determination R^2 between estimated and measured fluxes>0.75 (=correlation>0.87) **(1)**



Solar fluxes and AODs (at Solar Zenith Angle=60°) with a regression. Data are from North-Africa, Tamanrasset station in 2006 Mar-May-season.

Example: net solar flux at the AOD=0.5 is ~305 Wm^{-2} and at the AOD=0 ~360 Wm^{-2}, thus the $ADREE_{AOD=0.5}=(305\ Wm^{-2}-360\ Wm^{-2})/0.5=-110\ Wm^{-2}$.

Model data

- **In the following slides are simulations from models: BCC-AGCM2.0.1, CAM4-Oslo, GMI, HadGEM2-ES, OsloCTM2 and SPRINTARS-v384 compared with observation based results**
- **This study extends later on by models ECHAM, MPIHAM, GISS MATRIX, GISS modelE, CAM5 and others (hopefully!).**
  - Required fields: **RSUS (CTRL), RSDS (CTRL), RSDSCS (CTRL and ZERO), OD550AER** and if possible ABS550AER, OD440AER and OD870AER
    - **ADREE=(1-Albedo)*(ADRE)/OD550AER**
    - **Albedo=RSUS/RSDS, ADRE=RSDSCS(CTRL)-RSDSCS(ZERO)**
    - RSU(D)S:=shortwave up(down)welling surface flux clear sky (no clouds)
    - RSDSCS:=shortwave downwelling surface flux clear sky (ZERO stands for sky without aerosols)
    - OD550AER:=AOD at 550 nm and ABS550AER:=AAOD at 550 nm

Introduction to results

- **In the following slides results shown are preliminary:**
- **Before submission of this study to a journal:**
  - More models are included in the near future
  - Probably some updates of fields by models

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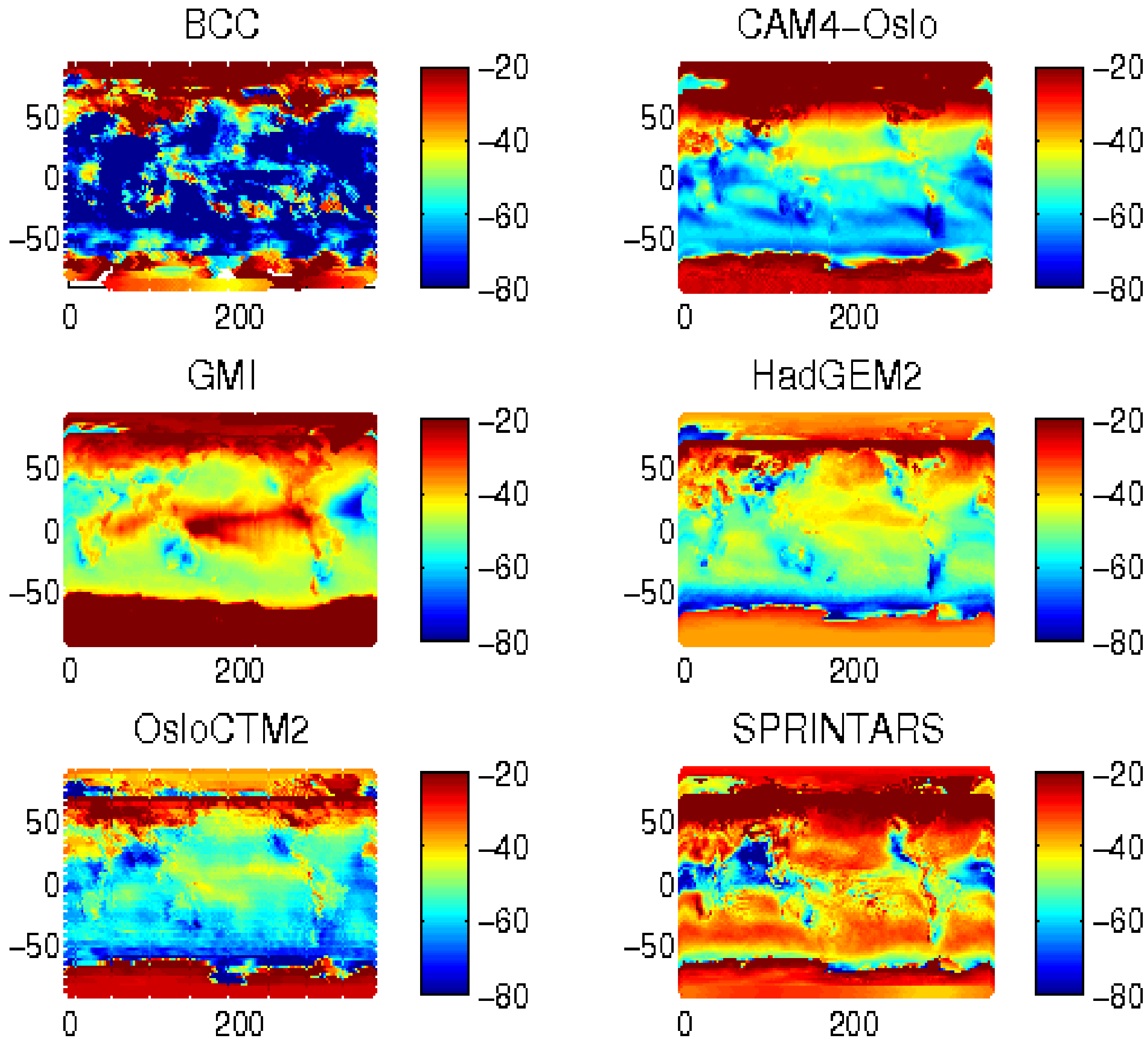
Results - models

- The weakest ADREE mainly at the glaciers for the all models due to the large albedo
- Visible differences between the models
- Totally some differences in magnitudes, but regional changes of the simulations are in a better agreement



The annual global ADREE in 2006 at the surface simulated by the six models. Simulation of CAM4-Oslo is averaged over few years, not only 2006. Units in Wm^{-2}.

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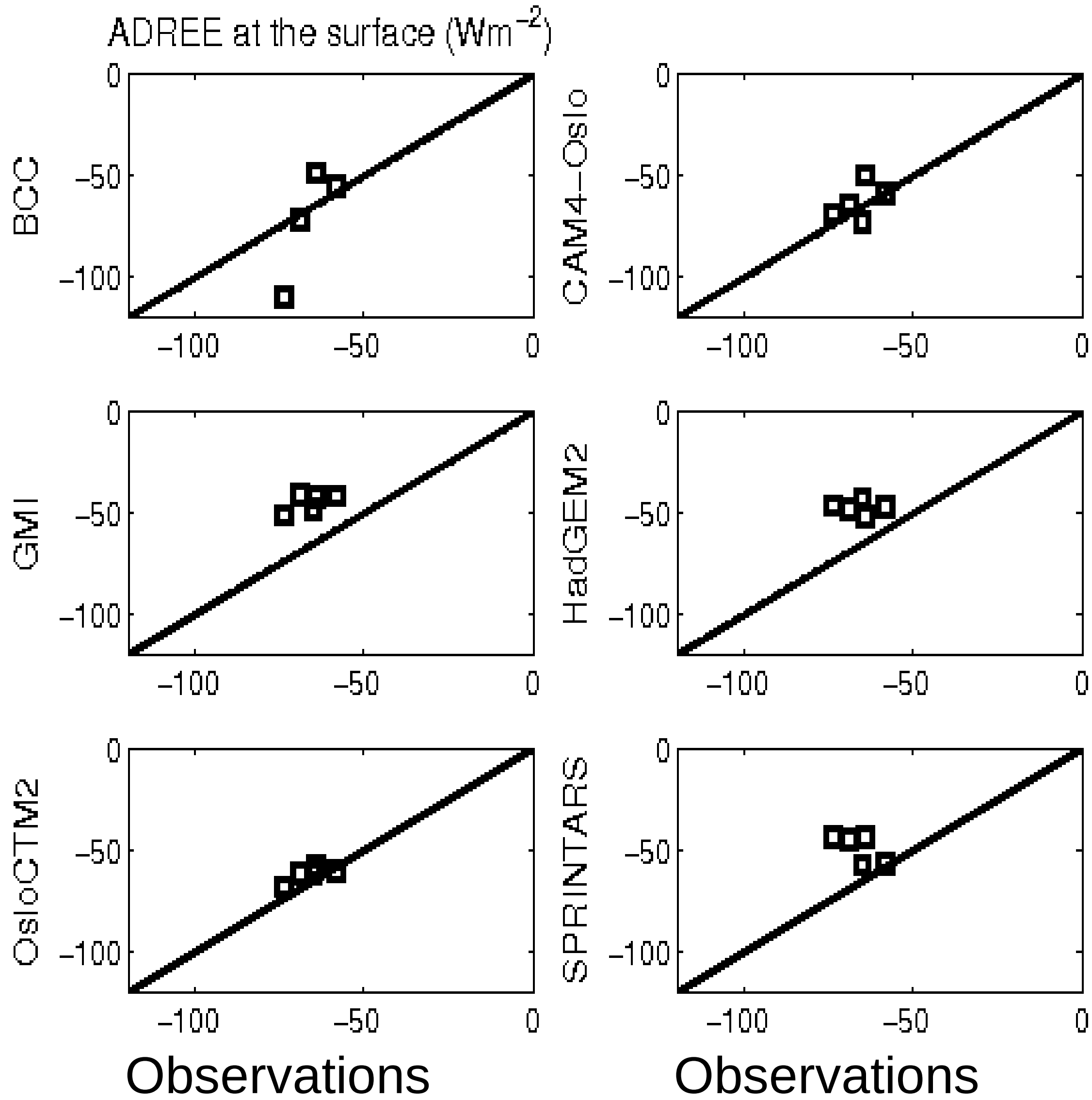
Results

- Seasonal average ADREE for different stations (figure)

- A good agreement between CAM4-Oslo, OsloCTM2 and observation based results, but otherwise some discrepancies: mainly models underestimate the ADREE compared with observations

- Here the observation based results satisfied all thresholds in data-analysis (class 1)



In the vertical axes: simulation by models, the horizontal axes: observation based method.

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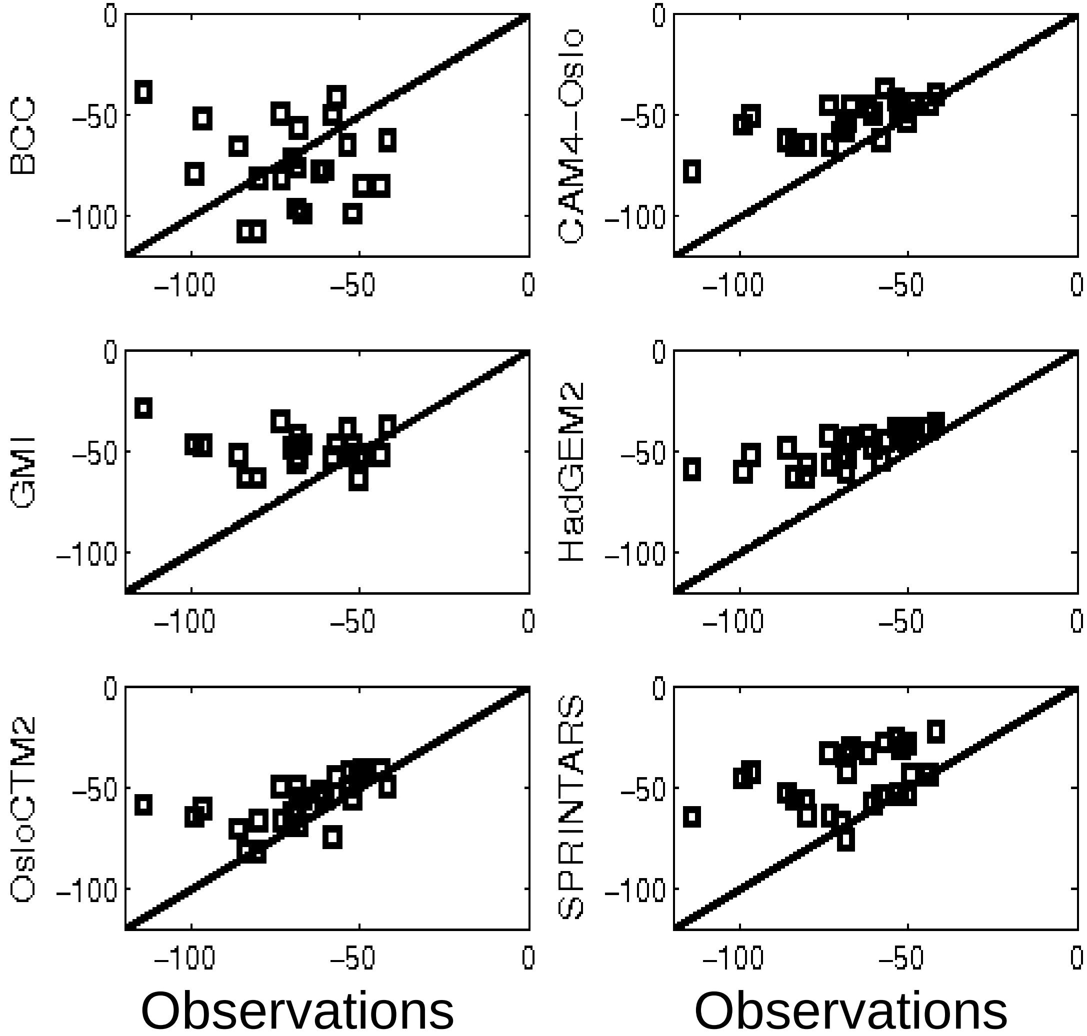
Results

- The results with reduced requirements in data-analysis (class 2)
- Observation based method provided the larger ADREE than GMI, HadGEM2 and SPRINTARS, but slightly weaker than BCC
- CAM4-Oslo and OsloCTM2 are closer with the observation based results
- Need more analysis magnitude below -80 Wm^{-2} (although they are only poorer class results): clear discrepancy between observation based results and model simulations



In the vertical axes: simulation by models, the horizontal axes: observation based method.

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Results

- Generally the models provided 10% weaker ADREE
- The seasonal averaged ADREE for stations varies from -45 to -85 Wm^{-2} and the average result based on observation is -66 Wm^{-2}

	Average	STD	Corrcoef	MAD
BCC	-84.7	38.4	0.46	26.2
CAM4-Oslo	-62.8	9	0.46	6.6
GMI	-44.6	4.6	0.63	21.5
HadGEM2	-47	3	-0.12	19.1
OsloCTM2	-61.7	3.7	0.79	5.1
SPRINTARS	-49.2	7	-0.67	16.9
Observations	-66	5.7		

Average and standard deviation of the ADREE in addition of the correlation coefficient and Mean Absolute Deviation. Units in Wm^{-2}, but corrcoef.

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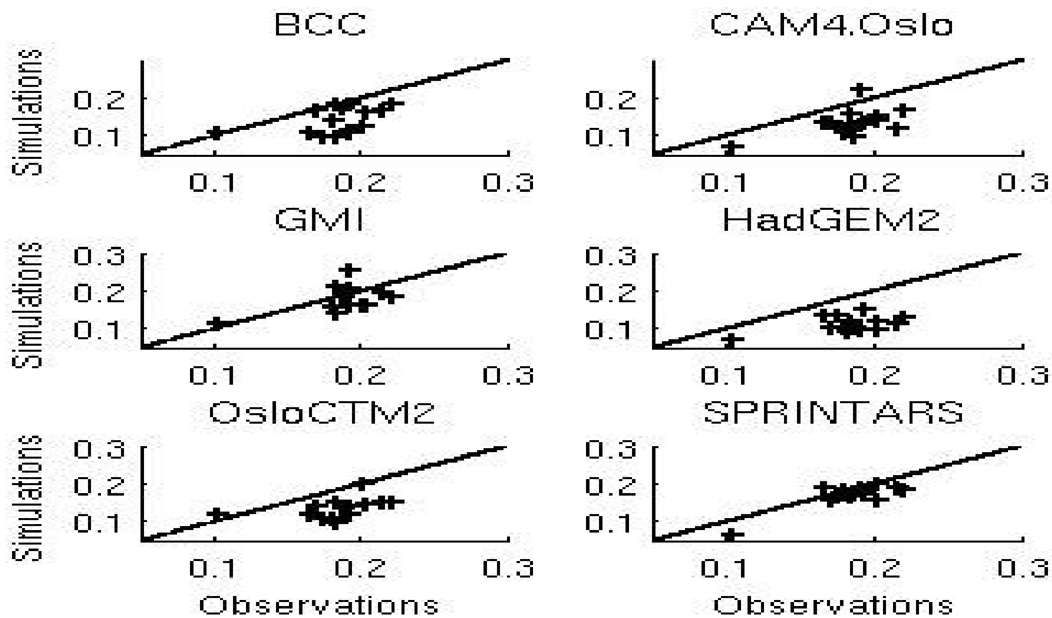
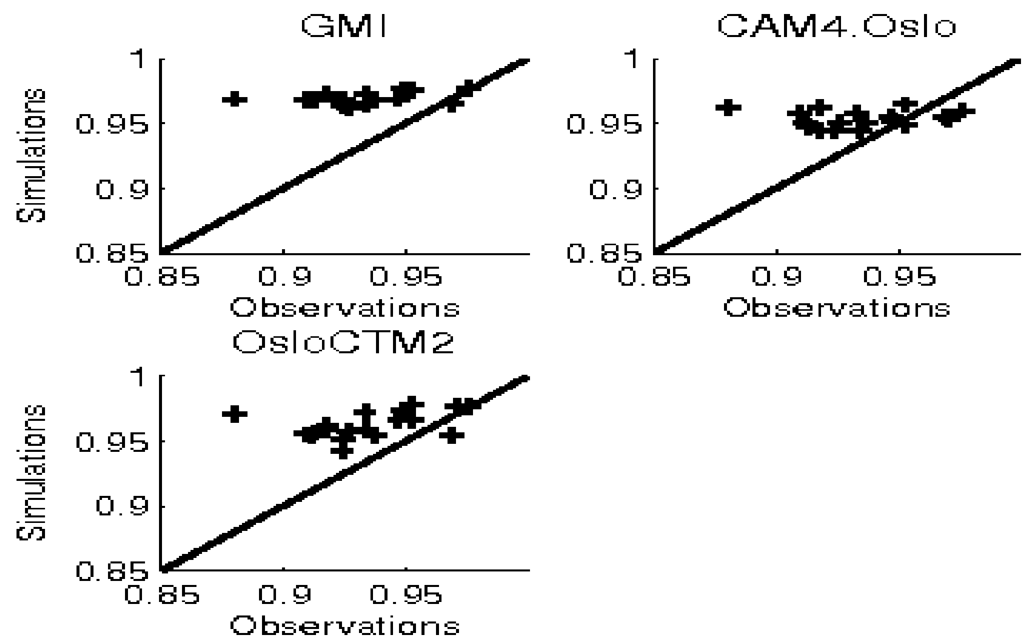
Results

- Here preliminary surface albedo and the SSA at 550 nm comparison
- The AERONET sky level 2.0 data
- The SSA is overestimated by models, but also albedo contains some discrepancy



Albedo: in the vertical axes simulation by models, the horizontal axes AERONET observations.



SSA at 550 nm: in the vertical axes simulation by models, the horizontal axes AERONET observations.

In the near future – aerosol optical properties

- Improvement of data selection: the AERONET sky level 2.0 data are here used for the SSA (level 2.0 data are limited for example to large AODs), but the goal is to use the AERONET sky level 1.5 data using surface solar flux measurements as a criterion for data selection
  - Flux measurements are very accurate and good for selection of data; aerosol optical properties are closer with real values if flux simulations based on these are in a good agreement with measured ones*
  - On the other hand: for the AOD near zero, the SSA has a large uncertainty → a bit problematic, but possible to solve

***this is valid without some compensations, for example underestimated albedo and overestimated SSA possibly produce the same flux and furthermore the same ADREE as in real case**

Conclusions

- **Generally observation based method provides stronger aerosol direct radiative effect efficiency than models**
- **The best candidate to explain this is the SSA**
  - Models overestimate the SSA providing weaker ADREE
- **So far two models simulated the ADREE closer with the observation based results than the other models**
- **This study will be extended with more models and submission of this paper will be in the next year**

Acknowledgements

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THANK YOU!

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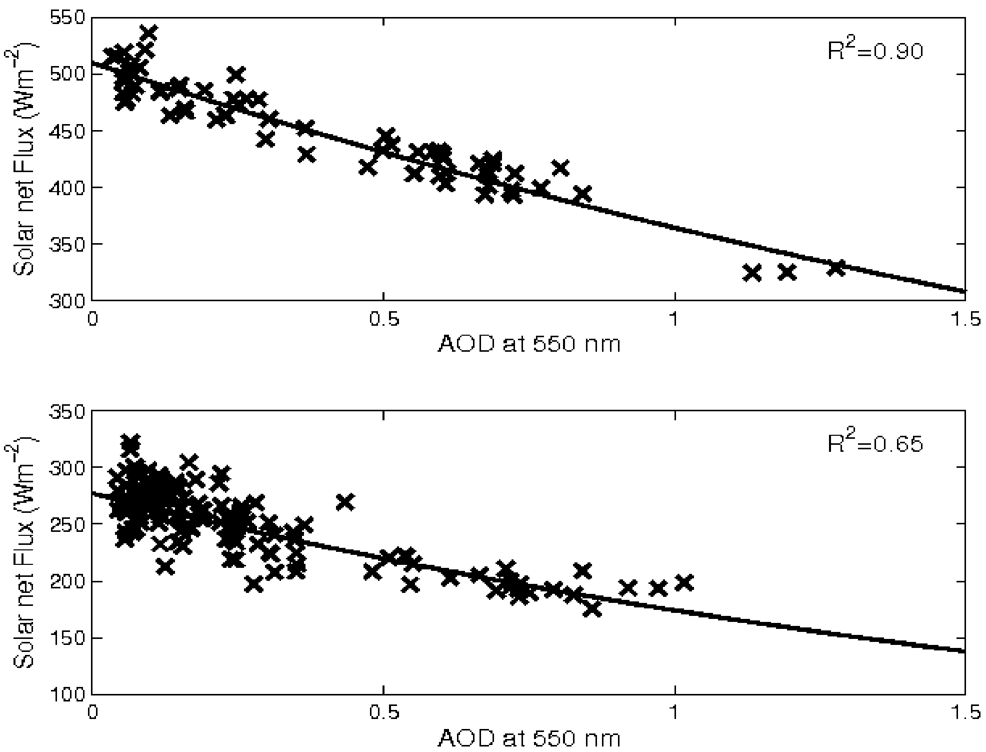
Quality classification, extra slide

- Quality classification in the regression method; class 1, class 2:
- Class 2: A change of AOD observations large enough
  - AOD<0.1: flux with no aerosols is accurate
  - AOD>0.3: regression is possible to fit
- Class 1: the previous threshold and in addition coefficient of determination *R^2* between estimated and measured fluxes>0.75 (=correlation>0.87)



The uppermost regression passed into class 1, but the undermost is not due to the class 1 criterion