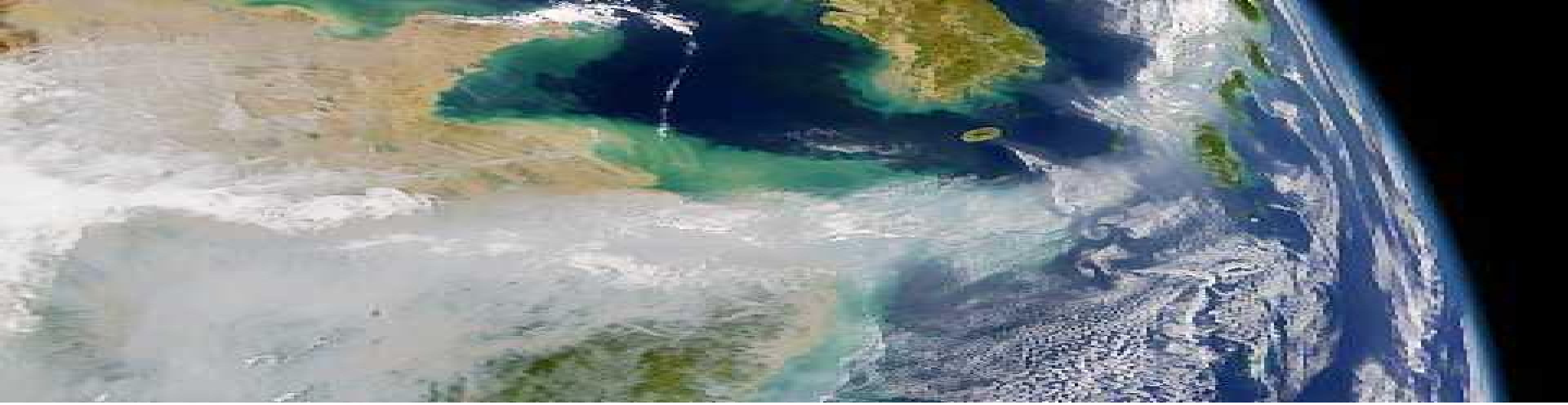

On the use of satellite remote sensing to determine direct aerosol radiative effect over land : A case study over China

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Outline

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- **Method and the study area**
- **Results**
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  - ADRE over China
  - Aerosol-free flux from the satellite method and comparison with model results
  - Cases of positive ADRE

Introduction and motivation for the study

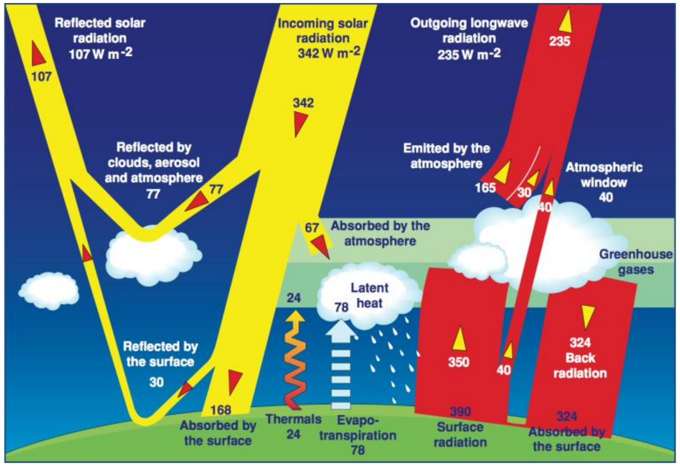
Aerosol direct SW radiative effect ADRE

- At the top of the atmosphere:

$$ADRE_{TOA} = F^{\uparrow}_{TOA,no\_aer} - F^{\uparrow}_{TOA,aer}$$

$ADRE_{TOA} < 0$, *cooling*

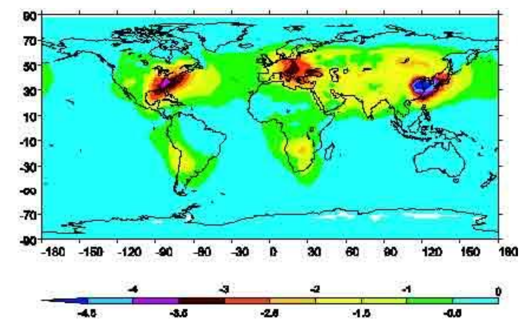
$ADRE_{TOA} > 0$, *warming*



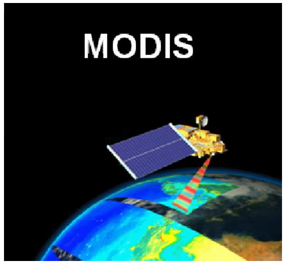
- Contribution from both natural and anthropogenic aerosol.
- Estimates of ADRE vary and uncertainties exist due to aerosols high temporal and spatial variation and relatively short lifetime in the atmosphere.

Aerosol direct SW radiative effect ADRE

- Estimates of ADRE can be obtained by
  - Radiative transfer models
  - Radiative transfer models coupled with observations e.g. from remote sensing instruments
  - Using multi-sensor remote sensing data



- The remote sensing approach is based on using coincident broad band flux and AOD observations
  - CERES –SSF data; CERES broadband fluxes combined with MODIS AOD
  - The AOD data is used to estimate the value for aerosol-free flux, which can not be obtained from the observations



Motivation

- The satellite based method has been used previously
  - Over ocean e.g.: Loeb and Manalo-Smith, 2005, Zhao et al. 2008, Cristopher 2011,
  - Over land e.g.: Patadia et al., 2008, Sena et al., 2013
  - Over land and ocean: Feng and Christopher 2013.

- Even though the satellite based approach has been used in various studies, there has been less focus on the method itself

Key questions

- The satellite method includes a number of assumptions, e.g. that the aerosol type does not change systematically over a month
  - Does the method work in an environment having highly variable aerosol conditions?
- How good is the estimate for aerosol-free flux obtained from the satellite method?
- Is the satellite method working over some surface / with some aerosol type / loading better than other and is there some method parameter indicating that?

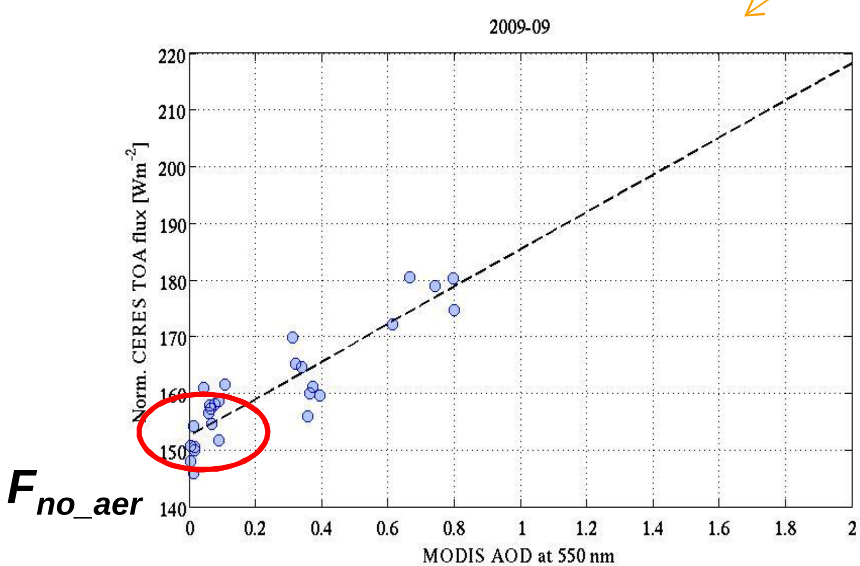
Method and the study area

Deriving instantaneous ADRE using coincident CERES SW fluxes and MODIS AODs

Coincident TOA SW flux and AOD observations are collected over a month in each 0.5 deg. grid cell

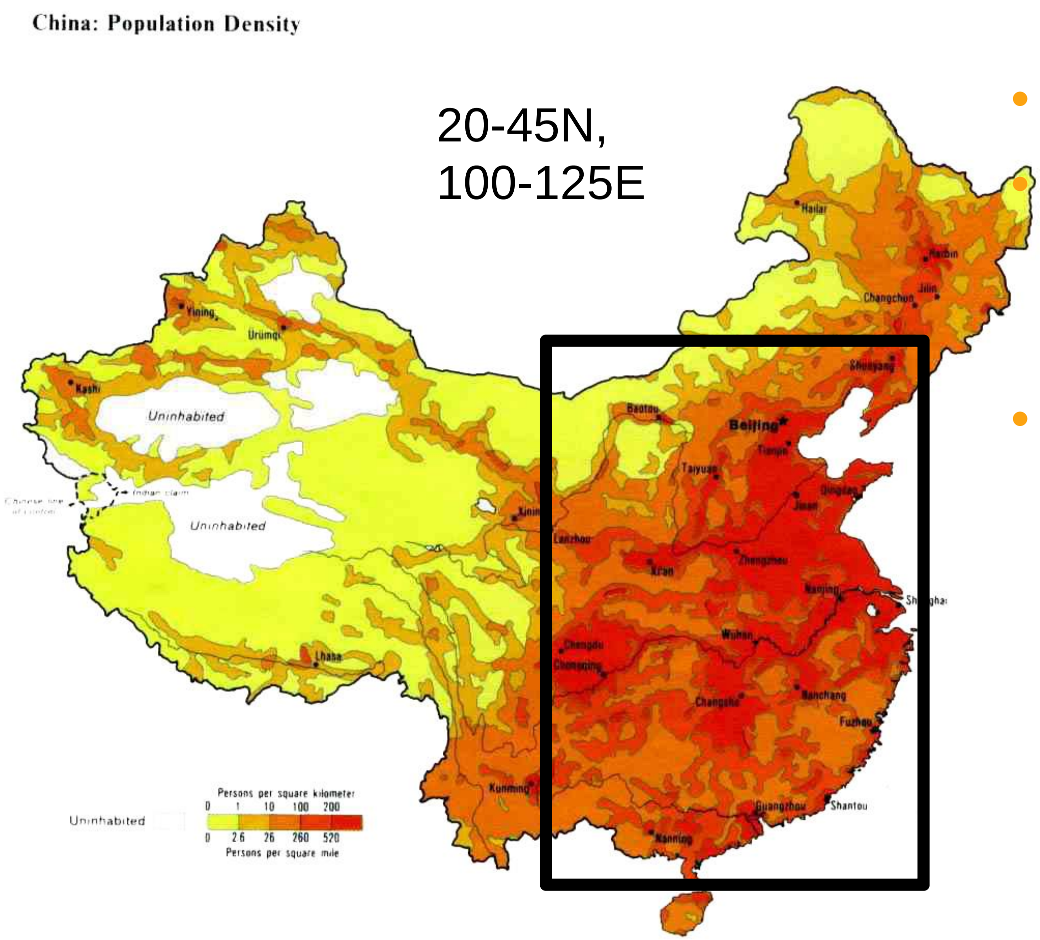
$$ADRE_{TOA} = F^{\uparrow}_{TOA,no\_aer} - F^{\uparrow}_{TOA,aer}$$

CERES observation (grid cell monthly mean)



- Criteria for successful regression e.g.:
  - observations are flagged cloud free (based on MODIS)
  - Number of obs./month ≥10
  - Correlation coefficient ≥|0.2|

The study area

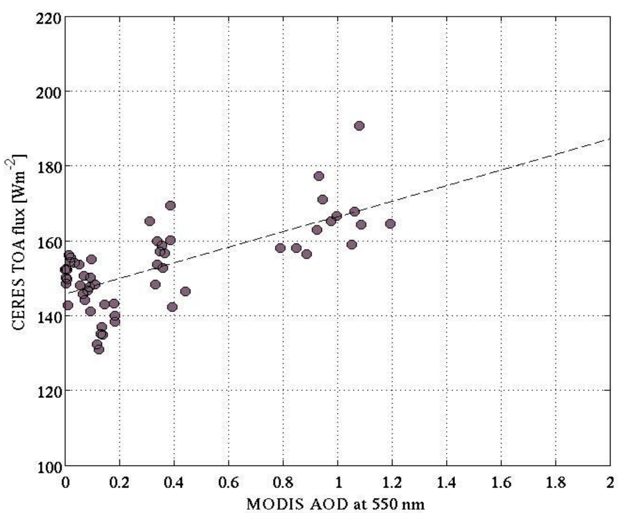


20-45N,
100-125E

- Study period March-October 2009
- CERES – SSF data from TERRA
    - observations over inland water were removed
- Radiative transfer simulations were also carried out as a reference
    - no "validation" data available
    - e.g. aerosol-free TOA fluxes

Results 1

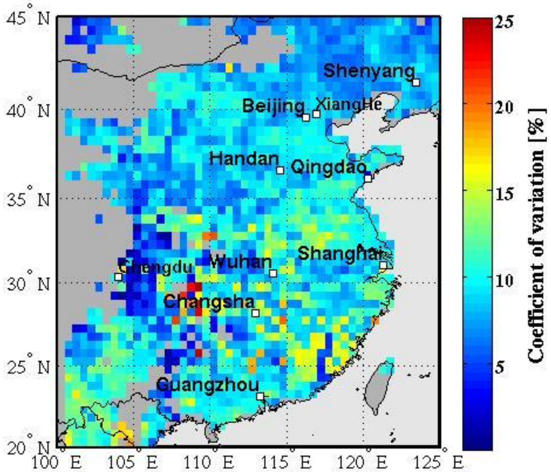
Normalization of the CERES fluxes



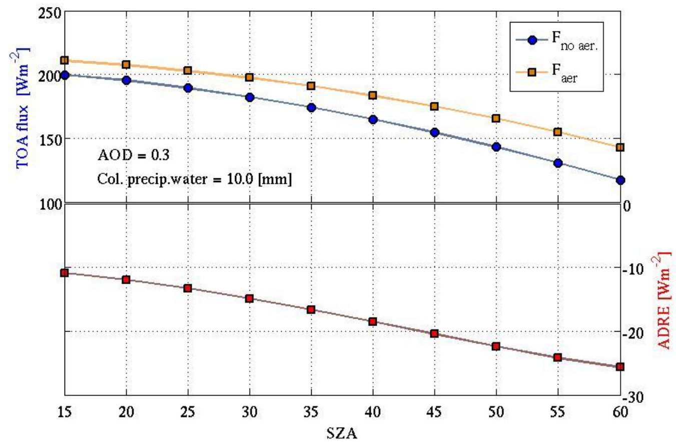
Aerosols, SZA, water vapour content, DOY, surface…

Relative variation of SZA and water vapour within the study area

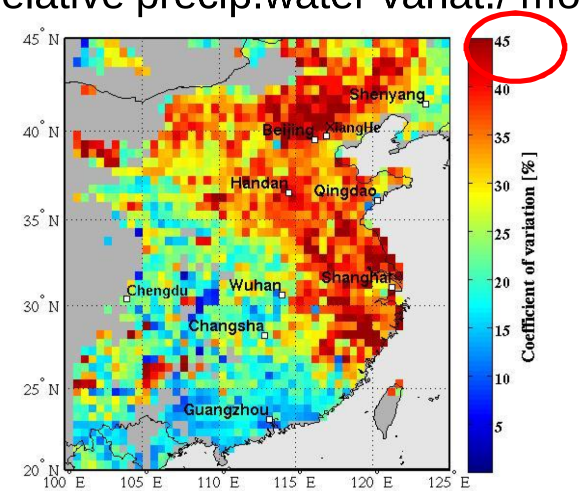
Relative SZA variation / month



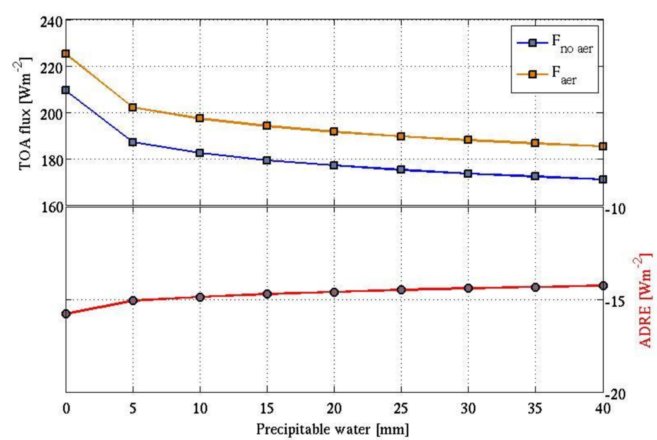
TOA fluxes and ADRE vs. SZA



Relative precip.water variat./ month



TOA fluxes and ADRE vs. precip. water



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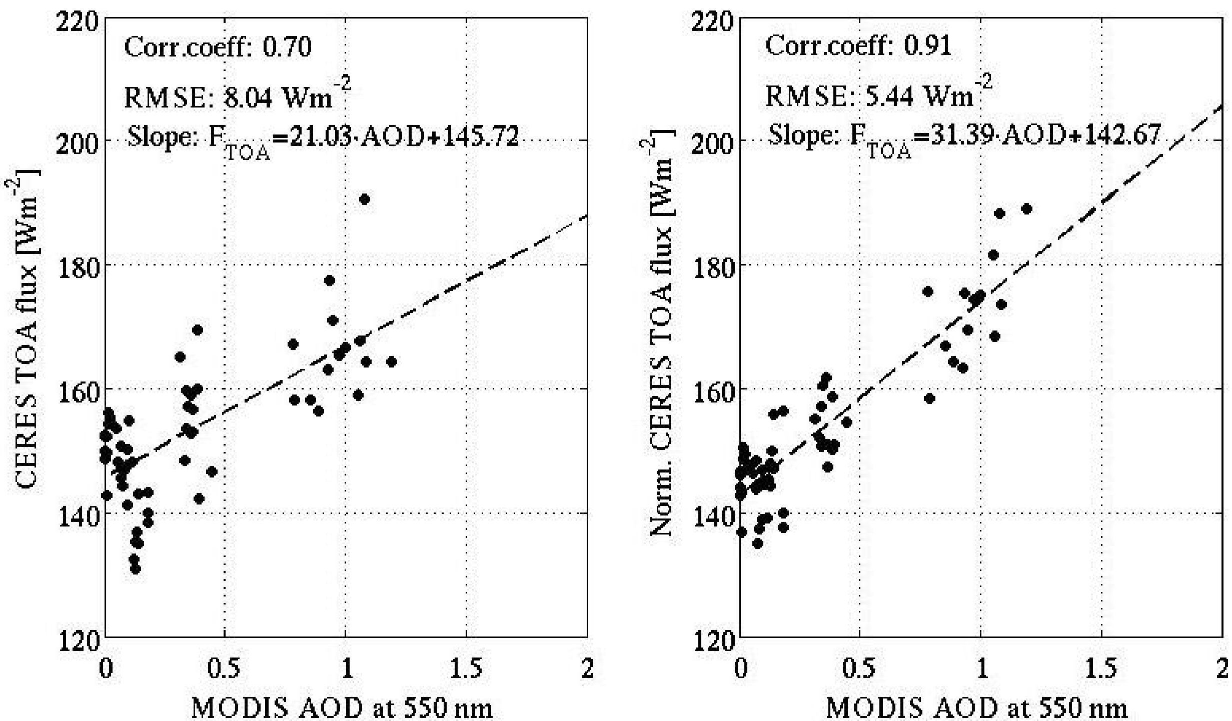
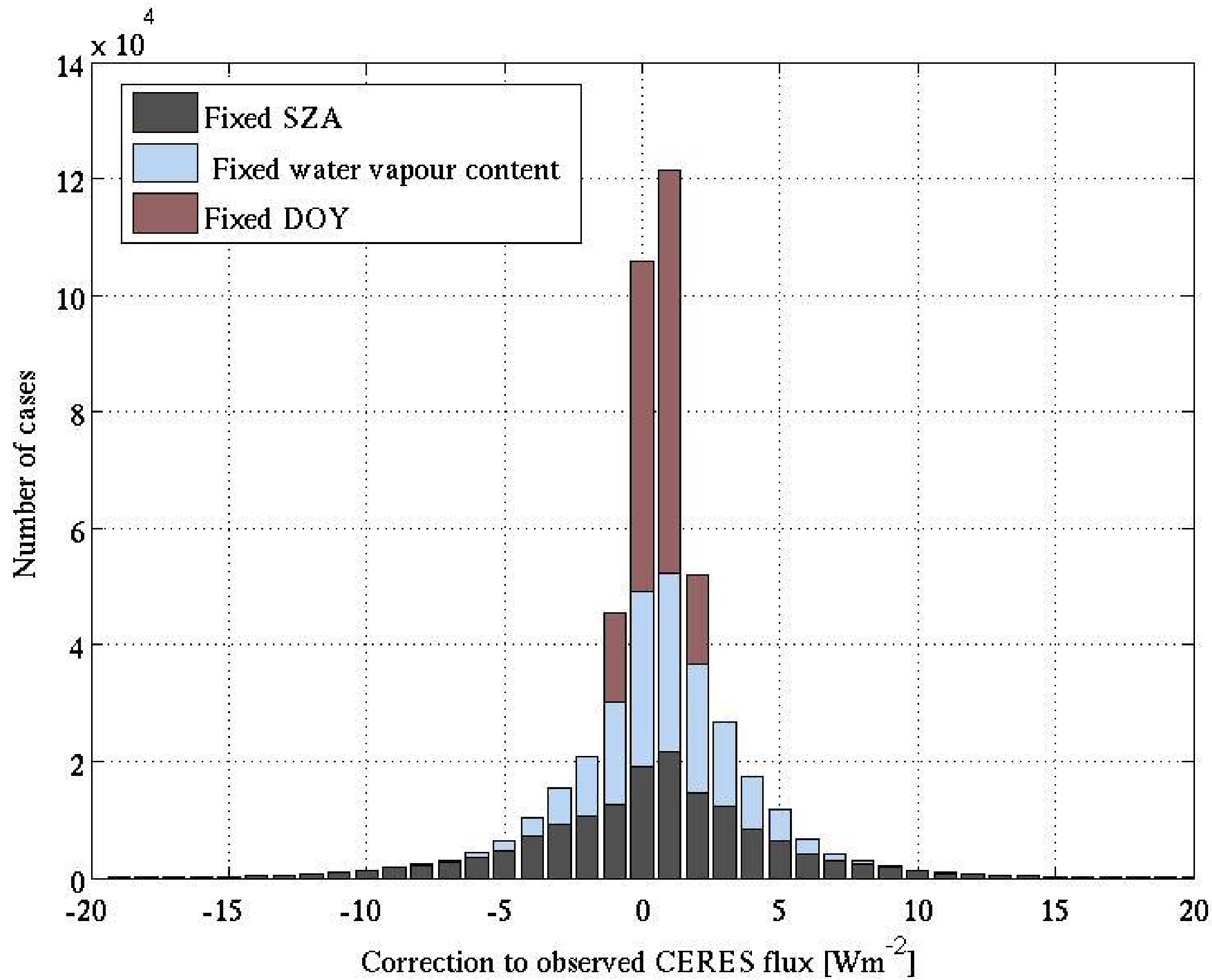
Example of normalization



- Normalization to fixed SZA, water vapor and DOY
  - modeled fluxes
- After normalization:
  - Increased correlation between AOD and fluxes
  - Decreased RMSE
  - Somewhat lower estimate for F_{no_aer}

Absolute change in observed CERES fluxes due to normalization

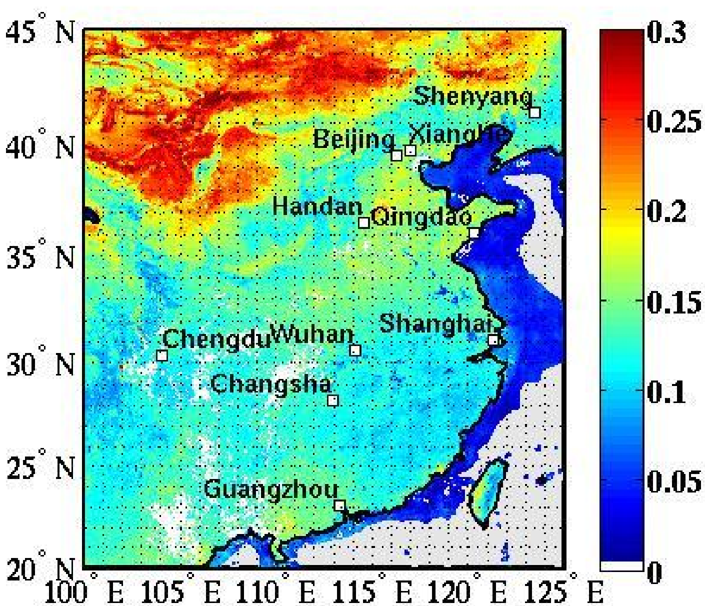


Results 2

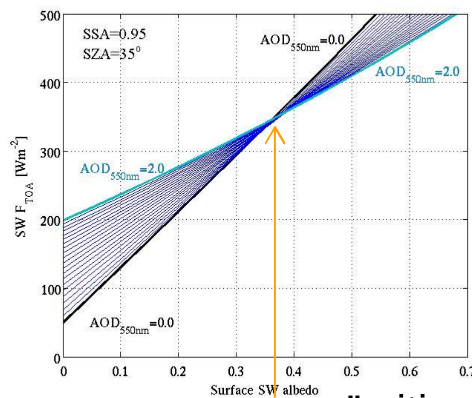
ADRE from the satellite based method

What to expect?
ADRE as a combination of surface and aerosols

MODIS black-sky SW albedo



ssa=0.95



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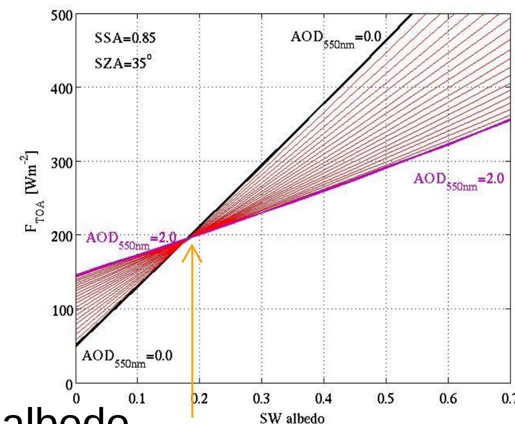
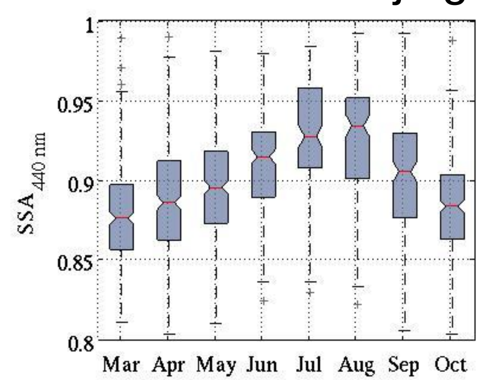
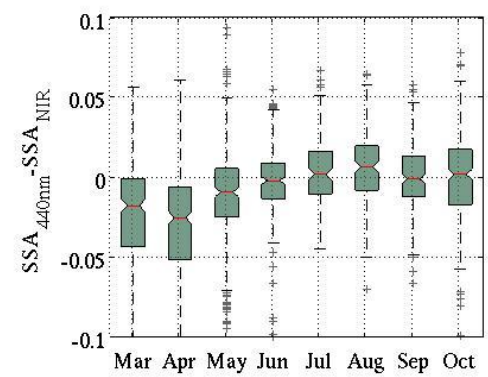


”critical” albedo

Beijing SSA from AERONET



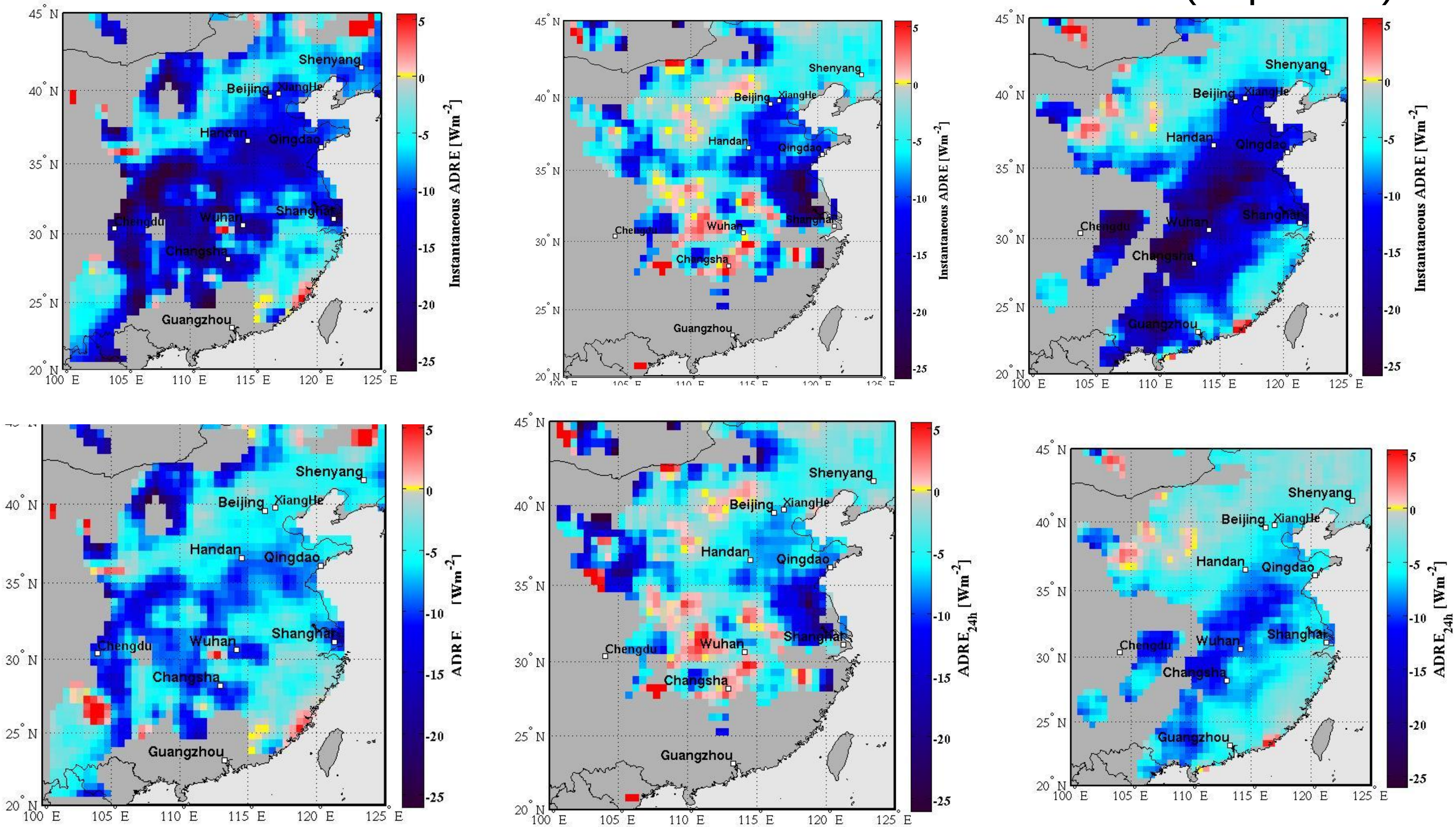


Seasonal median ADRE obtained from the satellite method

Spring (Mar.-May) | Summer (Jun.-Aug.) | Autumn (Sept. Oct.)

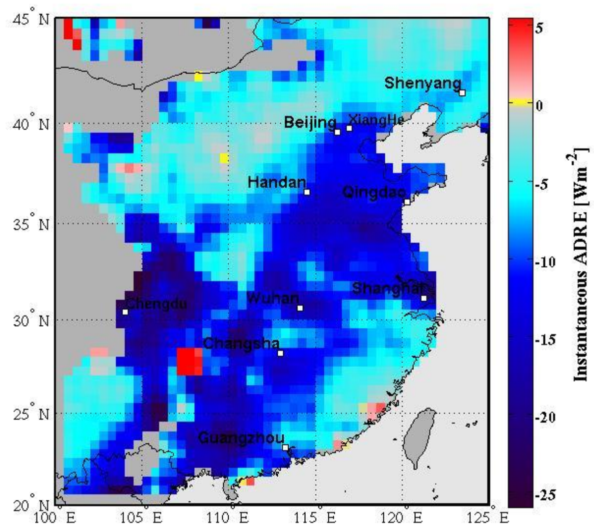
Inst.

24 h.

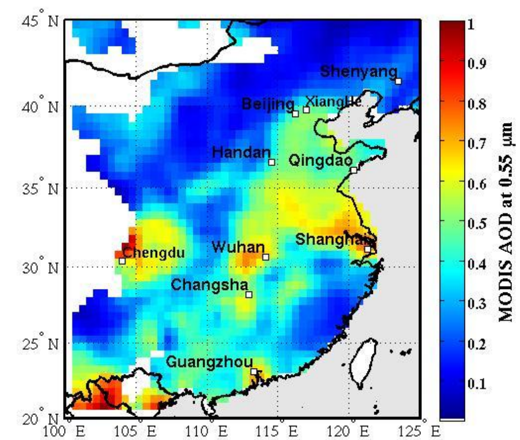


ADRE vs. AOD

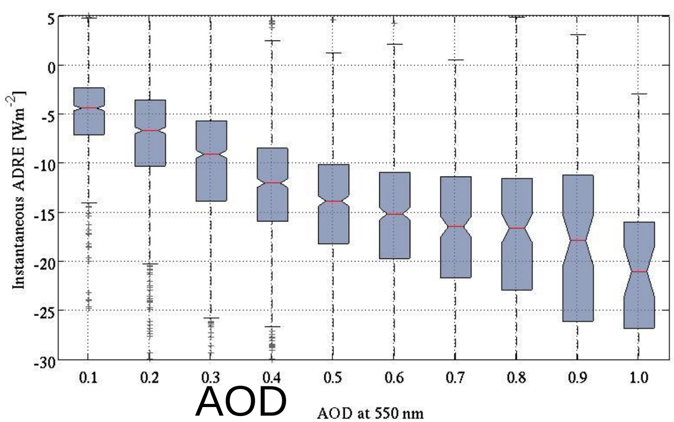
Inst. ADRE Mar.-Oct. 2009



AOD Mar.-Oct. 2009
(only obs. Included in the fitting)



Inst. ADRE [Wm-2]



AOD

24h ADRE median over the study area and period:
-5.0 Wm^{-2}

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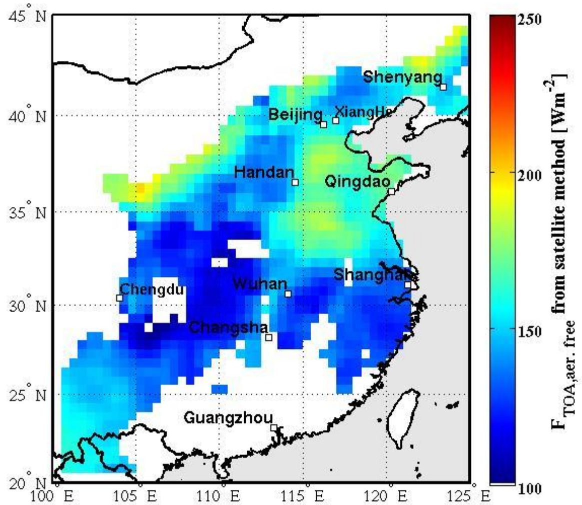
Results 3

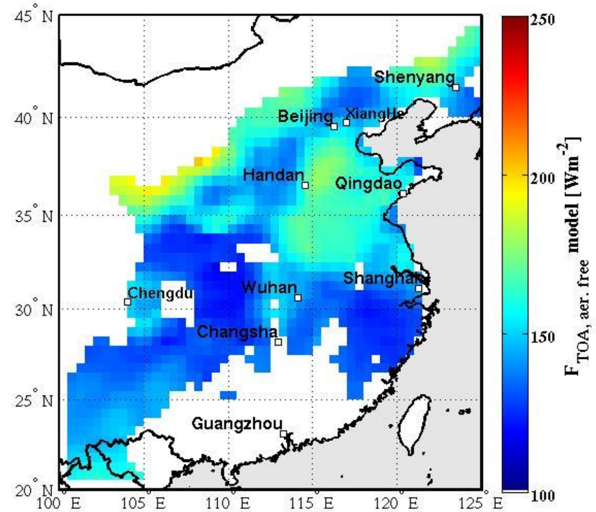
Aerosol-free flux from the satellite method and comparison with modeled values

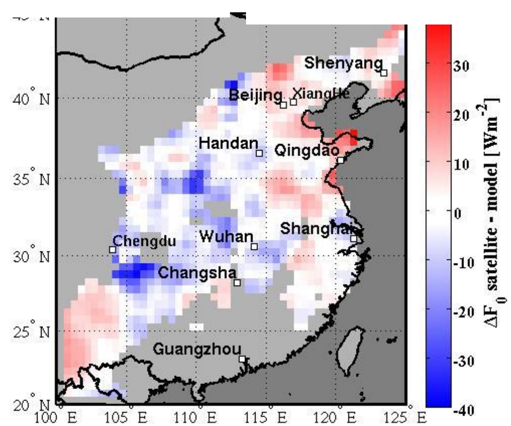
Aerosol – free TOA flux from the satellite fitting

Satellite method



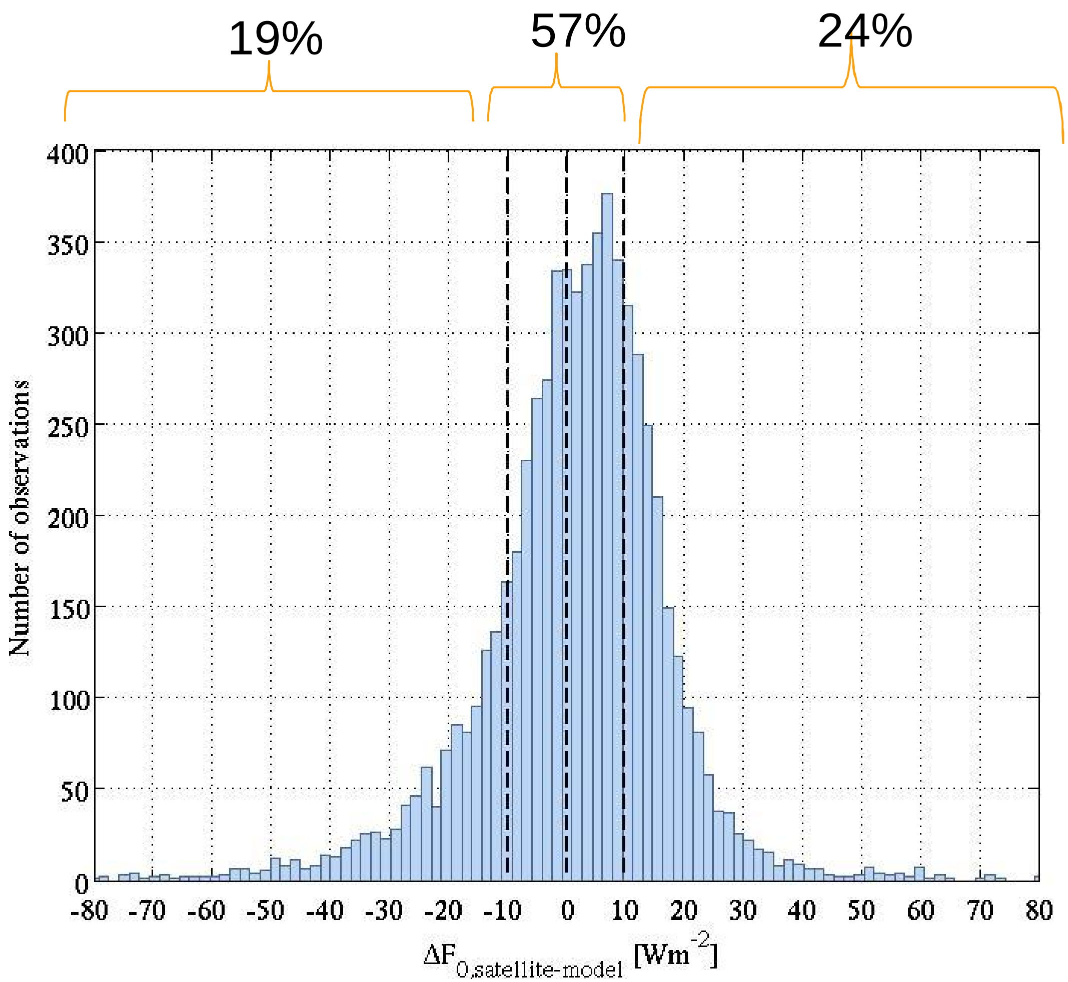
Model





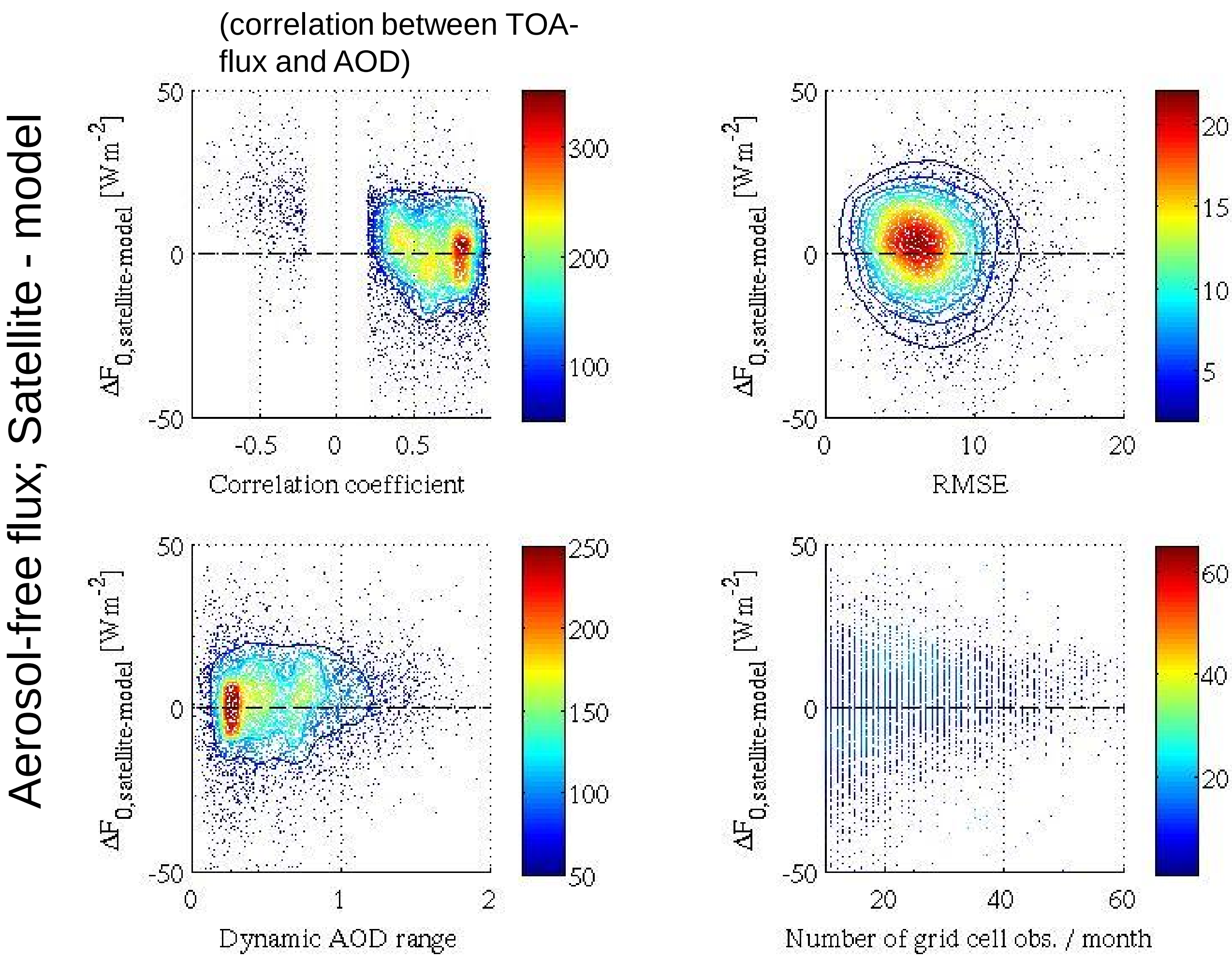
Anomaly satellite method - model

Difference of aerosol-free fluxes (satellite – model)



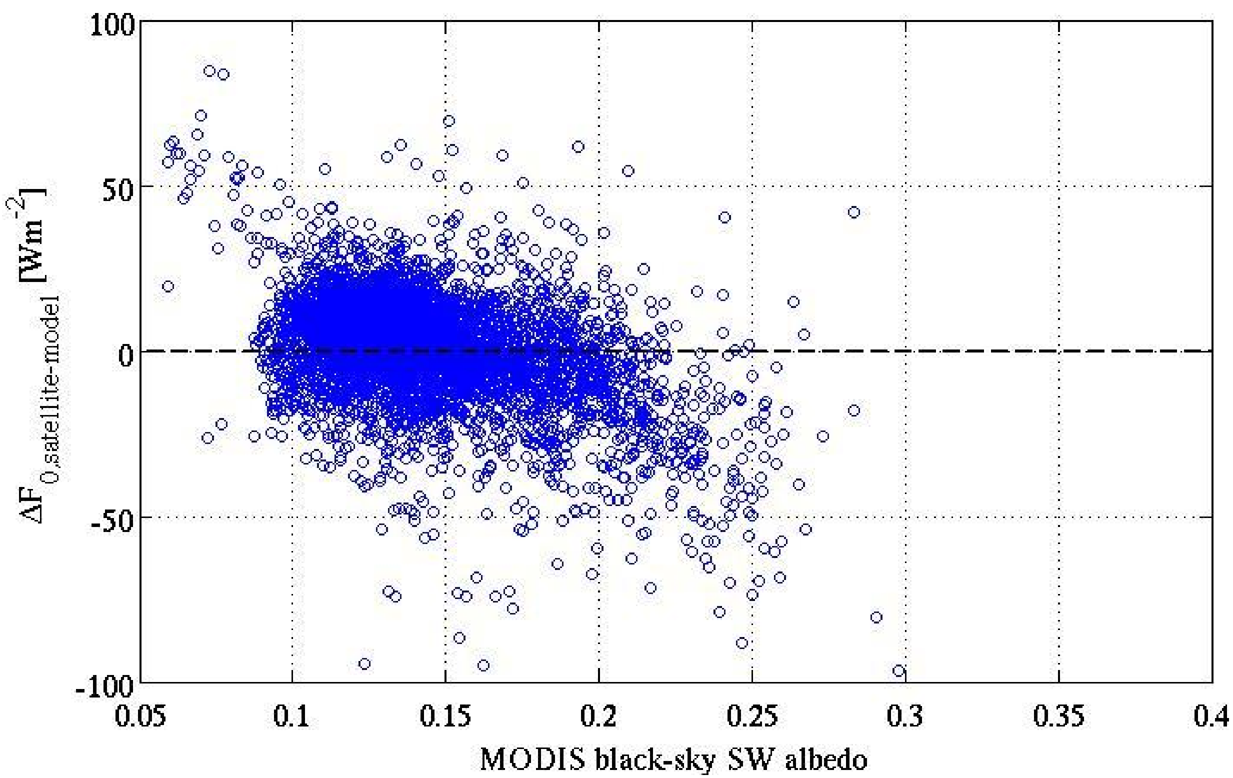
- In 57% of cases the difference between satellite and model was within ±10 Wm^{-2}.
- During summer months (Jun-Aug) the relative number of “extreme differences” was largest.

The aerosol –free flux difference vs. parameters related to TOA flux- AOD fitting

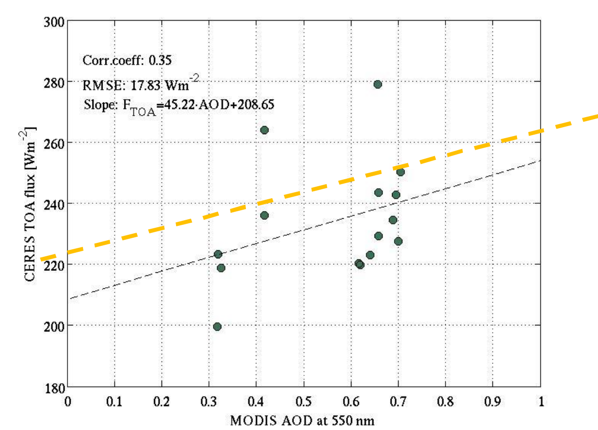


- High positive correlation does not necessarily indicate good agreement between satellite method and model
  - For negative correlation satellite method provides systematically larger fluxes
- with large dynamical AOD range and large number of observations less “extreme” differences

Aerosol-free flux difference vs. surface albedo



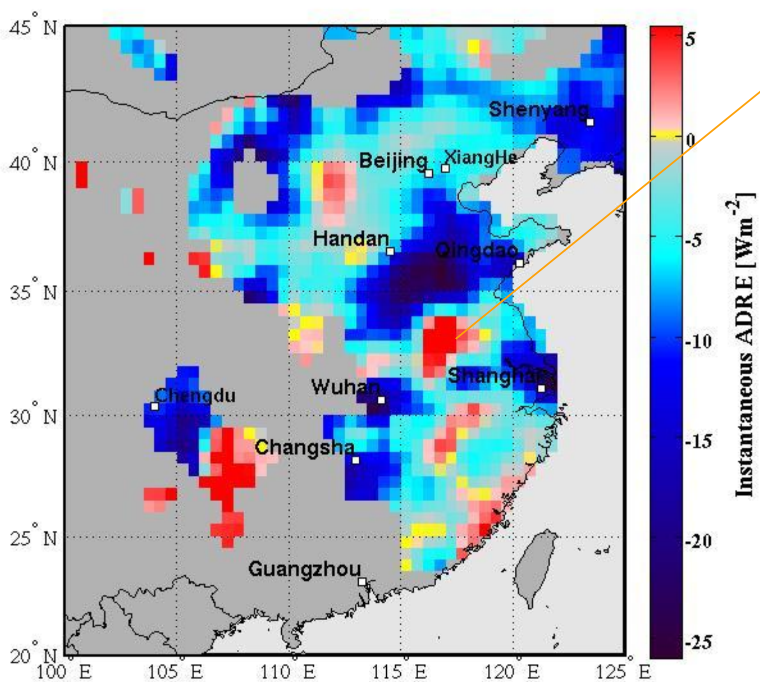
- Correlation -0.45
- Over bright surfaces satellite method gives often lower values for aerosol-free flux than model .

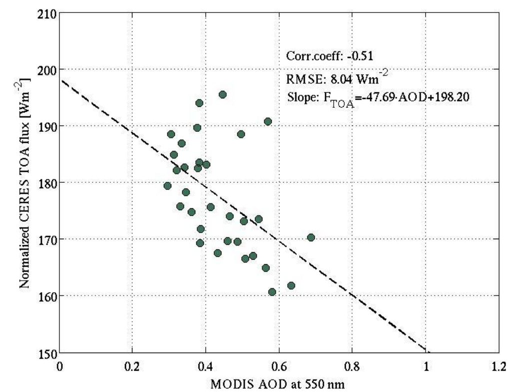


Results 4

Cases of positive ADRE; Real effect or method artifact?

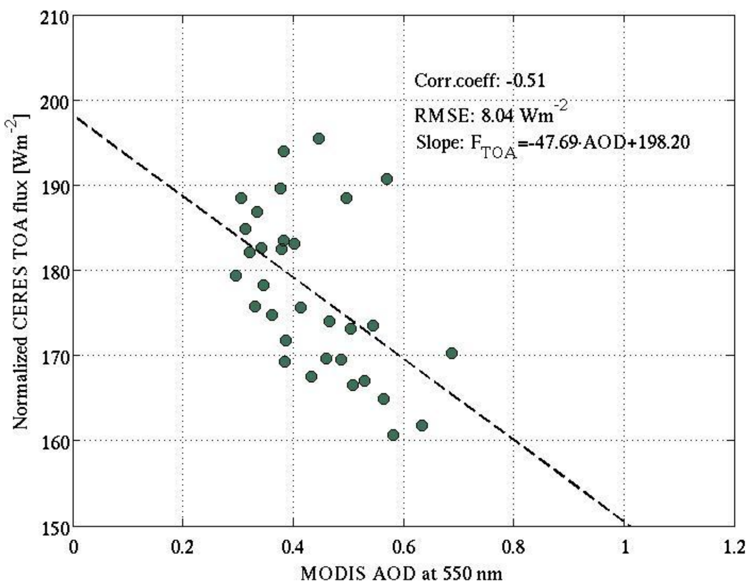
Cases of positive ADRE





- Especially during summer months positive ADRE was observed over unexpected places.
- Even after normalization the correlation between TOA fluxes and AODs was highly negative

Cases of positive ADRE



- - RT simulations show that the aerosols should have SSA ~ 0.7 to produce positive ADRE over the surface.
- - Especially AOD ~ 0.5 the flux values differ considerably
- - Possible explanations: subvisual clouds, change in aerosol type (mixture) or both

Summary

- Results indicate that the normalization especially to a fixed SZA increases the correlation between AOD and TOA fluxes
  - Overall the difference to modeled aerosol-free flux becomes somewhat smaller
- The resulting median 24 h ADRE over the area is -5 Wm^{-2}
  - Similar estimates found in the literature
- Positive values of ADRE over eastern part of the study area, especially during summer months, is most probably a method artifact due to subvisual clouds, change in aerosol type or both.