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Is climatological AOD averaged over the last 16 years stable?

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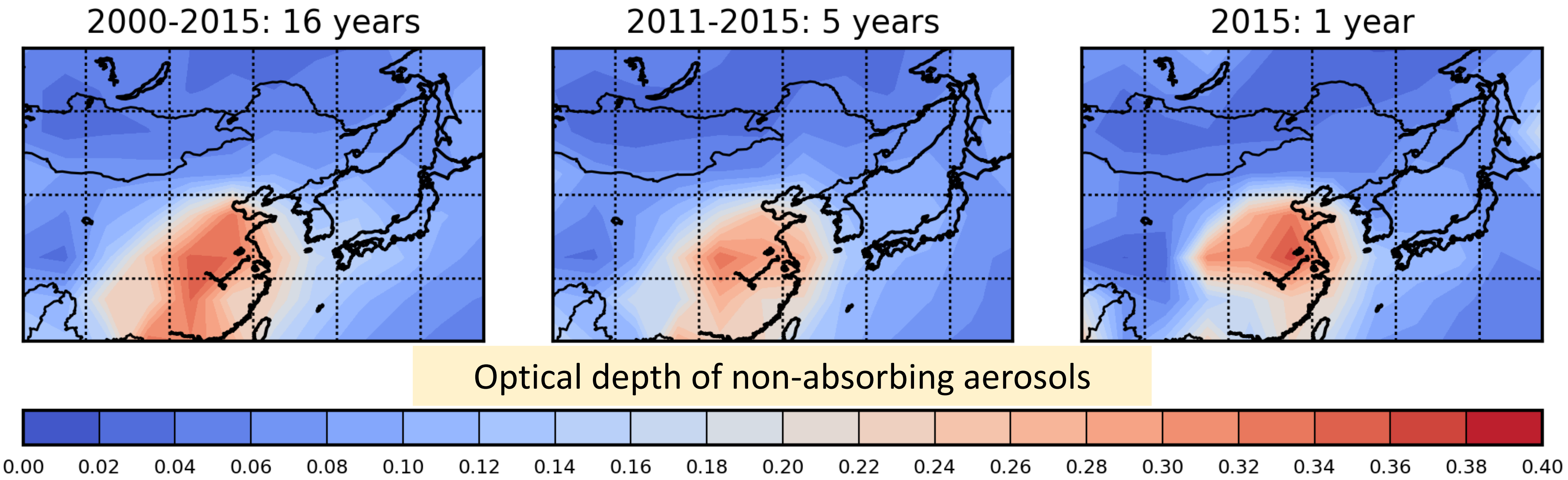
Why do we care about the length of AOD observations?

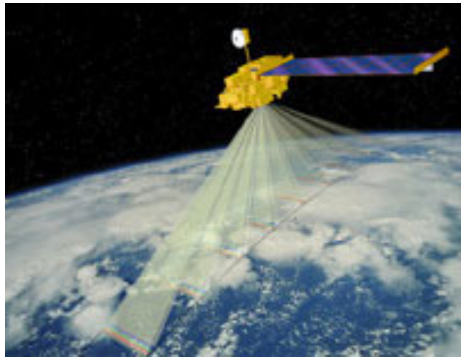
- WMO standards require at least 30 years of observations without data gaps to define climatology for a variety of climate applications.
- NASA's Earth Observing System (EOS) satellites have provided unique AOD observations to study the Earth system over the last 16+ years.
- *Loew* [2013] shows that the length of satellite observations strongly affects the calculation of long-term trends and interactions between variables.
- The models participating in Aerocom have substantially improved their capabilities in modeling aerosols. However, there remains uncertainty in both satellite observations used as reference datasets and AEROCOM model simulations even when we compare climatological AOD between the observations and models.

Objectives



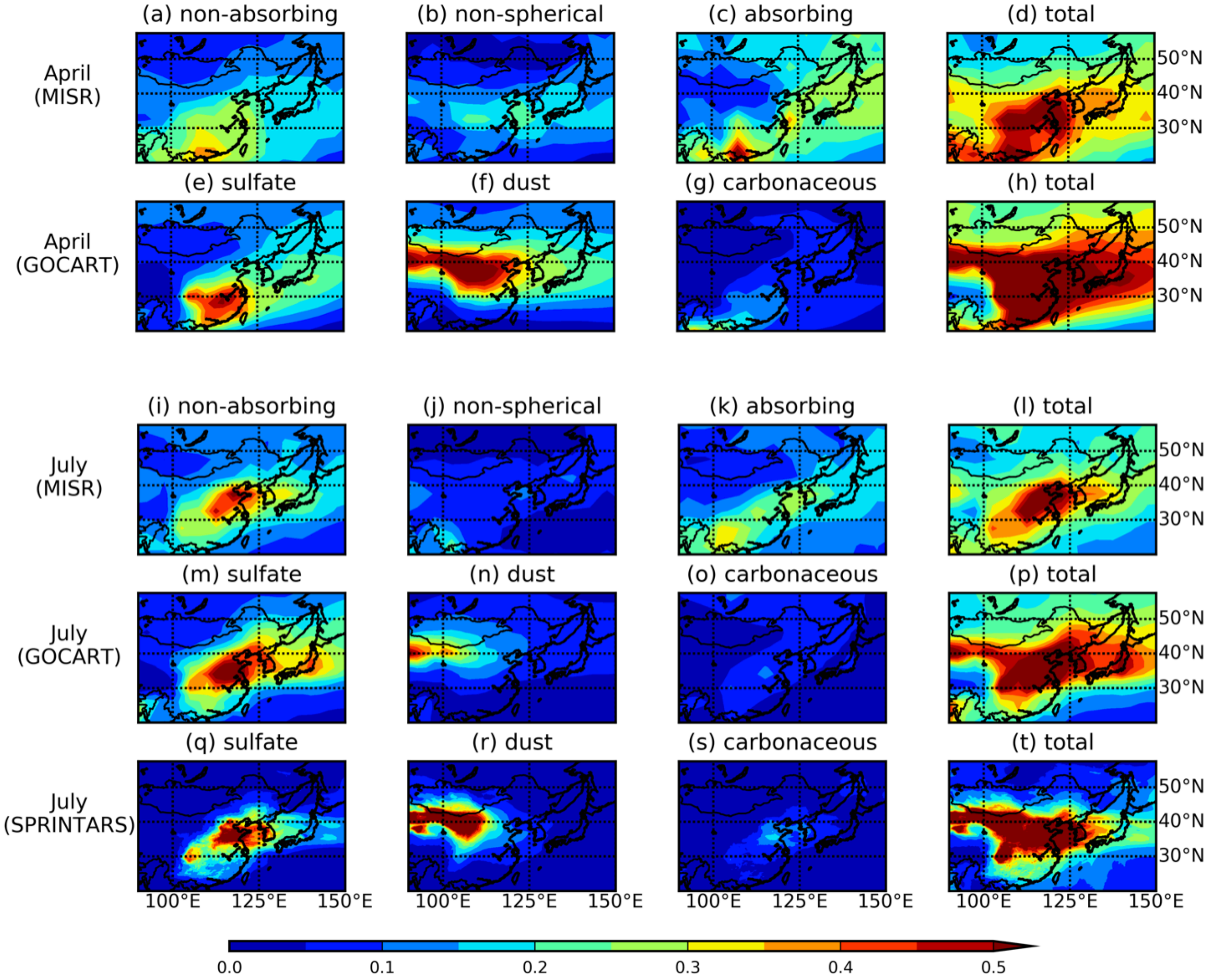
- Are the 16 years of MISR measurements enough to build AOD climatology?
  - ✓ Quantify the impact of the length of observations on climatological mean AOD: measure stability of the AOD climatology.
- How do the Aerocom models simulate optical depths for different types of aerosols?
  - ✓ Evaluate the climatological seasonal cycle of AOD in the models.

Data



- MISR L3 Joint Aerosol (JOINT_AS) :
  - algorithms based on [*Braverman and Di Girolamo*, 2002]
  - Global statistical summaries of MISR Level 2 AOD: 8-dimensional histograms of AOD at 558 nm for different types of aerosols
  - Resolution: 5 x 5 degrees (57.5 S – 57.5 N) & monthly
  - The size of data files is significantly reduced from original L2 data, while approximating key information (marginal distributions and approximate moments of 8 aerosol types).
  - The processed monthly mean optical depth for total, non-absorbing, absorbing and non-spherical aerosols and example source codes are publicly available (https://dx.doi.org/10.6084/m9.figshare.3753321.v1 , AOD_monthly_2000-Mar_2016-FEB_from_MISR_L3_JOINT.nc).
- Aerocom hindcast simulations (HCA-0) using AeroCom emissions
  - GOCART, HadGEM2, and SPRINTARS (March 2000 – February 2005)
- Variables: seasonally averaged optical depths of total, non-absorbing (sulfate), absorbing and non-spherical (dust) aerosols at 550 nm

Comparison of AOD by component [*Lee et al.*, 2016]

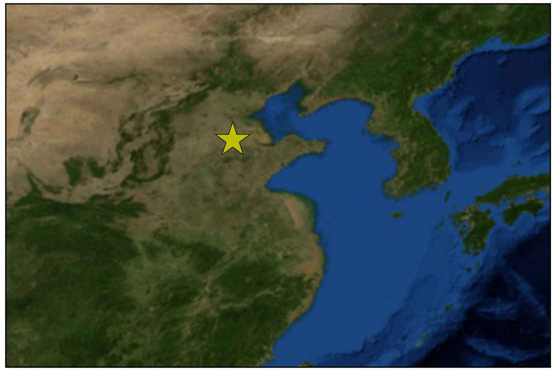


- Using MISR Level 3 Joint Aerosol product, we can calculate monthly climatological moments (mean, standard deviation, skewness and so on) of AOD for 8 different aerosol types.

AOD in MISR	AOD in models
absorbing aerosols	**carbonaceous aerosols (od550bc+od550oa)**
non-spherical aerosols	**dust (od550dust)**
non-absorbing	**sulfate aerosols (od550so4)**

Uncertainty of the multi-year mean AOD due to temporal subsampling

SON mean AOD over the 16 years: 0.362



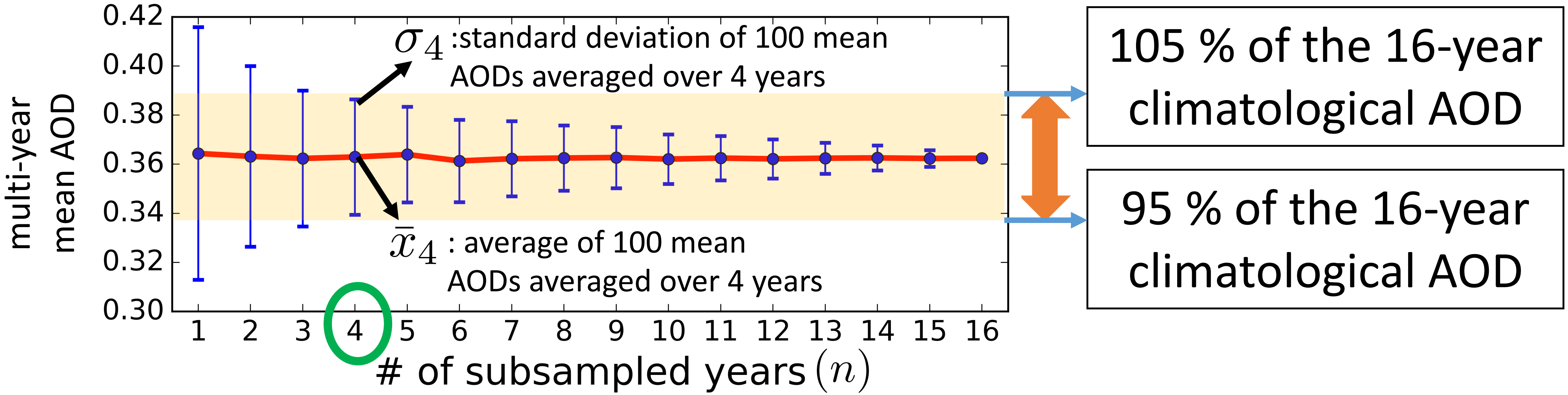
- Subsample the 16 seasonal means (SON) between 2000-2015 without replacement 100 times => 100 multi-year means of AOD

for sample_size (n) = 1, 15 # years

for number_sample = 1, 100 # random subsets

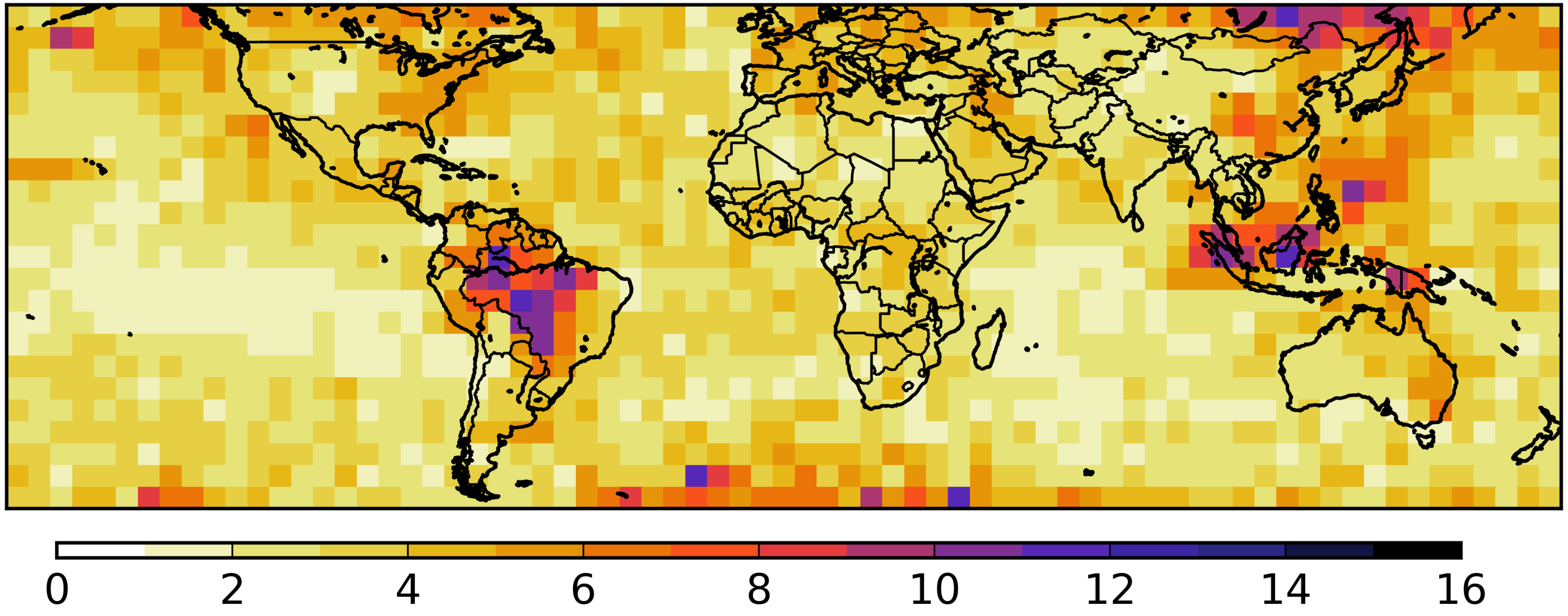
sub_climatology[ ] = CALC_MULTI_YEAR_CLIM( )

- ex) for *n*=4, (2002, 2003, 2005, 2015) (2004, 2007, 2008, 2009).. (2002, 2003, 2004, 2015)



$$(95\%\ \text{clim. AOD}) < \bar{x}_n \pm \sigma_n < (105\%\ \text{clim. AOD})$$

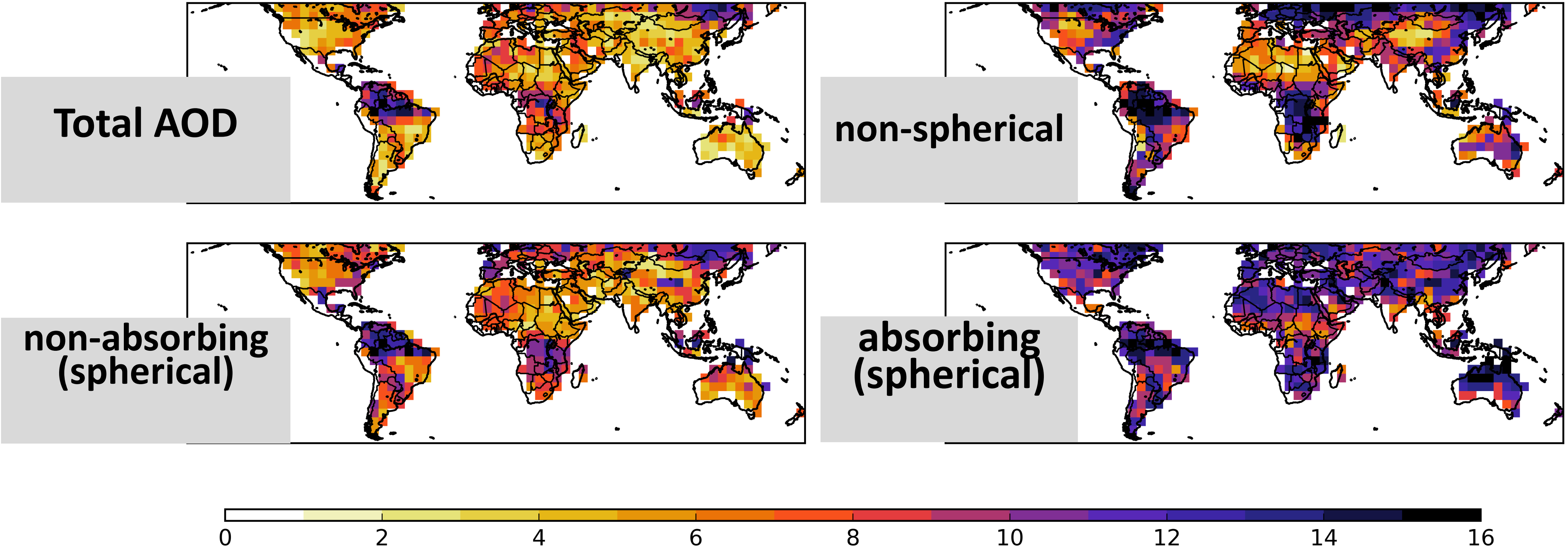
minimum # of years (***n***) required to calculate climatological AOD (annual mean) with ±5% accuracy



Global mean: 3 years
Mean over land: 3.74 years
Mean over ocean: 2.73 years

- Overall, the 16-year observation record is valuable to define climatological AOD.
- In some regions (e.g. Amazon and Maritime continent), 16 years may not be long enough to build the climatology of annual mean AOD.
- Evaluation of simulated AOD needs to be done for the maximum overlap periods between observations and models.

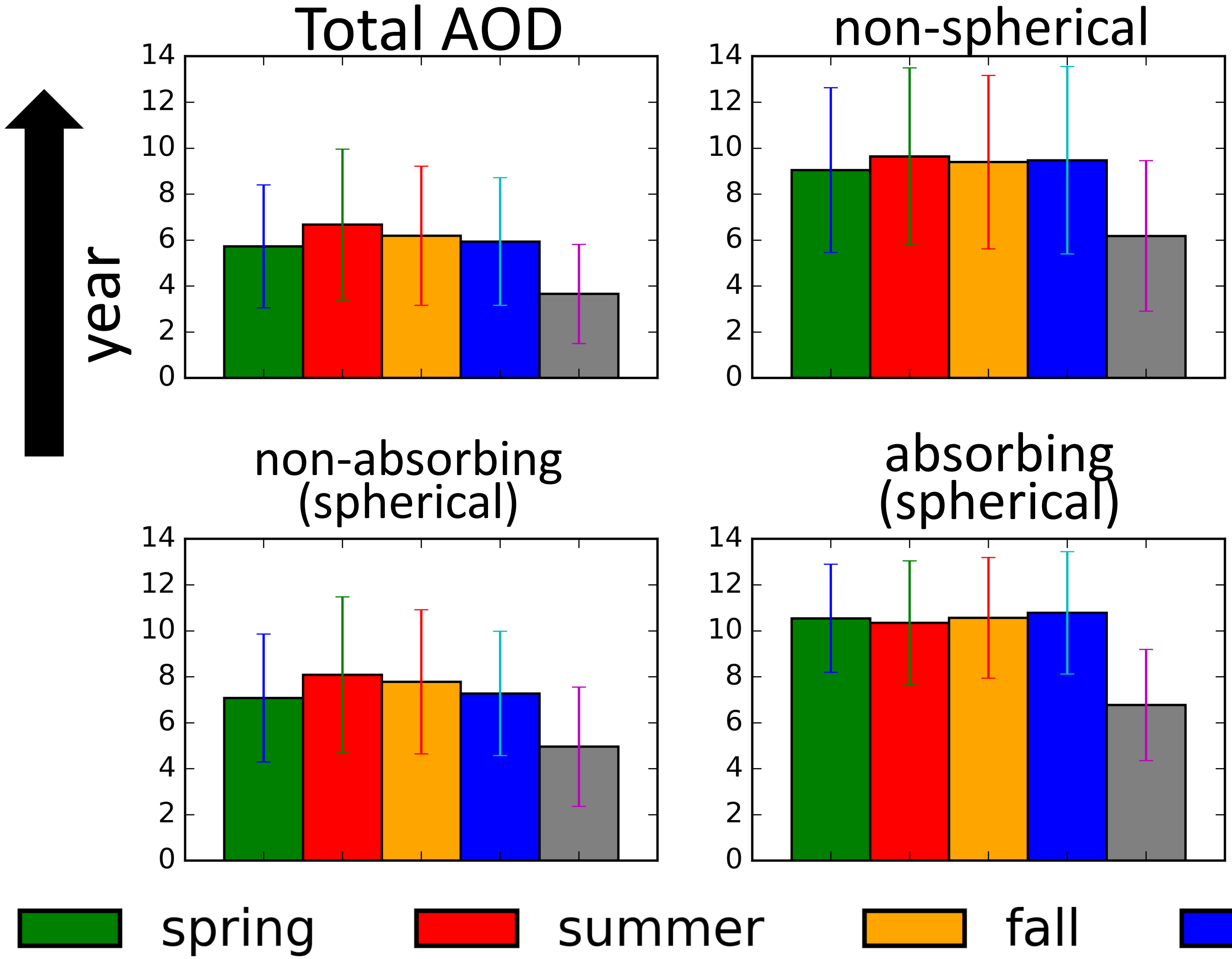
Stability of the multi-year mean AOD by component (for spring: March-April-May)



- The uncertainty due to temporal subsampling becomes large when generating climatological AOD by components, especially for non-spherical and absorbing AOD.
- Nevertheless, over the major sources of non-spherical and absorbing aerosols (e.g. the Sahara Desert and Central Africa), 'stable' climatological AOD can be defined using 16-year observation record.

How long is long enough to define stable climatological AOD?

(# of years for ±5% accuracy averaged over the globe, land only)



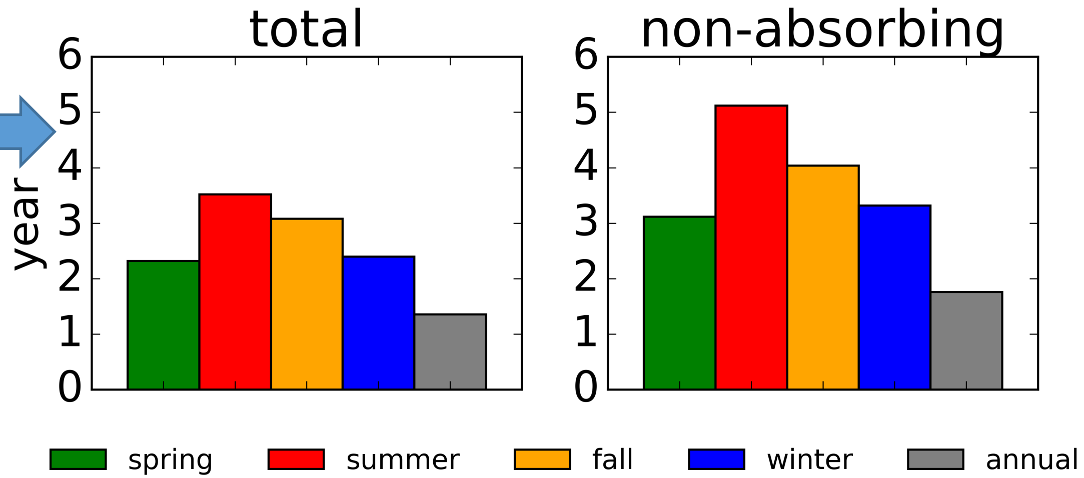
- The stability of multi-year mean AODs does not show clear seasonal variability.
- The 16+year MISR data provide useful information to examine global mean AOD and (hopefully) related radiative forcing. However, the stability varies considerably by locations even for the annual mean AOD climatology.

- Are the 16 years of MISR measurements enough to build AOD climatology?
  - ✓ Quantify the impact of the length of observations on climatological mean AOD.
- How do the Aerocom models simulate optical depths for different types of aerosols?
  - ✓ Evaluate the climatological seasonal cycle of AOD in the models.

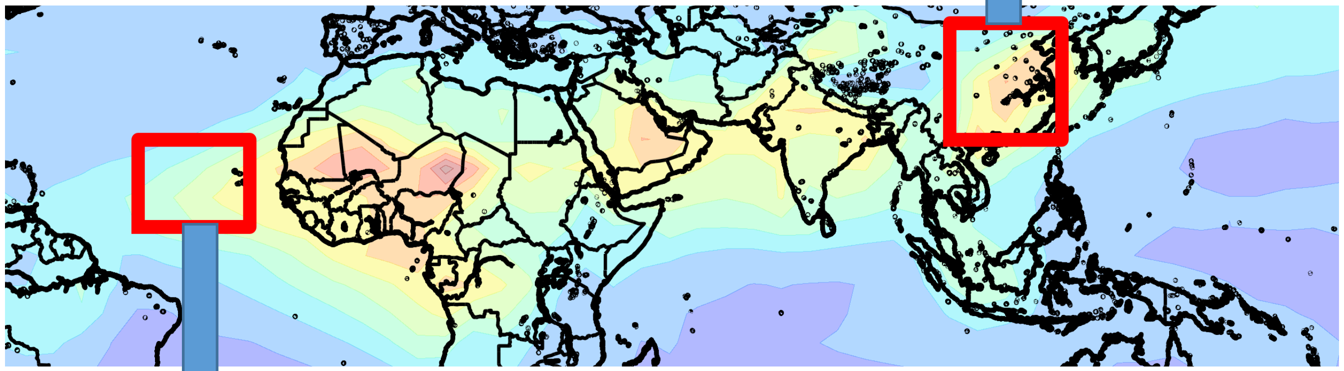
Stability of the seasonal AOD climatology in MISR (March 2000 – February 2005)

East China [22.5-42.5N, 102.5-122.5E]

- The aerosol emissions over the region impacts the aerosol loading over the North Pacific and mainland North America [Zhang et al., 2007;Yu et al., 2008; Wang et al., 2014]

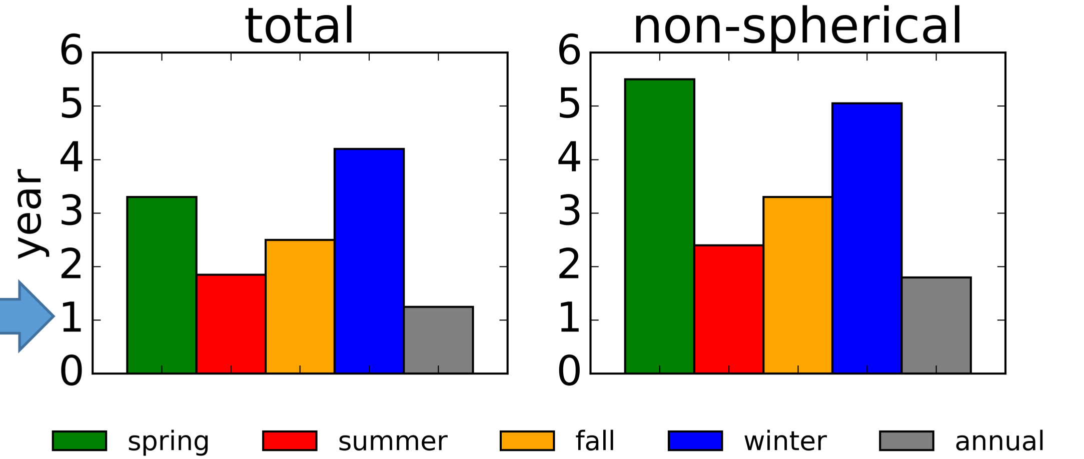


minimum # of years for ±10% accuracy

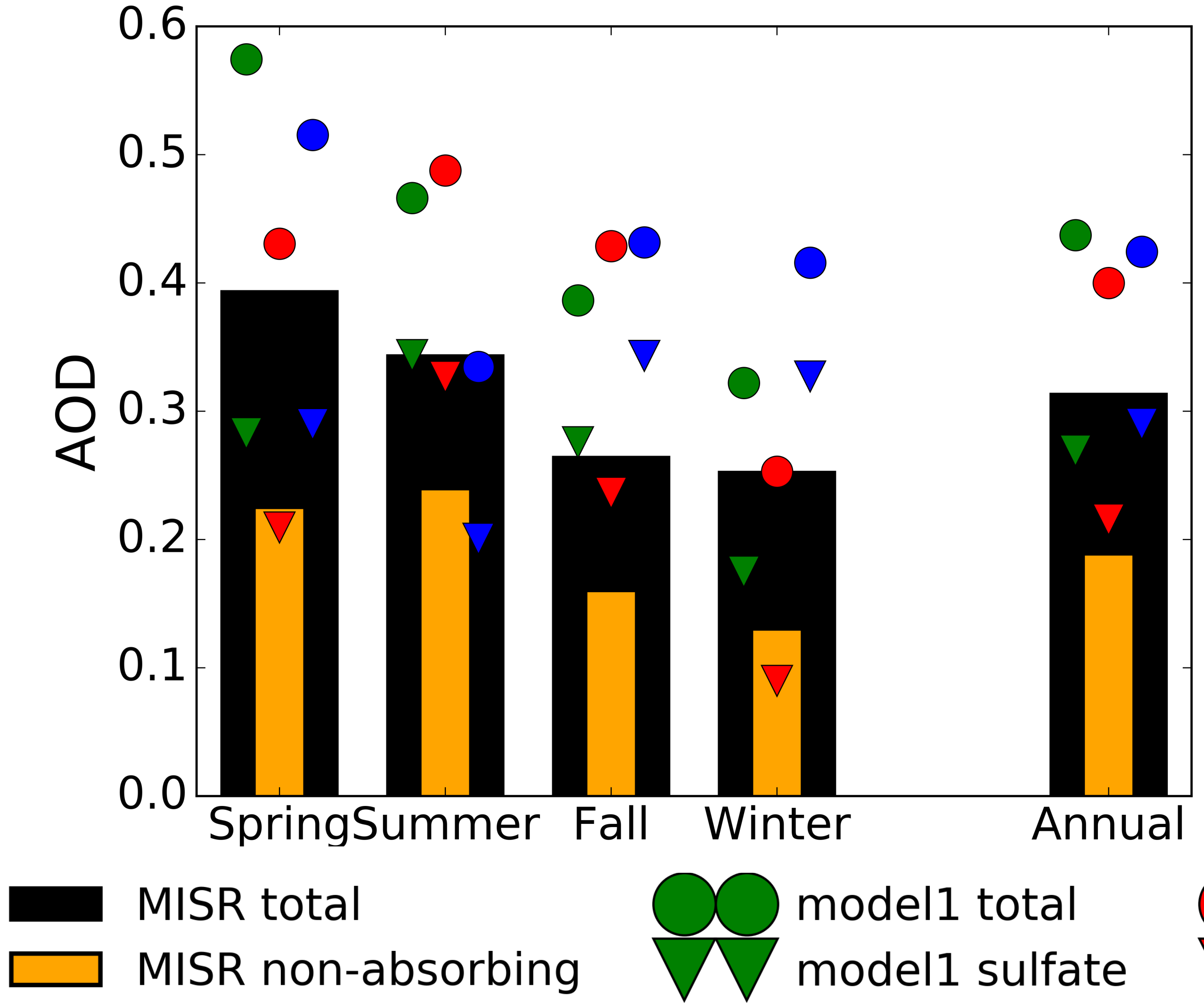


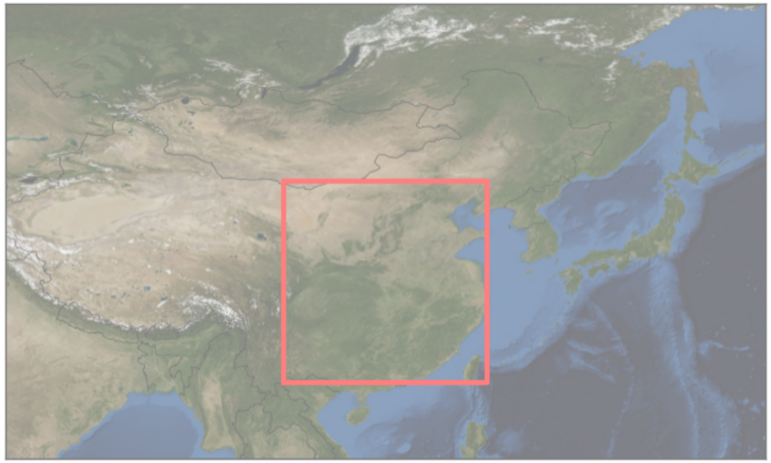
West of the Sahara Desert [7.5-22.5N, 42.5-22.5W)

- directly downwind from the largest source of dust aerosols on Earth



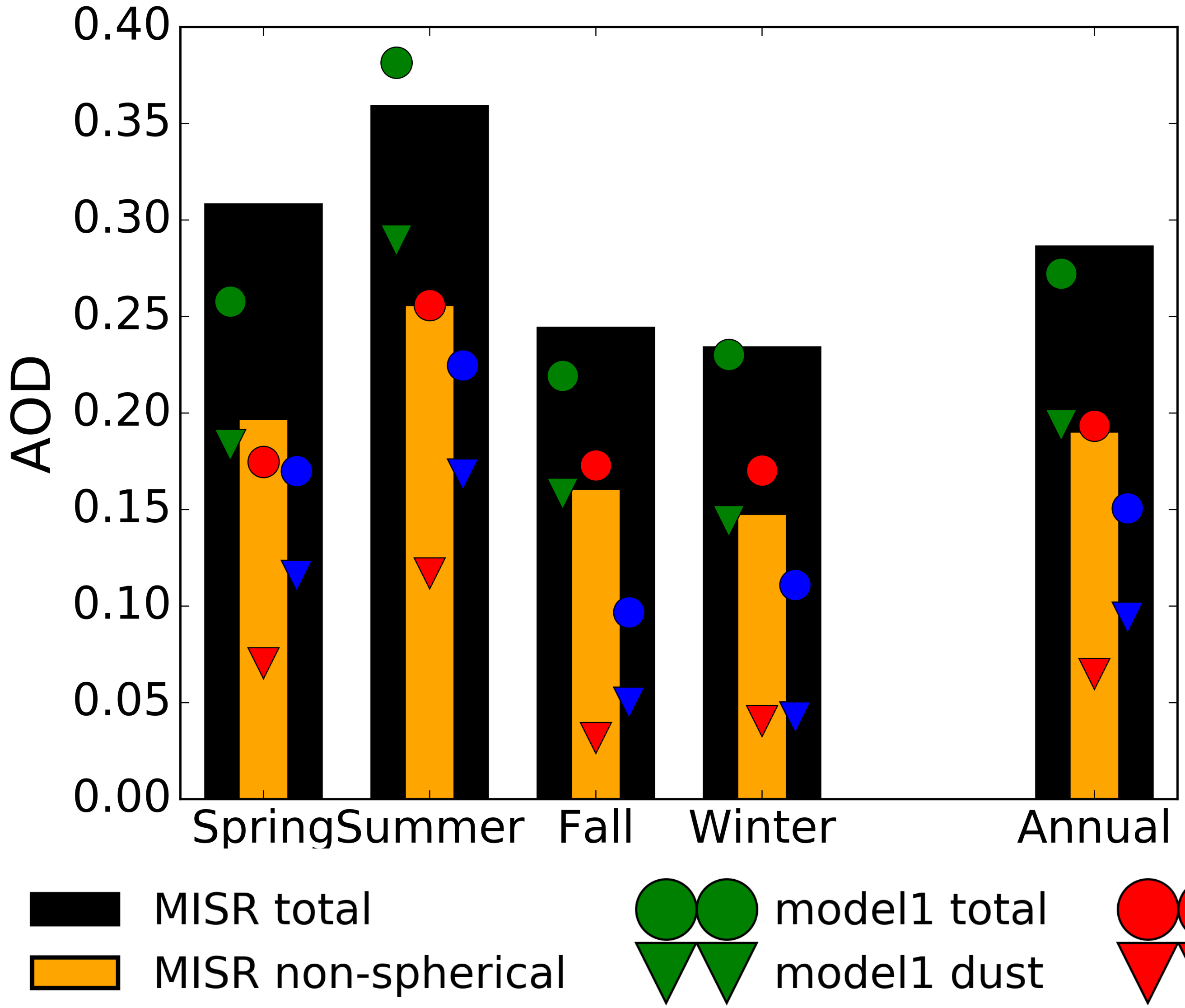
Climatological seasonal cycle of AOD (East China)





- The majority of AOD results from non-absorbing (sulfate) aerosols in MISR and the three models.
- In MISR, the total AOD peaks in spring whereas the non-absorbing AOD is highest in summer.
- Model 1 (green) exhibits positive biases, but a good agreement in the overall seasonal cycle.

Climatological seasonal cycle of AOD (west of the Sahara Desert)

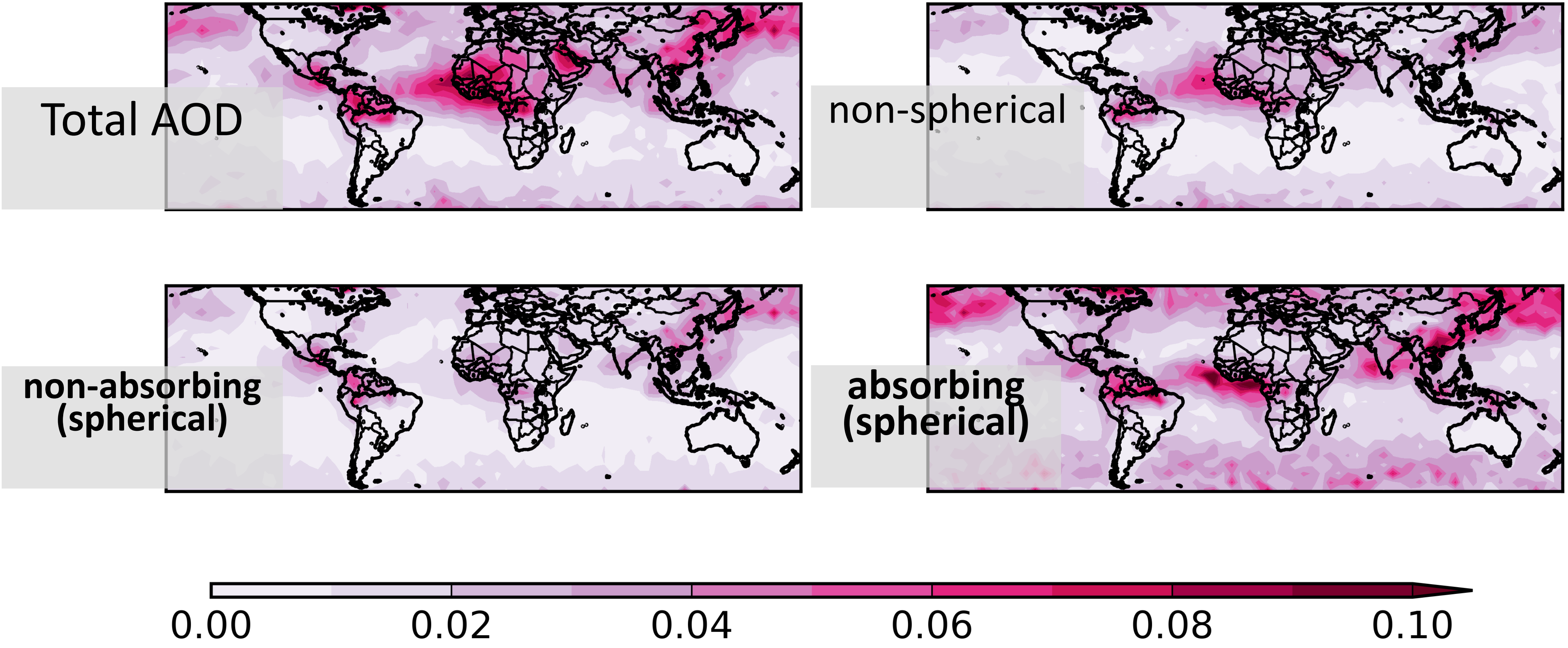


- In MISR and models, both the total and non-spherical AOD are highest in summer. CALIPSO data show the same seasonal cycle [*Yu et al.*, 2015].
- All models reproduce a reasonable seasonal cycle in the total and dust AOD.
- However, Model 2 and 3 exhibit negative biases against MISR.

Summary

- The length of satellite observation records affect the climatological aerosol optical depth (AOD), especially the multi-year mean of optical depth by components.
- At a global scale, the climatological AOD defined using more than 10 years of MISR data is stable.
- However, the large uncertainty of climatological mean AOD in some regions indicates that we do need longer observations to obtain reliable AOD climatology by components.
- In East China, one Aerocom model shows good agreement in the seasonal cycle of AOD. In west of the Sahara desert, the three models can reproduce the observed seasonal cycle.
- Please visit JPL's Regional Climate Model Evaluation System website (RCMES, http://rcmes.jpl.nasa.gov) to download the processed MISR L3 JOINT_AS data and reproduce the plots presented today.

Interannual variability of AOD in spring
(temporal standard deviation of AOD over the 16 years)



±5% criteria is arbitrary. If the criteria is $\sigma_n < 0.01$, (for spring: March-April-May)

- The standard deviation (σ_n) across subsampled AODs whose sample size is n or larger than n is smaller than 0.01.