Review of paper:

Satellite observations of aerosol and clouds over southern China from 2006 and 2015: analysis of changes and possible interaction meachanisms.

by N.Benas et al.

Positives

- exploring co-located changes in aerosol and cloud retrievals for insights
- picking a (S.China) region, where aerosol loads have been changing on decadal scales
- looking for consistency by exploring different aerosol and cloud products

Concerns

- AOD is a poor indicator for CCN concentrations – AODf is much better (I suggest MISR)
- CALIPSO typing cannot really distinguish between pollution and wildfire (and wildfire is not so effective for CCN as pollution) thus looking as GFED (biomass, van der Werf) emissions rather than also industrial emissions (IPCC6, Smith) is not convincing
- the examined region is relatively small
- the opportunity to contrast impacts with aerosol increase (before 2008) and aerosol decrease (after 2012) is missed
- many data limitation / inconsistencies are recognized but not further explored … so the value of the paper is limited and the suggested links remain speculative.

General comments:

This study examines co-located 'observational data' based on satellite retrievals for aerosol and clouds over time. Here, a relatively small region over China is picked since over the larger China region the (fine-mode) aerosol loads after many decades on continued increase have been decreasing over the last decade. Co-located cloud properties over the same period were examined. The associations suggest that for aerosol impacts on low water clouds the first indirect effects (Twomey) seem unimportant (which is not completely surprising as baseline CCN concentrations are already very high), while cloud lifetime impacts (aerosol solar absorption and heating associated evaporation for less cloud cover) seem more relevant. Hereby it is suggested that the reduced aerosol load and absorption is recent years might explain increases to low altitude cloud cover and to liquid water content.

There are many (admitted) observational limitations, especially with respect the interpretation of aerosol type thus I recommend also to look at the fine-mode AOD of the MISR retrieval, which I placed on ftp ftp://ftp-projects.zmaw.de/aerocom/satellite/mis_v23/
It seems very promising to examine cloud property changes in regions where large changes in aerosol loading have occurred. However for that region an opportunity is missed by just exploring periods of a recent AOD decline (especially since 2012), whereas it was contrasted by a strong AOD increase before 2008. Thus opposing cloud property changes should have been observed, if there was an aerosol impact on clouds. Unfortunately even with these AOD changes the aerosol loading was quite high so that CCN concentrations may been already saturated with respect to droplet formation which in part explain the largely 'missing' first indirect effect.

Overall, I like the paper but I am sometimes dismayed at the recognition of shortfalls without going into further detail. The data-consistency (e.g. CLARA) also is often a major handicap so that despite of significant data-analysis often there remain relatively little useful information to work. The use of reanalysis data is an interesting aspect, and I just wonder if they the MODIS data assimilation in MACC actual changes in cloud-properties in the examined China regions are simulated. I suggest also not to look just at biofuel but also fossil fuel emission (trends) as alternate aerosol change indicator although working with actual AODf is probably best.

Minor comments:

figures

Figure 1 biomass burning emissions are at a maximum in spring but AOD/ AODf reductions (of MISR see below) are largest in fall. I would also add seasonalities of MISR data (AOD, AODfine and AODnonsphere[dust])

Figure 2 MODIS data over land have limited accuracy and MISR data are there usually more accurate … although the reduced AOD in that region is not questioned. The component AOD type assignments of CALIPSO involve many assumptions and should not be overinterpreted

Figure 3 the AOD reductions by MODIS and CALIPSO are max in October, for which GEFD changes can be hardly used to explain. Also consider that the CALIPSO ‘smoke’ in fact could be ‘pollution’

Figure 4 cloud fraction is relatively high (ca 80%) so that the number of successful pixels in MODIS retrievals maybe very small and that CALIPSO will miss cases with strong pollution below clouds. Why is the water cloud phase dominant in the coldest seasons (that is not very intuitive). Also I would assume the largest cloud-fraction, COT and LWP during the monsoon season in summer, which the seasonality does not show.

Figure 5 the increase to LWP and cloud cover change have a strong local signature so I wonder if working with large regional changes is too simple. Even these annual averages display strong variations over time, so that I wonder if the identical ‘trends’ are significant. Also COT an REF retrievals are only possible for overcast conditions – so in that context tendencies in overcast cloud conditions would be of interest as well.

Figure 6 AVHRR over the years have different overpass time (trends may reflect in part daily cycles) and different sensors, so CLARA may not have the homogeneity needed for long-term trends. On the other hand the long time series is of advantage as (industrial) fine-mode AOD likely increased until 2008 and likely decreased since 2008 over China. So if there is a cloud property response I would expect a clear bi-polar response, which I do not see.

Figure 7 the largest cloud property changes (increases to all examined cloud properties!) are in December – not the month with the largest AOD changes (October). Also the largest AOD and AODf values of MISR in that region are in spring (consistent with your Figure 1)

Figure 8 the changes in October are likely pollution rather than smoke and the category of dust mixtures is too imprecise for me to be useful.

Figure 9 Wouldn’t it be better to show the histogram just for Oct and Nov when you focus on Oct and Nov changes. Actually I am bit uncomfortable just to focus on two individual months rather than on an entire season – in the context of meteorological variability

text

page 2 / 20 there are some issues with the total AOD, since the it is contaminated by larger dust particles, which do not contribute as smaller particles from wildfire and pollution to particle concentrations and potential CCNs. MODIS only offers to total AOD and there are issues with the accuracy over land (for which the data are applied here) and the opportunity to retrieve aerosol maybe be limited by the relatively high low cloud cover. And the aerosol typing of CALIPSO is only quantitative – especially for ‘mixtures’ and it is extremely difficult to distinguish between pollution and biomass aerosol types. I think the use of MISR data also should be included in order to include AOD trends, especially since MISR also addressed the AODf.

page 2 / 40 the mentioning of the GFEDv4 data is an interesting concept to justify aerosol changes due to biomass burning, but I would argue that industrial emission reductions (talk to Steve Smith to provide his industrial emission data for that region) are much more likely to explain satellite observed AODf reductions in recent years.

page 3 / 10 the MODIS data for (liquid) cloud cover is the most reliable property (though possibly biased by the overpass time and also dependent on the non-obscurance by higher altitude clouds). Details (LWC, Reff and COT) only refer to an overcast cloud subsample – so I wonder if also changes for overcast low cloud pixels can be addressed as well

page 3 / 15 I wonder how stable the CLARA data-set is, especially involving AVHRR data with drifting overpass time and different sensors.

page 3 / 30 consistent changes of different data is certainly a help but for clouds I wonder how independent the cloud retrievals (other than cloud cover) are.

page 4 / 12 what is a pixel? (I assume a 1x1 lat-lon region), thus there are 50 pixels in the regions investigated region

page 4 / 20 domestic burning may be largest in winter … but what about industrial emissions as I also expect that mitigations (e.g. to electric vehicles) have lowered emissions?

page 4 / 35 the aerosol typing of calipso should be taken with care. What does ‘polluted dust’ really tell you on fractions of dust and pollution? without a good distinction between pollution and smoke how to argue via biofuel (GFED) rather than fossil fuel (IPCC6) changes?

page 4 / 38 given the potential of advection it would be useful also to look at trends including surrounding regions (at least for the aerosol data)

page 5 / 2 MODIS pixels for AOD are usually provided at 10x10km so the use of ‘pixel’ here for 1x1 deg is a bit misleading

page 5 / 16 please also add industrial emissions in Figure 3 (contact S.Smith, who provides industrial emissions over time – also for China – for IPCC6 simulations)

page 5 / 42 it does not seem too intuitive why there should be so much less liquid water clouds the monsoon season: is this an artifact since there are more ice clouds so that the lower altitude clouds cannot be seen?

page 6 / 5 the 1x1 region based changes to water cloud cover and water content show a lot of sub-regional signals … so maybe also aerosol data (e.g. AODf data) should be examined on that basis…?

page 6 / 20 in figure 6 changes in the y-axis direction are relevant, so that the Reff results are rather meaningless – other than could drops were relatively large in 2003 … which however was identified in the text as an artifact. Although Figure 6 is a nice analysis the results may not be robust enough to make good cases for cloud property changes.

page 6 / 20 the changes to aerosol (earlier) and cloud (later) do not have the quite same seasonality … and the admittance of potential meteorological causes is good though limiting to the goals of the study.

page 7 / 5 unfortunately no renalaysis data are shown (in that context it would be interesting if reanalysis sees the same ‘trends’ for aerosol and cloud properties as the observations. The reanalysis also could address if there were changes to the monsoon (strength and location) … e.g. were there trends in precipitation and are there temporal shifts (e.g. associated potentially with temporal delay with more fine-mode aerosol)? Also do the reanalysis data see shifts in fine-mode AOD altitude as indicated by CALIPSO?

page 7 / 25 to exclude monsoon impacts the focus is on changes to aerosol and clouds in the dry season … so maybe this can be even part of the title.

page 7 / 37 add ‘rapid’ after ‘more’

page 8 / 1 also aerosol from pollution is absorbing (ssa ~ 0.92) – although usually not so strong as from fresh biomass aerosol (ssa ~ 0.85).

page 8 / 13 if there I so much low altitude cloud cover in Oct and Nov, how reliable is the CALIPSO statistics (other than the strong trend changes within 1 month seem highly suspicious)

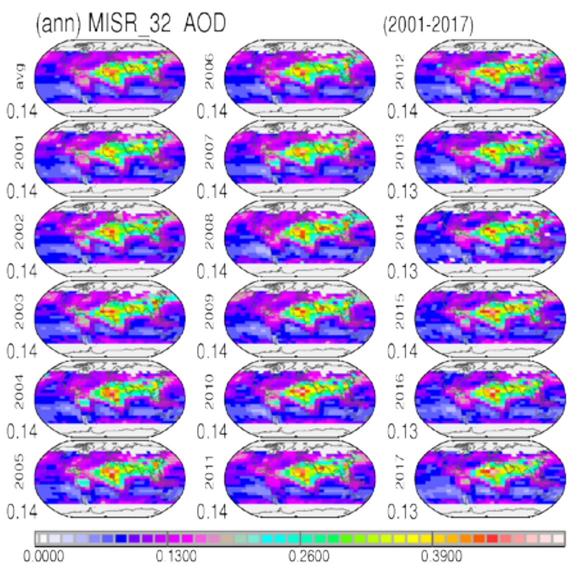
page 8 / 35 interesting but speculative, although possible at least to some degree

page 9 / 10 to make the stated case on absorbing aerosol decrease in that region (other than aerosol in that region is absorbing to start with) it would be useful to demonstrate that these aerosol reductions are associated with the fine-mode AOD (at this point there is a reliance on Calipso typing which is quite general and its association with biomass burning is not very convincing as also urban/industrial (fossil fuel) emissions were reduced and may be even more relevant.

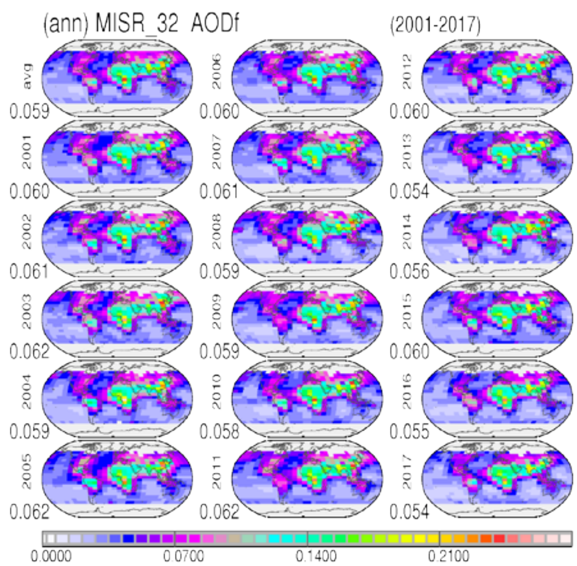
page 9 / 20 the disclaimer is warranted (though disappointing)

Here the MISR data for AOD (dust +pollution + wildfire) and AODf (only pollution + wildfire) are analyzed for changes. In the context of impacts on clouds the fine-mode AOD is more relevant since it determines the aerosol number concentration (MODIS and CALIPSO data of the study only address total AOD which is contaminated by coarse mode dust contributions – so here both total AOD as well as AODf are examined. Since MISR has limited coverage in the analysis monthly data were averaged on a 12(lon)x6(lat) degree grid. Difference maps to the local 18 year ***dAODf*** *(2001-2017) - annual* ge (2000-2017) better highlight differences.

AOD *(2001-2017) – annual*

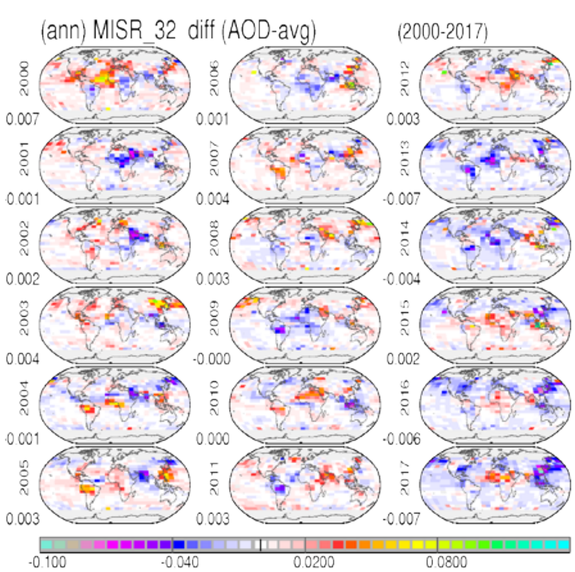


AODf *(2001-2017) – annual*

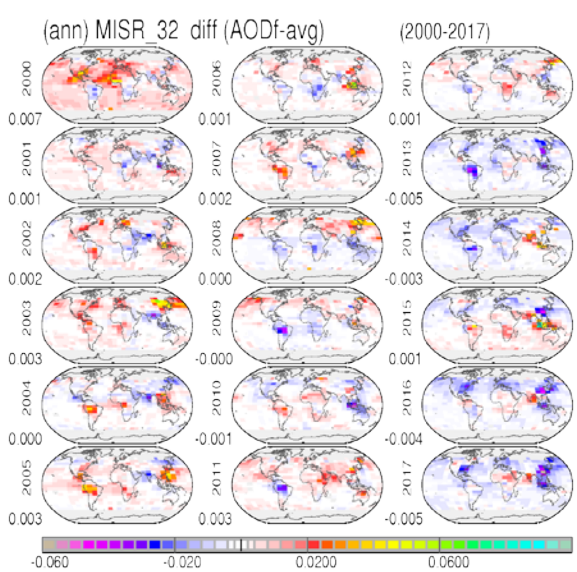


differences to the long-time (17 year) local averages ….

dAOD *(2001-2017) - annual*

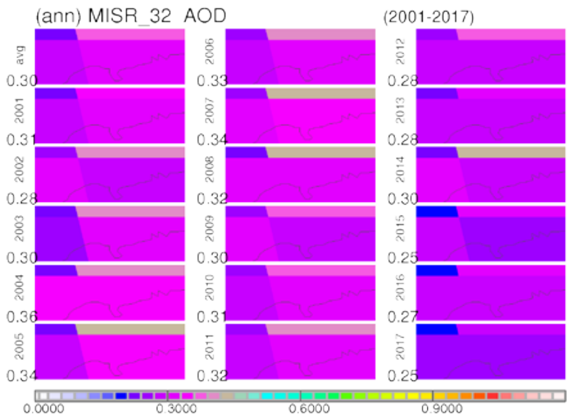


dAODf *(2001-2017) - annual*

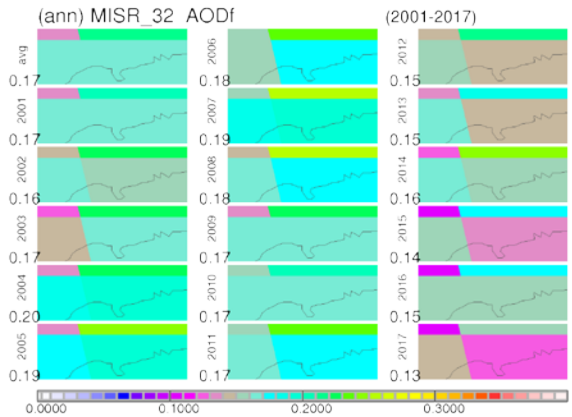


Here the MISR data

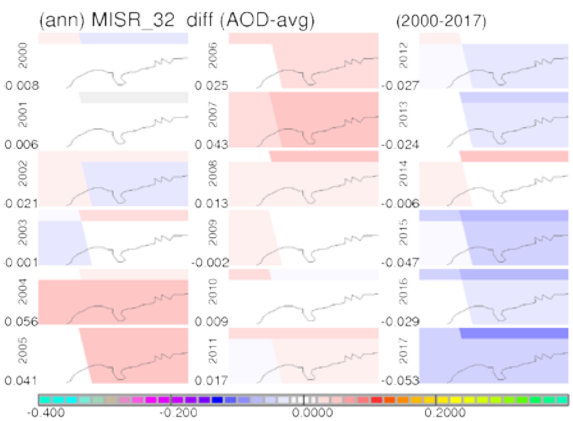
AOD *(2001-2017) – annual South China*



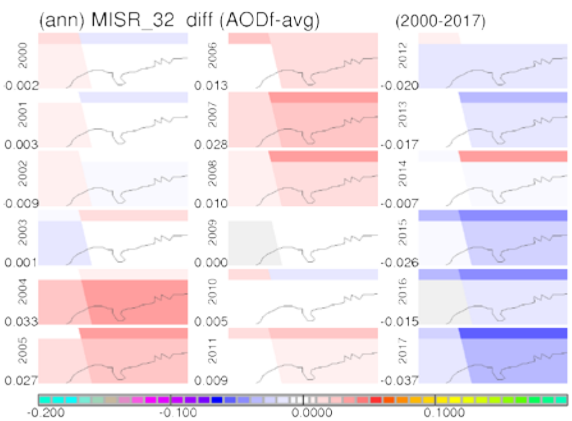
AODf *(2001-2017) – annual, South China*



*d**AOD** (2001-2017) – annual, South China*



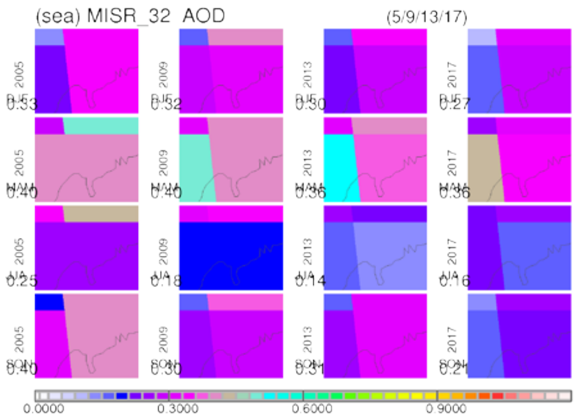
*d**AODf** (2001-2017) – annual, South China*



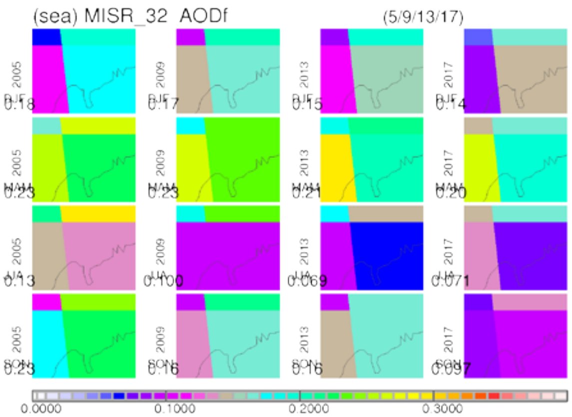
Over the South China region almost half for the AOD is NOT in the fine-mode. Compared to the relative large AOD between 2004 and 2008 there is reduction in AOD and AODf since then.
In 2012 and 2013 the reductions are mainly due to the fine-mode (AODf) while lower values from 2015 to 2017 are caused by both fine-mode (AODf) and coarse-mode (AOD minus AODf).

Thus anomalies are now examined on a seasonal basis.

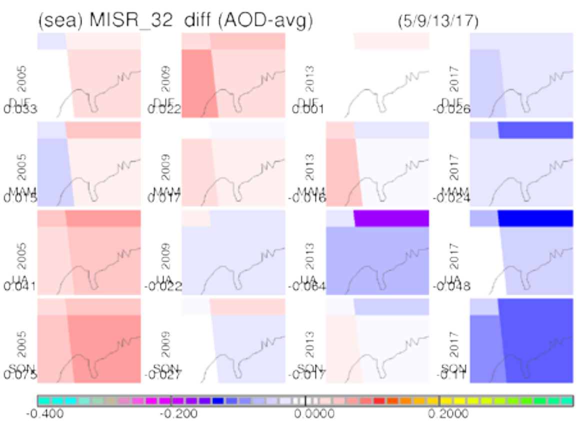
***AOD** (05,09,13,17) – seasonal, south China*



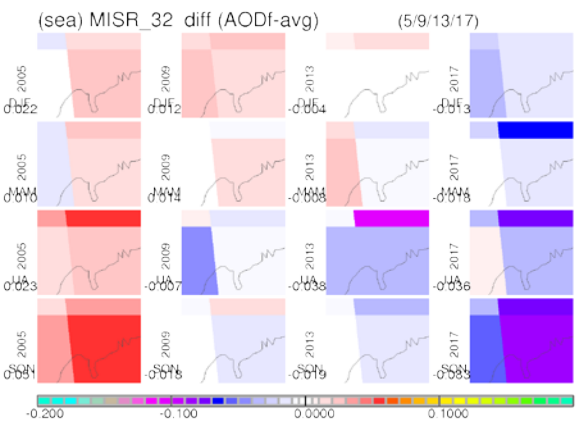
***AODf** (05,09,13,17) – seasonal, south China*



*d**AOD** (05,09,13,17) – seasonal, south China*

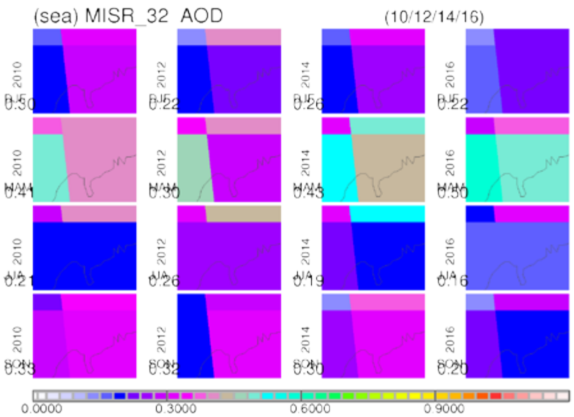


*d**AODf** (05,09,13,17) – seasonal, south China*

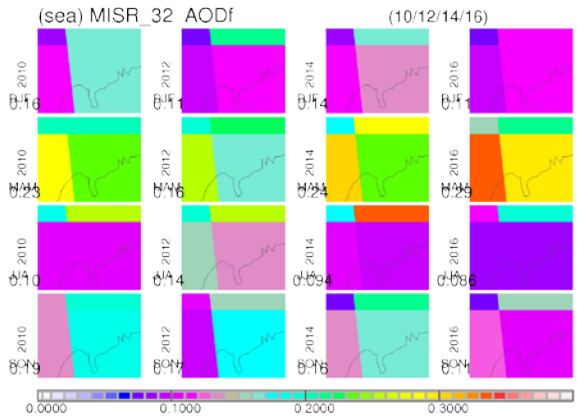


The AODf reductions are larger during summer and fall, reductions in winter and fall are smaller in 2017.

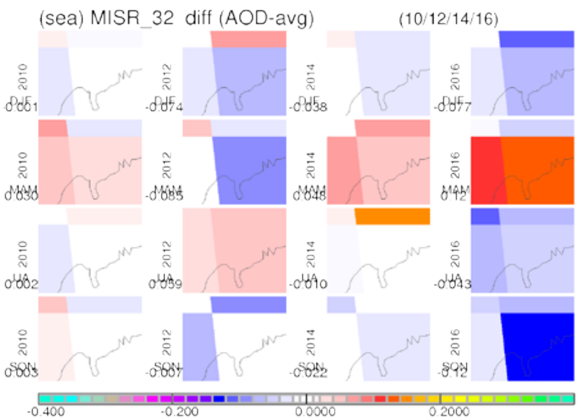
***AOD** (10,12,14,16) – seasonal, south China*



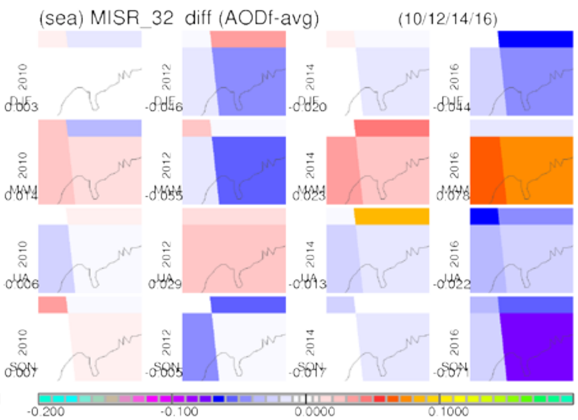
***AODf** (10,12,14,16) – seasonal, south China*



*d**AOD** (10,12,14,16) – seasonal, south China*



*d**AODf** (10,12,14,16) – seasonal, south China*



The AODf reductions are largest in fall during fall and winter, reductions in winter and summer are smaller and there is even an spring increase in 2012 and 2016.