UPDATES ON THE INTERNATIONAL COOPERATIVE FOR AEROSOL PREDICTION MULTI-MODEL ENSEMBLE (ICAP-MME)

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CURRENT ICAP OPERATIONS - as of May 2018

U.S. NAVAL RESEARCH LABORATORY

Organization	BSC	Copernicus/ ECMWF	JMA	Meteo France	NASA	US Navy	NOAA	FMI	UKMO
Model	MONARCH	CAMS	MASINGAR	MOCAGE	GEOS-5	NAAPS	NGAC	SILAM	MetUM
Status	QO	O-24 hrs	QO	O	QO	O	O	O	O
Meteorology	Inline NMMB	Inline IFS	inline AGCM	Offline ARPEGE	Inline GEOS-5	Offline NAVGEM	Inline GFS	Offline IFS	Inline UM
Resolution	1.4x1 (0.7x0.5)	0.4x0.4	0.375x0.375	1x1	0.25x0.31	0.33x0.33	1x1	0.5x05	0.35x0.23
levels	24 (48)	60	40	47	72	60	64	60	70
DA	LETKF[p]	4DVar	2DVar LETKF[p]	2018	2DVar +LDE	2DVar 3DVar, EnKF[p]	NA	3Dvar[p], 4Dvar[p], EnKF[p]	4DVar
Assimilated Obs	DAQ MODIS+DB	DAQ MODIS DT+DB PMAp	MODIS L3, AHI[p], CALIOP[p]	NA	Neural Net MODIS	DAQ MODIS, AVHRR[p] VIIRS[p] CALIOP[p]	NA	NA	MODIS Dust AOT
Species	Dust, Sea Salt BC, OC (POA,SOA) Sulfate	BC, OC Dust Sea Salt Sulfate	BC, OC Dust Sea Salt Sulfate	BC, OC Dust Sea Salt Sulfate, Nitrate, Ammonium	BC, OC Dust Sea Salt Sulfate Nitrate	Anthro+bio B. B. Smoke Dust Sea Salt	Dust BC, OC Sea Salt Sulfate	BC, Dust, OC, Sea Salt, Sulfate, Nitrate, B.B. Smoke	Dust
Size Bins	8 (dust, salt) bulk for others	3 (dust, salt), bulk for others	10 (dust, salt), bulk for others	6	5 (dust, SS), 2(BC, OC), 3(NI*), bulk sulfate	bulk	5 (dust, SS), 2(BC, OC), bulk sulfate	4 (dust), 5 (SS), 3 (B.B. Smoke), 2 (sulfate), bulk for others	2
Antho. & Biogenic Emission	HTAPv2.1 (anthro), MEGANv2.04 (biogenic)	MACCity (anthro), MEGAN (biogenic)	MACCity	MACCity (anthro.) MEGAN-MACC (biogenic)	EDGAR V4.1/4.2, AeroCom Phase II, GEIA	MACCity, BOND, POET	EDGAR V4.1, AeroCom Phase II, GEIA	MACCity, STEAM, MEGANE, HTAP(Coarse PM)	NA
Bio. Burn. Emissions	GFAS	GFAS	GFAS	GFAS	QFED	FLAMBE	GBBEPx	GFAS, IS4FIRES	NA

➢ The ICAP-MME is run daily w/ 1x1 deg res at 00Z for 6 hrly fcasts out to 120 hrs w/ a 1-day latency.

➢ Modal AOT (550nm) and dust AOT (550nm) data in NetCDF is available publically.

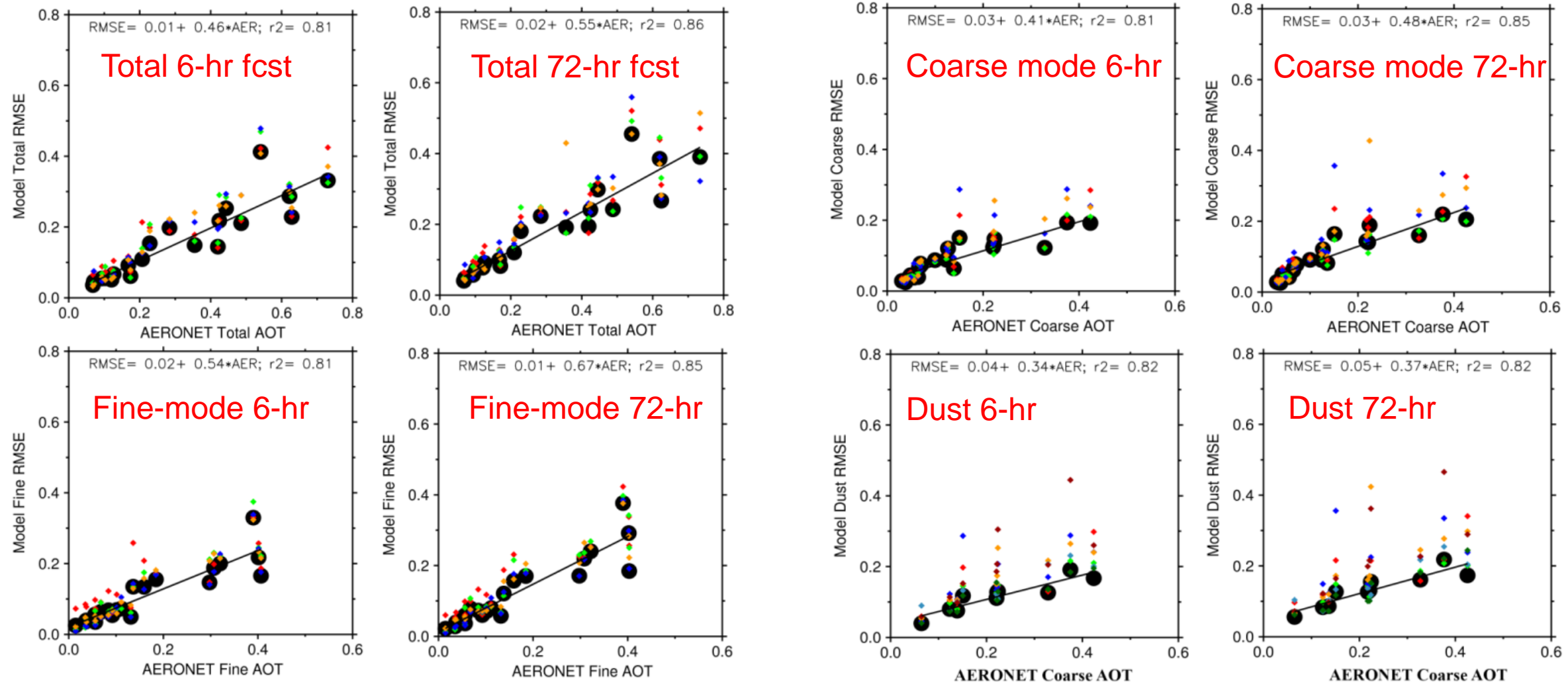➢ Green means proposed. Red means changes occurred last year. "p" means prototype.

Plots of analysis time (tau=0 hr) field is now available.

ICAP Model Data Flow
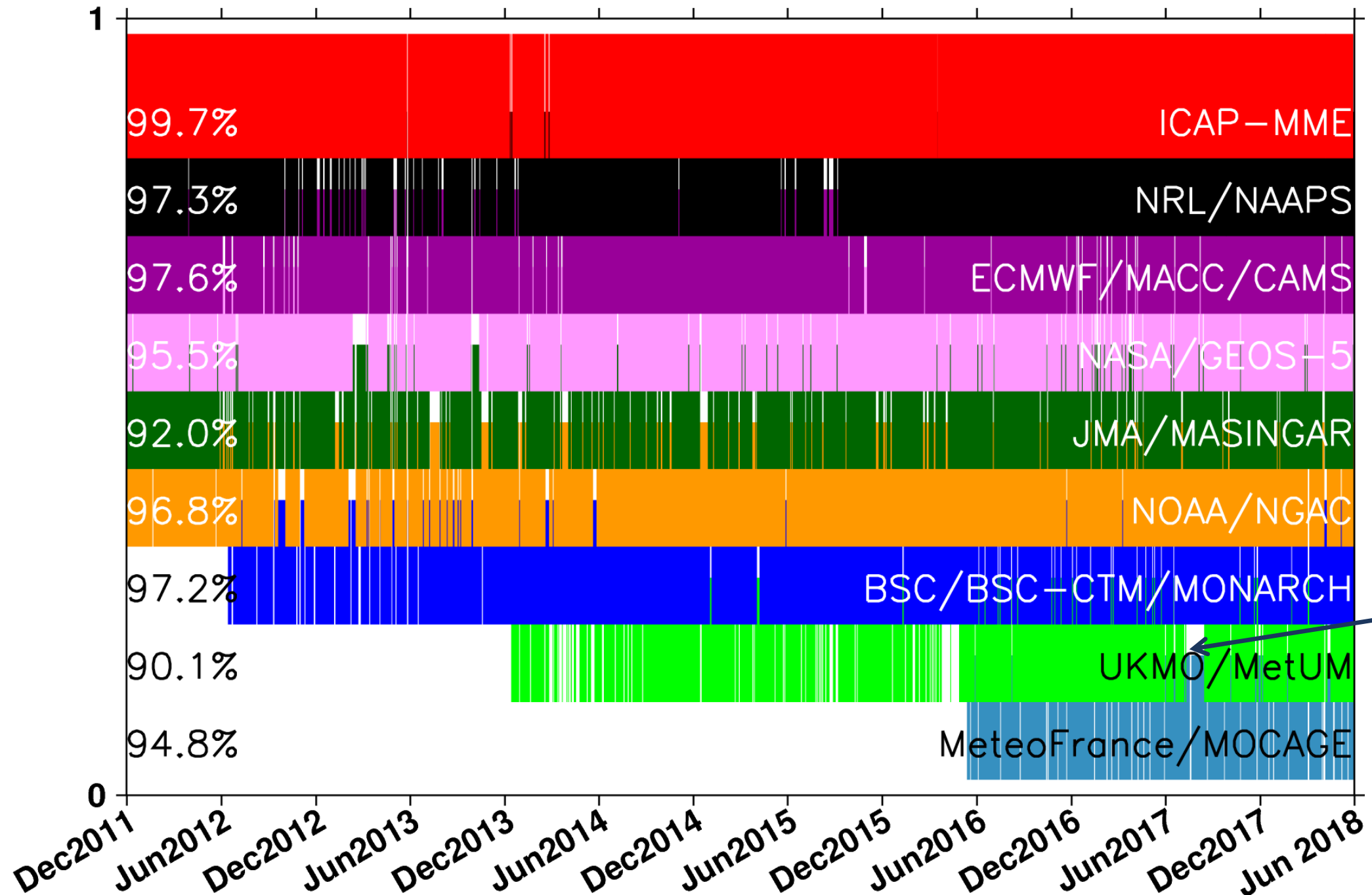
Black dot is MME
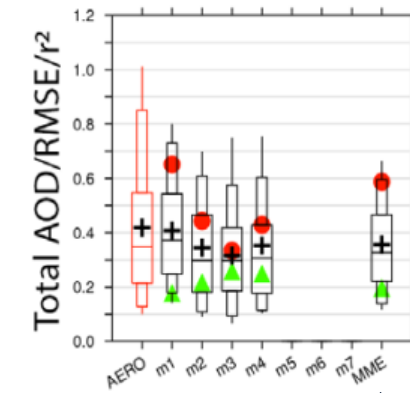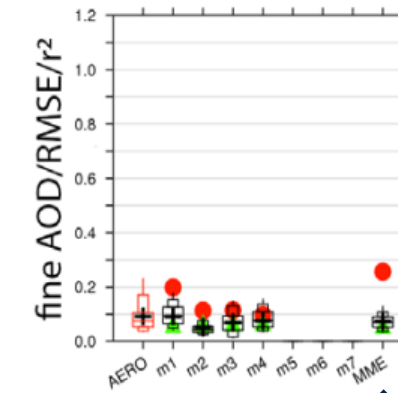

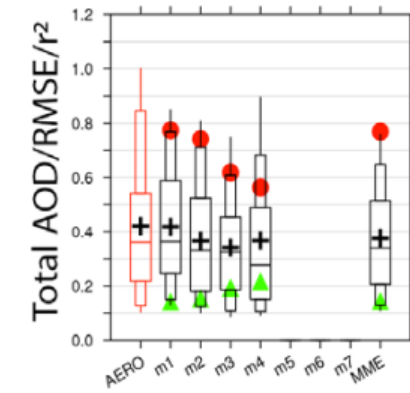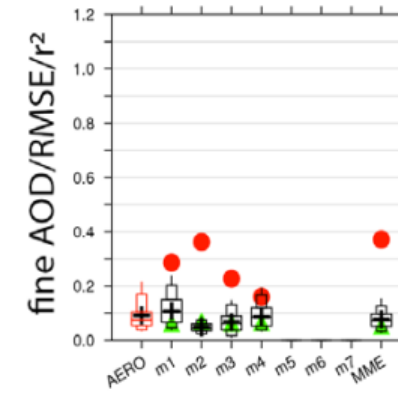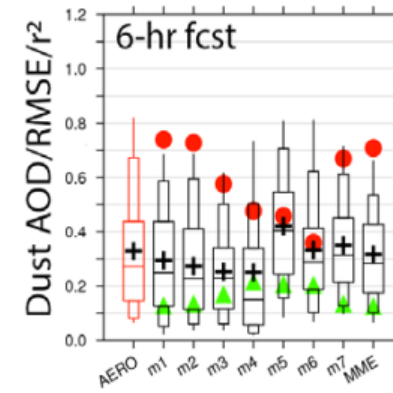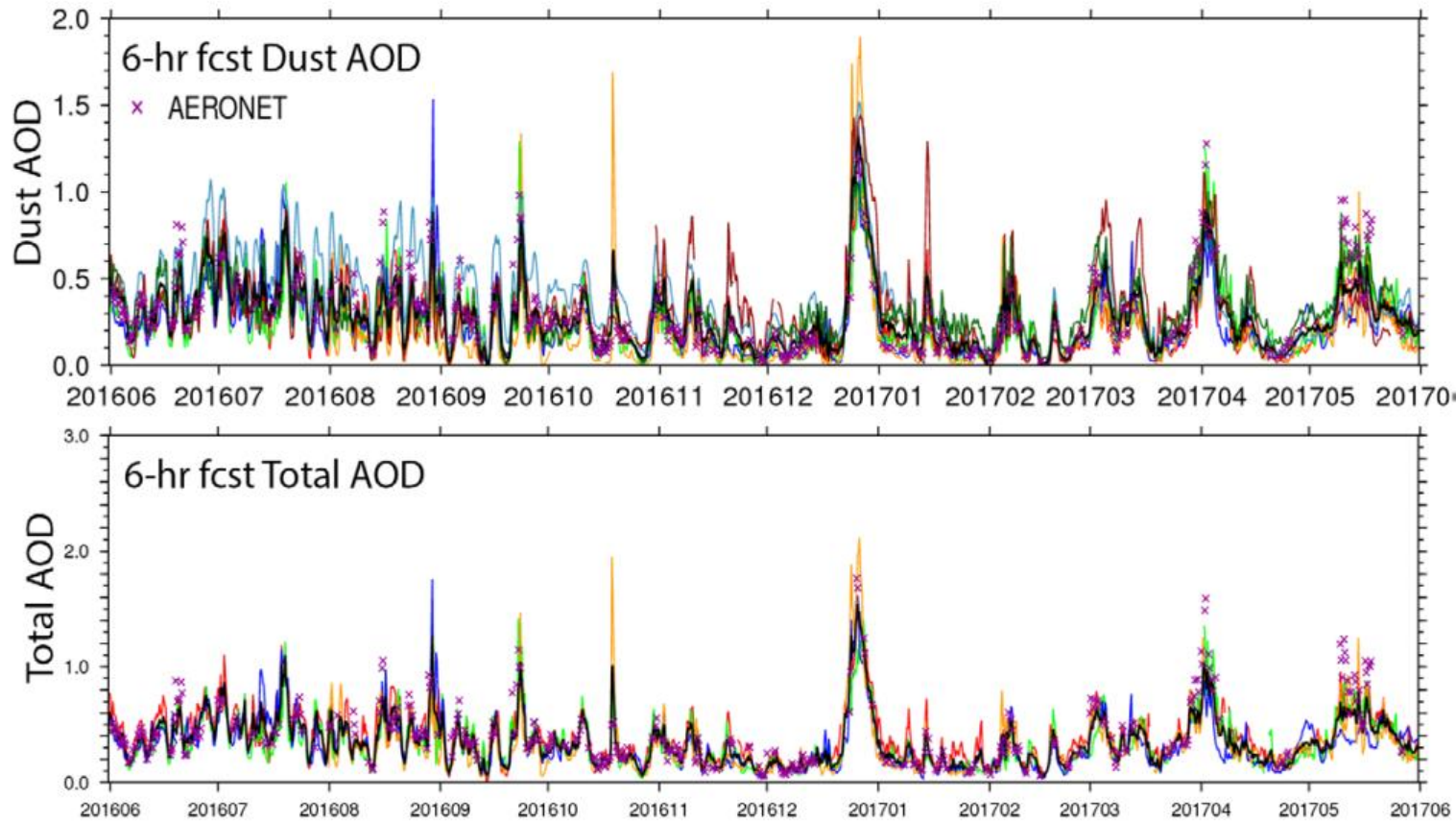- ICAP MME (consensus) is overall the top performer for all modes.
- Similar result as in Sessions et. al. (2015)
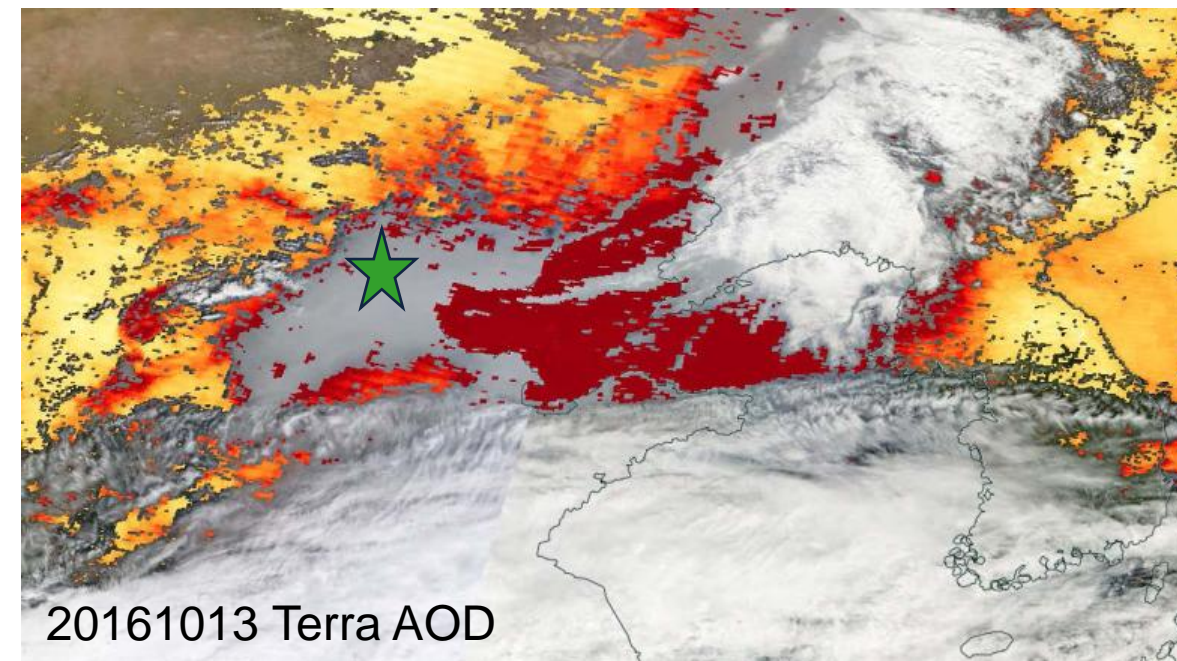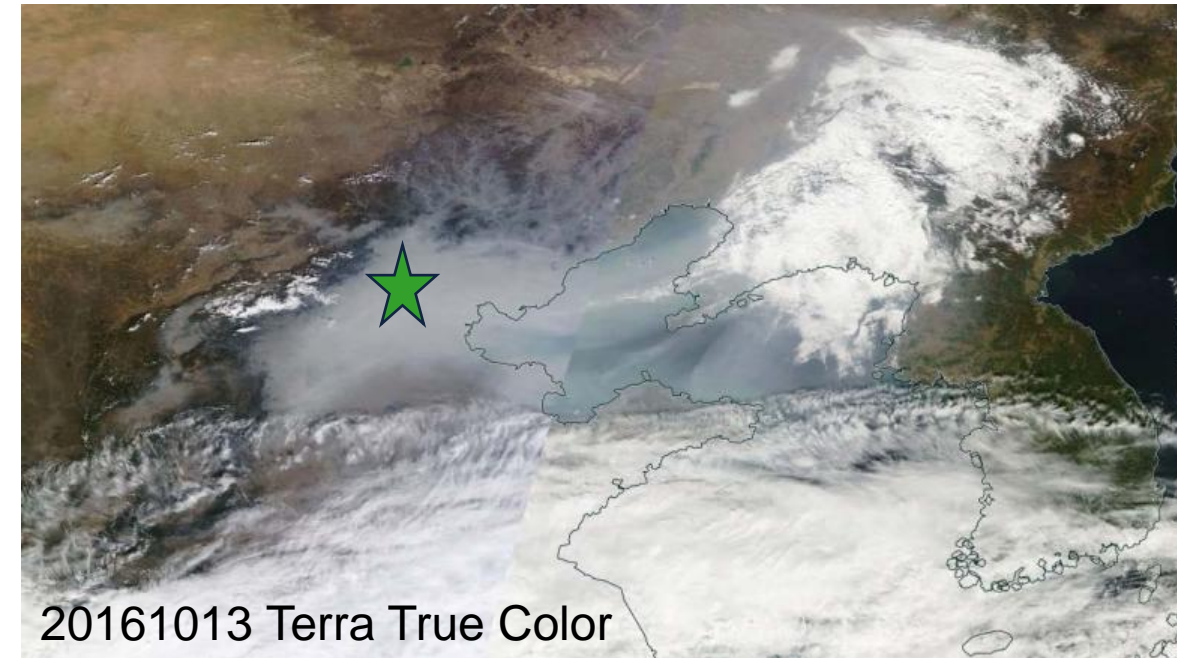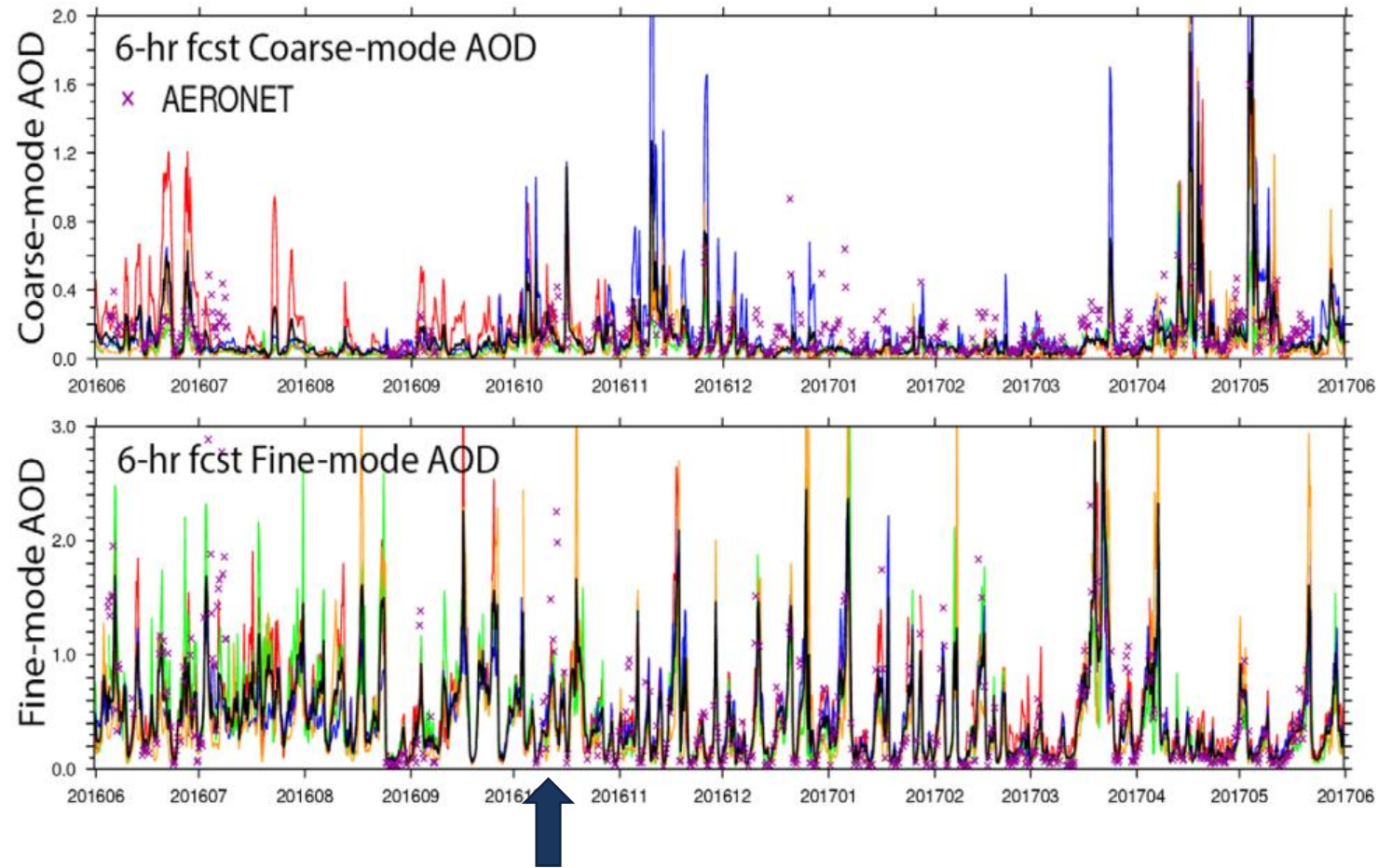
MME   MME   MME

➢ All the models perform relatively well at this benchmark site for African dust.
➢ ICAP MME ranks either the 1st or 2nd RMSE/ r^2. And the AOD range is good.

6-hr fcst Coarse-mode AOD
× AERONET

6-hr fcst Fine-mode AOD

20161013 Terra True Color
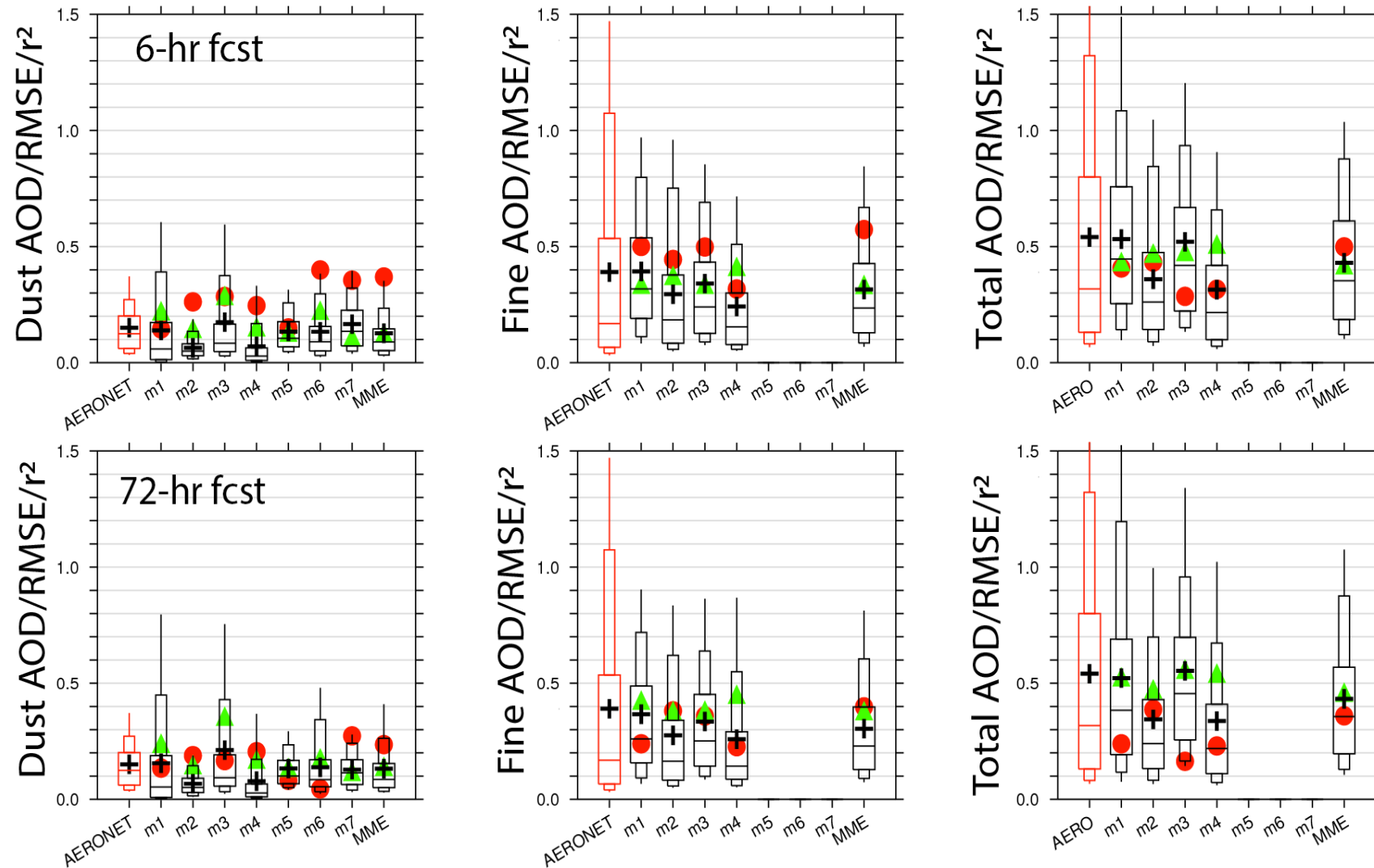
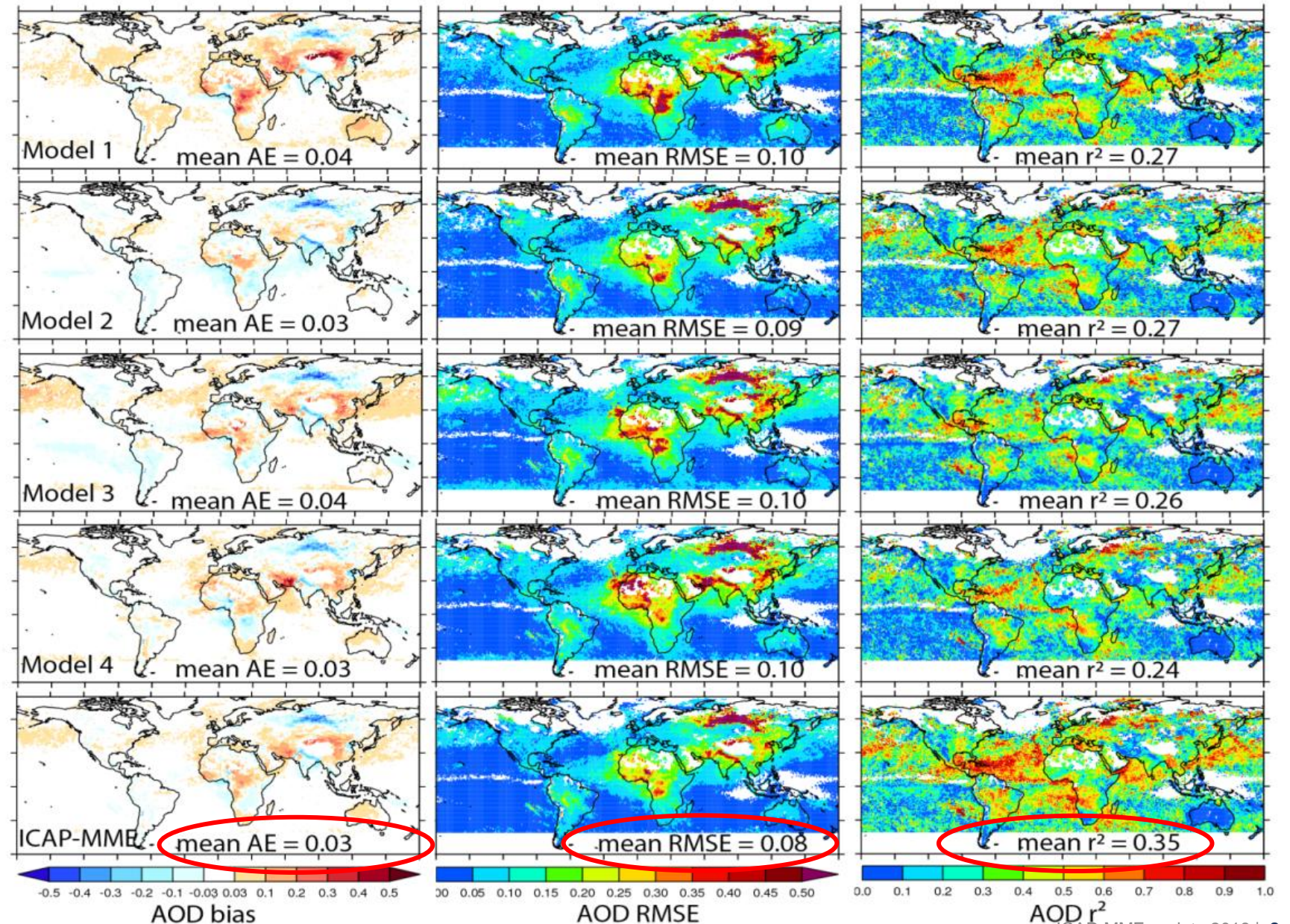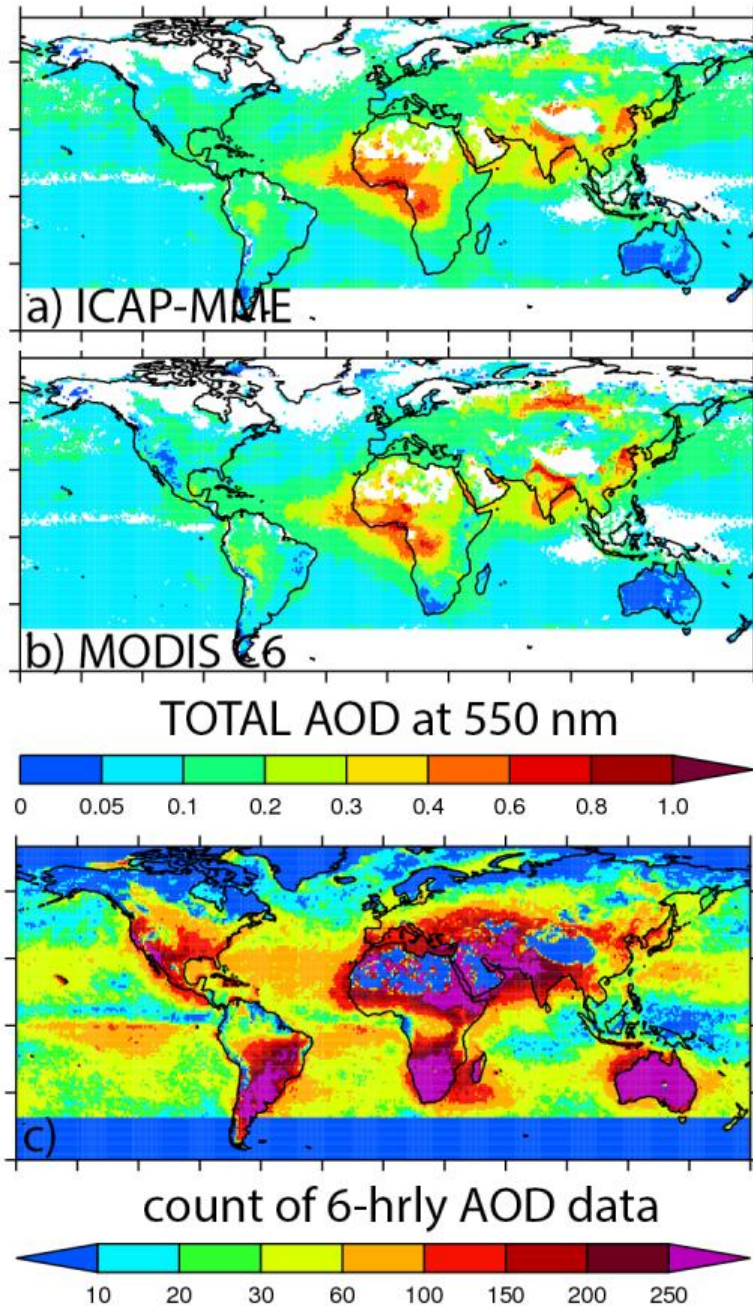20161013: None of the models capture this pollution event!
➢ There is large day-to-day variability in fine-mode AOD.
➢ Satellite AOD retrievals fail in such high AOD events.

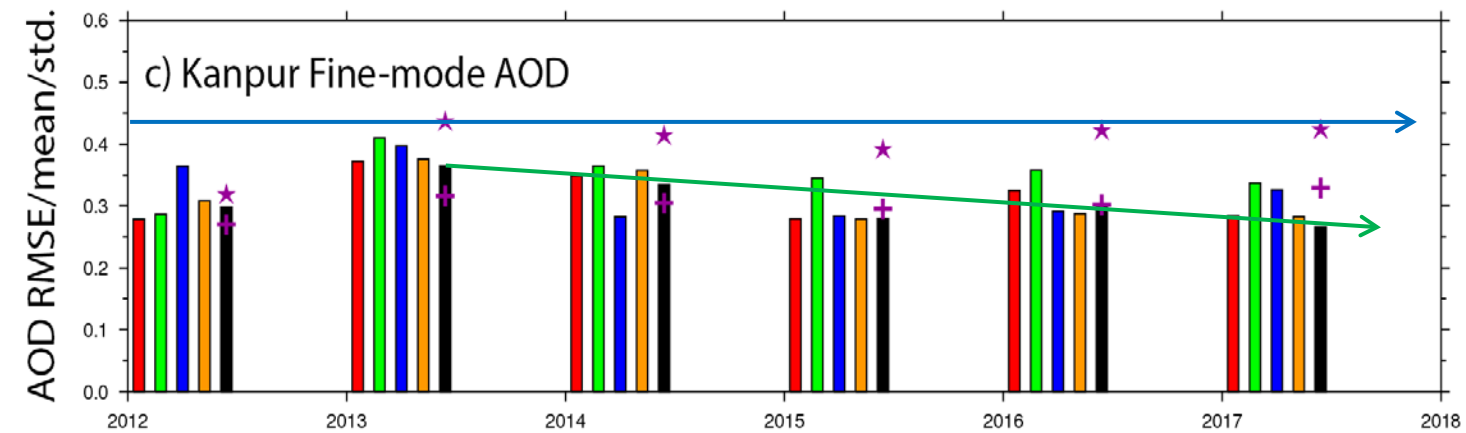20161013 Terra AOD

Multi model verification at Beijing

➢ Models perform less well at Beijing. Fine-mode events seem more challenging than dust events.
➢ ICAP MME ranks either the 1st or 2nd RMSE/ r^2.

a) ICAP-MME

b) MODIS C6

TOTAL AOD at 550 nm

c) count of 6-hrly AOD data

Model 1   mean AE = 0.04   mean RMSE = 0.10   mean r² = 0.27

Model 2   mean AE = 0.03   mean RMSE = 0.09   mean r² = 0.27

Model 3   mean AE = 0.04   mean RMSE = 0.10   mean r² = 0.26

Model 4   mean AE = 0.03   mean RMSE = 0.10   mean r² = 0.24

ICAP-MME   mean AE = 0.03   mean RMSE = 0.08   mean r² = 0.35

AOD bias   AOD RMSE   AOD r²

➤ ICAP MME has the smallest absolute error, smallest RMSE, and largest r2 overall.

Evolution of ICAP-MME performance over 2012-2017

Black: MME
+ AERONET mean
★ AERONET std.

a) Beijing Fine-mode AOD

c) Kanpur Fine-mode AOD

AOD RMSE

| | 0.05 | 0.15 | 0.25 | 0.35 | 0.45 | 0.55 | 0.65 | 0.75 |
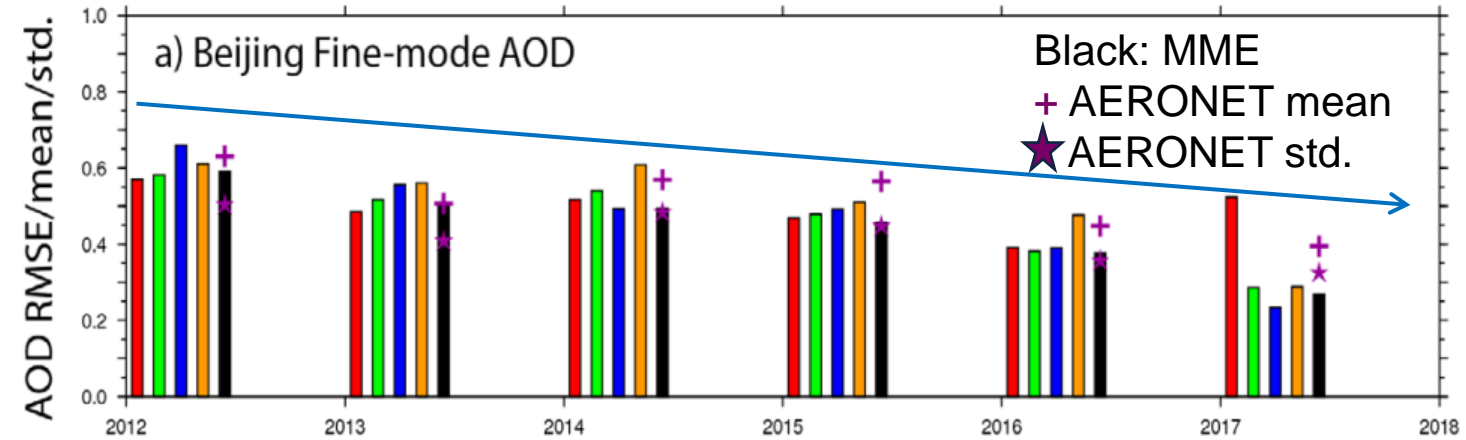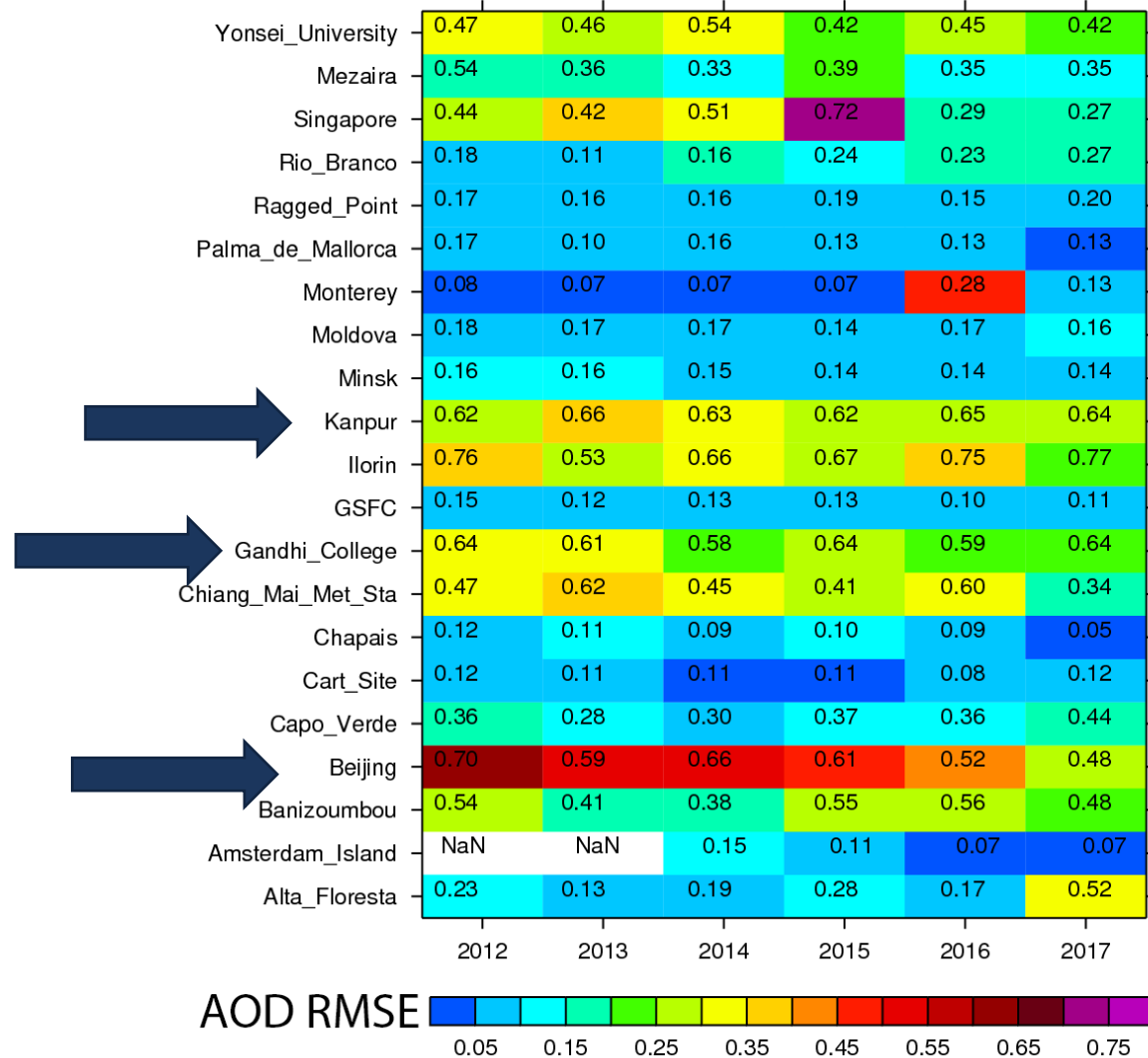
> ICAP-MME performance in terms of AOD RMSE shows little trend overall for the 21 regional representative sites.
> Exceptions: Beijing: a significant reduction in fine-mode AOD RMSE is found, mainly due to a decrease in fine-mode AOD.
>> Two Indian sites: there are reductions in fine-mode AOD RMSE but no significant change in the yearly-mean fine-mode AOD, suggesting a result of model improvement over the region.
> Large Interannual variability in regions influenced by biomass burning smoke and dust.

ICAP-MME   Model 1   Model 2   Model 3 — Major update   Model 4 — Major update
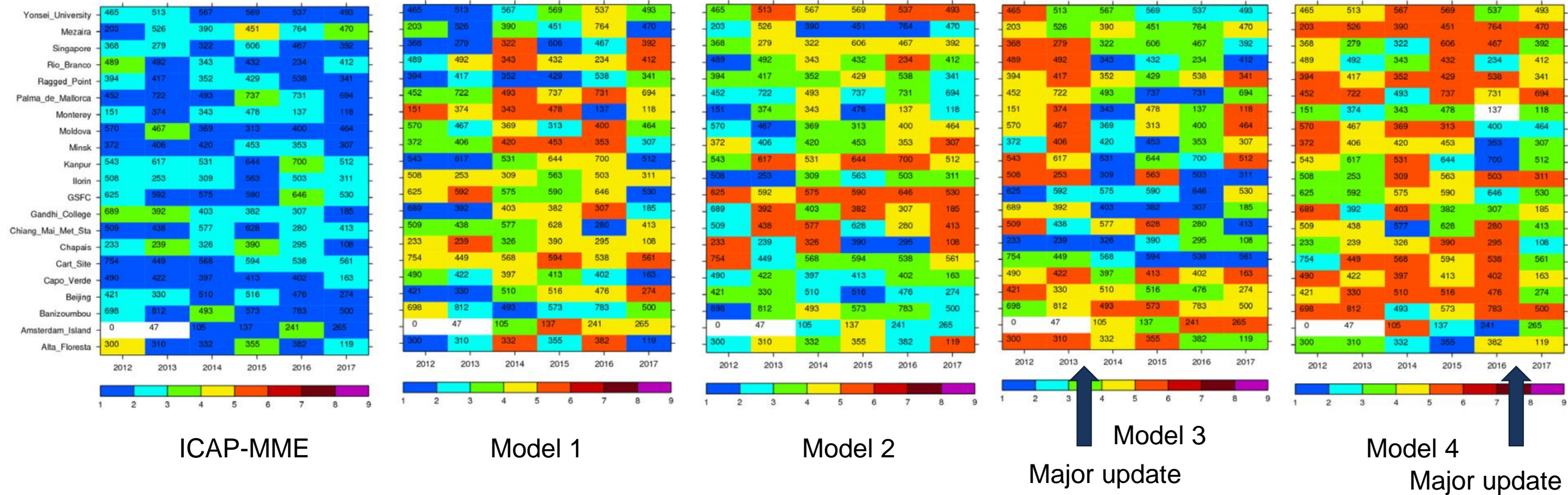
- ICAP-MME performance is stable and reliable over the years compared to individual models.
- AOD RMSE of the ICAP-MME is not always the lowest for a given species, site or year, but it is relatively low and stable.
- Consensus MME wins in the long run because of its averaging of independent models.

Error forecast model for ICAP-MME AOD
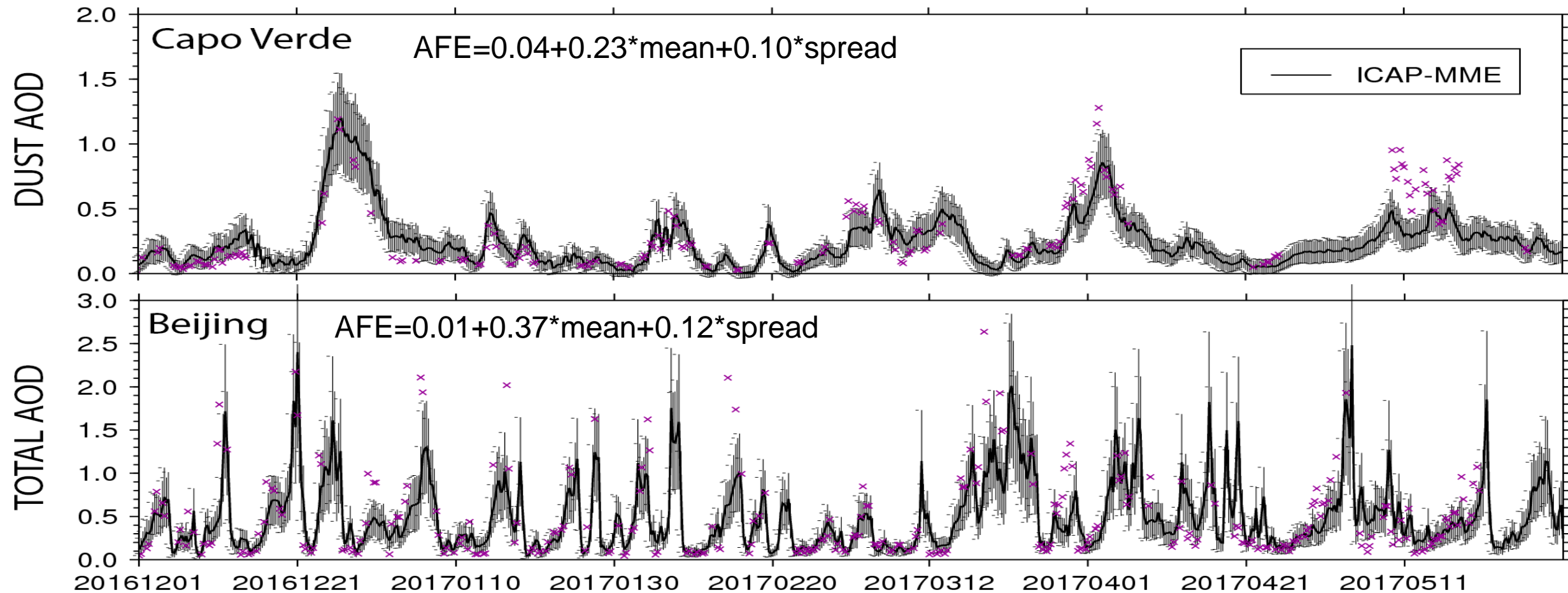
> ICAP-MME ensemble mean and spread are found to be good predictors for absolute AOD forecast error globally, except for over India, where they have little correlation with forecast error.
> Multivariate regression models of absolute forecast error are derived based on both ensemble mean and spread for total and dust AOD forecasts at different forecast lengths.
> These regression models can potentially be applied for probabilistic AOD forecasts.

- Global community is growing, up to 8 multi specie and 1 dust only model feeding the ICAP-MME system.

- ICAP-MME update paper submitted to QJRMS special supplement on ensembles.

- ICAP-MME performance is stable and reliable over the years compared to individual models. Consensus MME wins in the long run because of its averaging of independent models.

- ICAP-MME performance in terms of AOD RMSE shows little trend (2012-2017), except over Beijing, because of a steady reduction of pollutions over the years. Model skills over India is also improved possibly from emission inventory improvements.

- ICAP-MME ensemble mean and spread are good predictors for absolute AOD forecast error globally, except for over India, where they have little correlation with forecast error. Multivariate regression models of absolute forecast error are derived based on both ensemble mean and spread for total and dust AOD forecasts at different forecast lengths. These regression models can potentially be applied for probabilistic AOD forecasts.

- Next step is to have surface concentration ensembles and verification.

- 4-core reanalysis ensembles, including speciated AOD, surface concentration and PMs.