

# To what extent does biomass burning effect NWP? Consolidation of recent NASA IDS and ONR findings

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With help from Samuel Atwood<sup>5</sup>, Jennie Bukowski<sup>5</sup>, Robert Holz<sup>6</sup>, Derek Posselt<sup>7</sup>, Edward Hyer<sup>1</sup>, Undaysankar Nair<sup>8</sup>, Alexa Ross<sup>6</sup>, F. Joe Turk<sup>7</sup>, Peng Xian<sup>1</sup>

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# Aerosol particles in NWP

## A little context

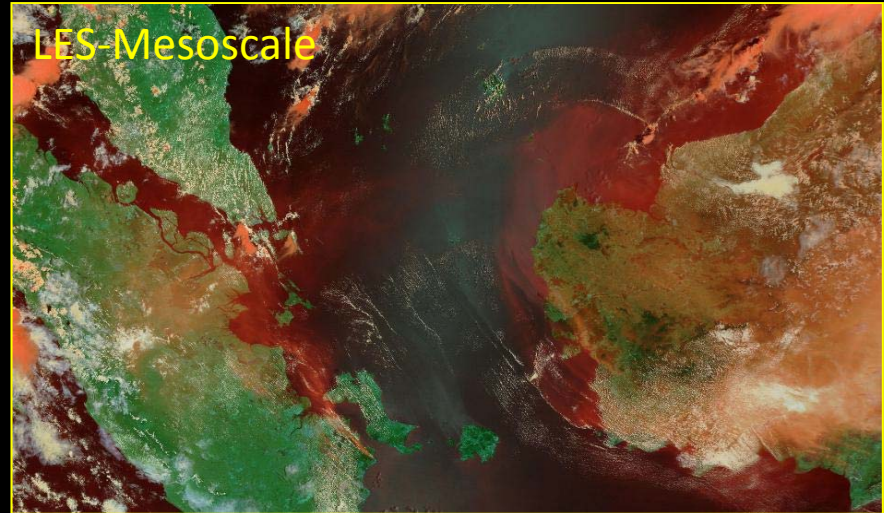
- Aerosol particles are known to perturb atmospheric state through radiation and thermodynamic processes. Research is largely related to “climate”.
- To what extent does knowledge of aerosol perturbations to the systems influence or improve the analysis and prediction of core “weather phenomenon” in the context of Numerical Weather Prediction?
  - Radiation/Heat fluxes, Temperatures, Winds, Clouds, Precipitation?
  - Data Assimilation?
- How important is important? Depends on the efficacy of your system and your toleration for sensitivity.
- “Climate impacts” and “NWP” are two sides of the same coin, with perhaps seasonal prediction sandwiched in the middle.
  - NASA IDS: Do aerosol particles affect dynamics, clouds and precipitation?
  - ONR: Where should aerosol particles be in regard to other NWP priorities?

# Biomass burning as a context for NWP model sensitivity: Four scales of predictability

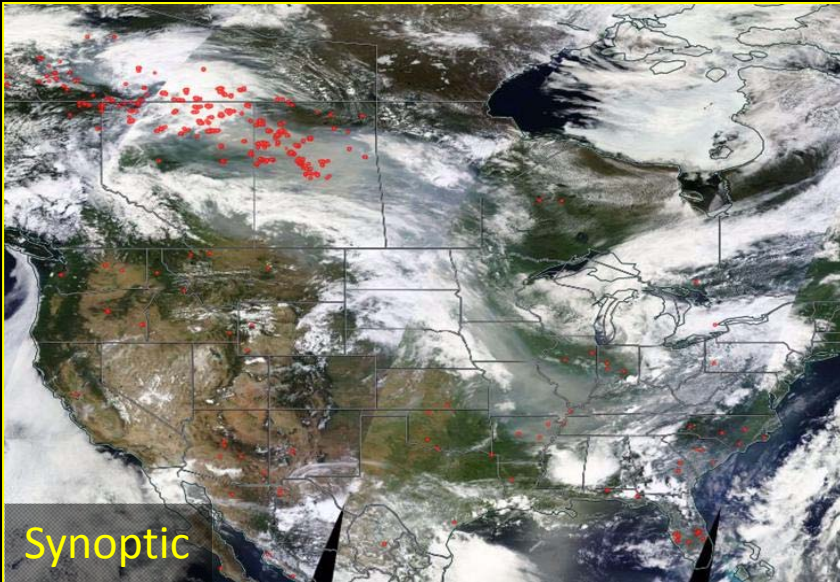
CFD/Microscale



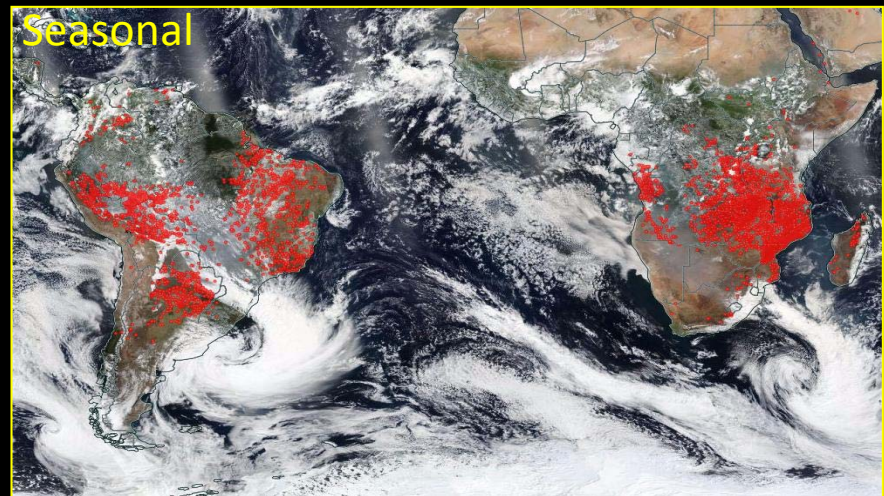
LES-Mesoscale



Synoptic



Seasonal



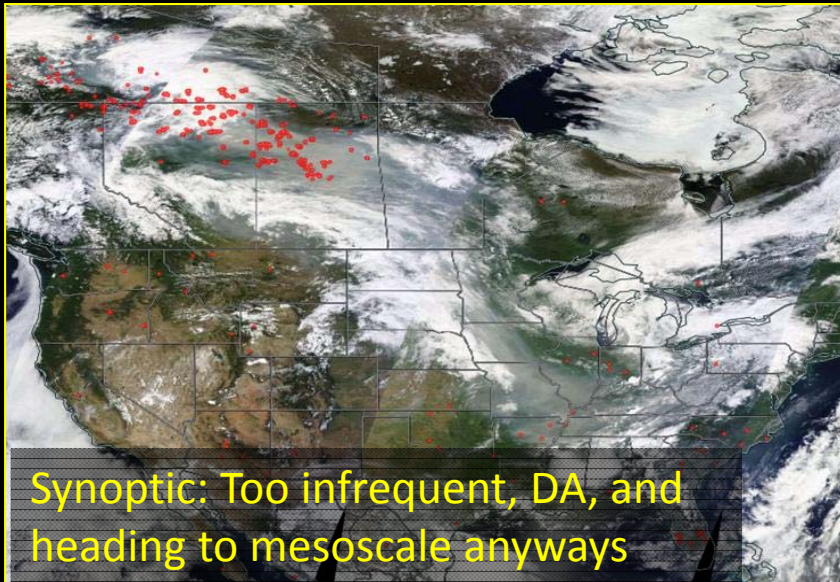
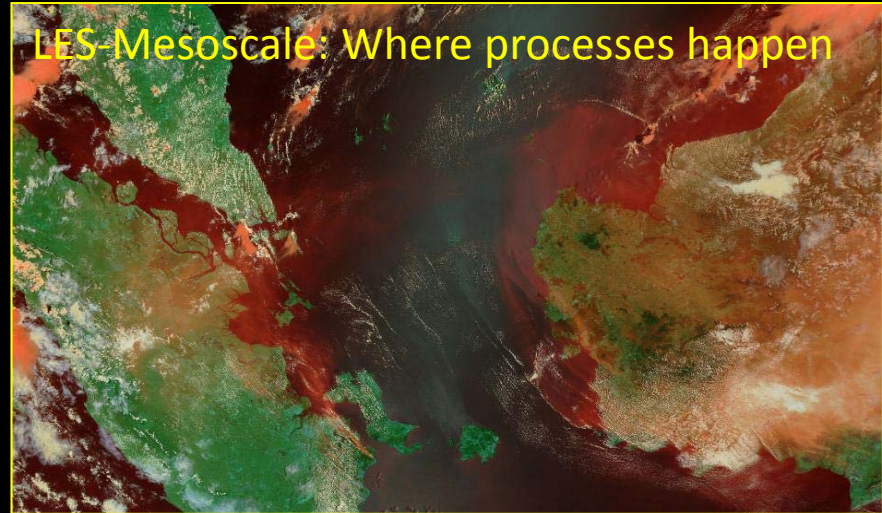
# Biomass burning as a context for NWP model sensitivity: Four scales of predictability

CFD/Microscale: Too fine, too stochastic



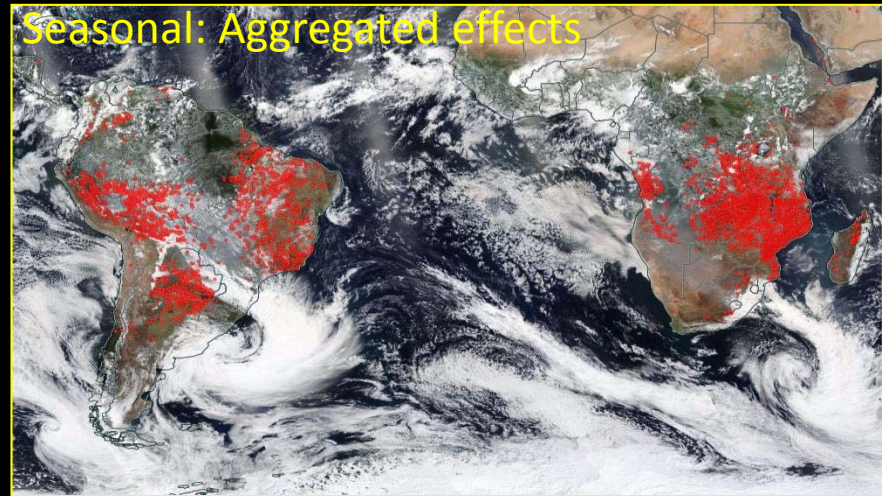
The Current Business End?

LES-Mesoscale: Where processes happen



Synoptic: Too infrequent, DA, and heading to mesoscale anyways

Seasonal: Aggregated effects



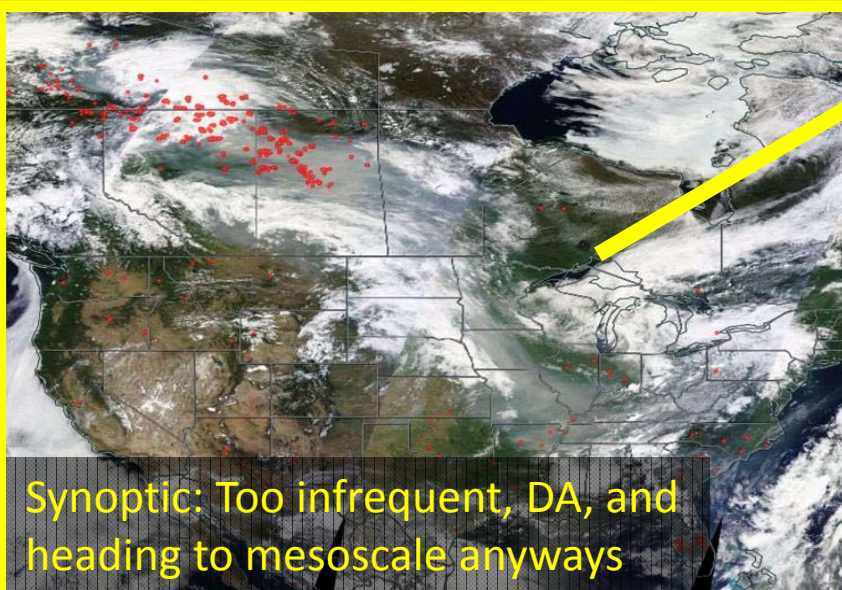
# Biomass burning as a context for NWP model sensitivity: Four scales of predictability

CFD/Microscale: Too fine, too stochastic



The Current Business End?

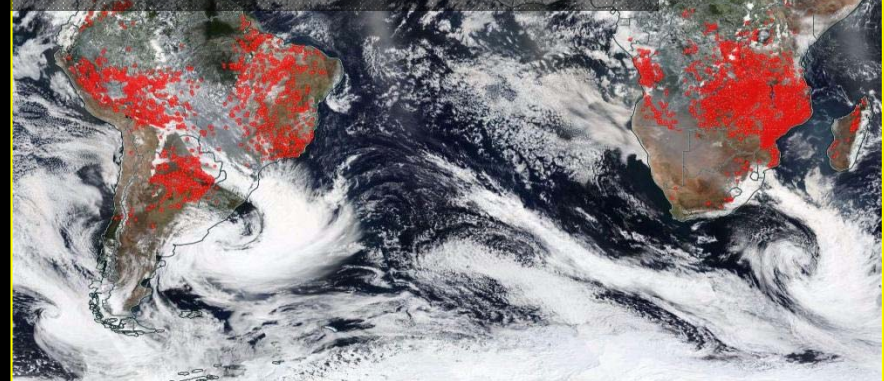
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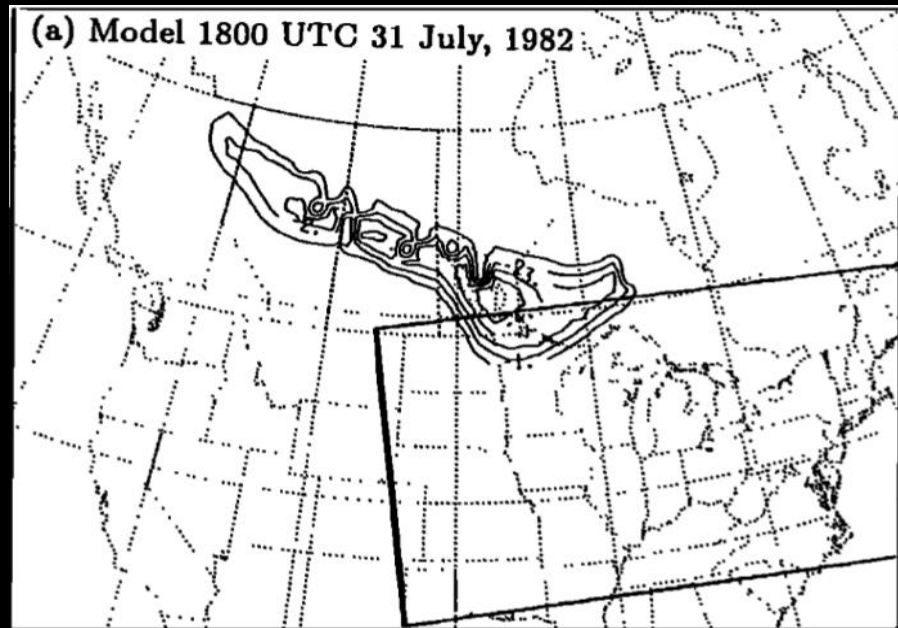
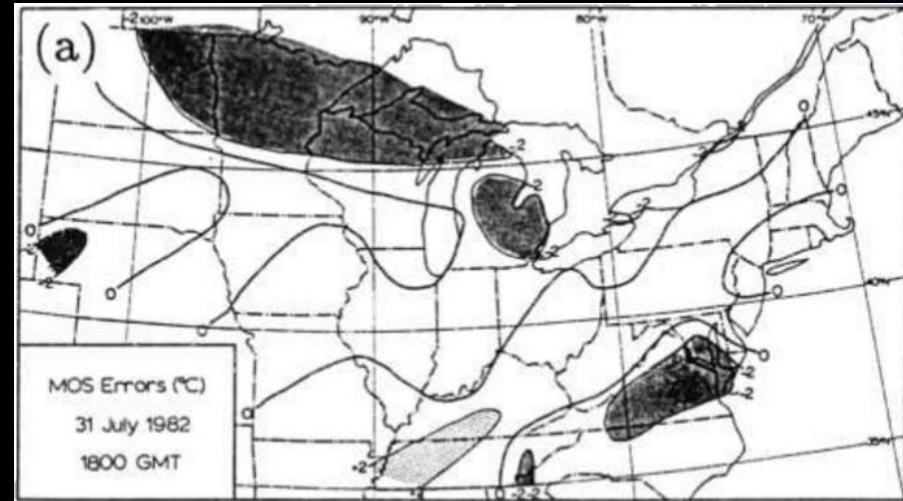
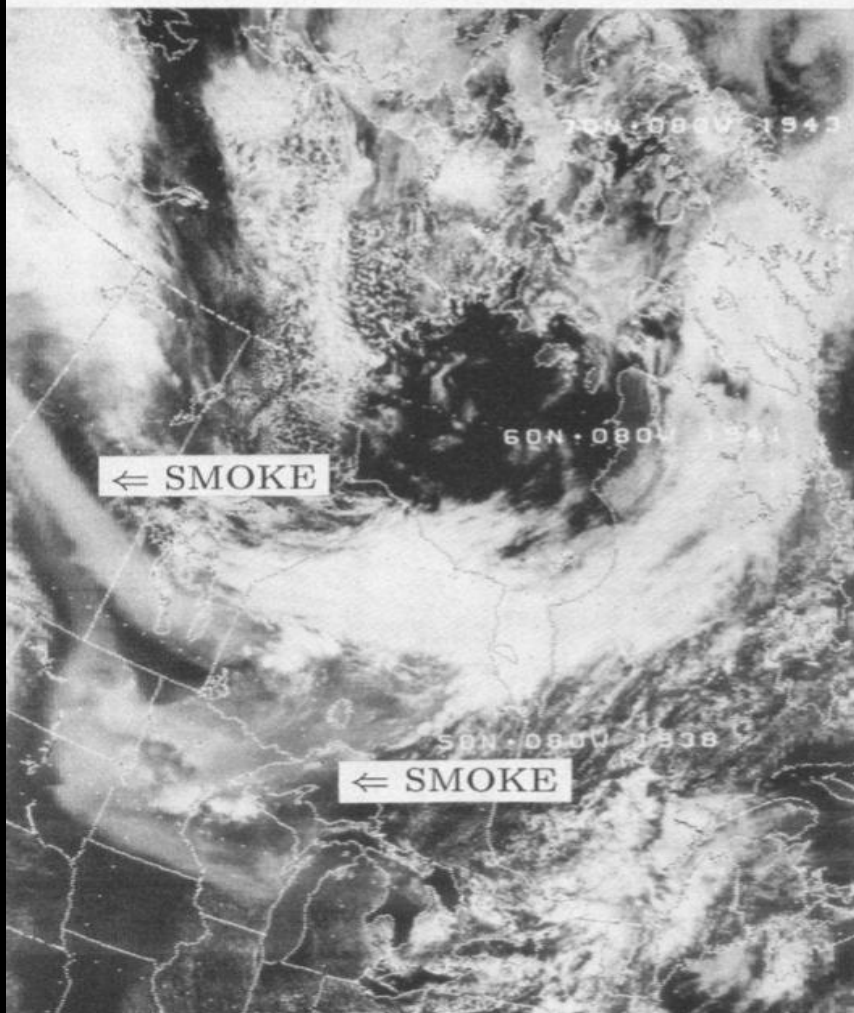
Seasonal: Aggregated effects

Wait 20 minutes for Angelia.....



# Synoptic: Clearly surface temperature impacts have seen for some time-Westphal and Toon (1991)

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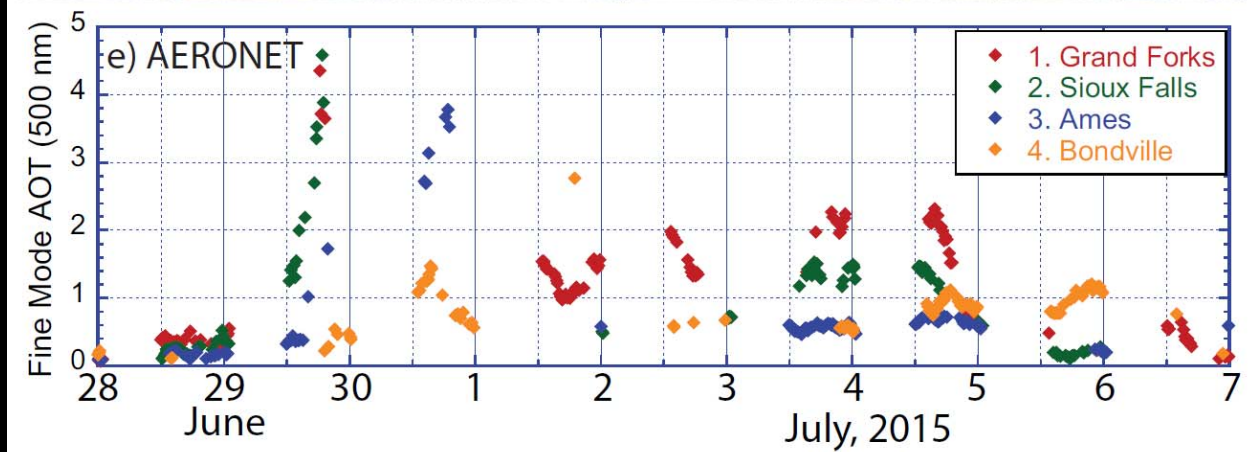
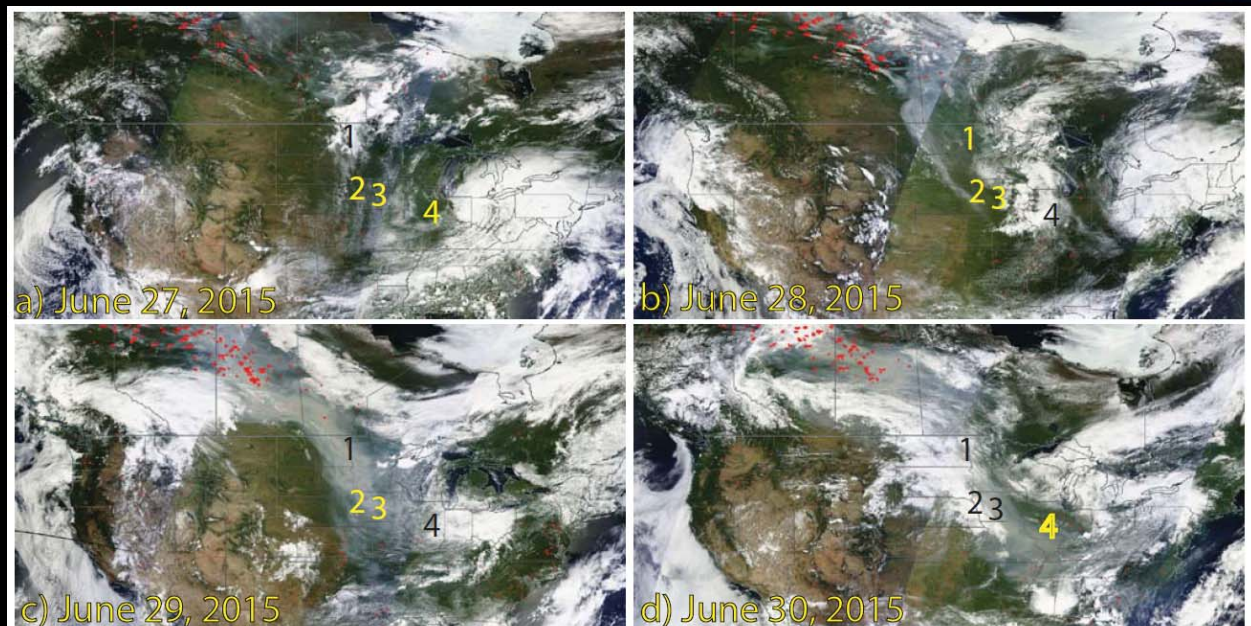


Westphal, D. L., and O. B. Toon (1991), Simulations of microphysical, radiative, and dynamical processes in a continental-scale forest fire smoke plume, *J. Geophys. Res.*, 96(D12), 22379–22400, doi:10.1029/91JD01956.

- Synoptic smoke events make a good radiation perturbation step function for understanding model sensitivities to radiation.

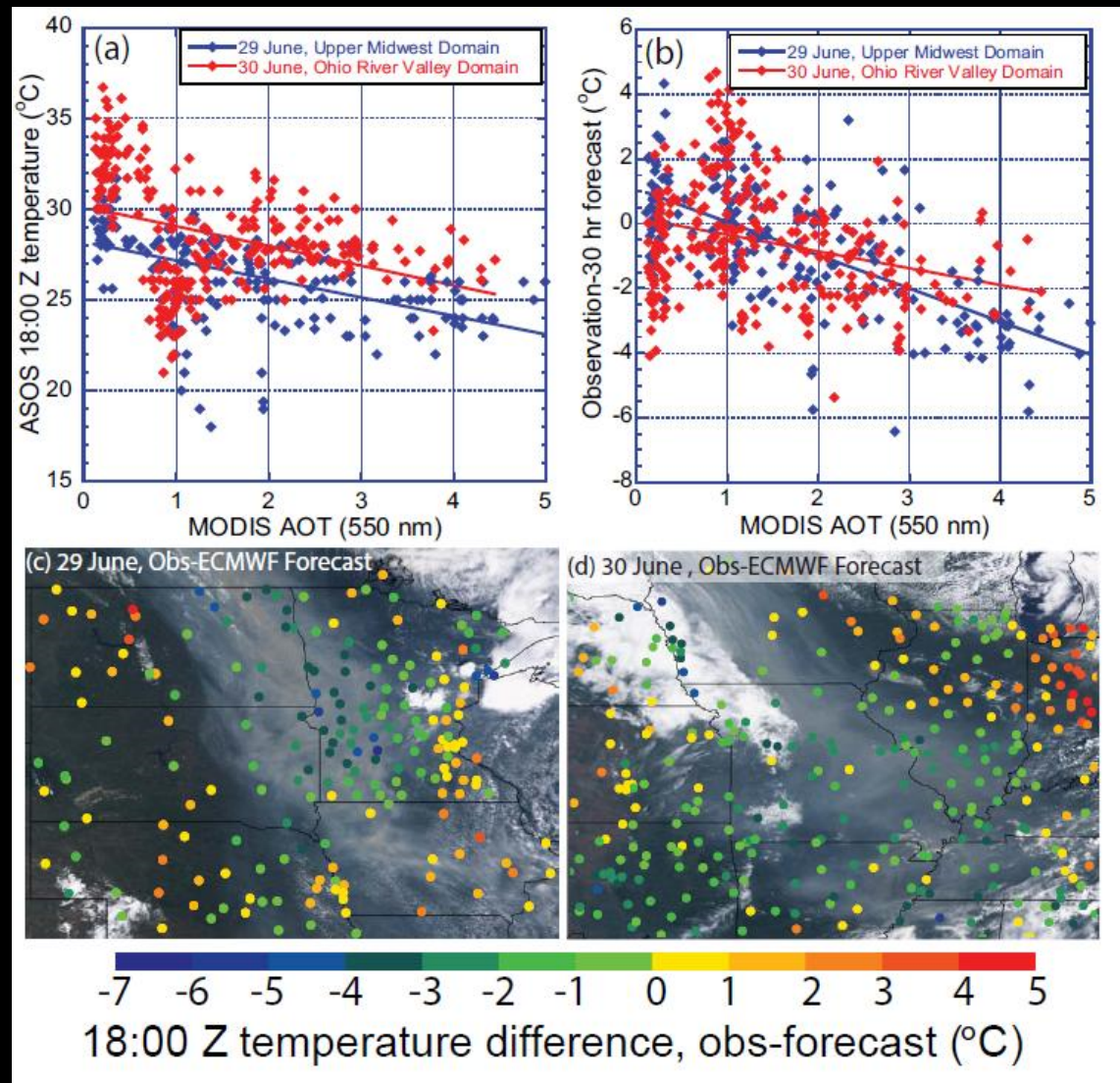
- Massive smoke events in 2015 out of boreal Canada make for a good case study.

Plumes were observed passing over eastern Europe



# Recent observational update Zhang et al., (2016): Canada Smoke

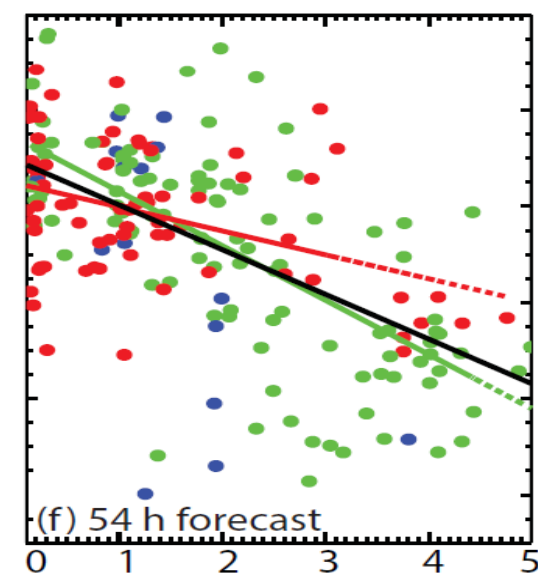
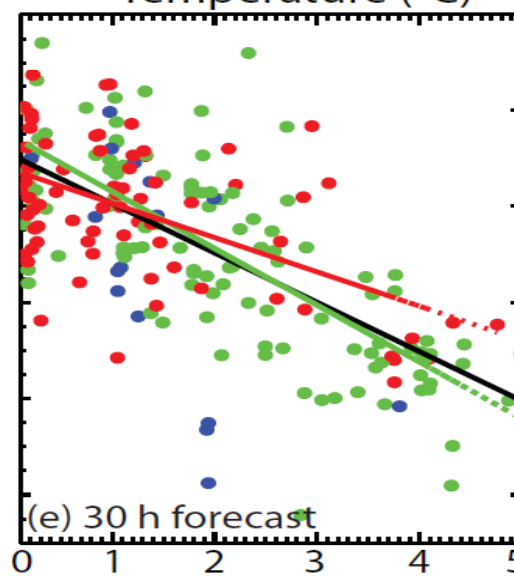
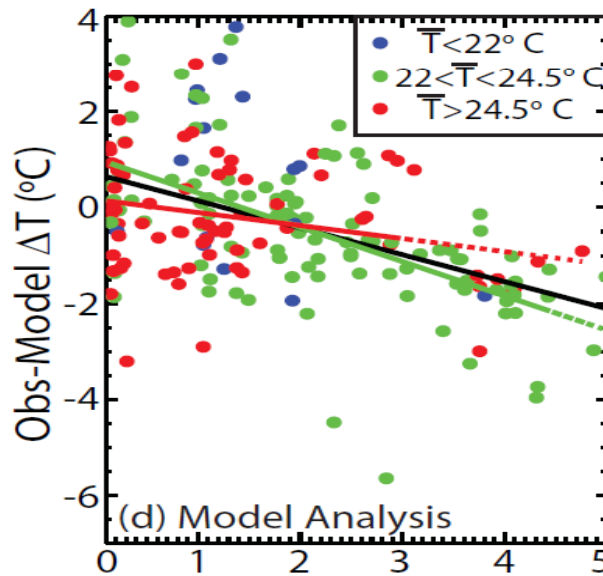
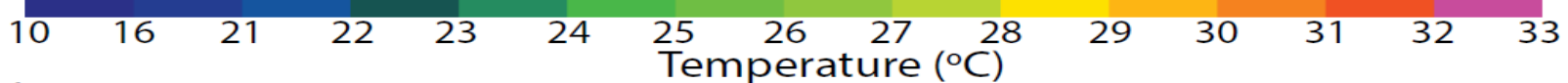
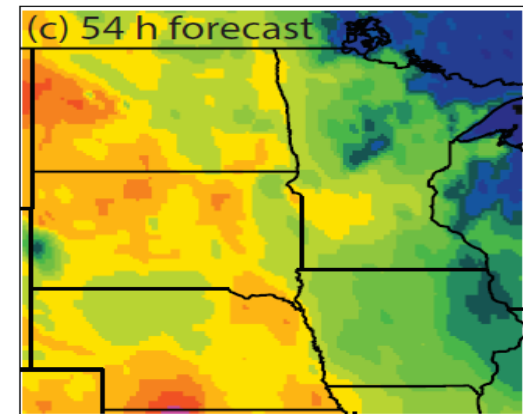
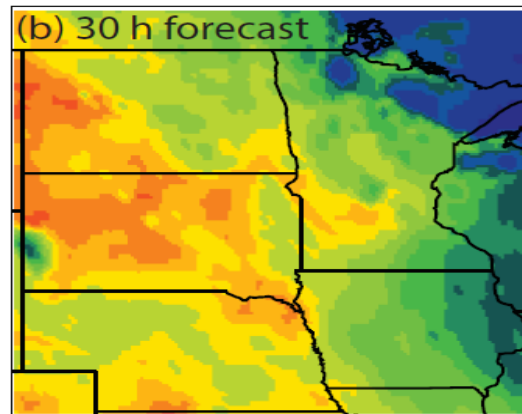
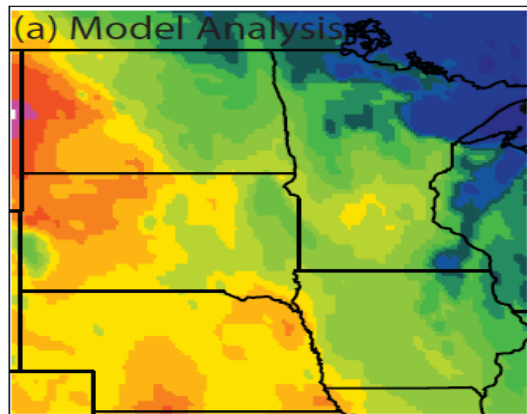
- Comparing ECMWF as well as GFS and UKMO TIGGE runs, sensitivity in surface temperature is  $1^{\circ}\text{C}$  per unit  $550\text{ nm AOT}^{-1}$ .
- Historically “better” models showed higher sensitivity to aerosol impacts. First things first.



Zhang, J., Reid, J. S., Christensen, M., and Benedetti, A.: An evaluation of the impact of aerosol particles on weather forecasts from a biomass burning aerosol event over the Midwestern United States: observational-based analysis of surface temperature, *Atmos. Chem. Phys.*, 16, 6475-6494, doi:10.5194/acp-16-6475-2016, 2016.



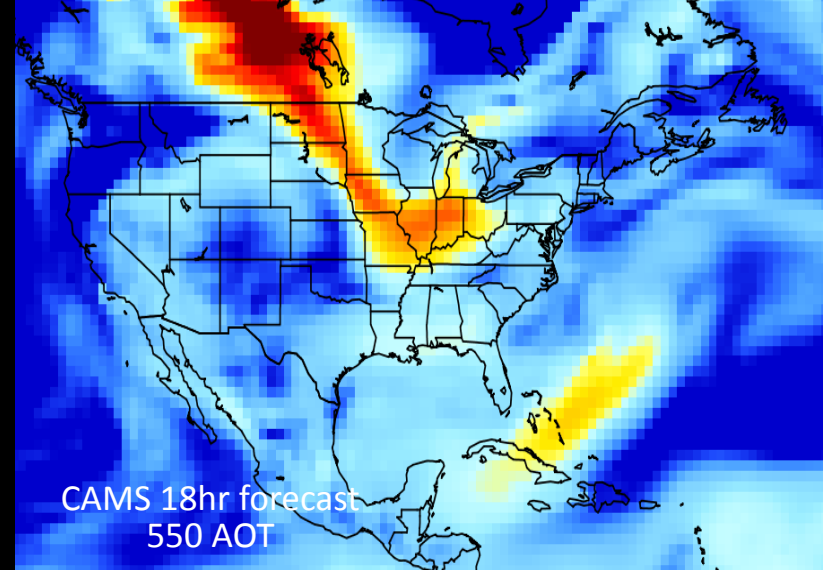
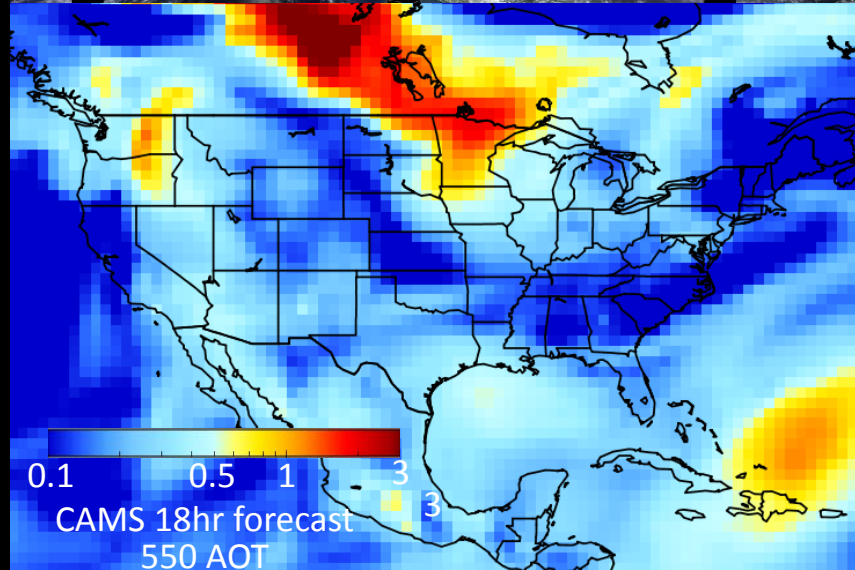
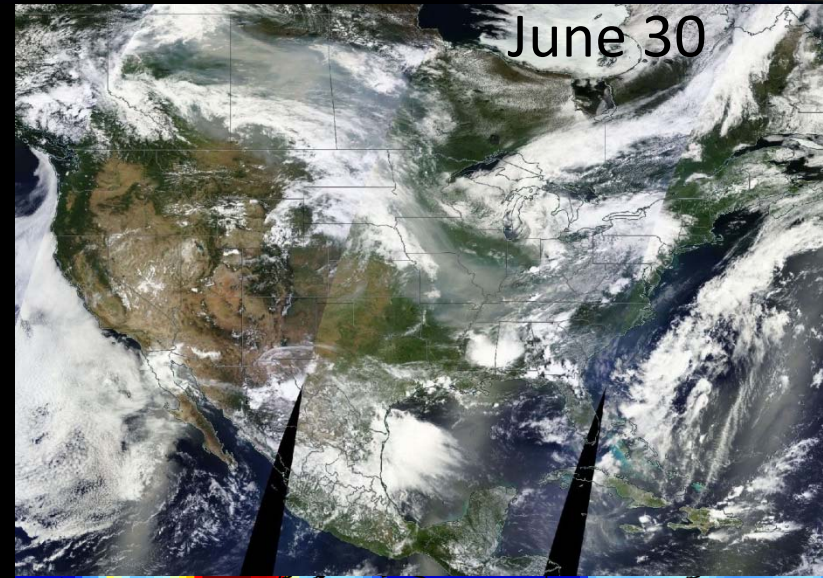
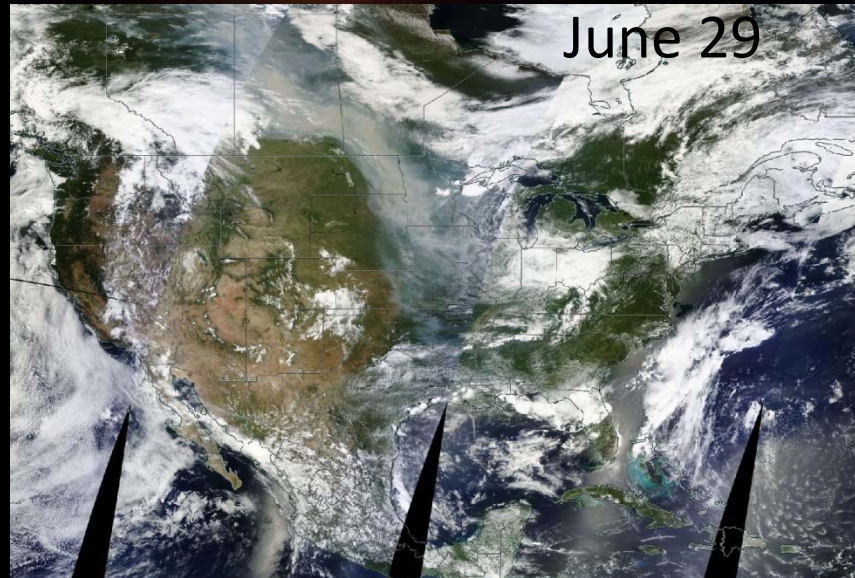
# Smoke effects increase slightly with forecast time.



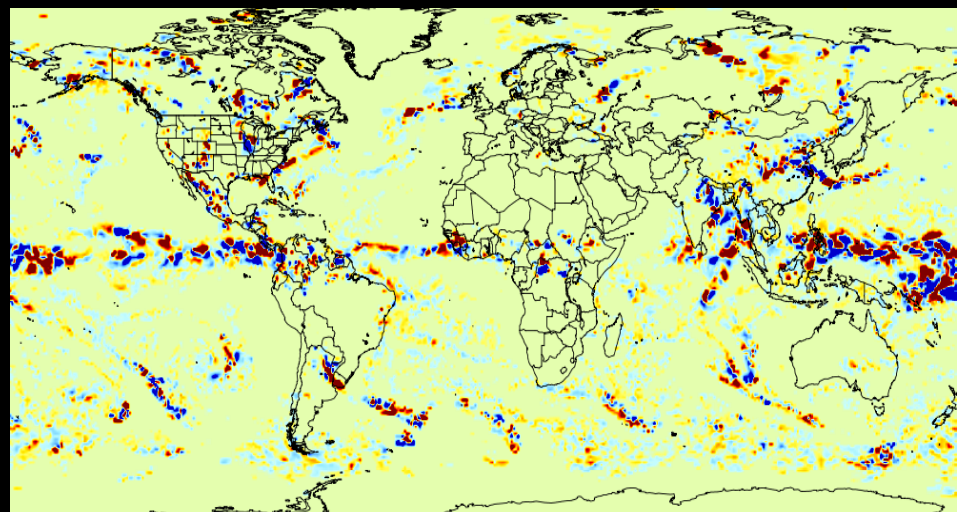
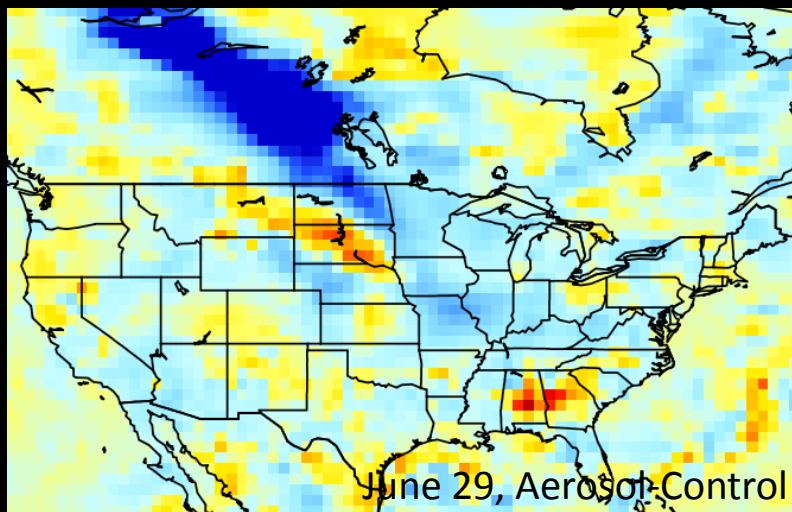
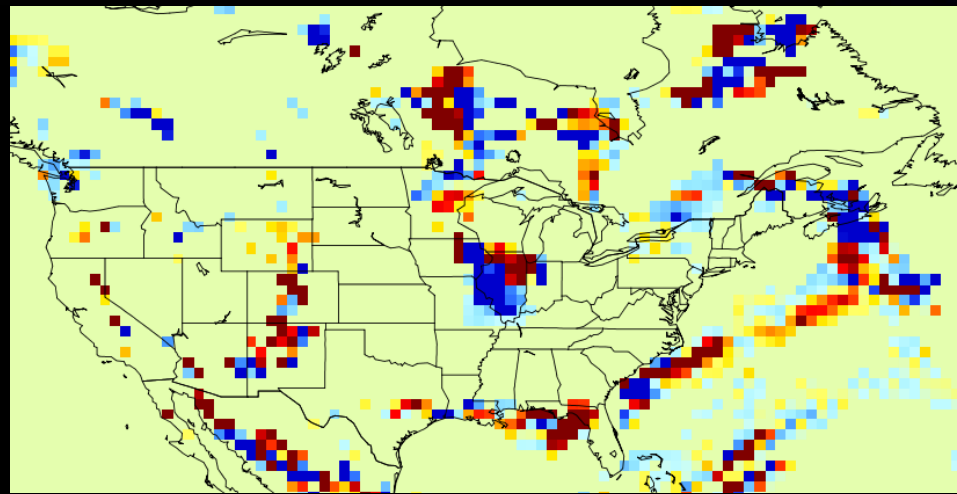
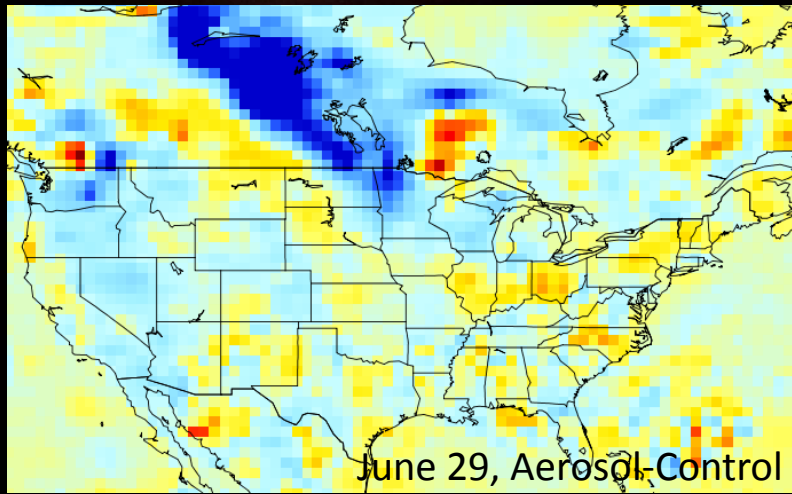
MODIS C6 Aerosol Optical Thickness (550 nm)

# Ang in the game, CAMS response

Underestimated AOT day 1 & 2 , picked it up day 3

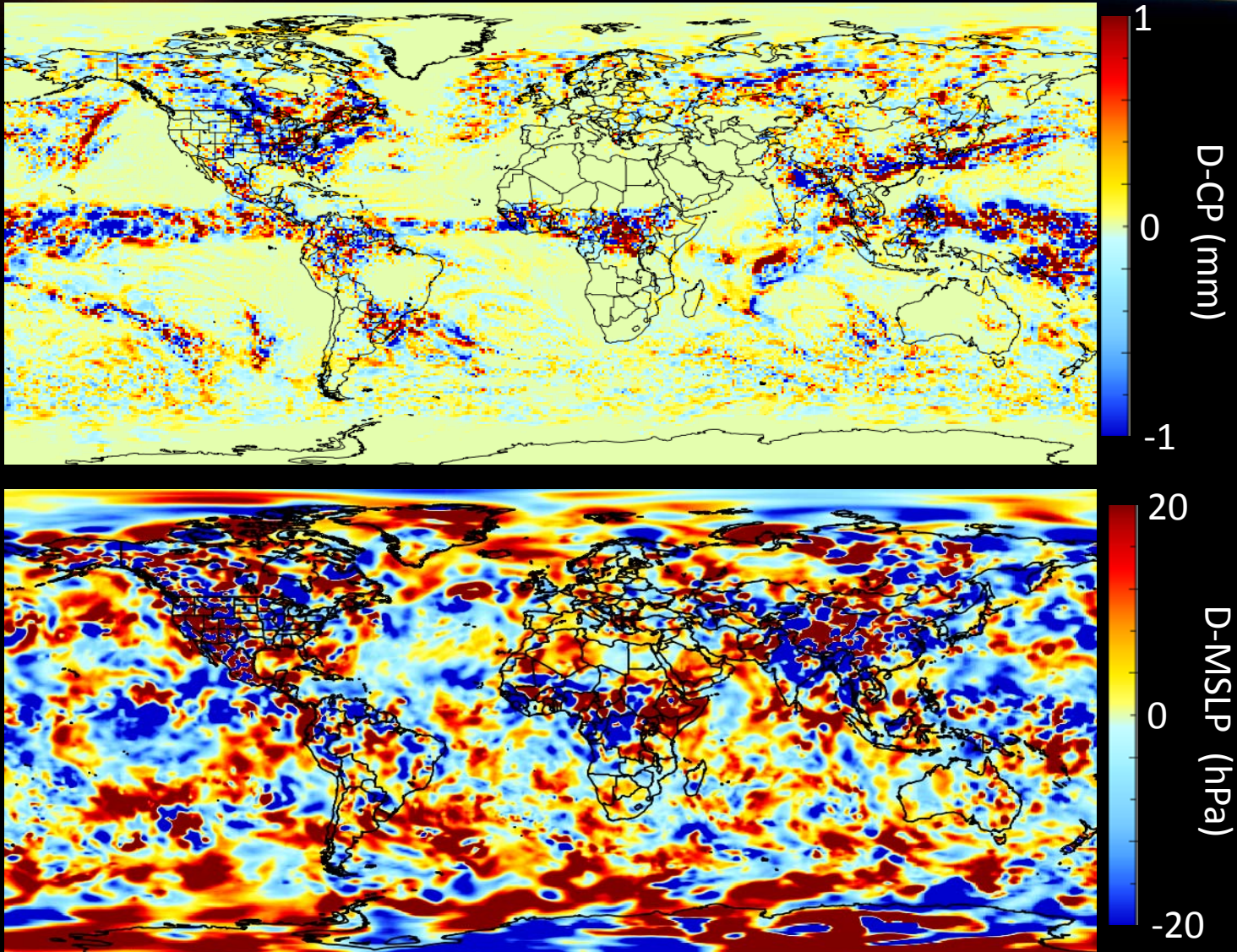


# 2 m T difference in 18 hour forecast. Hmm, why the positive perturbations? Its complicated



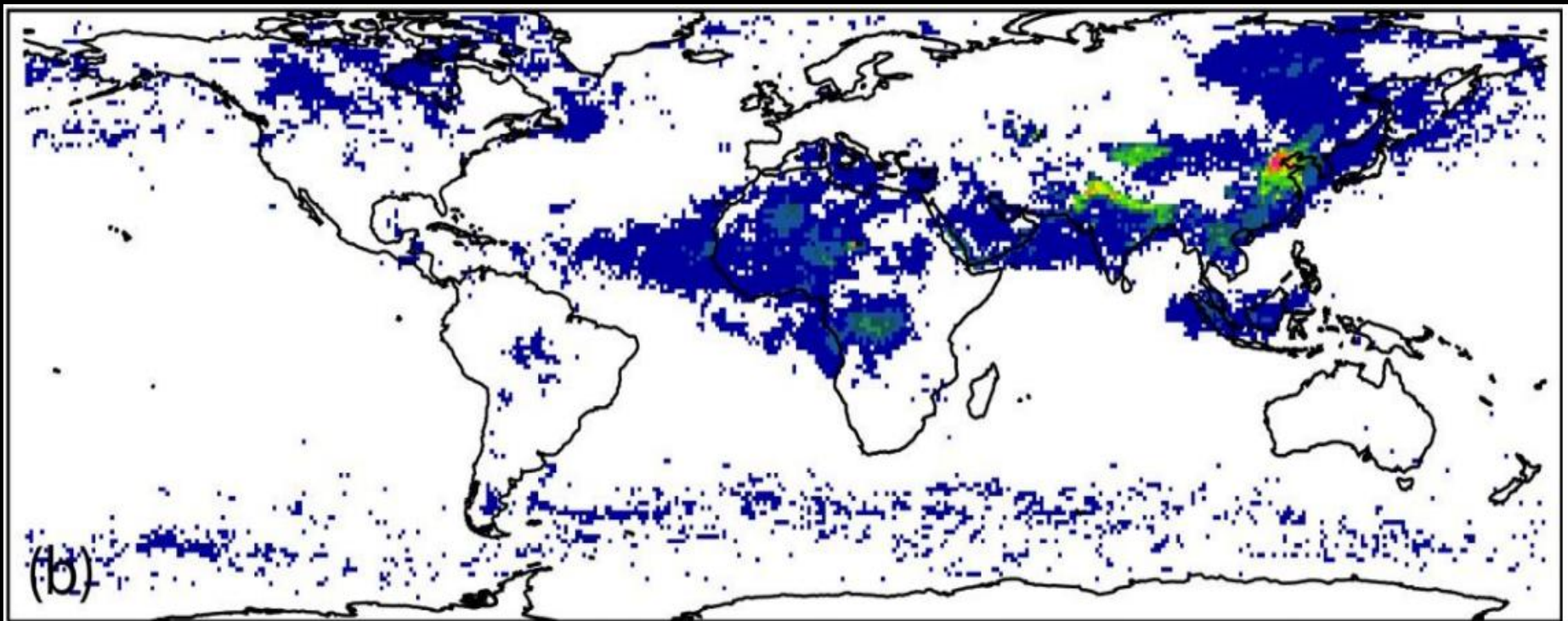
# How about at 5 days?

The bottom line is we need to be careful about scoring.



# Bit of a pickle: Effects of large events are significant on surface properties, but they don't happen very often

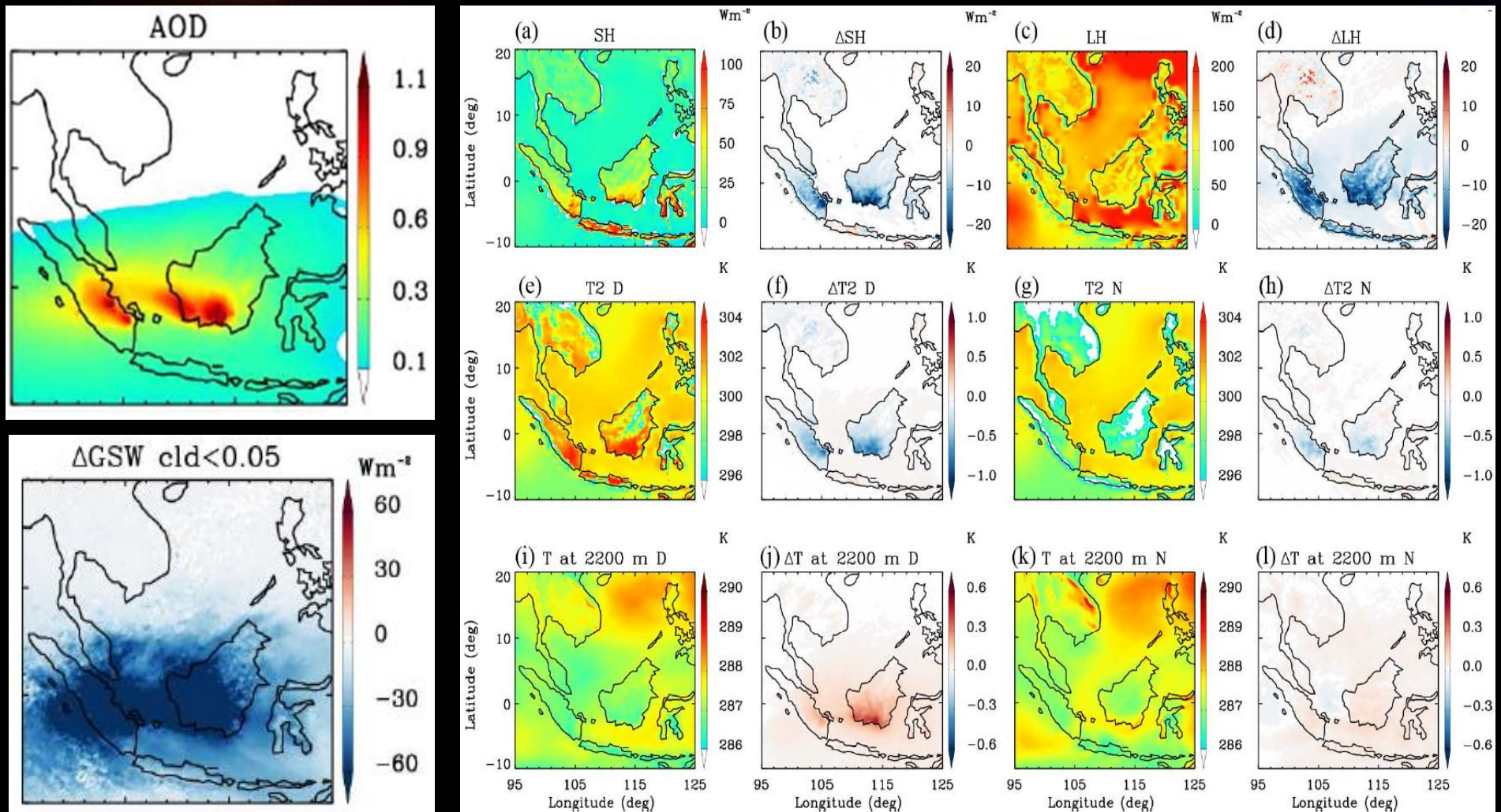
- Extreme events, are well, extreme.
- Consequently they don't manifest in bulk error stats in scorecards.



16 32 48 64 >80

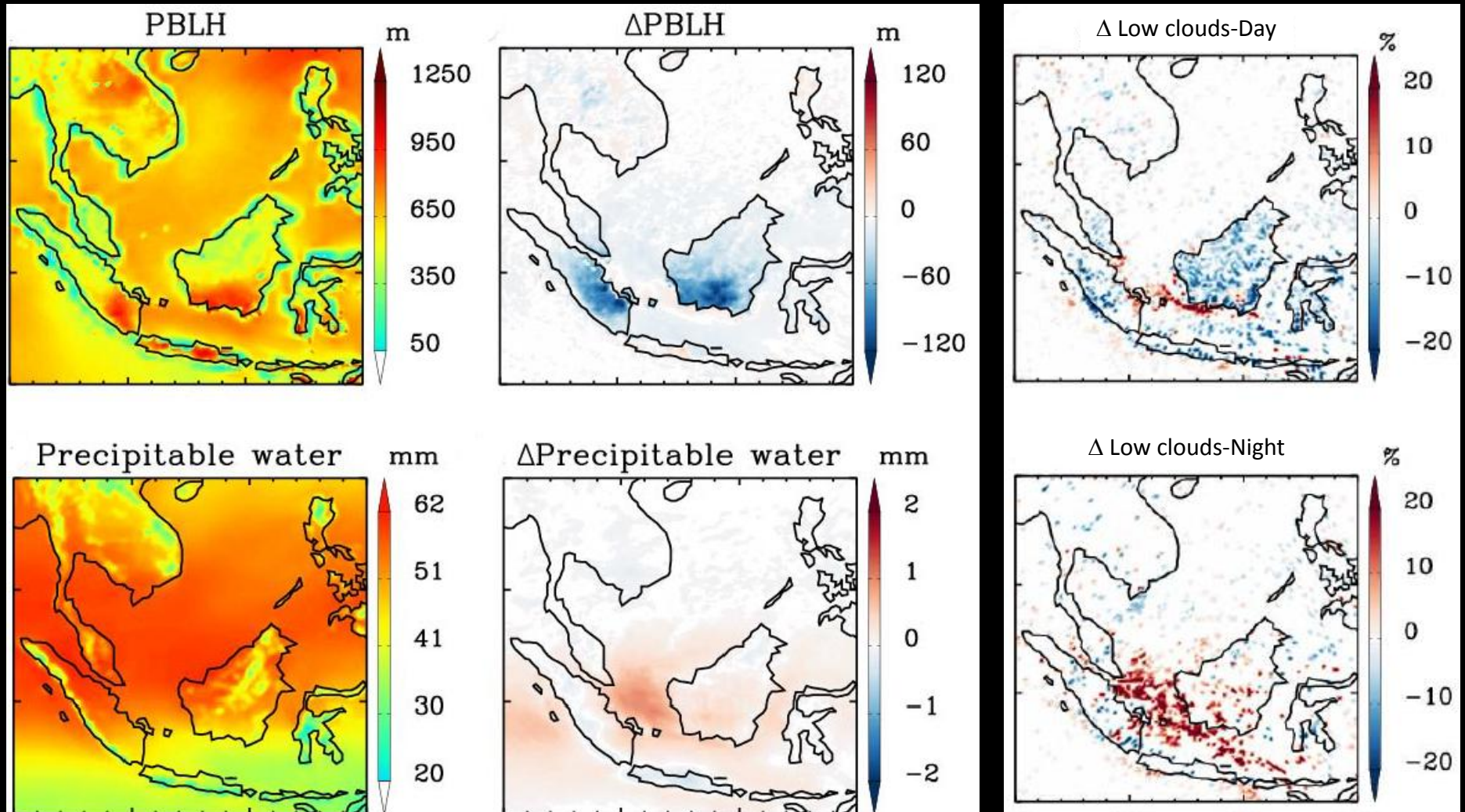
Number of days with AOT > 1 at 550 nm

# Going to mesoscale: Ge et al. study on Oct 2006 El Nino Smoke at mesoscale-perturbations on par with mid-latitudes



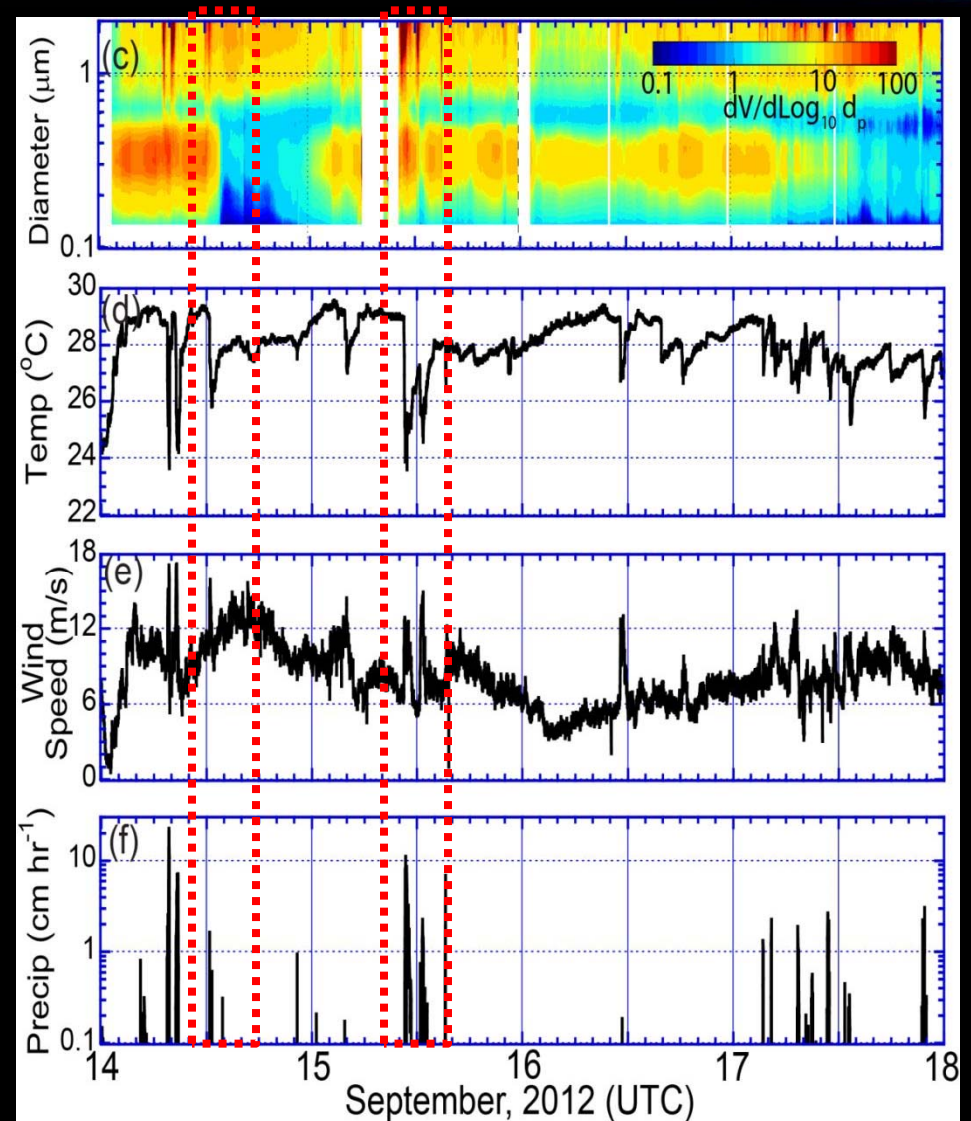
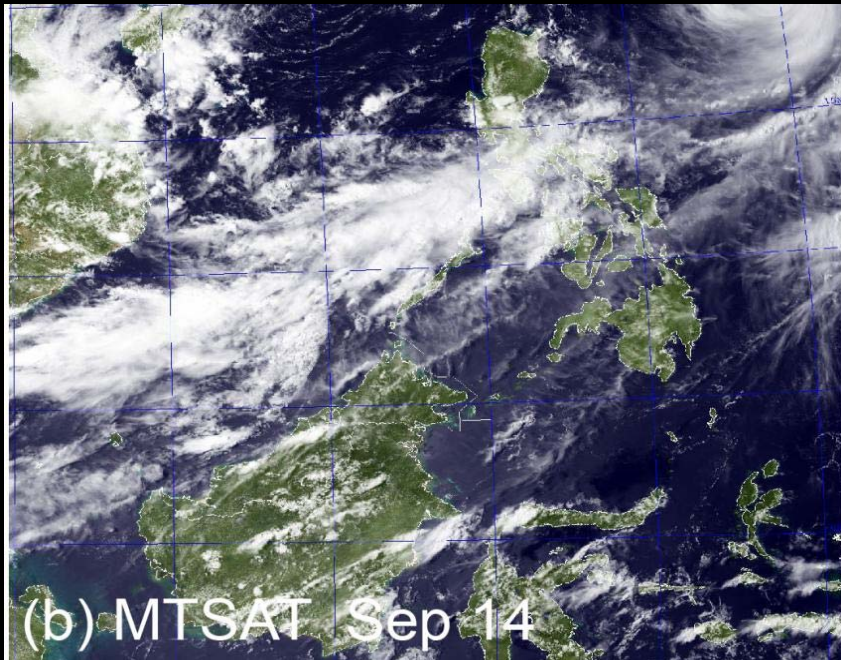
Ge, C., Wang, J., and Reid, J. S.: Mesoscale modeling of smoke transport over the Southeast Asian Maritime Continent: coupling of smoke direct radiative effect below and above the low-level clouds, *Atmos. Chem. Phys.*, 14, 159-174, doi:10.5194/acp-14-159-2014, 2014.

# Now at mesoscale PBL impacts manifest themselves



# Now, the finest levels-where -cloud boundaries

- Estimation of aerosol ingestion into clouds is where the rubber meets the road for indirect effects.
- If we want particles to influence cloud microphysics, we need a way to deal with sub-pixel flows around clouds



Reid, J. S., et al., (2016), Aerosol meteorology of Maritime Continent for the 2012 7SEAS southwest monsoon intensive study – Part 2: Philippine receptor observations of fine-scale aerosol behavior, *Atmos. Chem. Phys.*, 16, 14057-14078, doi:10.5194/acp-16-14057-2016, 2016.



# My closing thoughts



- We know aerosol particles can have a strong impact on atmospheric and cloud state. Biomass burning is a good example specie for studying how step functions in radiation or microphysics relate to model error.
- Surface temperature and feedbacks with the PBL are obvious. In some locations model can provide information on cloud impacts.
- Inline aerosol will improve aerosol advection. So as aerosol scientists it is worth perusing.
- But should NWP care about aerosol science? Is it worth their wall time?

Most of the time at this point, probably not (sorry). We need other improvements from them before they need us.

Sometimes yes, and maybe only include radiation when really needed. Statistical post processing?

Really depends on how good your model is in the first place. In time, aerosol particles may become more important

What is the right way to score. Analysis? Seasonal? Lets hear from Angela...