Atlantic Aerosol and Precipitation: Main Issues

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<u>Aerosol Effects on precipitation</u>:

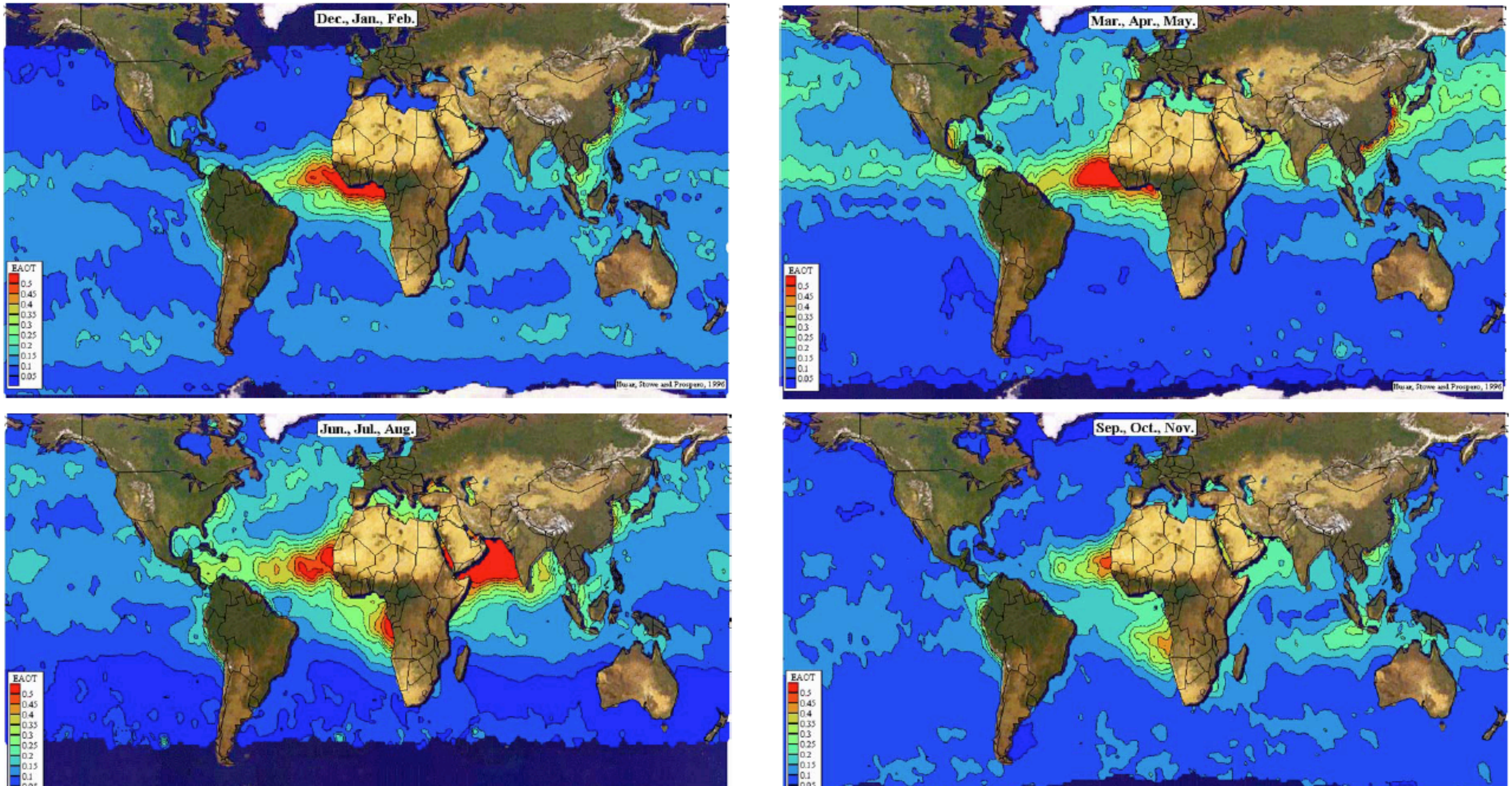
- Direct Effect: absorption and scattering of solar radiation => static stability (SST, tropospheric temperature)

- Indirect Effects: CCN/IN => cloud drop size, droplet number => precipitation efficiency

<u>Current knowledge</u>: CONTROVERSIAL

– aerosol types (sizes, chemistry, background concentration, etc.)
– precipitation types (warm vs. cold rain, orography vs. instability rain, etc.)
– **observational uncertainties** (cloud contamination of aerosol measurement, meteorological influences, etc.)
– modeling uncertainties (parameterization, aerosol representation)

African aerosol are outstanding in their strength and persistence

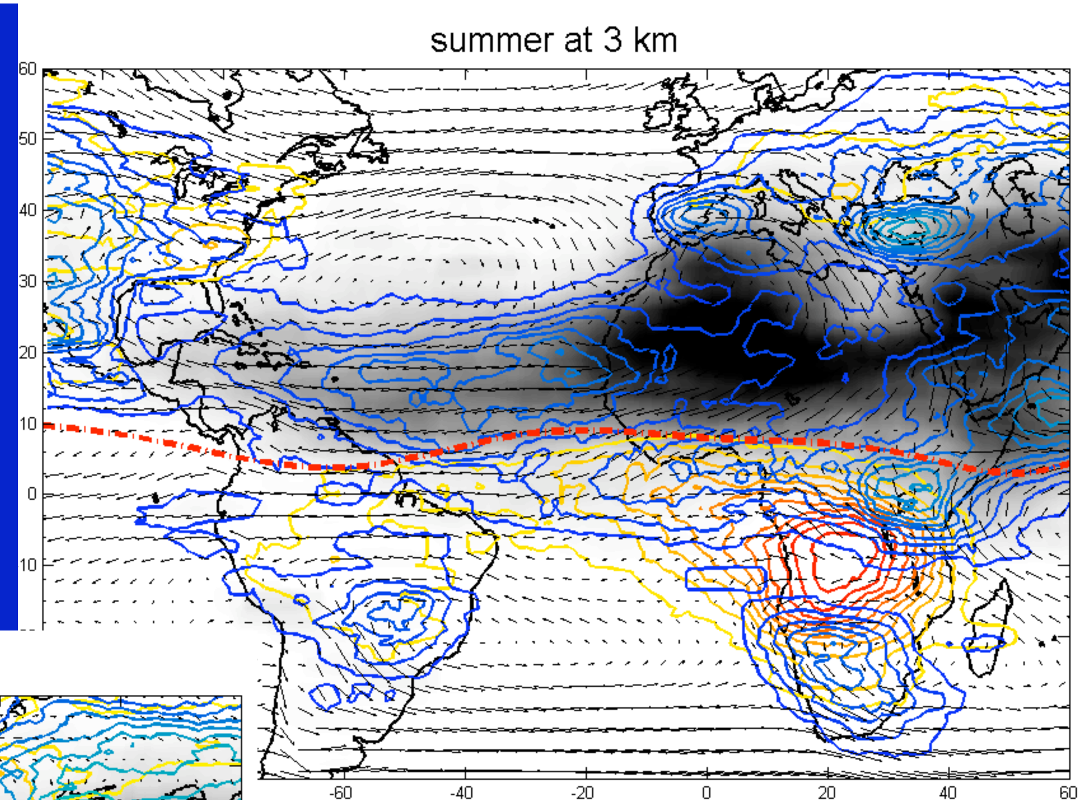


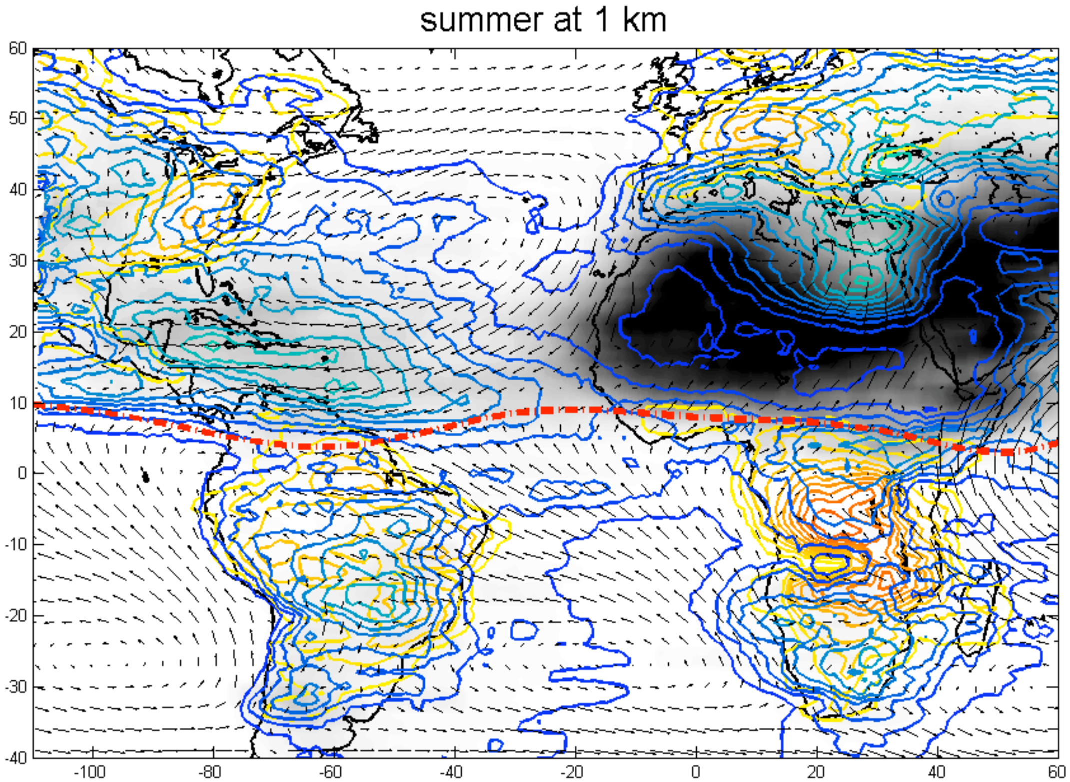
Seasonal Averages of Aerosol Optical Thickness Retrieved with NOAA AVHRR Satellite.

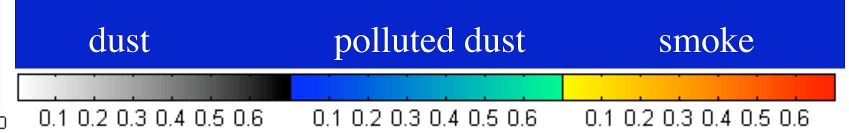
Husar, Prospero, and Stowe, J. Geophys. Res., 102 (D14), 16,889-16,909, 1997.

CALIPSO VMF
MERRA

by Aaron Adams







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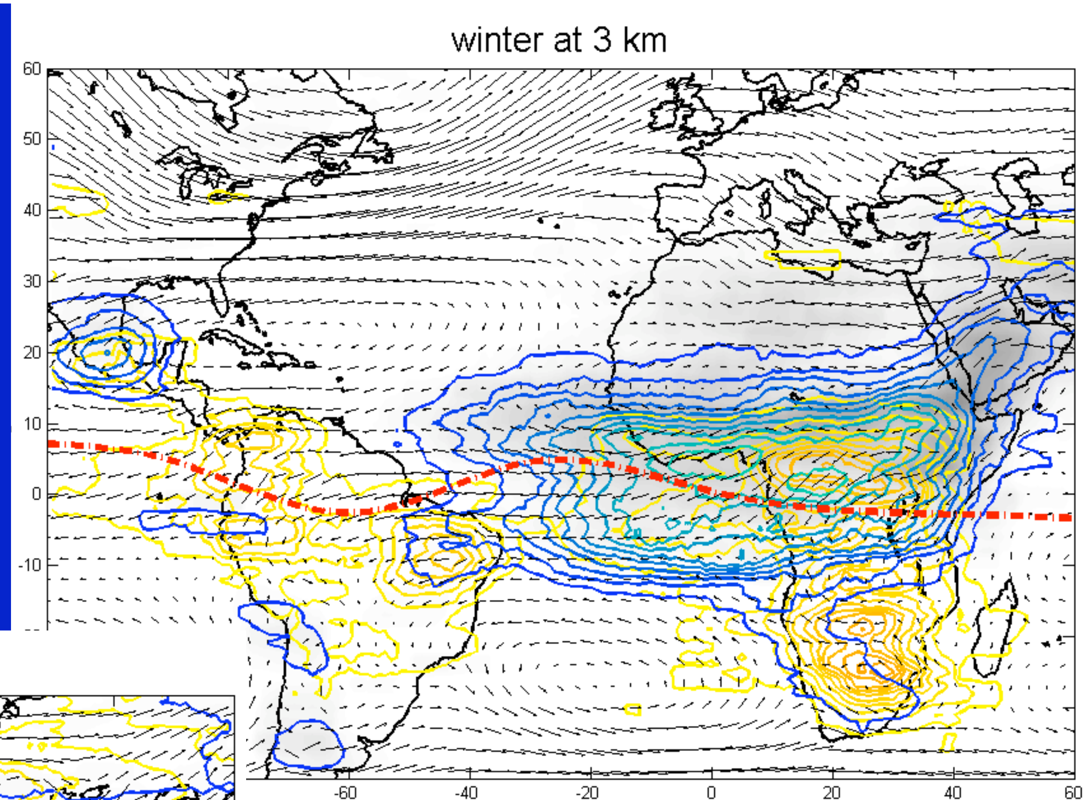
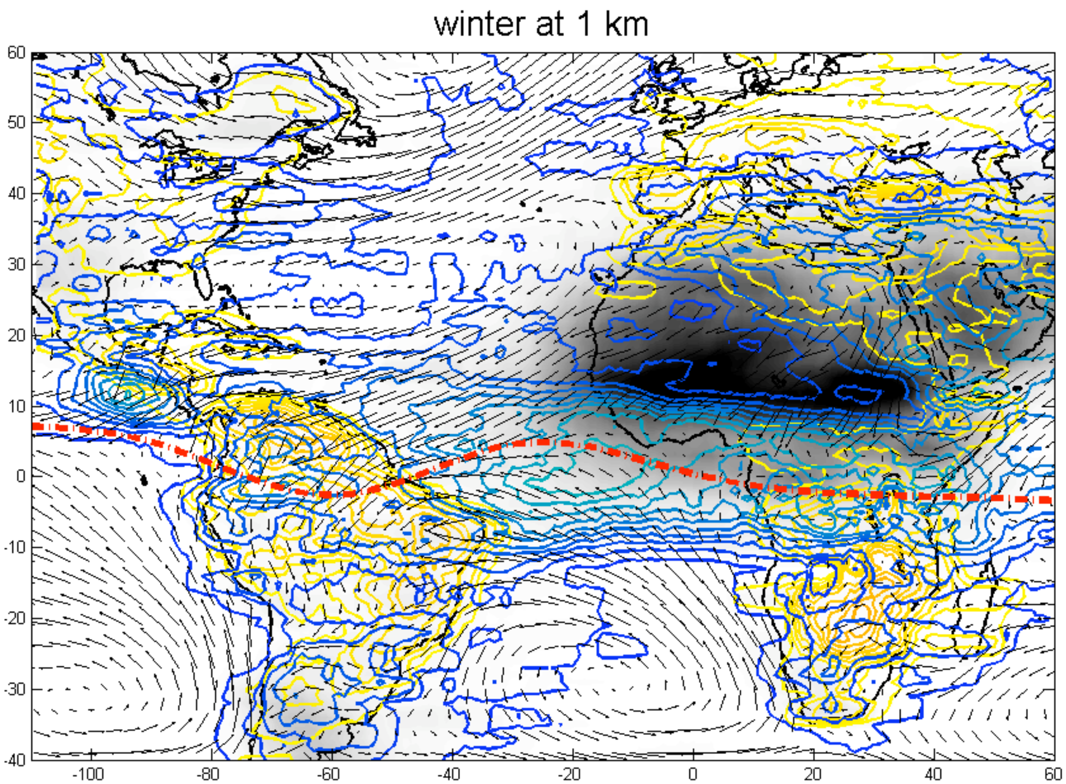
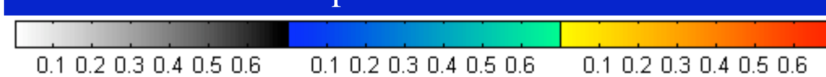
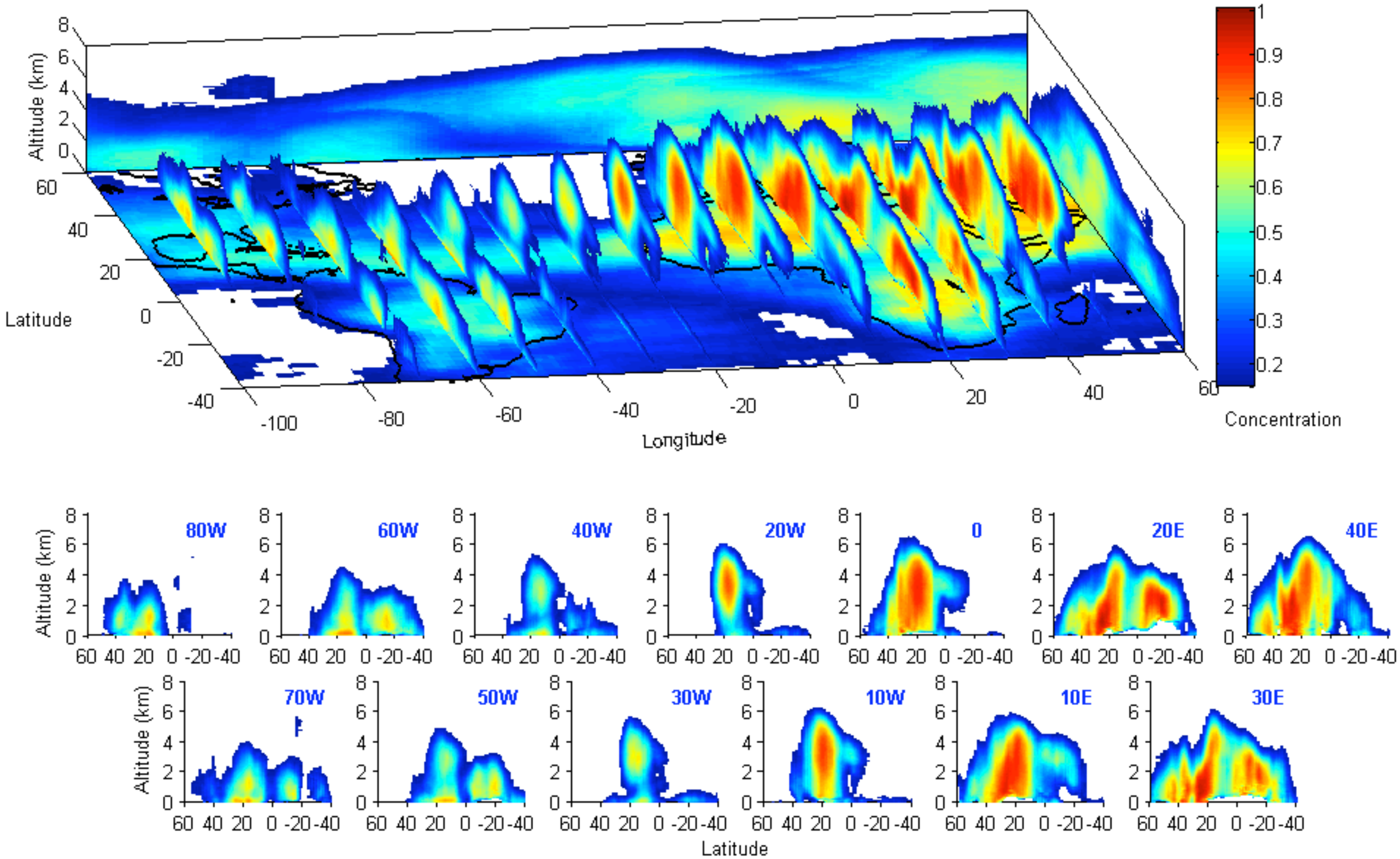




dust
polluted dust
smoke



Occurrence Probability of Total Aerosol in Boreal Summer



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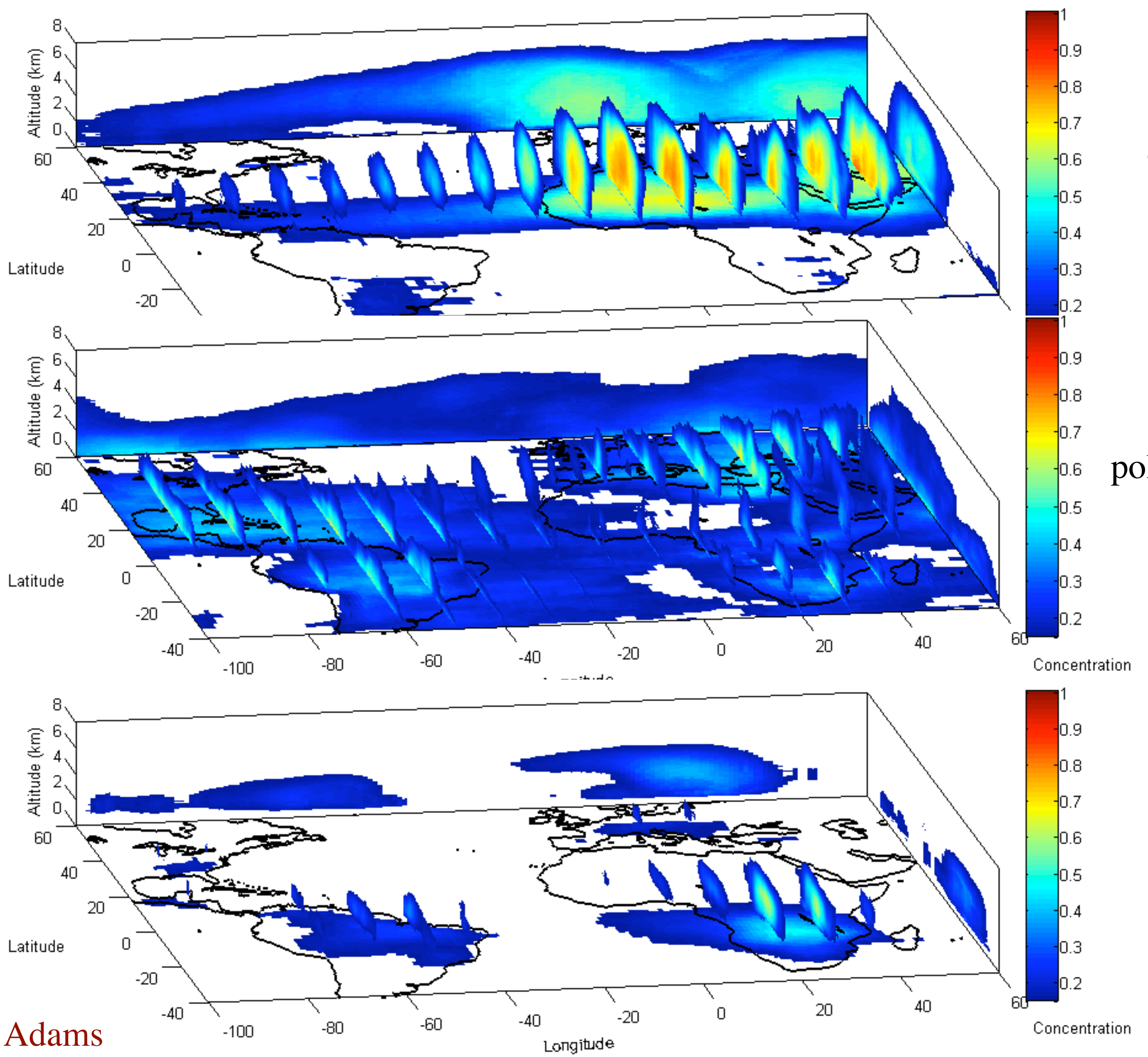

dust

polluted dust

smoke

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Observed Aerosol Influence on Precipitation in the Pan-Atlantic Region:

Amazon:

- Increases in total rainfall, occurrence of intense events, and ice formation when aerosol amount is elevated during the peak of biomass burning season (Lin et al. 2006);
- suppressed rain associated with high concentration of aerosol (Jones and Christopher 2010);

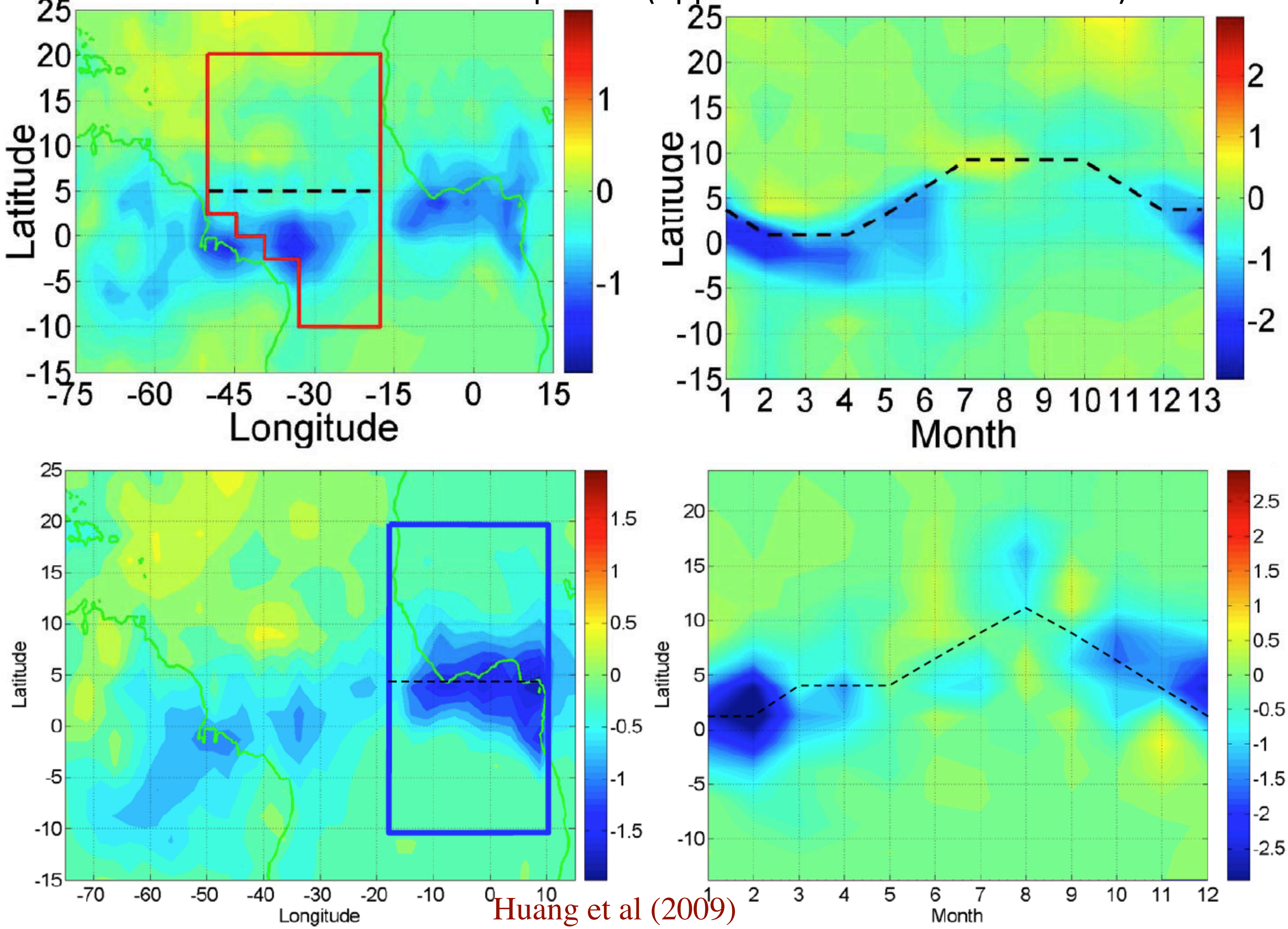
West Africa:

- suppressed Sahelian rainfall by dust (Hui et al. 2008)
- suppressed coastal rainfall in boreal winter in months of high aerosol concentration (Huang et al 2009);

Tropical Atlantic:

- suppressed rainfall at the southern edge of western ITCZ in winter in months of high aerosol concentation (Huang et al. 2009);
- Northward shift of the ITCZ rainfall in summer during dust outbreaks (Wilcox et al. 2010)

Differences in Rainfall Composites (upper - lower terciles in aerosol)



Huang et al (2009)

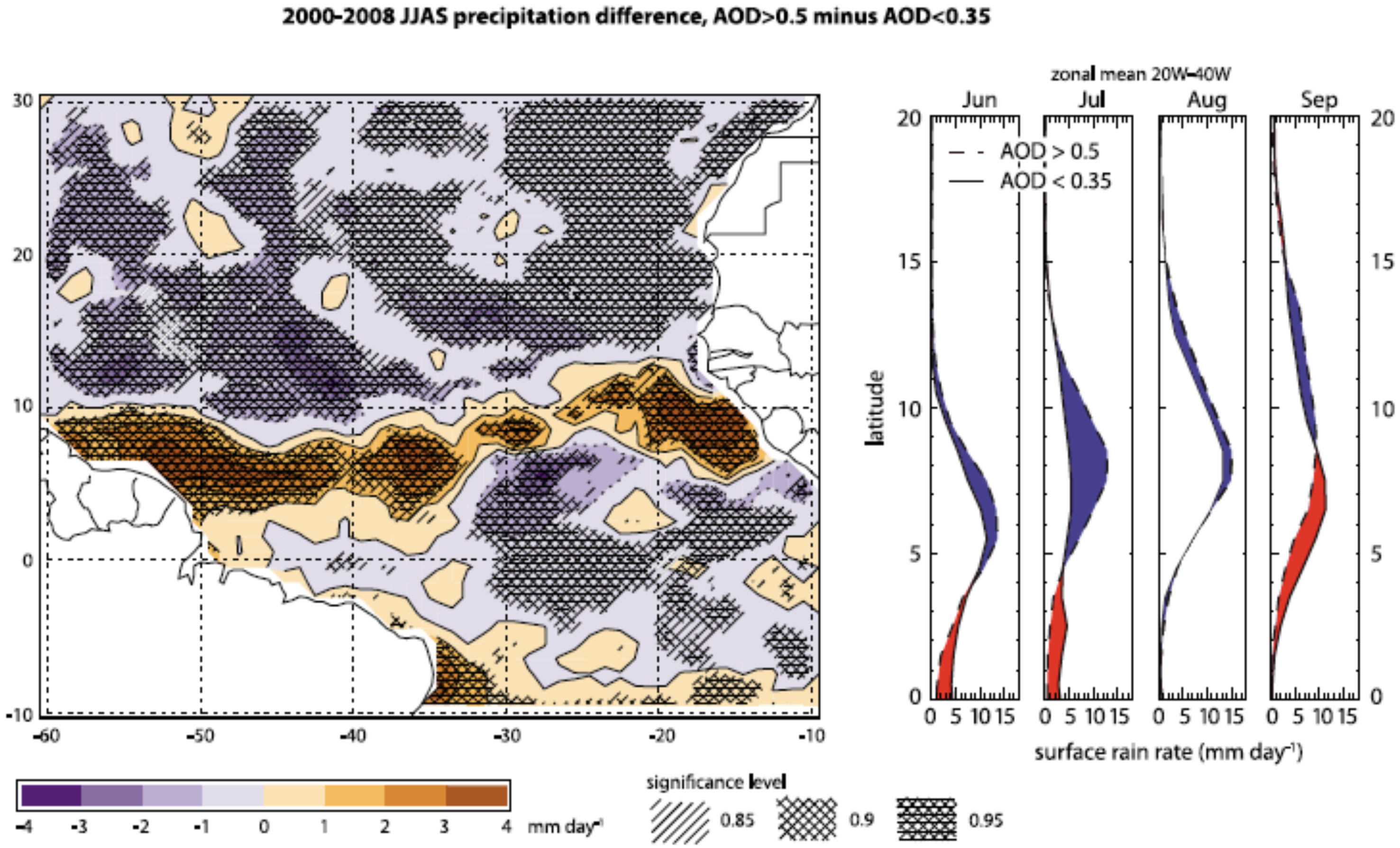


Figure 4. Difference in P (in mm d^{-1}) between dust outbreak conditions and low dust conditions. (left) Spatial distribution where the degree of hatching indicates level of significance of the difference compared to variability of pentad averages. The mean position of the ITCZ during the JJAS season is 8°N latitude. (right) Zonal-mean averaged 20° to 40° W by latitude of P during dust outbreak conditions (dashed) and low dust conditions (solid). Higher values during dust outbreaks denoted in blue, and lower values in red.

Wilcox et al. (2010)

Major Challenges in Large-Scale Observations of Aerosol Effect on Precipitation

Cloud contamination of satellite measurement of aerosol/washout by precipitation

Solution – Avoid pointwise analysis: (i) back trajectories; (ii) lag correlation, (iii) aerosol data outside precipitation region, (iv) exclusion of aerosol data in cloudy area;

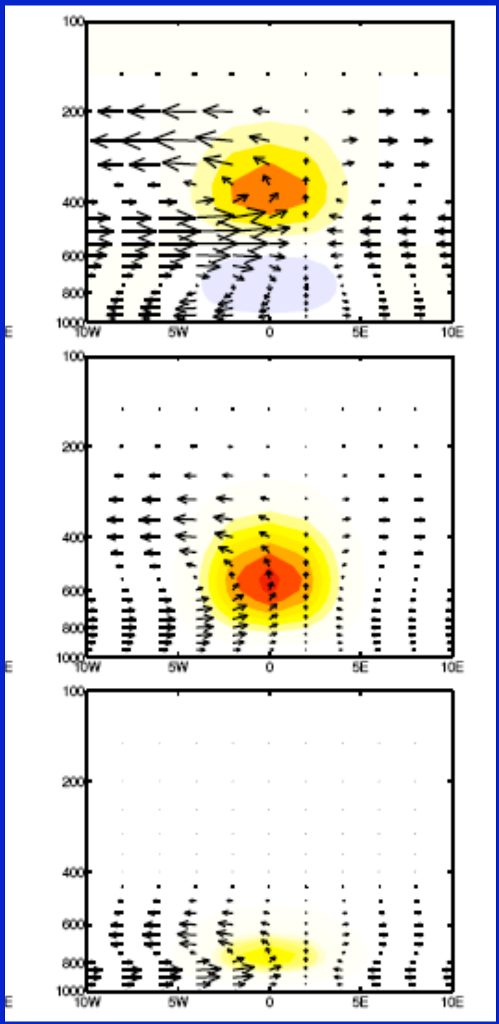
Meteorological influences:

Solutions: (i) include meteorological fields (large-scale patterns; statistical tools - regression, PCA, etc.); (ii) examine aerosol-precipitation relationship in different regimes (static stability, convective threshold, total water content, etc.)

Main Issues

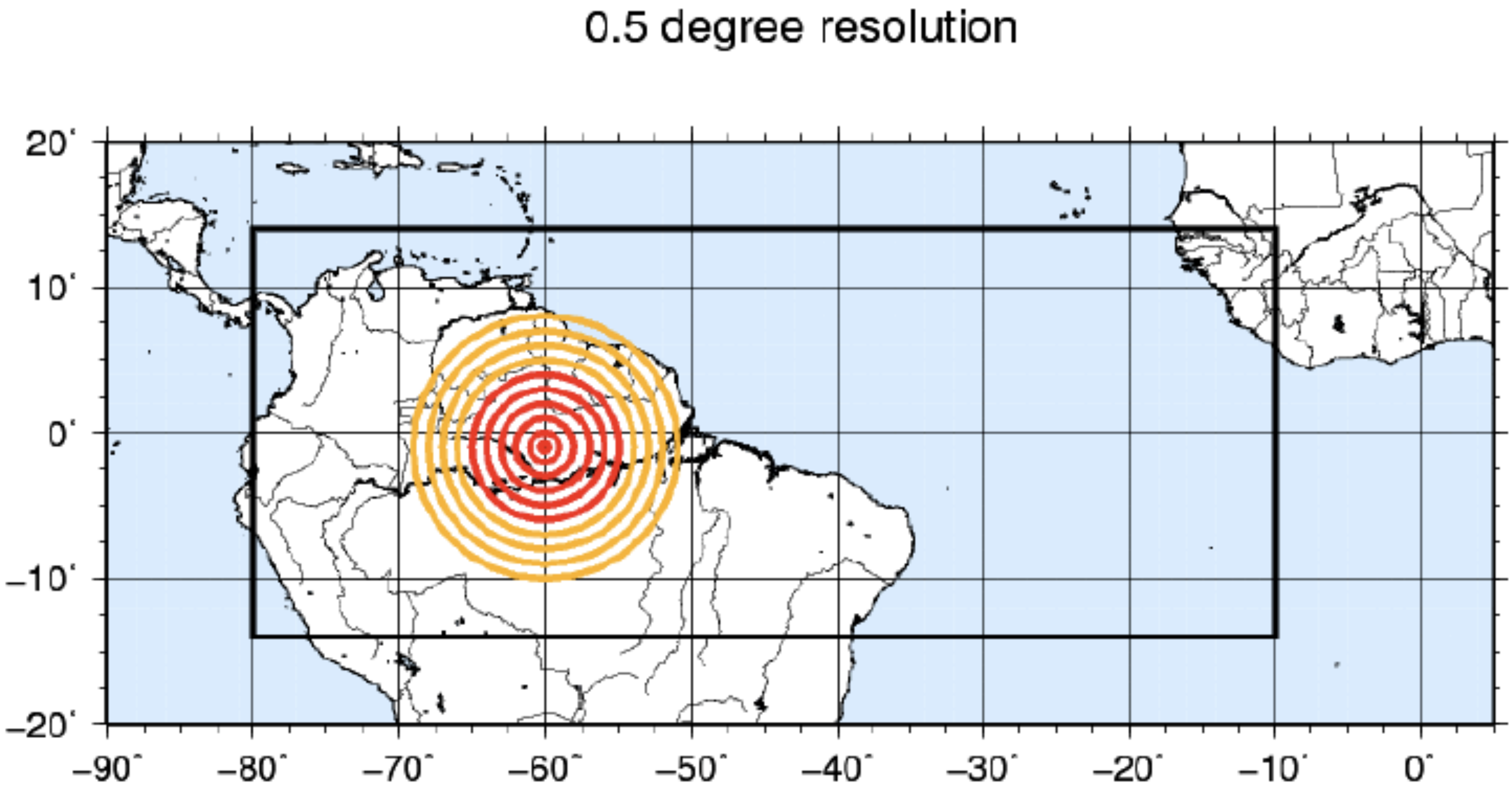
- On climate scales, unless aerosol affects surface evaporation, it would not change the total rainfall amount, only the timing and location of precipitation;
- On regional scales, changes in precipitation patterns may have significant impact on society (and the dynamical systems?);
- Aerosol effect on precipitation is one of the areas in the climate study that may potentially make groundbreaking advancement in the near future. The communities of aerosol and cloud/precipitation are very active in research on this subject and are vary wary of meteorological influences;
- The pan-Atlantic region is the most ideal natural laboratory for the study of aerosol effect on precipitation;
- Studies of aerosol effect on precipitation in the pan-Atlantic region can be competition (for resources) but also complement (in science) to studies of the climate dynamics of the region;
- What can this community (climate dynamics) offer to the studies of aerosol effect on precipitation?
- To what degree should research programs on the tropical Atlantic climate include aerosol effect on precipitation?

An Alternative Hypothesis on a Possible Root Cause of the Equatorial Zonal Wind/SST Biases in Climate Models

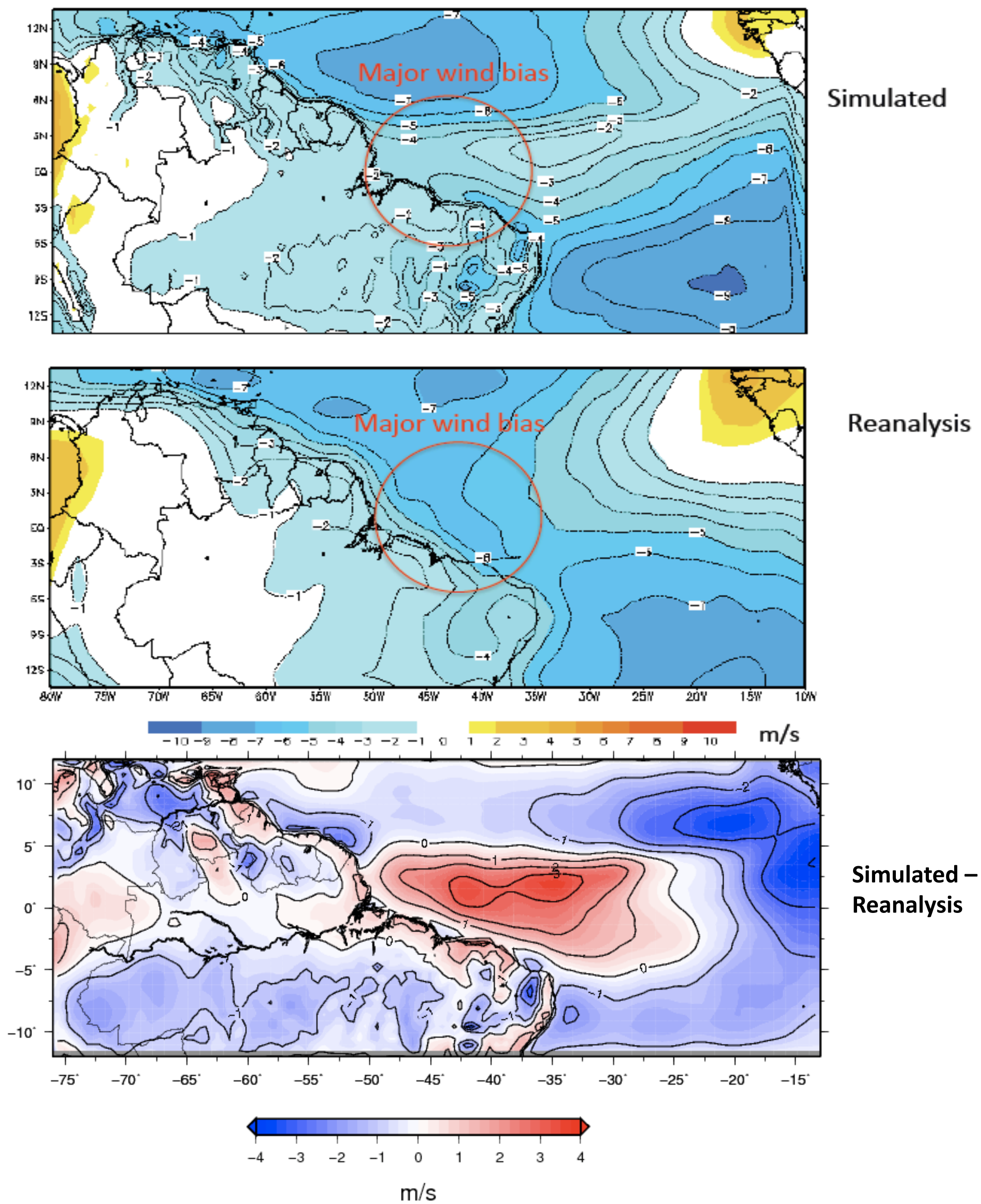


The root cause of the equatorial Atlantic zonal wind/SST biases is partially the misrepresentation of the diabatic heating structure over the Amazon in climate models.

WRF, 1 month simulation



David Zermeno



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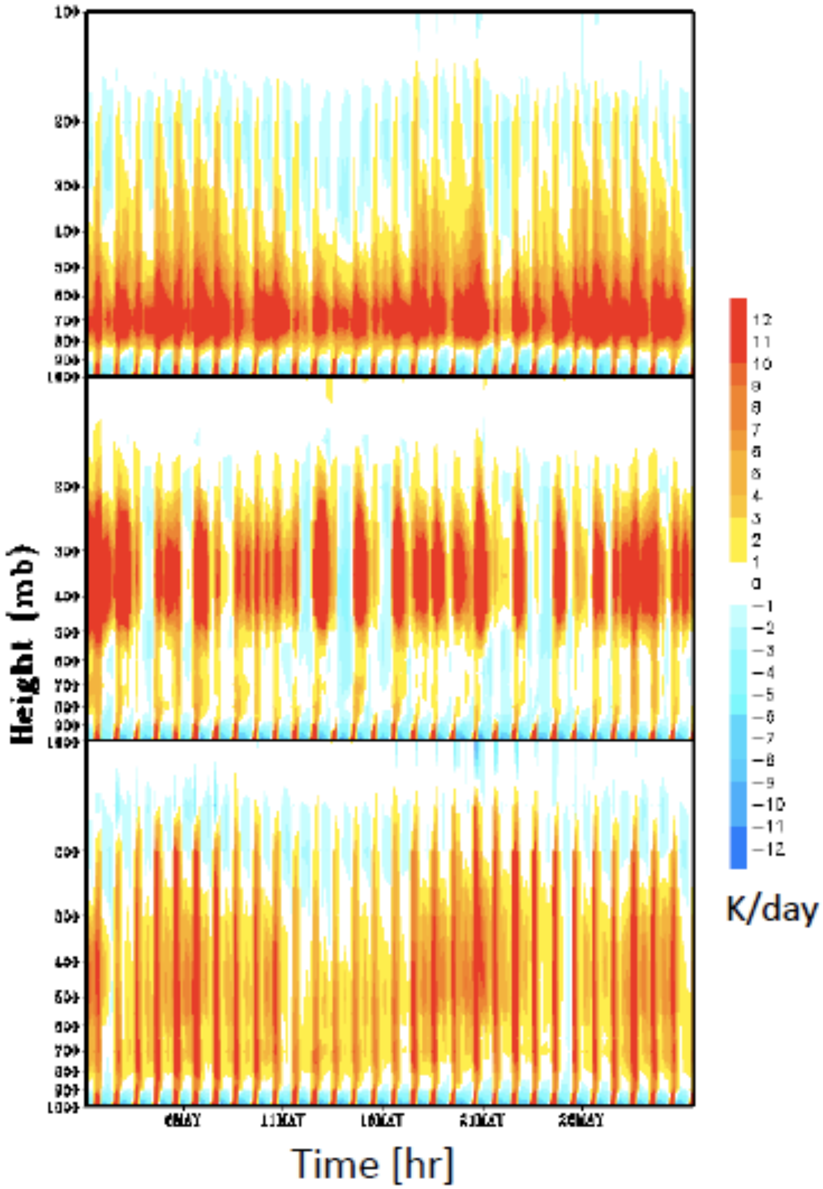
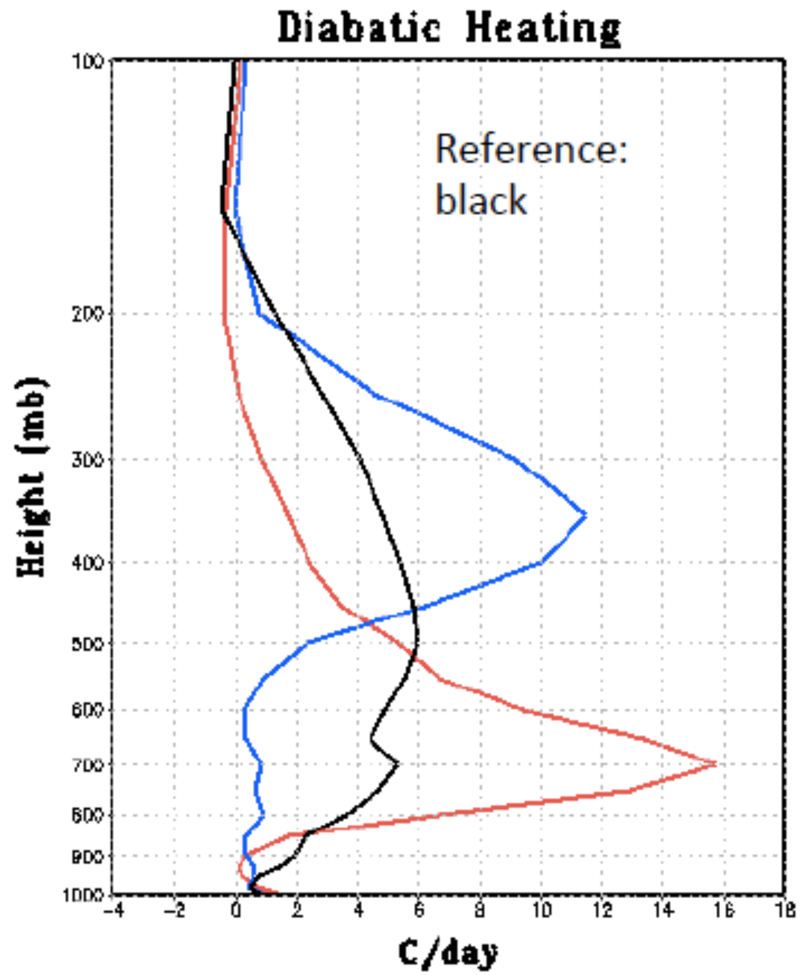
Three Examples
Forced to equal areas
(May 2005 Simulation)





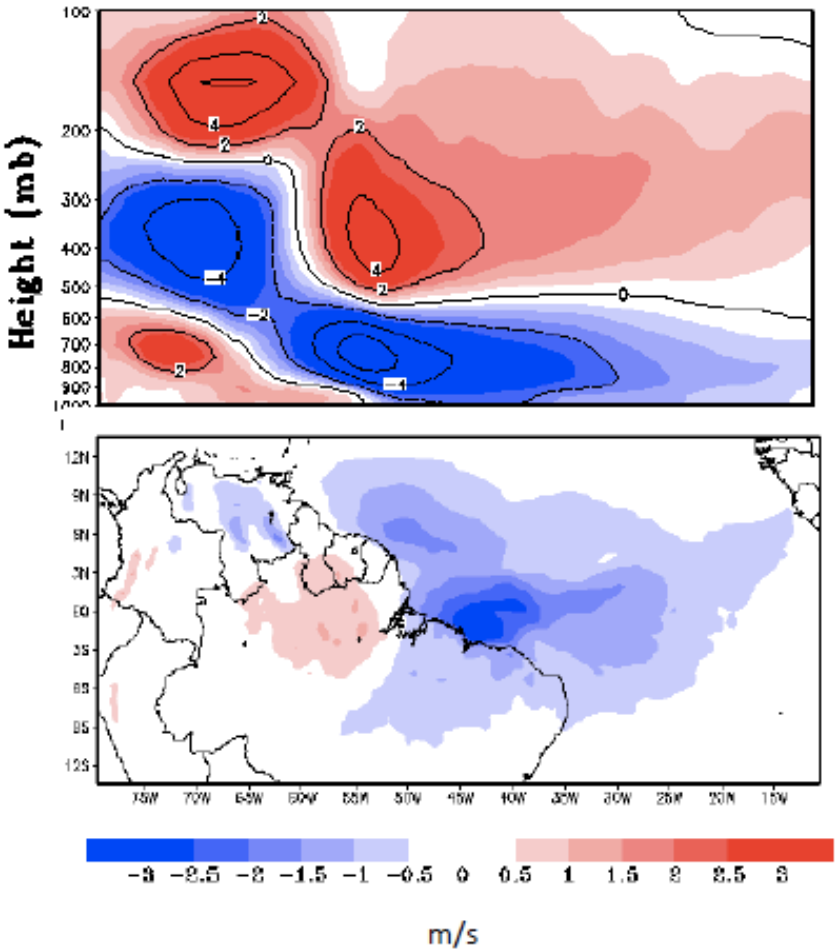
Top heavy profile: upper panel

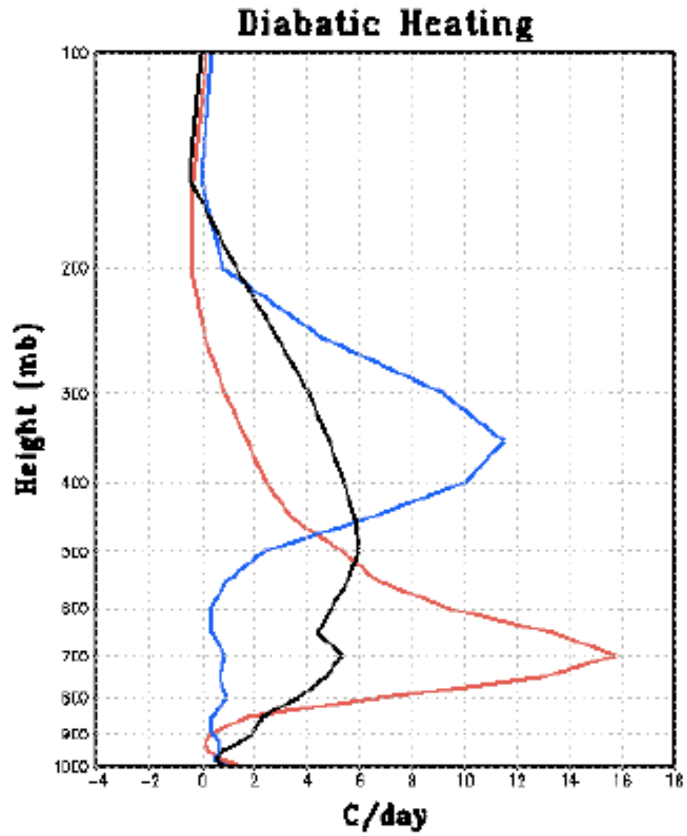
Bottom heavy profile: mid panel

Reference: Lower panel

The heat is approximately the same for the three profiles

u-wind component difference:
The bottom heavy profile simulation
"minus" the top heavy





Future Work:

- **Test the sensitivity of equatorial Atlantic climate to heating structures in a coupled model (CSM5? CAM2.5? Text A&M regional coupled model? …….?)**
- **Diagnose diabatic heating structures vs. the equatorial Atlantic biases in weather prediction and climate models (18 so far)**
- **Compare sensitivities to diabatic heating structures vs. precipitation**