A Study of Atmospheric Heating by Black Carbon Aerosols and its Impacts

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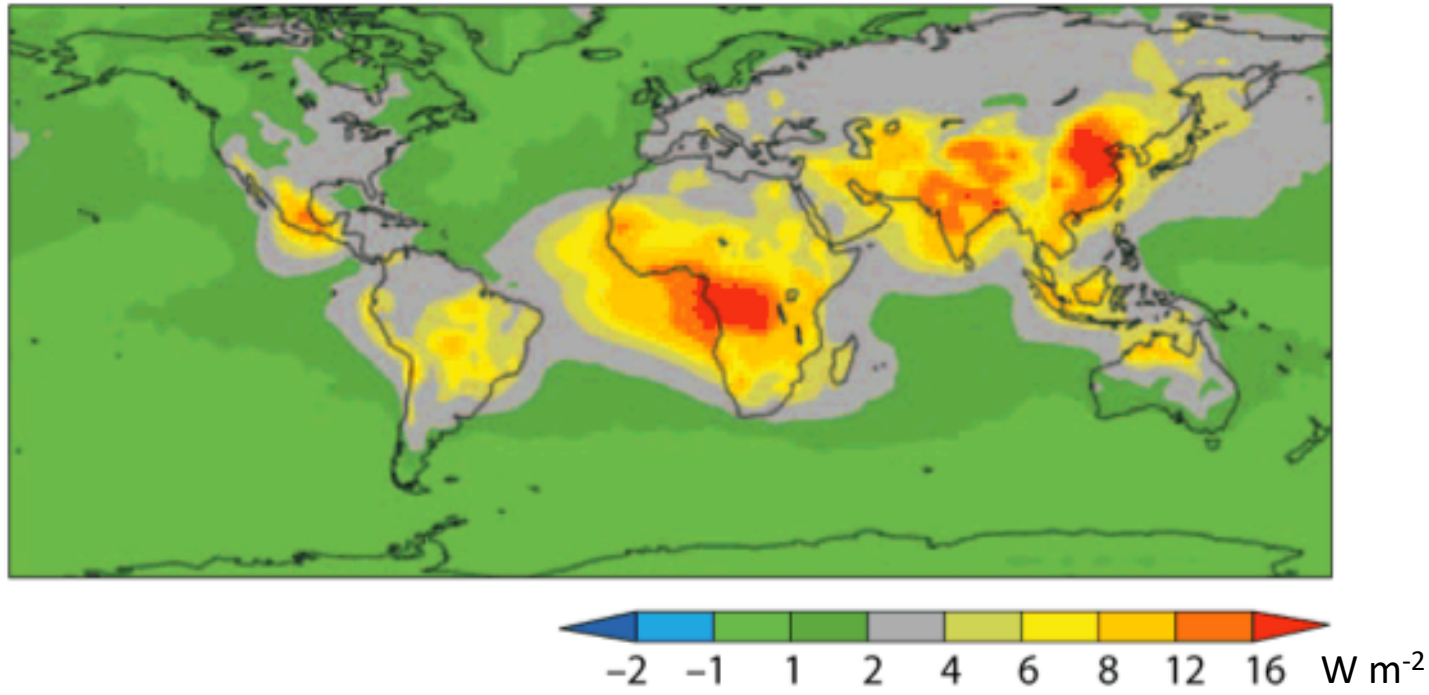
All-sky solar heating of the atmosphere by light-absorbing aerosols

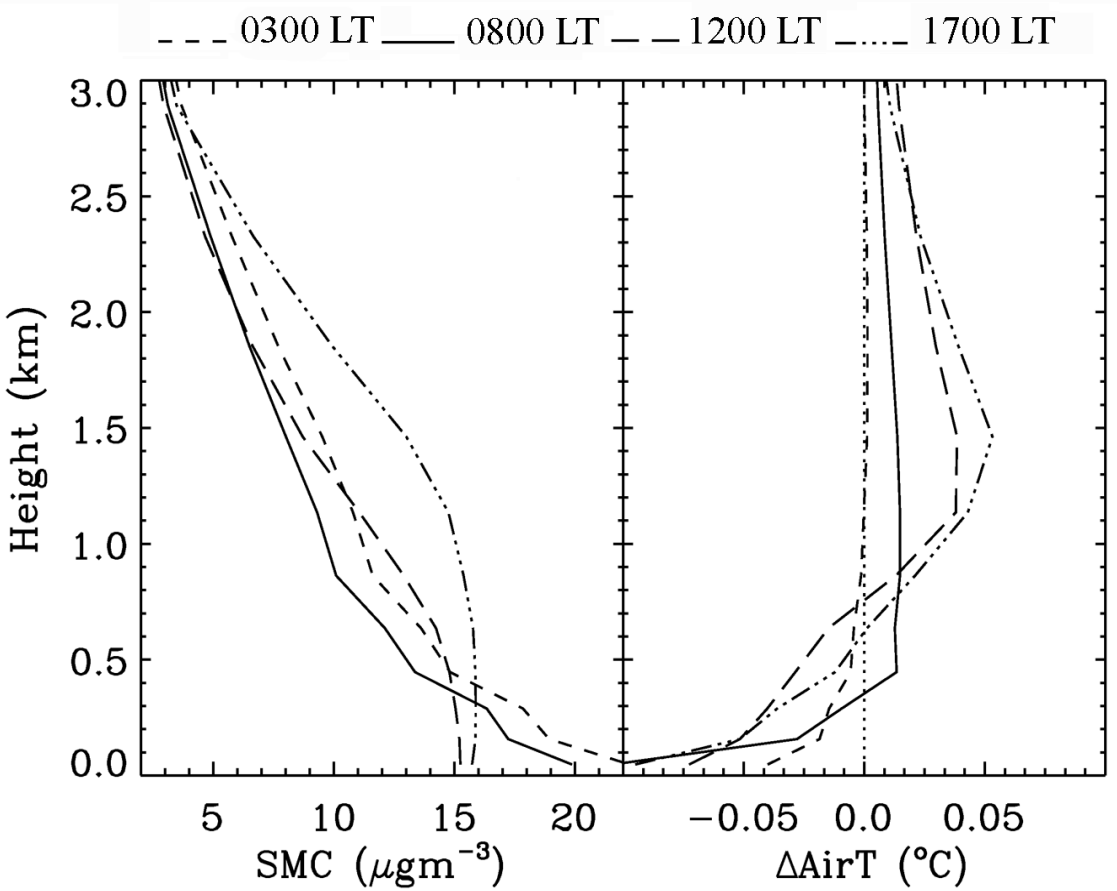


from: Chung et al. (2005) via Ramanathan and Carmichael (2008)

Solar heating of the atmosphere by aerosol absorption of sunlight is widespread in the tropics, subtropics and Asia. But global observations do not yet discriminate the distribution of light-absorbing aerosols from all aerosols.

Chung, C., Ramanathan, V., Kim, D., & Podgorny, I. A. *J. Geophys. Res.* **110** (2005)
Ramanathan, V., and G. Carmichael *Nature Geosci.*, **1**, 221-227 (2008)

Smoke mass concentration (SMC) profiles in model simulations of smoke over Central America.



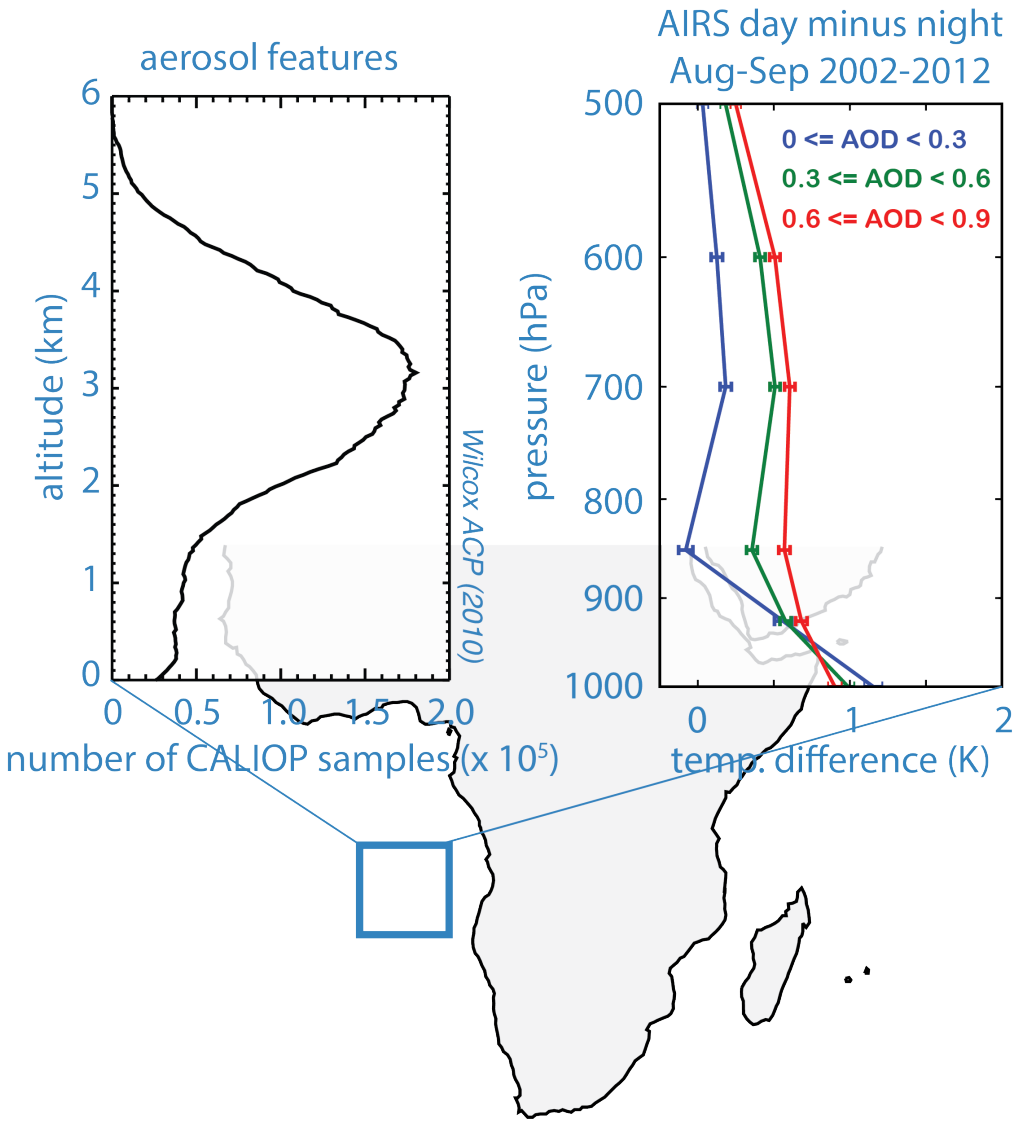
from: Wang and Christopher (2006)

Profile of change in air temperature due to direct radiative effect of smoke aerosols.

Absorption of sunlight heats the air and cools the surface.

The resulting change in air temperature is stronger during the day and minimal at night.

Wang, J., and S.A. Christopher, *J. Geophys. Res.*, **111** (2006).

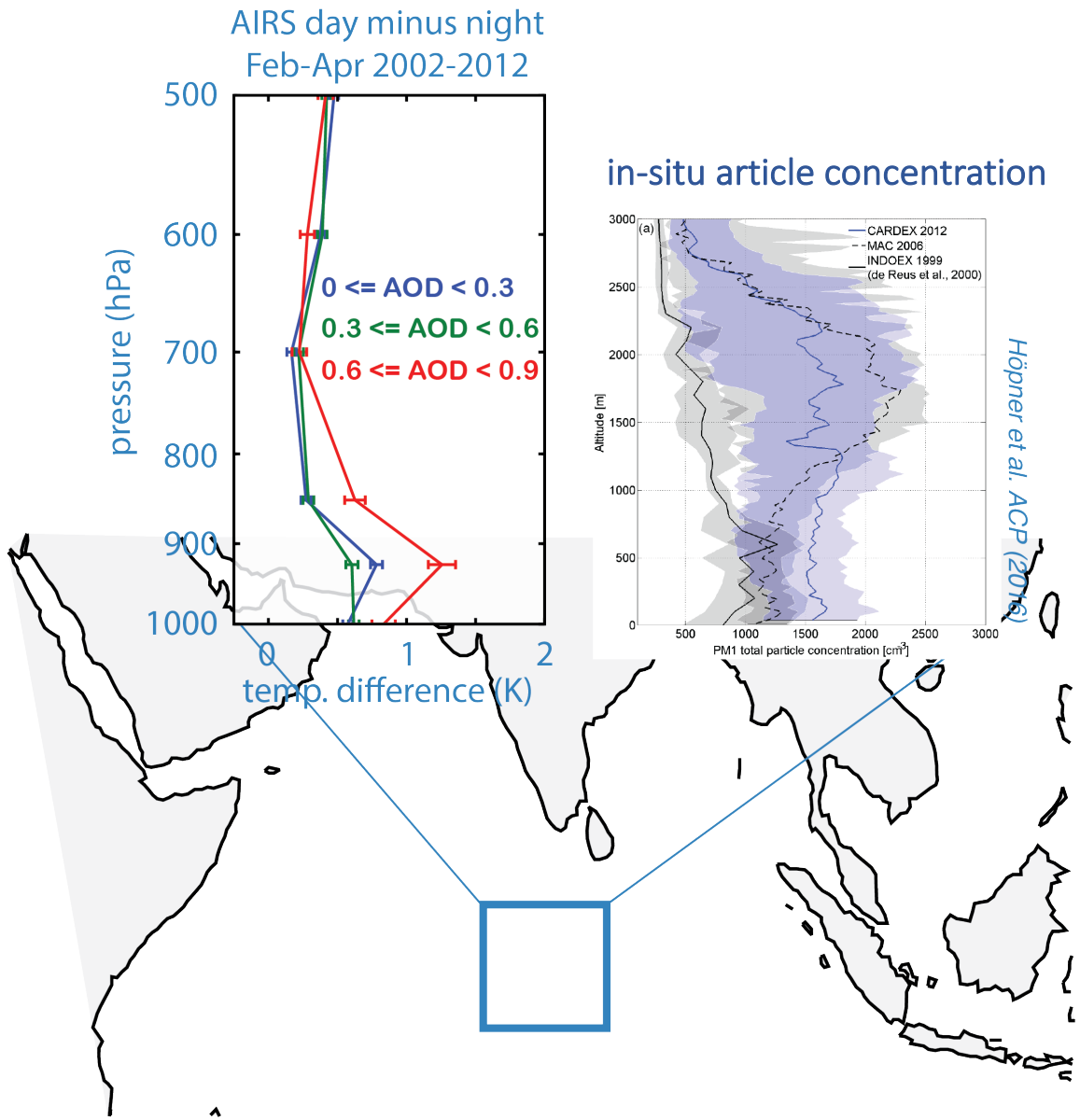


Over the southeast Atlantic Ocean smoke overlays stratocumulus clouds.

Day minus night temperature retrievals from the AIRS sounder systematically increase with aerosol optical depth from MODIS.

DRI

Wilcox, E. M., *Atmos. Chem. Phys.*, **10**, 11769-11777 (2010).

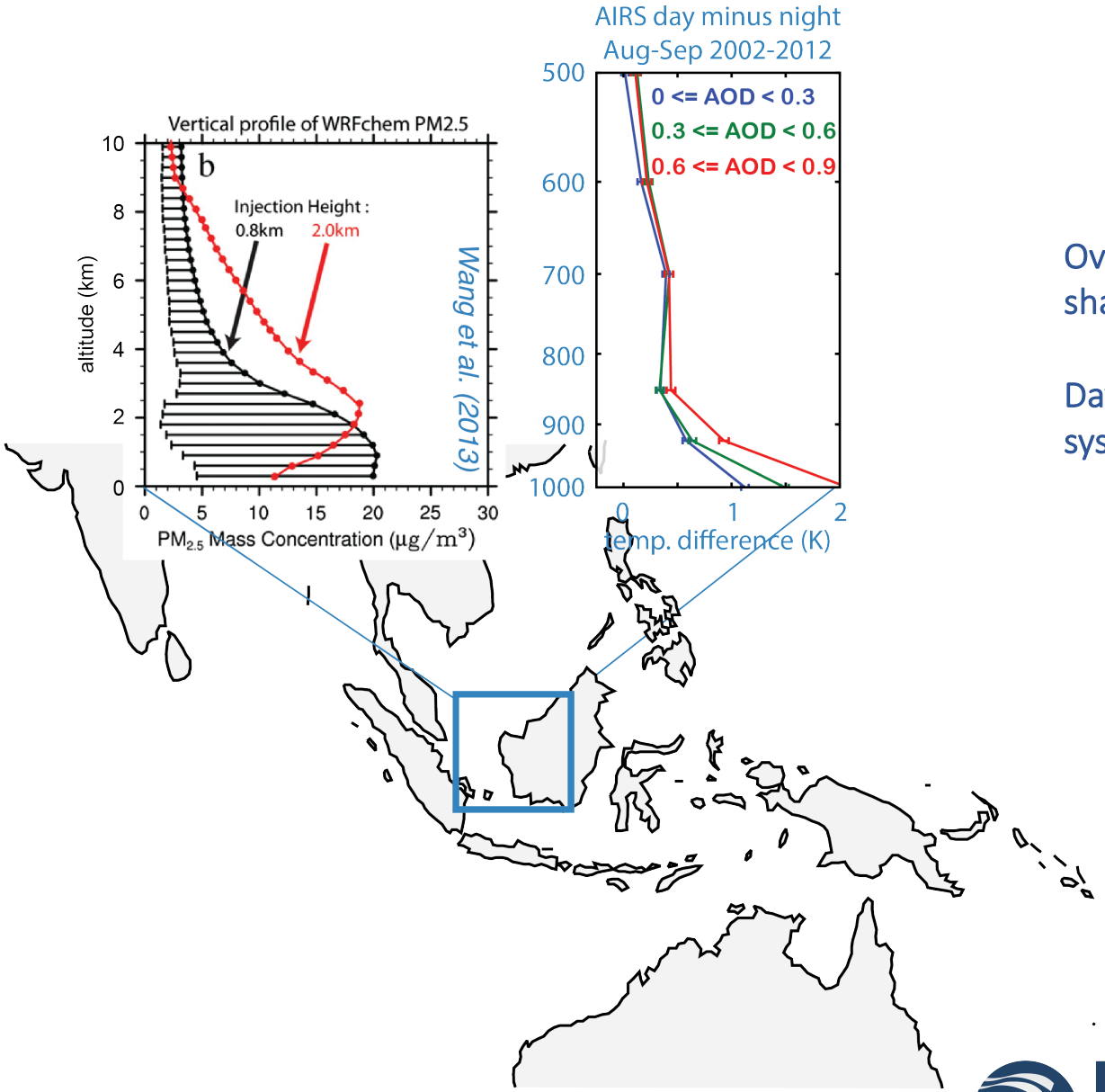


Over the northern tropical Indian Ocean smoke and pollution mixes with shallow cumulus clouds.

Day minus night temperature retrievals from the AIRS sounder systematically increase with aerosol optical depth from MODIS.

DRI

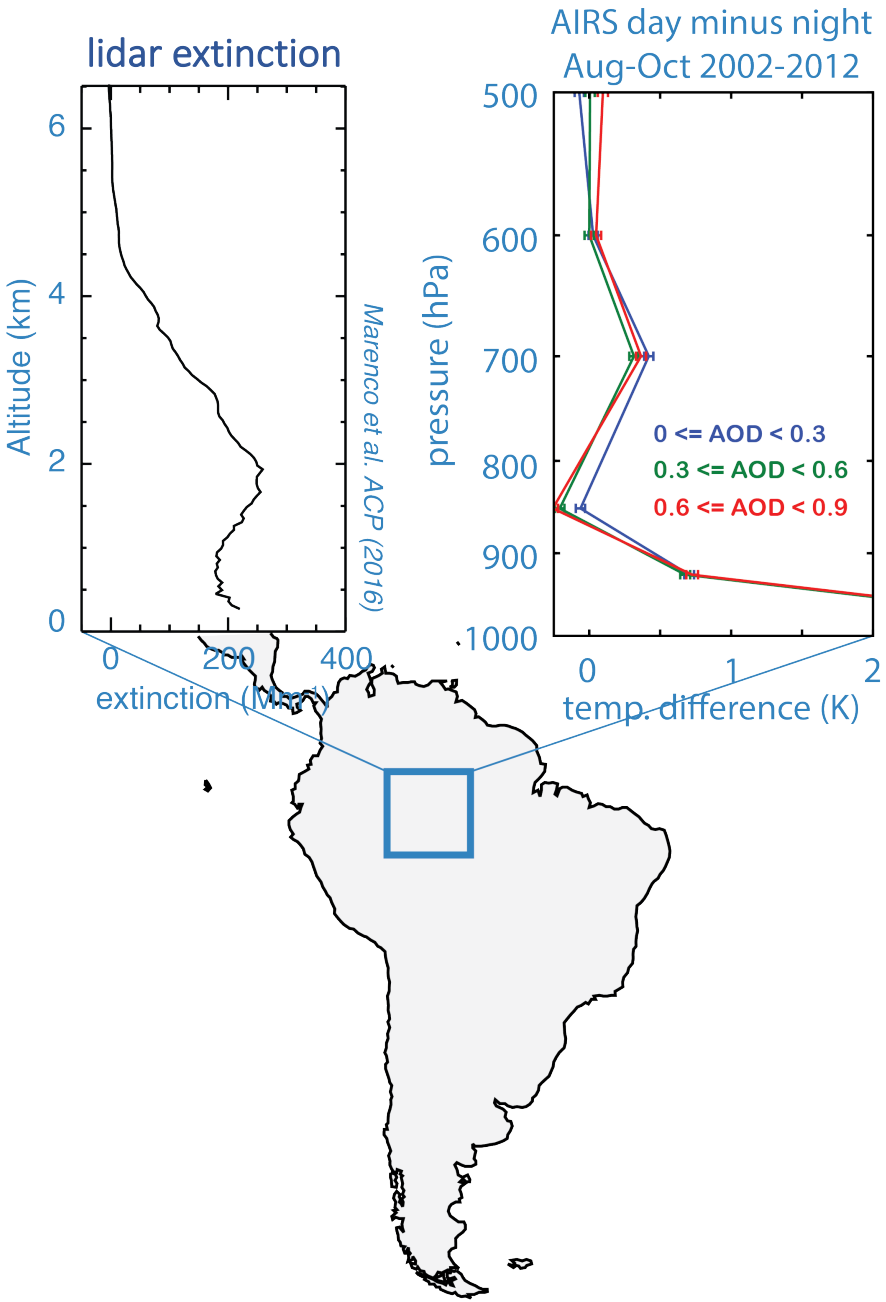
Höpner, F., Bender, F.M., Ekman, A.M., et. al.,. *Atmos. Chem. Phys.*, **16**, 1045-1064 (2016).



Over Indonesia and the Java Sea smoke and pollution mixes with shallow cumulus clouds.

Day minus night temperature retrievals from the AIRS sounder systematically increase with aerosol optical depth from MODIS.

Wang, J., Ge, C., Yang, Z., et al., *Atmos. Res.*, **122**, 486-503 (2013).



Over the Amazon, smoke mixes with cumulus clouds.

Day minus night temperature retrievals from the AIRS sounder does not indicate a systematic increase with aerosol optical depth from MODIS.

But prior work has shown that aerosol heating is present in daytime AIRS temperature profiles, so perhaps the diurnal cycle of convection is masking the signal in the day minus night difference.

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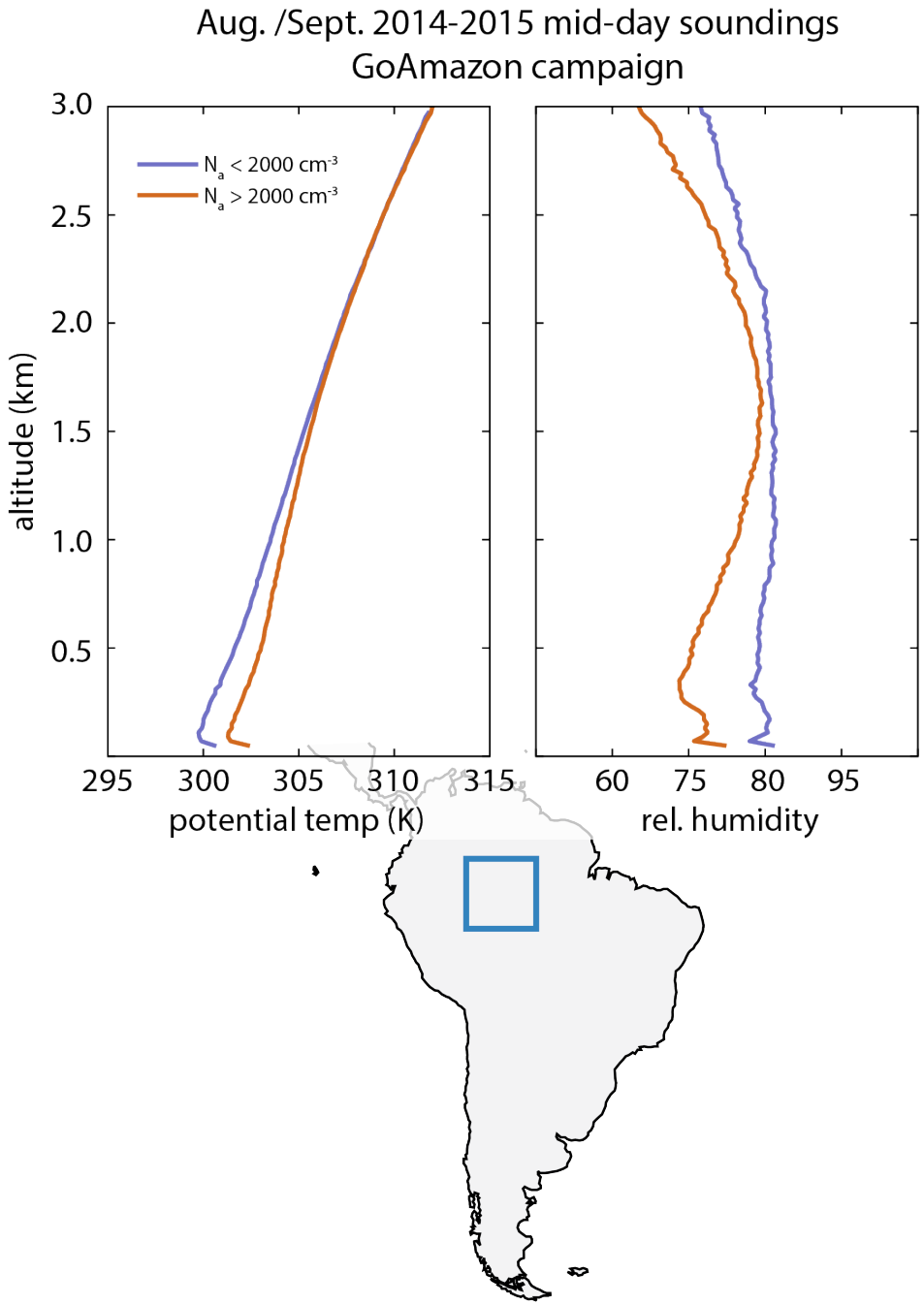
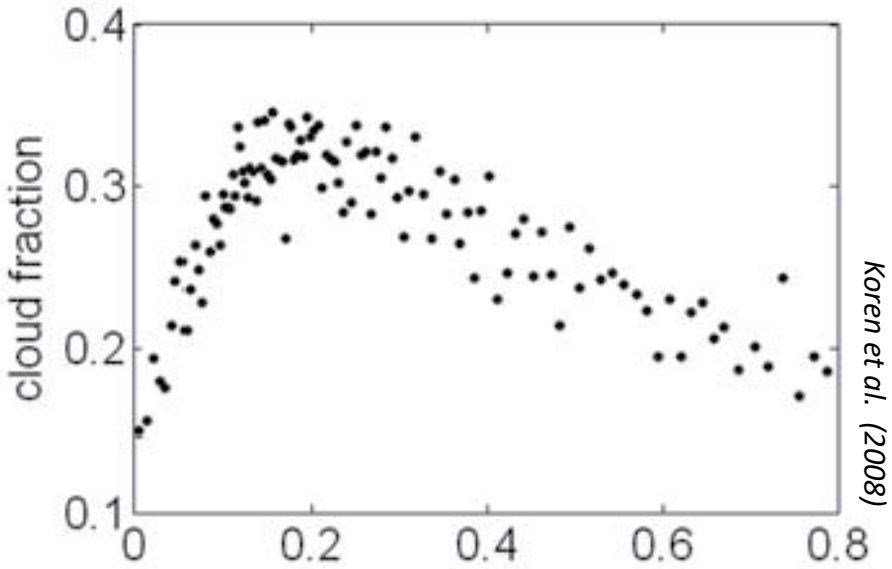
Marenco, F., Johnson, B., Langridge, J.M., et. al., *Atmos. Chem. Phys.*, **16**, 2155-2174 (2016).





Under polluted conditions, boundary layer is warmer and drier, which has been previously argued to reduce cloud cover.

Curiously, we have found that over the Southeast Atlantic Ocean and tropical Indian ocean more pollution leads to a warmer and more humid boundary layer, which promotes cloud development.

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Koren et al. *Science* **321**, 946 (2008).

These environments include aerosols over clouds and aerosols mixed with clouds. Ultimately, we will need more comprehensive retrievals of aerosol properties of light-absorbing aerosol layers above clouds.

Some MODIS and OMI retrievals have been demonstrated by this community.

Hypothetical hyperspectral aerosol retrievals for smoke over clouds were explored in Xu et al. (2018) and found to provide possible constraints on:

- smoke layer height above cloud,
- the imaginary part of smoke refractive index,
- and the effective variance of cloud droplet size

This would provide better global constraints on radiative heating of the atmosphere by light-absorbing aerosols.

Xu, X., Wang, J., Zeng, J., Hou, W., Meyer, K.G., Platnick, S.E. and Wilcox, E.M., 2018. A pilot study of shortwave spectral fingerprints of smoke aerosols above liquid clouds. JQSRT, 221, pp.38-50.

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Summary

In several oceanic regions, the day minus night temperature contrast appears to be a reliable indicator of the atmospheric heating from light-absorbing aerosols.

A diurnal cycle in mid-level convection may mask the signature in some locations, such as the Amazon.

Low cloud responses to aerosol heating of the atmosphere differ in sign and magnitude, e.g. over the Amazon aerosol absorption burns off clouds, while over the SE Atlantic and N. tropical Indian Ocean.

A broadly applicable indicator of the thermodynamic impact of light-absorbing aerosols will help in discriminating conditions that lead to increasing vs. decreasing cloudiness in response to aerosol absorption.

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