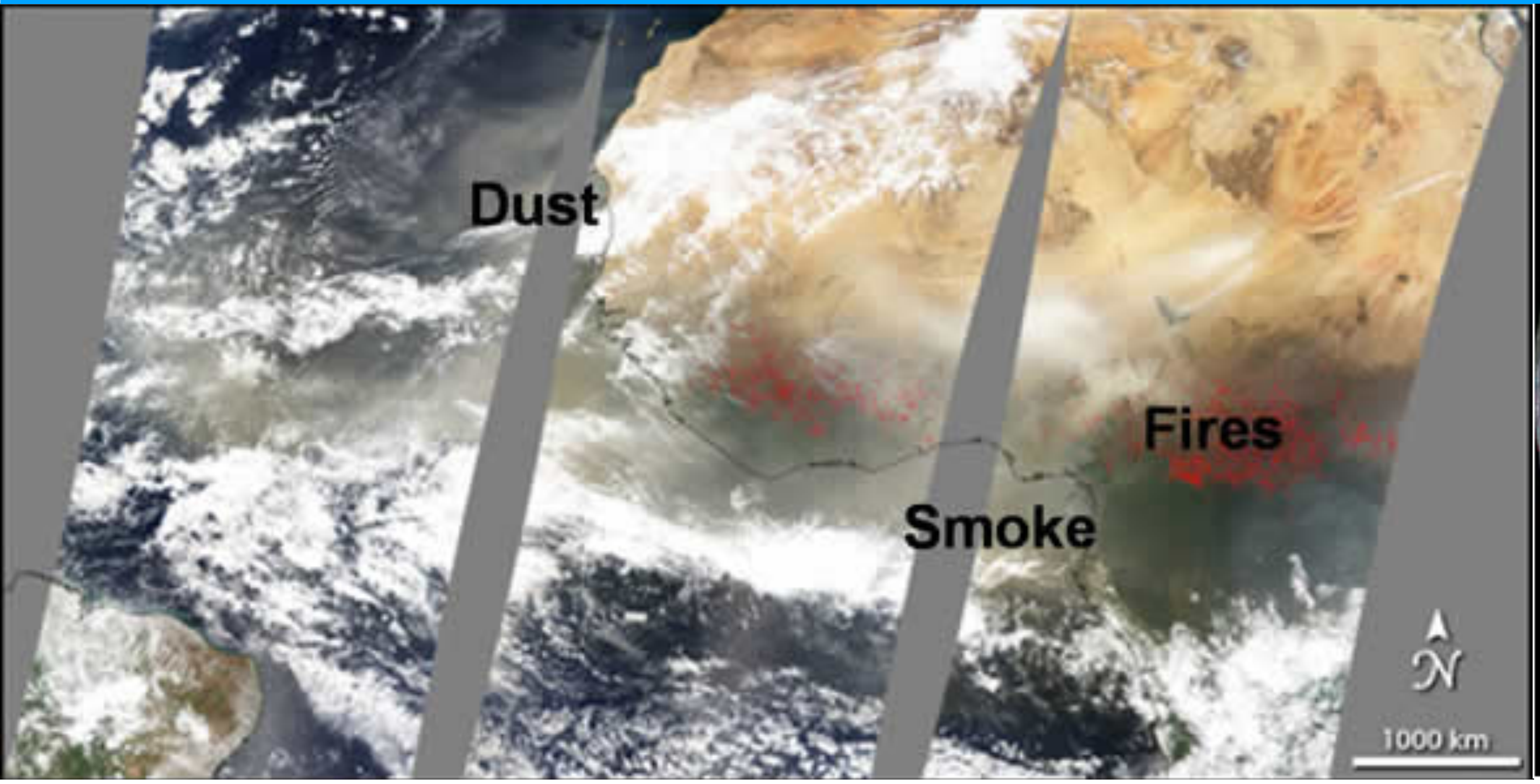
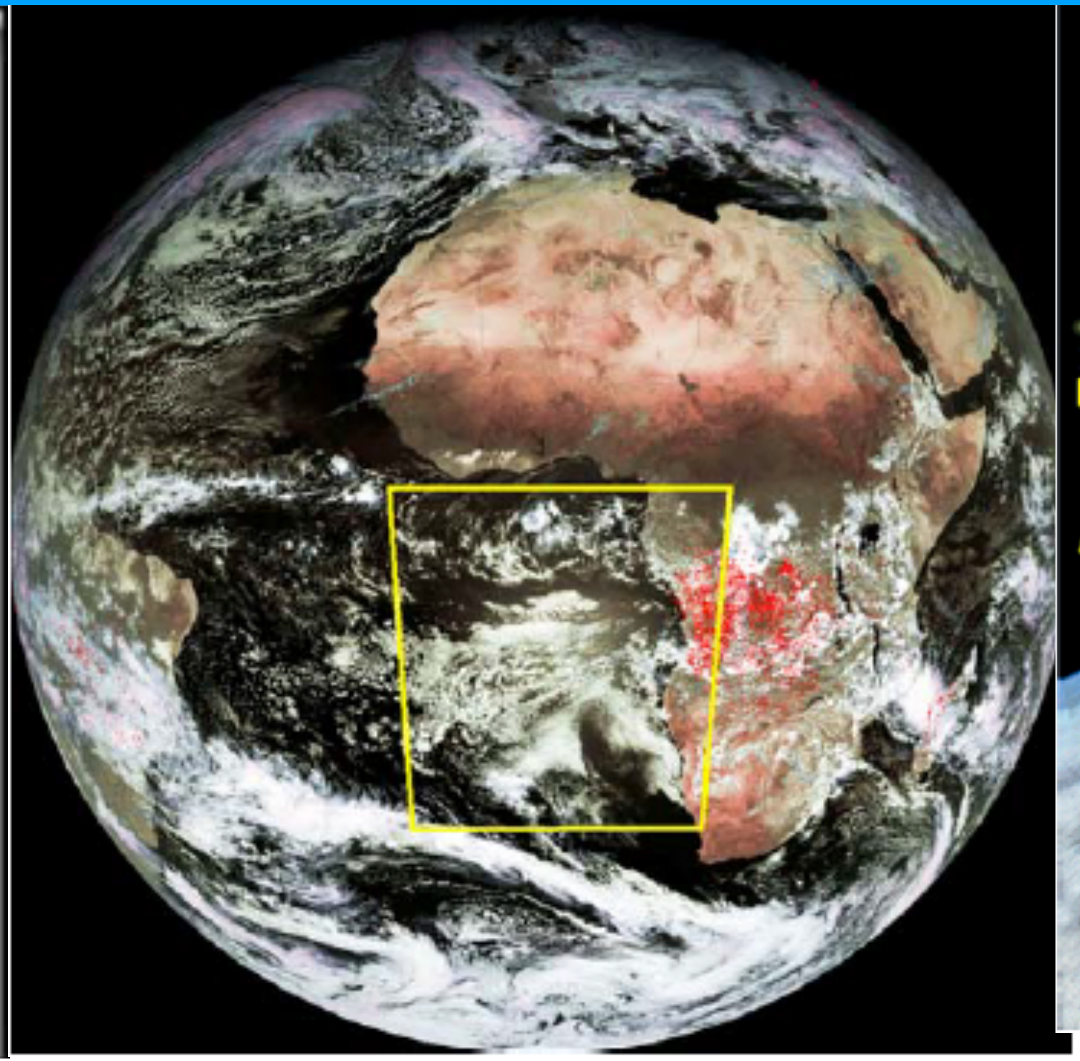
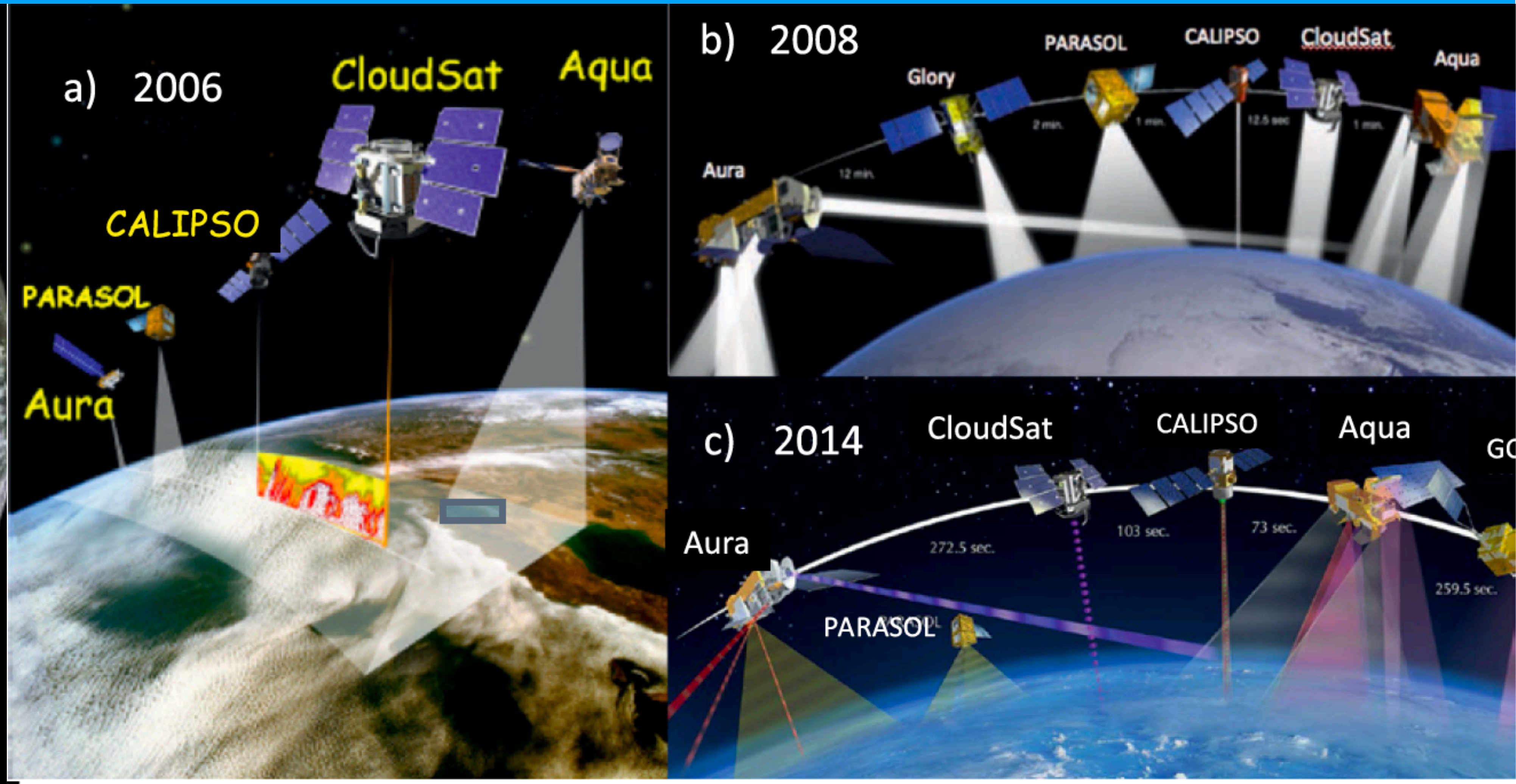
Impact of smoke and non-smoke aerosols on radiation and low-level clouds over the South East Atlantic from colocated satellite observations



Modis image, January 2005. Credit: Met Office



Meteosat-7 full disc image.
Constantino and Bréon, 2010



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Alejandro Baró Pérez[1,2], Abhay Devasthale[3], Frida A.-M. Bender[1,2], and Annica M. L. Ekman[1,2]

Funding provided by the Swedish National Space Agency (SNSA) grant 16317

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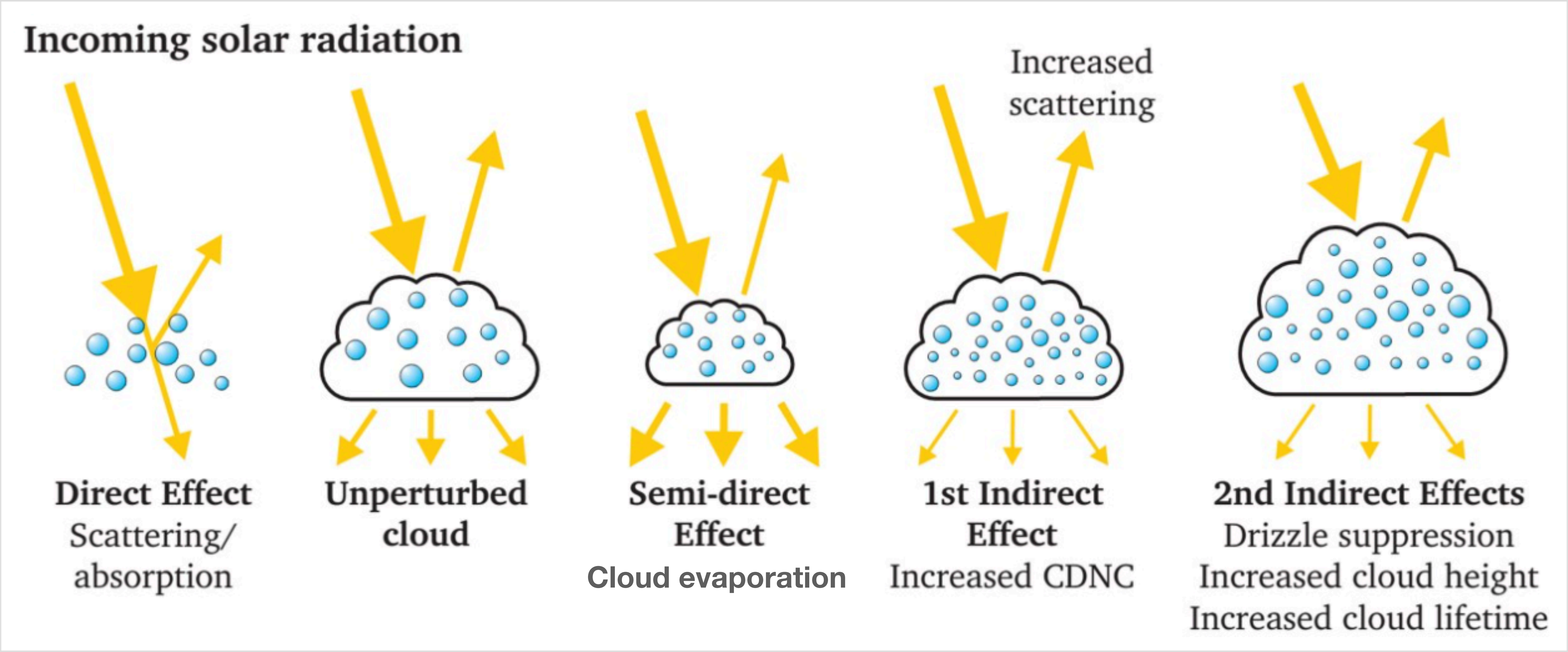
Stockholm University
Department of Meteorology

Atmospheric aerosols

Atmospheric aerosols → **Suspensions of small solid and/or liquid particles (excluding cloud particles) in air that have negligible terminal fall speeds. (Wallace and Hobbs, 2006)**

Aerosol effects



https://allaboutaerosol.wordpress.com/aerosol-in-the-atmosphere/

Atmospheric aerosols

Atmospheric aerosols

- Contribute to the largest uncertainty in current estimates of global anthropogenic radiative forcing.

⬇

- Effects on the shallow warm clouds that cover large areas of the ocean and provide a cooling effect.

Absorbing aerosols, eg. black carbon and soil dust.

⬇

Strong absorption of solar radiation

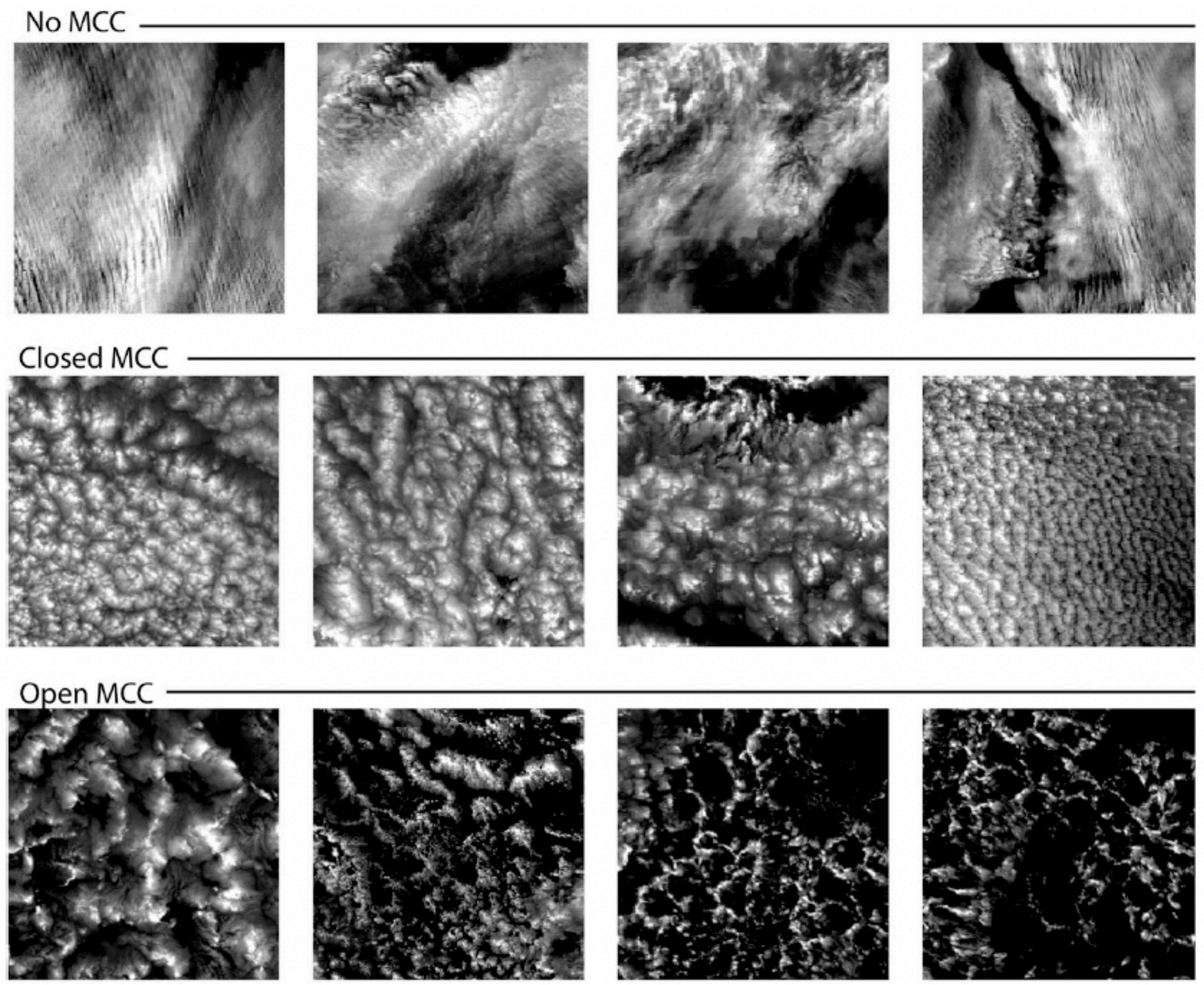
⬇

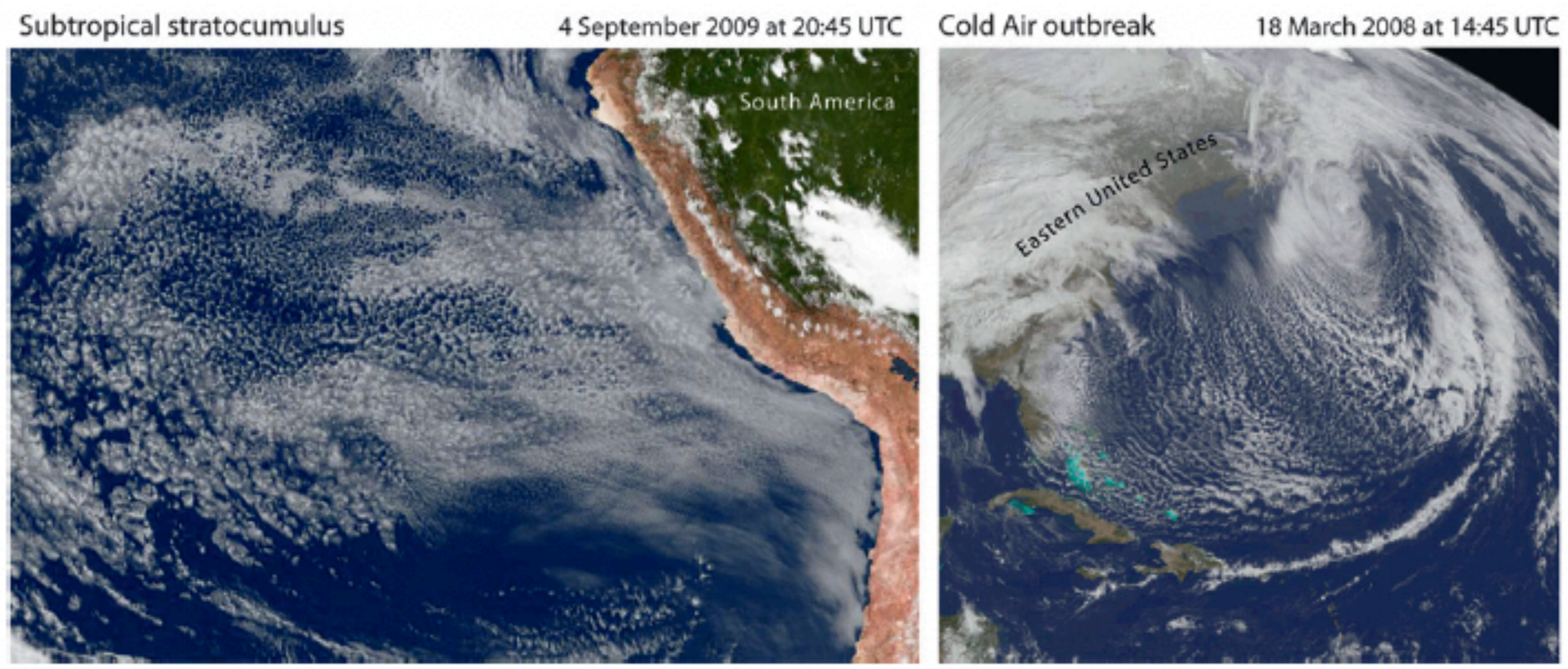
The direct and indirect effects of absorbing aerosol are poorly constrained.

Stratocumulus clouds (Sc)

The name comes from Latin 'stratus' (layer) and 'cumulus' (heap)

- **Sc are low level clouds.**
- **Layering is typically achieved through capping by a temperature inversion.**





Different mesoscale structure types occurring in stratocumulus(Wood, 2010).

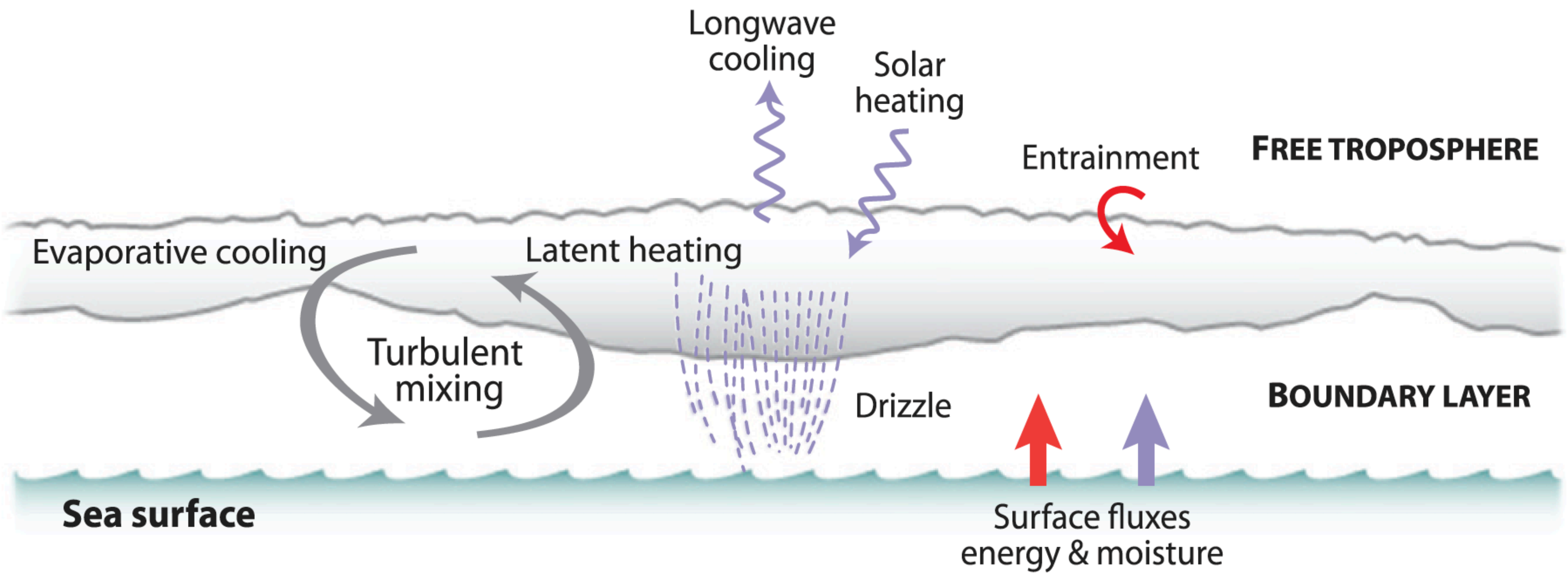
- **Sc are propelled mainly by the cloud top radiative cooling**

↓

-Turbulent mixing.

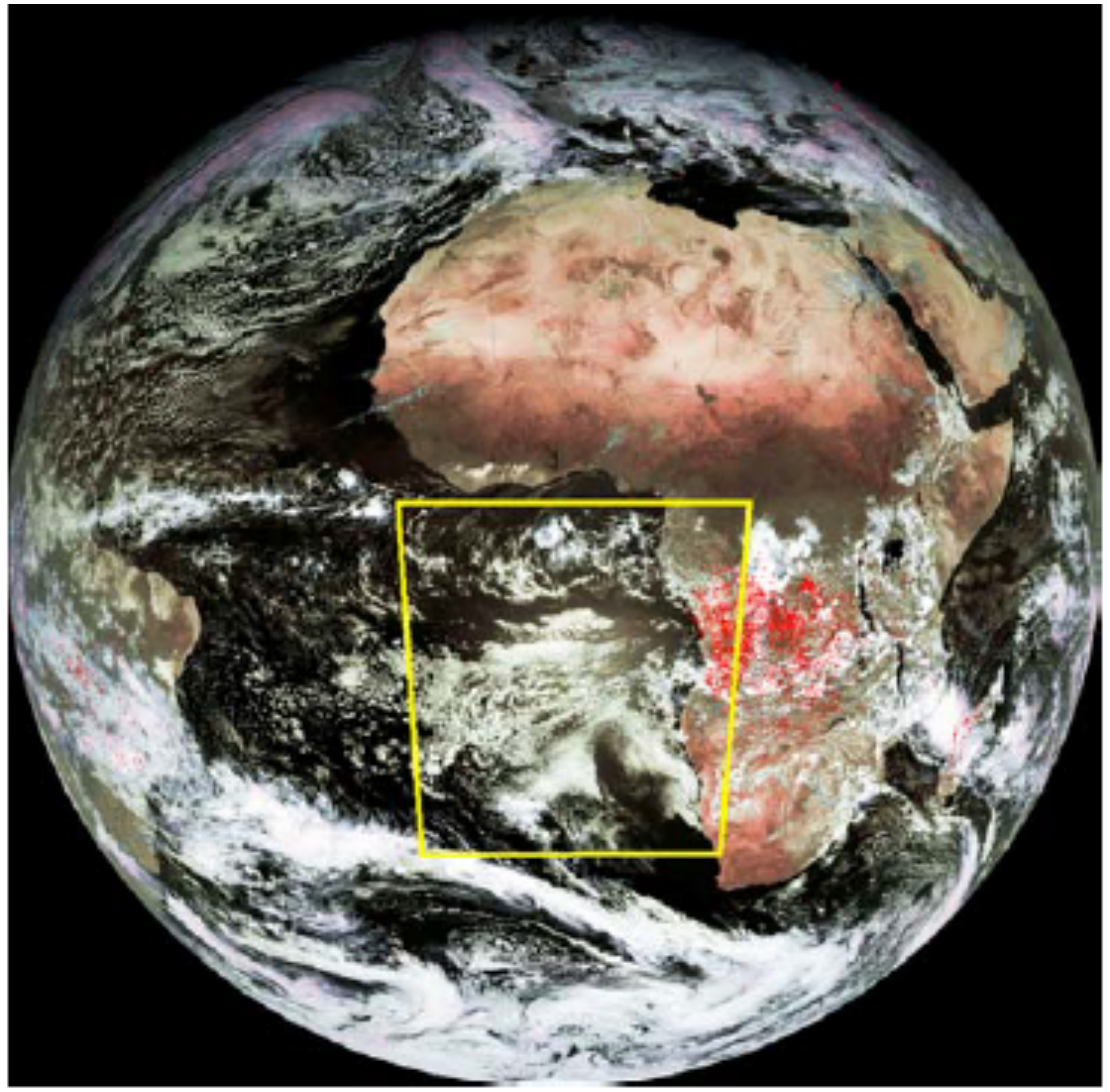
-Coupling with the surface.

-Surface fluxes of energy and moisture.



Key processes occurring in the stratocumulus-topped boundary layer (Wood, 2010).

Southeast Atlantic

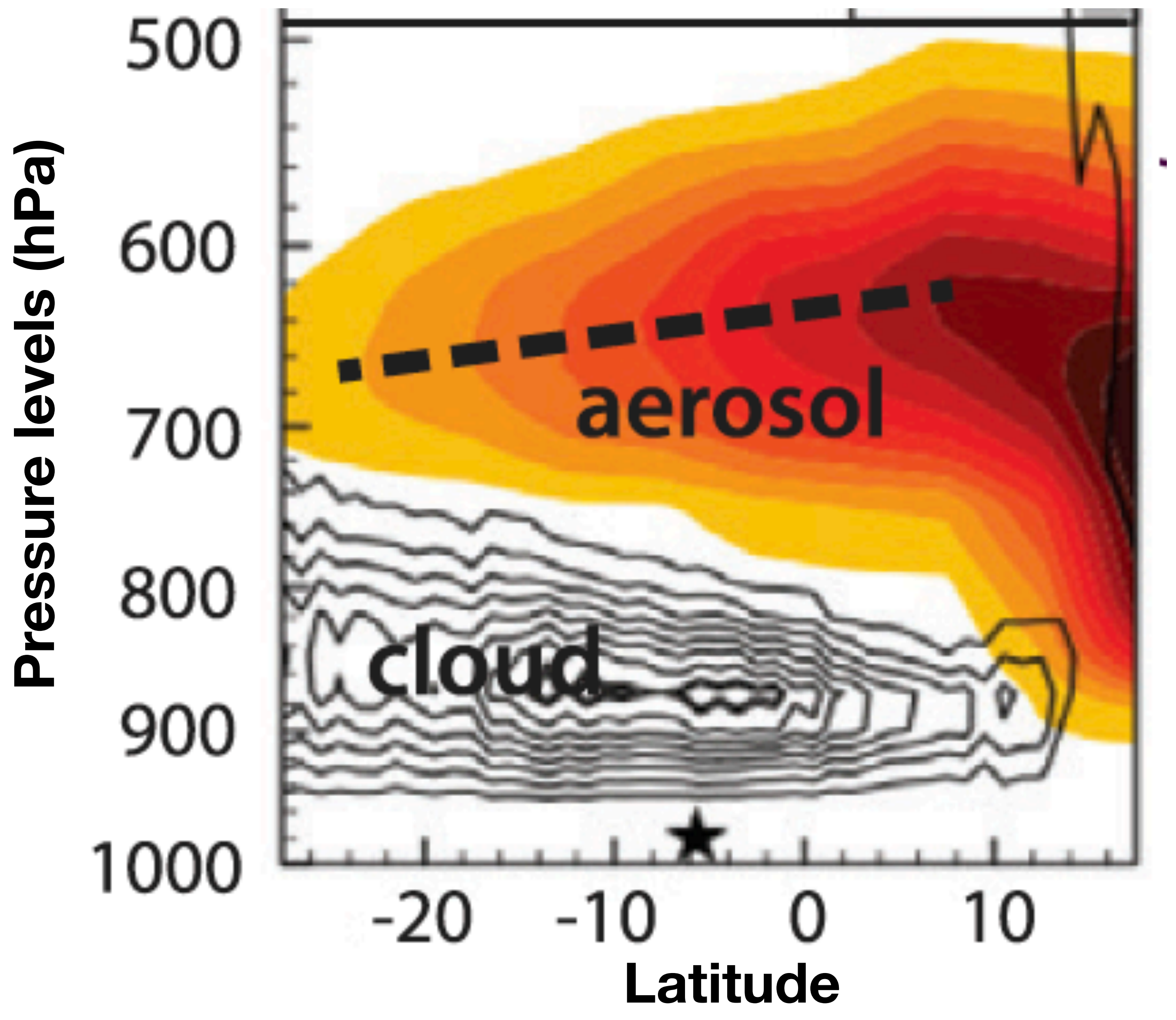


Meteosat-7 full disc image.
Constantino and Bréon, 2010

-One of the largest stratocumulus cloud decks in the planet.

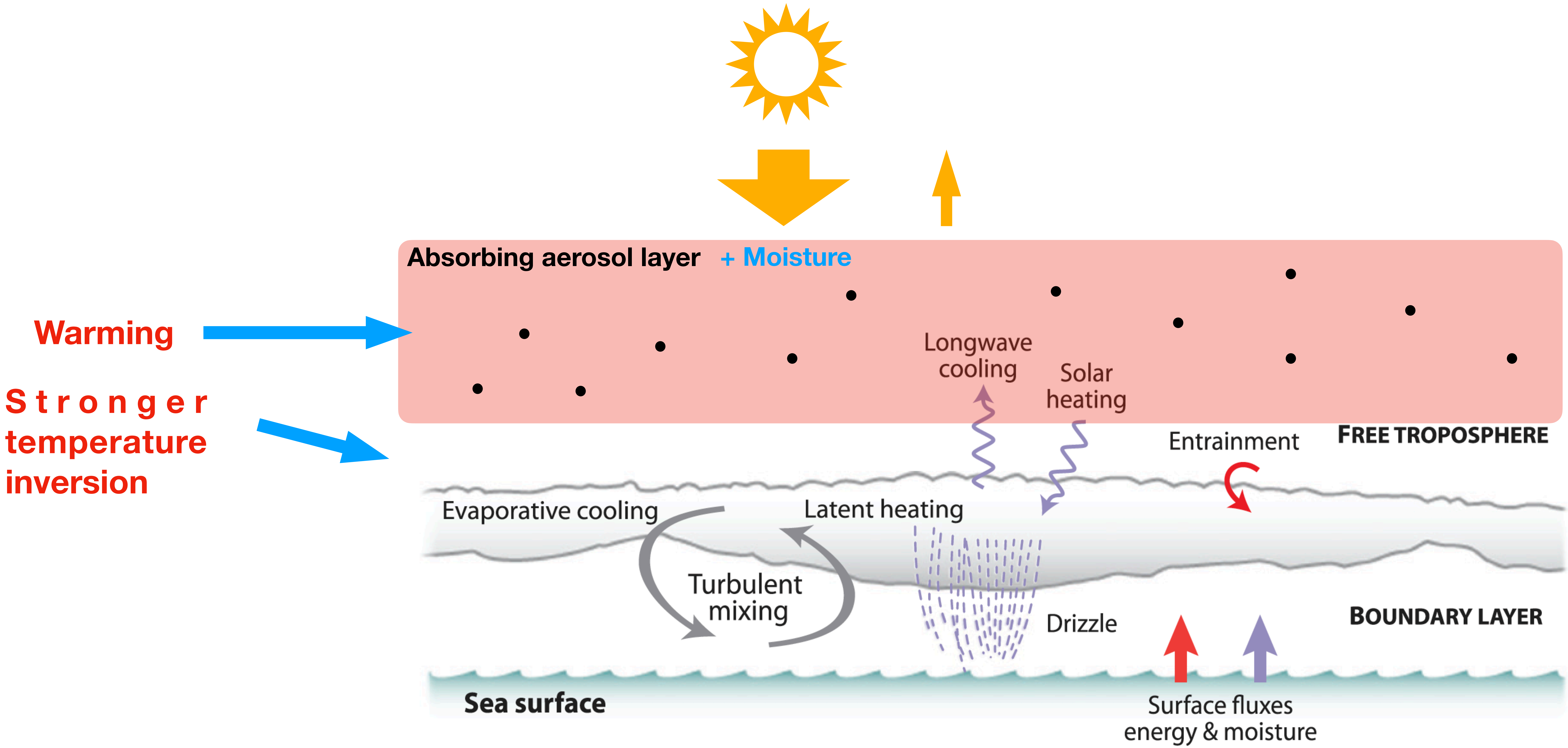
-Black carbon from biomass burning fires on the southern African subcontinent is transported westwards over the cloud decks.

Mainly during the period June-October (biomass burning season)



Zuidema et al, 2016

Absorbing aerosols above Sc clouds



Key processes occurring in the stratocumulus-topped boundary layer (Wood, 2010).

A-Train formation

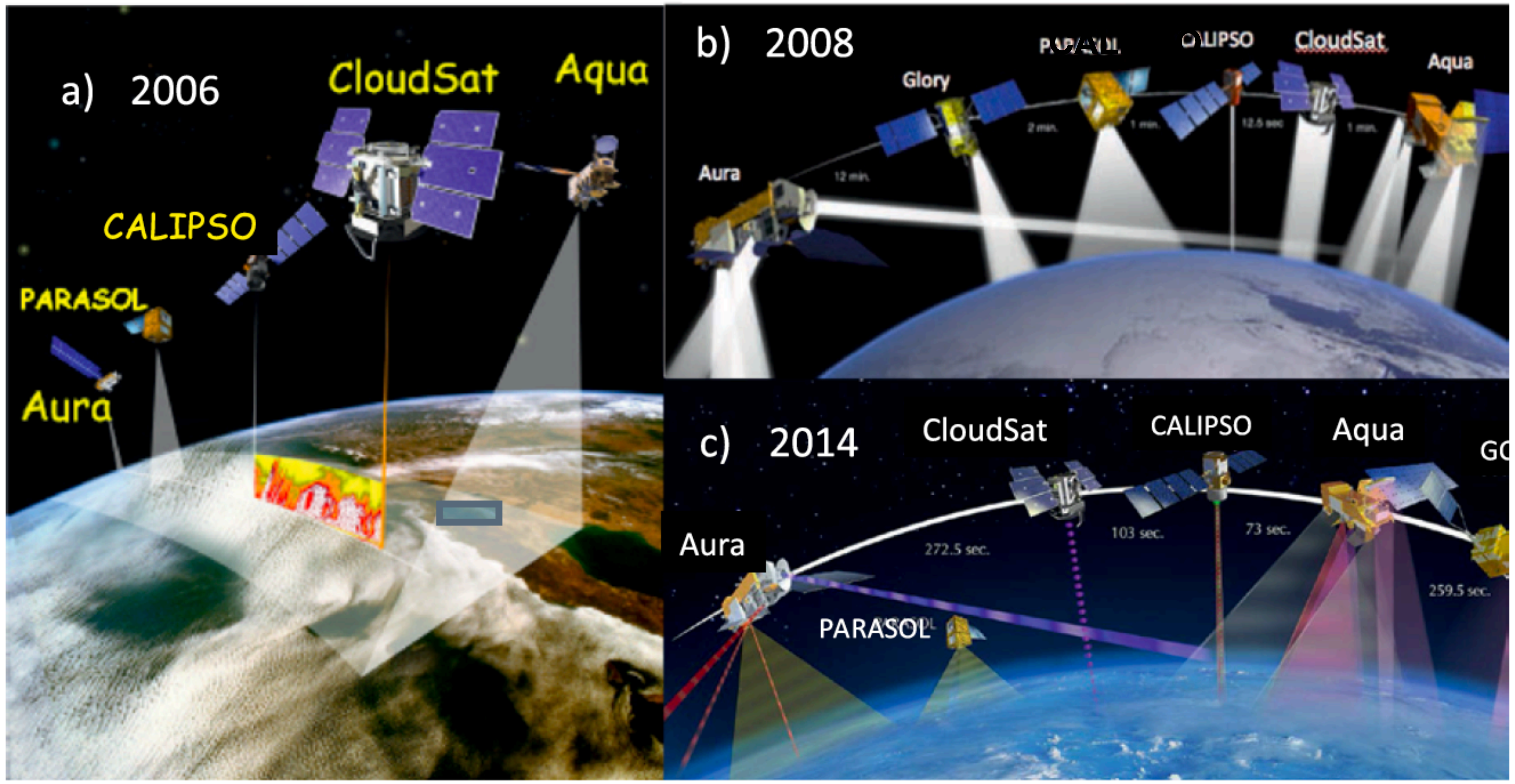


Fig. 1. (a)–(c) Three depictions of the A-Train illustrating how it has evolved over time. The current A-Train configuration is shown in (c).

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CALIPSO

Retrievals provide:

-Vertically resolved distribution of aerosol.

-Accurate aerosol and cloud heights.

-Discrimination of aerosols into several types.

Cloudsat

-Include retrievals from CALIPSO and MODIS (Aqua).

-High vertical resolution profiles of radiative fluxes and atmospheric heating rates.

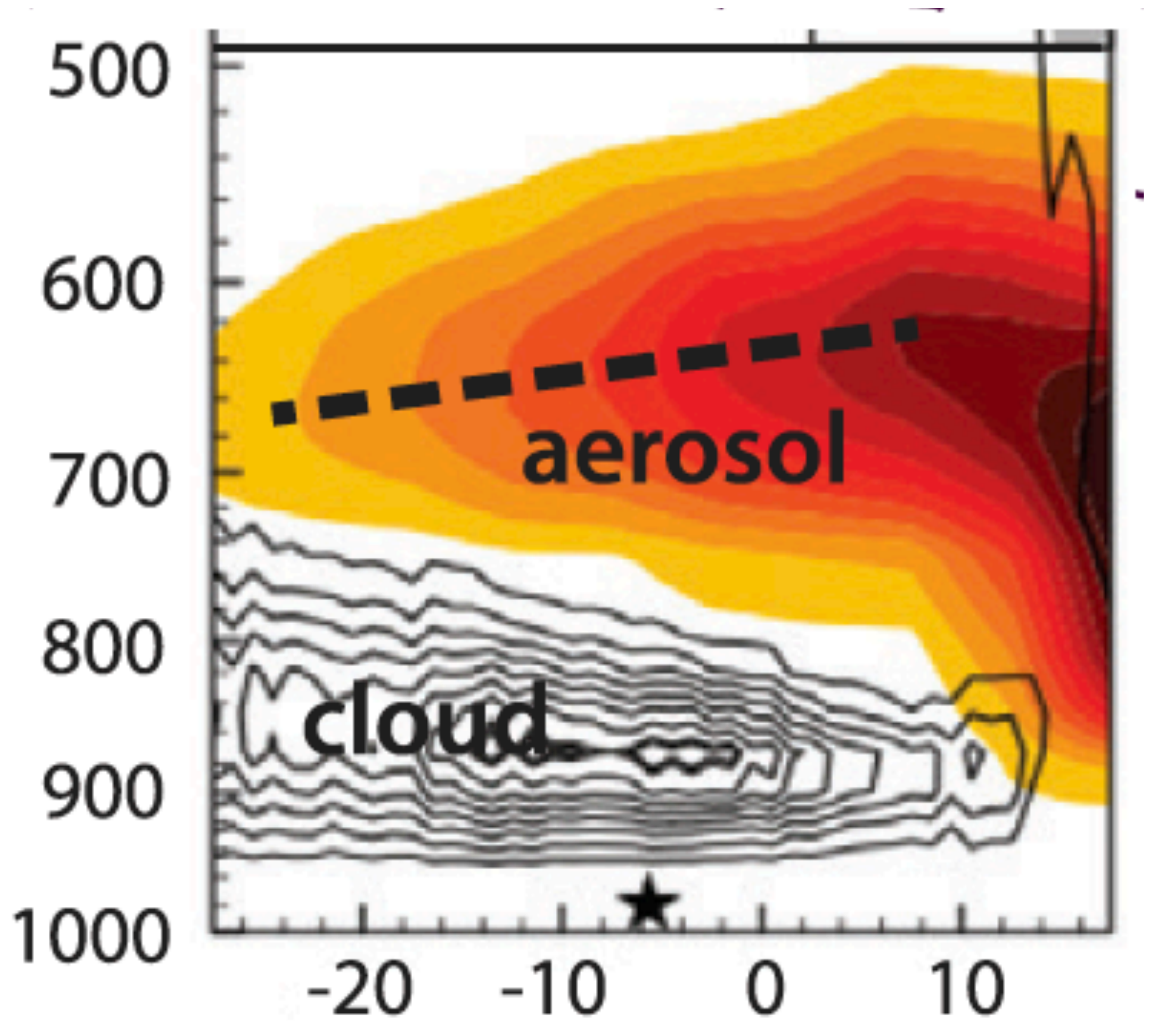
" Impact of smoke and non-smoke aerosols on radiation and low-level clouds over the Southeast Atlantic from co-located satellite observations." (2021)

Authors: Alejandro Baró Pérez, Abhay Devasthale, Frida Bender and Annica Ekman

We explore situations when moist aerosol layers overlie stratocumulus clouds over the Southeast Atlantic during the biomass burning season (June to October).

Main goal:

To separate and quantify the impacts of aerosol loading, aerosol type, and humidity on the radiative fluxes, including cloud top cooling.



Zuidema et al, 2016

Direct and semi-direct effects

Materials and methods

Satellites and models used in the study

Satellite/reanalysis	Products and variables	Resolution
CALIPSO	Merged aerosol and cloud layer data: – aerosol top and base altitudes (km) – cloud top altitudes (km) – aerosol type Aerosol profile data products: – extinction coefficient at 532 nm – column optical depth tropospheric – aerosols at 532 nm – temperature[a] – relative humidity[a] – pressure[a]	Horizontal: 5 km Vertical: 60 m
CloudSat	2B-FLXHR-LIDAR product: – radiative fluxes – atmospheric heating rates ECMWF-AUX product: – temperature[b] – specific humidity[b] – pressure[b]	Vertical: 240 m
ERA5	Wind speed and direction	Horizontal: 31 km

Variables with superscript "a" are derived from the Modern-Era Retrospective analysis for research and applications, Version 2 (MERRA-2) data product. Variables with a superscript "b" are derived from the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis.

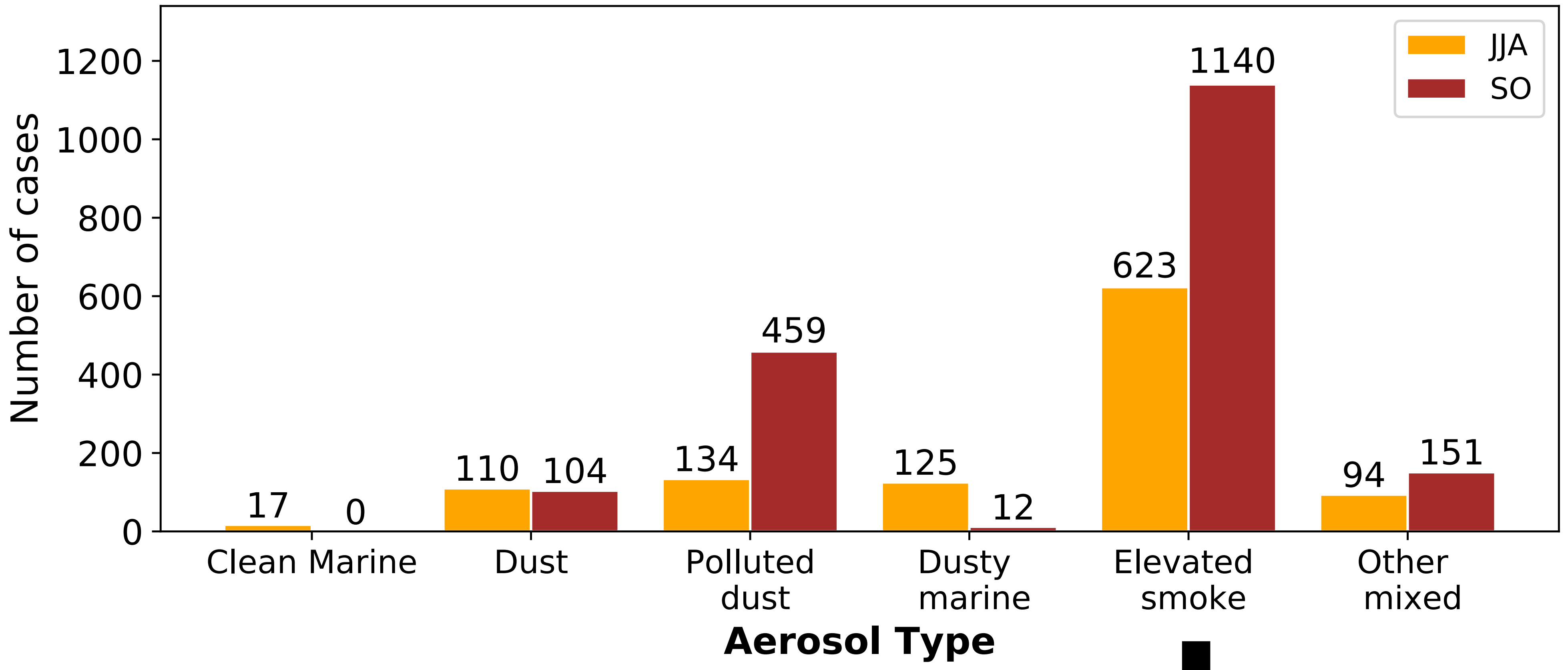
Reanalysis: Model simulations that has been strongly constrained by observations

Area selected for the study (years 2007-2010)

- **Seasons: June-July-August (JJA) and September-October (SO).**

Results

Aerosol types identified within the aerosol layers by the CALIPSO aerosol discrimination algorithm.

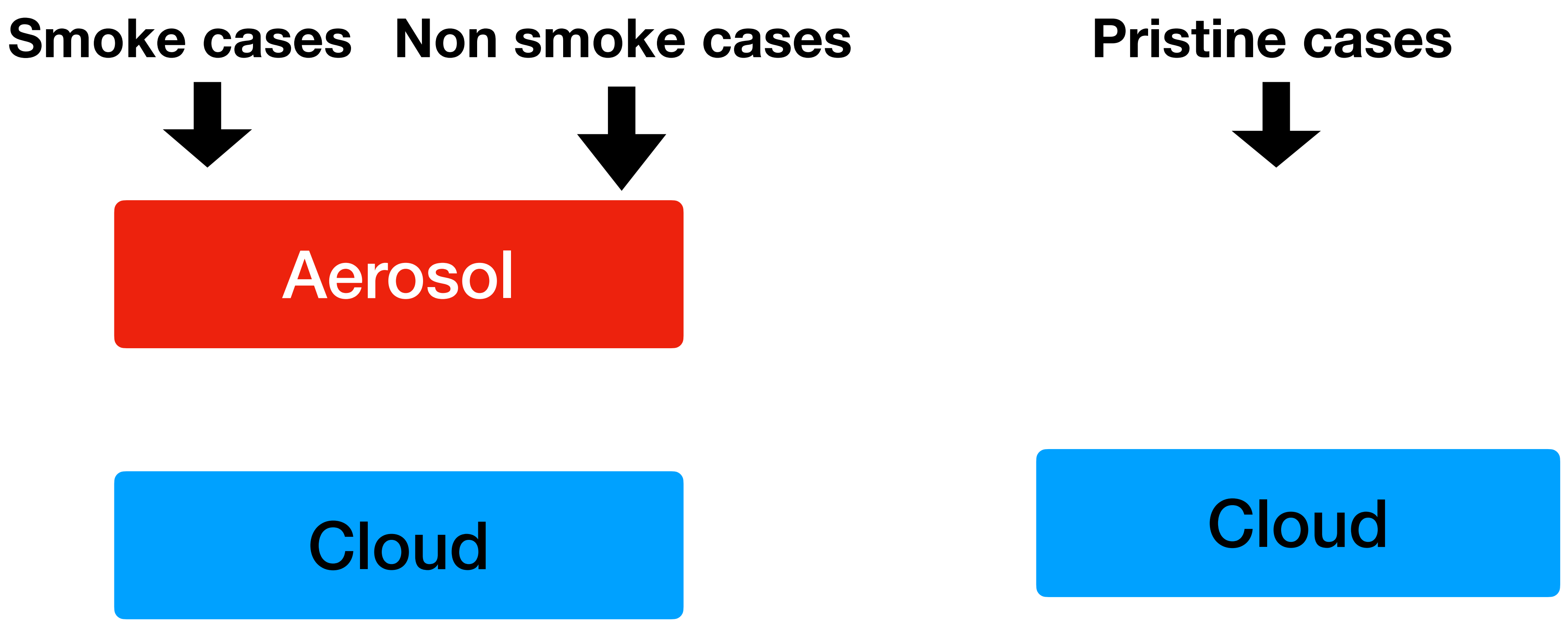


- **Elevated smoke predominates.**
- **Non negligible number of non-smoke aerosol situations.**

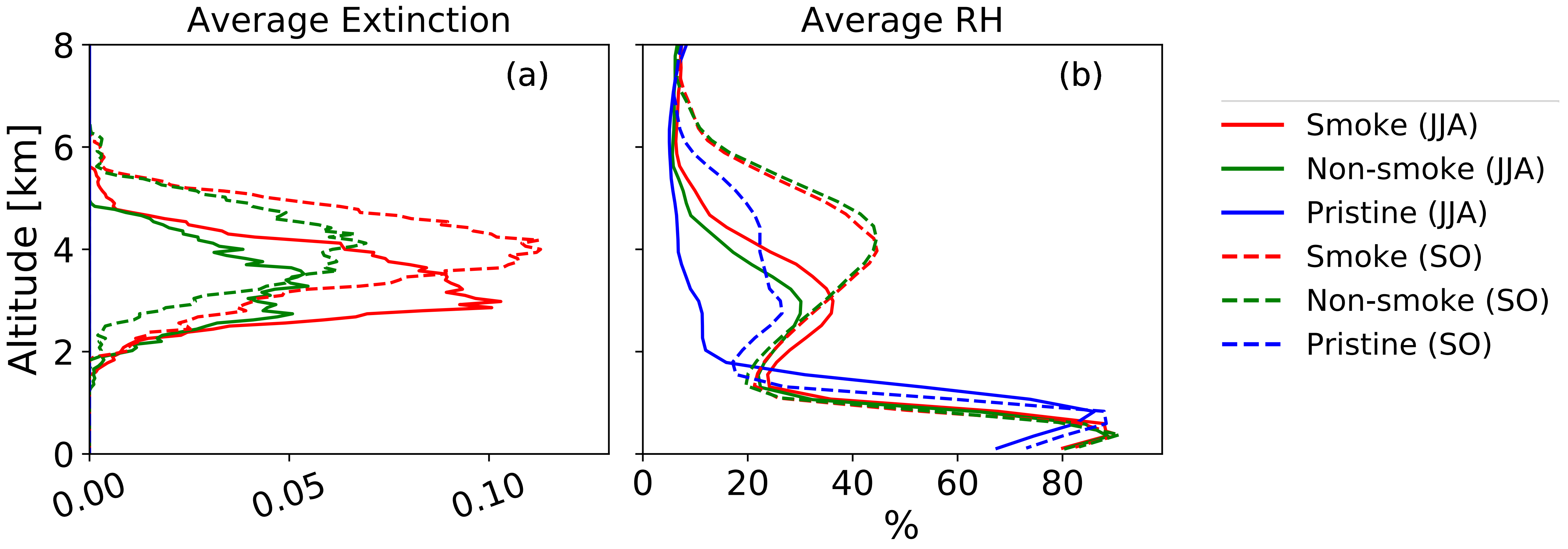
Smoke cases

The rest of the aerosol types are grouped in the non smoke cases

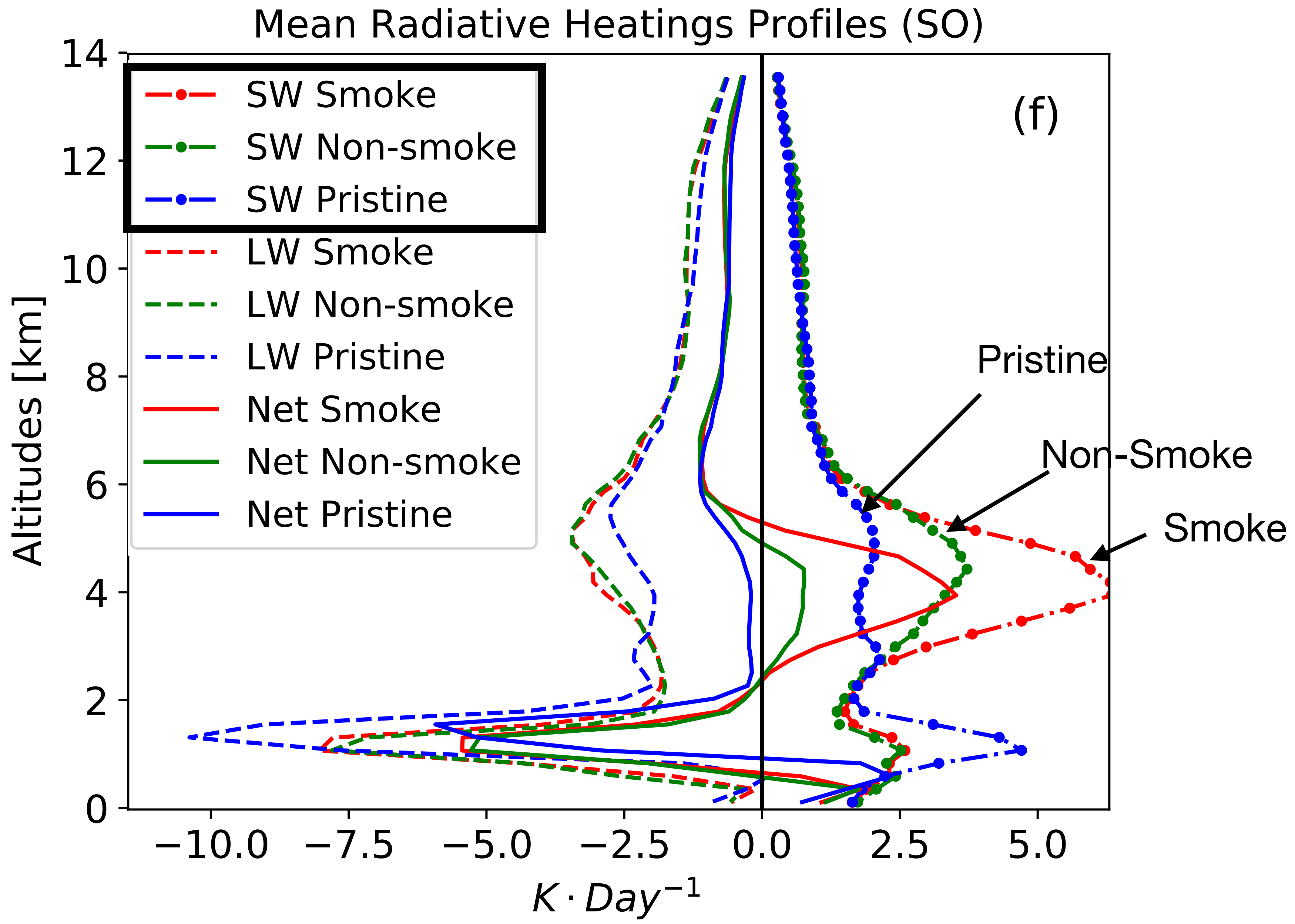
We analysed three different situations:



Results



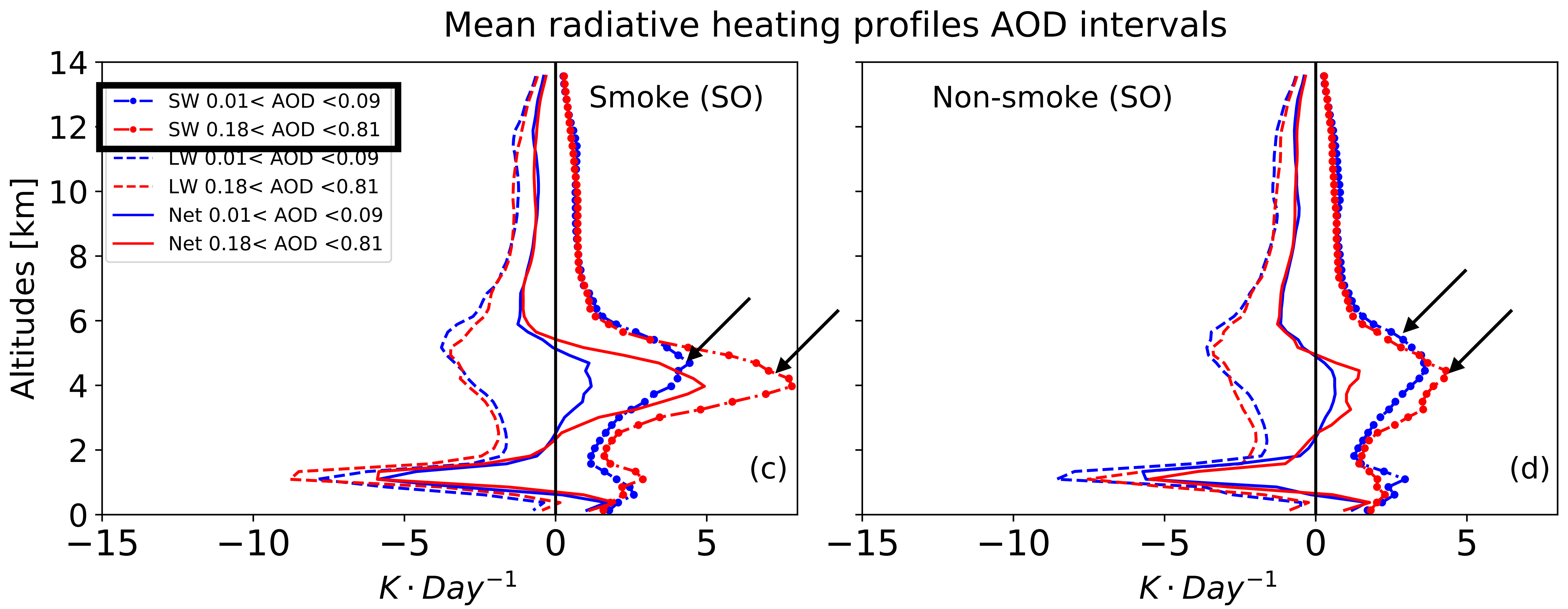
- Higher average extinction in the smoke than in the non-smoke cases.
- Higher moisture in the aerosol cases compared to pristine cases.



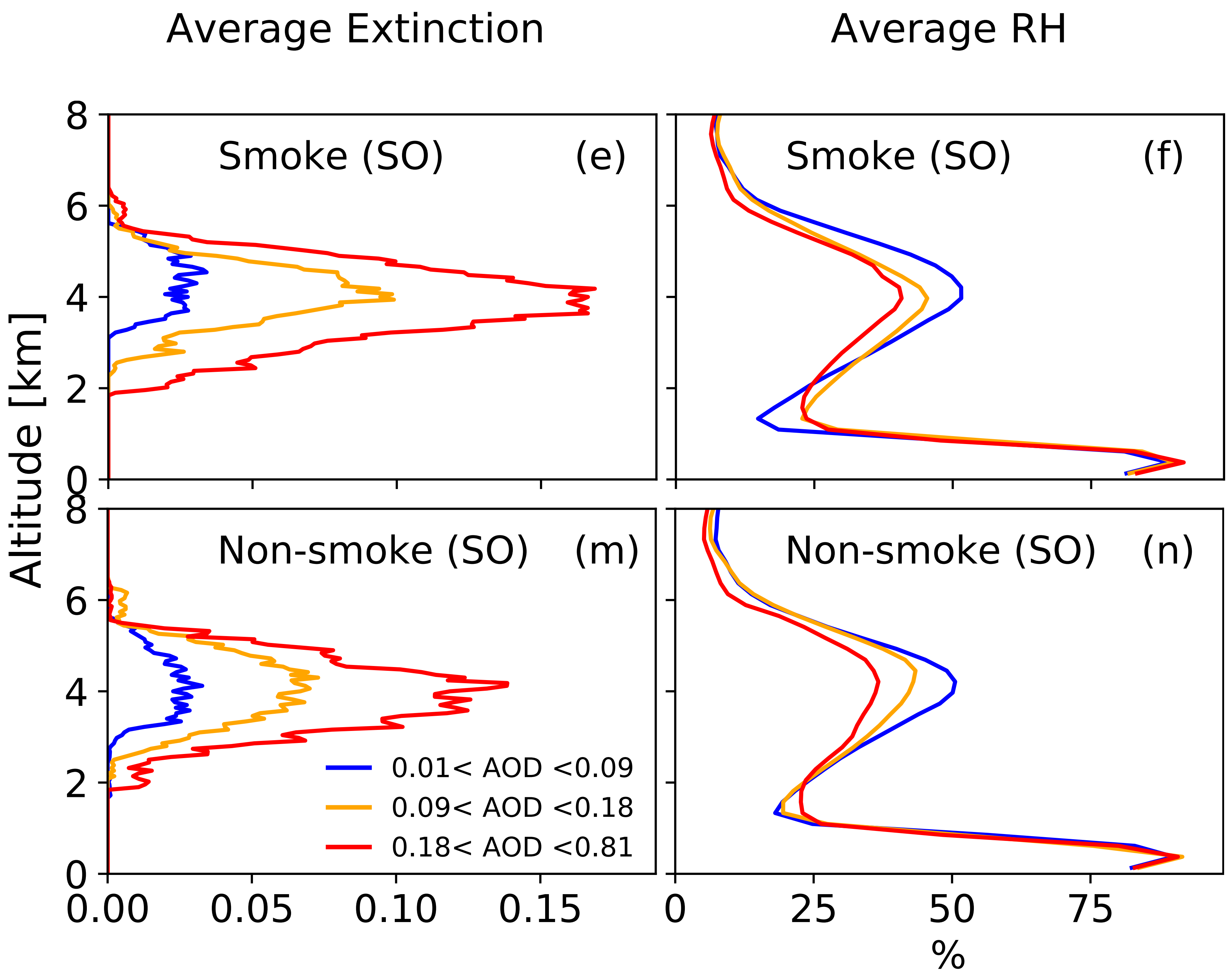
- SW heating at aerosol layer altitudes is higher in the smoke cases than in the rest of the cases.

- LW cooling is stronger in the pristine cases in SO

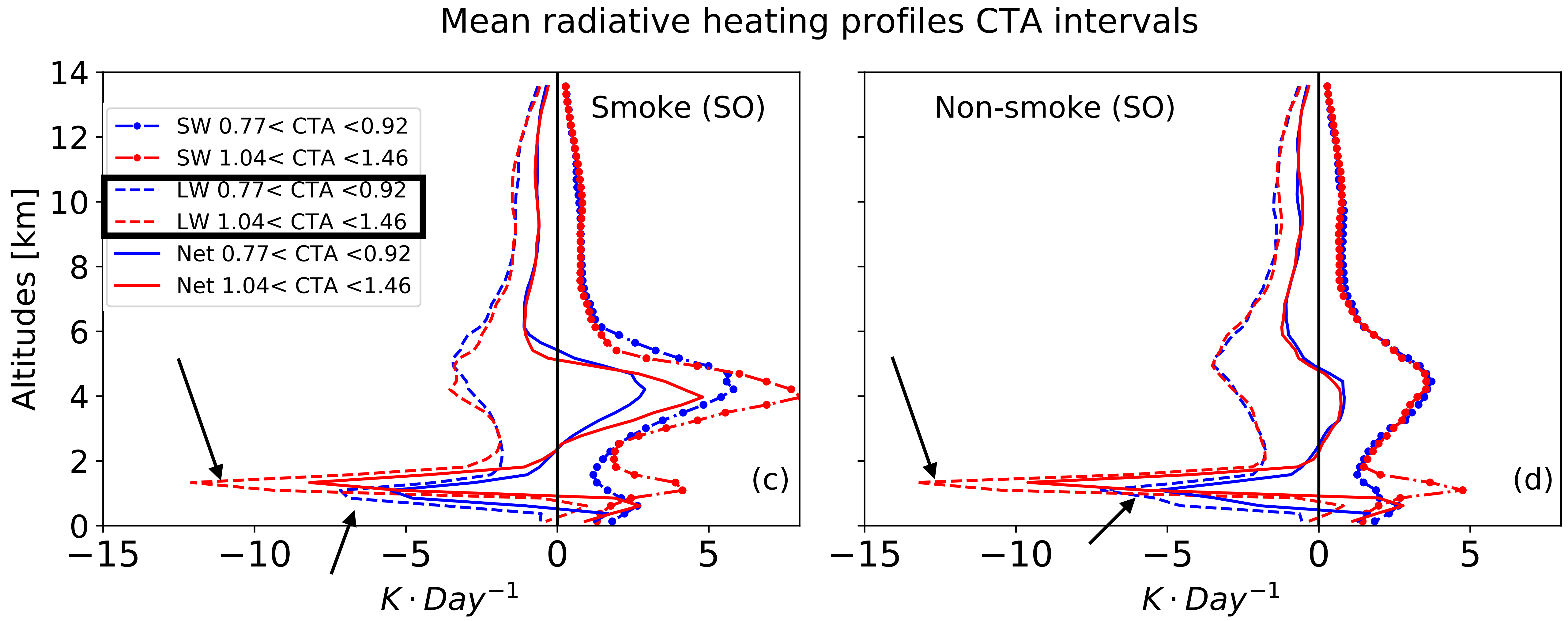
Results



- **SW heating at aerosol layer altitudes increases with aerosol loading.**
- **Heating rates are higher with smoke compared to non smoke cases.**



- **We do not observe a monotonous increase of the moisture in the aerosol layer with increasing AOD.**



- **Cloud top LW cooling rates mostly associated with the variations of the cloud top altitude (CTA) and not with the moisture in the aerosol layer.**

Summary and conclusions

- Smoke is the dominant aerosol type overlaying the stratocumulus clouds.
- A substantial amount of other kind of aerosols were also detected within the aerosol plumes.
- Aerosol cases are associated with enhanced level of moisture in the free troposphere.
- No monotonous increase of the moisture of the aerosol layer with increasing AOD during SO.
- SW heating of the aerosol layer increases with aerosol loading and heating rates are higher with smoke compared to non smoke cases.
- Strong variability in the cloud top LW cooling rates is mostly associated with variations of the cloud top altitude (CTA)

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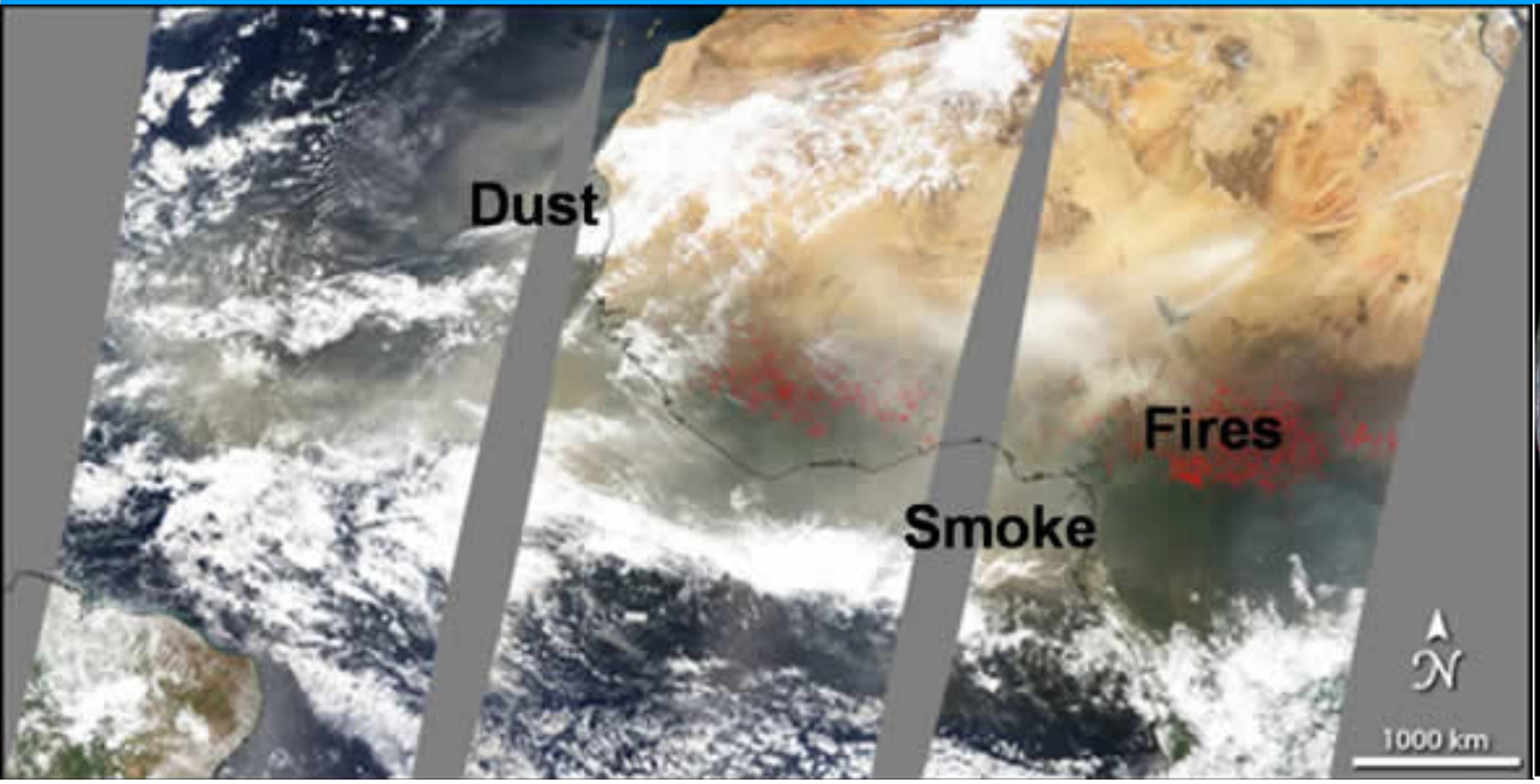
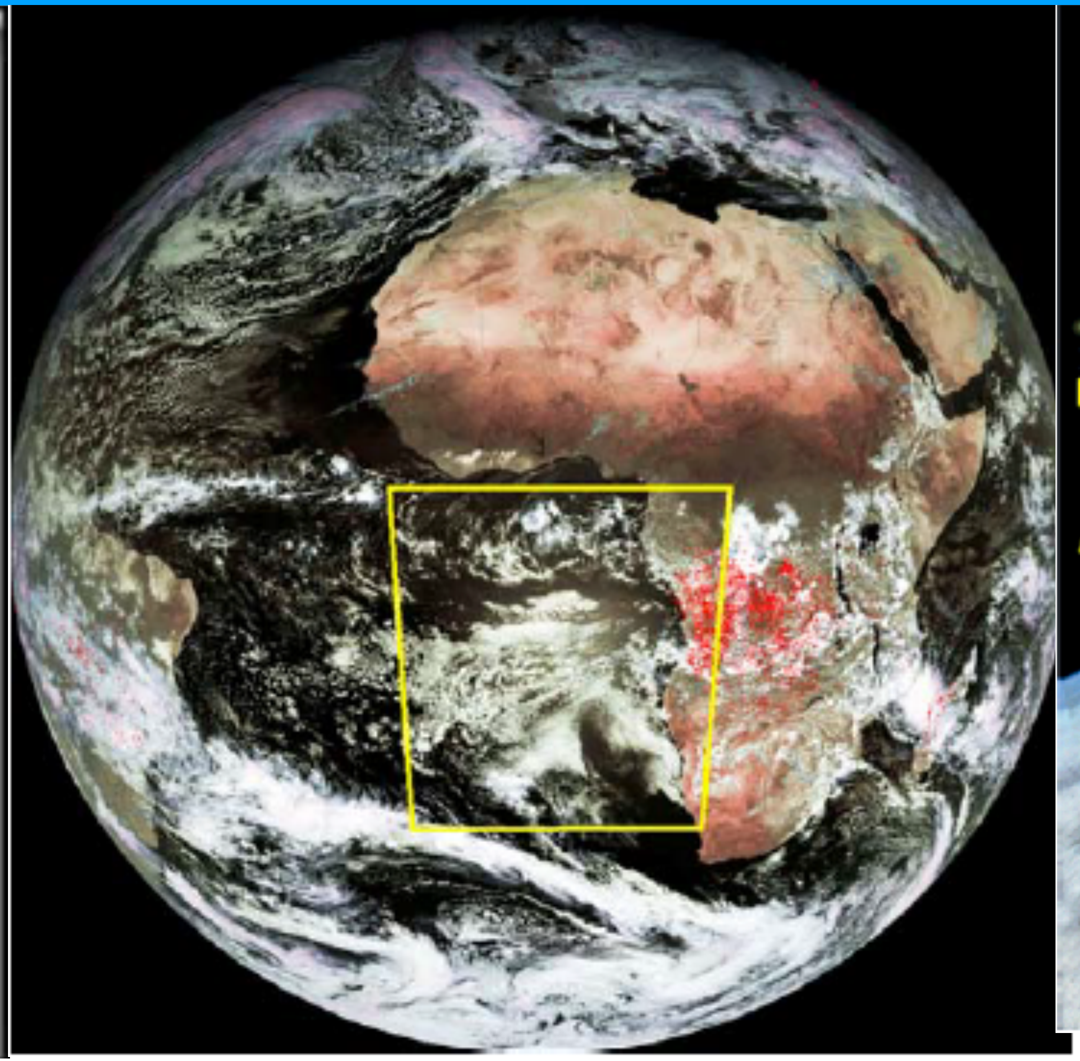


Modis image, January 2005. Credit: Met Office



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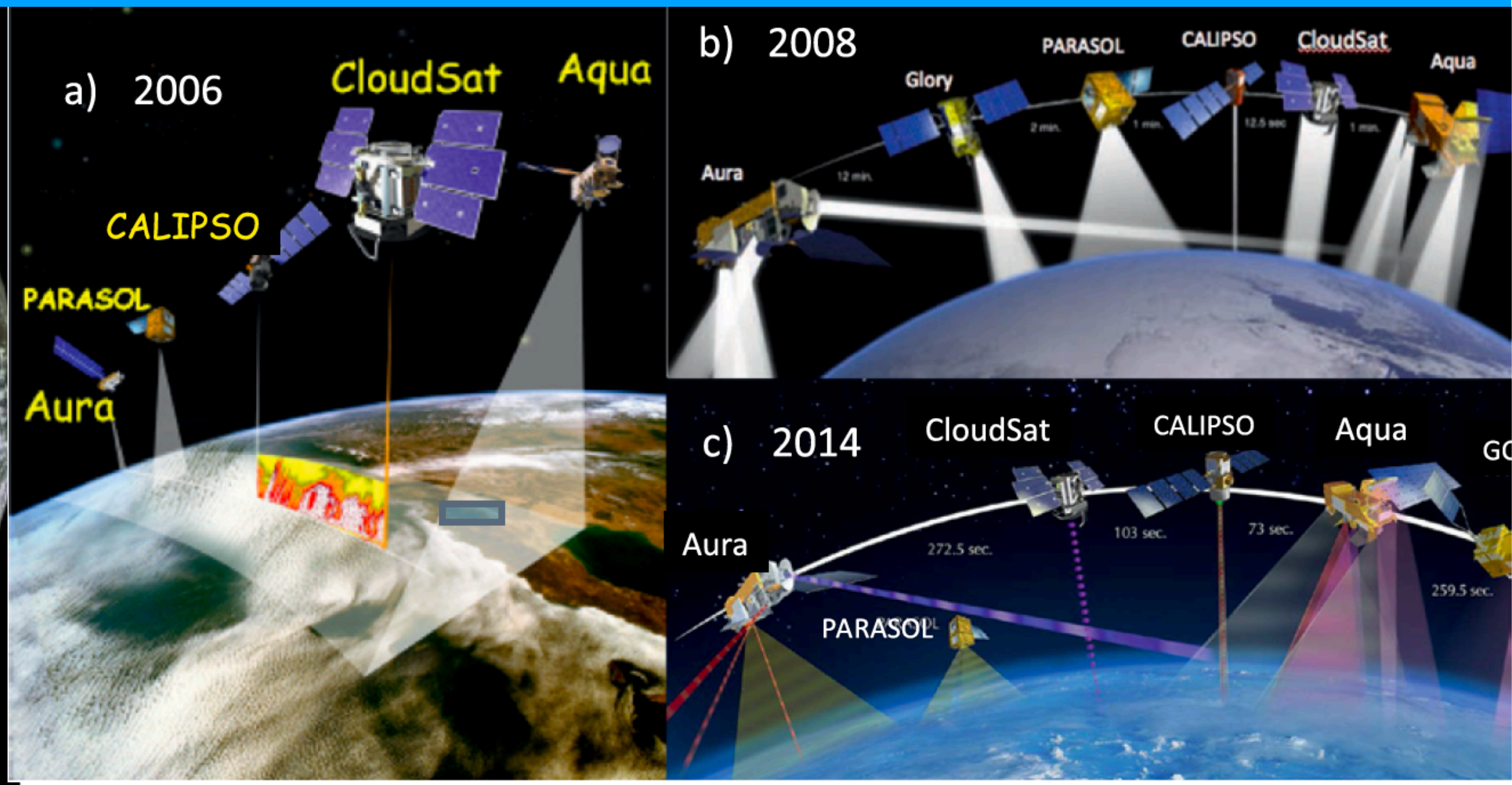

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Thank you!!!