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THE STATE UNIVERSITY
OF NEW JERSEY

RADAGAST Reprise: new results from West Africa

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and other
contributors to the JGR Special Issue

JGR Special Issue: RADAGAST

Slingo, A., N.A. Bharmal, G.J. Robinson, J.J. Settle, R.P. Allan, H.E. White, P.J. Lamb, M.A. Lele, D.D. Turner, S. McFarlane, E. Kassianov, J. Barnard, C. Flynn, and M. A. Miller, 2008: Overview of observations from the RADAGAST experiment in Niamey, Niger. Part 1: Meteorology and thermodynamic variables. *Journal of Research-Atmospheres*, 113, doi: 1029/2008JD009909.

Slingo, A., H.E. White, N.A. Bharmal, and G.J. Robinson, 2009: Overview of observations from the RADAGAST experiment in Niamey, Niger. Part 2: Radiative fluxes and divergences. *Journal of Geophysical Research-Atmospheres*, 114, doi: 10.1029, in press.

Bharmal, N.A., A. Slingo, G.J. Robinson, and J.J. Settle, 2009: Simulation of surface and top of atmosphere thermal fluxes and radiances from the RADAGAST experiment. *Journal of Geophysical Research-Atmospheres*, 114, doi:10.1029/, in press.

Settle J.J., N.A. Bharmal, G.J. Robinson, and A. Slingo, 2008: Sampling uncertainties in surface radiation budget calculations in RADAGAST. *Journal of Geophysical Research-Atmospheres*, 113, doi: 10.1029/2008JD010509, 23 pages.

Turner, D.D., 2008: Ground-based retrievals of optical depth, effective radius, and composition of airborne mineral dust above the Sahel. *Journal of Geophysical Research-Atmospheres*,113, doi: 10.1029/2008JD010054, 14 pages.

McFarlane, S.A., E.I. Kassianov, J. Barnard, C. Flynn, and T. Ackerman, 2009: Surface shortwave aerosol forcing during the ARM Mobile Facility deployment in Niamey, Niger. *Journal of Geophysical Research-Atmospheres*, 114, doi: 10.1029/2008JD010491, in press.

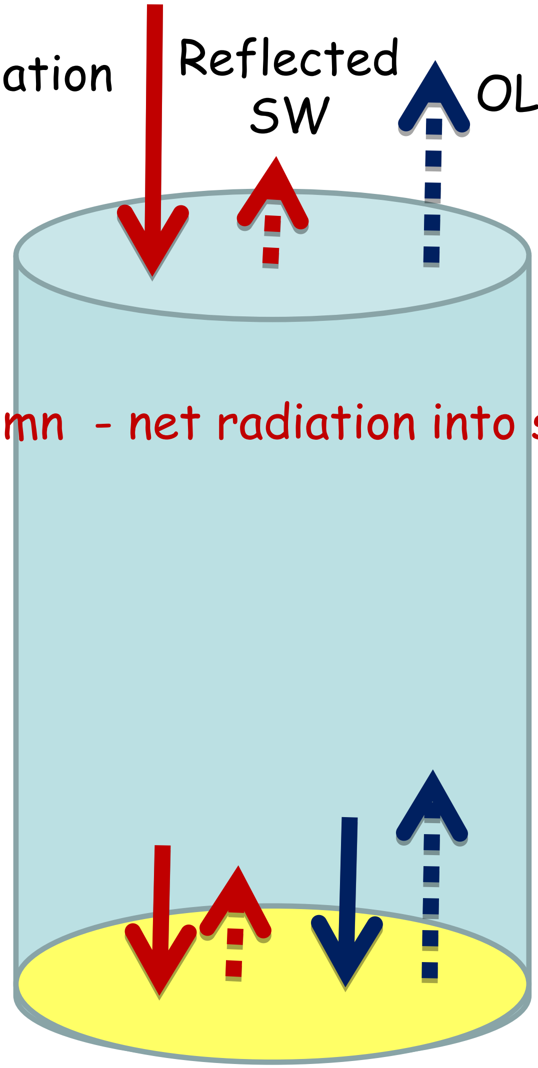
P. Kollias, M.A. Miller, K.L. Johnson, M.P. Jensen, and D.T. Troyan, 2009: Cloud, thermodynamic, and precipitation observations in West Africa during 2006. *Journal of Geophysical Research- Atmospheres*, 114, doi: 10.1029, in press.

Miller, R.L., A. Slingo, J.C. Barnard, and E. Kassianov, 2009: Seasonal contrast in the surface energy budget of the Sahel. *Journal of Geophysical Research-Atmospheres*, 114, doi: 10.1029/, in press.

Outline

- brief overview of RADAGAST
- factors that may control the radiative balance
- the wet season
- the dry season
- a year-long column radiation budget in the Sahel
- conclusions and recommendations

Radiative Flux Divergence Primer

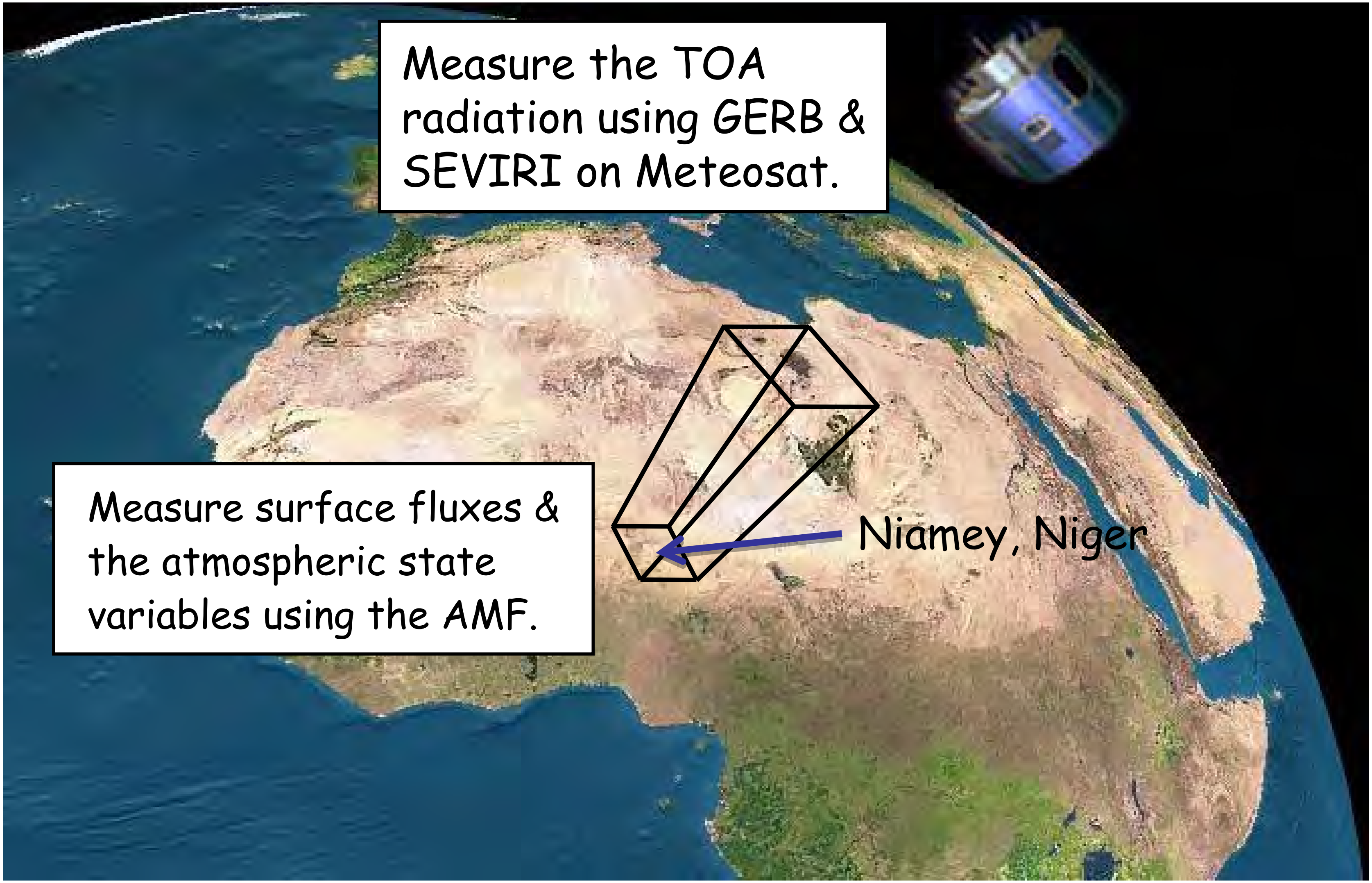


Incoming – Outgoing= net radiation into column

Radiative Flux Divergence = net radiation into column - net radiation into surface

- positive values imply heating
- negative values imply cooling

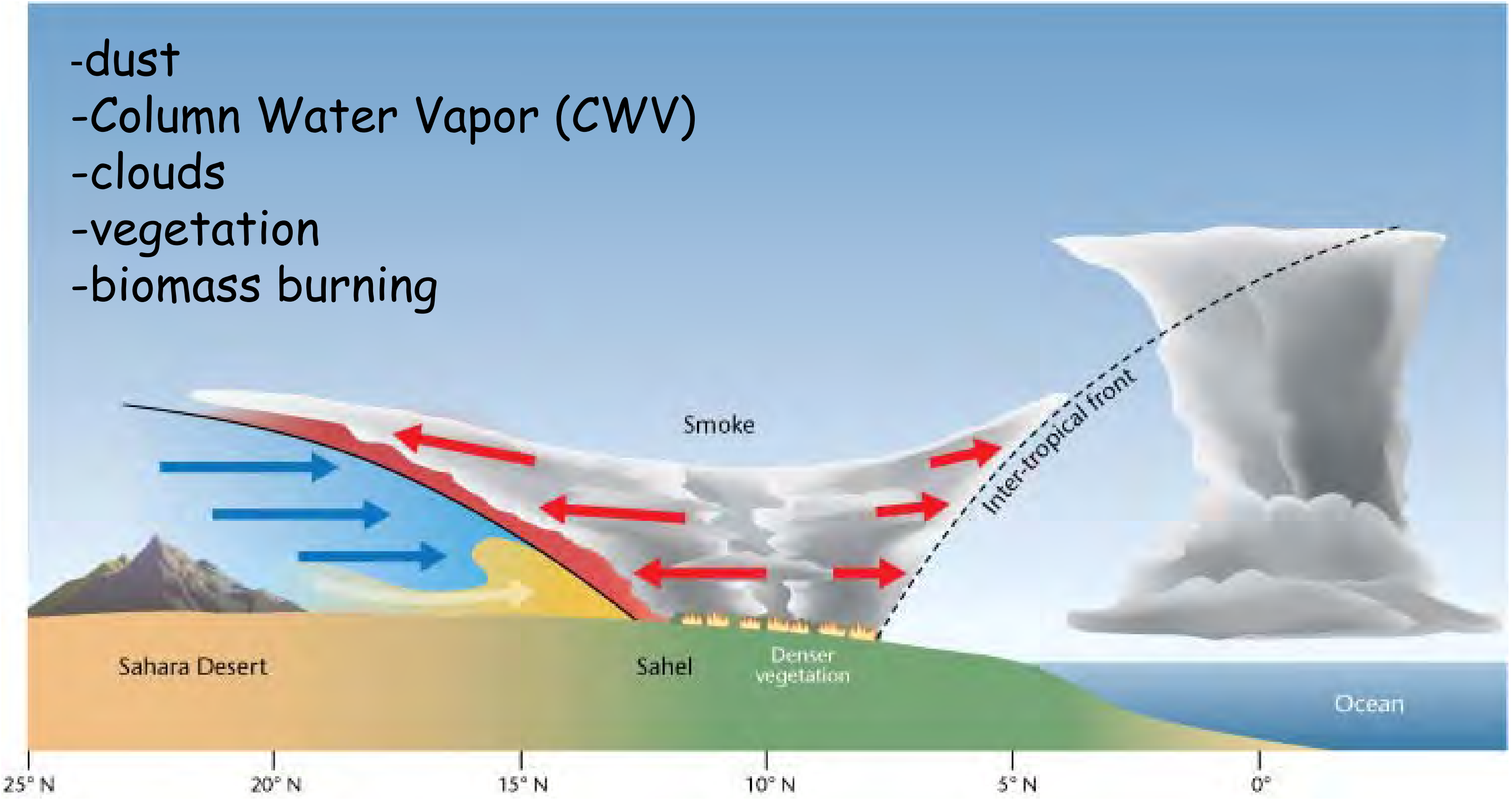
Downwelling–Upwelling= net radiation into surface



Measure the TOA radiation using GERB & SEVIRI on Meteosat.

Measure surface fluxes & the atmospheric state variables using the AMF.

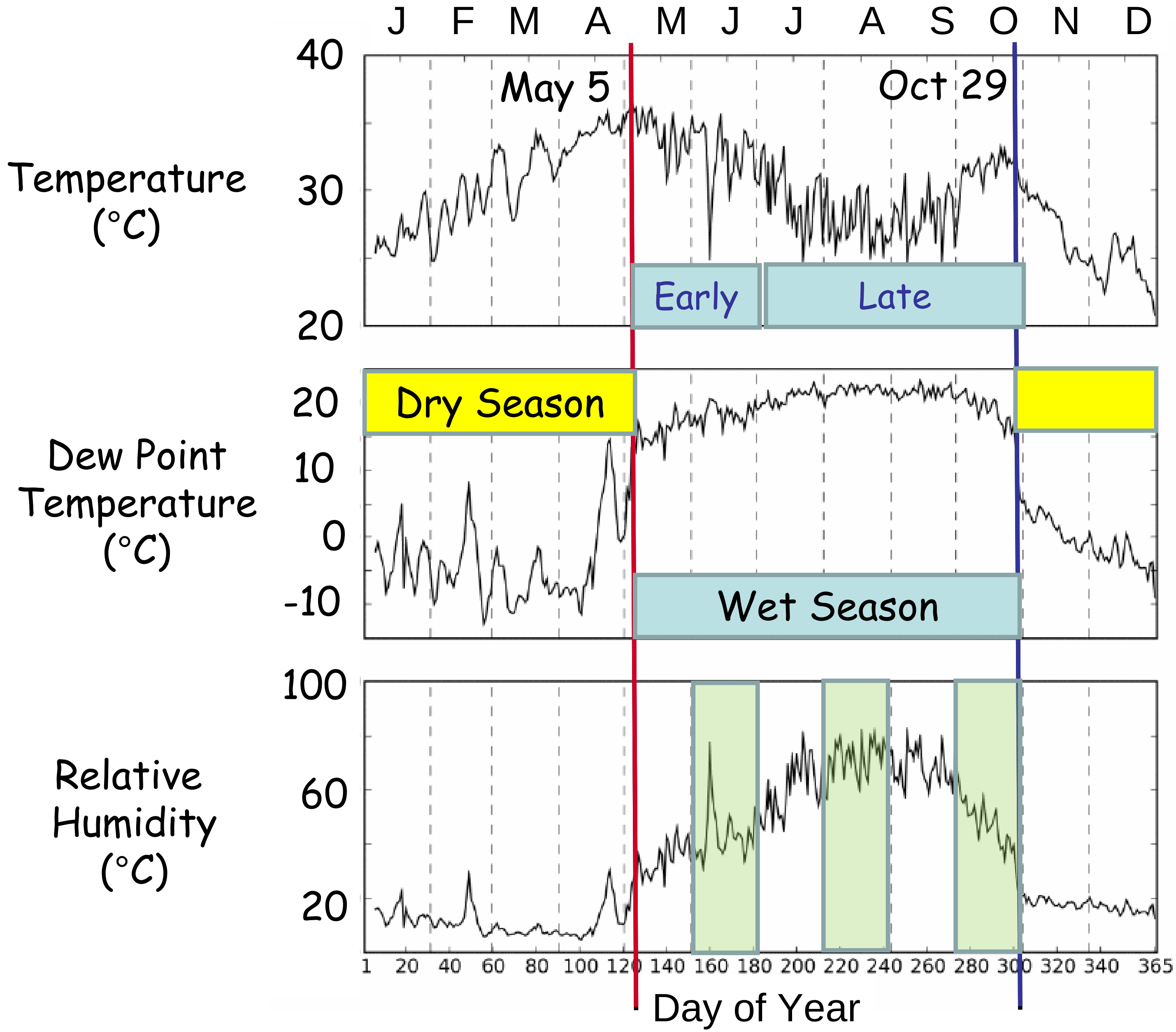
Factors that may control the TOA, surface, and total column radiative divergences in SW and LW:



- -dust
- -Column Water Vapor (CWV)
- -clouds
- -vegetation
- -biomass burning

Haywood et al., JGR, 2008

RADAGAST Reprise



maximum
temp
in April

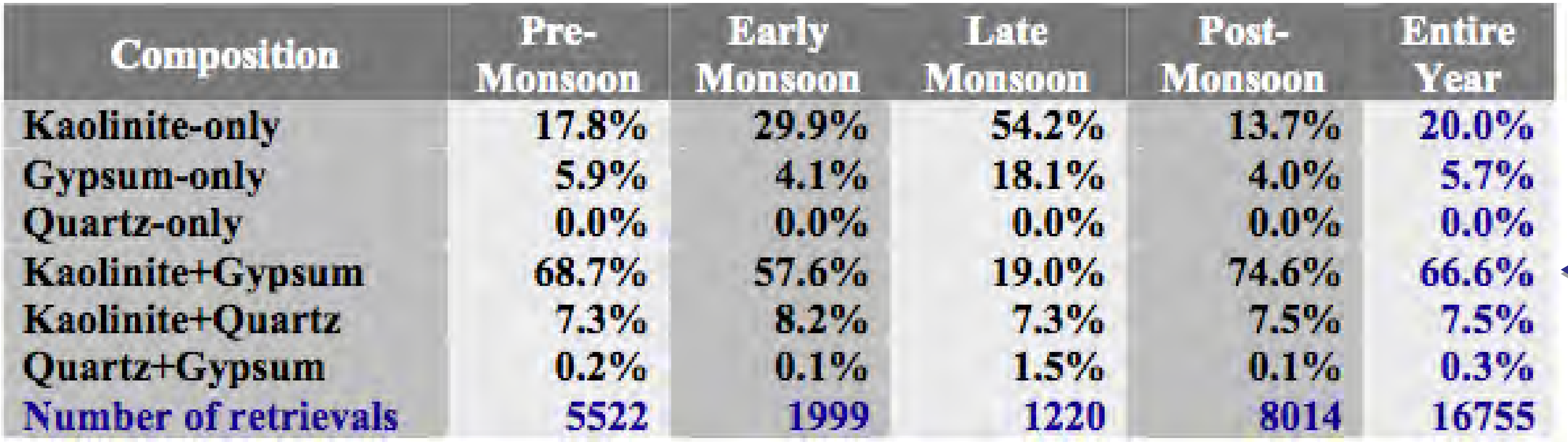
steady temp
decrease

dew point
rises rapidly
and plateaus

echoes Column
Water Vapor
(CWV)

Cloud Analysis

The mineral composition of radiatively significant dust for 2006



Composition	Pre-Monsoon	Early Monsoon	Late Monsoon	Post-Monsoon	Entire Year
Kaolinite-only	17.8%	29.9%	54.2%	13.7%	20.0%
Gypsum-only	5.9%	4.1%	18.1%	4.0%	5.7%
Quartz-only	0.0%	0.0%	0.0%	0.0%	0.0%
Kaolinite+Gypsum	68.7%	57.6%	19.0%	74.6%	66.6%
Kaolinite+Quartz	7.3%	8.2%	7.3%	7.5%	7.5%
Quartz+Gypsum	0.2%	0.1%	1.5%	0.1%	0.3%
Number of retrievals	5522	1999	1220	8014	16755

- Kaolinite (or minerals with similar refractive properties) present in 94% of cases.

- A radiatively significant mixture of Kaolinite and Gypsum is the most common mineral configuration.

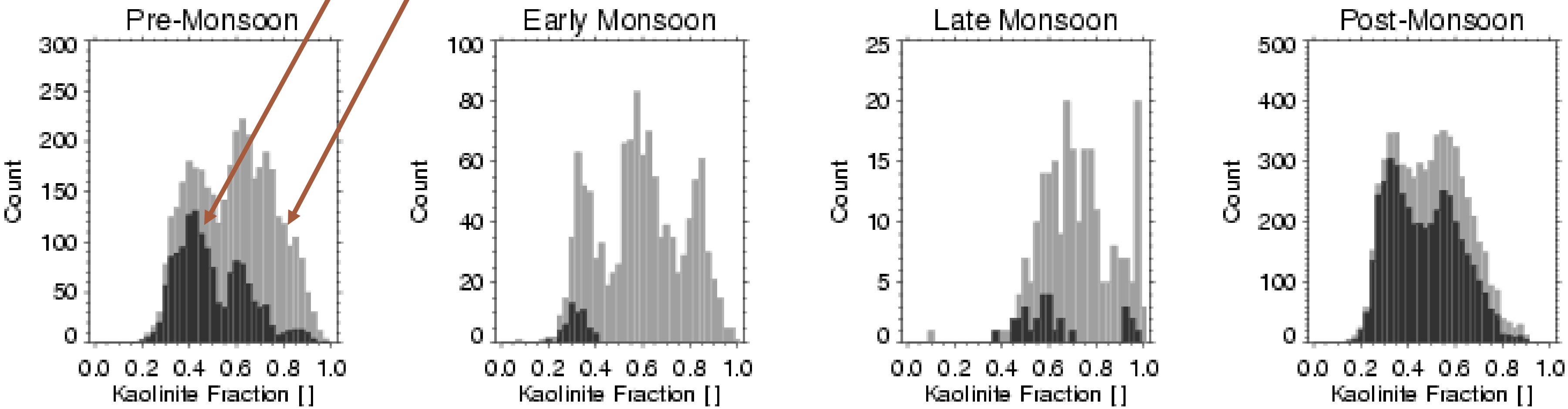
- fraction dependent on period→ implies dependence on trajectory

Turner, D.D., JGR, 2008

What is the fraction of Kaolinite in the Gypsum/Kaolinite mixture?

- Kaolinite fraction defined as $F_{kao} = {}^{\tau_{kao}}\!/\!_{\tau_{tot}}$
- Kaolinite fraction correlated with trajectory direction

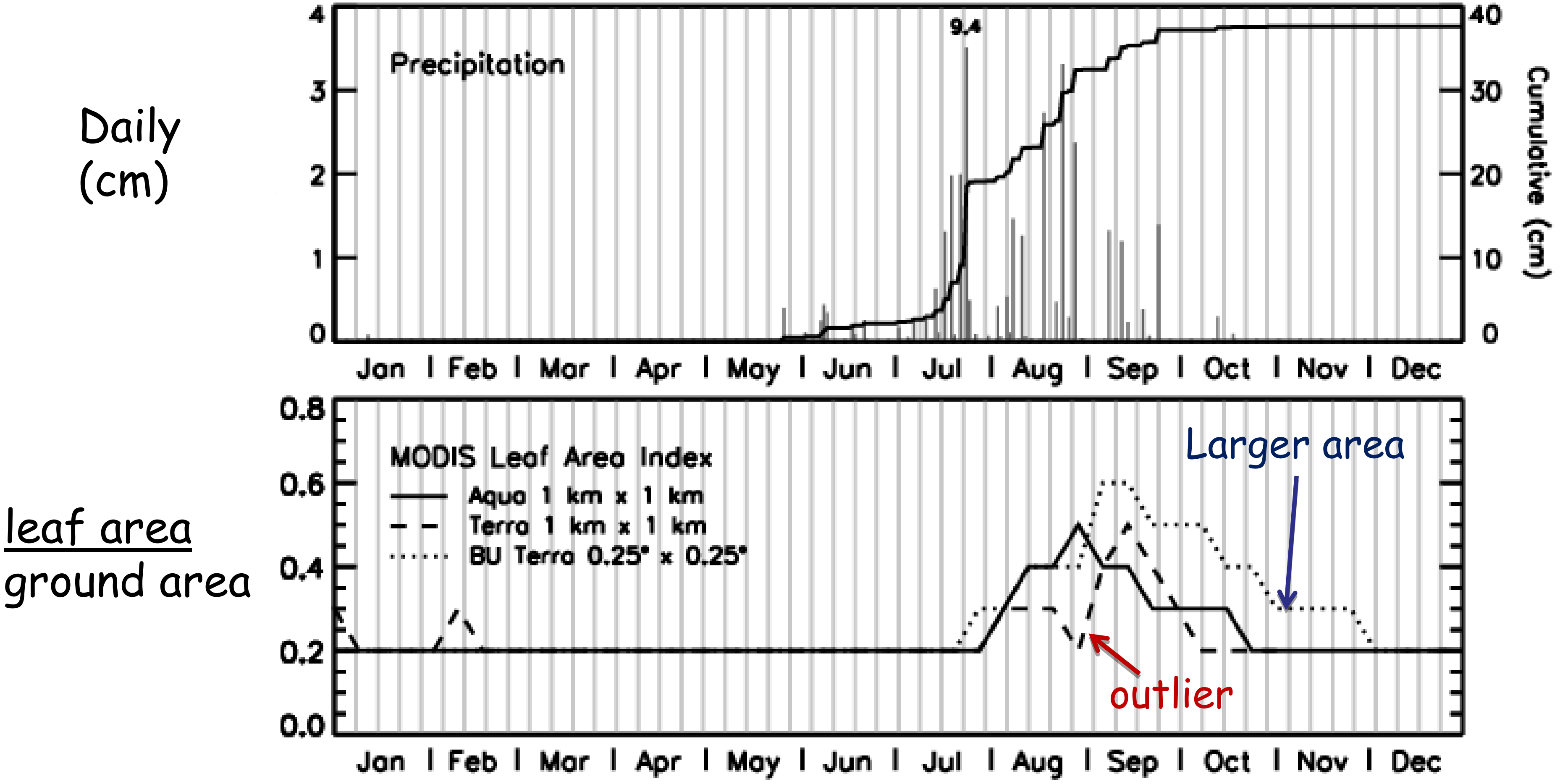
Black: easterly octant only → smaller Kaolinite → larger Gypsum
Gray: all directions



Turner, D.D., JGR, 2008

THE WET SEASON

Rapid greening of the surface in late July

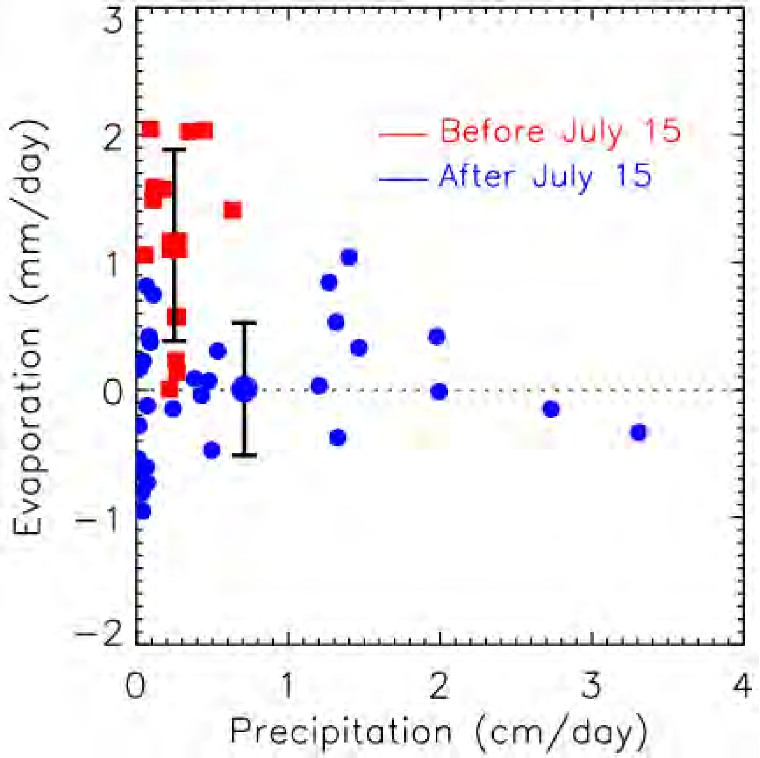


Miller, R. L., A. Slingo, J. C. Barnard, and E. Kassianov (2009)

Evaporation anomalies following rainfall suggest a link to vegetation.

Evaporation anomaly following rainfall

(The anomaly is computed relative to the five days prior to the rain event.)

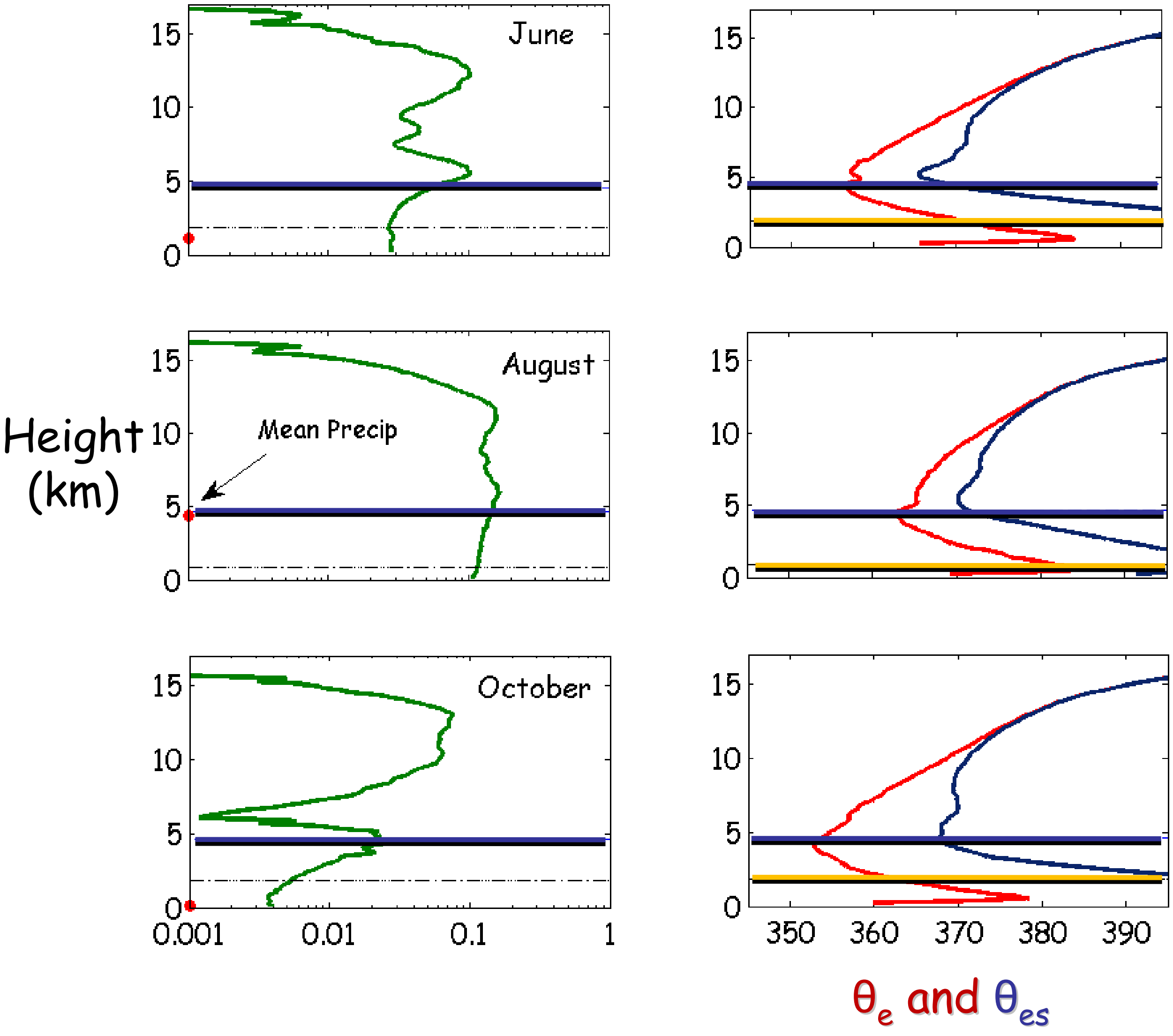


- Early in the rainy season (red), the evaporation rate increases temporarily following the occurrence of precipitation.
- At the height of the rainy season, the evaporation rate becomes independent of the precipitation produced by recent precipitation events (blue).

Vegetation growth in July helps evaporation to decorrelate with precipitation → roots tap moisture deep within the soil that was possibly stored during the previous rainy season.

Miller, R. L., A. Slingo, J. C. Barnard, and E. Kassianov (2009)

Cloud fraction and thermodynamic profiles are sensitive to indicators

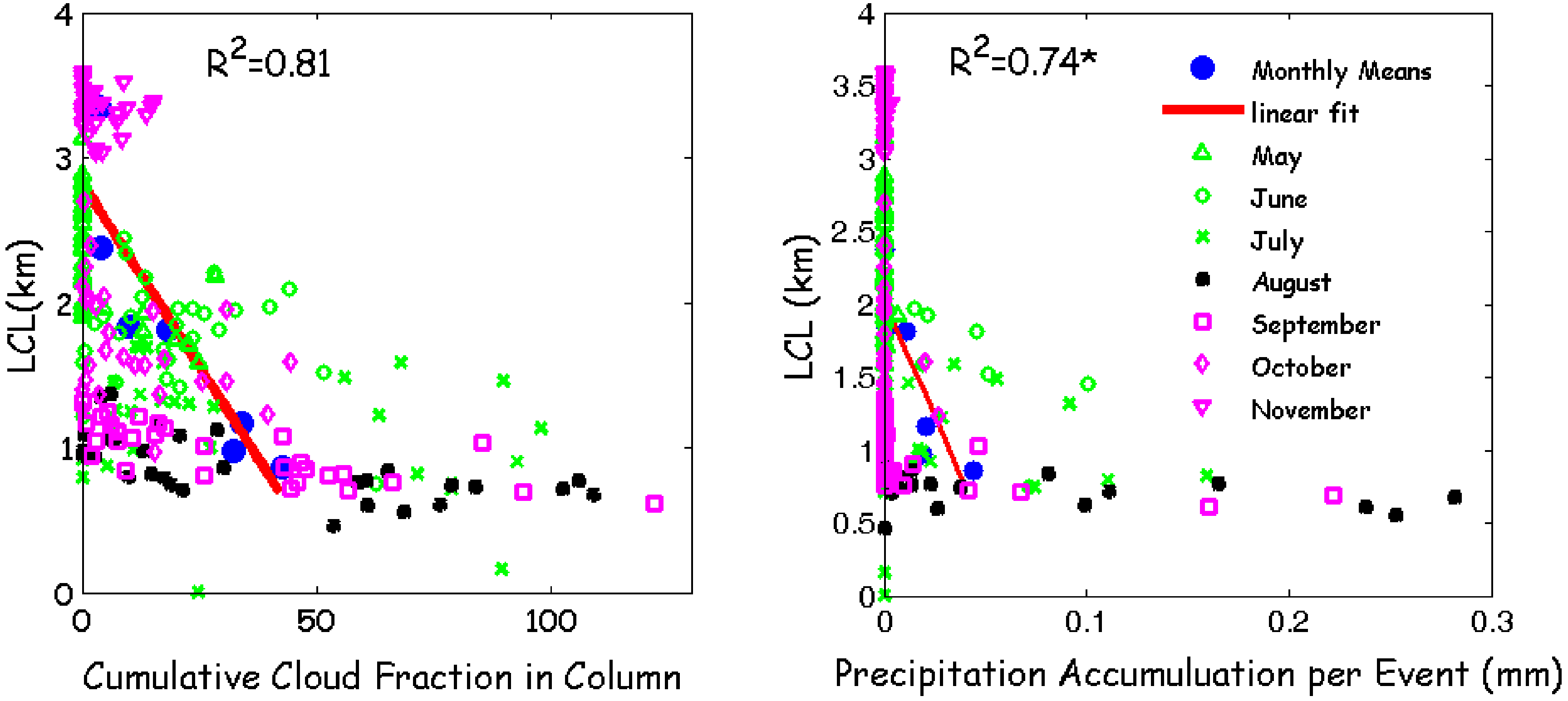


- CAPE large and nearly constant through wet season
- Cloud fraction peaks near freezing level
- Minimums in θ_e and θ_{es} near freezing level
- LCL sinks into shallow monsoon layer

Kollias, P, M.A Miller, K.Johnson, M. Jensen, D. Troyan, 2008

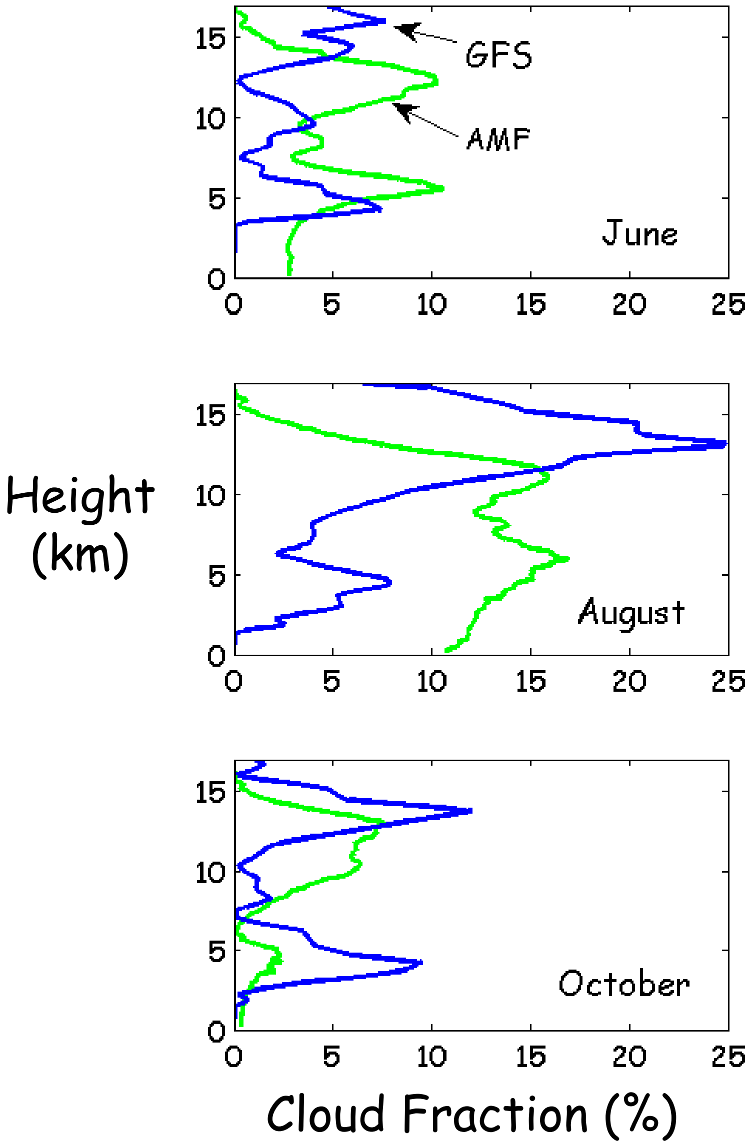
RADAGAST Reprise

The height of the LCL is inversely proportional to the cumulative cloud fraction and precipitation accumulation per event.



No relationships between changes in CAPE and changes in cloud fraction, precipitation accumulation, or precipitation intensity are present in these data.

RADAGAST Reprise



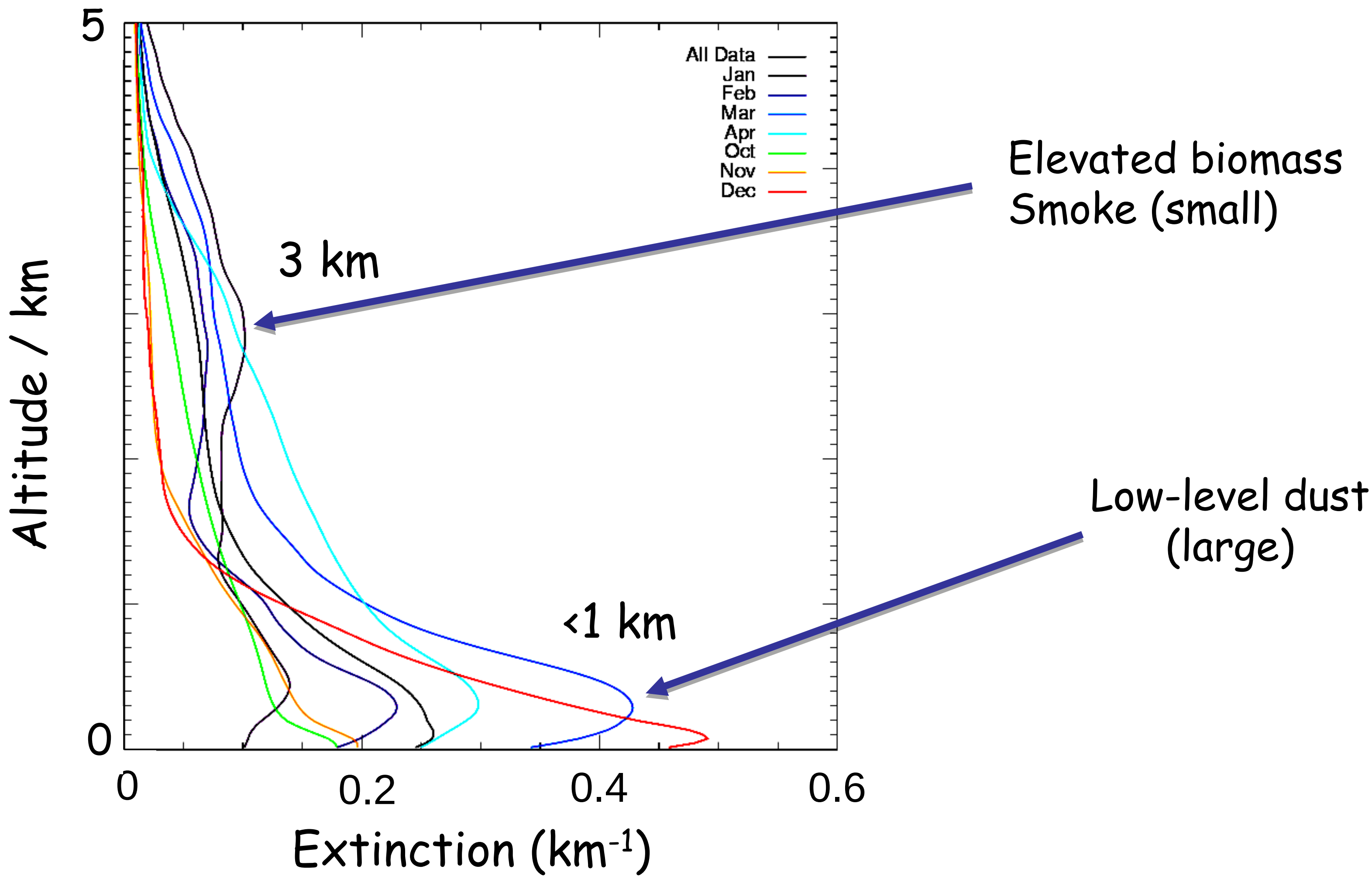
- GFS cloud initialization data
  - mandatory radiosonde data
  - satellite retrievals of temperature
  - satellite-derived cloud motion vector
  - aircraft
  - cloud fraction parameterization: Xu and Randall (1996)

- August
  - GFS 10-15 km cloud fraction larger than AMF
  - AMF 0-10 km cloud fraction larger than GFS

Kollias, P, M.A. Miller, K.Johnson, M. Jensen, D. Troyan,

THE DRY SEASON

The vertical profile of aerosol extinction from a Lidar and MFRSR



3 km

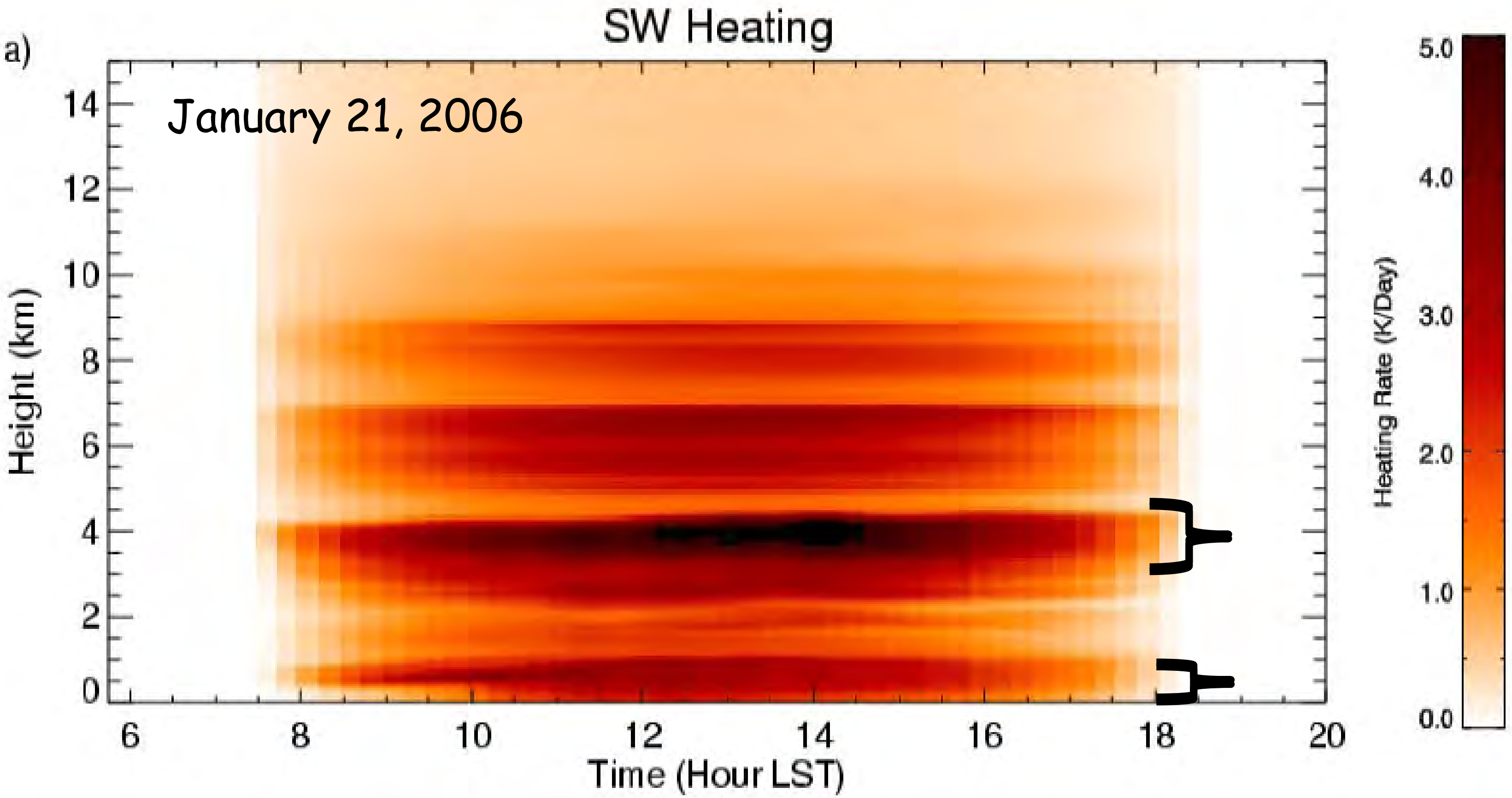
Elevated biomass Smoke (small)

<1 km

Low-level dust (large)

McFarlane, S.A., E.I. Kassianov, J. Barnard, C.Flynn, T.P. Ackerman, JGR, 2008

The SW heating is concentrated in moist layers, as identified in soundings.

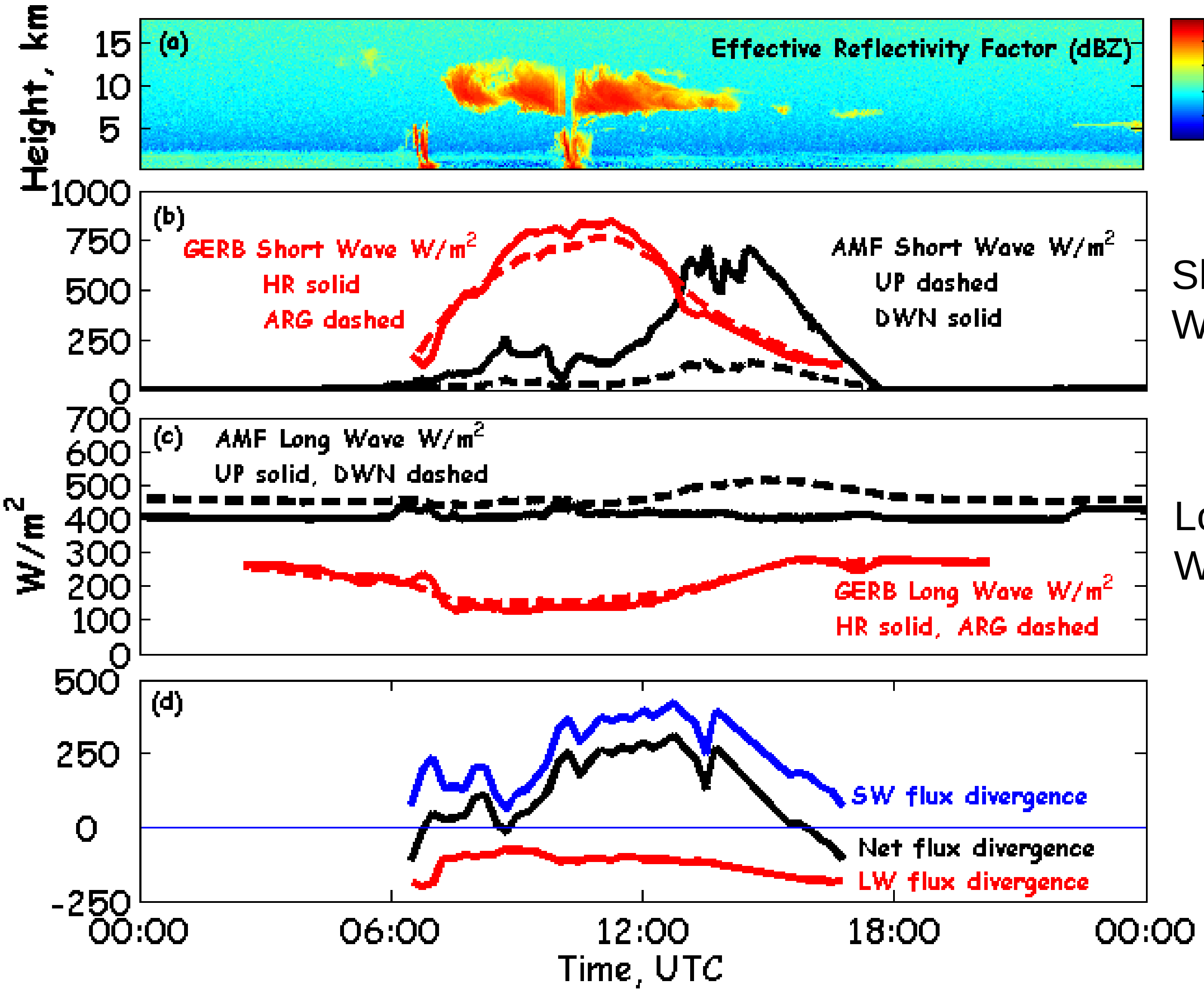


- Strong aerosol extinction between 3-4 and below 1-km
- Above 5-km, SW heating is due to water vapor absorption

McFarlane, S.A., E.I. Kassianov, J. Barnard, C.Flynn, T.P. Ackerman, JGR, 2008

RADIATIVE DIVERGENSE ACROSS THE ATMOSPHERIC COLUMN IN 2006

RADAGAST Reprise



Red-TOA
Black-surface

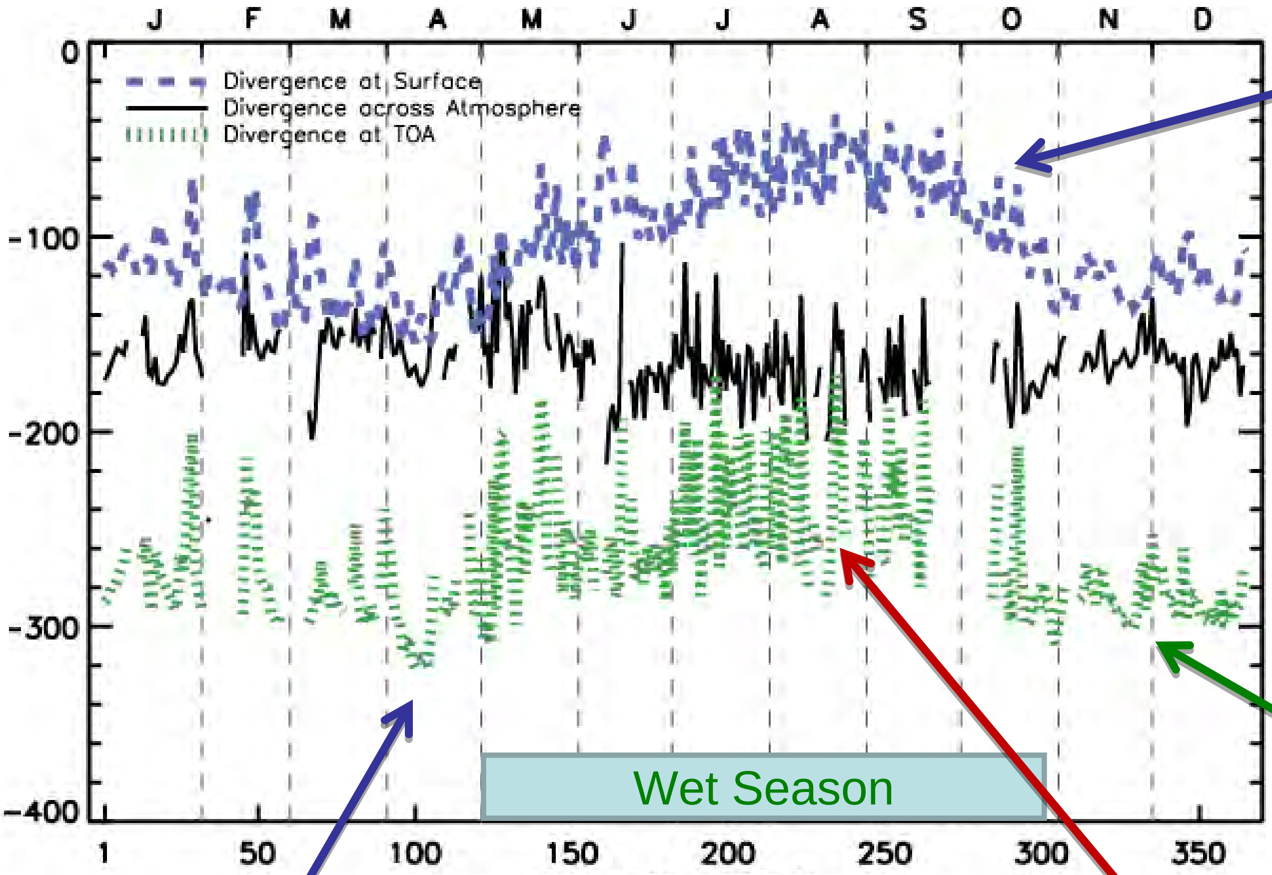
Short
Wave

Long
Wave

Miller , M.A. and A. Slingo (2007)

RADAGAST Reprise

Changes in the cooling at the TOA are caused by changes at the surface.



Longwave Divergence Wm-2

Day of the Year, 2006

Surface Divergence

LW Divergence relatively constant

TOA Divergence

minimum cooling at surface at TOA

As CWV increases, the atmosphere loses longwave energy to the surface with about the same increasing efficiency with which it traps OLR.

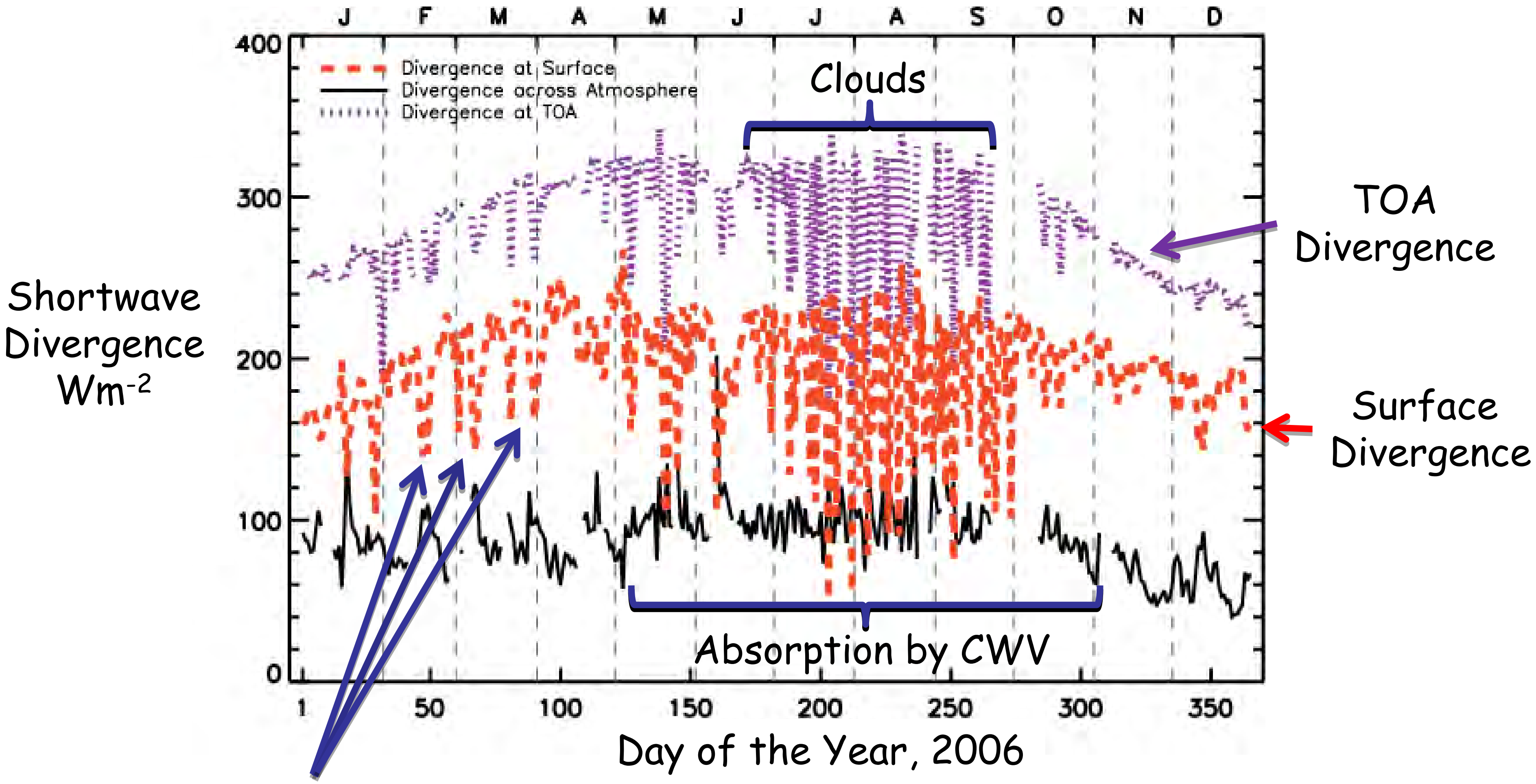
maximum cooling at surface and TOA

-surface temperature is the highest, CWV lowest

Slingo, A., H.E White, N.A. Bharmal, G.J. Robinson (2008)

RADAGAST Reprise

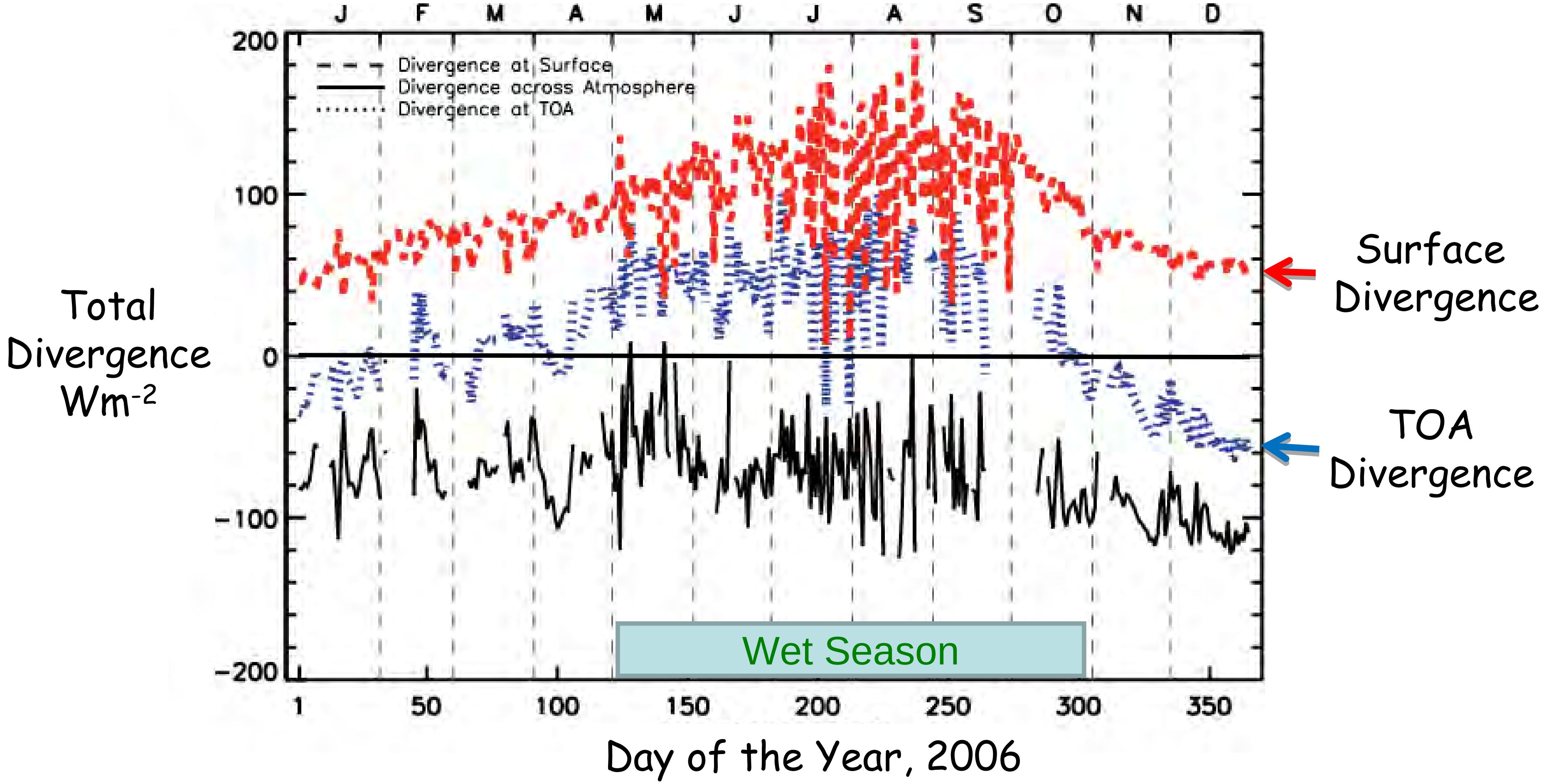
Shortwave divergence is mainly determined by the CWV and aerosol loadings.



The effect of clouds on the net column shortwave flux divergence is smaller than their effect on the component fluxes.

Slingo, A., H.E White, N.A. Bharmal, G.J. Robinson (2008)

The atmosphere continually loses radiative energy to space at a steady rate of approximately 75 Wm^{-2}.



- Small positive net gain of radiation at the TOA during the course of the year
  - region gains energy during summer and loses energy in winter
- Surface gains radiative energy at all times of the year

Slingo, A., H.E White, N.A. Bharmal, G.J. Robinson (2008)

In Memoriam

Tony Slingo

Banazoumbou, Niger, Africa
Photo: Pete Lamb

Conclusions and Recommendations

- The radiative impacts of the dust are trajectory dependent and heating rates may exceed 2.5°K/day in the dust layer
- The LCL is strongly correlated with the cumulative cloud fraction and accumulated precipitation.
- As the CWV increases, the atmosphere loses longwave energy to the surface at about the same increasing efficiency with which it traps OLR, thus keeping the atmospheric longwave divergence roughly constant.
- The shortwave divergence is mainly determined by CWV and aerosol loadings and the effect of clouds is much smaller than on the component fluxes.
- ARM needs a GERB-like satellite.