ARM Science Team meeting, Monterey, March 2007

RADAGAST

Radiative Atmospheric Divergence using Arm mobile facility Gerb and Amma STations

Results from the ARM Mobile Facility in Niamey and the RADAGAST project

Tony Slingo, Environmental Systems Science Centre
University of Reading

- with important contributions from:
  - Mark Miller and the AMF team
  - Richard Allan, Nazim Ali Bharmal, Gary Robinson, Jeff Settle (ESSC, UK)
  - Jim Haywood, Sean Milton and colleagues (UK Met Office)
  - Peter Lamb and Mouhamadou Issa Lélé (CIMMS, Oklahoma)
  - Tom Ackerman, Sally McFarlane and colleagues (PNNL)
  - Dave Turner (University of Wisconsin-Madison)
  - John Ogren and Anne Jefferson (NOAA)

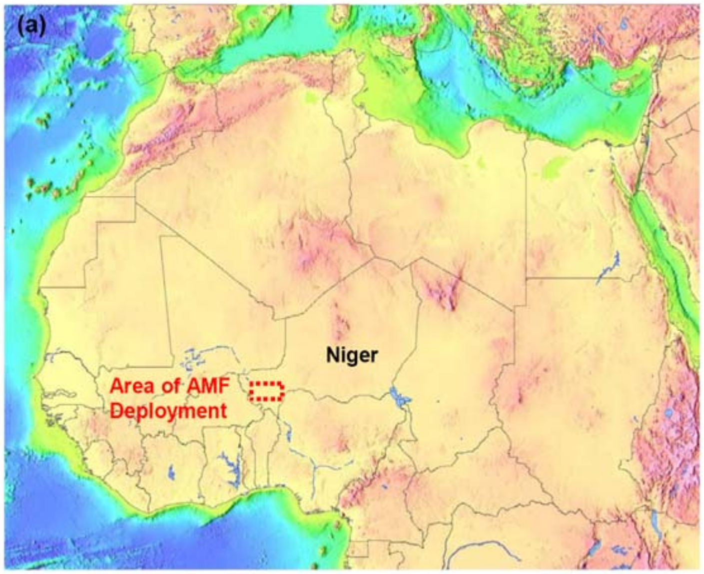
Overview of talk

- Brief background to the RADAGAST project
- ARM Mobile Facility and deployment in Niamey
- Selected results
  - Overview of measurements through the dry and monsoon seasons in 2006
  - Aerosols, including the major dust storm in March 2006
  - Other selected results from posters
- Summary, conclusions, etc

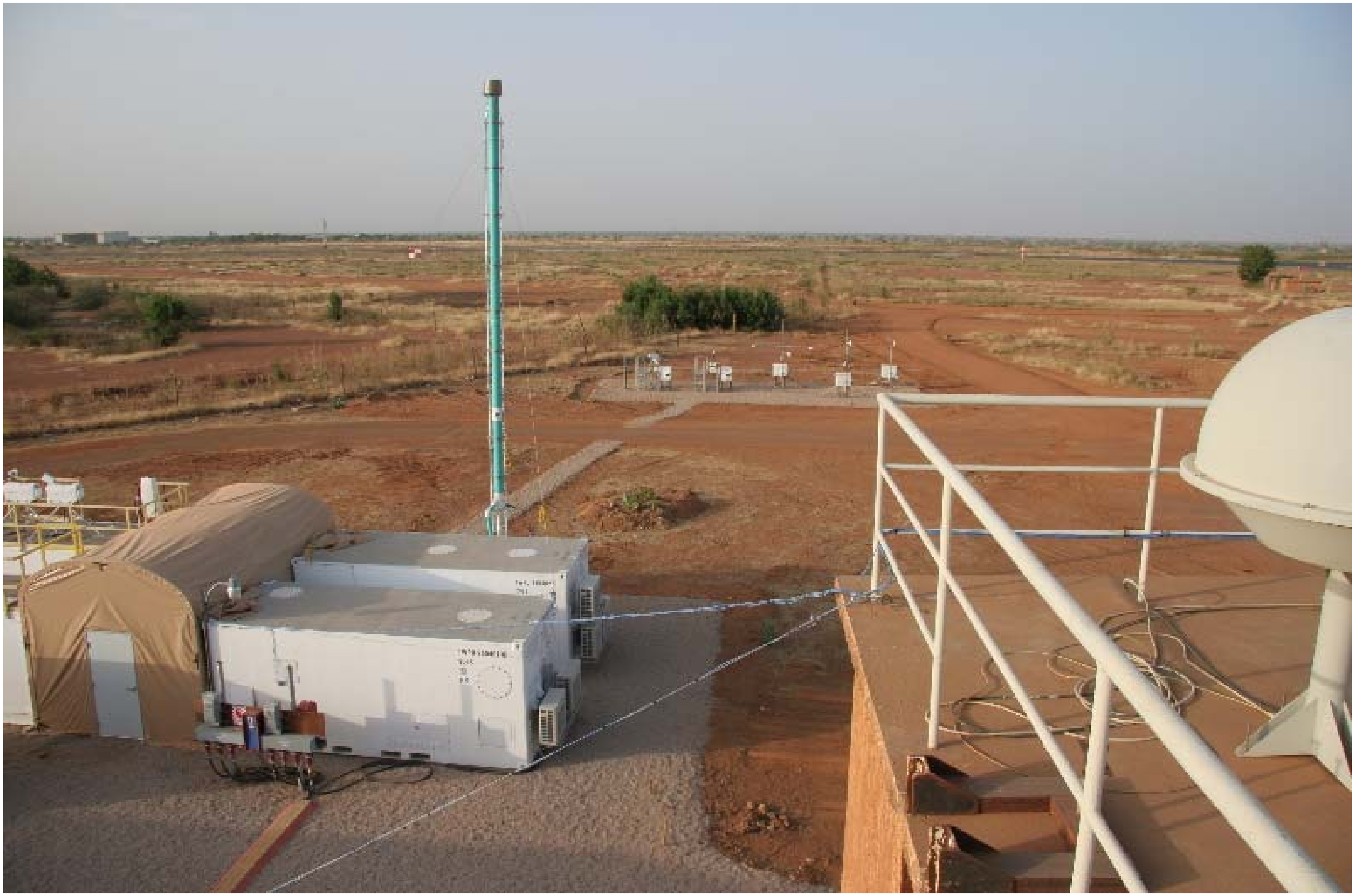
The RADAGAST project

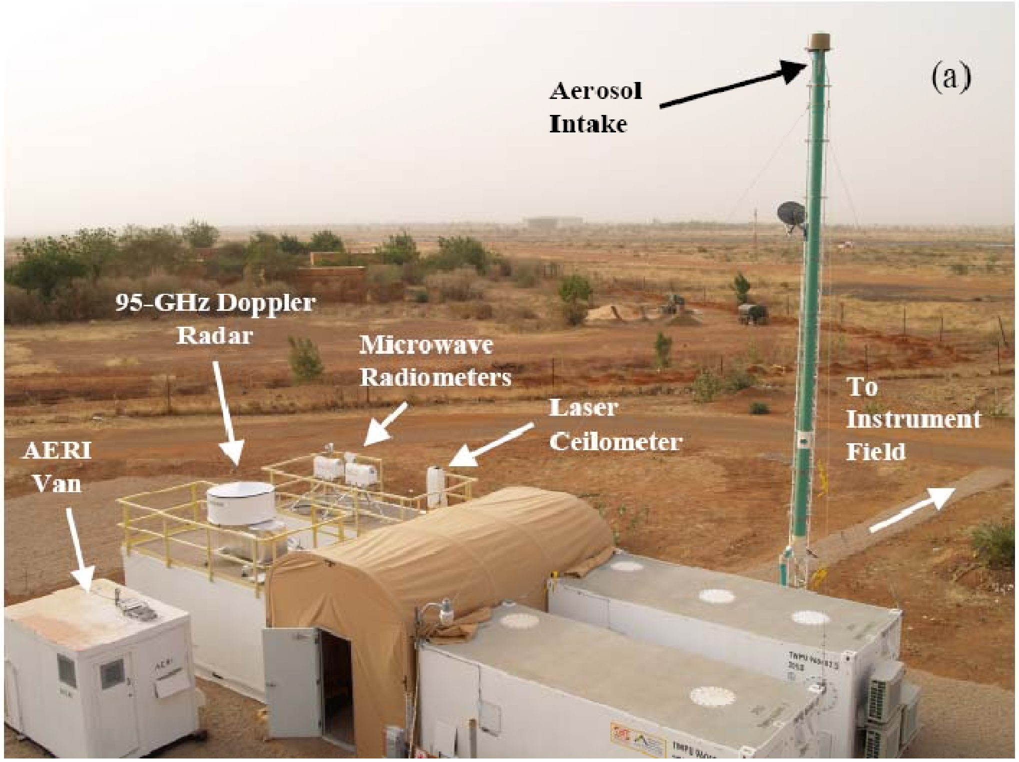
- Radiative Atmospheric Divergence using ARM Mobile Facility, GERB data and AMMA stations
  - led by Tony Slingo, ESSC, Reading University, UK
- Links the **ARM Mobile Facility** with **GERB** (Geostationary Earth Radiation Budget instrument on Meteosat) & **AMMA**
- The objective is to derive the divergence of radiation across the atmosphere:
  - by combining the AMF measurements of the surface radiative fluxes and vertical structure of the atmosphere with GERB data from the top of the atmosphere and AMMA observations
  - study the radiative properties of aerosols (desert dust, biomass), water vapour and clouds
  - provide comprehensive observations for testing radiation codes

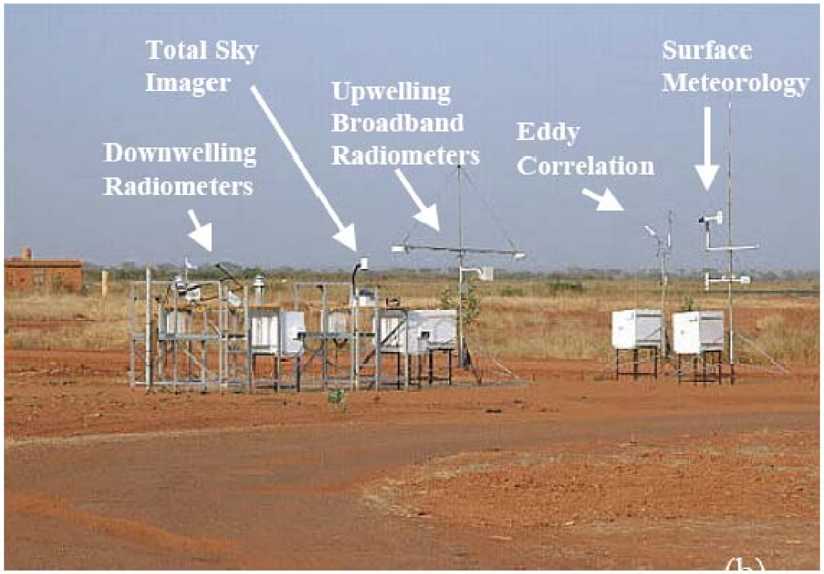
Area of deployment



Aerial view of AMF deployment, Niamey airport. Image © TerraMetrics





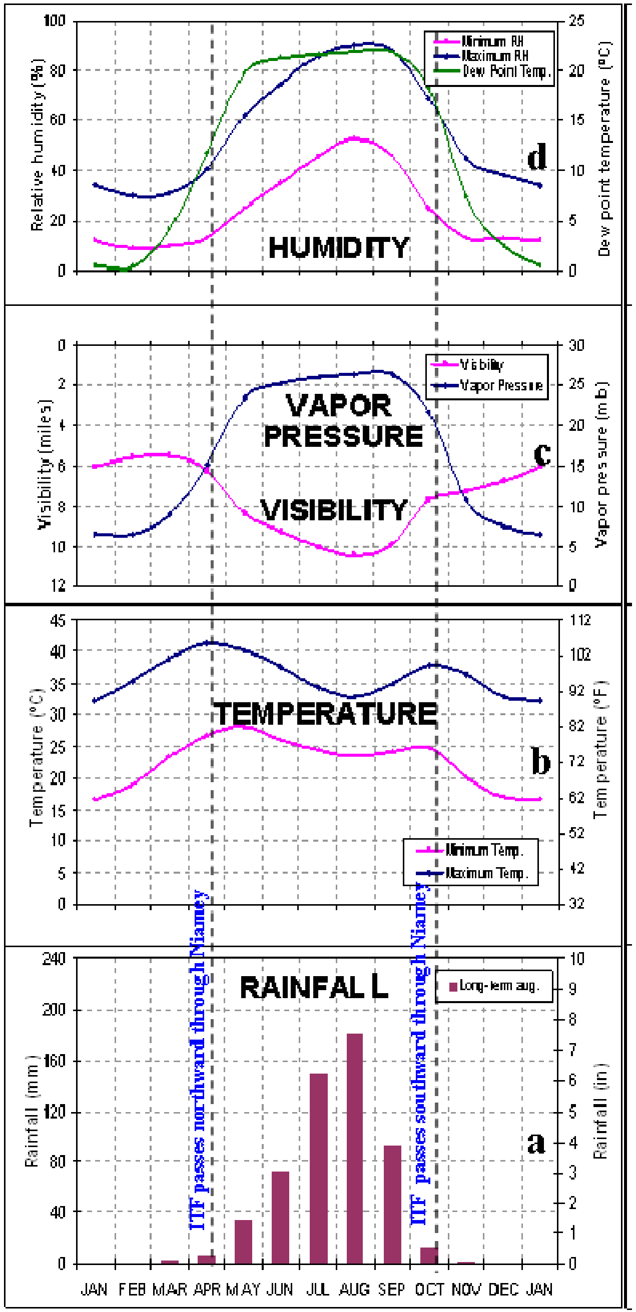


Overview of the main site at Niamey airport. The “instrument field” (right) is located about 100m from the main facility (left)

Figure 5. The AMF ancillary site at Banazambou, Niger, Africa. Broadband downwelling radiation is measured on the platform on the left-hand side of the picture and broadband downwelling on the lateral beam attached to the pole on the right-hand side of the picture. Standard meteorological variables are measured atop the pole on the right-hand side of the picture and the solar panel that provides power is the tilted silver plate in the center.

SEVIRI and GERB on Meteosat

- SEVIRI is the operational imager
  - 12 narrow spectral channels
  - covering solar (4 vis/NIR) and thermal (8 IR) regions
  - sub-satellite resolution ~1km / ~3km
- GERB measures the broadband radiation budget
  - shortwave and total: 0.32-4μm and 0.32-30μm
  - subtraction results in longwave: 4-30μm
  - sub-satellite resolution is ~45km, but there is also an High Resolution (HR) product (~10km) using SEVIRI
- Both instruments have ~15 minute temporal resolution
  - Meteosat-8 is the operational satellite, launched August 2002
  - Meteosat-9 launched December 2005 is currently backup

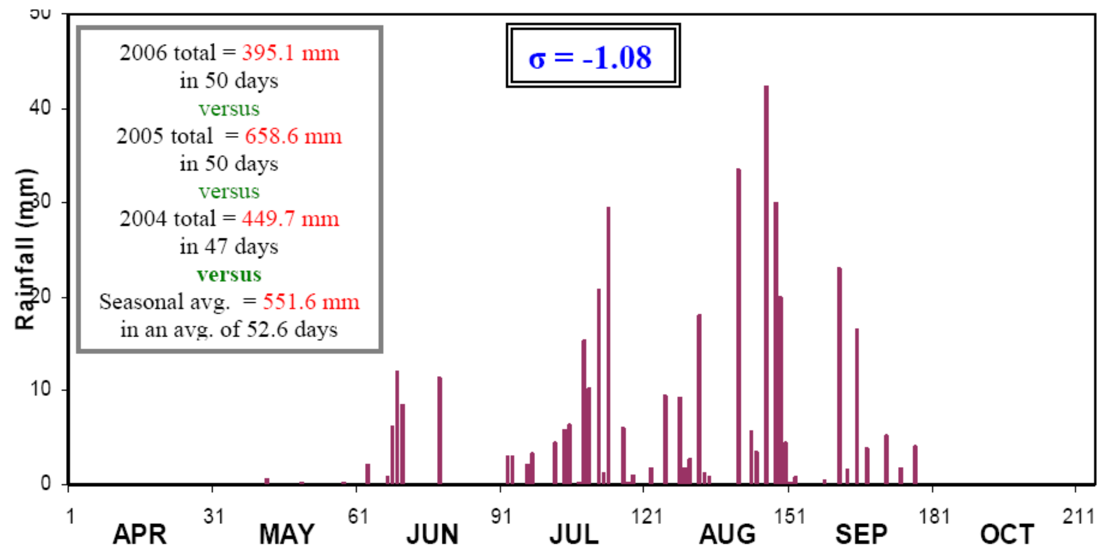


Long-term average annual cycles of climate parameters relevant for the deployment of the ARM Mobile Facility in Niger

From: Lamb and Lélé

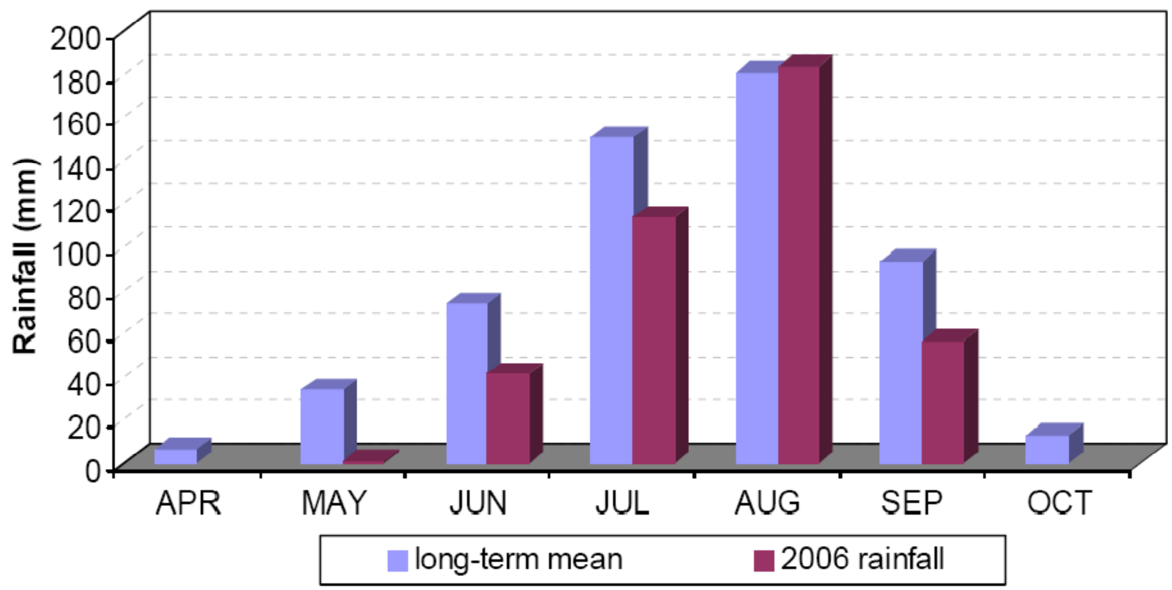
Niamey daily rainfall

April – October 2006



Niamey monthly rainfall

April – October 2006 and 1941-2000 long-term mean

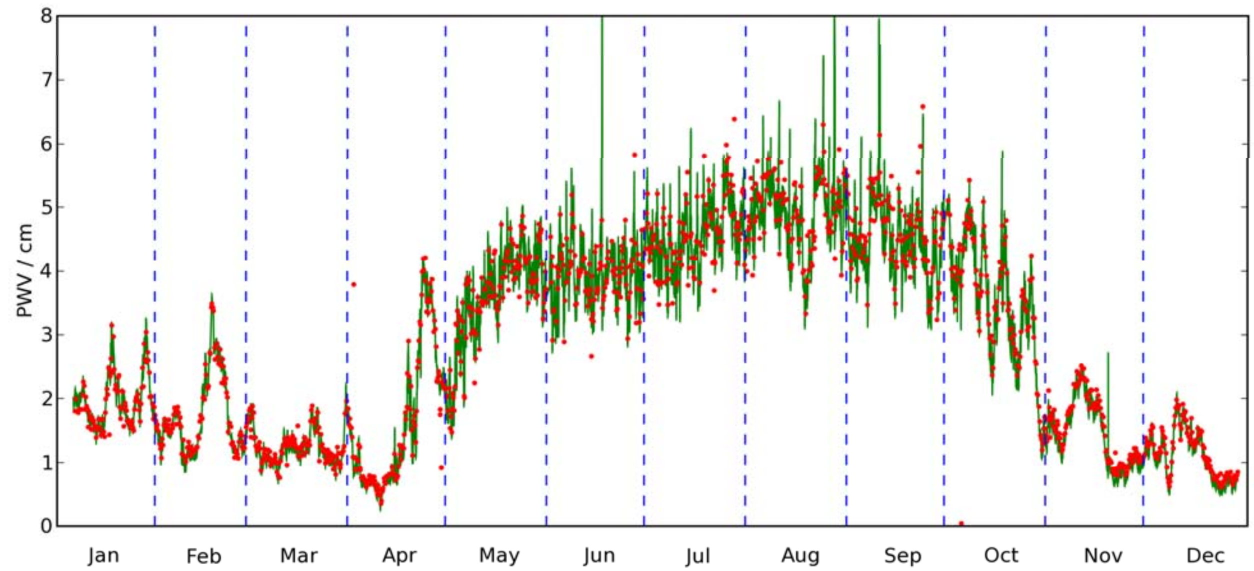


From: Lamb and Lélé

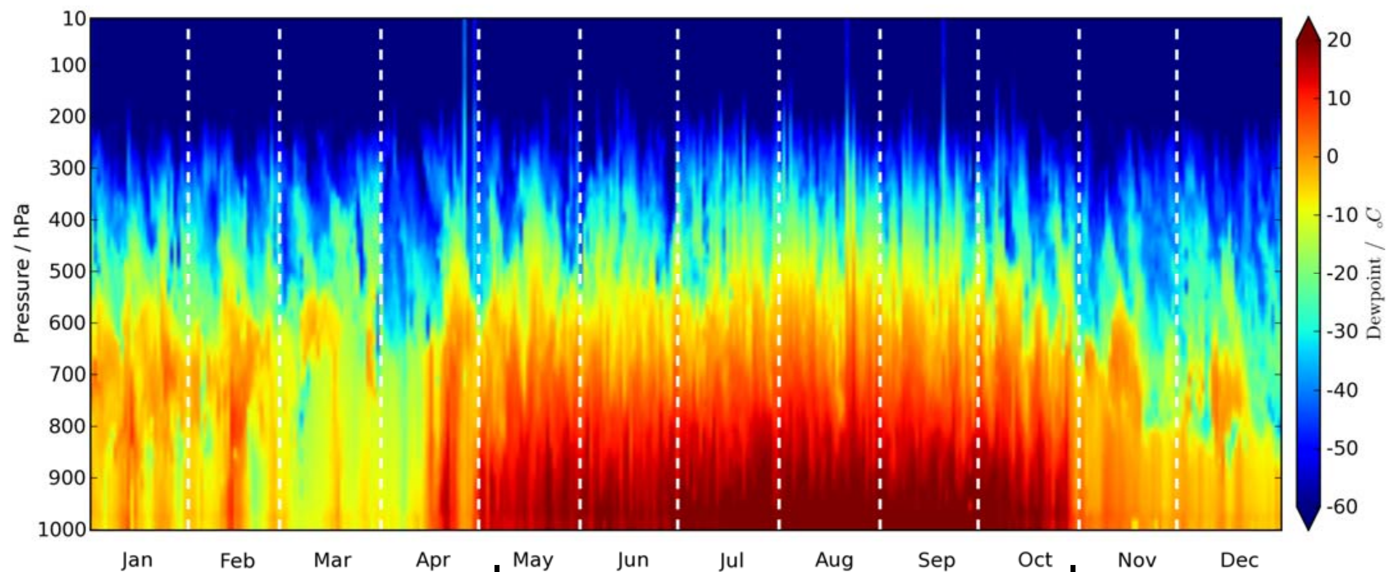
Column water vapour (cm)

Green: Radiometer

Red: Sonde



Sonde dew-point temperature (^oC)

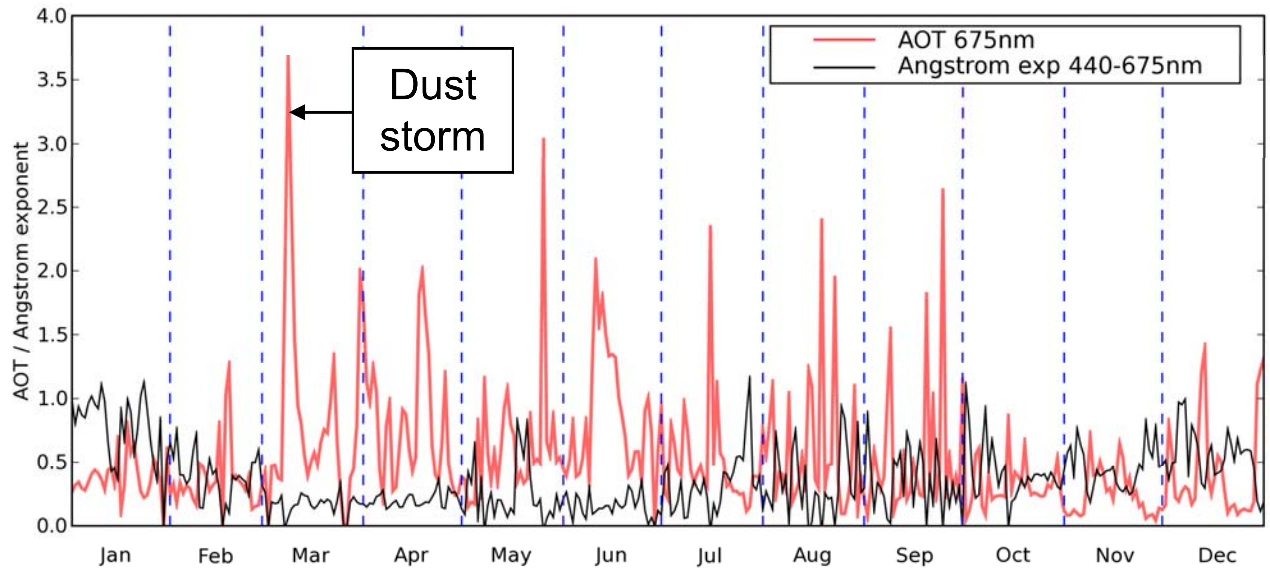


May 5: ITF passes Niamey to North

October 29: ITF passes Niamey to South

Red: Aerosol Optical Thickness at 675nm from the AERONET site at Banizoumbou

Black: Angstrom exponent

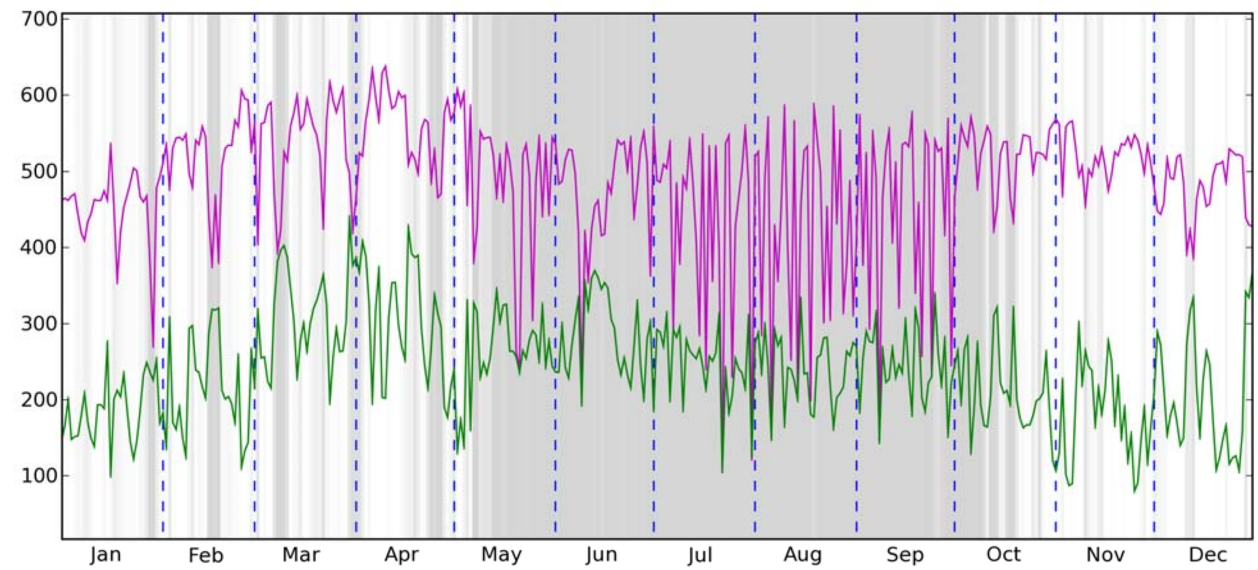


Downward Solar flux (daily averages Wm^{-2})

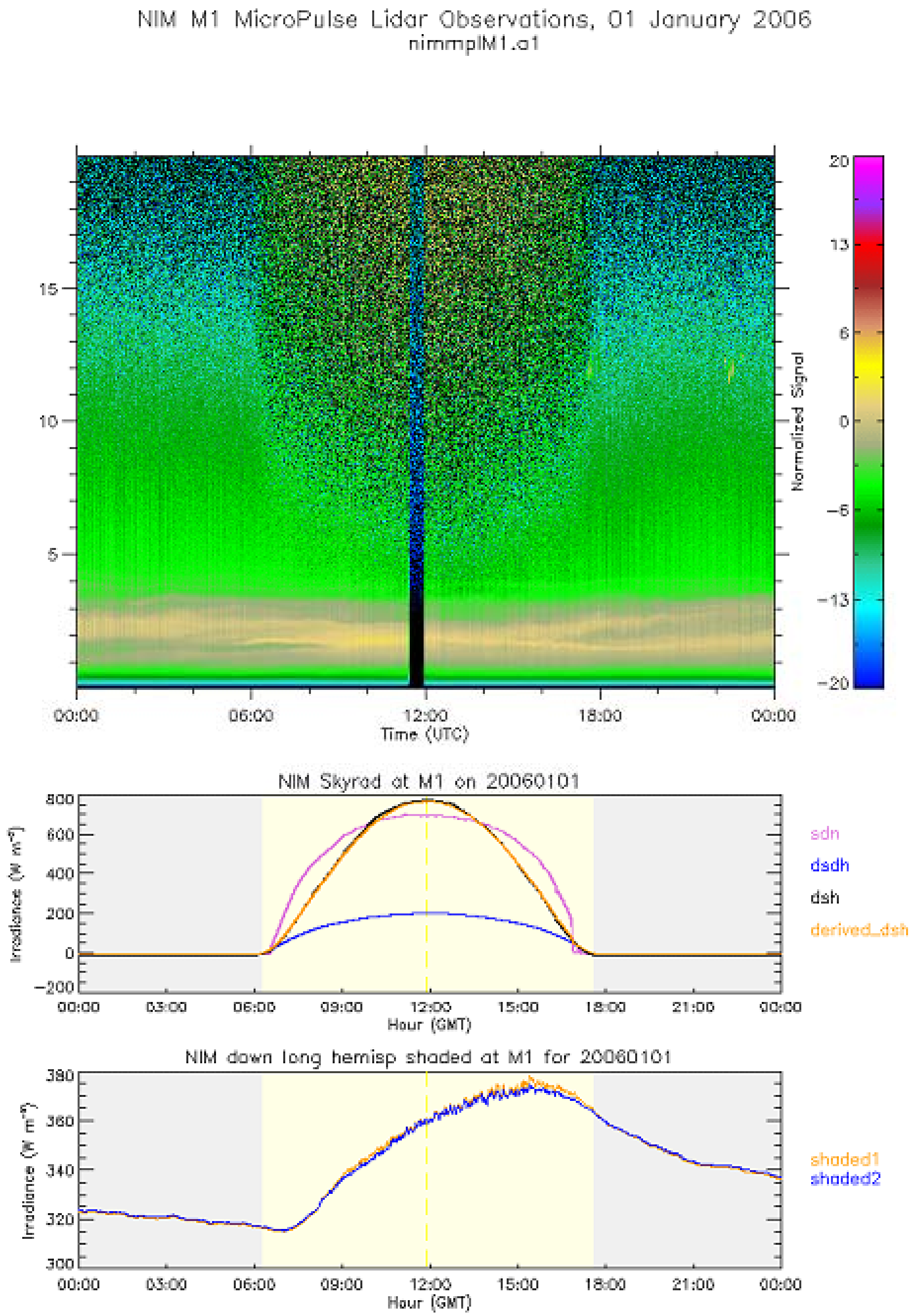
Purple: Total

Green: Diffuse

Grey bands: clouds



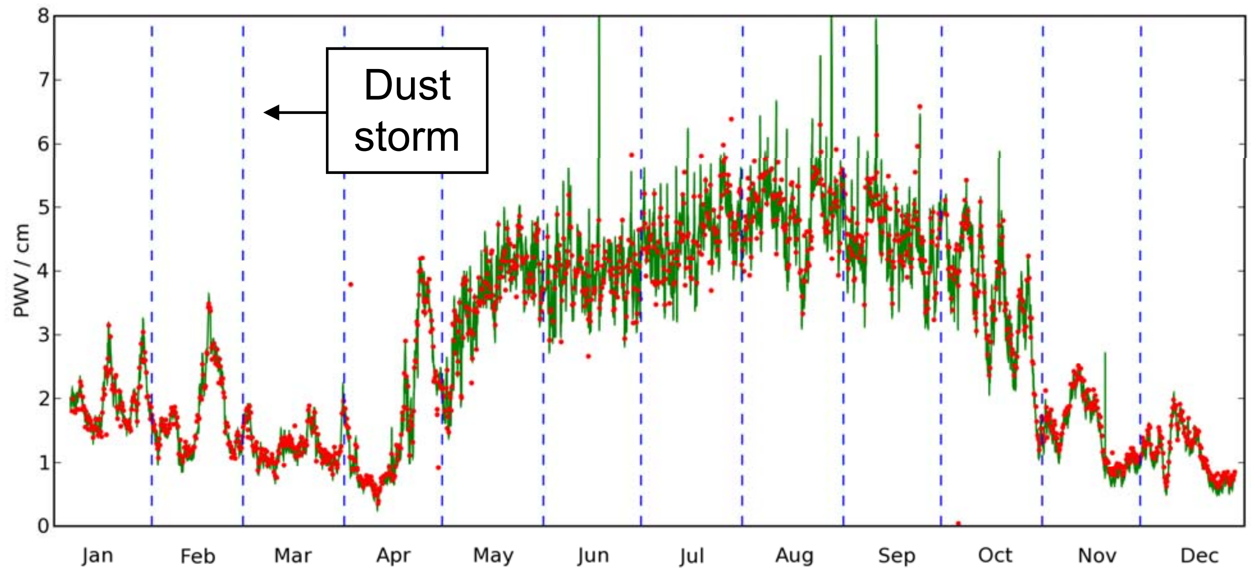
Downward solar fluxes are controlled by clouds and by aerosol


NIM M1 MicroPulse Lidar Observations, 01 January 2006
nimmplM1.a1
Time (UTC)
Normalized Signal
NIM Skyrad at M1 on 20060101
Irradiance (W m⁻²)
Hour (GMT)
sdn
dsdh
dsh
derived_dsh
NIM down long hemisp shaded at M1 for 20060101
Irradiance (W m⁻²)
Hour (GMT)
shaded1
shaded2

Column water vapour (cm)

Green: Radiometer

Red: Sonde

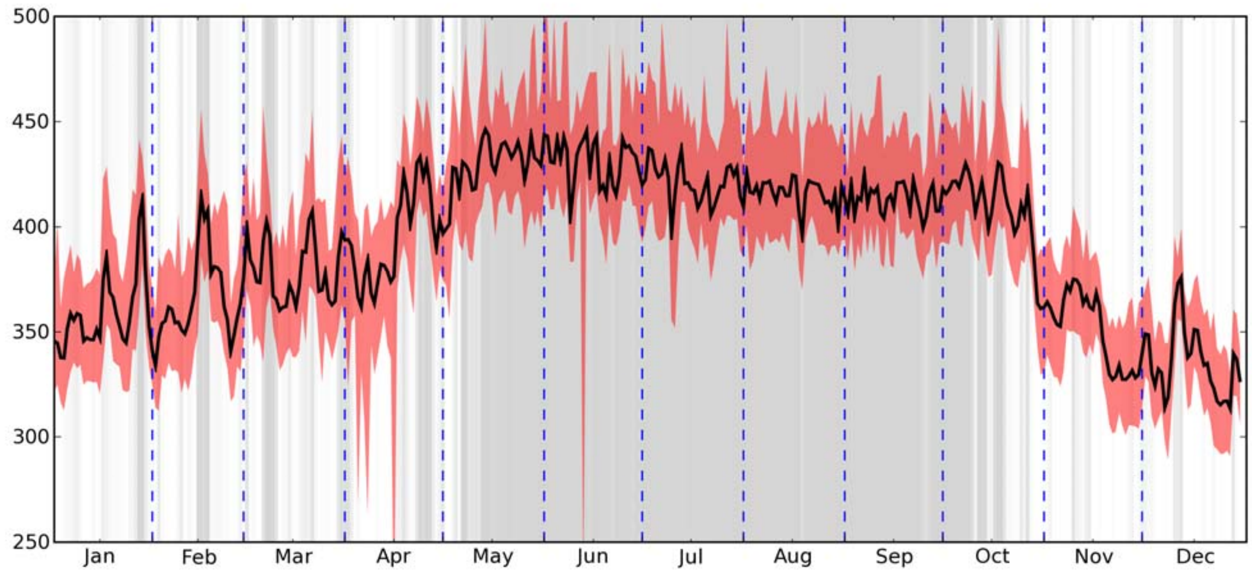


Downward Thermal flux Wm^{-2}

Black: Daily average

Red: variability

Grey bands: clouds

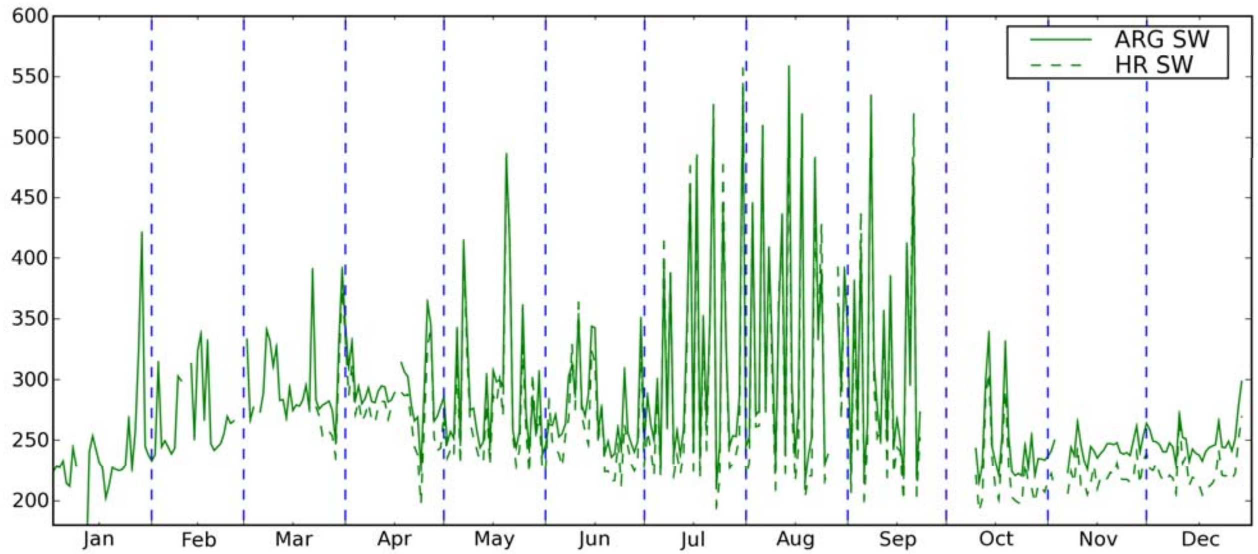


Downward thermal fluxes are controlled by clouds, column water vapor, atmospheric temperatures and ……?

GERB reflected solar Wm^{-2}

ARG: Standard product (50km resolution)

HR: High Resolution hybrid product using SEVIRI imager data (10km resolution)



GERB OLR Wm^{-2}

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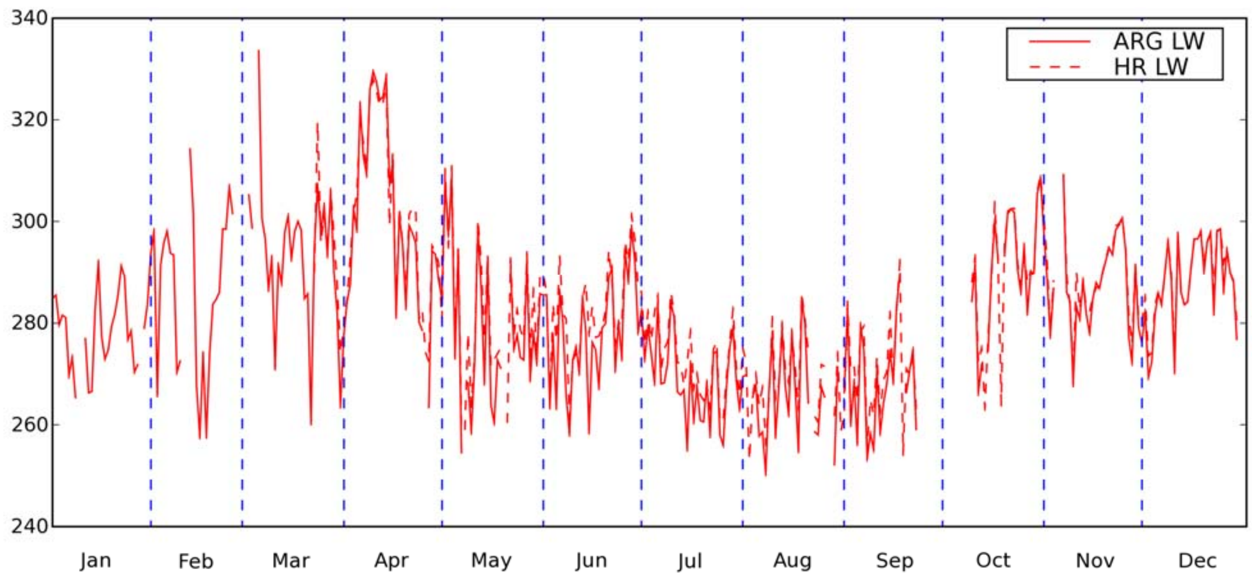

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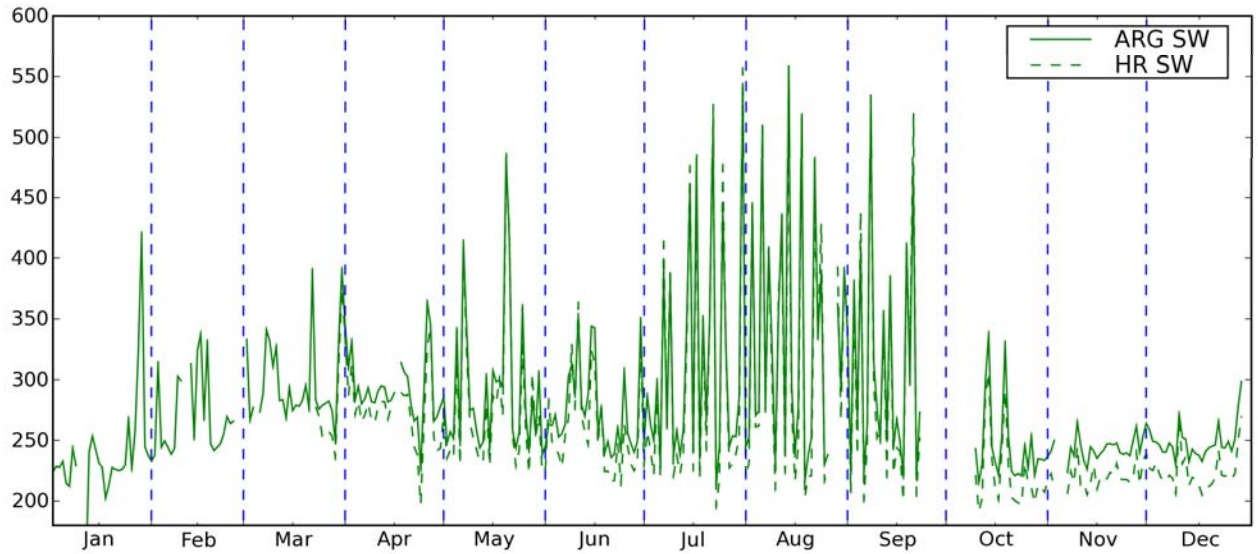
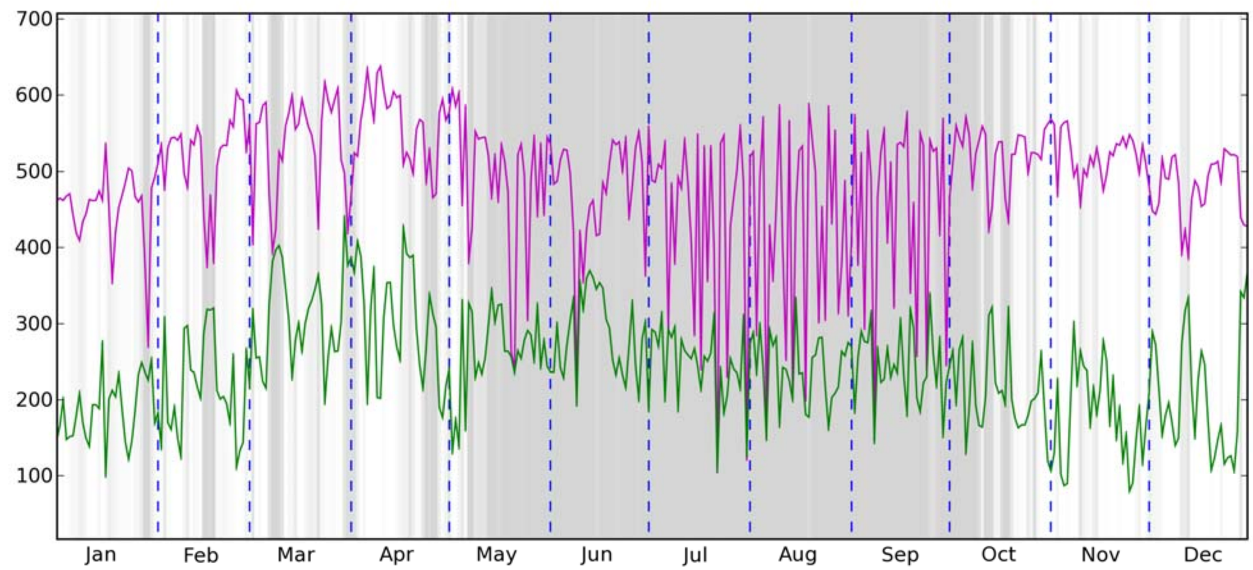


Downward Solar flux (daily averages Wm^{-2})

Purple: Total

Green: Diffuse

Grey bands: clouds

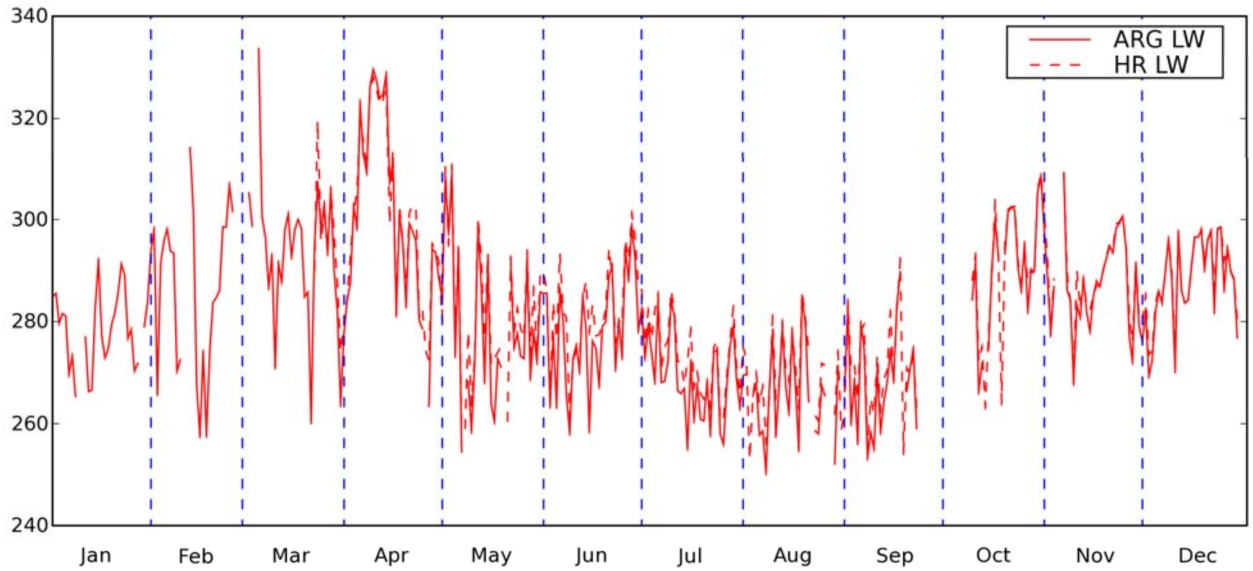


GERB and AMF fluxes will be combined to calculate atmospheric divergence

GERB OLR Wm^{-2}

ARG: Standard product (50km resolution)

HR: High Resolution hybrid product using SEVIRI imager data (10km resolution)

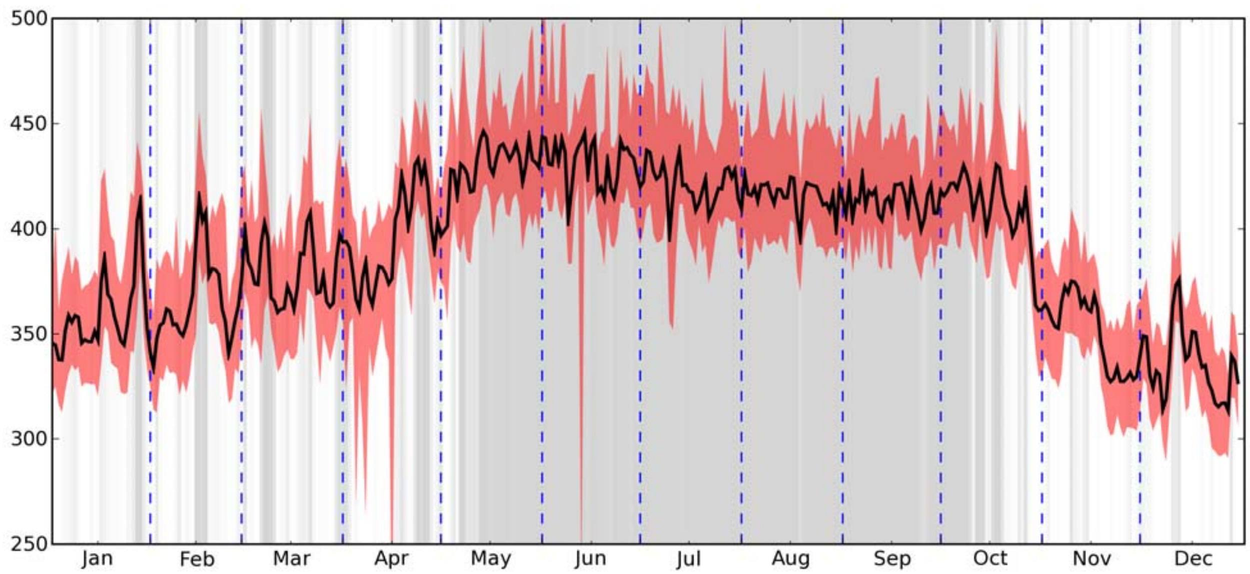


Downward Thermal flux Wm^{-2}

Black: Daily average

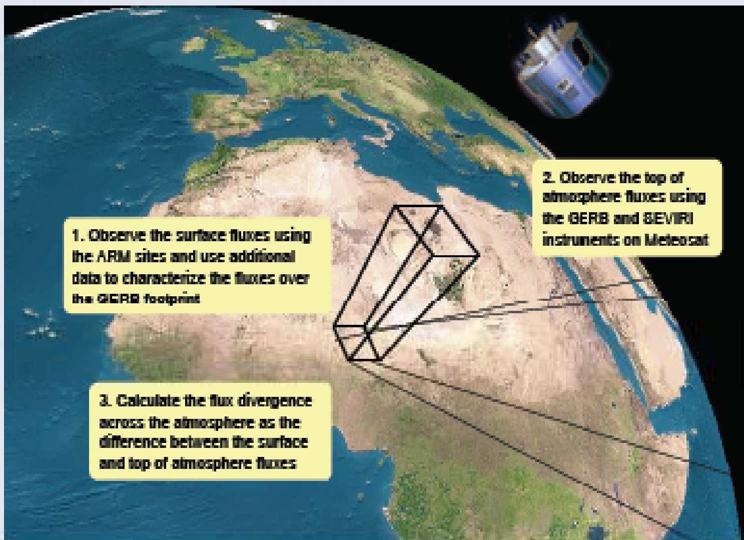
Red: variability

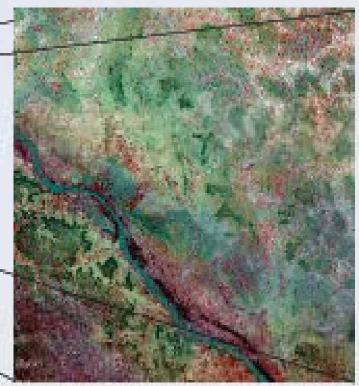
Grey bands: clouds



GERB and AMF fluxes will be combined to calculate atmospheric divergence

The principal aim of RADAGAST is to characterize the radiative flux divergence across the atmosphere. At the top of atmosphere the data are provided by the GERB instrument on Meteosat 8, with a footprint at the surface of ~40km. At the surface, the fluxes are measured continuously at a point by the AMF instruments.





RADAGAST: basic methodology

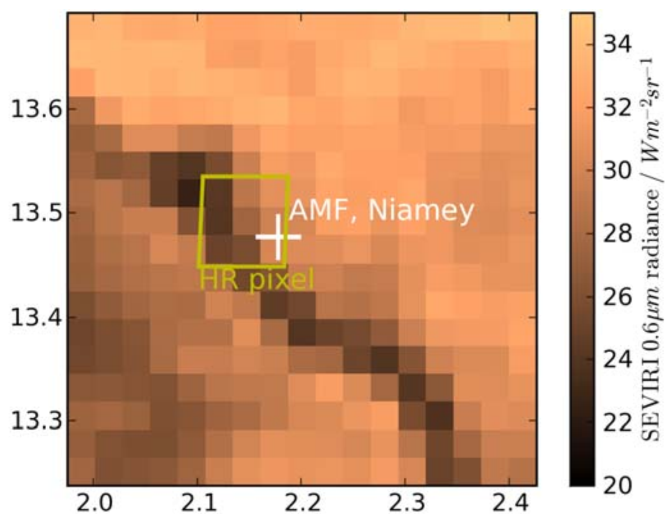
The land surface can be very heterogeneous at the scale of a GERB footprint (~50km). How well do fluxes measured at a point represent the spatial average across the GERB footprint? How well does a time average at a fixed point represent the same time average over the larger area?

To address these questions we are using flux measurements from AMF radiation instruments deployed at the main site at Niamey airport (NIA) and at a rural site 50km further East at Banizoumbou (BAN).

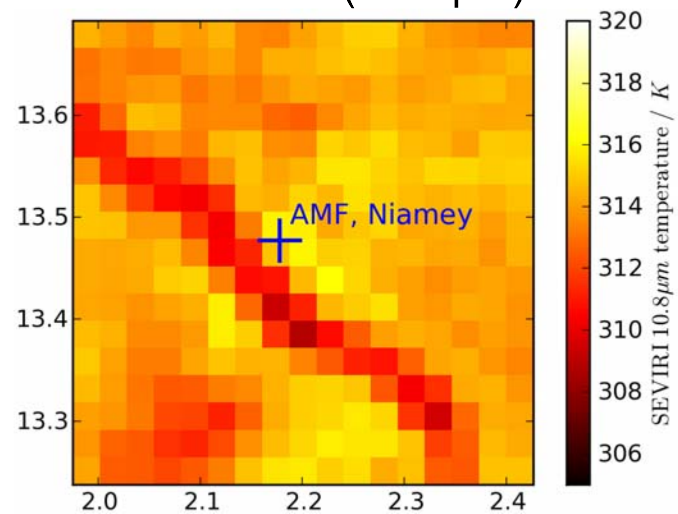
The high resolution SEVIRI imager radiances provide detailed information on the atmospheric and surface inhomogeneities within the larger GERB pixels

Average clear-sky radiances for November 2006

Visible radiances (0.6 μm)



Window radiances (10.8 μm) at 1200 UT



SEVIRI radiances within the GERB pixel that includes Niamey. Visible radiances are averaged over daylight hours only. The HR pixel covers a much smaller area and is associated with lower albedo compared to the GERB pixel: the ratio of radiances in the GERB pixel to those from the HR pixel is 1.09. The corresponding ratio of the fluxes is 1.10 ± 0.02

Observations of the impact of a major Saharan dust storm on the atmospheric radiation balance

A. Slingo[1], T.P. Ackerman[2], R.P. Allan[1], E.I. Kassianov[2], S.A. Mcfarlane[2], G.J. Robinson[1], J.C. Barnard[2], M.A. Miller[3], J.E. Harries[4], J.E. Russell[4] & S. Dewitte[5]

[1]Environmental Systems Science Centre, University of Reading, UK.

[2]Pacific Northwest National Laboratory, Richland, Washington, USA

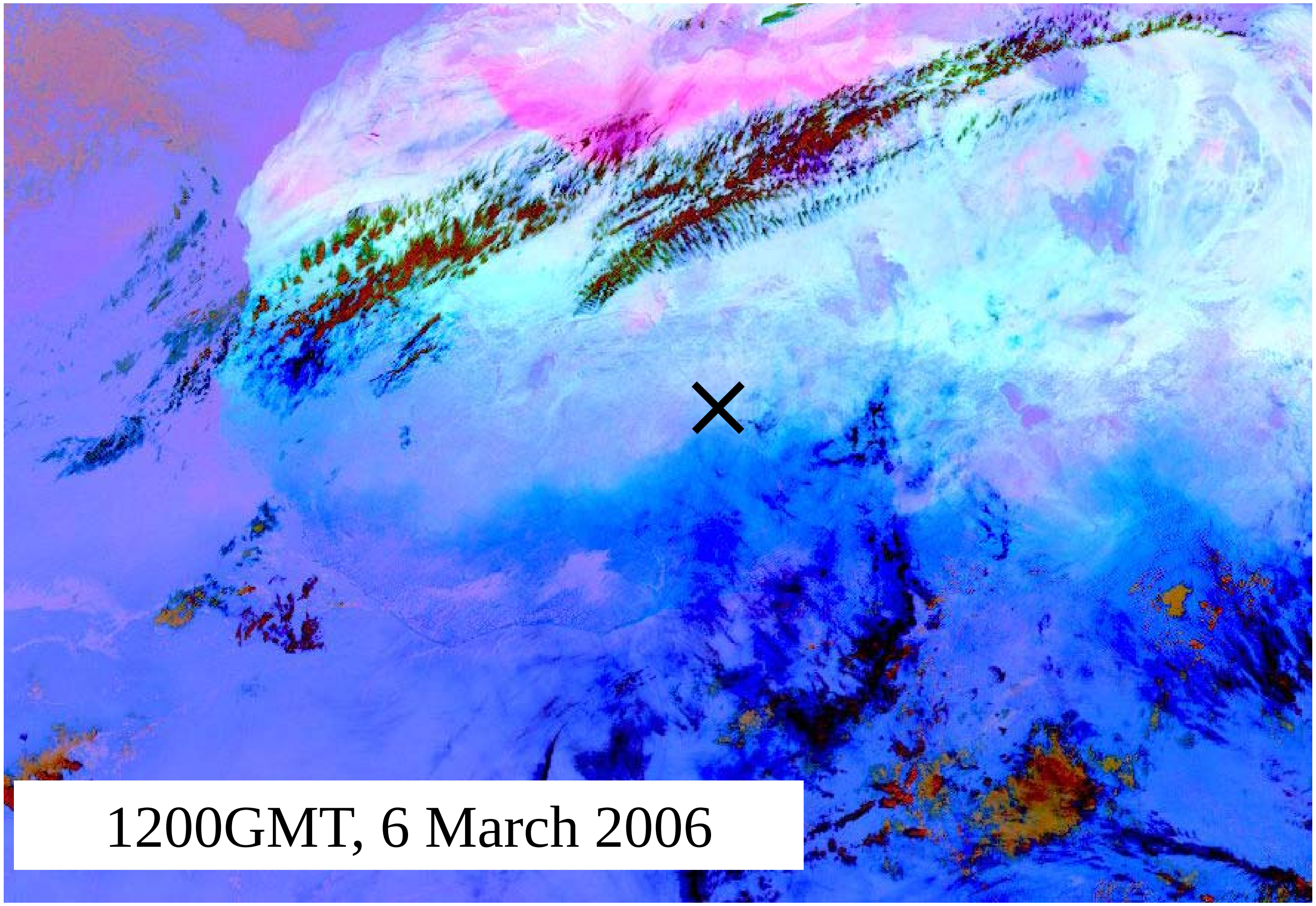
[3]Brookhaven National Laboratory, Atmospheric Science Division, Upton, New York, USA

[4]Blackett Laboratory, Imperial College London, London, UK

[5]Royal Meteorological Institute of Belgium, Brussels, Belgium

Geophys. Res. Lett., 2006, **33,** L24817, doi: 10.1029/2006GL027869

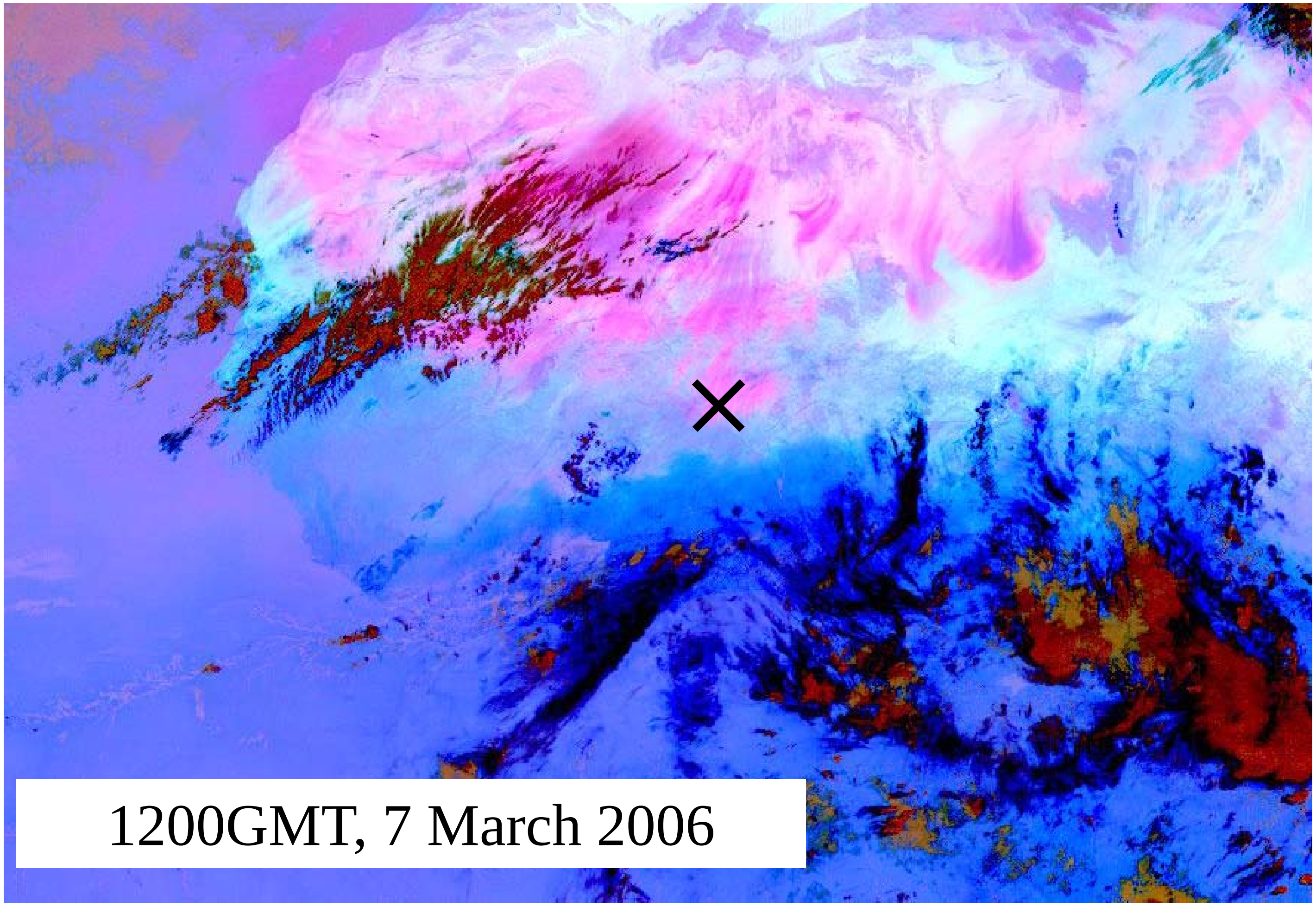
In these false-colour images, the dust appears pink or magenta, water vapour dark blue, thick high-level clouds red-brown, thin high-level clouds almost black and surface features pale blue or purple.



On 6 March, unusually strong northerly winds bring cold air at low levels over the desert, creating a broad front of dust as the air moves south.

The location of Niamey is marked by a cross.

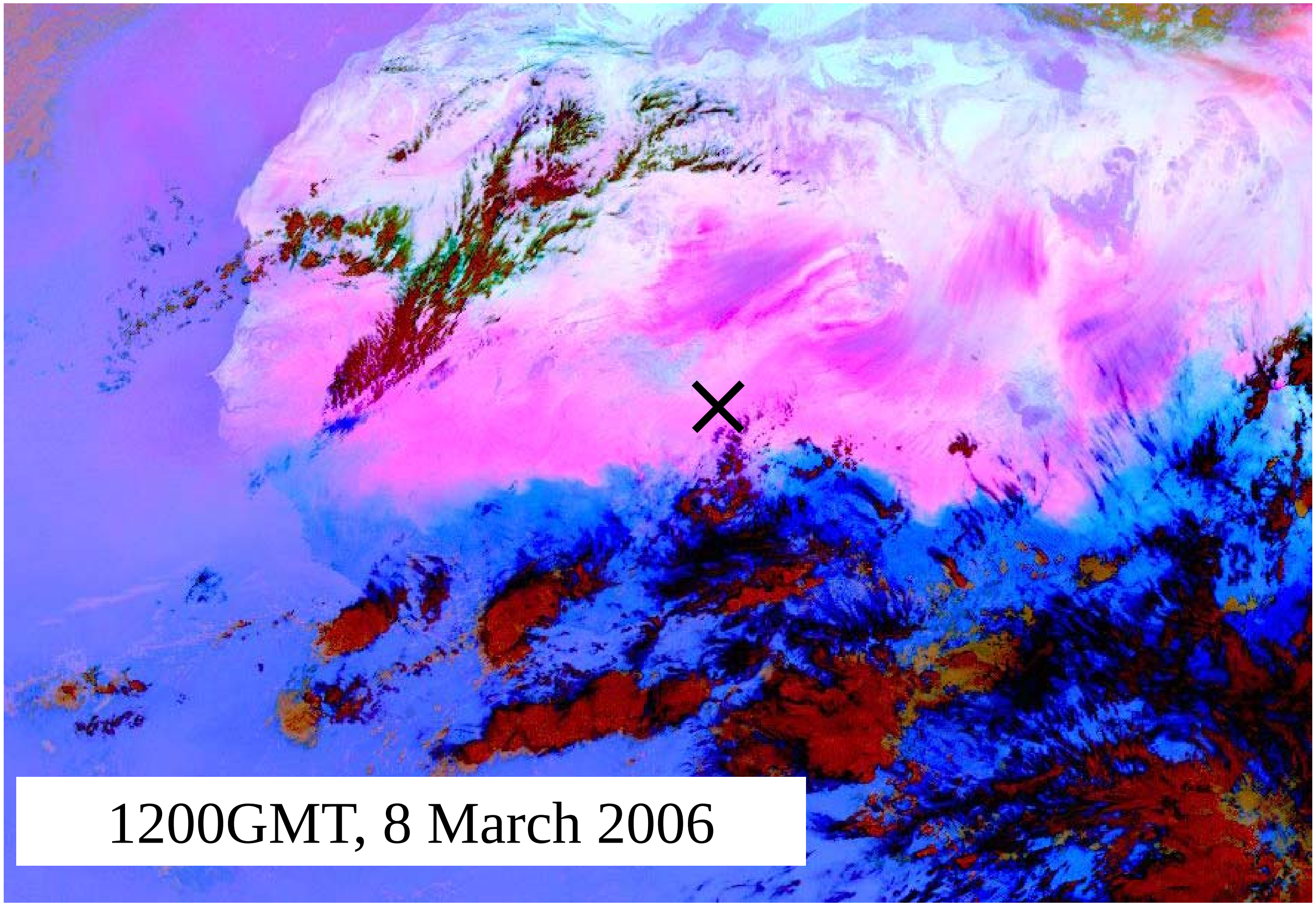
In these false-colour images, the dust appears pink or magenta, water vapour dark blue, thick high-level clouds red-brown, thin high-level clouds almost black and surface features pale blue or purple.



The shallow layer of cold air cannot rise over the mountains of the central Sahara (light blue in colour), so it is forced to follow the valleys. Streaks appear where it accelerates through gaps in the topography.

The dust reached Niamey at 0930 on 7 March.

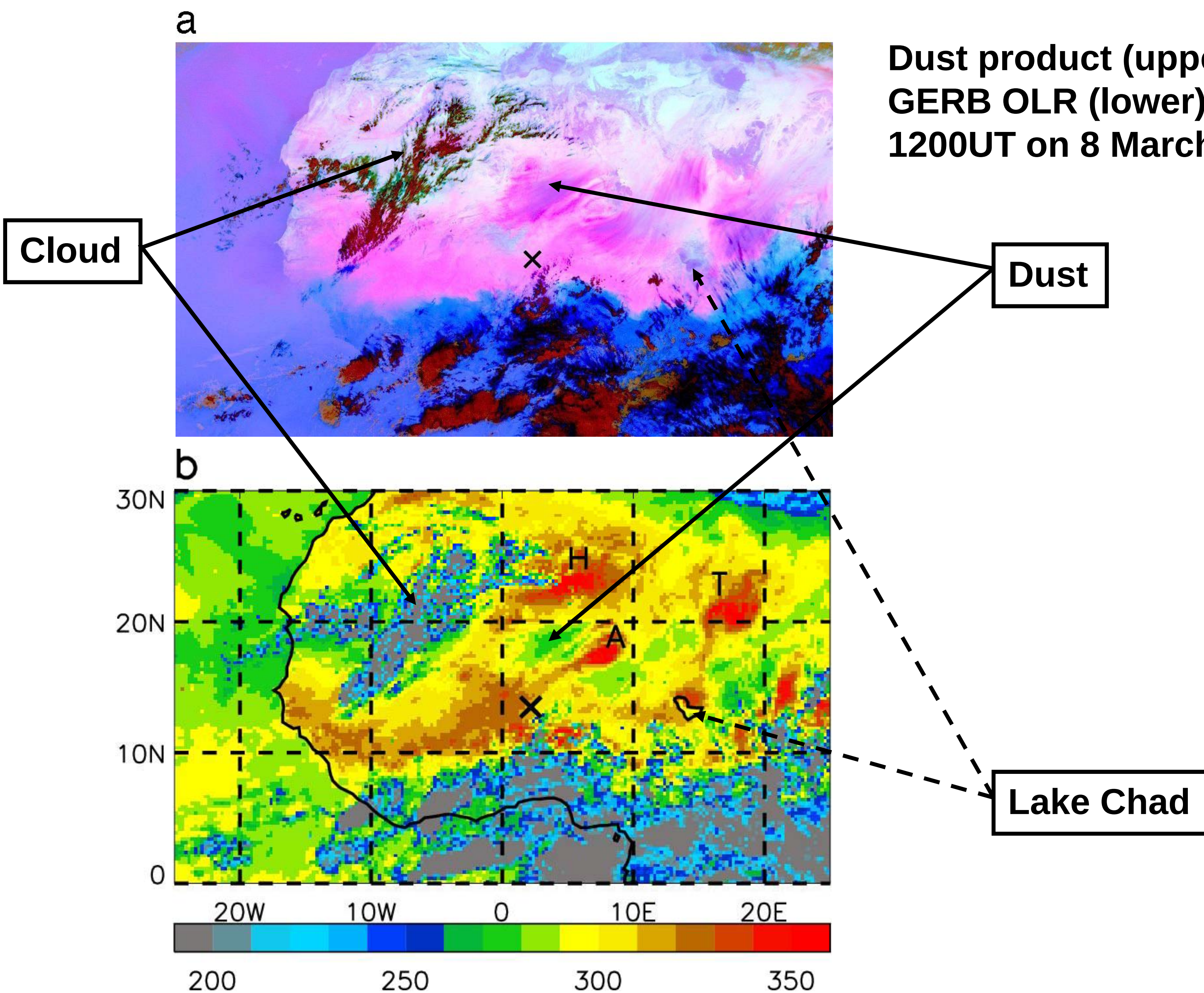
In these false-colour images, the dust appears pink or magenta, water vapour dark blue, thick high-level clouds red-brown, thin high-level clouds almost black and surface features pale blue or purple.

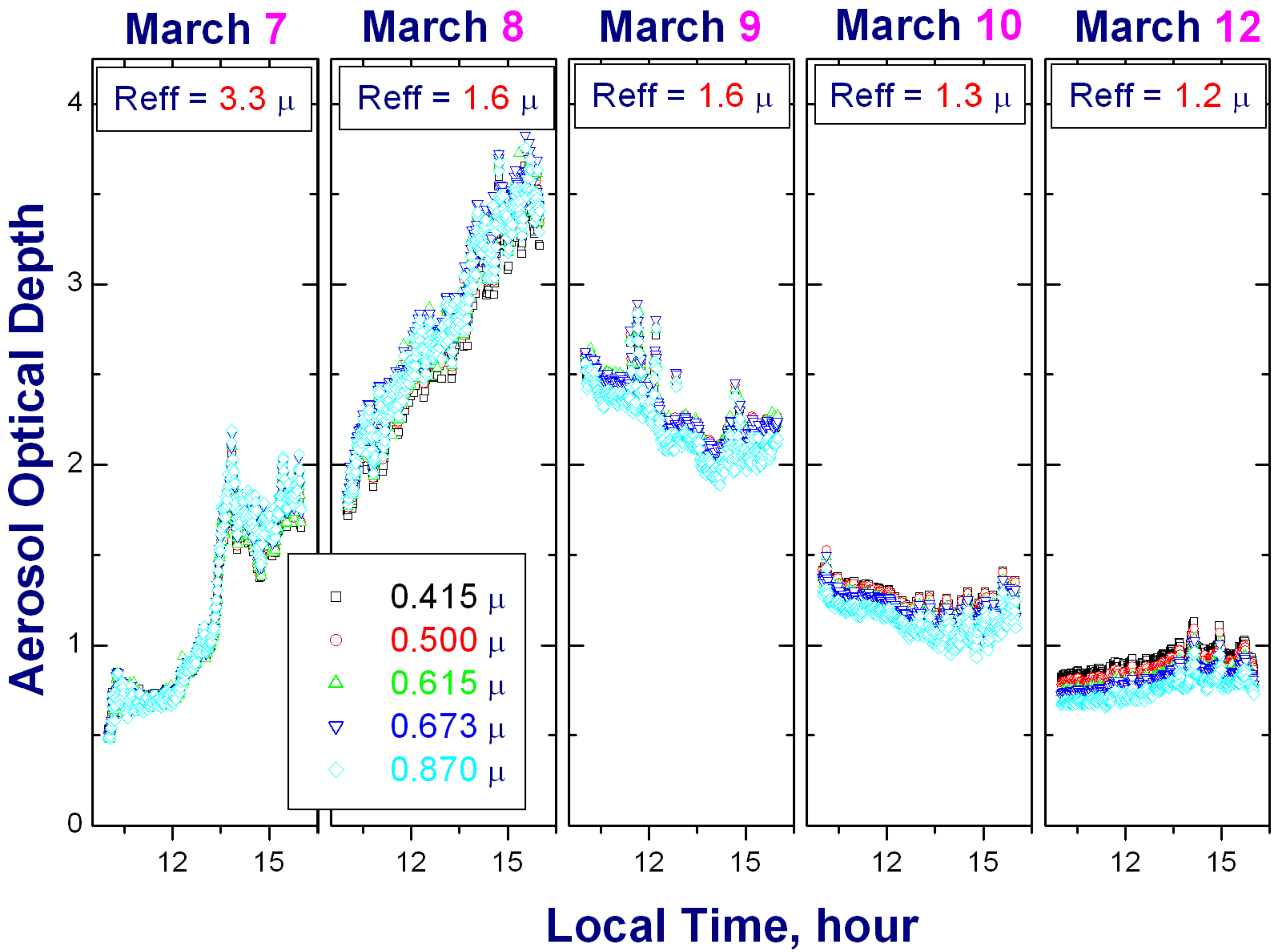


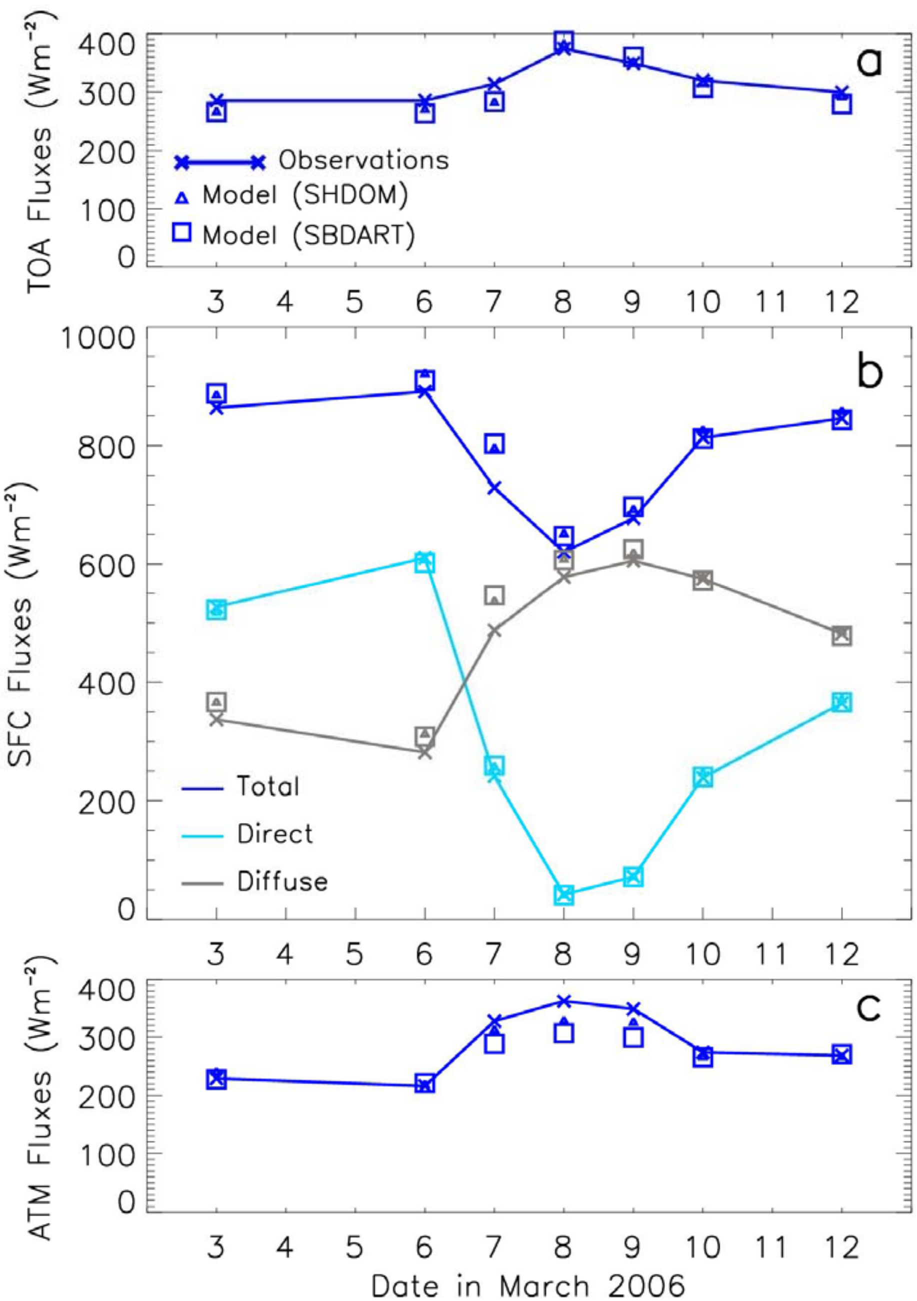
By 8 March, dust covers the whole of West Africa and is moving out over the Atlantic.

Animation available: http://radagast.nerc-essc.ac.uk

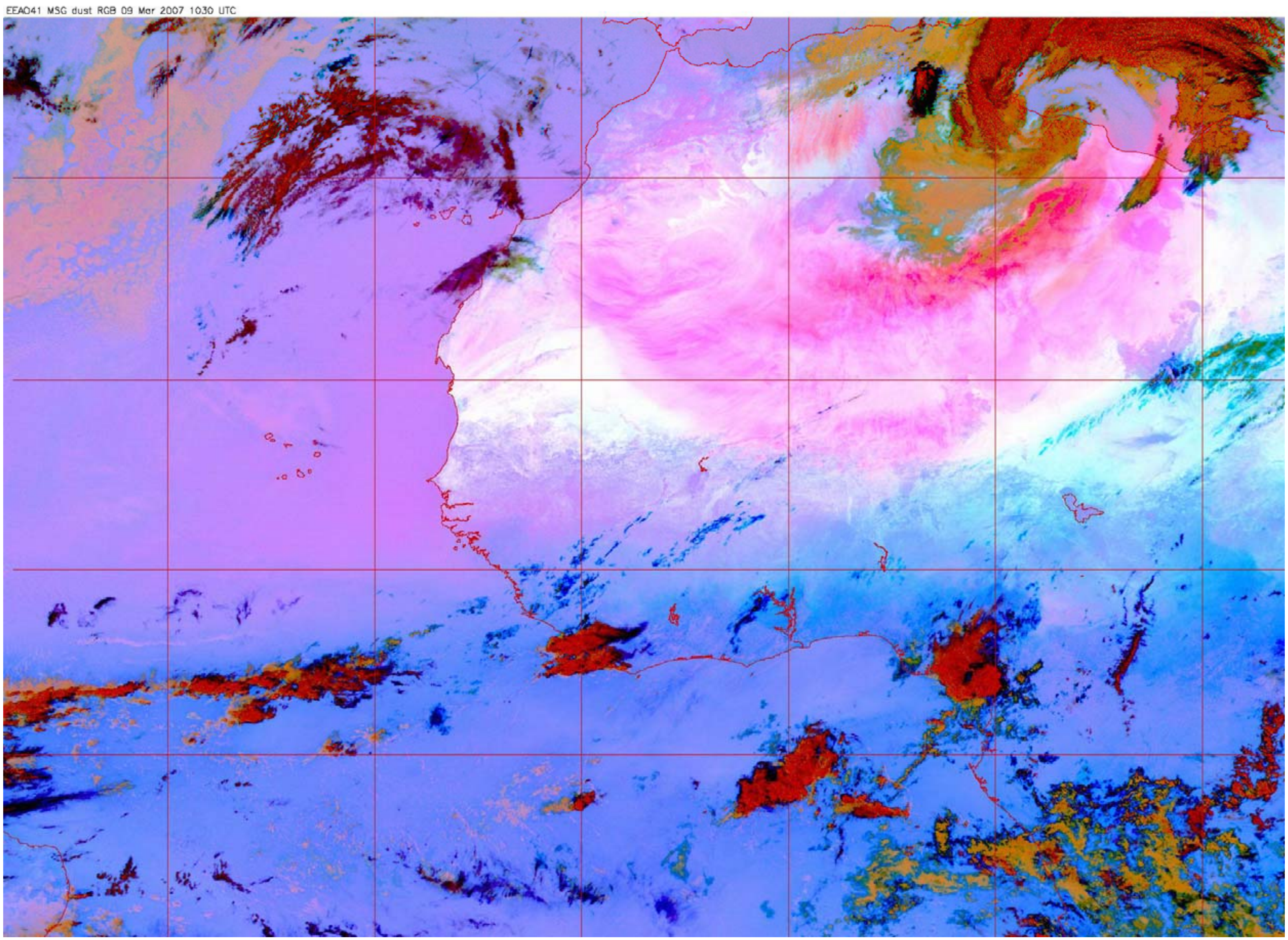
Dust product (upper) and GERB OLR (lower) for 1200UT on 8 March 2006




March 7
March 8
March 9
March 10
March 12
Reff = 3.3 μ
Reff = 1.6 μ
Reff = 1.6 μ
Reff = 1.3 μ
Reff = 1.2 μ
0.415 μ
0.500 μ
0.615 μ
0.673 μ
0.870 μ
Aerosol Optical Depth
Local Time, hour
0
1
2
3
4
12
15


TOA Fluxes (Wm^-2)
a
Observations
Model (SHDOM)
Model (SBDART)
SFC Fluxes (Wm^-2)
b
Total
Direct
Diffuse
ATM Fluxes (Wm^-2)
c
Date in March 2006

EEAO41 MSG dust RGB 09 Mar 2007 1030 UTC



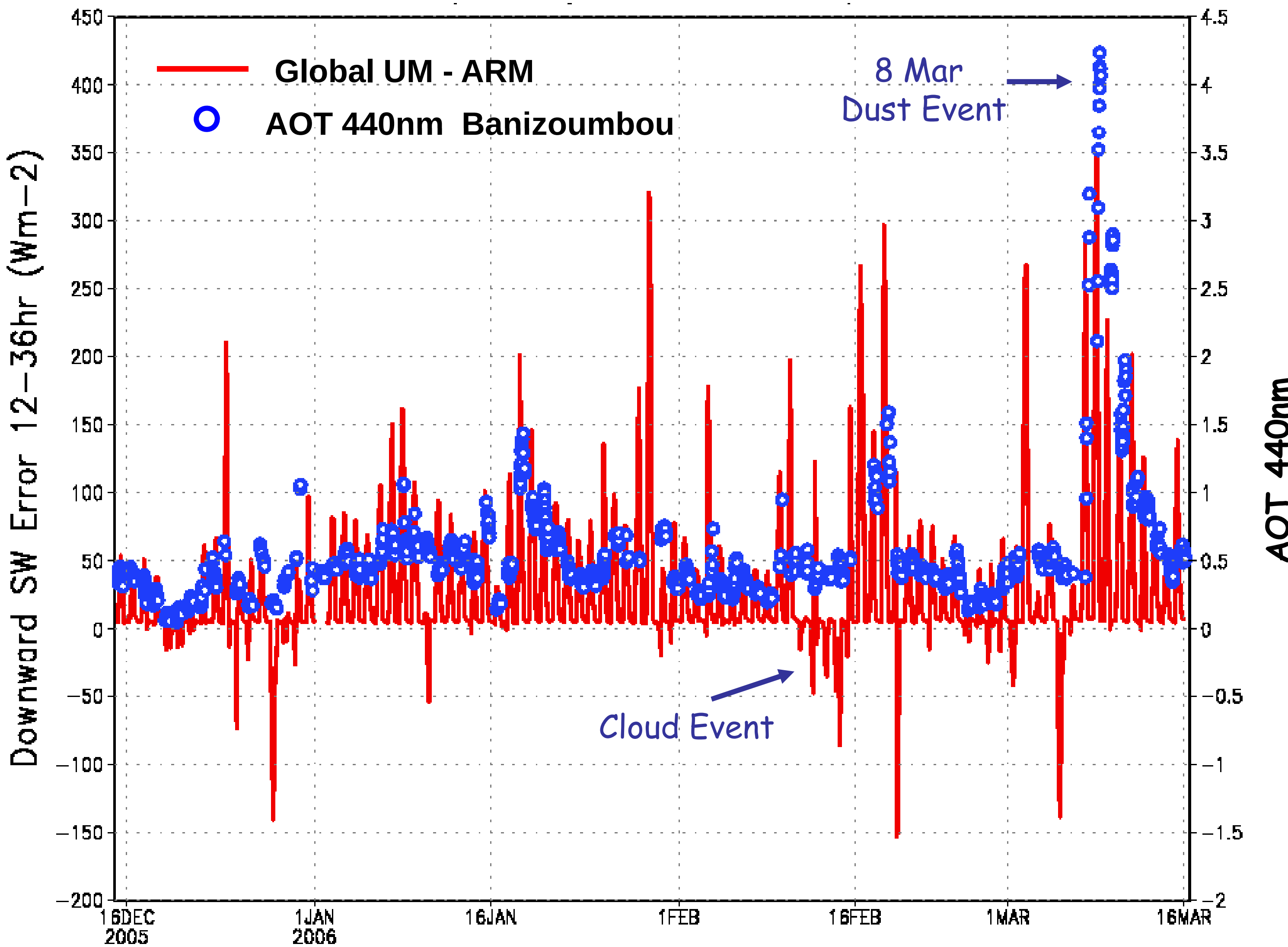
Evaluation of the Met Office NWP model over West Africa during the dry season

Sean Milton, Glenn Greed & Malcolm Brooks

Met Office, Exeter, UK

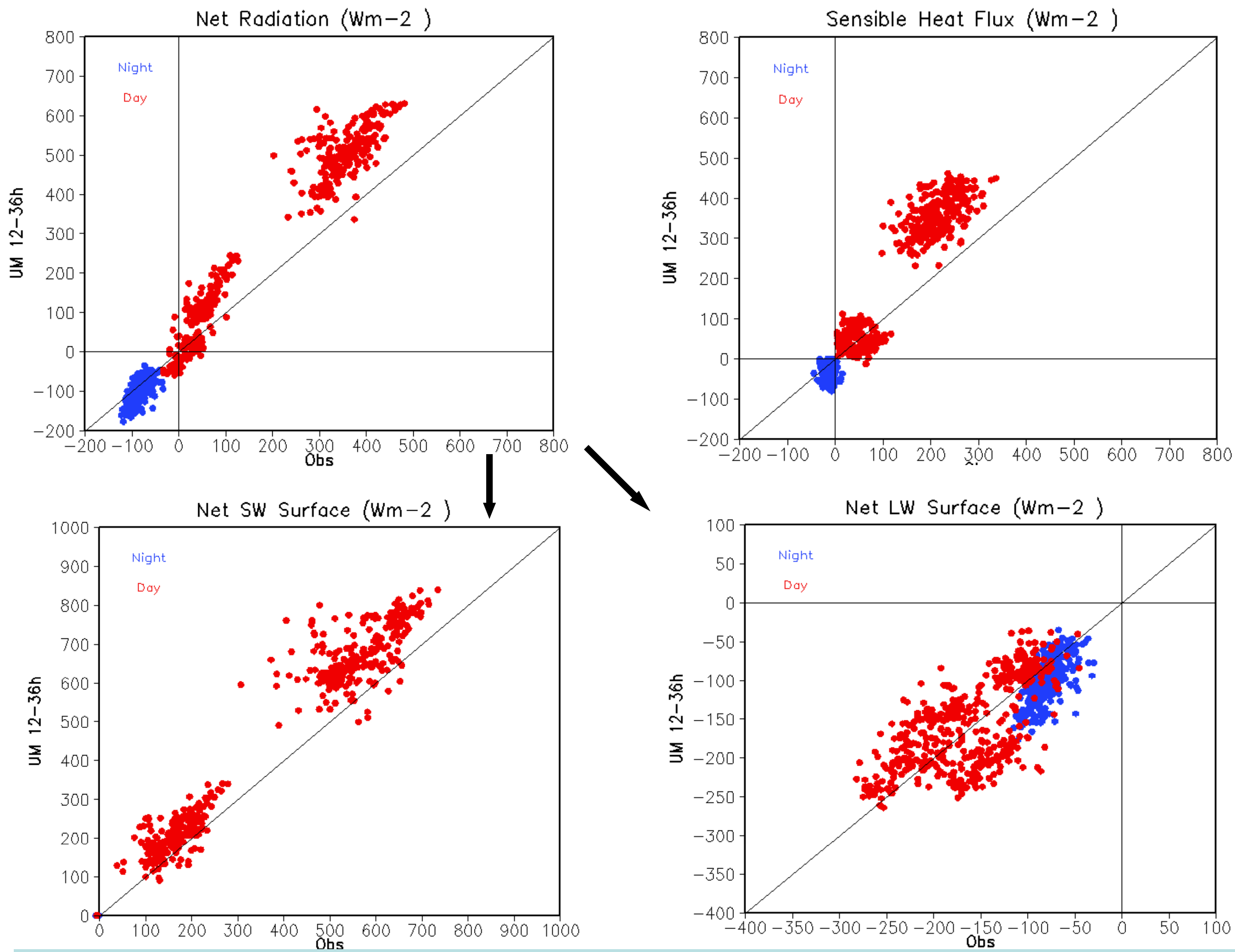
The global NWP model currently has a background aerosol climatology, but regional models (not shown) include the aerosol transport scheme developed in the climate model

Mean Error in Downward SW surface radiation vs. AERONET AOT 440nm - Banizoumbou



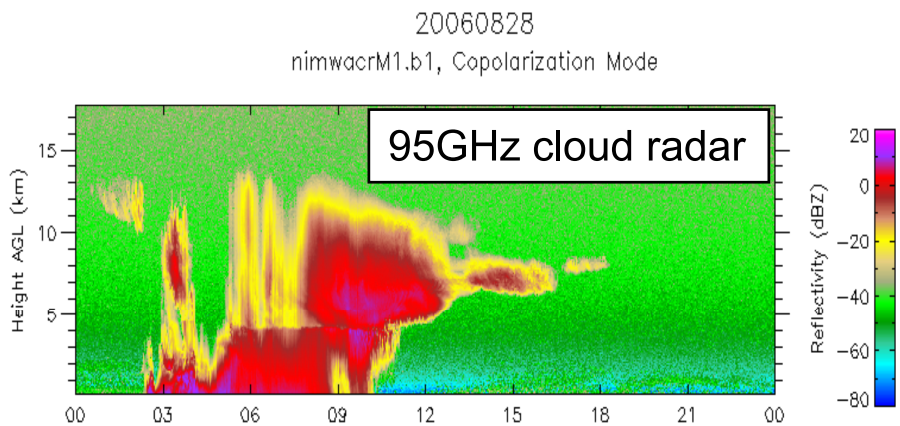
Met Office

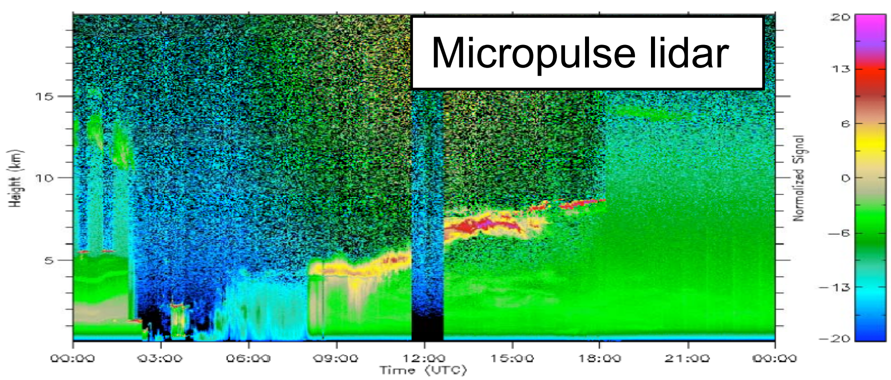
UM vs ARM – Surface Energy Balance. Mid Dec – mid Apr

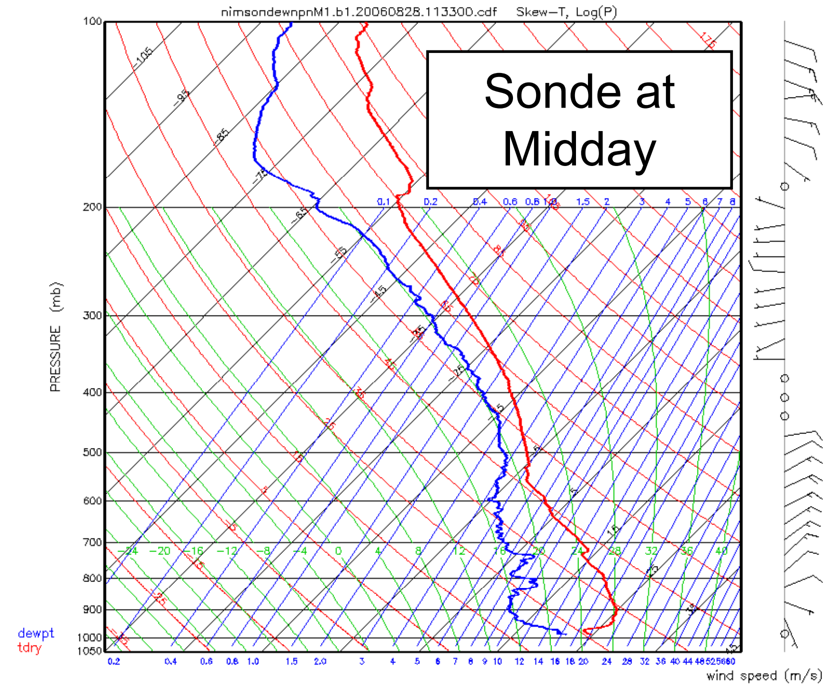


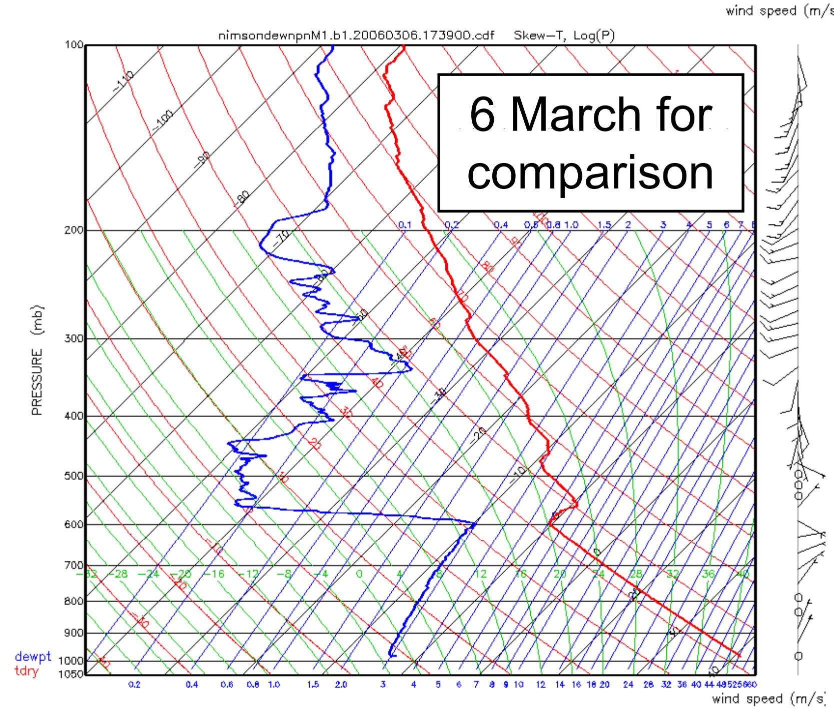
3 hourly averaged fluxes for UM (12-36hr forecasts) & ARM data

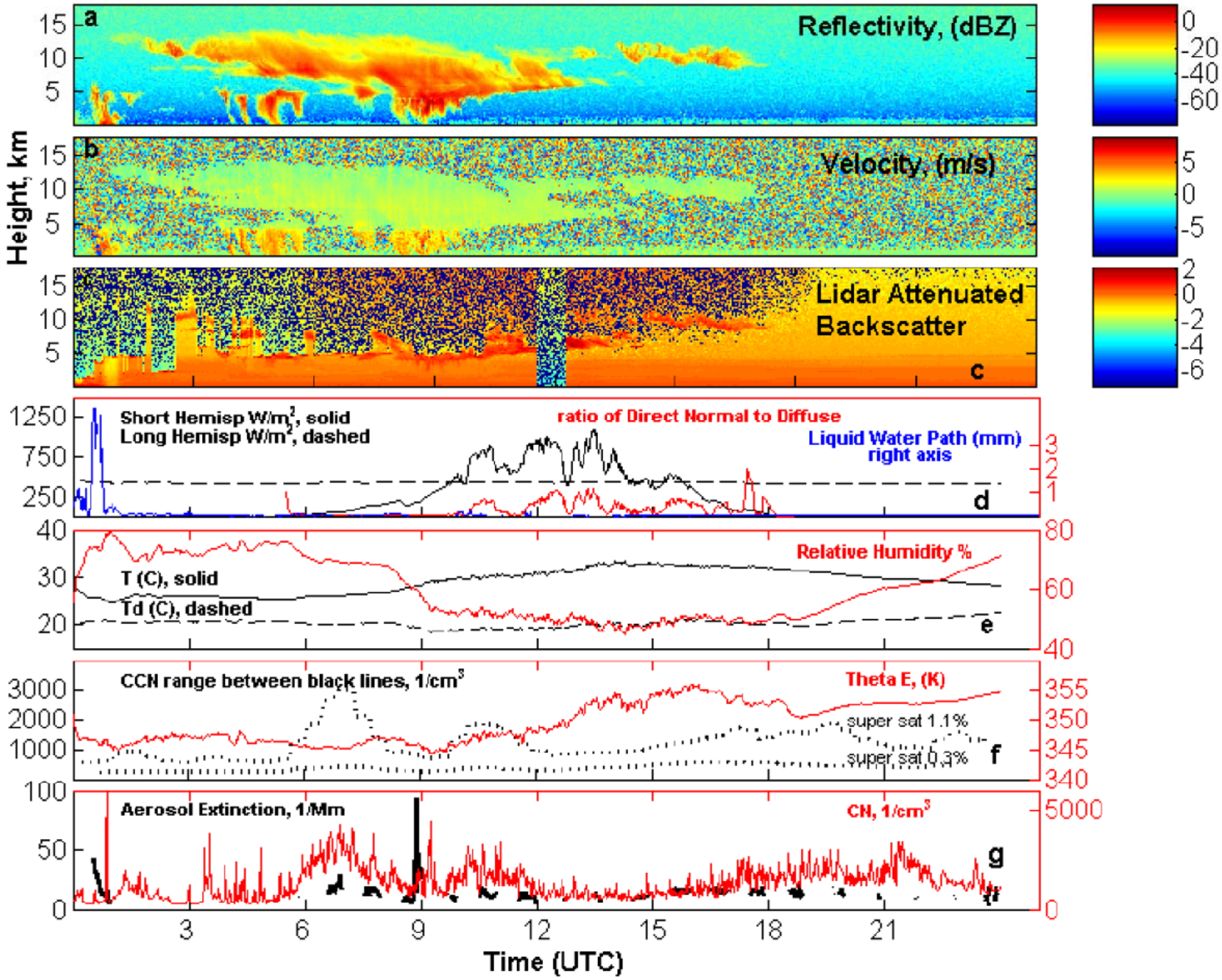
Summer monsoon season





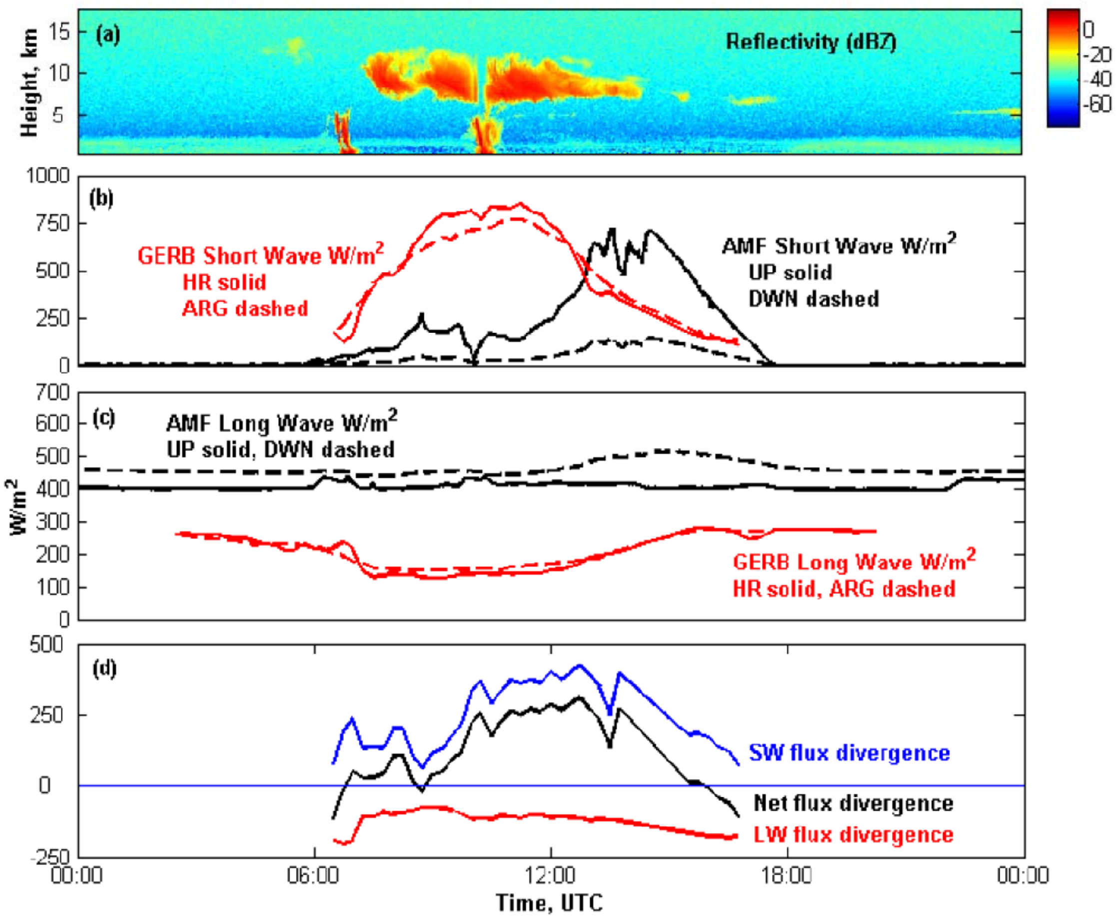






Data from various AMF instruments collected on 9 July 2006

Data from the AMF and Meteosat-8
21 September 2006



95 GHz radar

Shortwave fluxes

Longwave fluxes

Flux divergence across atmosphere

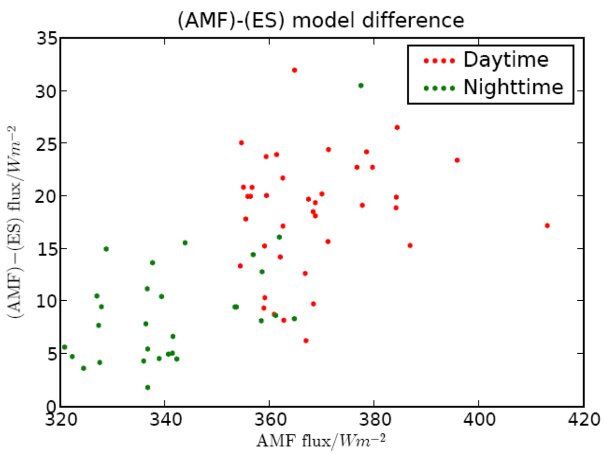
Comparisons with the Edwards/Slingo radiation code

- One of the main RADAGAST objectives is to provide comprehensive observations for testing radiation codes
- We have compared longwave simulations by the Edwards and Slingo (1996) radiation code with observed fluxes from the AMF broad-band radiometers and (in radiance mode) with AERI radiances, for cloud-free conditions
- Unlike the NWP comparisons shown earlier, these are stand-alone tests, running the code with input from the observed thermodynamic profiles
- This has produced some very interesting differences
- The work has benefitted from collaboration with Eli Mlawer (AER), who carried out parallel calculations with LBLRTM

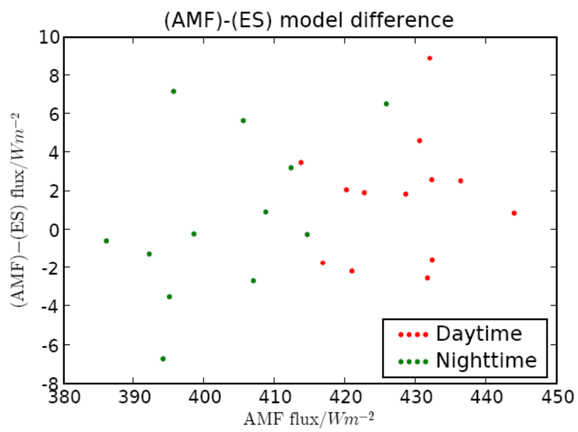
Comparisons with Edwards/Slingo radiation code

The code was run for the whole of 2006; the main profile information is from sondes

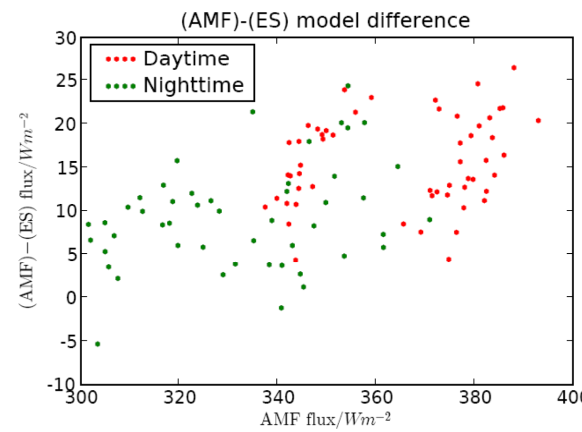
January 2006



August 2006



November 2006



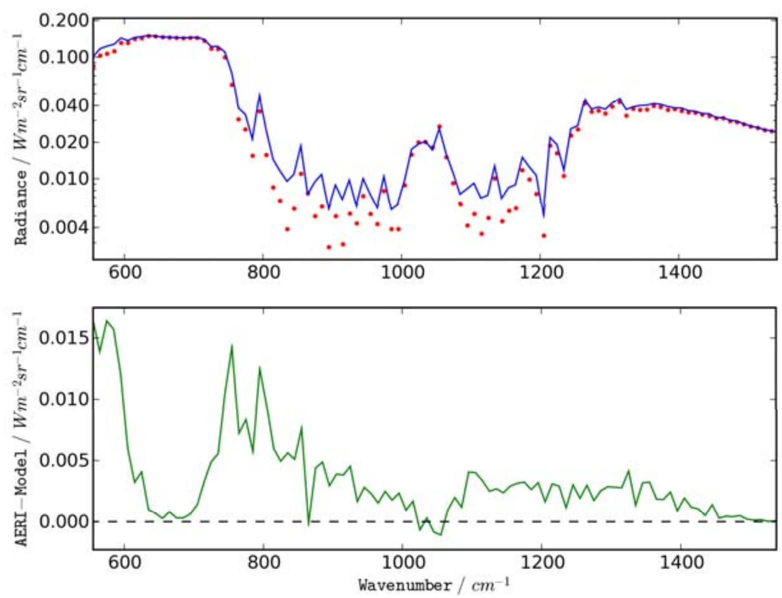
Comparison with AERI radiances, 25 November 2006

Low aerosol loading

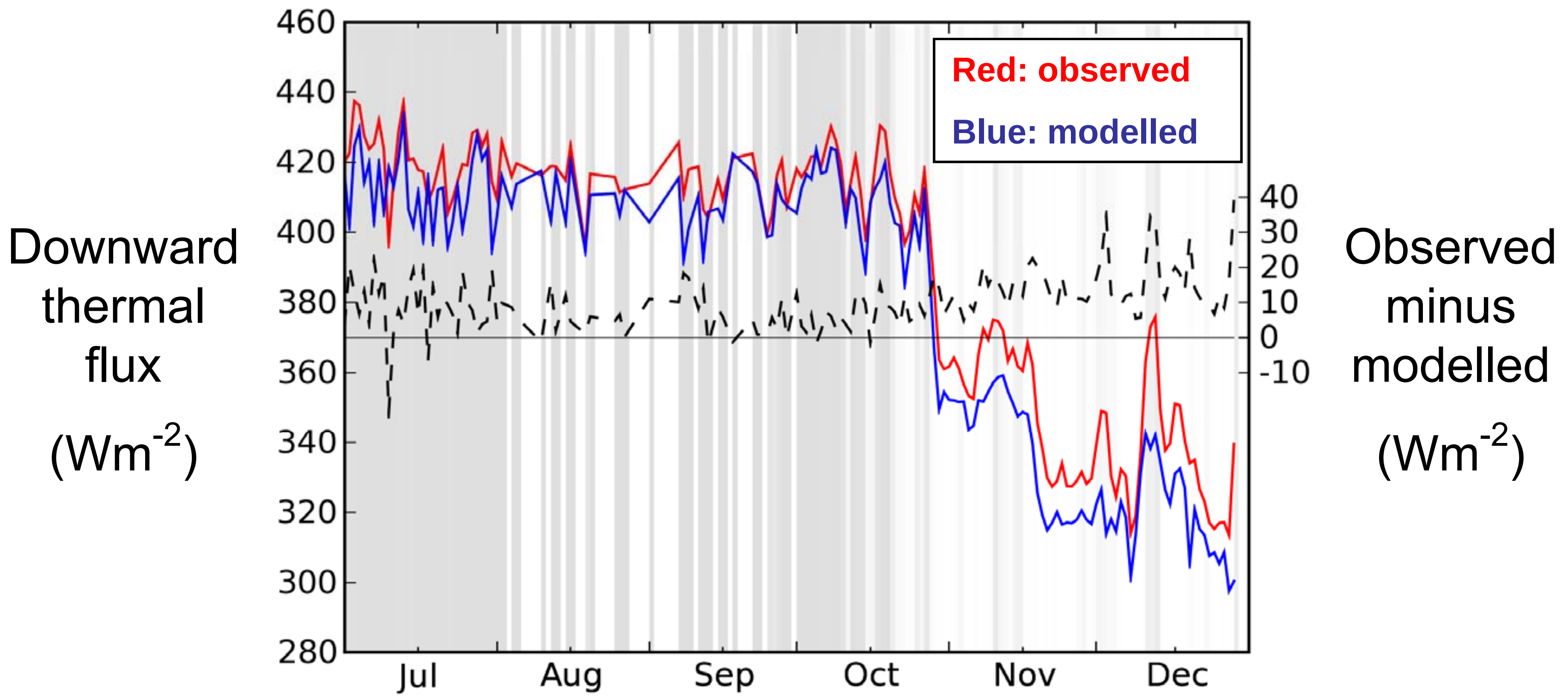
7 mm column water vapor

Blue: observed radiances

Red: modelled radiances



Comparisons with Edwards/Slingo radiation code

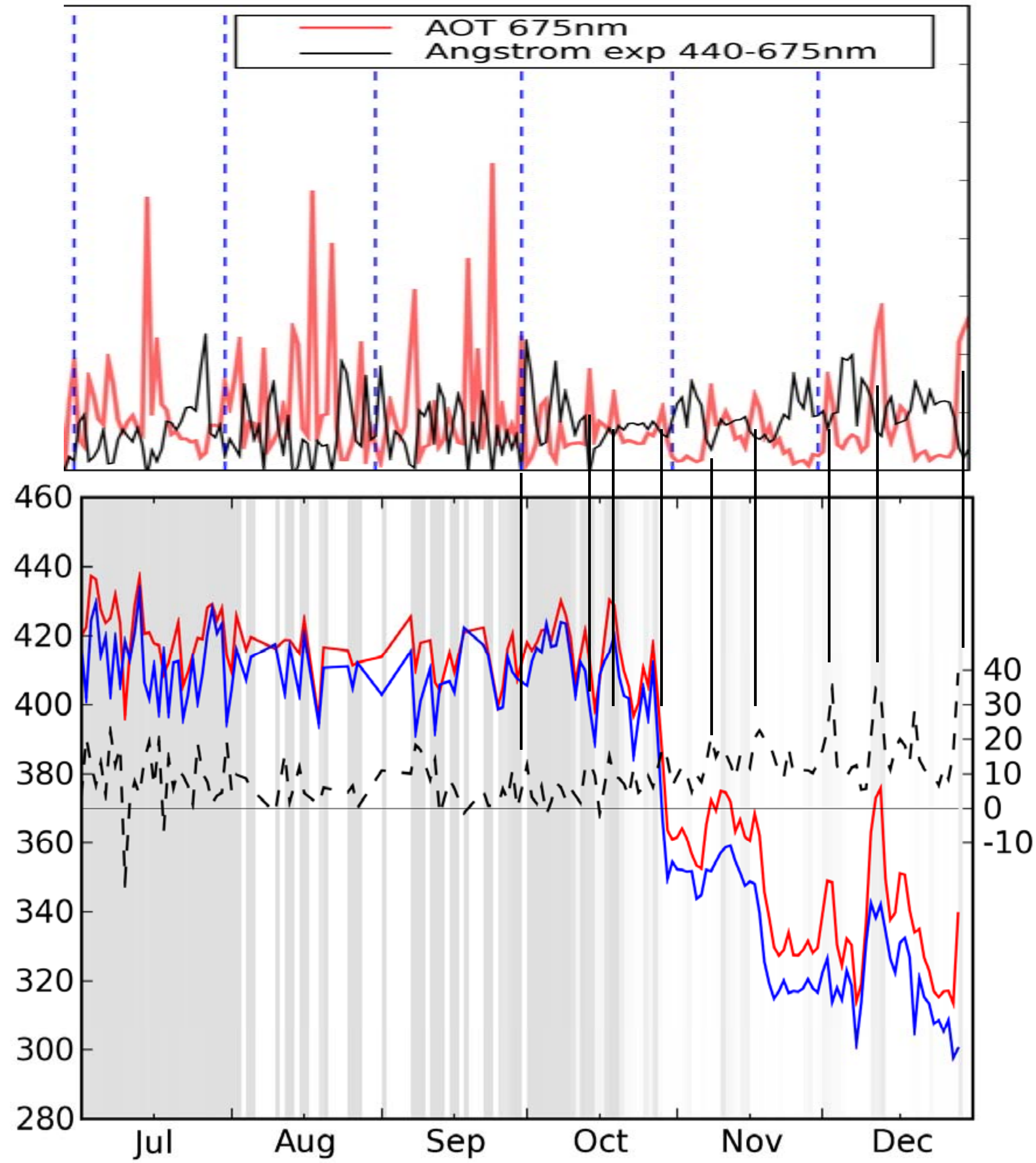


The large reduction in column water vapour in October controls the downward longwave fluxes, as shown earlier, but not the differences.

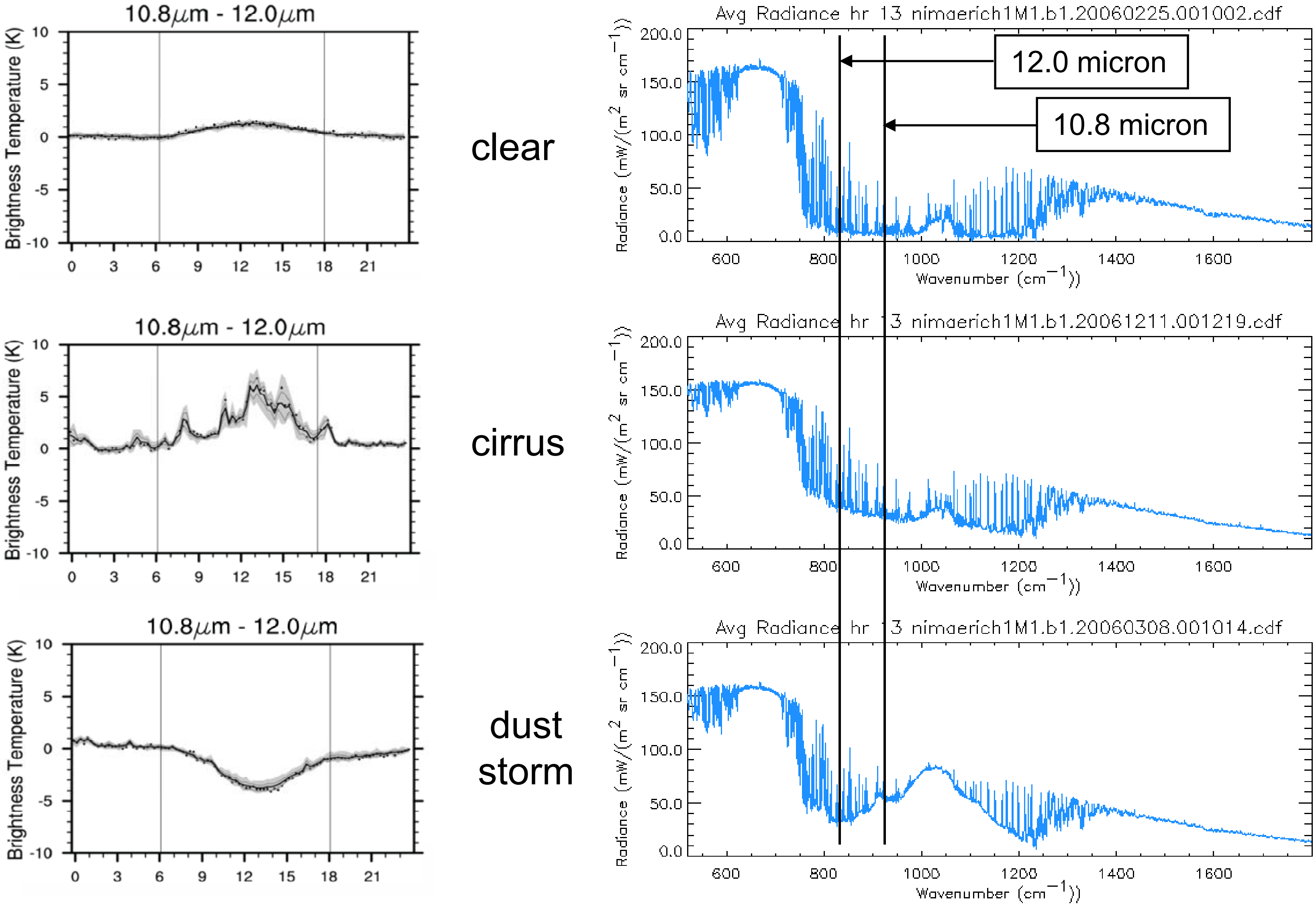
Could aerosol be causing the flux differences during the dry season?

Every peak in the Banizoumbou AOT time-series after September has a corresponding peak in the downward thermal flux difference.

However, that doesn't *necessarily* mean that the cause of the differences is aerosol; it could still be thin and/or high cloud that becomes relatively more important because of the dry atmosphere (and which also fools the aerosol retrieval).



SEVIRI 10.8–12.0 micron radiances and AERI spectra at the same time



Characterization of Dust Type and Properties at Niamey, Niger Using Downwelling Infrared Radiance Data

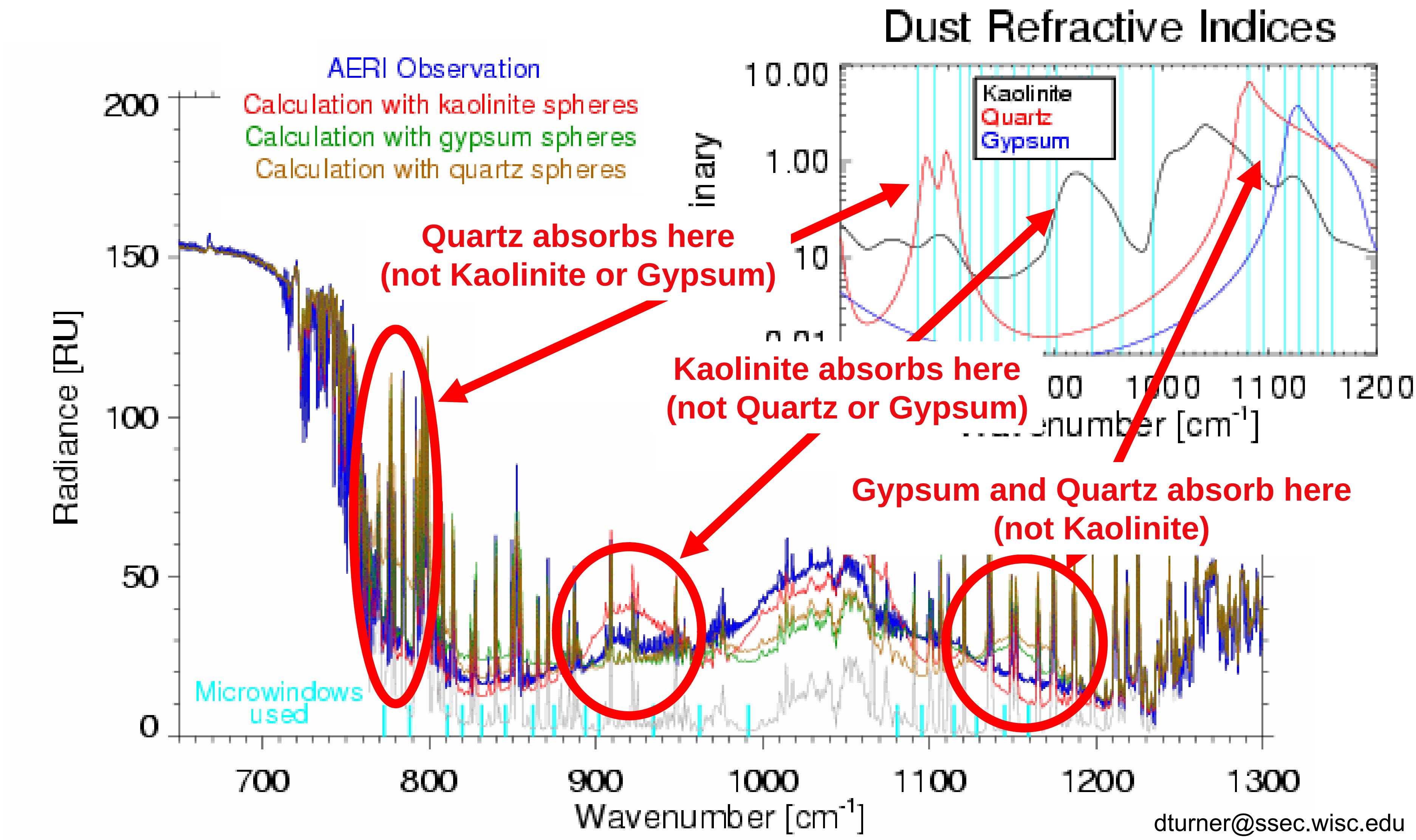
Sarah Bedka and Dave Turner

Space Science and Engineering Center

University of Wisconsin - Madison

Contribution to Tony Slingo's Plenary Presentation
Thursday 29 March 2007
ARM Science Team Meeting
Monterey, California

Infrared Spectral Signatures of Different Mineral Types



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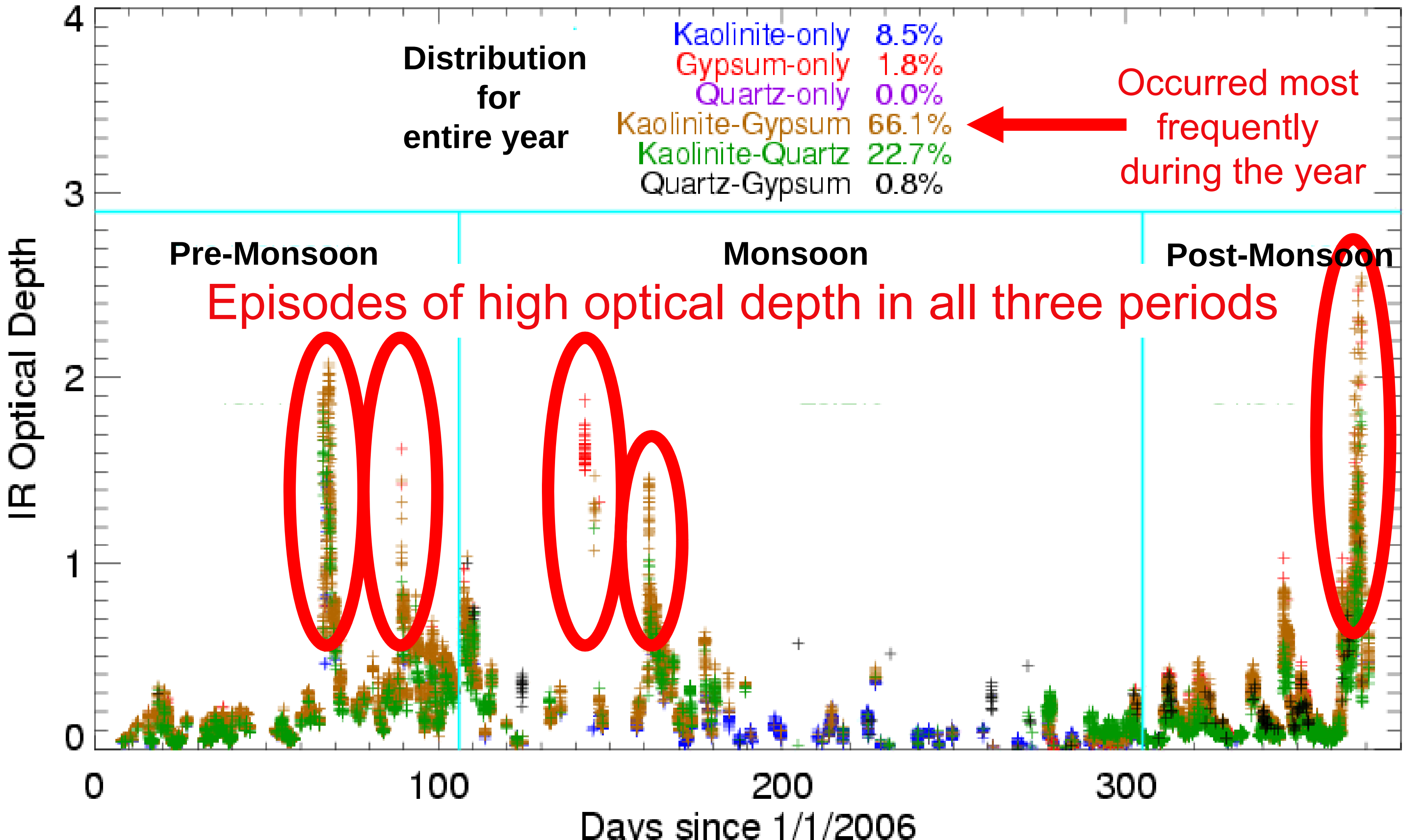
Dust Optical Depth and Composition Distribution



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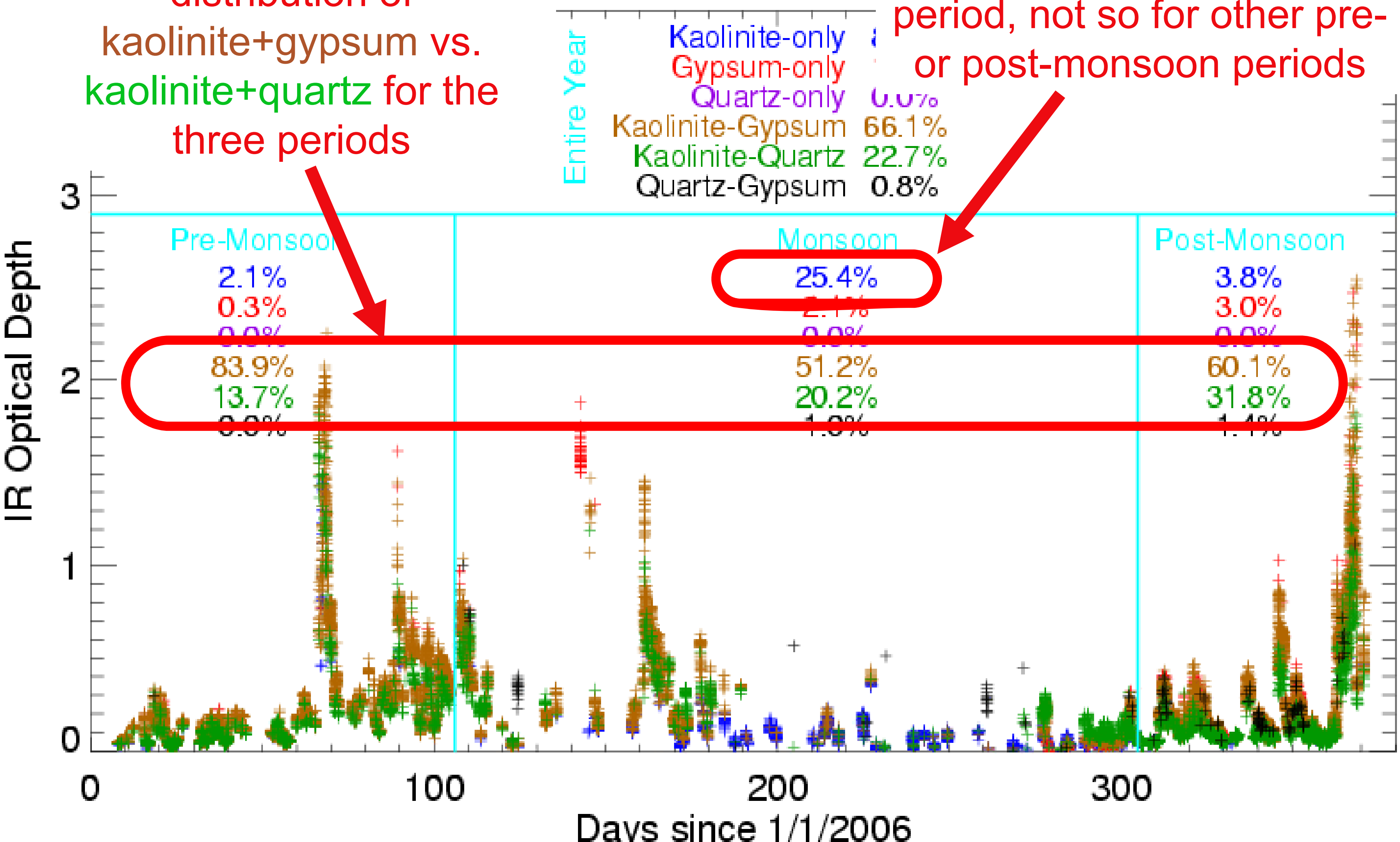
Dust Optical Depth and ...ition Dist...

Significantly different distribution of kaolinite+gypsum vs. kaolinite+quartz for the three periods

Kaolinite-only was best fit frequently during monsoon period, not so for other pre- or post-monsoon periods



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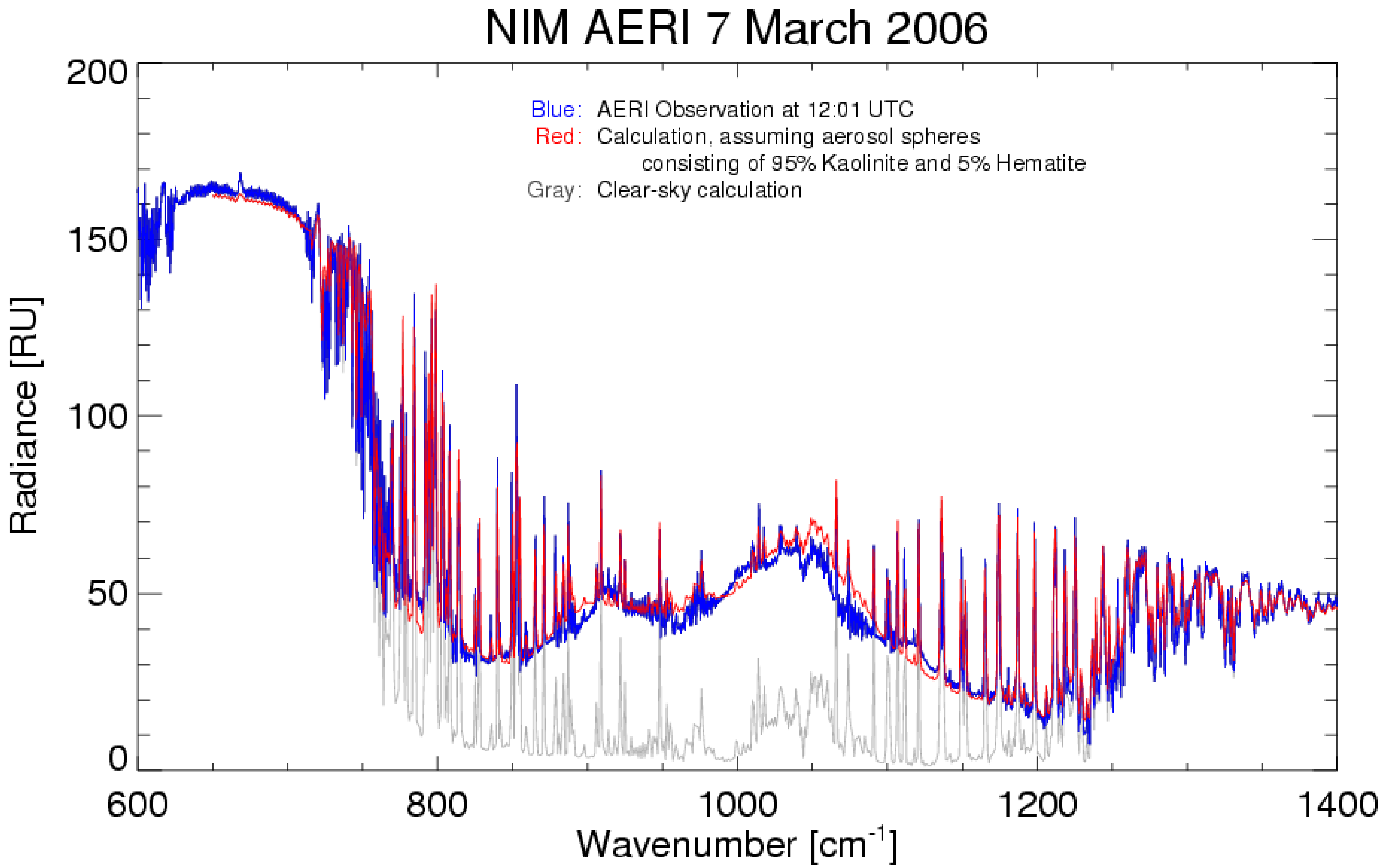


NIM AERI 7 March 2006
Blue: AERI Observation at 12:01 UTC
Red: Calculation, assuming aerosol spheres consisting of 95% Kaolinite and 5% Hematite
Gray: Clear-sky calculation
Radiance [RU]
Wavenumber [cm-1]
200
150
100
50
0
600
800
1000
1200
1400

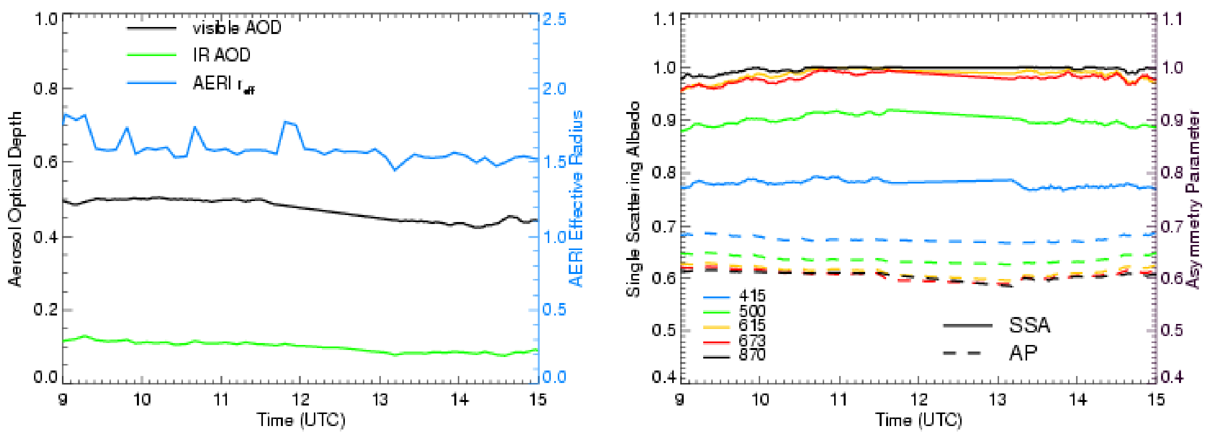
Radiative Forcing of Saharan Dust Aerosol at Niamey, Niger

S. McFarlane, E. Kassianov, C. Flynn, D. Turner, T. Ackerman

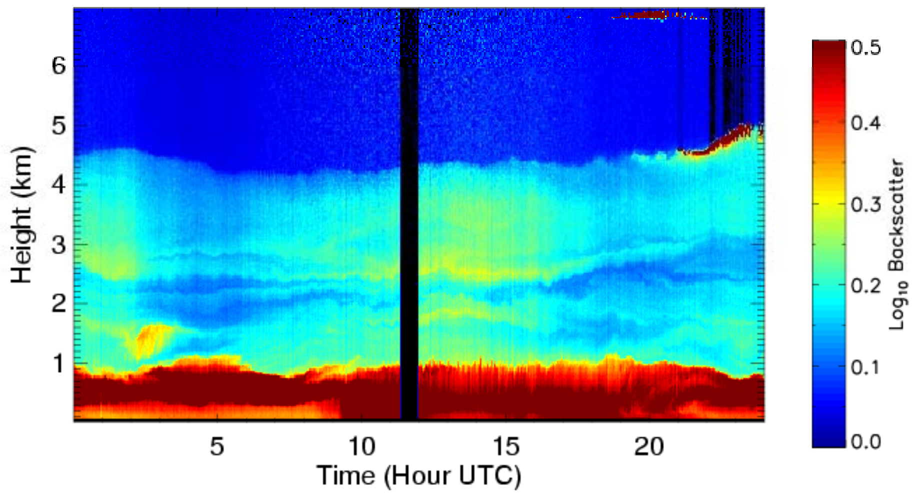
With contributions from J. Mather and J. Barnard

Aerosol properties at Niamey

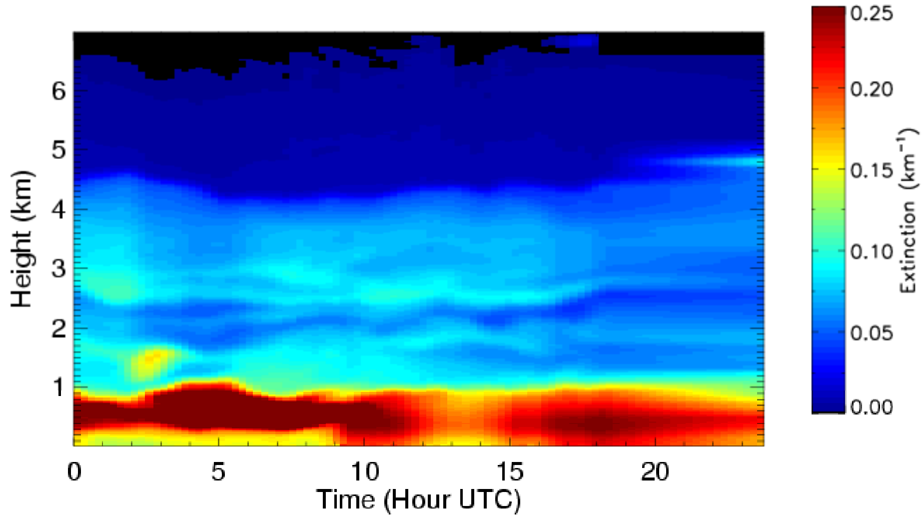
- Retrievals of column visible AOD, g, ω from MFRSR (Kassianov et al.)
- Retrievals of infrared AOD, r_{eff} from AERI, assuming kaolinite (Bedka & Turner)
- Vertical profile of extinction from MPL
- Interpolate aerosol properties over missing/cloudy periods
- Caveats:
  - Aircraft flights during DABEX show frequent cases of biomass burning aerosol overlying dust; we assume column values
  - Currently not requiring consistency between AERI/MFRSR views of aerosol
  - Issues with MPL calibration and possible temperature-dependent diurnal cycle



Jan 21 case (DABEX flight indicated dust only)



MPL corrected backscatter

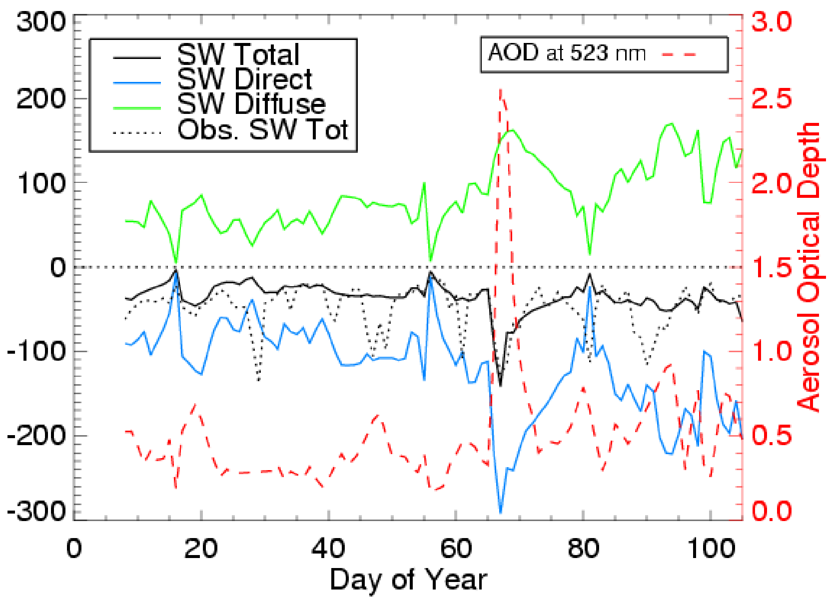


MPL calculated extinction profile

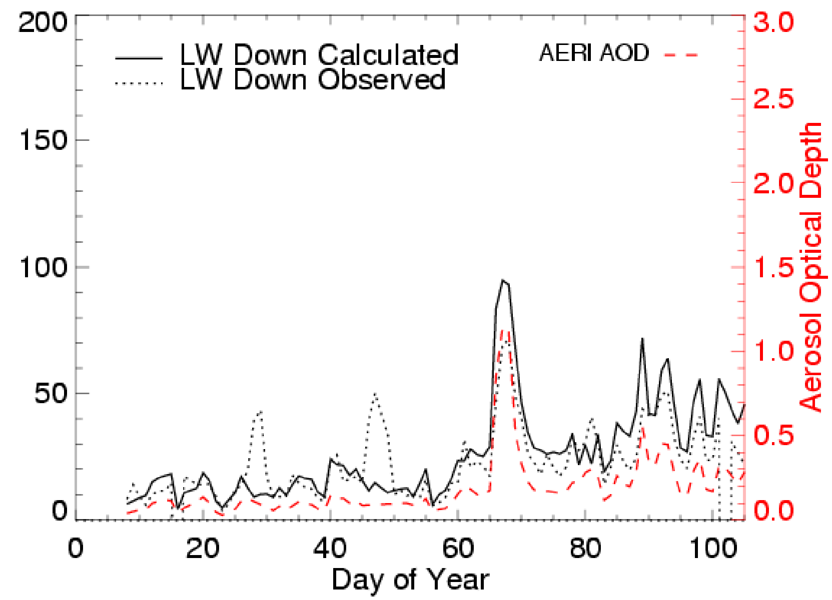
January 21

Calculated daily average SW and LW radiative effects at surface due to aerosol only (Jan-Apr 2006)

Shortwave (Wm^{-2})



Longwave (Wm^{-2})



- Daily average effect of aerosol on surface fluxes during dry season is -36.5 Wm^{-2} on SW and +26.8 Wm^{-2} on LW

DABEX aircraft measurements

The Dust and Biomass Experiment (DABEX) was part of the African Monsoon Multidisciplinary Analyses (AMMA) SOP-0 (Special Observing Period) that took place during January-February 2006 within sub-Sahelian West Africa.

The UK BAe-146 atmospheric research aircraft at Niamey

biomass burning aerosol

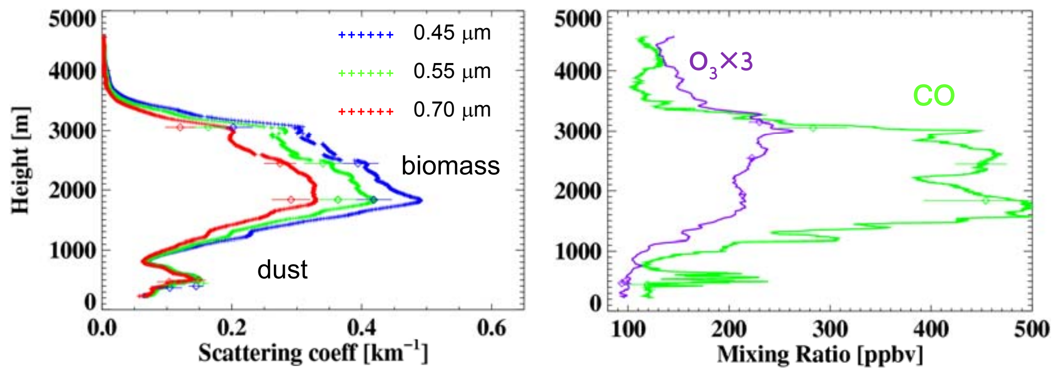
Mineral dust

Flying in a 'clear slot' between the low-level dust and the elevated biomass burning haze over Niger (flight B161)

From: Jim Haywood, Ben Johnson and Simon Osborne (Met Office)

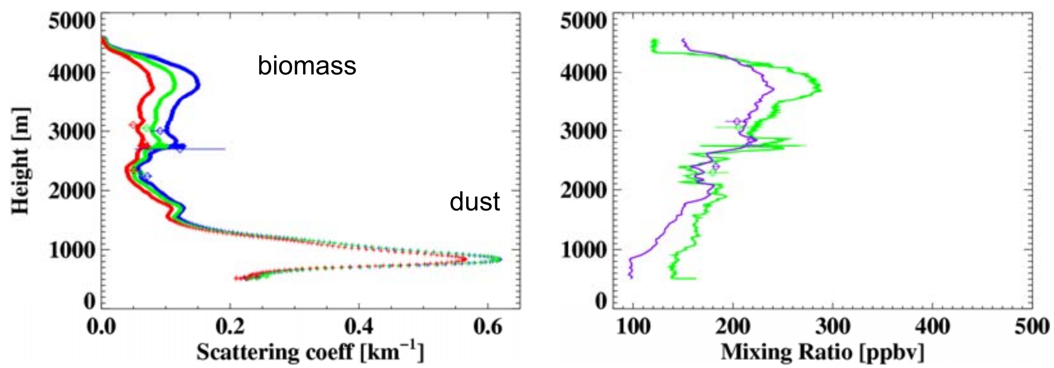
A common feature through DABEX was the presence of an aged biomass burning layer overriding a low-level mineral dust layer. The aged biomass burning layer constituted a regional haze that was a constant presence in DABEX.

The strengths of these layers (i.e. their contribution to the optical depth) varied from day to day as is shown on the right. CO and O_3 are strongly correlated with scattering in the biomass burning layer, but O_3 shows depletion in the dust layer possibly due to uptake on the particles.



Flight B159 (19 January 2006)

(a) total scattering coefficients and (b) ozone (multiplied by 3 for scale purposes) and carbon monoxide concentrations.



Flight B160 (21 January 2006)

(a) total scattering coefficients and (b) ozone (multiplied by 3 for scale purposes) and carbon monoxide concentrations.

Aerosol optical properties observed during DABEX (Niamey, January 2006), compared with SHADE and SAFARI

Data source & aerosol type	**Observed** single scattering albedo: ω	**Mie-calculated** single scattering	**Mie-calculated** extinction: K_{ext} (m^2 g^{-1})	**Mie-calculated** assymetry parameter: g
DABEX generic aged biomass aerosol	**0.73-0.90**	**0.83**	5.0	0.59
SAFARI A790 aged biomass aerosol	0.89-0.93	**0.91**	5.0	0.59
DABEX (B160 & B161) generic dust	**0.98-1.0**	**0.98**	0.72	0.71
SHADE A797 dust	**0.93-0.97**	**0.95**	0.42	0.74

What is the possible wider relevance of these measurements?

- 2005 was the most active hurricane season in recent history
  - total storms 28 (record), hurricanes 15 (record), major hurricanes (cat 3+) 7, of which 5 made landfall in the USA, including of course Katrina
- 2006 in contrast was a weak hurricane season
  - total storms 10, hurricanes 5, major hurricanes (cat 3+) 2
  - no significant tropical storms made landfall in the USA
- WHY?

How Nature Foiled the 2006 Hurricane Forecasts

Eos, Vol. 88, No. 9, 27 February 2007

By W. K. M. Lau and K.-M. Kim

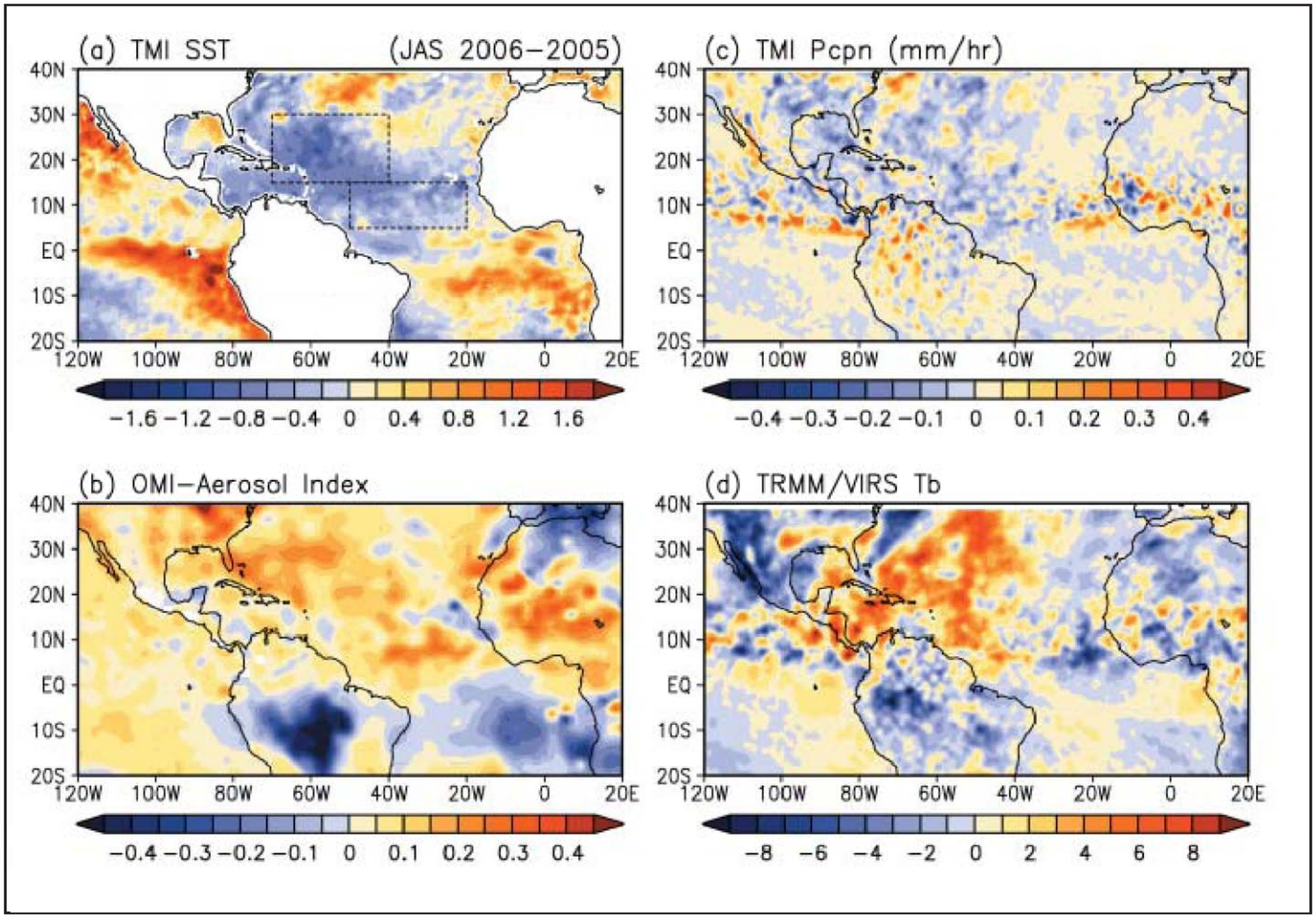


Fig. 2. Maps show difference between JAS 2006 and 2005 (2006 minus 2005) of (a) SST (°C), (b) OMI/AI (units are nondimensional), (c) TMI rainfall (millimeters per hour), and (d) Visible Infrared Scanner cloud top temperature (T_b, °C).

Summary and future work

- Over a year of data from the AMF, GERB and SEVIRI
  - several articles and press releases: http://www.arm.gov
  - major dust storm in March 2006 (Slingo et al., *Geophysical Research Letters*, 30 December 2006)
  - overview paper by Miller and Slingo in *Bulletin of the American Meteorological Society* (scheduled for August 2007)
- Aerosol has a large influence on solar fluxes (expected) and appears to have a significant influence on thermal fluxes (unexpected)
- Ongoing work includes:
  - analysis of AMF and GERB fluxes throughout 2006, for clear and cloudy conditions, and comparisons with radiation and NWP models
  - developing the methodology to derive area-average surface fluxes, including exploiting the data from the second site at Banizoumbou
  - combining AMF and GERB data to derive atmospheric divergence
  - Radagast website; http://radagast.nerc-essc.ac.uk