Fennec:
The Saharan Climate System
(part of the AMMA legacy)

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Mohamed Bechir, (ONM Mauritania)
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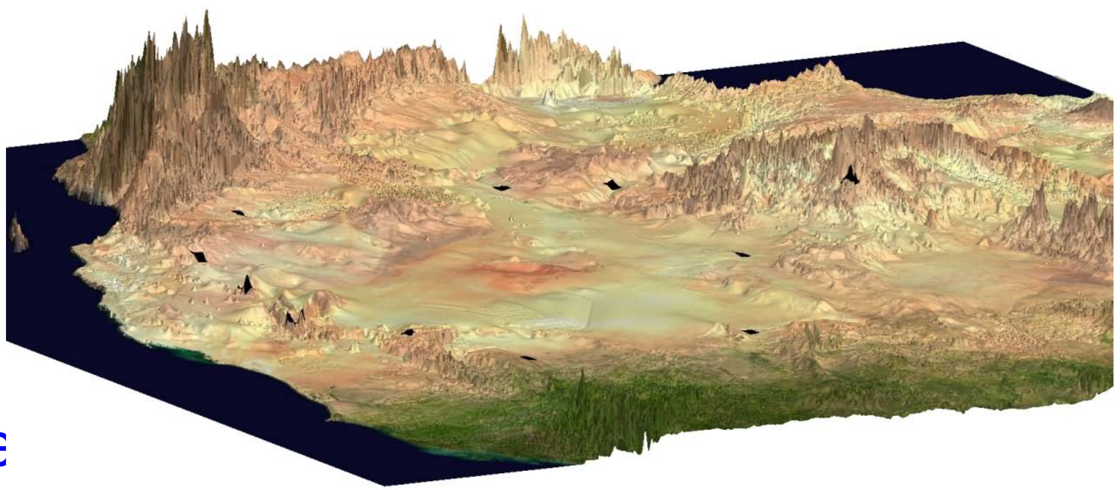
The Fennec ‘Parents’

and many, many other researchers, scientists and engineers

WAM and the Saharan Heat Low

- The Saharan Heat Low region is vital to the West African Monsoon



- The Heat Low region has virtually no routine met observations

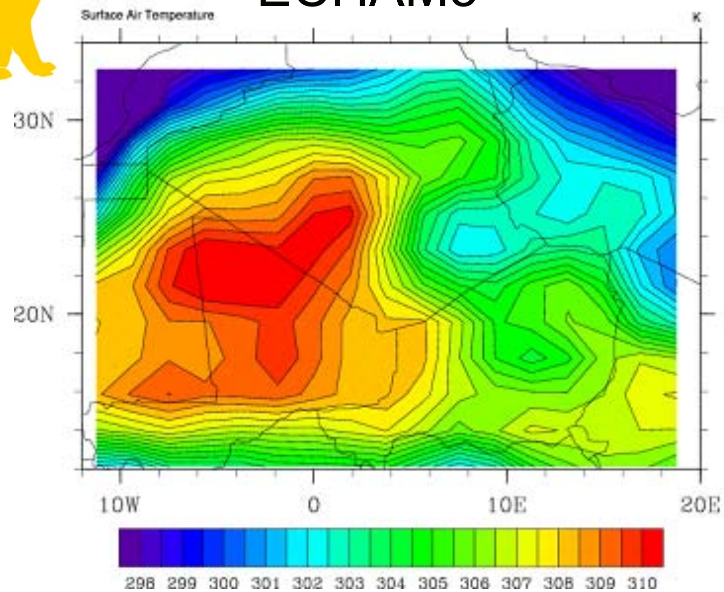
- Much of what we know about the Saharan Heat Low comes from numerical products

- This is a worrying situation!

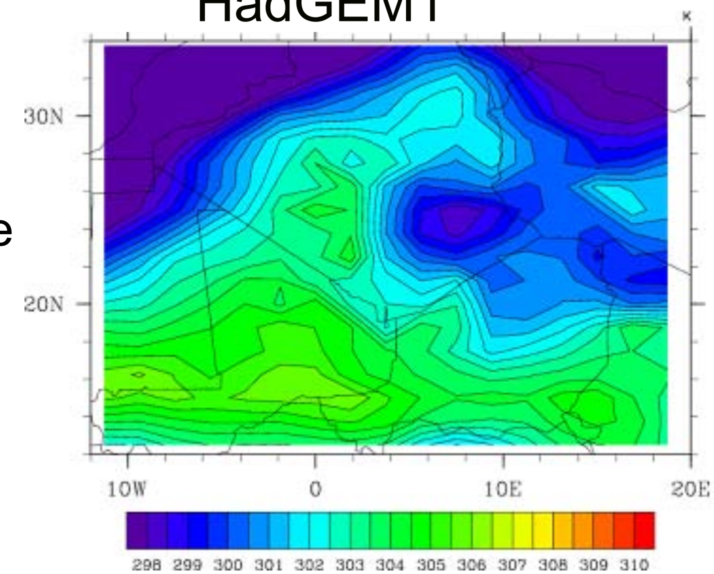
CMIP3 Climate Models

2m Temperature 1970-1999

ECHAM5

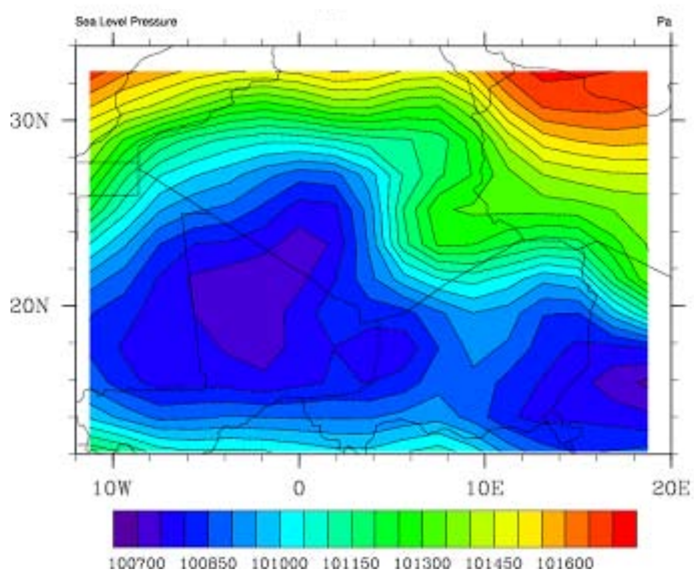


HadGEM1

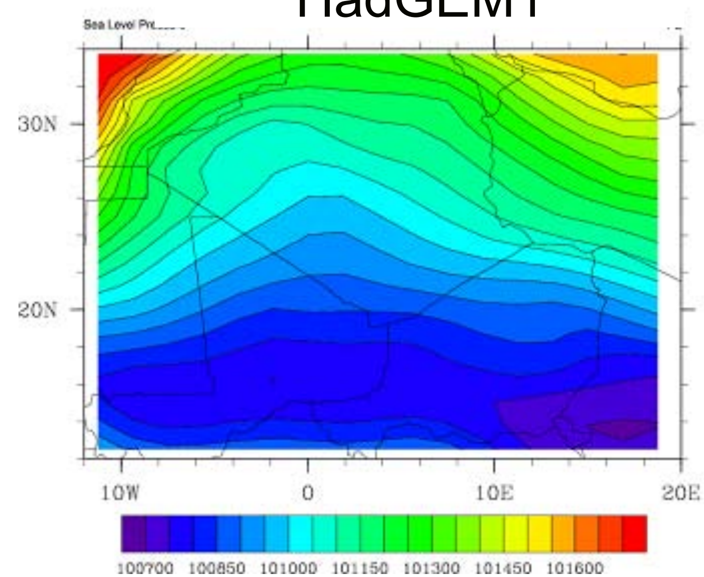


MSLP 1970-1999

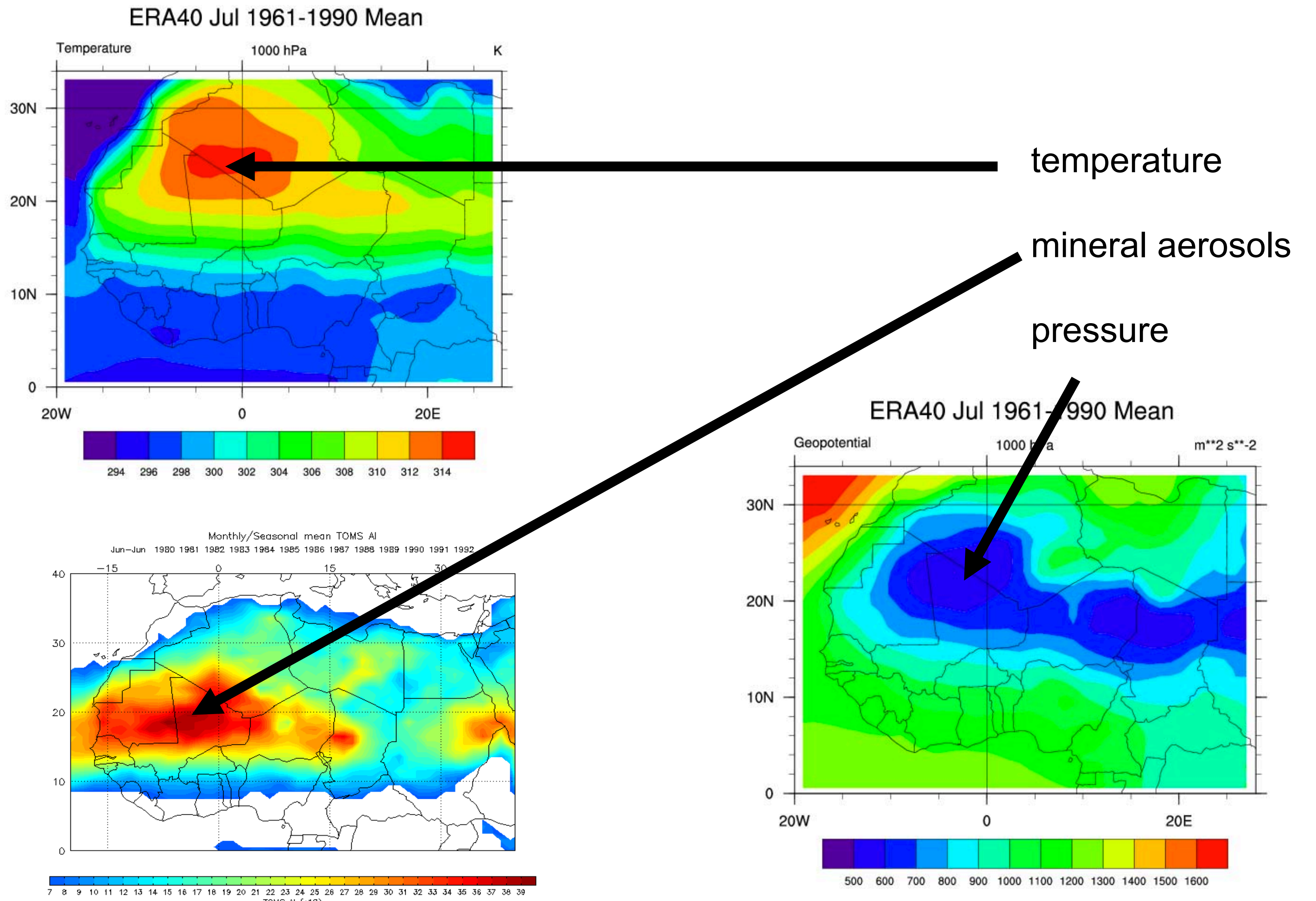
ECHAM5



HadGEM1

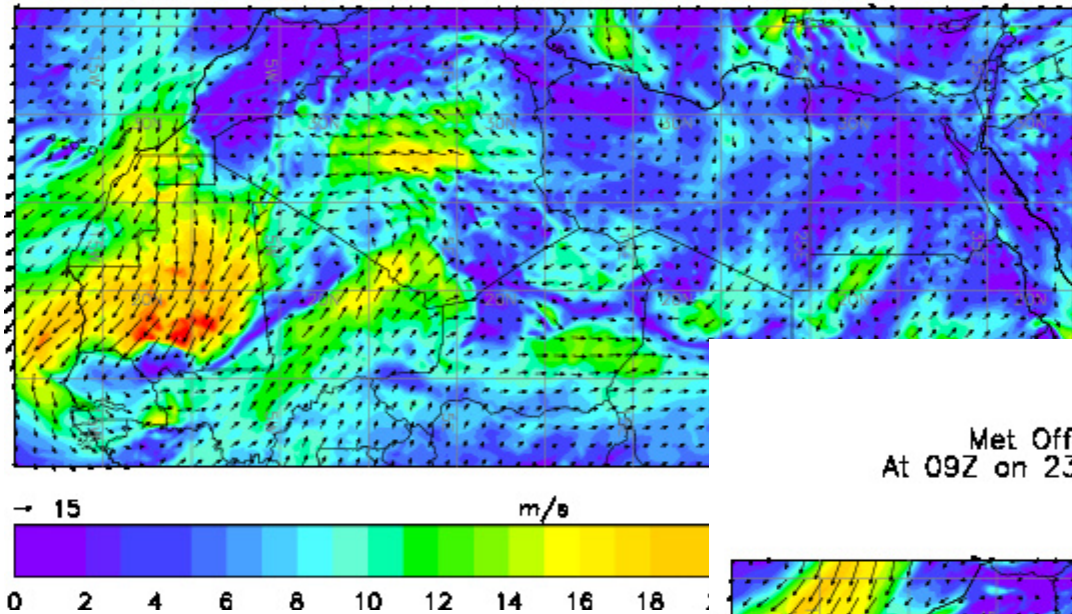


The central Sahara is the locus of numerous extremes in the Earth System: It is interesting in its own right



Met Office Africa Model Horizontal Winds
At 09Z on 22/06/2012, from 06Z on 22/06/2012

925hPa Wind T+003



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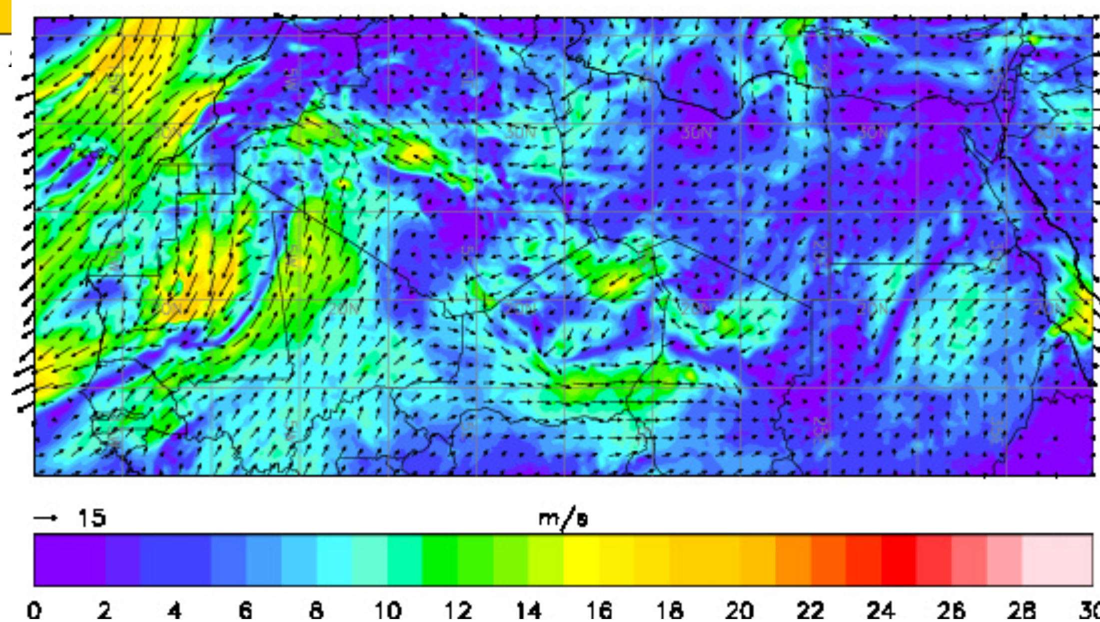
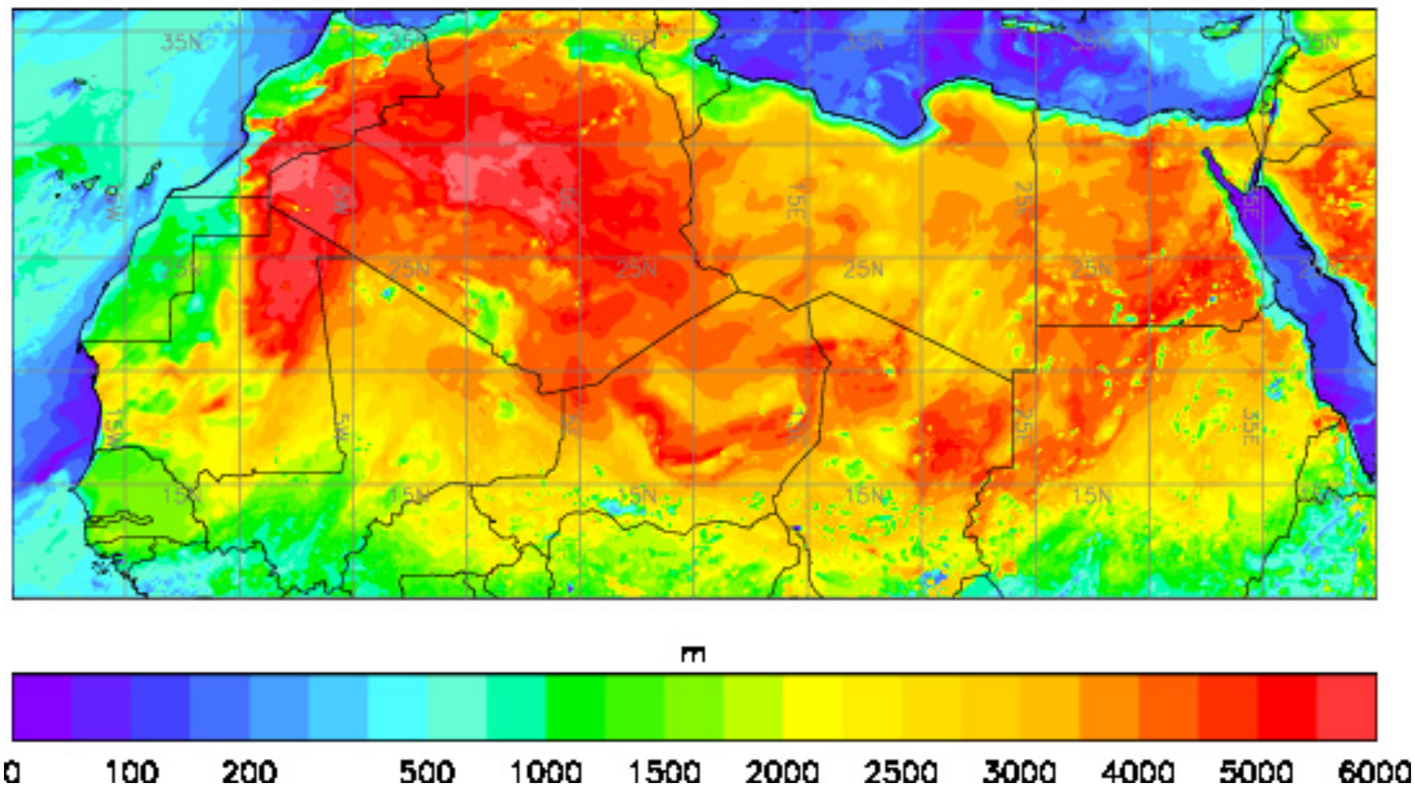
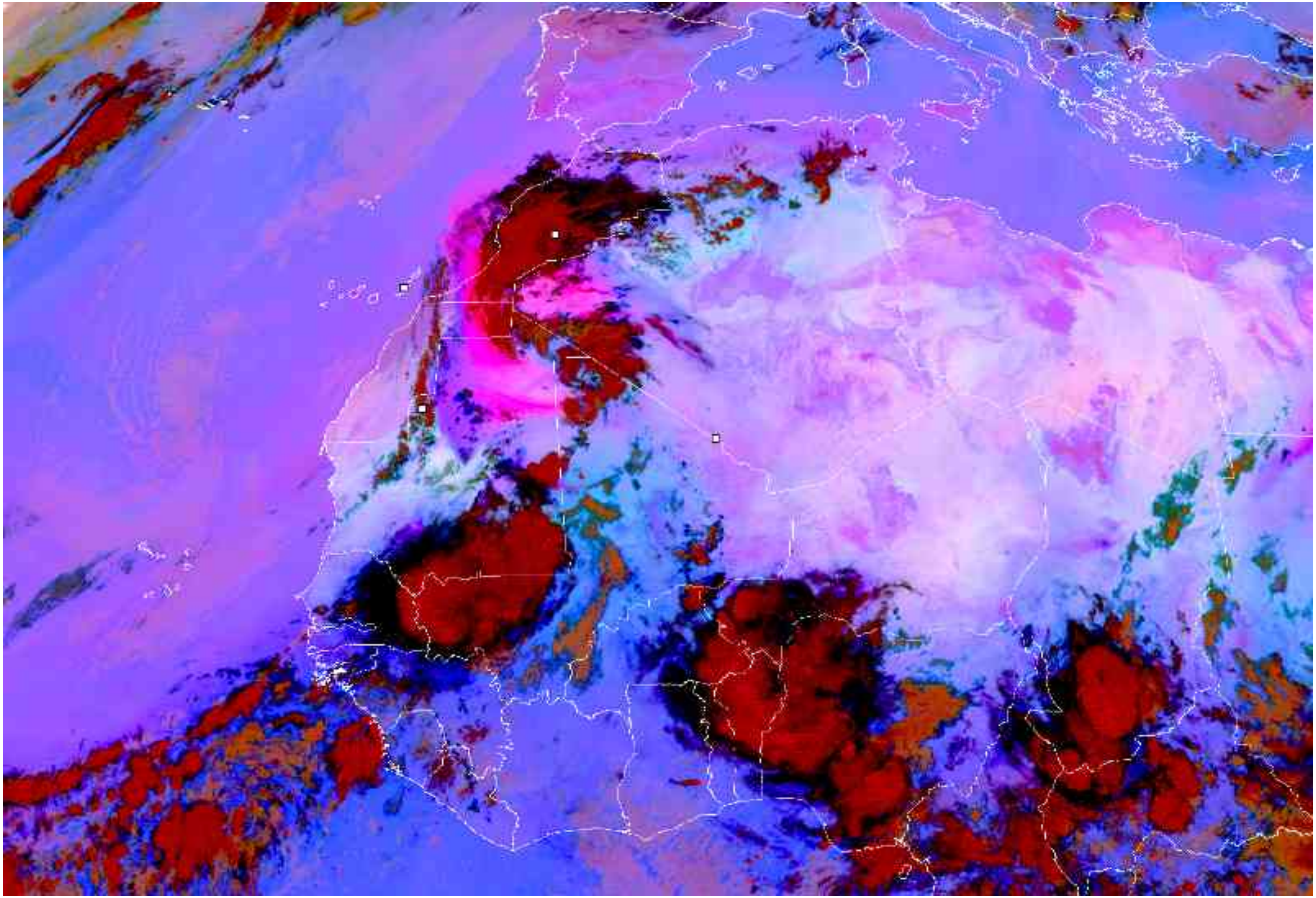


Met Office Africa Model Boundary Layer
At 15Z on 23/06/2012, from 06Z on 23/06/2012

Bounday Layer Depth T+009



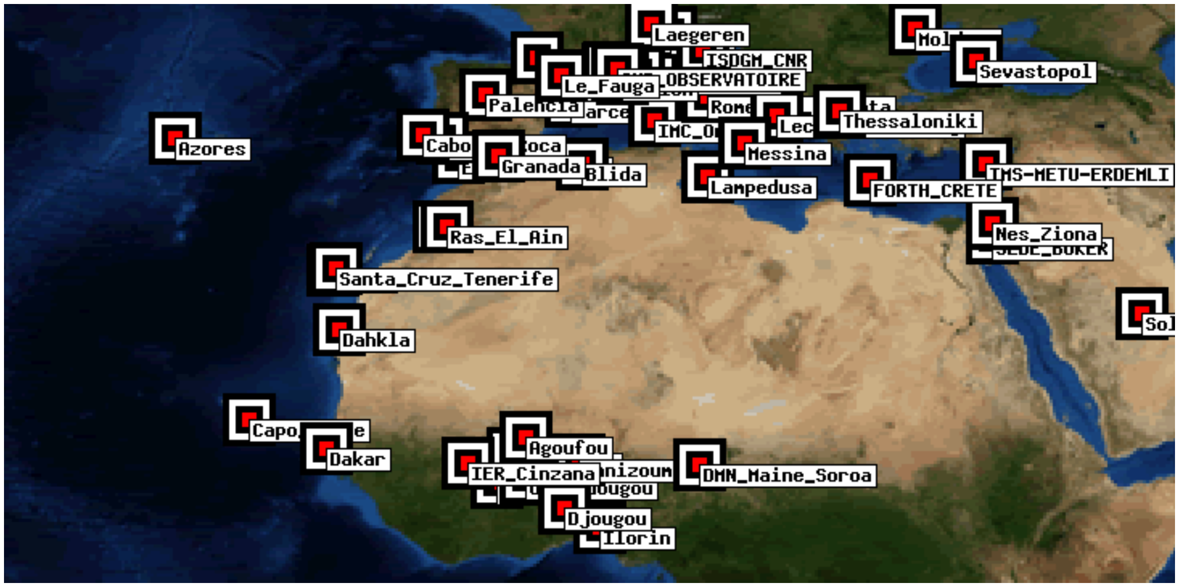
0930 on 21 June 2012 to 0330 on 24 June 2012 Hourly steps



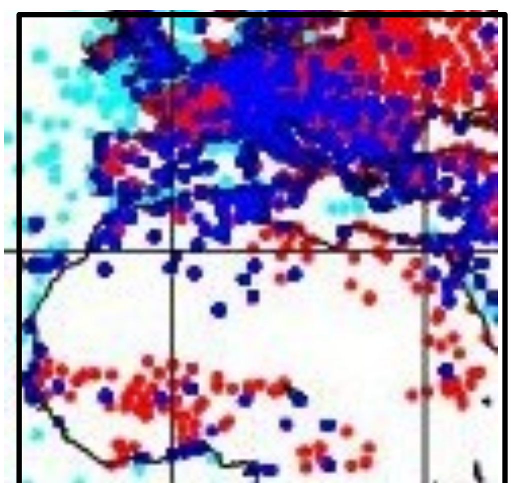
Saharan Climate System

- ✓ Widespread acknowledgement of importance – role in WAM onset, cessation, strength
- ✓ Insight from central Sahara derives from numerical model products
- One view of the Saharan Heat Low: dust laden homogenous mass of hot air which is influenced by processes on its edges e.g. Atlantic inflow, Monsoon incursions, mid-latitude transients
- Is this view correct?
- Do the models capture the key processes important to the Heat Low? Is dust in the right place at the right time? Is the interaction between dust and radiation correctly specified? Without observations, how do we know any of this?

Met Observations are currently on the fringes of the Sahara

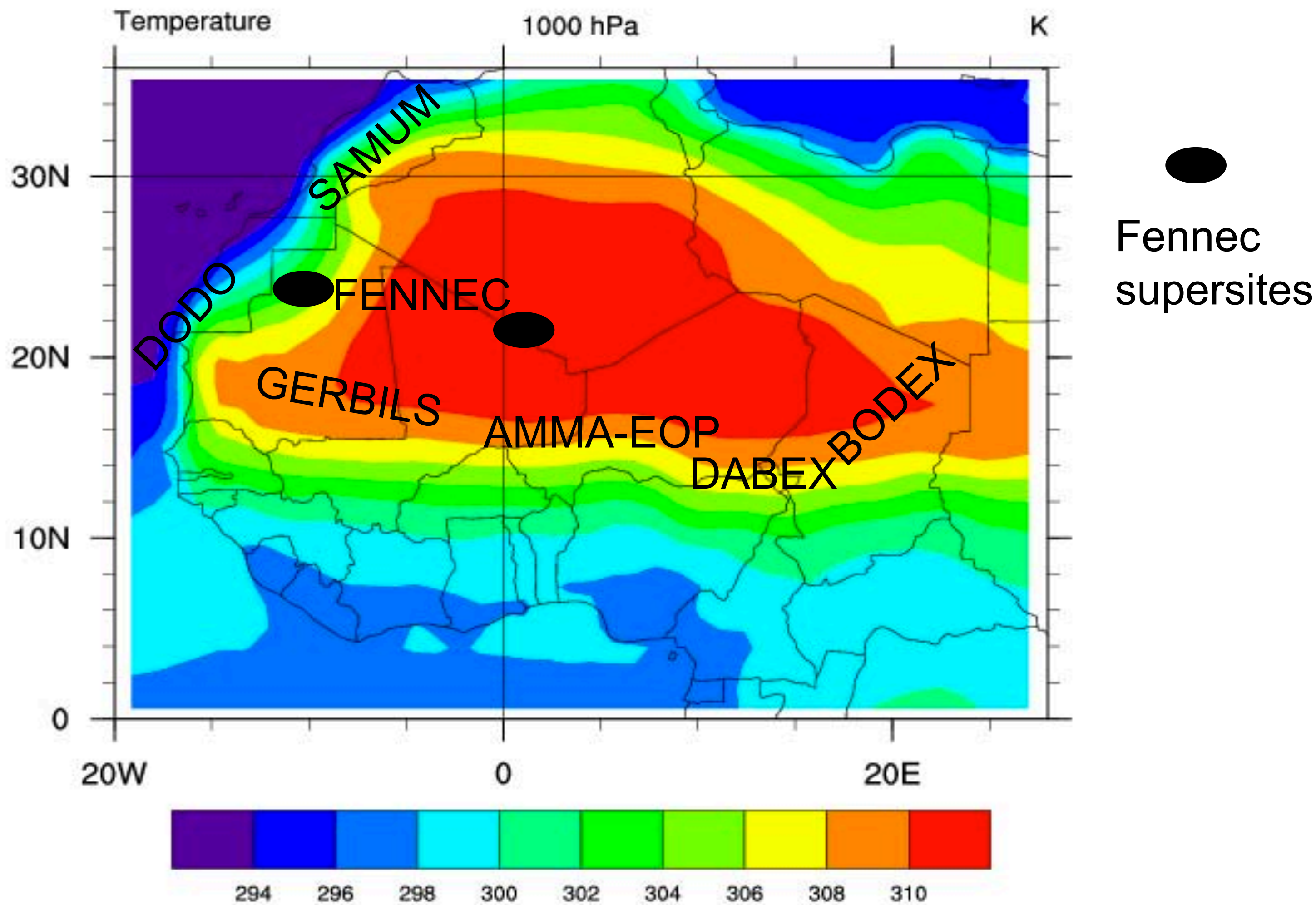


Aeronet Level 2 Sites operational >1yr
aeronet.gsfc.nasa.gov/



Surface synops/metar
14 April 2009
www.ecmwf.int/products/forecasts/d/charts/monitoring/coverage/dcover/

Other campaigns have worked at the edges of the Sahara.
Fennec the first to work in the central Sahara



Mean June Temperature K

Broad Fennec aims

- New data set for central Sahara from aircraft, ground, model and satellite observations
- Characterisation of thermodynamic, dynamic and compositional structure of central Sahara's troposphere
- A quantitative assessment of model errors and how these can be reduced
- The mechanisms of dust emission, transport and radiative forcing from the planet's largest summer source
- **Fennec is a significant legacy of AMMA**
- **Note: You probably have not heard much information about Fennec. The field programme was in a complicated region. Publicity was not possible until now.**

Fennec Organisation: Work Packages

Mainly 'Service and Data' Packages

- WP1 Ground Campaign
- WP2 Airborne Programme
- WP3 Earth Observation
- WP4 Modelling

'Science' Packages

- WP3 Earth Observation
- WP5 Dynamics
- WP6 Radiation
- WP7 Dust Generating Mechanisms

For details on institutional involvement, see Fennec project poster

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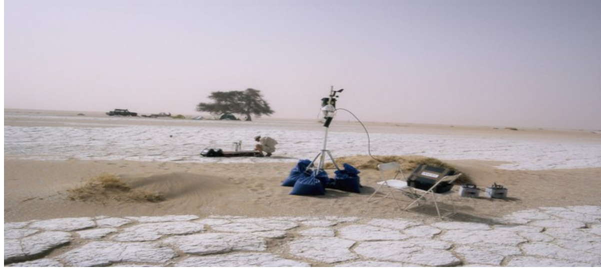
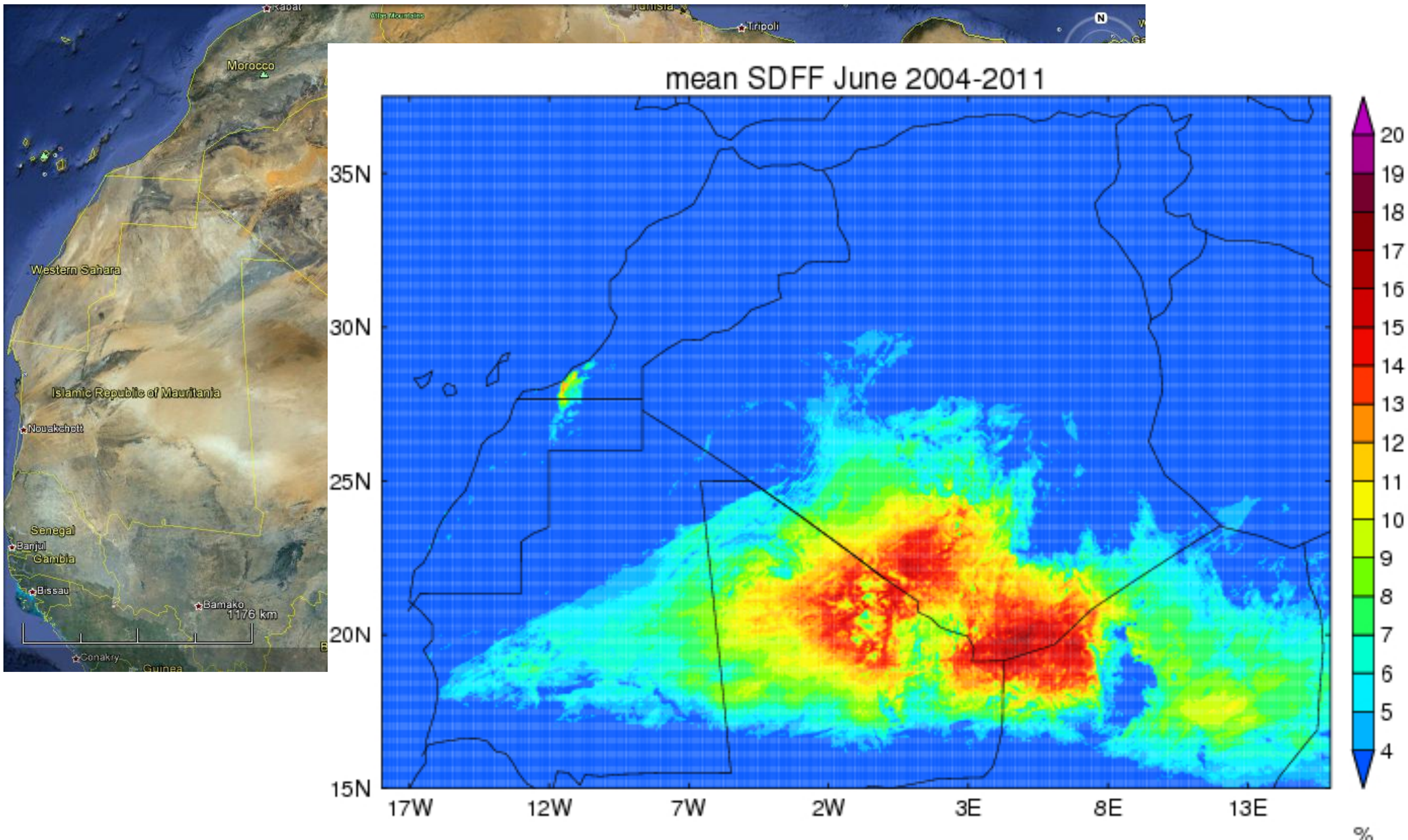
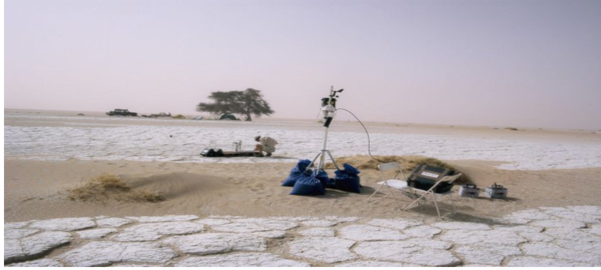
WP1: Ground Campaign



- Two Supersites (Bordj Mokhtar - Algeria, Zouerat – Mauri)



WP1: Ground Campaign
Supersite: Bordj Badji Mokhtar:
(Thursday 1730 **17:30 Pr.8B .7 John Marsham)**



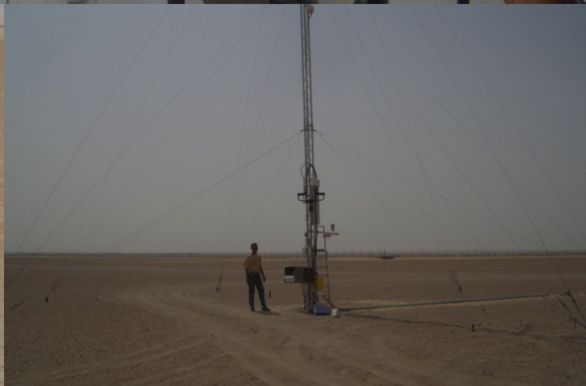
- June 2011:
  - Cimel photometer, Lidar (HALO photonics 1.5 micron), nephelometer, aerosol filters: aerosol properties: concentrations, morphology, size, SSA, composition, spectral absorption, visibility
  - 15m Flux tower (T, q, u,v,p, SW, LW, Qe, Qs, G, 10m and 15m 20-Hz sonic anemometer), visibility
  - Sodar
  - 4-8 radiosondes daily + enhanced sondes at Tam, In Salah, Tindouf
- June 2012:
  - Cimel photometer
  - 15m Flux tower
  - 4-8 radiosondes daily
- June 2011-present
  - Flux tower

Flux: sonics, vis etc (above) Sodar & sondes (right)

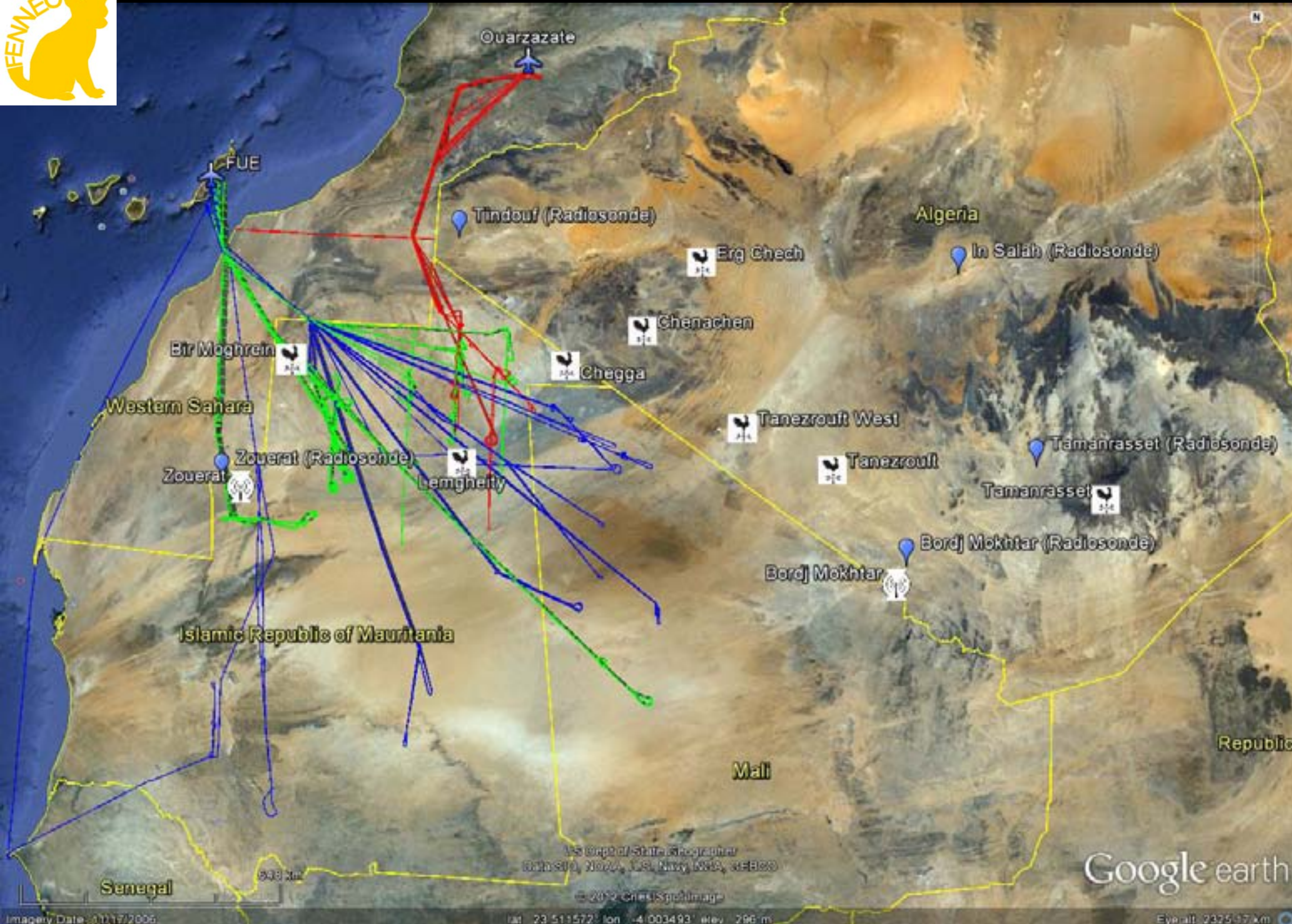
Lidar (u,v,w, dust)

Bordj Badji Mokhtar Supersite: run by ONM Algerie

heat and radiative fluxes



FENNEC


Ouarzazate
FUE
Tindouf (Radiosonde)
Algeria
Erg Chech
In Salah (Radiosonde)
Chenachen
Bir Moghrein
Chegga
Western Sahara
Tanezrouft West
Tamanrasset (Radiosonde)
Zouerat (Radiosonde)
Zouerat
Lemghetty
Tanezrouft
Tamanrasset
Bordj Mokhtar (Radiosonde)
Bordj Mokhtar
Islamic Republic of Mauritania
Republic
Mali
Senegal
Google earth

Fennec AWS network:
5 AWSs in remote desert in Algeria
3 in Mauritania
3 minute averages transmitted to Satellite

Installed by ONM Algeria & Mauritania

WP2: Airborne Programme

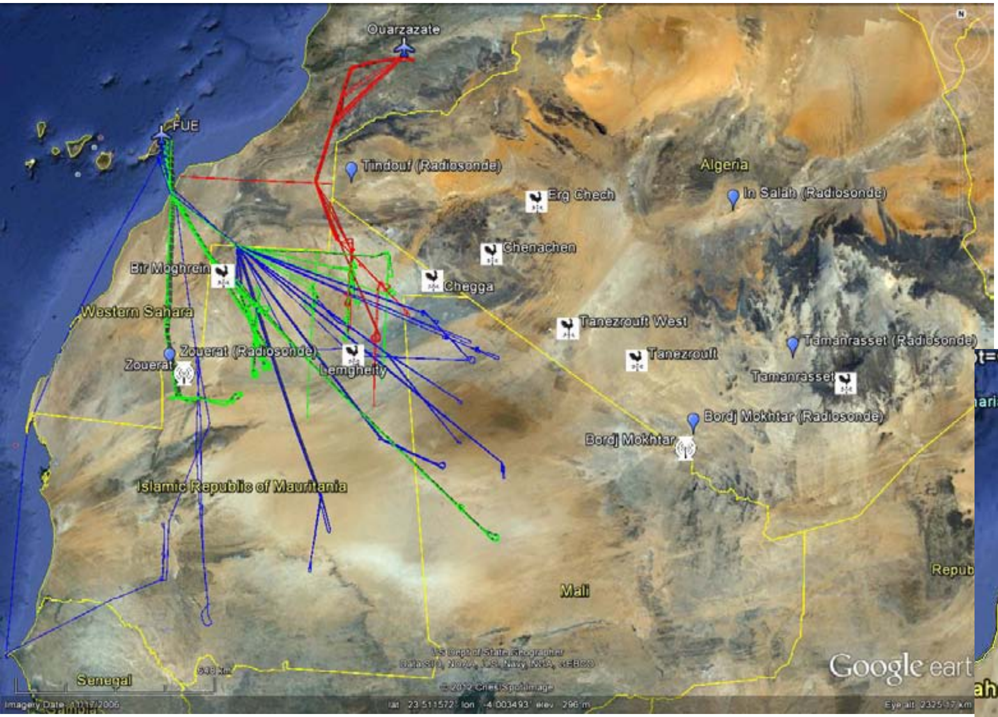
- 3-D structure of troposphere essential for modelling, Earth-Obs, aerosol-radiative impacts, aerosol transport
- First dedicated programme for central Sahara

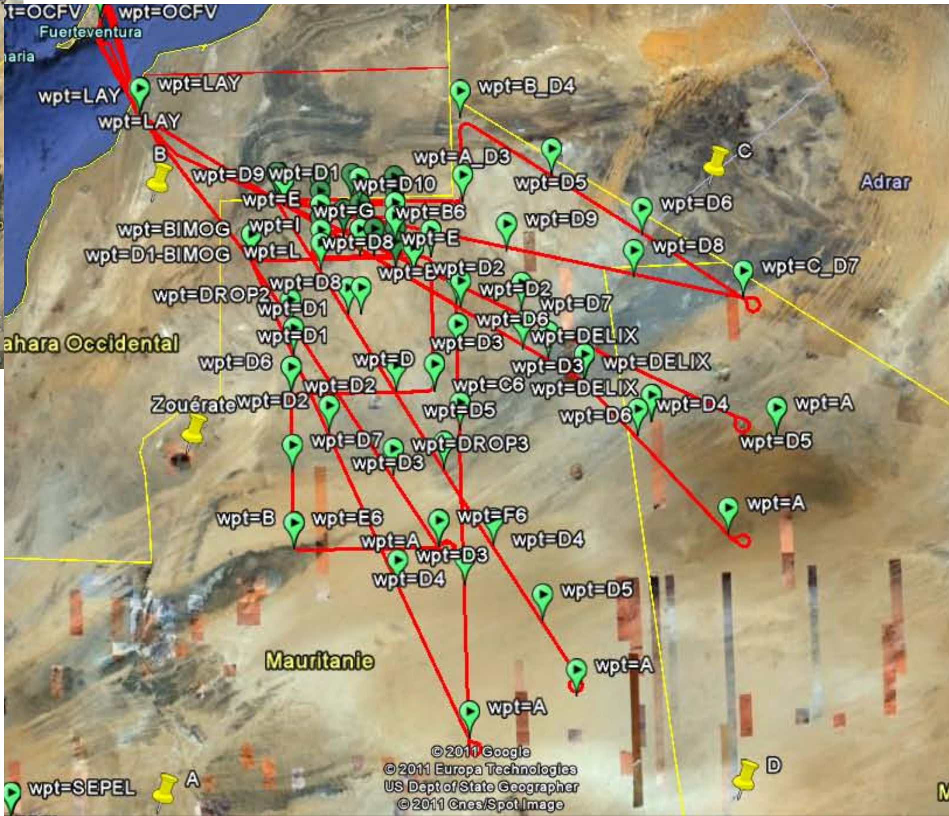
- UK BAe146 + F20 = 200 hours over central Sahara
- April 2011 from Ouarzazate, Maroc (BAe146)

- June 2011 from Fuerteventura
  BAe146 16 flights (83 hours) 72 dropsondes
  F20 18 flights, 137 dropsondes
- June 2012 from Fuerteventura (BAe146)
  14 flights, 63 hours 49 dropsondes

- Key instrumentation includes: downward LIDAR, upgraded Low Turbulence Intake for coarse mode on 146, in-situ measurements, low level flights

Fennec Flying:
April 2011 from Ouarzazate: BAe-146
June 2011 from Fuerteventura: BAe-146 and F20
June 2012 from Fuerteventura: Bae-146



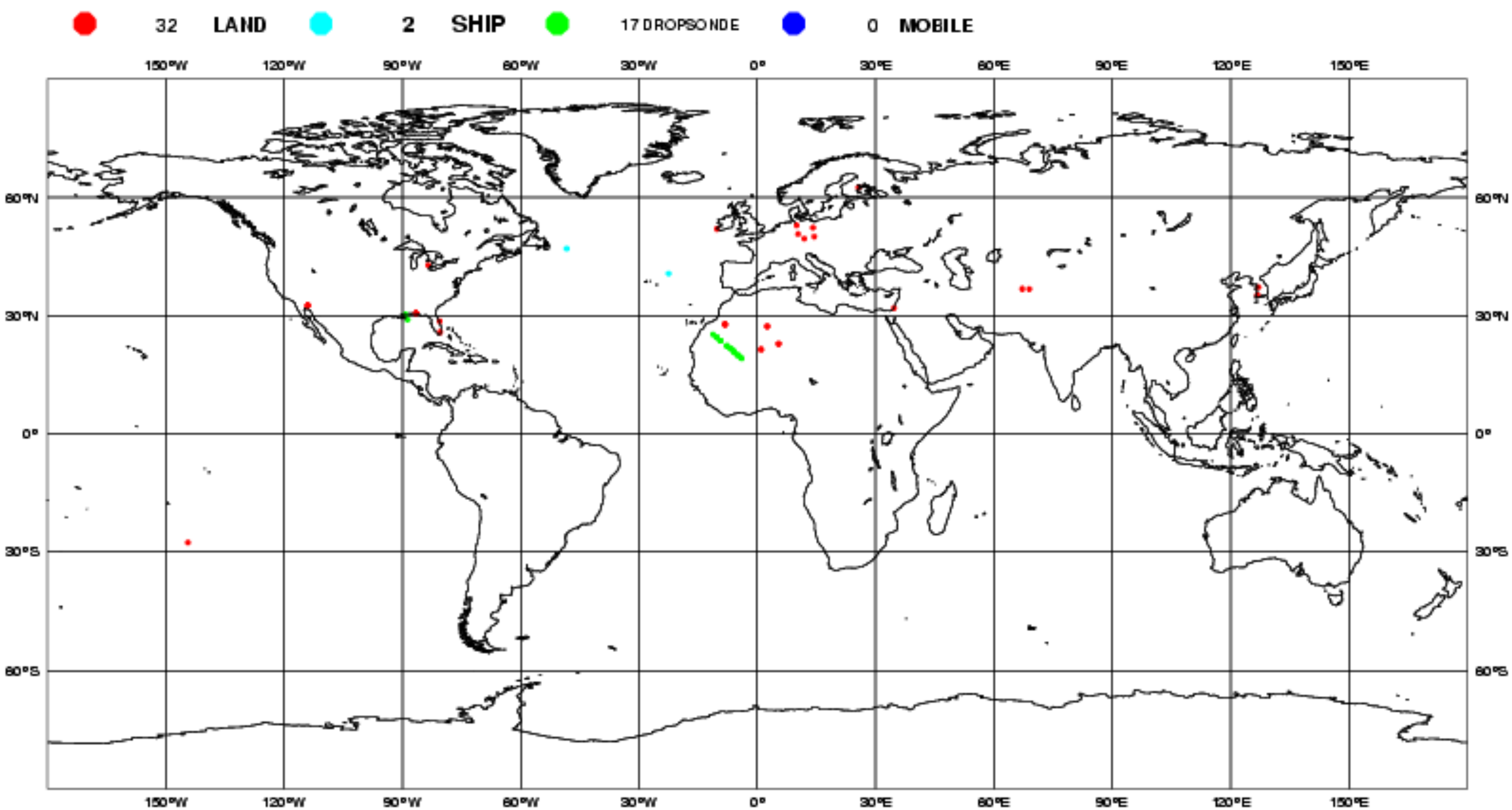


<u>Flights plans included:</u>
Synoptic surveys
Heat-flux
Radiation
Cold-pool outflows
Dust outbreaks
Saharan heat-low assessments
Low Level Jets

A sample of results so far....

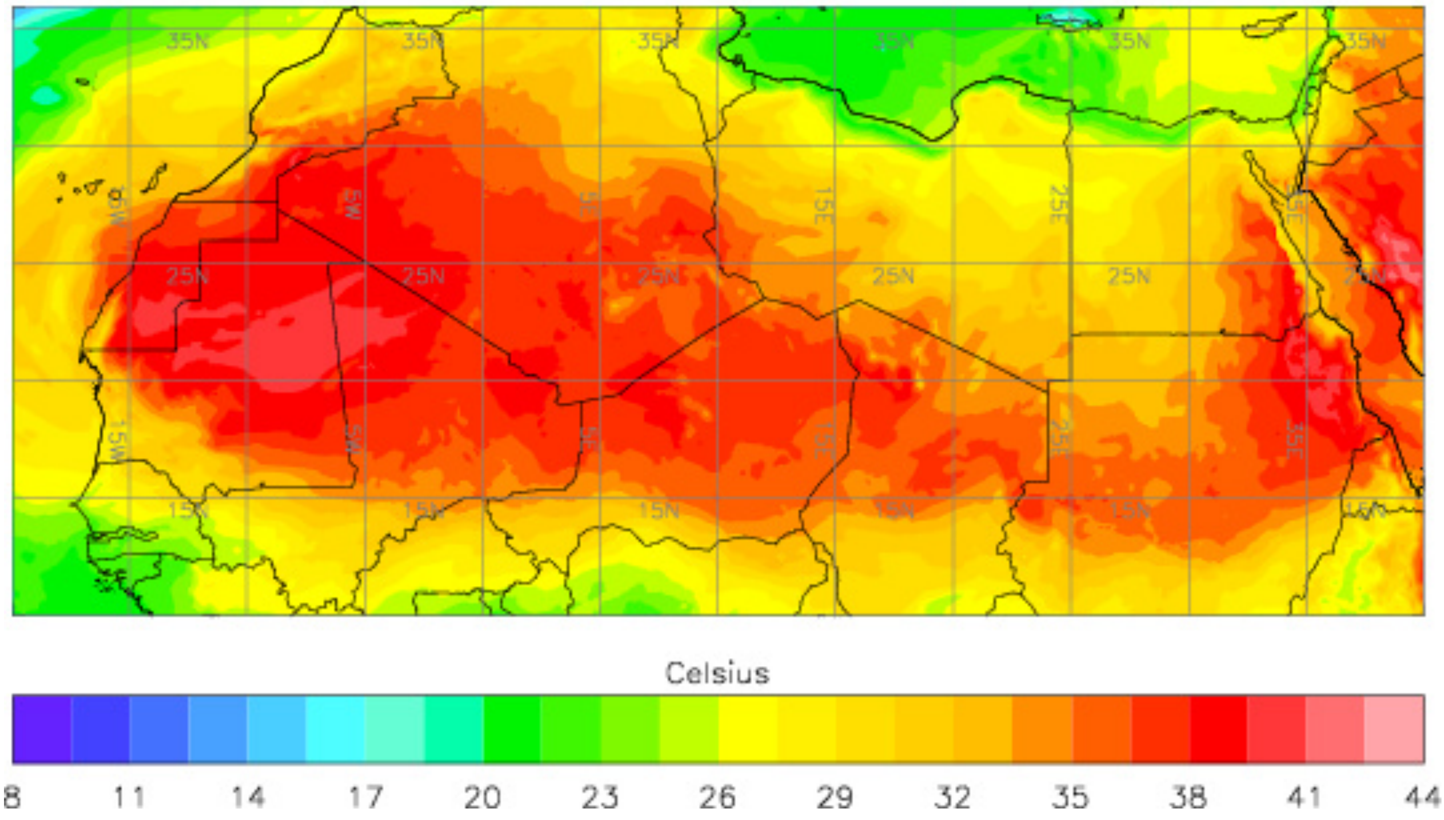

ECMWF Data Coverage (All obs DA) - Temp
22/Jun/2011; 18 UTC
Total number of obs = 51

Note Fennec dropsondes (green) and radiosondes (red)

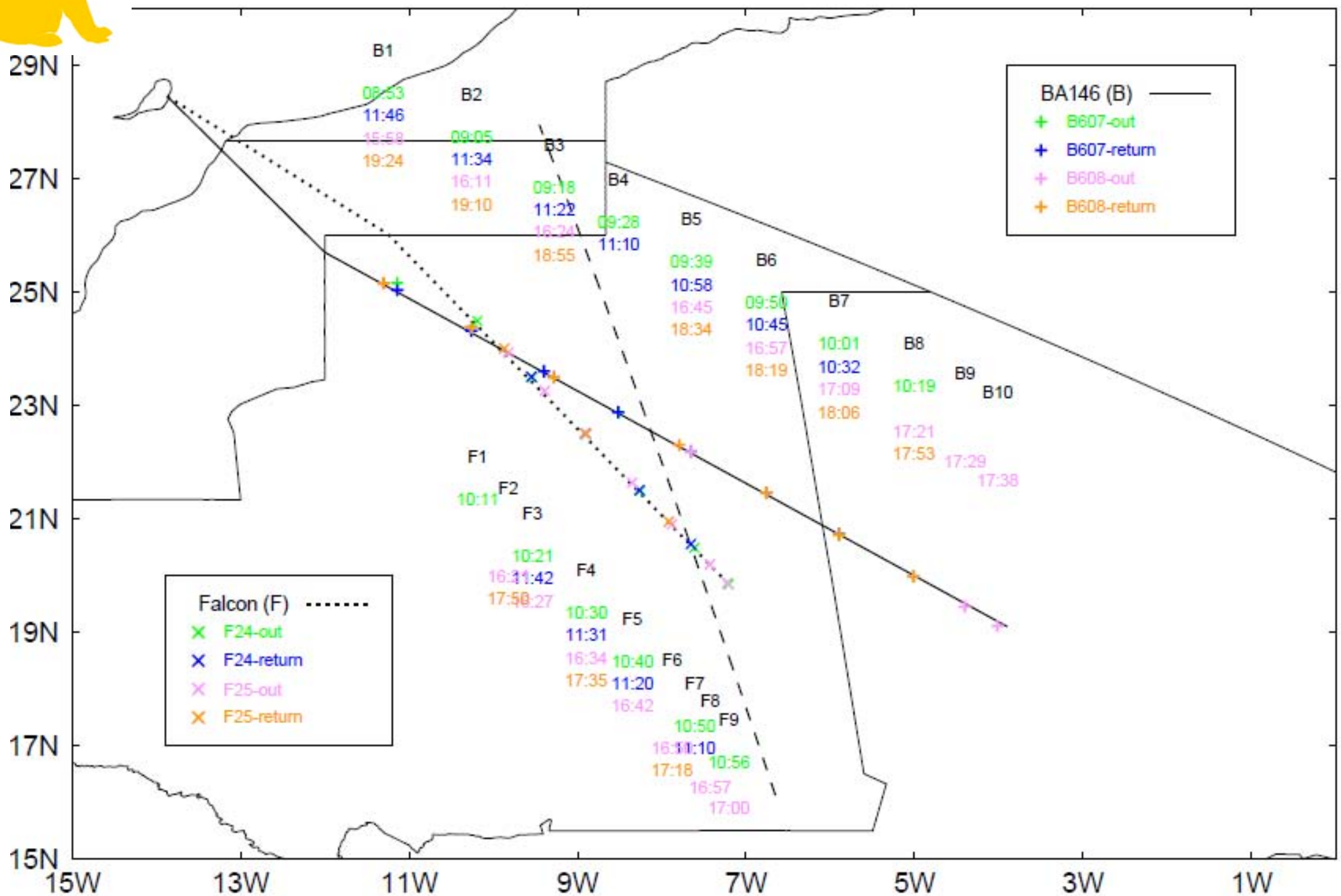


ECMWF

Heat Low 22 June 2011

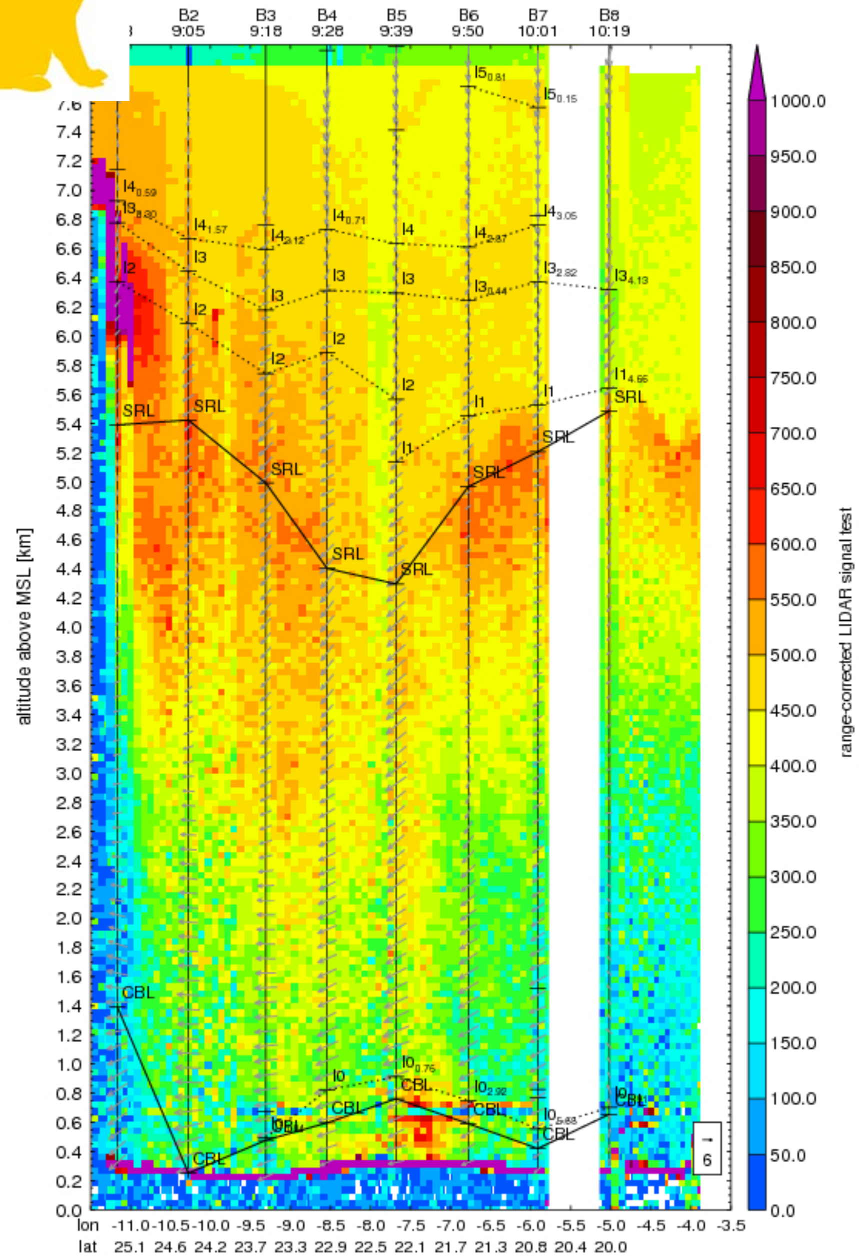


‘Heat Low’ Flights 22 June 2011: Bae-146 and F20

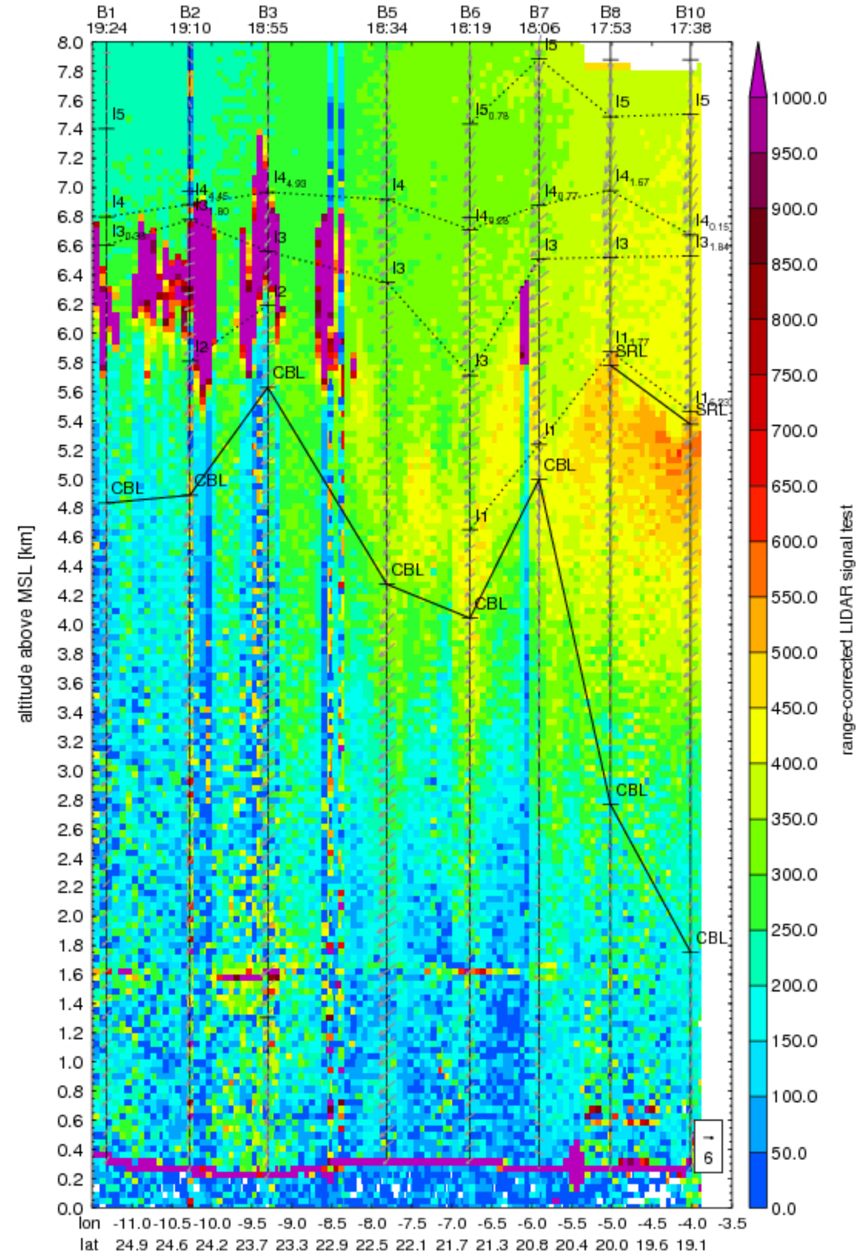


See Engelstaedter **Pr.8B .9**

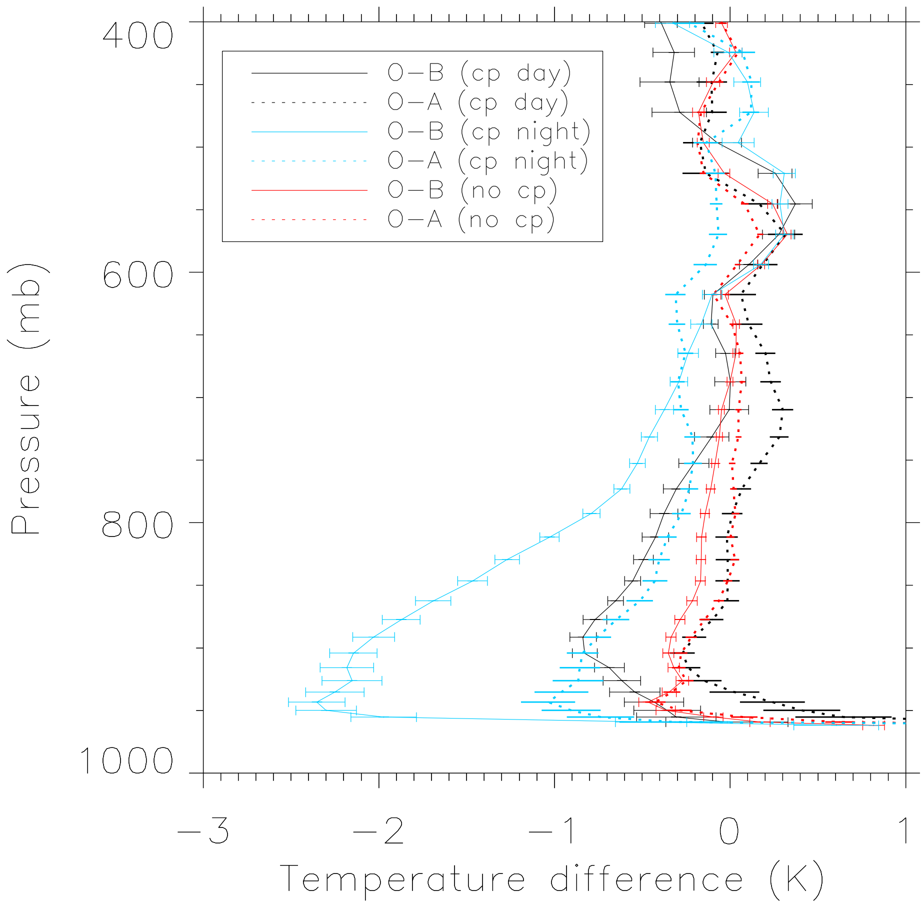
Morning



Late afternoon



NWP temperature bias



NWP model errors (solid lines) are much larger when there are cold pools/night-time cold pools seen in *Fennec* data

0-B: Obs – Model first guess (solid)
O-A: Obs – Analysis
Night-time cold pools: 13 profiles
Day-time cold pools (07 to 18Z): 7 profiles
No cold pools: 104 profiles
Assimilation impacts (solid *versus* dashed) small for no cold pools, large for (day-time) cold pools – error is not caused by dust.
Analysis errors (dashed) significant for temperature in night-time cold pools
Cold pools increase the monthly mean error by 1±0.3K (at 1% sig. lev.)
Luis Garcia-Carreras, Univ Leeds

See also: Po.8B.16 How a dusty cold pool can change the evolution of the Saharan atmospheric boundary layer Cecile Kocha

Bae-146 Instrumentation
Particle counters - Dust

CDP:
Cloud Droplet Probe

PCASP: Passive Cavity Aerosol Spectrometer Probe

CIP: Cloud Imaging Probe

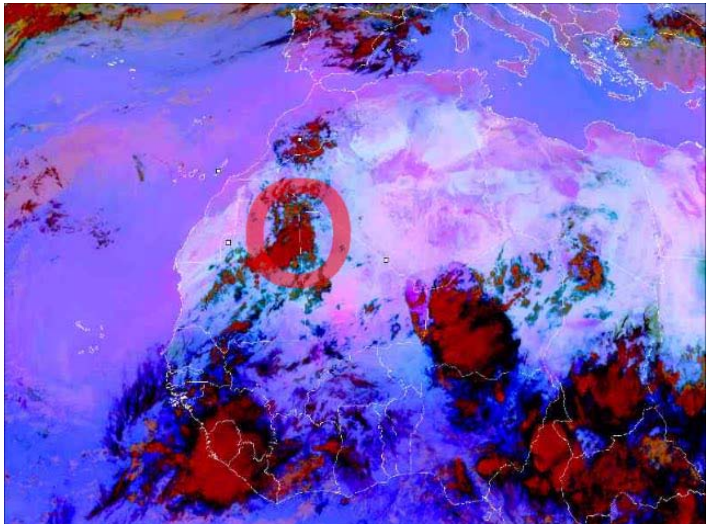
All size and count individual suspended particles
Can measure particles of any composition,
but PCASP and CDP must have corrections applied to scattering properties of the particles
Resolution 10Hz or better

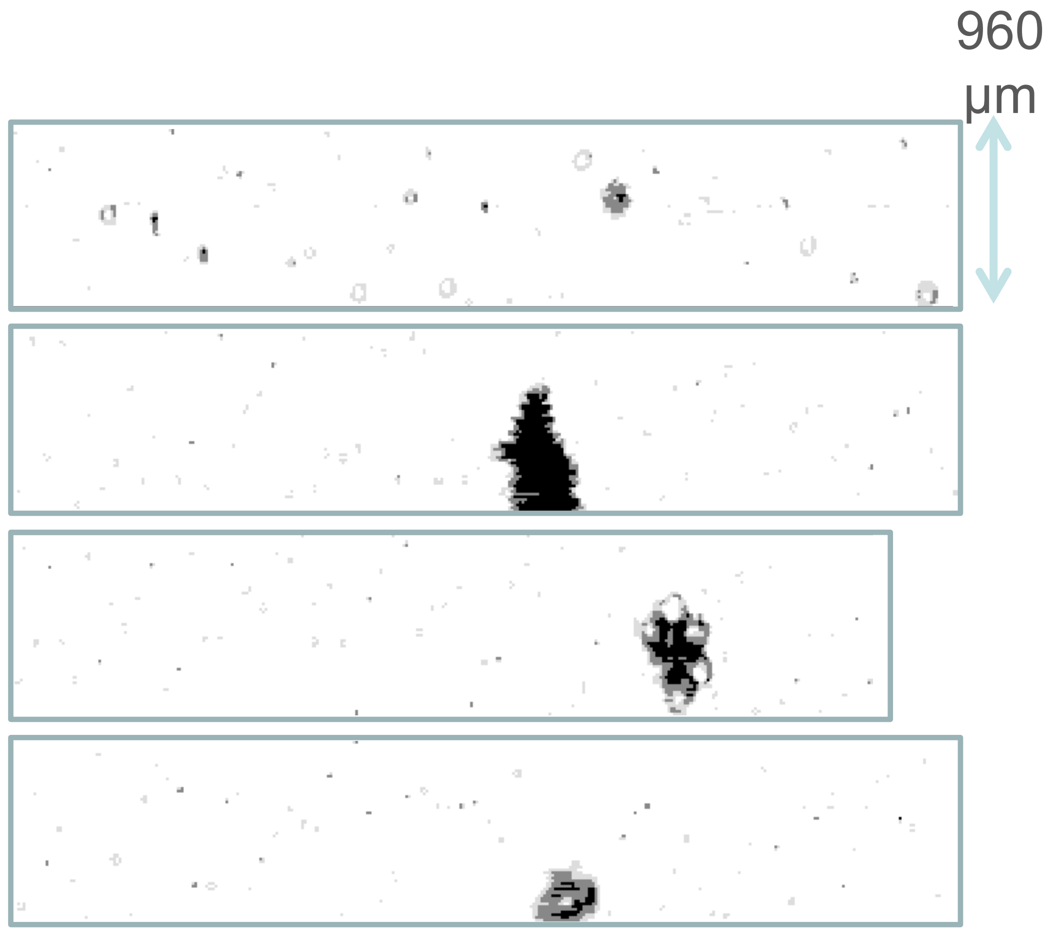
Slide from Phil Rosenberg, Leeds

Observations of large dust particles

Bae-146 flights: B600, B601, B602

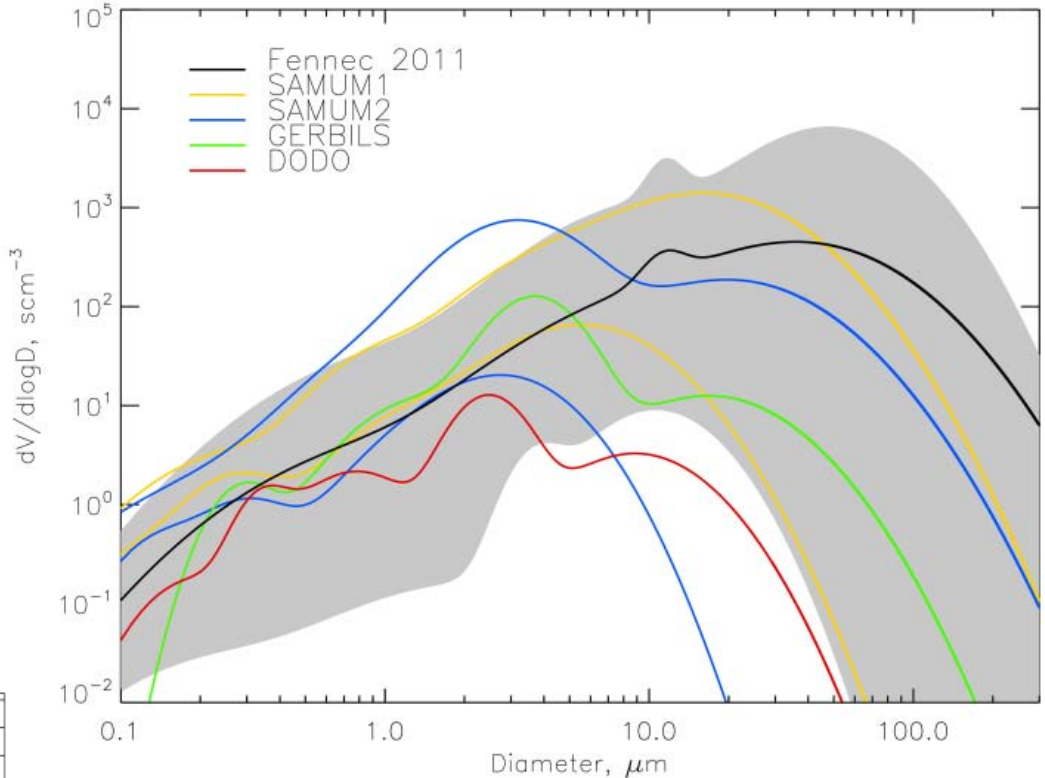
17 June 2011



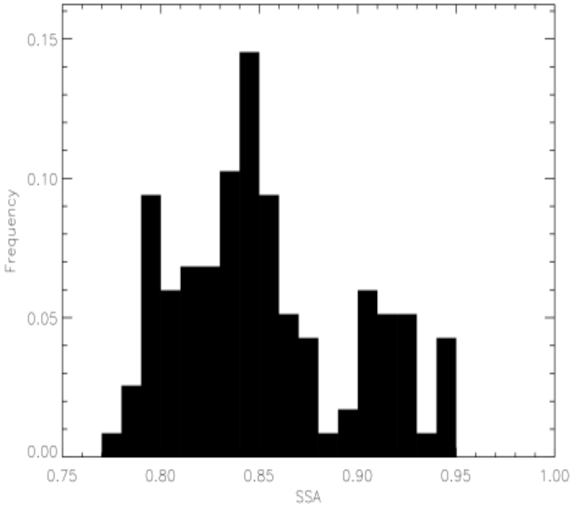


Slide from Phil Rosenberg, Leeds

Dust particles are much bigger than we previously thought



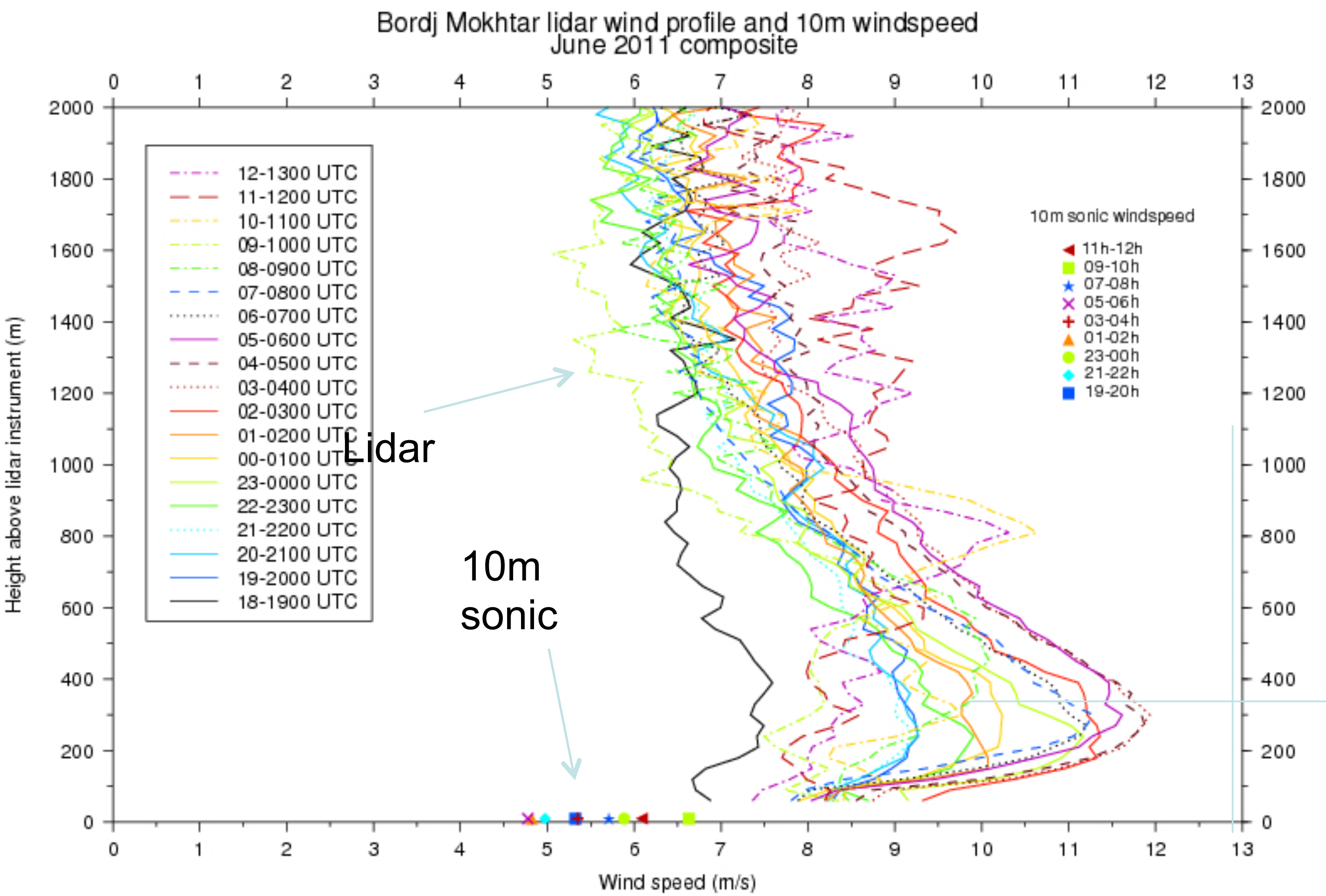
Size Distributions measured with PCASP,CDP and CIP during Fennec on BAe-146.
Grey shading is range seen during Fennec, black line is Fennec mean



SSA calculated assuming refractive index of 1.53+0.003i

Ryder et al., manuscript in preparation

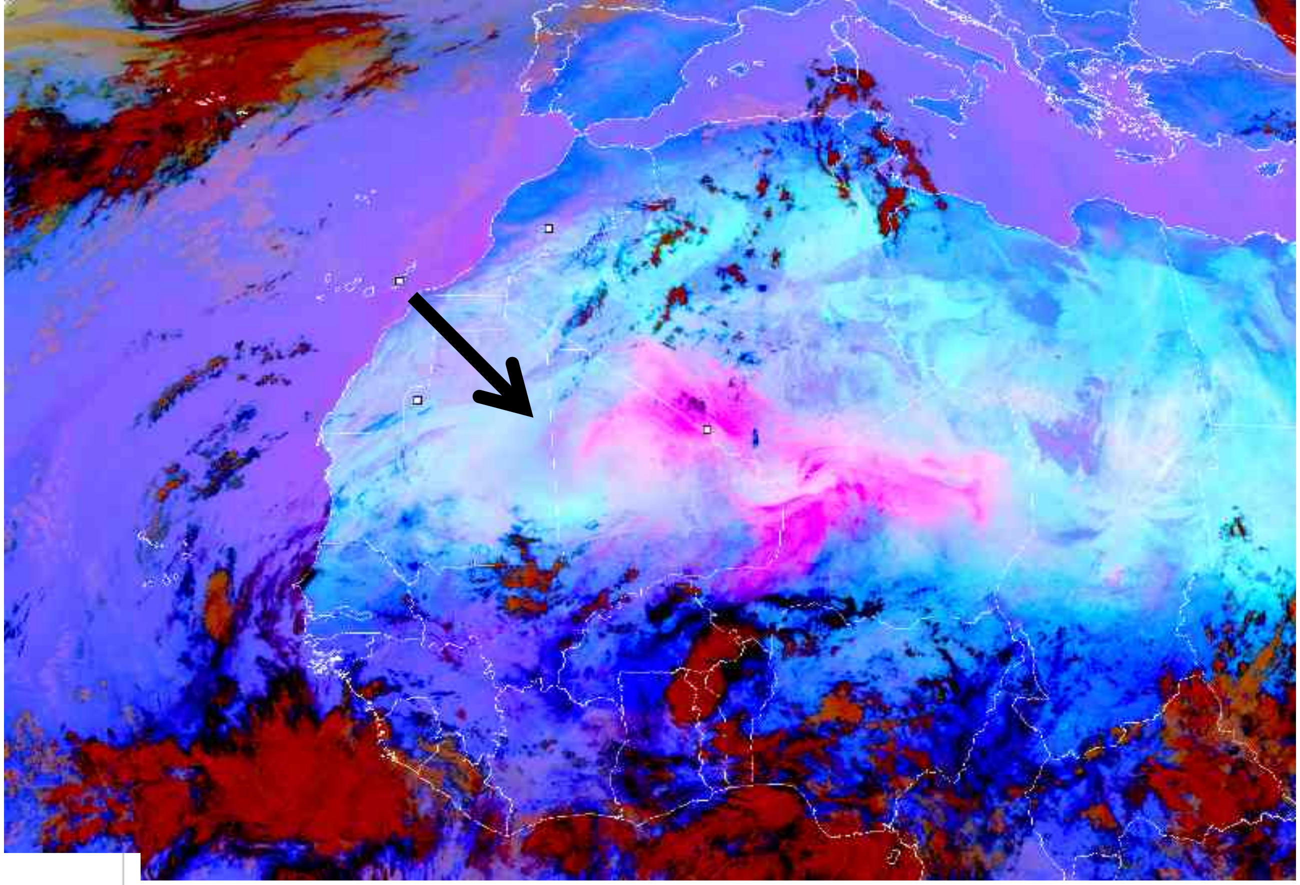
Low Level Jets occur frequently in the central Sahara

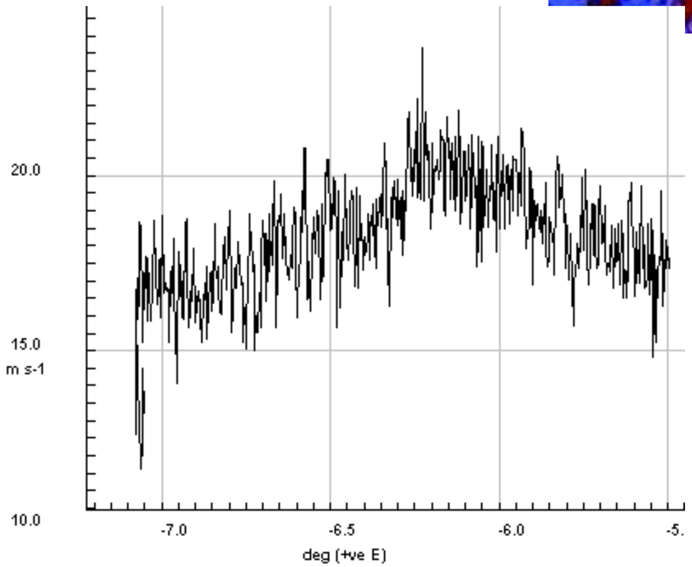


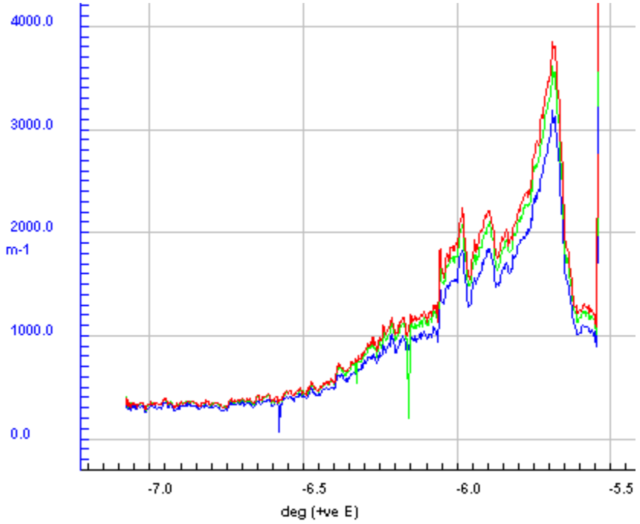
See Allen et al poster **Po.8B.2**

16 June 2012
Strong Low Level Jet
Modest SEVIRI dust Detection

Highest nephelometer and AOD of all Fennec flights

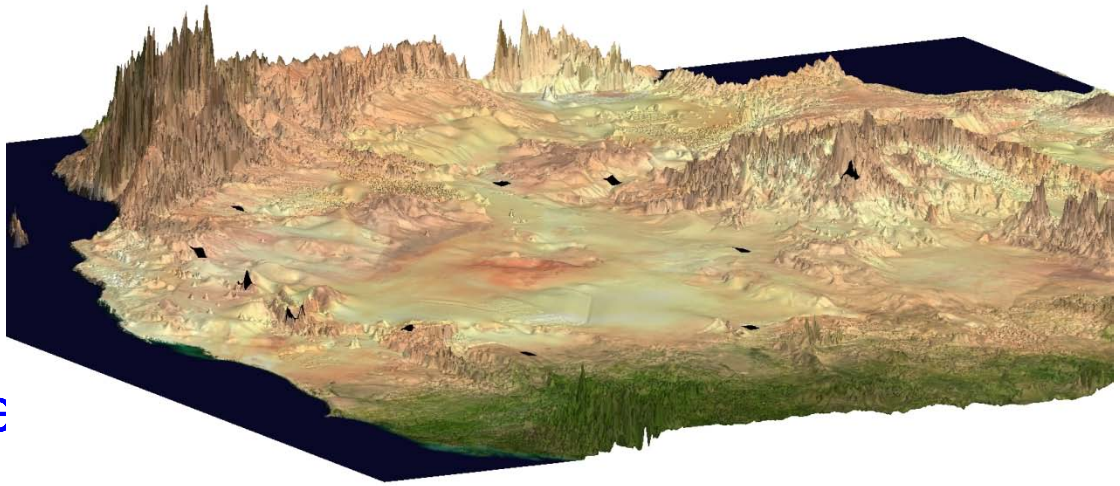






Saharan Heat Low and the WAM

- The Saharan Heat Low region is vital to the West African Monsoon



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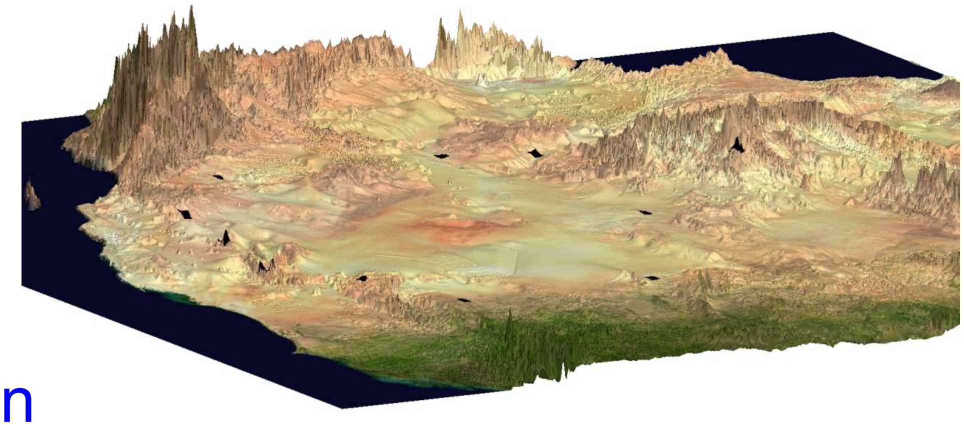
- This is a worrying situation

Saharan Heat Low and the WAM



- The Saharan Heat Low structure is complicated and evolves rapidly spatially and temporally
- Absence of key processes in models (e.g. cold pools) leads to large temperature bias
- Dust particles are much larger than we think– this has key implications for heating (and NWP bias)
- We can't see some significant dust events from satellite products
- There is a case for continued observations from the Heat Low region if we are serious about prediction

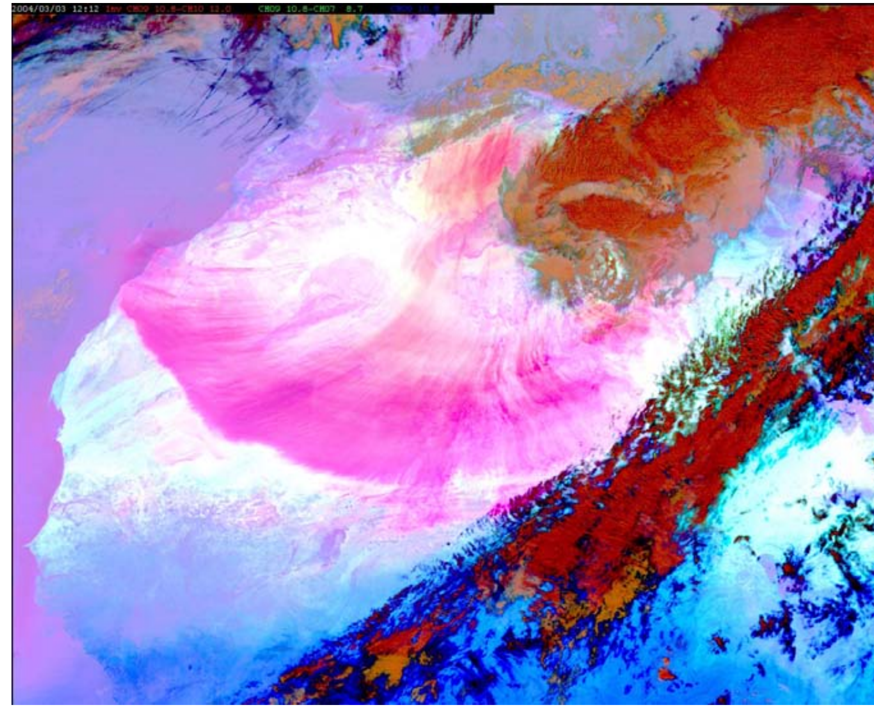
Special acknowledgement to the ground-based teams in Algeria and Mauritania that made Fennec possible

Algerie: Azzedine SACI, Abdelkader OULADICHIR, Bouziane OUCHENE, Mohamed Salah FERROUDJ
Observers at Bordj Badji Mokhtar: Mohamed BENABDELKRIM, Limame BELMOKHTAR, Abdallah REGGANI
Observers at In Salah: Mohamed BOUKAR, Mabrouk OULADICHIR, Abdelrahim ELARBI, Sidali DIALI, Abdelkarim MEDDAH, Abdelhamid TOUMI, Mohamed BEKKAY, Abdelrahmane BENYAKOUB
Observers at Tamanrasset: Bouabdallah KHEDIM, Lahcene AILAL, Abdelrahmane ZAMAKI, Mohamed Adel TOUMI
Mohamed LAMARI, Mohamed TAGABOU, Mohamed KADDOURI, Mohamed ZOUKANI, Mbarek HOUTIA
Observer at Tindouf, Smain BRIK, Fouad SEDDIK

Mauritania: Zouerat and Bir Moghrein + AWSs: Abdoulaye GANDEGA, Dieh Mohamed FADEL, Souleymane TRAORE, Alioune Ould MOUD, Sidate DEYANE, cheich ould Mini, Ould Baba Hana

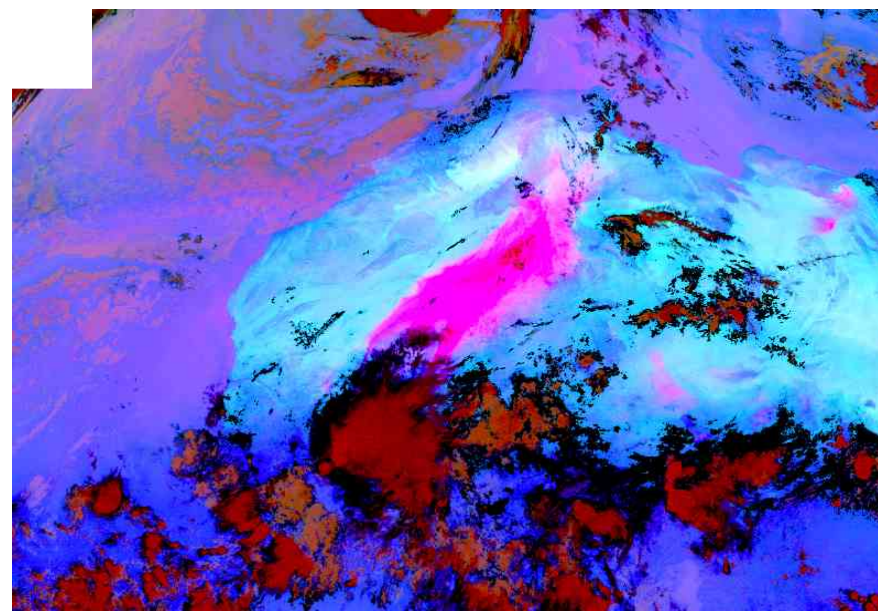
Zouerat radiosondes: Janvier BENTEFOUET, Aboubakry LY, Tango Clovis, Fall ALY, SY Dahirou

Explaining dust loadings: more than dust mechanisms



Dust production may be high
Loading may be relatively low
because of residence time
Large scale structure divergent
Dust clears in strong NE flow

$$\nabla.\vec{v} > 0$$



MCC outflow
Dust production may be high
Loadings high **and** also persistent
Large scale structure convergent
Dust advected into weak NE flow

$$\nabla.\vec{v} < 0$$