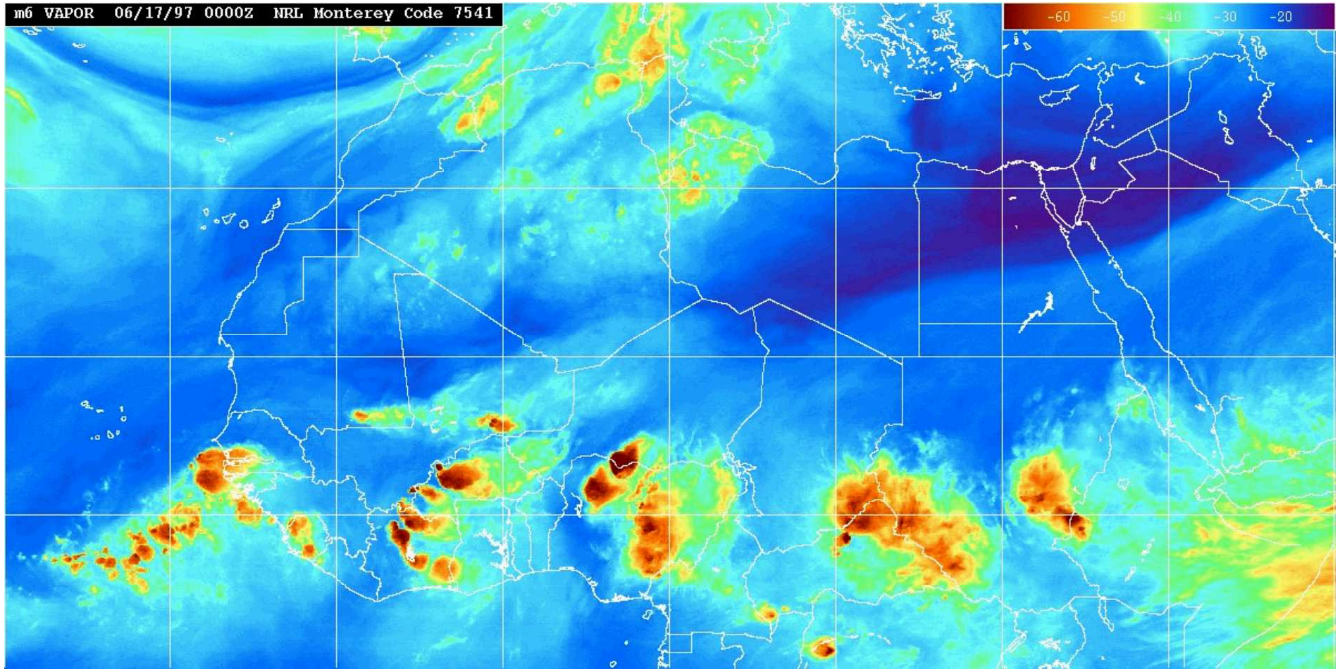
Free Tropospheric Humidity in the Tropics: METEOSAT observations, Convection and large-scale dynamics

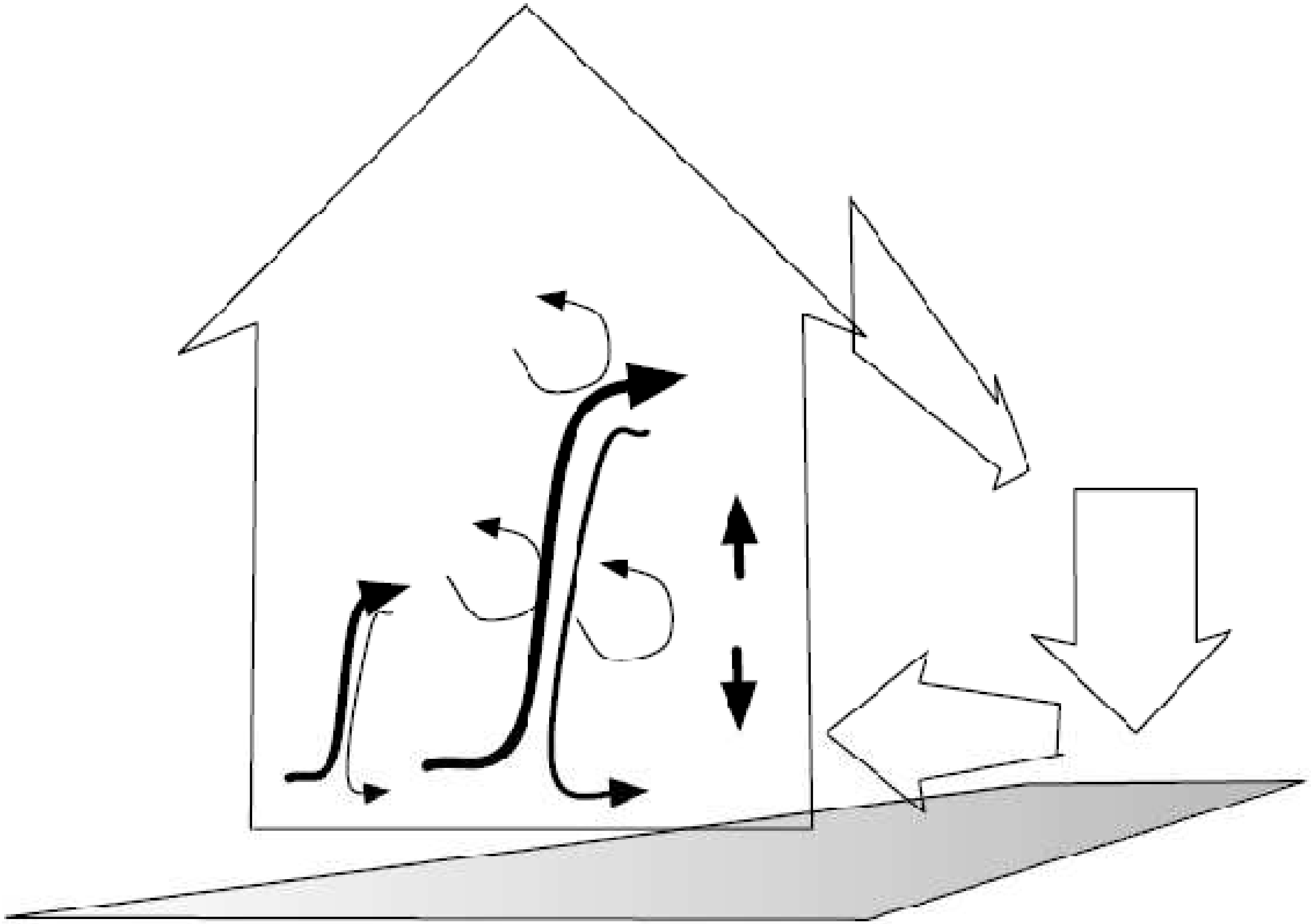


Rémy Roca[1] Laurence Picon[1] Hélène Brogniez[2] and Julien Lémond[1]

[1] Laboratoire de Météorologie Dynamique, Paris, France

[2] Laboratoire Atmospheres, Milieux, Observations Spatiales" (LATMOS)

Acknowledgements to many others colleagues from Toulouse, Offenbach, Chicago etc…



Sherwood et al 2009

Outline of the talk

1. Why and how to look at the free tropospheric relative humidity?
- **-FTH and OLR**
- **-FTH and convection**
- **-The AC paradigm**

2. Interannual variability of the eastern Mediterranean troposphere
- Why this region ?
- The METEOSAT WV channel long-term archive
- Dynamical explanation

3. Extra-tropical Dry air intrusions over Sahel
- The case study of the 1992 season
- Interannual variability
- 2006 and the MJO mode of dry intrusions

4. Conclusions & Perspectives

The relative importance of different parts of atmosphere to the WV feedback

(Held and Soden, 2000)

$$\delta OLR = \sum_{k=1}^{N} \left[\frac{\partial OLR}{\partial T_k} \delta T_k + \frac{\partial OLR}{\partial e_k} \delta e_k \right]$$

Assuming fixed rh and a uniform small perturbation of temperature

$$\delta T$$

Then noting

$$\delta e = rh \frac{de_s}{dT} \delta T$$

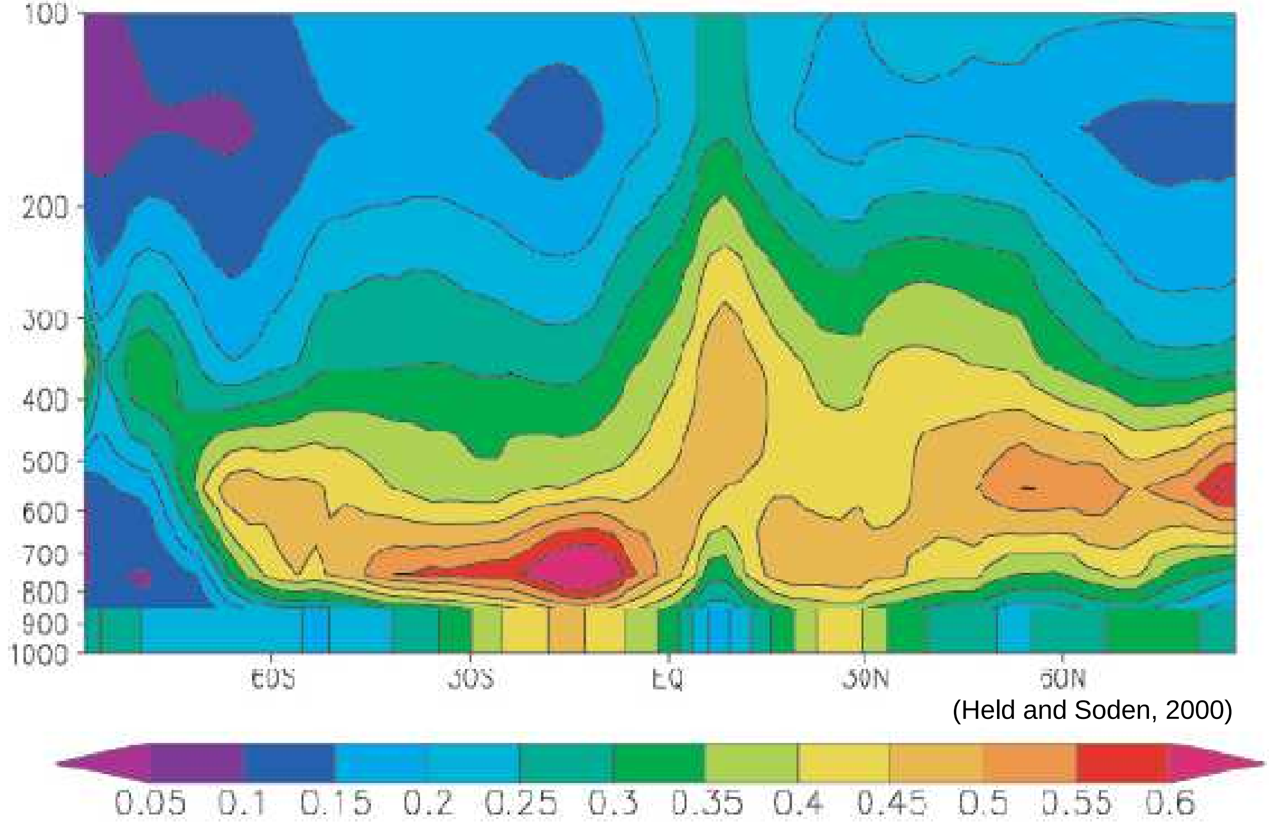
$$Q_e^k = \frac{\partial OLR}{\partial e_k} rh \frac{de_s}{dT} \qquad Q_T^k = \frac{\partial OLR}{\partial T_k}$$

$$\delta OLR = \sum_{k=1}^{N} \left[Q_T^k + Q_e^k \right] \delta T$$

The relative importance of different parts of atmosphere to the WV feedback

All computations July T,q from ECMWF, clouds from ISCCP

$$Q_T^k$$

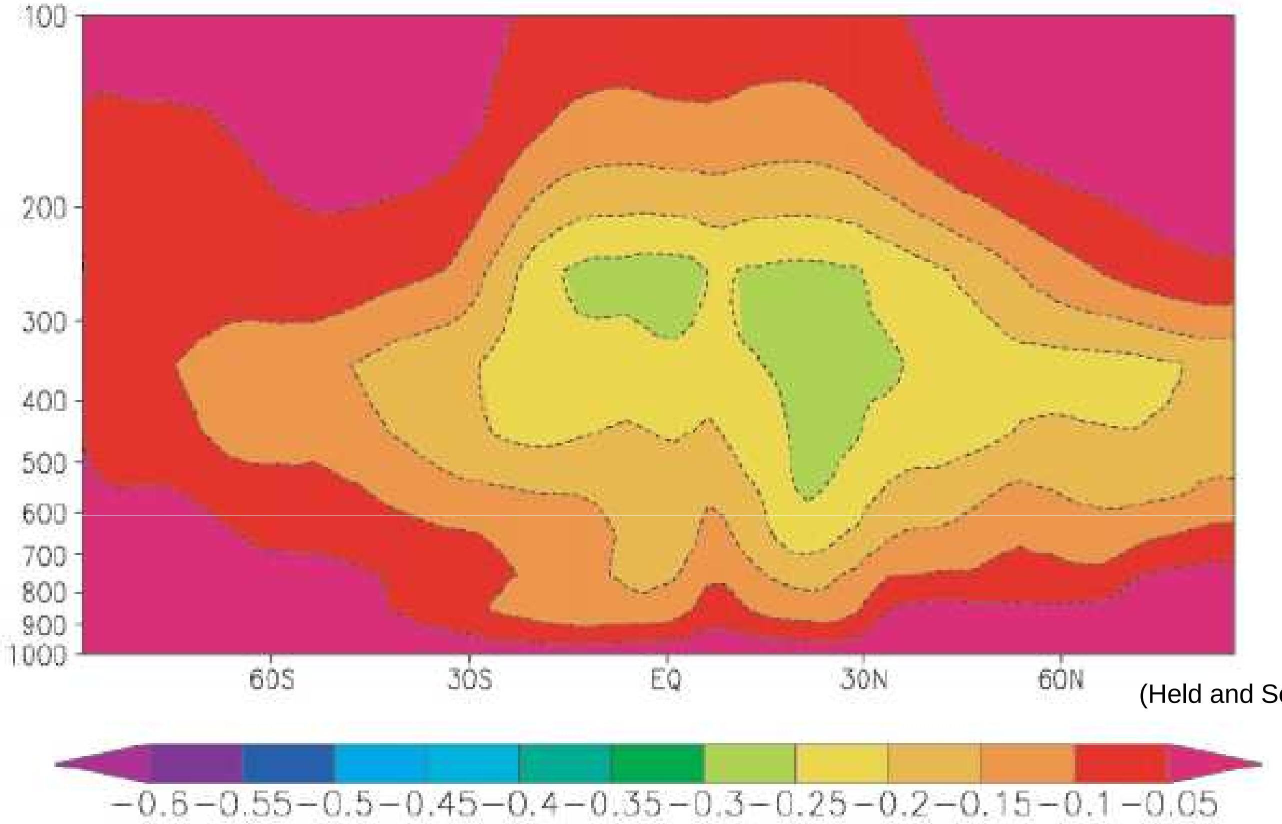


(Held and Soden, 2000)

- Max sensitivity altitude depends on cloud tops
- Away from the deep tropics, lower levels are contributing

The relative importance of different parts of atmosphere to the WV feedback

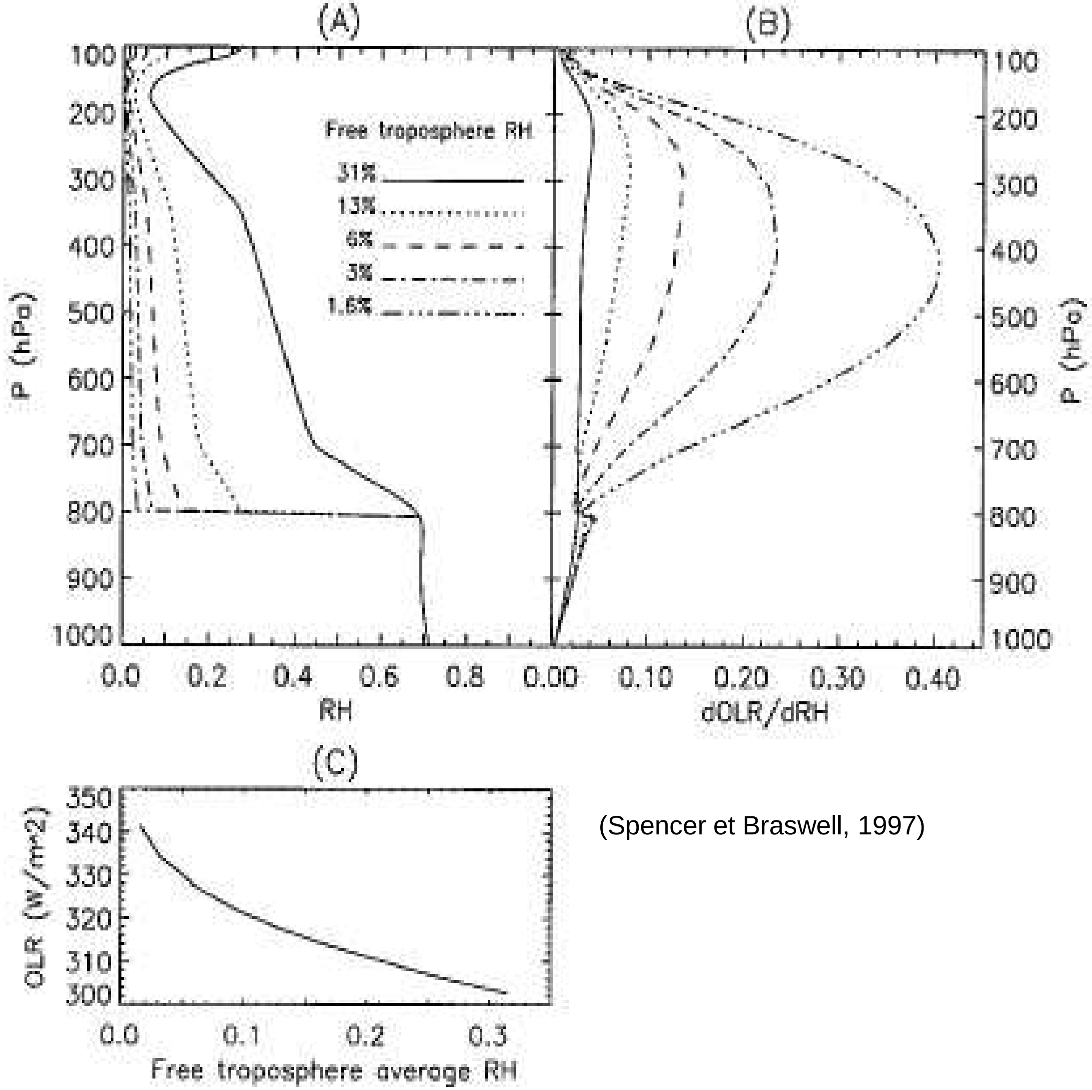
$$Q_e^k$$



(Held and Soden, 2000)

- Max sensitivity mid to upper troposphere in the **intertropical region**
- Dry free trop important (cloud effect otherwise in the moist regions)
- 90% of the wv feedback (Uniform T, rh=cte) above 800 hPa.
- 55%due to 30s-30n region 2/3 of which (35% total) due to the **100-500 hPa region**

The relative importance of different parts of atmosphere to the WV feedback



(Spencer et Braswell, 1997)

Relative variability in dry zones

Small RH perturbations Emphasizes strongly the dry subtropical free troposphere

$$\delta e \propto e_s$$

Shine and Sina 90s, emphasized the boundary layer

$$\delta e \propto e$$

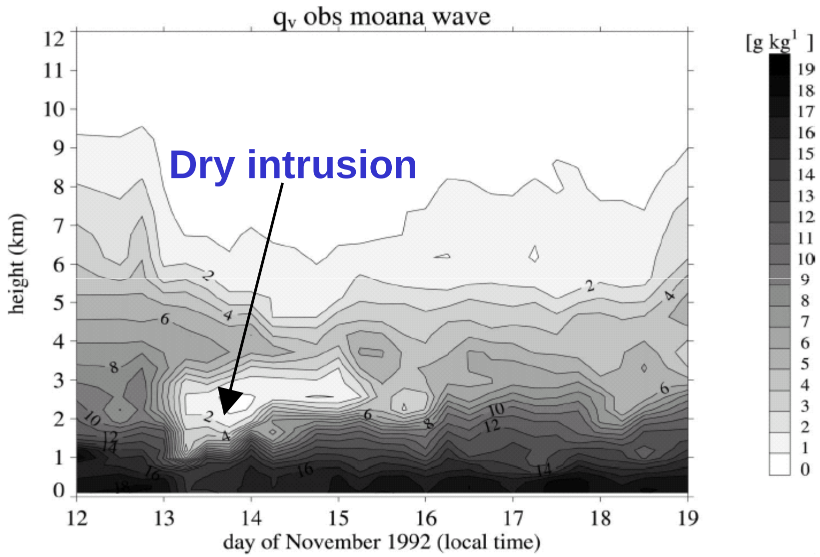
Held and Soden computations reads

$$\delta e \propto \frac{e}{e_s}\frac{de_s}{dT} \propto \frac{e}{T^2}$$

Environmental dry air influences cloud top height

Indirect effect: dry air entrainment decreases buoyancy

TOGA-COARE Region



(from Redelsperger et al 2002)

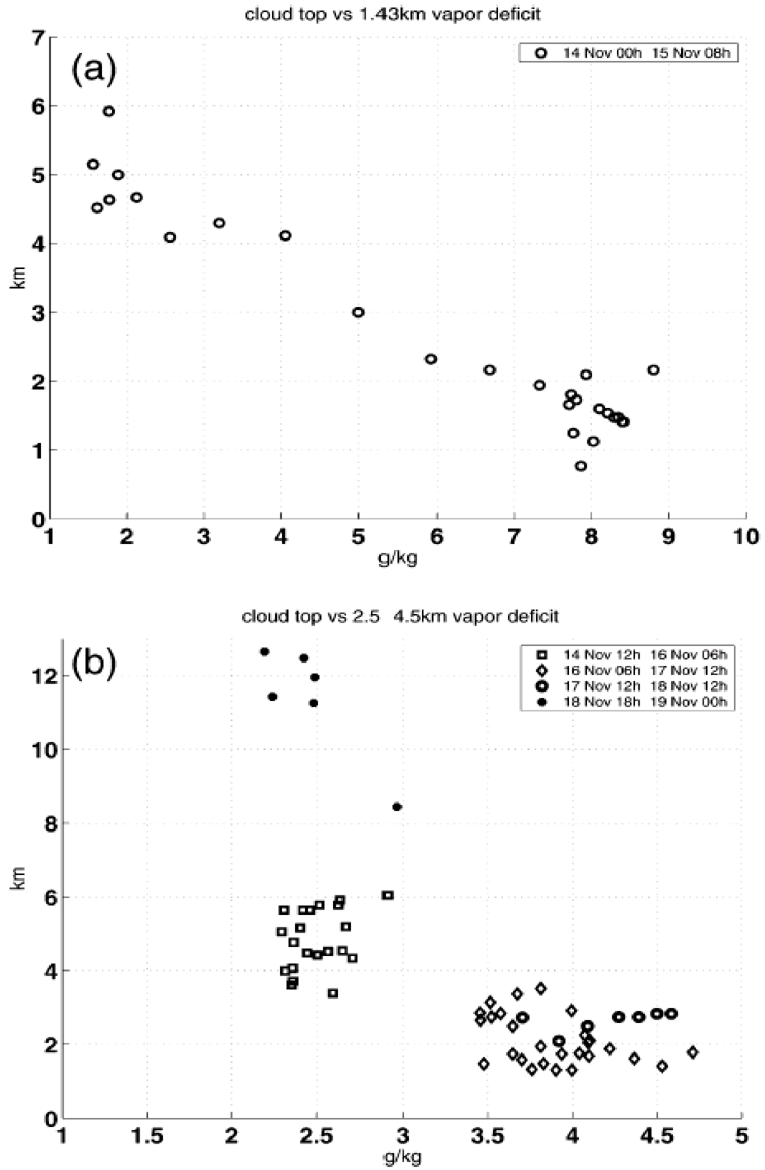
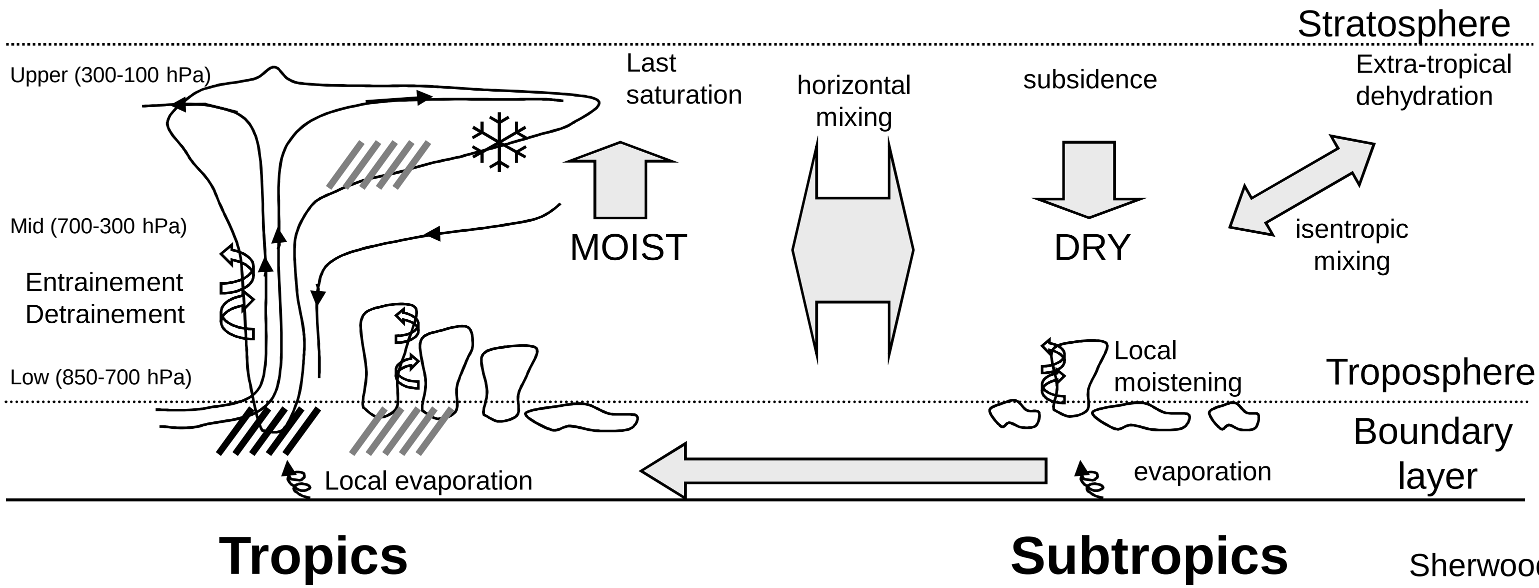


FIG. 16. Mean cloud-top heights (km) for selected periods as a

Dry intrusions inhibit convection

The full picture

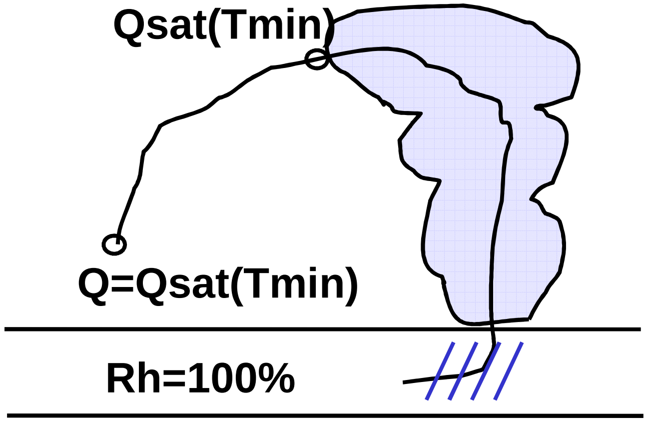


Sherwood et al, 2009

What tool and background to apprehend this coupled relationship between water vapor and convection at many scales ?

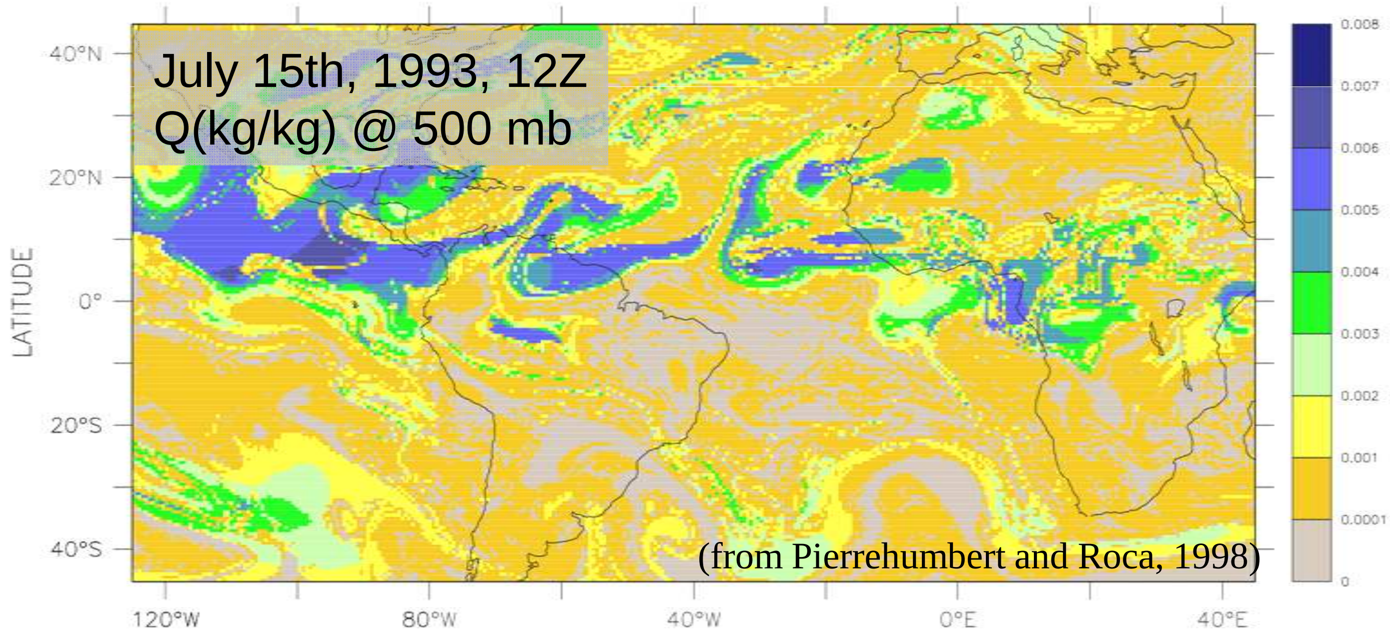
A tool for studying the free tropospheric humidity THE AC paradigm

A conceptual model of advection-condensation (Pierrehumbert, 1998) "last saturation models"



- Source: in the saturated boundary layer
- Sink: sur-saturated moisture is rained out
- Keep track of rain encountered in NCEP

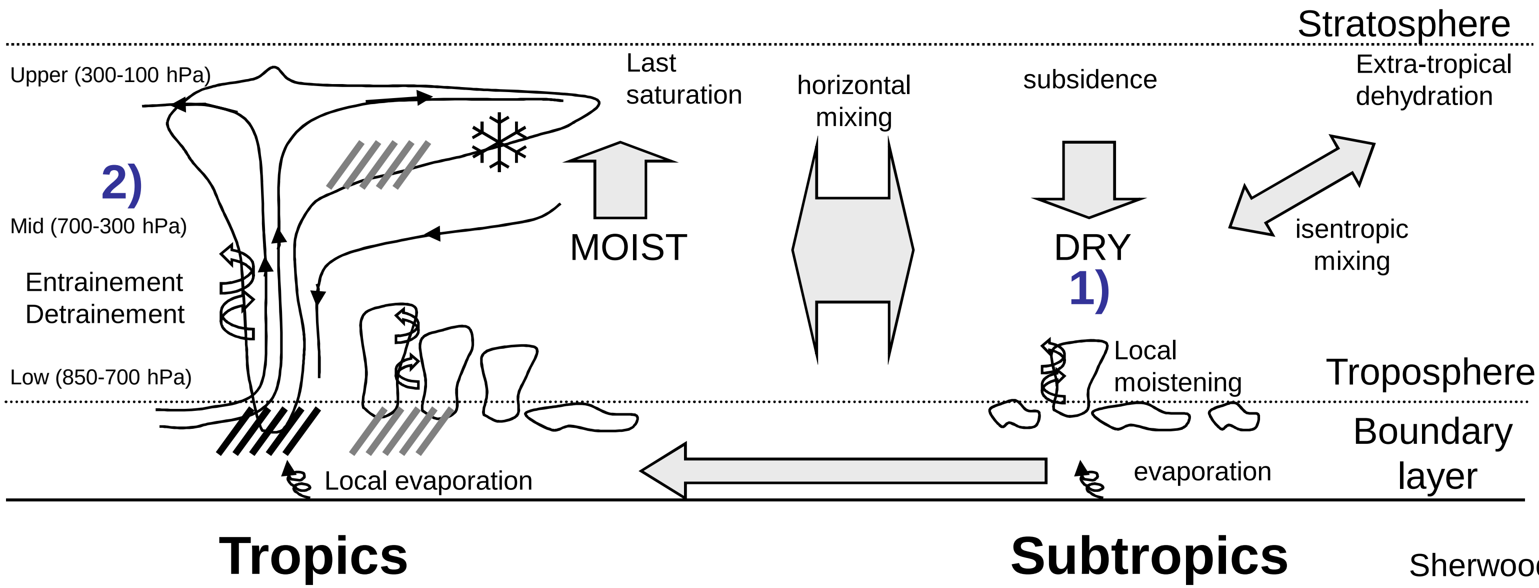
Cloud condensed water is neglected



(from Pierrehumbert and Roca, 1998)

Trajectories are computed at a given level every 0.5° backward in time to 12.5 days using NCEP reanalysis 4xdaily 3D wind

The full picture



Sherwood et al, 2009

Two observational examples of such interactions in this framework:
1) an analyse of the humidity distribution in a dry free troposphere over the subtropics
2) An analyse of the interaction between dry free troposphere layers and deep convection in West Africa

Outline of the talk

1. Why and how to look at the free tropospheric relative humidity?

-FTH and OLR

-FTH and convection

-The AC paradigm

2. Interannual variability of the eastern Mediterranean troposphere

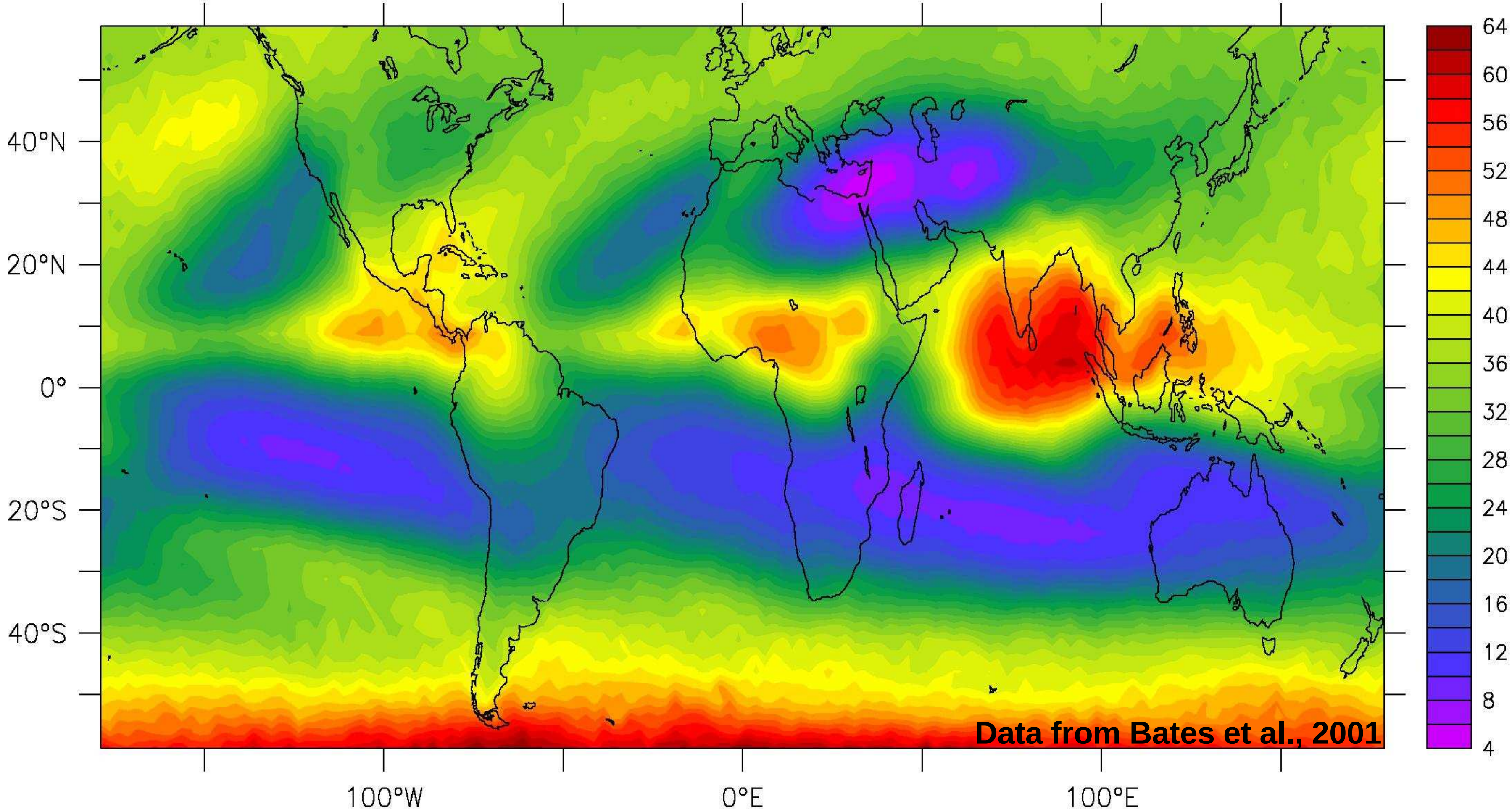
- Why this region ?
- The METEOSAT WV channel long-term archive
- Dynamical explanation

3. Extra-tropical Dry air intrusions over Sahel

-The case study of the 1992 season
- Interannual variability
- 2006 and the MJO mode of dry intrusions

4. Conclusions & Perspectives

NOAA based Upper Tropospheric Humidity
Juillet 1980-1998



The driest zone in the world is located over the Eastern Mediterranean sea

METEOSAT 1984-1996 Archive evaluation using radiosoundings

- **RAOB soundings archive from ECMWF**

  Profiles are completed to the top of the atmosphere using climatologies (R. Armante, ARA Team at LMD)

- **RTTOV-7.1 (Matricardi et al., 2001)**

  Every sounding is simulated in METEOSAT-5 WVEBBT

- **Radiances data from ISCCP-DX dataset**

  Cloud clearing is performed using the cloud DX dataset

  Homogenization as in Picon et al., (2003) but with ERA40 instead of ERA15

  All radiances are expressed in METEOSAT-5 WVEBBT

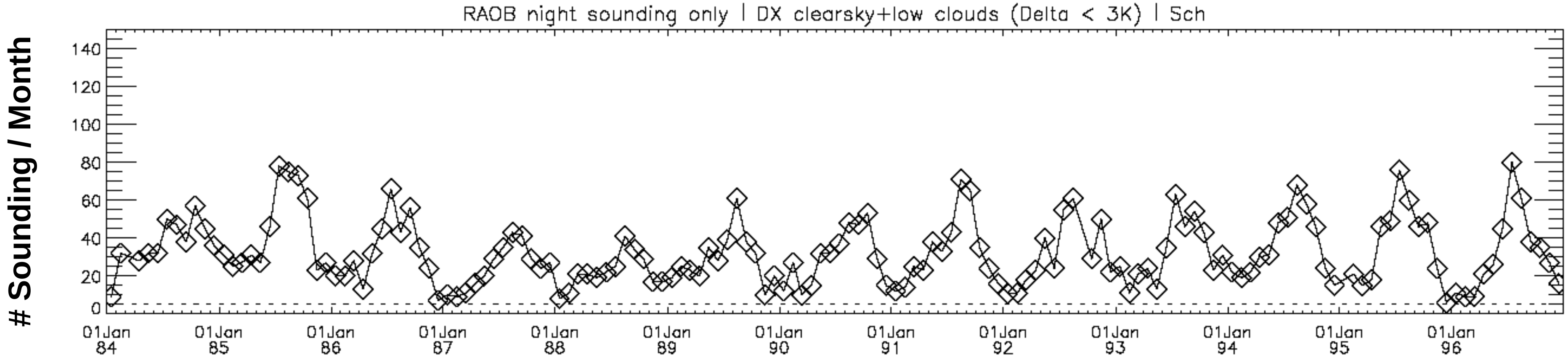
- **Soundings selection**

  Collocation within 0.625° and BT* match within 3K otherwise rejected

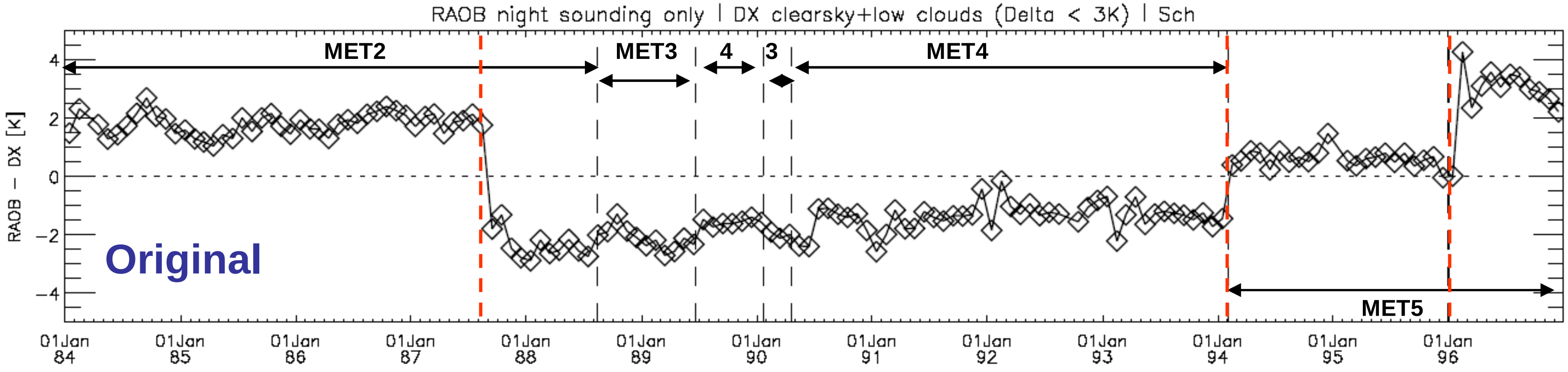
  Reject the « warning flagged » RTTOV simulations

  RH > 5% ; RH < 100% etc….

  Only NIGHT time soundings



METEOSAT 1984-1996 Archive evaluation using radiosoundings



Upgrade of calibration technique
(Schmetz, 1989)

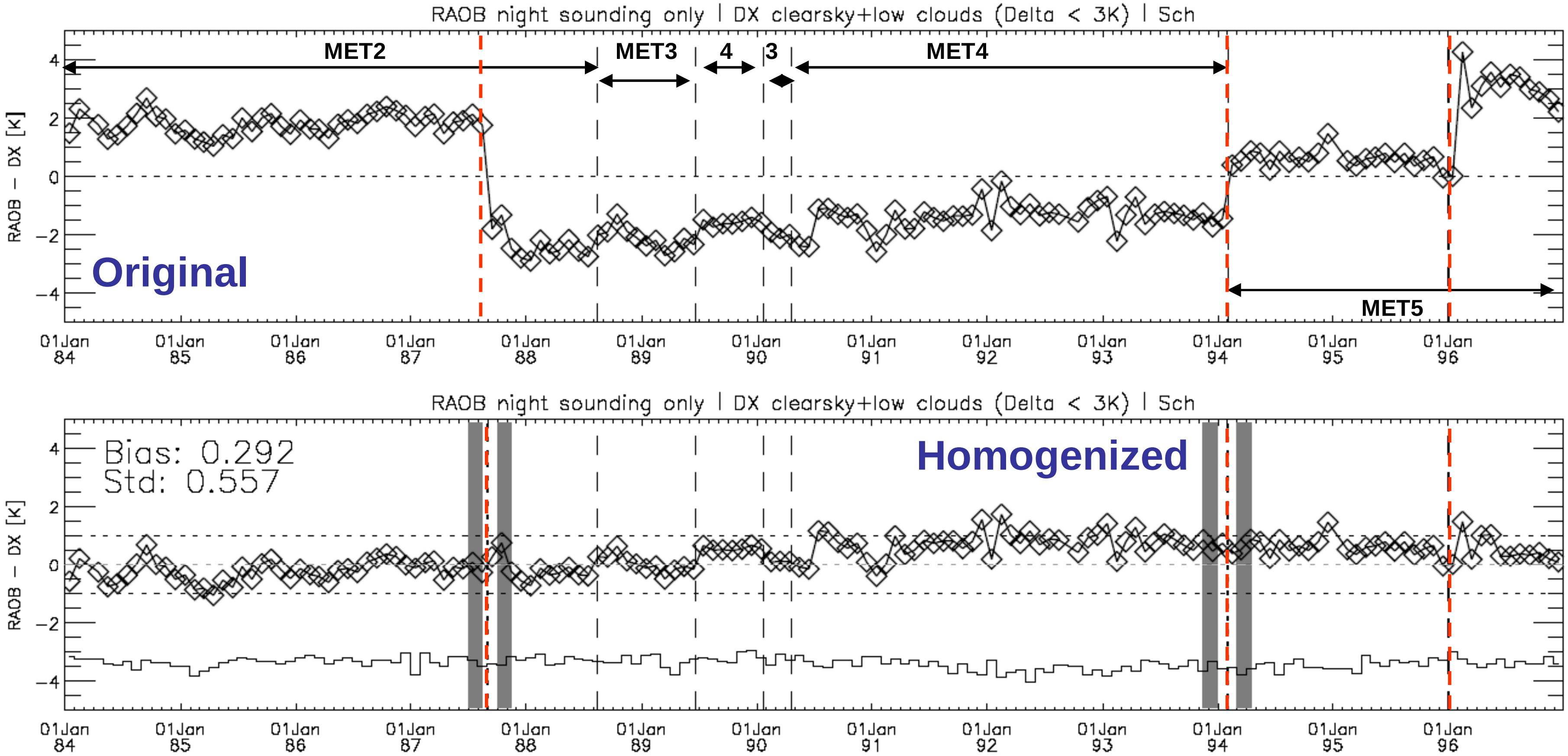
Upgrade of calibration technique
(van de Berg, et al., 95)

ISCCP DX
Normalized
Instead of nominal

- **Two upgrades corrected according to the work of Picon et al., JGR, 2003 but with ERA40 instead of ERA15.**

- **The DX data change of implementation corrected thanks to interaction with ISCCP people (V. Golea)**

METEOSAT 1984-1996 Archive evaluation using radio soundings

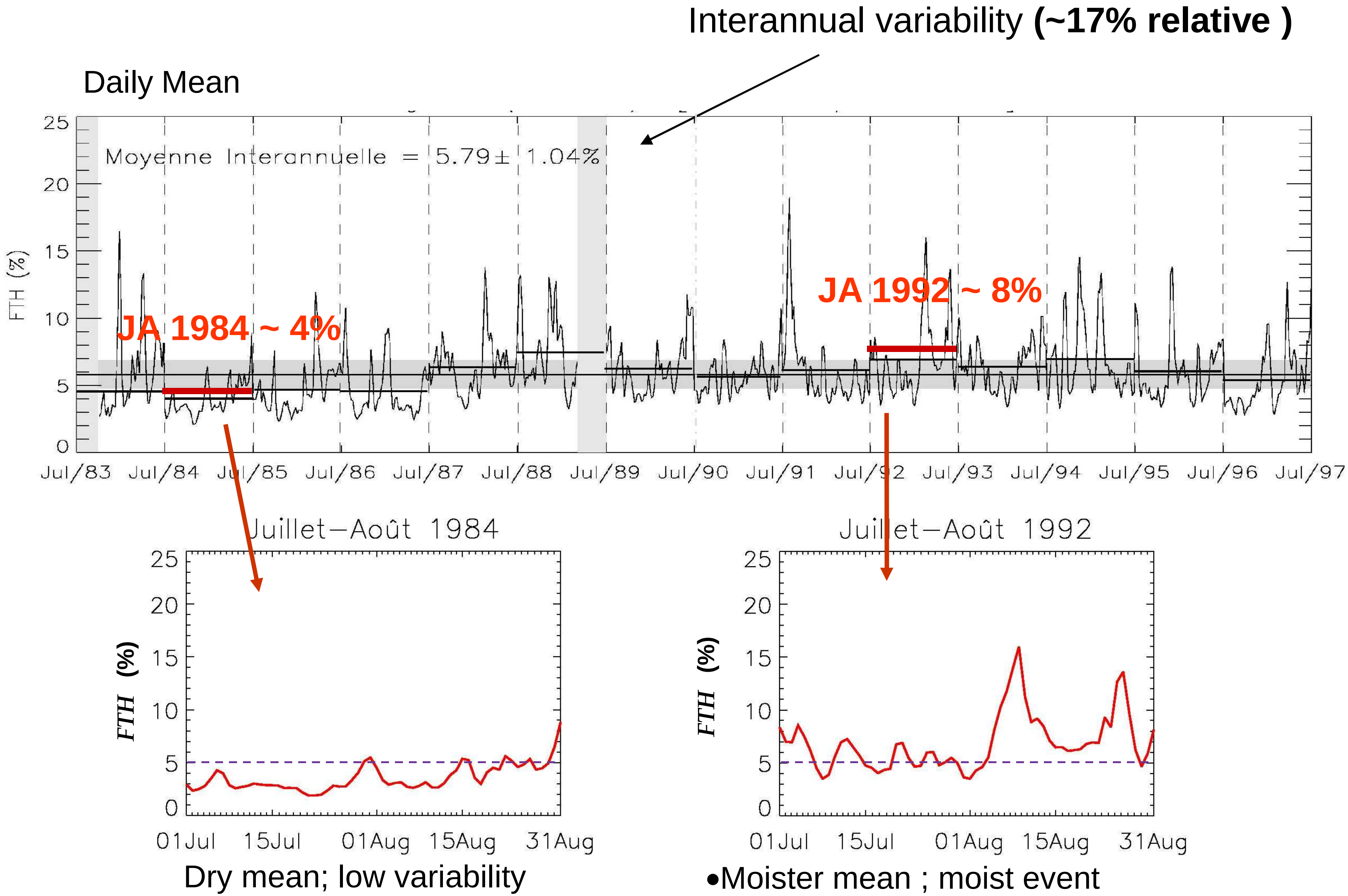


- **0.5K standard deviation indicating an effective homogenization**

- **Negligible bias with respect to radio sondes archive as expected from the calibration reference period selected (Mars-April 1994) and calibration technique**

- **Normalization to HIRS-12/NOAA-12 following Bréon et al., (JGR, 2000) ~ -3K on the DX brings the difference RAOB-SAT in agreement with numbers in literature (e.g., Soden and Lanzante, 1996).**

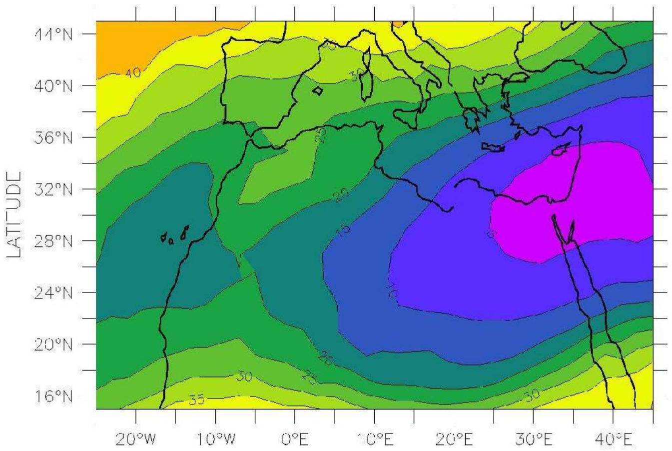
Eastern Mediterranean region



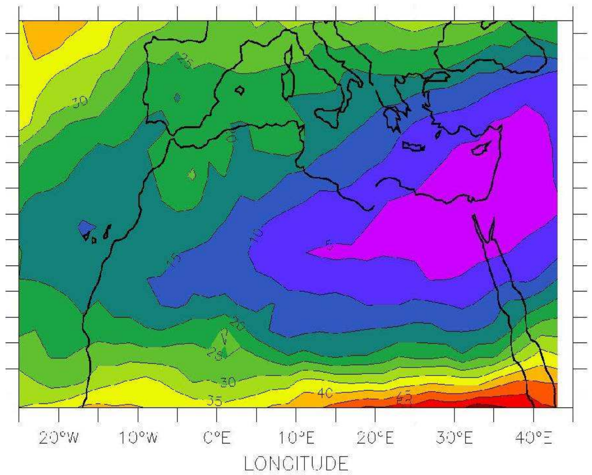
Eastern Mediterranean region

Relative Humidity obtainted from Reconstruction:
4xdaily 0.5° 12.5 days back

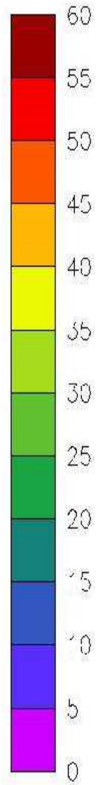
July-August 1984



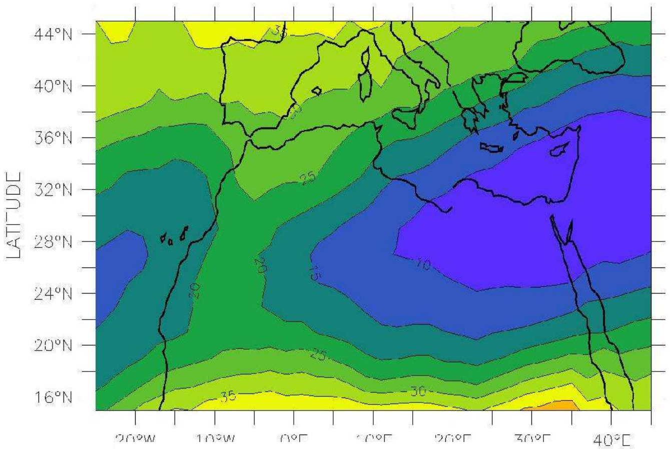
FTH (%)



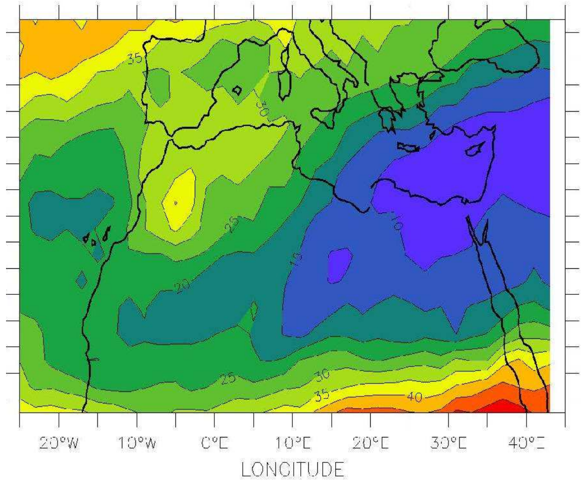
RH rec. @ 500hPa (%)



July-August 1992

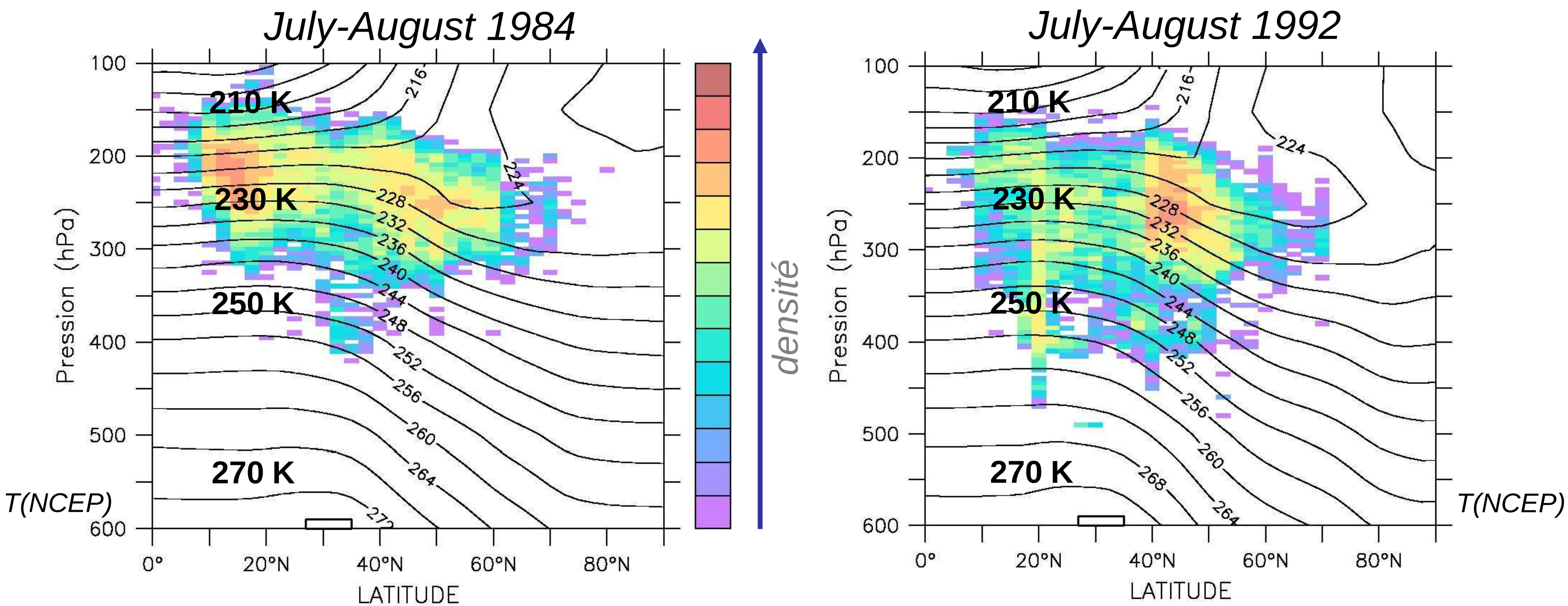


FTH (%)



RH rec. @ 500hPa (%)

Eastern Mediterranean region: dynamical interpretation



Tropical / extra-tropical mixing of air

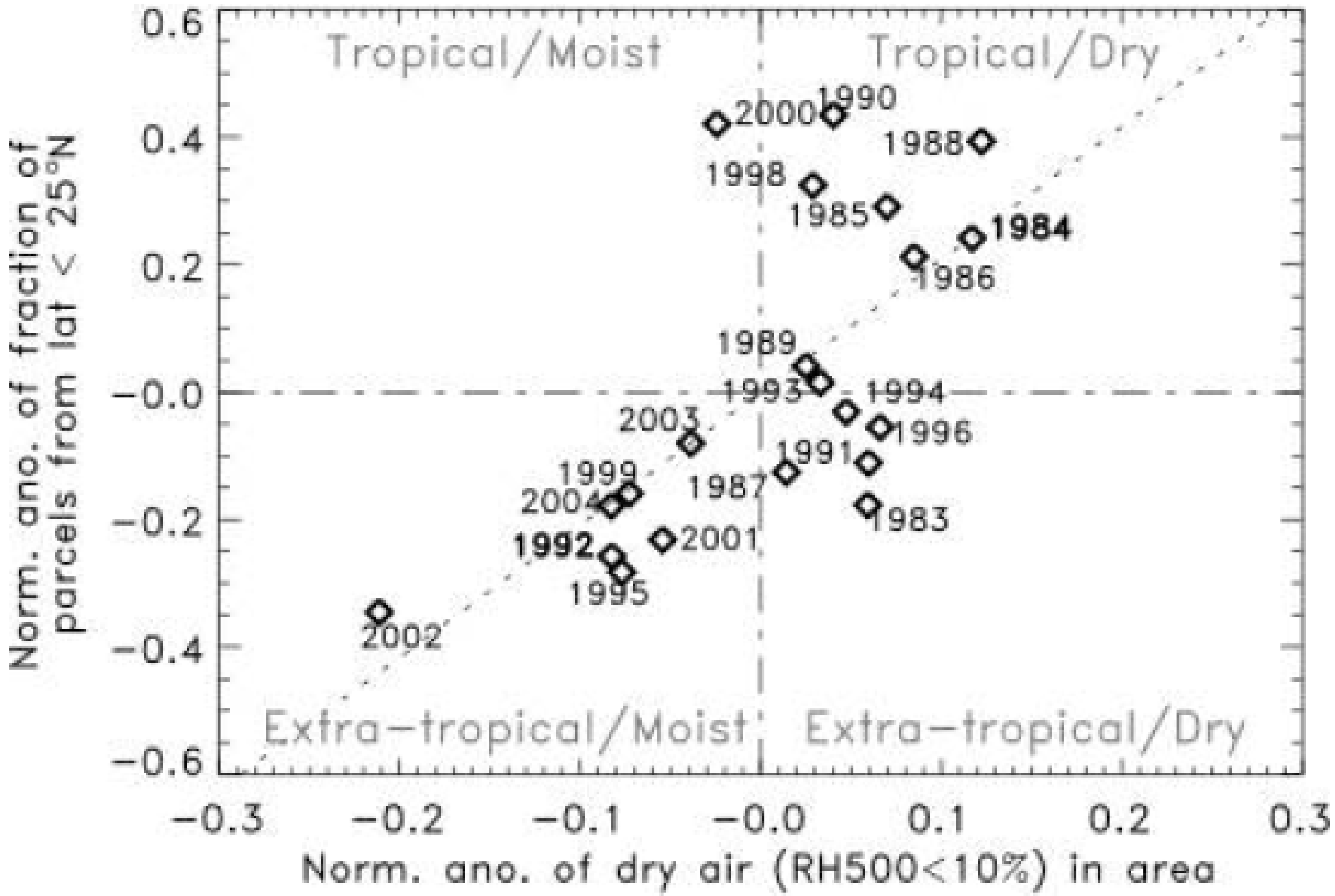
Last saturation in the mid-to-upper levels of troposphere (400 and 150 hPa) :

Environment of last saturation +/- cold (252 to 220 K)

which controls relative humidity of the arrival region (T_{500hPa} ~ cste)

Eastern Mediterranean region: dynamical interpretation

Interannual scales



Brogniez et al, 2009

Outline of the talk

1. Why and how to look at the free tropospheric relative humidity?

- **-FTH and OLR**
- **-FTH and convection**
- **-The AC paradigm**

2. Interannual variability of the eastern Mediterranean troposphere

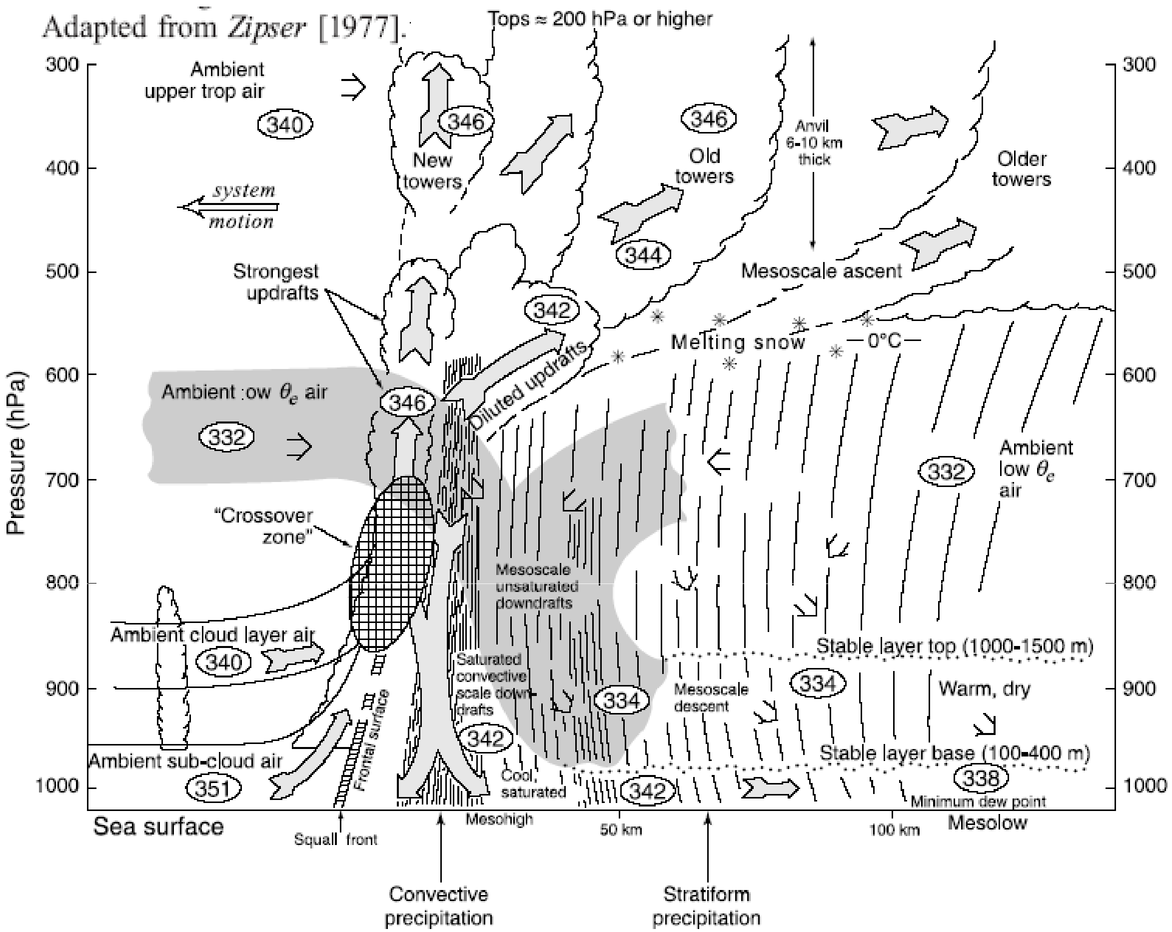
- Why this region ?
- The METEOSAT WV channel long-term archive
- Dynamical explanation

3. Extra-tropical Dry air intrusions over Sahel

-The case study of the 1992 season
- Interannual variability
- 2006 and the MJO mode of dry intrusions

4. Conclusions & Perspectives

Dry air and squall lines: more complex situation



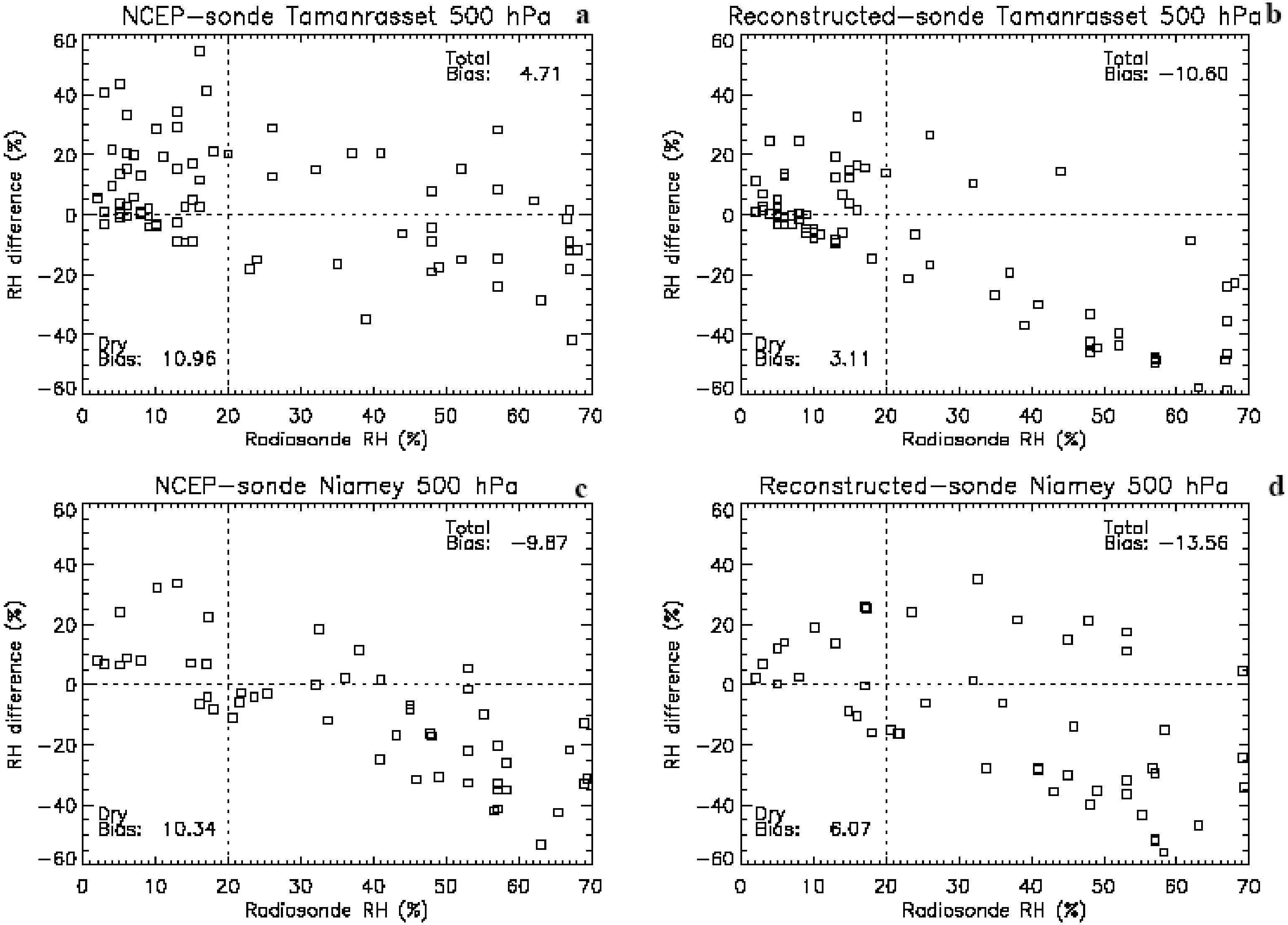
The environmental dry in the mid-troposphere, either ahead of or behind the squall line (rear inflow), favors the evaporation of rainfall which fuels the mesoscale circulation of the line.

Nevertheless this mid-tropospheric dry air zone is **one of the elements** for convection to organize into squall lines (shear, low level moisture, topography, waves, AEJ,…)

Evaluating the Lagrangian model reconstructed humidity in West Africa

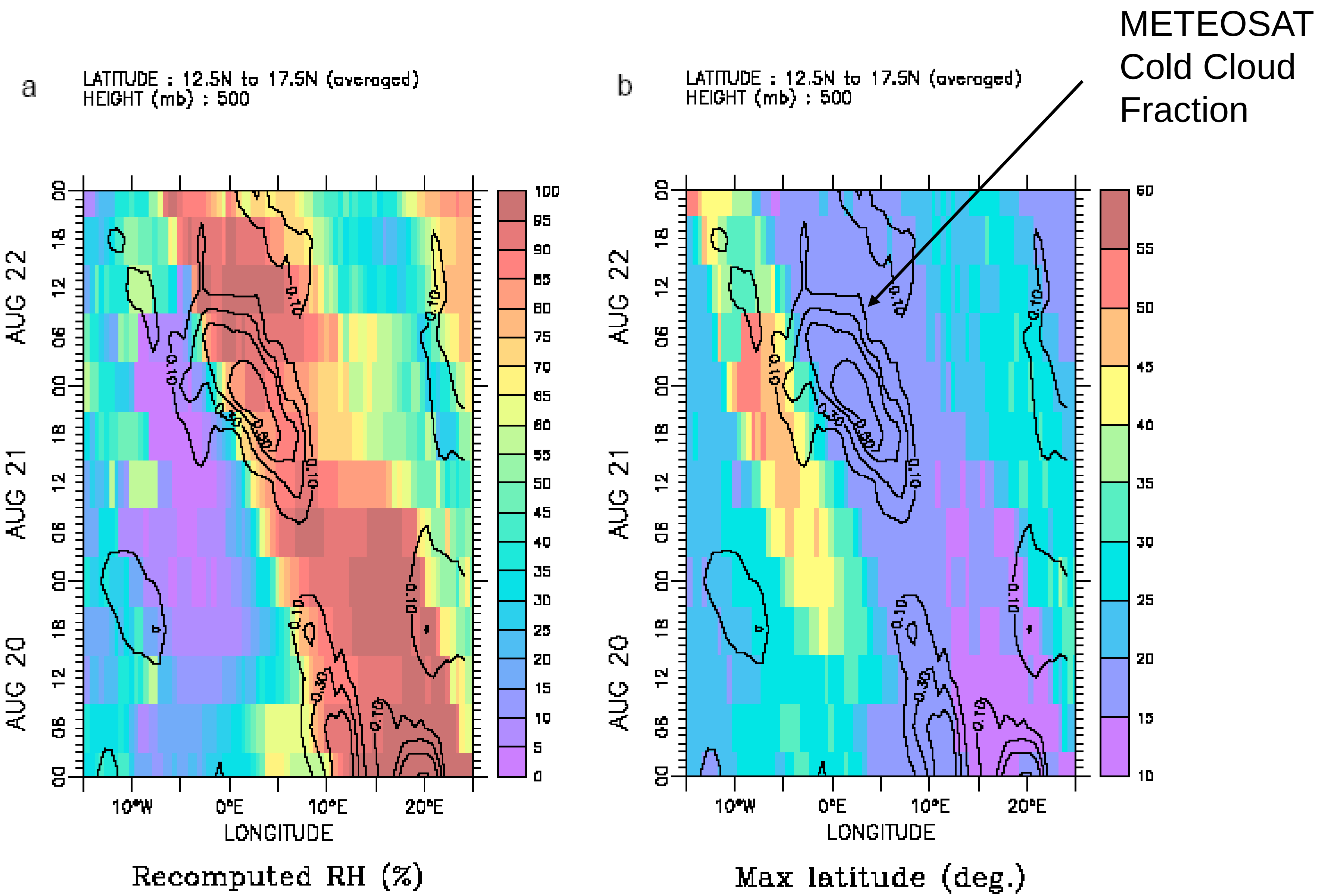
July 1992

NCEP **RECONSTRUCTION**



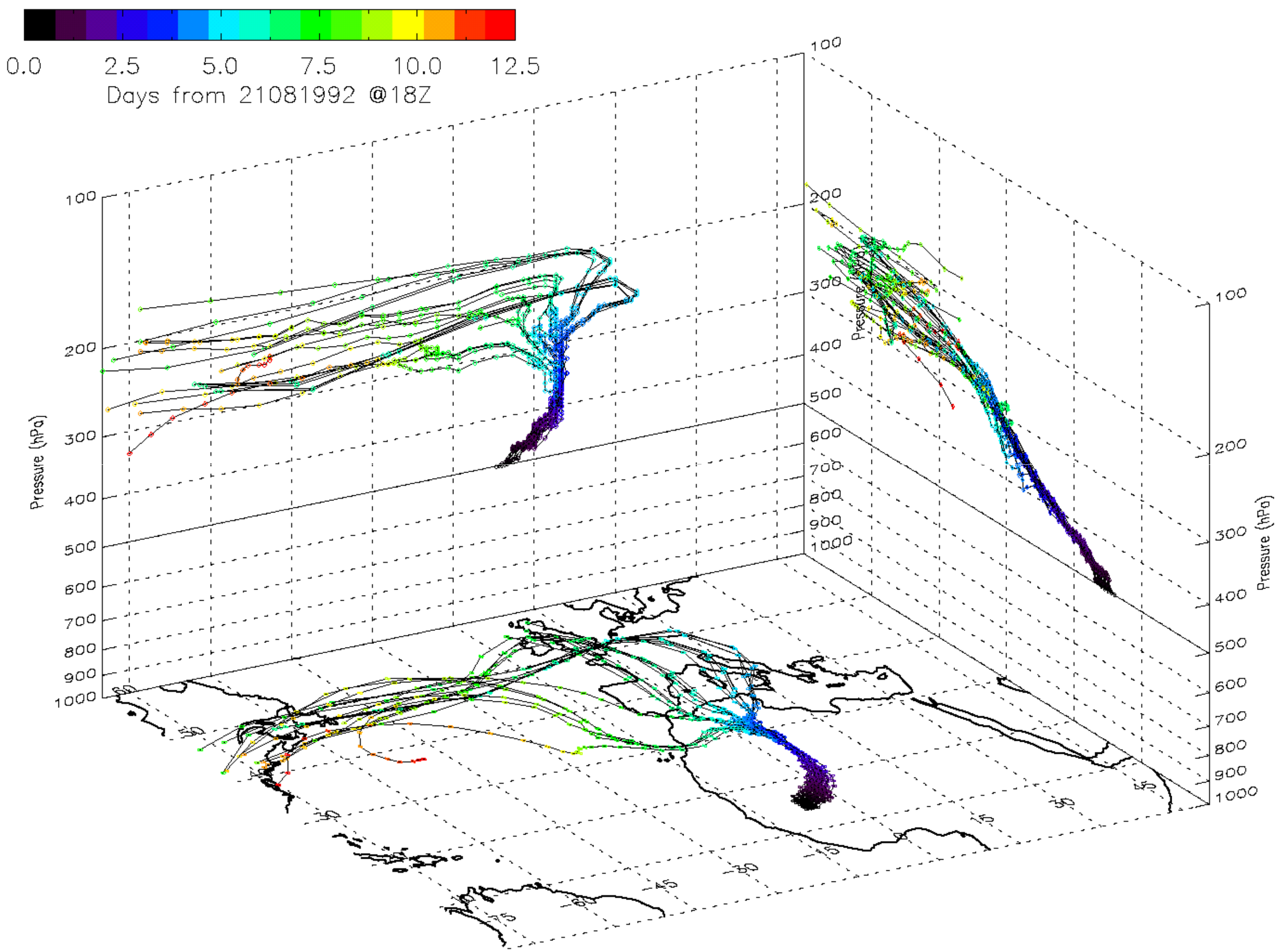
Bias slightly better than NCEP in the dry regimes

Dry air in the immediate environment of squall lines

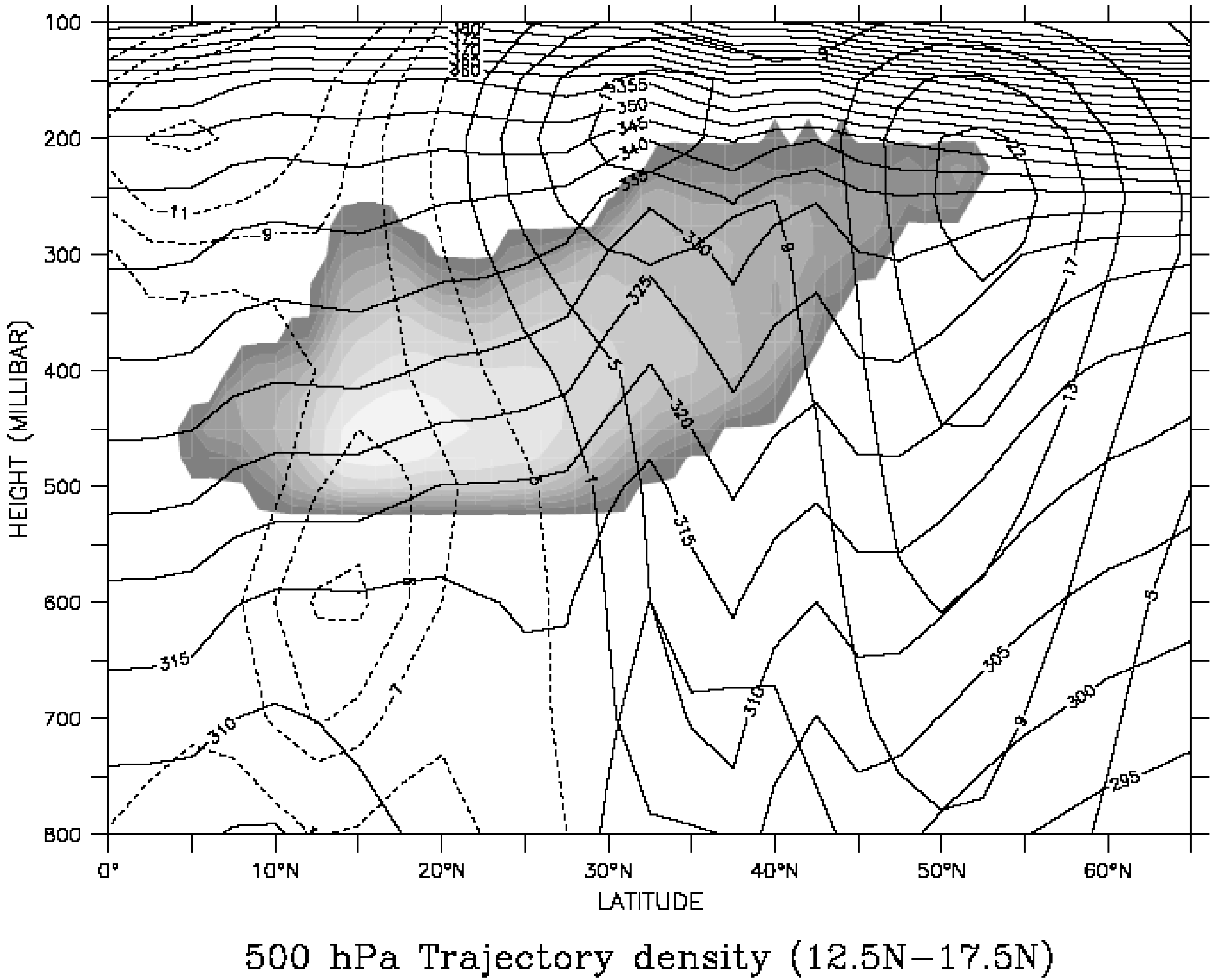


Dry and extratropical air…

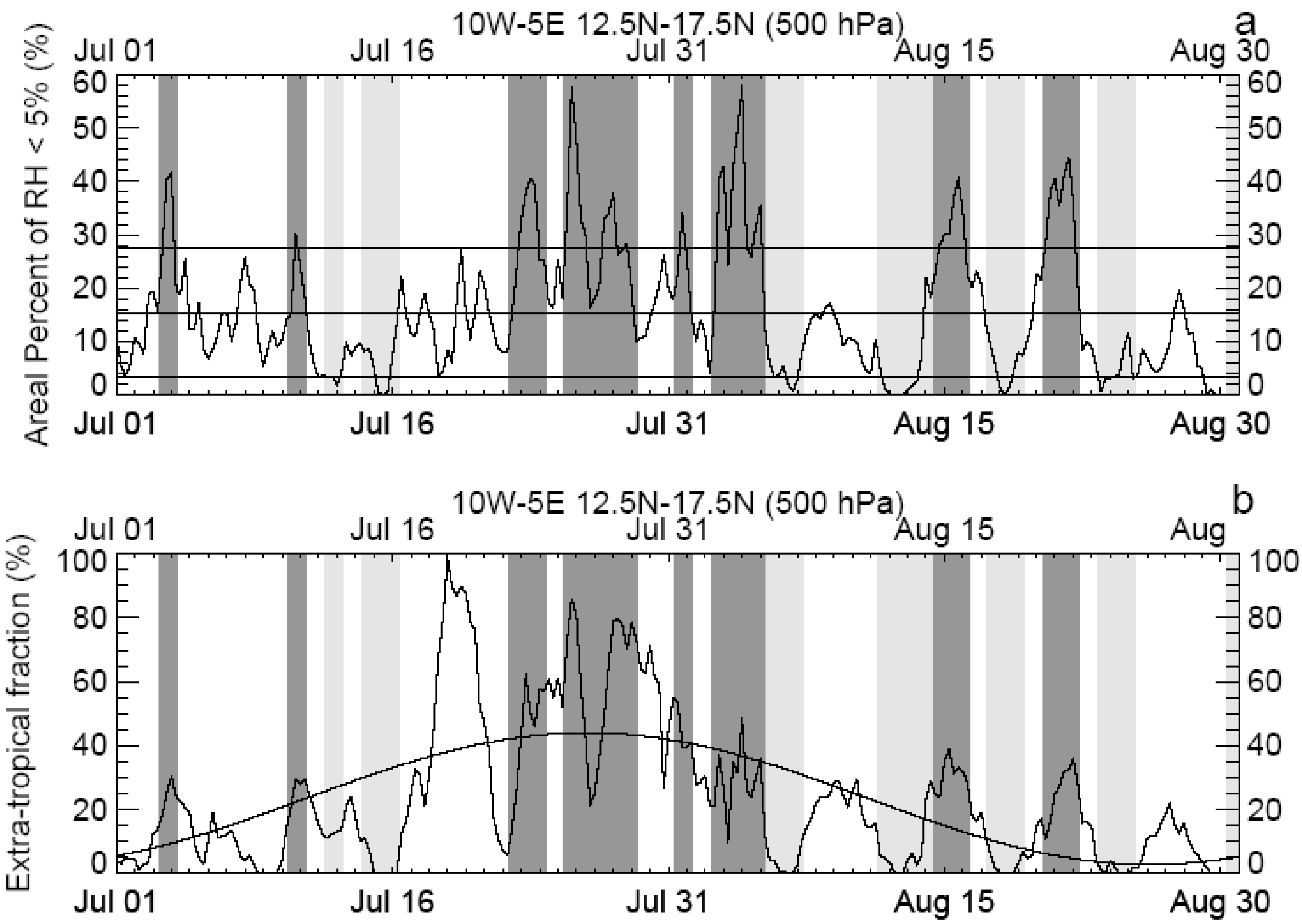
Dry air from the midlatitudes comes to Sahel troposphere



Dry air over Sahel: Polar Jet origins



Dry air over Sahel



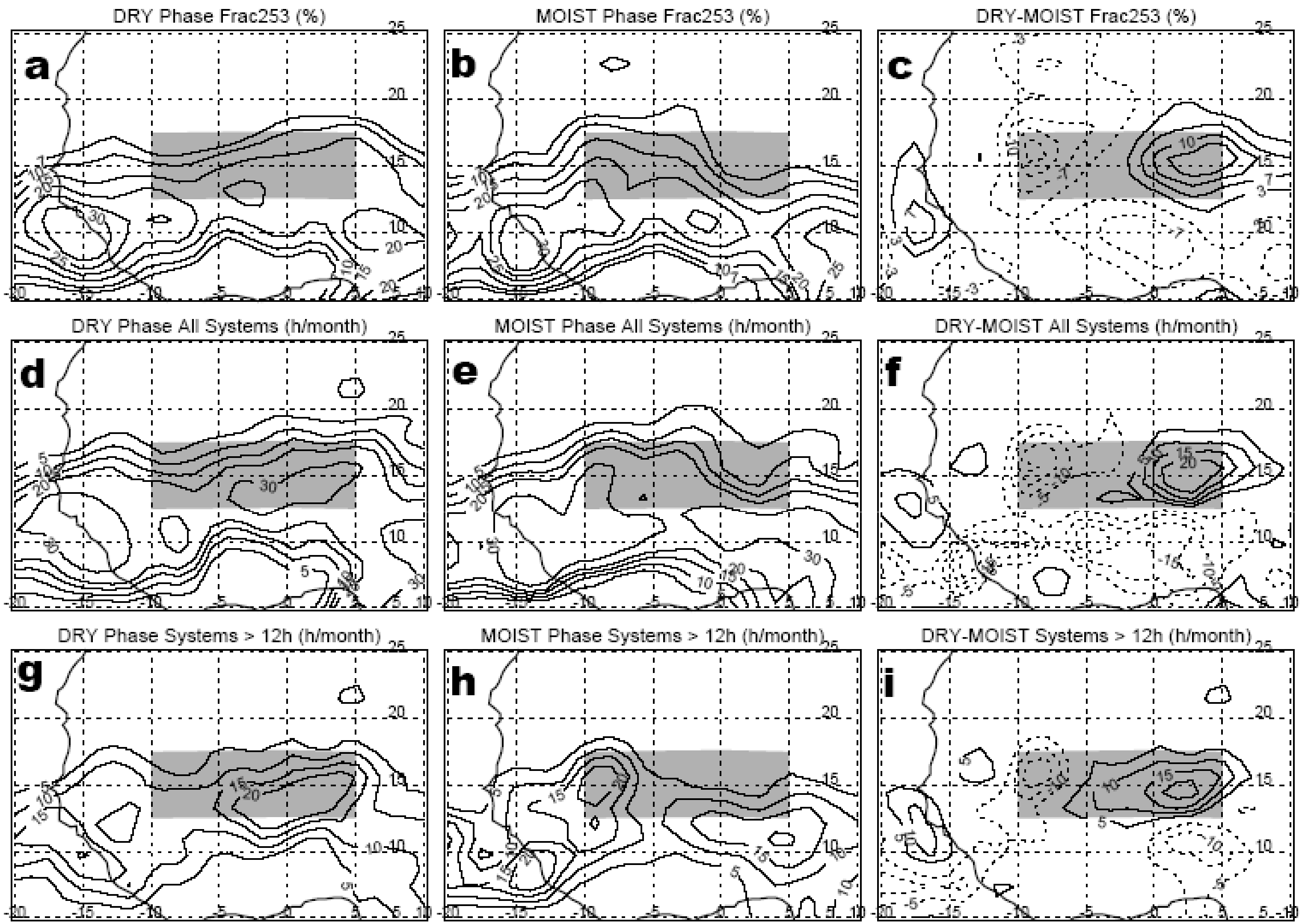
… intraseasonal variability

Compositing the convective systems to the phases

Cold Cloud Fraction

All Convective Systems

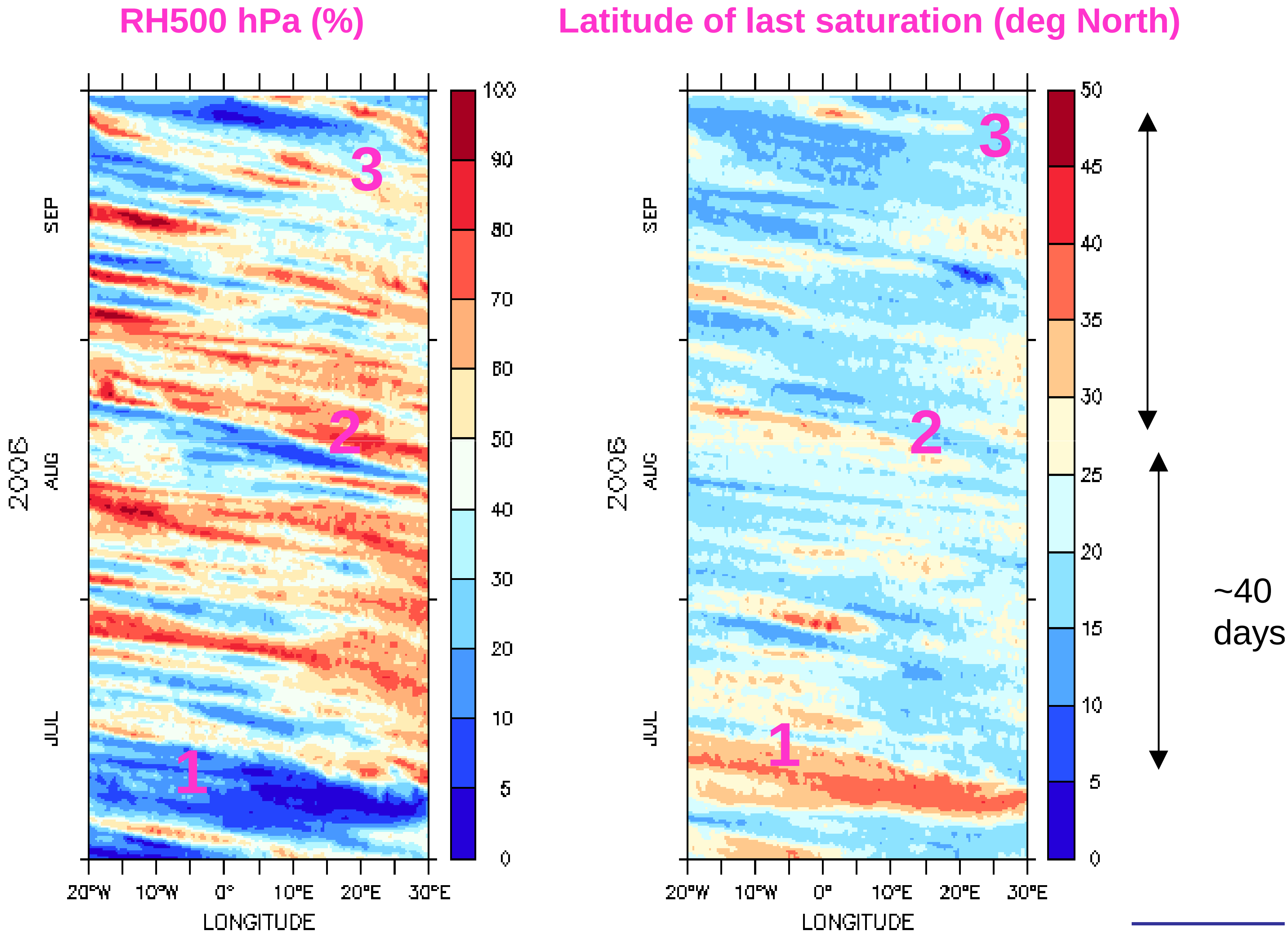
Long (>12h) Convective Systems



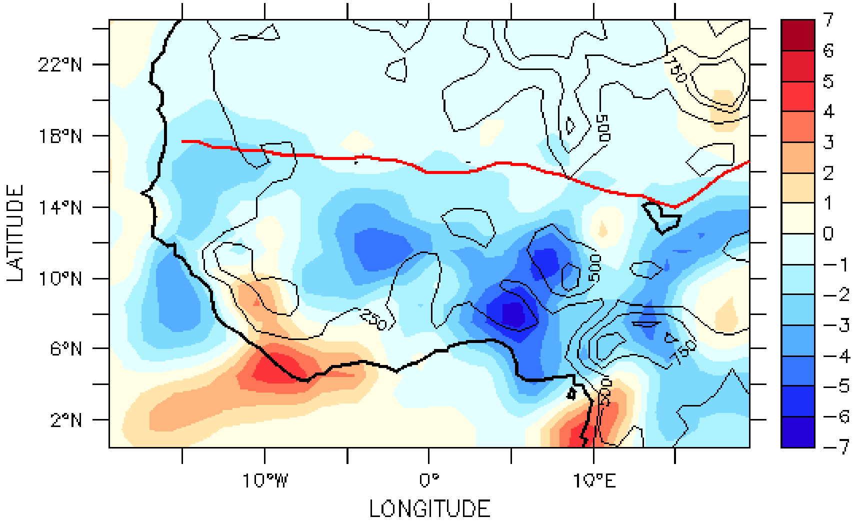
More long lasting systems in dry phases

Roca et al., JAS, 2005

AMMA 2006 the full season hovmuller

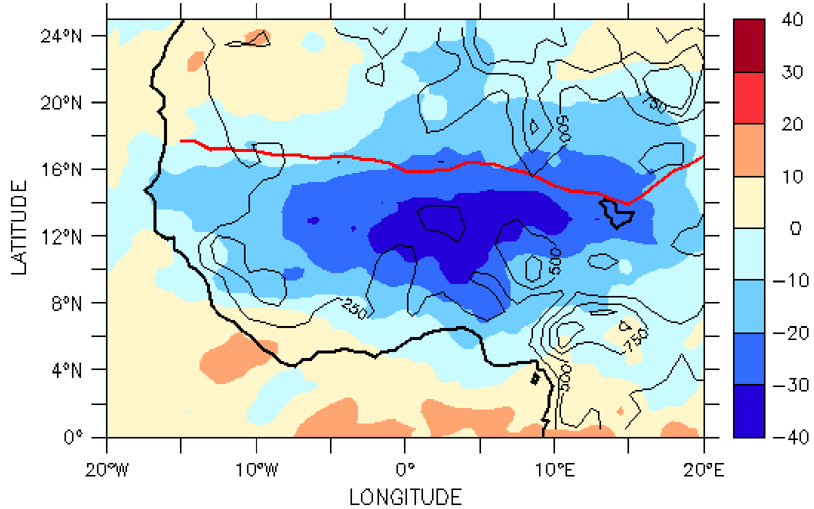


The dry air from the extratropics inhibits deep clouds at the MJO scale



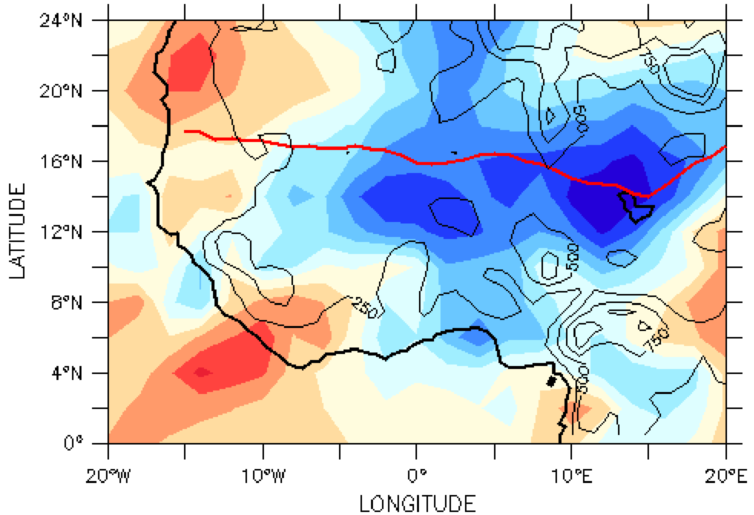
OBS

Rain anomaly (mm/day)



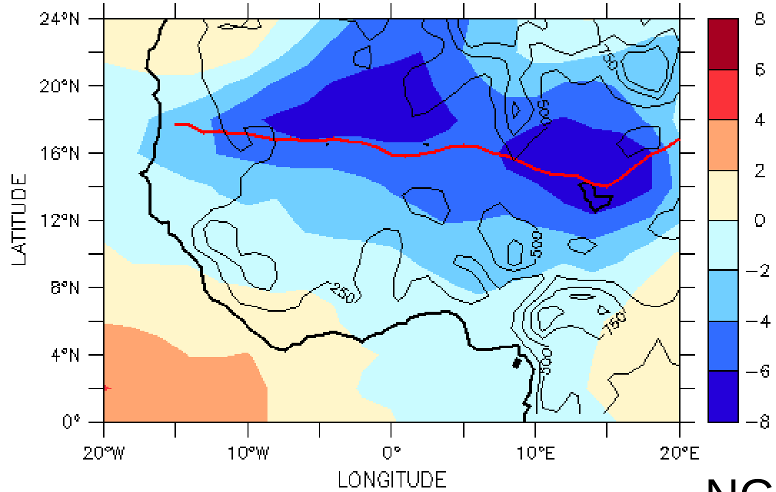
NCEP

RH500 Anomaly (%)



OBS

Free Tropospheric Humidity Anomaly (%)



NCEP

Precipitable Water Anomaly (mm)

Outline of the talk

1. Why and how to look at the free tropospheric relative humidity?

-FTH and OLR

-FTH and convection

-The AC paradigm

2. Extra-tropical Dry air intrusions over Sahel

-The case study of the 1992 season

- Interannual variability

- 2006 and the MJO mode of dry intrusions

3. Interannual variability of the eastern Mediterranean troposphere

- Why this region ?

- The METEOSAT WV channel long-term archive

- Dynamical explanation

4. Conclusions & Perspectives

Conclusions

- **METEOSAT WV archive**

  After manipulation, the archive is homogenized and compared to the favorably with RAOB archive (σ~0.5K). Still issues with absolute calibration: need to choose a reference to correct bias.
  Potential for assimilation.

- **Eastern Mediterranean dry regions**

  Driest place on Earth's troposphere
  Interannual variability is radiatively significant and is due to mixing from extra-tropics/tropics. Well defined process at play: key region for climate

- **Dry intrusions over Sahel**

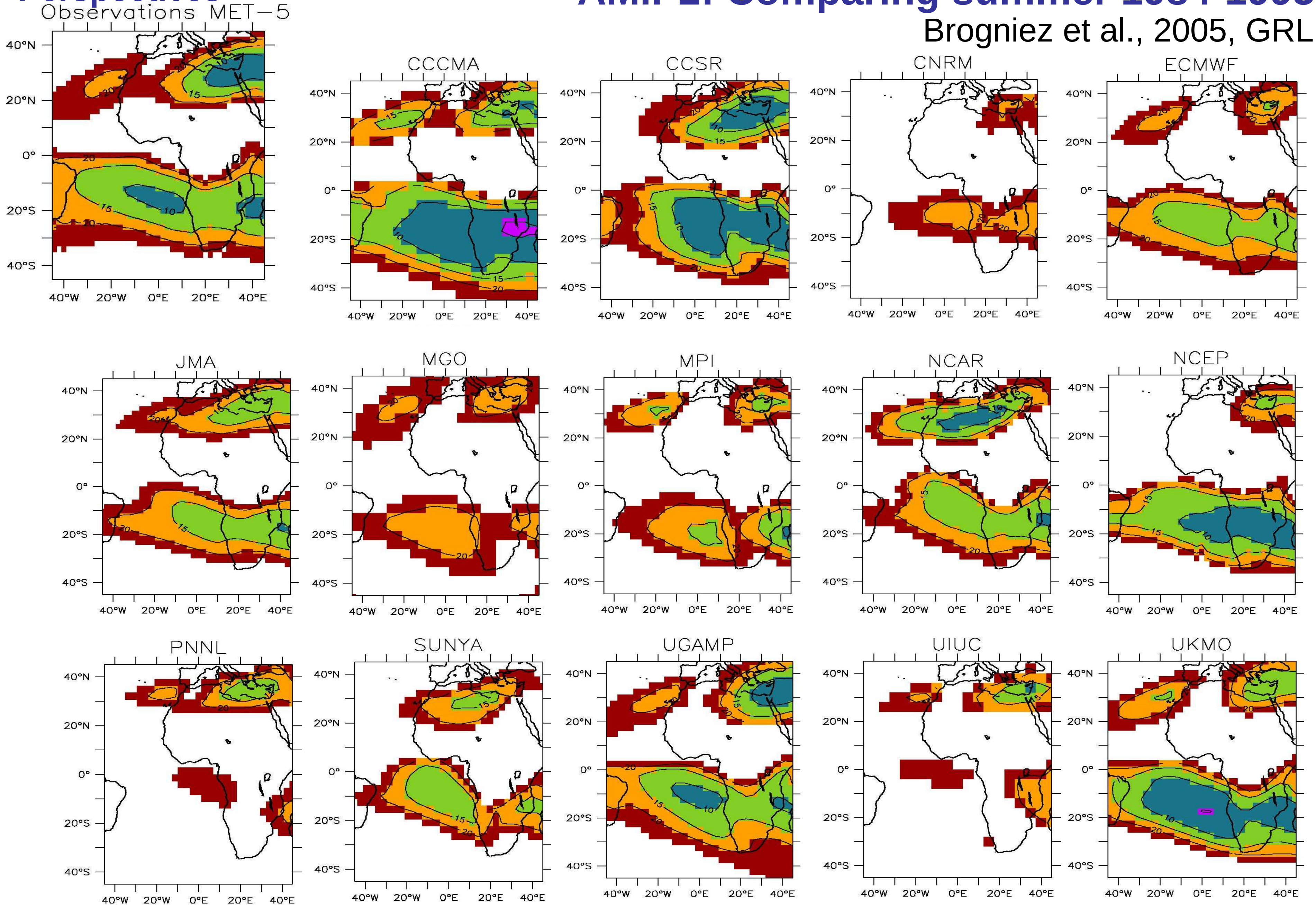
  Dry air from the extra-tropics penetrate down to the Sahelian mid troposphere and influence the occurrence of deep convection.

Free Tropospheric Humidity is still poorly represented in climate models ->

Perspectives

AMIP2: Comparing summer 1984-1995

Brogniez et al., 2005, GRL



The Megha-Tropiques mission

Overview

Indo-french mission realized by

The Indian Space Research Organisation et the

Centre National d'Etudes Spatiales

Dedicated to the

Water and energy cycle in the Tropics

Low inclinaition on the equator (20°);

865 km height

High repetetivity of the measurements

Launch foreseen in september 2009 March 2010

WEB site http://megha-tropiques.ipsl.polytechnique.fr

The Megha-Tropiques mission
Scientific objectives

Atmospheric energy budget in the intertropical zone and at system scale (radiation, latent heat, …)

Life cycle of Mesoscale Convective Complexes in the Tropics (over Oceans and Continents)

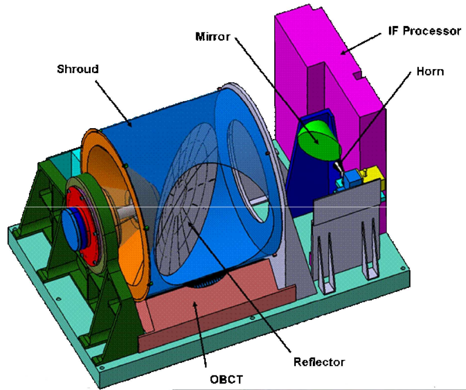
Monitoring and assimilation for Cyclones, Monsoons, Mesoscale Convective Systems forecasting.

Contribution to climate monitoring :

- **Radiative budget (complementary to CERES)**
- **Precipitation (enhanced sampling in the tropics)**
- **Water vapour (enhanced sampling in the tropics),**

The Megha-Tropiques mission
Payloads (1/2)

- **ScaRaB** : wide band instrument for inferring longwave and shortwage outgoing fluxes at the top of the atmosphere (cross track scanning, 40 km resolution at nadir)



- **Saphir** : microwave sounder for water vapour sounding : 6 channels in the WV absoption band at 183.31 GHz. (cross track, 10 km)

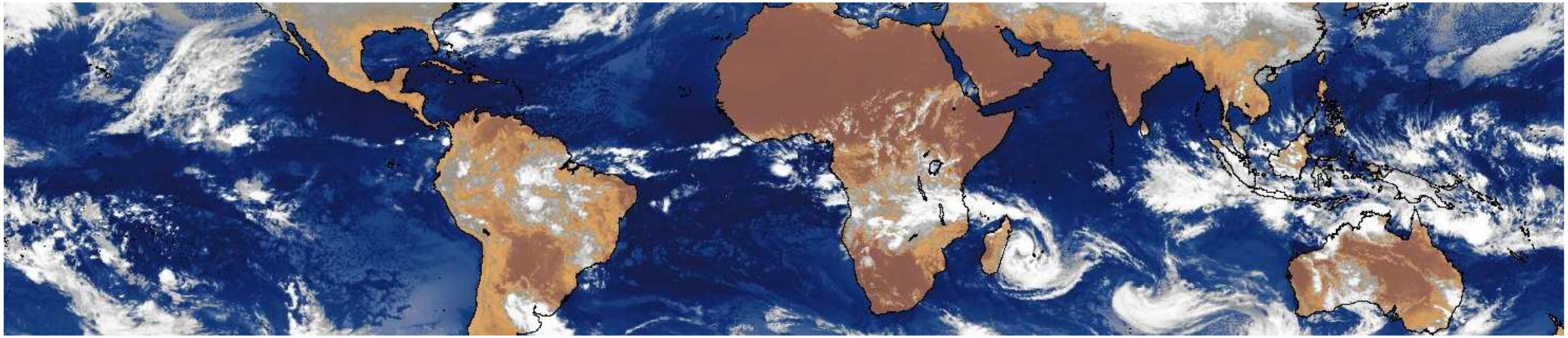
- **MADRAS** : microwave imager for precipitation : channels at 18, 23, 37, 89 and 157 GHz, H and V polarisations. (conical swath, <10 km to 40 km)


MARFEQ RF Hardware

The Megha-Tropiques mission
Payloads (2/2)

- **GPS RO: water vapor profile …**

- **GEOSTATIONARY DATA**
  - **Cloud mask for the MW algo**
  - **Quicklook for interpreting MT data**
  - **Basic inputs for MCS tracking algorithm**
  - **Basic inputs for Level 4 rainfall (radiation) products**



The Megha-Tropiques mission
Orbit (1/2)

Megha-Tropiques
Orbite par rapport à la Terre

Phasage = [14; -1; 7] 97

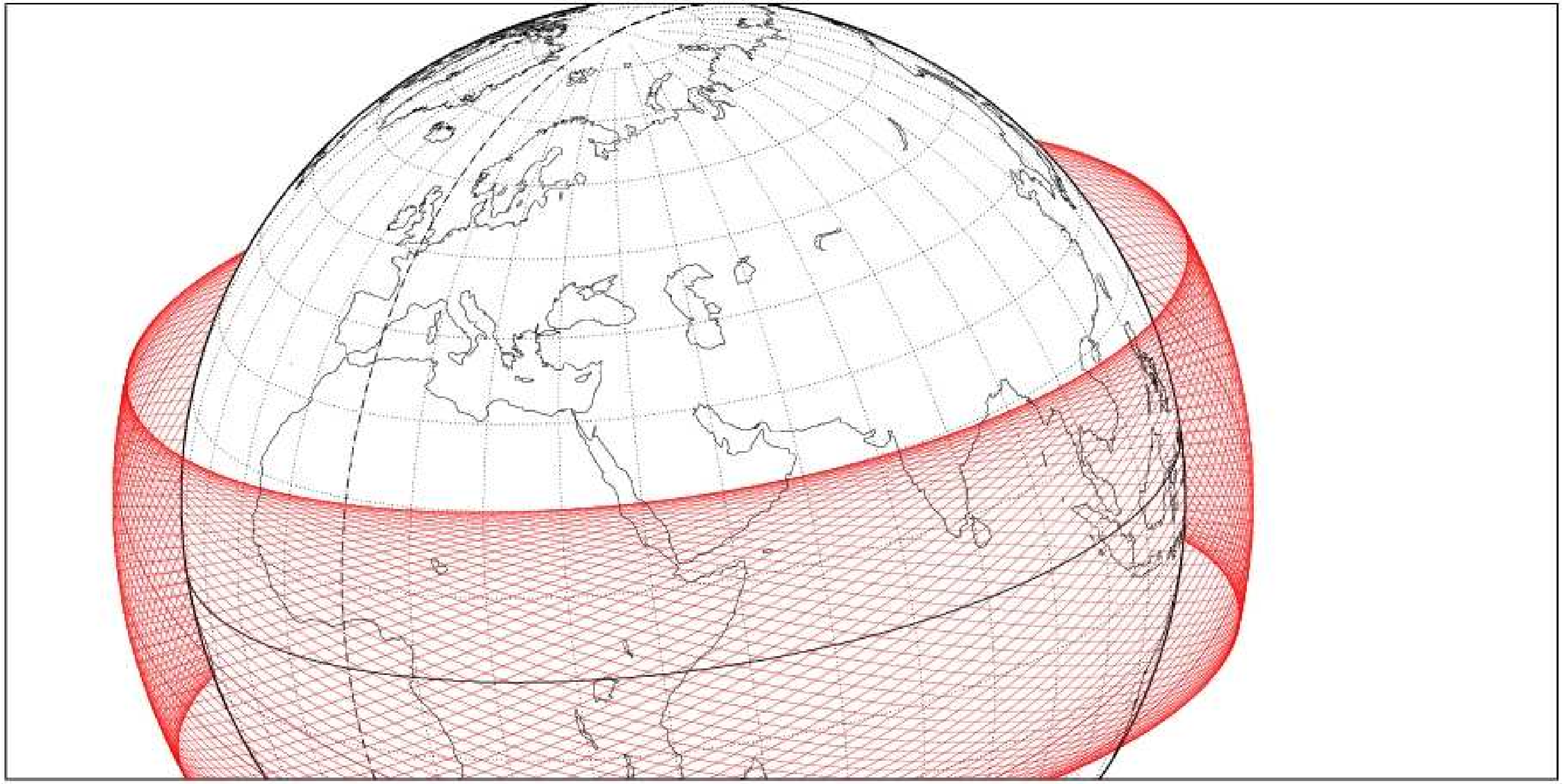
>>> Durée représentée : 7.00 jours

Altitude = 865.5 km a = 7243.678 km

Inclinaison = 20.00 °

Période = 101.93 min * Révol./j.=14.13

Décalage à l'équateur = 2892.0 km (26.0 °)



Projection : Orthographique CP: 20.0 ° N; 45.0 °E /CZ: 30.0 ° N; 60.0 ° E Noeud asc. : -180.00 ° [00:00 TSM] Ιξιων

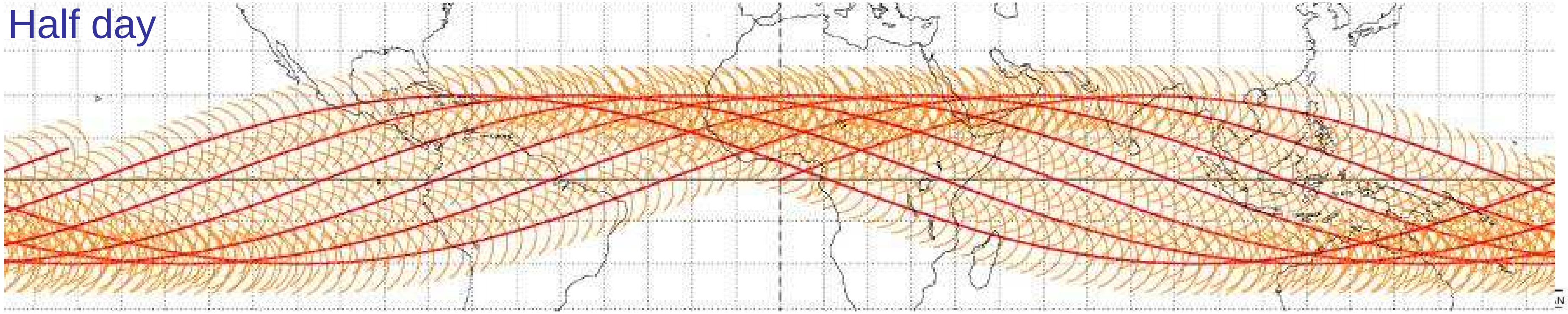
Propriété : (sans) Aspect : Oblique MC ⋆ LMD

⊕ T.:Azimutal - Grille : 10° {4.2} [-90.0/ +70.0/ +45.0] [+8] EGM96 Ατλας

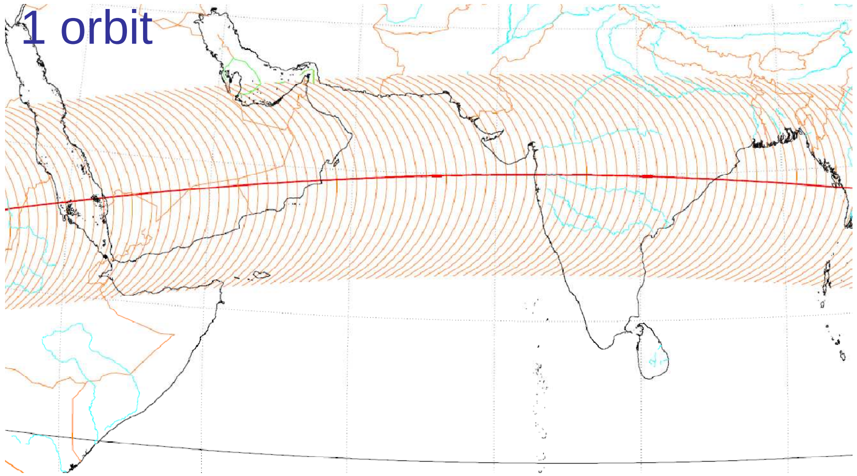
The Megha-Tropiques mission

Orbit (2/2)

Half day

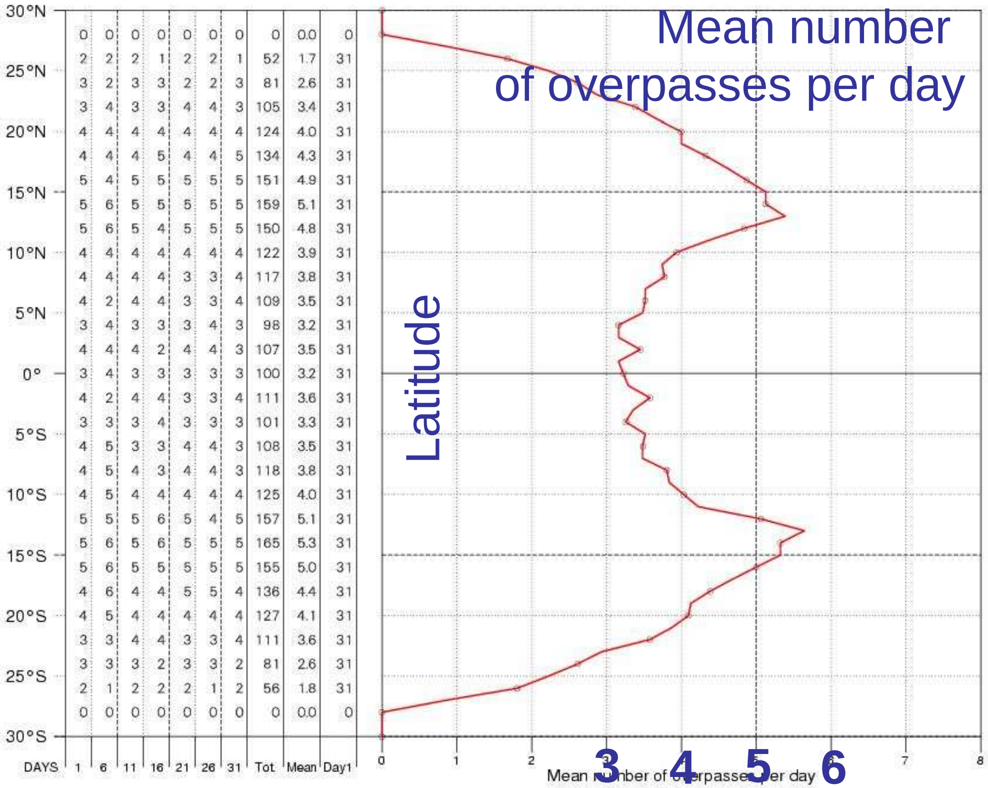


1 orbit



1	6	11	16	21	26	31	Tot	Mean	Day1
0	0	0	0	0	0	0	0	0.0	0
2	2	2	1	2	2	1	52	1.7	31
3	2	3	3	2	2	3	81	2.6	31
3	4	3	3	4	4	3	105	3.4	31
4	4	4	4	4	4	4	124	4.0	31
4	4	4	5	4	4	5	134	4.3	31
5	4	5	5	5	5	5	151	4.9	31
5	6	5	5	5	5	5	159	5.1	31
5	6	5	4	5	5	5	150	4.8	31
4	4	4	4	4	4	4	122	3.9	31
4	4	4	4	3	3	4	117	3.8	31
4	2	4	4	3	3	4	109	3.5	31
3	4	3	3	3	4	3	98	3.2	31
4	4	4	2	4	4	3	107	3.5	31
3	4	3	3	3	3	3	100	3.2	31
4	2	4	4	3	3	4	111	3.6	31
3	3	3	4	3	3	3	101	3.3	31
4	5	3	3	4	4	3	108	3.5	31
4	5	4	3	4	4	3	118	3.8	31
4	5	4	4	4	4	4	125	4.0	31
5	5	5	6	5	4	5	157	5.1	31
5	6	5	6	5	5	5	165	5.3	31
5	6	5	5	5	5	5	155	5.0	31
4	6	4	4	5	5	4	136	4.4	31
4	5	4	4	4	4	4	127	4.1	31
3	3	4	4	3	3	4	111	3.6	31
3	3	3	2	3	3	2	81	2.6	31
2	1	2	2	2	1	2	56	1.8	31
0	0	0	0	0	0	0	0	0.0	0

DAYS



MADRAS sampling over 20°S-20°N
Min 3 per day
Max 5 per day