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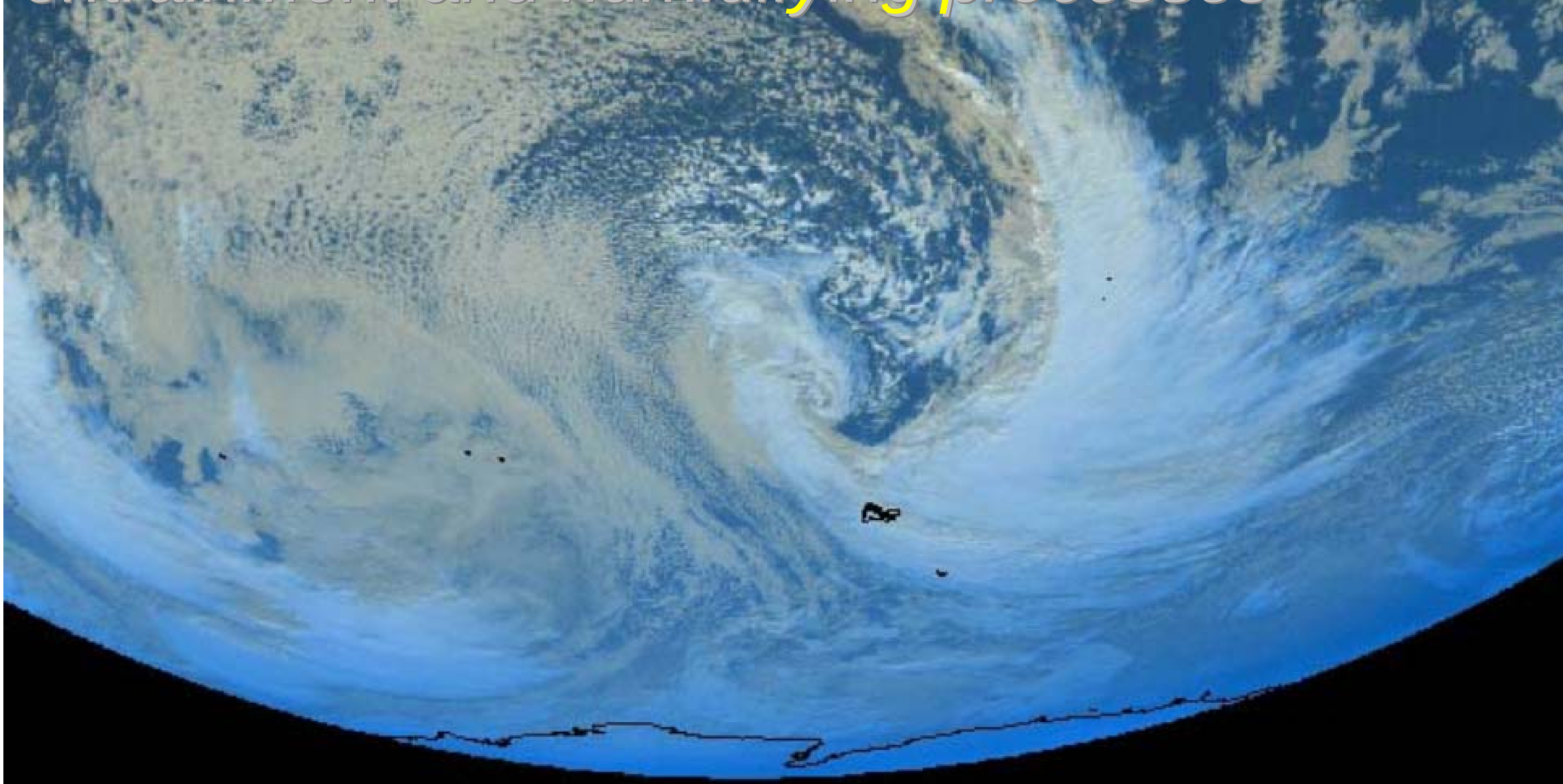
Evolution of convective cloud top height: entrainment and humidifying processes



EUROCS Workshop, Madrid, 16-19/12/2002

Summary

Questions:

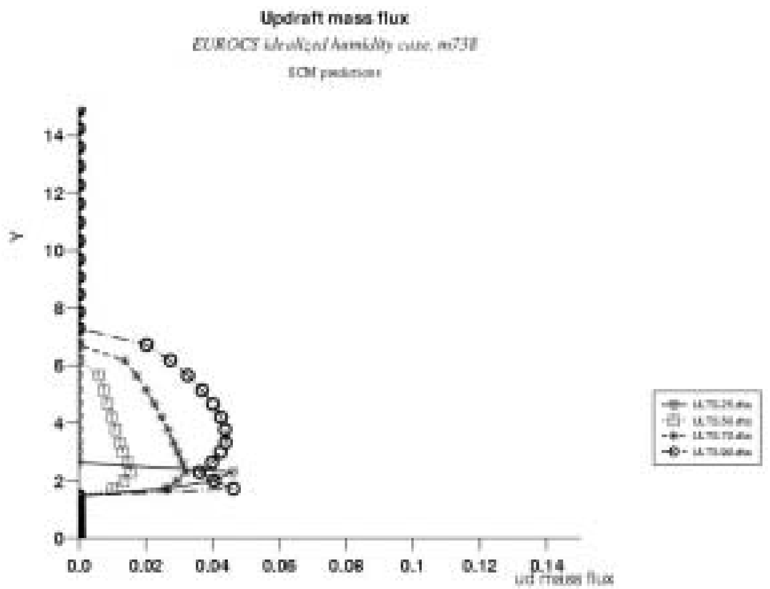
1. *(1D EUROCS idealized humidity case, 3D)* What impact on diurnal cycle if the ARPEGE convective scheme sensitivity to humidity is removed?

2. *(1D EUROCS diurnal cycle of deep convection case, 3D)* Cloud top height evolutions: link with saturation deficit & its diurnal phase

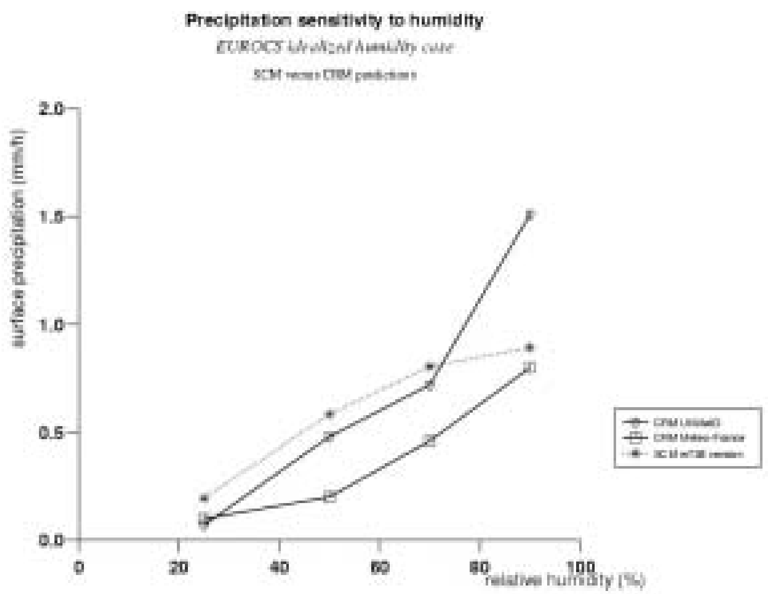
EUROCS idealized humidity case

ARPEGE operational version

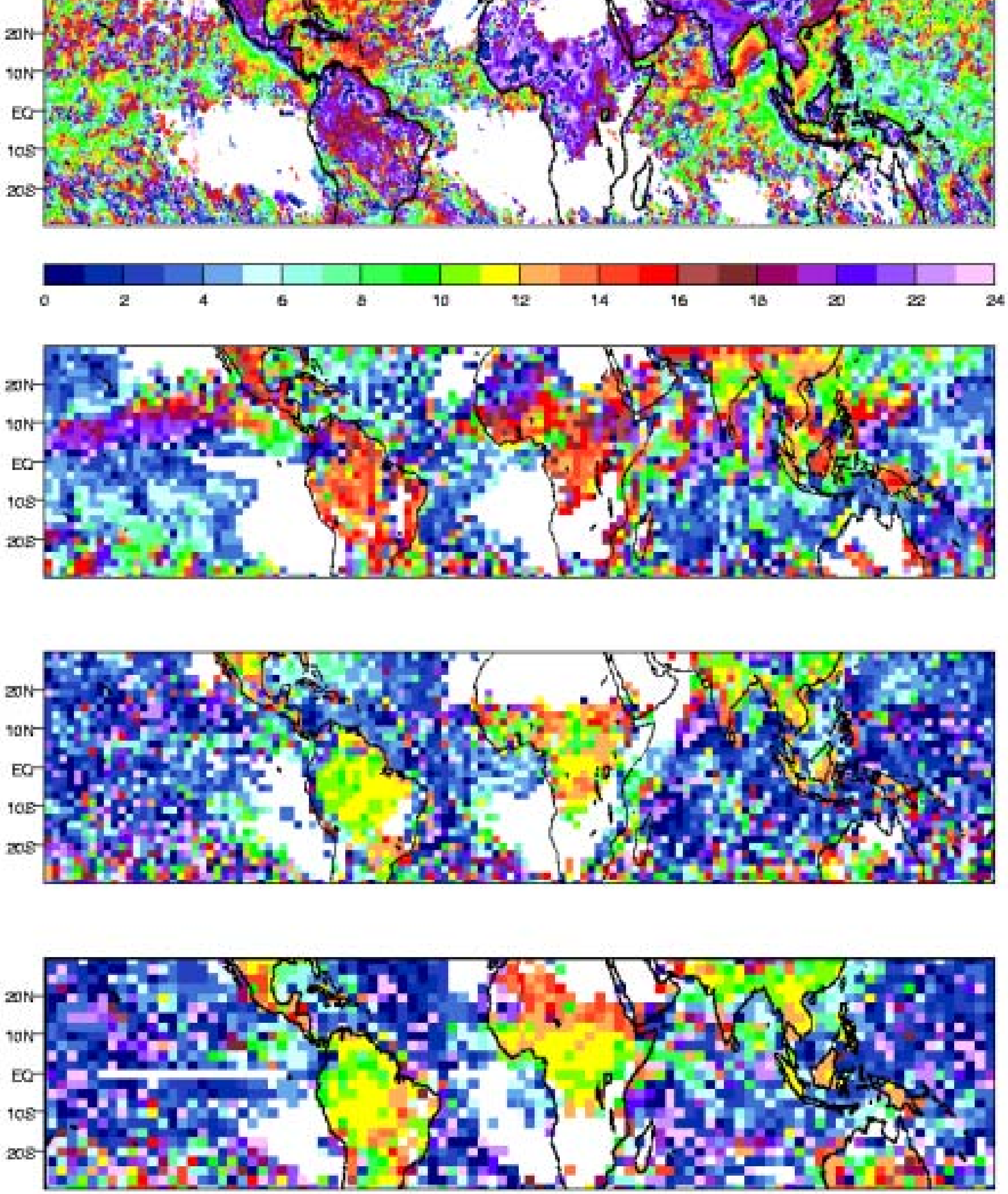
Mass fluxes for the 4 environmental humidities



Precipitations vs the 4 humidities.
Continuous: CRMs
Dotted: SCM



Diurnal cycle of convection / JJA



Observations
Yang and Slingo MWR 2001

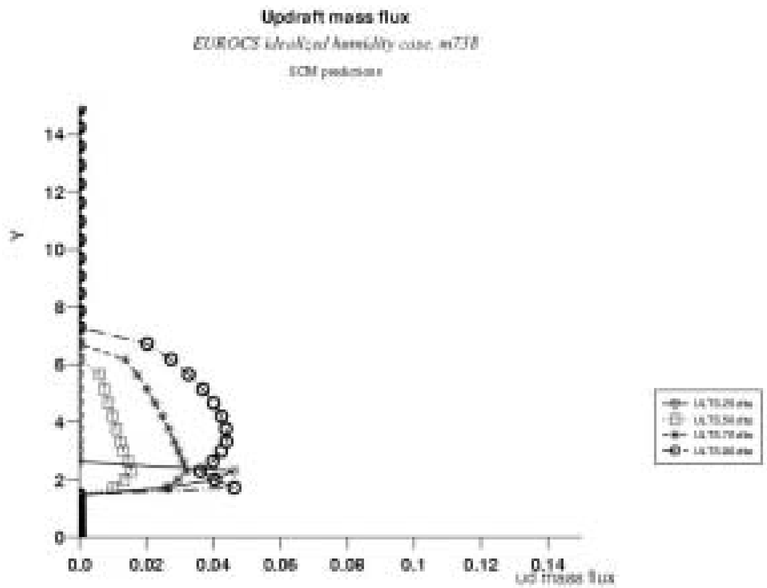
ARPEGE NWP Model
J.M. Piriou 2002

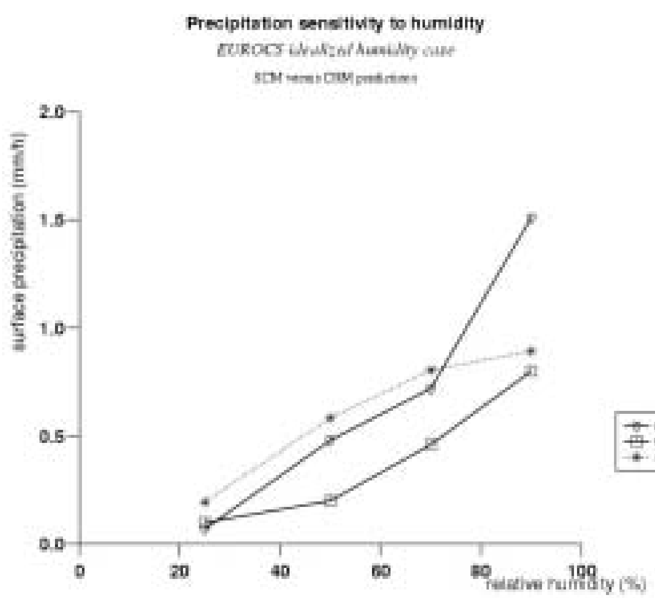
IFS NWP Model
Beljaars 2002

Unified Climate Model
Yang and Slingo MWR 2001

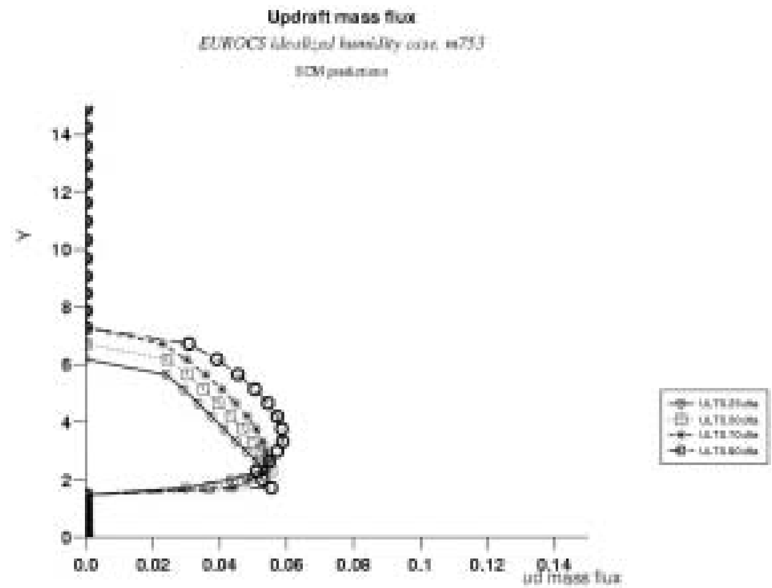
EUROCS idealized humidity case

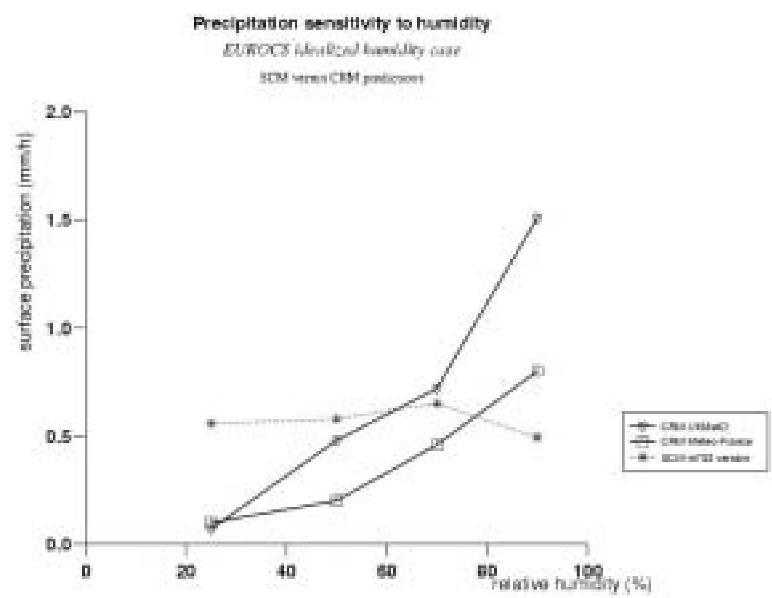
ARPEGE operational version



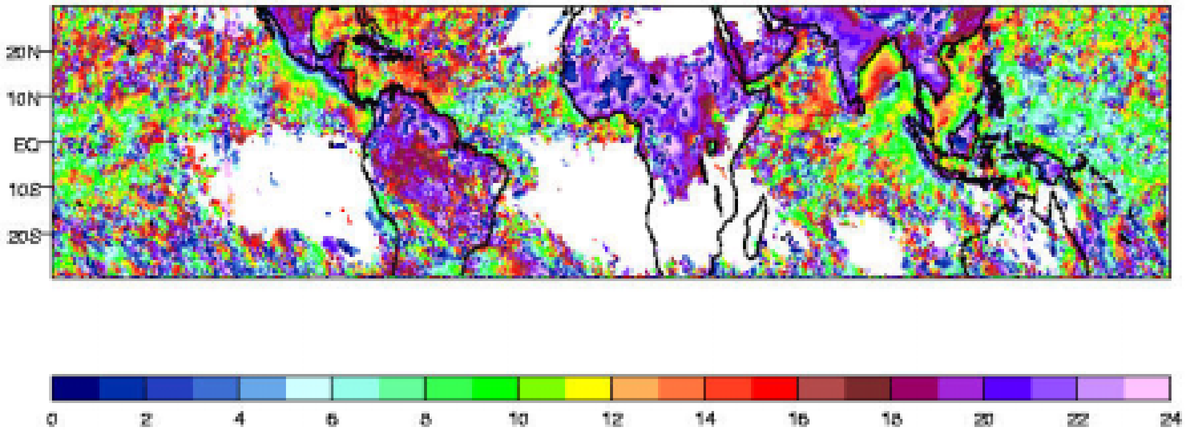


Operational + reduced entrainment

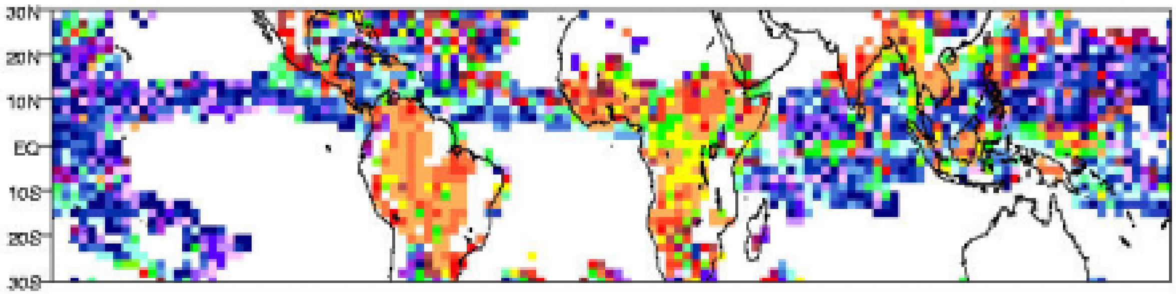




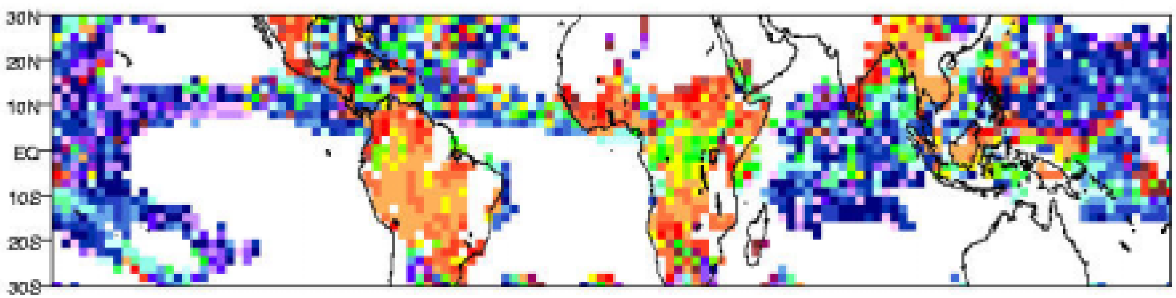
Diurnal cycle of convection



Observations
Yang and Slingo MWR 2001



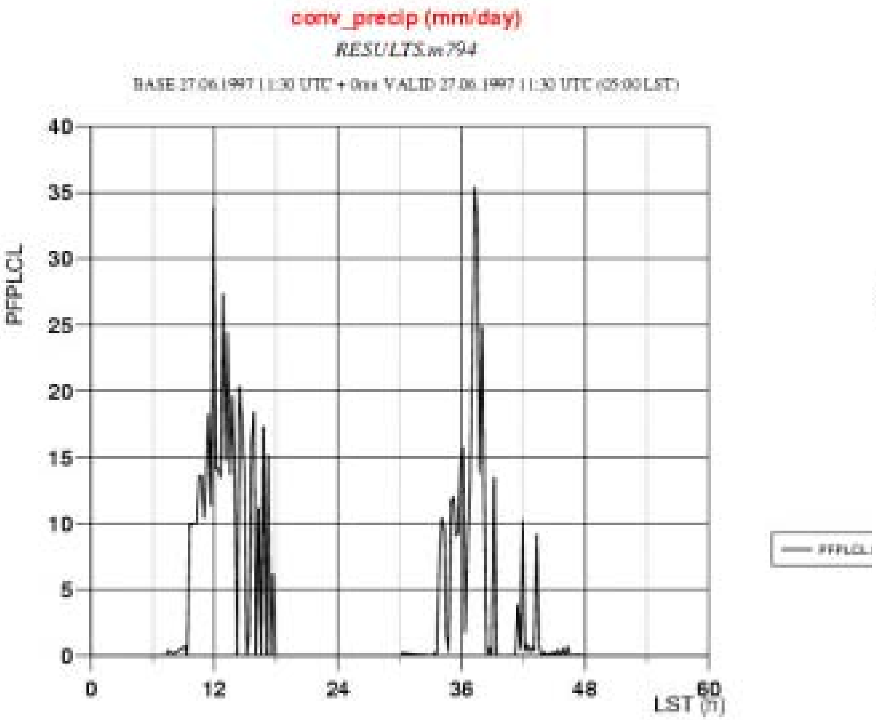
CONTROL = ARPEGE NWP operational model, 10 two days pred.déc 2002



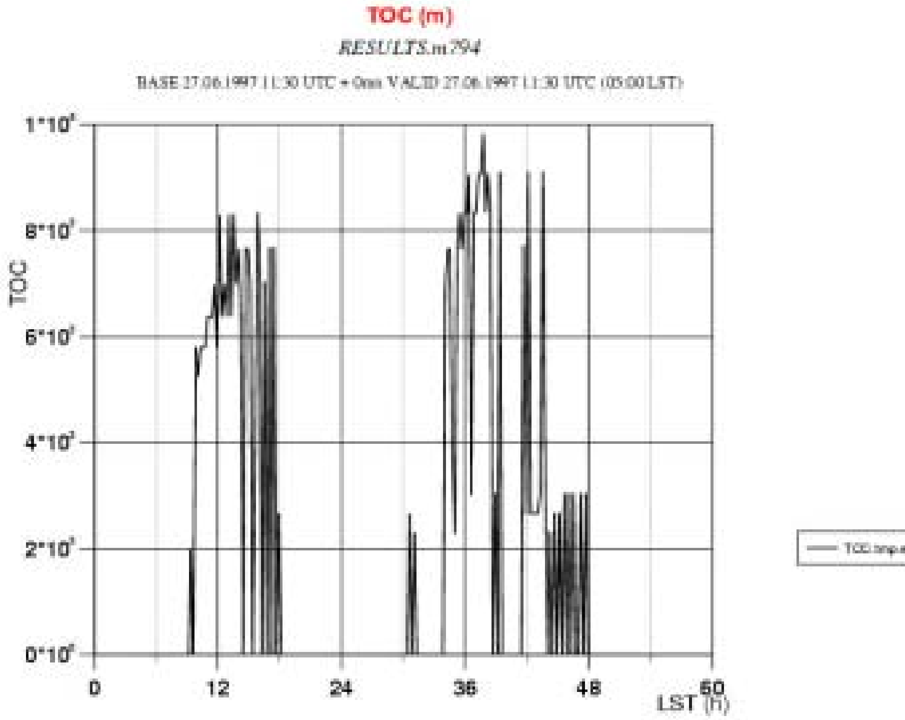
CONTROL
+ Reduced entrainment

EUROCS diurnal cycle of deep convection

Convective precip.

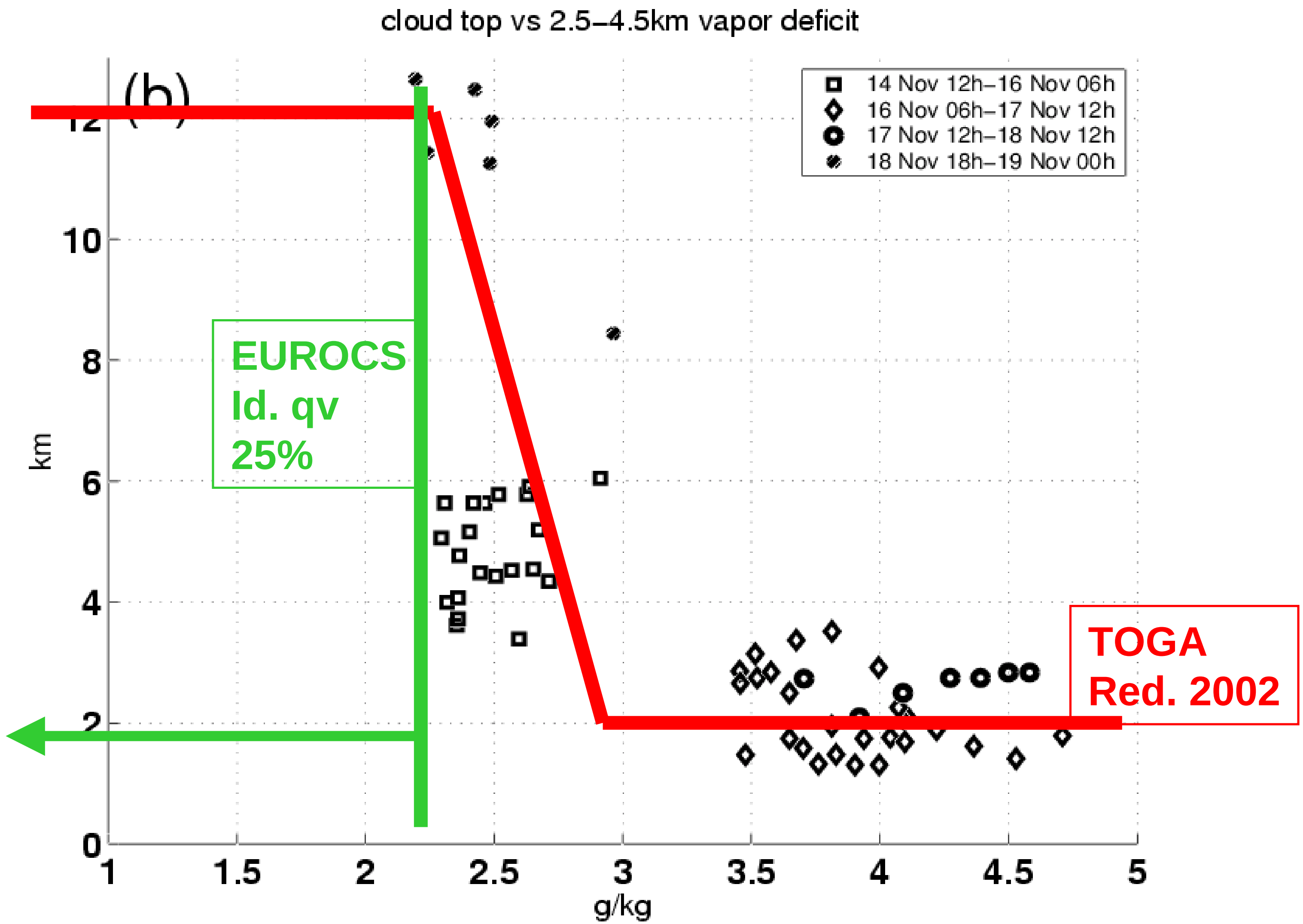


Cloud top height

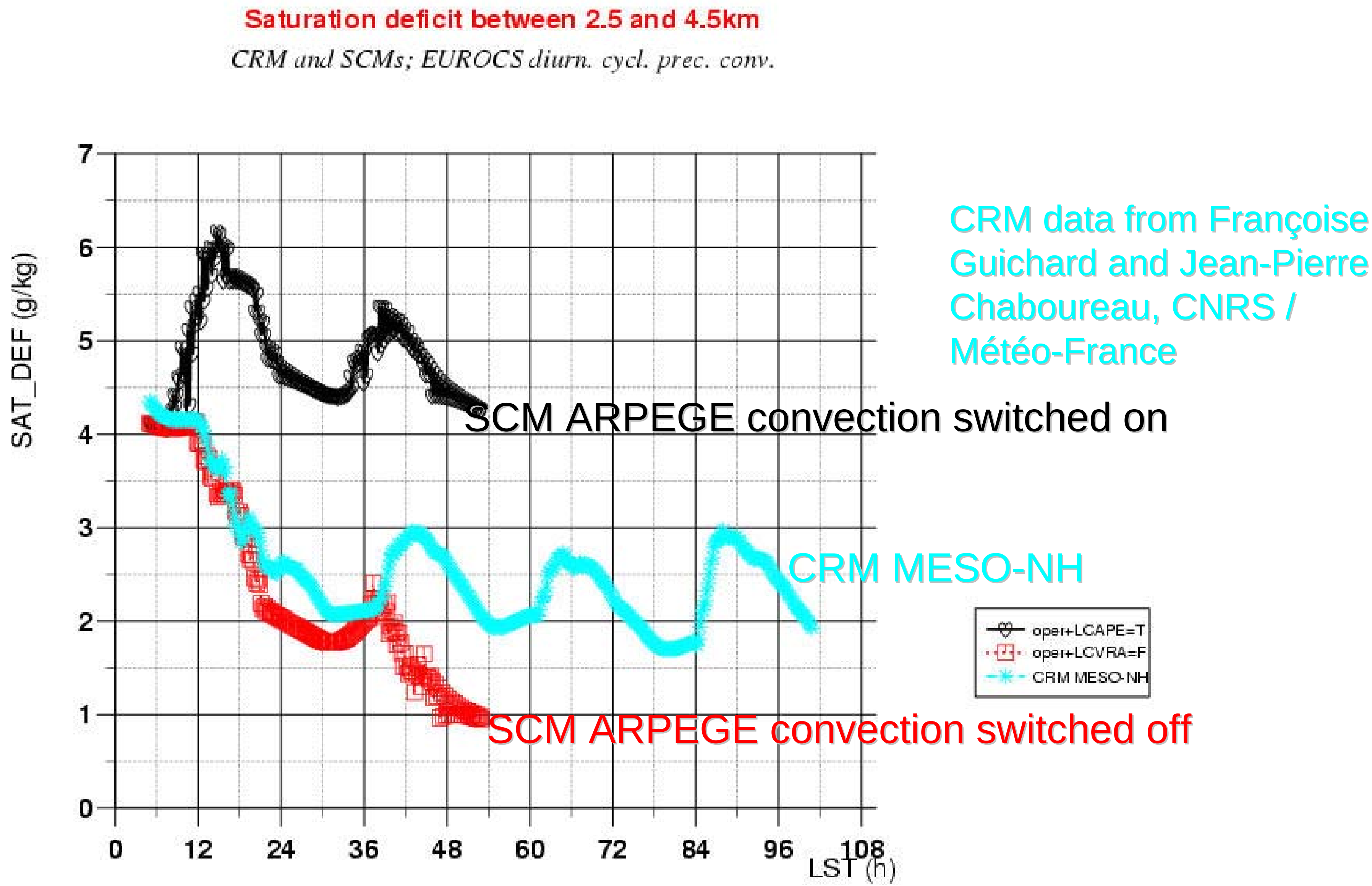


SCM run; operational ARPEGE physics

Sensitivity to humidity: top of clouds

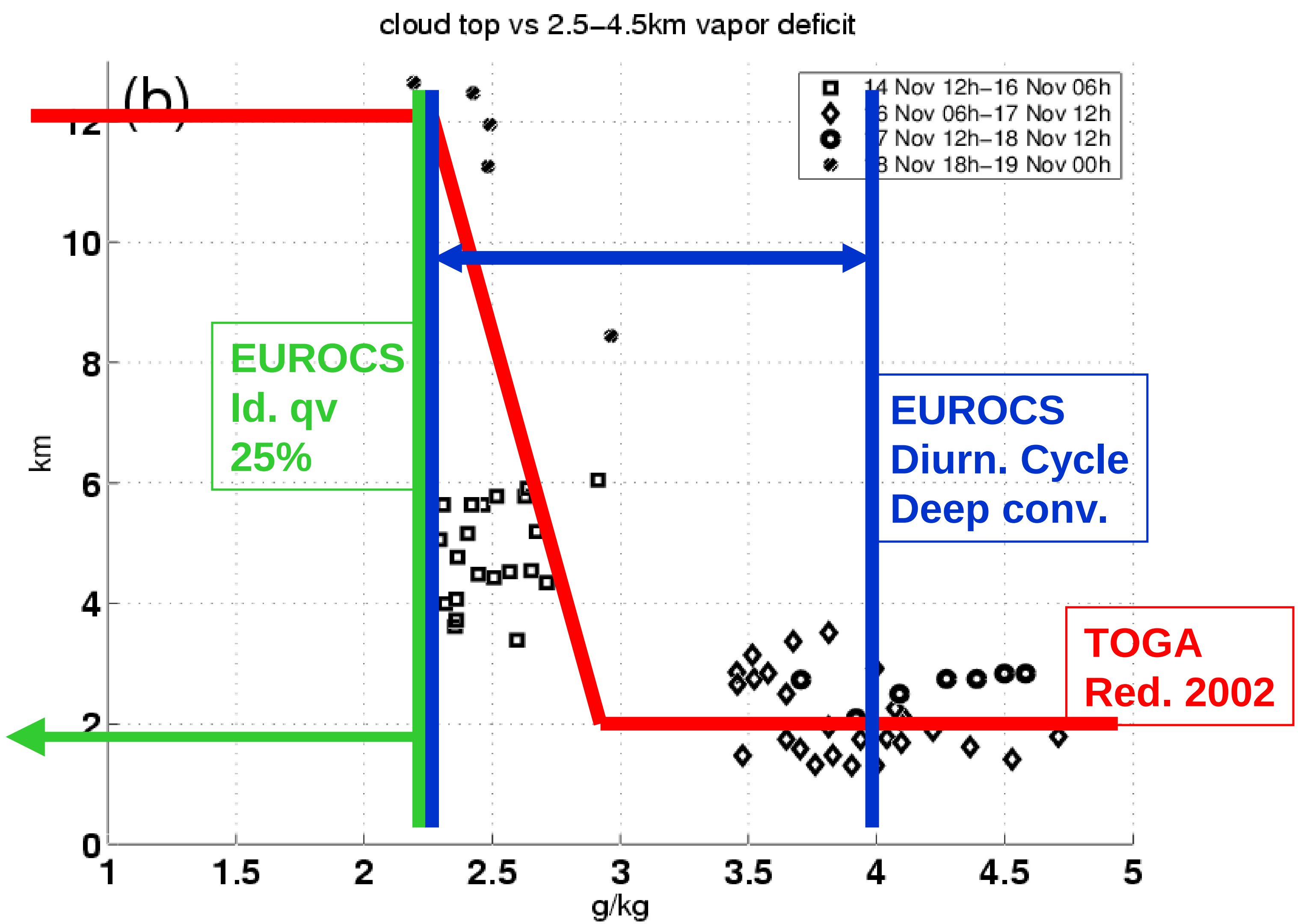


TOGA-COARE / J.L. Redelsperger, D. Parsons, F. Guichard, JAS 2002

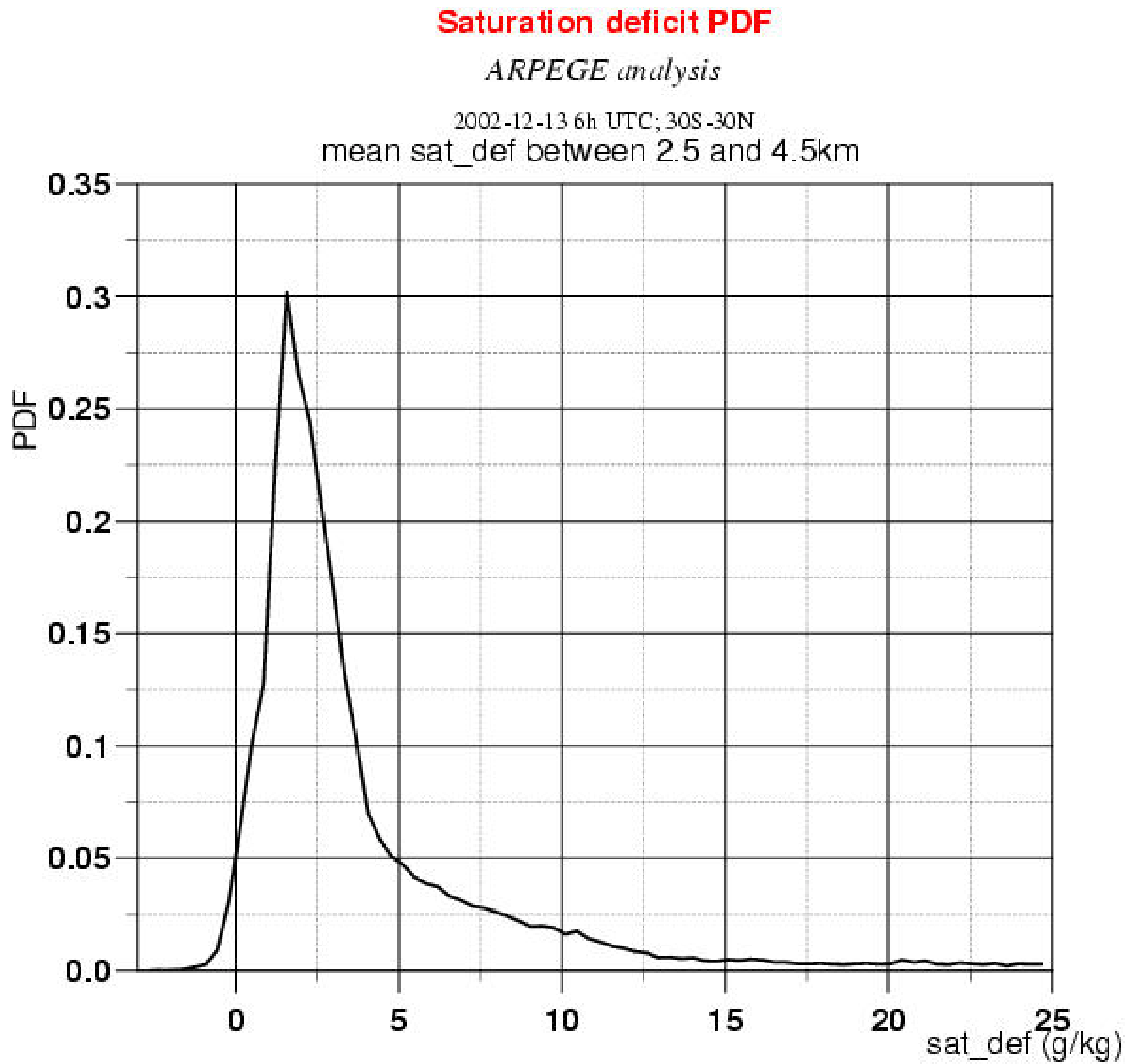


EUROCS diurnal cycle of deep convection

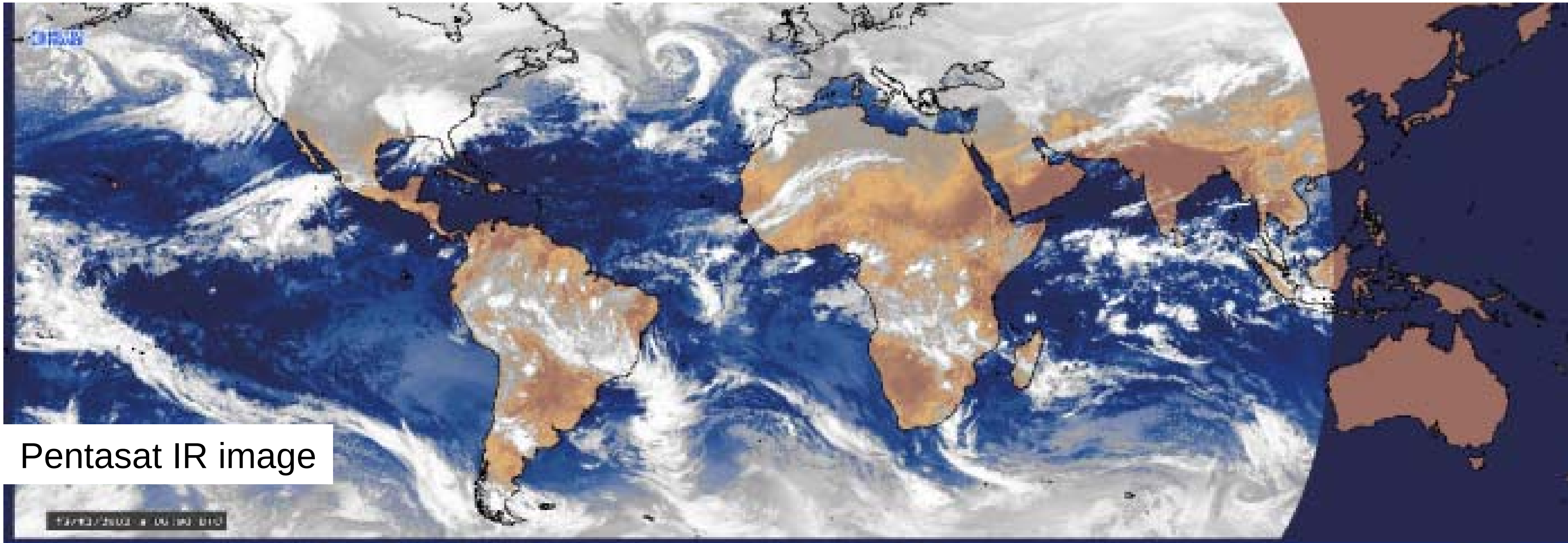
Sensitivity to humidity: top of clouds



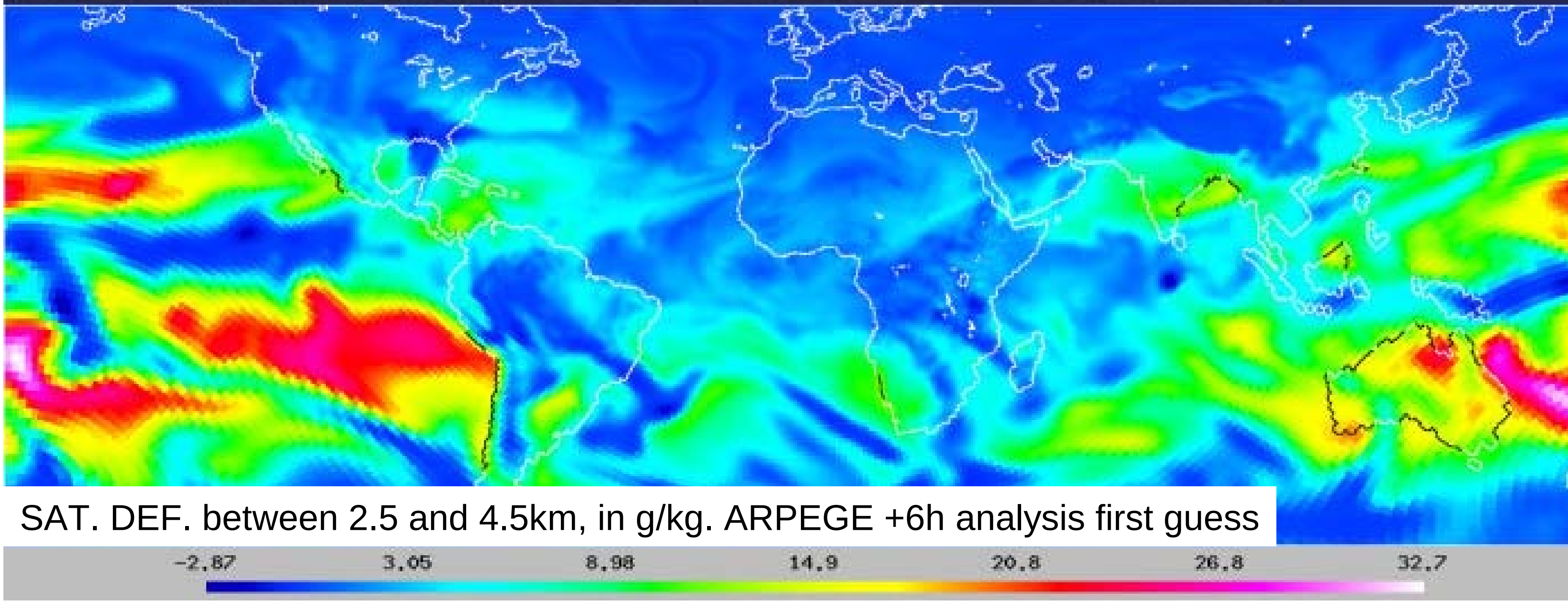
TOGA-COARE / J.L. Redelsperger, D. Parsons, F. Guichard, JAS 2002



Saturation deficit PDF
ARPEGE analysis
2002-12-13 6h UTC; 30S-30N
mean sat_def between 2.5 and 4.5km
PDF
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0.0
0
5
10
15
20
25
sat_def (g/kg)

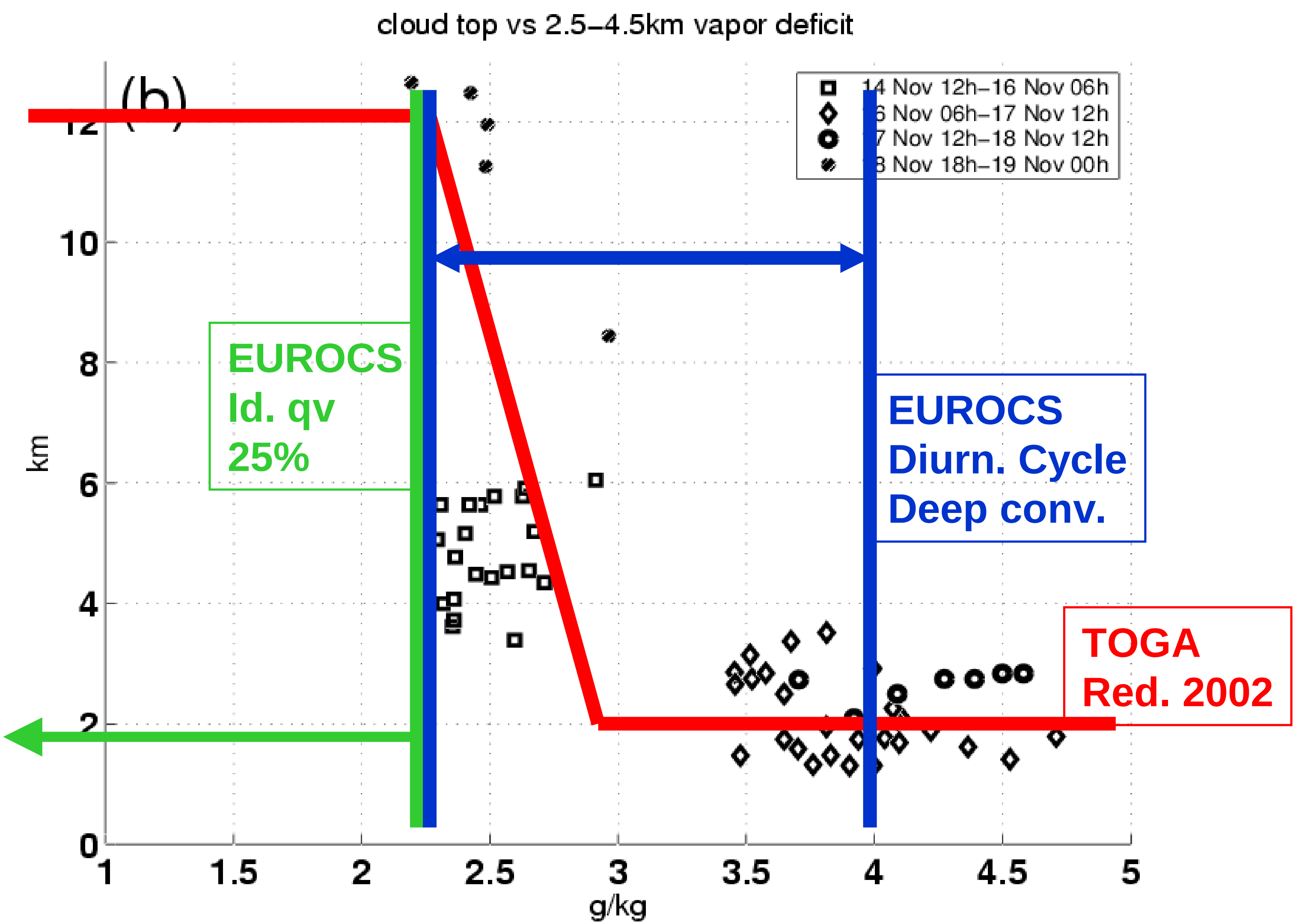


Pentasat IR image

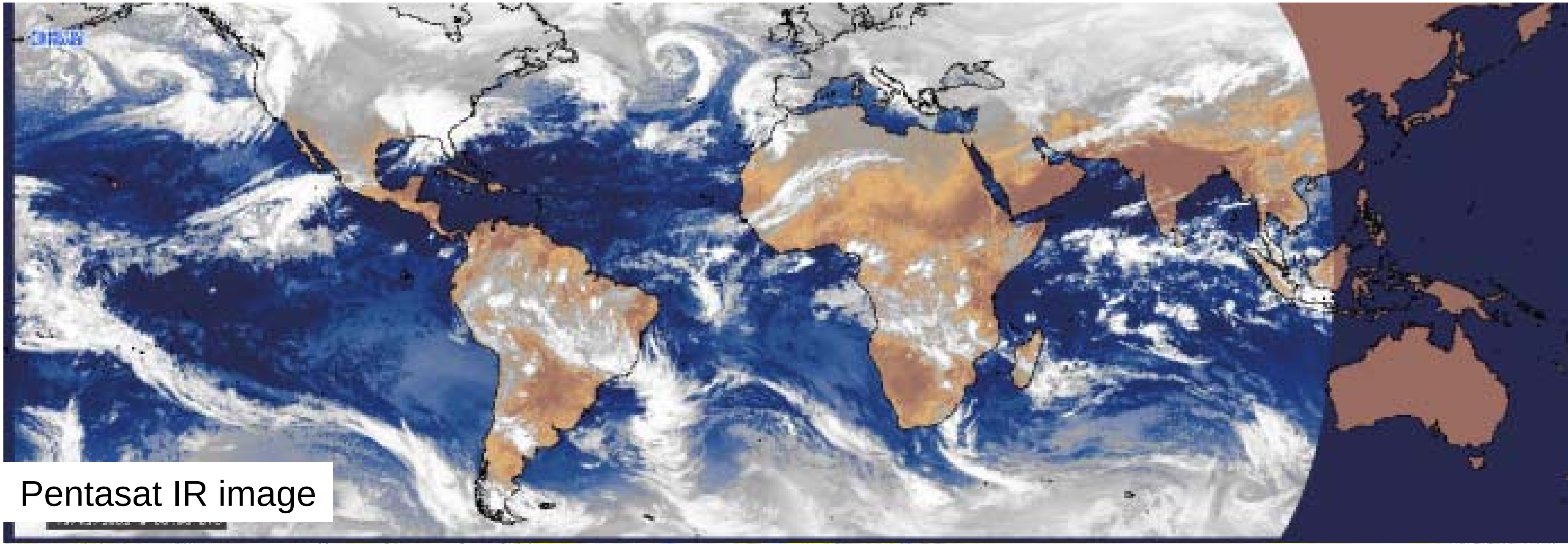


SAT. DEF. between 2.5 and 4.5km, in g/kg. ARPEGE +6h analysis first guess

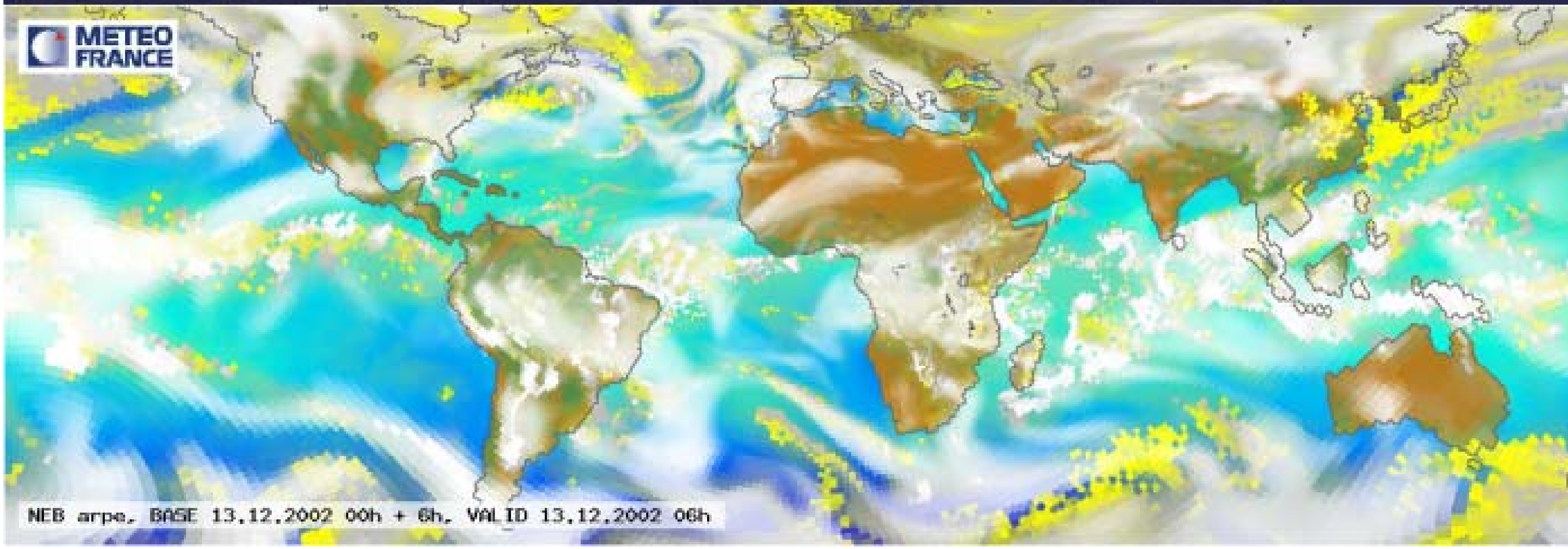
Sensitivity to humidity: top of clouds



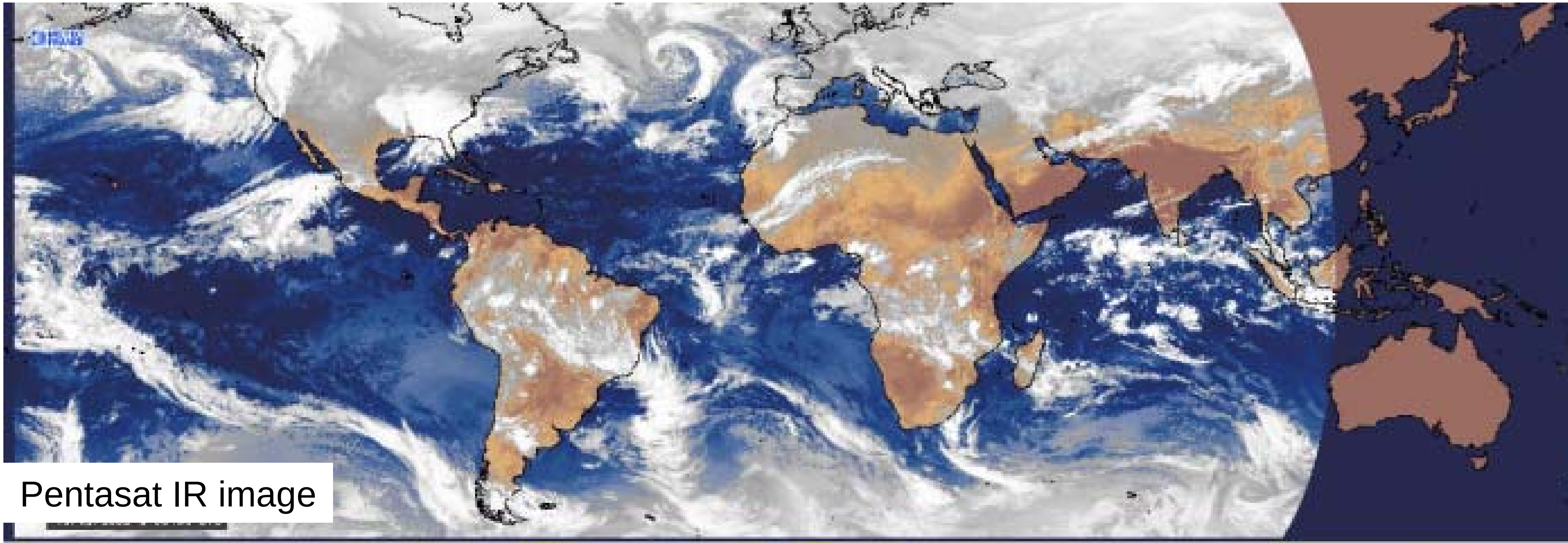
TOGA-COARE / J.L. Redelsperger, D. Parsons, F. Guichard, JAS 2002



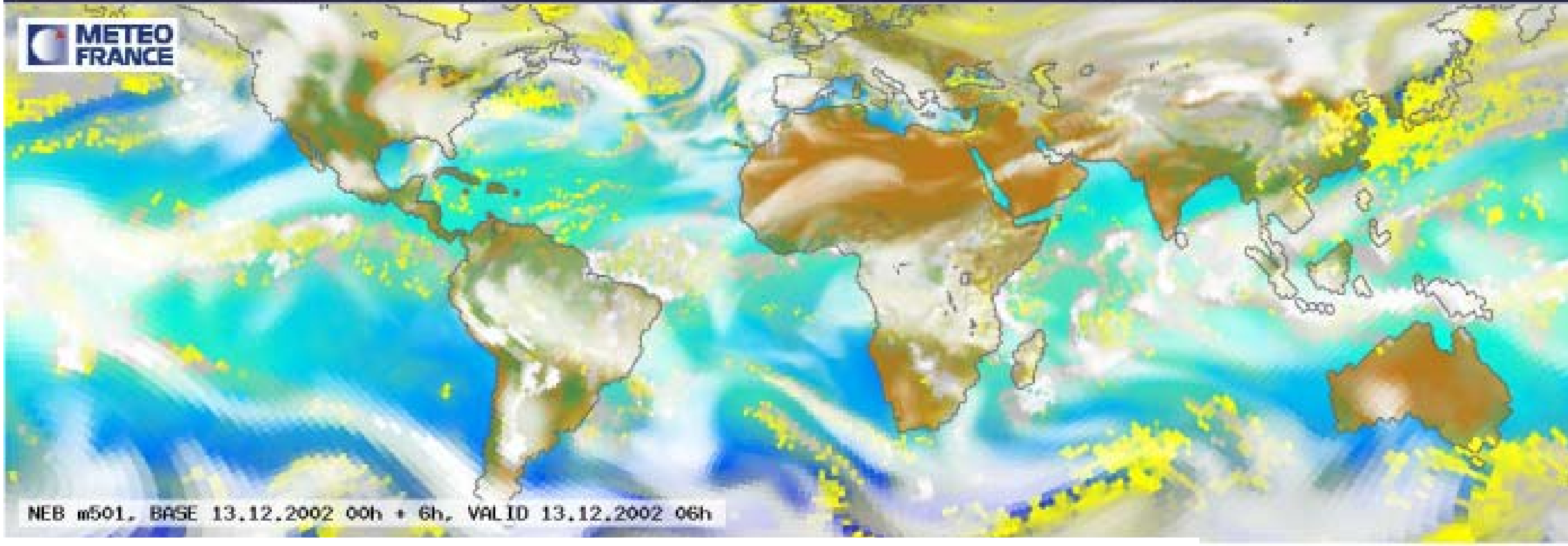
Pentasat IR image



Composite cloudiness image. ARPEGE +6h analysis first guess



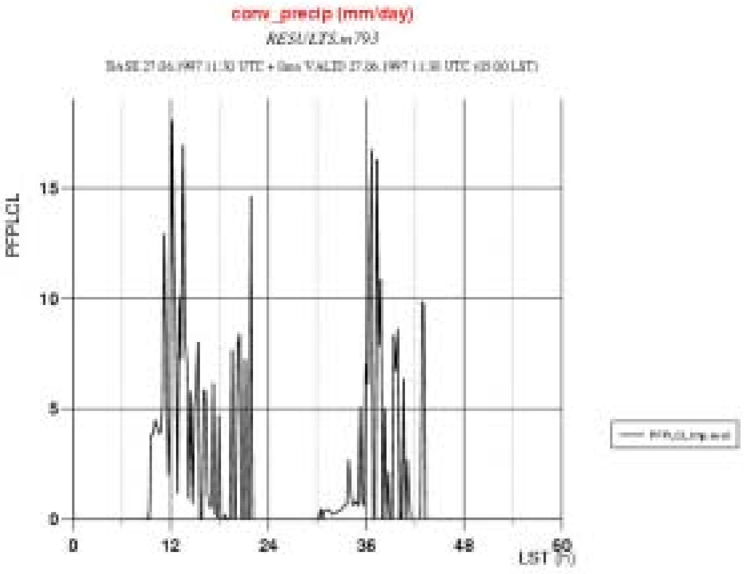
Pentasat IR image



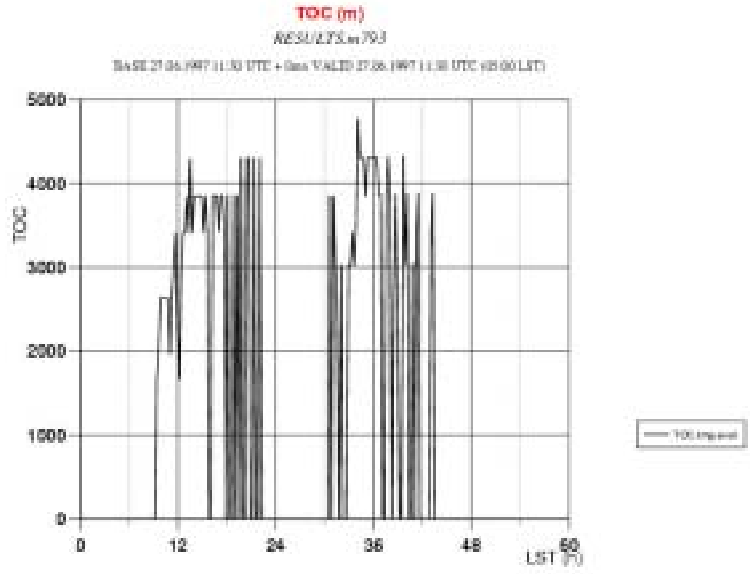
Composite cloudiness image. ARPEGE +6h modified analysis first guess

EUROCS diurnal cycle of deep convection

Convective precip.



Cloud top height



SCM run; modified ARPEGE physics: ad hoc TOC as a function of saturation deficit

Conclusions / perspectives *(1/2)*

- ARPEGE convection scheme sensitivity to humidity seems OK only for « wet » atmospheres, i.e. sat. defs (2.5 > 4.5km) < 2.5 g/kg, but likely underestimated for dry atmospheres

- Reducing entrainment rates to suppress the sensitivity in the idealized case ➔ small impact on diurnal cycle. The 3h phase lag of precipitation of ARPEGE vs other models remains yet unexplained

Conclusions / perspectives *(2/2)*

The sensitivity of cloud top height to environmental humidity seems to be for saturation deficits (2.5 > 4.5km) between 2 and 3 g/kg:

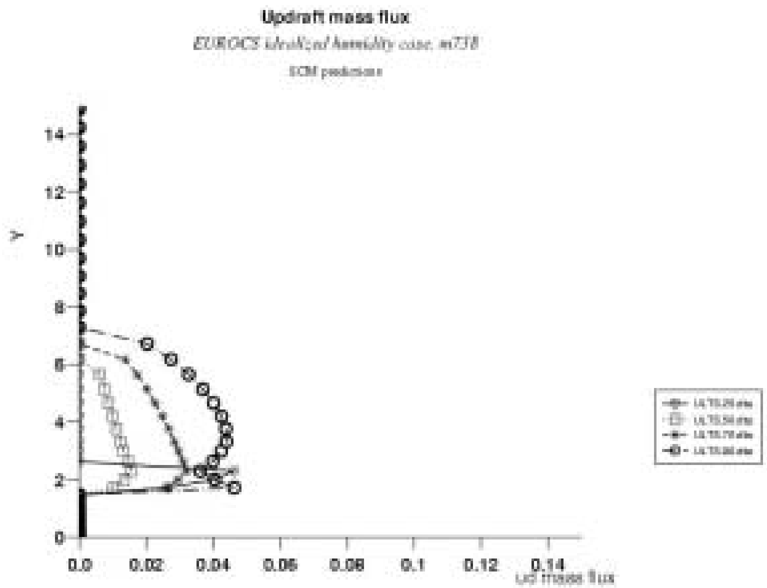
1. TOGA-COARE (Redelsperger, Parsons and Guichard, JAS 2002)
2. CRM MESO-NH in EUROCS diurnal cycle of deep convection case
3. 5sat image versus ARPEGE global analysis of saturation deficits

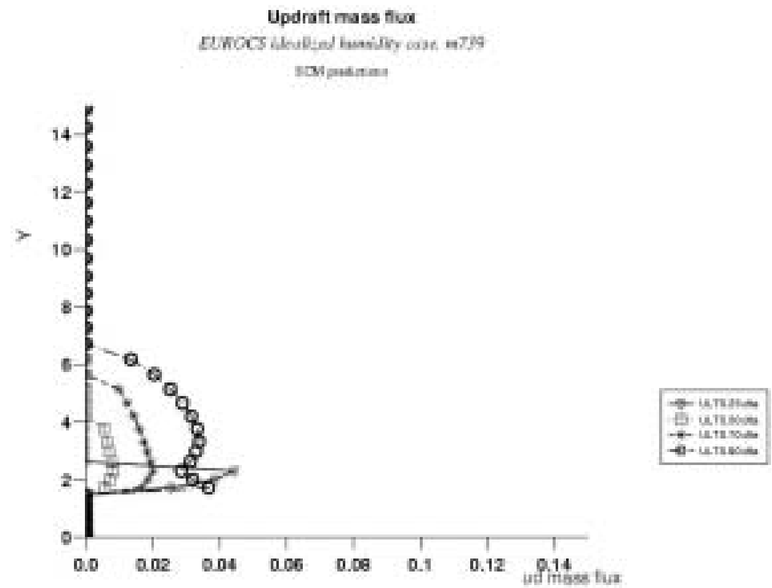
> Humidifying a dry atmosphere: a good candidate to explain large phase lags of precipitation vs surface forcings, from diurnal to 10 days time scales?

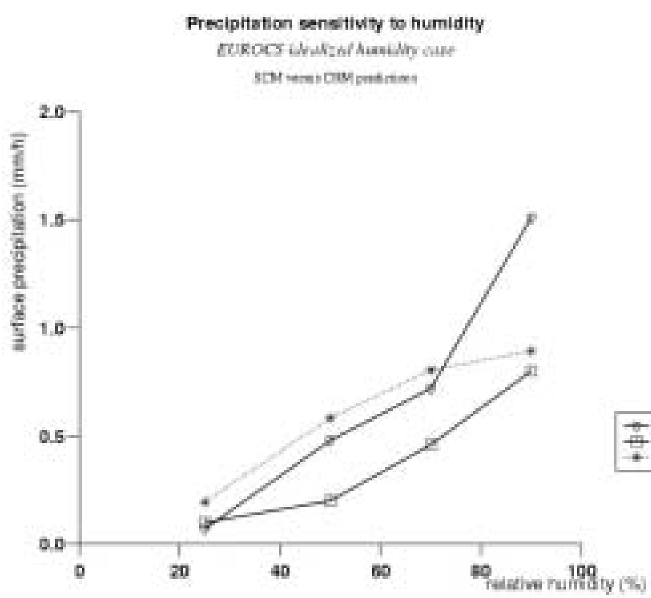
Perspectives: (i) retune the entrainment in drier contexts than previously done, to get the right cloud tops / (ii) increase humidification rate below cloud top / (iii) see impact on diurnal cycle!

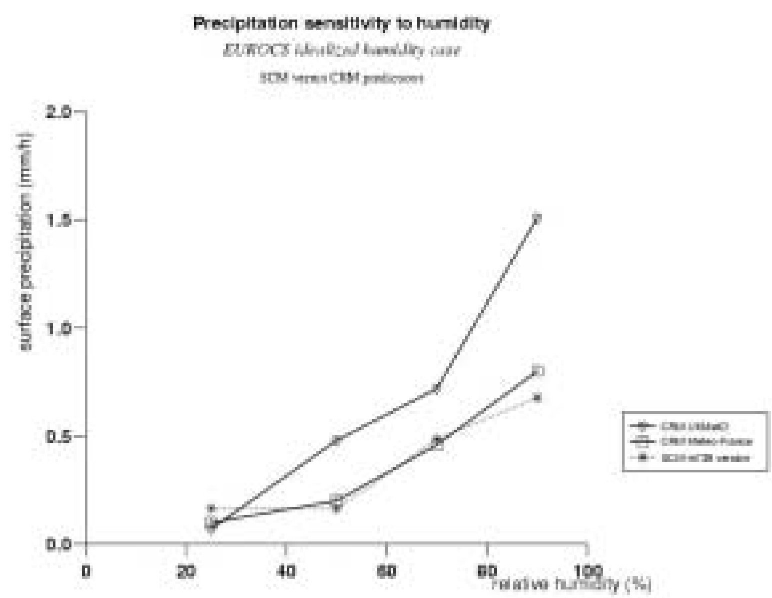
EUROCS idealized humidity case

Operational version	Operational + « no relax towards und. »









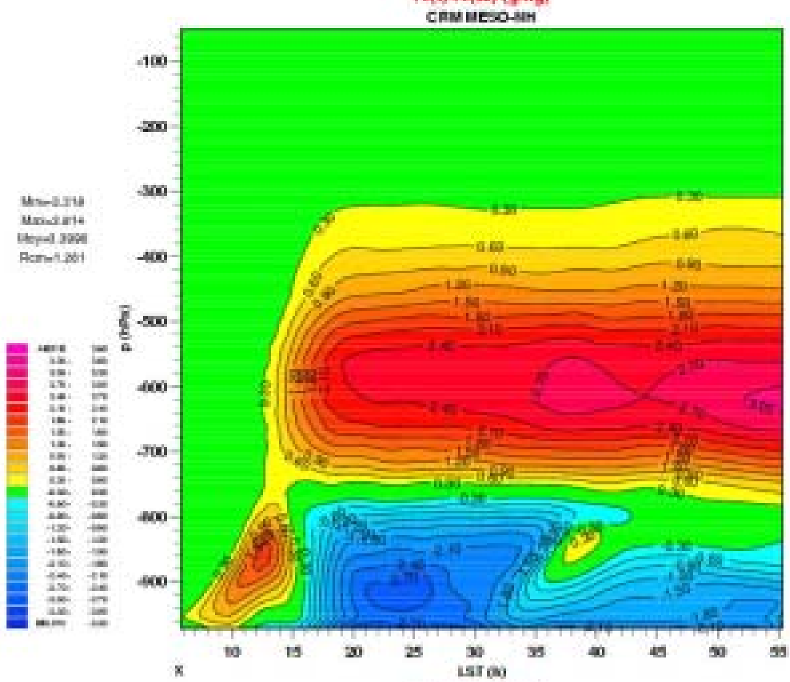
Entrainment: undilute plume relaxation

$$\frac{\partial \mu_c}{\partial \phi} = \frac{\partial \mu_c}{\partial \phi} und + \lambda(\overline{\mu} - \mu_c) + \beta(\mu_{und} - \mu_c)$$

$$\mu = T, qv$$

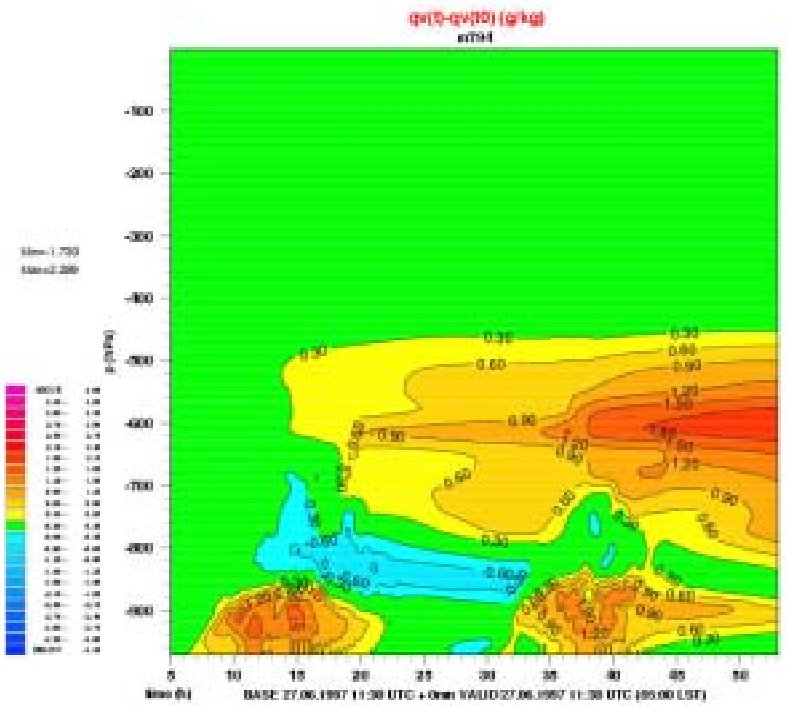
Towards environment

Towards undilute: easy way to take into account that a rather constant fraction of ascents remain undiluted, without having to use negative entrainments in the expression just on the left

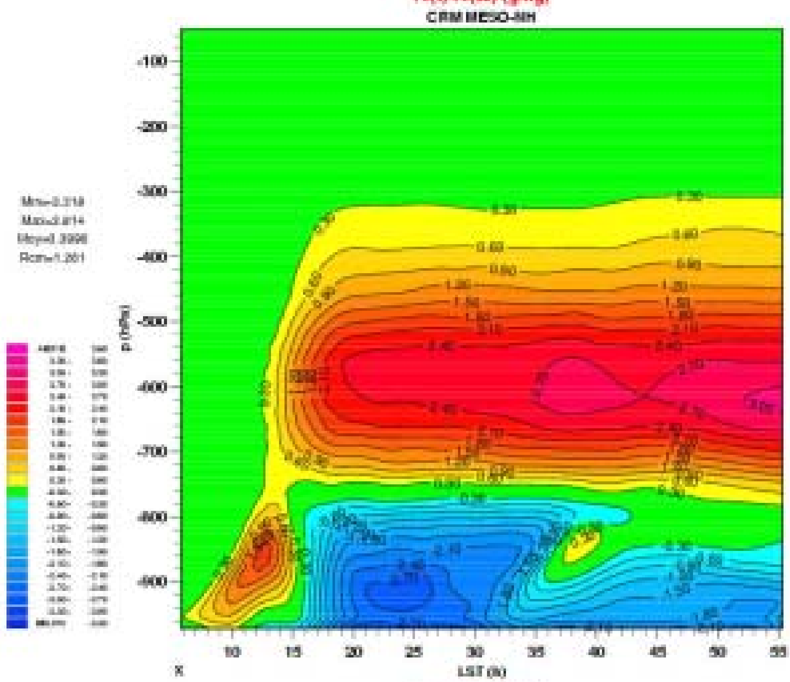


CRM MESO-NH (reference) prediction; data from Françoise Guichard and Jean-Pierre Chaboureau, CNRS / Météo-France

Time-height cross-sections of th difference between current humidity (g/kg) and initial one

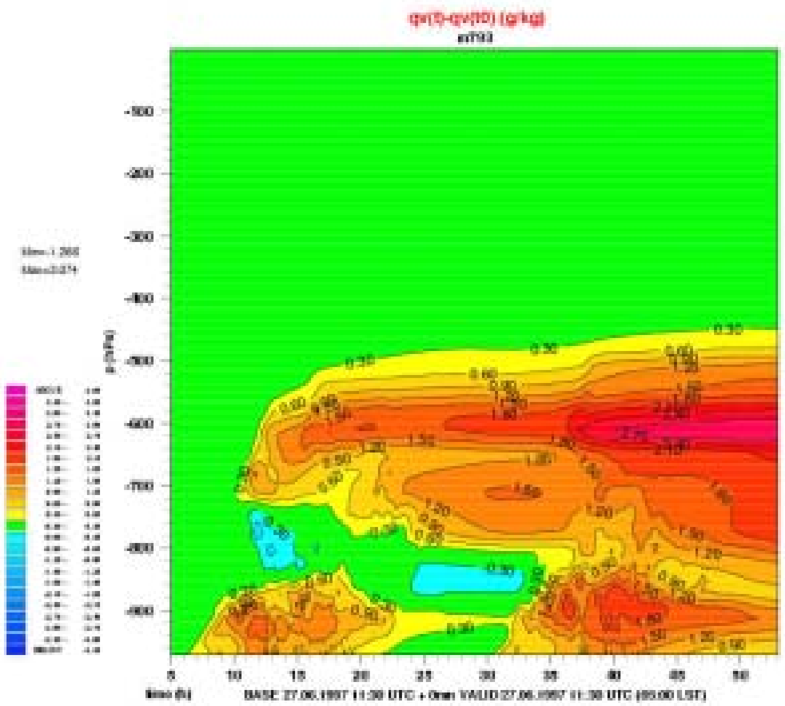


SCM operational ARPEGE



CRM MESO-NH (reference) prediction; data from Françoise Guichard and Jean-Pierre Chaboureau, CNRS / Météo-France

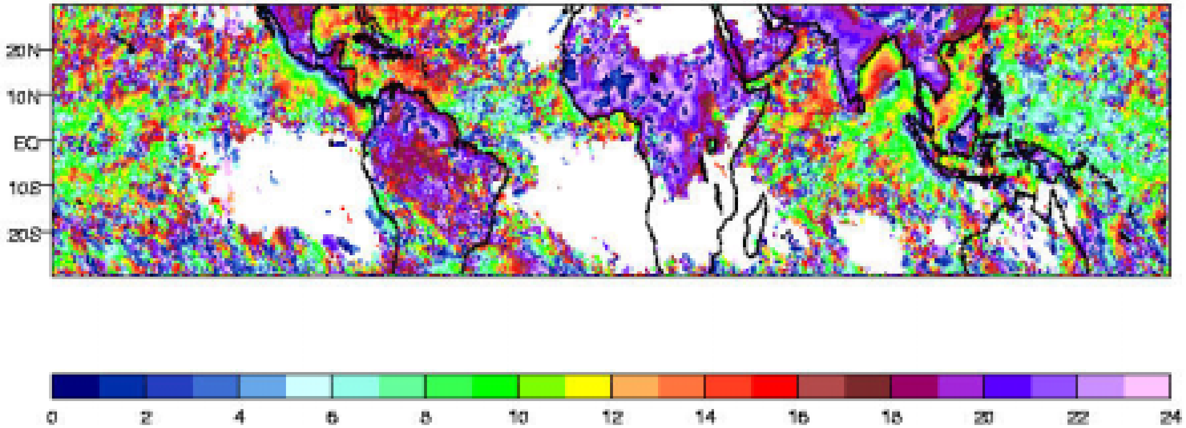
Time-height cross-sections of th difference between current humidity (g/kg) and initial one



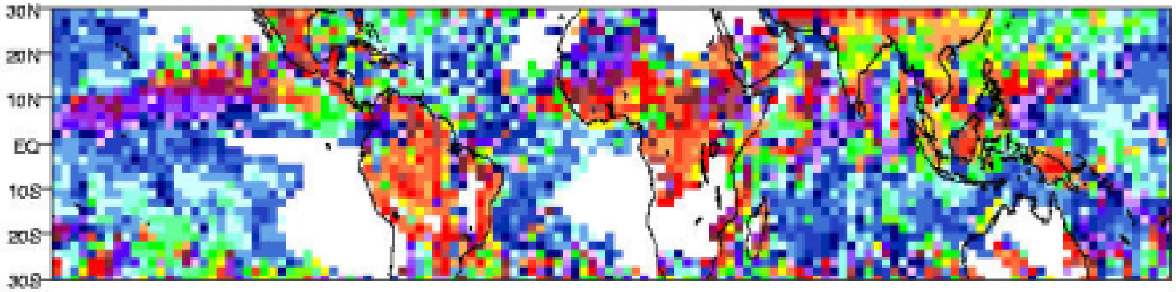
SCM modified ARPEGE: ad hoc TOC as a function of saturation deficit

	Present operational schemes	*Trends, or under progress*
Radiation	Geleyn and Hollingsworth (1979), Ritter and Geleyn (1992)	More accurate infra-red exchanges between surface and layers
Grid-scale cloud scheme	Diagnostic in ql/i, all supersaturation removed, liquid/ice condensation ➔ T, melting/ freezing/ evaporation/ Kessler (1979), Clough and Franks (1991)	Prognostic ql/i and/or qr/s
Subgrid-scale cloud scheme (convection)	mass-flux scheme, CISK-type closure and triggering, water vapour budget using a Kuo-type closure, downdrafts, momentum flux	Entrainment & dry intrusions, modified trigger functions (use of TKE, CIN) / Revised shallow and deep conv.
Turbulence	1st order closure scheme after Louis (1979), Louis and al. (1981), using a flux-gradient K-theory with Ri dependency, variable roughness lengths over sea (Charnock)	PrognosticTKE scheme, mixing « Betts » conservative variables thetal and qt instead of theta and qv

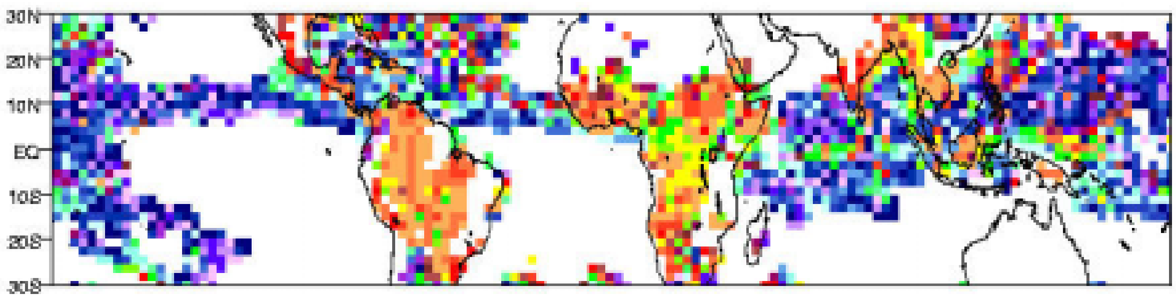
Diurnal cycle of convection



Observations
Yang and Slingo MWR 2001



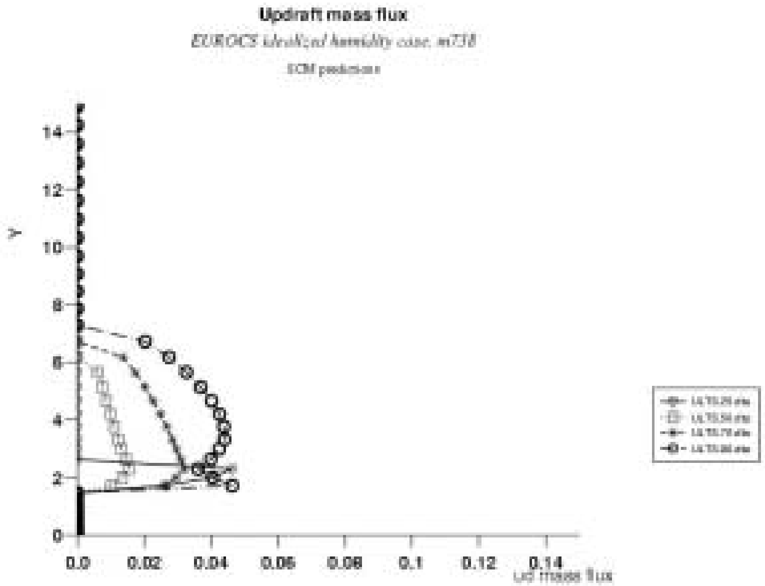
ARPEGE NWP model
JJA 2002

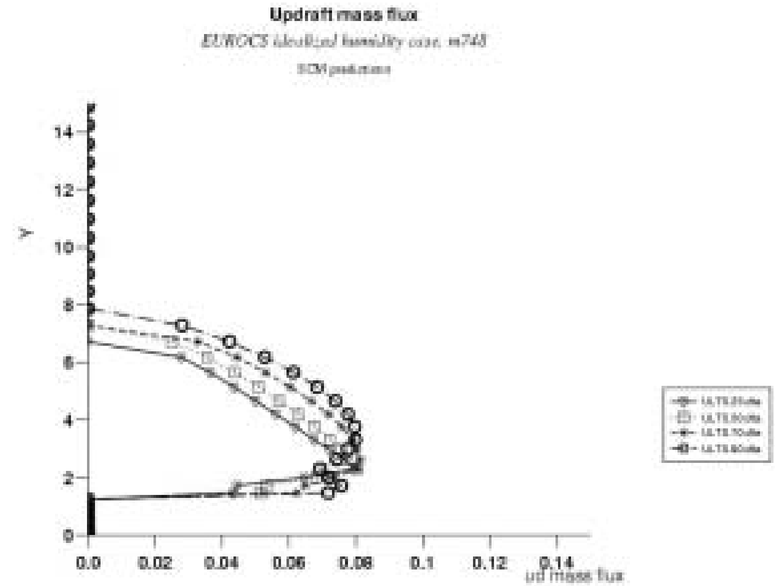


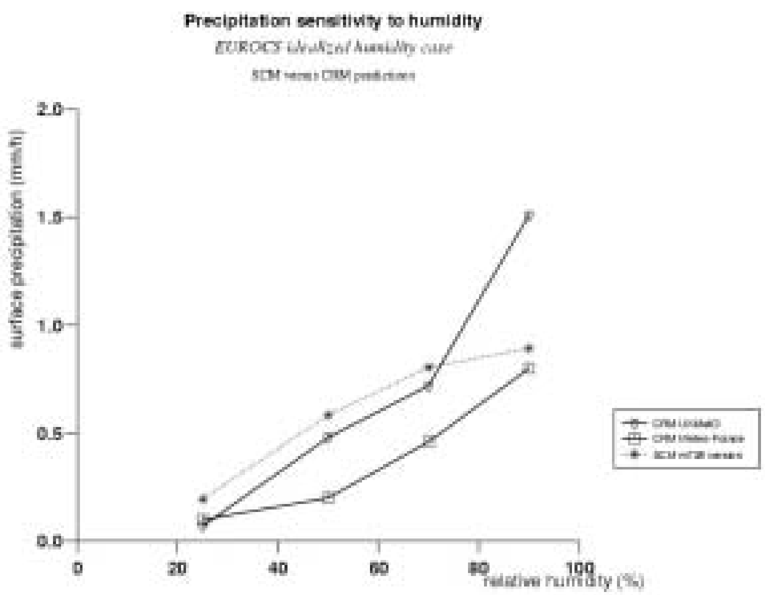
ARPEGE NWP model
10 days CAPE dec 2002

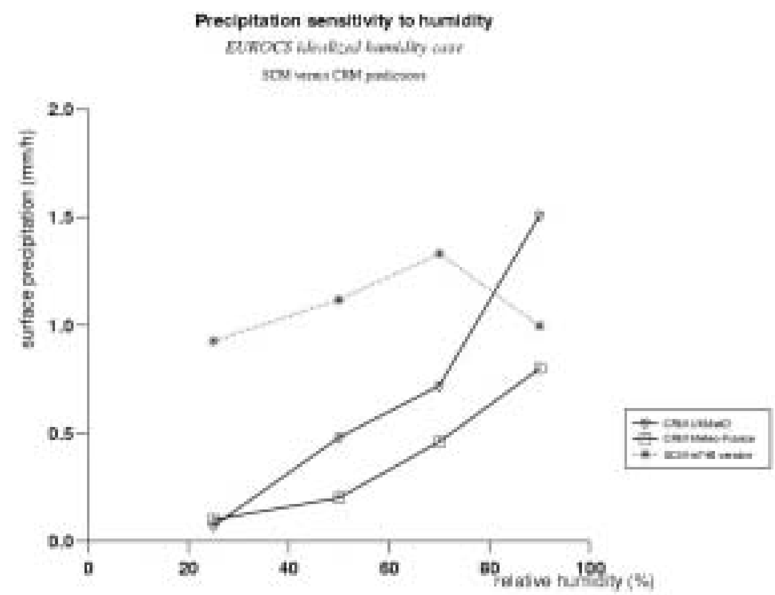
Operational version

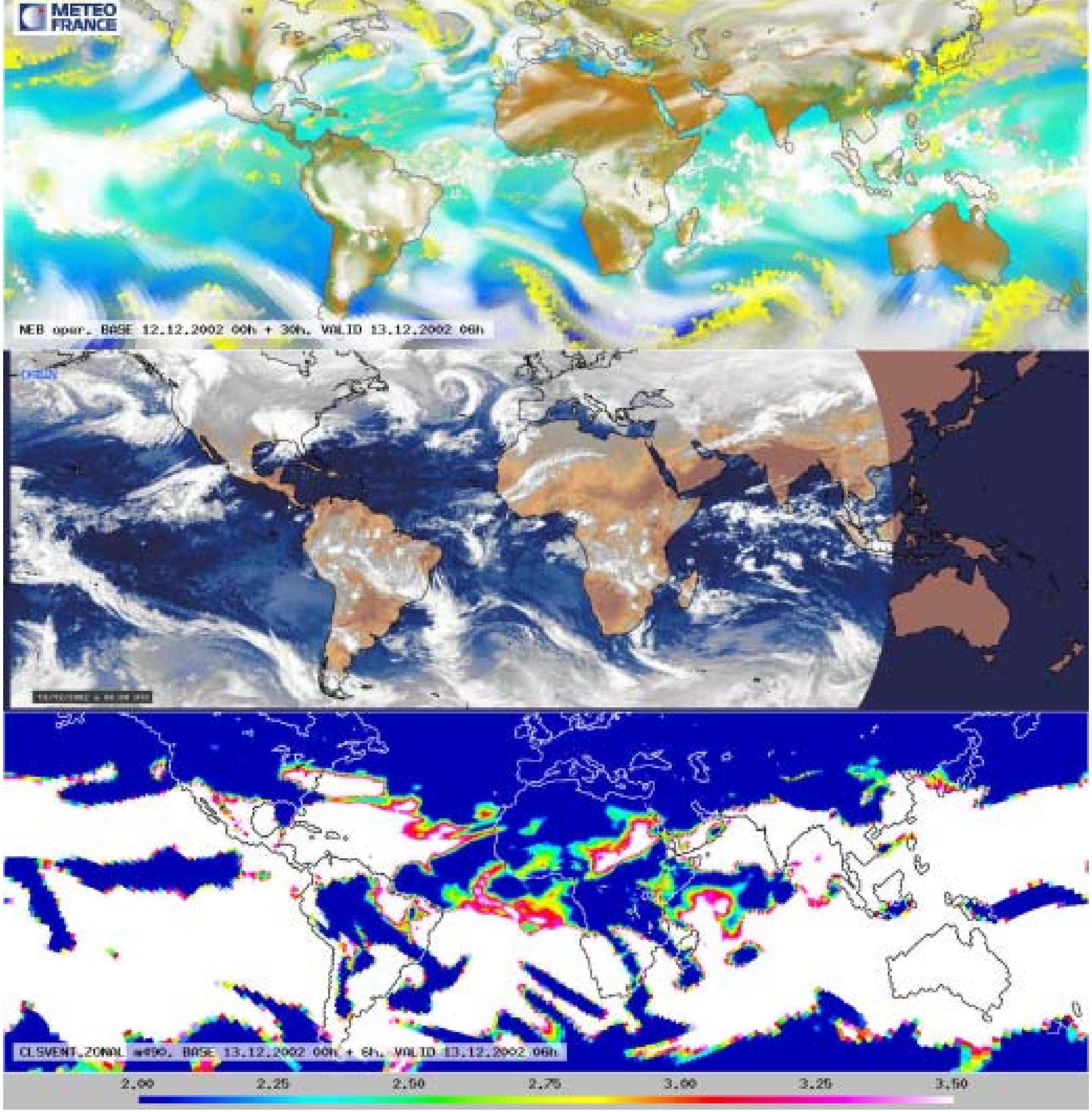
Operational + reduced entrainment



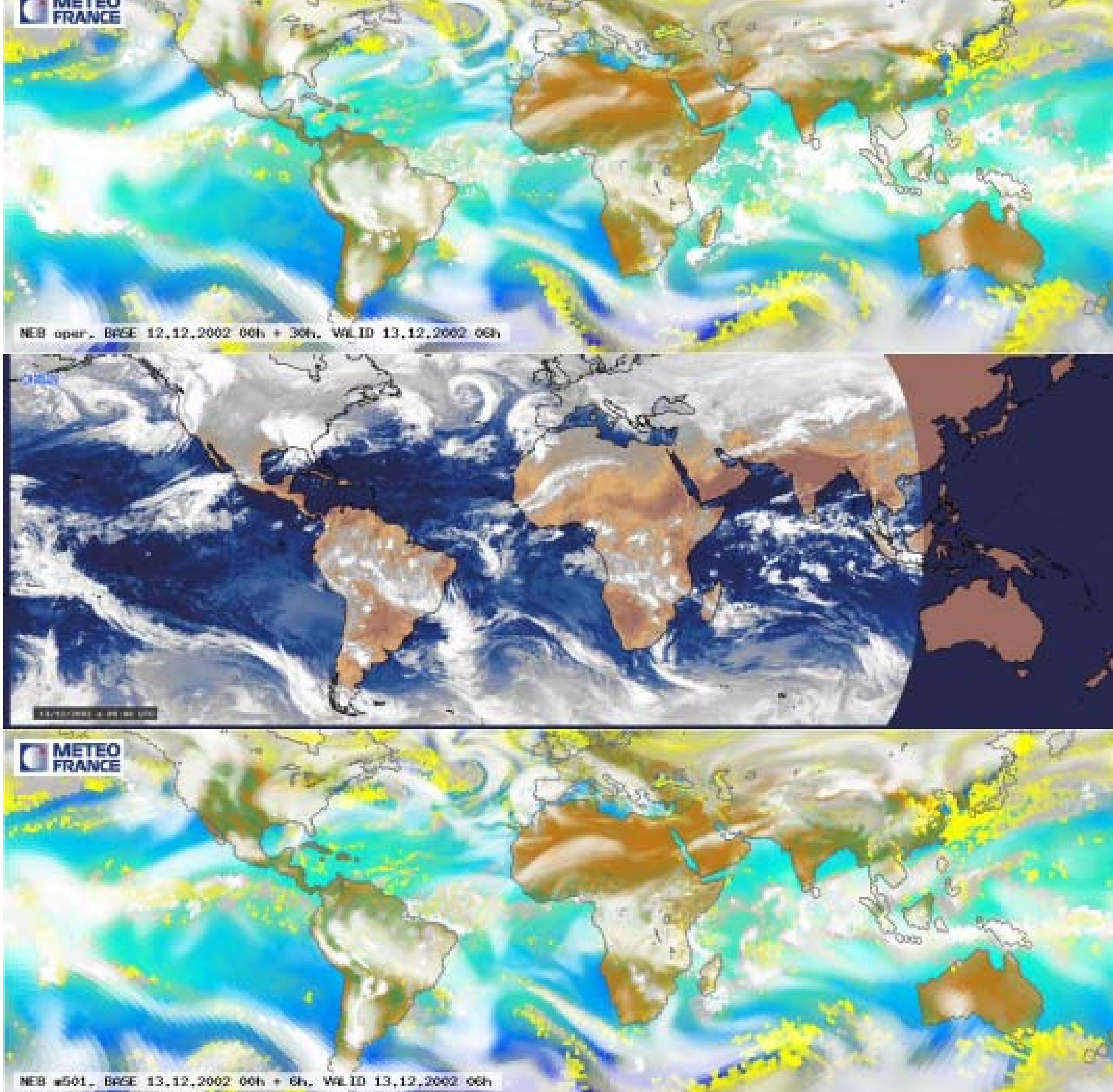








METEO FRANCE
NEB oper. BASE 12.12.2002 00h + 30h. VALID 13.12.2002 06h
CLSVENT.ZONAL m490. BASE 13.12.2002 00h + 6h. VALID 13.12.2002 06h
2.00
2.25
2.50
2.75
3.00
3.25
3.50


METEO FRANCE
NEB oper. BASE 12.12.2002 00h + 30h. VALID 13.12.2002 06h
METEO FRANCE
NEB m501. BASE 13.12.2002 00h + 6h. VALID 13.12.2002 06h