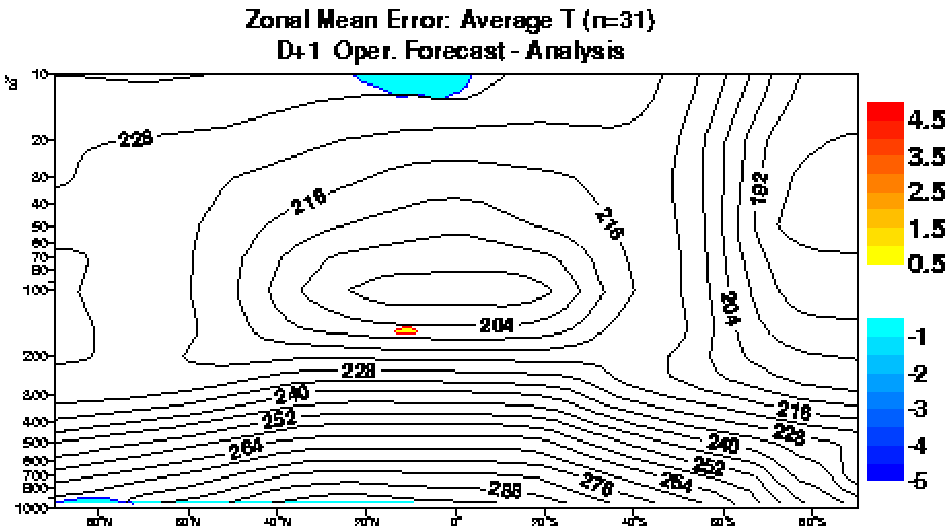
Model biases

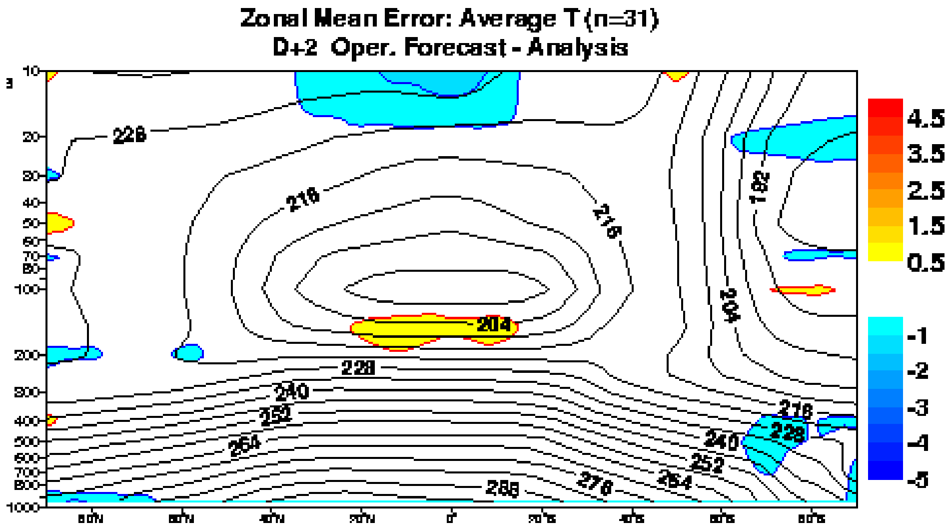
Anton Beljaars (ECMWF)

with contributions by: Antonio Garcia-Mendez, Anna Ghelli,
Isabel Trigo, Pedro Viterbo, Xubin Cheng

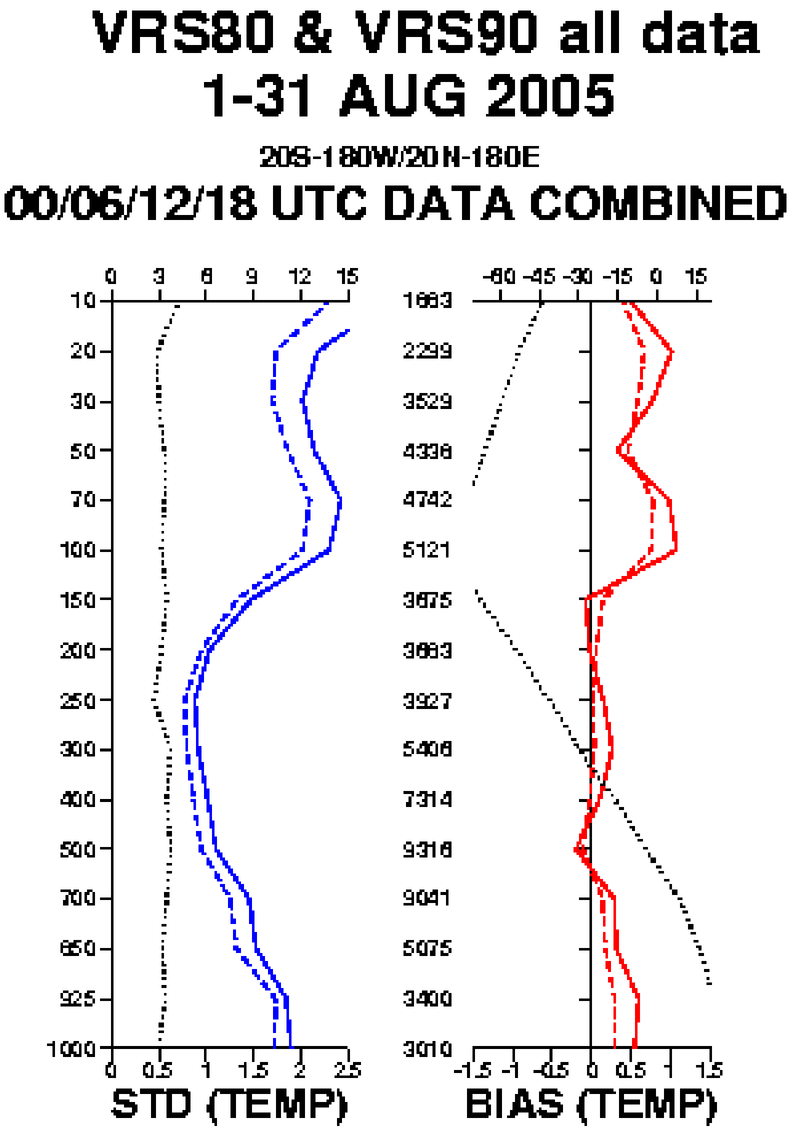
- **Temperature**
- **Moisture & spinup**
- **Land surface**
- **Ocean surface**

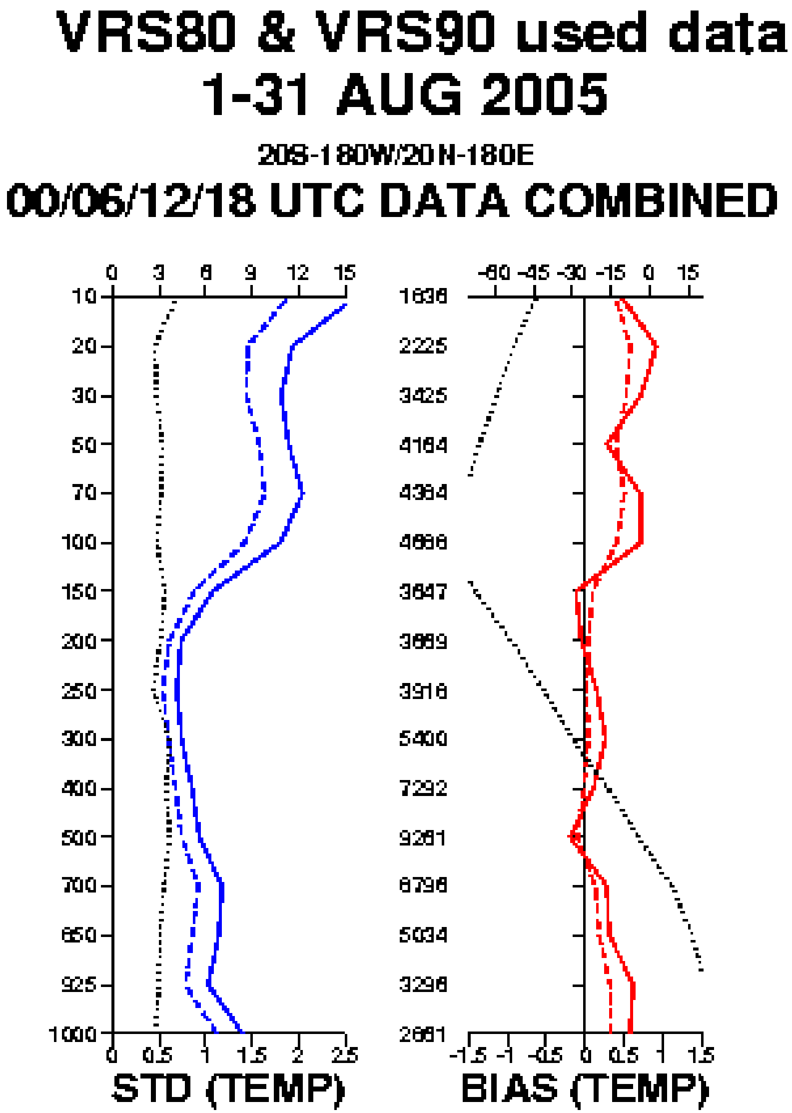
Systematic errors (differences): Monthly averages of temperature 200508 (fc-an)

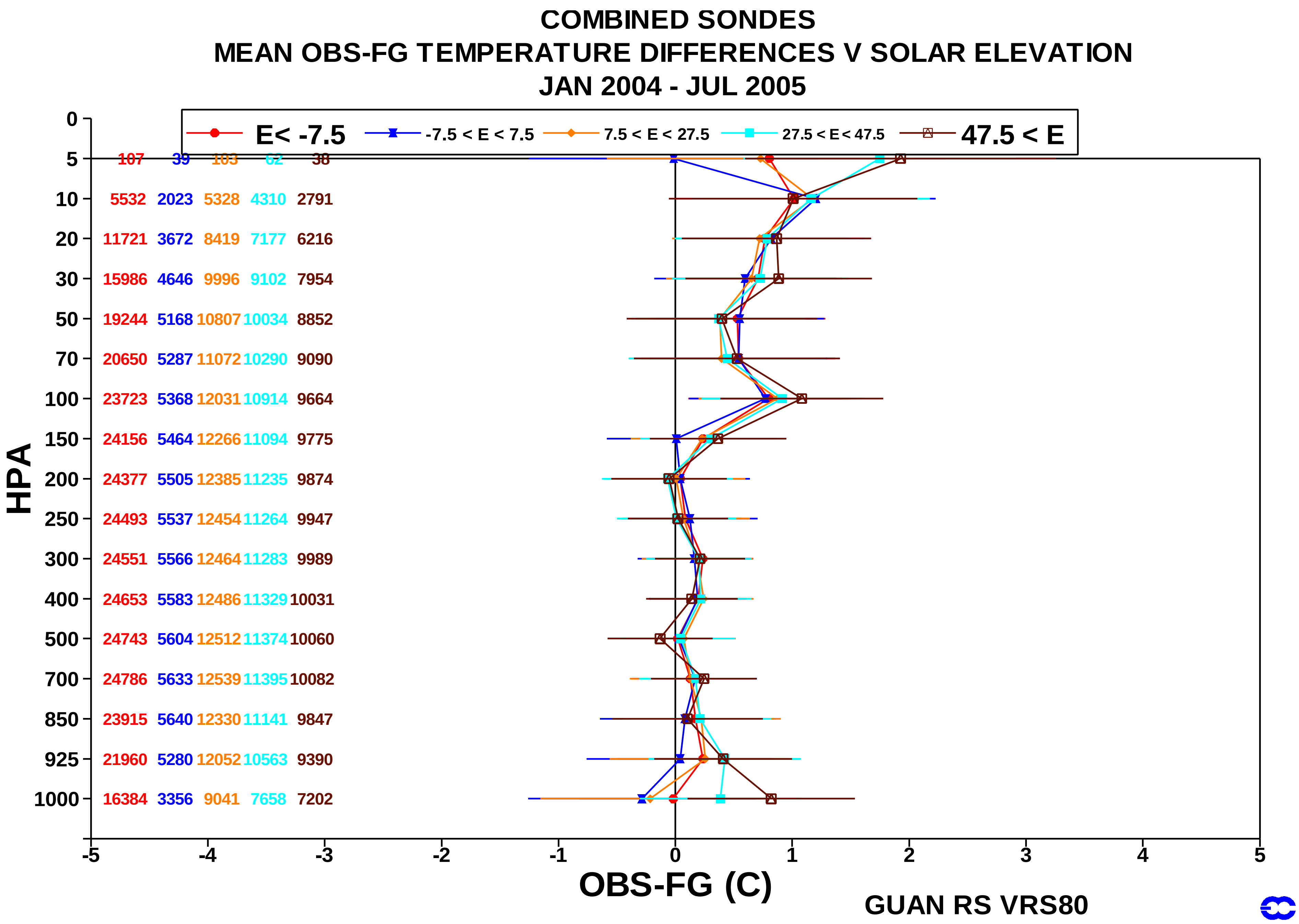


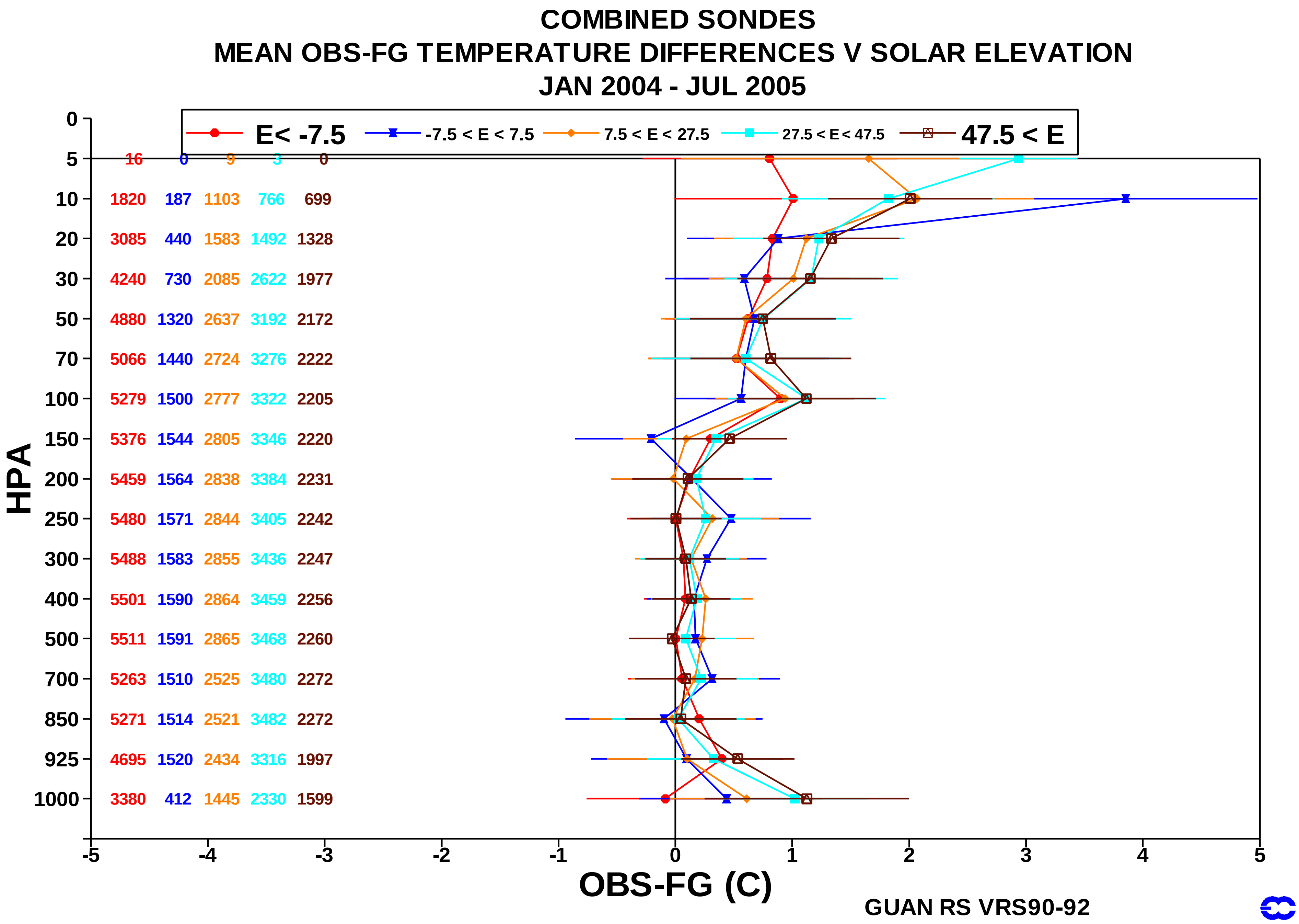


Radio sonde statistics of temperature for August 2005 (20N-20S)



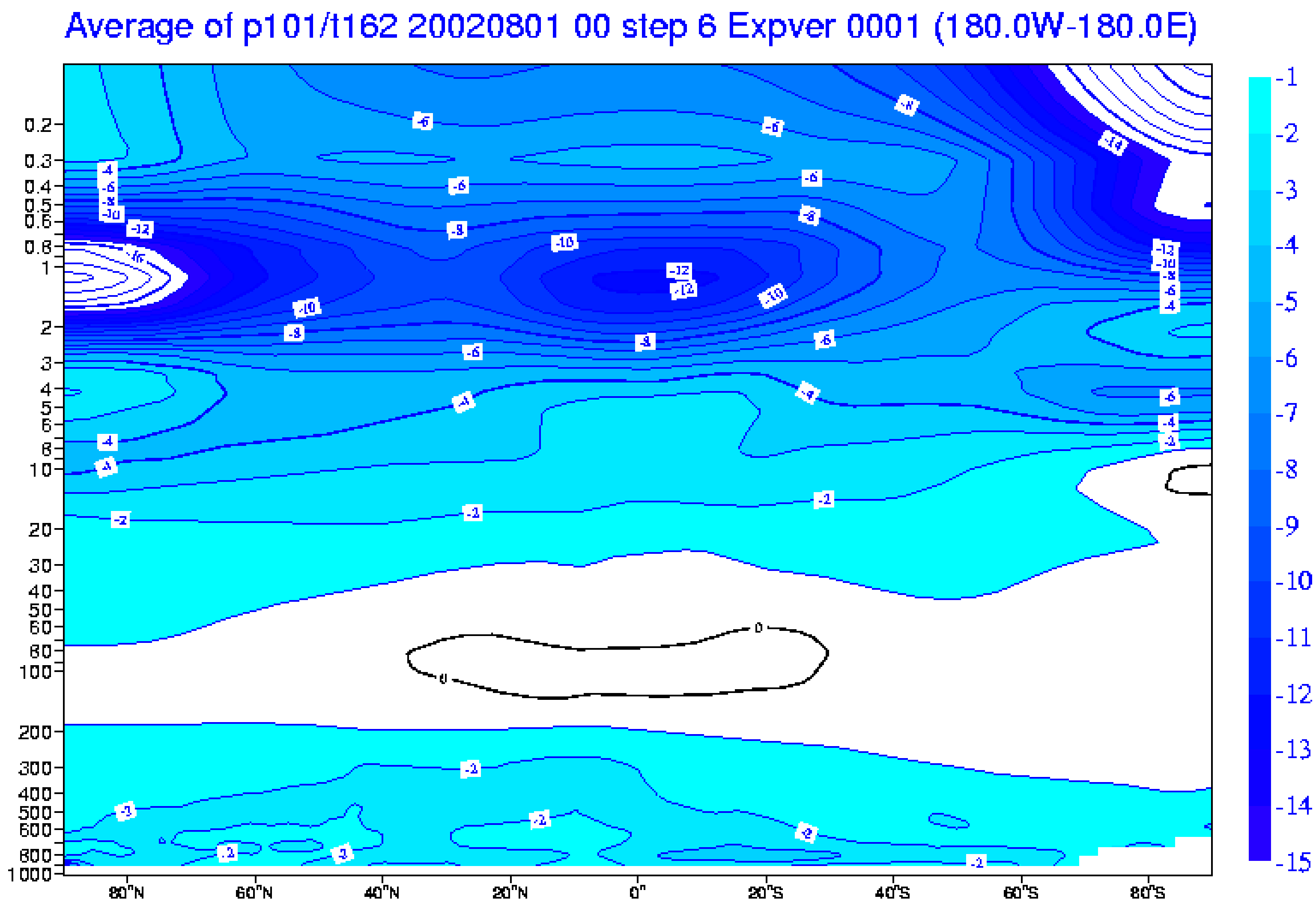



COMBINED SONDES
MEAN OBS-FG TEMPERATURE DIFFERENCES V SOLAR ELEVATION
JAN 2004 - JUL 2005
E< -7.5
-7.5 < E < 7.5
7.5 < E < 27.5
27.5 < E < 47.5
47.5 < E
HPA
OBS-FG (C)
GUAN RS VRS80

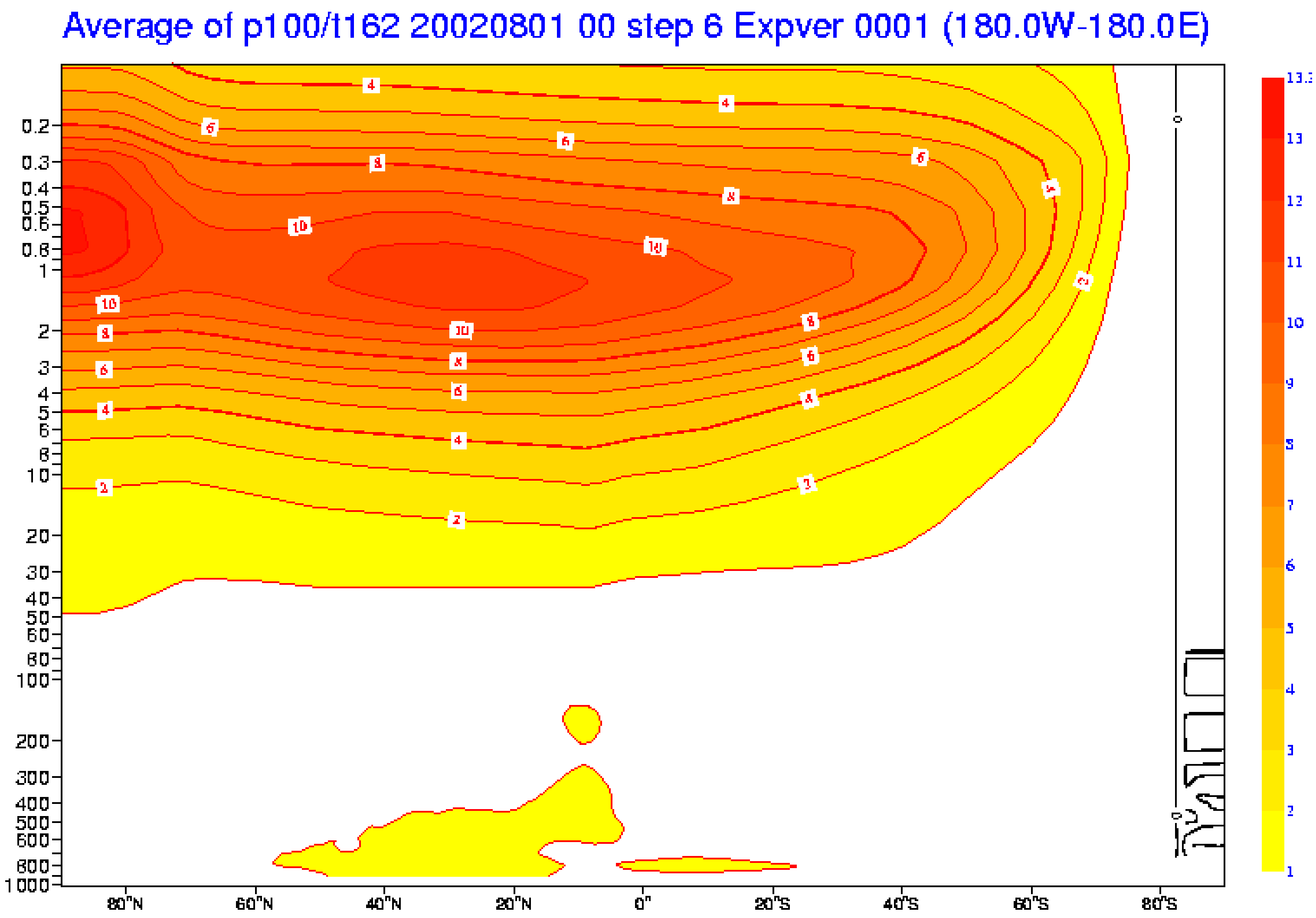


HPA	E< -7.5	-7.5 < E < 7.5	7.5 < E < 27.5	27.5 < E < 47.5	47.5 < E
5	16	0	9	3	0
10	1820	187	1103	766	699
20	3085	440	1583	1492	1328
30	4240	730	2085	2622	1977
50	4880	1320	2637	3192	2172
70	5066	1440	2724	3276	2222
100	5279	1500	2777	3322	2205
150	5376	1544	2805	3346	2220
200	5459	1564	2838	3384	2231
250	5480	1571	2844	3405	2242
300	5488	1583	2855	3436	2247
400	5501	1590	2864	3459	2256
500	5511	1591	2865	3468	2260
700	5263	1510	2525	3480	2272
850	5271	1514	2521	3482	2272
925	4695	1520	2434	3316	1997
1000	3380	412	1445	2330	1599

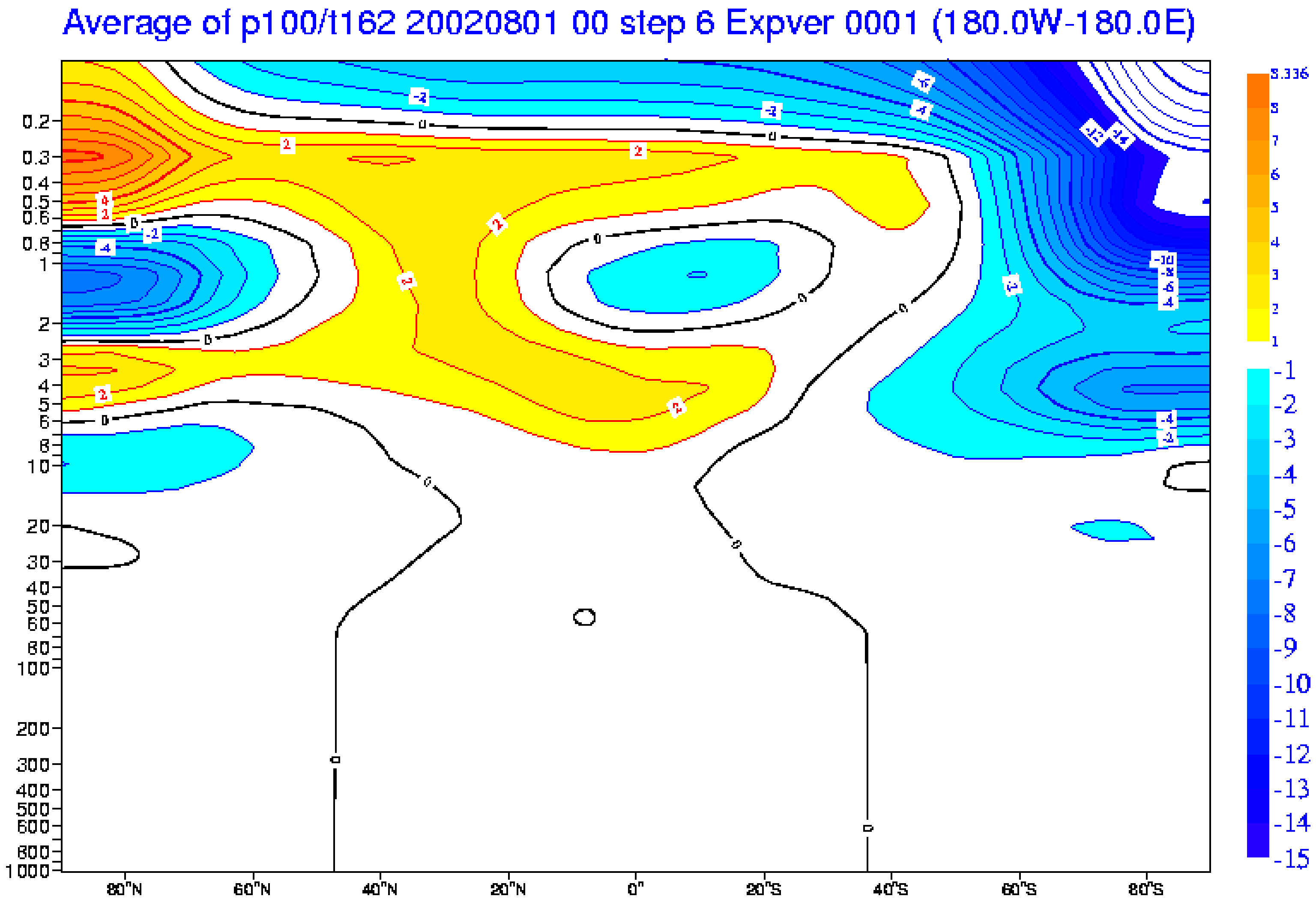
Long wave radiation tendencies averaged over August 2002 (ERA40)



Short wave radiation tendencies averaged over August 2002 (ERA40)

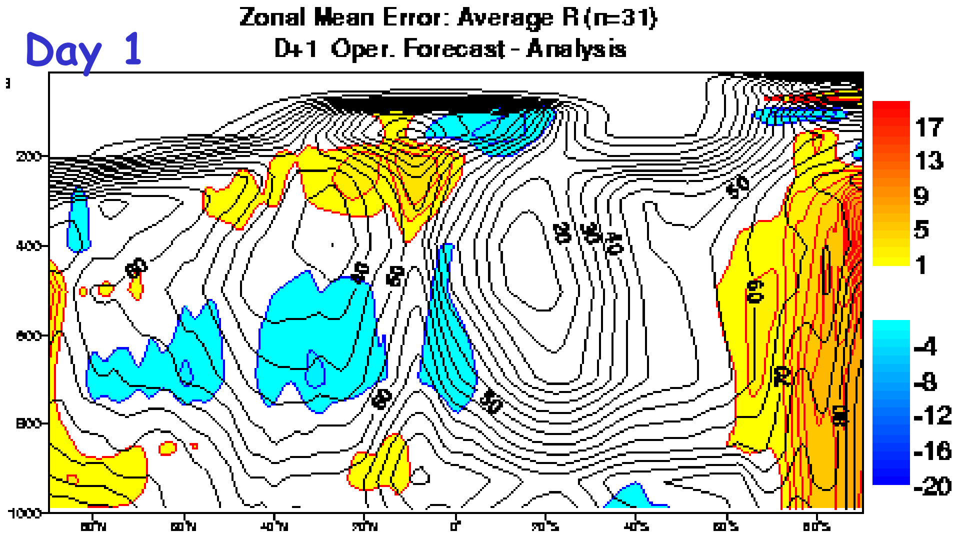


Long + short wave radiation tendencies averaged over August 2002 (ERA40)



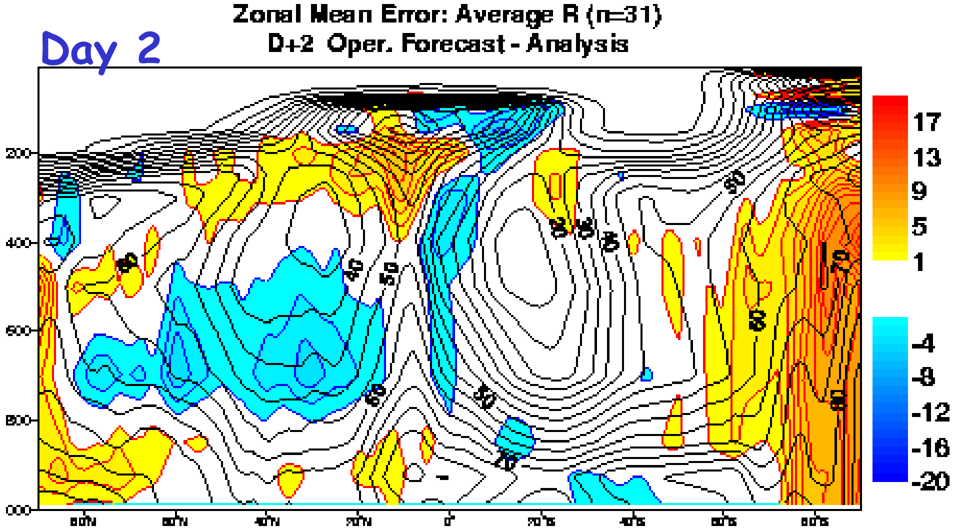
Systematic differences: Monthly averages 200508 (fc-an)

Day 1

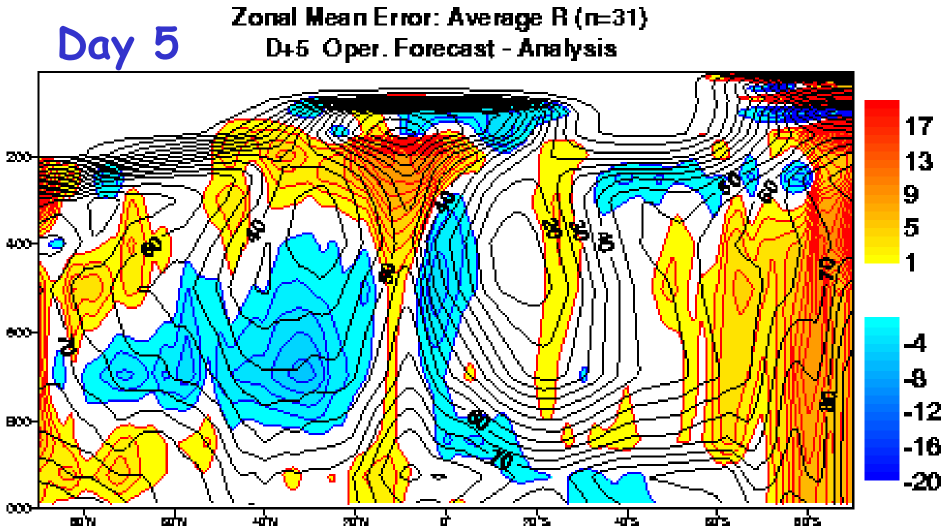


Relative humidity (%)

Day 2



Day 5



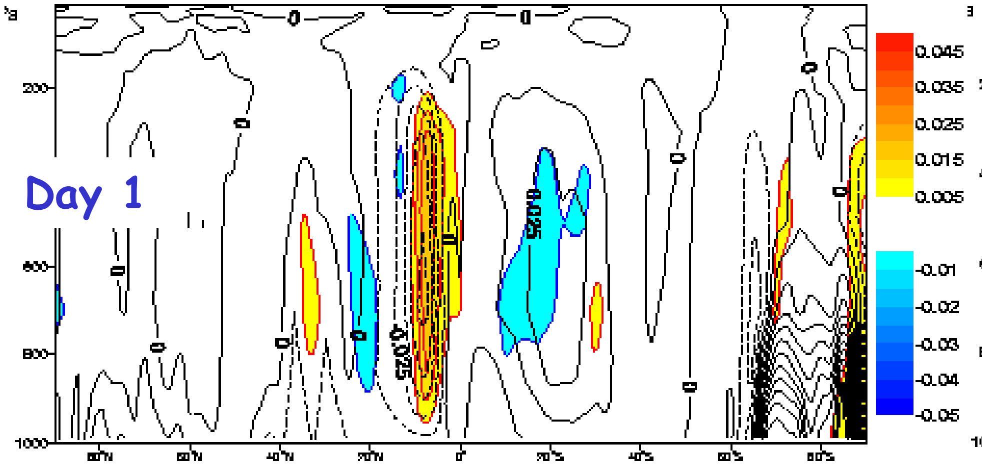
Systematic errors (differences): Monthly averages 200508 (fc-an)

Vert. Velocilty (Pa/s)

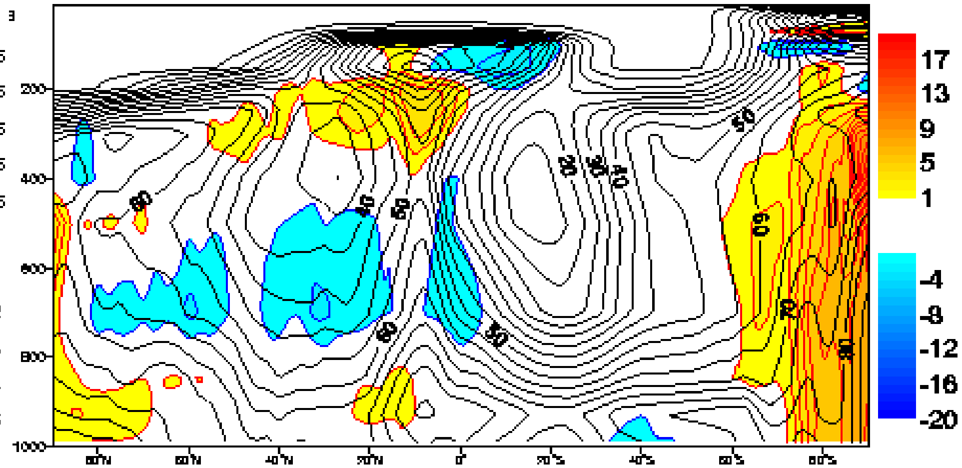
Relative humidity (%)

Day 1

Zonal Mean Error: Average w (n=31)
D+1 Oper. Forecast - Analysis

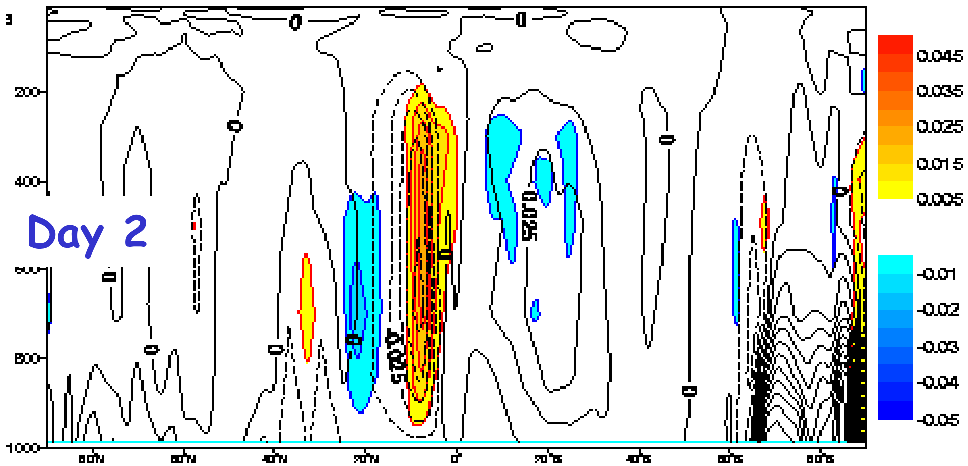


Zonal Mean Error: Average R (n=31)
D+1 Oper. Forecast - Analysis

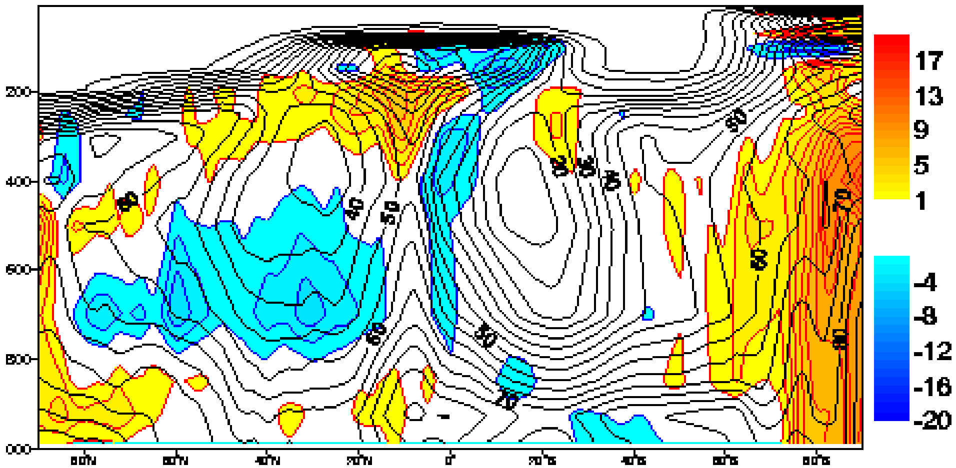


Day 2

Zonal Mean Error: Average w (n=31)
D+2 Oper. Forecast - Analysis

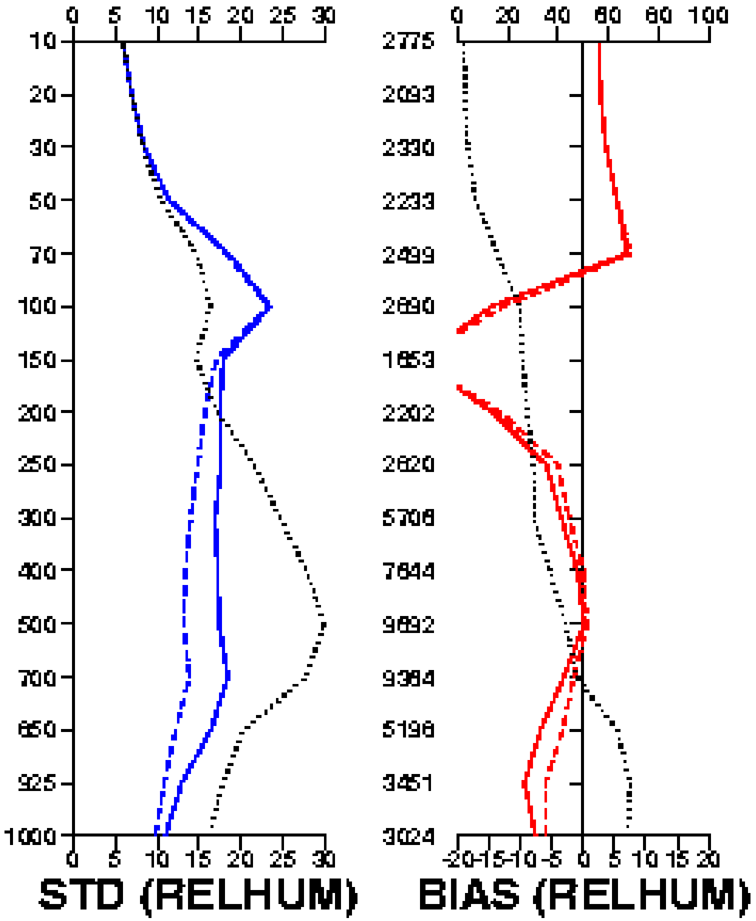


Zonal Mean Error: Average R (n=31)
D+2 Oper. Forecast - Analysis

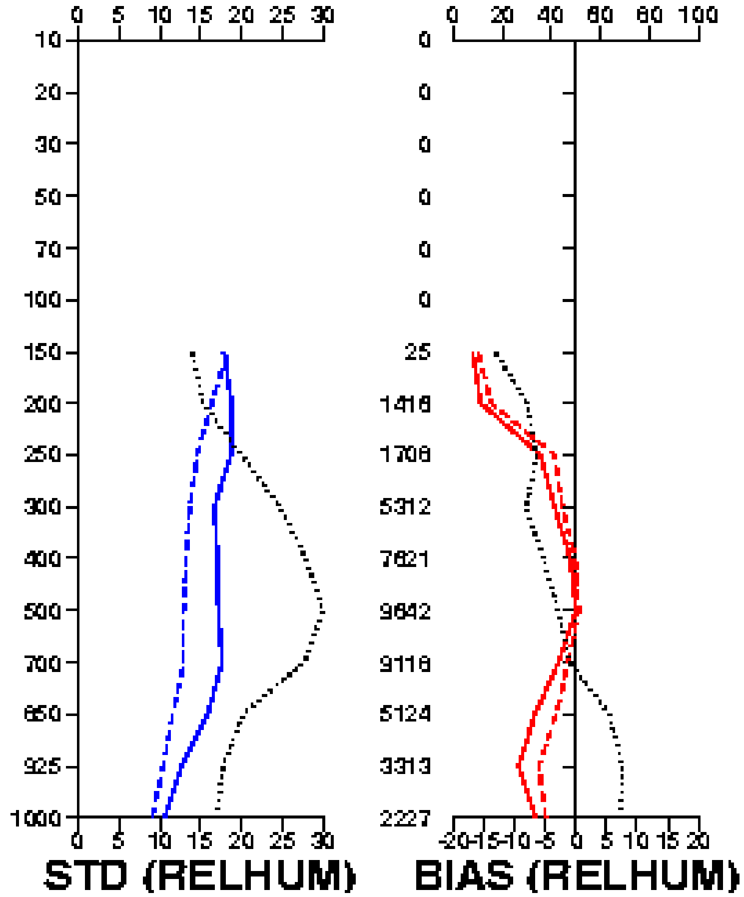


Radio sonde statistics of relative humidity for August 2005 (20N-20S)

All VRS80&VRS90 sondes

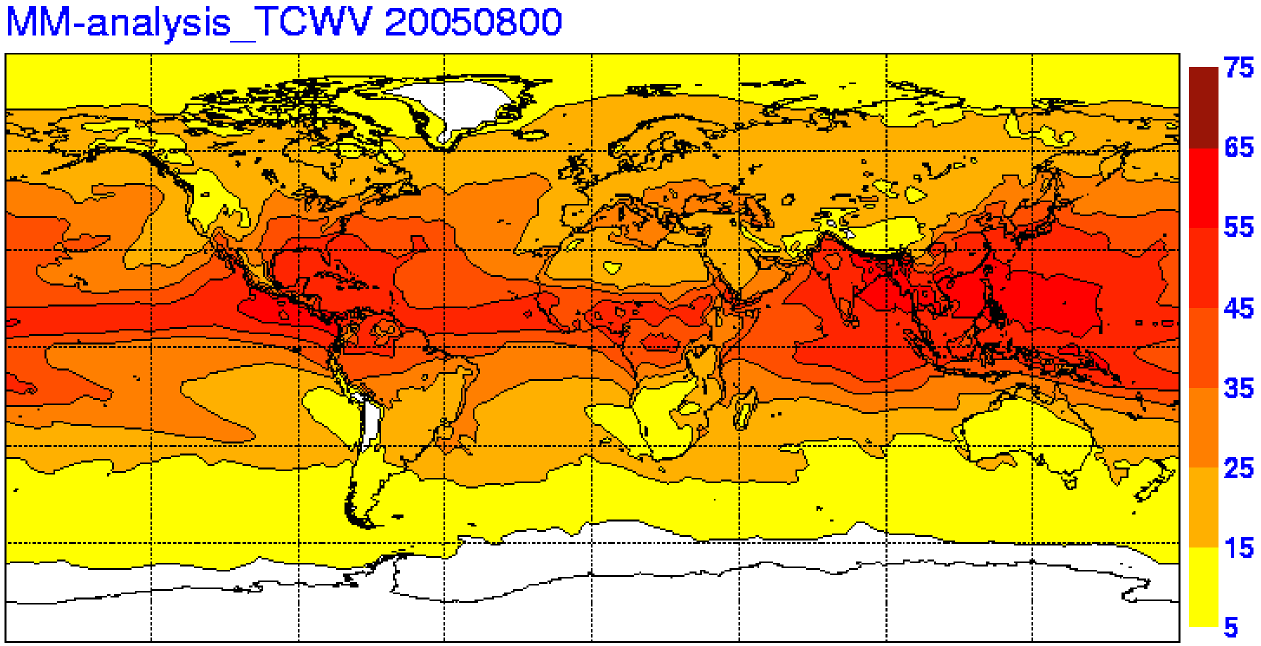


Used VRS80&VRS90 sondes

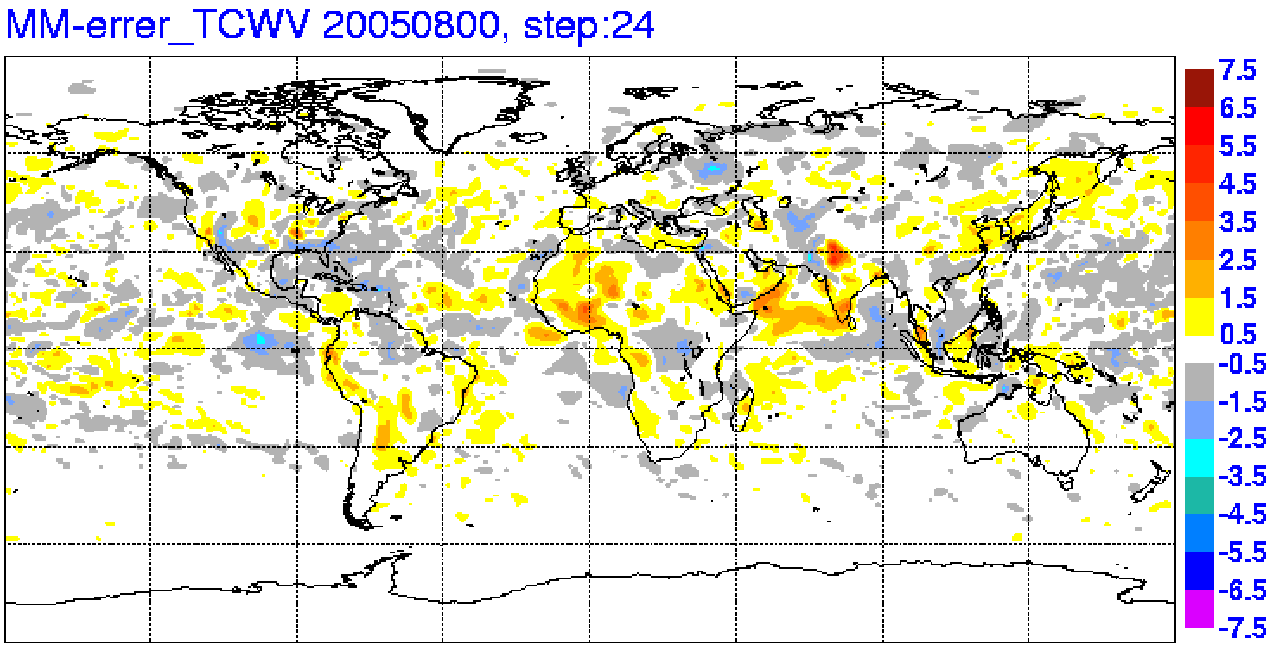


Systematic errors (differences): Monthly averages 200508 (fc-an)

Total column water vapour

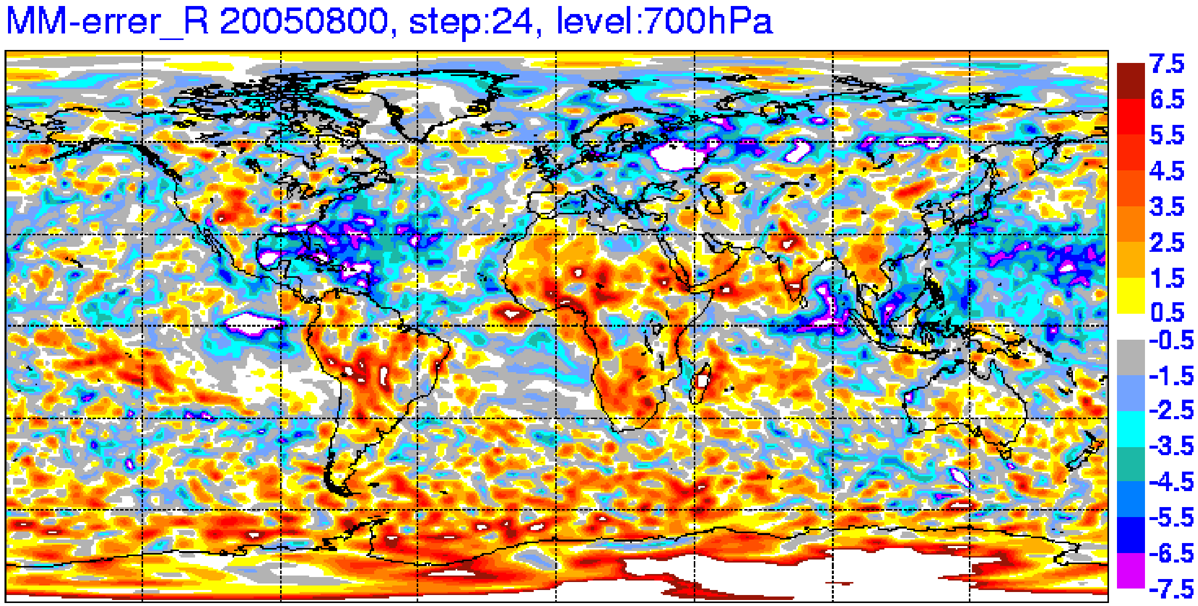


Total column water vapour (24-hr fc –AN)

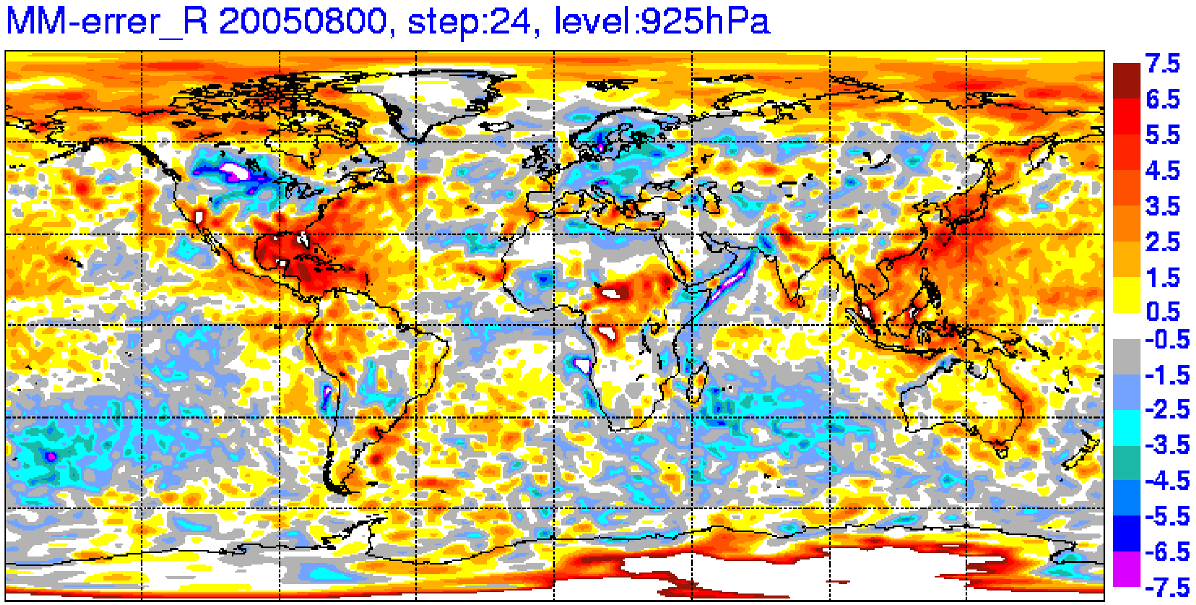


Systematic differences: Monthly averages 200508 (fc-an)

Relative humidity difference (%)
700-hPa
(24-hr fc – anal)

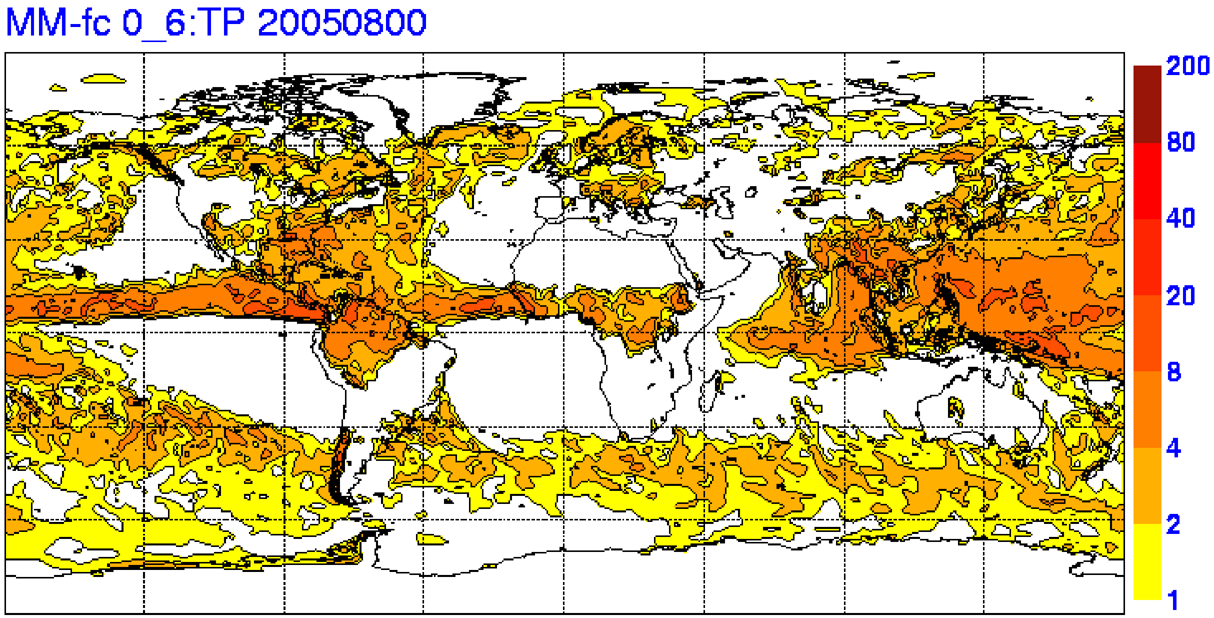


Relative humidity difference (%)
925-hPa
(24-hr fc – anal)

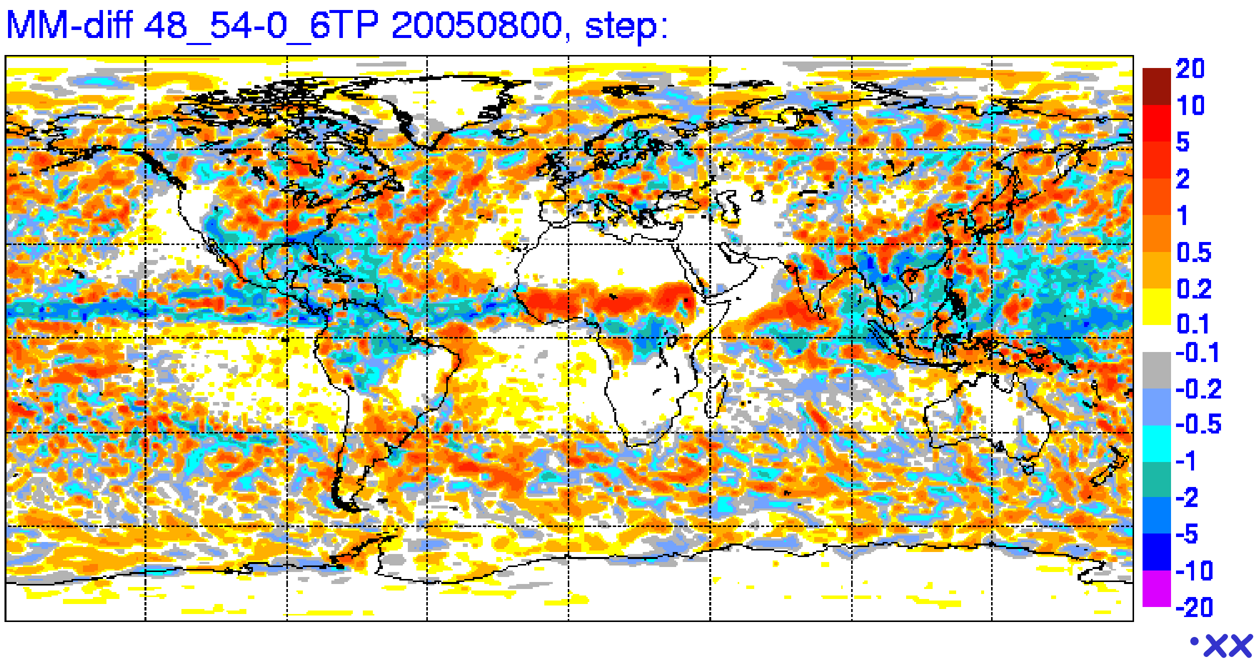


Systematic differences: Monthly averages 200508 (fc-an)

Total precipitation
(mm/day)
(0_6 hrs)

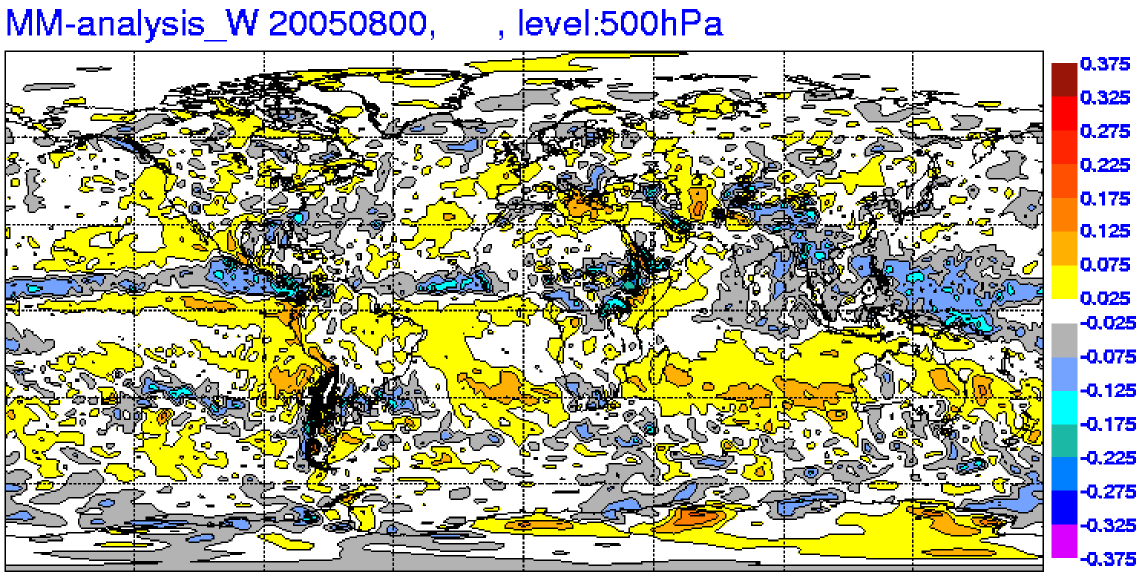


Total precipitation
difference
(mm/day)
(48_54-0_6 hrs)

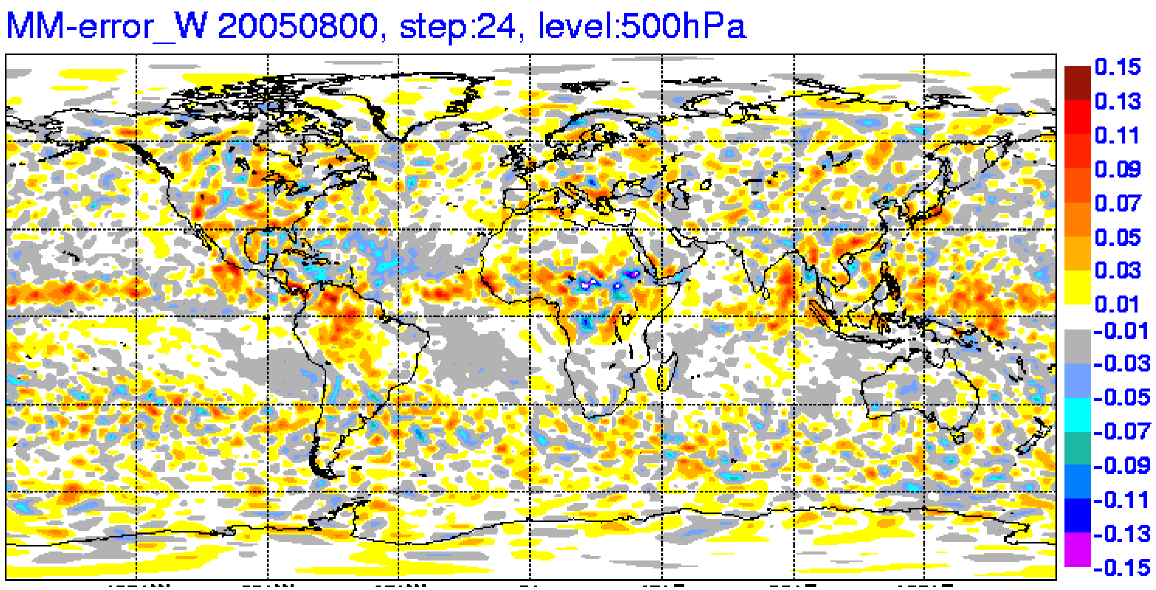


Systematic differences: Monthly averages 200508 (fc-an)

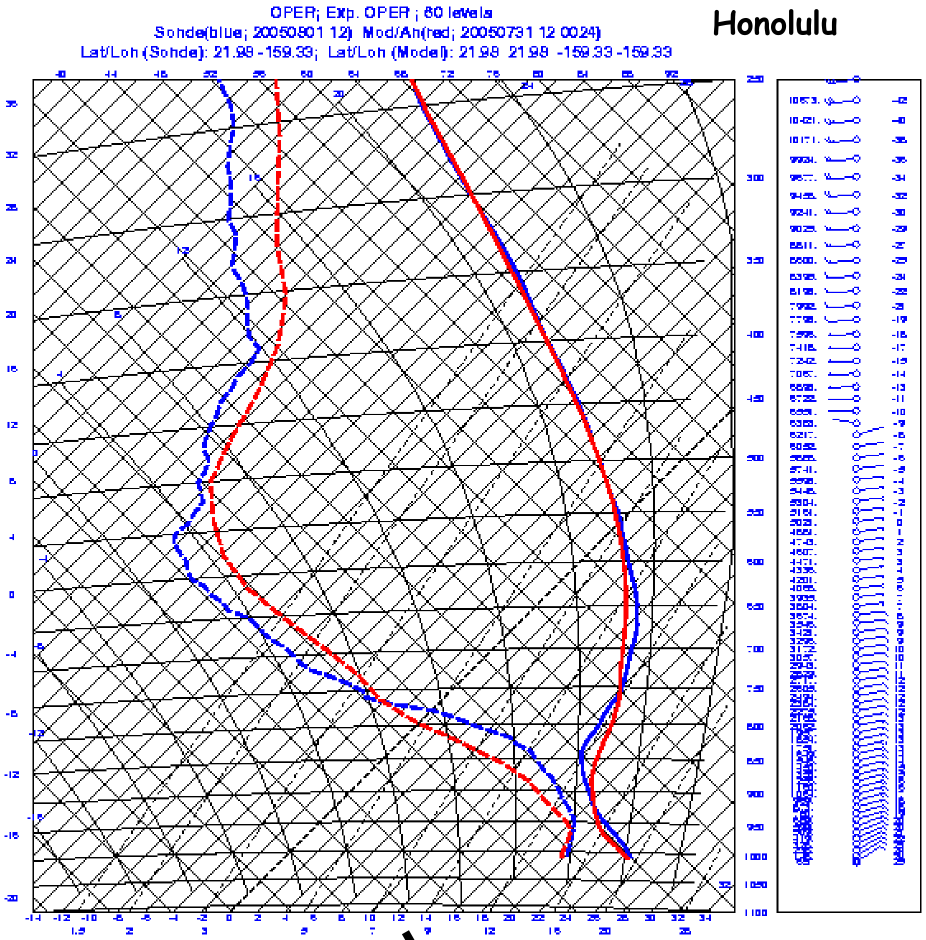
Vertical velocity
(Pa/s)
500-hPa
(an)



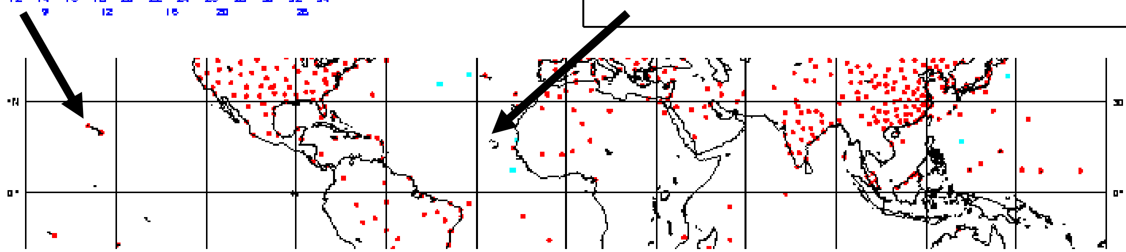
Vertical velocity
difference (Pa/s)
500-hPa
(24-hr fc-an)



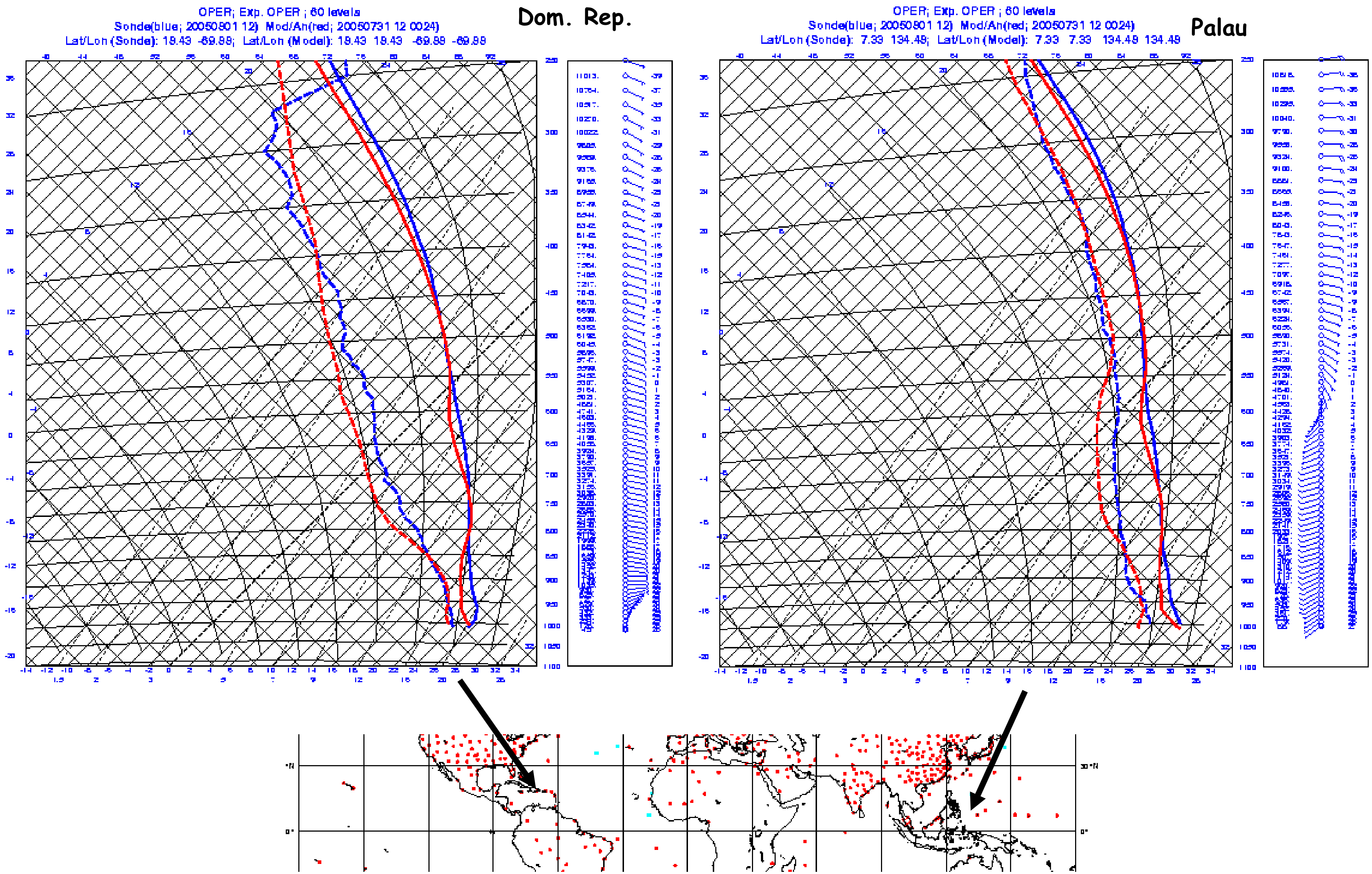
Monthly averaged thermodynamic profiles 200508: (24 Hr fcsts/Sonde)



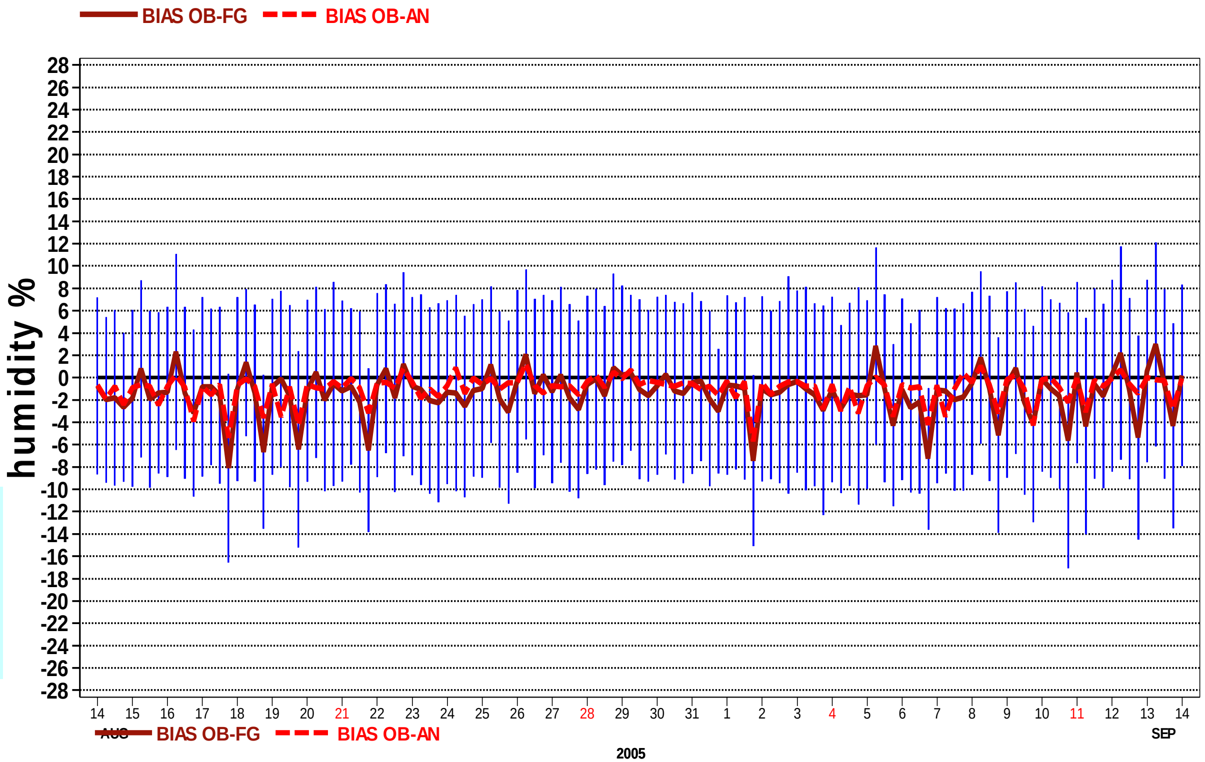
Canary Islands



Monthly averaged thermodynamic profiles 200508: (24 Hr fcsts/Sonde)

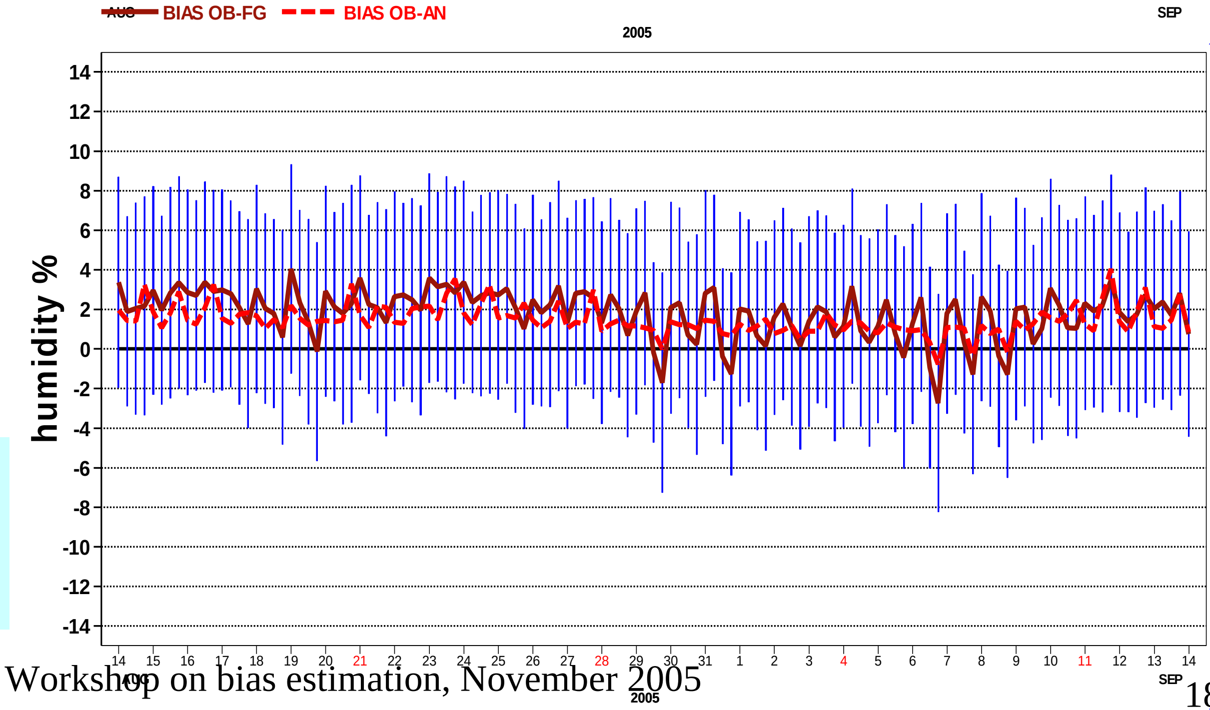


Radiosondes-land
sfc-700 hpa
obs-FG
obs-AN



Model 1 to 2 % too moist compared to sondes

SYNOP's-land
obs-FG
obs-AN

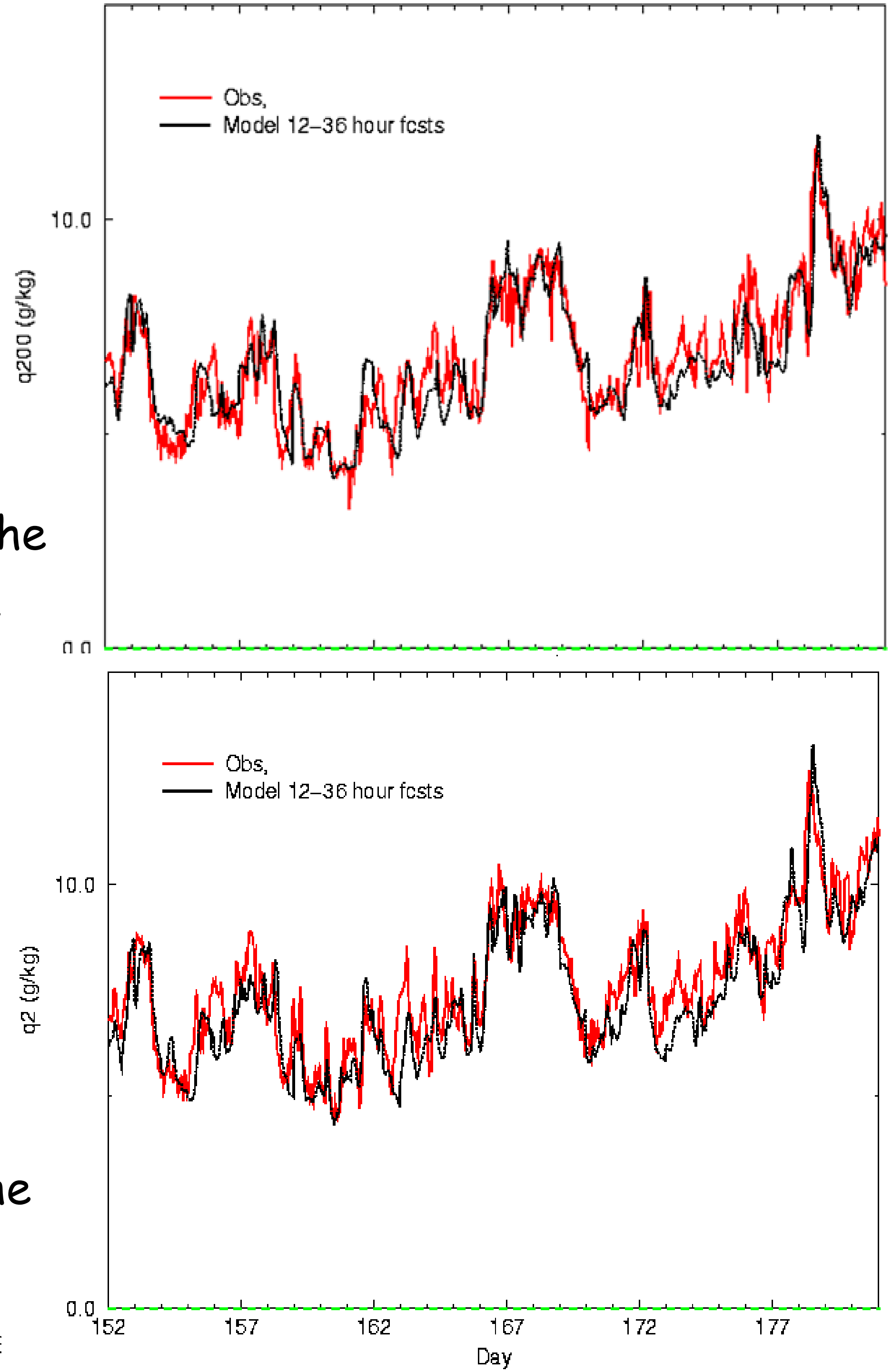


Model about 2 % too dry compared to SYNOP's

Time series of q at Cabauw (Netherlands)

200 m above the surface

2 m above the surface



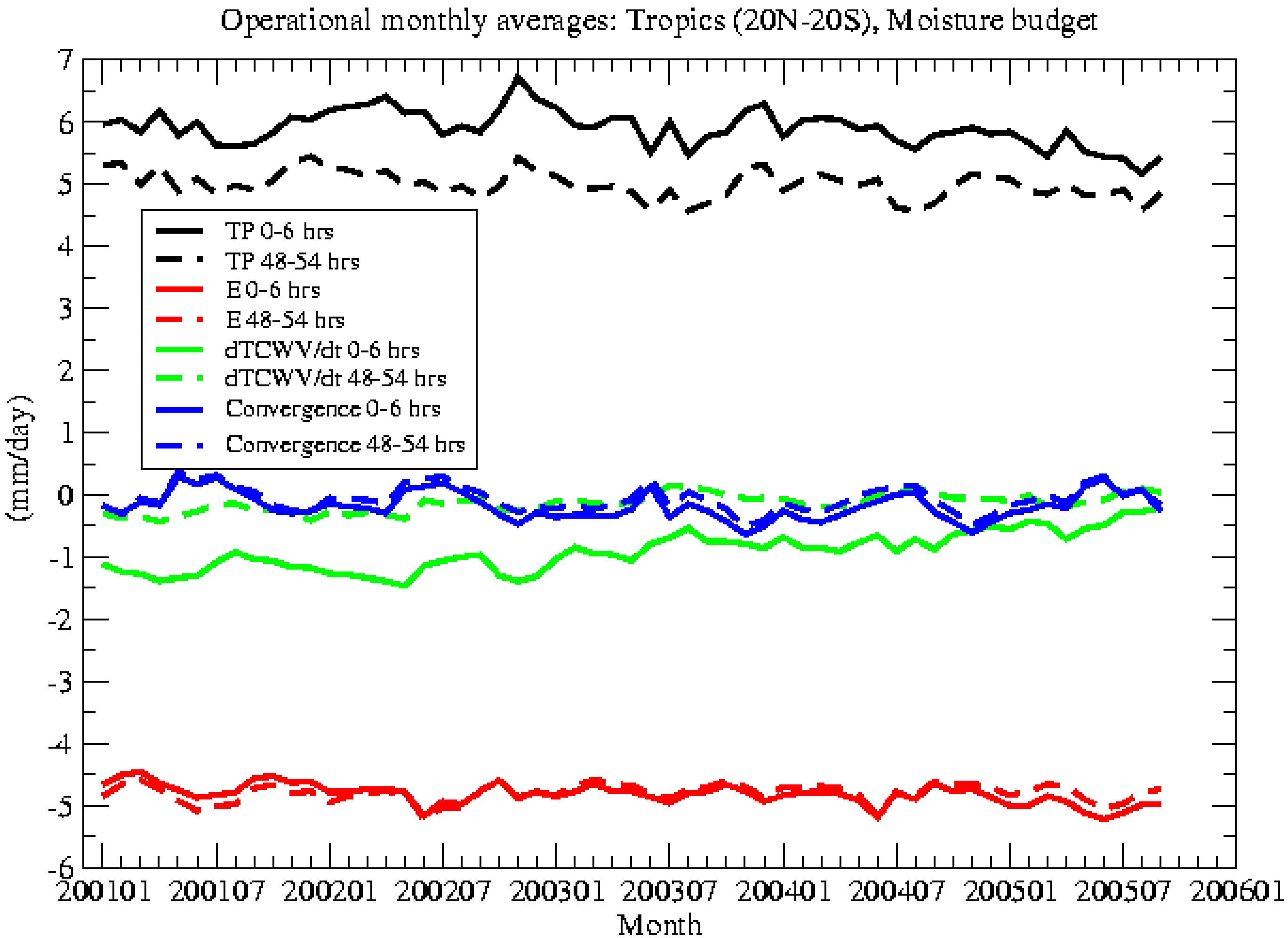
Data: Fred Bosveld, KNMI

Conclusions on moisture

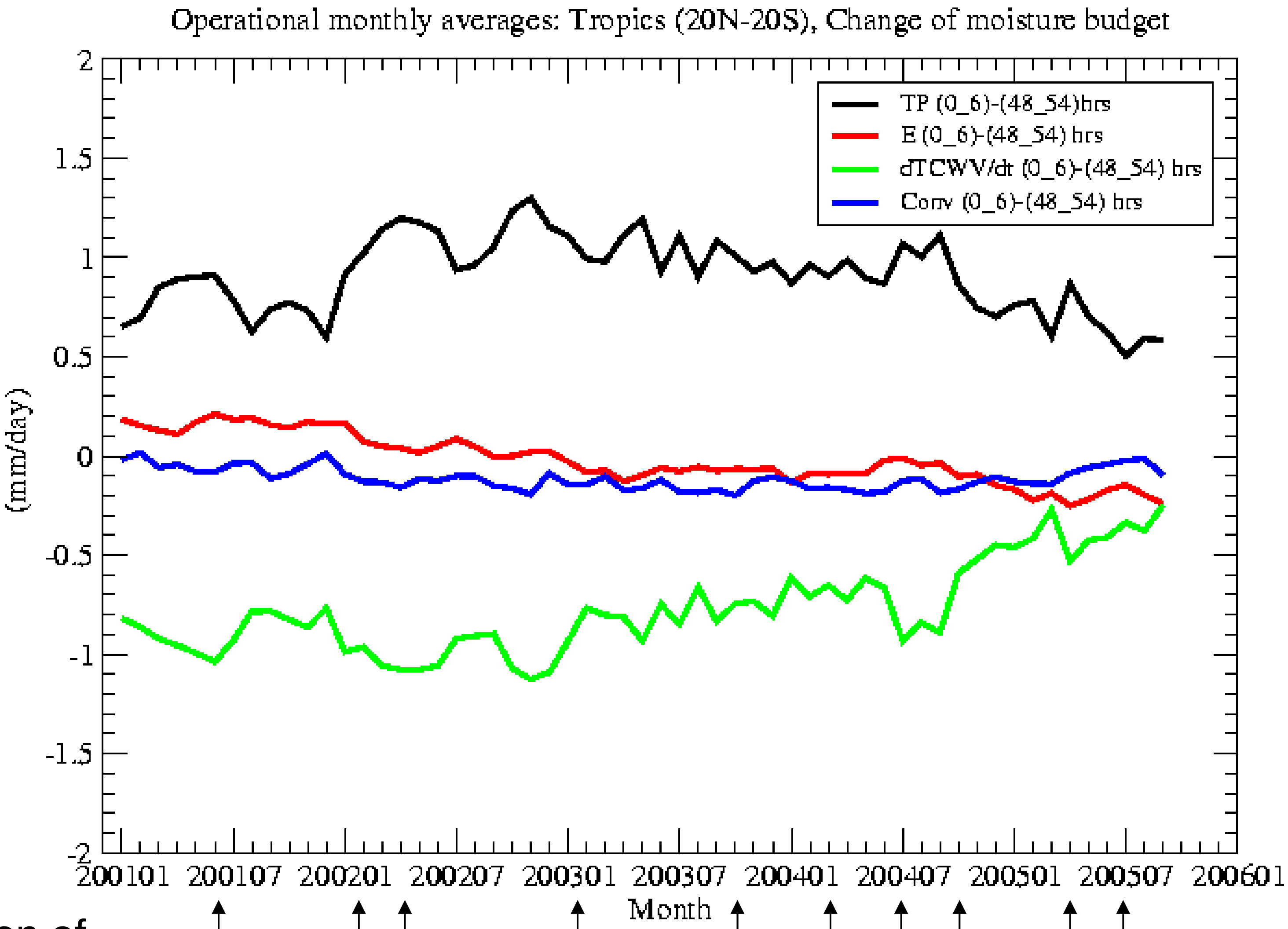
- Errors are small
- The errors with respect to analyses are confirmed by sonde profiles
- Moisture structure is controlled by:
  1. Advection (Vertical + horizontal)
  2. Boundary layer diffusion (including shallow convection clouds + stratocumulus clouds)
  3. Deep convection
- Errors in moisture are likely to be related to errors in all 3, but vertical motion (divergent motion) may dominate
- Moisture acts like a tracer: dynamic link between moisture increments and divergent flow is needed (more emphasis on dynamic control variable rather than q to adjust moisture in 4DVAR?)

History of spin-up (20N-20S)

$$\frac{dTCWV}{dt} = -P - E + Convergence$$



History of spin-up (20N-20S)



List with selection of model changes. In addition there were many changes to the use of satellite data.

24R3: Conv.+supersat

28R1: Conv. changes

29R2: Assim. Rain, limit q-incr

23R4:

26R3: AIRS, New q-anal

29R1: Moist BL, num. 1^{st} step

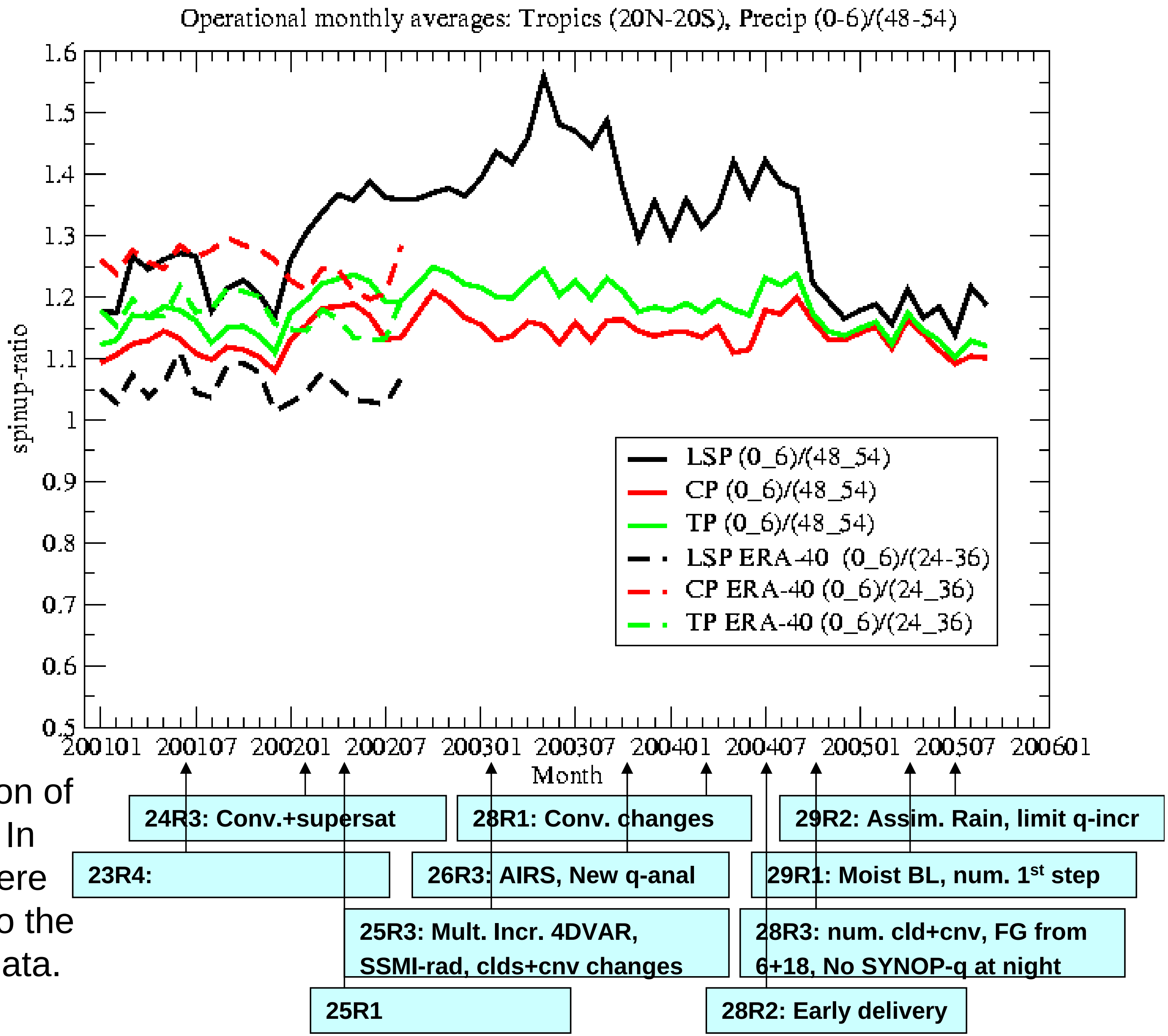
25R3: Mult. Incr. 4DVAR, SSMI-rad, clds+cnv changes

28R3: num. cld+cnv, FG from 6+18, No SYNOP-q at night

25R1

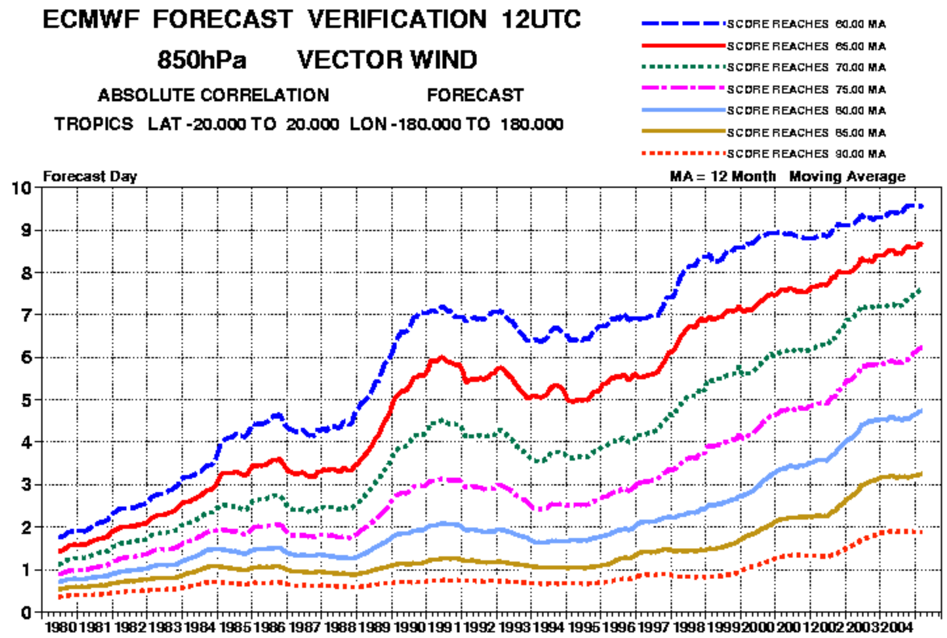
28R2: Early delivery

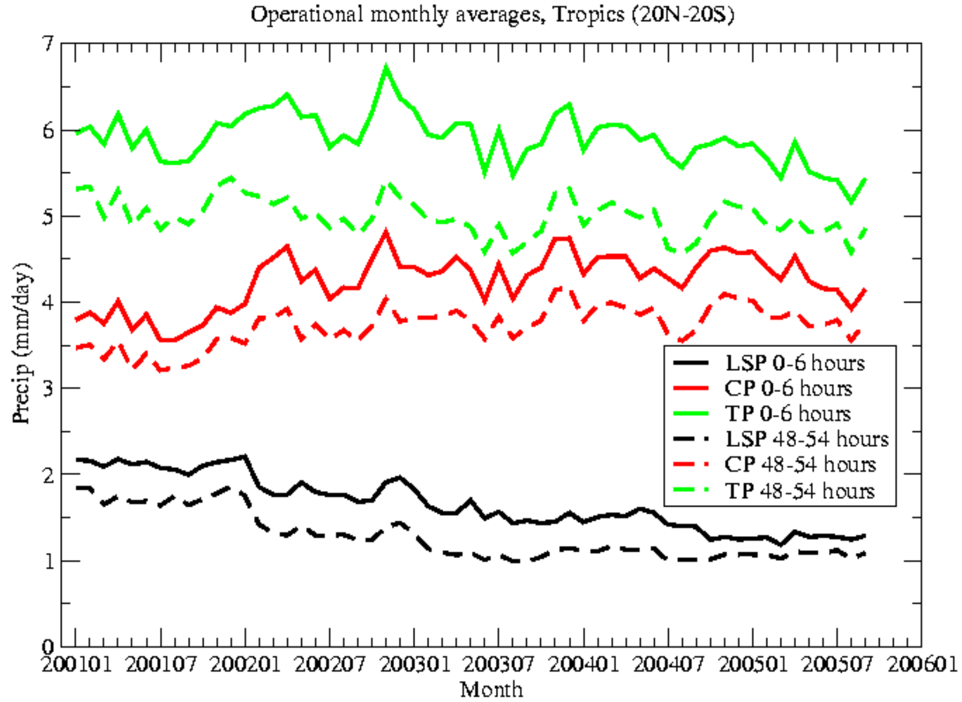
History of spin-up (20N-20S)

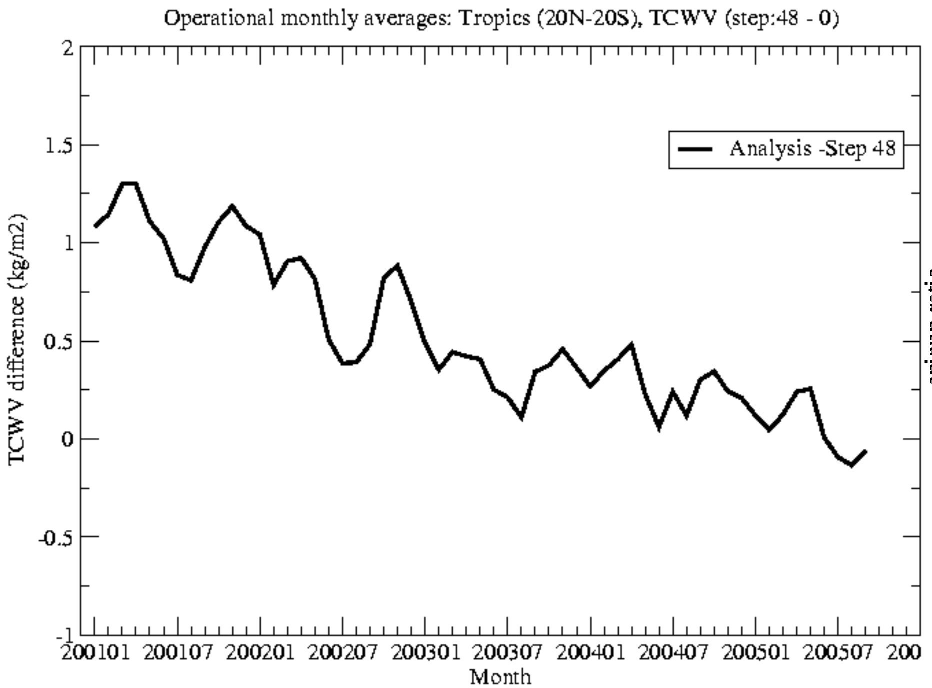


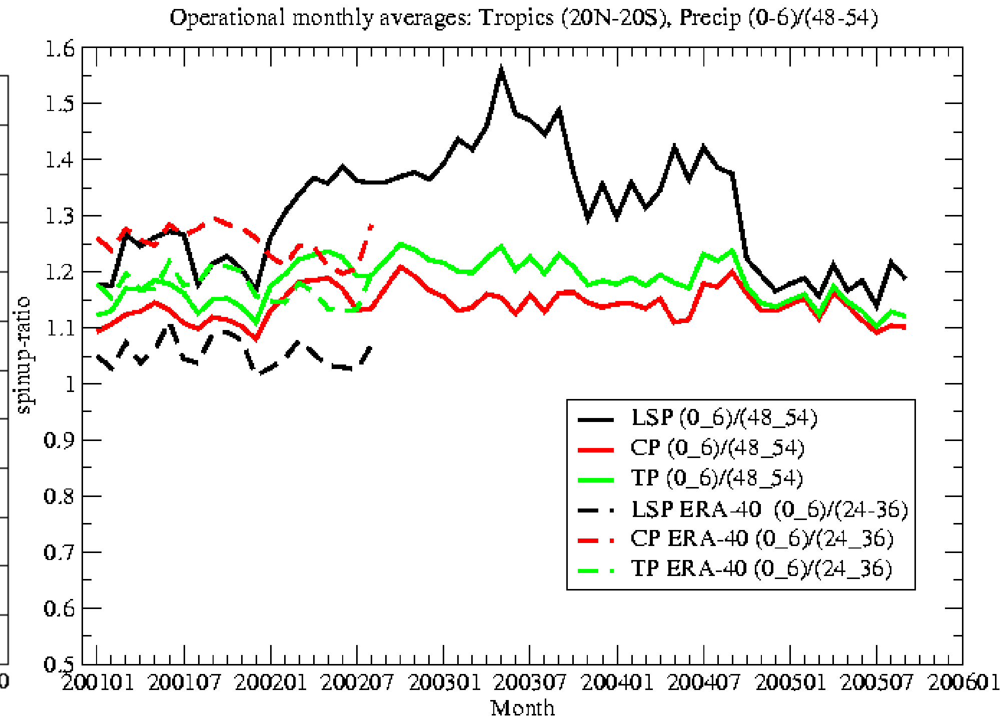
List with selection of model changes. In addition there were many changes to the use of satellite data.

History of spin-up (20N-20S)









Conclusions on spin-up

- Spin-up has improved with:
  1. A modest reduction in precipitation spindown
  2. A substantial reduction in TCWV spindown
  3. A change from increase of evaporation during the forecast to a decrease of evaporation. (BL has become more dry in analysis).
- It is difficult to make a precise link between model changes and impact on spin-up
- Model changes and data assimilation changes (including use of satellite data) have contributed
- It is impossible to verify TCWV within 1 kg/m2 using radio sonde data.

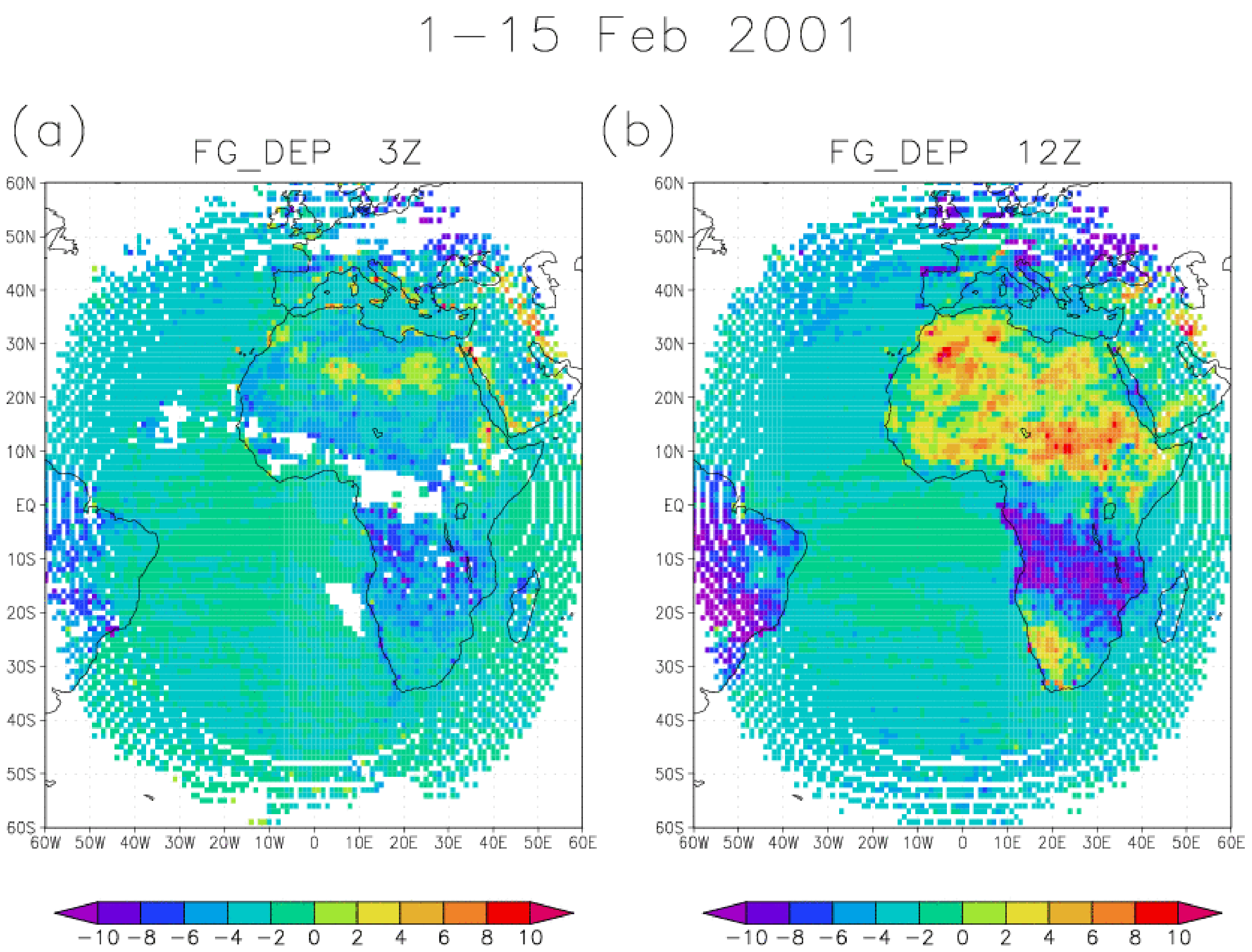
Surface skin temperature (radiative surface temperature) as seen "from the top of the atmosphere"

- The use of remote sensing channels that peak in the lower troposphere requires an accurate background field of skin temperature
- Current model skin temperatures have large errors over land, underestimating the diurnal cycle, in arid/semi-arid areas

METEOSAT

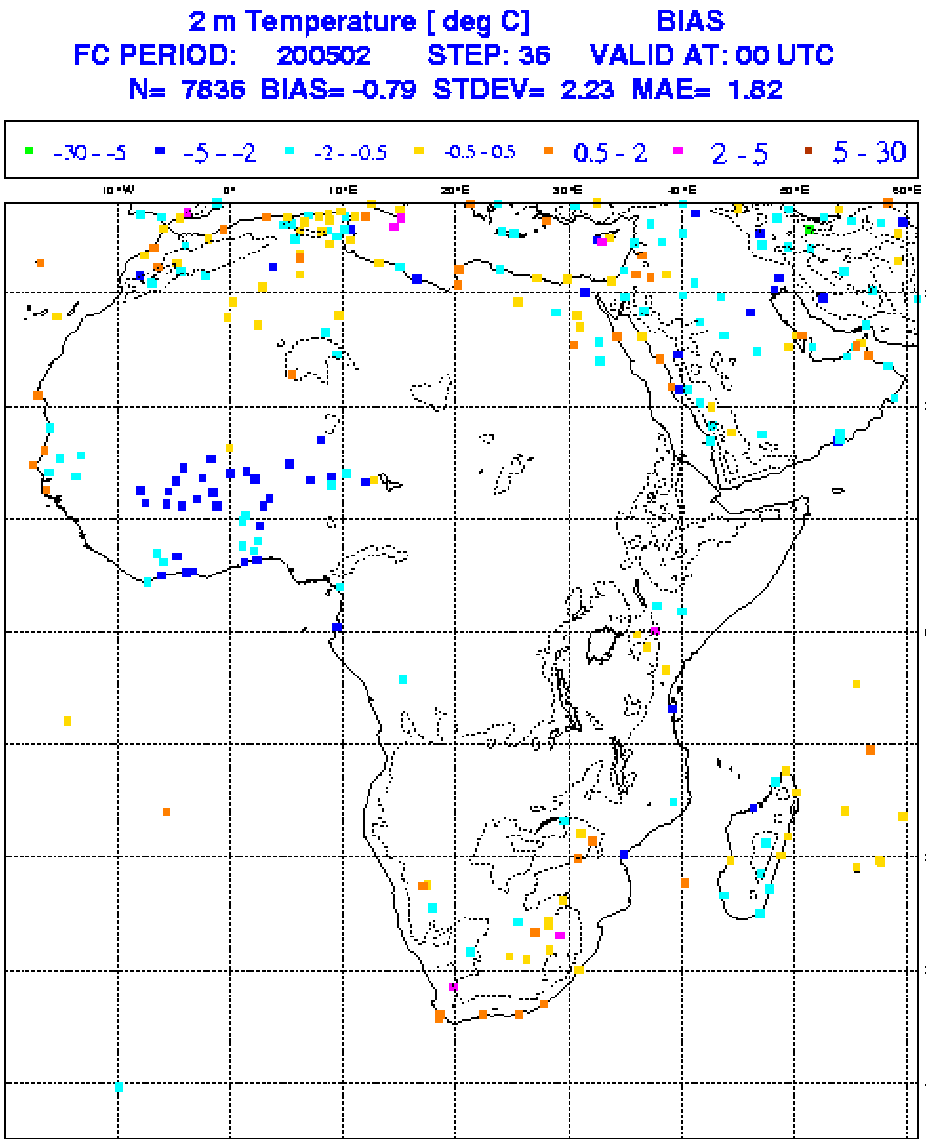
Clear sky Tb window channel

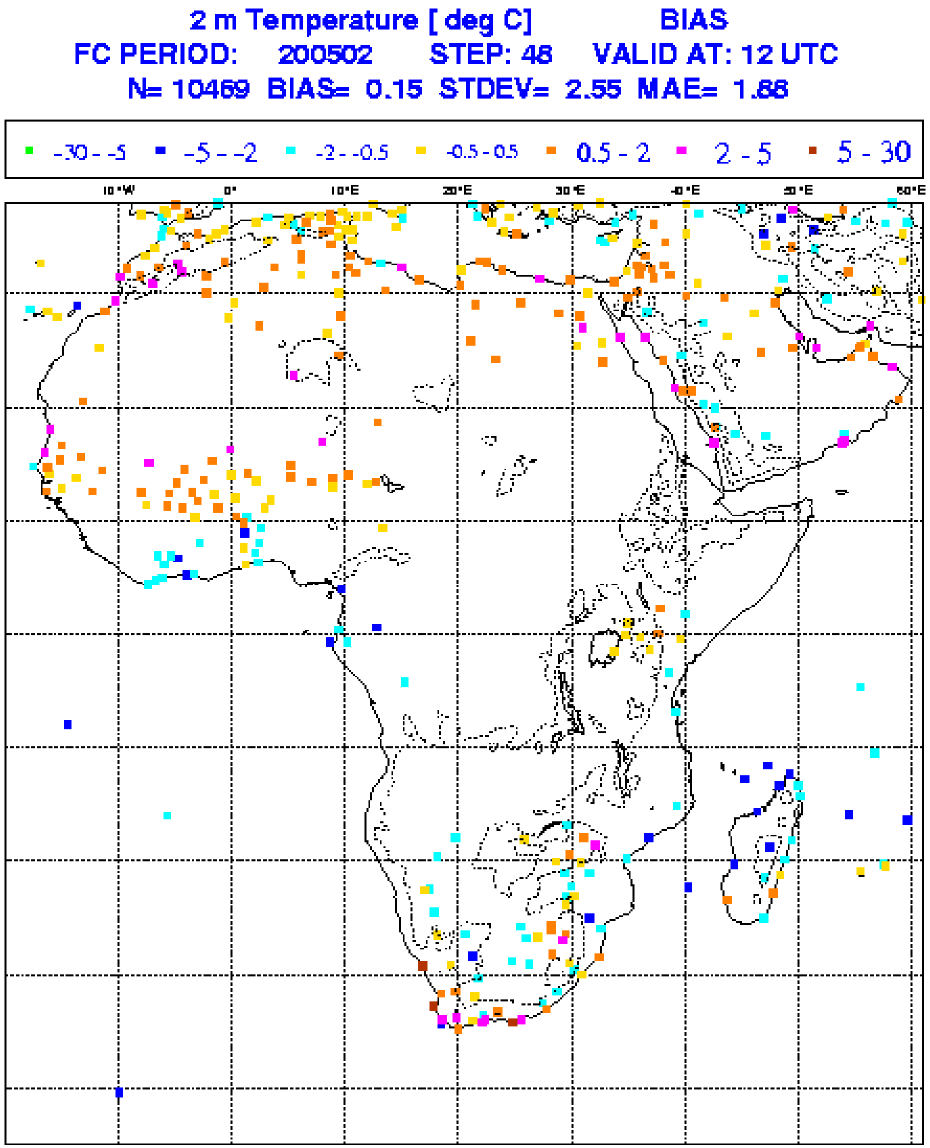
OBS - model



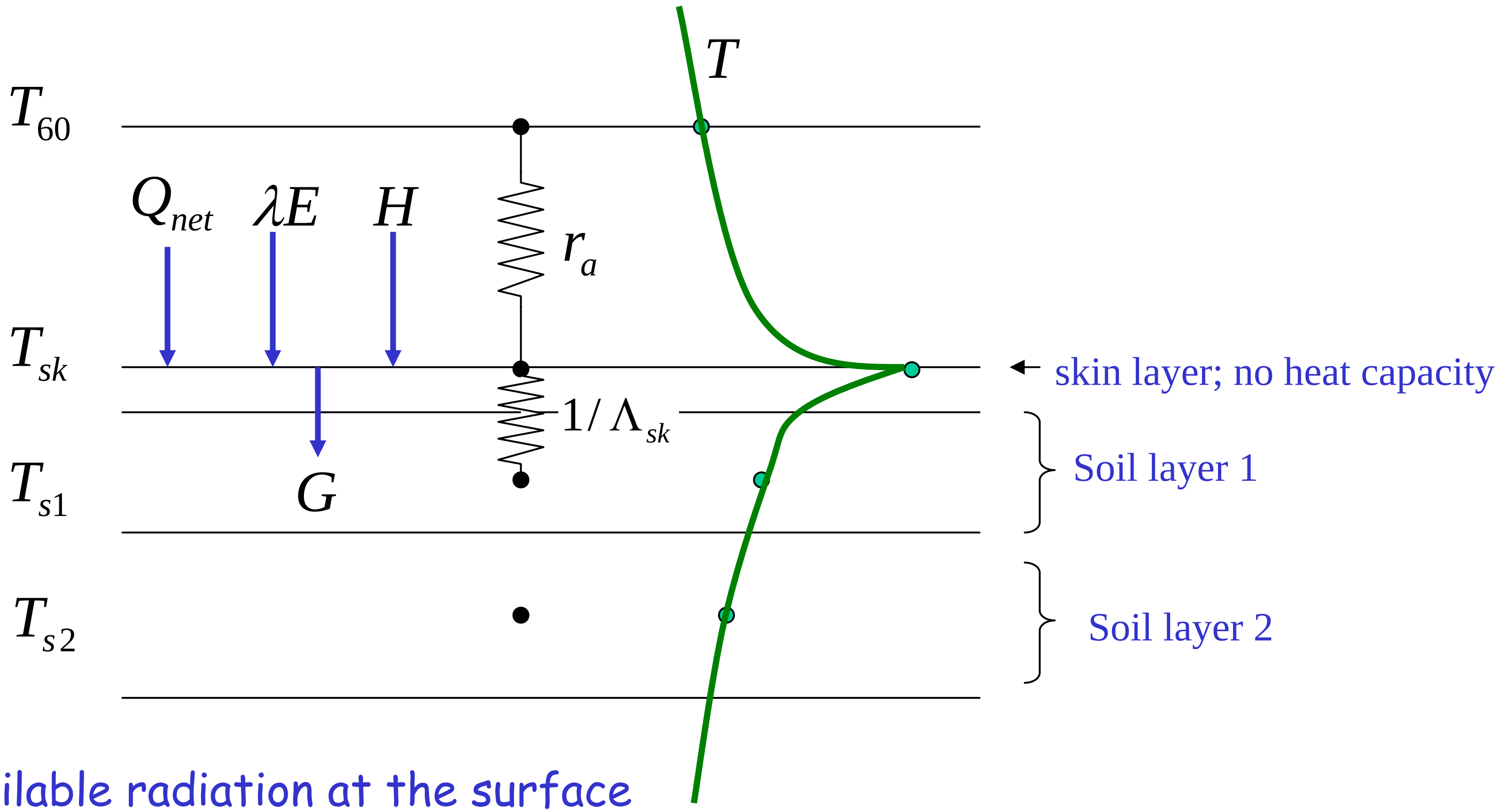
Trigo and Viterbo, 2002

2m temperature verification (February 2005)





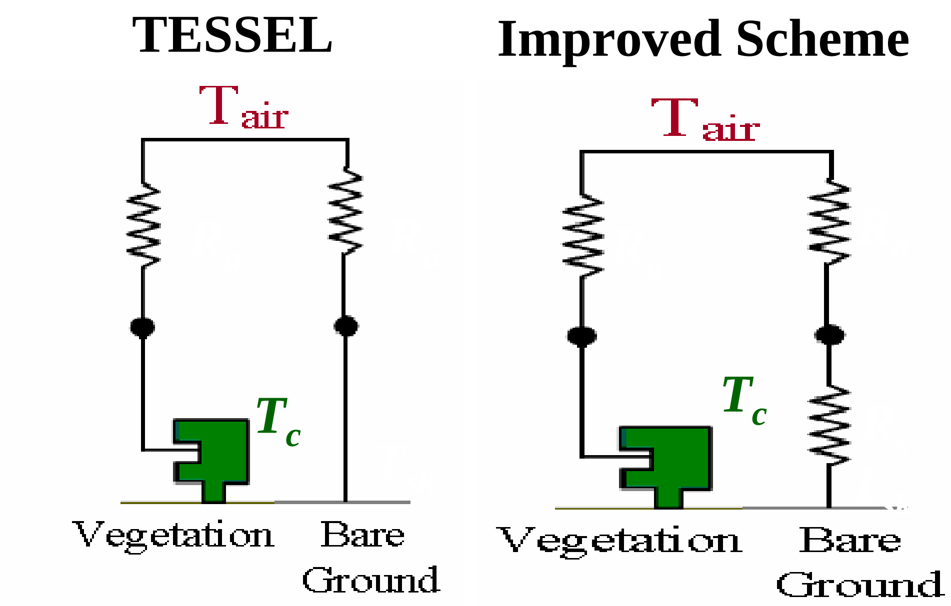
What controls the surface skin temperature?



- Available radiation at the surface
- Partitioning of available energy between sensible and latent heat flux
- Aerodynamic coupling of skin to atmosphere (in TESSEL controlled by land roughness lengths for momentum and heat)
- Coupling of skin (vegetation canopy, litter layer, dry top soil layer) to underlying soil

Coupling to the atmosphere

- Possible solution for low vegetation tiles
  - Bare ground contribution to the sensible heat flux: Introduce a resistance Rs, mimicking the wind shielding effect of the surrounding vegetation.



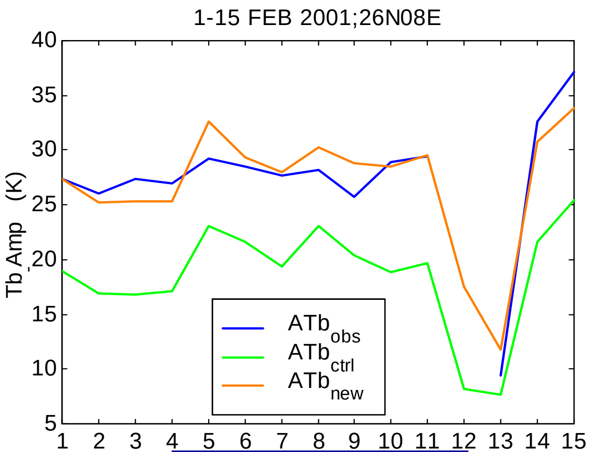
$$R_s = \frac{1}{a + b u_*^2}$$

- Parameters a and b (fixed for each grid point) in Rs are estimated by fitting the modelled daily amplitudes of Tb_BG to Meteosat clear sky observations, for the window channel.

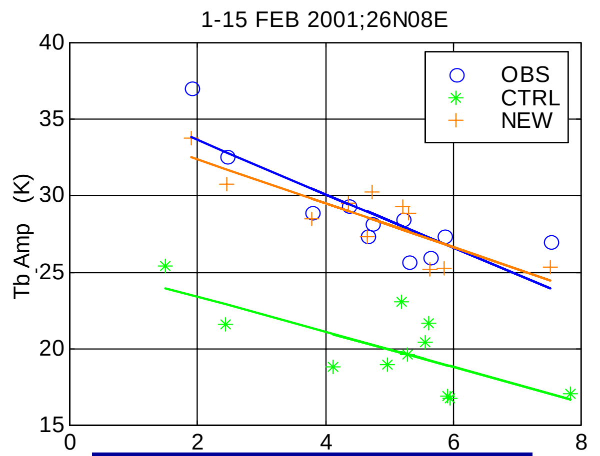
Development and validation

- SCM + (radiative transfer model) applied to points in semi-arid areas. Triple collocation of model, point observations and METEOSAT ensures that the improvements to skin temperature do not degrade two-metre temperature
- Preliminary results (Western Sahara, one point). Amplitude of Tb diurnal cycle:

Calibration period: 2001

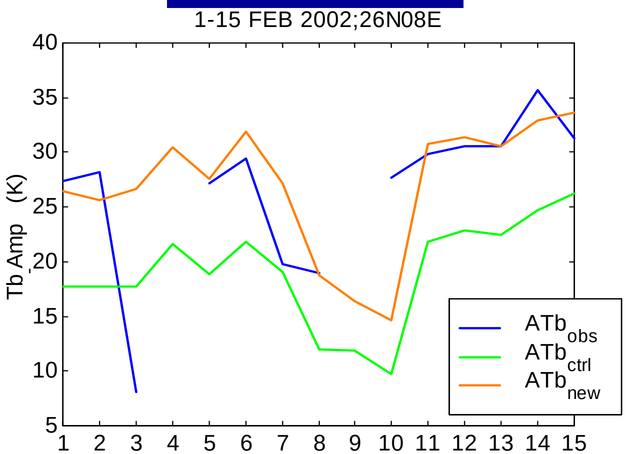


Day of the month

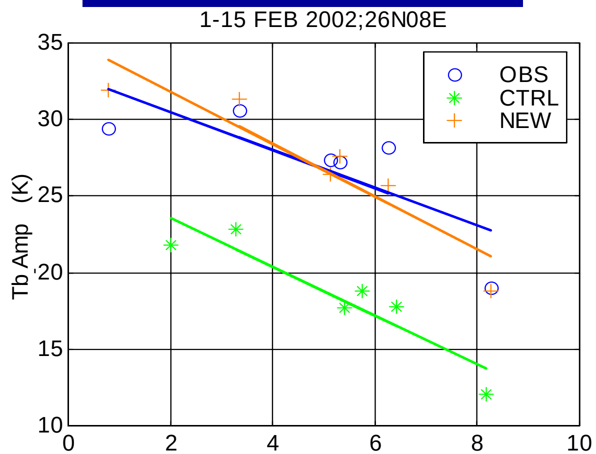


10m wind speed (ms^{-1})

Validation period: 2002



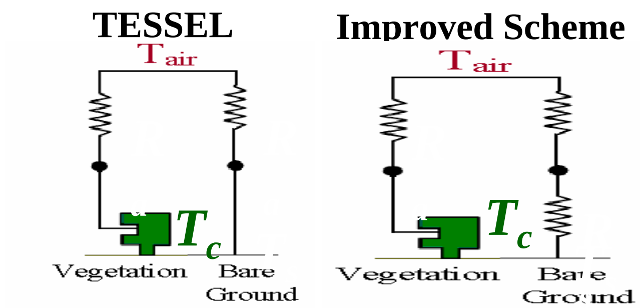
Day of the month



10m wind speed (ms^{-1})

Skin temperature: Coupling to the soil

- Model changes
  - Turbulent orographic form drag (TOFD) parameterisation
  - Tested additional resistance to heat (Rs)
  - Reduce coupling from skin to soil (Λ)
- Future
  - Test the changes above in data assimilation, assess Tsk against GOES/METEOSAT



Cycle	T2		Tskin	
	Day	Night	Day	Night
26r3	310	293	320	290
TOFD	309	292	322	289
TOFD+Rs+Λ	309	290	325	286

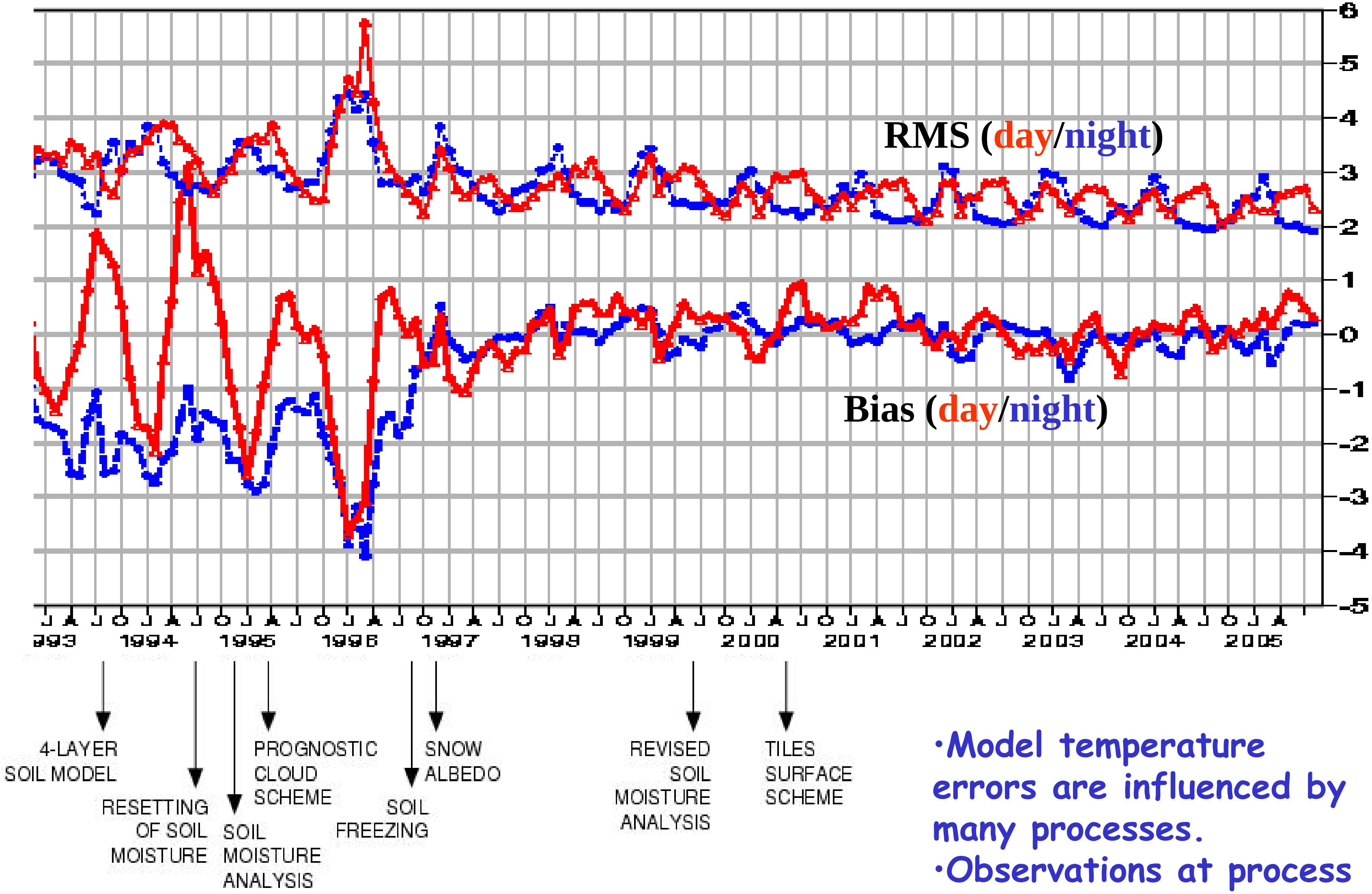
Summary Sahara

Tb amplitude: Model - Observations

	1-15 Feb 2001	1-15 Feb 2002
Control	-8.9 K	-8.5 K
Revised	-0.4 K	-0.1 K

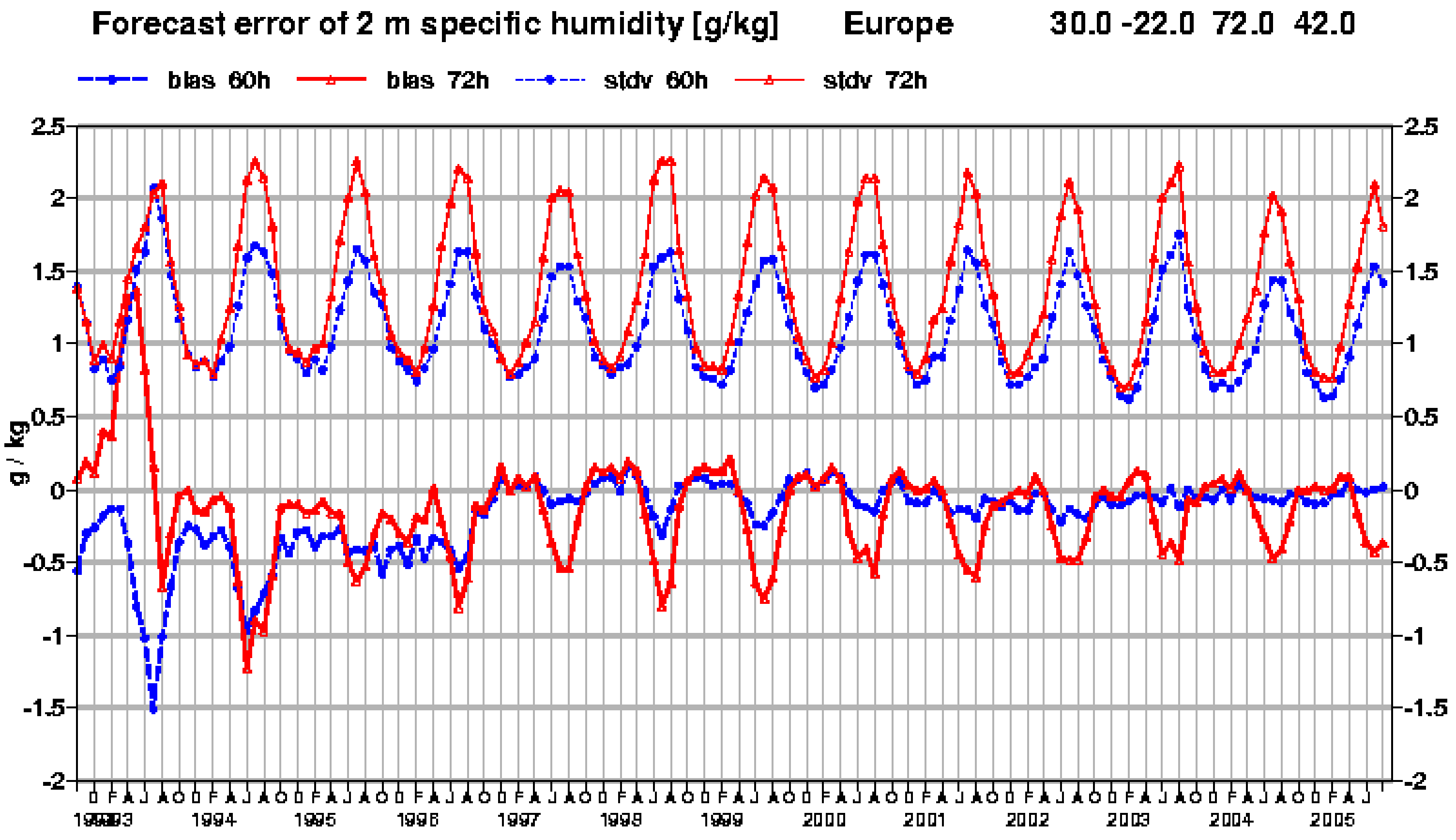
- The revised formulation is capable of removing the very large model bias in the diurnal amplitude
- Parameters calibrated in 2001, are used unchanged in 2002, with equal success

History of 2m T-errors over Europe in the ECMWF model (step60/72)

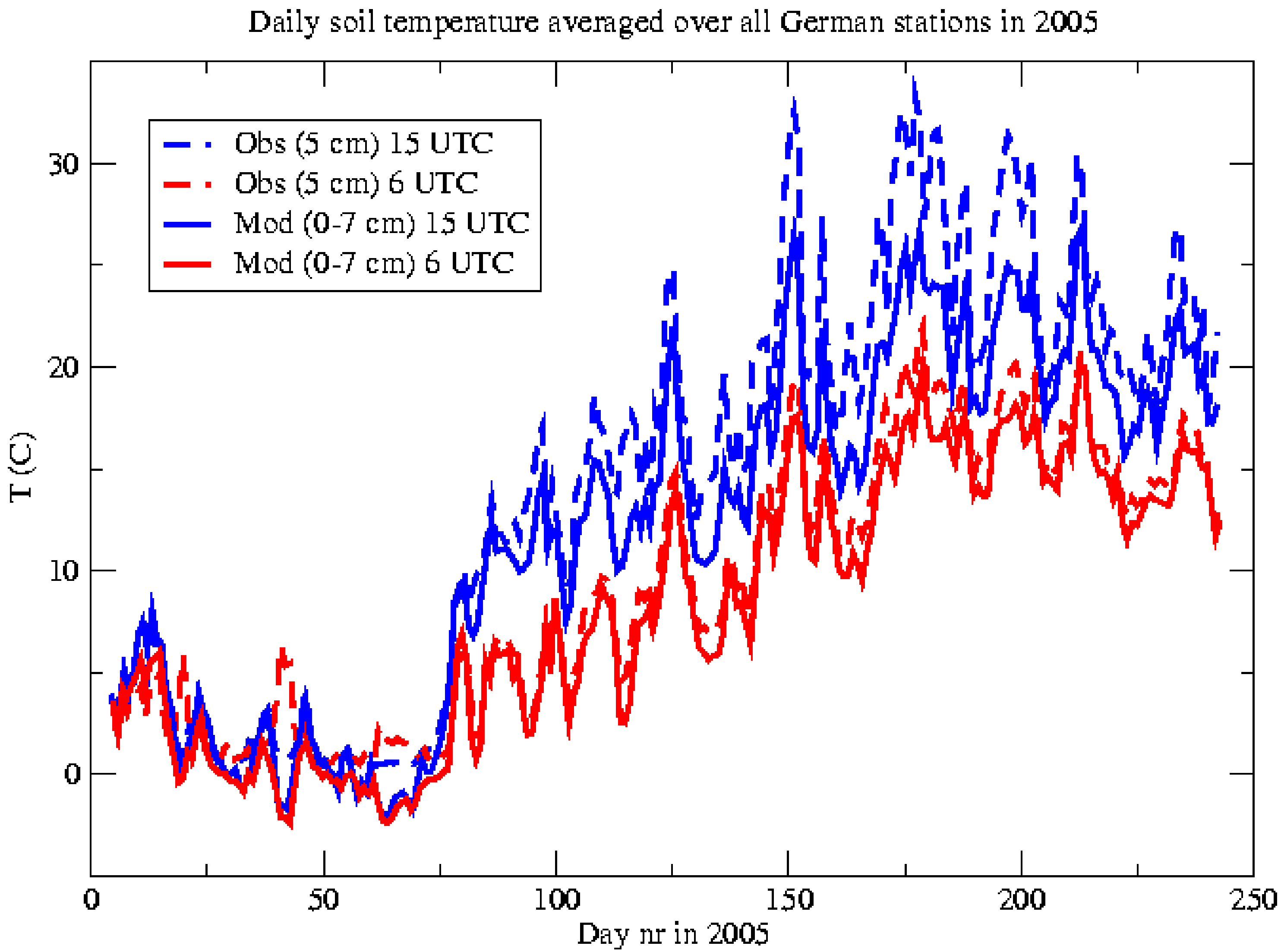


- Model temperature errors are influenced by many processes.
- Observations at process level are needed to disentangle their effect

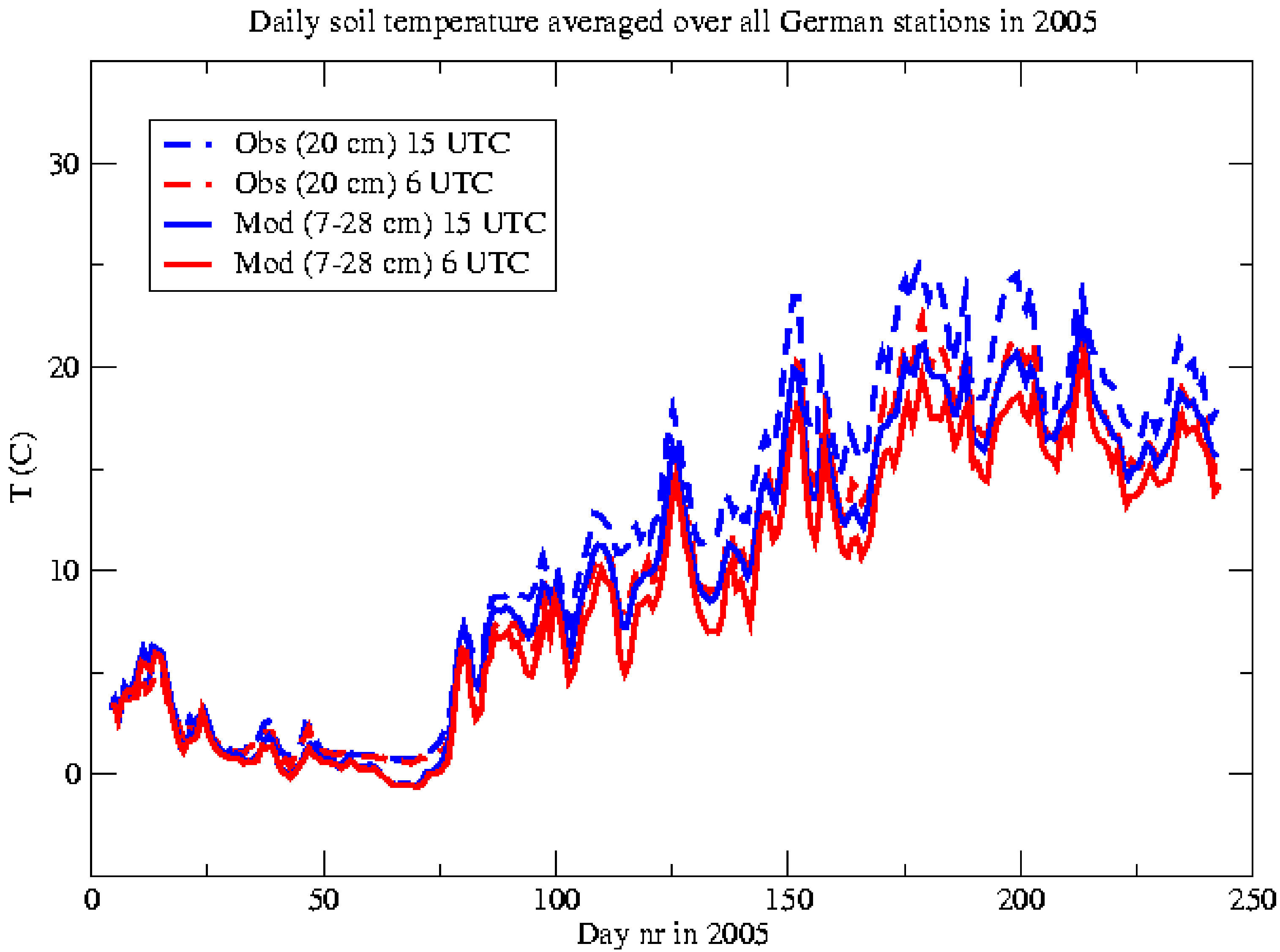
SYNOP (2m) humidity verification over Europe (monthly)



Soil temperature verification over Germany (layer 1)

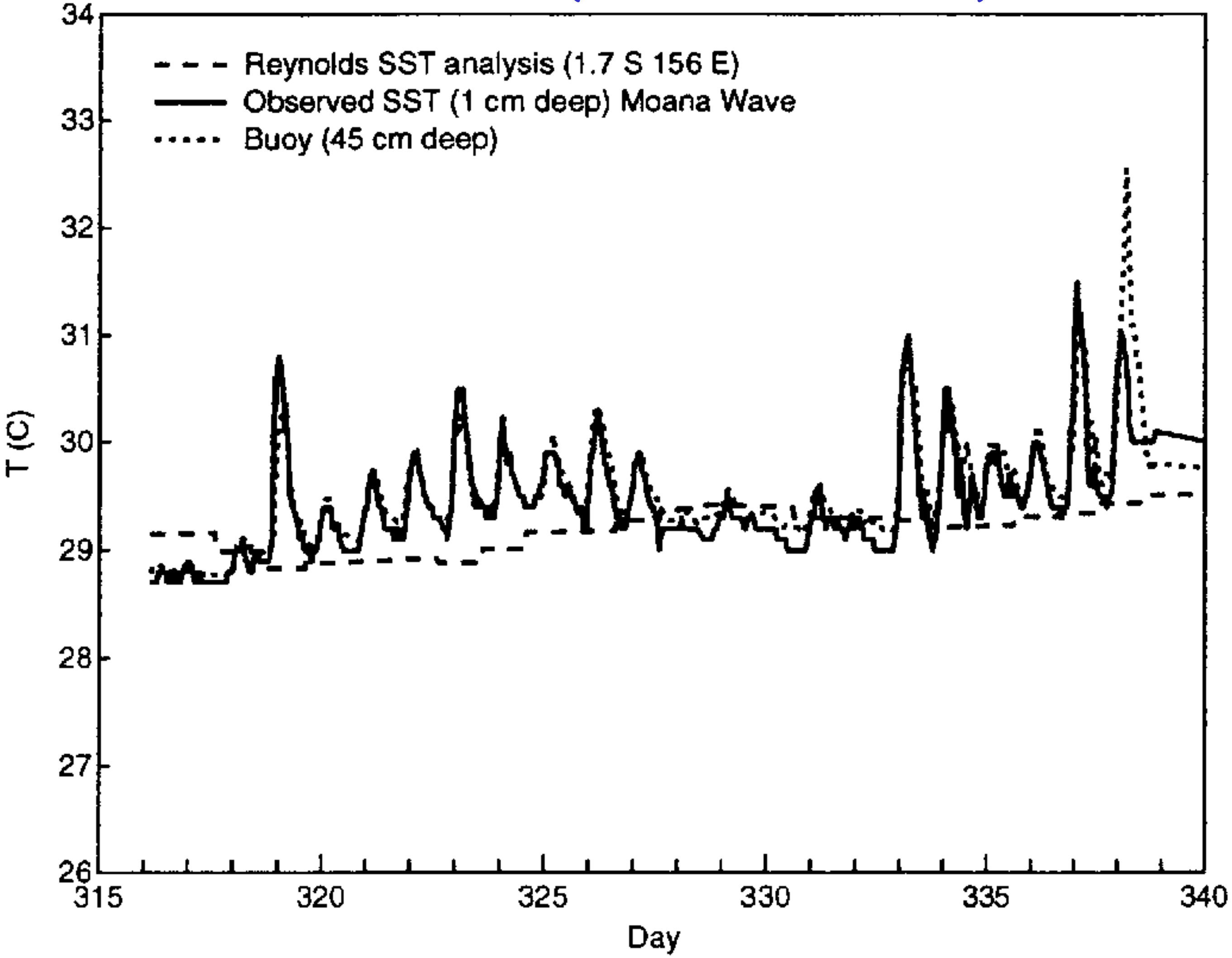


Soil temperature verification over Germany (layer 2)



Ocean warm layer effect (diurnal cycle)

TOGA/COARE data (19921111-19921203)



Fairall et al.

Ocean warm layer model

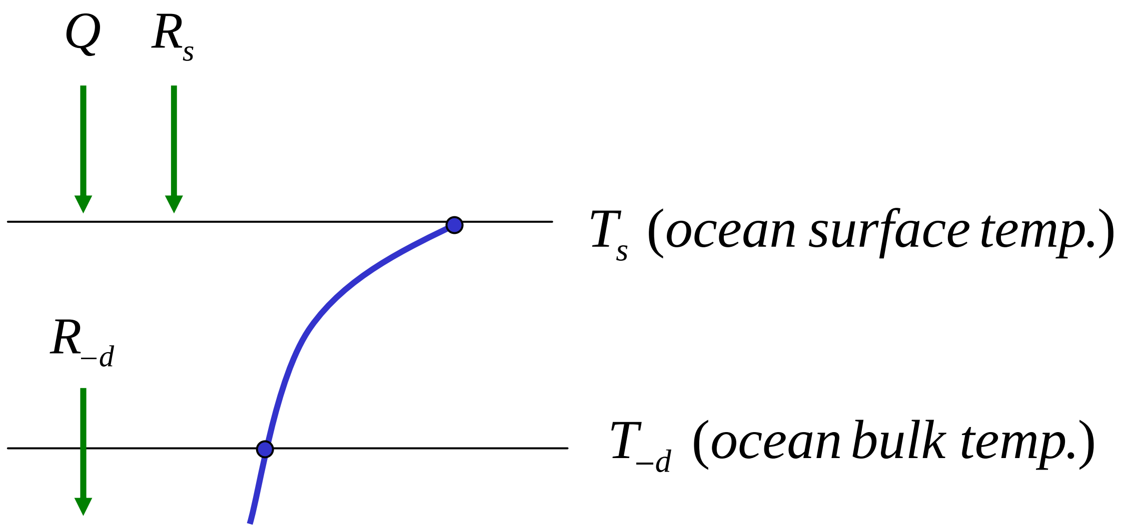
$$T_s - T_{-d} = \frac{Q + R_s - R_{-d}}{d\rho_w c_w \nu / (\nu + 1)} - \frac{(\nu + 1) k u_{*w}}{d\phi(d/L)} (T_s - T_{-d})$$

$Q = H + \lambda E + R_{LW}$

$v = shape\ param.\ for\ temp.\ profile\ (0.3)$

$d = depth\ scale\ (3m)$

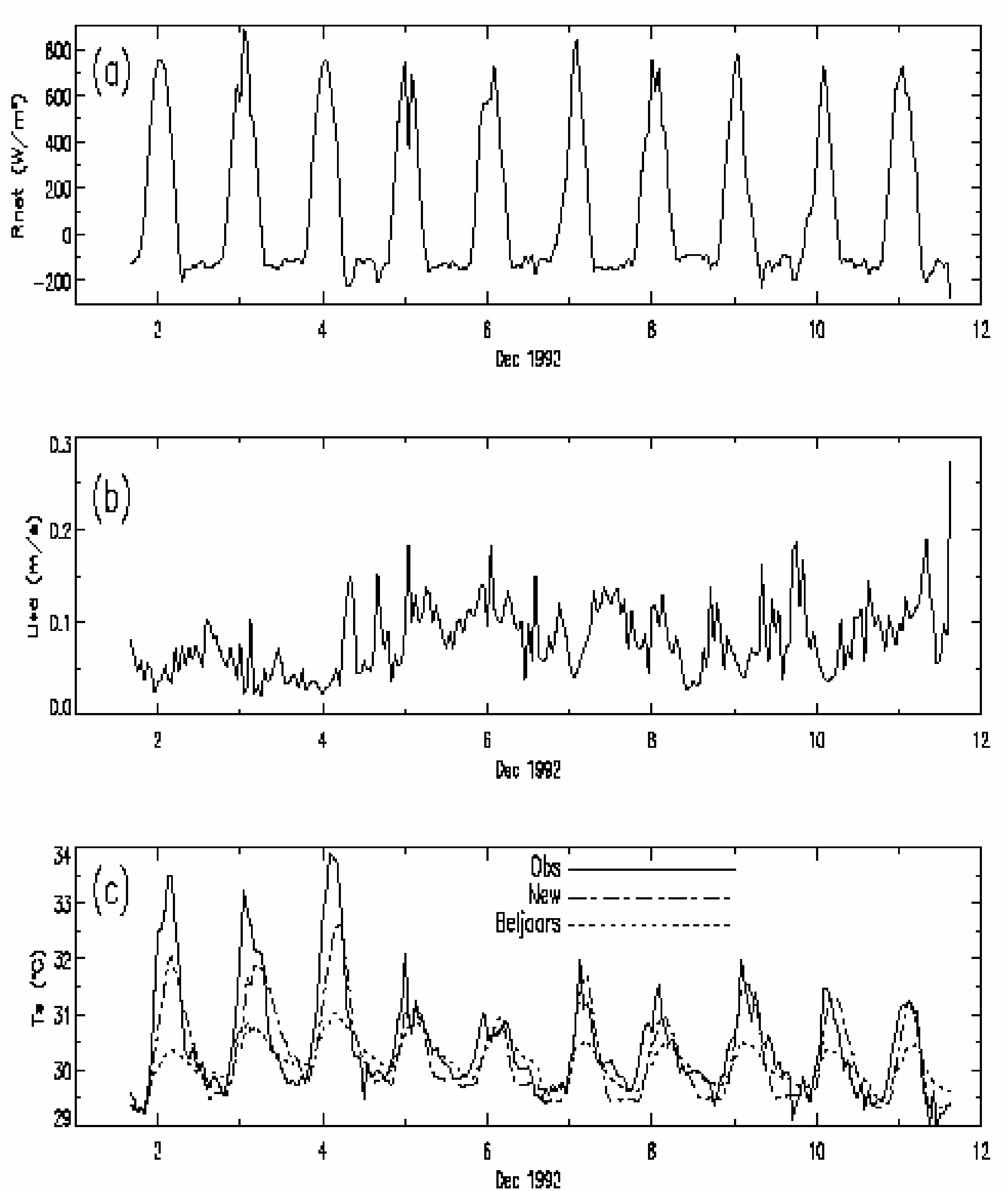
$u_{*w} = friction\ velocity$



Cheng and Beljaars 2005

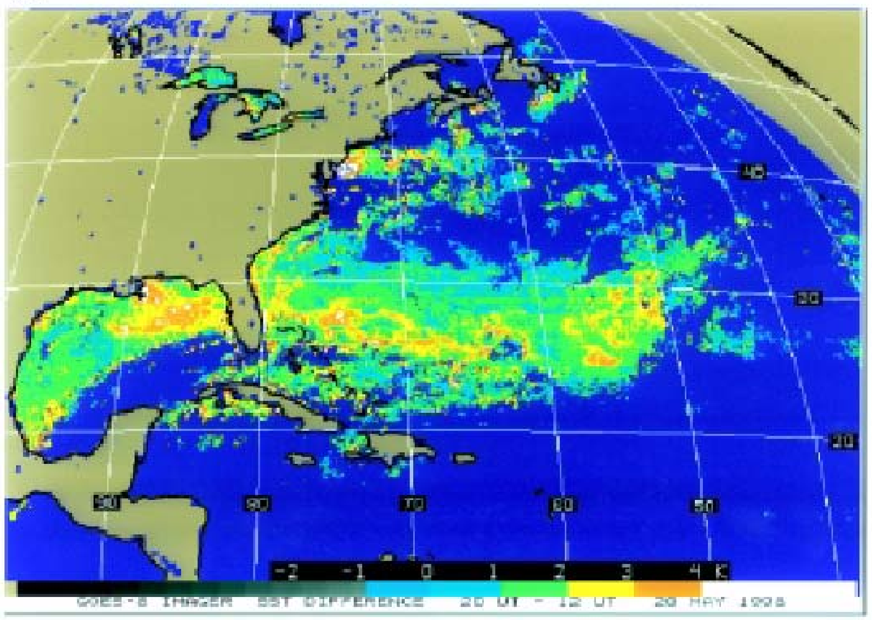
Ocean warm layer model

Observations during TOGA/COARE (December 1992)

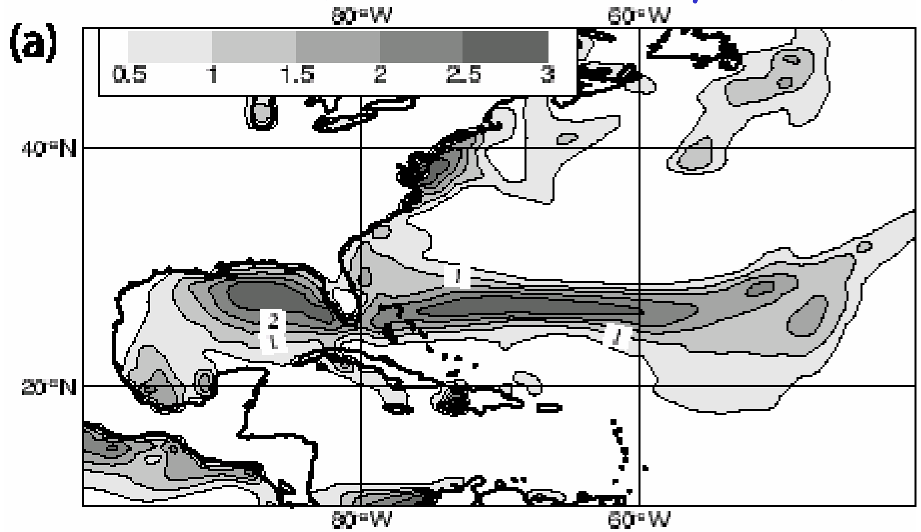


Diurnal cycle of ocean surface temperature

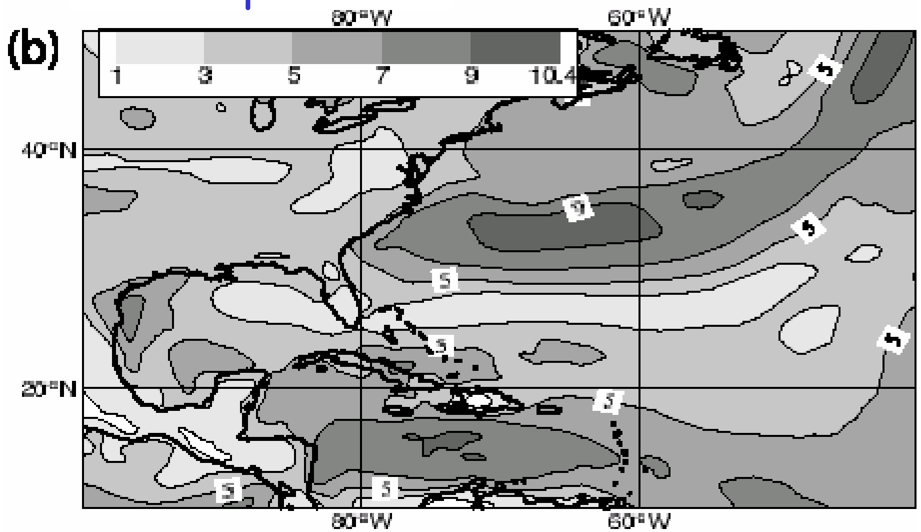
Derived from GOES (Wu et al. 1999)



Ts difference between 12 UTC and 20 UTC (model 20-22 may 1998)



Wind speed



Concluding remarks

- Temperature errors are small except in stratosphere. Radio sondes give info up to 10 hPa.
- Moisture structure near boundary layer top shows errors related to BL cloud processes.
- Day time land humidity shows dry bias in summer (shallow convection).
- Spin-up is very subtle and moisture observations are not calibrated well enough to distinguish between model and observation biases.
- SYNOP's and radio sondes show systematic differences.
- Land "radiative" surface temperature shows large biases related to unknown coupling coefficients between air, surface skin and soil. These coefficients depend on: location, vegetation, surface condition (e.g. wetness), flow, solar elevation.
- Diurnal cycles in ocean surface temperature may be relevant for data assimilation.