First results of the AMIP2 GCMs evaluation using Meteosat Water Vapor data

Hélène Brogniez, Rémy Roca, Laurence Picon
Laboratoire de Météorologie Dynamique, Ecole Polytechnique, 91128 Palaiseau, FRANCE
brogniez@lmd.polytechnique.fr

1 Introduction

The humidity of the mid and upper troposphere has an important role in the tropical climate because of the non-linear relationship between the vertical distribution of the water vapor and the radiation budget (Spencer and Braswell, 1997). Therefore, to have a good representation of the atmospheric system, General Circulation Models (GCMs) should reproduce the correct moisture of the upper levels.

In the frame of the subproject 34 (Roca and Picon, 1999), the Meteosat water vapor data are used to evaluate the distribution of upper level moisture and of convection as well as their links. The proposed evaluation was first based on a model-to-satellite approach which consists in a direct comparison of Meteosat-5 radiances simulated from GCMs and the observed radiances (Roca *et al.*, 1997). Because no cloud profile was available at the beginning of this work, the present work focuses on the clear sky areas. For this purpose, the observed and simulated clear sky water vapor brightness temperatures (BTs) are inverted in terms of a mean relative humidity of a tropospheric layer and compared.

2 The retrieval of the mean relative humidity

The Meteosat Water Vapor (WV) channel is centered on 6.3µm and, in clear sky, is sensitive to the humidity and temperature of a large layer of the troposphere. In previous works (Soden and Bretherton, 1993; Schmetz *et al.*, 1995) the clear sky WV BTs are inverted in terms of Upper Tropospheric Humidity (UTH). These methods developed for different WV radiometers (Meteosat-6.3µm, GOES-6.7µm ...) define the UTH on different layers of the troposphere. The parameters for the retrieval are also computed in different ways.

Roca *et al.* (2002) define the Free Tropospheric Humidity (FTH) which is derived from Meteosat-6.3µm clear sky BTs from:

$$ln\left(\frac{p_0 FTH}{cos\theta}\right) = aBT_{6.3\mu.} + b$$

where p_0 describes the thermal structure of the column and θ is the satellite viewing angle. a and b are obtained for each pixel from a look-up table computed with a radiative transfer code (Morcrette and Fouquart, 1985; Roca, 2000) for two profiles of constant relative humidity (5% and 50%). Because there is an important contribution of the whole 800-100hPa layer to the observed WV radiance, the FTH is defined as the mean relative humidity of the free troposphere weighted by the corresponding weighting function. This algorithm was validated with radiosondes of the INDOEX experiment and revealed a small bias of 2.7% and a standard deviation of 6% (Roca *et al*, 2001). A sensitivity study showed that low clouds, with a cloud top pressure greater than 700hPa, have a small impact on WV BTs (Roca *et al*, 2002). The ISCCP DX product (Rossow and Garder, 1993) is used to select the clear and low clouds areas. Then, the

FTH algorithm is applied on the selected BTs over the Africa and Tropical Atlantic region. The spatial resolution of the FTH is a regular mesh of 0.625. This product is built using the Meteosat database of LMD containing a homogeneous set of Meteosat-5 radiances (07/1983-02/1994, every 3 hours) (Picon *et al.*, 2002). Monthly means of FTH are produced over 1984-1993 in order to allow AMIP comparisons. On Figure 1 are represented the mean BT (left) and the mean FTH (right) for July 1992. We see two particularly dry areas: one in the North East of Africa and one covering a large region in the South Hemisphere (SH). Those two regions correspond to warm BTs and are linked to large subsiding areas.

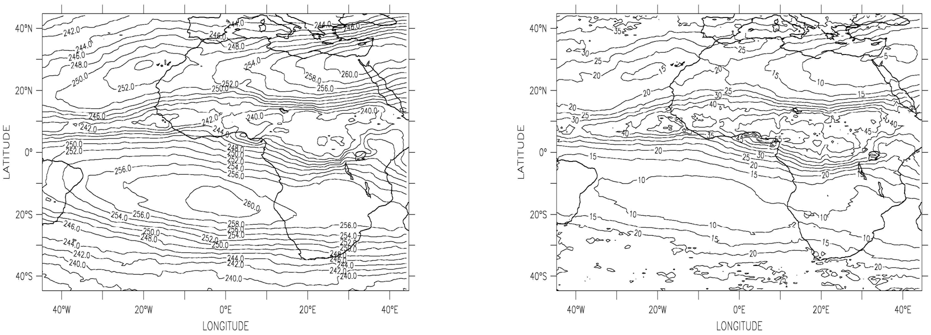

Figure 1: MET5 BT (left) and FTH (right) for July 1992. Intervals are 2K and 5%.

Note that an uncertainty is introduced by the calibration of the Meteosat-5 WV channel. Bréon and Jackson (2000) have estimated an absolute bias of -1.5K with a calibration study between Meteosat-5 radiances and NOAA/HIRS radiances. The impact of this bias is small in dry regions (bias of 1.5% for a FTH equal to 10%).

3 The FTH used for the intercomparison

The radiative transfer code mentioned above is used to compute the simulated WV BTs from humidity and temperature profiles for each GCM. A local look-up table containing the parameters of the retrieval (a, b and p_0 in eq(1)) is also calculated in the same way than for the observations. Then, the error due to the retrieval method is not considered in the comparisons.

The FTH is then retrieved for each of the 16 evaluated GCMs (available profiles of q and T). Because there was no available information about the simulated clouds, only dry regions without high or medium cloud can be compared. These regions are determined with a threshold of 25% in FTH. Figure 2 shows the mean seasonal cycle of this dry FTH in the SH and the simulated mean seasonal cycles. The mean GCM is in good agreement with the observed mean seasonal cycle and get the maximum of dryness of July. However, there is a large spread (9% in July) between all seasonal cycles simulated by the models.

4 The JJA distribution of dry FTH (≤ 25%)

Figure 3 shows the driest regions of the observed FTH for JJA (FTH ≤ 25%) (left) and two illustrations of extreme simulations (centre and right). In the observed JJA, there is one large dry area in the South and two areas of low FTH in the North with an extreme dryness in the East of the Mediterranean Sea.

First, some GCMs have a good location of the dry structures in both hemispheres (Fig. 3 centre). However, a few GCMs do not simulate the spread of the dryness in the SH (Fig. 3 right).

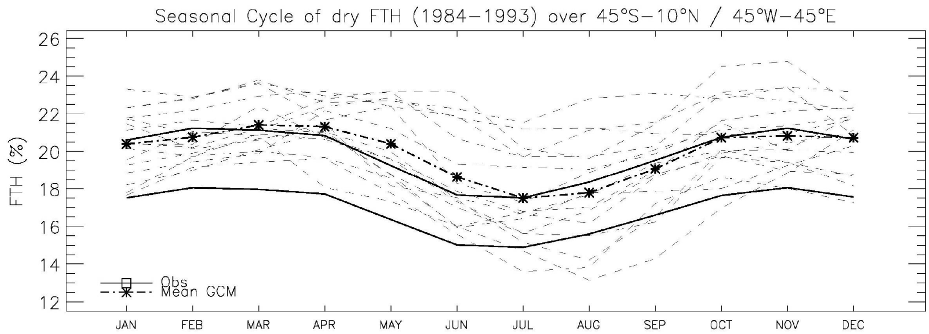

Figure 2: Mean seasonal cycles of FTH (≤ 25%). Average over 45°S-10°N/45°W-45°E. Full lines are for the observed dry FTH with the uncertainty. Dotted line with stars is for the FTH of the mean GCM. Dashed line is for each evaluated GCM.

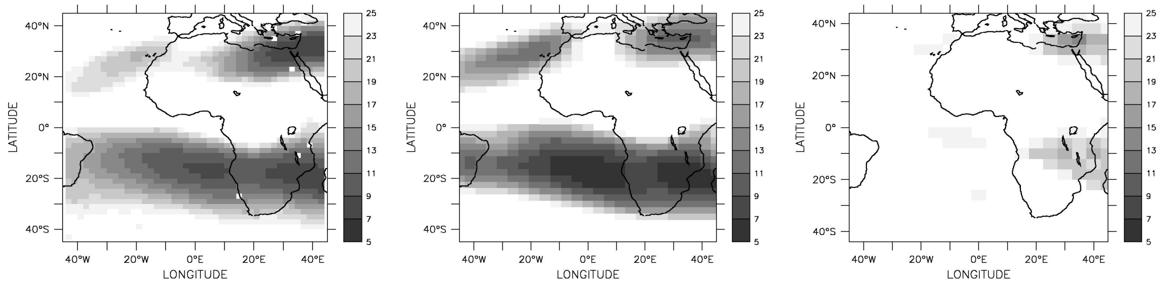

Figure 3: Dry FTH (≤ 25%) for JJA. Observation (left) and 2 GCMs (centre and right).

To avoid the problem of location of the structures, we focused on each simulated dry area of the SH. For each GCM, we evaluated the mean and the standard deviation over their dry region (Fig. 4). The driest grid point of the SH is also computed to test the minimum of FTH reached by the models in the area. The studies of the observed and simulated means are similar (around 18%, left) when considering the mean GCM and the uncertainty of calibration. However, on Figure 4 (right) is indicated that the mean GCM has a standard deviation small compared to the observation over this dry region and shows that some GCMs have a too weak variability. The GCMs are further classified according to the minimum of FTH encountered over their dry area.

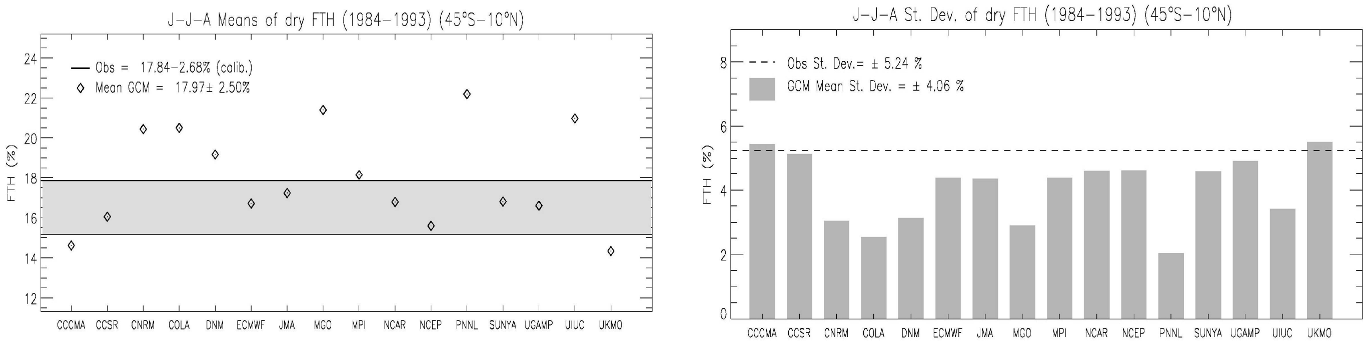

Figure 4: Mean (left) with the uncertainty of calibration (grey area) and standard deviation (right) over the dry SH for JJA.

Table 1 shows that six GCMs do not reproduce the observed extreme dryness. They are too moist by more than 5% and these models have a small spatial variability. Three models are more than 2% too dry but their spatial variation over the region agrees with the observed variation. Finally, seven GCMs reach the correct extremum of the SH and have a good spatial variability compared to the observed one.

Too moist (≥ 5%)	*Too dry (≥ 2%)*	*In agreement*
CNRM, COLA, DNP, MGO, PNNL, UIUC	CCCMA, CCSR, UKMO	ECMWF, JMA, MPI, NCAR, NCEP, SUNYA, UGAMP

Table 1: Classification of the 16 GCMs according to their minimum of FTH over the Southern Hemisphere.

5 Summary and Future work

The simulated dry regions for each GCM are considered in this study. The results show that the mean GCM describes well the observed mean seasonal cycle over the SH. In this preliminary study, 7 models out of 16 models agree with the observed FTH both in their representation of the minimum and in their spatial variability during JJA. The other models reproduce well the mean over the region but their simulated minimum of FTH is either too dry by more than 2% or too moist by more than 5%. These latter models exhibit too weak a variation over the studied region. A similar analysis over the northern Hemisphere nevertheless indicates that some models can be too moist in the N.H. whereas they are too dry in the SH. Next step of this work is the extension of this analysis to the interannual variability over the 1984-1993 period. The availability of cloud profiles from some models could allow to broaden our comparisons to the convective areas and to further evaluate the relationships between the variability of the dry regions and the convective ones.

References

Bréon F-M and D. Jackson, 2000: Calibration of the METEOSAT water vapor channel using collocated NOAA/HIRS 12 measurements. *J. of Geoph. Res.*, **105**, 11,925-11,933.

Morcrette J-J and Y. Fouquart, 1985: On systematic errors in parametrized calculations of longwave radiation transfer. *Quat. J. of Roy. Met. Soc.*, **111**, 691-709.

Picon L. R. Roca, S. Serrar, J-L Monge and M. Desbois, 2002: A new Meteosat "Water Vapor" archive for climate studies. *Accepted in J. of Geoph. Res.*

Roca R., L. Picon, M. Desbois, H. Le Treut and J-J Morcrette, 1997: Direct comparison between Meteosat water vapor channel and GCM results. *Geophy. Res. Let.*, **24**, 147-150.

Roca R. and L. Picon, 1999: Evaluation of convection and upper level moisture and their links using Meteosat water vapor channel data. *AMIP II Diagnostic Subproject 34*.

Roca R., 2000: Validation of GCMs cloudiness using Meteosat observations. ECMWF/EuroTRMM Workshop on the Assimilation of precipitation and cloud radiances in NWP. Reading, UK, 6-9 November, pp 185-205.

Roca R. H. Brogniez, L. Picon and M. Desbois, 2001: High resolution observations of free tropospheric humidity from Meteosat over the Indian Ocean. MEGHA-TROPIQUES 2nd Scientific Workshop. Paris, France, 2-6 July.

Roca R., H. Brogniez, L. Picon and M. Desbois, 2002: Free Tropospheric Humidity observations from Meteosat water vapor data. Proceeding for the AMS conference, San Diego, USA, Feb 2003.

Rossow W. and L. Garder, 1993: Validation of ISCCP cloud detections. *J. Climate*, **6**, 2370-2393.

Schmetz J. and co-authors, 1995: Satellite observation of upper tropospheric relative humidity, clouds and wind field divergence. *Beitr. Phys. Atmosp.*, **68**, 345-357.

Soden B. and F. Bretherton, 1993: Upper Tropospheric Humidity from the GOES-6.7 µm channel: Method and Climatology for July 1987. *J. of Geoph. Res.*, **98**, 16,669-16,688.

Spencer R. and W. Braswell, 1997: How dry is the tropical free troposphere? Implications for global warming theory. *Bull. of Am. Met. Soc.*, **78**, 1097-1106.