A preliminary study of the clear-sky greenhouse effect and its links with water vapor over land in the tropics

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GENERAL CONTEXT: Water vapor greenhouse effect is a key parameter in understanding the radiative equilibrium of the Earth's climate (2). So far, most of the studies concerning this issue have been made over the ocean (blackbody emission approximation, little changes in surface temperature). A non-linear relation between the greenhouse parameter (Ga) and the the Free Troposphere Humidity (FTH) has been established (4) and estimates of the water vapor feedback parameter have been calculate over large areas of the globe (1).

OUR WORK: We want to extend to the tropical land the studies that have been made on Ga and its relations with the FTH and the Surface Temperature (Ts). We use the Column Radiative Model (CRM) and the McClatchey tropical profile (3) for a theoretical study and the Clouds and the Earth's Radiant Energy System (CERES) and the Humidity Sounder for Brasil (HSB) for a data analysis.

Space-time coincidence between radiosondes+CRM OLR and CERES OLR mesurements over land

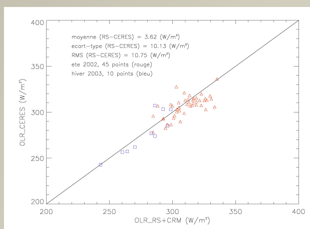


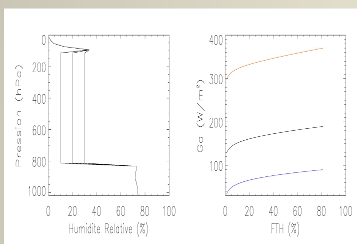
Fig.1

Data: june, july and september 2002 + january 2003, 30°S-30°N.
Space coincidence: 1° lat*1°lon.
Time coincidence: between 1 h before and 1 h after the radiosonde launching.

As we would like to study the clear-sky greenhouse effect over the tropical land, we compare the Outgoing Longwave Radiation (OLR) results given by CRM+radiosondes to the OLR of reference given by the CERES measurements. The plot shows that the model is in good agreement with the satellite data. We consider reliable the CRM longwave fluxes over the tropical land. We can proceed to a first theoretical study of the relations between Ga, FTH and Ts with the McClatchey tropical profile and CRM.

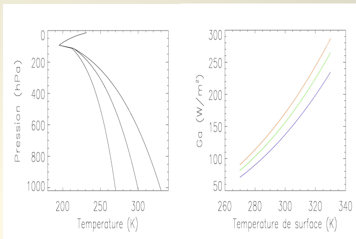
Relations between Ga, FTH and Ts for the McClatchey tropical profile with CRM

Greenhouse effect parameter: $Ga = \varepsilon \cdot \sigma \cdot Ts^4 + (1-\varepsilon) \cdot LW^{\downarrow}_{surf} - OLR$ (1)



We create Relative Humidity (RH) profiles with homogeneous FTH (left) going from 1% to 81% keeping the initial temperature profile. We obtain the right-hand figure that shows a strong dependence of Ga to Ts (for three different Ts) and a non-linear dependence of Ga to FTH. Here $\varepsilon = 1$.

Fig.2 Ts=330 K (red), Ts=300 K and (black) and Ts=280 K (blue)



We create temperature profiles with constant lapse rate and with Ts going from 270 K to 330 K (left). We obtain the right-hand figure that shows a slightly non-linear dependence of Ga to Ts for three diffrerent homogeneous-FTH RH profiles. For these plots, the surface emissivity ε is equal to one as well.

Fig.3 FTH=80 % (red), FTH=40 % (green) and FTH=10 % (blue)

Scatterplots obtained from the CERES SSF products and the FTH retrieved from the Brightness Temperature (BT) of the 183±1 GHz HSB's water vapor chanel

Relation to get the FTH estimate from HSB's BT: $\log(FTH) = a \cdot BT + b$ (5)

In order to compute the FTH estimate with the relation above, all HSB's BT where converted to nadir measurements.

The a and b coefficients to retrieve FTH from HSB's BT where determined by a linear fit between the left and the right hand side of the relation estimated from 813 radiosondes (RTTOV radiative transfert model) over tropical lands. For the Ga calculation, longwave fluxes, surface emissivities and surface temperatures are given by CERES SSF products.

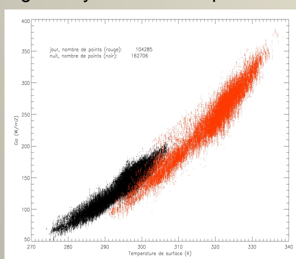


Fig.4 Ga vs Ts. We can observe two different regimes for Ga over land: the day regime (red) and the night regime (black).

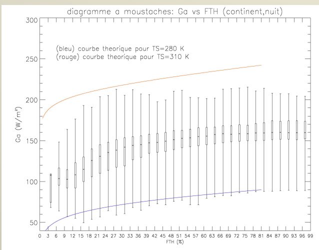


Fig.5 Ga vs FTH at night. We recognize, over the land, the same non-linear relation between Ga and FTH that exists over the ocean (5).

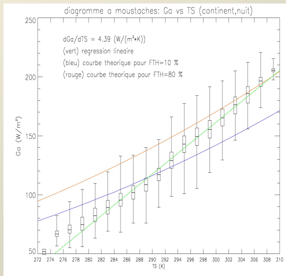


Fig.6 Ga vs Ts at night. We compute, with a linear fit, the water vapor feedback sensitivity parameter for all land surface:

$$\frac{dGa}{dTs} = 4{,}39 \text{ W/(m}^2\text{*K)}$$

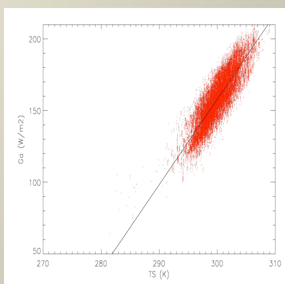


Fig.7 Ga vs Ts over deserts at night. The linear fit gives us the water vapor feedback sensitivity parameter for the deserts:

$$\frac{dGa}{dTs} = 5{,}96 \text{ W/(m}^2\text{*K)}$$

Conclusions/Perspectives:

- Over the tropical land, as over the ocean, there is a non-linear relation between Ga and FTH. The dependence of Ga to Ts is slightly non-linear. The water vapor feedback sensitivity parameter is higher for desert than for the other tropical surfaces.
- We will extend the study to the 9-month data of HSB's BT that exists waiting for the launch of Megha-Tropiques. This satellite will allow us to go further in our purpose with the radiation budget instrument (Scarab) and the humidity sounder (Saphir) it will have on board. We will also work on a way to get a better estimate of the FTH with the HSB's BT. We would like to use Meteosat Second Generation data to retrieve FTH for long-time periods over specific tropical zones. It would be interesting to compare our results to GCM's to see if they reproduce correctly the Ts and FTH influences on the greenhouse effect parameter.

Main references: Inamdar and Ramanathan 1998 JGR (1), Held and Soden 2000 Annu. Rev. Energy Environ. (2), McClatchey et al. 1971 Environ. Res. Paper n°354 (3), Roca et al. 2002 JGR (4), Soden and Bretherton 1993 JGR (5).