PHOTOMETRIC CHARACTERIZATION OF EARTH'S INTEGRATED INFRARED EMISSION

I.Gomez Leal[1], F. Selsis[1], E. Pallé[2]

[1]Université de Bordeaux, Laboratoire d'Astrophysique de Bordeaux, BP 89, F-33271 Floirac, France. gomezleal@obs.u-bordeaux1.fr
[2] Instituto Astrofisico de Canarias, c/Via Lactea s/n,E-38205, Tenerife, Spain.

Nowadays the search of Earth-like planets is scientifically possible. We are interested in the characterization of this type of planets by low resolution spectral observations. In this work a globally-integrated longwave infrared emission model of the Earth is presented. We used infrared emission maps (longitud, latitude, time) and a geometrical model to transformed them into a point-like signal received at a distance of 10 pc. We will compare the case using satellite observations from NASA's GEWEX program and the case using maps from a 3D General Circulation Model of the Earth developped by the Laboratoire de Météorologie Dynamique de Paris (in collaboration with Francis Codron).The analysis of the time series and the light curves performed by this model allows to determine the 24-hour rotatinal period of the planet, establish some atmospherical differences between seasons and identify the view of large continents and oceans.

1. THE MODEL

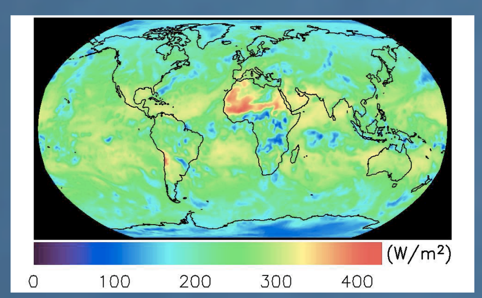


Figure 1. Thermql emission map of the Earth.

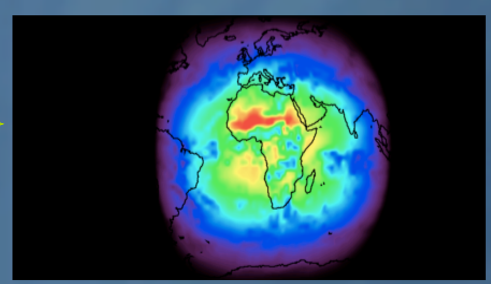


Figure 2. Planetary disk seen by an observer situated at (0,0) degrees longitud-latitude.

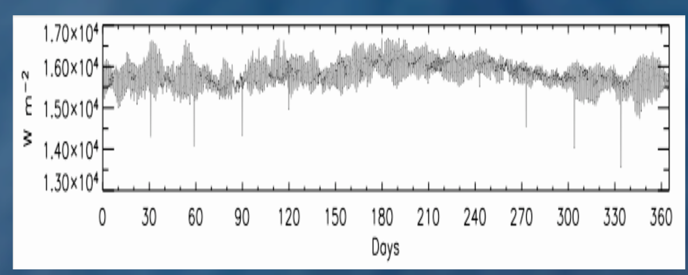


Figure 3. Point-like signal during the year of 2001 for an observer at (0,0) degrees longitud-latitude.

In order to model the point-like signal of the Earth, we have use satellite maps from the NASA's GEWEX program [1] which show the far infrared emission between 4 and 100 microns of the layer on the top of the atmosphere (Fig. 1), these images have a 1 square degree resolution (longitude,latitude) and a time resolution of 3 hours. For each map,the planetary disk view by the distant observer is determined (Fig. 2) and the flux received is integrated to have a point-like time signal(Fig. 3).

2. TIME SERIES ANALYSIS

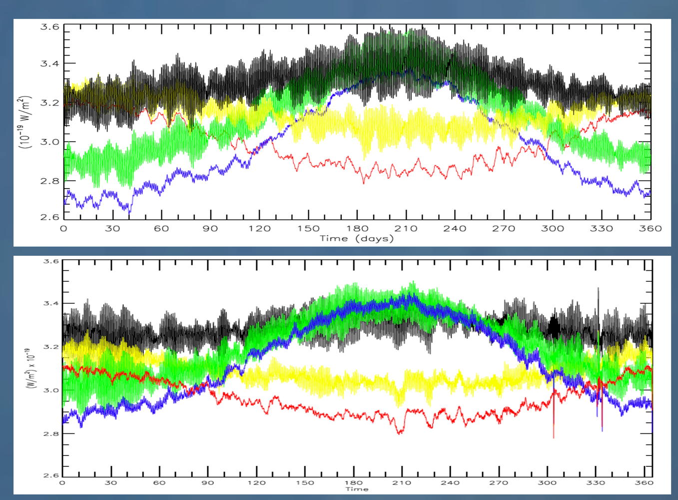


Figure 4. Thermal emission variation of the Earth during the year 2001 for GCM (top) and GEWEX (down) cases by declination of observer's view: 0° longitude and a latitude of 0°(black) equator, 45°(green), -45°(yellow), 90°(red) north pole et -90°(blue) south pole. Flux received at 10 pc.

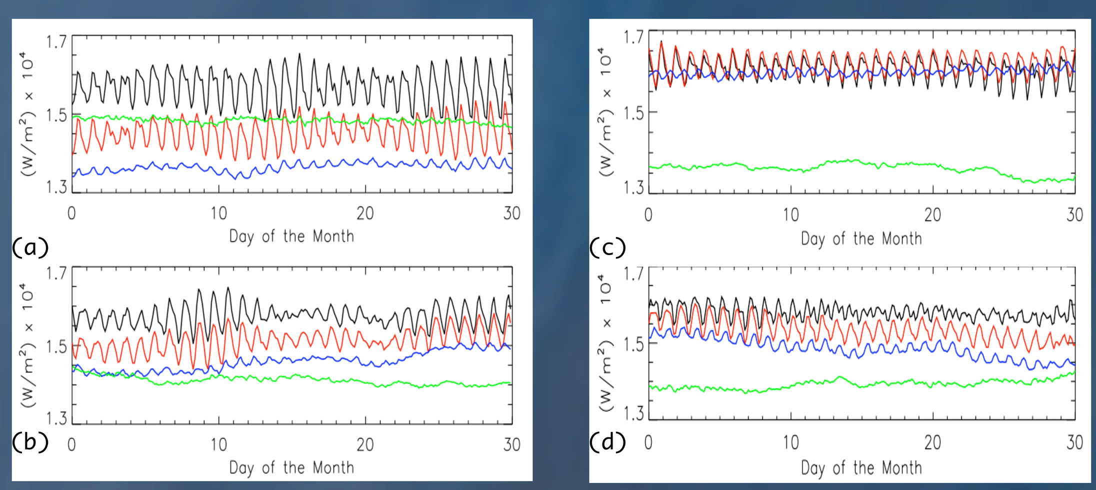
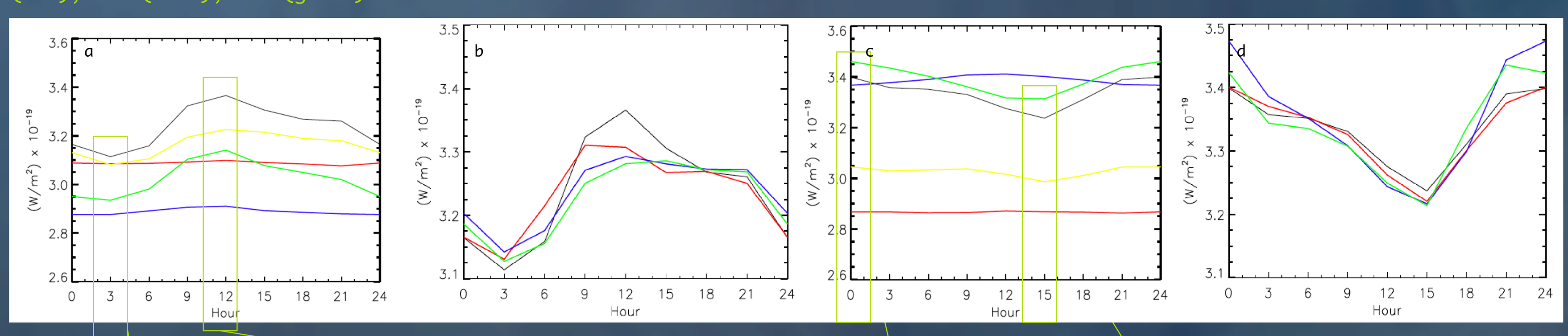


Figure 5. Infrared emission variation (GEWEX case), for January (a), April (b), July (c) and October (d) at 0° longitude and latitudes: 0°(black) equator, 45°(red), 90°(blue) north pole et -90°(green) south pole.

For each case, we have compared the annual variability of the infrared emission through 22 years, from 1983 to 2005 (Fig. 4). We haven't observed important differences between years (i.e. no correlation with the solar cycle). The global flux is dominated by the Northern Hemisphere emission: the flux maximum is produced at the en of July-beginning of August, during the North Hemisphere summer.Continents, and desserts in particular, emit more infrared radiation than the oceans.It is in this part of the globe where most of the continental masses and desserts are placed whereas the oceans dominate the southern hemisphere. In order to make a seasonal study, we have choose four representative months: january,april, july and october (Fig. 5). Varying the point of view of the distant observer, we can notice that the infrared emission shows a flux maximum in July from the equator to the north latitudes, which confirms this "northern behaviour" of the planet. There is a daily variability, that allows to determine the rotational period, although this variability is too little for polar observers. Moreover, as this variability is shown by the alternation of continental masses and oceans, it is affected by the presence of clouds that masks the surface signal during the months of atmospheric instability (April and October).

Figure 6. Typical day for January (a) and (b) and July (c) and (d). Differences in latitude (a), (c): 0°(black) equator, 45°(green), -45°(yelllow), 90°(blue) north pole and -90°(red) south pole. Differences in longitude (b), (d): 0°(black) equator, 90°(red), 180°(blue), -90°(green).



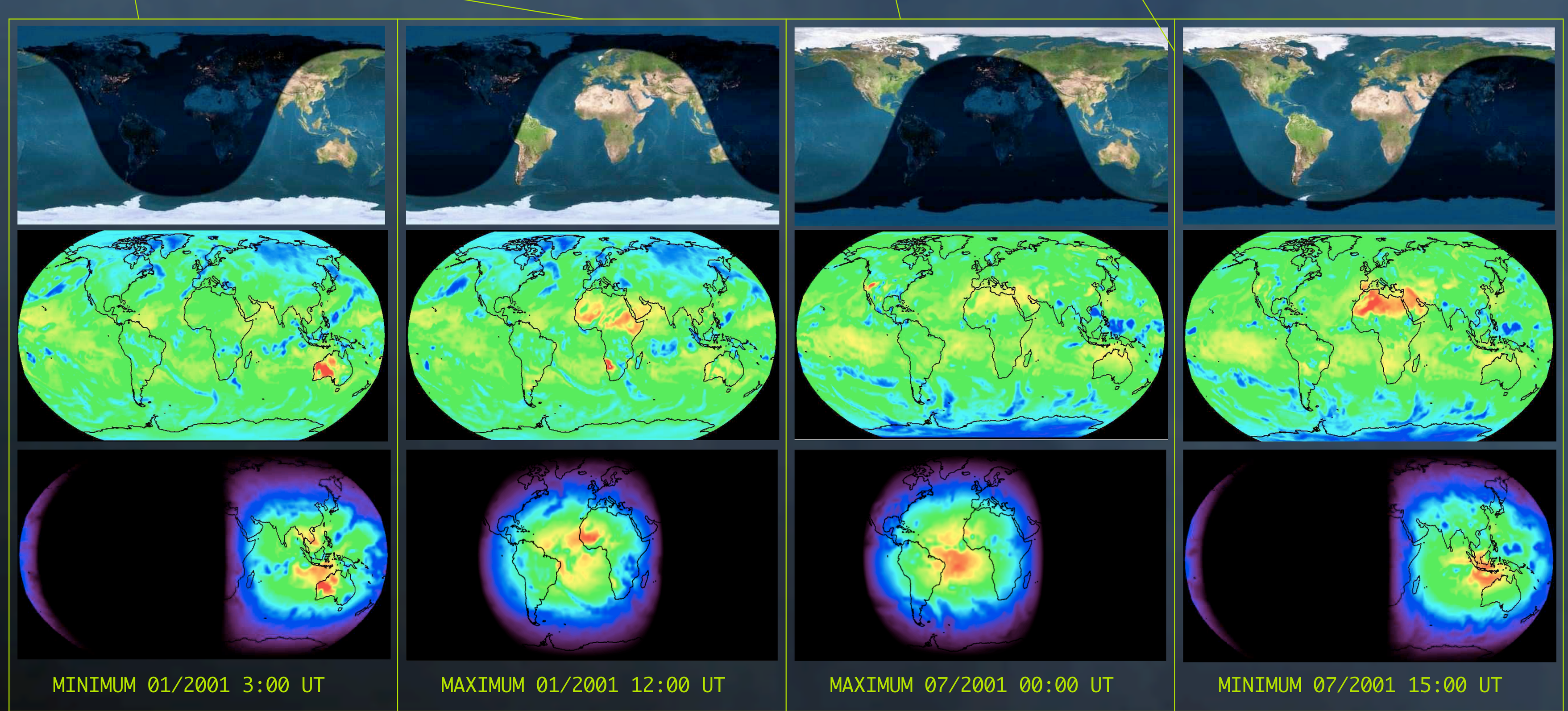


Figure 7. Flux maps for maxima (b),(c) and minima (a),(d) points for the months of January (left) and July (right) on 2001.: From top to the bottom: Visible flux day/night maps, thermal flux maps and planetary disk seen by the observer.

The atmospheric variations add stochastic variabitities to the signal. In order to study this systematic variations and having the rotational period of the planet we have built a typical day by determining the mean flux at each hour of a day along each month. The signal shows an emission maxima when the Sahara dessert is placed in the central part of the planetary disk view by the observer whereas the signal shows a minimum when Indonesia and the Pacific ocean are in the center of the disk. That could be useful to place large continental or oceanic masses.

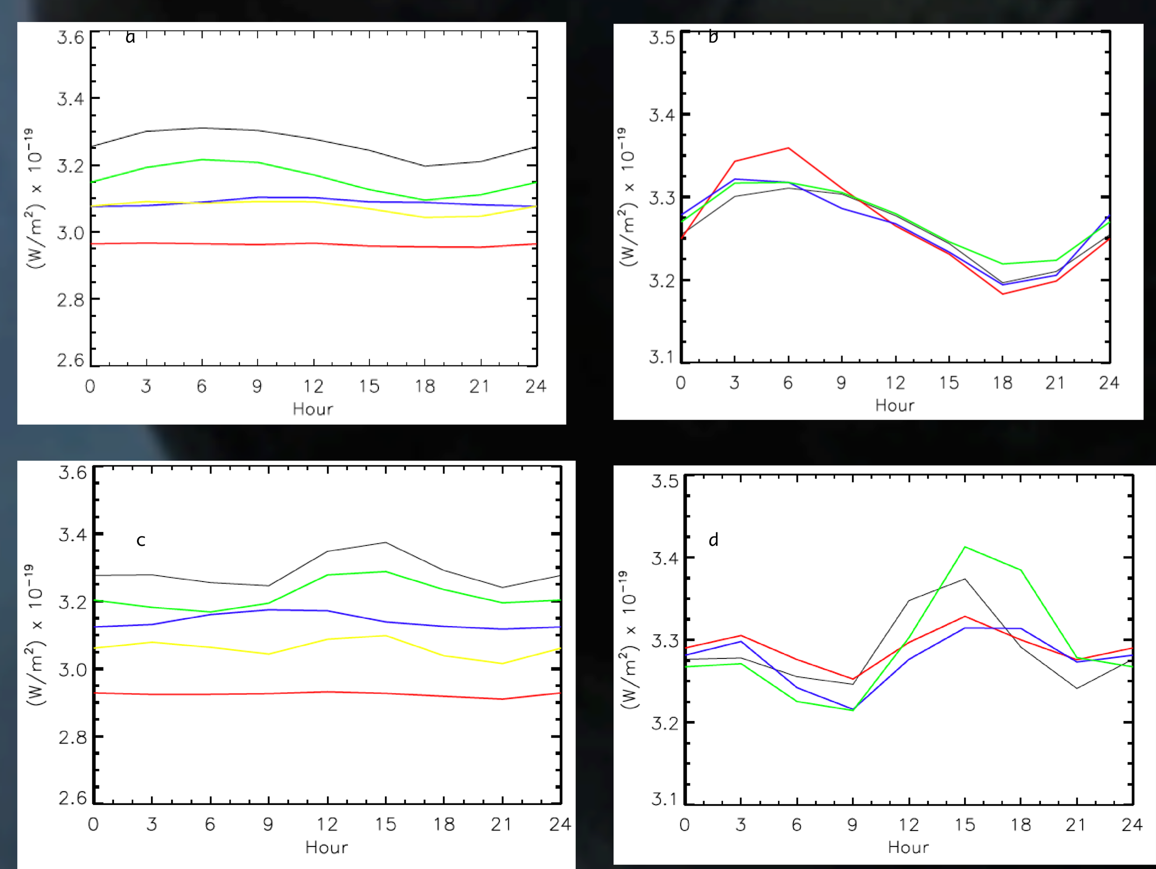


Figure 7. Typical day for April (a) and (b) and October (c) and (d). Differences in latitude (a), (c): 0°(black) equator, 45°(green), -45°(yelllow), 90°(blue) north pole and -90°(red) south pole. Differences in longitude (b), (d): 0°(black) equator, 90°(red), 180°(blue), -90°(green).

4. ROTATIONAL PERIOD

Looking for a rotational period, we have made the autocorrelation of the signal.The 24-hour period is clearly shown because the continental-ocean distribution has a great variation with longitude introducing a period in the signal. The Earth emission reaches its maximum at 10 microns and the atmosphere is relatively transparent between 8 and 12 microns, so this variability of the surface emission is detectable at the top of the atmosphere emission. The 24-hour period is by this way clearly detected by a distant observer at different latitudes from 0 to 45 degrees and for the stable season in the north polar case. In the south pole the continental distribution is more homogeneous so the rotation period cannot be determined.

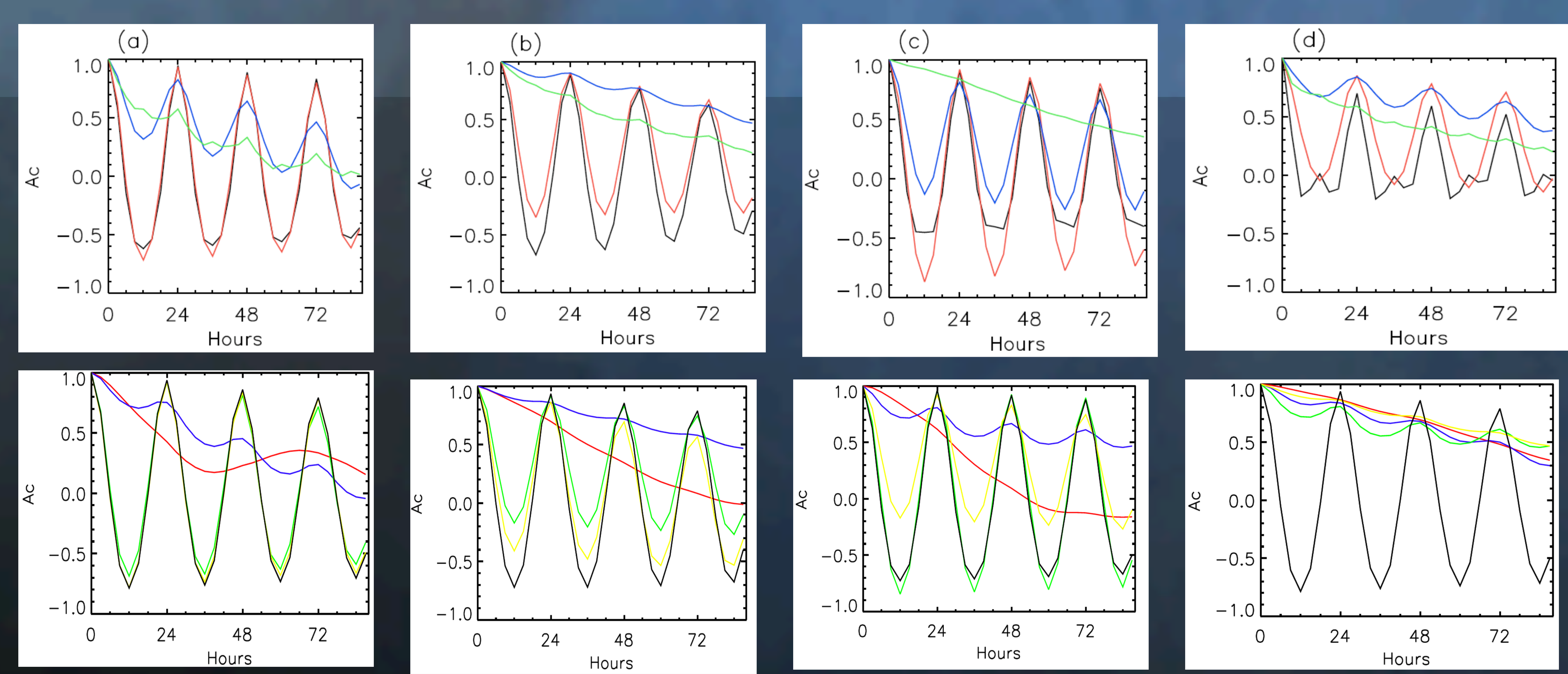


Figure 8. Autocorrelation for GEWEX times series (top) of Januery (a), April (b), July (c) and October (d) 2001, and viewing latitudes: 0°(black) equator, 45°(red), 90°(blue) et -90° (green). Autocorrelation of GCM time series(bottom), and viewing latitudes: 0°(black) equator, 45°(green), -45°(yelllow), 90°(blue) north pole and -90°(red) south pole.

5. CONCLUSIONS

From flux maps, the model creates a received by a distant observer. The analysis of the time series and the light curves allows to determine the 24-hour rotational period of the planet, establish some atmospherical differences between seasons and identify the view of large continents and oceans.

A further detailed analysis of the period of the atmospherical phenomena and a combined signal Moon-Earth is on progress.

6 . References

[1] http://gewex-srb.larc.nasa.gov/common/php/SRB_data_products.php

[2] Pallé, E., Ford, Eric B., Seager, S., Montañés-Rodríguez, P. & Vazquez, M., 2008, ApJ, vol 676, 2, 1319-1329.

[3] Moskovitz, N. A., Gaidos, E. & Williams, D. M., 2008, AsBio, vol 9, 3, 269-277.

[4] Selsis, F., 2004, ASP Conference Series, vol 321, 170-182.

[5] Wordsworth, R., Forget, F., Millour, E., Madeleine, J. -B., Eymet, V., & Haberle, R., 2010, 41st Lunar and Planetary Science Conference, LPI Contribution No. 1533, p.1913