Atmos. Chem. Phys. Discuss., 14, C13053–C13067, 2015
www.atmos-chem-phys-discuss.net/14/C13053/2015/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Signature of tropical fires in the diurnal cycle of tropospheric CO as seen from Metop-A/IASI" *by* T. Thonat et al.

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Received and published: 29 April 2015

First, we would like to thank the referee for his/her suggestions which have helped improving the content of the paper and the analysis of the results. The answers to his/her questions are given below.

- The influence of the thermal contrast on the sensitivity of our retrievals to CO, and, through that, its influence on the day-night difference of CO is indeed an important question. Quantifying this influence is a difficult task: our retrieval gives access to an integrated content of CO (not a profile), and without knowing the true profile of CO corresponding to the IASI overpass, we can just make a hypothesis on the mechanism explaining the diurnal signal of CO. Section 4.1 shows that the different vertical sensi-

tivity to CO between night and day has an influence on the retrieved diurnal signal of CO. The day-night difference of qCO4A, which only depends on the diurnal variation of the weighting function, displays almost the same seasonality as our diurnal signal of CO. However, we conclude that the impact of the vertical sensitivity is not decisive. In the revised version of the paper, we go further in the analysis of the link between the thermal contrast and our CO retrievals.

Figure A1 in the attached files shows: (i) the difference of the thermal contrast between day and night for July 2008 in southern Africa; (ii) the corresponding day-night CO. The thermal contrast over the ocean is indeed quite stable between day and night but mostly higher during daytime. On the continent the day-night difference of the thermal contrast is everywhere positive and exceeds 20 K on the West and South West of the area. The comparison between both maps of Fig. A1 reveals that diurnal signal of CO and thermal contrast have quite different spatial distributions. West and South-West of the area, the diurnal signal of CO is not at its highest; and it reaches its maximum values for an average day-night difference of the thermal contrast.

Figure A1. (top) Day-night difference of the thermal contrast in July 2008 (in K), in July 2008 in southern Africa. (bottom) Day-night difference of IASI CO (in ppbv).

This is confirmed by Fig. A2 which plots retrieved CO by day, by night and day-night, against thermal contrast, for the same area and during the fire season. A high/low thermal contrast doesn't necessarily leads to a high/low IASI CO retrieval, by day or by night. The same is true for the day-night difference of CO. Moreover, values of the diurnal signal of CO higher than 10 ppbv (red in Fig. A2c), which are the ones we are interested in since they are related to fires, correspond to a wide range of thermal contrast variations between day and night; and for these values the correlation between day-night CO and thermal contrast is weak (R $\sim$ 0.2).

Figure A2. (a) IASI CO (in ppbv) by day as a function of the thermal contrast (in K), between June and October 2008, in southern Africa, on land. (b) Same as (a), by night.

(c) Same as (a), for the day-night difference. Values of day-night CO higher than 10 ppbv are displayed as red crosses, whereas values lower than 10 ppb are plotted in blue.

- In section 4.1, we study the influence of the weighting function on the retrieved diurnal signal of CO via the day-night difference of qCO4A. Given that qCO4A is the product of the weighting function and the input profile in 4A, and that only one input profile is used, the day-night difference of qCO4A only depends on the variation of the weighting function. The first part of this response showed that there was no clear correlation between the thermal contrast and the diurnal signal of CO. This second part is a discussion on the meaning of the day-night difference of qCO4A.

Figure A3 in the attached files shows, for July 2008 in southern Africa, maps of the day-night difference of: (i) (total) CO, (ii) qCO4A, (iii) ΔqCO and (iv) thermal contrast. The day-night difference of qCO4A is very uniform in the area, where most values are comprised between 0 and 10 ppbv. ΔqCO, which may also be impacted by the thermal contrast, has a completely different spatial distribution from qCO4A. So, although the day-night difference of qCO4A is a component of the retrieved day-night difference of CO, it mostly plays the role of a bias and does not introduce any geographical pattern seen in day-night CO.

Figure A3. (top left) Day-night difference of IASI CO (in ppbv), in July 2008 in southern Africa. (top right) Day-night difference of qCO4A (see text in section 4.1) (in ppbv). Day-night difference of ΔqCO (in ppbv). (bottom right) Day-night difference of the thermal contrast (in K).

The input profile in 4A corresponds to average CO conditions. In order to see what would be the effect of the variation of the vertical sensitivity with a more polluted profile, we use a modified profile in 4A, the 'v1' CO profile plotted in Fig. A4, which is characterized by a string excess of CO near the surface.

Figure A4. Black: reference profile of CO used as input in 4A for the retrieval of IASI

CO (in ppbv). Red: a polluted profile in the boundary layer.

First, it is worth noting that the CO retrievals computed with the v1 CO profile as input in 4A are very close to the ones computed with the reference profile, by day, by night, and also for the day-night difference of CO. This shows that our retrieval method is lowly dependent on this input variable.

Figure A5 is similar to Fig. A3 but with all 4A computations made with the v1 CO profile. The day-night difference of qCO4A is still very uniform but a little higher than with the reference profile: the mean difference is 1 ppbv with a SD of 2 ppbv. Other modified profiles have been used, with different repartitions of CO along the first layers of the troposphere: despite the fact that the day-night difference of qCO4A could have higher values, its distribution is always quite uniform. The day-night total CO always displays the same geographical patterns, which gives confidence in this signal.

These results have been added to the revised version of the manuscript,

Figure A5. Same as Fig. A3, with the polluted profile 'v1' (see Fig. A4) used as input in 4A.

Figure A6 is similar to Fig. 10 in the paper, but it also shows the values of the day-night difference of qCO4A computed with the v1 CO profile (blue points). Due to the heavy computations requested to process the whole time series, we only plotted here 4 points in January and 4 points in July. As expected from above discussion, the day-night difference of qCO4A obtained with the v1 profile is higher than with the reference profile. However, it is still low compared to the diurnal signal of CO. More importantly, the amplitude of the signal has not changed. This suggests that the amplitude of 15 ppbv found for the diurnal signal of CO is not decisively influenced by the variations of the vertical sensitivity.

Figure A6. Evolution of the day-night difference of the integrated content qCO4A on land, and of fires, between July 2007 and June 2012 in southern Africa. Red: day-night difference of qCO4A. Blue dots: day-night difference of qCO4A computed with the v1 CO profile as input in 4A. Black dashed: MODIS BA. Purple dashed: GFED3.1 CO emissions. Cyan dashed: GFAS1.0 CO emissions.

Section 4.1 has been extended in the revised version to take these new elements of discussion into account.

Specific comments

1. Page 26009 and Figure 1. If I understand it correctly, you use model temperatures from ECMWF but retrieve the surface temperature. I would like to see show maps of thermal contrasts (for day and night) in parallel to the CO distributions in Figure 1. This would be helpful also for analysing the results.

-> The required maps are provided as Fig. A7 in the attached files. They will be provided as supplementary material. Their use in the analysis of the retrieved CO columns is not straightforward. Basically, it can be seen that the regions characterized by high values of CO, or high values of the diurnal CO signal do not display strong thermal contrast conditions. Usually, the thermal contrast is positive during the day and negative during the night. The effect of the thermal contrast on the day and night weighting functions is already seen in Fig. 9.

Figure A7. Ts-Tfirst_layer (in K), by day (left) and by night (right), from January, April, July and October 2008. Ts comes from IASI, Tfirst_layer comes from ECMWF reanalysis.

2. Section 3.2.1. and Figure 2 (also for the other Figures): Please specify how the averages have been performed, both for the total columns and for the difference: what is gridding? Do you consider per grid cell daily means from which you compute the difference (in each cell)? It is for these reasons unclear why the difference (Figure2d) contains so many gaps. That is important also for the discussion per region in section 3.2.3. Note that Figure 2 is too small and blurry. Lat/long (mentioned in the text) are

unreadable.

-> Gridding has been specified in section 3.1 and 3.2.1, and the way the difference is made has also been described a little more in section 3.2.2. The monthly mean of the day-night difference of CO is computed as follows: first the 0.75°x0.75° daily means of the clear-sky retrievals of CO made at 9:30 a.m. and 9:30 p.m. are calculated; then, for each grid cell, the difference between 9:30 a.m. and 9:30 p.m. is computed for each day and averaged over the whole month.

IASI orbits by day and night hardly, if not never, cross each other near the equator. In July for example, the number of day-night differences used to compute the monthly mean (at the scale of a 0.75°x0.75° pixel) ranges from 1 around 2°S to 15 around 20°S. During the wet season (i.e. form November to March), the number of points available to compute the monthly mean of day-night CO is also limited by the number of clear-sky observations available.

In Fig. 6 (Section 3.2.3), areas H1 and H2 are never totally covered; in addition, the monthly means in these areas are calculated from the few days where the day-night difference of CO is available. We have added to Fig. 2 maps of the number of days from which the monthly mean has been calculated. This will also help the discussion in Section 3.2.3.

3. In section 3.3 (page 26016, line 1) you mention a correlation coefficient of 0.6. Do I get it right that this is by excluding the two regions AfsE and AmC? If yes it should be made clearer in the abstract and in the conclusion (26020, line 13) that the 0.6 correlation coefficient is not considering the entire dataset (and it would in fact be good to give the value for the entire dataset as well).

-> Fig. 8 has been remade to fix a problem with the average computation. The conclusions are the same except it is for the entire dataset that we have R2∼0.6. We only mention R2 value for the entire dataset in the revised paper. As suggested by referee 1, we have also extended the comparison to the GFAS1.0 dataset: R2 reaches 0.7 for

GFAS1.0, highlighting a better agreement with IASI day-night CO.

4. Section 4.2. The fact that the CO2 and CO day-night differences exhibit opposite signs is surprising. The proposed mechanisms could indeed lead to this but even if the smoldering phase emits more CO than CO2, the flaming phase is still expected to release significant amounts of CO, which would follow the same uplift mechanism as that proposed for CO2. Why are these enhancements not better seen in the IASI CO data? Or would this mean (again supposing that the proposed diurnal cycle is real) that the CO excess from the mid-troposphere is underestimated (as a significant fraction of CO in the upper troposphere would have been subtracted)?

-> CO and CO2 are both emitted and uplifted during the day, during the flaming phase of the combustion, with the approximate following repartition of emissions: 90% of carbon emissions is CO2 and 10% is CO; but our hypothesis is that the CO that is uplifted after the night (i.e. after the smoldering phase has released large quantities of it, but almost no CO2) is more important.

Technical corrections

All technical suggestions have been taken into account in the text. We just have a few remarks on the followings.

6. Page 26009, line 16. What is meant with “A negative thermal contrast has symmetric effects”? Temperature inversions also increase sensitivity significantly.

-> The sentence has been changed: “A negative thermal contrast, on the contrary, decreases the sensitivity near the surface.” (See Fig. 2 and 3 in Thonat et al., 2012.)

7. Page 26010, line 5: Is it sound to use the term mid-tropospheric CO considering the possible impact of the sensitivity to the lowest layers? Furthermore, “tropospheric CO” is used in other occasions (e.g. in the abstract). I would suggest being homogeneous in the notations throughout, to define clearly these terms and verify that they are consistent with what is actually measured.

-> The sensitivity to CO in the mid-troposphere has been defined more precisely in Section 2.2. The reference to the mid-troposphere remains only to characterize the maximum of the sounder’s sensitivity to CO, its sensitivity to CO at night and the emissions of CO. Otherwise we now always use “tropospheric CO”.

9. Page 26013, line 5-6. “The daytime signal is observed just above the fire”. Are you referring here to the spatial location (in which case this is optimistic – see general comment 2) or to the better match is the maxima of the CO excess as compared to the emissions (From Figure 4)?

-> The diurnal signal of CO can indeed be important where fires are not indicated by the MODIS BA, but the main signal is always located in their vicinity (for example it is not located over the oceans). “The day-night is observed just above fires” has been replaced by “The day-night signal mostly captures CO over fires”.

10. Page 26013, line 10: Where is transport from the NH seen? Is it not too far South to be affected by NH transport?

-> In this period (November-April), sources are only located in the North and the high concentrations of CO in the studied area are only found near the equator.

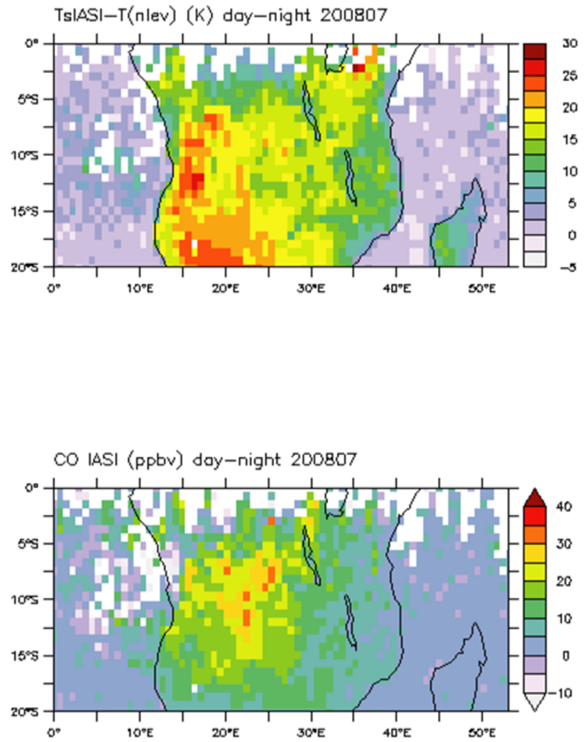

TsIASI–T(nlev) (K) day–night 200807
CO IASI (ppbv) day–night 200807
0°
5°S
10°S
15°S
20°S
0°
10°E
20°E
30°E
40°E
50°E

Fig. 1.

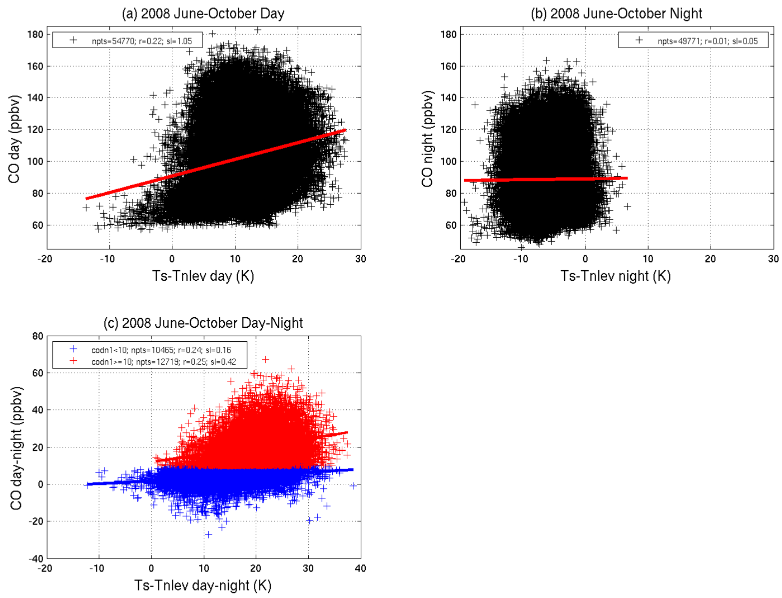

(a) 2008 June-October Day
npts=54770; r=0.22; sl=1.05
CO day (ppbv)
Ts-Tnlev day (K)
(b) 2008 June-October Night
npts=49771; r=0.01; sl=0.05
CO night (ppbv)
Ts-Tnlev night (K)
(c) 2008 June-October Day-Night
codn1<10; npts=10465; r=0.24; sl=0.16
codn1>=10; npts=12719; r=0.25; sl=0.42
CO day-night (ppbv)
Ts-Tnlev day-night (K)

Fig. 2.

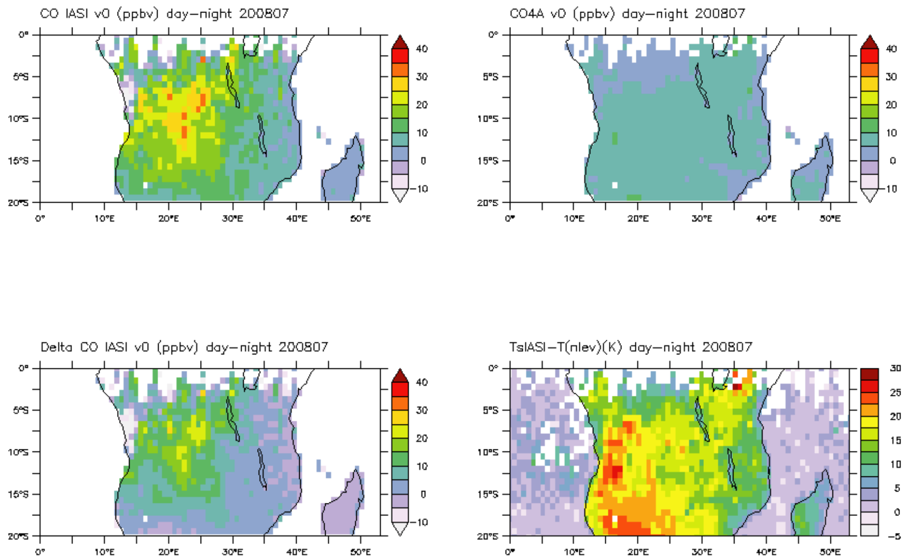

CO IASI v0 (ppbv) day−night 200807
CO4A v0 (ppbv) day−night 200807
Delta CO IASI v0 (ppbv) day−night 200807
TsIASI−T(nlev)(K) day−night 200807

Fig. 3.

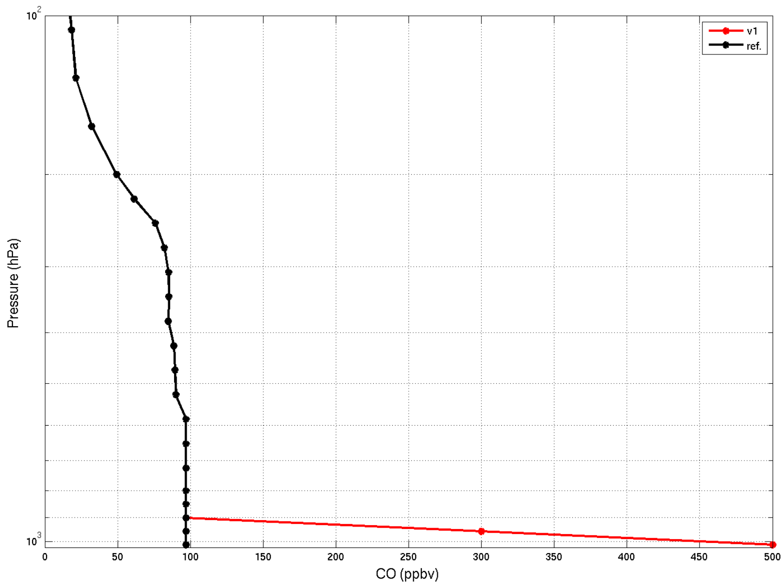
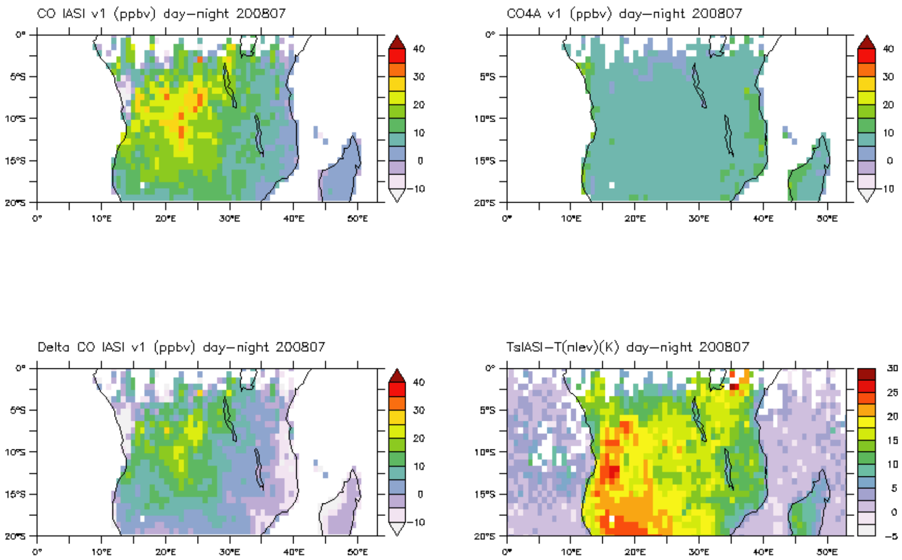
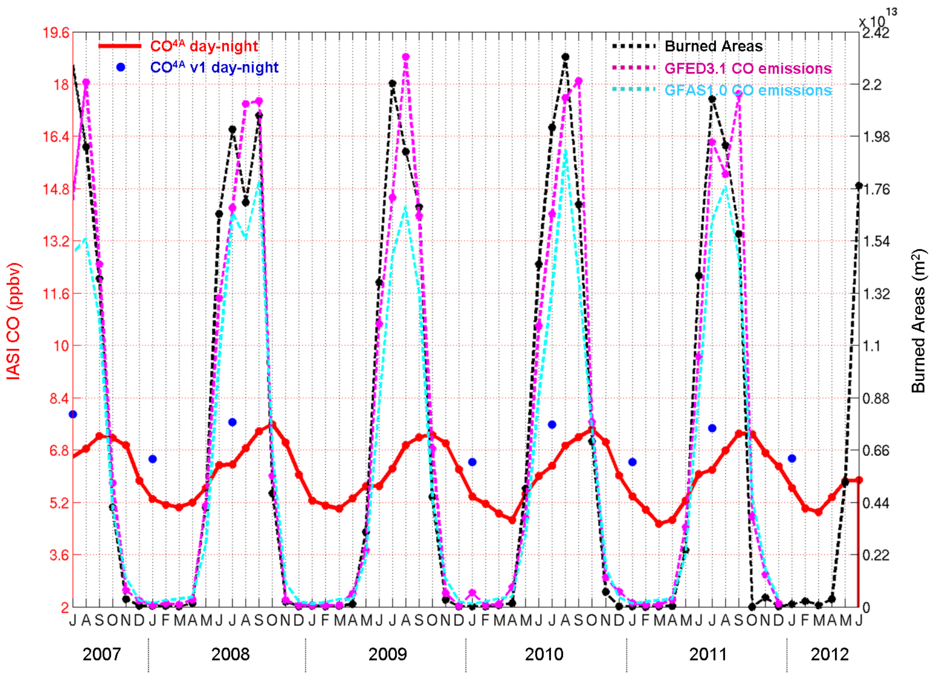

v1
ref.
Pressure (hPa)
CO (ppbv)

Fig. 4.



CO IASI v1 (ppbv) day−night 200807
CO4A v1 (ppbv) day−night 200807
Delta CO IASI v1 (ppbv) day−night 200807
TsIASI−T(nlev)(K) day−night 200807

Fig. 5.



CO4A day-night
CO4A v1 day-night
Burned Areas
GFED3.1 CO emissions
GFAS1.0 CO emissions
IASI CO (ppbv)
Burned Areas (m2)
x 10^13
2007
2008
2009
2010
2011
2012

Fig. 6.

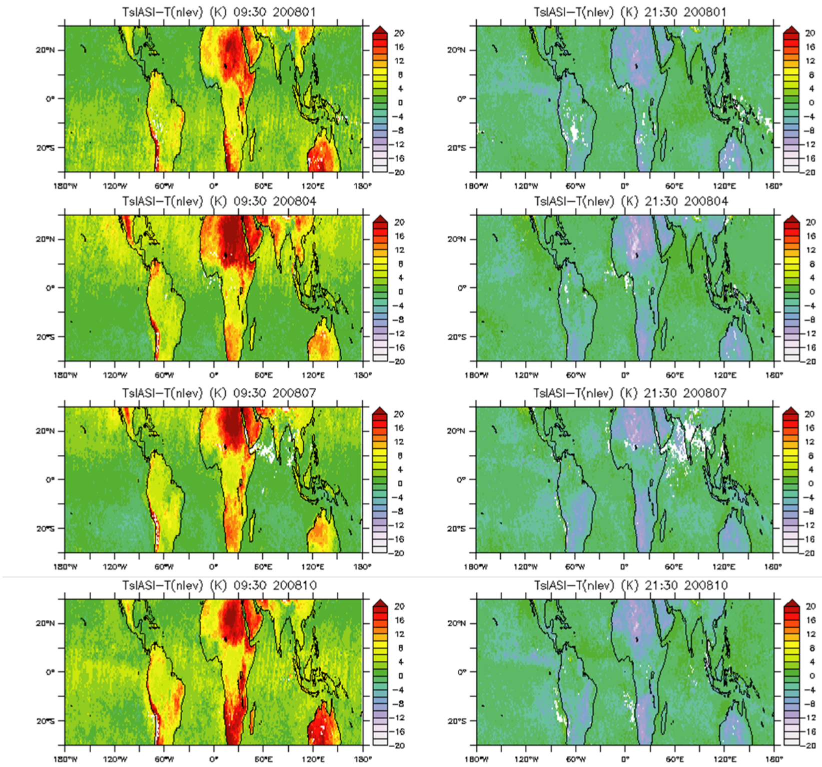

TsIASI−T(nlev) (K) 09:30 200801
TsIASI−T(nlev) (K) 21:30 200801
TsIASI−T(nlev) (K) 09:30 200804
TsIASI−T(nlev) (K) 21:30 200804
TsIASI−T(nlev) (K) 09:30 200807
TsIASI−T(nlev) (K) 21:30 200807
TsIASI−T(nlev) (K) 09:30 200810
TsIASI−T(nlev) (K) 21:30 200810

Fig. 7.