MTG-IRS L2 data assimilation into the ECMWF model

Progress report 30.10.2018

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Update since the last progress meeting

- Second season of passive monitoring finished, 1.6-31.8.2017.
- Passive monitoring experiment against ERA5, 1.1-31.3.2017.
- Plenty of technical developments
  - New code type implemented for L2 profiles to enable active use of data
  - New variables implemented for blacklisting
  - Thinning implemented for L2 profiles, thinning distance 125 km, same as for IASI radiances
  - First guess check implemented but limits to be adjusted after observation errors are properly diagnosed via Hollingsworth – Lonnberg and Desroziers methods.
- First single observation tests

Investigations on tropopause

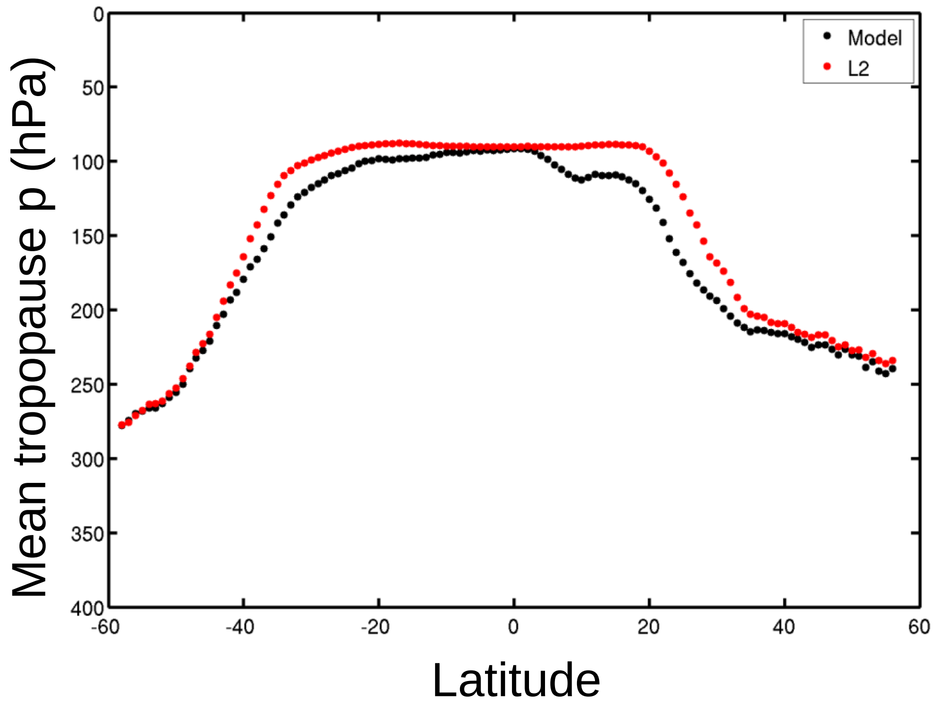
Geodisc	Mean temperature difference (L2 – model)	Standard deviation	Mean height difference	Standard deviation
NH, winter	-2.8 K	7.6 K	-24.2 hPa	44.8 hPa
TR	-1.4 K	5.7 K	-9.6 hPa	26.7 hPa
SH	-2.1 K	4.7 K	-16.4 hPa	30.5 hPa
NH, summer	-0.8 K	5.0 K	-10.3 hPa	31.3 hPa
TR	-2.3 K	6.7 K	-14.4 hPa	30.6 hPa
SH	-2.9 K	8.8 K	-23.2 hPa	51.1 hPa

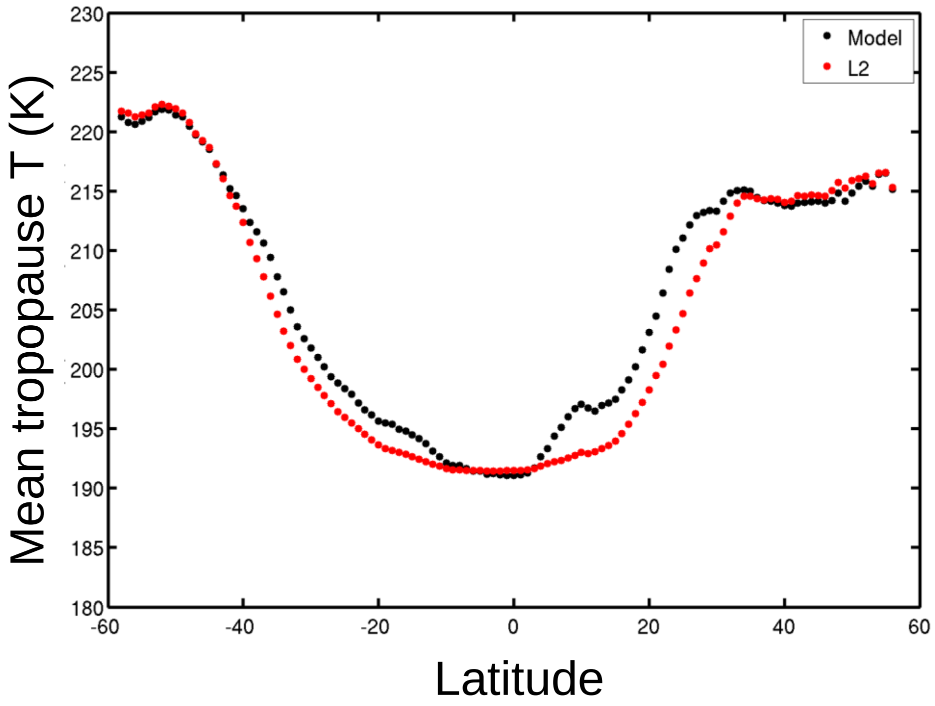
Meteosat geodisc
Data over sea
$OmC < 1$
$qi_T < 1.5$

Tropopause: the lowest level at which the lapse rate decreases to 2 K/km or less

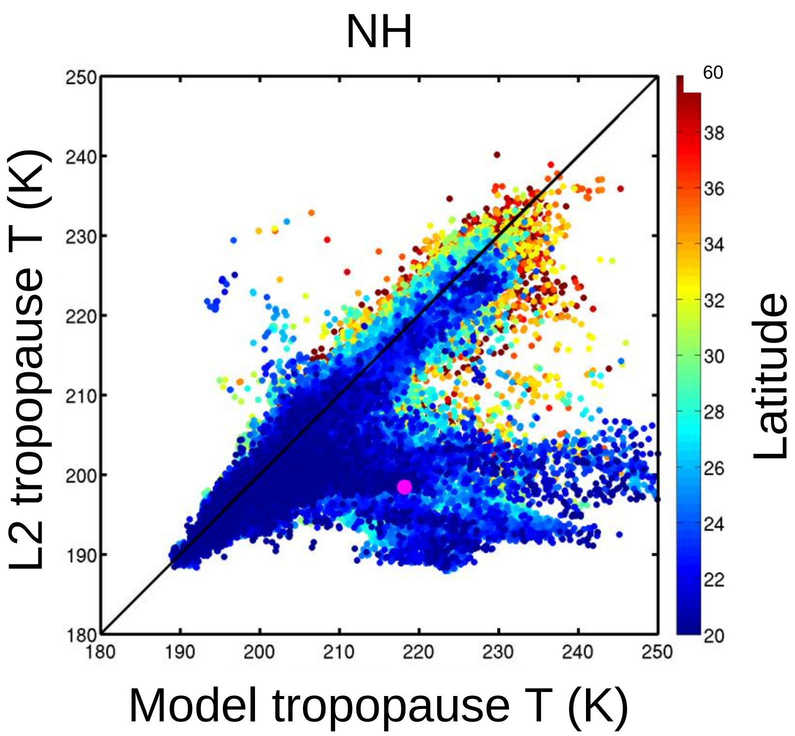
Mean tropopause height and temperature (January 2017)

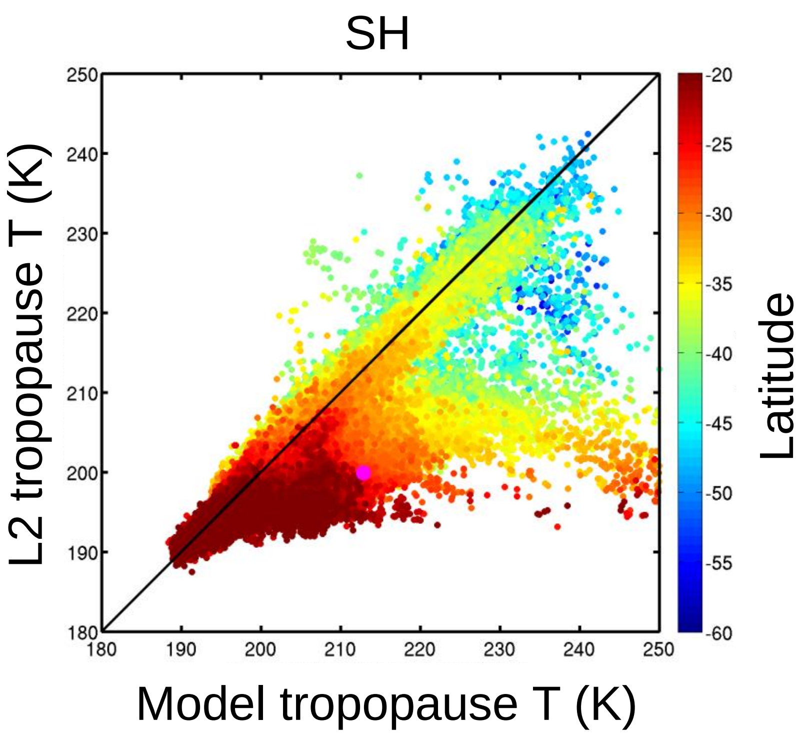
Model
L2





Tropopause temperature comparison (January 2017)

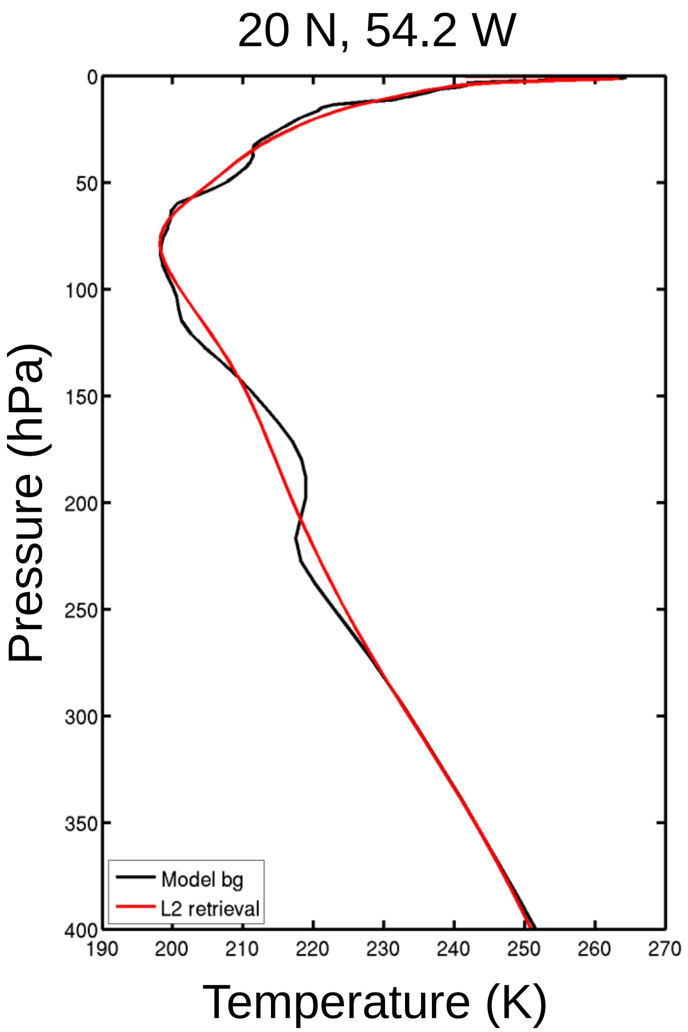


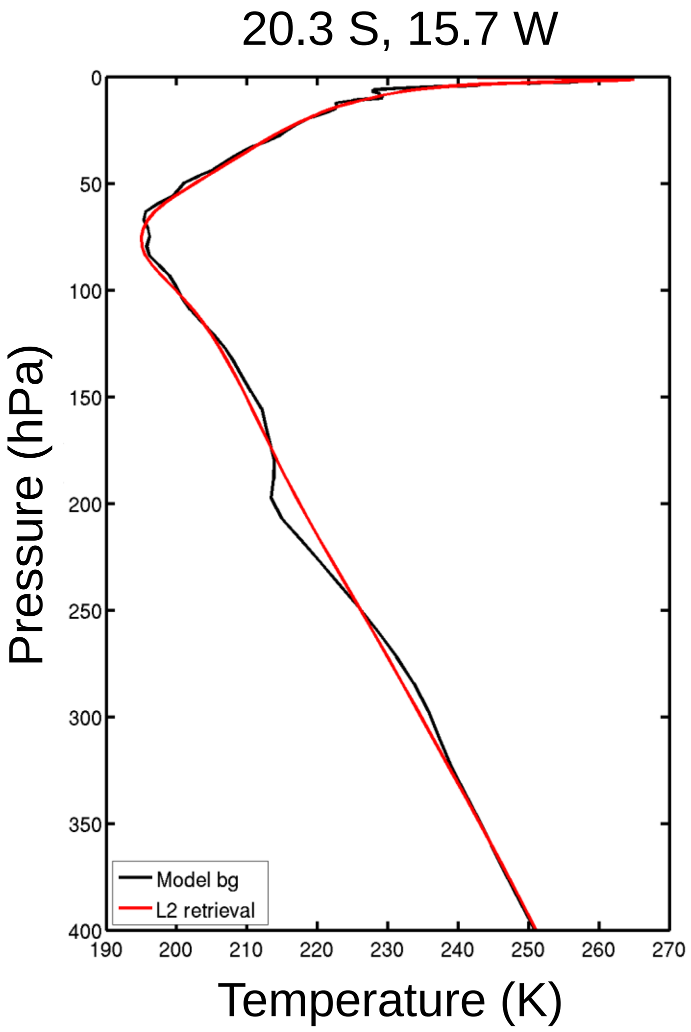


Example profile 1

Example profile 2

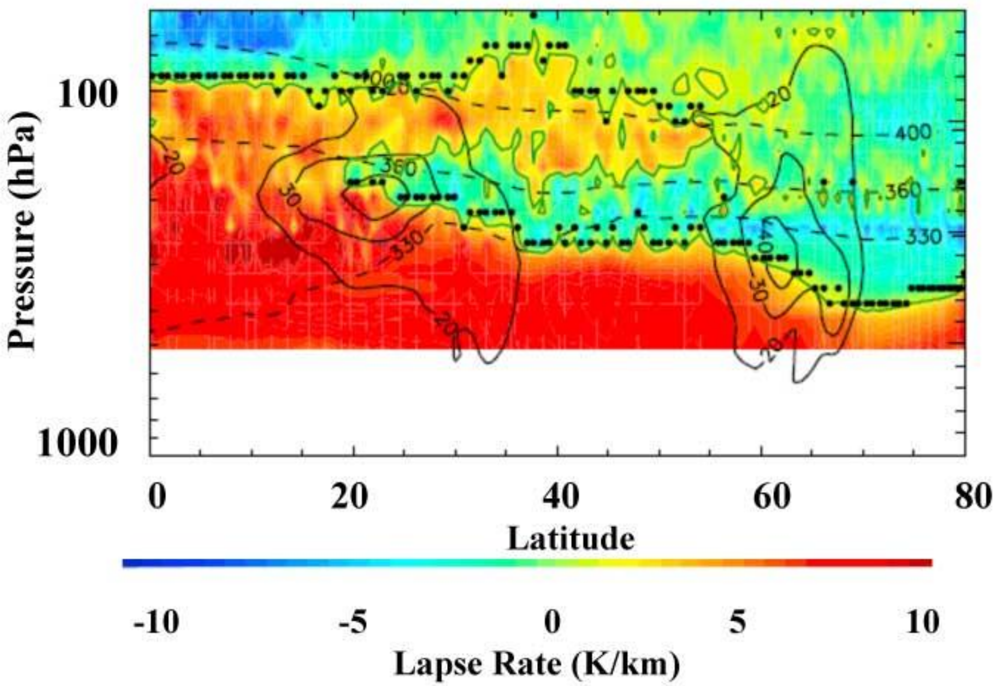
Example profiles, double tropopause



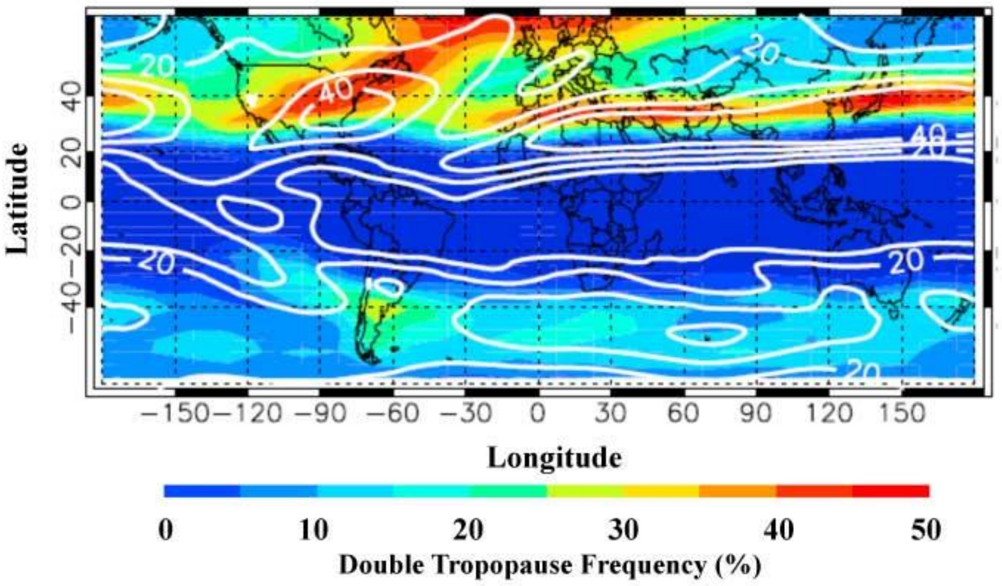


Double tropopause: in midlatitudes the higher tropical tropopause overlapping the lower polar tropopause

Double tropopause, investigations in literature



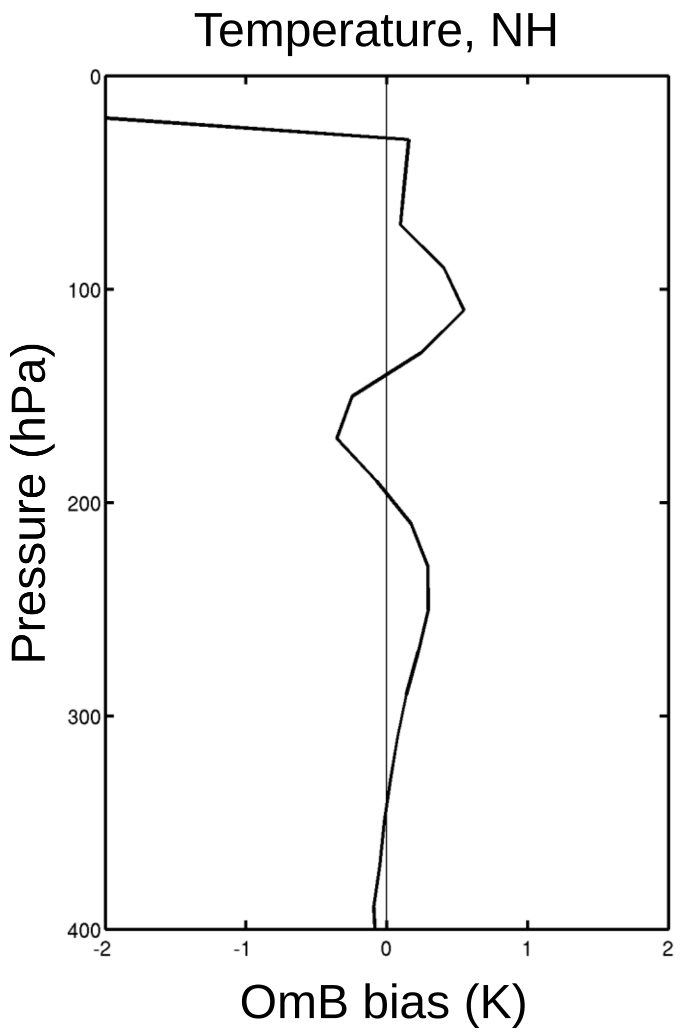
Along track cross section of the lapse rate calculated from HIRDLS temperatures at 08:00 UTC on 1/26/2006. Black filled circles indicate the tropopause identified using the WMO double tropopause criterion.

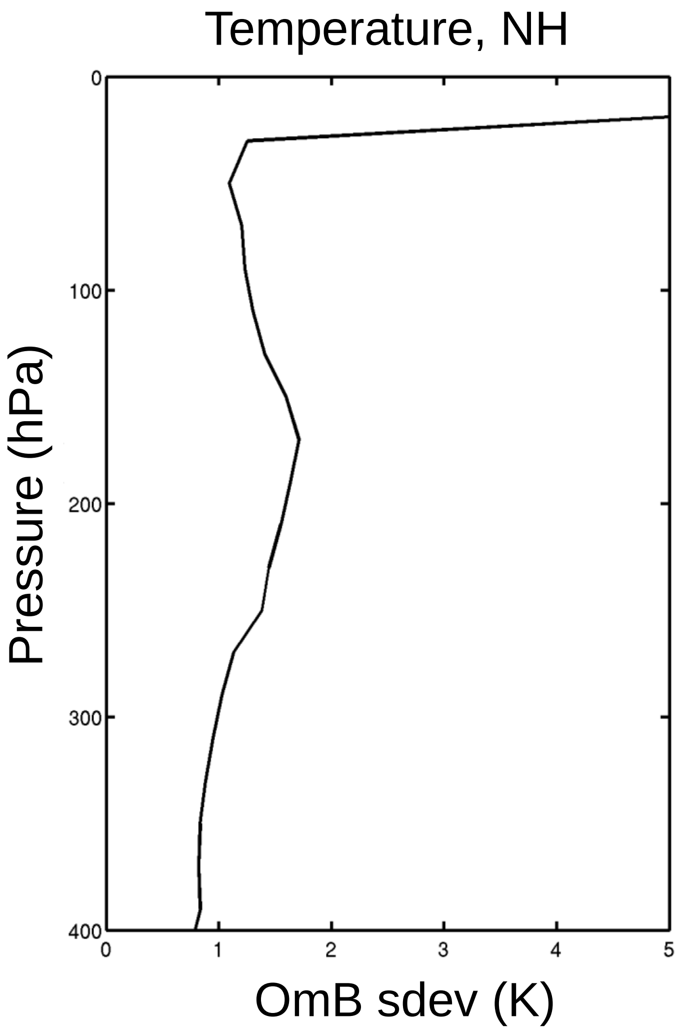


Double tropopause frequency of occurrence is obtained from HIRDLS Level 2 data 2005 - 2007 for December-January-February. The frequency is the percentage of profiles with a double tropopause. (White contours are the 200 hPa mean zonal wind.)

Reference: Peevey, T., et al., (2012), Investigation of double tropopause spatial and temporal global variability utilizing High Resolution Dynamics Limb Sounder temperature observations, J. of Geophys. Res.

OmB statistics 1.1-31.3.2017 (L2 – model bg)





Summary of the findings

- The model tropopause is on average warmer and at lower altitude than the L2 tropopause.
  - Model has more often the double tropopause structure in the midlatitudes
- The double tropopause can be seen in the OmB bias and as increased OmB sdev statistics
  - More pronounced on the winter hemisphere.
- Scatter plots of the tropopause temperatures indicate that in case of single tropopause, the L2 and model have quite good agreement.
- In the tropics the L2 tropopause height and temperature are not varying much, model has more spread.
- Properly designed first guess check and realistic observation errors are required for successful assimilation.

Investigations on low level inversions

- Low level inversions have been investigated
  - Over regions where strong and sharp inversions are known to occur very frequently
  - Over MTG geodisc area
- Periods: 1.1-31.3.2017, 1.6-31.8.2017
- |OmC| < 1, $qi_T < 1.5$

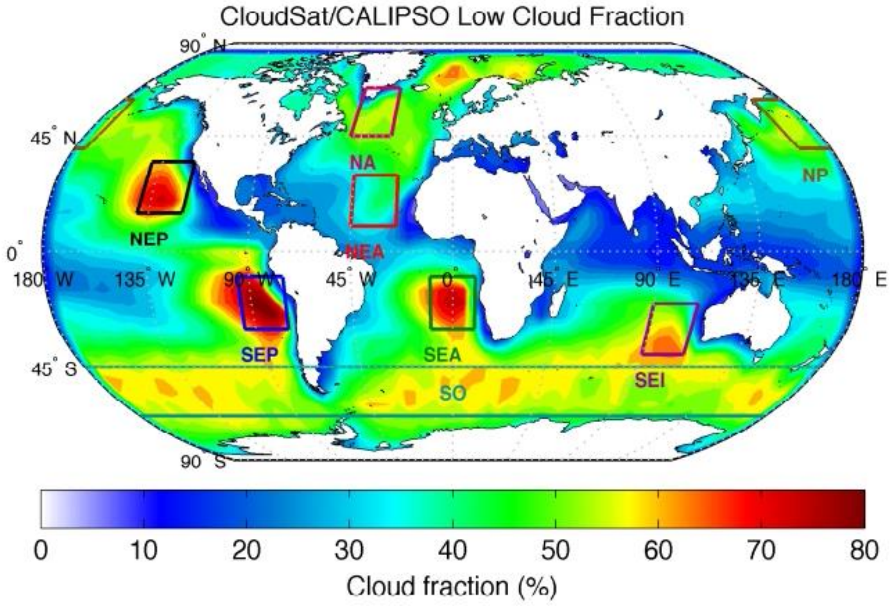
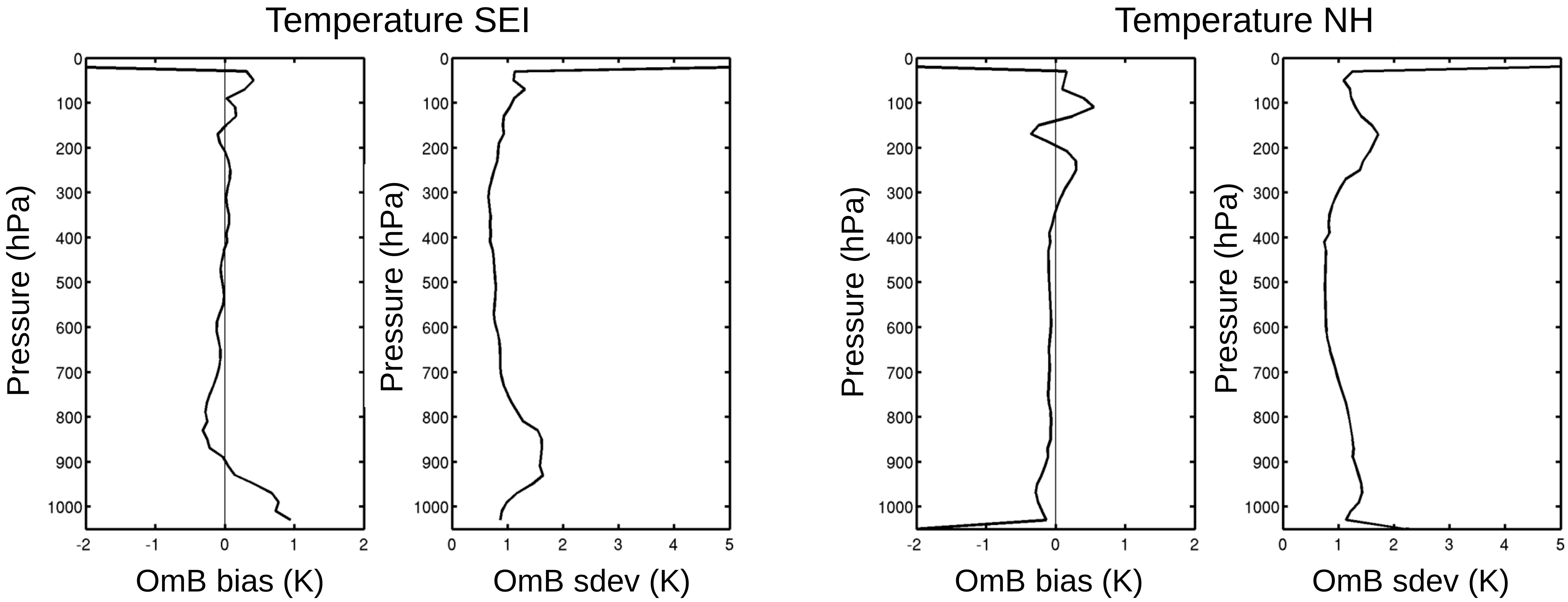


Figure 2. Global distribution of annually averaged low-cloud fraction from 5 years of CloudSat/CALIPSO data from 2006 to 2011. The colored rectangular boxes mark typical regions with persistent low-cloud amounts. The regions are Northeast Pacific (NEP), Southeast Pacific (SEP), Northeast Atlantic (NEA), Southeast Atlantic (SEA), Southeast Indian Ocean (SEI), North Atlantic (NA), North Pacific (NP) and Southern Ocean (SO). The locations of the displayed regions are adopted from Klein and Hartmann (1993) and are specified in Table 1.

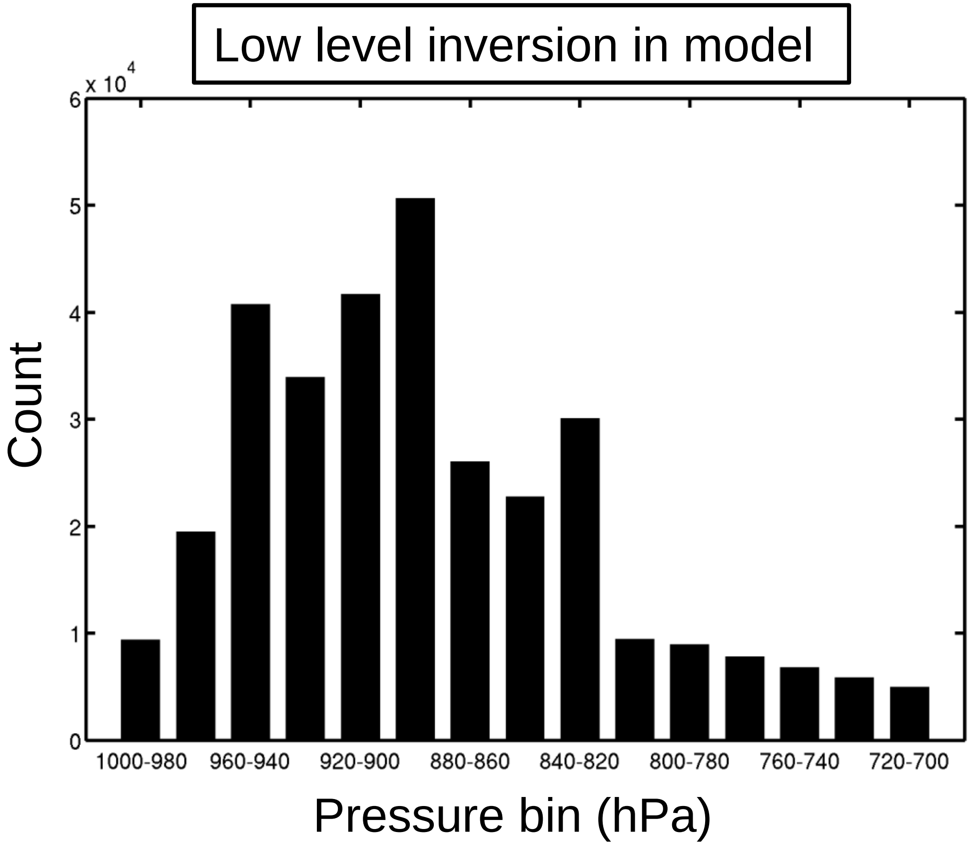
Investigations on low level inversions (all areas over sea)

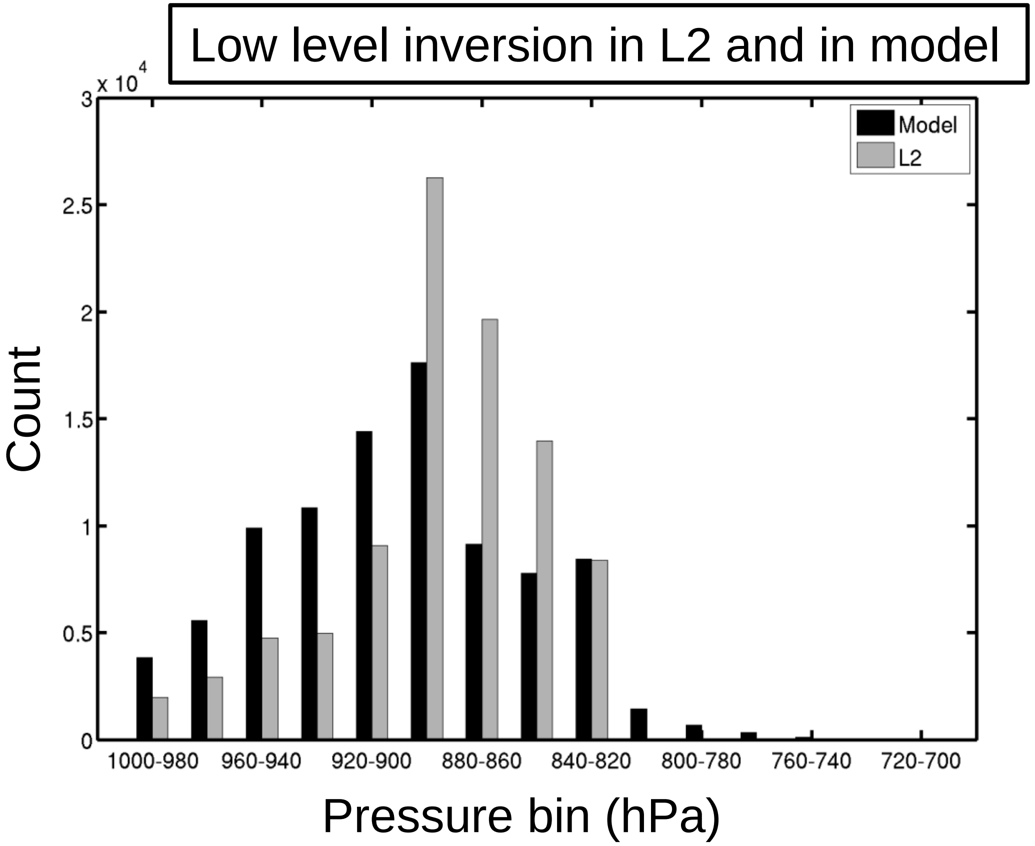
	Model: % of low level inversions 1.1-31.3.2017	L2 profiles: % of low level inversions 1.1-31.3.2017	Model: % of low level inversions 1.6-31.8.2017	L2 profiles: % of low level inversions 1.6-31.8.2017
NEP	89.7	34.1	86.9	50.5
SEP	88.3	54.1	86.9	48.7
NEA	78.3	20.6	83.2	38.1
SEA	93.8	59.9	91.6	57.3
NP	38.2	2.9	97.0	63.1
SEI	95.5	56.3	82.4	18.7
NA	48.9	6.2	91.4	46.0
SO	55.6	11.0	61.8	11.6
Geodisc NH	64.6	10.8	79.3	33.4
Geodisc TR	67.3	17.6	67.0	18.2
Geodisc SH	67.6	19.4	68.5	14.0

OmB statistics 1.1-31.3.2017 (L2 – model bg)

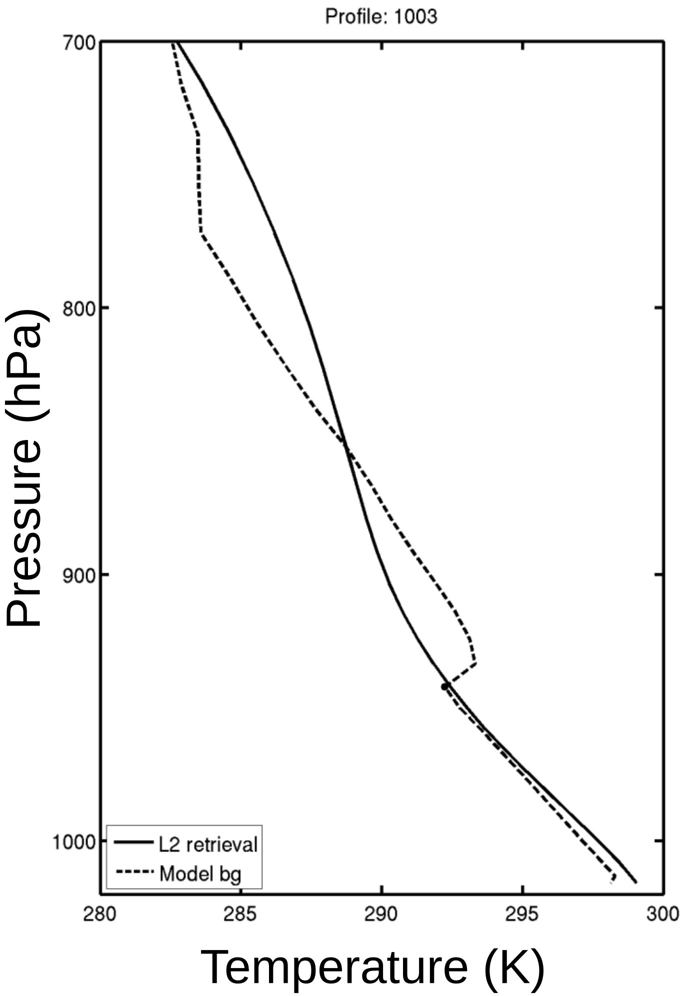


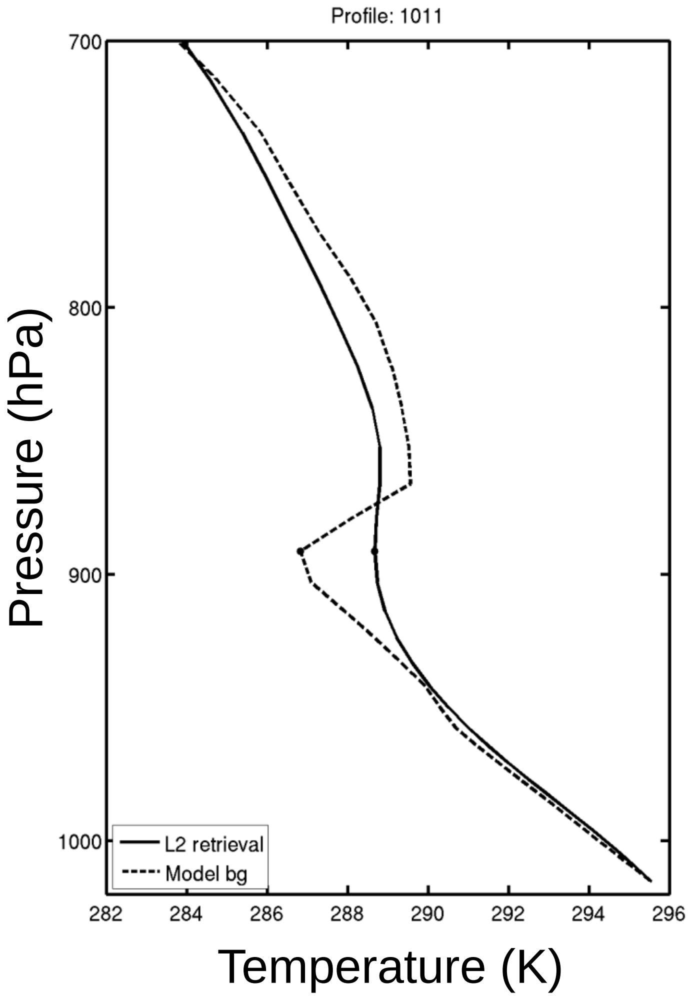
Inversion base (SH geodisc, 1.1-31.1.2017)





Example profiles





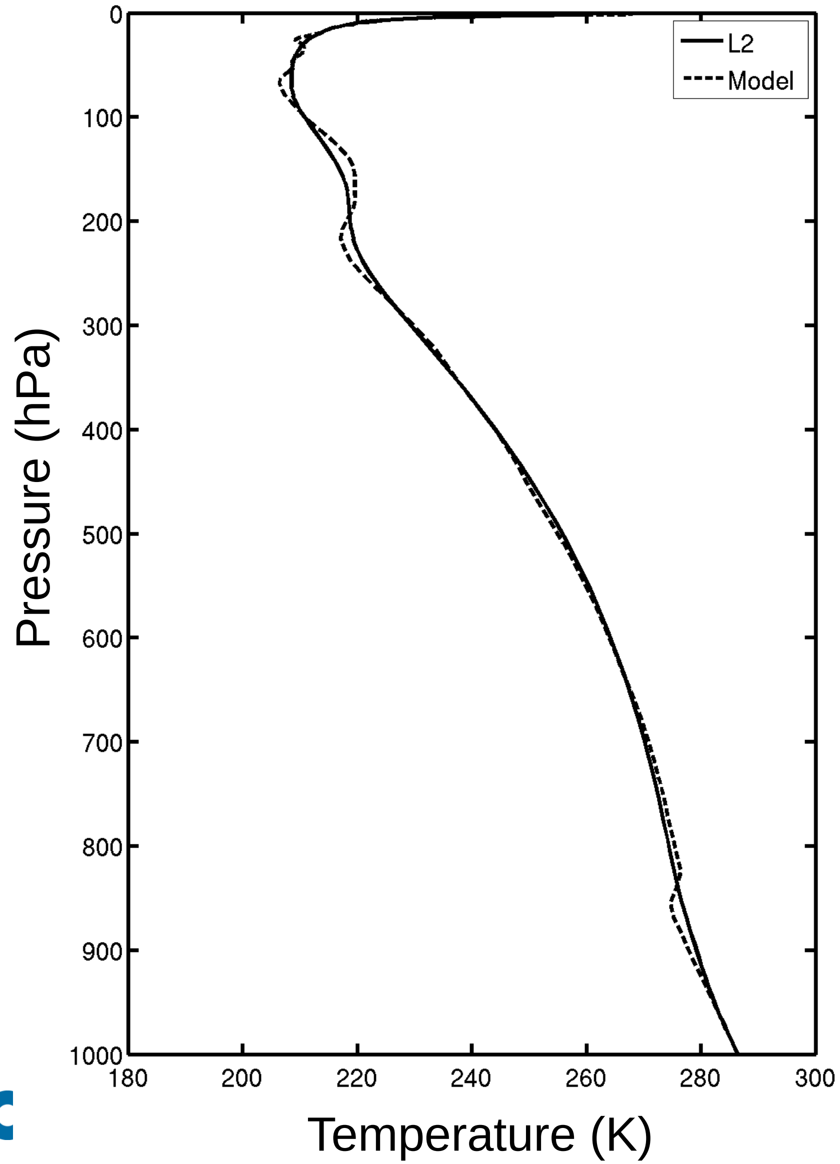
Summary of the findings

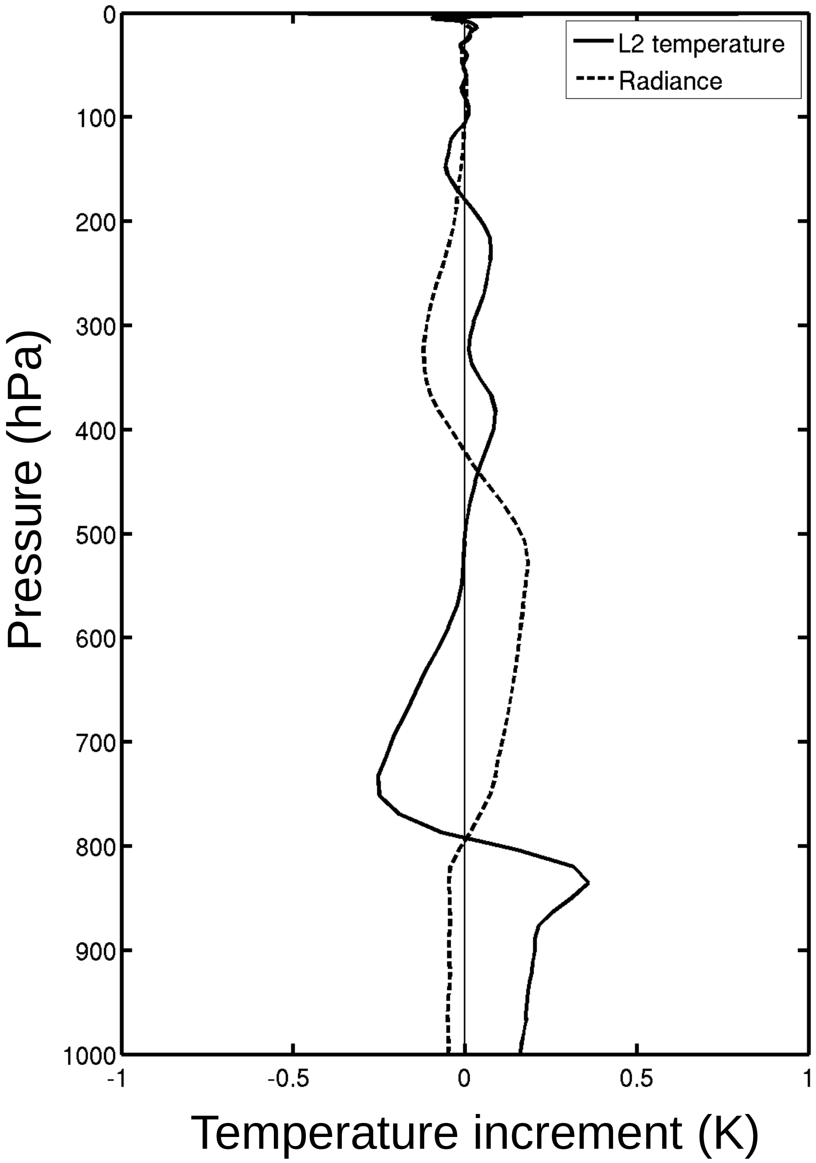
- Model is capturing the low level inversions much more frequently than L2
  - L2 inversions are smooth, and on average found from higher altitudes than the model inversions
- OmB statistics clearly show the missing inversions over regions where inversions are very frequent.
- Again, properly designed first guess check and realistic observation errors are required for successful assimilation.
- One possibility could be (seasonal) blacklisting of low level data in regions where it is known that inversions are very likely to occur.

Single observation experiment with a L2 profile (case 1)

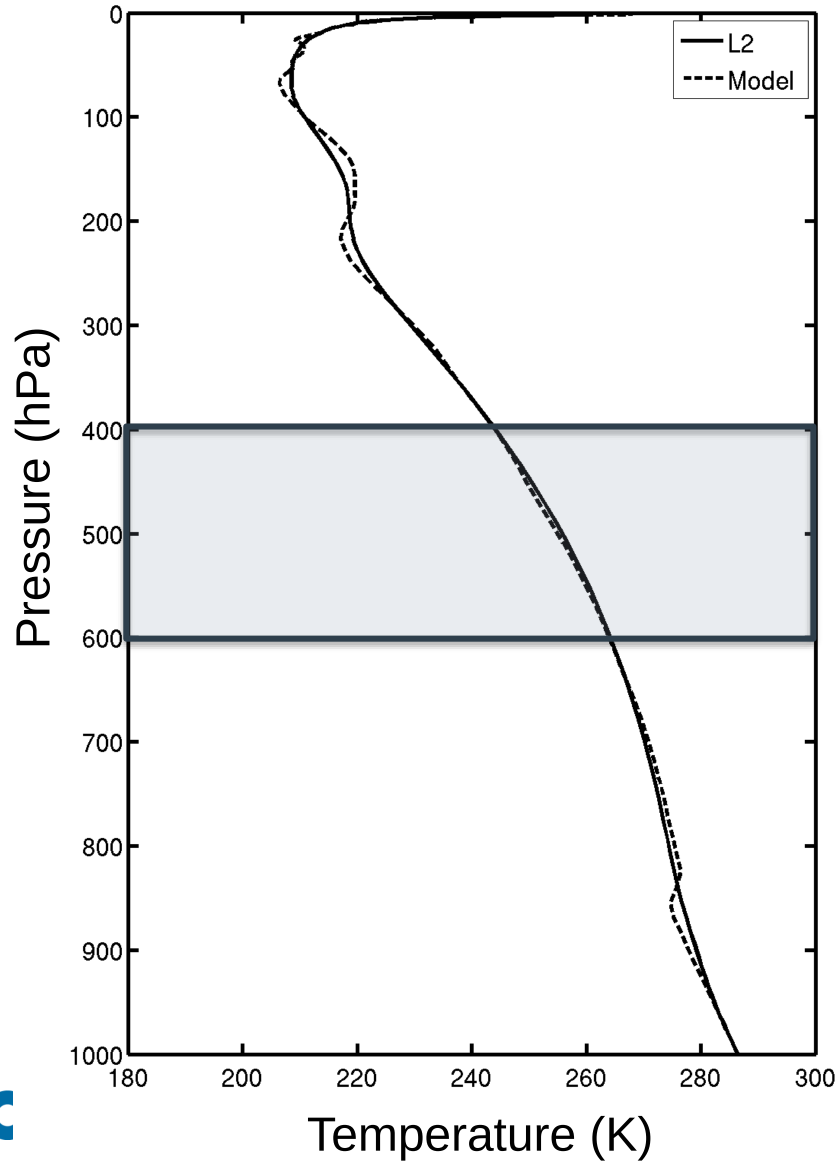
- 1.1.2017, 12.38 UTC
- 39.26 N, 33.41 W
- All IASI channels are cloud free according to ECMWF cloud detection scheme
- OmC = 0.36
- QI_T = 0.75
- Temperature observation error 2 K
- Specific humidity observation error 0.005 Kg/Kg

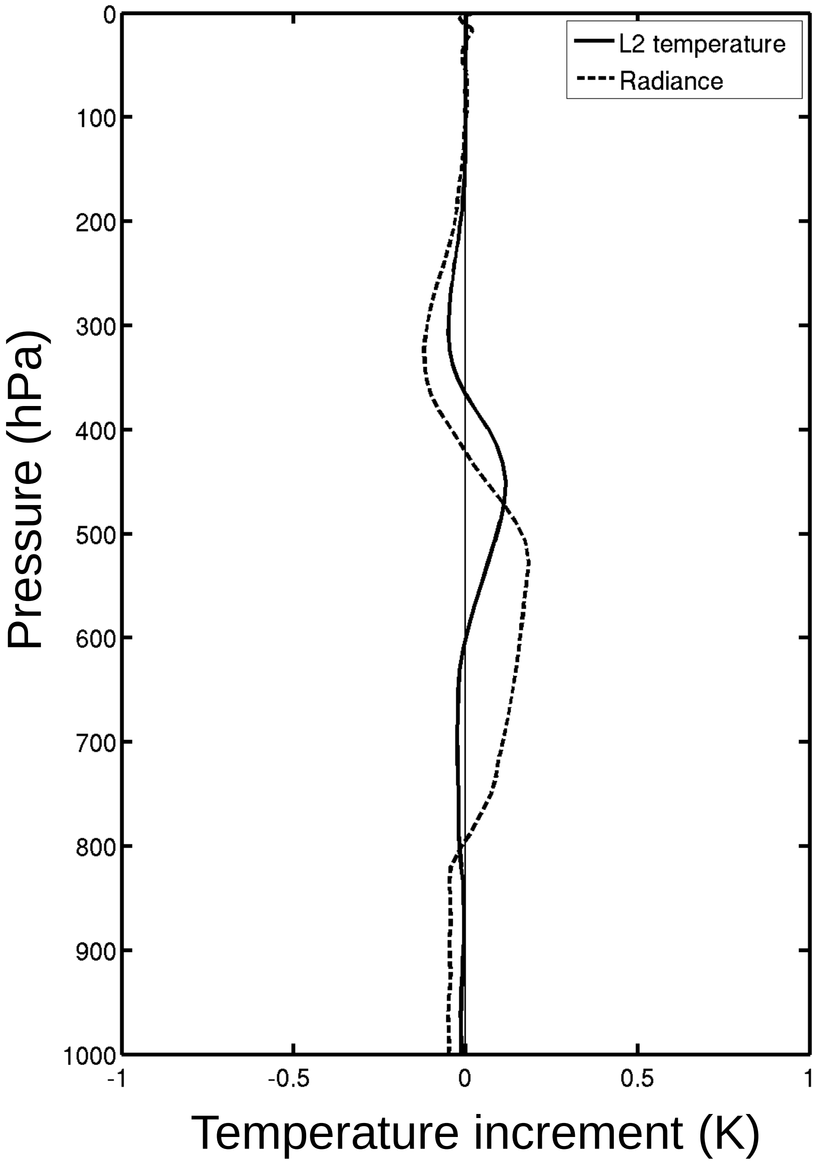
Analysis increments, complete L2 temperature profile assimilated



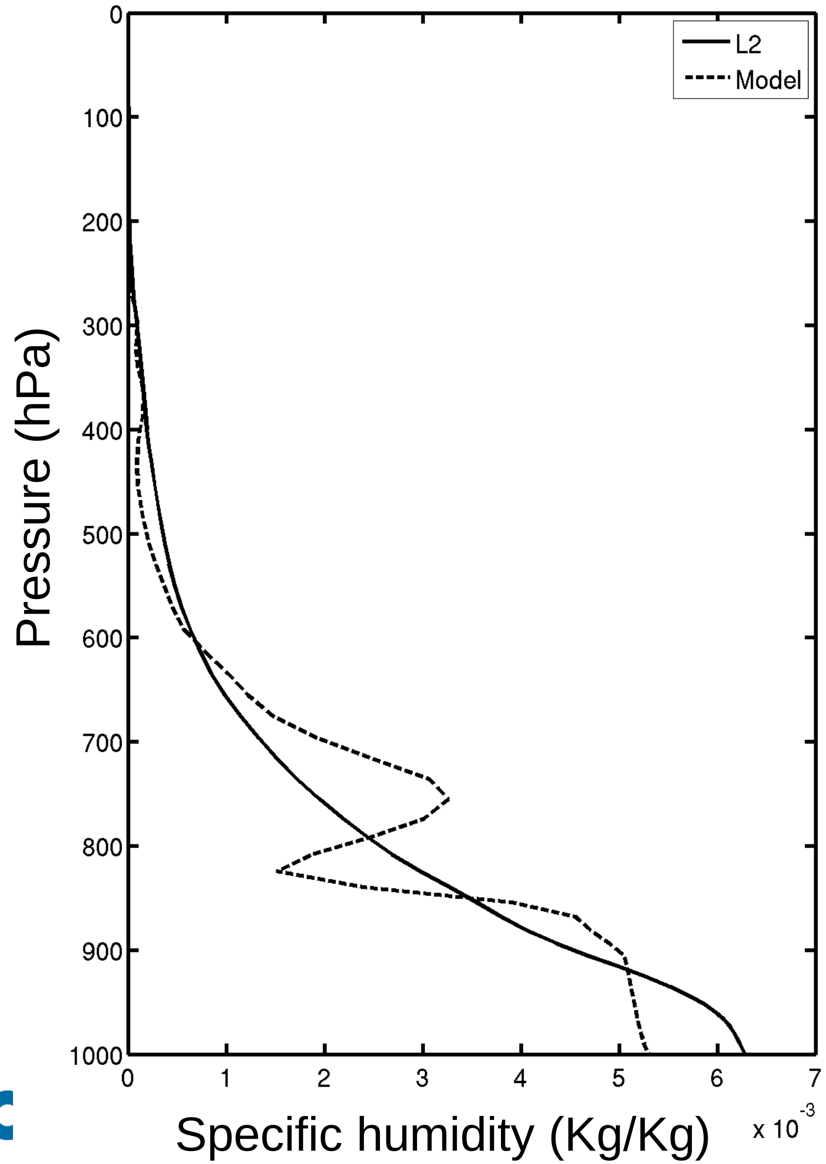


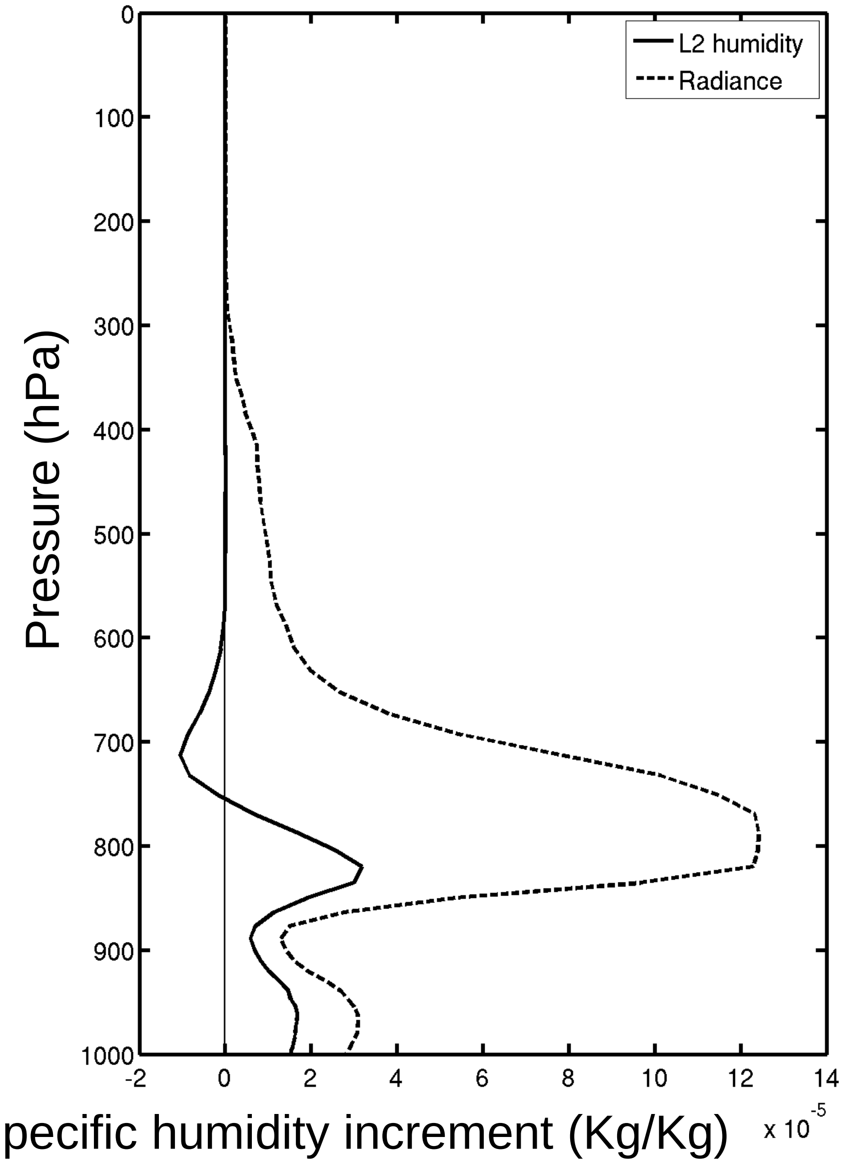
Analysis increments, L2 temperature between 400 – 600 hPa assimilated





Analysis increments, complete L2 humidity profile assimilated





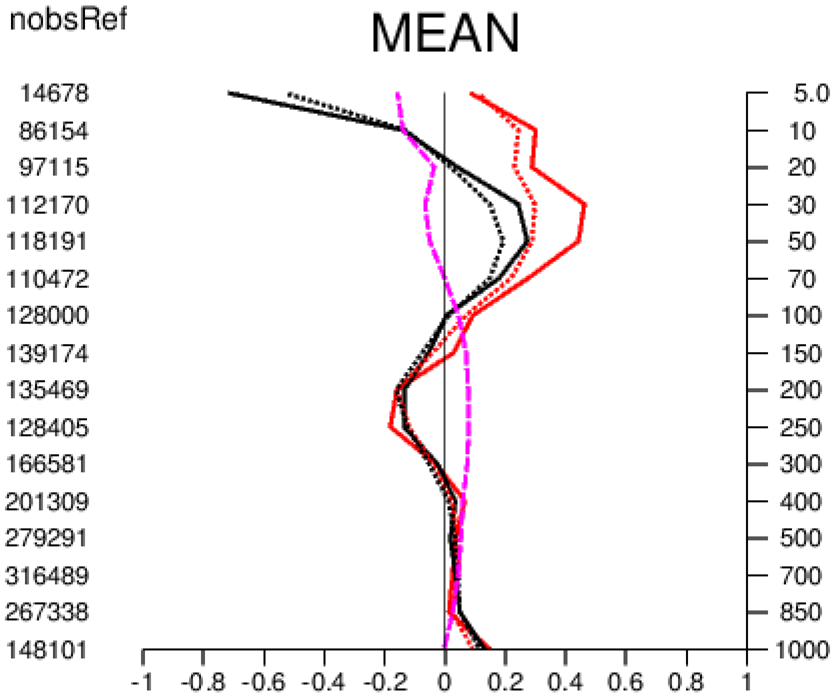
Summary of findings

- Selected model temperature profile has a low level inversion as well as double tropopause while from the L2 profile both are missing.
  - Temperature assimilation increment indicates that the model profile is modified towards the missing structures
  - If data from the “problematic” altitudes are blacklisted, assimilation of L2 temperature profile is bringing in more similar information than assimilation of the IASI radiance profile.
- L2 humidity profile is much smoother than the model profile
  - Analysis increments have similarities but also differences compared to assimilation of the radiance profile
- Both T and q single observation experiments indicate the importance of understanding and taking into account the observation error correlations.

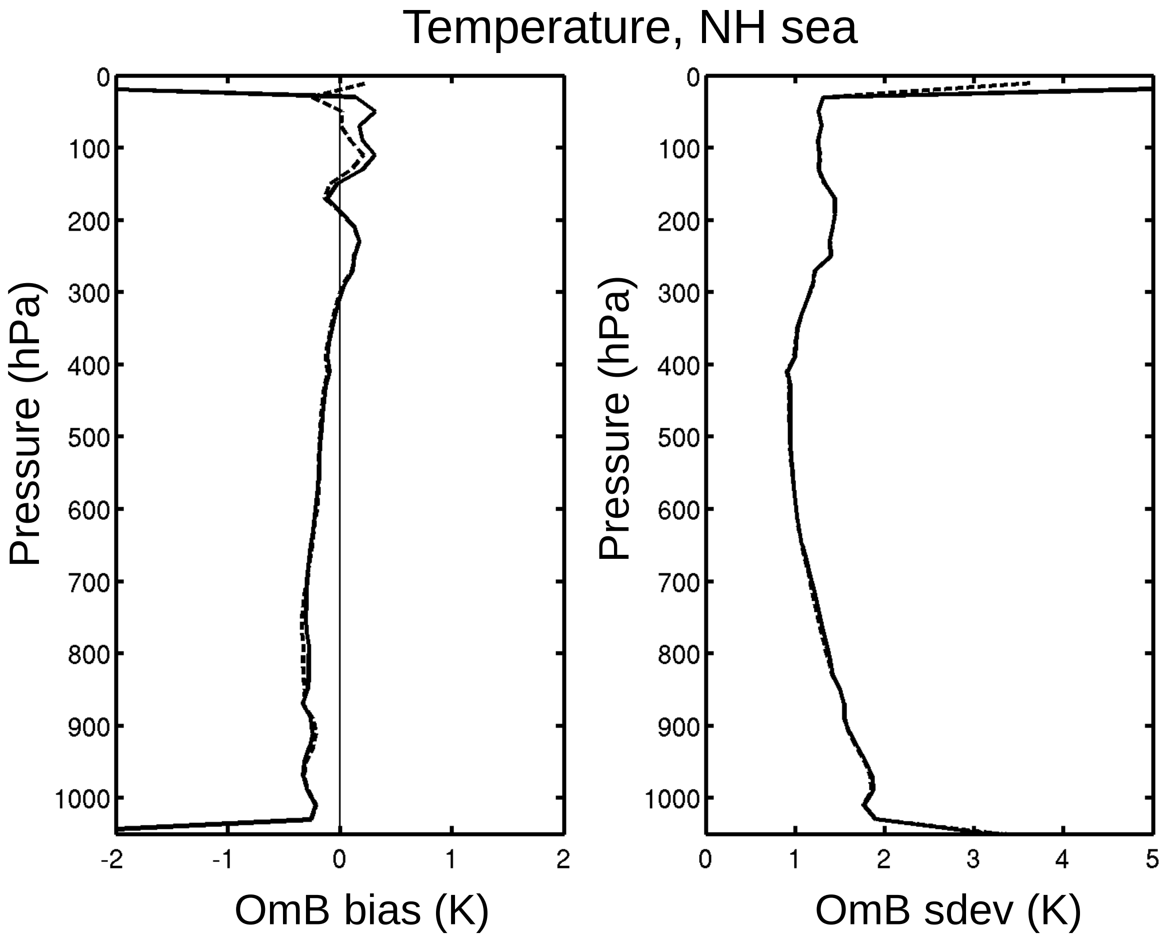
Passive monitoring against ERA5

1.1-31.3.2017

Comparison against radiosondes:
OmB bias operational model ______
OmB bias ERA5 ______



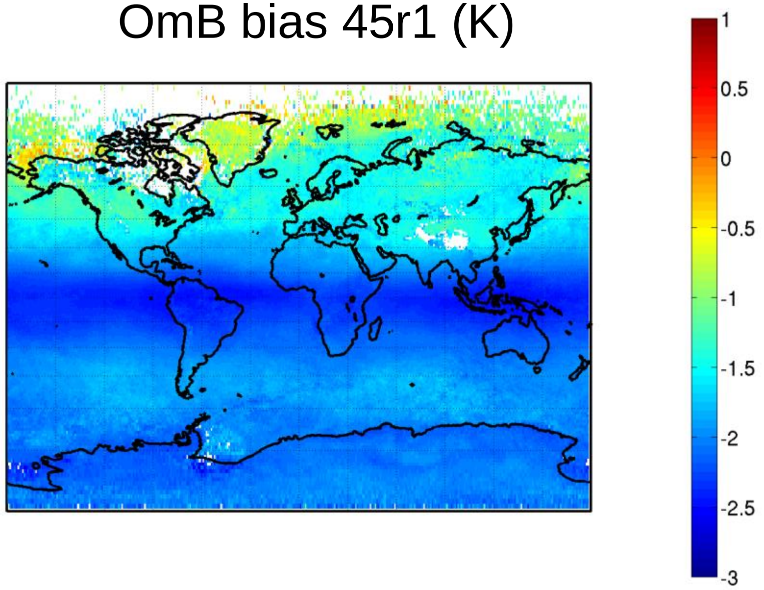
Comparison against L2 temperature:
OmB bias operational model ______
OmB bias ERA5 _ _ _ _ _



Passive monitoring against ERA5 (L2 – model)

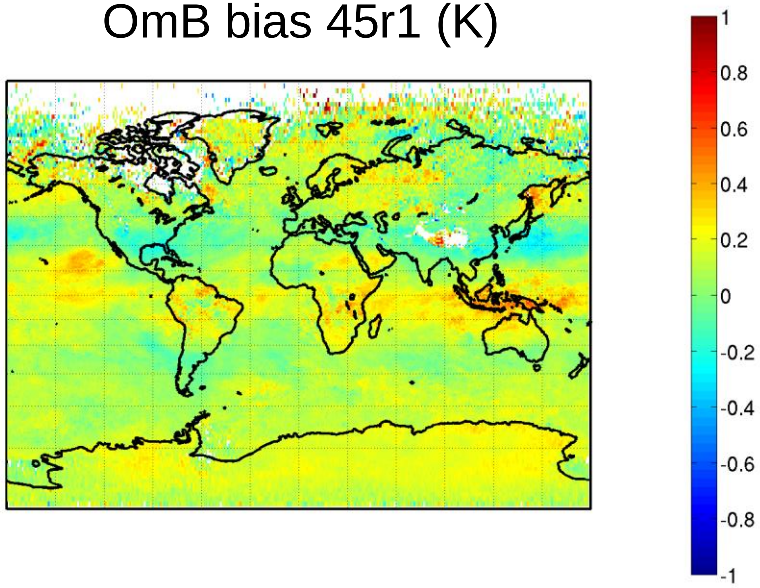
OmB bias 45r1 (K)

0 – 10 hPa



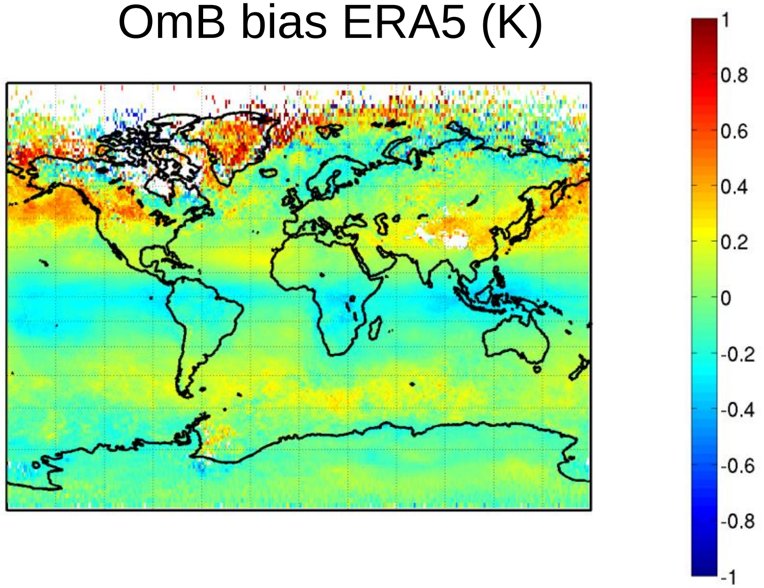
OmB bias 45r1 (K)

30 – 40 hPa



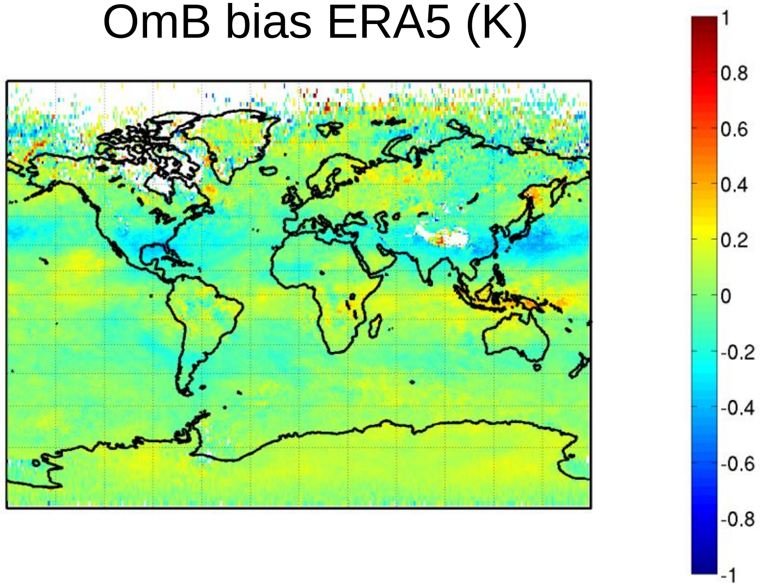
OmB bias ERA5 (K)

0 – 10 hPa



OmB bias ERA5 (K)

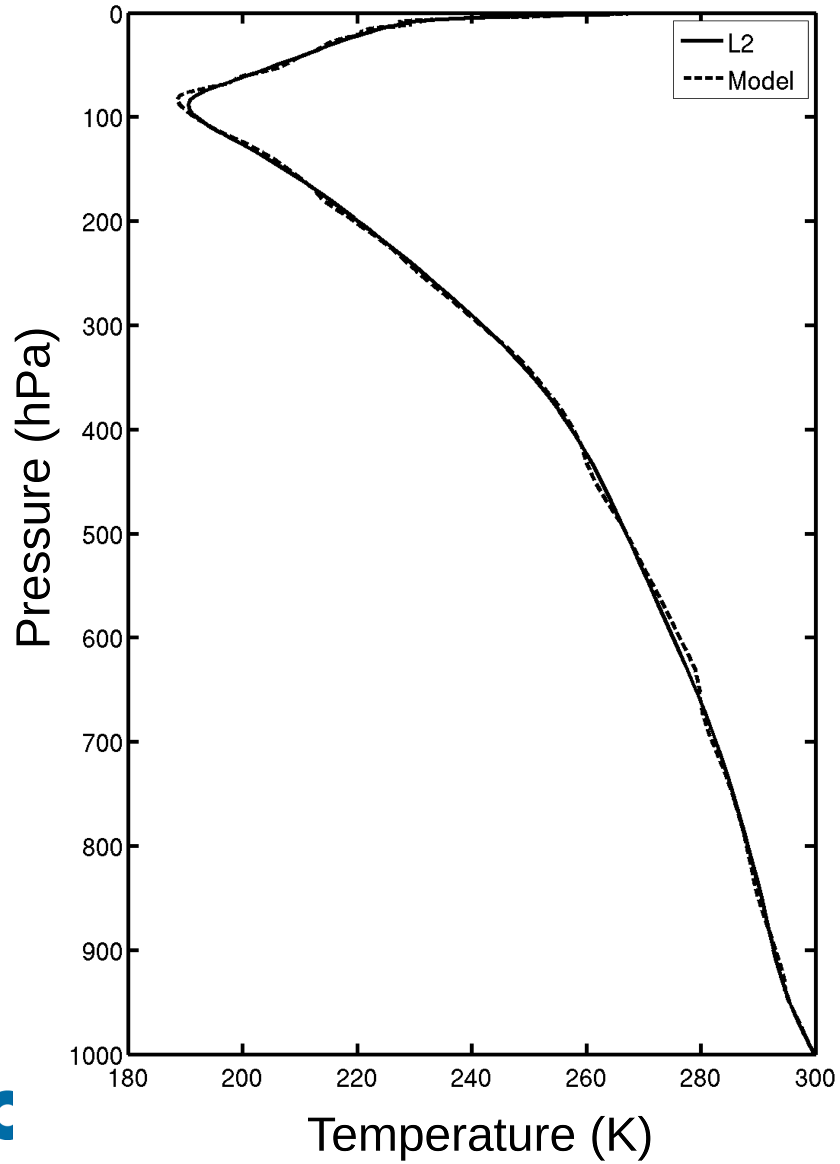
30 – 40 hPa

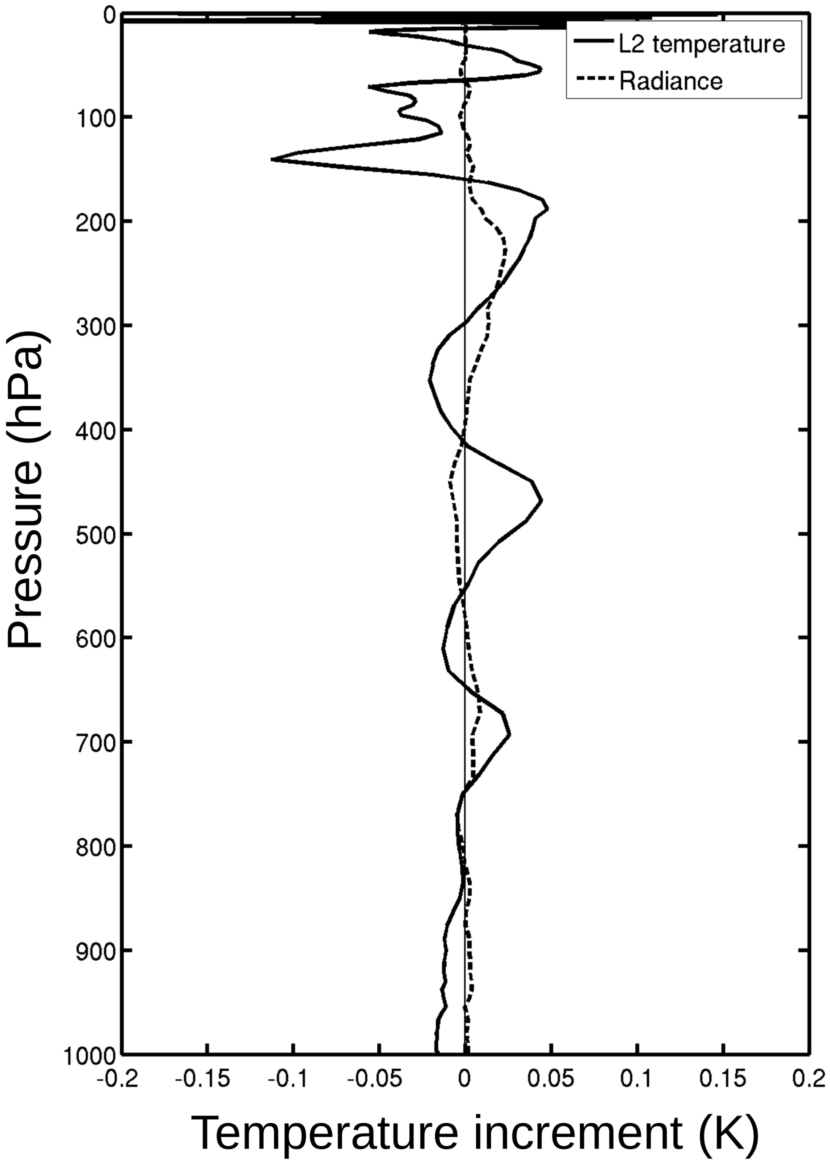


Single observation experiment with a L2 temperature profile (case 2)

- 1.1.2017, 17.03 UTC
- 1.02S, 62.72E
- All IASI channels cloud free according to ECMWF cloud detection scheme
- OmC = -0.11
- $QI_T = 0.45$
- Temperature observation error 2 K

Analysis increments, whole L2 temperature profile assimilated (case 2)





Summary of findings

- The negative OmB bias (L2 – 45R1) at high levels originate from ERA5
  - L2 temperature profiles agree very well with ERA5
  - ERA5 and operational IFS have different model bias characteristics in stratosphere, neither of them is correct when compared to radiosondes
- Case 2 single observation experiment indicates that assimilation of L2 T profile produces more noisy analysis increments.
- Assimilation of L2 temperature at very high levels not recommended, in practise it is assimilation of ERA5 model bias.

Ongoing work

- Diagnose **R**
  1. L2 T and q profiles active, experiment used to diagnose **R** with Hollingsworth-Lonnberg method
  2. Possibly some retuning of observation errors
     - For IASI observation errors are scaled by a factor of 1.75, for CrIS by a factor of 2.2
  3. Implement **R** from steps 1+2, run new experiment from which **R** is diagnosed with Desroziers method
     - Currently in IFS **R** is used only to take into account inter channel error correlations for radiances, framework for L2 needs to be technically implemented.
  4. Possibly retuning of the observation errors and some adjustments to make the **R** well behaving
- Current blacklisting decisions (accept only):
  - $QI_T < 1.5$
  - “clear” profiles |OmC| < 1
  - data only over sea

Thoughts towards future

- L2 retrievals look sensible. However, some profiles are smooth and missing small scale vertical structures.
- At ECMWF assimilation framework for L2 retrievals is technically in place and running. It can be used and adapted for various studies with L2.
- Future outlook will depend on the findings on **R:**
  - If the L2 error structures are complicated, scene dependent, cloud dependent, season dependent etc, implementing and testing various **R**s taking these into account would require extension of the current project.
- Possibly huge potential in L2 q
  - It has been demonstrated that assimilation of humidity sensitive radiances has clear positive impact on wind (4D tracing of humidity structures)
  - Could similar impact be achieved by assimilating L2 humidity / 3D winds?
  - 3D winds will be accurate only if L2 humidity is accurate, understanding of quality and characteristics of L2 q is in a key role.