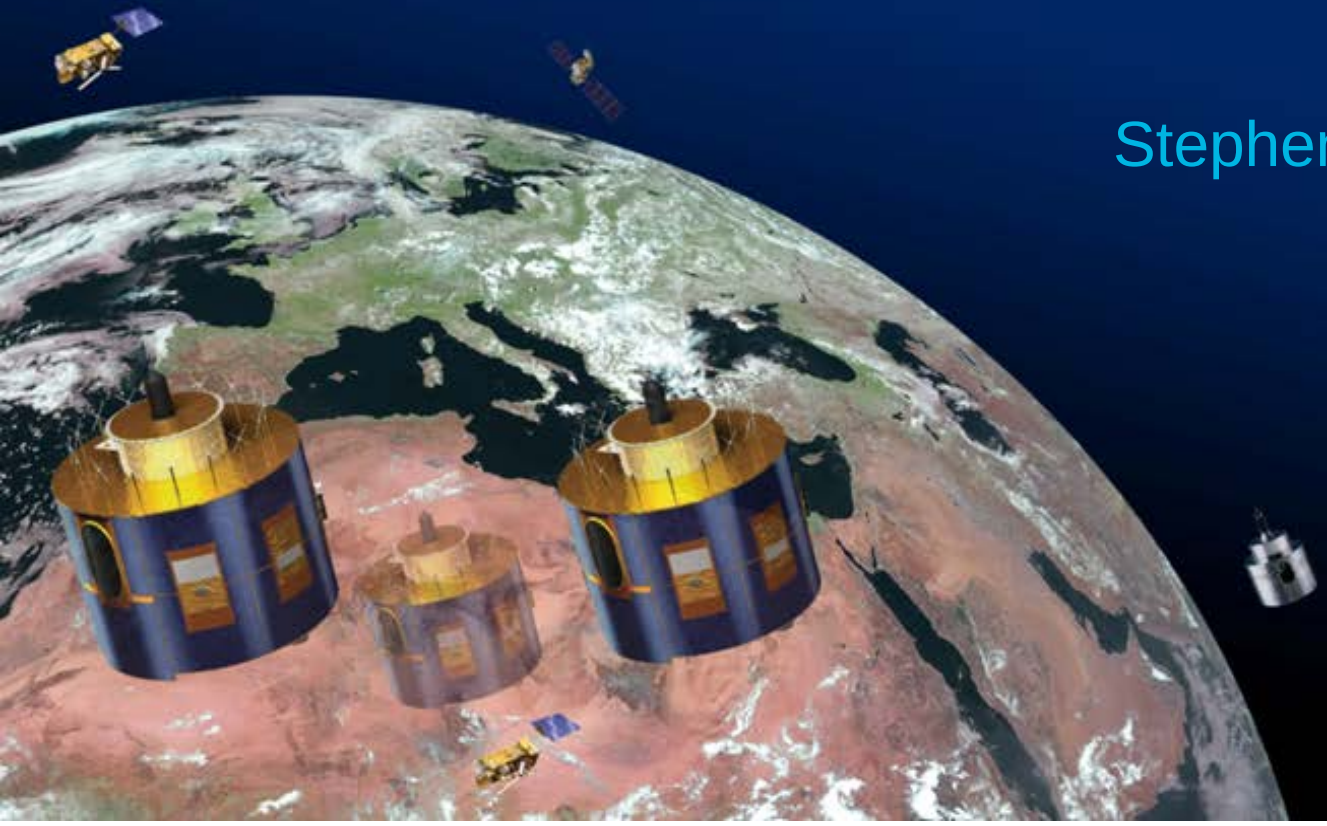


The MTG-IRS level 2 processor: physical basis, selected results and planned evolution

Stephen Tjemkes, Stefano Gigli and Rolf Stuhlmann

EUMETSAT

Overview

- MTG-IRS: mission and instrument
- Level 2 processor: overview
- Demonstration projects
- Outlook

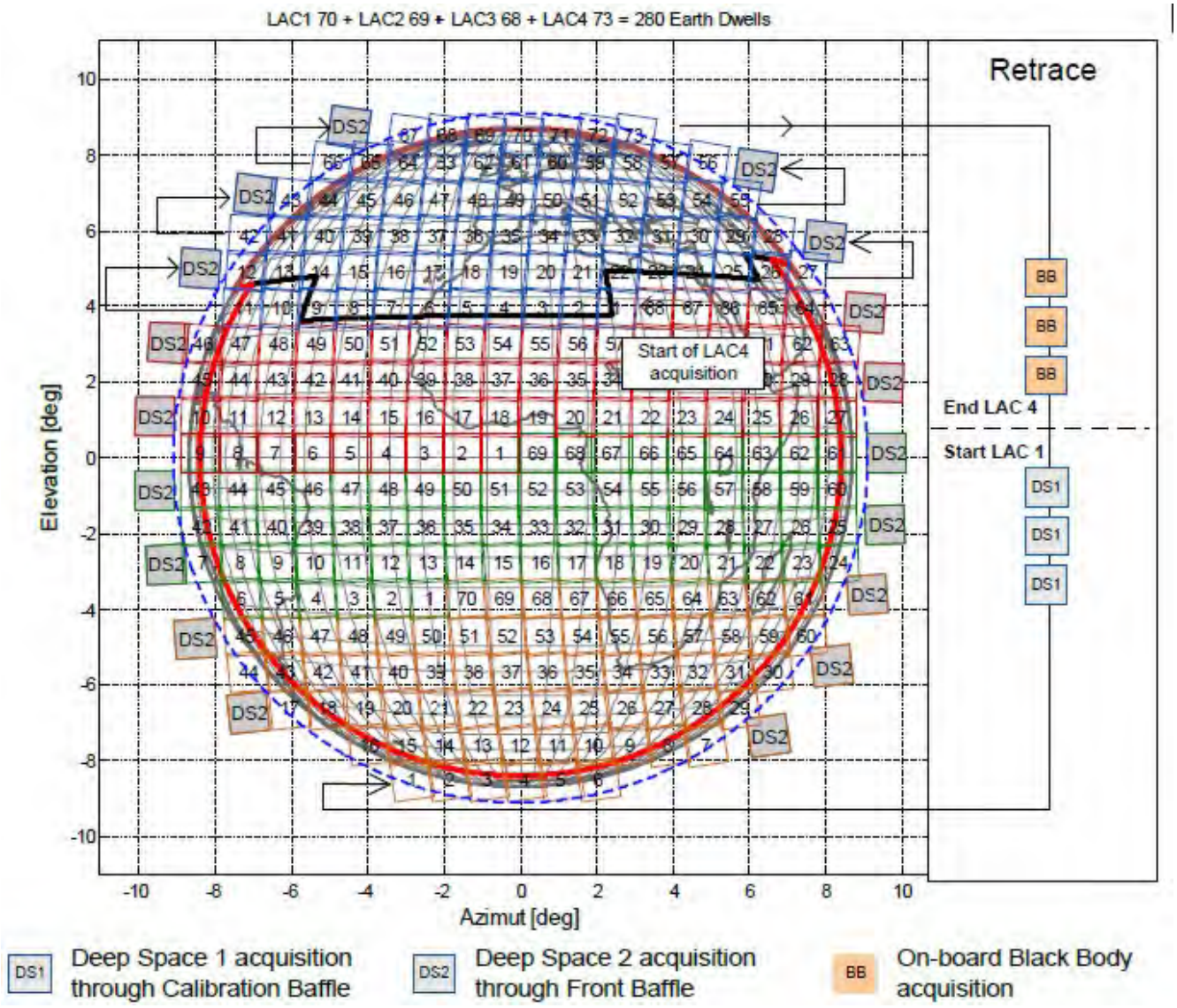
MTG-IRS: Mission and instrument

- Meteosat Third Generation:
  - Constellation of 3 EUMETSAT instruments and 1 EU/ESA instrument on two separate platforms:
    - MTG-I: FCI and LI
    - MTG-S: IRS and Sentinel 4
- IRS is developed to provide high spatial and temporal information on specific humidity and temperature especially for pre-convective situations as requested by operational user community

MTG-IRS: instrument

- Step and stare mode: one stare in 10 sec
- Two large detector arrays (160x160 elements), each detector consists of 9 sub-detectors.
- Spatial sampling of 4 km at SSP
- Temporal sampling: 4 x ¼ Full Disc in 1 hour
- Spectral Domain: LWIR: 700 – 1210 cm-1, MWIR: 1600 – 2175 cm-1
- Sampling: 0.625 cm-1
- There is **no** build in imager

MTG-IRS: Acquisition



MTG-IRS: Data volume

- MTG-IRS: 1 Dwell = 25600 fov in 10 sec
- Comparison (fov/sampling time)
  - IASI 1-PDU = 2760 fov / 180 sec:
  - CrIS 1 Granula = 1080 fov / 32 sec
- Substantial increase in data volume

MTG-IRS level 2 processor

- EUMETSAT decided to develop a new Level 2 processor for MTG-IRS because
  - MTG-IRS is a radical new instrument with new challenges and problems
  - the main application is regional scale forecast
- The processor
  - grounds on the fundamental radiative transfer equation,
  - is physically based and
  - can potentially use the full spectral coverage of the instrument

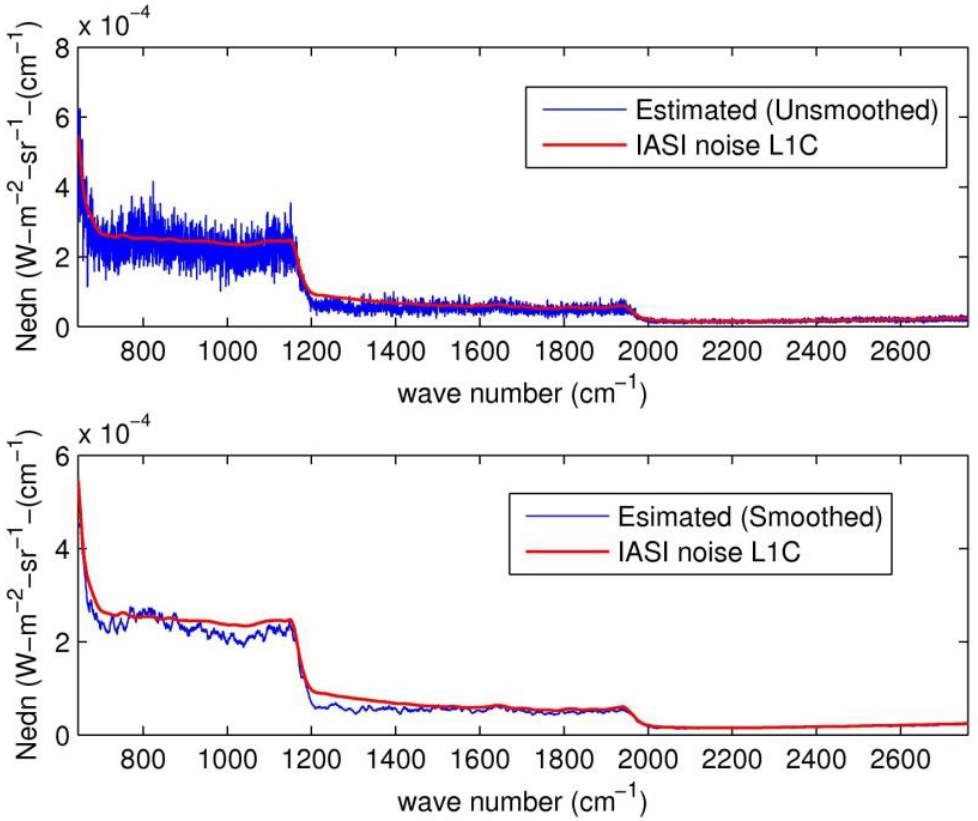
MTG-IRS Level 2 processor

- End-To-End processor
  - Scene analysis using information contained in spectra
  - retrieval only over clear sky area at Day-1
  - 1D-VAR with
    - T, q, O3, surface emissivity and temperature as state vector
    - OSS as RTM
    - ECMWF forecast state and flow dependent error covariance for a-priori
  - Post-processing for data assimilation applications

1DVAR

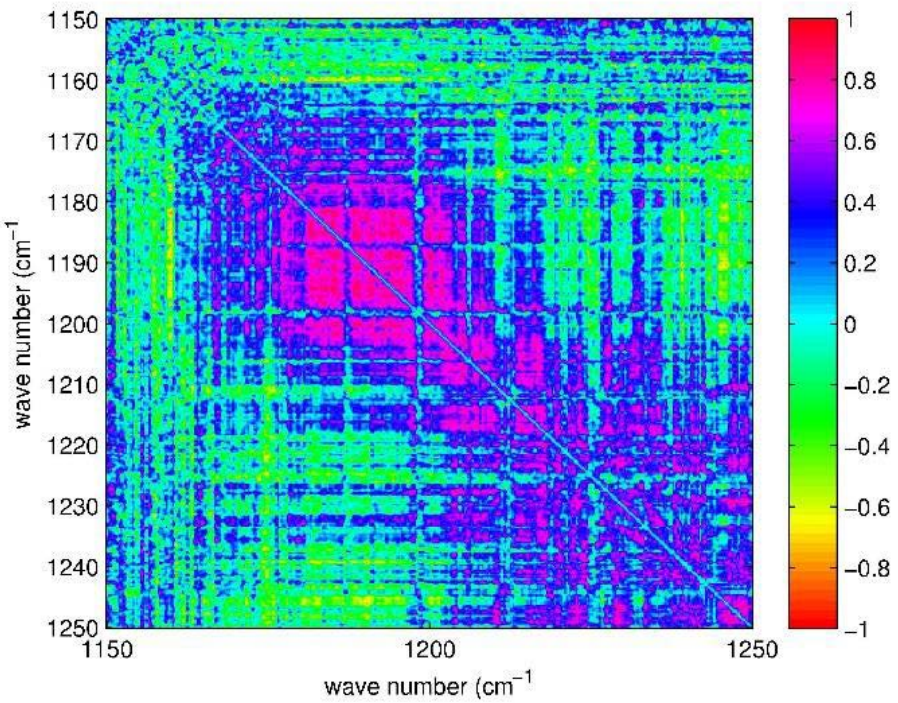
- Critical components
  - Radiometric error covariance, in particular any correlation
    - Normally provided by characterisation of instrument but now we have a method to derive this from in-flight earth observations
  - Background error covariance
    - Generated twice per day from ECMWF ensemble forecast system and adopted for 1DVAR (Holm and Kral, 2011)

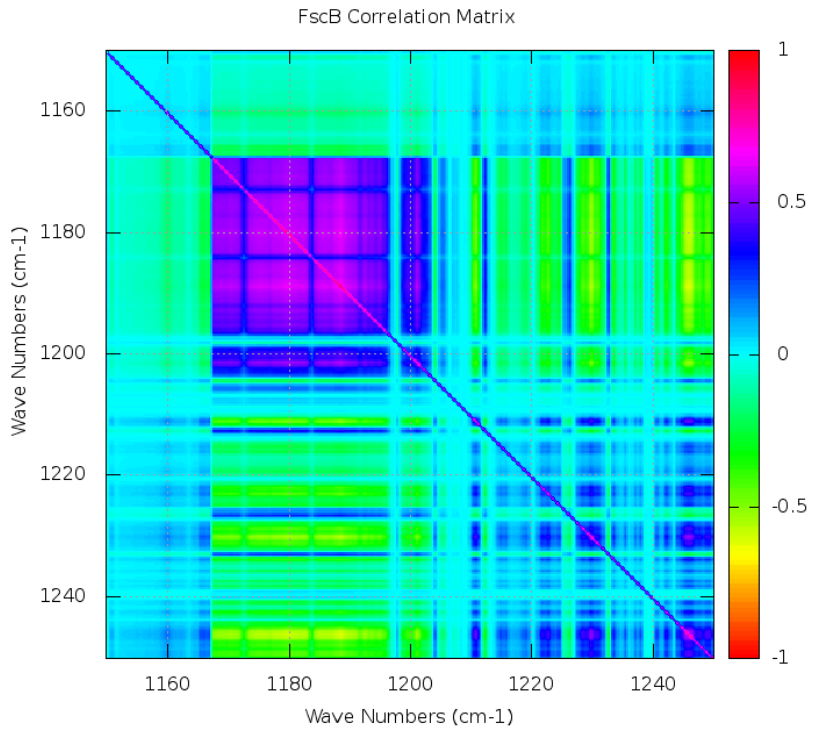
Example: IASI radiometric error covariance



- Serio et al: Appl Optics 2015

IASI example II





- The error covariance matrix for the IASI level 1C data for spectral channels between 1150 and 1250 cm^{-1}, derived from actual Earth observations (left) compared to a theoretical model which depicts correlated errors induced by realistic micro-vibrations (right). In both cases the correlated errors due to apodisation which affect the neighbouring spectral channels are removed

Post process

- Mainly a transformation of level 2 products from physical space to feature space

$$S_s = S_o^{-1/2} K S_a^{1/2} = U \Lambda V^t$$

  - Solution is linear combination of true state and background state
  - For dominant eigenvectors the effect of background is minimal.

Validation

- Validation suffers from a significant inconsistency in the time/space sampling of atmosphere between satellite and in-situ measurement.
  - This can be corrected for by inflating error covariance matrix (if known), but this is ignored in general (Pougatchev et al, 2009).
- Ultimately: if the user is (un) happy we are (un) happy
  - This implies to embrace/involve the users during the development of the processor
- In mean time: intercomparison study and demonstration projects

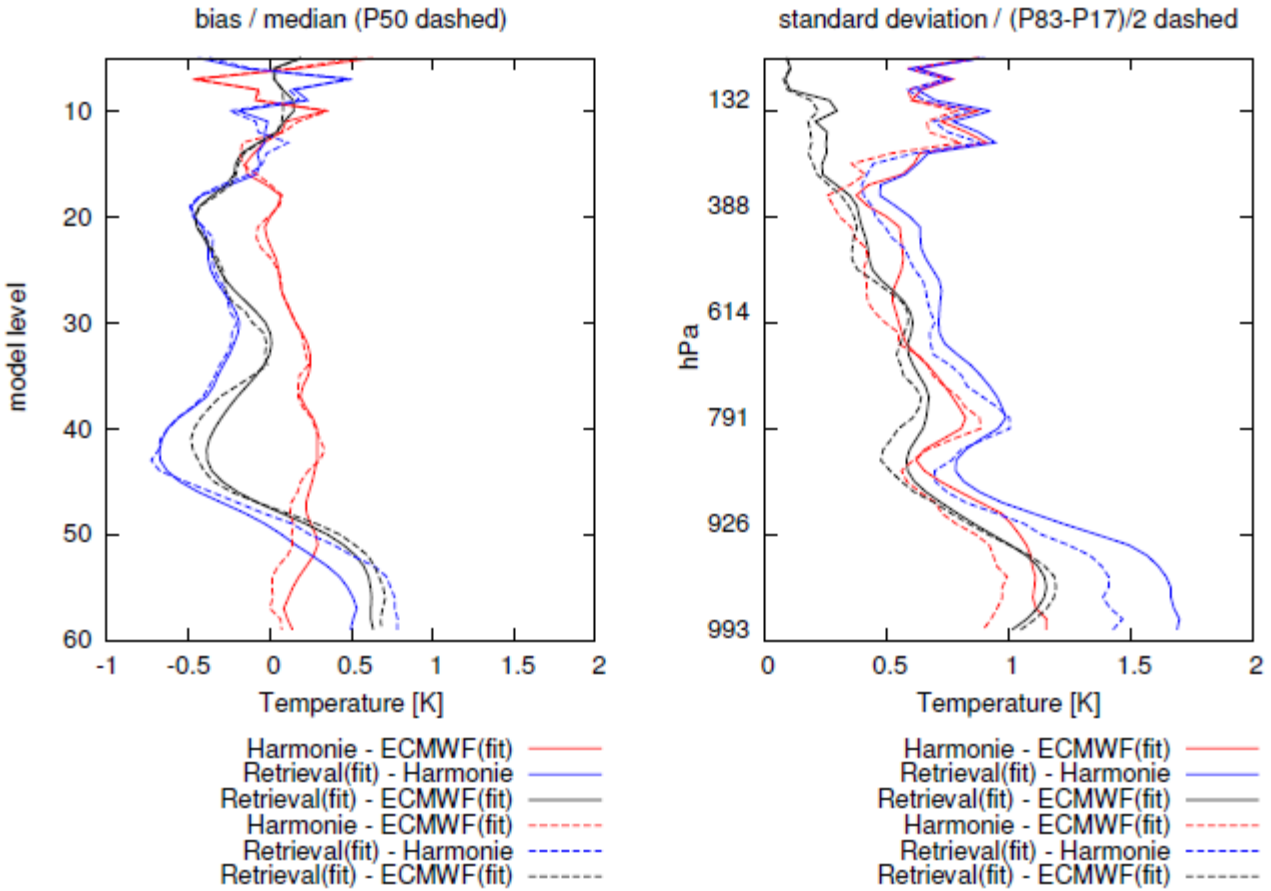
Retrieval intercomparison

- To identify strength and weakness of different approaches
- To identify way forward of open issues (e.g. Bias correction, Forward Model Errors)
- Objective is to do detailed analysis using a small set of carefully chosen cases
- Established a reference dataset
  - RS taken from GRUAN site manu, with collocated clear IASI observations
- Multi phase approach
  - First limited comparison of RTM
  - Comparison of retrievals using synthetic data
  - Comparison of retrievals using real data
- Participants: NASA (D. Zhou, X. Liu), NOAA (A. Gambacorta, Q. Liu), Met Office (S. Havemann), SSEC (B. Smith, N. Smith, P. Antonelli), KIT (M. Schneider), SI (C. Serio), EUMETSAT (T. August, S. Tjemkes)

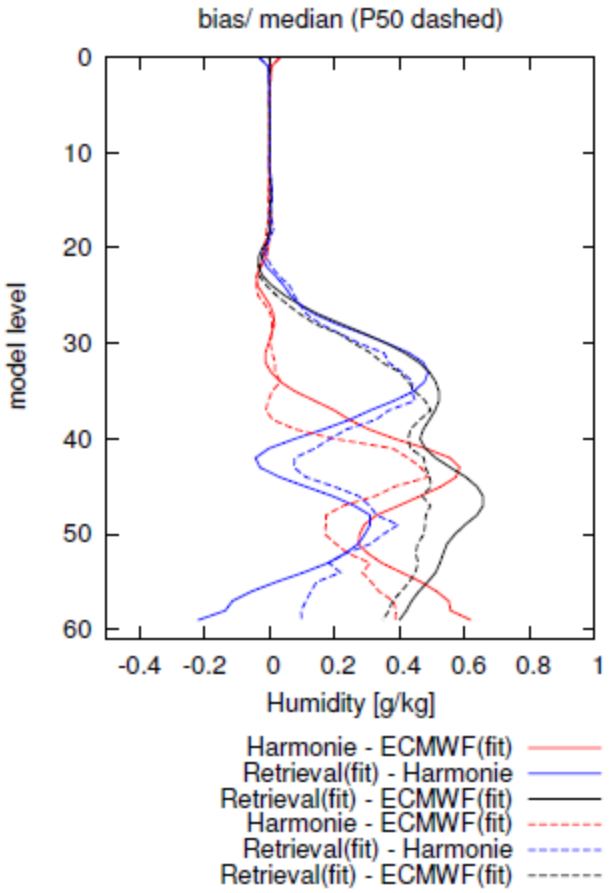
Demonstration projects: example

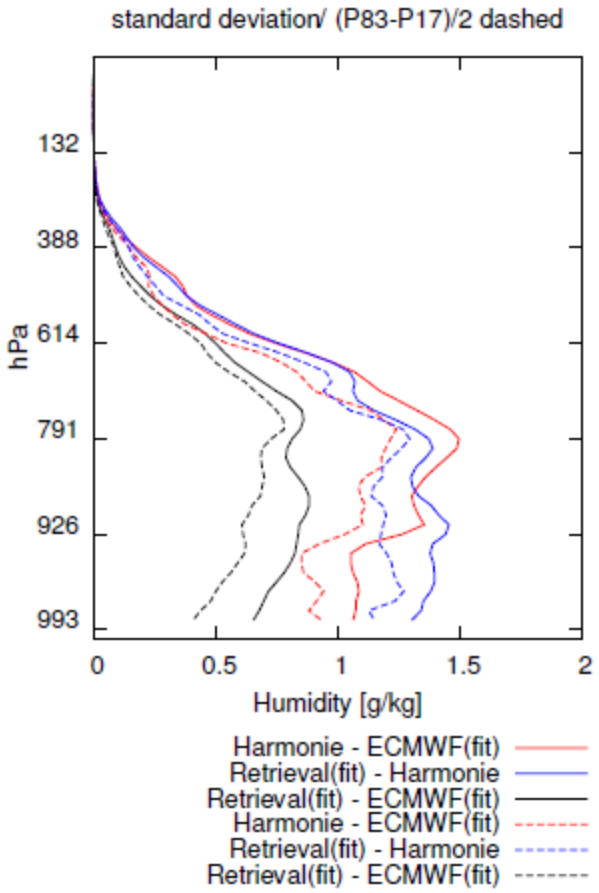
- Assimilation in regional scale NWP by KNMI over Europe and P. Antonelli over Hawaii
  - Validation of the level 2 products to determine if assimilation is feasible
  - Setup the technical infrastructure to assimilate the transformed retrievals
  - Perform retrieval over limited time period

Sample results: T-profile compared to Harmonie

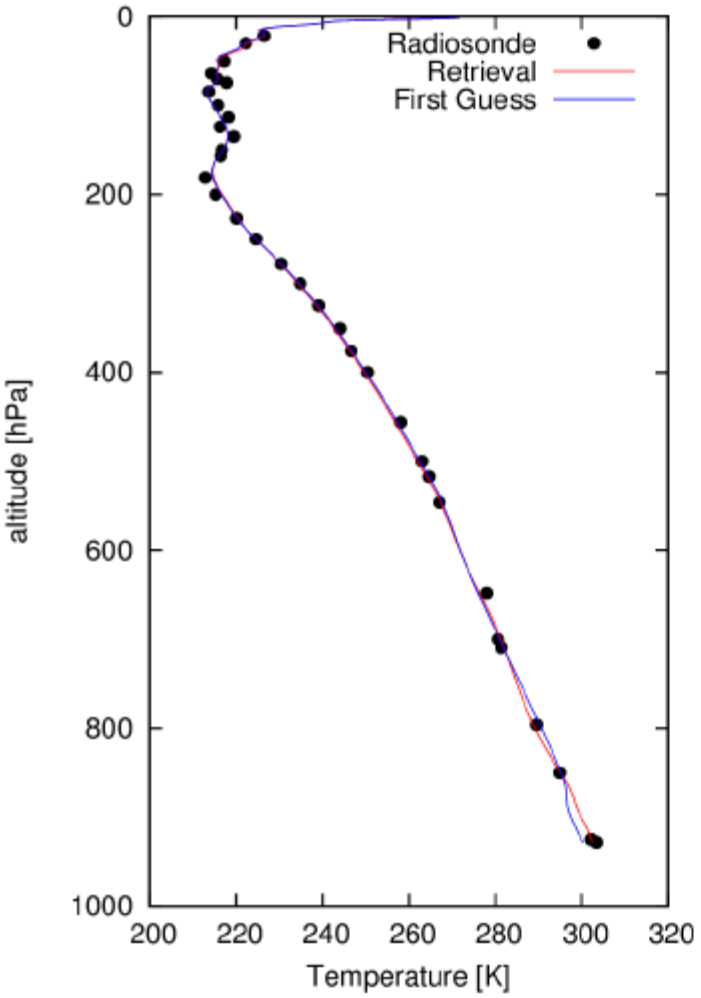


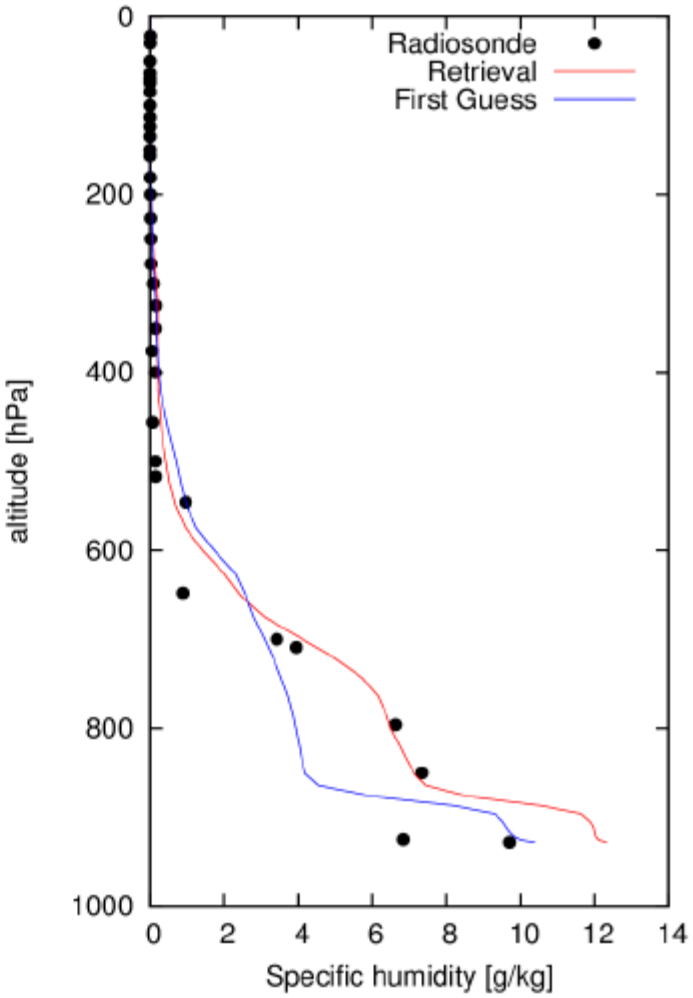
Sample results: q-profile compared to Harmonie



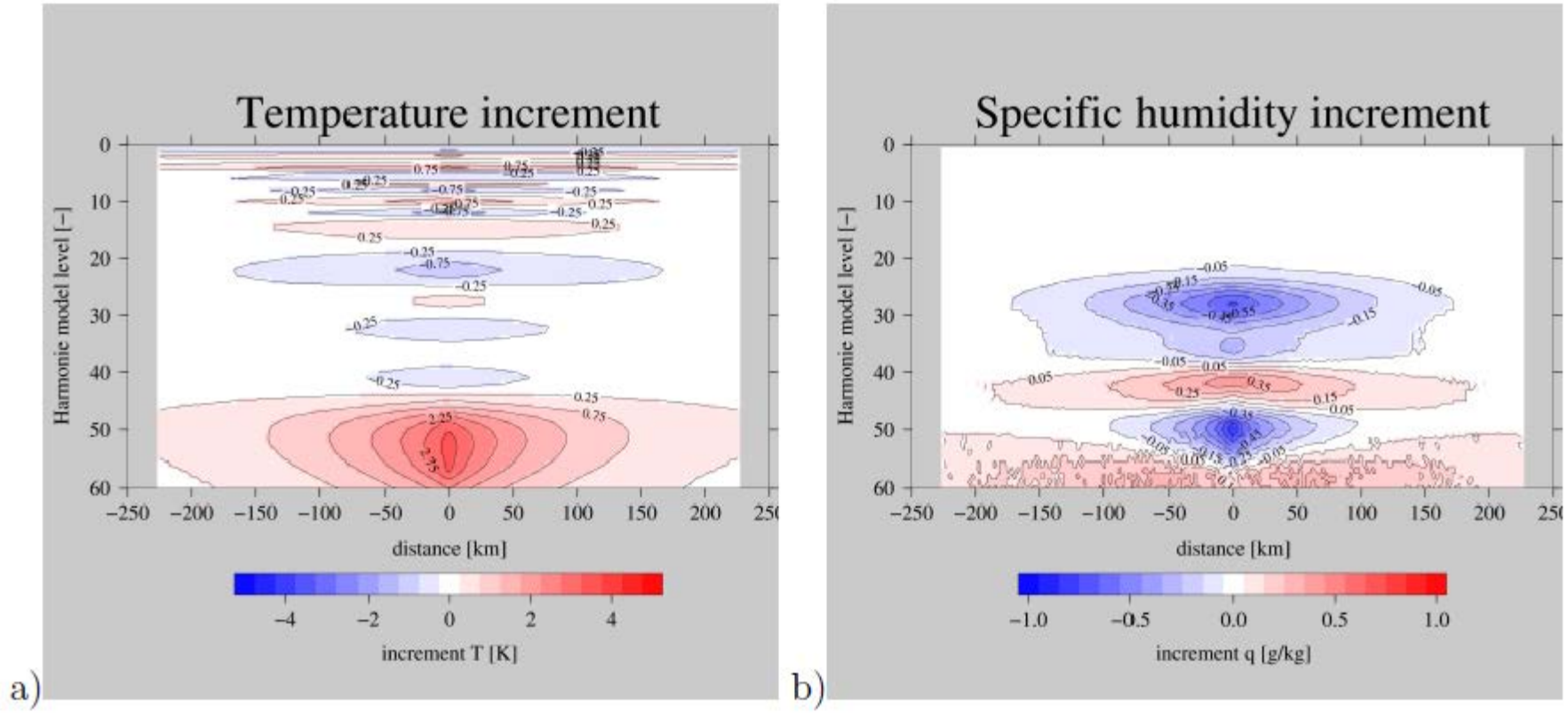


Single profile assimilation: Comparison to RS

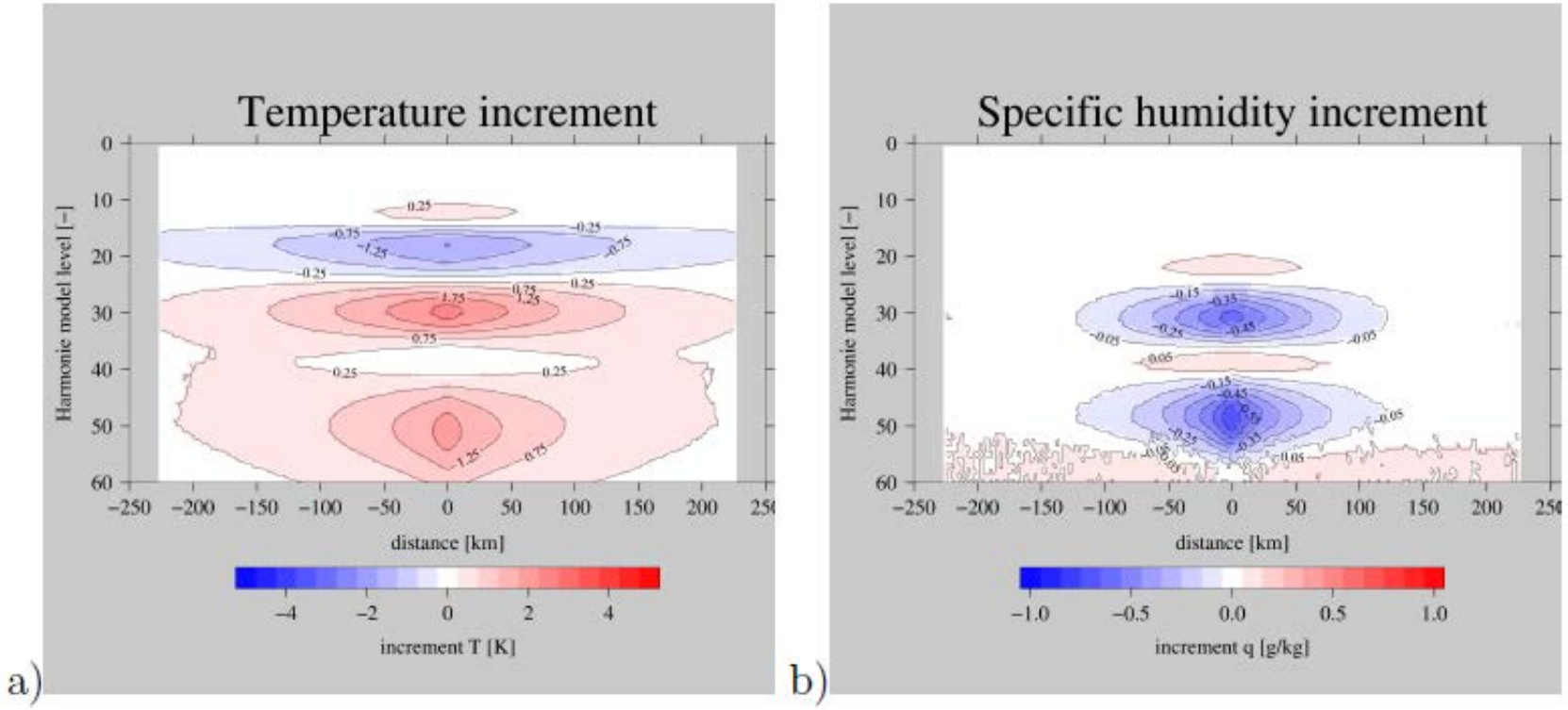




Single profile retrieval: direct assimilation of T/Q profile



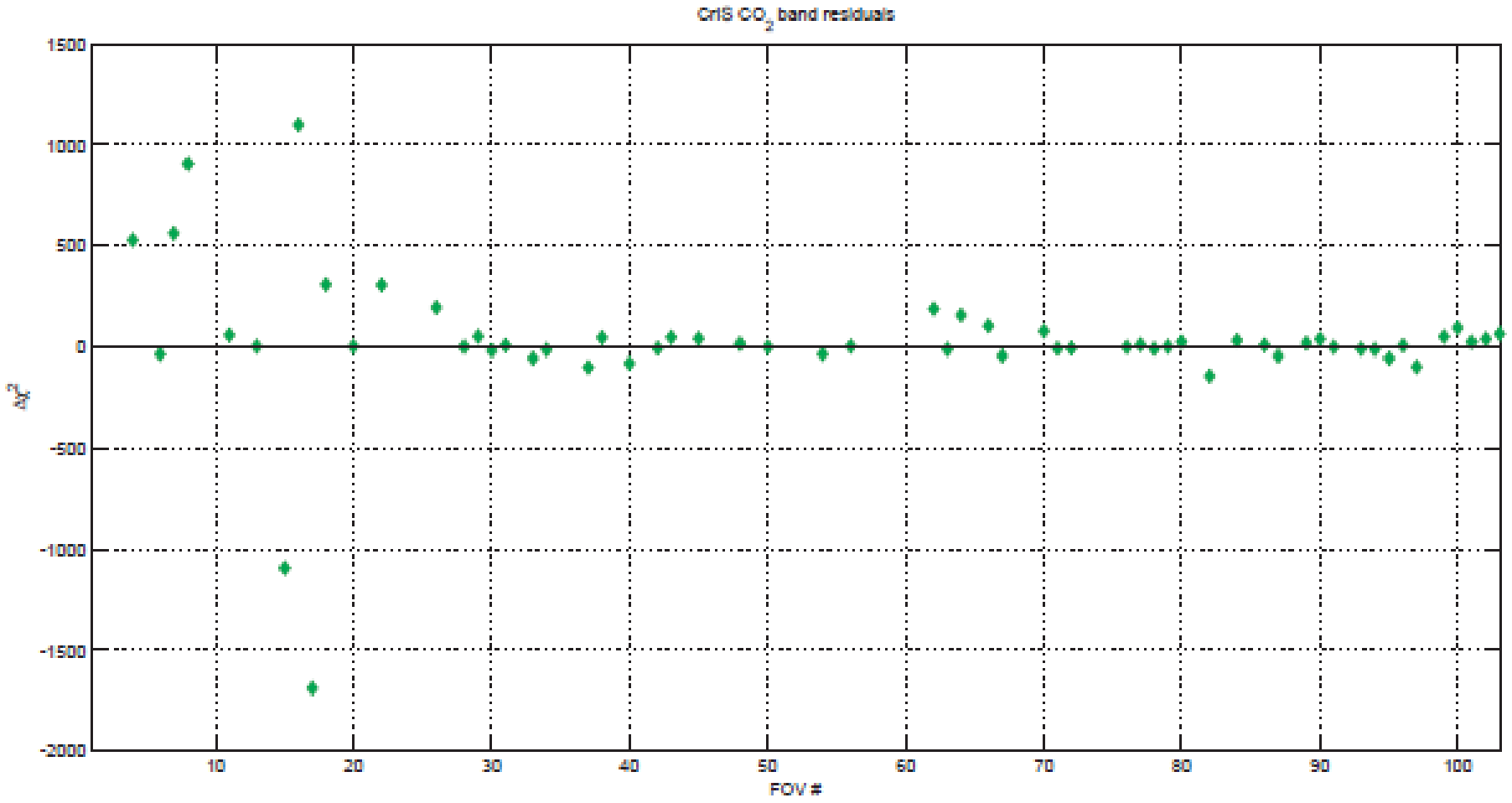
Single profile retrieval: assimilation of transformed product



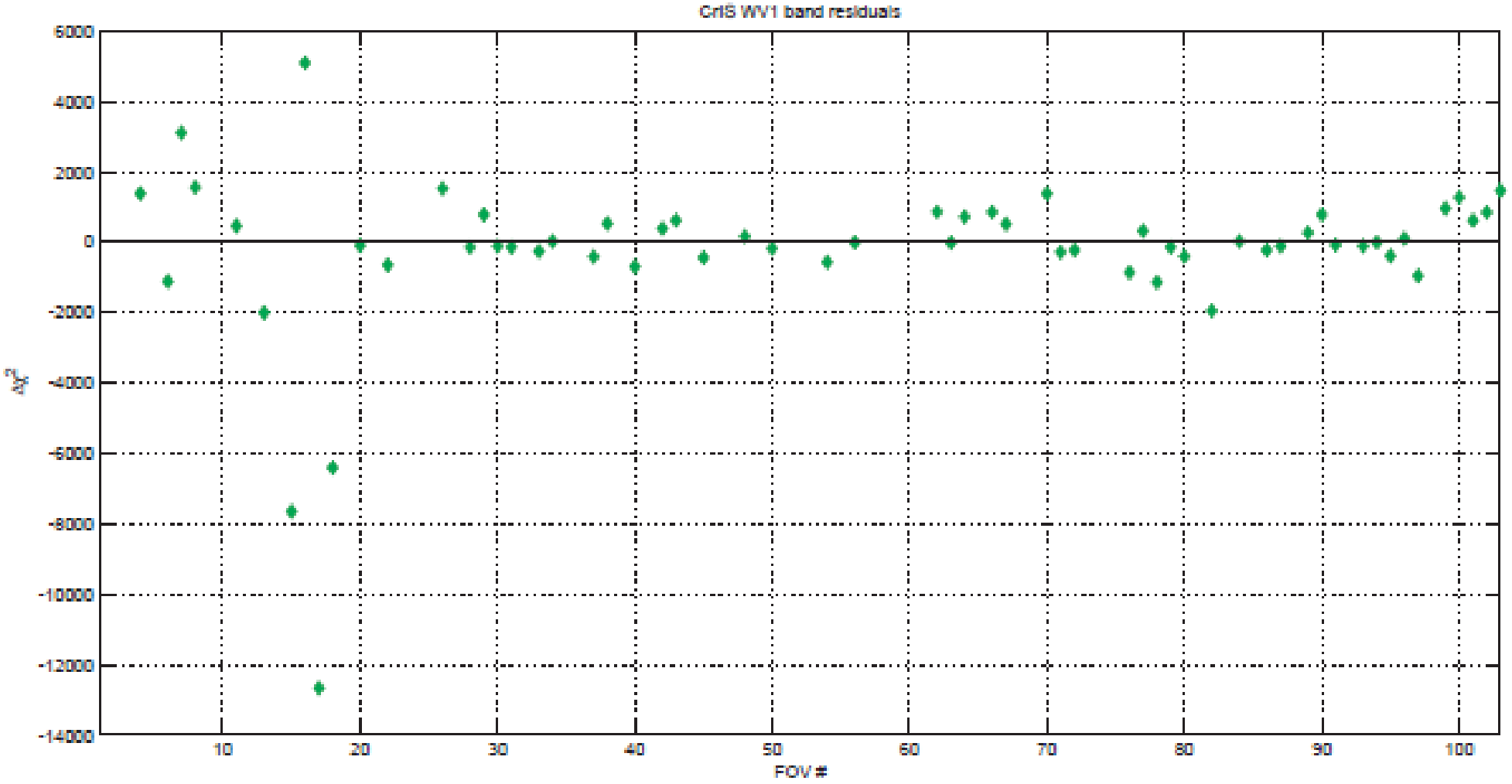
Impact on forecast

- Period of 3 weeks is too short to say anything conclusive.
- On next slides show illustration from Antonelli et al where impact is documented through comparison with CrIS observations.

CO2 domain: 650 - 780



WV: 1088 - 1261


CrIS WV1 band residuals
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
10
20
30
40
50
60
70
80
90
100
FOV #

Demonstration Projects

- Projects considered so far:
  - DA in regional scale NWP, will be continued with DA in global scale NWP
  - 2D Analysis using LAPS (FMI), NiNjo (DWD) and MESAN (SHMI)
  - 3D analysis for NWC (KNMI)
    - Mixed results (positive FMI, DWD, neutral SHMI, KNMI) mainly because of the small datasets considered.

Evolution of Demonstration Projects

- Move from historical case studies to a NRT demonstration context:
  - running the processor over a long period (many months) using all available observations (IASI, CrIS) and provide the data in NRT to users

Evolution of processor

- Change minimisation method to make the method robust using the information matrix

$$-\Lambda^t \Delta y + \Delta x^a + \left(\Gamma + \Lambda^t \Lambda\right)\Delta x = 0$$

- Above equation is in feature space and represents a set of 30 equations
- Evaluate possibilities to perform retrievals in OSS node space
- Critically evaluate the a-priori error covariance with respect to
  - Representation errors, i.e. sampling at different scales by NWP and satellite
  - Representation of small scale variability

Summary

- Introduced MTG-IRS mission and level 2 processing,
  - To validate the processor
    - Comparison to independent observations/model data
    - Involve the users especially nwc
    - the intercomparison study
- Presented the current evolution plans
  - L2 processor
    - To explore retrievals in OSS node space and minimisation in feature space
  - Validation
    - NRT demonstration
- Further information:
  - http://www.eumetsat.int/website/home/Satellites/FutureSatellites/MeteosatThirdGeneration/MTGResources/index.html
  - select the “MTG Reports from EUMETSAT Scientific Studies”

Last slide

- Thank IRS Mission Advisory Group for continuous support:
  - Antonelli, Paolo (SSEC), Clerbaux, Cathy (Latmos, France), De Haan, Siebren (KNMI, The Netherlands), Fontan, Anne-Claire (Météo-France, France), Friedl-Vallon, Felix (KIT, Germany), Gregow, Erik (FMI, Finland), Holm, Elias (ECMWF, UK), Iršič-Žibert, Mateja (ARSO, Slovenia), Koepken-Watts, Christina (DWD, Germany), Lavanant, Lydie (Météo-France, France), Martinez, Miguel (AEMET, Spain), Pavelin, Edward (Met Office, United Kingdom), Serio, Carmine (DIFA, Italy), Strelec Mahović, Nataja (DHMZ, Croatia), Vocino, Antonio (CNMCA, Italy)
- Contact: Stephen.tjemkes@eumetsat.int
- Questions?