

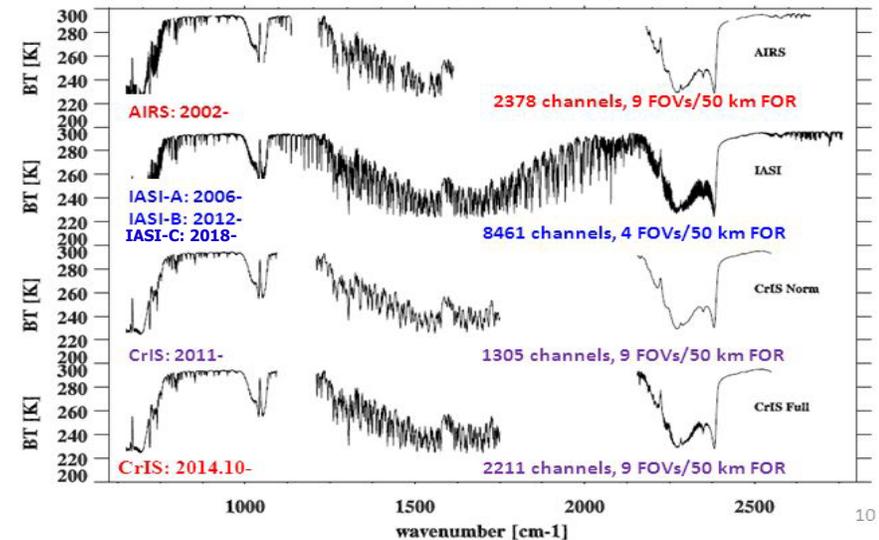
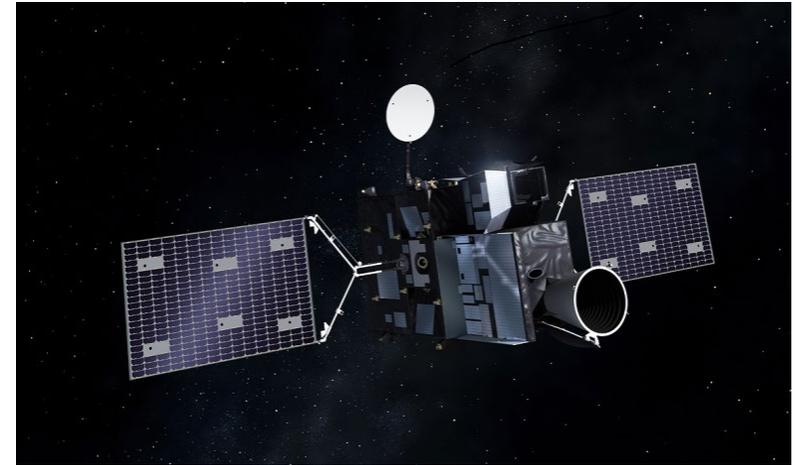
MTG-IRS: Scientific Improvements For a User-Friendly Mission

D. Coppens, B. Theodore, T. August,
T. Hultberg, C. Goukenleuque, Jochen Grandell

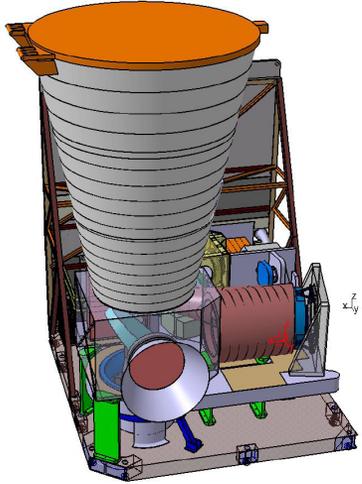


The IRS mission

- The Infrared Sounder (IRS) is one of the two MTG-S instruments; it is developed by OHB (Germany) and Thales (France)
- It aims at providing high-spatial and temporal information of atmospheric temperature and moisture structures; main targeted users: NWC, NWP
- There has never been (yet) any operational IR sounder in GEO. IRS is however related to GIFTS (US, abandoned) or GIIRS (China, demonstrator currently flying)
- IRS will capitalize on 20 years experience of operating IR hyperspectral sounders from the LEO: AIRS, CrIS and IASI



IRS instrument



IRS is an imaging FTS, based on a Michelson interferometer:

- Corner cube mechanism (CCM) similar to IASI
- **3 laser beams** for monitoring the CCM speed variations as well as its 3D position
- Maximum **OPD on ground**: 0.828 (LWIR) or 0.829 (MWIR) cm
- **Detector**: 160x160 pixels (500x500 km) measured in 10 sec, **two spectral bands**: 700-1210 and 1600-2175 cm⁻¹

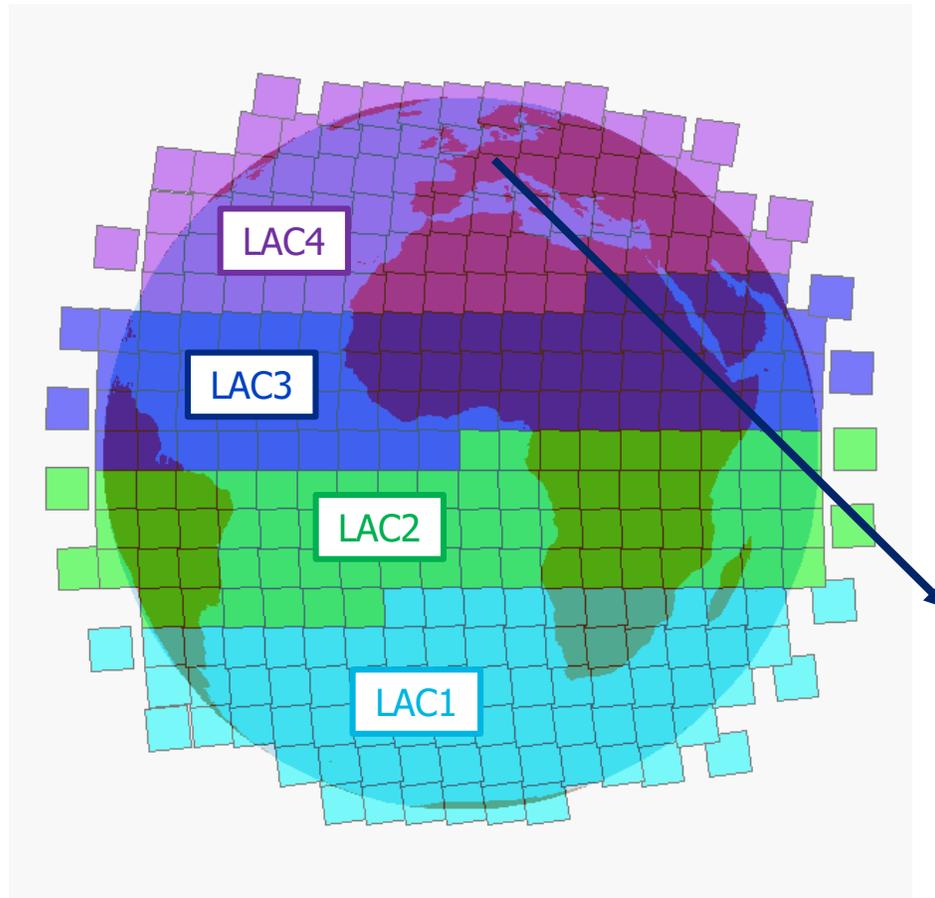
IRS is a step forward wrt. IASI:

- New technology
- Larger field, better spatial resolution
- Higher temporal repetition
- New user community → stringent timeliness requirement to cope with NWC needs...
- Different instruments → different calibration methods/sequences

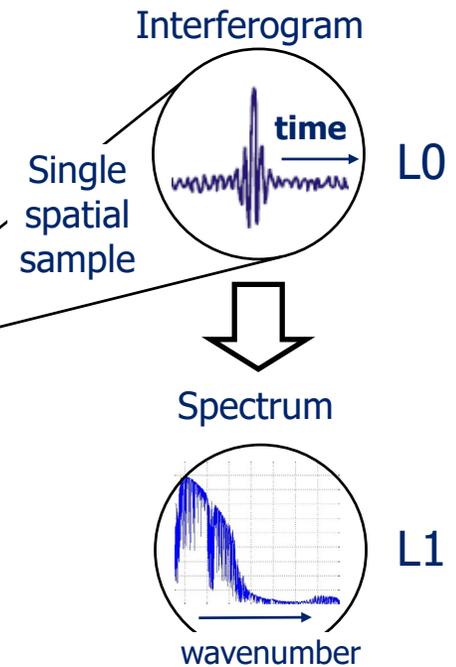
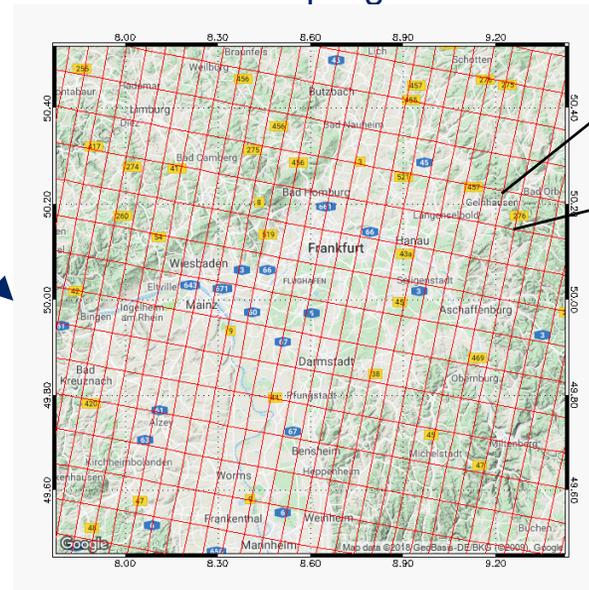
IASI	IRS
<i>Instrument</i> Single laser	<i>Instrument</i> Multiple lasers
<i>On-board processing</i> Non-Linearity correction Spike detection Radiometric calibration	<i>On-board processing</i> Non-Linearity correction Spike correction Filed compensation (software)
<u>L1 processing</u> Spectral calibration Spectral Resampling Spectral shape removal and apodisation	<u>L1 processing</u> Apodisation Radiometric Calibration Spectral calibration Resampling Spectral shape removal

IRS scanning sequence

- ✓ The Earth disk is split in 4 Local Area Coverage (LAC) zones, each of them covered in 15 min by a succession of “steps and stares” called dwells
- ✓ LAC4 (northern mid-latitudes) will be covered every 30 minutes
- ✓ LAC1, 2, 3 will be alternatively viewed in-between



Each dwell consists of 160x160 pixels yielding a high spatial sampling



IRS is a challenge...

- For the industry...
- ... but also for the users who will need to cope with unprecedented amount of data !
- For users to draw the best benefits of IRS products, EUMETSAT strives to make them as user-friendly as possible. This includes:
 1. Information content: uniformization (1.1), spectral sampling (1.2)
 2. Compression: distribution of the spectral radiances as principal components
 3. Timeliness: the L2 processing has been completely redesigned to improve the availability of the L2 products
 4. User awareness: test data generation & distribution

1.1 - Uniformization

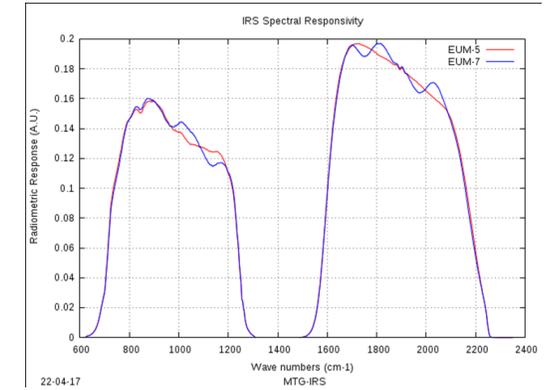
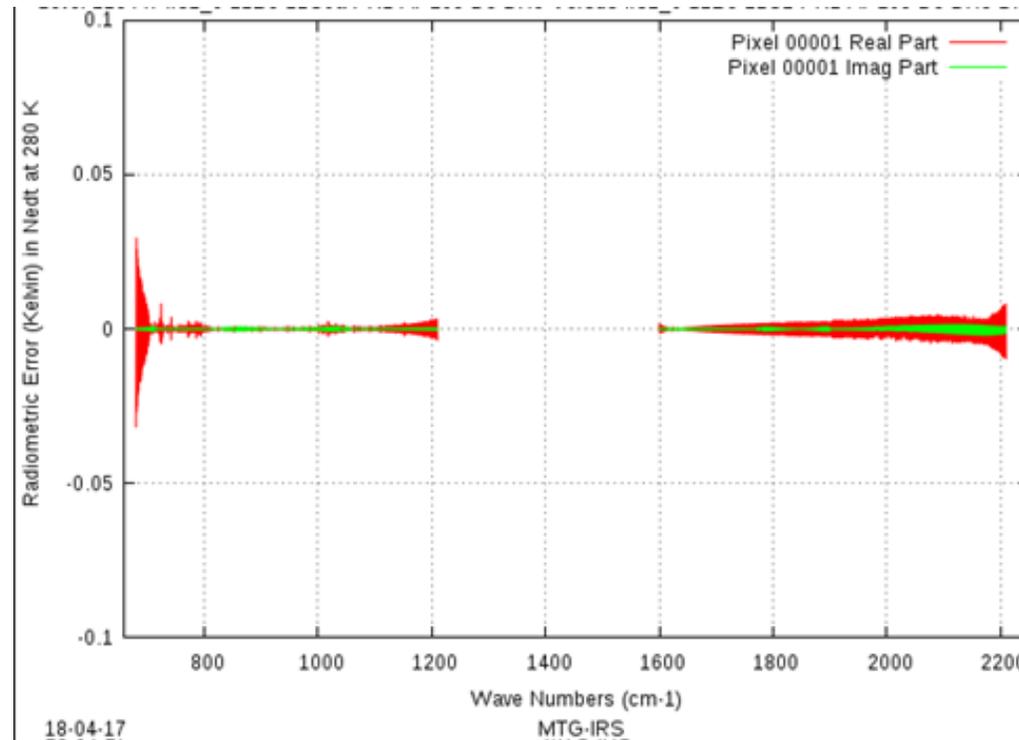
- Uniformization is a specificity of the EUMETSAT HSIR L1 processing
- It consists in **removing instrument effects** from the spectra not corrected by the on-board/on-ground processing
- Impact on IRS L1 processing: **an accurate SRF estimation is required**
- Impact for users of the IRS L1 products: IRS L1 radiances have the same spectral response function
 - ✓ no temporal variation
 - ✓ independent of the detector position
 - ✓ independent of the spectral channel

→ No need to update the forward models

1.1 - Uniformization - example

Effect of the radiometric response variability

**With
Uniformisation**



1.2 - IRS L1b spectral sampling

Mission specification:

- ✓ Maximum OPD (Optical Path Difference) of 0.8 cm → spectral sampling of 0.625 cm⁻¹

Current situation:

- ✓ The interferograms received on ground are with a band dependent max OPD of 0.828/0.829 cm
→ Spectral sampling of 0.6031/0.6036... cm⁻¹

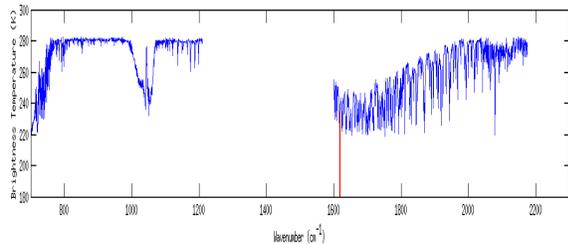
Three options have been envisaged:

- ✓ Keep the L0 sampling (band dependent, 0.6031... cm⁻¹ in LWIR, 0.6037 cm⁻¹ in MWIR)
- ✓ Under-sample to 0.625 cm⁻¹ (to have similar spectral sampling of CrIS, GIIRS or HIRAS)
 - ✓ Information loss → Loss of 28 channels in band 1, 31 in band 2
 - ✓ Introduction of artefacts
- ✓ Oversample of the L0 grid (to e.g. 0.6 cm⁻¹)
 - ✓ No artefact introduced
 - ✓ Similar spectral sampling in each band

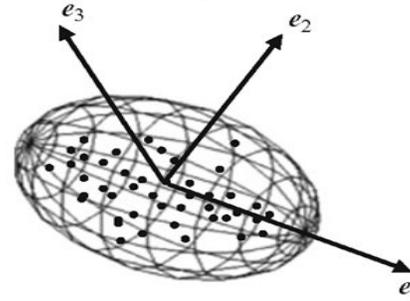
→ Decision to keep the instrument sampling to avoid the sampling error

2 - Principal components compression

IRS L1b spectrum



eigenvectors



PCS

Atmospheric signal
+ noise

Residuals

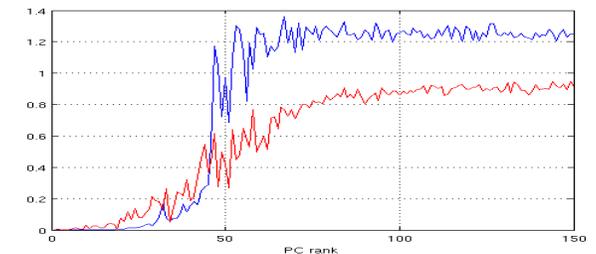
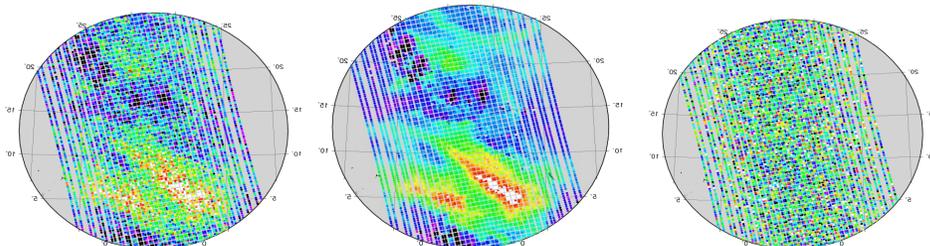
Noise

PC compression with static eigenvectors based on a large global set of past observations works very well but could miss rare features

Global?

Local?

Eigenvectors computed for the local set of current observations retain more noise and less atmospheric signal.



2 - Principal components compression

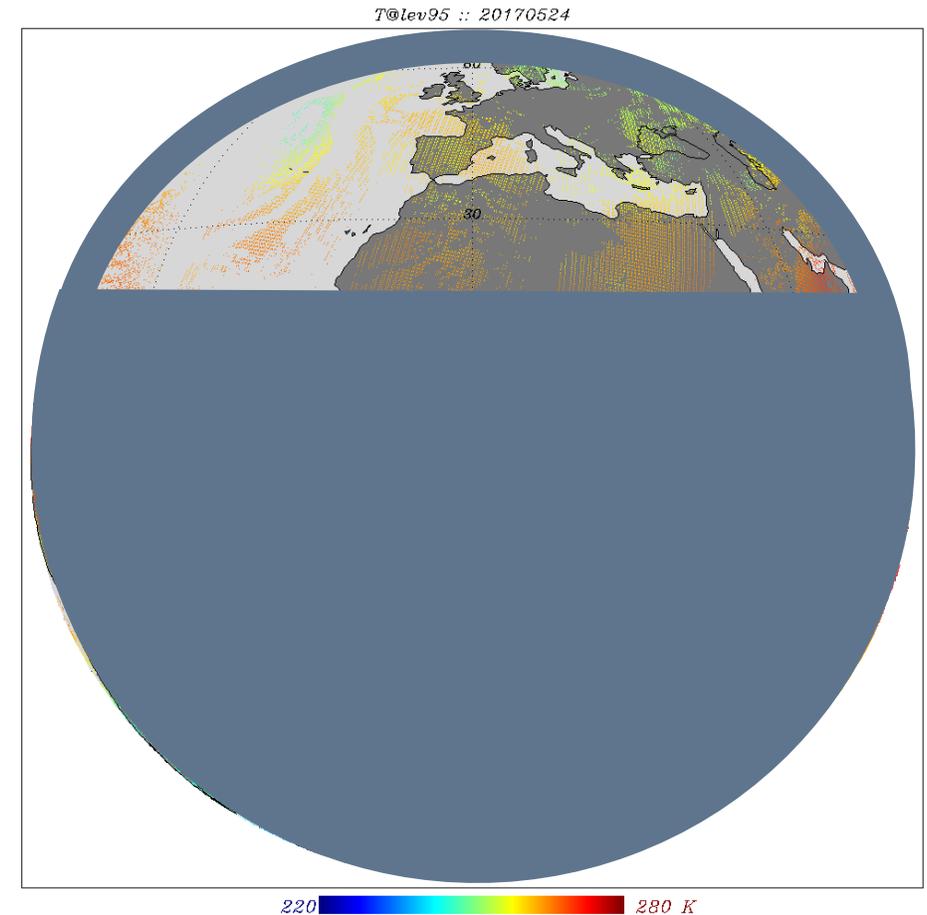
	Global	Local
Data Producer	Eigenvectors (EV) monitored and maintained off-line	Extra on-line computations: EV-decomposition for each dwell
User	Static EV basis	New EV basis / dwell
	(PCS + quality indicators)/pix	(PCS + quality indicators)/pix + EV/dwell
	Less noise in leading PCs Weak signal distinguished from noise	More noise in leading PCs Less noise/signal separation
	New features not retained in PCS → EV basis update may be required	All local "strong enough" signals retained in leading scores

2 - Hybrid PC approach for the level 1 products

- **A new method has been proposed**: Distribution global PCs on a stable (fixed) basis + n local PCs to capture possible outliers, called **hybrid approach**.
- ✓ Experiments have been performed on case studies to validate the number of local PCs: 5 local PCs allow to completely capture the atmospheric signal
- ✓ For example, the local PCs are good to capture the trends at 923 cm⁻¹ (CFC-12) and at 948 cm⁻¹ (SF6)

3 - IRS L2 processing status in 2016

- ✓ Only clear sky (~10-15% of possible retrievals)
- ✓ LAC-4
- ✓ No slanted views
- ✓ Slow processing, does not meet users requirements of 30 minutes for the level 2



3 - Why not use the IASI experience?

Why use the IASI heritage?

- ✓ Similar types of measurements for IRS (assuming L1 SRF uniformisation)
- ✓ IRS spectral bands are within IASI spectral bands
- ✓ IASI L2 operational products are globally validated and reliable
- ✓ CPU-wise, IASI L2 processing is very efficient
- ✓ Maintainability across EUMETSAT hyperspectral missions

IRS specificities, needing immediate assessment:

- ✓ IR-only, no micro-wave companion
- ✓ Coarser spectral resolution/coverage
- ✓ viewing geometry
- ✓ Data volume: ~100x more than IASI
- more sensitive to clouds
- sounding precision, AC/AQ detectability
- high local zenith angles, quasi-limb view
- CPU-effective processing required

Opportunities for future:

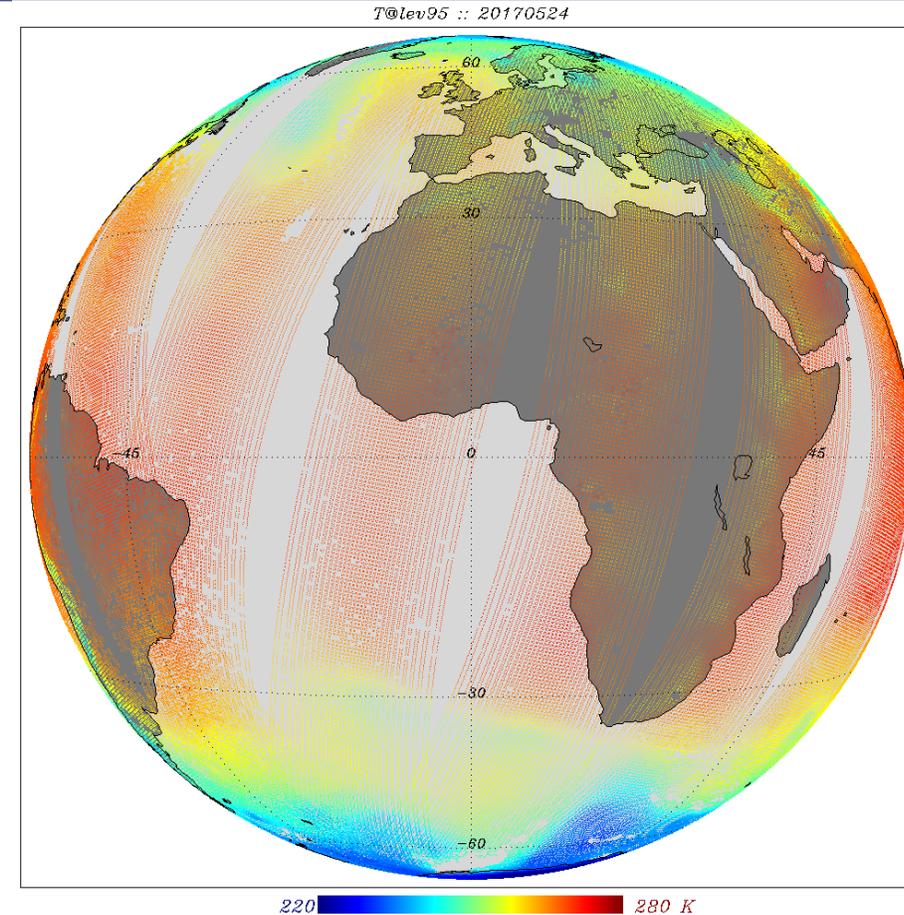
- ✓ High spatial resolution
- ✓ High temporal repetition
- ✓ Complementarity GEO/LEO



Currently addressed through internal and external studies

3 - IRS L2 processing – now

- ✓ All sky retrievals
- ✓ All LACs
- ✓ Slanted views are studied
- ✓ 100 times faster processing, which meets users requirements of 30 minutes for the level 2



4 - Test data for MTG – IRS

Types of use for test data

Check of format and data contents

- No high physical realism needed
- Identical (very close) to final contents and format
- Good documentation

Continuous pre-launch data stream for final infrastructure and processing tests

Technical tests of data processing and methods (applications)

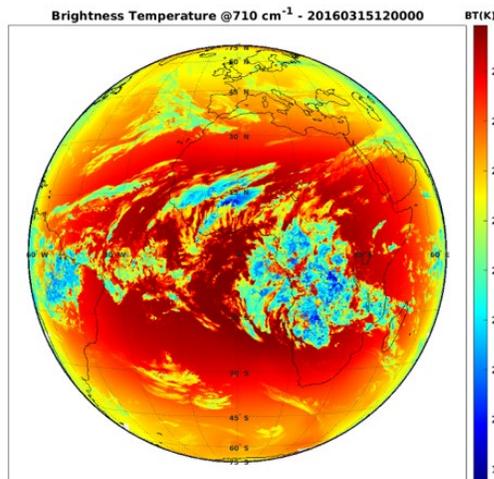
- Realistic underlying profiles and RT (L2: retrieval method)
- Realistic range of atmospheric situations and observing conditions
- Realistically simulated instrument & noise characteristics

Scientific investigations of data characteristics or methods and applications

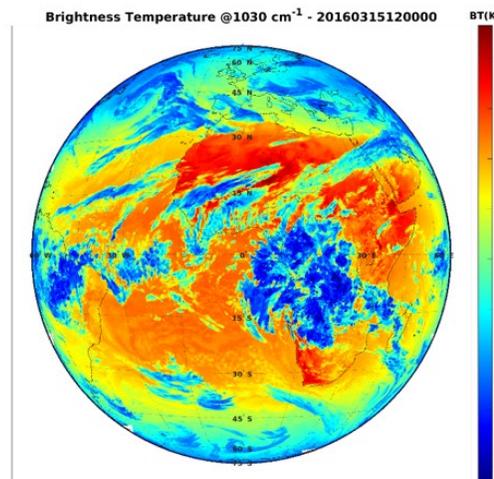
- Simulated data with fully controlled and understood atmospheric conditions and instrument characteristics
- or
- Data as realistic as possible, potentially based on very high resolution NWP
- Realistic observing conditions and use of full instrument and noise characteristics

4 - Test data for IRS

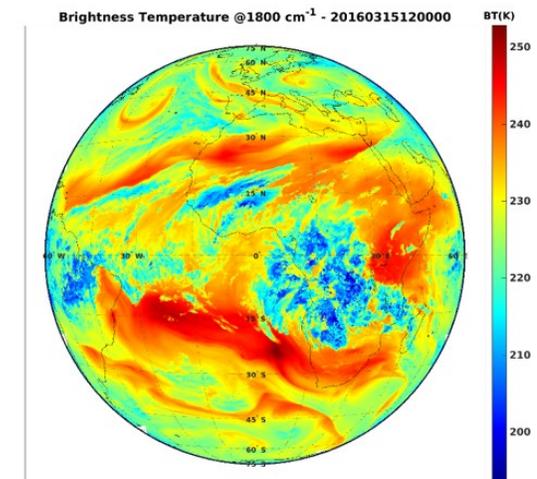
- ✓ EUMETSAT is currently working closely with the user community to understand their needs and prepare test data
- ✓ **Example:**
 - ✓ Full coverage of the Earth's disc as seen by MTG-IRS
 - ✓ Cloudy scenes
 - ✓ Take account of the Atmospheric state along the geostationary line of sight



CO2 region



Ozone channel



Water vapor channel

Summary

- ✓ **The MTG IRS Level-1 and Level-2 processings are being consolidated**
➔ The operational processing development has started beginning of 2018
- ✓ **Some open issues have been addressed:**
 - ✓ **Uniformization:** no need to provide the users with terabytes of SRF data
 - ✓ **Spectral sampling:** best spectral information will be provided to the users
 - ✓ **Data dissemination:** improvement of the information content using hybrid principal component compression
 - ✓ **Level-2 processing:** complete redesign based in IASI experience, all LACs, all sky + processing time now well under the requirements
- ✓ **IRS on MTG-S is on-track, to be launch in 2023.**

Thanks for your attention