

# Hyperspectral Infrared L2 Product Development at EUMETSAT

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*EUMETSAT*

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- The EUMETSAT Hyperspectral Infrared L2 products
- Updates and preparation of the next generation of instruments
- On going developments



# The EUMETSAT Hyperspectral Infrared L2 products

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	Platform	Lifespan	Orbit	Sampling	Footprint
IASI	Metop	2007-2030	LEO	0.25 cm <sup>-1</sup>	12 km
IASI-NG	Metop-SG	2025-2046	LEO	0.125 cm <sup>-1</sup>	12 km
IRS	MTG-S	2025-2041	GEO	0.61 cm <sup>-1</sup>	4 km

## EUMETSAT HSIR products

Level	Description
L1C	Radiances
L1D	Principal Components
L2	Geophysical Variables

Products: 3D Winds

- Type: 3D fields
- Algorithm: Optical Flow



EUMETSAT AC SAF Products

Products: CO, O<sub>3</sub>, NH<sub>3</sub>, HNO<sub>3</sub>, SO<sub>2</sub> ...

Products: Temperature, Humidity and Ozone

- Type: Profiles
- Algorithm: PWLR<sup>3</sup> (ML)

Products: Cloud mask, fraction, top height and phase

- Type: Single layer
- Algorithm: OEM

Products: Surface temperature and emissivity

- Type: Skin SST/LST and ε PCs
- Algorithm: PWLR<sup>3</sup> (ML)

Products: Atmospheric composition (CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>)

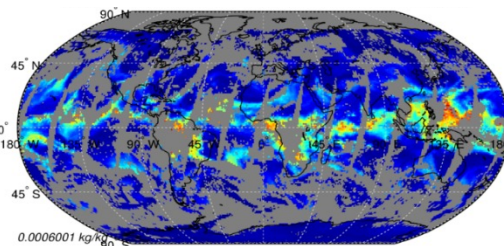
- Type: Profiles or column
- Algorithm: PWLR<sup>3</sup> or ANN (ML)



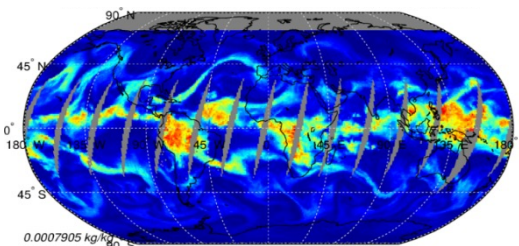
# The PWLR<sup>3</sup> algorithm for HSIR geophysical products

## PWLR<sup>3</sup>: Piece-Wise Linear Regression in 3D

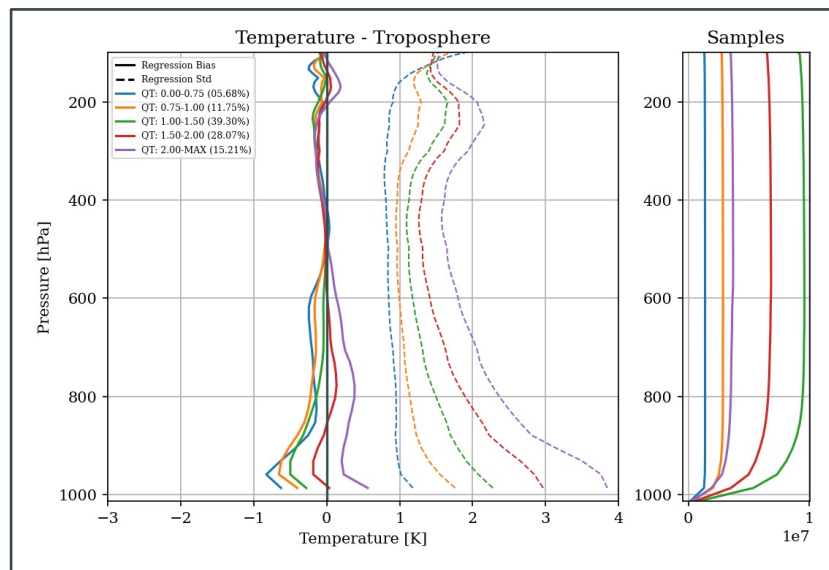
- ✓ ML for Geophysical Retrievals
- ✓ IR-MW Synergy
- ✓ Horizontal correlation
- ✓ Use of full IASI spectra (PCs)
- ✓ Ensemble retrieval approach
- ✓ Robust Error Characterization



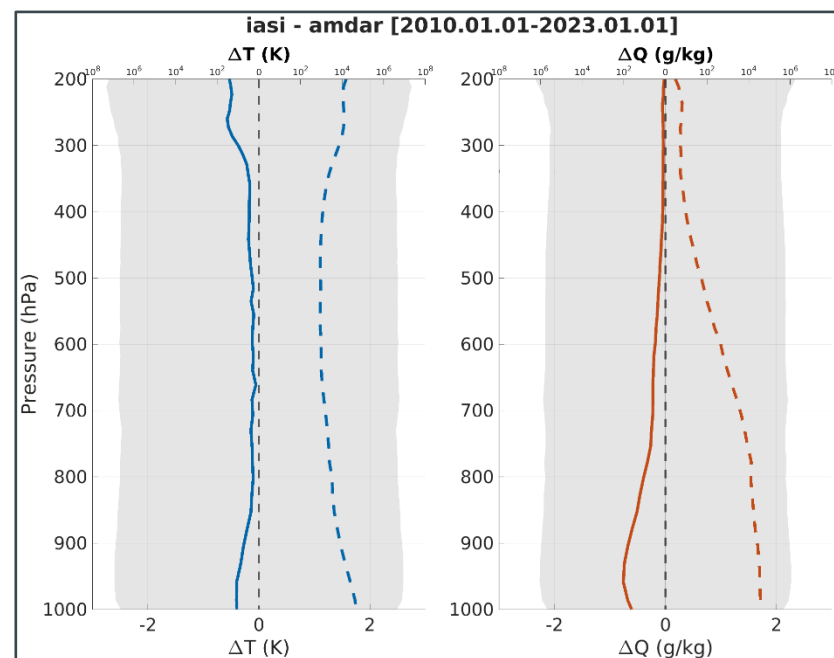
OEM clear sky



PWLR<sup>3</sup> full sky



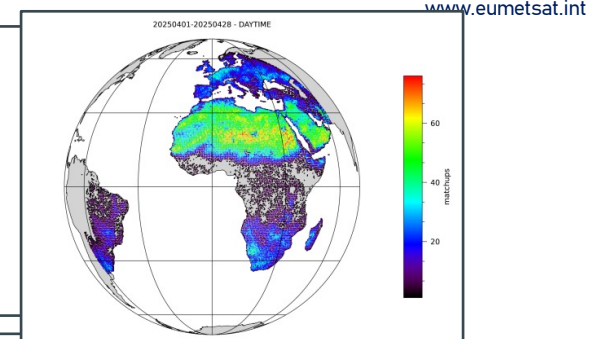
Impact of quality indicator ( $Q_i$ ) stratification on IASI-IGRA Temperature comparison



2010-2023 IASI-AMDAR Comparison Temperature (left) and Humidity (right)

## Q2/2025: PWLR<sup>3</sup> quality update (IASI L2 v6.8)

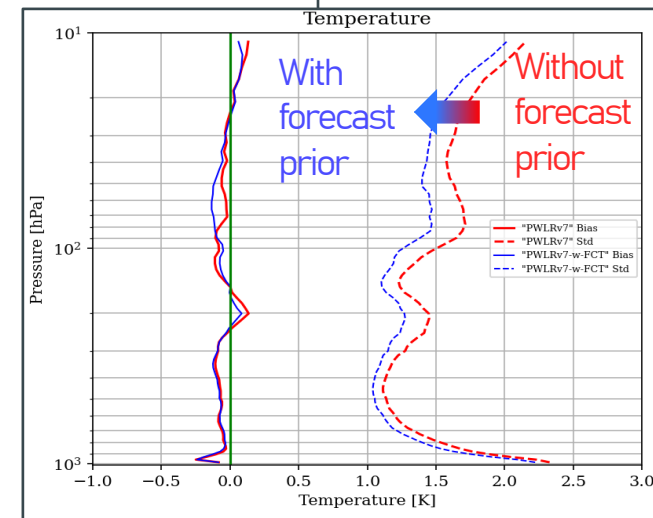
- PWLR<sup>3</sup> can now be used as single main algorithm
- Will be used to provide **high quality IRS L2 products** despite the very high data rate



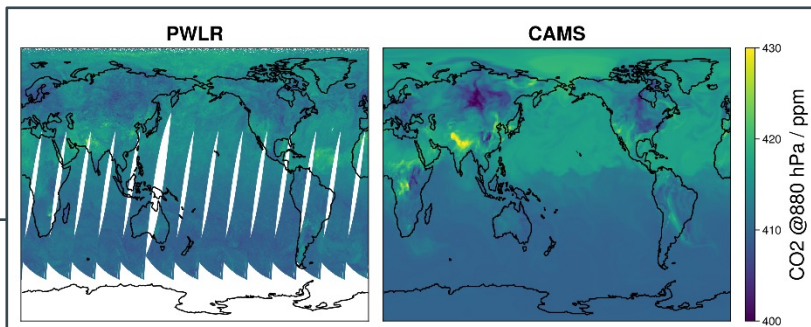
## 2027: New major version and new format (IASI L2 v7, IRS/IASI-NG)

- Fix grid → Sigma levels
- Scalar  $Q_i$  → Full error estimation profiles
- New demonstrational products:
  - TWLC/TWIC
  - CO<sub>2</sub>/N<sub>2</sub>O vertical information
  - Instability indices
  - T/q profiles with forecast prior

IRS PWLR<sup>3</sup> LST test data



Impact of using FCT prior on PWLR<sup>3</sup> Temperature



Detection of tropospheric CO<sub>2</sub> features in the v7 IASI L2 PWLR<sup>3</sup> CO<sub>2</sub> product

## Using L2 observation operators to assimilate HSIR PWLR<sup>3</sup> profiles

- ✓ L2 observation operators
  - Readily available and **applicable in cloudy situations**
  - Can be constructed such that they **eliminate systematic errors**
- ✓ Helps to deal with **high data rate** instruments like IRS
- ✓ EUMETSAT Studies:
  - Study #1 with ECMWF: Salonen et al. 2024
  - Study #2: on going, on regional assimilation (end in 2026)

Observation operator:

$$H = EV(AC_{xx}A^T)_{[1:n]}$$

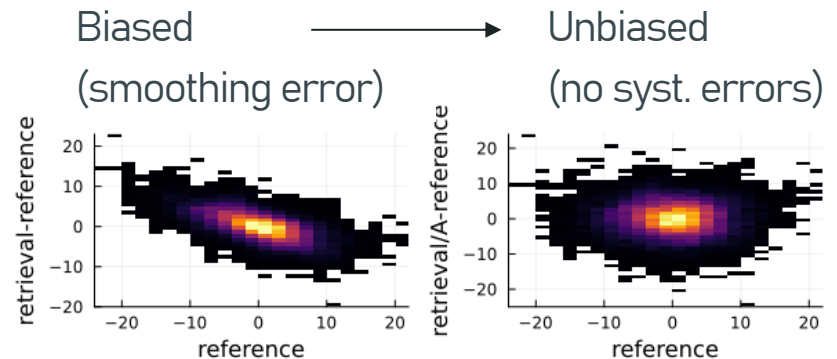
To use in assimilation cost function as

$$(Hx - 1/A Hx_r)^T R^{-1} (Hx - 1/A Hx_r)$$

A: Averaging Kernel

C<sub>xx</sub>: Natural variability of the profiles

AC<sub>xx</sub>A<sup>T</sup>: atmospheric variability that can be retrieved



Scaling the retrieval by 1/A increases random noise, **but removes systematic errors**: a key trade-off in L2 assimilation.



Surface emissivity can be retrieved from HSIR spectra using a physically meaningful linear programming retrieval

Emissivity,  $e$ , modeled as a combination of 87 ASTER base spectra,  $B$ .



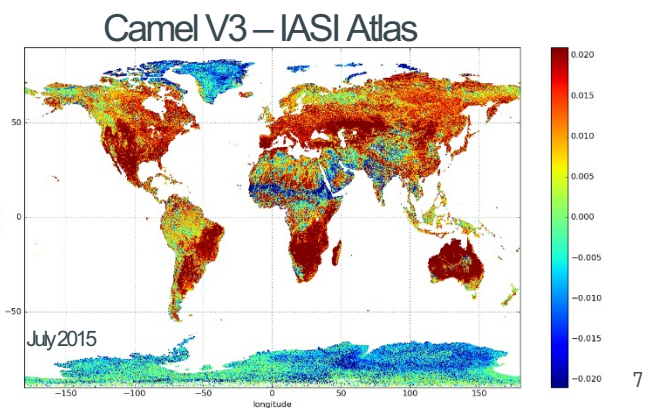
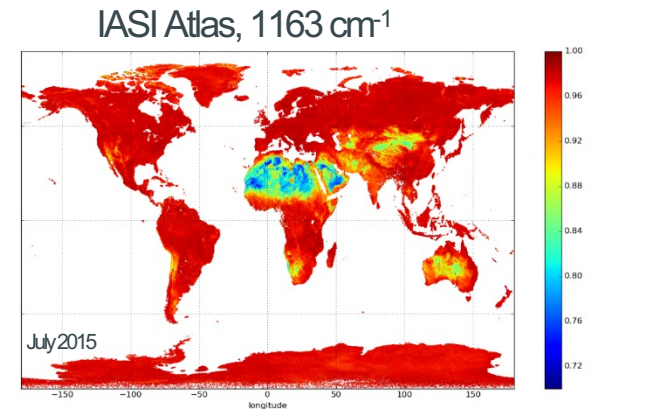
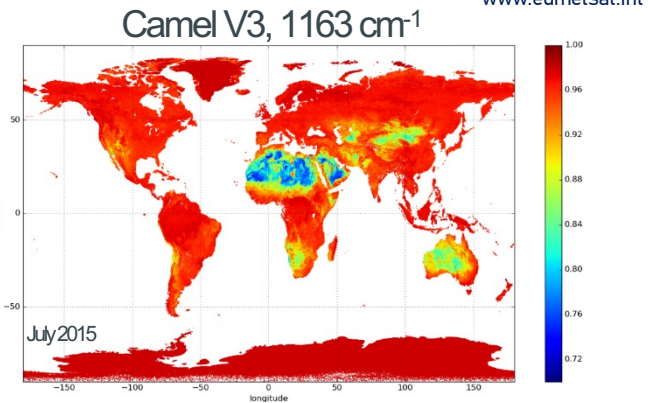
$$\begin{aligned}
 e &= B\lambda_0 \\
 0 &\leq \lambda_0 \\
 \sum \lambda_0 &= 1
 \end{aligned}$$

Radiance fit by simultaneous adjustment of emissivity and surface temperature,  $T_s$ .



$$\begin{aligned}
 & \text{Minimize } \sum |r_{IASI} - r_{LP}| \\
 r_{LP} &= r_F + KTs\Delta T_s + KeB(\lambda - \lambda_0) \\
 r_F &= RTTOV(e, T_s) \\
 0 &\leq \lambda \\
 \sum \lambda &= 1
 \end{aligned}$$

Expected for IASI L2 v7, a bit later for new instruments





- EUMETSAT is preparing for IASI-NG and IRS L2 operations
  - Use of IASI heritage for IASI-NG and IRS...
  - ... and vice versa: next gen developments are used to improve IASI L2
- EUMETSAT is improving its HSIR L2 products
  - Continuous improvement of existing products
  - Development of new products and innovative algorithms
  - Use partners expertise and users feedbacks to provide the best products for all instruments

