Total column water vapor for Sentinel-4 and Sentinel-5

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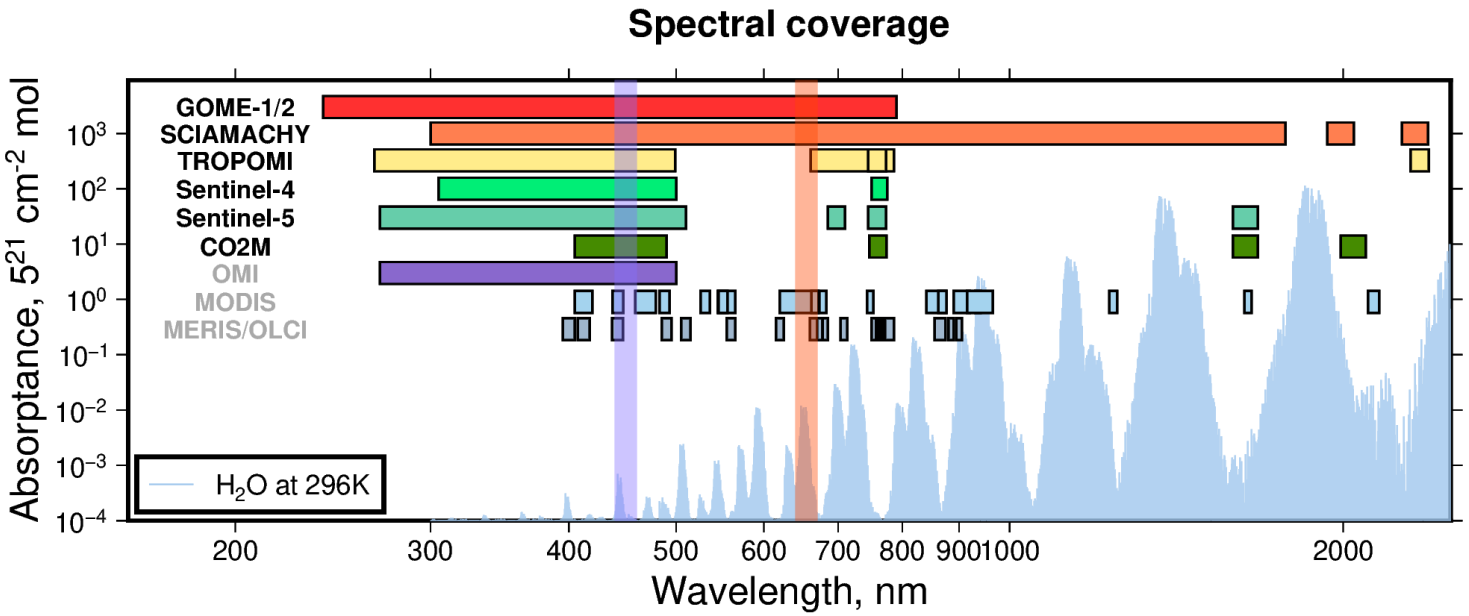
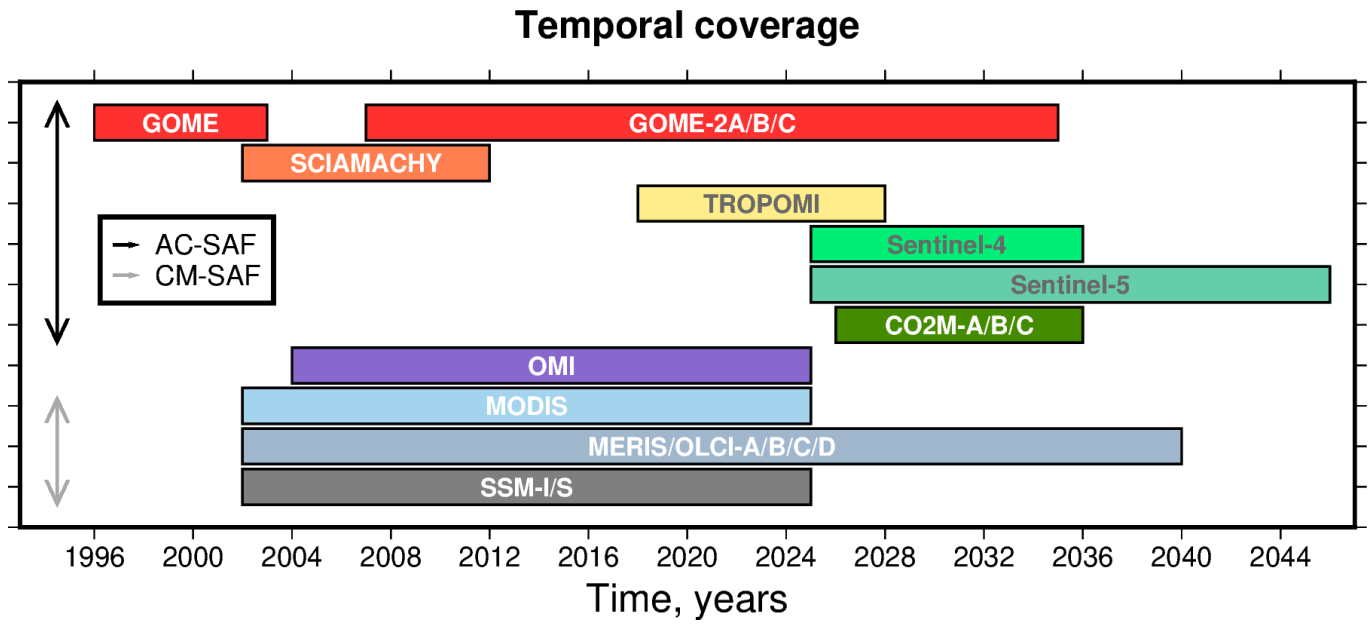
Motivation: platforms





The **blue band of water vapor** is the weakest but it is sensed by more sensors and the surface is less reflective in the UV

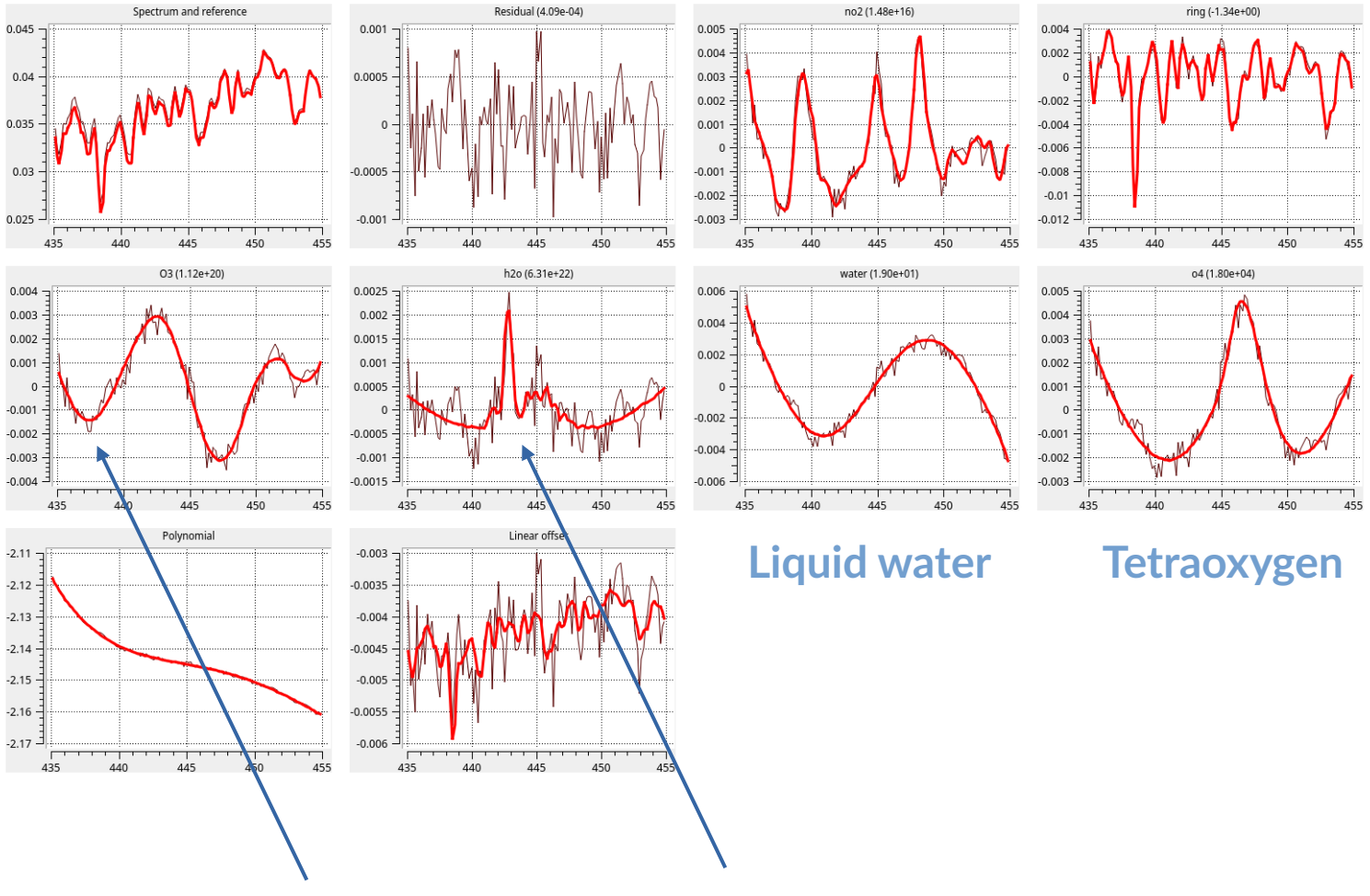
→ best trade off between sensitivity and coverage over both land and oceans

Fitting windows are different from other works

TROPOMI (S5P) 435 – 455 nm
GOME-2 (MetOp) 427.7 – 455 nm

GOME, SCIAMACHY, UVN (S4 and S5) yet to be defined

Motivation: DOAS



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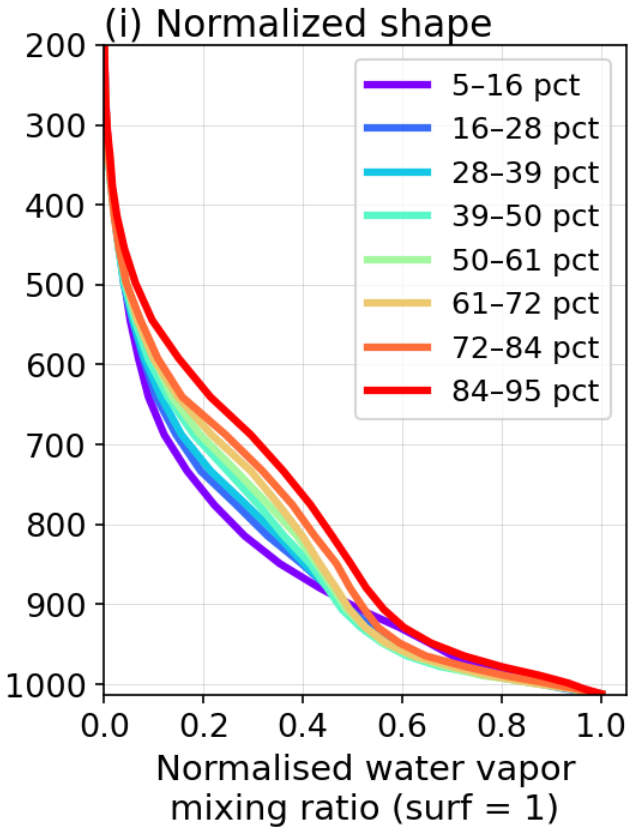
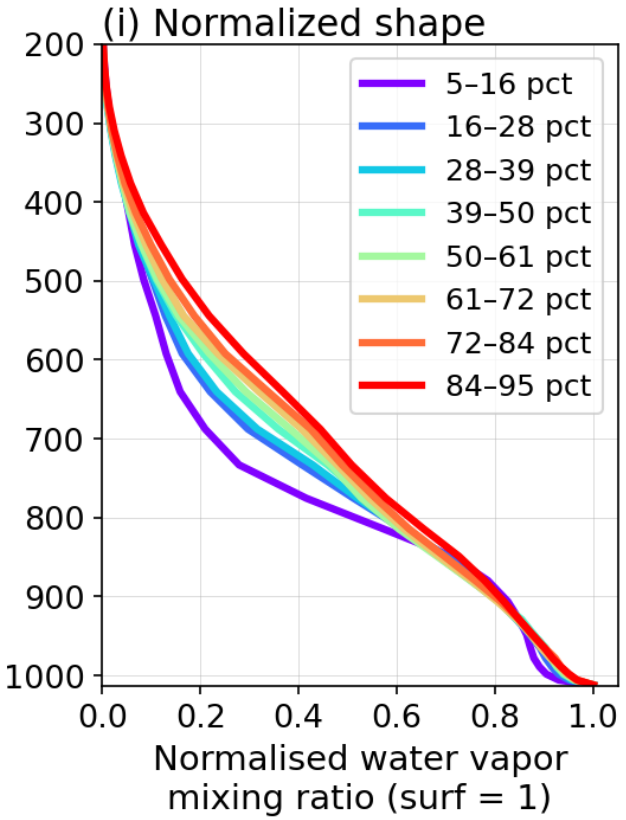
Suboptimal cross-sections account for most of the residuals

Algorithm: a-priori WV profiles for Sentinel-4

Mediterranean Sea
35-42°N, 10-25°E
July 8:00 UTC



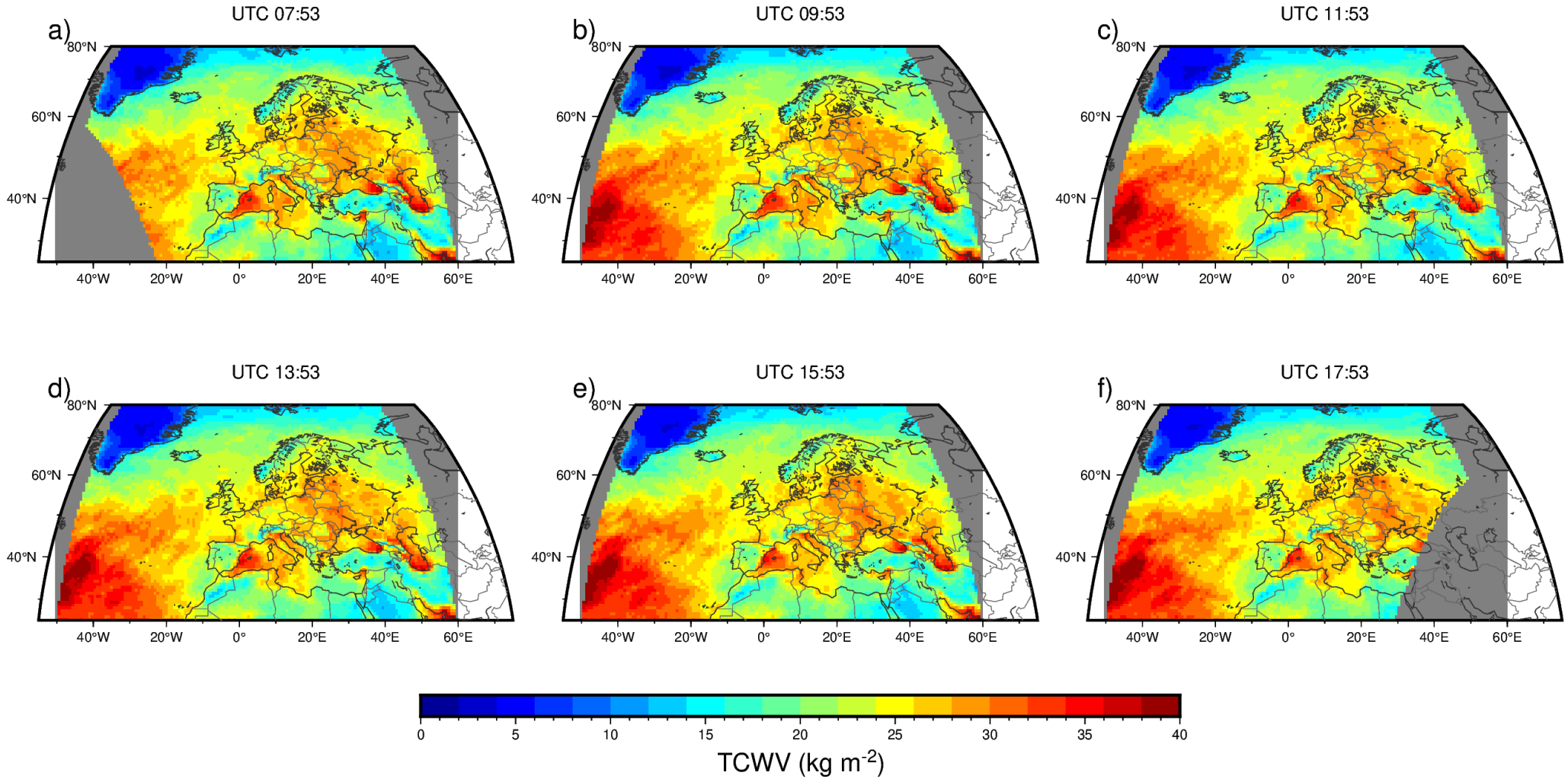
Continental Europe
47°-54°N, 5°-20°E
July 8:00 UTC



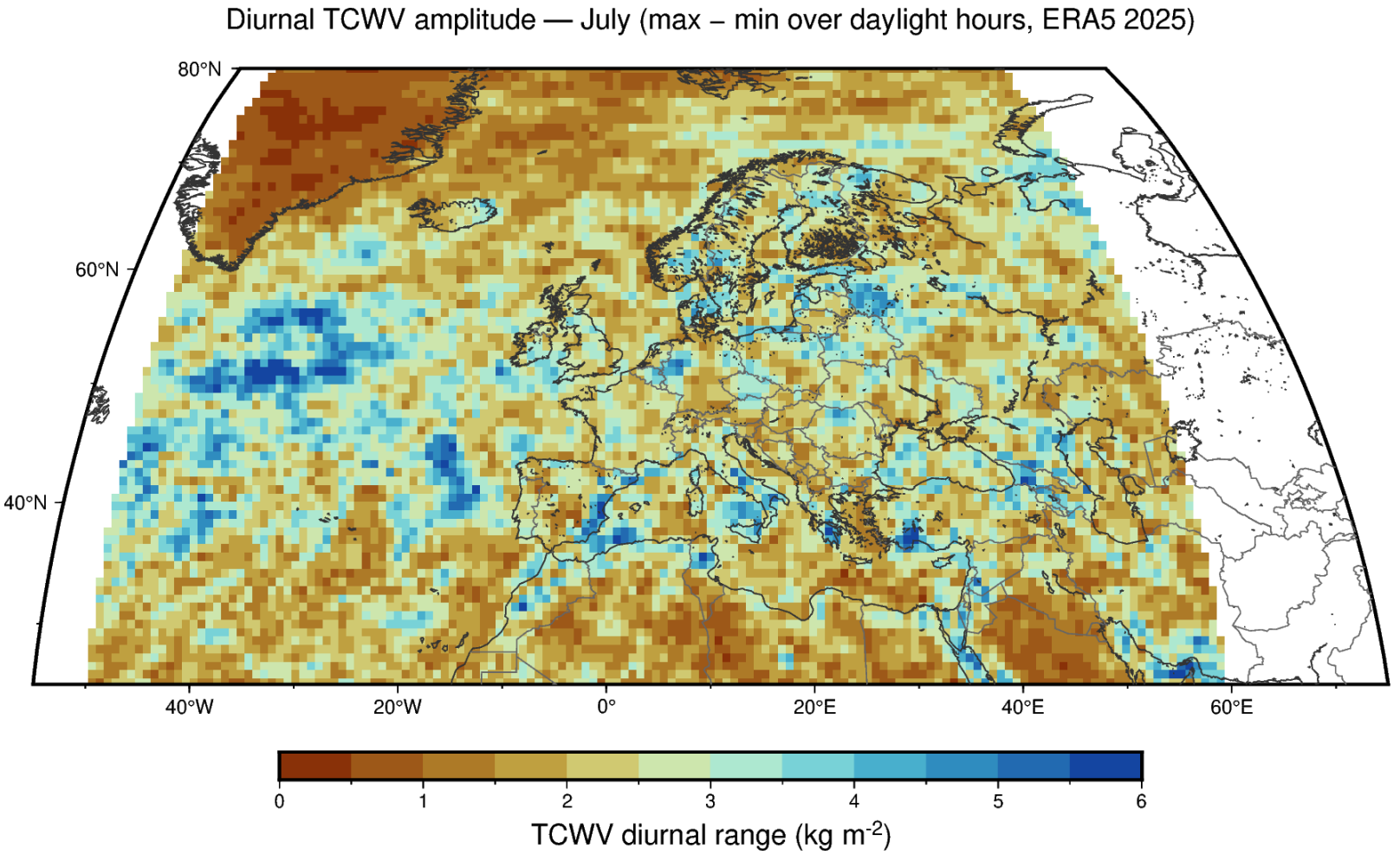
- S4_TARGET_HOURS: HH + 0.8793 h for HH = 0..23 (scan midpoint ≈ HH:52:45 UTC, derived from March 2026)
- ERA-5 for 2025 only
- ERA5 resolution: 1-hourly (unlike polar sensors which use 6-hourly), 0.25° side
- Iteratively compute VCD with box air mass factors to match the proper TCWV range for a given profile

Algorithm: TCWV daily cycle

Sentinel-4 GCA — mean TCWV at different scan times (July 2025, ERA5)

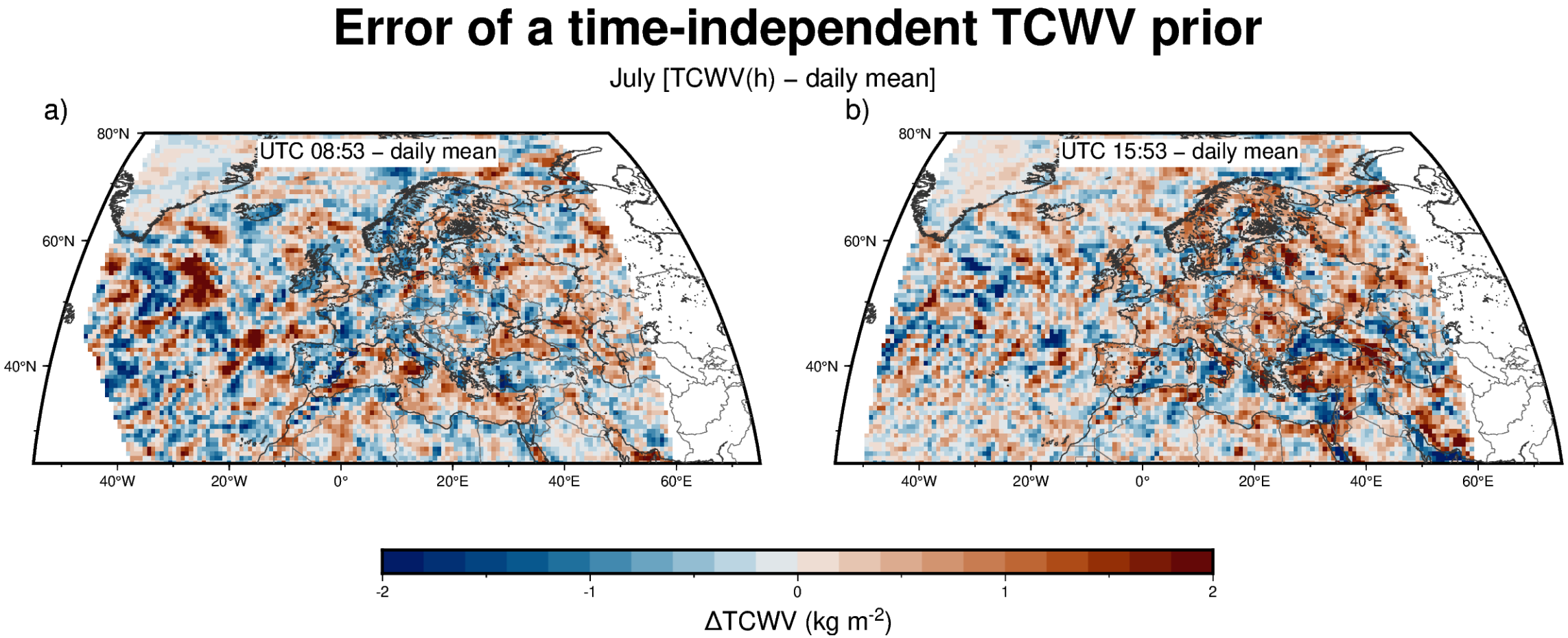


Algorithm: TCWV diurnal range

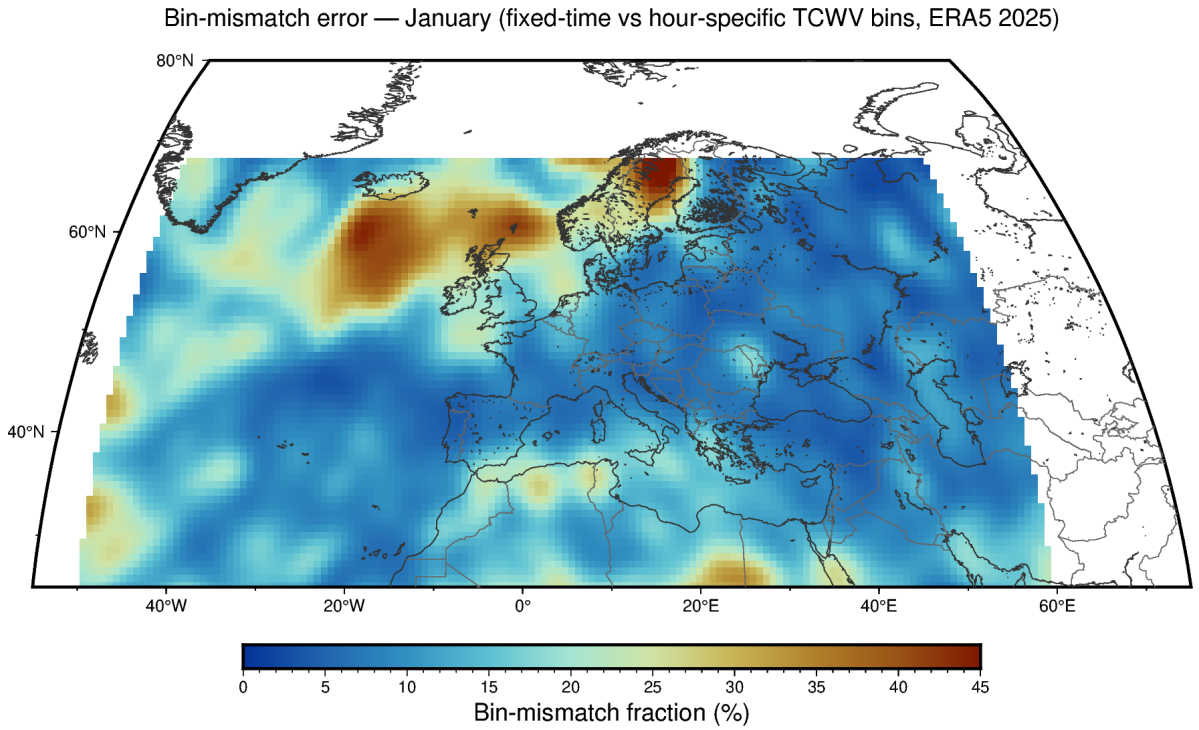


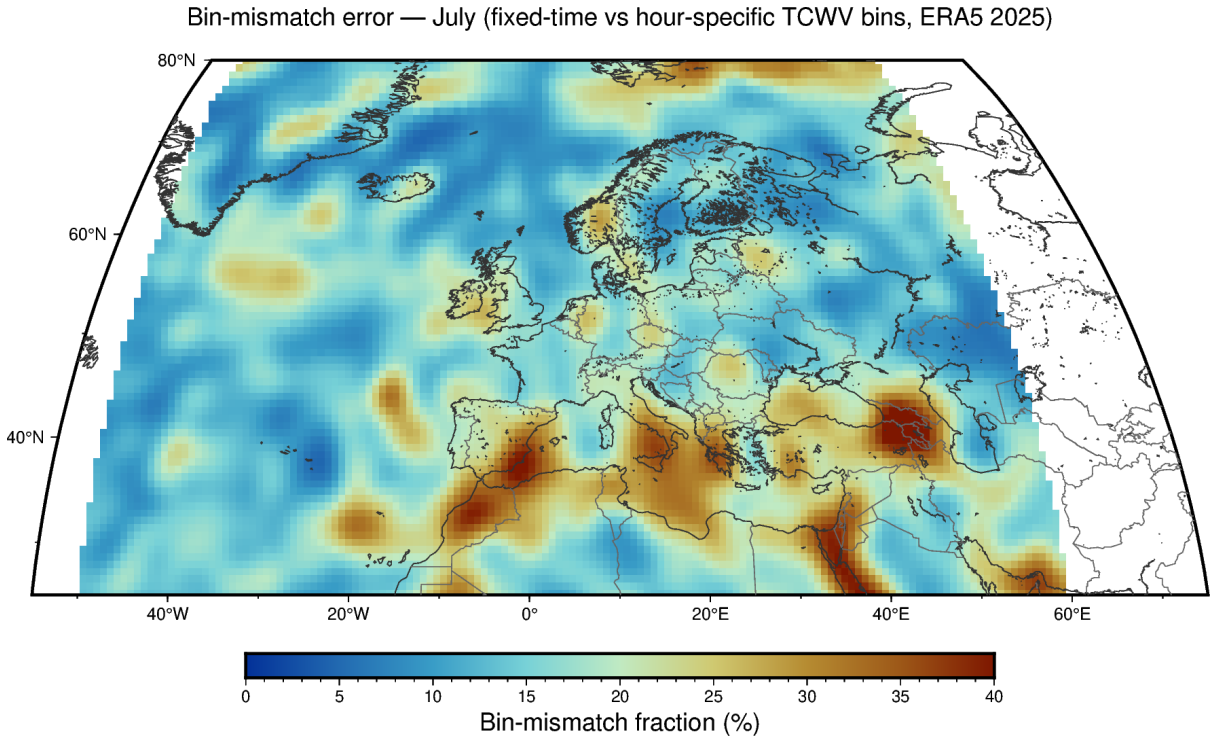
- Dry regions have the smallest diurnal range
- Europe reaches 2–6 kg/m².
- The ocean as well (2–6 kg/m²).
- A typical TCWV retrieval precision target is 1–2 kg/m² — so the diurnal swing is 2-5× larger than the retrieval uncertainty.

Algorithm: TCWV systematic error



Algorithm: bin-mismatch fraction in prior profiles





On average across all daylight pixels, about 1 in 6 of the 8 TCWV bins would be misclassified if daily-mean bin boundaries are used instead of hour-specific ones.

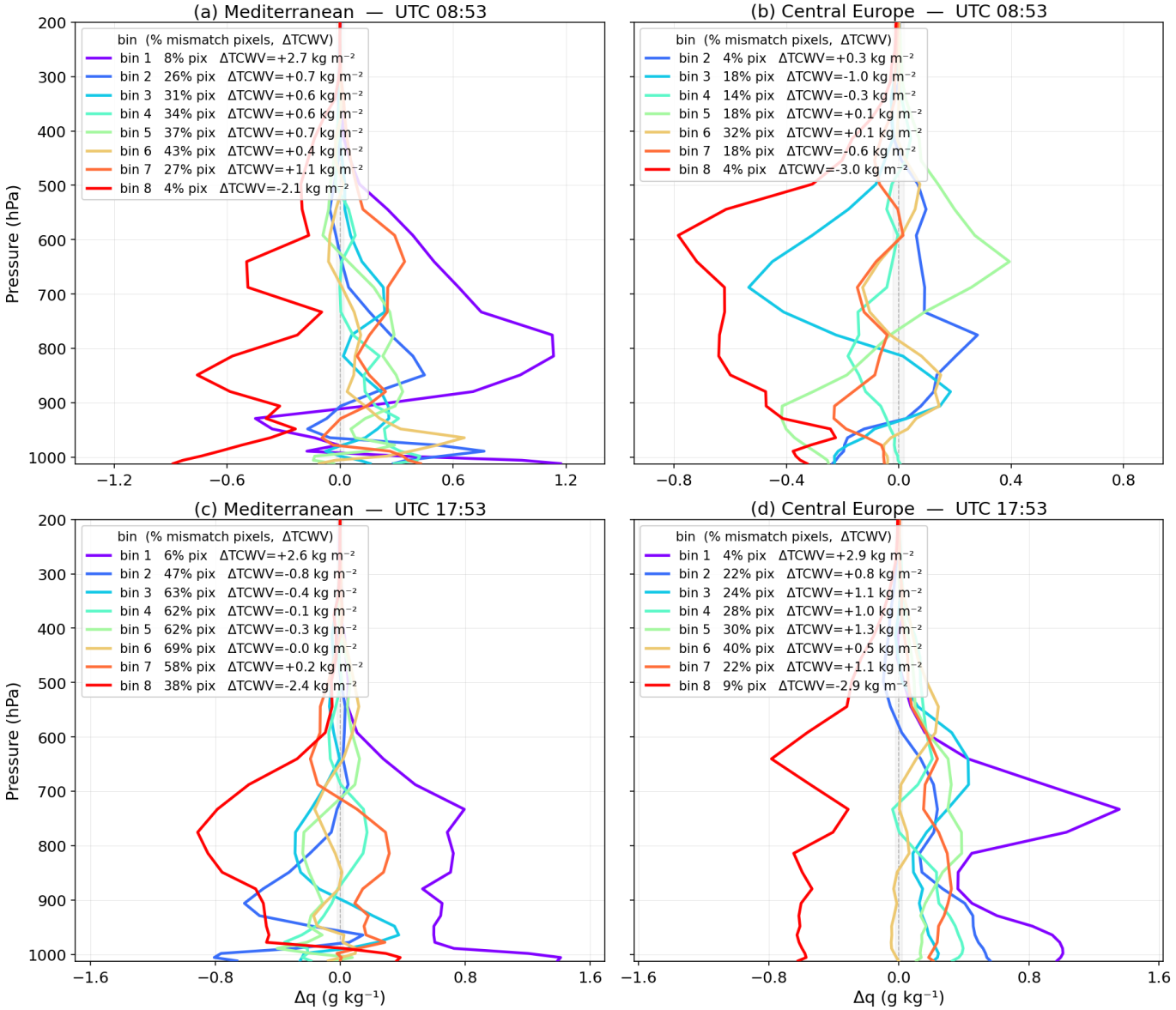
	mean	median	p95	max
January	14.5%	11.1%	39.1%	70%
July	17.0%	14.2%	40.2%	80%

Algorithm: a-priori WV profiles for Sentinel-4

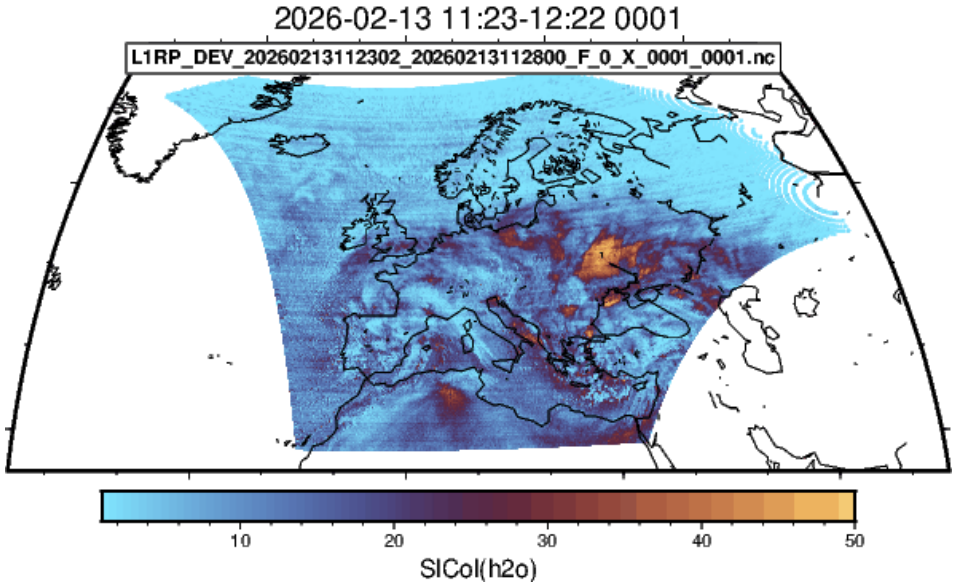
Positive Δq (retrieval uses a wetter profile than it should) for bins shifted upward in the afternoon, and negative for the morning.

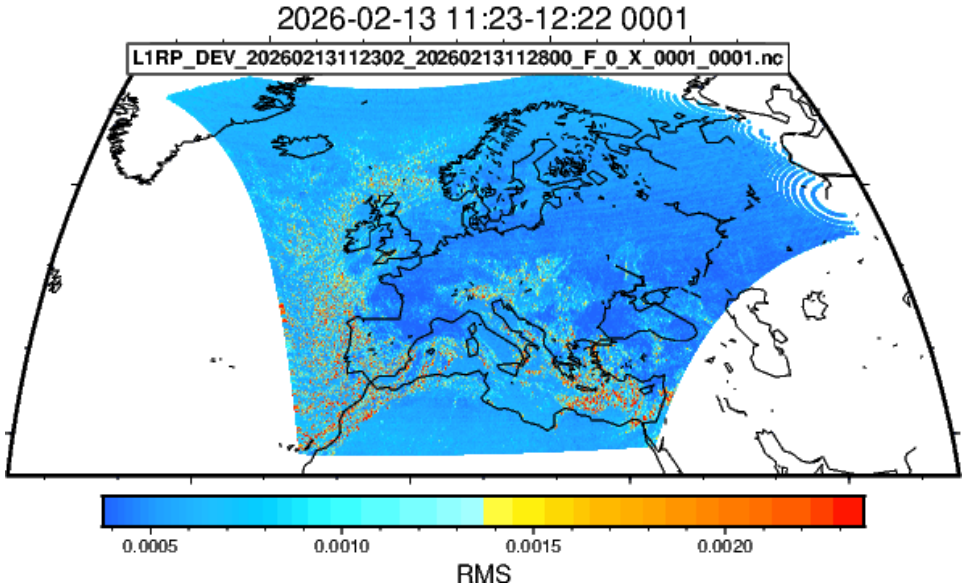
Mean profile error when bin is misclassified by fixed-time prior — July 2025

$\Delta q(z) = \langle q_{\text{assigned}}(z,h) - q_{\text{correct}}(z,h) \rangle_{\text{mismatch pixels}}$



Algorithm: a-priori WV profiles for Sentinel-4

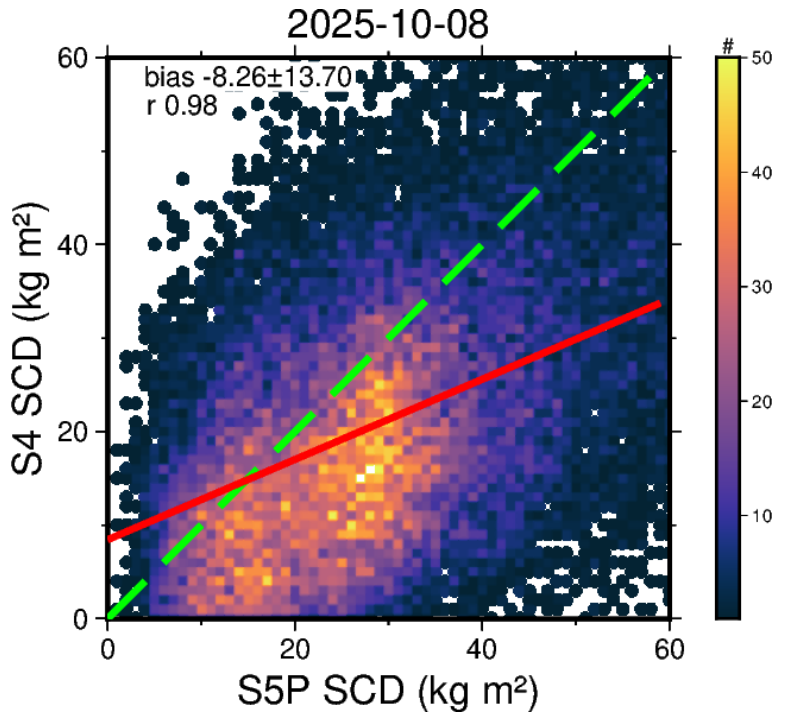




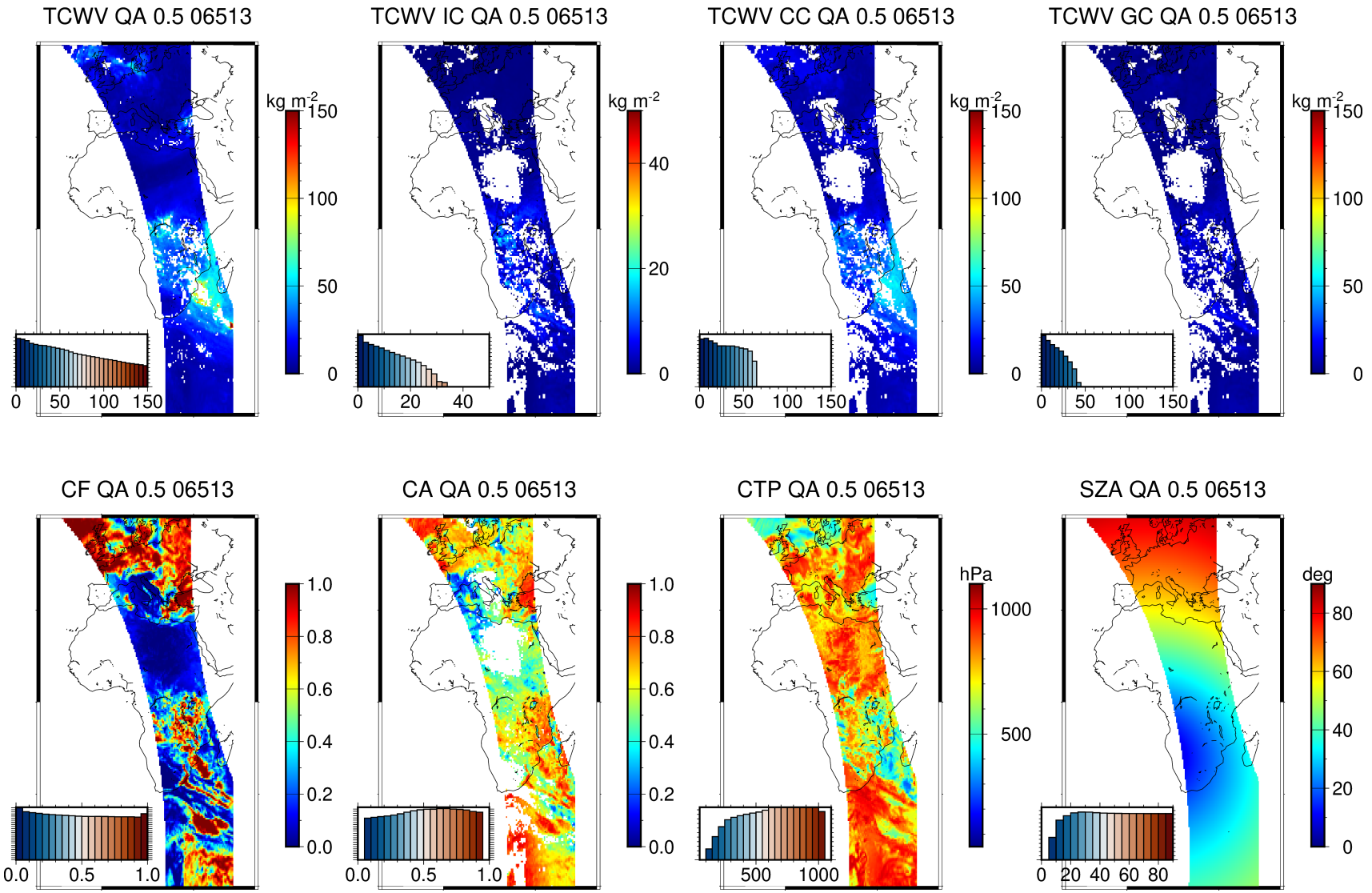
- Prototype v0.0 functional → SCD
- De-striping not implemented
- AMF not implemented

- Initial comparison to TROPOMI-S5P

  - Random bias component acceptable (r 0.98)
  - Systematic bias component present (bias -8.26 kg m^{-2})



Explicit cloud correction (ongoing)



Real clouds are not Lambertian surfaces as assumed in the present version of the retrieval algorithm but are densely packed media of liquid and ice scatterers.

This enhances absorption of water vapor inside a cloud (**apparent increase of water vapor concentration**) and proportionally shields the gaseous column below the bottom layer of a cloud and the surface (**ghost column**).

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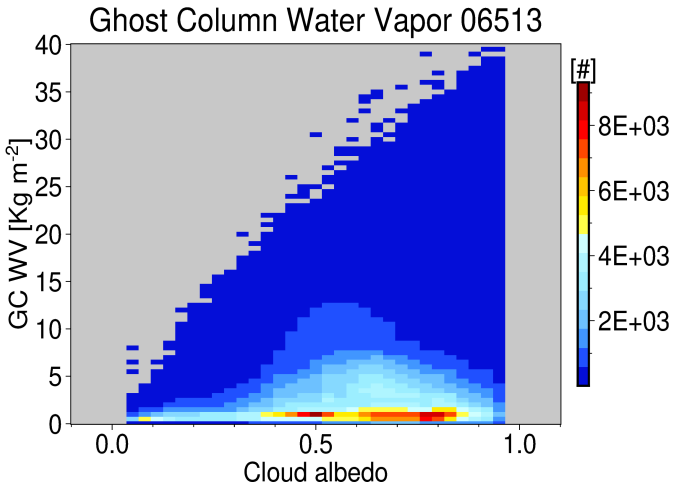

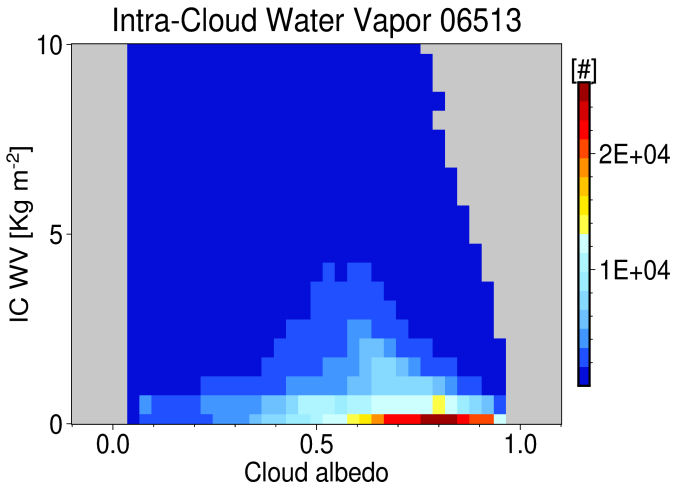

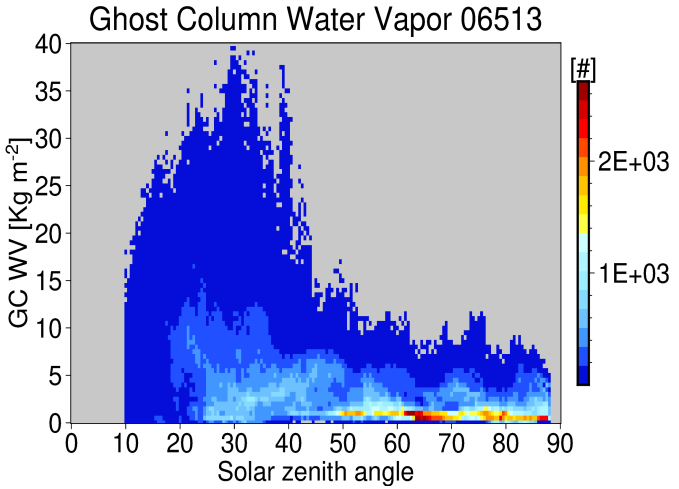

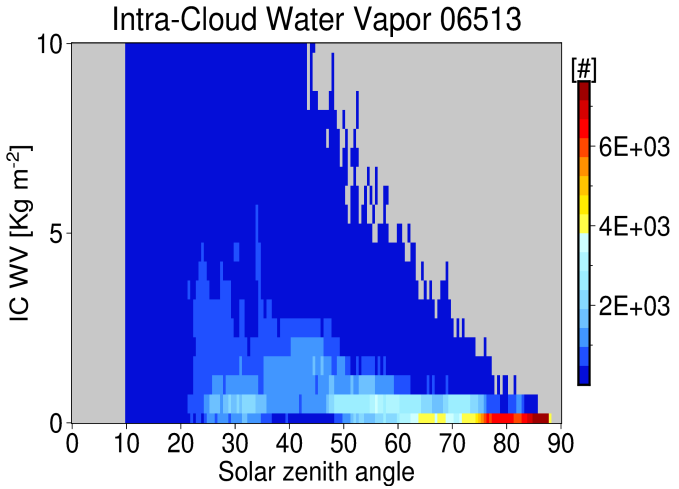

Explicit correction strategies

(1) the ingestion of properties of clouds allowing multiple scattering inside and below them, requiring a full transfer assessment of the radiation field inside and below the cloud

(2) the assumption of a linear dependency between cloud optical thickness (or albedo), solar zenith angle and the intracloud gas column. This means that thin clouds correspond to greater water vapor corrections and otherwise.

Status and Outlook

- Sentinel-4 prototype is being tested on the newest data batches
- De-striping algorithm developed (2 pass: frequency + time domains)
- VCD in line with expectations, need to fine-tune fitting window
- Sentinel-5 data and ISRF received only recently
- Cloud correction is a long-standing task …