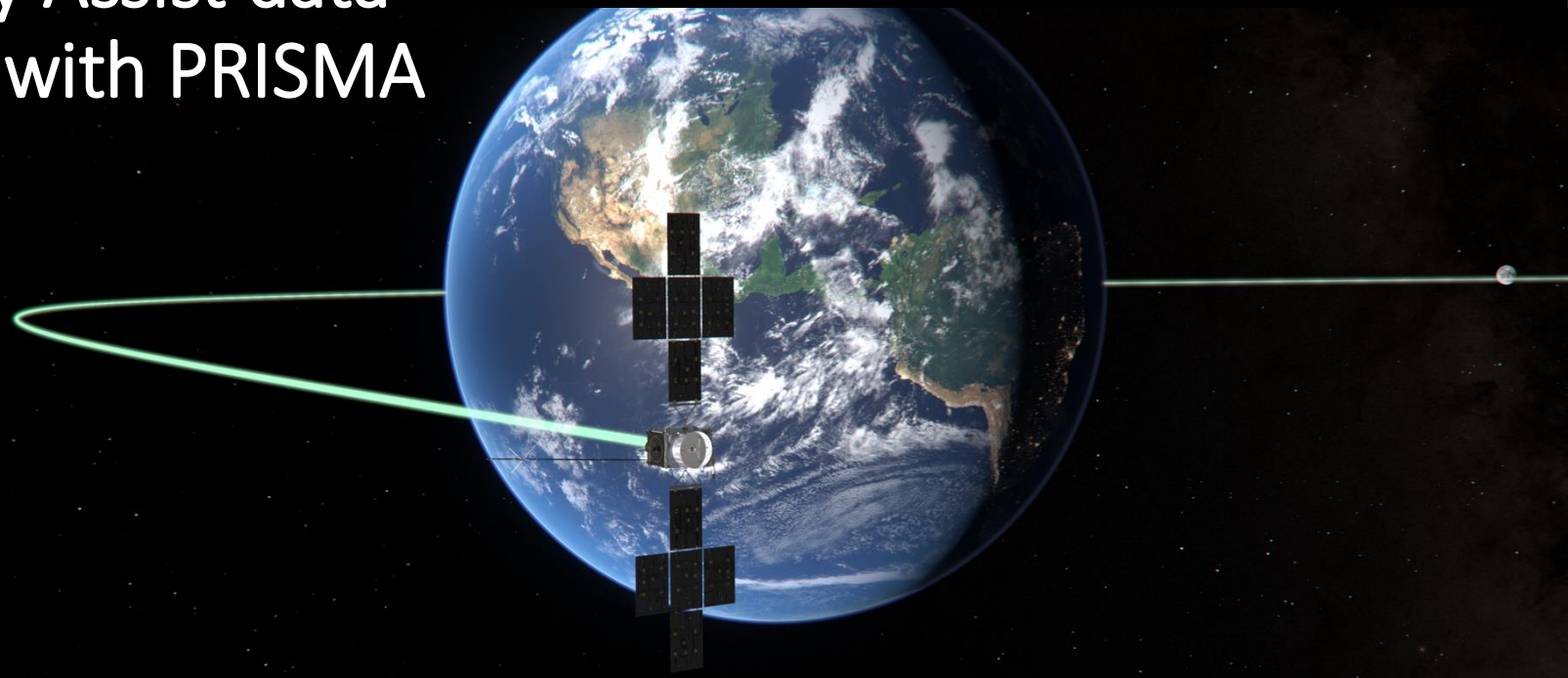
JUICE-MAJIS Earth Gravity Assist data overview and comparison with PRISMA



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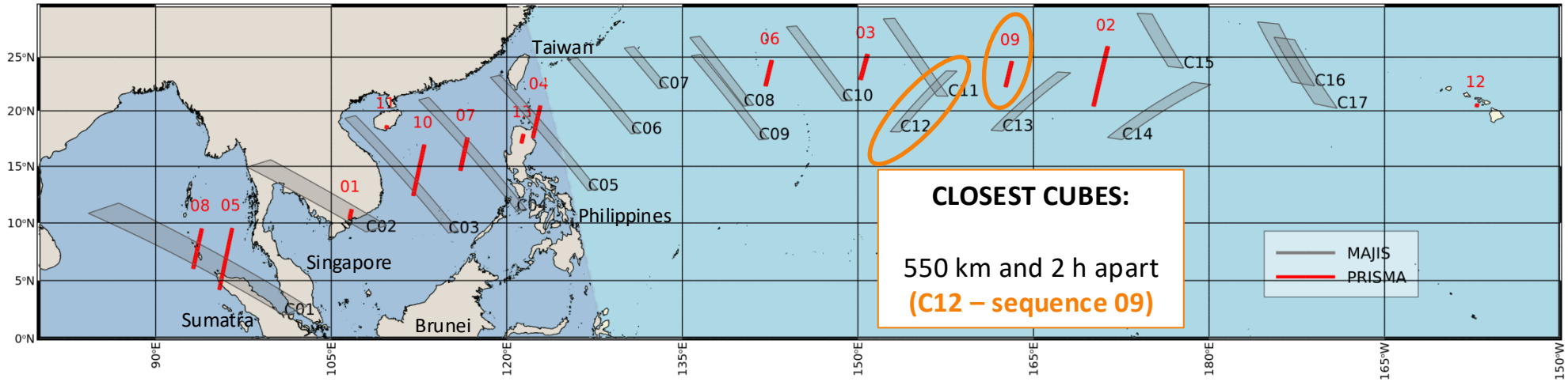
EARTH GRAVITY ASSIST (EGA) OVERVIEW

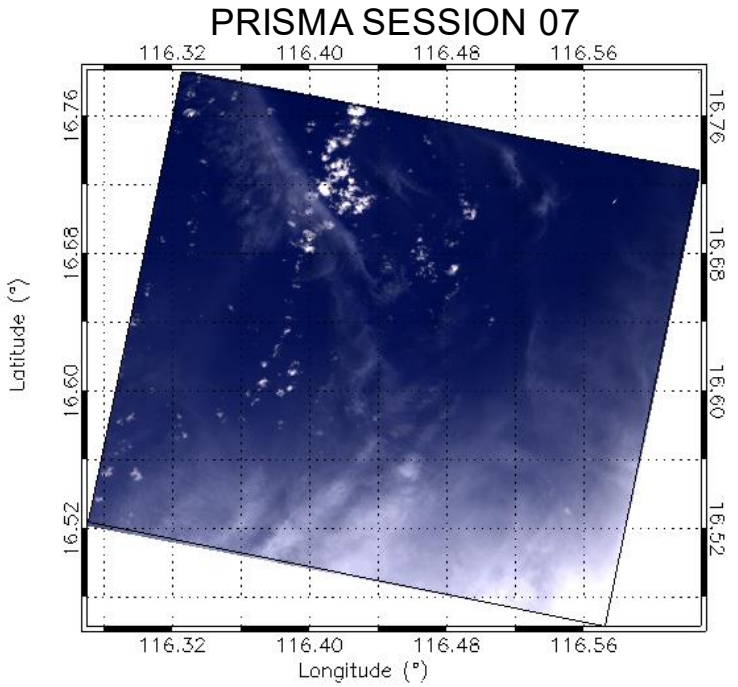
- **20/08/2024** - JUICE Lunar-Earth Gravity Assist (LEGA). Only *Earth-Gravity-Assist* (**EGA**) data acquired by **MAJIS** are analysed here;
- Simultaneous campaign from Earth-observing spectrometers' to test MAJIS performances: EnMAP, TROPOMI, IASI, PRISMA**;**
- **Italian Space Agency**-led imaging spectrometer **PRISMA** used here as proxy for comparing MAJIS observations;

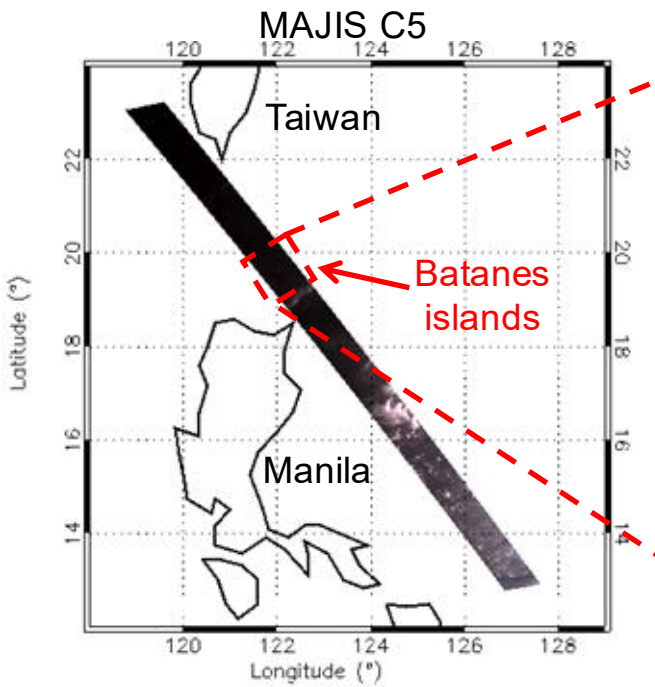
	Spectral range [nm]	Average spectral resolution [nm]	EGA average spatial resolution [m/pixel]	EGA incidence angles [°]	EGA emission angles [°]	EGA local times [h]
MAJIS	**500 – 2350** (*VISNIR*) 2270 – 5560 (*IR*)	4 (*VISNIR*) 6 (*IR*)	1400	23 – 130	0 – 66	03:00 – 10:30
PRISMA	**400 – 2500**	12	30	20 - 24	1 - 21	~ 10:30

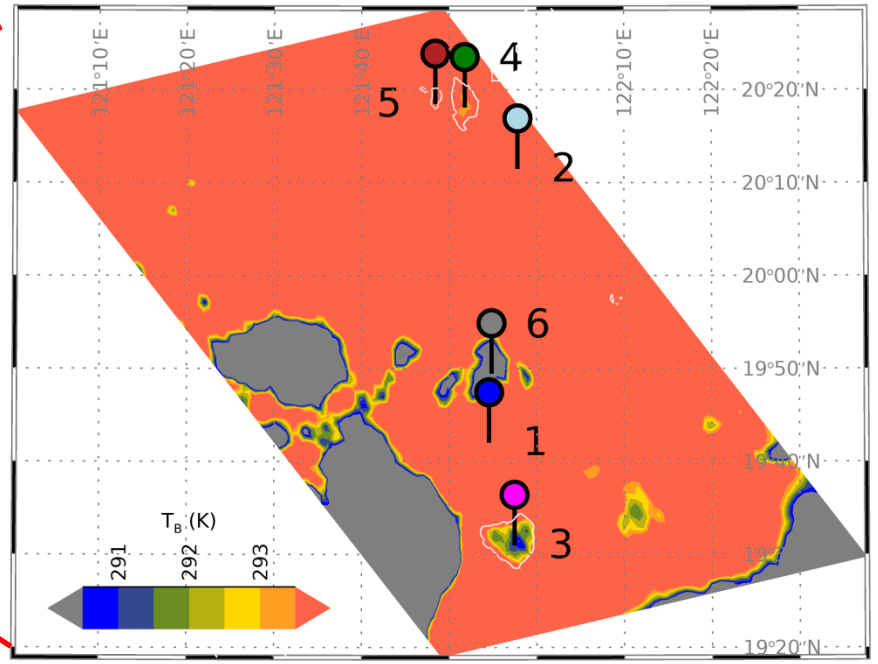


- EGA pointing mostly limited to ocean;
- **Surface features detected** by comparing the shapes of low brightness temperature (T_B) regions with known coastlines.

MOSTLY OCEAN AND CLOUDS, BUT…

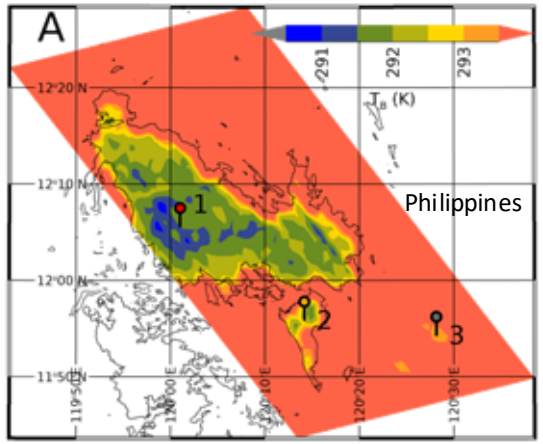


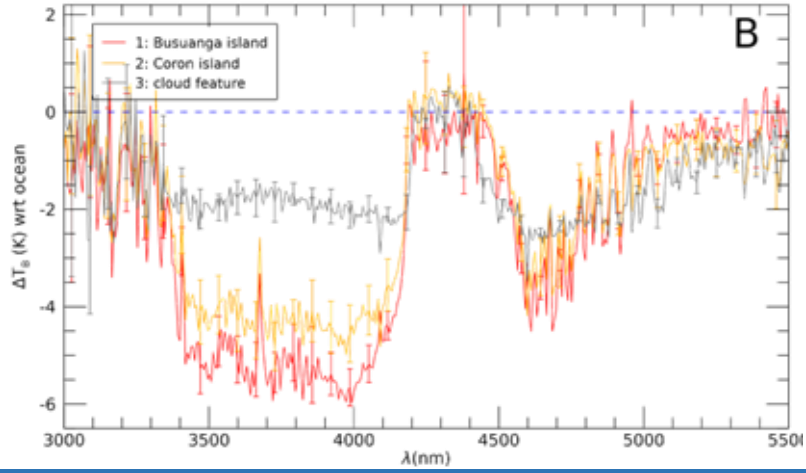




- **No surface detecion** in the VIS-NIR in EGA orbits due to clouds' obstruction and poor illumination conditions;

- Thermal brightness contrast between ocean, land and clouds in the thermal range → Batanes and Philippinae islands

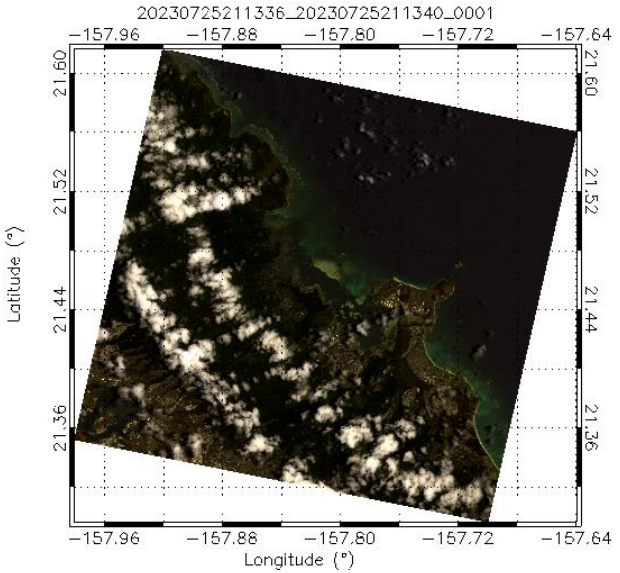


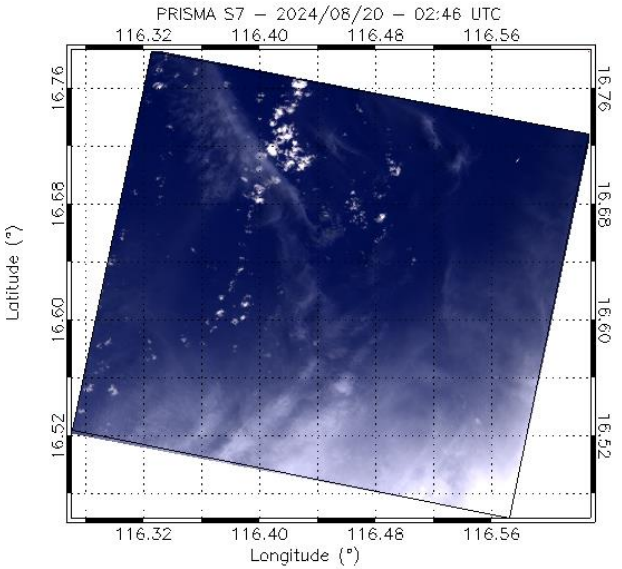


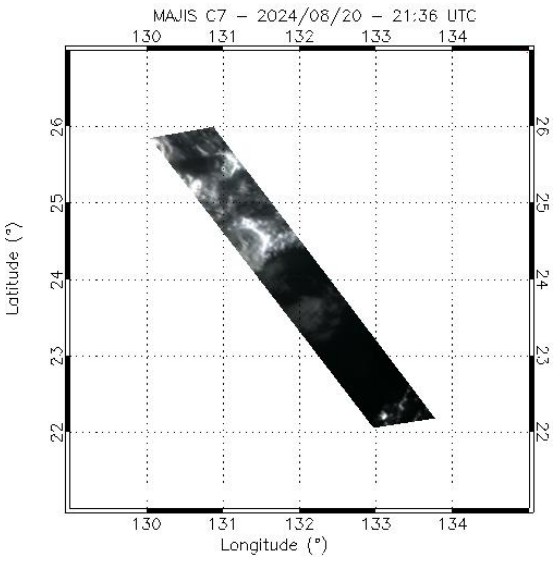
MOSTLY OCEAN AND CLOUDS, BUT…

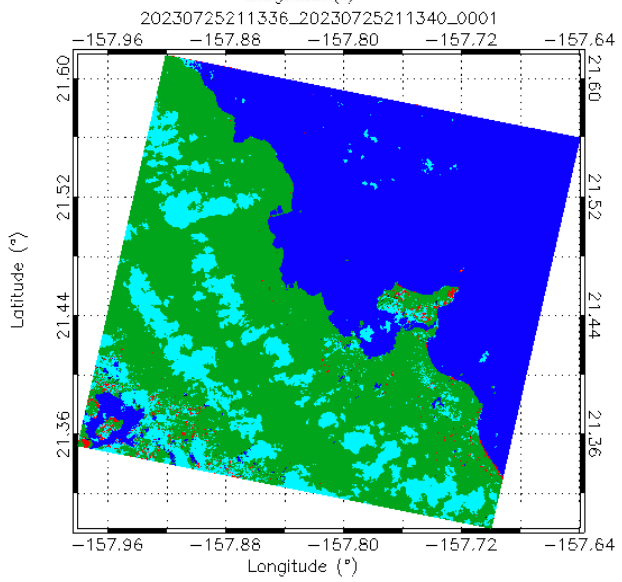
Spectral indexes for the identification of surface features and clouds (Oliva et al., 2026).

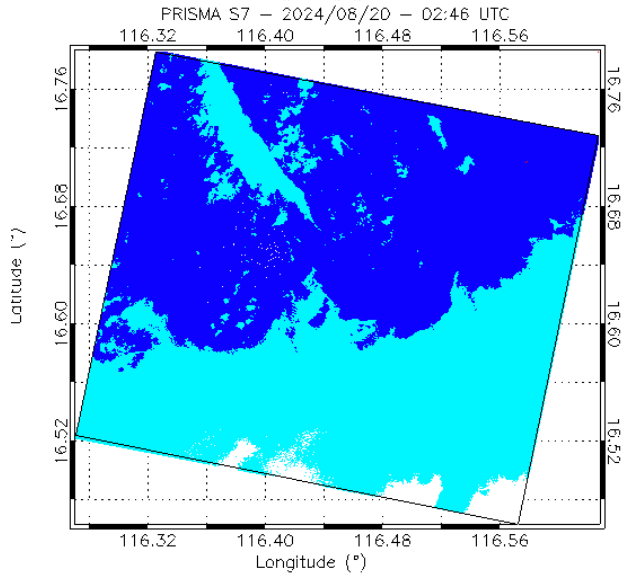
SPECTRAL CLASS	SPECTRAL INDEX
Vegetation	NDVI: $\frac{R_{860} - R_{650}}{R_{860} + R_{650}}$
Sand/Soil	NDSI: $\frac{R_{570} - R_{620}}{R_{570} + R_{620}}$
Ocean	NDWI: $\frac{R_{430} - R_{900}}{R_{430} + R_{900}}$
Ice Clouds	$\frac{R_{1670}}{R_{1800}}$
Cloudy	pixels not assigned to surface types

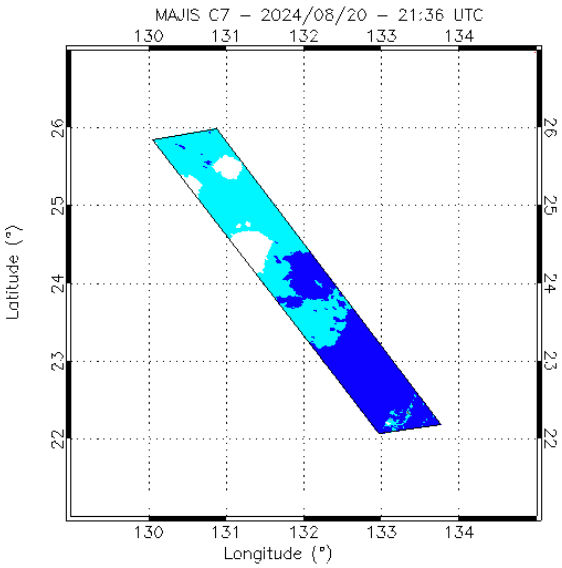






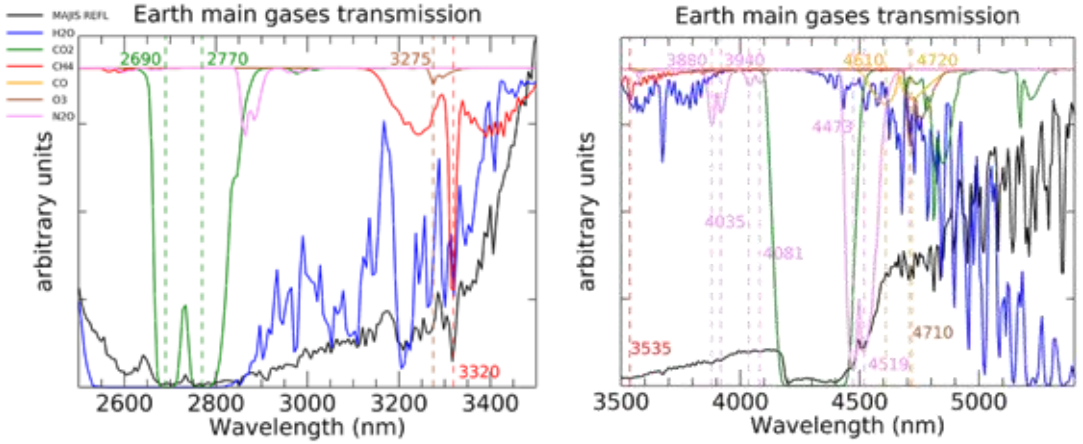


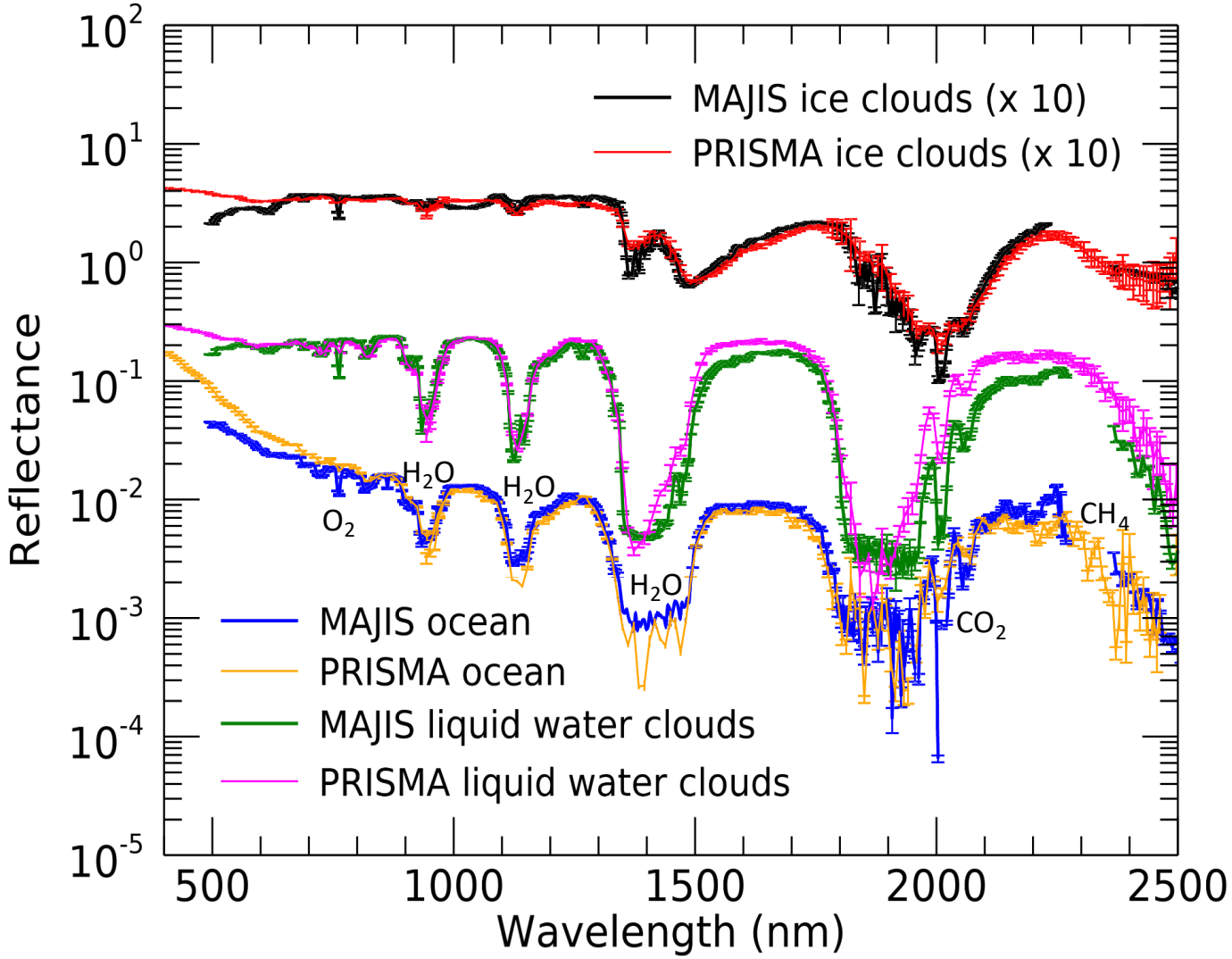




RADIOMETRIC/SPECTRAL COMPARISON: OCEAN, CLOUDS, GASES

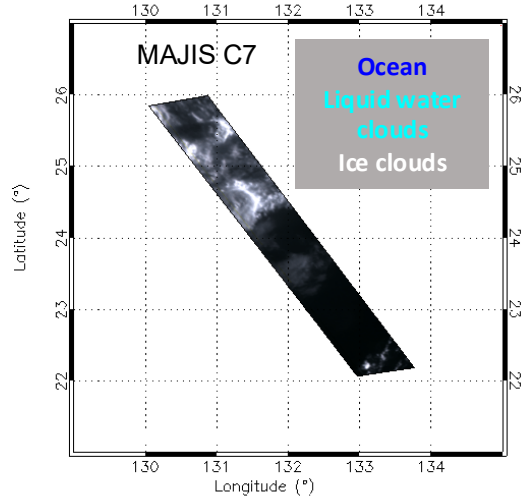
- No spatial/temporal coincidence → search both datasets for radiometrically comparable observations related to **ocean** and **liquid**/**solid** water clouds;
- Radiometric and spectral agreement;
- Main differences below λ = 700 nm → possible straylight contamination;
- Different shape of water absorption bands → changing atmospheric vertical structure;
- Main Earth gases detected in both datasets (H_2O, CO_2, O_2, CH_4);
- **MAJIS IR** range → N_2O, CO, **high altitude O_3, CO_2**

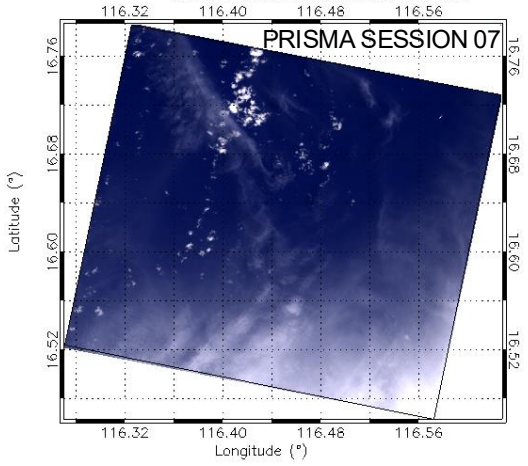


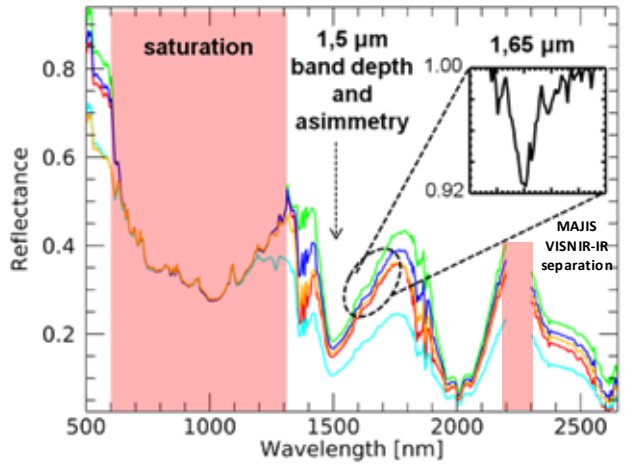


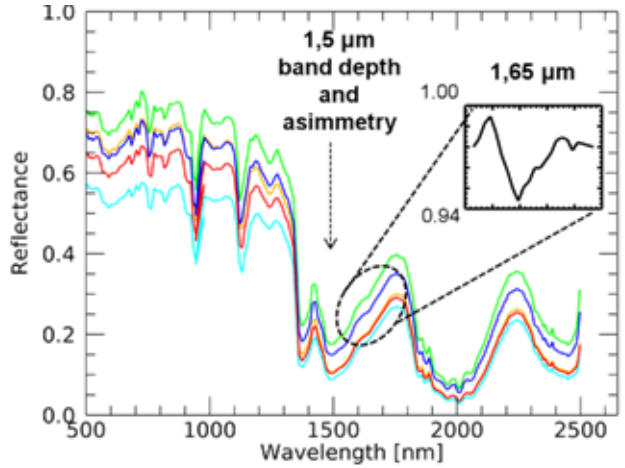
ICE FEATURES

- Ice selected with the condition $\frac{R_{1670}}{R_{1800}} < 1$ (shift of the 1500 nm H_2O ice absorption band to longer wavelengths with respect to the liquid phase);
- Preliminary analysis (K-means) → **solar** range mainly clustered in terms of increasing continuum intensity (clouds' opacity ↑ from **cyan** to **green**);
- The **thermal** range also carries information on the temperature and, hence, on the clouds' altitude.

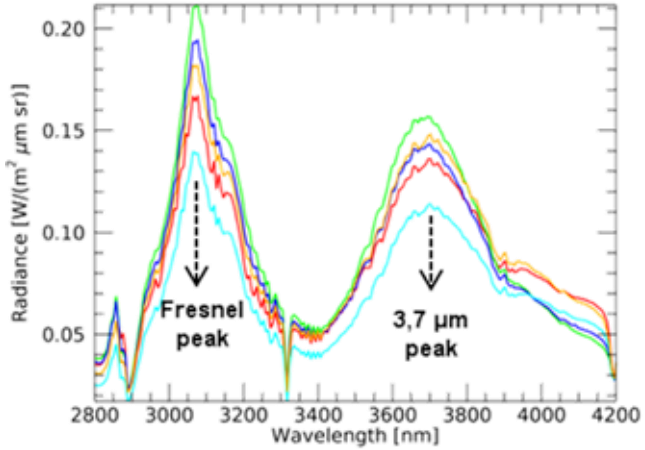


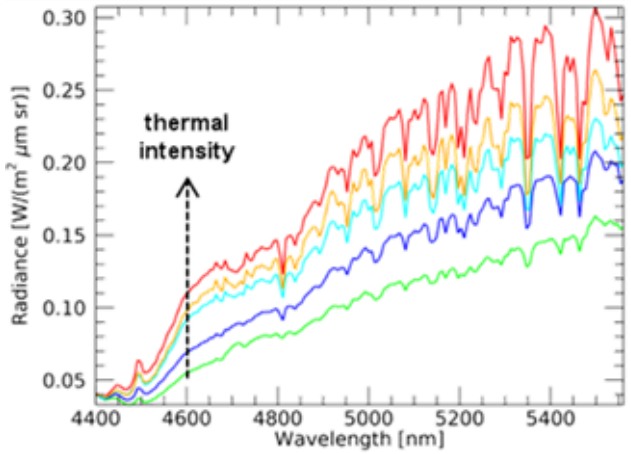






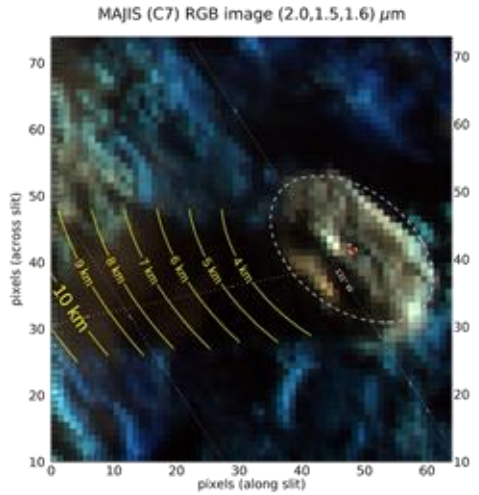
MAJIS





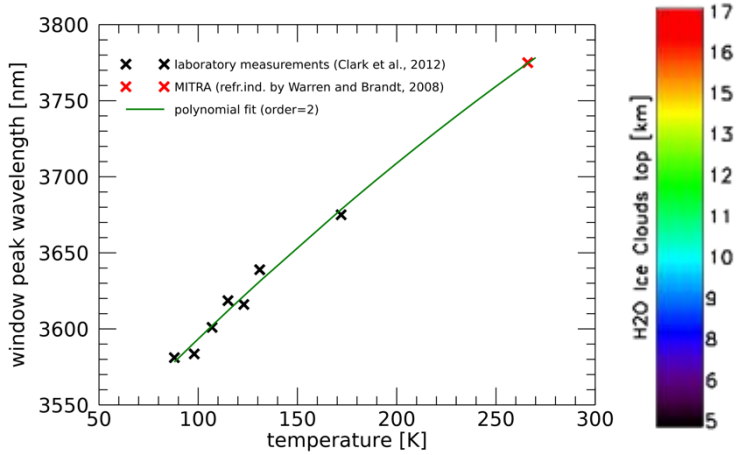
CLOUDS' ALTITUDE

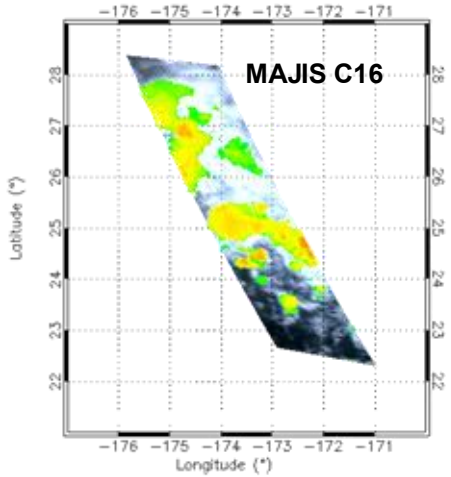
CLOUD SHADOW ANALYSYS



mostly relative heights

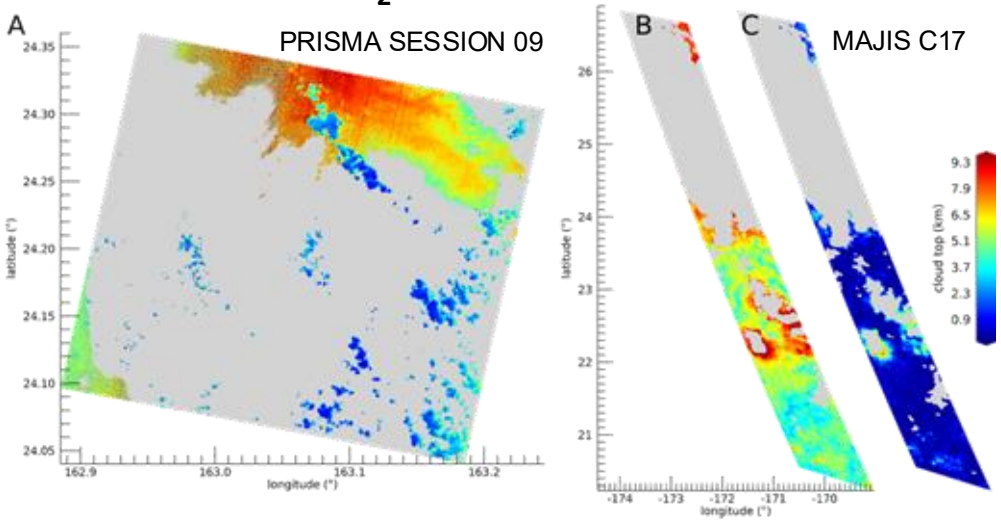
ICE TEMPERATURE FROM 3,7 μm PEAK WAVELENGTH





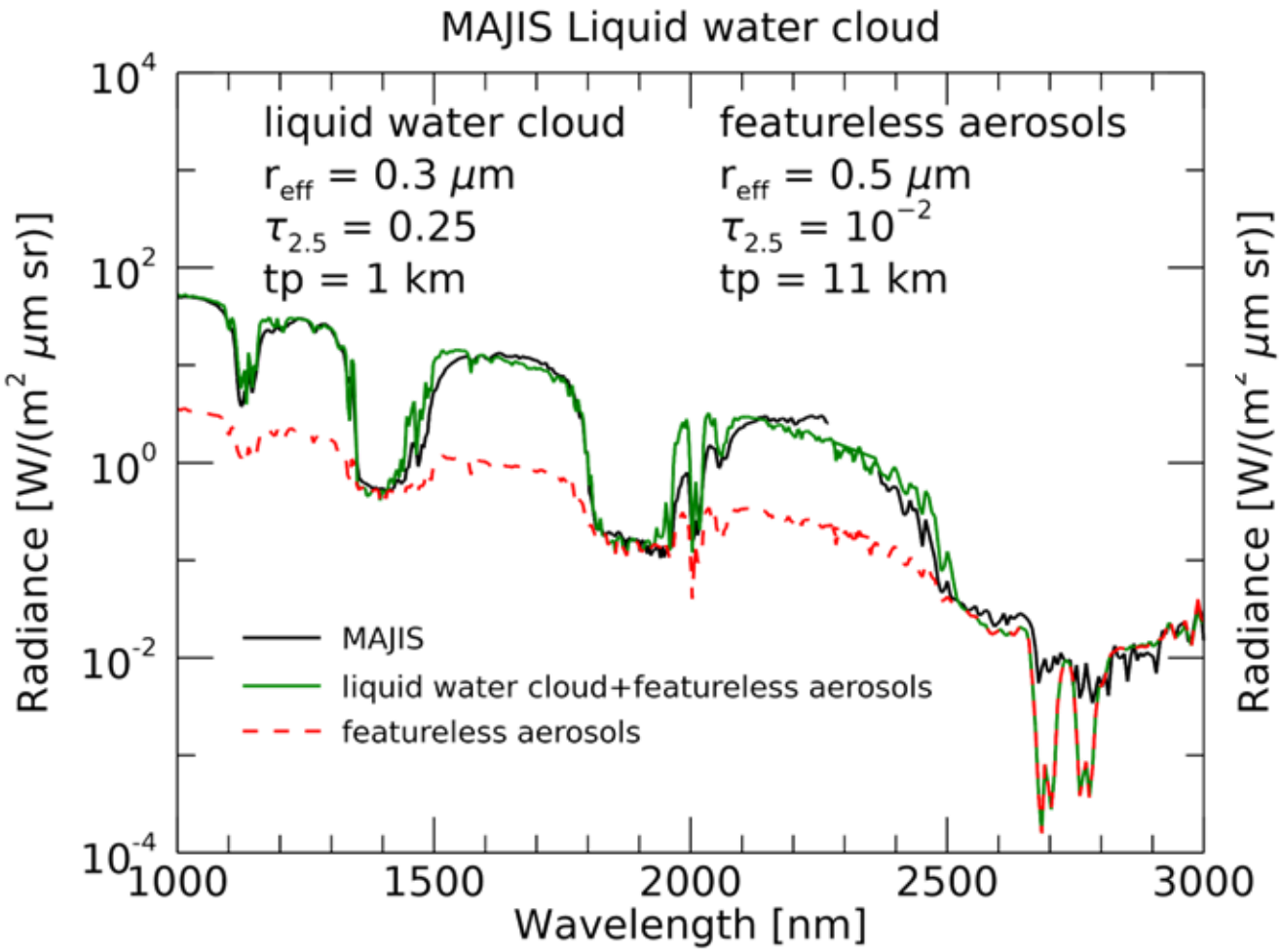
- Same method as Filacchione et al. (2016) → ice temperatures extended to Earth tropospheric ones (optical constants by Warren and Brandt, 2008).
- Altitudes derived assuming the clouds in thermal equilibrium with the surrounding tropospheric air.

760 nm O_2 BAND DEPTH ANALYSIS



- Consistency between MAJIS and PRISMA at similar local times → lower alitudes spotted in PRISMA thanks to its higher spatial resolution (MAJIS likely more affected by cloud mixing within the IFOV);
- These methods rely on specific assumptions and exploit wavelengths that carry information on different ranges of altitudes. Nevertheless, the range of results is consistent. In particular, **scattering is not considered** in any of these simplified approaches.

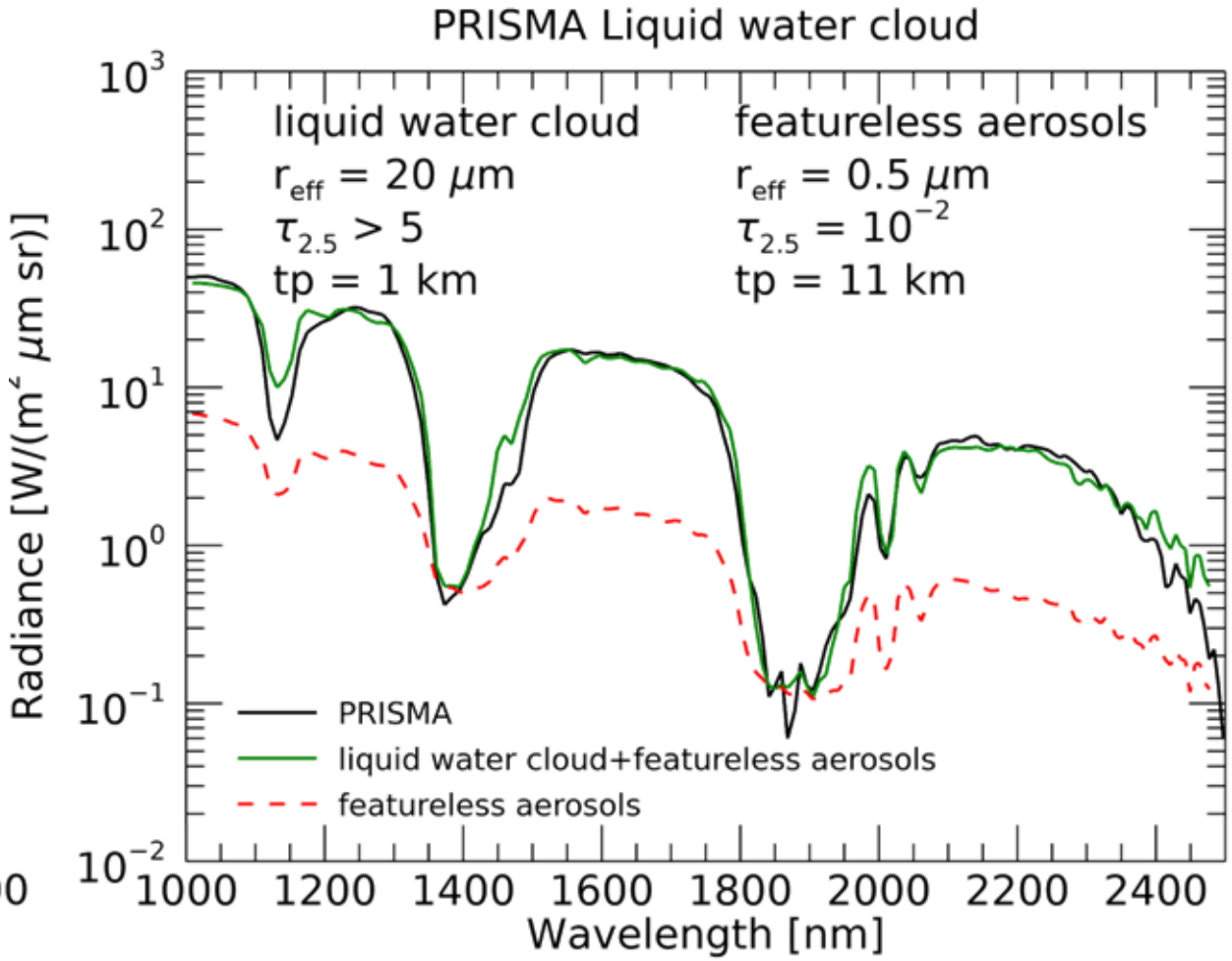
CLOUDS' ALTITUDE: RT MODELING (1000 – 3000 nm)



Stratospheric aerosols at tropopause

+

Spray marine boundary layer aerosols



Stratospheric aerosols at tropopause

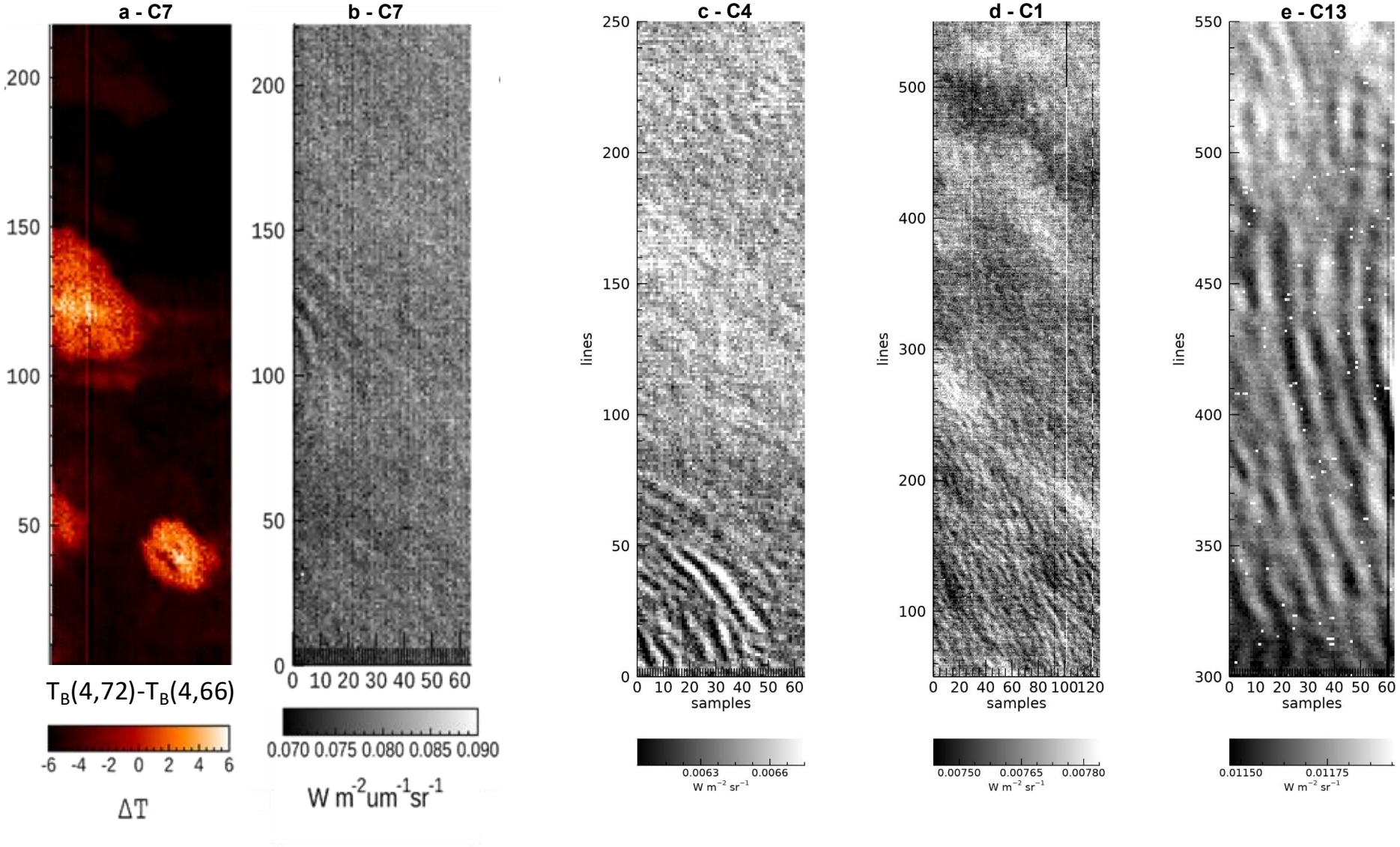
+

Stratus cloud

HIGH ALTITUDE FEATURES: O_3-CO_2 EMISSION / GRAVITY WAVES

- O_3 4.7 µm band is observed both as emission (ΔT>0, above high altitude convective clouds) or absorption (ΔT<0, over background clouds), resulting from the contrast with respect from the thermal emission (panel **a**) → difficult to infer actual emission height.

- The CO_2 emission peak at 4,3 µm probes higher altitudes (panels **b** to **e**), where wave structures are detected (likely thunderstorm-induced, **D'Aversa et al., 2026**);



SUMMARY AND CONCLUSIONS

- RADIOMETRIC/SPECTRAL COMPARISON WITH THE ITALIAN SPACE AGENCY-LED PRISMA SPECTROMETER DATA:
  - GOOD AGREEMENT OVER OCEAN AND CLOUDS;
  - ASSESSMENT OF SATURATION / STRAYLIGHT REGIMES;

- DETECTION OF EARTH MAIN GASES AND SURFACE FEATURES THROUGH CONTRAST WITH THE OCEAN IN THE THERMAL RANGE;

- FIRST ASSESSMENT OF ICE PROPERTIES THROUGH EARTH'S CLOUDS ANALYSIS (**IN VIEW OF JUPITER'S ICY SATELLITES INVESTIGATION**):
  - OPACITY;
  - CRYSTALLINITY;
  - TEMPERATURE;

- STUDY OF EARTH CLOUDS (**EXTRAPOLATION TO JUPITER MULTI-LAYERED CONVECTIVE CLOUD STRUCTURE**):
  - ICE DETECTION;
  - CLOUDS' ALTITUDE;
  - MICROPHYSICAL PROPERTIES (RT MODELING);

Oliva et al., 2026

- DETECTION OF HIGH ALTITUDE EMISSIONS AND GRAVITY WAVES (**EXTRAPOLATION TO JUPITER DIFFERENT CHEMISTRY/CIRCULATION**);

- *DEFINITION OF SPECTRAL INDEXES FOR SURFACE/CLOUDS IDENTIFICATION* (**not shown here**, **USEFUL FOR NEXT EGA IN SEPTEMBER 2026**);

- **EGA AS A FIRST BENCHMARK OF MAJIS PERFORMANCES FOR A PLANETARY TARGET WITH AN ATMOSPHERE, IN VIEW OF JUPITER SYSTEM EXPLORATION**.