Seeing Titan with VIMS infrared eyes during 13 years : from changing atmospheric features over the poles to global surface mapping

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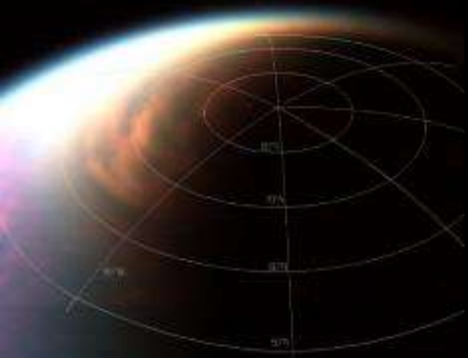
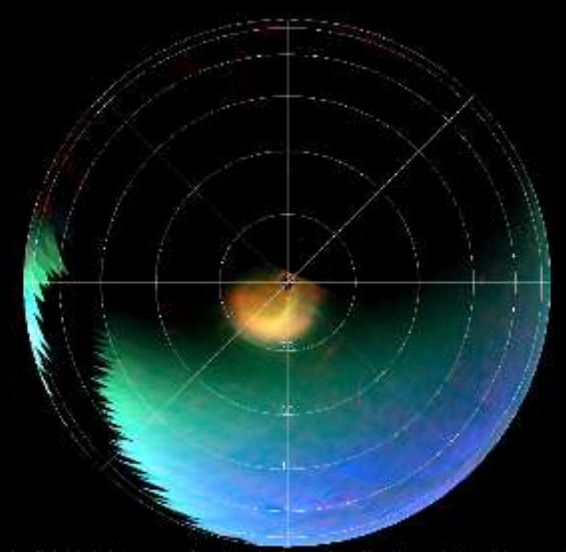
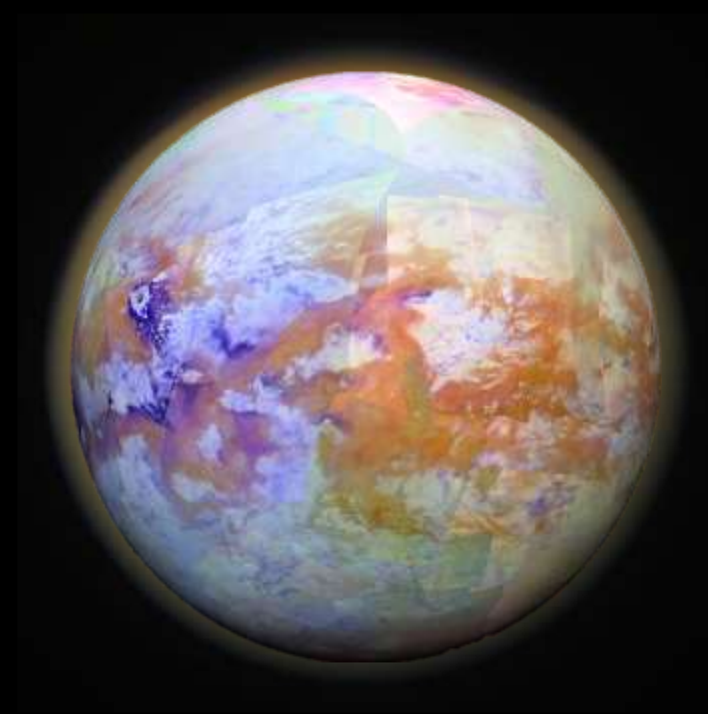






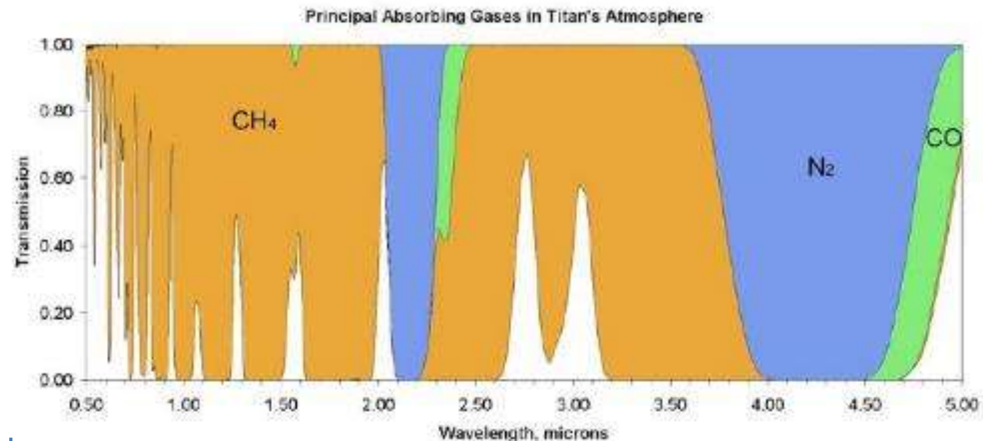
The Visual and Infrared Mapping Spectrometer (VIMS)

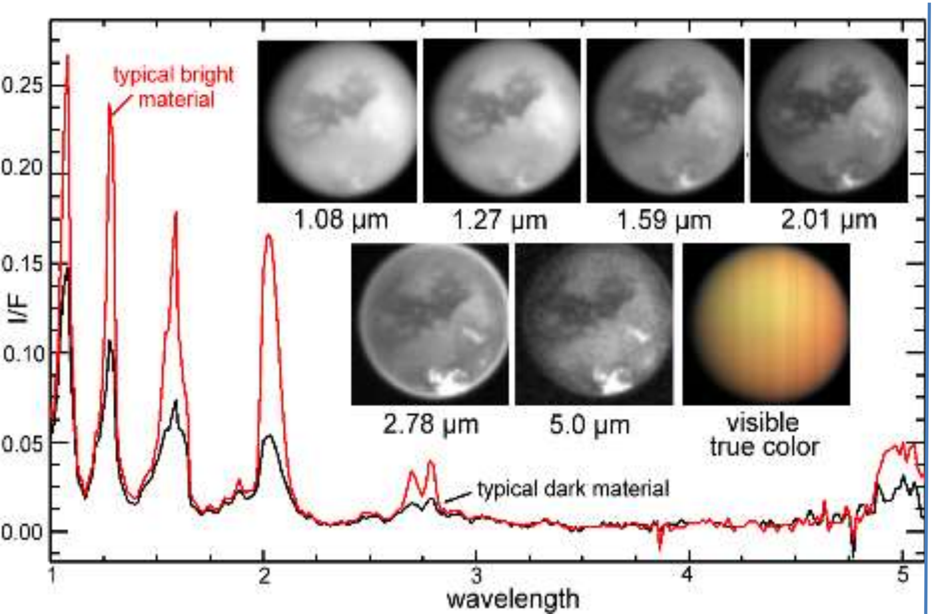
→Imaging spectrometer with up to 64x64 pixels, in 352 spectral channels from 0.3 to 5.1 µm

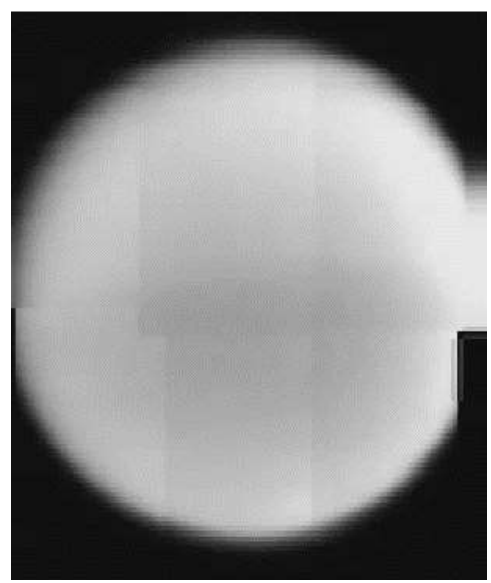
→ The surface is seen in 7 “windows”

→ The spectral dimension can be used to detect and map the clouds

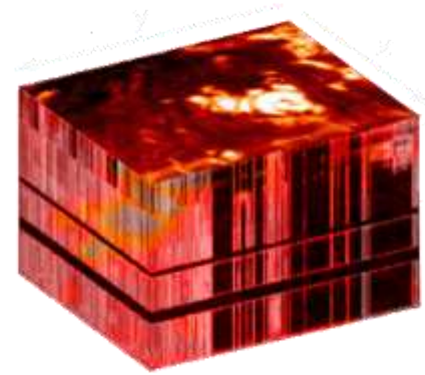
→ ~60000 individual data “cubes”







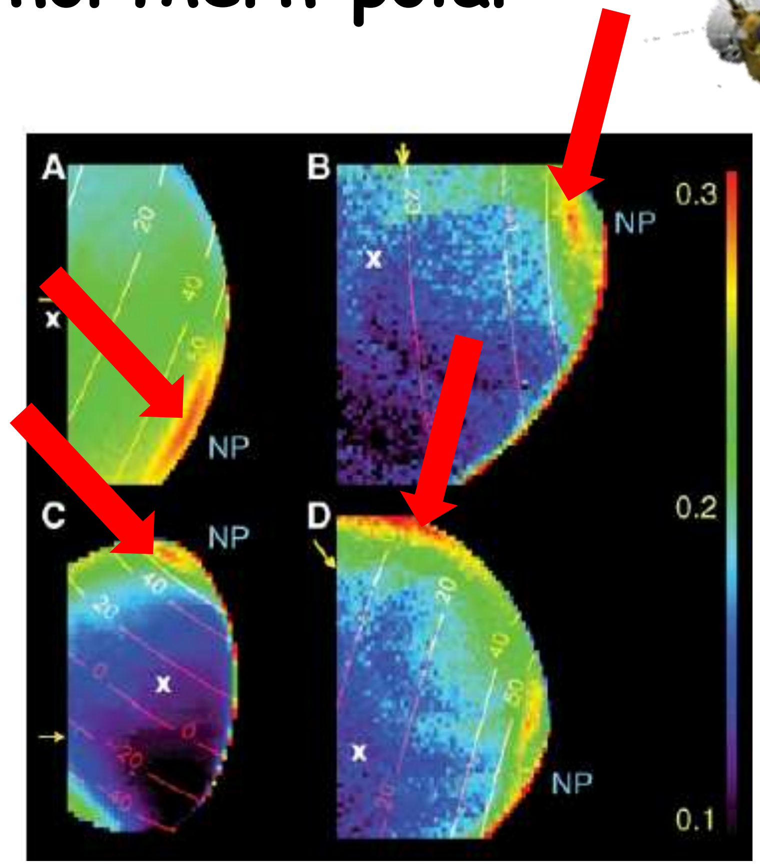
(x,y,λ) : two spatial dimensions and one spectral dimension



1-Atmospheric features over the poles

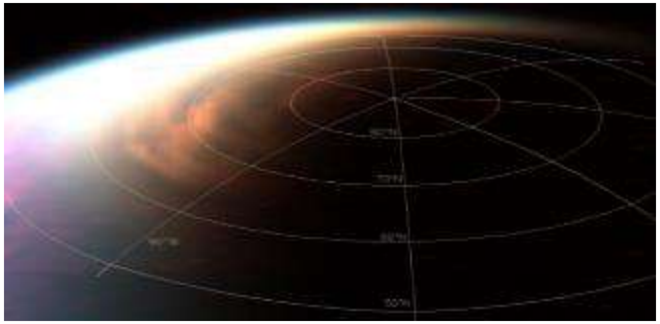
First evidence of a northern polar cloud

- Griffith et al. (2005) → detection of a vast polar ethane cloud at all longitudes, and latitudes from 56° up to 68°



Albedo at 2.8 µm (Griffith et al., Science 2005)

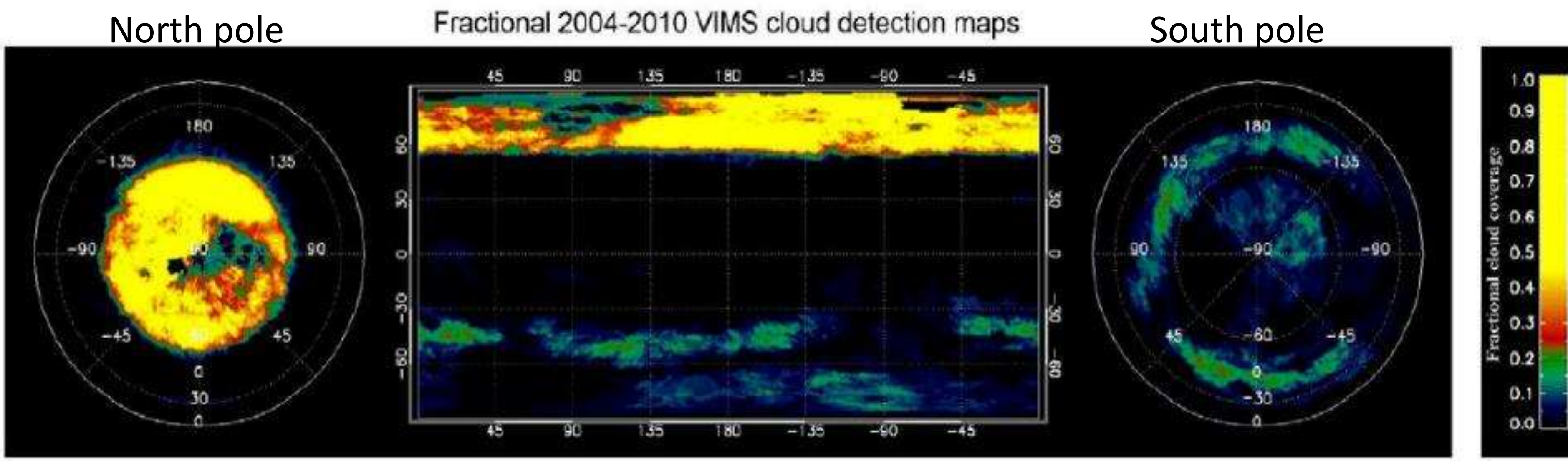
- Best imaging conditions in Dec. 2006



Le Mouélic et al., Planet Space Sci. 60, 2012

Global distribution and temporal evolution of clouds

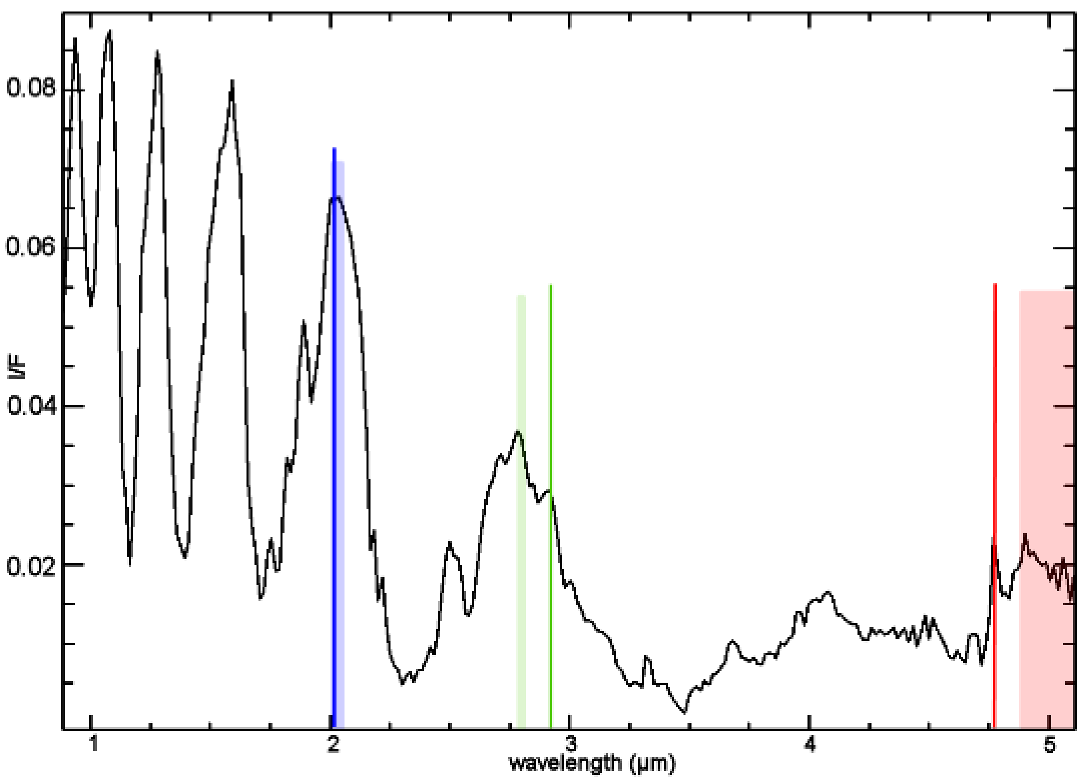
- Global study of the VIMS data set (Rodriguez et al., 2009, 2011, …), mostly focused on tropospheric clouds
- Distribution in agreement with complementary ISS studies (Turtle et al., 2011, 2018)



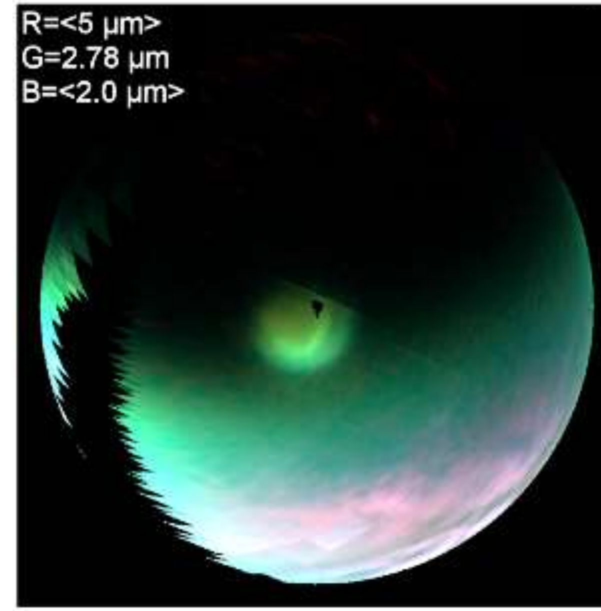
Rodriguez et al., Nature, 2009

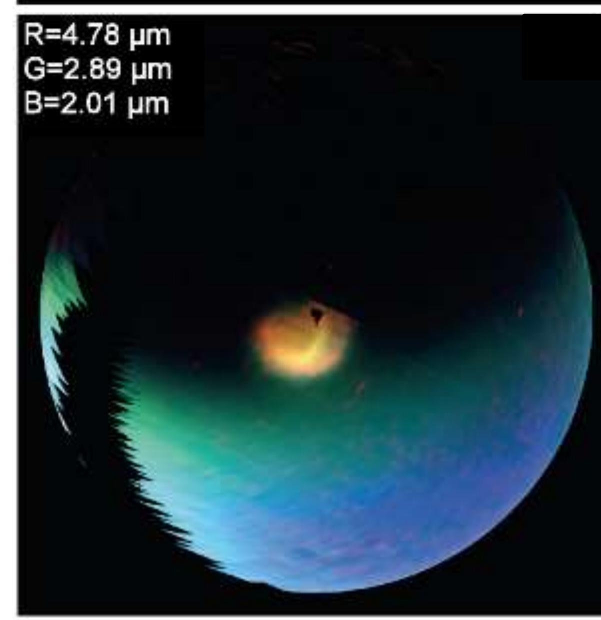
Our approach : Systematic cartographic survey of the poles

- Computation of global hyperspectral mosaics for 127 targeted flybys between 2004 and 2017
- Computation of global maps at diagnostic wavelengths



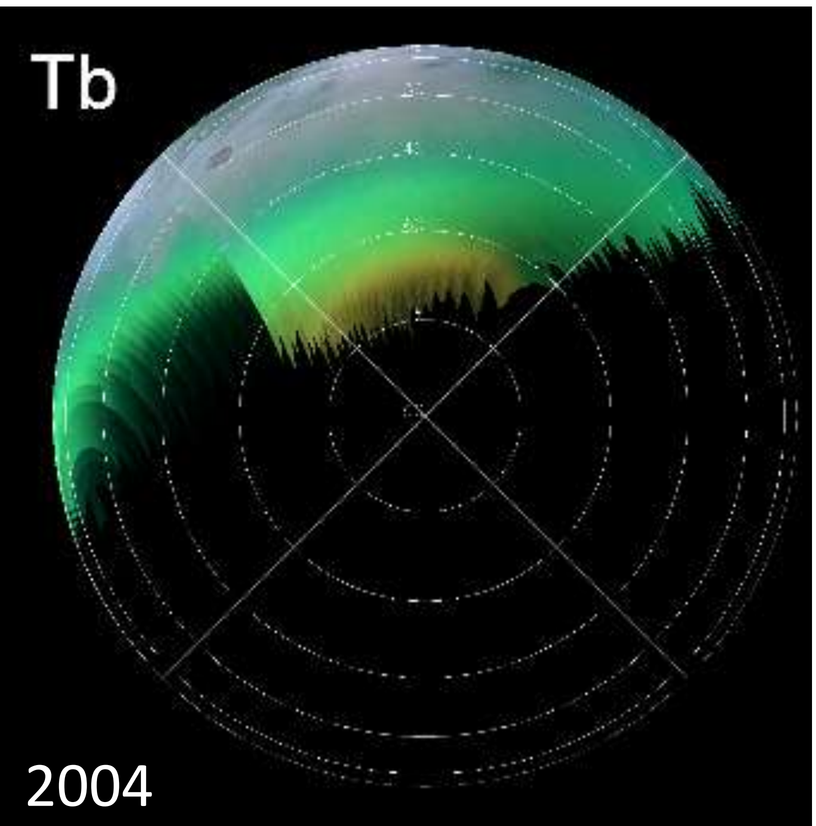
Le Mouélic et al., Icarus 311, 2018

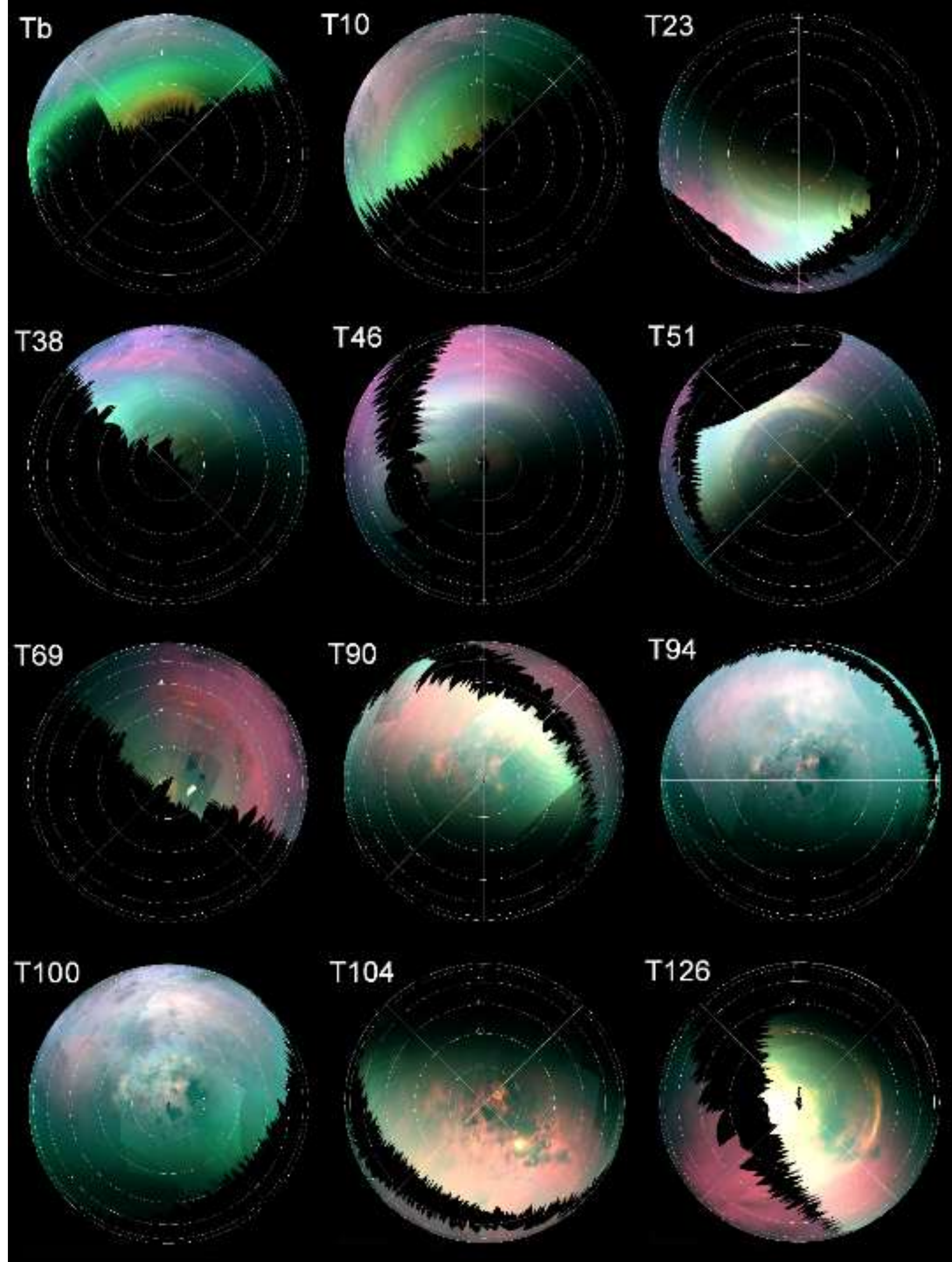




The north pole

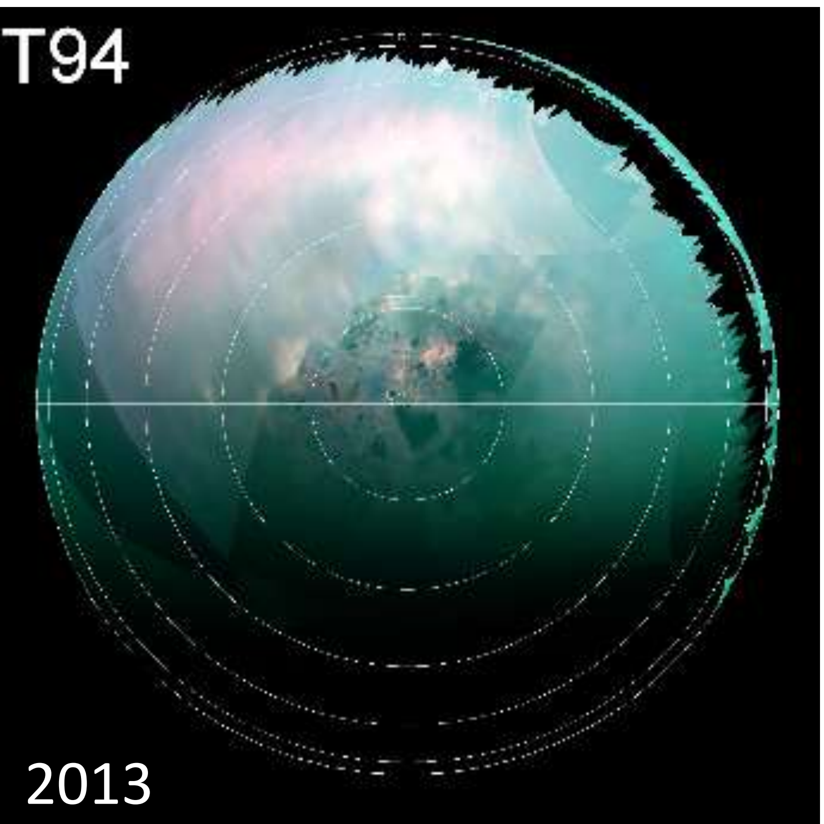
- The north cloud system was already present in first flybys

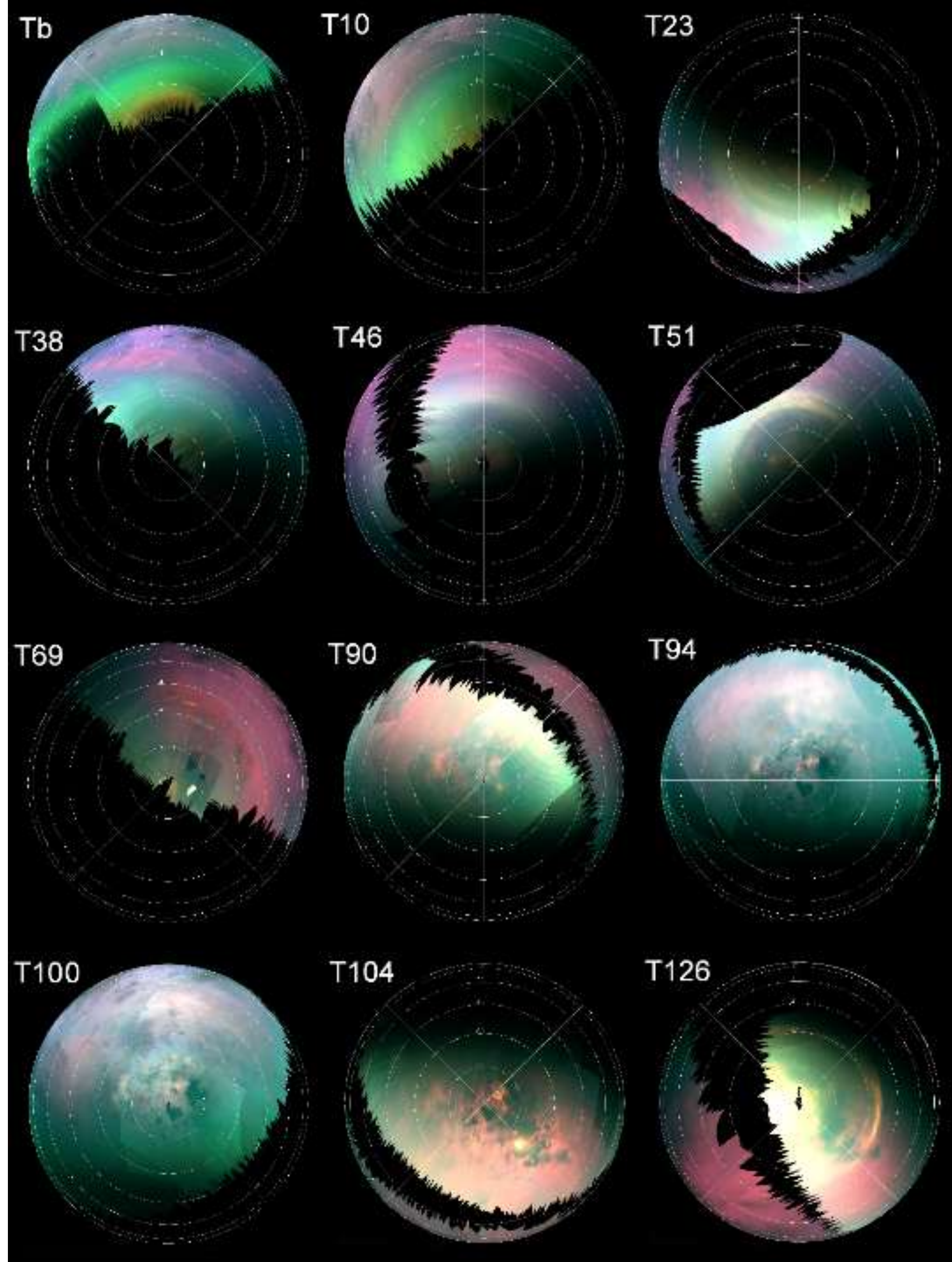




The north pole

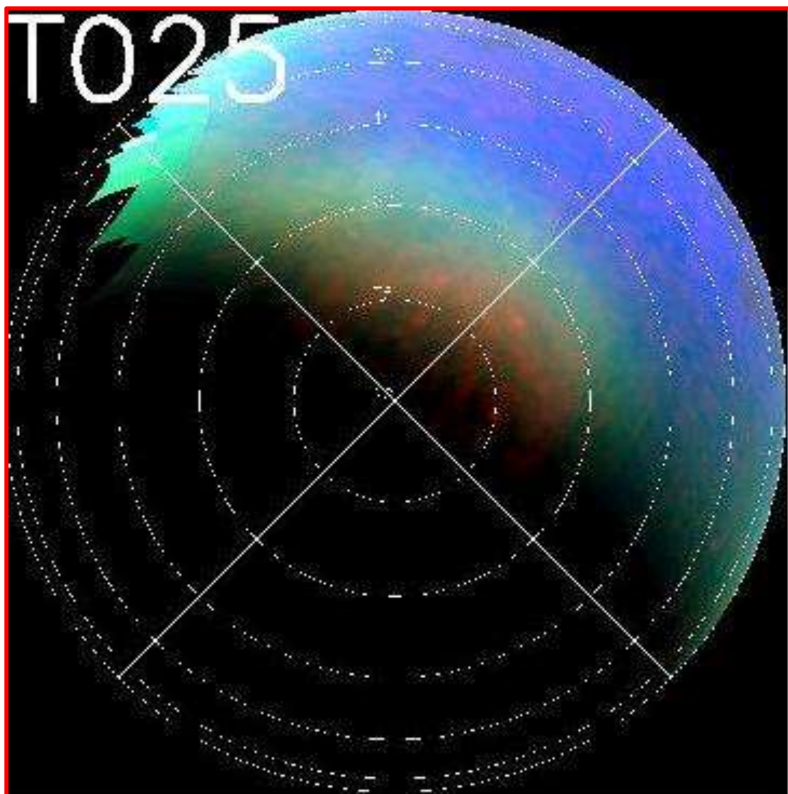
- It vanished at the equinox, revealing progressively the underlying lakes



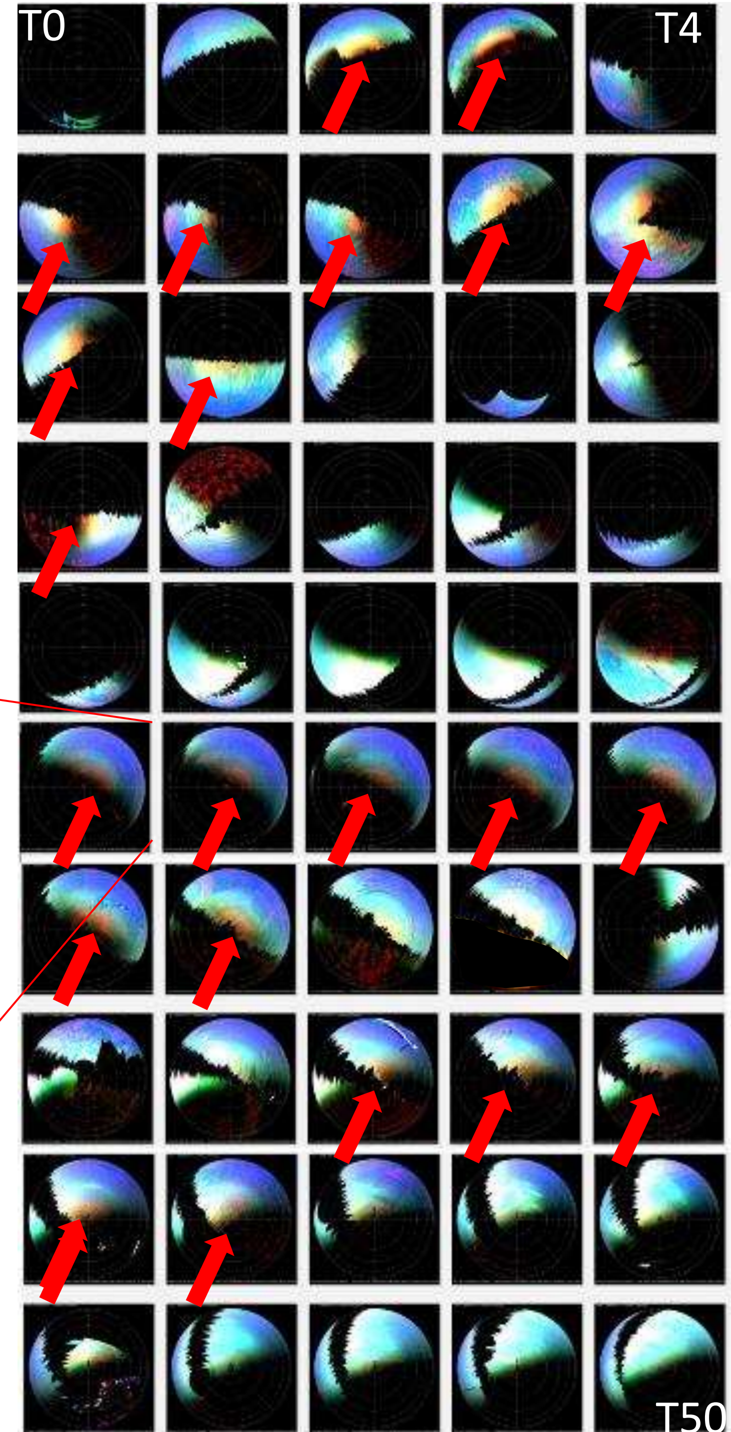


HCN spectral signatures in the north

- Can be tracked down up to 2008 in our set of global maps,

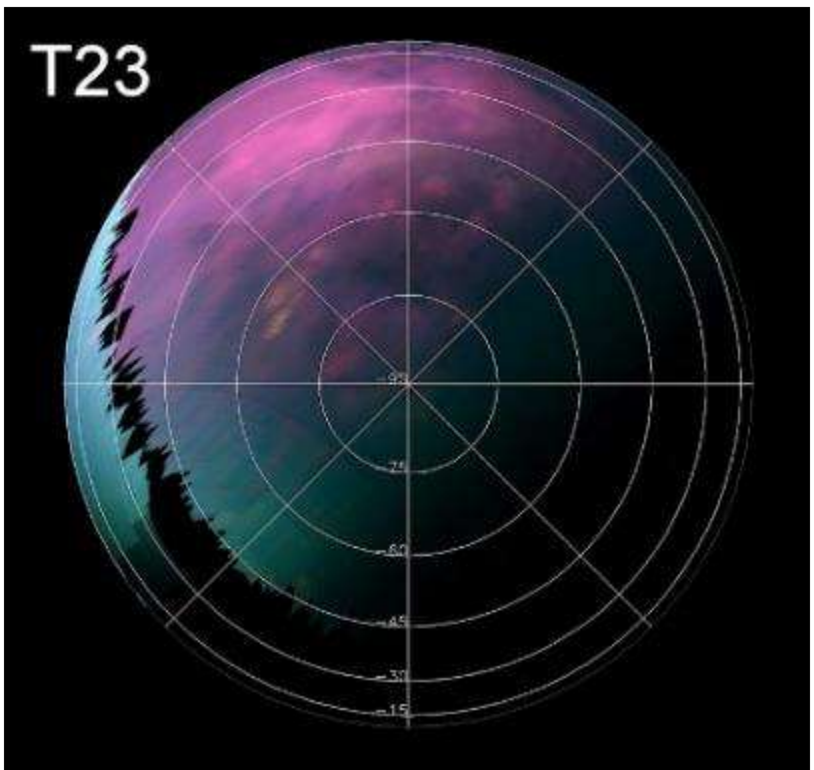


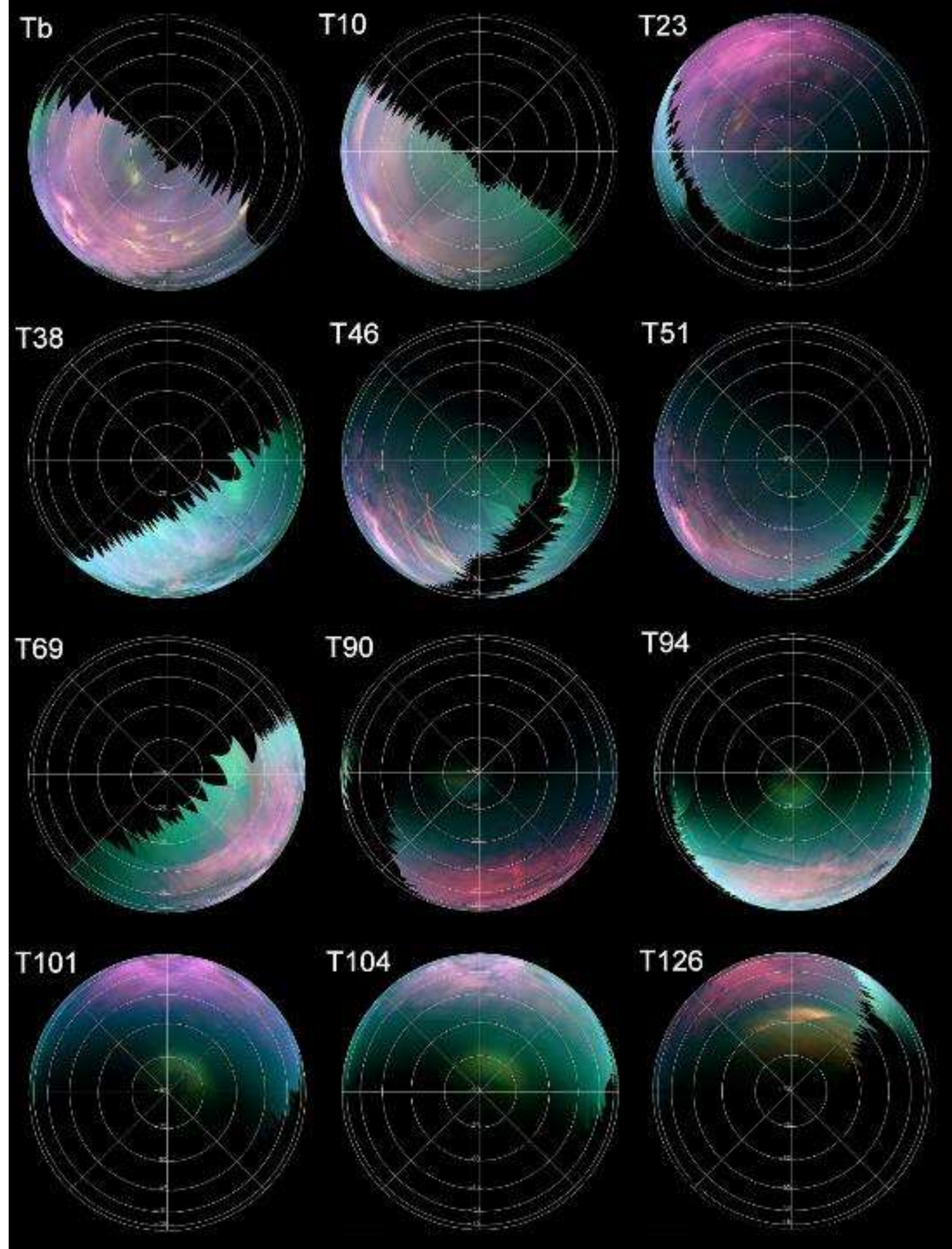
R=4.78 µm
G=2.78 µm
B=2.01 µm



The south pole

- Clear skies at the begining of the mission

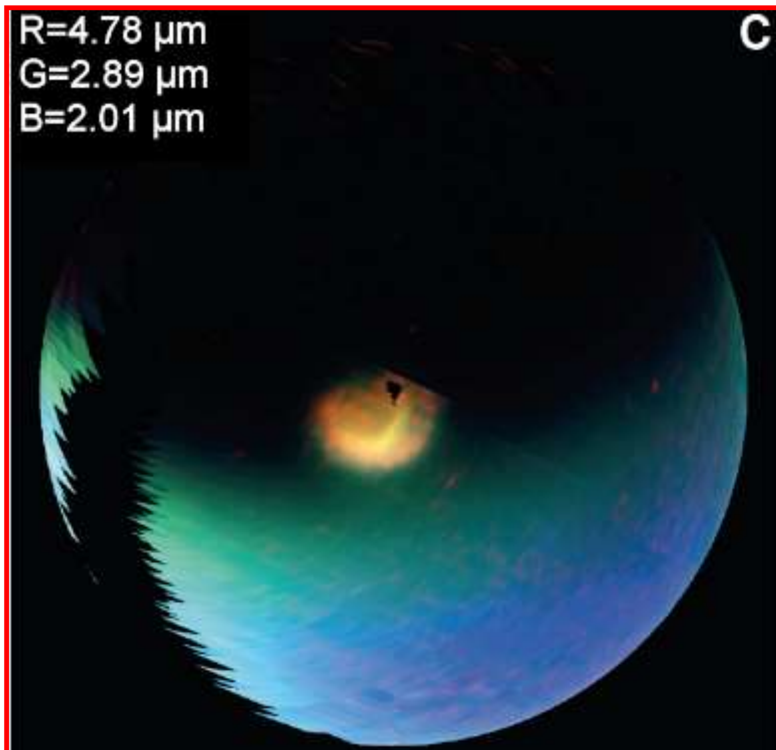


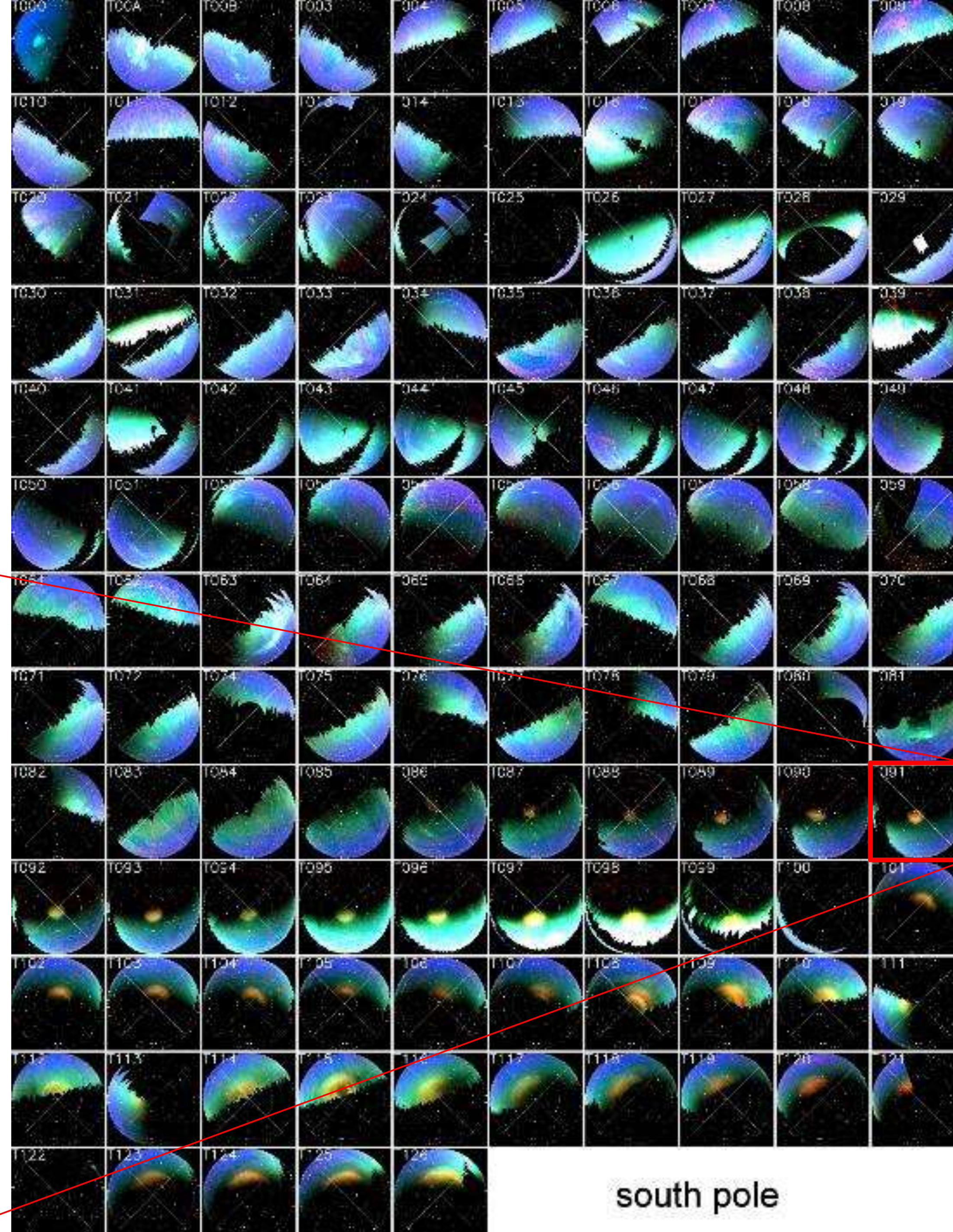


The south pole

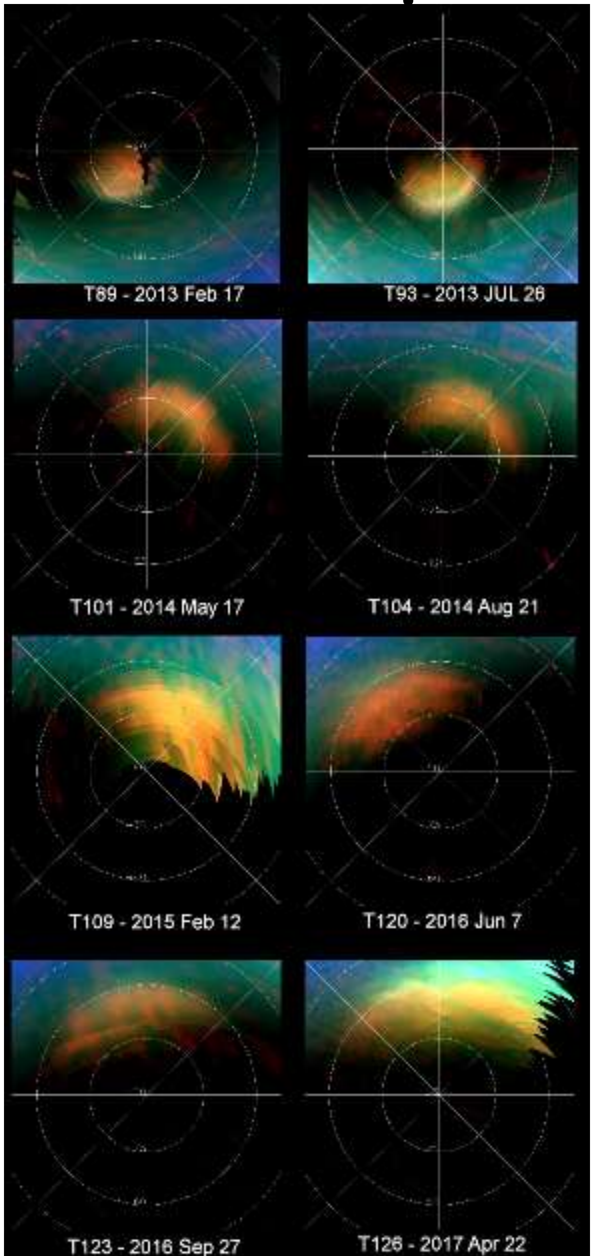
- Clear skies at the begining of the mission

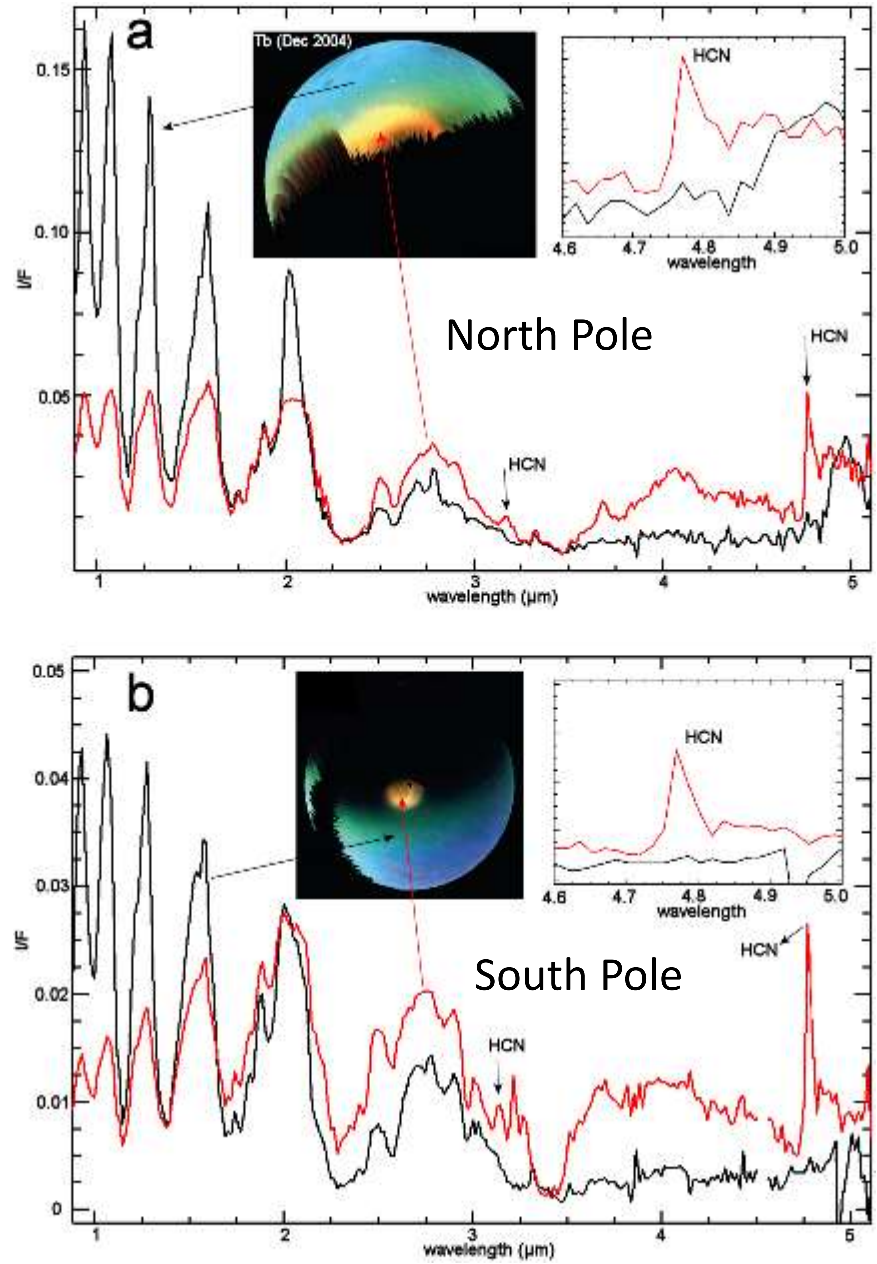
- An HCN-rich cloud appeared in 2012





The south pole

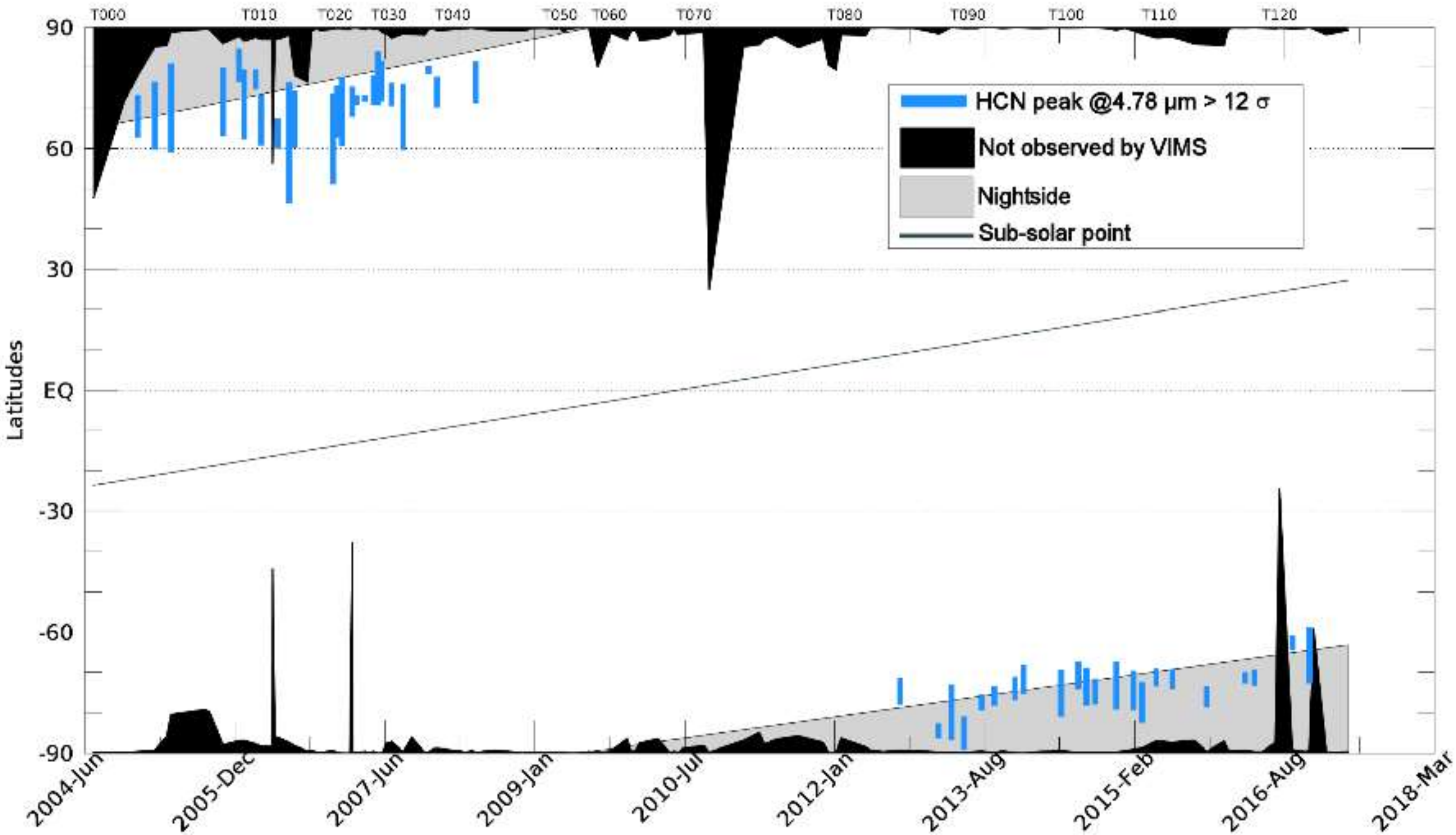




Le Mouélic et al., Icarus 311, 2018

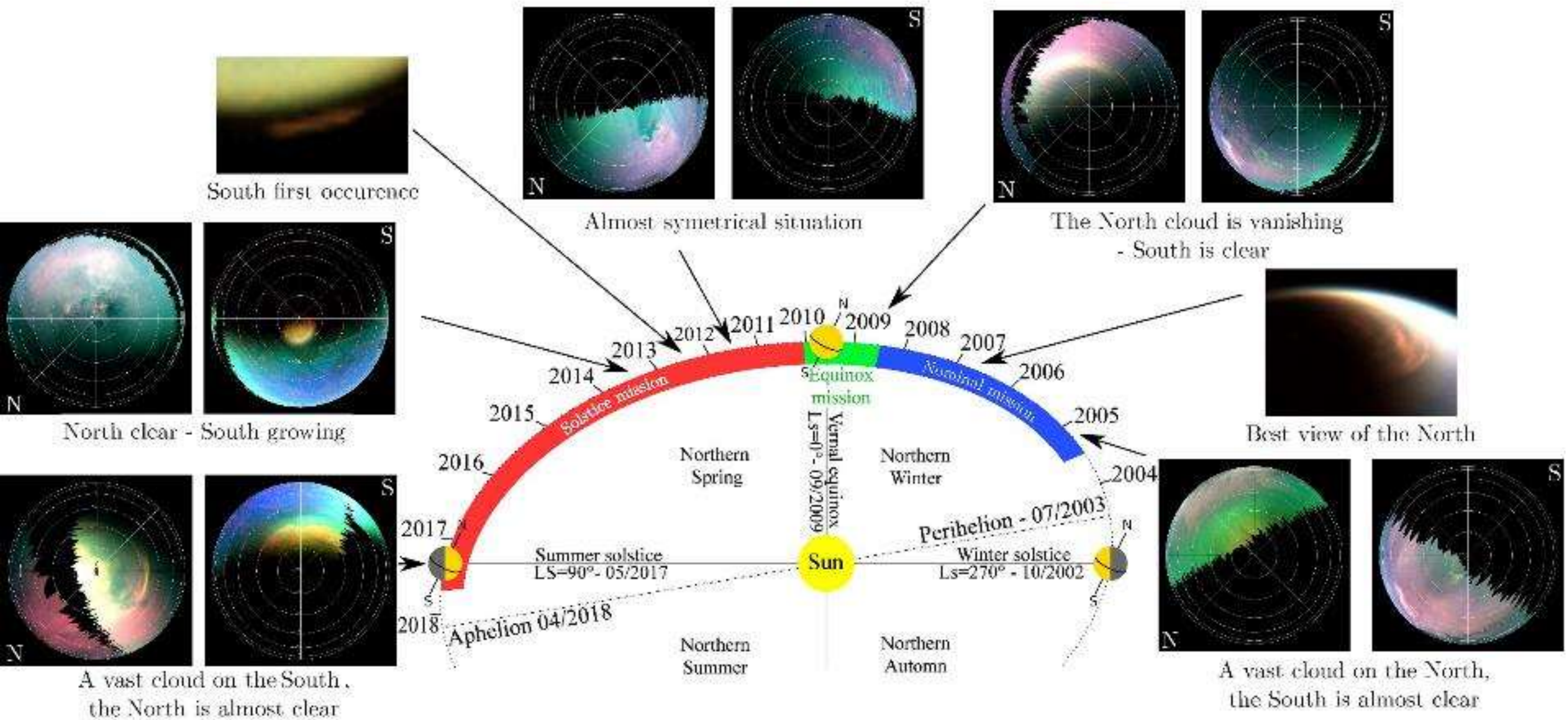
Temporal evolution

- Evolution of the HCN signature with time



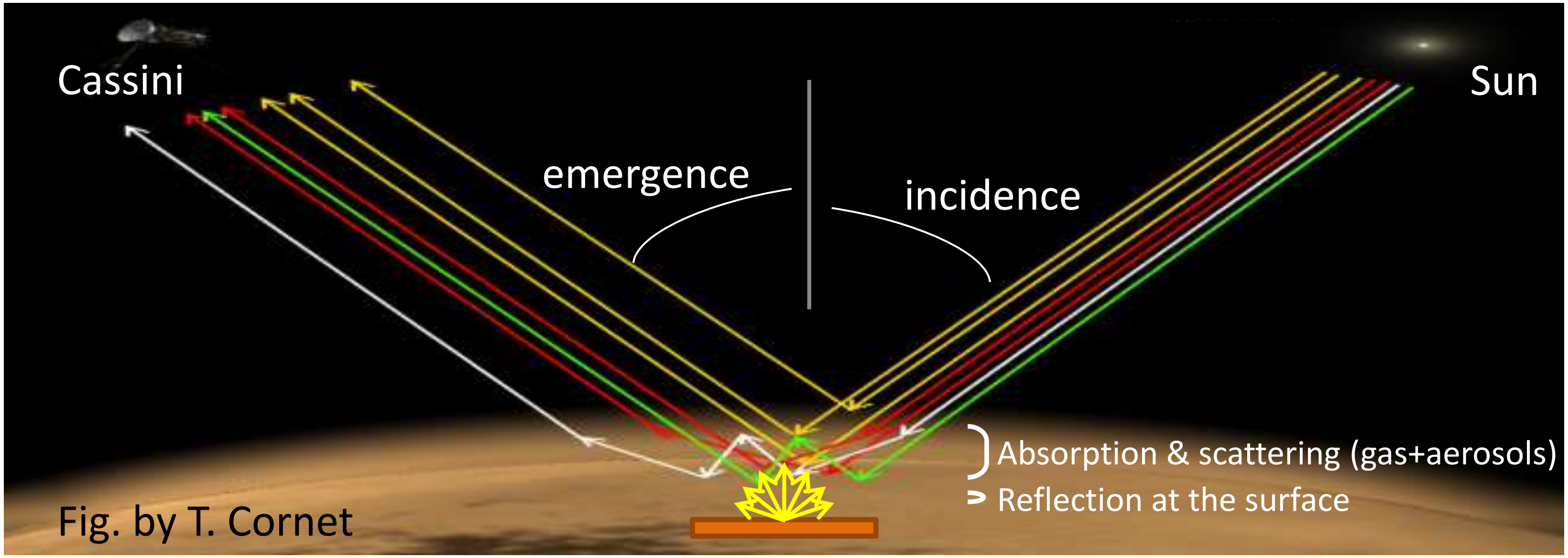
Summary of the poles survey

- Monitoring the seasonal evolution over half a Titan year…

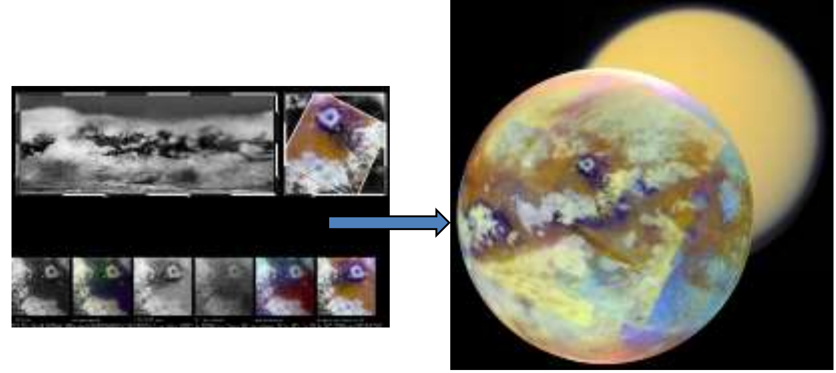


Le Mouélic et al., Icarus 311, 2018

2-Seeing the surface through the atmosphere : a cartographic challenge (nightmare ☺?)



Building a global hyperspectral mosaic



- Radiometric calibration of the cubes (dark subtraction, flat field,…) and computation of navigation files (SPICE)
- Sort of the cubes with low spatial resolutions used as background and high resolutions put ontop
- Set of filters to remove cubes acquired in extreme geometry
    - i < 80°
    - e< 80°
    - phase < 110°
    - airmass (1/cos i + 1/cos e) < 7
    - time exposure (avoid saturated pixels) : between 20 and 300 ms

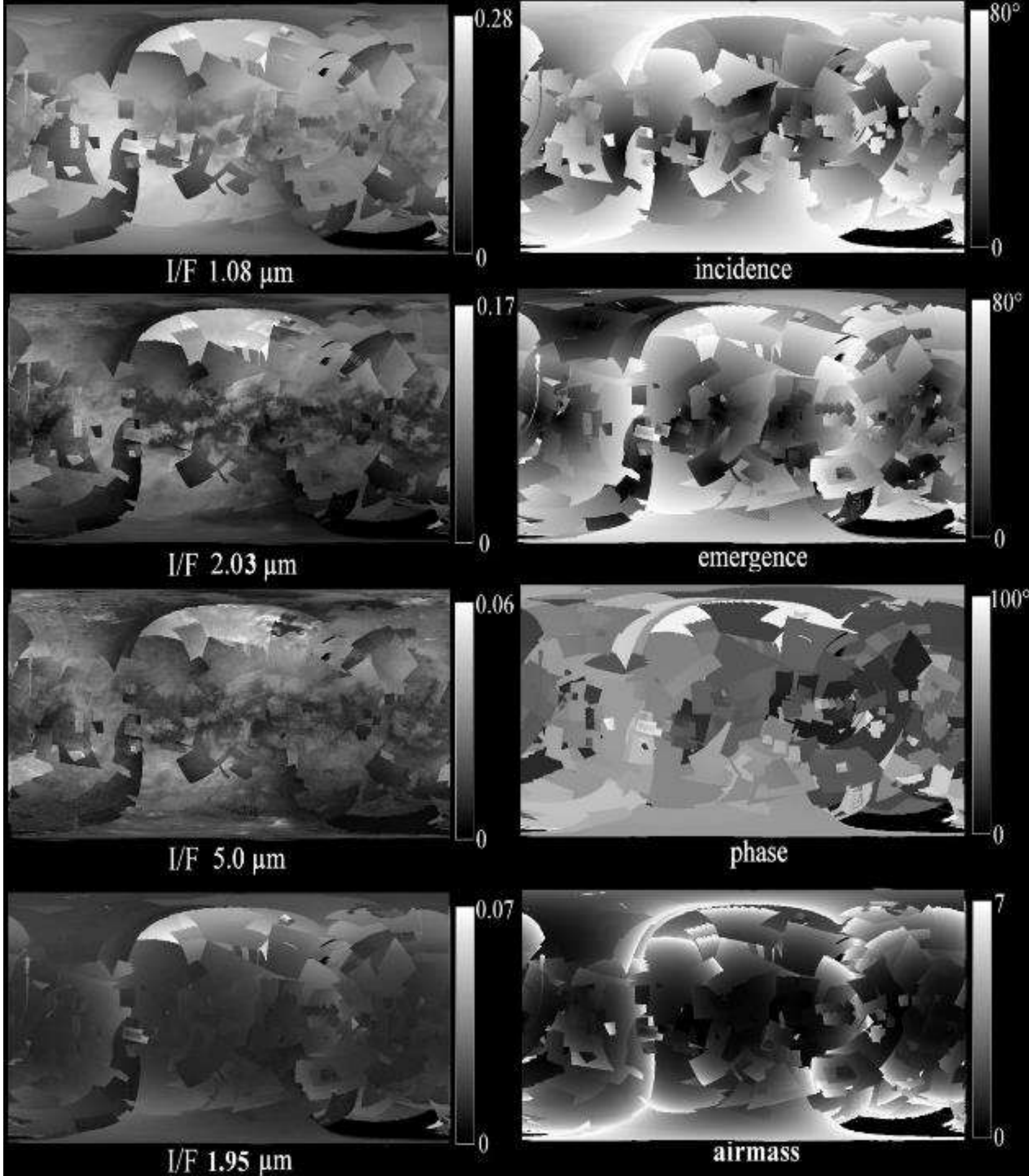
→ mosaic at 32 pixels/degree (1.4 km/pixel) of the 256 spectral channels between 1 and 5 µm

→ ***Define series of processing steps to remove seams and emphasize spectral (compositional) variations***

Global mosaic and corresponding geometry

→ the seams are due to the varying observing geometry

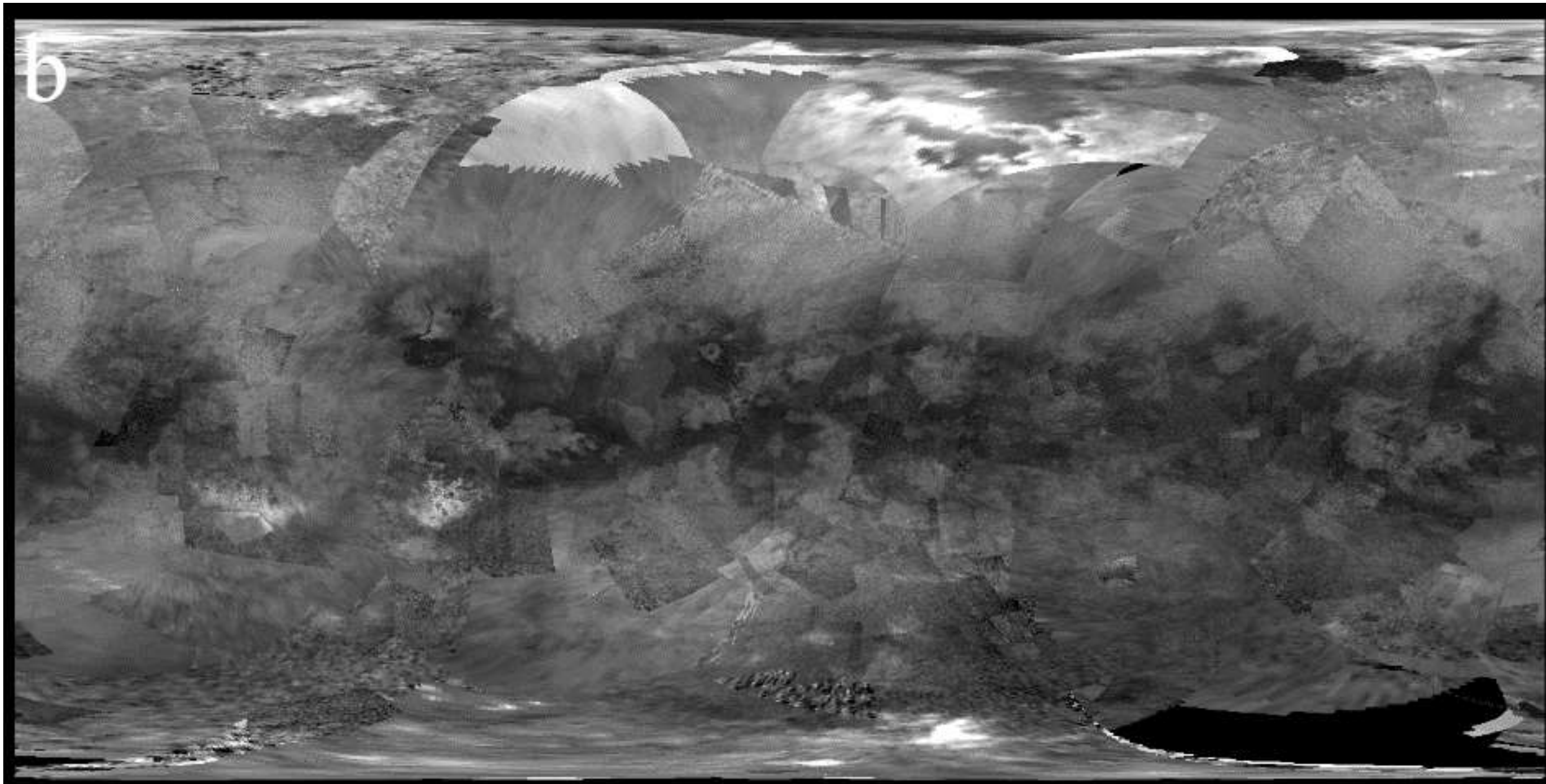
- Absorption, scattering by gas/aerosols (i,e,phi,lambda, airmass)
- Aerosol and surface photometric function
- Residual calibration artifacts (wavelength shift)
- Temporal changes (clouds/ surface/atmosphere) …



Mosaic at 5 μm : the easiest case

- Almost no aerosol scattering → only needs to be corrected from surface photometry

Mosaic at 5 μm : the easiest case



• Divided by a Lunar lambert and rayleigh phase function (Cornet et al., 2012)

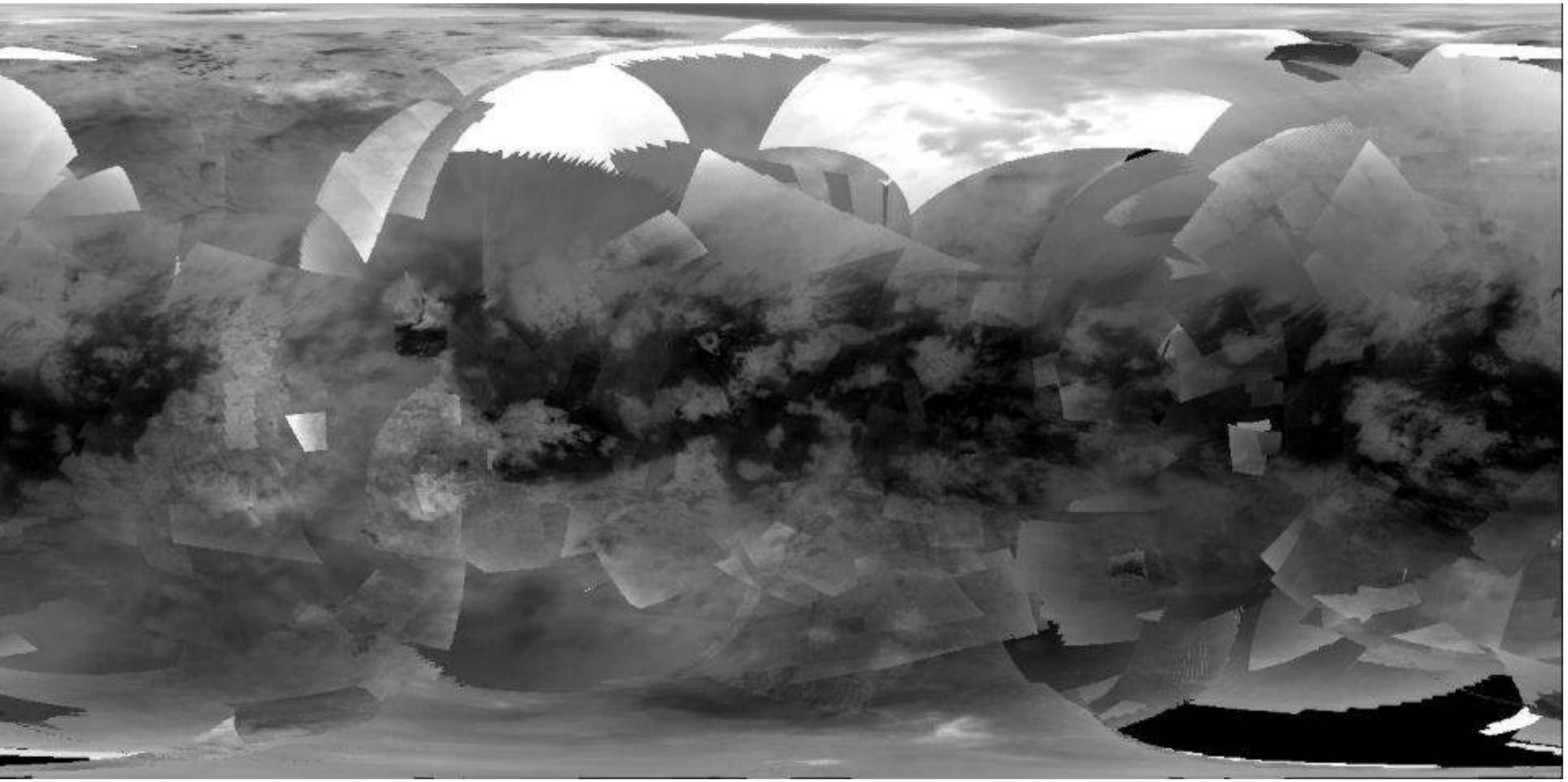
$A\,\mu_0/(\mu_0+\mu)P(g) + (1-A)\mu_0$ with A=0.285

More complicated case: the 2.03 μm window

- Uncorrected map

2.03 µm window divided by photometric fonction

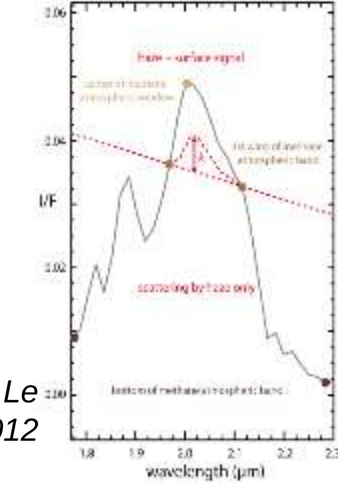
- Map corrected from surface photometry only (☹)

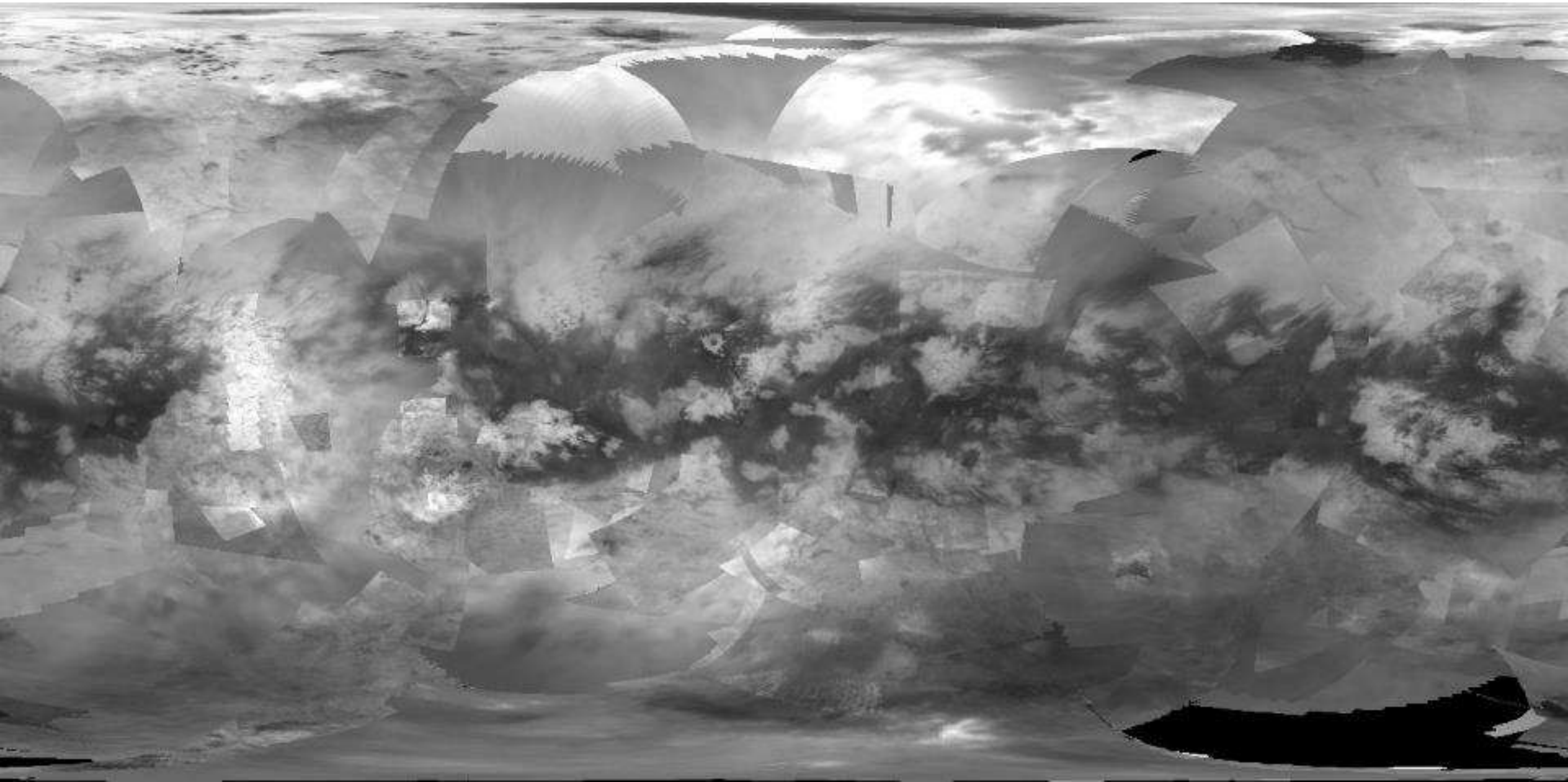


2.03 µm window minus band wings divided by photometric fonction

- Map corrected from atmosphere & surface photometry

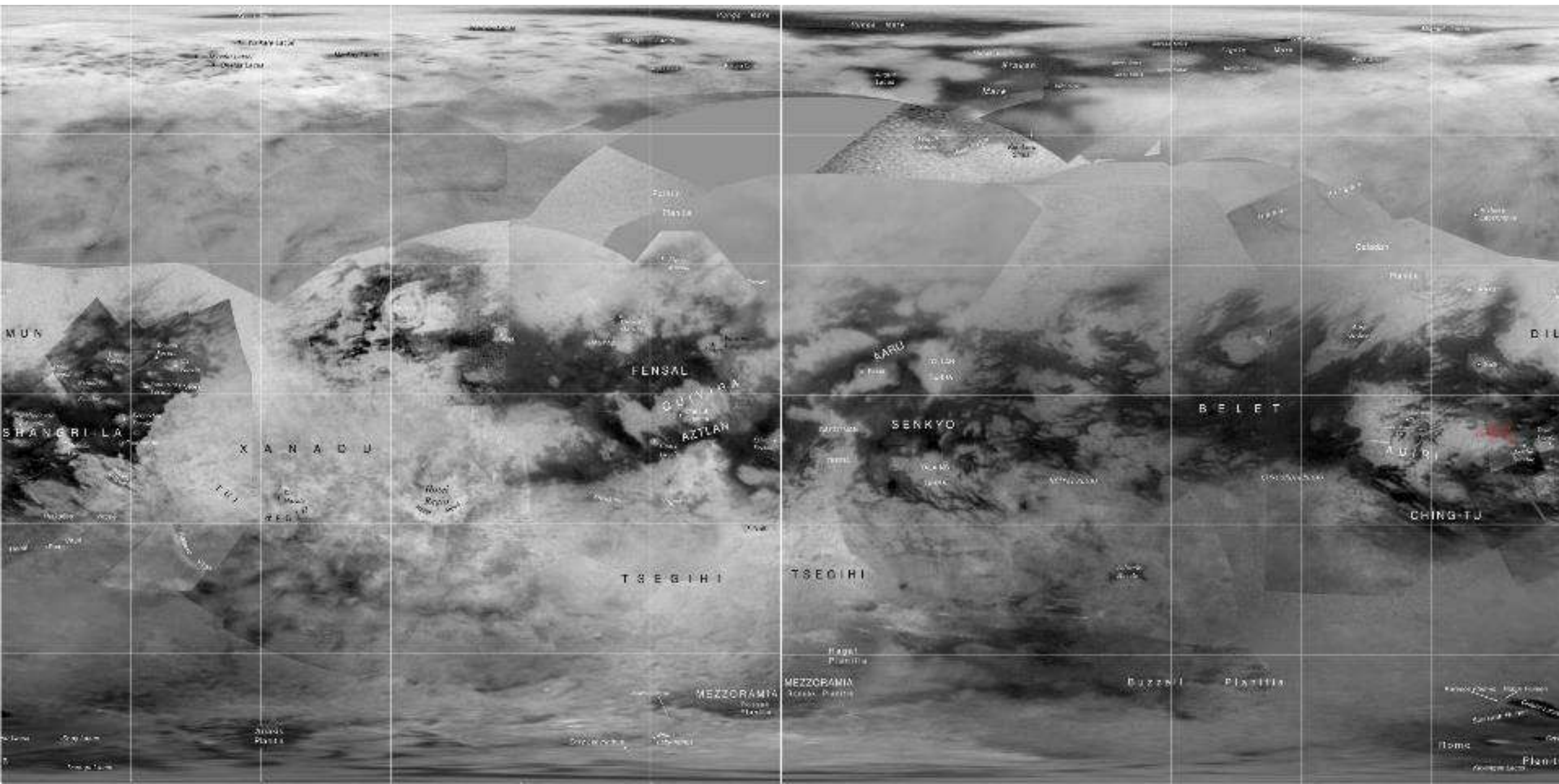
Approach from Le Mouélic et al., PSS, 2012





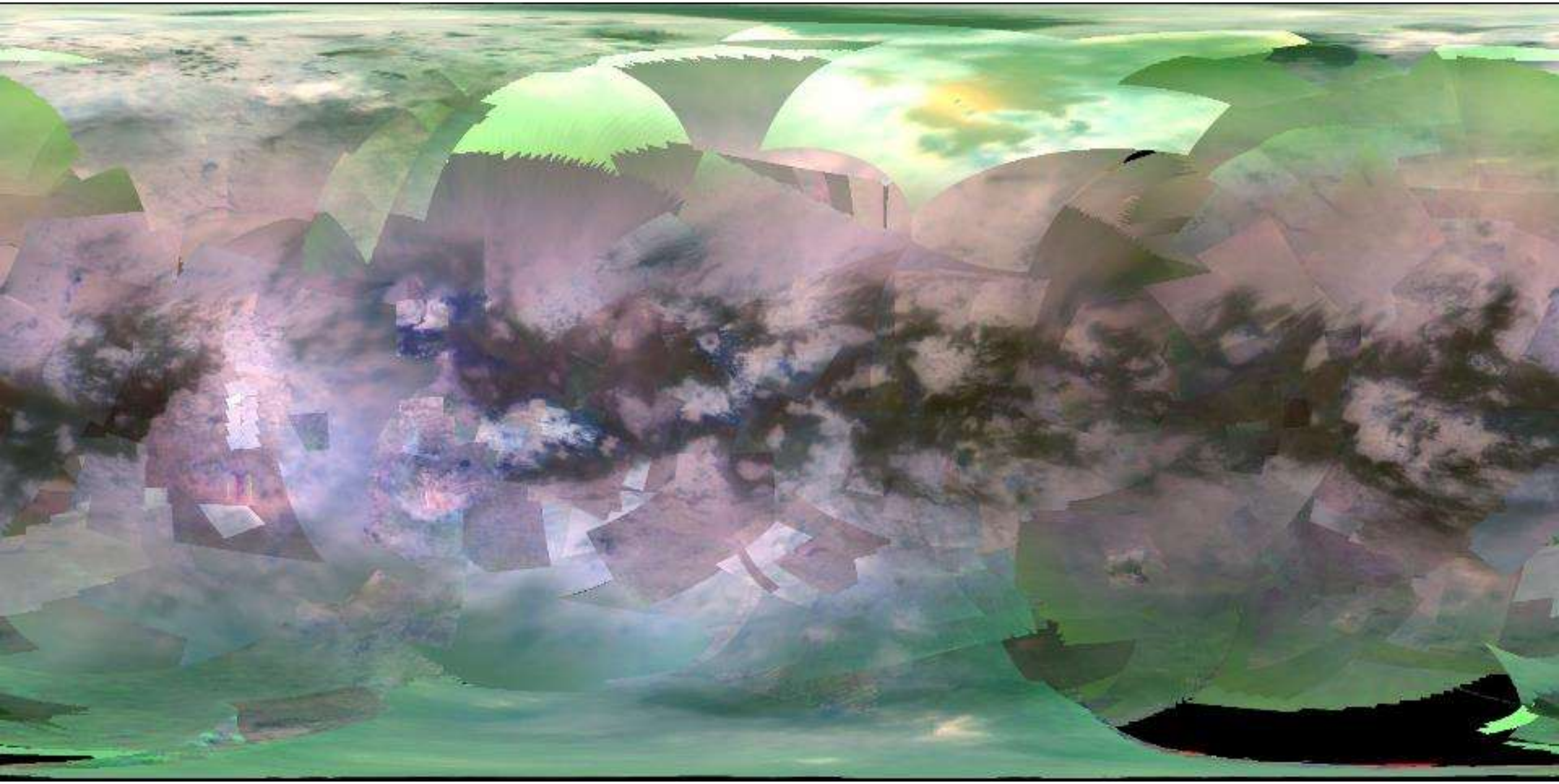
Comparison with ISS

(2015 public basemap)



Combining wavelengths to produce RGB false color composites

- Map corrected from surface photometry & atmosphere
- R= 2 µm, G= 1.59 µm, B=1.27 µm   corrected from scattering & geometry



The most powerful tool in surface mapping: using band ratios…

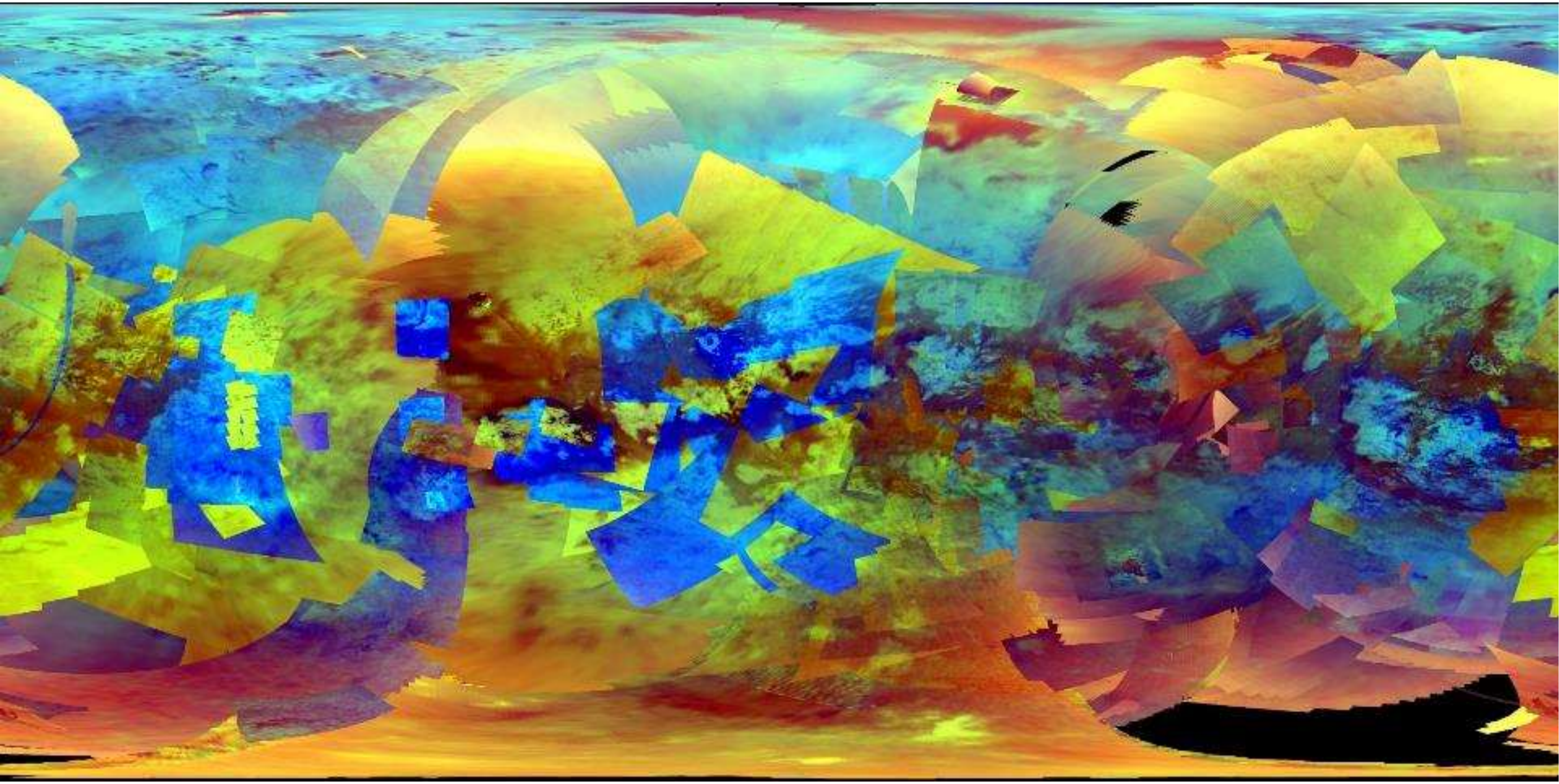
R=1000 nm, G=900 nm, B=415 nm **R= 750/415 nm, G=750/950 nm, B=415/750 nm**

➡ The band ratios remove albedo variations and the local slopes effects and better emphasize subtle spectral variations than RGB composites of single bands.

- Drawback : Extremely sensitive to calibration residuals (& atmospheric effects on Titan)

First try of band ratios on the global data set

- R=1.59/1.27, G=2.03/1.27, B=1.27/1.08 µm : ☹

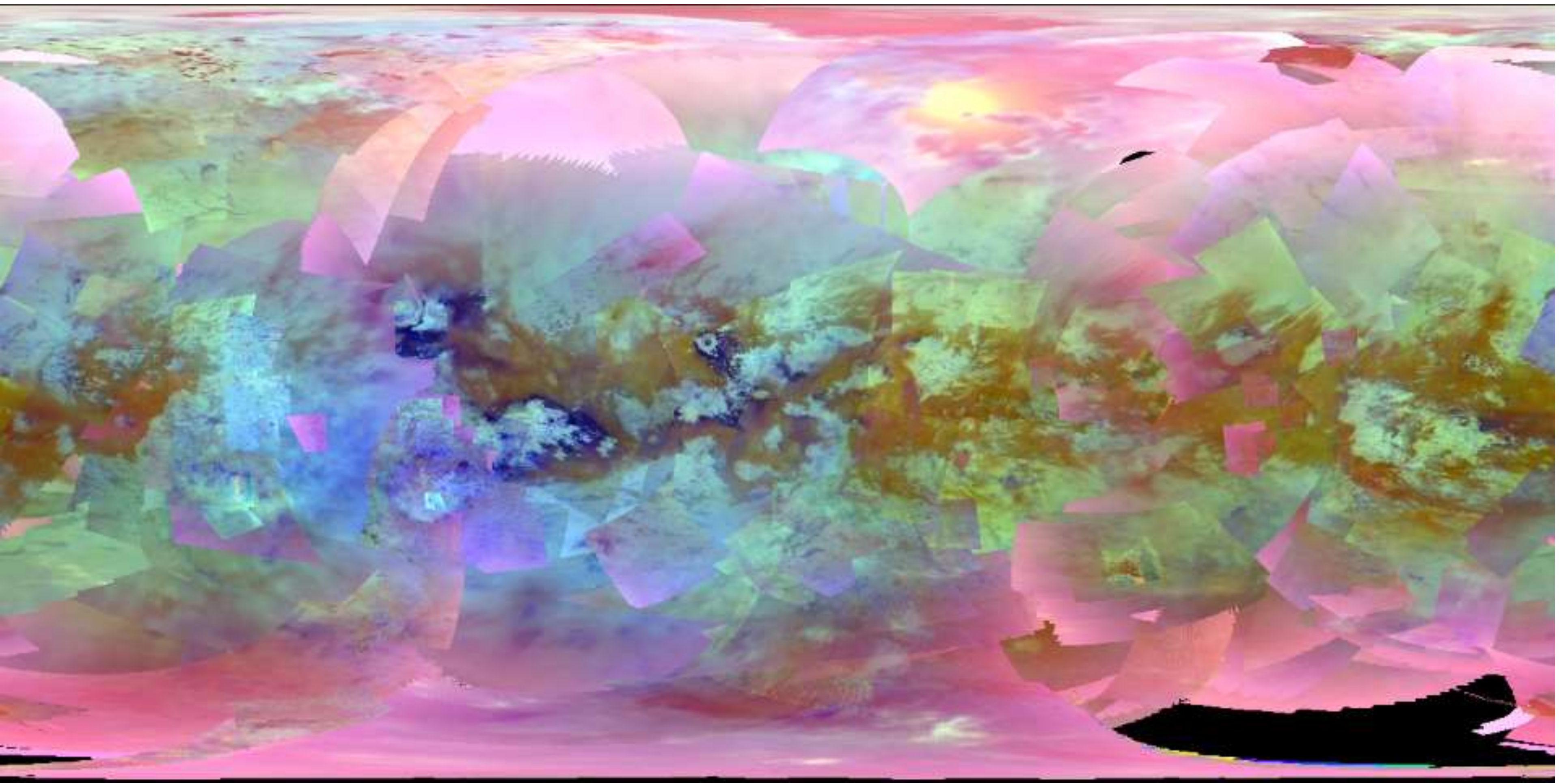


→ Is this modern art ? Not usable for science…

After a lot of head scratch…

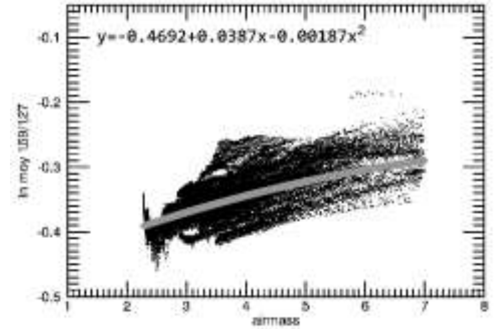
- R=1.59/1.27, G=2.03/1.27, B=1.27/1.08 µm
- Refinement of the wavelength selection and calibration - ☺

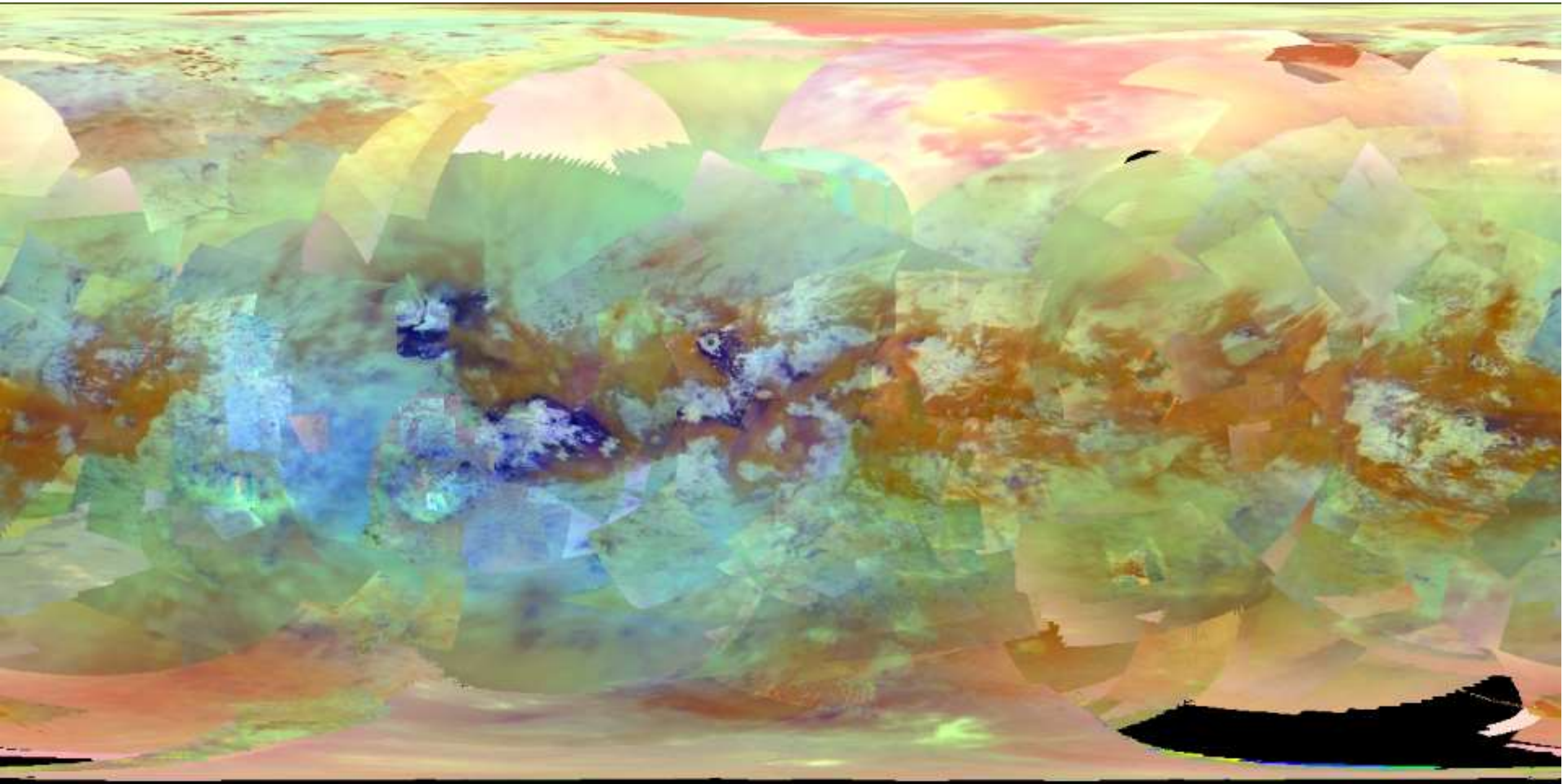
  brown colors=dune fields



After a lot of head scratch…

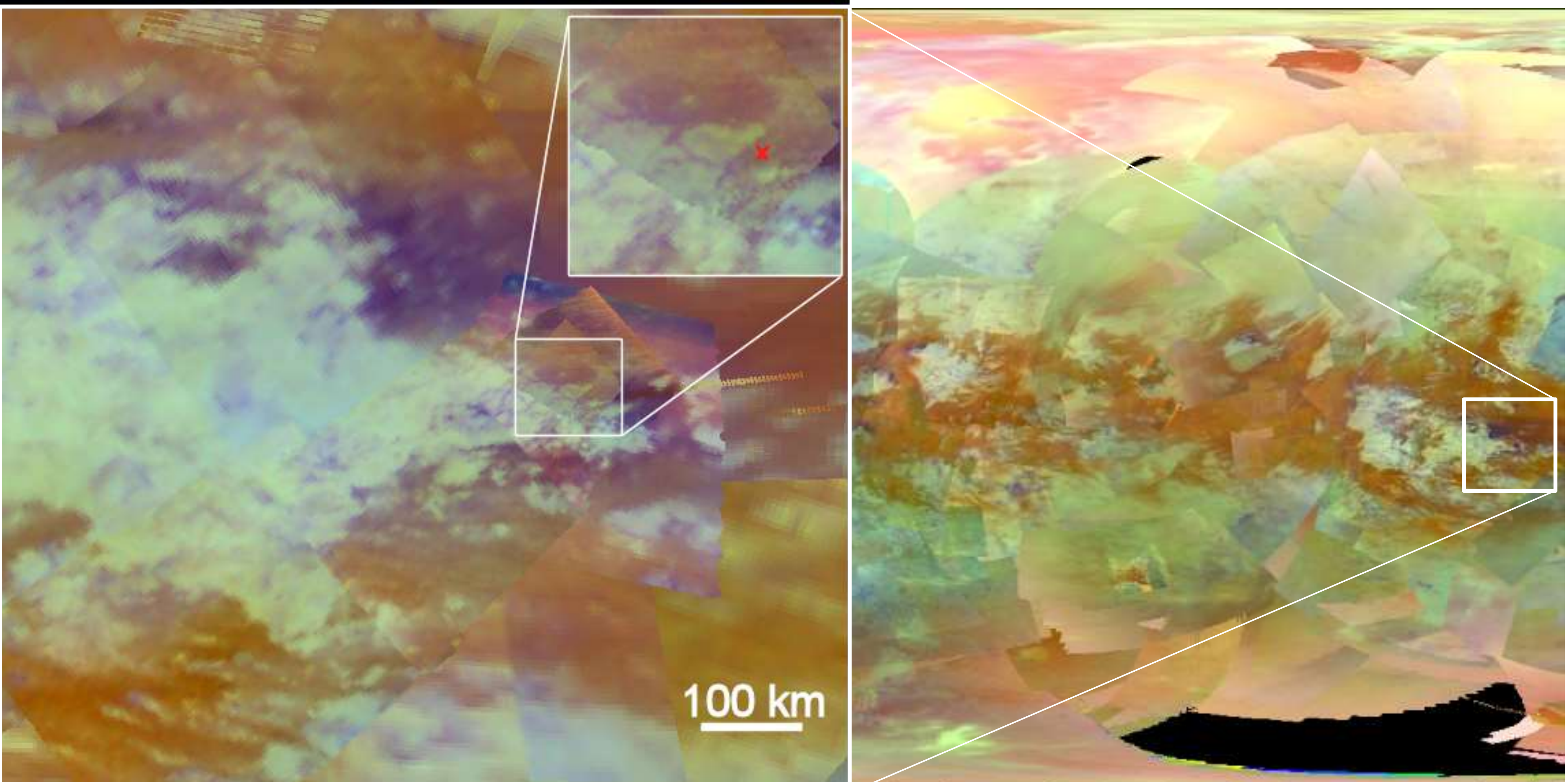
- R=1.59/1.27, G=2.03/1.27, B=1.27/1.08 µm
- Refinement of the wavelength selection and calibration
- Additional atmospheric empirical cleaning filter (dependence with airmass) - ☺



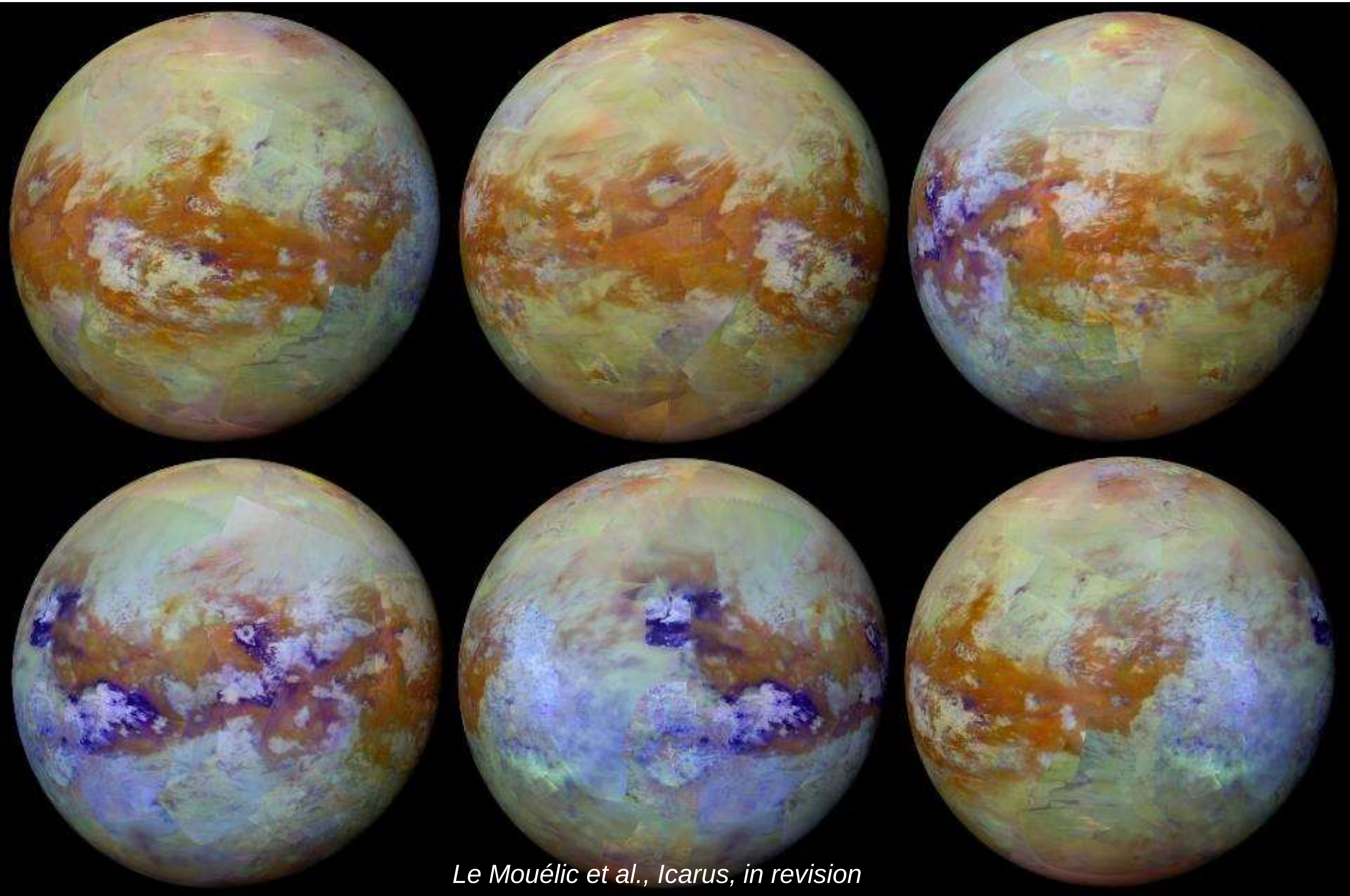


Zoom on the Huygens site…

- Some places are well imaged
- Some others will require a new spacecraft…



Orthographic views



Le Mouélic et al., Icarus, in revision

Thanks for your attention…

…waiting for new Titan images

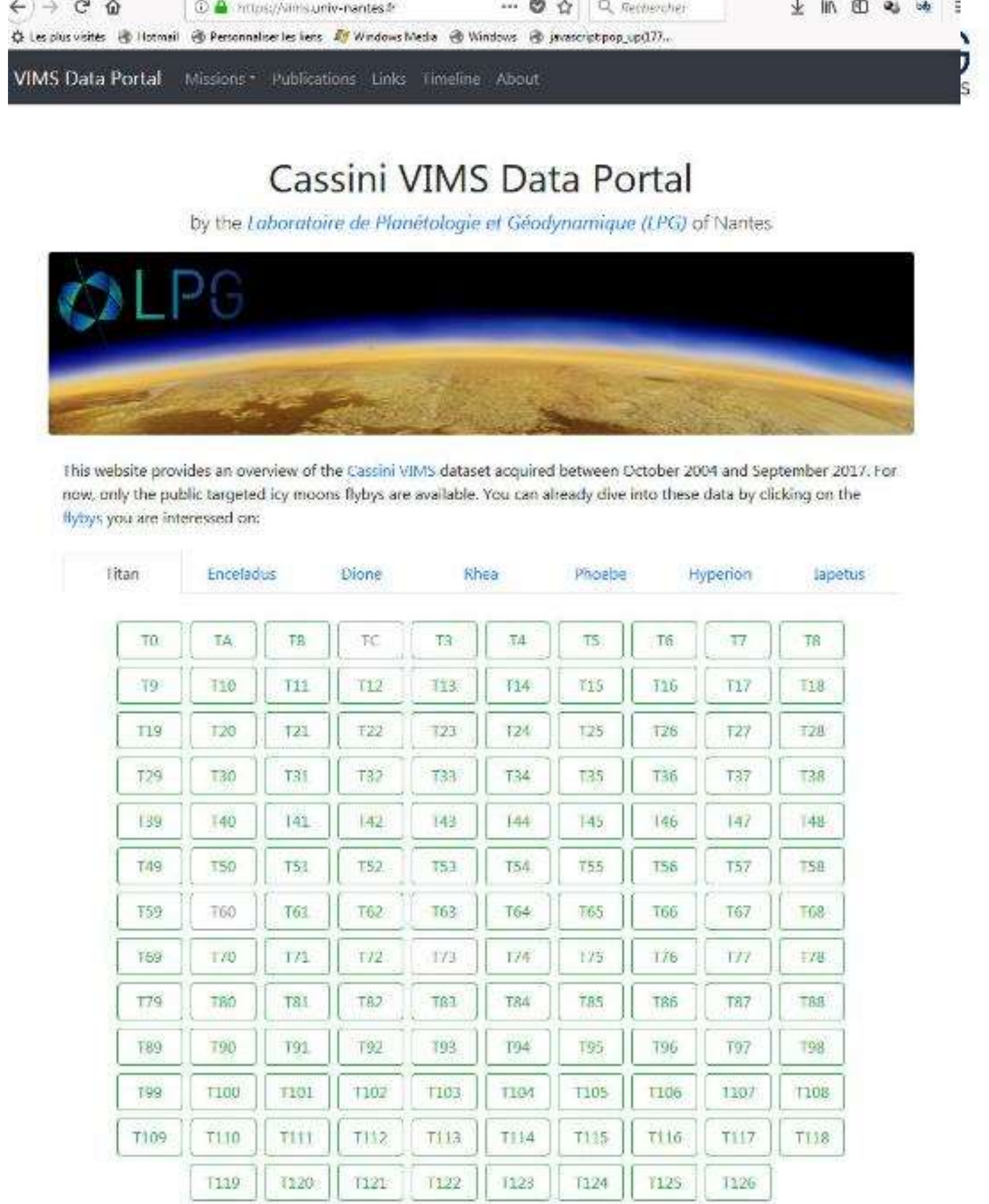
Some advertising :

- Ever wanted to walk on Titan ? : Come to see the ***Virtual Reality experience***…

- VIMS data portal at LPG : ***https://vims.univ-nantes.fr***

data portal at LPG

vims.univ-nantes.fr



(work done by B. Seignovert)