



Universidad
del País Vasco

Euskal Herriko
Unibertsitatea



Grupo de Ciencias Planetarias
Zientzia Planetarioen Taldea



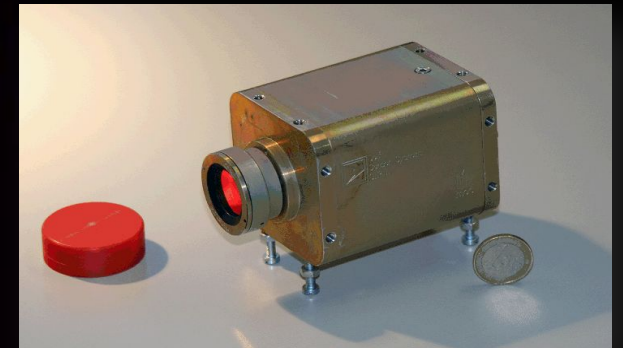
Science with the Mars Webcam

*Unveiling the Martian
climate using the Visual
Monitoring Camera on Mars
Express*

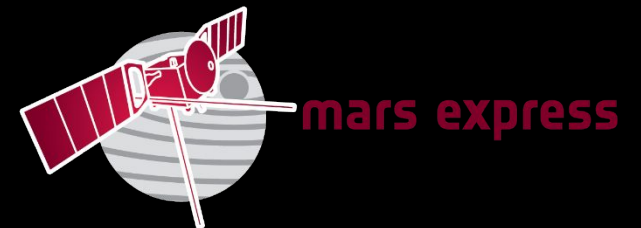
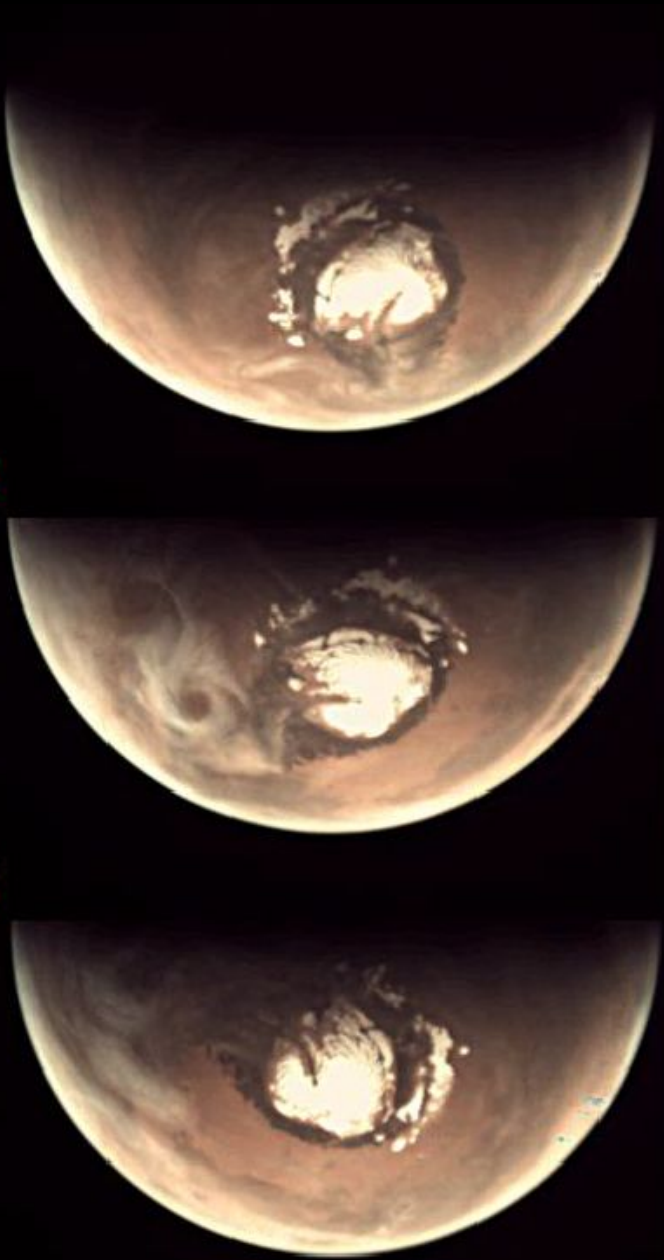
Jorge Hernandez-Bernal,
Eleni Ravanis

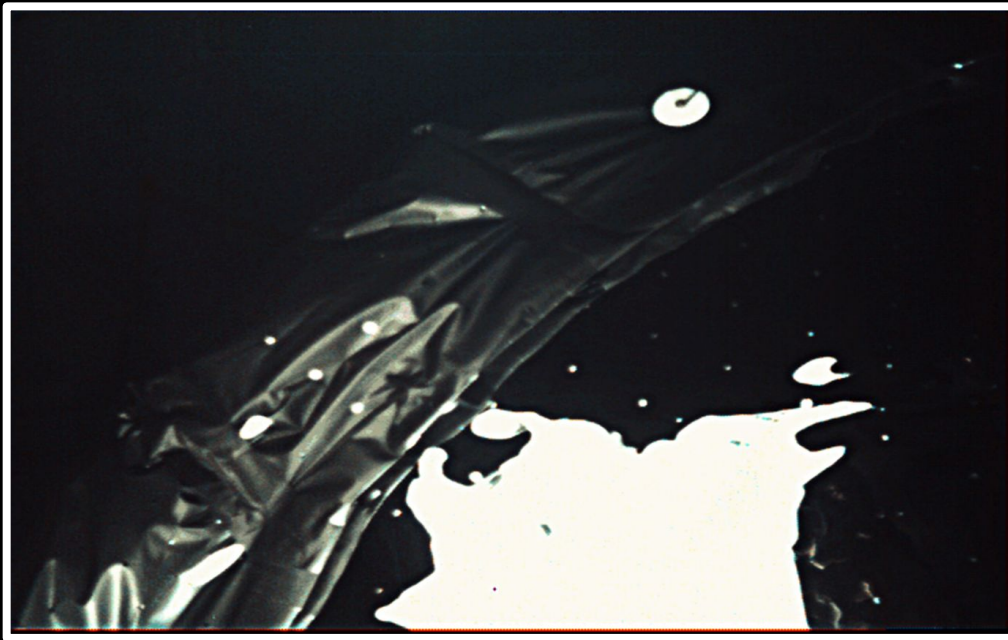


Mars South pole, imaged by VMC 8th January 2019
Image credit: ESA



Part 1: History and operations of VMC *Eleni Ravanis*

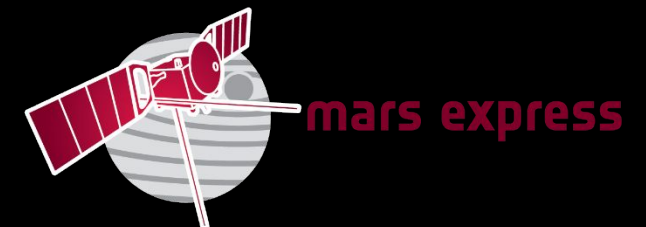




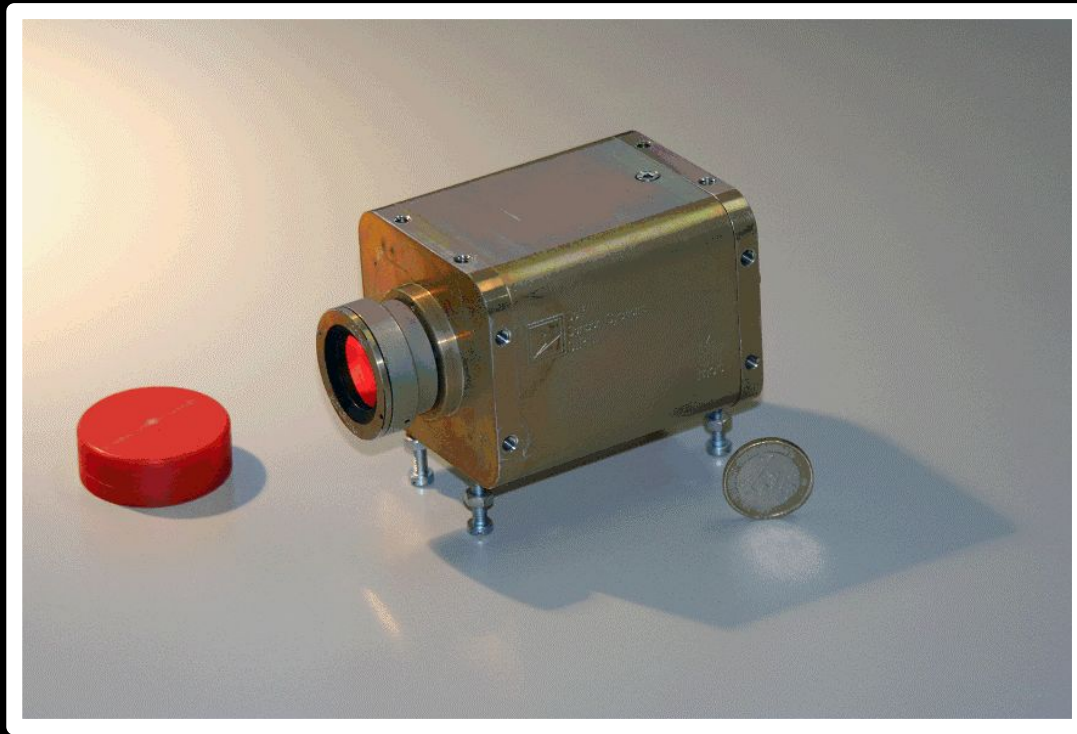
©ESA

VMC history

- Visual Monitoring Camera (VMC) originally intended to monitor the Beagle-2 lander
- In 2007 VMC was switched on again and images used for outreach purposes
- In 2016 VMC was given scientific instrument status
- Over past 2 years we have been working towards a full data processing pipeline
- Originally commanding for the VMC done by ESOC, ESAC took over in June 2018
- Eleni Ravanis started work in October 2018, as a YGT specific to VMC



VMC Specifications



Optics

- Focal length: 12.3 mm
- FOV: $\sim 40^\circ \times 31^\circ$ (0.7x0.5 rad)
- Wavelength range: 570-740nm (b&w), 400-650nm (color, Bayer filter)

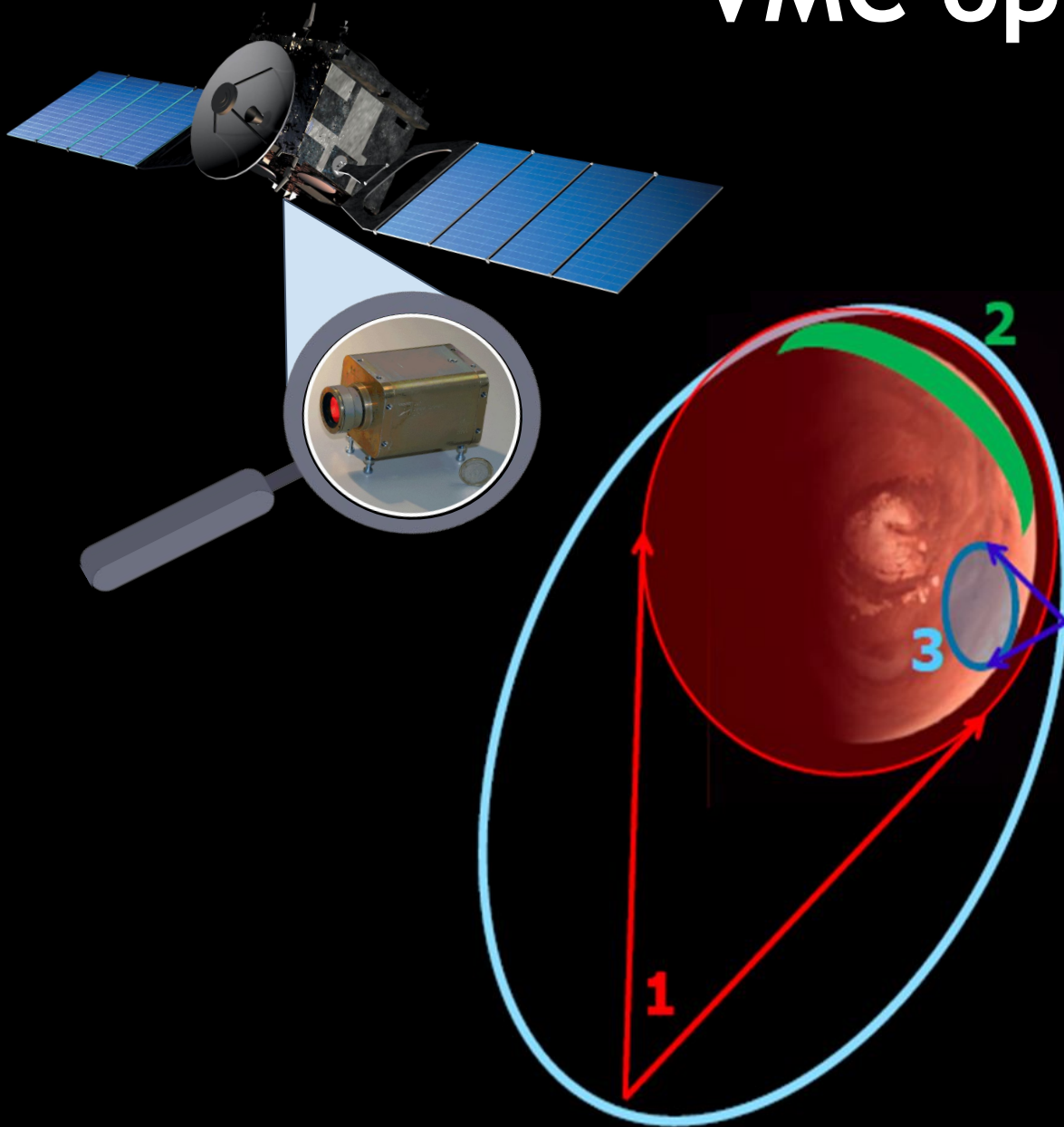
Detector

- Pixel pitch: $14 \times 14 \mu\text{m}$
- Size: 640x480 px

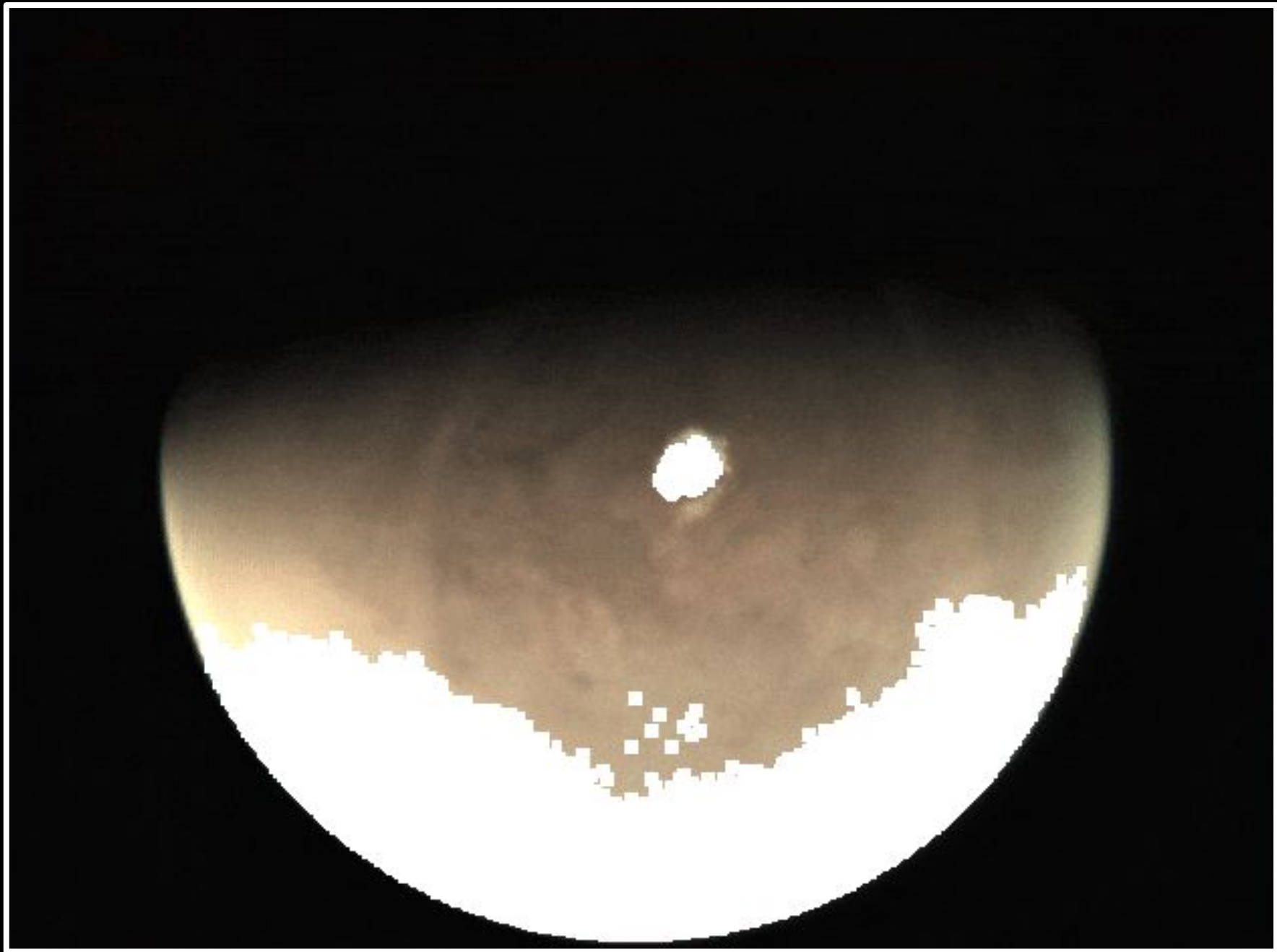


"An ordinary camera in an extraordinary location"
(Ormston et al. 2011)

VMC operations



- Inclined 19° from the normal view direction of the other science instruments
- Different data protocol to other instruments, so cannot observe at the same time
- Normally observe close to apocentre when other instruments do not observe (1)
- When the timeline is fixed for other instruments, we add pericentre observations (2 and 3)



Credit: ESA/ UPV/EHU Bilbao. Video composed of VMC images

VMC calibration

Flat-fields

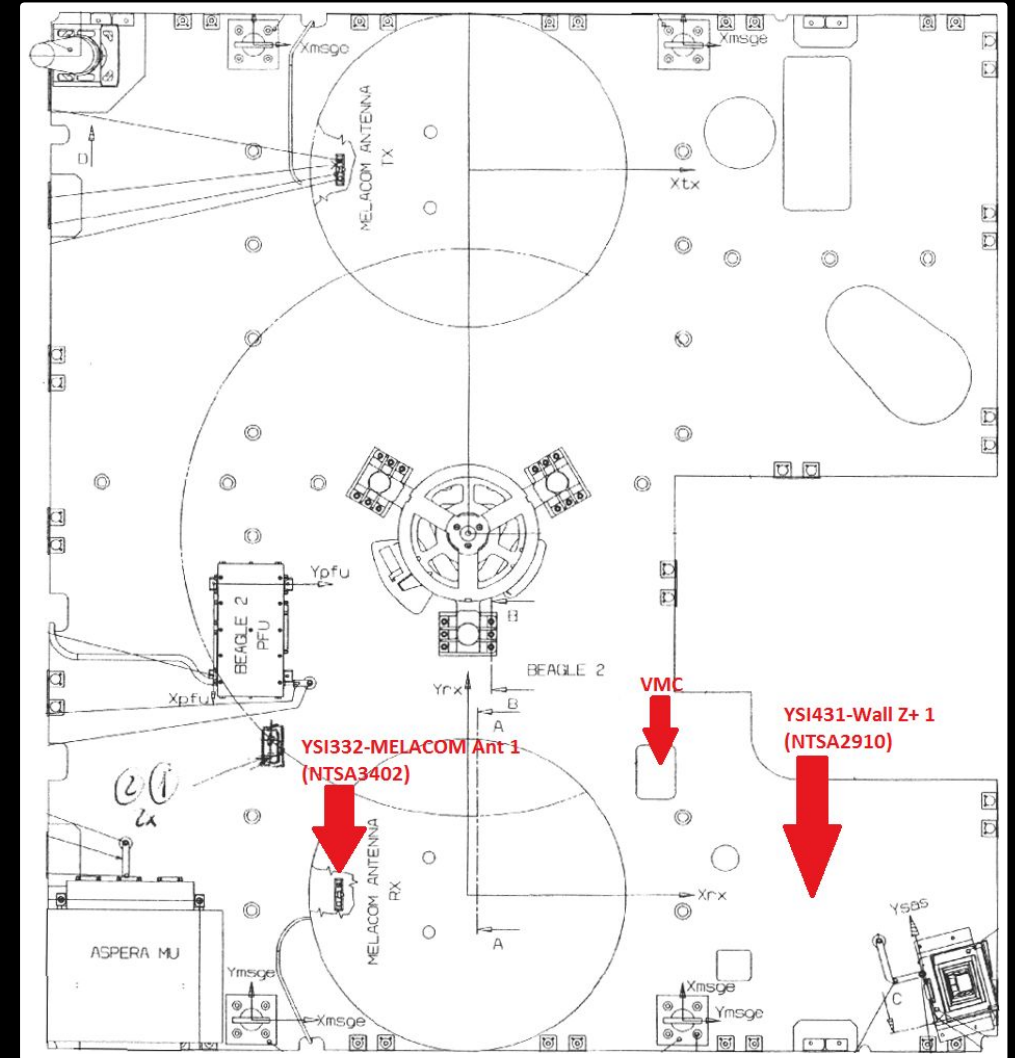
- No ground calibration
- We take quasi-flat fields over flat parts of Mars at pericentre

Dark current

- Point to dark sky aka not Mars, for longer exposures we take multiple images to extract the stars in post-processing

Temperature/ dark bias

- We have T from a 'VMC sensor'; temp changes of $>15^{\circ}\text{C}$ thus suspected to be T of electronics rather than the CCD itself
- Analysis underway, there are other temperature sensors we could potentially use instead



VMC calibration: Boresight offset

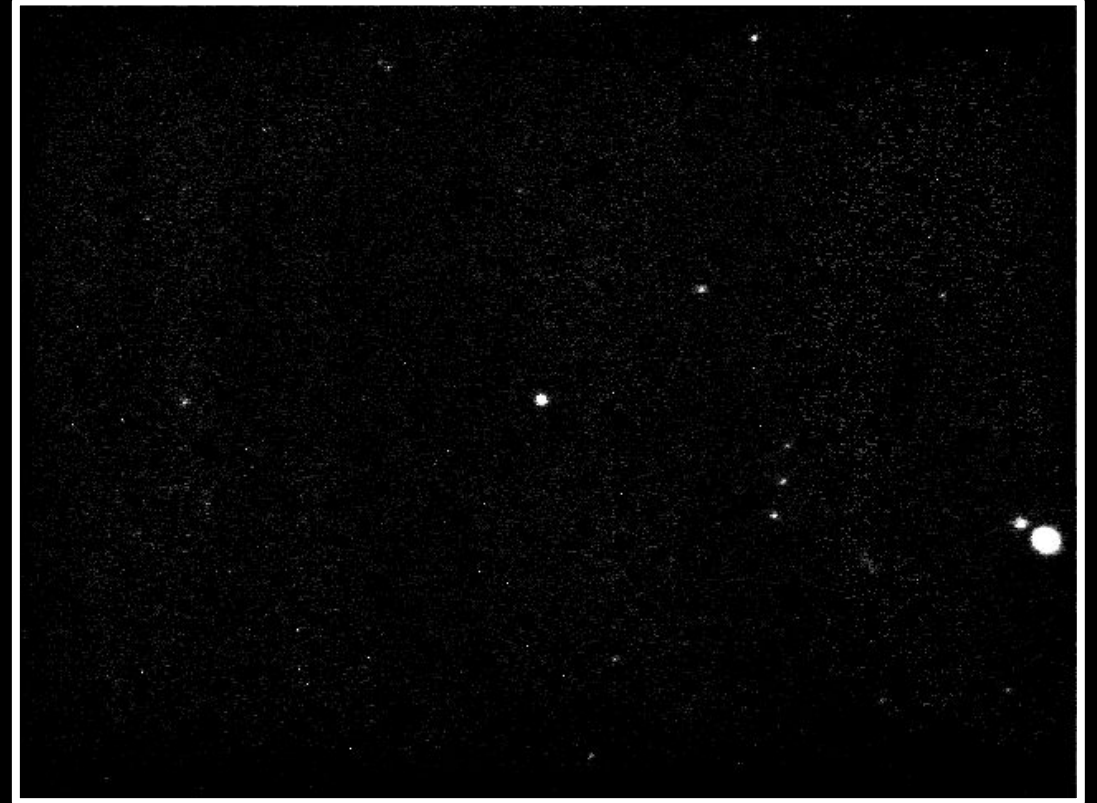
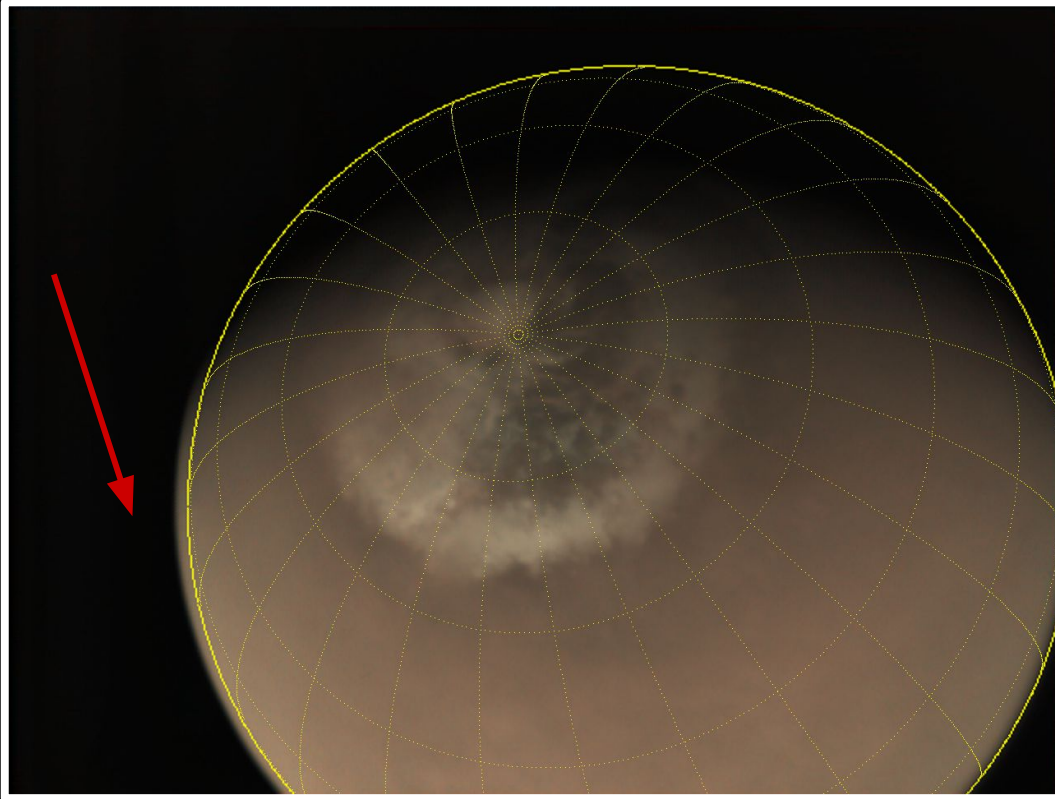
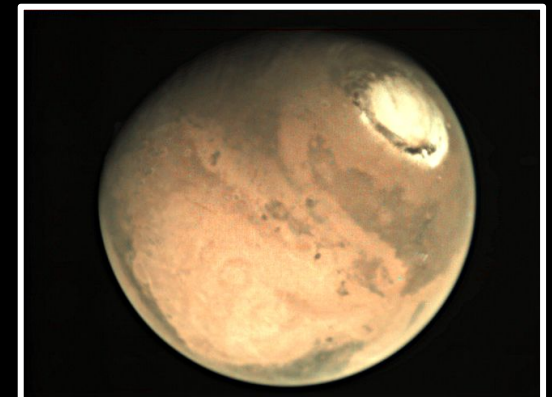
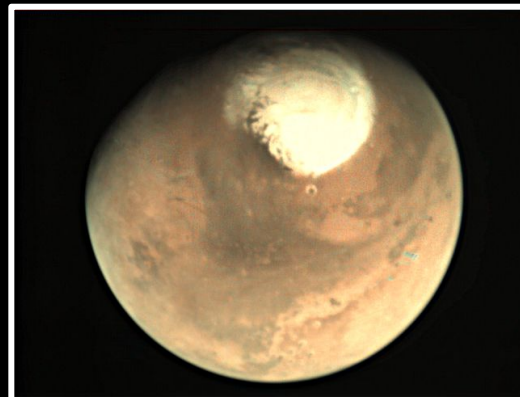
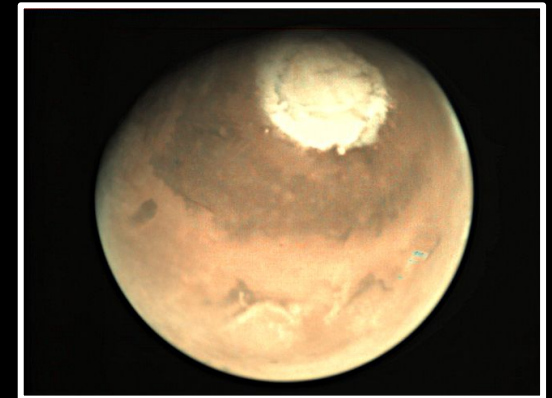
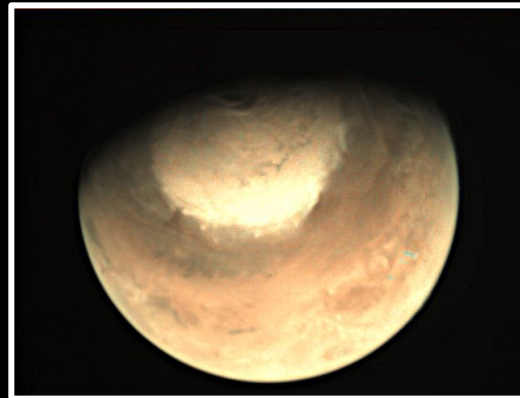
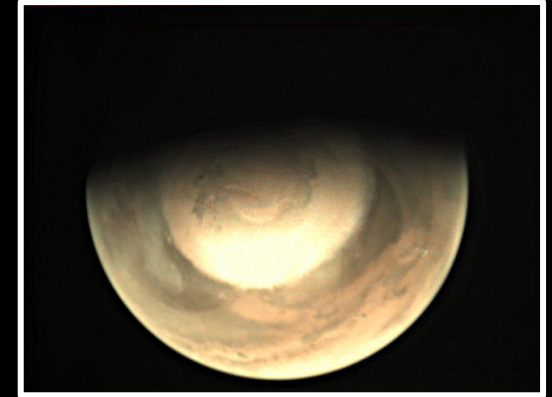
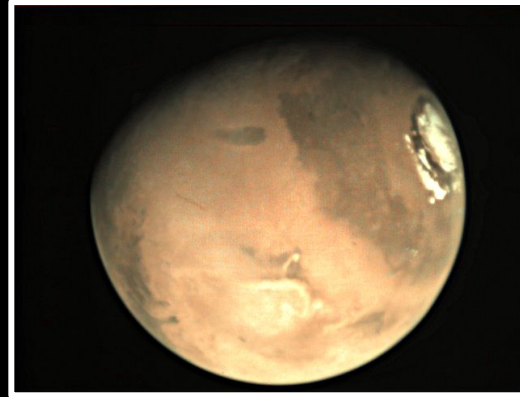


Image credits: *ESA, UPV/EHU Bilbao*

Use star observations and compare the actual position of stars in the image compared to predicted position (+ we caught Deimos!)

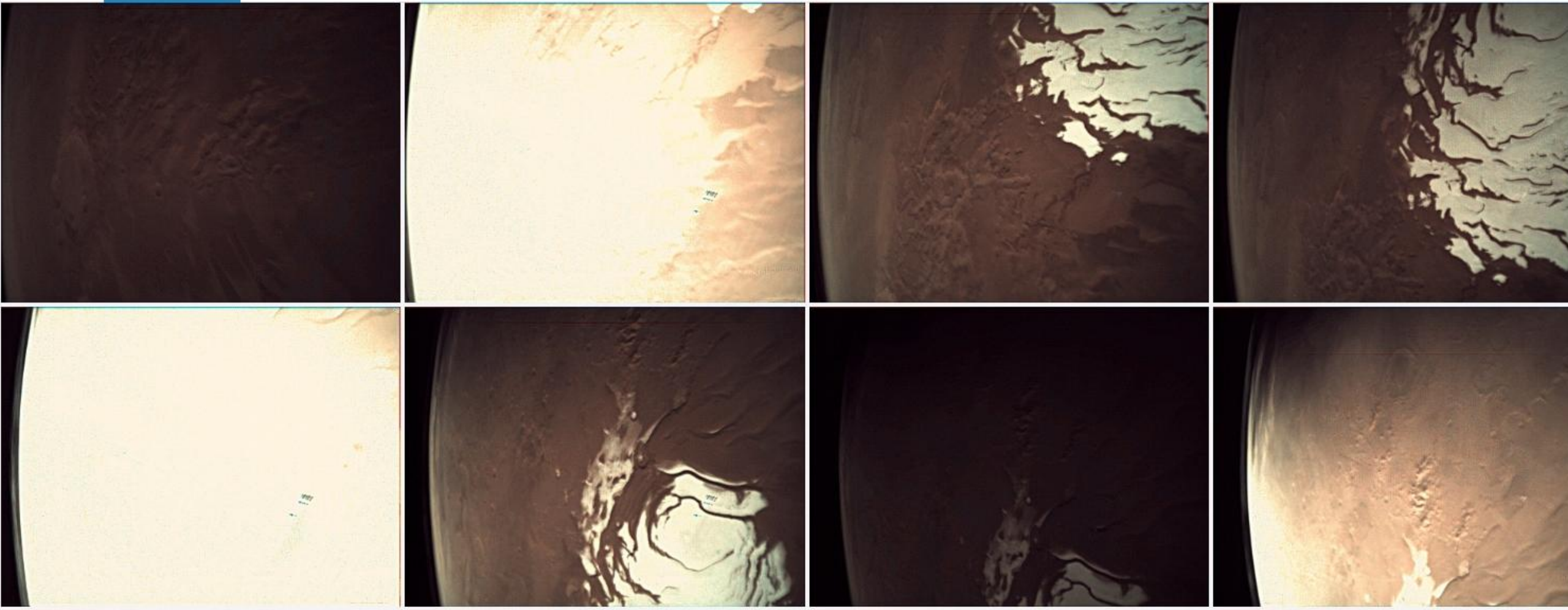
VMC and CESAR

- VMC Seasons case: will soon be available for use by high school students
- Other VMC science cases to come over the next year



VMC outreach: Flickr

[flickr.com/esa_marswebcam/](https://www.flickr.com/esa_marswebcam/)



VMC outreach

twitter.com/esamarswebcam



VMC - Mars Webcam

@esamarswebcam

The Visual Monitoring Camera (VMC) is mounted on Mars Express, one of ESA's deep-space probes now orbiting the Red Planet.

Darmstadt, Germany

blogs.esa.int/vmc

Joined June 2010

Tweet to VMC - Mars Webcam

26 Followers you know

Tweets 1,321 Following 15 Followers 11.1K Likes 157 Lists 1

Following

Tweets Tweets & replies Media

Pinned Tweet



VMC - Mars Webcam @esamarswebcam · 25 Oct 2018

We spotted a curious cloud! There's been lots of discussion abt the bright streak that has appeared on our images in recent weeks #H2O Our #Mars experts have answers! esa.int/Our_Activities...



ESA Science @esascience

Over the past few weeks, the @esamarswebcam on our #Mars Express mission has been observing an elongated cloud hovering near Arsia Mons volcano. Not linked to volcanic activity, this water-ice cloud is... Show this thread

4 58 115

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NASA Solar System @...

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@ESA_ExoMars @ESA_...

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ESA space history @ESA_...

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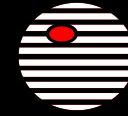


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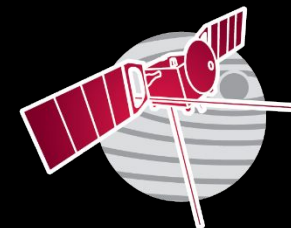


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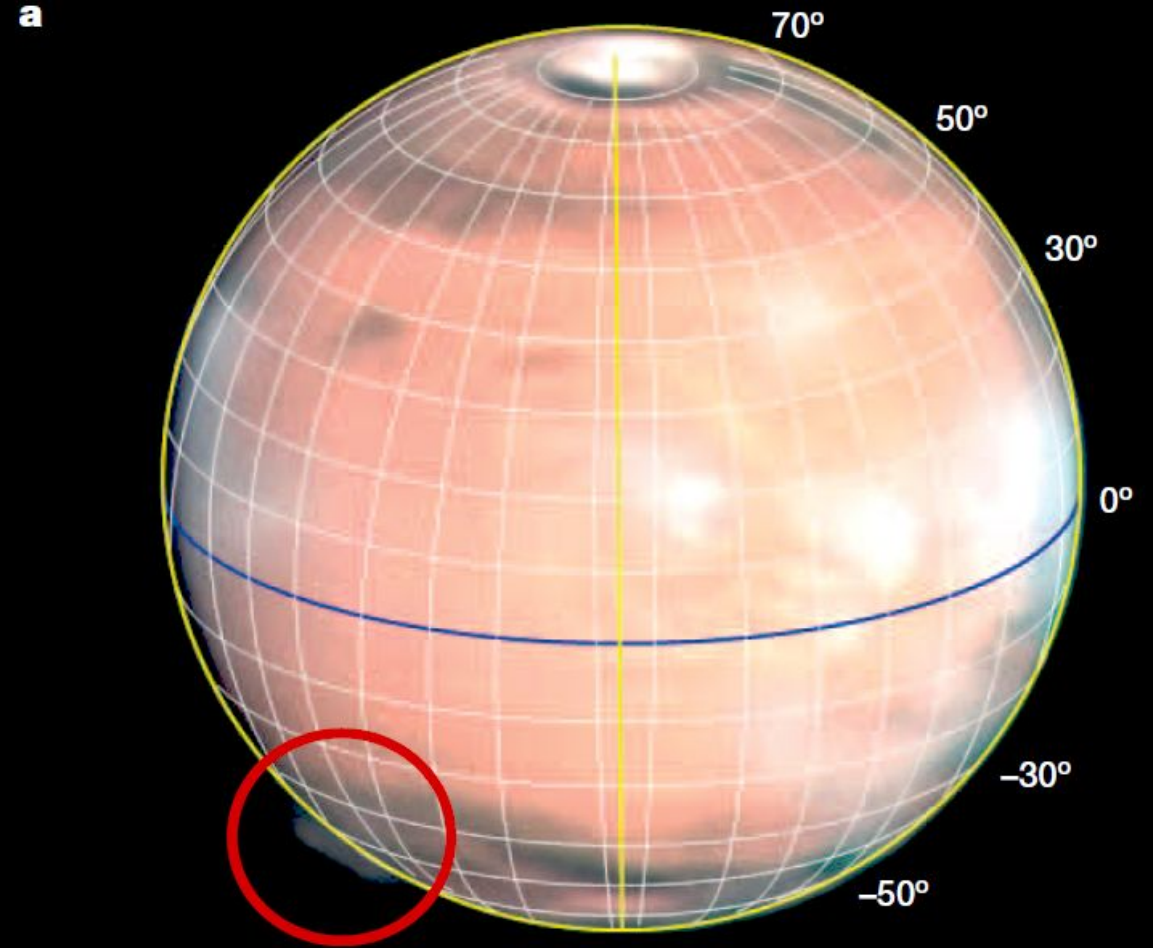
Part 2: Science with VMC

*Jorge Hernandez-
Bernal*



mars express

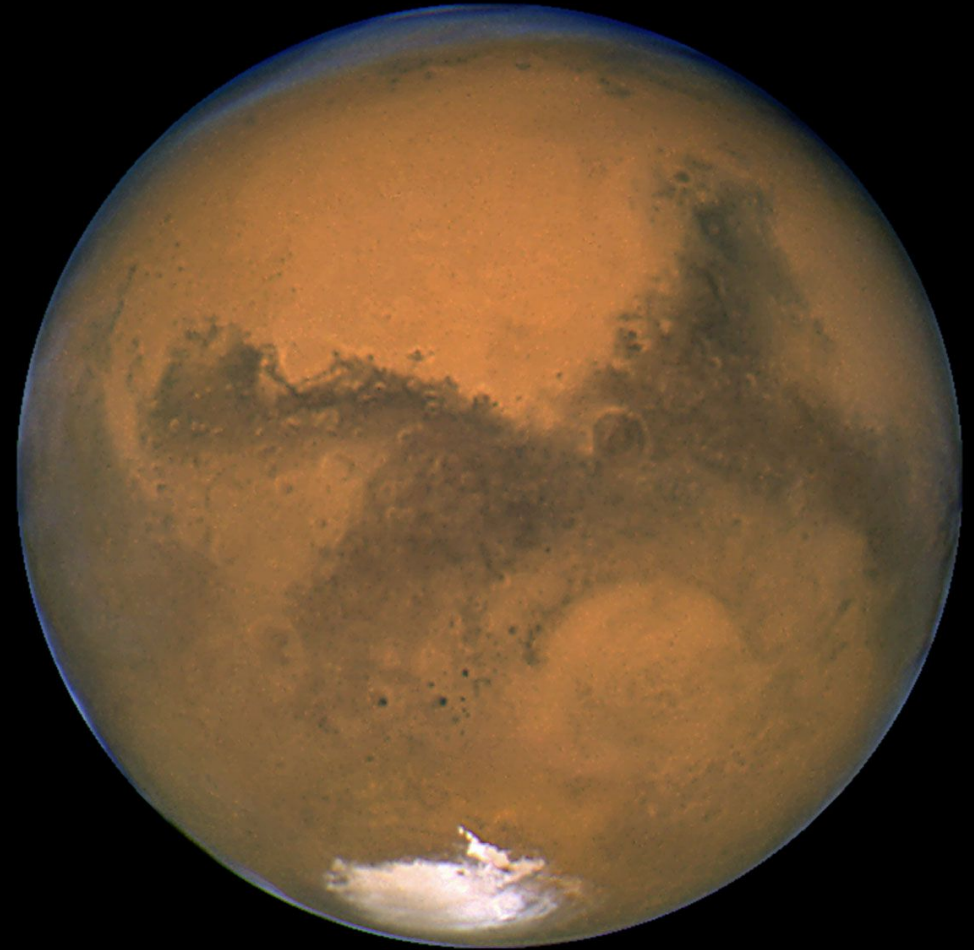
- 2015 Sánchez-Lavega Nature paper on high altitude plume
- 2016 Contract between ESA and the Group of Planetary Sciences of the University of the Basque Country (UPV/EHU)
 - Agustín Sánchez-Lavega is VMC Science Team Leader
 - Upgrade VMC to science instrument
 - ESA support for a full time contract (Currently Jorge Hernández-Bernal)



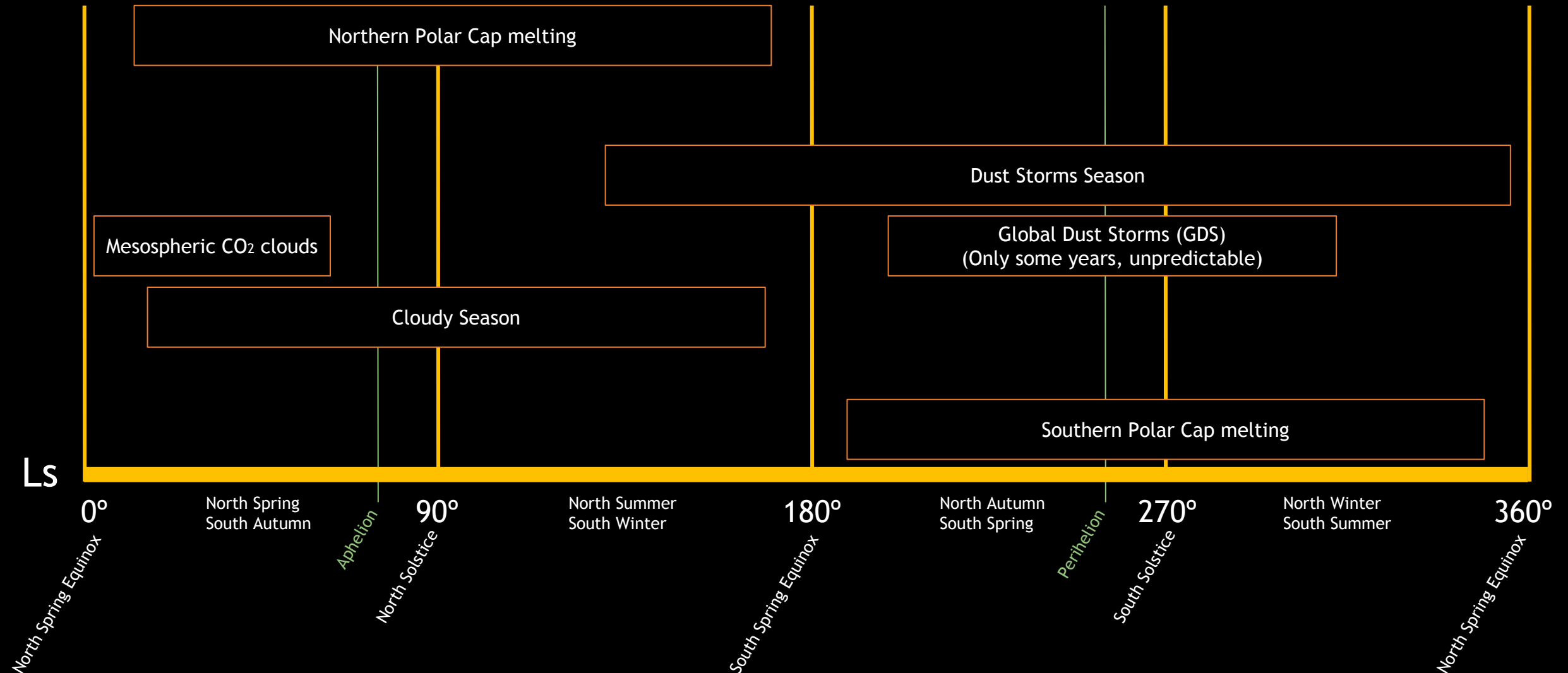
Sánchez-Lavega et al., Nature, 518, 525, 2015

A brief introduction to Martian Climate

- Orbital characteristics
 - Farther from the Sun than Earth
 - Martian Year ~ 2 Earth Years
 - Axial Tilt $\sim 25^\circ$ -> Seasons (like Earth)
 - More Eccentric orbit ~ 0.09
 - Rotation Period: 24h40m
- Atmospheric characteristics
 - 96% CO₂
 - Surface Pressure 0.006 atm
 - Low thermal inertia
 - High amounts of dust
 - No inner magnetic field

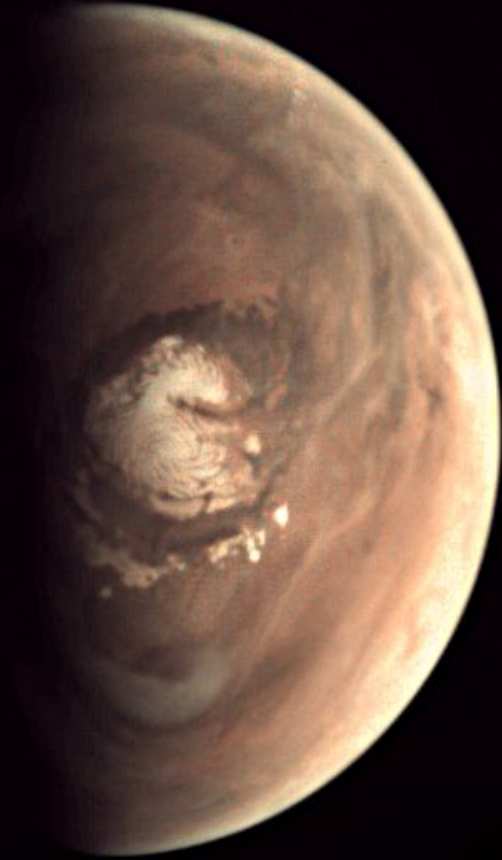


Weather along the Martian Year



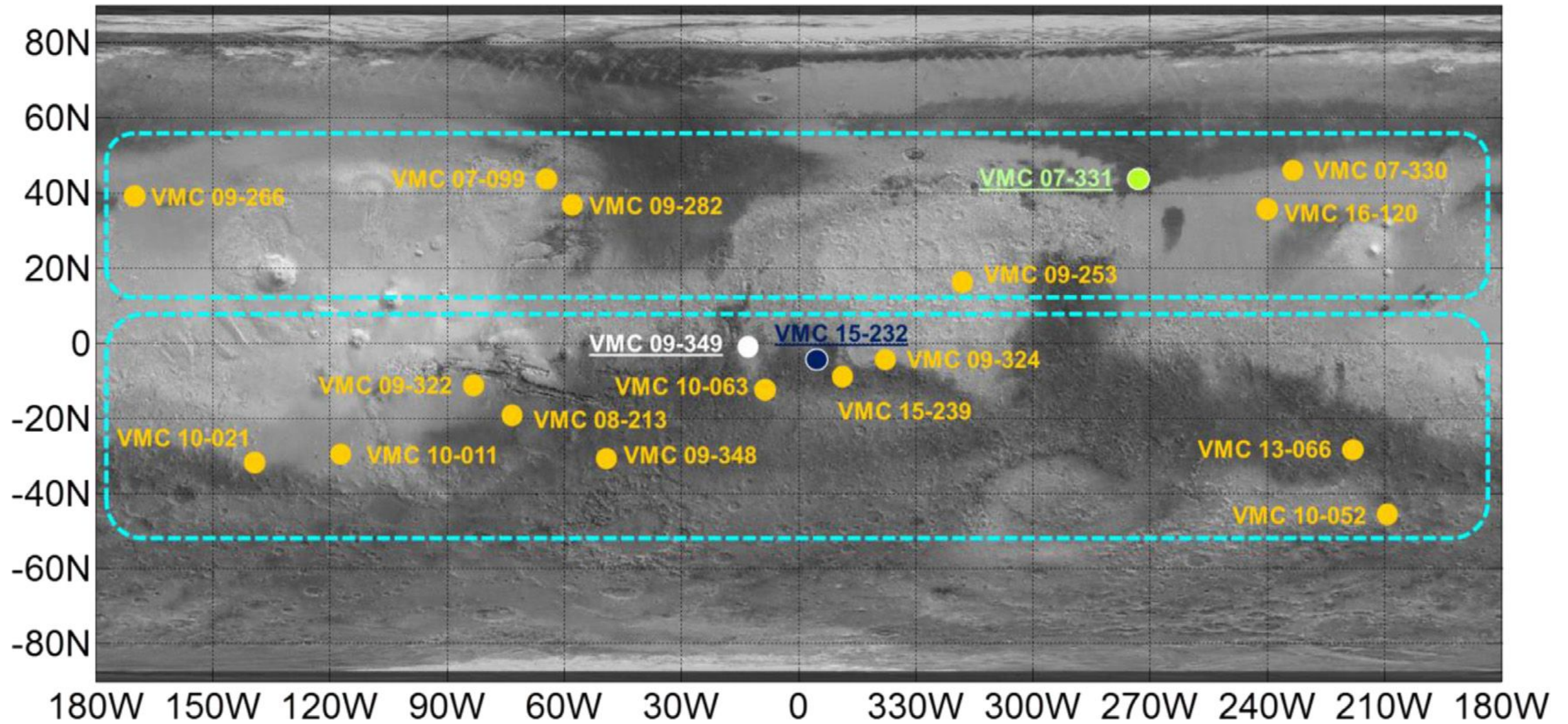
VMC Science topics

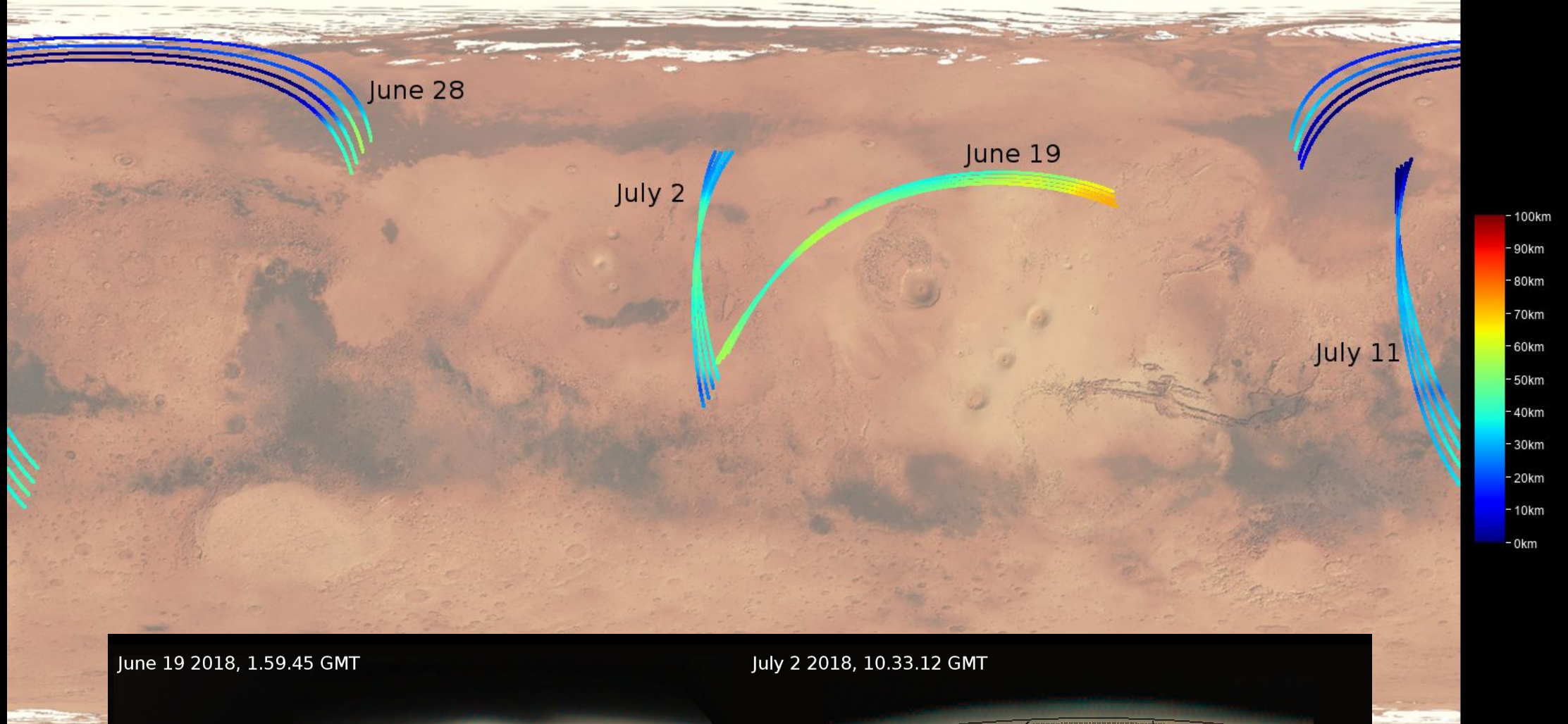
- Ongoing/Published work
 - Limb aerosols
 - Twilight clouds and aerosols
 - Double Cyclone
 - MY 34 Global Dust Storm
 - Arsia Mons Elongated cloud
- Other ideas to be developed
 - Mars Close to eclipse
 - Interannual Variabilities
 - Polar Caps recession
 - Polar circulation
 - Meteor Showers and fireballs



Limb Aerosols

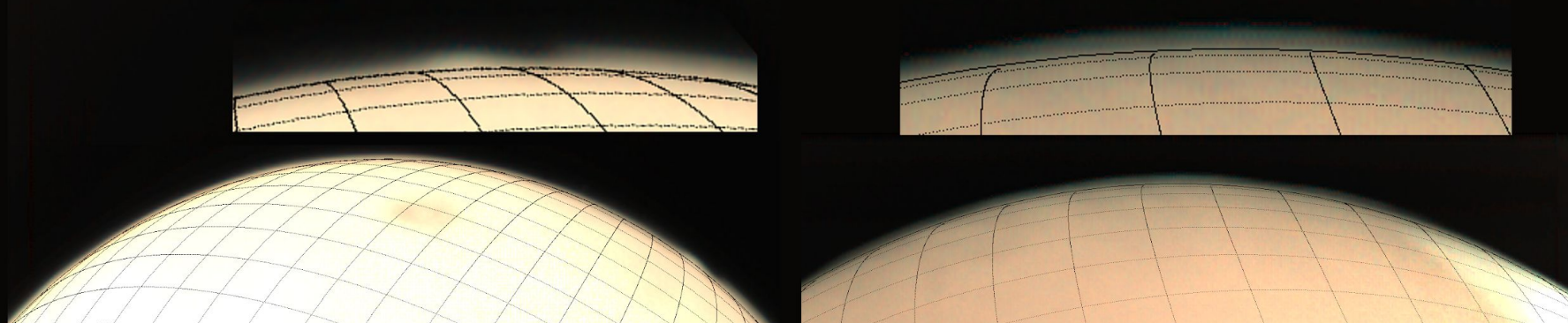
- A paper already published covering years 2007-2016 (Sánchez-Lavega et al., Icarus, 299, 194, 2018)
- VMC making 1 near limb observations per week (as agreed with ASPERA)
- New analysis techniques being developed:
 - Improved geometry analysis
 - Automated analysis
 - Basic composition from RGB?
- High interest in Terra Cimmeria around North Summer Solstice
- CO2 clouds tests starting in April





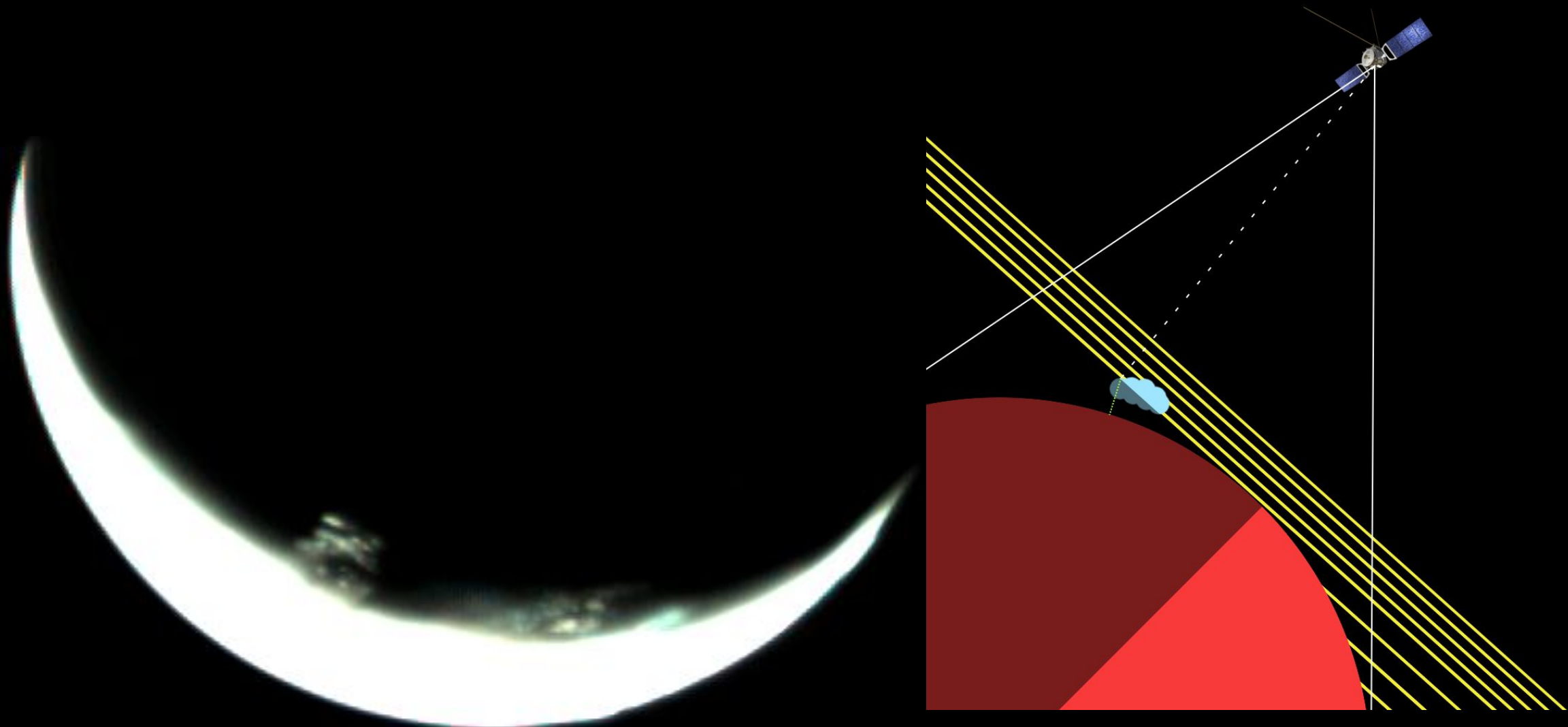
June 19 2018, 1.59.45 GMT

July 2 2018, 10.33.12 GMT



Current ongoing work

Twilight Clouds

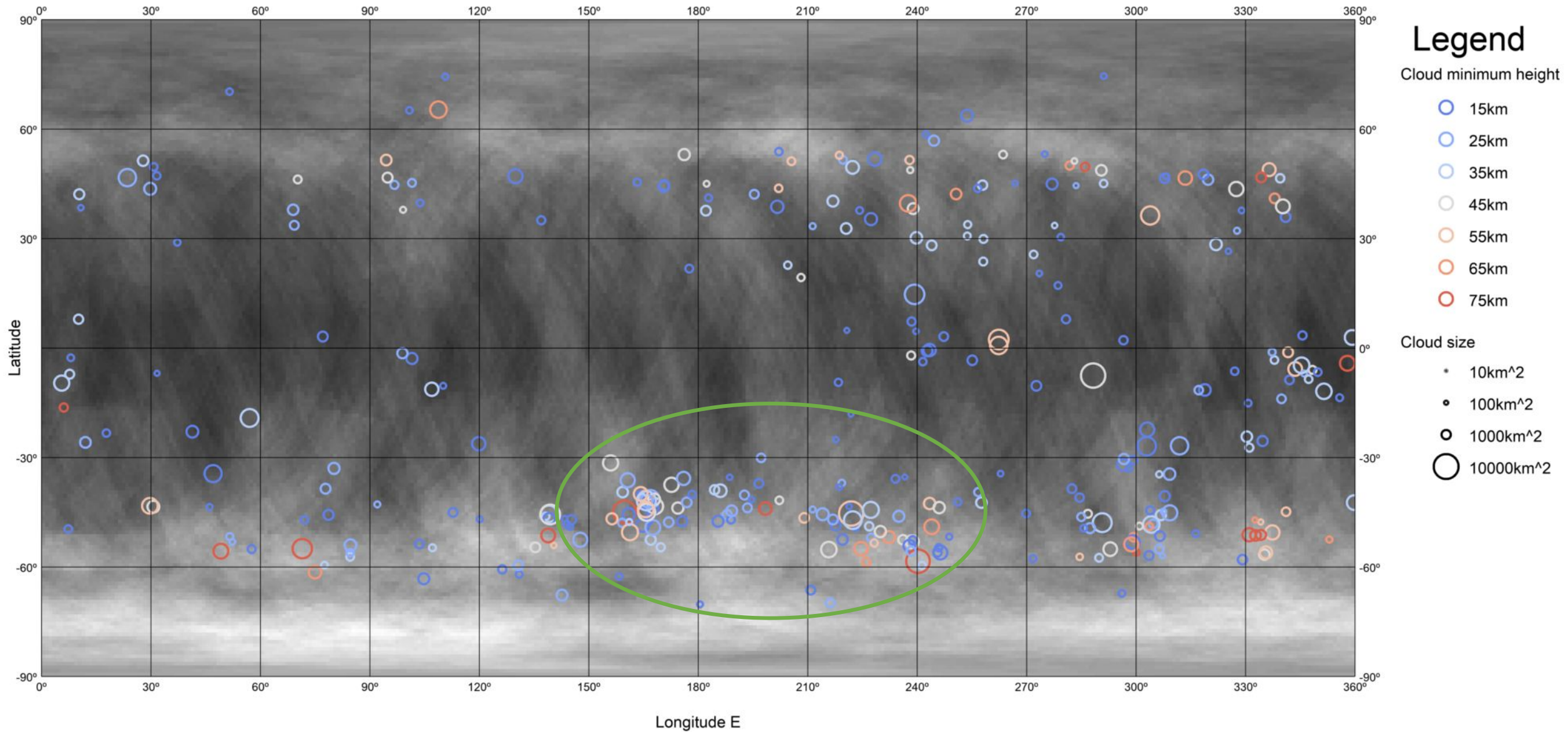


A large, bright crescent moon dominates the left side of the frame. On the dark, cratered surface of the moon, a small, bright, irregularly shaped cloud is visible near the bottom center of the crescent. The background is a solid black.

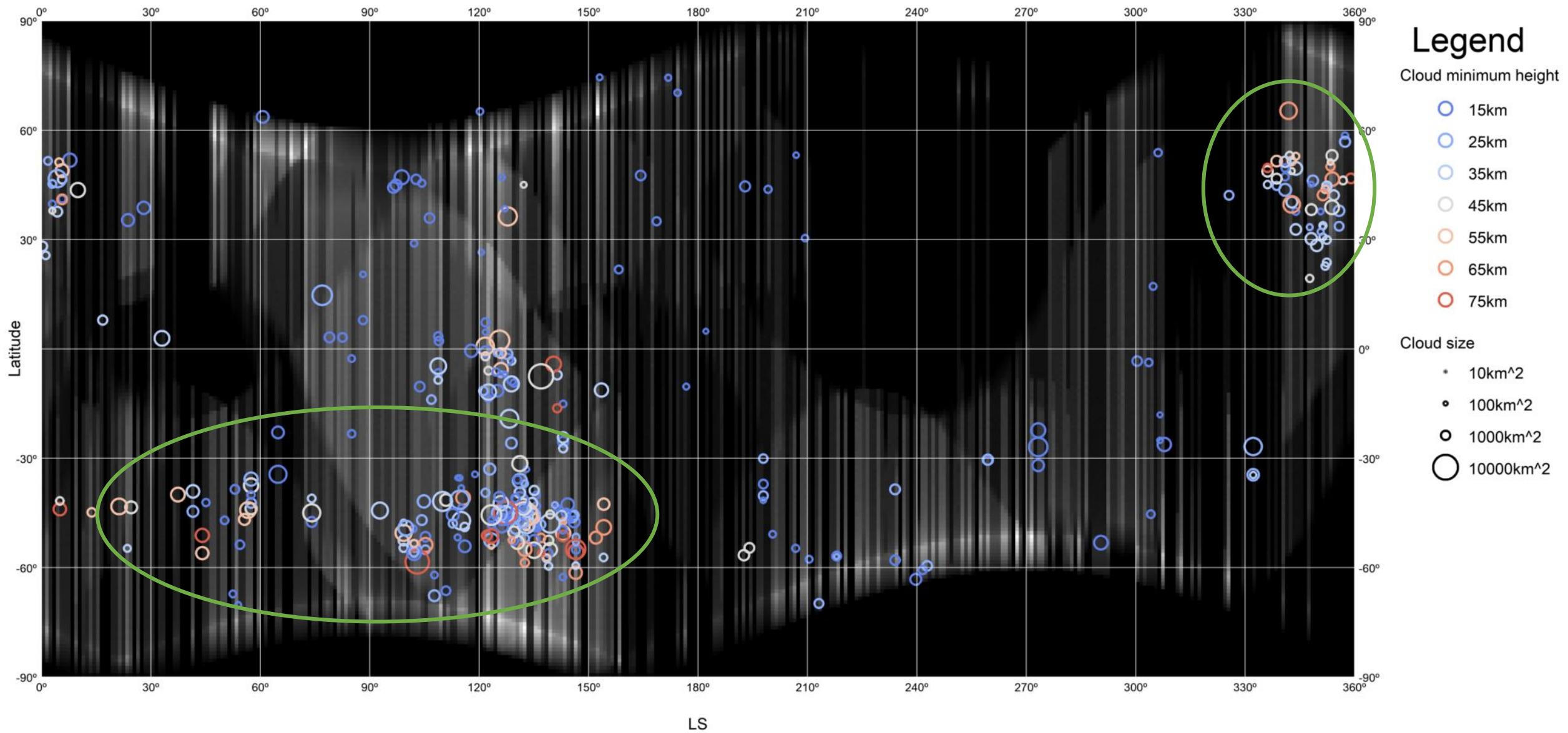
Twilight Clouds

- A cloud in the twilight can receive sunlight illumination if it is high enough. Then it appears bright in the night.
- By measuring the distance of the bright cloud to the terminator, we can estimate its “minimum-height”
- We have developed techniques for:
 - Using this as a general tool to estimate cloud heights (already applied to Arsia Mons cloud and Global Dust Storm)
 - Automated detection of these clouds
- We are investigating interannual patterns in the apparition of these twilight clouds.
- Presented in EPSC 2018

Martian Year 30-34



Martian Year 30-34



- Most of twilight clouds were detected in the morning.
- The most significant areographic and seasonal concentration of twilight clouds took place over Terra Cimmeria and Terra Sirenum after North Summer Solstice.

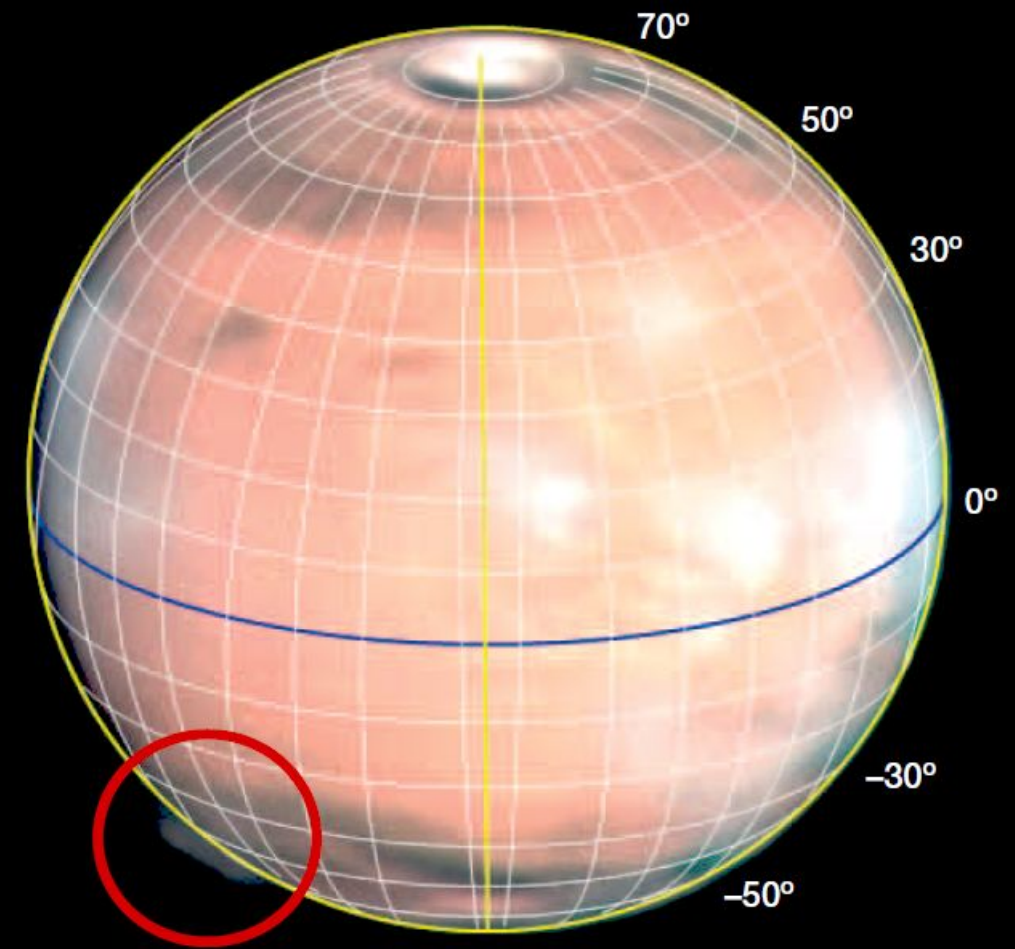
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- The 2012 high altitude plume was found in the morning, in similar region and season.

Are they related in some way?

VMC will be keeping an eye on it!

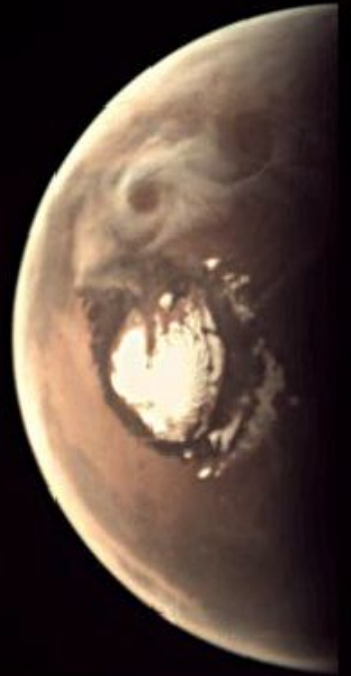
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Sánchez-Lavega et al., Nature, 518, 525, 2015

A double cyclone

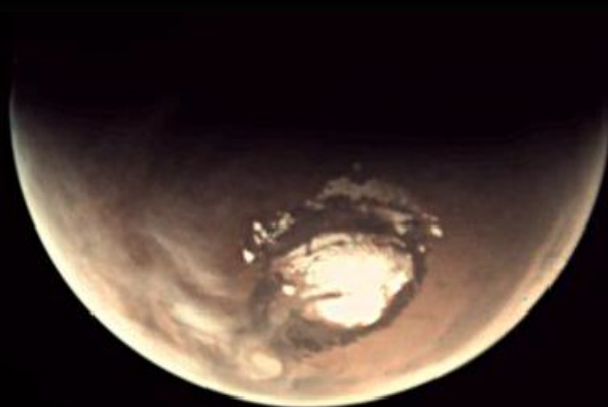
- Already published: Sánchez-Lavega et al., JGR Planets, 123,3020, 2018
- Observed double annular cyclone and an accompanying second structure in 2012 VMC images at Ls 120° and latitude 60°N. Then traced in different instrument images from 1995 to 2018 (MY 22-34)
- Double cyclone (accompanying structure) found in 2006, 2008 and 2012
- Vortices grow in the morning hours, then a part of the cloud evaporates and winds weaken as insolation increases.
- Might be a proxy for interannual climate variations.



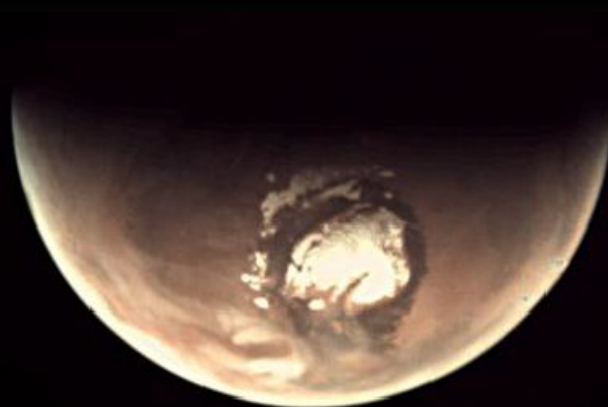
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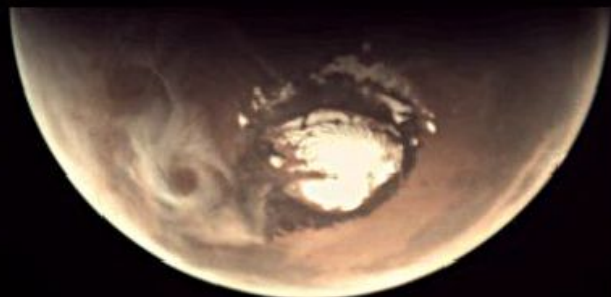
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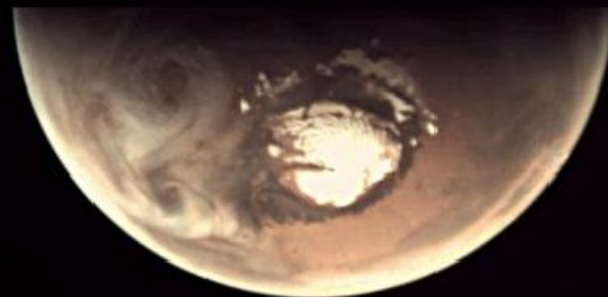
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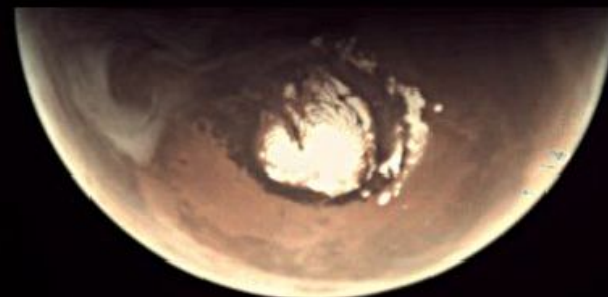
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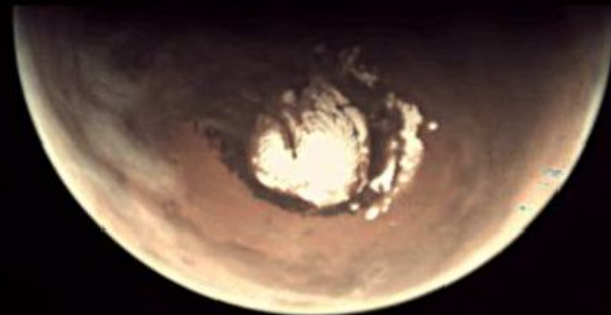
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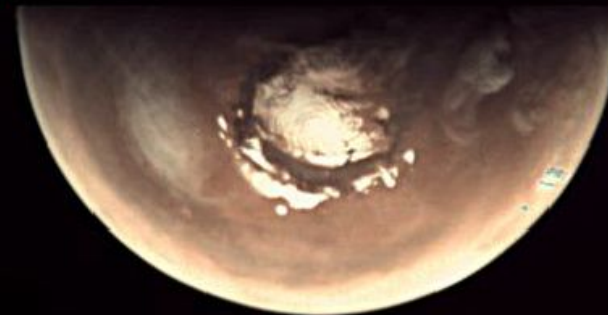
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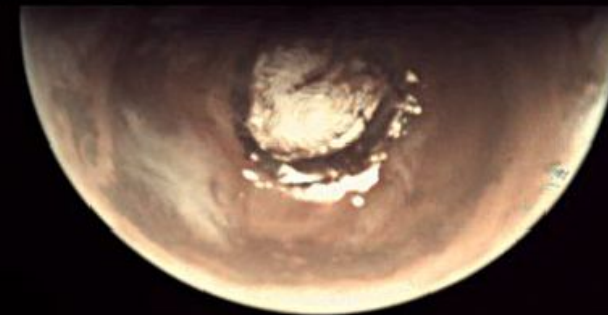
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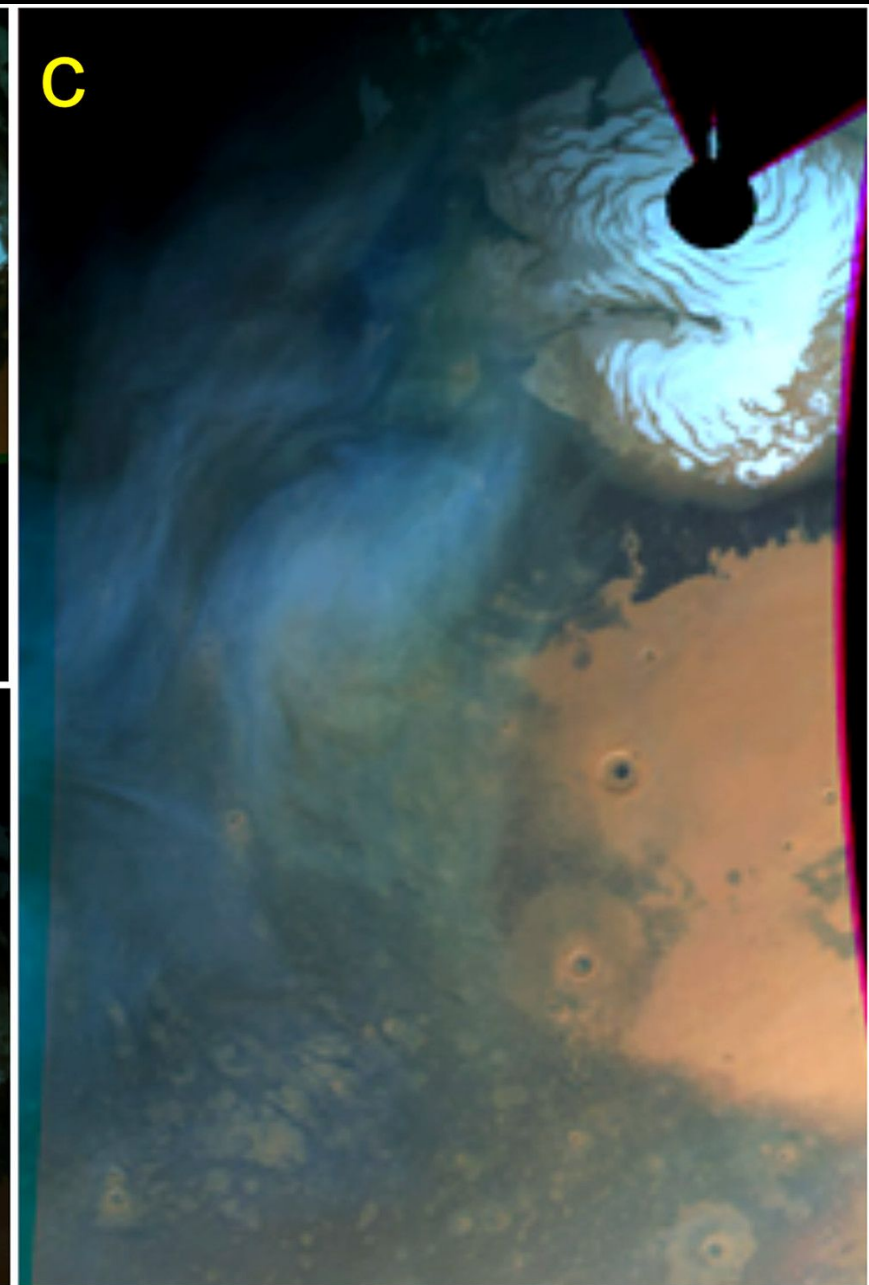
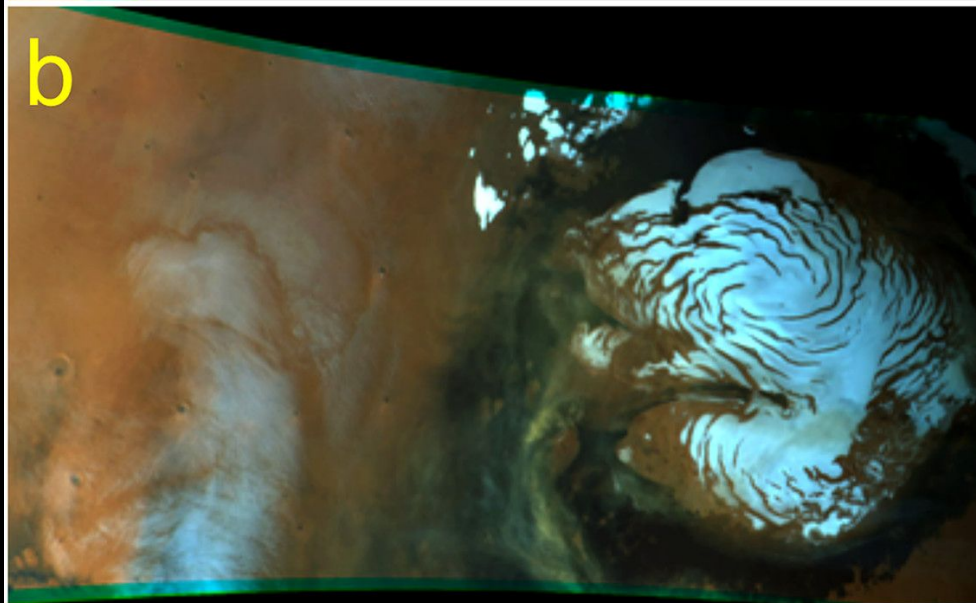
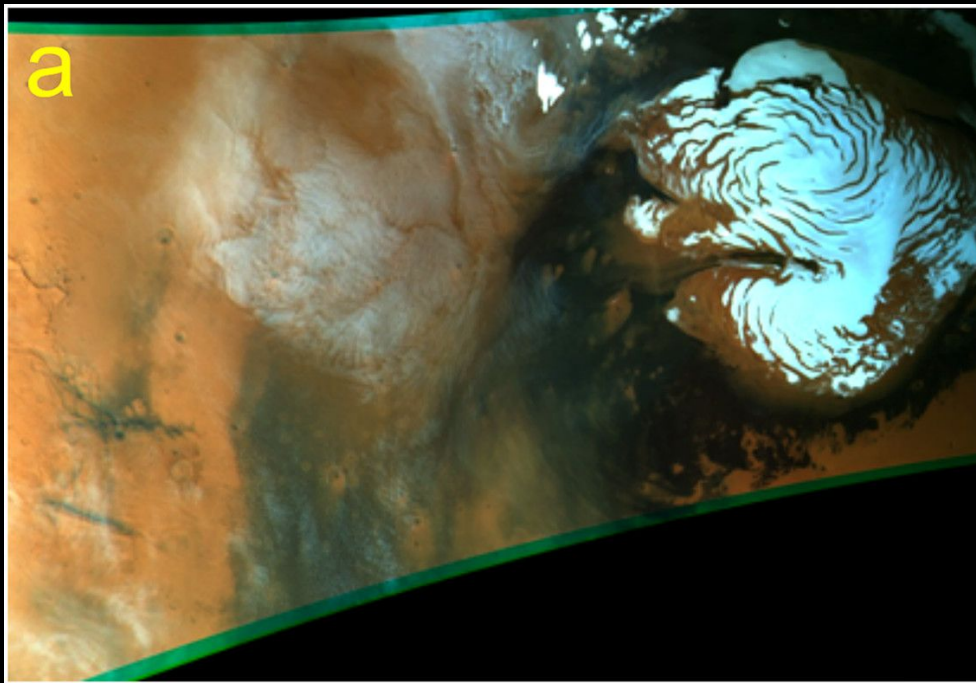
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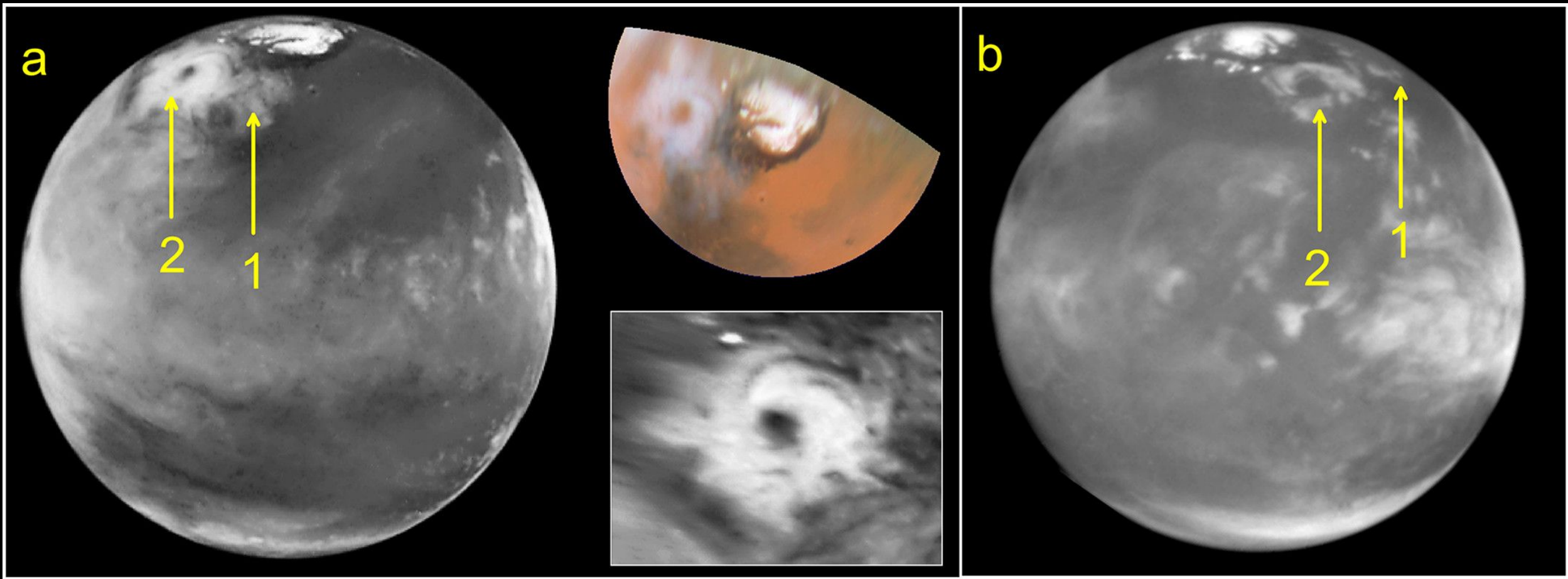
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MEX/VMC 2012



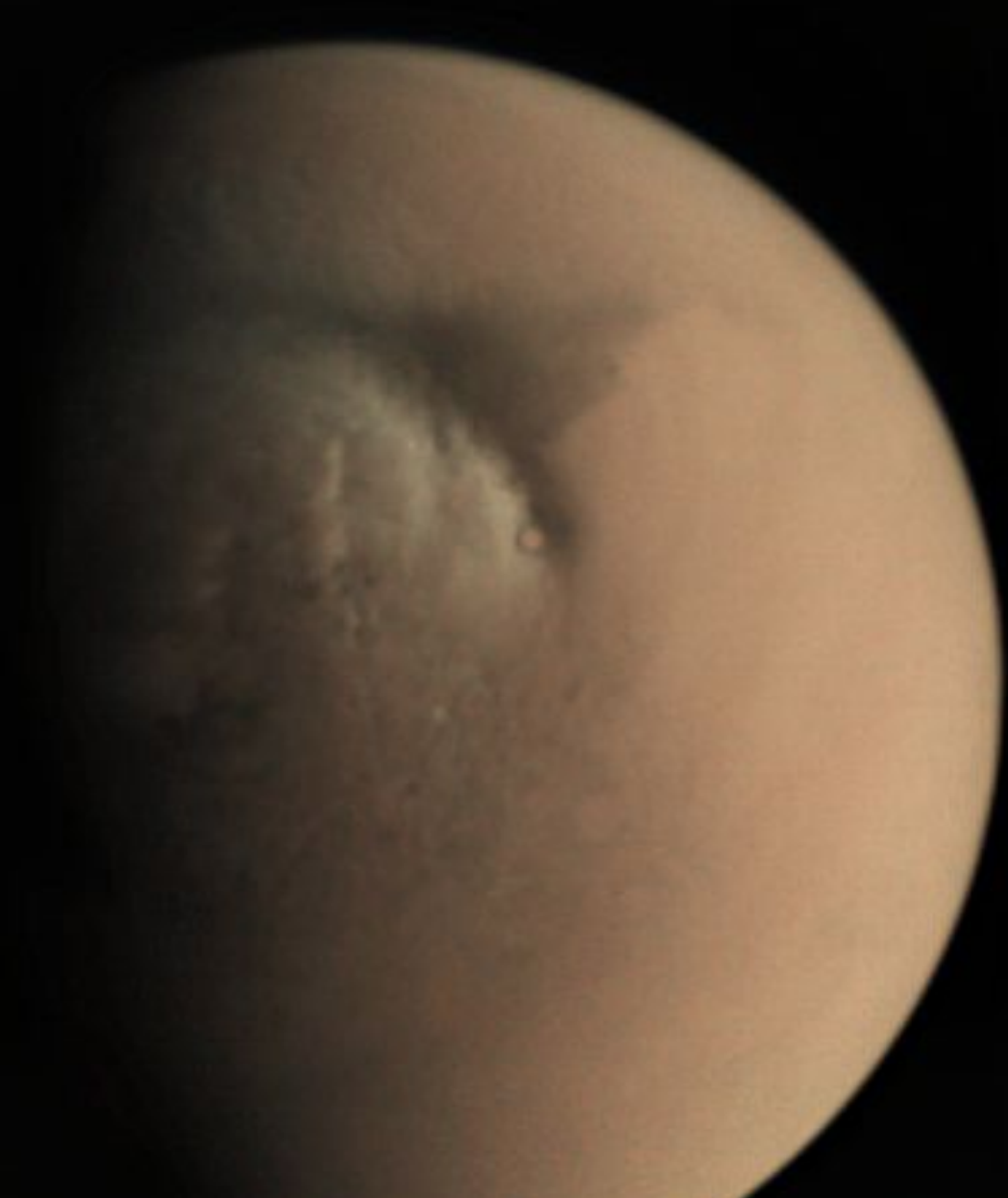
MEX/HRSC 2014 (Courtesy H. Hoffmann)

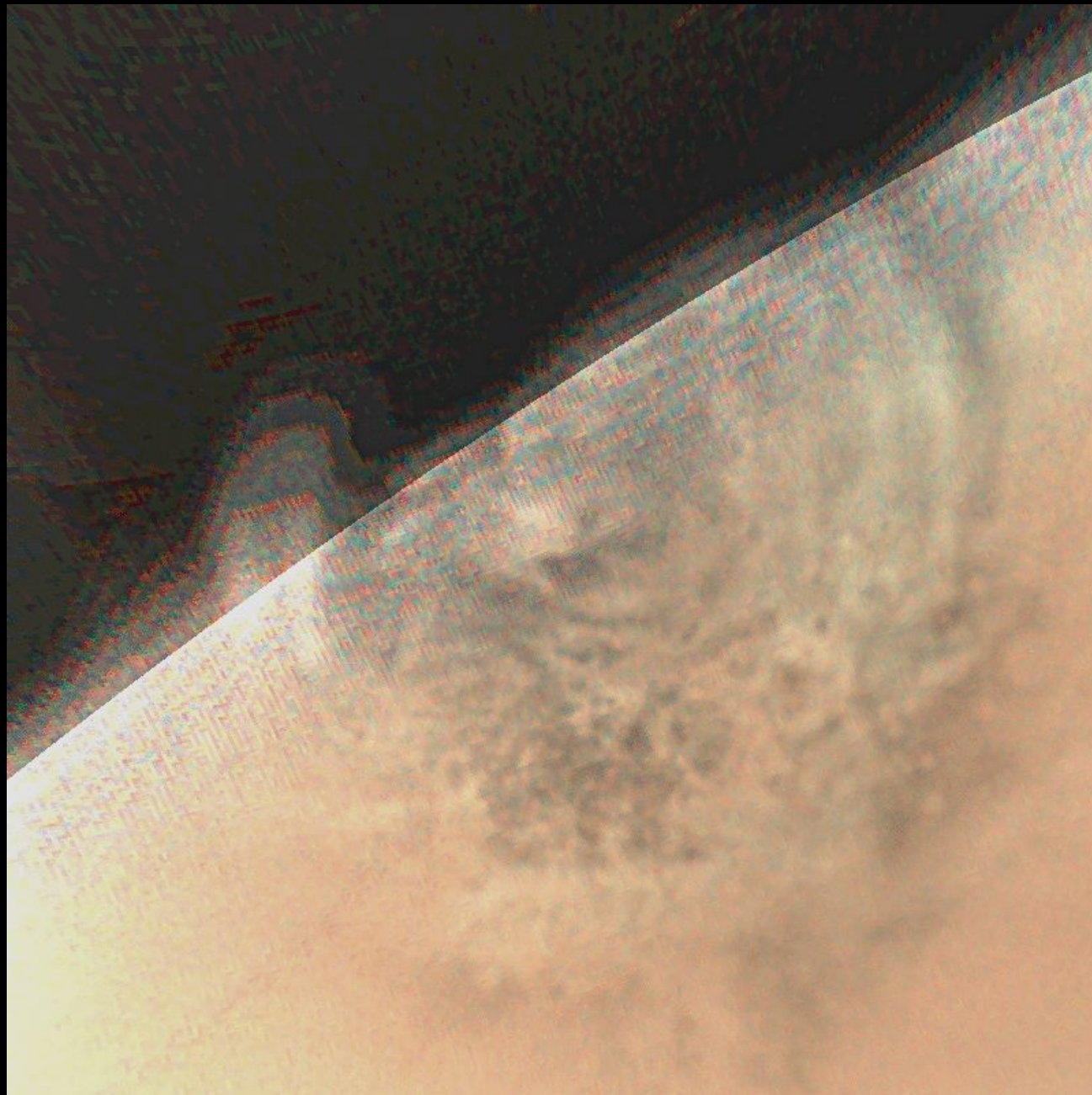


Hubble WFPC2 1999

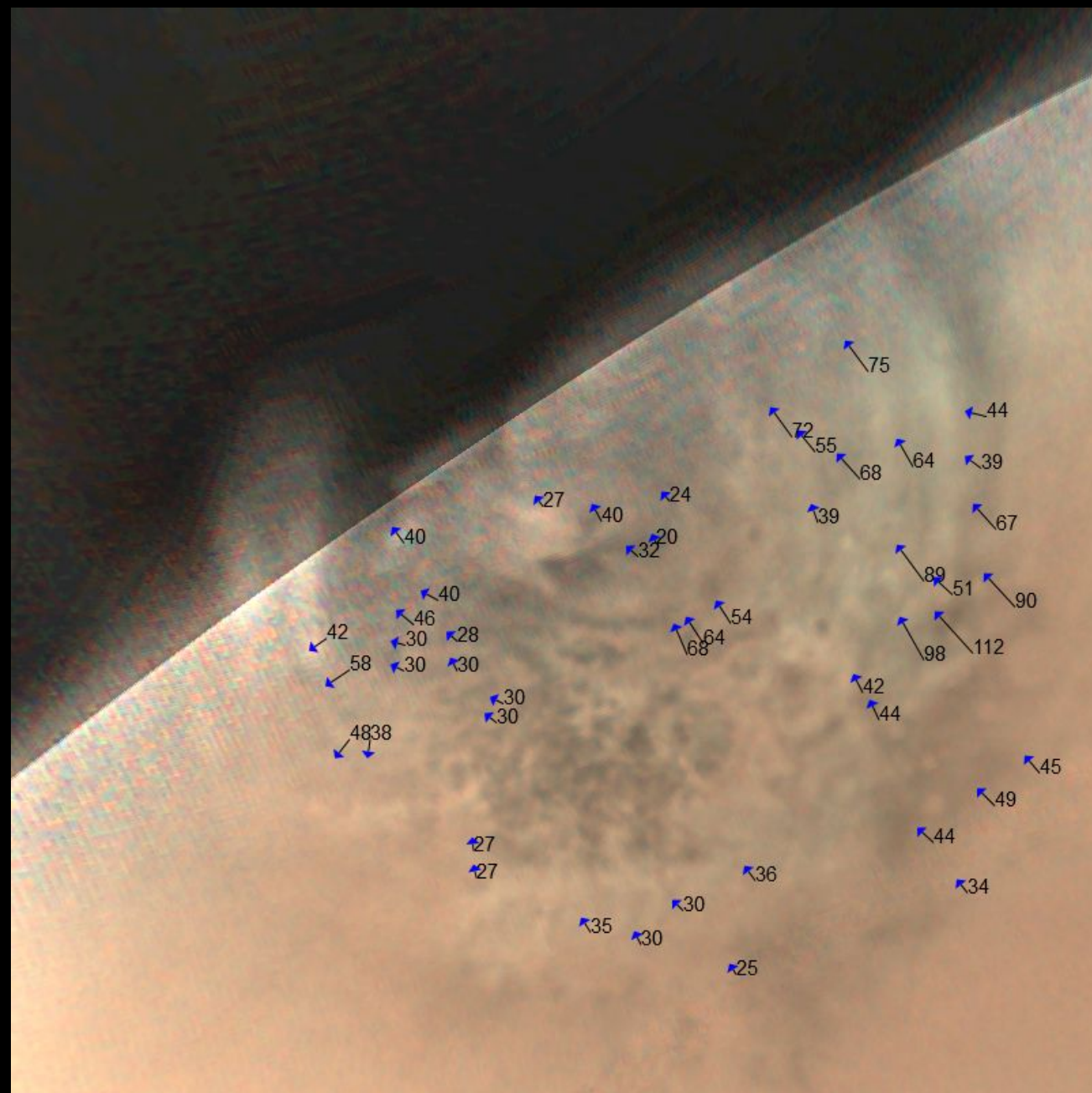
MY34 Global Dust Storm

- VMC succeeded to obtain a good coverage of the South Polar Region.
- Long observations provided images separated by 20-40 minutes, suitable for cloud-tracking of aerosols over the region.
- Spiral shaped bands spotted crossing the terminator and showing in the night.
- Limb observations at equatorial and northern latitudes.
- Presented at AGU 2018
- To be submitted to JGR Planets special Issue on 2018 Global Dust Storm



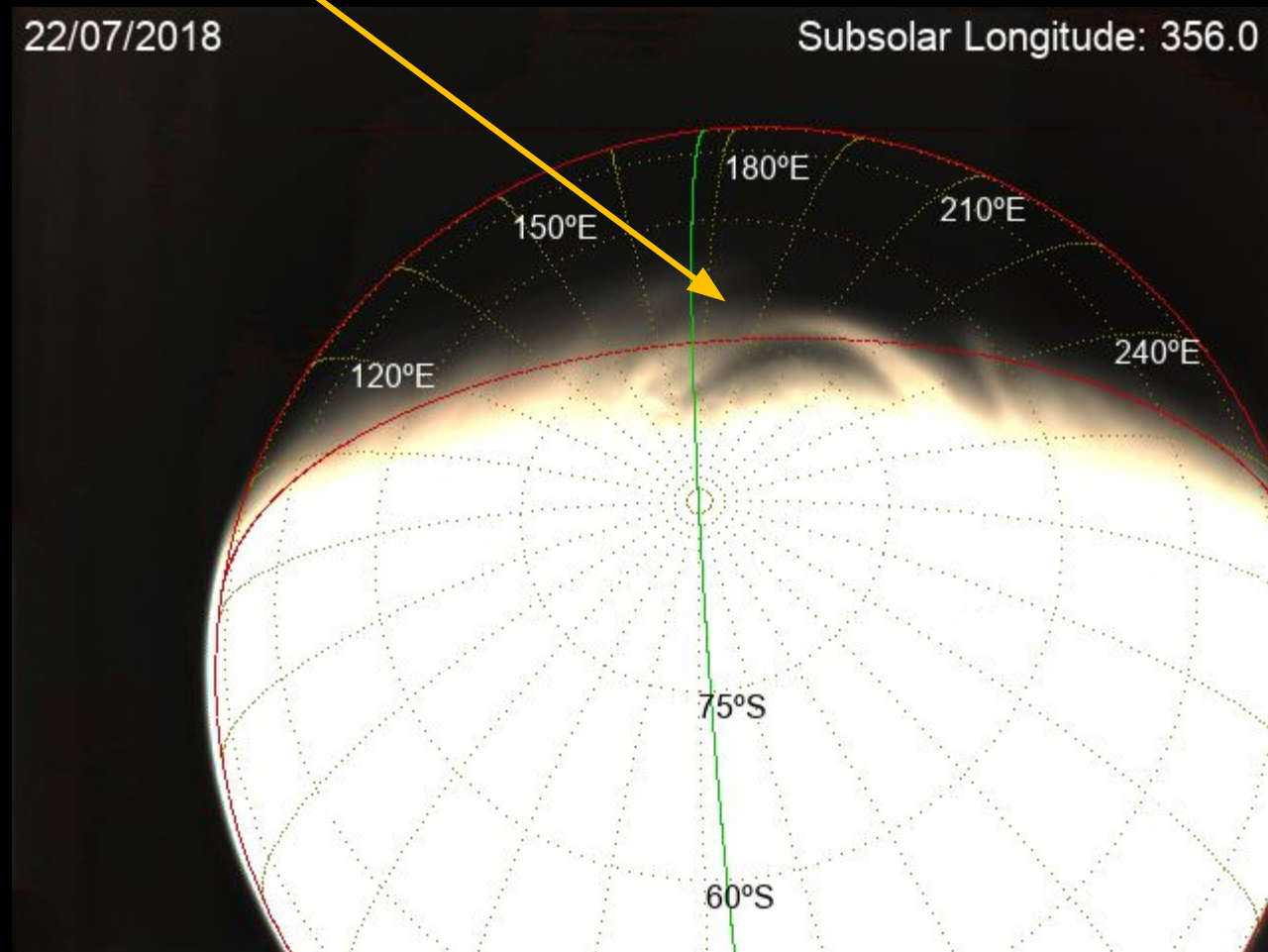
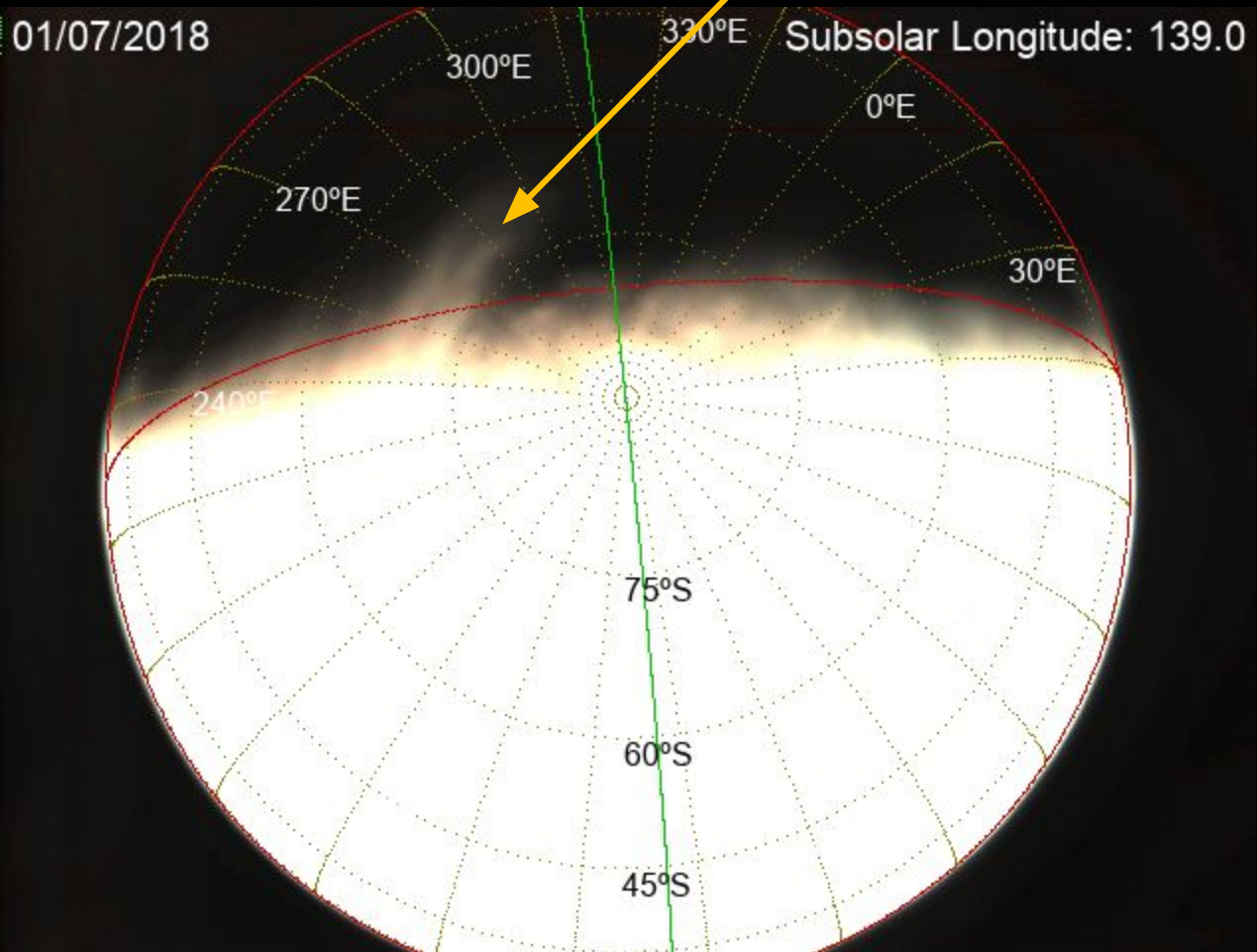


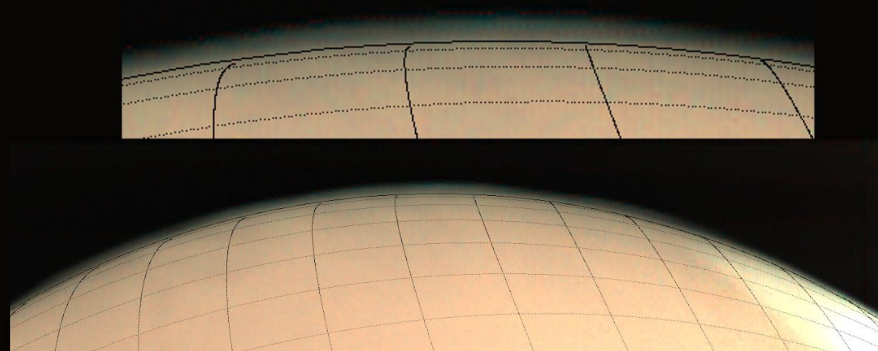
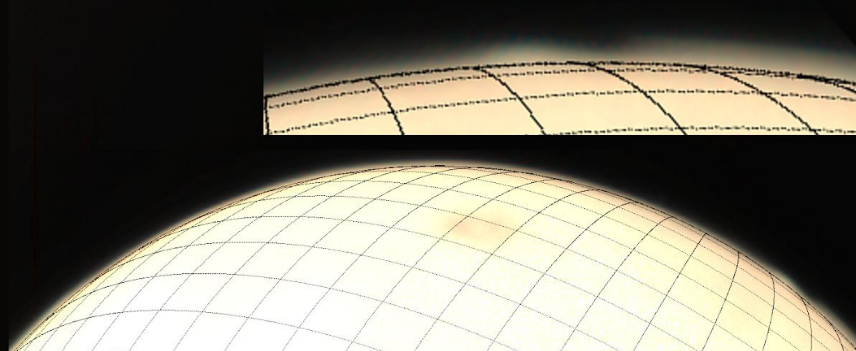
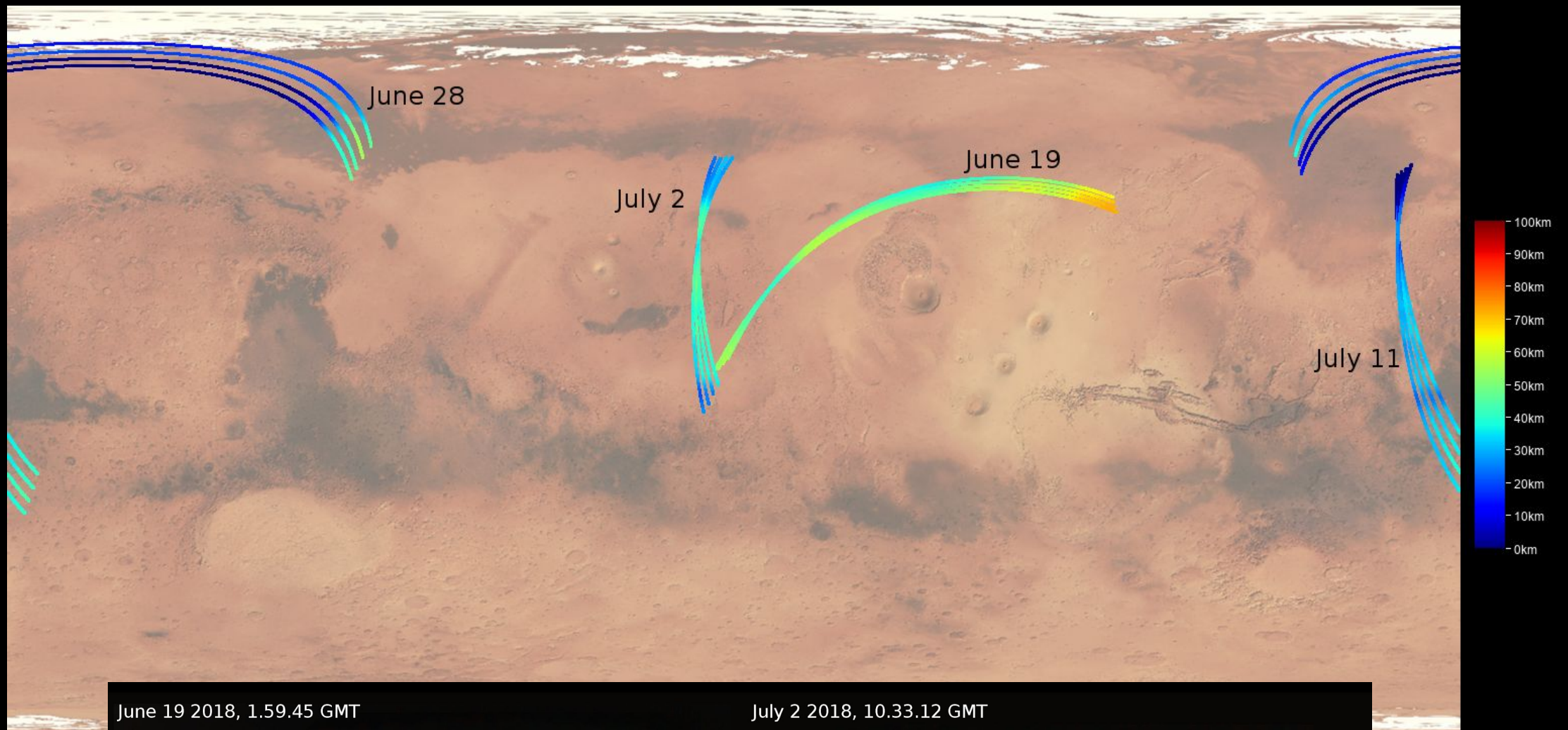
Aerosols moving on July 1



Aerosols moving on July 1

Bands in the night





Arsia Mons elongated cloud

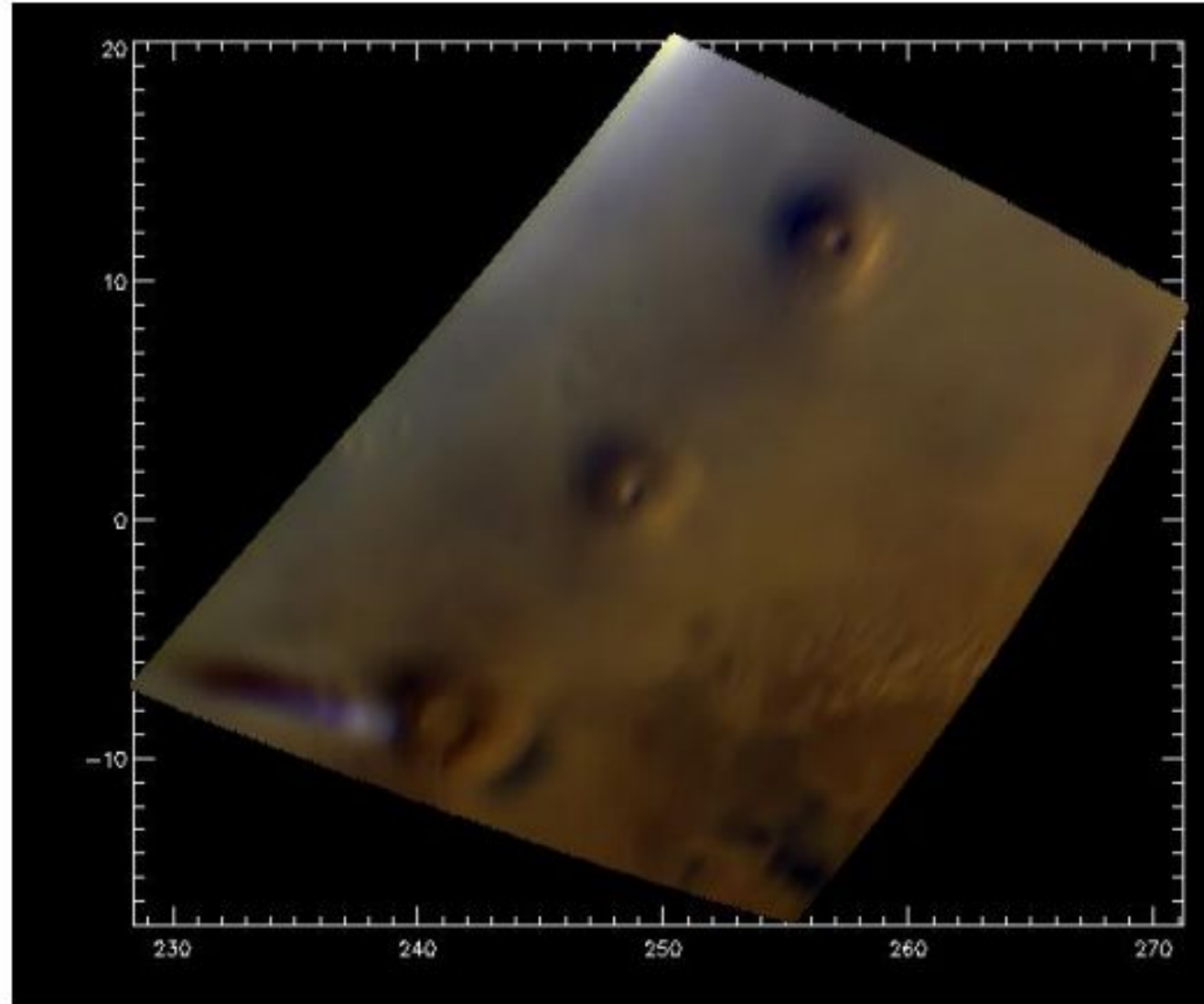
- Found initially on September 13 2018, the cloud became impressive in the following weeks.
- Later found every martian year in Arsia Mons around South solstice since VMC started to survey Mars. Similar structure found in other season in Ascraeus Mons.
- Also spotted by MEX/OMEGA, MEX/HRSC, MAVEN/IUVS, MOM/MCC, and amateurs. Ongoing collaborations.



20/10/2018 06:41 MY34,Ls272.6 Loct:7.9h(2.2h) Sun:29.3°

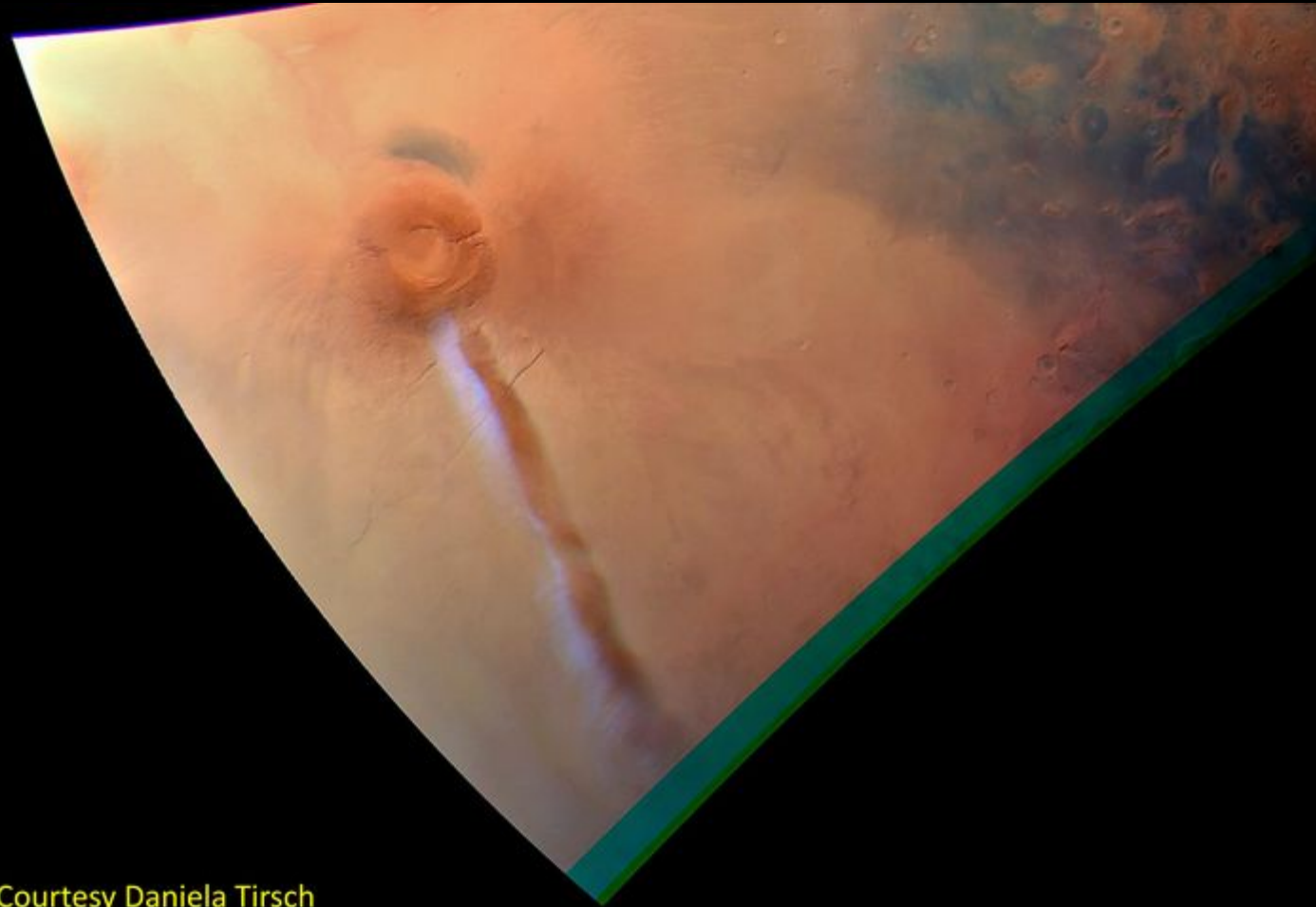


Seen by MEX/OMEGA



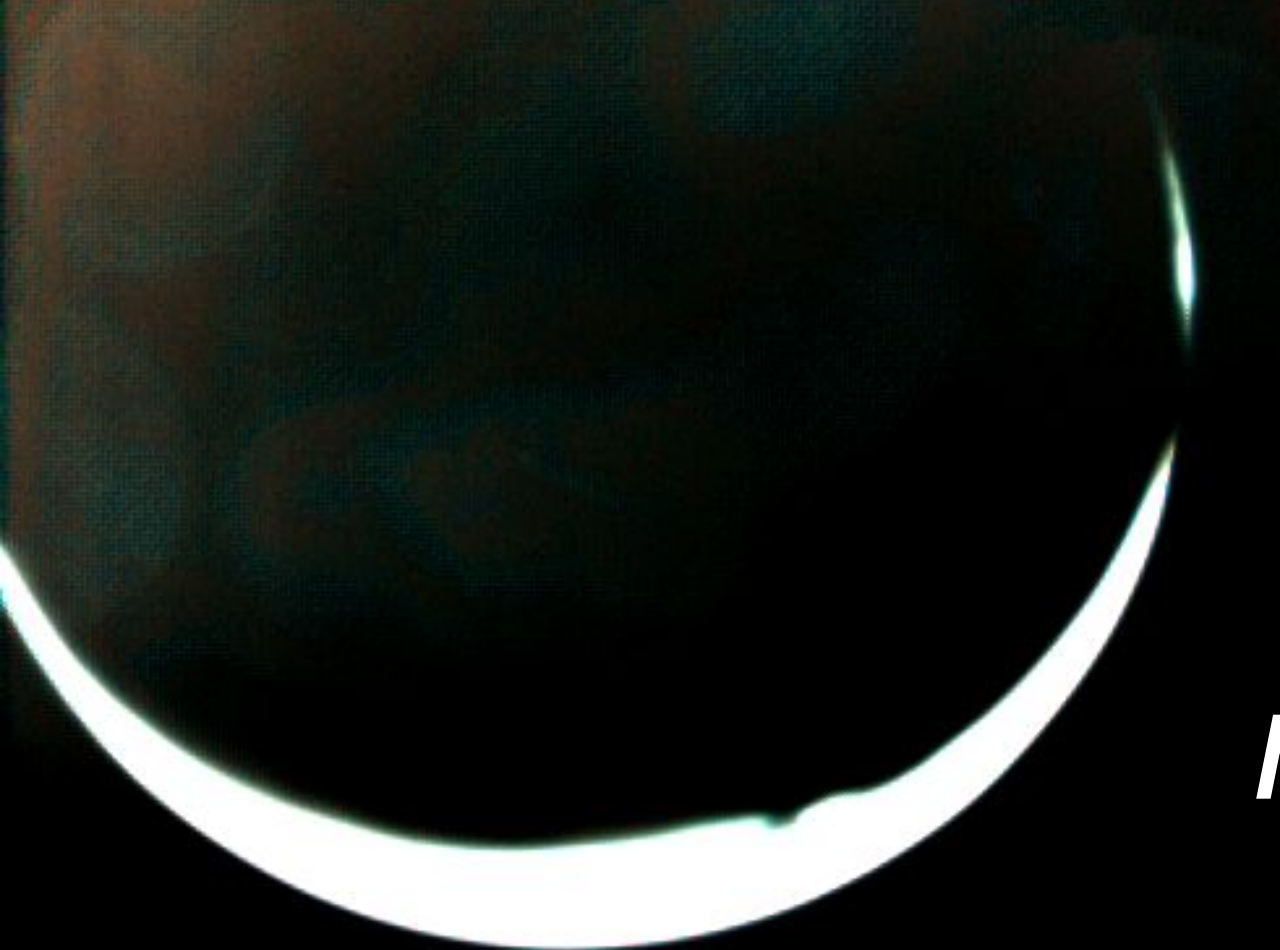
Courtesy Brigitte Gondet

Seen by MEX/HRSC



Courtesy Daniela Tirsch

Other ideas to be developed



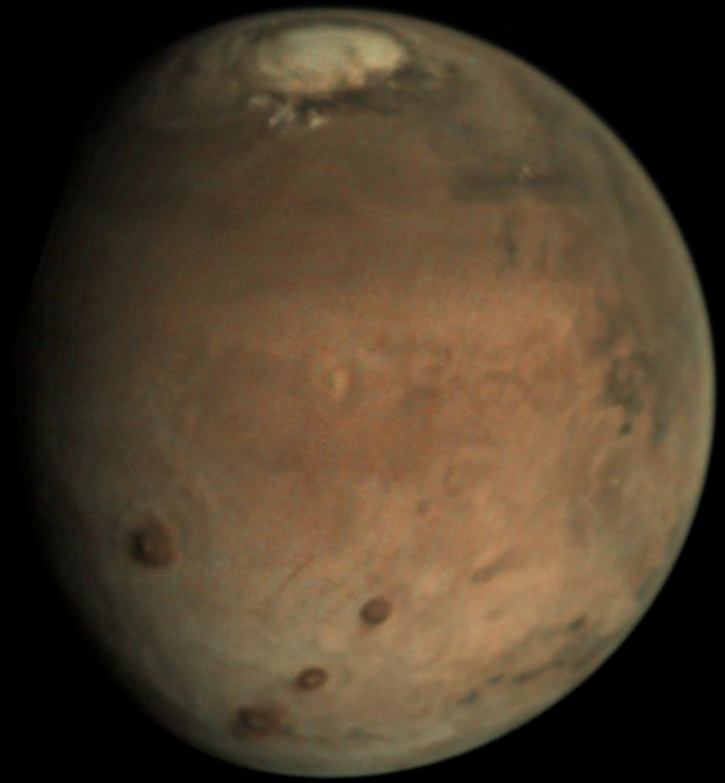
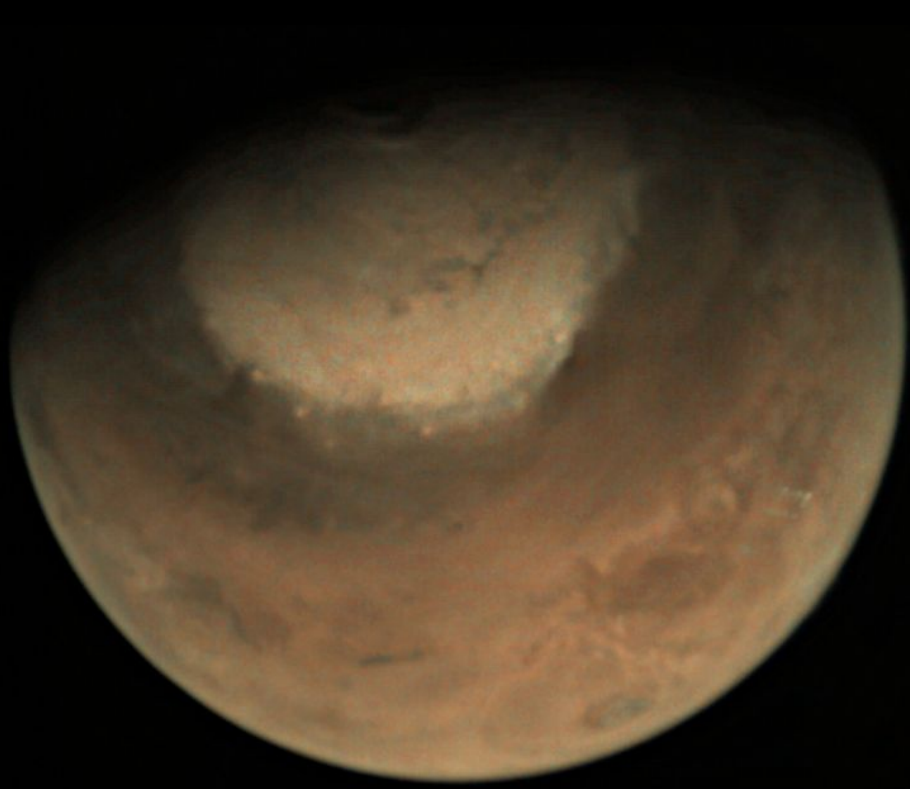
Mars Close to Eclipse

- Forward scattering in the limb would allow the detection of faint aerosols



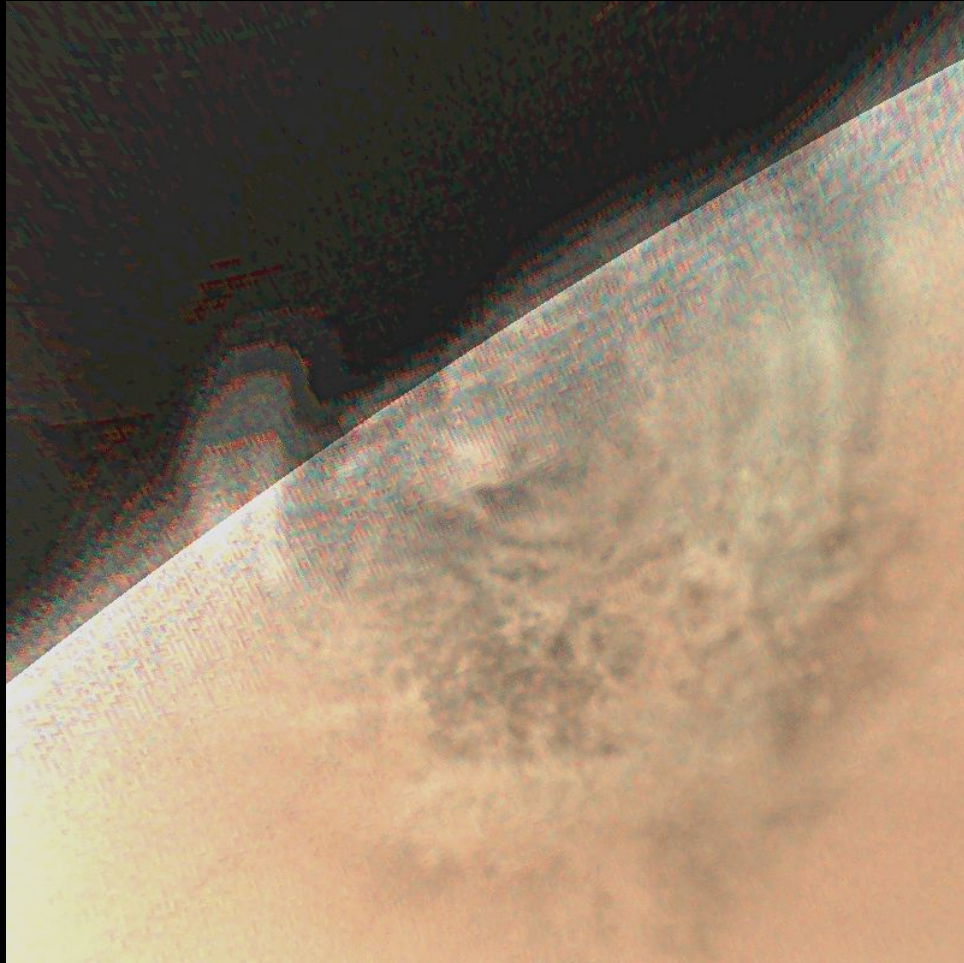
Interannual variabilities

- How is the martian climate different from year to year?
- Study of differences in repeating atmospheric aerosol structures
- Main topic of Jorge's PhD thesis



Polar caps recession monitoring

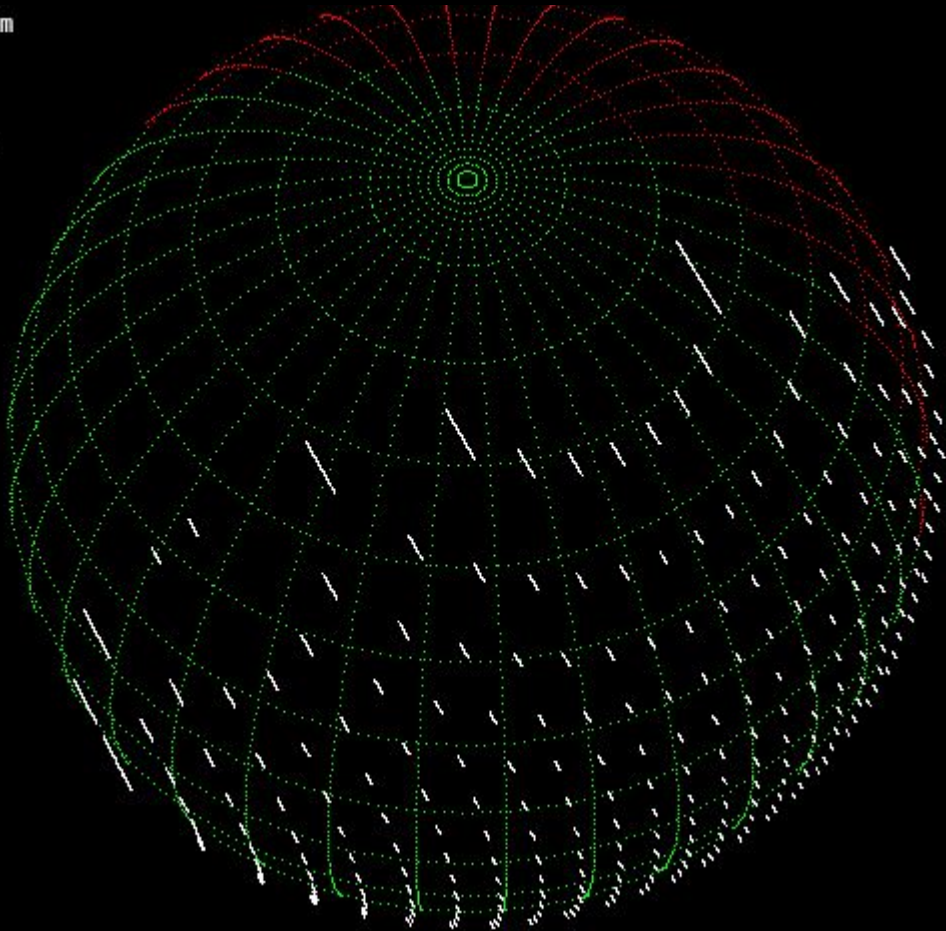
- VMC takes many images showing the evolution of polar caps along time.
- Automated analysis to be developed



Polar circulation

- Can VMC help to understand Mars' polar circulation?

Dist. 13919km
N. Obs: 260
Bmax: 0.17
Bmean: 0.06
Bsum: 142.25



Meteor showers and Fireballs

- Test monitoring of fireballs in the upper atmosphere, taking advantage of our wide field of view.
- Specific planning and analysis techniques developed.
- Difficulty: low sensibility and cosmic rays (just testing)
- First test was aborted due to technical problems.

Conclusions

- VMC is an ordinary camera in an extraordinary place!
- We are working on both Technical and Science aspects to improve VMC possibilities and results
- We are using VMC for monitoring of the martian atmosphere, and we are obtaining new results on martian climate and its variations from year to year.

Thank you!

New Martian Year 35: March 23 2019



...and Happy New Martian Year 35!