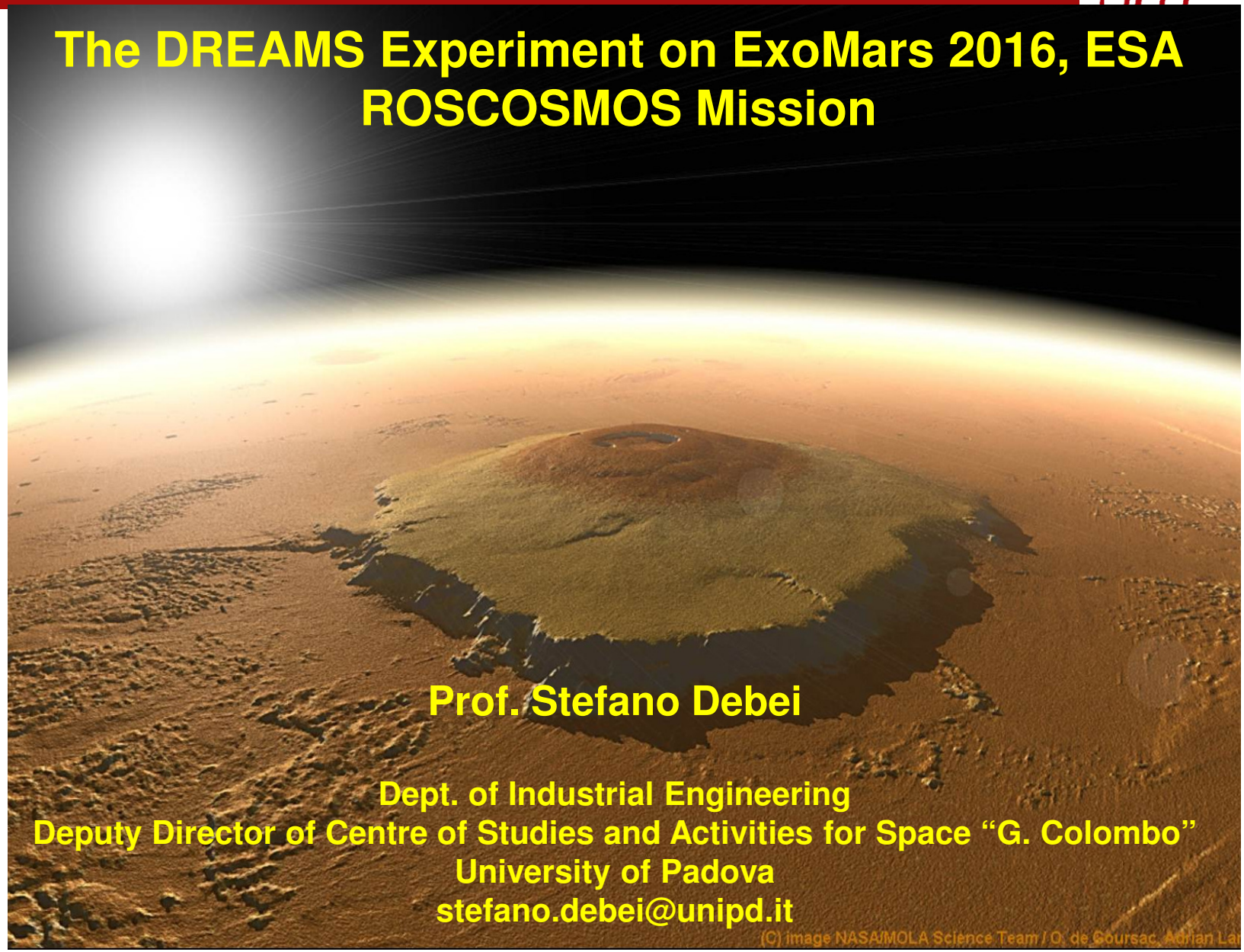
The DREAMS Experiment on ExoMars 2016, ESA ROSCOSMOS Mission



Prof. Stefano Debei

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Deputy Director of Centre of Studies and Activities for Space "G. Colombo"
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stefano.debei@unipd.it

Outline

- University of Padova
- CISAS "G. Colombo"
- Why Exploring Mars?
- DREAMS experiment
- Conclusion

University of Padova: some historycal events

Padua University, one of the oldest in the World, has been founded on 1222

A primacy: The first woman in the World to be awarded with University degree:

Elena Lucrezia Cornaro Piscopia in 1678

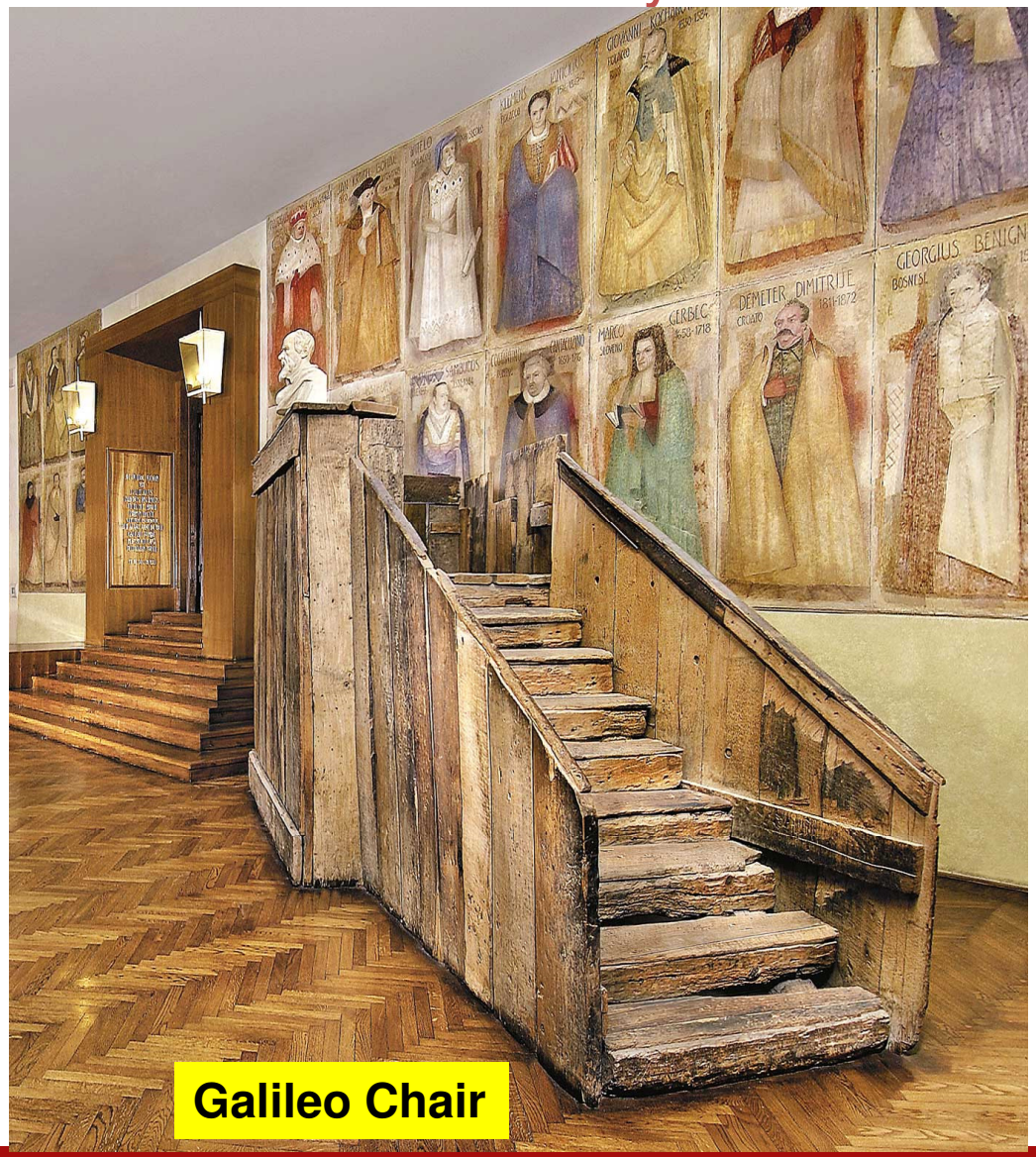
A lot of Eminent Alumni studied at Padua and for Astronomy:

- Nicolaus Copernicus from 1501 to 1503 during his Italian periods

- Galileo Galilei Professor within 1592-1610

http://unipd.it

University of Padova: some historycal events



“Hall of 40”:
40 portraits of Eminent Alumni coming for all over the Europe

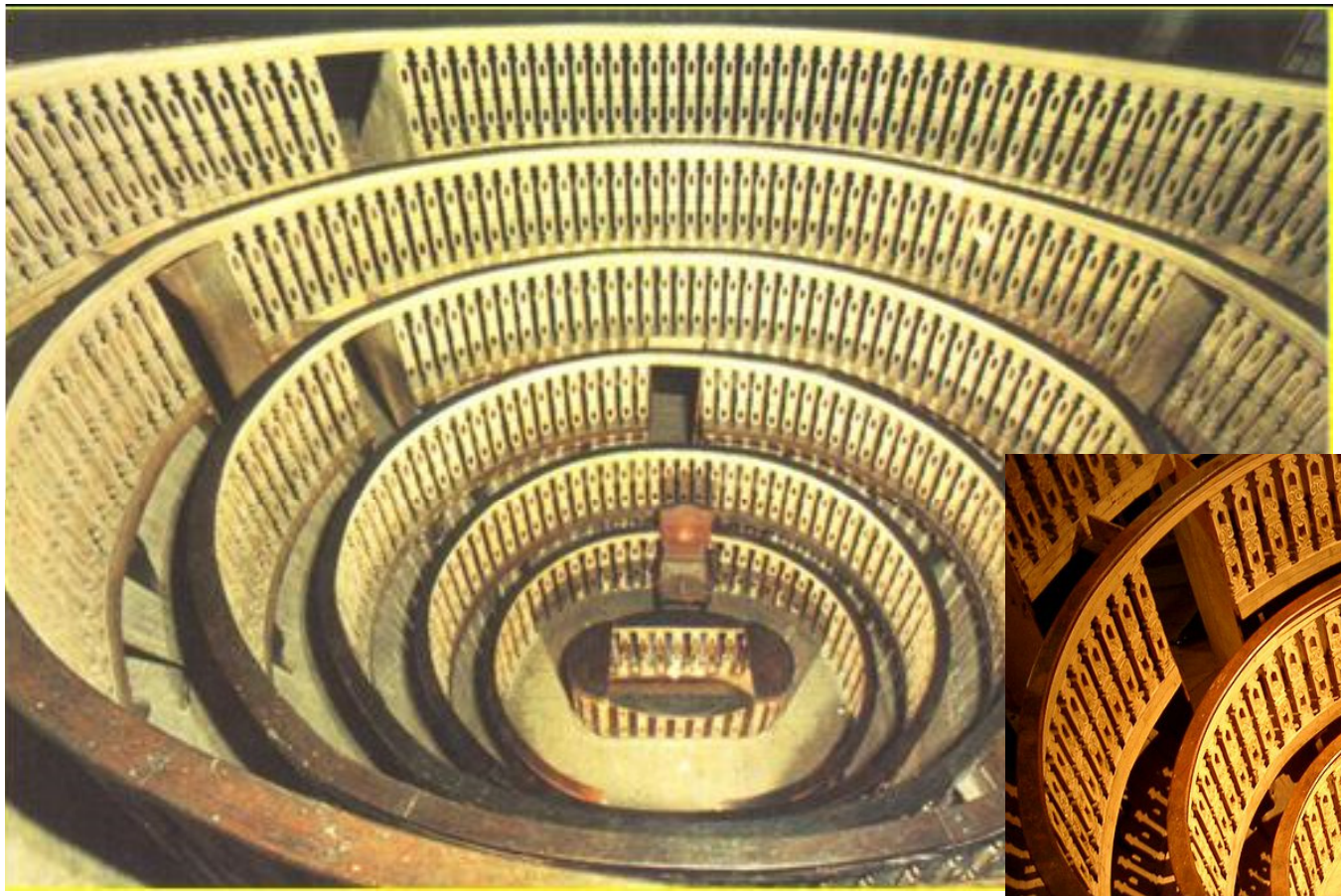
University of Padova: Scientific and Academic Structures

Schools (replaced the Faculties) of:

- Agricoltural Sciences and Veterinary Medicine
- Law
- Engineering
- Medicine
- Psychology
- Science
- Human and Social Sciences and Cultural Heritage

Galileian School: High level post graduated school

University of Padova: Anatomical Theatre



Inaugurated in 1595 and remained in use until 1872

University of Padova: Scientific and Academic Structures

Totally 32 **Departments** covering all the Disciplines

Totally 55 **University Centres**, Science and Technological Centres, Reserach Organisation in particular:

Centre of Studies and Activities for Spaces "G. Colombo"

University of Padova has in addition 15 **Museums**

http://unipd.it

CISAS "G. Colombo"

CISAS, founded in 1991, includes more that 40 professors and researchers, most of them active in Space Research since the early days.

In addition more than 50 people are part of the staff, including departments technicians, graduate fellows and engineers, doctors with external and internal post-doc grants.

Members of Departments make their own laboratories and infrastructures available for CISAS staff, while new equipment and instrumentation are continuously acquired by the Center.

The fundation of CISAS is on the tradition in Space Research developed within the University over the last 30 years and initiated by

Prof. Giuseppe (Bepi) Colombo

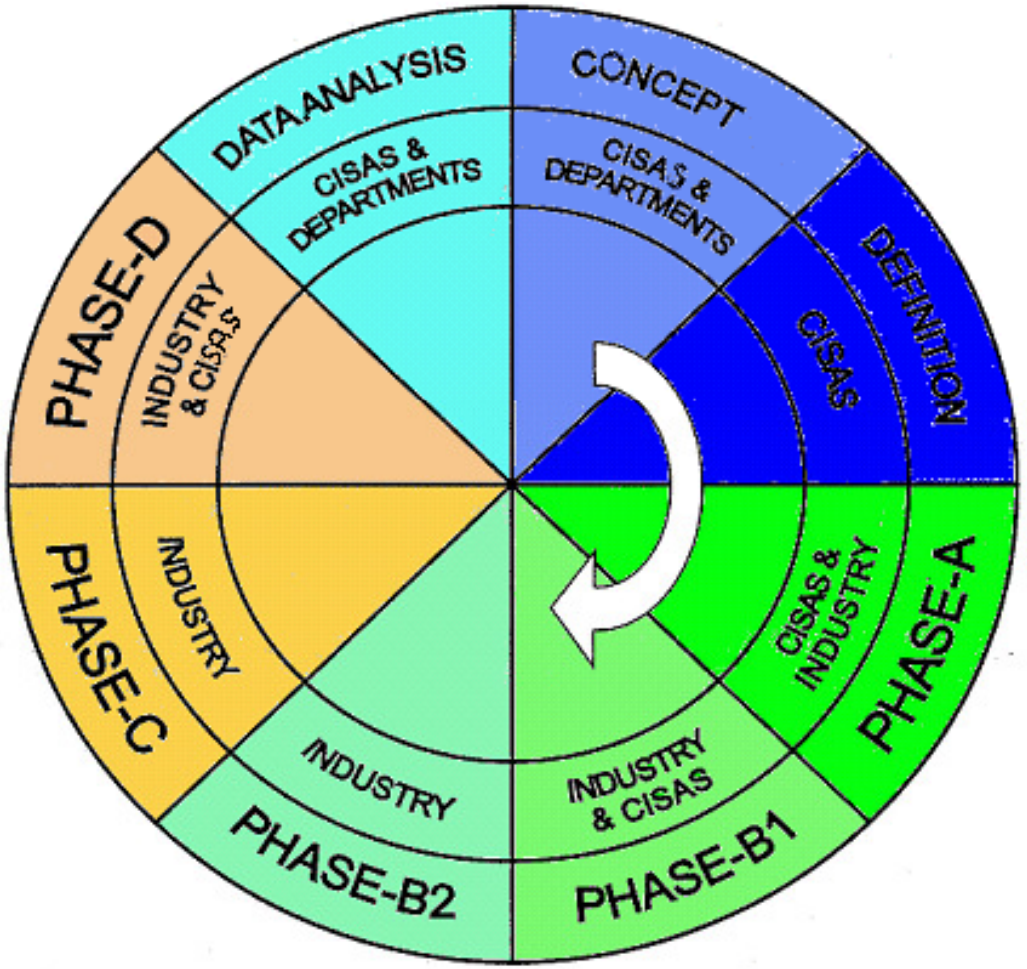
CISAS “G. Colombo”- Mission

throughout space studies, research and PhD school, CISAS aims at contributing to:

the inter and multidisciplinary formation of a innovative profile of Graduates and Researchers with knowledge of the different fields required by fundamental sciences, applied research and industrial activities

CISAS "G. Colombo"

The Rationale



Definition

Tipically Industrial phase

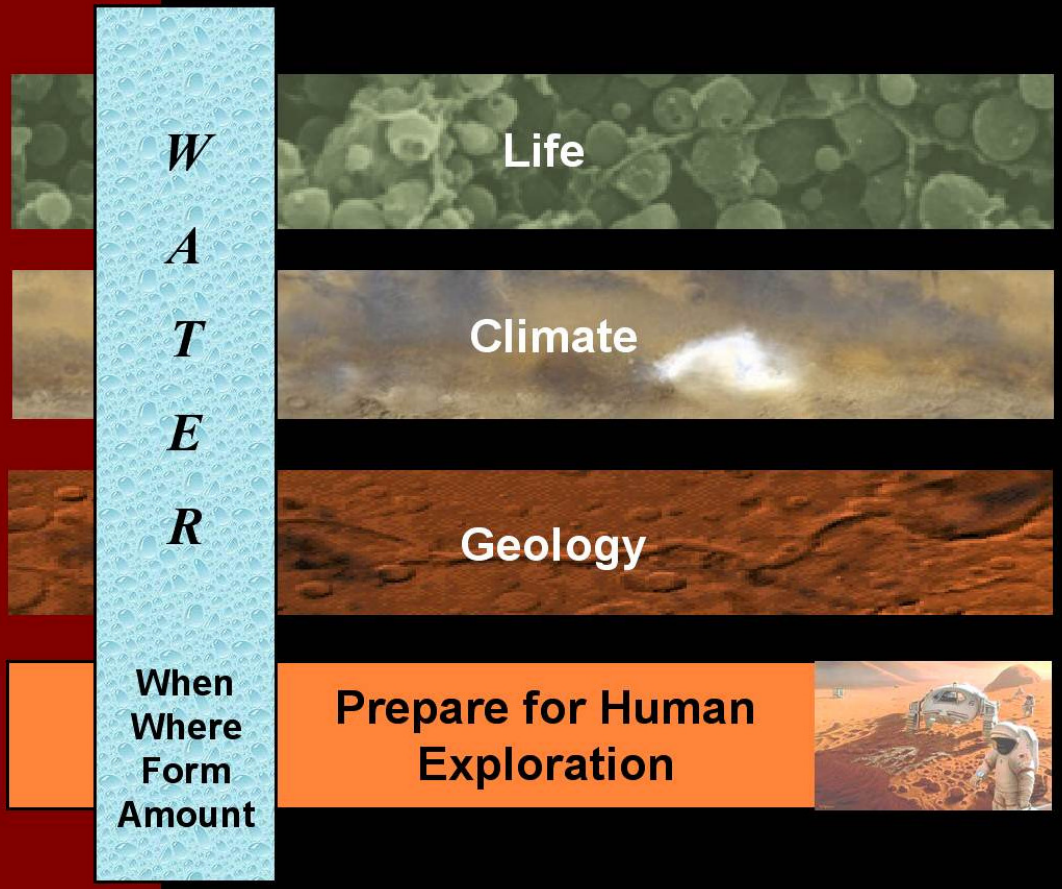
CISAS “G. Colombo”

Main Space Project/Program

- HASI: CASSINI-HUYGENS
- PFS Mars ‘96
- MARS EXPRESS and VENUS EXPRESS
- ROSETTA
- BEPI-COLOMBO
- **ExoMars 2016**
- JUICE
- Space Robotics and Automation

Why Exploring Mars? "Following the Water…(not only on Mars)"

- When was it present on the surface?
- How much and where?
- Where did it go, leaving behind the features evident on the surface Mars?
- Did it persist long enough for life to have developed?



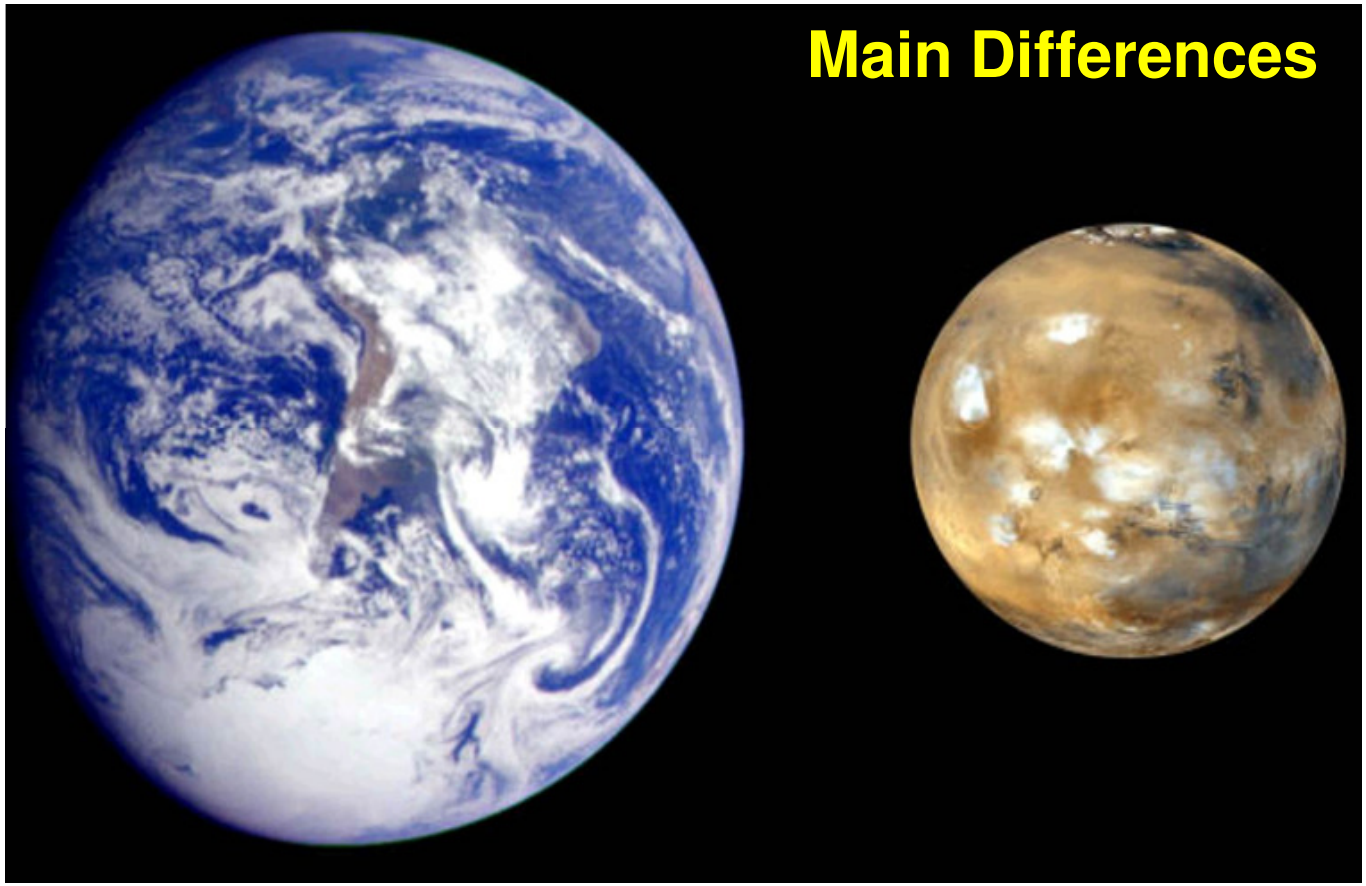
Understand the potential for life elsewhere in the Universe

Characterize the present and past climate and climate processes

Understand the geological processes affecting Mars' interior, crust, and surface

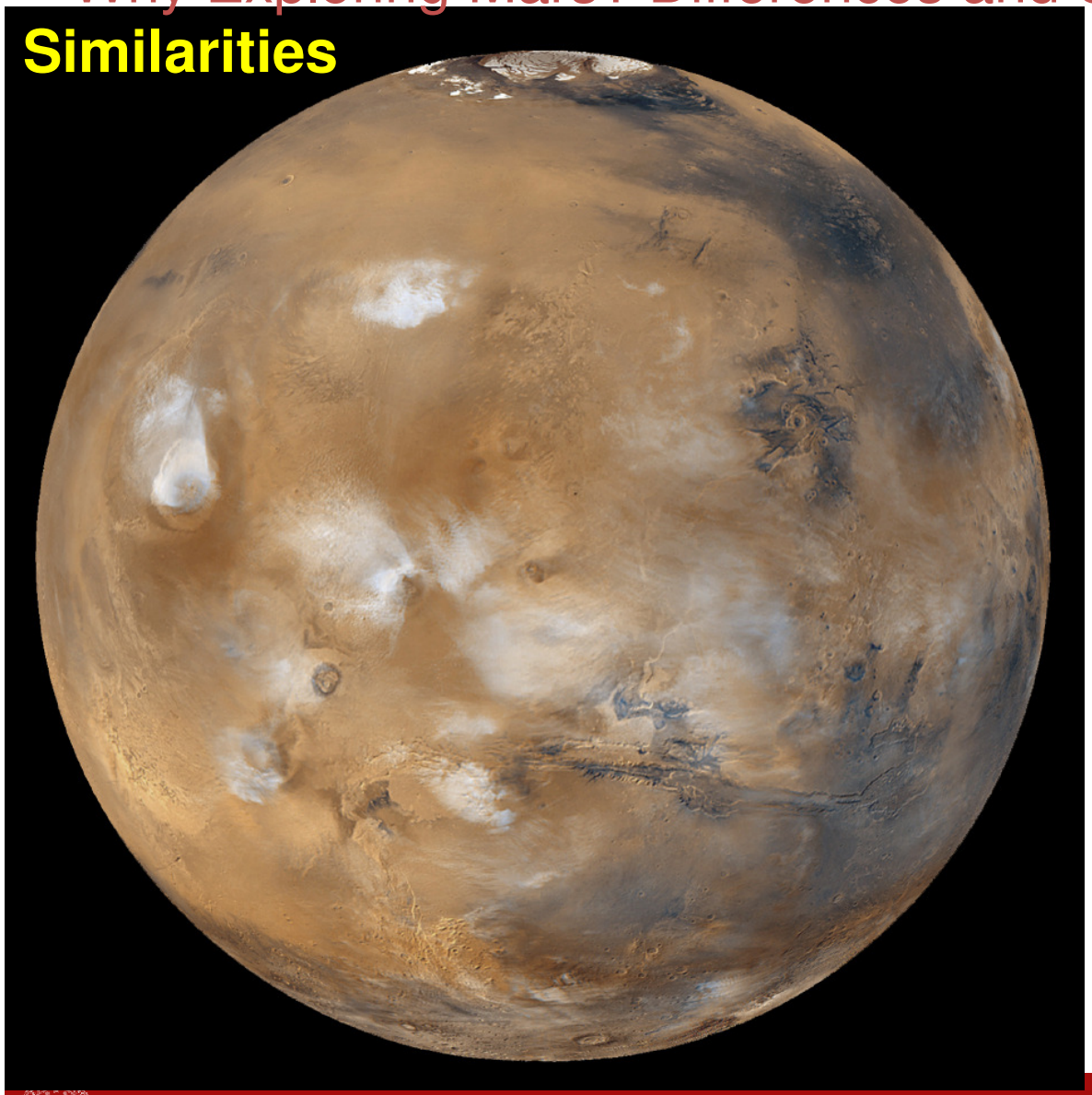
Develop Knowledge & Technology Necessary for Eventual Human Exploration

Why Exploring Mars? Differences and Similarities with Earth



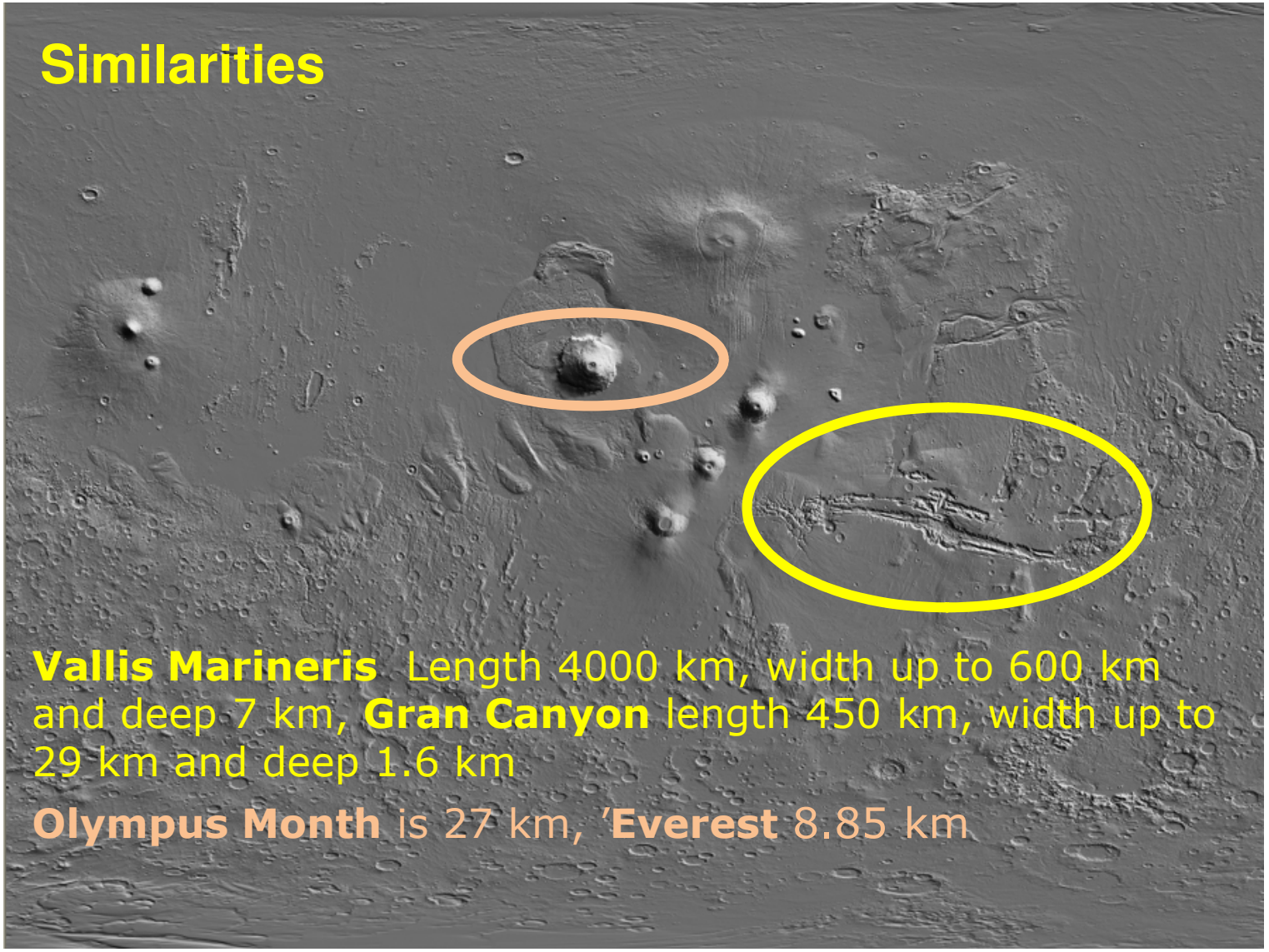
- "Distance" from the Sun
- Dimension
- Gravity
- ElectroMagnetic Field
- Absolute Pressure
- Atmosphere
- …..

Why Exploring Mars? Differences and Similarities with Earth

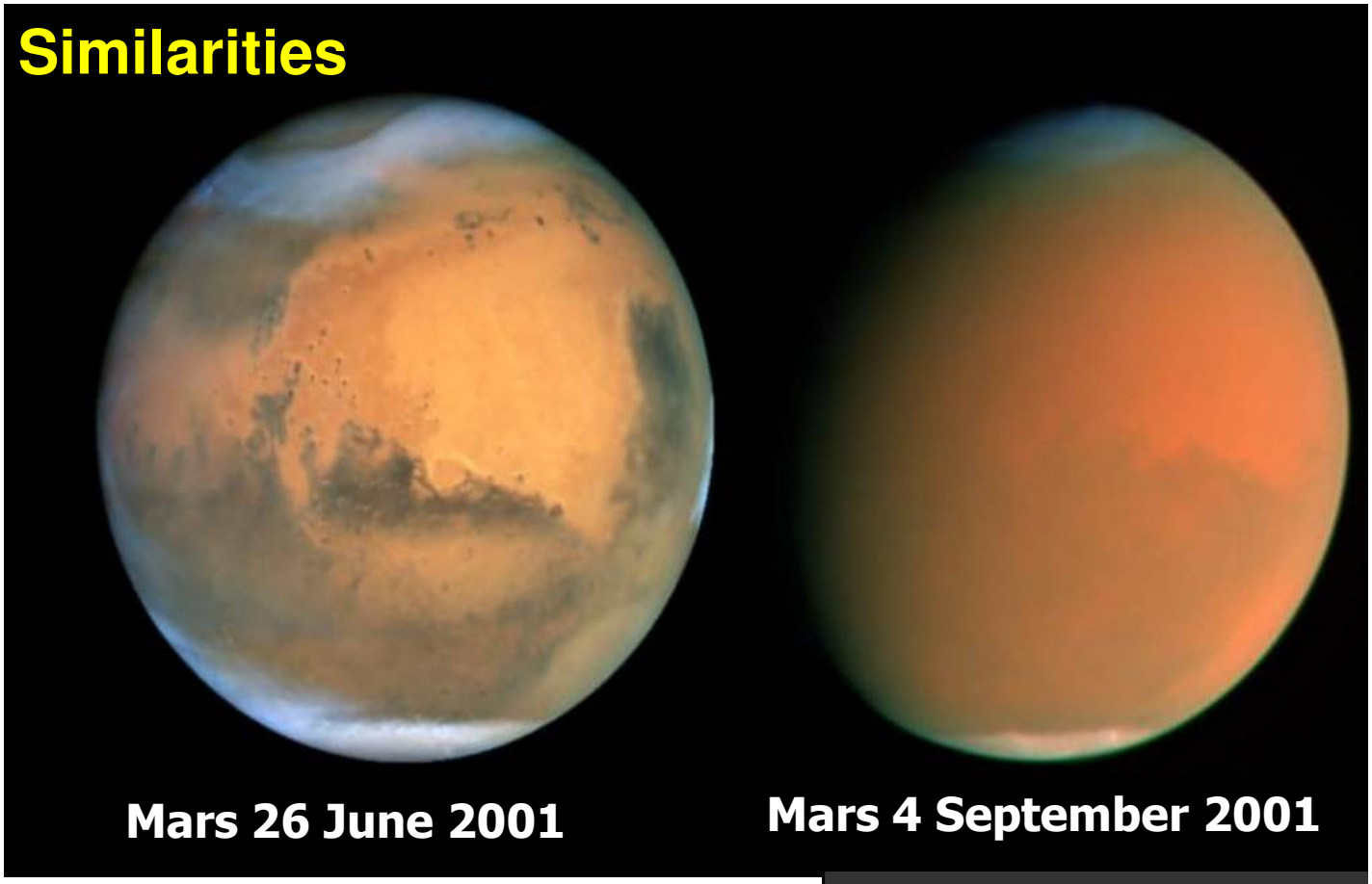


- **Mountains**
- **Vulcans**
- **Clouds**
- **Glaced Poles**
- **….**

Why Exploring Mars? Differences and Similarities with Earth

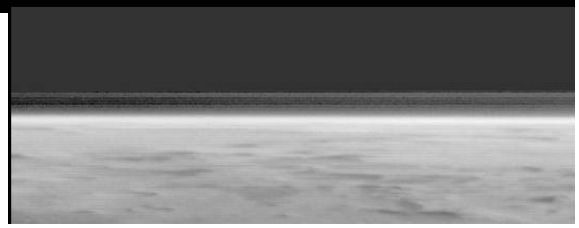


Why Exploring Mars? Differences and Similarities with Earth

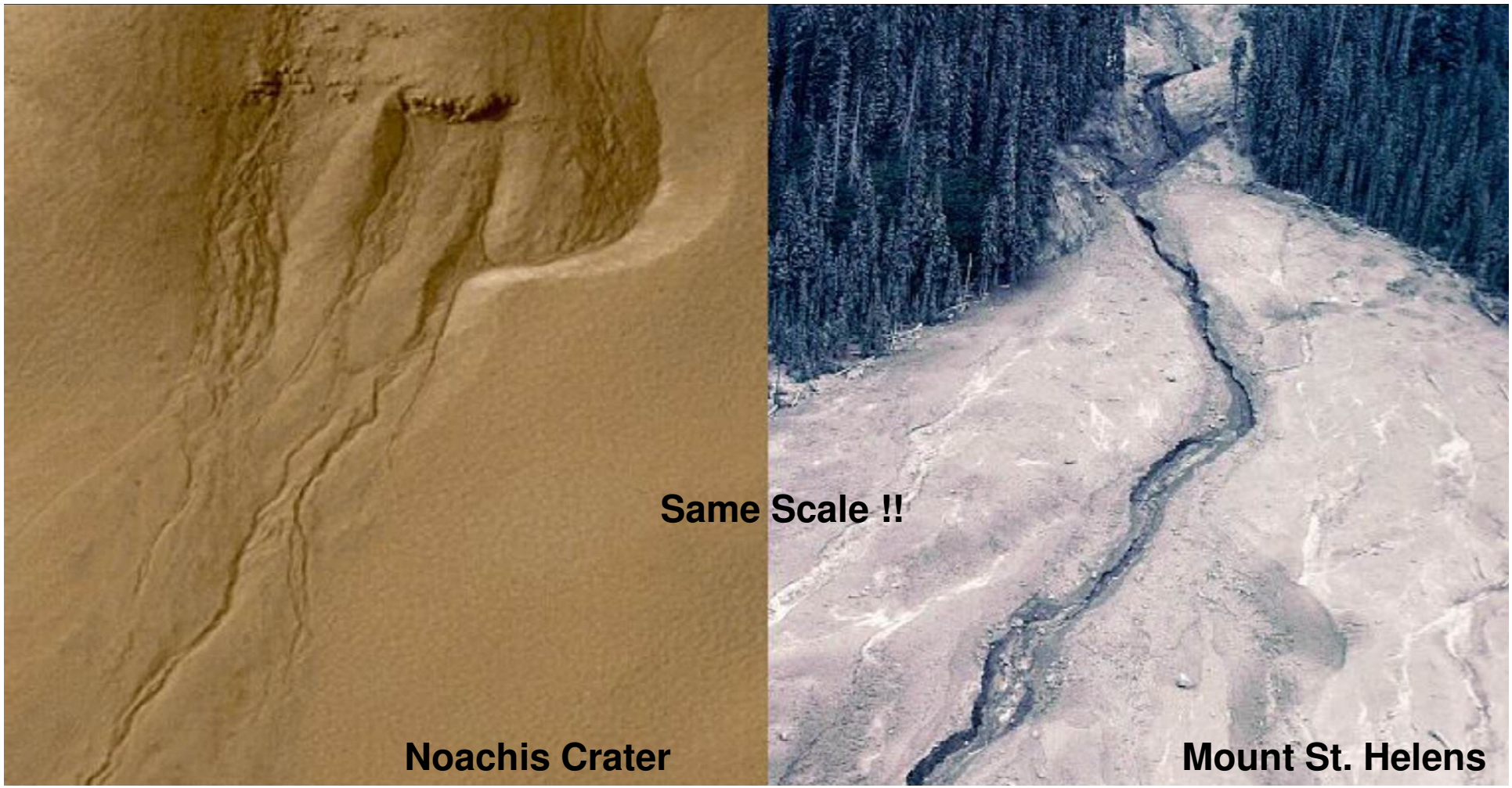


Seasons

Dusts all over the Planet

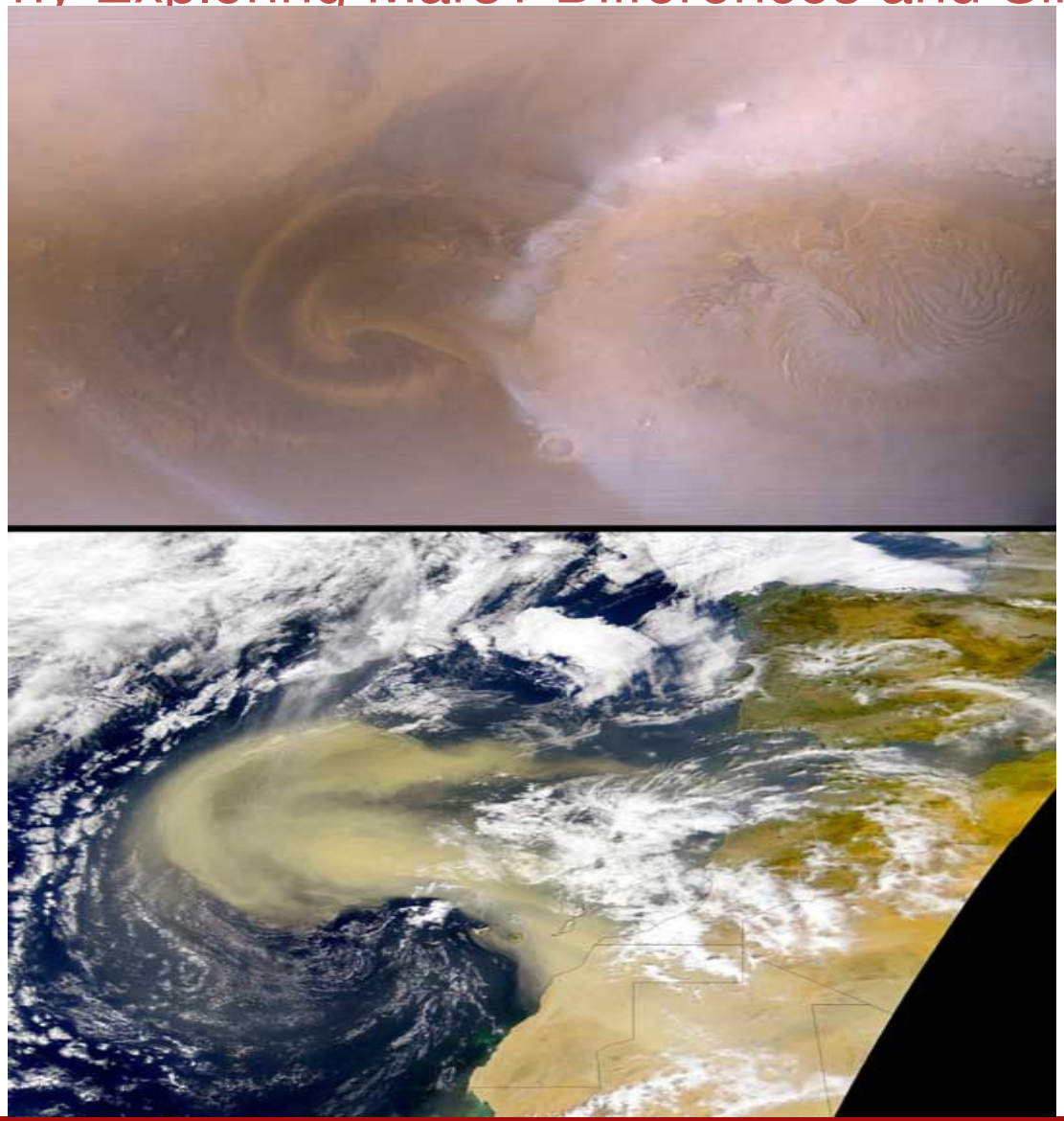


Why Exploring Mars? Differences and Similarities with Earth



Mars and Earth Similar landscape

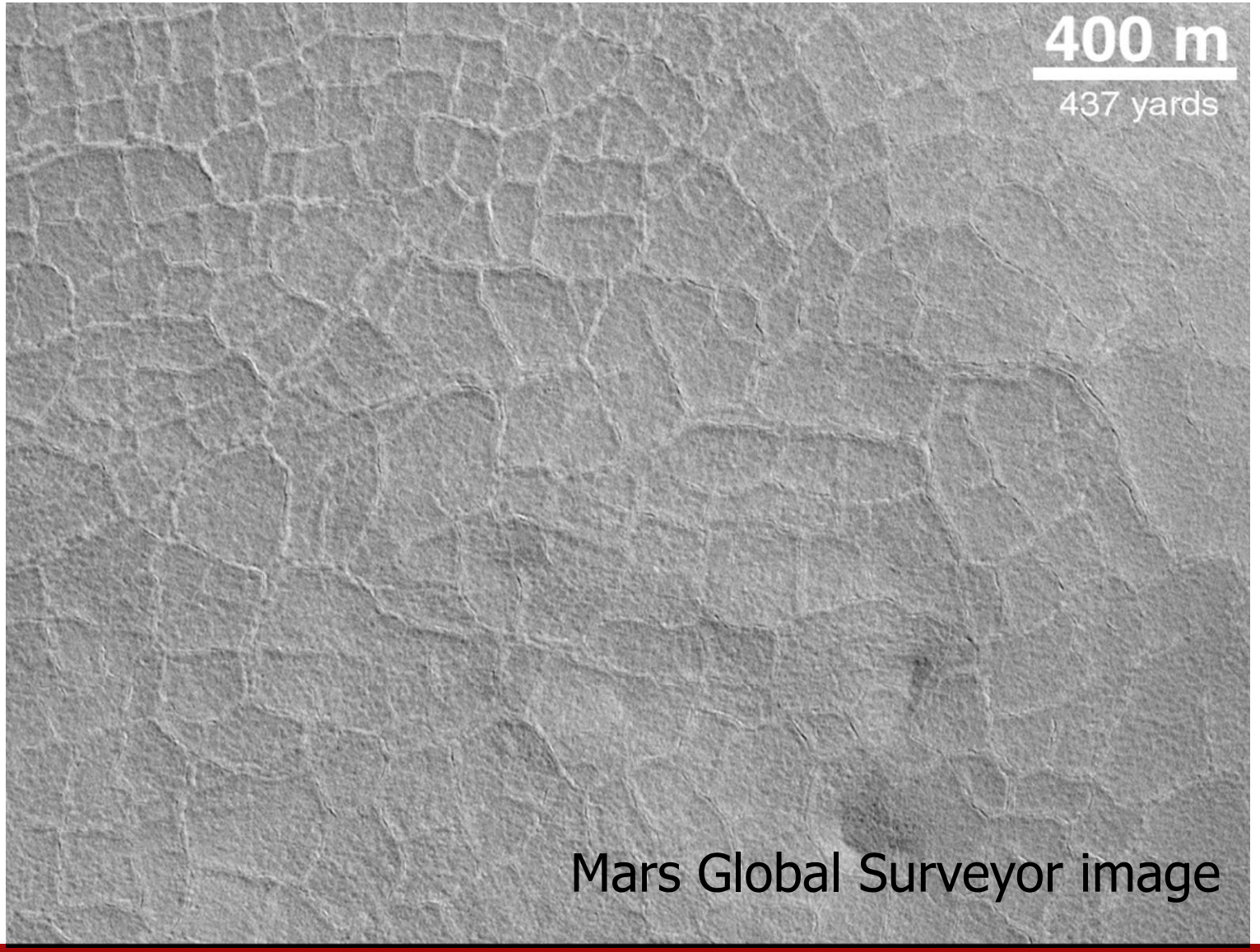
Why Exploring Mars? Differences and Similarities with Earth



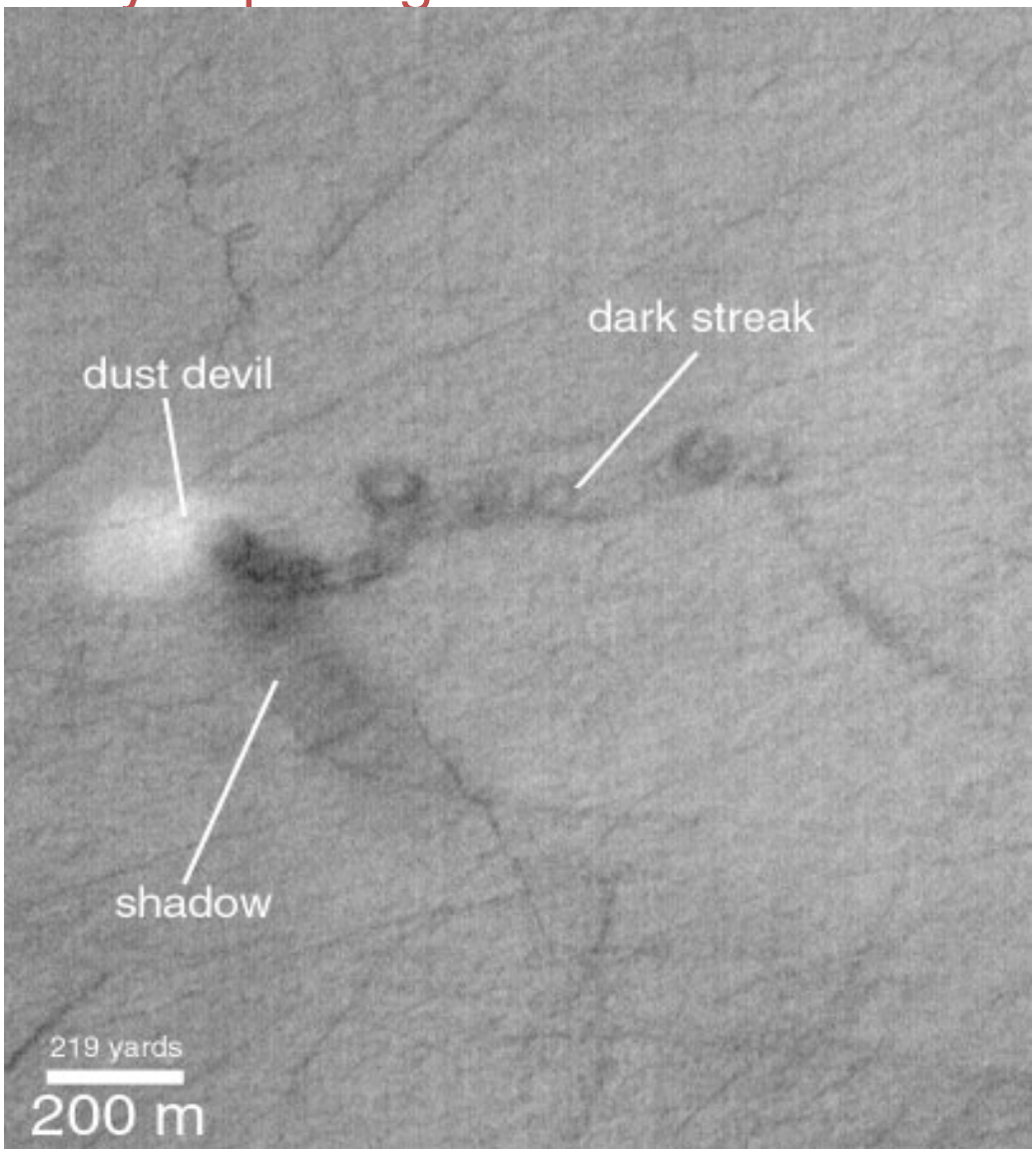
weather
cyclonic events

Why Exploring Mars? Differences and Similarities with Earth

Why Exploring Mars? Differences and Similarities with Earth



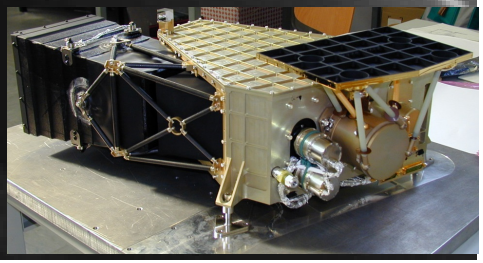
Why Exploring Mars? Differences and Similarities with Earth



Dust Devil are present on Earth too with similar size and modality

Why Exploring Mars? Differences and Similarities with Earth

Caption:
OSIRIS image of atmospheric structures of Mars
Credits:
ESA © 2007 MPS
for OSIRIS Team
MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA



Why Exploring Mars? Differences and Similarities with Earth

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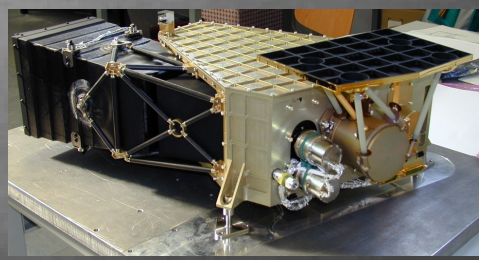
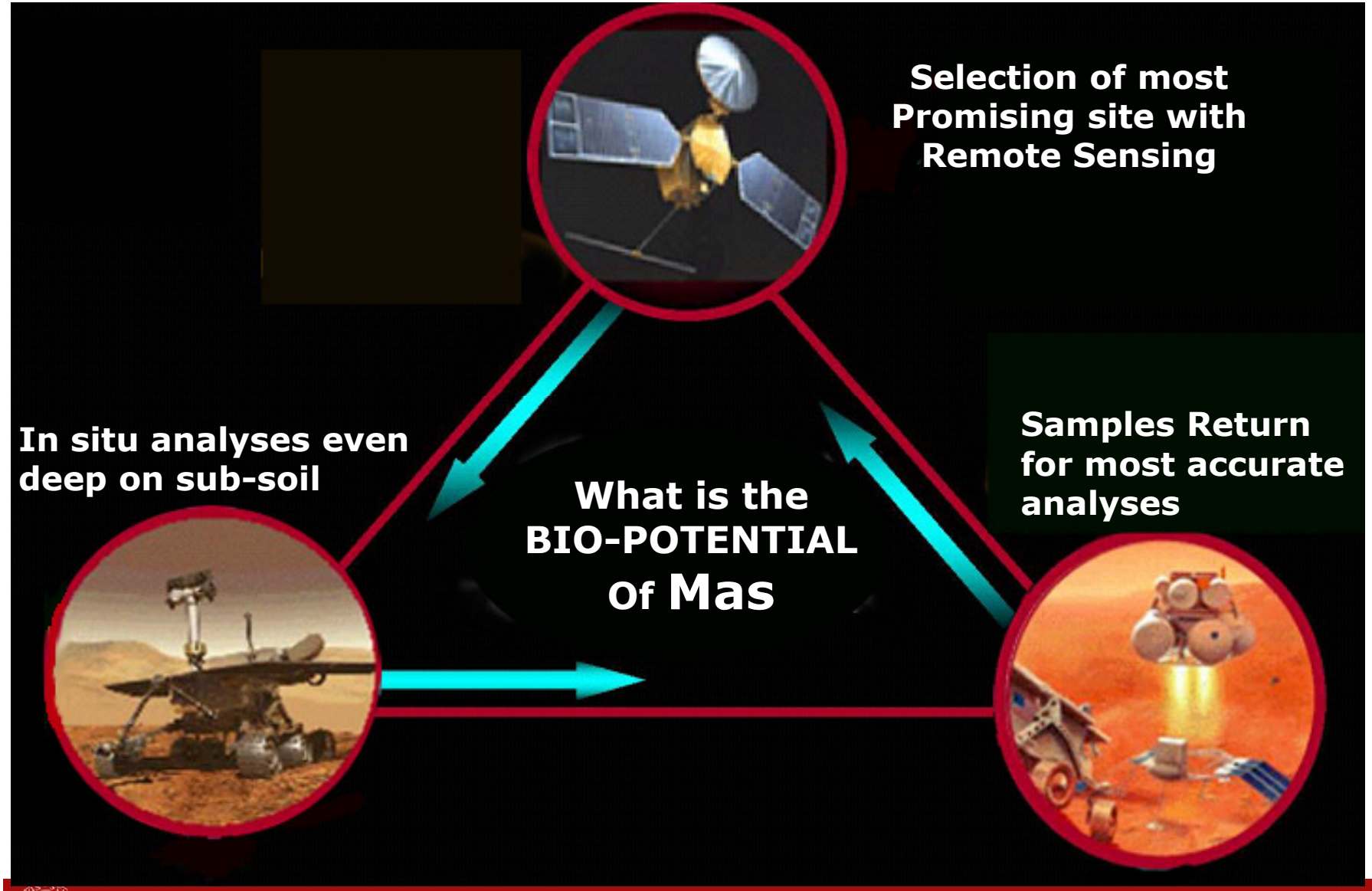
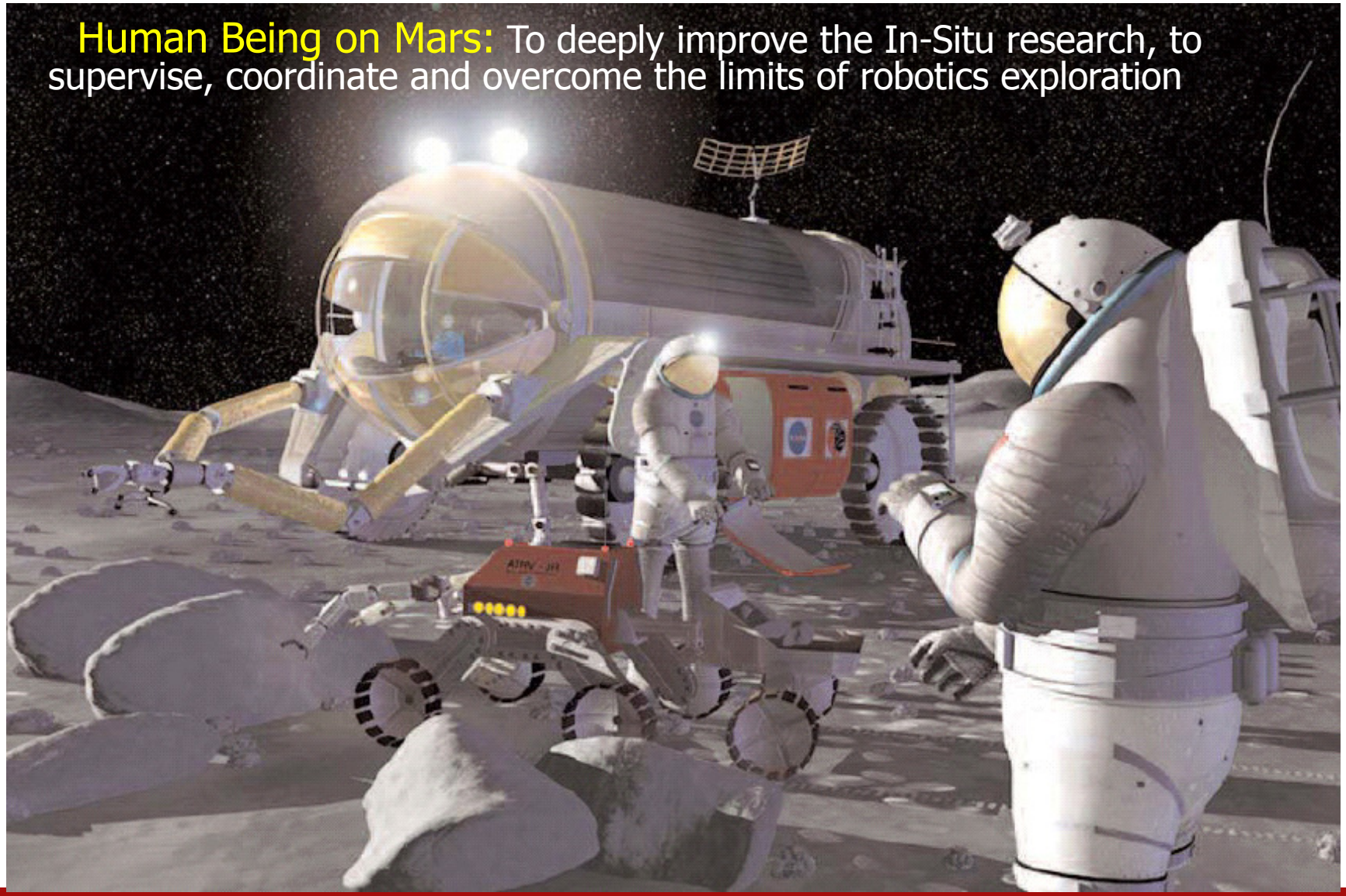


How Exploring Mars? The Exploration Approach presently…



How Exploring Mars? The Exploration Approach the next generation

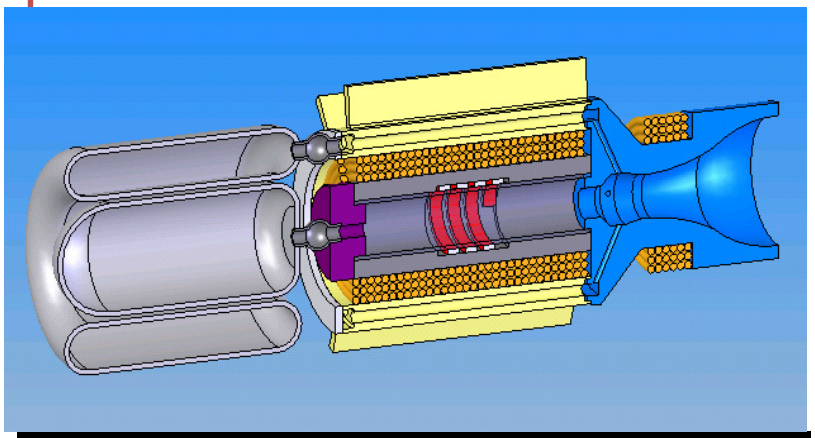


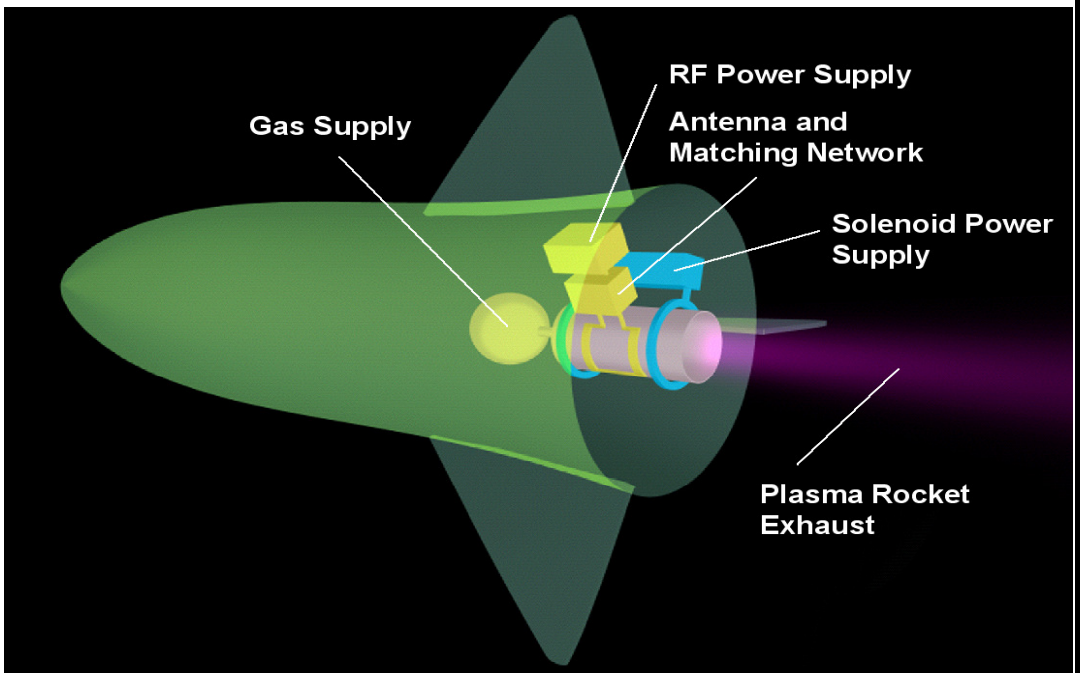
How Exploring Mars? The Exploration Approach the next generation….not only for Mars Exploration

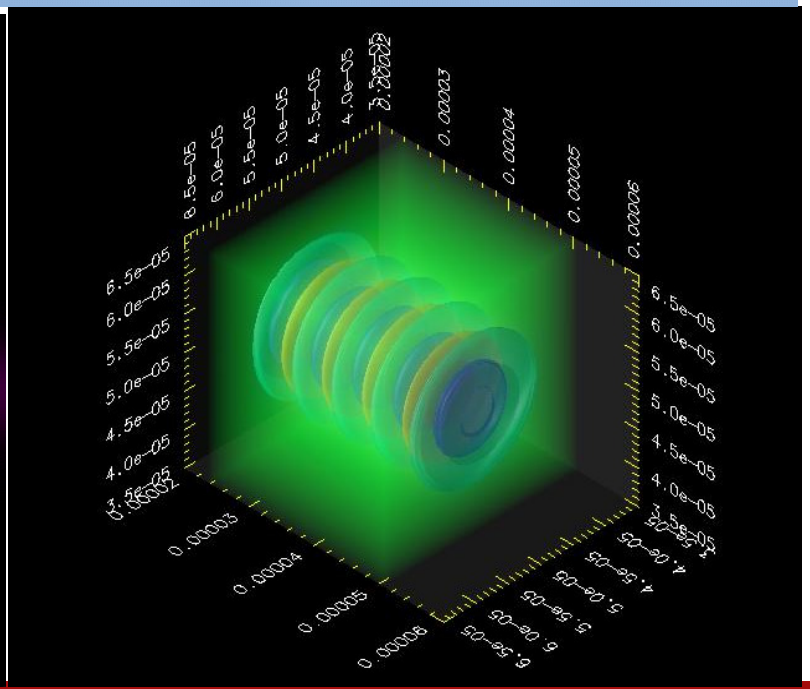
“Electrical” Propulsion

Will allow not only Astronauts on Mars, but…

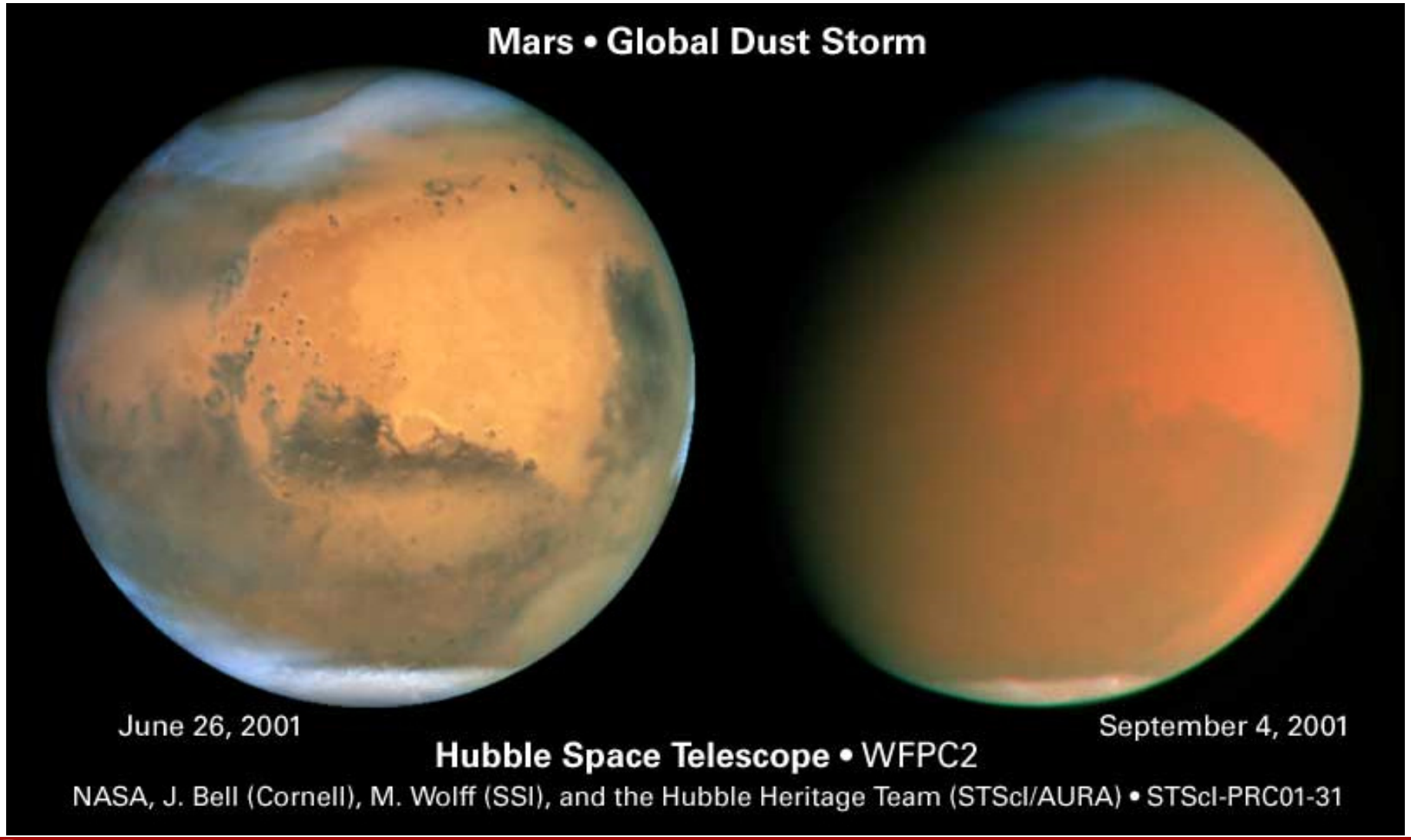
…less fuel, more P/Ls, Far Range Mission, shortened journey



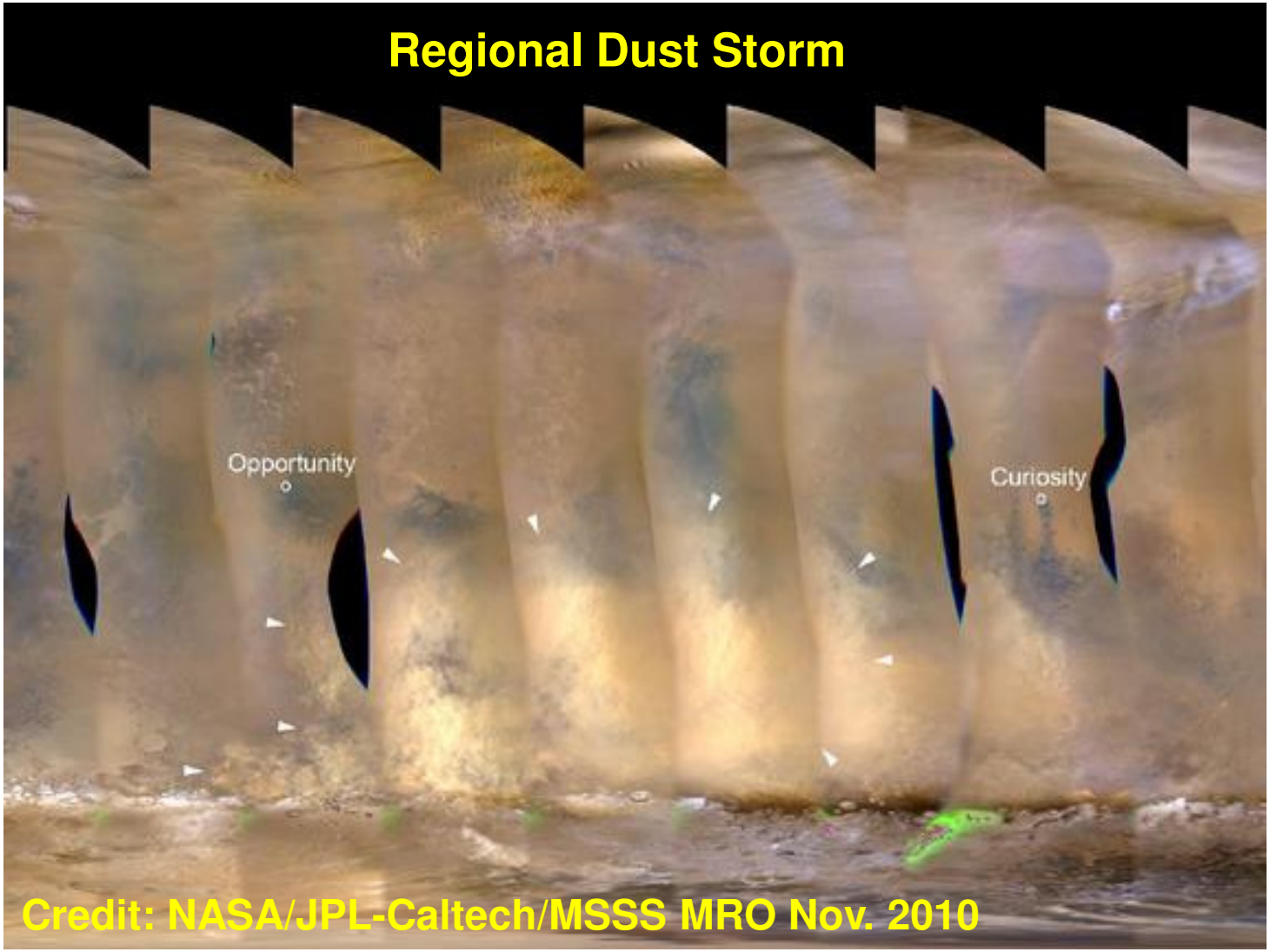




How Exploring Mars during Dust Storm : ExoMars 2016 and Dreams

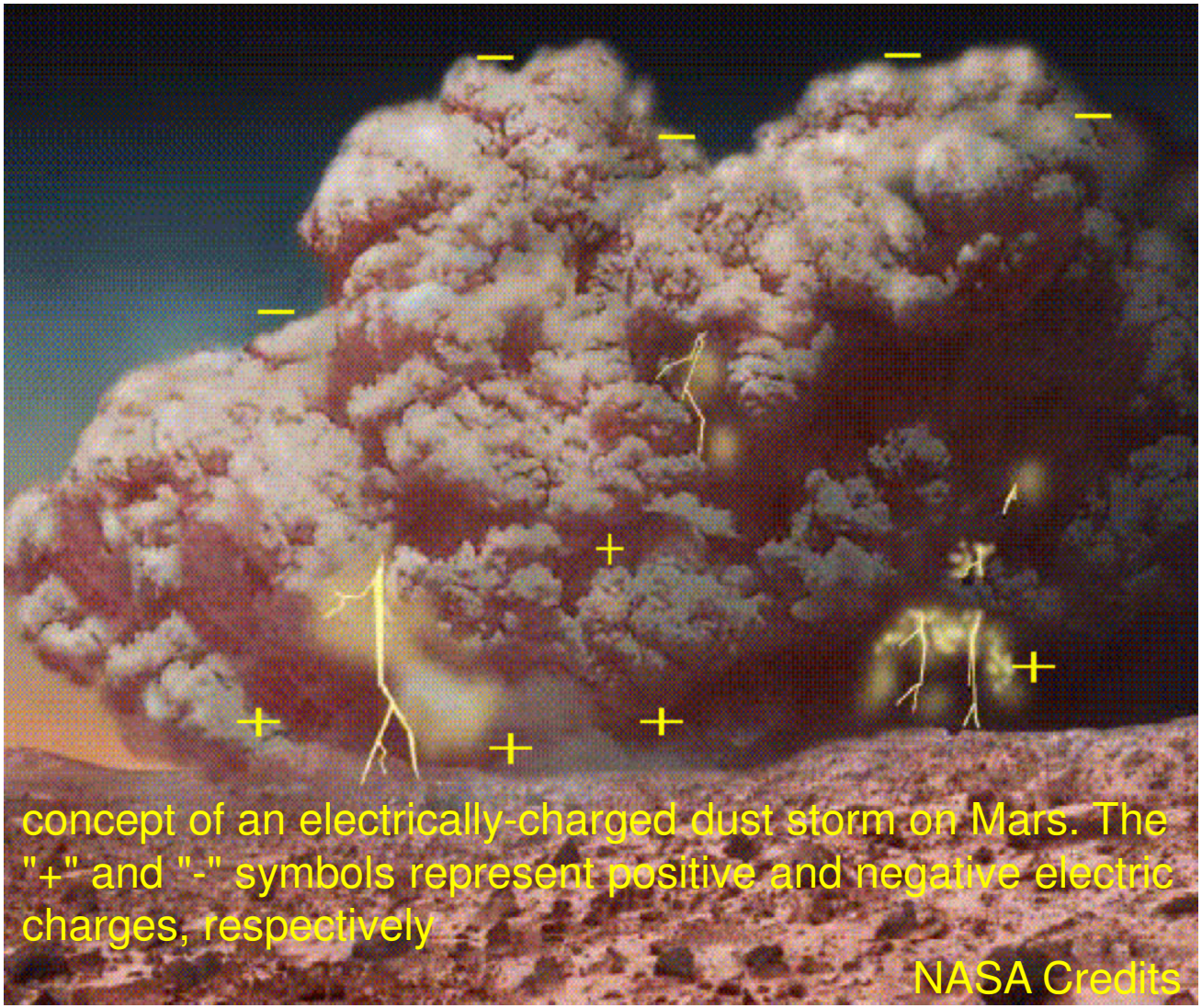


How Exploring Mars during Dust Storm : ExoMars 2016 and Dreams



How Exploring Mars during Dust Storm : ExoMars 2016 and Dreams

How Exploring Mars during Dust Storm Season: ExoMars 2016 and Dreams



How Exploring Mars during Dust Storm Season: ExoMars 2016 and Dreams

Global and regional dust storm, dust devil strongly impact atmospherical parameter globally and locally. The Dreams Experiment selected by ESA on 2011 and delivered on April 2015, has been proposed integrating several sensors in order to measure the relevant environmental parameters of Mars atmosphere such as:

Pressure, Temperature, Relative humidity, wind speed, opacity, solar radiation and, for the first time on Mars, electrical properties

How Exploring Mars during Dust Storm Season: ExoMars 2016 and Dreams

- The ExoMars Program is carried out by ESA and Roscosmos
- 2 missions are foreseen:
  - 2016 – Orbiter + EDM
  - 2018 – rover+lander
- ExoMars program is a step forward both for technological achievements and **scientific goals**

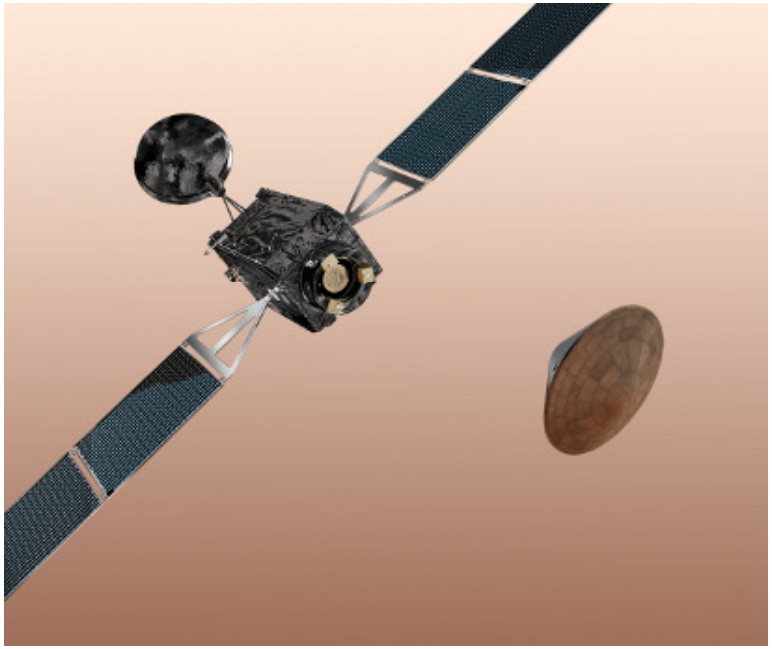
How Exploring Mars during Dust Storm Season: ExoMars 2016 and Dreams

- Technological achievements:
  - EDL of a payload on the surface of Mars
  - Surface mobility with a rover
  - Access to the subsurface to acquire samples
  - Sample acquisition, preparation, distribution and analysis

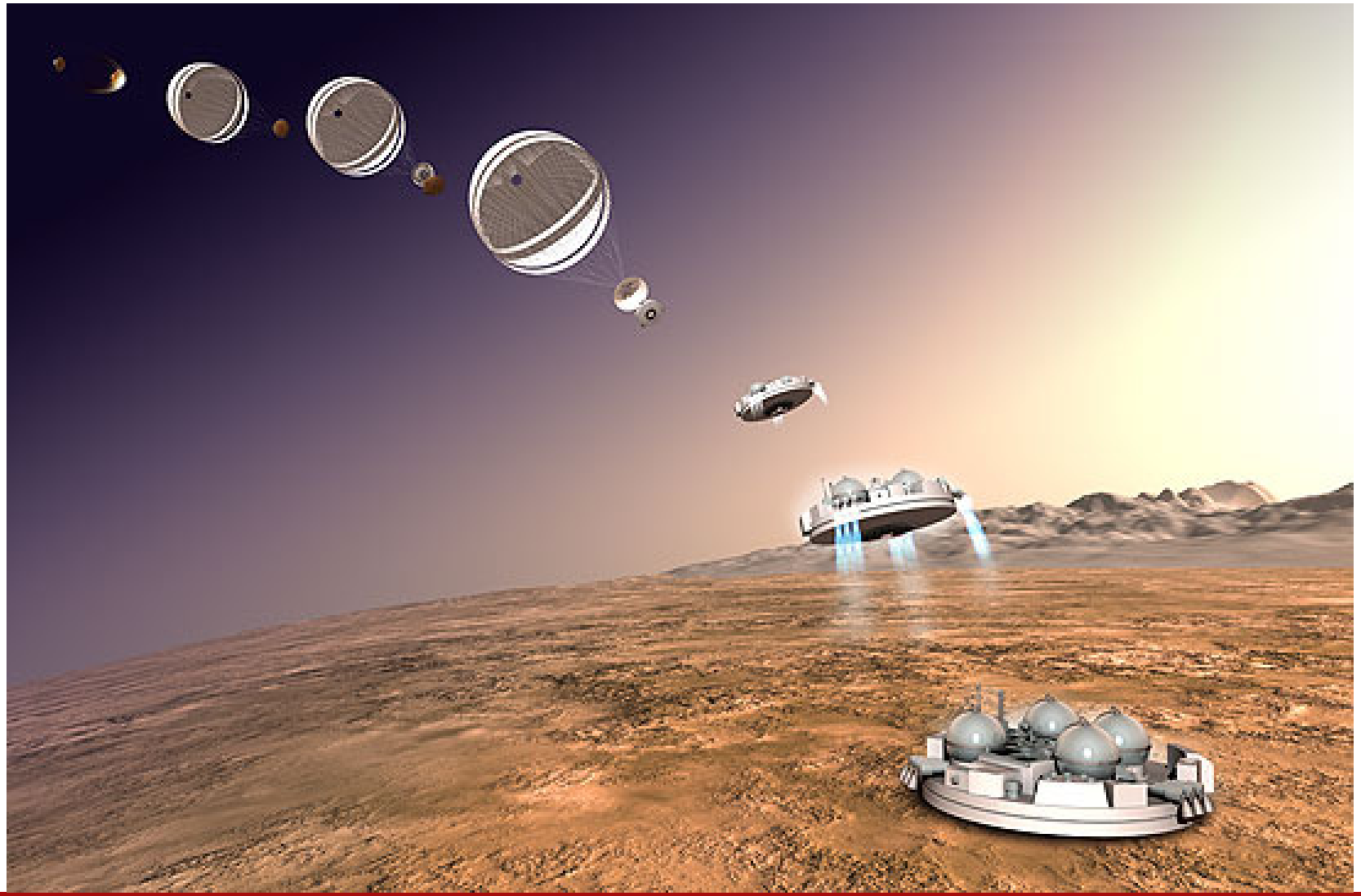
- Scientific achievements:
  - Search for signs of past and present life on Mars (rover)
  - Investigate how the water and geochemical environment varies (rover)
  - Investigate Martian atmospheric trace gases and their sources (orbiter)
  - **Measuring key meteorological parameters even during the statistical dust storm season (EDM and lander)**
  - **Study the electrical properties of the martian atmosphere (EDM and lander)**

How Exploring Mars during Dust Storm Season: ExoMars 2016 and Dreams

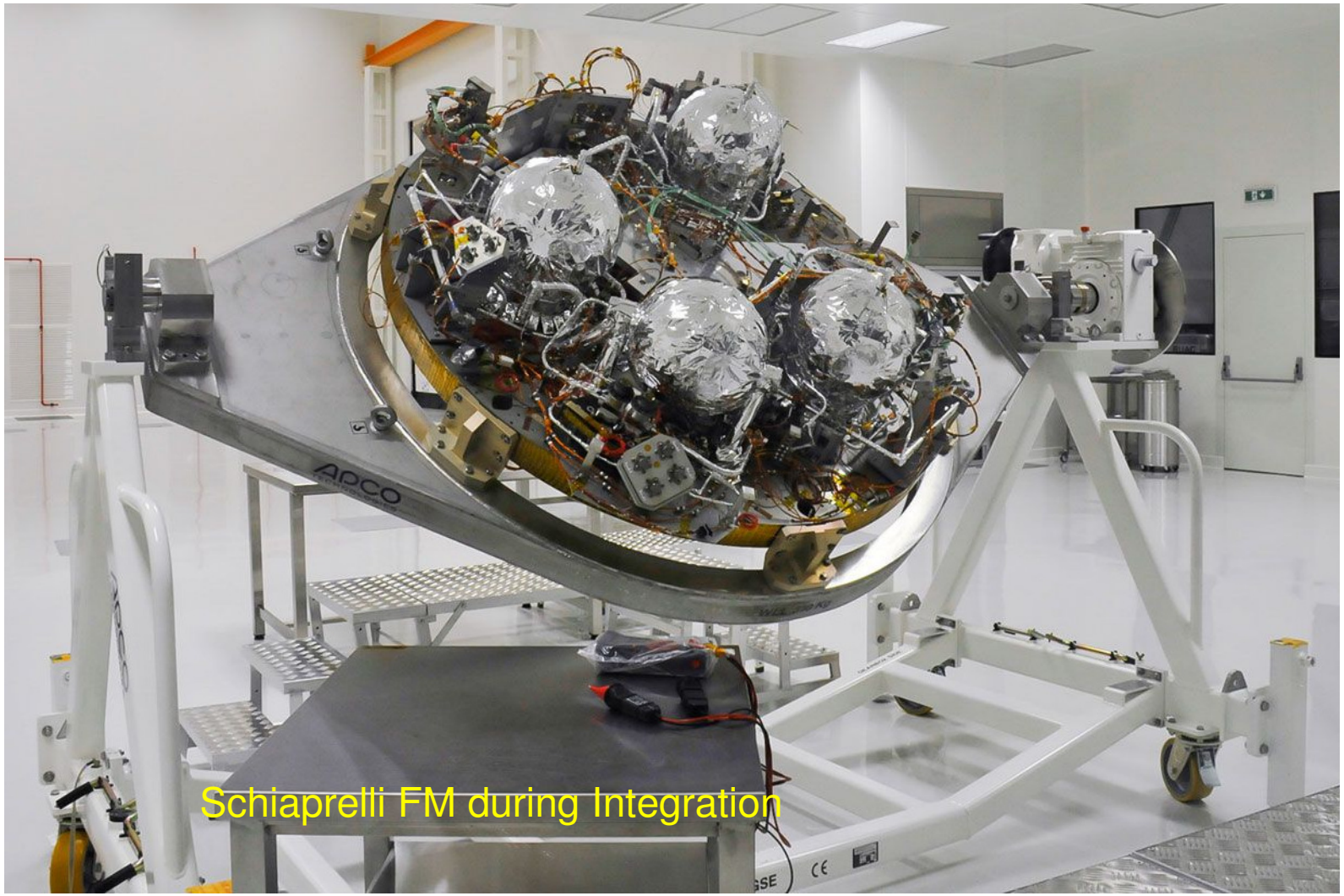
- The EXM Spacecraft Composite (TGO) will be launched in early January 2016 and will arrive at Mars on October of 2016
- Prior to arrival at Mars, the EDM will be released from the Orbiter Module and will enter the Mars atmosphere from a hyperbolic arrival trajectory.
- Total entry mass of the EDM: 600 kg
- It will arrive during the Mars Global Dust Storm Season (around L_S = 244°)
- The EDM Surface Platform (ESP) is designed to survive on the surface of Mars for a nominal science operations period of 2 sols up to 4 sols
- The EDM will provide Europe with the technology for landing on the surface of Mars with a controlled landing orientation and touchdown velocity



ExoMars 2016, Schiaparelli Entry and Descent Module where Dreams is accomodated



ExoMars 2016, Schiaparelli Entry and Descent Module where Dreams is accomodated



Schiaprelli FM during Integration

ExoMars 2016, Schiaparelli Entry and Descent Module where Dreams is accomodated

Dreams for Exomars 2016

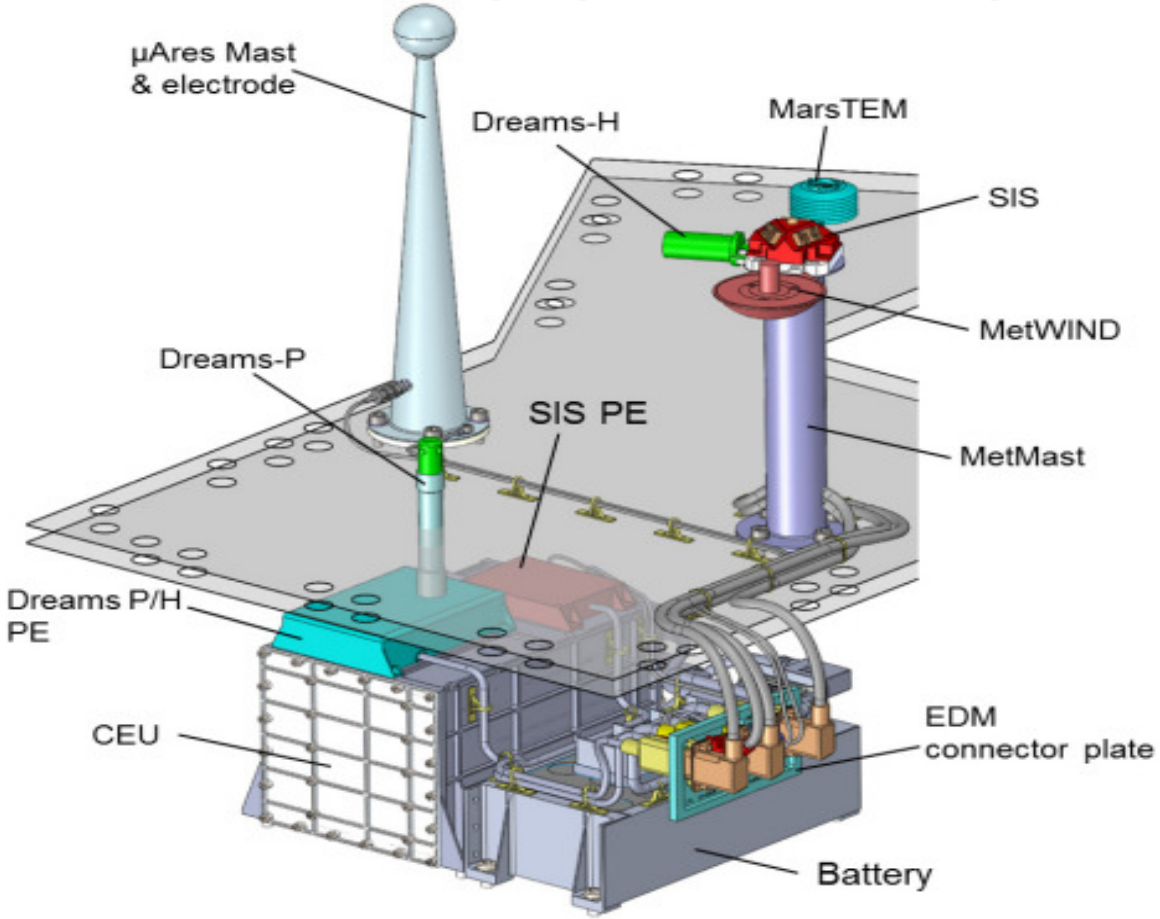
- **DREAMS - An integrated multi-sensor scientific payload for Mars Atmospheric Exploration**

- Scientific requirements are derived from the main objective of the experiment which for the first time will characterize the landing site environment in dusty conditions which basically means to measure:
- dust properties/abundance
- First ever measurement of electric activity on Mars
- meteorological state through the environmental parameters such as Temperature, Pressure, Humidity and Wind Speed

- System Requirements are derived from the Martian environmental conditions, from the EDM I/F specifications and from the Exomars 2016 mission profiles which requires DREAMS to operate autonomously after Mars touchdown with its own Battery

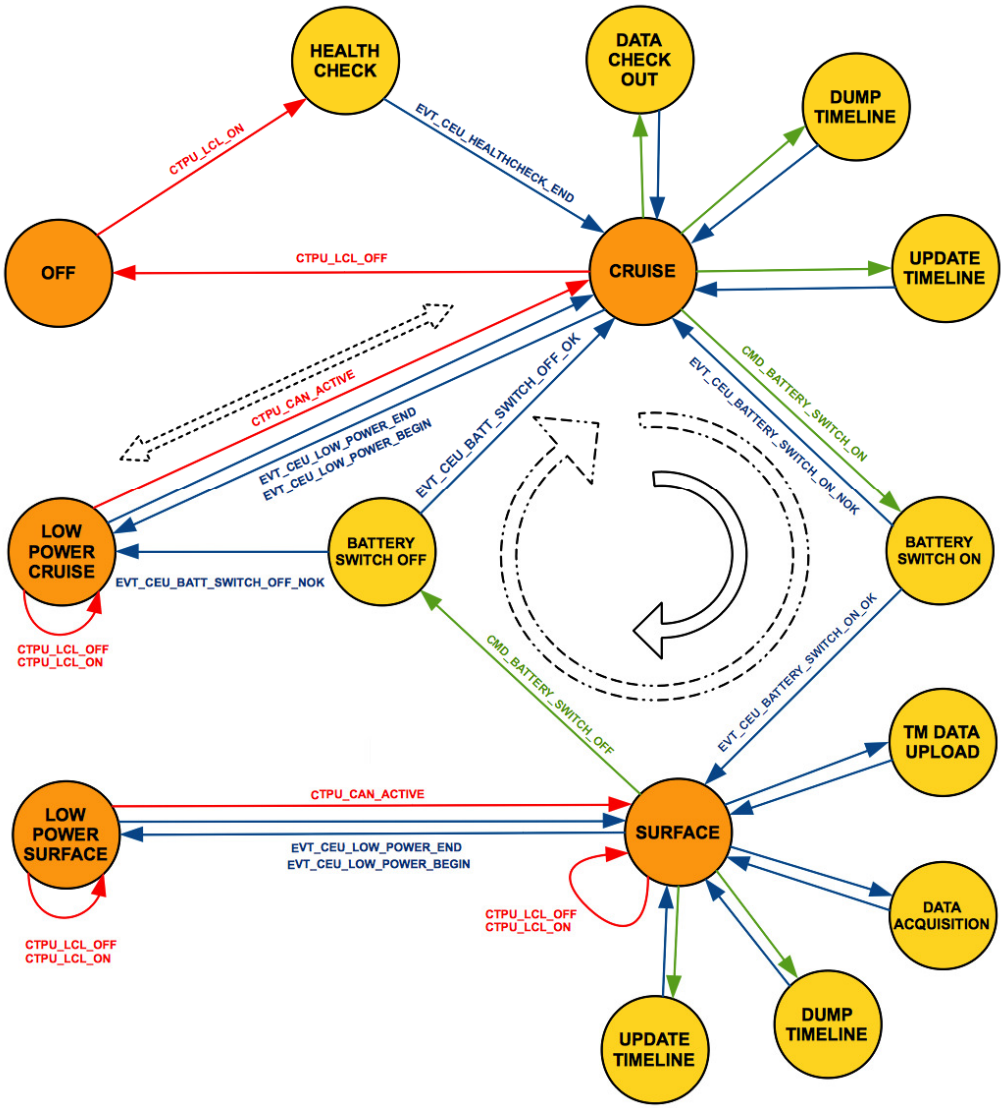
Dreams for Exomars 2016

DREAMS will <u>autonomously</u> measure Absolute Pressure, Relative Humidity, Temperature, Wind Velocity, Atmospheric opacity and solar radiation, electrical properties of atmosphere



DREAMS is an international cooperation between Italy (CISAS and INAF-OAC, PI and Co-PI) France (Latmos), England (Oxford University), Finland (FMI), Spain (INTA) ASI Is the Lead Founding Agency

Dreams for Exomars 2016

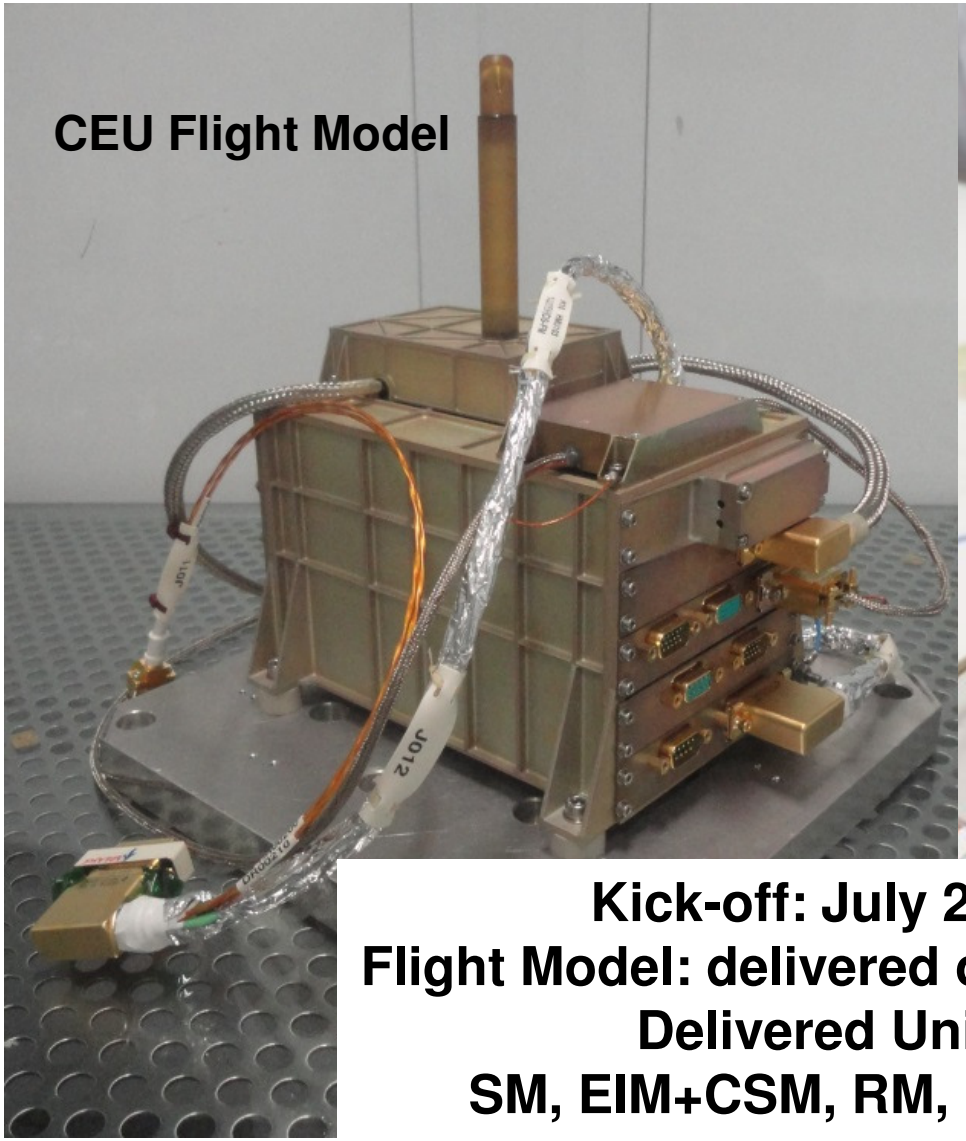


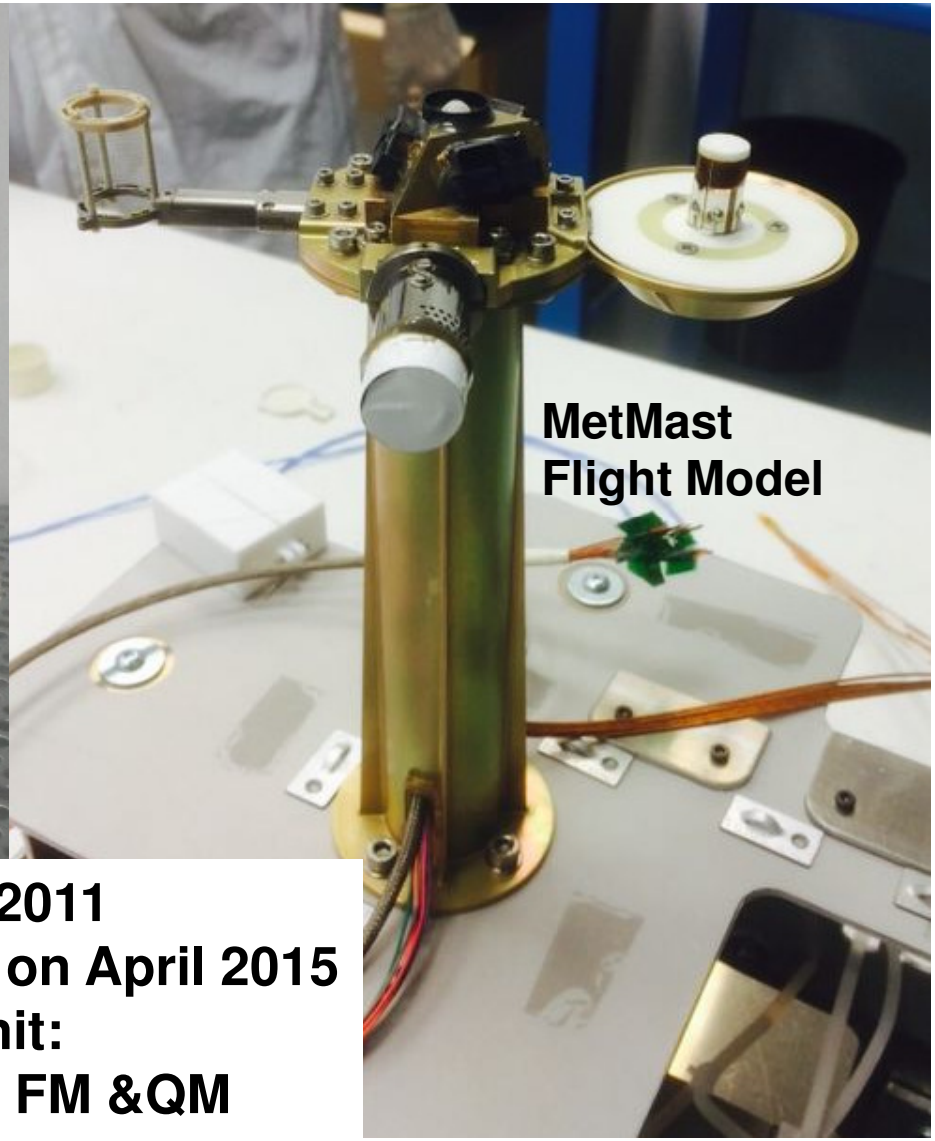
DREAMS STATE DIAGRAM

Legend:

- CTPU states
- CAN bus commands (TC/CMDs)
- CEU internal events
- CEU transition state
- CEU stable state
- Surface battery switch-on process
- Battery switch-on test procedure
- Fail safe switch-on path

Dreams for Exomars 2016

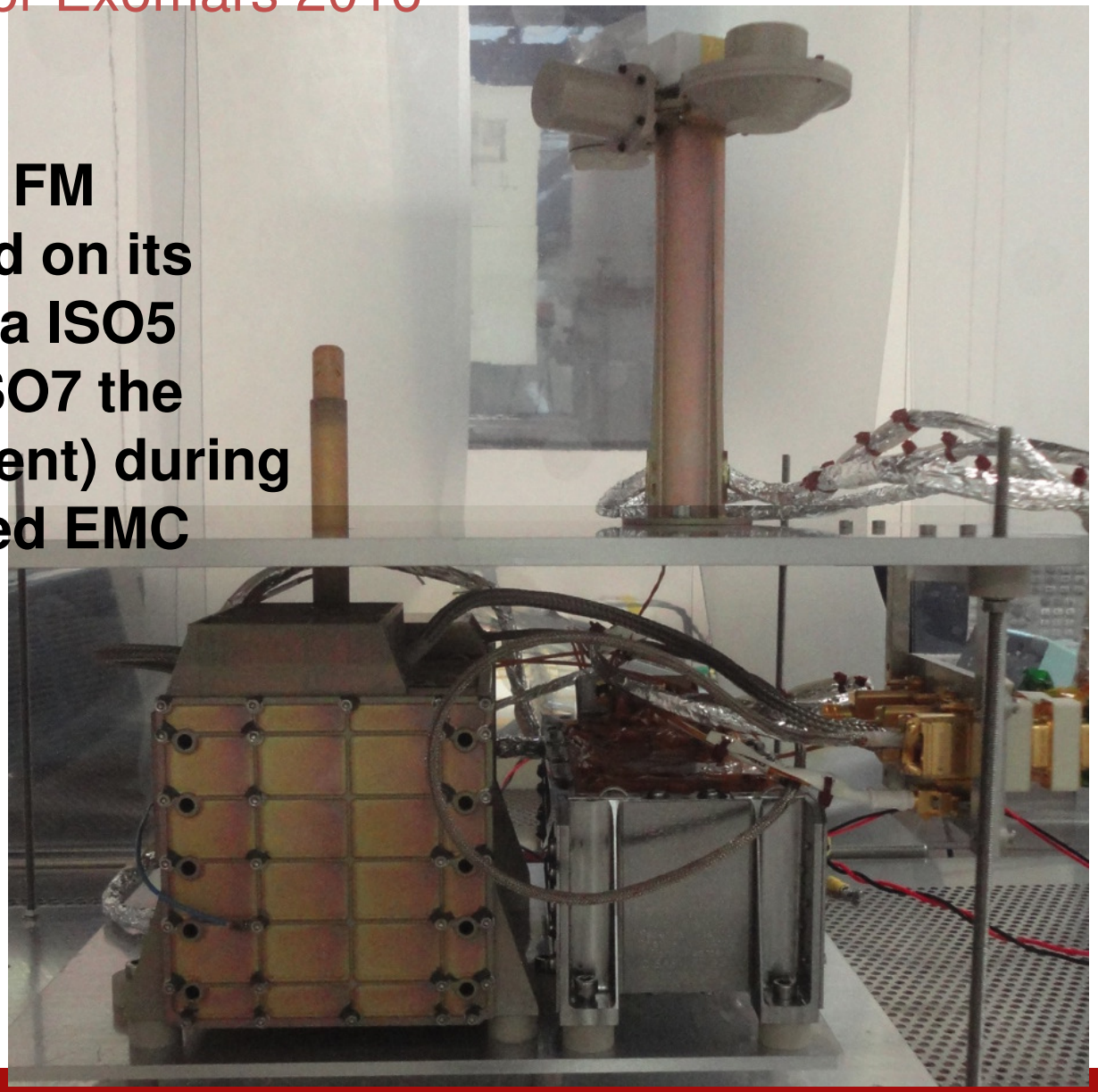




Kick-off: July 2011
Flight Model: delivered on April 2015
Delivered Unit:
SM, EIM+CSM, RM, FM &QM

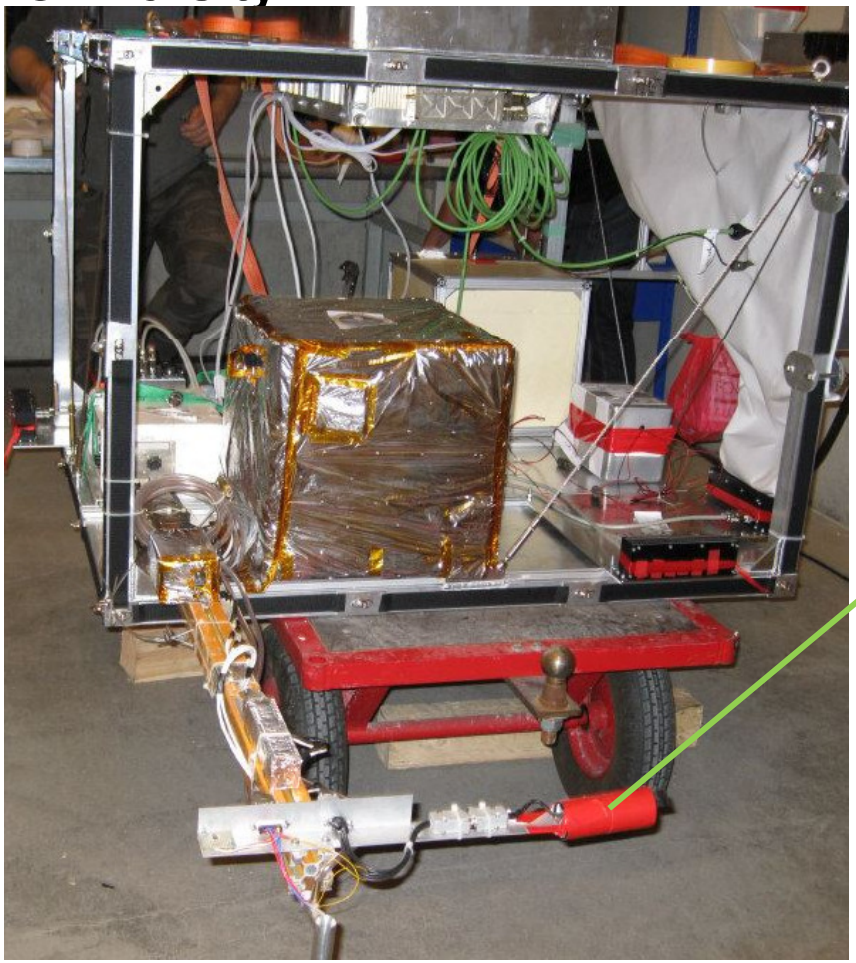
Dreams for Exomars 2016

DREAMS FM Integrated on its MGSE in a ISO5 bench (ISO7 the requirement) during Conducted EMC



Dreams for Exomars 2016 and Missus Experiment

Martian Thermometer prototype tested on ESA BEXUS (Stratospheric baloon) on 2013 with MISSUS experiment made by Engineering Stundent of Padua University

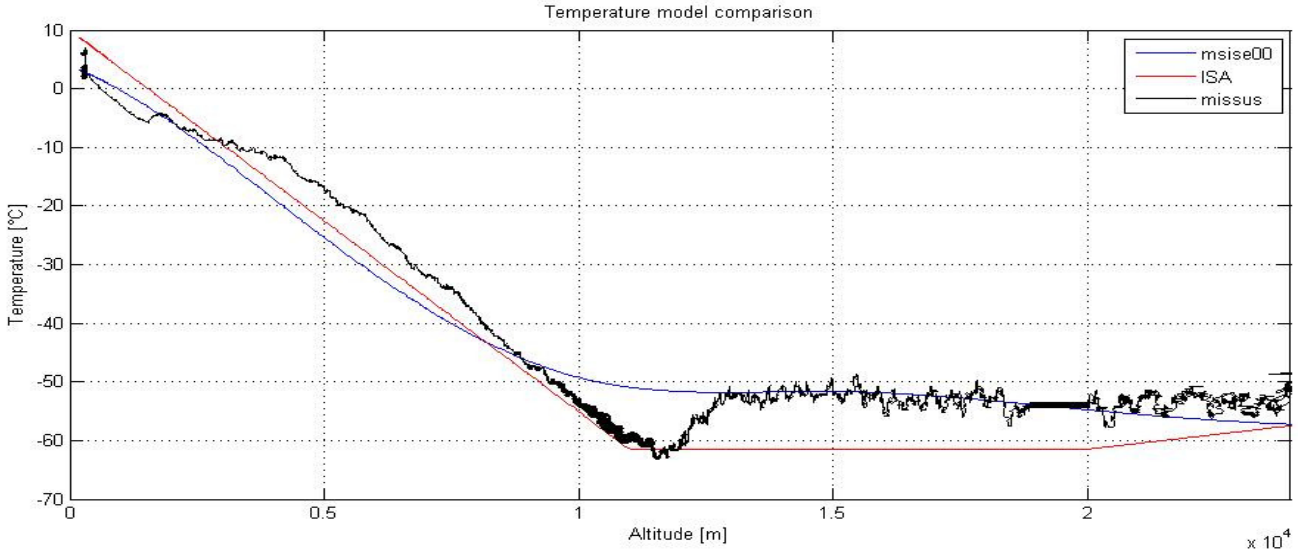


Dreams for Exomars 2016 and Missus Experiment

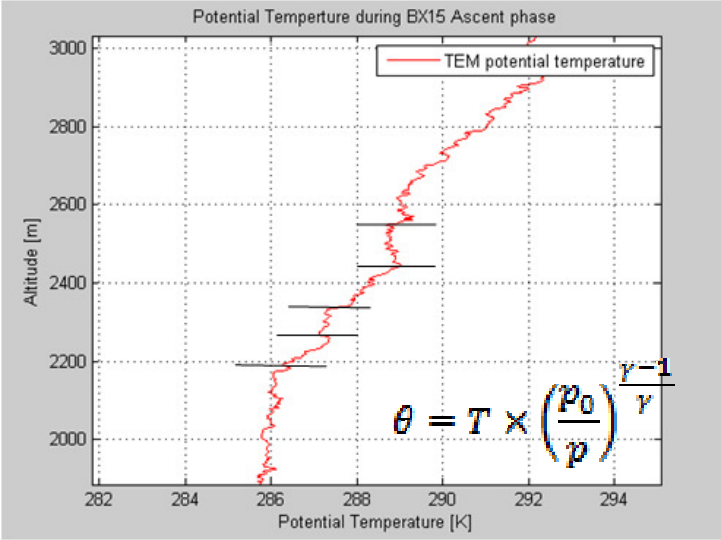
The Team designed realized calibrated and testess Missus Experiment form the electronics to each single sensors

Startosferic baloon, reaching 30-35 [km] altitude, represents a Martian Analogue for what concerns absolute pressure

Dreams for Exomars 2016 and Missus Experiment



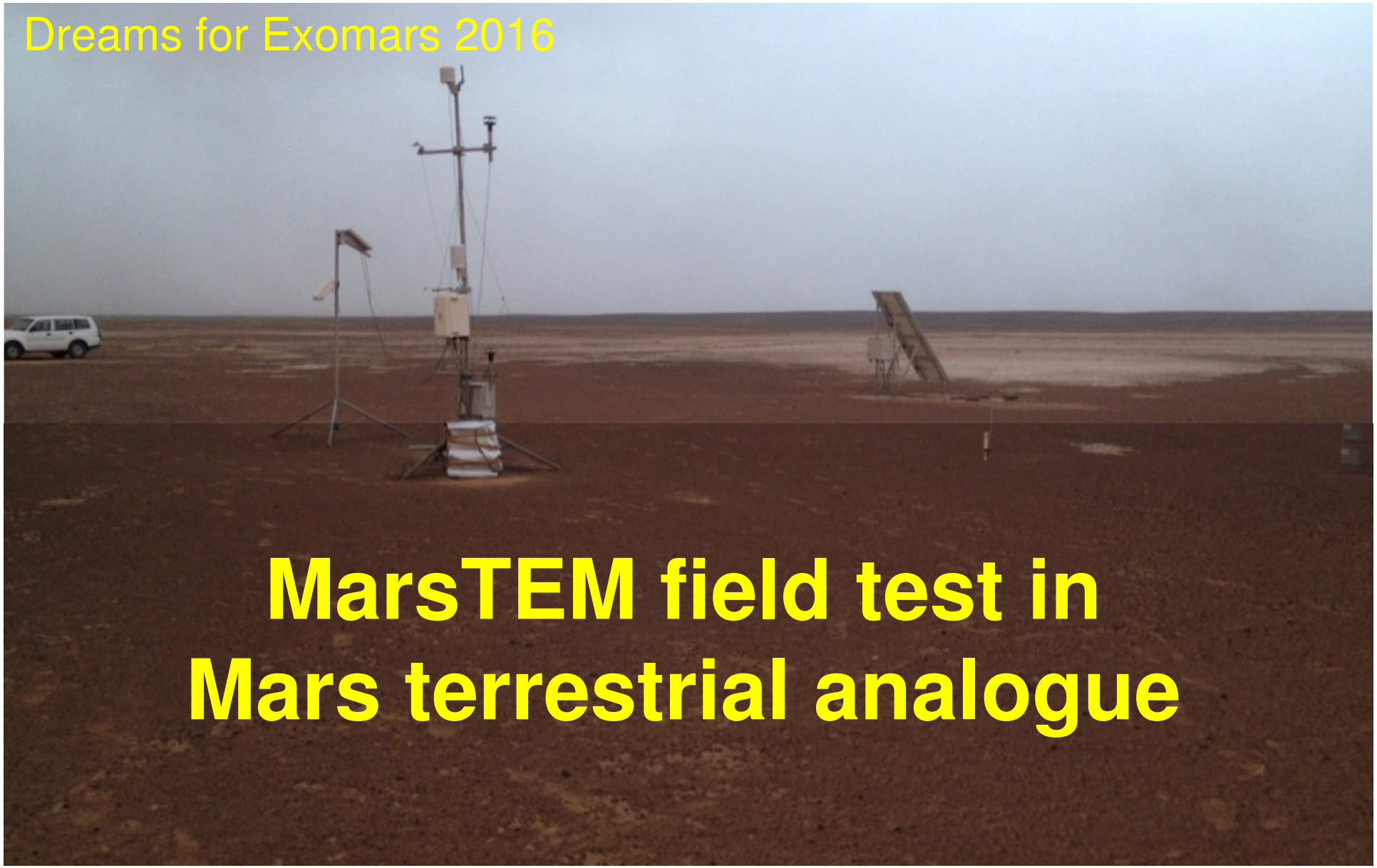
- Signal Filtered with multistady Wavelet very efficient to "remove" noise whose frequency band is within 1 – 260 Hz
- Lowest noise frequency is very close to high signal frequency



Atmopshere stability:
- Comparison with CALIPSO new clouds model
- Potential Temperature θ
- Buoyancy N^2

$$N^2 = \frac{g}{T}\left(\frac{\partial T}{\partial z} + \frac{g}{C_p}\right)$$

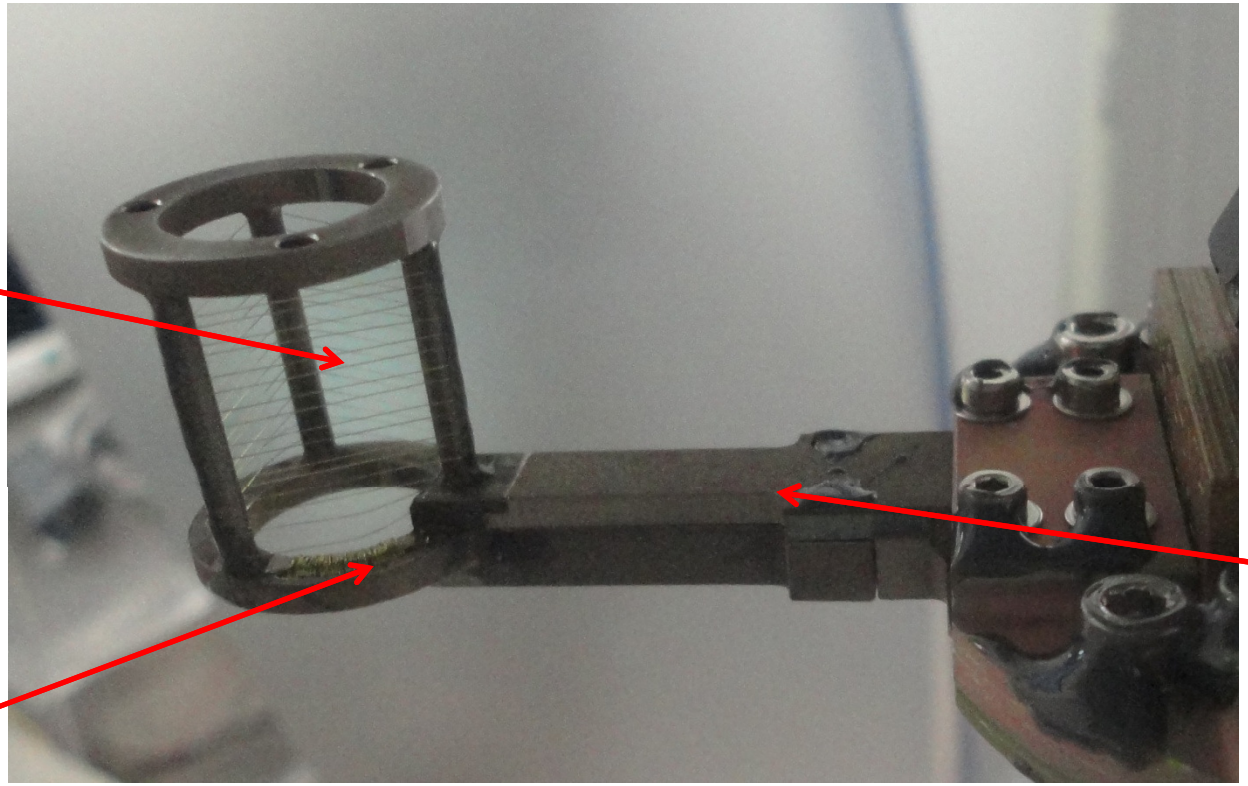
Dreams for Exomars 2016



MarsTEM field test in Mars terrestrial analogue

Dreams for Exomars 2016: MarsTem

Fine sensor (40.6 Ohm@21.3)



Titanium Structure (Ti6Al4V)

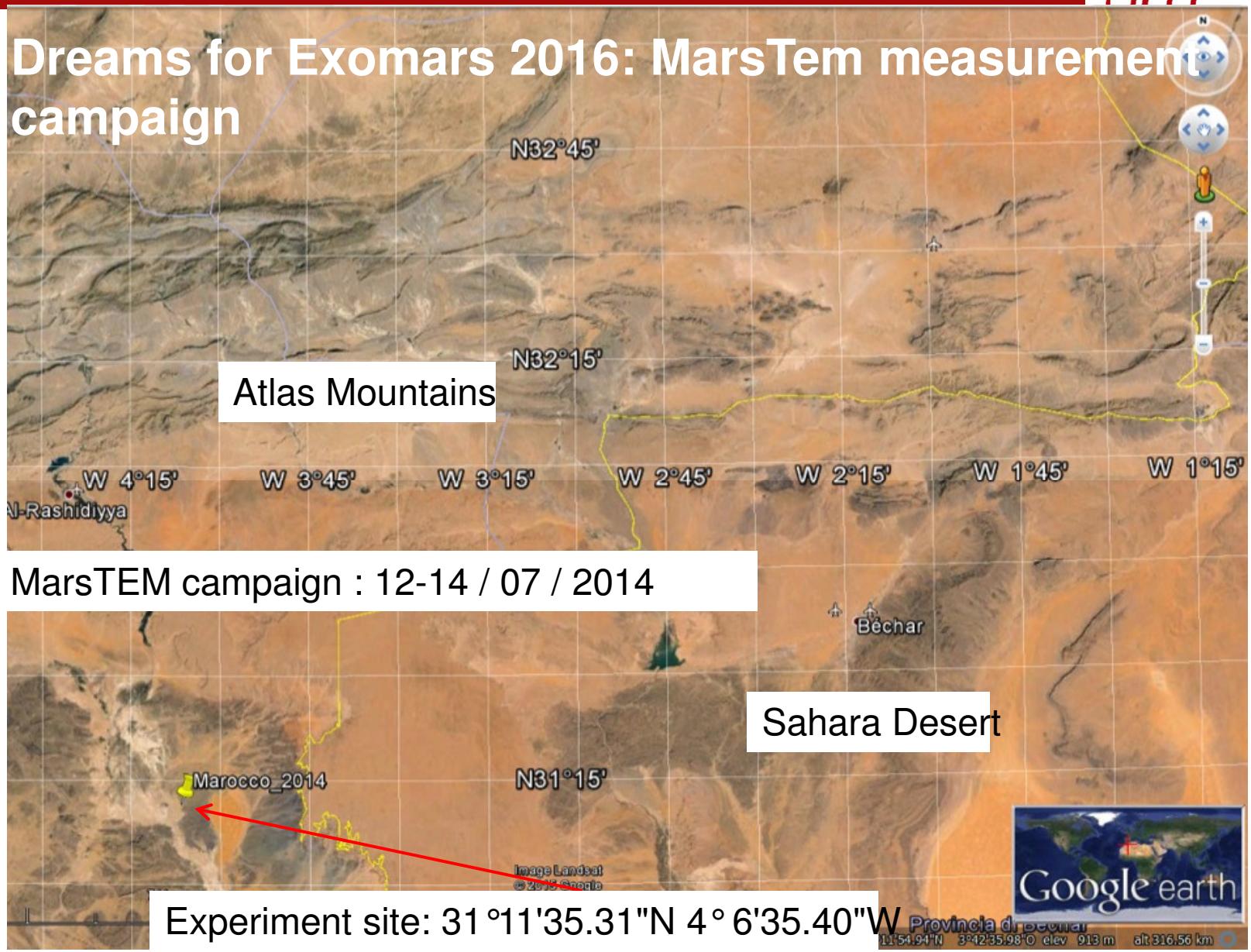
Coarse sensor (36.6 Ohm@21.3)

Mass: 9 g (w/o cabling)

Overall dimension: 50 x 18 x 21 mm (l x w x h)

∅0.0508 mm Platinum wire with Polyamide insulator (thickness 0.01 mm)

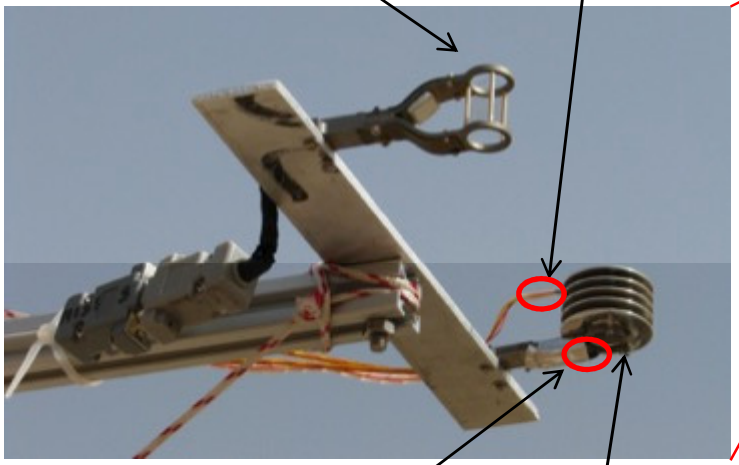
Dreams for Exomars 2016: MarsTem measurement campaign



Dreams for Exomars 2016: MarsTem Measurement Campaign

MISSUS TEM
Without shield

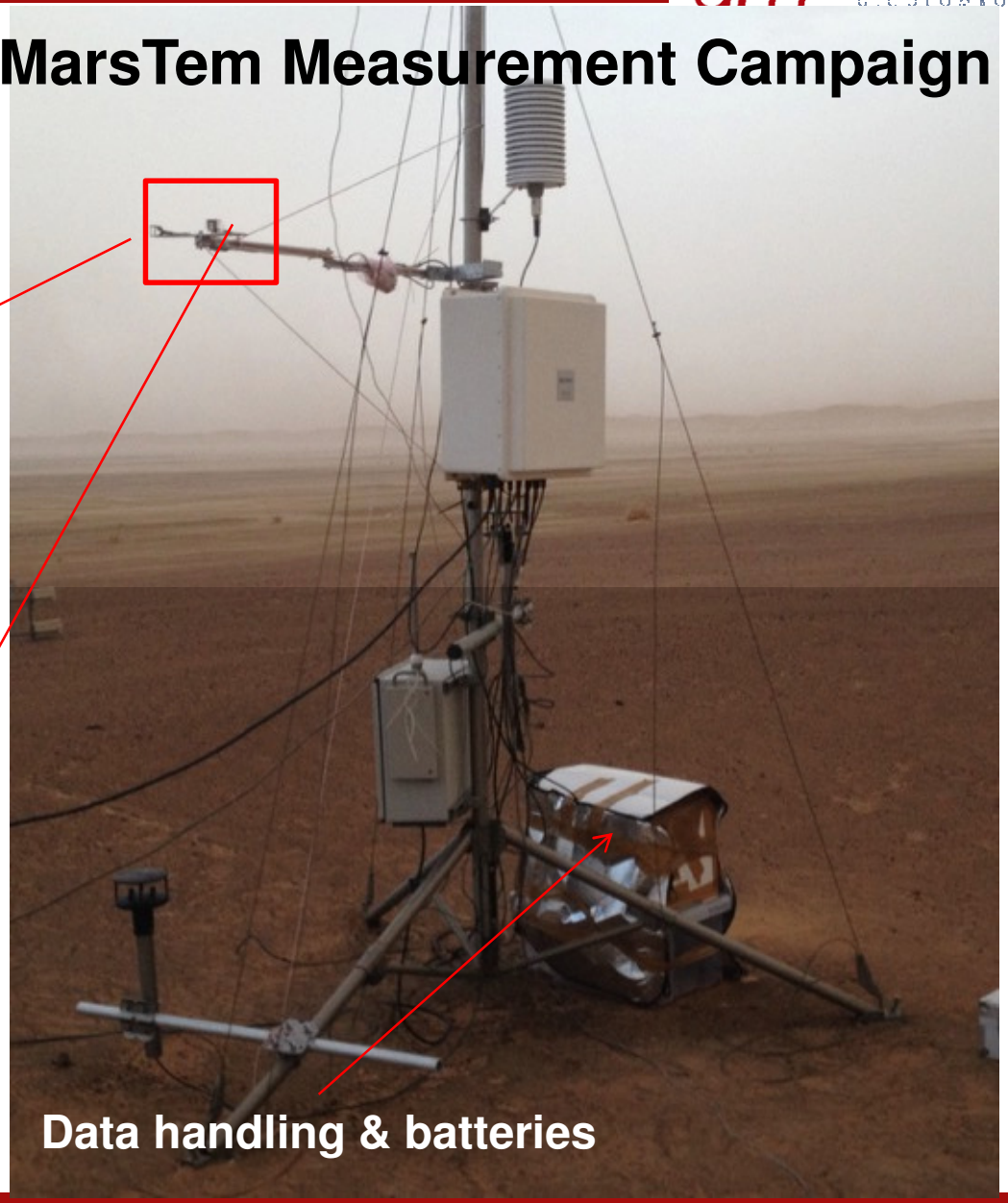
PT100-B
directly on
aluminum shield



PT100-A
below in shadow

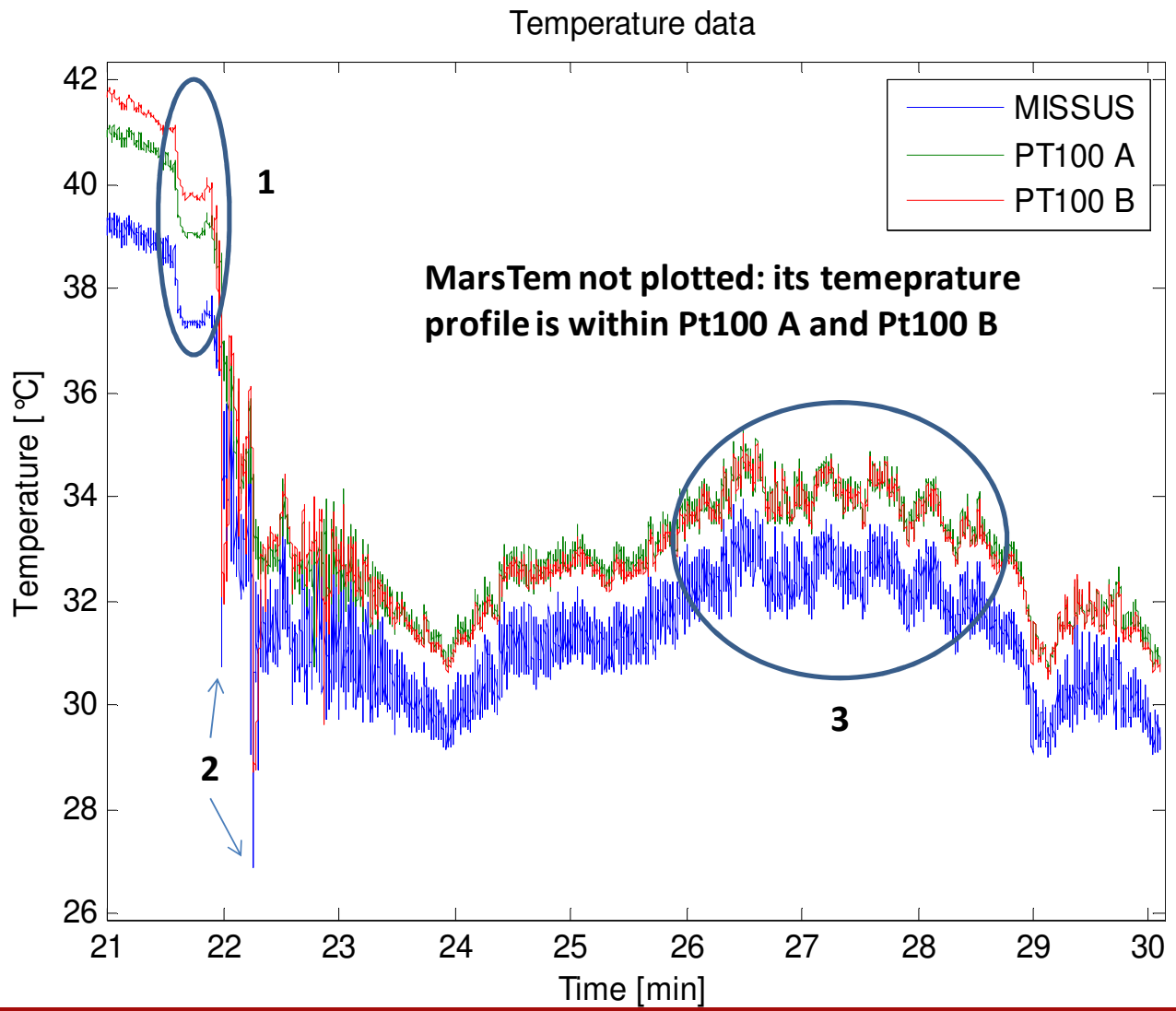
MarsTEM
with
shield

Height: 2.17m



Data handling & batteries

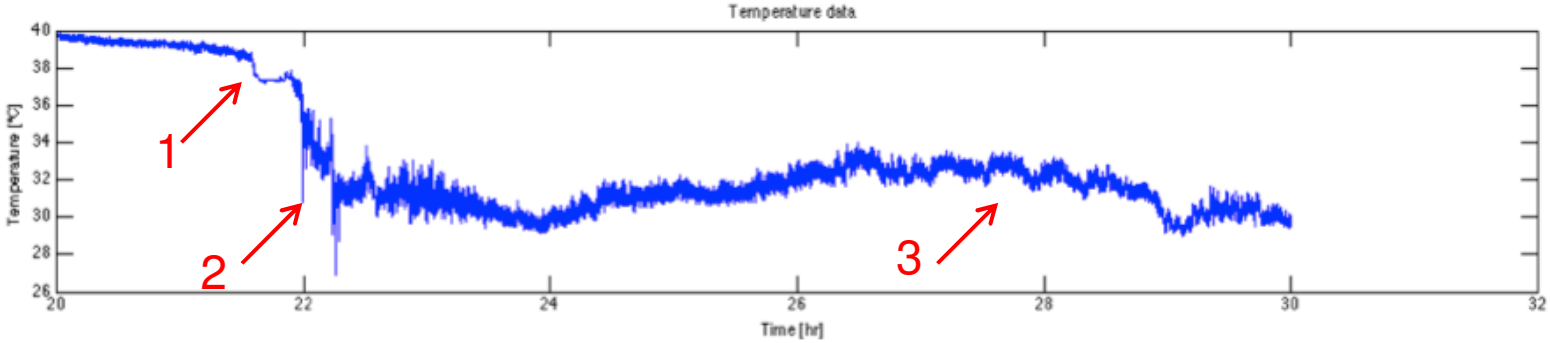
Dreams for Exomars 2016: MarsTem Measurement Campaign



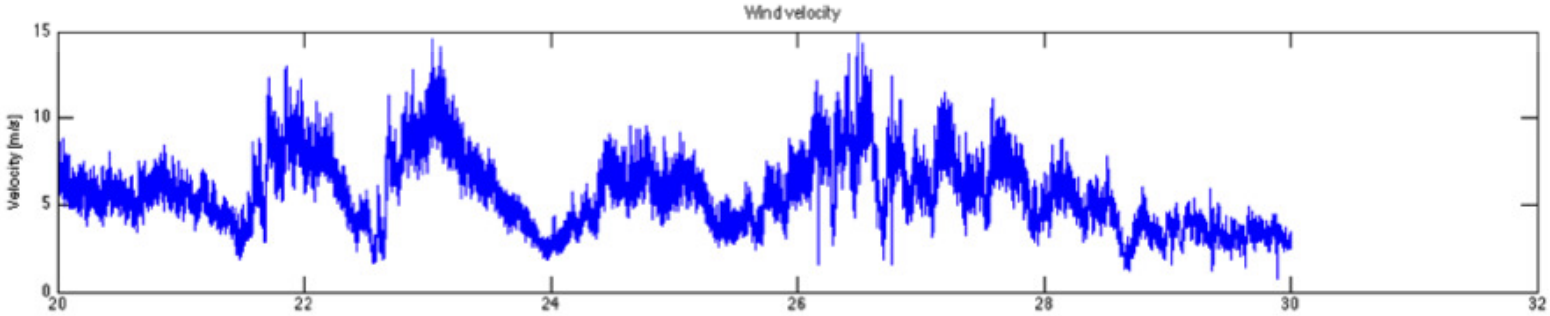
Events 1, 2, 3 to be investigated!

Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation

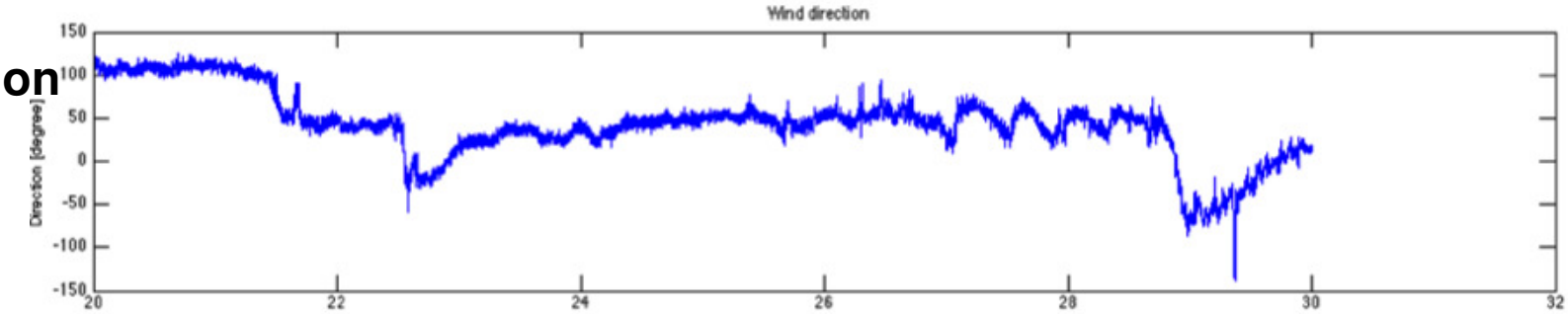
Temperature



Wind Speed

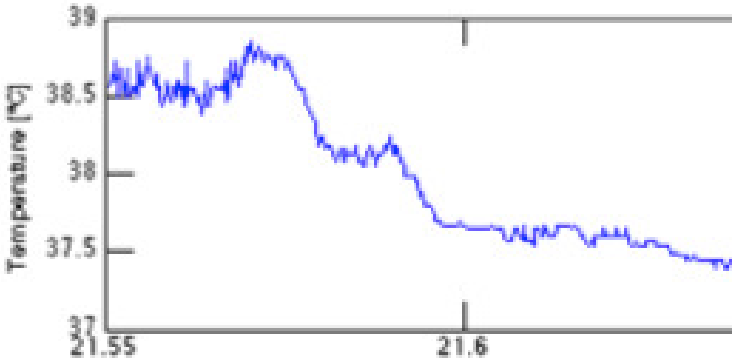


Wind Direction

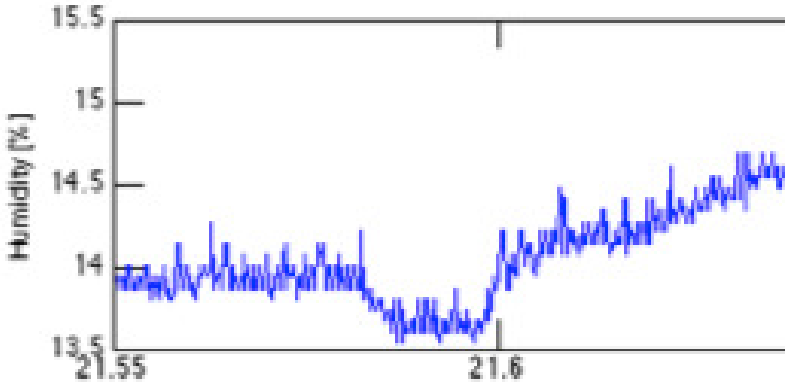


Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #1

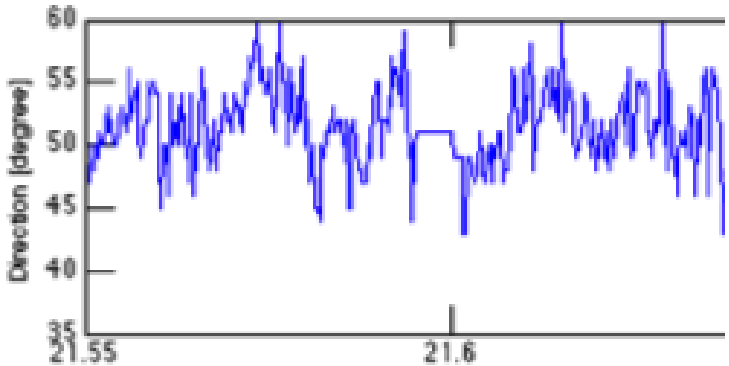
Temperature



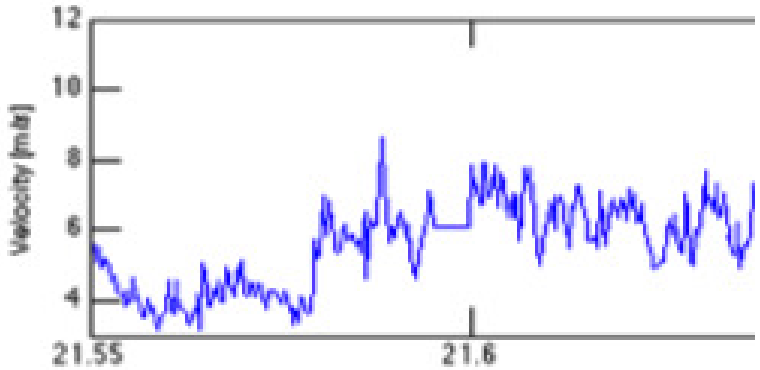
Relative Humidity



Wind Direction



Wind speed



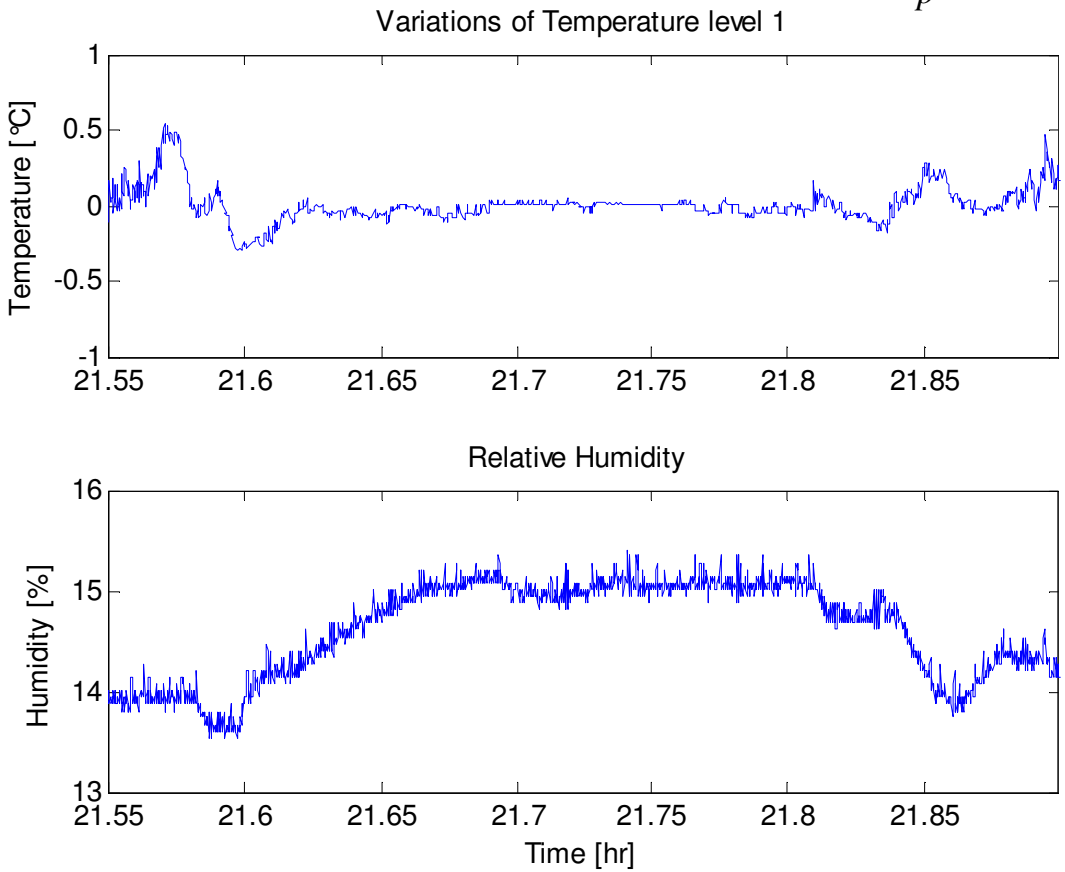
Temperature decrease, relative humidity decrise, wind direction changes and the wind speed as well! What we can tell….

Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #1

Specific heat: $C_{p\ humid} > c_{p\ dry}$

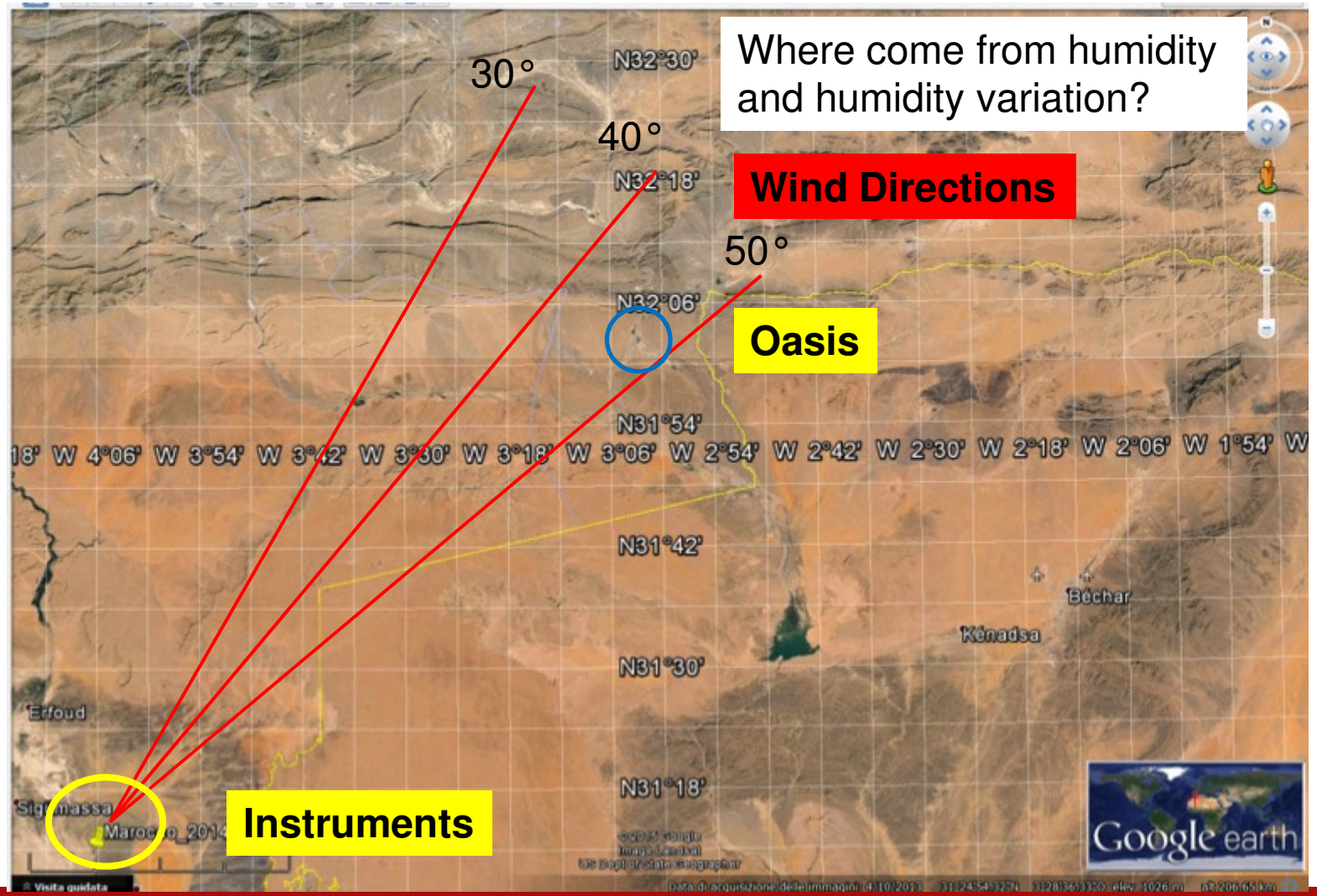
$$T' \propto \frac{1}{C_p} Q'$$

T' = ±0.4°C for dry air
T' = ±0.07°C for humid air



Where come from humidity and humidity variation?

Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #1



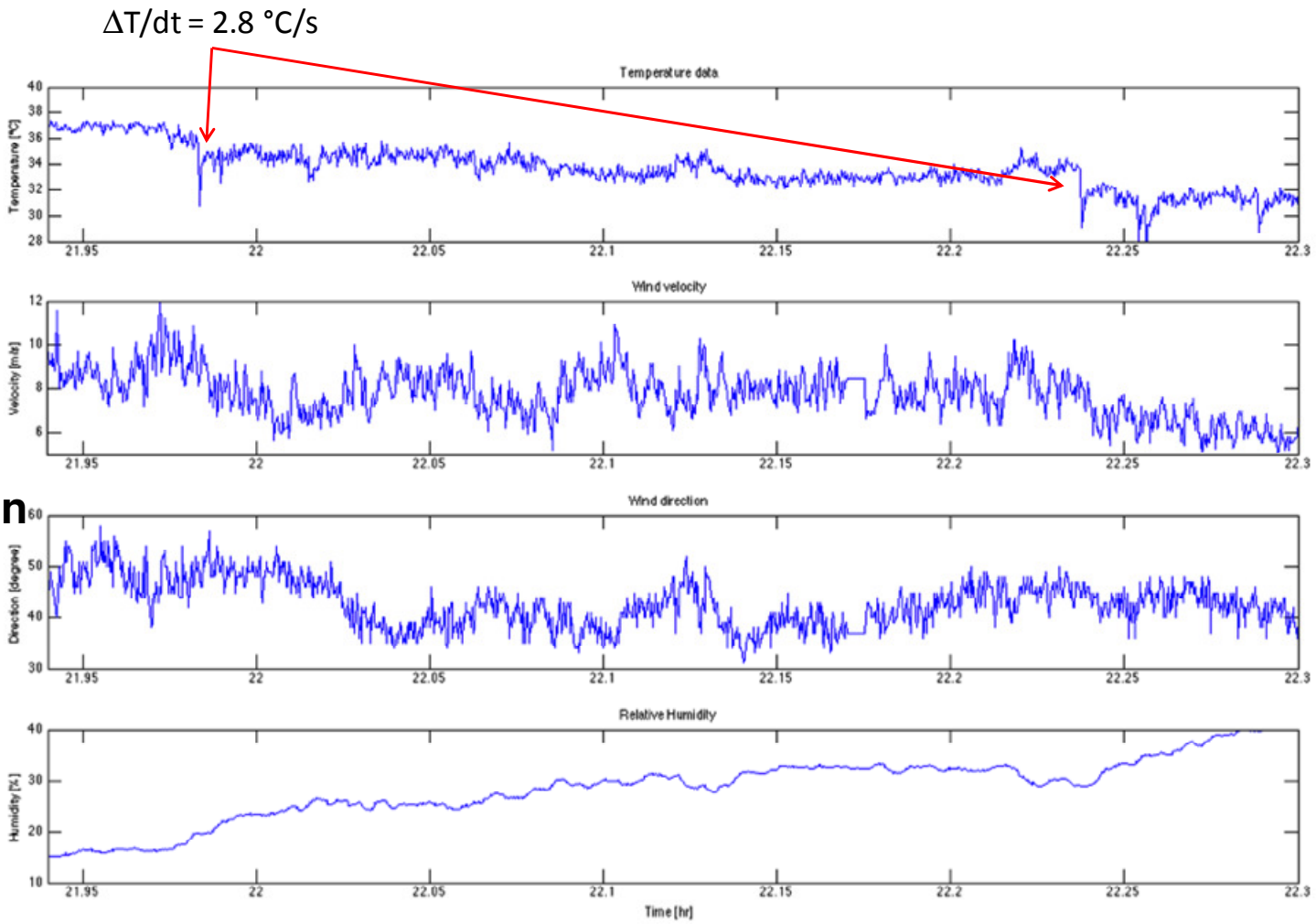
Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #2

Temperature

Wind Speed

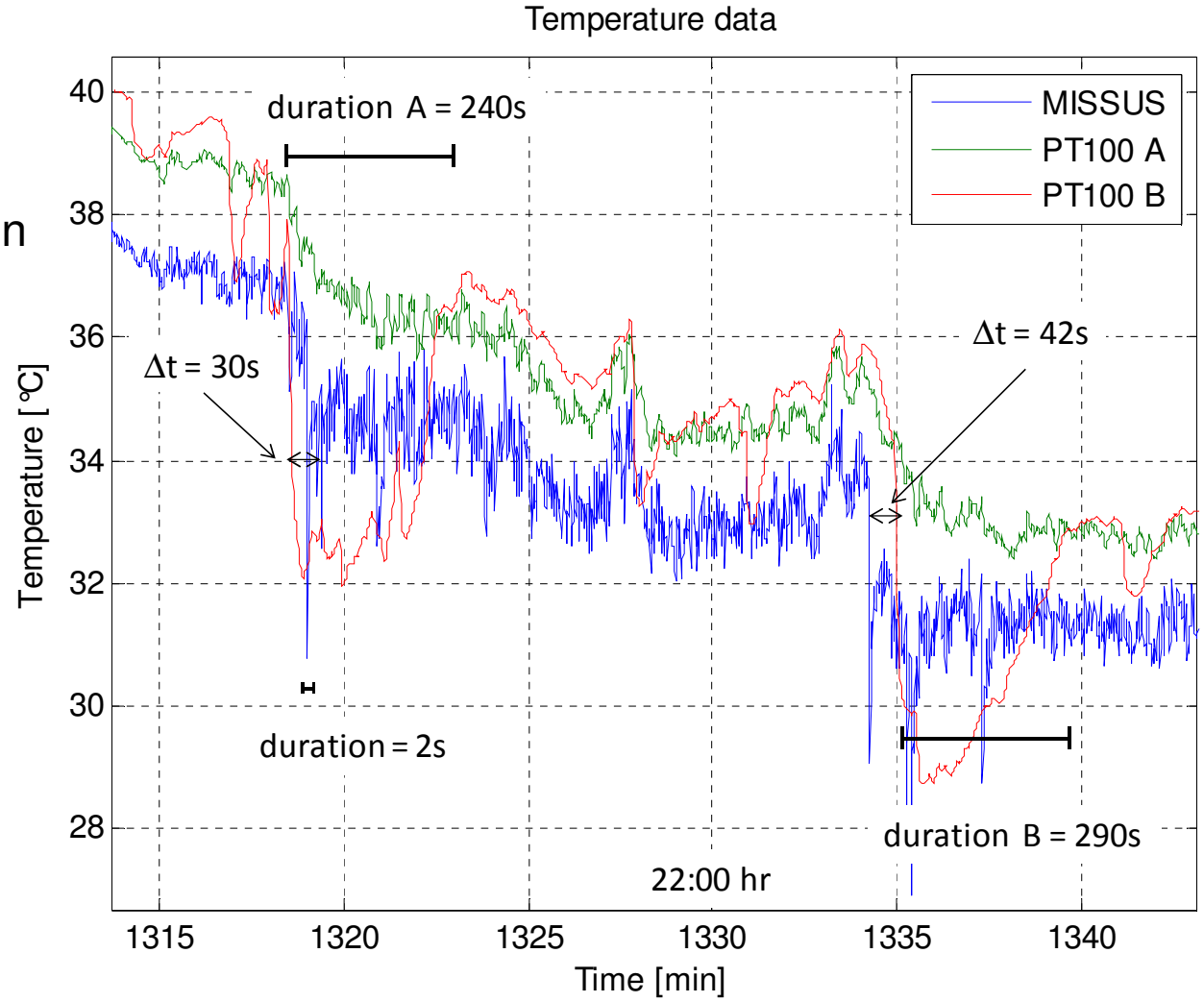
Wind Direction

Rel. Humidity

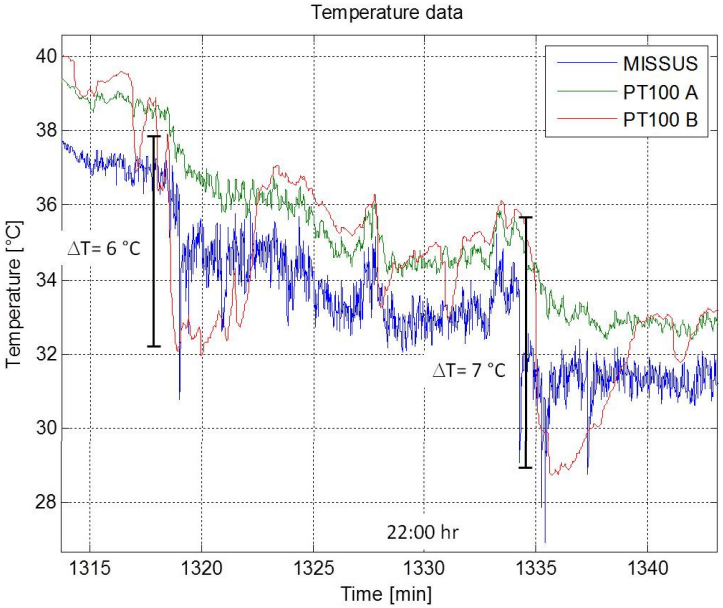


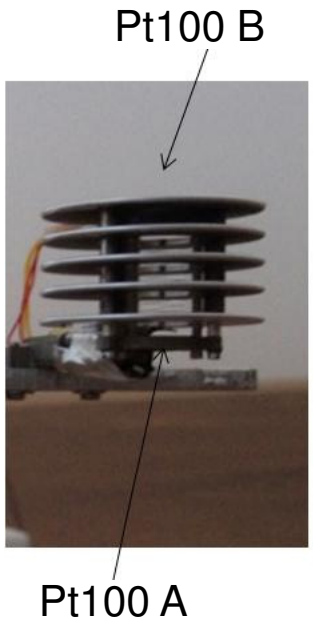
Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #2

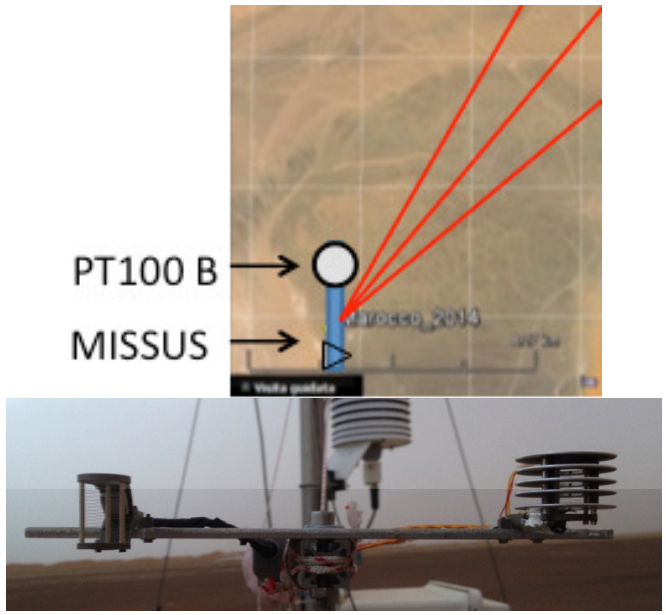
Looking in detail temperature variation and its dynamics



Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #2





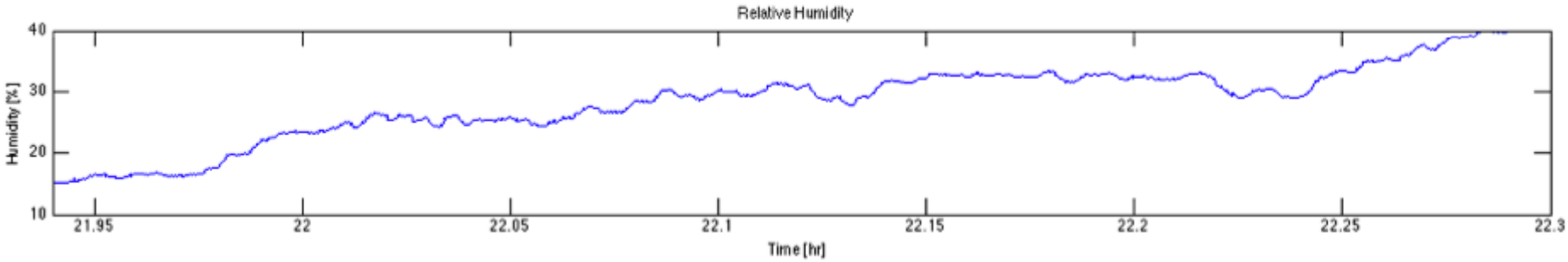


Whats happened?

	Feature A: 240 [s]	Feature B: 290 [s]
Δt between PT100B & MISSUS	+ 30 s	-42 s
ΔT event for MISSUS	≈6°C	≈7°C
ΔT event for PT100B	≈6°C	≈7°C
Duration of event for MISSUS	2 s	2 s
Duration of event for PT100B	240 s	290 s

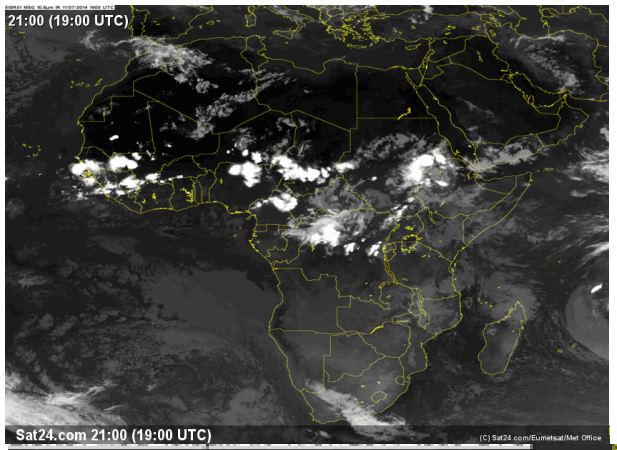
Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #2

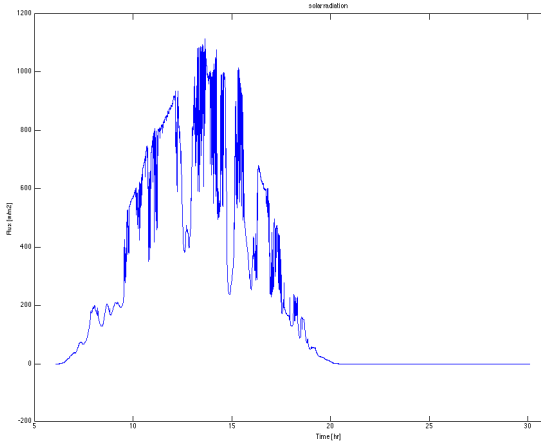
In addition: Humidity is rising from 15% up to 50% and more!!

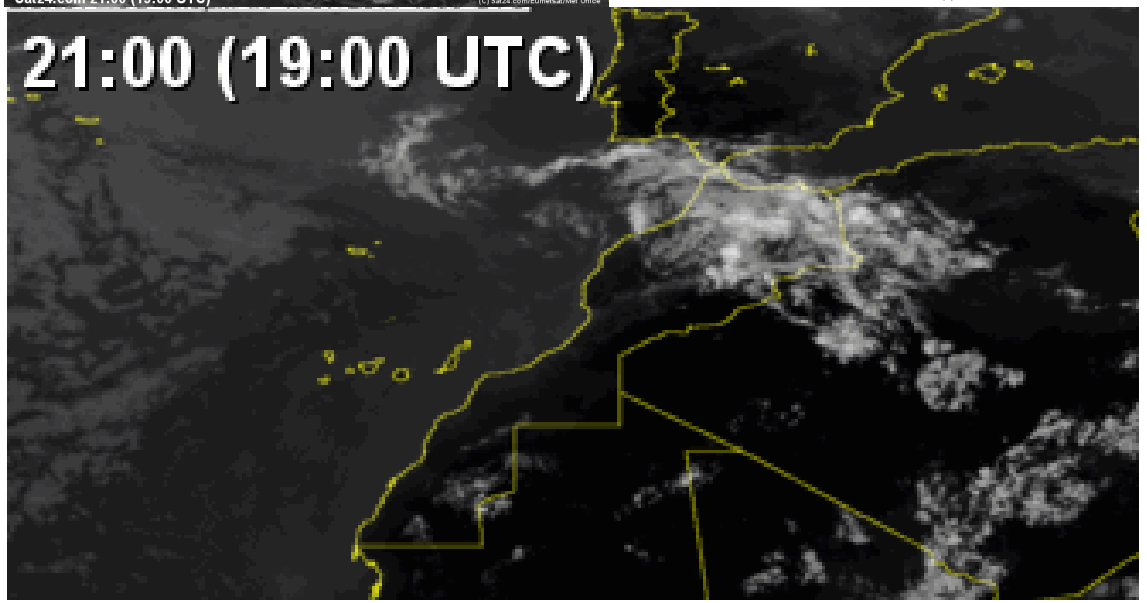


Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #2

Let's check weather condition…







Cloudy day

…not only!!

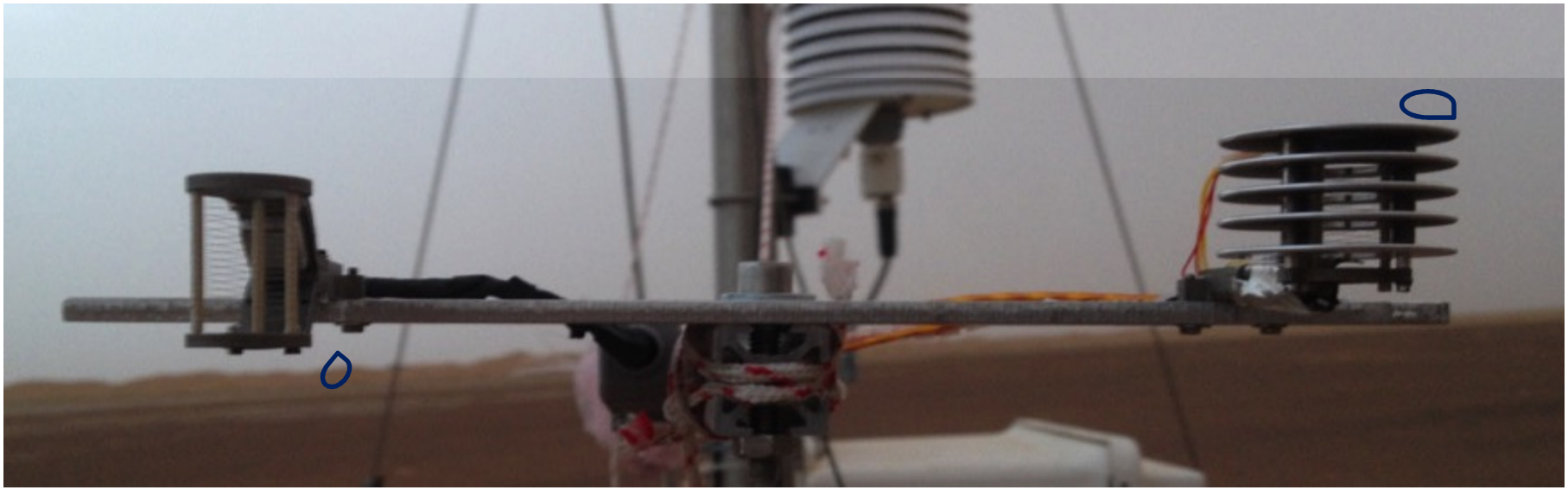
Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #2

Local guards observed and noted weak rain within 21:15 and 22:30

rain droplets on sensors!!!

Droplet diameter <0.2cm
(from Kinzer 1951)

Raindrop cooler
(cfr. Anderson 1998)



Raindrop continued its fall till ground

Raindrop stopped until evaporation

Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3

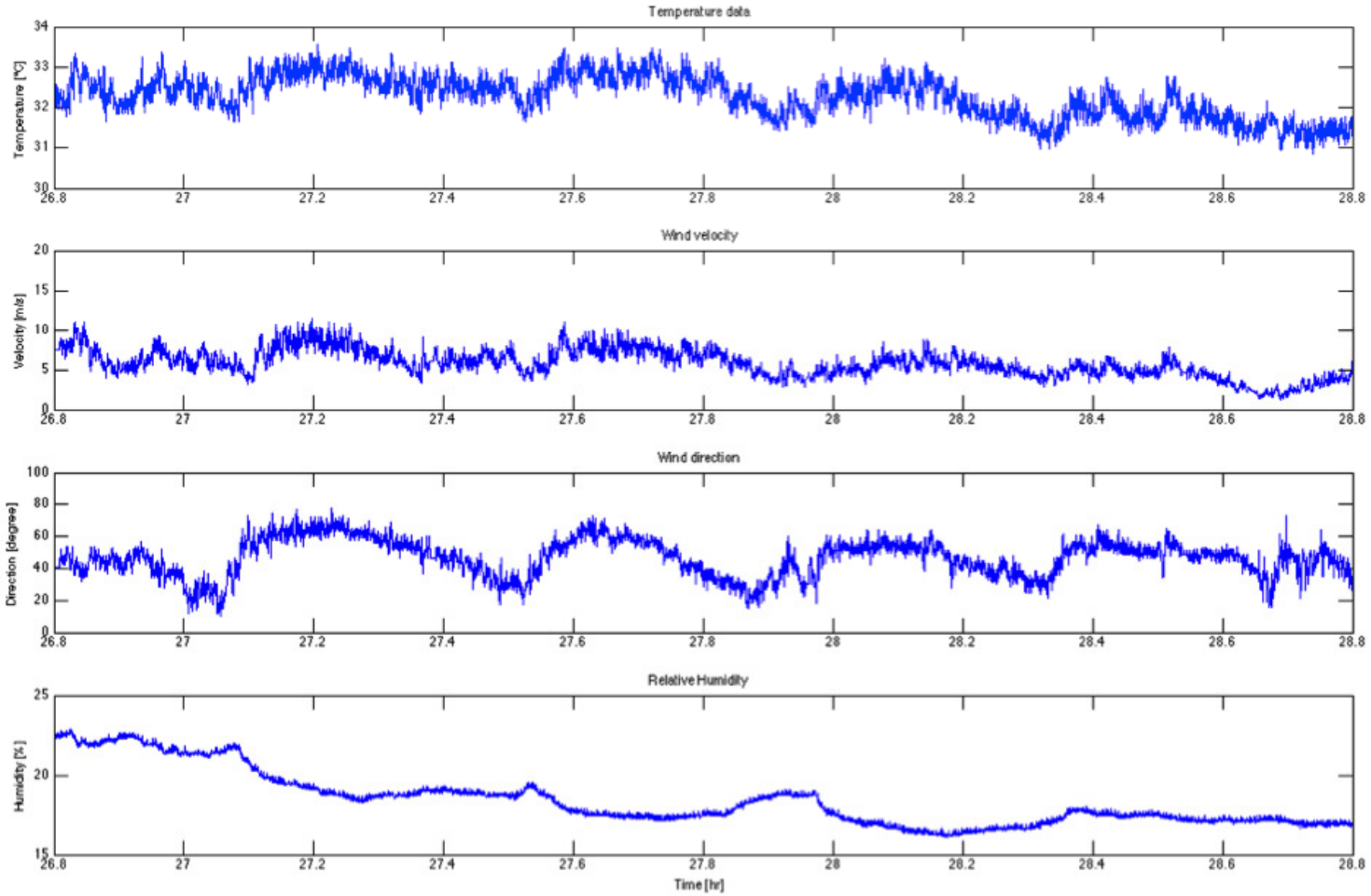
Why fluctuation with aproximately the same period?

Temperature

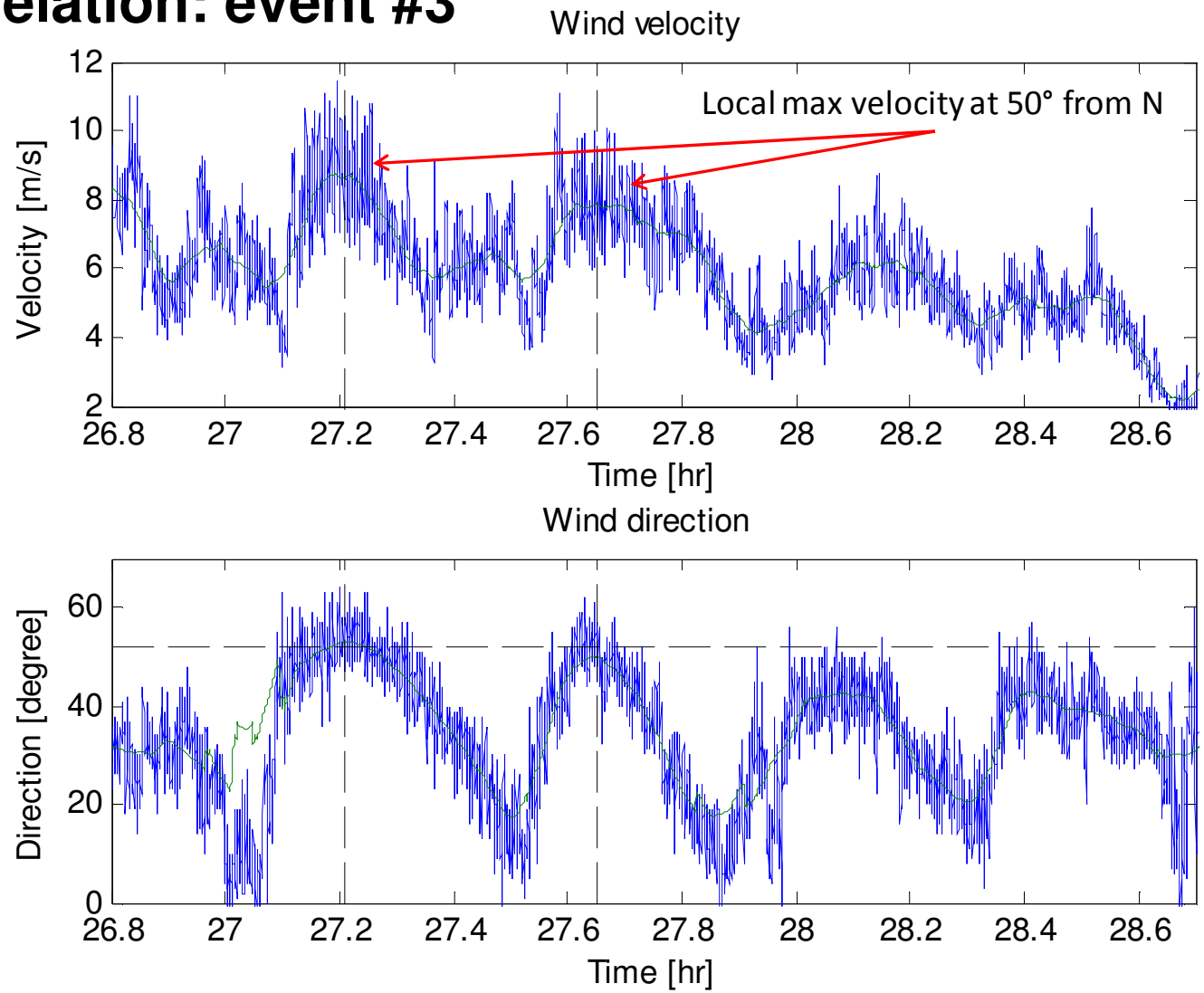
Wind Speed

Wind Direction

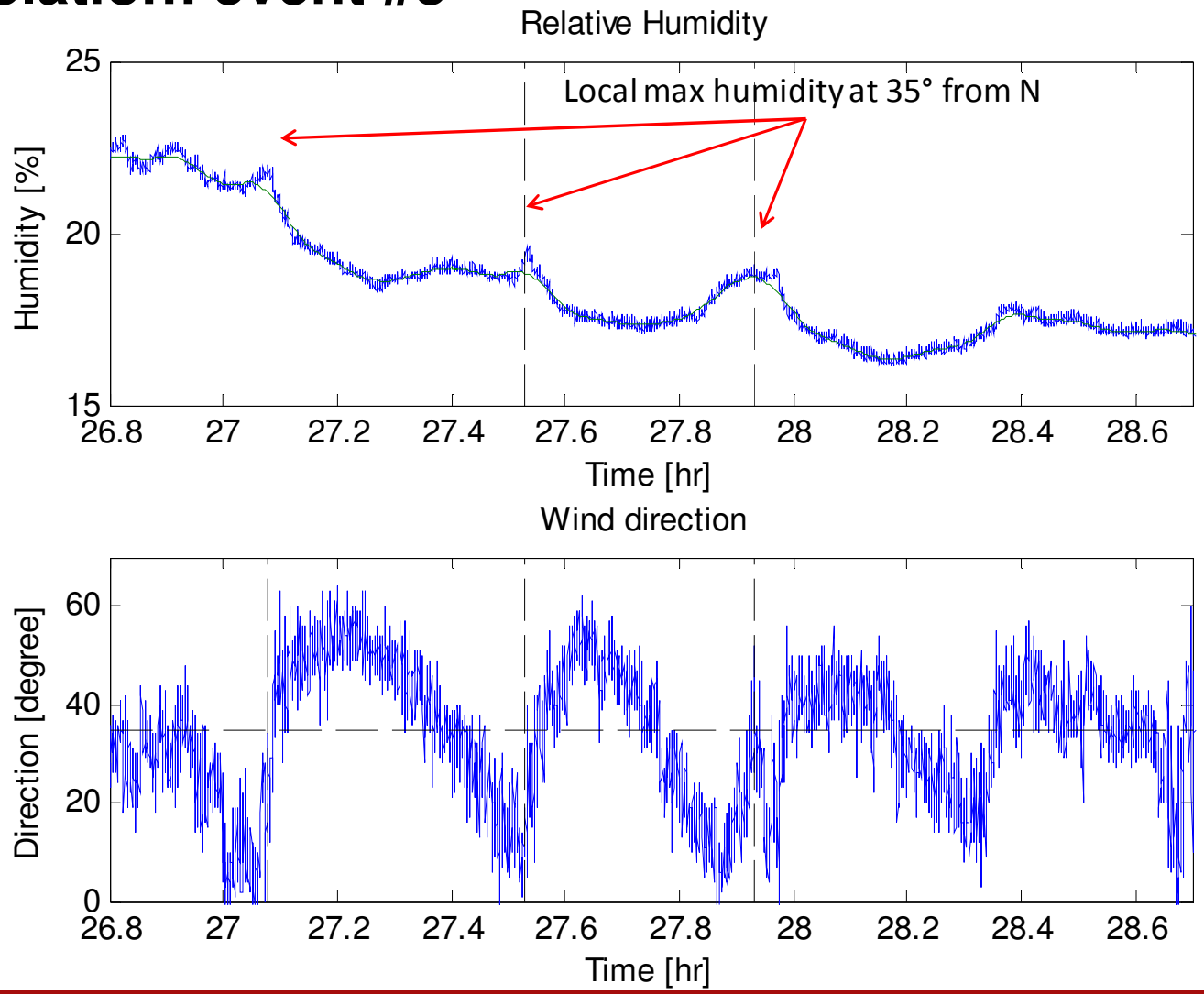
Rel. Humidity



Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3

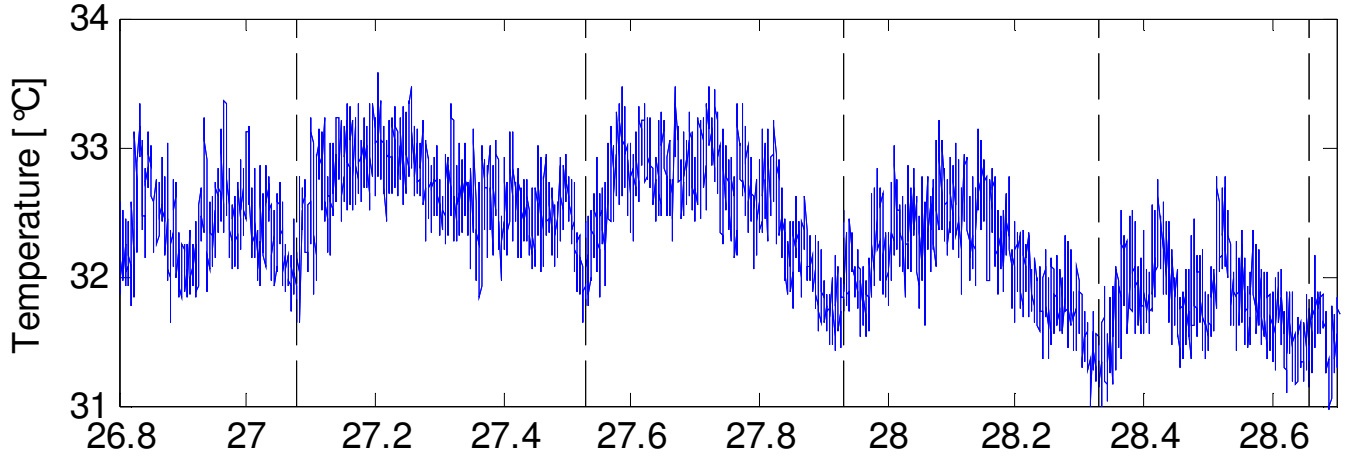


Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3



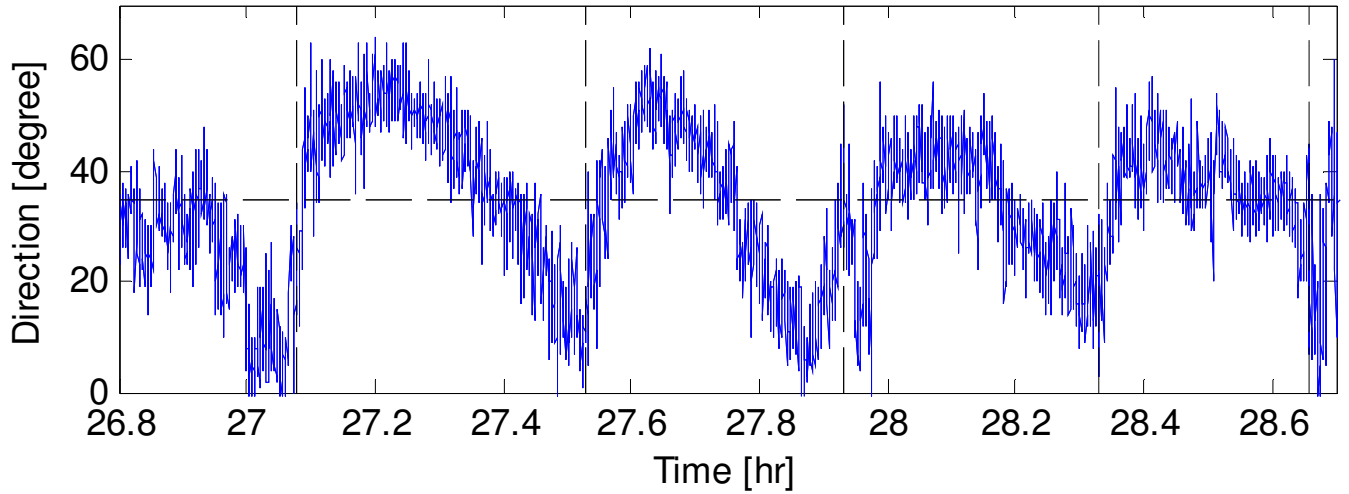
Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3

Temperature data

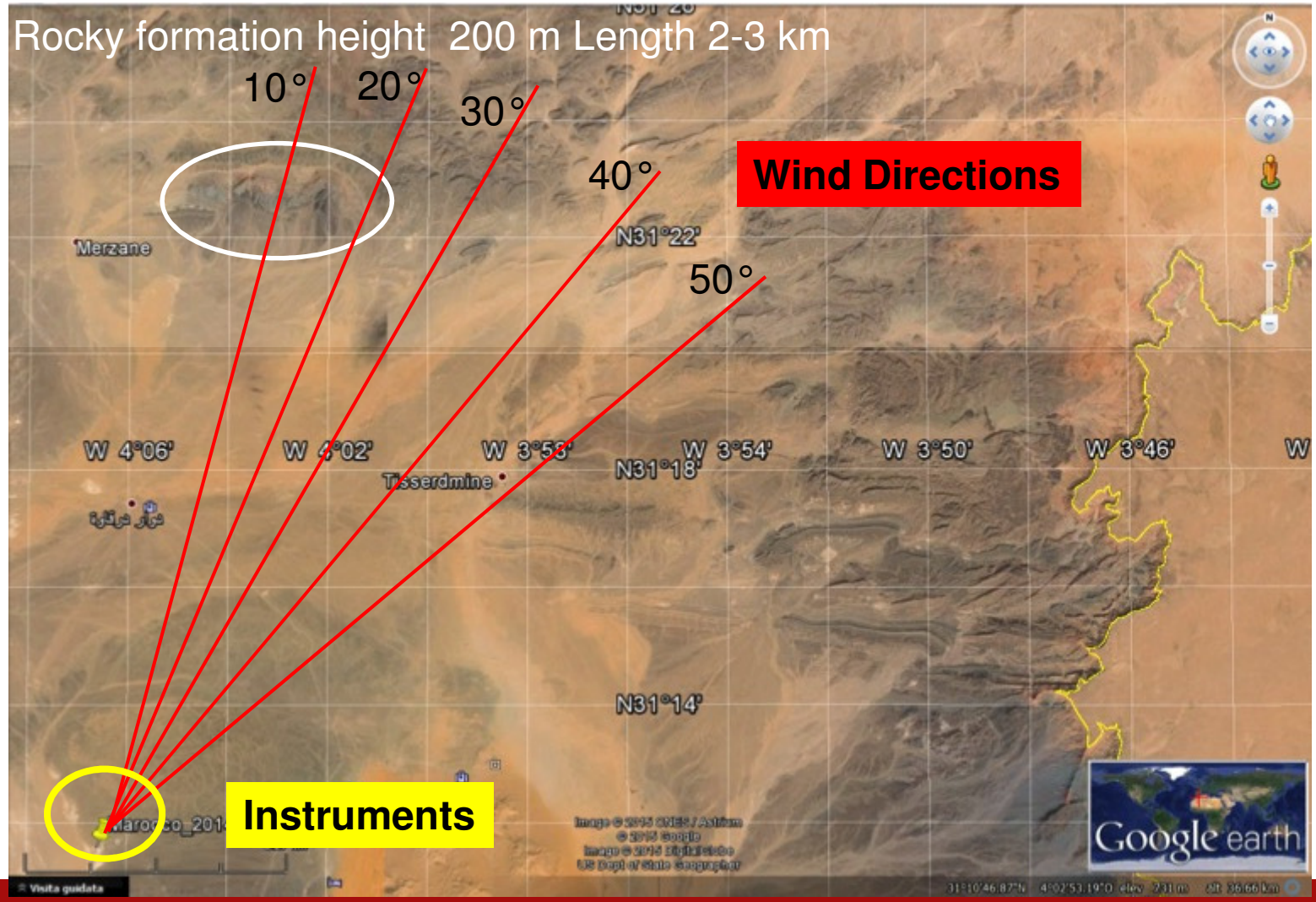


Period = 1368s ≈ 23 m

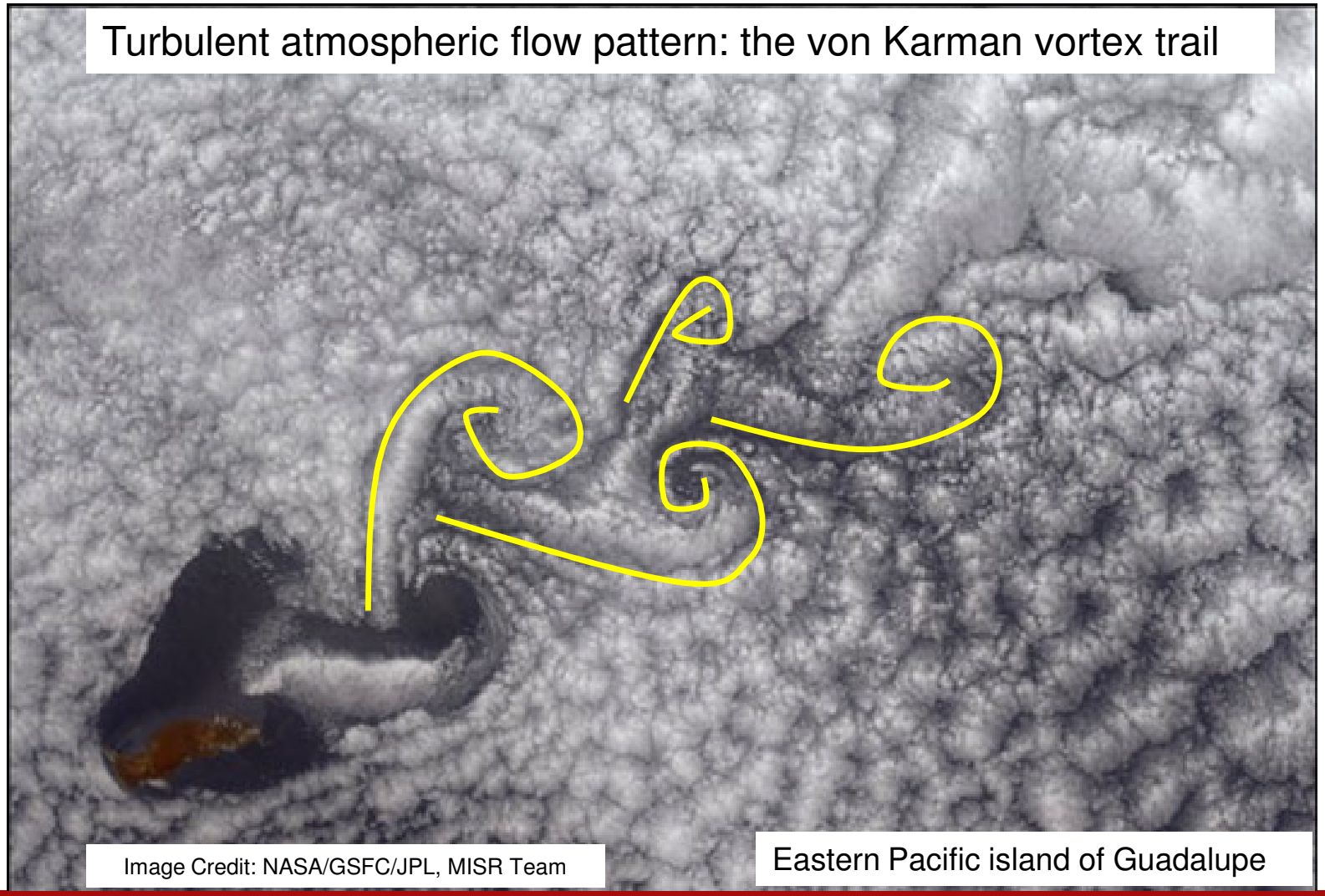
Wind direction



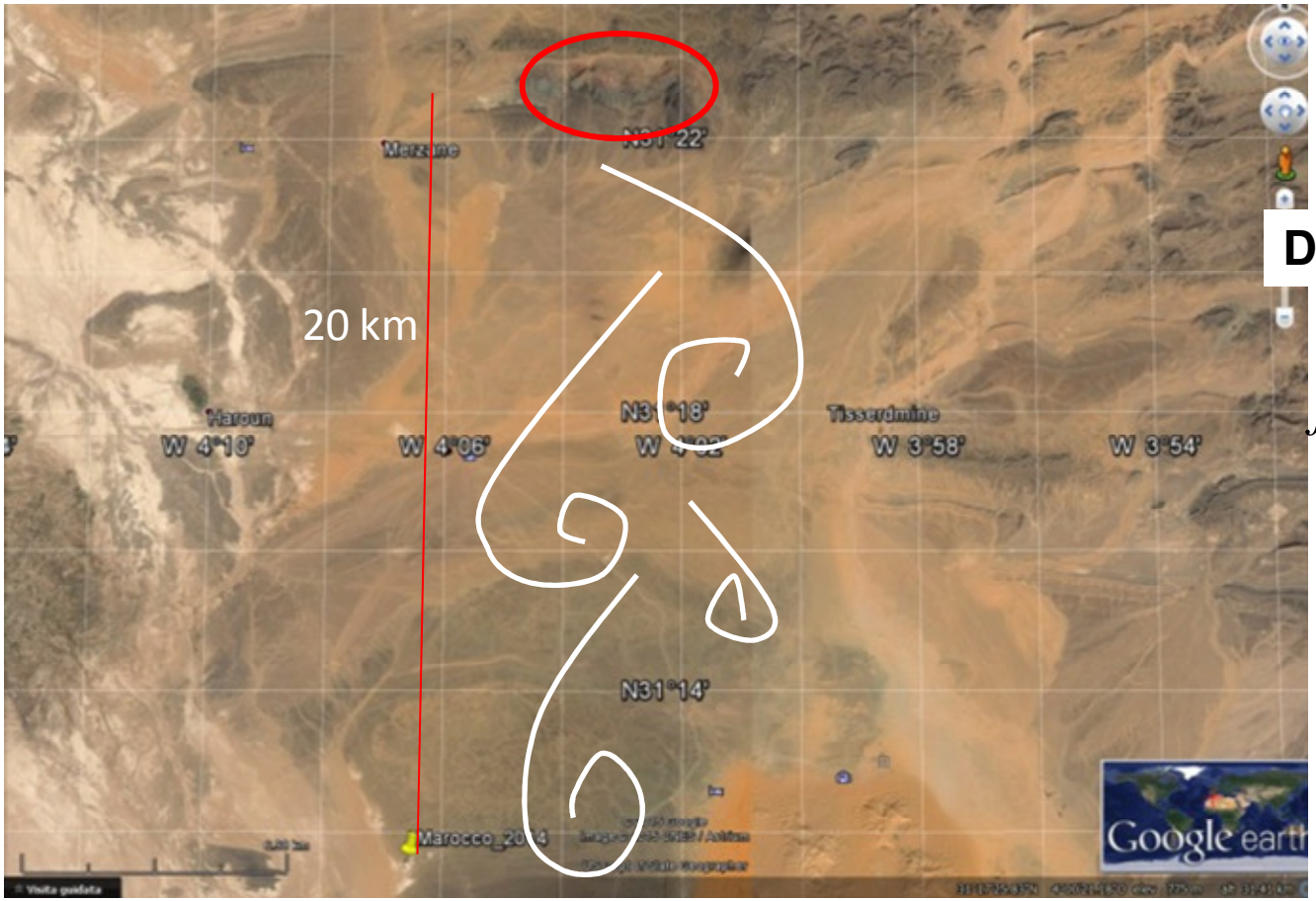
Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3



Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3



Dreams for Exomars 2016: MarsTem Measurement Campaign data correlation: event #3



Detach. Vortex Frequency

$$f = v/d \cdot 0.198\left(1 - \frac{1.97}{\mathrm{Re}}\right)$$

formation length between 2-3 km the period of vortex detachment is between 1200 s and 1890 s

Observed period = 1368s

Dreams for Exomars 2016

On the basis of previous space project and of DREAMS as well, the following road-map can be proposed for a Space (not only) research project

- Propose, design, realise, testing and calibration of experiment (e.g. DREAMS)
- Test the experiment or an its representative model in a terrestrial analogue
- Training of people starting from undergraduated students (e.g. Missus)
- Learn how to interpretated data to obtain measurements (MultiDisciplinary)
- Study, Implement and develop “ad hoc” data fusion algorithms (high level formation)
- Design and implement an integrated pipeline for data for each sensors and data fusion
- Open the collaboration to the Scientific Community as much as possible in a structured way , preserving national financial and national scientific contribution whose cofunding is not at all negligible

Dreams for Exomars 2016

Third IEEE WORSHOP
"Metrology for Aerospace"
Florence, 22-23 June 2016

THANK SO MUCH FOR YOUR ATTENTION!!!