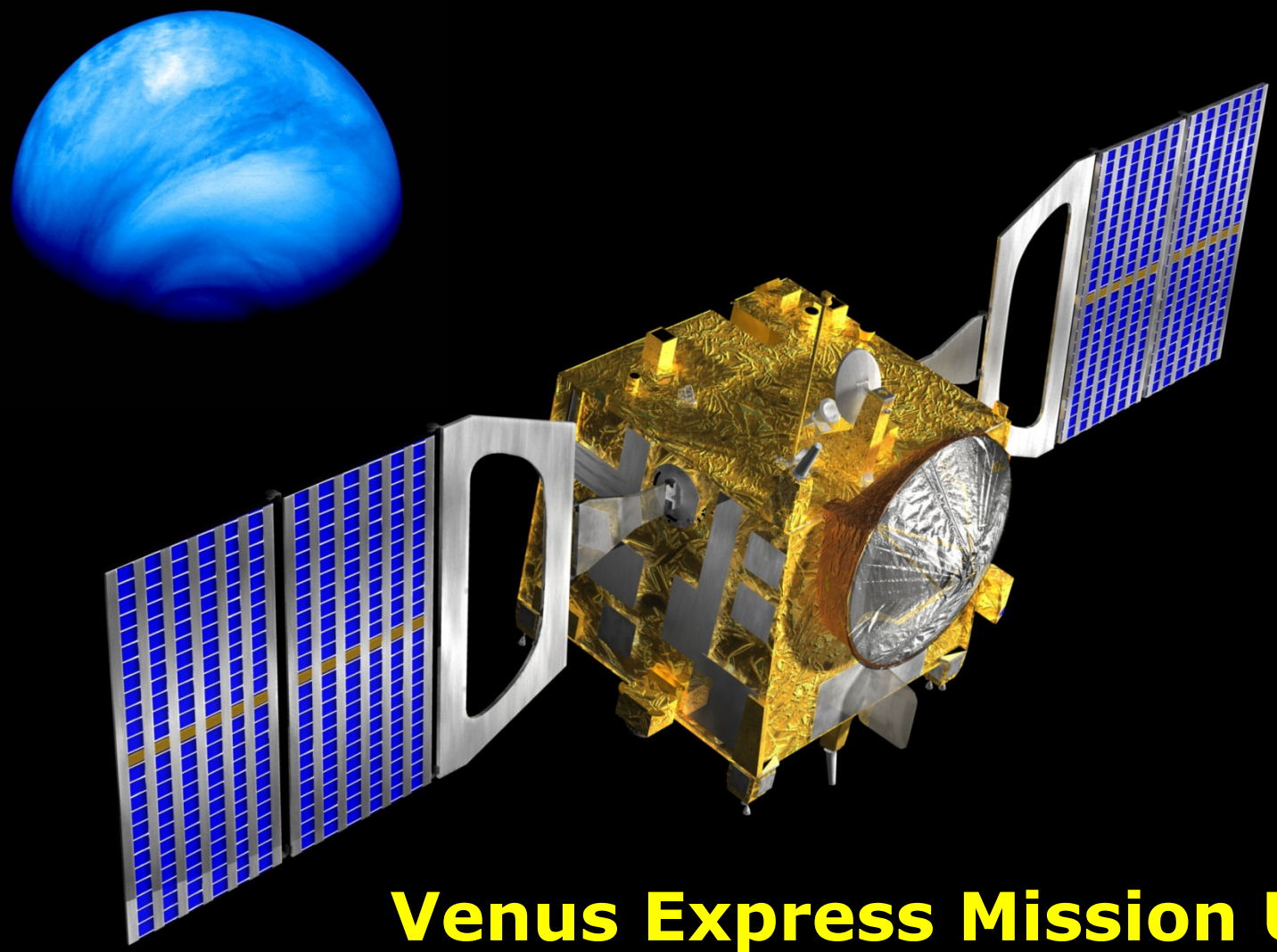


Venus Express Mission Update

Håkan Svedhem
ESA/ESTEC

Mission Status (1)

1. The spacecraft is in an excellent condition and the fuel and power situation is very good, even after over seven years in orbit.
    a. Amount of remaining fuel somewhat uncertain as it is inherently difficult to measure. Se following slides.
2. Occasional anomalies have occurred but these have all been understood and solved quickly. They mostly relate to data transmission and the SSMM.
3. Over 5000 Gbit of science data has now been downloaded to ground from six scientific instruments.
4. 15 earth occultation season have taken place so far. Typically radio science observations have been carried out every 1-3 orbits. More than 600 atmospheric profiles have been collected.
5. 13 atmospheric drag campaign have been performed. Well above 100 measurements down to an altitude of 165km has been collected.

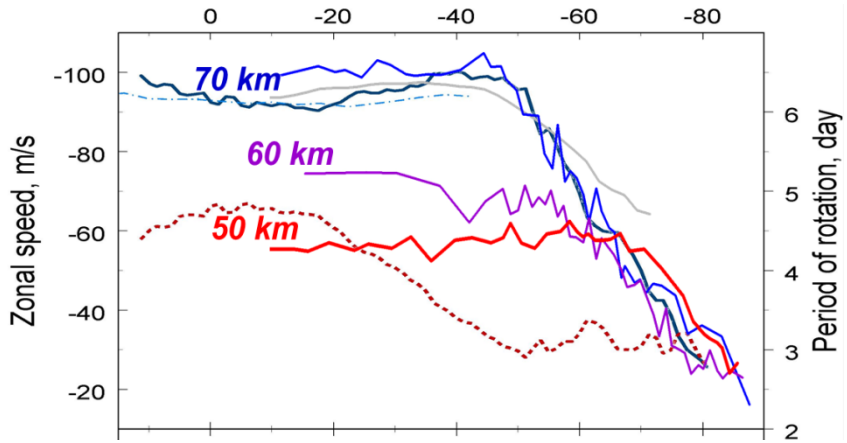
Mission Status (2)

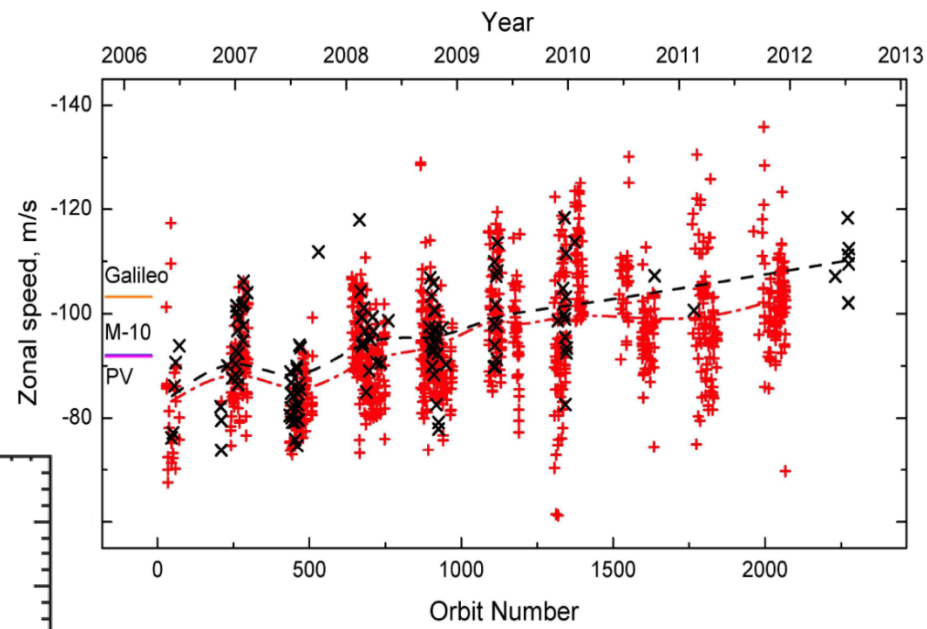
1. A major orbit control manoeuvre (7-9 m/s) are carried out regularly at about 2 months interval, rising the pericentre altitude when it reaches 190 km to compensate for the downward drift. The rate of the downward drift, up to 4 km/day in altitude, is increasing with time. The manoeuvres are now carried out as a sequence of 1.6 m/s (or less) manoeuvres to ensure that sufficient fuel is available in the buffer "sponge".
2. The data archive (PSA) is in a good state, with all but one investigation archived and up to date. See www.rssd.esa.int/psa
3. Data workshops for new users of data from the missions are organized at ESAC, Spain. Next one will take place in spring 2014 and will be specially intended for users of Virtis and VMC data. Please contact me if interested.

A few important recent findings

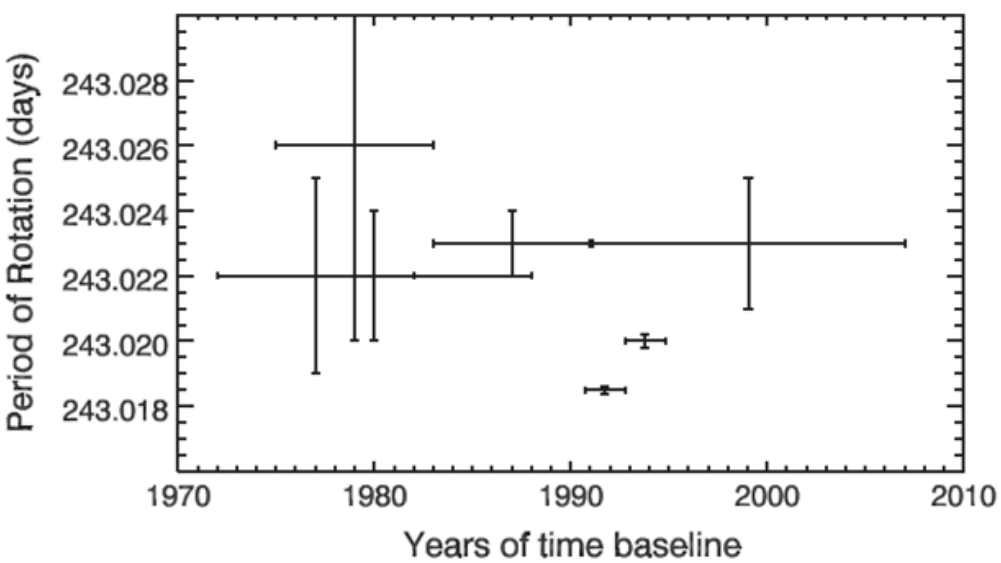
1. Secular increase in the wind speed at the cloud top (VMC).
2. Large temporal variations in the mesospheric SO2 abundance.
3. Anisotropic distribution of atmospheric gravity waves.

Winds at the cloud level





[Khatuntsev, 2012]

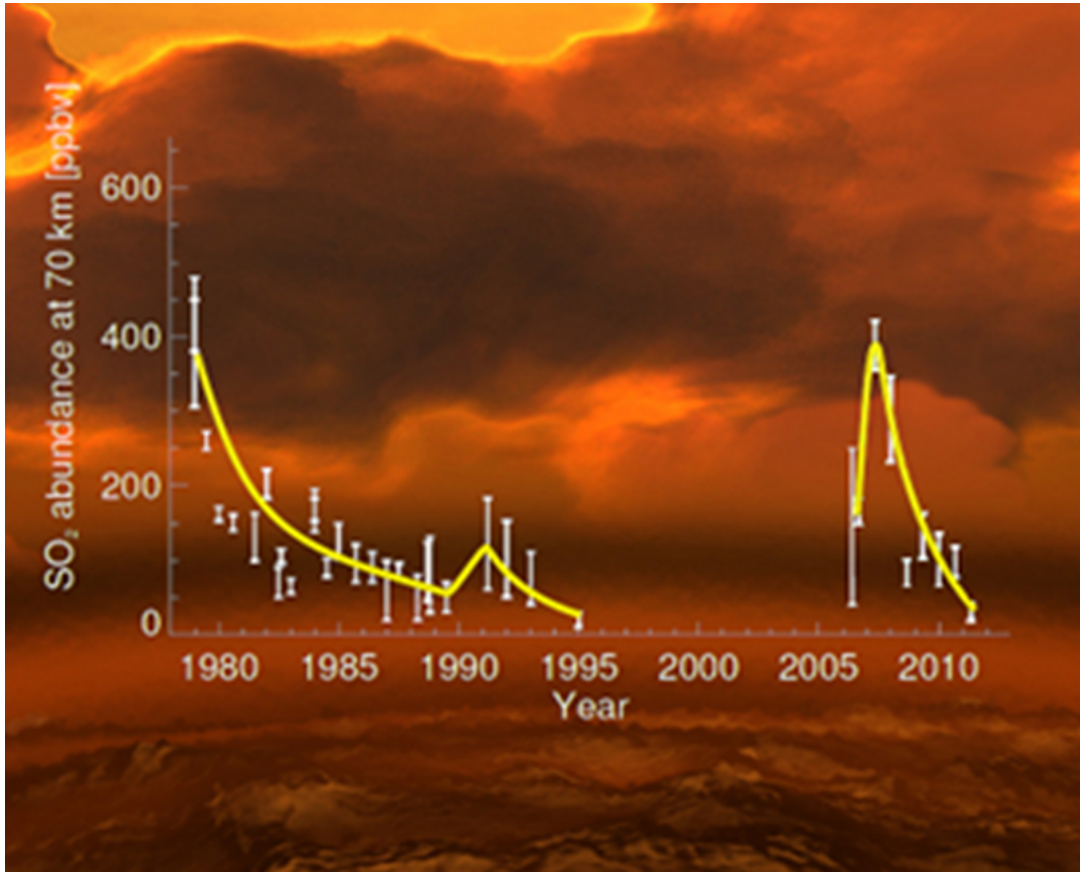


[Helbert, 2011]

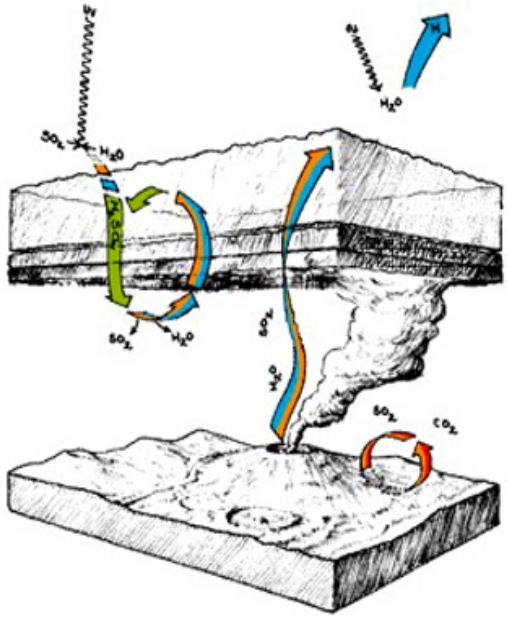
Now wind data over six years reveal a dramatic 30% increase in super-rotation rate!

Relation to change in solid planet rotation rate?

Mesospheric SO_2 changes



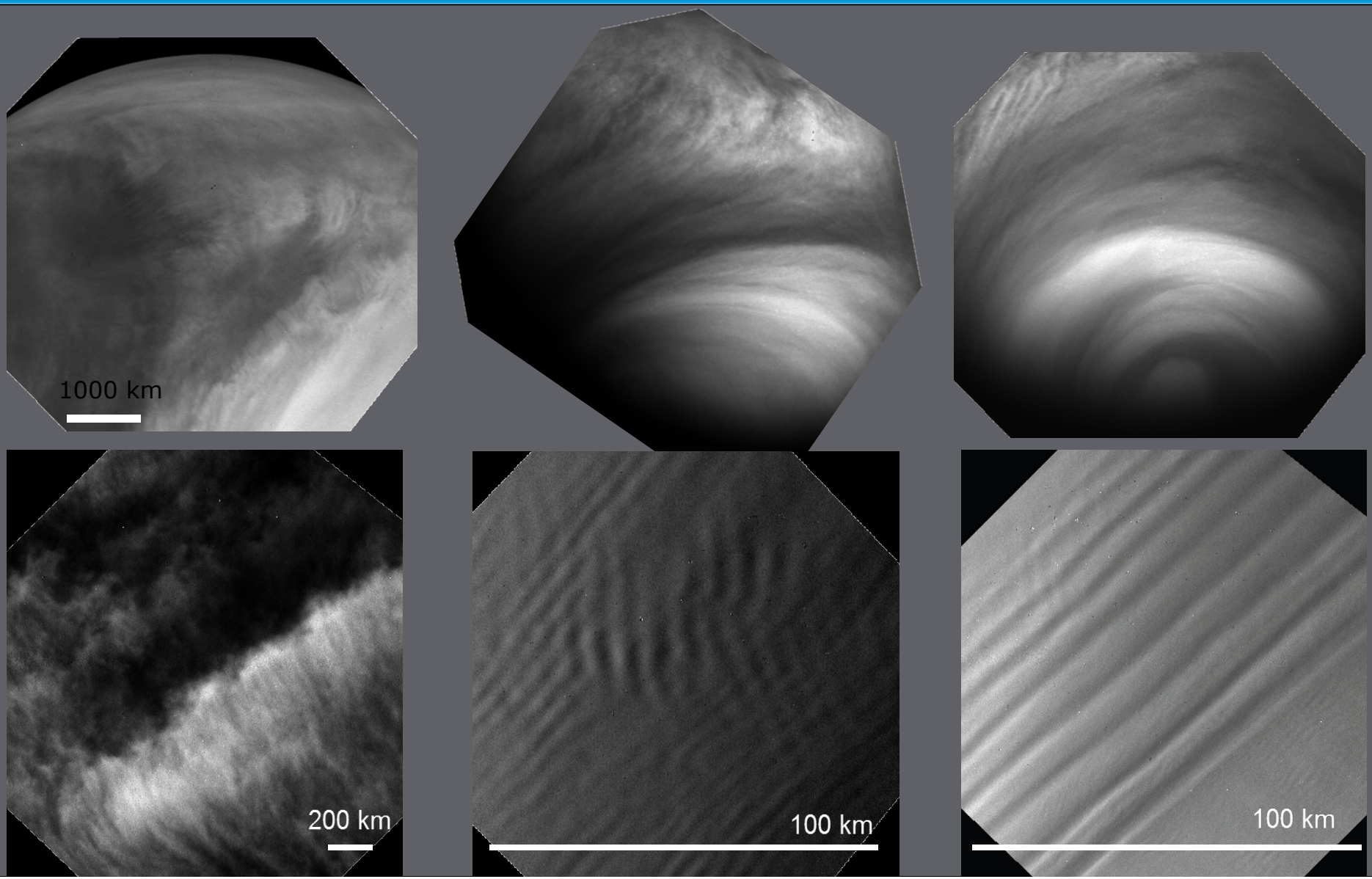
Marcq, 2012



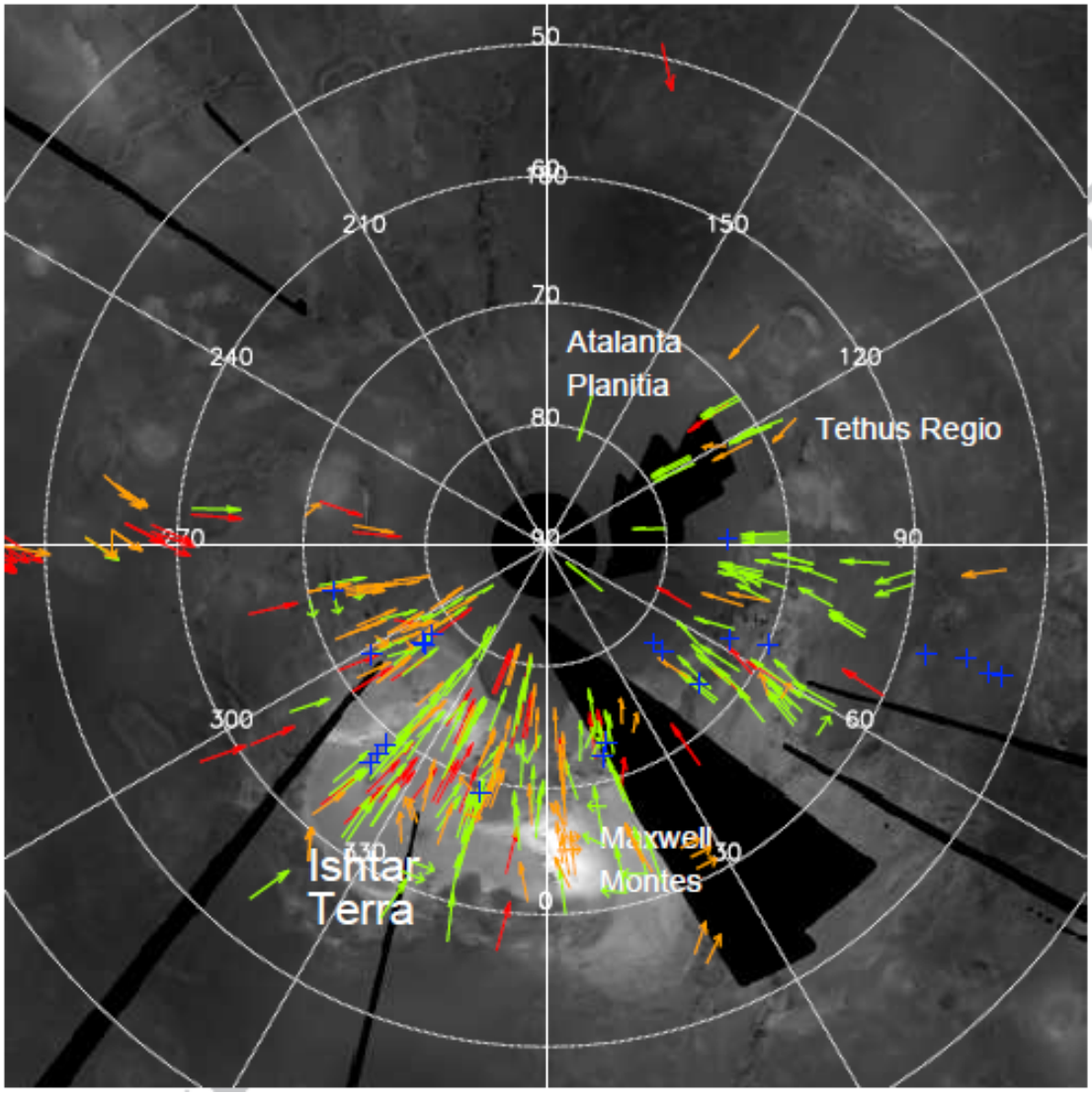
Venus Express shows episodic injection of SO_2 into mesosphere.

- Is this an connected with volcanic activity (like Pinatubo)?
- Or is it simply atmospheric variability (like El Niño / La Niña)?

Cloud top morphology and small scale structures - identification of waves



Location of horizontal gravity waves from VMC data



[Piccialli, 2013]

Northern hemisphere. To be interpreted with care as strong biases in the data set do exist.

Compatible with observation of vertical gravity waves as observed by Radio Occultation measurements [Tellmann, 2012].

Future operations

1. End 2013 and 2014 operations is focussing on a number of topics following recent findings and will be executed as campaigns of up to two months duration
    a. Atmospheric changes
        - SO2 variations
        - NO variations
        - Superrotation
    b. South Pole dynamics
    c. Thermal structure, waves
    d. Surface changes and anomalies
2. 2014 will include an aerobraking campaign and related low altitude in situ measurements and imaging

Mission operations funding

1. Venus Express was in 2012 approved for extension with full funding until end 2014.
2. Preliminary approval for funding until end of 2015 has been given, however, new insights has shown the fuel and/or oxidizer may run out during 2014.

Estimate of fuel/oxidizer evolution (1)

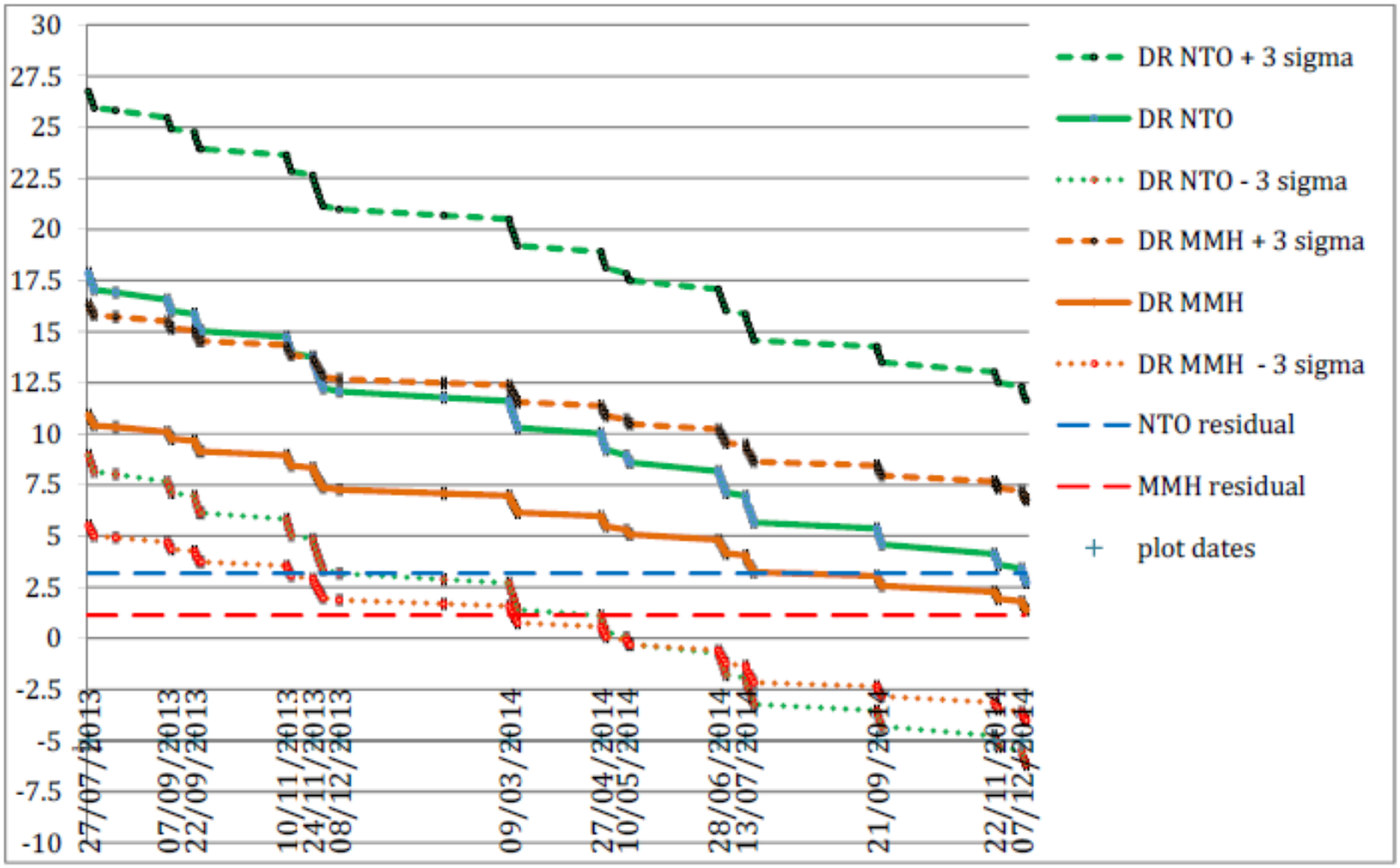


Figure 4 Scenario 1 Predicted Propellant Consumption for Original Long Term Orbit (based on Dead Reckoning Data)

Estimate of fuel/oxidizer evolution (2)

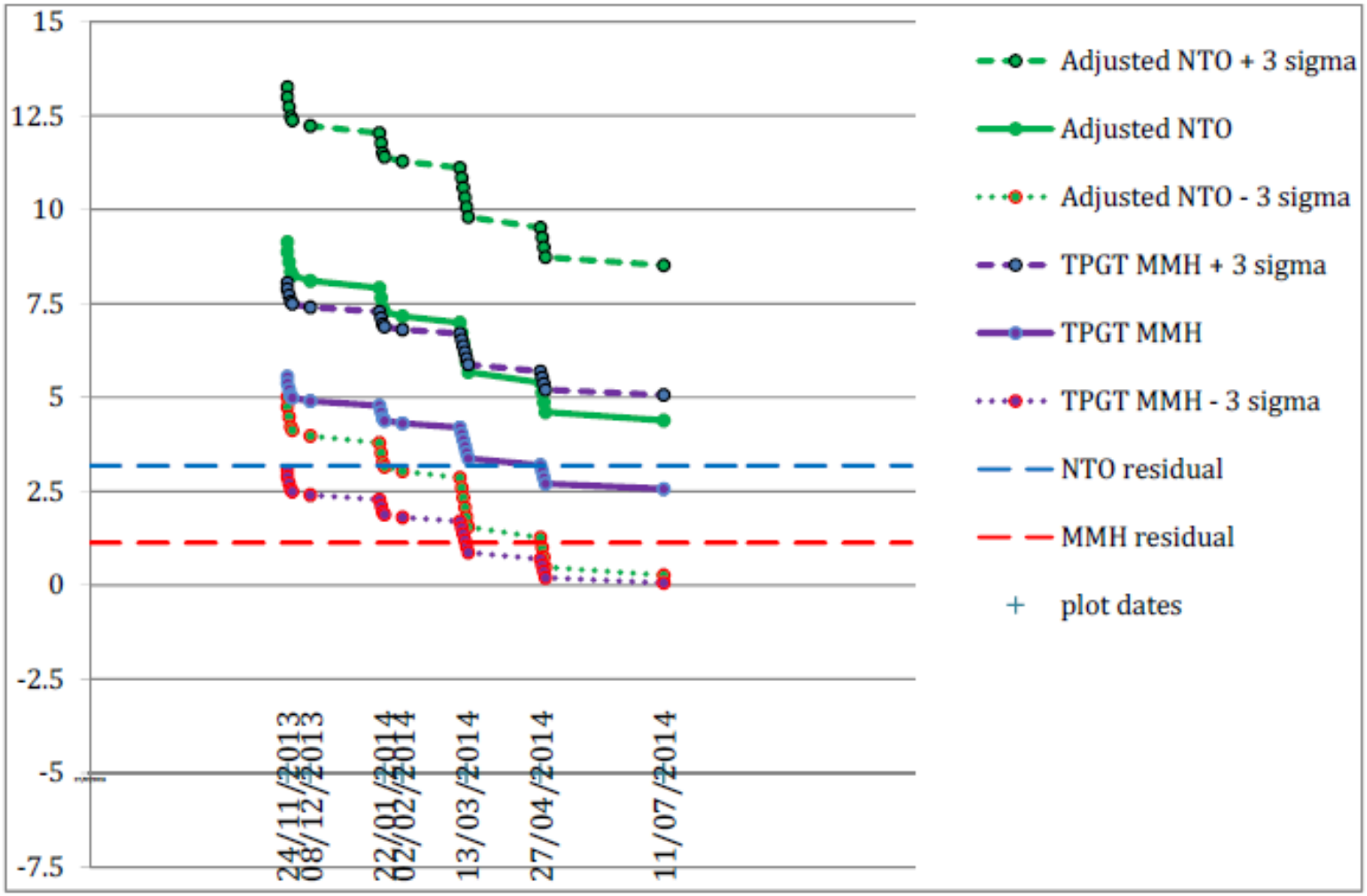


Figure 10 Scenario 3 Predicted propellant consumption for Aerobraking Campaign in June/July 2014

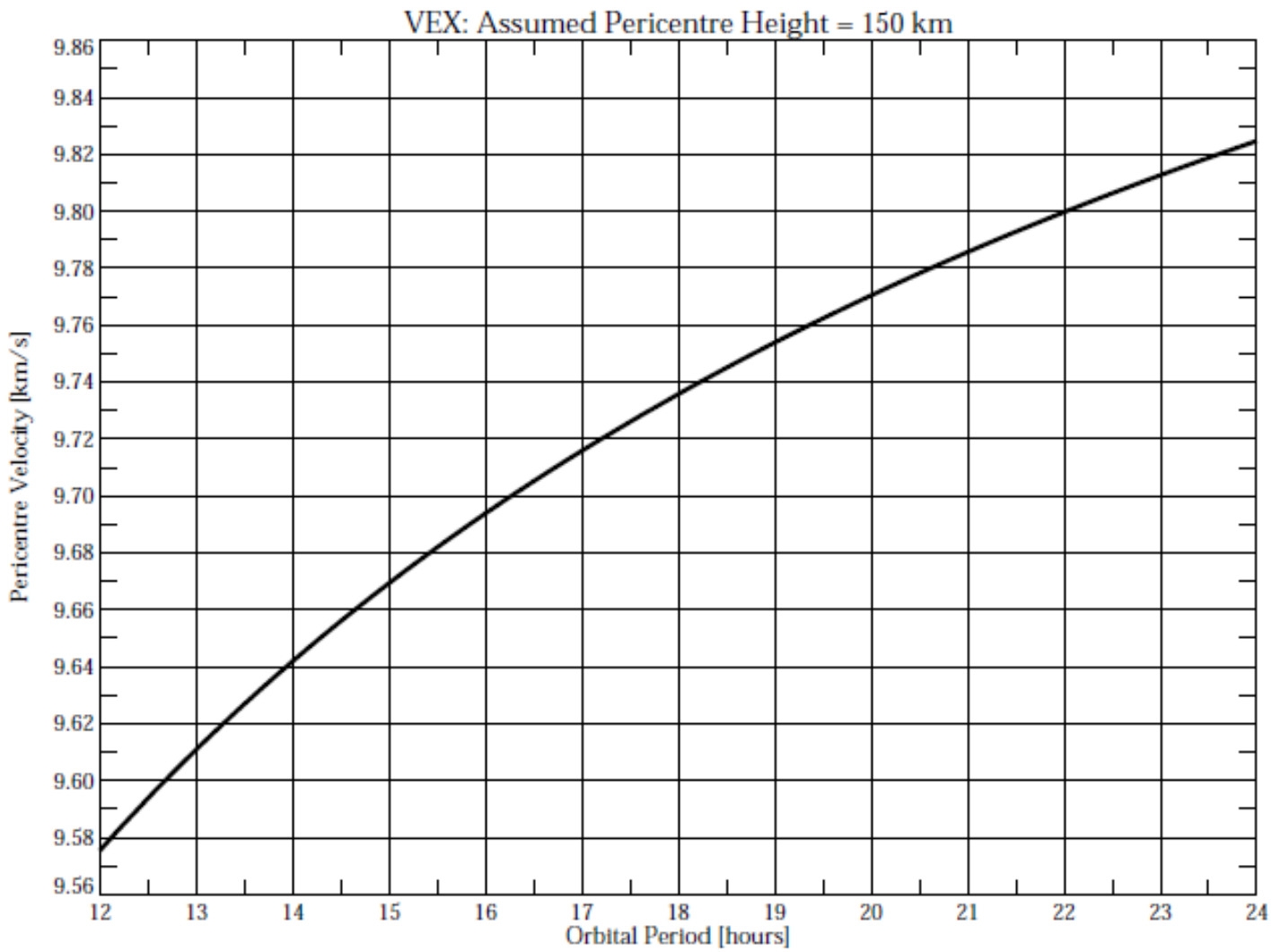
What is aerobraking?

1. Using the drag of atmosphere against the spacecraft body in order to reduce spacecraft speed. This will result in a lower apocenter altitude and a shorter orbital period.
2. The major limiting factors in aerobraking are s/c design and the related capability to maintain a stable attitude, and the capability to withstand dynamic loads and aerothermal heat flux.
3. Venus Express has a body/solar array layout that results in a dynamically stable attitude
4. A software mode to operate the spacecraft is during aerobraking is a part of the on board software. Aerobraking was howevere never intended to be used as a part of the nominal mission and only limited testing of this has been performed.
5. The most limiting factor on Venus Express will be the aerothermal heat input on the Multi Layer Insulation.

Venus Express Aerobraking

1. A reduction of the orbital period and apocentre altitude was discussed in 2010
    a. Achieve new opportunities for science observations in new orbit, lower/shorter than the present 24 h orbit
    b. Reduce the pericentre downward drift and so save fuel and extend the operational life of the mission
2. At a review in 2011 it was considered that aerobraking would be too risky to carry out as a part of the active science mission and it was recommended to carry it out as an end of mission activity.
3. Recent estimates of the amount of remaining fuel show that we may run out of fuel mid 2014
4. Two suitable time frames for aerobraking have bee identified, Feb/ March and June/July 2014.
5. ESA is now considering these opportunities and will make a decision in a few weeks time.

Pericentre veocity vs Orbital Period

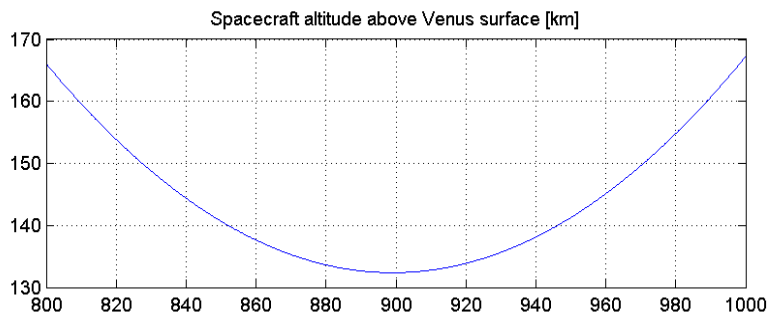


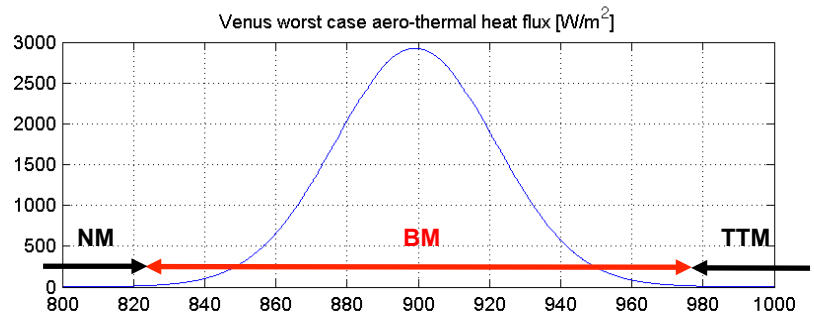
Delta-V needed for Reduction of orbital period:

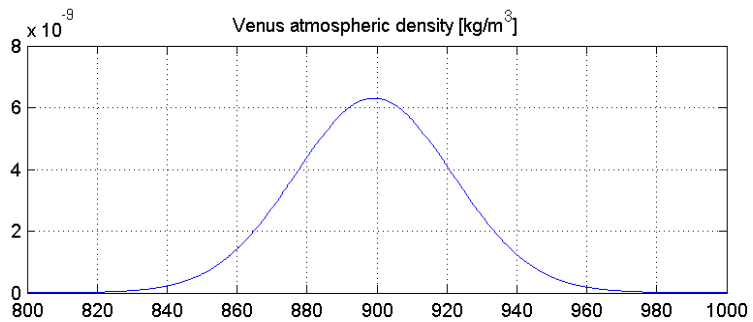
24h-18h 90m/s
18h-16h 42m/s
18h-12h 116m/s

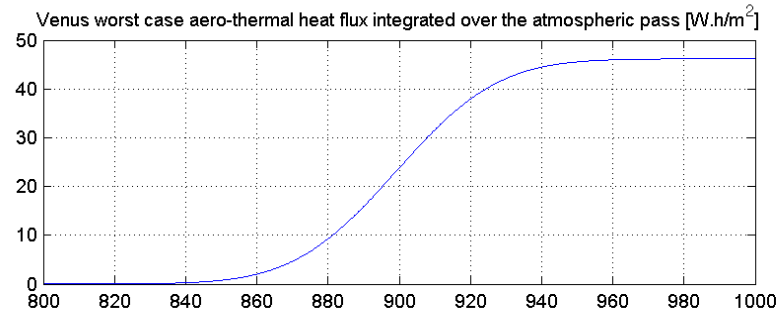
Aim for experimental demonstration of concept:
24h-23h 12 m/s

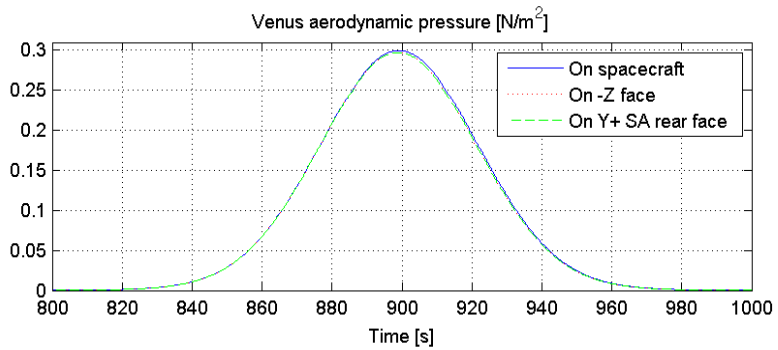
Parameters to consider

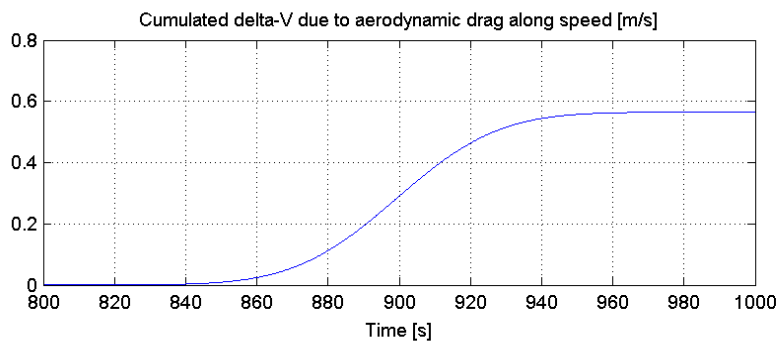












Relation of key parameters

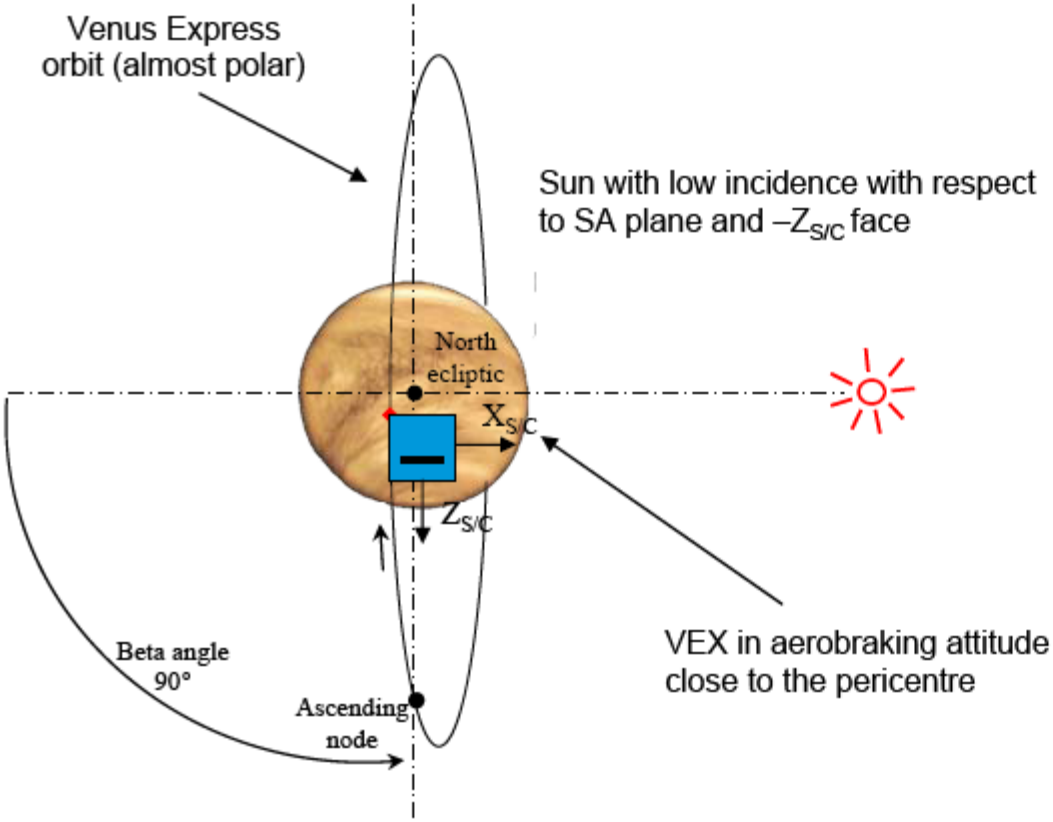
	Peak aerodynamic pressure	Aerodynamic delta-V (m/s)	Thruster delta-V in BM & TTM (m/s)	Delta-V over one plateau (m/s)
1	0.08 N/m²	0.16	0.007	5
2	0.20 N/m²	0.38	0.008	12
3	0.32 N/m²	0.60	0.007	18
4	0.40 N/m²	0.76	0.007	23
5	0.50 N/m²	0.95	0.006	29

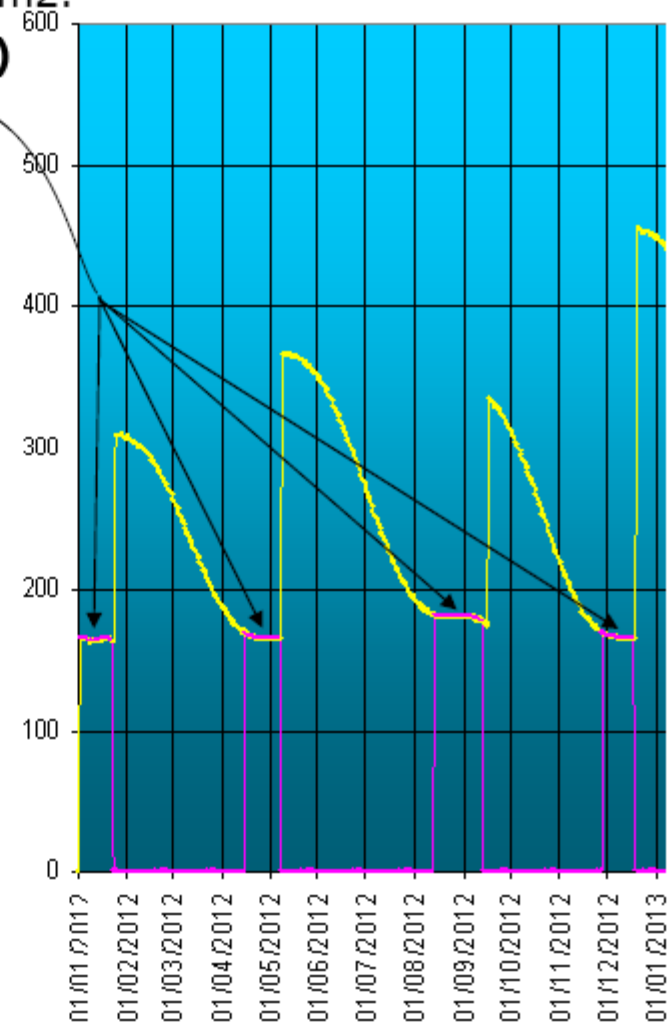
Optimum conditions for aerobraking

Reference case = most favourable conditions for Sun Aspect Angle allowing a Heat Flux of about 3000 W/m2 <> Dynamic Pressure of 0.3 N/m2.

→ Sun at 90° from the VEX orbit plane **(Beta Angle)**

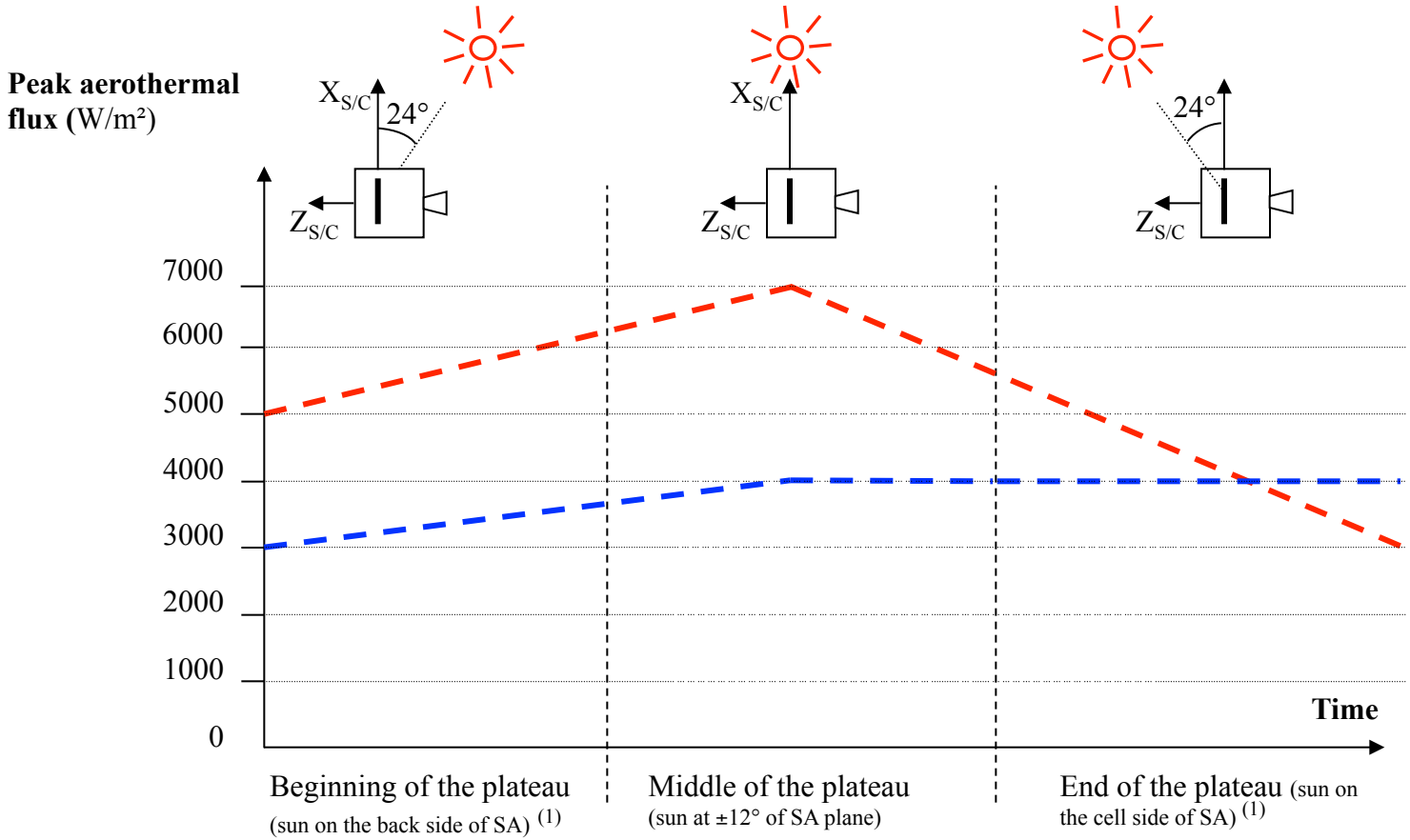
→ ß= 90° <> Middle of Plateaus





View from above Venus orbit plane

Aerothermal flux limitations

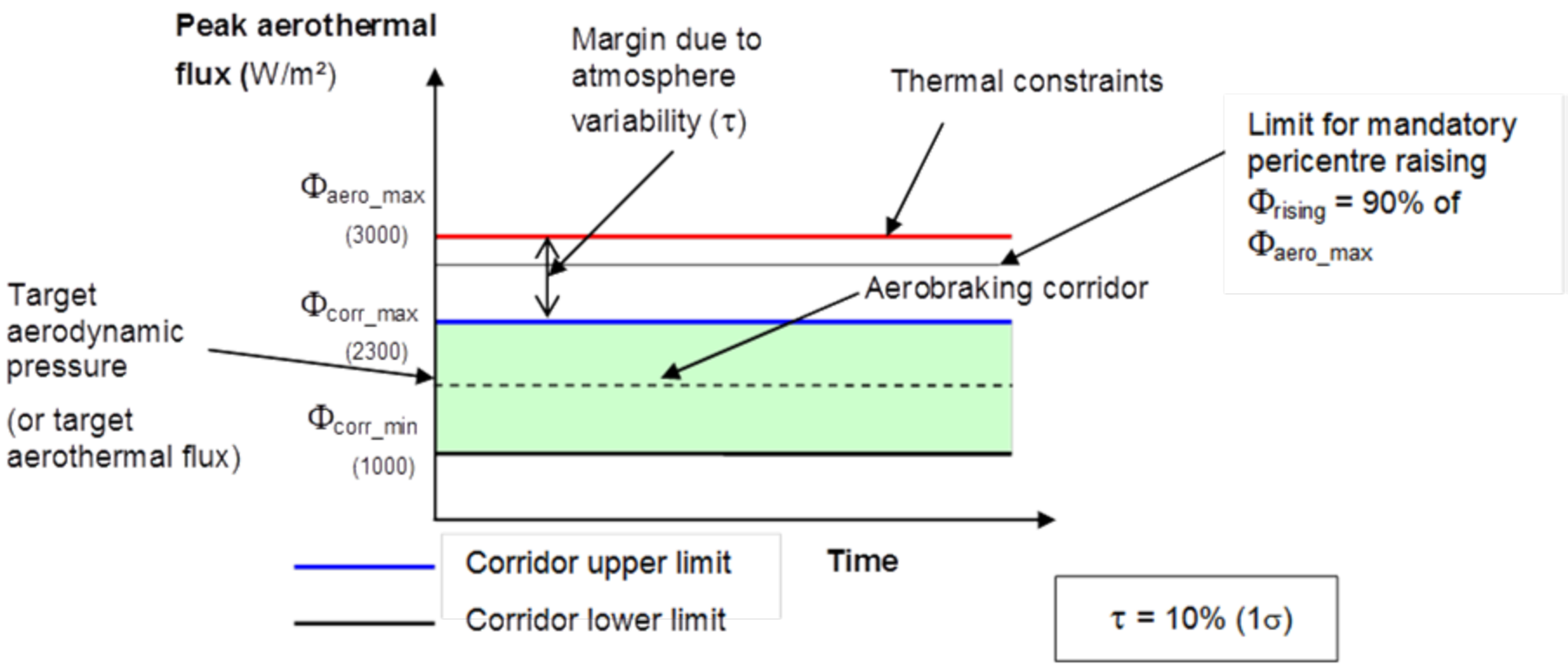


Thermal constraint due to the solar array

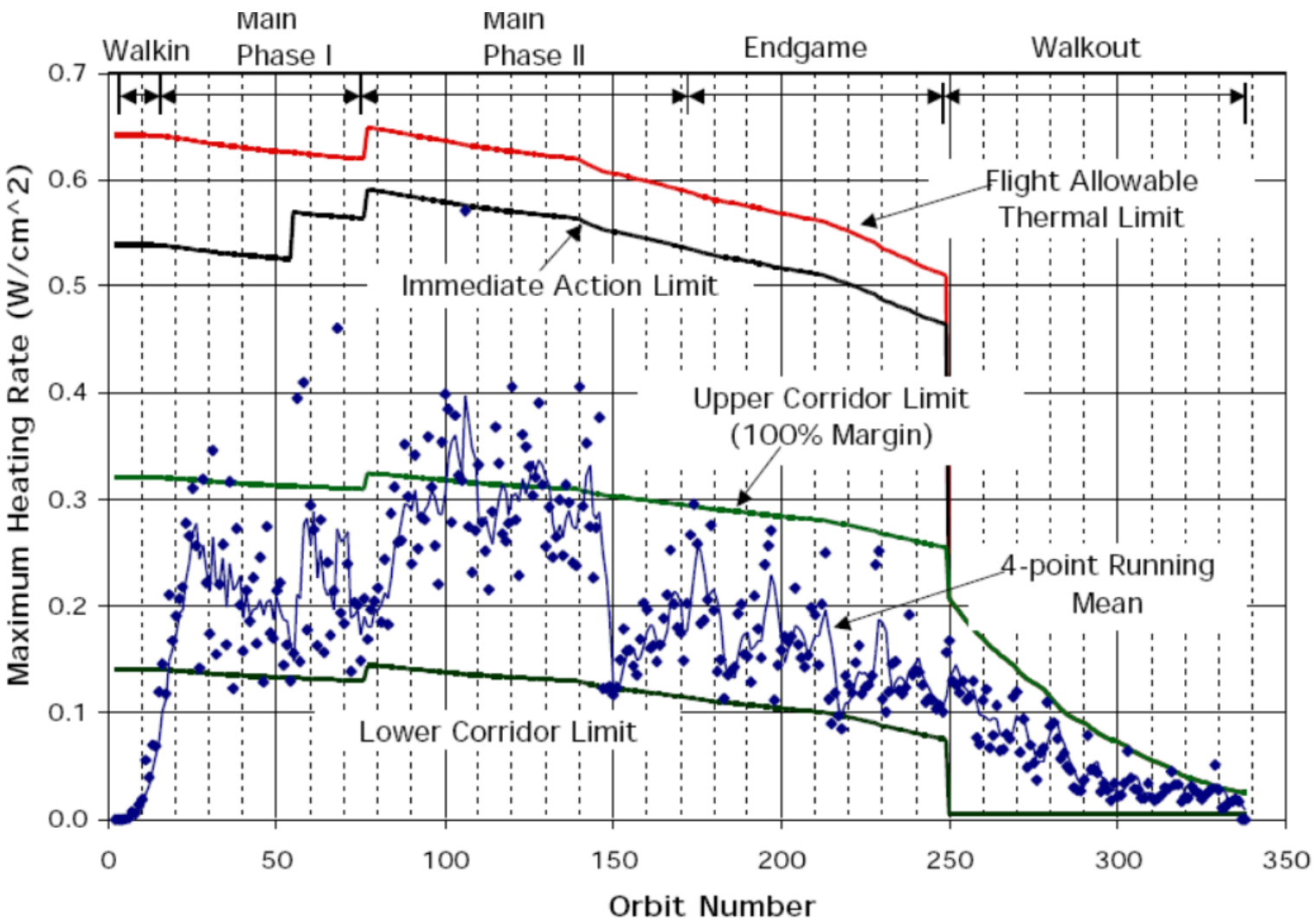
Thermal constraint due to the MLI

Note (1) : Depending on the plateau the sun will be illuminating the back side of the SA either at the beginning or at the end of the plateau

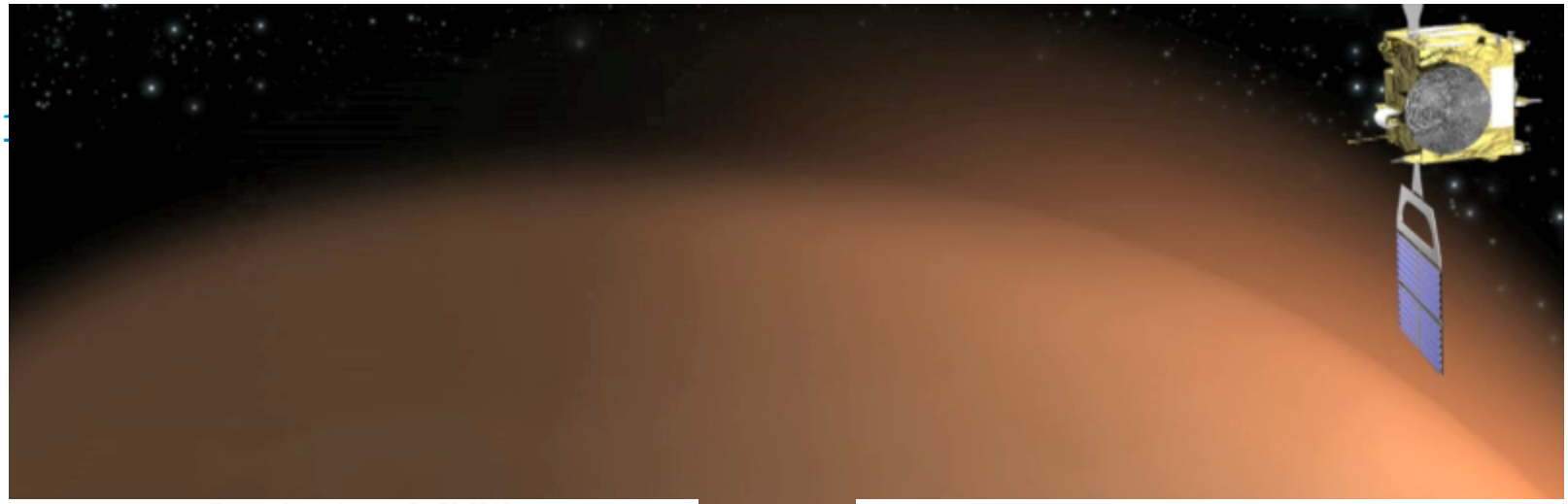
Determining Aerothermal flu limits

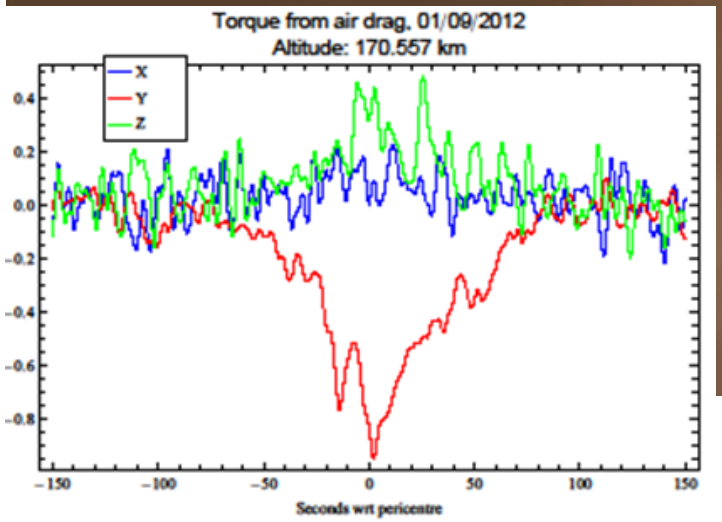


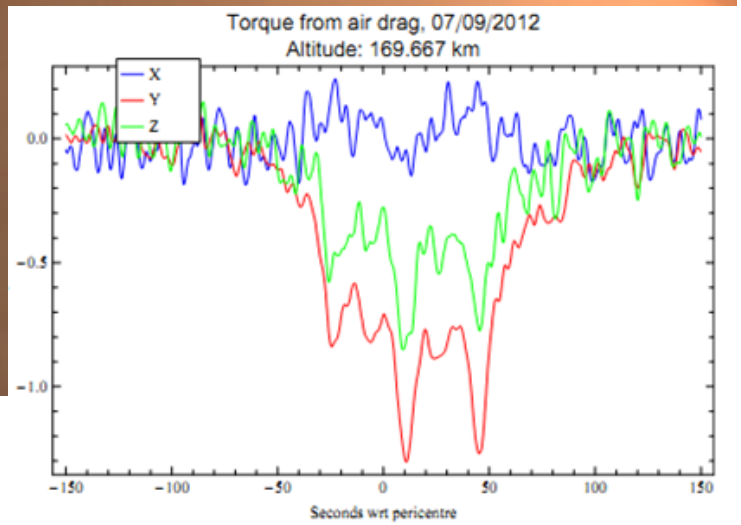
Example from Mars Odessey



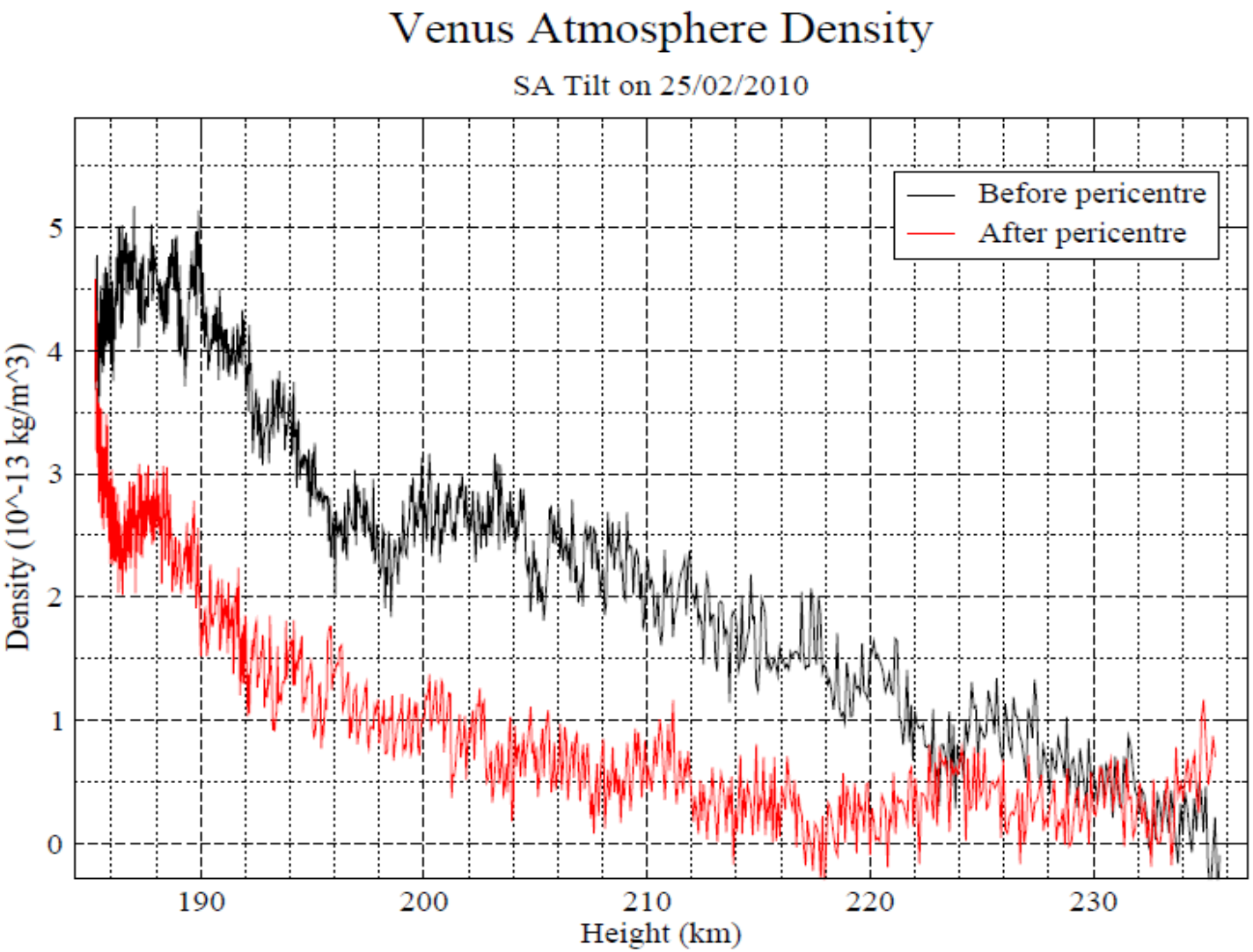
Preparation for aerobraking (1): Torque technique for measuring atmospheric density at low altitudes







Initial tests at high altitude using induce torque when tilting solar arrays



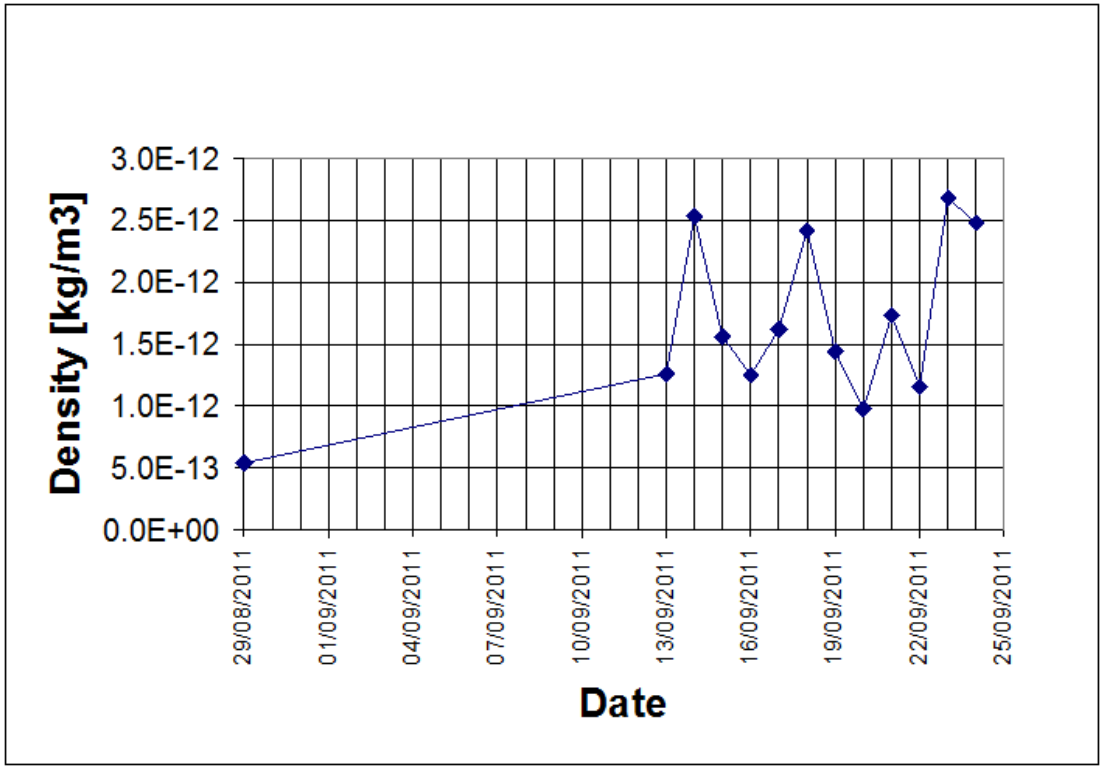
Preparation for aerobraking (2)

1. A full test of the aerobraking mode at high altitude (well outside the atmosphere) was carried out 19 Nov 2013.
2. Preliminary findings show that all tested parameters are as expected.
3. In this mode the s/c is using thrusters for attitude control in place of reaction wheels. During the simulated period of aerobraking thrusters were activated three times.

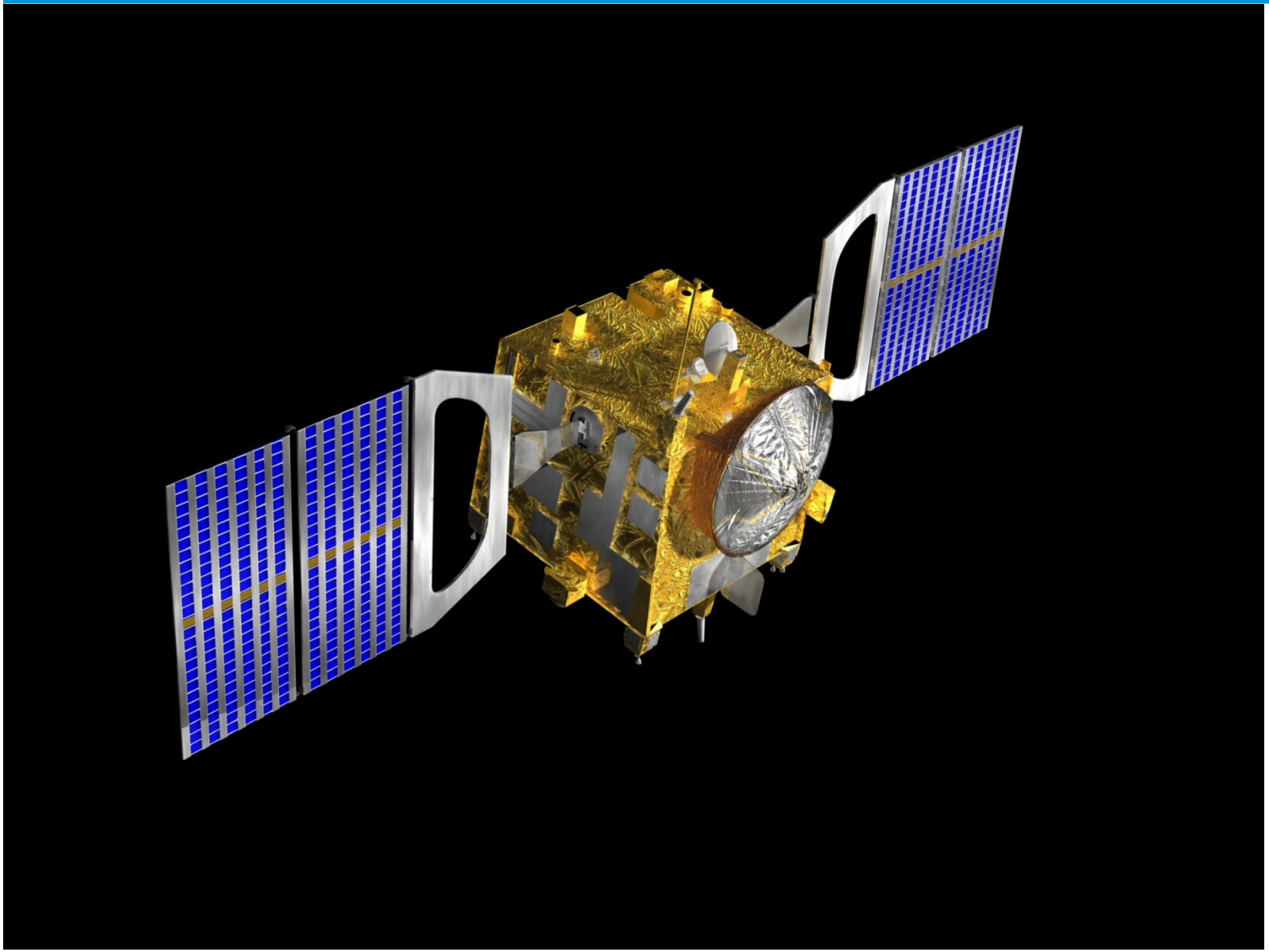
Science of Aerobraking

1. Using on board accelerometers, atmospheric density can be estimated at any point along the track through the atmosphere.
    a. $m\ a_z = ½\ \rho\ S\ v^2\ C_z$
    b. Sensitive to about 10^{-11} kg/m^3 corresponding to about 155 km
2. Measurements will be taken as low as at 130 km altitude
3. Measuring total density in a region not accessible by other methods
4. Collecting information across the terminator region where the density gradient can be very steep
5. Collecting information in the high latitude region around 76 deg North
6. Searching and characterising atmospheric waves, and possibly winds
7. Carrying out magnetic field measurements at very low altitude

High day to Day variablity from Drag/ Torque measurements at 165km



Venus Express



European Space Agency