Nightside Winds at the Lower Clouds of Venus with Akatsuki/IR2

Javier Peralta

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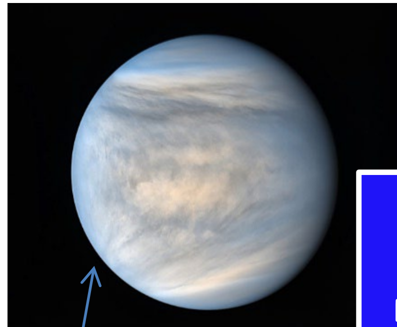
Venus and its atmospheric super-rotation.



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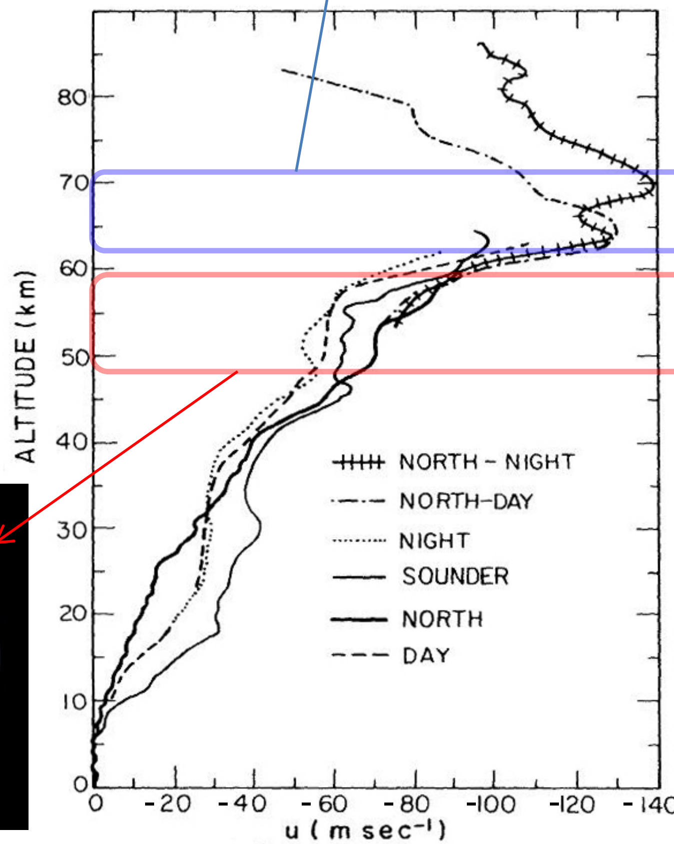
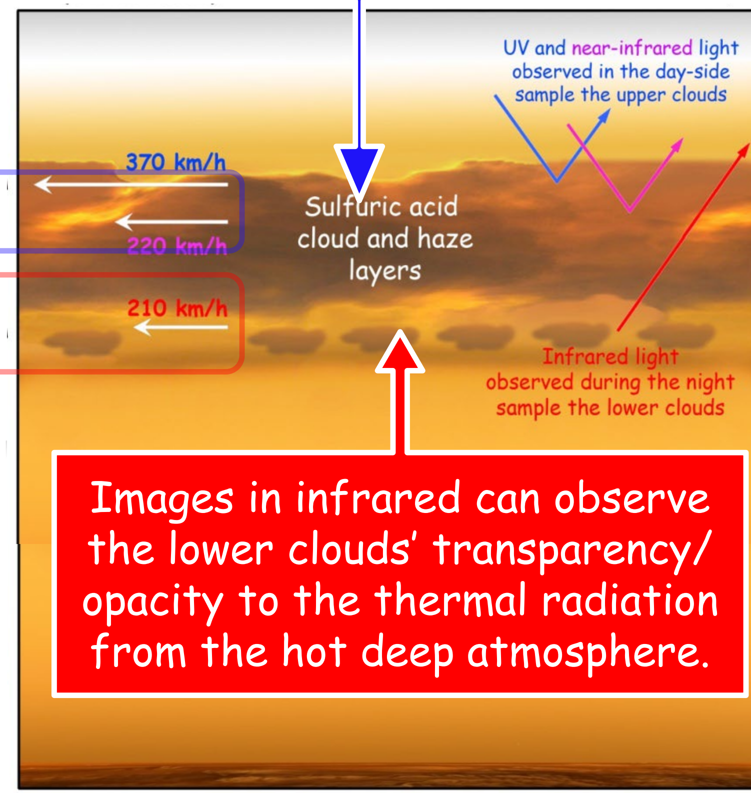
Images in ultraviolet and near-infrared wavelengths can sense the Sunlight reflected on the Upper Clouds of Venus.



Steven W. Bougher, Donald M. Hunten, Roger J. Phillips(1997). *Venus II*, The University of Arizona Pressより



Images in infrared can observe the lower clouds' transparency/ opacity to the thermal radiation from the hot deep atmosphere.

Venus Surface

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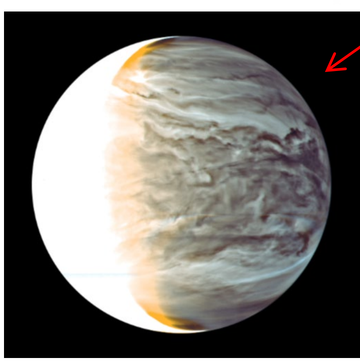

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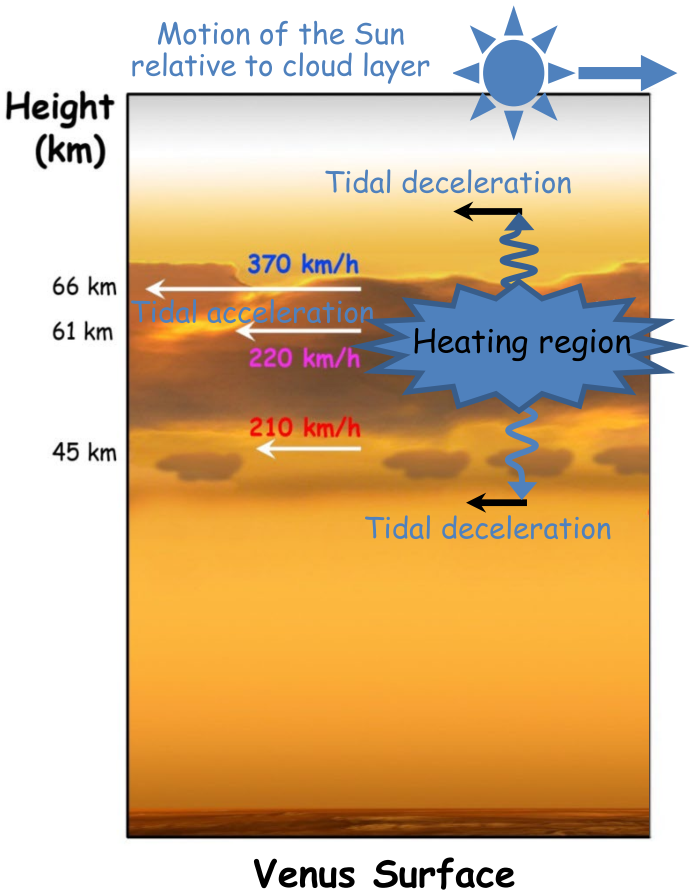
Competing hypotheses for the Super-rotation.

Solar Tides are candidate:

- Periodic heating of the Sun causes excitation of a Tidal Wave propagating to the East.
- Wave accelerates Westwards the cloud layer.
- Dissipated above/below, decelerating winds.



Gierasch-Rossow-Williams mechanism:

- Heating at equator and cooling in polar regions leads to rising & sinking motion and Hadley circulation begins.
- The resulting circulation would be mainly balanced by the equatorward transport by eddies/waves.

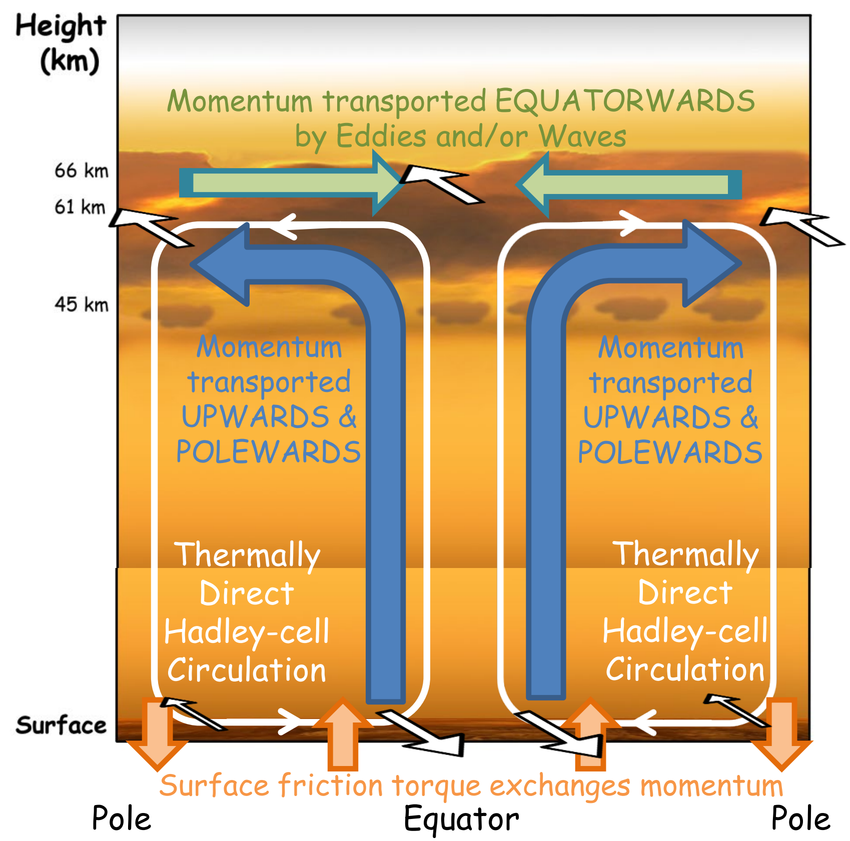
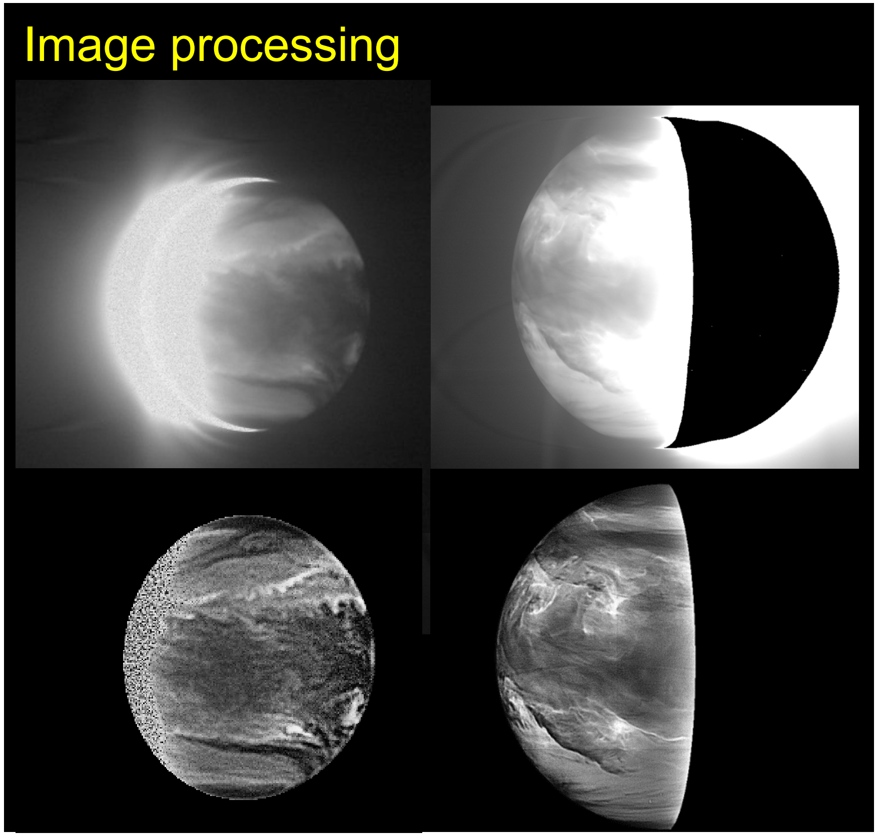
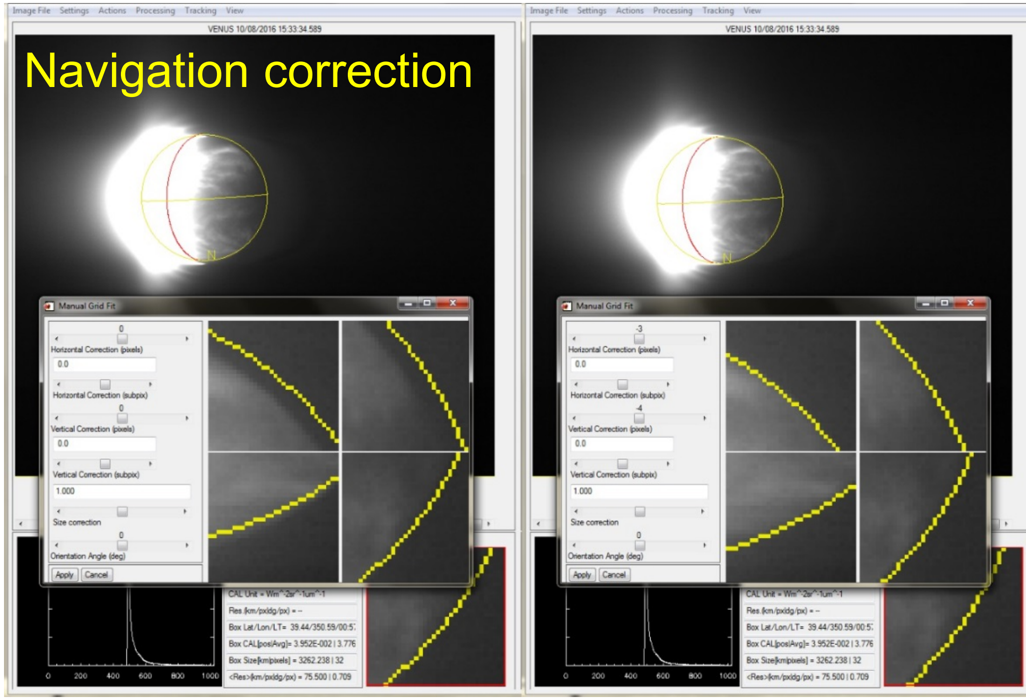


Image processing and navigation correction.





- Full dataset of AKATSUKI-IR2:
  - A total of 466 images covering from March to November 2016.
  - 2.26-μm images were used after removal of light pollution from very intense day-side.
- Refined image navigation achieved with our own interactive software.

Our findings in brief.

1. Our manual cloud-tracking measurements confirms the presence of recurrent jets at the equator.

2. For the first time, possible effects of the solar tides have been detected in the night side of Venus and at the lower clouds.

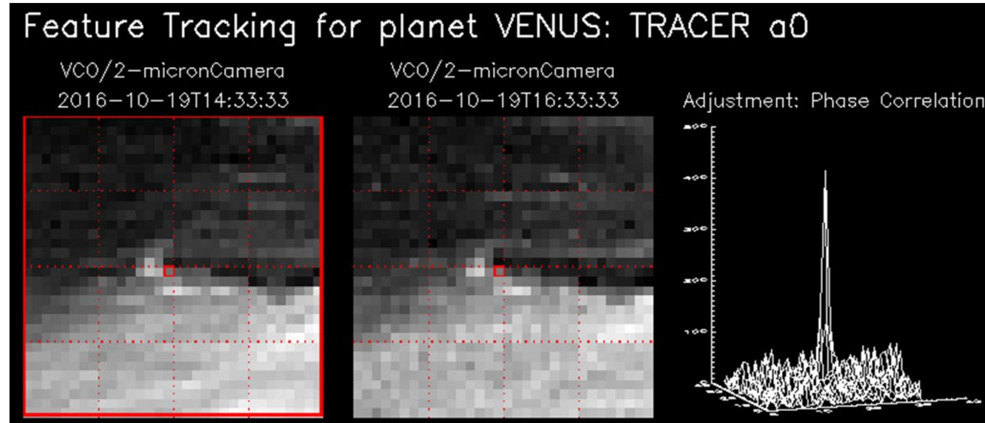
3. First long-term study of the lower clouds’ winds between 30ºN and 30ºS reveals decadal variations of up to ~30 m/s.

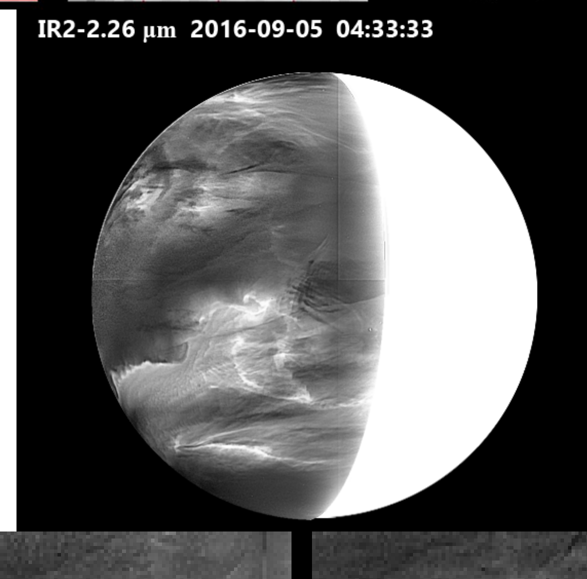
About (1/3): Confirmation of equatorial jets.

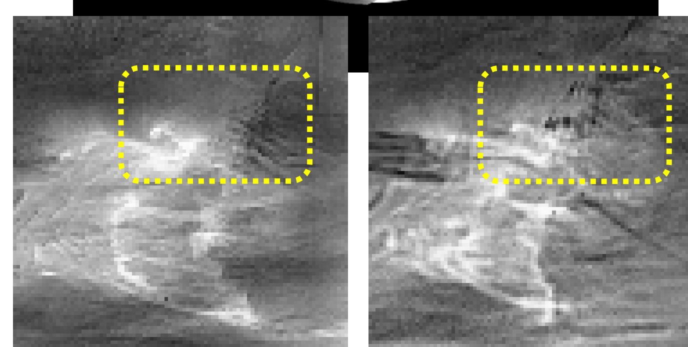
Procedure of Manual Tracking:
1. Cloud match with “Phase Correlation”.
2. Visual Validation (discard waves).

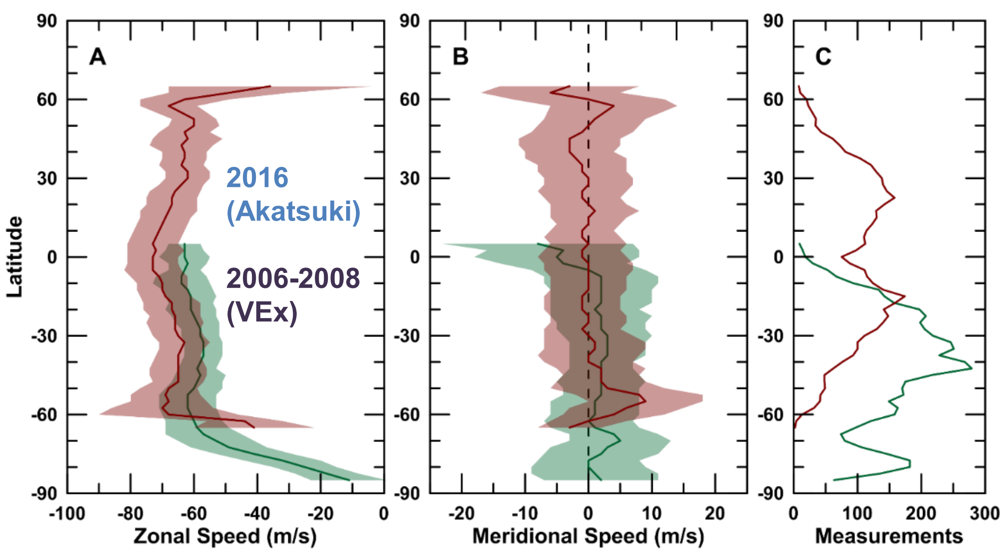
A total of 2,947 wind measurements obtained with Manual Tracking (Peralta & Muto), and >149,000 have measured automatically (Horinouchi et al.)

Faster wind speeds than Venus Express (VEx), confirming existense of the equatorial jets.









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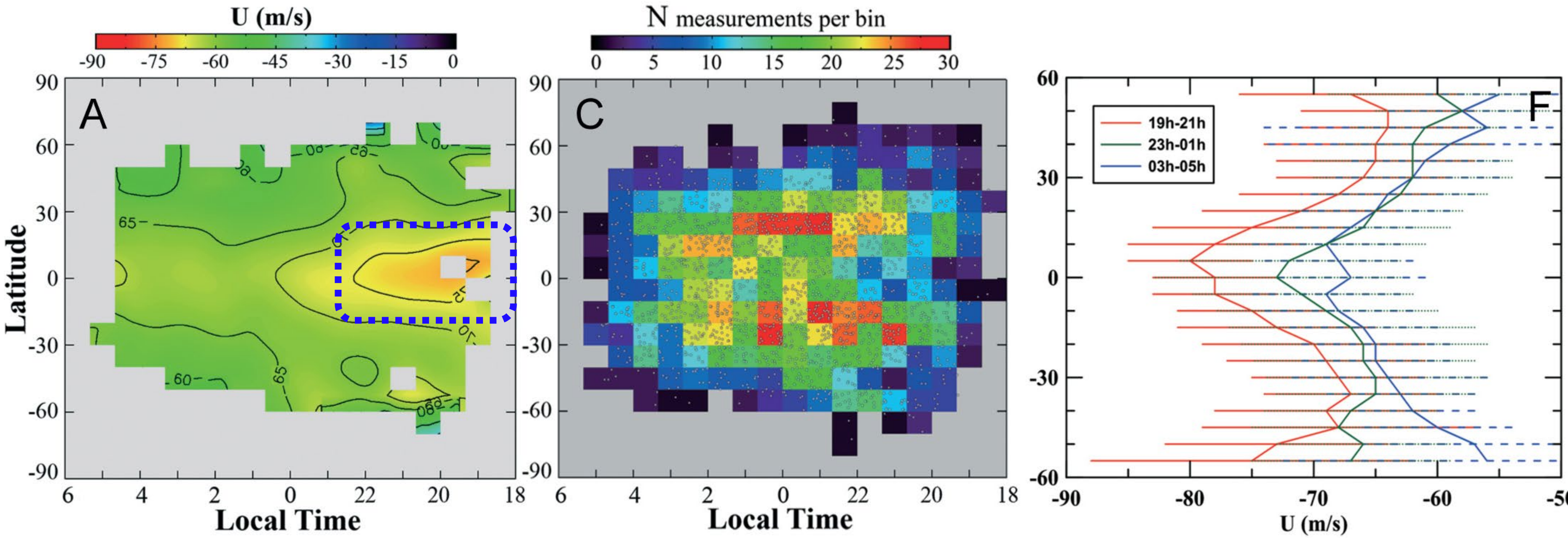
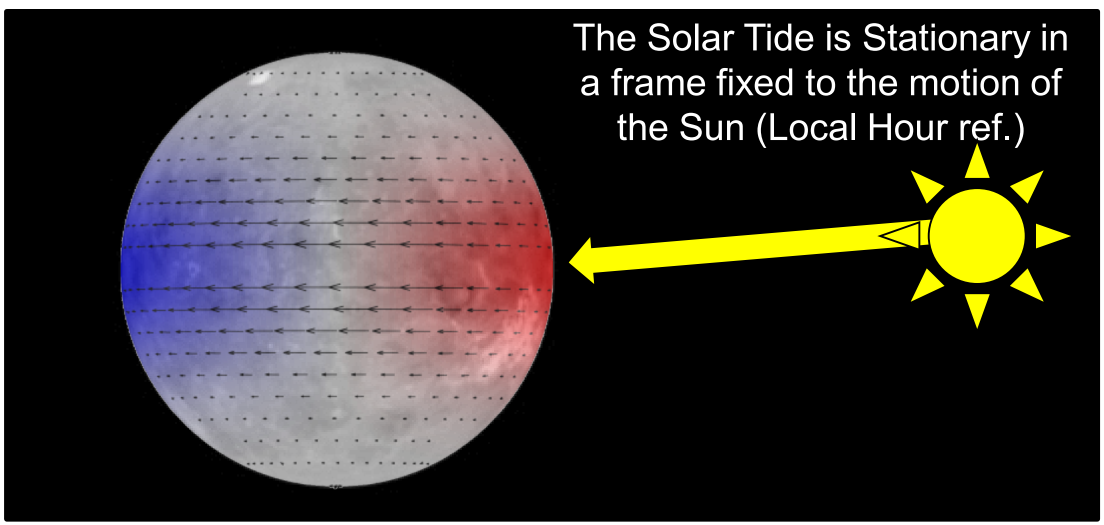
About (2/3): effect of Solar Tides.





For the first time ever, weak acceleration for local time 18h–23h is detected!

Solar Tides might be able to "penetrate" down to the lower clouds?

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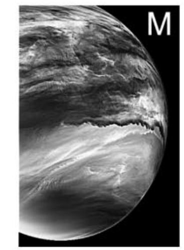
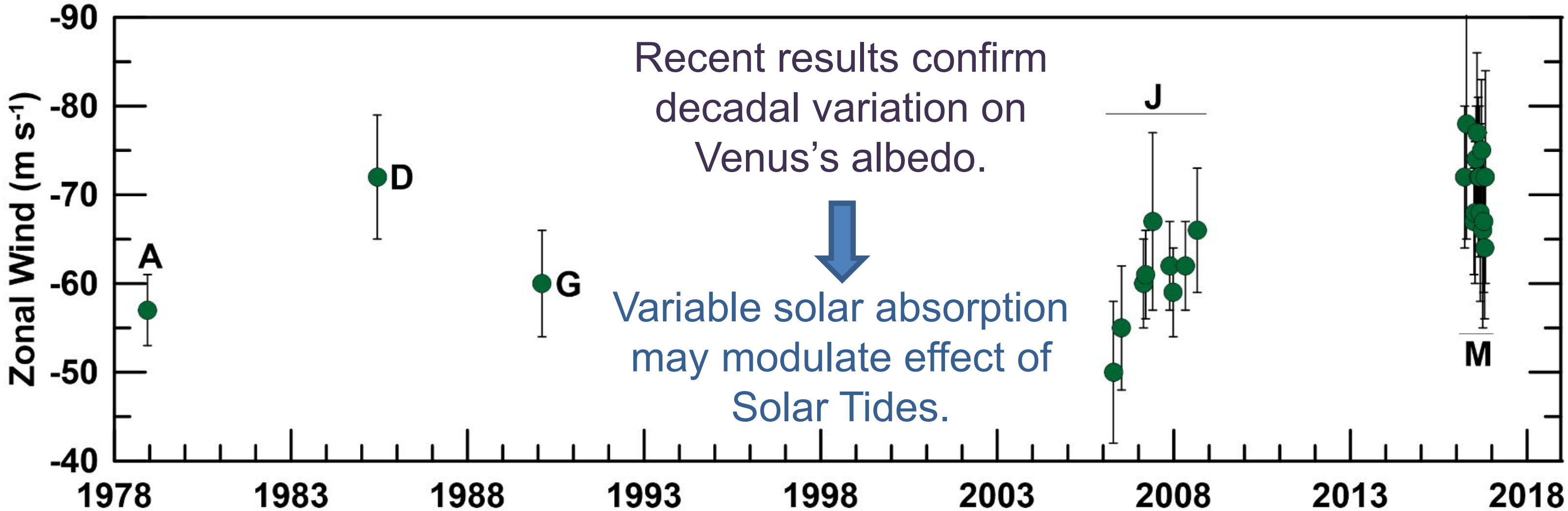
About (3/3): Decadal Changes in the winds.



(A)Pioneer Probe

(G) Galileo Flyby



Recent results confirm decadal variation on Venus's albedo.

Variable solar absorption may modulate effect of Solar Tides.

(D) Vega Balloon

(J) Venus Express

How were these results possible?

1. Our manual cloud-tracking measurements confirms the presence of recurrent jets at the equator.
   - ❑ Our human-supervised “phase-correlation” technique effectively rules out faster speeds belong to “waves”.

2. For the first time, possible effects of the solar tides have been detected in the night side of Venus and at the lower clouds.
   - ❑ Over 2,900 wind measurements from high-quality IR2 2.26-μm images (more than 460) acquired from a near-equatorial orbit of Akatsuki.

3. First long-term study of the lower clouds’ winds between 30ºN and 30ºS reveals decadal variations of up to ~30 m/s.
   - ❑ Possible thanks to the combination of Akatsuki with past measurements from telescopes and missions Pioneer Venus, VEGA balloons, Galileo and Venus Express.

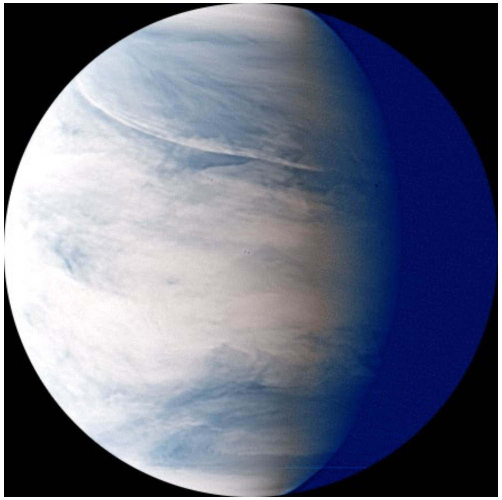
Significance of our findings.

1. Our manual cloud-tracking measurements confirms the presence of recurrent jets at the equator.
   - ❑ Strengthen previous discovery with Akatsuki and confirms that instabilities and vortices are possible at the lower clouds.

2. For the first time, possible effects of the solar tides have been detected in the night side of Venus and at the lower clouds.
   - ❑ Plausibility of the competing hypotheses for explaining the Super-rotation of Venus. This is very important for improving the Numerical Simulations of Venus's atmosphere.

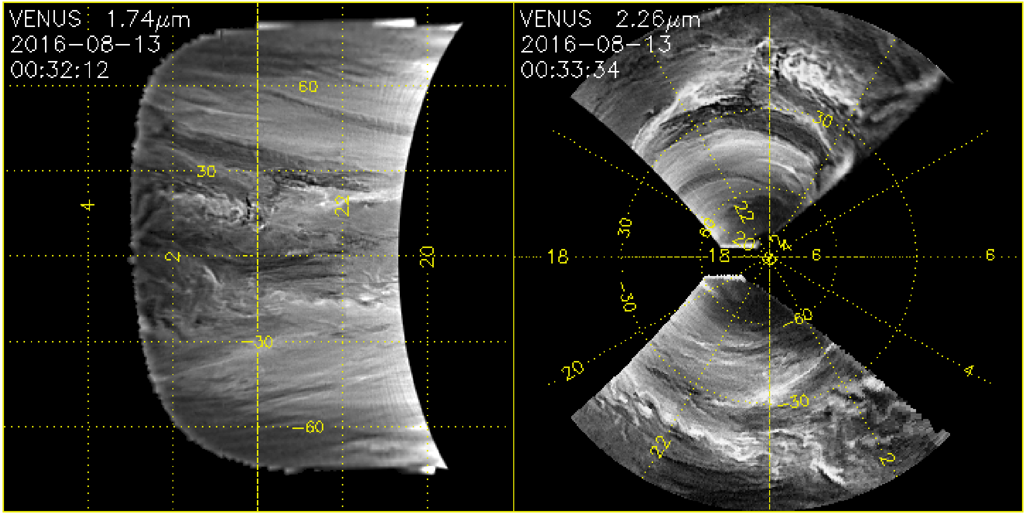
3. First long-term study of the lower clouds' winds between 30ºN and 30ºS reveals decadal variations of up to ~30 m/s.
   - ❑ Suggests that the role of the solar tides to maintain the Super-rotation may be variable along time, probably due to changes in the atmospheric absorption of the solar radiation.

Concluding Remarks: Akatsuki in support of Open Science.



<u>TO SUPPORT OPEN SCIENCE we share:</u>

- 2,947 wind vectors manually measured, with the full coordinates (longitude, latitude, local time), clouds' size and radiance, emission angle, and further derived magnitudes (vector magnitude and angle, angular velocity, …).
- 90 animations of the clouds' motions.
- More than 100 images displaying the positions of the cloud tracers.
- Detailed morphology for 2,000 cloud tracers.



Acknowledgements

18 co-Authors from 4 countries and 13 institutions:

- ISAS/JAXA (Japan), the University of Tokyo (Japan), University of the Basque Country (Spain), Hokkaido University (Japan), Institute of Astrophysics and Space Sciences (Portugal), Southwest Research Institute (CO, USA), AIST (Japan), Kyoto Sangyo University (Japan), University of Colorado Boulder (CO, USA), School of Physical Sciences (Japan), University of Wisconsin-Madison (WI, USA), Hokkaido Information University (Japan) and University of Shiga Prefecture (Japan).

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Image (false colour) of lower clouds at the nightside of Venus, taken by IR2 at 1.74 μm (Credits: JAXA / ISAS / DARTS / Damia Bouic).

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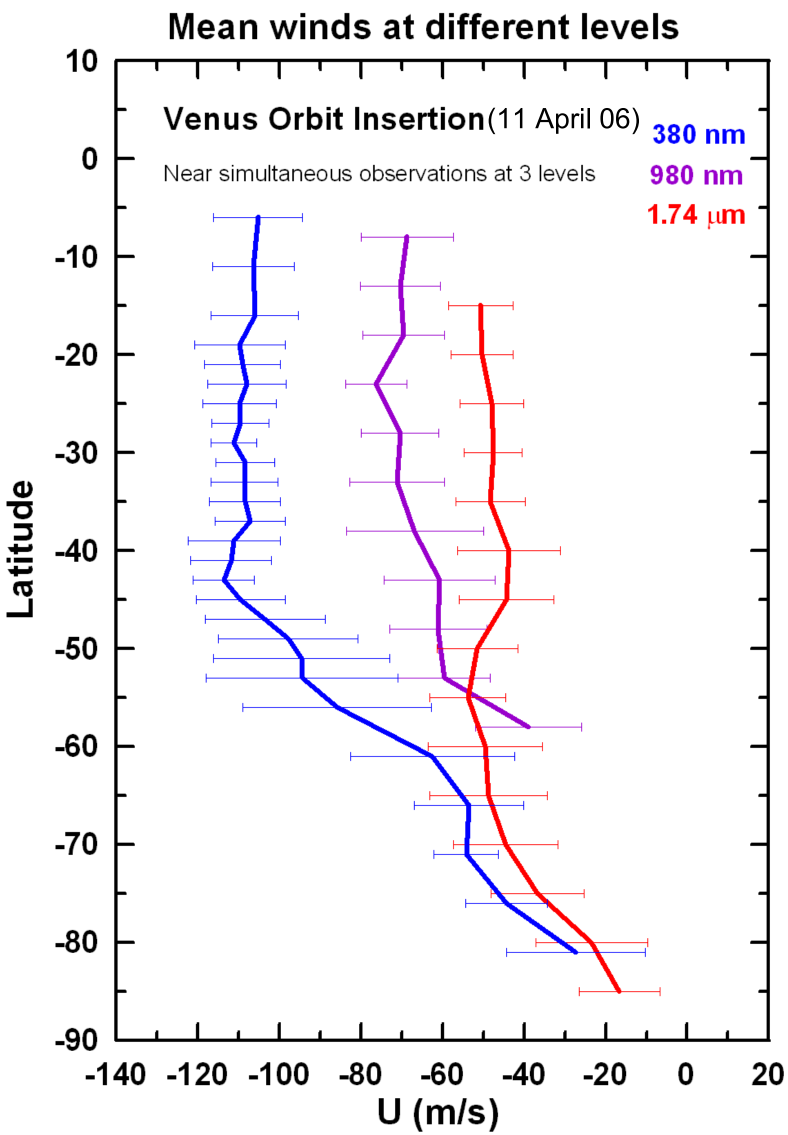
Javier Peralta, Keishiro Muto, Ricardo Hueso, Takeshi Horinouchi, Agustín Sánchez-Lavega, Shin-ya Murakami, Pedro Machado, Eliot F. Young, Yeon Joo Lee, Toru Kouyama, Hideo Sagawa, Kevin McGouldrick, Takehiko Satoh, Takeshi Imamura, Sanjay S. Limaye, Takao M. Sato, Kazunori Ogohara, Masato Nakamura and David Luz.

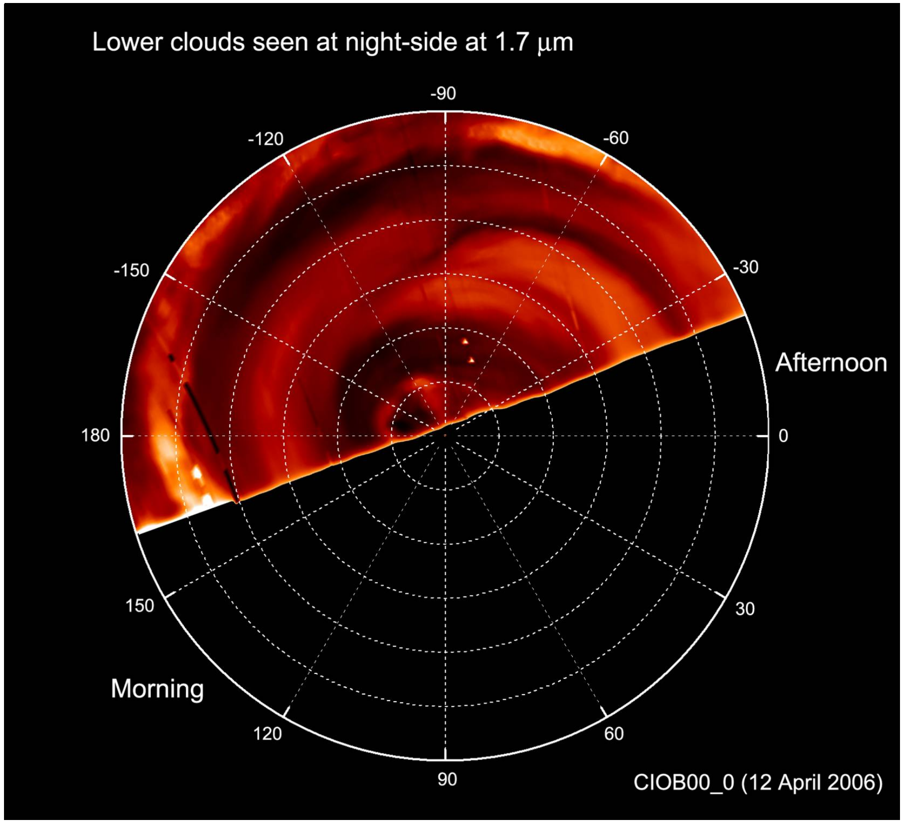
どうもありがとうございます!

Brief introduction: planet Venus and its atmospheric super-rotation (2/2).



Westward Winds from Venus Express images at 380 nm.
Westward Winds from Venus Express images at 980 nm.
Westward Winds from Venus Express images at 1.74 μm(*).

(*) Night lower clouds can be seen at 1.74, 2.26 and 2.32 μm.



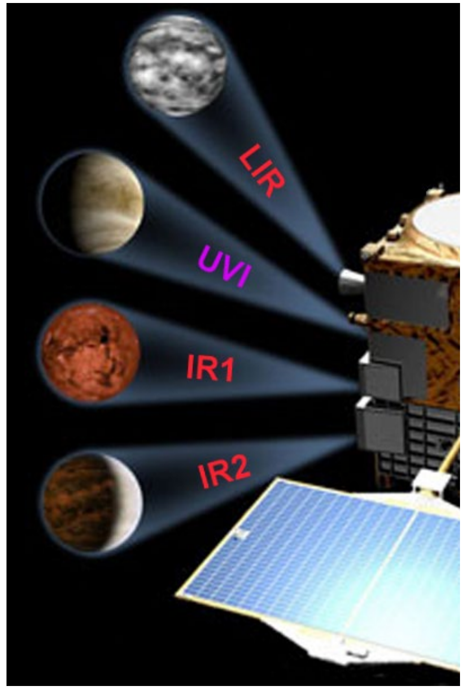
Brief introduction: data used.

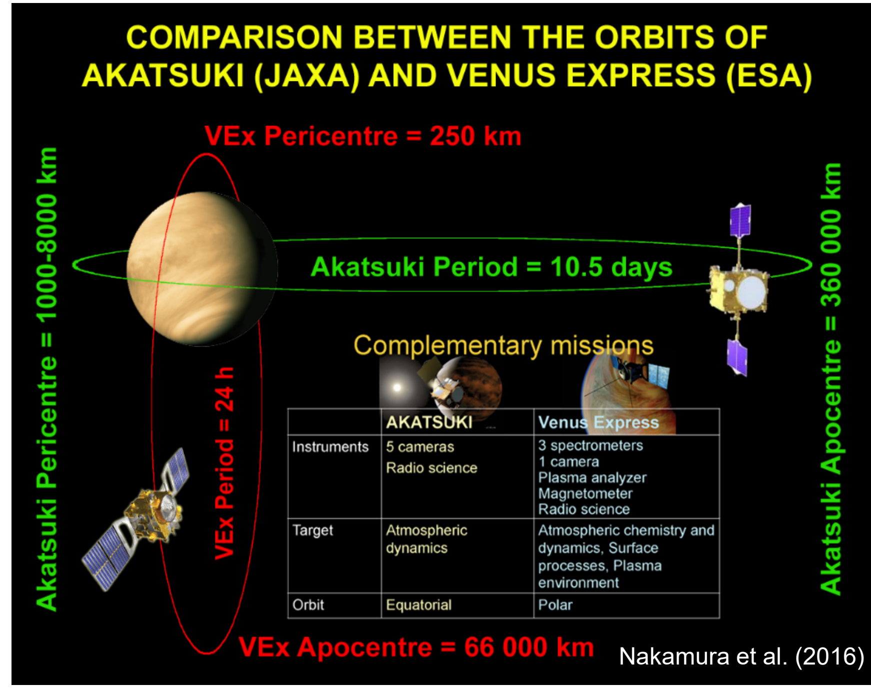
In December 7 of 2015, JAXA's Akatsuki arrived at Venus.

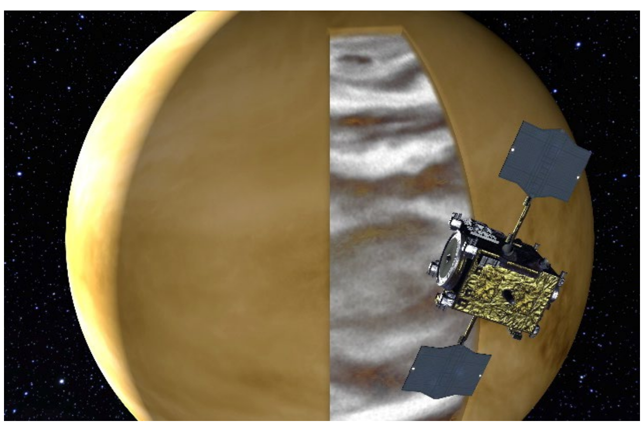
Conversely to Venus Express, Akatsuki's orbit is equatorial and its cameras can observe the motions of the clouds at lower latitudes of Venus.

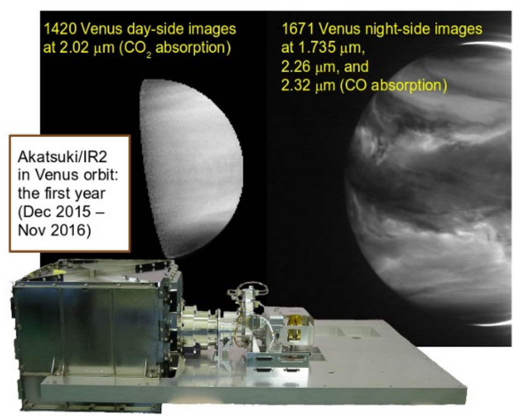
Along March–October 2016, the camera IR2 observed the lower clouds of the night side of Venus with filters ar 1.74,2.26,2.32 µm.

In December 2016, IR2 and IR1 paused observations and have been "in silence" since then…



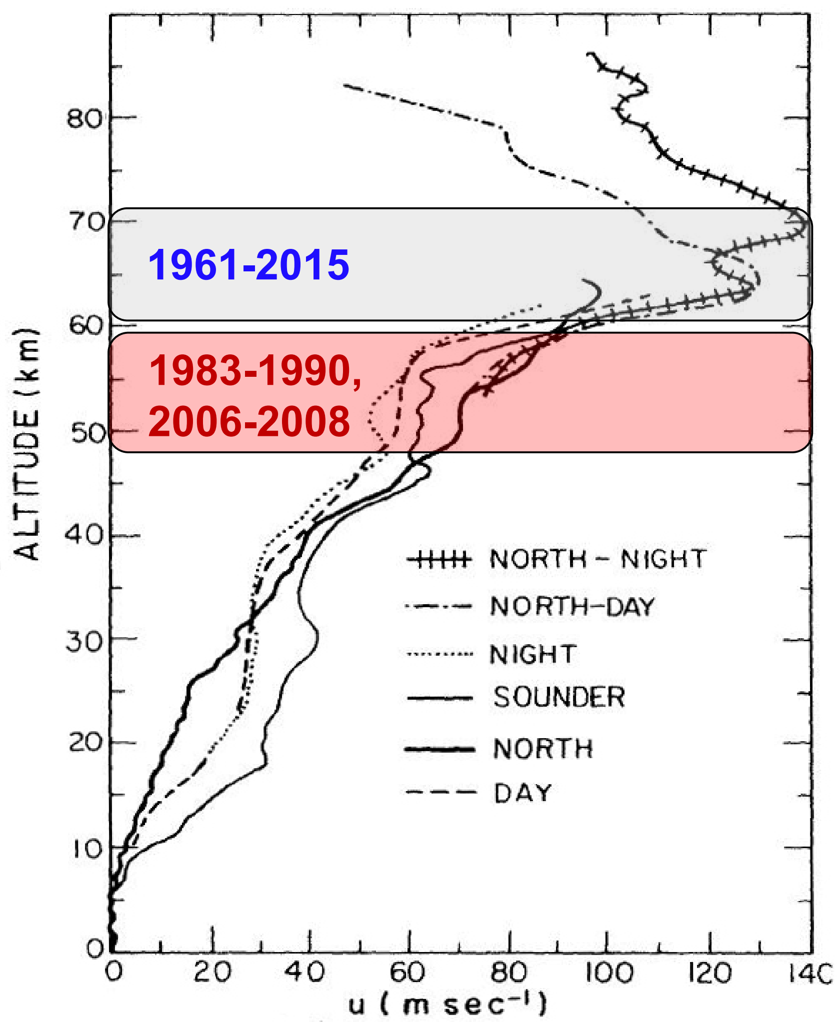


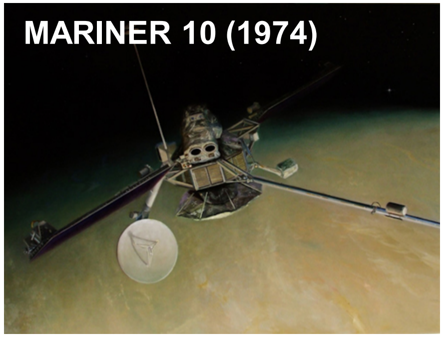


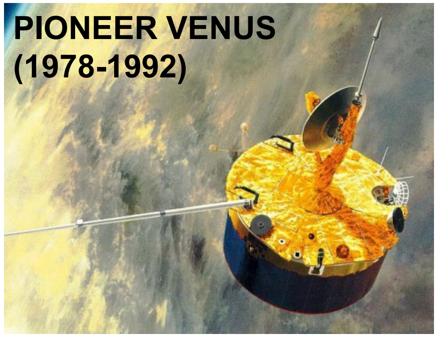


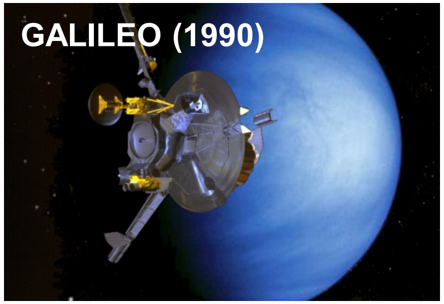
PtSi-CSD/CCD 1024 x 1024 pixels	1.735 micron (night)	0.04 micron	Clouds, Particle size
	2.26 micron (night)	0.06 micron	
	2.32 micron (night)	0.04 micron	CO below clouds
	2.02 micron (day)	0.04 micron	Cloud-top height
	1.65 micron (cruise)	0.30 micron	Zodiacal light

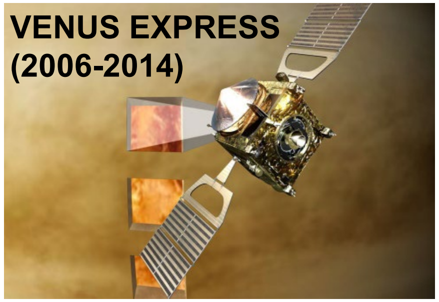
Unfortunately, the superrotation at the lower clouds have been poorly measured.

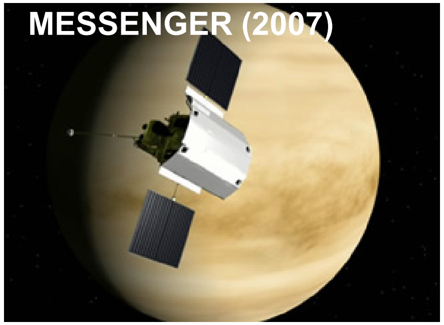




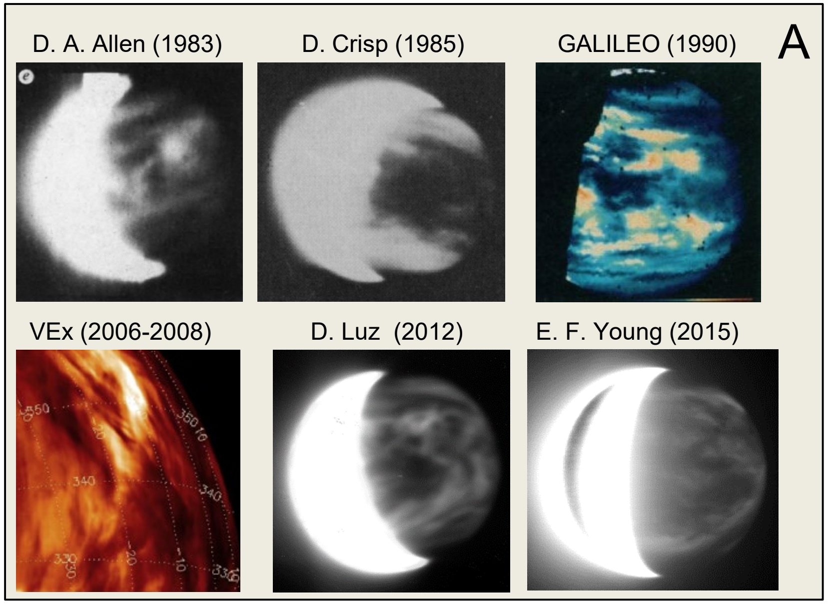








Superrotation at the lower clouds before the arrival of Akatsuki.

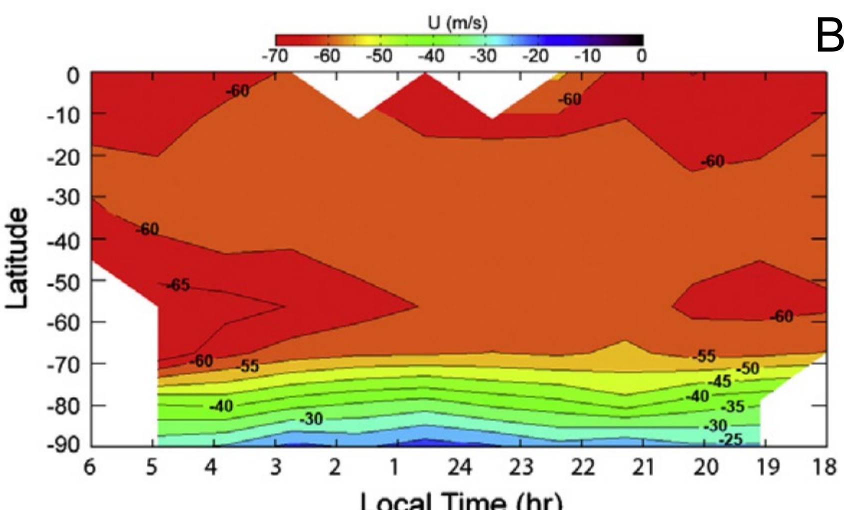


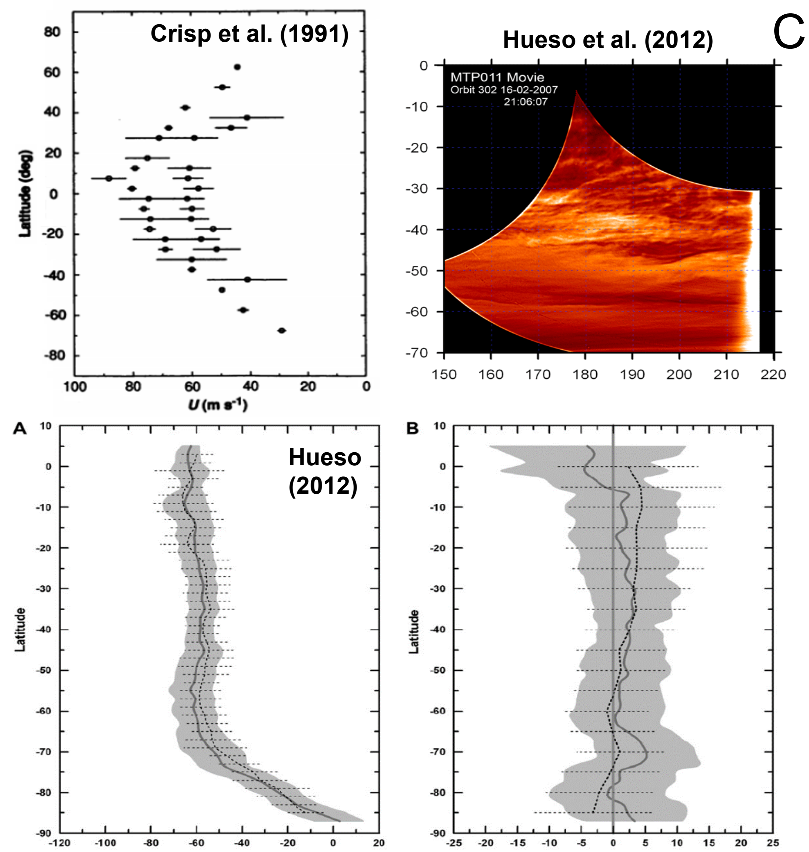
What about the deeper clouds before Akatsuki?

A) The deeper clouds cannot be seen on the dayside. Low-latitude clouds never seen with high resolution images.

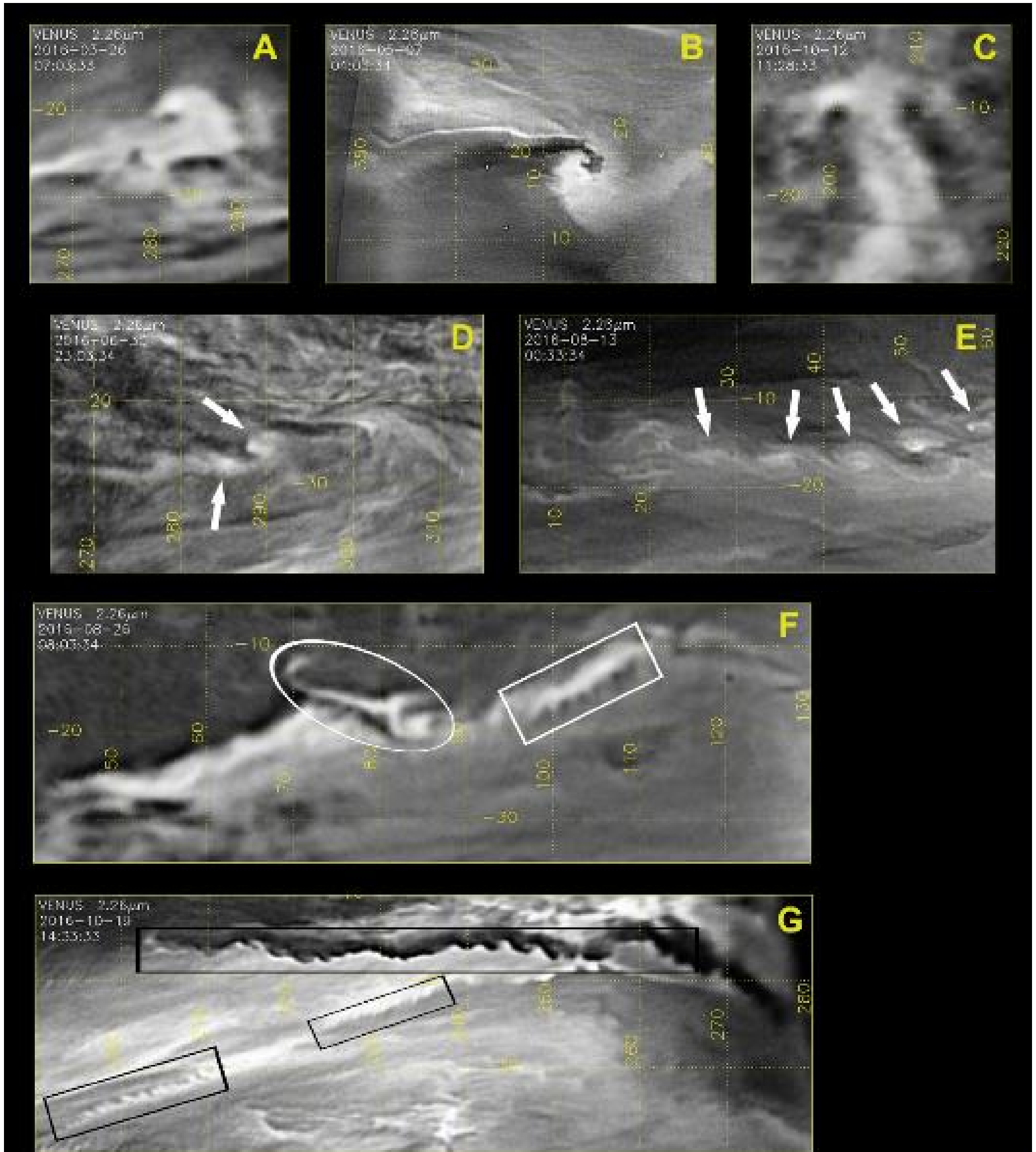
B) No effect of the solar tides apparent on the lower clouds' winds during Venus Express misión (Hueso et al. 2012).

C) Accurate winds only in south hemisphere (Hueso, 2012).

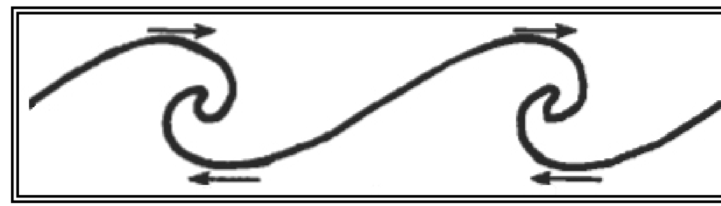


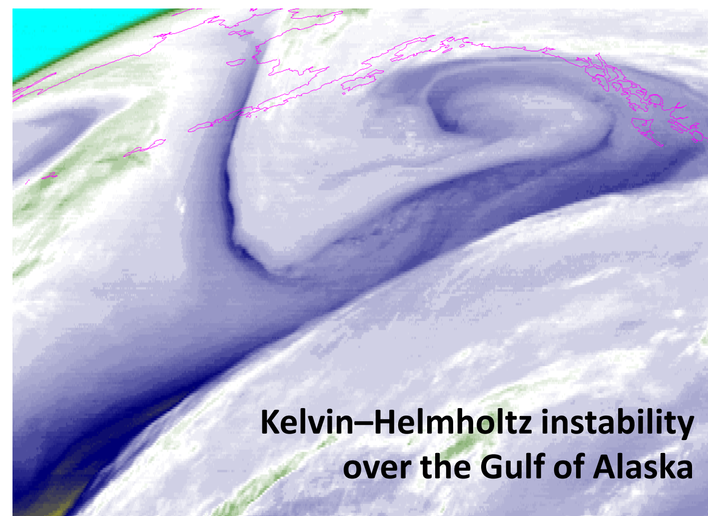


Akatsuki/IR2 displays new cloud types: instabilities and vortices (Icarus, Under Review)

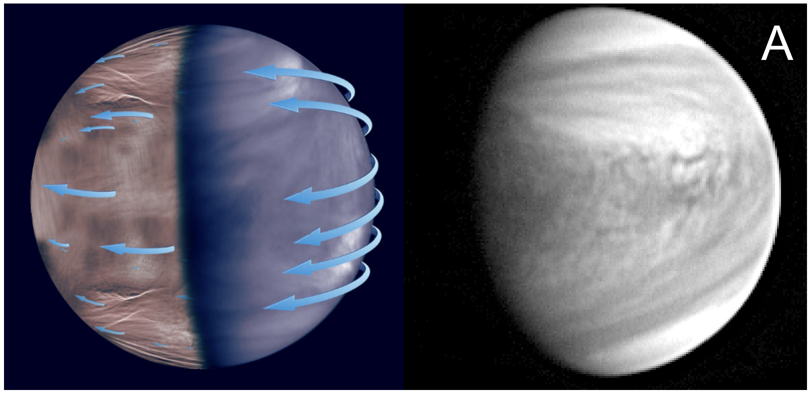


Eddies & Vortices	Instability-like Clouds
Cases: 31	Cases: 22
Length:	Length: 950—6,580 km
90—2,540 km	Wavelength:
Wavelength: N/A	100—2,575 km
Orientation: N/A	Orientation: -40º—+30º





Upper clouds studied with detail from first telescope observations to Akatsuki.



What have we discovered about the upper clouds?

A) Superrotation on nightside upper clouds more “chaotic” tan on the dayside (Peralta et al. 2017).

B) Winds increase along the years (Kouyama et al. 2013; Khatuntsev et al. 2013; Hueso et al. 2015).

C) Solar tides clearly affect the superrotating winds (Hueso et al. 2015; Horinouchi et al. 2018).

D) Space missions have enabled to see upper clouds with impressive detail (Belton 1976; Titov 2012;Yamazaki 2018)