Temperature and Wind in the Venusian Upper Atmosphere Measured by Ground Based Infrared Spectroscopy

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Motivation:

Knowledge about the Global Structure of Venus Atmosphere Dynamics & Temperature in the Upper Atmosphere

Investigations:

- description / explanation of variability in temperatures and winds
  - → on different time scales (wave activity, tides, solar activity)
  - → depending on location of planet
- cross-validation with other detections, ground and space-based
- altitude information due to coop. of different observation techniques
- update of VIRA (currently used standard atmosphere of Venus) [1]
- verifications and update of global circulation models (GCMs) [2,3]

Observing Method & Instruments:

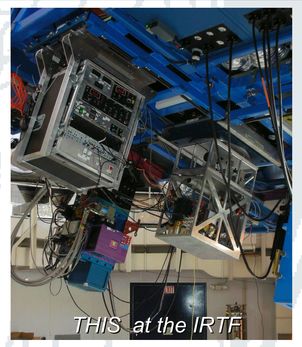
Spectroscopy:
- mid infrared at 10 µm, non-LTE CO_2 emission lines
- temperatures from line widths
- Doppler winds from frequency positions
- probing altitude: ~110±10 km

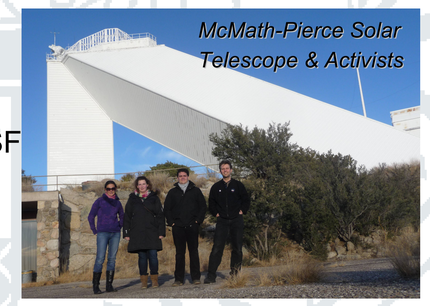
Technique:
- heterodyne* spectrometer; potential: high spectral resolution up to 10^7

Instruments:
- THIS (Tuneable Heterodyne Infrared Spectrometer) Cologne [4]
- HIPWAC (Heterodyne Instr. for Planetary Wind And Composition) NASA GSF

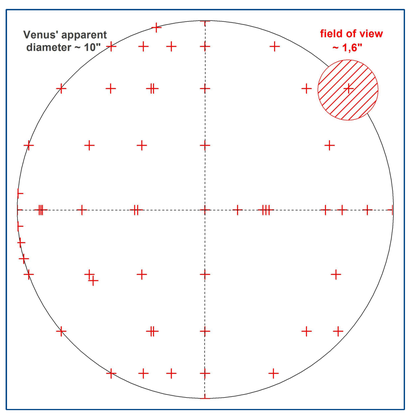
Telescopes:
- McMath-Pierce-Solar Telescope, Kitt Peak, Az, USA
- NASA IRTF, Mauna Kea, Hi, USA


HIPWAC and PIs at the IRTF

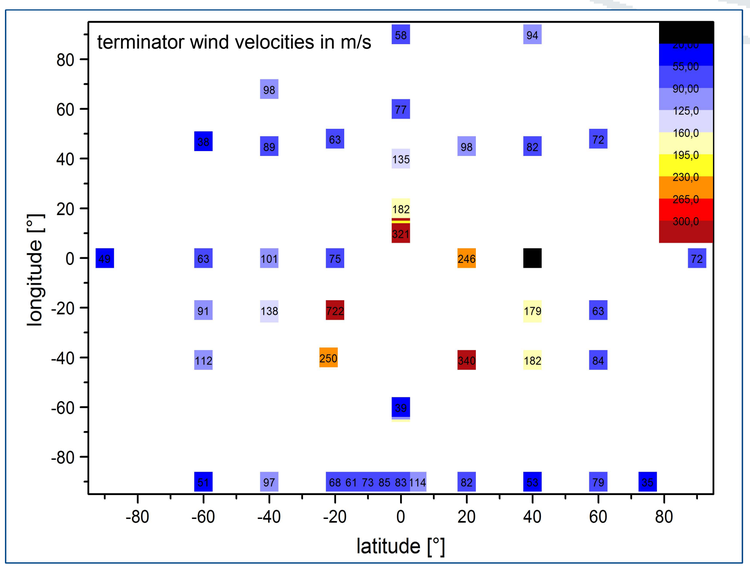

THIS at the IRTF


McMath-Pierce Solar Telescope & Activists

Temperatures and Winds from Observation in June 2011:

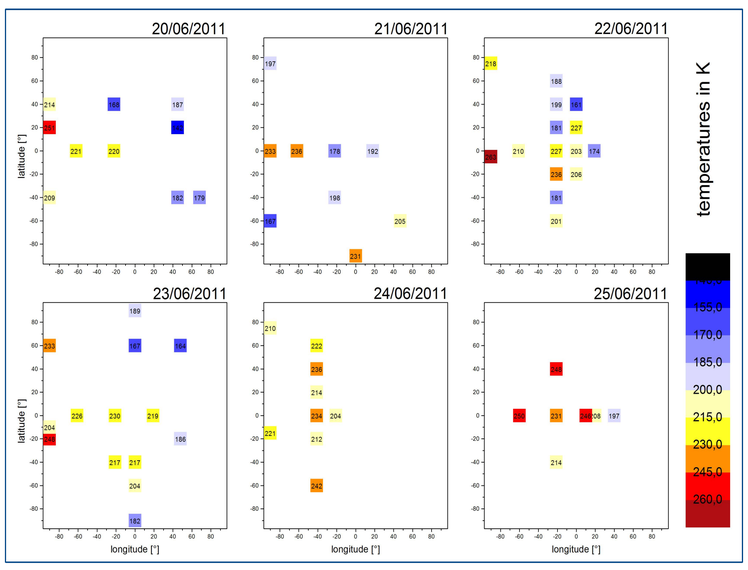


Observing Geometry:
- observed positions (red crosses)
- close to superior conjunction
- illumination: >96%
- apparent diameter: 10” (black circle)
- FOV*: 1.6”(small red circle)
- figure at left gives relative sizes
- 79 position over the entire planetary disk
- obs. taken with THIS on Kitt Peak



Wind Observations:
- terminator velocities [v(term)] retrieved from individual observations
- assumption: pure SS-AS flow following $\sin^2$ decrease with SZA
- expectation: same v(term) for each observation:
  - → in general only small deviation (data in blue)
  - → stronger deviation in the center of the apparent disk (data in red, yellow)
- strong deviation due to geometric issues (small line-of-sight wind component)
- higher v(term) were found in 2009 [8]

Temperature Observations:
- temperature information from width of CO_2 non-LTE emission line
- probing altitude: ~110 ± 10km
- temperatures between 140 – 260K errors: 5 – 10K
- deviations from a simple sub-solar distance behavior
- strong variations within days up to 50K
- temperatures are similar to previous observations in 2009 were
  - → values between 160 - 240K were found
  - → also day-to-day variations up to 50K are higher than found in 2009 [5,6]



Wind Observation at the Equator & CML*:
- CML* observations
  - → follows a SS-AS* flow behavior
  - → $\sin^2$ decrease of flow describes observations better than linear decrease (SZA*)
  - → difference in hemispheres → additional component
- observations at equator
  - → follows roughly a SS-AS* flow behavior but: several strong deviations
  - → no distinct v(term)* behavior
  - → pure SS-AS* flow is not the answer

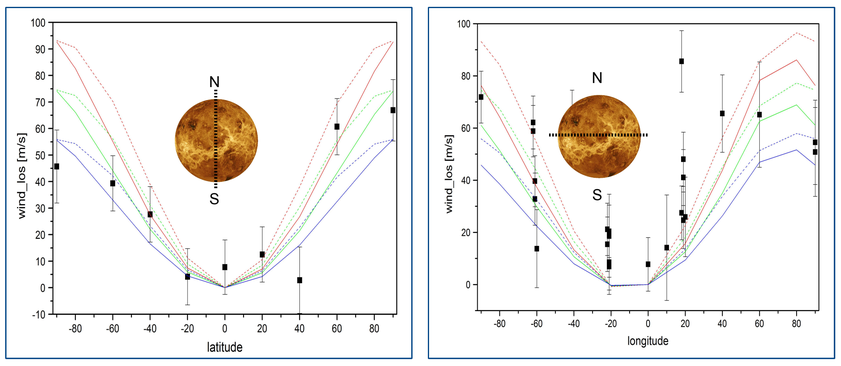
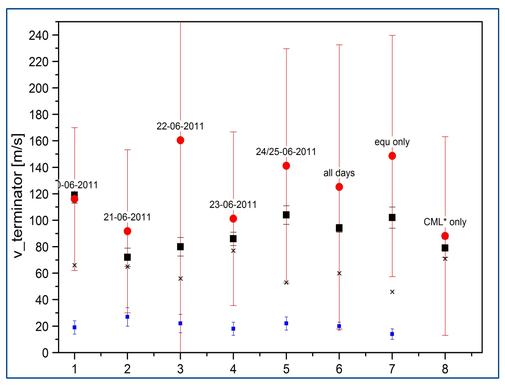


Fig: Measured LOS winds (black) and calculated LOS* winds for a given v(term)*; v(term) = 100m/s (red), 80m/s (green), 60m/s (blue) pure SS-AS flow with a linear (solid) / $\sin^2$ (dashed) decrease with SZA**



Pure SS-AS* Flow vs. Combination of a Global Zonal and SS-AS* Flow:
- mean v(term) retrieved from a set of individual observations (red):
  - → v(term) between 90 - 160m/s
  - → huge SD* show limitation of a pure simple SS-AS* flow assumption
- zonal component (blue) and v(term) (black squares) from two component fits :
  - → additional zonal wind ~ 20m/s
  - → lower v(term): 70 - 120m/s
  - → small confidence (x) corresponds to huge SD* for the pure SS-AS flow case
- conclusion: → additional component (global, periodic)
  - → short term temporal variations

* poster_pedia:

- ***CML:*** Central Meridian Longitude
- ***FOV:*** field-of-view at a given wavelength with a given size of telescope
- ***heterodyne:*** in a heterodyne instrument an infrared signal from the sky gets superimposed to an infrared signal from a laser; the frequencies of the signals are slightly different; a detector is sensitive to the difference signal which is in the radio range (easier to process) and still contains the full spectral information
- ***LOS wind:*** line-of-sight wind
- ***RSZ flow:*** in the case of Venus the “retrograde super-rotation zonal”-flow is fast (faster than the solid body rotation) global flow in the retrograde direction
- ***SD:*** standard deviation
- ***SS-AS flow:*** this global atmospheric feature is the flow from the hot sub-solar point on Venus to the anti-solar point driven by solar insolation
- ***SZA:*** solar zenith angle: angle between the local zenith and the Venus-Sun line
- ***v(term):*** maximum terminator wind velocity of a simple structured global SS-AS flow

Overview of Observations 2010 - 2012:

Table 1: Overview Observations 2011/2012

#	date	telescope	quality of data	remarks
1	2010-08	McMath-Pierce Solar Telescope, Kitt Peak	sparse dataset	due to bad weather
2	2011-06	McMath-Pierce Solar Telescope, Kitt Peak	comprehensive dataset	9 days of obs.
3	2011-11	McMath-Pierce Solar Telescope, Kitt Peak	no data	due to bad weather
4	2012-03	McMath-Pierce Solar Telescope, Kitt Peak	comprehensive dataset	7 days of obs.
5	2012-05	IRTF, Mauna Kea	comprehensive dataset	6 days of obs.

References:

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[8] M. Sornig,et al, Icarus, submitted in 2012