

The Huygens Doppler Wind Experiment
Measuring Titan Atmospheric Dynamics

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Outline

- Winds in the Solar System
- Measuring Winds
- Huygens at Titan : DWE
- Outlook



Winds in the Solar System (1)

- Sun
 - Radial: Solar Wind
 - Zonal: Differential Rotation
- Venus: Superrotation
- Earth
 - Surface (!!)
 - Upper Atmosphere: Jet Streams



Winds in the Solar System (2)

- Mars: Dust Storms
- Jupiter: Banded Zonal Wind System
- Saturn: Ditto, but more symmetric
- Neptune: Retrograde Zonal Wind
- Titan.....



Measuring Winds (1)

- Cloud Tracking
 - Zonal Scales
 - Restricted Altitudes

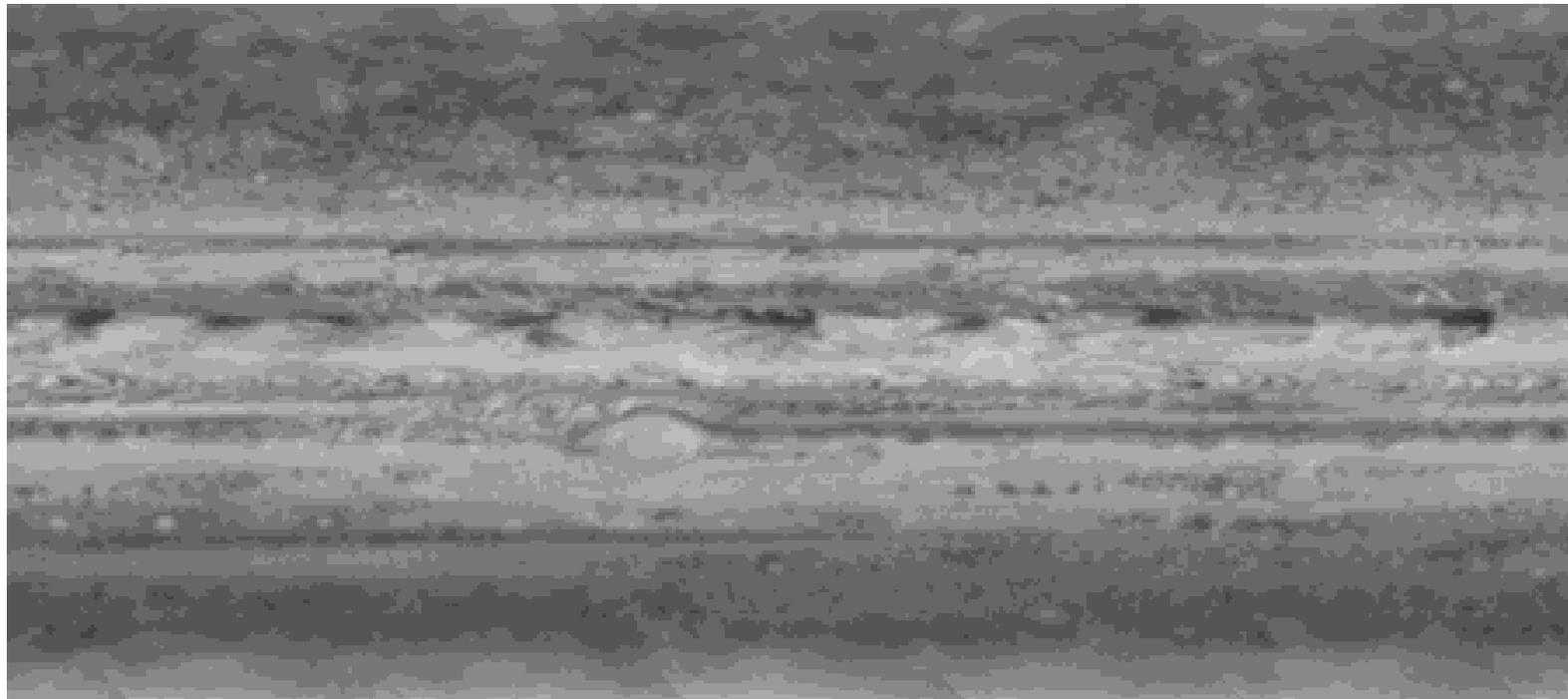


Cassini: Winds on Jupiter

+75°

0°

-75°

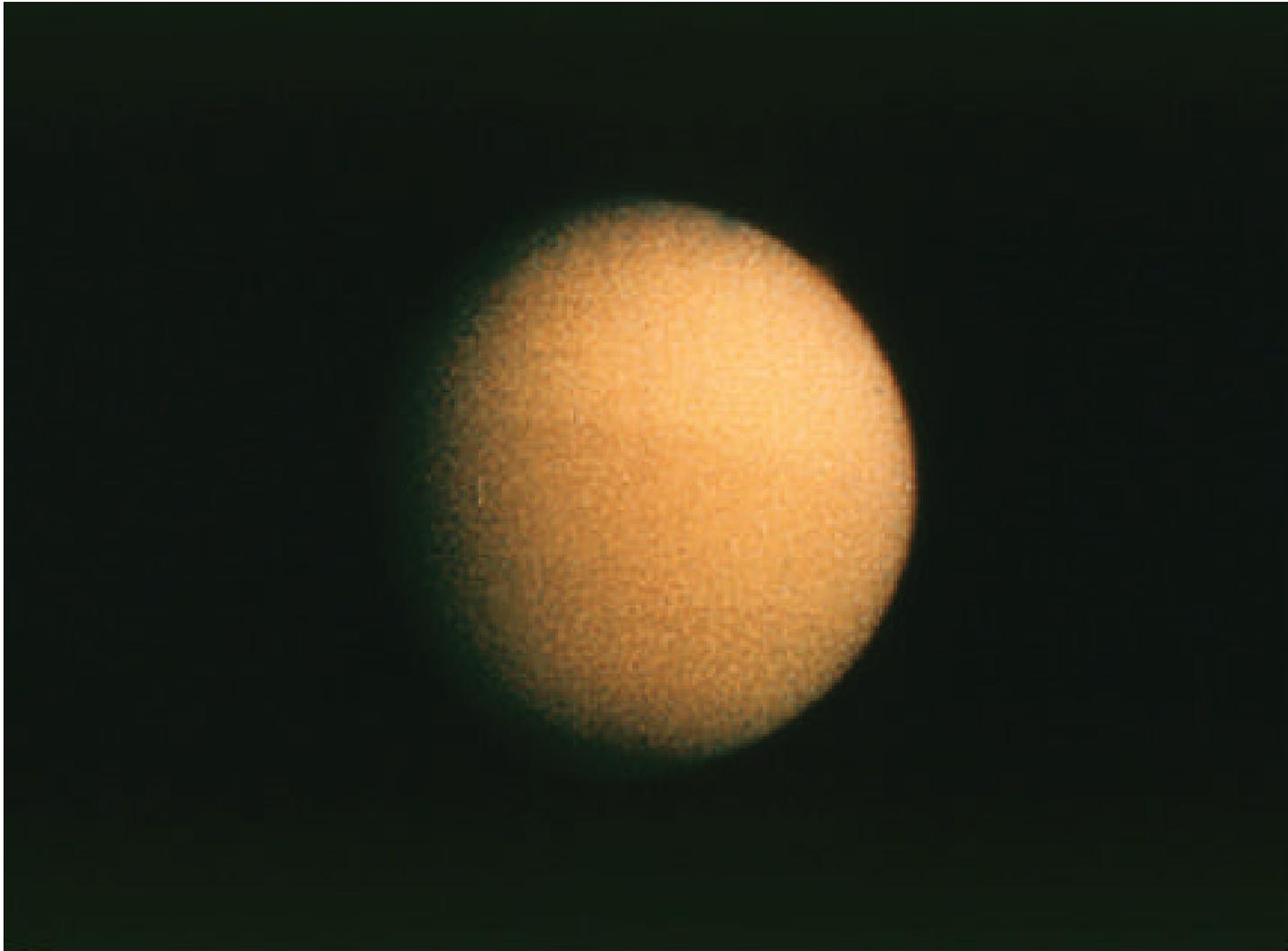


16 April 2004



Huygens DWE

Voyager : *Clouds on Titan*

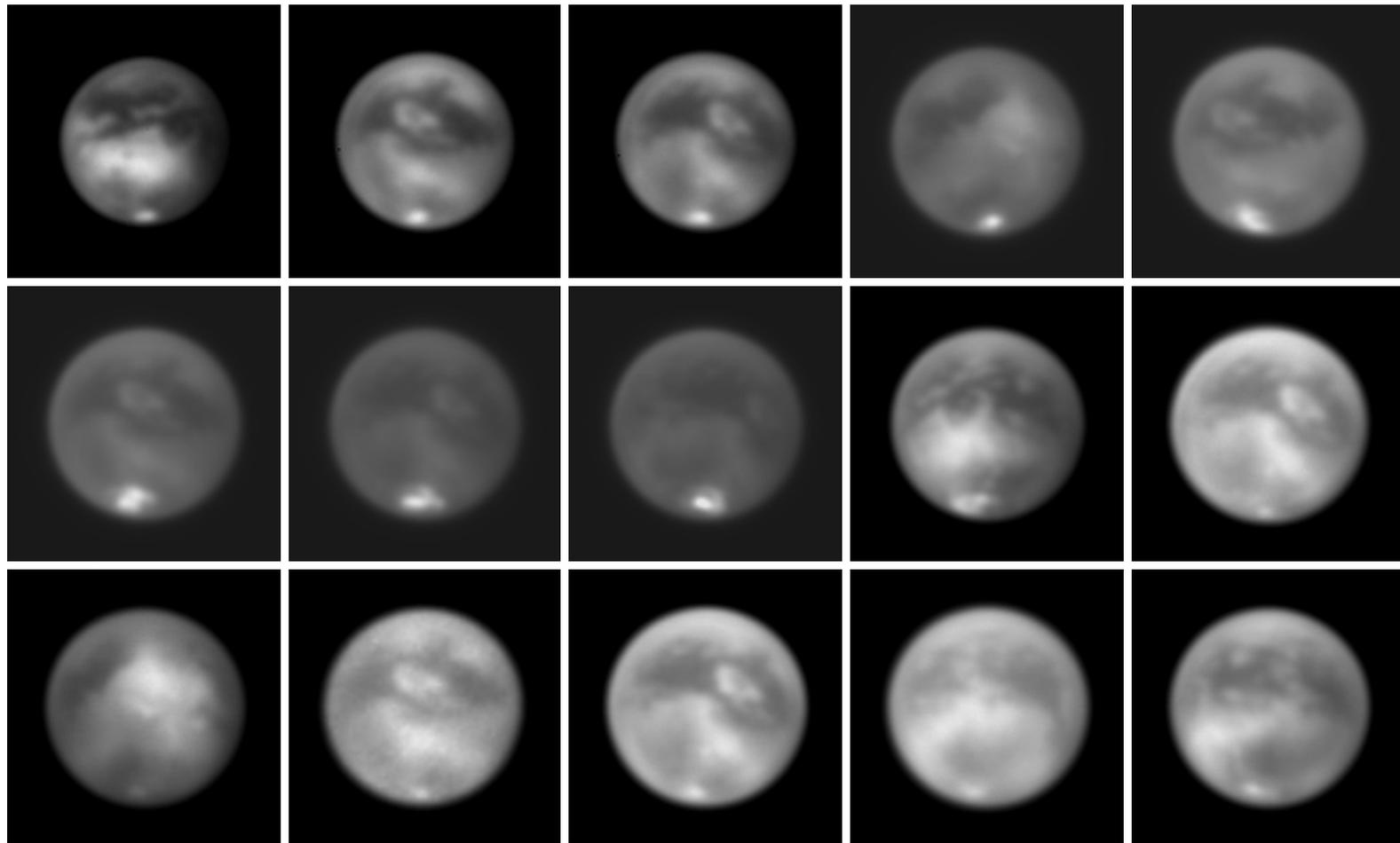


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Huygens DWE

Keck Titan Monitoring Project: Oct. 2003 - Jan. 2004



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Huygens DWE

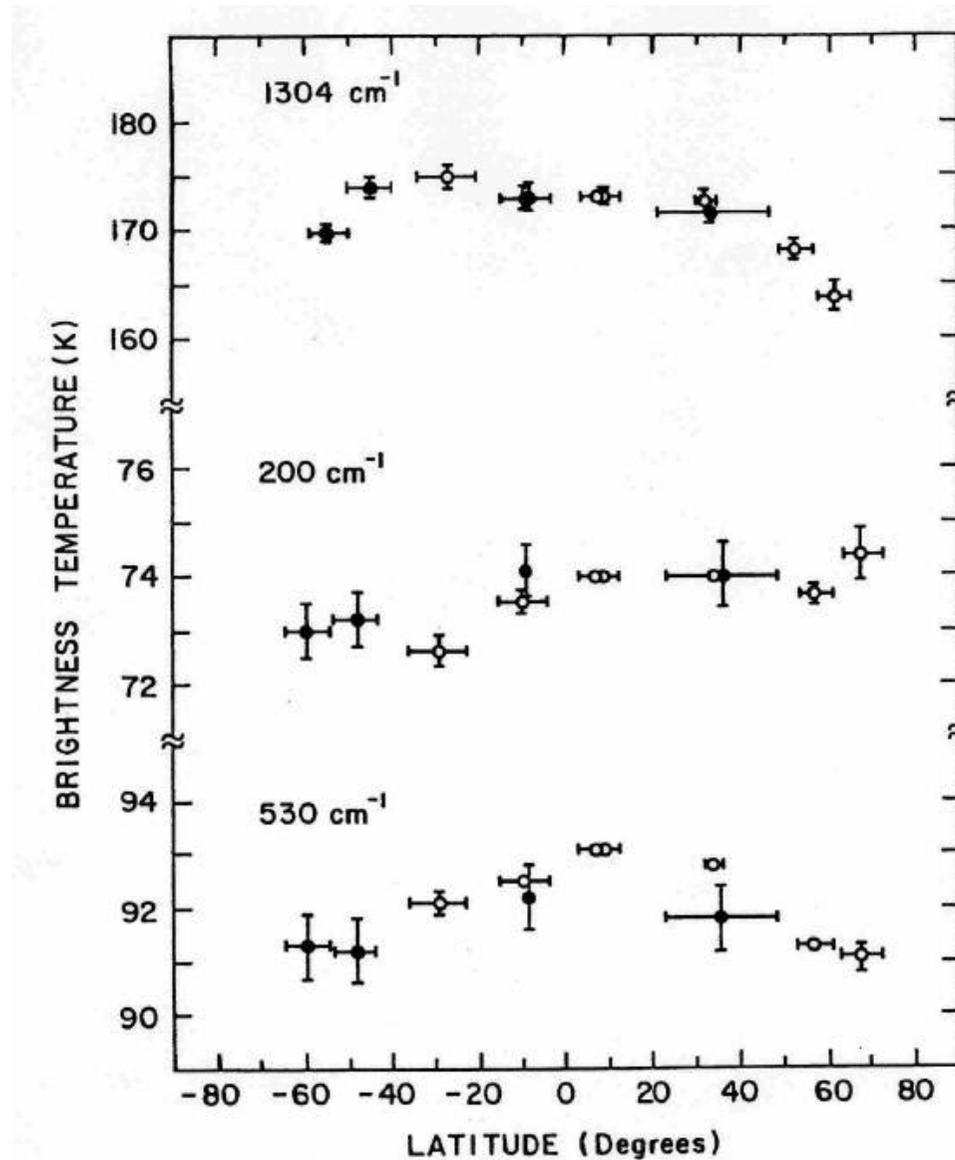
Measuring Winds (2)

Global Scale, Variable Altitude

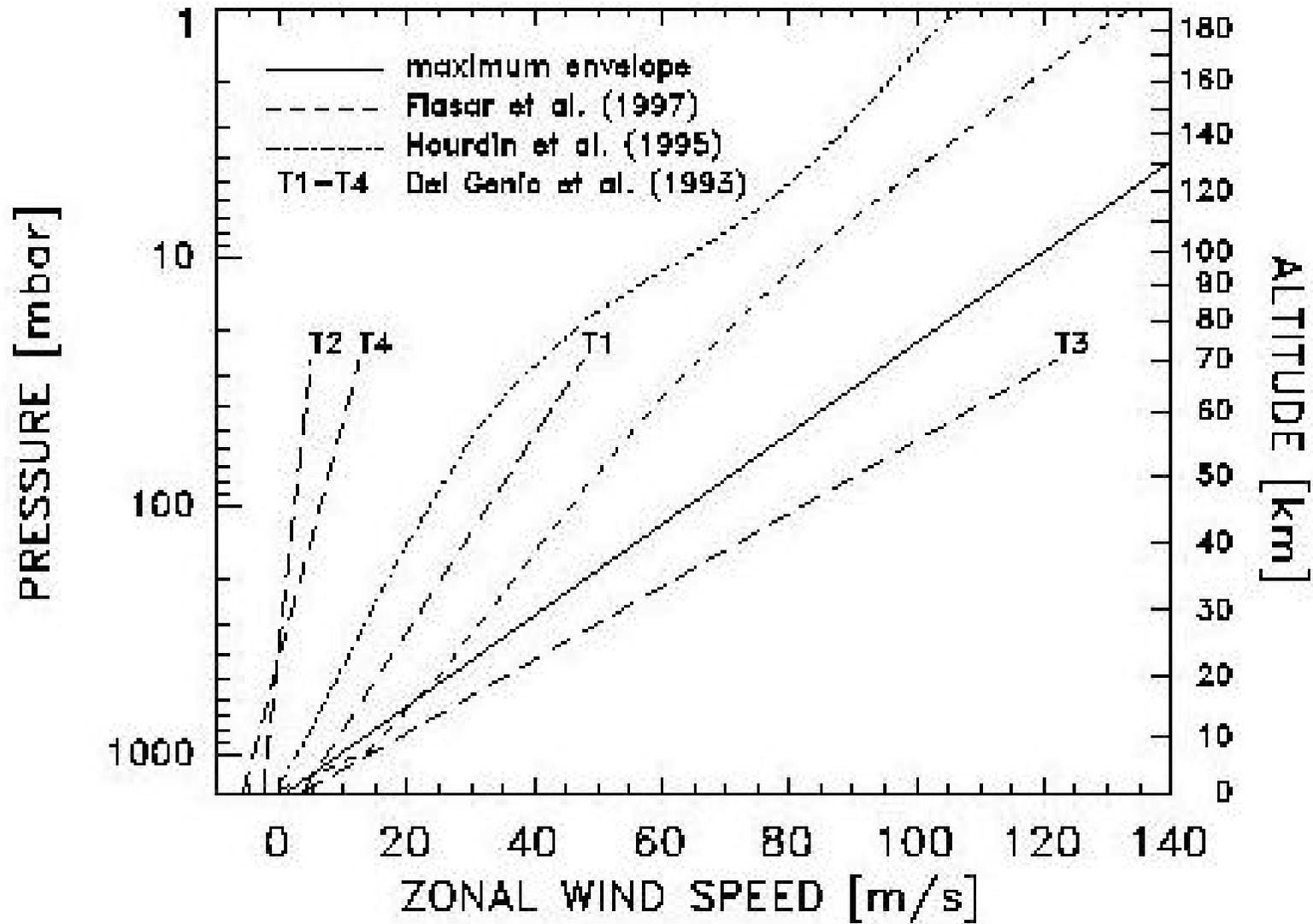
- Indirect Indicators
 - Latitudinal Temperature Contrast
 - Oblate Isobars (Stellar Occultations)



Voyager: IRIS Titan temperatures



Zonal Wind Models



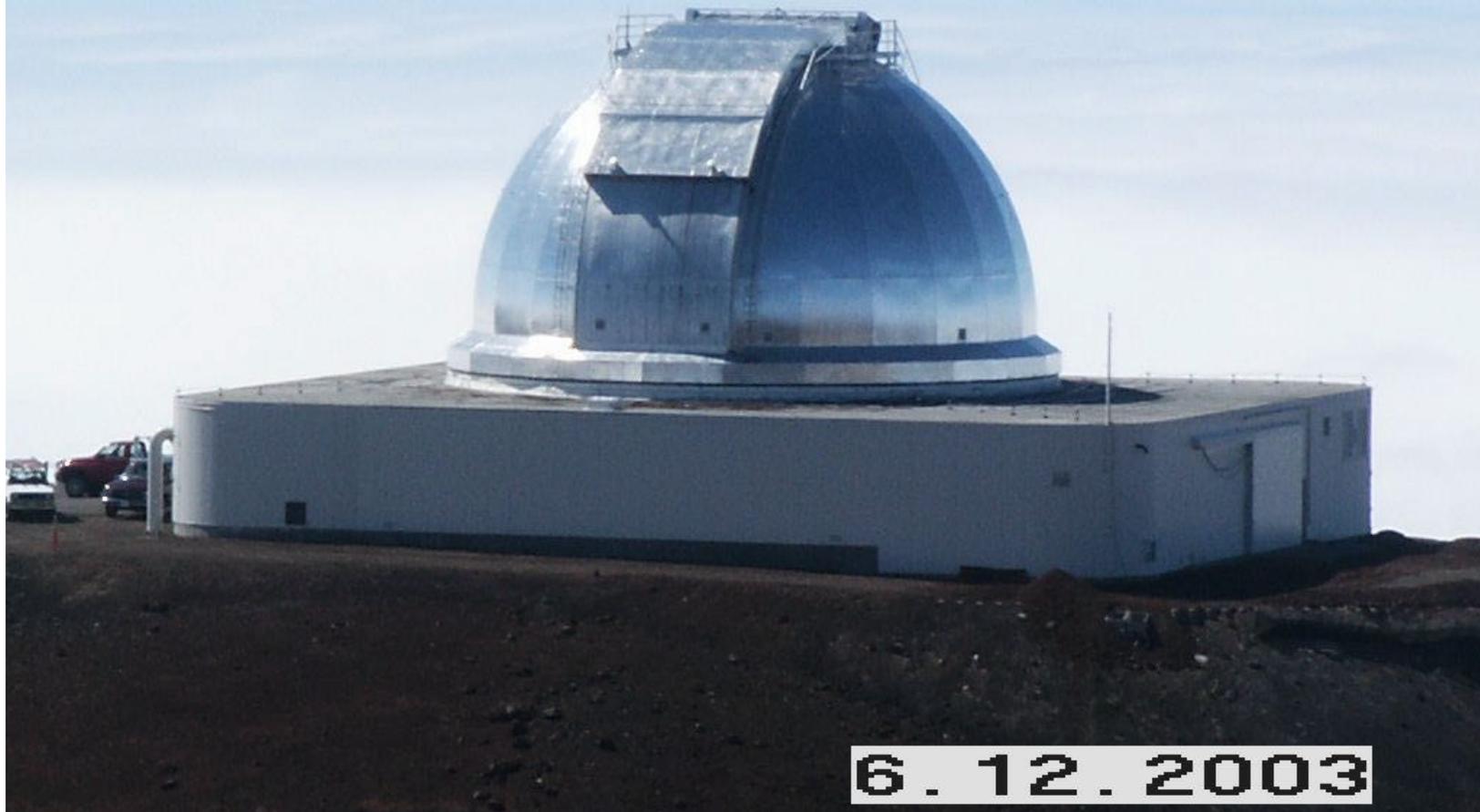
Measuring Winds (3)

Global Scale, Variable Altitude

- Direct (Doppler) Methods
 - IRTF/Subaru 12 μm Ethane Emission Lines
(Kostiuk et al., 2002)
 - VLT-UVES Optical Spectra
(Luz et al., 2004)
 - Plateau de Bure Submm Lines
(Marten et al., 2004)



NASA Infrared Telescope Facility, IRTF
Mauna Kea , Hawaii

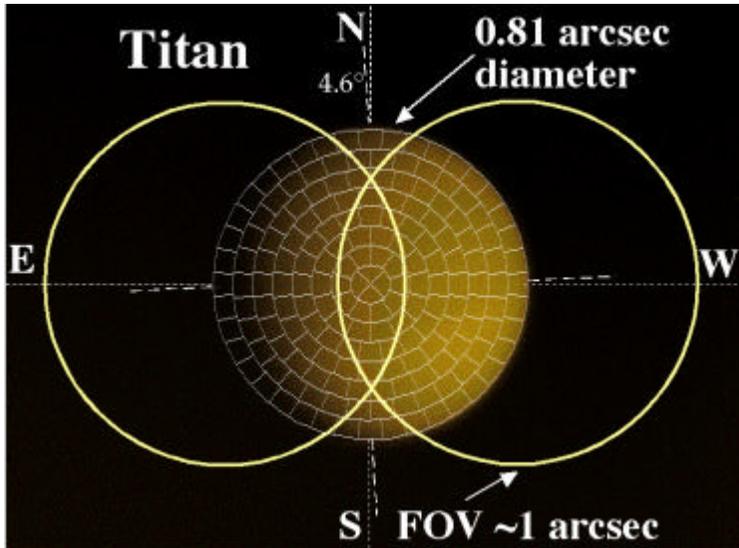


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Huygens DWE

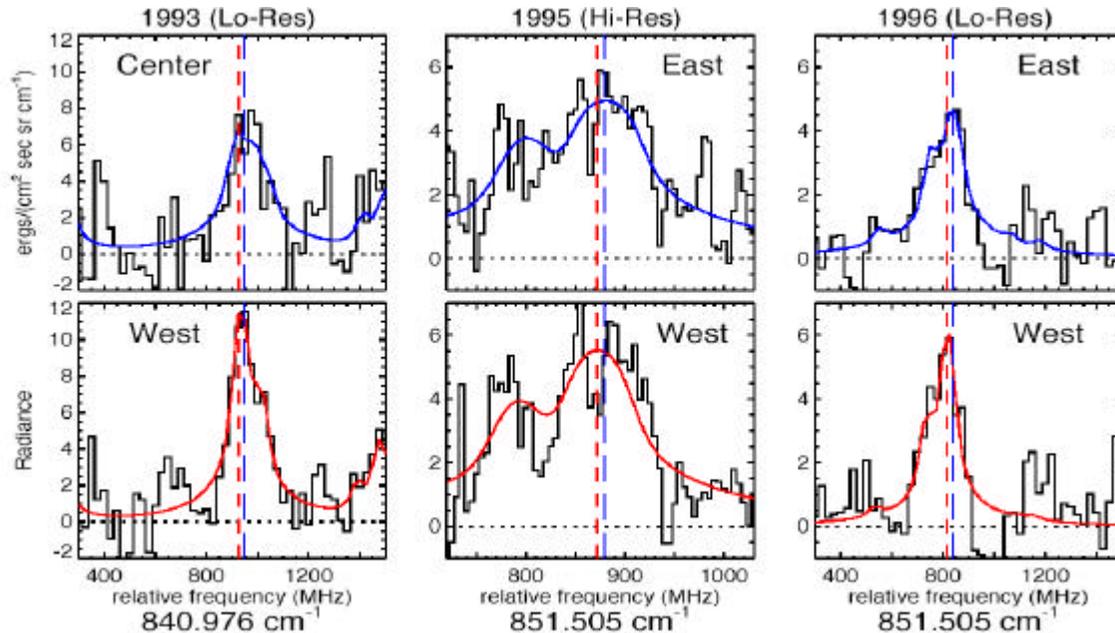
First Direct Measurement of Winds on Titan



GSFC Infrared Heterodyne Spectrometer at NASA IRTF, Mauna Kea, Hawaii

Doppler Shifts of Ethane Emission Lines from Titan's E - W Atmosphere

Zonal Wind is Prograde
Speed ~ 210±150 m/s



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Huygens DWE

Mauna Kea: *Subaru*

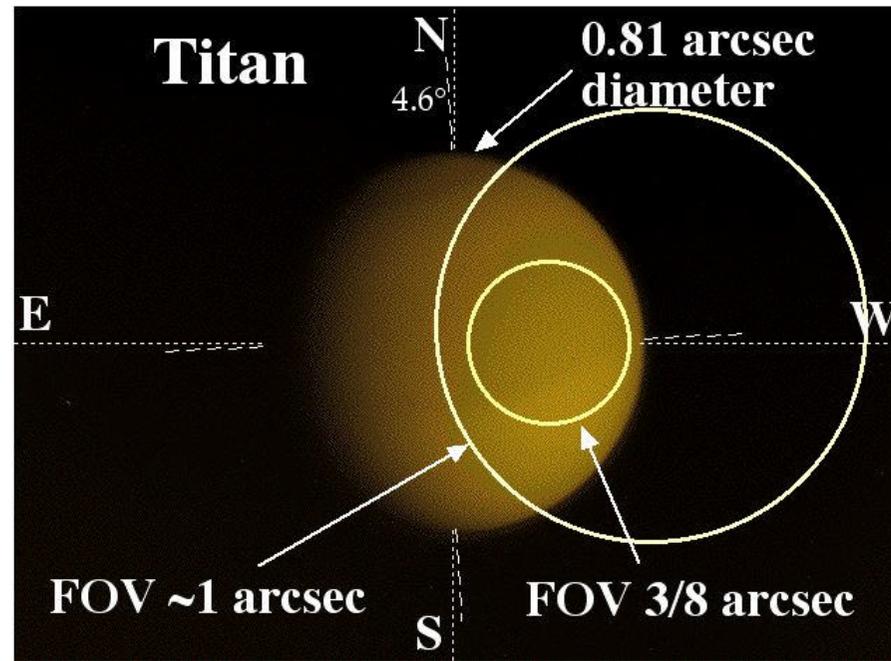


16 April 2004

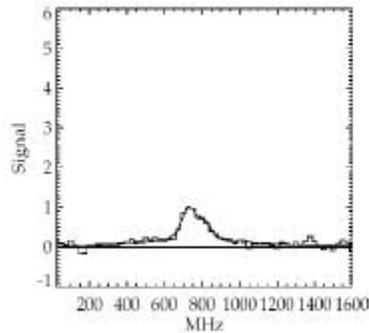


Huygens DWE

HIPWAC Improvement for 8-m Subaru vs. 3-m IRTF

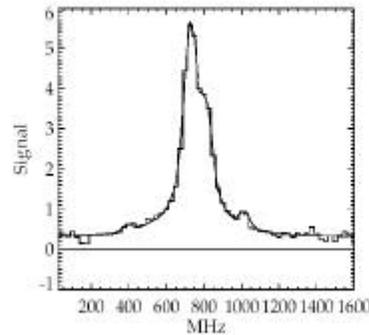


a. IRTF

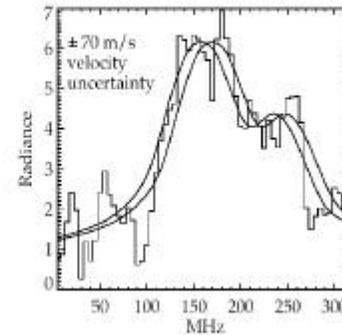


Low (0.0008 cm^{-1}) Resolution
Intensity

b. Subaru

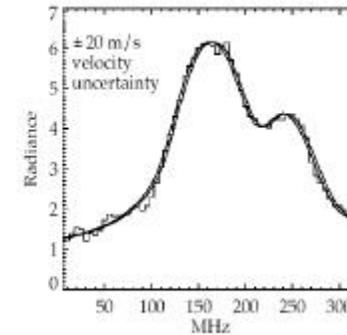


c. IRTF



High (0.00016 cm^{-1}) Resolution
Noise/Velocity Retrieval

d. Subaru

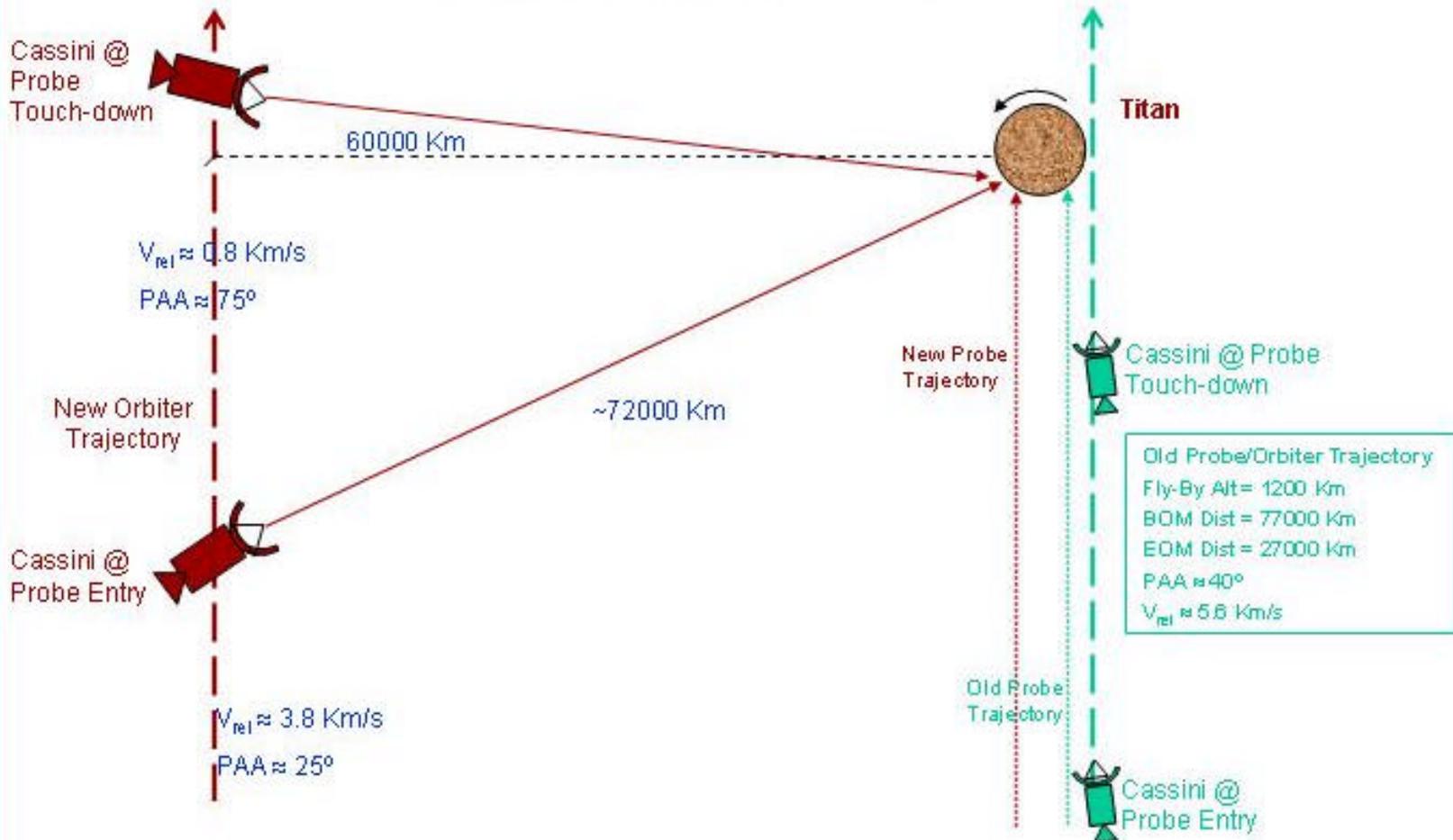


Huygens at Titan: DWE

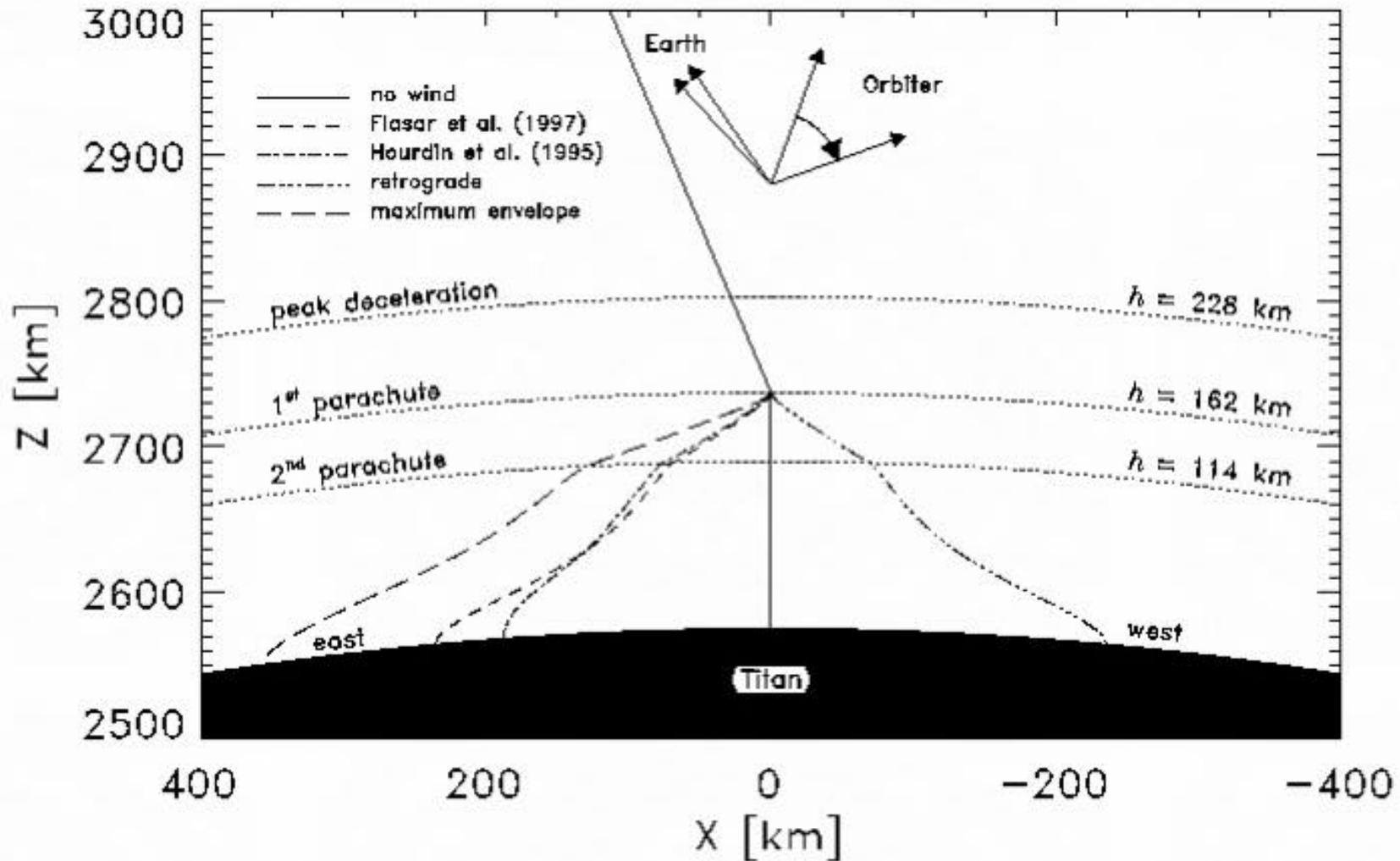
- *In situ* determination of zonal wind speed along Huygens descent path
- *Approach*: Measure radio Doppler shift of Huygens carrier signal => radial velocity
 - Input parameters:
 - Huygens descent speed, meridional speed
 - Huygens starting position
 - Cassini position & velocity



New vs. Old Mission



Huygens Descent Paths on Titan



Wind Retrieval

Doppler shift: $f_R = -\frac{v_{LS}}{c} \cdot f_0$

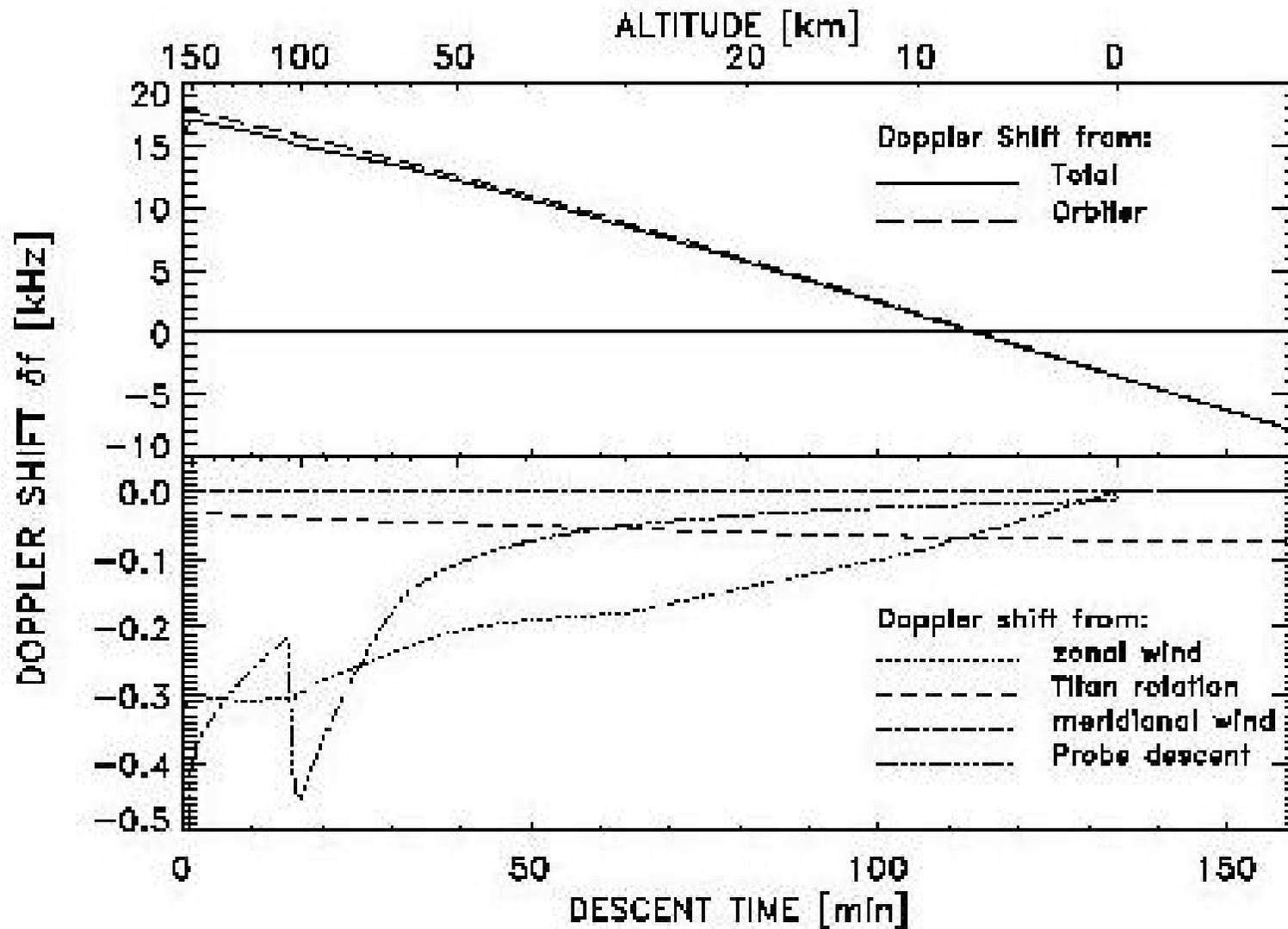
$$v_{LS} = (\vec{v}_{des} + \vec{v}_{NS} + \vec{v}_{EW} - \vec{v}_C) \cdot \vec{n}_{LS} \quad \text{in IAU-Titan Frame}$$

$$\Rightarrow v_{EW} = \frac{1}{\text{COS}g_{DWC}} (v_{LS} + v_C \cdot \text{COS}g_C - v_{des} \cdot \text{COS}g_{des} - v_{NS} \cdot \text{COS}g_{NS})$$

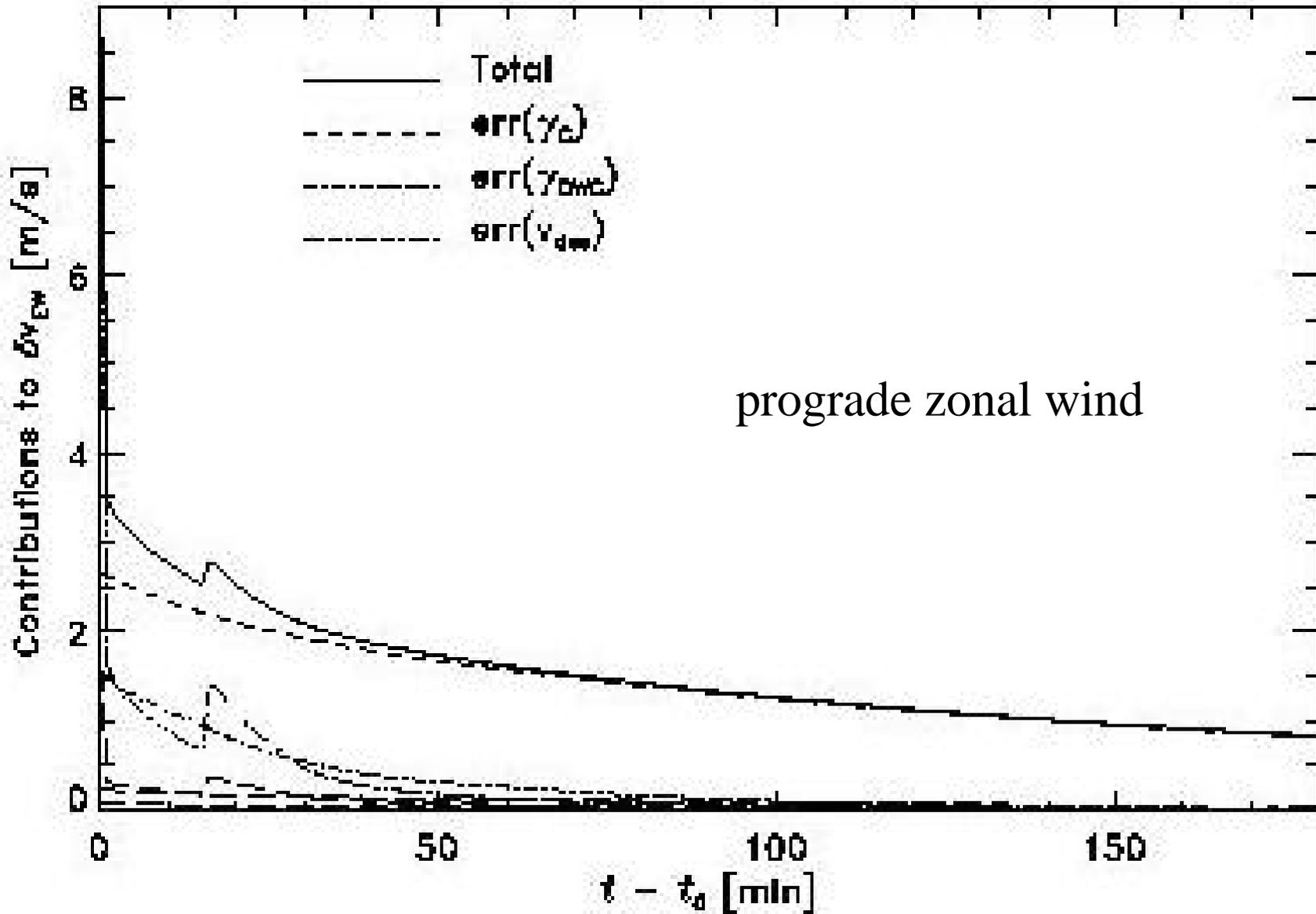
Error Analysis $\text{err}(x) = \left| \frac{\partial v_{EW}}{\partial x} dx \right|$



Doppler Contributions



Error Contributions

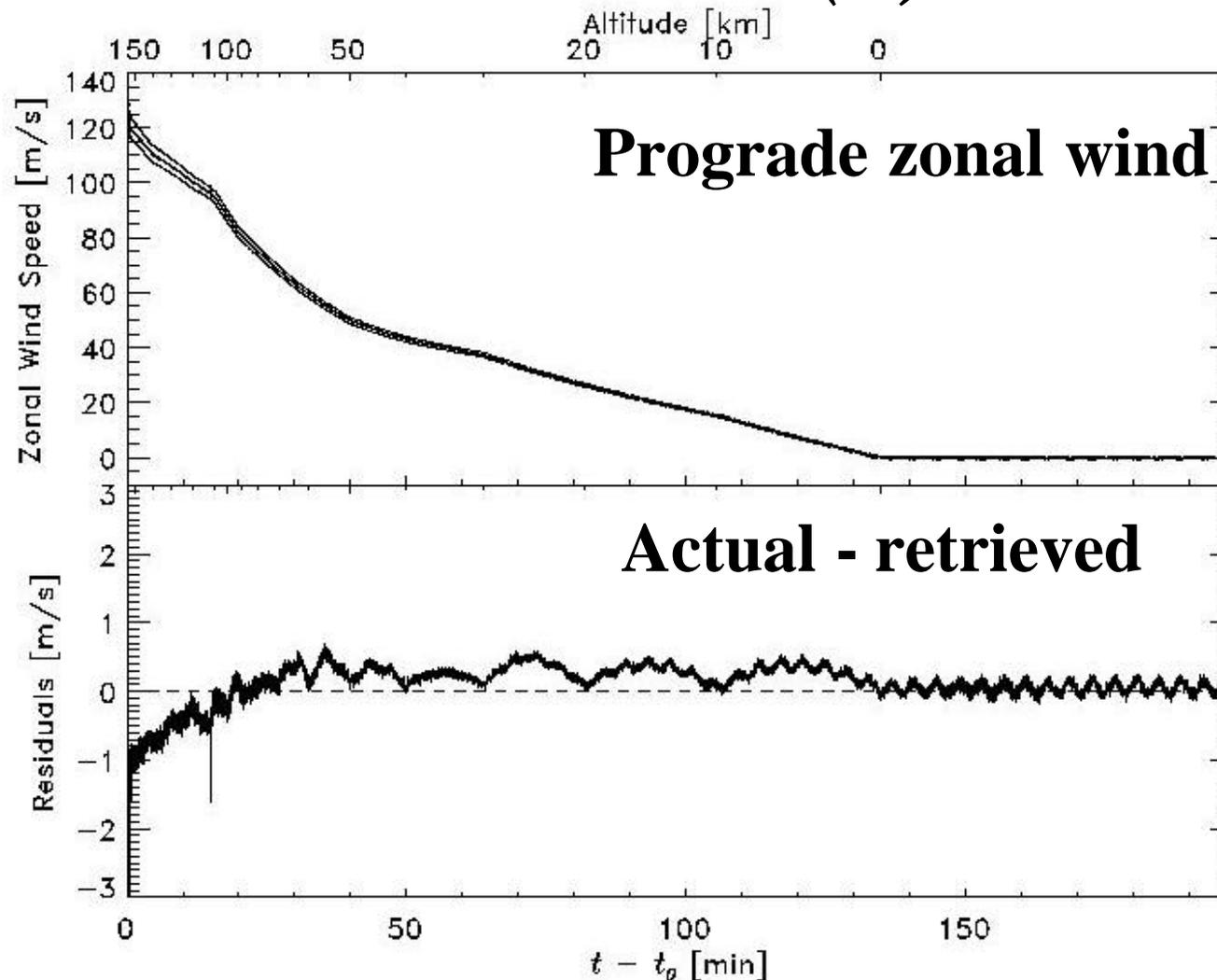


Wind Retrieval Simulation

- Simulation data constructed as follows:
 - in-flight checkout data (F8) as zero reference
 - Cassini trajectory predictions
 - nominal descent model
 - zonal wind: prograde or retrograde
 - meridional wind: ± 1 m/s



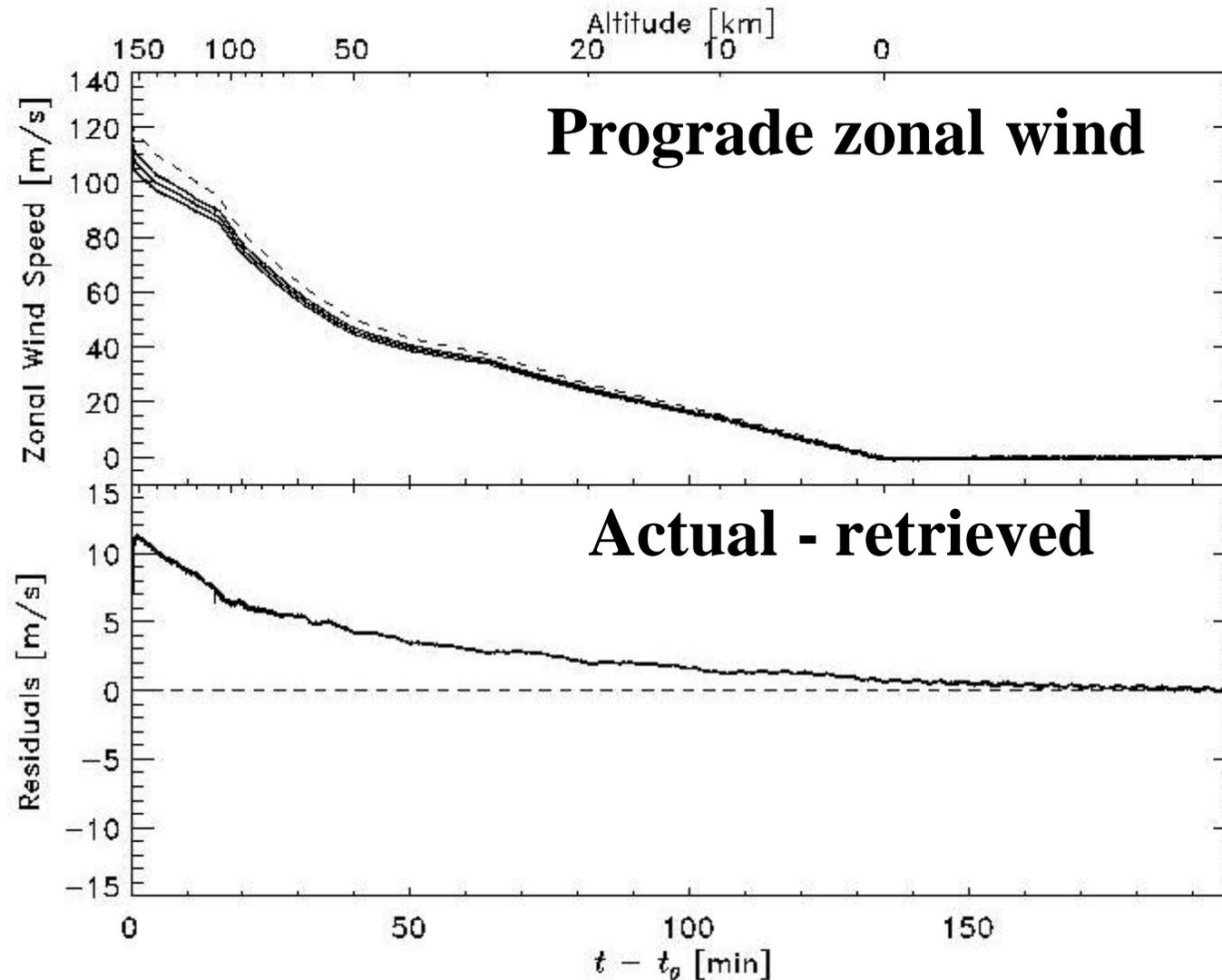
Simulation Results (1)



assumed initial position = true initial position



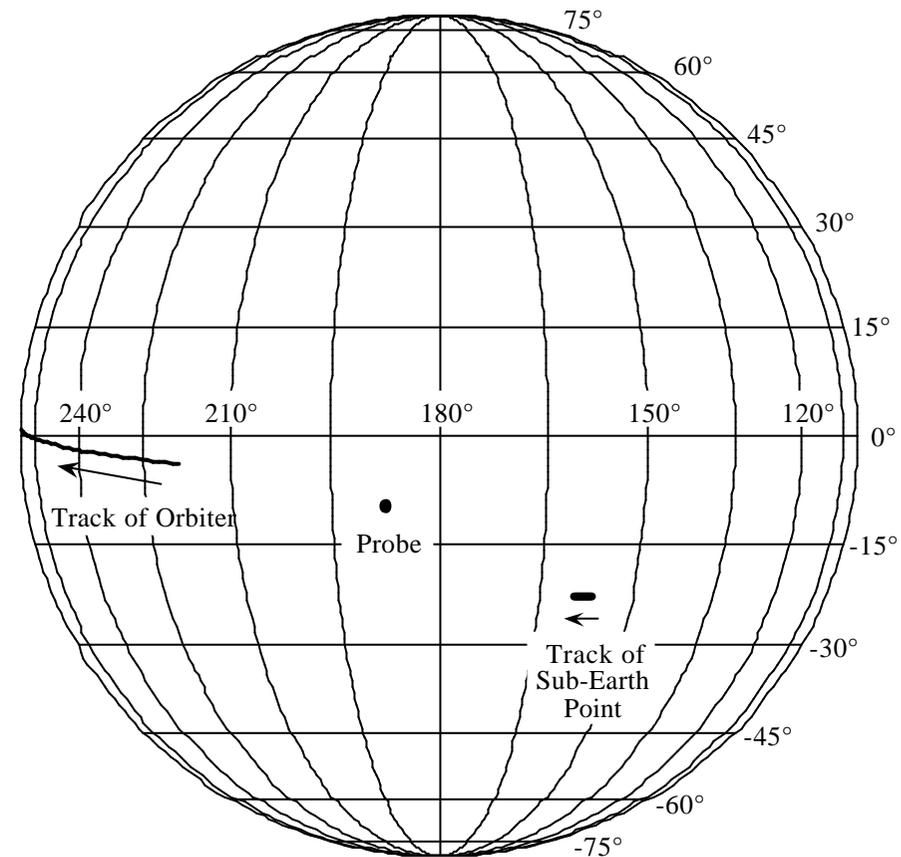
Simulation Results (2)



assumed initial longitude = true initial long. + 50 km

DWE from Earth: Geometry

- Huygens descent (14 Jan 2005)
 - antenna pointed $\sim 30^\circ$ from Earth
 - Better SNR than GLL Probe
- Probe velocity projection in direction to Earth nearly antiparallel to projection in direction to Orbiter
 - Separation may allow discrimination of meridional wind component
- Huygens descent in view over Pacific Ocean



Outlook at t_0 – 9 months

- Robust DWE wind retrieval algorithm
 - Systematic errors of longitudinal position and zonal wind speed decrease during descent
 - Moderate meridional motion and latitudinal position errors have virtually no impact
 - Relative wind profile (wind shear) retrievable with cm/s accuracy
- Huygens Mission: Go / NoGo

DWE Vote: Go!

