Saturn Atmospheric Results from Cassini/VIMS 07-25-2006

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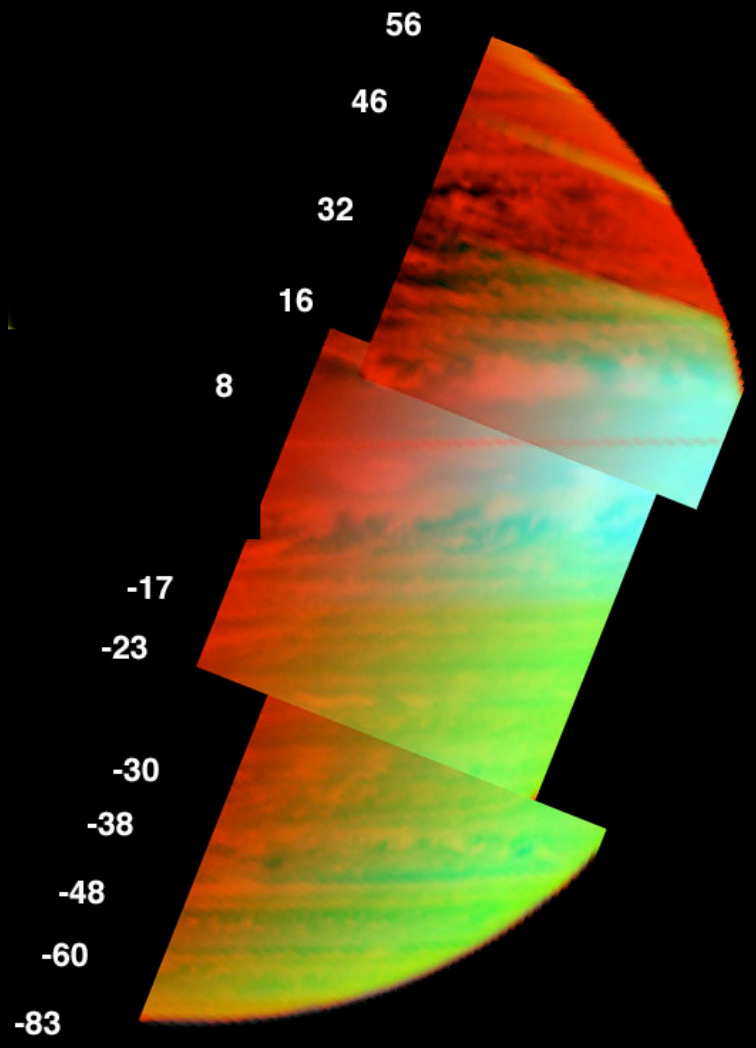
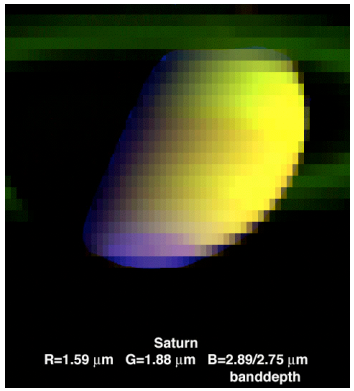
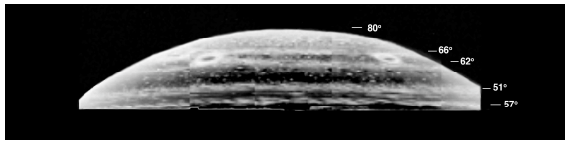
and the
Cassini/VIMS Science Team

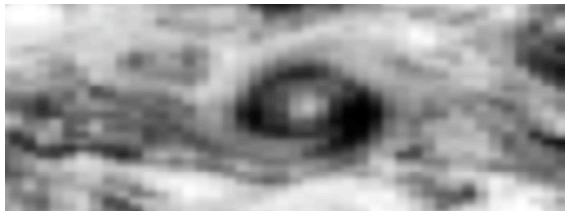


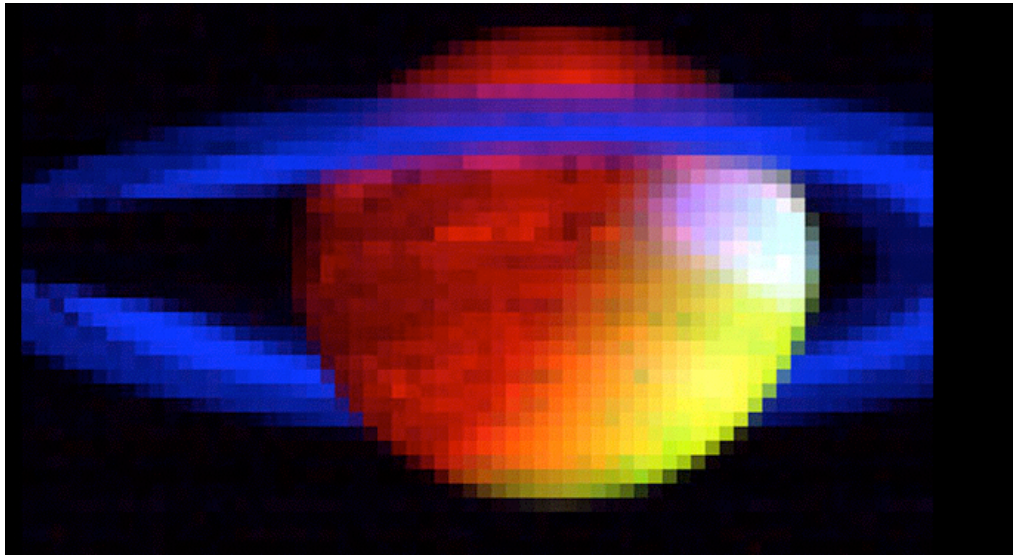
Agenda

- Cassini Overview:
  - Goals at Saturn
  - General Methods
- VIMS Instrument
- Composition
- 3-D Cloud
- Winds









Saturn Atmospheric Science

- Atmospheric Science Goals
  - Thermal structure
  - Dynamics and Weather
  - Composition
  - Internal structure

Saturn Atmospheric Science

How do we achieve these goals?

- Remote sensing:
  - Reflected Solar radiation
    - ISS, UVIS, and VIMS
  - Internally produced radiation (e.g. thermal)
    - CIRS and VIMS
  - Emission by energetic particles (e.g. auroral)
    - CIRS, ISS, UVIS, and VIMS
- In-situ:
  - Occultations of Saturn
  - Gravitational passes
    - RSS
  - Probes, but Saturn will have to wait :(

Cassini Remote Sensing Instruments: Spectral Coverage

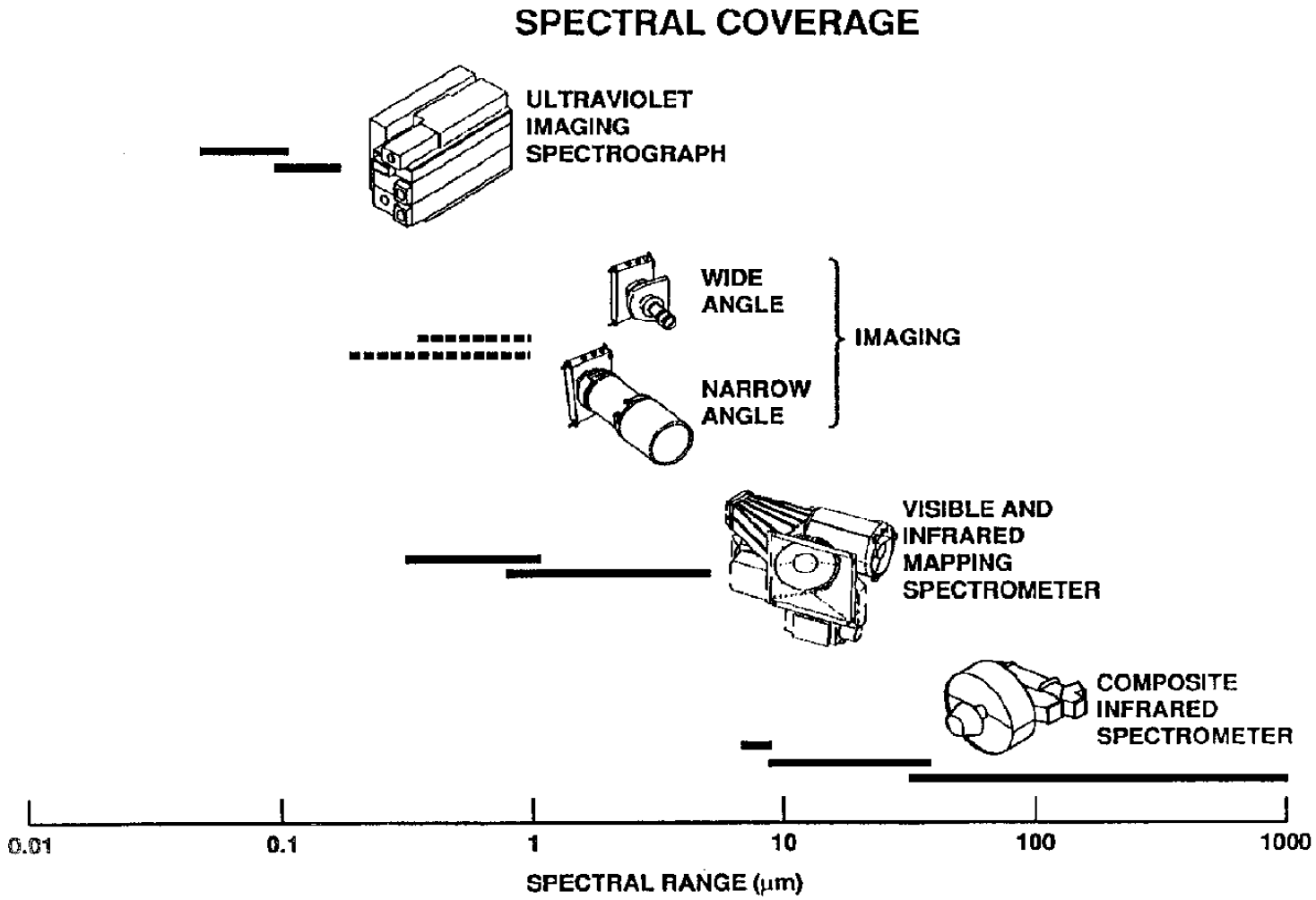
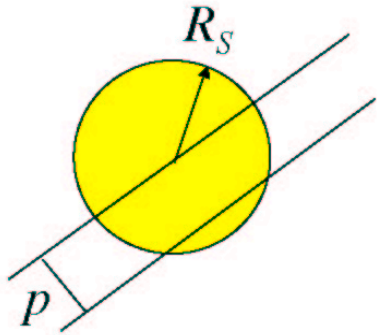


Fig. 3

Cassini Atmospheric/Ionospheric Occultations: Scientific Objectives

- Determine the global fields of temperature, pressure, and winds in the stratosphere and troposphere of Titan and Saturn
- Determine the small scale structure due to eddies and waves
- Constrain the distribution of methane in Titan's atmosphere
- Improve the H_2/He ratio in Saturn's troposphere
- Determine the variations in NH_3 abundance in Saturn's atmosphere
- Search for Titan's ionosphere; interaction with Saturn's magnetosphere
- Study the behavior of Saturn's ionosphere with latitude and solar zenith angle; investigate its interaction with rings and magnetosphere



- Orbit Geometry Required
  - Sufficient Number of Occultations that
    - Cover the Northern and Southern hemispheres
    - are well distributed in latitude
  - Non-Grazing Occultations ($p/R_S < \sim 0.7$)

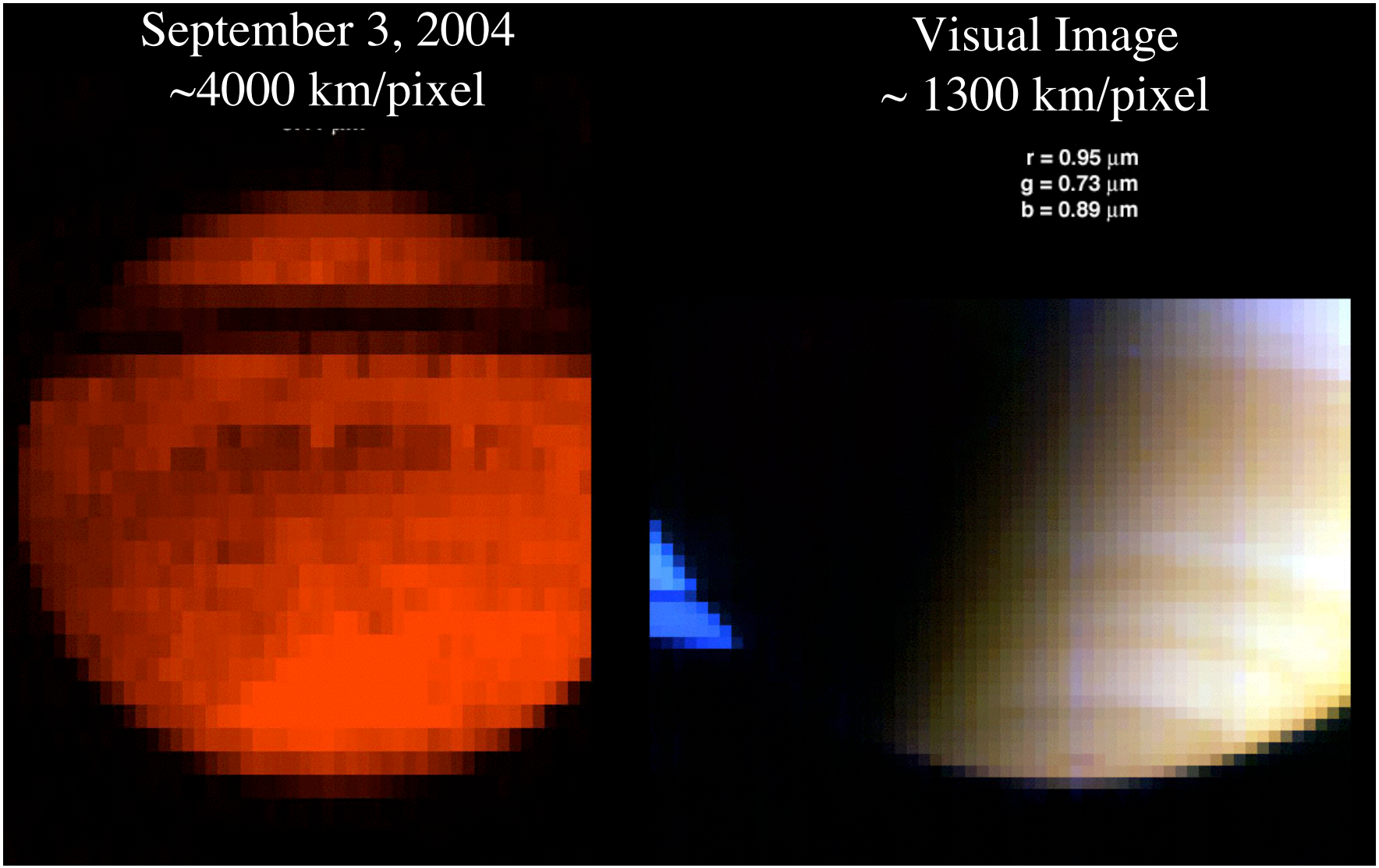
VIMS

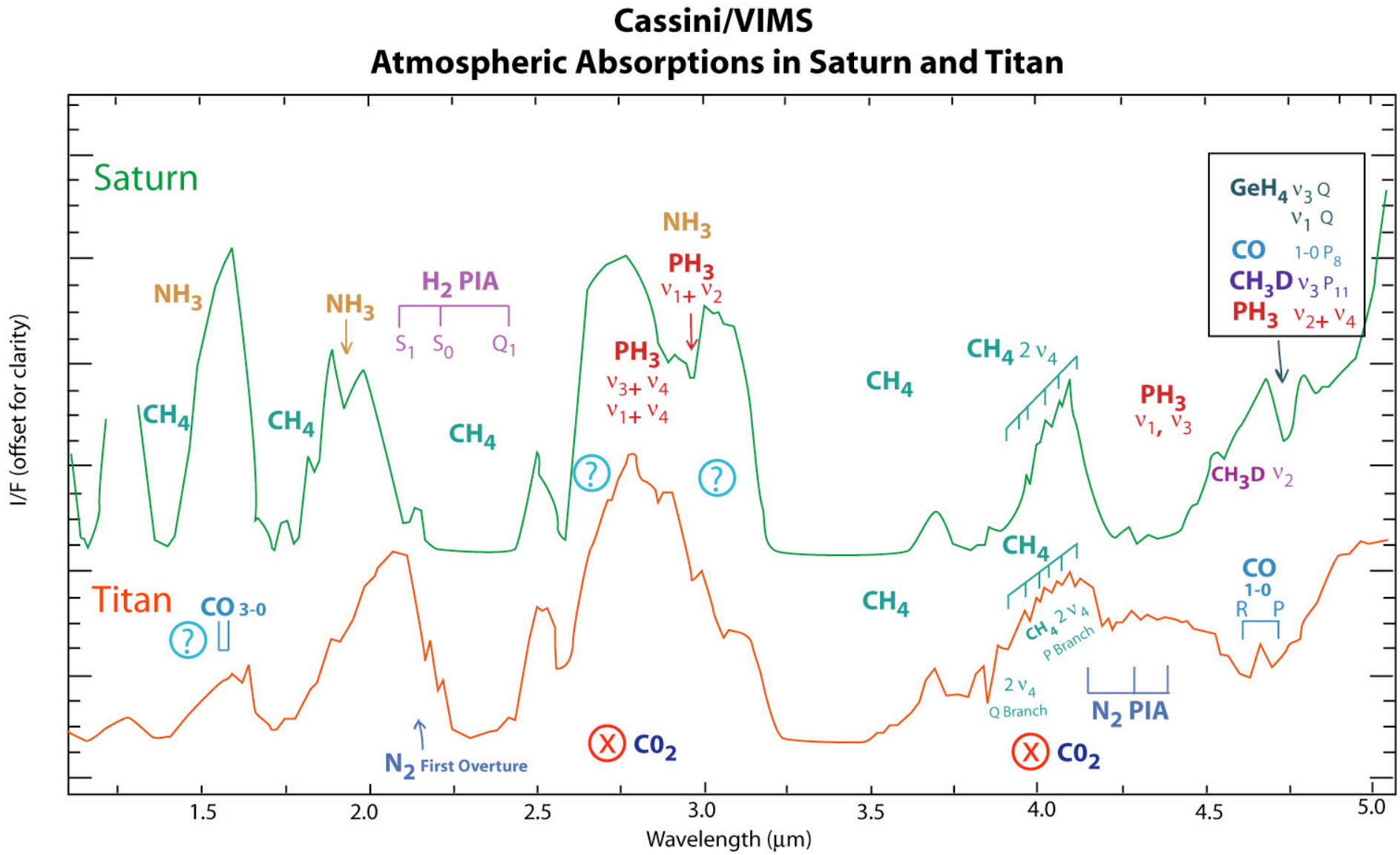
Visual and Infrared Mapping Spectrometer

- 0.35 to 5.2 microns in 352 wavelengths
- IFOV: 0.5 x 0.5 mrad (standard)
- High resolution IR: 0.5 x 0.25 mrad
- High resolution VIS: 0.17 x 0.17 mrad
- Images up to 64 x 64 pixels square.

SATURN IN A NEW LIGHT:

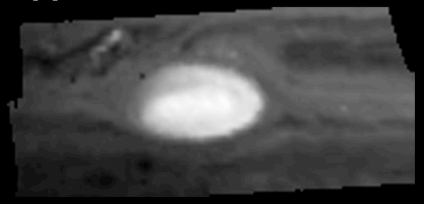
Thermal Glow vs Reflected Sunlight




Cassini/VIMS
Atmospheric Absorptions in Saturn and Titan
Saturn
Titan
NH3
CH4
NH3
CH4
H2 PIA
S1 S0 Q1
CH4
NH3
PH3
ν1+ ν2
PH3
ν3+ ν4
ν1+ ν4
CH4
CH4 2 ν4
PH3
ν1, ν3
GeH4 ν3 Q
ν1 Q
CO 1-0 P8
CH3D ν3 P11
PH3 ν2+ ν4
CH3D ν2
CO 3-0
CH4
CH4 2 ν4
P Branch
2 ν4
Q Branch
N2 PIA
CO
1-0
R P
N2 First Overture
CO2
CO2
I/F (offset for clarity)
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Wavelength (μm)

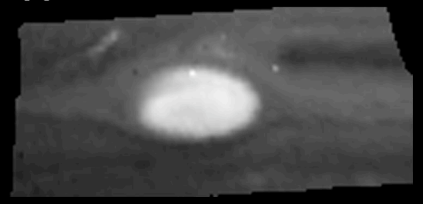
Vertical Structure and Ammonia Ice in the Great Red Spot and Environs

Upper Level Clouds/Hazes



1.94 μm

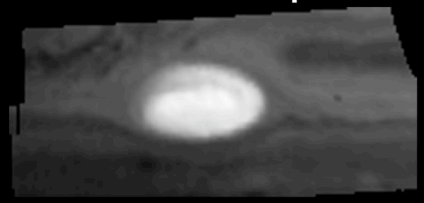
Upper Level Clouds/Hazes



RED

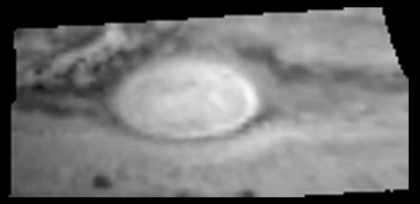
2.05 μm

Ammonia Absorption



1.99 μm

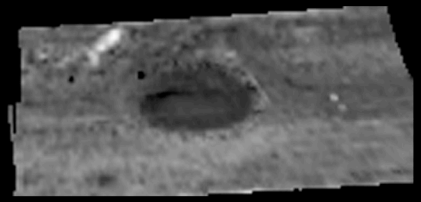
Tropospheric Clouds/Hazes



GREEN

1.60 μm

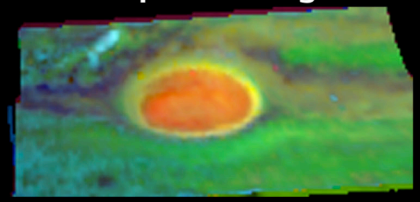
Ammonia Band Depth

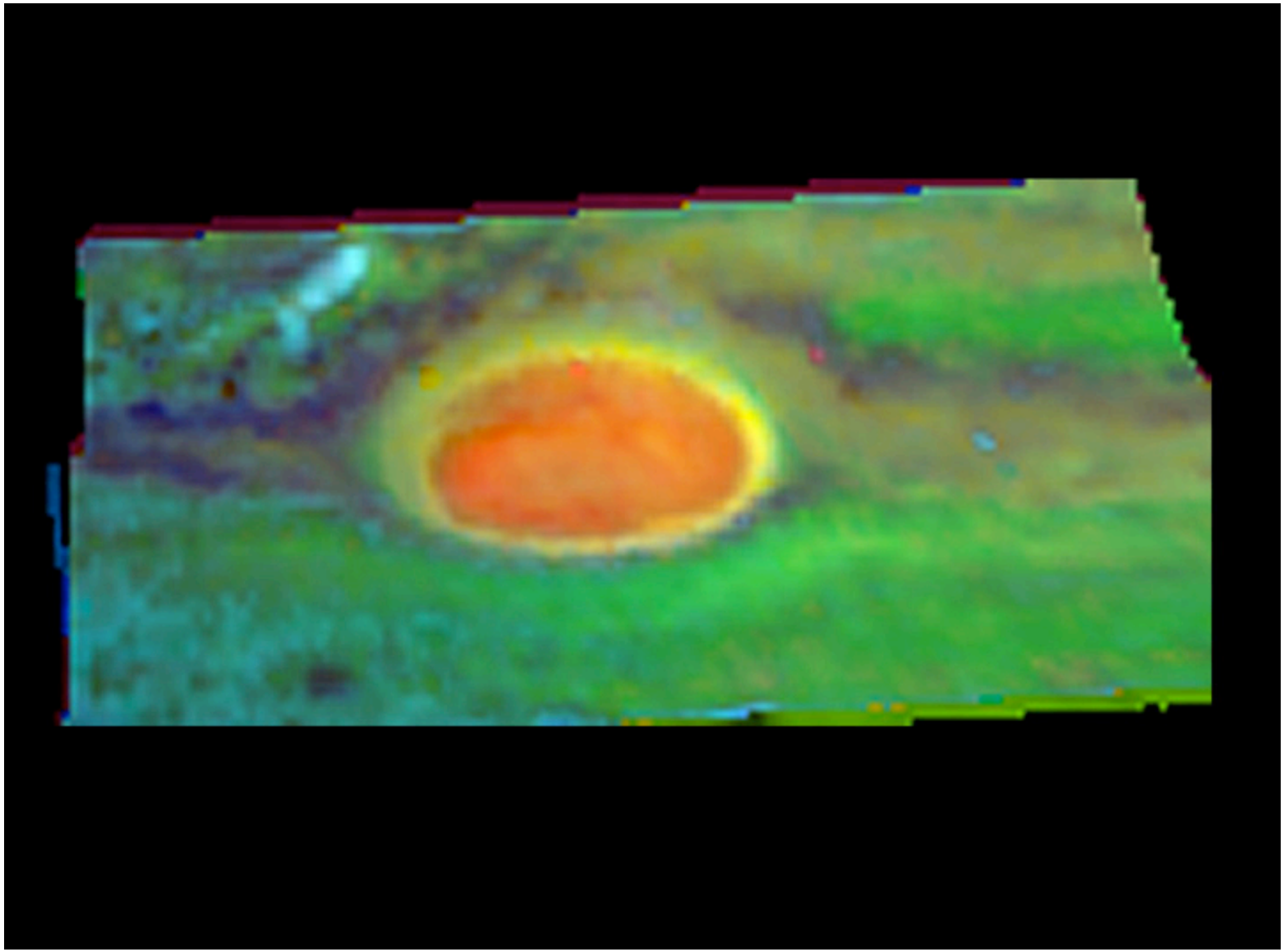


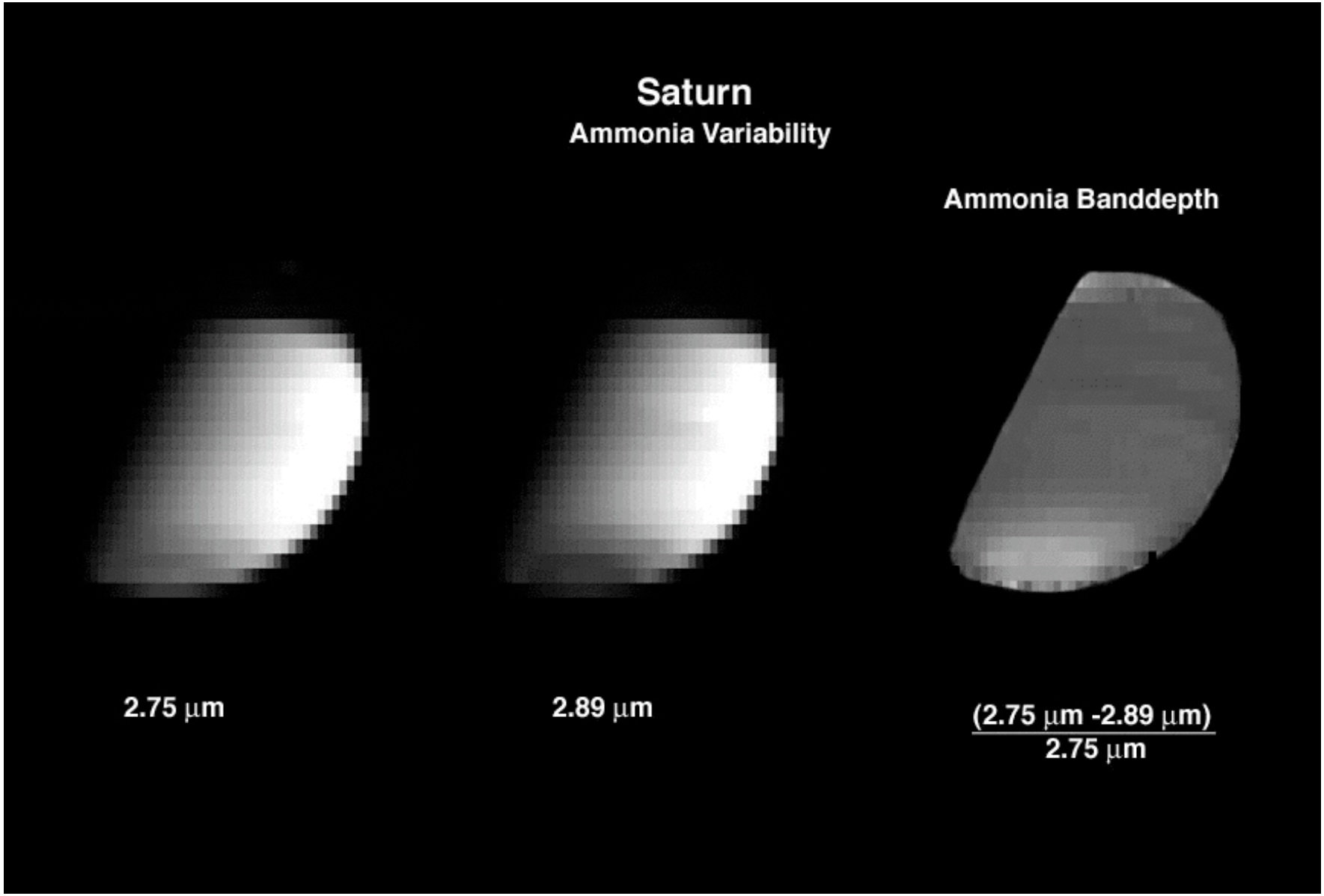
BLUE

$$\frac{I/F_{1.94\,\mu m} - I/F_{1.99\,\mu m}}{I/F_{1.94\,\mu m}}$$

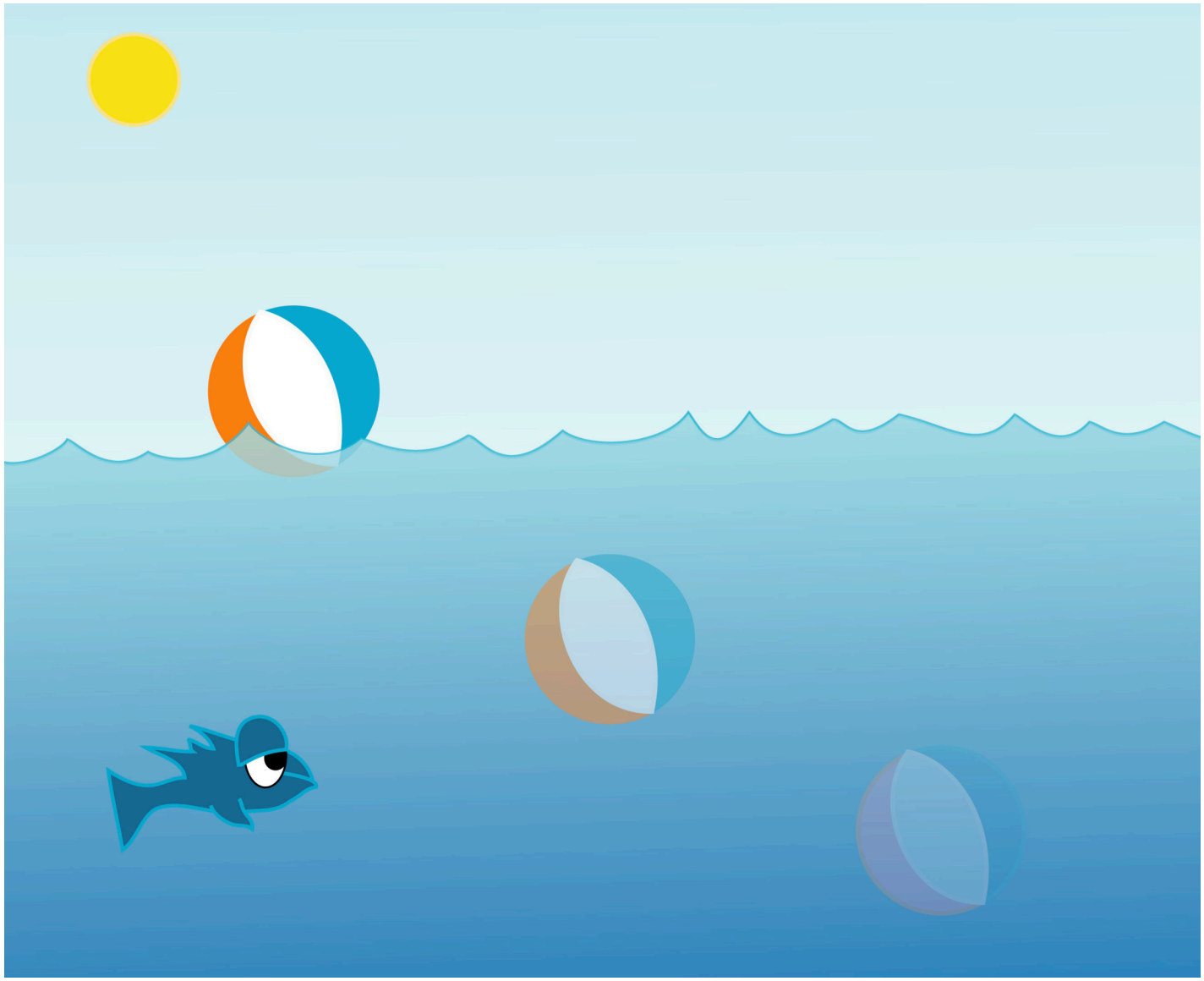
Composite Image





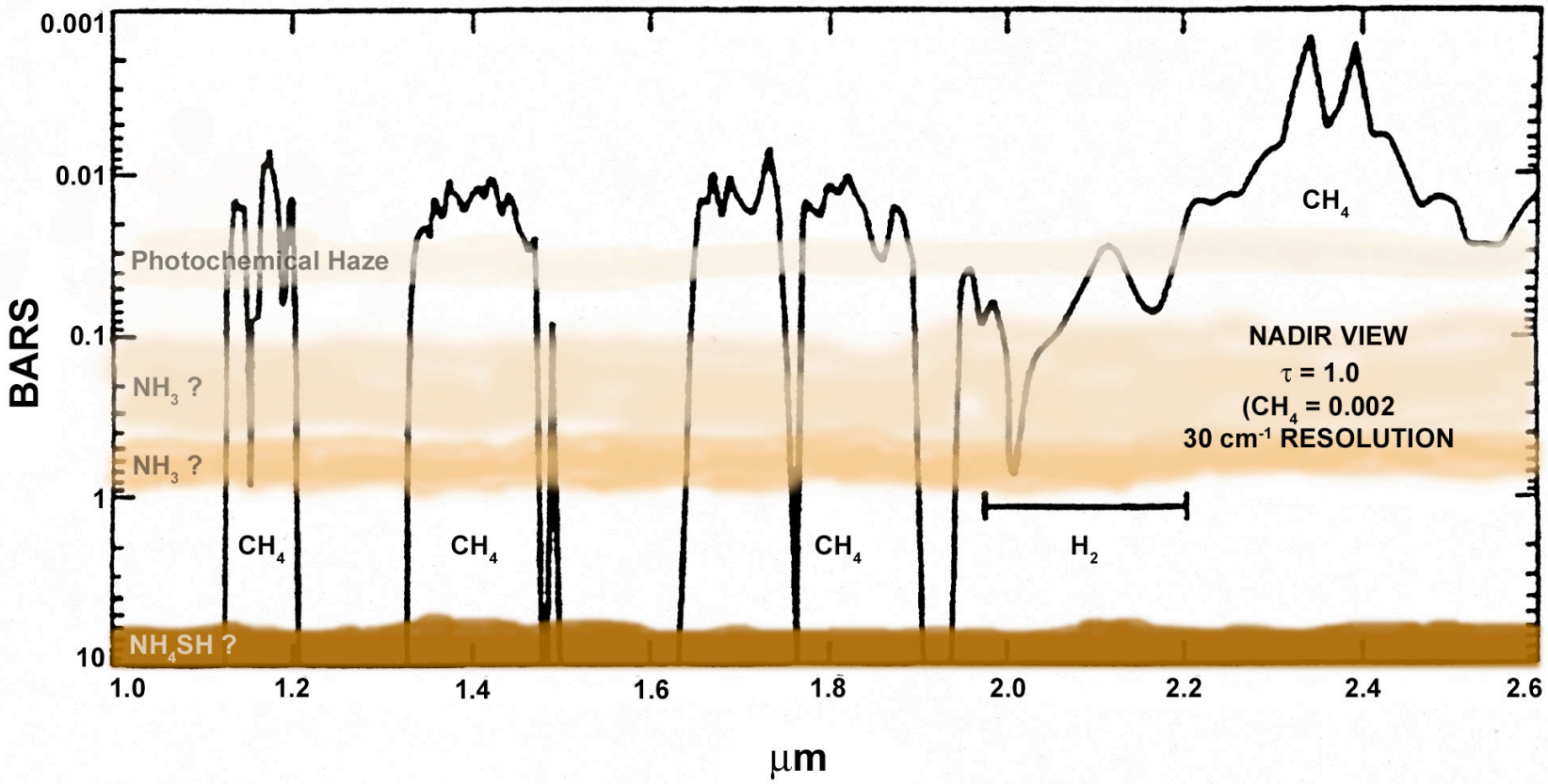

Saturn
Ammonia Variability
Ammonia Banddepth
2.75 μm
2.89 μm
(2.75 μm -2.89 μm)
2.75 μm

Atmospheric (or Liquid…) Stratigraphy: Telling Depths By Color and Brightness

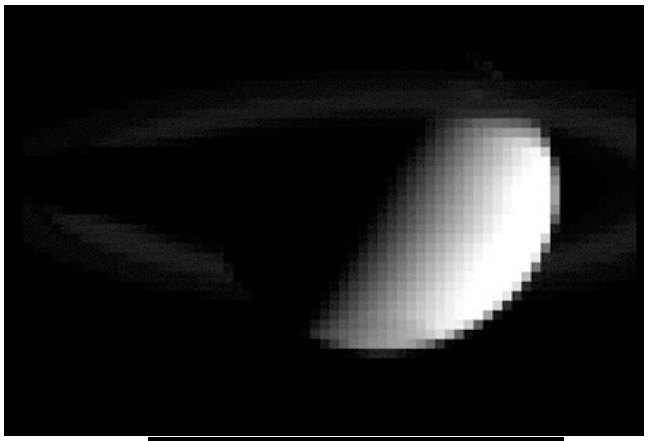


SATURN EFFECTIVE PRESSURE LEVEL

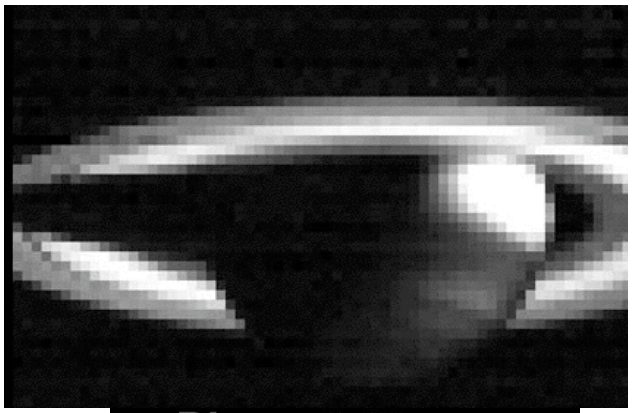
1.0 - 2.6 μm



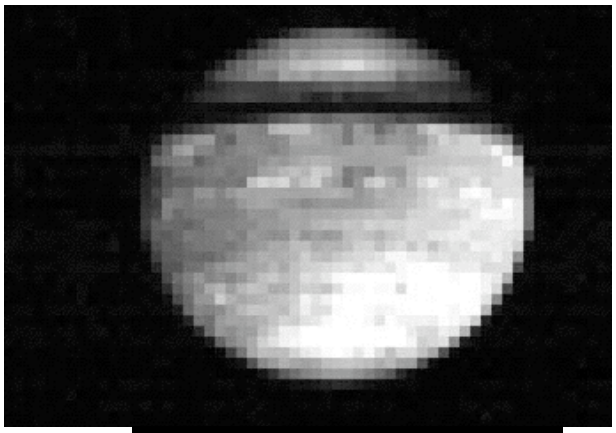
Saturn Cloud Morphology



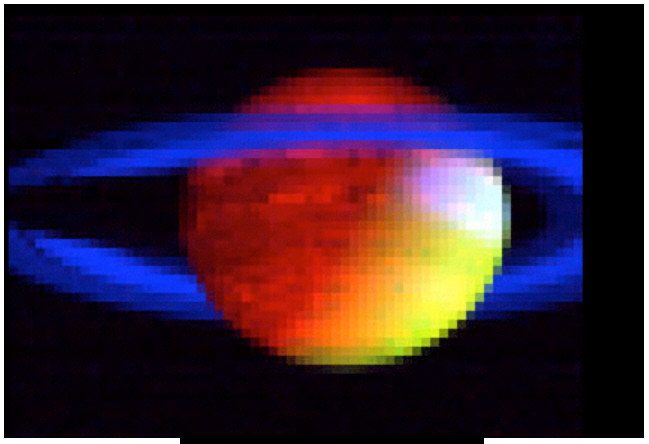
Green = 1.59 μm
Continuum



Blue = 2.12 μm
H_2 Band Reflectivity

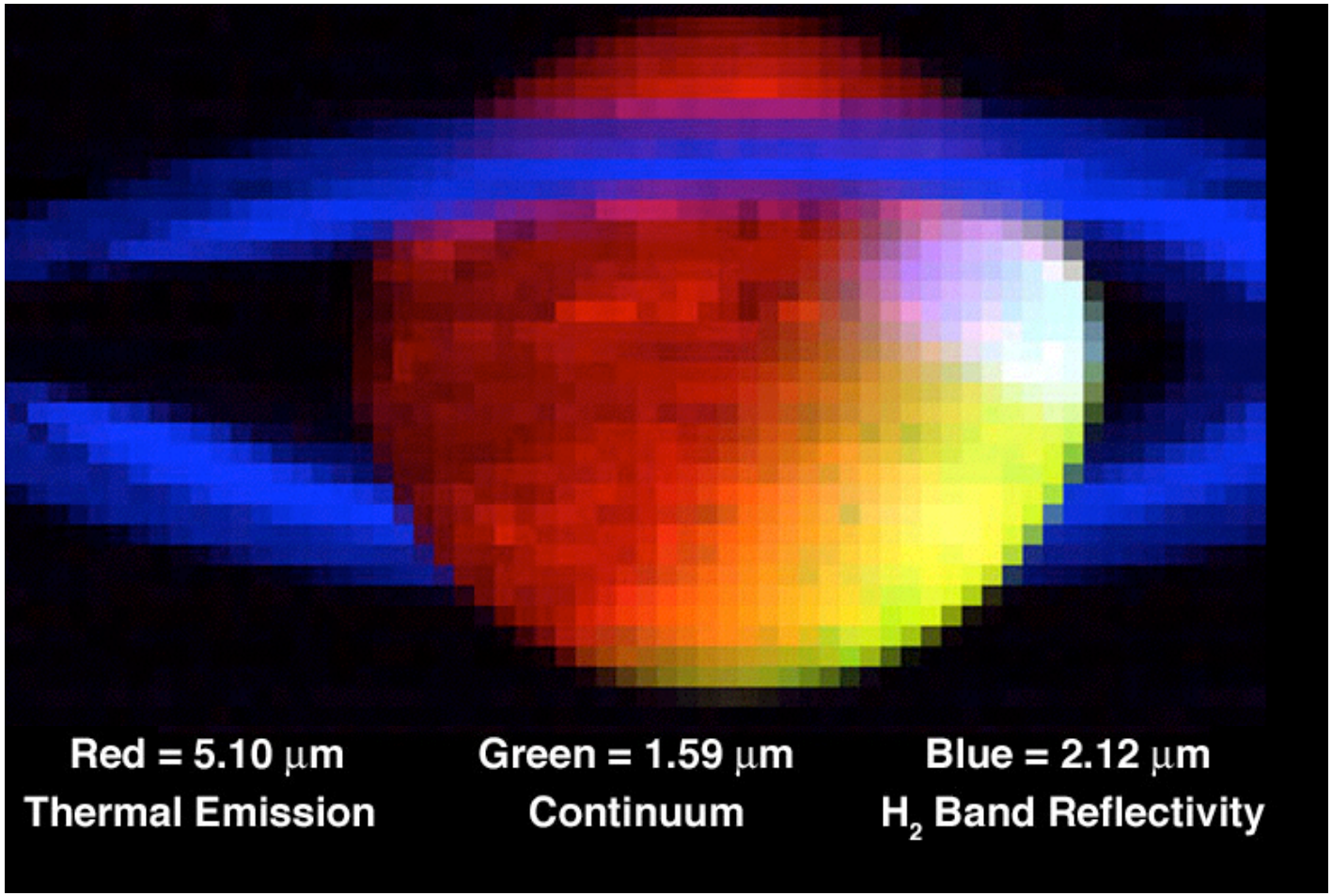


Red = 5.10 μm
Thermal Emission



Composite

Saturn
Cloud Morphology



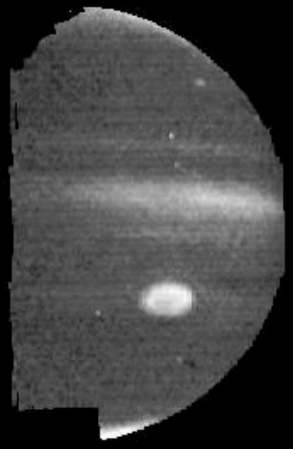
Clouds everywhere.

Enhanced high-altitude clouds over Equatorial Region

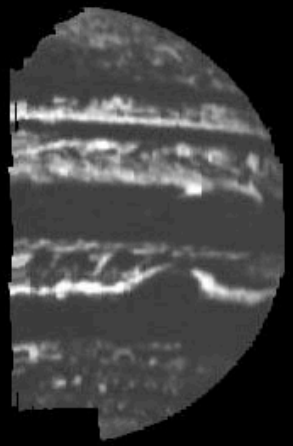
Enhanced longitudinal variability in large-particle region near cloudbase near 8 degrees S. latitude

Jovian Clouds in Three Dimensions

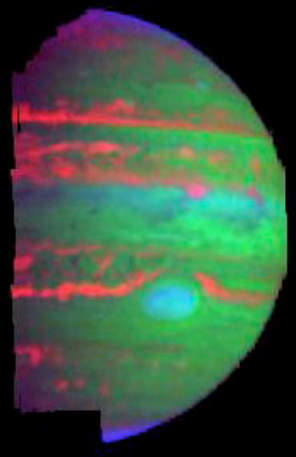
1.61 µm



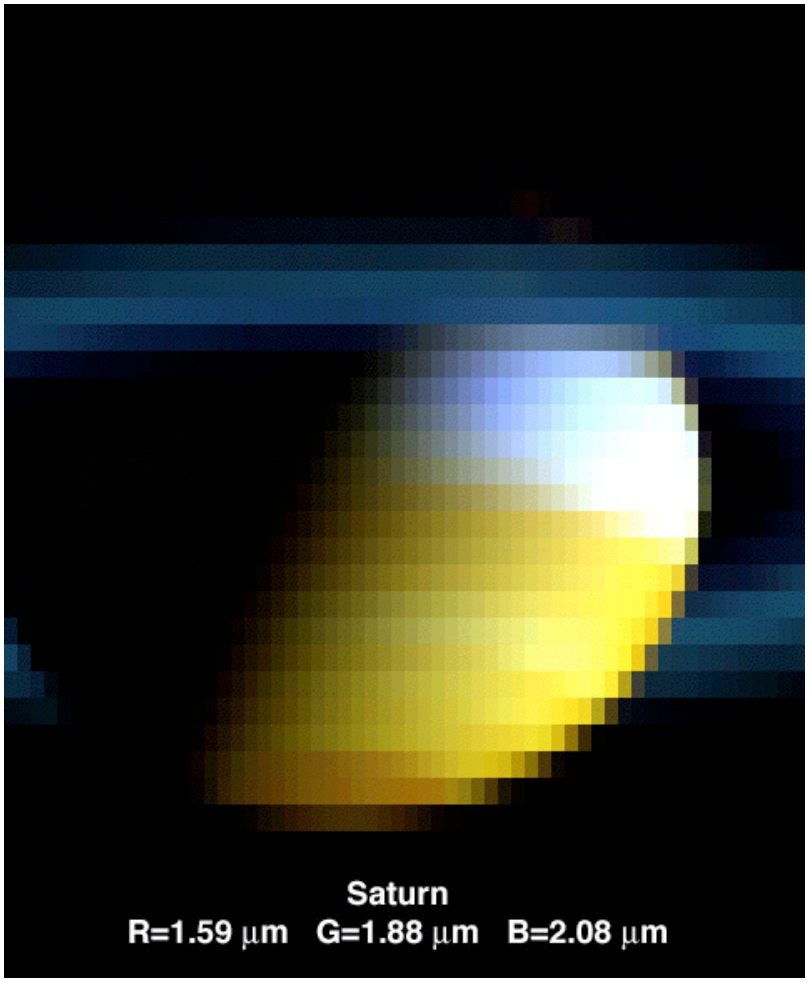
2.17 µm



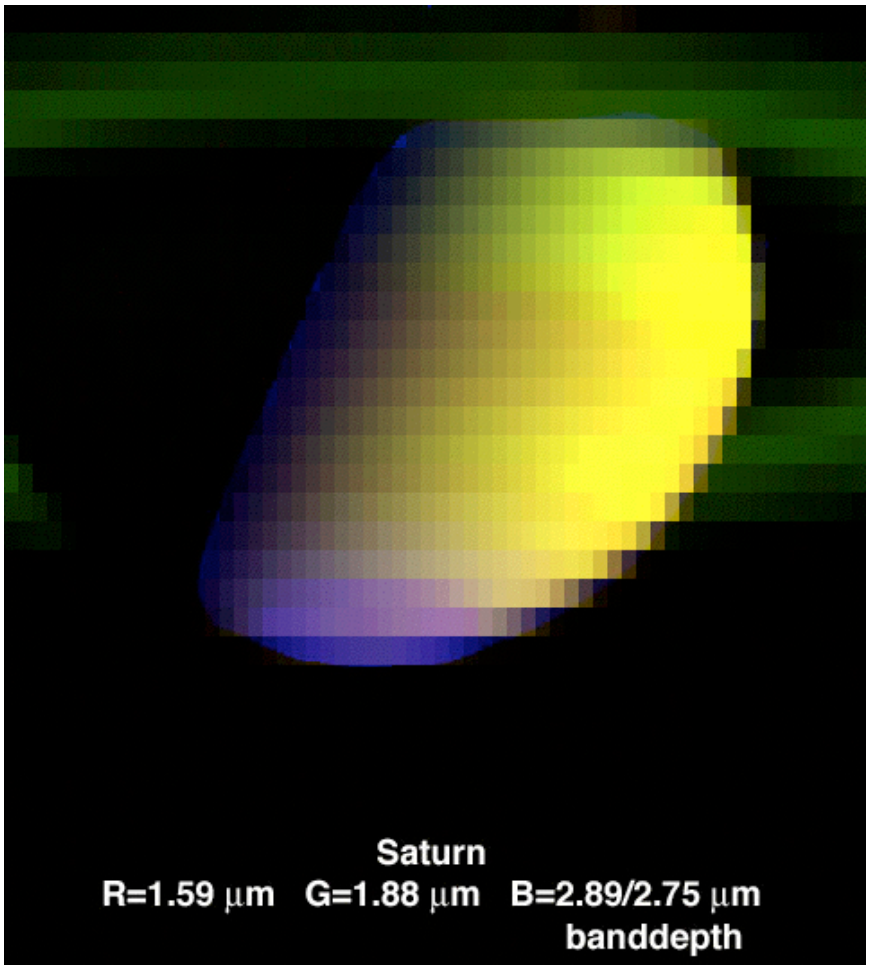
4.99 µm



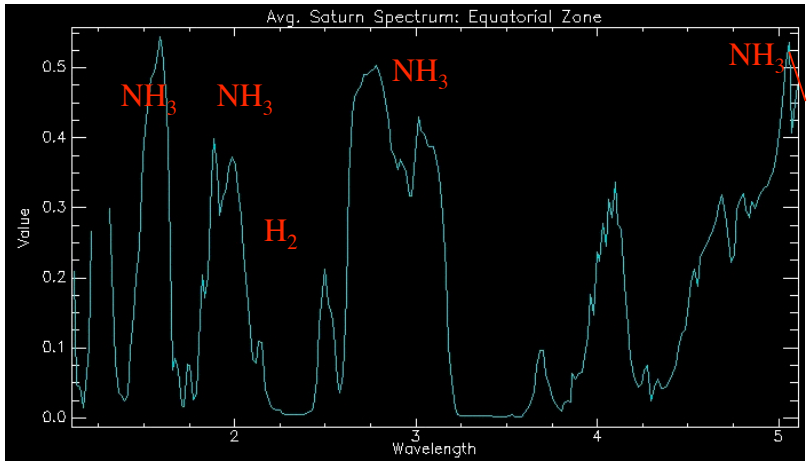
South Polar Region

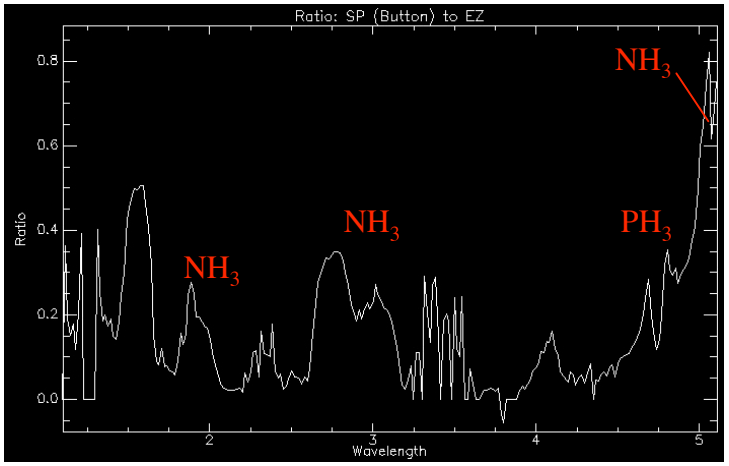


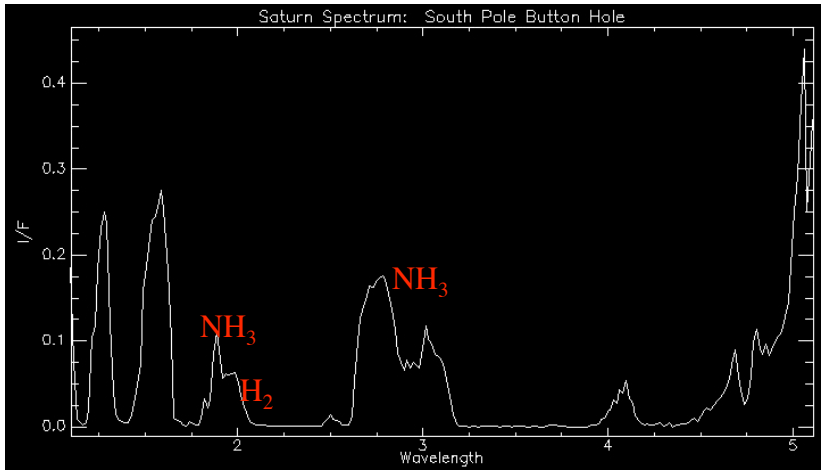
Less cloudiness and enhanced ammonia absorption in South Polar region



Near-IR Spectra
South Pole vs Equatorial Zone

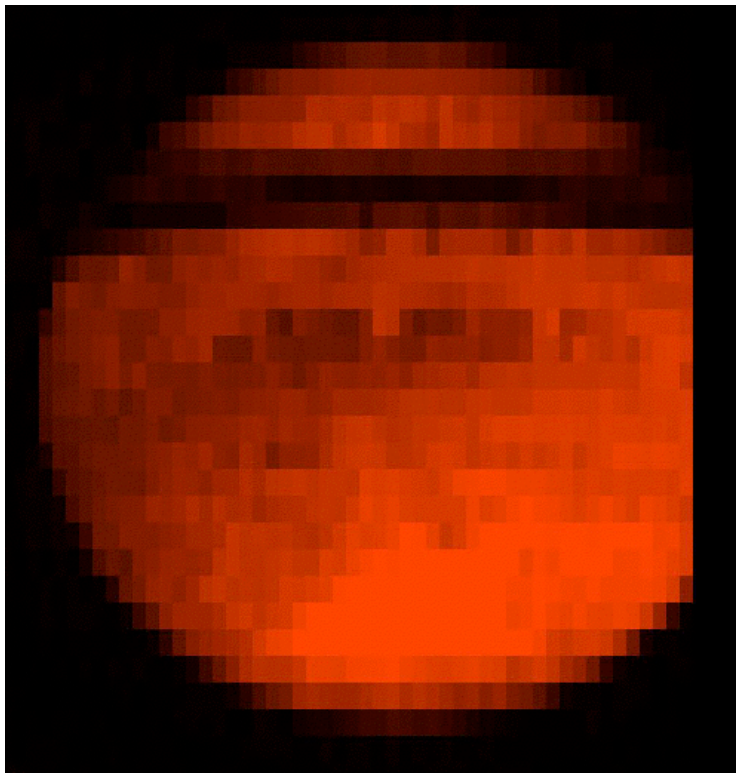


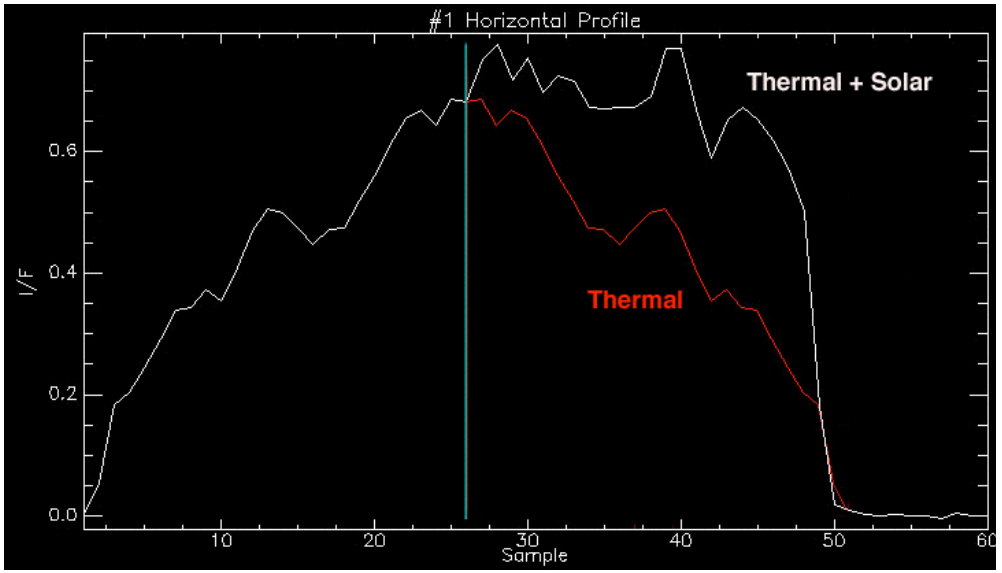




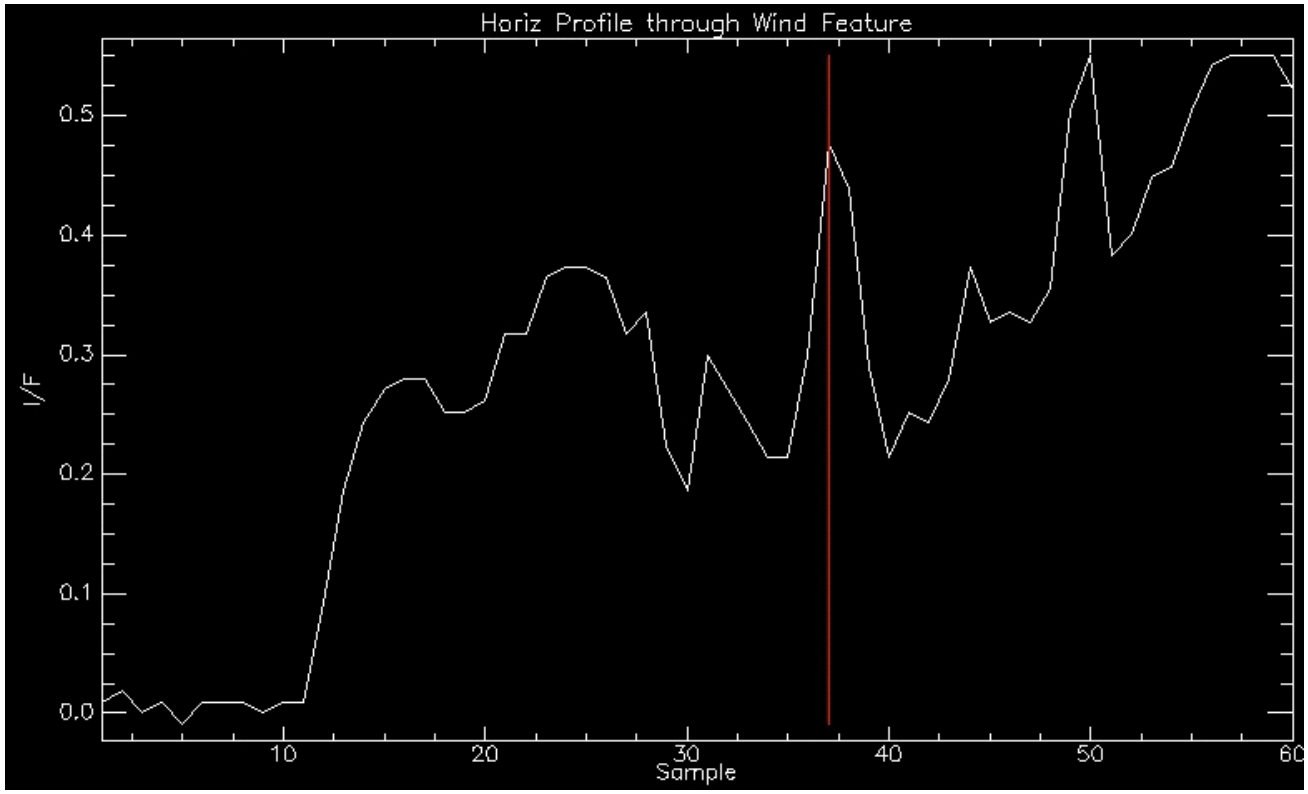
Enhanced NH_3 abundance at South Pole

SATURN
5-μm THERMAL EMISSION





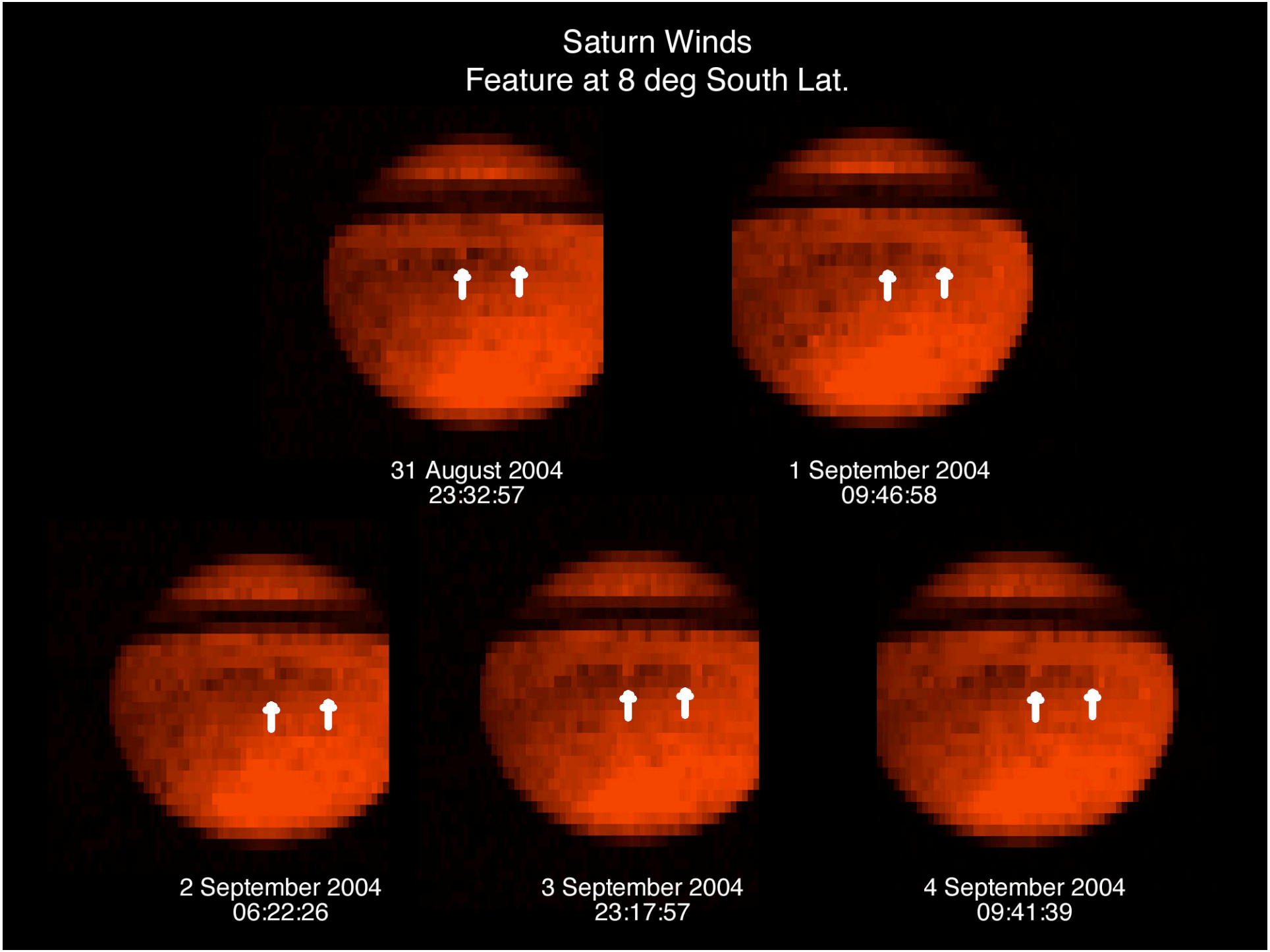
5-μm Longitudinal Profile: Cold Features at 8° S. Lat



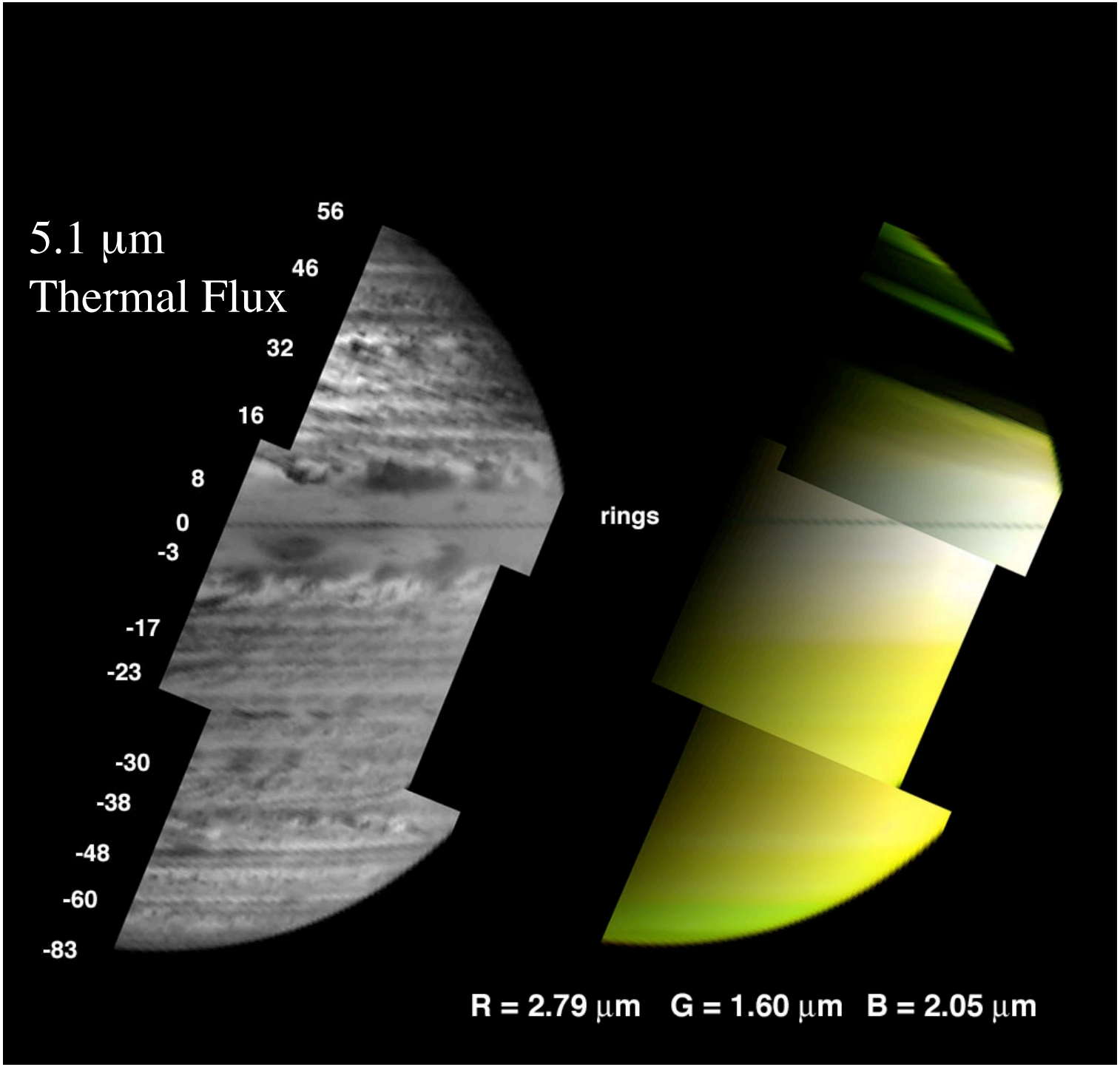
$I/F_{typical}/I/F_{cold} \sim 2.2$

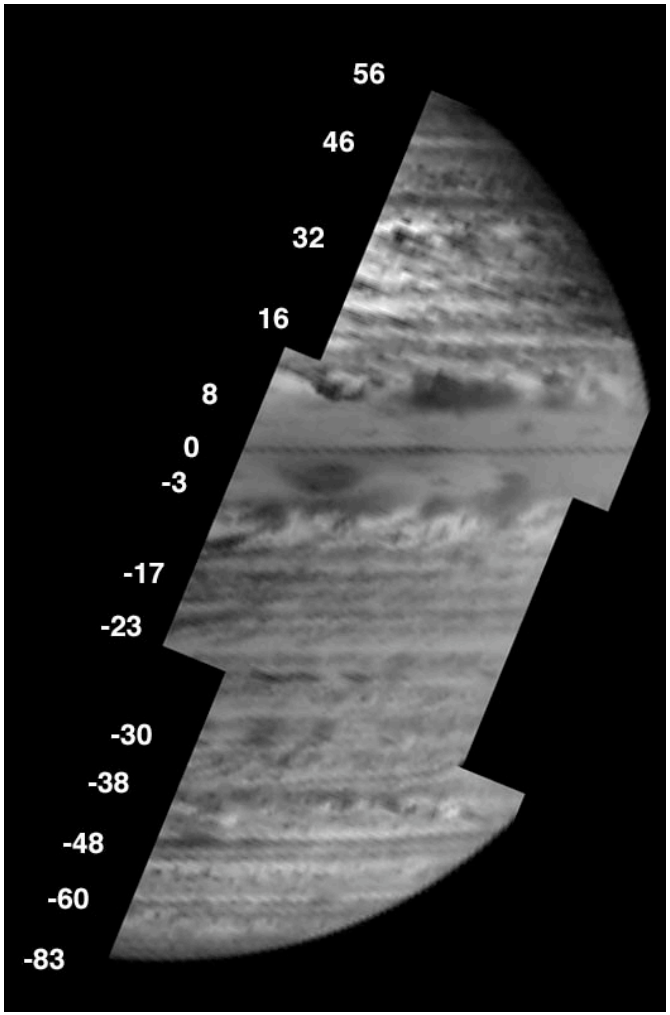
Corresponds to $\Delta T \sim 50K$ (Not viable), or $\Delta\tau_{Abs} \sim 0.8$ (OK)

Typically, $\tau_{Abs} \sim 4$; Cold spots ~ 4.8; vs Jupiter ~ 0 - > 8


Saturn Winds
Feature at 8 deg South Lat.
31 August 2004
23:32:57
1 September 2004
09:46:58
2 September 2004
06:22:26
3 September 2004
23:17:57
4 September 2004
09:41:39

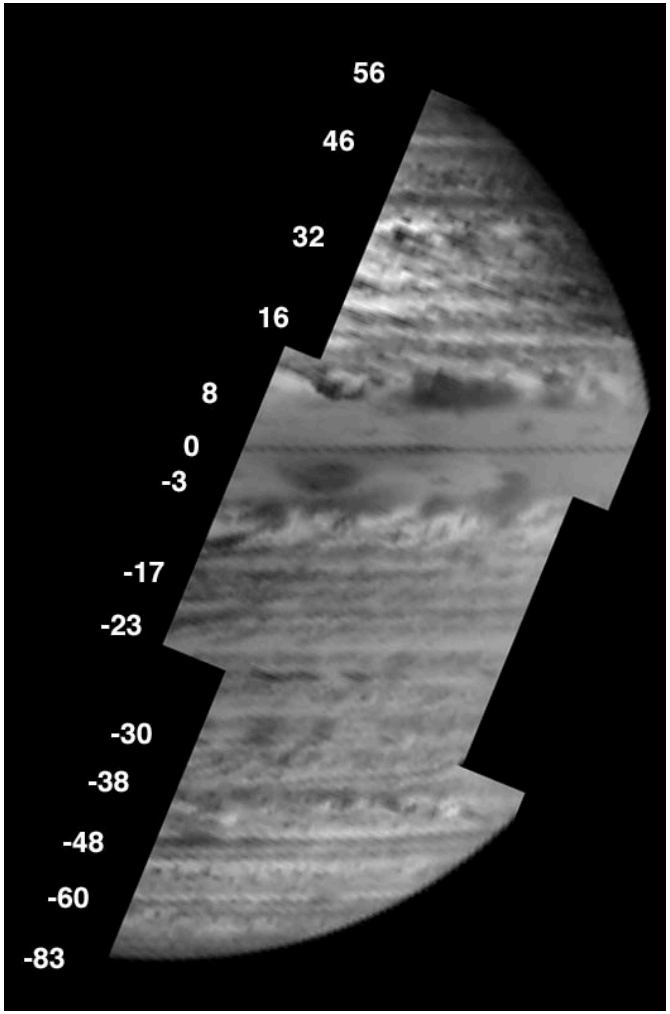

June 28, 2005
600 km/pixel
rings
R = 2.79 μm G = 1.60 μm B = 2.05 μm


5.1 μm
Thermal Flux
56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83
rings
R = 2.79 μm G = 1.60 μm B = 2.05 μm



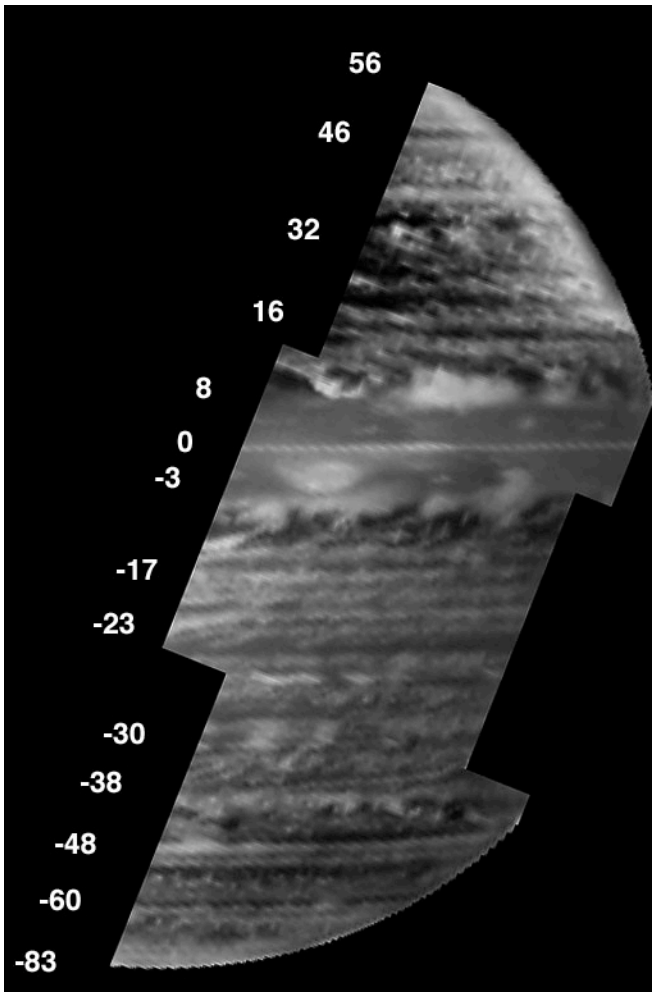
Thermal Flux:
Shows Cloud-free Areas Best

Clouds in Silhouette Block Saturn's Thermal Flux

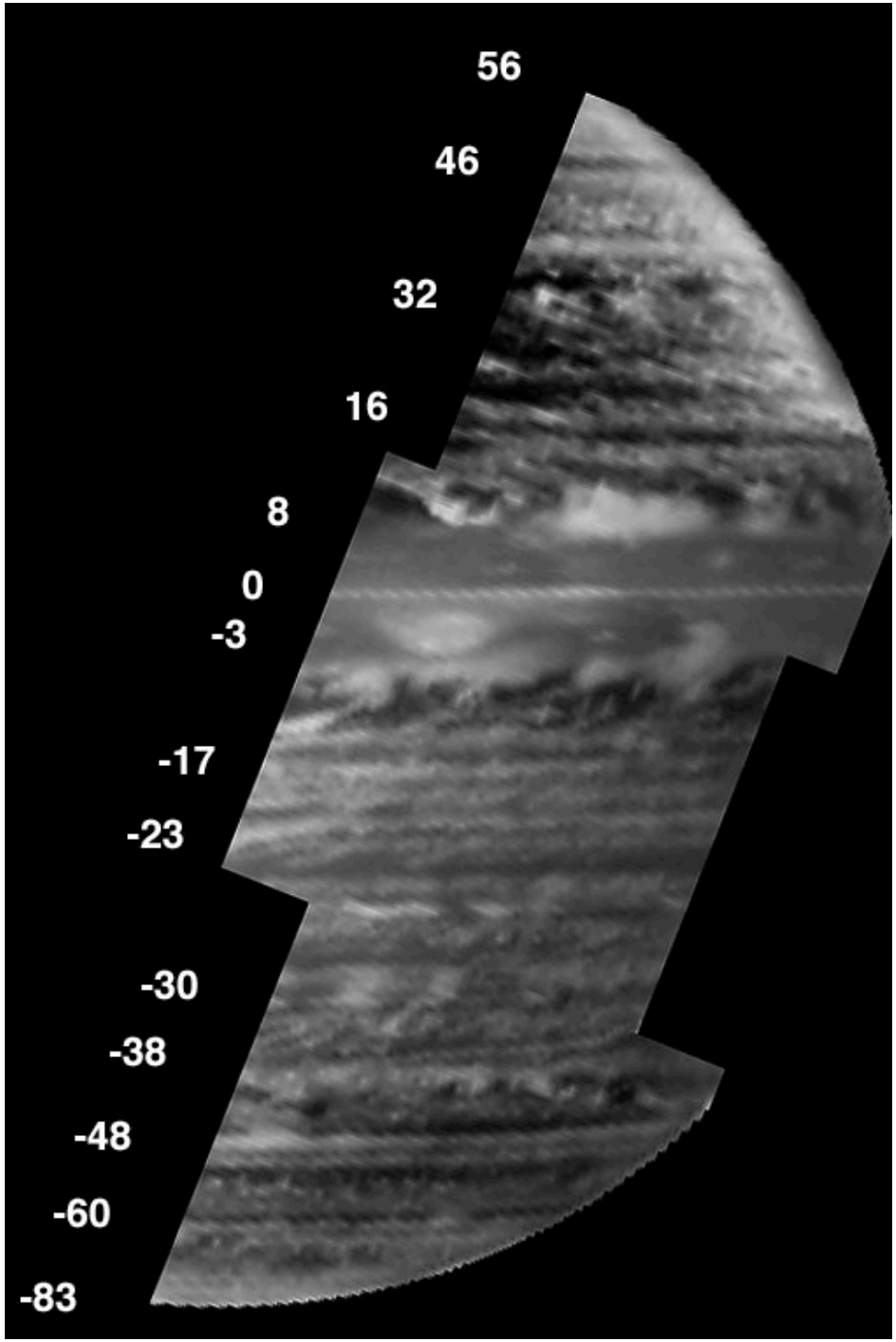


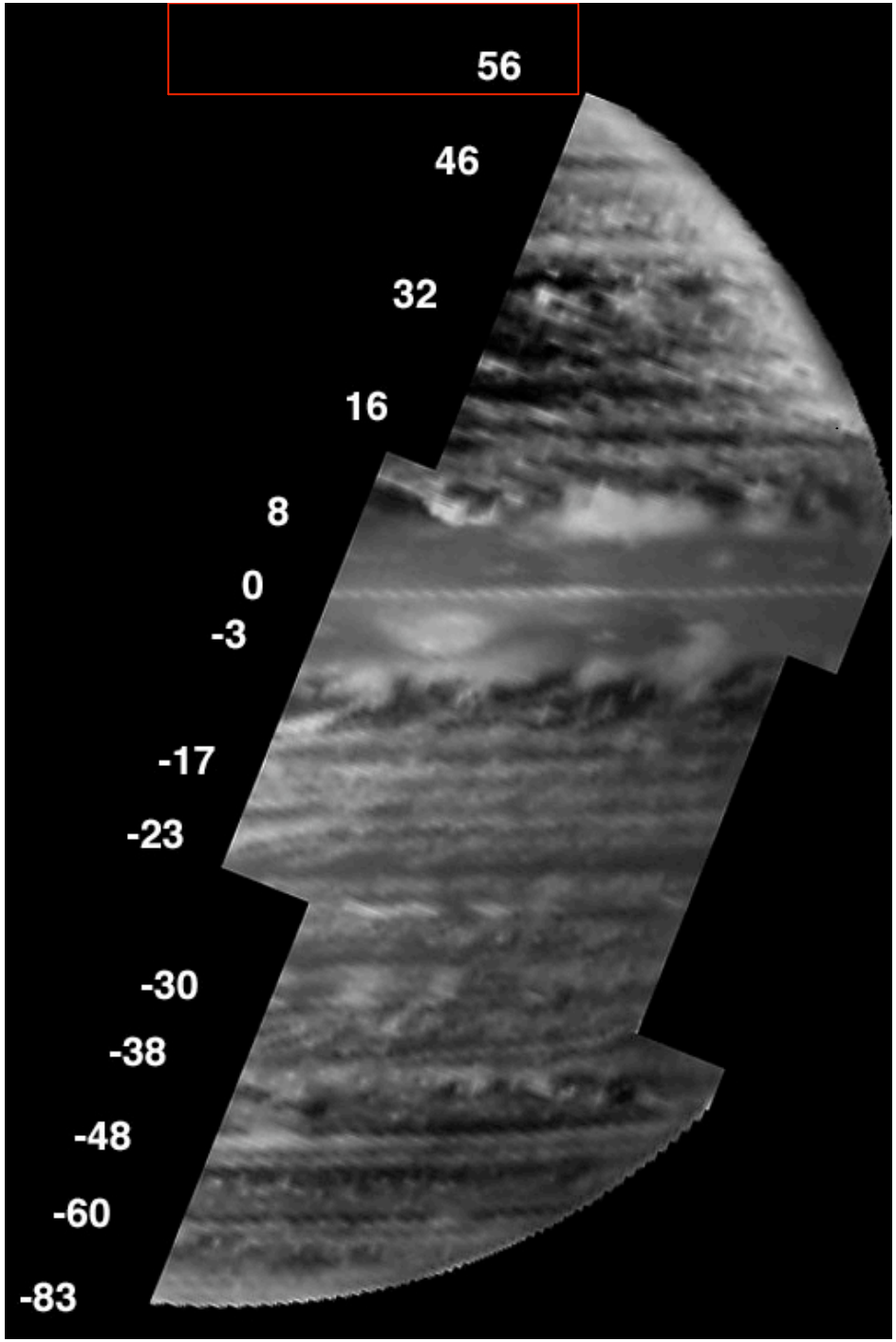
Thermal Flux:
Shows Cloud-free Areas Best

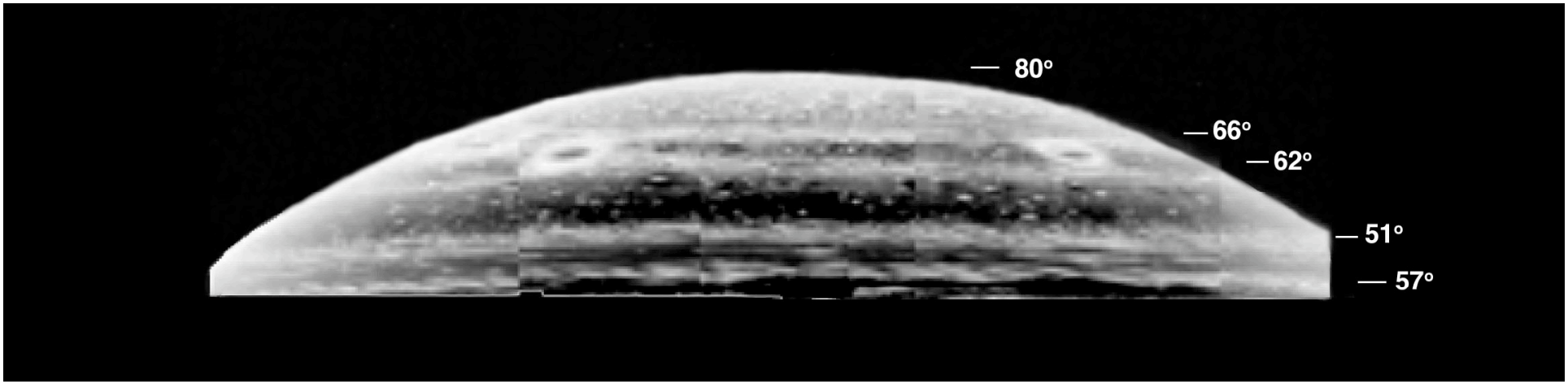
Clouds in Silhouette Block Saturn's Thermal Flux

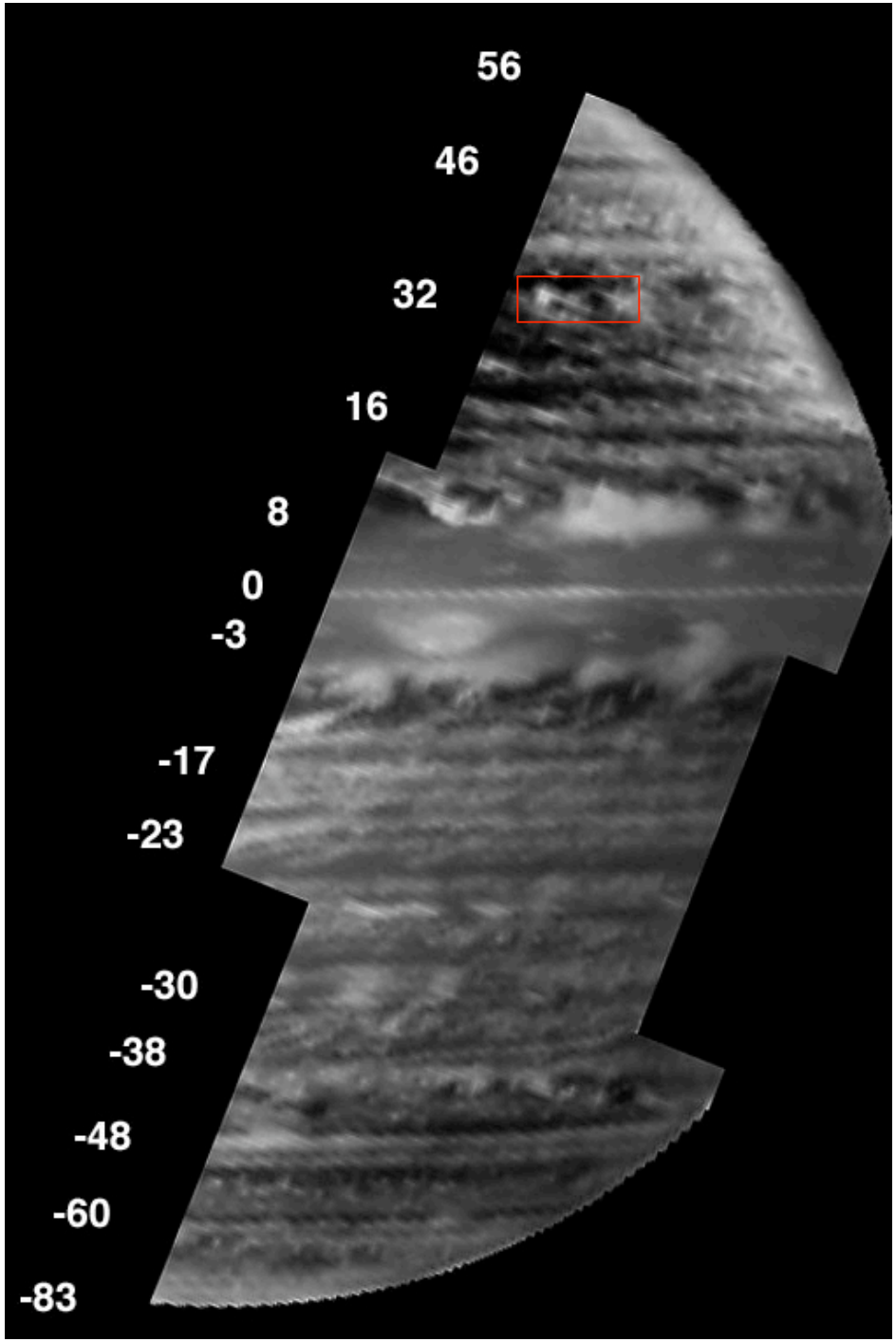


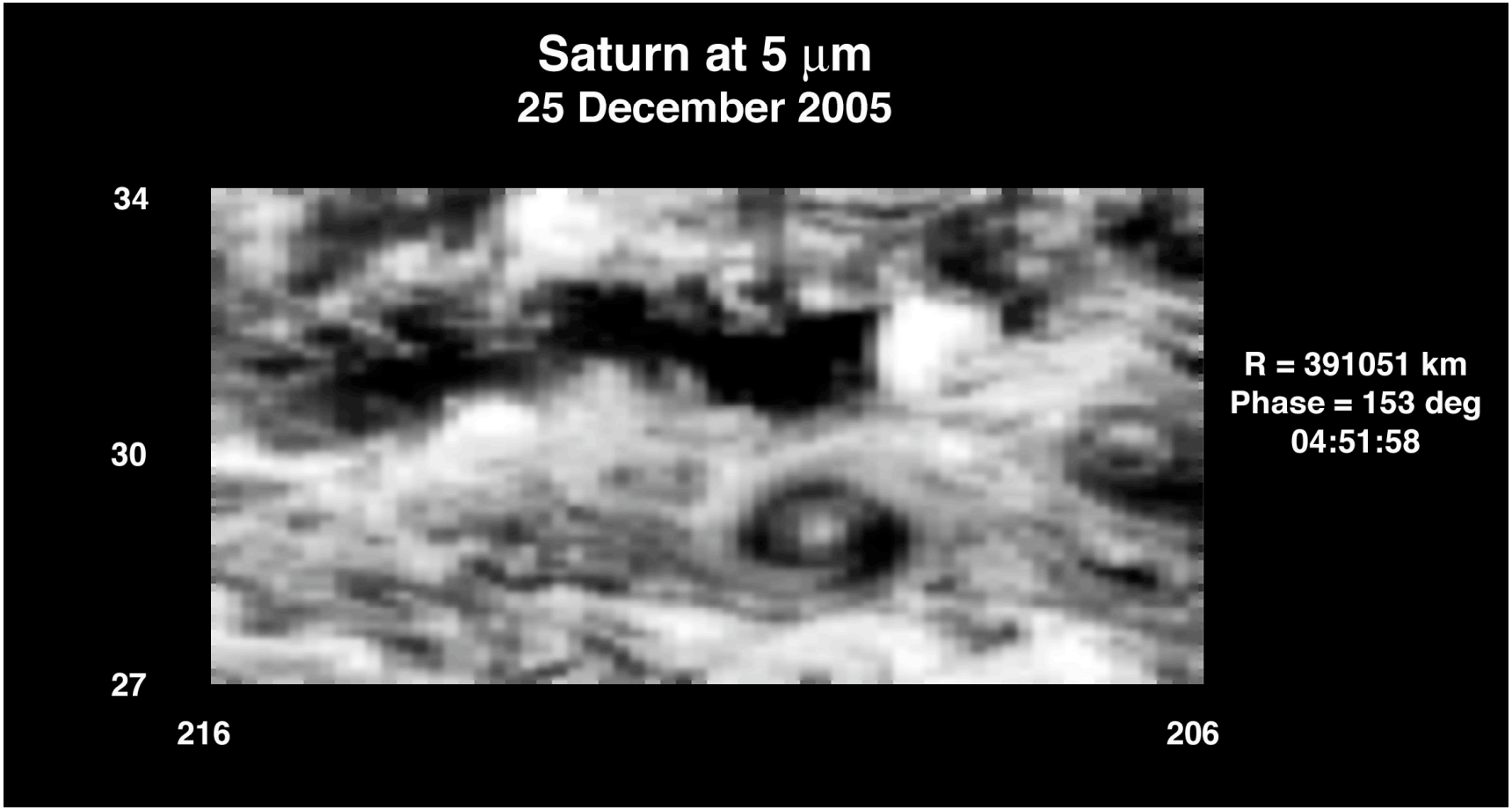
"Inverted" Thermal Flux:
Shows Thermal Opacity, Indicative of Cloudy Areas Dominated by Large-Particle Aerosols Near 2-3 Bars (Not NH_3, Most Likely NH_4SH)


56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83


56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83

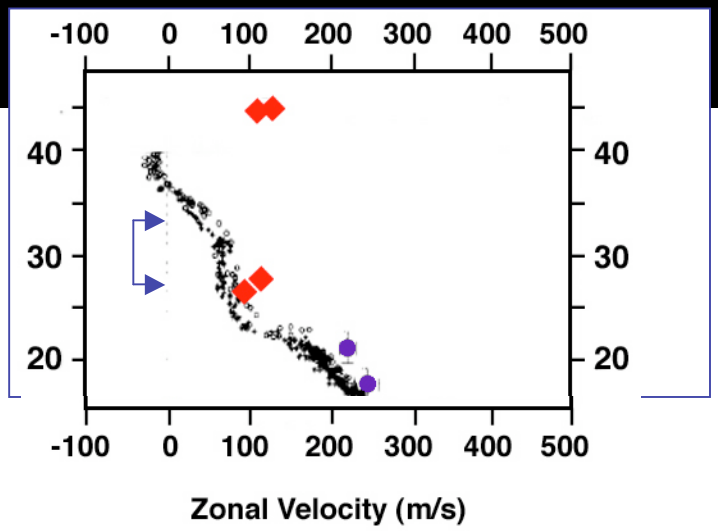

80°
66°
62°
51°
57°

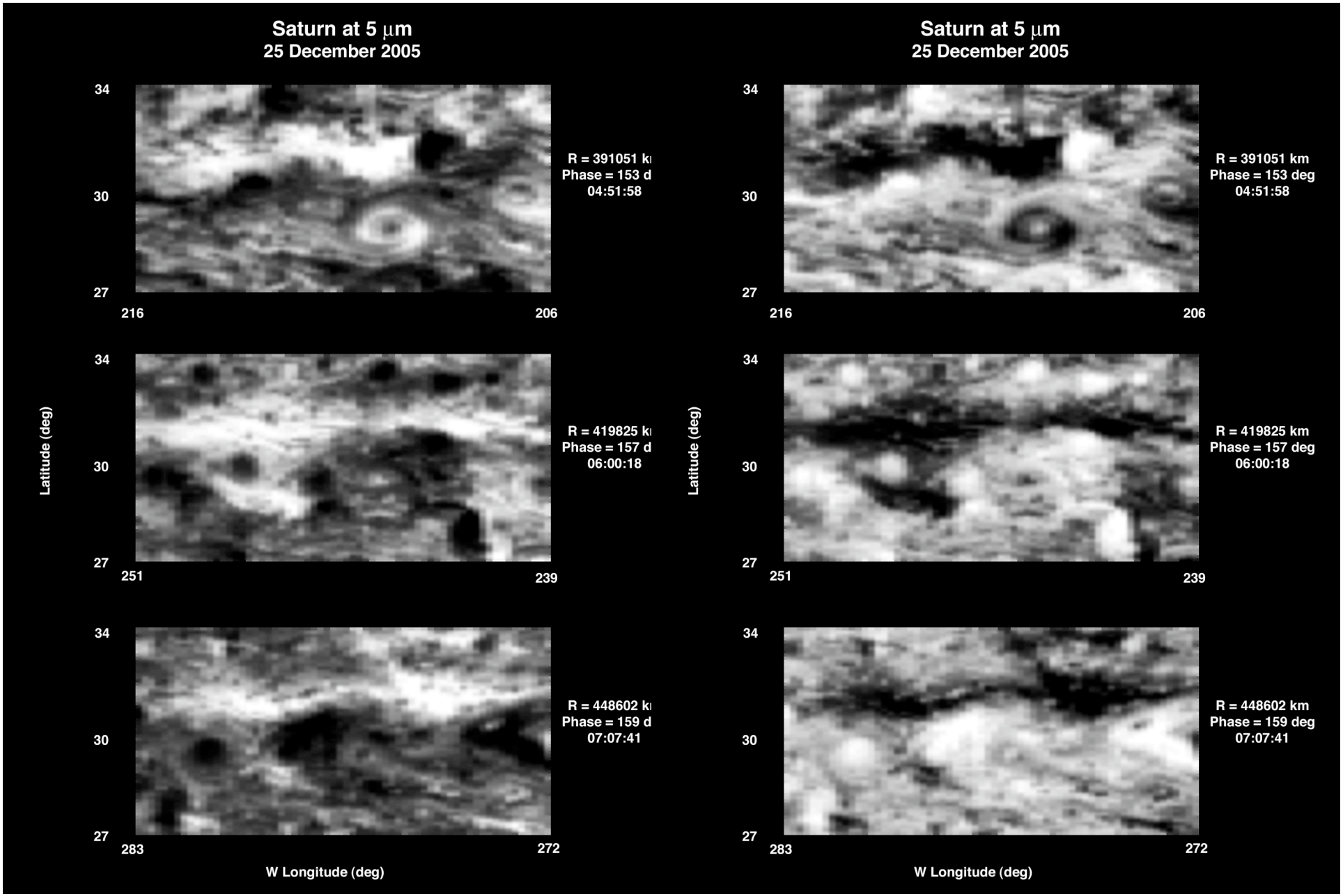

56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83

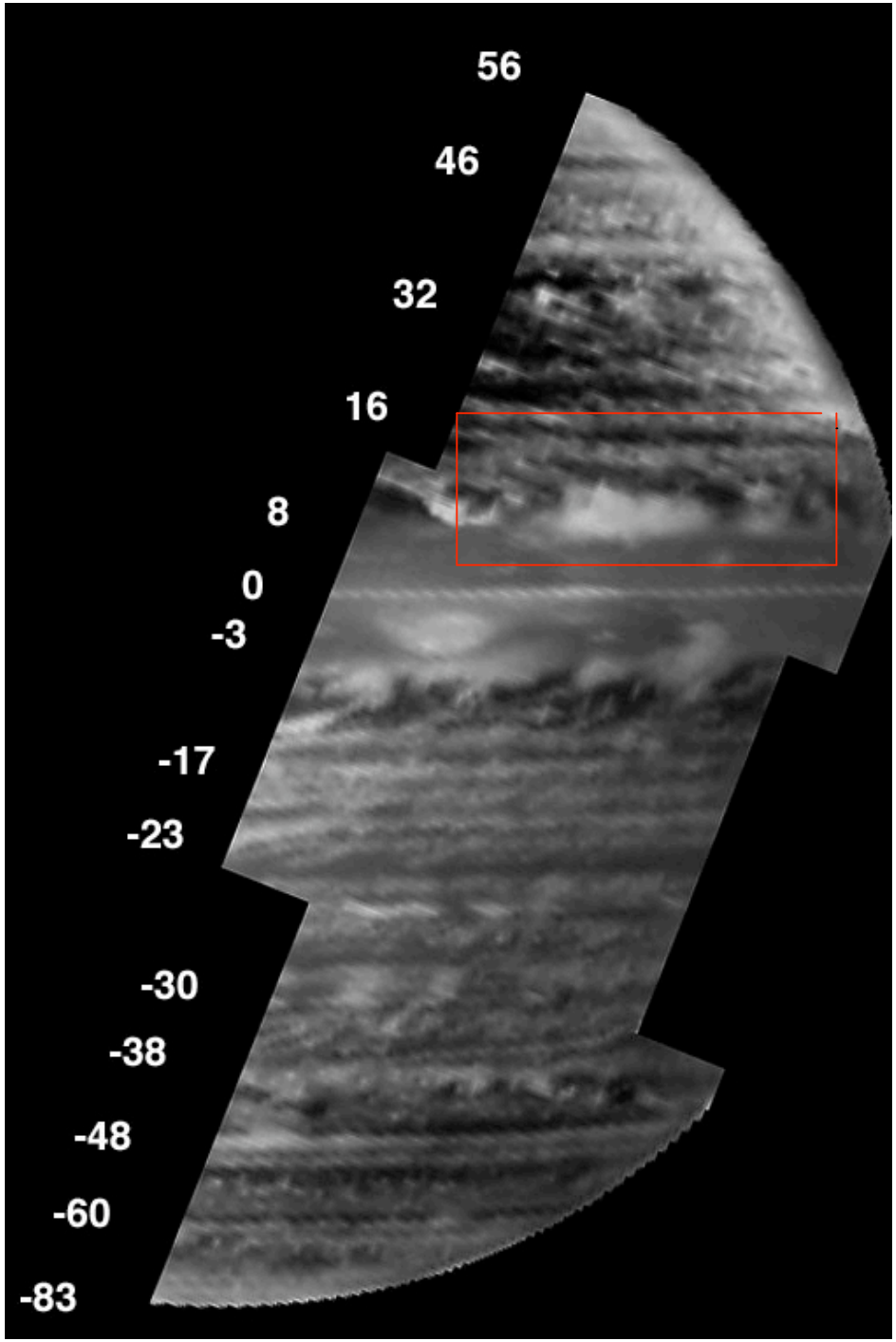

Saturn at 5 μm
25 December 2005
34
30
27
216
206
R = 391051 km
Phase = 153 deg
04:51:58

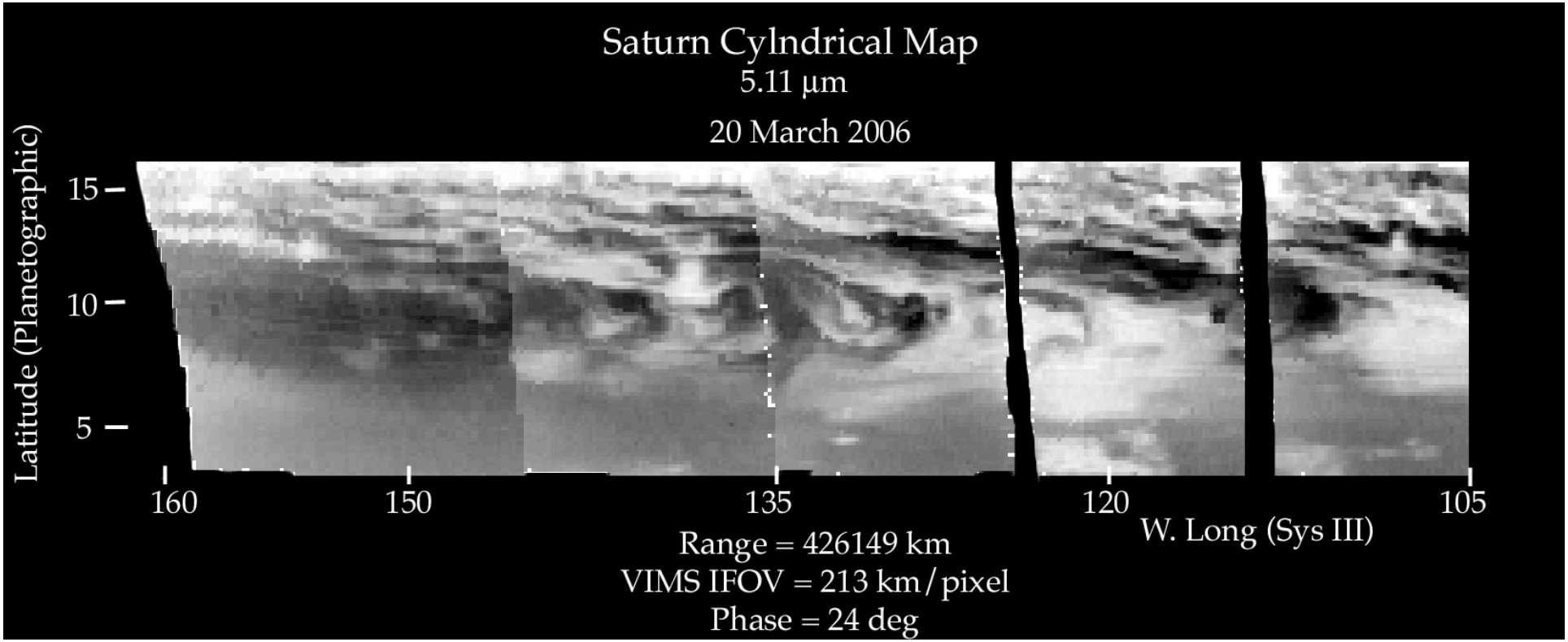
Saturn at 5 μm
25 December 2005

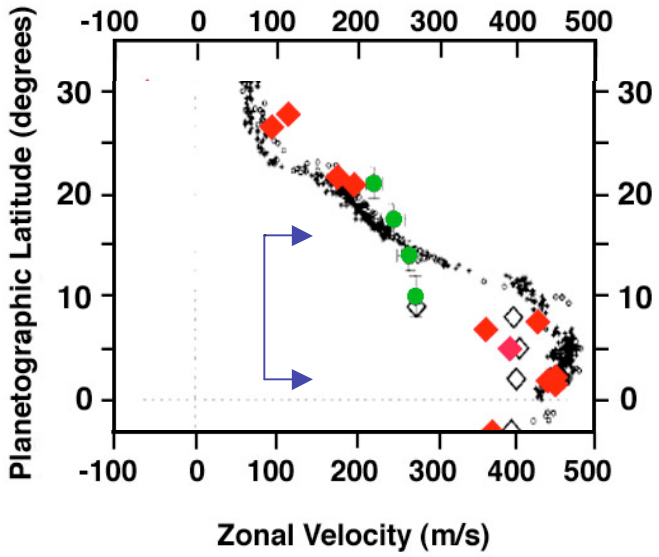
R = 391051 km
Phase = 153 deg
04:51:58

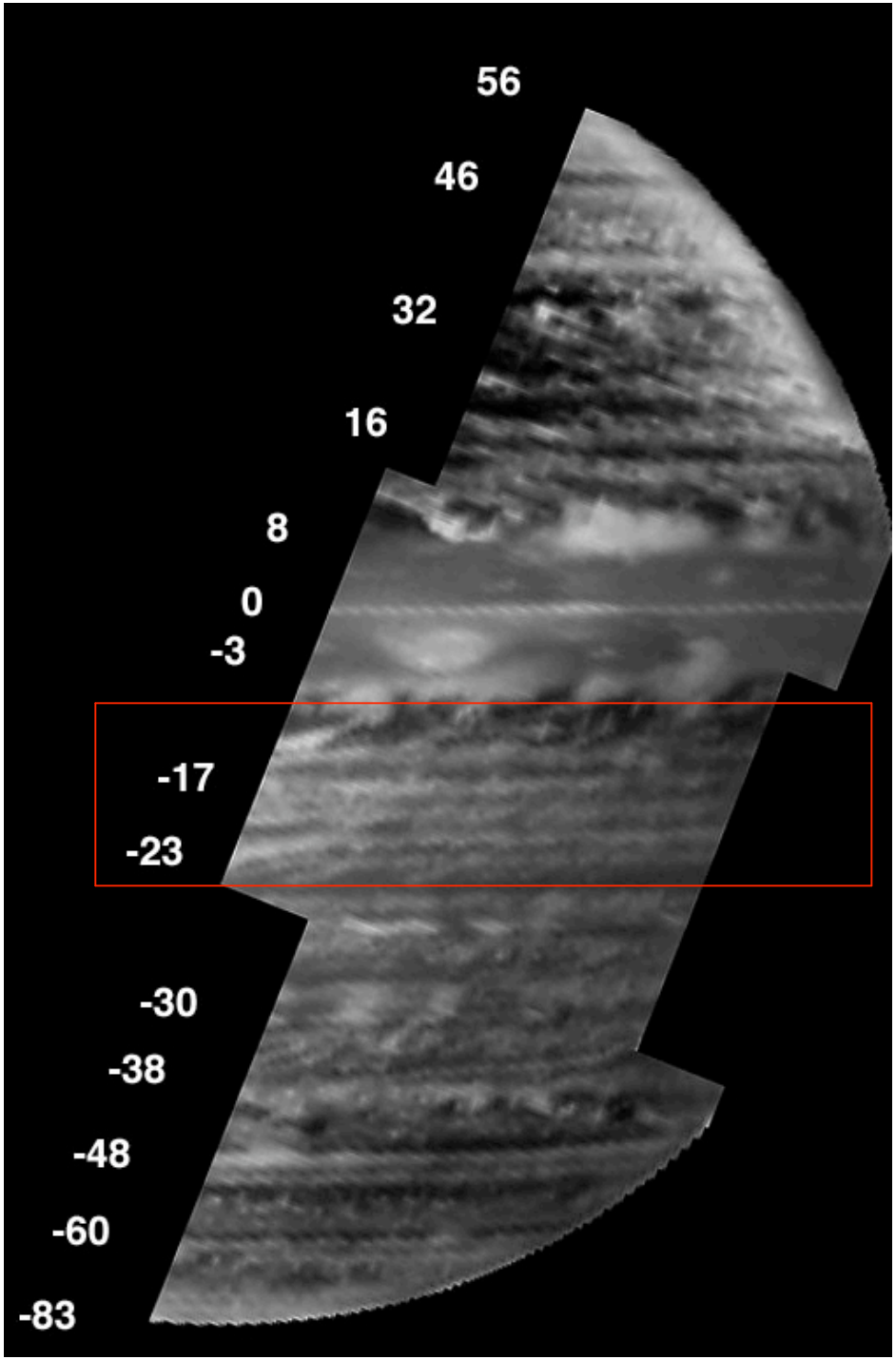



Saturn at 5 μm
25 December 2005
34
30
27
216
206
R = 391051 k
Phase = 153 d
04:51:58
34
30
27
251
239
R = 419825 k
Phase = 157 d
06:00:18
34
30
27
283
272
R = 448602 k
Phase = 159 d
07:07:41
Latitude (deg)
W Longitude (deg)
Saturn at 5 μm
25 December 2005
34
30
27
216
206
R = 391051 km
Phase = 153 deg
04:51:58
34
30
27
251
239
R = 419825 km
Phase = 157 deg
06:00:18
34
30
27
283
272
R = 448602 km
Phase = 159 deg
07:07:41
Latitude (deg)
W Longitude (deg)

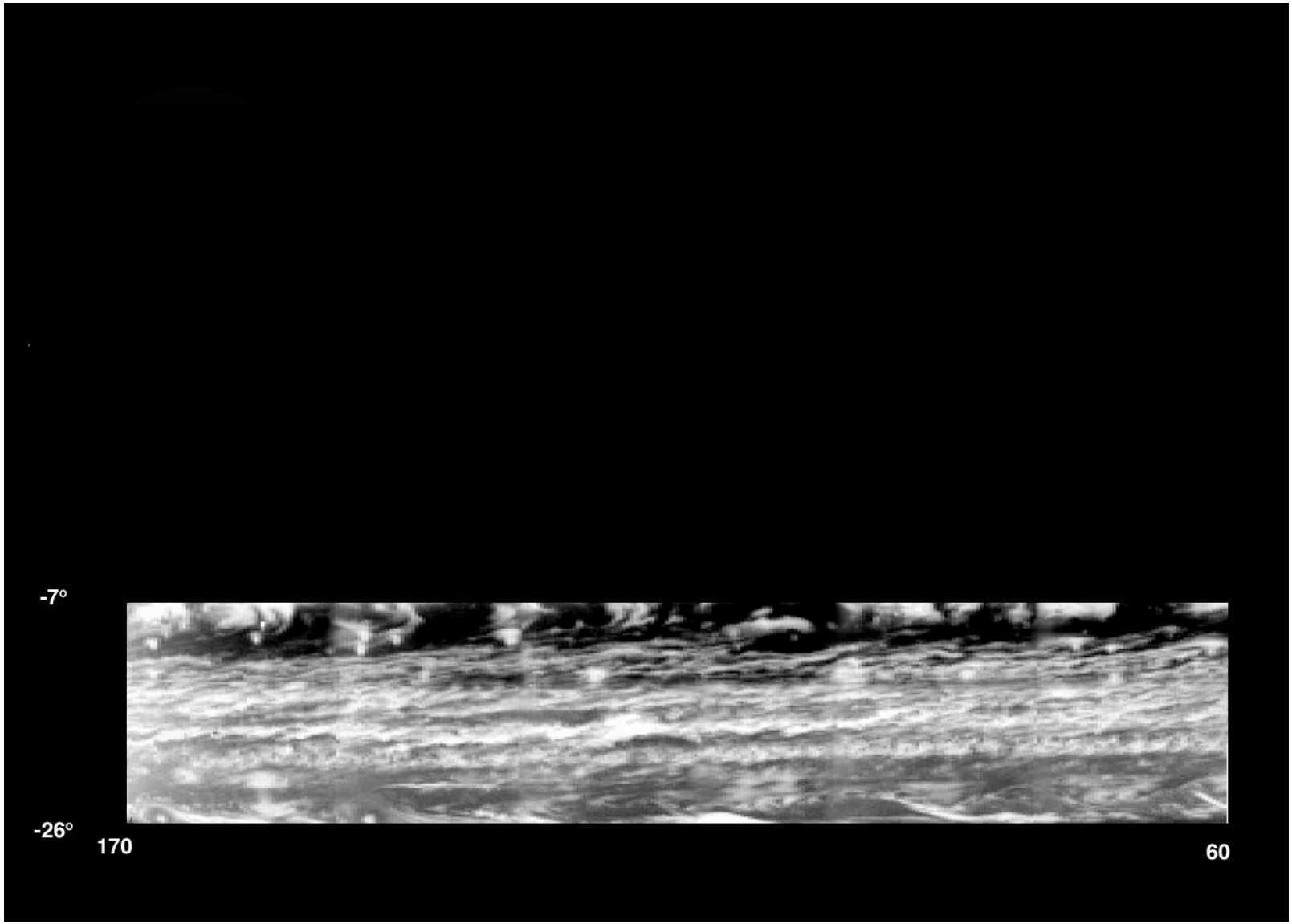

56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83


Saturn Cylndrical Map
5.11 µm
20 March 2006
Latitude (Planetographic)
15
10
5
160
150
135
120
105
W. Long (Sys III)
Range = 426149 km
VIMS IFOV = 213 km / pixel
Phase = 24 deg


Planetographic Latitude (degrees)
-100
0
100
200
300
400
500
30
20
10
0
Zonal Velocity (m/s)

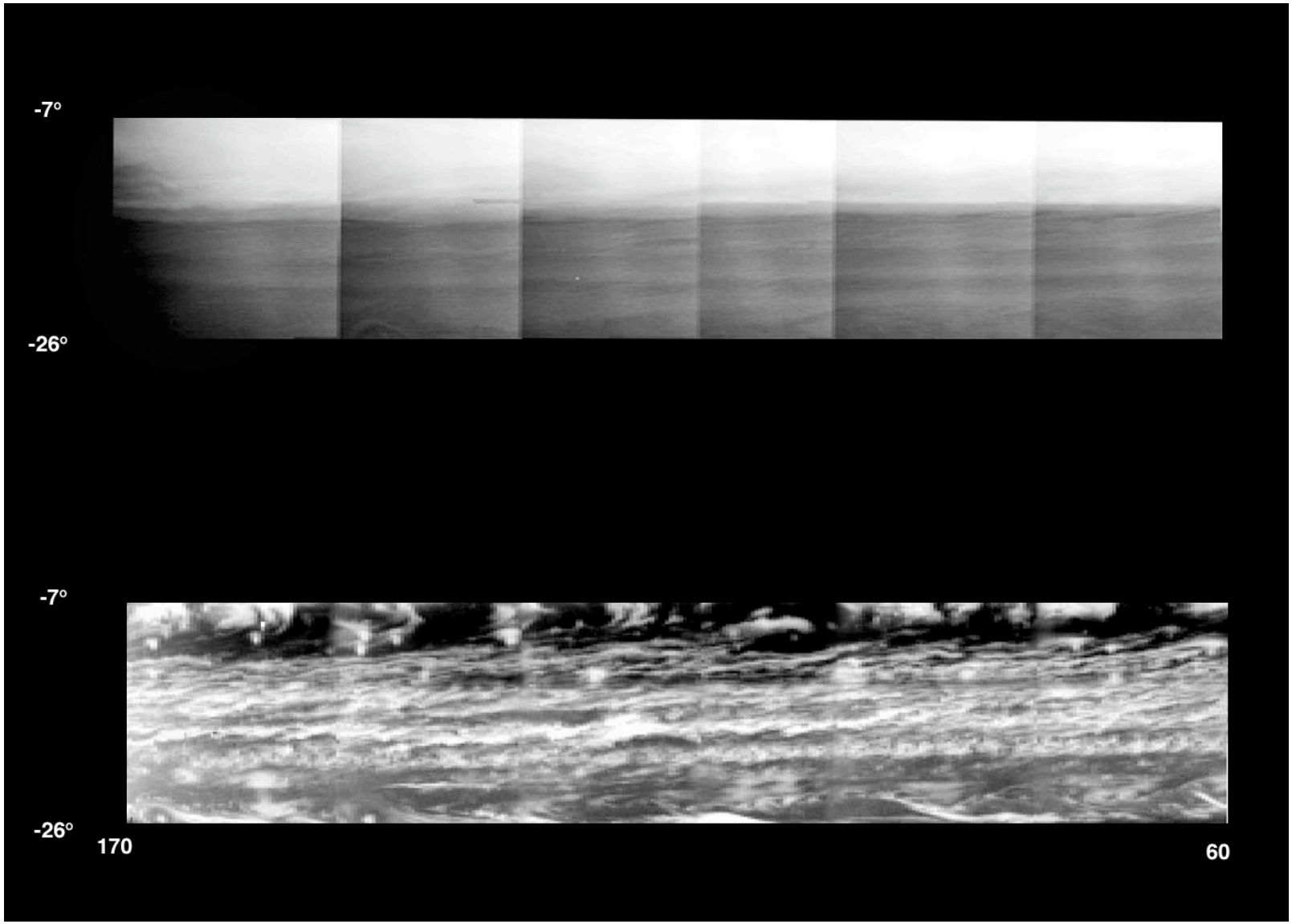

56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83

Thermal
Opacity
Of
Deep Clouds



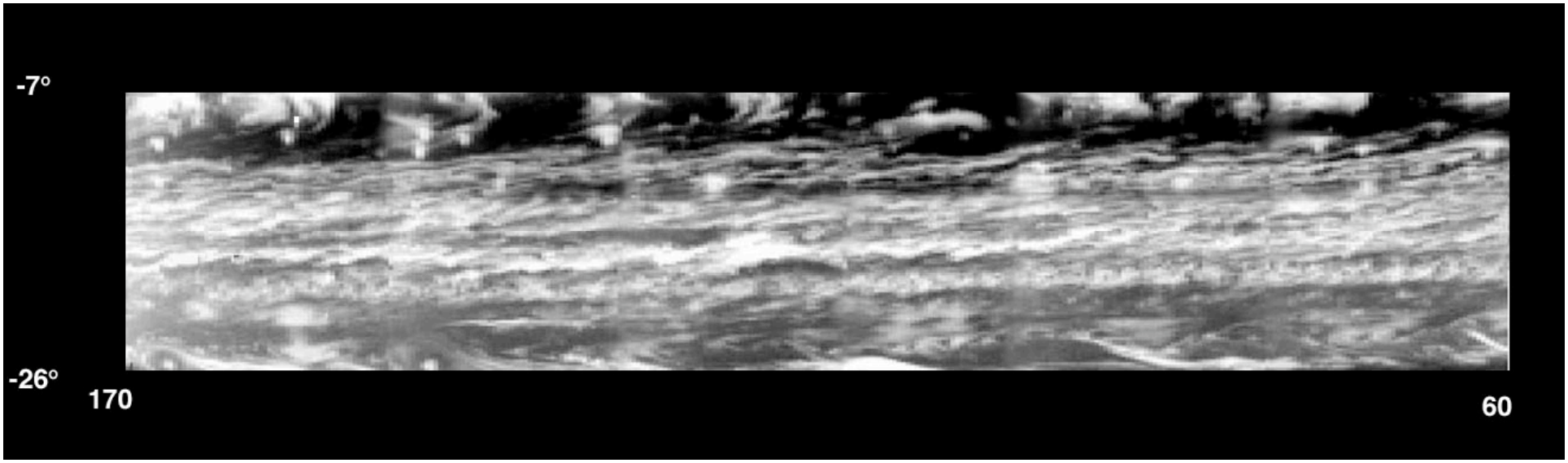
Reflected Sunlight From Cloud Tops

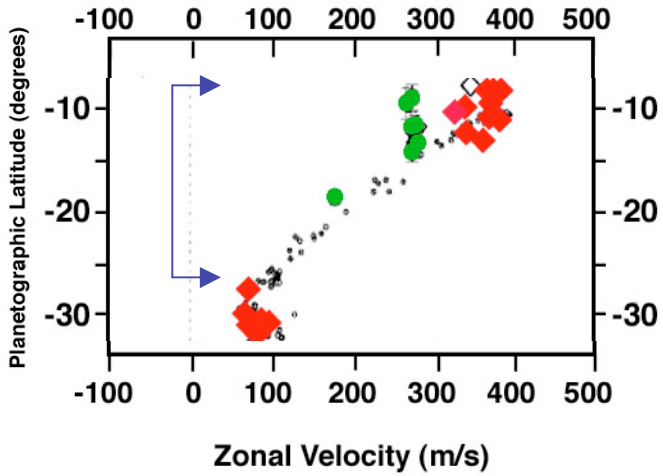
Thermal Opacity Of Deep Clouds

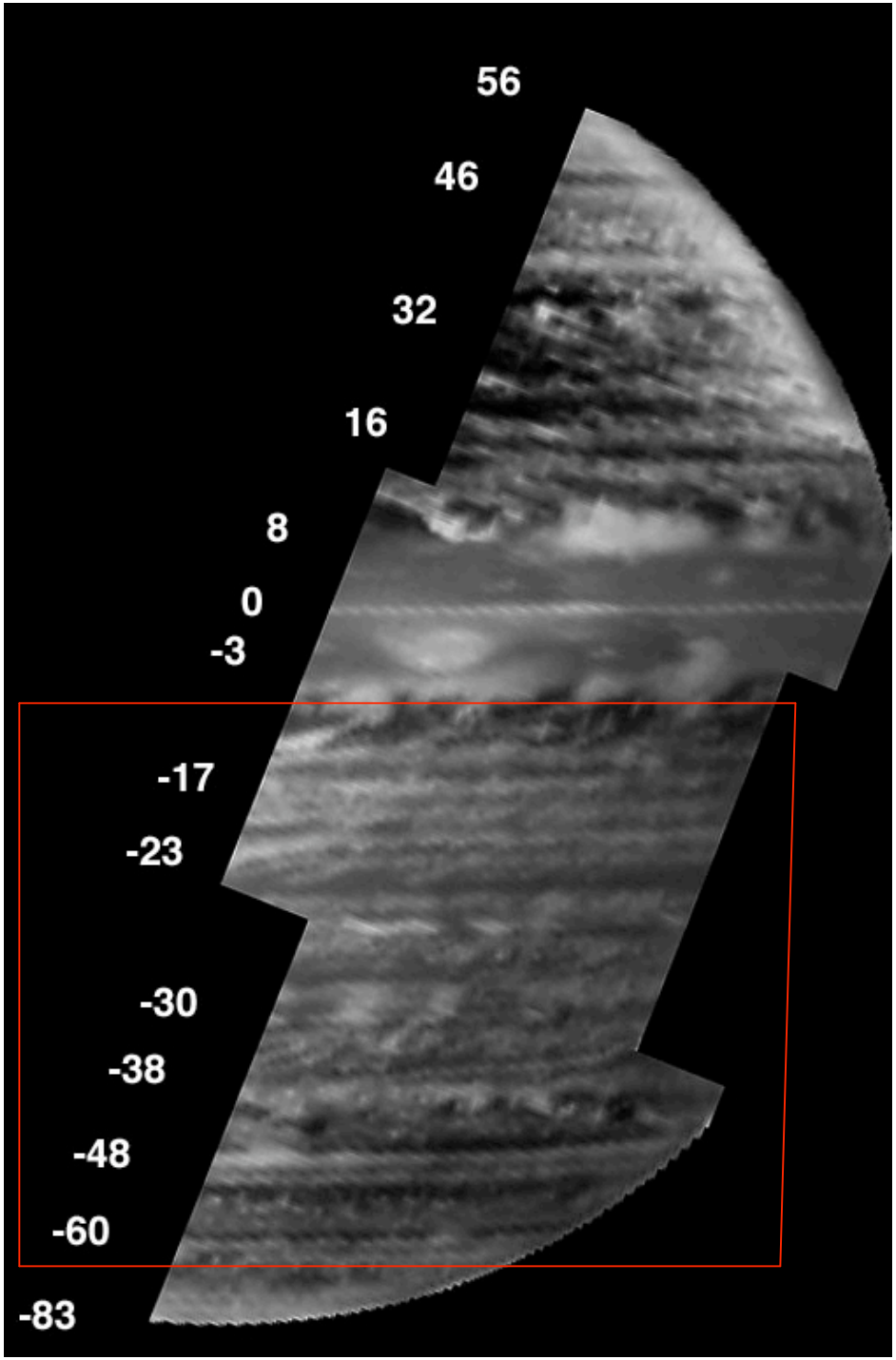


Saturn Southern Tropical Region
March 8, 2005

IFOV: ~ 260 km

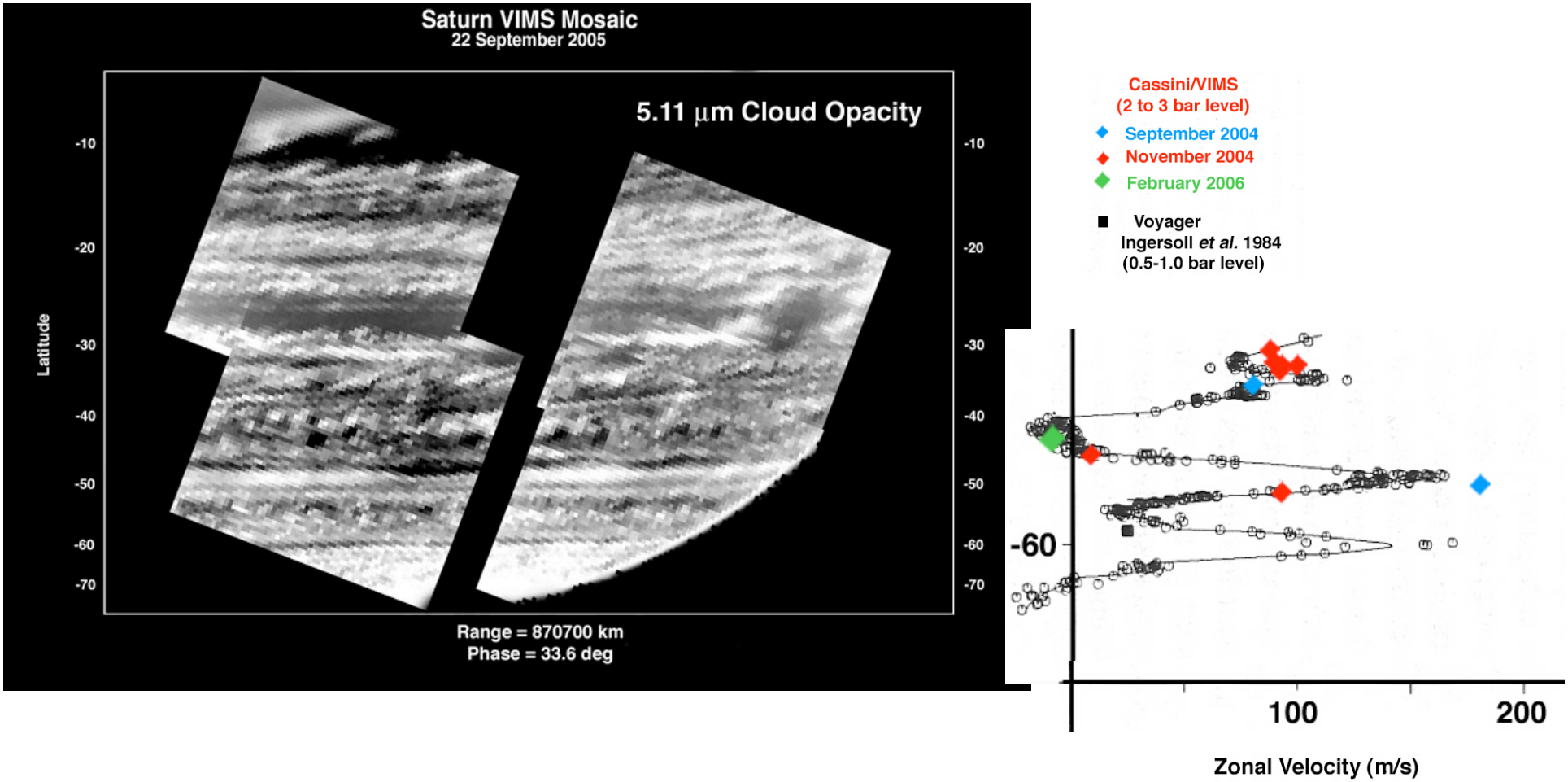





56
46
32
16
8
0
-3
-17
-23
-30
-38
-48
-60
-83

Saturn Southern Hemisphere

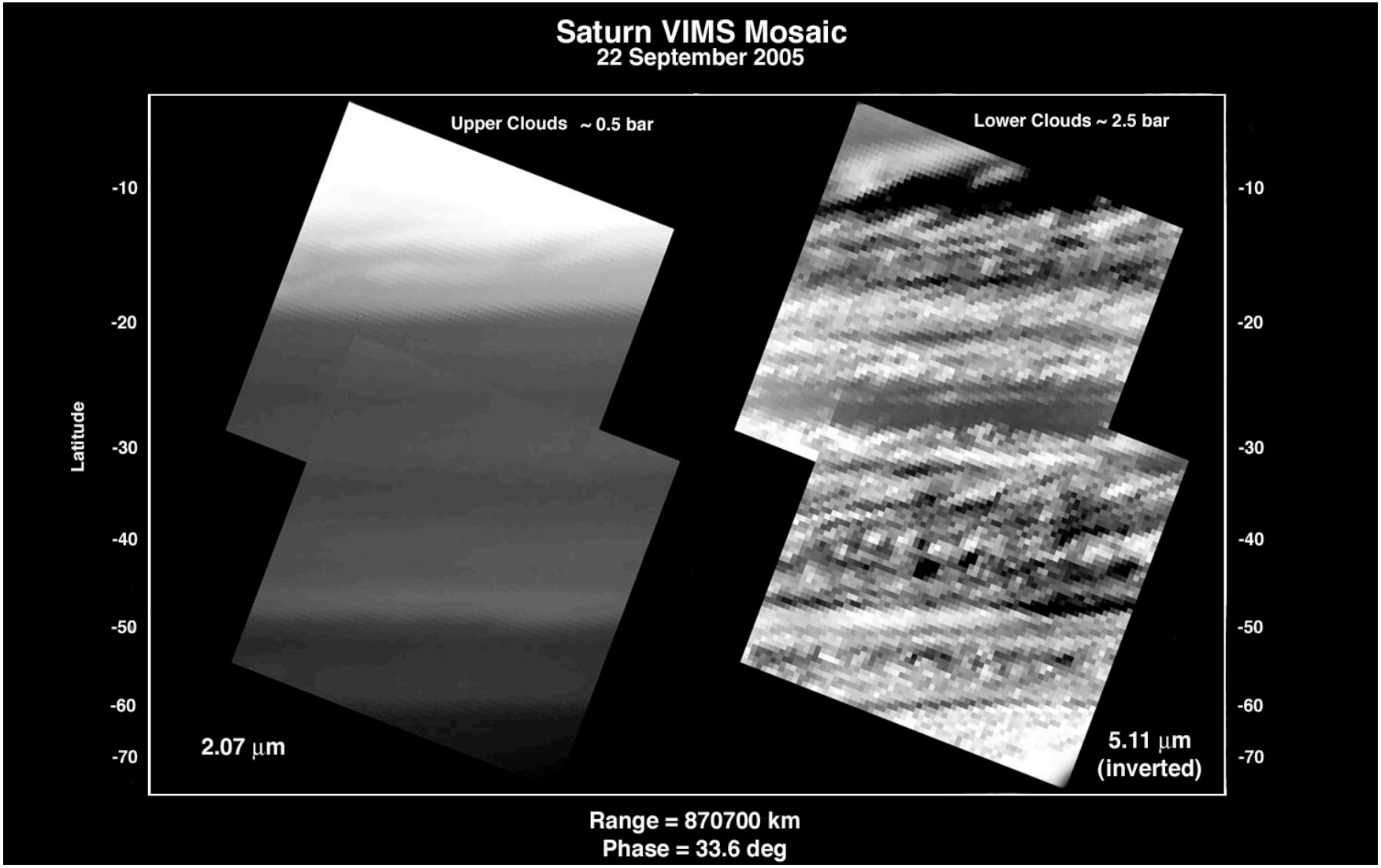
IFOV 435 km

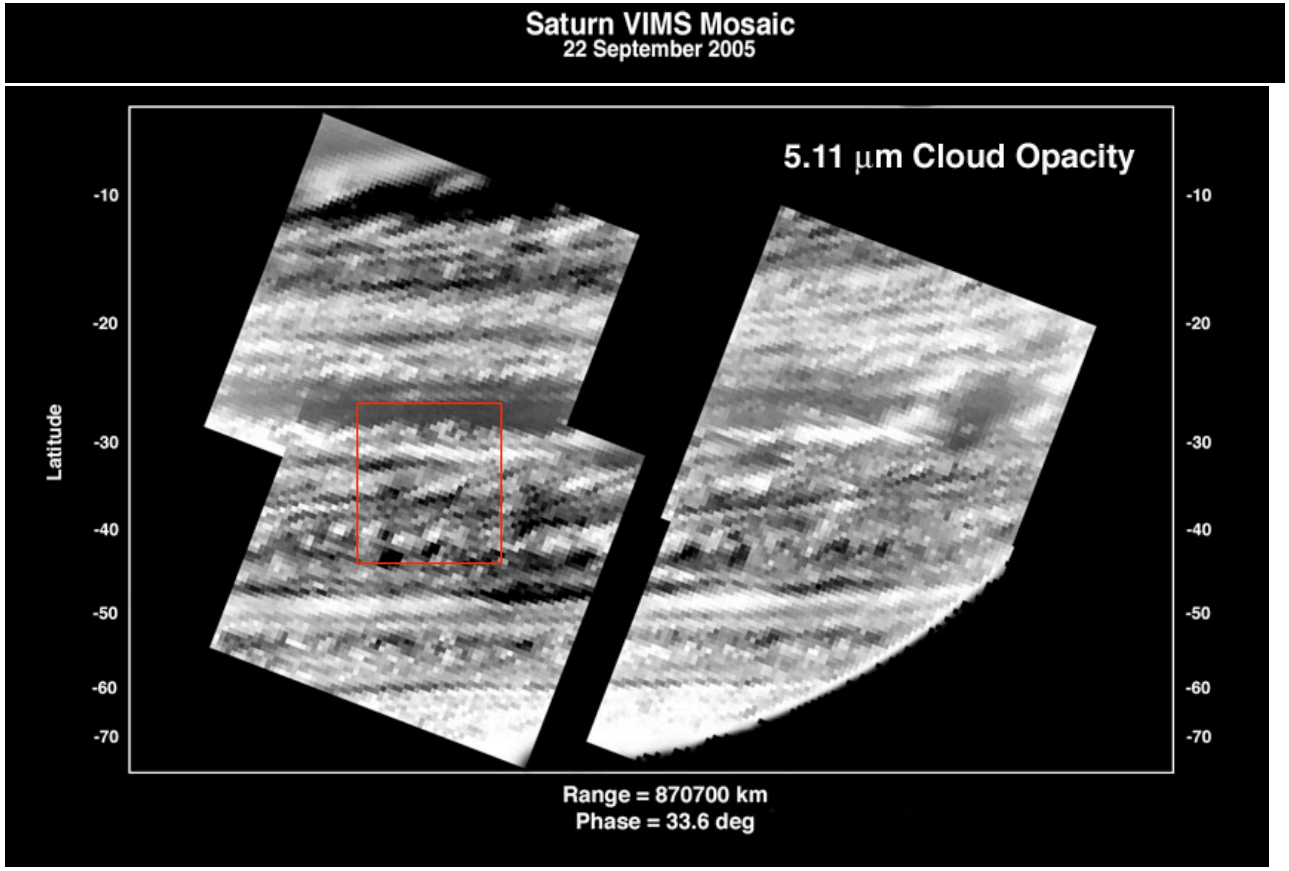


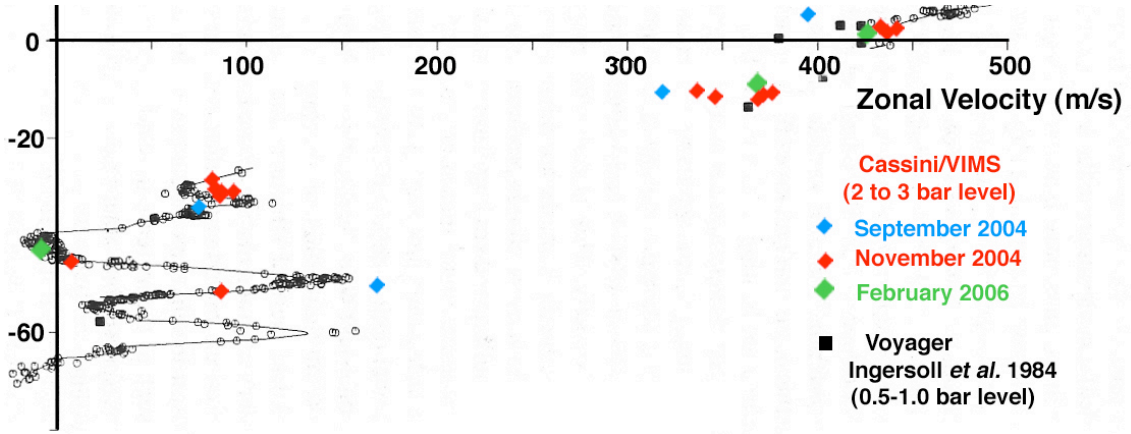
New Views: September, 2005

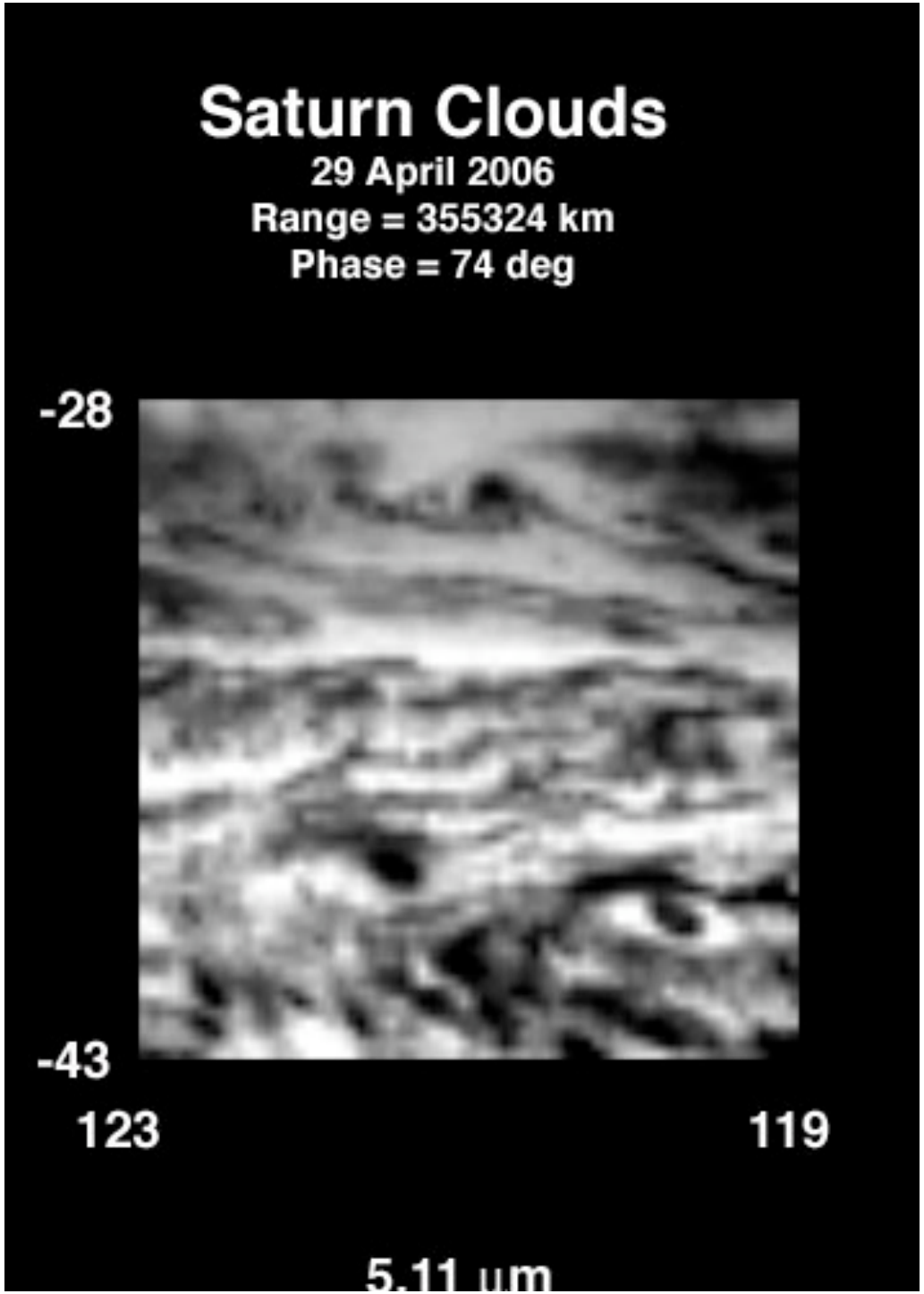
Visible View:
Reflected Sunlight From Cloudtops

Thermal View ("Inverted"):
Interior Thermal Flux Blocked by Thick Clouds at Depth




Saturn VIMS Mosaic
22 September 2005
5.11 μm Cloud Opacity
Latitude
-10
-20
-30
-40
-50
-60
-70
Range = 870700 km
Phase = 33.6 deg

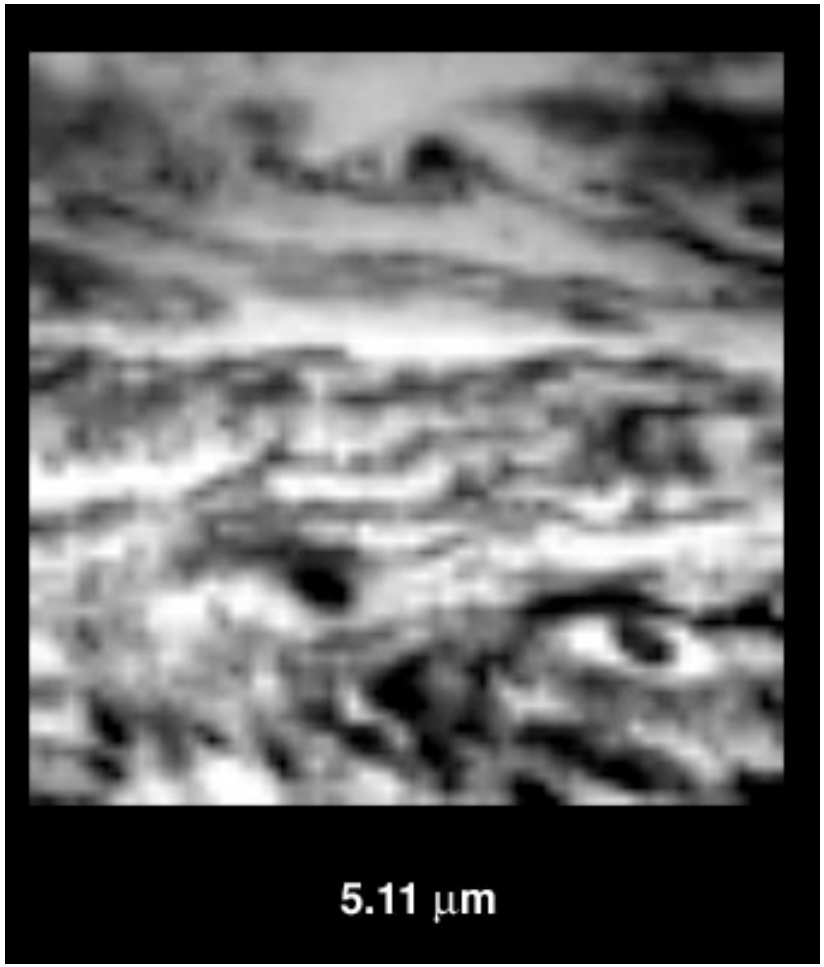

0
-20
-60
100
200
300
400
500
Zonal Velocity (m/s)
Cassini/VIMS
(2 to 3 bar level)
September 2004
November 2004
February 2006
Voyager
Ingersoll *et al.* 1984
(0.5-1.0 bar level)


Saturn Clouds
29 April 2006
Range = 355324 km
Phase = 74 deg
-28
-43
123
119
5.11 µm

Saturn Mid-Southern Latitudes

IFOV 178 km

April 29, 2006
Feature Following Campaign



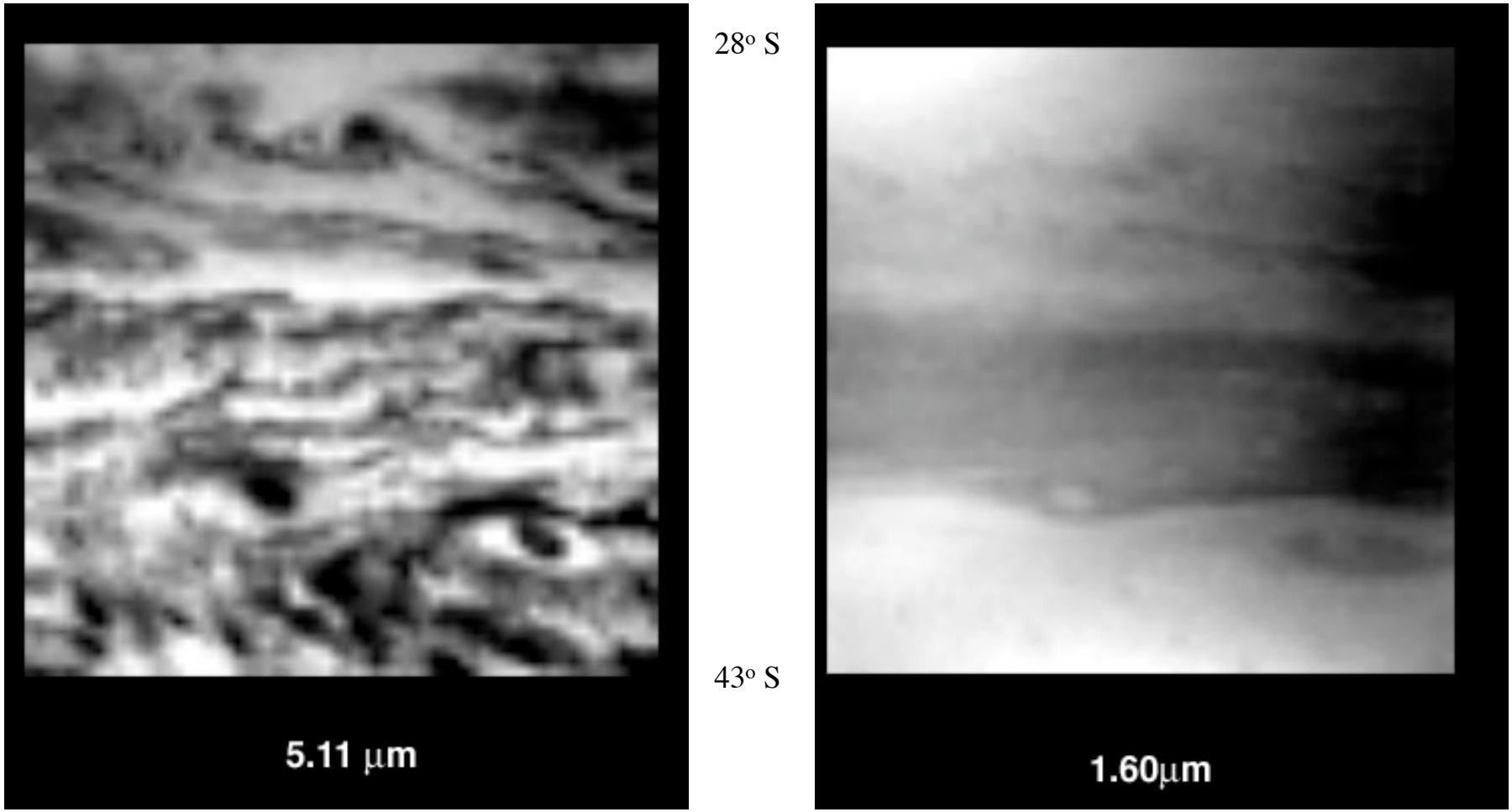
28° S

43° S

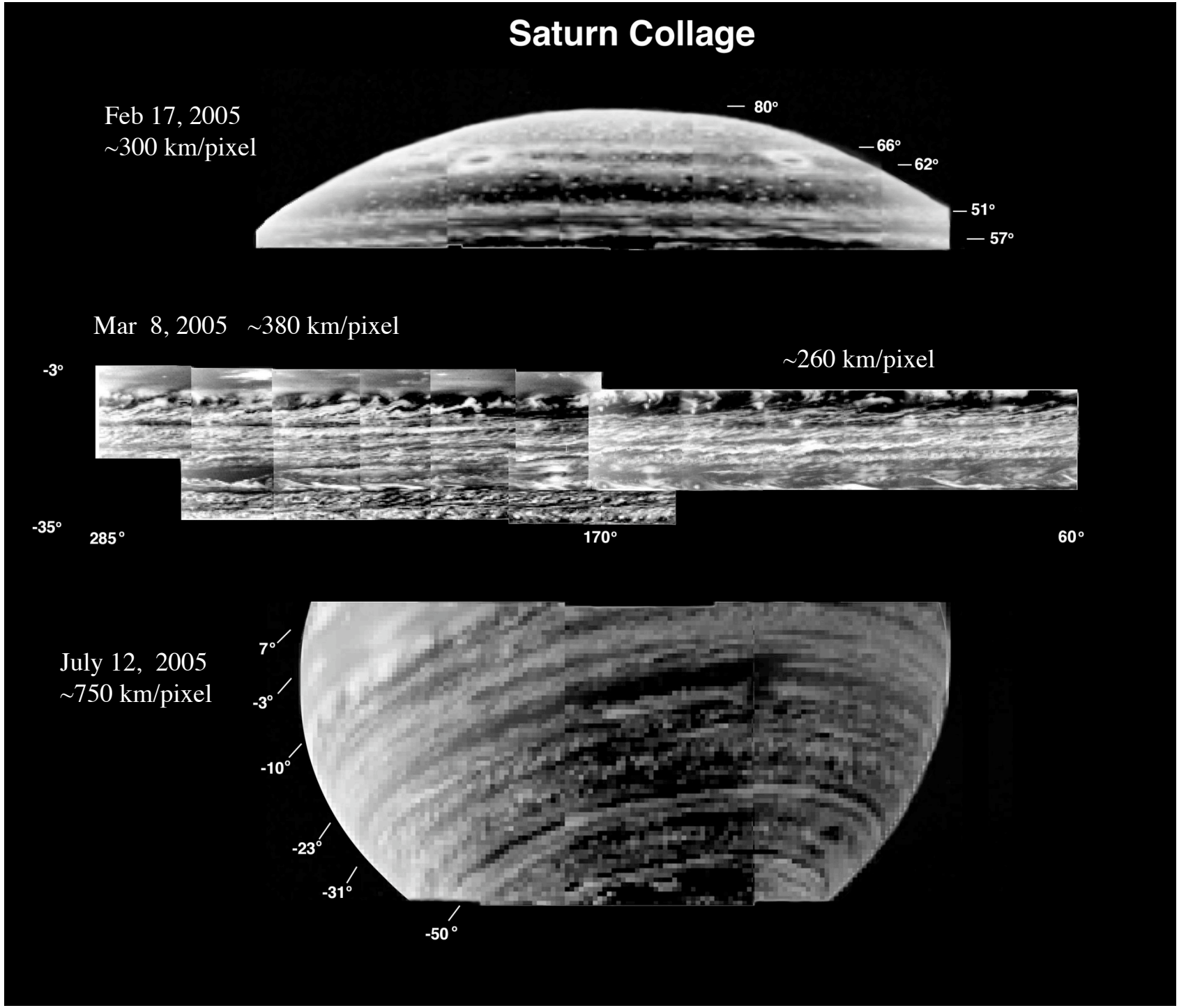
Saturn Mid-Southern Latitudes

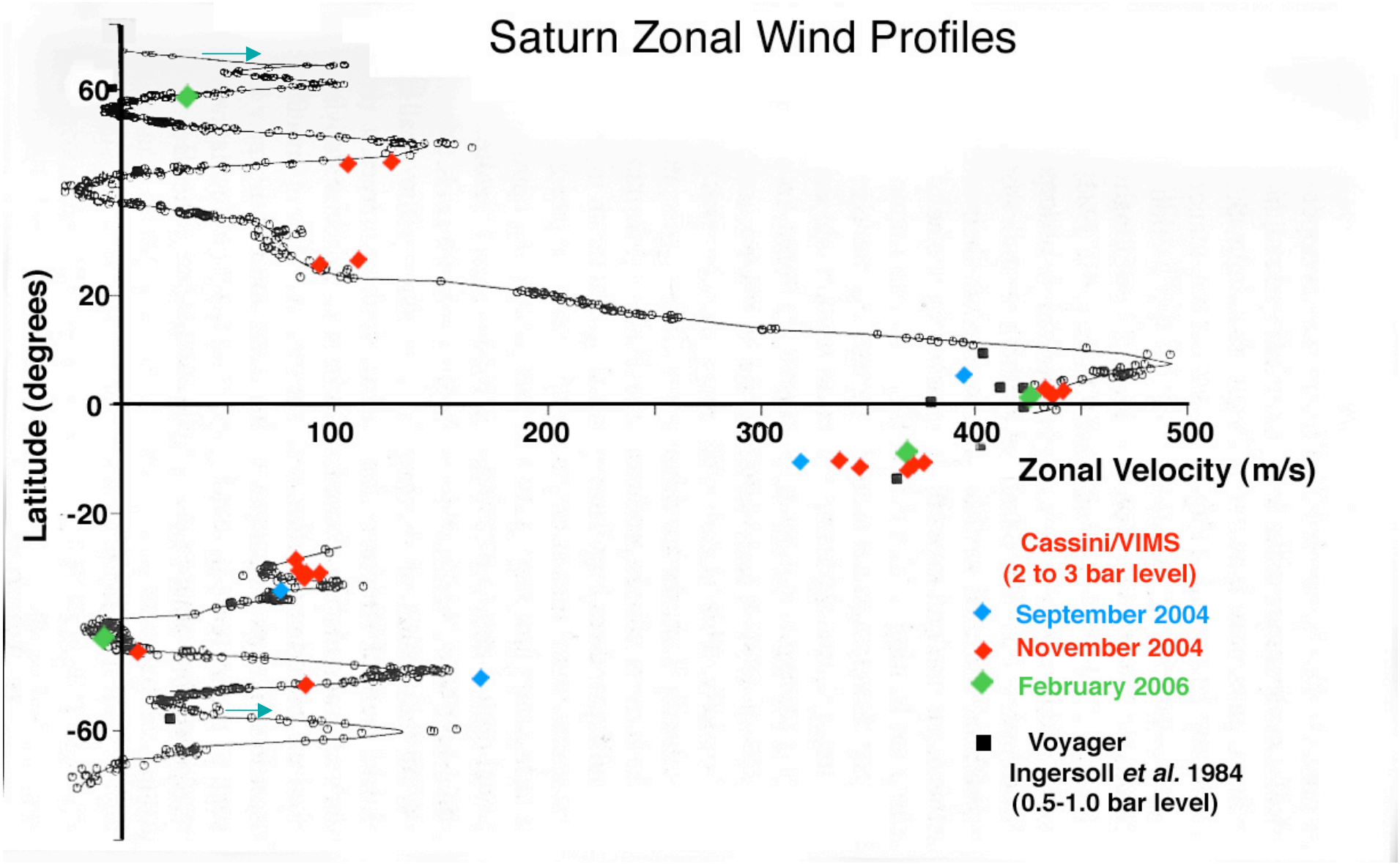
IFOV 178 km

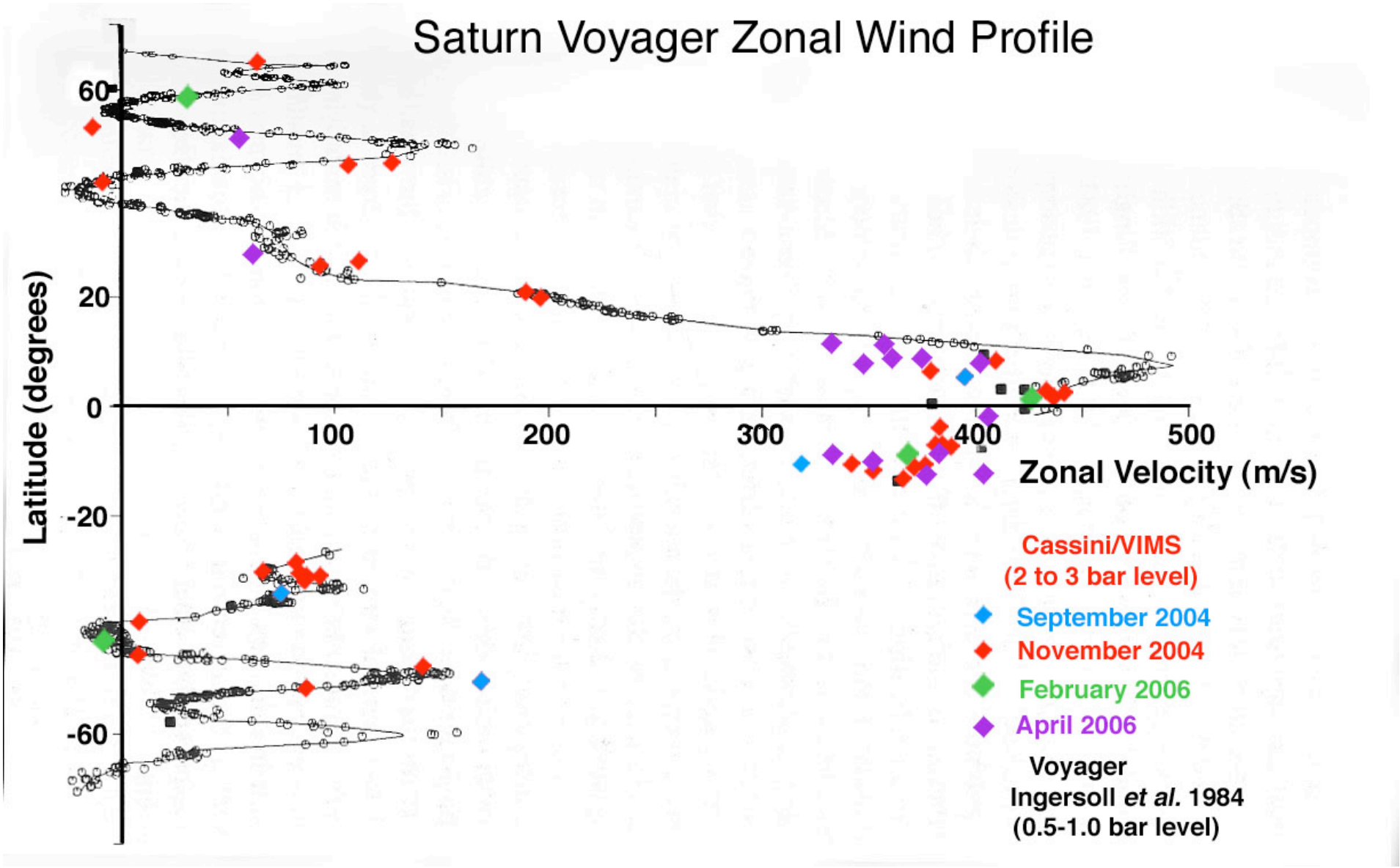
April 29, 2006
Feature Following Campaign



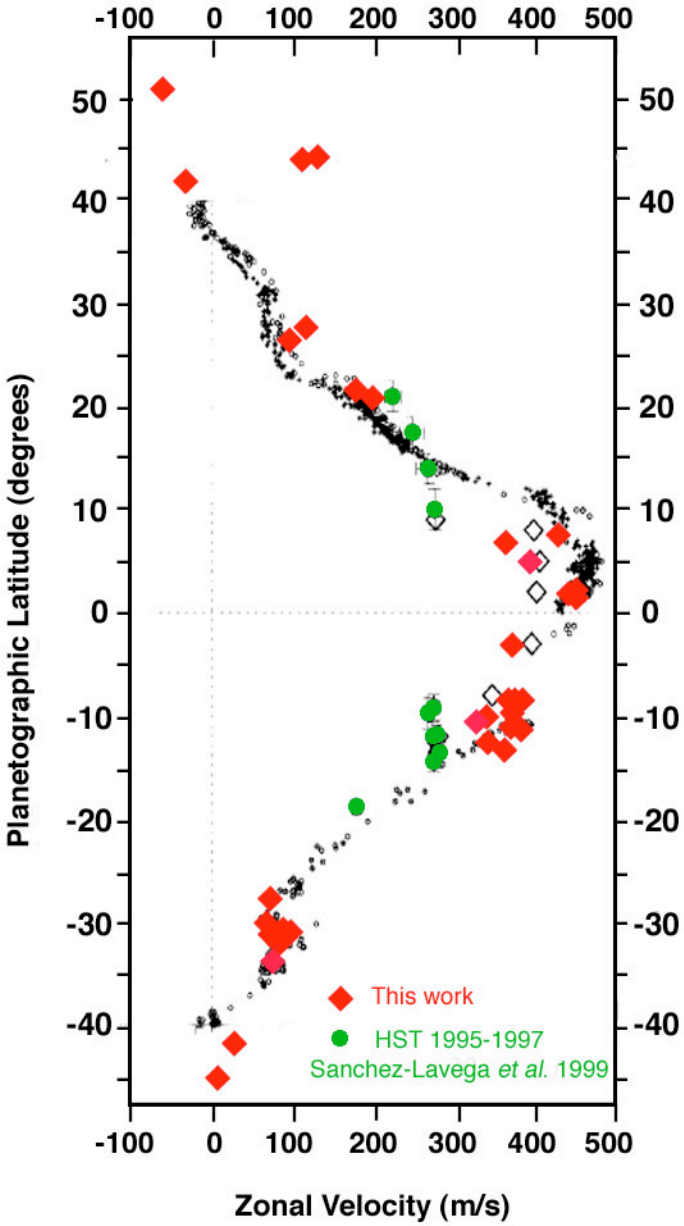
Saturn Collage



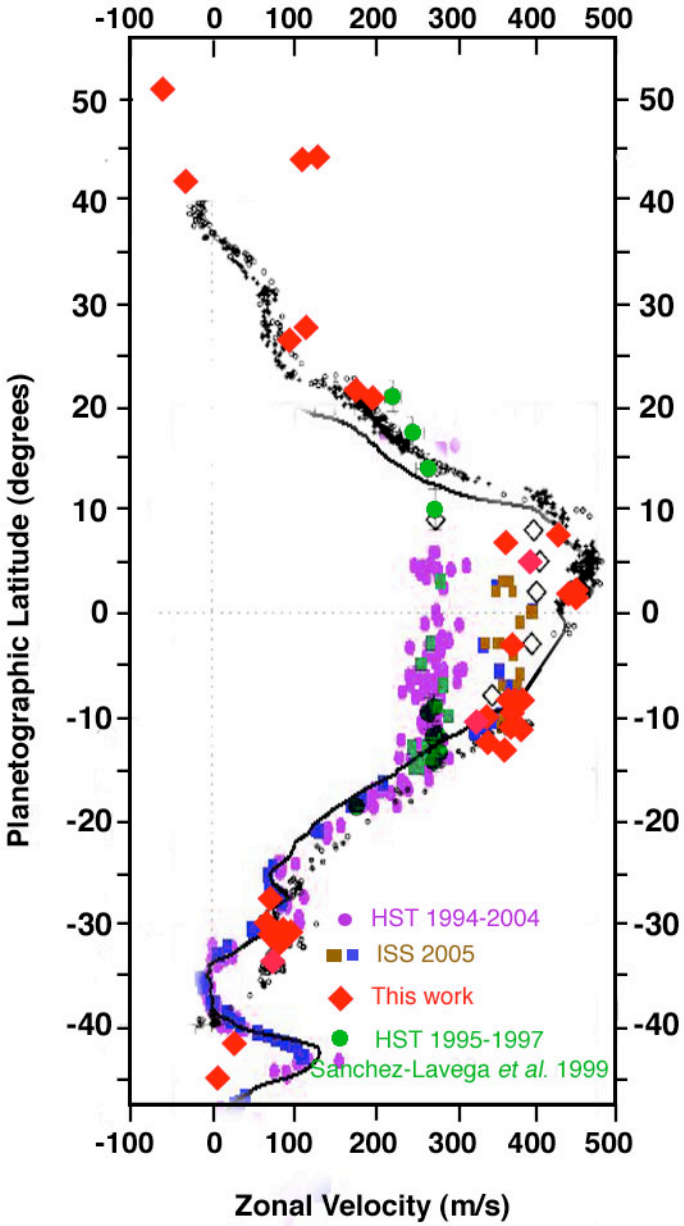

Saturn Zonal Wind Profiles
60
20
0
-20
-60
100
200
300
400
500
Latitude (degrees)
Zonal Velocity (m/s)
Cassini/VIMS
(2 to 3 bar level)
September 2004
November 2004
February 2006
Voyager
Ingersoll et al. 1984
(0.5-1.0 bar level)

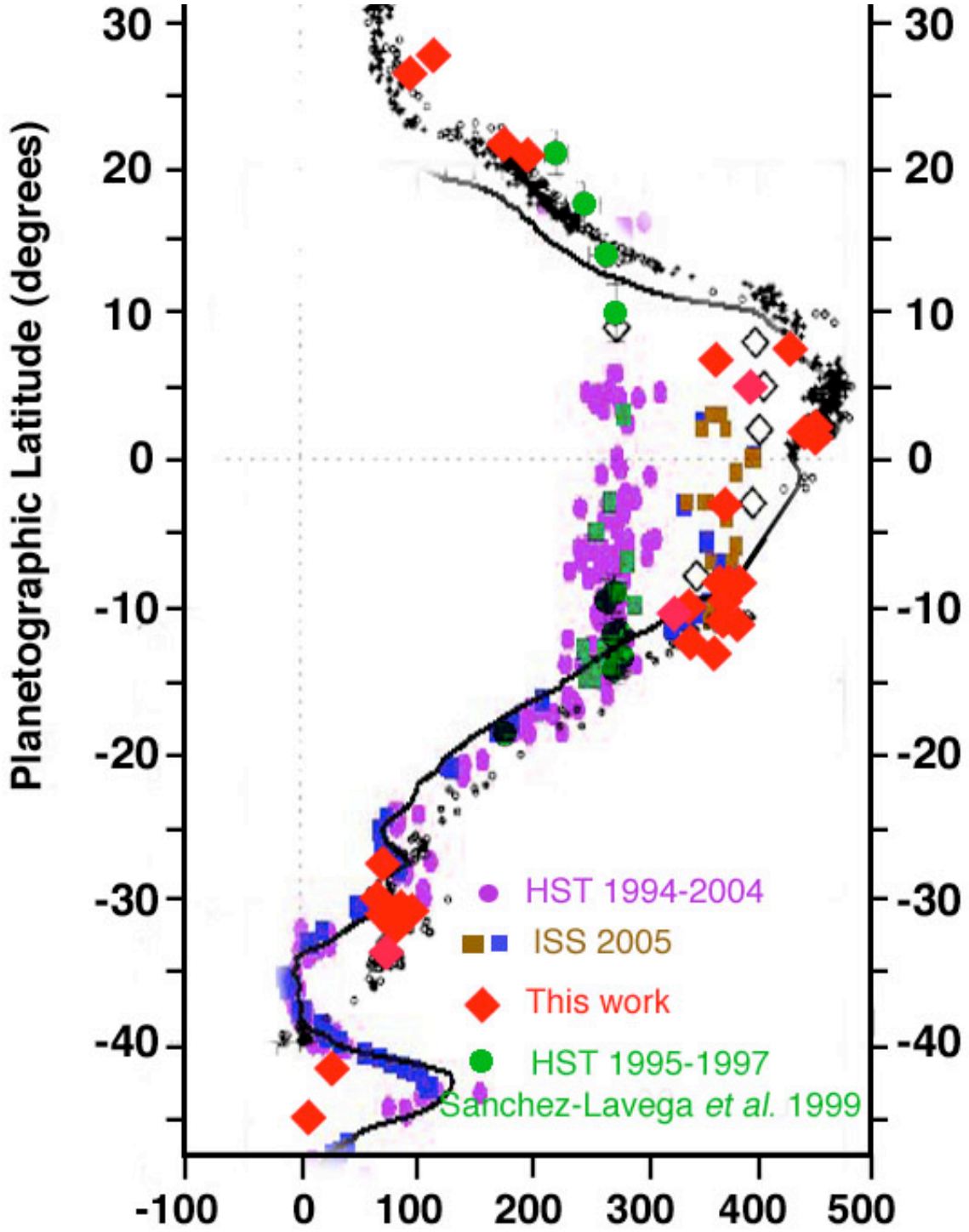

Saturn Voyager Zonal Wind Profile
Latitude (degrees)
60
20
0
-20
-60
100
200
300
400
500
Zonal Velocity (m/s)
Cassini/VIMS
(2 to 3 bar level)
September 2004
November 2004
February 2006
April 2006
Voyager
Ingersoll *et al.* 1984
(0.5-1.0 bar level)

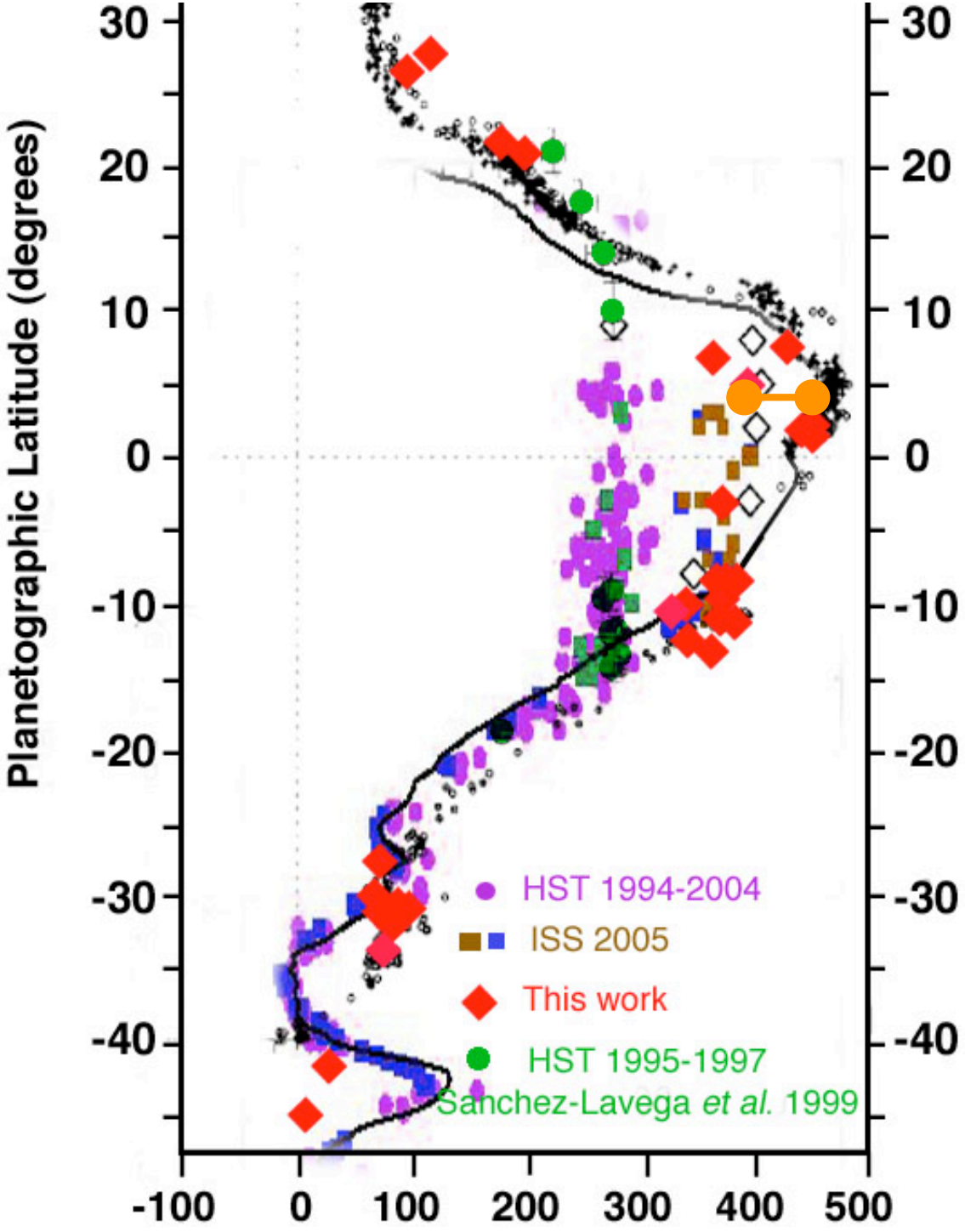
Saturn Wind Profiles: Voyager, HST & Cassini



Saturn Wind Profiles: Voyager, HST & Cassini




Planetographic Latitude (degrees)
30
20
10
0
-10
-20
-30
-40
-100
0
100
200
300
400
500
HST 1994-2004
ISS 2005
This work
HST 1995-1997
Sanchez-Lavega et al. 1999



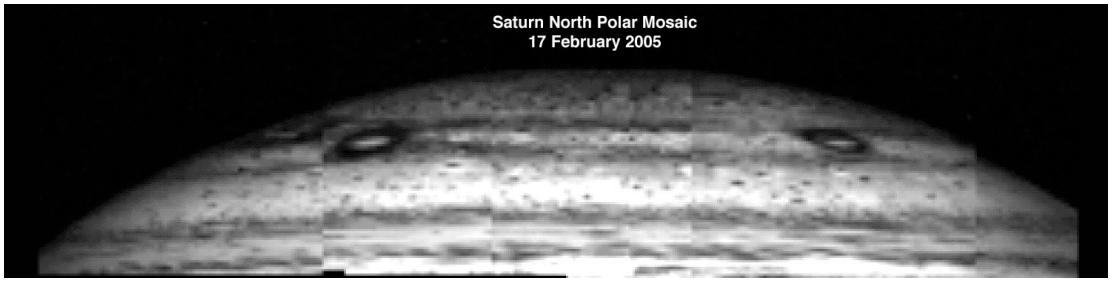
Mean Shear
at 3º North, from
~1 to 2 bars:
~-2 m/sec/km

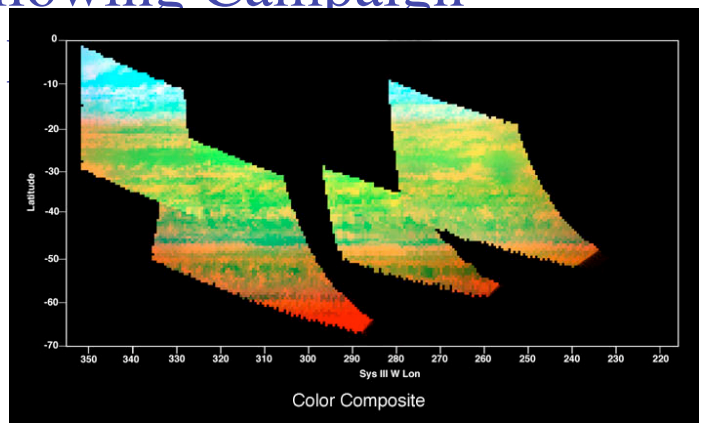
Galileo Probe
At 6º North in
Jupiter, from
~1 to 2 bars:
-2.5 m/sec/km

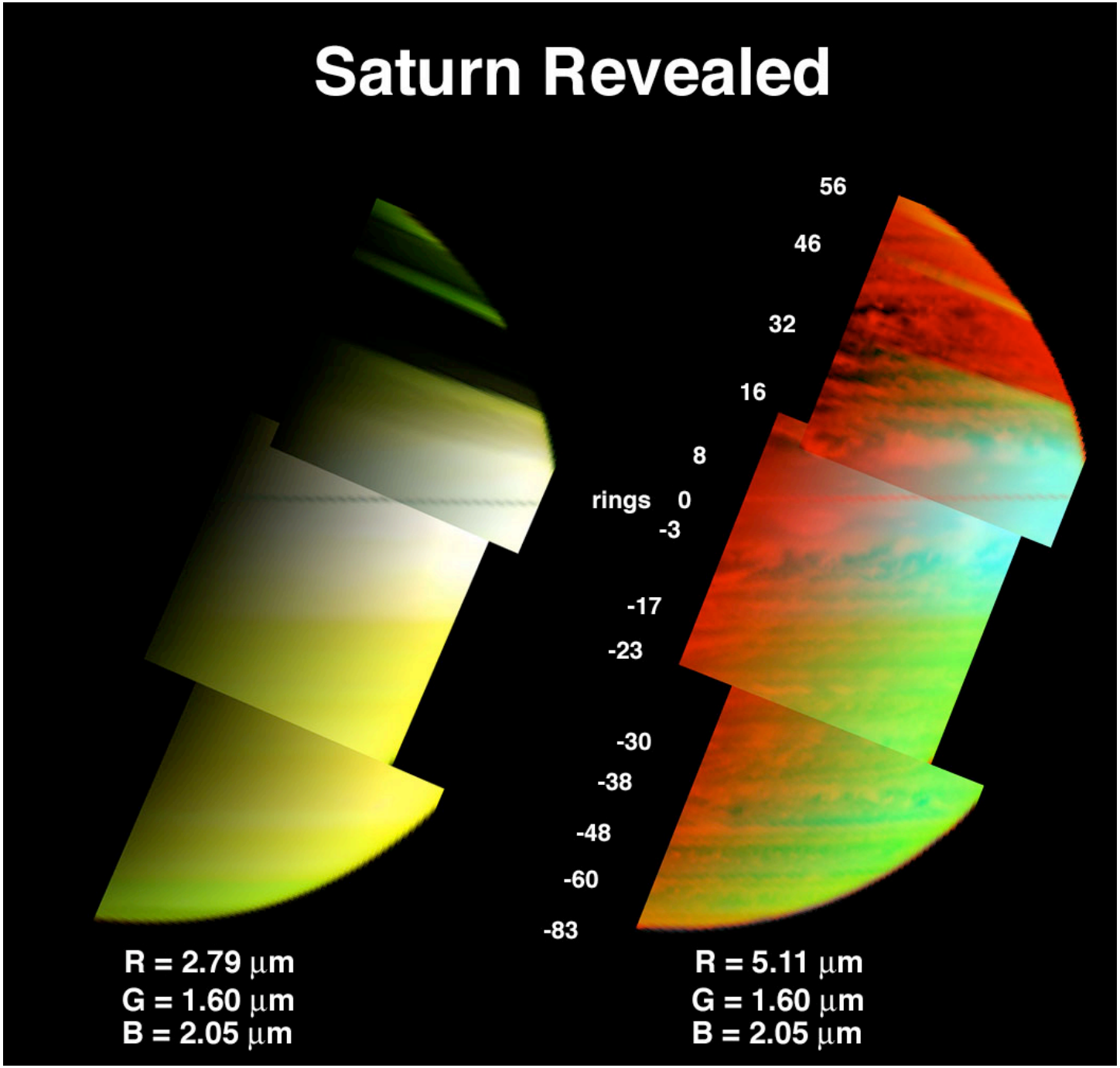
Clouds Saturn's Deep Clouds/Storms

- A New Look at Global Circulation
  - A New View of Saturn's Zonal Cloud Structure
  - Saturn's Deep-Level Winds and Wind Shears

- **<u>What Next</u>**: Continued Exploration/Characterization
  - Continue to Inventory Features Over Planet at High-Resolutio
  - Polar Views, Movies
  - 3-D Structures with Feature Following Campaign
  - Follow Movement Evolution of






Saturn Revealed
56
46
32
16
8
rings 0
-3
-17
-23
-30
-38
-48
-60
-83
R = 2.79 μm
G = 1.60 μm
B = 2.05 μm
R = 5.11 μm
G = 1.60 μm
B = 2.05 μm