Spin Up of Uranus' Zonal Winds via Solar Heating

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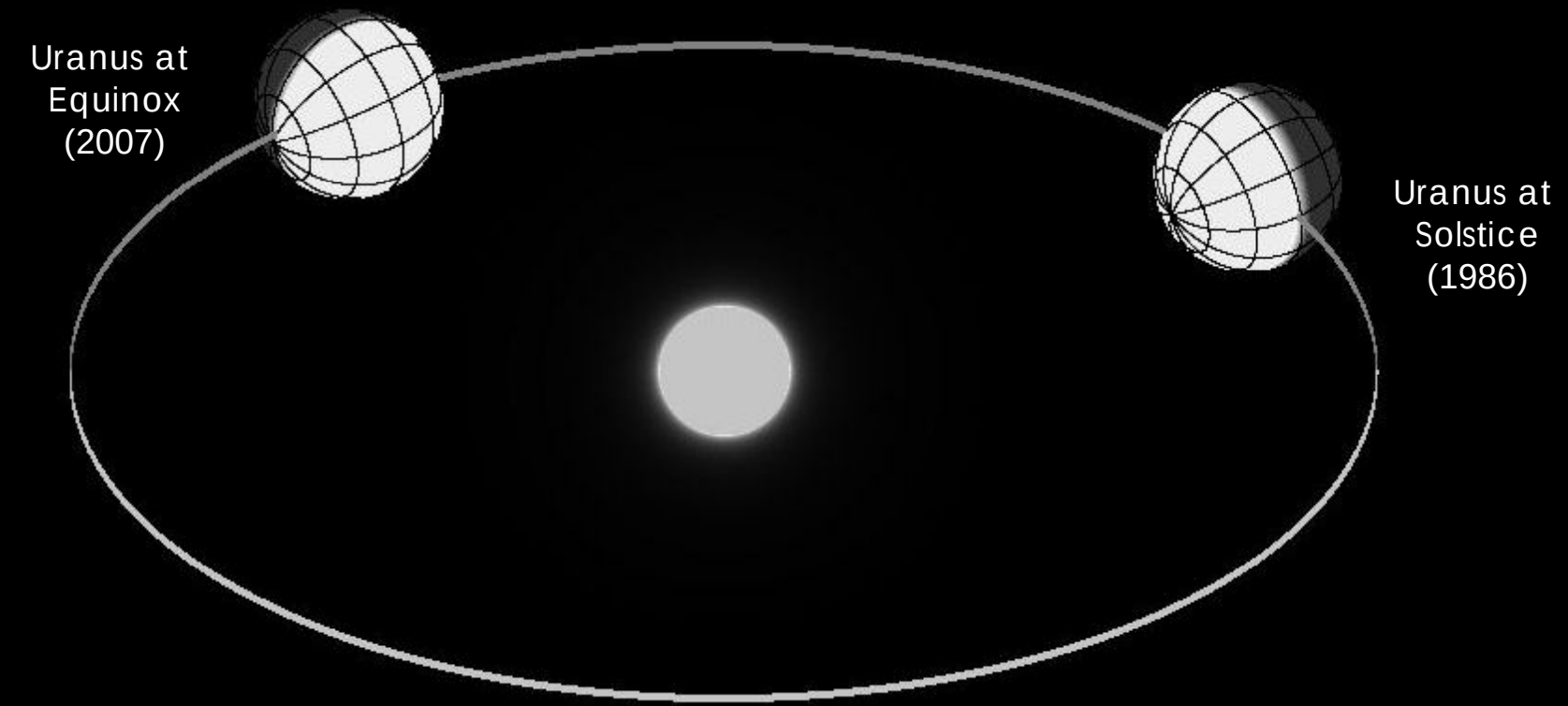
Background

- Planet's axial tilt is responsible for the strength of seasons
- Uranus' axial tilt is very large: 97^{o}
- Solstice: 1986, Equinox: 2007



Background

	Jupiter	Saturn	Uranus	Neptune
Equilibrium Temperature (K)	113	83	60	48
Effective Temperature (K)	124	95	59	59

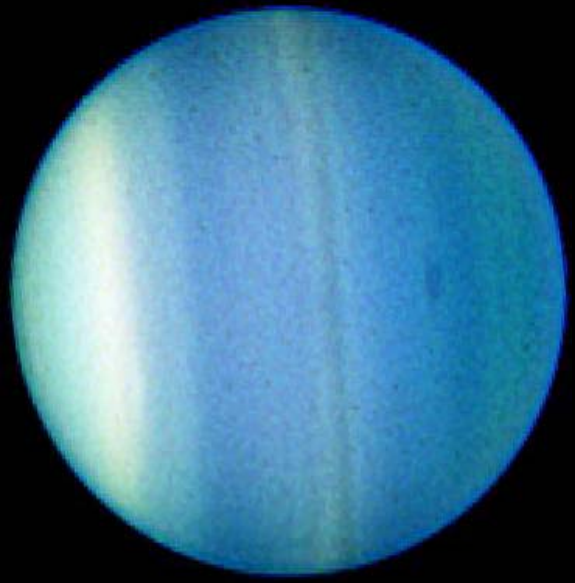
- Equilibrium Temperature: The temperature a planet will be if only heated by the Sun

- Effective Temperature: The actual observed temperature

- Uranus' equilibrium and effective temperature are very close; the Sun is almost entirely responsible for its energy flux

Observations: Images

Voyager Observation
At Solstice (1986)

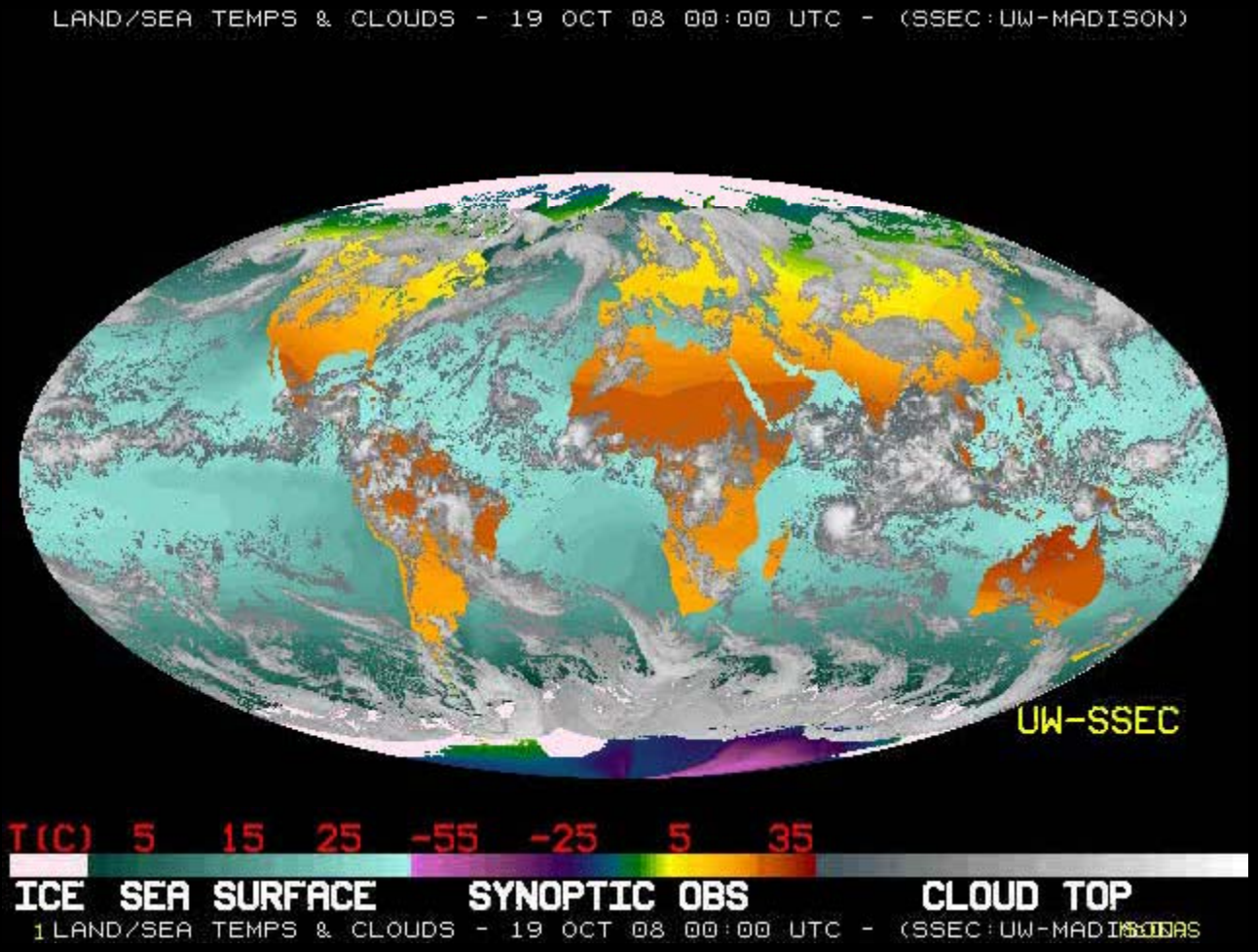


HST Observation
At Equinox (2007)

Comparison of Equinox images vs. Solstice images show numerous changes:

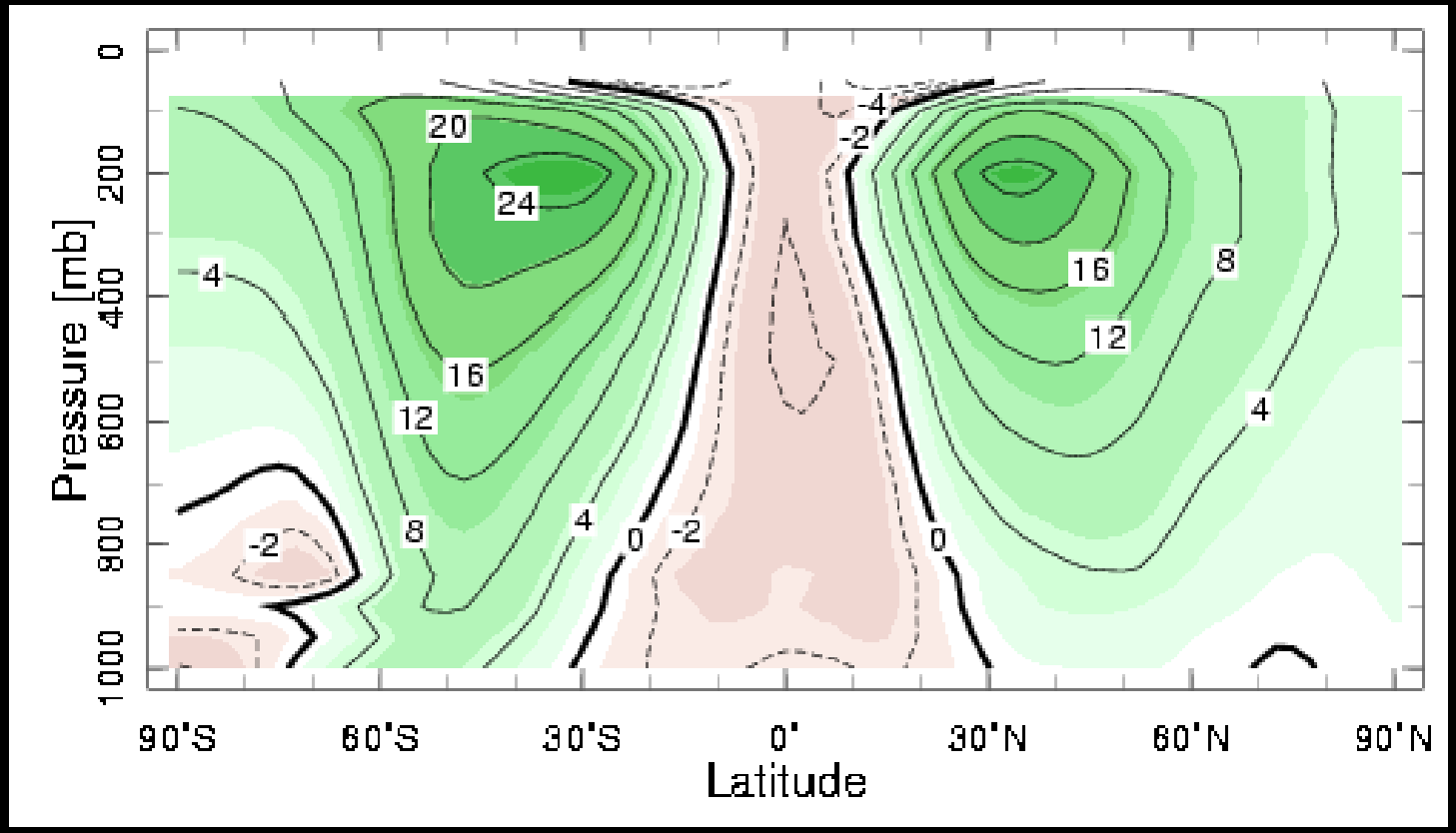
- Clouds
- Banding
- Storms
- Zonal Winds?

Background: Zonal Winds



Zonal Winds are the averaged East-West winds which flow around the planet.

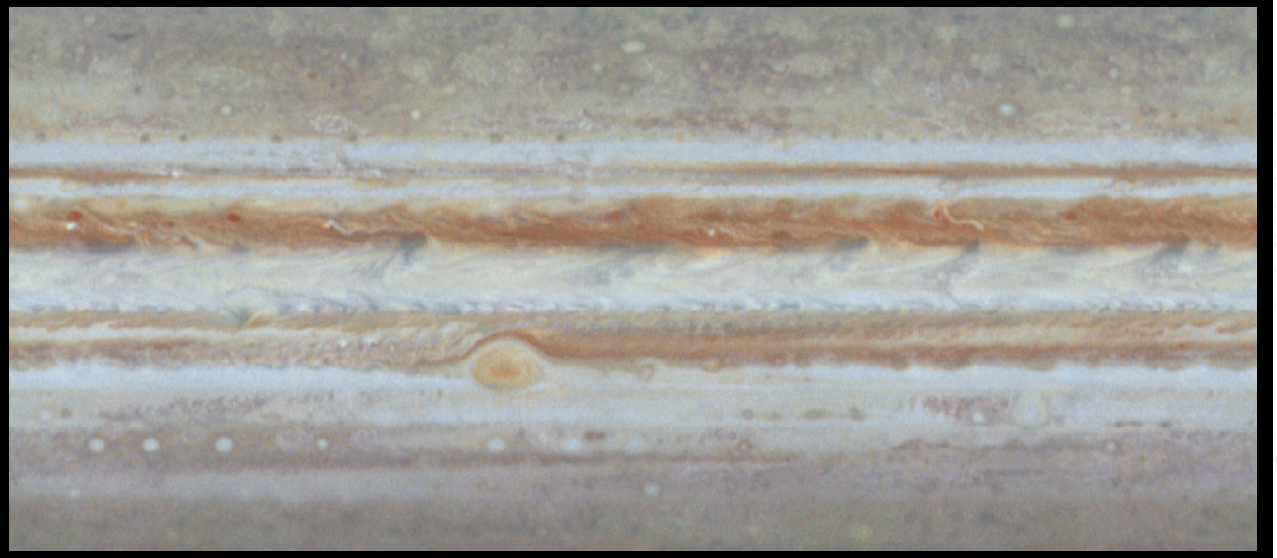
Observations: Zonal Winds

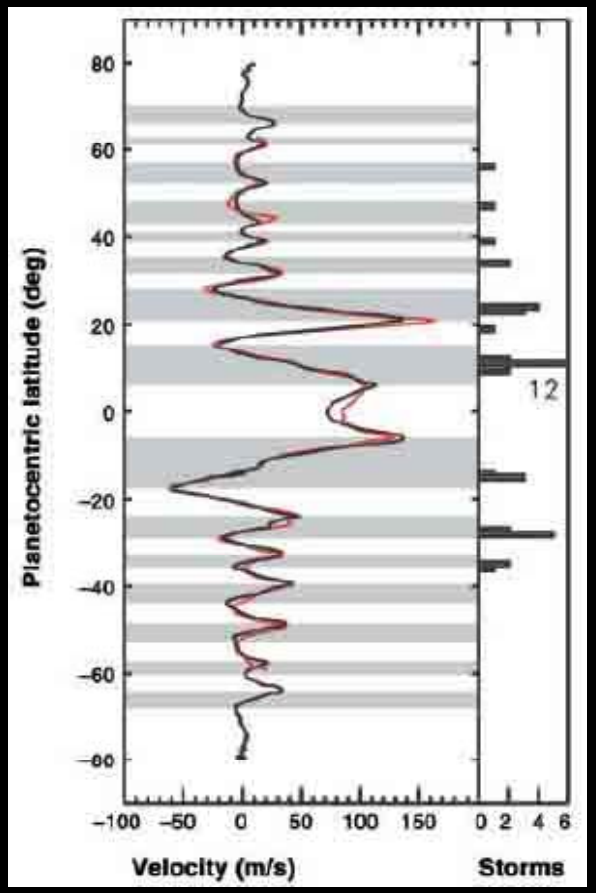


Latitude-height diagram of Earth's zonal winds.

Background: Zonal Winds

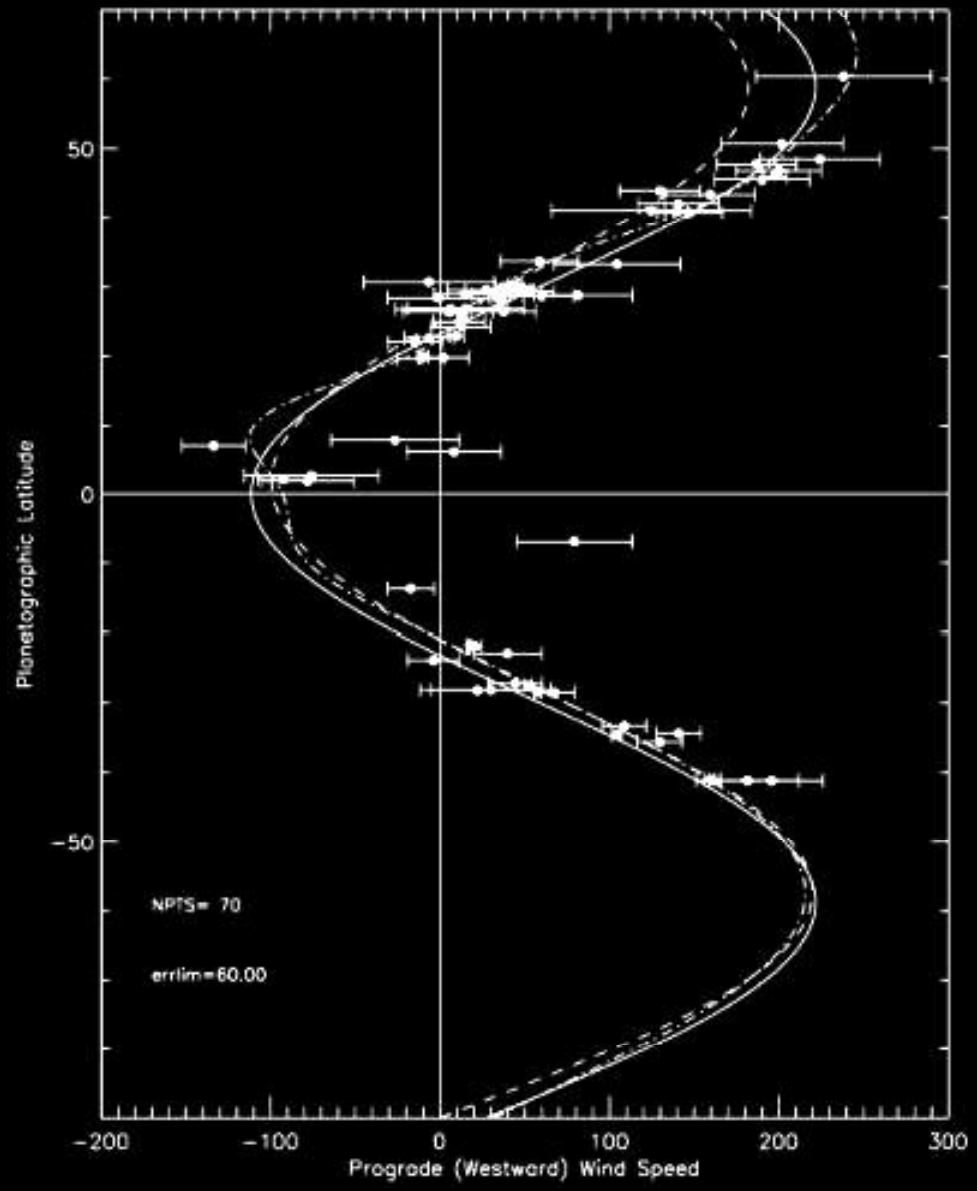
- Not all planets have just 3 jets
- Jupiter and Saturn have at least 20





Observation: Zonal Winds

- Based on cloud measurements, Uranus has 3 jets like Earth.
- Solid line is Voyager Solstice measurement
- Dotted-dashed line is recent measurement near equinox.
- Note asymmetry!



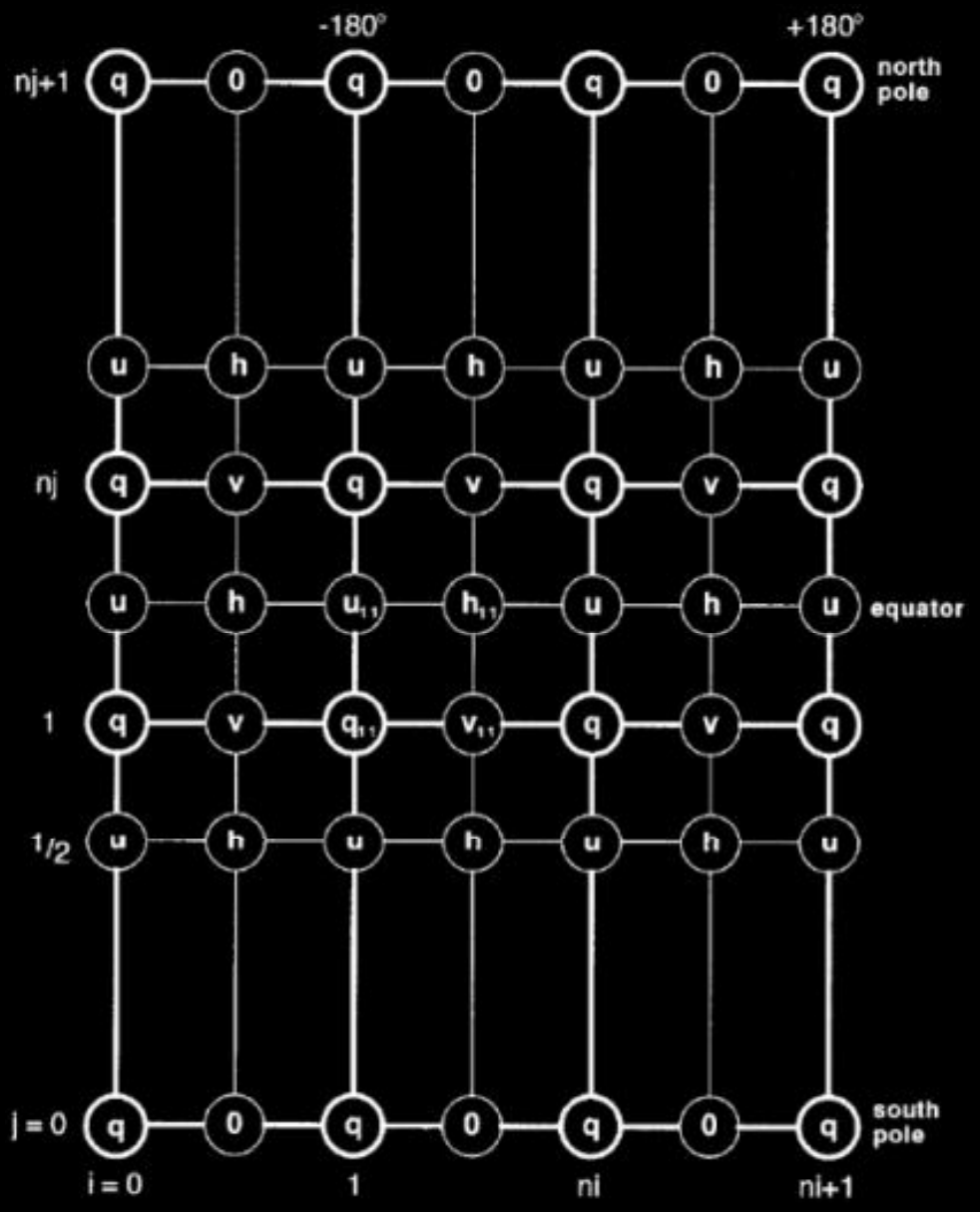
Modeling

- We have modified the EPIC General Climate Model (GCM) to simulate seasonal change on Uranus

- The model splits the planet into a grid, and integrates the "primitive equations" for fluid flow at each gridpoint.

$$\frac{\partial u}{\partial t} = qvh - \dot{\theta}\frac{\partial u}{\partial \theta} - \frac{1}{r}\frac{\partial}{\partial \phi}(C_pT + \Phi + K)$$

$$\frac{\partial v}{\partial t} = -quh - \dot{\theta}\frac{\partial v}{\partial \theta} - \frac{1}{R}\frac{\partial}{\partial \lambda}(C_pT + \Phi + K)$$

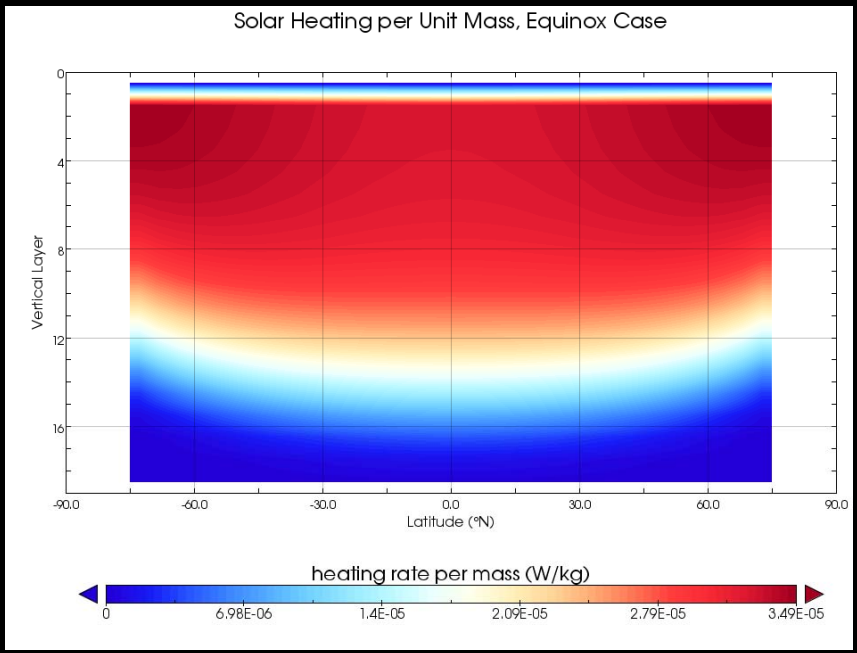


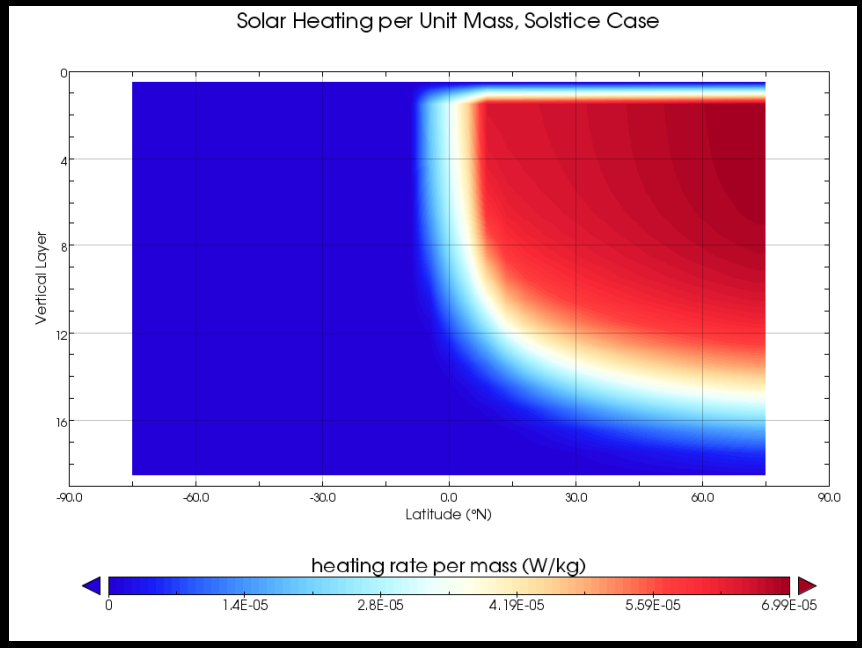
Model Changes

- We have added the effect of sunlight as a heating term

$$A_n = F_o cos\,(\theta)\left(e^{-\frac{P_n - \Delta P}{H}}\right)\left(1 - e^{-\frac{\Delta P}{H}}\right)$$

- Term varies both daily and seasonally





- Also altered heating scheme from Newtonian to Radiative

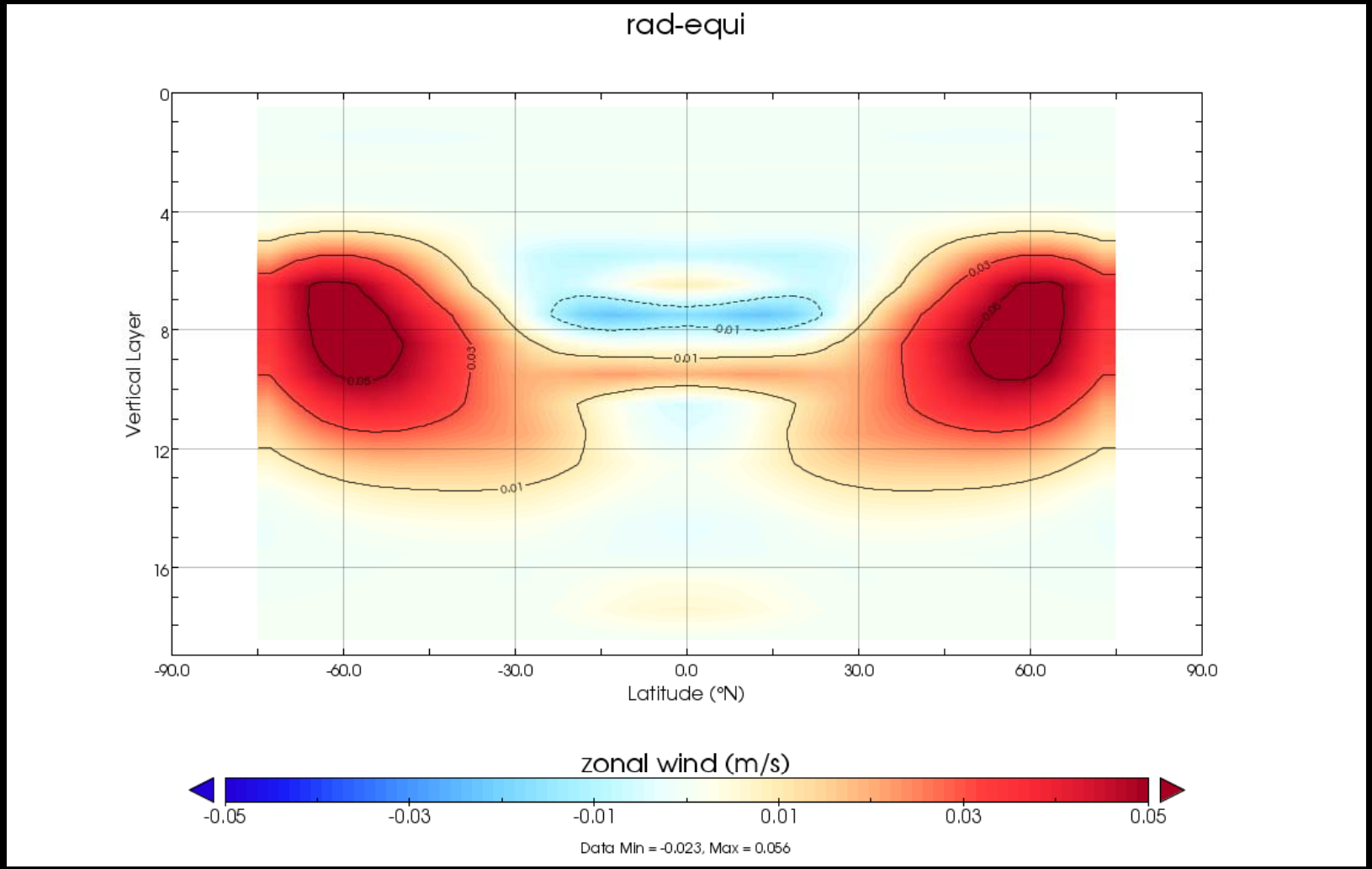
Model Parameters

Ran “spin-up” experiments:

- Initialize planet with zero winds
- Introduce sunlight as a heating term to drive dynamics
- Analyze zonal winds produced
- Experiments performed at equinox and at solstice

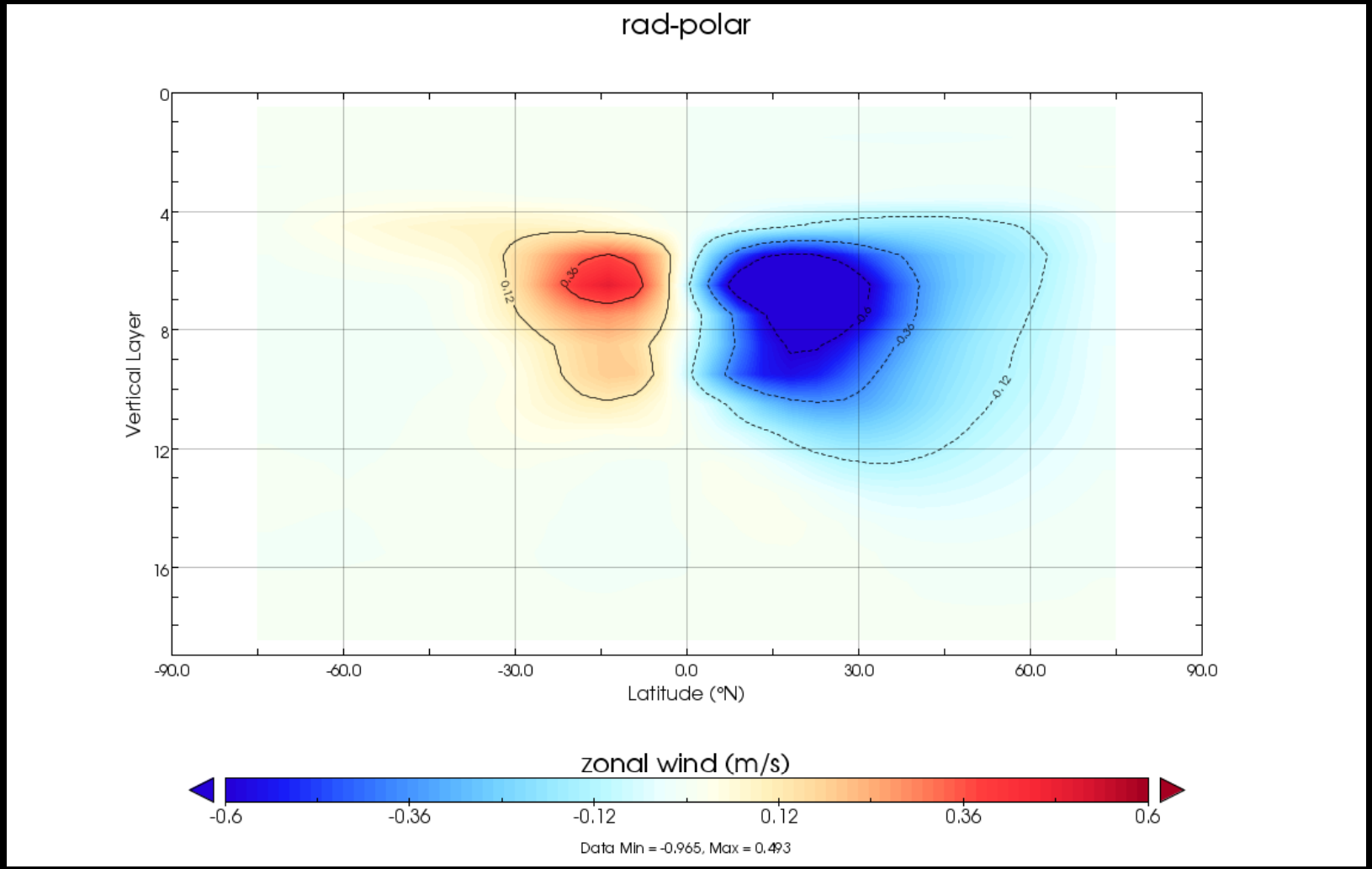
Model Results

Equinox heating:

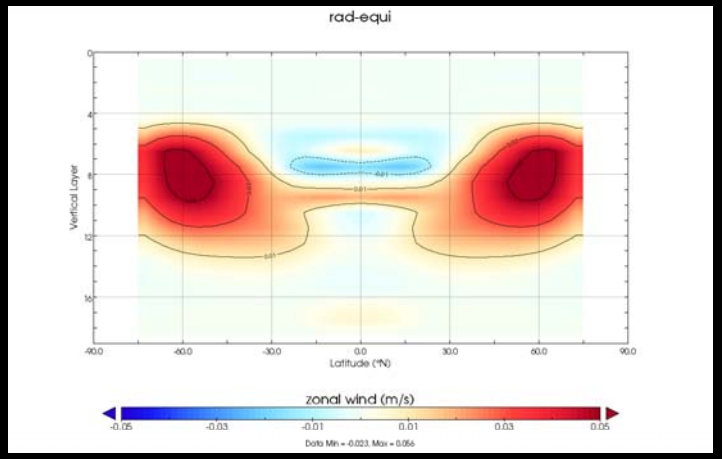


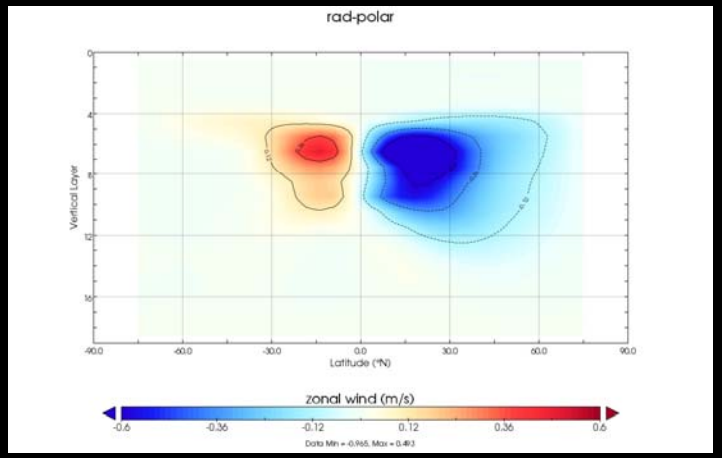
Model Results

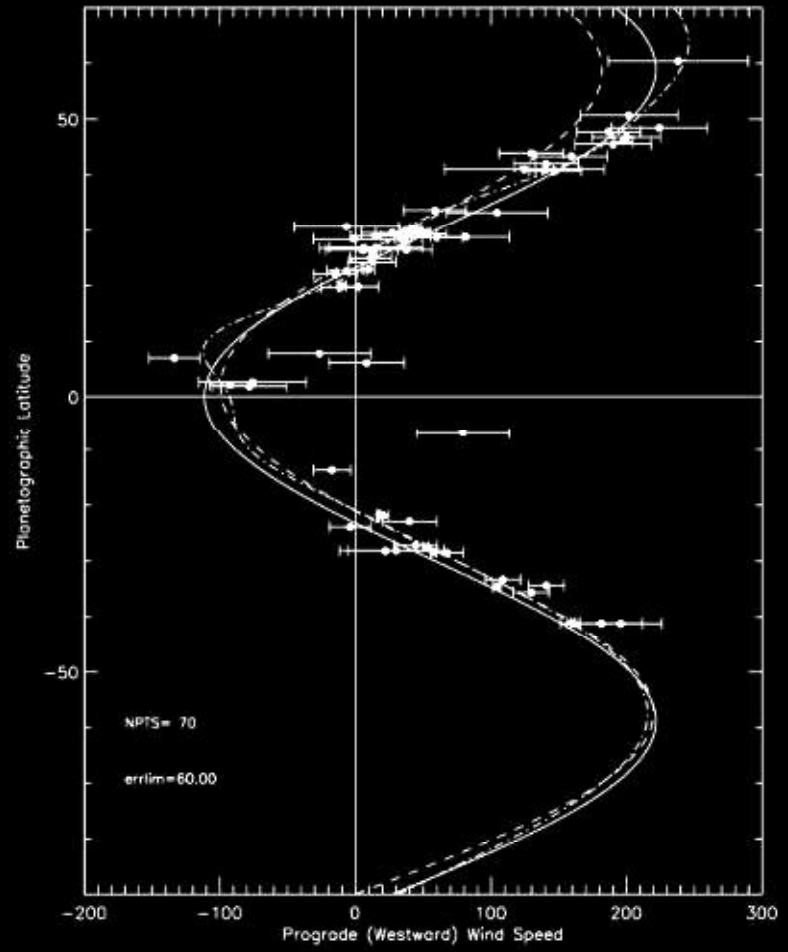
Solstice heating:



Comparison to Observations







- Equinox heating compares favorably with overall winds
- Solstice heating may explain recent asymmetry

Conclusions

- Equinox heating produces symmetric zonal winds
  - Fits well to general shape of observed zonal winds
  - May reinforce from equinox to equinox

- Solstice heating produces asymmetric zonal winds
  - Fits well to recent observed asymmetry about equator
  - May mutually interfere from solstice to solstice

Future Work:

- Long term, multi-year simulations
- Cloud Dynamics
- Storm Longevity
- Increased Physics

Use of NMSGC funds

- 2007 Division of Planetary Sciences meeting
  - Presented model changes to planetary community
- 2008 trip to Comparative Planetology Laboratory
  - Work with collaborator to implement model changes
  - Began initial simulations
- 2007 NMSU tuition