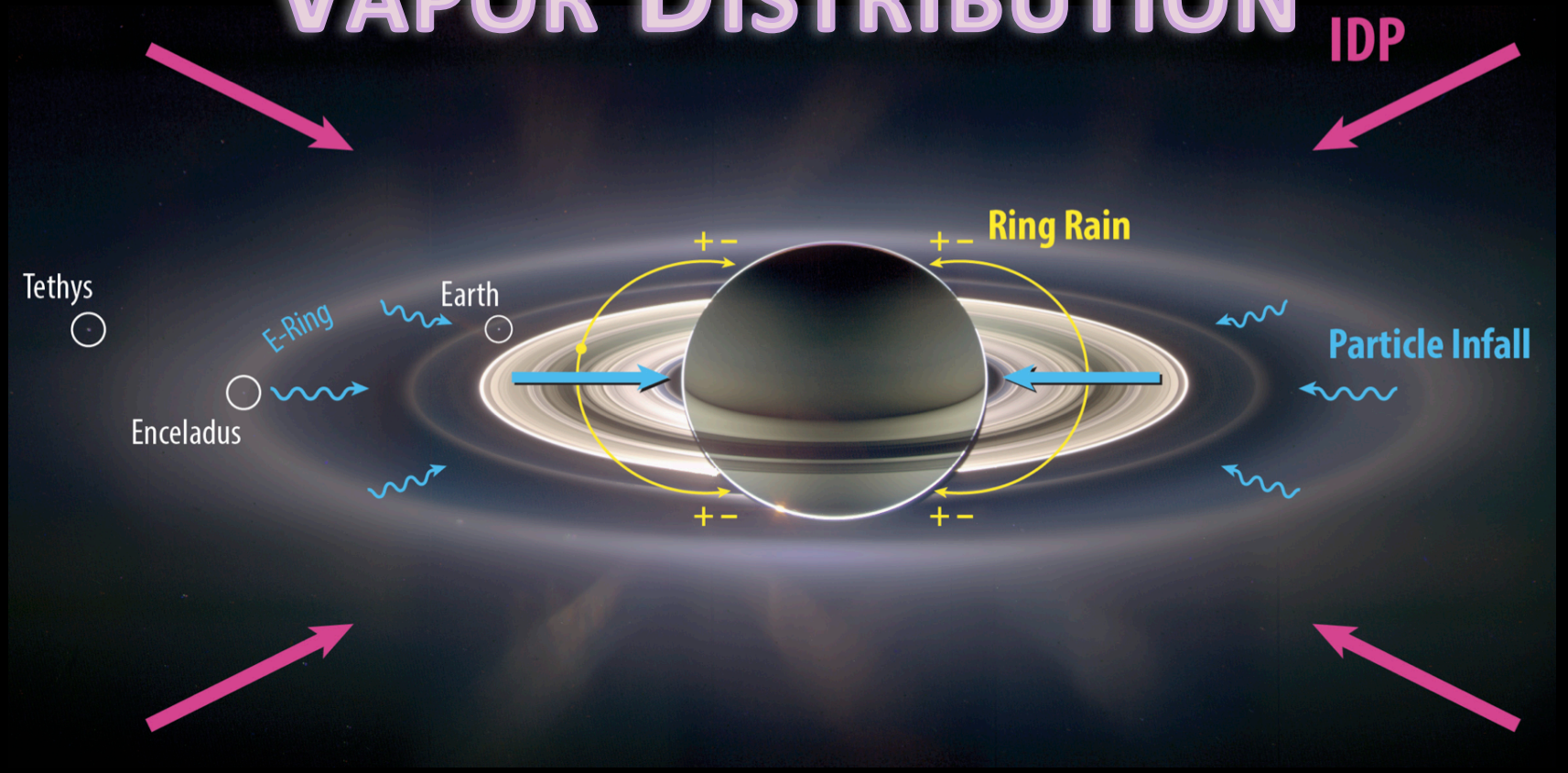
Saturn's Stratospheric Water Vapor Distribution



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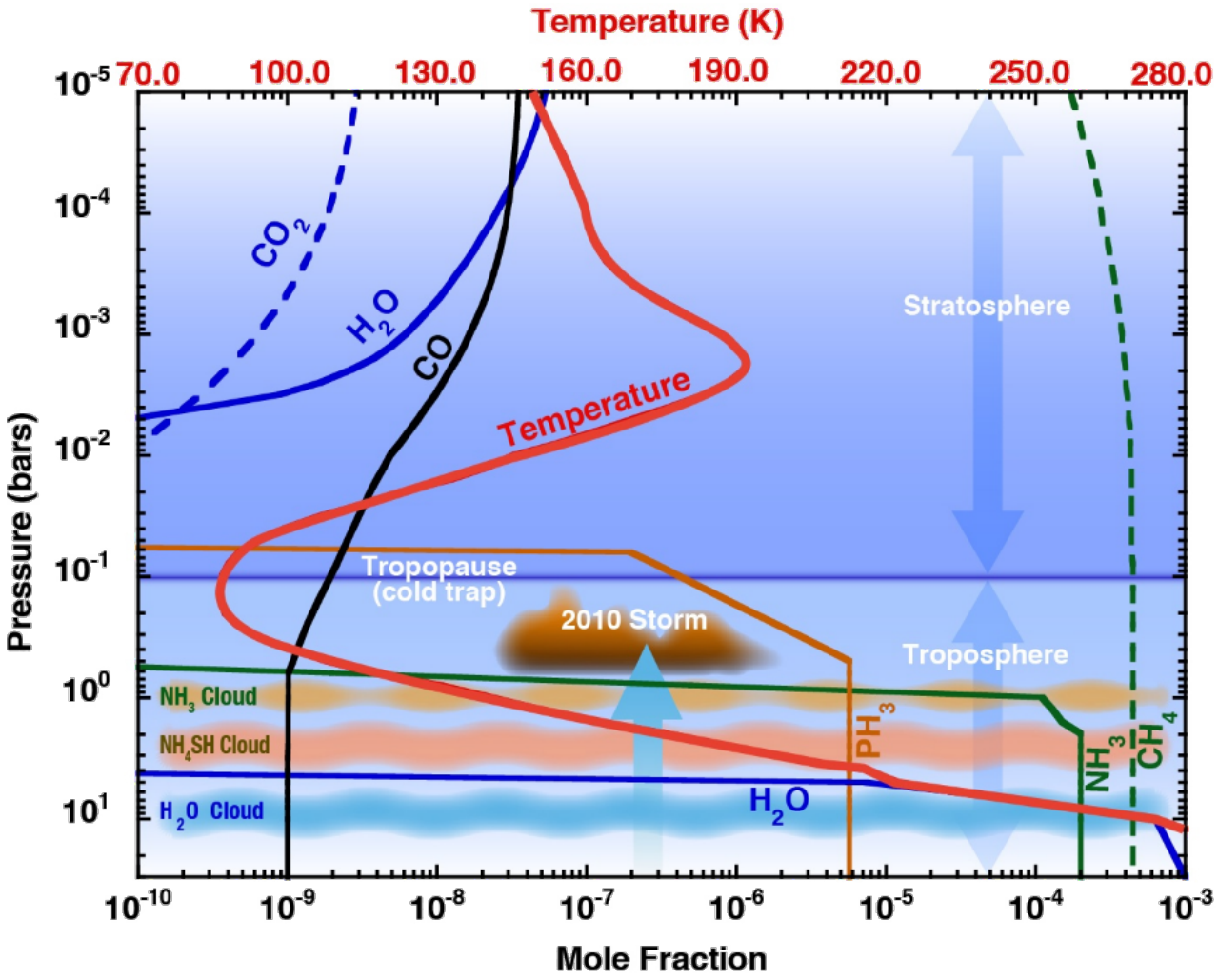
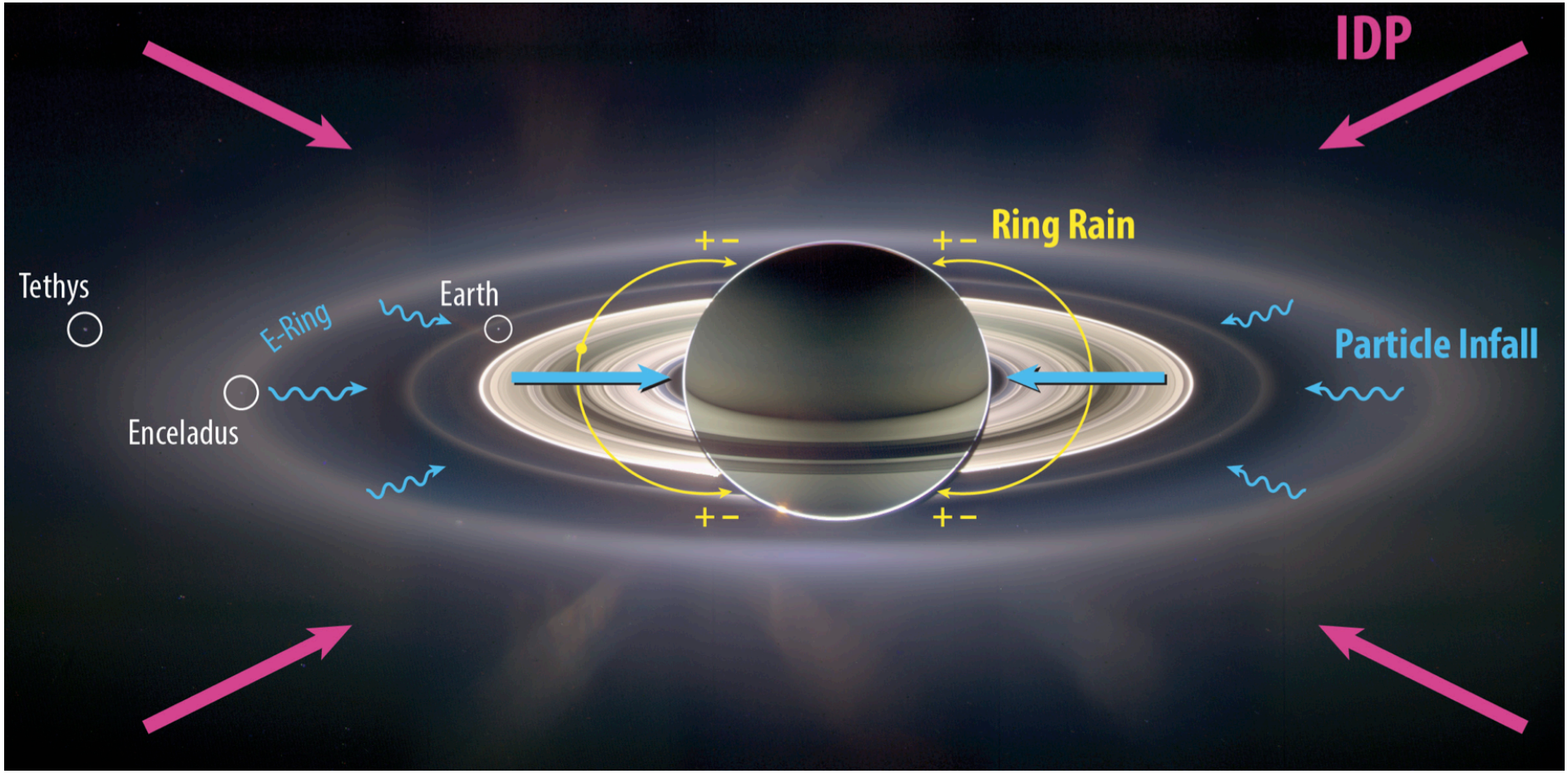
Background - Saturn's Atmosphere

- Stratosphere: the mole fraction profile of H_2O falls off with increasing pressure due to condensation as the temperature drops towards the tropopause.
- Troposphere: for > solar O/H the internal H_2O is expected to be > 1000ppm.

- Measuring the column abundance of H_2O with latitude and season constrains the external source and allows us to study oxygen photochemistry
- Periodic storms, such as the GWS storm of 2010, will waft water to the upper troposphere as displayed by the blue arrow.
- H_2O abundance changes in the disturbed stratosphere following the Saturn storm allow theories to be developed about the stratospheric/tropospheric connection.

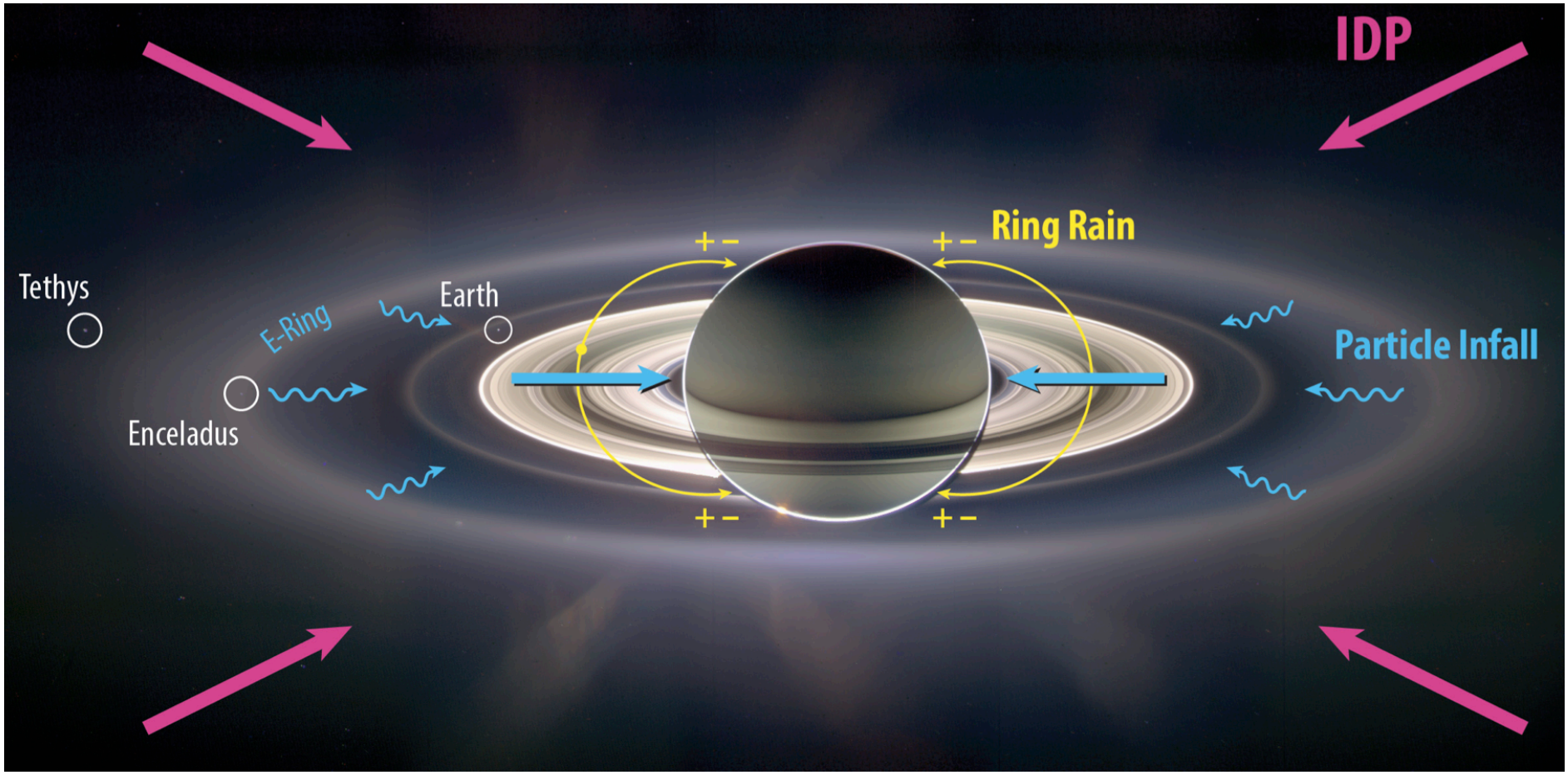


Possible Sources



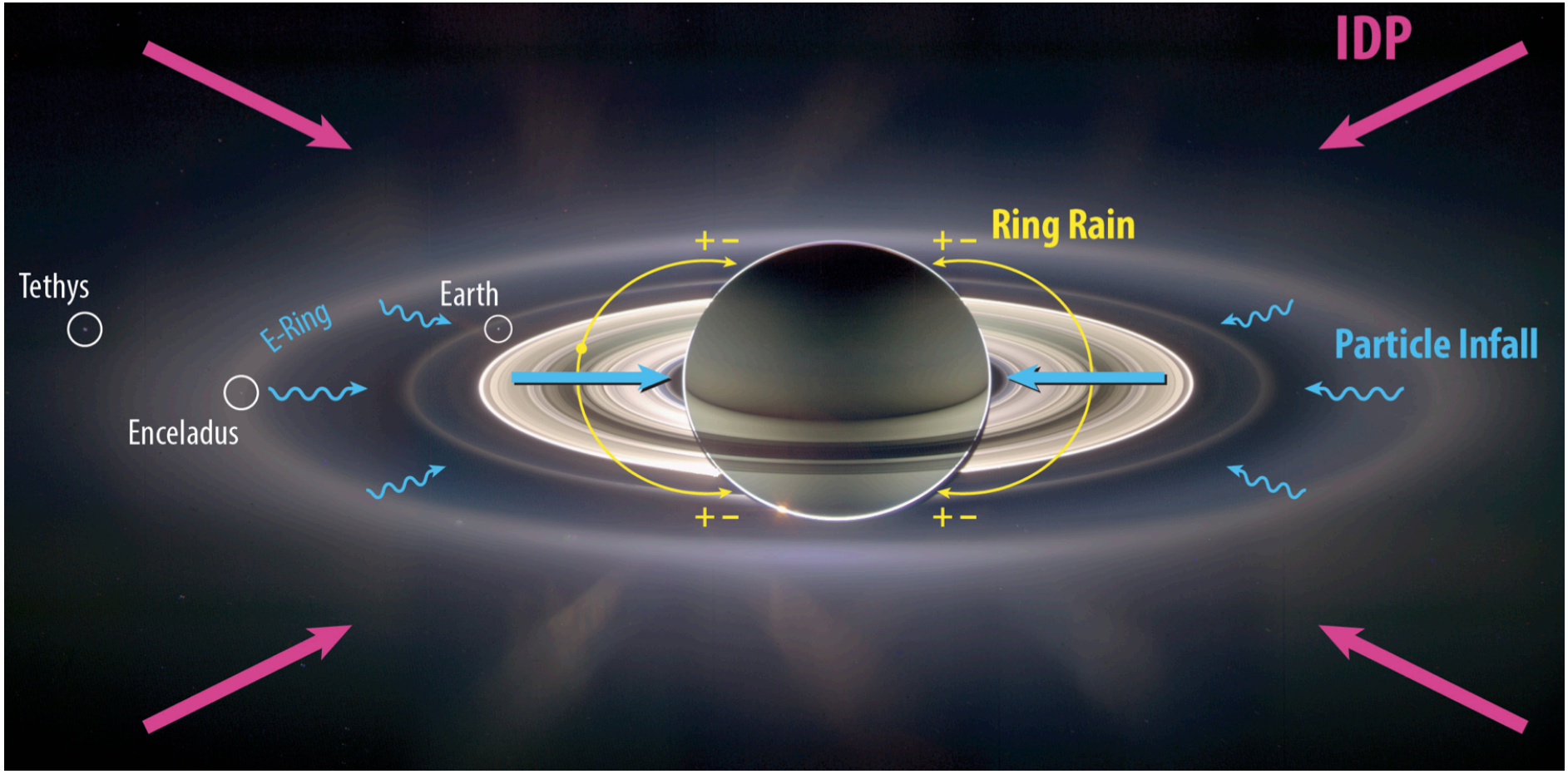
- "IDP" -- interplanetary dust particles falling in to the atmosphere
  - This source would produce a nearly constant with latitude stratospheric water profile since this source is isotropic

Possible Sources



- "Particle Infall" – a neutral source coming from the main rings or E-ring particles that are supplied with water from the plumes of Enceladus.
    - A narrow peak in the stratospheric latitudinal water profile over Saturn's equator would indicate neutral infall whereas a broad peak centered on the equator would be consistent with a source in the E-ring

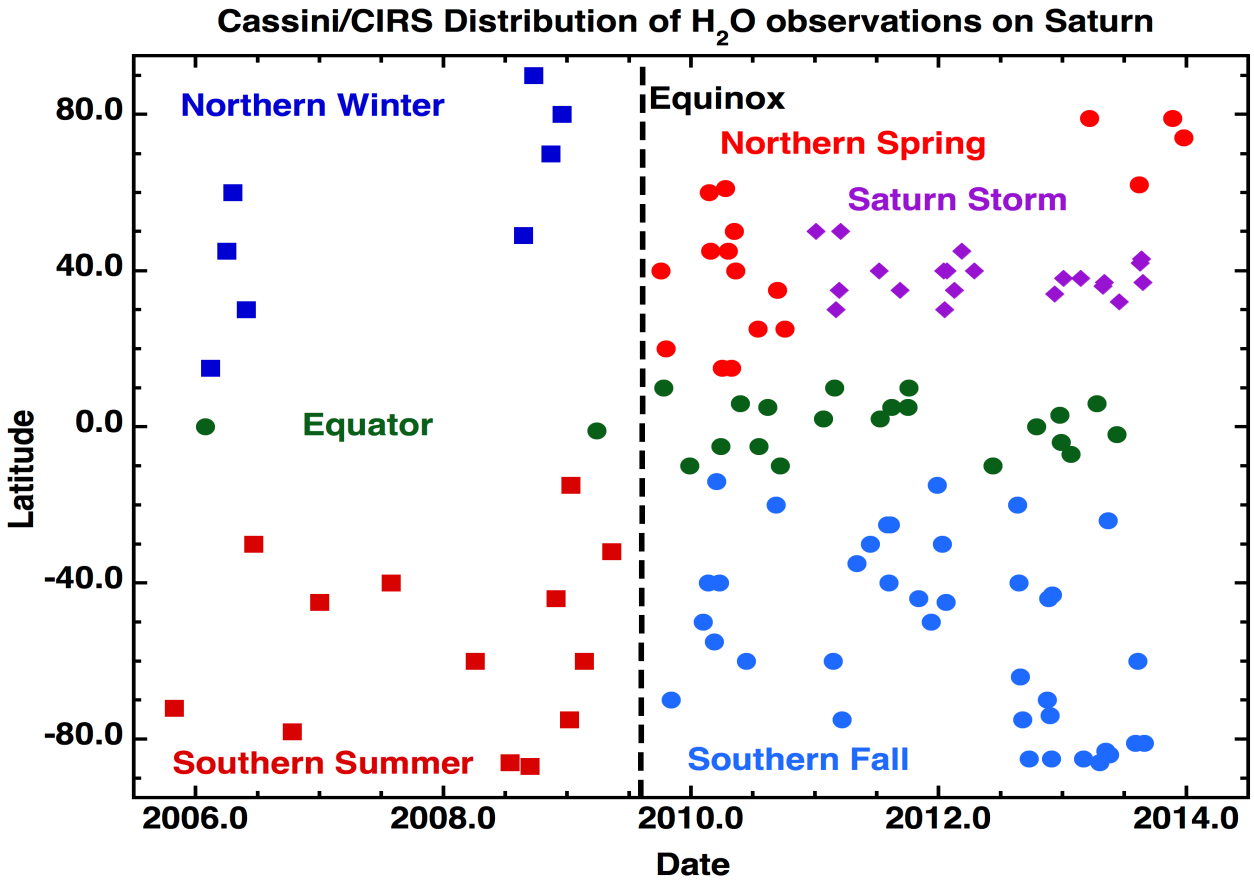
Possible Sources



- "Ring Rain" from Saturn's main rings – via ions transported along magnetic field lines
    - This source would produce a fine latitude structure with peaks at 50°N and 44°S

Observation Distribution

- Distribution of observations taken during the Cassini mission in order to specifically target the stratospheric water problem.

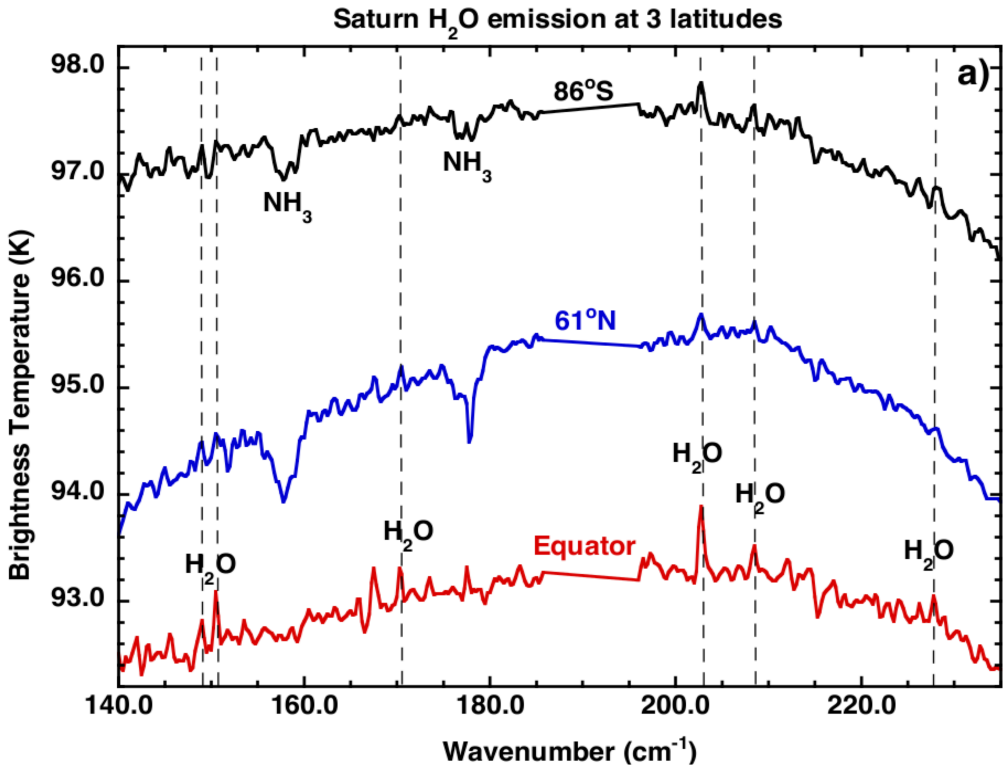


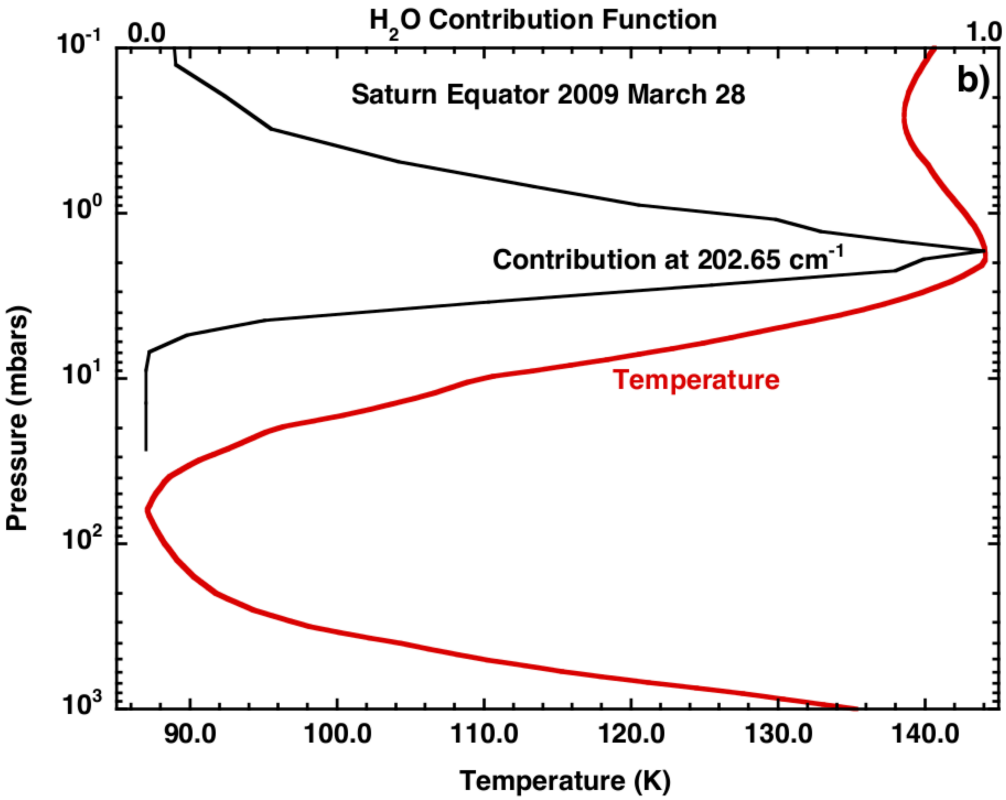
- 0.5cm^{-1} spectral resolution data using CIRS FP1
  - The resulting spatial resolution is between 5-10° in latitude

- Observations are held at a constant latitude and emission angle while the planet rotates.

- FP1 is offset to the edge of the planet for high emission angles.
  - Moves weighting functions into the stratosphere

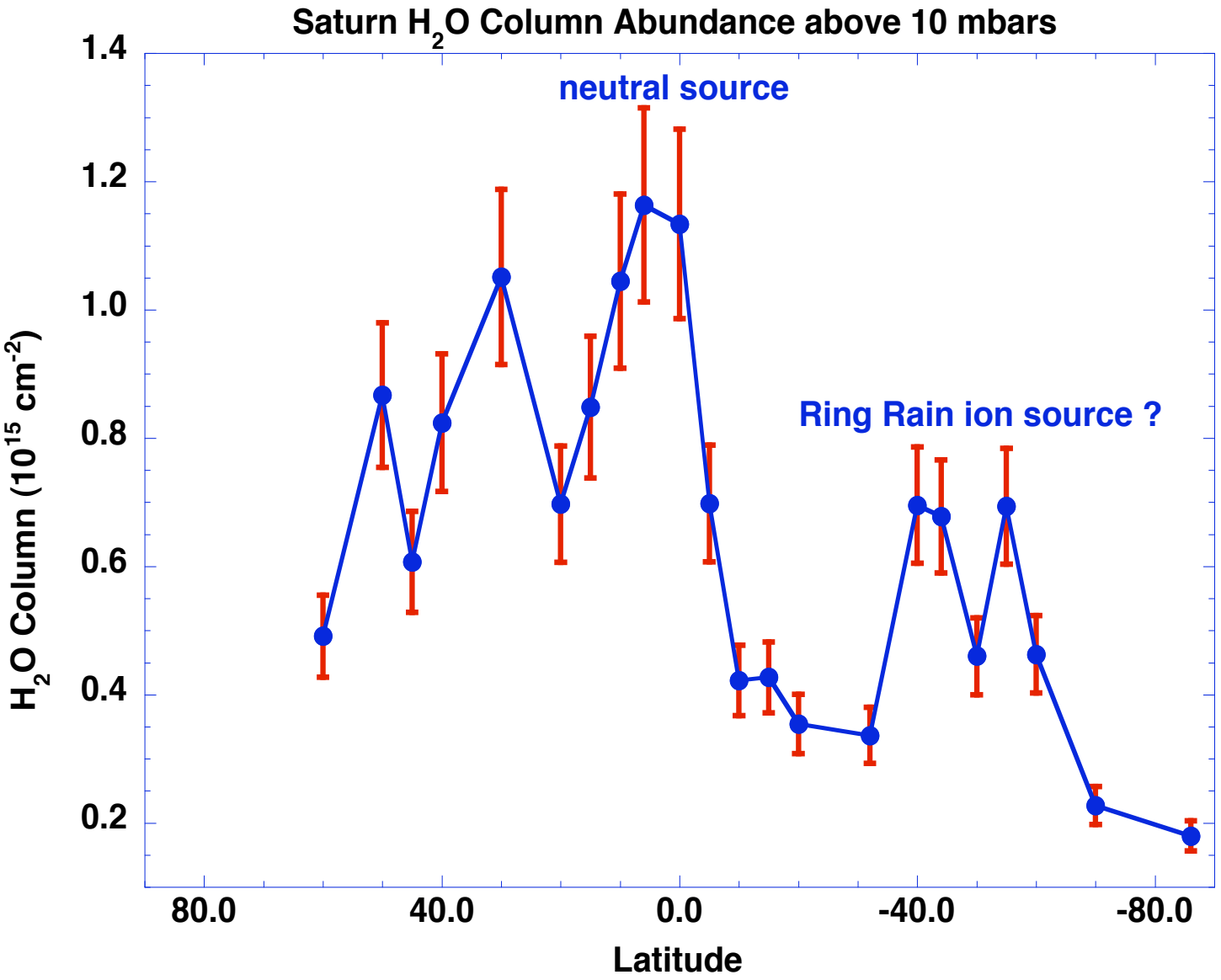
Sample Data


Saturn H2O emission at 3 latitudes
a)
86°S
61°N
Equator
NH3
NH3
H2O
H2O
H2O
H2O
H2O
Brightness Temperature (K)
Wavenumber (cm-1)
98.0
97.0
96.0
95.0
94.0
93.0
140.0
160.0
180.0
200.0
220.0


H2O Contribution Function
b)
Saturn Equator 2009 March 28
Contribution at 202.65 cm-1
Temperature
Pressure (mbars)
Temperature (K)
0.0
1.0
10-1
100
101
102
103
90.0
100.0
110.0
120.0
130.0
140.0

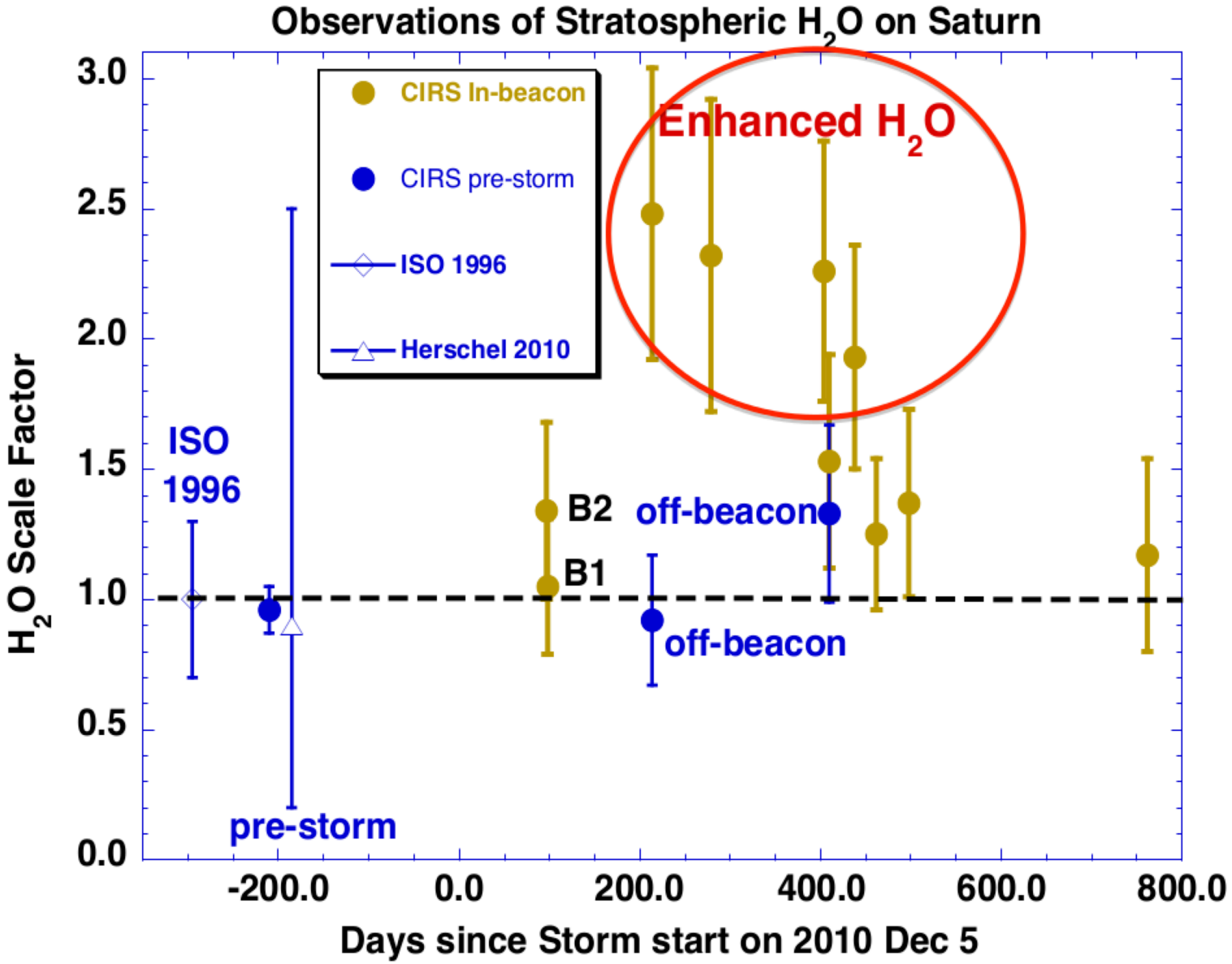
Initial Results

Pre-Storm: 2005-2010



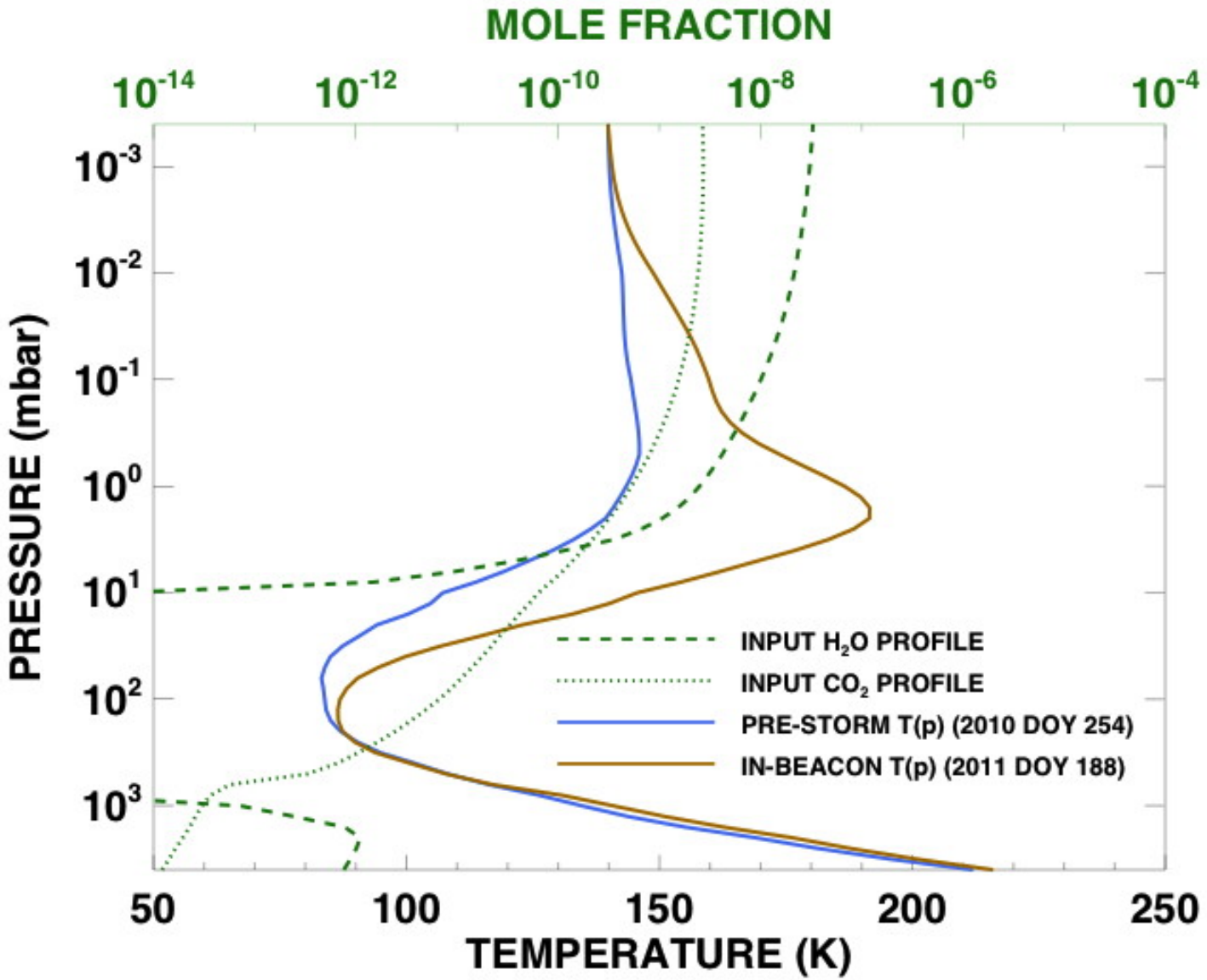
Storm Results

Storm H_2O: 2011-2013



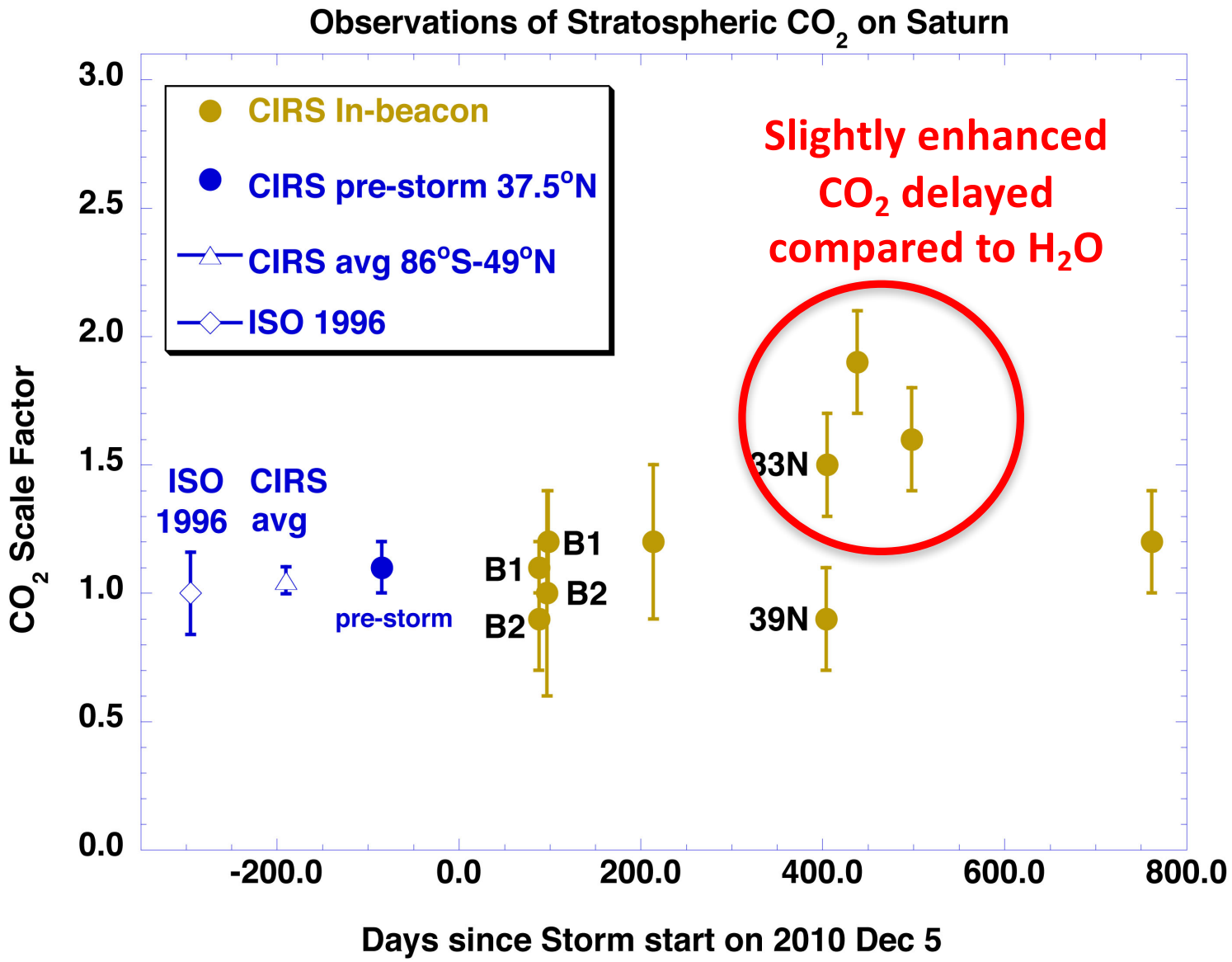
Storm Results

Profiles of Temperature, H_2O, and CO_2



Storm Results

Storm CO_2: 2011-2013



Conclusions

- H_2O and CO_2 in Saturn's stratosphere are derived from one or more external sources, including the rings.
- Measurements from 2005-2010 indicate H_2O may be supplied by a neutral source but could also have a 'ring rain' component.
- Further studies of the meridional profile of H_2O needed for 2013-2017 to see what, if any, seasonal changes there are in the H_2O profile.
- H_2O in the stratospheric vortex or "beacon" reaches a maximum value of 2.5x pre-storm in July 2011 and slowly decays back to pre-storm values by Jan 2013.
- H_2O is not enhanced at longitudes outside of the beacon.
- CIRS In-beacon H_2O abundances are lower than the 3-10x increase measured by Herschel/PACS (Cavalié et al. 2012 & private communication).
- CO_2 exhibits a 1.5x to 2x enhancement over pre-storm values later than the peak in H_2O, but it also decays back to nominal values by Jan 2013.
- Saturn's stratospheric aerosols may have an icy core surrounded by hydrocarbons.
- Heating in the beacon may have caused sublimation of water ice-bearing aerosols resulting in increased abundances of gaseous H_2O. This, in turn, altered the photochemistry in Saturn's stratosphere for a year or more before returning to normal.