DWTS

The Doppler Wind And Temperature Sounder

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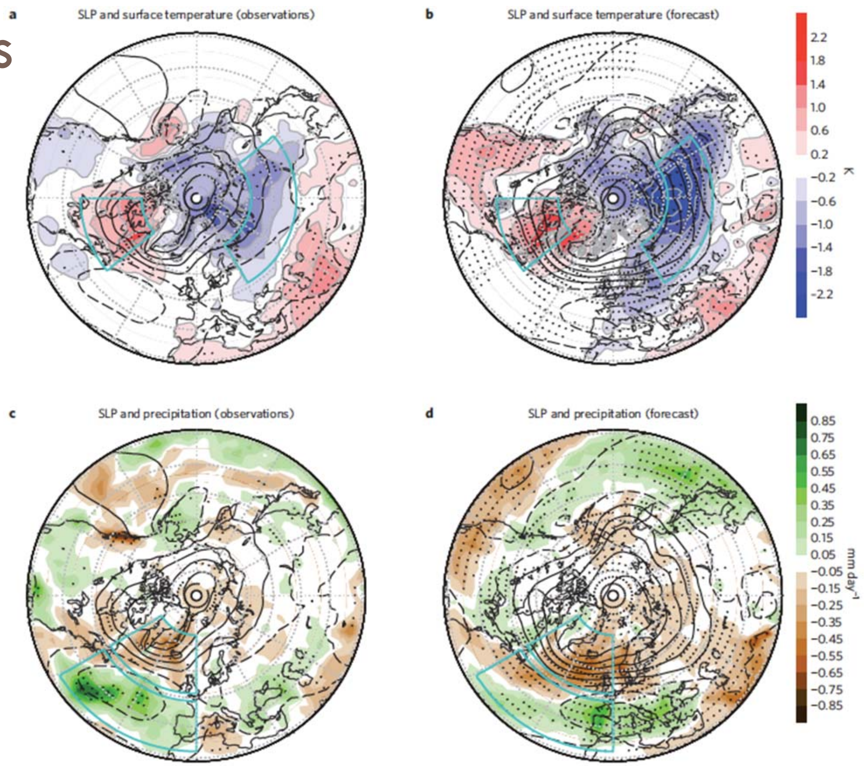
DWTS: Motivation

Why measure the upper atmosphere?

1. Weather Forecasting
2. Severe Storm Impact
3. Space Weather

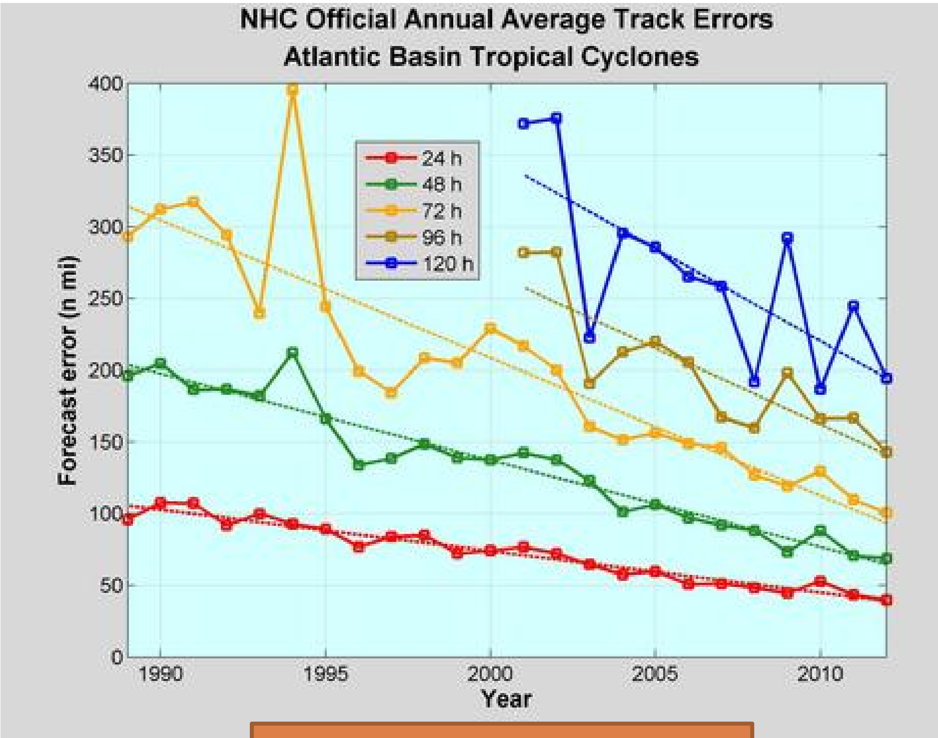
Weather Forecasting

- Medium- and long-range weather is well-known to be significantly affected by stratospheric dynamics
  - *Baldwin and Dunkerton (2001)*: Stratospheric harbingers can be used as a predictor of tropospheric weather regimes
  - *Thompson et al. (2001)*: Dynamic coupling of stratosphere and troposphere yields statistically significant predictability on monthly and yearly timescales
  - *Charron et al. (2010)*: Discuss stratospheric extensions to improve tropospheric forecasts
  - *Sigmond et al. (2013)*: Showed enhanced predictability by using a good representation of the stratosphere.
- *Forecast improvements await the first global stratospheric wind and temperature observation system!*

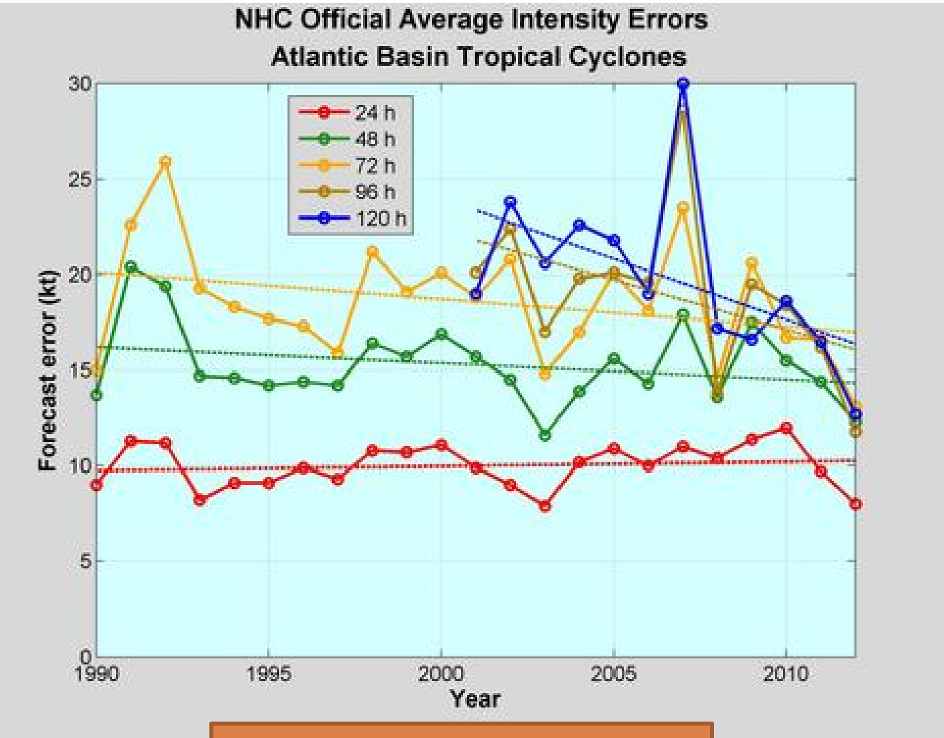


Severe Storm Intensity

- Predicting tropical cyclone **<u>intensity</u>** has been limited by lack of global stratospheric wind measurements



Track Error



Intensity Error

Space Weather

Office of Science and Technology Policy

White House OSTP released Space Weather report last Friday:

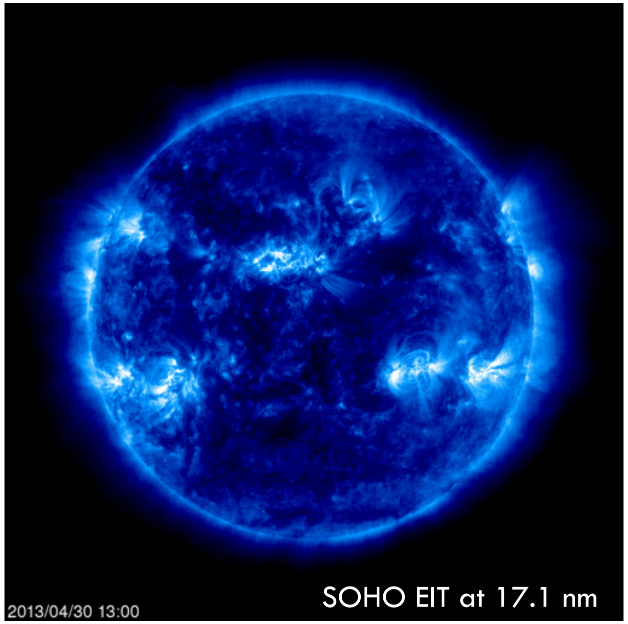
"Space Weather Observing Systems: Current Capabilities and Requirements for the Next Decade"

Calls out the critical gap in wind measurements of the upper atmosphere.

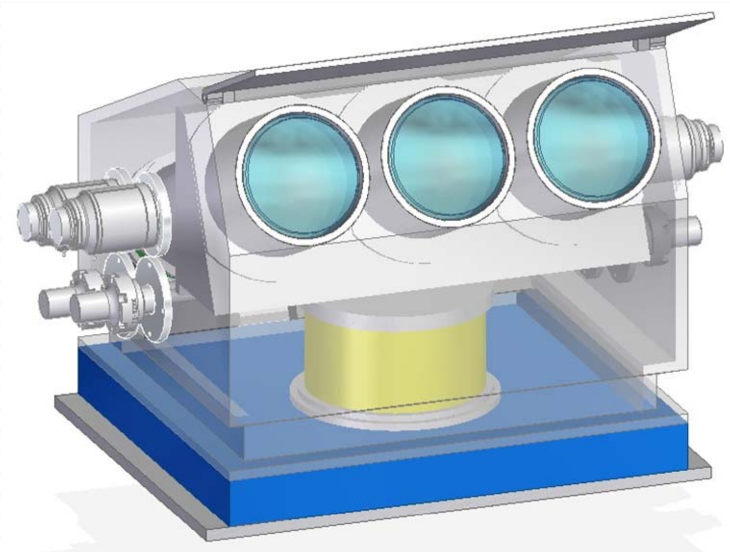
Space Weather

Critical effects on communication, commerce, civilian and military space assets

- Electric Power Grid: Large scale blackouts and damage to transformers
- Global Satellite Communications: Widespread service disruptions
- GPS Positioning and Timing: Degradations of military weapons accuracy, air traffic management, transportation, navigation, commerce, wireless comm., and more
- Satellites & Spacecraft: Loss of satellites/space situational awareness, increased risk of satellite loss and to astronaut health

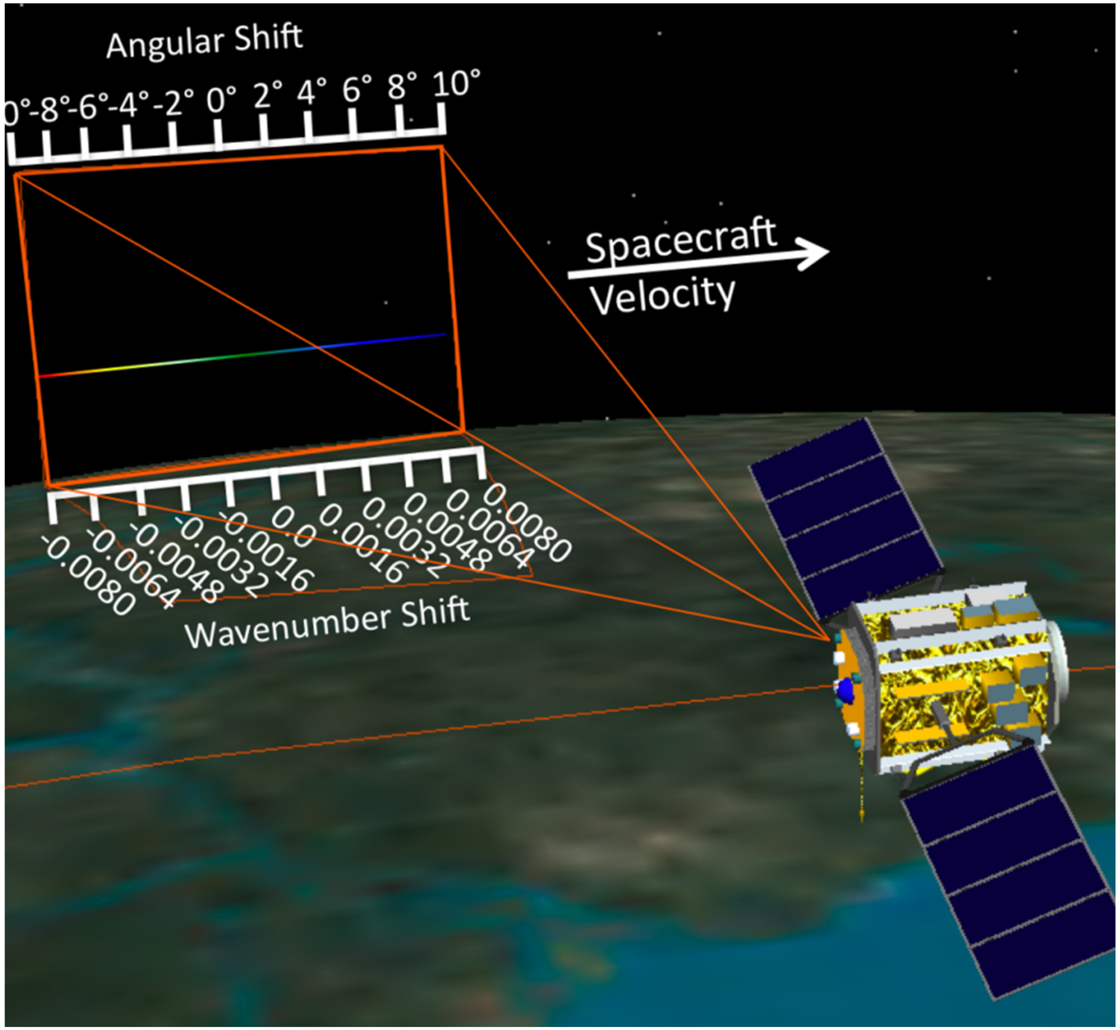


DWTS: Measurement Concept

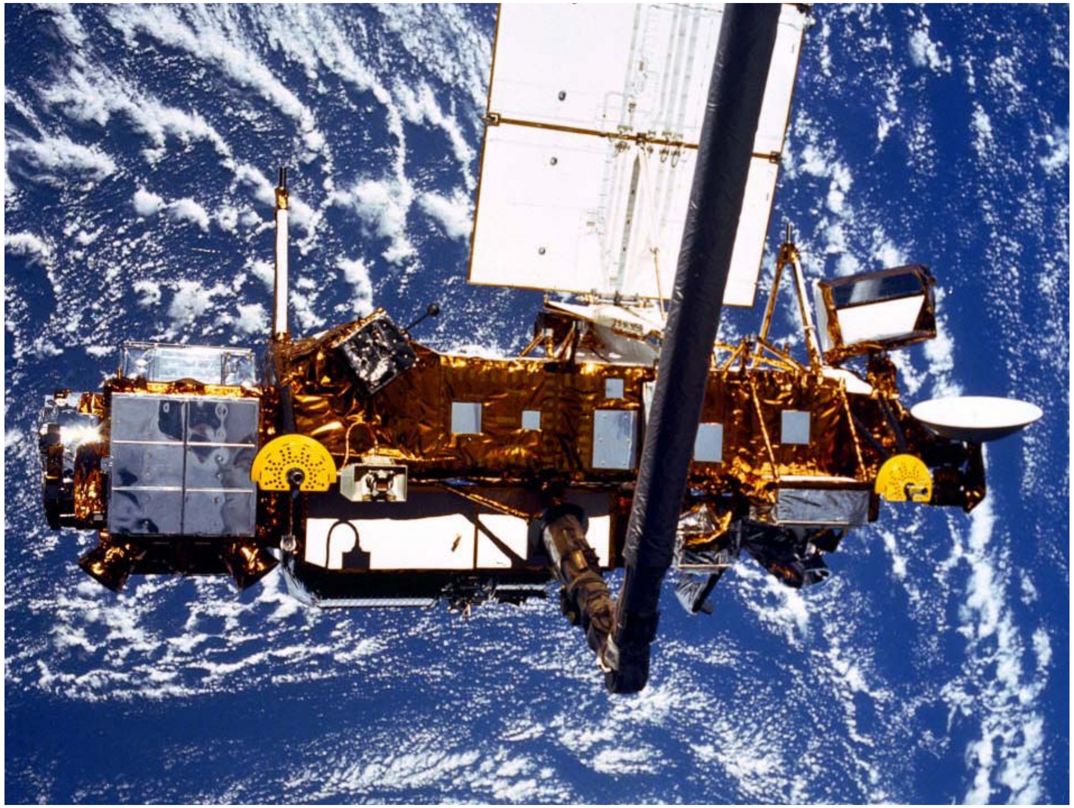


Doppler-modulated Gas Correlation

- Gas-filter correlation radiometer imaging the limb to the side of the spacecraft
- Leading-edge pixels see blue-shifted emission; trailing pixels see red-shifted emission.
- Each row collects a full Doppler scan for each air parcel at that altitude

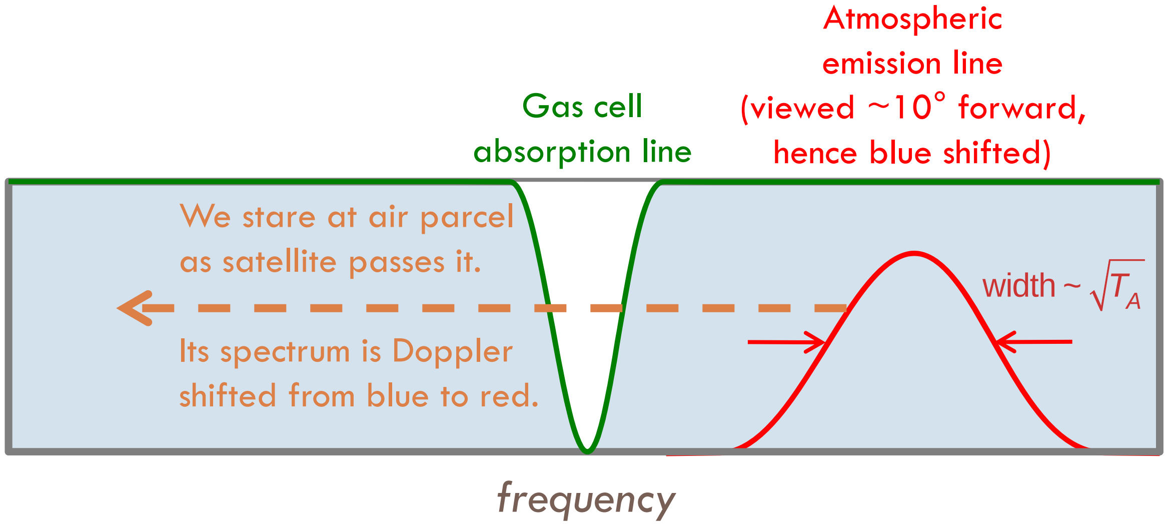


Measurement Heritage



- Doppler-shifted limb spectra have been thoroughly studied and modeled, e.g. from HALOE and many other NASA satellite missions
- Gas correlation radiometry has been used successfully by HALOE, MOPITT and others

Doppler Spectroscopy



Doppler Spectroscopy

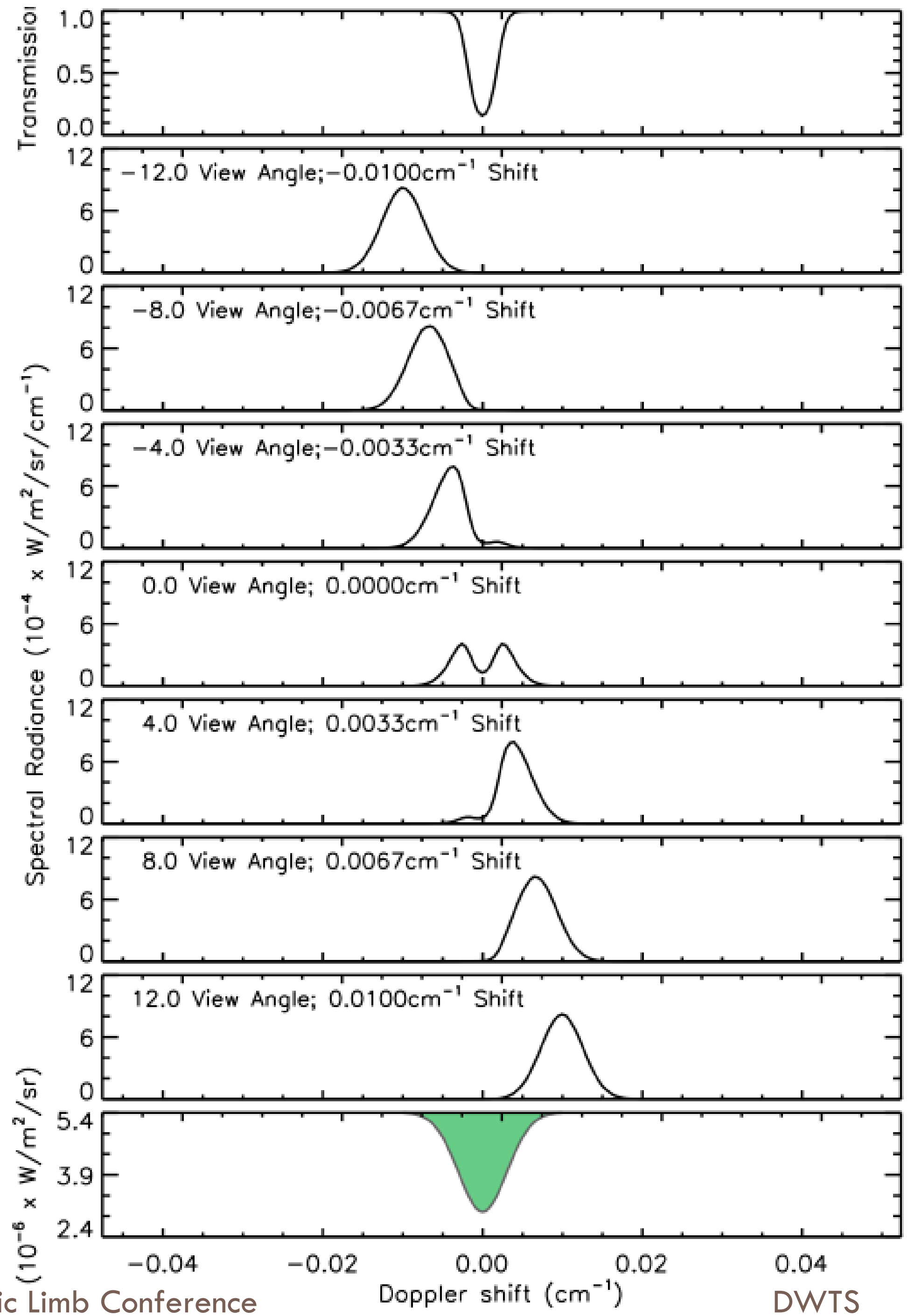
Top: Gas-cell transmittance vs. wavenumber showing a CO_2 absorption line.

Middle 7 panels: Atmospheric emission from this CO_2 line reaching 7 different columns of detector

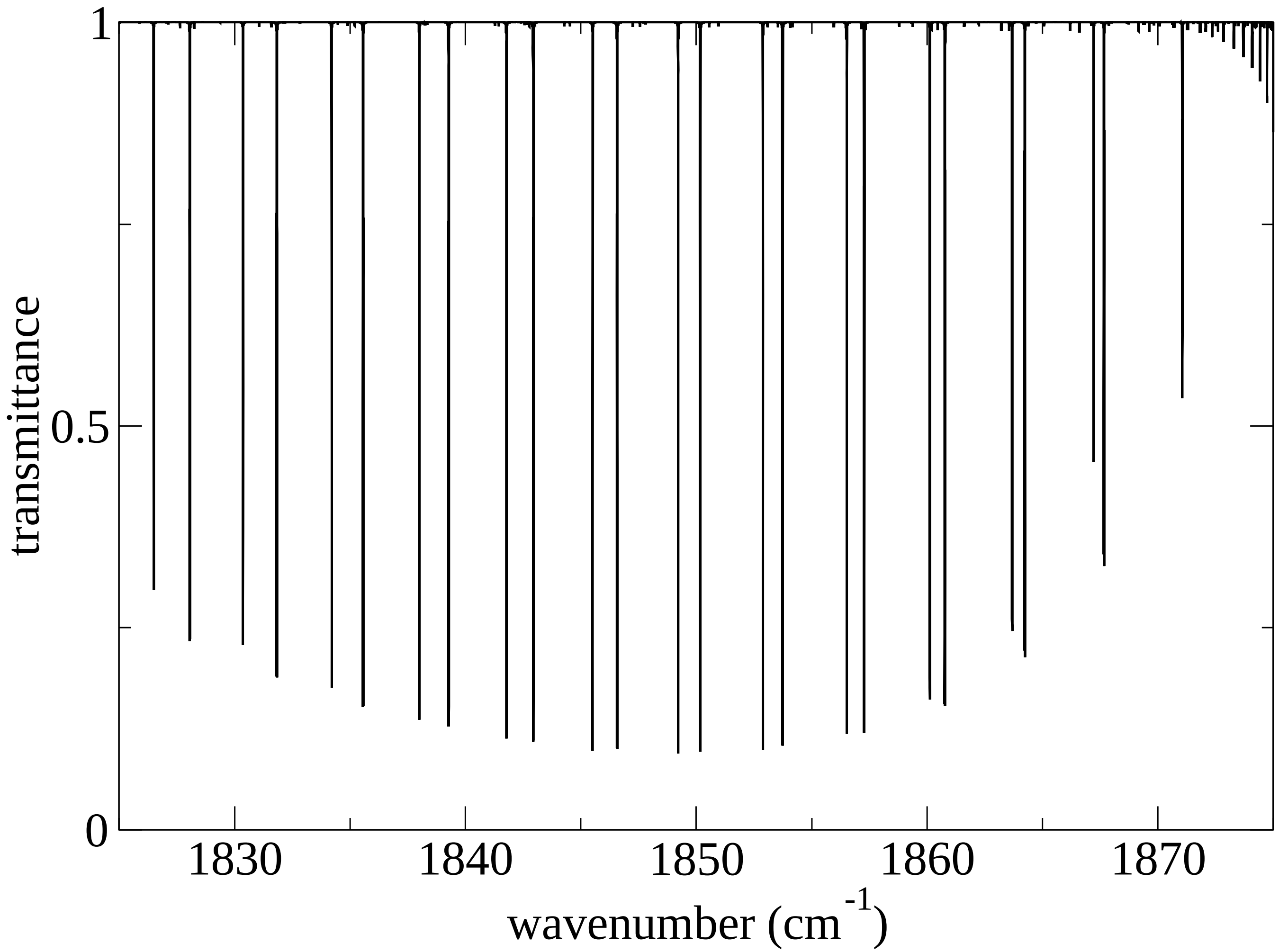
Bottom: Doppler integrated signal is formed by combining measurements across a row.

Width of the measured signal indicates the air temperature.

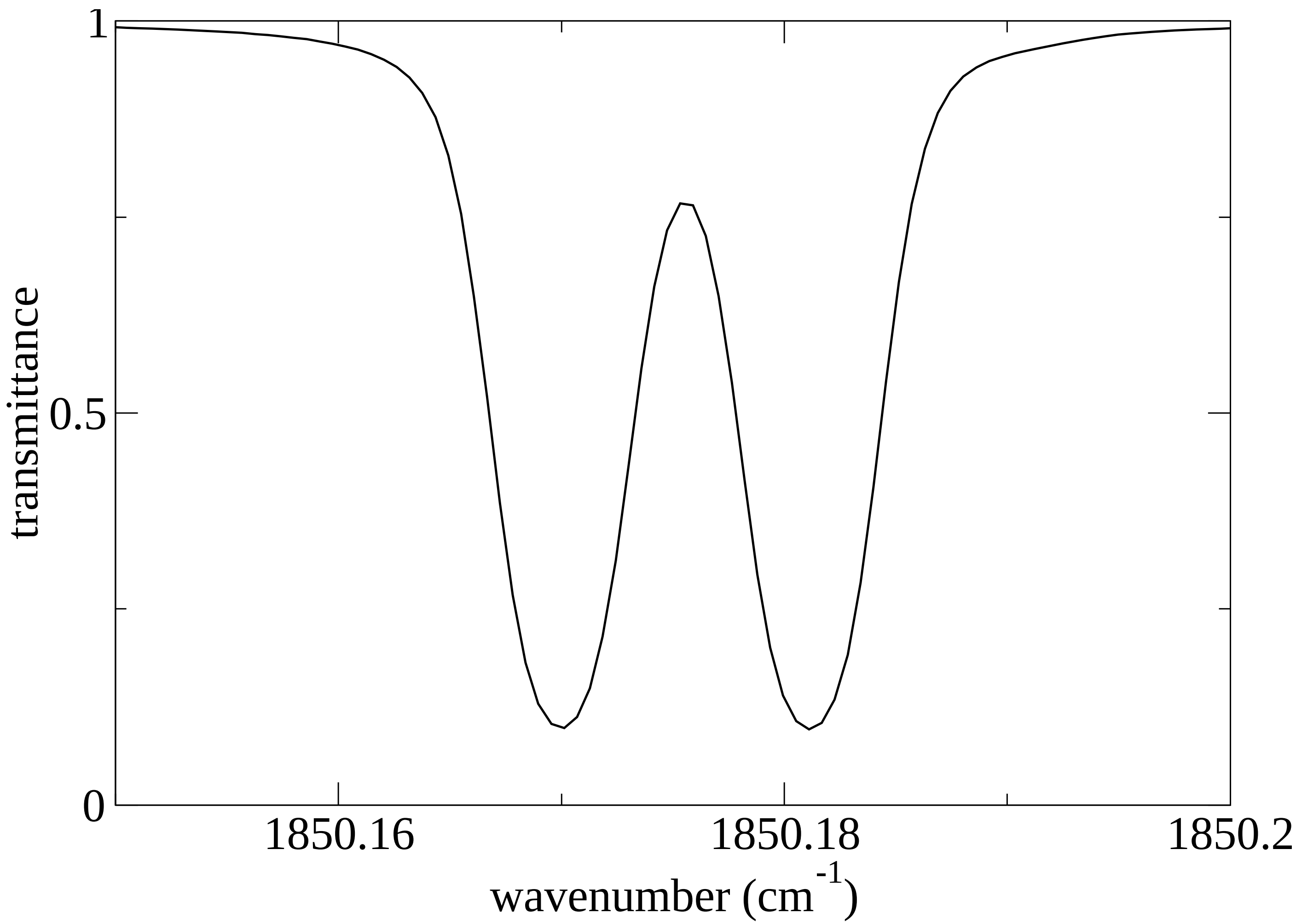
Cross-track winds appear as a shift along horizontal axis. Along track winds scale the horizontal axis. Total area of the signal (normalized by the maximum) provides a direct calibration of cell pressure.



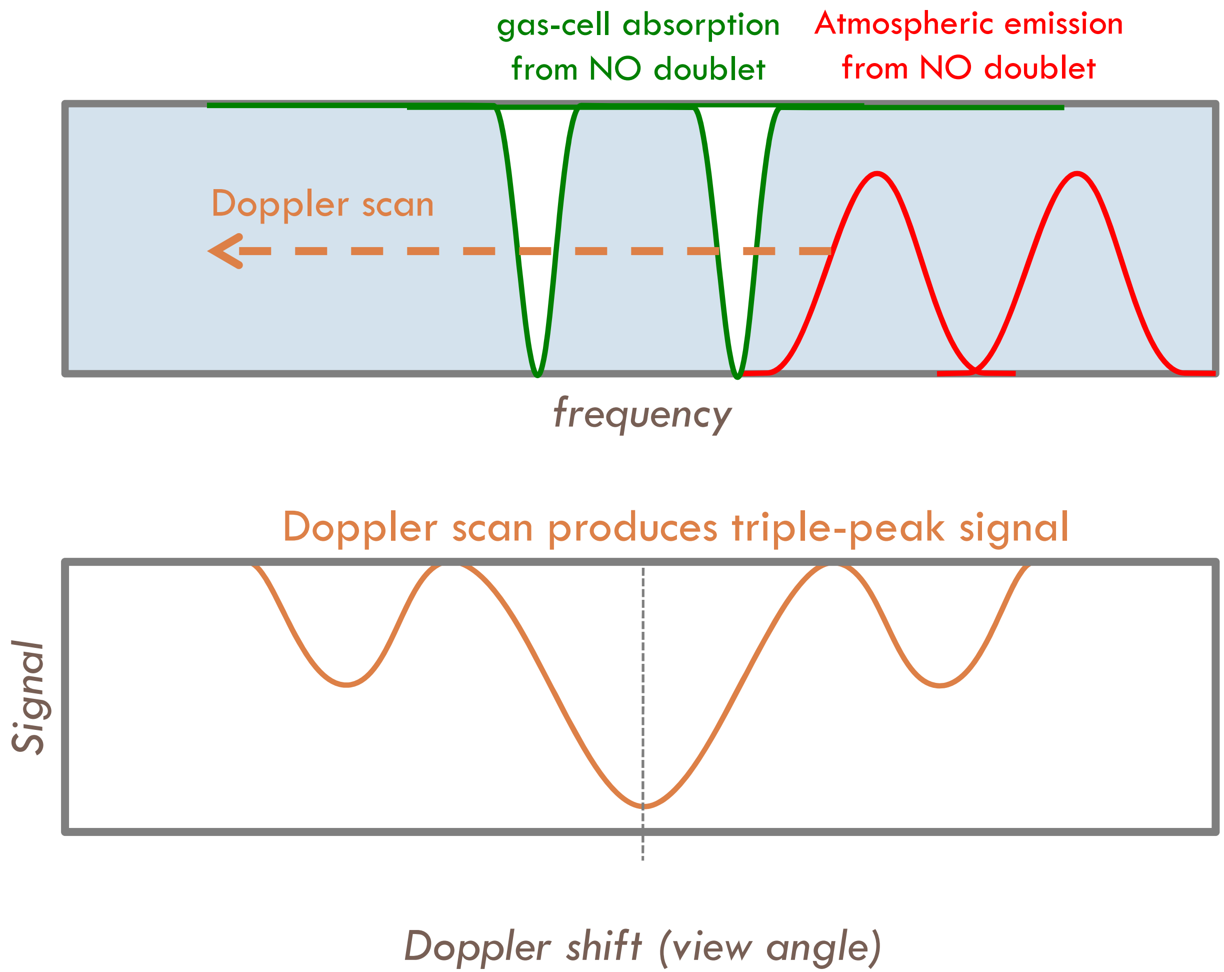
Nitric oxide spectrum at 5.4 microns



Lambda-doubling in NO spectrum



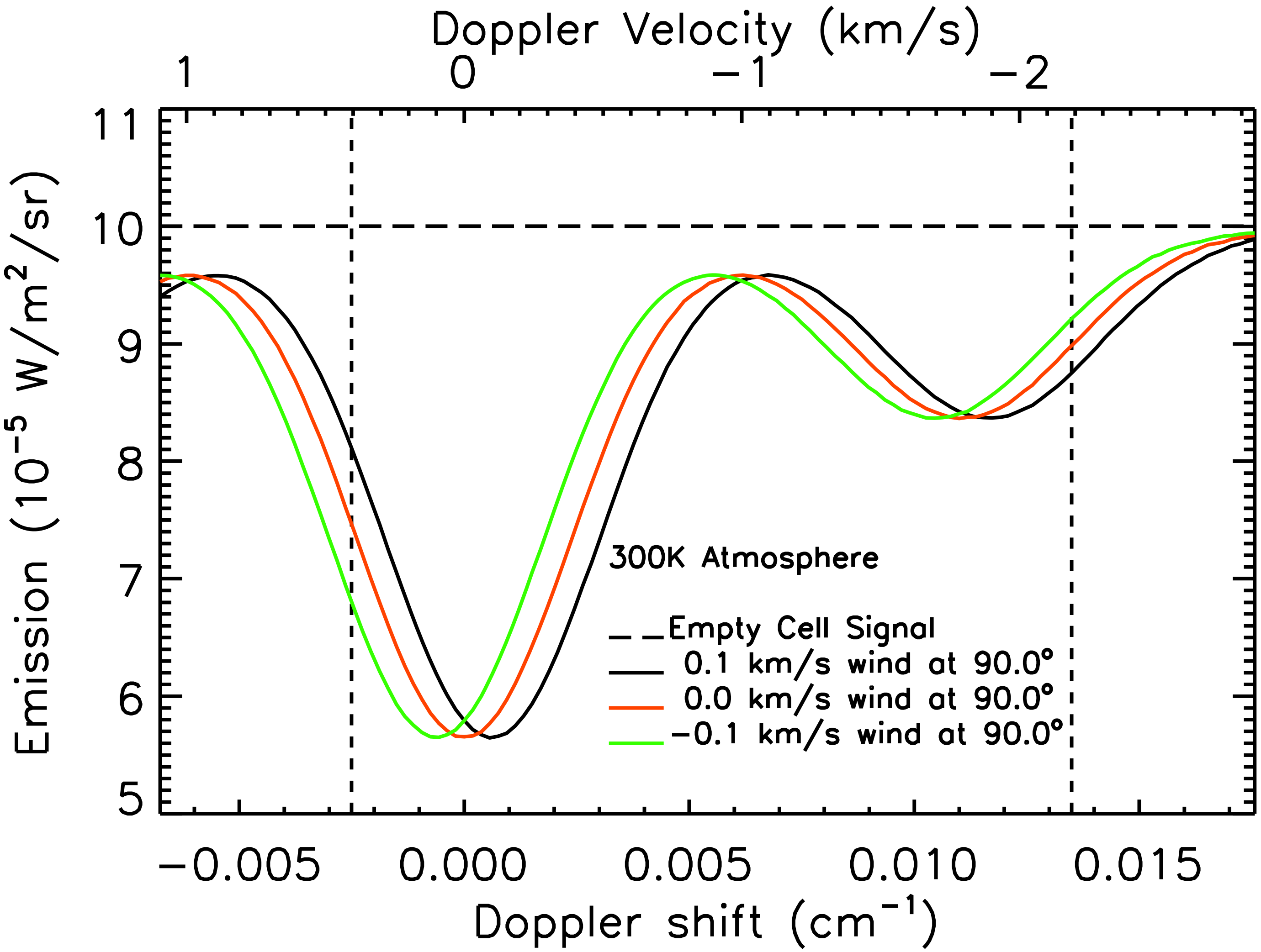
NO doublets produce multi-peak signal

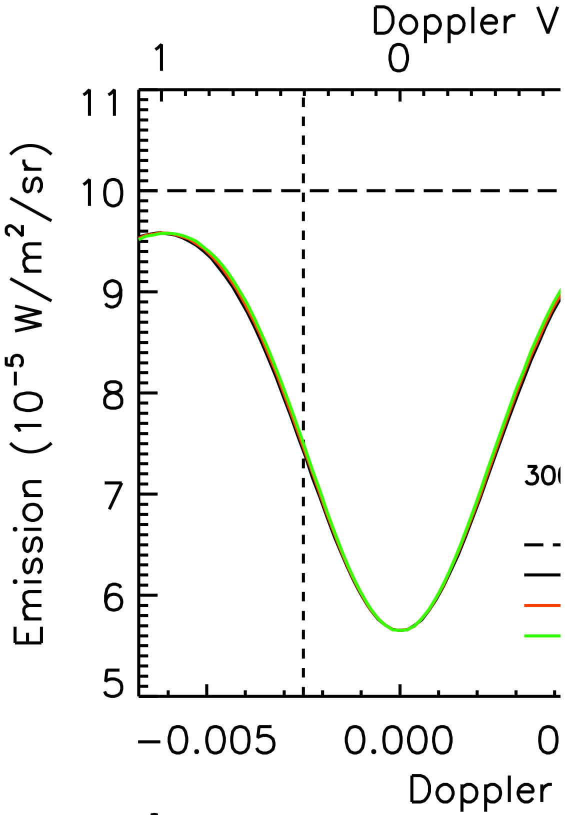


DWTS Performance

Full performance evaluation with rigorous radiometric simulations

Cross-track winds *shift* the signal





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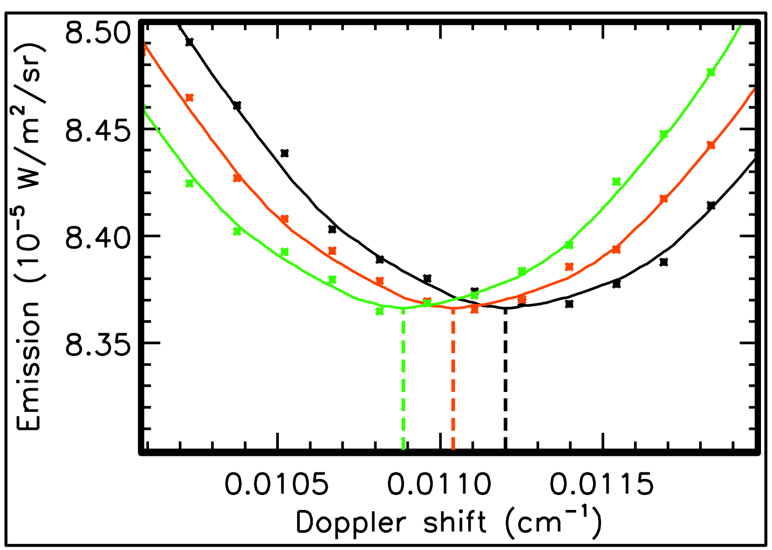
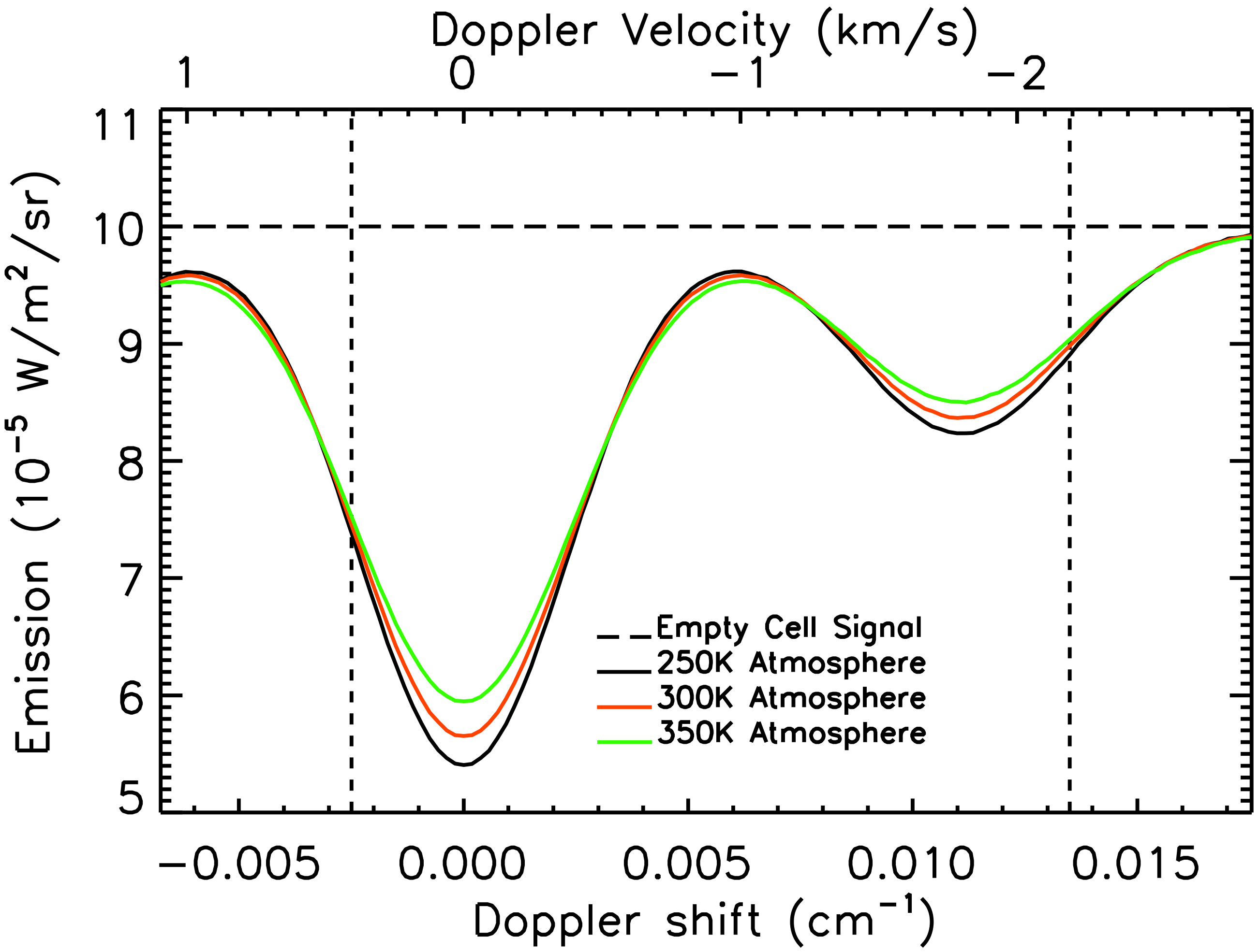
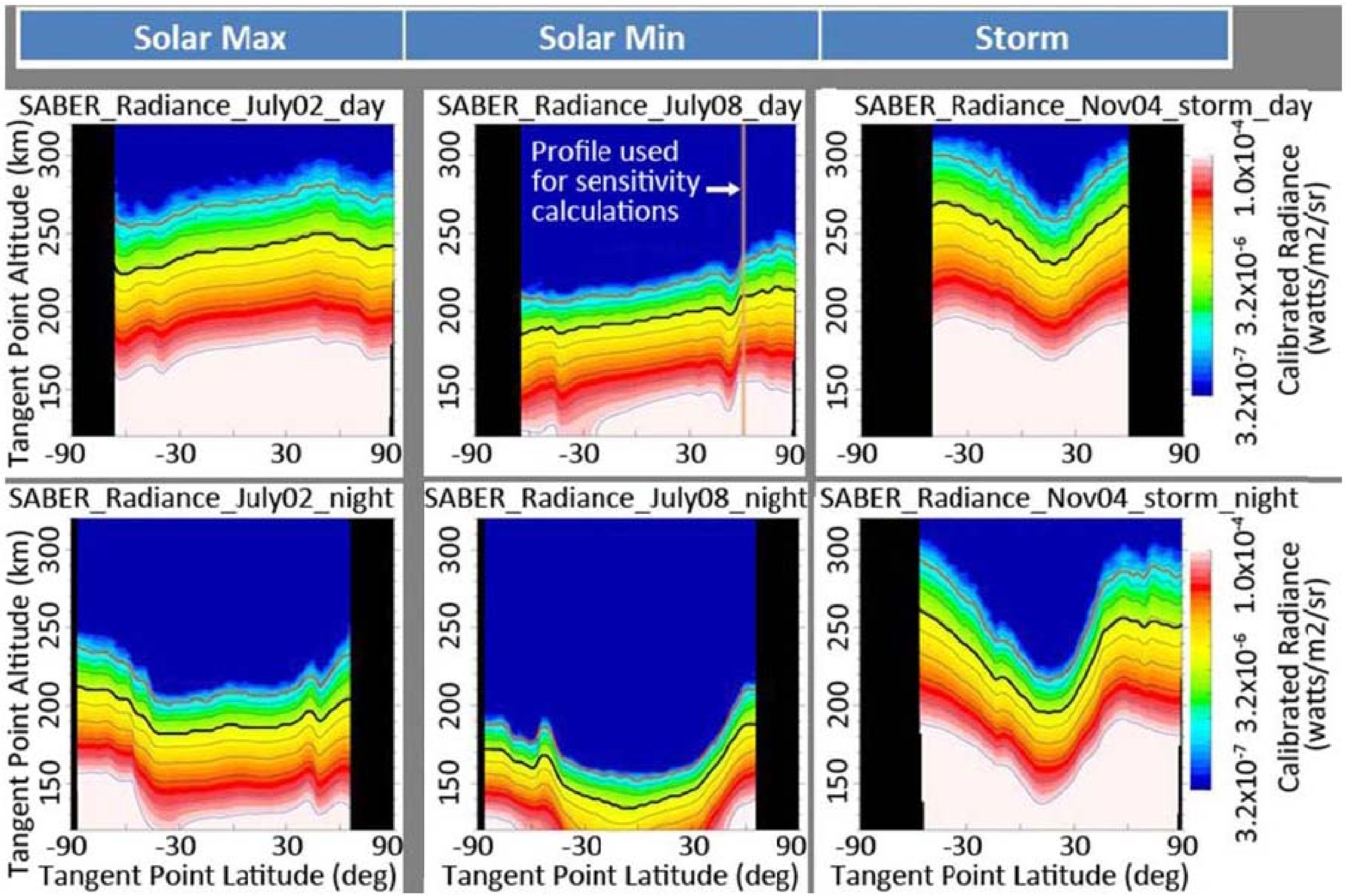
Three-hump signal from NO doublets reveals this scaling



Signal *width* indicates temperature

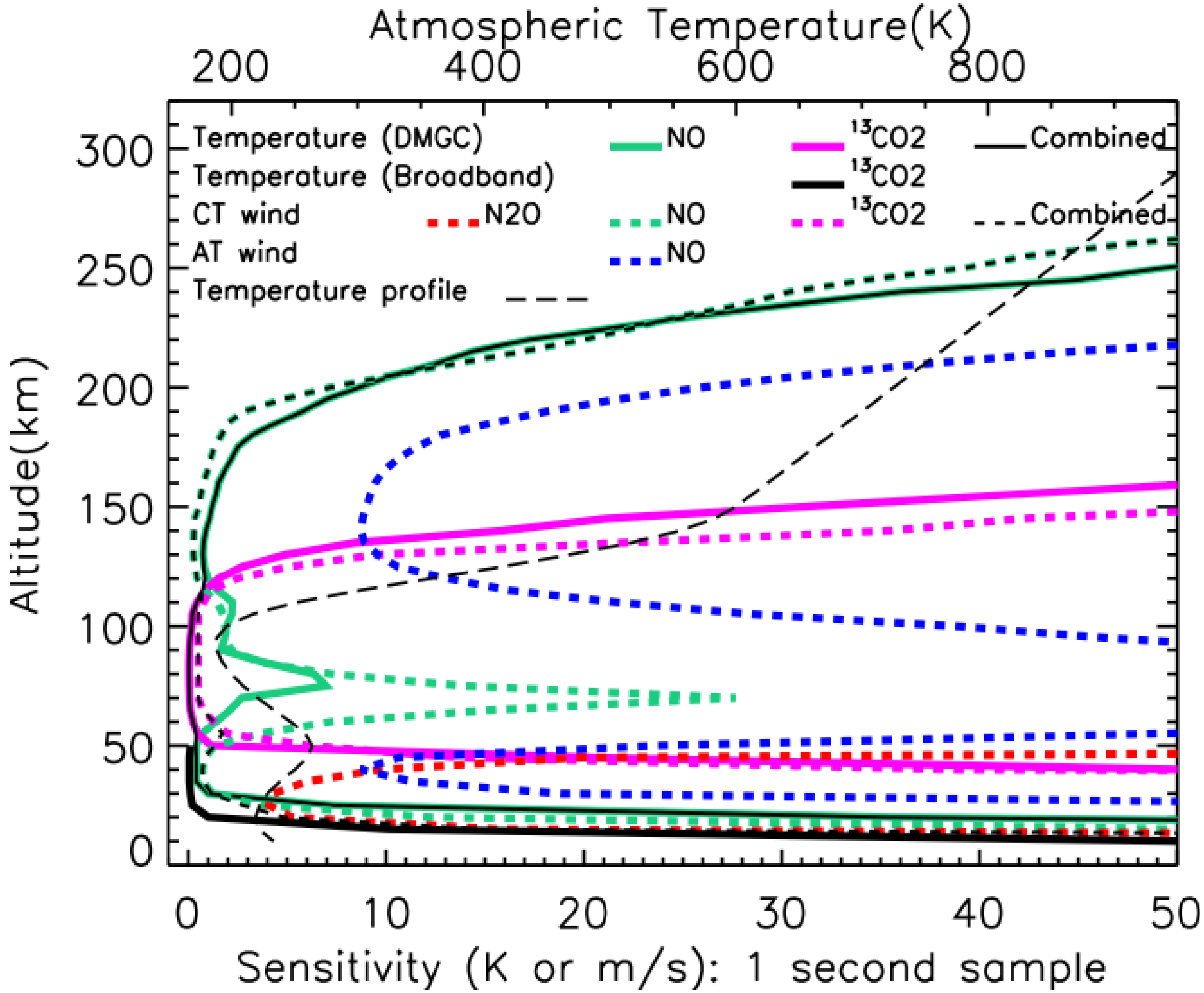


Effect of solar activity



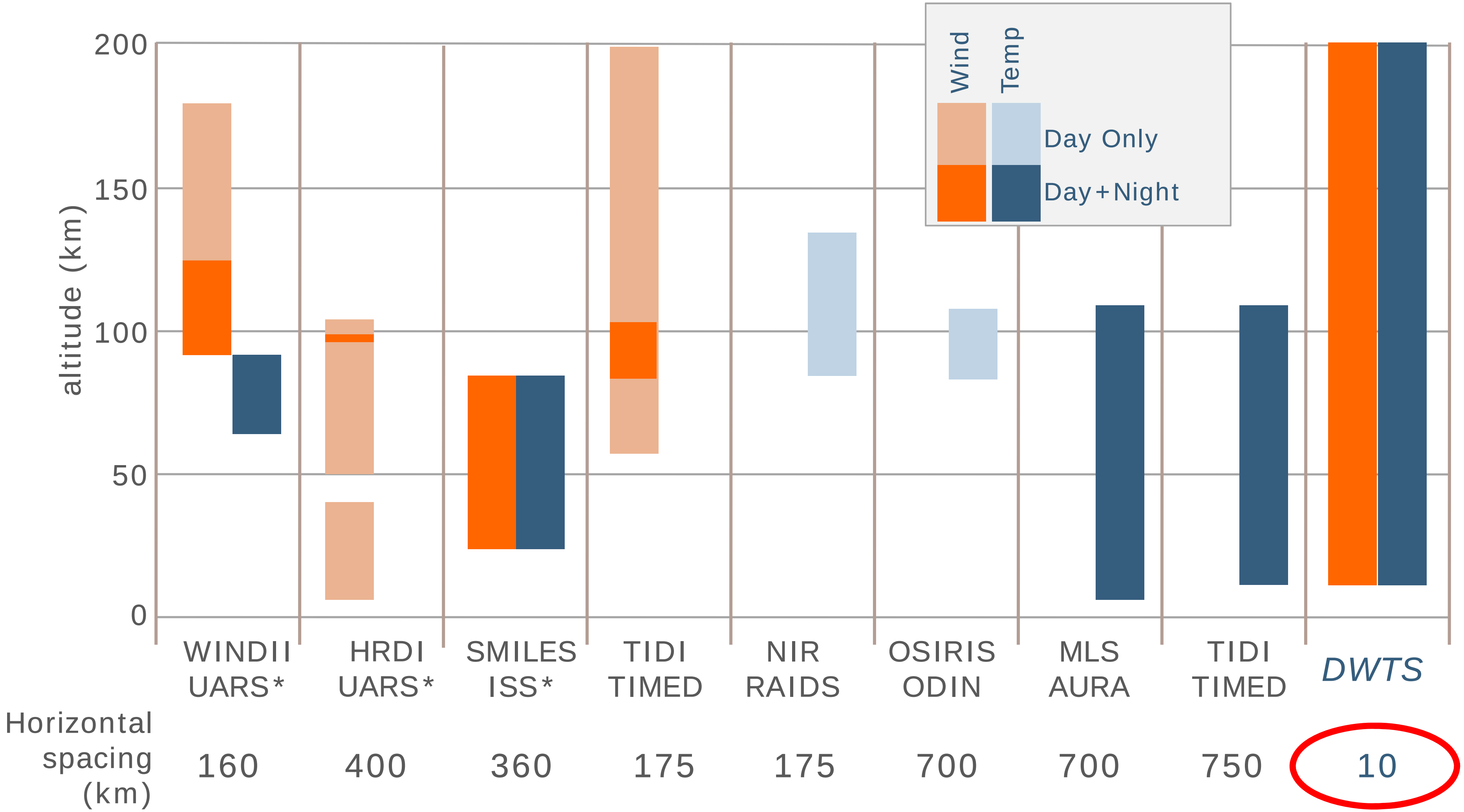
Upper limit of measurement for day, night, at solar max, min and storms. Light blue is predicted maximum retrieval altitude. Green has S/N 10 times greater than threshold.

Predicted Sensitivity

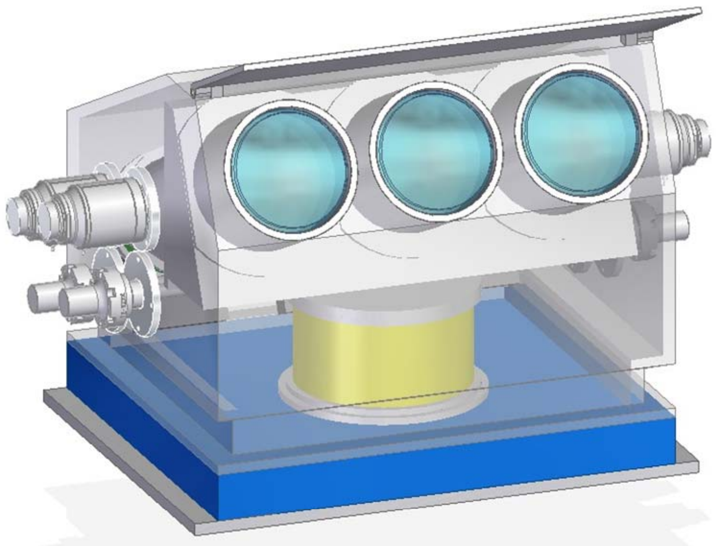


- Night-time, solar min conditions (i.e. worst case)
- Wind precision better than 2 m/s up to 185 km
- Temperature precision better than 2 K up to 170 km

Comparison with Other Instruments

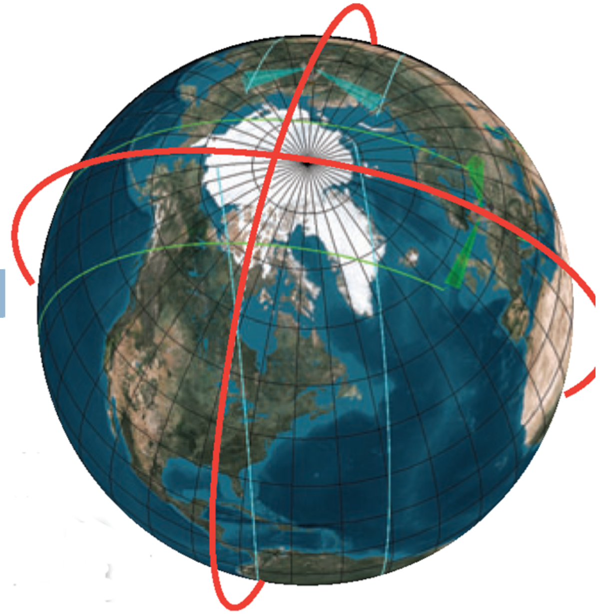


Compact 3-channel design



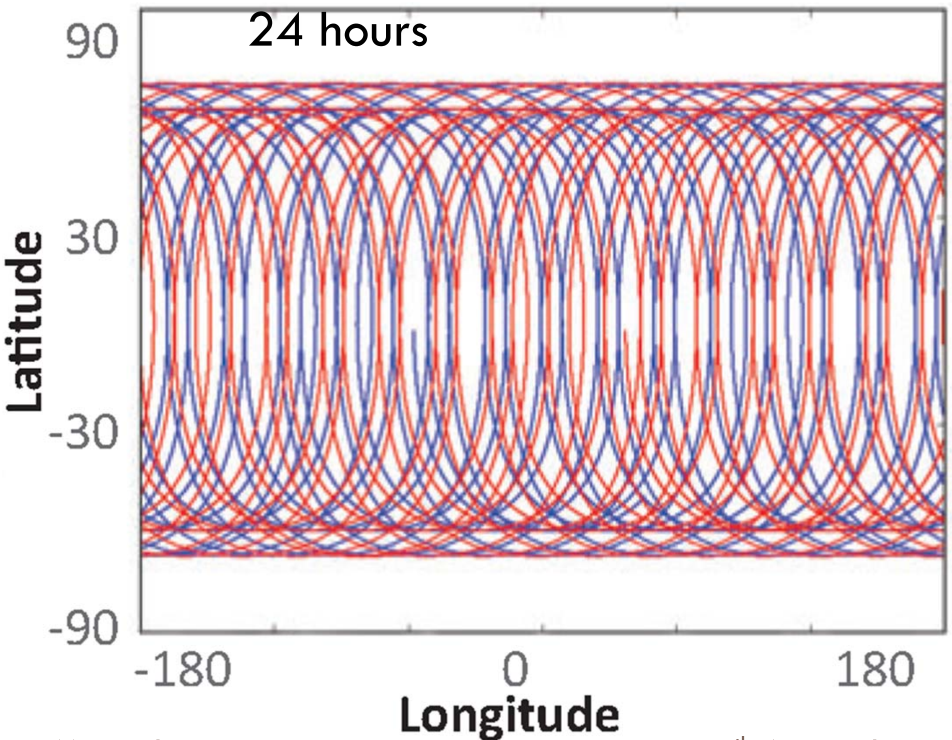
DWTS Design Specs		
mass	7.0 kg	
power	7.4 Watts	
volume	14 x 20 x 30 cm	
data rate	20 kbps avg	
spectral bandpasses	NO	1851 ± 22 cm^{-1}
	N_2O	2165 ± 10 cm^{-1}
	$^{13}CO_2$	2270 ± 12 cm^{-1}
FOV	20 x 20 deg	
aperture	5 cm diameter	
focal length	10 cm	

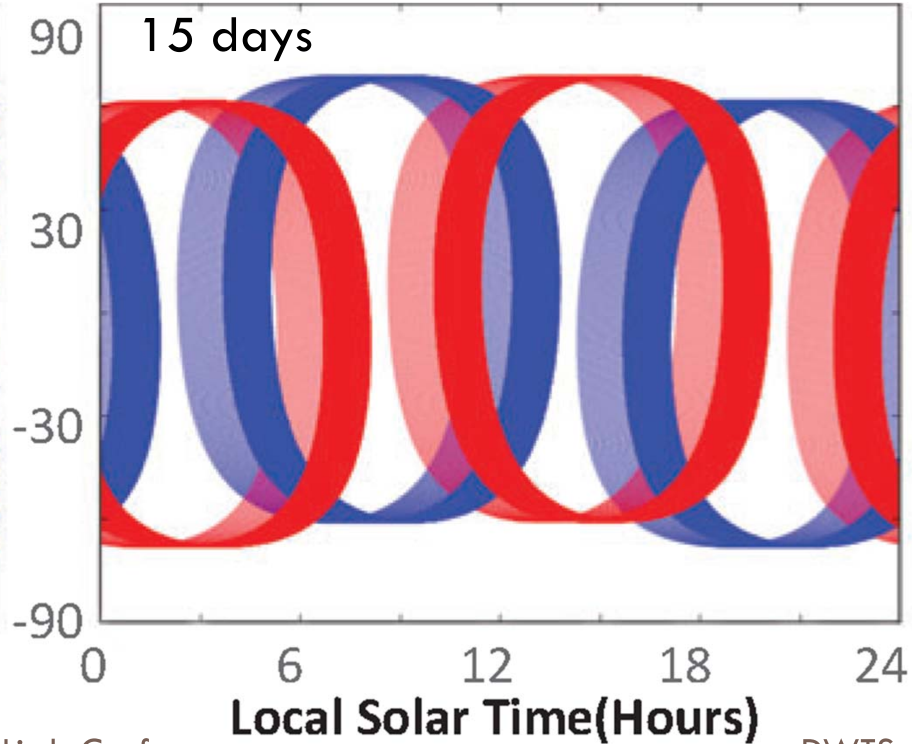
Global Coverage



DWTS gives daily global coverage, and bi-weekly full local-solar time sampling

Example coverage with only 2 microsats





Conclusion

- There is a critical need for high-altitude wind and temperature observations (e.g. new US Presidential study and GAO report)
  - Weather forecasting
  - Severe storm prediction
  - Space weather monitoring

- DWTS uses new approach with tested technology and will provide global winds and temperatures from cloud-top to 250 km. (Such measurements are unavailable from other technologies.)

- Currently in discussions with NASA, JAXA and CSA to deploy first implementation. Envision a small constellation of small-satellites in LEO providing the critical wind and temperature data for weather, storm prediction and space weather needs.