## DWTS

Doppler Wind and Temperature Sounder

The next step for improving weather forecasts

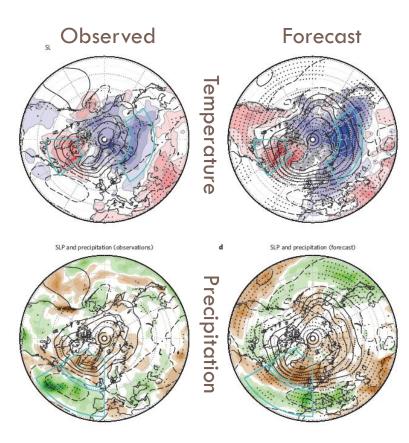
#### **DWTS:** Motivation

Why measure winds in the upper atmosphere?

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

### Weather Forecasting

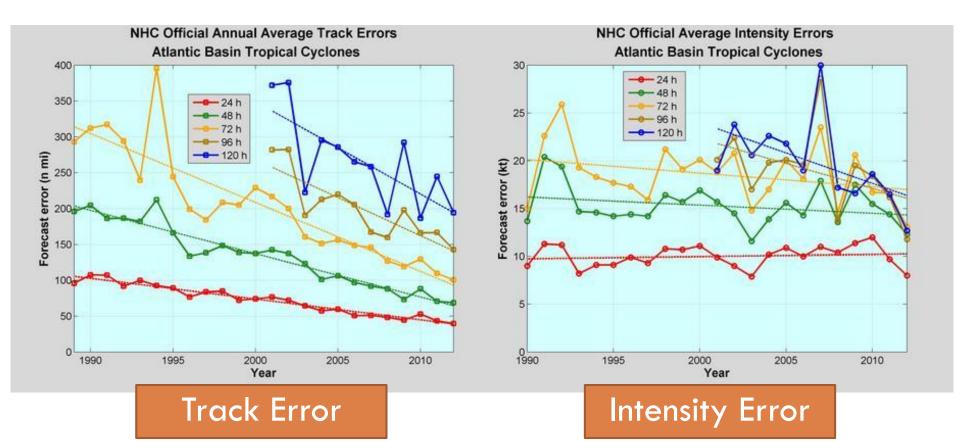
- Medium- and long-range weather is well-known to be significantly affected by stratospheric dynamics
  - Baldwin and Dunkerton (2001): Stratospheric harbingers can be used as a predictor of tropospheric weather regimes
  - Thompson et al. (2001): Dynamic coupling of stratosphere and troposphere yields 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!



From Sigmond et al., 2013

### Severe Storm Intensity

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



### Space Weather



Office of Science and Technology Policy

White House OSTP recently released Space Weather report:

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

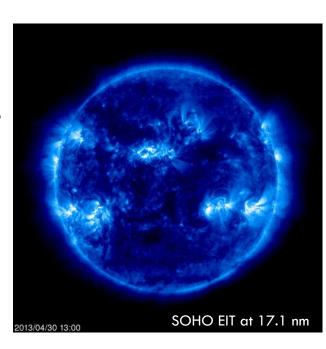
Calls out the critical gap in measurements of mesospheric winds and temperature and neutral winds.

Environmental Parameter	Platform/Asset (owner)	Req	Requirements	suts	Me	Measurement	nent				Dat	3 Avail	Data Availability				Comments
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	TIMED/SABER (NASA)				¥1	H	Et.						H			H	TIMED // EOL: FY14; No NRT data available
	DMSP/SSMIS (DoD)				ts	-	#a	5	0	n n	0	0	n n	n n	2	0	U) Current stated EOL for DMSP F19 is 2021 per CSAT
	JPSS/ATMS (DoC)				uş.	H	ut:						F				JPSS // EOL: >FY22; Mesosphere capability discussed but not planned
	MetOp/AMSU (EUMETSAT)				115	H	22			H		H	ı				MetOp // EOL: >FY22; Mesosphere capability not planned
	AURA/MLS (NASA)	Γ	Γ		u <sub>s</sub>	H	12	(1)	(3)	(3)		H	H			H	AURA // EOL: uncertain; Utilitity is good; Availability is uncertain
	ODIN/OSIRIS (ESA)				45	-	22					H	H	F		H	ODIN//EOL: TSD
	Lidar Network (NSF)					41	壮		H	H			H	Г		H	NSF-sponsored ground stations at a handful of American sector and Europian sites
	VHF Radars (NSF)					n	22			H			H	Г		H	NSF-sponsored ground stations at a handful of American sector and Europian sites
esospheric Wind	Wesospheric Winds (Speed & Direction)		-			H	H										
	TIMED/TIDI (NASA)				22.	H	23.						H			H	TIMED // EDL: FY14, No NRT data available
	MF/HF Radars (NOAA & NSF)					19	22		H	Н		Н	H			H	NSF sponsored ground stations at a handful of American sector and Europian sites
	VHF Radars (NSF)					==	22		-	H		H	H			H	NSF sponsored ground stations at a handful of American sector and Europian sites
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	C/NOFS/NWM (DoD)				43.	F	22.	Þ	2				H			H	C/NOFS EQU: FY12 ; quality has been limited by solar conditions, single satellite
	SENSE/WINCS (DoD)				ts	H	22		f	חר		H	Н	П	H	Н	Coverage limited by single in situ measurement
	TIMED/TIDI (NASA)				¥5		tt						H			H	TIMED EOL: FY14, no NRT data available
	Optical Interferometer Network (NSF)					73	22						Н			H	NSF-sponsored ground stations at a handful of American sector and Europian sites
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	GRACE (NASA)				4tt	F	źr.			H		H	H			H	GRACE in extended mission ops., No NRT data available
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	SWARM (ESA)				¥3.		22		H	Н		Н	Н			Н	SWARM // EOL: FY16, NRT data availability unknown; operational products not assured
	TIMED/TIDI (NASA)					Н	Н		H	Н		Н	Н	П	H	Н	TIMED // EOL: FY14, No NRT data available
	TIMED/SABER (NASA)				115		22			H			H			H	TIMED // EOL: FY14, No NRT data available
	Optical Interferometer Network (NSF)					73	22			Н			Н				NSF-sponsored ground stations at a handful of American sector and Europian sites
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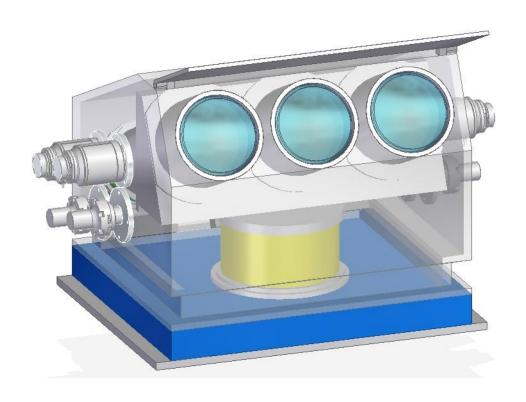
### Space Weather

# 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



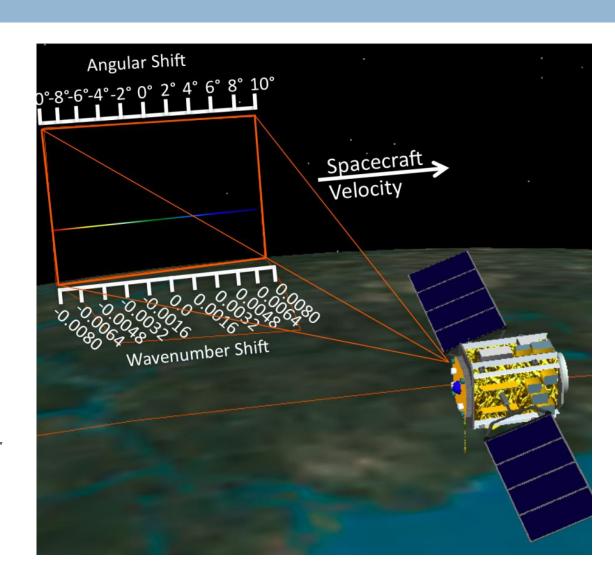
### **DWTS: Measurement Concept**



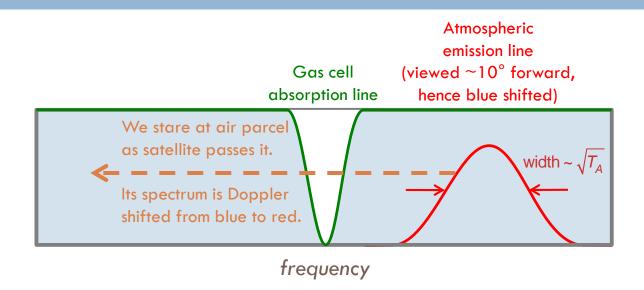
Courtesy Space Dynamics Lab

### 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 redshifted emission.
- Each row collects a full
  Doppler scan for each air
  parcel at that altitude



### Doppler Spectroscopy



## Doppler Spectroscopy

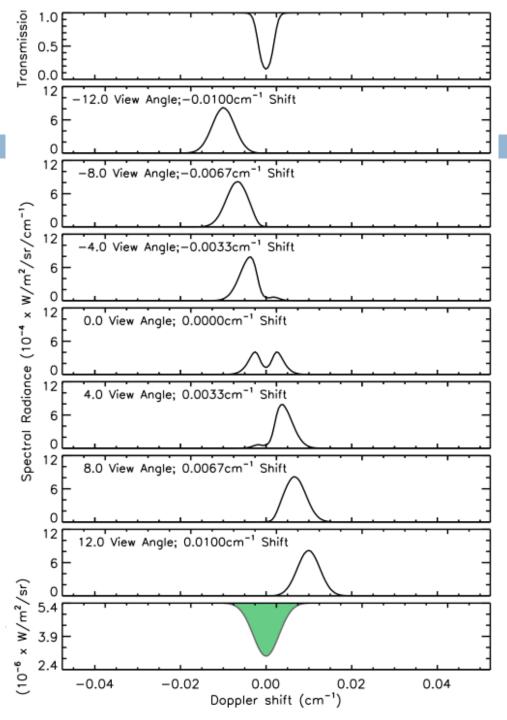
**Top:** Gas-cell transmittance vs. wavenumber showing a  $CO_2$  absorption line.

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

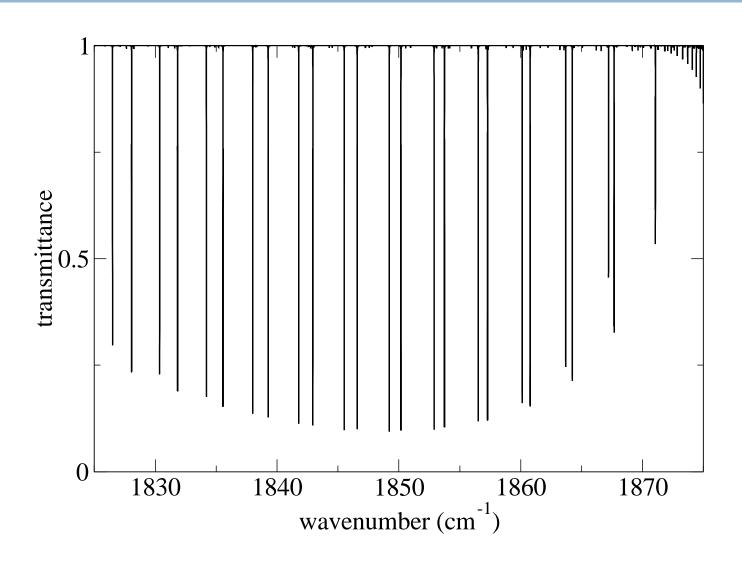
**Bottom:** Doppler integrated signal is formed by combining measurements across a row.

Width of the measured signal indicates the air temperature.

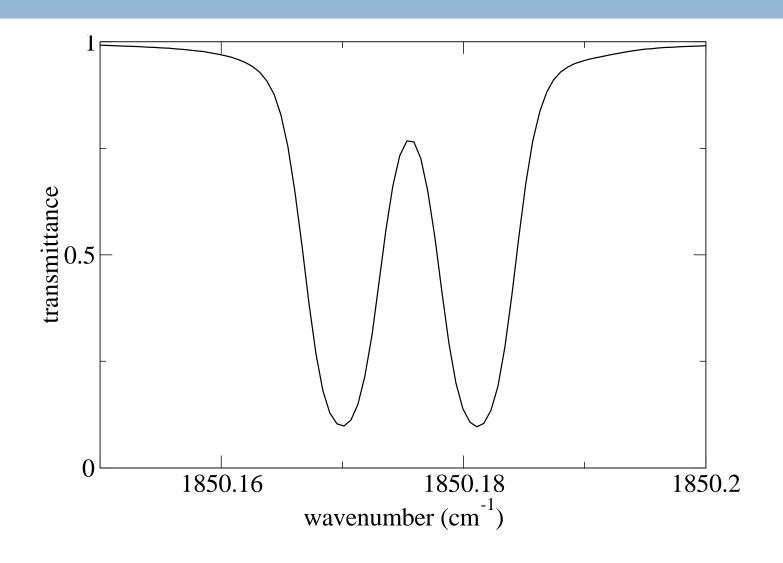
Cross-track winds appear as a shift along horizontal axis. Along track winds scale the horizontal axis. Total area of the signal (normalized by the maximum) provides a direct calibration of cell pressure.



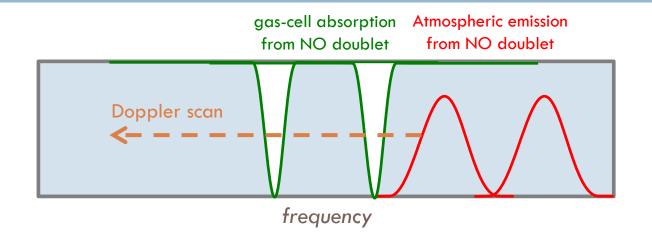
### Nitric oxide spectrum at 5.4 microns

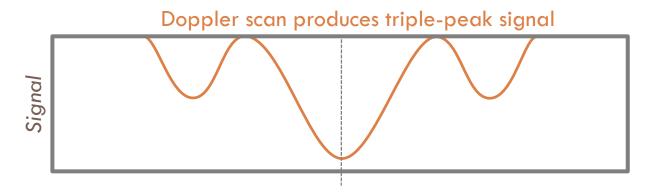


### Lambda-doubling in NO spectrum



### NO doublets produce multi-peak signal



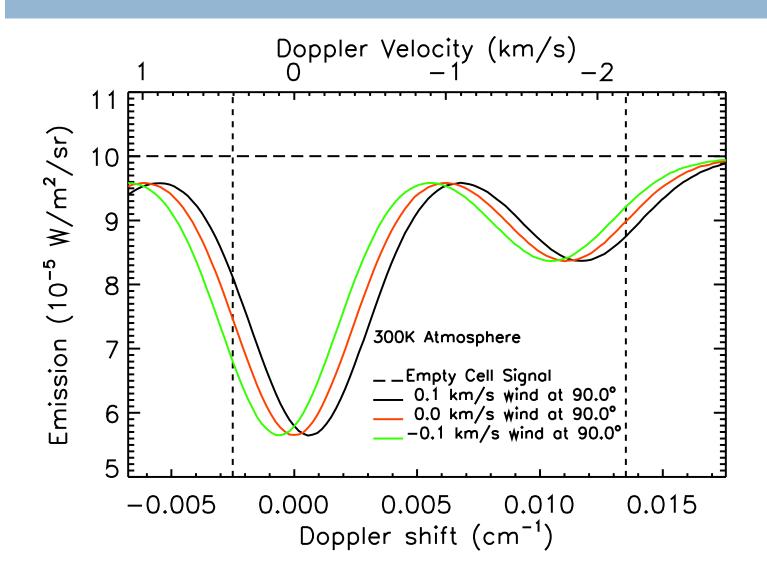


Doppler shift (view angle)

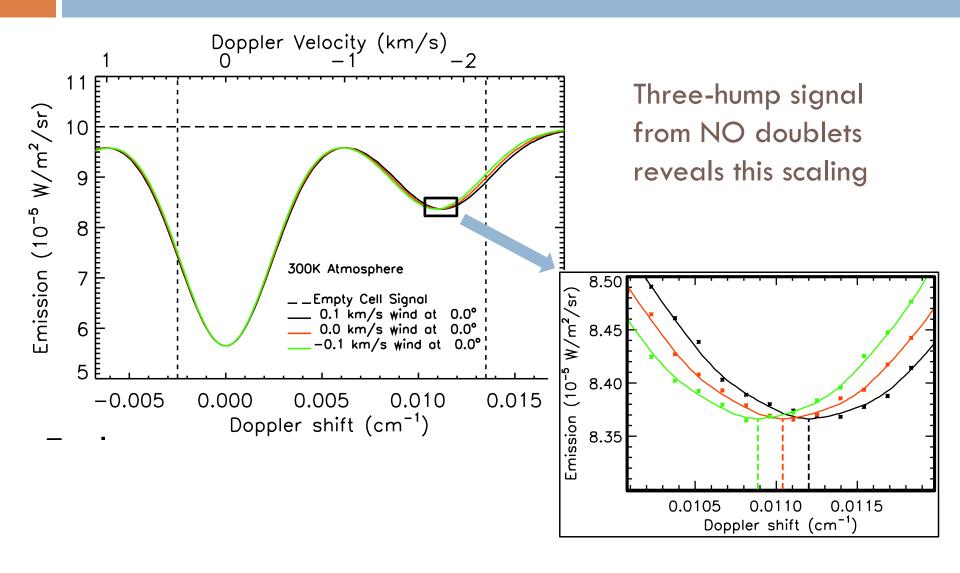
#### **DWTS** Performance

- Full performance evaluation with rigorous radiometric simulations
  - Day/night
  - Various solar activity levels
  - Along- and cross-track sensitivities
  - Temperature precision
  - Coverage statistics

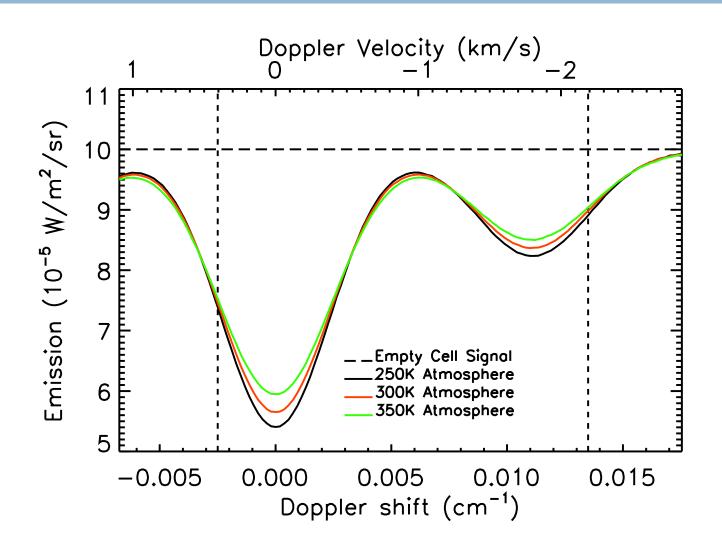
### Cross-track winds shift the signal



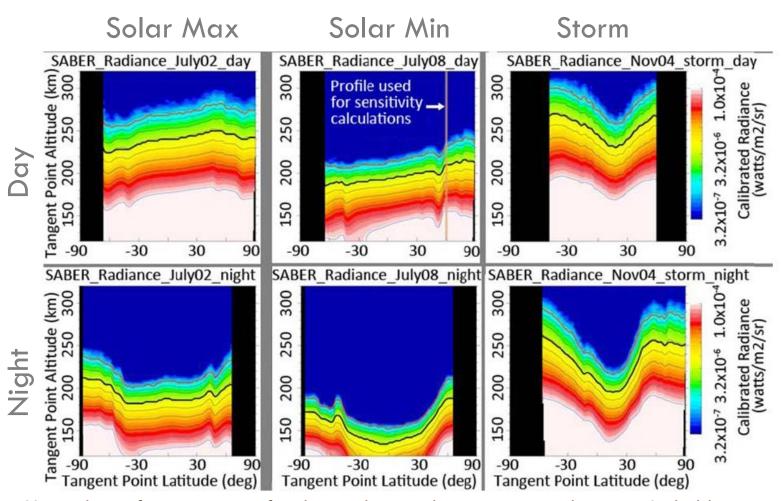
### Along-track winds scale the spectrum



### Signal width indicates temperature

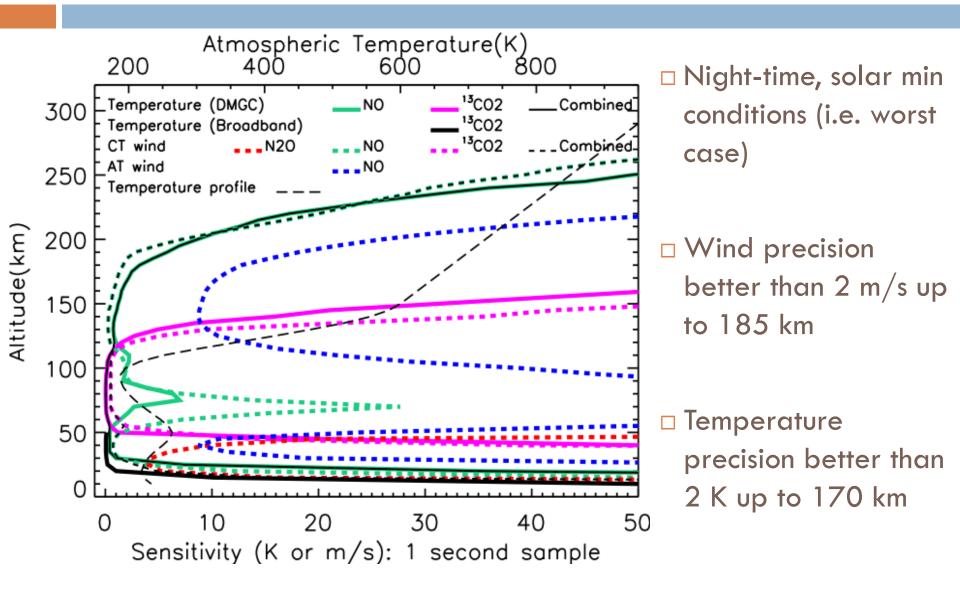


### Effect of solar activity

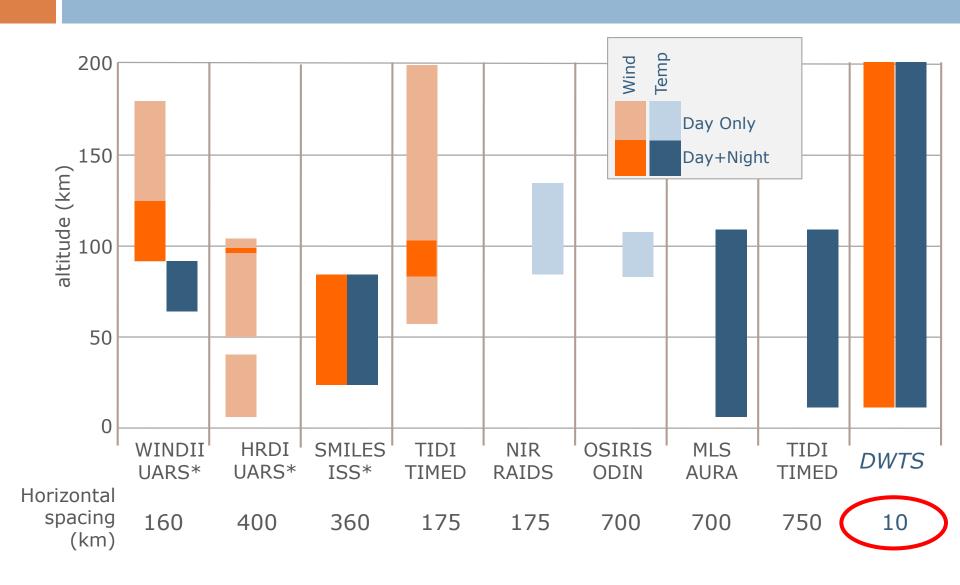


Upper limit of measurement for day, night, at solar max, min and storms. Light blue is predicted maximum retrieval altitude. Green has S/N 10 times greater than threshold.

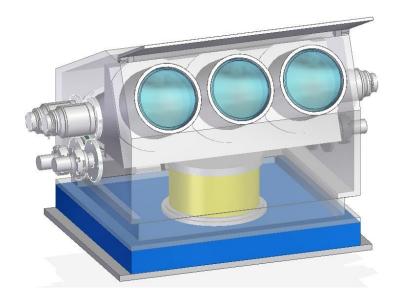
### Predicted Sensitivity



### Comparison with Other Instruments



### Compact 3-channel design

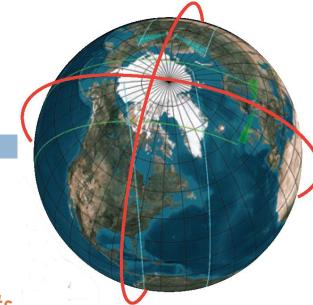


Courtesy Space Dynamics Lab

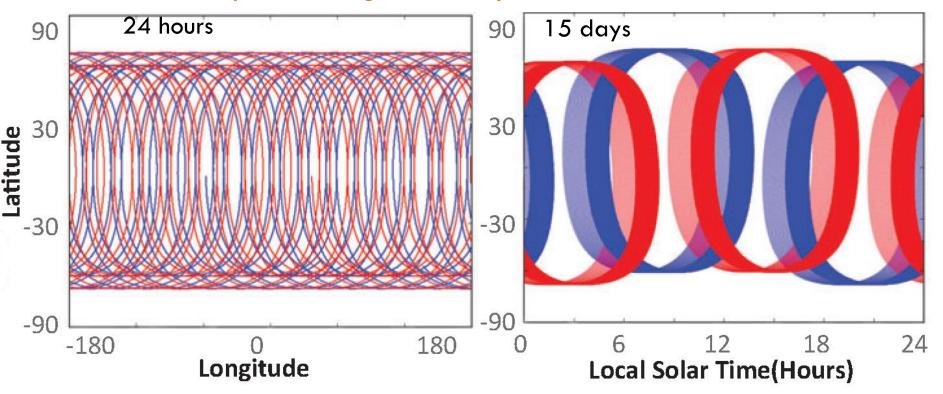
DWTS Design	n Specs	
mass	7.0 kg	
power	7.4 Watts	5
volume	14 x 20 x	< 30 cm
data rate	20 kbps c	gvg
spectral	NO	$1851 \pm 22 \text{ cm}^{-1}$
bandpasses	$N_2O$	$2165 \pm 10 \text{ cm}^{-1}$
	<sup>13</sup> CO <sub>2</sub>	$2270 \pm 12 \text{ cm}^{-1}$
FOV	20 x 20 d	deg
aperture	5 cm dian	neter
focal length	10 cm	

### Global Coverage

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



Example coverage with only 2 microsats

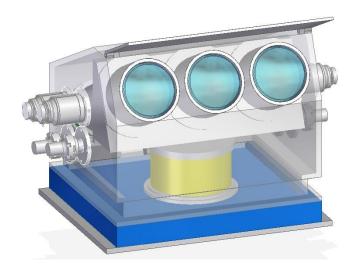


#### **DWTS**

- 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 NOAA, Taiwan, NASA, JAXA and CSA to deploy first satellite. When fully implemented, a constellation of small-satellites in LEO will provide the critical wind and temperature data for weather, storm prediction and space weather needs.

### The End

#### **DWTS**



#### Earth + DWTS

