Wind and Temperature measurements, 15 to 200+ kilometers, day and night: Planned demonstration on the ISS

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Abstract

Wind and temperature sounding from near cloud-top to 200+km, day and night is now possible using a Doppler Modulated Gas Correlation technique (Gordley and Marshall, 2011). The technique has been independently analyzed by Ball Aerospace engineers who have designed a pathfinder prototype instrument (DWTS_Doppler Wind and Temperature Sounder) being proposed for implementation on the International Space Station (ISS) through CASIS (http://www.isscasis.org/About/AboutCASIS.aspx). CASIS manages the International Space Station U.S. National Laboratory. This small, static, moderately cooled mid IR imager will achieve global monitoring of upper atmosphere wind and temperature with unprecedented spatial temporal and diurnal coverage. This opens the door to major advances in atmospheric research and weather forecasting from troposphere through thermosphere (SPARC Data Assimilation Workshop, 2012).

Figure 1 depicts the observation geometry of this simple MIR camera observing the port limb, perpendicular to the ISS velocity vector, through a gas cell.

Figure 2 illustrates the potential DWTS advance in wind and temperature sounding, relative to past sensors.

DWTS retrieves kinetic temperature by measuring Doppler line widths. Wind vectors are inferred from the measured Doppler shift. The cross-track (CT) vector comes from absolute shift and along-track (AT) vector comes from the shift scale of spectral shift per observation angle. **Figure 3** illustrates these measurements. Shown is the measured emission from one limb location as it passes through the DWTS FOV, filtered by the gas cell. Also shown is how the signal is analyzed to retrieve those three parameters. For details see Gordley (2011) or the GATS DWTS website at http://www.gats-inc.com/projects_dwts.htm.

Figure 4 shows the ISS Nanoracks DWTS 6U unit (60 x 20 x 10 cm) in a hinged position to allow a clear port view to the limb. It is proposed to be located on the ISS Japanese Experiment Module, JEM shown in **Figure 5**.

The DWTS is a simple MIR camera with a gas cell before the objective lens. To cover the range from tropopause to over 200 km it requires three cameras, each with a different gas cell. Tropopause to 50 km uses N_2O at 4.5 microns. Stratopause into lower mesosphere requires CO_2 at 4.3 microns, and higher altitudes require NO at 5.3 microns. The pathfinder baseline technology demonstration will have just one camera implementing the CO_2 channel. However, other channels could be added if funds allow. **Figure 6** illustrates the optical design for this camera. **Figure 7** shows the COTS Teledyne camera with Ricor cooler, proposed for the pathfinder system.

This is the first step toward a constellation of dual-sided DWTS instruments on 6 small satellites in separate orbits. Such a constellation would allow near real-time global monitoring of the atmospheric temperature and wind structure from 15 to 200+ kilometers both day and night.

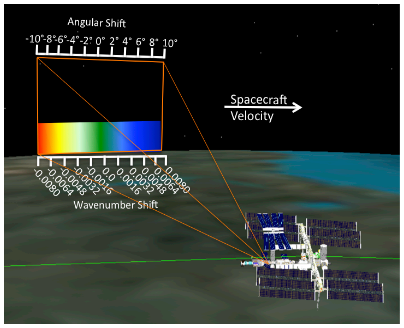
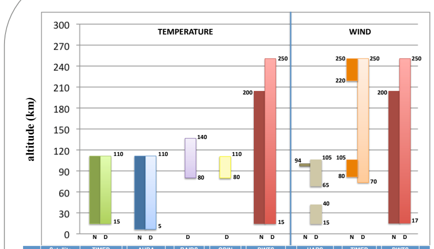


Figure 1. The DWTS instrument will view to the port side of the ISS and view the Earth's limb with a 20° horizontal and 10° vertical FOV.



Resolution	Satellite Instrument	TIMED SABER	AURA MLS	RAIDS NIR	ODIN OSIRIS	DWTS	UARS HRDI	TIMED TIDI	DWTS
	Vertical	2.0 km	4 km 10 above 90	1.0 km	1.5 km	2 km	5 km	2.5 km	2-3 km
	Horizontal Along Track	400 km	175 km	175 km	700 km	10 km	700 km	750 km	10 km
	Along Sight	≅ 300 km	≅ 300 km	≅ 300 km	≅ 300 km	≅ 300 km	≅ 300 km	≅ 300 km	≅ 300 km

Figure 2. DWTS will dramatically improve the altitude coverage and along-track resolution of wind speed and temperature, both day (D) and night (N), compared to other past and current instruments.

References

Larry L. Gordley and Benjamin T. Marshall, "Doppler wind and temperature sounder: new approach using gas filter radiometry", J. Appl. Remote Sens. 5, 053570 (2011); doi:10.1117/1.3666048.

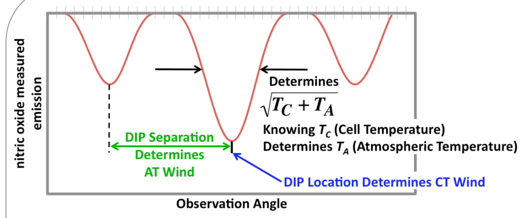


Figure 3. Emission observed (measured) from one limb location as it passes through the DWTS FOV and filtered by the gas cell. Also illustrated is the analysis used to determine temperature and wind. Example is for nitric oxide emission, which produces the half dips (side lobes) due to lambda doubling of line transitions.

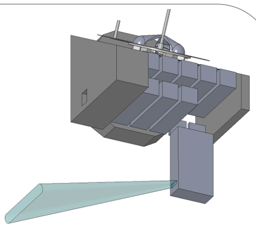
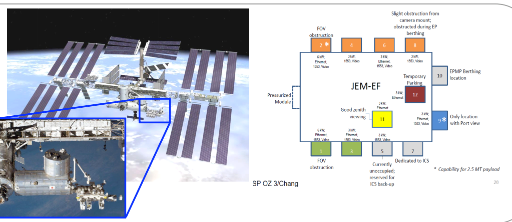


Figure 4. Nanoracks implementation of DWTS to be installed on the ISS JEM showing the separate external experiment modules. DWTS proposes to use two modules with a hinge mechanism to lower the viewpoint and avoid obscurations in the FOV.

Figure 5. The image on the left shows the JEM module on the ISS and the diagram on the right shows the experiment slots on the JEM. Out of all the available options, the Nanoracks external experiment module in slot 4 provides the best FOV for DWTS.



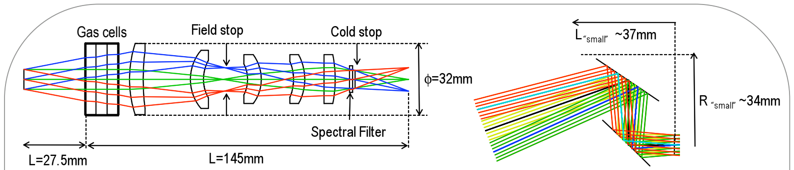
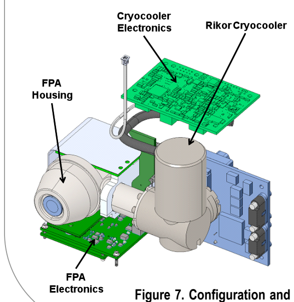


Figure 6. DWTS can be implemented with a simple refractive design, providing good stray-light rejection in a compact package, reimaging to the cold stop. Gas cells are in front of the optics to allow a single low-cost optical assembly. Fold mirrors in front of entrance aperture turn the beam to the desired limb angle relative to the optical train configuration for Nanoracks.



Performance Parameter	Expected Performance
Spectral band	3 – 5.0 µm nominal (0.4 – 5.0 µm if required)
Array Format	640 x 512
Pixel pitch (µm)	15
NEDT (for 300 K background)	25 mK @ F/4.5
FPA operating temperature	120 – 150 K
F/#	2.5 – 4.5
Pixel operability (%)	99.5 %
Frame rate (Hz)	30 or 60 Hz, 120 Hz max
Ambient temp range (°C)	-40 to +70
Integration mode	ITR, IWR, snapshot and rolling shutter
Integration time to above NEDT	~ 17 ms
Size and weight (with Ricor K562S) without electronics	2" (W) x 3" (H) x 4" (L) 350 grams
Size and weight (with Ricor K527L) without electronics	Dewar: 1.3: diameter x 5" length Cooler: 1.4" diameter x 3.2" length 600 grams total weight
Steady state power	~ 4 W (without cooler control electronics)
Estimated cooler MTTF (hours)	> 25,000 (K527) > 8,000 (K562S)

Figure 7. Configuration and performance specifications for the commercial Teledyne HMIR camera, which is ideally suited for DWTS application.