Assessment of the Information Content of Hyperspectral Infrared Sounders

Eric S. Maddy, Sid A. Boukabara

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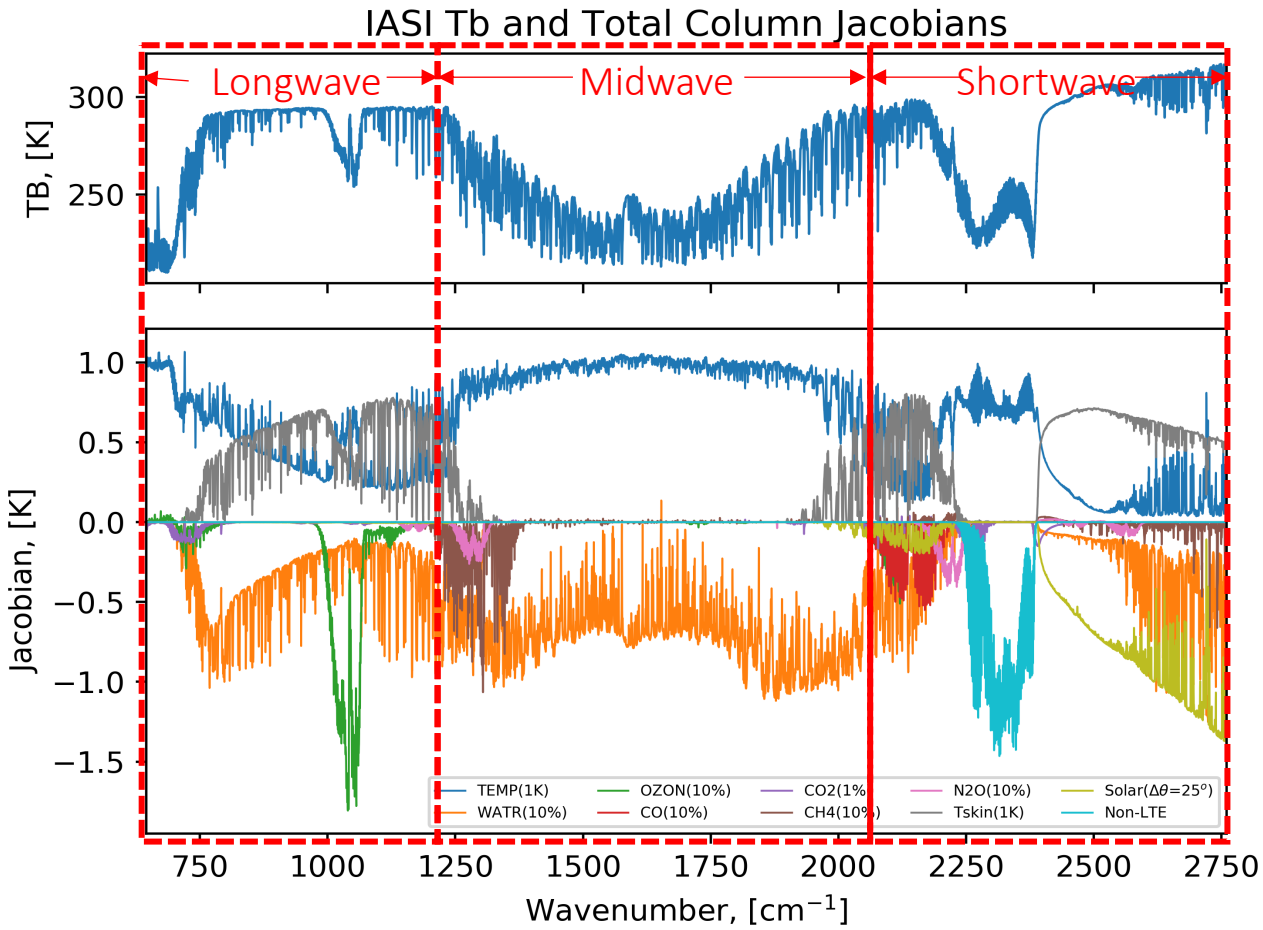
Experiment Setup

- Clear-sky, ocean simulations using CRTM(USSTD MLS/Tropical) for IASI and CrIS Full Spectral Resolution
- Geophysical background covariance assumed diagonal (nearly) with temperature and water vapor standard deviations ~1.5-2K and 25-40% (inflated MIIDAPS-AI(IR) errors).
- Instrument Noise covariance assumed diagonal and equal to Root-Sum-Squared (RSS) of
  - NEΔT – scaled noise (0.5, 1.0, 2.0) from nominal IASI and/or CrIS
  - Errors due to trace gases (expected variability/uncertainty in O3, N2O, CH4, CO, CO2), surface emissivity, non-lte, solar reflectance
  - Catch all 0.2K – forward model parameterizations and spectroscopy, calibration, etc.
- Diagnostics (degrees of freedom, retrieval error covariance) computed for non-simultaneous geophysical state retrievals
  - Retrievals for Temperature and Tskin are performed ignoring Water (Water 10% column spectral Jacobian added to Instrument Covariance)
  - Retrievals for Water performed ignoring Temperature (1K column Temperature perturbation spectral Jacobian added to Instrument Covariance)
- Diagnostics normalized to LW (CrIS Nominal NEDT) for Temperature and MW (CrIS Nominal NEDT) for Moisture



Assessments have been computed for full band and partial band coverage of 15μm (All,CO2-only), 4.3μm (All,CO2-only), 6.7μm (All,P-branch,R-branch). More channels usually -> higher information content.

While absolute values of DOF and errors may change, the take-home messages are similar when compared in a normalized sense. Same is true for assumptions of background errors.

Following uses full band computations. Bands identified in above figure.

Summary – Assessment of Information Content of Hyperspectral Sounder

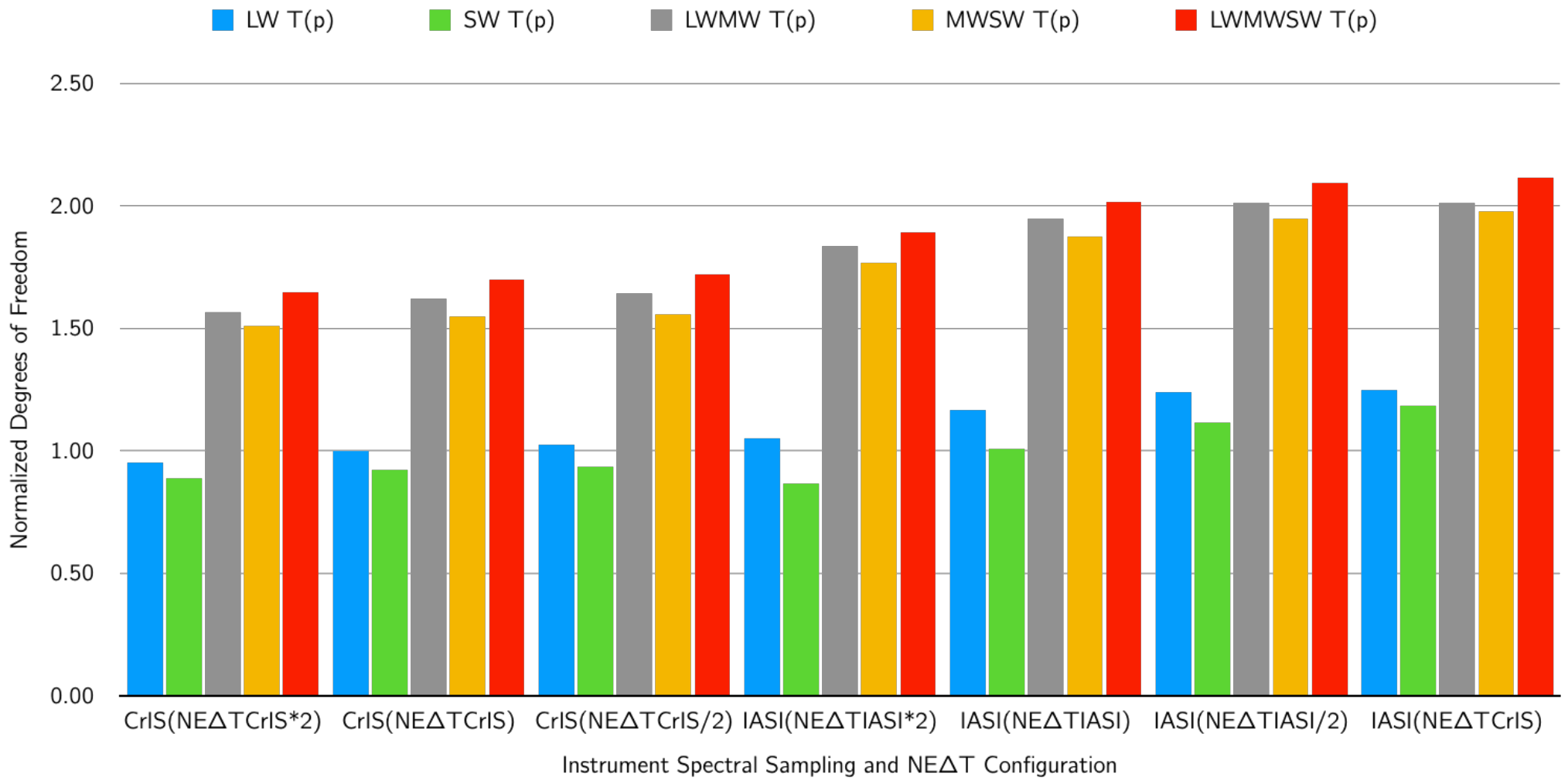
	CrIS ($NE\Delta T_{CrIS}$*2)	CrIS ($NE\Delta T_{CrIS}$)	CrIS ($NE\Delta T_{CrIS}$/2)	IASI ($NE\Delta T_{IASI}$*2)	IASI ($NE\Delta T_{IASI}$)	IASI ($NE\Delta T_{IASI}$/2)	IASI ($NE\Delta T_{CrIS}$)
Stratospheric Error (10hPa-100hPa)							
LW T(p)		*					
SW T(p)							
LWMW T(p)							
MWSW T(p)							
LWMWSW T(p)							
Upper Tropospheric Error (100hPa-500hPa)							
LW T(p)		*					
SW T(p)							
LWMW T(p)							
MWSW T(p)							
LWMWSW T(p)							
Lower Tropospheric Error (500hPa-Surface)							
LW T(p)		*					
SW T(p)							
LWMW T(p)							
MWSW T(p)							
LWMWSW T(p)							
Degrees of Freedom Total (10hPa-Surface)							
LW T(p)		*					
SW T(p)							
LWMW T(p)							
MWSW T(p)							
LWMWSW T(p)							
MW qH2O(p)		*					

>15% Improvement	5% - 15% Improvement	Within 5%	5% - 15% Degradation	>15% Degradation

- Normalized average responses computed over TROPICAL, MLS atmospheres.
- Stratospheric T(p) error reduced at higher spectral resolution and lower noise.
- Adding MW to LW or SW improves information content and reduces estimated sounding error across the board (all noise levels, all spectral resolutions).
- LW slightly better than SW in lower troposphere; otherwise results are comparable.

Diagnostics normalized to LW (CrIS Nominal NEDT) for Temperature and MW (CrIS Nominal NEDT) for Moisture
Diagonal Hash (assessment computed skipping every other channel – interferometer spectral correlation)

Normalized Temperature Degrees of Freedom For Signal

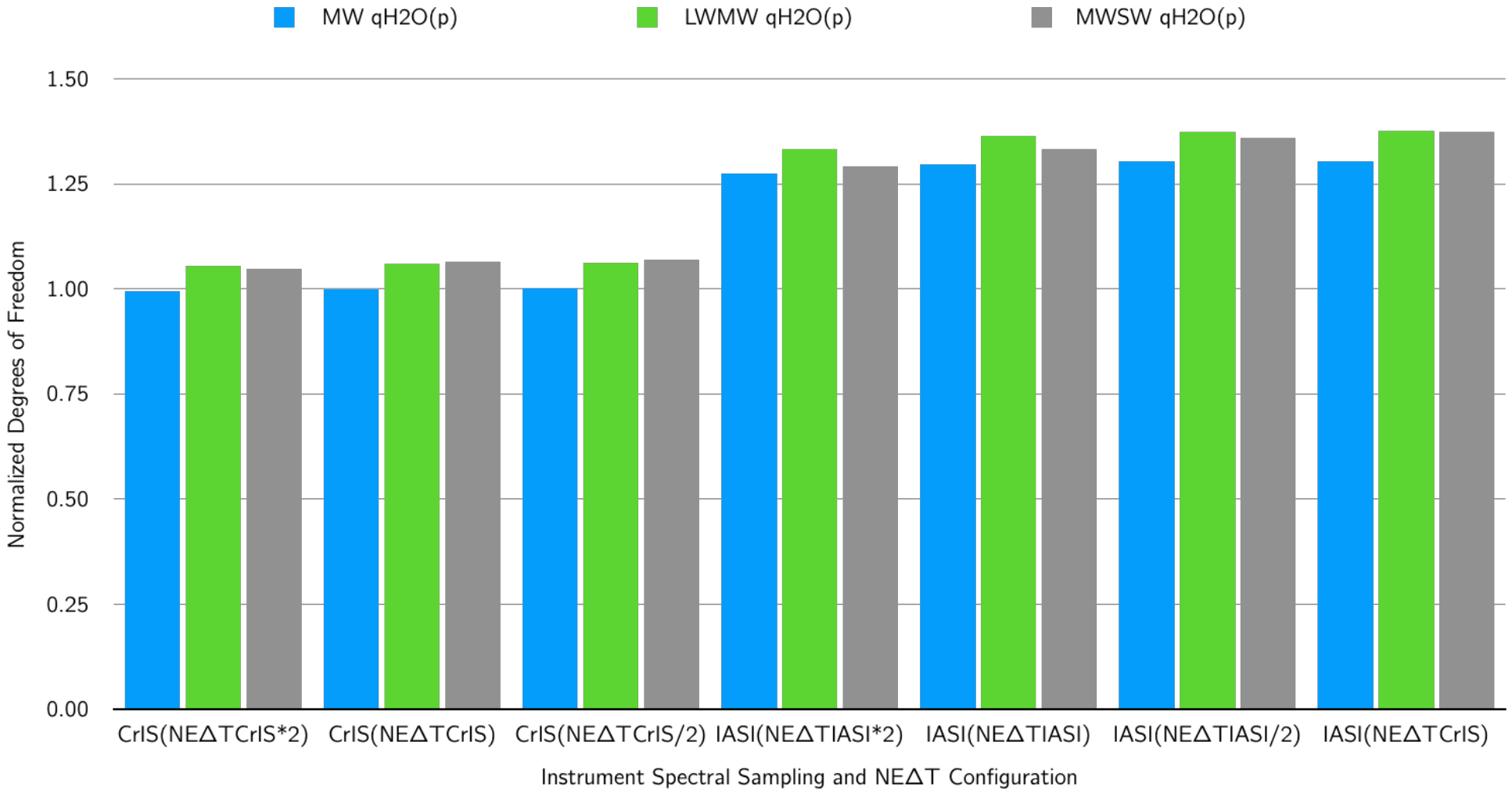


Information content assessment depends on 3 factors –

1st order: band coverage/combinations, 2nd order: resolution, 3rd order: instrument noise levels

Combination of bands (LWMW, MWSW) in an optimal sense requires spectroscopy and RT implementations in the bands to agree and cross state errors (e.g. T/Q) to be well characterized.

Normalized Water Degrees of Freedom For Signal



Spectral resolution/sampling (CrIS -> IASI) is main driver of information content for water sounding. Band coverage/combination is a 2nd order effect - LWMW equivalent or slightly better for most spectral resolutions/noise configurations.

Summary/Main take aways

- We performed an internal government study to assess the clear-sky information content of hyperspectral sounder configurations.
- In particular, we focused on temperature and moisture sounding and used IASI and CrIS nominal spectral sampling and noise levels to anchor/normalize trade space.
- We found that the drivers of temperature sounding information content are (in order of importance): band coverage, spectral resolution, and instrument noise
  - Adding MW to LW or SW improves information content and reduces estimated sounding error across the board (all noise levels, all spectral resolutions).
  - LW slightly better than SW in lower troposphere; otherwise results are comparable.
  - Stratospheric sounding can be improved at higher spectral resolution (IASI-like) and lower noise.
- We found that the main driver of water sounding information content is spectral resolution.
  - >20% increase in water sounding degrees of freedom moving from CrIS to IASI spectral resolution/spacing.