



PBL Thermodynamic Characterization and its Variability from NAST-I During the WH²YMSIE Field Campaign



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A41I-2724

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INTRODUCTION

The National Airborne Sounder Testbed-Interferometer (NAST-I) suborbital system (<2.6 km IFOV; 0.25 cm⁻¹ within 645–2700 cm⁻¹) serves as a spaceborne instrument simulator and pathfinder for future satellite capabilities and airborne science experiments. The NAST-I measurements are made to advance understanding of science critical for weather, climate, chemistry, and radiation applications. Here we present some groundbreaking capabilities of NAST-I measurements and corresponding geophysical retrievals and their potential benefits toward improved atmospheric state and composition characterizations needed for science applications of particular importance toward enhancing characterization and understanding of the Planetary Boundary Layer (PBL).

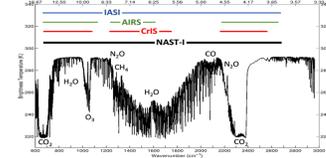
Initial results of PBL height estimation and thermodynamic characterization and their time evolution from NAST-I measurements during the WH²YMSIE field campaign are presented.

NAST-I: BRIEF DESCRIPTION AND OBJECTIVES

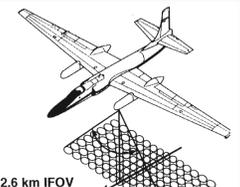
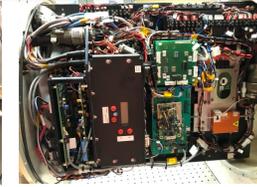
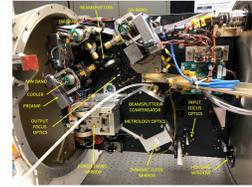
NAST-I was developed in 1997-1998; refurbished in 2009, 2016, & 2022.

NAST-I Sensor Characteristics:

- Michelson interferometer (FTS).
- ~8500 spectral channels, ~650-2800 cm⁻¹ at 0.25 cm⁻¹ spectral resolution.
- Spatial resolution ~130 m/km flight altitude.
- Radiances ~0.5 K absolute accuracy with 0.1 K precision.



NAST-I spectral coverage encompasses all satellite IR sounders with a higher (or equivalent) spectral resolution and higher spatial resolution.



NADIR 2.6 km IFOV
20 km ALTITUDE
± 23 km GROUND COVERAGE

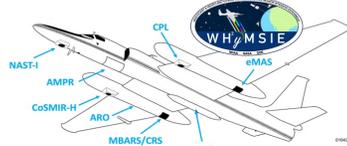
- Aircraft Accommodation:**
- ER-2 Nose cone or wing super pod
 - PROTEUS underbelly pod
 - WB-57 underbelly pallet.

NAST-I Field Campaigns:

- Before AIRS launch (<2002): 9 missions collecting geophysical field state characterization for satellite remote sensing system risk mitigation (sensors and algorithms).
- After AIRS launch (>2002): 13 missions for advanced satellite remote sensor Cal/Val (e.g., Aqua AIRS, MetOp IASI, & SNPP/JPSS CrIS), and airborne science.
- Recent field campaigns: FIREX-AQ (August 2019) and WH²YMSIE (Oct-Nov 2024)

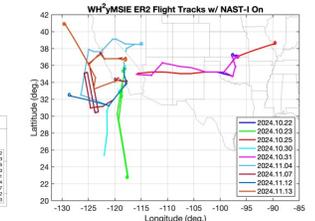
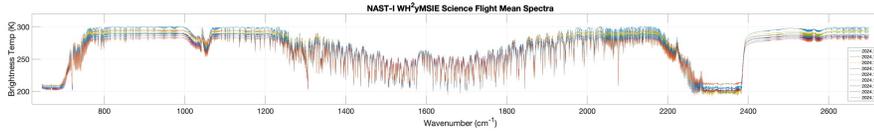
WH²YMSIE FIELD CAMPAIGN AND NAST-I DATA ACQUISITION

- WH²YMSIE (West-coast & Heartland Hyperspectral Microwave Sensor Intensive Experiment) is the very first step forward towards an integrated, intelligent, and affordable PBL observing system of systems.
- WH²YMSIE ER-2 payload will provide a first-of-a-kind PBL sensor architecture prototype, acting as a testbed for technology and retrieval concepts.
- To bring together multiple observing nodes – i.e., space, suborbital, and ground – from passive and active sensors to enable a comprehensive and coherent picture of essential PBL thermodynamic variables such as temperature, water vapor, height, and hydrometeors to provide new understanding of the PBL.
- To mature PBL technology, retrieval algorithms, and modeling capabilities.



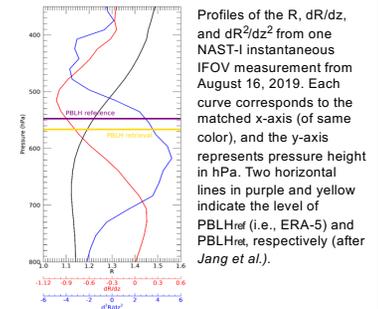
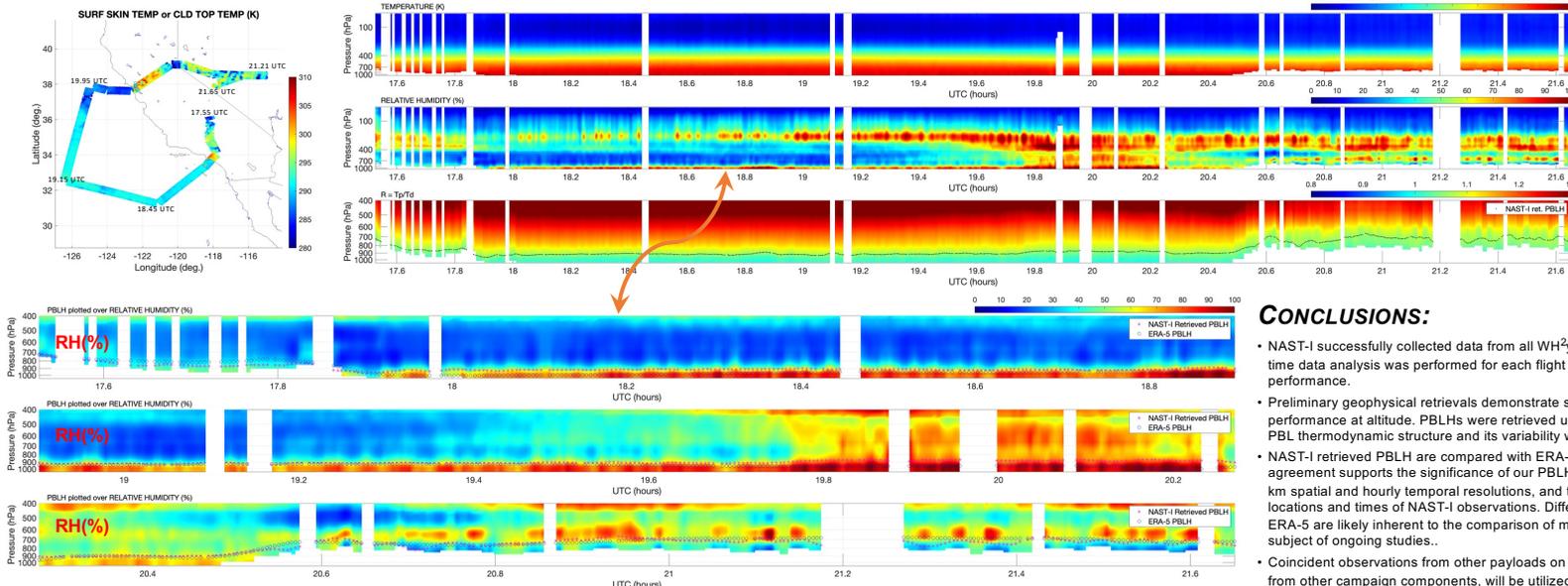
WH²YMSIE science flights and NAST-I data acquisition at ER-2 20 km altitude:

- 10/22/2024: 12,883 science spectra collected (~5.1 hours)
- 10/23/2024: 10,387 science spectra collected (~4.1 hours)
- 10/25/2024: 17,589 science spectra collected (~7.0 hours)
- 10/30/2024: 8,229 science spectra collected (~3.2 hours)
- 10/31/2024: 14,391 science spectra collected (~5.7 hours)
- 11/04/2024: 11,141 science spectra collected (~4.5 hours)
- 11/07/2024: 12,272 science spectra collected (~4.9 hours)
- 11/12/2024: 9,412 science spectra collected (~3.7 hours)
- 11/13/2024: 10,920 science spectra collected (~4.3 hours)



PBL INFERENCES UNDER EVALUATION WITH WH²YMSIE NAST-I DATA (QUICK LOOK SAMPLES)

- Data collected during the 11/04/2024 flight are used here to demonstrate NAST-I PBLH retrieval and thermodynamic parameter variability in the PBL.
- This flight covers both land and ocean surfaces, and under clear and cloudy sky conditions.



Profiles of the R , dR/dz , and dR^2/dz^2 from one NAST-I instantaneous IFOV measurement from August 16, 2019. Each curve corresponds to the matched x-axis (of same color), and the y-axis represents pressure height in hPa. Two horizontal lines in purple and yellow indicate the level of PBLH_{ref} (i.e., ERA-5) and PBLH_{ret}, respectively (after Jang et al.).

CONCLUSIONS:

- NAST-I successfully collected data from all WH²YMSIE science flights. Near real-time data analysis was performed for each flight to ensure excellent NAST-I performance.
- Preliminary geophysical retrievals demonstrate science-quality NAST-I operational performance at altitude. PBLHs were retrieved using NAST-I measurements, and the PBL thermodynamic structure and its variability were characterized.
- NAST-I retrieved PBLH are compared with ERA-5 reanalysis model results. Positive agreement supports the significance of our PBLH estimation method. ERA-5 has 25-km spatial and hourly temporal resolutions, and the ERA-5 data are interpolated to locations and times of NAST-I observations. Differences found between NAST-I and ERA-5 are likely inherent to the comparison of measurements and models, but the subject of ongoing studies..
- Coincident observations from other payloads on the ER-2, as well as those available from other campaign components, will be utilized in further investigations.

References:

- Gambacorta et al., "The West-Coast Hyperspectral Microwave Sensor Intensive Experiment (WH²YMSIE)", IGARSS 2024, Athens, Greece, Jul. 7–12, 2024.
- Zhou et al., "Thermodynamic product retrieval methodology for NAST-I and validation", *Appl. Opt.*, **41**, 6957–6967, 2002.
- Jang et al., "Planetary boundary layer height estimation: methodology and case study using NAST-I FIREX-AQ field campaign data", submitted to *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, 2024.