Calibration Validation Of The Cross-track Infrared Sounder (CrIS) With The Aircraft Based Scanning High-resolution Interferometer Sounder (S-HIS)

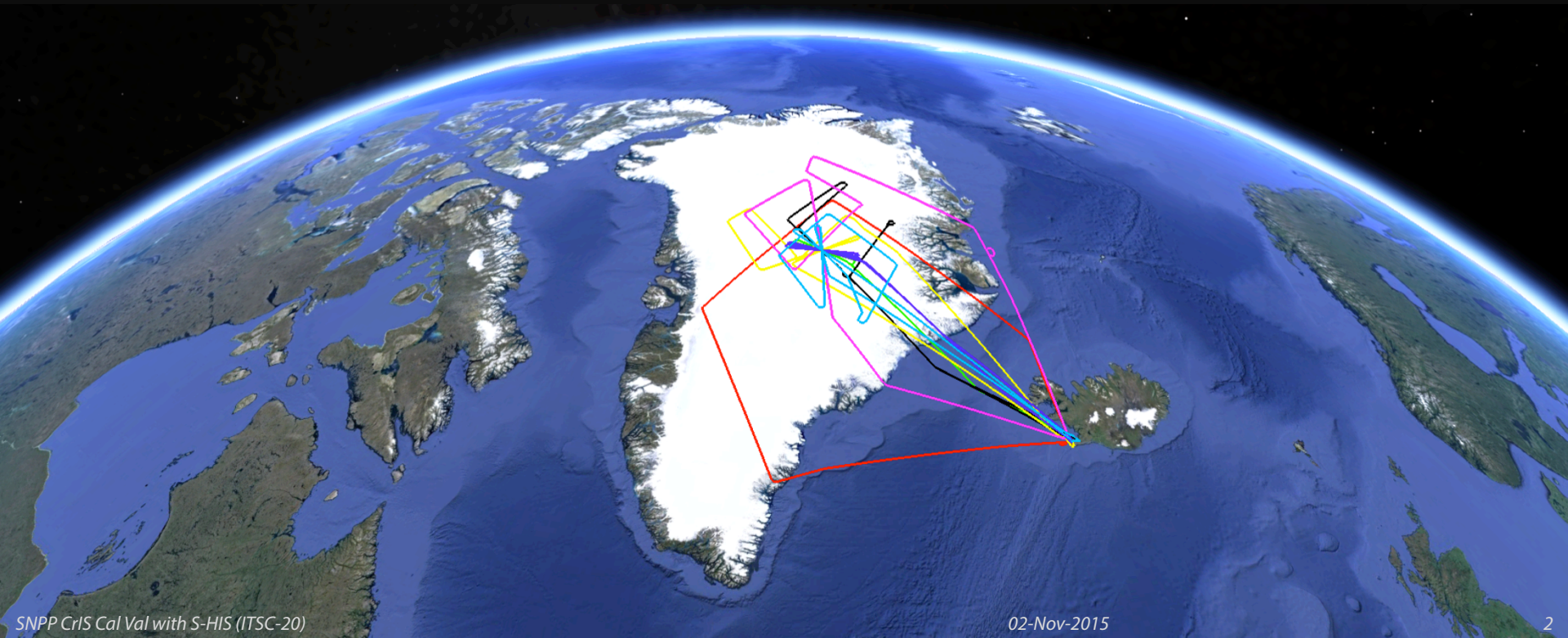
Joe K. Taylor[1], David C. Tobin[1] Henry E. Revercomb[1], Fred A. Best[1], Ray K. Garcia[1], Aronne Merrelli[1], Mitch Goldberg[2]

[1] *Space Science and Engineering Center, University of Wisconsin-Madison*

[2] *Joint Polar Satellite Systems Office, National Oceanic and Atmospheric Administration*

ITSC-20, Lake Geneva WI

- *Introduction*
- Cross Track Infrared Sounder (CrIS)
- Scanning High-resolution interferometer Sounder (S-HIS)
- Comparison Results
- Conclusion



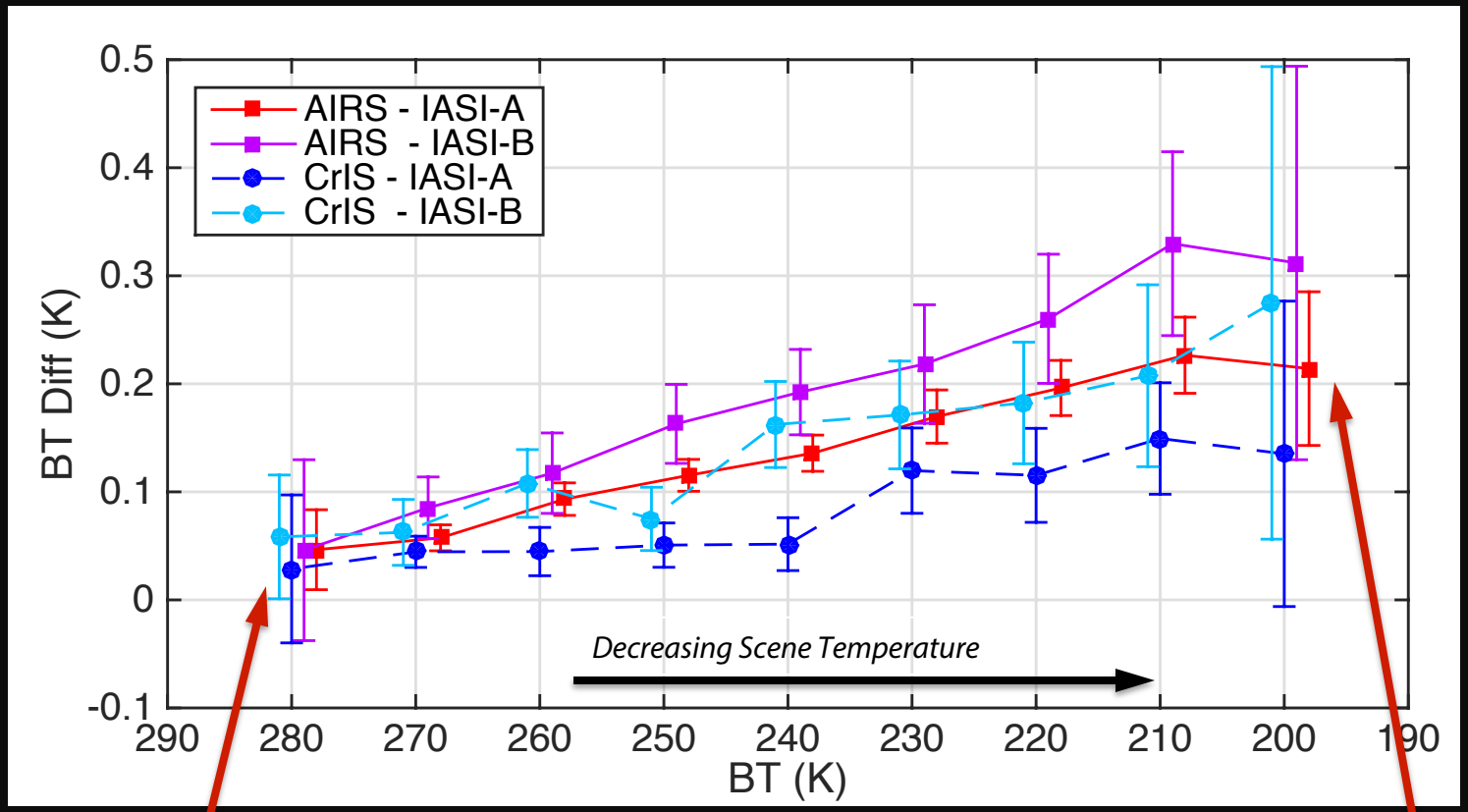
Introduction: SNPP Calibration Validation Campaign 2015

- Purpose:
  - To continue SNPP calibration validation with a specific focus on assessment of the calibration accuracy for cold Earth scenes, retrieval evaluation and satellite cross-validation
- Approach:
  - Based in Keflavik Iceland, with flights over Greenland
  - The Northern location provides extremely good opportunities for multiple satellite overpasses in a single flight
  - The Greenland Summit Station is extremely well equipped with ground based instrumentation
- Aircraft: NASA ER-2
- Payload: S-HIS (UW-SSEC), NAST-I (LaRC), NAST-M (LL), MASTER (AMES)
- S/C under-flights: SNPP, Aqua, Metop-A, Metop-B
- Base location / schedule: Keflavik, Iceland, 7-31 March, 2015
- Flight hours: ~ 42 hrs science, 65 hrs total; 7 mission science flights

Larar, Tobin, et al. "SNPP-2 Arctic Validation Experiment." http://www.jpss.noaa.gov/science-seminars-archive.html (to be posted)

Assessment of the calibration accuracy for cold Earth scenes

Mean SNO differences for 910-930 cm^{-1}



Error-bars represent statistical matchup uncertainty, not sensor uncertainty

0.050 K Agreement

> 0.3 K relative differences

D. Tobin

High altitude airborne calibration validation of satellite instruments

- High Altitude Airborne Calibration Validation:
  - Relatively low total uncertainty
  - Relatively short and simple traceability chain
  - Covers most spectral channels with double obs-calc (DOMC) methodology

- S-HIS
  - Proven to be extremely dependable (typically > 99.8% uptime)
  - Accurately calibrated airborne reference instrument
  - Well defined and documented radiometric uncertainty and traceability

Operating from Iceland in March… not without challenges

Strong winds disrupt flights out of Iceland

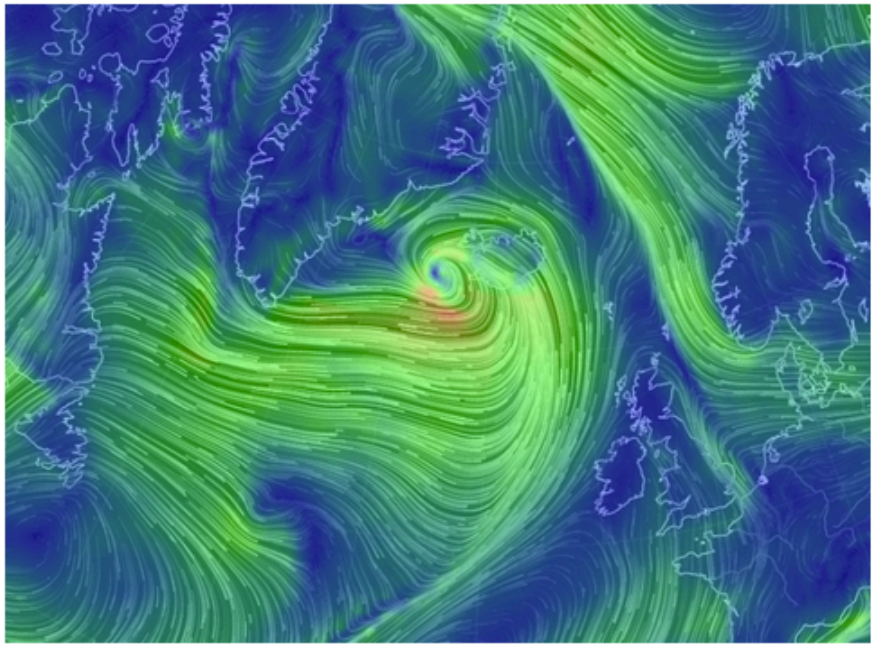
ICELAND, TRAVEL, WEATHER

By Erlingur Nordal

Four flights scheduled to depart the Icelandic capital Reykjavik on route to the US w result of gale-force winds on Tuesday, while a number of others were delayed, anno country's main international airport.

Extreme Weather Tomorrow Could be Worst of Winter So Far

BY ALËX ELLIOTT | NATURE & TRAVEL | March 13, 2015 15:35

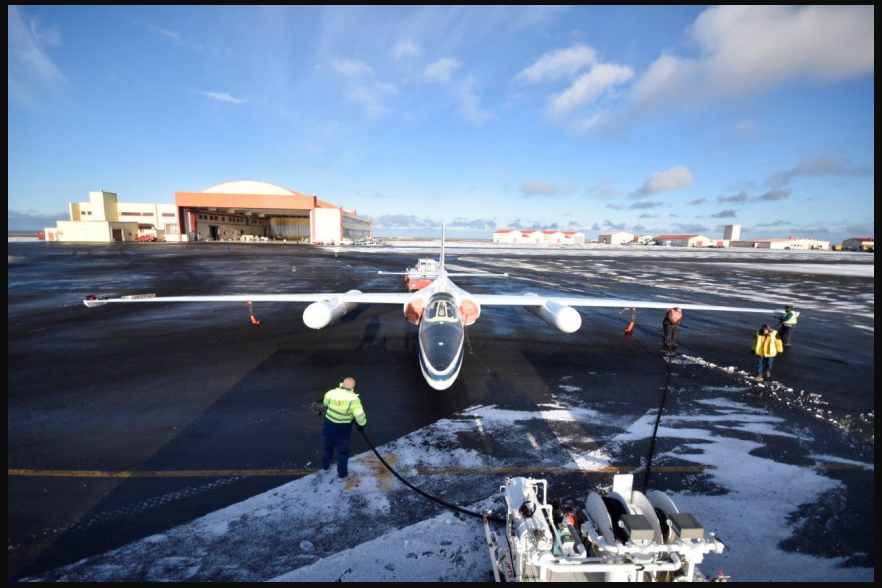


In a season of more storms than most can remember, tomorrow's forecast (Saturday) is being touted as probably the worst so far this winter. Some outlets are even planning on staying shut and all domestic flights have been canceled, starting this afternoon.

Per March 12 weather brief: "Steady winds of 50 kts, gusts to 70 kts, and a forecast calling for 90 kts within a couple of days…"

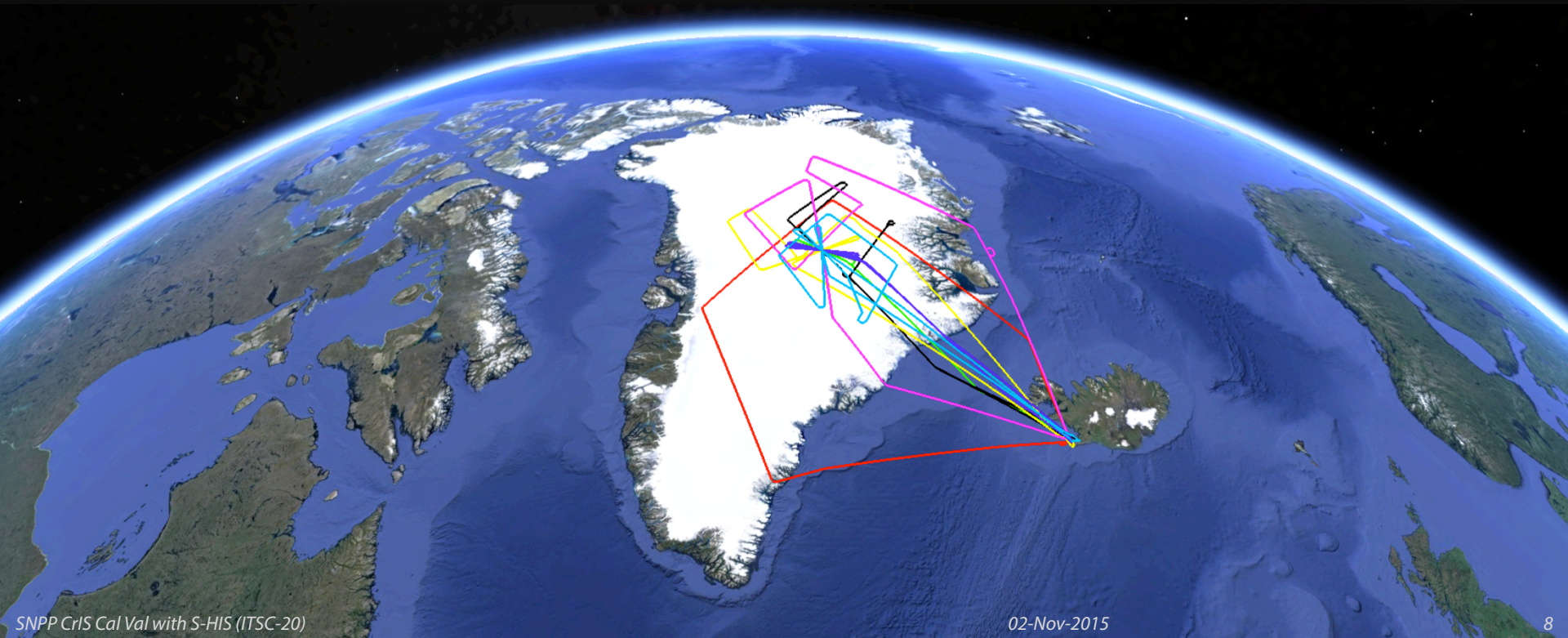
Content courtesy A. Larar (NASA LaRC)

"If you don't like the weather in Iceland, wait 15 minutes…"
Fly when the weather allows

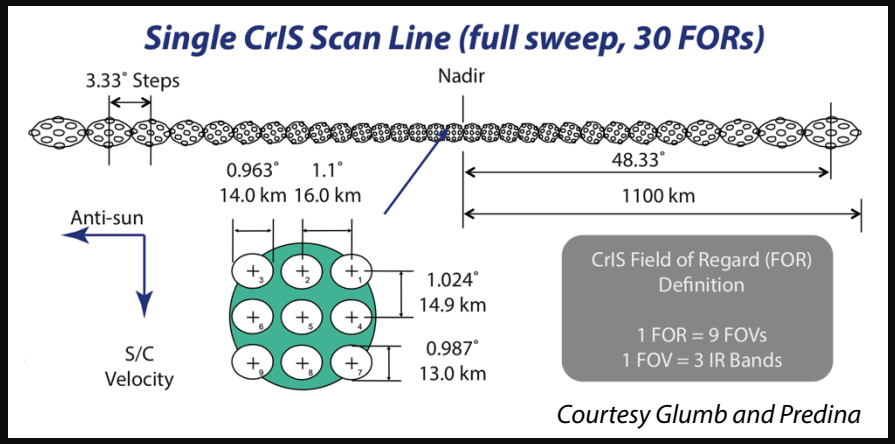


photos c/o Brian Hobbs and Stu Broce (NASA AFRC)

- Introduction
- *Cross-track Infrared Sounder (CrIS)*
- Scanning High-resolution interferometer Sounder (S-HIS)
- Comparison Results
- Conclusion



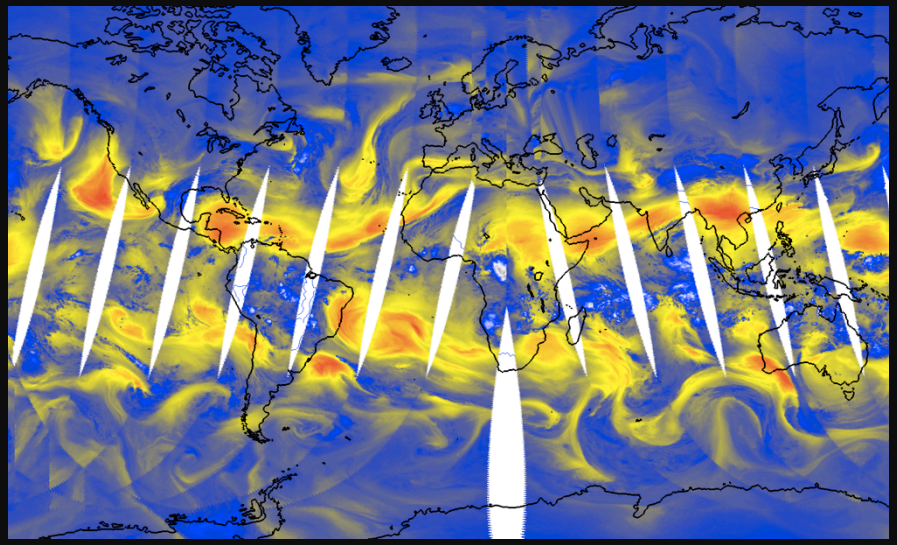
Cross-track Infrared Sounder (CrIS)



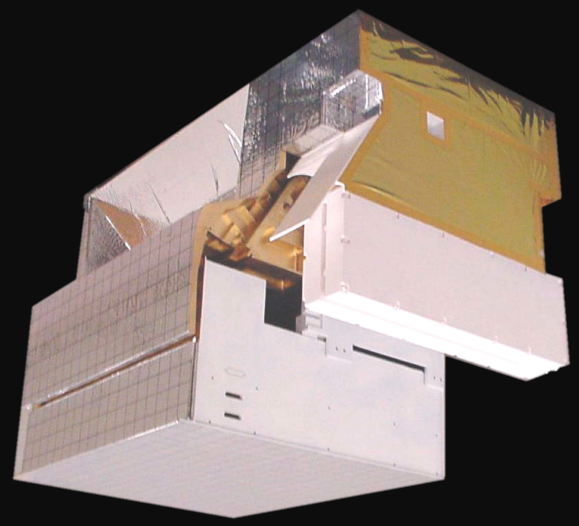
Courtesy Glumb and Predina

- IFOV: ~1° (0.017 rad, 14 km footprint at nadir)
- Scene Coverage: nadir ± ~50° (2200 km swath)
- Spectral Coverage and sampling:
  - LW: 650 – 1095 @ 0.625 cm^{-1}
  - MW:1210 – 1750 @ 1.25 cm^{-1} *
  - SW: 2155 – 2550 @ 2.5 cm^{-1} *
  - *0.625 cm^{-1} spectral sampling in all bands after 12/4/2014 (full spectral resolution)*
- DA Plane Mirror FTS

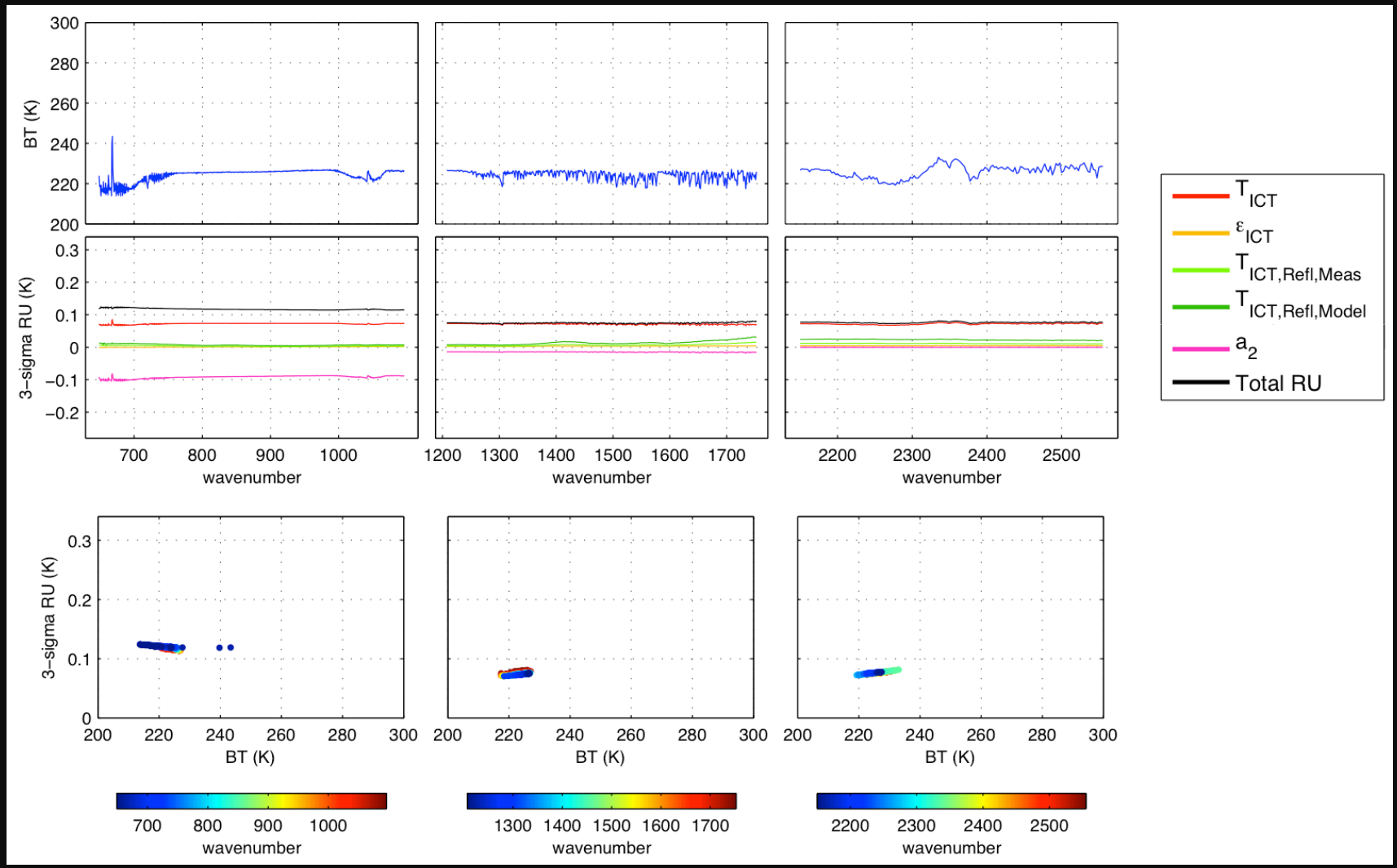
Global Water Vapor Map from CrIS (D. Tobin)



24 February 2012, 1580 cm^{-1} BT

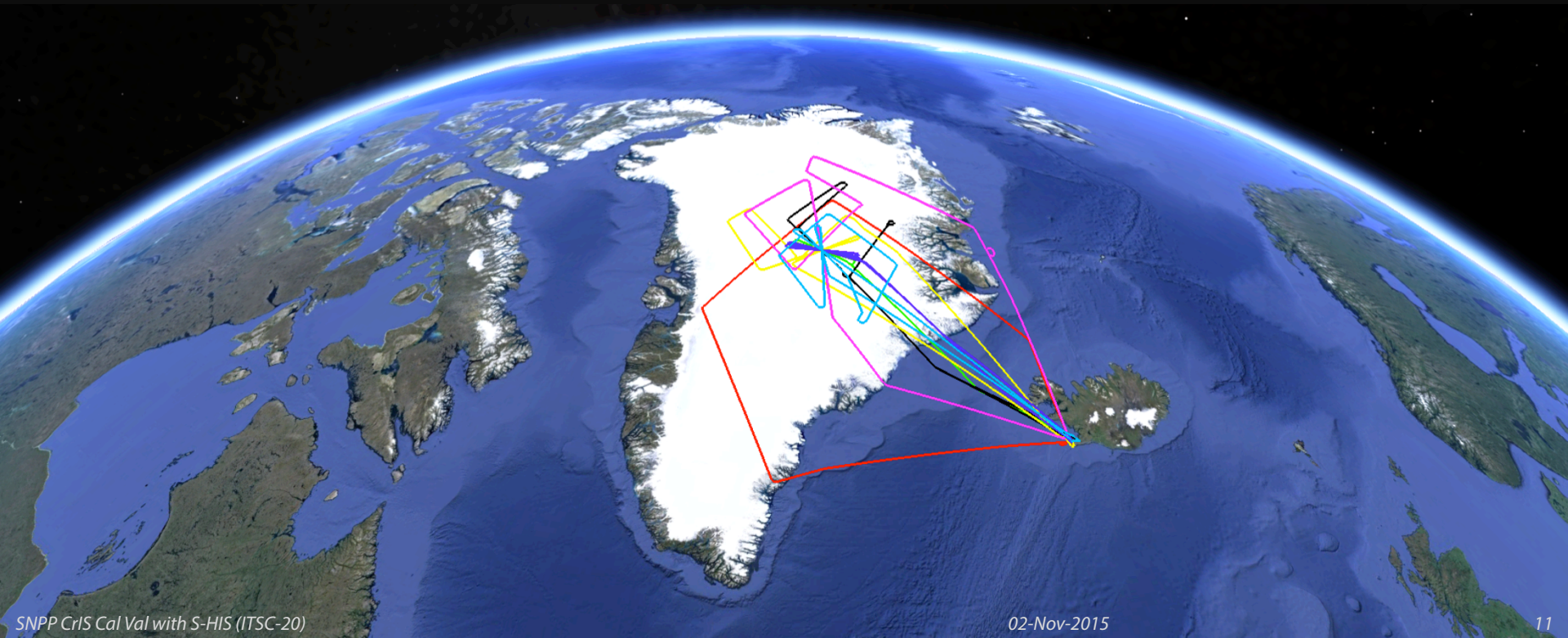


Example CrIS 3-sigma RU estimates for a cold, high cloud spectrum

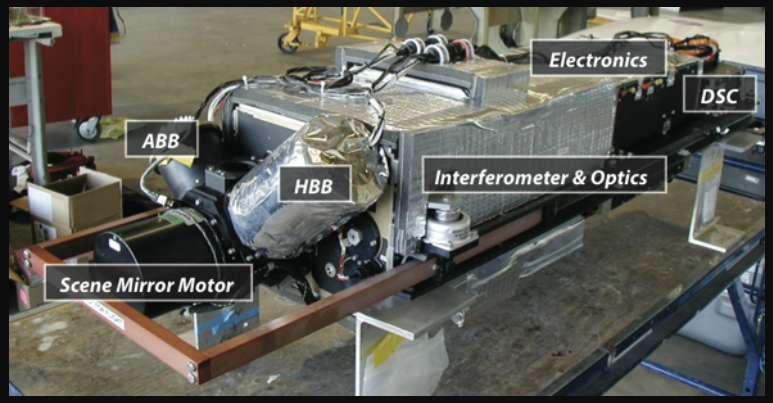


Tobin, David, et al. "Suomi-NPP CrIS radiometric calibration uncertainty." Journal of Geophysical Research: Atmospheres 118.18 (2013): 10-589.

- Introduction
- Cross-track Infrared Sounder (CrIS)
- *Scanning High-resolution interferometer Sounder (S-HIS)*
- Comparison Results
- Conclusion

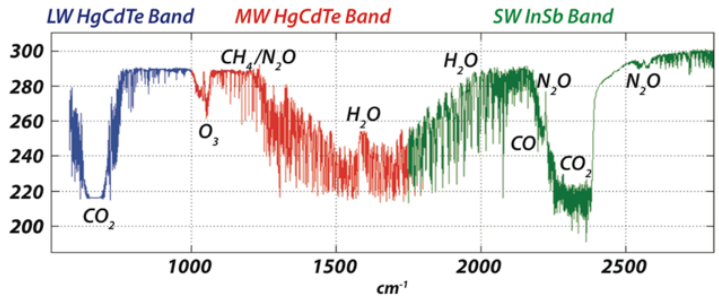


Scanning High-resolution Interferometer Sounder (S-HIS)



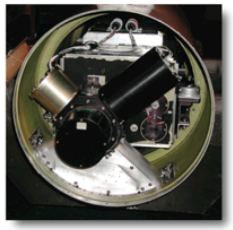
- IFOV: 5.7° (0.1 rad, 2 km from 20 km, at nadir)
- Scene Coverage: nadir ± 40° typical (33 km swath), programmable
- Spectral Coverage:
  - LW: 580 – 1200 cm^{-1}
  - MW: 1030 – 1810 cm^{-1}
  - SW: 1760 – 3000 cm^{-1}
- Spectral Sampling: 0.5 cm^{-1}
- DA plane mirror; residual tilt sampling and correction

S-HIS mounted on AV-6, Zone 25



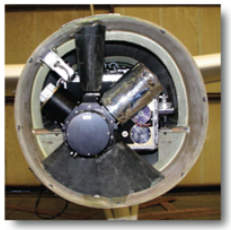
Sample upwelling S-HIS brightness temperature spectra.

WB-57 wingpod



ER-2 centerline pod

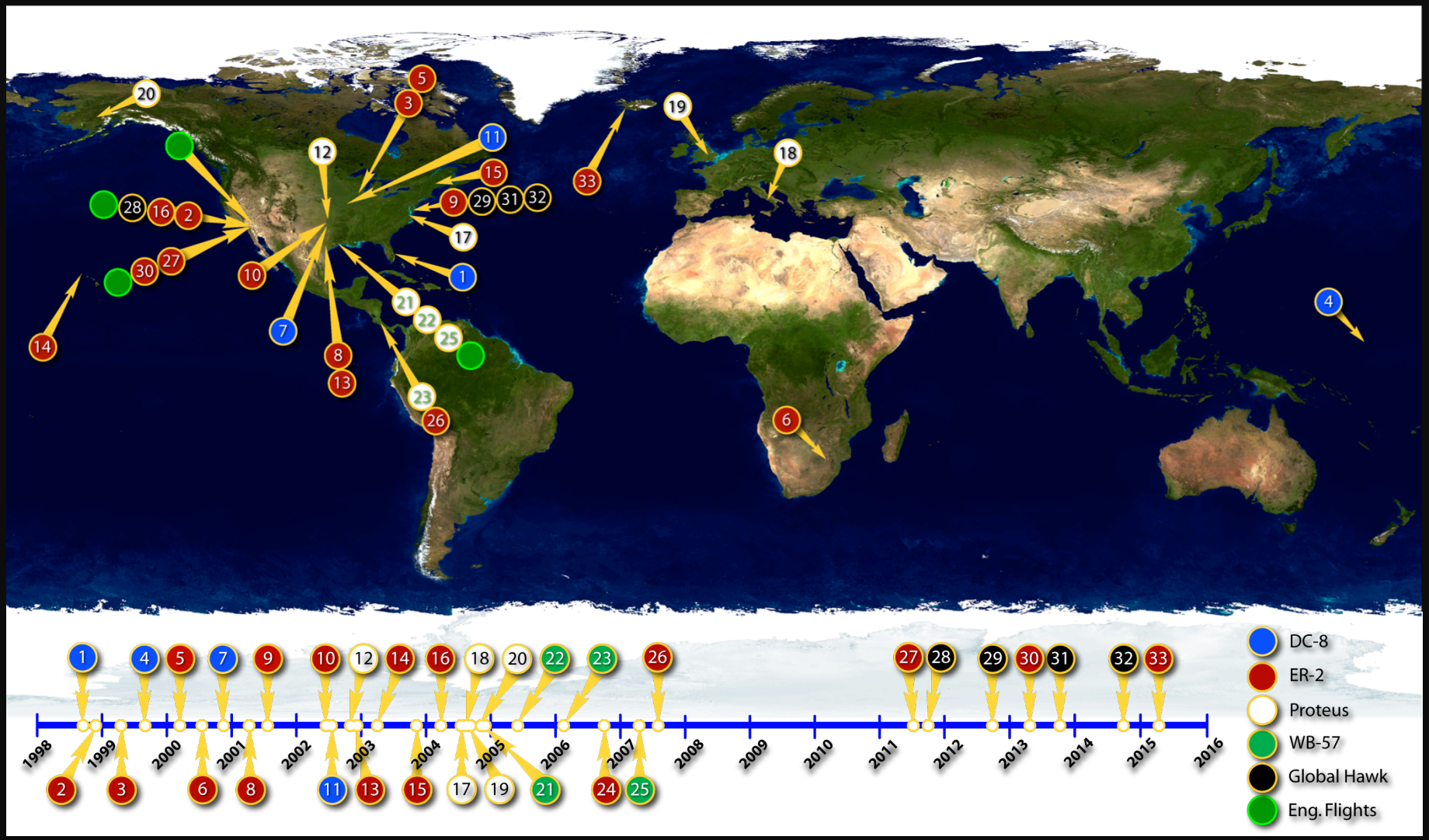
DC-8



Proteus wing boom

- Upwelling infrared radiances at high spectral resolution and high radiometric accuracy between 3.3 and 18 microns.
- Temperature, water vapor vertical profiles
- Trace gas retrievals
- Cloud Radiative Properties
- Surface Emissivity & Temperature
- Calibration Validation

S-HIS Instrument Overview

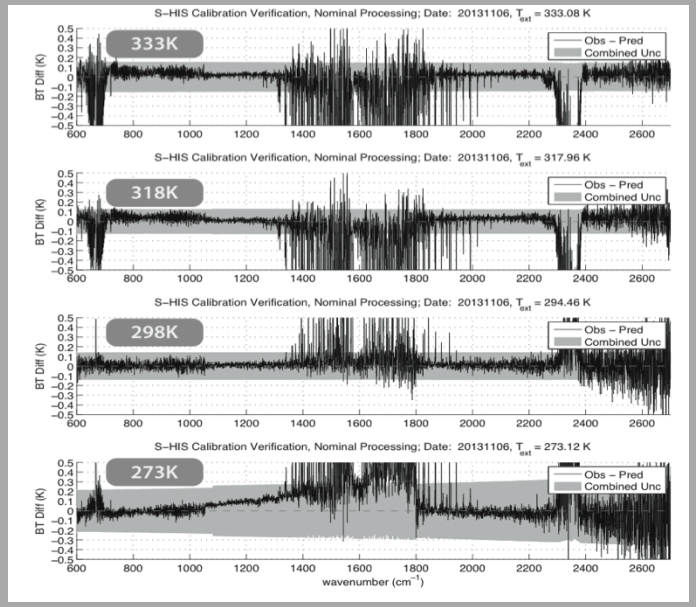


33 missions on 5 platforms, typically > 99% instrument uptime

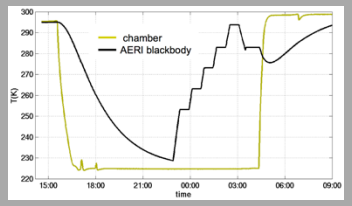
S-HIS Calibration, Calibration Verification, and Traceability

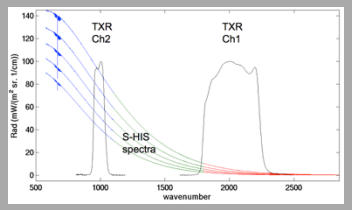
- Instrument calibration during flight using two on-board calibration blackbodies
- Pre-integration calibration of on-board blackbody references at subsystem level
- Pre and post deployment end-to-end calibration verification
- Periodic end-to-end radiance evaluations under flight like conditions with NIST transfer sensors

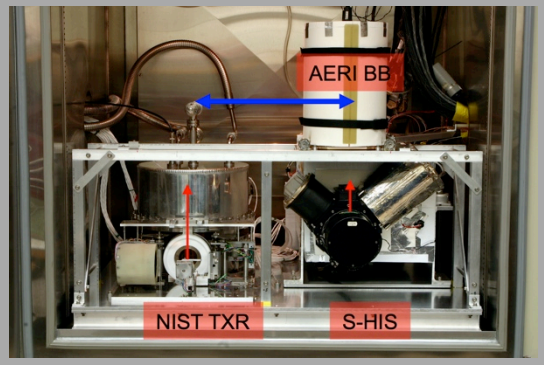
Post Mission End-to-End Calibration Verification

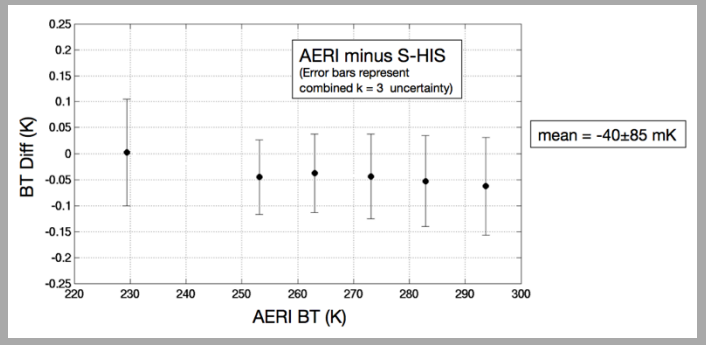


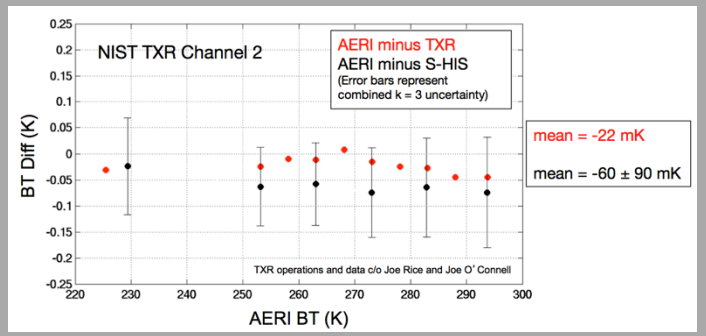
NIST TXR Validation of S-HIS Radiances



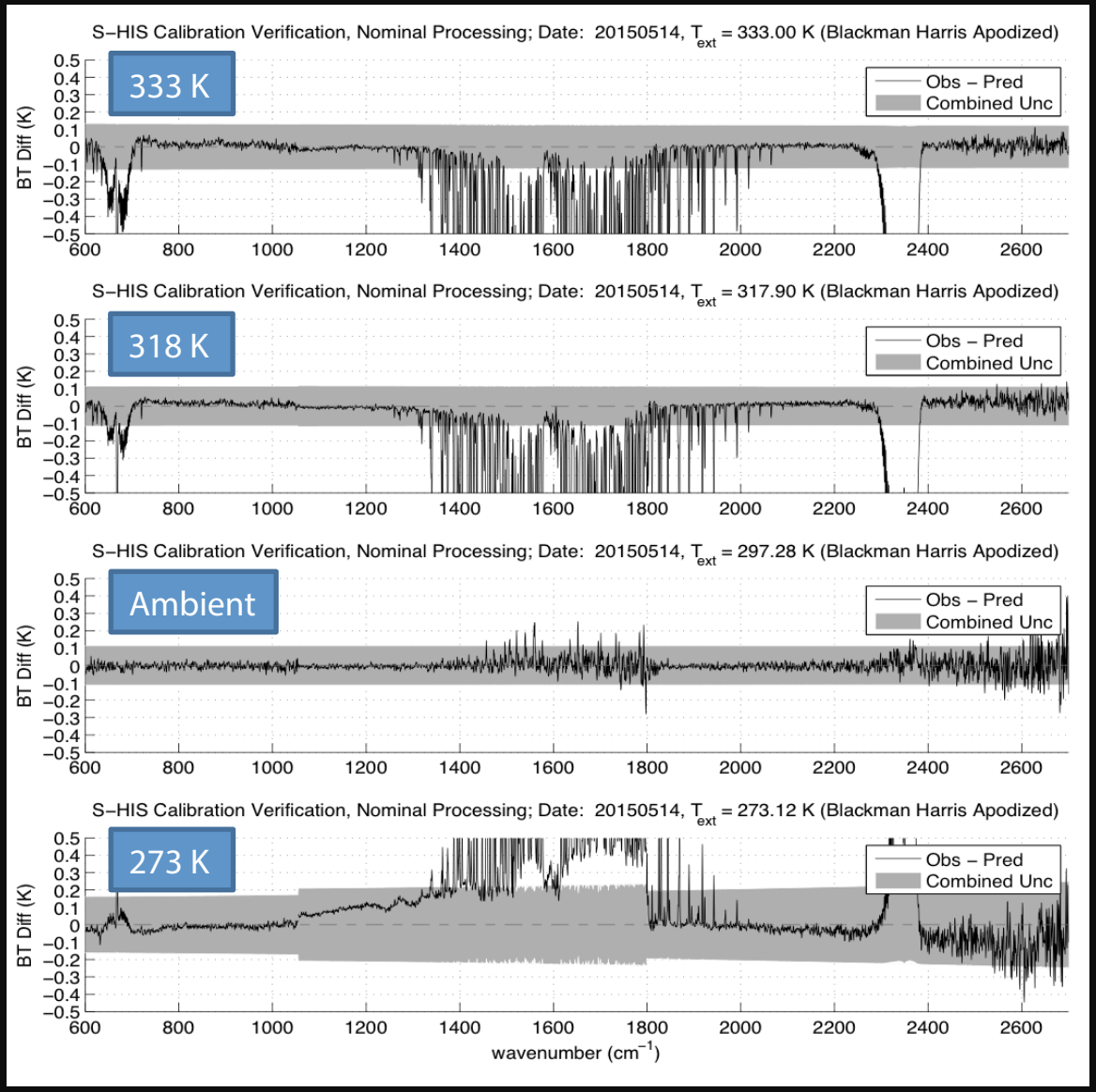








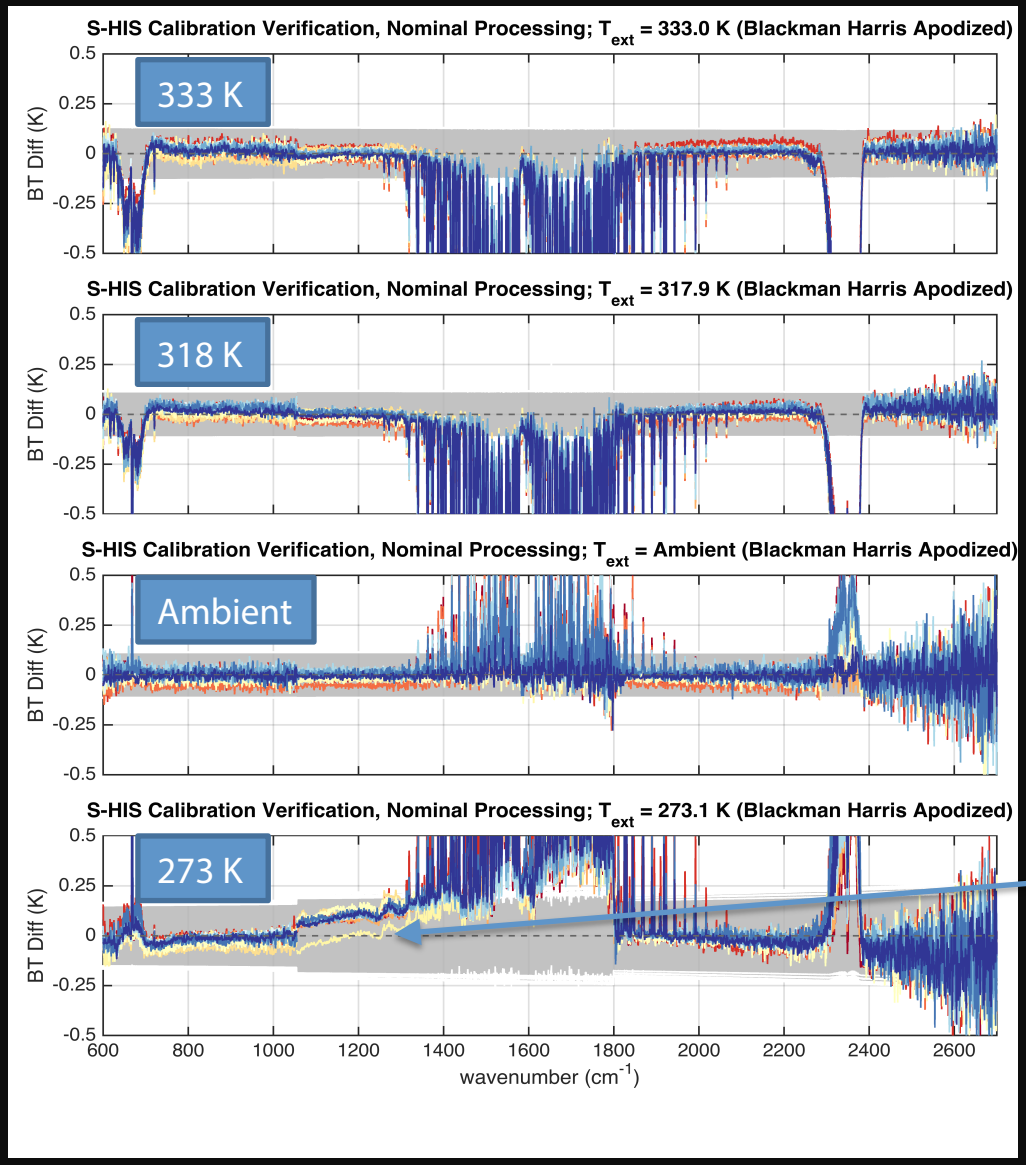
Pre and post deployment end-to-end calibration verification

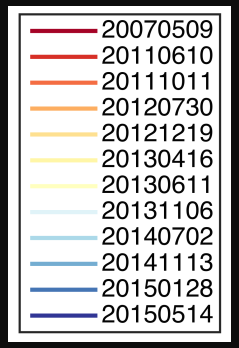


Post SNPP 2015 Example

- Data acquired for external blackbody temperatures of 333K, 318K, ambient, and Ice Bath Blackbody
- Atmospheric emission/absorption not included in predicted BT (i.e. no LBLRTM)
- S-HIS NLC is optimized for 'flight' detector and instrument temperatures
- Significant spectral overlap of S-HIS detector bands is useful for evaluating calibration (esp. NLC)
- Lab:
  - $T_{HBB} = 333$ K
  - $T_{ABB} \approx 295$ K
- Flight:
  - $T_{HBB} \approx 300$K
  - $T_{ABB} = 230 – 250$K

Pre and post deployment end-to-end calibration verification

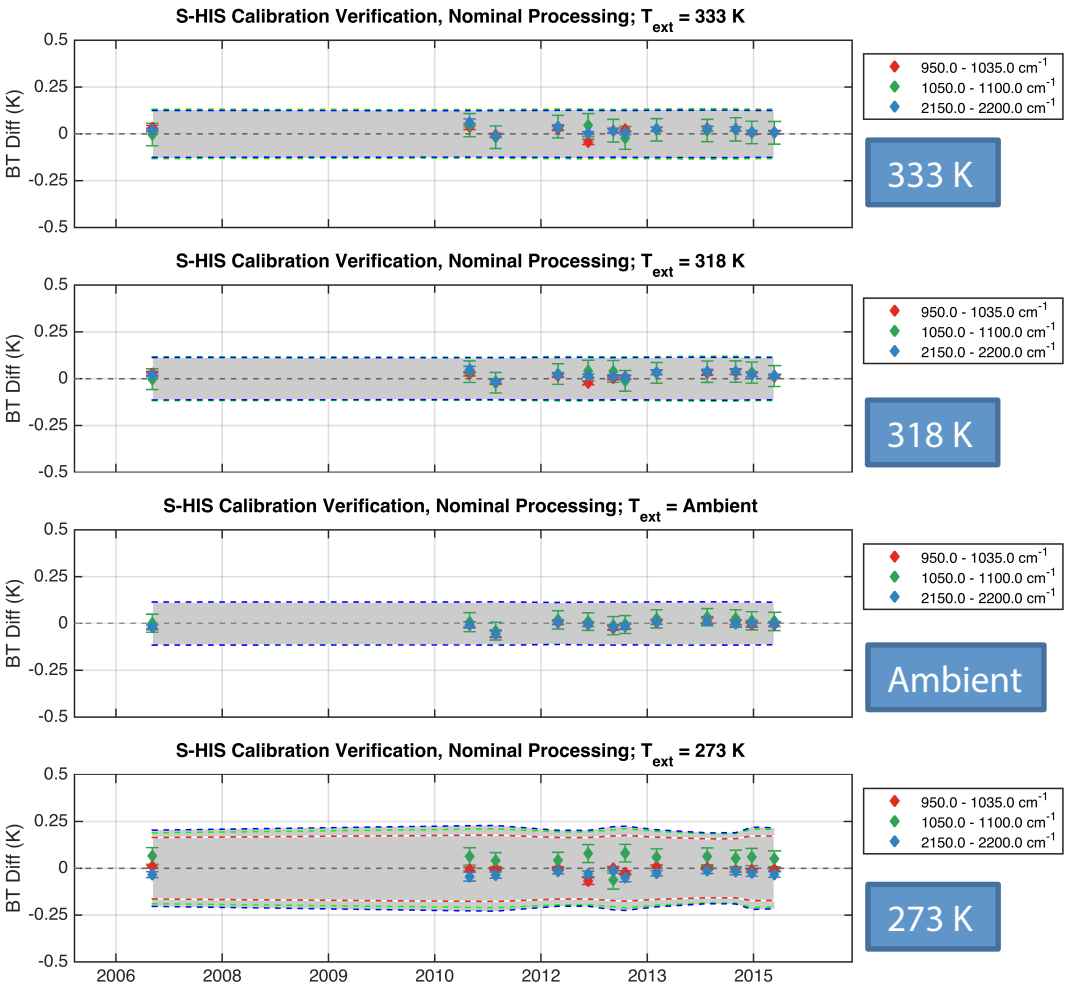




2013-04-16:

- Stirling cooler failing during testing.
- Detector temperature increased to ~85K during calibration verification.
- Primary impact is on MW nonlinearity (note the outlier spectra for Ice Bath blackbody)

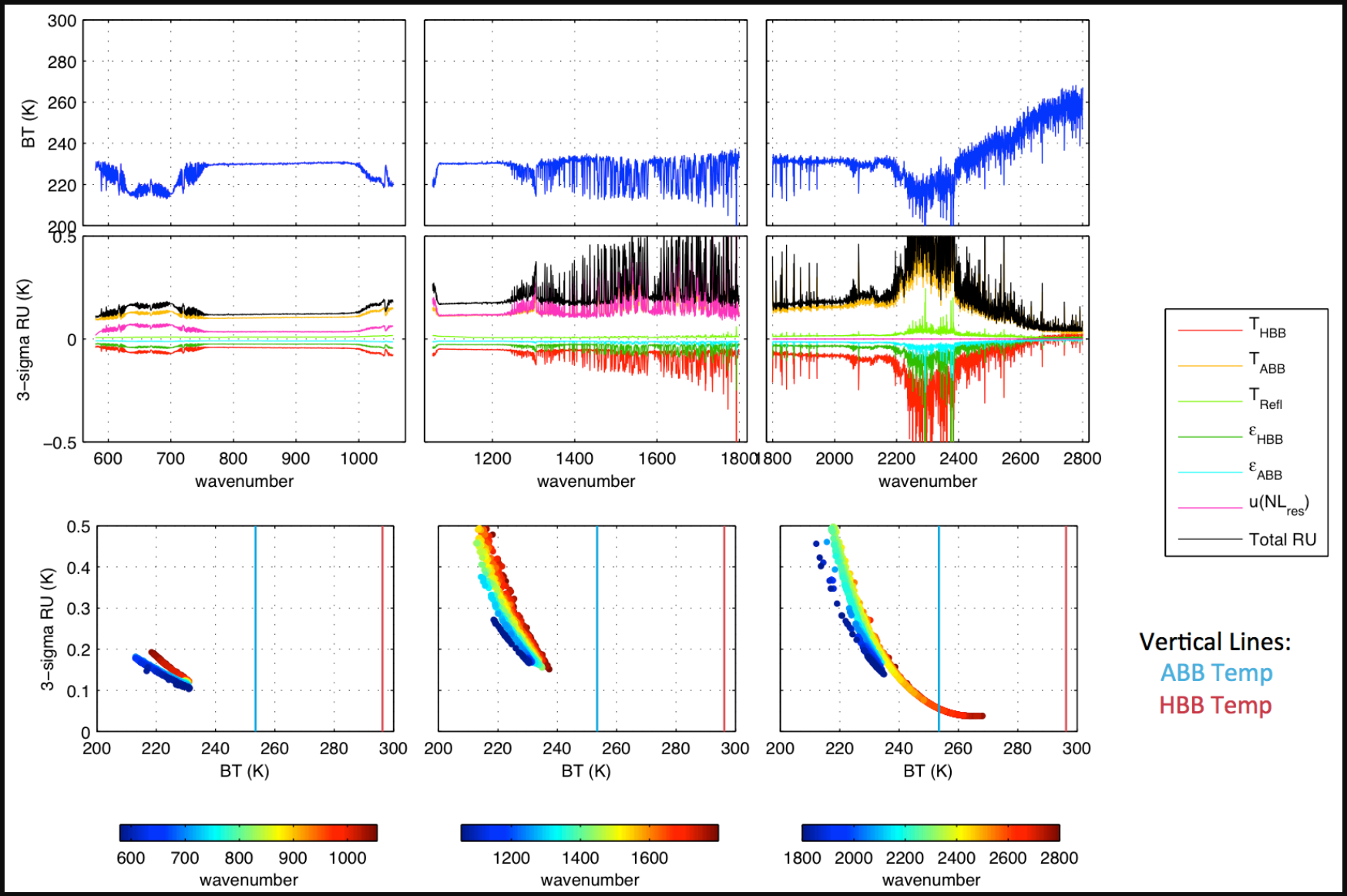
Pre and post deployment end-to-end calibration verification



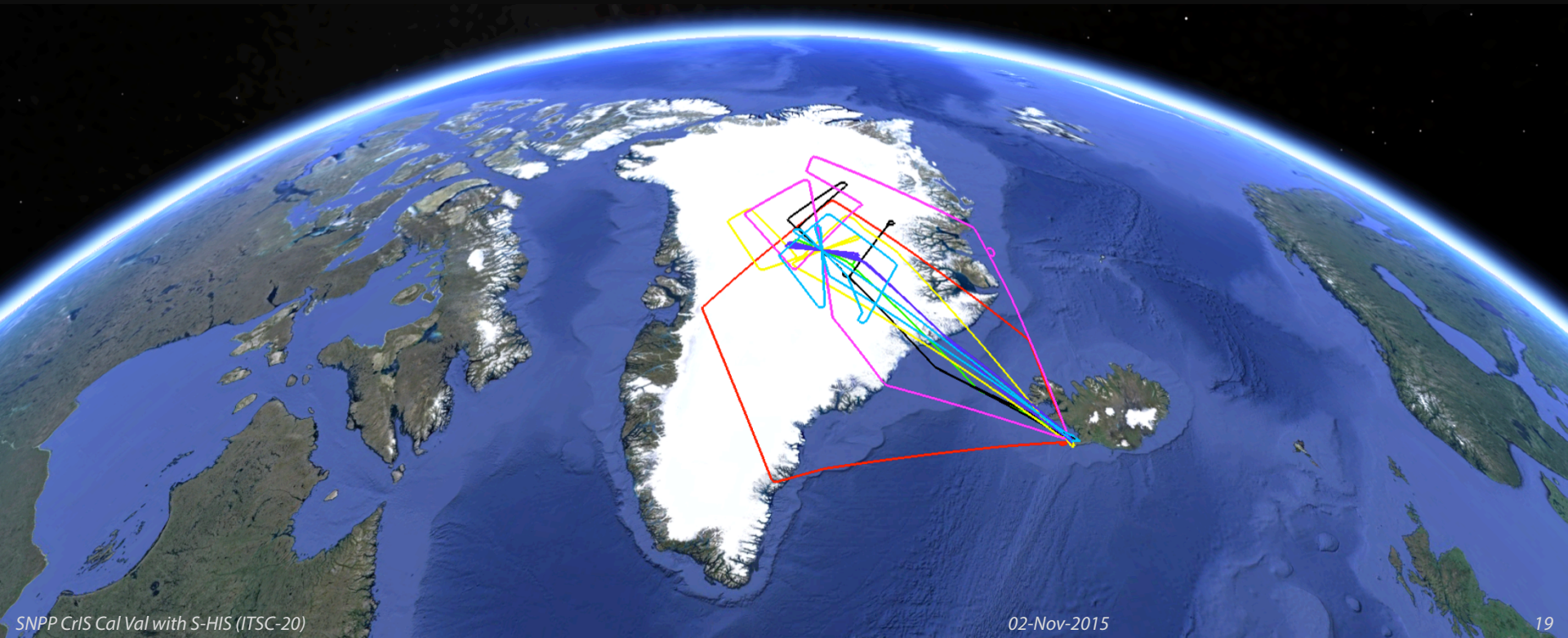
- Shaded area represents maximum RU for 3 band averages
- Dashed lines indicate RU for respective average
- Error bars represent statistical variation in average (RMS/sqrt(N_{bin}))

S-HIS Radiometric Uncertainty

(for flight conditions encountered during the SNPP overpass on 2015-03-29)

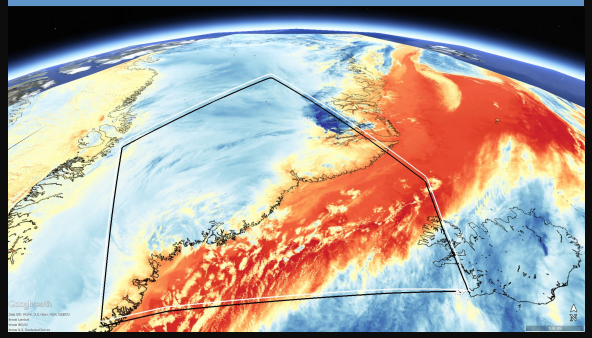


- Introduction
- Cross-track Infrared Sounder (CrIS)
- Scanning High-resolution interferometer Sounder (S-HIS)
- *Comparison Results*
- Conclusion

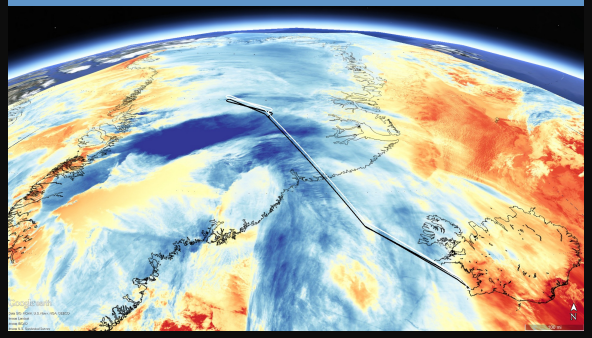


Flight Summary (VIIRS SVI05 images)

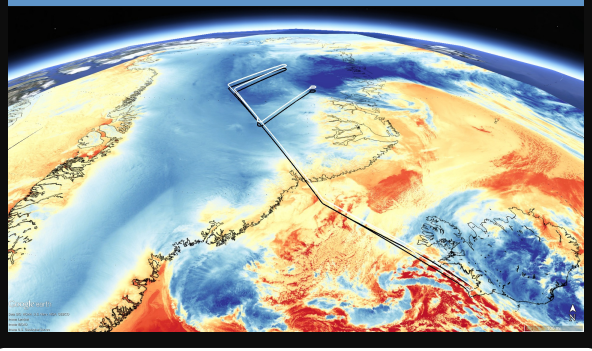
2015-03-15, SNPP Overpass #1



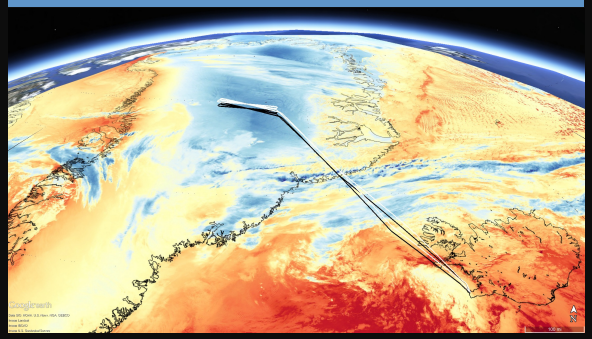
2015-03-24, SNPP Overpass



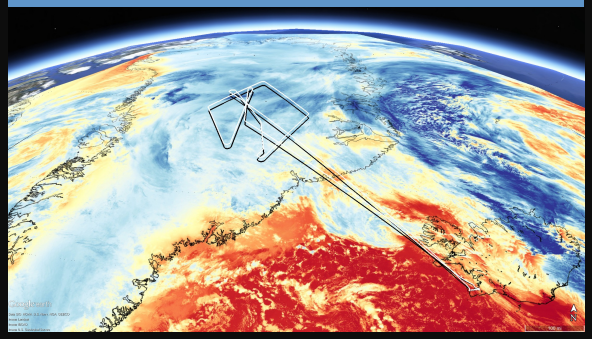
2015-03-29, SNPP Overpass

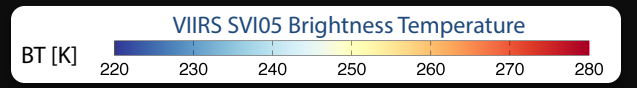


2015-03-19, Multiple legs over Summit

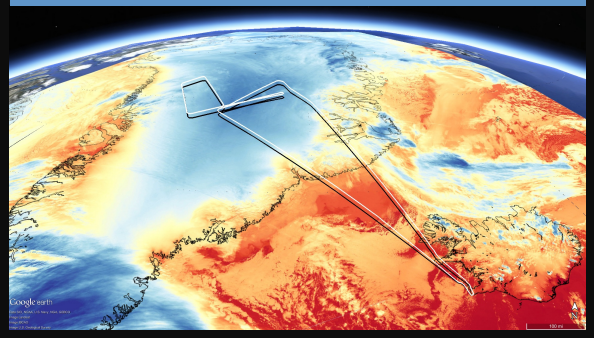


2015-03-25, SNPP Overpass

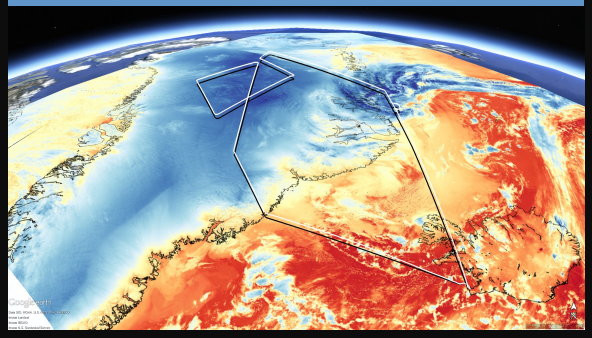




2015-03-23, SNPP Overpass

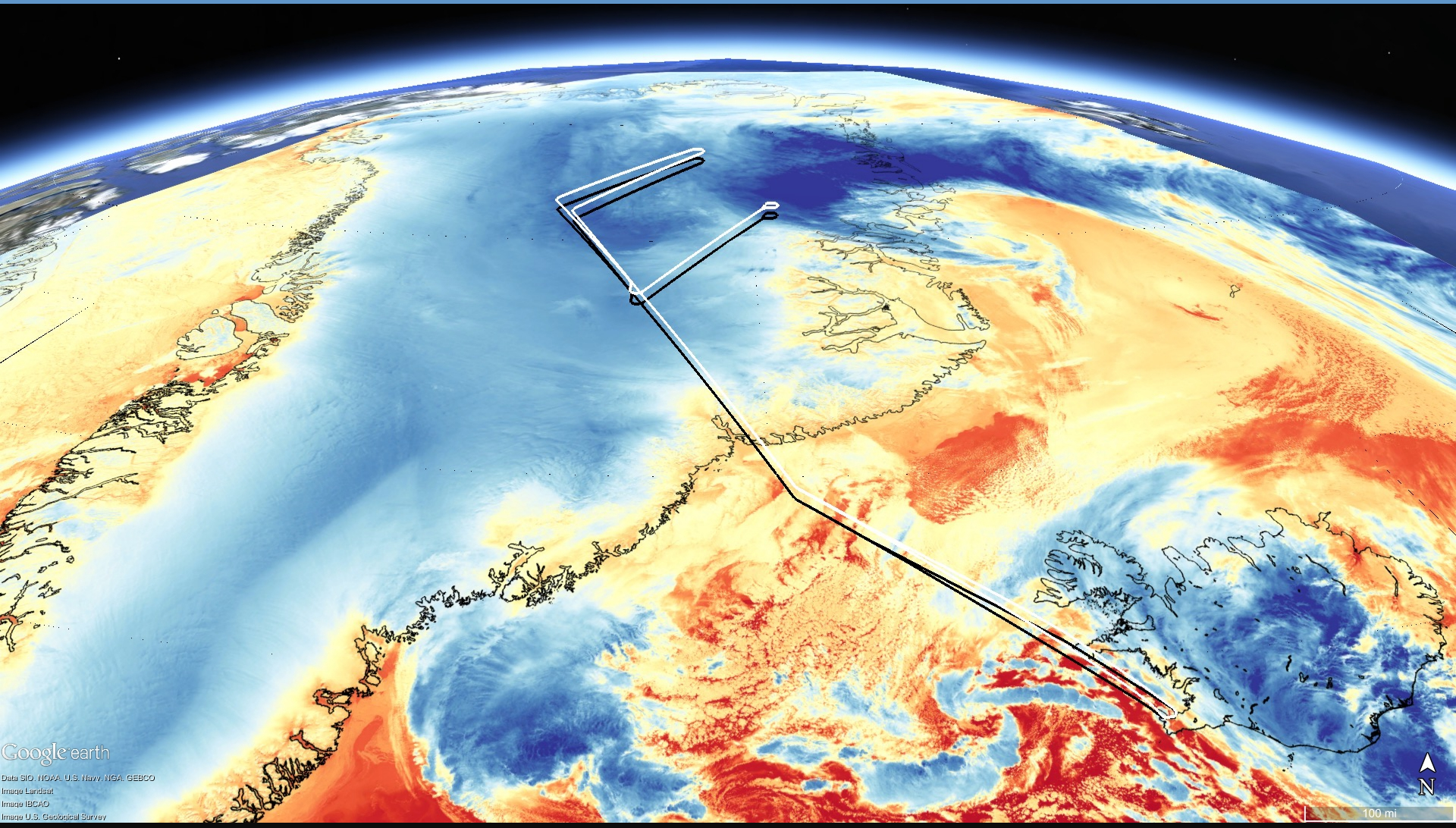


2015-03-28, SNPP Overpass #1



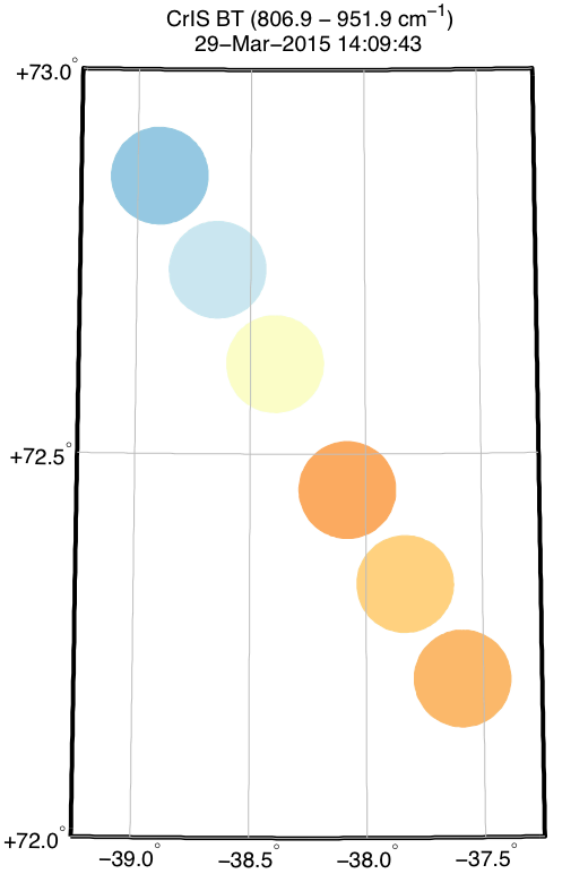
2015-02-23	Engineering test flight; SNPP
2015-03-07	Transit flight
2015-03-15	SNPP, METOP-B, SNPP
2015-03-19	Multiple passes over Greenland Summit Station
2015-03-23	METOP-A, SNPP, Aqua
2015-03-24	SNPP • poor scene conditions for SNPP radiance comparison
2015-03-25	METOP-A, SNPP, METOP-B, Aqua • poor scene conditions for SNPP radiance comparison
2015-03-28	SNPP, SNPP
2015-03-29	Aqua, METOP-A, METOP-B, SNPP
2015-03-31	Transit flight

2015-03-29, SNPP Overpass

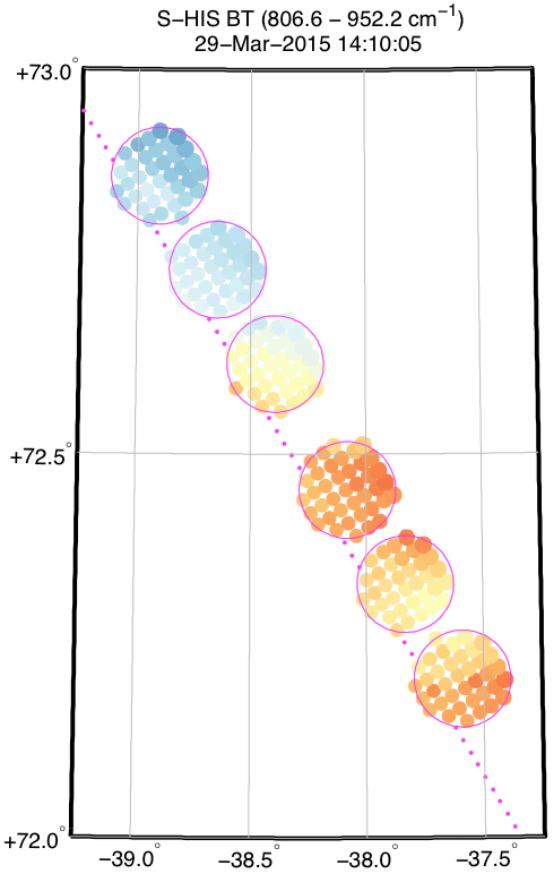


Preliminary analysis and results: refined footprint selection completed for CrIS cases (example for 2015-03-29)

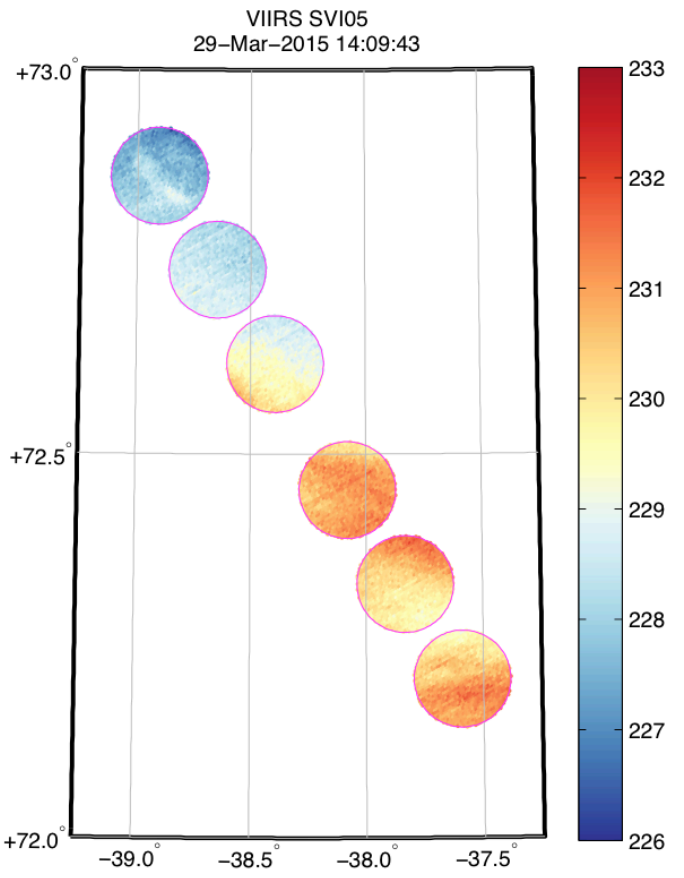
- For non-uniform cloudy scenes footprint selection becomes increasingly important:
  - (1) Temporal variability
  - (2) inadequate coverage of the satellite footprint for high clouds
- Useful to use satellite IR imager for refined footprint selection



CrIS Mean BT (806.9 – 951.9 cm^{-1})

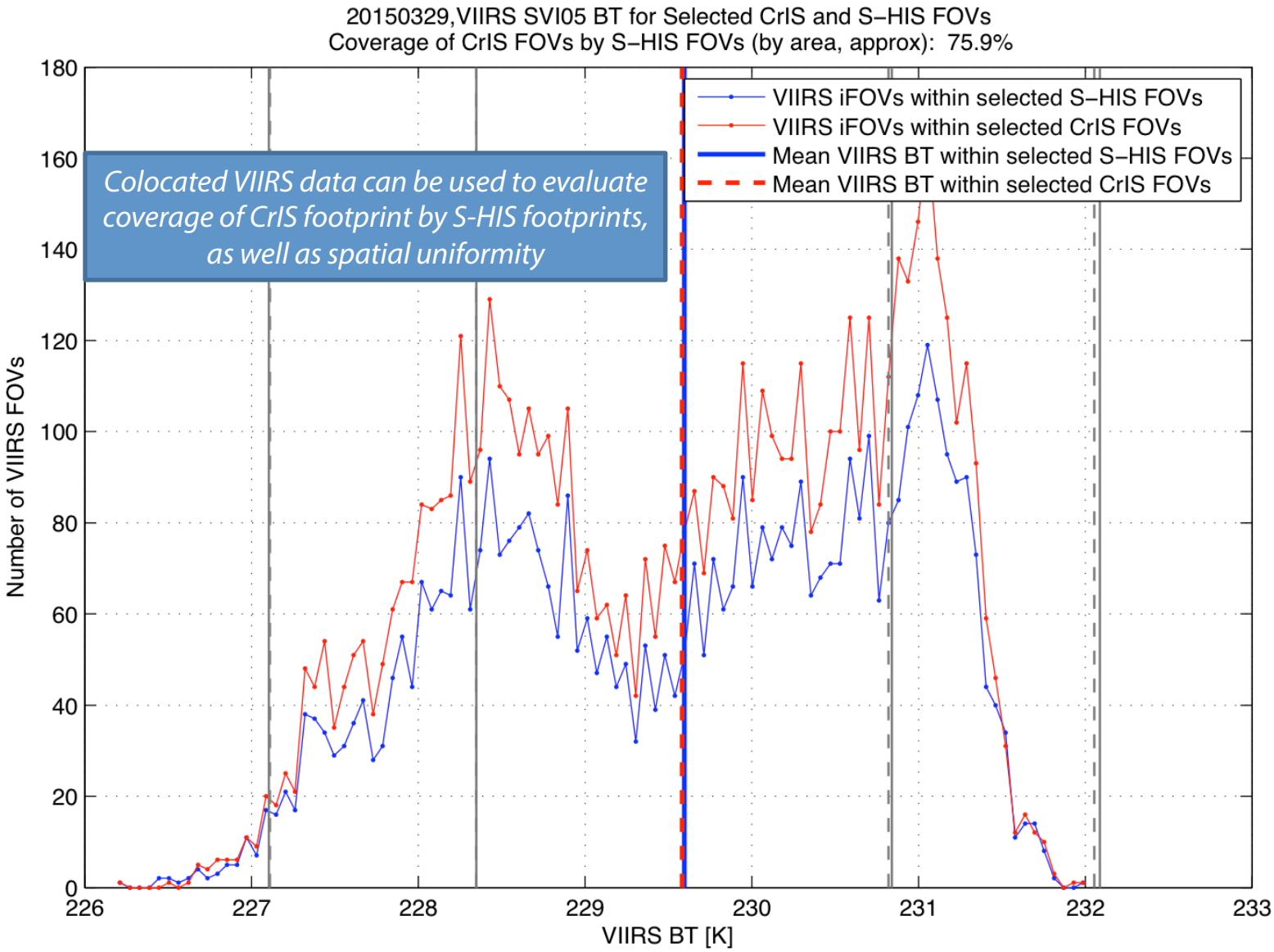


S-HIS Mean BT (806.6 – 952.2 cm^{-1}) within selected CrIS FOVs



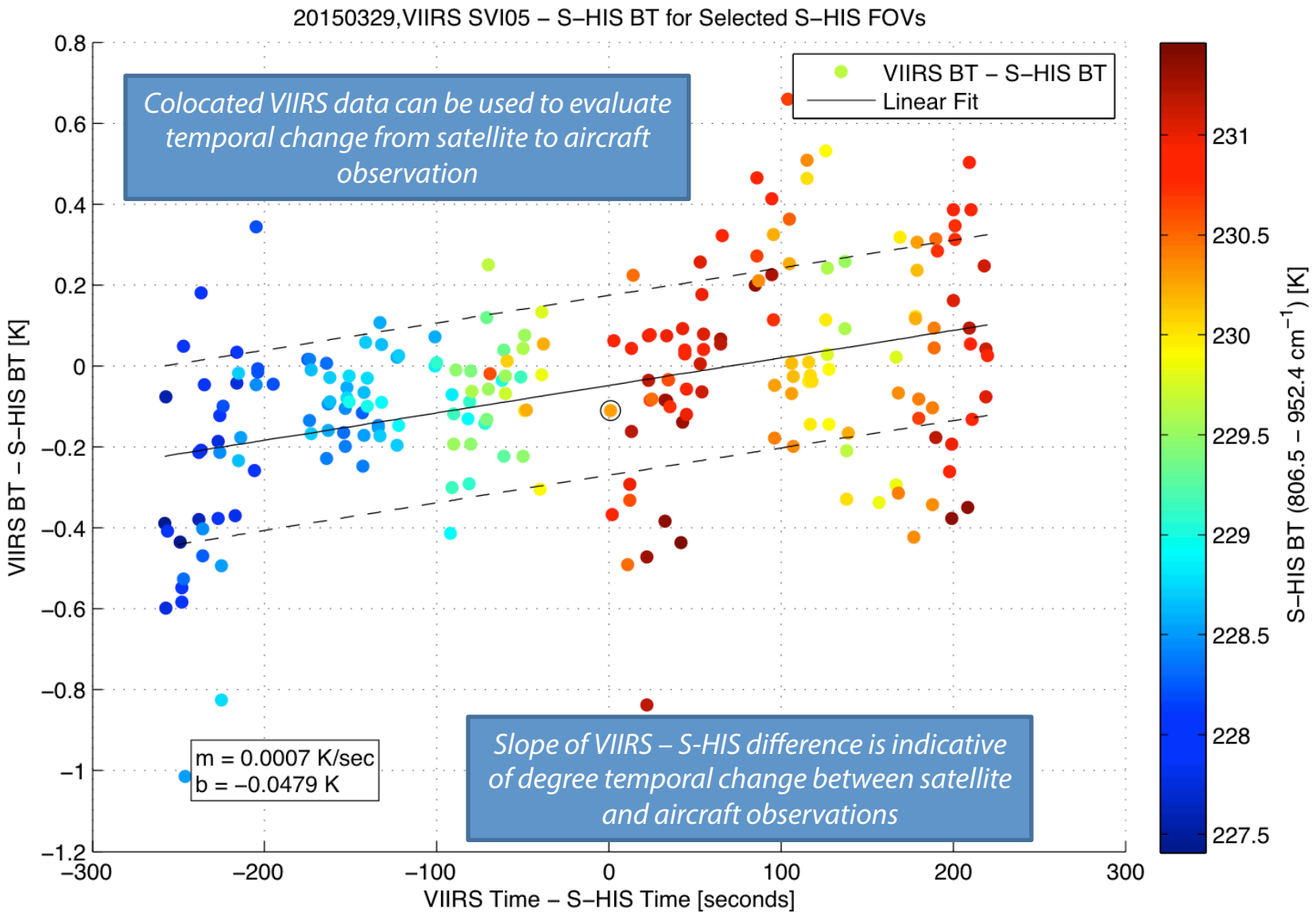
VIIRS SVI05 BT within selected CrIS FOVs

Preliminary analysis and results: refined footprint selection completed for CrIS cases (example for 2015-03-29)

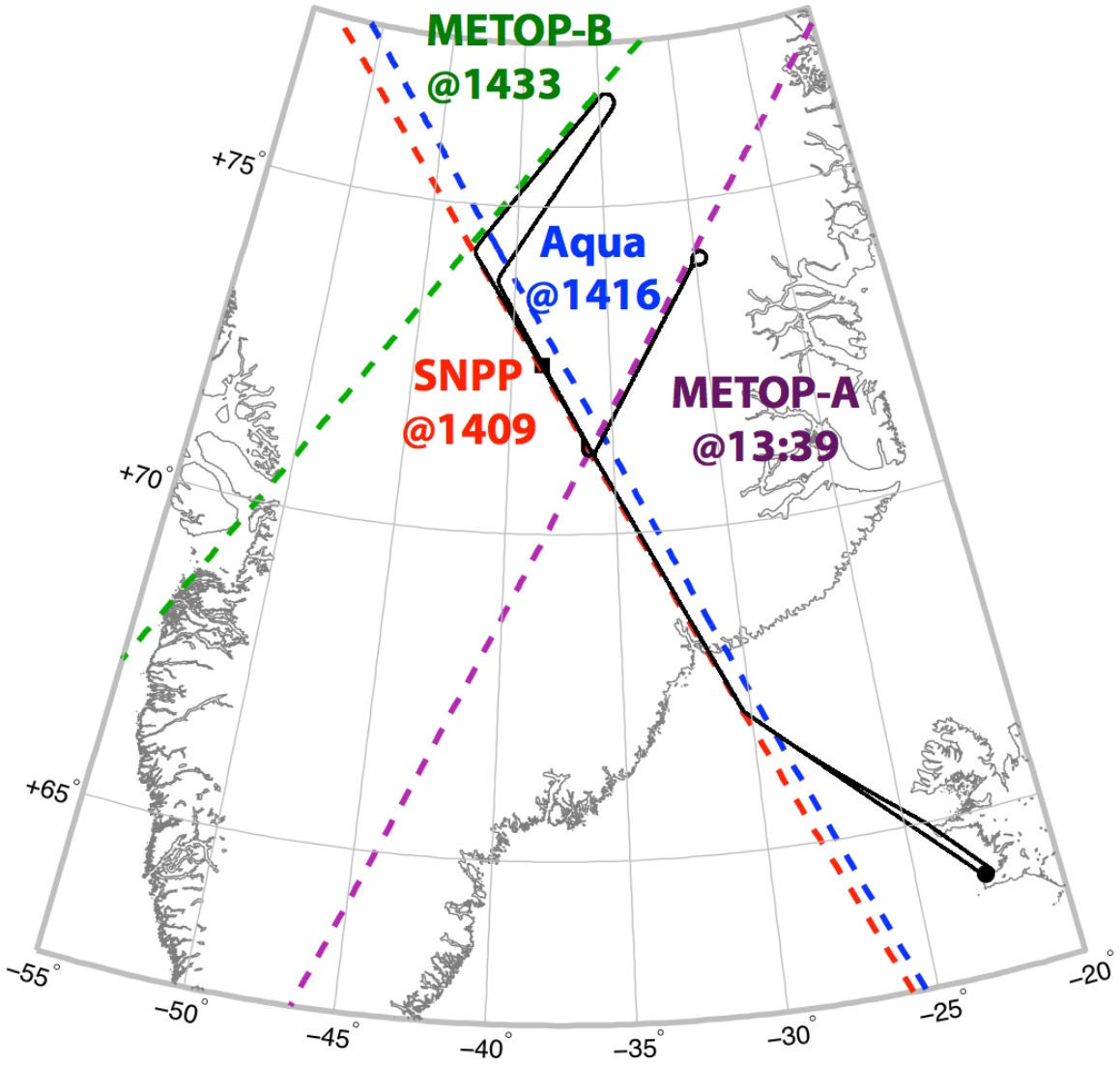


Colocated VIIRS data can be used to evaluate coverage of CrIS footprint by S-HIS footprints, as well as spatial uniformity

Preliminary analysis and results: refined footprint selection completed for CrIS cases (example for 2015-03-29)

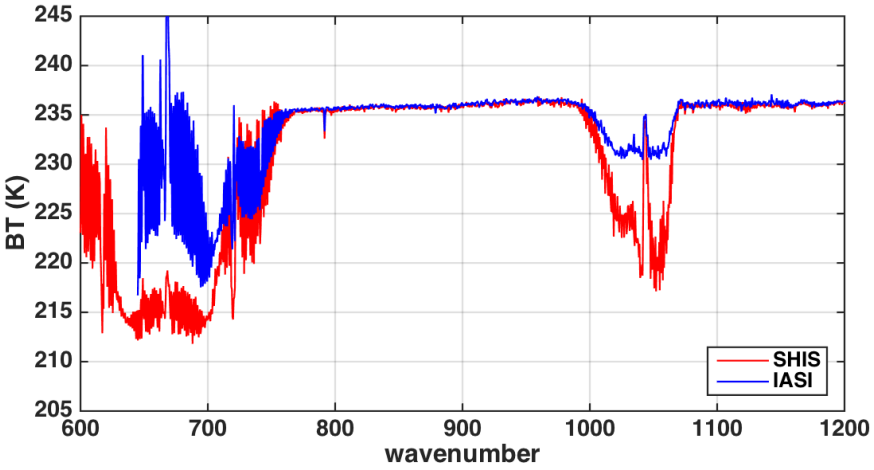


Preliminary Analysis and Results:
29 March Flight: Nadir underflights of METOP-A, S-NPP, Aqua, and METOP-B

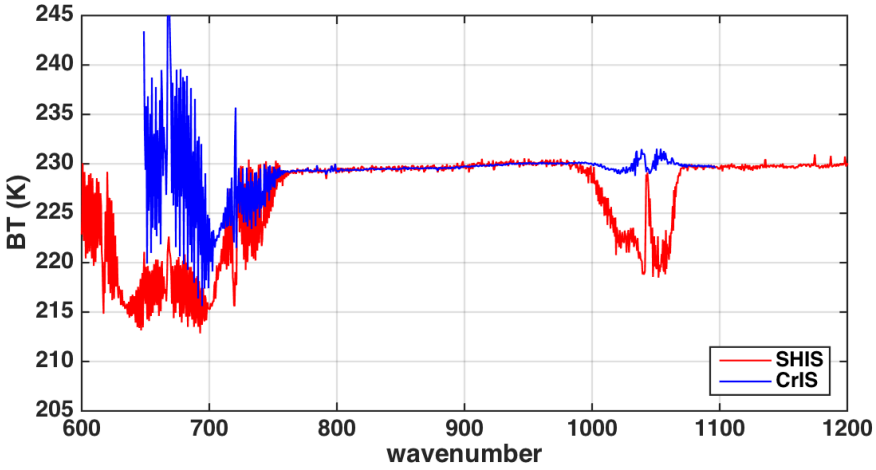


Preliminary Analysis and Results: 29 March Flight: Nadir underflights of METOP-A, S-NPP, Aqua, and METOP-B

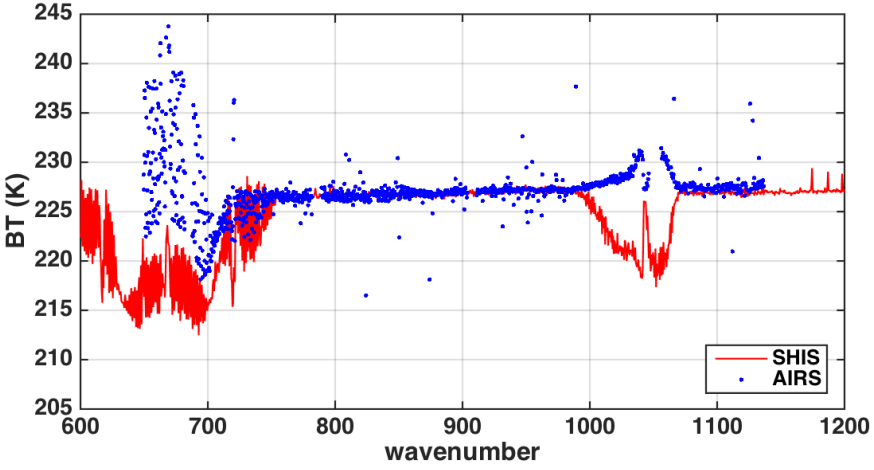
METOP-A underflight at 13:39 UTC



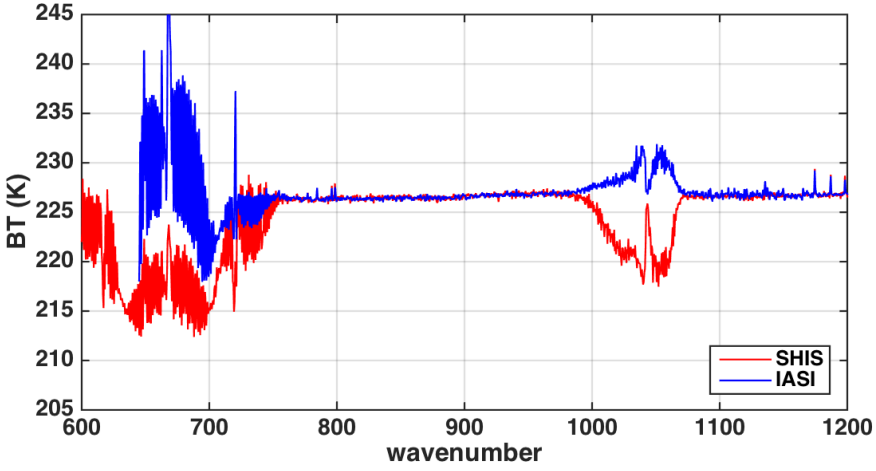
S-NPP underflight at 14:09 UTC



Aqua underflight at 14:16 UTC

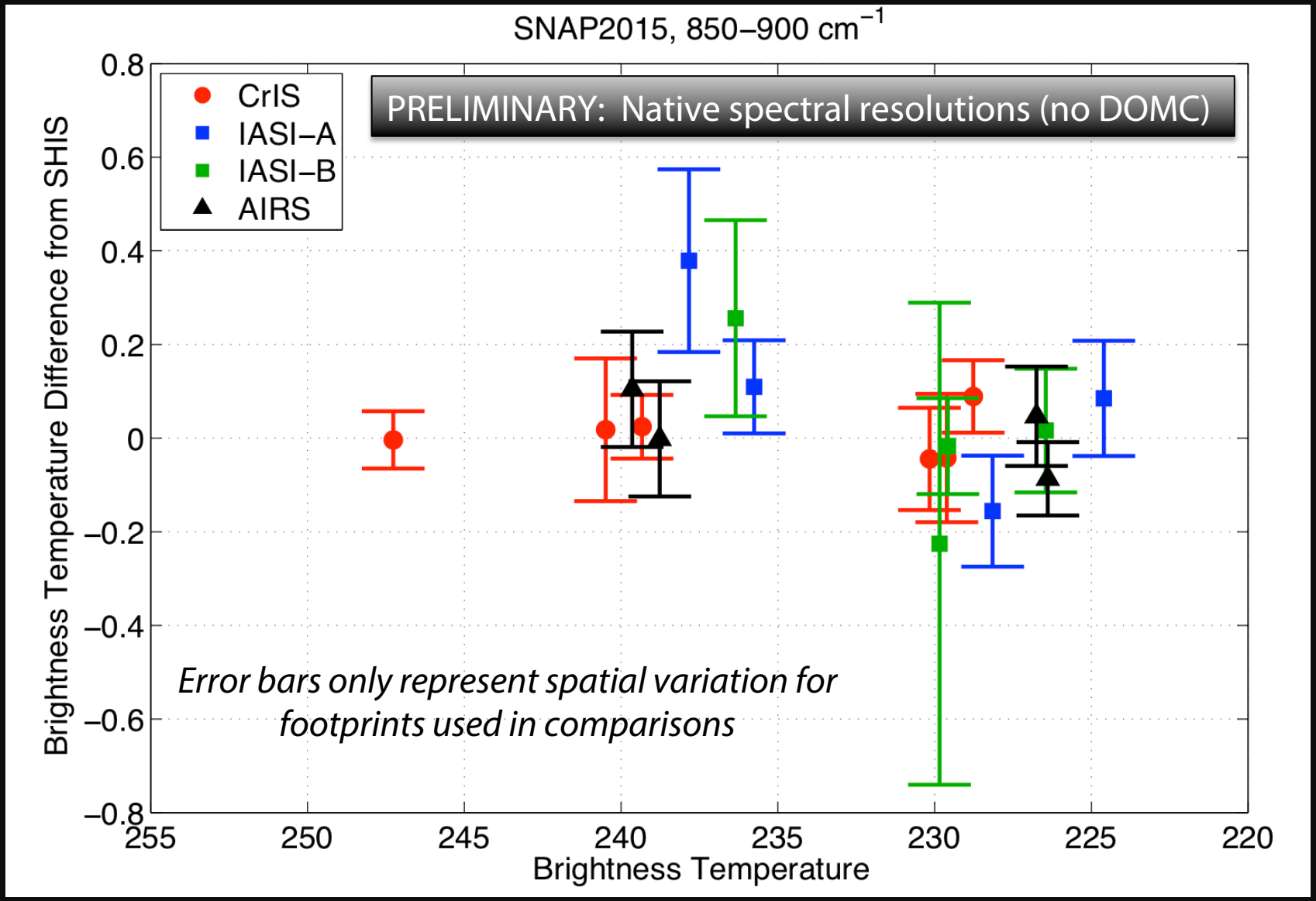


METOP-B underflight at 14:33 UTC



Similar comparisons performed for all flights/underpasses

Preliminary Analysis and Results: SNPP Calibration Validation Campaign 2015



Summary

- The S-HIS has proven to be a reliable and accurately calibrated reference instrument with a well defined radiometric uncertainty and traceability path.
- We have a well defined process/system for producing preliminary (~6 hours) and final (~3 month) radiance and retrieval products.
- Preliminary results are very encouraging, showing campaign cold scene radiance differences to be less than those SNO-derived

- Analyses completed:
  - Preliminary radiance comparisons (no DOMC) for all overpasses (CrIS, IASI-A, IASI-B, AIRS)
  - Refined footprint selection for S-HIS / CrIS cases
  - Assessment of scene quality for S-HIS / CrIS cases
  - S-HIS RU assessment for all overpasses
- Current tasks
  - Complete DOMC comparison for CrIS cases
  - Refine footprint selection for IASI-A, IASI-B, and AIRS to S-HIS inter-comparisons
  - Complete DOMC comparison for IASI-A, IASI-B, and AIRS cases

Acknowledgements

- Sponsors[1]: NOAA & NASA
- Instrument teams: S-HIS (UW-SSEC)[2], NAST-I (NASA-LaRC), NAST-M (MIT-LL), MASTER (NASA Ames)
- Aircraft team: ER-2 (NASA AFRC)
- Mission planning[3]: NASA LaRC, UW-SSEC
- Correlative measurement teams: Summit ground site[4], UK Met Office and BAe146 team
- Host base of operations: Keflavik International Airport (South Air, Icelandic Coast Guard, Isavia, and Icelandic Met Office)
- Weather product support: UW SSEC & CIMSS, NOAA /NESDIS STAR ASPB[5], et al.

[1] Campaign/Program Sponsors: Drs. Mitch Goldberg (NOAA NESDIS/JPSS) and Jack Kaye (NASA SMD)

[2] UW-SSEC S-HIS Team: Hank Revercomb, Dave Tobin, Joe Taylor, Fred Best, Bob Knuteson, Bill Smith, Elizabeth Weisz, Dan DeSlover, Ray Garcia, Dave Hoese, Steve Dutcher, Claire Pettersen, Jon Gero, Denny Hackel, Coda Phillips, Nick Ciganovich, Dan LaPorte, Mark Werner, …

[3] Mission planning: Bill Smith, Allen Larar, Dave Tobin, Chris Moeller

[4] Summit / campaign liaison: Claire Pettersen (UW-SSEC)

[5] Weather product support: Brad Pierce, NOAA/NESDIS STAR ASPB