Visualizing Cold Air Aloft with Radio Occultation and Hyperspectral Infrared Sounders: Investigating Aviation Safety Purposes

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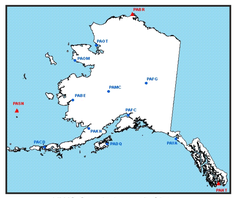
BACKGROUND

Problem: The Need for Real-Time 3D Observations

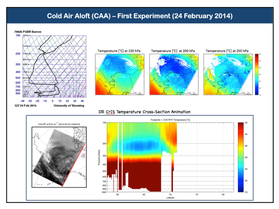
- Cold upper air temperatures, ~ -65ºC, at jet cruising altitudes are an aviation safety concern as jet fuel can gelify
- Meteorologists of the National Weather Service (NWS) CWSU in Anchorage, AK provide weather information to air traffic controllers who overlook parts of AK and the Arctic Ocean to the North, where cold air is commonly present
- NWS forecasters have made known the need for more information on cold air aloft, specifically in the form of real-time 3D observations
  - This is because forecasts are not time always timely enough, and observations are only available from the sparse radiosonde network (launches 2x/day) and isolated aircraft reports
- With real-time 3D obs, forecasters could better issue pilot advisories to alert when fuel temps need to be monitored or flight paths diverted

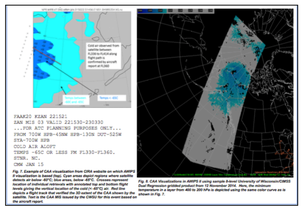


NWS Sonde Launch Sites
http://www.ua.nws.noaa.gov/nws_upper.htm

Parallel Efforts: Use of Hyperspectral IR Sounders

- Collaboration on this cold air aloft issue is going on between Anchorage, AK NWS office & researchers at GINA, CIMSS, SPoRT, & CIRA as part of the NOAA JPSS proving ground and risk reduction (PGRR) activities
- A PGRR proposal was recently funded to develop visualization tools for 3-D temperature fields from real-time hyperspectral infrared (IR) sounder retrievals (Stevens et al., 2015; Smith et al., 2015; Weisz et al., 2015)
  - Utilizes direct broadcast capabilities and the Community Satellite Processing Package (CSPP) to provide visualizations of NUCAPS and Dual-Regression retrievals in real time
  - Preliminary results look very promising



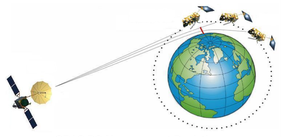


Slide and figure taken from ITSC-20 presentation of Smith et al. and Weisz et al.
Shows example visualizations made using the hyperspectral infrared CrIS Dual Regression product

This Work: Investigating Utility of GPS RO

GPS Radio Occultation (RO) Background

- Temperatures derived from GPS signals occulted by Earth's atmosphere
- Dry Temp product stated to have high accuracy in upper-troposphere and lower-stratosphere (UTLS)
- Measurements pseudo-random in time and space
- Low horiz. resolution: ~200km along ray
- High vert. resolution: 0.1-1km from trop. to strat.



GRAS RO Measurement Depiction
Courtesy EUMETSAT

Previous Conclusions:

- The higher vertical resolution of RO compliments IR sounders by providing more accurate information on the vertical location and minimum temperature of cold air aloft in UTLS region
- RO helps fill in the temporal gaps of radiosondes, but doesn't offer as many samples through time as IR sounders

**Key is to use combination of observations

Summary of Previous Conclusions on Utility of GPS RO data in Cold Air Aloft Issue

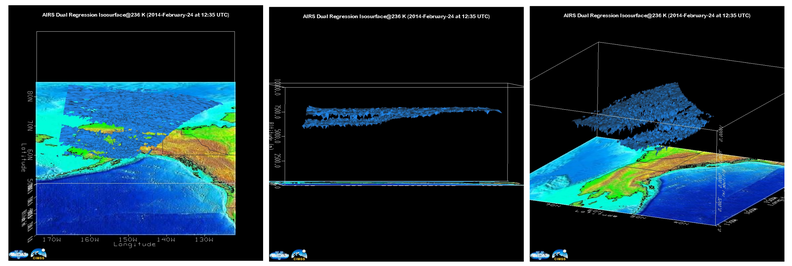
	Hyperspectral IR Sounders	Radio Occultation	Radiosondes
Vertical Resolution	Fair	Good	Good
Horizontal Coverage	Good	Poor	Poor
Time Frequency	Fair	Fair	Poor

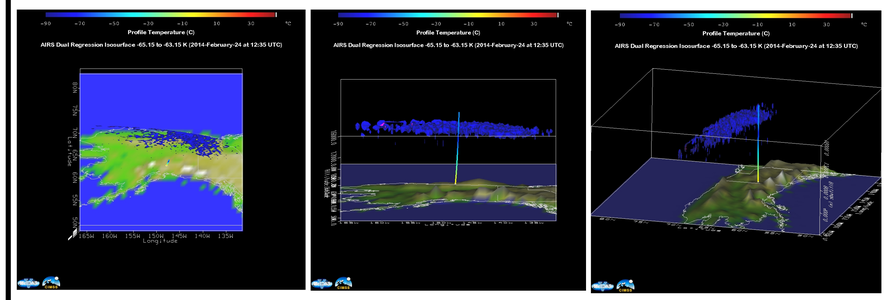
Previously Reported Recommendations:

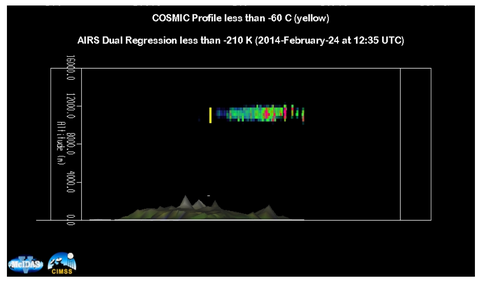
- 1] Have some form of real-time RO data available for NWS forecasters to use for cold air aloft purposes
  OR
- 2] Use RO to provide an 'uncertainty estimate cushion' on the IR sounder temperature profiles so advisories for the presence of cold air could be put out when a higher threshold temperature was reported by the IR sounders

RESEARCH

COLD AIR VISUALIZATIONS: Barrow, AK 24 Feb 2014







- Figure above shows volume rendering of <-60ºC temps for COSMIC (yellow line) and AIRS DR (blue to red pixels). Illustrates convenient method of demarcating vertical extent of cold air seen by both RO and IR sounder.
- Land height in figures is from geopotential heights of GFS

AIRS Dual Regression
-37ºC Isosurface

- Row of figures to the left highlight the location and height of -37ºC temperatures within the single AIRS IR sounder granule taken at12:35 UTC (Dual Regression retrieval)

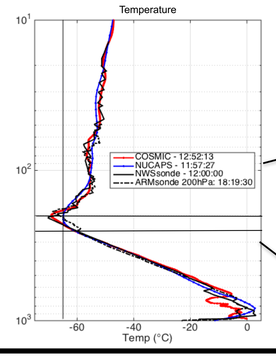
AIRS DR
-65 - -63ºC Isosurface
&
COSMIC

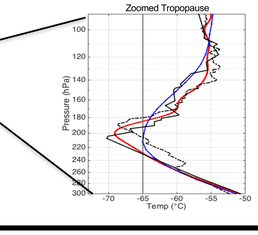
- This row of figures, as well as the figure below them, exemplify the benefit of having both IR sounder and RO measurements together—visualized is the AIRS DR 12:35 UTC granule and a 12:38 UTC COSMIC profile
- Row to left illustrates the -65ºC to -63ºC AIRS DR isosurface and the location/temperature (by color) of the the COSMIC RO profile

AIRS DR
&
COSMIC
<-60ºC
Volume Rendering

NUCAPS (11:57 UTC)
&
COSMIC (12:52 UTC)

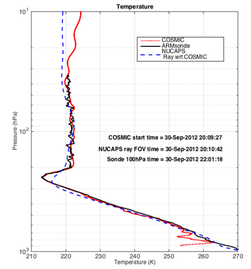
- Matched CrIS NUCAPS ~11:57 UTC and COSMIC RO 12:52 UTC profiles are overlaid with ~18UTC ARM and 12UTC NWS radiosonde to right
- Radiosondes and RO profiles capture the coldest <-65ºC temperatures while the IR sounder smooths over them

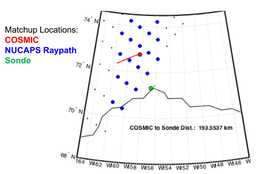




COSMIC RO AND NUCAPS IR SOUNDER COMPARISONS

Case Study Matchup
30 Sept 2012

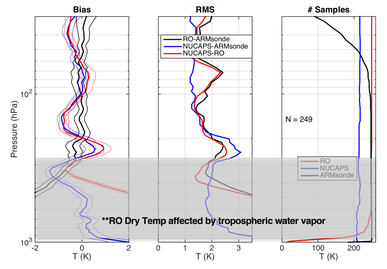




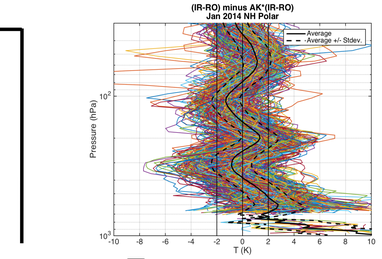
- Comparisons of COSMIC, NUCAPS, and ARMsonde temperatures over Barrow, AK are shown to left and below. NUCAPS "raypath-averaged" profiles are used to account for the horizontal resolution and geometry of the RO profile

  Left figure shows overlaid temperatures for a matchup case where again IR sounder is not able to capture the coldest tropopause temperatures

  Below figure shows 3hr/300km matchup statistics for 3 years. The NUCAPS-sonde and NUCAPS-RO biases show a characteristic ~350-100 hPa vertical oscillation that occurs when the IR sounder smooths over the cold temperature layer that the RO detects

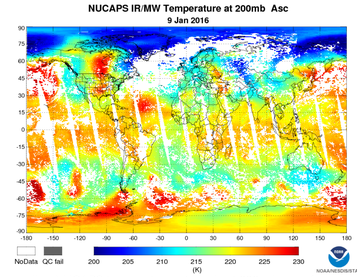


- Figure to the right quantifies the effect of the differing vertical resolutions of the RO and CrIS hyperspectral IR sounder measurements, or more specifically, what the RO is able to resolve in the vertical that the IR sounder is not due to inherent measurement techniques
- To quantify this effect, January 2014 Arctic zone (60-90N) NUCAPS and COSMIC matchup temperature differences were found. Next, CrIS averaging kernels (AKs) for each matchup NUCAPS temperature profile were computed. Finally, the following double differences were taken, with AK* denoting the AK application: AK*(IR-RO) – (IR-RO).
- On average, the RO is able to resolve just over 1 K larger magnitudes of temperatures than the CrIS sounder, but 32% of the time is able to resolve over 2 K larger magnitudes, and is seen for some cases to reach over 6 K



OPERATIONS

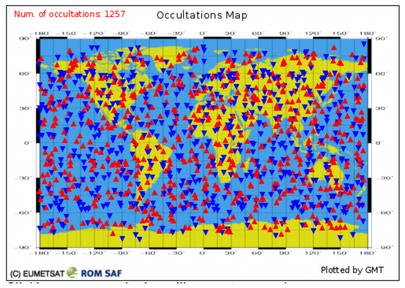
NOAA Operational IR Sounding (JPSS CrIS NUCAPS)



Ascending NUCAPS temperature retreivals at 200 mb level for single day.
From: http://www.star.nesdis.noaa.gov/jpss/EDRs/products_Soundings.php

- Hyperspectral IR sounder data is received via direct broadcast at the University of Alaska Fairbanks (UAF) Geographic Information Network of Alaska (GINA) and processed by the CSPP, which provides retrievals through both the NUCAPS and Dual-Regression (DR) software
- DR offers higher horizontal resolution with retrievals from single FOVs (NUCAPS retrieves on 4 combined FOVs) and has less data gaps

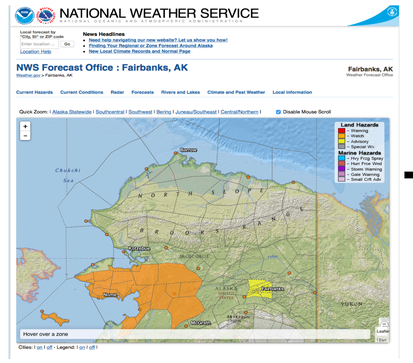
EUMETSAT Operational RO Sounding (MetOp GRAS)



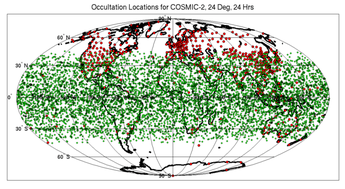
9 Jan 2016 MetOp-A & B GRAS profile locations. From: http://www.romsaf.org/visualization.php

- "NOAA/NESDIS and EUMETSAT are collaborating on an enterprise network to transmit large volumes of satellite data between the two agencies. A minimum of 10 Gbps bandwidth is being pursued. Testing is going well, and the goal is to get a component of this network operational in early 2017."
  - John Paquette at NOAA
- In the interim, real-time data is available from the ROMSAF: http://www.romsaf.org

NWS AK Forecast Offices

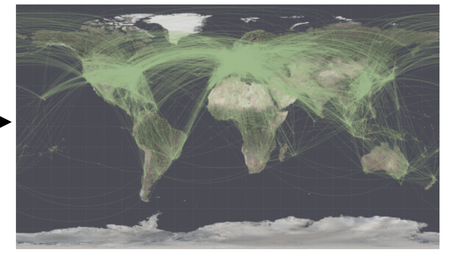


- NWS Weather Forecast Offices, such as those at Fairbanks, host real-time visualizations from satellite observations, including those pertaining to cold air aloft
- Available in AWIPS



Expected coverage of COSMIC-2 (Tropics) by end of 2016 (green) with radiosonde locations (red). COSMIC-2 (Polar) expected to be launched 2018/2019 to provide polar coverage.
From: Anthes R. (2014)

Users



- Users, including forecast meteorologists such as those at Alaska Fairbanks, access real-time visualizations of 3D observations
- Visualizations help them make improved forecasts and more informed decisions about issuing advisories and warnings concerning hazardous weather like cold air aloft

REFERENCES

- Stevens, Eric. et al. 2015, Using Hyperspectral Sounders to Detect Cold Air Aloft over Alaska, Annual AMS 4-8 Jan, Phoenix, AZ.
- Smith, N. et al. 2015, Novel applications of temperature soundings in high latitude regions–Aviation in Alaska, ITSC-20, 28Oct-3Nov, Lake Geneva, WI.
- Weisz, E. et al. 2015, Assessing hyperspectral retrieval algorithms and their products for use in direct broadcast applications, ITSC-20, 28 Oct - 3 Nov, Lake Geneva, WI.

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