Towards Aiding Aviation Safety: Detection of Cold Air Aloft Using COSMIC RO and Hyperspectral IR Soundings

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Roadmap

- Introduction: The Issue
- Background: Parallel Efforts
- Motivation & Objectives
- Results
- Conclusions
Cold upper air temps at jet cruising altitudes are aviation safety concern, as jet fuel can gelify.

Forecasters in AK NWS offices have made known the need for more information on cold air aloft, specifically real-time 3D obs.
- More common to fly over poles
- Forecasts not timely enough or always accurate
- Obs. only available from sparse radiosonde network (launches 2x/day) and isolated aircraft reports

With real-time 3D obs., forecasters could better issue pilot advisories that alert when fuel temps need to be monitored or flight paths diverted around cold air masses.

Cold air defined as -65°C, but fuels are monitored due to cold conditions at much higher temps, ~-40°C, as freezing properties of fuel mixture are dependent on numerous variables.

Introduction: The Issue

NWS Sonde Launch Sites
http://www.ua.nws.noaa.gov/nws_upper.htm
Parallel Efforts: IR Sounder Work

- Collaboration on 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
  - PGRR proposal was recently funded to develop visualization tools of 3D temperature fields from hyperspectral infrared sounders for real-time use
  - Preliminary results look promising

- Presented at 2015 AMS Annual
- Stevens, Eric. et al. 2015, Using Hyperspectral Sounders to Detect Cold Air Aloft over Alaska, Annual AMS 4-8 Jan, Phoenix, AZ.

- Results shown at recent ITSC-20 conference using NUCAPS retrieval products
- Smith, N. et al. 2015, Novel applications of temperature soundings in high latitude regions—Aviation in Alaska, ITSC-20, 28 Oct - 3 Nov, 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.
• RO Background
  – Temperature derived from GPS signals occulted by Earth’s atmosphere
    • Dry Temp product stated to have high accuracy in UTLS
    • Pseudo-random in time and space
    • Low horizontal resolution: ~200km along raypath
    • High vertical resolution: 0.1-1km from trop. to strat.

• Objective is to answer:
  – What additional information can RO provide to supplement IR sounders and radiosondes in the detection of cold air aloft?

    1) Can RO’s higher vertical resolution assist in assignment of the vertical extent of cold air?
    2) What is the frequency of RO profile occurrence?
1st Objective Question Method

- Use RO and hyperspectral IR sounder temperature profile matchup datasets

- Strict matchup criteria minimizes spatiotemporal mismatch errors

  - Feltz, M. et al. (2014), Application of GPS radio occultation to the assessment of temperature profiles from microwave and infrared sounders, AMT.

Prelim Results: 1) Can RO assist in assignment of cold air vertical extent?
Barrow, AK Cold Air Aloft Case
COSMIC, NUCAPS, NWS Sonde, ARM Sonde Matchup
24 Feb 2014

Prelim Results: 1) Can RO assist in assignment of cold air vertical extent?

- COSMIC is able to capture quite well the coldest temps seen by sondes
- NUCAPS captures general structure of temperature, but not able to resolve coldest tropopause level
Prelim Results: 1) Can RO assist in assignment of cold air vertical extent?

**COSMIC, AIRSv6 Comparisons 2007-2013**

*60-90°N*

**DJF**

**Mean Temperatures**

AIRS (——)

COSMIC (- - - -)

**AIRS – COSMIC 1km Layer Diffs**

Bias (——)

RMS (- - - -)

- **All Profiles (N=27398)**
- **25% Coldest (N=6849)**
- **5% Coldest (N=1369)**

Ref: 250mb = 34000ft

- COSMIC and AIRS profiles with coldest temps exhibit larger bias around flight altitudes than warmer profiles
Prelim Results: 1) Can RO assist in assignment of cold air vertical extent?

COSMIC2013, NUCAPS, GFS Comparisons
60-90°N
DJF: 2013-2014

Mean Temperatures

NUCAPS (——)
COSMIC (--- - -)
GFS (-----)

1km Layer Diffs
NUCAPS - COSMIC (——)
NUCAPS - GFS (- - -)
Bias (thick), & RMS (thin)

For subset of extreme cold cases bias between NUCAPS and GFS/COSMIC under 2K from 500-30hPa, while the RMS extends to over 2K

COSMIC & GFS agreement partly artificial due to assimilation of RO into forecast models
Multiple RO receivers providing measurements

- COSMIC/FORMOSAT-3 - 5 receivers, ~1600 events/day combined
- US Air Force C/NOFS Satellite - 1 receiver, ~150 events/day in equatorial region
- KOMPSAT-5 (Korean) - 1 receiver, ~600 events/day
- METOP Series GRAS - 2 receivers, ~1200 events/day combined
- COSMIC-2 Tropics to be launched Sept. 2016 and COSMIC-2 Polar in late 2018

Prelim Results: 2) What is the frequency of RO profile occurrence?

~ 1950 daily global avg.

~ 600 daily global avg.
Prelim Results: 2) What is the frequency of RO profile occurrence?

COSMIC/FORMOSAT-3
6(5) Receiver Network

- AK region Daily
- ~40/day

METOP-A GRAS
Single Receiver

- AK region Daily
- ~15/day

• RO offers varied amount of samples per day in pseudo-random locations
Prelim Results: 2) What is the frequency of RO profile occurrence?

Histogram of Alaska Region:
Monthly RO Profile AKST Hour

- RO helps fill in temporal gaps of radiosonde launches, but sounder offers far more observations
  - COSMIC and single GRAS provide ~2 samples/hr (48/day) in AK region

Conclusions

• User need made known: **real-time 3D observations**
  – Hyperspectral IR sounders to be integrated into AWIPS system under new proposal
  – Utility of RO as supplement is being investigated

• Higher vertical resolution of RO compliments IR sounders by providing more accurate information on vertical location and actual temperature of cold air aloft in UTLS region

• RO helps fill in temporal gaps of radiosondes, but doesn’t offer as many samples as IR sounders

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<thead>
<tr>
<th></th>
<th>Hyperspectral IR Sounders</th>
<th>Radio Occultation</th>
<th>Radiosondes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical Resolution</strong></td>
<td>Fair</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Horizontal Coverage</strong></td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Time Frequency</strong></td>
<td>Fair</td>
<td>Fair</td>
<td>Poor</td>
</tr>
</tbody>
</table>
Conclusions

***Key is to use combination of observations

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 could be put out when a higher threshold temperature was reported
Acknowledgments

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Thank You