OSE and OSSE Studies to Evaluate the Impact of Real and Simulated Global Hawk Data on Winter Storm Forecasts over Alaska and the Arctic

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Global Observing Systems Analysis (GOSA) Group: http://www.esrl.noaa.gov/gsd/gosa/

14\textsuperscript{th} Conference on Polar Meteorology and Oceanography
Weather and Climate Modeling in the Polar Regions
Seattle, Washington
January 26, 2017

26-Jan-2017

2017 AMS Annual Meeting
Sensing Hazards with Operational Unmanned Technology (SHOUT) Project and Motivation

- Project within NOAA’s Unmanned aircraft systems (UAS) program
- Test impact of real and simulated UAS data on forecasts using targeted observing with Global Hawk (GH)
  - Observing System Experiments (OSEs)
  - Observing System Simulation Experiments (OSSEs)
- Satellite gap mitigation (Soumi-NPP and JPSS-1/2)
- **SHOUT-El Nino Rapid Response (ENRR)**
  - Joint effort Feb 2016 with GH, G-IV, C-130’s
  - Improve U.S. West Coast forecasts
  - GH sampled 3 storms
  - 3rd Storm – Feb 21st – strong Atmospheric River
    - 66 total dropsondes released

http://www.esrl.noaa.gov/psd/enso/rapid_response/
SHOUT Global Hawk Instrumentation Payload

**Airborne Vertical Atmospheric Profiling System (AVAPS)**

- Temperature, wind, humidity
- 88 sondes
- ~80-115 hPa

**High Altitude Monolithic Microwave Integrated Circuit (MMIC) Sounding Radiometer (HAMSR)**

- Microwave radiometer operating at 25 spectral channels
- 3-D distribution of temperature, water vapor

**High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP)**

- Dual-frequency conical scanning radar
- 3-D winds, ocean vector winds, precip
- **Resolution**: 60 m vertical, 1 km horizontal
Ensemble Transform Sensitivity (ETS) Targeted Observing Technique

- Improve forecasts in verification region at selected *targeting and verification times*
- Calculates *gradient* of total forecast error variance to analysis error variance reduction

*Sample timeline*

- Ensembles 80 mem GEFS
- 4-5 days lead-time
- ETS-based technique
- 1-3 day lead-time
- Verification Domain and time
- Daily forecast briefings providing high-impact cases 4-5 days in advance
- ETS to identify areas of large error growth at 1-3 day lead time
- Subsequent flight path design

Zhang et al. (2016)
OSE Experiment Design during SHOUT-ENRR February 21 Storm Cycling Global Forecast System (GFS) model 2/21 18z to 2/22/ 12z

<table>
<thead>
<tr>
<th>Experiment Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL</td>
<td>All current operational observations</td>
</tr>
<tr>
<td>DROP</td>
<td>CTL + GH dropsondes</td>
</tr>
<tr>
<td>noNPP</td>
<td>CTL without Soumi-NPP satellite</td>
</tr>
<tr>
<td>DROP_noNPP</td>
<td>noNPP + GH dropsondes</td>
</tr>
</tbody>
</table>

ETS sensitivity at GH flight time (00z Feb 22\textsuperscript{nd}) for verification time (00z Feb 24\textsuperscript{th}) over AK verification domain

Results verified against ECMWF analysis using Anomaly Correlation and RMSE
ERA-Interim Moisture transport (IVT and IWV) at Targeting and Verification times

Targeting time

Verification Time
Assimilating dropsondes increases forecast skill and reduces error

**Anomaly Correlation**

- Anomaly Correlations AK Domain SLP
  - CTL
  - DROP
  - DROP_noNPP
  - noNPP

- Anomaly Correlations AK Domain 500 hPa HGT
  - CTL
  - DROP
  - DROP_noNPP
  - noNPP

**RMSE**

- RMSE AK Domain (SLP)
  - noNPP
  - DROP_noNPP

- RMSE AK Domain (500 hPa HGT)
  - noNPP
  - DROP_noNPP

**Relative RMSE (%)**

- AK Domain (SLP)
  - noNPP
  - DROP_noNPP

- AK Domain 500 hPa HGT
  - noNPP
  - DROP_noNPP
OSSE Experiment Design February Alaska Storm Cycling GFS model 2-3 days in advance of Verification Time of 00 UTC Feb 2

- **CTL**
  - Operational obs. only

- **ETS**
  - Automated ETS flight path design

- **LOW**
  - Sample rapidly developing Low-pressure

- **JET**
  - Sample jet exit region

- **MOIST**
  - Sample Atmospheric river

- 70-80 dropsondes per simulated GH flight
- **ETS** flight based on average 2-3 day ETS sensitivity
- Results verified against ECMWF T511 Nature Run
OSSE Simulated Flight Tracks

ETS (500 hPa)

LOW (500 hPa Vorticity)

JET (200 hPa Isotachs)

MOIST (700 hPa IWV)
Simulated dropsondes increase forecast skill among all flight tracks

Anomalous Correlations CONUS Domain SLP

Anomalous Correlations CONUS Domain 500 hPa HGT

CTL
ETS
LOW
JET
MOIST

CTL
ETS
LOW
JET
MOIST
Summary

• SHOUT-ENRR OSE impact results
  • Increased forecast skill and reduced error when using targeted GH dropsondes during current observing and potential future satellite data gaps

• OSSE studies
  • Validation of ETS technique shows it accurately identifies regions of increased error growth with higher forecast skill in AUTO path compared to CTL
  • Sampling upper-level jet streak and developing low show largest improvement over CTL forecasts in 1-3 day forecast lead times
  • Importance of both sensitive regions and key meteorological features

• Future Research needs
  • Further UAS campaigns to examine statistical significance of targeting
  • Dropsondes, microwave instruments, radar, and SST fluxes using UAS platforms

26-Jan-2017

2017 AMS Annual Meeting
Backup slides
Observing System Experiments (OSEs) and Observing System Simulation Experiments (OSSEs)

OSEs

REAL WORLD

Real atmosphere
observations
analysis
Model forecast

OSSE WORLD

Nature Run (simulated truth)
Synthetic observations
analysis
Model forecast

Verification

Courtesy: Lidia Cucurull

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Ensemble Transform Sensitivity technique

(a) Calculate Ensemble transform matrix
(b) Predict forecast error covariance (analysis and forecast error)
(c) Estimate prediction error variance reduction

The locations of sensitive regions is dependent on the area in which a forecast improvement is wanted, the verification area, but also the forecast length and the atmospheric flow between the targeting and verification times.

Zhang et al. (2016)
Comprehensive Evaluation of Relative RMSE in current and potential future observing systems

Reduction in forecast error of 1-5% across several variables

<table>
<thead>
<tr>
<th>Atmospheric Variable</th>
<th>DROP vs. CTL</th>
<th>DROP_noNPP vs. noNPP</th>
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<tbody>
<tr>
<td>200 Height</td>
<td>-3.46</td>
<td>-3.05</td>
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<tr>
<td>300 Height</td>
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