Use of UAS to Improve Weather and Climate Prediction

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Emerging Technology Panel
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TALK SUMMARY

- The role of UAS in environmental science.
- Weather Prediction Problem: Hurricanes and UAS
- The Challenge of Global Climate Change
- Role of UAS in Climate Change Science
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Forecasts are only as good as the models
Models are only as good as the data that goes into them
Key is improved data and improved observations

UAS have great potential to fill the gap between satellites and surface-based sensors to take measurements that will complement our existing platforms
NOAA is looking at a broad range of platforms for global information to fill this gap.
…..for a broad number of applications
Implementation Strategy: Regional UAS Testbeds

Unmanned Aircraft Systems

UAS Test Bases

Arctic

Pacific

Gulf & Atlantic
2008 Arctic Testbed

What is the population of ice seals in the Arctic?

Leads: R.Angliss (NMFS), G.Walker (UofAK), P.Hall (OMAO)
- Launch and recovery of Scan Eagle demonstrated from the NOAA ship *Oscar Dyson*
- Detailed review by NOAA Office of Marine and Aircraft Operations (AOC/MOC-P and OMAO)
- Significant ship coordination for integration and operations
NOAA deployed a Manta in Greenland in summer 2008, in support of an international team. Sensor package:

- Laser altimeter
- Visible camera
- Visible video
- Hyperspectral imager
- Standard Met. Package
- Iridium comms
- Differential GPS
Arctic Testbed Demo:
What is the volume of the melt water in a supra-glacial lake?

Photo: from Sarah Das

NOAA Mission requirement: Improve climate forecasts by reducing uncertainty in glacial ice-melt and its impact on sea level
Pacific UAS Demonstration – PacTest
Vandenberg AFB, California

Conducted as part of the UAS Pacific Testbed: Gary Wick (OAR), Todd Jacobs (NOS)
Conducted by SCRIPPS team: K Lehmann; H Nguyen and V Ramanathan

- Vandenberg AFB, Nov 1-2 and 8, 2008
- Total of 14 hours over 10 flights
- Flux testing over the ocean at altitudes of 1000, 2000, and 3000 ft
- Aerosol and ozone sampling at altitudes up to 12,000 ft
Pacific UAS Testbed Demo
What is the water budget of an atmospheric river?

Integrated Water Vapor
From SSM/I

Manta 2008 flux demo
Led by Scripps

Proposed
Global Hawk
2009-10 demo
with dropsondes
Joint with NASA & Northrop Grumman
TALK SUMMARY

The role of UAS in environmental science.

Weather Prediction Problem: Hurricanes and UAS

The Challenge of Global Climate Change

Role of UAS in Climate Change Science
Aerosonde was launched from NASA’s Wallops Flight Facility at 14:08 EST on Friday November 2, 2007.

Mission endurance was 17 hours 27 minutes and resulted in 7.5 hours of data collection in the core of the hurricane at altitudes less than 100m.
Take-off from Wallops Flight Facility (KWAL) 1600 UTC

Nominal altitude for the Aerosonde prior to entering the storm’s core circulation was between 300-600m.

Near the center, UAS altitude was ~150m.

Rendezvous with P-3 at storm center 0525 UTC

“Eye” loitering with vertical soundings (90-1500 m)
HALE: light - in-situ measurement using drop-sondes

Lightweight drop-sondes dispensed into developing weather event or storm at intervals to measure PTU and wind speed
Dropsonde Mechanical Design

- Foam housing
- 3.5 inch diameter
- 2.3 grams
- Air pathways for sensors

- Populated housing with attached streamer
- 38.3 grams
<table>
<thead>
<tr>
<th>Component</th>
<th>Mass (g)</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging – housing &amp; streamer</td>
<td>6.7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Circuit board, microprocessor, transmitter</td>
<td>12.2</td>
<td>3.0 - 3.6</td>
<td>0.015 – 28.9</td>
</tr>
<tr>
<td>Pressure Sensor</td>
<td>0.1</td>
<td>3 – 6</td>
<td>0.1 – 1.0</td>
</tr>
<tr>
<td>Humidity Sensor</td>
<td>0.1</td>
<td>2.4 – 5.5</td>
<td>0.0 – 0.5</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>0.1</td>
<td>3.3</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>GPS</td>
<td>2.1</td>
<td>2.7 – 3.3</td>
<td>39</td>
</tr>
<tr>
<td>Antennas</td>
<td>7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Battery</td>
<td>10</td>
<td>3.6</td>
<td>1200 mAh</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38.3g</strong></td>
<td><strong>3.6</strong></td>
<td><strong>17 – 27 hrs</strong></td>
</tr>
</tbody>
</table>
Global Hawk Test Planning
NASA Dryden Flight Research Center (DFRC)

- Two Global Hawks have been acquired by NASA DFRC, CA and will be used, in part, for earth science research and application studies.
- NOAA (with NASA and NCAR) is building a dropsonde system (100/flt); dropsonde sys. development coordinated by D. Fahey (NOAA).
WISDOM (Weather In-Situ Deployment Optimization Method): Deploying horizontal balloon sondes in an optimum manner around weather disturbances.

Objective: Improve hurricane track prediction in the 3 to 6 day period prior to landfall.
AL18

Early-cycle track guidance valid 0000 UTC, 19 September 2005
Students launching a WISDOM balloon/payload during the October 6, 2008 training session in Miami.
ETC’s GPS RF Tag:

- Deployed with the Tetroon balloons to collect location, wind data (.3 watts)

- Data transmitted real time via ETC’s ground station to NOAA/ESRL.
WISDOM balloon trajectories deployed around Hurricane Paloma, as located on Nov 12.
WISDOM Hurricane Paloma Launch November 7-9, 2008

WISDOM Balloon W000054 26K feet

3 day track Predict 11/07 12z GFS
11/07/2008 14:50z first data
11/27/2000 21:21z last data

20 days 7 hours flight time
Crossed International Date Line

Balloon altitude in feet vs. flight time in minutes
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Temperature rise: End of century temperatures with “business as usual” scenario.
Earth System models will allow improved prediction of long term climate.
Nonhydrostatic
Icosahedral
Model
Alexander E. MacDonald
Jin-Luen Lee

Nonhydrostatic GEs in flux form on Z - coord. with 3-D f - v solvers:

\[
\begin{align*}
\frac{\partial U}{\partial t} + \frac{\partial (uU)}{\partial x} + \frac{\partial (vU)}{\partial y} + \frac{\partial (wU)}{\partial z} + \gamma \rho \pi \frac{\partial \Theta}{\partial x} &= 0, \\
\frac{\partial V}{\partial t} + \frac{\partial (uV)}{\partial x} + \frac{\partial (vV)}{\partial y} + \frac{\partial (wV)}{\partial z} + \gamma \rho \pi \frac{\partial \Theta}{\partial y} &= 0, \\
\frac{\partial W}{\partial t} + \frac{\partial (uW)}{\partial x} + \frac{\partial (vW)}{\partial y} + \frac{\partial (wW)}{\partial z} + \left( \gamma \rho \pi \frac{\partial \Theta}{\partial z} - \rho \frac{\pi}{\rho} \rho^2 g \right) &= 0, \\
\frac{\partial \Theta}{\partial t} + \frac{\partial (u\Theta)}{\partial x} + \frac{\partial (v\Theta)}{\partial y} + \frac{\partial (w\Theta)}{\partial z} &= \Theta \frac{\pi}{\rho} \\
\frac{\partial \rho}{\partial t} + \frac{\partial (u\rho)}{\partial x} + \frac{\partial (v\rho)}{\partial y} + \frac{\partial (w\rho)}{\partial z} &= 0.
\end{align*}
\]

\((U, W, \Theta, \rho) = (pu, pw, p\theta, \rho), \quad \Theta(x, z, t) = \Theta(z) + \Theta'(x, z, t)\)

\(\rho(x, z, t) = \rho(z) + \rho'(x, z, t); \quad \nabla p = \gamma \rho \pi \Theta\)

\(p = p_0 \left( \frac{R\Theta}{p_0} \right)^\gamma; \quad \pi = \left( \frac{p}{p_0} \right)^\kappa\)
Satellites are excellent for column integrated constituents.

UAS allow us to determine the vertical distribution of the constituent: PROFILES.

Black carbon (blue) and sulfates (green).
• HALE aircraft could be used over large ocean areas to take PROFILES of:

• Atmospheric state
• Ocean state
• Chemistry
• Ice
Proposed: Global Unified Profiling System

Climate:

* Accurate climate sondes at every “climate point” (240 points equally distributed over oceans and polar regions) every three days.

* Detailed profiles of cloud properties, radiation, aerosols and chemistry.

* Buoys or AXBT’s at each ocean point.
Questions . . . .

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