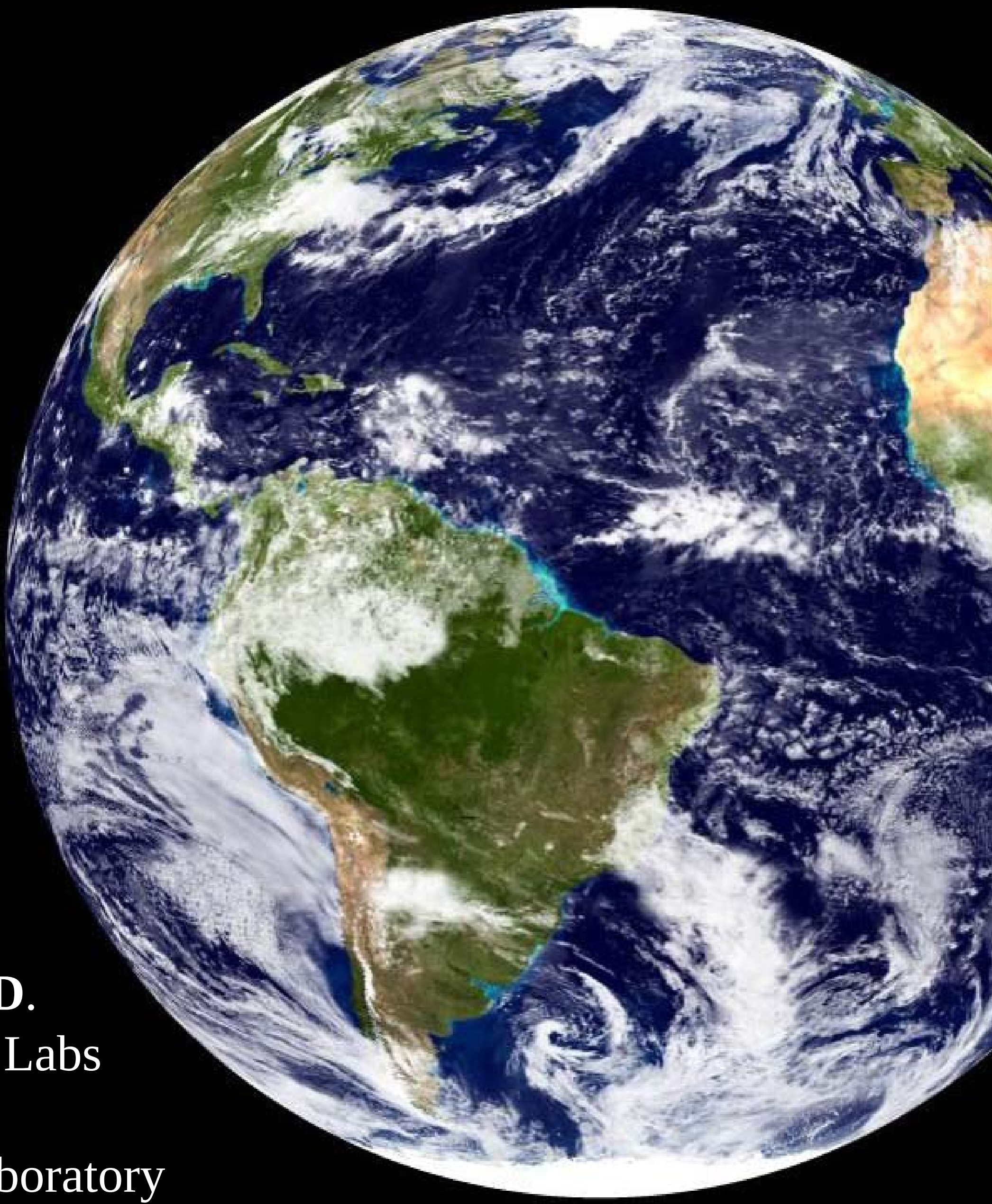
Use of UAS to Improve Weather and Climate Prediction



Unidata Workshop

Emerging Technology Panel

June 12, 2009

Alexander E. MacDonald, Ph.D.
Deputy Assistant Administrator for Labs
and Cooperative Institutes
& Director, Earth System Research Laboratory
National Oceanic & Atmospheric Administration

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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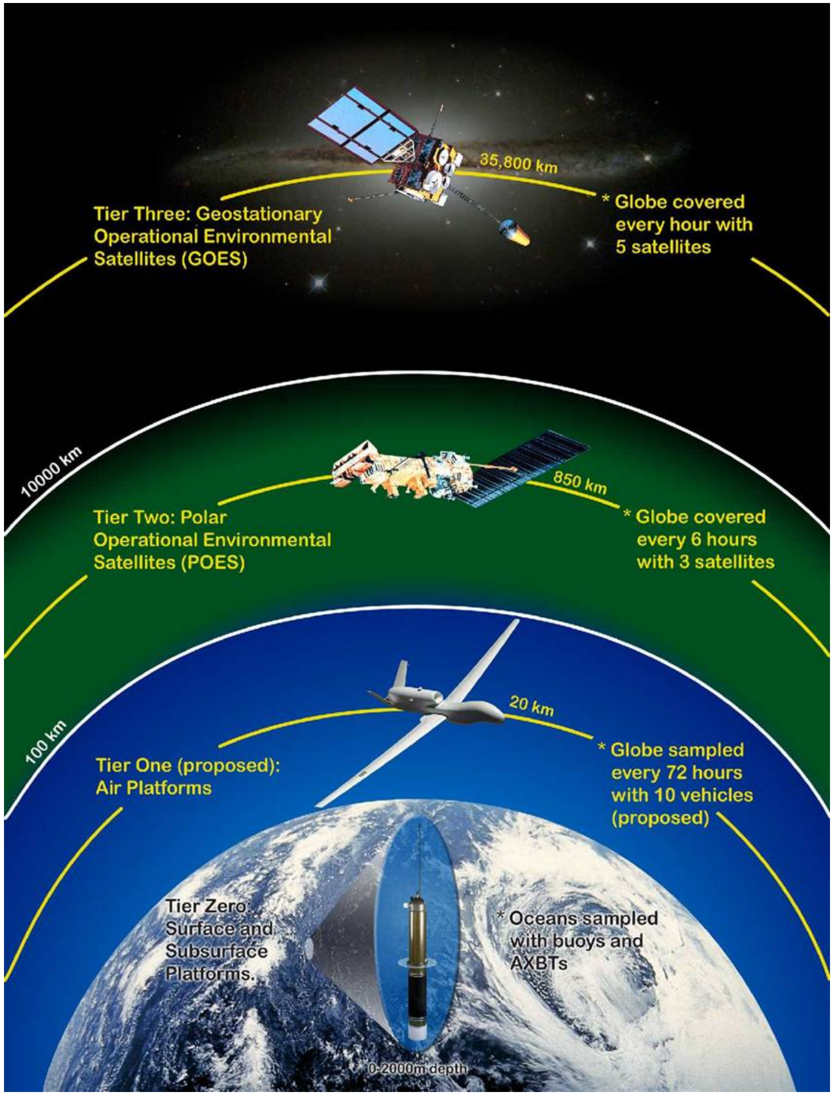
Observational Gap

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

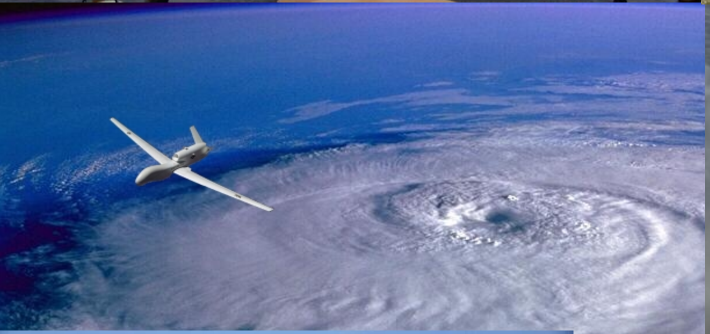
UAS have great potential to fill the gap between satellites and surface-based sensors to take measurements that will complement our existing platforms



NOAA is Looking at a Broad Range of Platforms For Global Information to fill this Gap……..

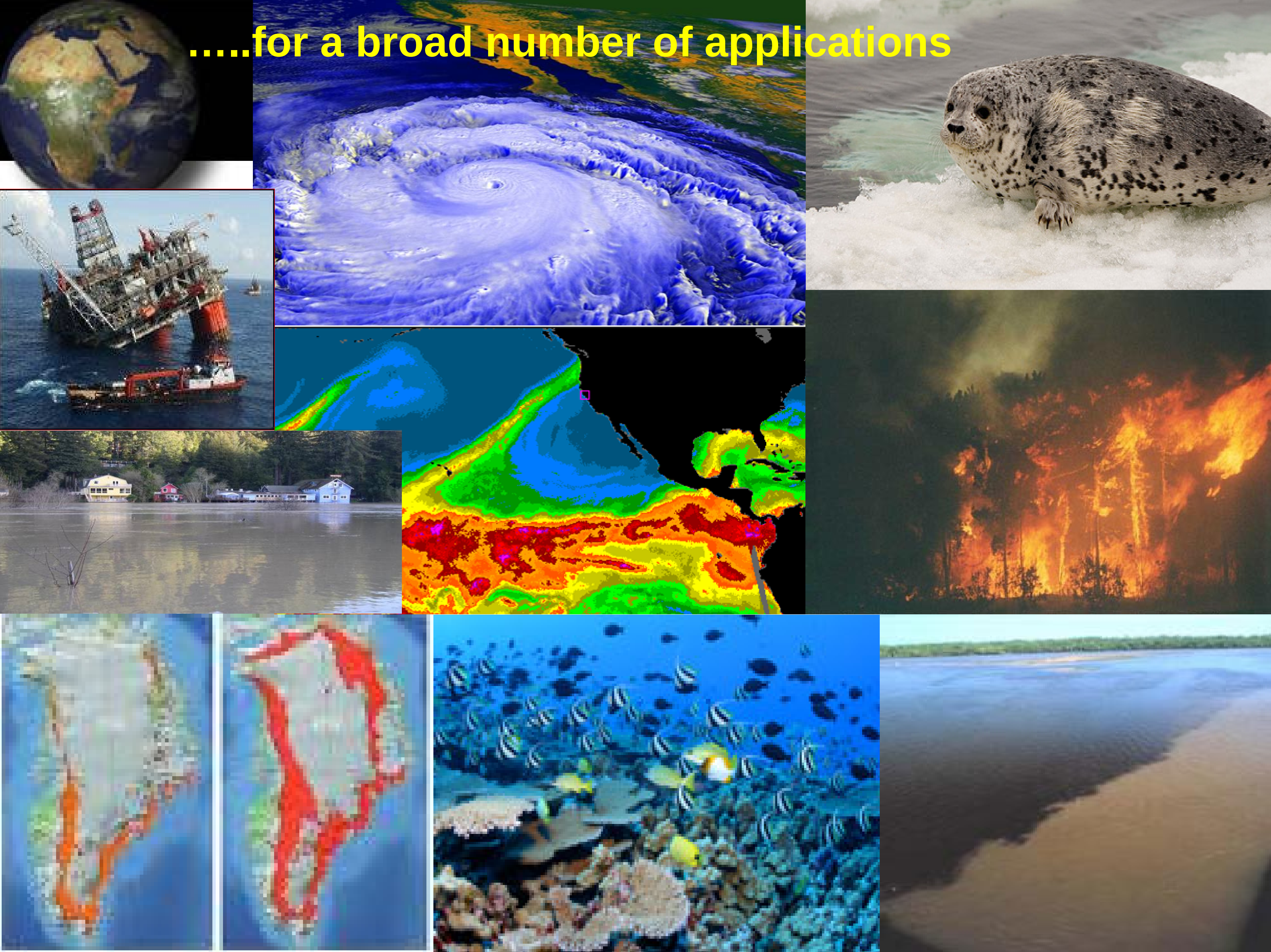




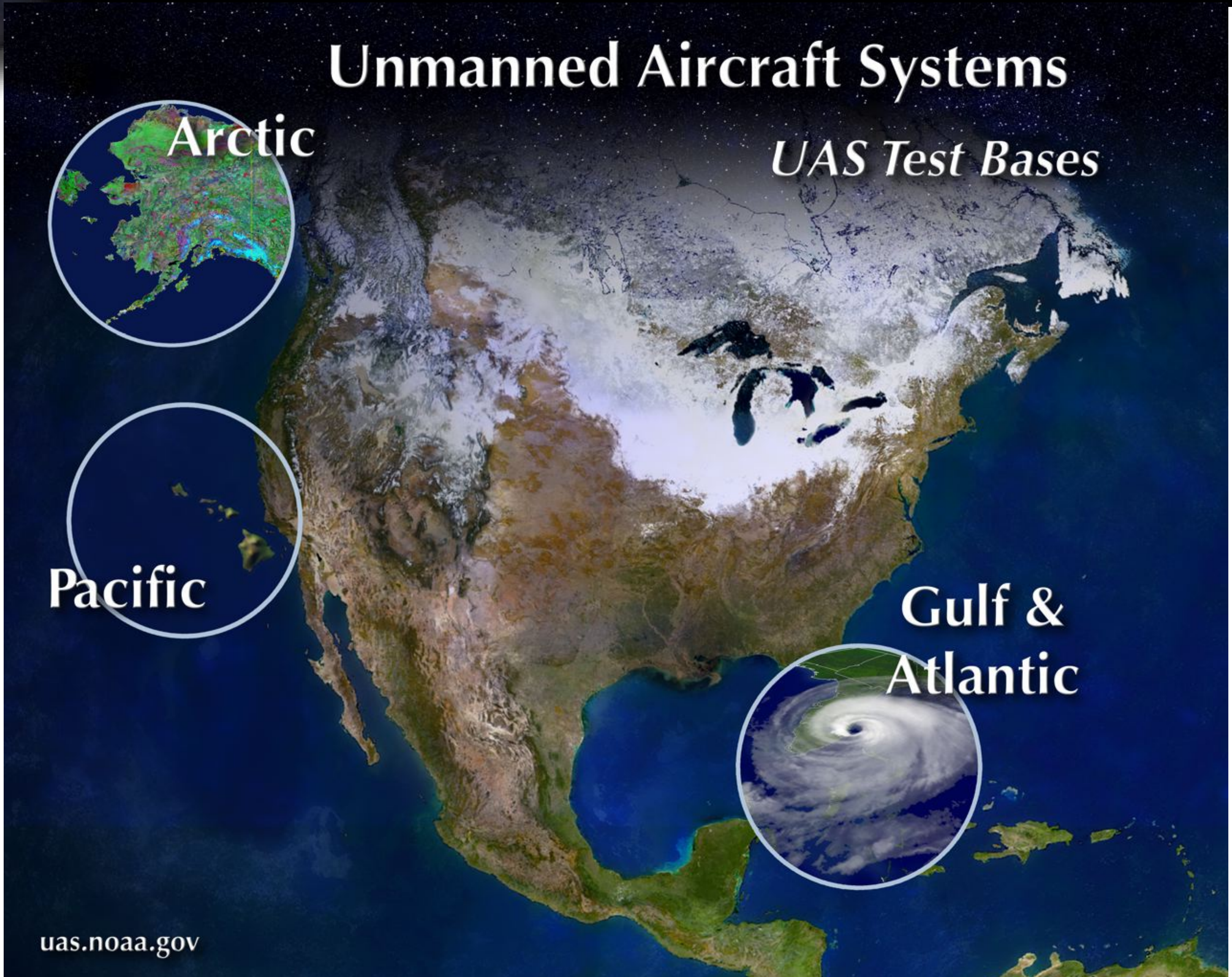





…..for a broad number of applications

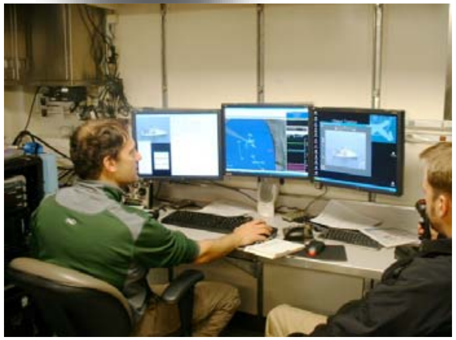


Implementation Strategy: Regional UAS Testbeds



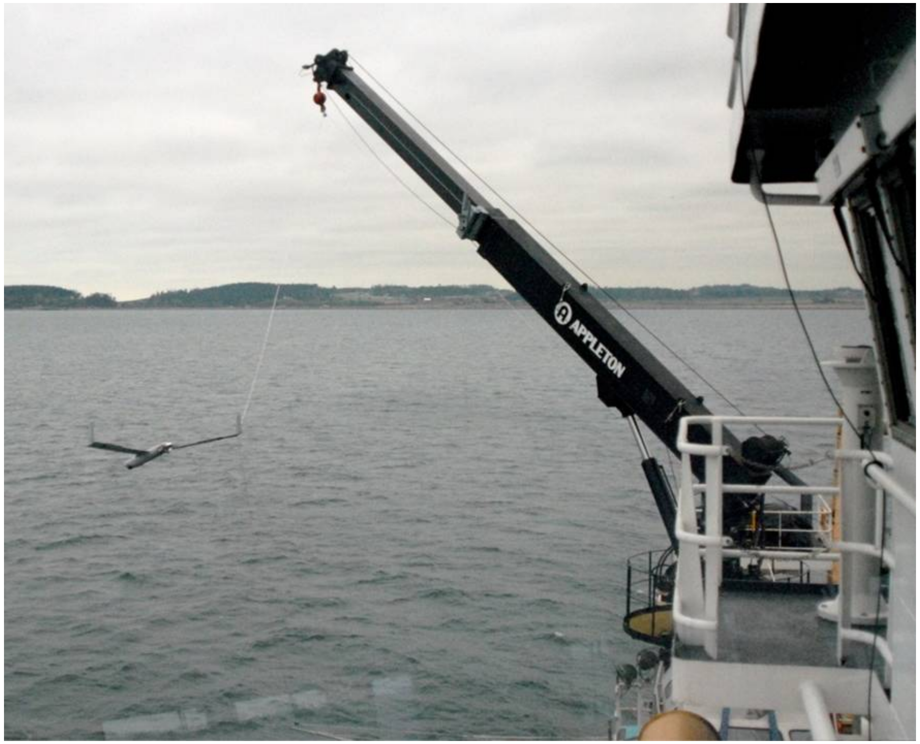
2008 Arctic Testbed

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



2008 Arctic Tests: Greenland

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
- Irridium comms
- Differential GPS

Arctic Testbed Demo:

What is the volume of the melt water in a supra-glacial lake?

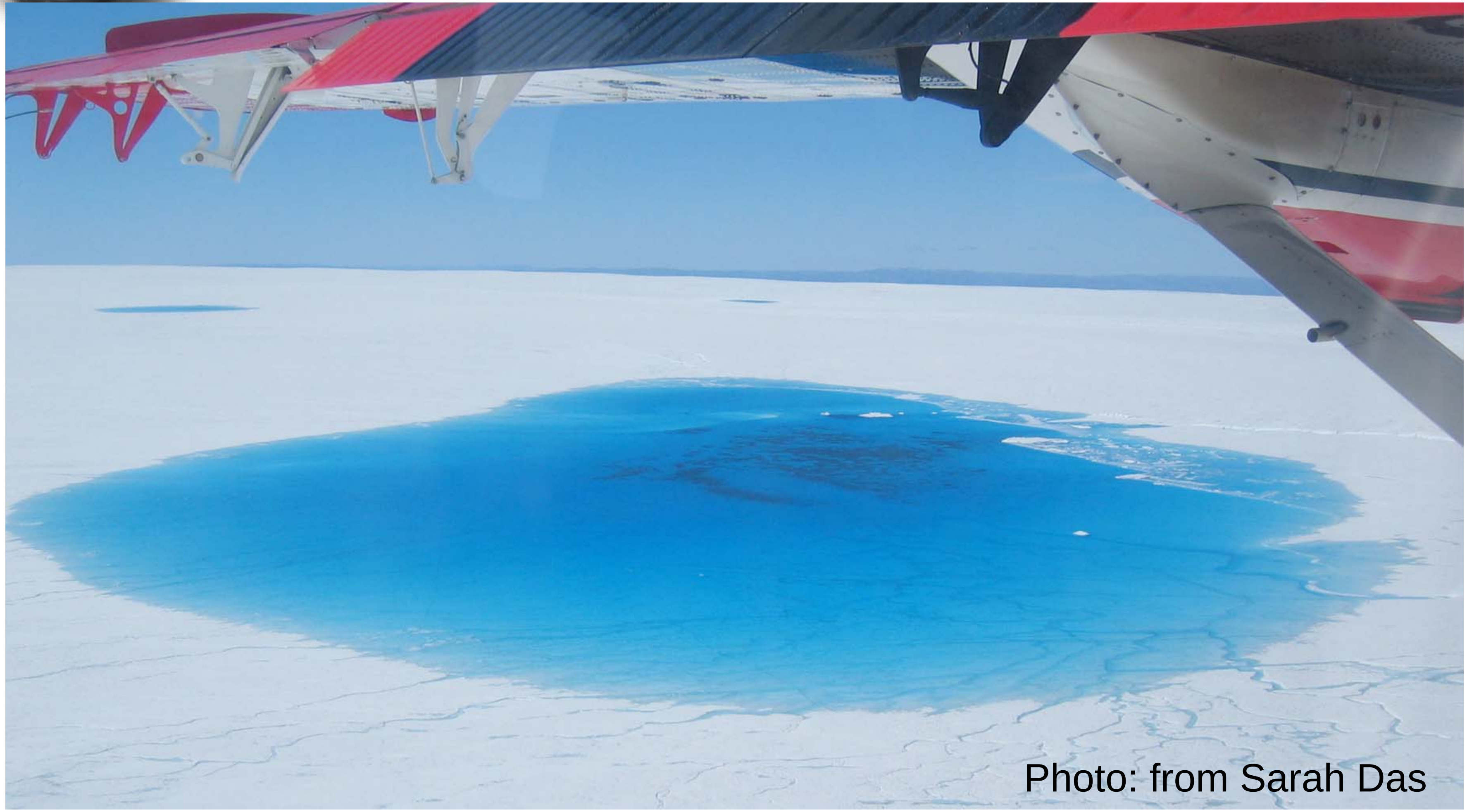
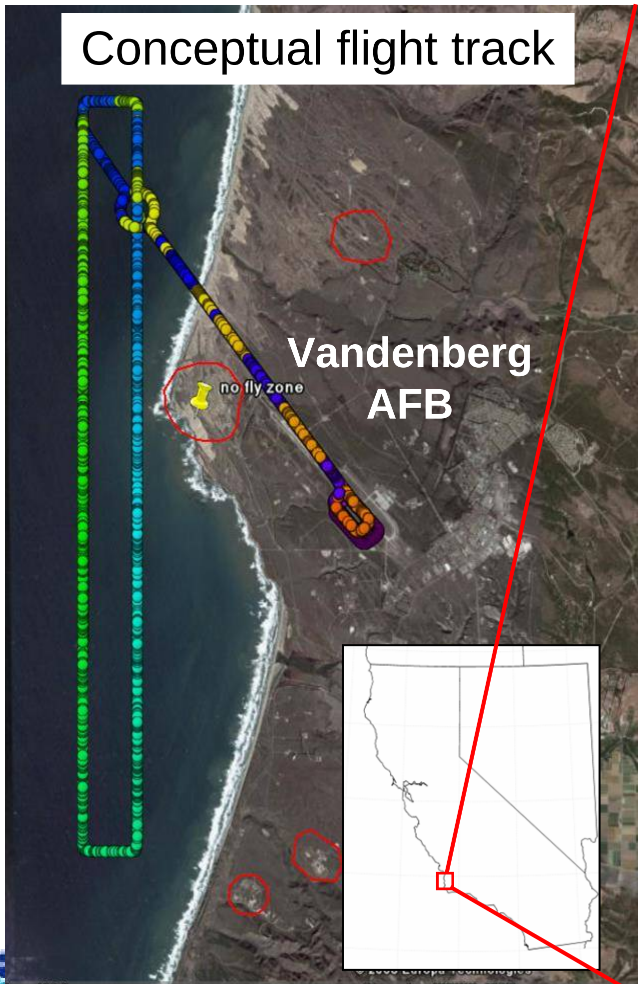


Photo: from Sarah Das

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

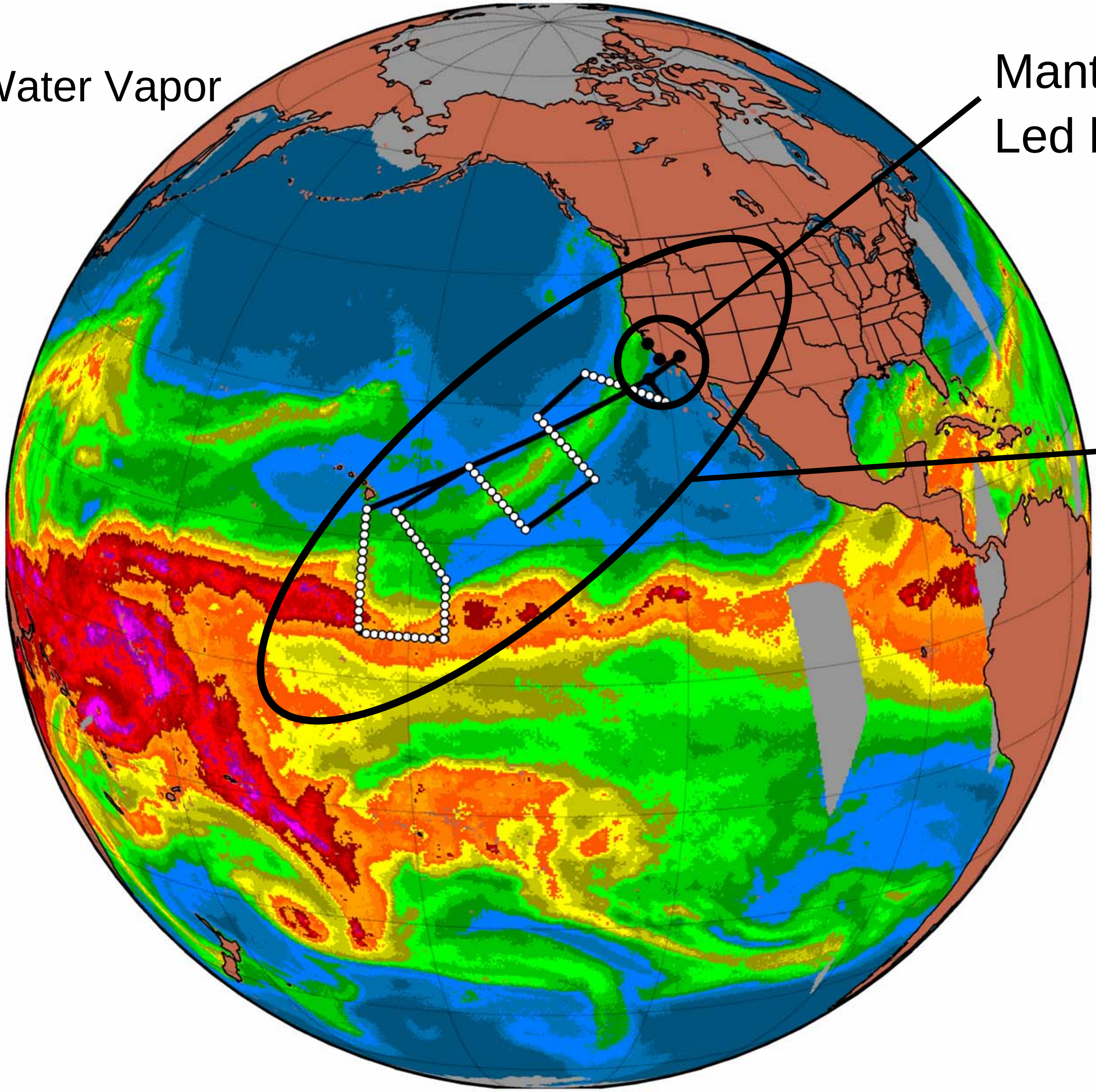
Conducted as part of the UAS Pacific Testbed: Gary Wick (OAR), Todd Jacobs (NOS)
Conducted by SCRIPPS team: K Lehmann; H Nguyen and V Ramanathan



- 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?



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NOAA/NASA Noel Aerosonde UAS mission

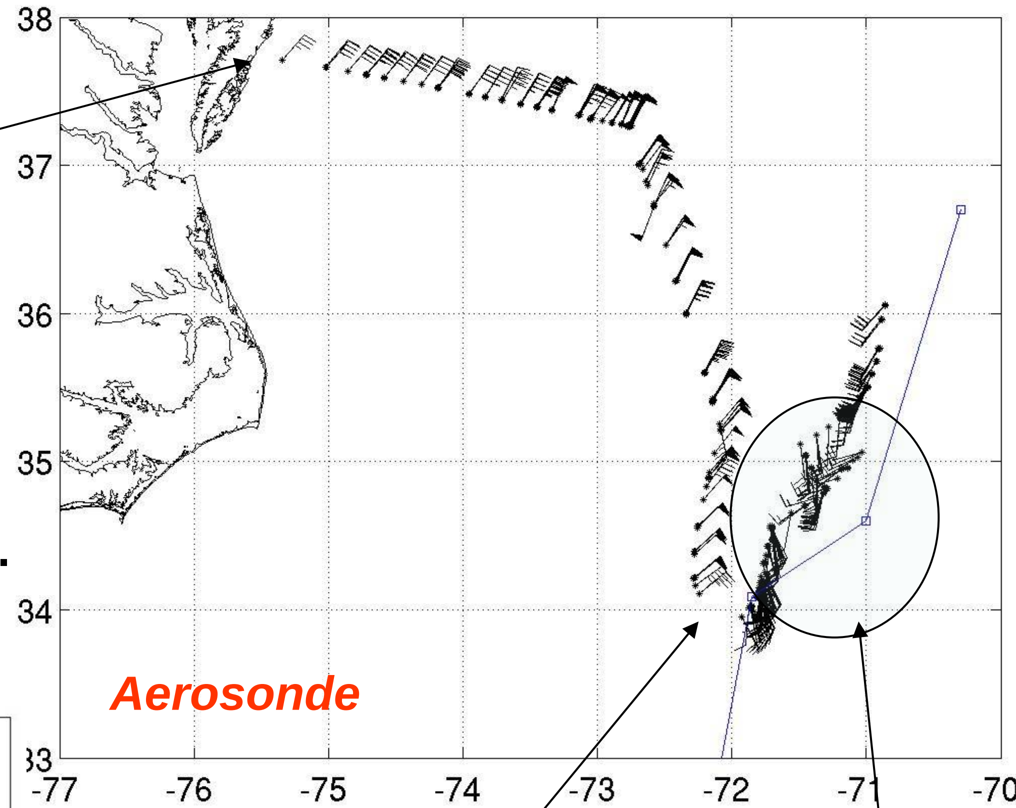
Aerosonde was launched from NASA's Wallops Flight Facility at 14:08 EST on Friday November 2, 2007.

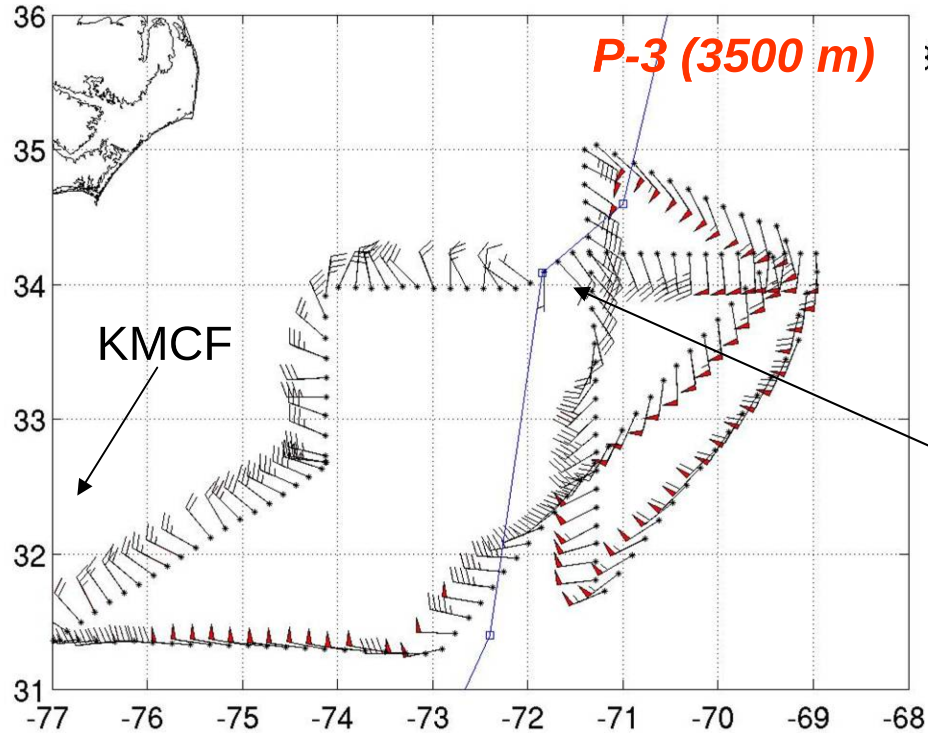
Mission endurance was 17 hours 27 minutes and resulted in 7.5 hours of data collection in the core of the hurricane at altitudes less than 100m.

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.

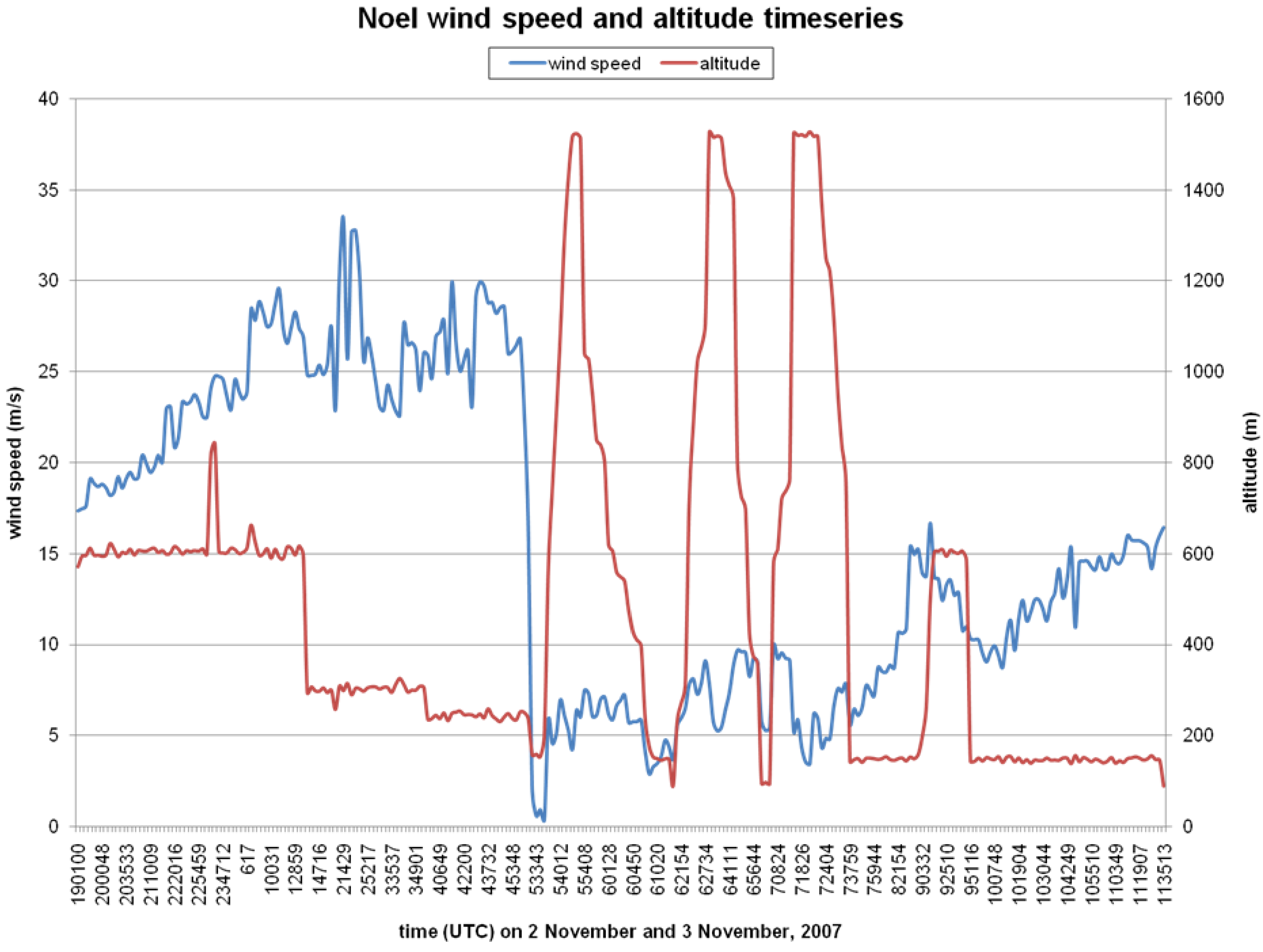
Near the center, UAS altitude was ~150m.



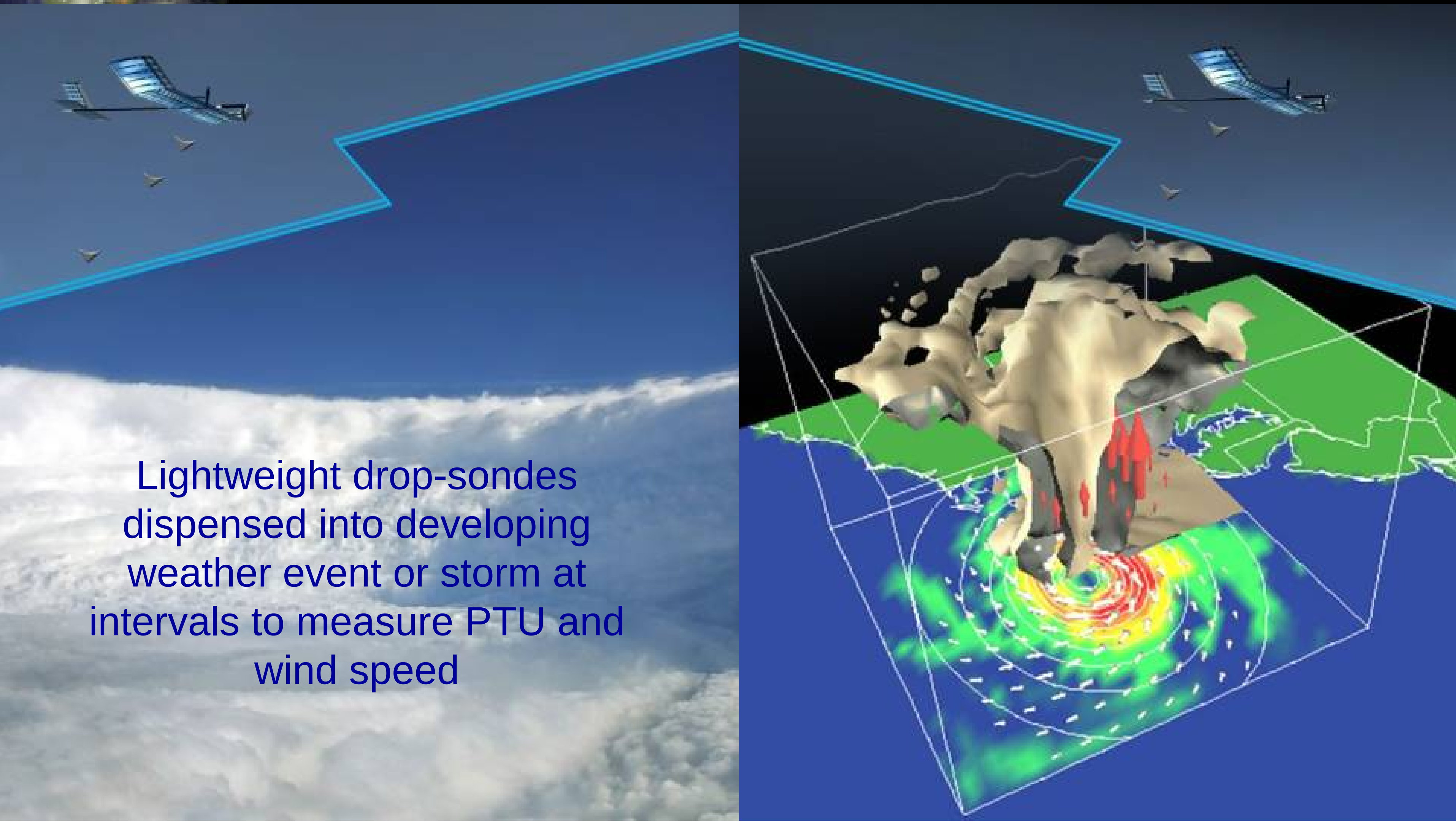


"Eye" loitering with vertical soundings (90-1500 m)

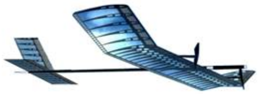
Rendezvous with P-3 at storm center 0525 UTC


Noel wind speed and altitude timeseries
wind speed
altitude
wind speed (m/s)
altitude (m)
0
5
10
15
20
25
30
35
40
0
200
400
600
800
1000
1200
1400
1600
190100
200048
203533
211009
222016
225459
234712
617
10031
12859
14716
21429
25217
33537
34901
40649
42200
43732
45348
53343
54012
55408
60128
60450
61020
62154
62734
64111
65644
70824
71826
72404
73759
75944
82154
90332
92510
95116
100748
101904
103044
104249
105510
110349
111907
113513
time (UTC) on 2 November and 3 November, 2007

HALE: light - in-situ measurement using drop-sondes

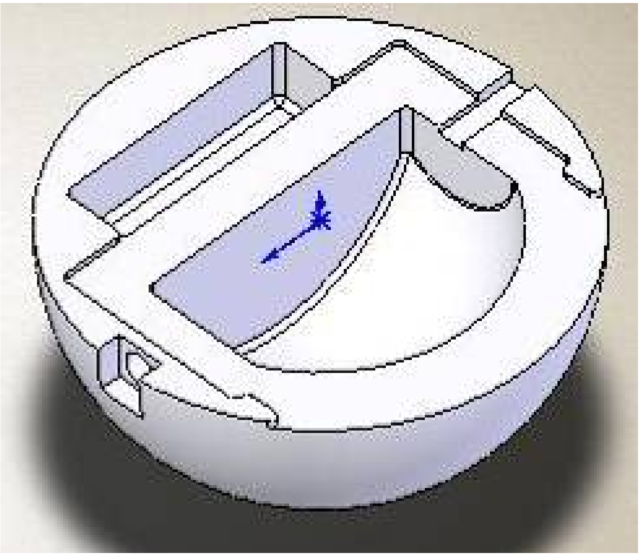


Lightweight drop-sondes dispensed into developing weather event or storm at intervals to measure PTU and wind speed

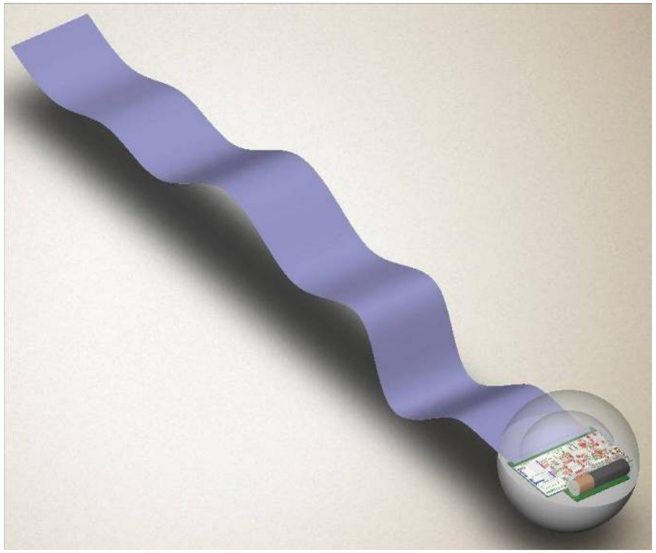


Dropsonde Mechanical Design

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



- Populated housing with attached streamer
- 38.3 grams



Dropsonde Electronics Specs

Component	Mass (g)	Voltage (V)	Current (mA)
Packaging – housing & streamer	6.7	--	--
Circuit board, microprocessor, transmitter	12.2	3.0 - 3.6	0.015 – 28.9
Pressure Sensor	0.1	3 – 6	0.1 – 1.0
Humidity Sensor	0.1	2.4 – 5.5	0.0 – 0.5
Temperature Sensor	0.1	3.3	<1.0
GPS	2.1	2.7 – 3.3	39
Antennas	7	--	--
Battery	10	3.6	1200 mAh
Total	**38.3g**		**17 – 27 hrs**

Global Hawk Test Planning
NASA Dryden Flight Research Center (DFRC)

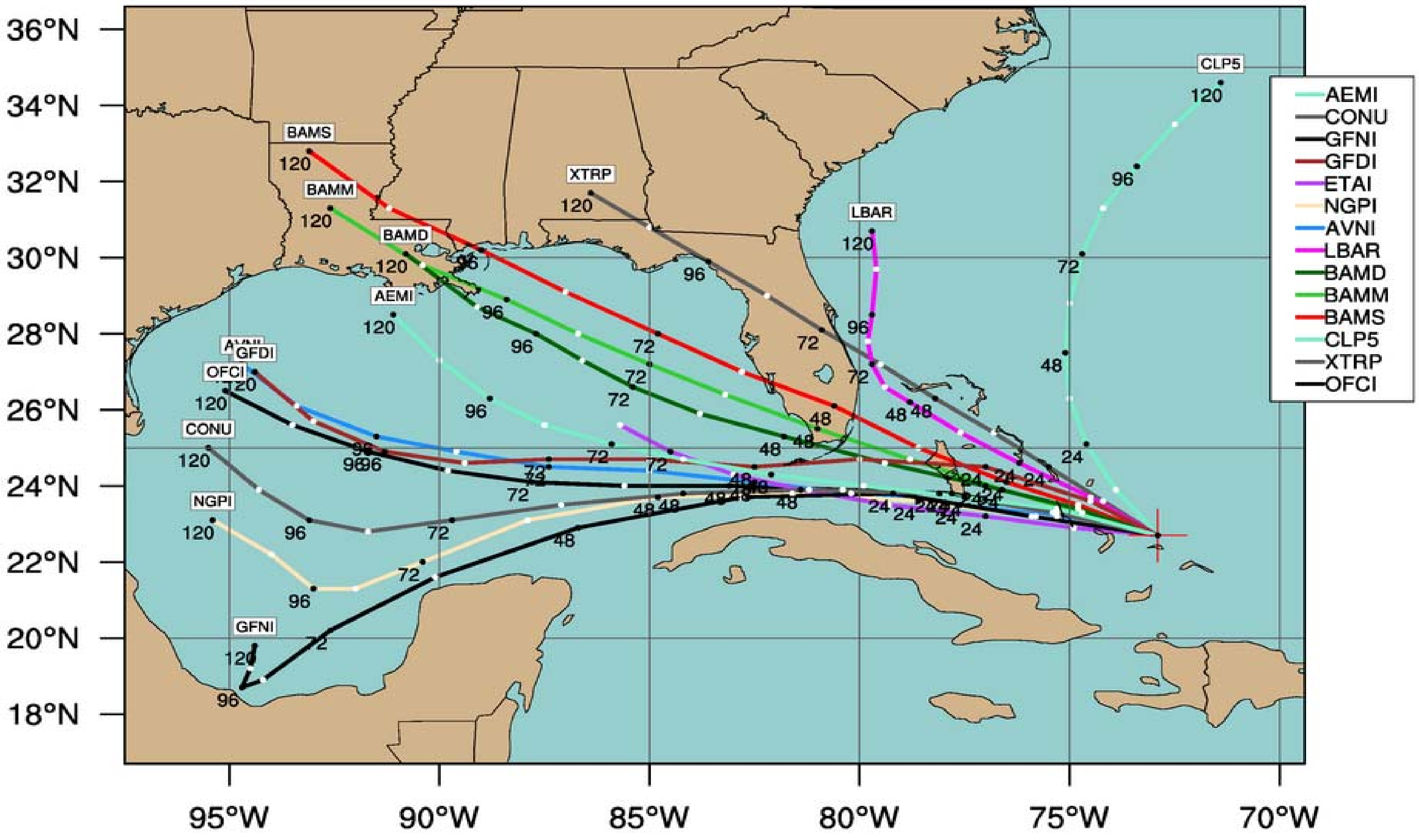
- Two Global Hawks have been acquired by NASA DFRC, CA and will be used, in part, for earth science research and application studies
- NOAA (with NASA and NCAR) is building a dropsonde system (100/flt); dropsonde sys. development coordinated by D. Fahey (NOAA)

WISDOM (Weather In- Situ Deployment Optimization Method): **Deploying horizontal balloon sondes in an optimum manner around weather disturbances.**

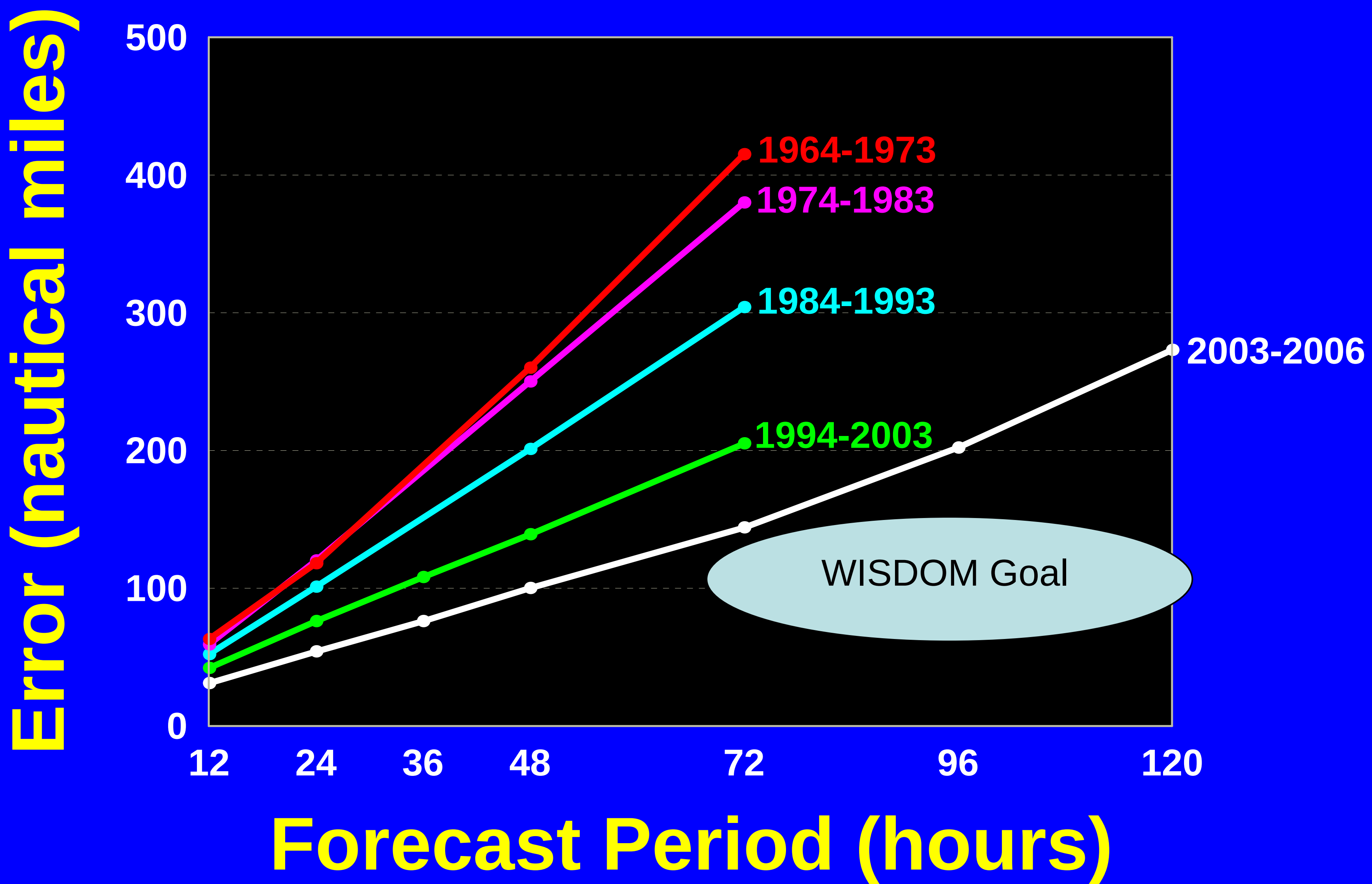
Objective: Improve hurricane track prediction in the 3 to 6 day period prior to landfall.

AL18

Early-cycle track guidance valid 0000 UTC, 19 September 2005



NATIONAL HURRICANE CENTER ATLANTIC TRACK FORECAST ERRORS



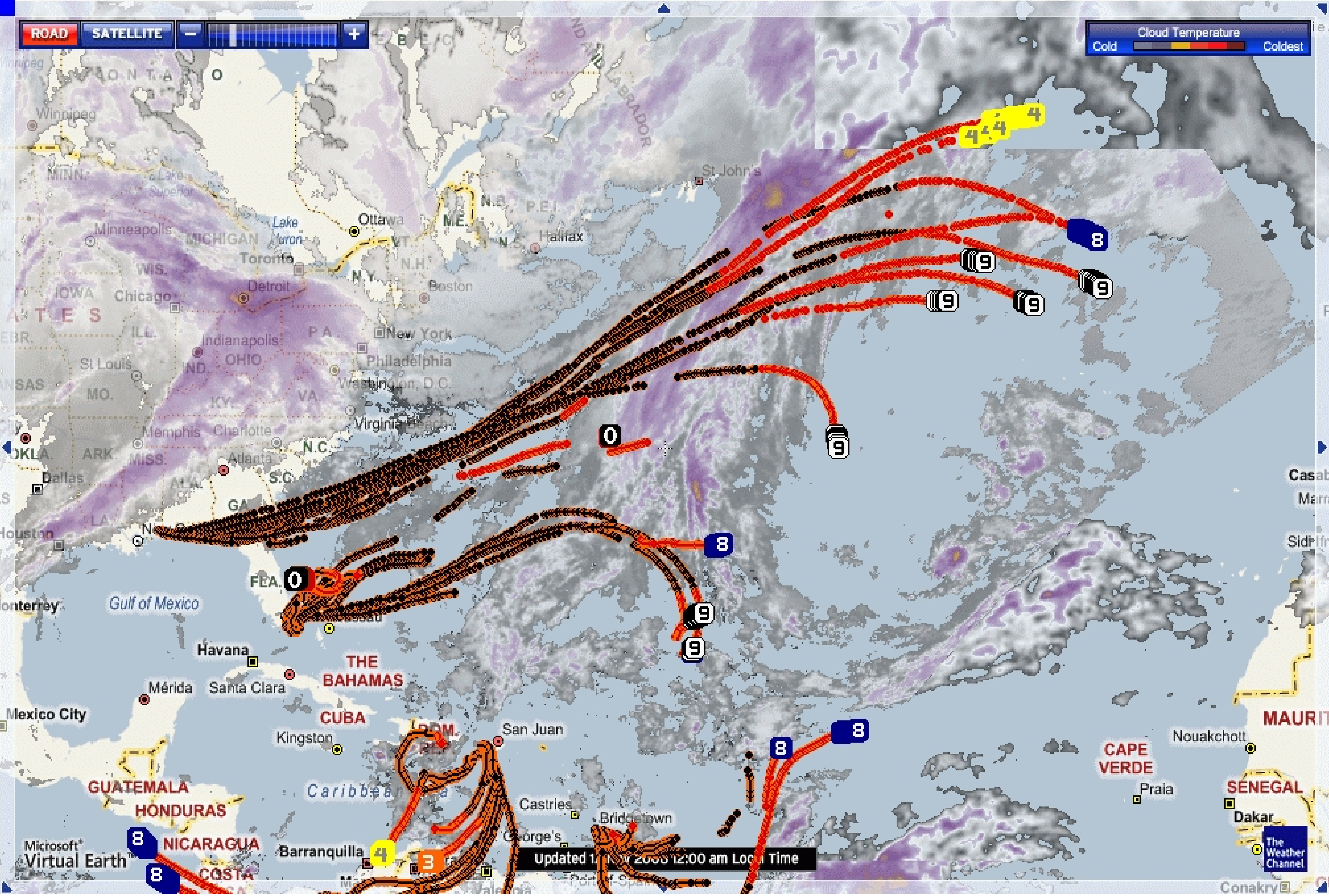
17 May 2007

Students launching a WISDOM balloon/payload during the October 6, 2008 training session in Miami.

ETC's GPS RF Tag:

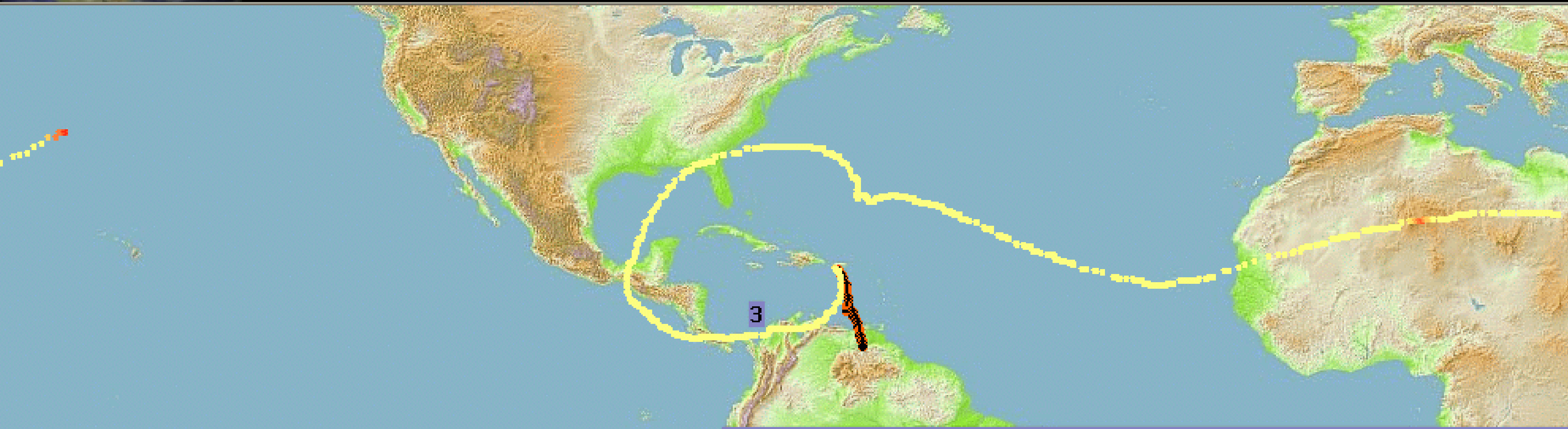
- Deployed with the Tetroon balloons to collect location, wind data (.3 watts)

- 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

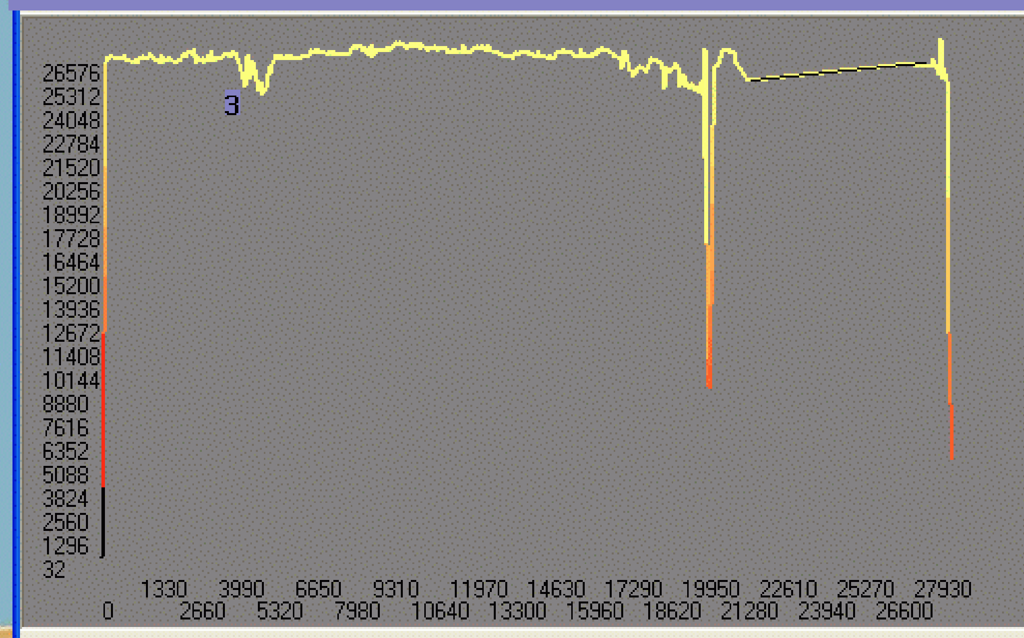


WISDOM Balloon W000054 26K feet

3 day track Predict 11/07 12z GFS
11/07/2008 14:50z first data
11/27/2008 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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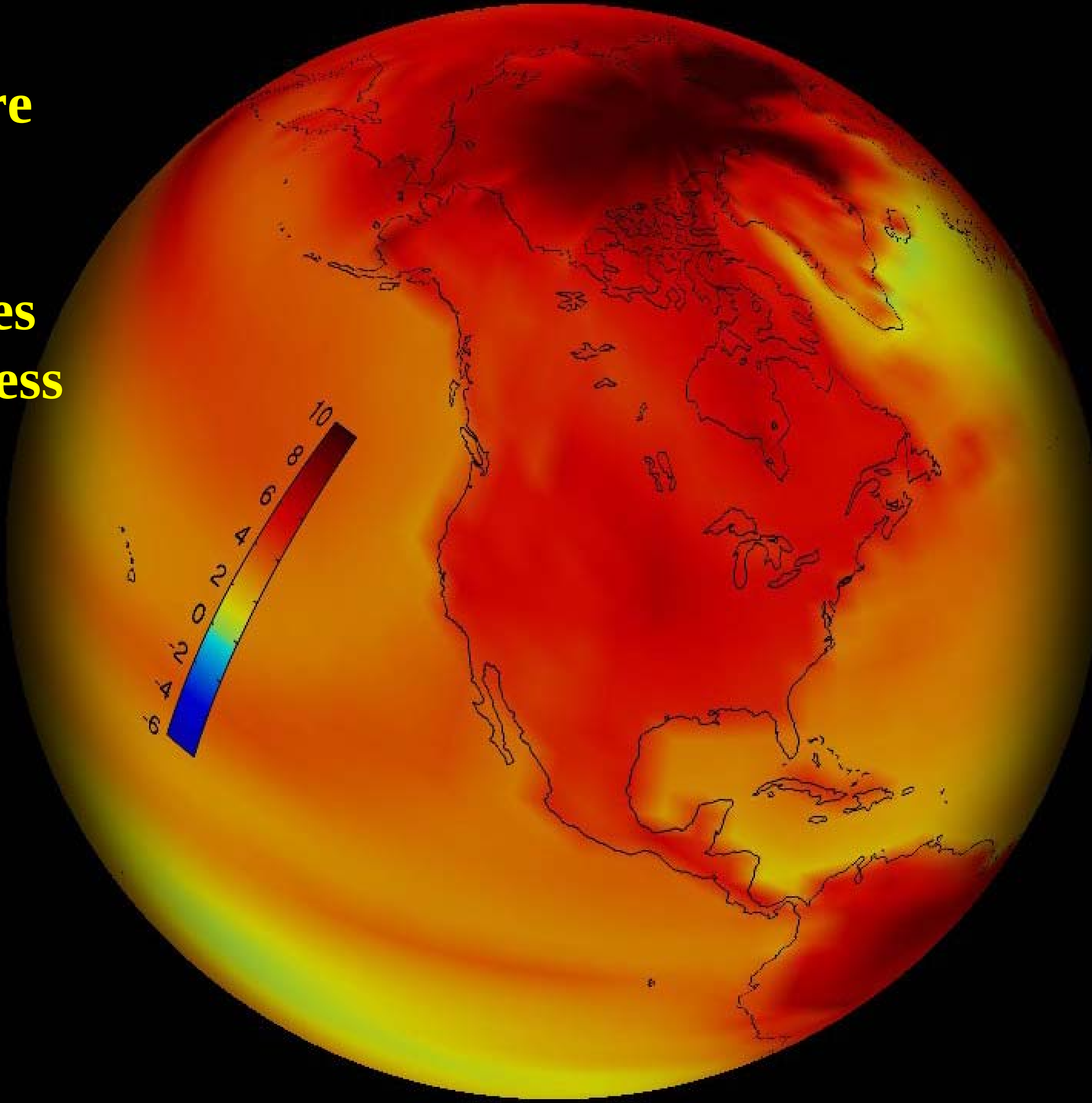
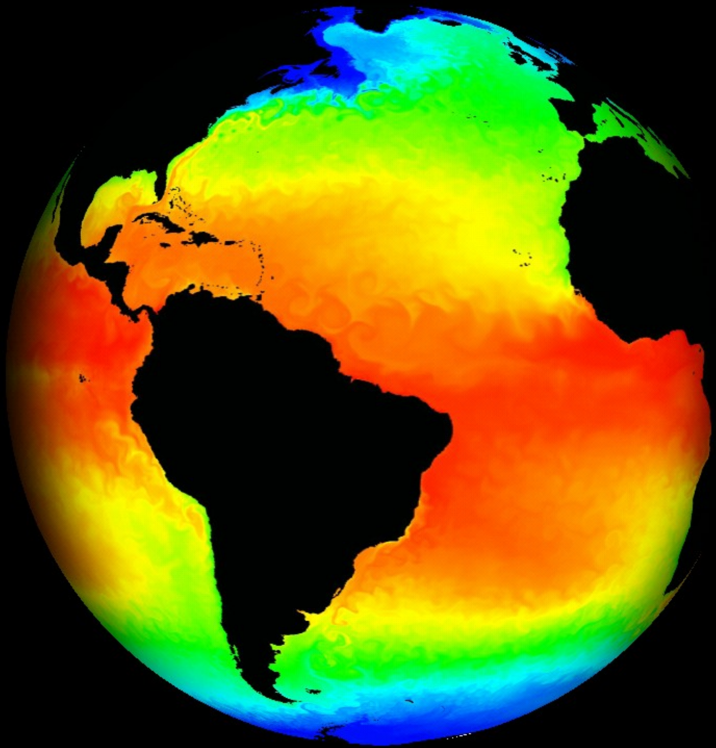
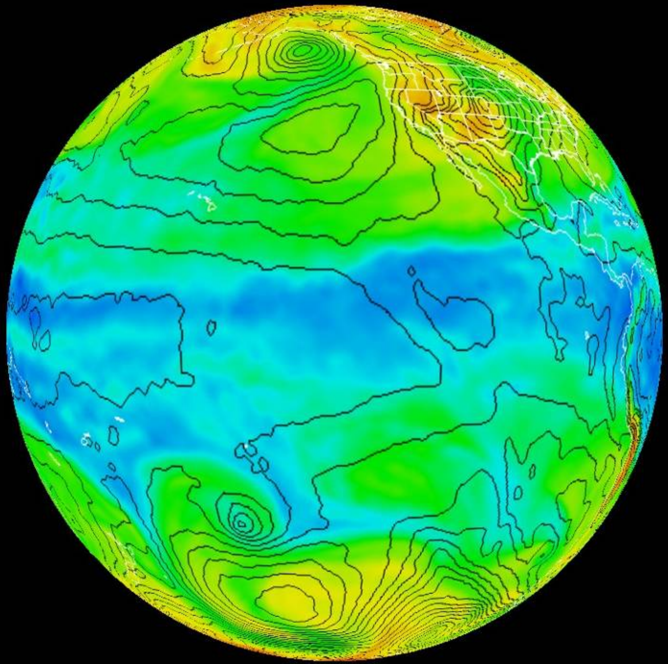
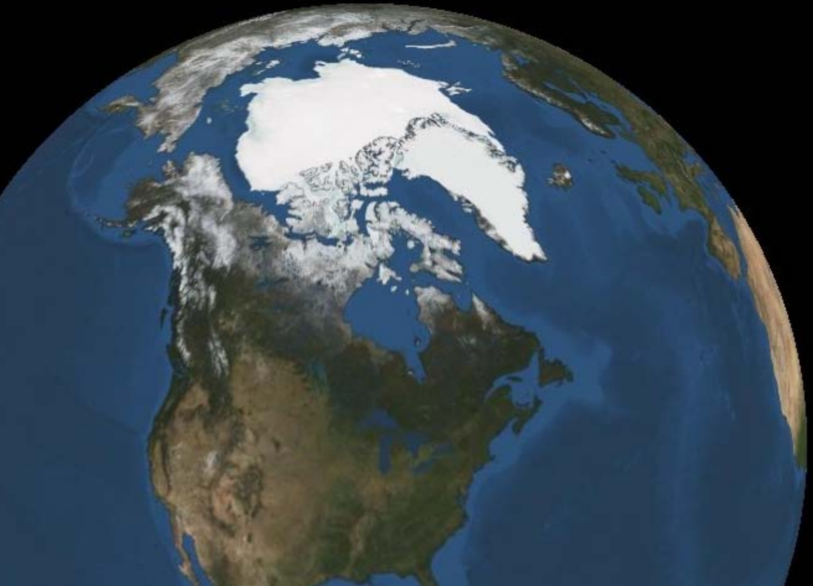
Temperature rise: End of century temperatures with “business as usual” scenario.

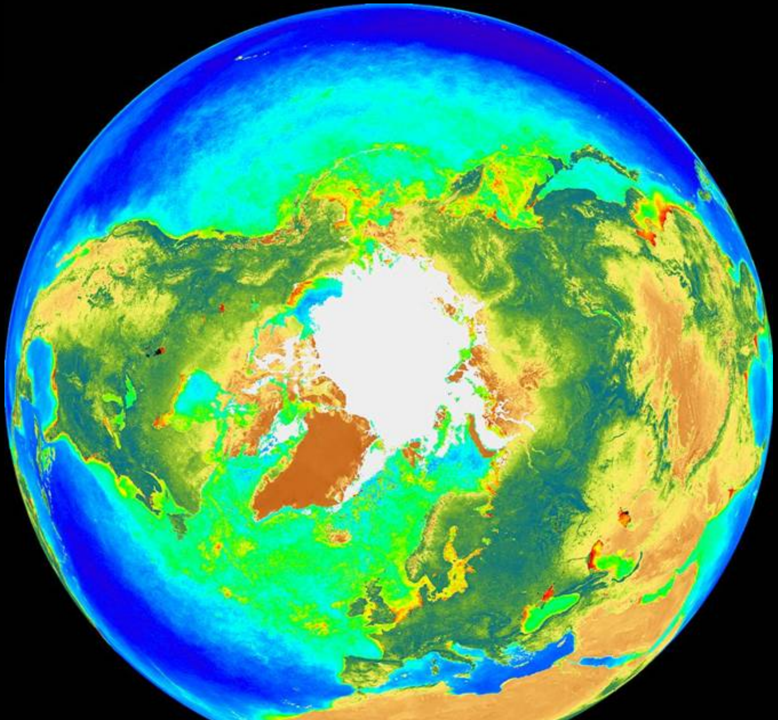




Earth System models will allow improved prediction of long term climate.



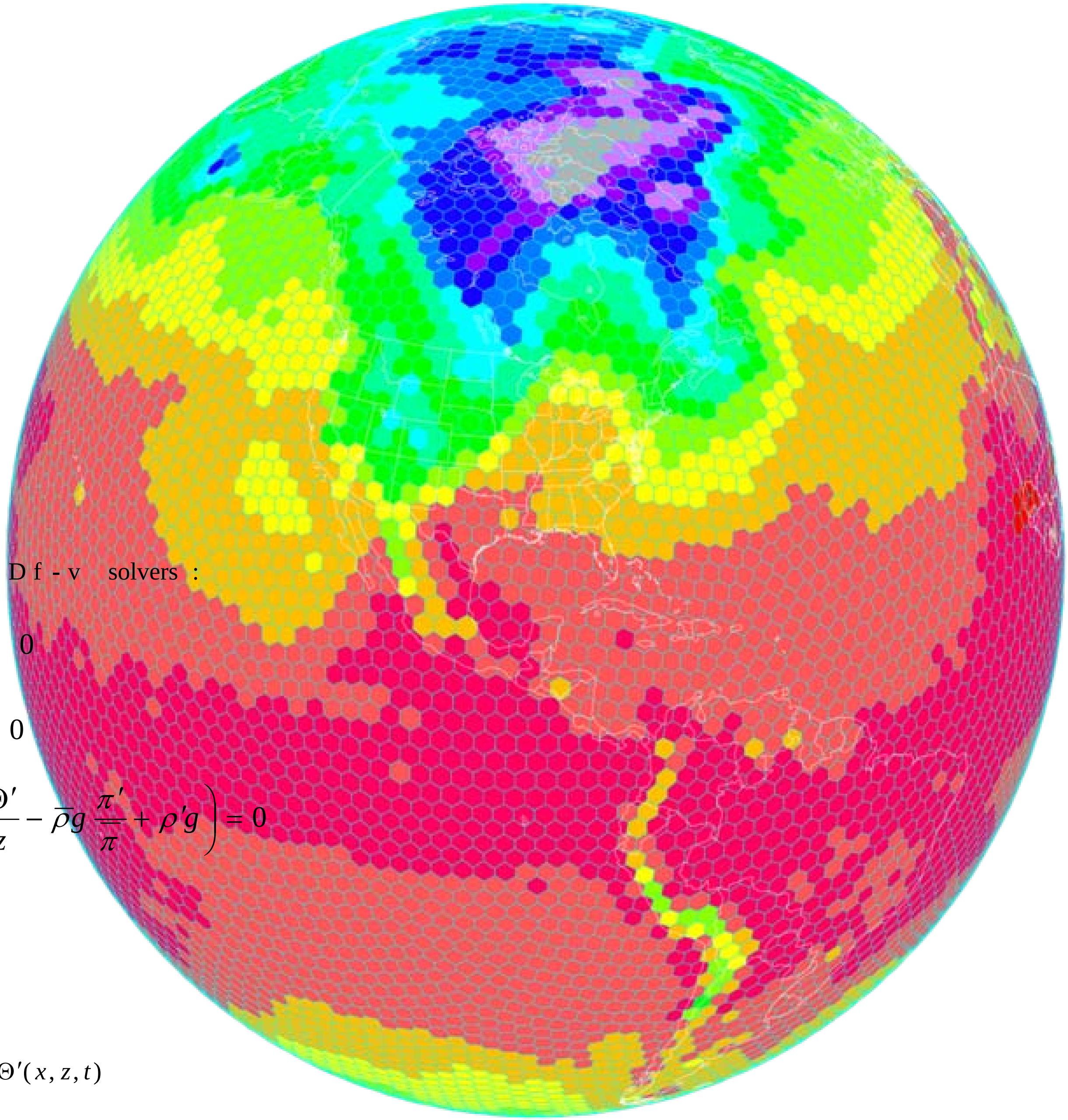




Nonhydrostatic Icosahedral Model

Alexander E. MacDonald

Jin-Luen Lee



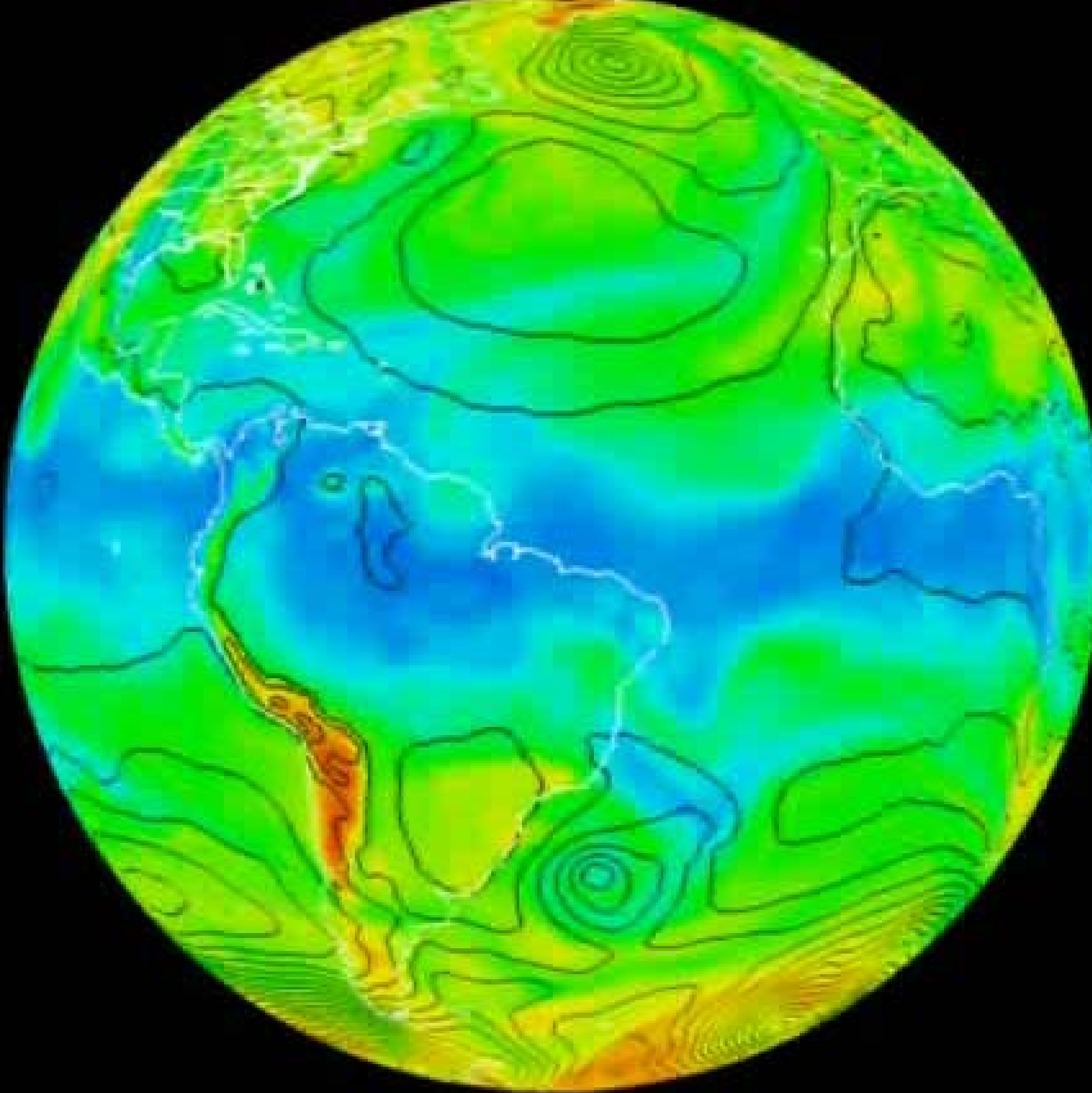
Nonhydrostatic GEs in flux form on Z - coord with 3 - D f - v solvers :

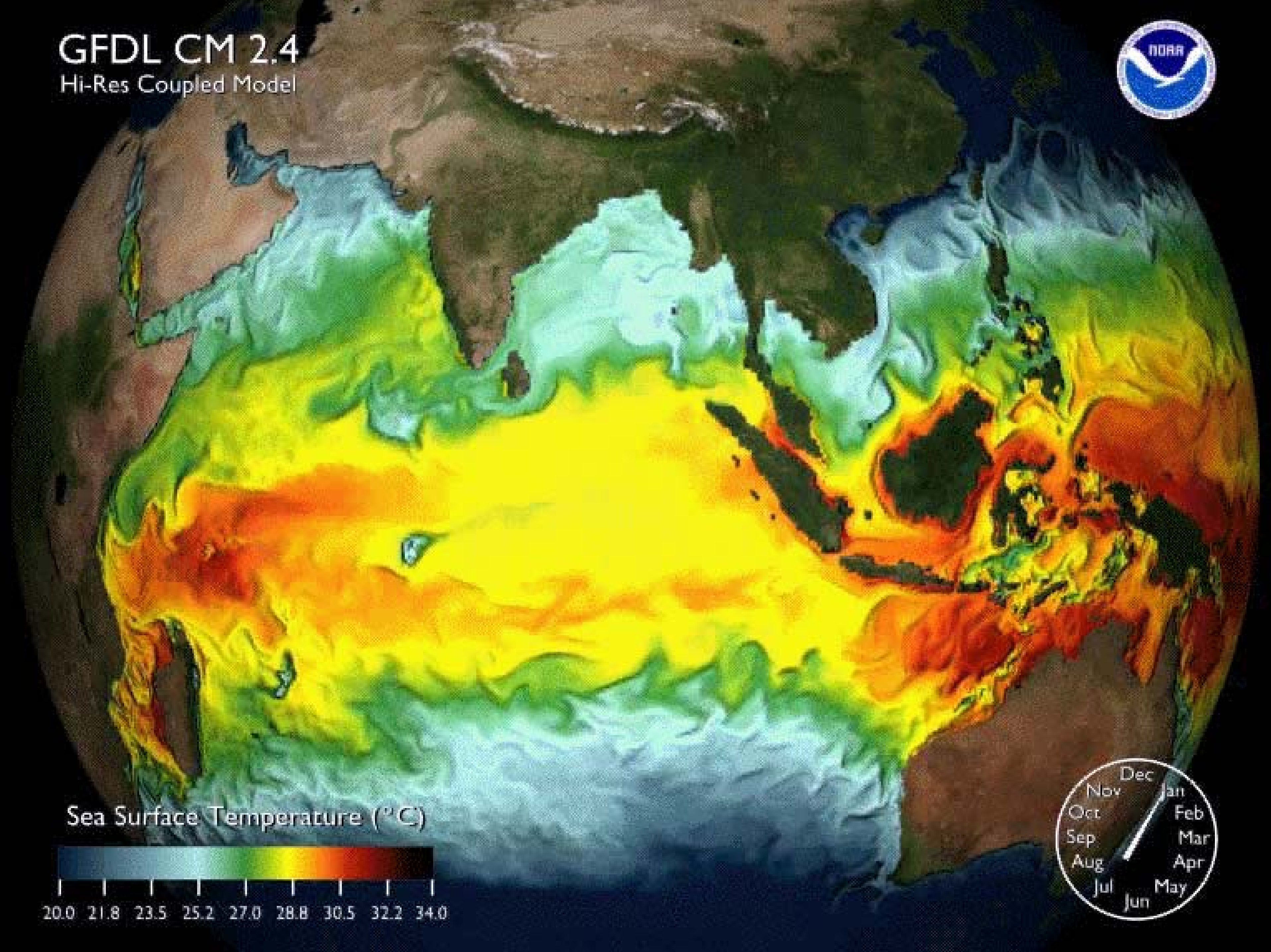
$$
\begin{cases}
\dfrac{\partial U}{\partial t} + \dfrac{\partial (uU)}{\partial x} + \dfrac{\partial (vU)}{\partial y} + \dfrac{\partial (wU)}{\partial z} + \gamma R \pi \dfrac{\partial \Theta'}{\partial x} = 0 \\
\dfrac{\partial V}{\partial t} + \dfrac{\partial (uV)}{\partial x} + \dfrac{\partial (vV)}{\partial y} + \dfrac{\partial (wV)}{\partial z} + \gamma R \pi \dfrac{\partial \Theta'}{\partial y} = 0 \\
\dfrac{\partial W}{\partial t} + \dfrac{\partial (uW)}{\partial x} + \dfrac{\partial (vW)}{\partial y} + \dfrac{\partial (wW)}{\partial z} + \left(\gamma R \pi \dfrac{\partial \Theta'}{\partial z} - \bar{\rho} g \dfrac{\pi'}{\pi} + \rho' g \right) = 0 \\
\dfrac{\partial \Theta'}{\partial t} + \dfrac{\partial (u\Theta)}{\partial x} + \dfrac{\partial (v\Theta)}{\partial y} + \dfrac{\partial (w\Theta)}{\partial z} = \dfrac{\Theta \dot{H}}{C_p T} \\
\dfrac{\partial \rho}{\partial t} + \dfrac{\partial (u\rho)}{\partial x} + \dfrac{\partial (v\rho)}{\partial y} + \dfrac{\partial (w\rho)}{\partial z} = 0.
\end{cases}
$$

$$(U, W, \Theta, \rho) = (\rho u, \rho w, \rho \theta, \rho); \quad \Theta(x, z, t) = \bar{\Theta}(z) + \Theta'(x, z, t)$$

$$\rho(x, z, t) = \bar{\rho}(z) + \rho'(x, z, t); \qquad \nabla p = \gamma R \pi \nabla \Theta$$

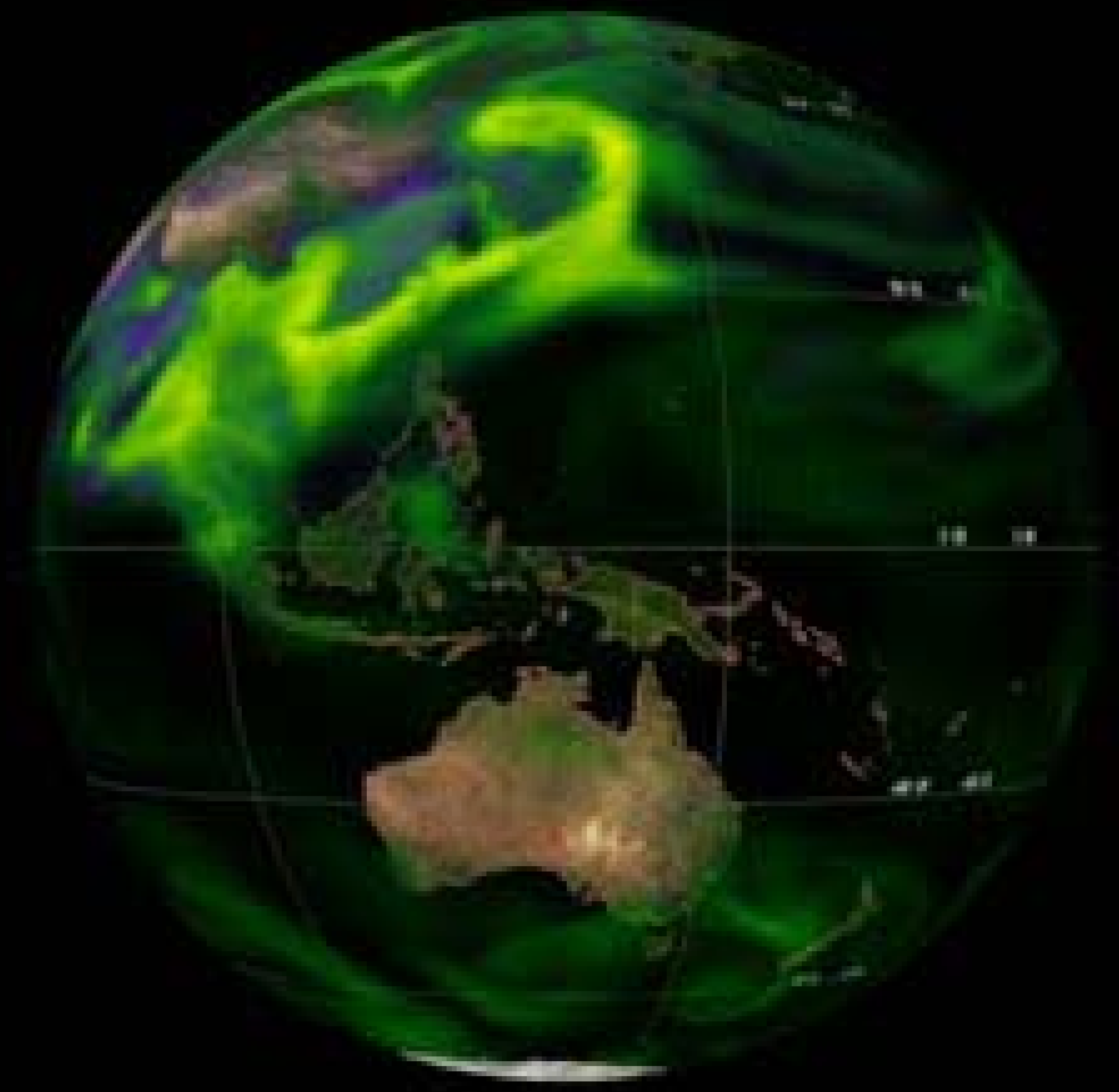
$$p = p_0 \left(\frac{R\Theta}{p_0} \right)^{\gamma}; \quad \pi = \left(\frac{p}{p_0} \right)^{\kappa}$$




GFDL CM 2.4
Hi-Res Coupled Model
NOAA
Sea Surface Temperature (°C)
20.0 21.8 23.5 25.2 27.0 28.8 30.5 32.2 34.0
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

Satellites are excellent for column integrated constituents.

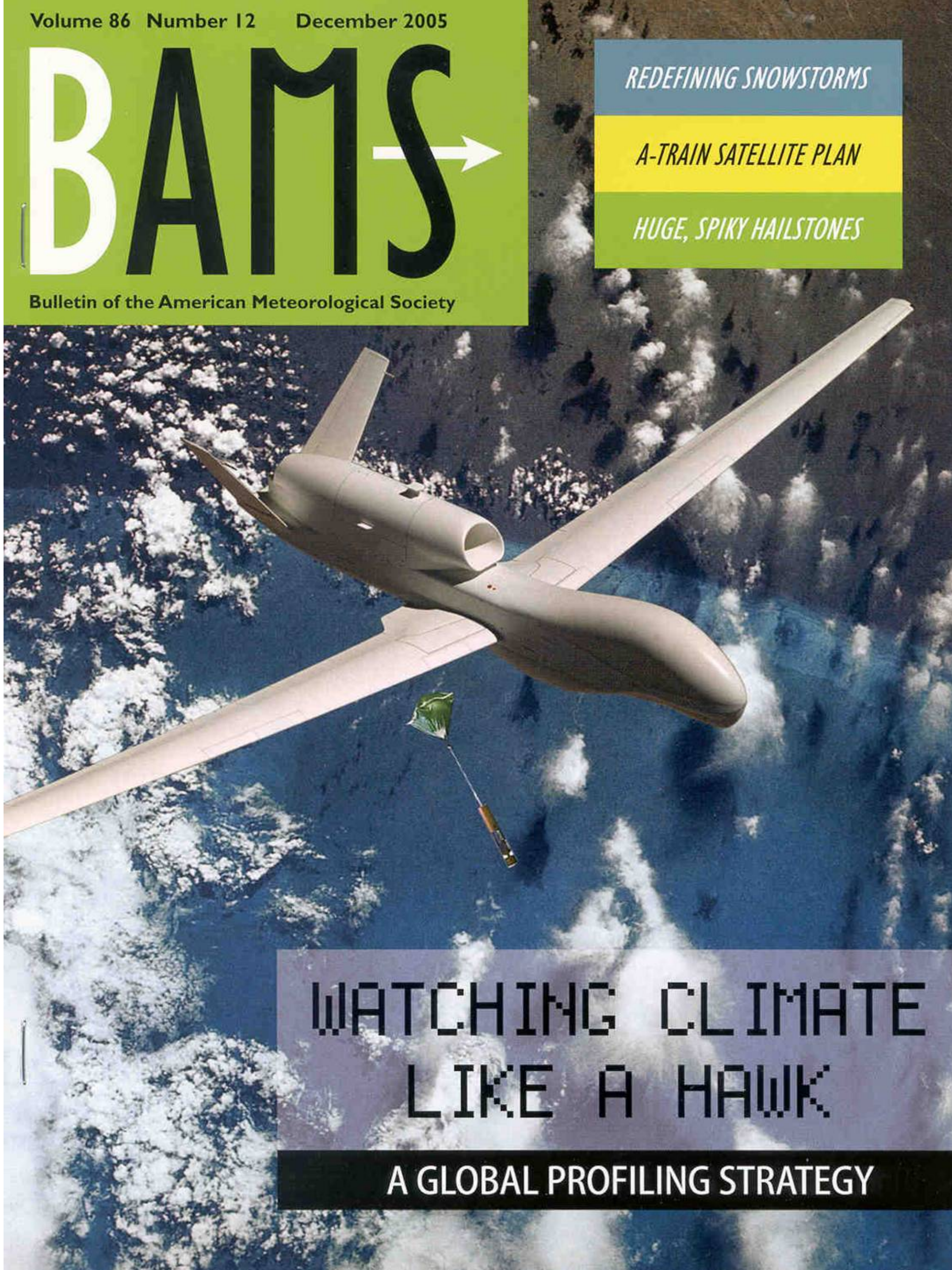
UAS allow us to determine the vertical distribution of the constituent: PROFILES.



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**



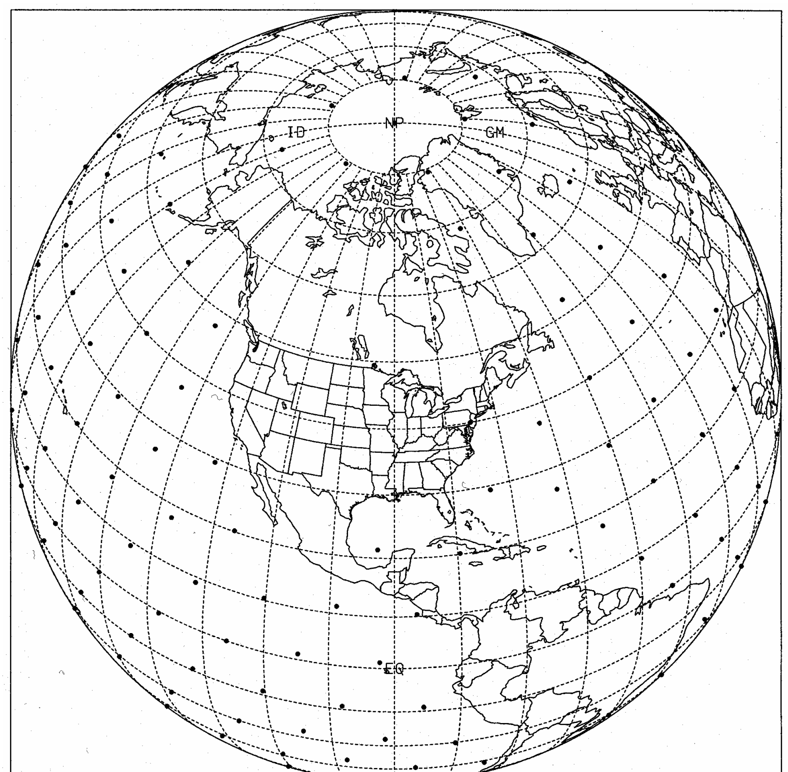
Proposed: Global Unified Profiling System

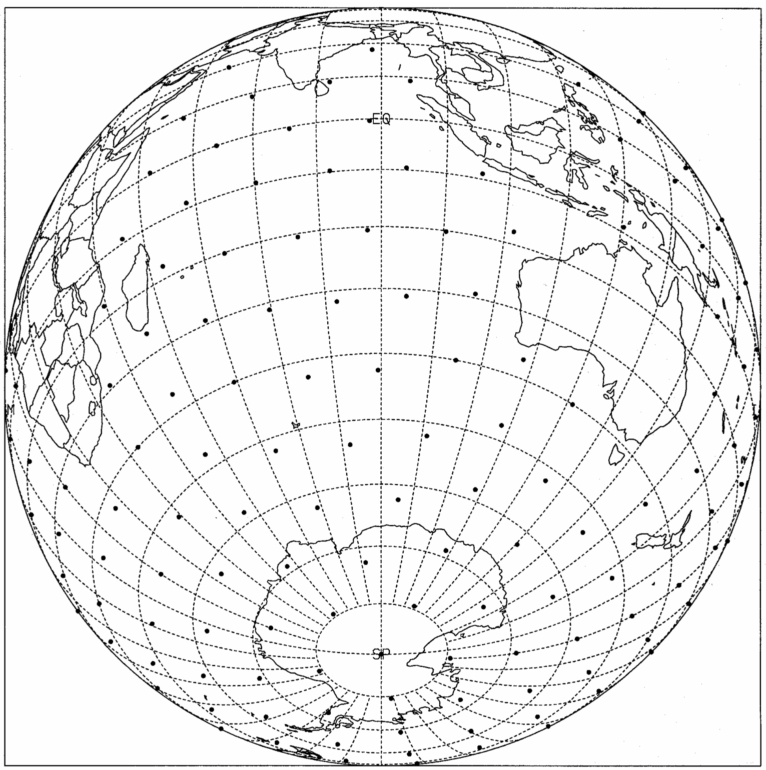
Climate:

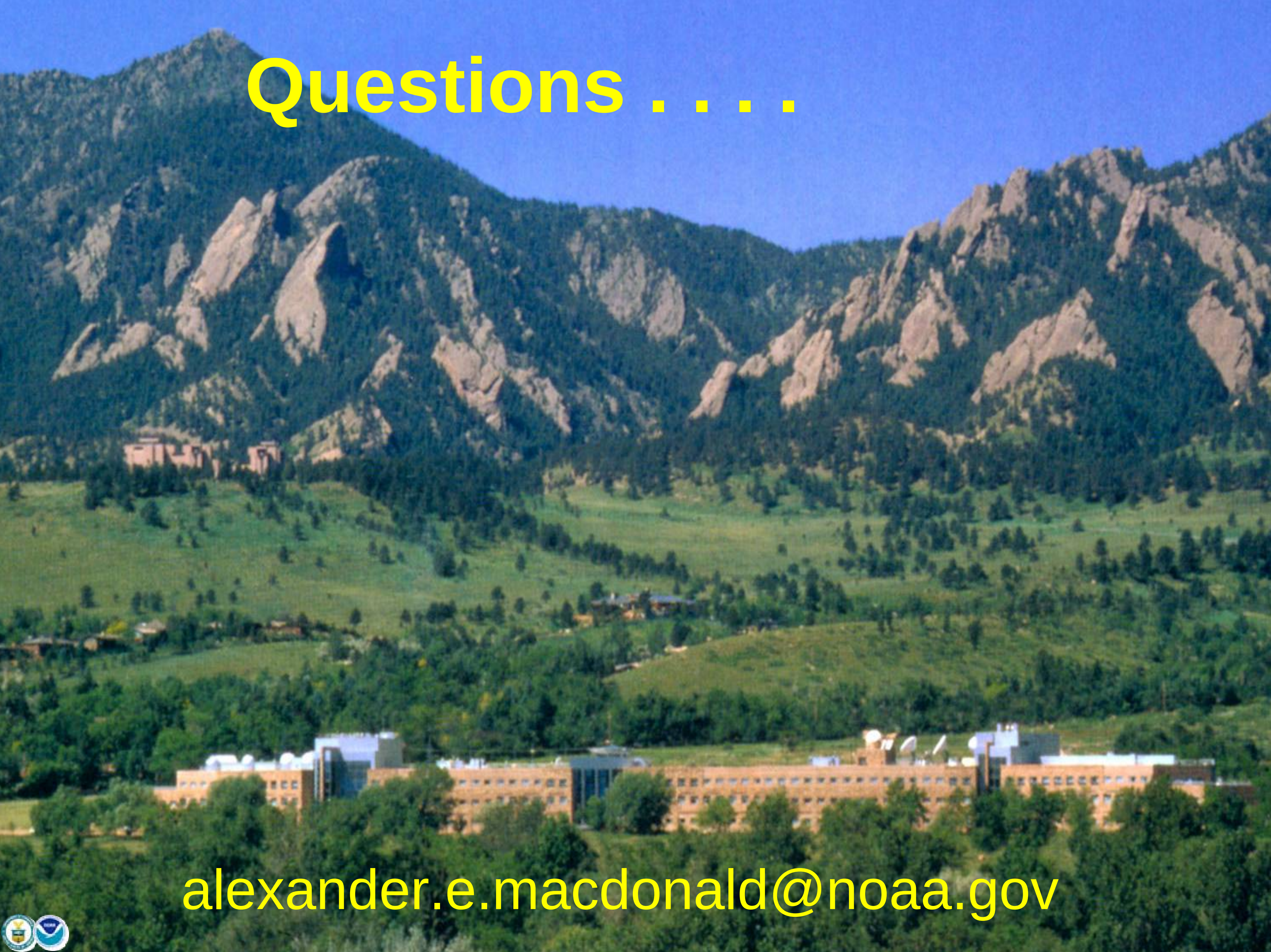
* Accurate climate sondes at every "climate point" (240 points equally distributed over oceans and polar regions) every three days.

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

* Buoys or AXBT's at each ocean point.






Questions . . . .
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