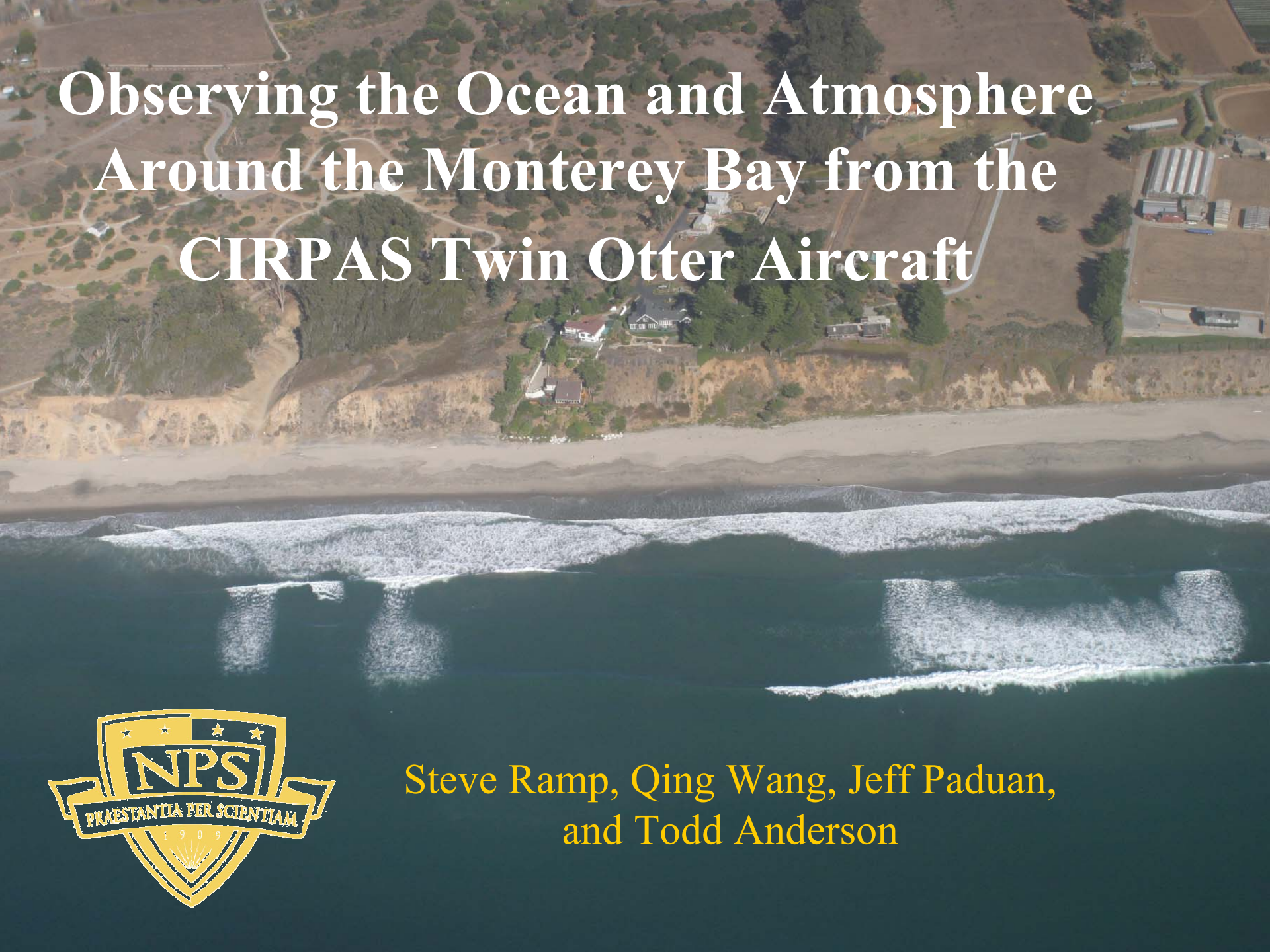
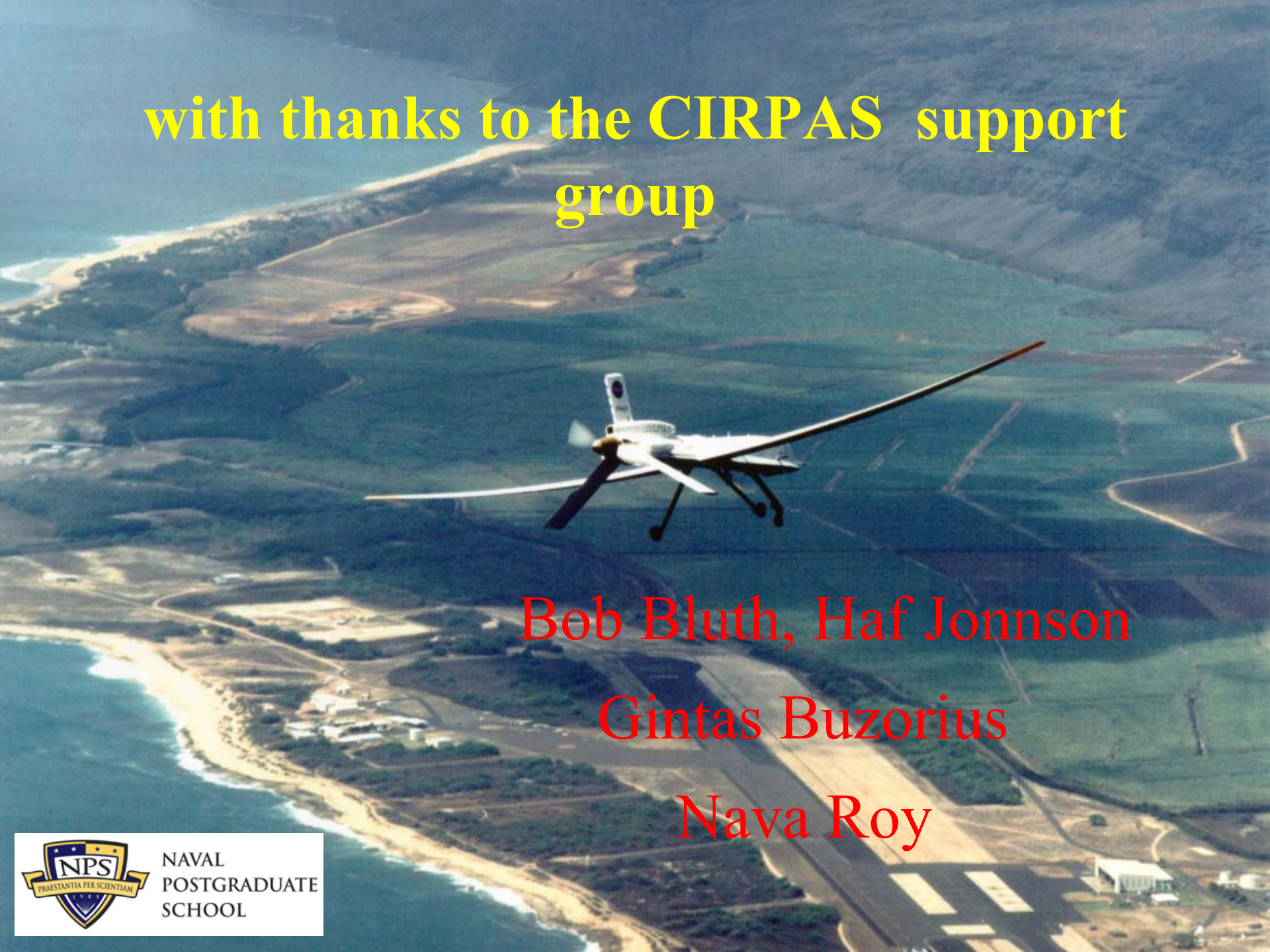
Observing the Ocean and Atmosphere Around the Monterey Bay from the CIRPAS Twin Otter Aircraft



Steve Ramp, Qing Wang, Jeff Paduan,
and Todd Anderson



with thanks to the CIRPAS support group

Bob Bluth, Haf Jonnson

Gintas Buzorius

Nava Roy

NAVAL POSTGRADUATE SCHOOL

Talk Outline

- Concept of operations
- Show some hardware (briefly)
- Highlight projects
- Show some results
- Moving to the future

A Typical Observing System Might Include..

- Aircraft Observations
- CODAR HF Radars [Surface Currents]
- Moored Buoys [Currents and Hydrography]
- AUVs [Gliders and Propeller-Driven]
- Networking [acoustic, wireless]
- Cabled Observatories
- Modeling and Data Assimilation
- Delivery of data and “information” to Users

De Havilland Twin Otter

Maximum endurance/altitude:

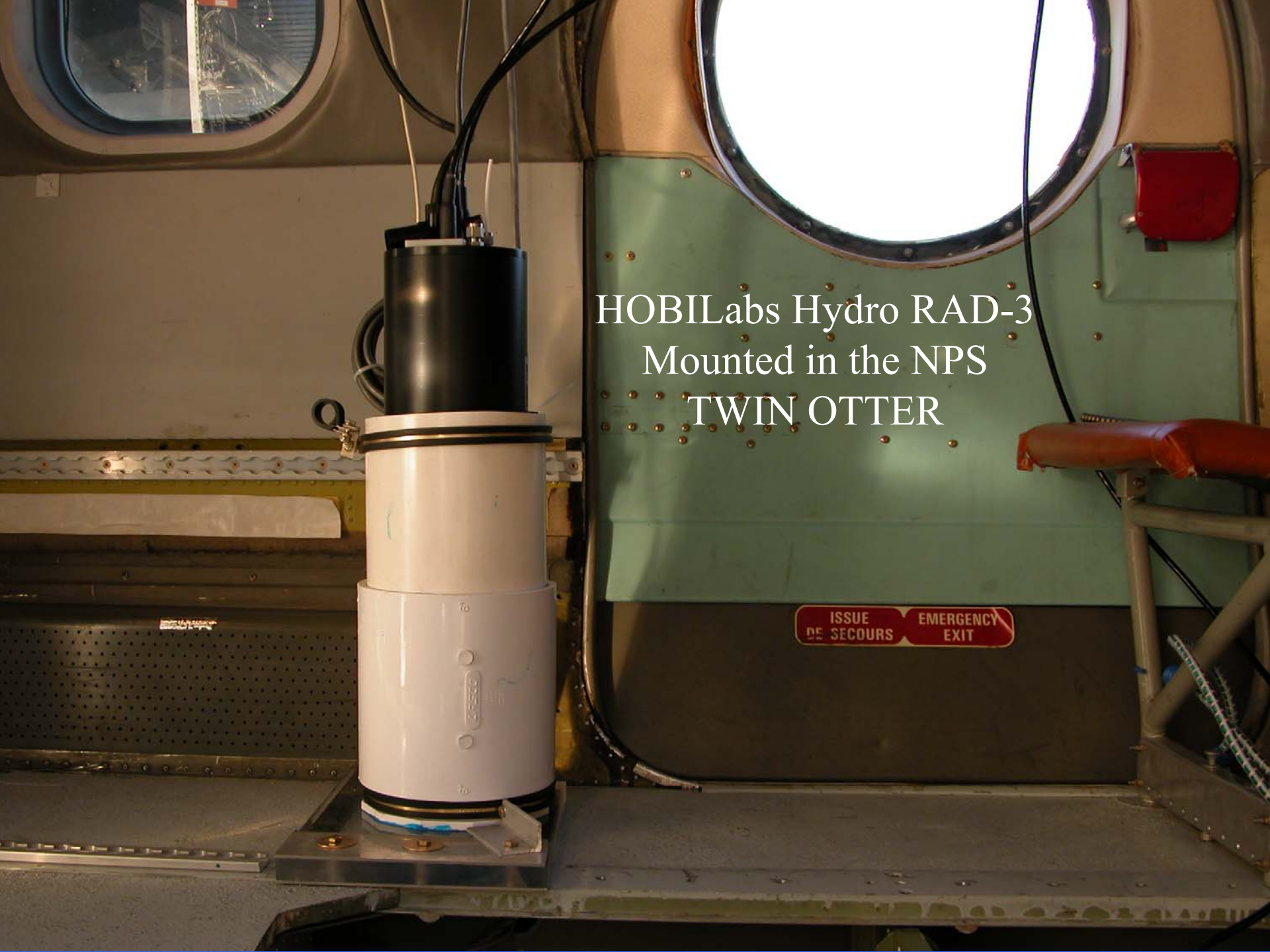
12 hours at 25,000 feet

Payload: 6000 lbs

Operational Speed Range: 70-160 KIAS

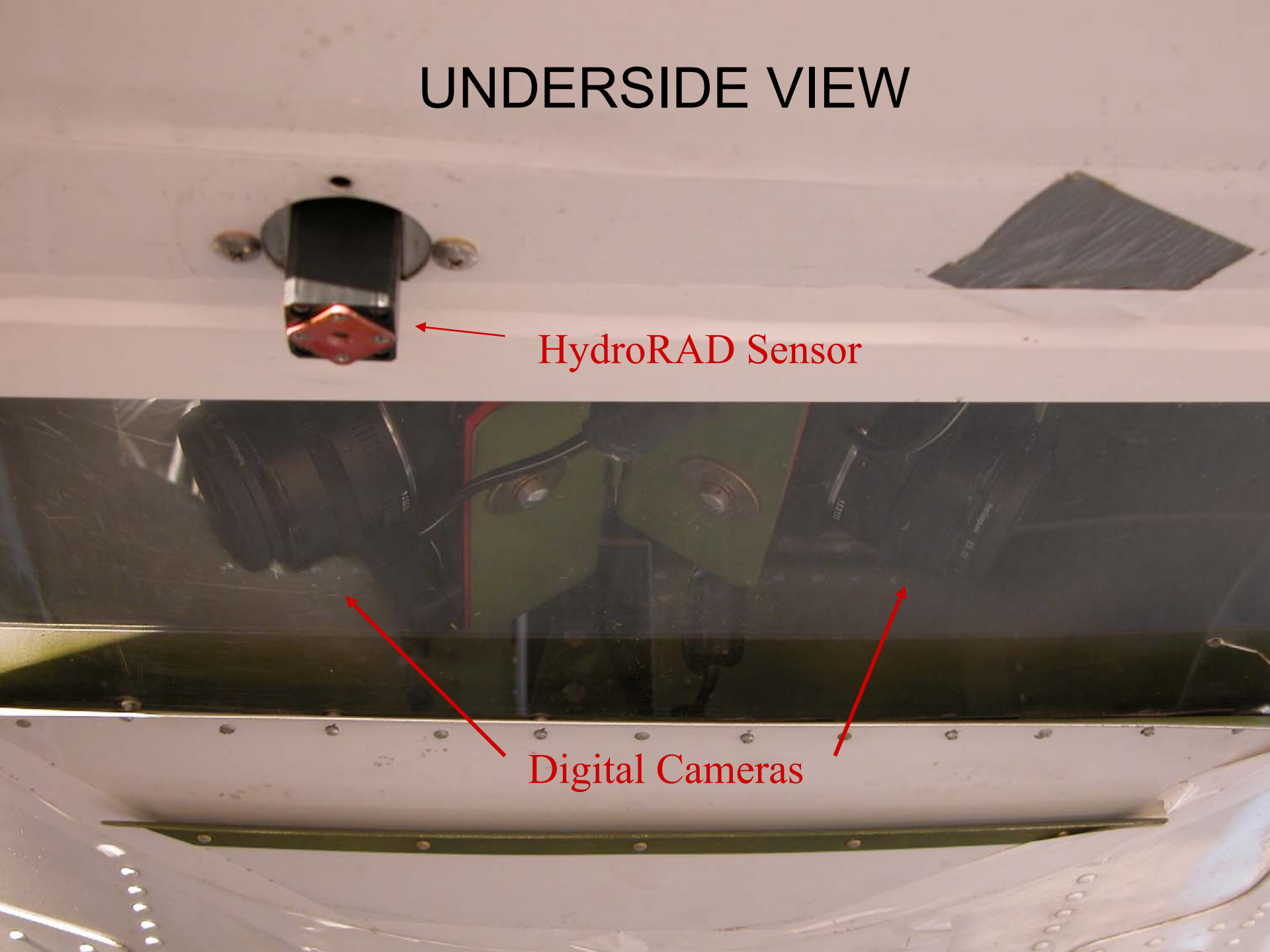
Aircraft Instrumentation

- ATMOSPHERE
  - Atmospheric Pressure
  - Air and Dew Point Temperature
  - Wind Speed and Direction
  - Turbulent Flux Measurements
  - Aerosols
- OCEAN
  - Sea Surface Temperature
  - Ocean Color
  - Sun Glint
  - Surface Wave Height


HOBILabs Hydro RAD-3
Mounted in the NPS
TWIN OTTER
ISSUE
EMERGENCY
EXIT


6 mp Digital Cameras
(Canon 10D)

UNDERSIDE VIEW



Projects:

- PAST: The Autonomous Ocean Sensing Network (AOSN) I and II

- FUTURE: The Adaptive Sampling and Prediction System (ASAP)

The AOSN-II Goals

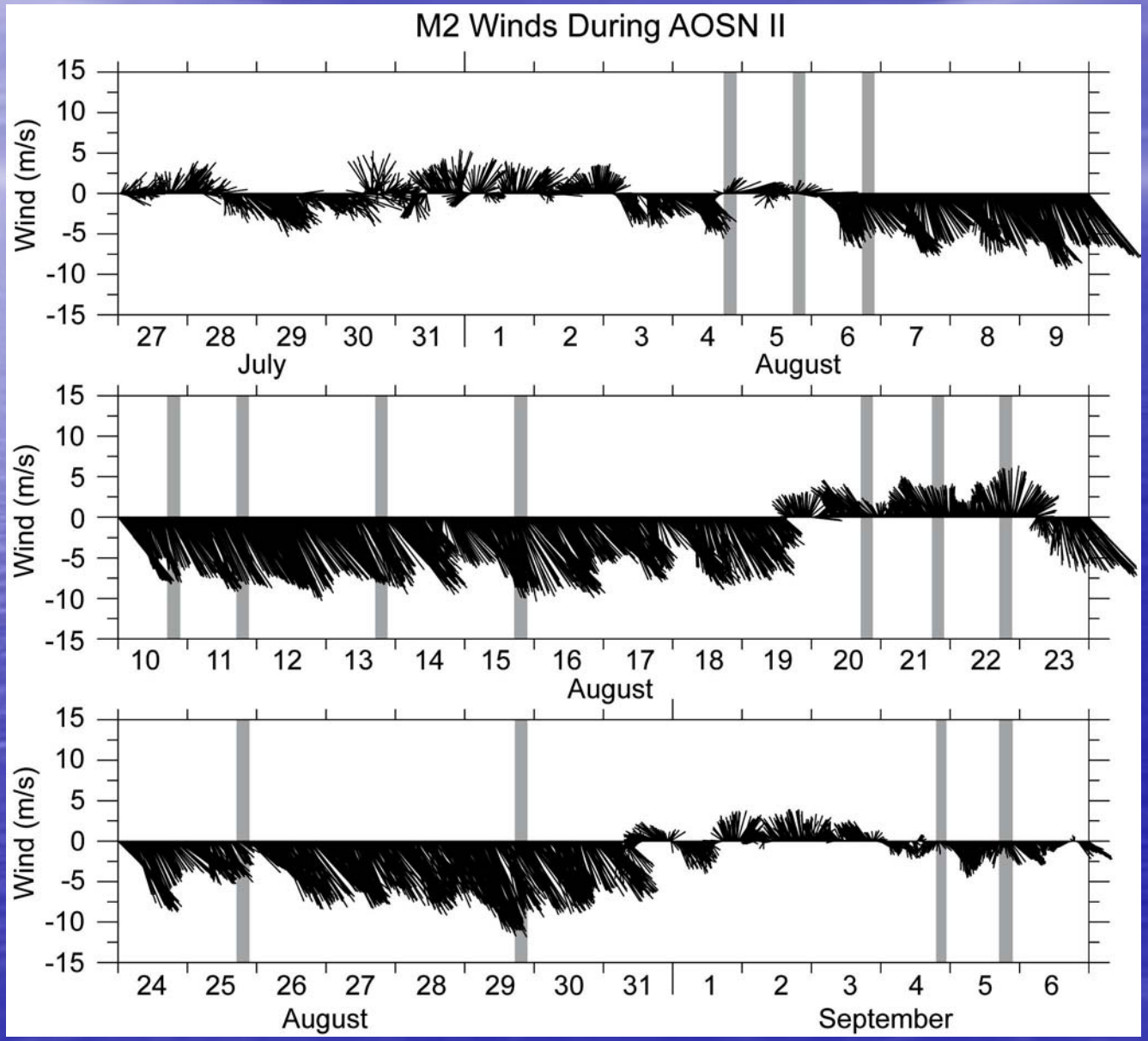
- Scientific: Understand and Predict Coastal Upwelling off Point Ano Nuevo
  - Upwelling/Downwelling
  - Biological Response

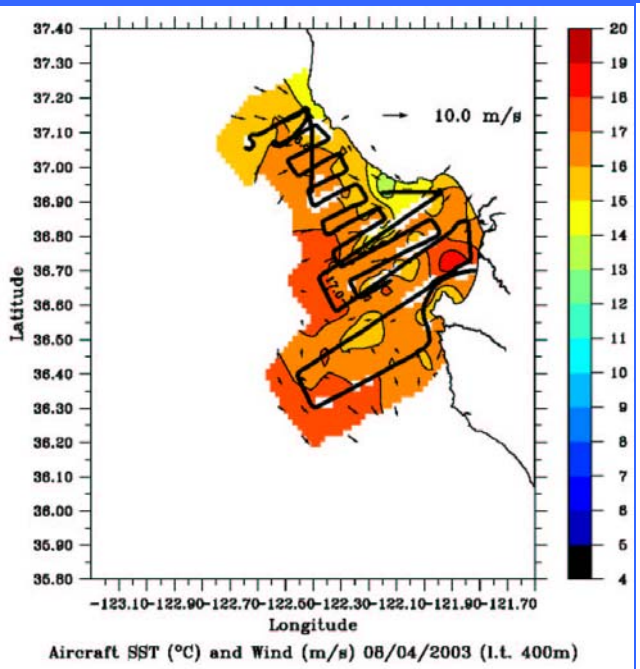
- Operational: Develop and use Adaptive Sampling Techniques to Focus Observational Effort
  - Feature Tracking vs. Repeat Grid Sampling
  - Optimize Limited Resources

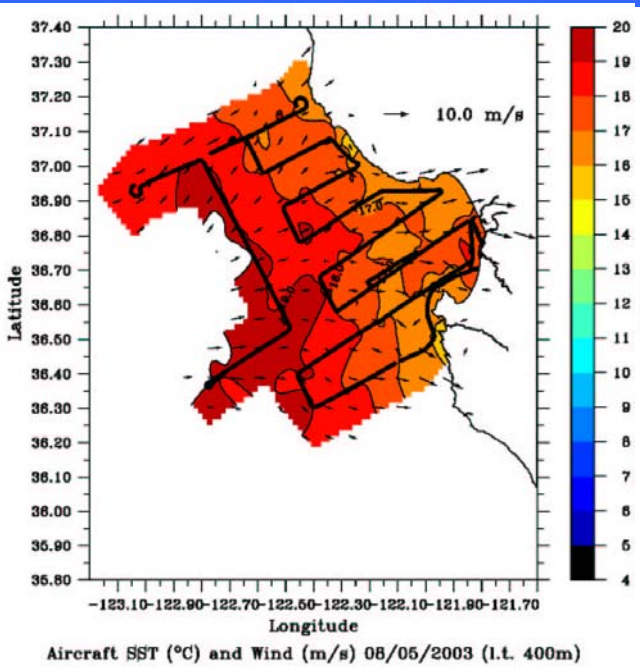
What Does Adaptive Sampling Mean?

- One: Collect Real-Time Data
- Two: Quality Control/Move to WWW
- Three: Assimilate into Numerical Models
- Four: Predict Tomorrow's Conditions
- Five: Blend Model Output: "Best" Forecast
- Six: Reposition Assets
- Seven: Collect Real-Time Data
- Eight: Repeat

WIND FORCING DURING AOSN-II SUMMER 2003




10.0 m/s
Latitude
Longitude
Aircraft SST (°C) and Wind (m/s) 08/04/2003 (l.t. 400m)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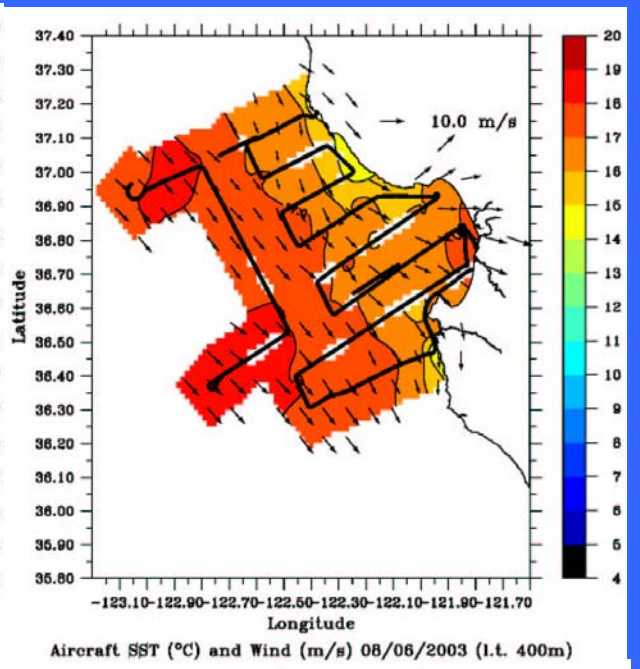
Aircraft SST (°C) and Wind (m/s) 08/05/2003 (l.t. 400m)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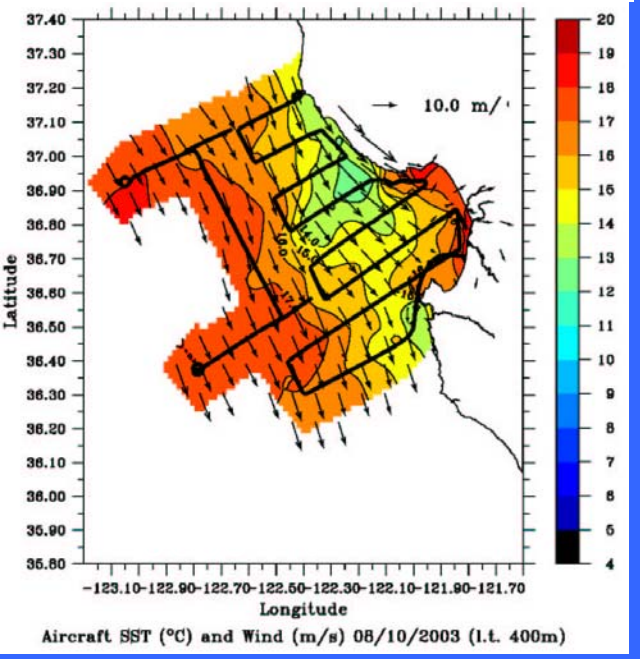
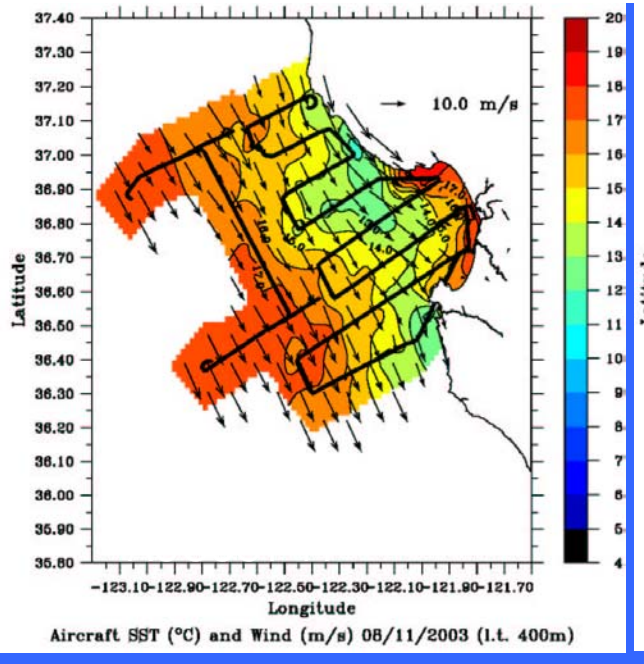
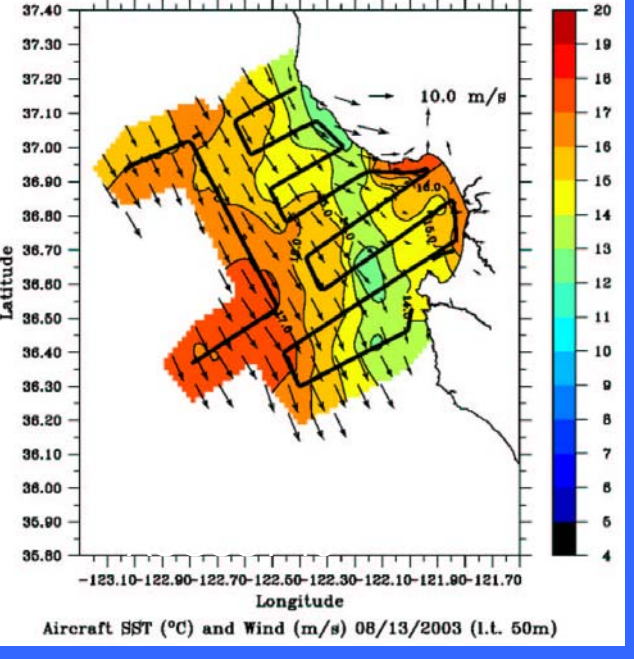
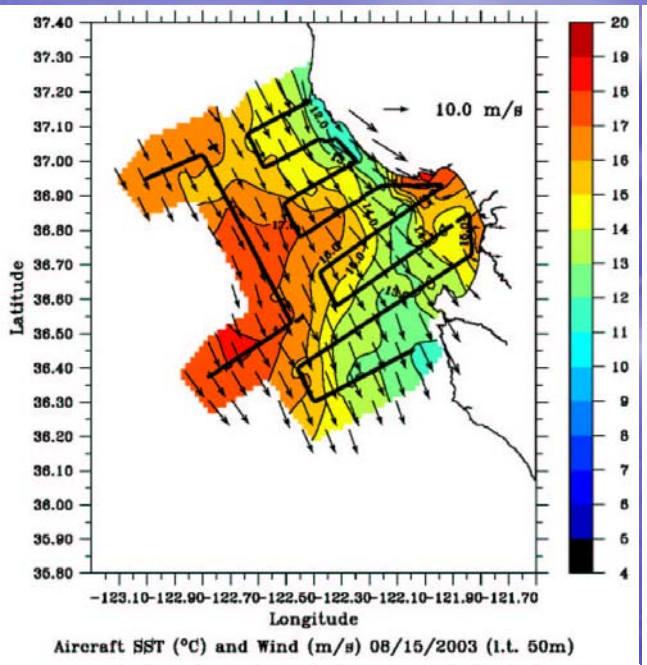
Aircraft SST (°C) and Wind (m/s) 08/06/2003 (l.t. 400m)


Latitude
Longitude
Aircraft SST (°C) and Wind (m/s) 08/10/2003 (l.t. 400m)

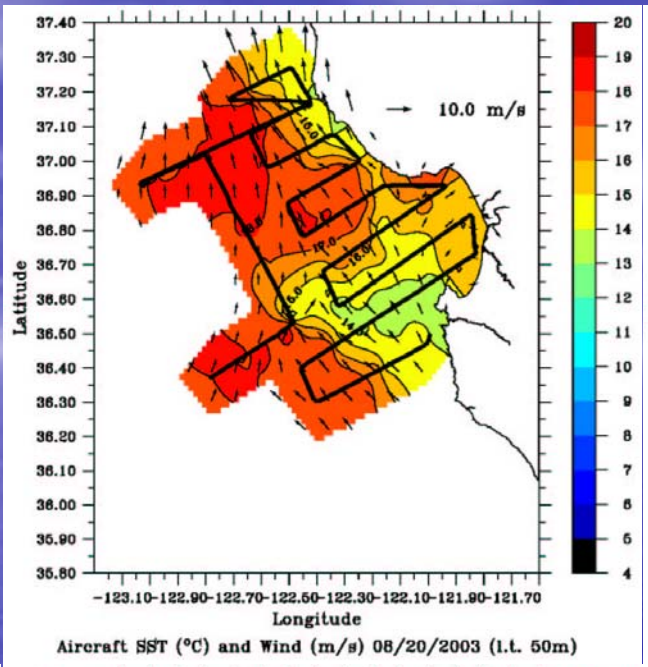

10.0 m/s
Latitude
Longitude
Aircraft SST (°C) and Wind (m/s) 08/11/2003 (l.t. 400m)


10.0 m/s
Latitude
Longitude
Aircraft SST (°C) and Wind (m/s) 08/13/2003 (l.t. 50m)

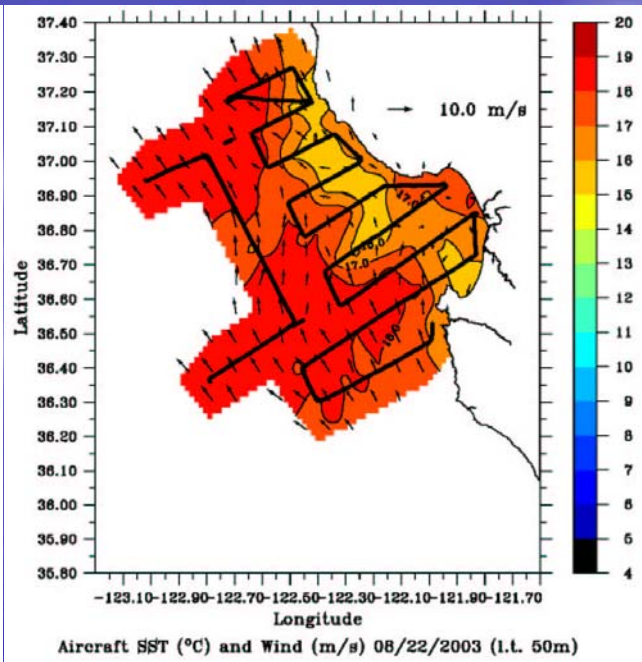

August 13, 2003



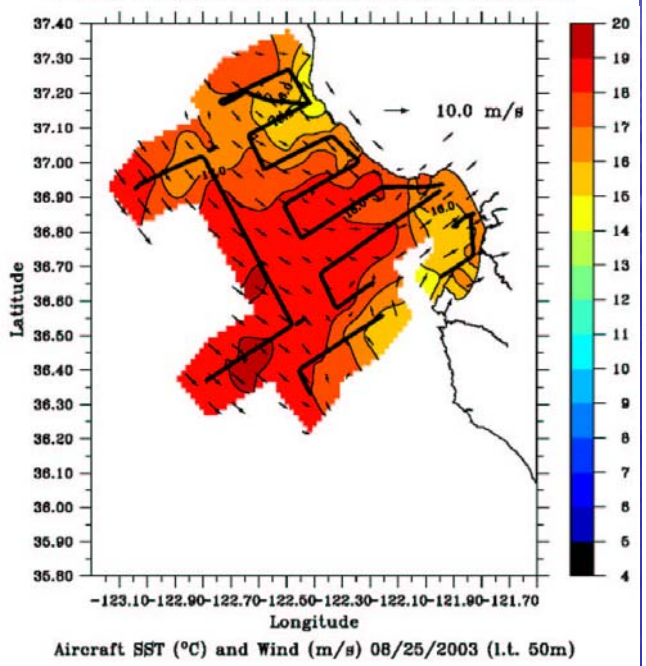
Aircraft SST (°C) and Wind (m/s) 08/15/2003 (l.t. 50m)



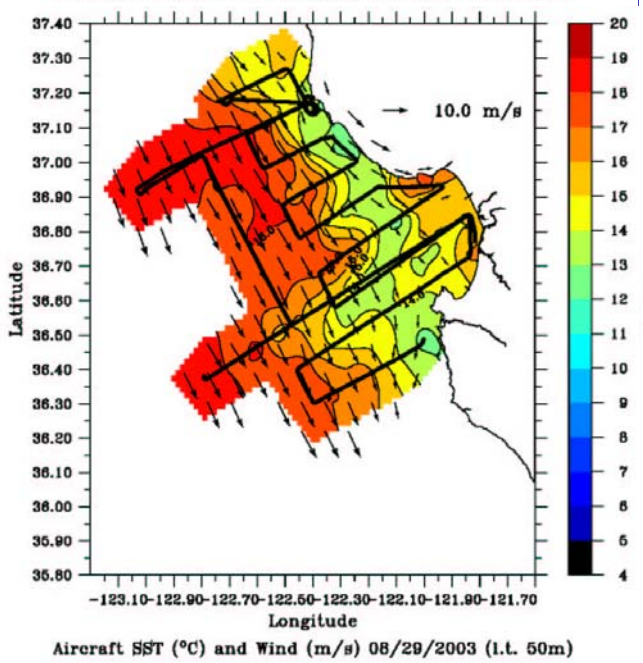
Aircraft SST (°C) and Wind (m/s) 08/20/2003 (l.t. 50m)



Aircraft SST (°C) and Wind (m/s) 08/22/2003 (l.t. 50m)



Aircraft SST (°C) and Wind (m/s) 08/25/2003 (l.t. 50m)



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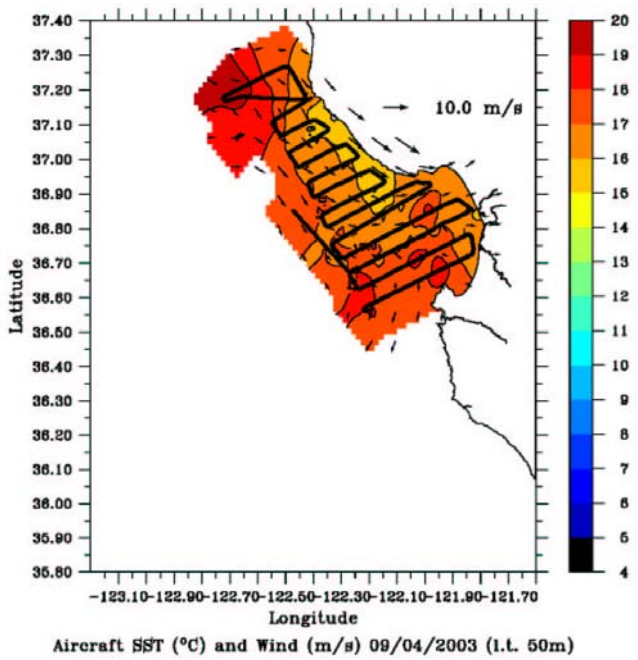
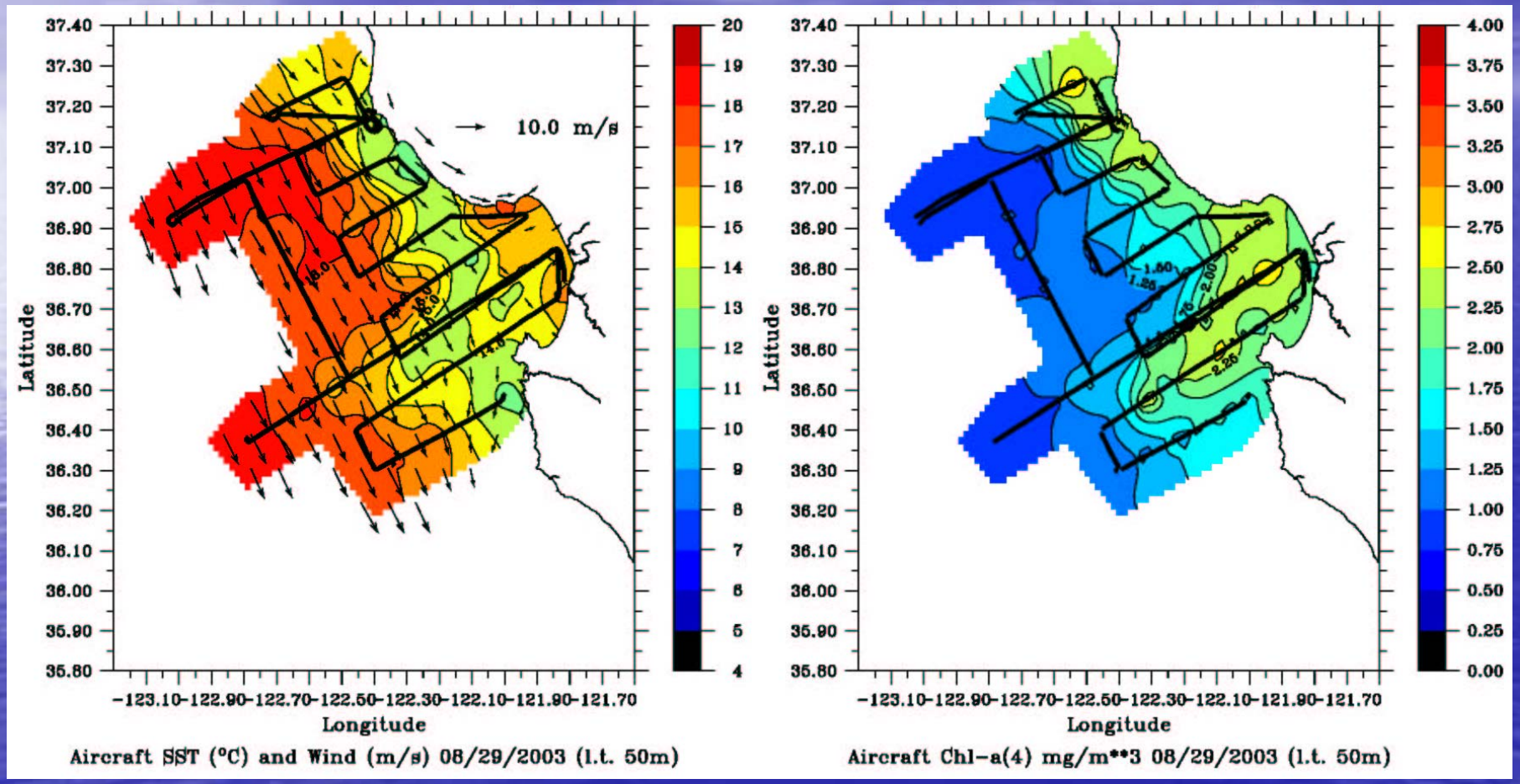
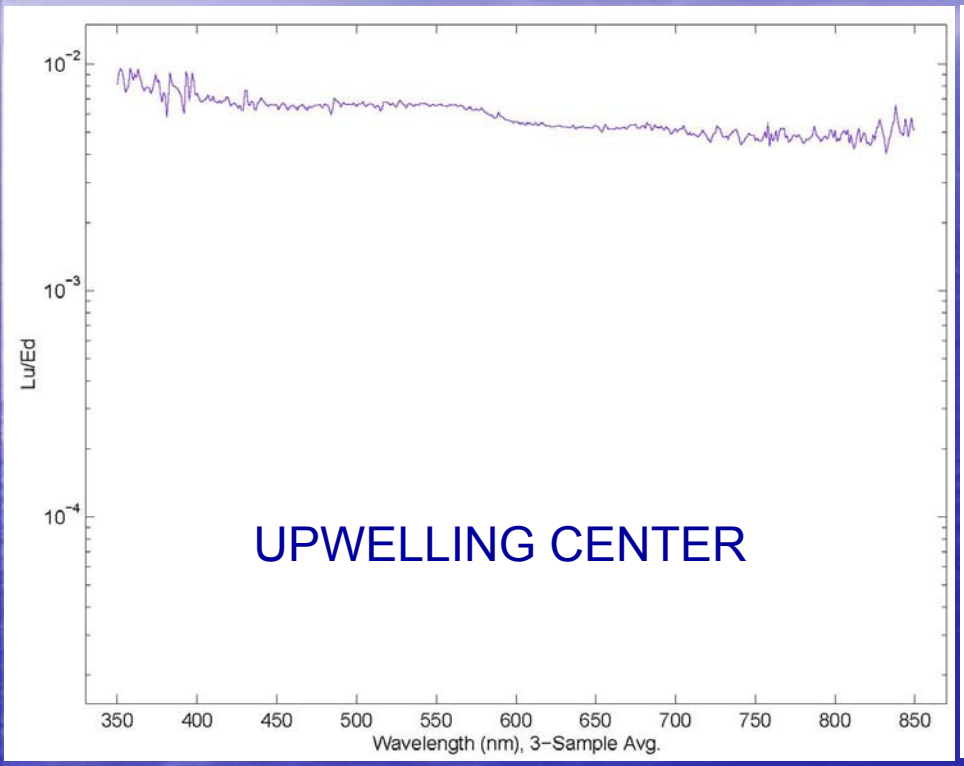


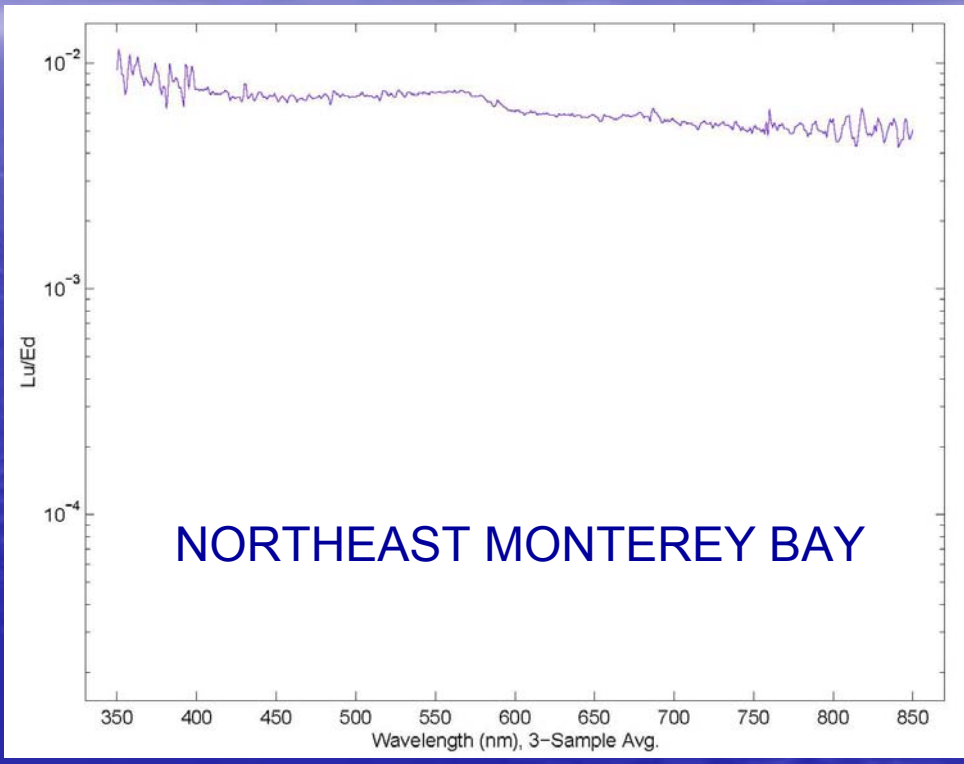
Aircraft SST (°C) and Wind (m/s) 09/04/2003 (l.t. 50m)

SST and Chl-a, August 29, 2003

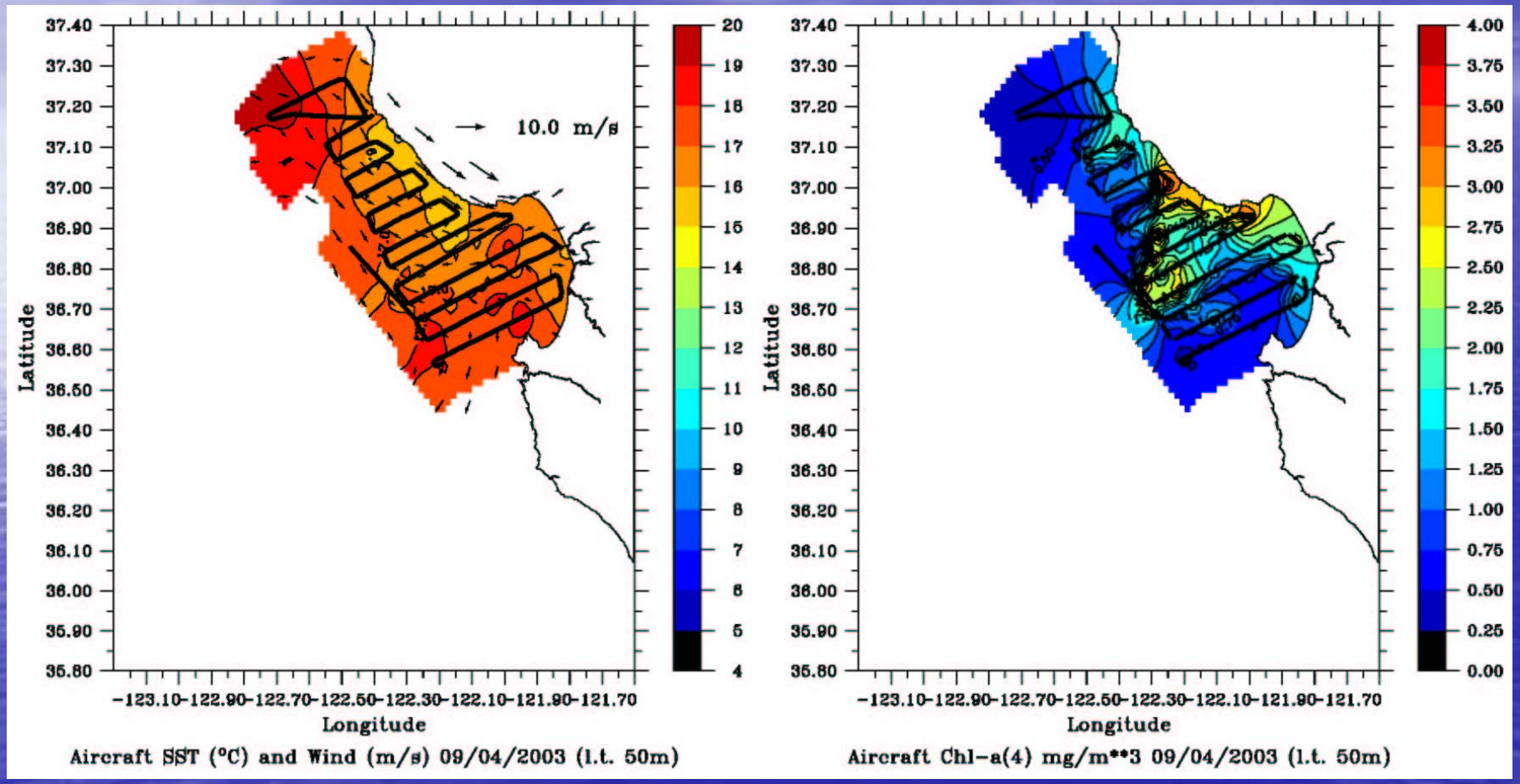


Ocean Color Spectra August 29, 2003

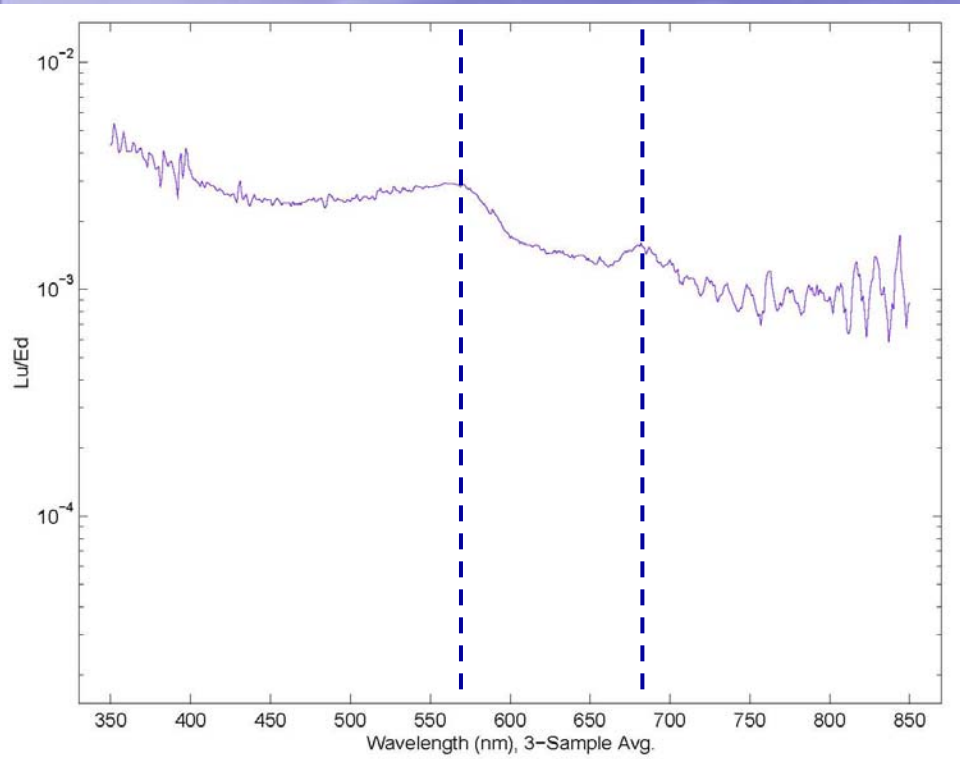




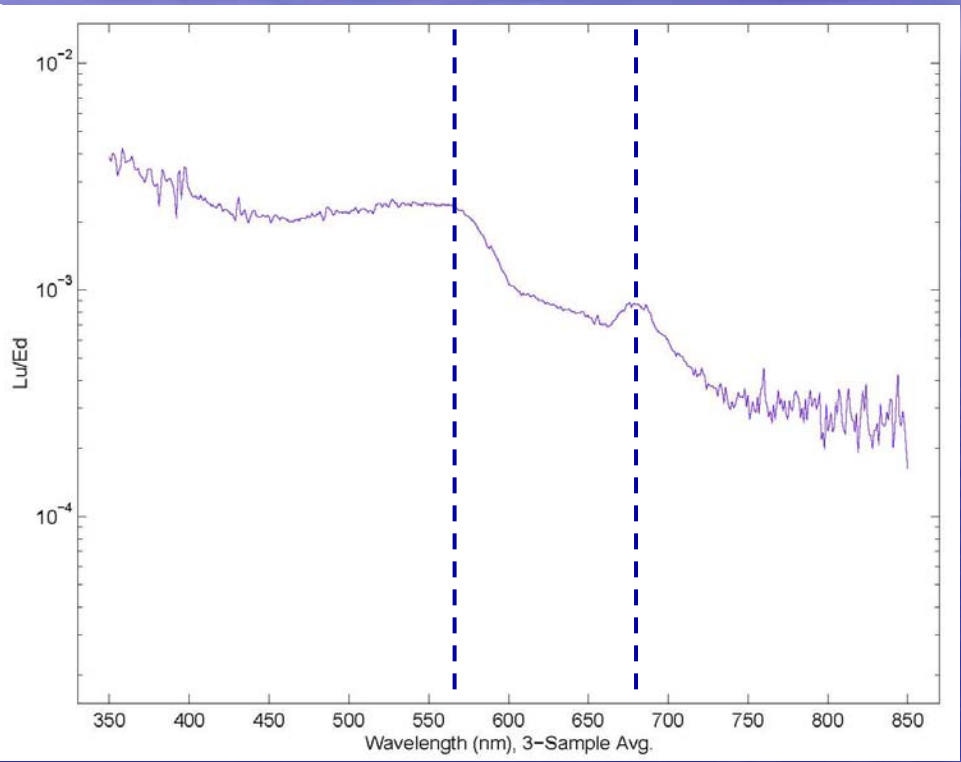
SST and Chl-a, Sept. 4, 2003



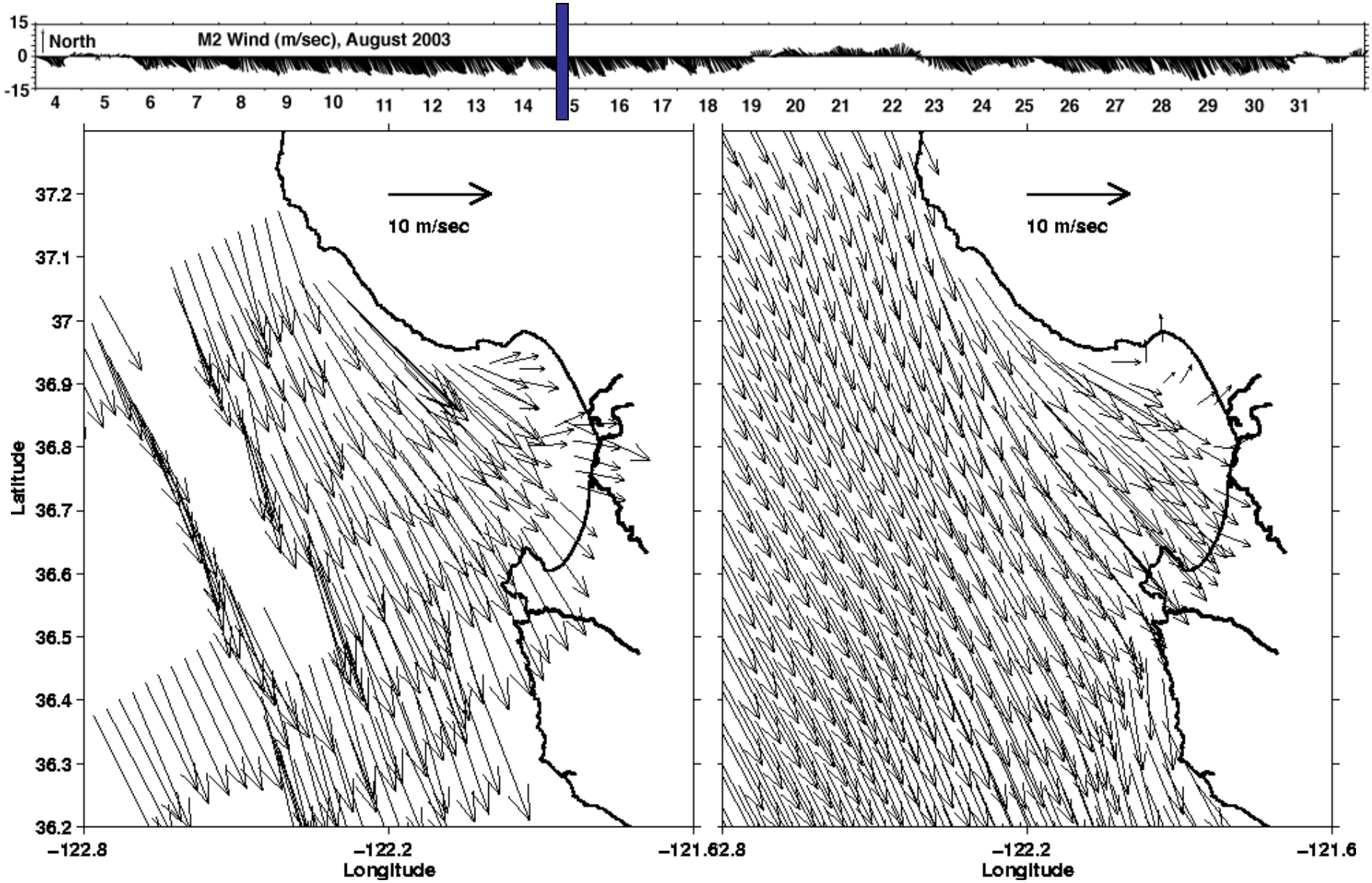
Ocean Color Spectra Sept. 4, 2003



UPWELLING CENTER

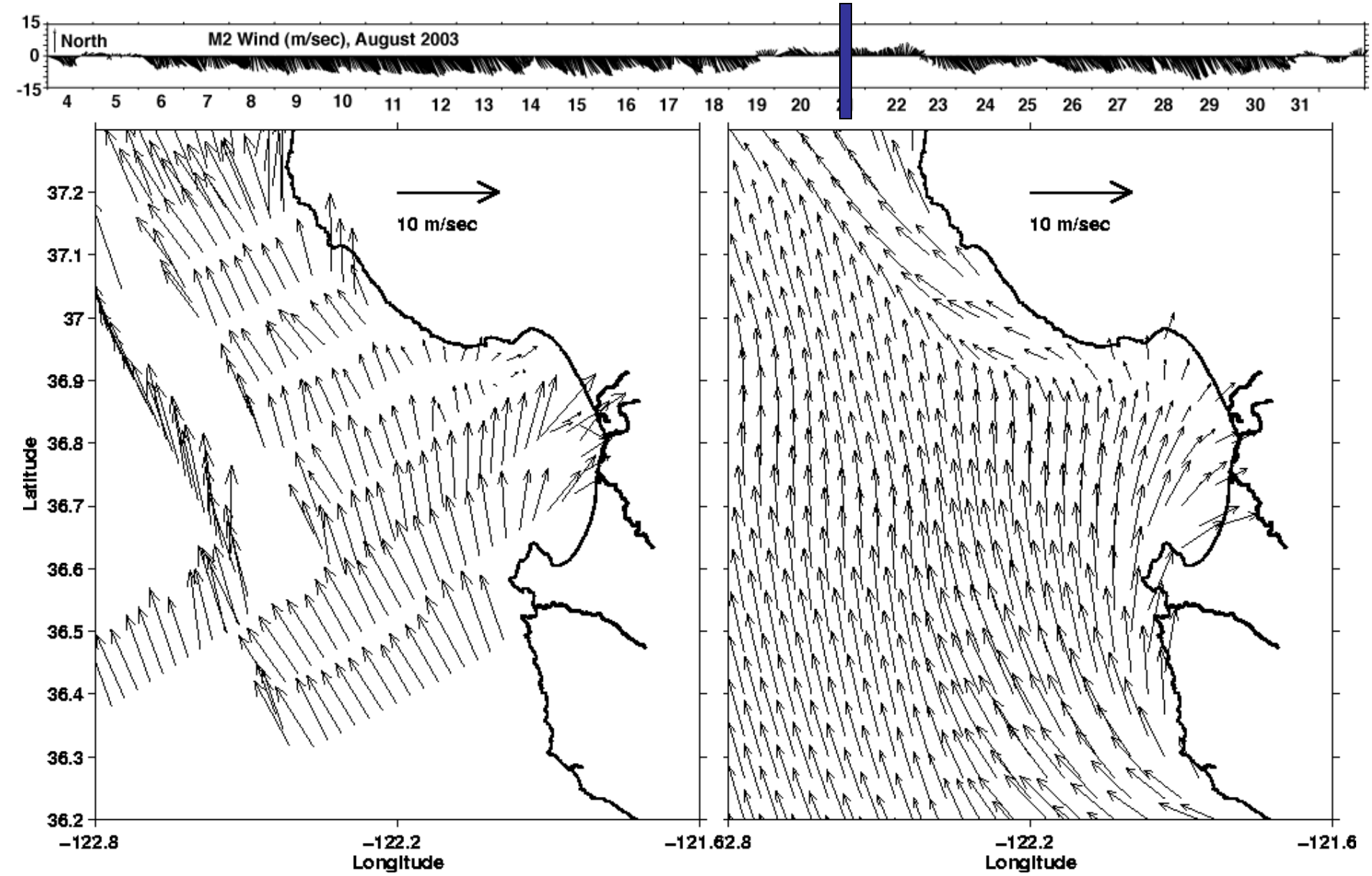


NORTHEAST MONTEREY BAY



Aircraft Wind

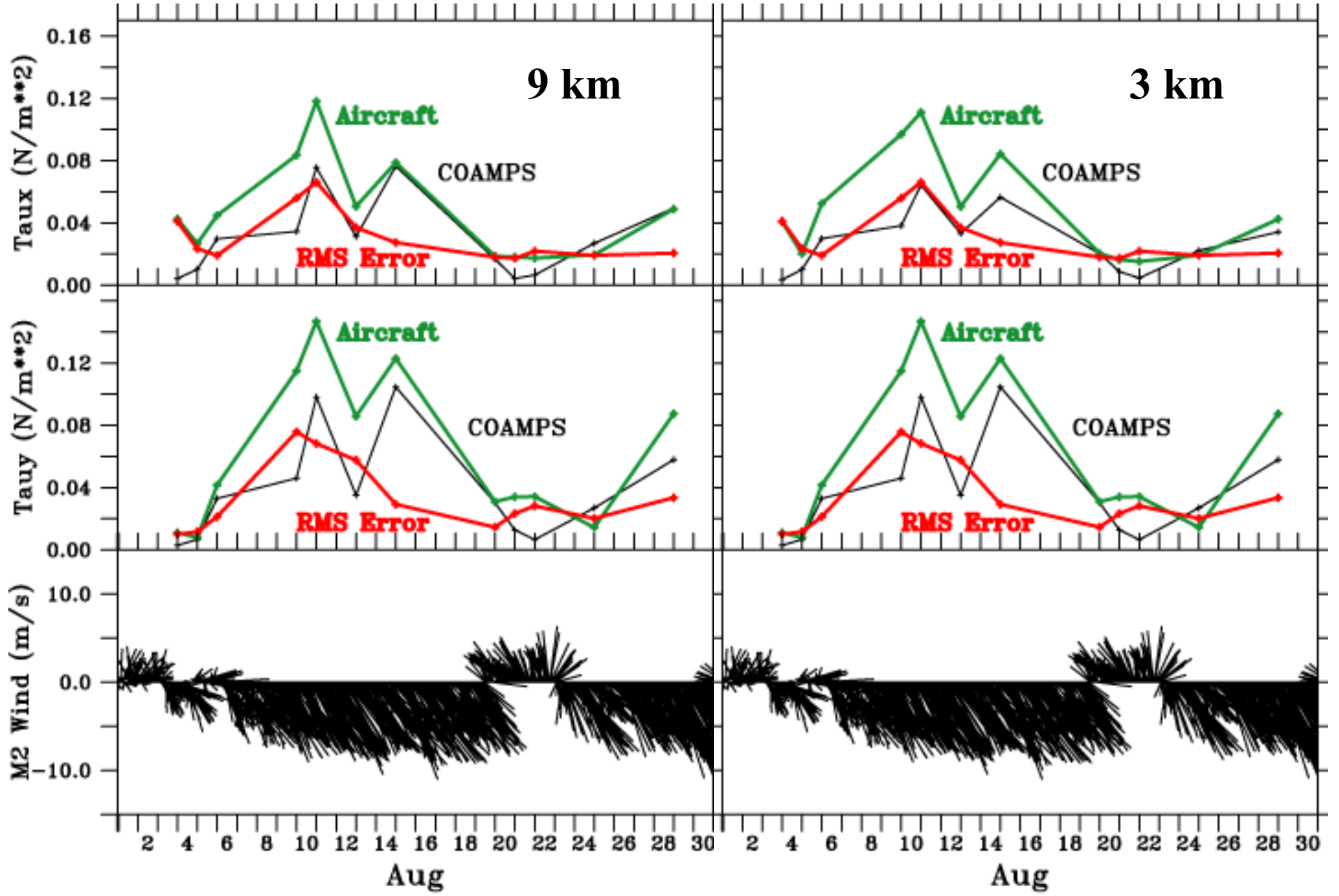
COAMPS 3km Wind



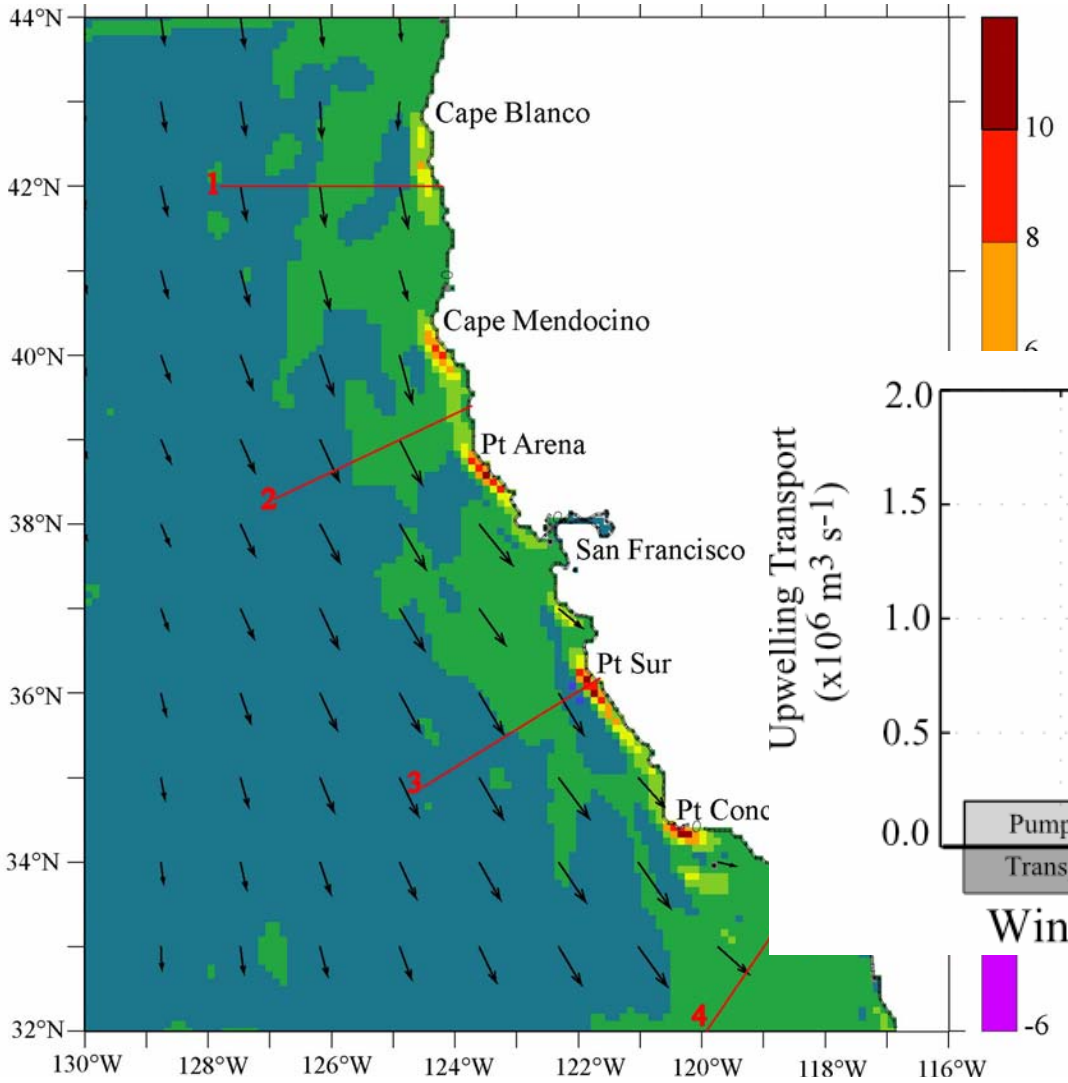
Aircraft Wind

COAMPS 3km Wind

RMS Diff-August 2003

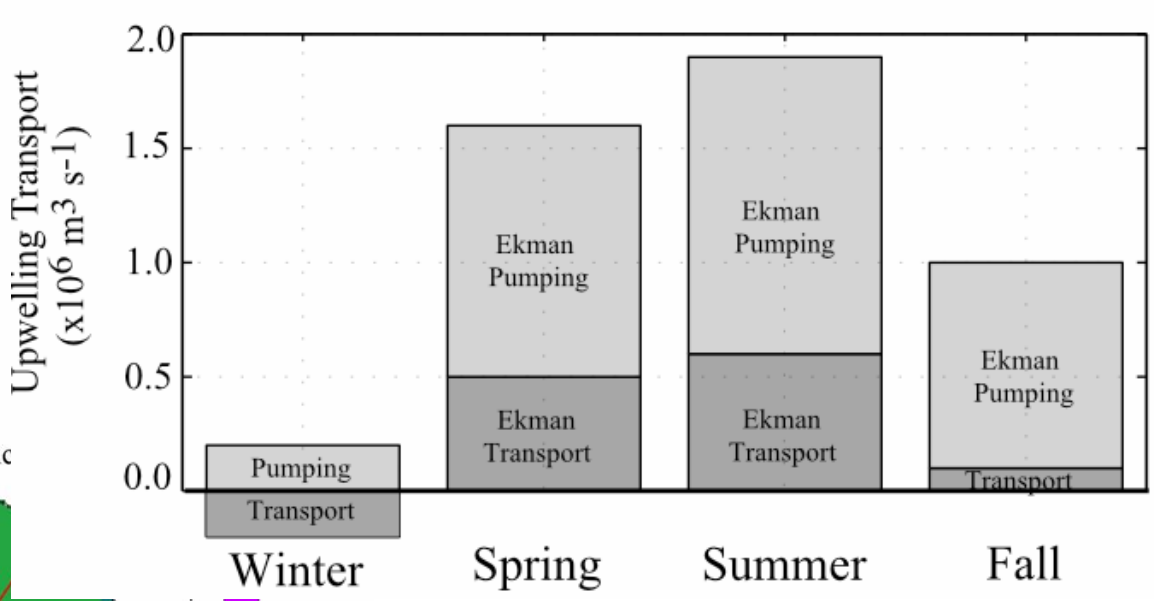


July Wind Stress Curl (10^{-6} N/m^3) From 9 km COAMPS™



Curl-driven Ekman pumping is as important as coastal upwelling but more geographically isolated

CCS-Wide Upwelling



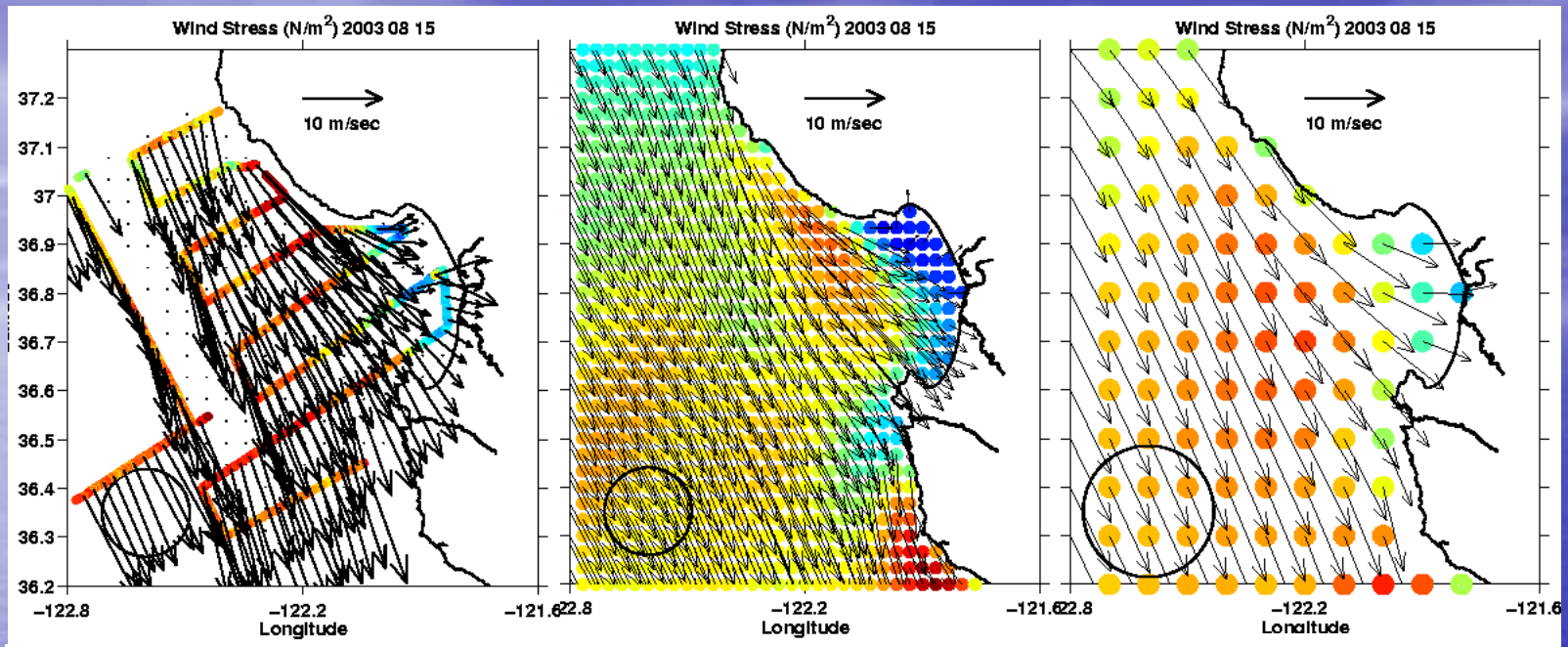
Pickett and Paduan (JGR, 2003)

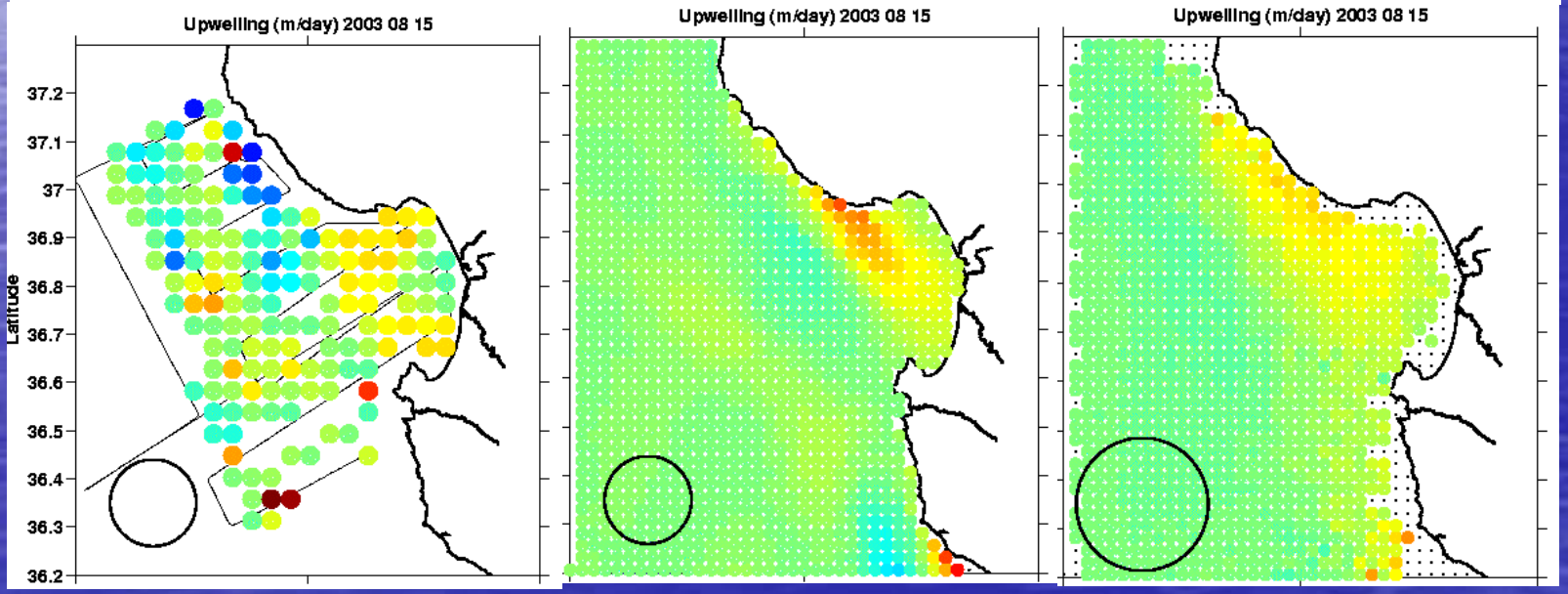
15Aug

Aircraft Wind

COAMPS 3km Wind

COAMPS 9km Wind





15 30 20 10 10 0 5 10 20 0 30

N/m^2 m/day

Aircraft Curl

COAMPS 3km Curl

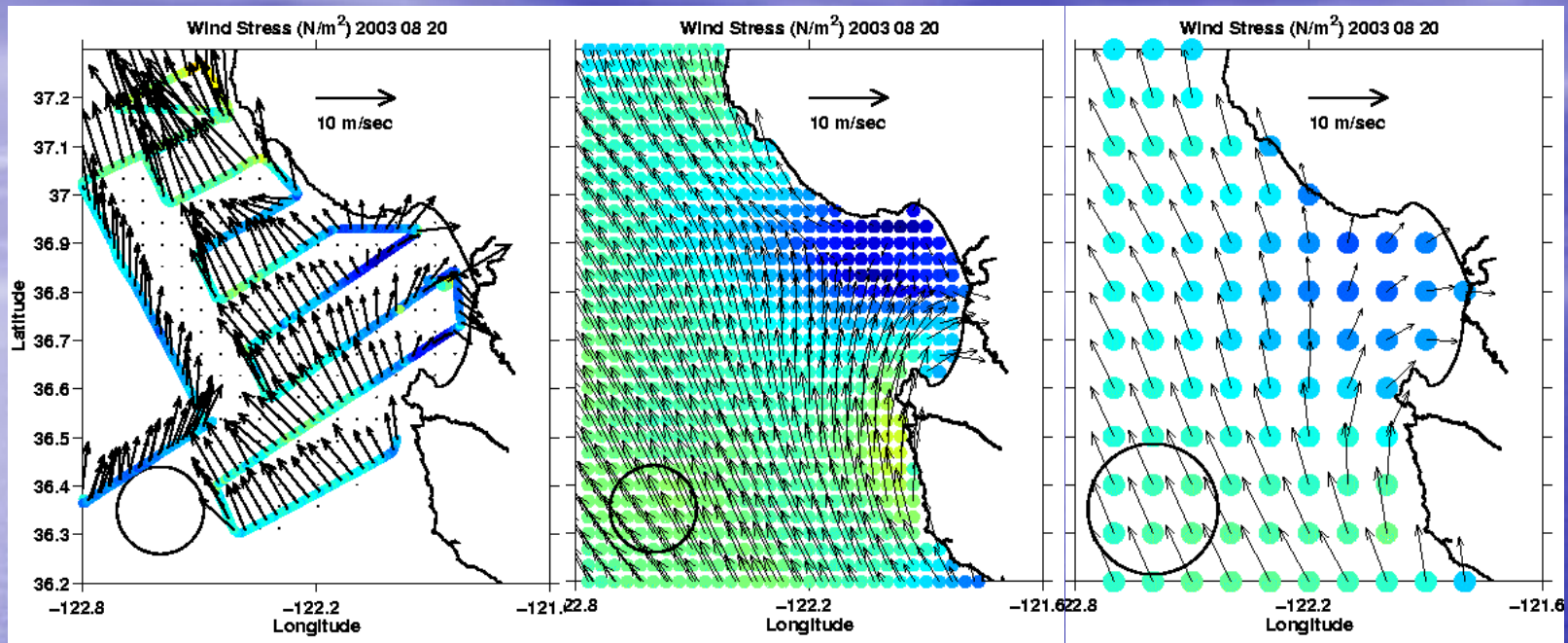
COAMPS 9km Curl

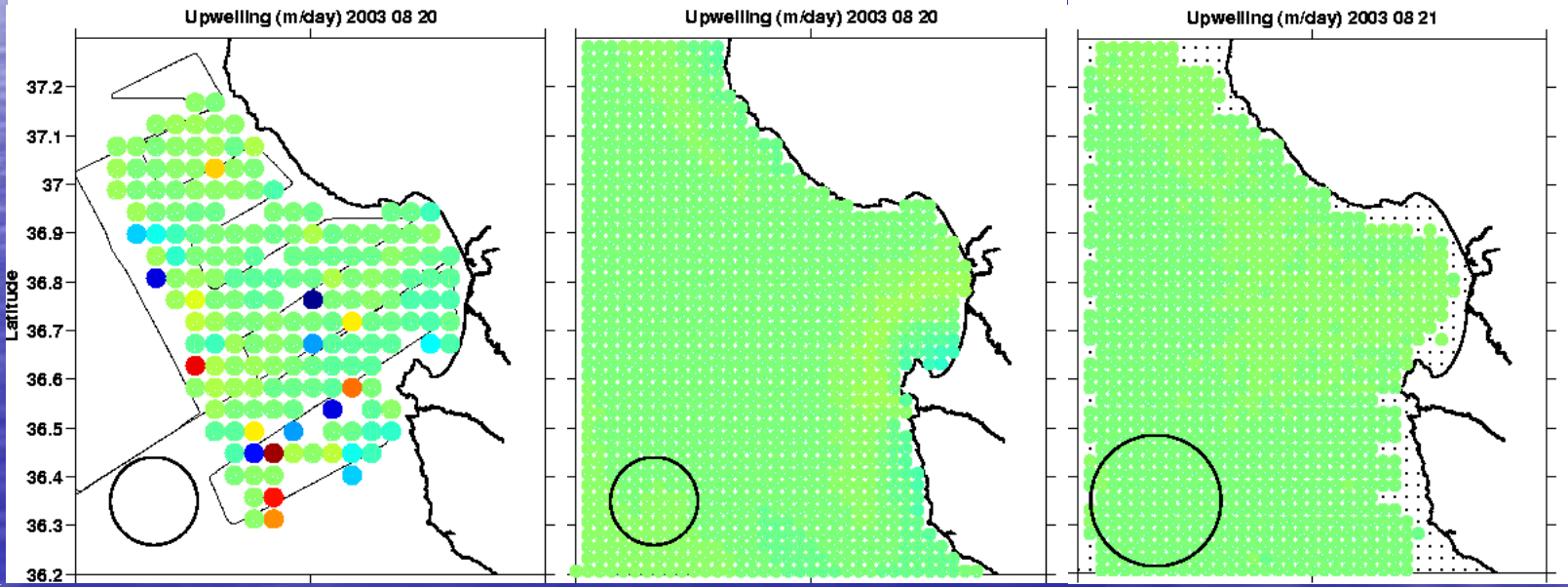
20Aug

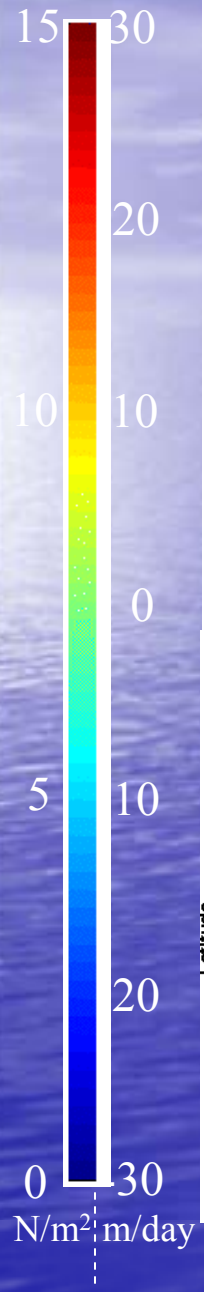
Aircraft Wind

COAMPS 3km Wind

COAMPS 9km Wind







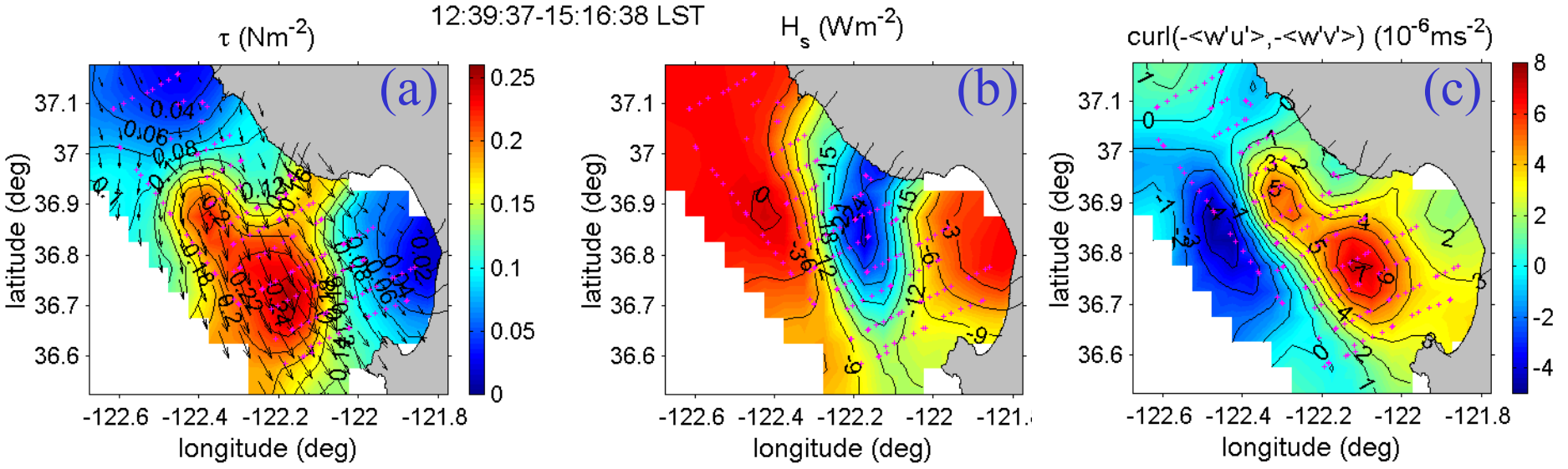
Aircraft Curl

COAMPS 3km Curl

COAMPS 9km Curl

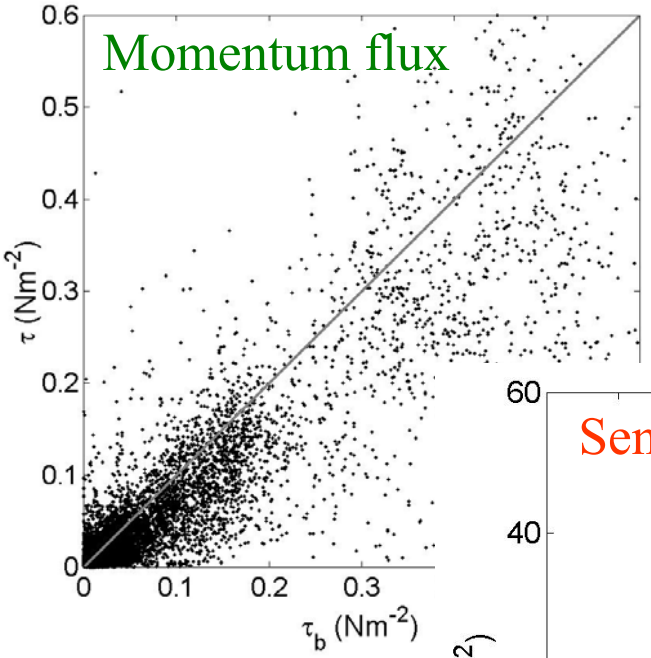
Turbulence Flux Calculation for AOSN-II, 2003

- **10 Hz wind turbulence, temperature, and water vapor from CIRPAS Twin Otter during AOSN-II 2003, 40 flights.**
- **Calibration done for wind turbulence, and water vapor.**
- **Eddy correlation method using 5 km averaging, resulted in 3695 flux measurements with -2 < z/L <0.2.**

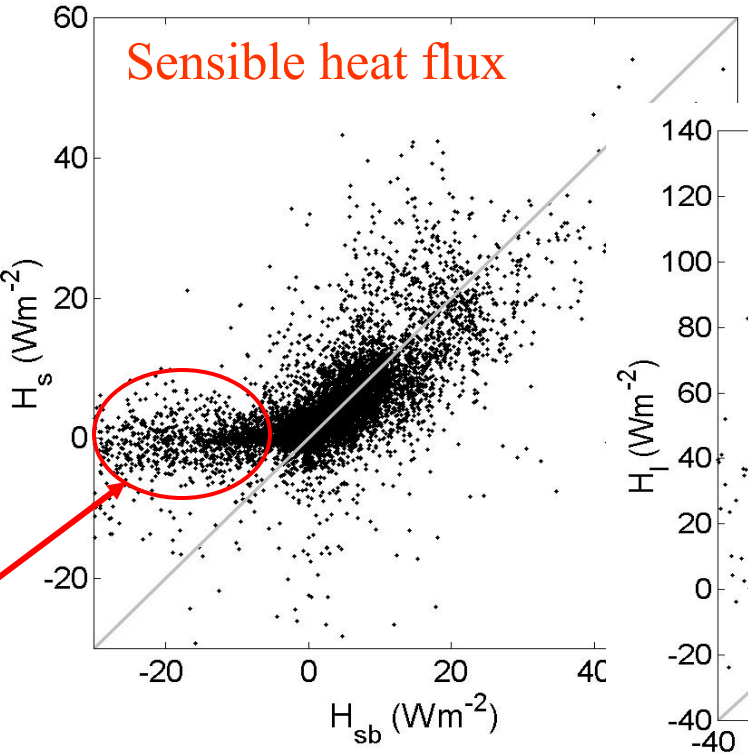


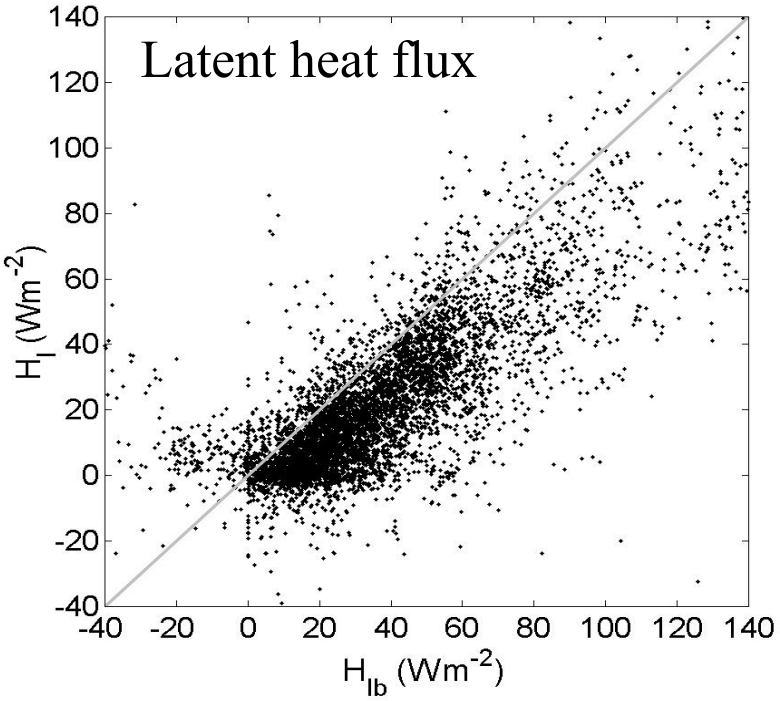
Spatial variation of near-surface turbulence (a) momentum, (b) heat fluxes and (c) stress curl on July 13, 2003 under northwesterly wind condition. Pink Lines are the flight track.

Flight-level Fluxes vs. Bulk Aerodynamic Formulation



- overestimates stress at large values
- large discrepancy in sensible heat flux in stable regime
- bulk overestimates latent heat flux





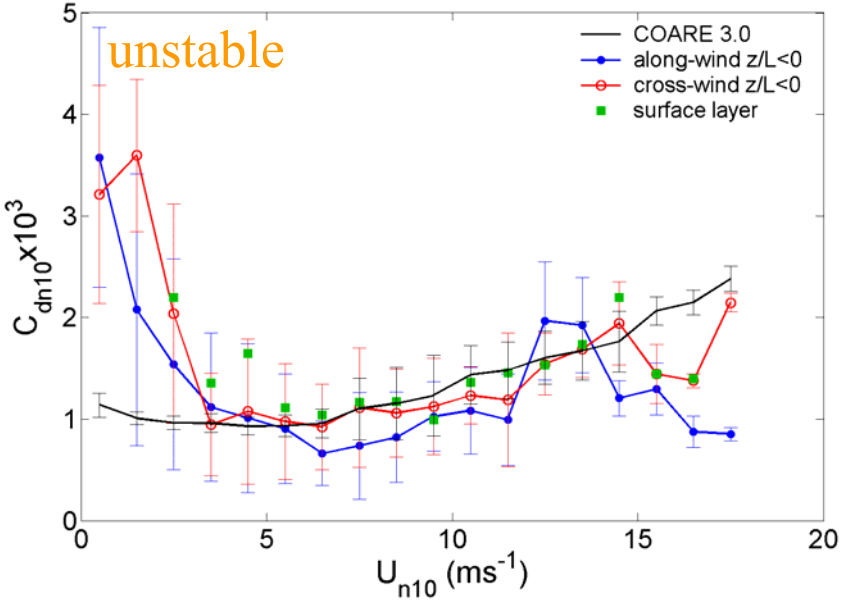
Eddy correlation Vs. Bulk method (COARE 3.0)

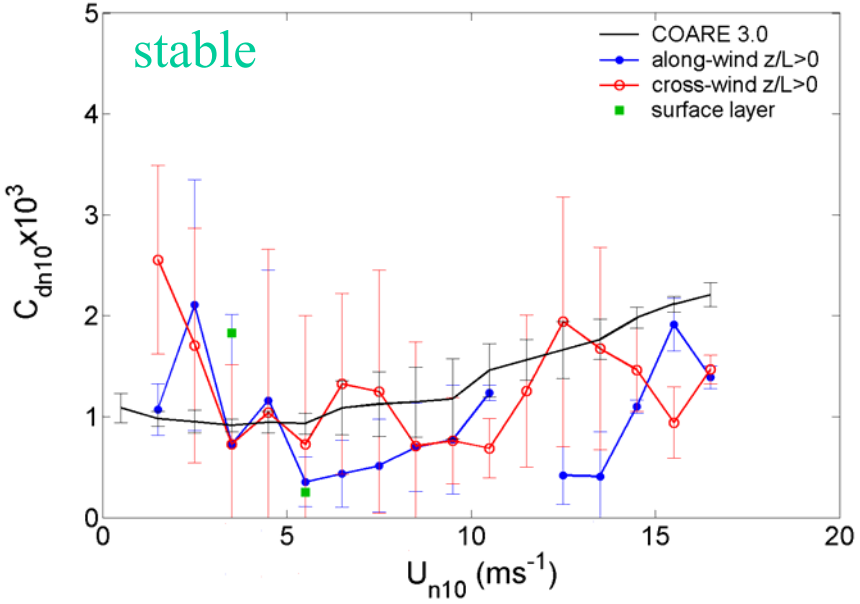
Stable regime

Correction of Aircraft Obtained Surface Fluxes

Corrections needed: (measurements were not made at surface, but 30 m above)

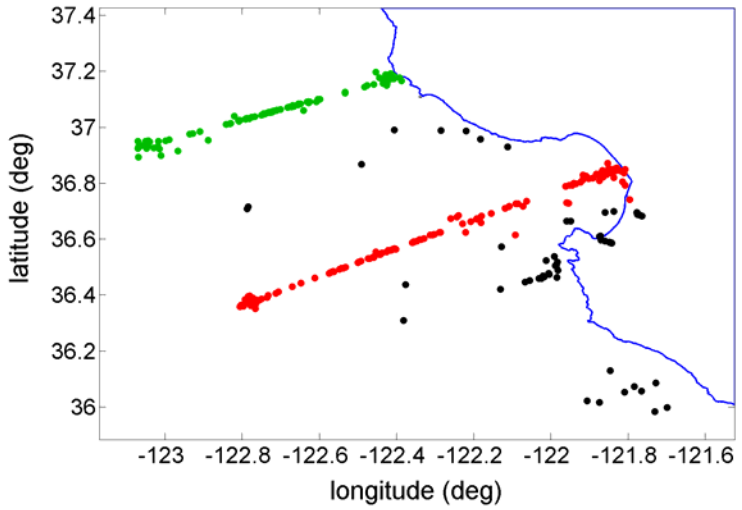
- **The effects of roll structure on the alongwind and crosswind difference**
- **Vertical flux divergence**

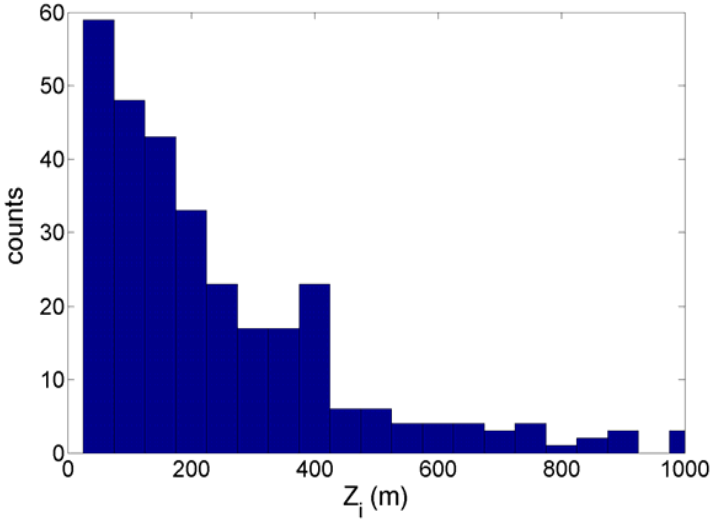


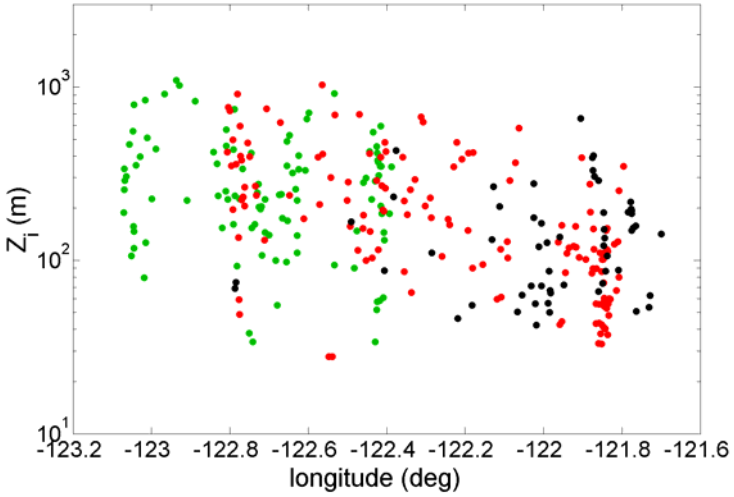


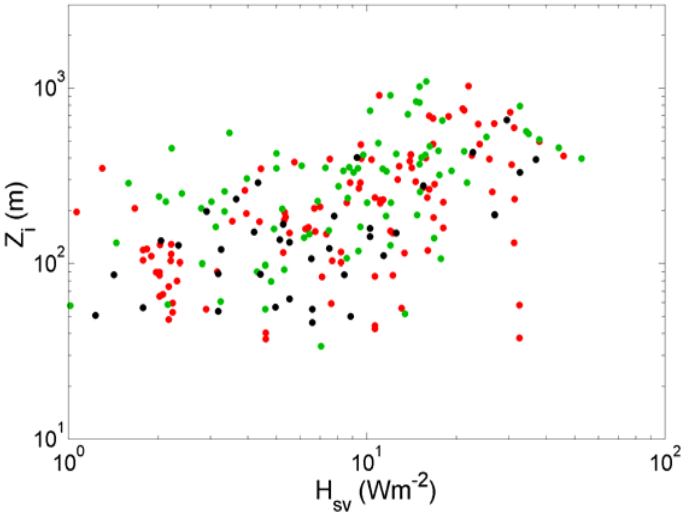
The COARE bulk parameterization does well in the unstable surface layer; more uncertainties are seen in stable surface layer.

Boundary Layer Height Variation in the Monterey Bay Region









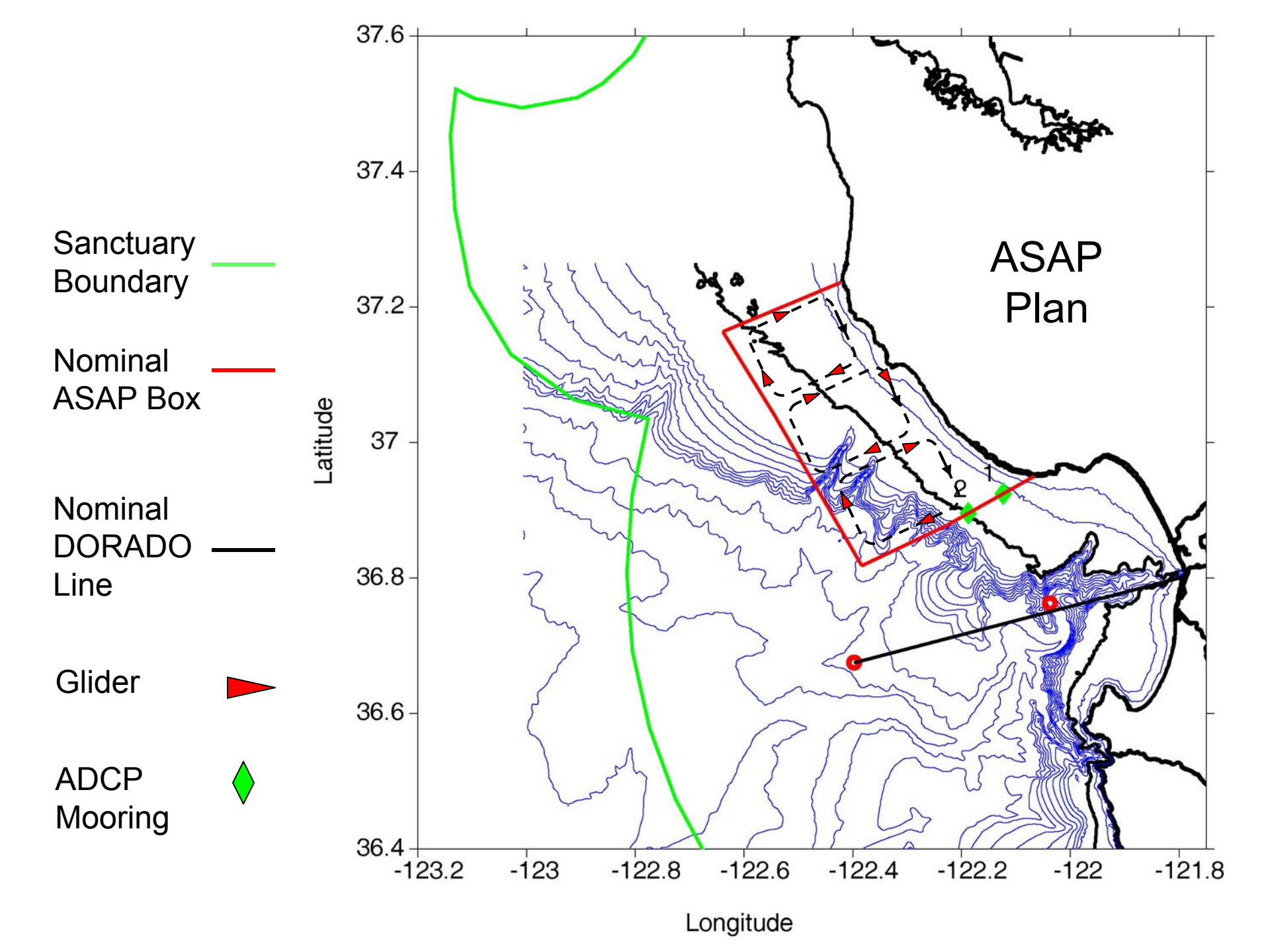
Aircraft soundings analysis

The Adaptive Sampling and Prediction (ASAP) Program

A Multi-University Research Initiative Sponsored by the United States Department of Defense.

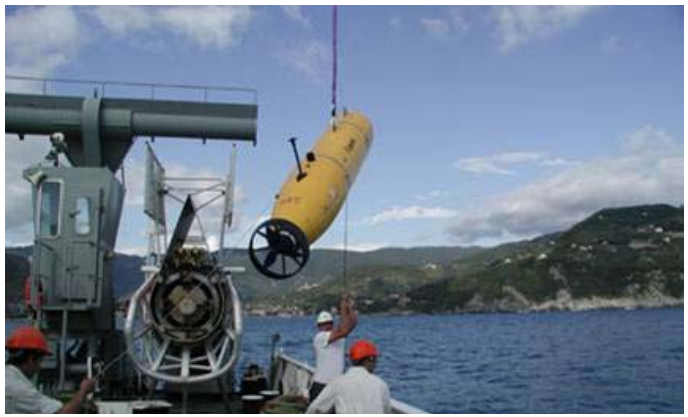
ASAP Overall Goal

Learn how to deploy, direct, and utilize autonomous vehicles most efficiently to sample the ocean, assimilate the data into numerical models in real or near-real time, and predict future conditions with minimal error.


Sanctuary Boundary
Nominal ASAP Box
Nominal DORADO Line
Glider
ADCP Mooring
ASAP Plan
Latitude
Longitude
37.6
37.4
37.2
37
36.8
36.6
36.4
-123.2
-123
-122.8
-122.6
-122.4
-122.2
-122
-121.8

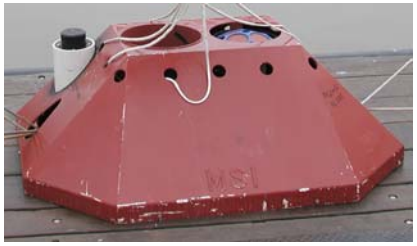
Observing the Terms

(a slide in progress)



?

$$\rho_0 c_p \left(\frac{\partial T}{\partial t} + \nabla \cdot (uT) + \frac{\partial}{\partial z}(wT) \right) = \frac{\partial Q}{\partial z}$$



Conclusions….

- Aircraft flying below clouds provides reliable input to nowcasting and forecasting systems
- Most sensors are small, light, and inexpensive and could be flown on UAVs
- Spatial observations probably the only way to verify and improve coastal atmospheric models