

Improving Observations of Coastal Storms

Allen B. White, PhD
Research Meteorologist
Physical Sciences Division
Earth System Research Laboratory
National Oceanic and Atmospheric Administration
325 Broadway, Mail Code R/PSD2,
Boulder, CO 80305

Tel: 303-497-5155
E-mail: allen.b.white@noaa.gov
Web: www.esrl.noaa.gov/psd

BIOGRAPHICAL SKETCH

Dr. White is a research meteorologist with NOAA's Earth System Research Laboratory in Boulder, CO, where he leads the Coastal Processes Team in the Water Cycle Branch of the Physical Sciences Division. His research interests are in boundary layers and turbulence, coastal weather, air pollution meteorology, and instrument algorithm development. He worked for 18 years in the Cooperative Institute for Research in Environmental Sciences at the University of Colorado before becoming part of the Federal workforce last October. Dr. White received his Ph.D. in Meteorology from Penn State in 1996. He is the author of more than 50 scientific journal articles, and he has received several rewards for his research.

ABSTRACT

Costal storms account for 71% (\$7B) of U.S. disaster losses annually. In addition, over 50% of the U.S. population lives in coastal areas that account for less than 20% of the nation's land, and coastal development still is increasing. As a result, more homes, businesses and lives will be vulnerable to coastal storms and more accurate forecasts will be required to reduce risk associated with hazardous weather. Over the last decade, research conducted by the NOAA's Earth System Research Laboratory has begun to address these issues through a series of focused wintertime field experiments conducted along the U.S. West Coast.

These experiments collected new meteorological observations, both to support research on the physical processes related to coastal storms and to aid operational 0-48 h weather forecasting. In particular, a new bulk water vapor transport tool has been developed to help improve short-term (<~6 h) precipitation forecasts in mountainous terrain. The tool uses coastal Doppler wind profilers to measure the upslope component of the flow aloft and collocated GPS receivers to measure the integrated water vapor content. The product of these two variables produces a bulk water vapor flux. The flow at the surface often bears little resemblance to that at a controlling level (where the correlation between the water vapor flux and mountain precipitation is maximized) due to the ubiquitous presence of shallow terrain-blocked flows, thus highlighting the need to obtain upper-air wind measurements for this particular application. The tool is described in the context of the intense West Coast storm that inundated California with heavy precipitation in early January 2008. Numerical weather prediction results are also shown to highlight the deficiency of model and human forecasts of heavy precipitation enhanced by mountains.

Finally, improving the forecast lead time of coastal storms impacting the Western U.S. will require a winter storms reconnaissance program analogous to NOAA's hurricane reconnaissance mission. NOAA's Unmanned Aircraft System (UAS) Program will test and evaluate the use of unmanned aircraft to provide much needed offshore measurements in developing storms.

Improving Observations of Coastal Storms

Allen White¹, Dan Gottas^{1,2}, Sara Michelson^{1,2}
Isidora Jankov^{1,2}, Jian-Wen Bao¹, Paul Neiman¹
Seth Gutman¹, Marty Ralph¹, Dave Kingsmill^{1,2},
Tim Schneider¹, Gary Wick¹

¹NOAA Earth System Research Laboratory
Boulder, Colorado

²Cooperative Institute for Research in Environmental Sciences, University of Colorado
Boulder, Colorado

Coastal storms, including hurricanes account for 71% (\$7B)
of annual U.S. disaster losses

Presidential Disaster Declarations

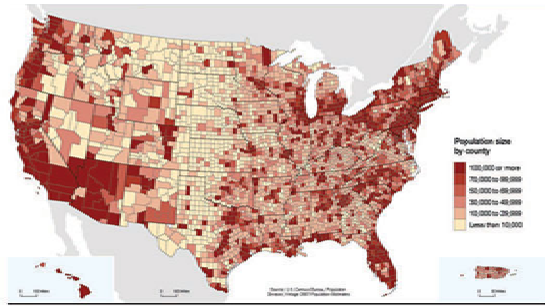
January 1, 1965 to June 1, 2003



Mapped Total: 1,214*

*Prior to January 1, 1965, 165 declarations did not have county designations. Therefore, of the total declared disasters (1,399), only 1,214 are included in the Mapped Total.

Source: FEMA's National Emergency Management Information System



Over 50% of the U.S. population lives in coastal areas that account for less than 20% of the nation's land



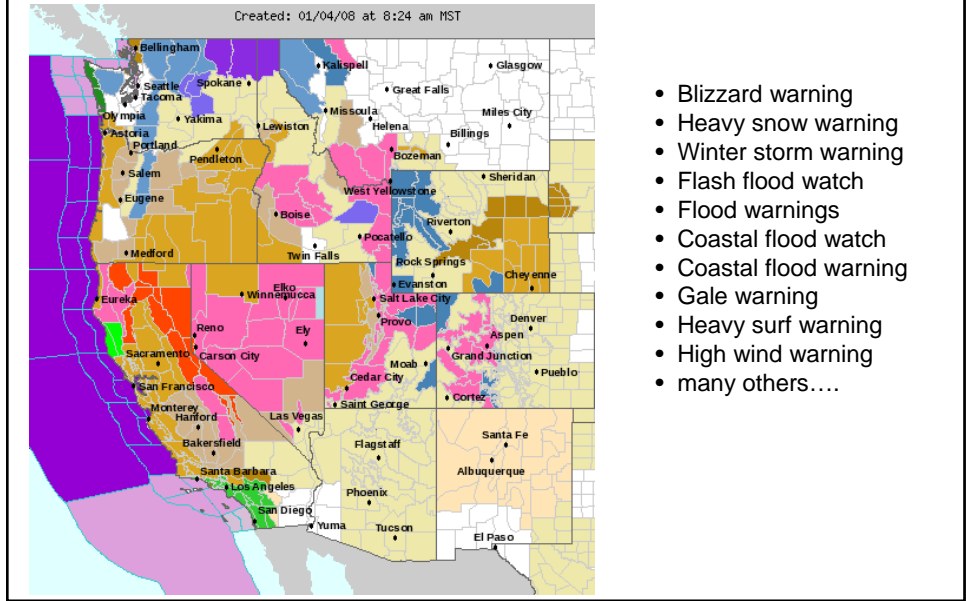
25% of the coast will be developed by 2025, versus 14% in 1997

Source: U.S. Census Bureau

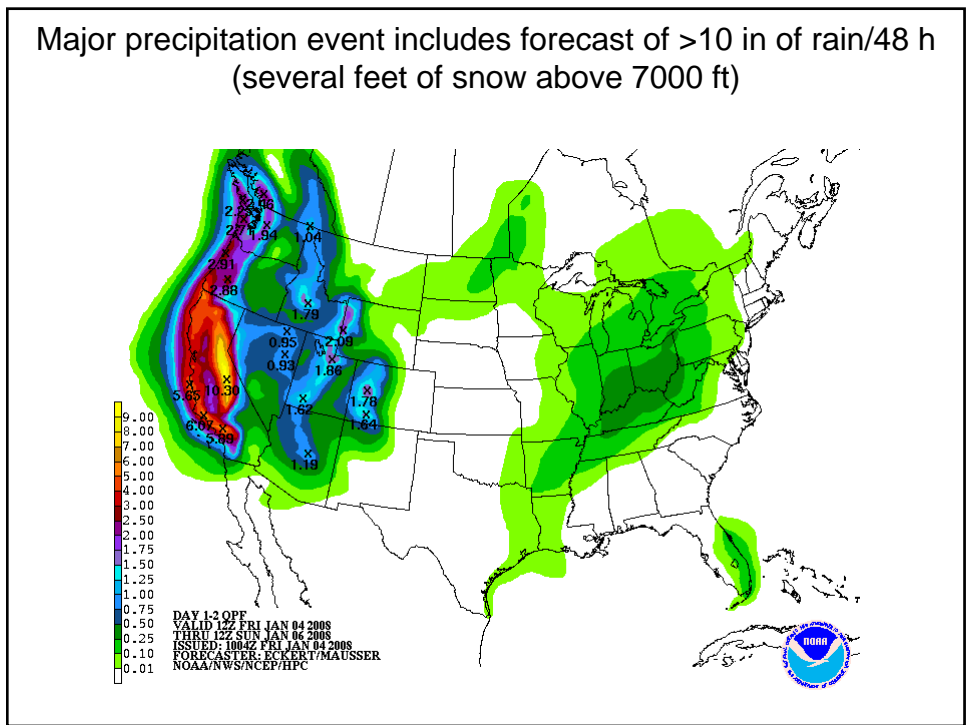
Atmospheric Rivers

- Atmospheric rivers (ARs) represent the “business end” of west coast winter storms, and yet are poorly monitored
- Developments over the last 10 years have led to creation of a real-time monitoring technique for ARs at the coast
- NOAA has an unmanned aircraft program that will help detect and monitor atmospheric rivers over the Eastern Pacific to provide forecasters with more lead time for the precursor conditions that cause extreme precipitation events

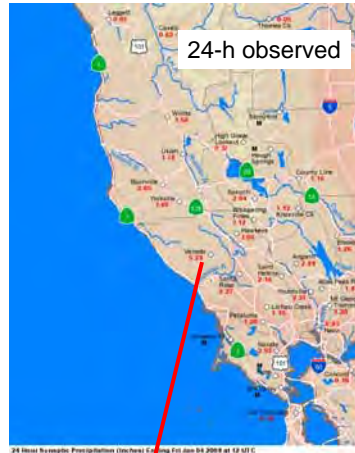
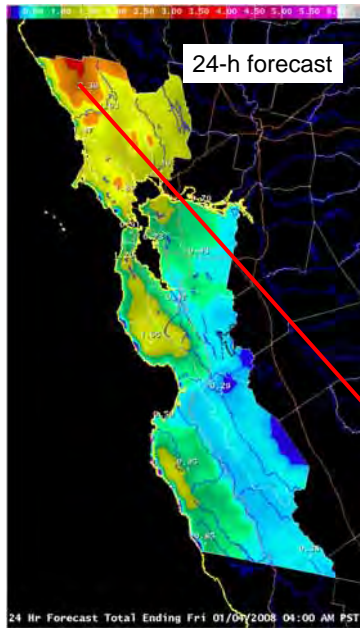
Major West Coast Storm 4 January 2008: NWS Watches and Warnings



Major precipitation event includes forecast of >10 in of rain/48 h
(several feet of snow above 7000 ft)

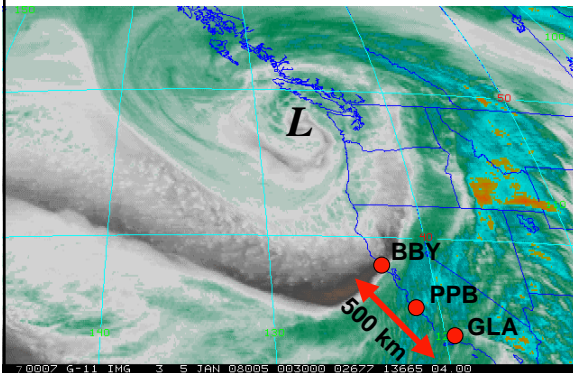


QPF in extreme events is very difficult



Max Forecast = ~ 3 in rain/24 h
 Max Observed = ~ 5 in rain/24 h
 This type of difference is not uncommon.

Three experimental observing sites monitored atmospheric river conditions upon land-fall



Distance from BBY to GLA ~500 km, i.e. the average width of an atmospheric river

Each "site" (●) includes

- coastal wind profiler
- coastal GPS-met receiver
- surface met package
- mountain rain gauge

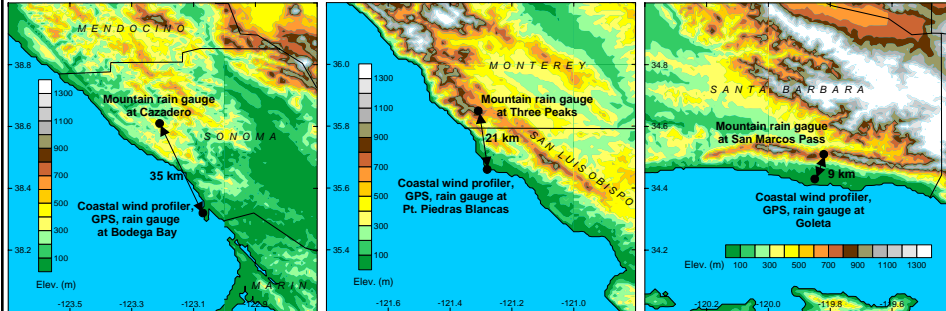
The integrated observing strategy has been developed from past experiments, and the sites are deployed as part of the Hydrometeorology Testbed, Coastal Storms Program, and "Weather-climate connection" projects.

Bodega Bay (**BBY**; 12 m MSL) + Cazadero (Mountain site; 475 m MSL)

Pt. Piedras Blancas (**PPB**; 11 m MSL) + Three Peaks (Mountain site; 1021 m MSL)

Goleta (**GLA**; 3 m MSL) + San Marcos Pass (Mountain site; 701 m MSL)

Three atmospheric river monitoring "sites"



Northern "couplet"

Central "couplet"

Southern "couplet"



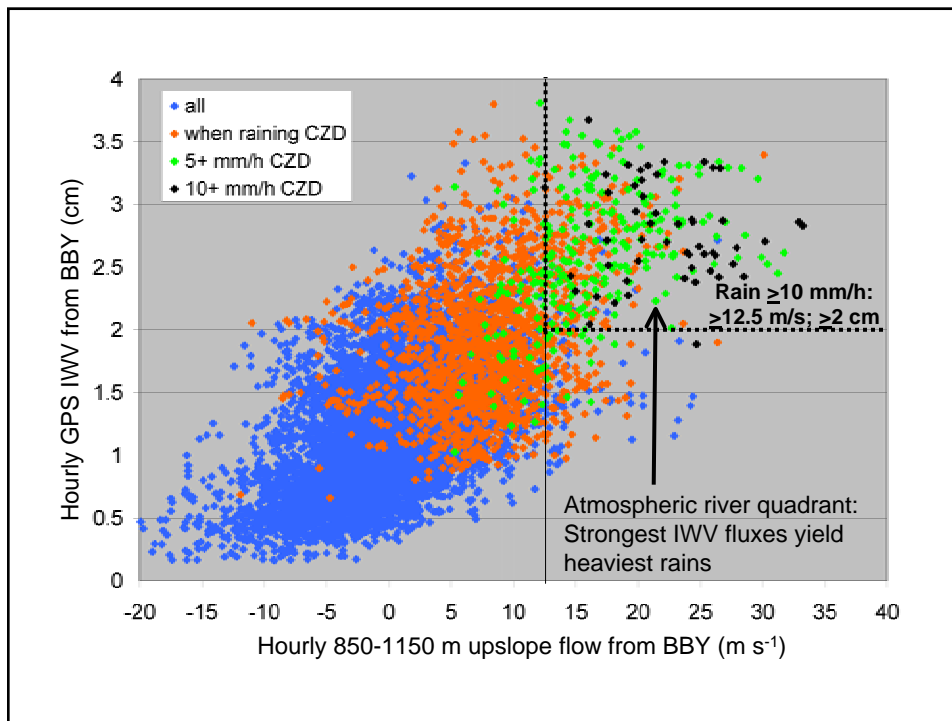
Wind profiler

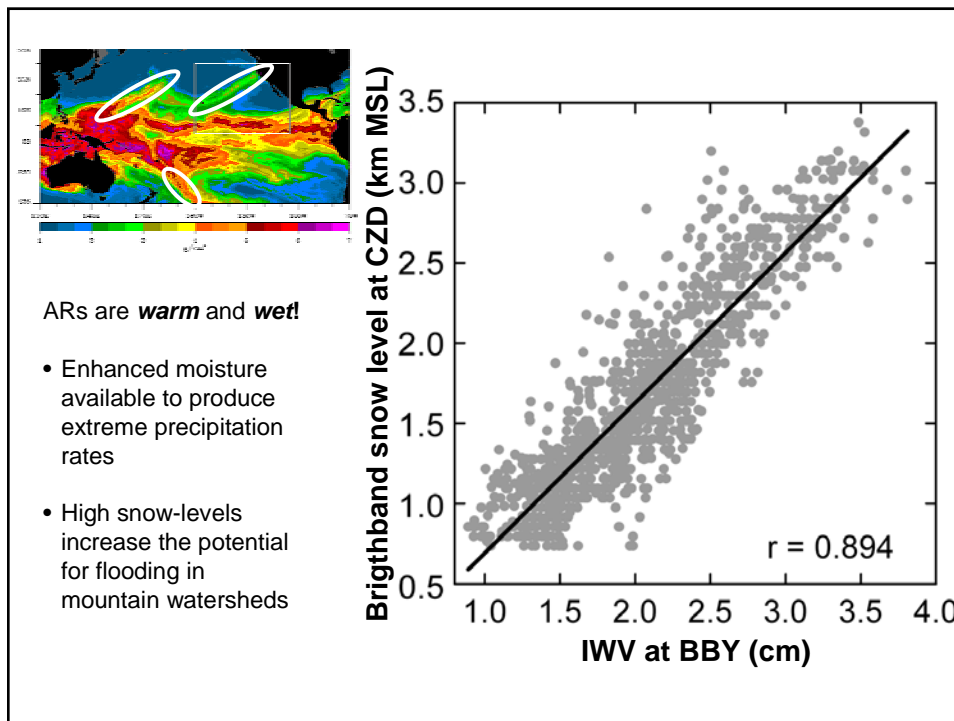
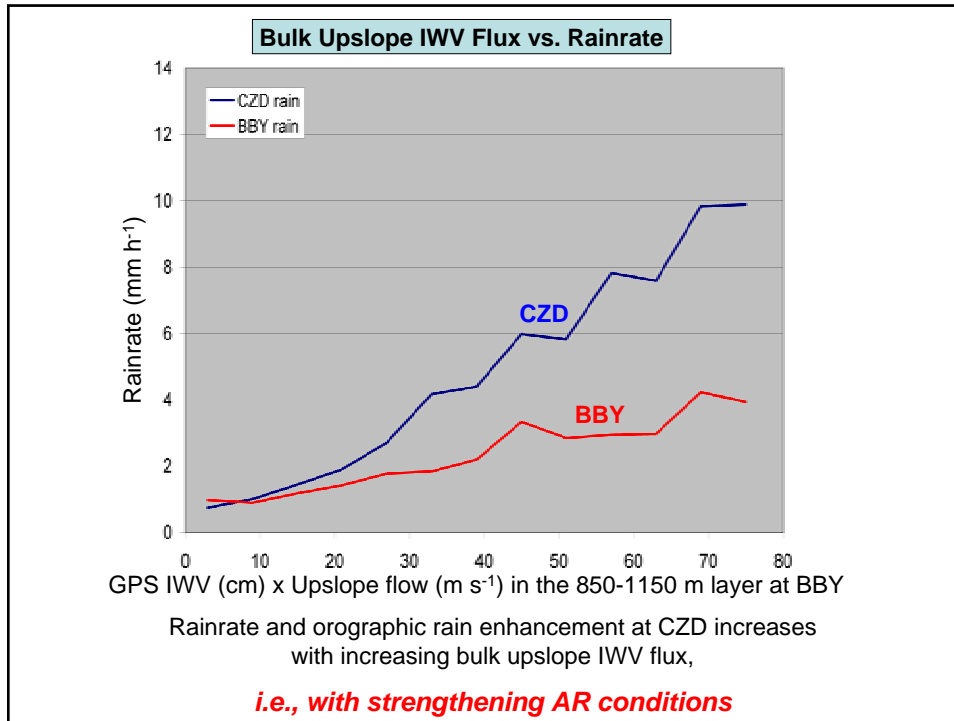


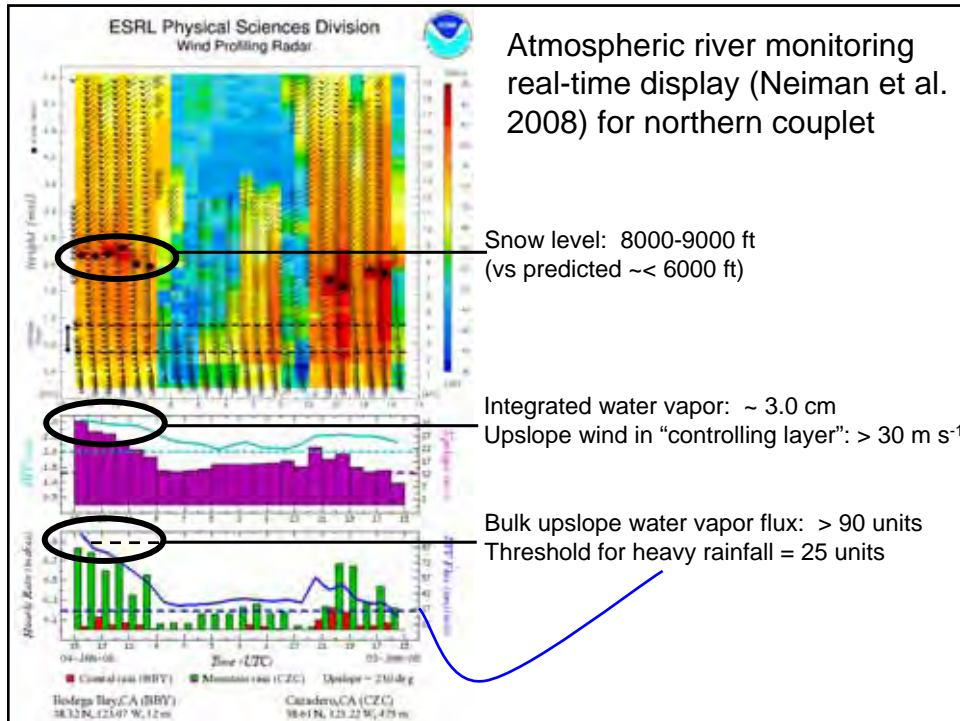
GPS receiver



Rain gauge w/ T/RH

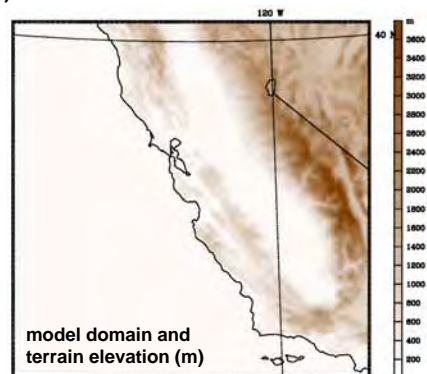




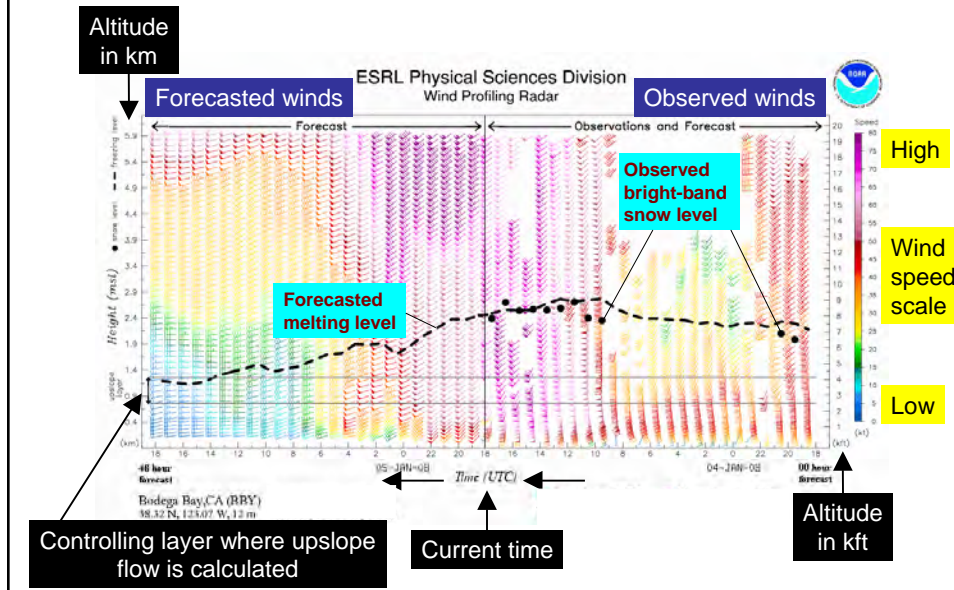


Forecast Model Configuration

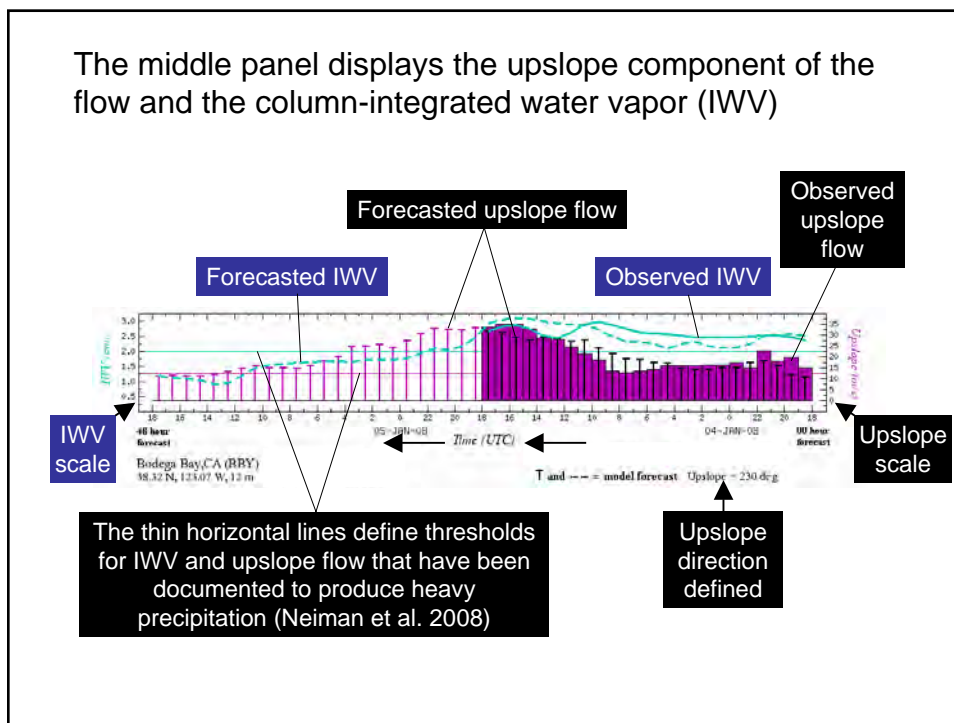
- Model type: Advanced Research WRF (ARW)
- Grid Configuration:
 - 3 km horizontal grid spacing
 - 30 vertical layers
- Forecast duration: 48 hour forecast
- Model Physics:
 - Ferrier microphysics
 - RRTM long-wave radiation
 - Dudhia short-wave scheme
 - MRF surface layer scheme
 - thermal diffusion land-surface scheme
 - YSU boundary layer scheme
- Initial and boundary conditions:
 - NAM forecast



The forecast model verification display consists of three panels
 The top panel displays wind profiles and snow levels



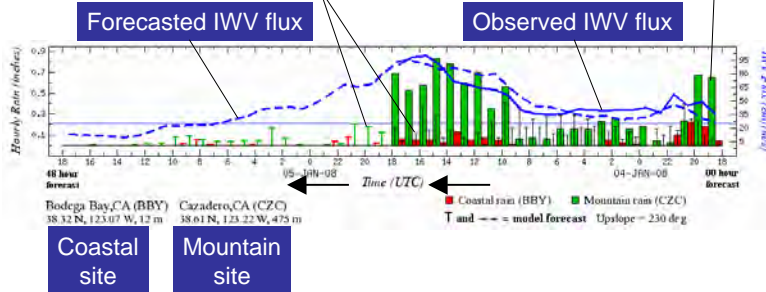
The middle panel displays the upslope component of the flow and the column-integrated water vapor (IWV)



The IWV and upslope flow from the middle panel are combined to produce a bulk, layer-mean, IWV flux, which is displayed in the bottom panel along with the coastal and mountain hourly rainfall

Forecasted rainfall (T posts):
Red = coastal site
Green = mountain site

Observed rainfall (bars):
Red = coastal site
Green = mountain site

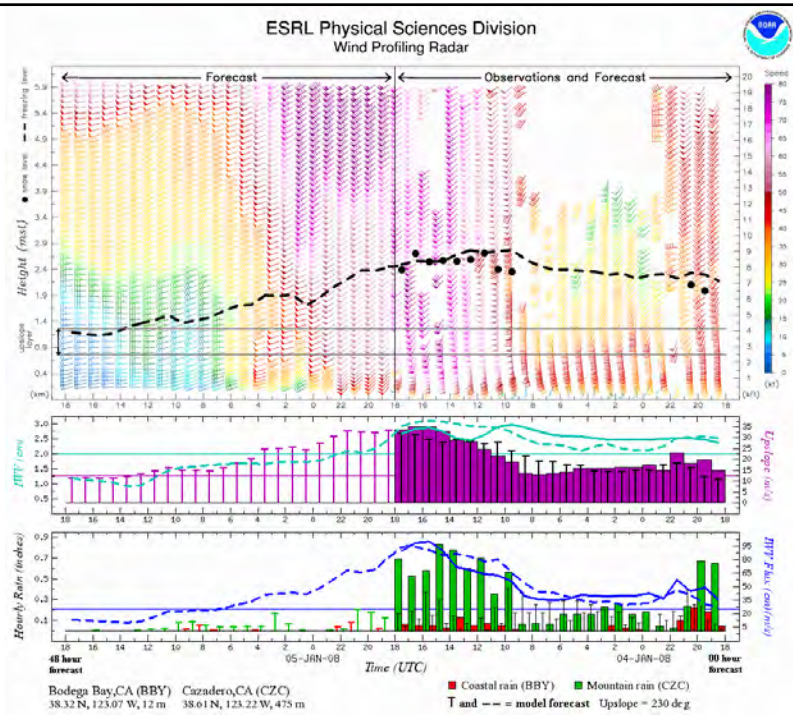


The thin blue horizontal line gives the IWV flux threshold determined by multiplying the IWV and upslope flow thresholds defined in the middle panel

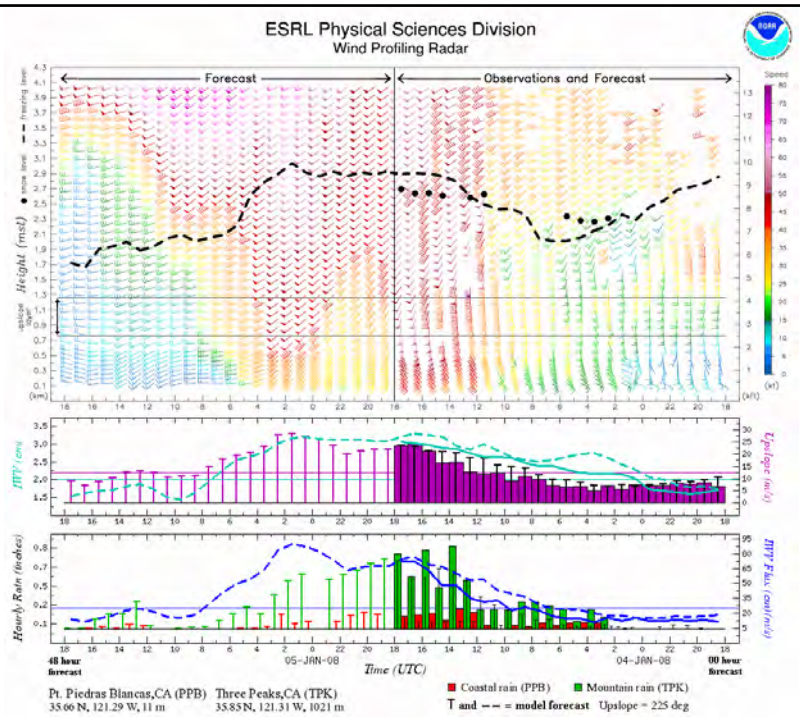
Day 1
Forecast
verification:
Northern
couplet

Dashed lines and
T posts
represent
model
output

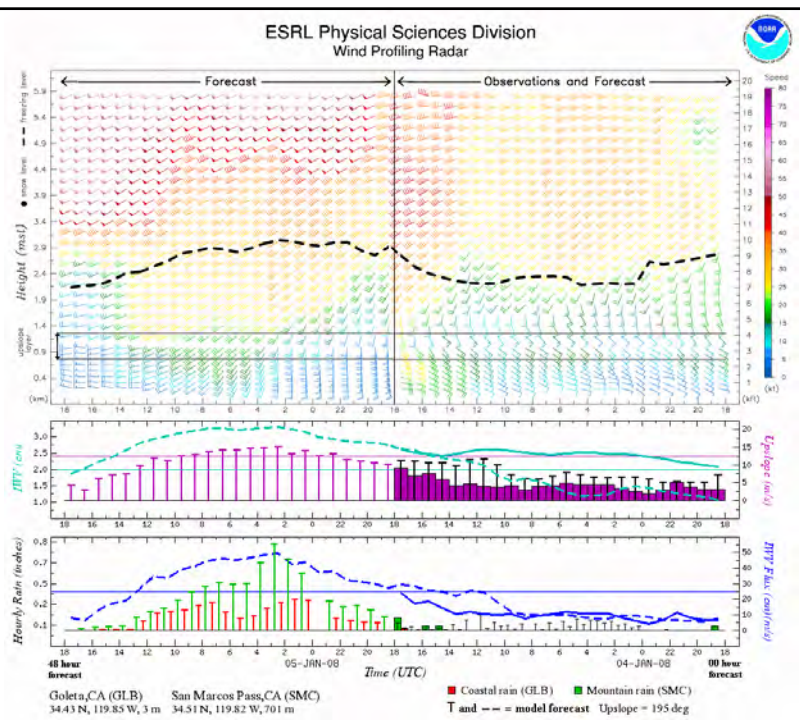
Solid lines and filled
bars show
observed
data

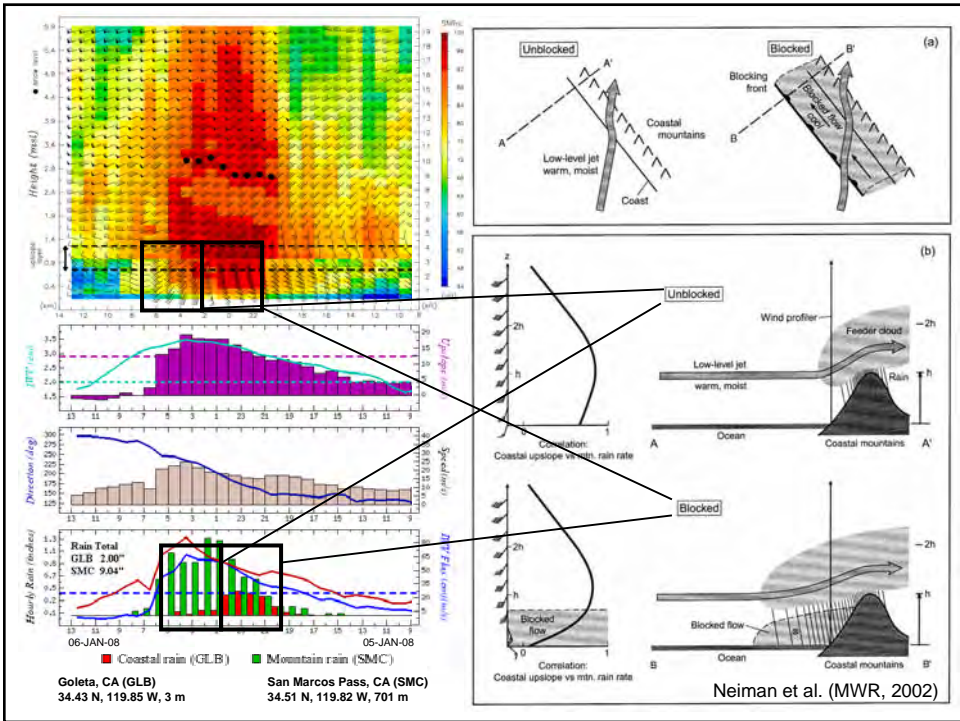
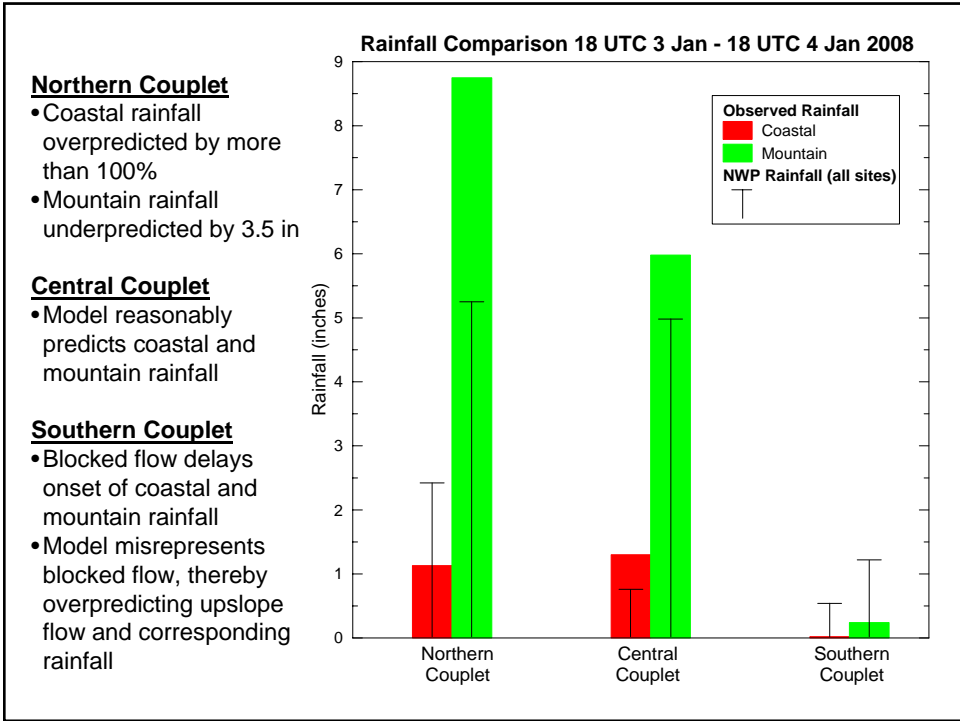


Day 1
Forecast
verification:
Central
couplet

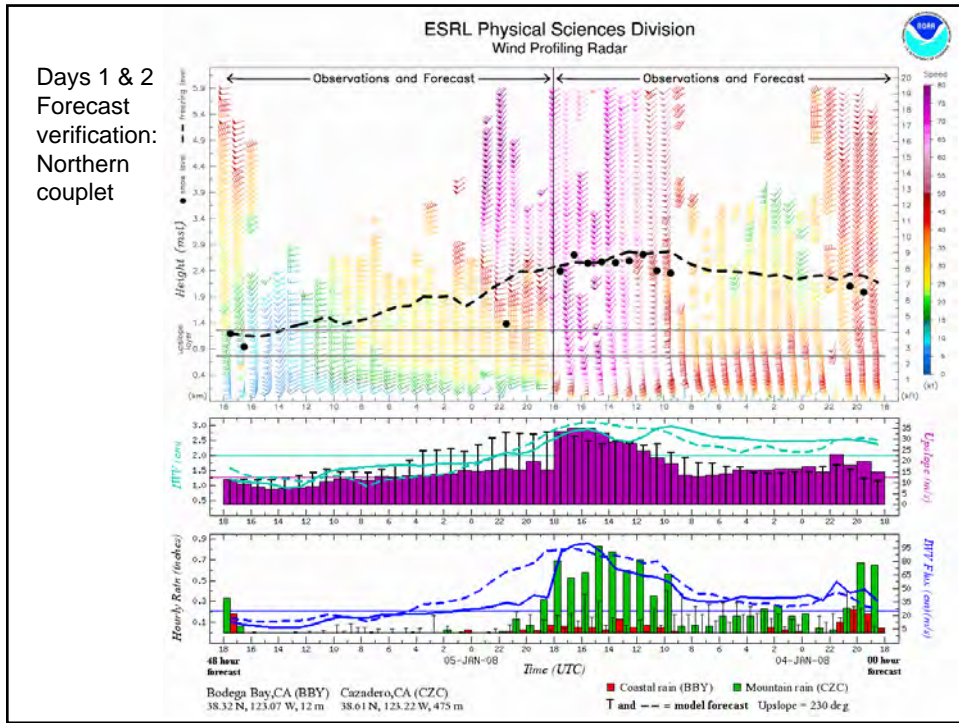


Day 1
Forecast
verification:
Southern
couplet

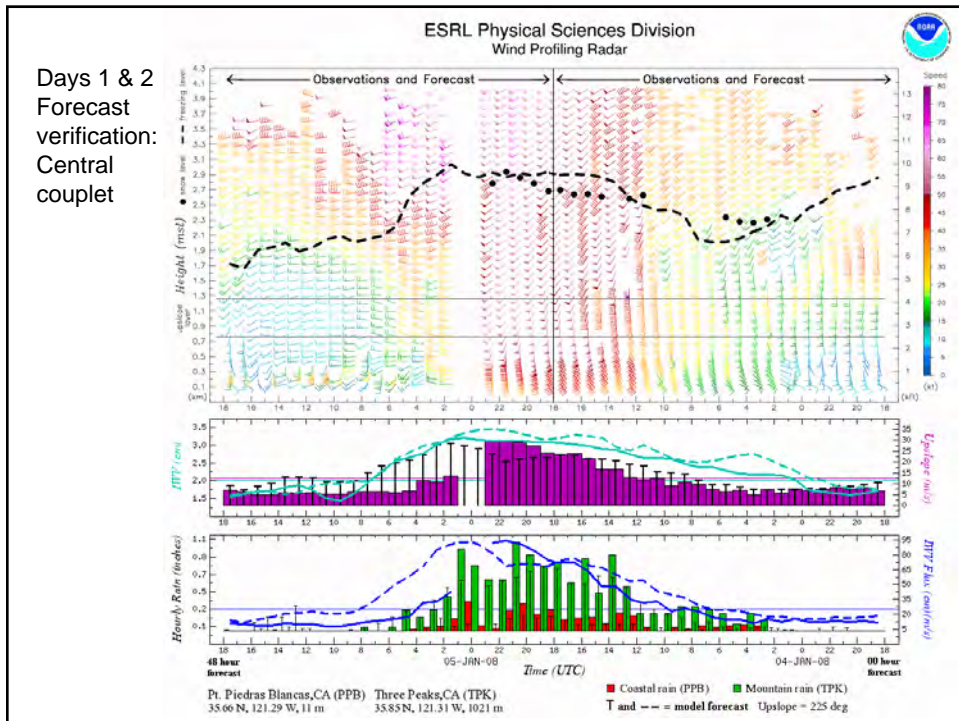


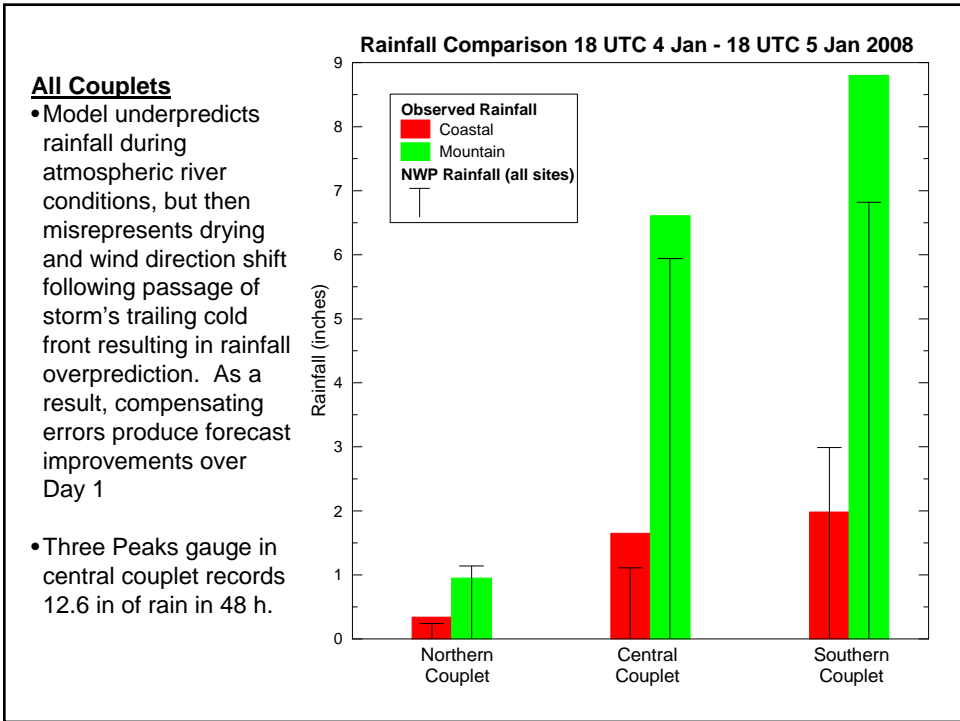
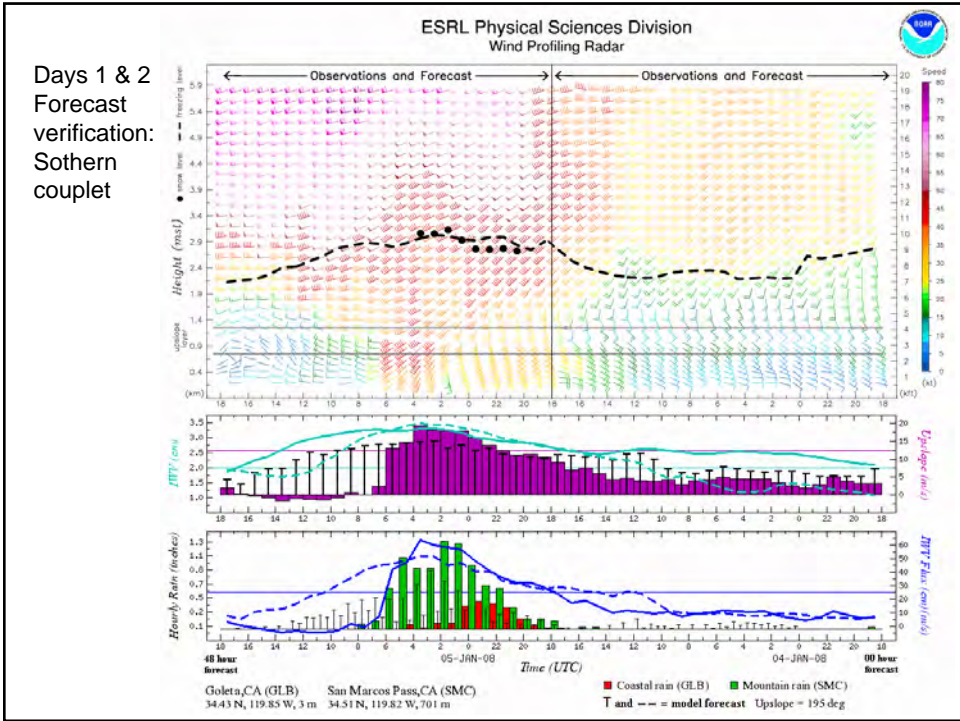


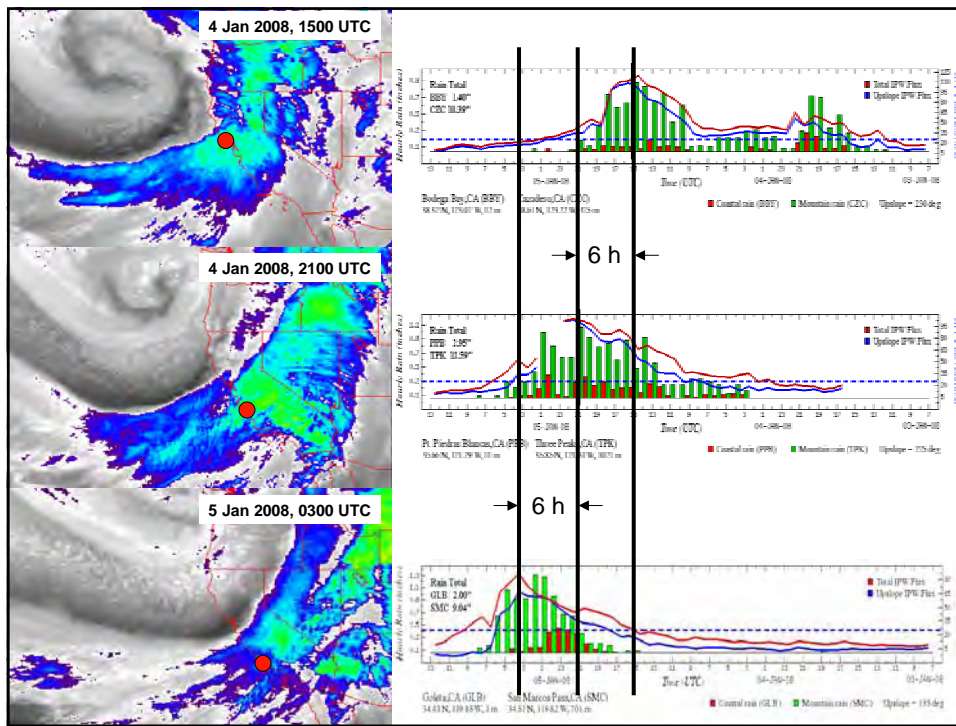
Days 1 & 2
Forecast
verification:
Northern
couplet



Days 1 & 2
Forecast
verification:
Central
couplet







Implementation Strategy: Regional UAS Testbeds



Planning of Global Hawk Tests

NASA Dryden Flight Research Center (DFRC)

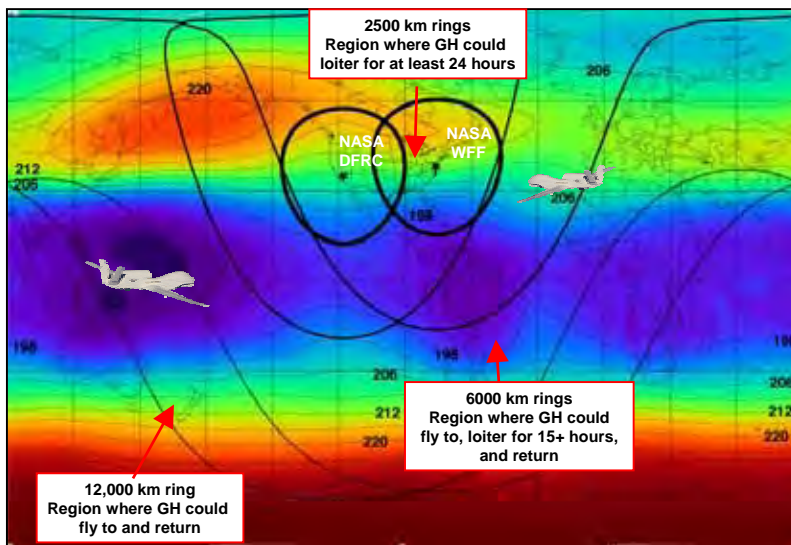
- Two Global Hawks have been acquired by NASA DFRC, CA, and will be used, in part, for [earth science research and application studies](#)
- NOAA (with NASA and NCAR) is building a dropsonde system (100/ft)



- Fully autonomous
- Communication: UHF Line of Sight, INMARSAT Beyond Line of Sight
- 25600 lbs GTOW, 9100 lbs Empty Wgt, 14500 lbs Max Fuel
- Wingspan 116 ft
- 210 - 335 KTAS
- 1500 - 2000 lb payload, 10 kVA payload power
- Performance: Alt **65,000 ft**, Range **11,000 nm**, Endurance **31 hrs**

CONOPS

Global Hawk Surveillance Range

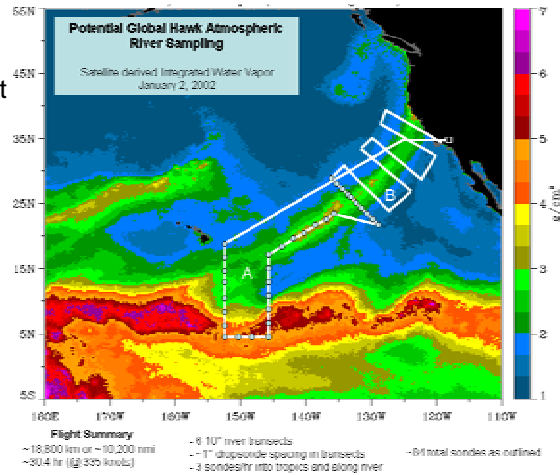


Paul Newman, NASA Goddard Space Flight Center



Atmospheric River Sampling with Global Hawk

- Enhanced atmospheric profile observations to improve winter storm forecasts on the west coast
- Primary measurements from dropsondes
 - wind profiling lidar and cloud radar would be beneficial
- Seek repeated transects across the atmospheric river
 - Characterize water vapor transport and evolution
 - Persistent monitoring of position and moisture content for improved forecasts



G. Wick, NOAA ESRL PSD

Summary

- By combining observations and forecast model output, a new forecast model verification tool has been demonstrated.
- This tool allows users to see how well a forecast model represents land-falling atmospheric rivers and their resulting impacts on orographic precipitation enhancement.
- In this case, the WRF model captured the large-scale forcing pretty well, but the coastal and mountain precipitation was represented poorly, especially for the northern couplet.
- The three atmospheric river monitoring couplets deployed along the CA coast provided valuable lead time to forecasters for when the atmospheric conditions leading to extreme precipitation would occur, especially in So-Cal, where debris flow is a major concern.
- NOAA will test and evaluate the use of unmanned aircraft to detect and monitor hazardous weather and improve its prediction