

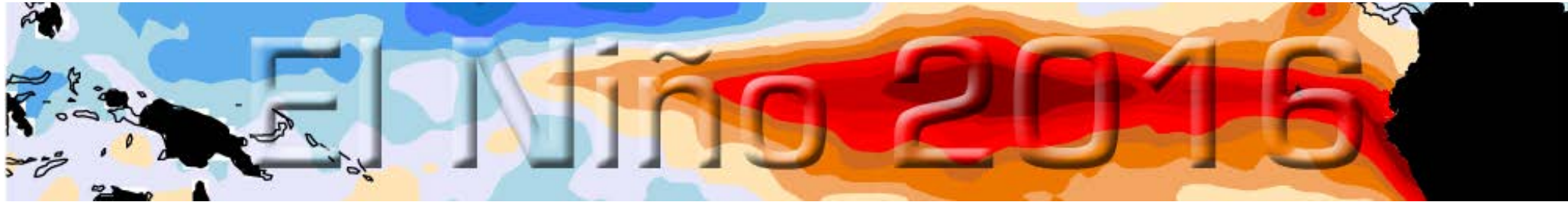


NOAA El Niño Rapid Response (ENRR) Field Campaign

Ryan Spackman (STC) and Randy Dole (CIRES)
and ENRR Science Team

NOAA Earth System Research Laboratory
Physical Sciences Division

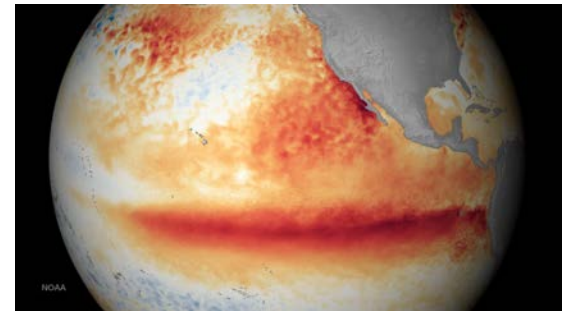
10 January 2017



Overview

Overarching Goal: Determine the atmospheric response to the major 2015-16 El Niño and its implications for predicting extratropical storms and west coast rainfall

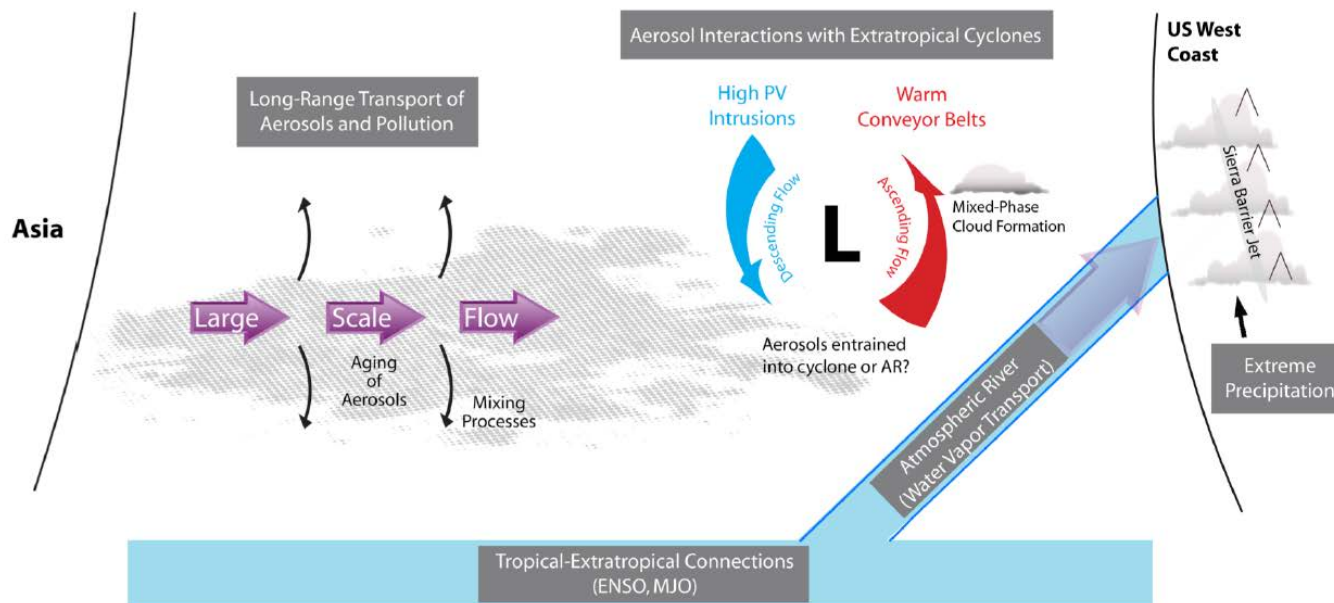
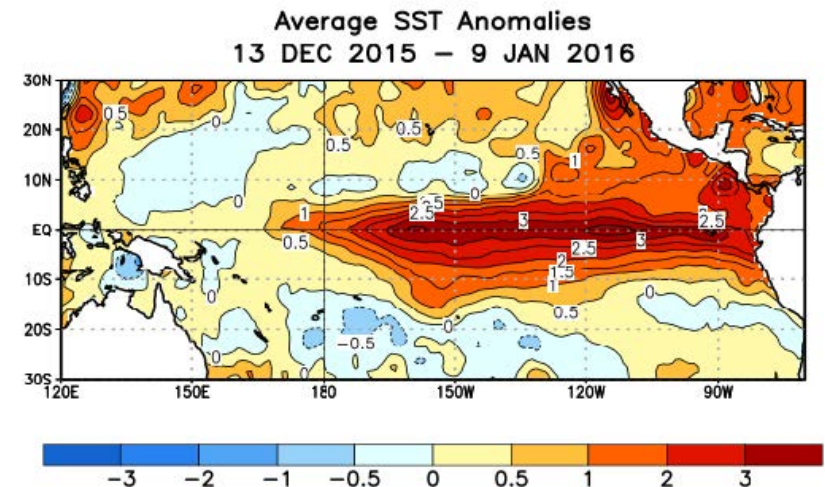
- Conducted the first field campaign targeting central tropical Pacific convection at the heart of an ongoing El Niño
- Planned and executed in less than 6 months
- Observe and understand the physical processes characterizing the first step in the chain leading to North American weather impacts
- Identify data assimilation and satellite uncertainties and model deficiencies



El Niño Rapid Response (ENRR)

- 2015-16 very strong El Niño is among top three on record
- Interesting differences from 1982-83 and 1997-98 with a more central Pacific focus in 2015-16 and variable downstream weather impacts in continental U.S.

ENRR Website: www.esrl.noaa.gov/psd/enso/rapid_response



Courtesy of J. R. Spackman, NOAA Earth System Research Laboratory

ENRR Focus:

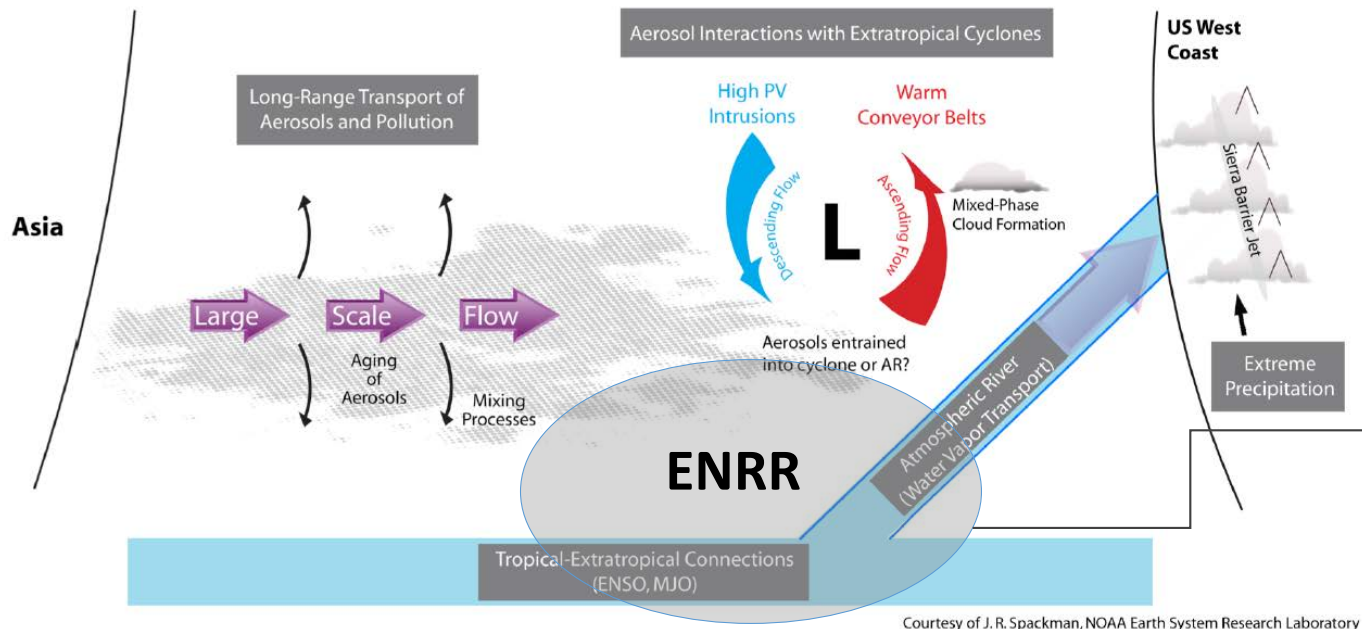
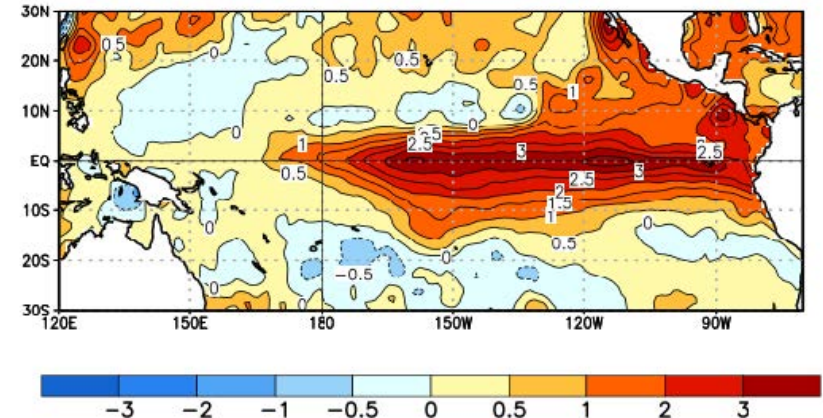
- Initial atmospheric response to deep convection in central tropical Pacific during El Niño
- Linkages between outflow from convection across the subtropical jet to extratropical impacts along the U.S. West Coast

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ENRR Website: www.esrl.noaa.gov/psd/enso/rapid_response

Average SST Anomalies
13 DEC 2015 – 9 JAN 2016

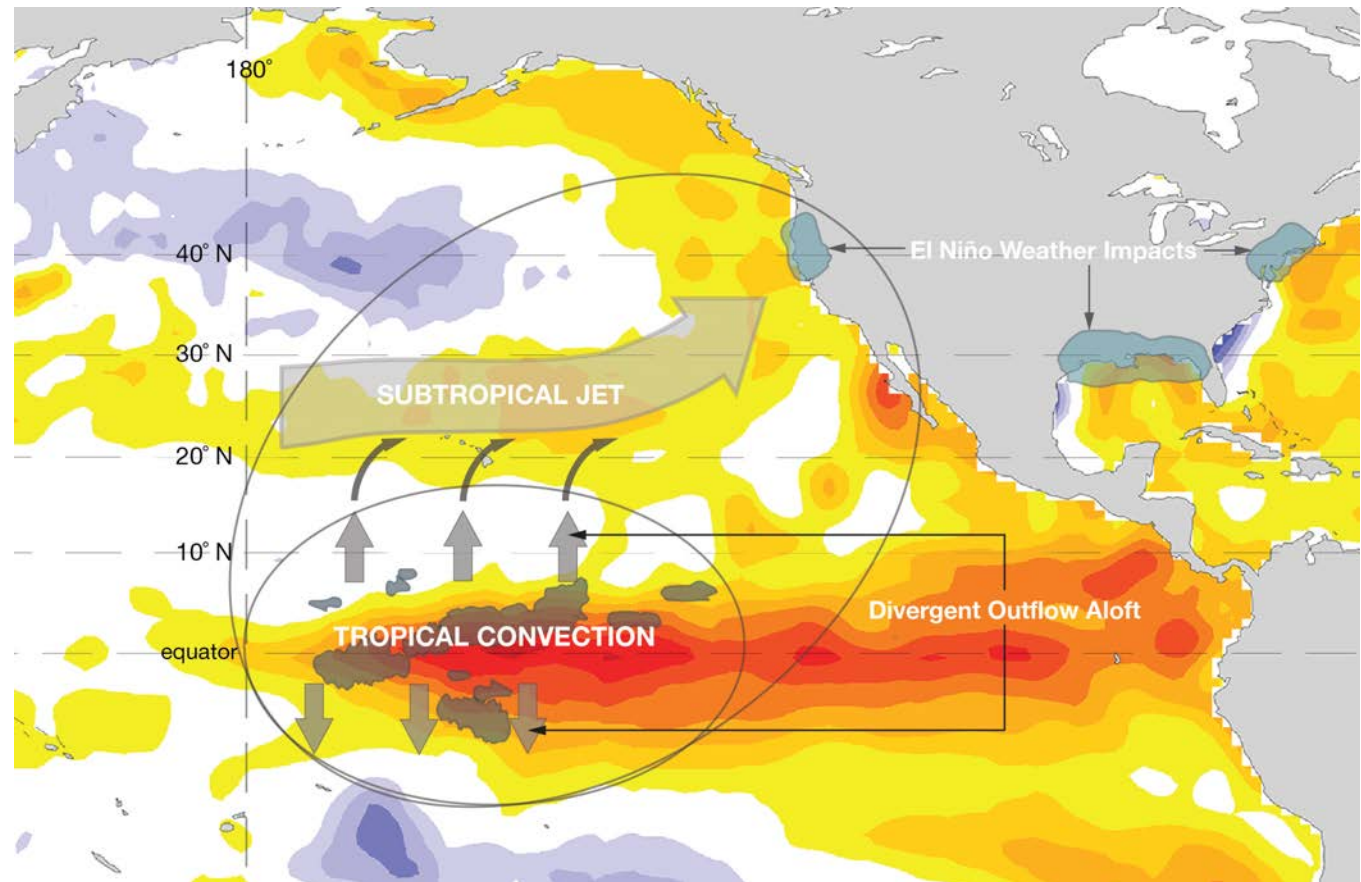


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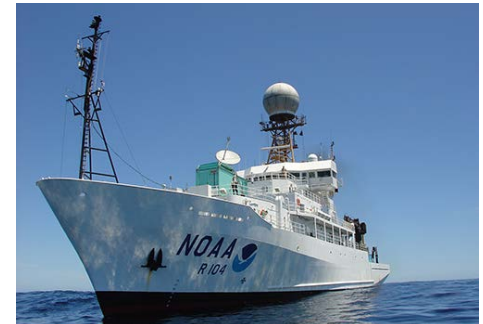
ENRR Science Questions

- How well do weather and climate models represent the tropical atmosphere's response to El Niño – the first step in the cascade of events connecting El Niño to global weather and climate impacts?
- To what extent do kinematic and thermodynamic observations near large-scale convection in the *sparsely* observed central equatorial Pacific during El Niño improve high-impact forecast metrics in the continental U.S.?



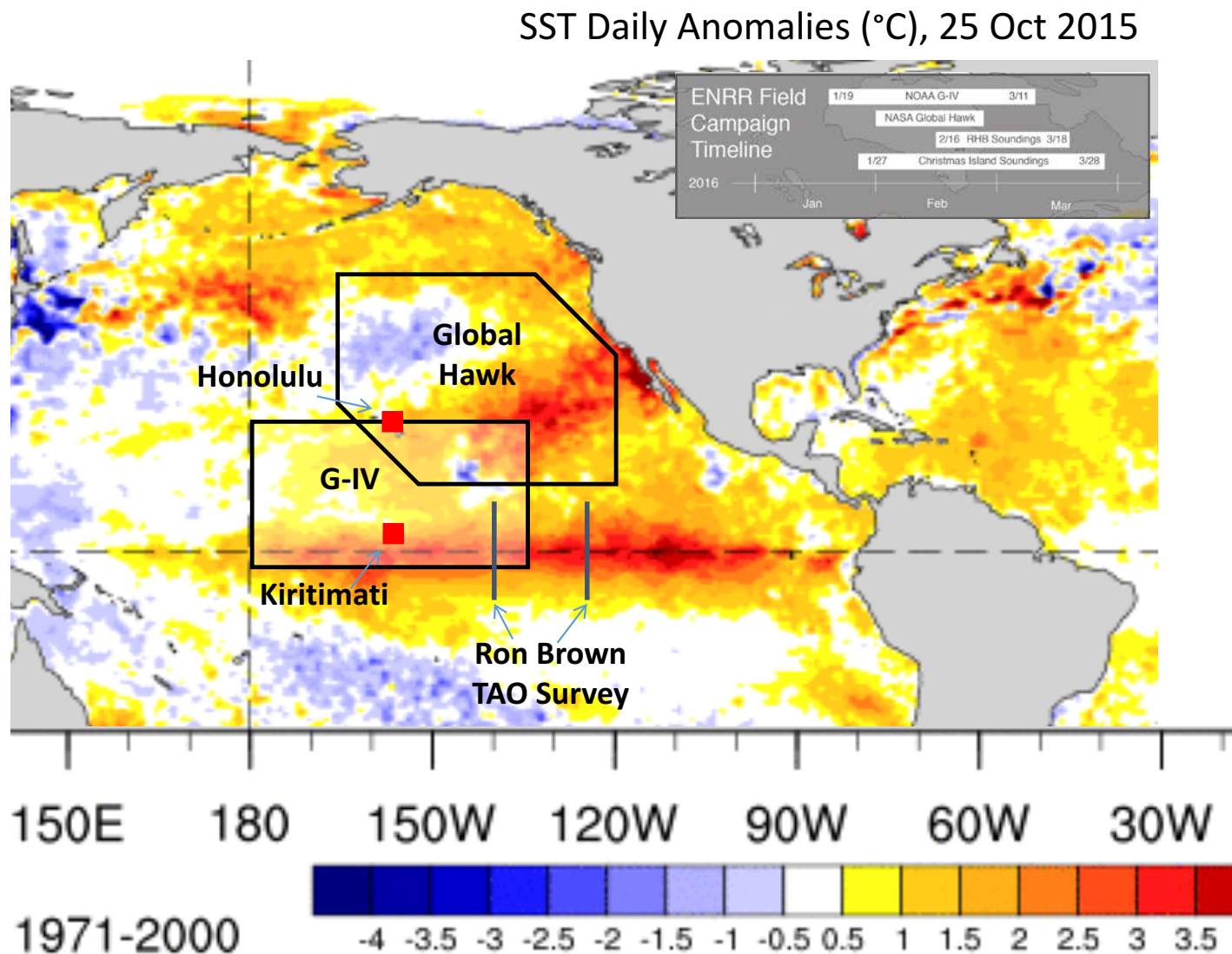
NOAA ENRR Field Campaign, Jan-Mar 2016

- NOAA G-IV conducted 22 science flights in 53 days from 19 Jan to 11 Mar operating from Honolulu and targeting outflow from deep convection north of the equator with dropsondes and tail doppler radar
- NASA Global Hawk completed 3 research flights (~24 hr duration) in 3 weeks in Feb operating from NASA Armstrong Flight Research Center and was supported by NOAA UAS SHOUT (Sensing Hazards with Operational Unmanned Technology)
- Radiosondes were launched twice daily on Kiritimati Island, 25 Jan – 28 Mar
- Radiosondes were launched up to 8 times daily from the NOAA Ron Brown during a TAO survey from Honolulu to San Diego, 16 Feb – 16 Mar, between 8°N and 8°S along 140°W and 125°W

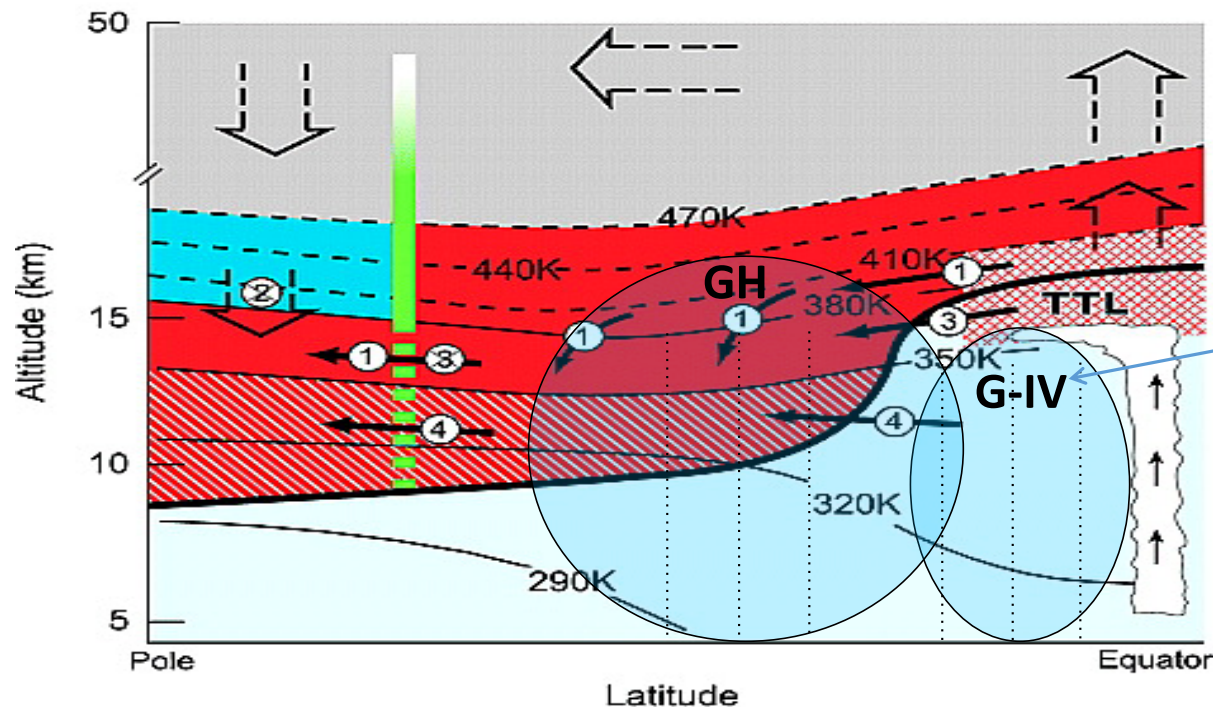


ENRR Implementation Strategy

- G-IV: Divergent outflow and jet extension processes in central and eastern tropical Pacific
- Global Hawk: Coupling to midlatitude weather with surveys in eastern Pacific midlatitudes to evaluate impacts on U.S. West Coast
- Kiritimati/Ron Brown: Survey of atmosphere and ocean conditions in eastern tropical Pacific

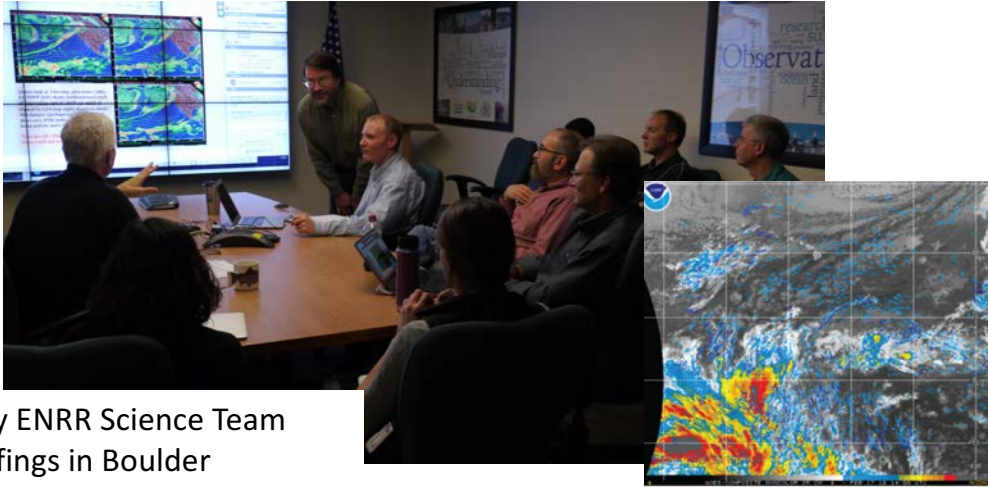


Meridional Perspective on Flight Strategies



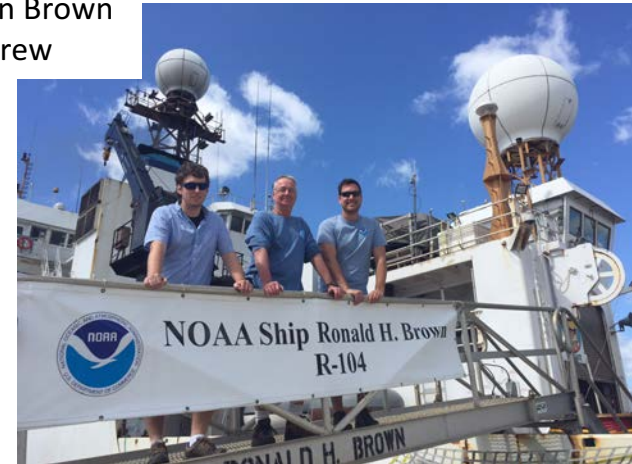
- G-IV: Divergent flow aloft in central/eastern tropical Pacific mostly reachable by G-IV at altitude of 12-14 km and captured by dropsonde measurements
- Global Hawk: Survey the subtropical jet and deep tropics where convection may extend above G-IV altitude

NOAA ENRR Field Campaign, Jan-Mar 2016



Daily ENRR Science Team Briefings in Boulder

NOAA Ron Brown Science Crew



NOAA G-IV Implementation Team in Honolulu

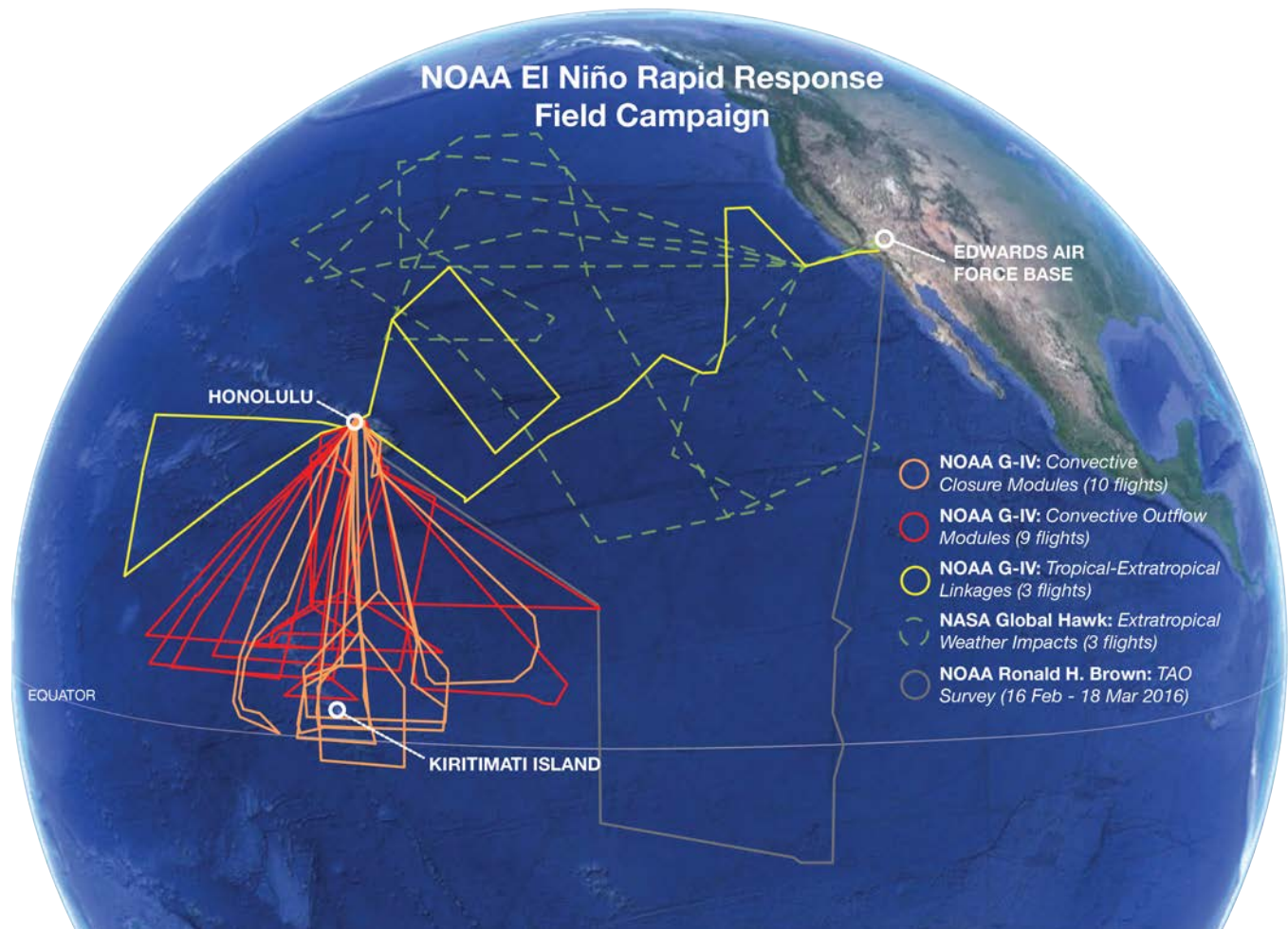


Radiosonde launch at Kiritimati Island



ENRR Field Campaign Summary

- 718 dropsondes deployed
NOAA G-IV: 628 sondes in 22 research flights
NASA Global Hawk (SHOUT): 90 sondes in 3 science flights
- 336 radiosondes launched
NOAA Ron Brown: 193 sondes
Kiritimati (2.01°S, 157.40°W): 124 sondes
- G-IV performed “coordinated” missions with Global Hawk, C-130s, and Alpha Jet

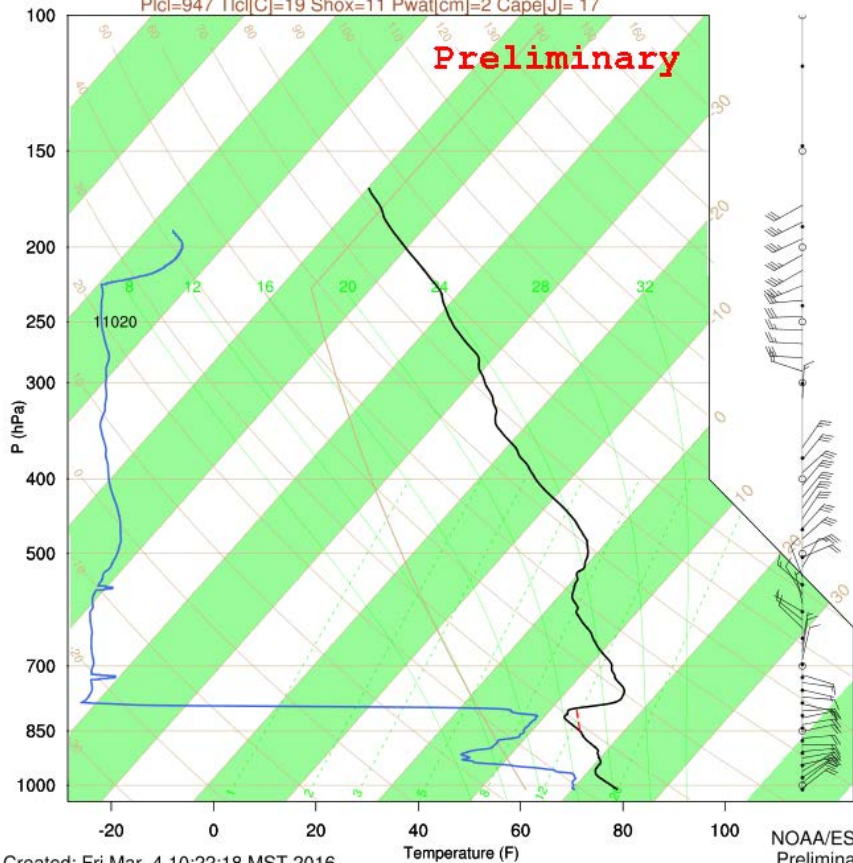


Convective Closure Module Soundings

G4 20160226_RF15: 02/27/16 023936 13.40 N , 156.34 W

Ptcl=947 Tlcl[C]=19 Shox=11 Pwat[cm]=2 Cape[J]= 17

Preliminary

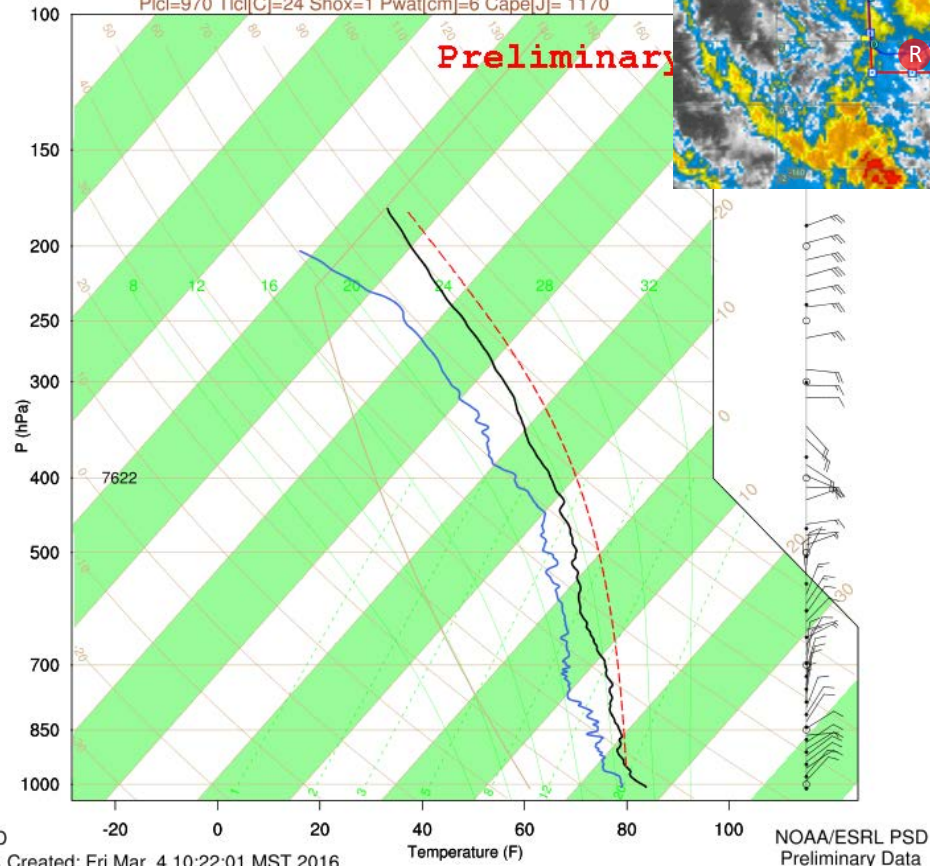


Created: Fri Mar 4 10:22:18 MST 2016

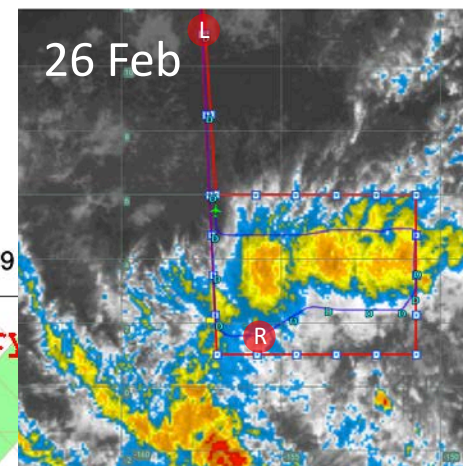
G4 20160226_RF15: 02/26/16 233929 1.61 N , 155.79

Ptcl=970 Tlcl[C]=24 Shox=1 Pwat[cm]=6 Cape[J]= 1170

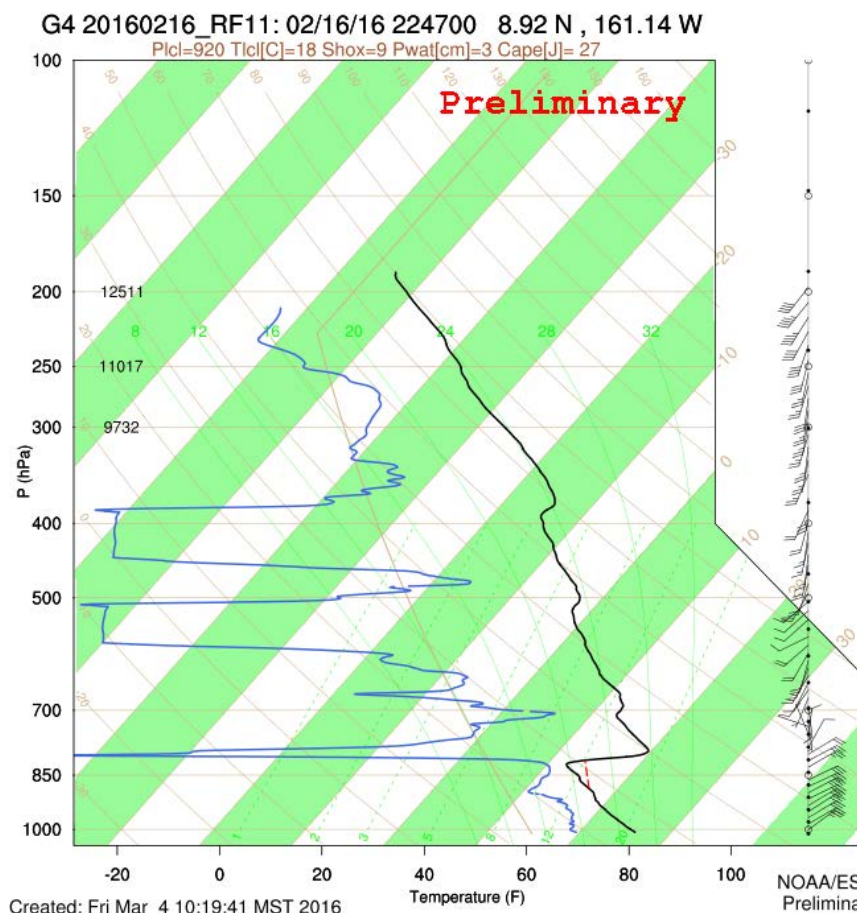
Preliminary



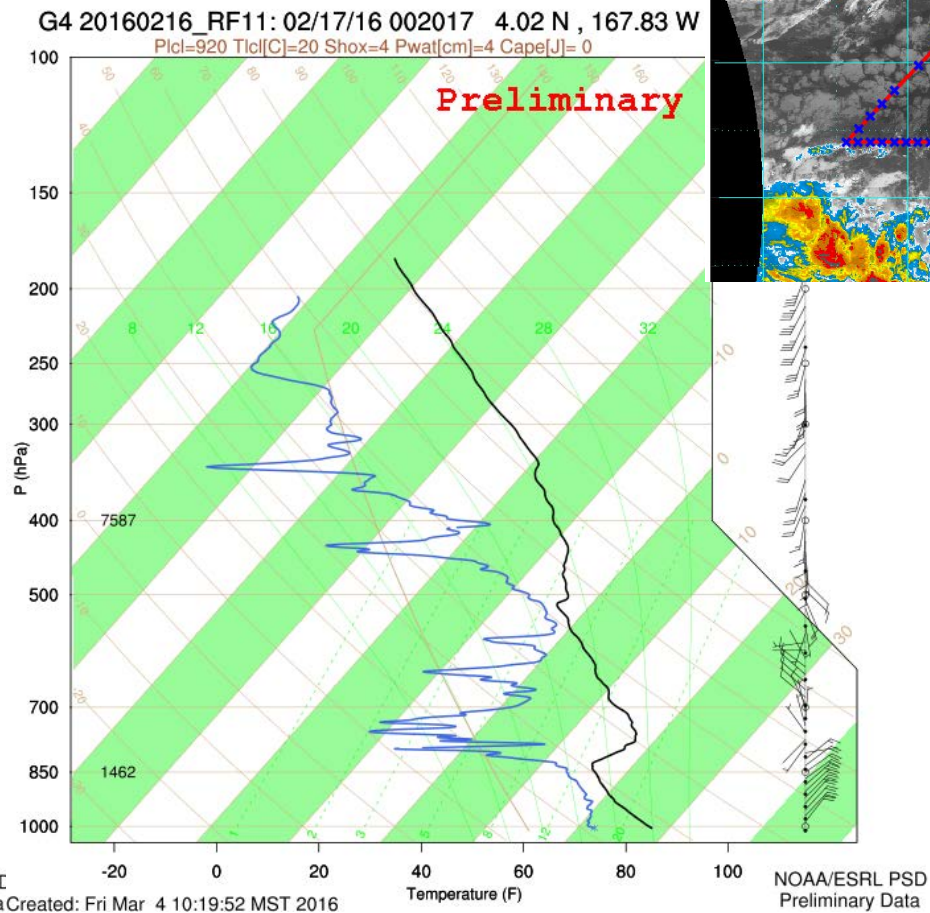
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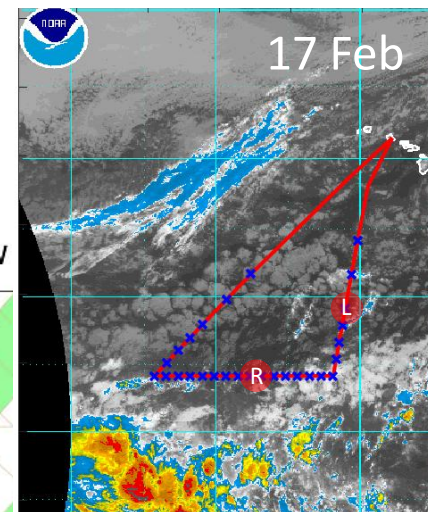
Convective Outflow Module Soundings



Created: Fri Mar 4 10:19:41 MST 2016

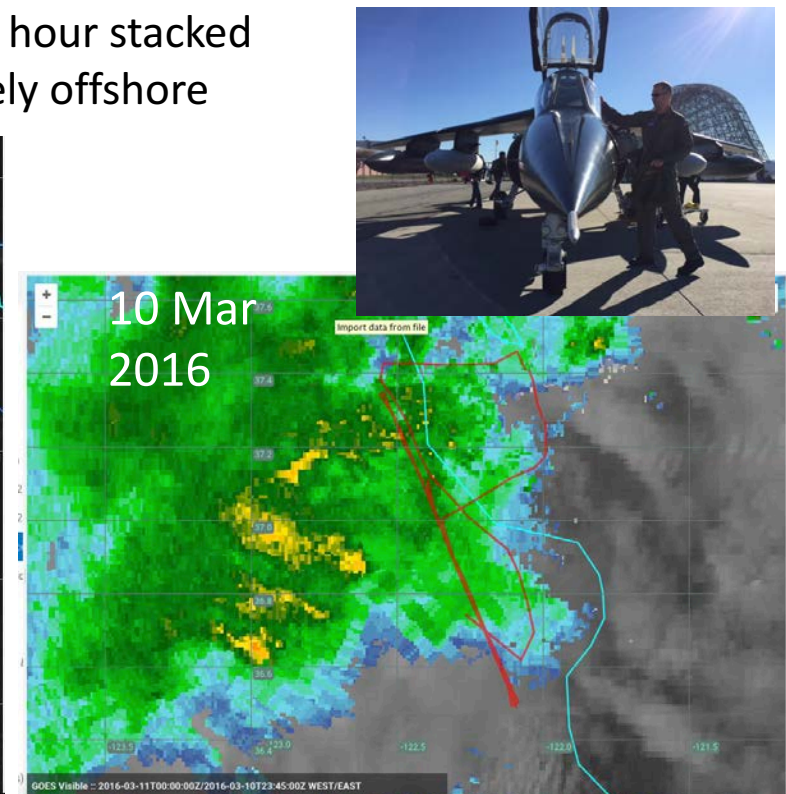
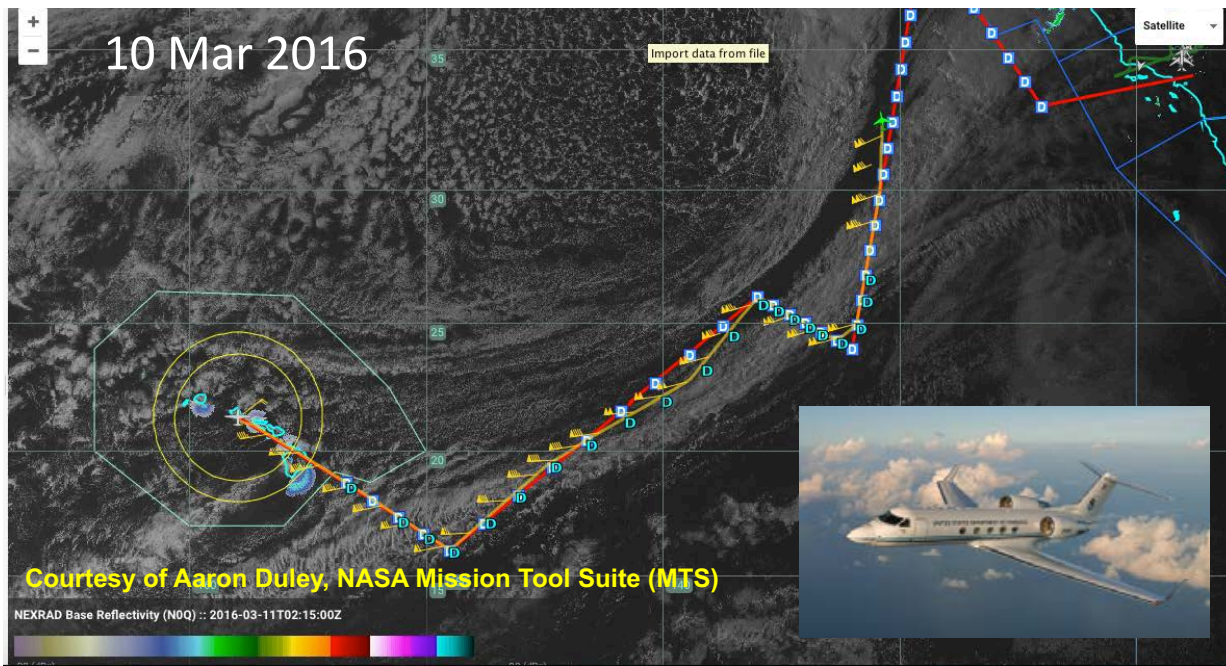


Created: Fri Mar 4 10:19:52 MST 2016



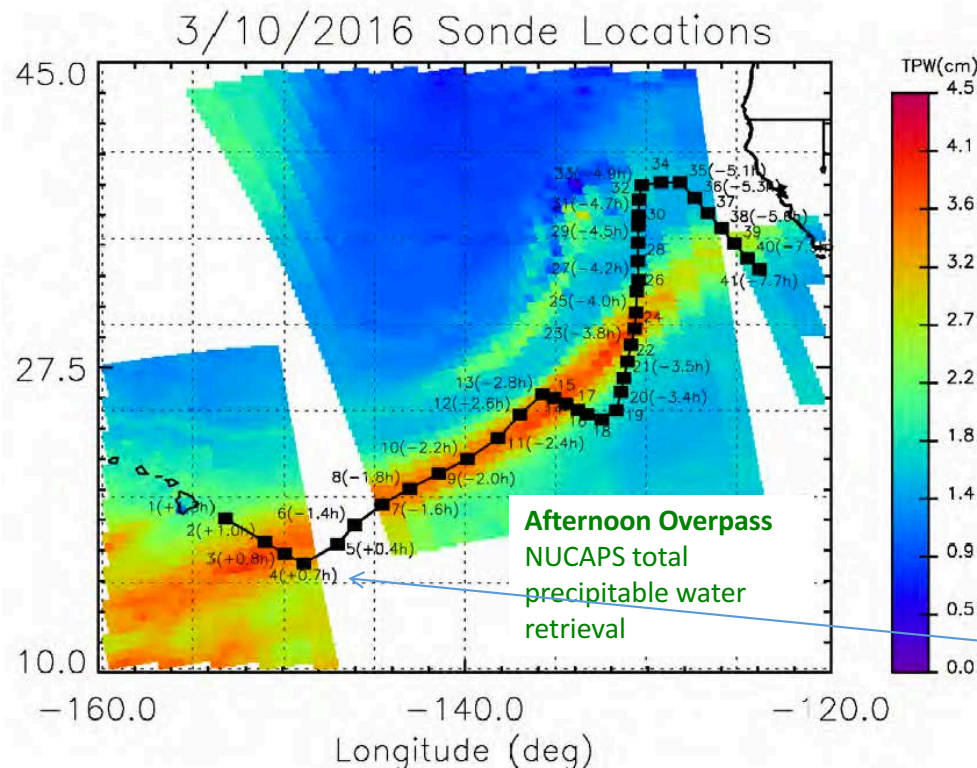
Tropical-Extratropical Linkages: NOAA G-IV Coordinated Flight with Alpha Jet

- G-IV flew multiple transects at 13 km altitude releasing dropsondes across a mature atmospheric river (AR) northeast of Hawaii making landfall along the northern CA coast
- Alpha Jet (based at NASA Ames in Bay Area) conducted a 1.5 hour stacked flight at low altitude in the warm sector of the AR immediately offshore



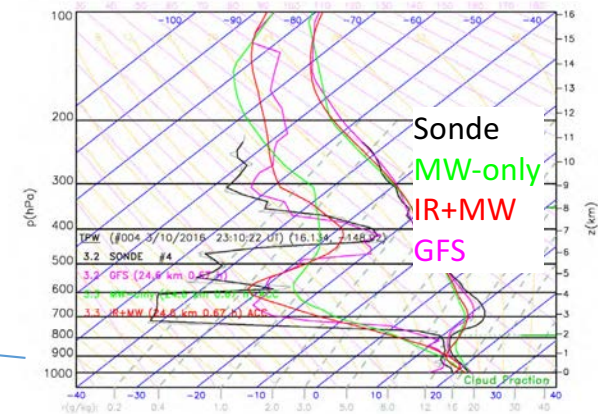
Dropsonde-Satellite-Model Comparisons

Morning and afternoon retrievals were performed from overpasses of Suomi-NPP based on **microwave-only (ATMS)** and **combined infrared and microwave (CrIS+ATMS)** sounding retrievals and compared with G-IV dropsondes and NCEP's **Global Forecast System** 3-9 hour forecasts



Colors: Total precipitable water from NOAA S-NPP satellite sounding algorithm (NUCAPS)
Boxes: Location of dropsondes from NOAA G-IV (time offset from overpass)

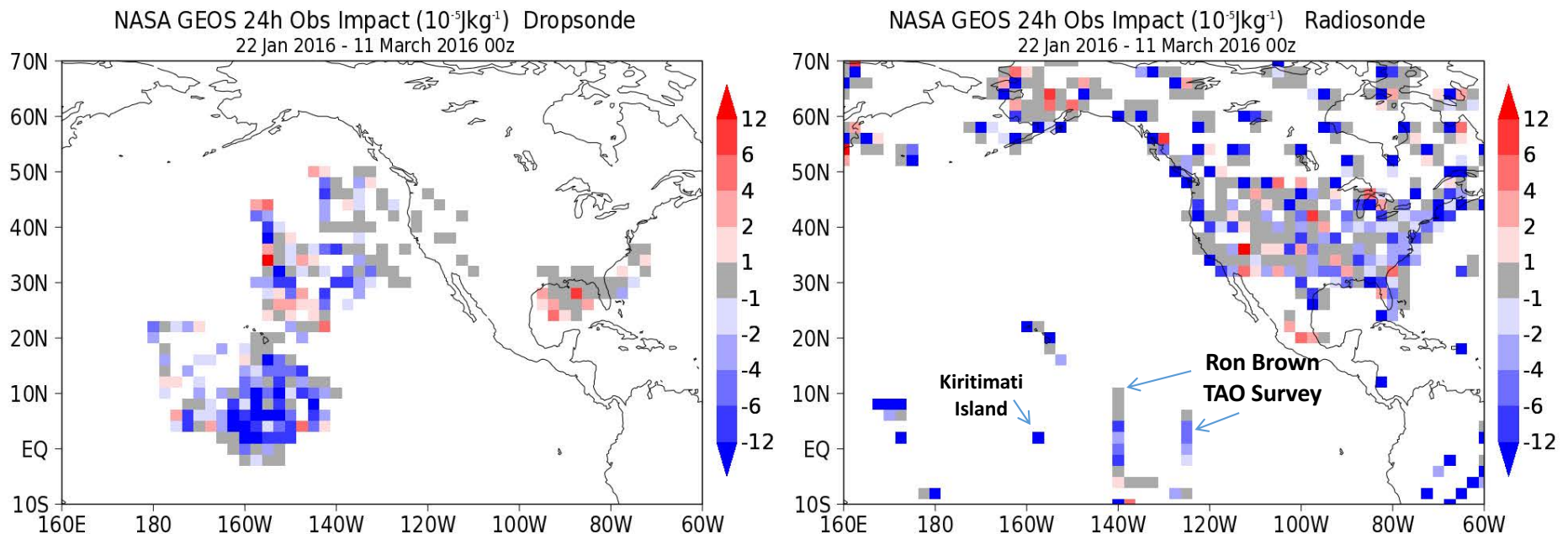
Dropsonde 4



Courtesy of Antonia Gambacorta, Chris Barnett
Science and Technology Corporation (STC) and NESDIS

Preliminary Results – Forecast Improvement

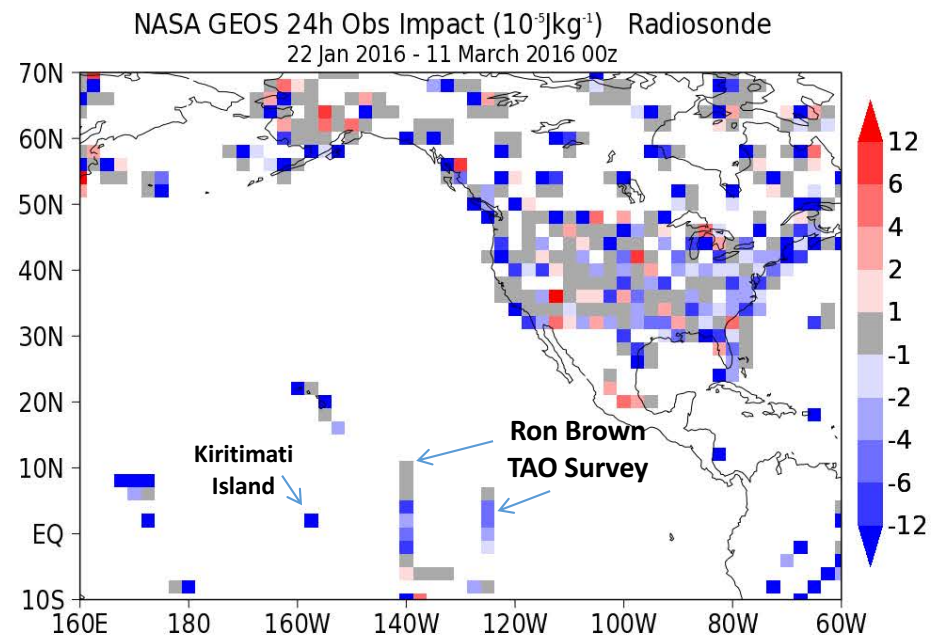
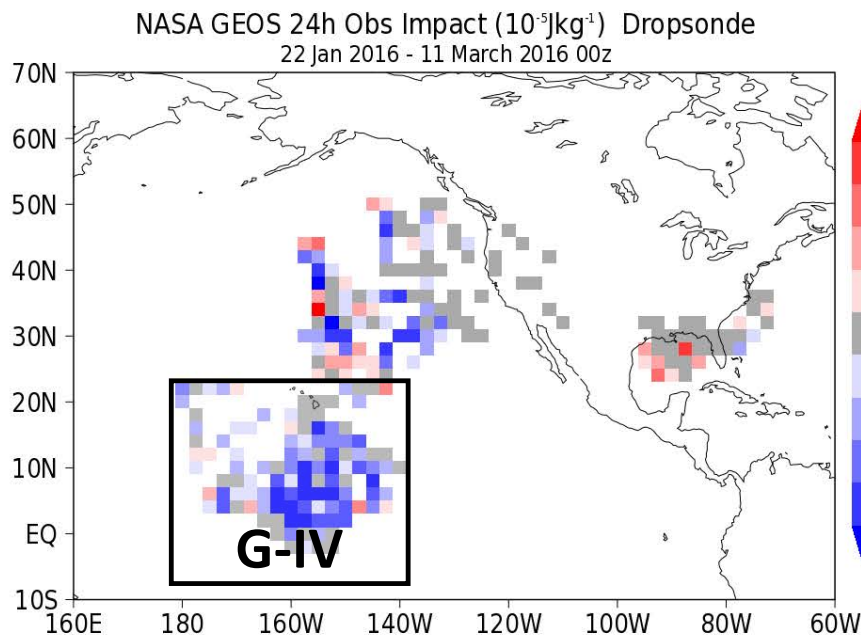
- In NASA GEOS-5 model, G-IV dropsondes (left) and Kiritimati Island and Ron Brown radiosondes (right) reduce 24-hr forecast error as measured by global total moist energy
- Given all obs around the world, of those taken from 20°N to 20°S, ENRR dropsondes have the greatest contribution to reduction of error on a “per observation” basis



Courtesy of Ron Gelaro (NASA GMAO) and Gilbert Compo (NOAA ESRL PSD)

Preliminary Results – Forecast Improvement

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Courtesy of Ron Gelaro (NASA GMAO) and Gilbert Compo (NOAA ESRL PSD)

ENRR Data Portal

https://www.esrl.noaa.gov/psd/enso/rapid_response/data_pub/

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PSD » ENSO » EL NIÑO RAPID RESPONSE

El Niño 2016

NOAA El Niño Rapid Response Field Campaign

JANUARY - MARCH 2016

PSD Leads: [Randall Dole](#) and [Ryan Soackman](#) | Media Relations: [Theo Stein@noaa.gov](#), 303-497-6288

The major El Niño of 2015-2016 presented an unprecedented scientific opportunity for NOAA to accelerate advances in understanding and predictions of an extreme climate event and its impacts through research conducted while the event was ongoing. ESRL's Physical Sciences Division (PSD) played a central role in the NOAA El Niño Rapid Response (ENRR) field campaign to determine key mechanisms affecting El Niño's impacts on the U.S. and their implications for improving NOAA's observational systems, models and predictions. The ENRR campaign spanned the central and eastern tropical Pacific to California. Multiple types of observing resources collected measurements from the air, ocean, and ground between January and March of 2016. Of particular interest was the increased risk for intense wintertime storms and heavy rainfall affecting the U.S. West Coast during this event's very strong El Niño. [READ MORE](#)

OBSERVATIONS IN THE FIELD...

- NOAA G-IV Aircraft**
The NOAA G-IV aircraft flew out of Honolulu, Hawaii carrying a suite of meteorological sensors and deploying dropsondes for 22 research flights from mid January to early March 2016.
- NOAA Research Ship Ronald H. Brown**
The NOAA Research Ship Ronald H. Brown launched up to 8-times daily radiosondes on the Tropical Atmosphere Ocean (TAO) survey cruise from February 16 to March 18, 2016 (Honolulu to San Diego).
- NASA Global Hawk Unmanned Aircraft**
The NASA Global Hawk, deployed through the SHOUT project led by NOAA's UAS Program, carried a suite of meteorological sensors and launch dropsondes during three research flights in February.
- Kiritimati Island Observations**
On Kiritimati (Christmas) Island, approximately 1,340 miles south of Honolulu, a radiosonde sounding system was set up with twice-a-day vertical soundings made continuously from late January through March 2016.
- Scanning X-Band Radar in San Francisco**
A scanning X-band radar will be deployed to the south San Francisco Bay as an experimental radar system, which will provide the more accurate rainfall estimates for the region that are needed to better manage and mitigate negative impacts. Starting in late January.

PSD researchers in Boulder, Colorado analyzed conditions and held daily forecast briefings, which were used to plan and coordinate field observations.

U.S. Department of Commerce | National Oceanic & Atmospheric Administration
Earth System Research Laboratory | Physical Sciences Division
http://www.esrl.noaa.gov/psd/enso/rapid_response/

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PSD » ENSO » EL NIÑO RAPID RESPONSE » DATA

NOAA 2016 El Niño Rapid Response Field Campaign Data Portal

Overview | **NOAA G-IV** | Kiritimati Island | Ronald H. Brown | Global Hawk | Santa Clara

ENRR DATA OVERVIEW

PSD is providing links to the data acquired as part of the ENRR campaign. Select from the platform "tabs" above. We will also include metadata, plots, sample code when possible. The page is in progress and we will continue to add to what we make available.

What's New!

- 10/10/2016: X-Band Radar data now now available for ftp.
- 09/29/2016: Global Hawk ozone data is now available for ftp.
- 09/21/2016: Dry bias corrected G-IV data is now available for ftp.
- 09/01/2016: Level 2 sonde data for Kiritimati Island and NOAA's Ronald Brown platforms are also available.

Related Data Information

- To see what observations were used, there are maps that provide a quick look successfully decoded into NCEP's production bufr data tanks.

U.S. Department of Commerce | National Oceanic & Atmospheric Administration
Earth System Research Laboratory | Physical Sciences Division
http://www.esrl.noaa.gov/psd/enso/rapid_response/data_pub/

KIRITIMATI ISLAND

On Kiritimati (Christmas) Island, approximately 1,340 miles south of Honolulu, a radiosonde system was used to collect vertical soundings of the atmosphere twice a day from late January through March 2016.

Jump to summary: Radiosondes | Surface Met

Radiosonde

TYPE: Atmospheric soundings
DATES: 20160126-20160327
TIMES: Twice daily launches, near 06 & 12z.
SPATIAL COVERAGE: Point: 2.01N, 157.40W
VARIABLES: Pressure, geopotential height, temperature, dewpoint, relative humidity, winds, latitude, longitude, altitude.
INSTRUMENT: Vaisala RS92-SGP radiosondes.
FORMAT: NASA-Ames format ASCII files ([format description](#)).
DATA ISSUES: Data have been reprocessed using corrected surface observations as initial conditions. "Level 2" data have also been subject to automatic quality control checks; more details are given in the file headers. More extensive quality control will be performed in the near with "Level 3" and "Level 4" data expected to be released in the first half of 2017.
CITATION: Please cite ESRL/PSD if using this data as the source and let us know if you are using this data in your research. A dataset DOI is in progress please email contact(s) to get the latest information. Journal articles documenting the dataset are in process, please email contact(s) to the latest information.
CONTACTS: esrl.psd.data@noaa.gov, Leslie.M.Hartman@noaa.gov
ISO METADATA: Coming Soon!

Surface Meteorology

DATES: 20160125-20160328
TIMES: Every 2 minutes through 2016-02-11 04:05:43, then every 1 minute
SPATIAL COVERAGE: Point: 2.01N, 157.40W
VARIABLES: Pressure, temperature, relative humidity, winds, precipitation.
INSTRUMENTS: Vaisala PT102B barometer, Vaisala HMP45C temperature and relative humidity probe, R.M. Young S103 anemometer, Texas Electronics tipping bucket.
FORMAT: NASA-Ames format ASCII files ([format description](#)).
DATA ISSUES: Data have been corrected for known measurement issues when possible and replaced with bad/missing flags when that was not possible have been visually screened for physically unreasonable values. See the metadata in the file header for basic details and contact information.
CITATION: Please cite ESRL/PSD if using this data as the source and let us know if you are using this data in your research. A dataset DOI is in progress please email contact(s) to get the latest information. Journal articles documenting the dataset are in process, please email contact(s) to the latest information.
CONTACTS: esrl.psd.data@noaa.gov, Leslie.M.Hartman@noaa.gov
ISO METADATA: Coming Soon!

Tail Doppler Radar

TYPE: (Raw) See HRD.doc
DATES: 20160121-20160310
TIMES:



Summary and Lessons Learned

- Despite programmatic challenges, NOAA demonstrated it is possible to *rapidly respond* to seasonal forecasts of a very strong El Niño
- ENRR was highly successful field campaign providing meteorological observations in the central tropical Pacific during the very strong El Niño
- ENRR provided an unprecedented dataset that will be examined for years to come
- Lesson Learned: Initiate partnerships with other agencies and academia/industry to leverage resources to better address system science before the rapid response
- Lesson Confirmed: Synchronize observing strategy with physical process understanding, satellite validation, and model development that informs the next generation global prediction systems

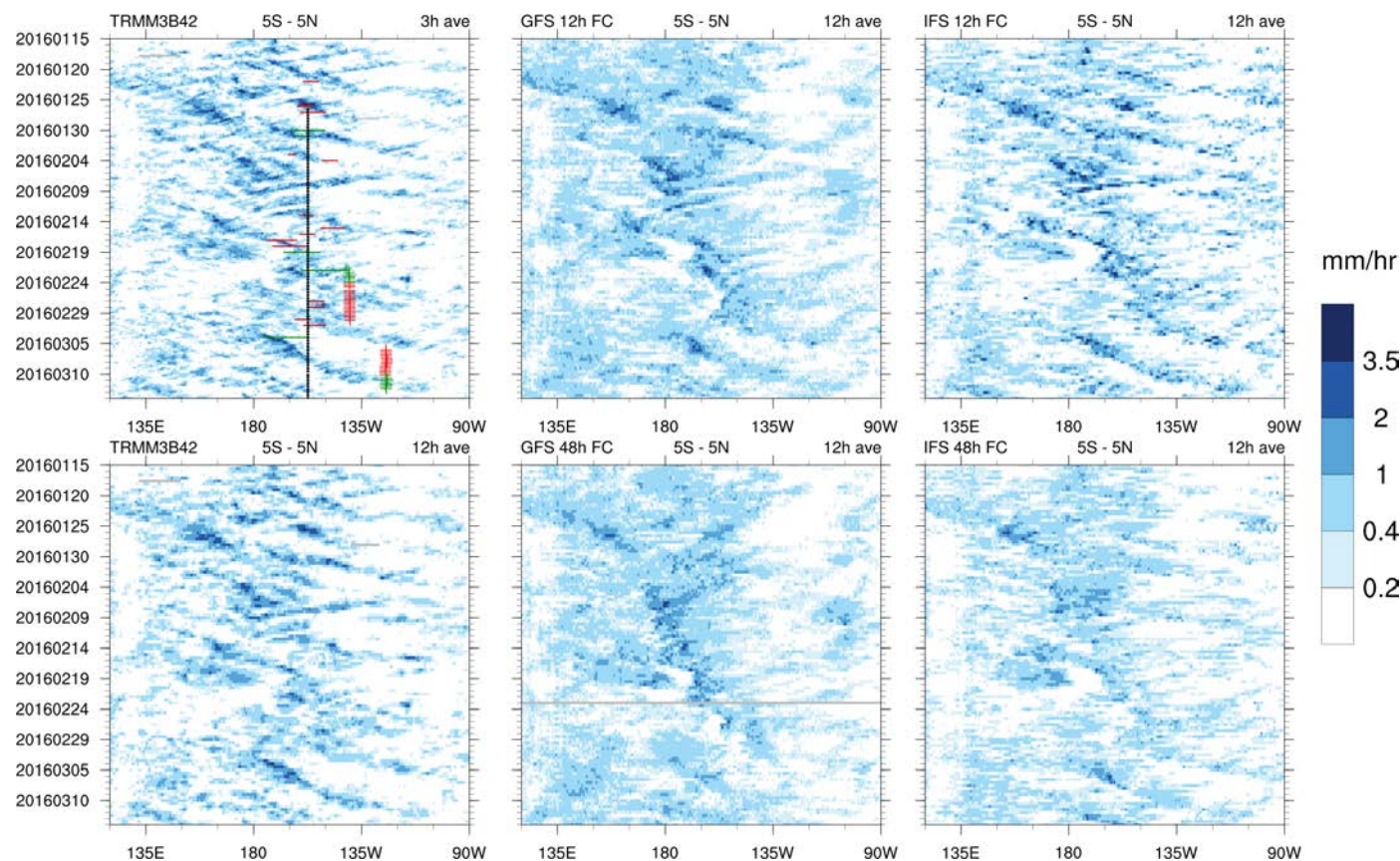
Next Steps and Future Directions

- **Model Improvements:** Examine the detailed physics associated with tropical convection and the linkages to jet processes in the extratropics and consider forecast model development approaches to implementing these schemes in process and operational global models
- **Forecast skill:** To what extent do thermodynamic and wind observations in data sparse regions reduce the error in 1 to 7-day forecasts? And how does this drive the observing strategy?
- **Integrated observing system development:** Use *in situ* measurements to refine satellite remote sensing algorithms to improve retrievals in data sparse regions
- **Outcomes from ENRR justify longer-term atmospheric and oceanic observations in data sparse tropical regions to examine air-sea interactions, large-scale convection and coupling to the midlatitude wave train for varying ENSO modes**

Supplementary Slides

Preliminary Results – Physical Process Understanding

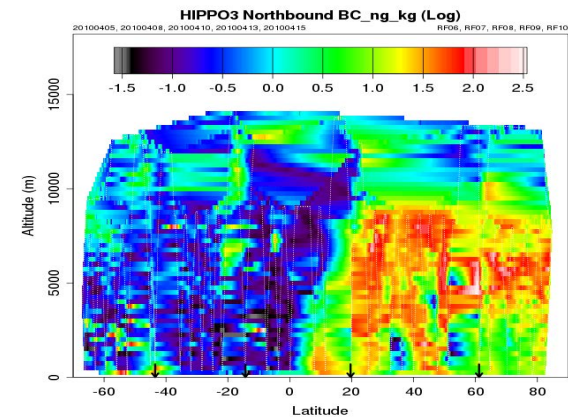
- Comparison of GPM data (left panels) with GFS and IFS model precipitation for 5°N to 5°S during ENRR period
- ENRR observations are overlaid on the Hovmöller in the upper left plot:
 - Kiritimati (black dots)
 - G-IV (long dashes)
 - Ron Brown (plus signs)
- IFS appears to better represent precipitation than GFS in tropics



Courtesy of Kiladis, Dias, Gehne (NOAA ESRL PSD)

CalWater 2019 Opportunity

- DOE G-1 payload includes extensive suite of aerosols and cloud microphysics
- NOAA G-IV can provide key met observations (dropsondes, tail Doppler radar) to support aerosol/cloud evolution studies

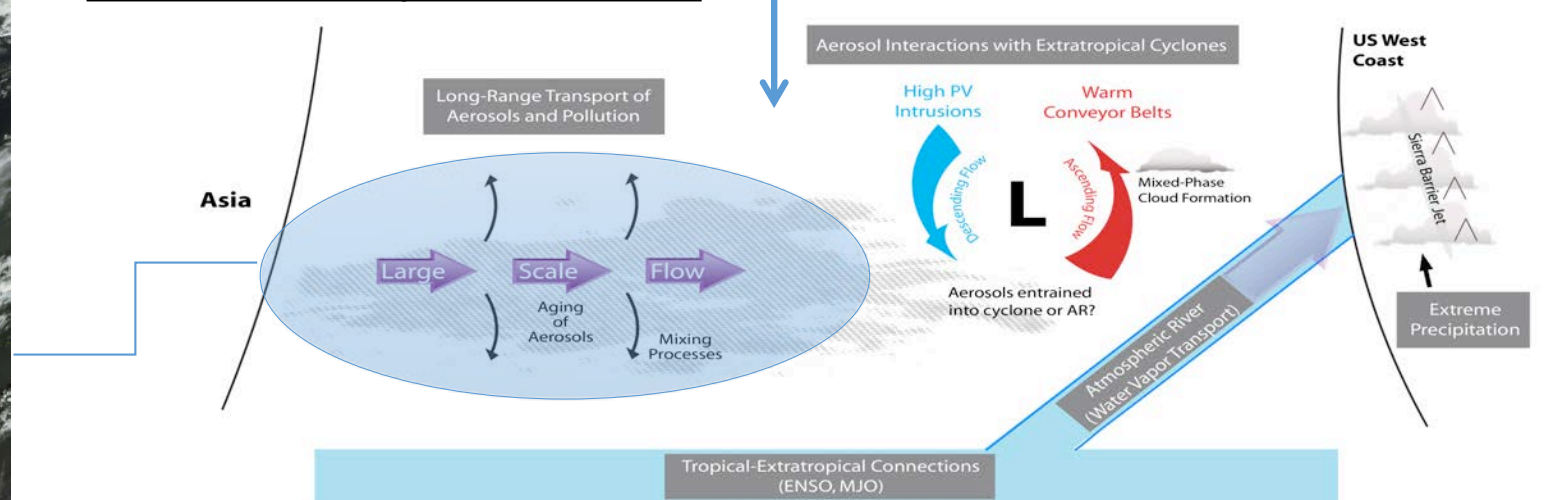


Midlatitudes are extremely polluted downstream of East Asia in springtime



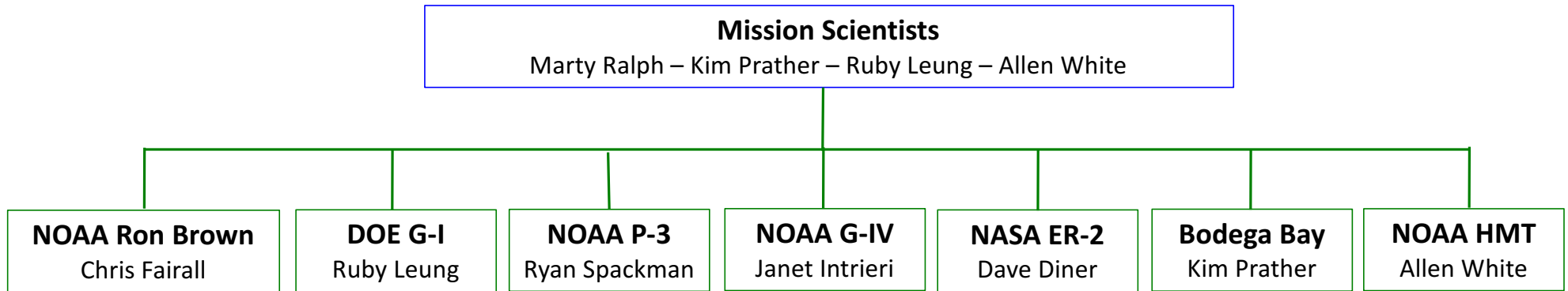
Dust and Pollution outflow from East Asia from MODIS imagery

CalWater 2 Conceptual Framework



Courtesy of J.R. Spackman, NOAA Earth System Research Laboratory

CalWater 2015 Campaign Management



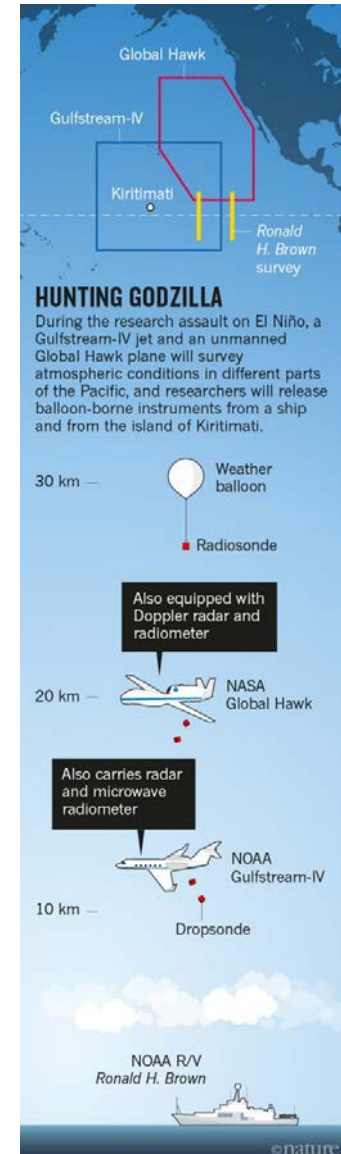
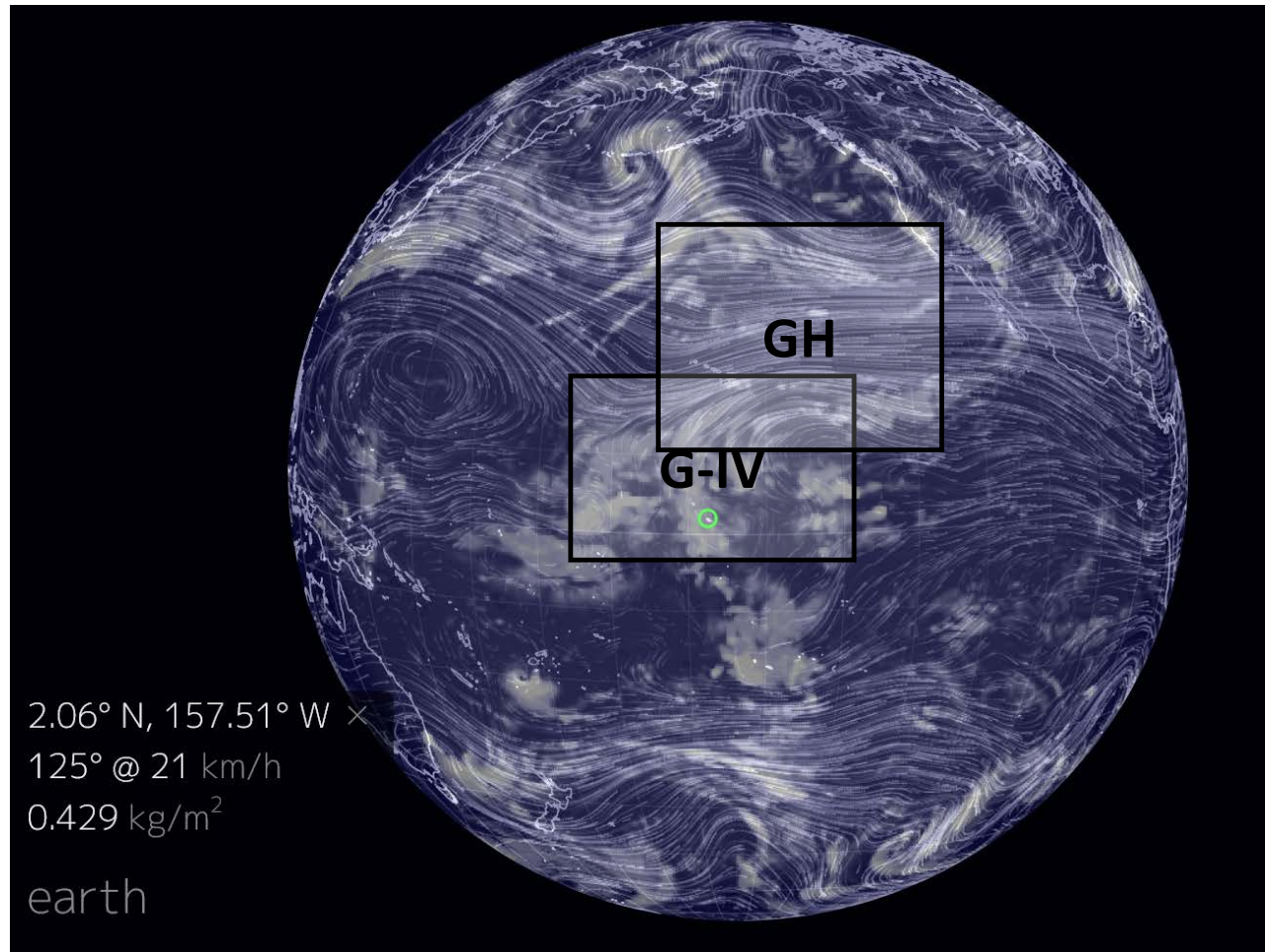
Working Group Planning Leads:

Flight Operations Science – Ryan Spackman
Forecasting – Jason Cordeira
Modeling and Analysis – Andrew Martin
Data Management – John Helly

Facilities Leads:

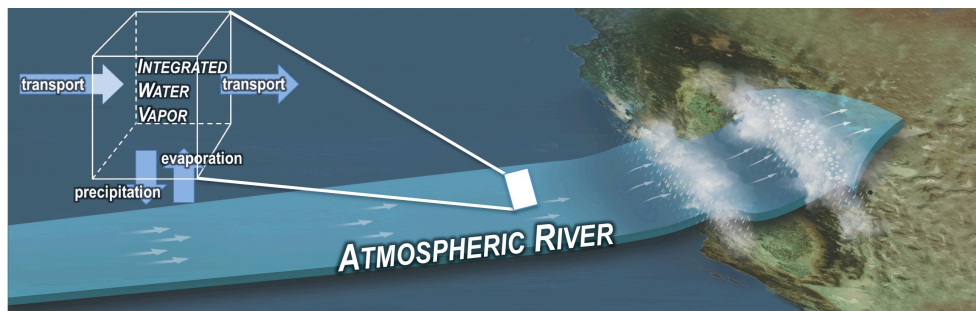
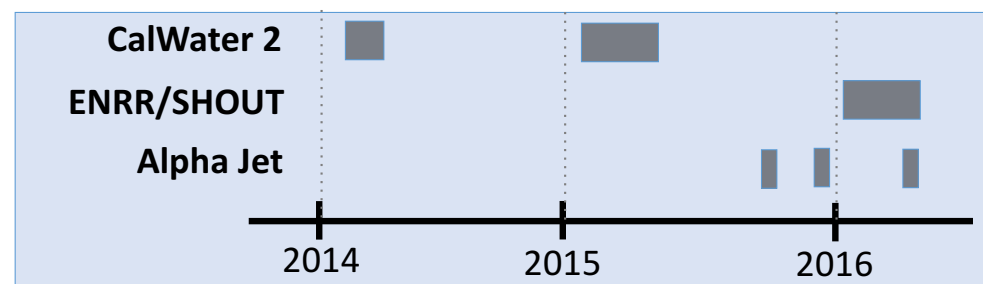
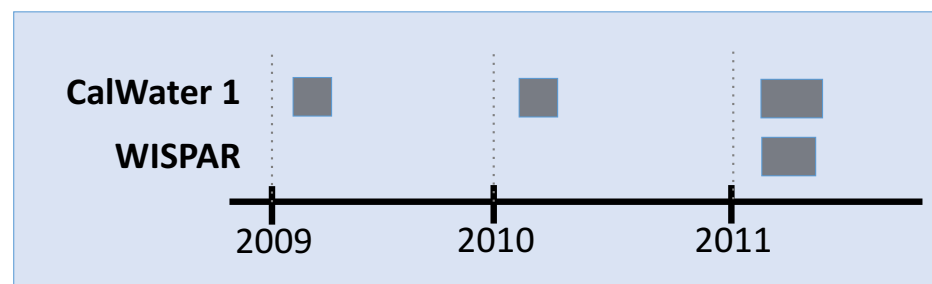
NOAA Ronald H. Brown – Adrienne Hopper
DOE AMF2 – Mike Ritsche and Amon Haruta
NOAA P-3 and G-IV – Paul Flaherty and Jack Parrish
DOE G-1 – Beat Schmidt and Mike Hubbell
NASA ER-2 – Brian Hobbs

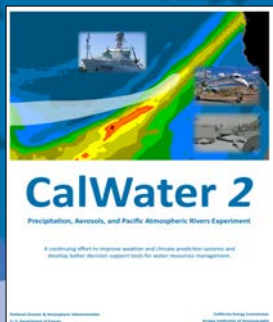
ENRR Implementation Strategy



Recent Major Process Study Field Campaigns

- CalWater 1 studies in 2009-11 included cloud and aerosol payload on DOE G-1 to study AR landfall processes
- WISPAR: Winter Storms and Pacific Atmospheric Rivers with the NASA Global Hawk
- CalWater 2014 with NOAA G-IV meteorology payload
- CalWater 2015 with NOAA G-IV, P-3, DOE G-I, NASA ER-2, NOAA Ron Brown, Bodega Bay studied ARs
- ENRR/SHOUT: NOAA El Niño Rapid Response Field Campaign with the NOAA G-IV, NASA GH, USAF C-130s, and NOAA Ron Brown examined tropical-extratropical linkages during the strong 2016 El Niño
- Alpha Jet flights target landfalling AR processes





Ralph et al.,
BAMS, 2016

CalWater 2015

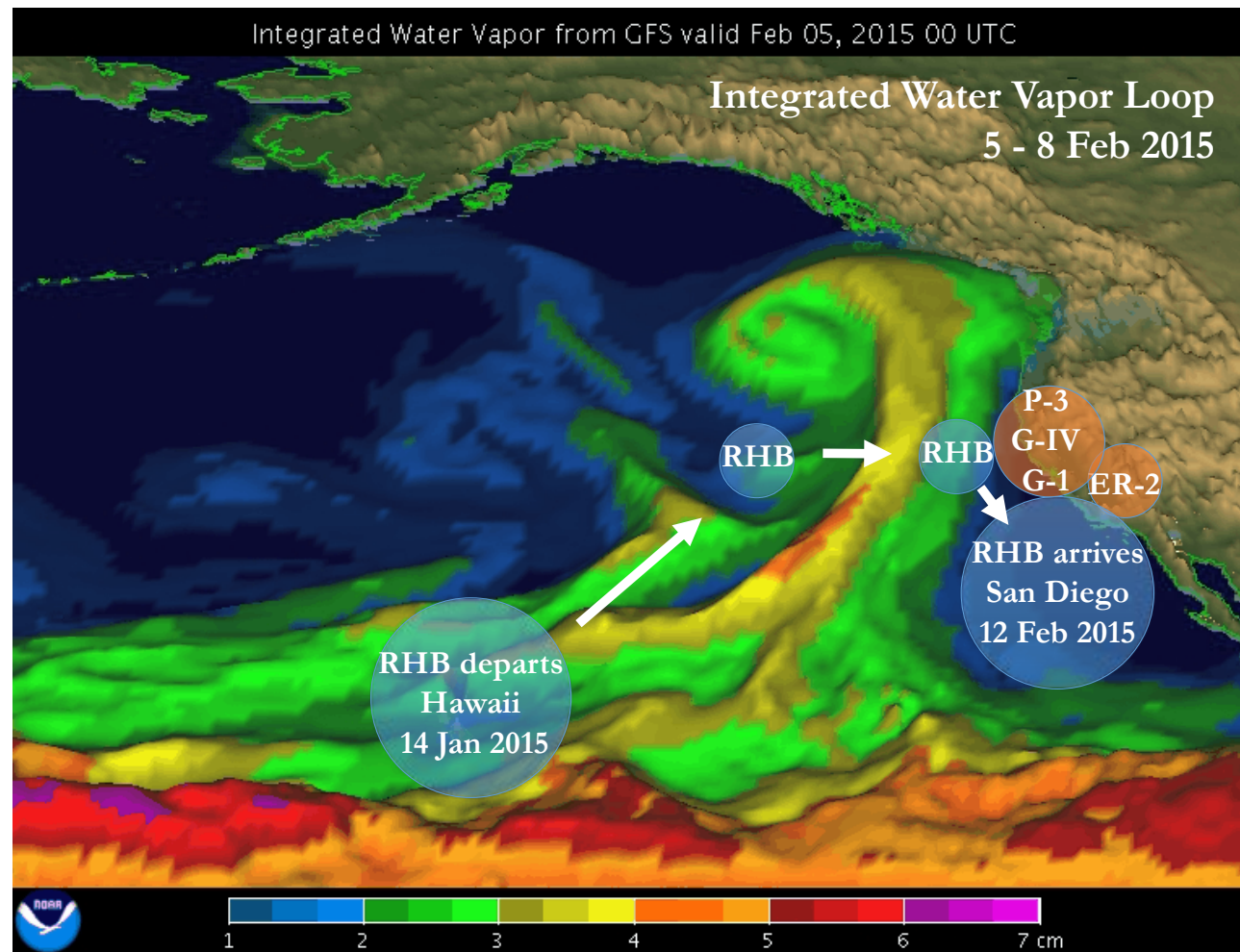
Precipitation, Aerosols, and Pacific Atmospheric Rivers Experiment

Marty Ralph, Kim Prather, Dan Cayan (Co-Leads)
Ryan Spackman (Flight Ops Scientist)
Scientific Steering Group: Paul DeMott, Mike Dettinger,
 Jim Doyle, Chris Fairall, Ruby Leung, Daniel Rosenfeld,
 Steven Rutledge, Duane Waliser, Allen White

CalWater 2015 Implementation

Intensive observations for 2 months in Jan-Feb 2015 with unprecedented interrogation of atmospheric rivers and related water vapor transport phenomena:

- 57 research flights
- 29 day research cruise
- 33 atmospheric river transects
- 444 dropsondes from P-3 and G-IV
- 300+ ship-based radiosonde launches
- Daily ship-based ozonesonde launches
- Coordination with NOAA HMT network and NSF-funded aerosol supersite observations

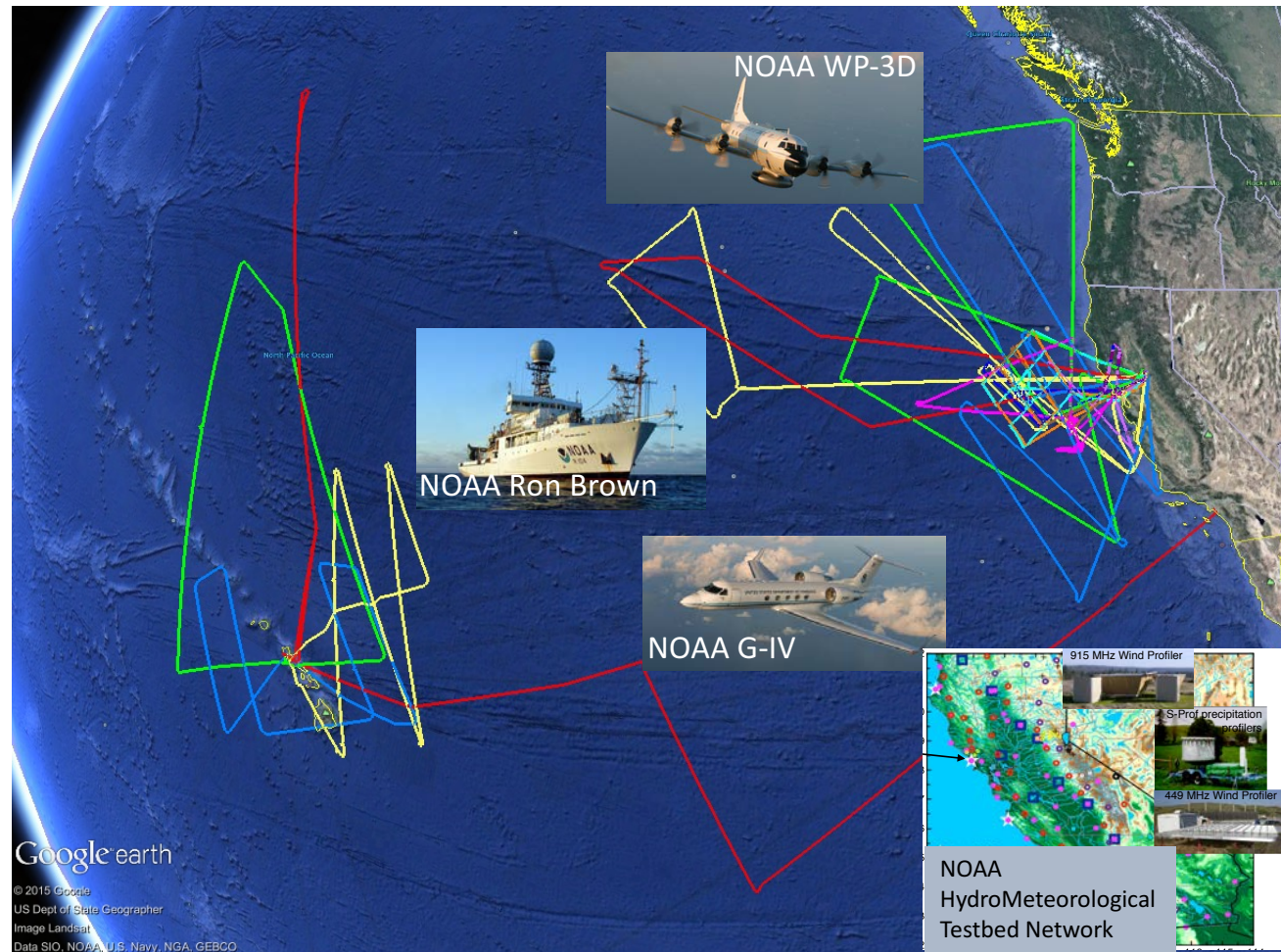


CalWater Website: www.esrl.noaa.gov/psd/calwater

Emerging CalWater 2015 Science Results

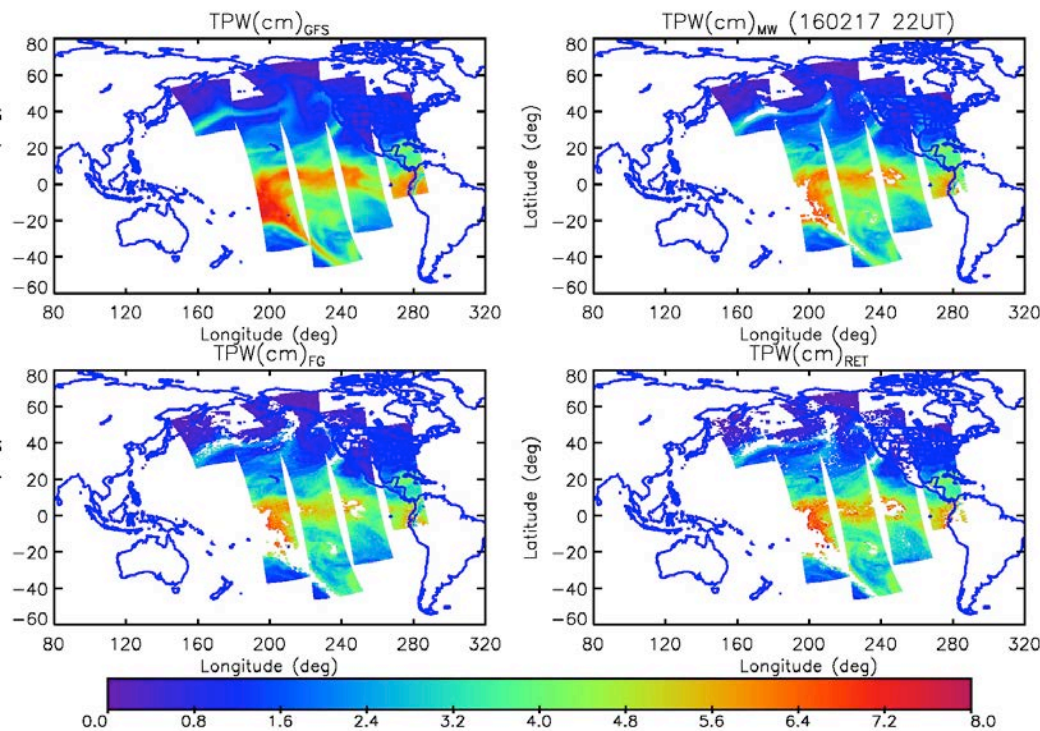
Several process studies are emerging from the intensive observations to address the CalWater 2015 science goals:

- **Water vapor budget of ARs**
- Air-sea flux interactions in ARs
- Aerosol-cloud interactions including role of direct and indirect aerosol impacts on precipitation
- Orographic control of precipitation and microphysical and barrier jet processes
- Tropical-extratropical connections
- Data denial/model integration studies with dropsonde observations

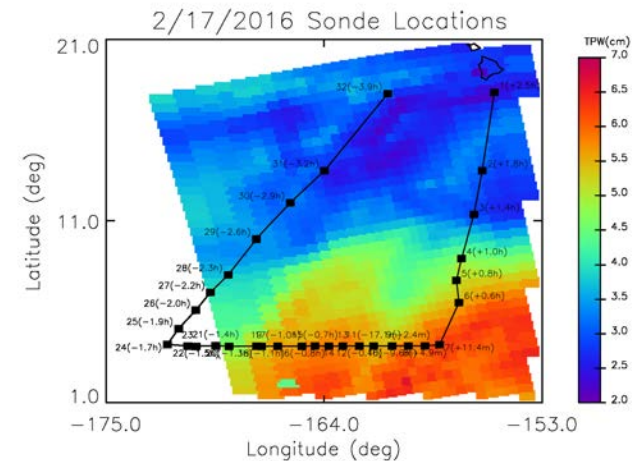


CalWater Website: www.esrl.noaa.gov/psd/calwater

Using the NOAA Unique CrIS ATMS Processing System (NUCAPS) to assess hyper-spectral sounding capability during AR events: a test case from February 17, 2016



A snapshot of the full region

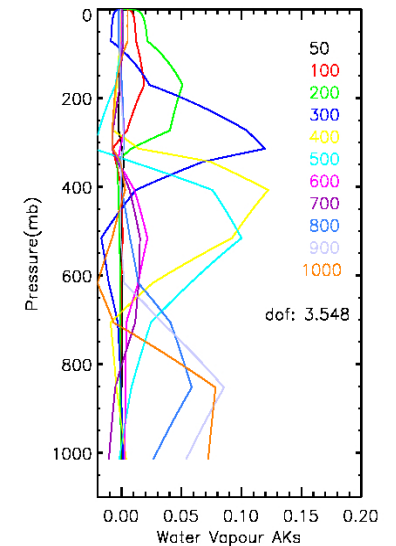
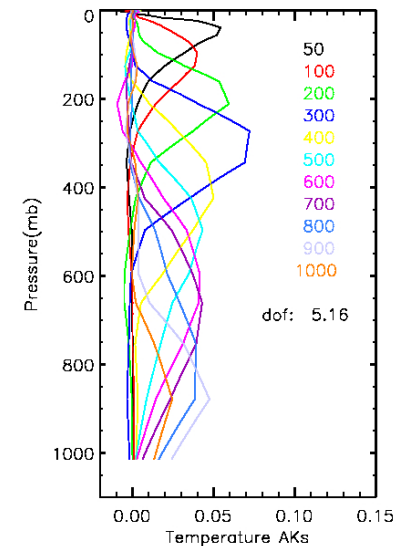
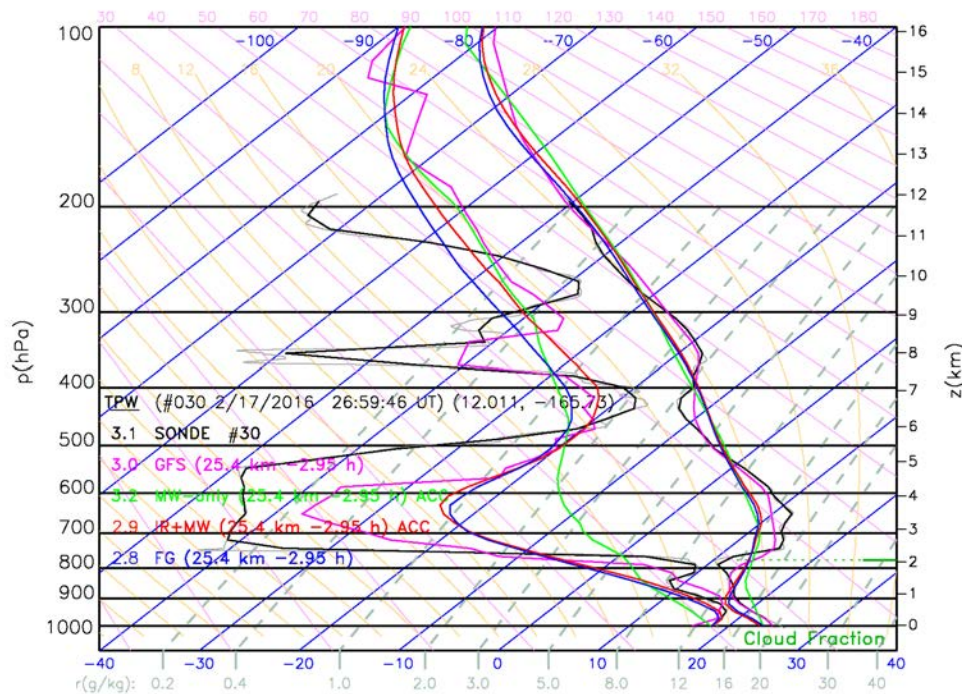


A close up figure over the flight path

➤ Satellite data can provide near real time (~0.5 hour), 3D context to a high impact weather event

Courtesy of Antonia Gambacorta, Chris Barnett
Science and Technology Corporation (STC) and NESDIS

February 17, 2016: a detailed comparison using dropsonde no. 30



➤ Averaging Kernels provide insights on NUCAPS effective vertical resolution (broadness of the peaks) and information content (magnitude of the peaks)

➤ we are building a diagnostic capability to assess NUCAPS performance under high impact weather events. This will serve to make improvements on the algorithm and ultimately enable a more intelligent use of NUCAPS products.

Courtesy of Antonia Gambacorta, Chris Barnet
Science and Technology Corporation (STC) and NESDIS