Using the NOAA Unique CrIS/ATMS Processing System (NUCAPS) to explore hyper spectral sounding capabilities during extreme events

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Introduction

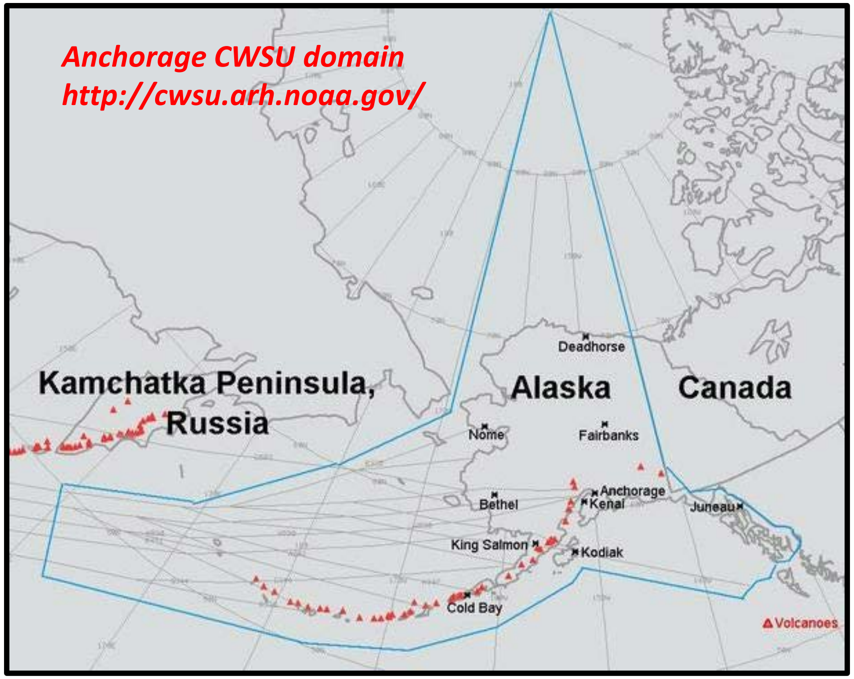
- The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is the NOAA operational algorithm to retrieve temperature, water vapor and trace gases from Suomi NPP CrIS and ATMS instruments.
- Modular design: same code of the AIRS/AMSU and IASI/AMSU/MHS MetOp A and B systems, also operational at NOAA/NESDIS/STAR and future JPSS.
- NOAA/NESDIS/STAR has been operationally running NUCAPS since 2013 and distributing its products in near real time (~3 hour latency) to the science community through CLASS.
- On September 3rd 2014, NUCAPS passed “stage 1 maturity“ at the JPSS validation review.
- NUCAPS temperature and moisture profiles viewable in AWIPS-II
- NUCAPS science code runs on the Univ. of Wisconsin’s NASA PEATE (Product Evaluation and Algorithm Test Element) archive
- Full implementation of NUCAPS in the Community Satellite Processing Package (CSPP) was completed in Dec. 2014 and became operational on Feb. 24th 2015.

How can NUCAPS soundings add value to the forecast of high impact weather events?

- We use NUCAPS to demonstrate the vertical profiling capabilities of hyper-spectral soundings in capturing high impact meso-scale phenomena over otherwise poorly sampled regions.
- NUCAPS implementation into CSPP direct broadcast enables unprecedented low latency data distribution, suitable for decision aid user applications.
- Our current initiatives focus on weather events of societal value:
  - Cold Air Aloft in Alaska
  - Atmospheric river landfall on the US west coast
- Primary goal is to develop and promote new user applications.
- Initiatives are also meant to encourage interaction between algorithm developers and users.

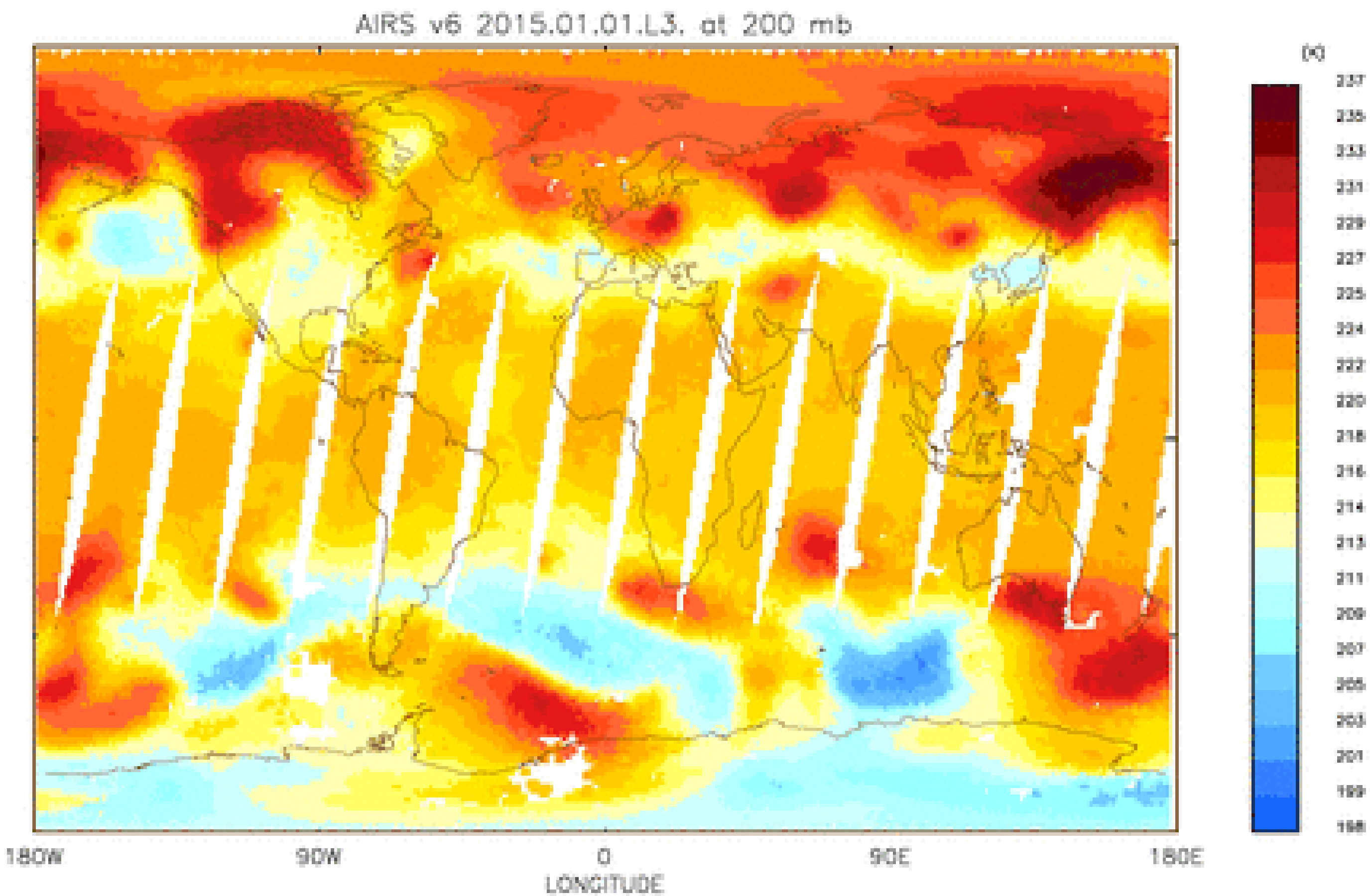
Cold Air Aloft (CAA) Initiative

- Cold Air Aloft (-65°C and below) is potentially hazardous to aircrafts due to the threat of fuel freezing at these extreme temperatures
- When these events occur, the Anchorage Alaska Center Weather Service Unit (CWSU) provides Meteorological Impact Statements (MIS) to Air Traffic Controllers to re-direct flights around Cold Air Aloft events.



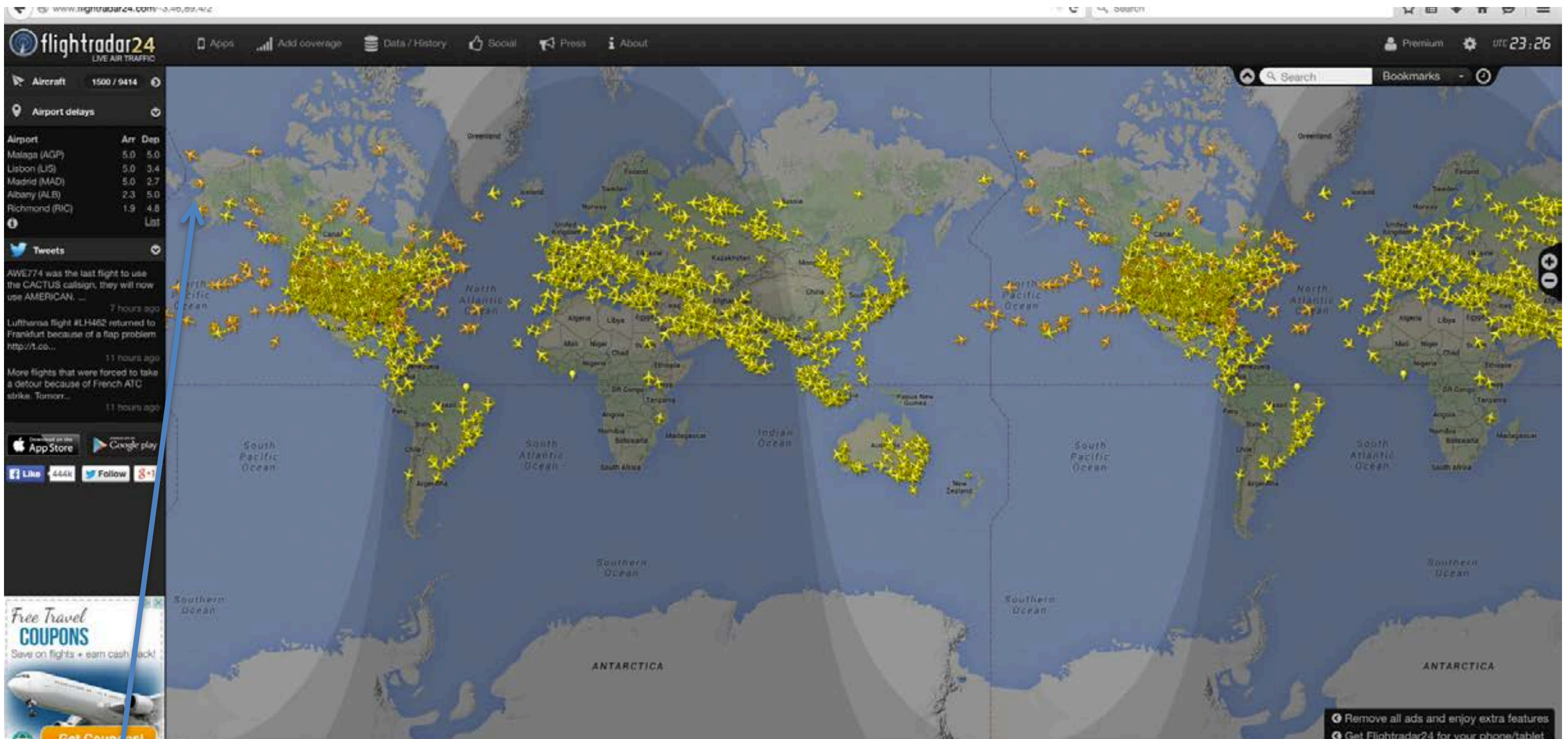
- In data sparse regions like Alaska, forecasters can only rely on model fields and limited radiosonde observations.
- Use of direct broadcast satellite observations provides an opportunity for forecasters to observe the 3D extent of the Cold Air Aloft in real-time, where conventional observations are lacking.
- Forecasters at the CWSU have expressed the need for an observational product from satellites that can be used to improve confidence in the model output.

Daily temperature maps at 200mb 2015/01/01 – 2015/04/05



CAA events

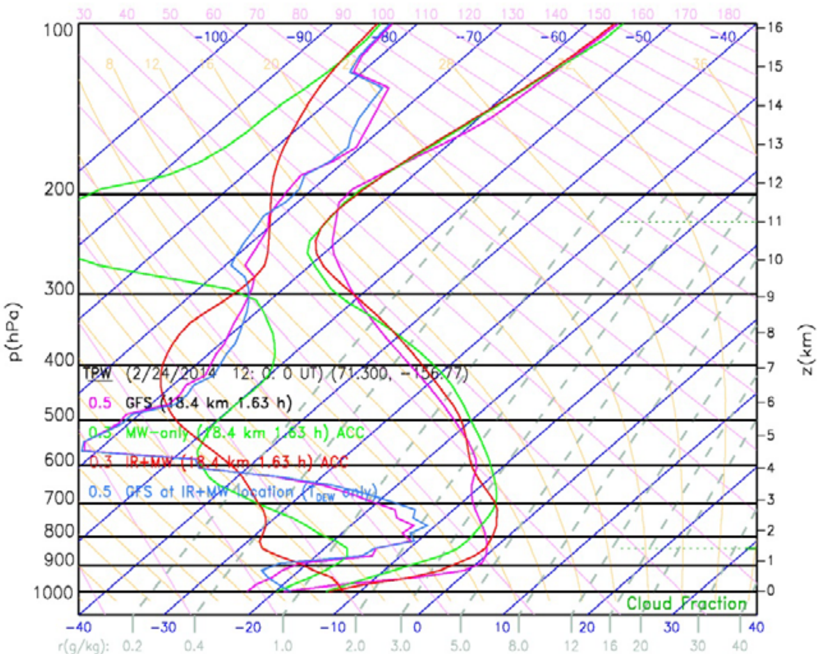
Snapshot of 2015/04/08 air traffic at 7:30 pm US East Coast Time

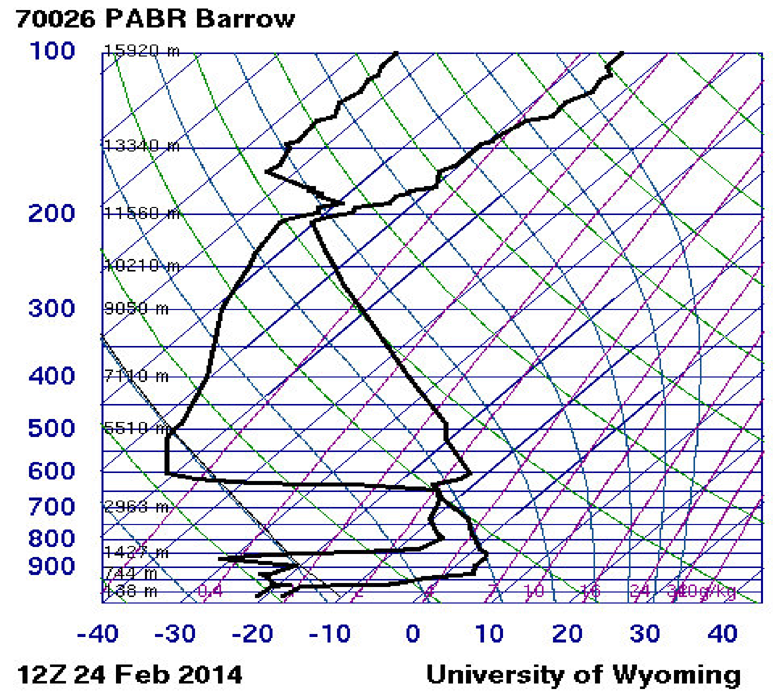


~41,000ft flights

Big question we are trying to answer in this initiative is whether retrievals can add value

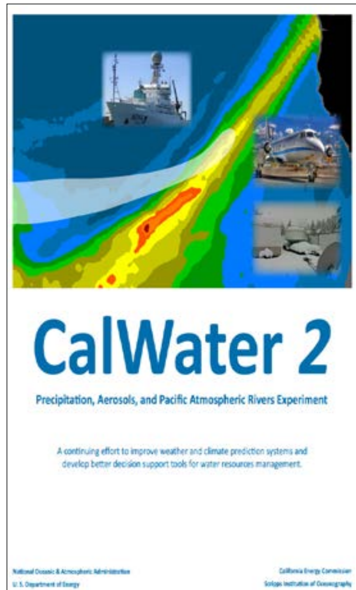
Cold Air Aloft example from February 24 2014

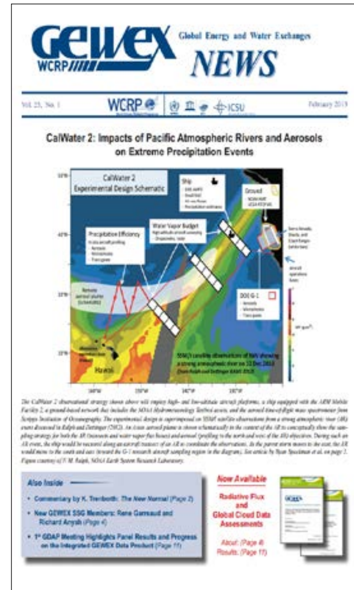




- Both NUCAPS-ATMS-only (green) and NUCAPS-CrIS+ATMS (red) show -60 degC at ~250 mb; at a lightly lower altitude than the GFS (magenta, 200 mb)
- We are now exploring new methods of data fusion and visualization that will rely on CSPP DB data access and produce a real time assessment of the extent and magnitude of CAA events.

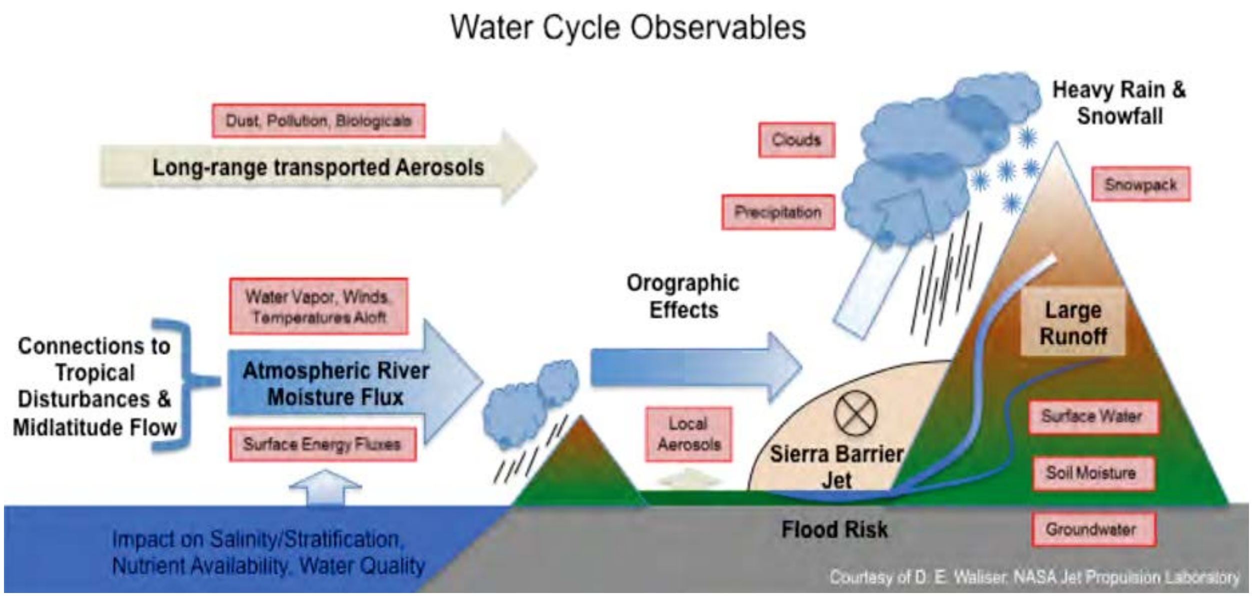
The CalWater Field Campaign





- CalWater 2 is a 5-year broad interagency vision to address key water cycle science gaps along the US West Coast
- Objective: to examine the development and structure of ARs before landfall to improve forecasts of extreme precipitation events along the US West Coast
- An opportunity for us to (1) evaluate NUCAPS moisture products in extreme environments; (2) to train and develop new user applications.

Understanding Atmospheric Rivers (ARs) Has National and Societal Value



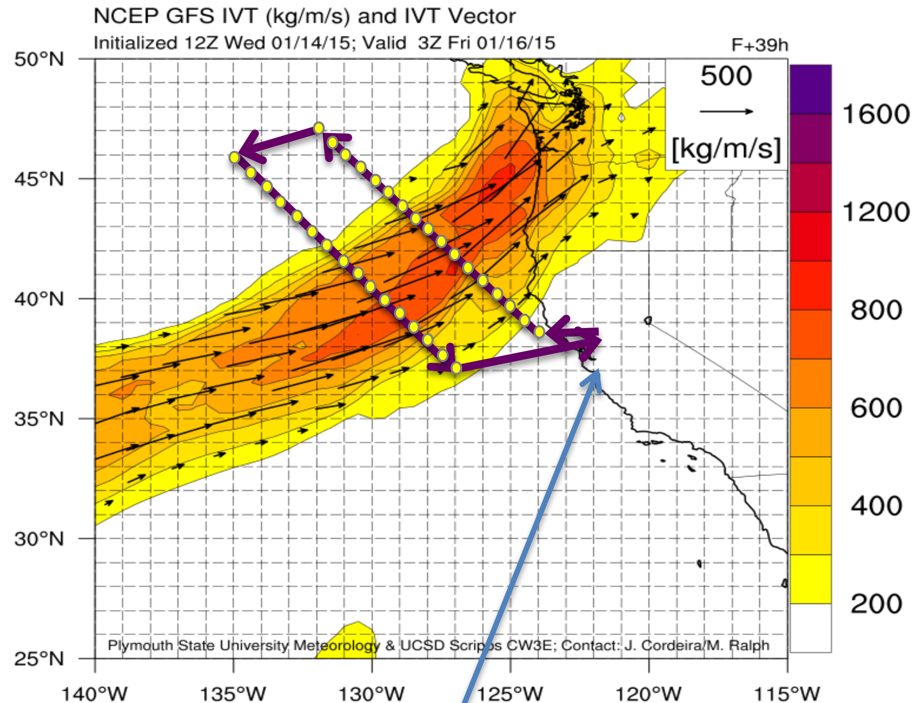
- ARs are spatially narrow filaments of enhanced water vapor transport
- 75% is below 2.25 km altitude
- ARs are the leading cause of severe storms, floods and extreme snowfall events over the US West Coast
- AR landfall forecast errors are large (~500km at 3-5 day lead time)

Example of Jan. 15, 2015 flight planning: Integrated Vapor Transport (IVT) forecast

- Vertical structure of water vapor in ARs is crucial to forecast integrated vapor transport correctly

- The 2014 CalWater campaign suggested NUCAPS retrievals from CrIS and ATMS could improve land falling forecasts

- In CalWater 2015 we demonstrated the capability to provide real time direct broadcast NUCAPS retrievals to a field campaign.



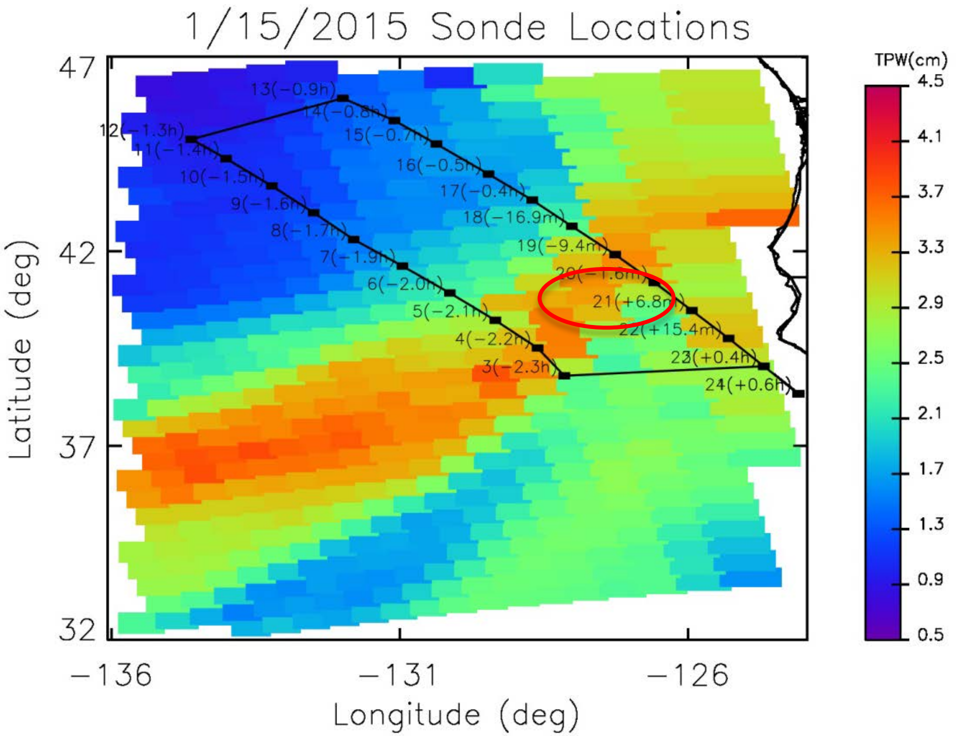
NOAA G-IV aircraft flight track
Take off time: 2100UT on 2015-01-15;
Landing time: ~0300UT on 2015-01-16
(flight duration ~ 6 hours)

NUCAPS was used to provide retrievals for flight planning and while aircraft was in the air

- We used Corvallis and Hawaii's CSPP direct broadcast to get NPP CrIS and ATMS near real time data ($\leq$ 1 hour latency) and run NUCAPS over the entire region of the campaign.

- We provided NUCAPS retrievals using the morning NPP overpass in support of flight planning during the 7AM LT teleconference briefings.

- Then we used the afternoon NPP overpass to regenerate and send retrievals of the entire study domain while the aircraft was in the air.



Near Real time NUCAPS TPW snapshot using NPP 2230UT overpass, overlapped with the G-IV flight track. Dots indicate drop sonde locations. Point 20: closest NUCAPS-drop sonde match (1.6 minutes apart)

The value of NUCAPS is that it sees the entire 3D domain of the field campaign in one snapshot

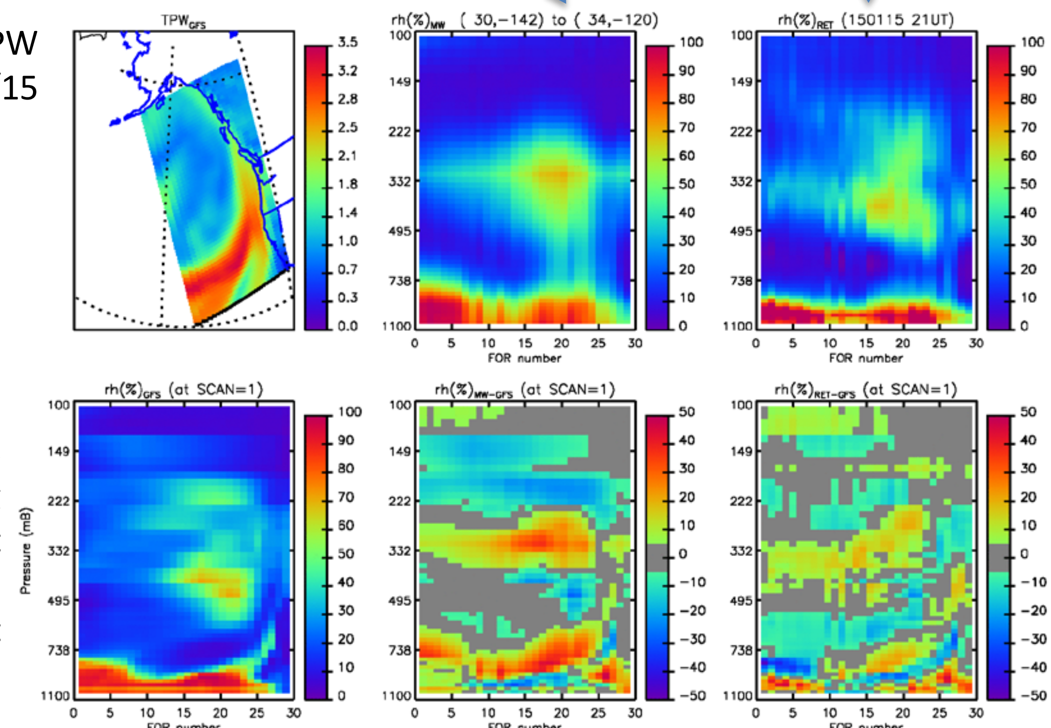
- NUCAPS “scanset” is acquired in 8 seconds
- Retrieval spatial resolution is ~50 km at nadir; ~70x134 km at edge of scan
- Differences shown at right could be due to retrieval errors or GFS errors
- In many cases these retrievals reveal structures many hours in advance of a model analysis (i.e., CrIS/ATMS have not been ingested in the model yet)

NUCAPS Microwave RH Retrieval cross section along scanset indicated on the top left figure. Insensitive to non-precipitating clouds

NUCAPS Microwave + Infrared RH retrieval cross section along same scanset. More sensitive to clouds but higher vertical resolution

TPW 2015/01/15

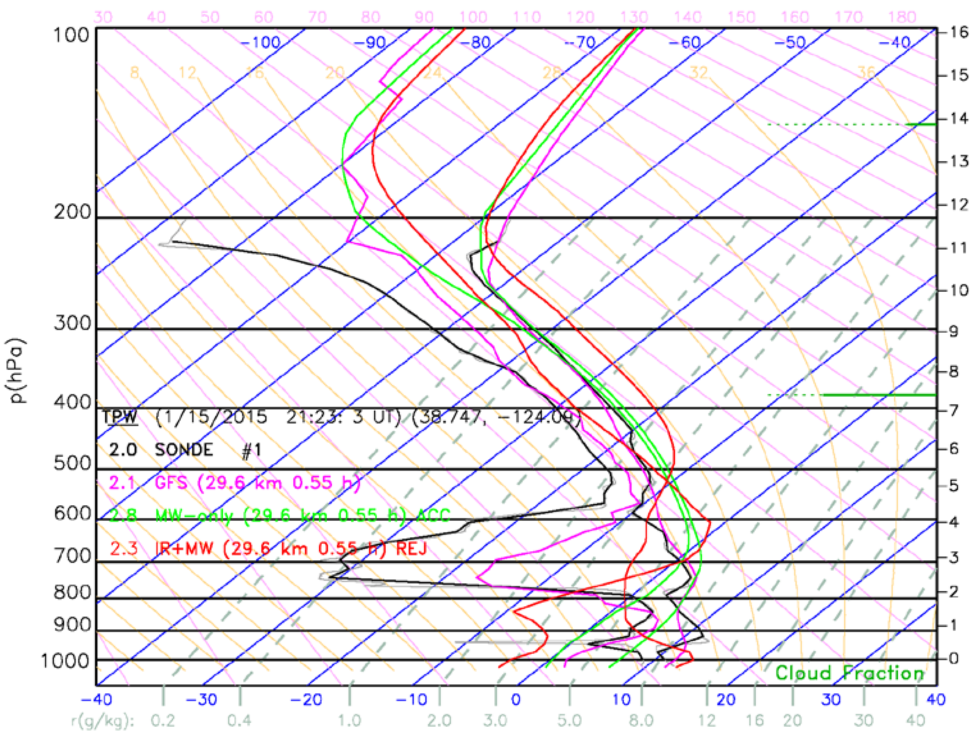
GFS RH cross section (along scanset indicated on top left



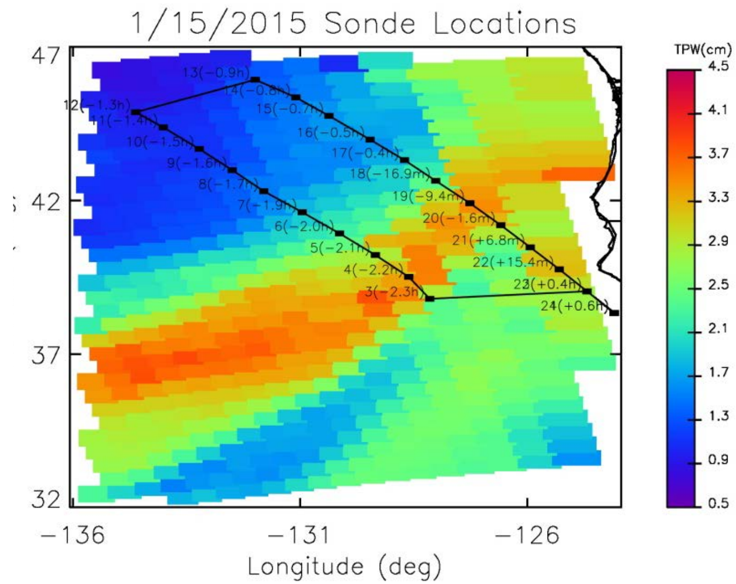
NUCAPS Microwave retrieval – GFS

NUCAPS Microwave + Infrared retrieval – GFS

Once drop-sondes are received, we can use campaign data for validation



Sonde, GFS, NUCAPS MW-Only, NUCAPS MW+IR
(GFS interpolated at NUCAPS location)



Use of these sondes should allow us to segregate and characterize GFS and retrieval errors

- NUCAPS sees the pre-AR moist and warm field; tends to reject under overcast conditions inside the AR; captures the post-AR relatively dry and colder field.
- Field campaign observations enable a more focused approach to validation relevant to NUCAPS than conventional radiosondes.

Lessons learned, planned enhancements and potential data fusion

- Intensive field campaign data are incredibly valuable for algorithm validation
  - Synergistic initiatives yield a large sample of in-situ data (~450 dropsondes and 175 radiosondes from CalWater-15 alone)
- NUCAPS is a test-bed to study new methodologies
  - NWP is already using NUCAPS CrIS channel selection
  - NWP is evaluating the use NUCAPS CCR approach
- Initiatives focus on regimes of societal importance that are traditionally difficult to validate
- We are now developing new visualization tools and decision aid user applications in collaboration with GINA, Univ. of Wisconsin and NASA SPoRT.

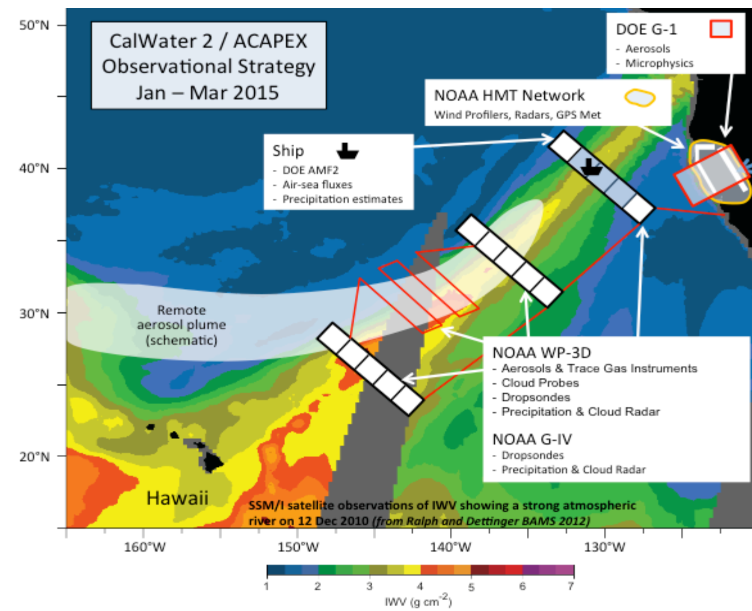
Future work and conclusions

- We are looking for more opportunities similar to CalWater, some candidates are:
  - 2015 Hazardous Weather Test-bed Spring Experiment (May/June)
  - Plains Elevated Convection at Night (PECAN, June 2015)
  - Late summer 2015, S-NPP field campaign w/ Global Hawk
- These campaigns provide ideal training materials for CSPP users
- It is sometimes said that “hyperspectral sounders see the weather before it happens”
  - Participation in these field campaigns is helping us demonstrating how modern hyper spectral IR+MW sounders can be used to improve regional weather forecasting

Back up

CalWater 2/ACAPEX Field Campaign

- Interagency Campaign:
    - Scripps (Marty Ralph, Kim Prather)
    - NOAA (Allen White, Ryan Spackman)
    - DOE (PI: L. Ruby Leung) ACAPEX = ARM Cloud Aerosol Precipitation Experiment
- White paper at
- http://esrl.noaa.gov/psd/calwater



Platform	Range of Obs	Expected Duration	Types of sensors
AR Observatories and Hydro-Met Testbed	ARO sites: CA(4), OR(2), WA(1)	Full campaign	Snow level radar (S-band), 449 MHz wind profilers, soil moisture, 10 meter surface tower
NOAA WP-3D	1-22 kft, 4000 km range	80h over 4 weeks	~150 dropsondes, W-band radar (clouds), IWRAP Radar, Tail Dopper Radar, Cloud Probes, SFMR
NOAA G-IV	1-45 kft	90h over 6 weeks	~300 dropsondes, Tail Doppler Radar, NOAA O3, SFMR
DOE G-1 with ~40 instruments	1-23 kft	120h over 8 weeks	Cloud properties (Liq/water content, size), aerosol properties (concentration, size, CCN), trace gases (H2O, O3, CO)
NOAA R.H. Brown	Can move ≤ 5 deg/day to stay within AR	30 days	AMF2: Aerosol Observing System, Ka ,X, W-Band Cloud Radars, DOE, Micropulse LIDAR, Wind Speed, Rain Guages RS-92 Sondes: ~260 (~half dedicated overpass time)