Recent analysis of the NOAA CrIS/ATMS EDRs in complex weather regimes

Wed. May 14, 2014

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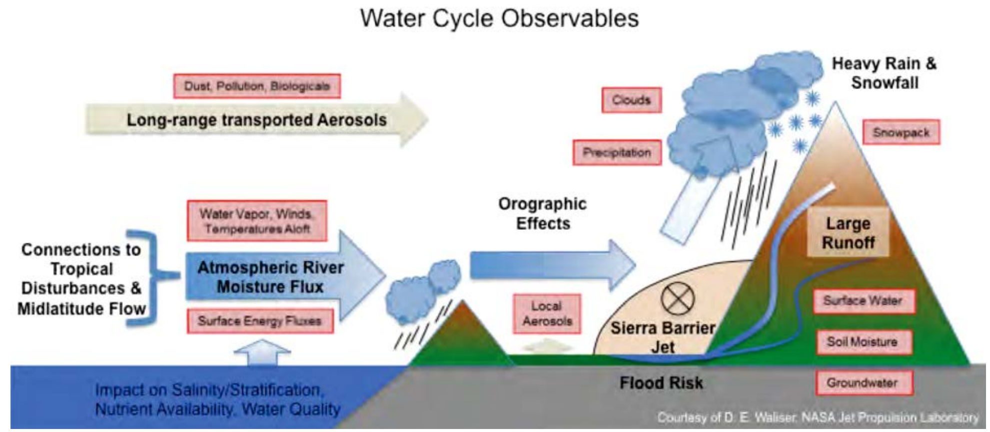
Discussion Points

- Brief introduction to atmospheric rivers (ARs)
- CalWater 2 Early Start Campaign, Feb. 2014
  - NUCAPS support of flight planning
  - Comparisons of NUCAPS to CalWater drop-sondes
- CalWater 2 Campaign, Jan/Feb 2015
  - Observing Platforms
  - Synergy with NUCAPS validation

Understanding Atmospheric Rivers (ARs) has national and societal value

- ARs are narrow regions of enhanced WV transport
  - responsible for ≈ 90% of mid-latitude transport (Zhu 1998 MWR)
  - 75% is below 2.25 km

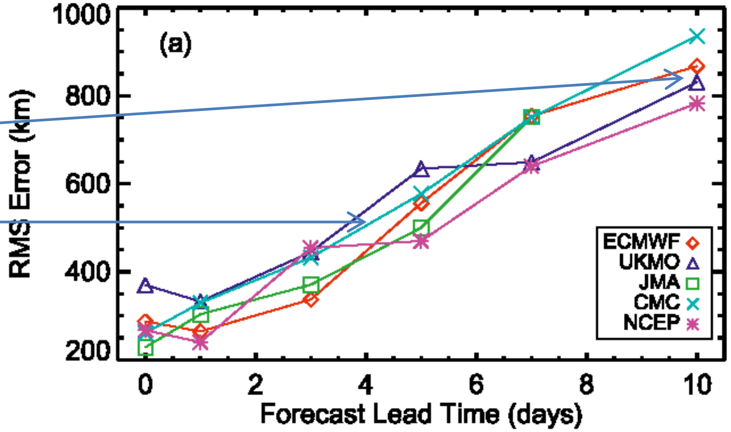


30-50% of annual precipitation on USA west coast is associated with ARs

- Typically within a few extreme precipitation events
- Strongest ARs can create major flooding
  - Jan. 6-8, 2009 a strong event damaged the Hansen Dam (White 2012 BAMS)
  - Warm moist conditions in ARs can accelerate snowmelt
- Northwest USA snowfall tends to come in a few powerful winter ARs
- AR events end ~40% of Northern California droughts (Dettinger 2013 J.Hydro.)
- Large ARs transport 13-26 km^3/day, ~7.5-15 times the average discharge of the Mississippi River (Ralph 2011 Eos)

Atmospheric Rivers are difficult to forecast

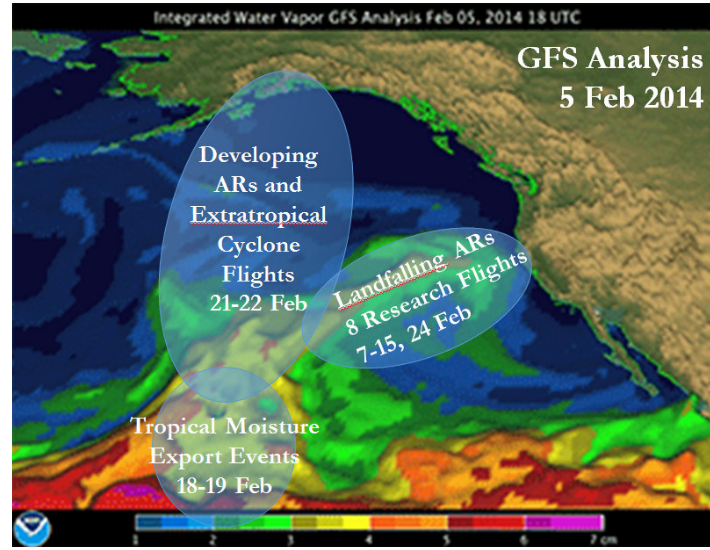
- **AR landfall forecast errors are large**
  - ~800 km at 10 day lead-time
  - 3-5 day forecast (~500 km) comparable with hurricane track errors (Wick 2013 Wea. & For.)



- Calwater 1 field campaign (2009-11) demonstrated that local aerosols and Sierra Barrier Jet plays a major role in modulating orographic precipitation
  - Aerosols carried in long-range flow was shown to affect land-falling ARs (Creamean 2013 Science)

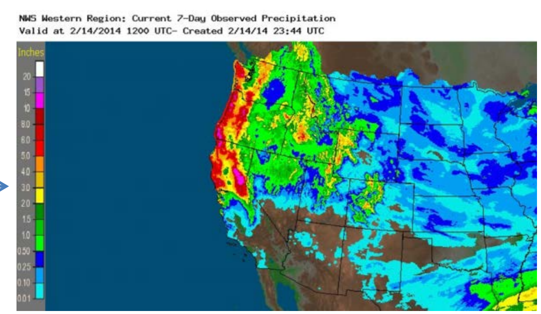
CalWater 2 Early Start NOAA Gulfstream-IV Flights

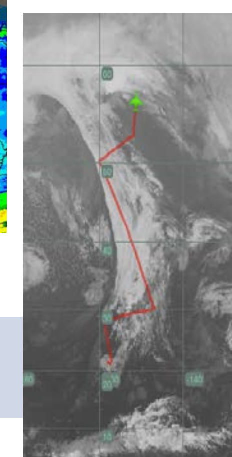
- <u>Objective</u>: Examine the development and structure of atmospheric rivers (ARs) before landfall to improve forecasts of extreme precipitation events along the US West Coast
- <u>Accomplishments</u>:



1. 12 research flights in Eastern Pacific in Feb 2014
2. Measurements included 190 dropsondes released between 8°N – 60°N and tail doppler radar
3. Observations included:

- 2 major land-falling AR events along west coast (Feb.7-15 and Feb. 24)
  - Landfall Feb. 12, 5-10” of rainfall
  - 1st rainfall of the year for many places
- A developing AR between Hawaii, Alaska and the AR source region between Hawaii and the ITCZ (4 research flights, Feb. 18-22)





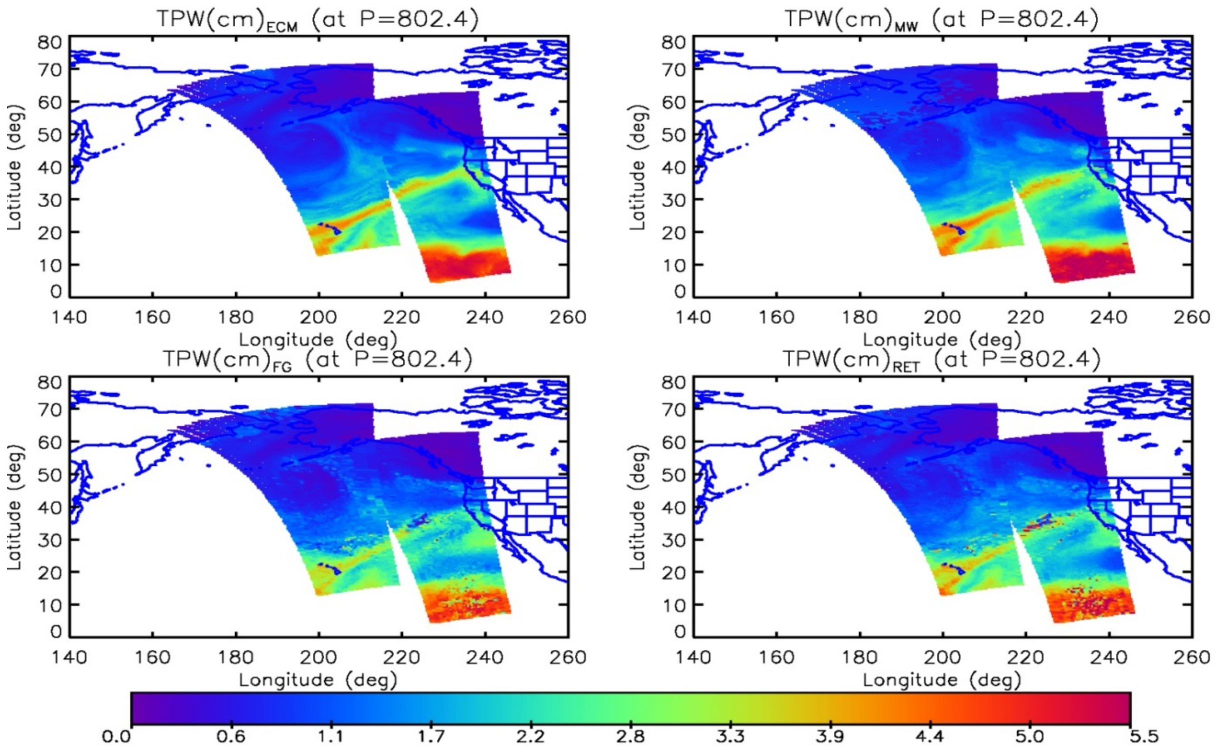
Flight Track (HI to AK) – Poleward developing AR

NUCAPS retrieval products easily see location of Atmospheric Rivers

ECMWF and NUCAPS Total Precipitable Water
(ignore label that says (at P=802.4)

Upper Left:
ECMWF
Analysis

Upper Right:
Microwave-
Only retrieval



Lower Left:
Statistical
Regression
retrieval

Lower Right:
Microwave +
infrared
retrieval

Note that the regression operator (lower left) is not as spatially coherent as the microwave physical retrieval (upper right). Many of these cases are rejected ; however, the regression operator is a more difficult first guess and leads the final product to have undesirable spatial structure in it.

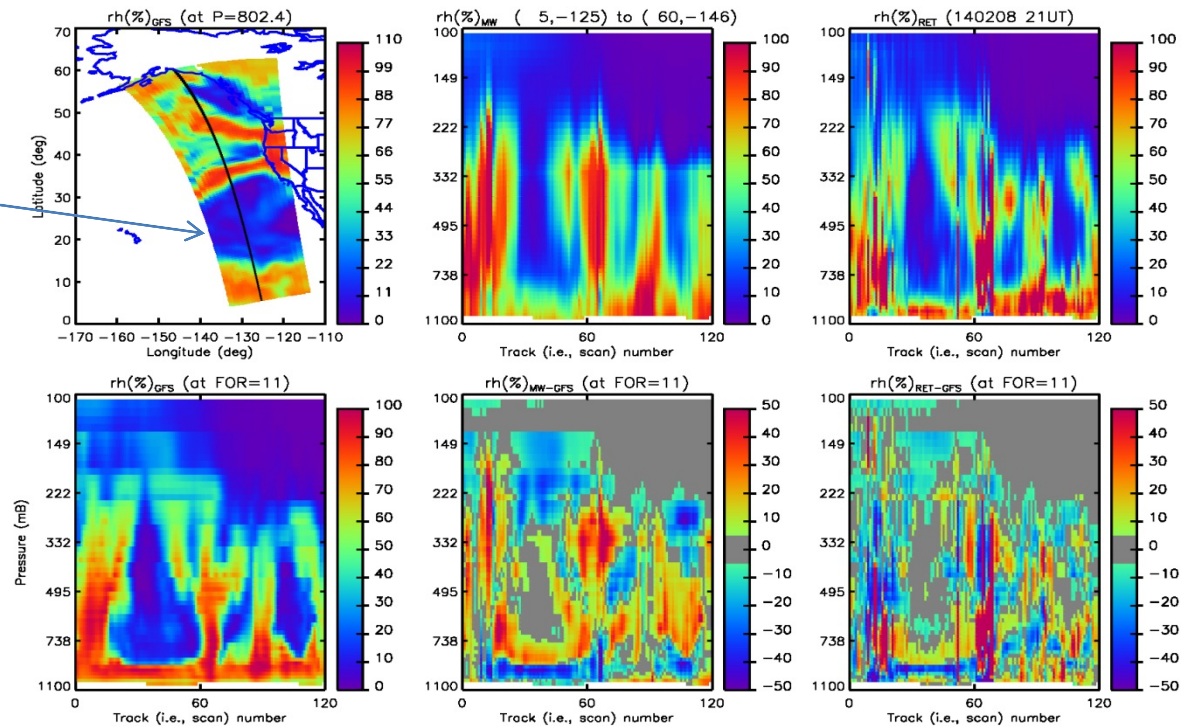
Provided near real time retrievals to Ryan Spackman (Mission scientist)

Used NUCAPS science code on U.Wisc PEATE system to process the data

GFS forecast (interpolated to retrieval time and location). Black line is location of cross-sections in other plots

Microwave-only retrieval

Final coupled retrieval



Cross-section of GFS going from south (Scan=1) to North (Scan=120)

Difference of Microwave-only retrieval and GFS

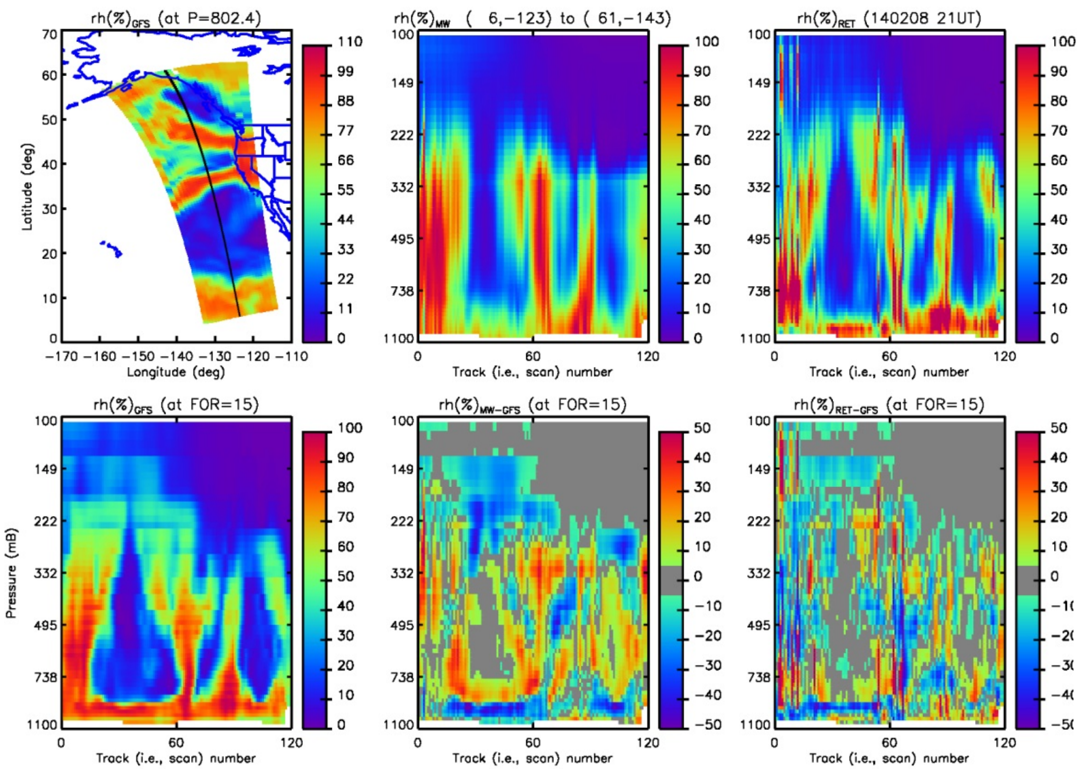
Difference of coupled retrieval and GFS

Note: Differences could be due to retrieval errors or GFS errors

Can Retrievals Improve Forecasts?
Slide/comments in red are from Ryan

Item 1: AR landfalling forecast errors are large (500 km at 5 day, 200 km at 1 day, Wick et al. 2013)

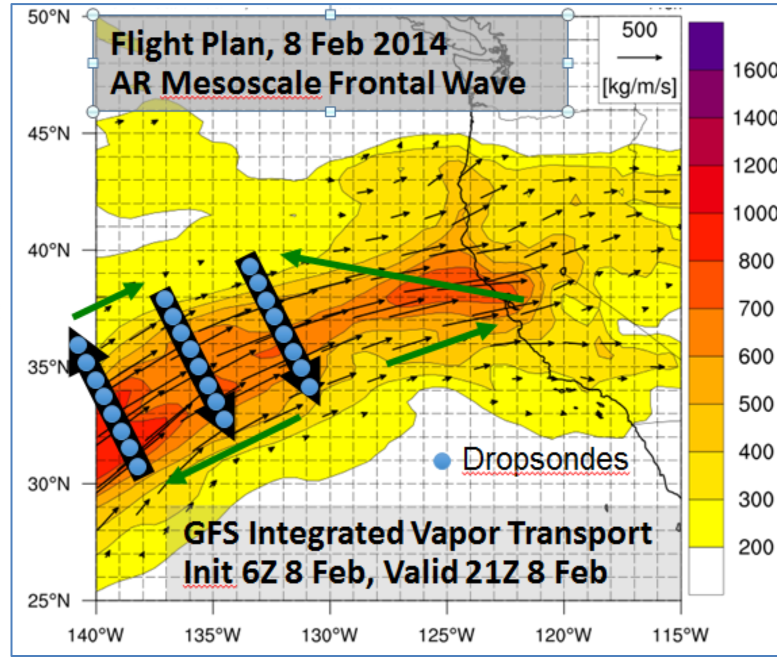
➤ Preliminary analysis suggests retrievals from CrIS and ATMS could improve landfalling forecasts



GFS interpolated to retrieval sampling

ATMS-only retrieval

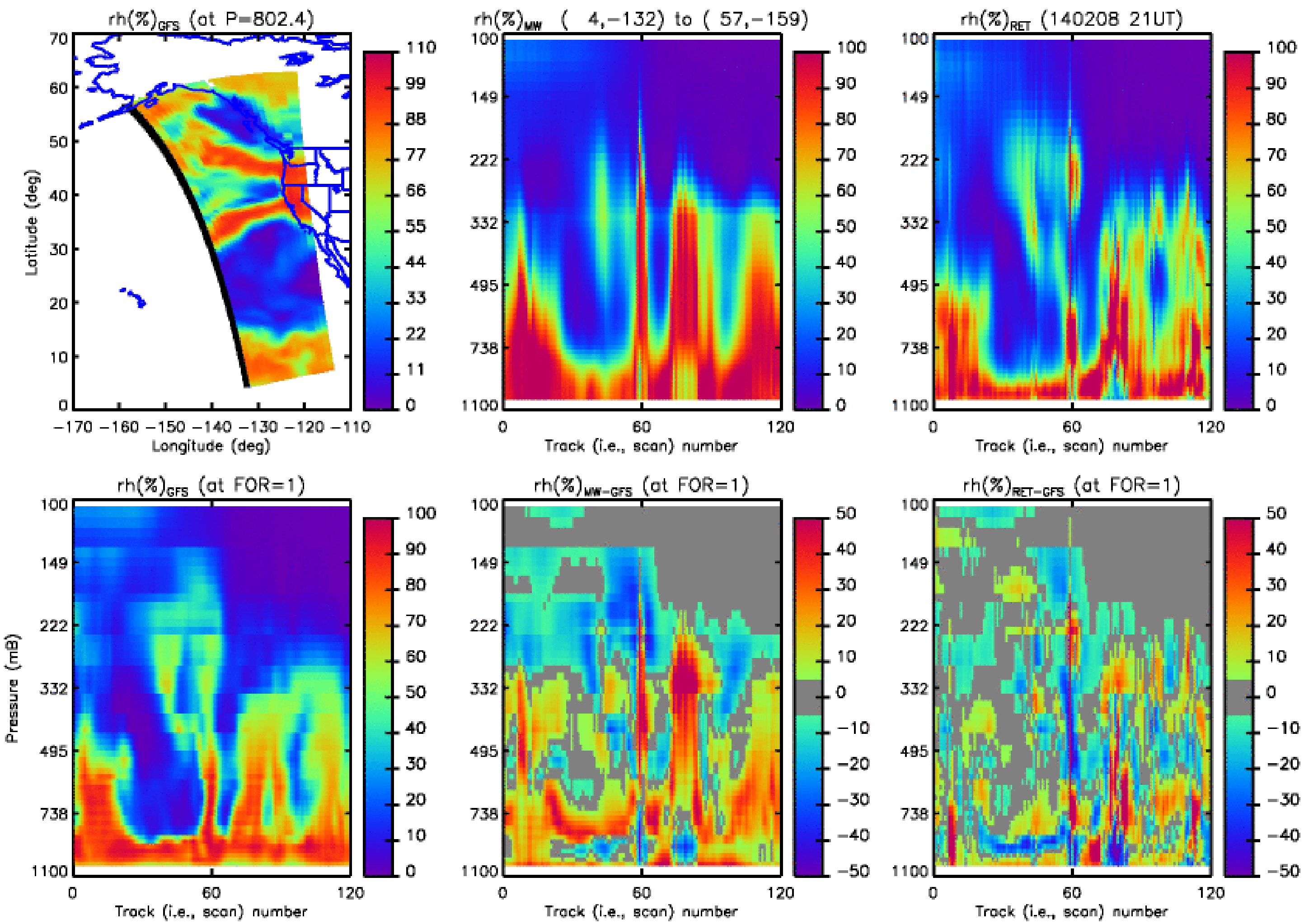
CrIS+ATMS Retrieval



Item 2: Vertical structure of water vapor in ARs is crucial to getting integrated vapor transport correct

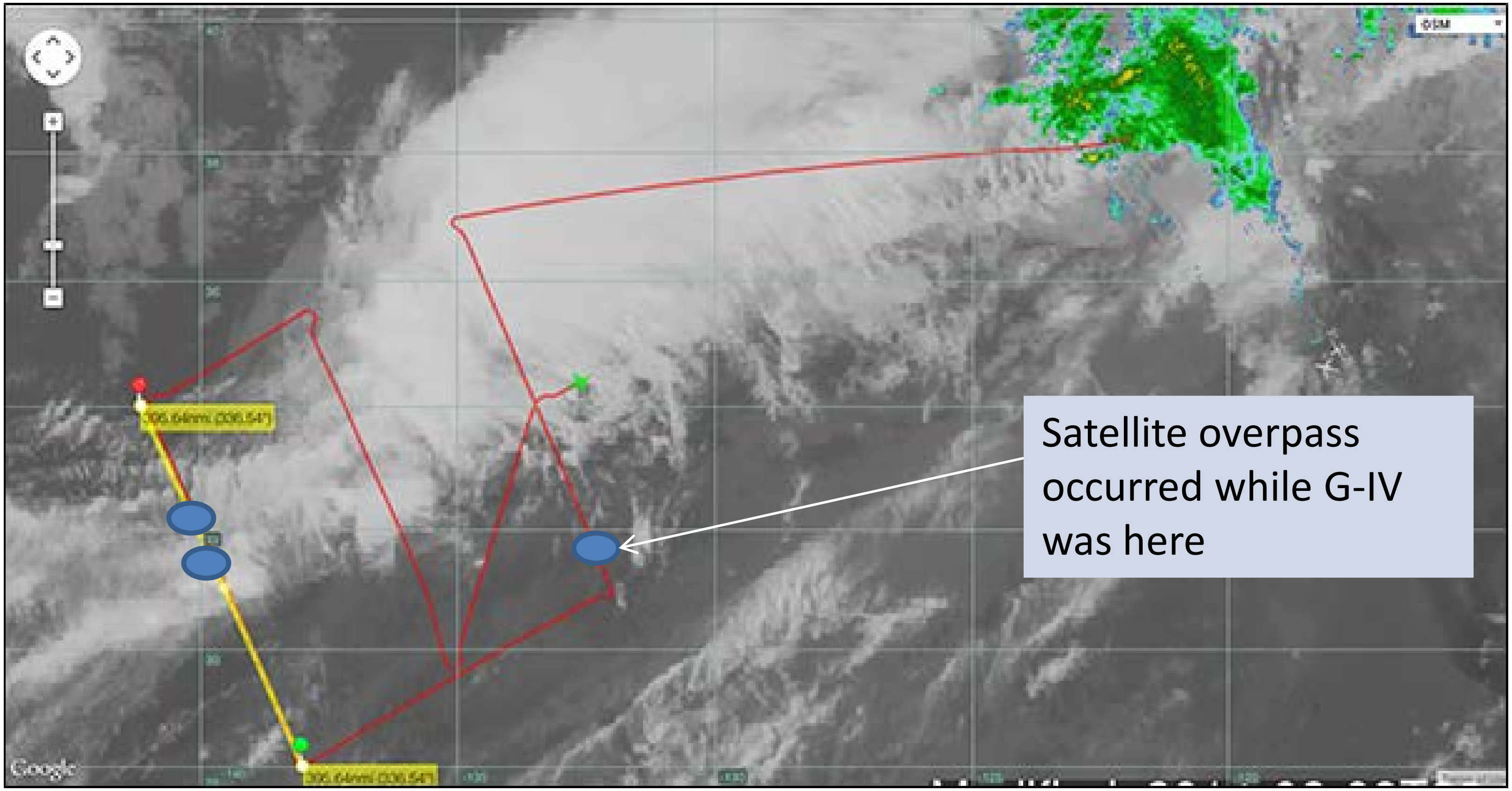
➤ Numerous discrepancies between model and dropsonde data were observed in vertical profiles of water vapor across ARs

Feb. 8, 2014 CrIS/ATMS Retrievals (NOTE: ignoring QC for this movie)



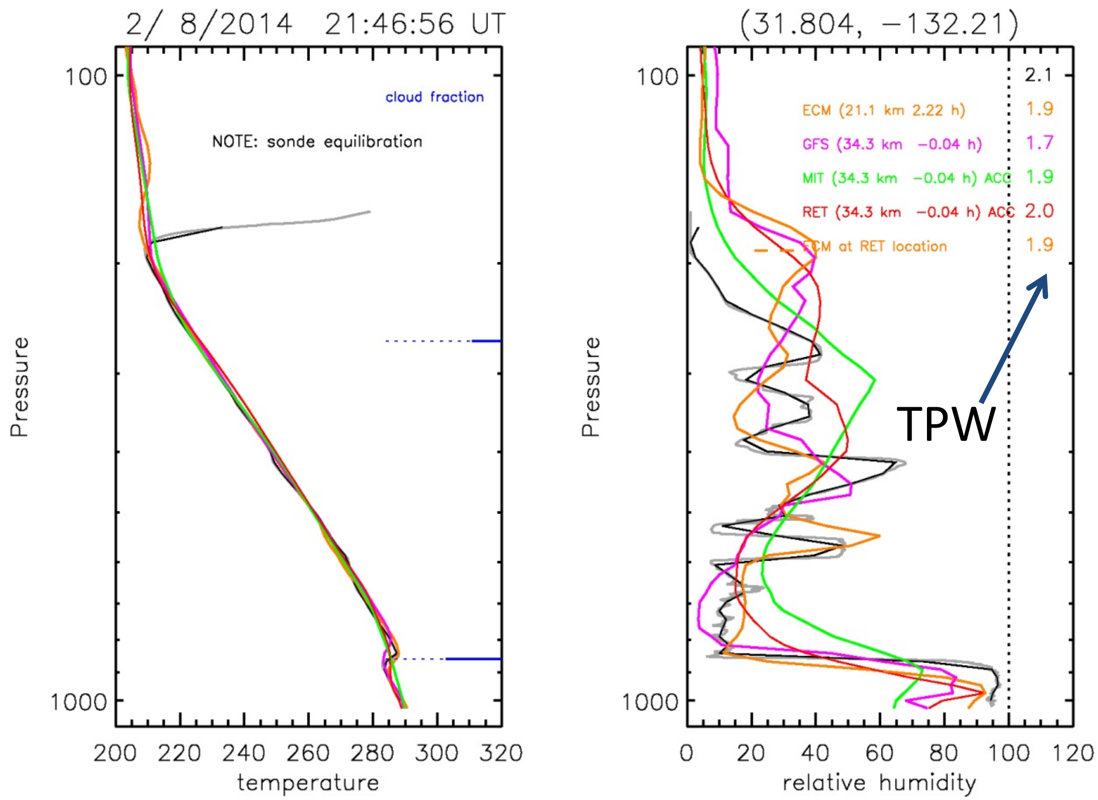
Flight pattern on Feb. 8, 2014
29 sondes were deployed

- Location of 3 sondes along the flight path selected for the next few slides



Comparison to dropsonde co-located (to satellite overpass time

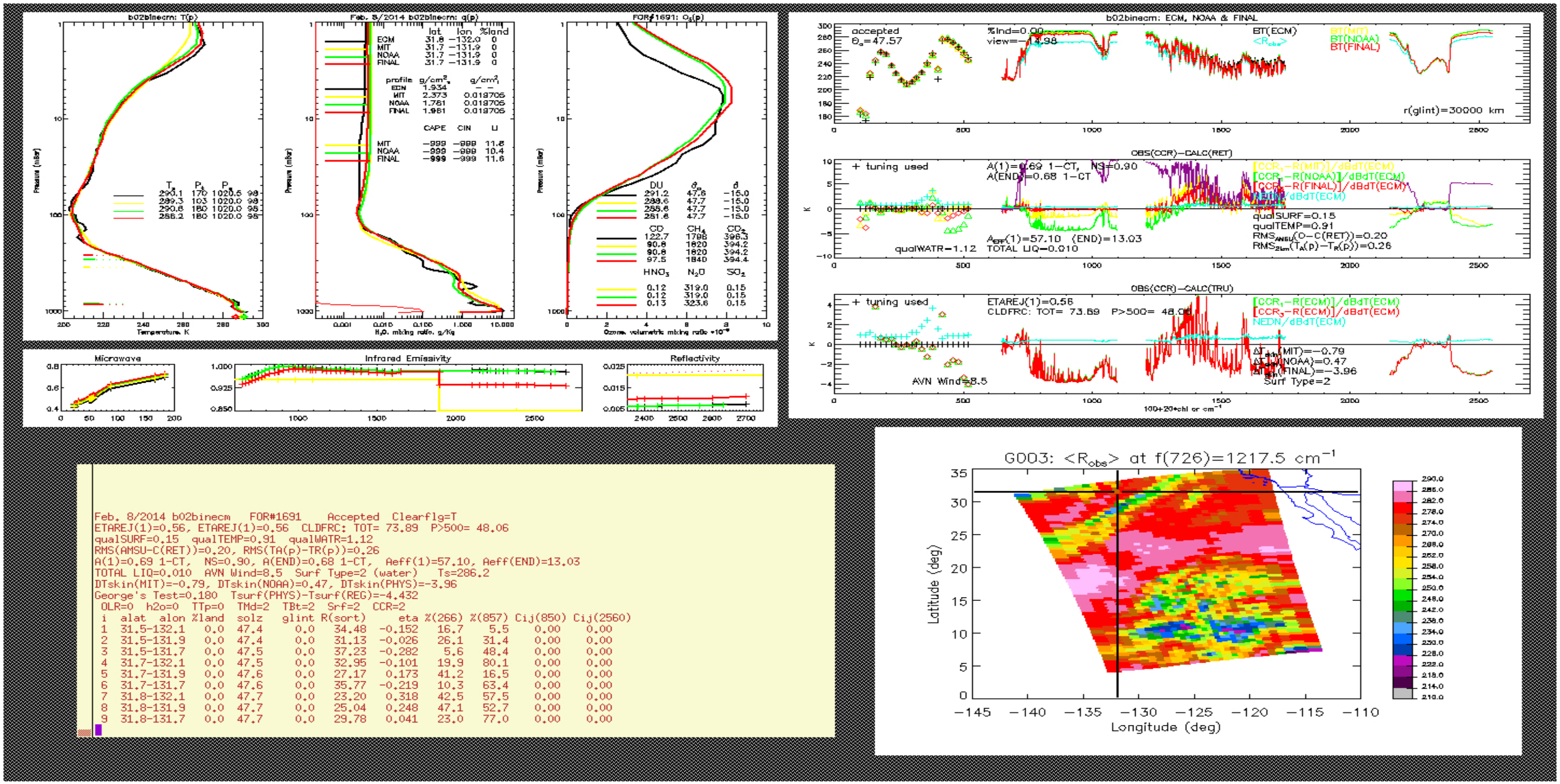
- Black = dropsonde
- Orange = ECMWF 0h analysis at location of the sonde
- Orange dashed is ECMWF at location of retrieval
- Cyan = GFS forecast interpolated to retrieval location
- Green = uW-only retrieval
- Red = IR+uW retrieval



This sonde was located south of the AR. Retrieval (and models) captured much of the vertical structure.

Diagnostic output for this scene (closest retrieval is an *accepted* case)

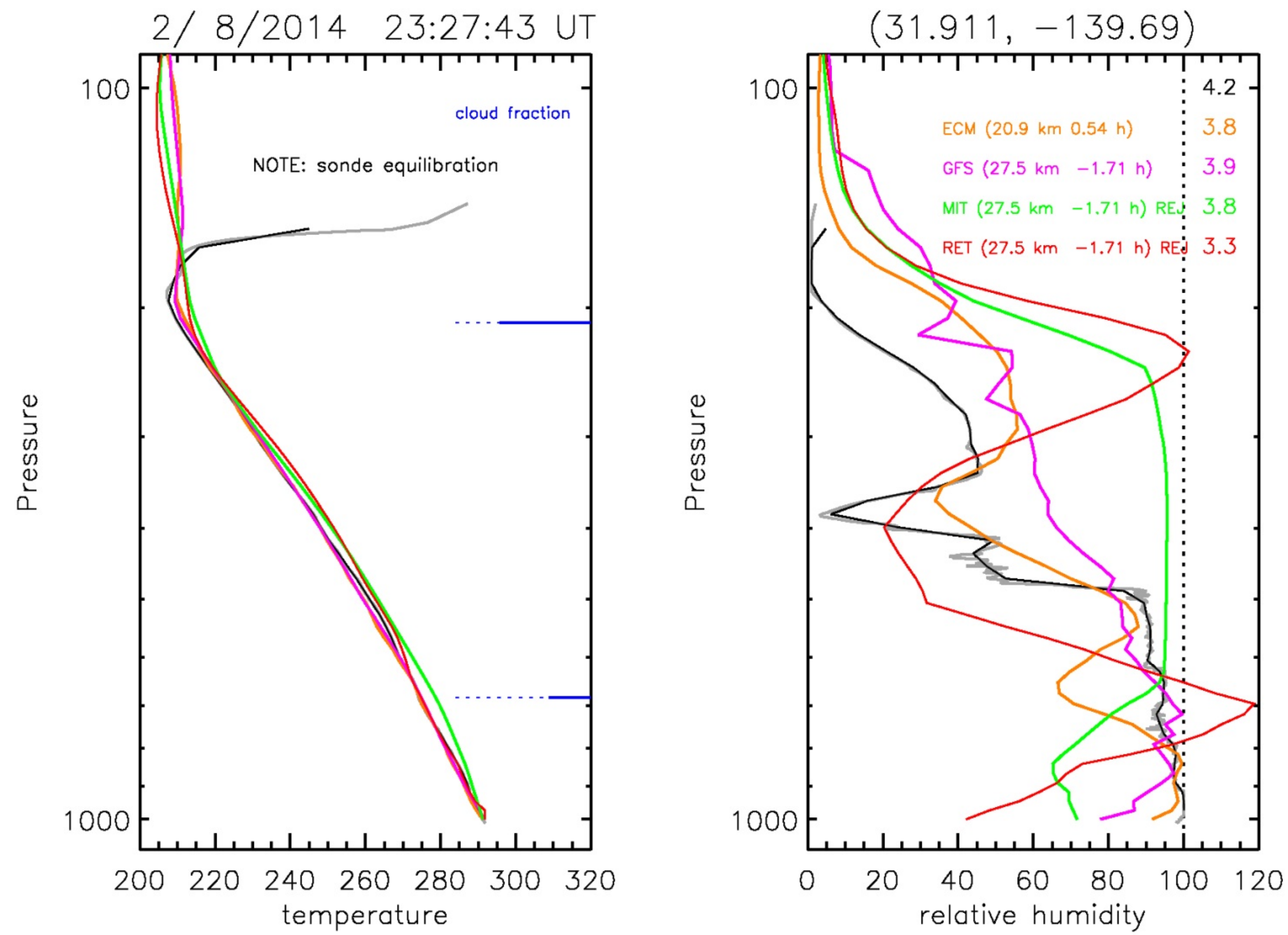
- Samples the region to the south of the AR
  - ECMWF in this graphic is 2.2 hours later



Atmospheric River scene
(sonde dropped 1.7 hour after satellite overpass)

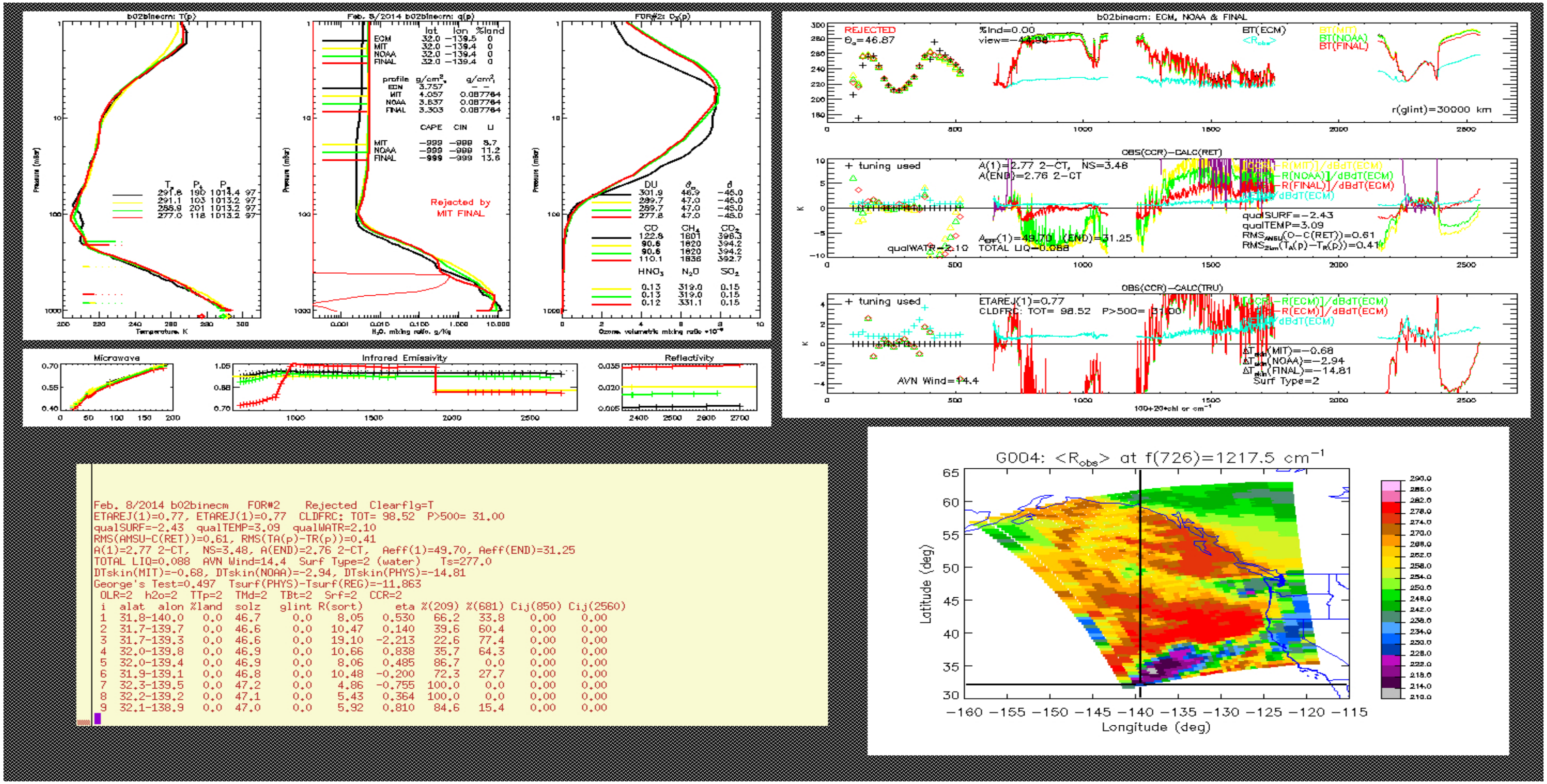
Both uW-only and couple retrieval are rejected at sonde location

Scene is too cloudy and probably precipitating



Diagnostic display for retrieval closest to sonde location (*rejected* case)

- Retrieval within the AR is rejected due to ~98% cloudiness, high liquid water content

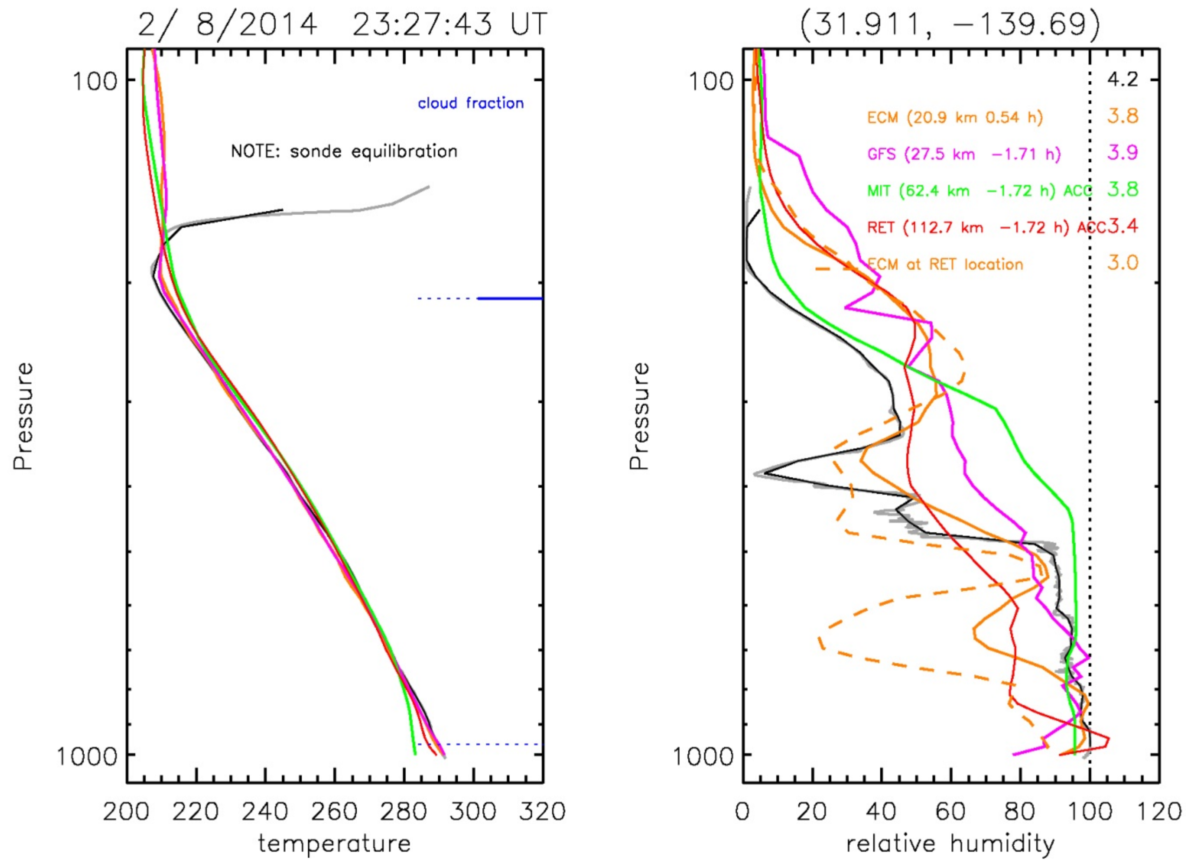


Same Sonde, selected closest ACCEPTED retrieval

In this plot the closest accepted retrieval (red) 113 km away was selected.

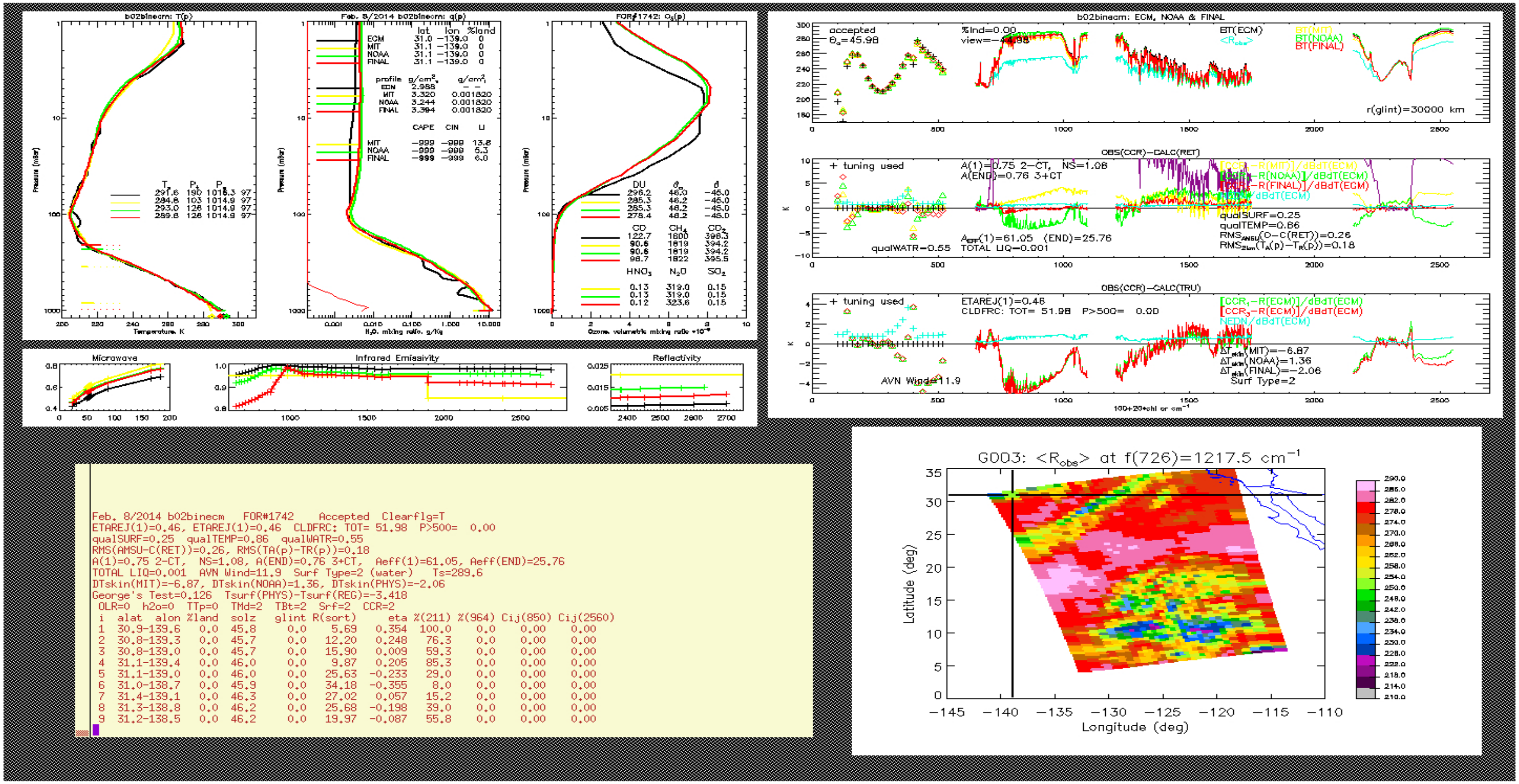
ECMWF is also shown at the retrieval location (dashed orange) .

This retrieval has 3.4 cm IWV compared to 4.2 cm for the sonde and 3.0 at ECMWF co-located with the retrieval



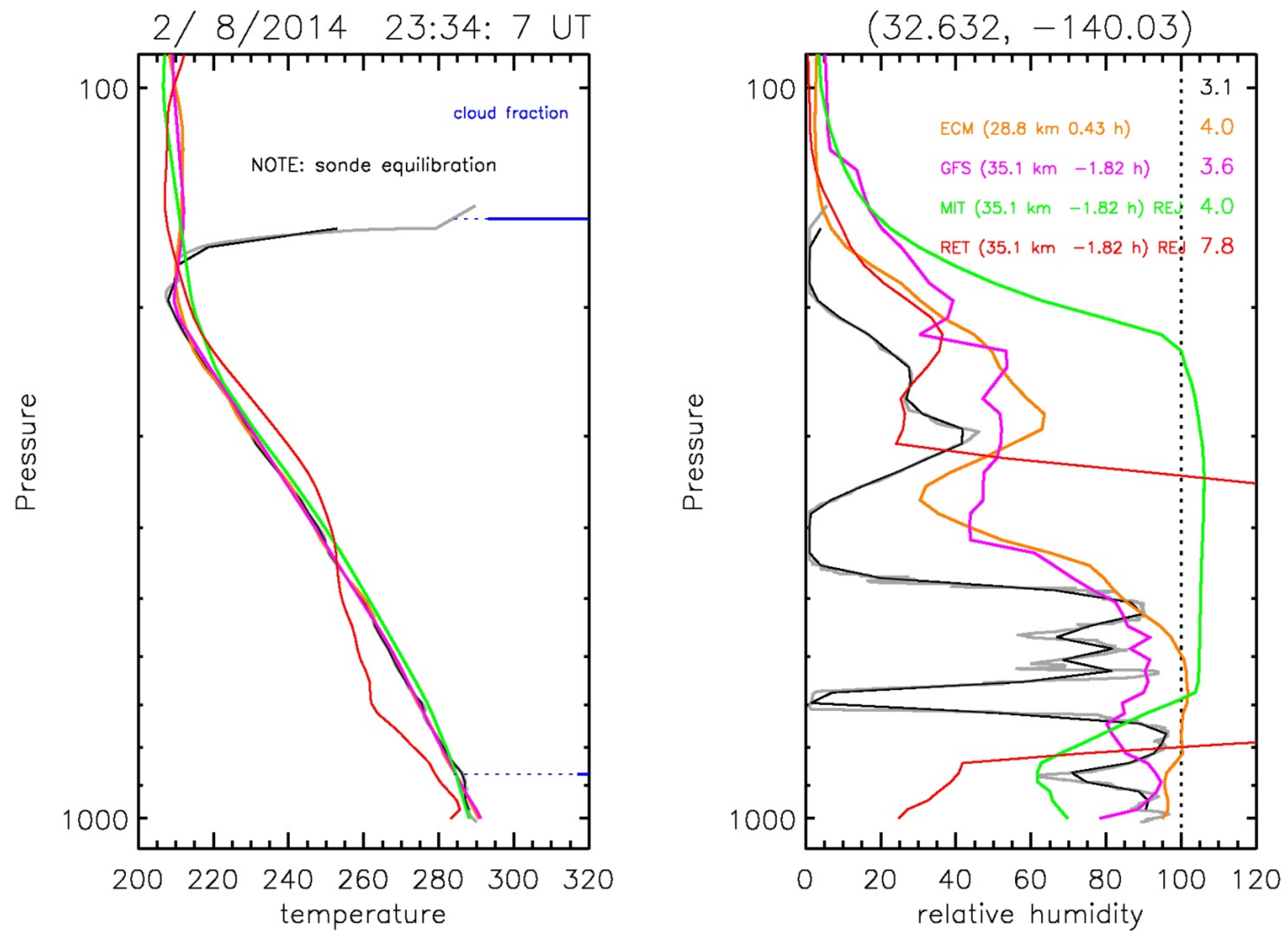
Diagnostic output for closest *accepted* retrieval

- Closest retrieval is to the south of the AR, not relevant for this sonde



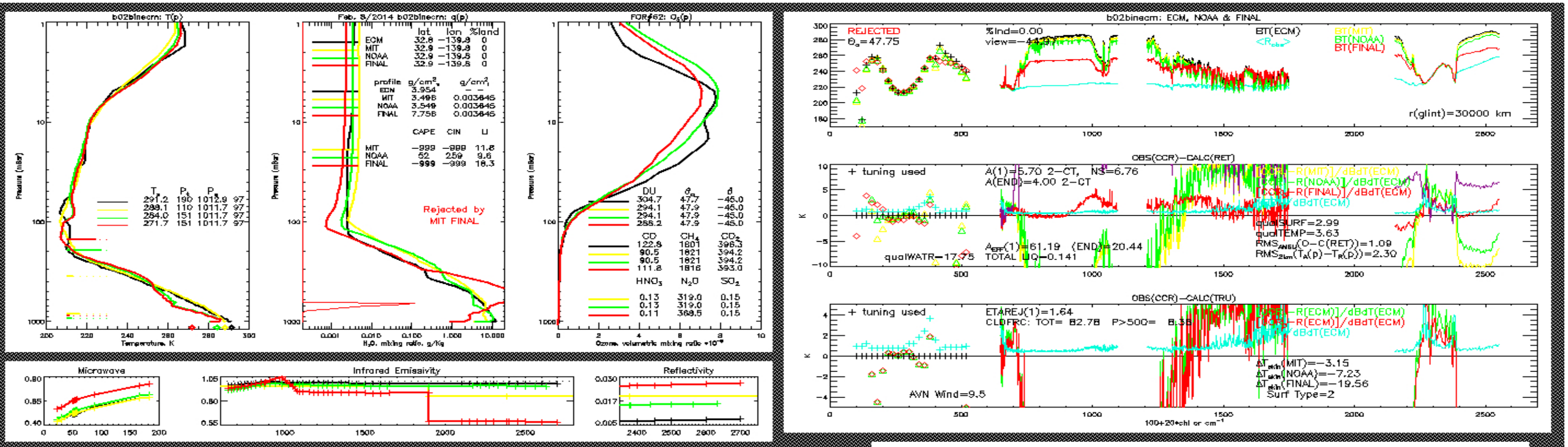
Another example of retrieval within atmospheric river

In this case the coupled retrieval within AR has *serious* problems (but we know it failed)



Diagnostic output for closest retrieval (*rejected*)

- Retrieval failed due to high level cloudiness (~80%) and very high liquid water

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Feb. 8/2014 b02binecm   FOR#62    Rejected  Clearflg=T
ETAREJ(1)=1.64, ETAREJ(1)=1.64  CLDFRC: TOT= 82.78  P>500=  8.38
qualSURF=2.99  qualTEMP=3.63  qualWATR=17.75
RMS(AMSU-C(RET))=1.09, RMS(TA(p)-TR(p))=2.30
A(1)=5.70 2-CT,  NS=6.76, A(END)=4.00 2-CT,  Aeff(1)=61.19, Aeff(END)=20.44
TOTAL LIQ=0.141  AVN Wind=9.5  Surf Type=2 (water)   Ts=271.7
DTskin(MIT)=-3.15, DTskin(NOAA)=-7.23, DTskin(PHYS)=-19.56
George's Test=0.444  Tsurf(PHYS)-Tsurf(REG)=-12.329
fg : CAPE=    52.6 J/kg   CIN=   259.5 J/kg   LI=     0.0 K
 OLR=2  h2o=2  TTp=2  TMd=2  TBt=2  Srf=2  CCR=2
 i  alat  alon %land  solz   glint R(sort)     eta %(151) %(870) Cij(850) Cij(2560)
 1  32.7-140.4   0.0  47.6     0.0    8.49  -0.874   70.6    8.7    0.00     0.00
 2  32.6-140.0   0.0  47.5     0.0    8.18  -0.353   72.7    8.7    0.00     0.00
 3  32.6-139.7   0.0  47.5     0.0    5.11   0.908   94.3    5.7    0.00     0.00
 4  32.9-140.1   0.0  47.8     0.0    9.40  -1.581   64.4    8.7    0.00     0.00
 5  32.9-139.8   0.0  47.7     0.0    7.86   0.716   72.9    8.7    0.00     0.00
 6  32.8-139.4   0.0  47.7     0.0    6.07   2.577   84.3    8.7    0.00     0.00
 7  33.2-139.9   0.0  48.0     0.0    9.44  -2.046   66.9    8.7    0.00     0.00
 8  33.1-139.5   0.0  48.0     0.0    7.95   0.082   73.6    8.7    0.00     0.00
 9  33.0-139.2   0.0  47.9     0.0    8.45   0.570   69.9    8.7    0.00     0.00
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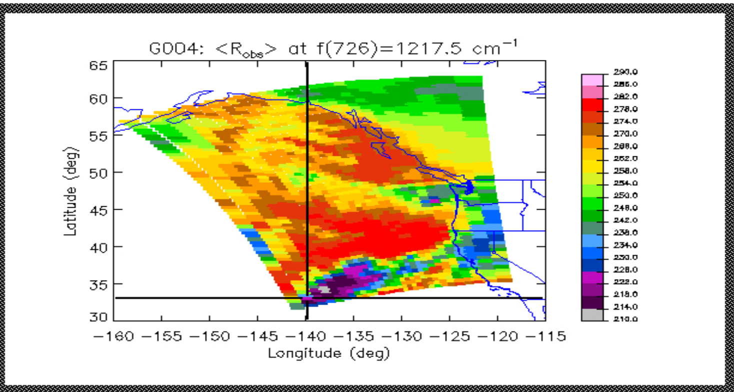
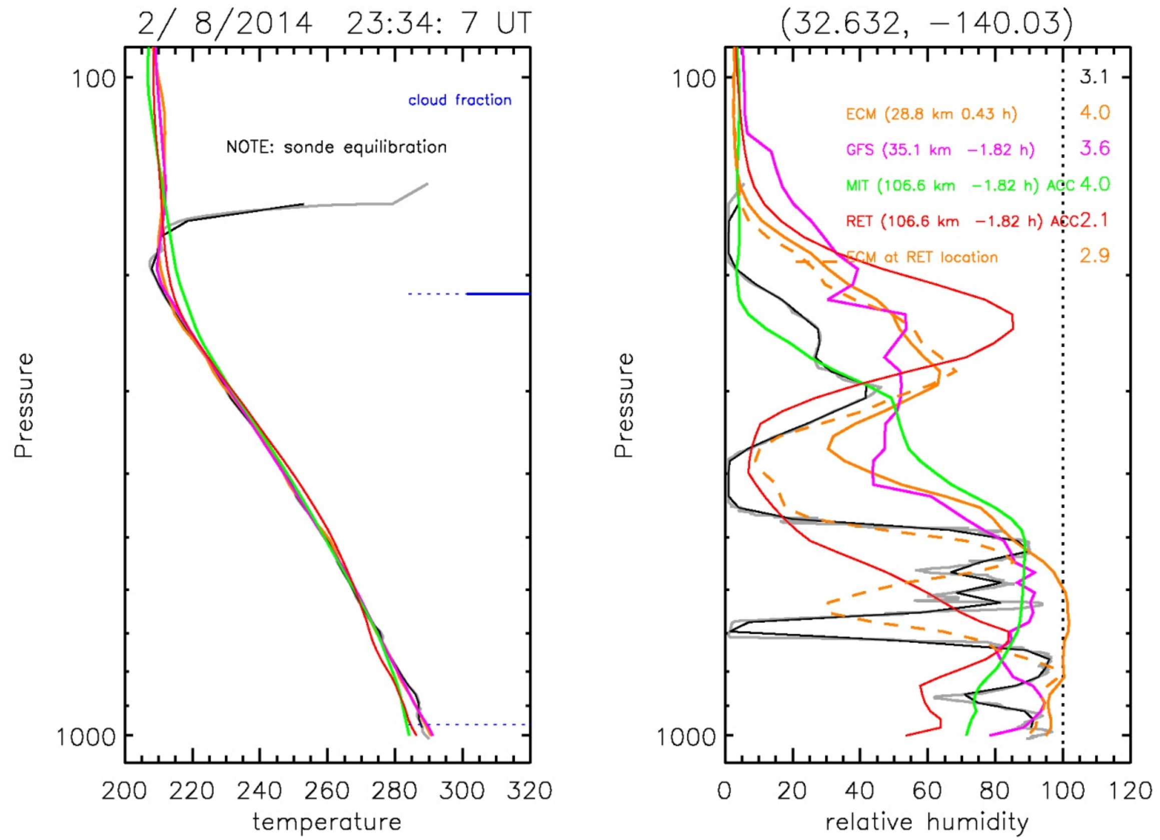


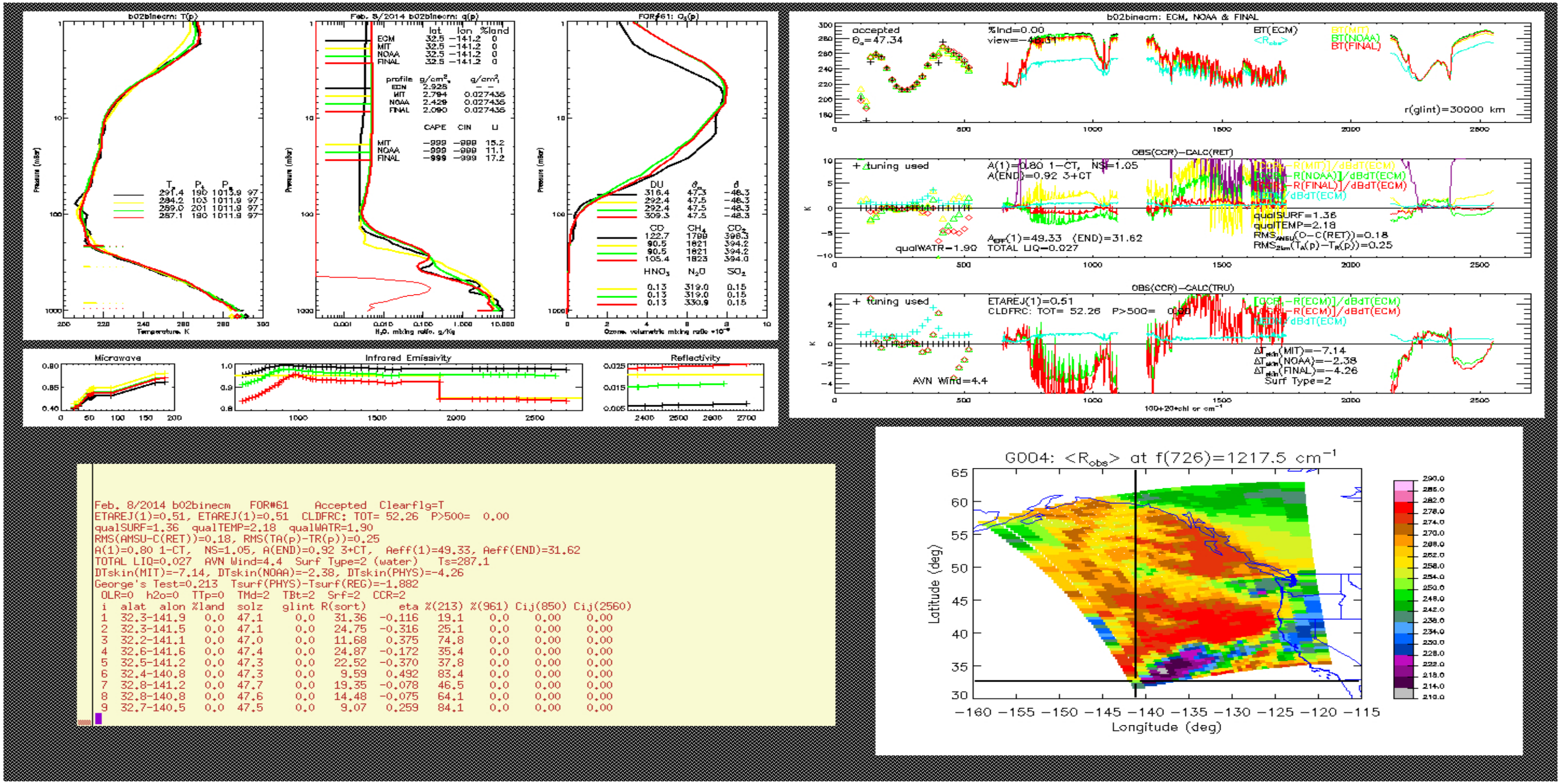
Same sonde with closest *accepted* retrieval

Closest accepted (126 km away) does not match the sonde, but compares well to ECMWF at that location (orange dashed)



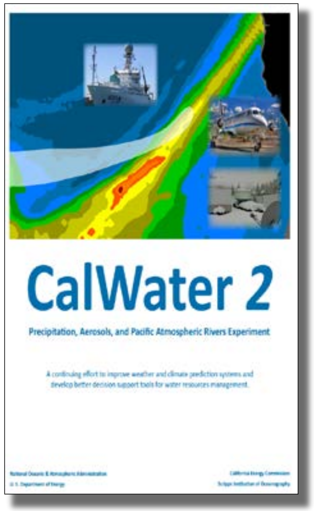
Diagnostic output for closest *accepted* retrieval

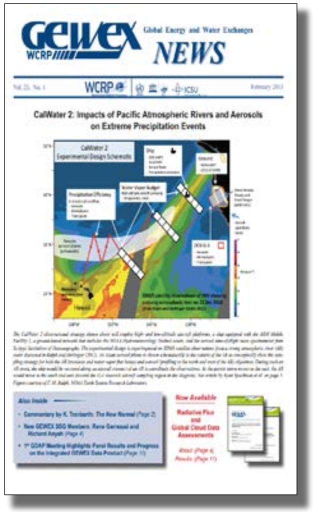
- In this case, the retrieval is near the AR, a very difficult case, very close to limits of acceptance



CalWater 2 Campaign Jan/Feb 2015

- CalWater 2 white paper is at http://esrl.noaa.gov/psd/calwater
- Coordinated with DOE ACAPEX (ARM Cloud Aerosol Precipitation Experiment)





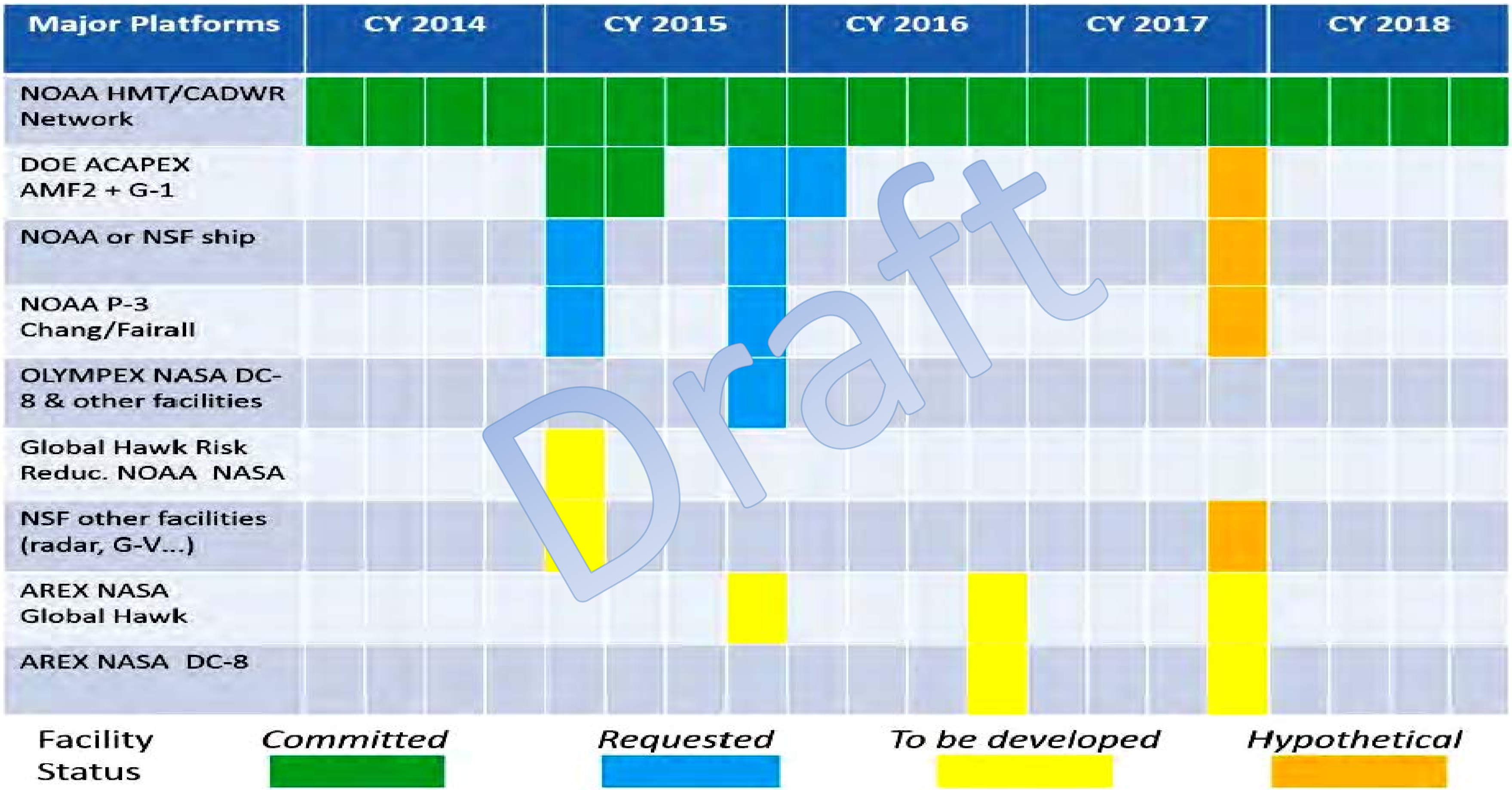
CalWater2 Goals and Science Questions

- Science questions:
  - Role of tropical water and convection in the genesis of ARs
  - Role of air-sea fluxes and ocean mixed layer in evolution of ARs
  - How much rainfall occurs over the ocean?
  - Role of coastal and Sierra Barrier Jets?
  - How do aerosols (both local and long-range) influence cloud and precipitation?
- Goals: Improve prediction systems and develop decision support tools

CalWater 2 five year plan

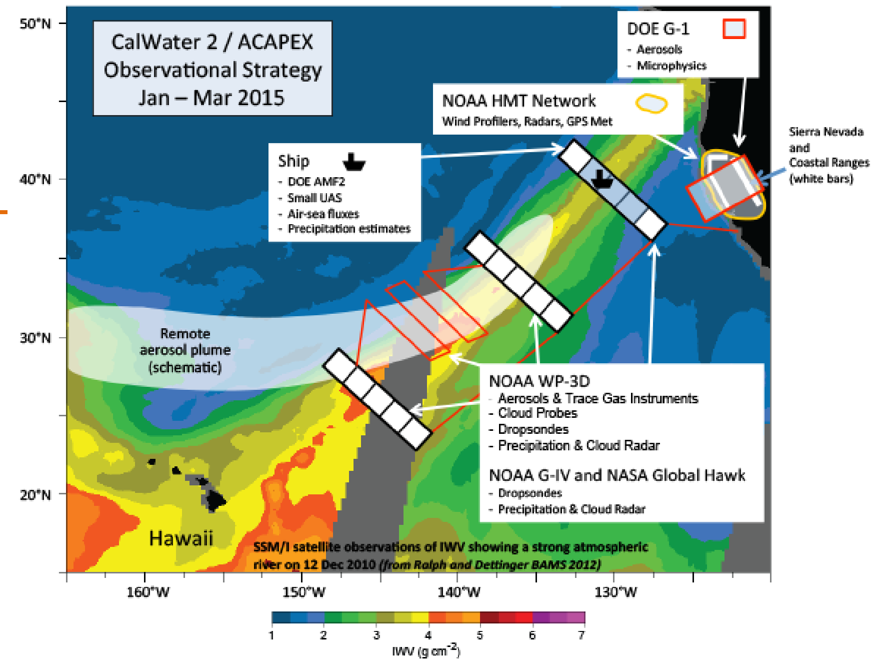
Broad inter-agency coordination

(Scripps, NOAA, DOE, NASA, NSF)



CalWater 2/ACAPEX Observing Strategy

ACAPEX = ARM Cloud Aerosol Precipitation Experiment



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, 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, N2O)
NOAA R.H. Brown	Moves ~5 deg/day	30 days	Aerosol Observing System, Ka ,X, W-Band Cloud Radars, DOE AMF2 , Micropulse LIDAR, Wind Speed, Rain Guages, Sondes

What can be done for CalWater 2

- Retrieval products (T(p), IWV, q(p), O3(p), etc.) can be provided from the archive as was done in Feb. 2012
  - In January 2015 will have ~2 hour latency (was ~8 hour in Feb. 2014)
- Also, there are 3 direct broadcast sites that can provide CrIS/ATMS with ~15 minute latency
  - Each site acquires observations within a radius of ~2000 km
  - Honolulu Hawaii, Corvallis Oregon, Fairbanks Alaska

What these products provide to the CalWater field campaign

- Satellite retrievals can provide synoptic-scale context for the sparse *in-situ* datasets
  - Retrievals can be used to characterize the regime outside the AR (these are usually the accepted cases)
  - Research retrievals can also be employed (e.g., precipitation estimates from ATMS, dust algorithms from CrIS) within the AR.
- BUT --- we are only within the field region for a few seconds
  - It would be mutually beneficial to consider satellite overpass time when planning the mission
    - Deploy more dropsondes with +/- 20 minutes of overpass
    - Ryan Spackman (STC at ESRL) is willing to work with us
- Also, Metop-A, B IASI can be provided, if desired
  - This satellite has overpasses at 9:30 am/9:30 pm local time
  - Latency of ~2 hours, could be of value for flight planning.

What we gain from CalWater 2

- I strongly believe that CalWater 2 is an ideal opportunity for satellite validation
  - We test our algorithm in situations that are nationally and socially relevant
  - These are difficult cases for the retrieval
    - As algorithm developers, we need these kinds of scenes to improve the retrieval skill and tailor the quality control.
      - e.g., we can test NUCAPS with ATMS as a formal *a-priori*
    - As participants in the campaign, we gain the expertise of the CalWater science team to develop meaningful products.
    - Other measurements that have been proposed (CO, O3, CO2, aerosols) will help the validation, since CrIS is sensitive to these
  - WFO's have shown interest in direct broadcast CrIS/ATMS products – this is an opportunity to demonstrate their value in the field

QUESTIONS?

Acronyms

- Infrared Instruments
  - AIRS = Atmospheric Infrared Sounder
  - IASI = Infrared Atmospheric Sounding Interferometer
  - CrIS = Cross-track Infrared Sounder
  - HES = Hyperspectral Environmental Suite
- Microwave Instruments
  - AMSU = Advanced Microwave Sounding Unit
  - HSB = Humidity Sounder Brazil
  - MHS = Microwave Humidity Sensor
  - ATMS = Advanced Technology Microwave Sounder
  - AMSR = Advanced Microwave Scanning Radiometer
- Imaging and Cloud Instruments
  - MODIS = MODerate resolution Imaging Spectroradiometer
  - AVHRR = Advanced Very High Resolution Radiometer
  - VIIRS = Visible/IR Imaging Radiometer Suite
  - ABI = Advanced Baseline Imager
  - CALIPSO = Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
- Other
  - EUMETSAT = EUropean organization for exploitation of METeorological SATellites
  - FOV/FOR = field of view or regard
  - GOES = Geostationary Environmental Operational Satellite
  - IGOS = Integrated Global Observing System
  - ILS = Instrument Line Shape
  - IPCC = Inter-government Panel on Climate Change
  - JPSS = Joint Polar Satellite System
  - METOP = METeorological Observing Platform
  - NDE = NPOESS Data Exploitation
  - NPP = National Polar-orbiting Partnership
  - NUCAPS = NOAA Unique CrIS/ATMS Processing System
  - OCO = Orbiting Carbon Observatory
  - STC = Science and Technology Corporation