Combining SEVIRI, IASI (and AMSU) profiles in a Short-Range, "All- Weather" forecasting tool
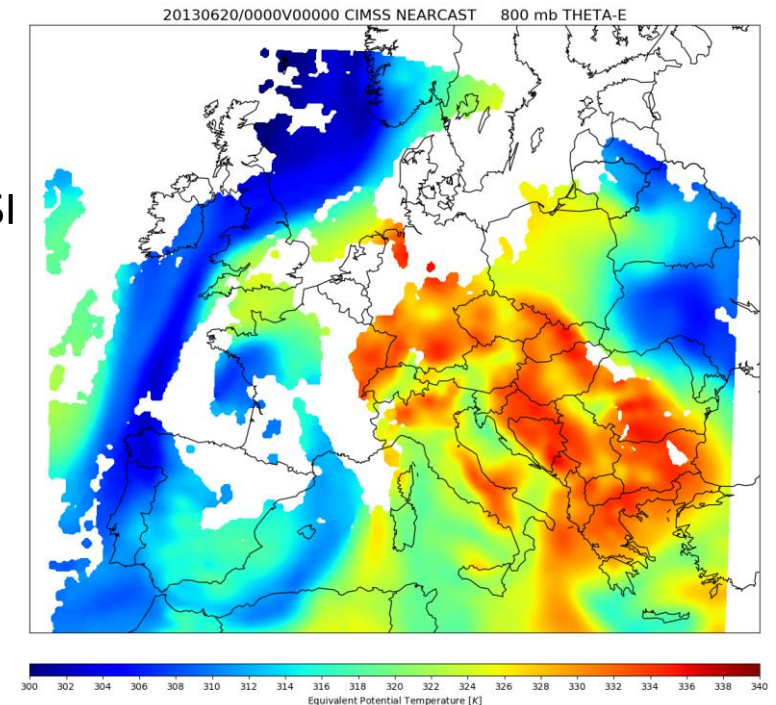
Ralph Petersen and Lee Cronce

Cooperative Institute for Meteorological Satellite Studies (CIMSS), Space Science and Engineering Center University of Wisconsin – Madison, Madison, Wisconsin

If we want forecasters to continue to play an important part in our national met. services, we must train them in the strengths and weakness of various satellite products and give them tools to use them to full advantage

Improving NearCasts and Removing Deficiencies using GOES-16 and JPSS

- The NearCast model is a quick-running Lagrangian analysis and forecast system designed to provide data-driven analyses and frequently updated short-range projections of satellite-based atmospheric moisture and stability observations to support operational forecasting

  - It accurately maintains the extremes and gradients of the observations in quickly produced real-time forecasts.

- The NearCast model was originally developed to run on the hourly GOES I-M series sounder profiles creating projections of each sounding layer out to nine hours.

  - It has been applied to SEVIRI and GOES-16 deep-layer moisture products

  - It has also been been adapted to use higher-vertical resolution CrIS and IASI profiles at high latitudes where GEO observations are not available.

- Forecasters have favorably evaluated the NearCast system in a variety of forecasting situations.

  - Less successful in far northern and eastern SEVIRI tests

20130620/0000V00000 CIMSS NEARCAST   800 mb THETA-E

300 302 304 306 308 310 312 314 316 318 320 322 324 326 328 330 332 334 336 338 340
Equivalent Potential Temperature [K]

Improving NearCasts and Removing Deficiencies using GOES-16 and JPSS

- A recurring shortcoming noted by forecasters is the presence of discontinuities due to data gaps in cloudy regions.

    - These gaps are inherent in the GOES atmospheric profiles used by the NearCast because the satellite retrievals are produced from infrared observations, thereby limiting their use to cloud-free areas.

- To address this issue, microwave-based moisture and temperature retrievals from Low Earth Orbiting (LEO) satellites are currently being tested as a means of filling the cloudy IR-void areas.

    - Although these coarser resolution microwave profiles are not available as frequently as GOES (or SEVIRI) observations, they have the advantage that they are 'all-weather' and generally not attenuated or contamination by clouds.

    - They also have a vertical resolution similar to that of GOES-based moisture products.

    - The inclusion of microwave retrievals:
        - Provides more spatial continuity in NearCast analyses and forecasts,
        - Offers a good means of exposing forecaster to this underutilized data source, and
        - Improves the quality of soundings and NearCasts at locations distant from satellite nadir
            - *Most notably north and south, but also east and west.*
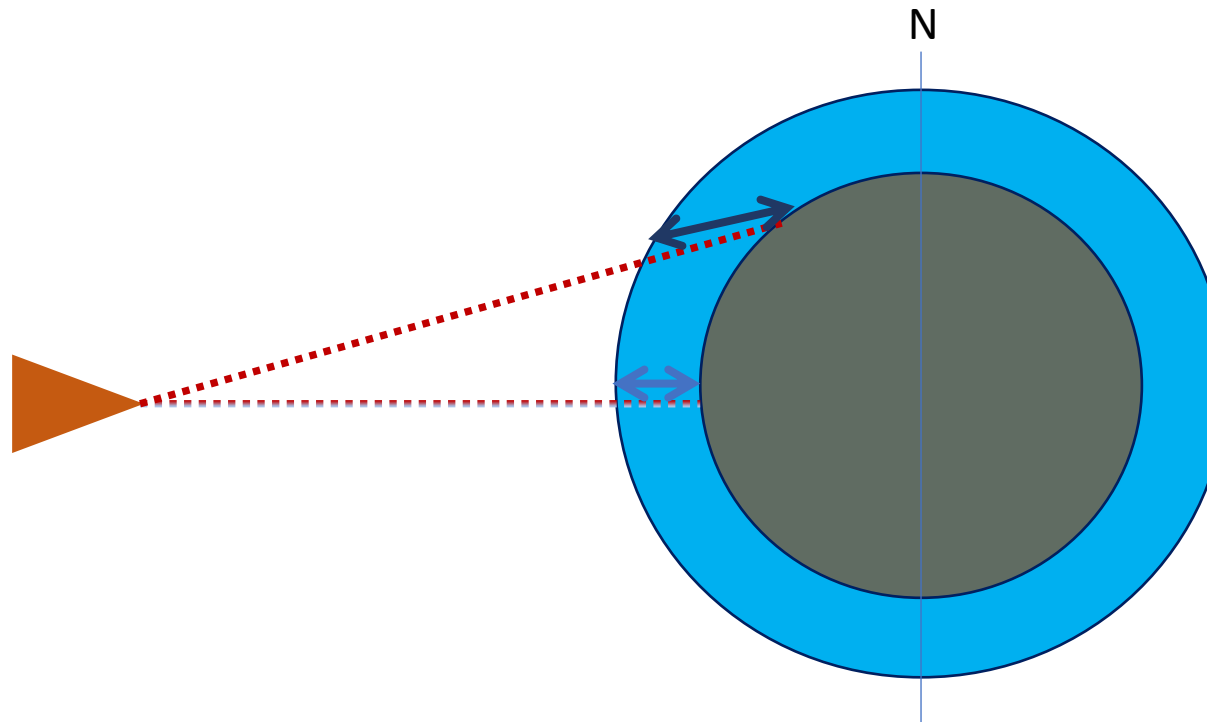
First, some geometry
- For illustration -

For an Earth, Atmosphere, Geostationary Satellite system:

The depth of the water vapor column observed
by the satellite at 60º latitude

Is more than double that at the equator

This factor can have substantial effects, especially on moisture retrievals at locations well away from the sub-satellite point – even using hyperspectral observations
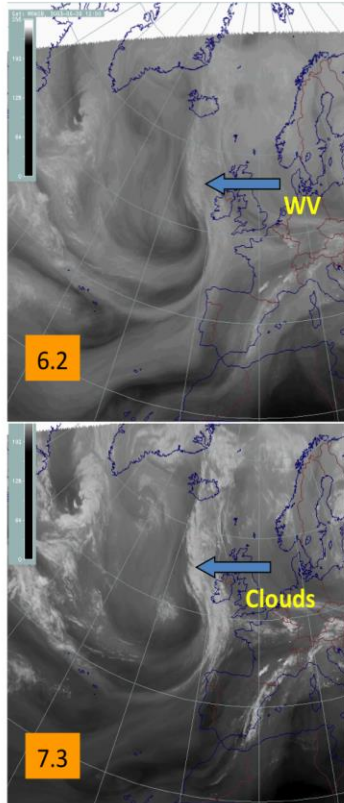

RMSE for Water Vapor (2km) - Mixing Ratio
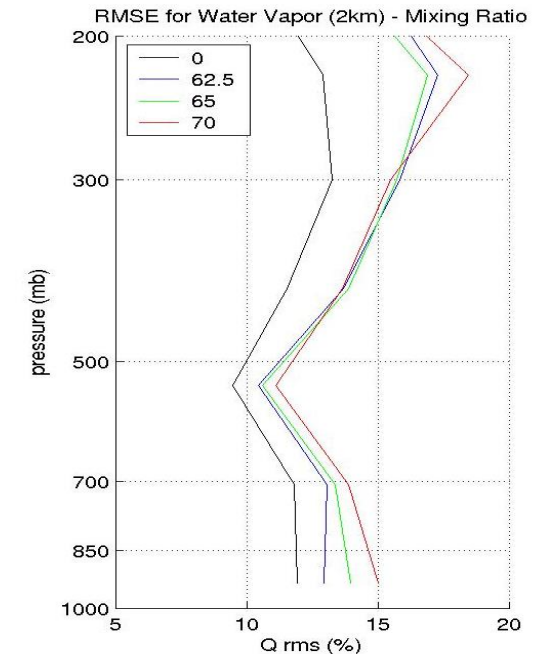
2 km layer water vapor mixing ratio percentage RMS (%) from simulated hyperspectral IR radiances (From Jun Lee)

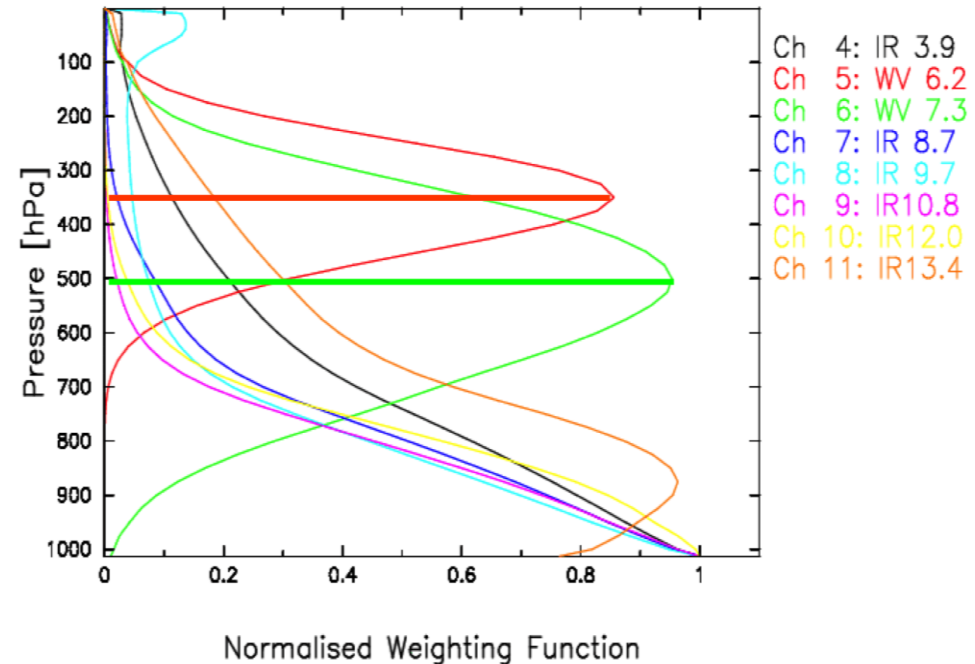# Producing Soundings from MSG-SEVIRI

Some Characteristics: WV 6.2 und 7.3

- WV content in two layers
  - Differentiation between WV content in the lower and higher middle troposphere
- AMV Calculation
- Height of semi-transparent clouds

6.2 / 7.3 — WV / Clouds

Max. signal in Ch05 from approx. 350 hPa
Max signal in Ch 06 from approx. 500 hPa
But: If there is no WV radiation from far below reaches the satellite

Standard Mid–Latitude Summer Nadir

Weighting functions Source: EUMETSAT

Ch 4: IR 3.9
Ch 5: WV 6.2
Ch 6: WV 7.3
Ch 7: IR 8.7
Ch 8: IR 9.7
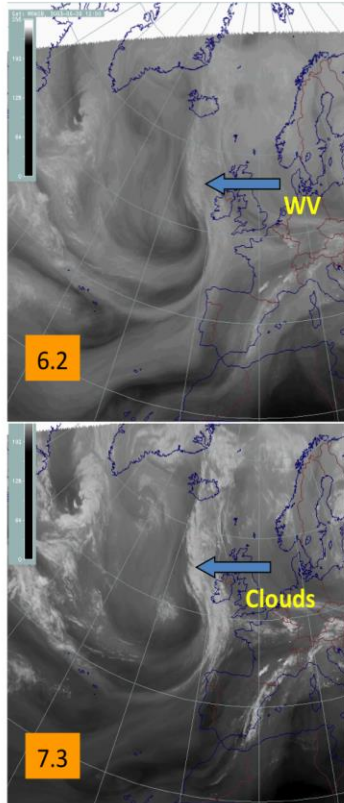Ch 9: IR10.8
Ch 10: IR12.0
Ch 11: IR13.4

- SEVIRI retrievals are in reality a form of **data fusion**: melds NWP and satellite radiance information
  - Correct errors in model first guess
  - Available at high temporal and horizontal resolution
  - Pre-convective environment
  - **Under-utilized**

How can we use this information better?
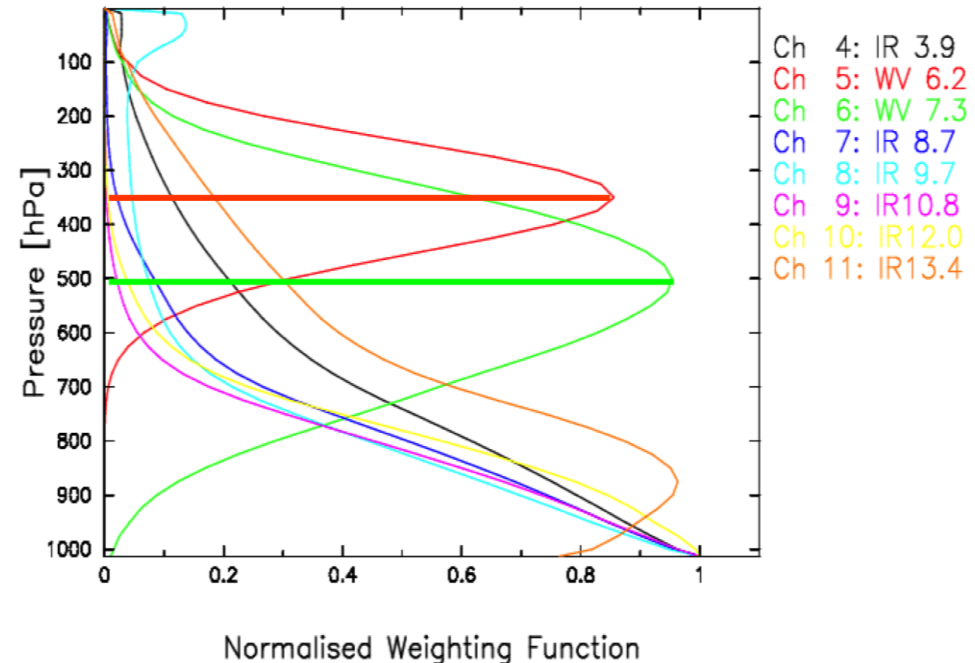
Producing Soundings from MSG-SEVIRI

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Ch 10: IR12.0
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- What do SEVIRI Water Vapor channels really "see"?
  - 6.7 micro channel observes the average temperature of the uppermost 5-10 mm of water vapor in the column of atmosphere being observed (*not a set atmospheric layer*)
  - 7.3 micron channel provides the average temperature of the uppermost 20-30 mm of water vapor
    - The retrievals combine these into a vertical profile of deep-layer PW

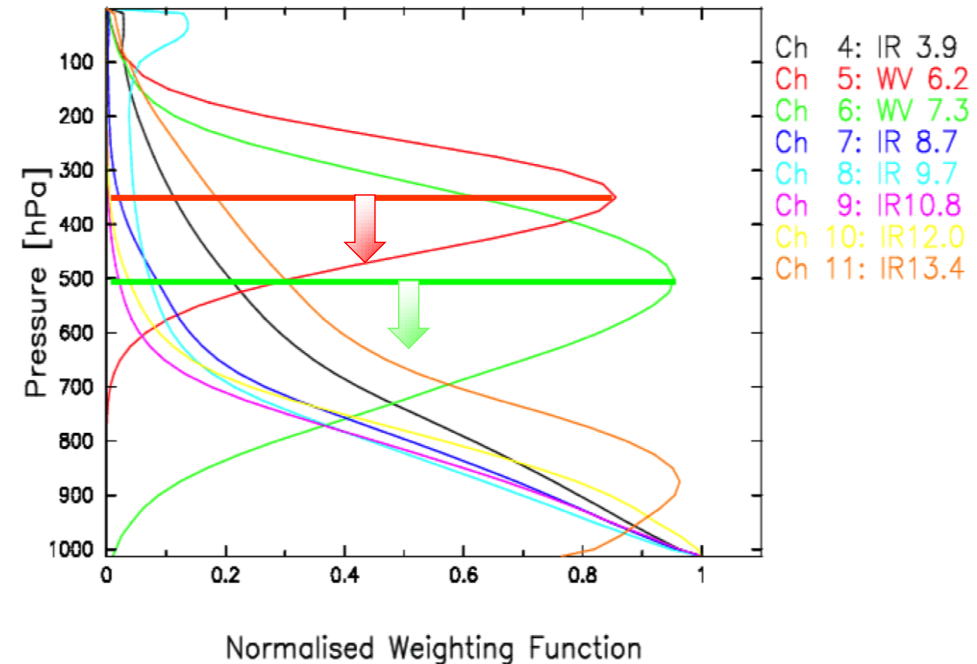# Producing Soundings from MSG-SEVIRI

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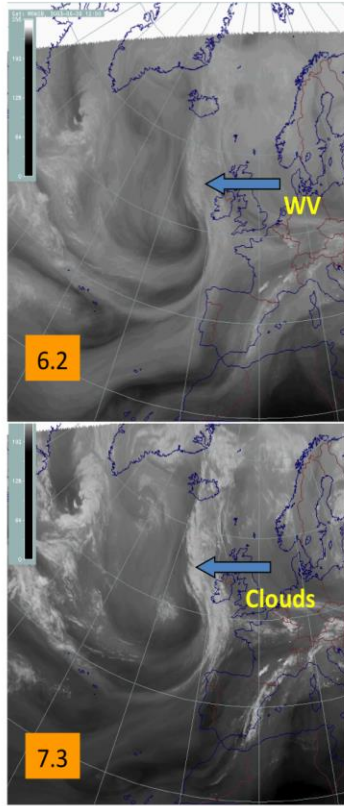
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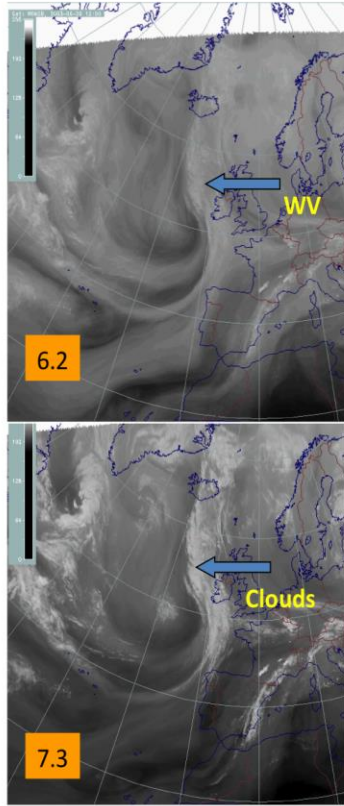Ch 8: IR 9.7
Ch 9: IR10.8
Ch 10: IR12.0
Ch 11: IR13.4

- When the upper atmosphere is very dry:
  - Because the 6.2 micro channel 'sees' only the uppermost 5-10 mm of water vapor, the channel will 'see' deeper into the troposhere and the weighting function is lowered
  - Corresponding, the 7.3 micro channel shifts downward to provide more information in the lower troposphere (which is good)

This 'dry-aloft' configuration produces a high quality moisture profile with reliable information about lower-tropospheric moisture
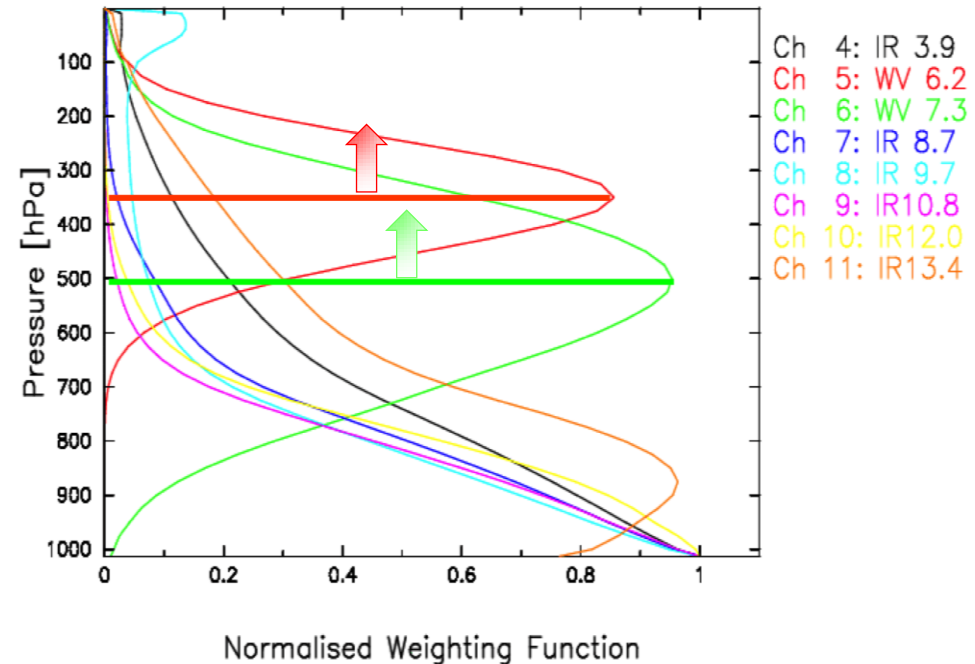
Producing Soundings from MSG-SEVIRI

Some Characteristics: WV 6.2 und 7.3

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Standard Mid-Latitude Summer Nadir

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Ch 9: IR10.8
Ch 10: IR12.0
Ch 11: IR13.4

- When the upper atmosphere is moist:
  - Because the 6.2 micro channel 'saturates' at upper levels and we 'see' very little into the troposhere as the weighting function is raised
  - Correspondingly, the 7.3 micro channel is shunt upward to provide less information about moisture in the lower troposphere (which is less good)

This 'moist-aloft' configuration produces a lower quality moisture profile with less reliable information about lower-tropospheric moisture

Improving use of Soundings from MSG and MTG-I/S
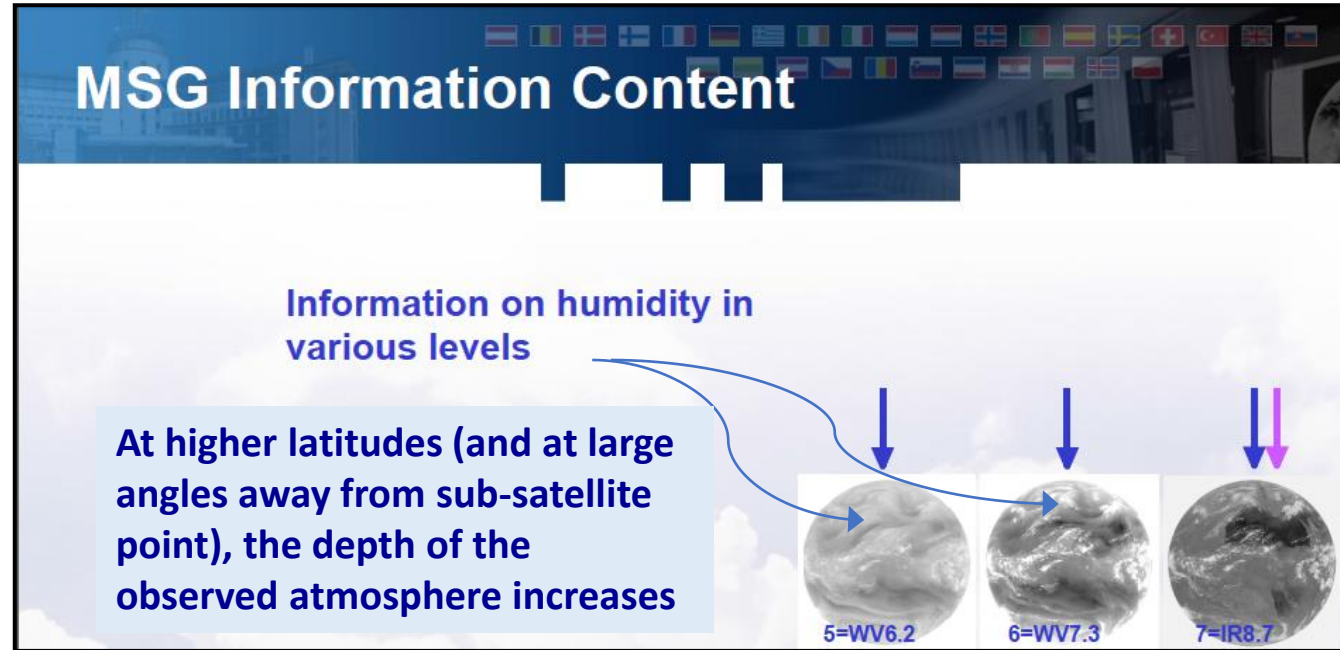
- As the angle of the atmosphere observed by the water vapor channels increases, the 'depth' of even a thin layer of moisture appears deeper than in reality
  - A thin layer of moisture in the upper atmosphere, which viewed directly above, appears much denser when viewed along a slanted path, creating a deeper layer in the atmosphere, with 'colder' 6.2 microchannel temperatures (which detect upper-most 5-10 mm of water vapor integrated along the observing path)
  - This upward shift occurs in the 7.3 micron channel, providing less reliable information about lower-tropospheric moisture, especially when there is a thin layer a moisture aloft.

This 'large slant angle' configuration produces a lower quality moisture profile with less reliable information about lower-tropospheric moisture, especially when there are only 'slightly moist' conditions aloft

Therefore, it is very important to be very careful to understand situations in which you can safely use Geostationary retrieval products at higher-latitudes, as well as NearCasts that rely on them.

Applying GOES NearCast Concept to JPSS

Detecting / Predicting Extreme Tropopause Temperature

- **NearCast Applications extend beyond Moisture**
- **Extreme upper-level cold events present hazards to jet aviation – Fuel can gel**
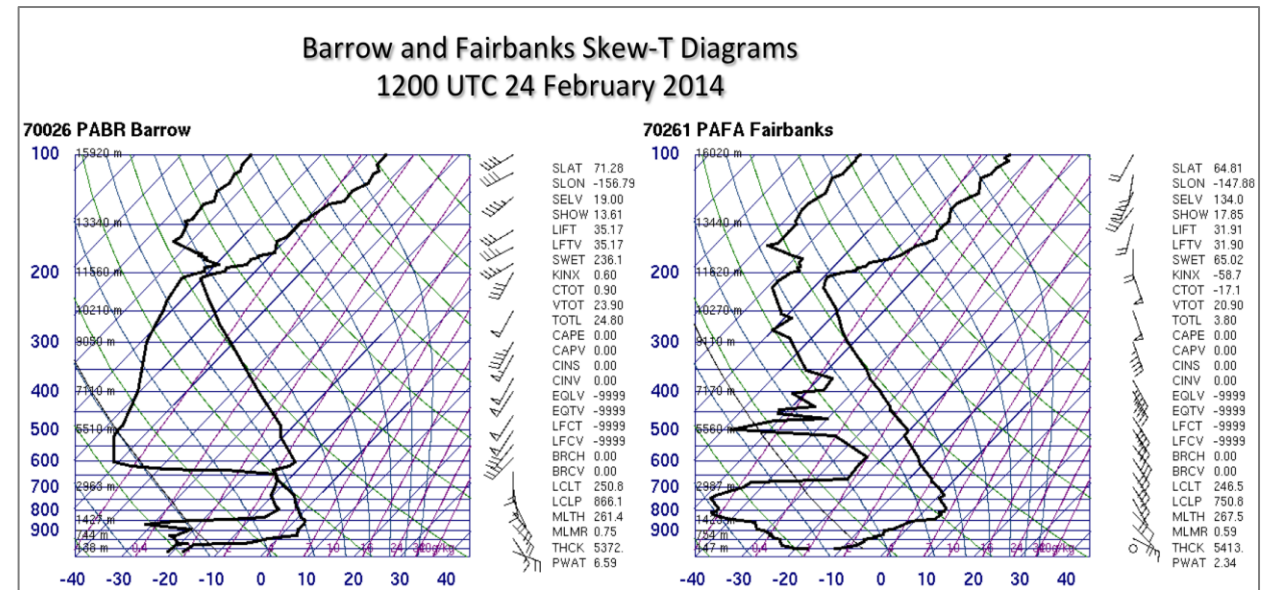
20140224/0645V00000 CIMSS NEARCAST

200 mb Temperature [°C]

•Barrow

•Fairbanks
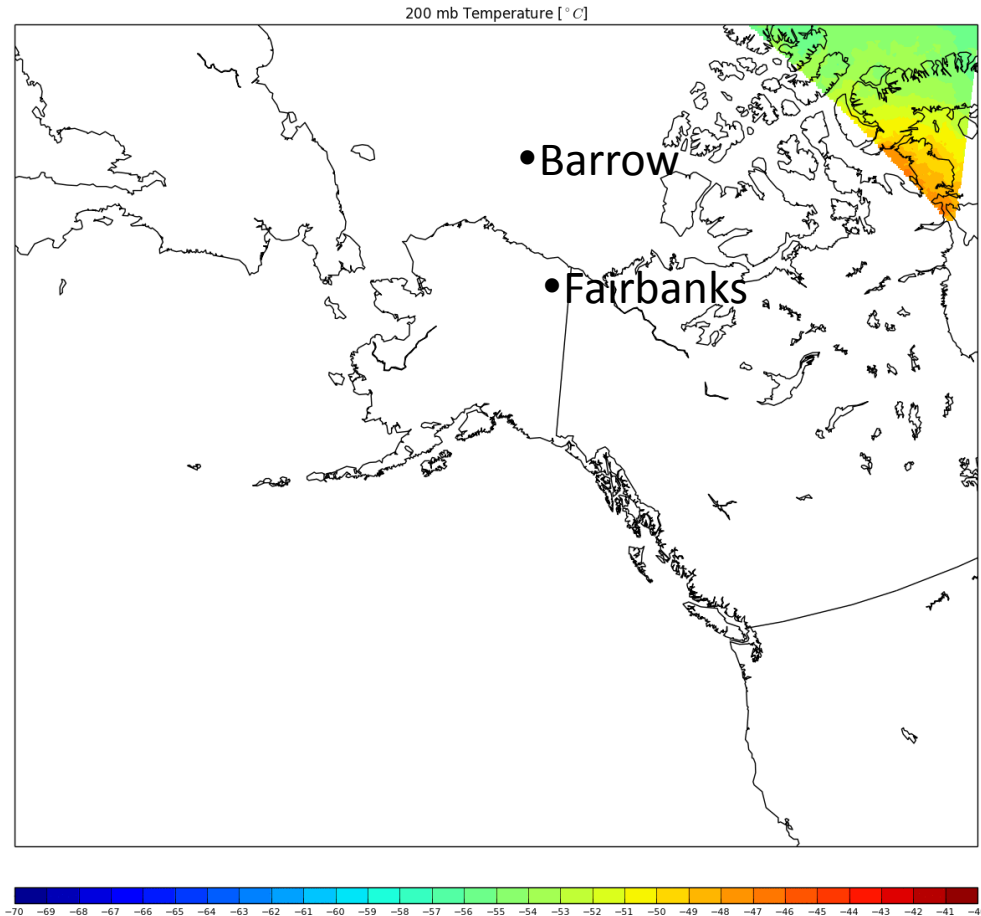
**CrIS – CIMSS Retrievals
(IR only)**

200 hPa (35000') Temperature

24 hours of NearCast Analyses and 9-hour Projection

Barrow and Fairbanks Skew-T Diagrams
1200 UTC 24 February 2014

Note: Retrospective example uses data collected 12 or more hours after event

Applying GOES NearCast Concept to JPSS

Demonstrating the utility of IR Hyperspectral Moisture Observations
- Little GOES over Alaska - Soundings are currently underutilized
- Microwave profiles can fill data *gaps – but with less vertical/horizontal detail*
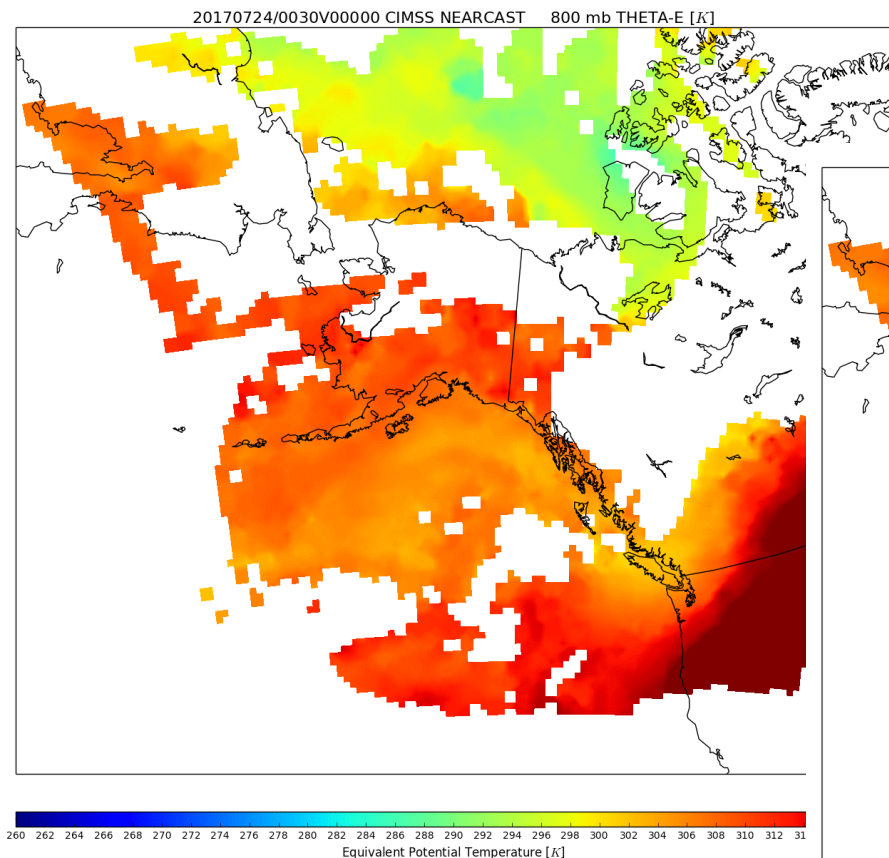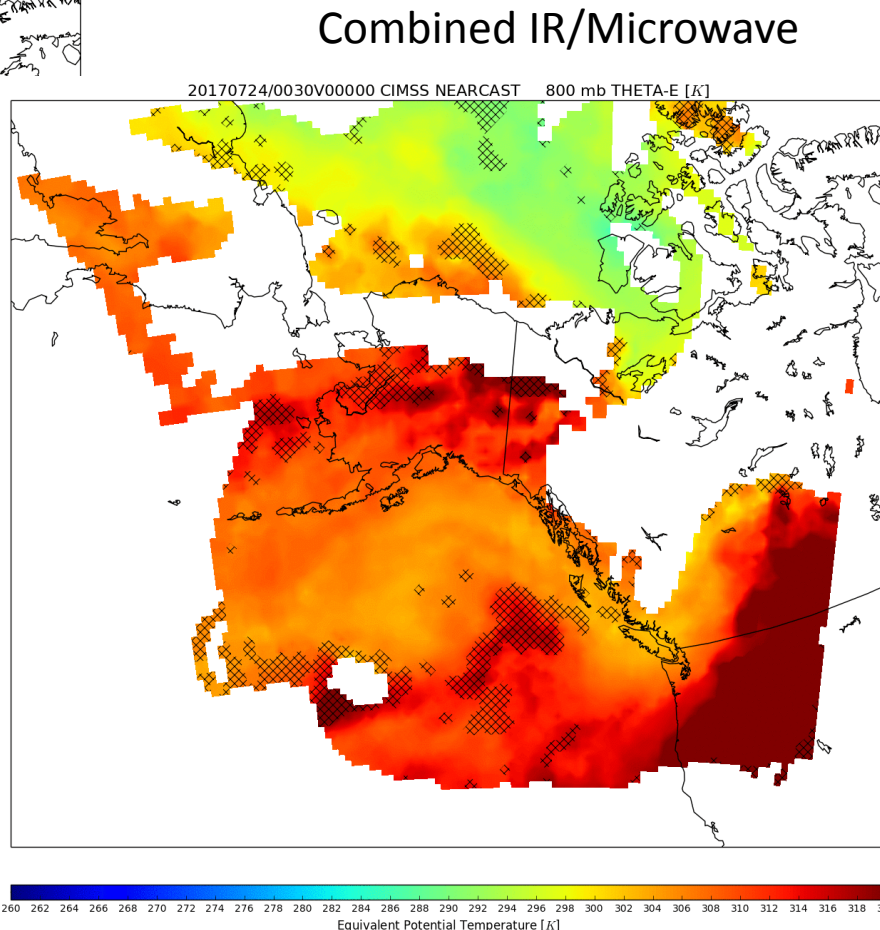 - ✓ *Need to differentiate different observation qualities to users*
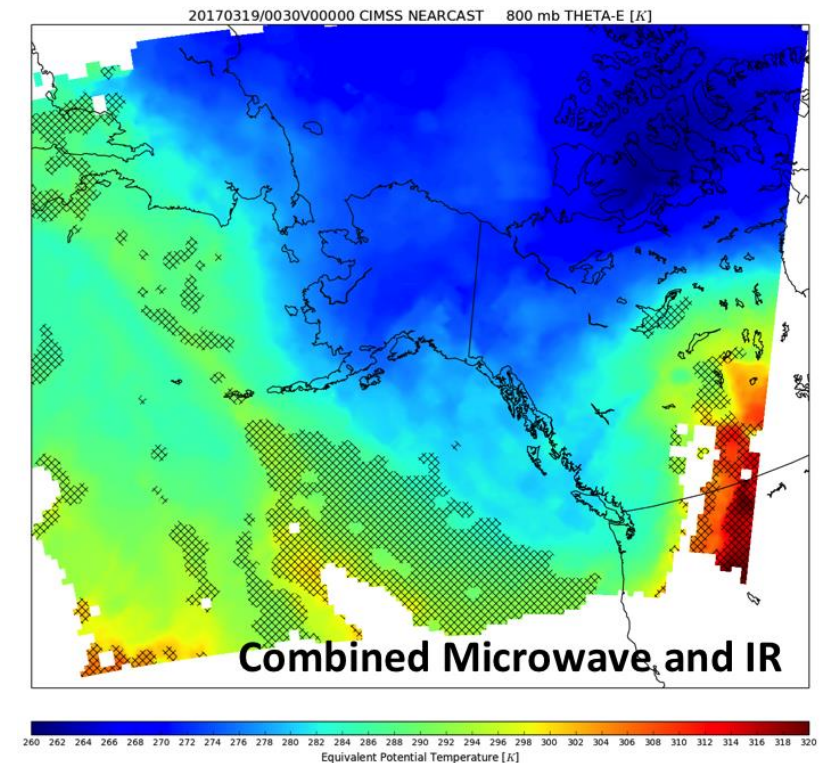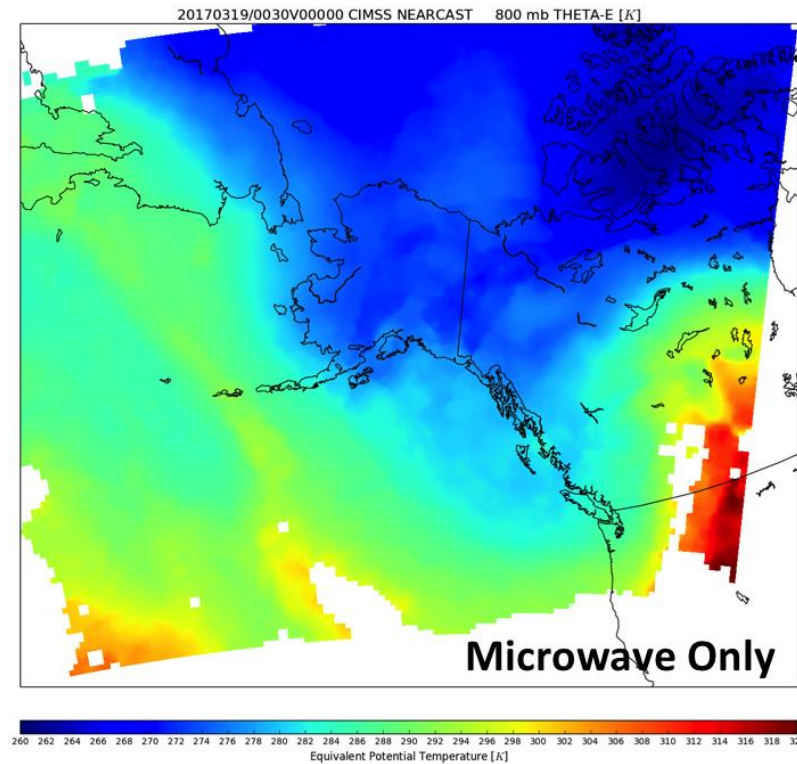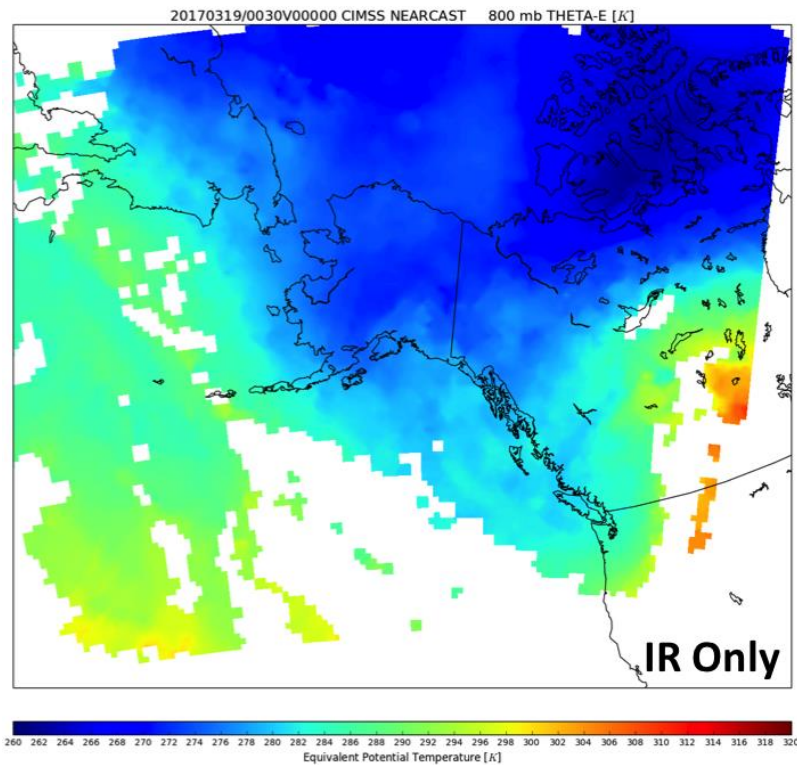
Applying GOES Application to JPSS

Demonstrating the utility of IR Hyperspectral Moisture Observations
- Little GOES over Alaska - Soundings are currently underutilized
- Microwave profiles can fill data *gaps – but with less vertical detail*
  - ✓ *Need to differentiate different observation qualities to users*

Combined IR/Microwave

IR only

New Application: NearCasts that combine IR/microwave observations of lower-level moisture:
1. Are useful in updating forecasts orographically forced precipitation along Canadian Coast, especially when sigma coordinates are implemented, and
2. Provide a ready means of monitoring and correction NWP errors – *Remember that relatively few moisture channels are used in NWP assimilation systems*

Applying GOES Application to JPSS

Demonstrating the utility of IR Hyperspectral Moisture Observations
- Little GOES over Alaska - Soundings are currently underutilized
- Microwave profiles can fill data *gaps – but with less vertical detail*
  - ✓ *Need to differentiate different observation qualities to users*

What other products would address additional needs of new/different users?

Profiles /Integrated CO_2, CH_4, O_3, CH_3, . . .
Smoke, Ice-edges, . . .

Can we combine SEVIRI and LEO retrievals to provide more useful, integrated products?

How can real-time SEVIRI and POES observations be combined to provide more useful, integrated products?

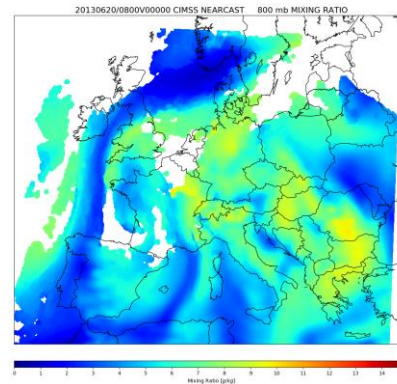SEVIRI profiles are available *Hourly*

NearCast Analyses are built by combining most recent observations with projection of previous data
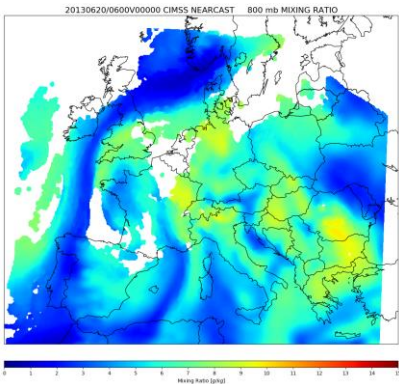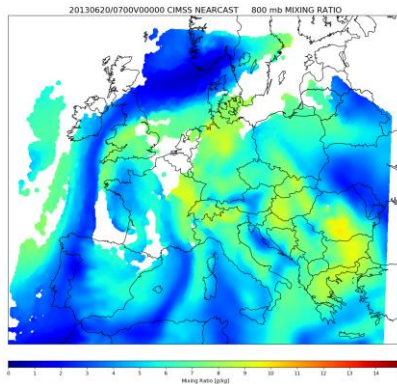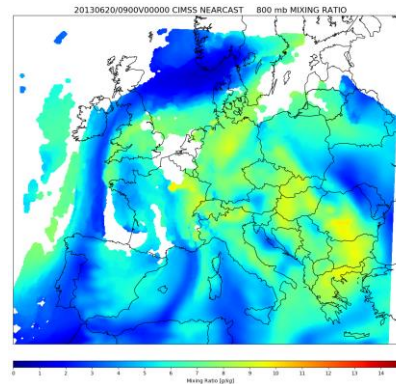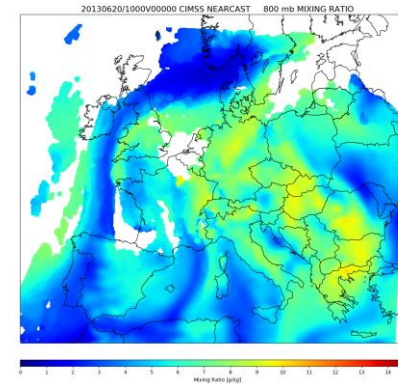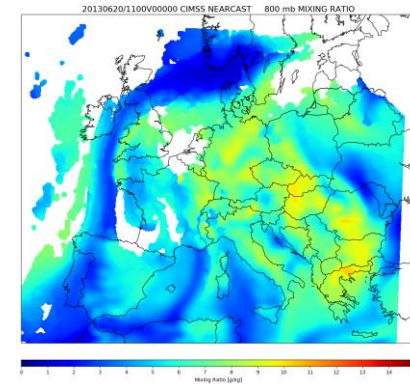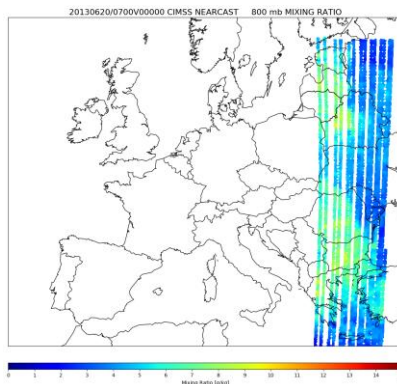

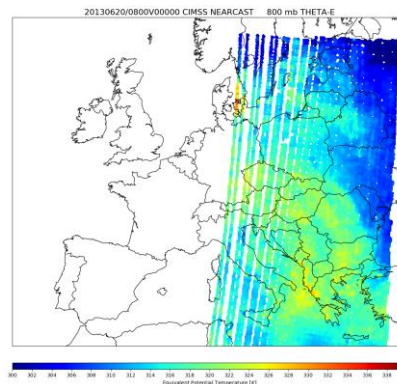| 06 UTC | 07 UTC | 08 UTC | 09 UTC | 10 UTC | 11 UTC |

IASI profiles are available *Intermittently*
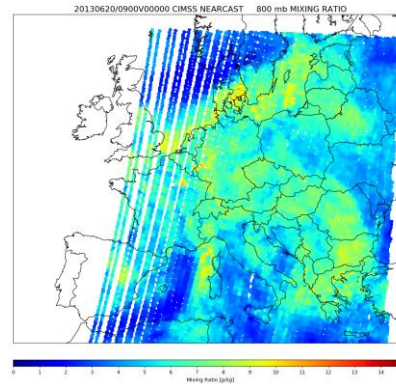
NearCast Analyses are again built by combining most recent observations with projection of previous data, <u>but episodically</u>
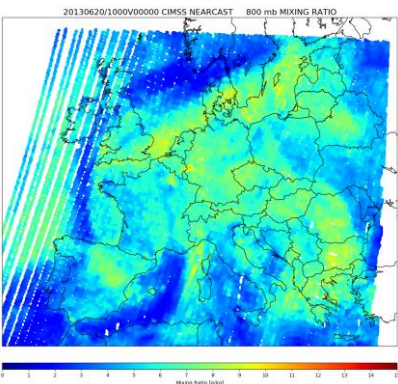

Hourly IASI Analyses adding data from:

| 0645 UTC | 0830 UTC | 0915+0930 UTC | 1015 UTC | 1100 UTC |
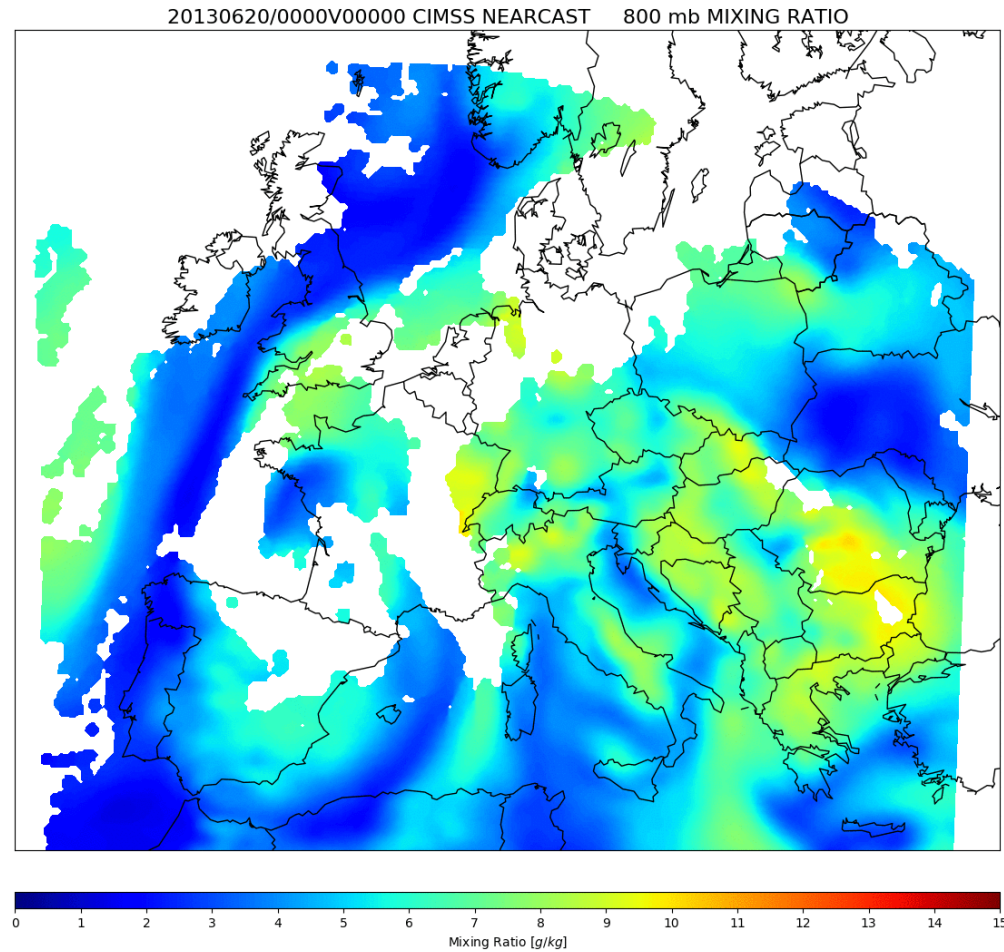
How can real-time SEVIRI and POES observations be combined to provide more useful, integrated products?

Hourly SEVIRI IR only

20130620/0000V00000 CIMSS NEARCAST   800 mb MIXING RATIO

800 hPa Mixing Ratio

Mixing Ratio [g/kg]

How can real-time SEVIRI and POES observations be combined to provide more useful, integrated products?

Hourly SEVIRI IR only

Hourly SEVIRI IR + Intermediate resolution POES

20130620/0000V00000 CIMSS NEARCAST   800 mb MIXING RATIO

20130620/0000V00000 CIMSS NEARCAST   800 mb MIXING RATIO

Mixing Ratio [g/kg]

To be successful, we need easy access to "real-time" (< 3-hour-old) global retrievals from CrIS, IASI and microwave sensors

NESDIS NUCAPS retrievals are an option, but are only available at microwave spatial resolution (~50km)

We would like to use higher-resolution EUMETSAT retrievals for both satellite systems in near-real-time use over Europe and for comparison us North America

Important for:
1) Pre-launch forecaster exposure for MTG-S
2) Filling "cloudy holes" in SEVIRI, MTG-I moisture products
3) Differentiating between IR and microwave inputs
   Improving then quality of retrieval information used by forecasters at high latitudes
4) Merging GEO and Polar observations adds continuity to GEO forecasters tools and provides improved observations at high latitudes

Summary: Combining SEVIRI, IASI (and AMSU) profiles can produce a useful short-range, "all- weather" forecasting tool

- The recurring shortcoming of the lack of spatial continuity in NearCast products due to data gaps in cloudy regions can largely be resolved using microwave-based moisture and temperature retrievals to fill the IR-data-void regions.

  - Including microwave retrievals not only provides more spatial continuity, it promises to be a good means of exposing forecaster to this underutilized data source.
  - Adding POES profiles also improves the quality of NearCasts at locations distant from satellite nadir (most notably north and south, but also east and west) by reducing the influence of errors in moisture retrievals at large "slant angles"

- To become operational, LEO retrievals need to be available as soon as possible
  - Process the retrievals as soon as the radiance data arrive
  - Post the products as as soon as they are produced
  - Include clear labels to differentiate between IR and microwave products
    - Needed so forecasts can use them correctly.

- CIMSS has recently obtained funding to continue this effort over the U.S. 👆🏼
  - We are considering running only one combined LEO/GEO system for all of North America
  - We look forward to continued cooperation with EUMETSAT on adapting our approaches/results to Europe
    - NWCSAF, retrieval providers and product users.