Satellite Meteorology & Spectrum Use

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A Tale of Two Hurricanes

Galveston, TX Sept. 1900

http://celebrating200years.noaa.gov/magazine/galv_hurricane/Galveston19001.html

New York City & Atlantic Coast October 2012 "Sandy"

KeystoneUSA-ZUMA/Rex Features

Weather Service Information On Each Hurricane

<u>TELEGRAM</u>

Washington, D.C.

Sept 9, 1900

To: Manager, Western Union

Houston, Texas

Do you hear anything about Galveston?

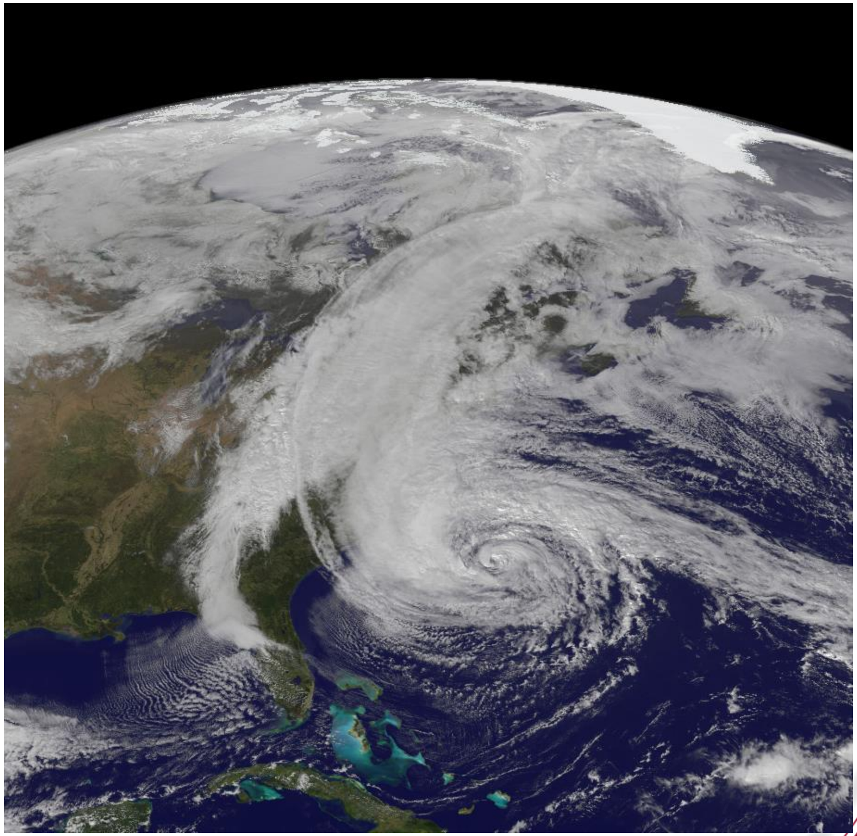
Willis L. Moore, Chief

U.S. Weather Bureau

Source: National Archives, General Correspondence

GOES-13 Image Sandy

October 2012



Source: NOAA

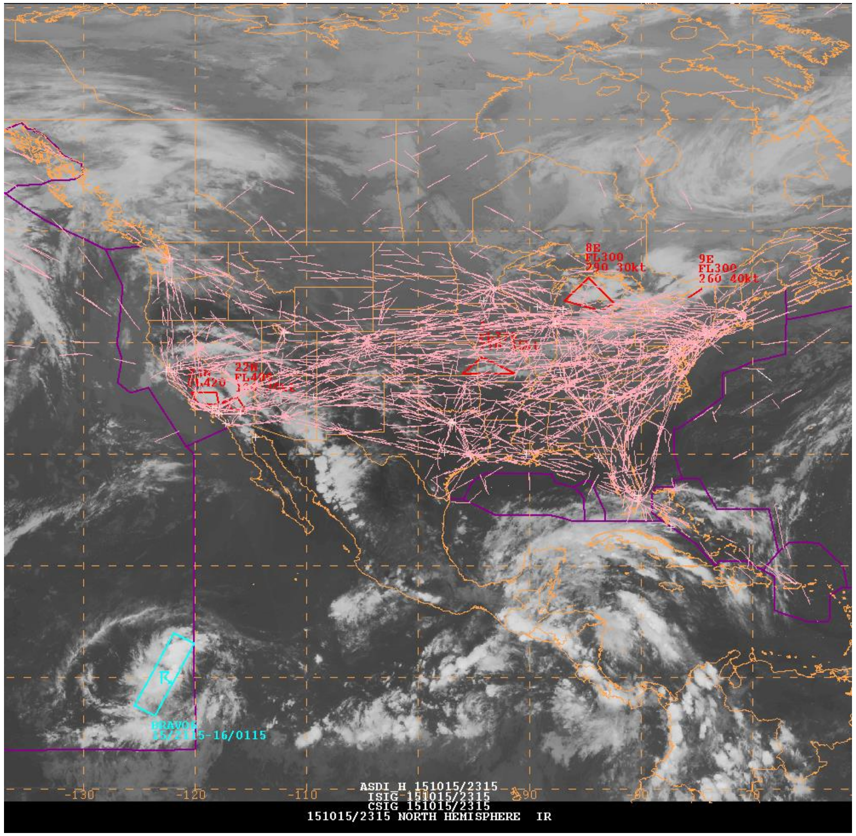
Strides in Meteorology Due to Satellites & Importance of Spectrum

- Significant improvements in weather forecasting have occurred since the first satellite was launched in 1960
  - *For example, average 3 day hurricane track error in 1980's was 300 miles, now it's down to less than 150 miles* of track error*
- Today optical, microwave and infrared payloads provide large volumes of data originating from space
- Satellites flown by a small number of administrations comprise the global operational satellite system
- Access to radio frequency spectrum makes these satellite systems possible
- Demand for spectrum to support commercial broadband is at an all time high
- The MetSat community and users must understand this new demand and react accordingly if impacts to meteorology appear likely before spectrum is shared or repurposed

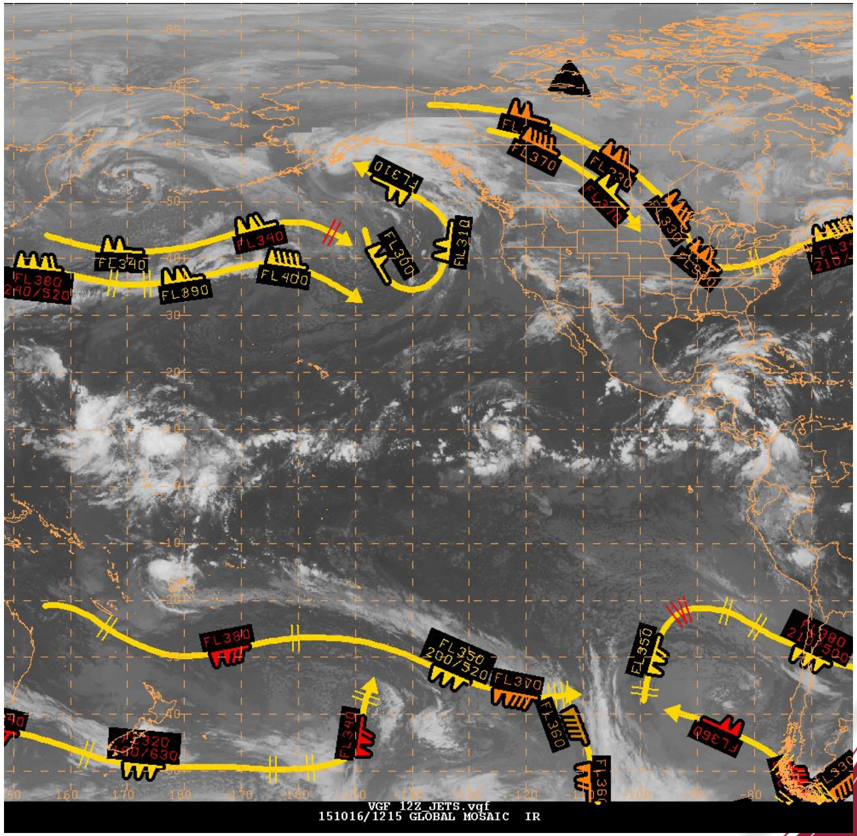
- Jason Samenow, "Prescient on wearable weather forecasts but not their accuracy", Washington Post, October 21, 2015

Aviation Example

Sat Image (1675-1695 MHz) Overlay with Flight Tracks Avoiding Areas



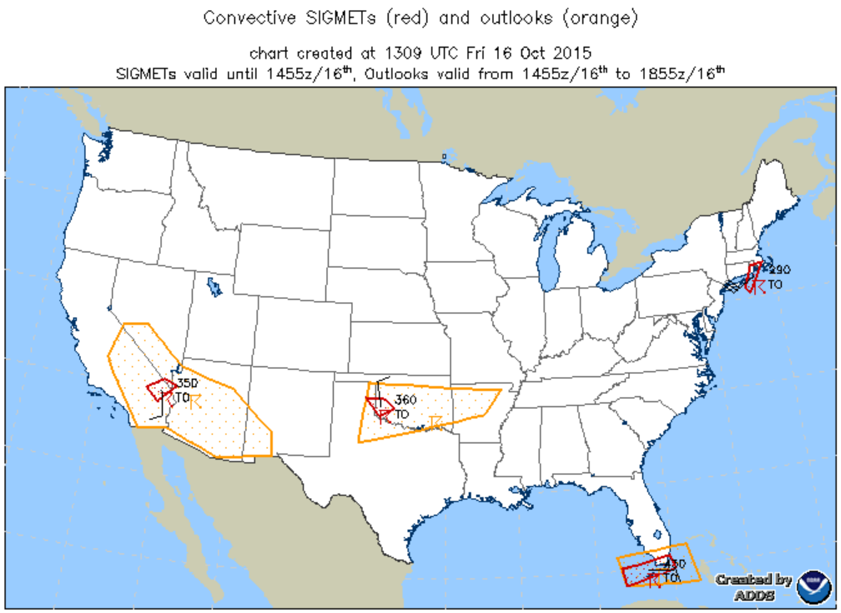
Jet Stream Overlaid on Convective SIGMET Sat Image Mosaic



Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

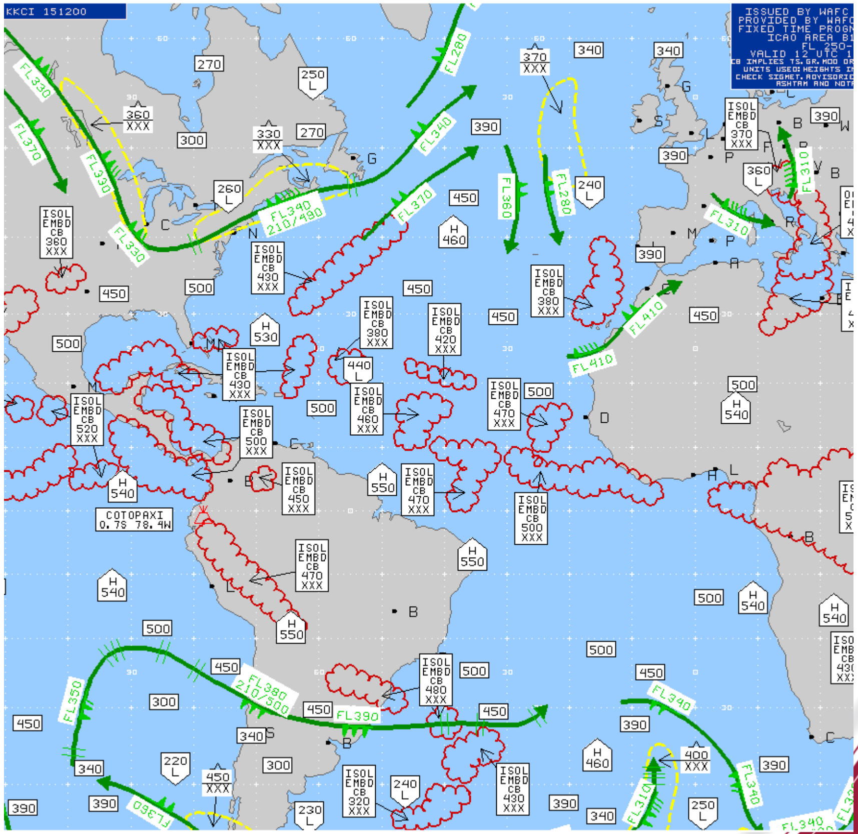
Aviation Products Derived From Images

Significant Meteorological Event Warnings to Airmen

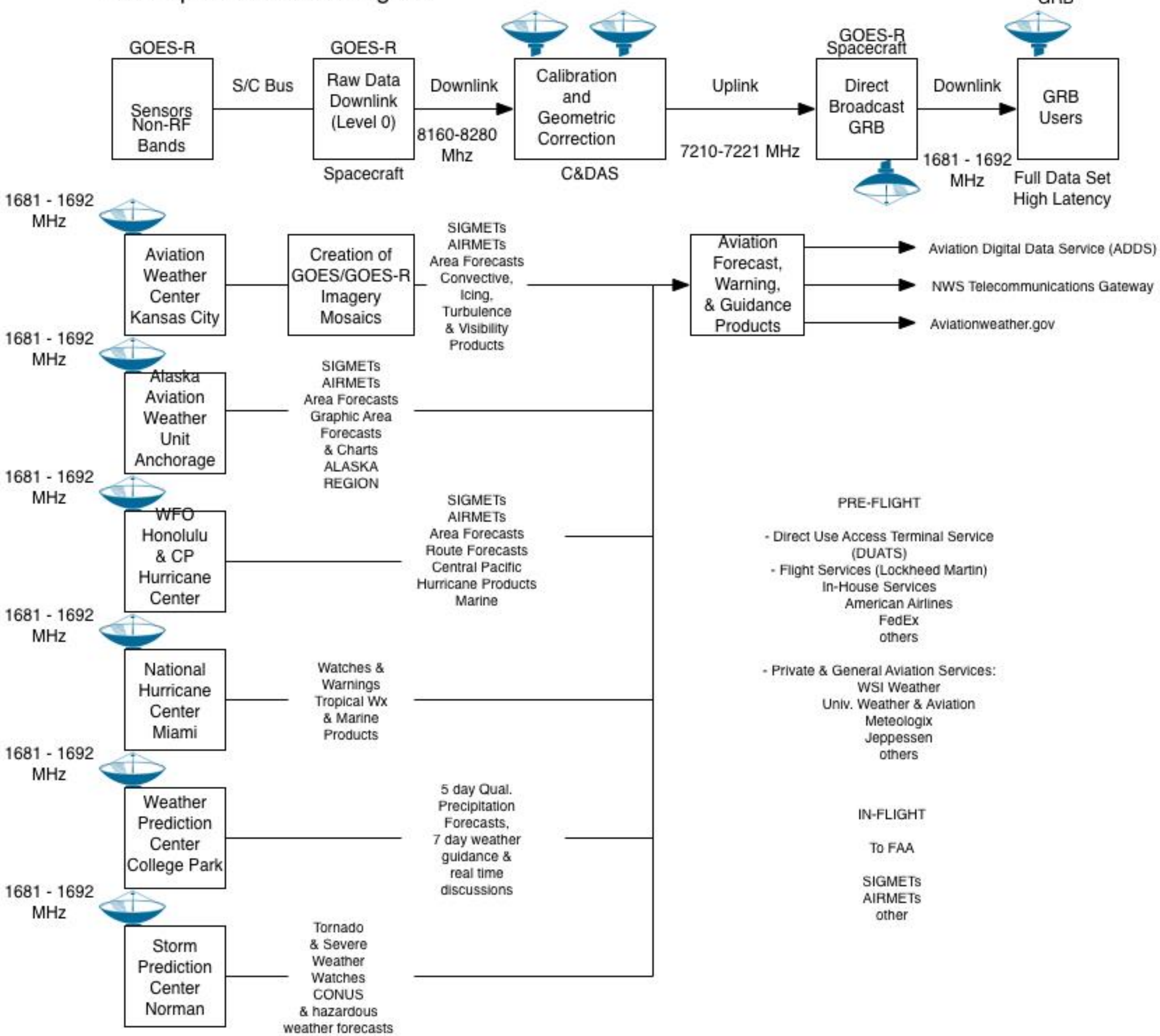


Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

Chart Posted on Government Website Developed From Image

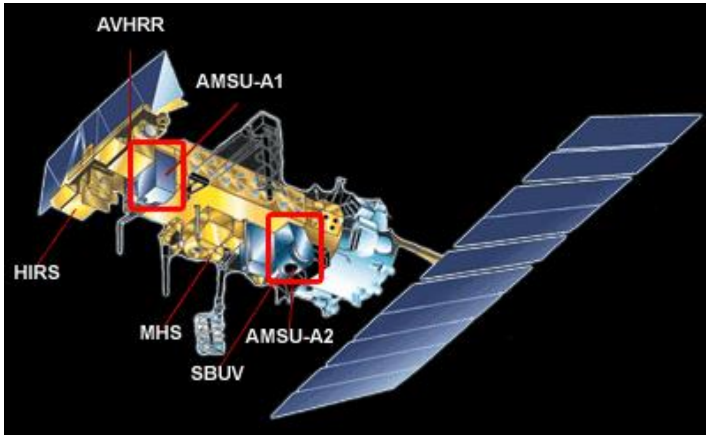


Aviation Weather Data Spectrum Flow Diagram

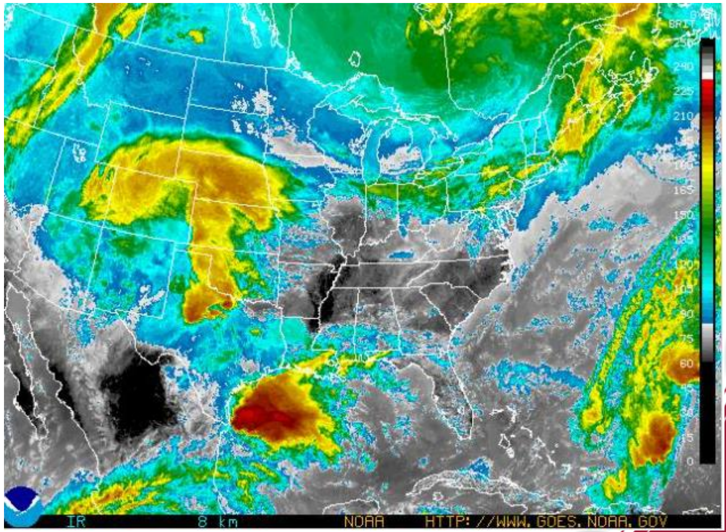


Key Uses of Spectrum for MetSats

1. Microwave Remote Sensing
2. Active Remote Sensing
3. Radio Occultation
4. Transmission of Raw Data to Command and Data Acquisition Stations & Uplink of Level 1b data to Spacecraft
5. Direct Broadcast of Satellite Data from the Spacecraft for government and non-government use
6. Dissemination or Relay of Hydrometeorological Data (DCS)
7. Emergency Managers Weather Information Network
8. Search & Rescue
9. Commercial Relay of Meteorological Data and Products
10. Command, Control and Telemetry of Observatory



NOAA and METOP Microwave Remote Sensing
Illustration Source: NASA via UCAR COMET Program

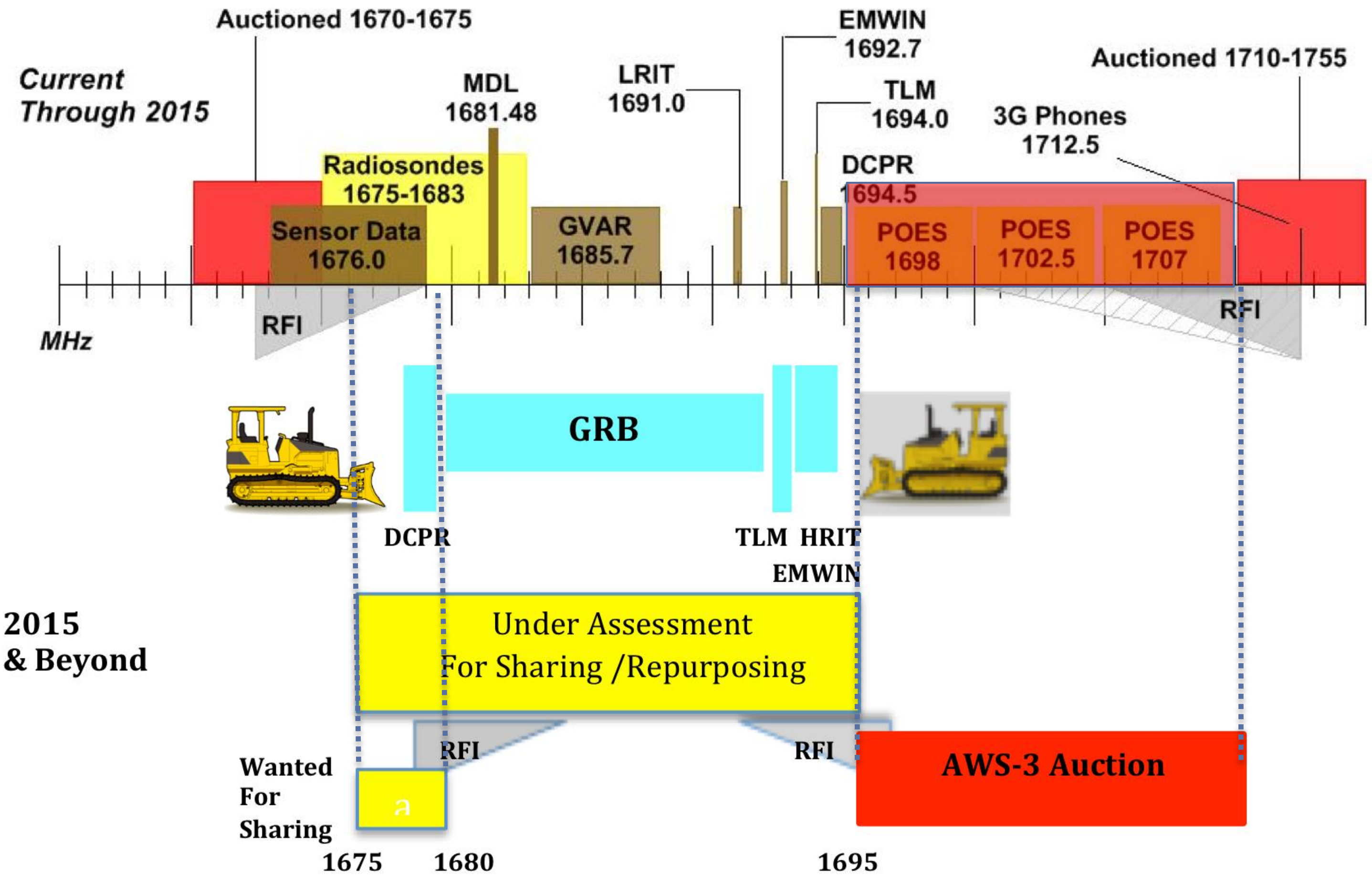


Eastern U.S. Infrared Image from GOES
Source: NOAA http://www.goes.noaa.gov

A GOES Direct Broadcast Example

- US domestic spectrum regulators, searching for more spectrum to support commercial broadband wireless, are studying all or part of 1675-1695 MHz, for spectrum sharing, which is the spectrum used for GOES and GOES-R direct broadcast downlinks, as well as DCS and EMWIN
- The potential for interference from proposed terrestrial transmitters and ground stations receiving the direct broadcast from geostationary satellites is an important consideration for regulatory officials
- End users, who benefit from meteorological or hydrological products, that are received in this spectrum, may not know that a Federal spectrum sharing action could have impacts upon their ability to obtain products which rely on that spectrum.

Domestic Spectrum Sharing & Studies

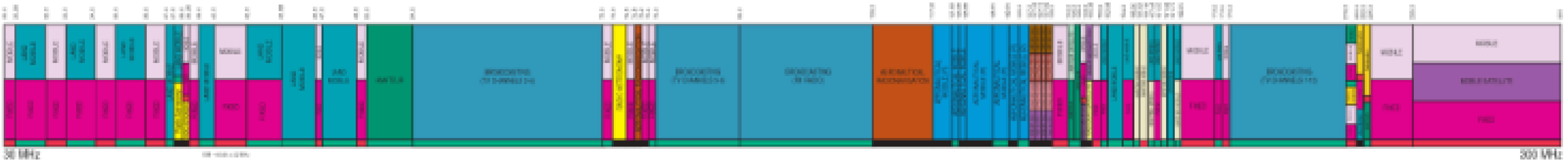


Increasing Needs for MetSat Bandwidth

- As meteorological satellite systems evolve, each new series generally produces more data and develops new products
  - *Some products have strict data latency requirements (e.g., space weather, geostationary lightning mapper products, severe weather warning)*
  - *Some products must be assured of delivery under all conditions, especially those which damage the terrestrial infrastructure (e.g., sending satellite data to the tropical cyclone/hurricane prediction centers)*
  - *Some new systems simply generate more data than can be redistributed via commercial satellite transponders or typical dissemination mechanisms*
- As commercial wireless broadband systems spectrum needs increase, so do new generation of meteorological satellites, although the satellite needs occur over a much longer time duration.

Regulatory Processes For Spectrum

- International decisions regarding spectrum usage are determined at the World Radiocommunication Conference (WRC) held every 3 to 4 years by the International Telecommunications Union (ITU) in Geneva.
  - *WRC-15 is underway this month, with many member administrations and non-government sector members participating in a 25-day long conference to revise the treaty-based ITU Radio Regulations, which includes spectrum for geostationary and non-geostationary satellite orbits.*
  - *Regional organizations, comprising multiple country blocks, submit inputs to the WRC, along with submissions from individual country delegations*
- Domestically, each countries radio spectrum regulator can make changes within their borders beyond that which is decided at the ITU



Source: Portion of United States Table of Frequency Allocations Wall Chart, DOC NTIA

Candidate Bands Above 6 GHz for Commercial Use Prior to Selection at ITU WRC

- 10 – 10.45 GHz
- 23.15 – 23.6 GHz
- 24.25 – 27.5 GHz
- 31.8 – 33.4 GHz
- 37.0 – 40.5 GHz
- 39.0 – 47.0 GHz
- 45.5 – 48.9 GHz
- 47.2 – 50.2 GHz
- 50.4 – 52.6 GHz
- 59.3-76 GHz
- 81-86 GHz

Note: This is not a comprehensive list and not the final list that will be selected for study. These are some of the band candidates submitted by regional organizations for final action In 2019

Spectrum Band Actions to Watch

- Proposed new bands for commercial wireless broadband for action in 2015 and 2019 still being submitted
  - *WMO expresses concern about protection of passive EESS systems in **50.2-50.4** GHz and **52.6-55.78** GHz*
  - *WMO is concerned with protection of passive EESS systems in **10.6-10.7 GHz; 18.6-18.6 GHz; 23.6-24 GHz; 31.3-31.8 GHz; 36-37 GHz; 50.2-50.4 GHz; 52.6-59.3 GHz; 86-92 GHz***
- Radio Local Area Networks proposed for **5350-5470 MHz** where altimeters, scatterometers and Synthetic Aperture Radars operate
- MetSat downlink frequencies for data and telemetry, including direct broadcast; including **1675-1695 MHz; 7750-7900 MHz; 8025-8400 MHz and 25.5-27 GHz**
- Spectrum for small satellites operation in **230-470 MHz** which overlap with Data Collection Systems and other meteorological systems
- Proposals to accommodate High Altitude Platform Stations (HAPS) which could create out of band interference in **23.6-24 GHz** and **31.3-31.8 GHz**
- Commercial communication frequencies in **3.7-4.2 GHz** currently used by Fixed Satellite Systems
- This is <u>not</u> a comprehensive list of all the bands under consideration which could impact meteorology

Note: This example may not reflect the position of any particular administration.

Summary

- Spectrum access is critical to satellite meteorology
  - *microwave measurements from active & passive sensors,*
  - *direct broadcast dissemination*
  - *radiometers, altimeters, scatterometers, or Synthetic Aperture Radars*
  - *Communication from or to spacecraft vehicles*
  - *Command, control and telemetry from or to spacecraft vehicles*
- There are no alternatives to the "measurement of naturally-occurring radiations, usually of very low power levels, which contain essential information on the physical process under investigation*"
  - *"Relevant frequency bands are determined by fixed physical properties [of the atmosphere] that cannot be changed or ignored, nor can they be duplicated in other frequency bands*"*
- Successfully receiving the satellite measurements from space and disseminating them by direct broadcast or commercial re-broadcast is an essential method of getting this data to end users

*WMO position filing with ITU on WRC-15
29 September 2015

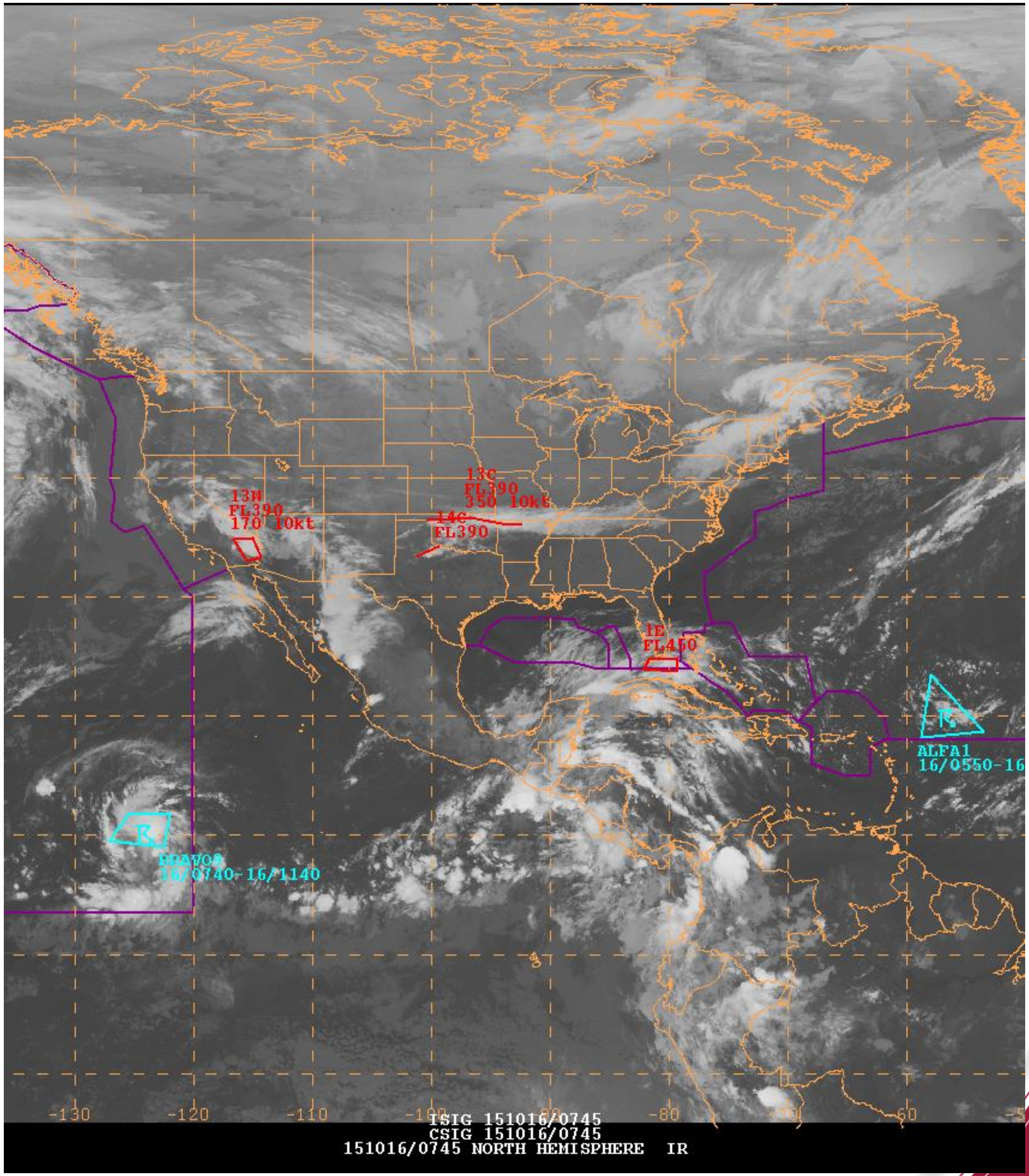
Domestic and International Aviation Weather Product Examples Using Direct Broadcast Spectrum in USA

Aviation Use Case Example

Satellite image mosaic created by the (US) National Weather Service's Aviation Weather Center (AWC) to aid in creation of Convective SIGMETs.

GOES satellite data is currently received by direct broadcast, and next generation GOES-R data will be used to support the creation of the mosaic, also from direct broadcast (1675-1695 MHz)

AWC meteorologists create forecast and warning products in support of commercial and general aviation using this image mosaic



Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

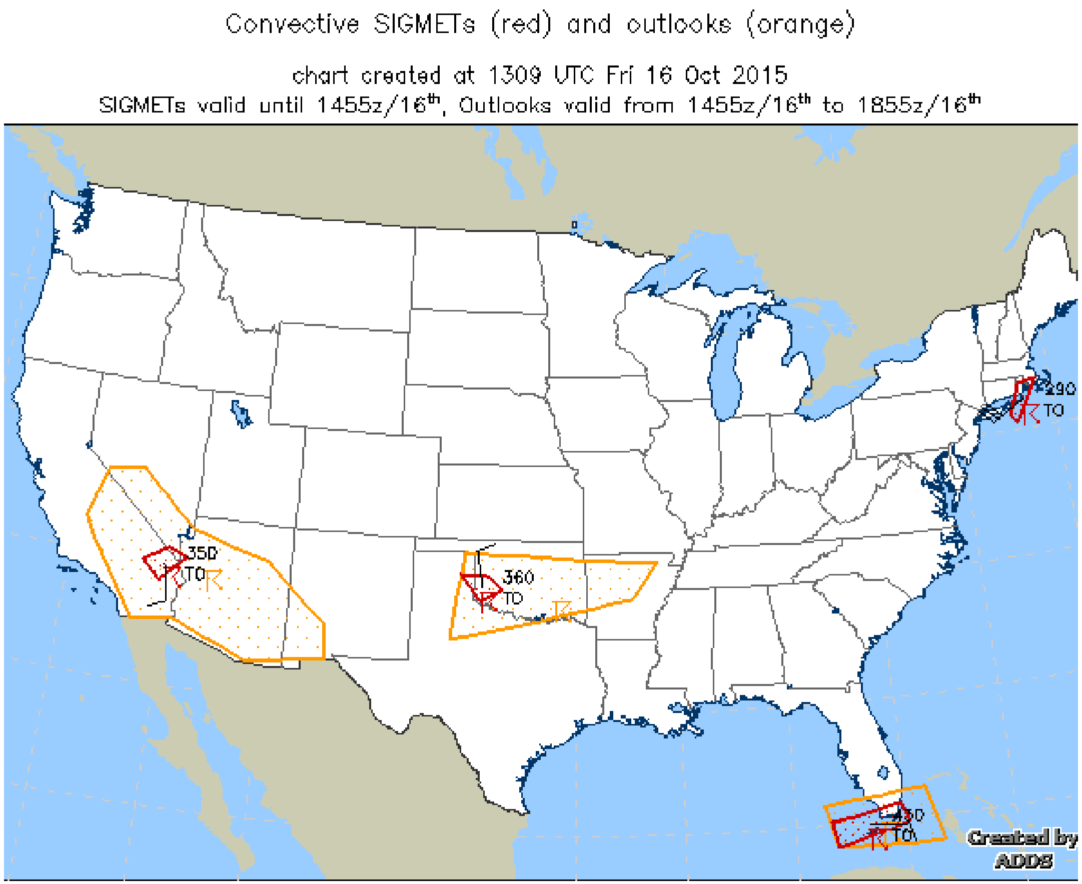
Forecaster Warnings Issued from Mosaic Data

Significant Meteorological Events (SIGMETs) issued by Aviation Weather Center (an ICAO Meteorological Watch Center) for use by domestic and international aviation

Each of the colored areas represents a weather event and will have a text-based SIGMET issued that is received by commercial and general aviation pilots

These areas were created by forecasters utilizing the satellite imagery mosaics as an input source

Non-instrument rated pilots might use this map to plan and avoid these areas as they plan their flight

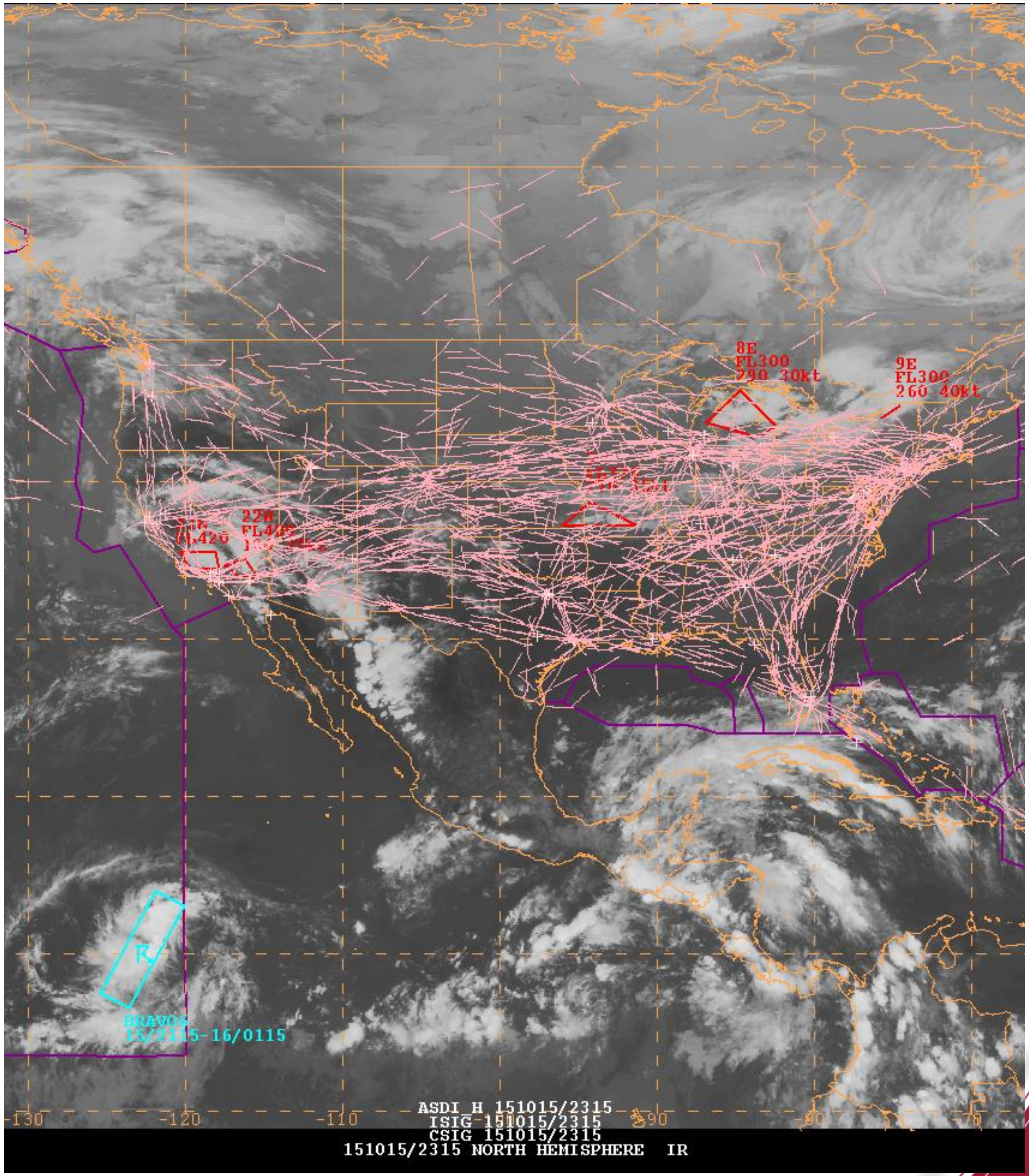


Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

Flight Tracks Overlay

Pink overlay shows actual flight routes for the time this image was applicable for forecast purposes.

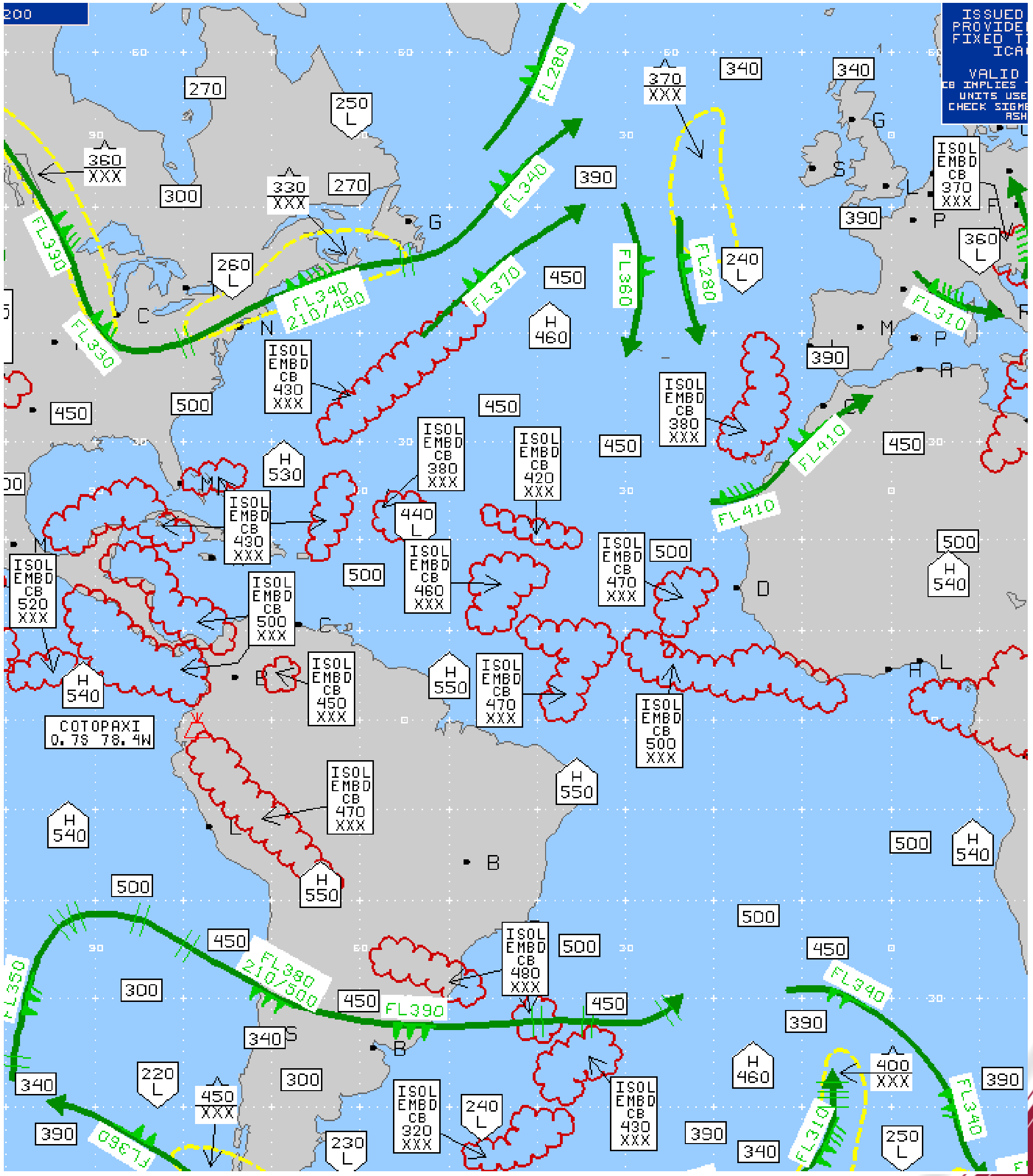
Note that severe areas highlighted in Red are weather and Convective SIGMET areas issued on that date, especially in western U.S. and over the Great Lakes region of U.S. Flights are actually routed around those areas of warning.



Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

Products Derived from Sat Imagery

Progchart derived from satellite mosaic as posted to http://aviationweather.gov for use by international aviators.



Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

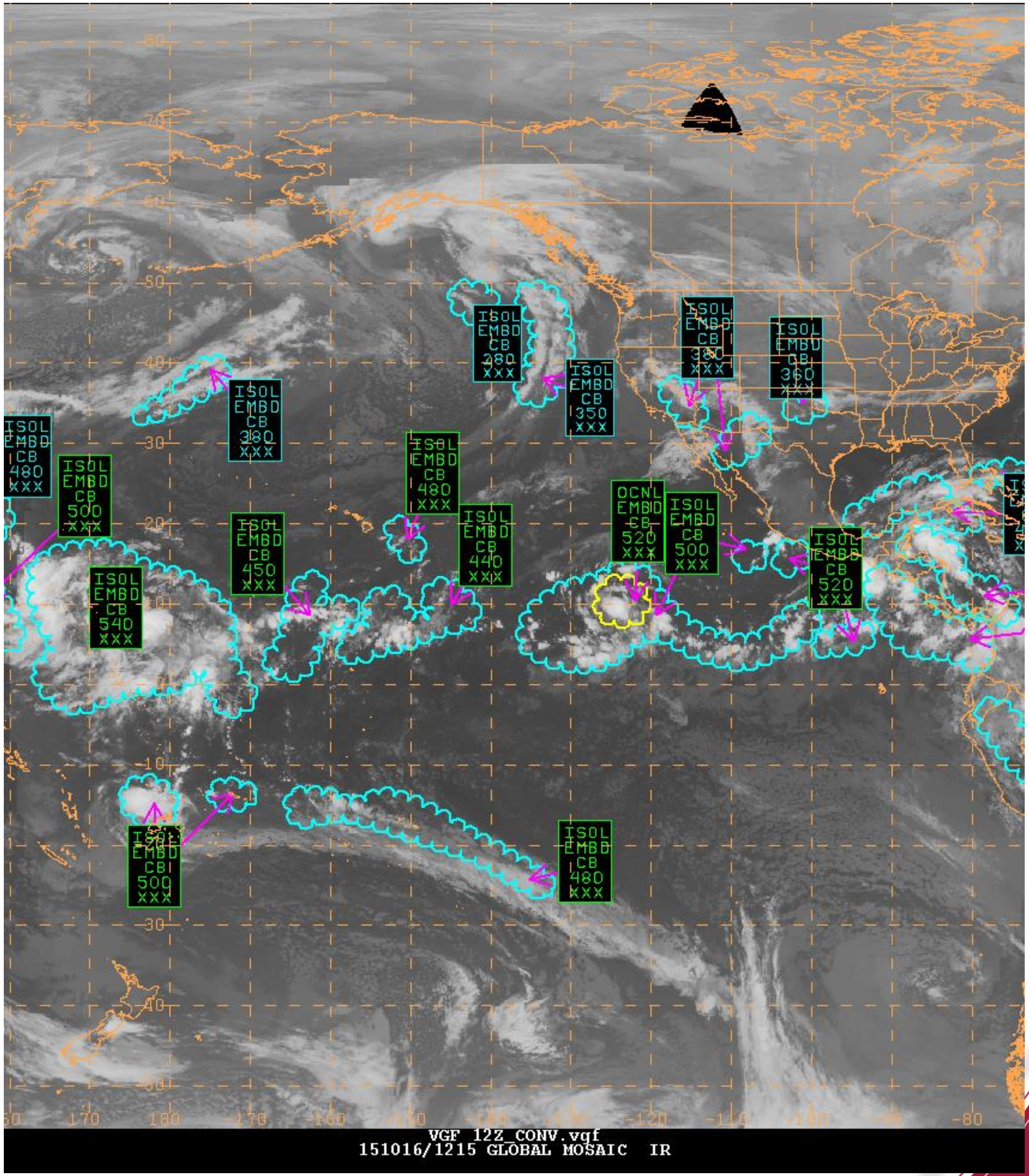
Convective Image Overlay for Aviation

This image product is overlaid with the forecast for the preceding 6 hours.

Blue lines indicate convective areas

Orange are land boundaries.

Imagery is from GOES satellites as received by direct broadcast at 1.6 GHz, with extreme high latitude regions using polar-orbiting satellite data



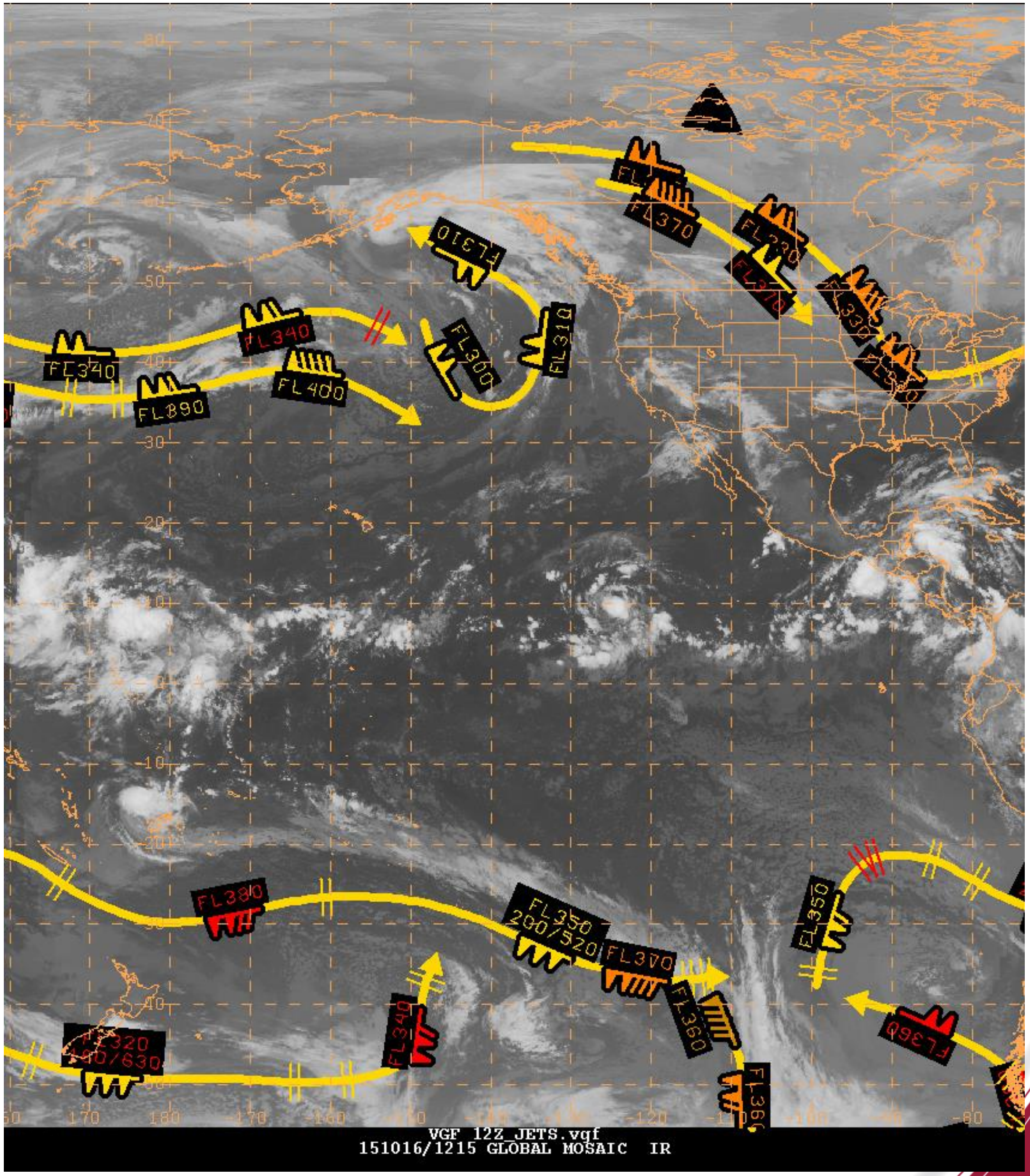
Source: NOAA / Aviation Weather Center
http://Aviationweather.gov

Jet Stream

The yellow images overlaid on this satellite mosaic show the jet stream annotated with appropriate meteorological markings.

All of these previously shown products would be impacted by radio frequency interference to the GOES / GOES-R direct broadcast at the Aviation Weather Center.

It should be noted that some commercial aviation companies and private sector meteorology companies do receive the GOES / GOES-R direct broadcast (at 1.6 GHz) and create enhanced or value-added aviation products.



Source: NOAA / Aviation Weather Center
http://Aviationweather.gov