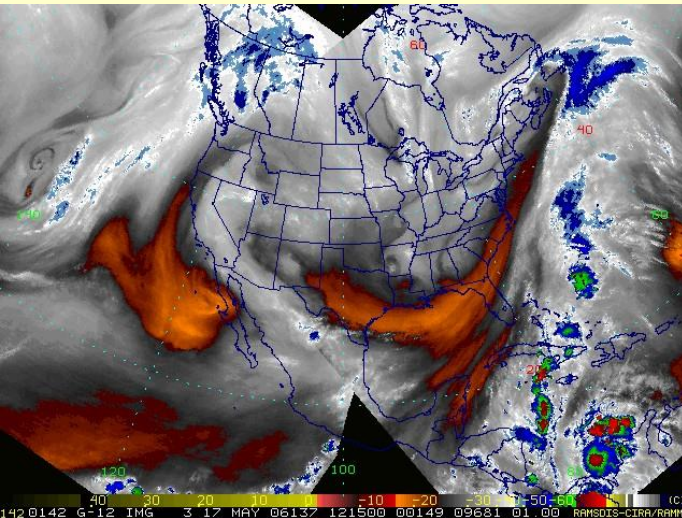
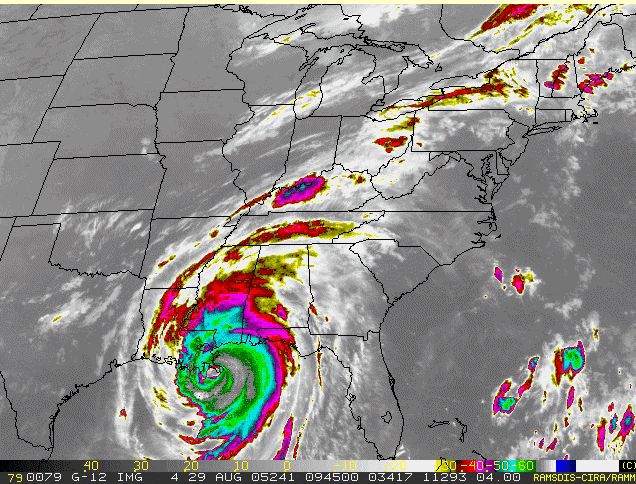


Satellite Imagery Interpretation

AMS/NOAA

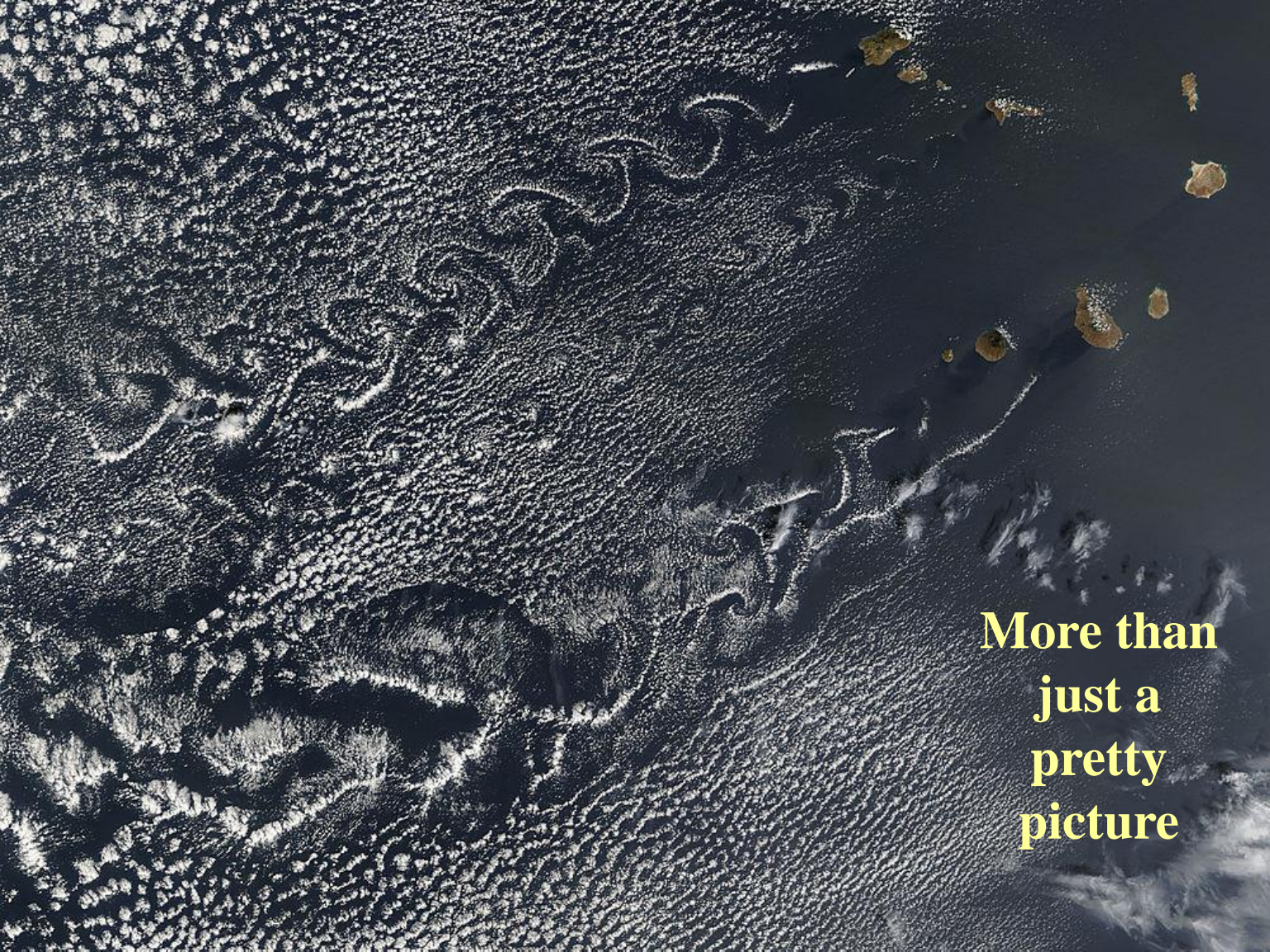


Objectives

- Describe the different types of satellites.
- State the differences between polar orbiting and geostationary datasets.
- Describe primary types of GOES satellite imagery and characteristics of each.
- List unique features identified in visible, IR and water vapor imagery.

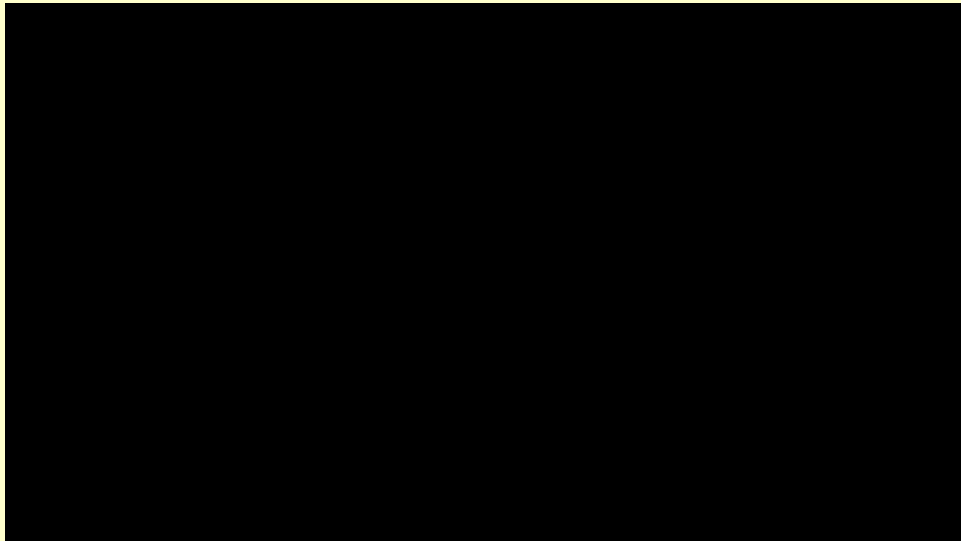
The SKY

- Biggest lab in the world.
- Available to everyone.
- Most people - Just like background music in the mall.
- We view from below, satellites view from above.



**More than
just a
pretty
picture**

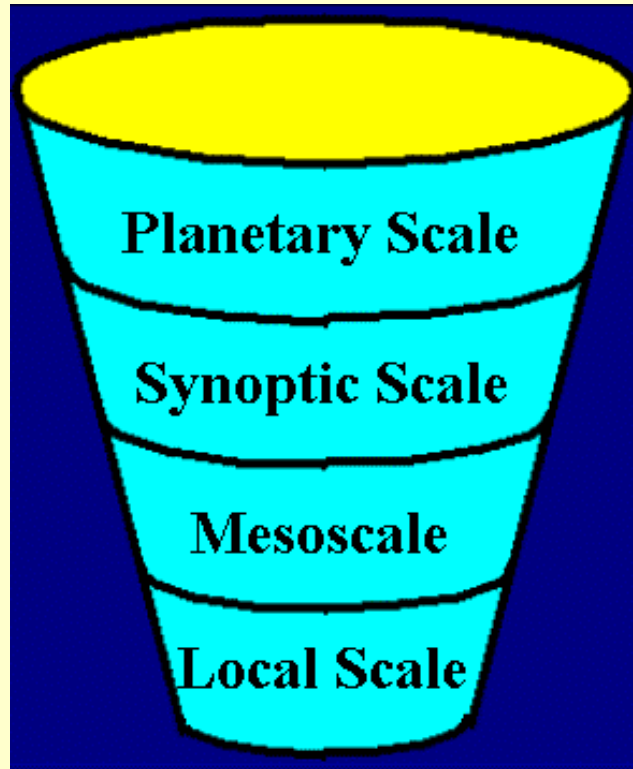
Keeping our eyes on the clouds...

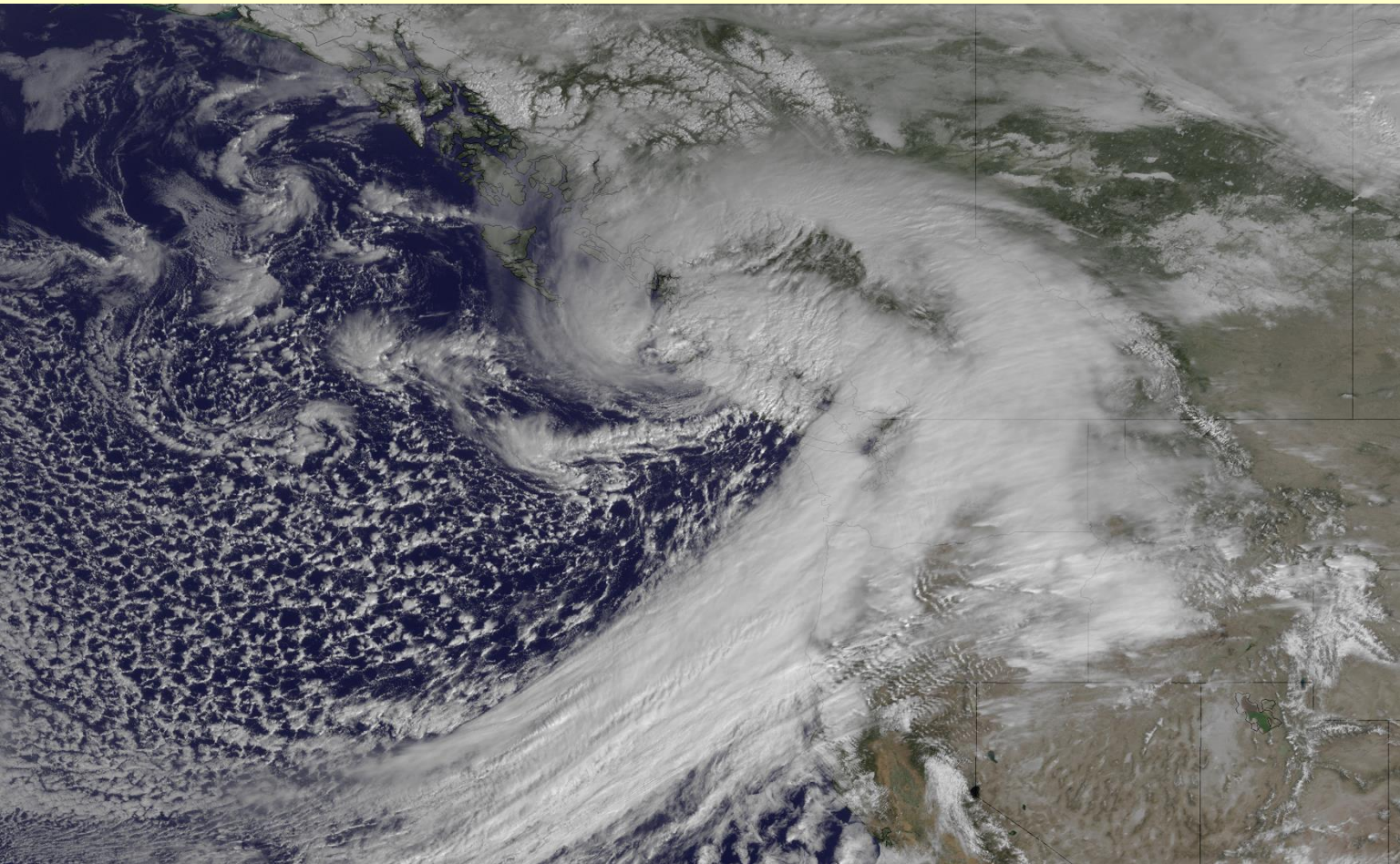


Why Are Satellites Important?

- Monitor atmosphere, land surface, and oceans at multiple scales using a single viewpoint.
- Consistent global, high-resolution coverage over oceans, rugged terrain, and sparsely populated regions.
- *An excellent* data set in the forecasters toolbox to help solve meteorology and hydrology problems.

Snellman Forecast Funnel





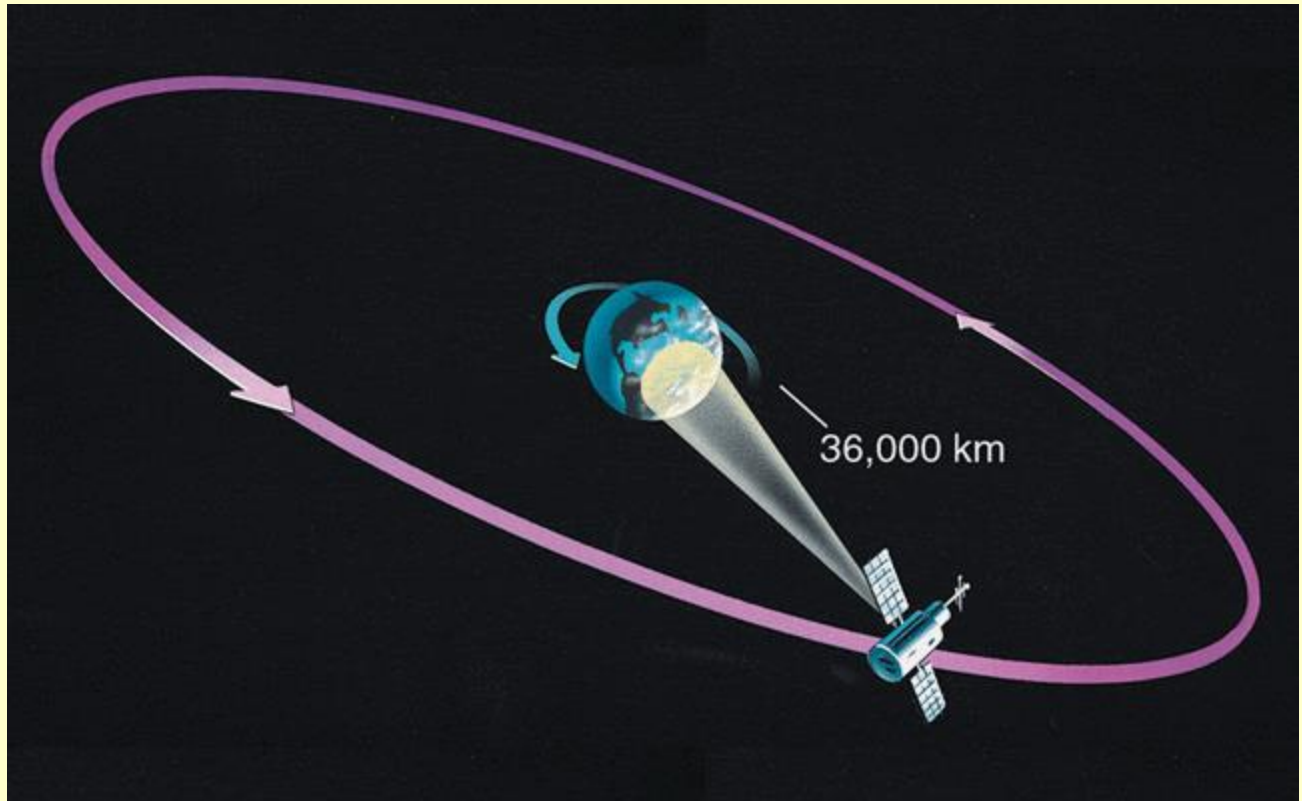
Scales of motion

March 12, 2012

Satellite Types

- Geostationary:
 - Same position near equator – same rotation speed as earth.
 - Constant height – 36000 km (22,400 mi).
 - Resolution - 1 km visible to 4-8 km IR and H₂O channels.
- Polar Orbiting:
 - Every orbit passes over the poles.
 - Height around 850 km (530 mi).
 - Scan earth in 2600 km (1600 mi) wide swaths.
 - View same location twice at equator; overlaps toward converging longitudes at poles.
 - Resolution – 250 m (4 times more detail than GOES)₉

Geostationary Satellite View



GOES Satellite

First GOES Satellite launched in 1975

Weather radar was widely used nearly twenty years before this in the 1950's.

Geostationary Satellite Global Coverage

- **GOES East (13) – 75W**
- **GOES West (15) – 135W**
- **GOES (South America) – 60W**
- **MTSAT (Japan) – 140E**
- **Meteosat (7) (Indian Ocean) – 57.5E**
- **Meteosat (9) Europe – 0°**



GOES Status

Last update: 08/16/2013 00:00:00

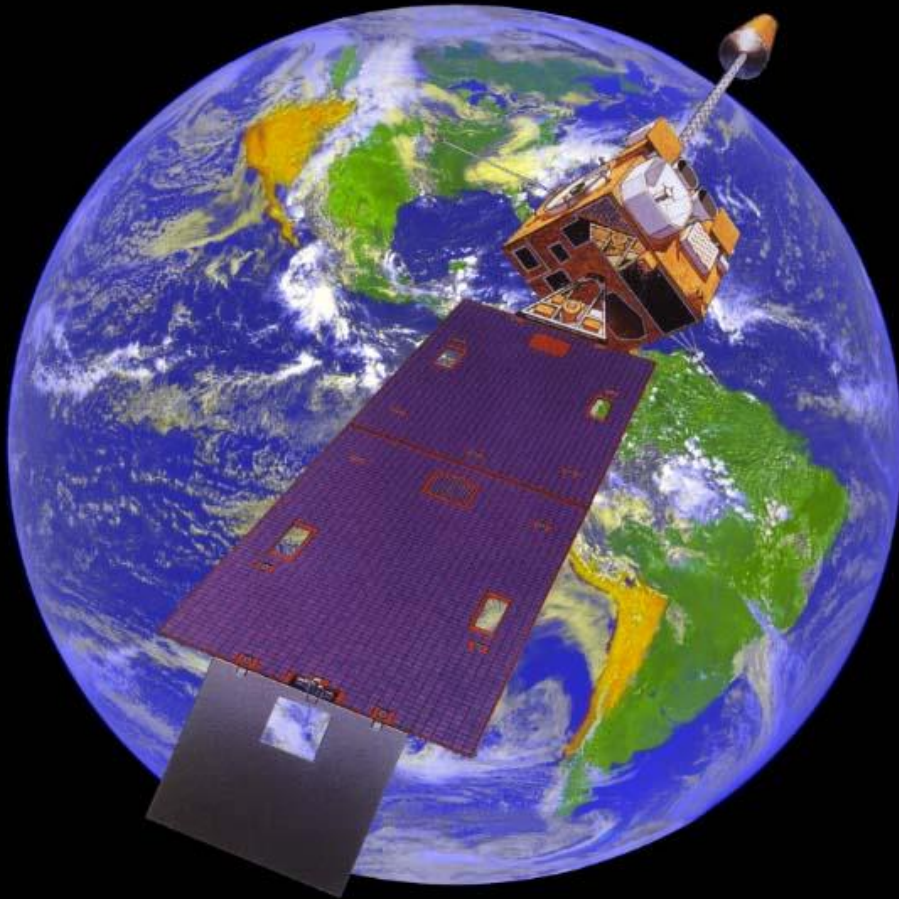
Welcome to the Geostationary Operational Environmental Satellites (GOES) spacecraft status page. This site provides up to date status information on each spacecraft and its various subsystems.

Select a spacecraft from the list below for a detailed status summary of that spacecraft. For more advanced reporting, select the [Filter](#) link.

Active Spacecraft and Operational Status

Spacecraft	Operational Status	Status
GOES 8	Decommissioned	RED
GOES 9	Decommissioned	RED
GOES 10	Decommissioned	RED
GOES 11	Decommissioned	RED
GOES 12	Decommissioned	RED
GOES 13	Operational East	GREEN
GOES 14	On-Orbit Storage	GREEN
GOES 15	Operational West	GREEN





Geostationary Satellite Views

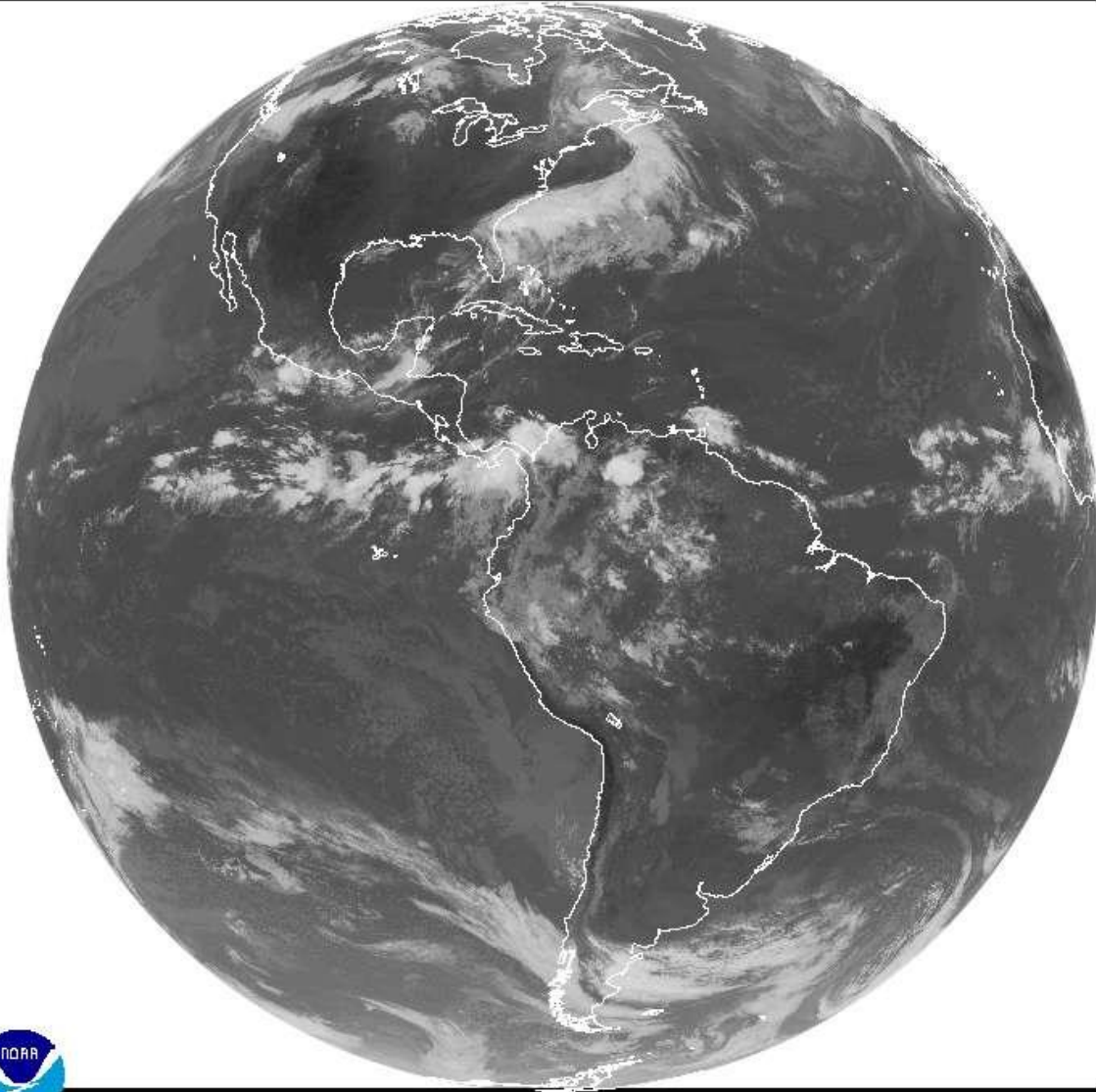


GOES



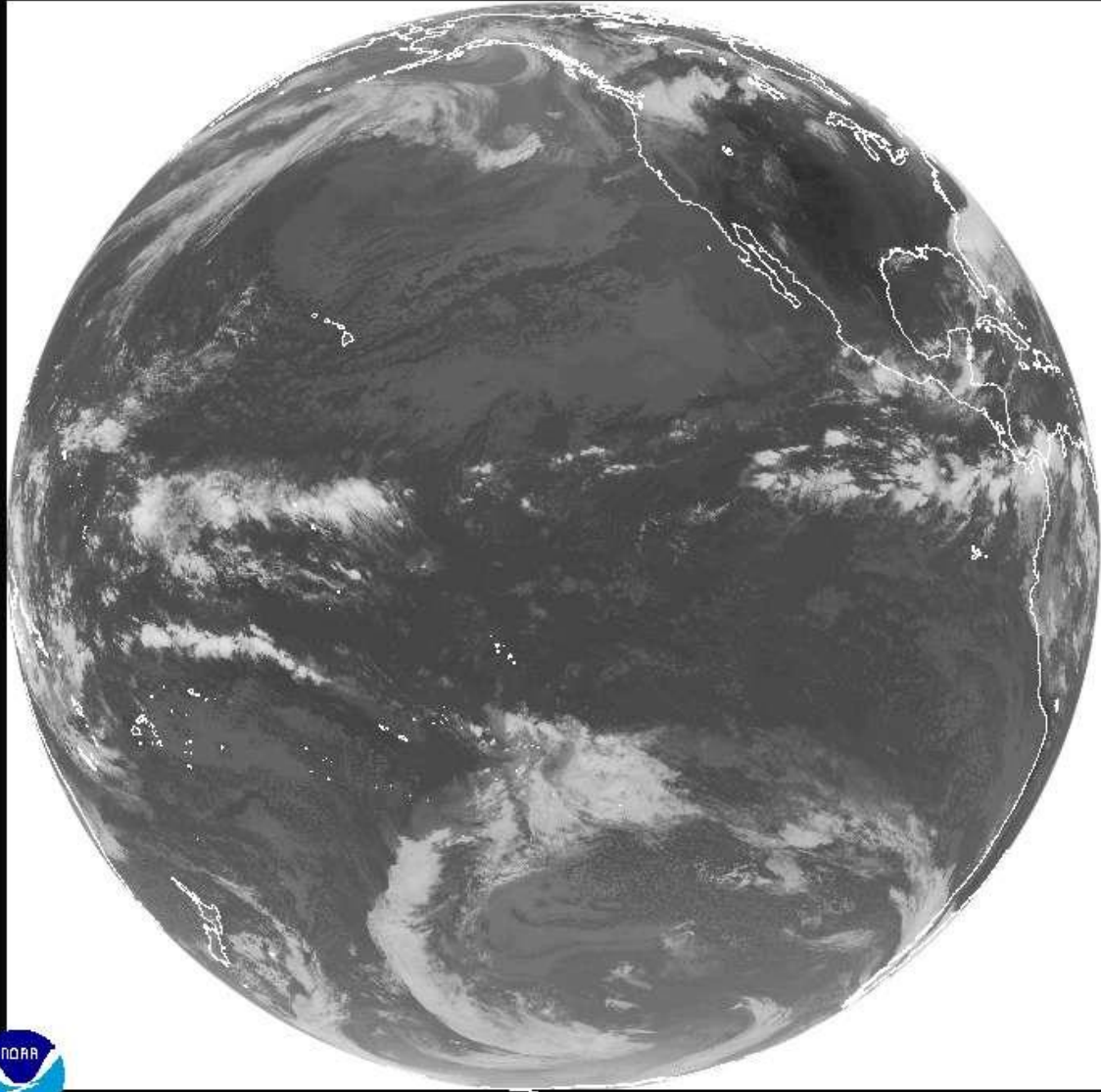
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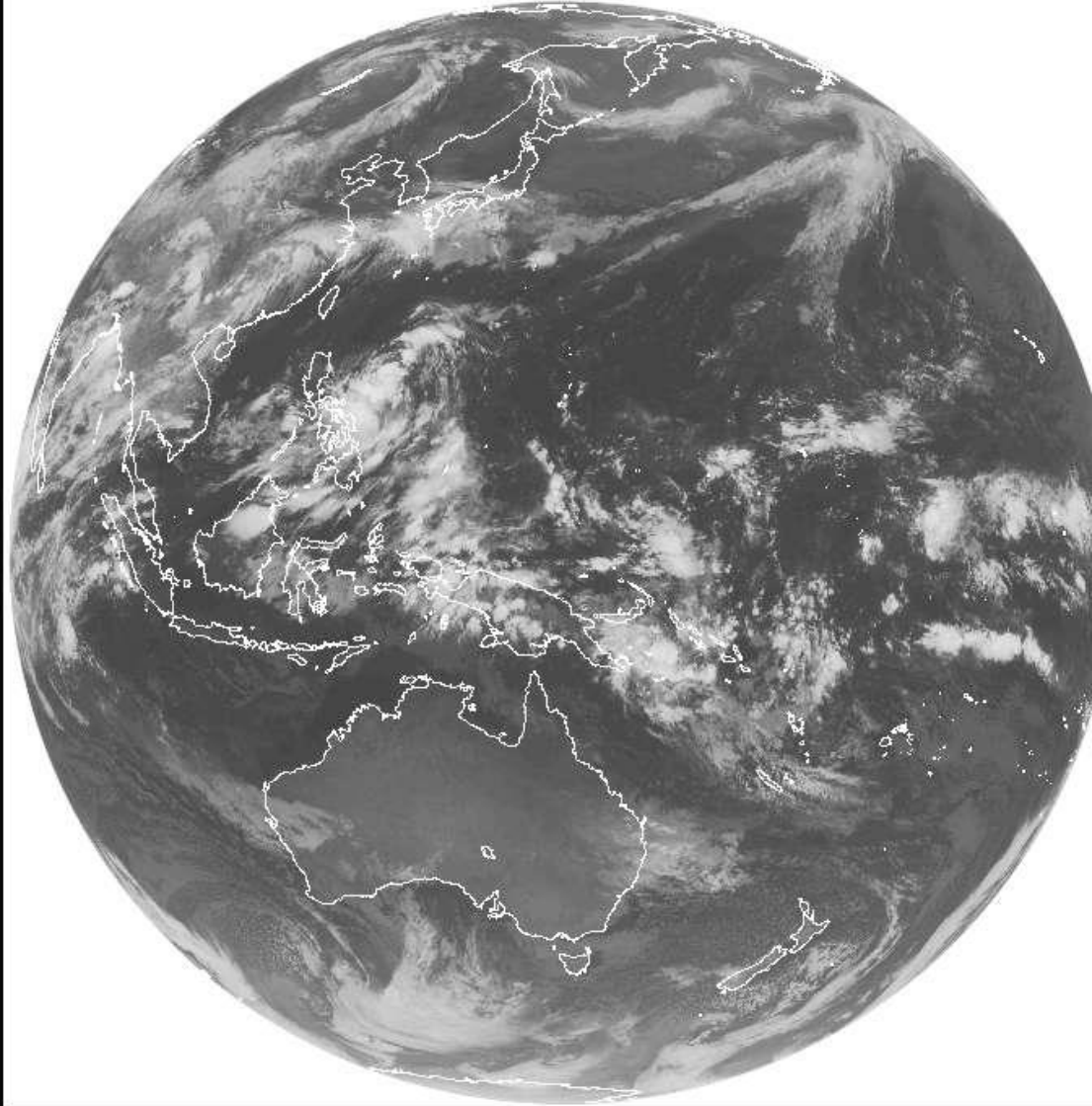


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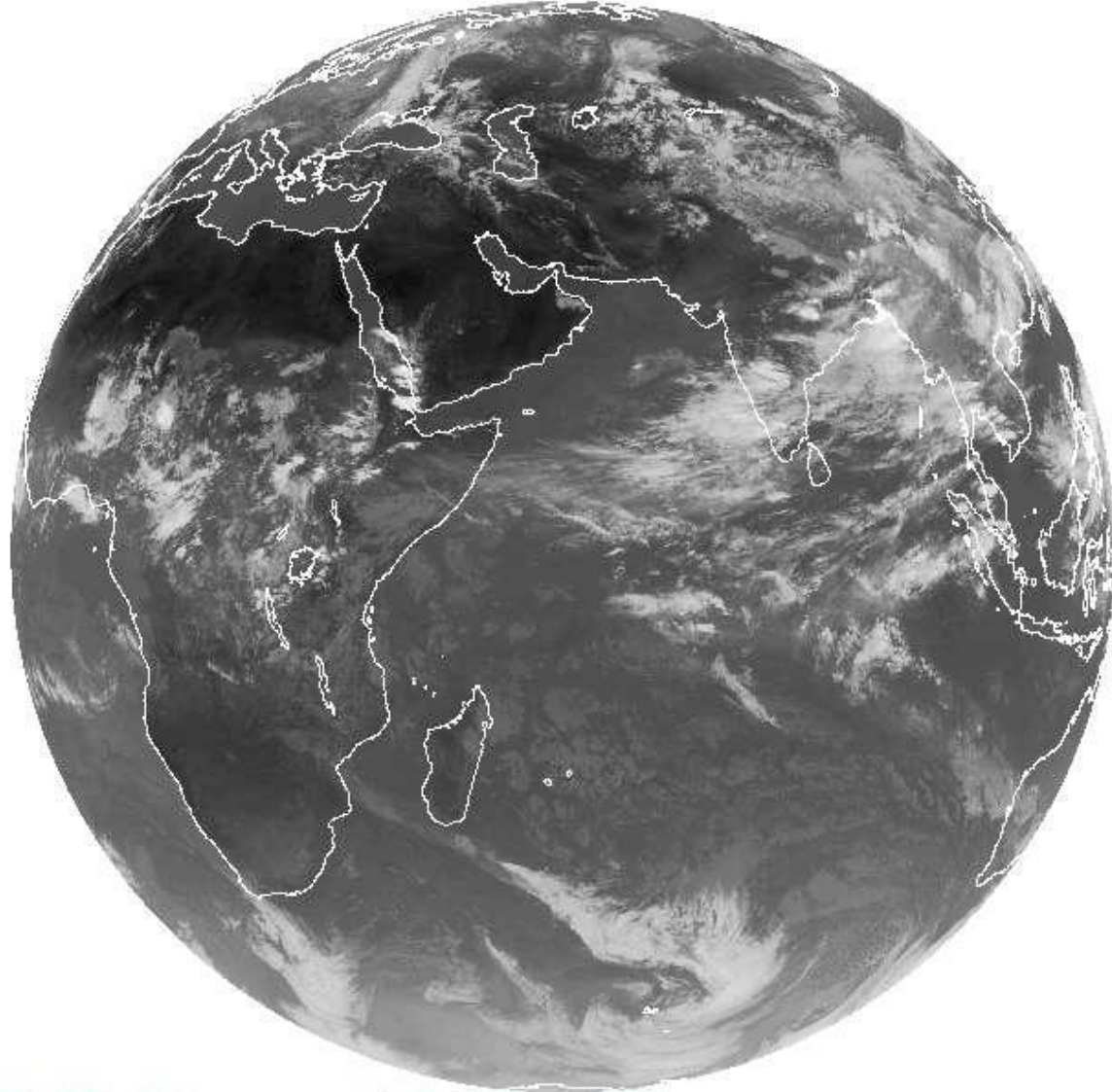


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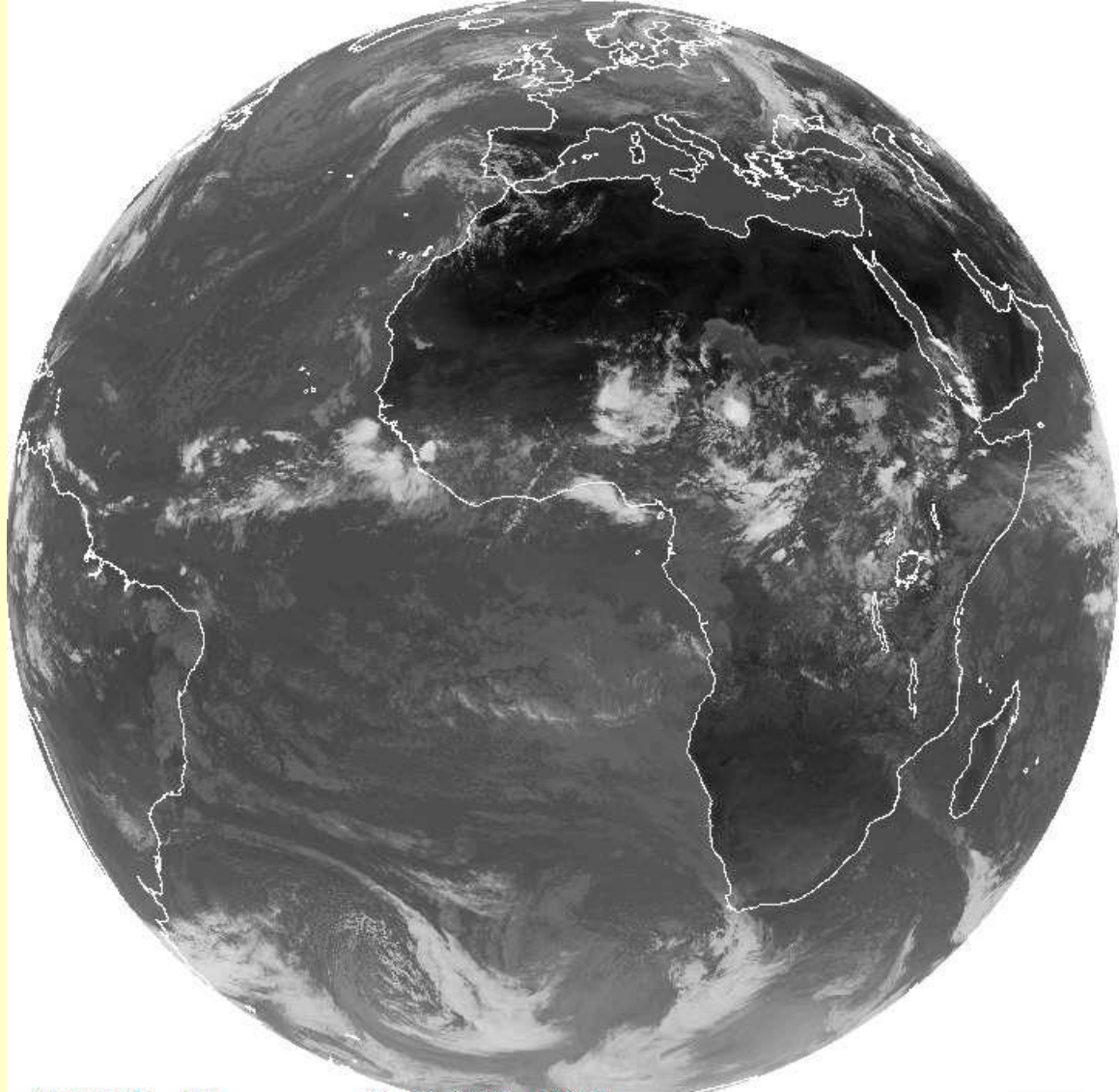


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METEOSAT IR 6 26 2012 1200Z

**Parallax error increases at higher latitudes.
GOES data less useful at latitudes above 60
degrees north and south. High clouds can
appear up to ten miles away from their actual
position.**

Polar Orbiting Satellites - POES

- Polar orbits.
- Same local solar time passage.
- Morning and afternoon satellites.
- Global coverage 4 times daily.
- AVHRR – Advanced Very High Resolution Radiometer.
- TOVS – Tiros Operational Vertical Sounder.



POES Status

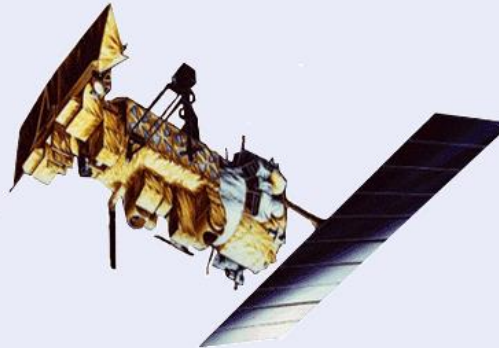
Last update: 06/04/2014 13:39:00

Welcome to the Polar Orbiting Environmental Satellites (POES) spacecraft status page. This site provides up to date status information on each spacecraft and its various subsystems.

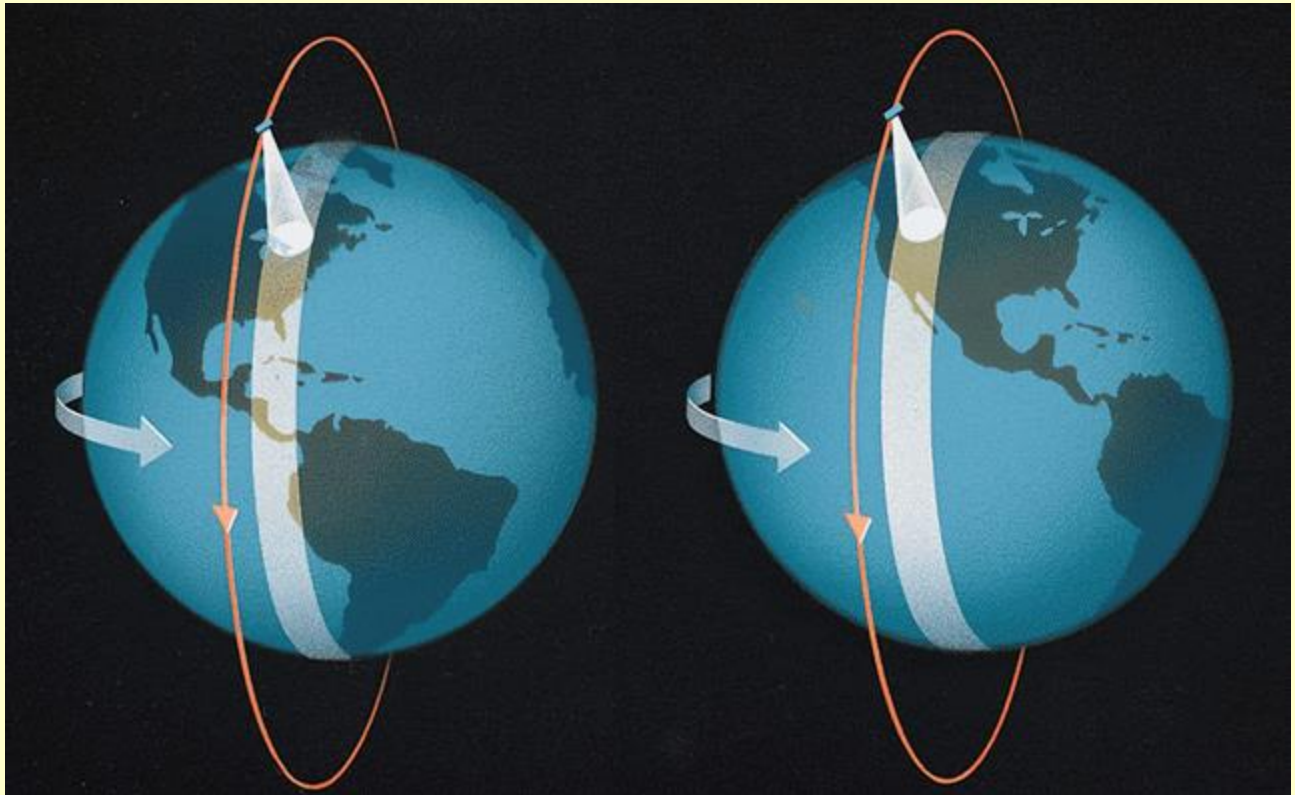
Select a spacecraft from the list below for a detailed status summary of that spacecraft. For more advanced reporting, select the [Filter](#) link.

Active Spacecraft and Mission Status

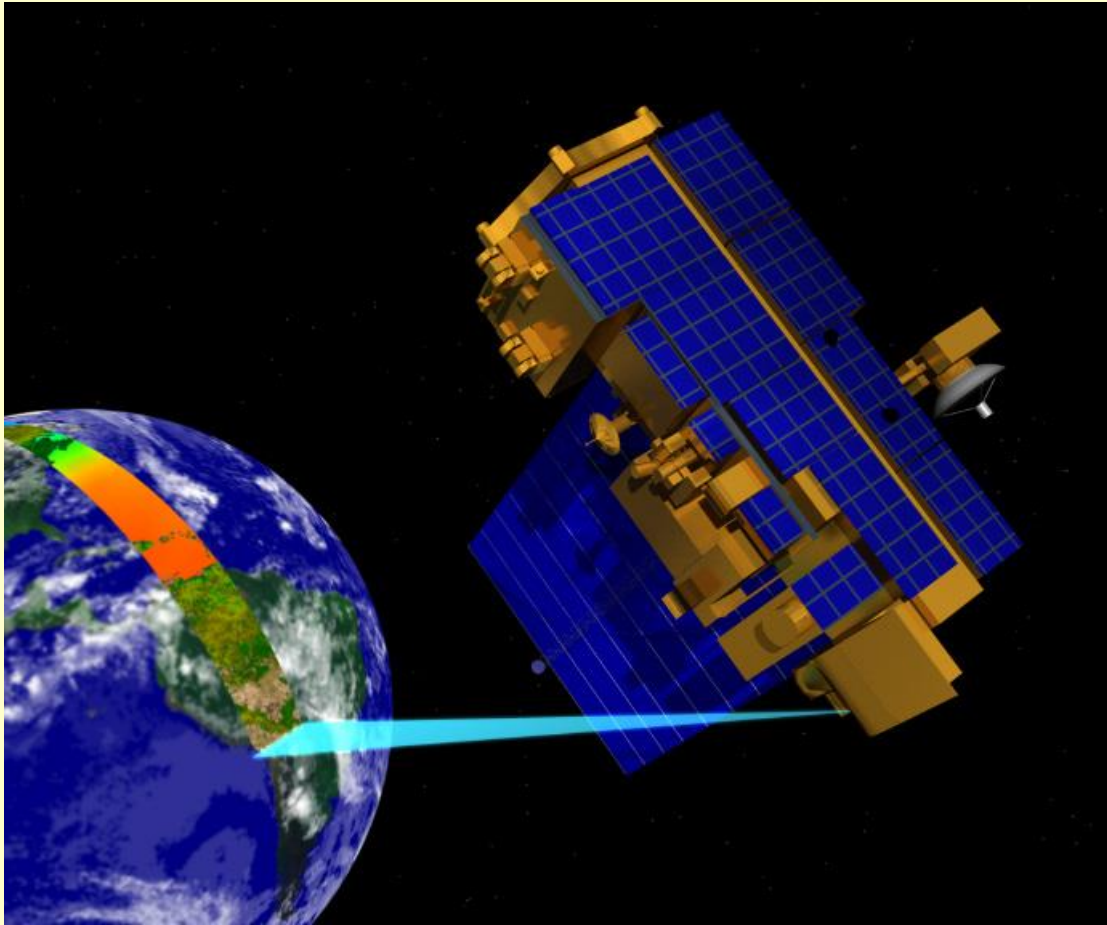
Spacecraft	Mission Operational Status
METOP-B	AM Primary
METOP-A	AM Backup
NOAA 11	Decommissioned 16 June 2004
NOAA 12	Decommissioned 10 Aug 2007
NOAA 14	Decommissioned 23 May 2007
NOAA 15	AM Secondary
NOAA 16	Decommissioned 9 June 2014
NOAA 17	Decommissioned 10 April 2013
NOAA 18	PM Secondary
NOAA 19	PM Prime Services Mission
SNPP	PM Primary



Polar Orbit Viewing Earth



Terra Satellite – MODIS Image



MODIS Web Site



NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

[+ NASA Homepage](#)

SEARCH

[GO](#)

MODIS

Web

[+ ABOUT MODIS](#)

[+ NEWS](#)

[+ DATA](#)

[+ IMAGES](#)

[+ SCIENCE TEAM](#)

[+ RELATED SITES](#)

[+ SEARCH](#)

[+ MODARCH](#)

DATA

The MODIS Data section contains everything from ATBDs to Product Descriptions to tutorials on ordering MODIS data from the various DAACs. [Peruse the Data section today.](#)

[Registration now open](#) for the 2012 MODIS Science Team Meeting on May 7-9, 2012.

NEWS

The MODIS news section details all the developing news surrounding the MODIS project.

[CIMSS Offers A Comparison of GOES, AVHRR, MODIS, and VIIRS IR Images](#)

IMAGES

Fires in northern Australia



Just a few days after the winter solstice, the 2012 northern Australia bushfire season roared to a fiery start with dozens of blazes speckling the Northern Territory and the northern tip of Western Australia...

DISCIPLINES



Atmosphere



Land

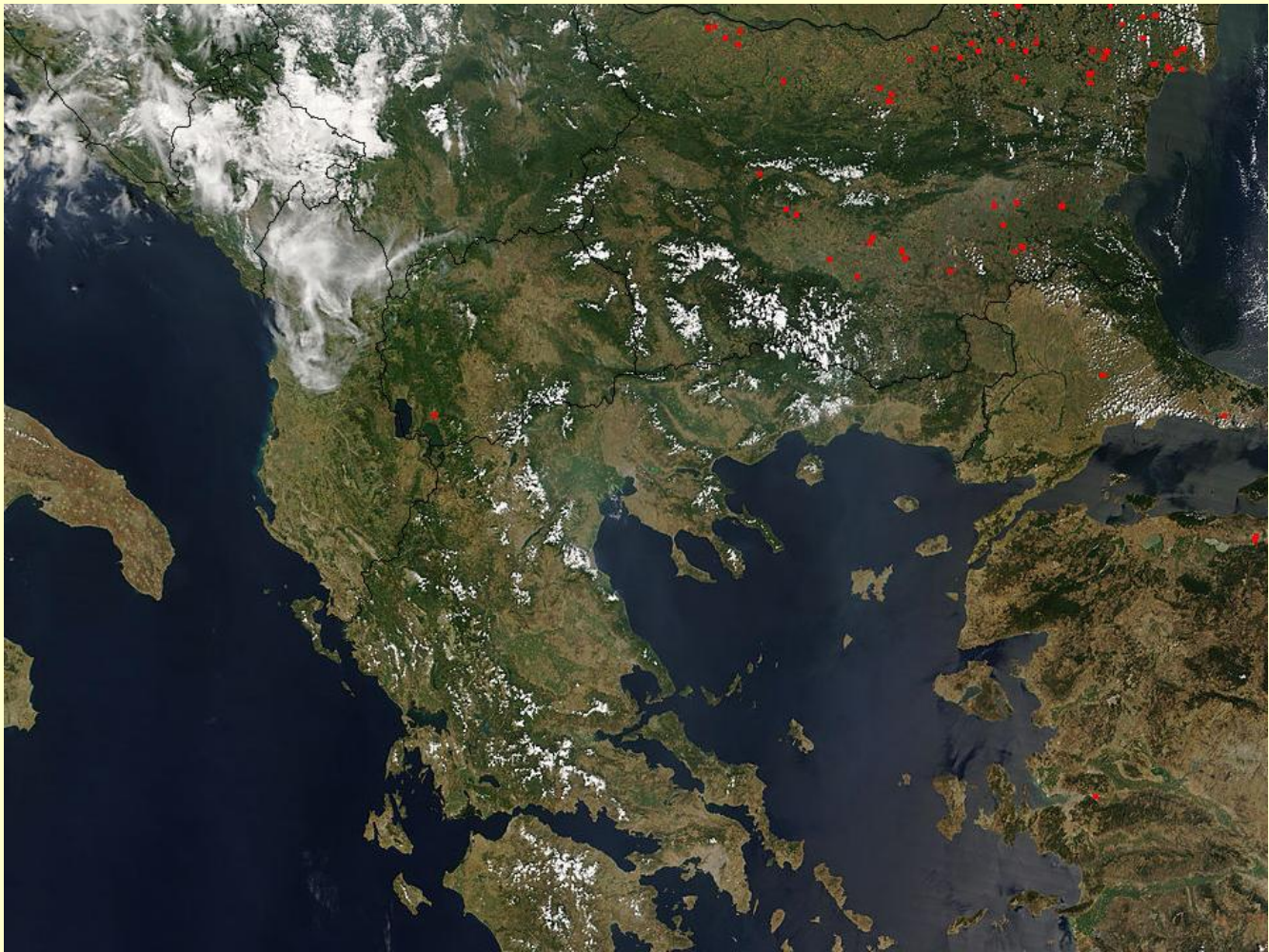


Ocean



Calibration

MODIS True Color



Terra Satellite image

Featured Terra Image:
Guitar Forest

[VIEW MORE EO IMAGES](#)

[DOWNLOAD](#)

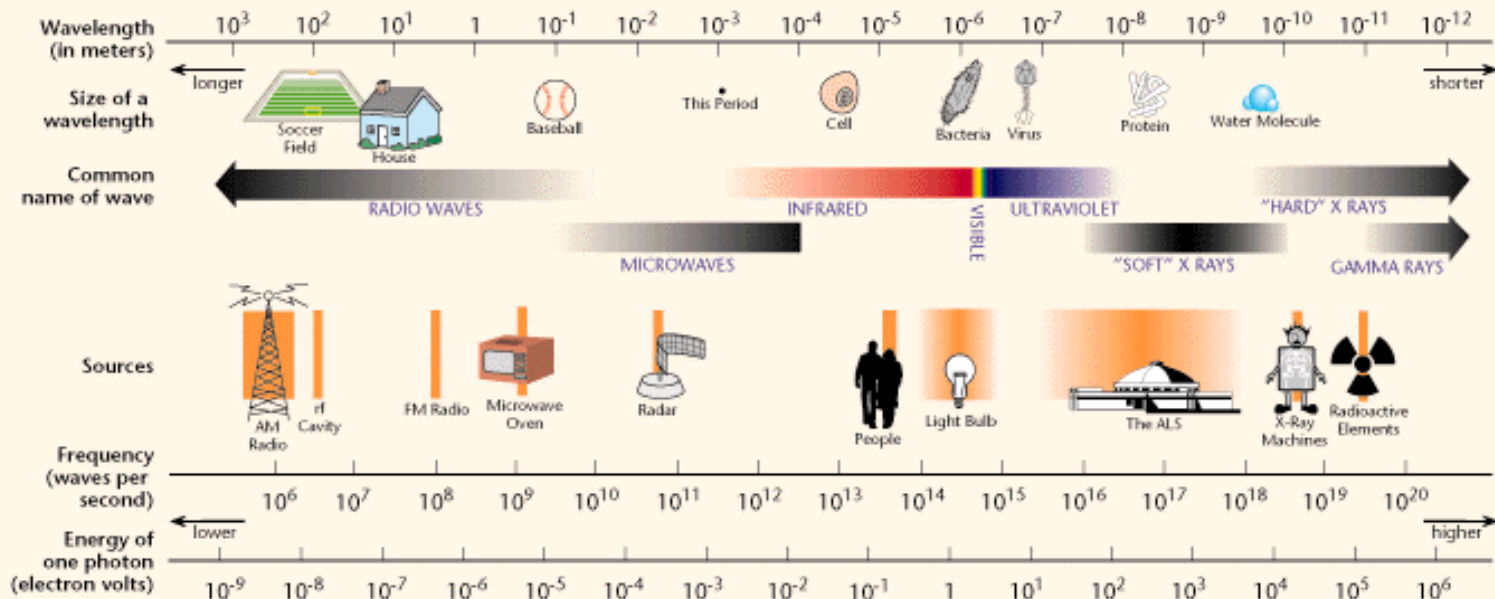


Pedro Martin Ureta created a piece of land art so that it could be viewed from an airplane. It turns out that it is visible from space, too.

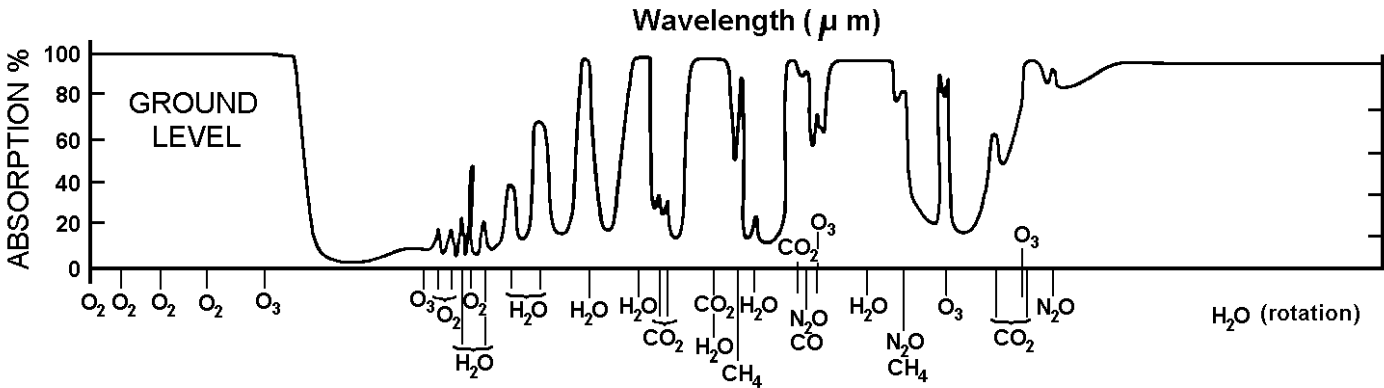
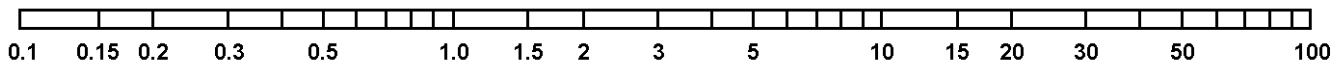
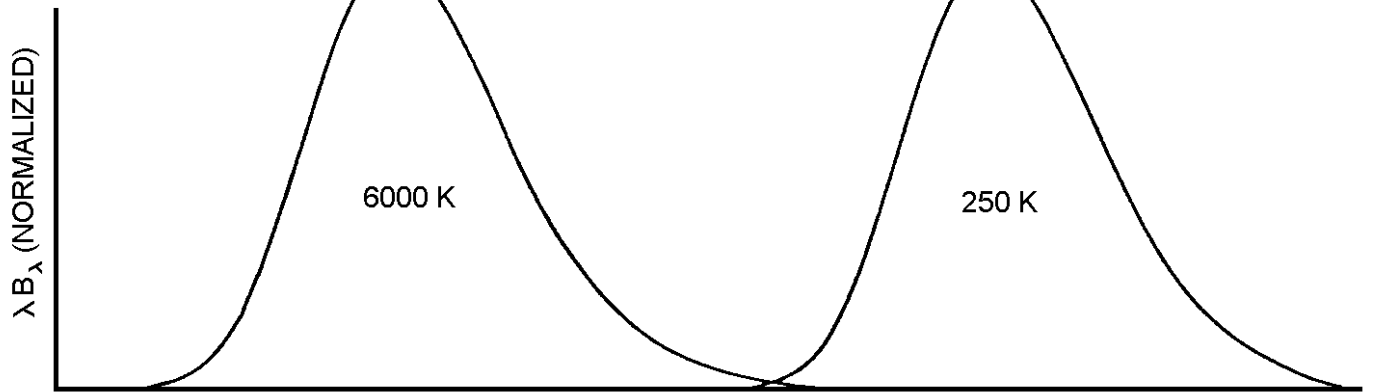
Satellite Radiometers

- Measure radiation of different wavelengths in discrete intervals.
- Intervals are called windows, channels or spectral bands.
- GOES measures five spectral bands; one visible and four IR.
- Use mirrors to scan a region.
- Transmit digital data to earth for processing.

THE ELECTROMAGNETIC SPECTRUM



Blackbody Curves



GOES Satellite Basics

- 5-channel Imager:
 - Visible (0.69 μm): Identify snow, fog, smoke.
 - Near-IR (3.9 μm): Distinguish water and ice clouds and cloud particle size.
 - Water Vapor (6.7 μm): Wind patterns, H₂O content, moisture plumes.
 - IR Window (10.7 μm): Cloud top and ground surface T.
 - CO₂ Absorption (13.2 μm): Cloud heights.
- 19-channel Sounder:
 - Hourly 10-km data vertical T and moisture distribution.



Imager - pictures

Imager Instrument Characteristics (GOES I-M)

Channel number:	1 (Visible)	2 (Shortwave)	3 (Moisture)	4 (IR 1)	5 (IR 2)
Wavelength range (um)	0.55 - 0.75	3.80 - 4.00	6.50 - 7.00	10.20 - 11.20	11.50 - 12.50
Instantaneous Geographic Field of View (IGFOV) at nadir	1 km	4 km	8 km	4 km	4 km
Radiometric calibration	Space and 290 K infrared internal backbody				
Calibration frequency	Space: 2.2 sec (full disc), 9.2 or 36.6 sec (sector/area) Infrared: 30 minutes typical				
System absolute accuracy	IR channels: less than or equal to 1 K Visible channel: 5% of maximum scene irradiance				
Imaging rate	Full earth disc, less than or equal to 26 minutes				



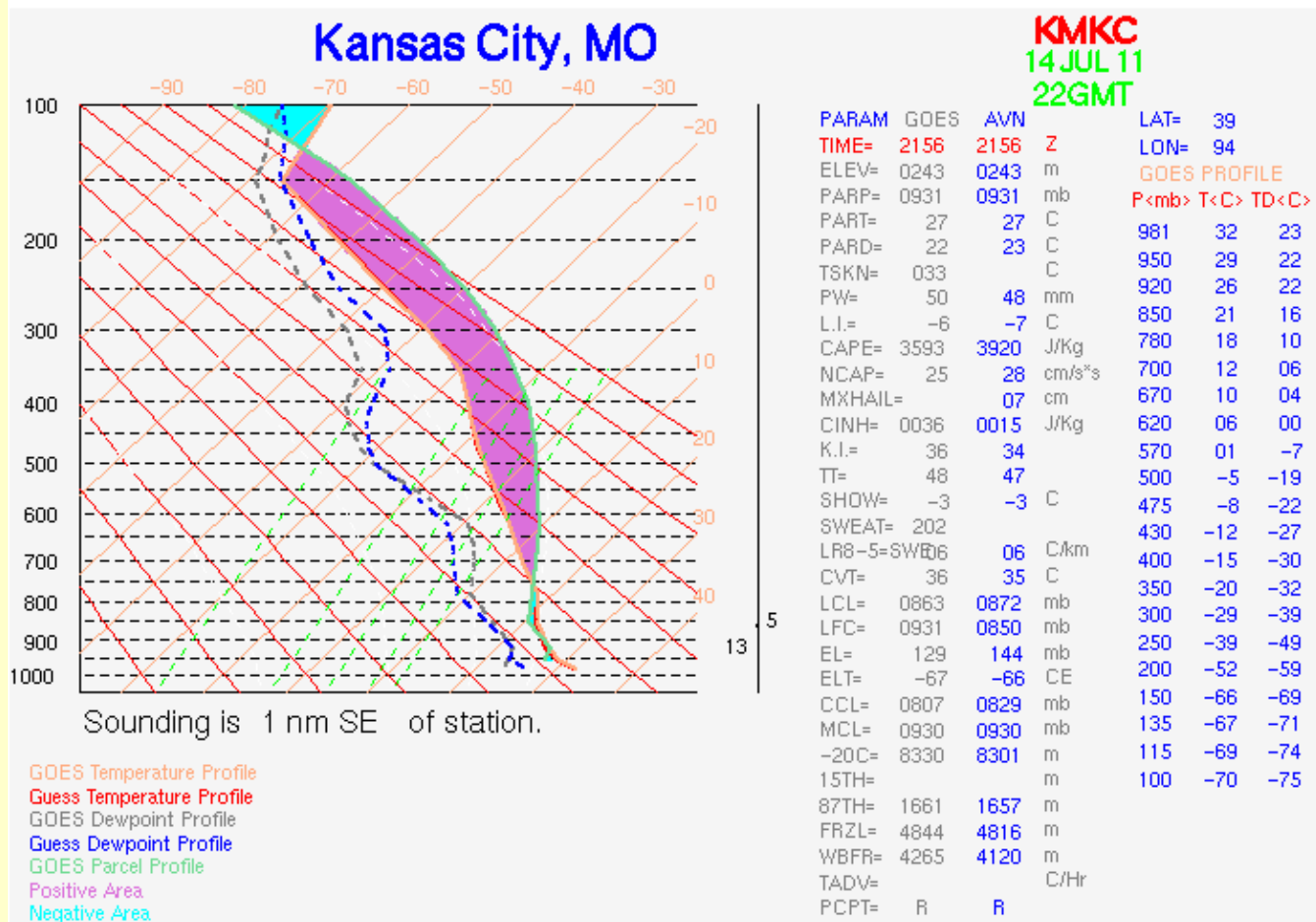
Sounder - profiles

Sounder Instrument Characteristics (GOES I-M)

Channel Numbers	Wavelength (um)	Maximum Temperature Range (K)
Long wave IR		
1	14.71	space - 280
2	14.37	space - 280
3	14.06	space - 290
4	13.64	space - 310
5	13.37	space - 320
6	12.66	space - 330
7	12.02	space - 340
Medium wave IR		
8	11.03	space - 345
9	9.71	space - 330
10	7.43	space - 310
11	7.02	space - 295
12	6.51	space - 290
Short wave IR		
13	4.57	space - 320
14	4.52	space - 310
15	4.45	space - 295
16	4.13	space - 340
17	3.98	space - 345
18	3.74	space - 345
Visible 19	0.70	Not Applicable

GOES Satellite Sounding - Kansas City, MO

[24 Hour Java Loop](#)
[24 Hour Sounding Archive](#)



Visible Imagery

- Reflected sunlight.
- Presented in shades of gray:
 - Dark: Low brightness – vegetation, water.
 - White: High brightness – clouds, snow fields.
 - Excellent detail of cloud features.
- Brightness depends on:
 - Albedo of underlying surface.
 - Position of sun and satellite with respect to Earth.

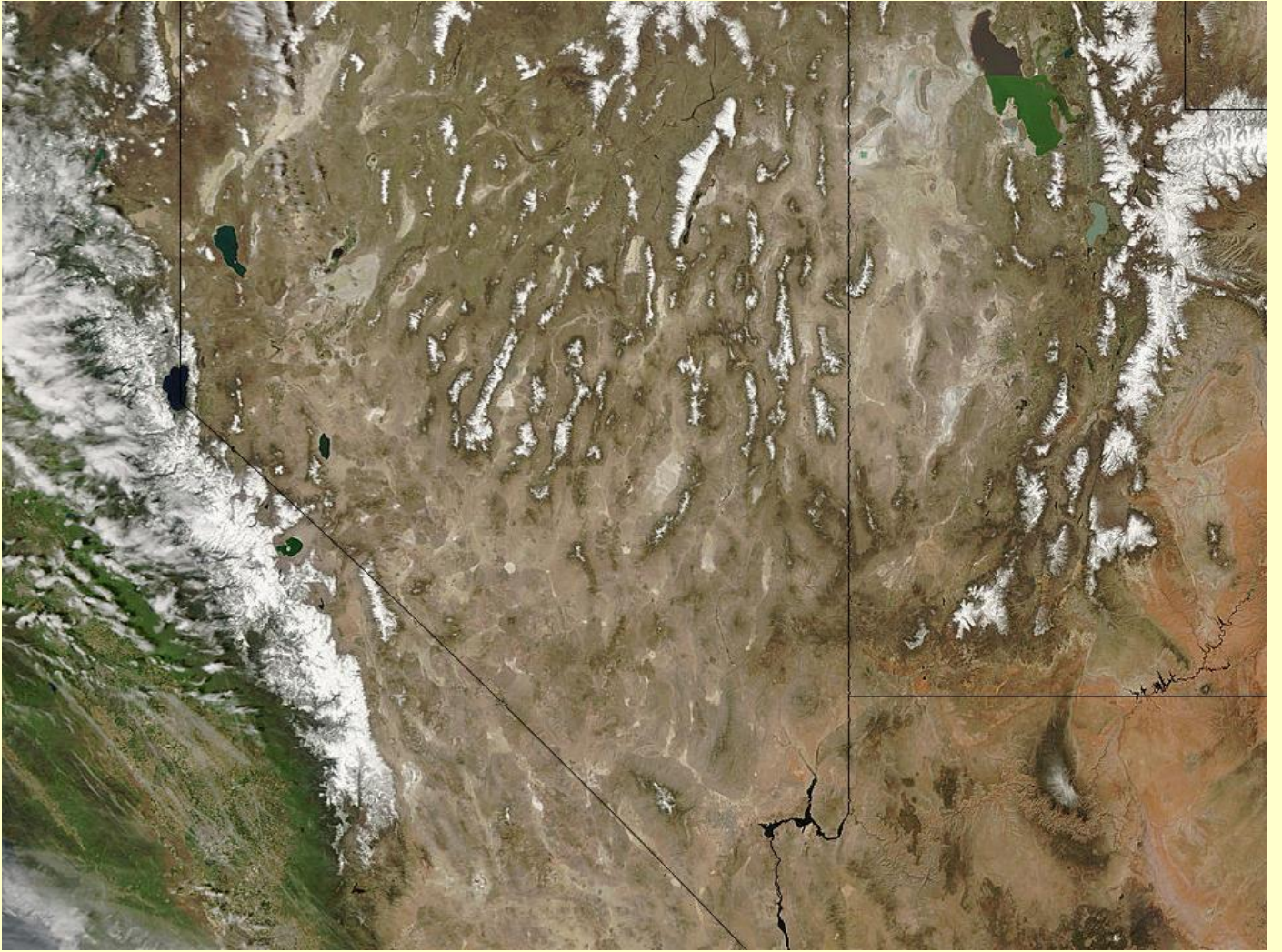
Albedo

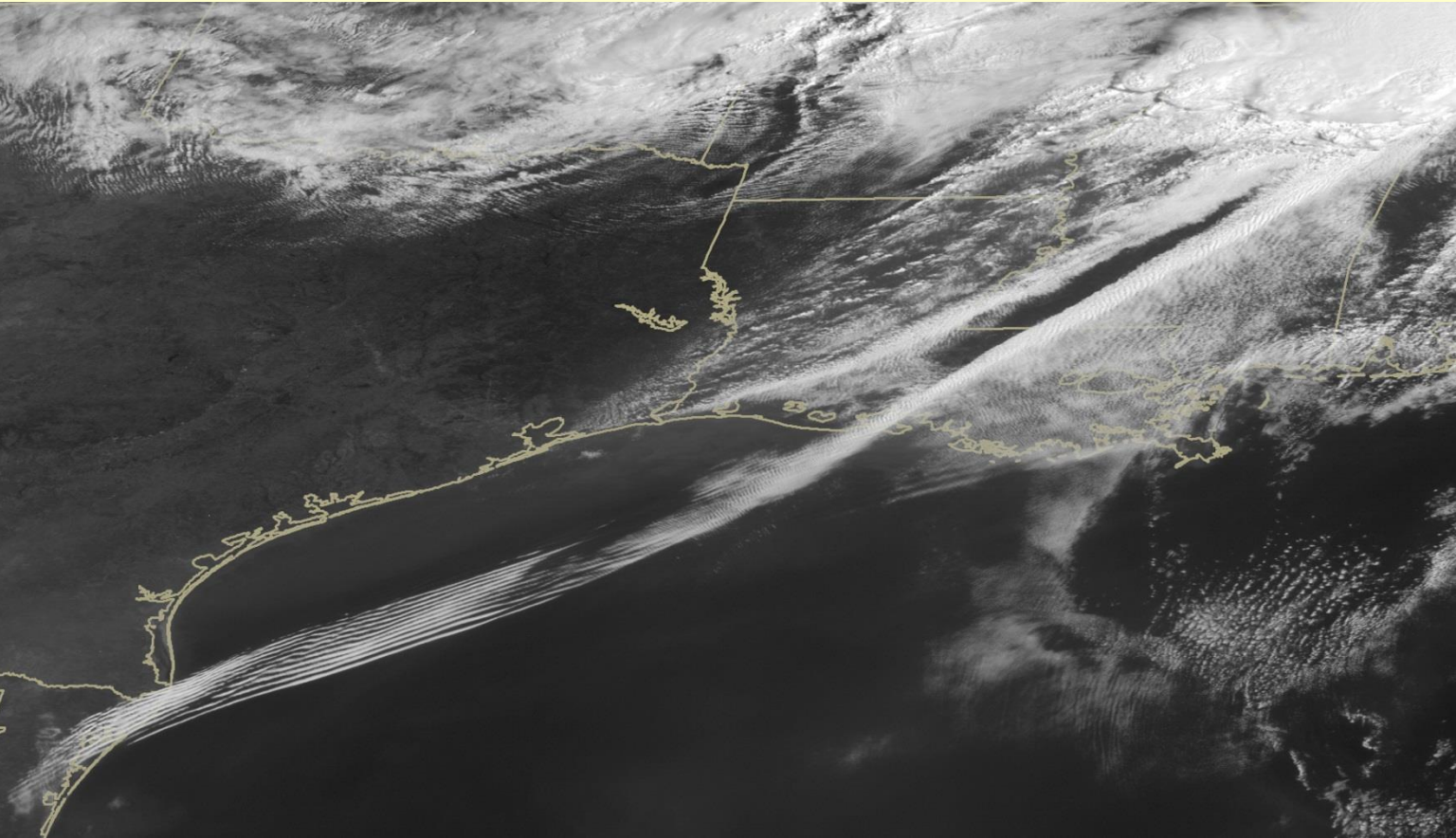
- Fraction of total radiation reflected by an object (surface).
- Varies according to:
 - Cloud cover.
 - Particles in air.
 - Angle of sun's rays.
 - Types of surface.

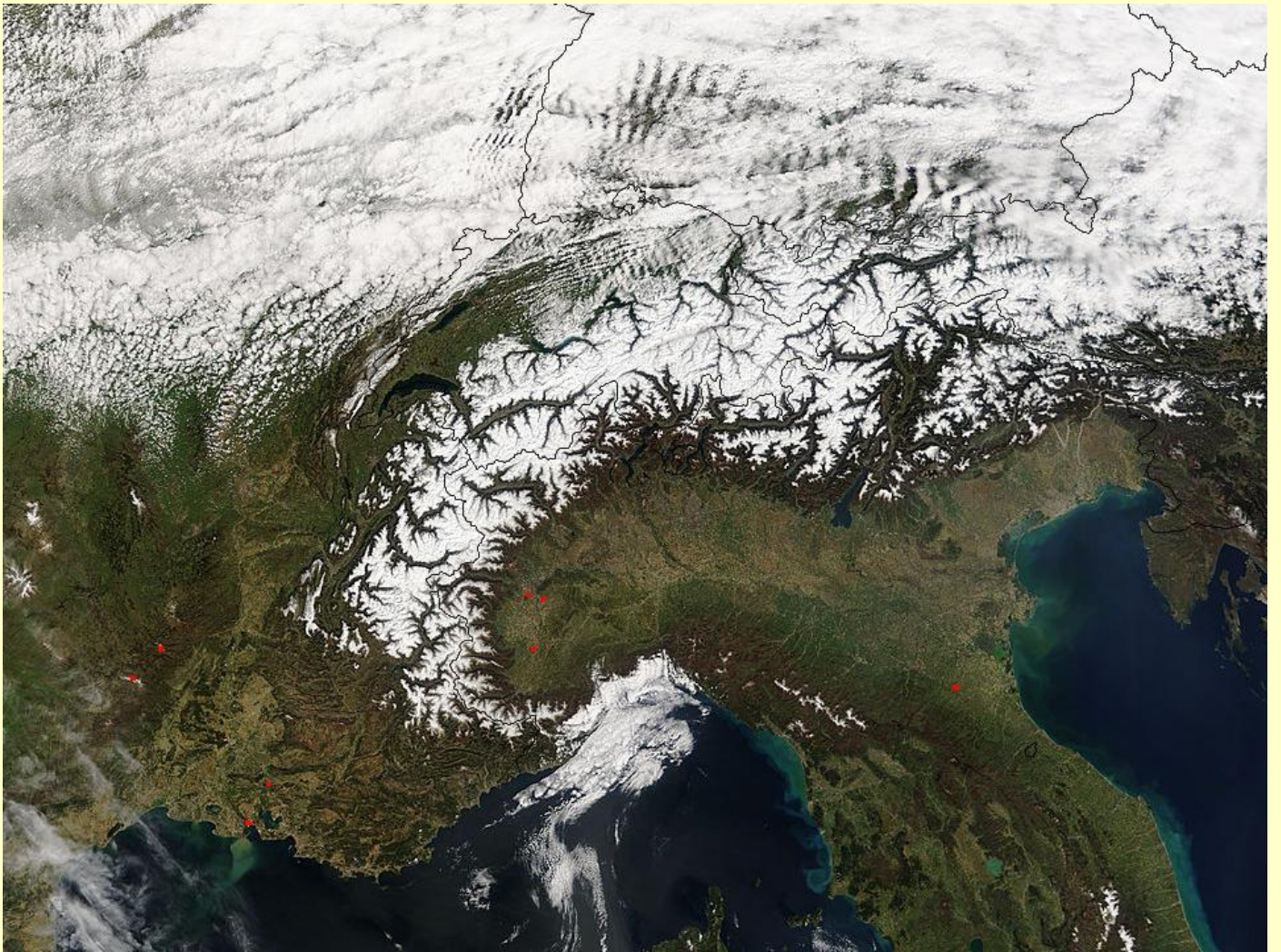
Typical Albedo of Various Surfaces

SURFACE	ALBEDO (PERCENT)
Fresh snow	75 to 95
Clouds (thick)	60 to 90
Clouds (thin)	30 to 50
Venus	78
Ice	30 to 40
Sand	15 to 45
Earth and atmosphere	30
Mars	17
Grassy field	10 to 30
Dry, plowed field	5 to 20
Water	10*
Forest	3 to 10
Moon	7

*Daily average.

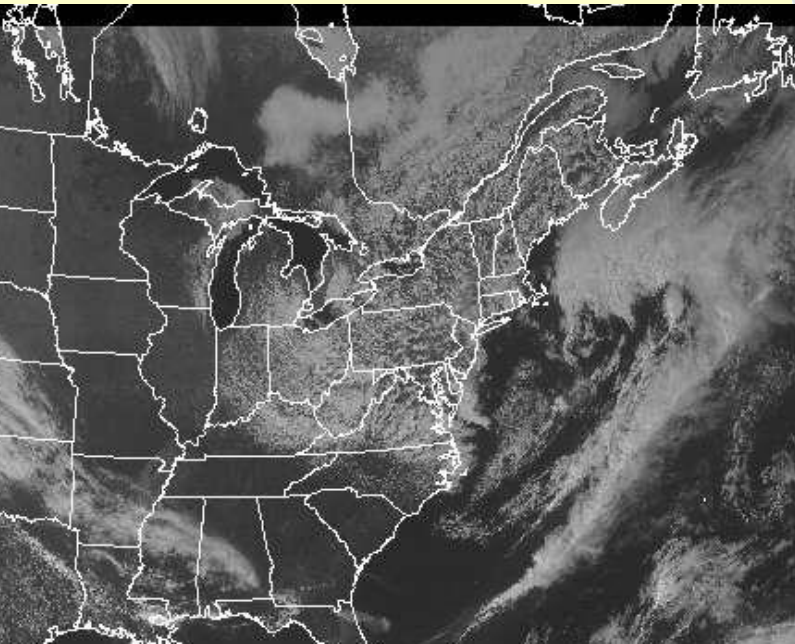
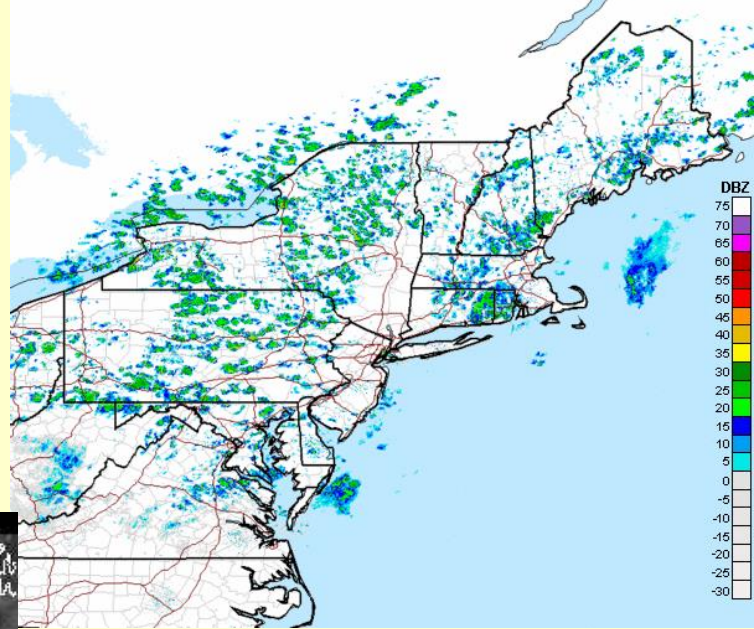








Scattered Showers



**11 April 2012
1945Z
(3:45 pm EDT)**

Summary – Visible Imagery

- Determine amount and extent of clouds.
- Recognize features:
 - Fronts/drylines
 - Moist/dry areas
 - Thunderstorm development and evolution
 - Land and water
 - Offers the best resolution
- Help explain a meteorological concept.

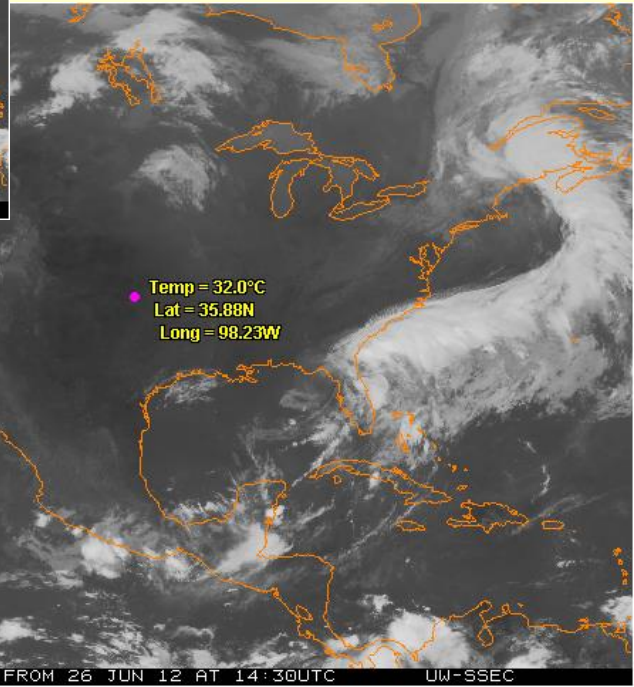
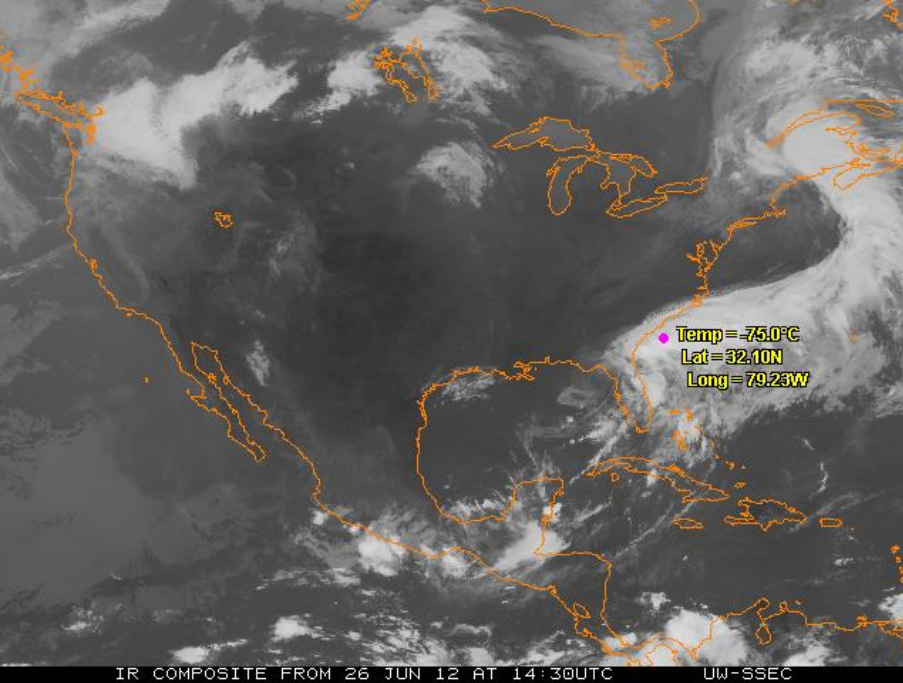
Animated Visible

- Observe Trends.
- Identify wind direction/speed at different levels.
- Relate land features to clouds.
- Evolution/movement of meteorological features.
- Better understand atmospheric processes.
- Help explain observed features and trends.

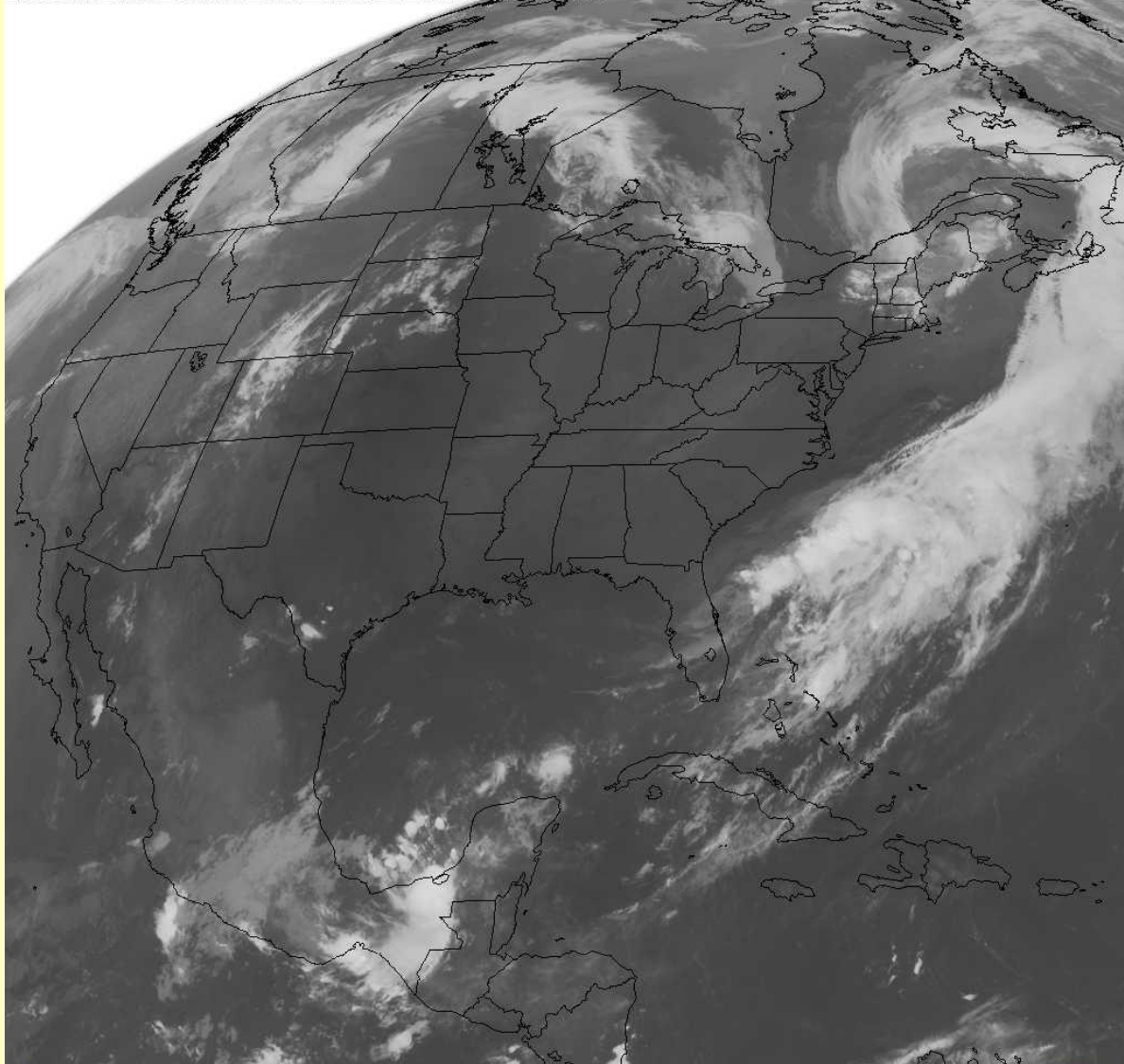
Infrared (IR) Imagery

- Distinguish the height of clouds.
- Determine cloud layers.
- Relate feature development/dissipation to warming/cooling trends.
- Observe surface temperature trends.
- Help identify upper air features.

Infrared Imagery

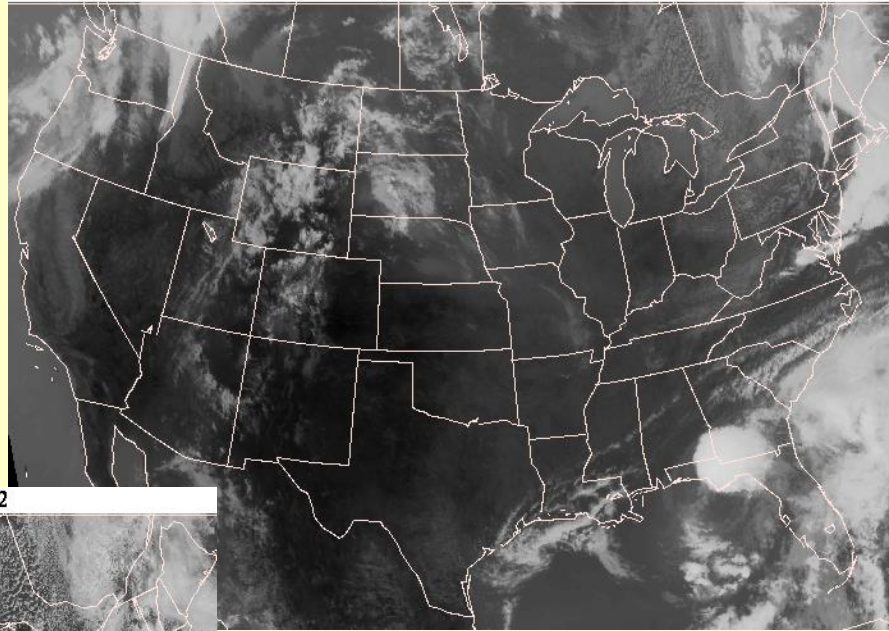


Temperature Map



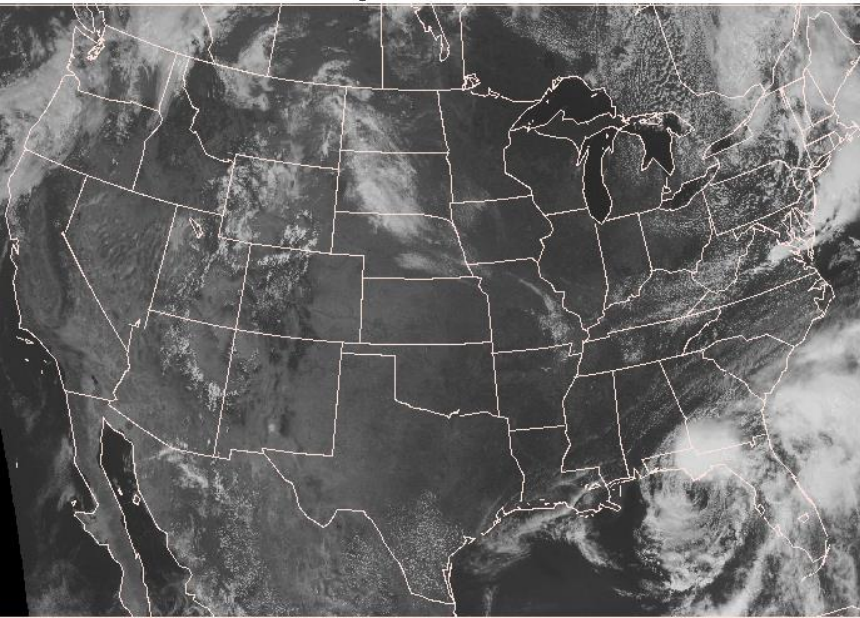
Infrared Image

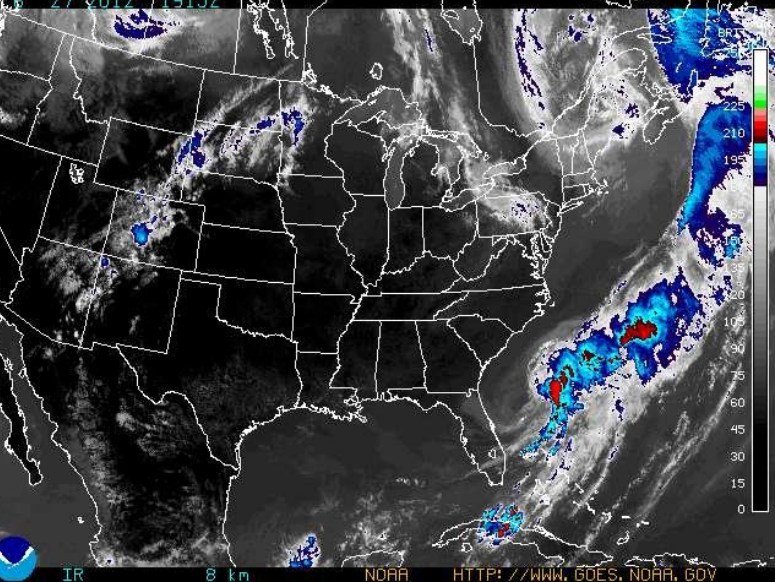
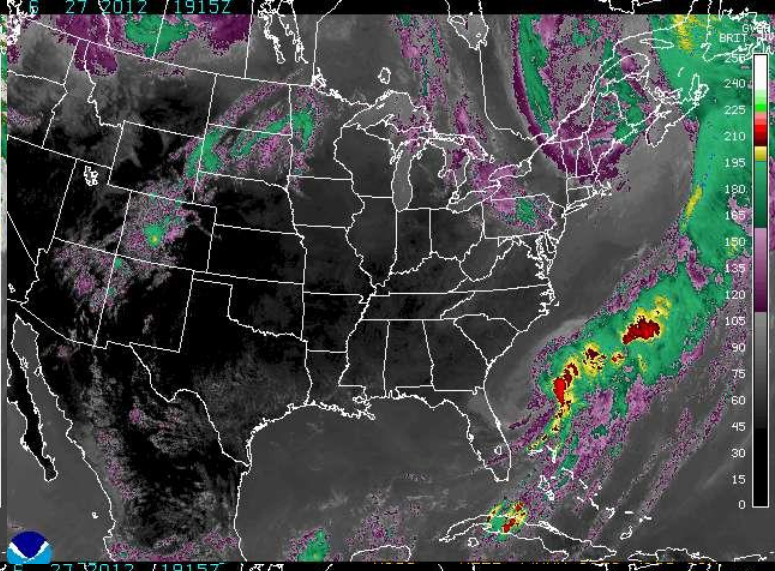
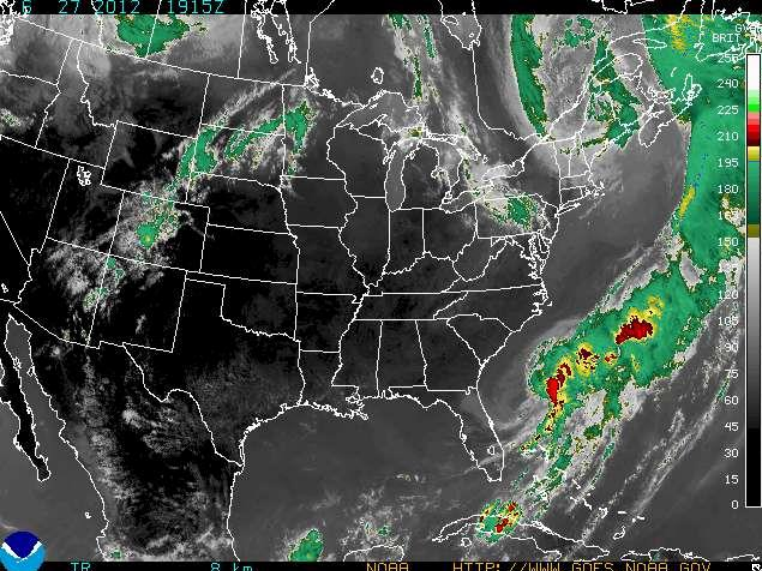
1815Z 25 JUN 2012



Visible Image

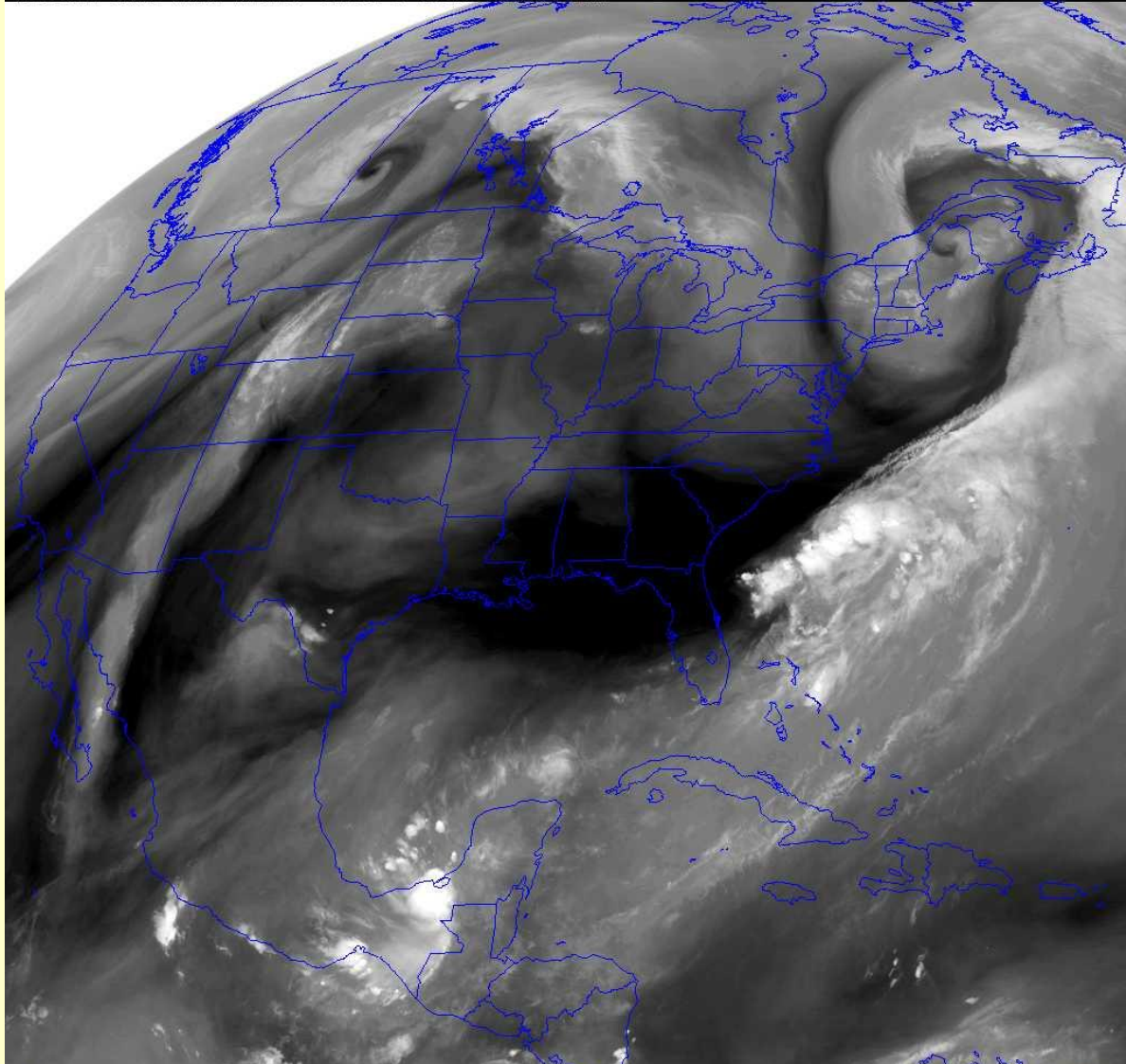
1815Z 25 JUN 2012



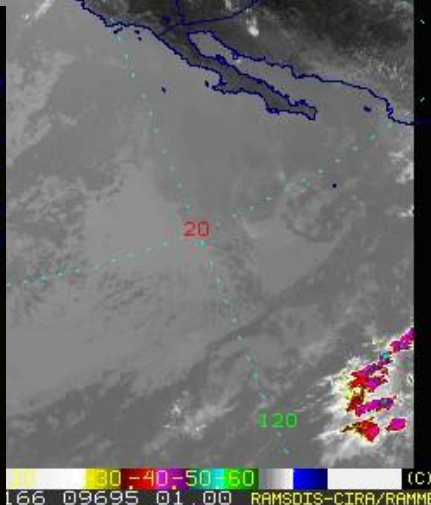
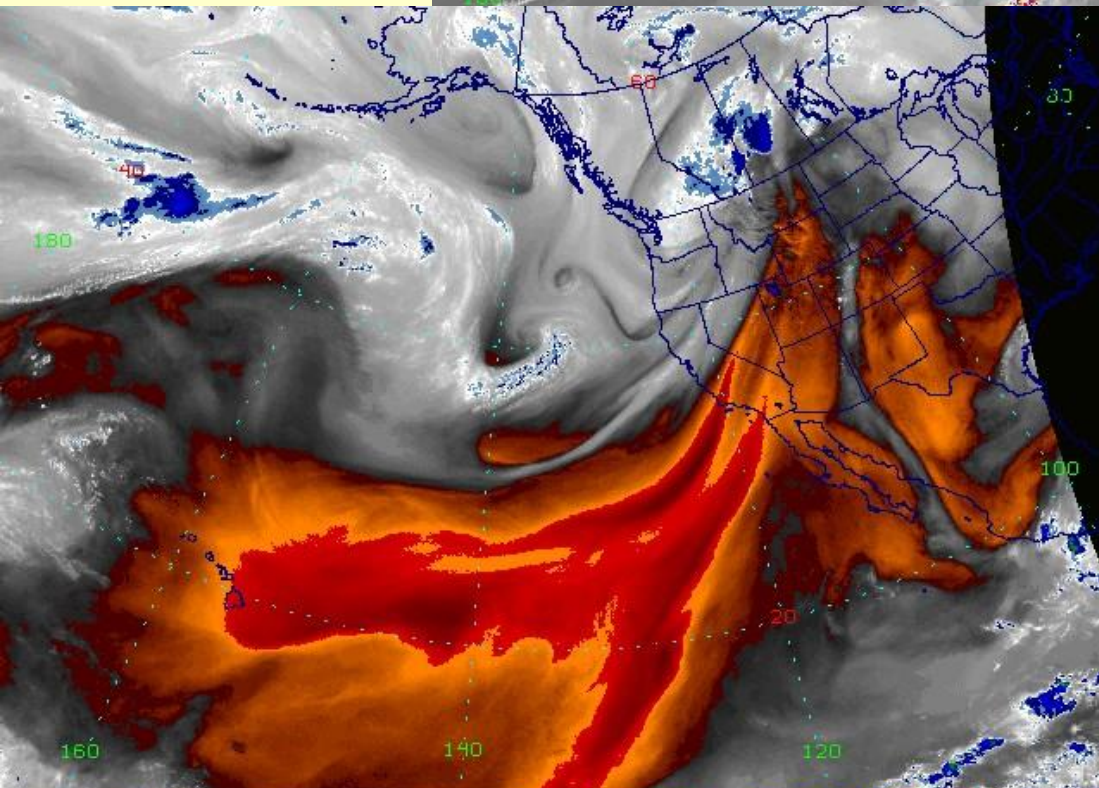
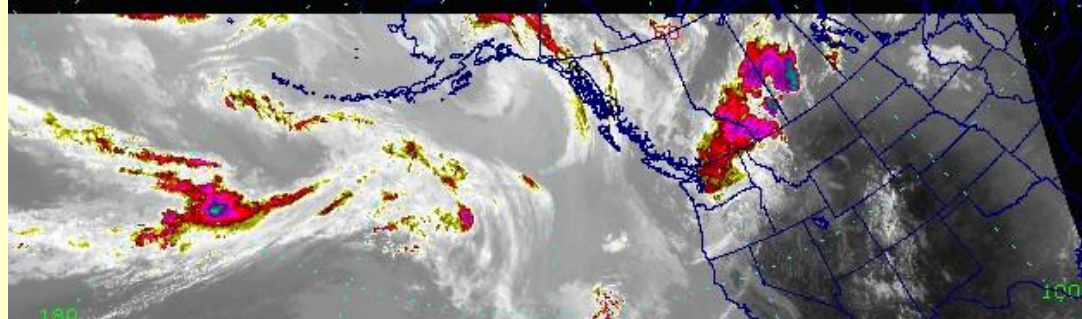


Water Vapor (WV) Imagery

- Detects amount and height of water vapor.
- Water vapor absorption at 6.7μ between 300-600 mb layer.
- Dark shades (b/w) and red (color) relate to less moisture.
- Clouds and bright gray shades relate to moisture.
- Moisture below ~ 800 mb not detected.
- Useful depicting large-scale flow and moisture layers – tracer.



Enhanced IR



Enhanced WV



Imagery Comparison

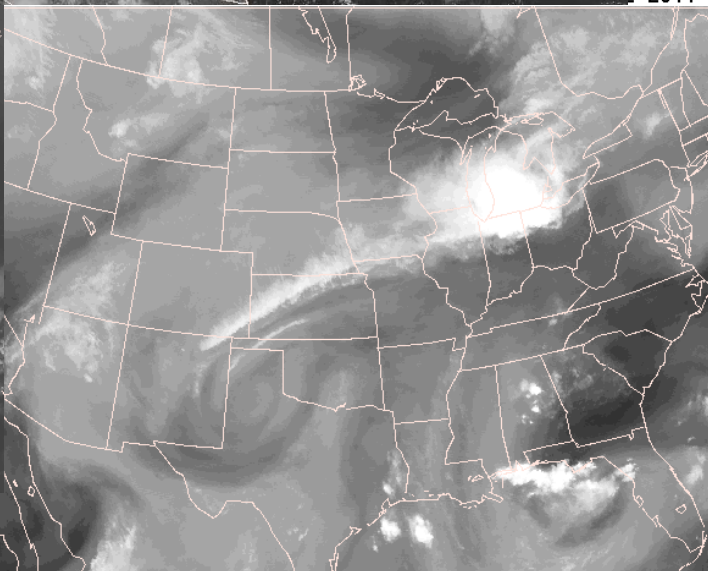
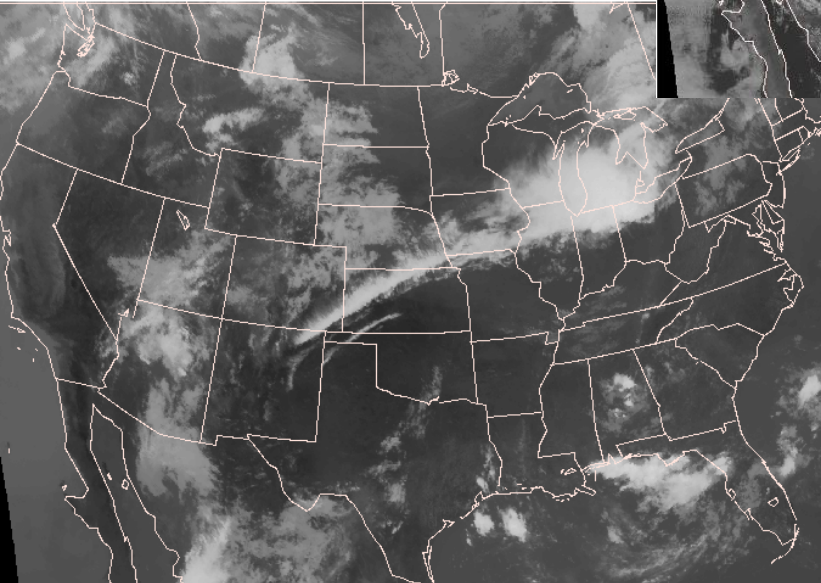
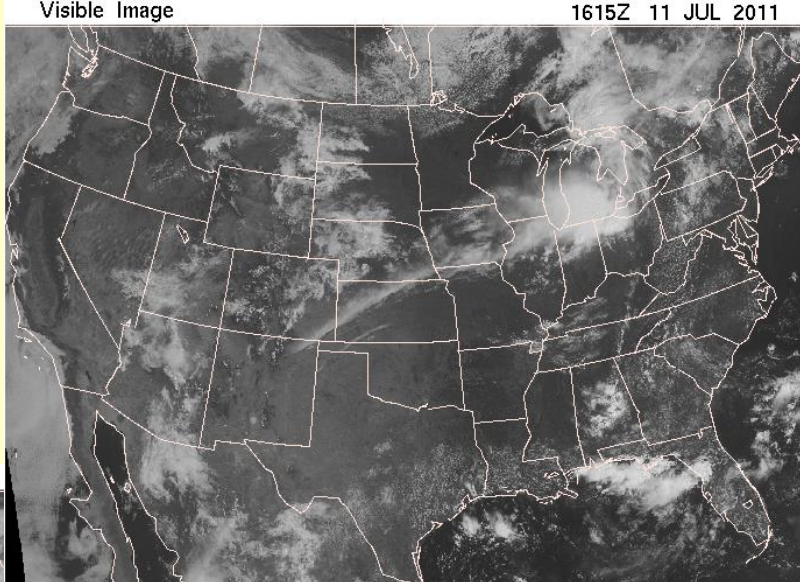
- **Visible**
- **Infrared**
- **Water vapor**

Satellite Imagery

Visible →

Infrared ↓

Water Vapor ↓



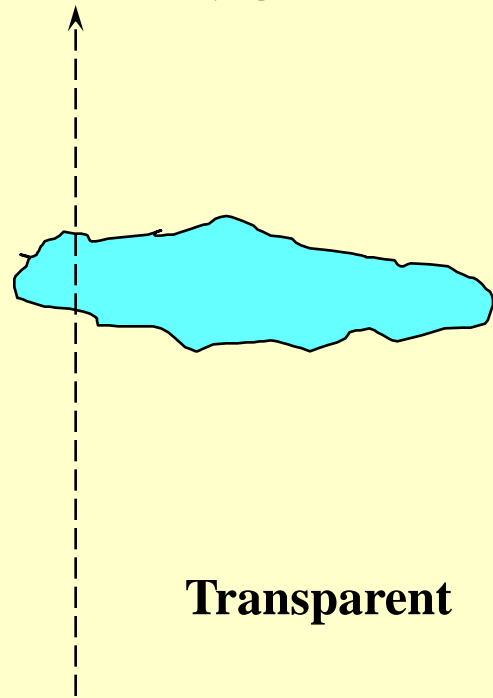
2011

Near IR (3.9 μ) Imagery

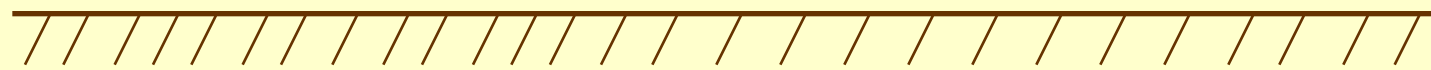
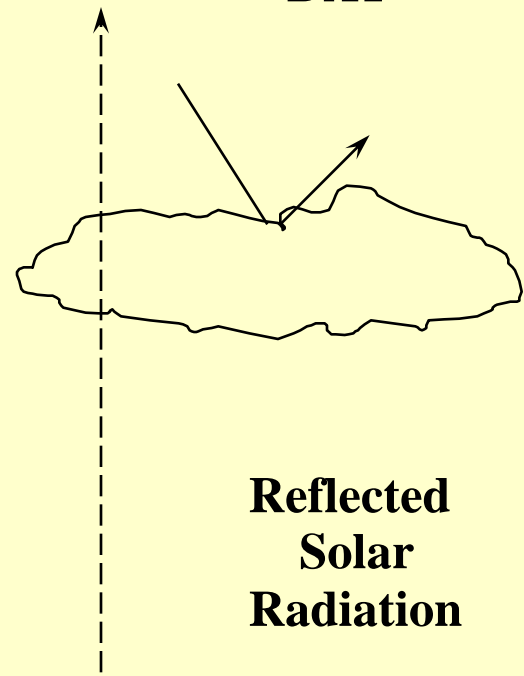
- Small overlap between reflected solar rad and emitted rad from Earth/clouds.
- Earth's sfc emits as black body at this λ – clouds do not.
- At this λ , Earth and solar emissions similar magnitude.
- Water clouds more reflective than ice clouds.
- Daytime – Reflected solar overwhelms emitted Earth.
- Nighttime – Emitted Earth dominates.
- Fires saturate the pixel footprints – Detect fires.
- Use in combo with 11 μ for fog/low cloud detection.

3.9 μm

NIGHT



DAY



HIGH CLOUDS - ANVIL CIRRUS

(ice)

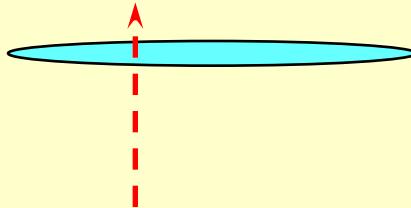
10.7 μm

COLD

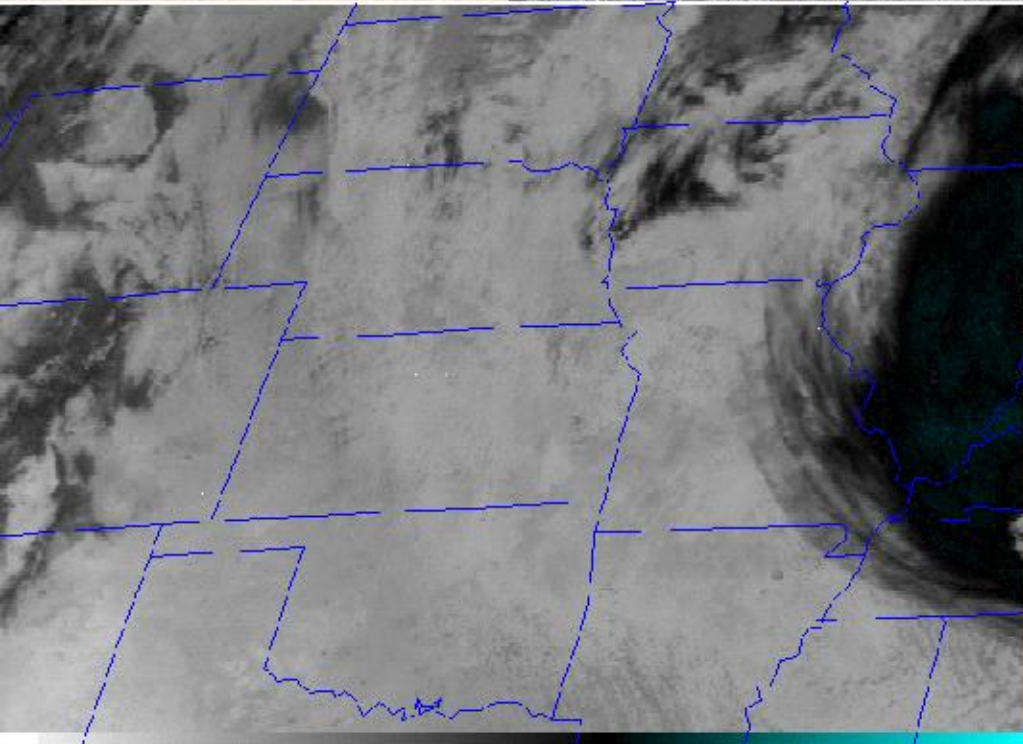
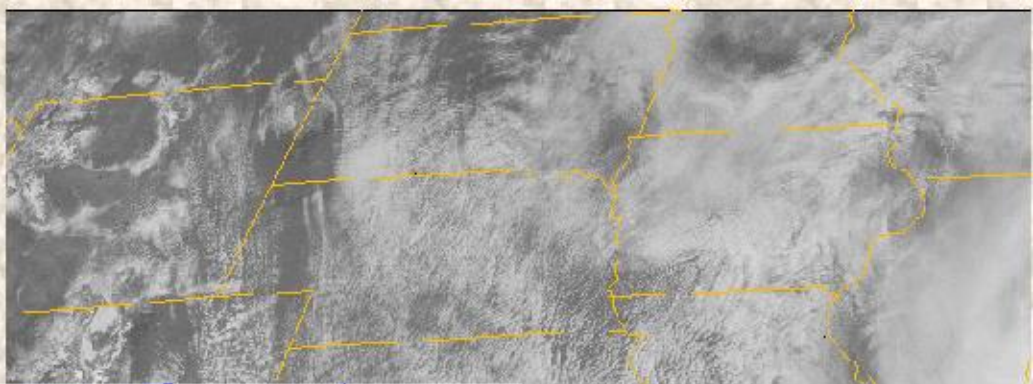


3.9 μm

relatively warm



Visible Image →



9 181500 03753 10991 02 00C100/RAMP

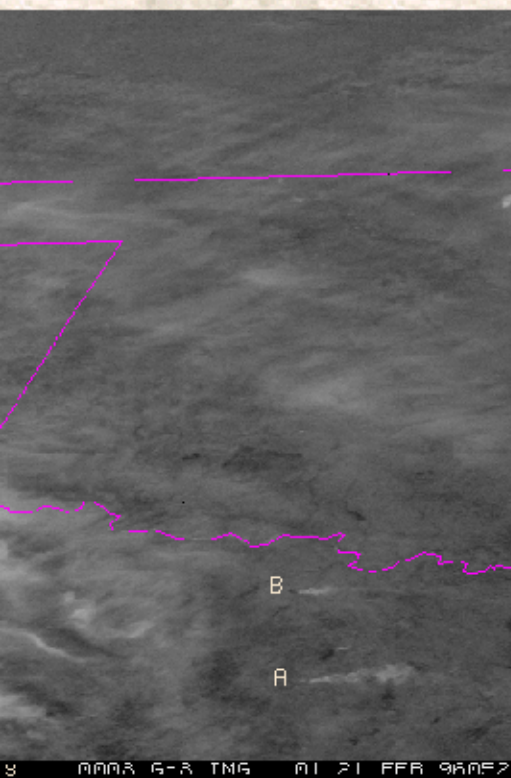
← 3.9 μ Image

0219030193 6-3 IMG 02 19 MAR 96029 8 507 13253 10989 02 00C100/RAMP

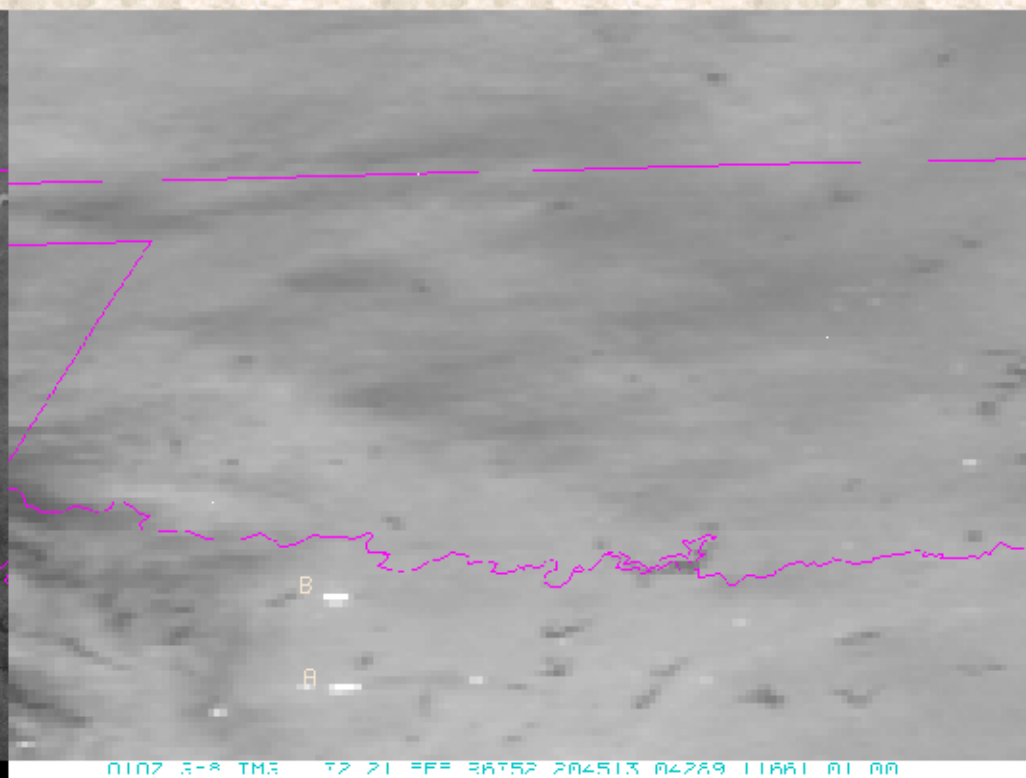
Using 3.9 μ imagery to detect fires

- Blackbody radiation at 3.9 μ increases rapidly with temperature.
- Fire need to be as large as the minimum resolution of the satellite.
- Temperature needs to be at least 4K warmer than surrounding area.
 - ▶ Typical grass fire - 325K
 - ▶ Heavy shrub beginning to ladder into timber - 450K
 - ▶ Active forest fire moving into crowns - 800K
- During daylight more difficult to detect due to reflected sunlight increasing the brightness and surface warming, but, can use visible imagery to see smoke.

Texas wildfires



Visible



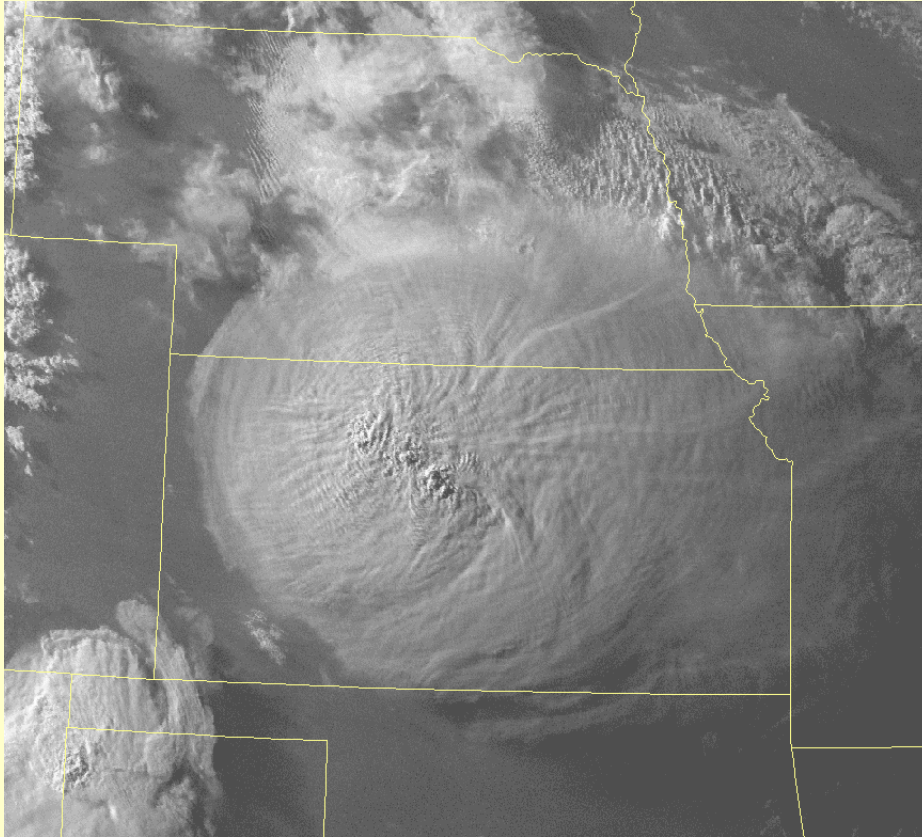
3.9 μ image

Thunderstorms

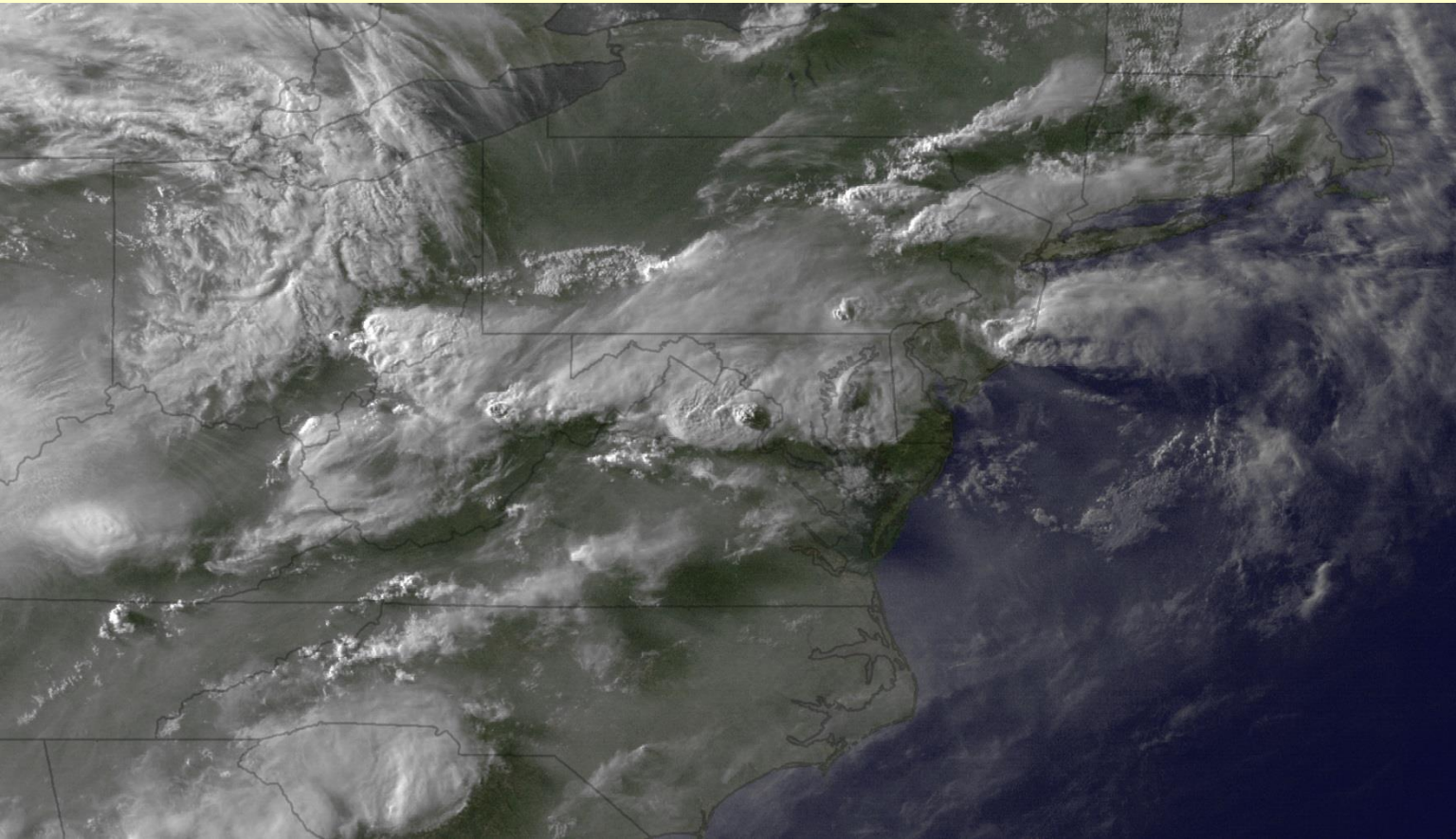
- Can see all scales of motion.
- Large complexes down to developing cumulus.
- Clouds outline moisture – shallow or deep.
- Identify boundaries.
- Severe signatures.
- Linear and clusters.

Thunderstorms over Kansas

- Weak flow aloft...anvil spreads out in all directions.

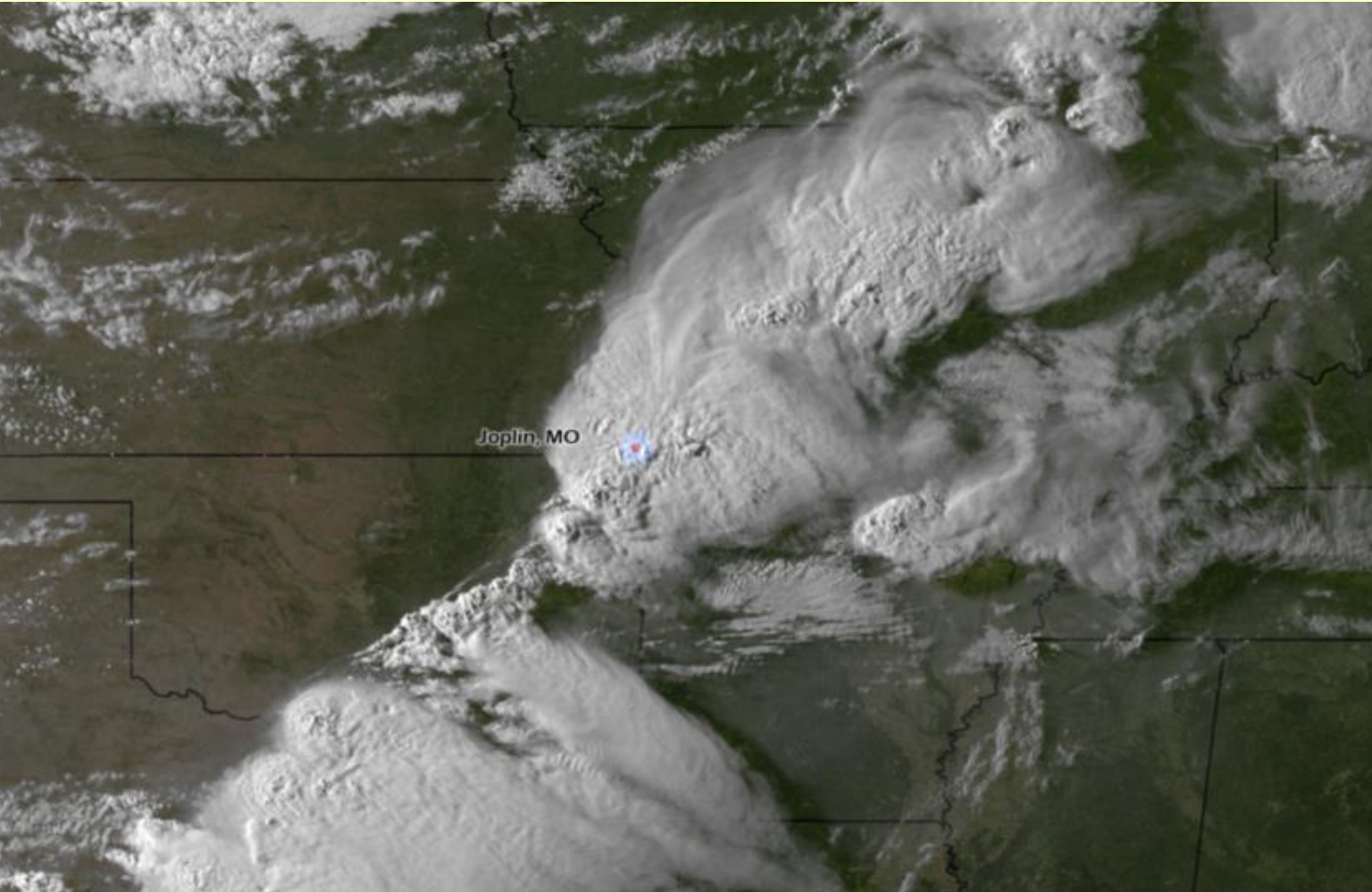


Macroburst

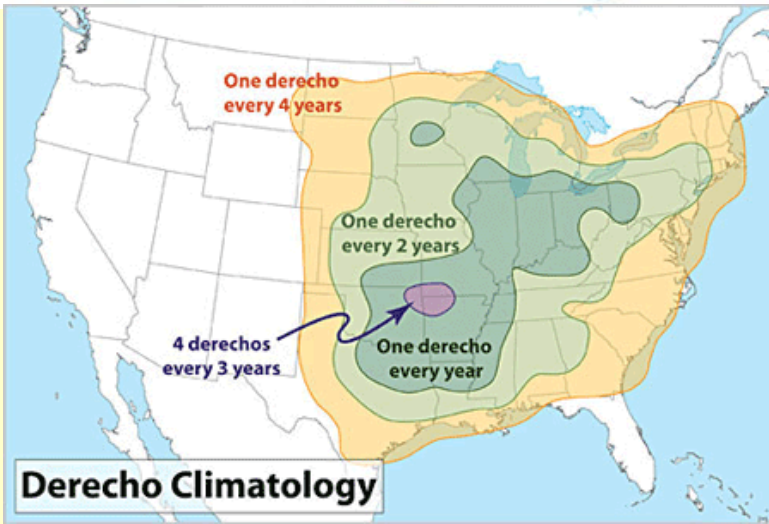
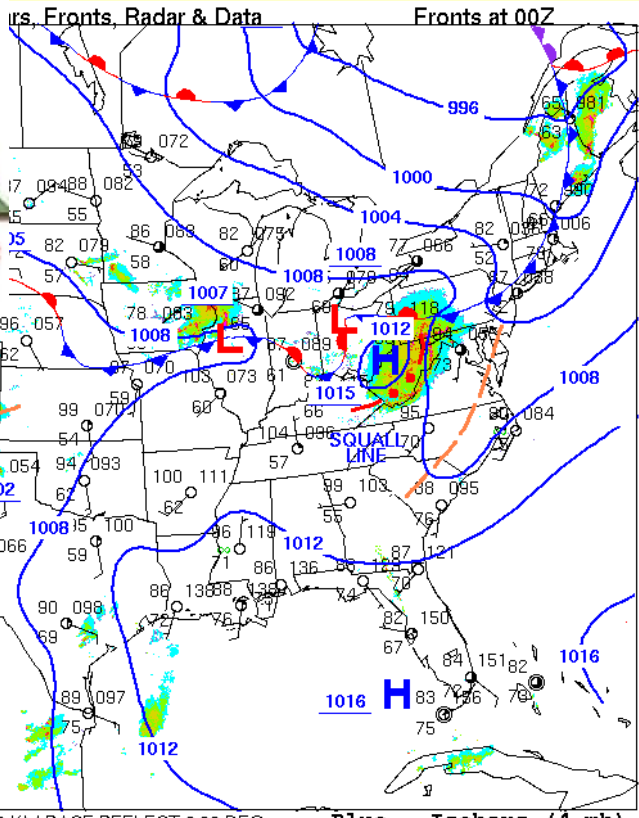
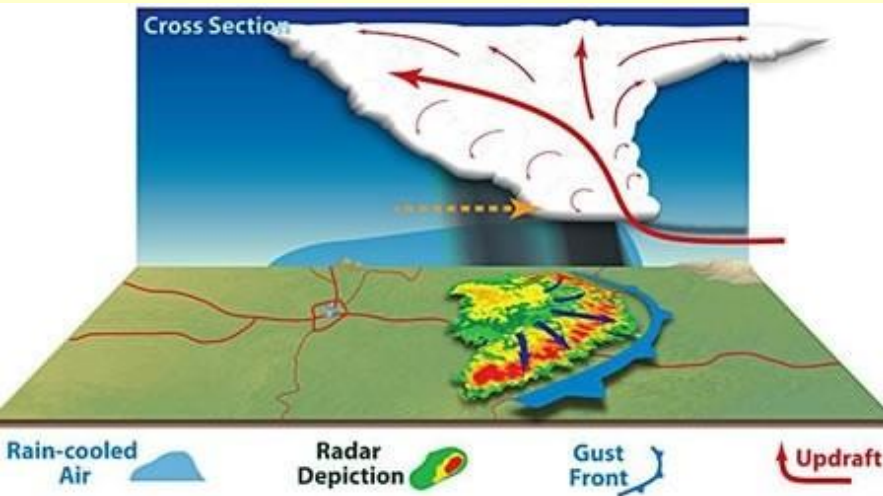


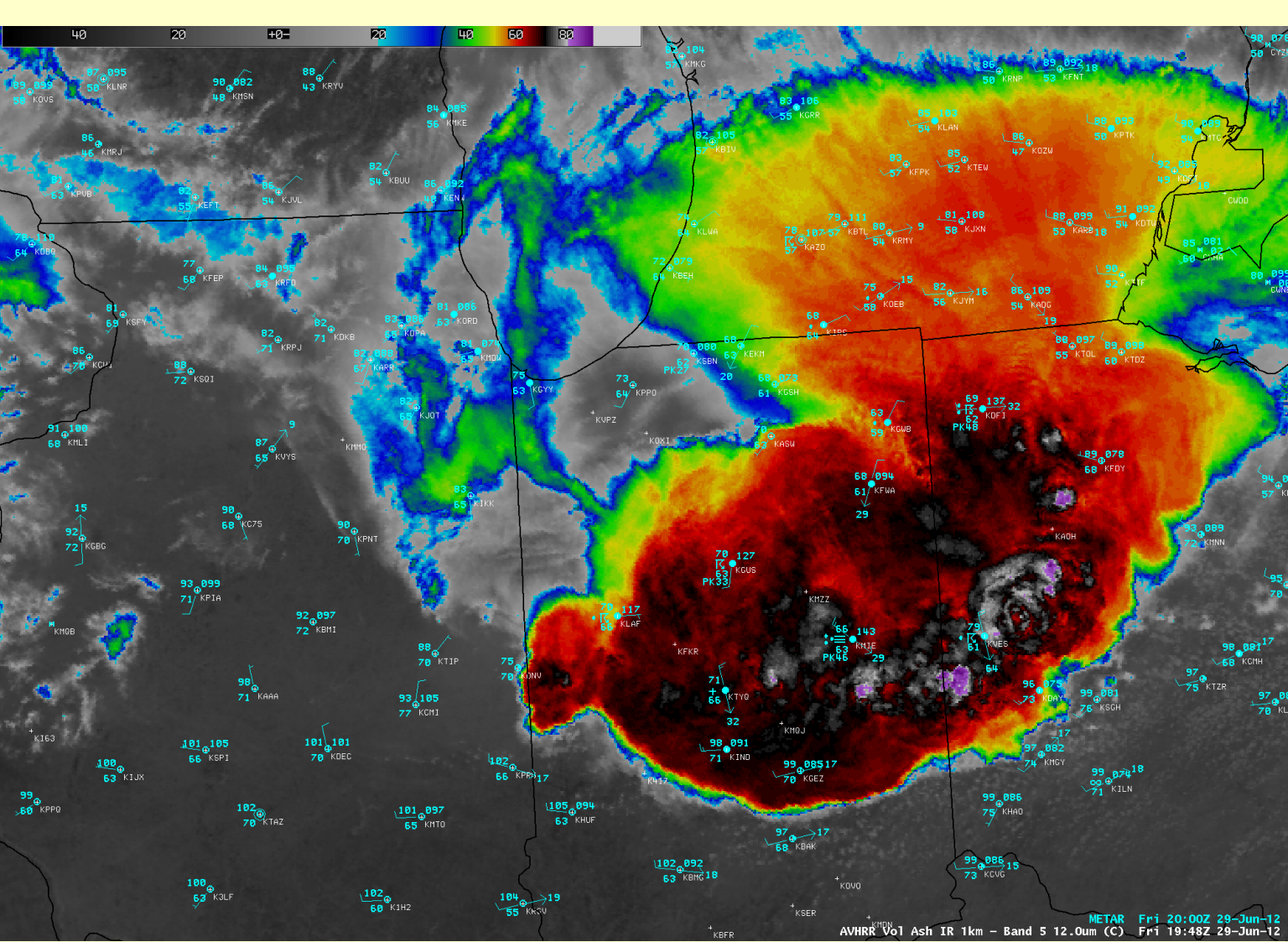
2345Z 3 July 2011

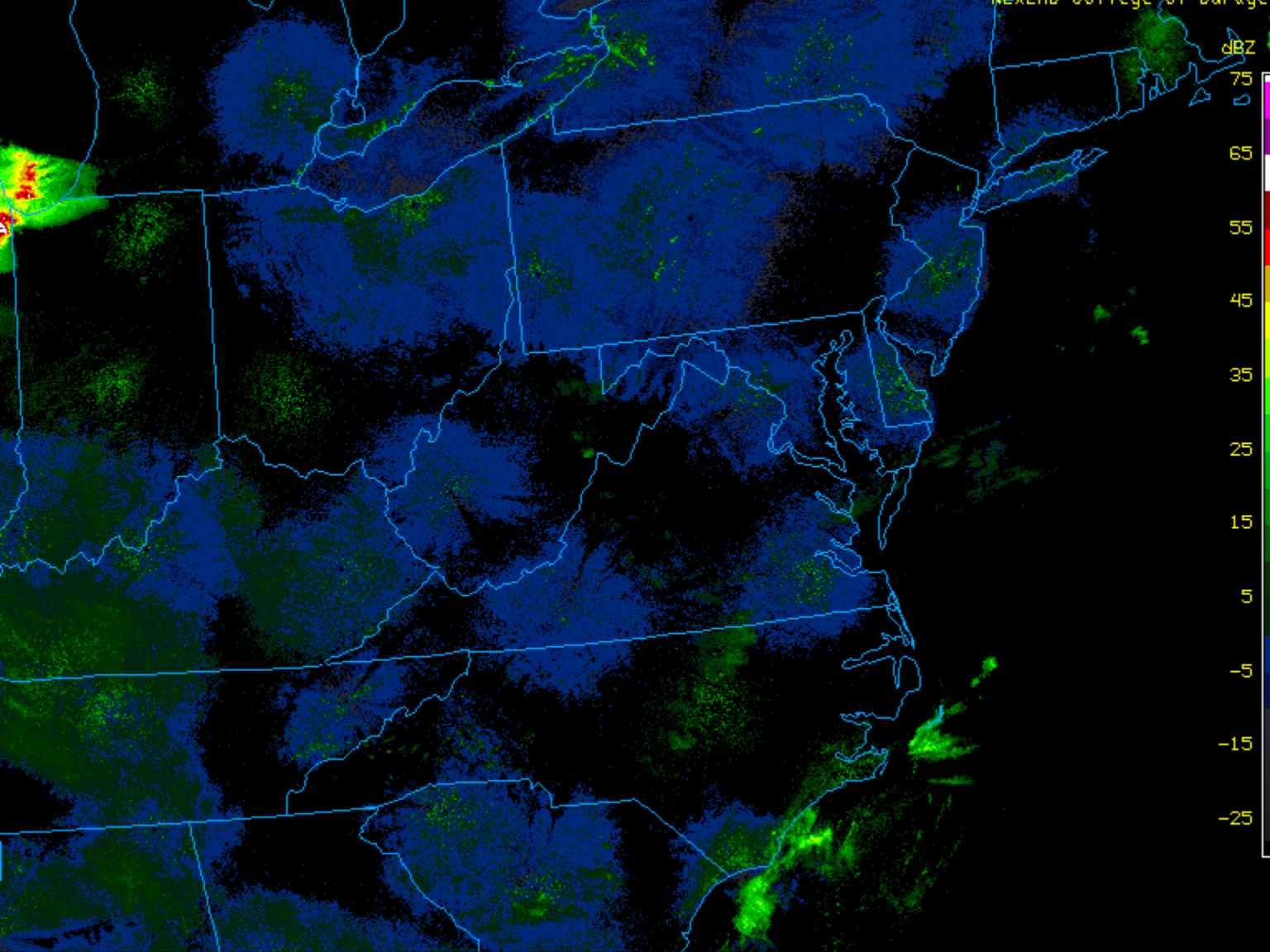
Joplin, MO – 22 May 2011 – EF5

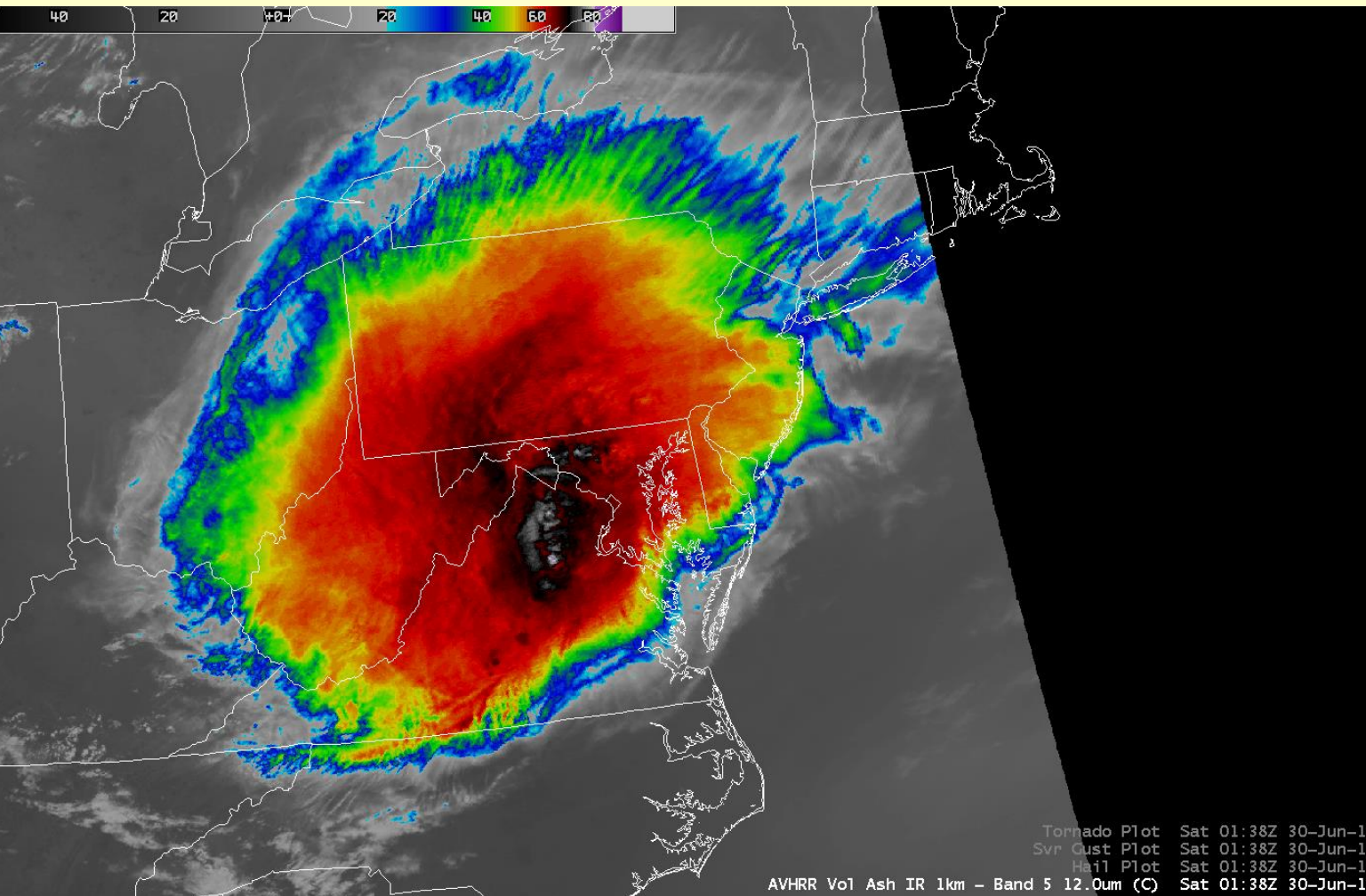


Derecho: family of downburst clusters







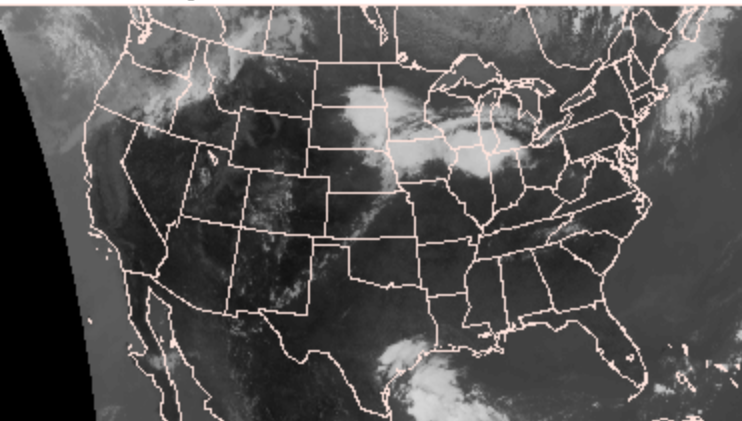


40 20 +0 20 40 60 80

Tornado Plot Sat 01:38Z 30-Jun-1
Svr Gust Plot Sat 01:38Z 30-Jun-1
Hail Plot Sat 01:38Z 30-Jun-1
AVHRR Vol Ash IR 1km - Band 5 12.0um (C) Sat 01:38Z 30-Jun-1

Infrared Image

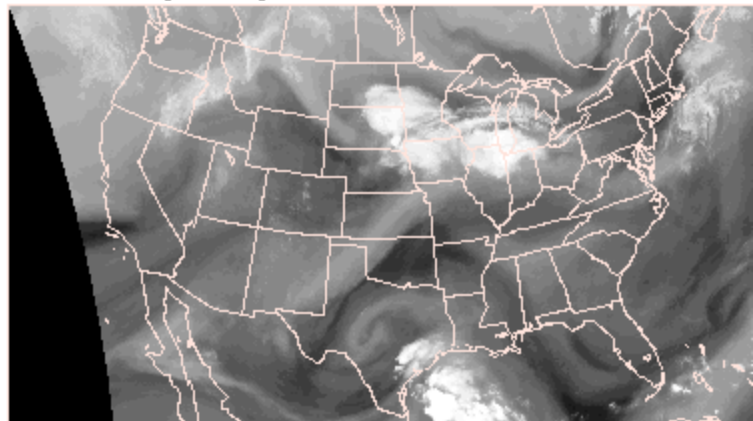
1715Z 29 JUN 2012



NCEP/NWS/NOAA

Water Vapor Image

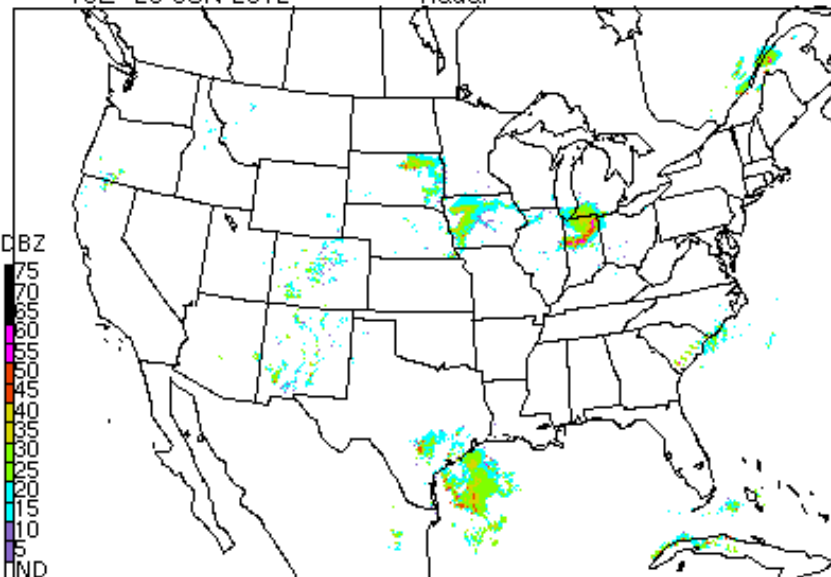
1715Z 29 JUN 2012



NCEP/NWS/NOAA

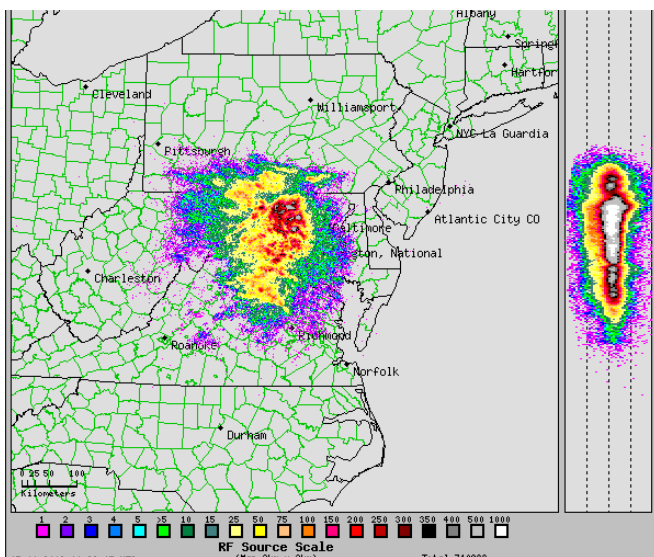
19Z 29 JUN 2012

Radar



NCEP/NWS/NOAA

NATIONAL 2 KM BASE REFLECT 0.00 DEG



07/01/2012 18:09:15 UTC

Fri Jun 29, 2012

RF Source Scale

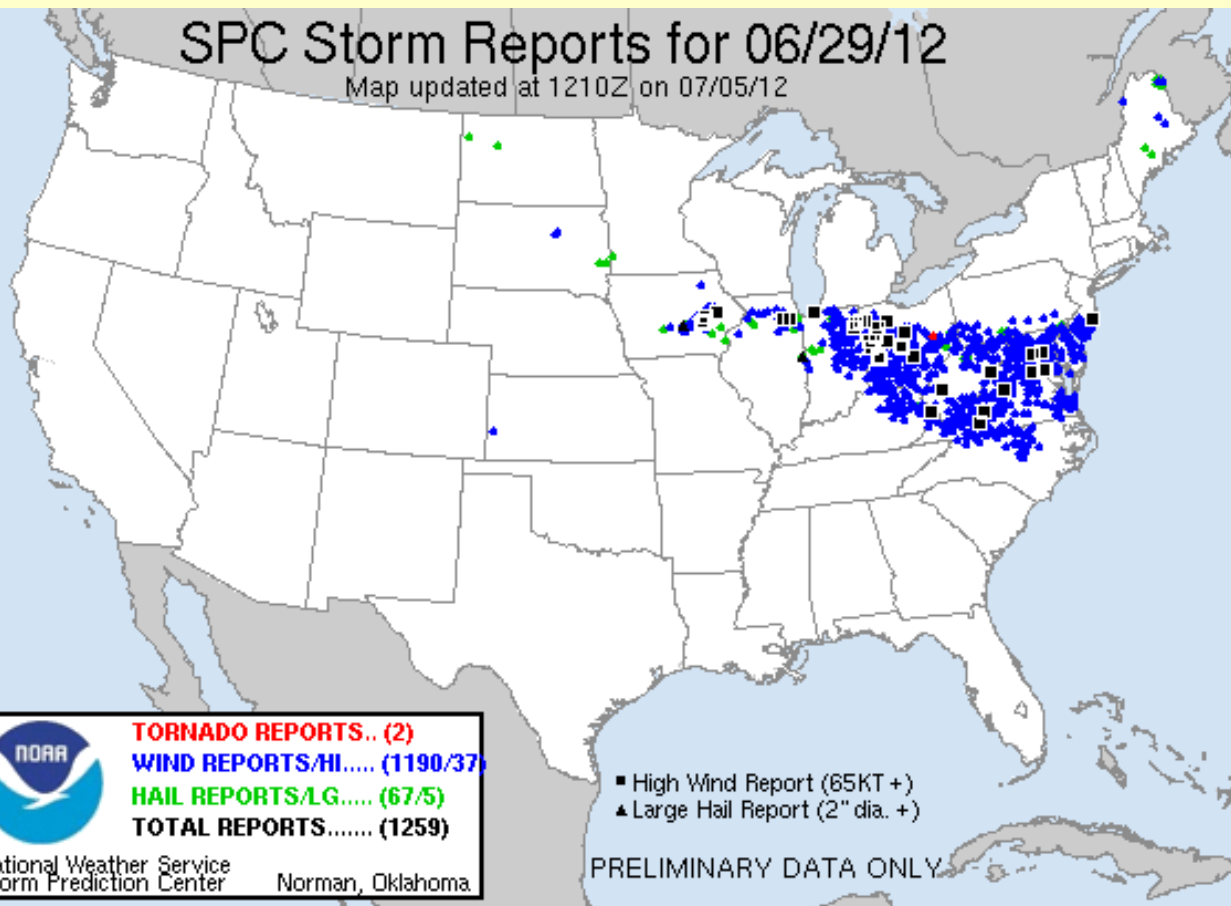
Saturday June 30, 2012 (1000 km)

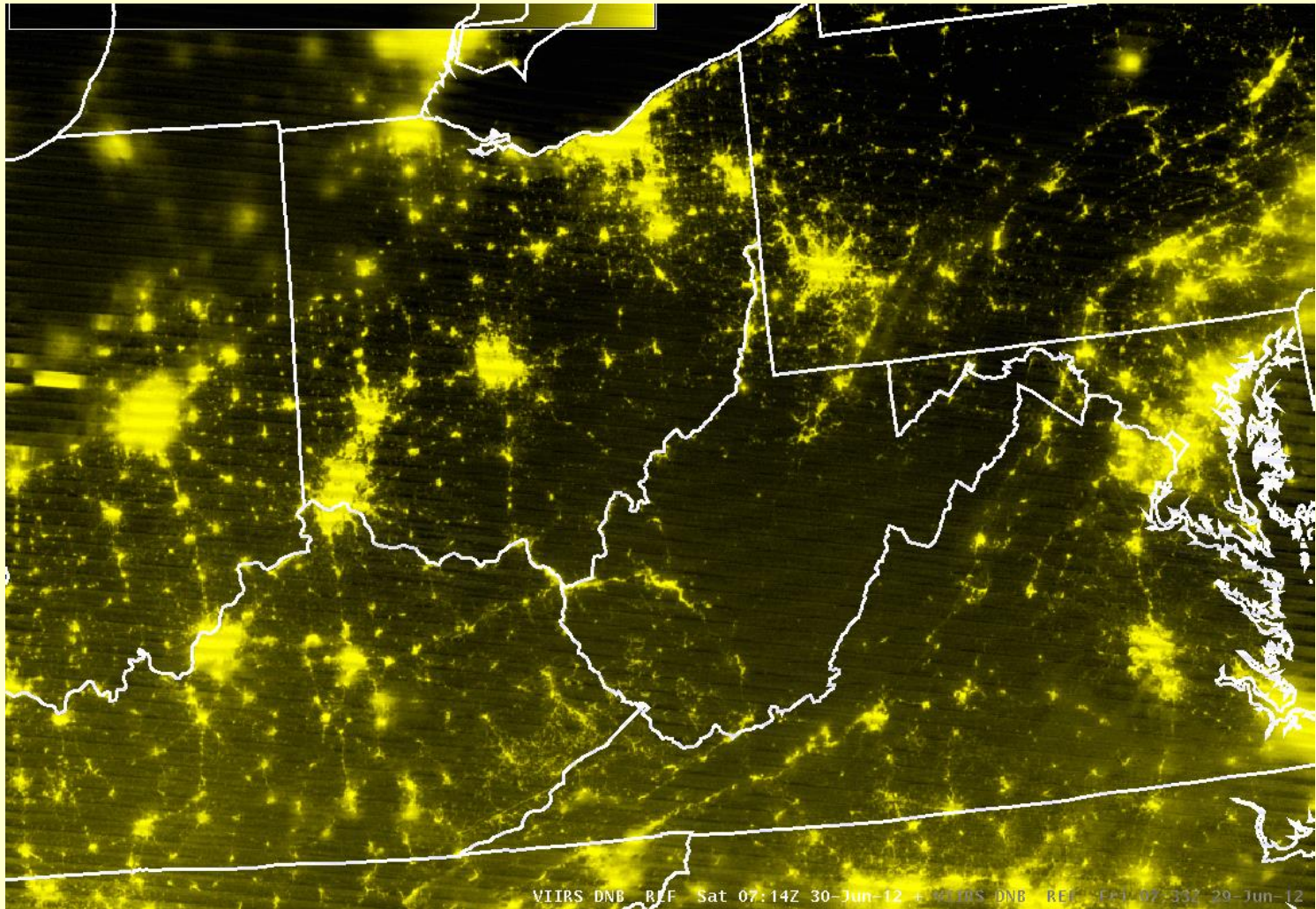
Total 719988

Sun Jul 01, 2012

SPC Storm Reports for 06/29/12

Map updated at 1210Z on 07/05/12





4 AM Friday morning vs 4 AM Saturday morning

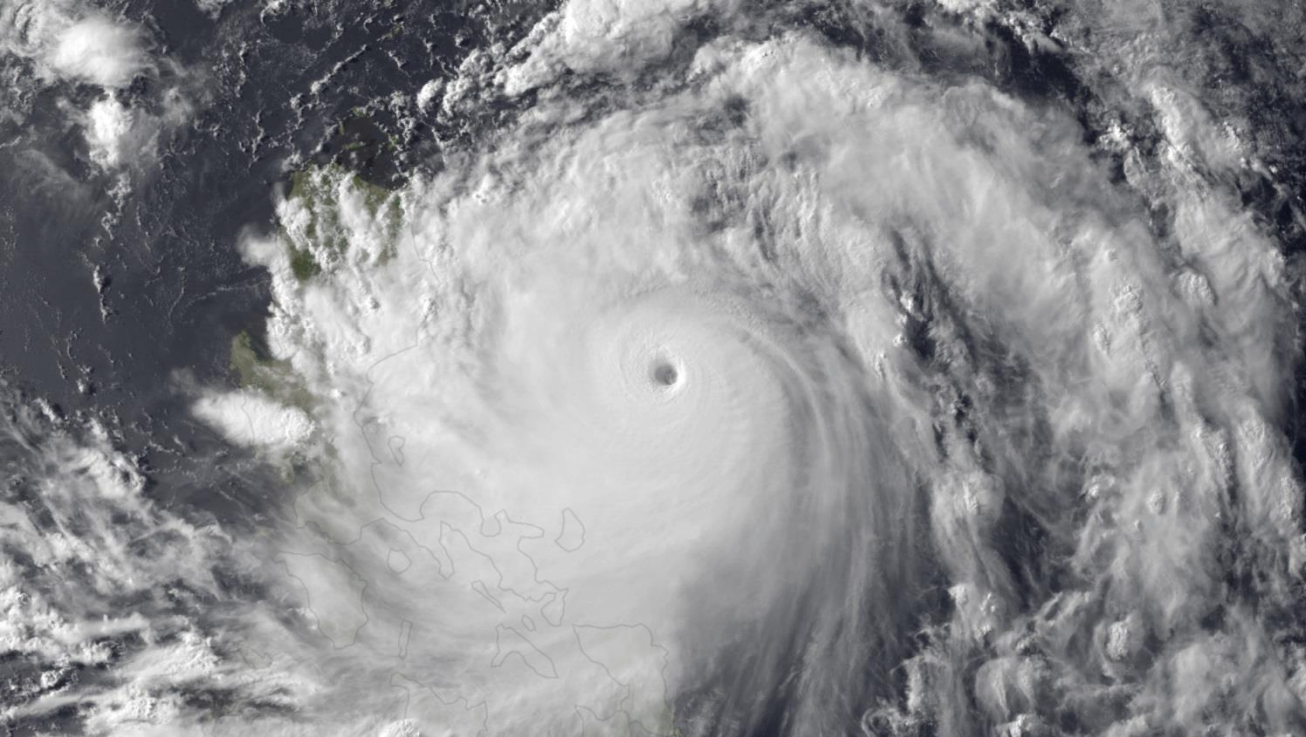
17 deaths

**1.25 million
w/o power**

**Montgomery Co.,
MD
38.6%**

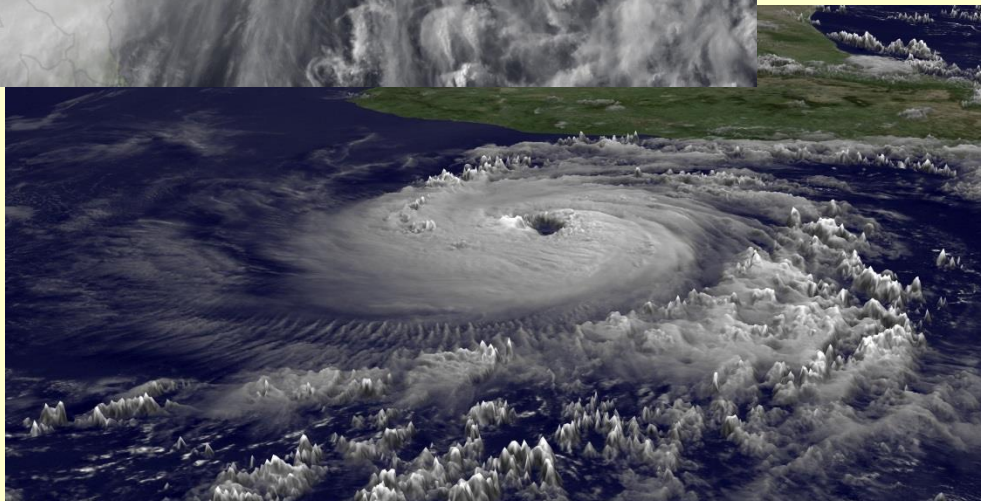


Hurricanes



Supertyphoon Songda
26 May 2011

Hurricane Adrian
9 June 2011

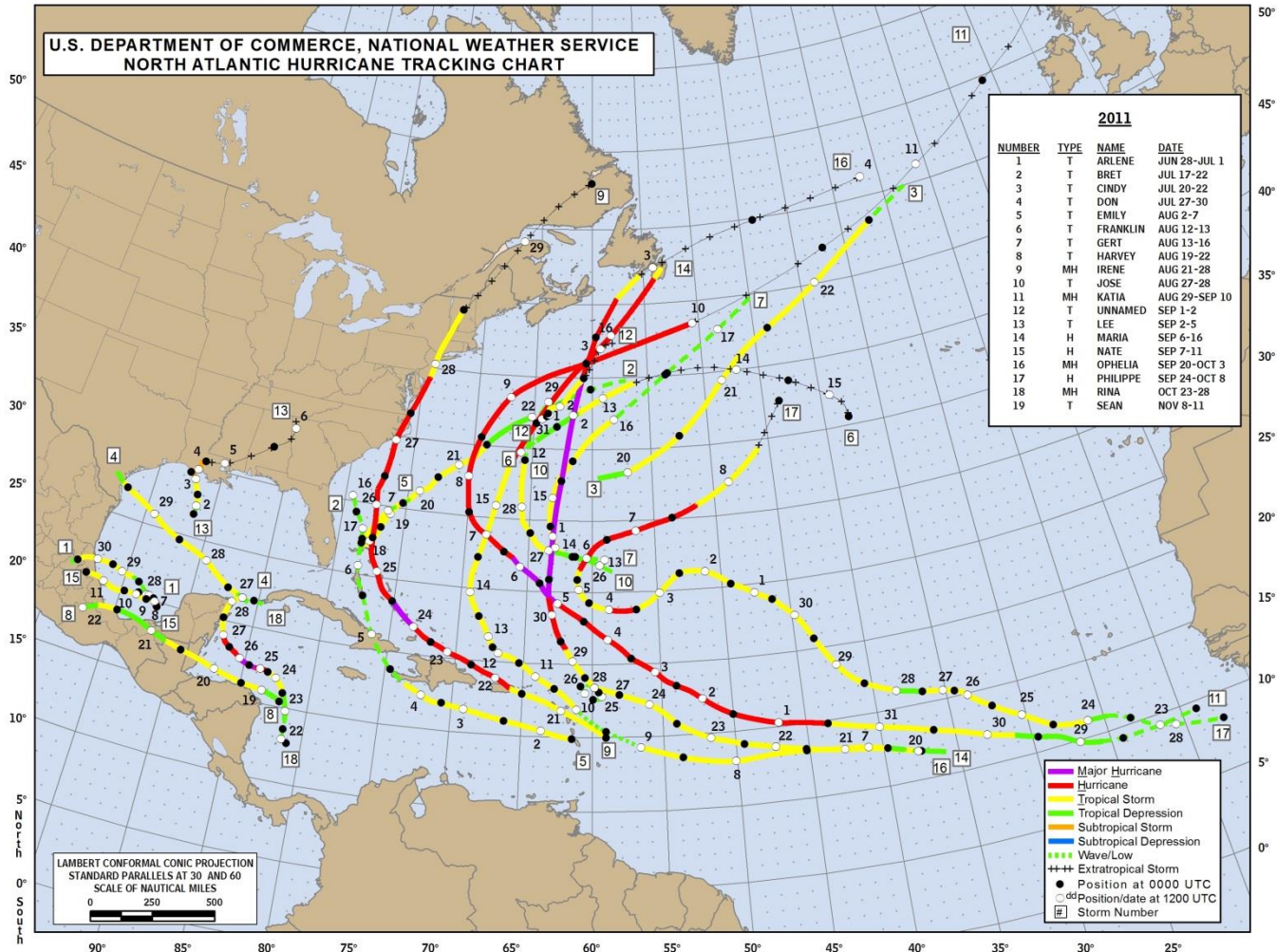


120° 115° 110° 105° 100° 95° 90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25° 20° 15° 10° 5° West 0° East 5° 10°

**U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART**

2011

NUMBER	TYPE	NAME	DATE
1	T	ARLENE	JUN 28-JUL 1
2	T	BRET	JUL 17-22
3	T	CINDY	JUL 20-22
4	T	DON	JUL 27-30
5	T	EMILY	AUG 2-7
6	T	FRANKLIN	AUG 12-13
7	T	GERT	AUG 13-16
8	T	HARVEY	AUG 19-22
9	MH	IRENE	AUG 21-28
10	T	JOSE	AUG 27-28
11	MH	KATIA	AUG 29-SEP 10
12	T	UNNAMED	SEP 1-2
13	T	LEE	SEP 2-5
14	H	MARIA	SEP 6-16
15	H	NATE	SEP 7-11
16	MH	OPIHELIA	SEP 20-OCT 3
17	H	PHILIPPE	SEP 24-OCT 8
18	MH	RINA	OCT 23-28
19	T	SEAN	NOV 8-11



LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF NAUTICAL MILES
0 250 500

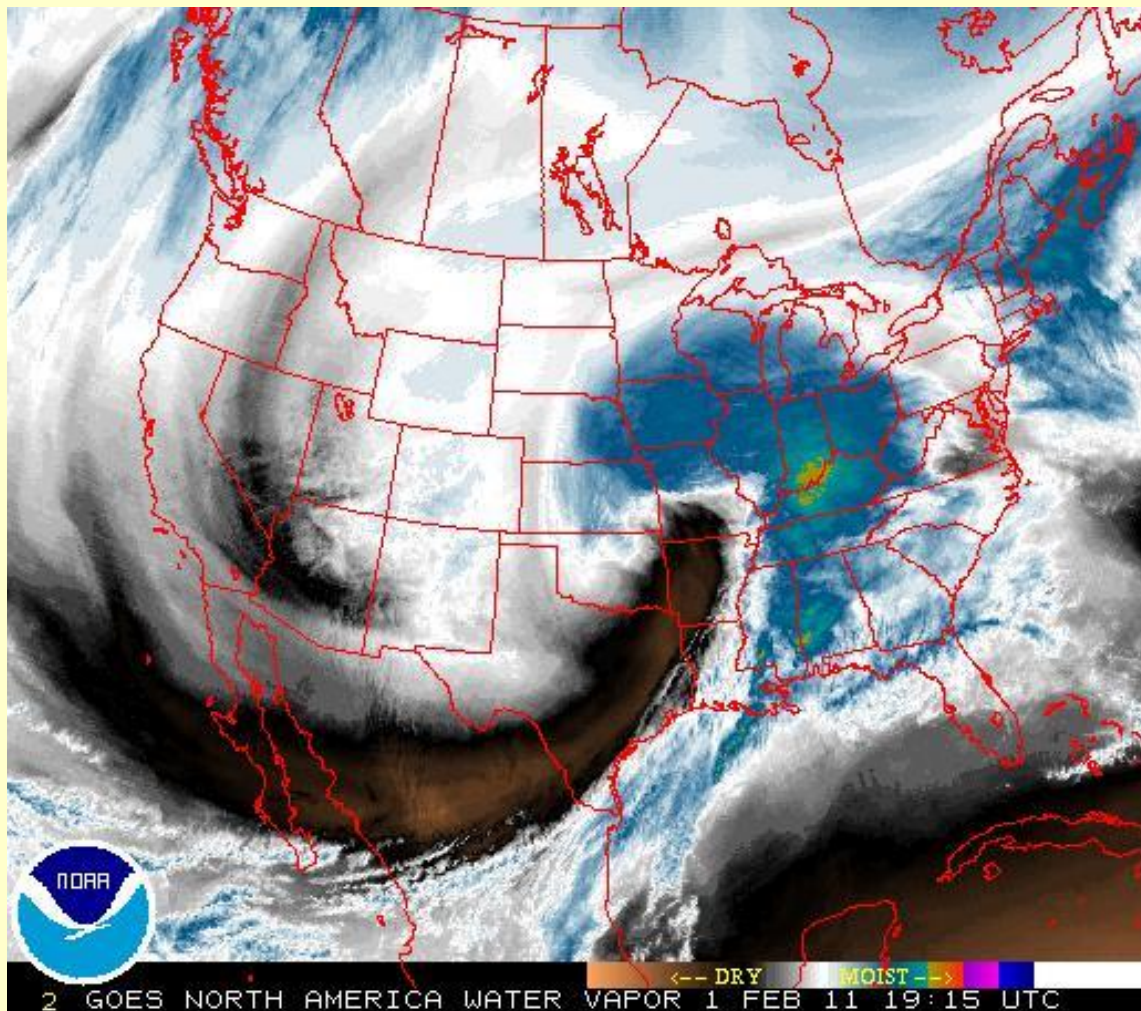
— Major Hurricane
— Hurricane
— Tropical Storm
— Tropical Depression
— Subtropical Storm
— Subtropical Depression
- - - Wave/Low
+++ Extratropical Storm
● Position at 0000 UTC
○ Position/date at 1200 UTC
 Storm Number

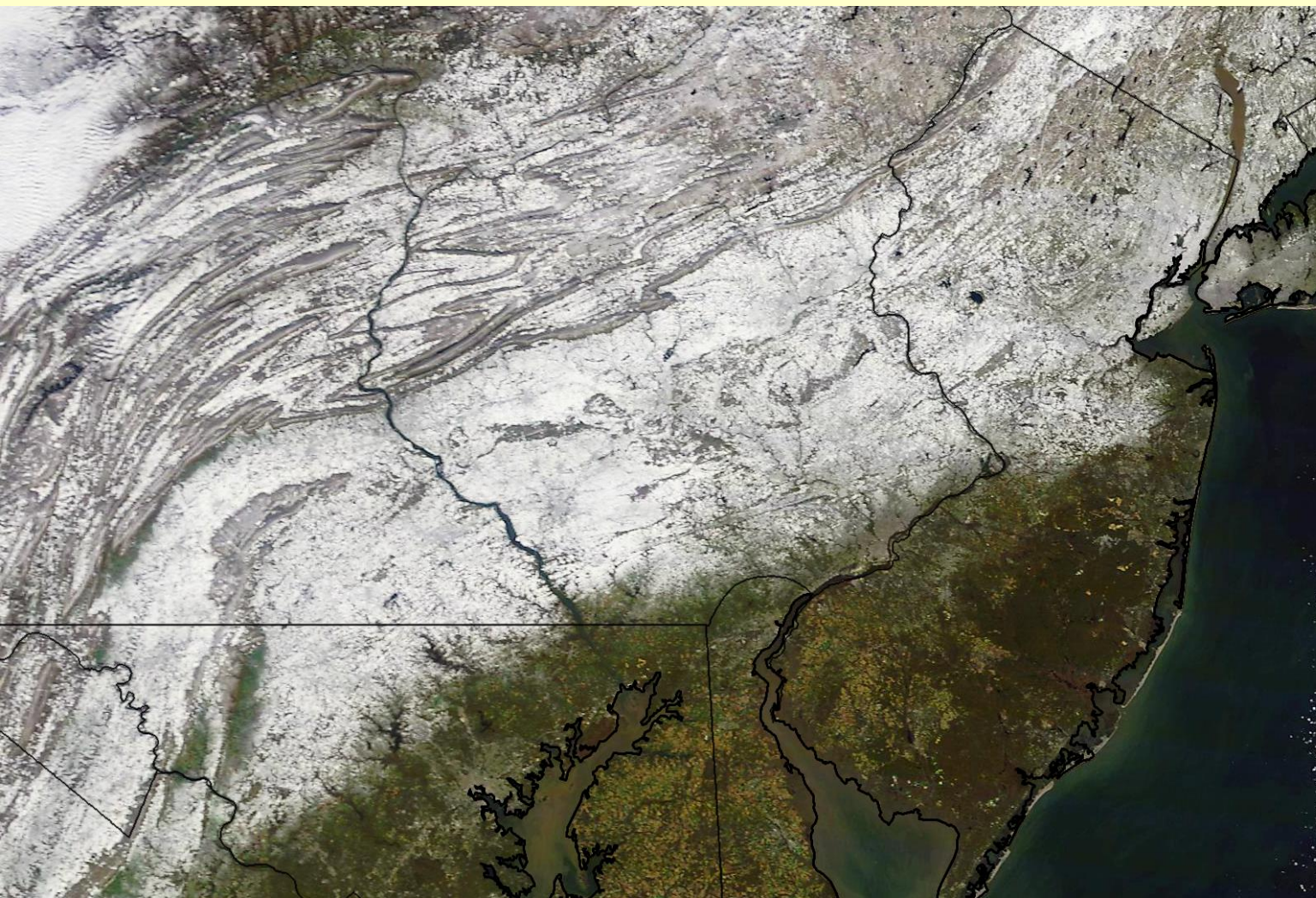
5° North
0°
5° South

50°
45°
40°
35°
30°
25°
20°
15°
10°
5°
0°

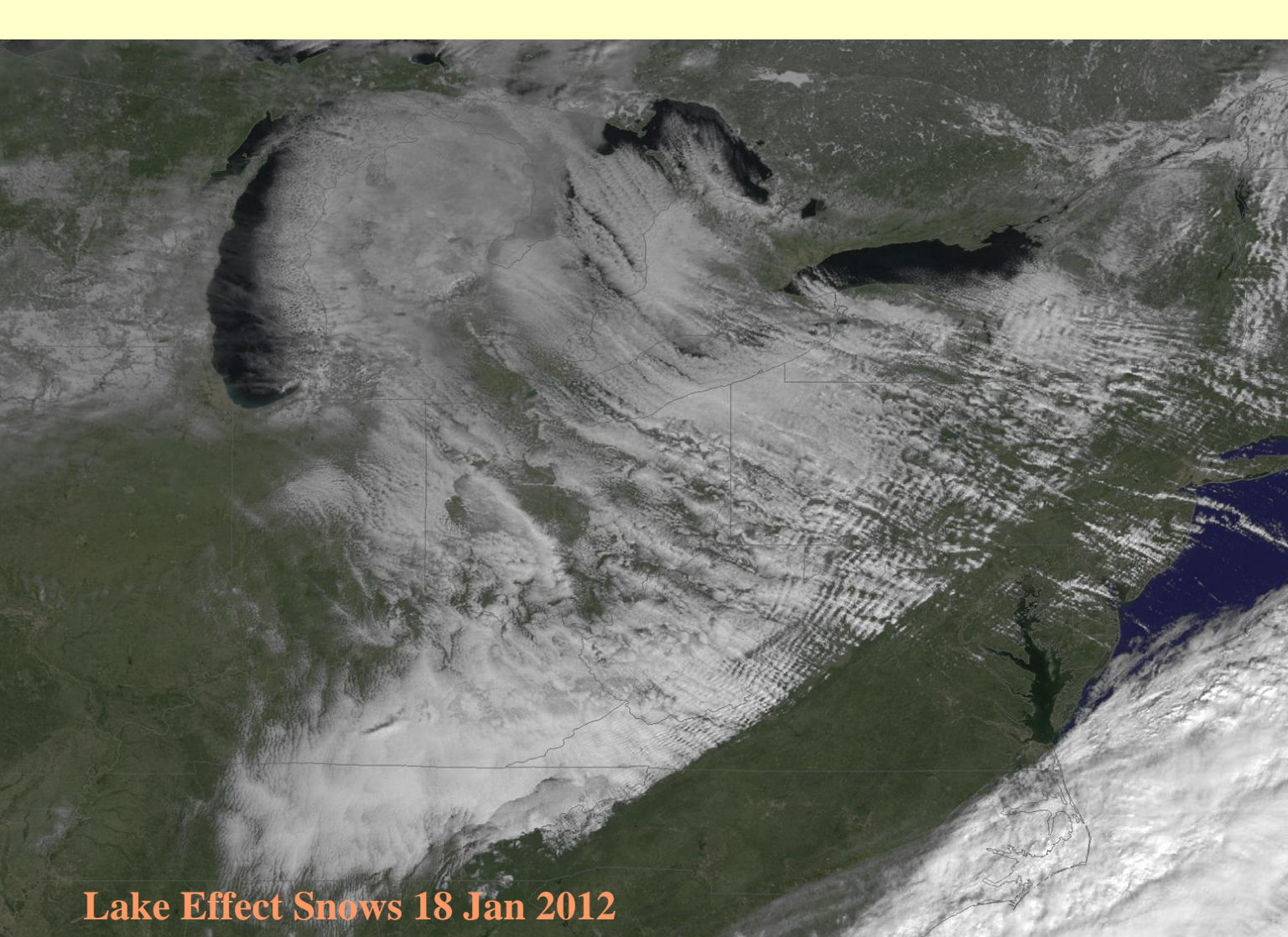
90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25°

Winter Storms





Halloween Storm 2011



Lake Effect Snows 18 Jan 2012

Blowing Dust

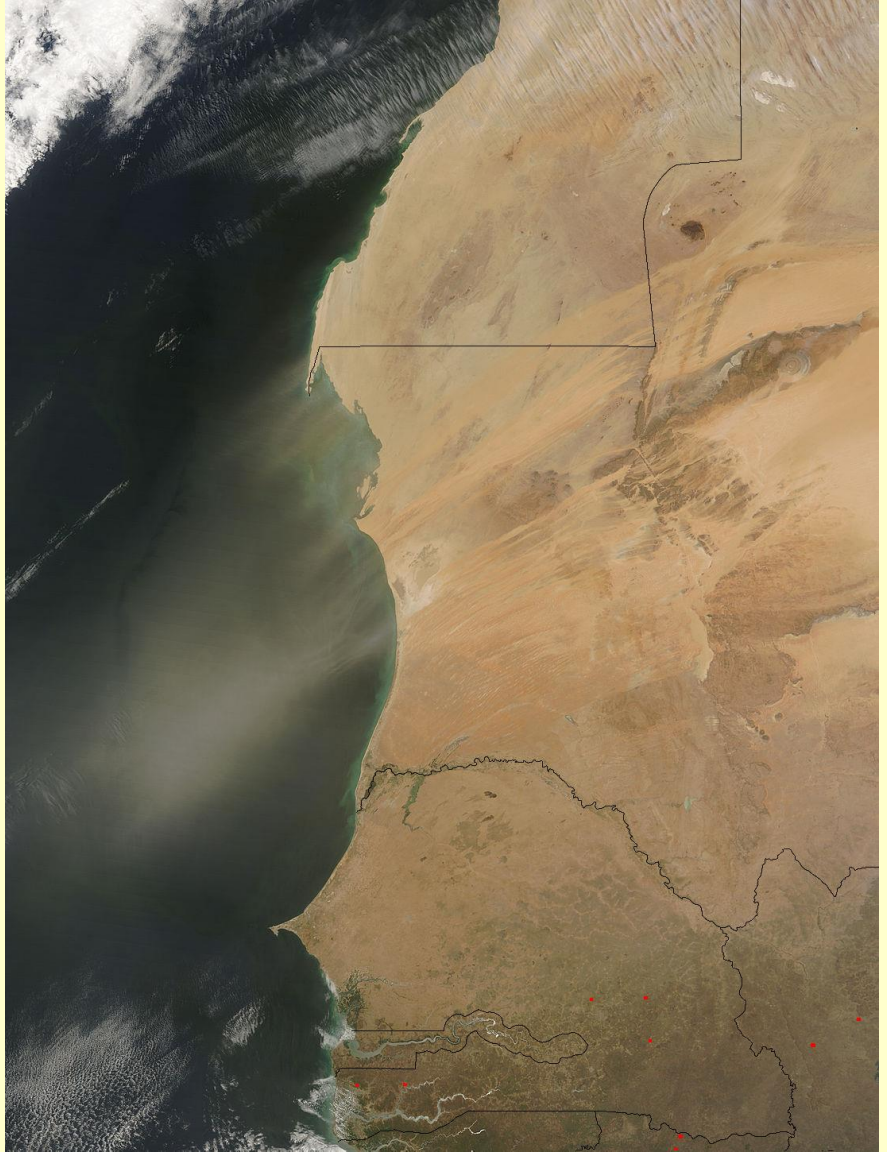
- Hazard to visibility and breathing.
- Reveal wind patterns.

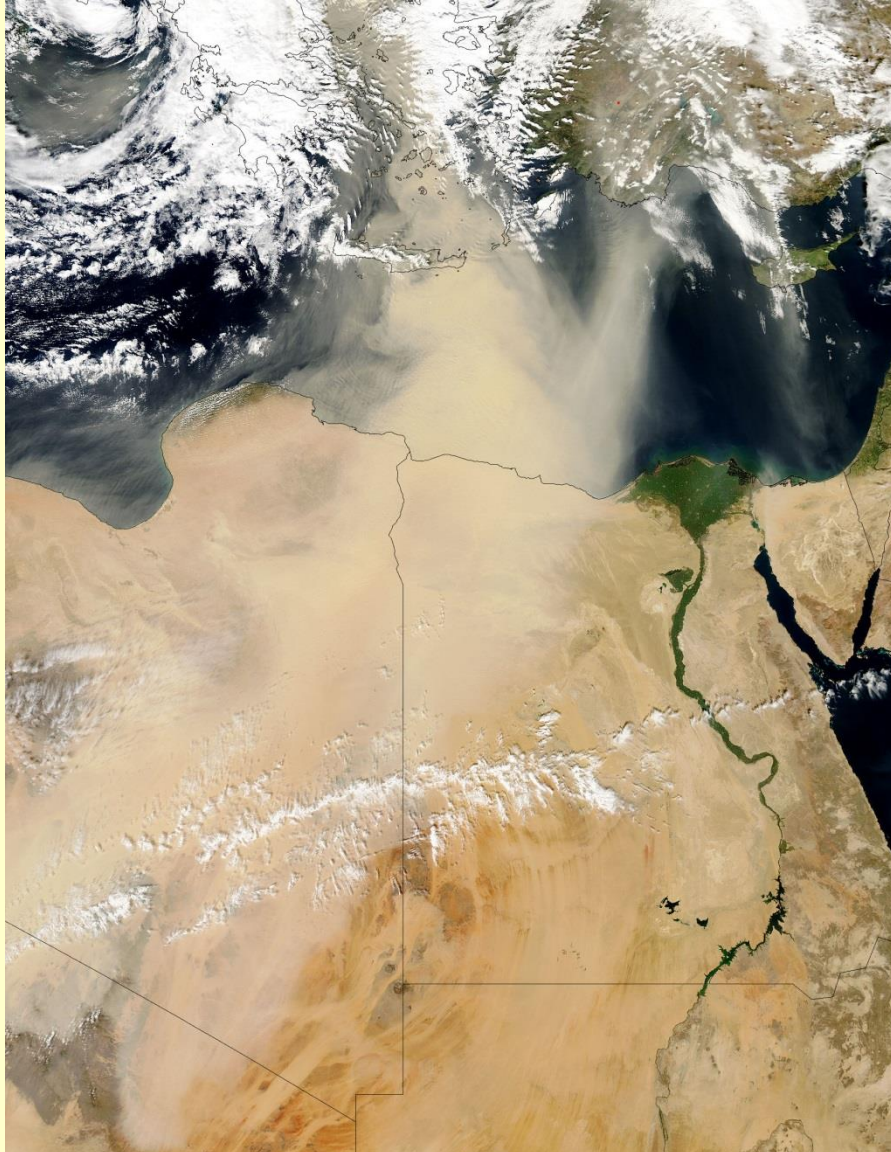


July 5, 2011

A giant dust storm known as a "haboob" covers Phoenix on Tuesday. The National Weather Service reported winds upwards of 60 mph in the area.
Rob Schumacher / AP

**Dust
from
Sahara**

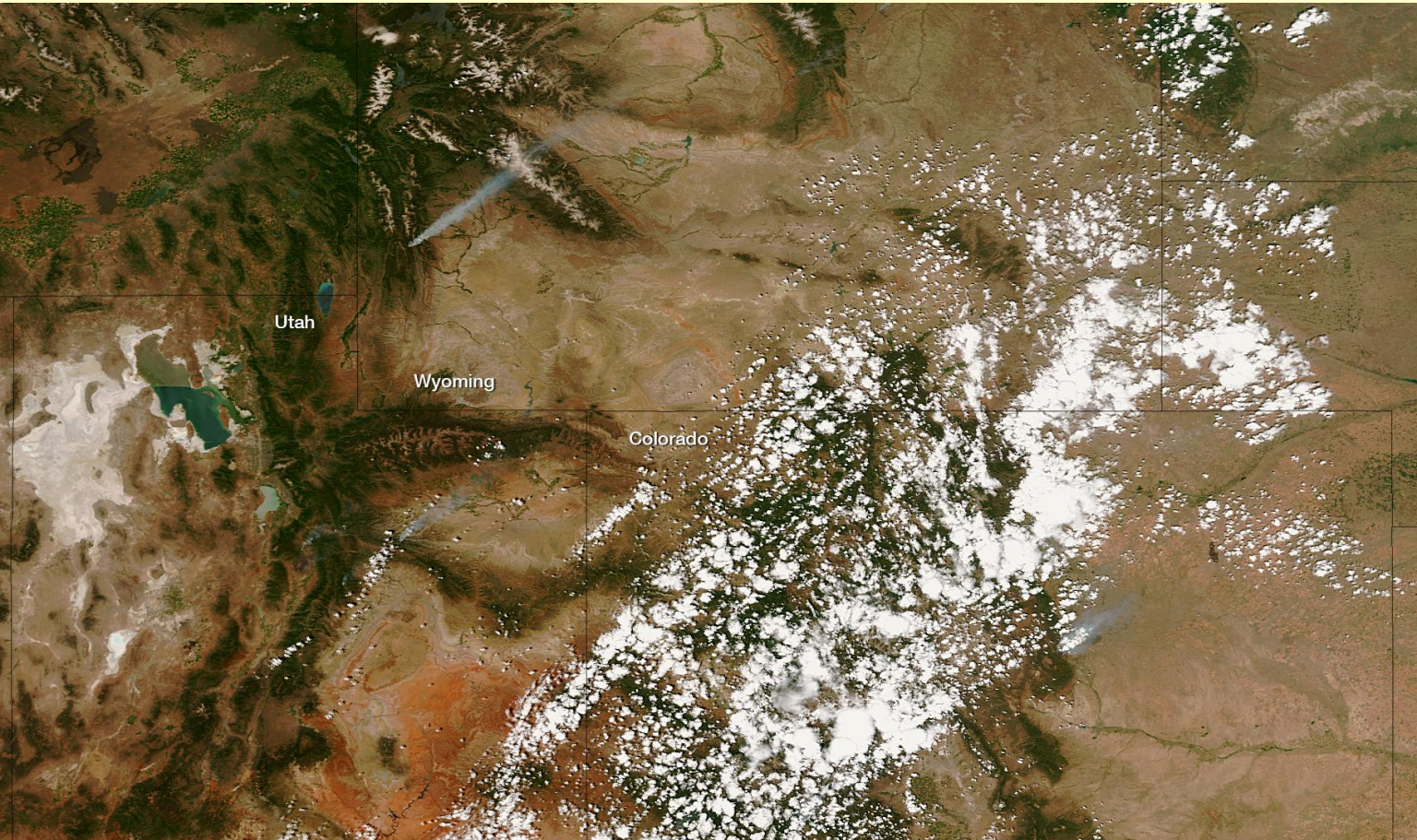




**Dust from
Sahara over
Mediterranean Sea**

Fire and Smoke

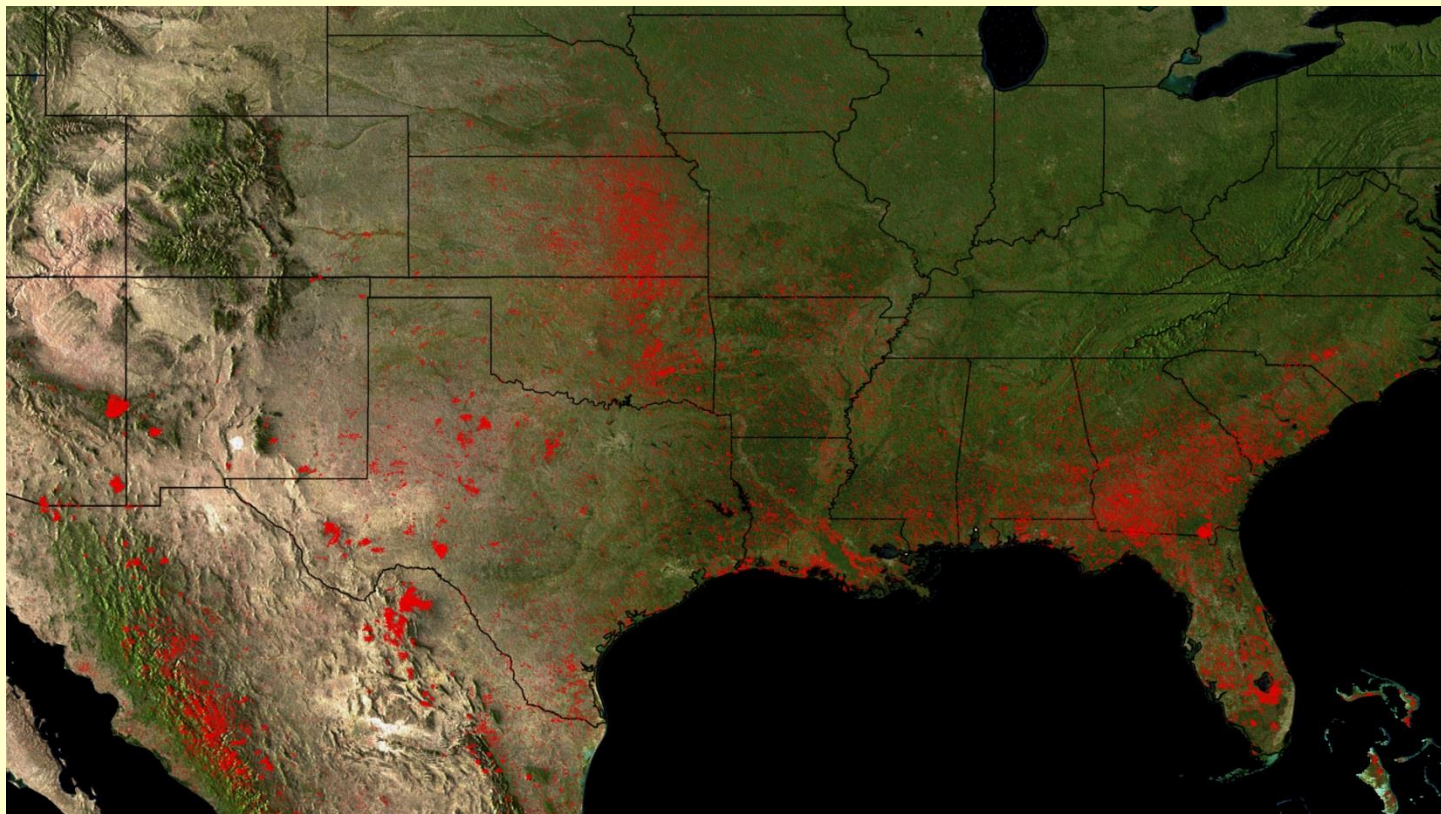
Wyoming, Colorado Wildfires – 26 June 2012



2011 Wildfires

~ 346,000

[NOAA AVHRR, GOES Imager, MODIS]



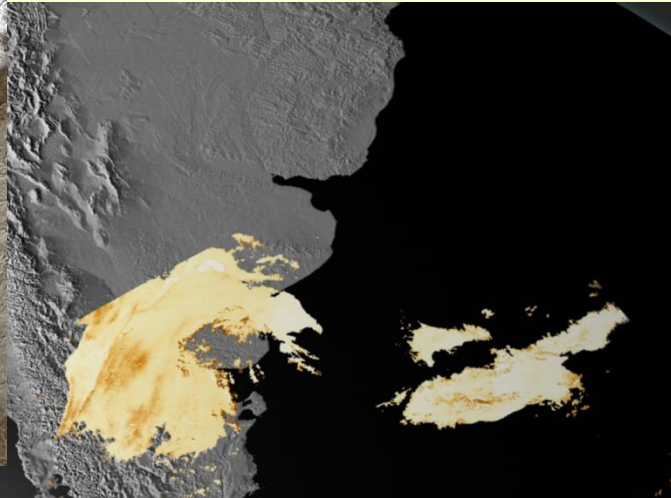
Volcanoes

Puyehue-Cordón

Chile

9 July 2011

Ash Cloud
13 June 2011



Cryosphere **(Ice, Snow)**

06 March 2009

Wilkins Ice Bridge Breakup



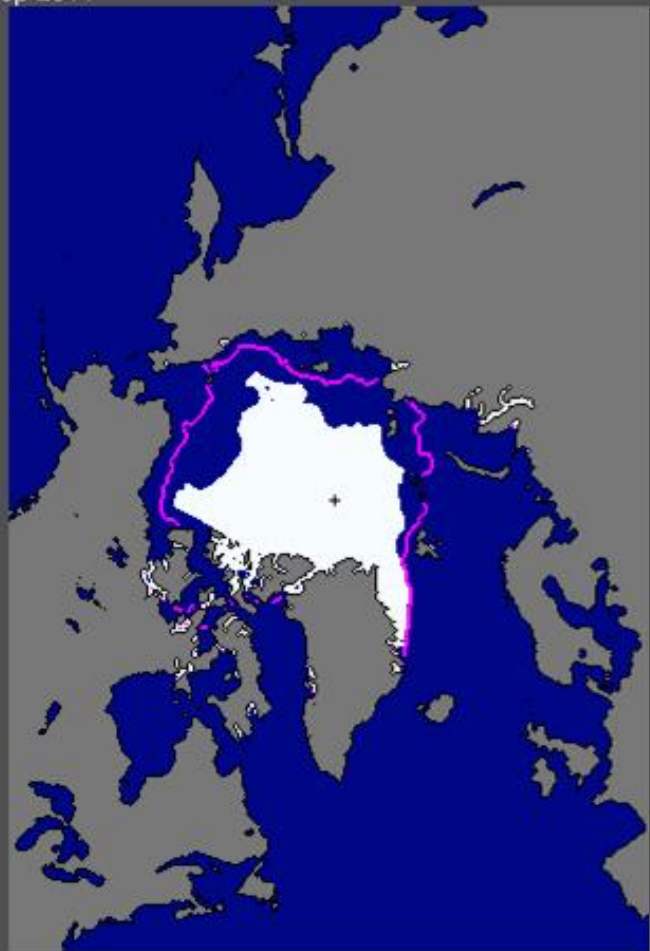
A satellite image showing a large ice island in the ocean east of Newfoundland. The image is a composite of satellite data, with a black outline tracing the coastline of Newfoundland and the surrounding ice fields. A white box in the lower-left corner indicates the area shown in the main image. The ice island is a large, irregularly shaped mass of white ice floating in the dark ocean. The surrounding ice fields are more fragmented and textured.

Ice Island east of Newfoundland

from Petermann
Glacier
30 June 2011

[MODIS Aqua]

Sea Ice Extent
Sep 2011



Total extent = 4.6 million sq km

Sea Ice Extent
Mar 2012



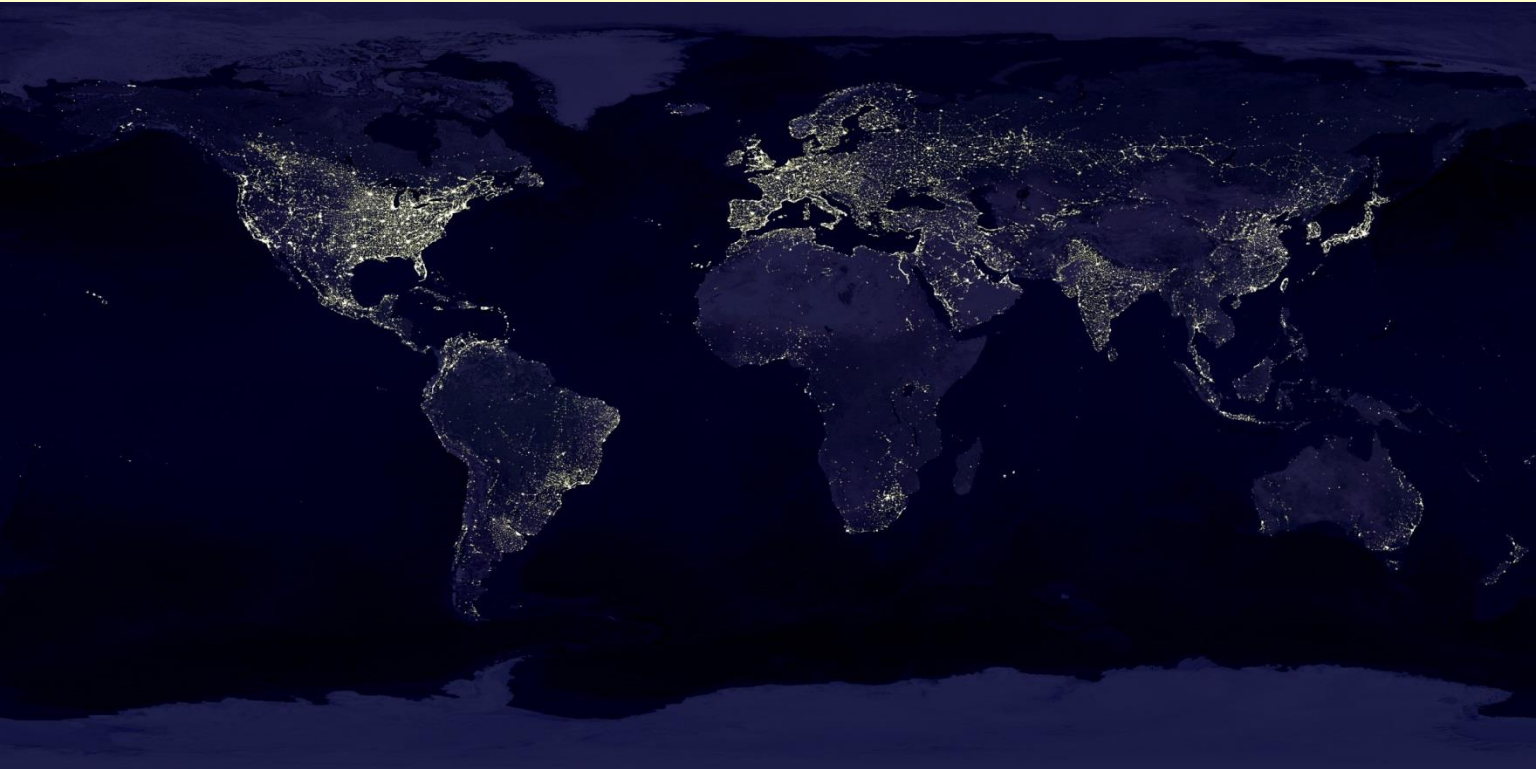
Total extent = 15.2 million sq km

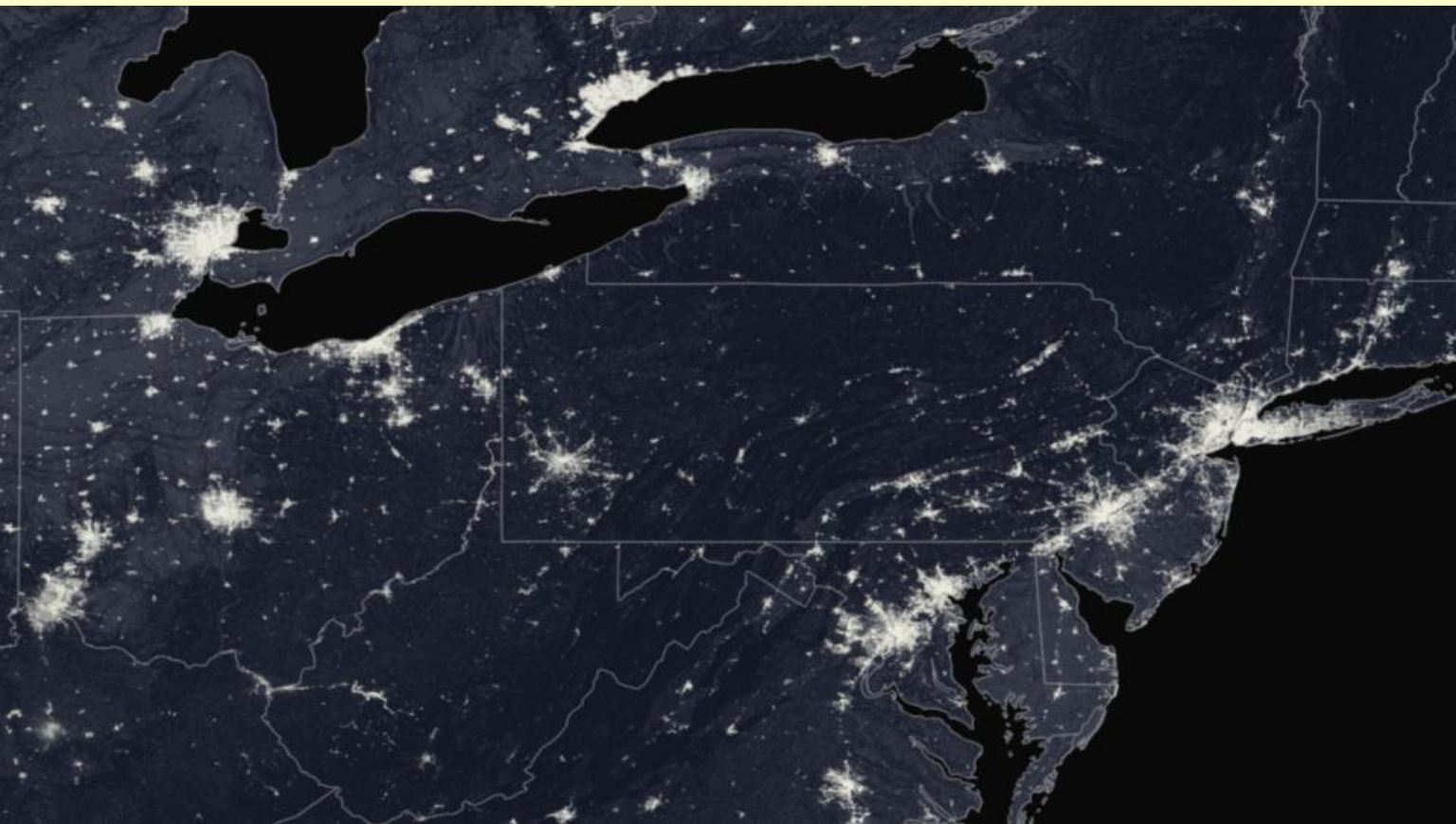
National Snow and Ice Data Center, Boulder, CO

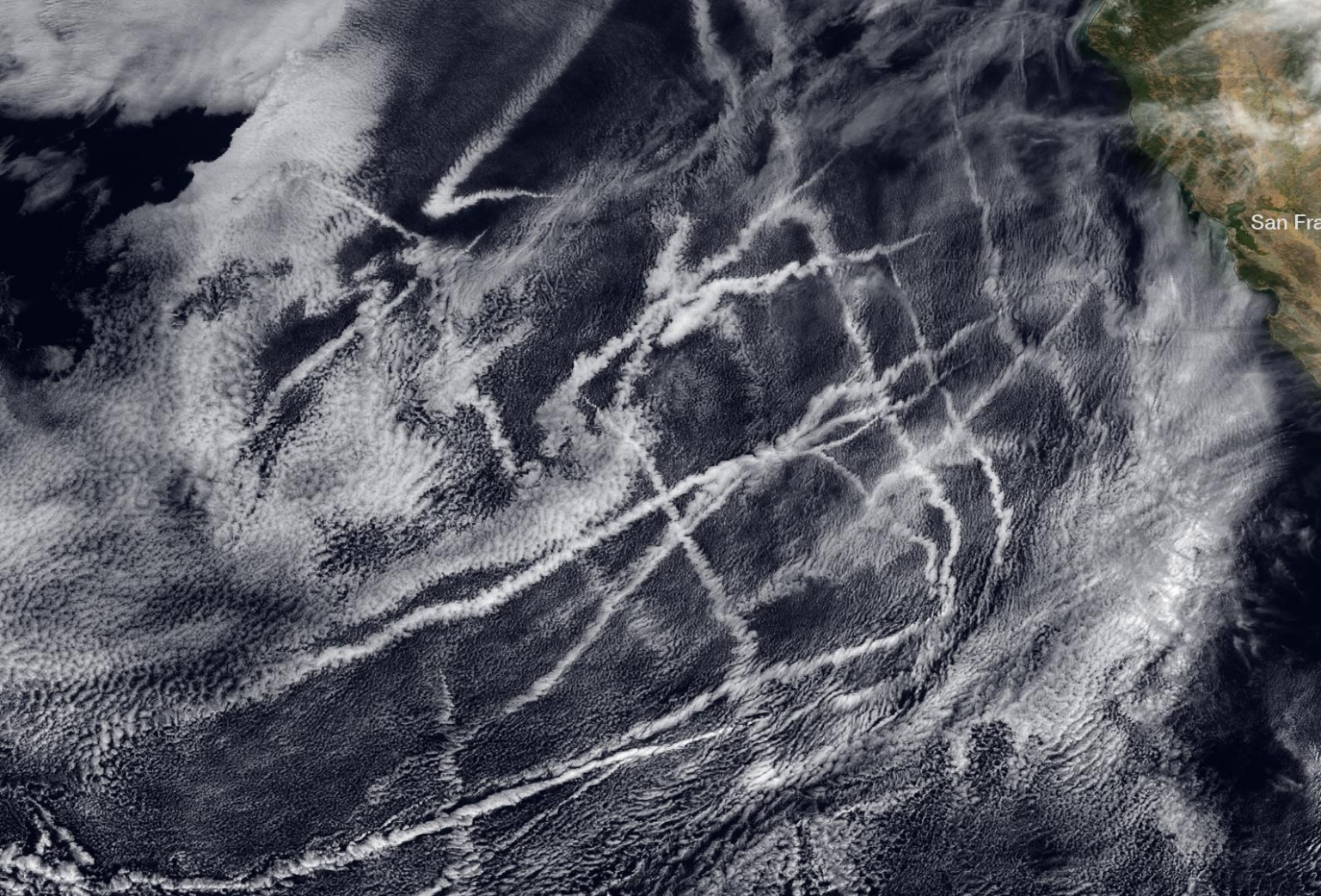
red
ice edge

Satellite Derived Products

“Earth shine”



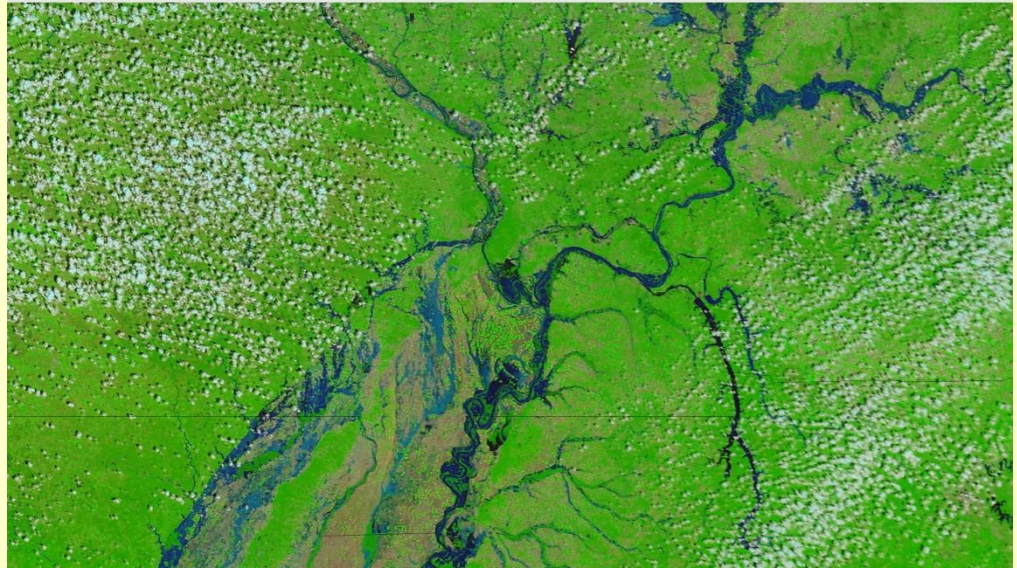
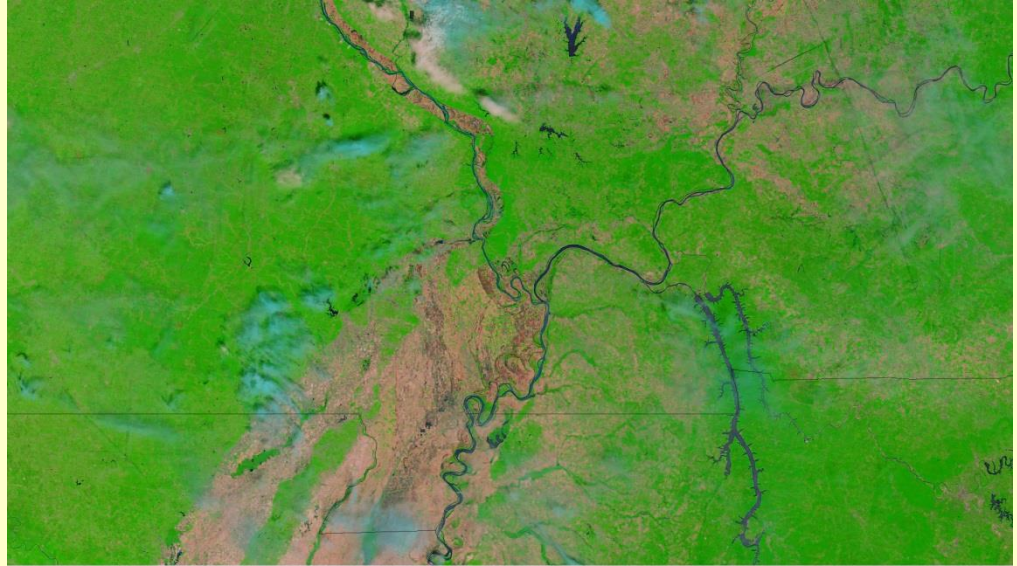




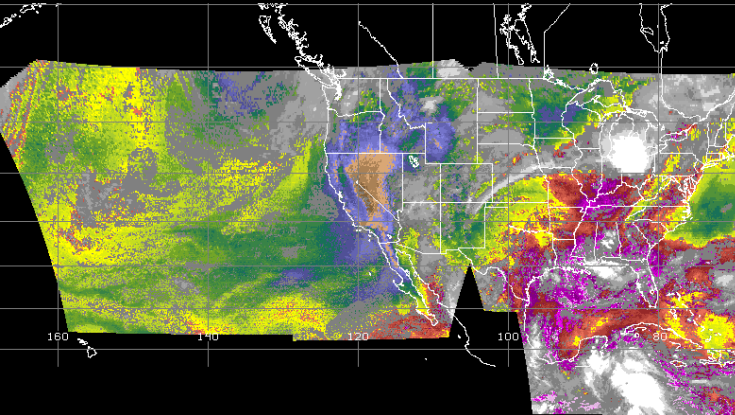
“Ship Tracks” – 2/12/2012

Mississippi – Ohio River Flooding

28 – 29 April 2011

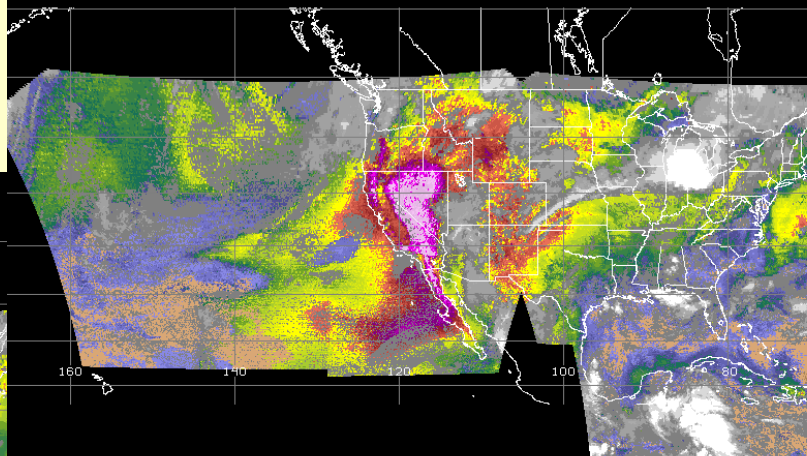


TPW 7/11/2011 18Z

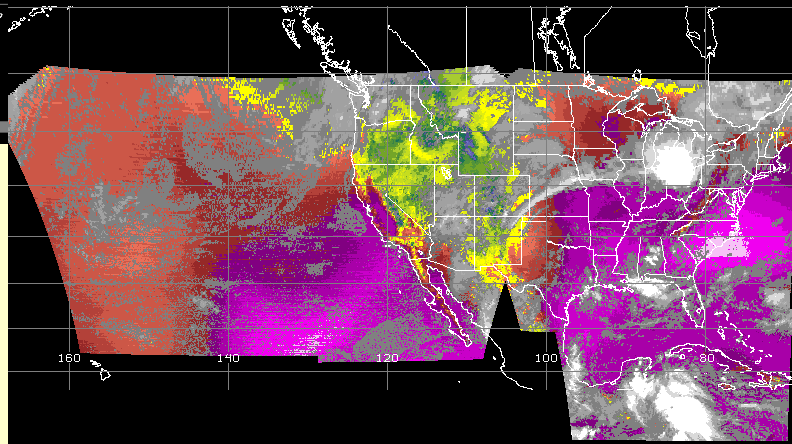


0 7 13 20 27 34 40 47 54 60 67
14 GOES TOTAL PRECIPITABLE WATER (MM) 11 JUL 11 18:00GMT

CCL 7/11/2011 17Z



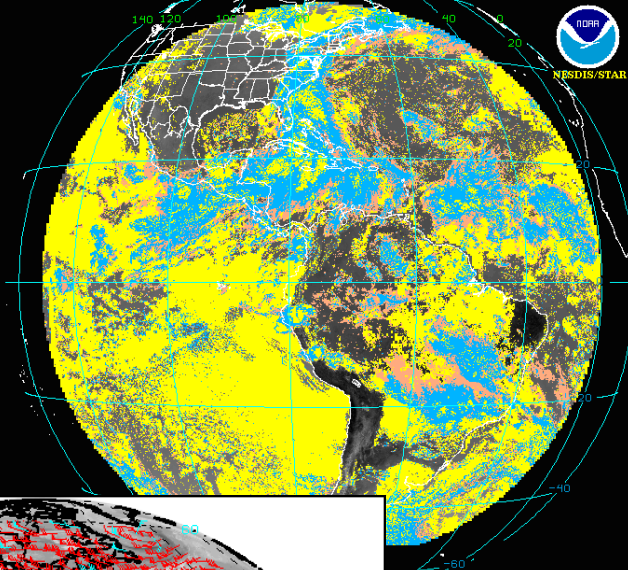
1000 940 880 820 760 700 640 580 520 460 400
1 FRZL 7/11/2011 18Z



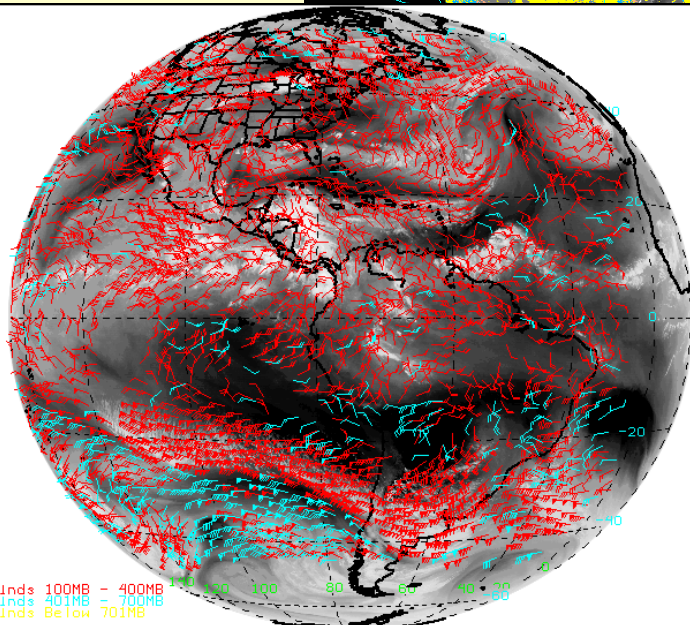
0 600 1200 1800 2400 3000 3600 4200 4800 5400 6000
14 GOES FREEZING LEVEL (M) 11 JUL 11 18:00GMT

Derived GOES Products

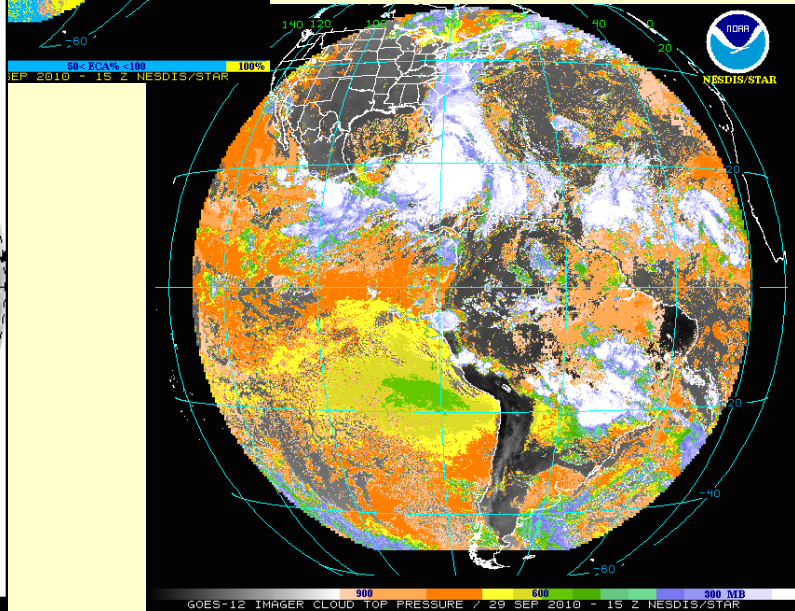
- Total Precipitable Water
- Convective Condensation Level
- Freezing Level



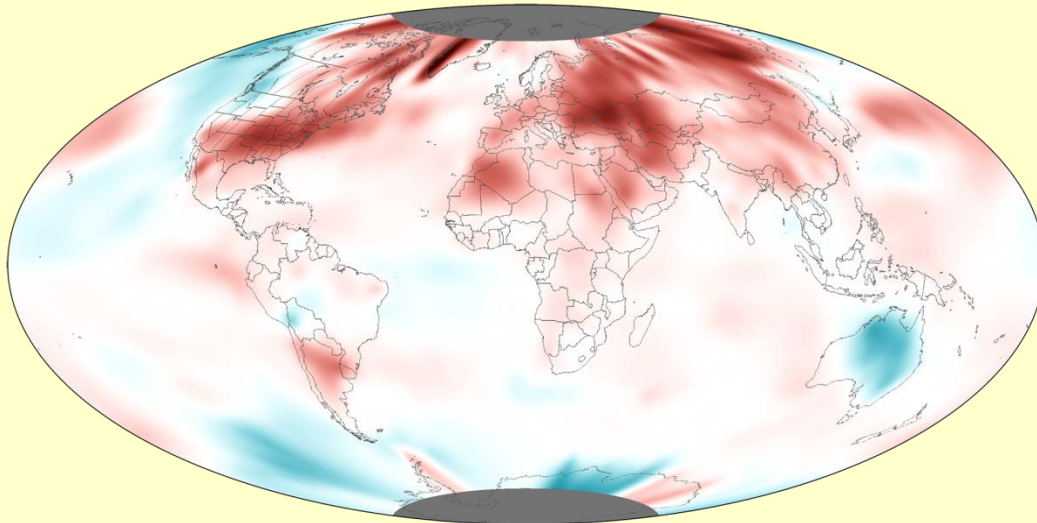
- Effective Cloud Amount
- Winds
- Cloud Top Pressure



Winds 100MB - 400MB
 Winds 401MB - 700MB
 Winds Below 701MB



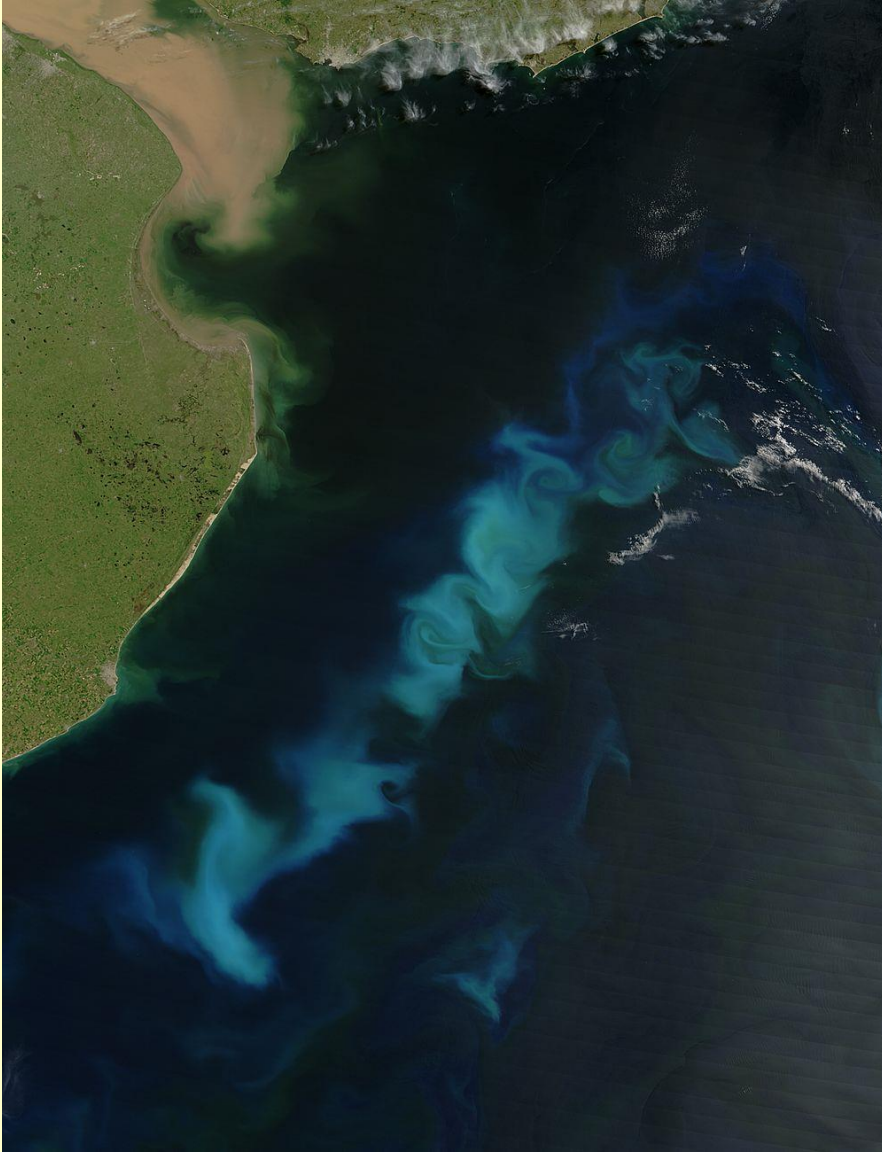
GOES-12 IMAGER CLOUD TOP PRESSURE / 29 SEP 2010 - 15 Z NESDIS/STAR



**May 2012
Temperature
Anomalies
(vs 1971-2000 avg)**

**GOES
Search
and
Rescue
saved 2,338 people
in 2010**

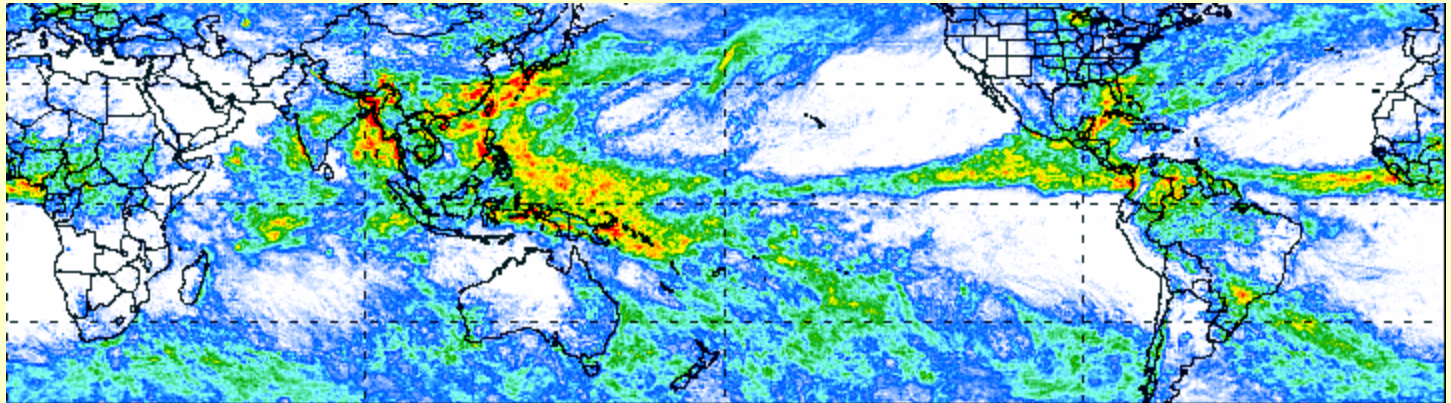




Off Argentina

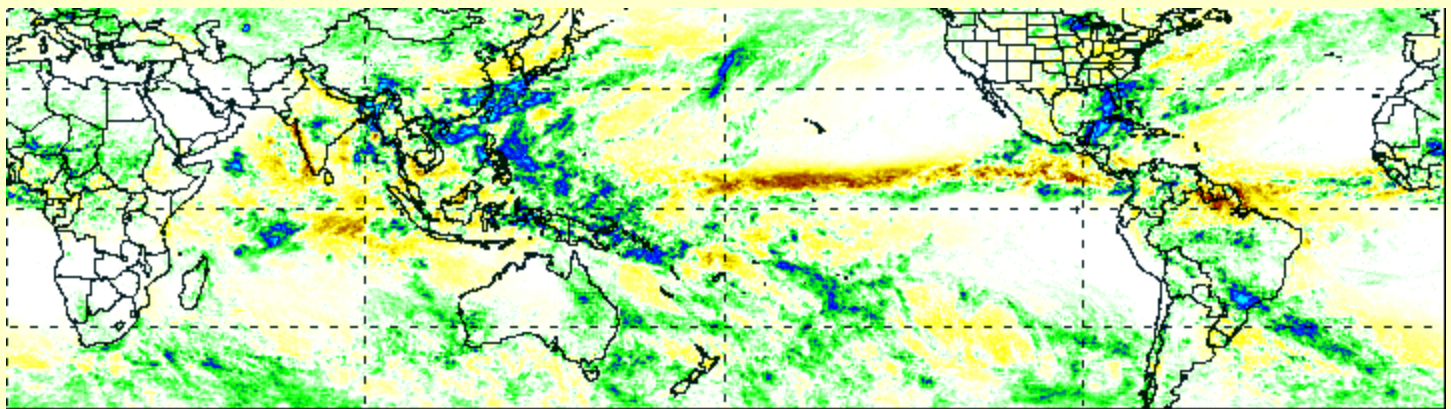
**sediment from Rio Plata
phytoplankton bloom**

TRMM – Tropical Rainfall Measuring Mission



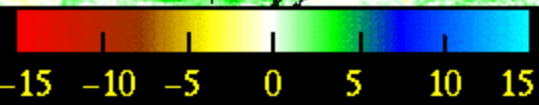
26 JUN 2012

Average Rainfall
For Last 30 Days (mm/d)



26 JUN 2012

Rainfall Anomalies
For last 30 Days (mm/d)



Summary

- Satellite imagery is the “real world”; not model “fantasy” world.
- See all atmospheric scales of motion in a single image.
- Identify features and postulate causes.
- Imagery can help explain weather events.
- Educate students (early age) in understanding our atmosphere through studying satellite imagery.

Satellite Links

Satellite Imagery and Loops:

<http://www.rap.ucar.edu/weather/satellite/>

Geostationary Satellite Server:

<http://www.goes.noaa.gov/>

RAMSDIS online:

http://rammb.cira.colostate.edu/ramsdgis/online/goes-west_goes-east.asp

NASA Global Hydrology and Climate Center:

<http://www.ghcc.msfc.nasa.gov/GOES/>

Space, Science and Engineering Center, U of Wisconsin, Madison:

<http://www.ssec.wisc.edu/data/>

Satellite Education:

<http://noaasis.noaa.gov/NOAASIS/ml/education.html>

Satellite learning links:

<http://noaasis.noaa.gov/NOAASIS/ml/education.html>

GOES Status:

<http://www.oso.noaa.gov/goesstatus/>

POES Status:

<http://www.oso.noaa.gov/poesstatus/>