Introduction to GOES-10
Part 2: Products/applications

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Research Satellite Meteorologists

NOAA/NESDIS/ORA(STAR)

Advanced Satellite Products Branch (ASPB)

Madison, WI

and many, many others

Cachoeira Paulista - São Paulo

26-30 November 2007

CIMSS

UW-Madison

Applications and products, and applications and products… from GOES

Image interpretation (…Oliver, Fujita, Purdom, Weldon, Gurka, Maddox, Adler, Heymsfeld, McCann, Forbes, and many more describing fog dissipation, intersecting cloud lines, dynamic/frontal patterns, overshooting thunderstorm tops, enhanced "V"s, MCC/MCS, and many more weather applications.)

Other **quantitative products**:

- motion vector winds, Dvorak tropical storm index

- SST, land surface temperature, fog product

- fires/smoke, SO2, O3

- cloud top temperature/effective cloud amount

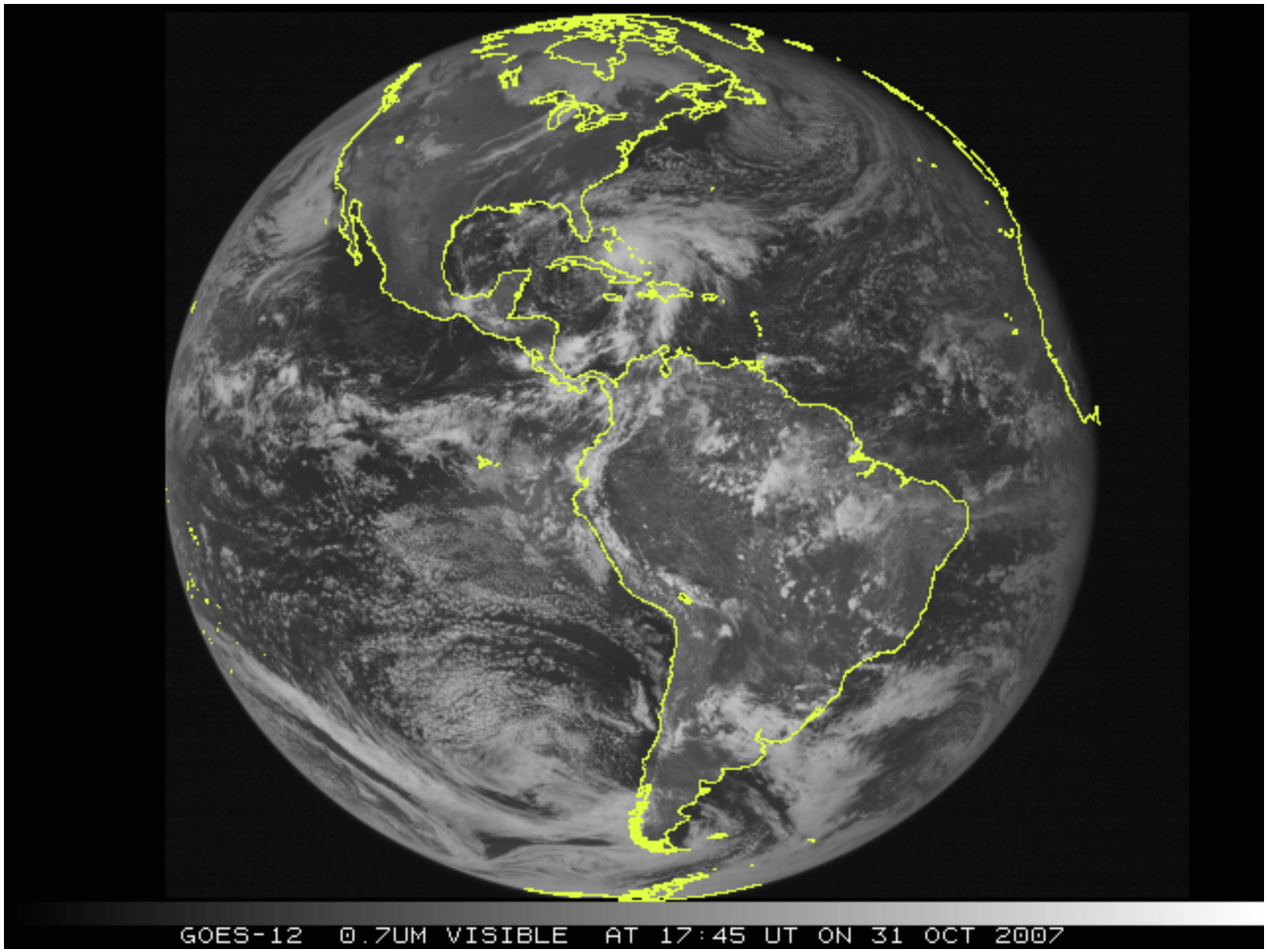
- precipitation estimates, convective downburst index

- vertical profiles (and their derivatives); assimilation of radiances and their derivatives (including profiles)

Imager

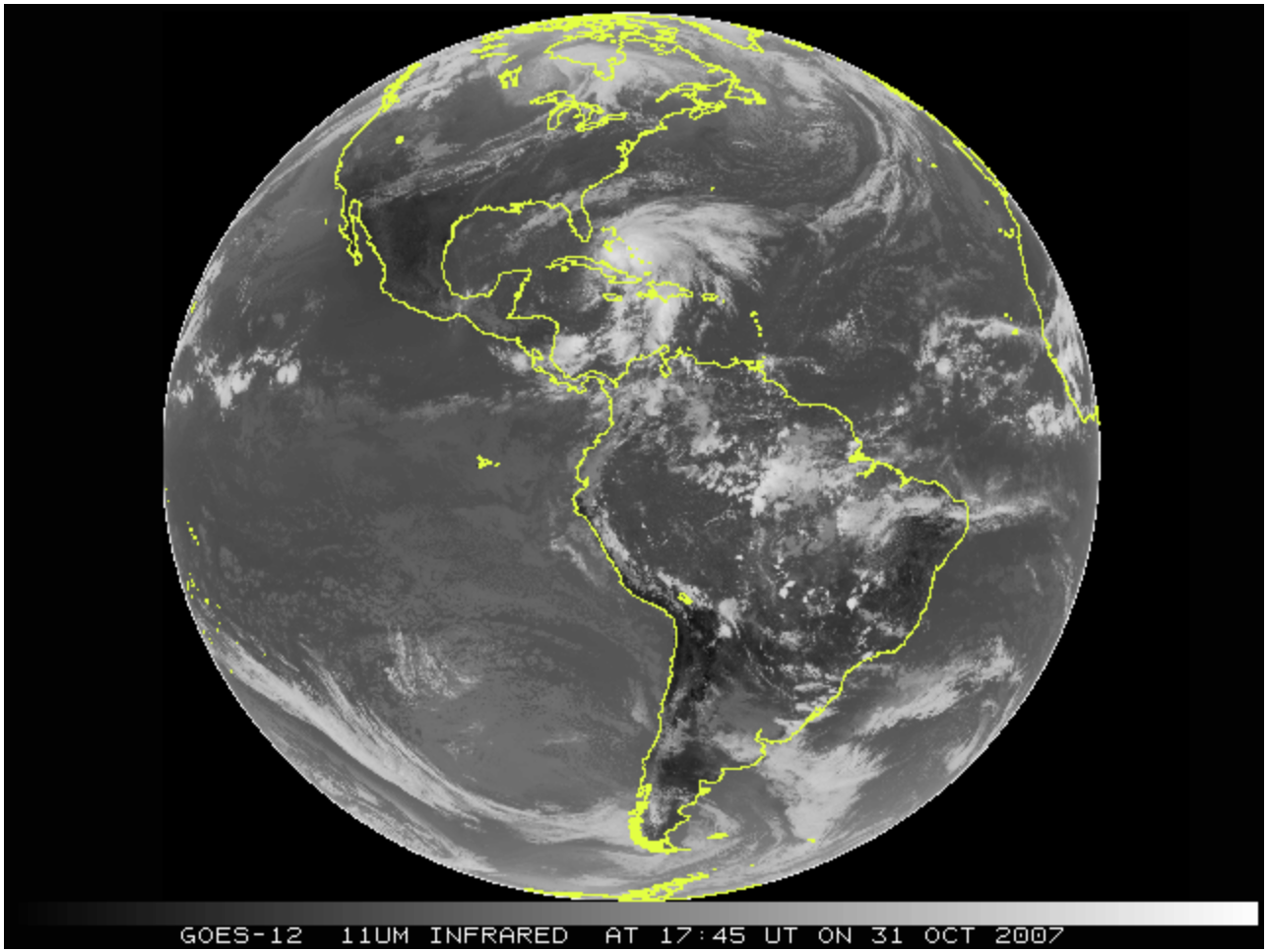
Sounder

GOES Visible



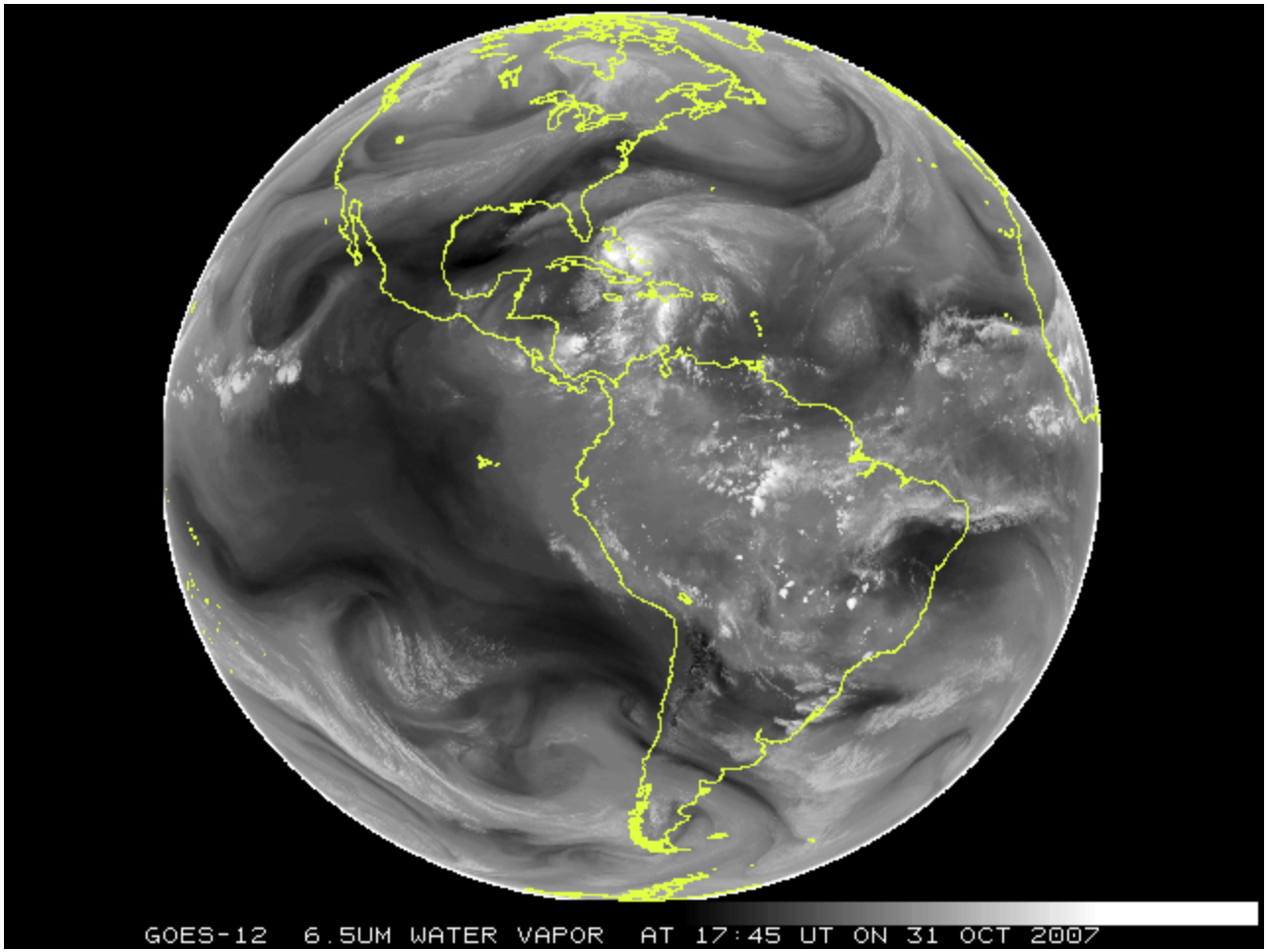
2007-10-31 at 1745 UT

GOES Longwave IR Window



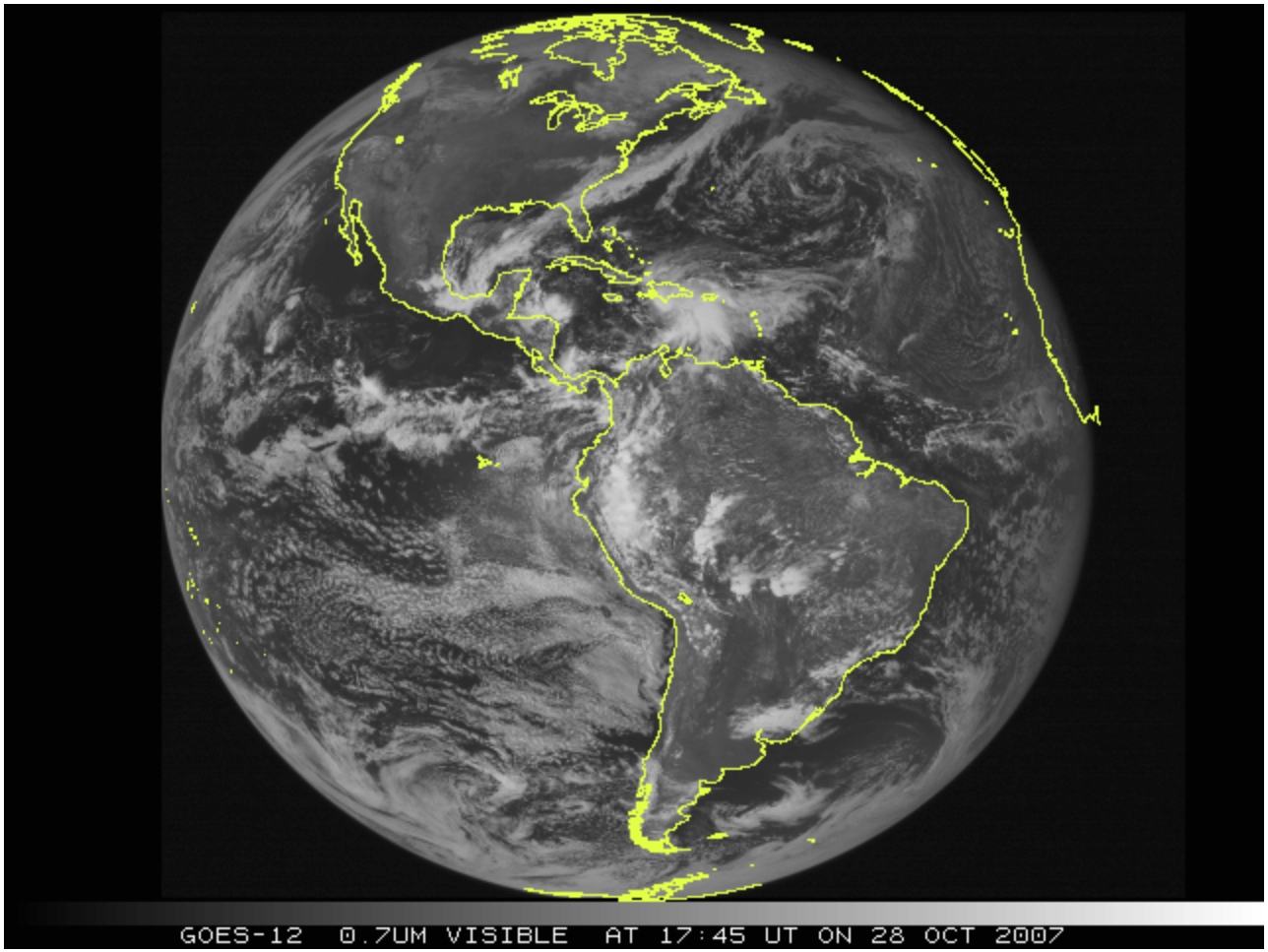
2007-10-31 at 1745 UT

GOES Upper Level Water Vapor



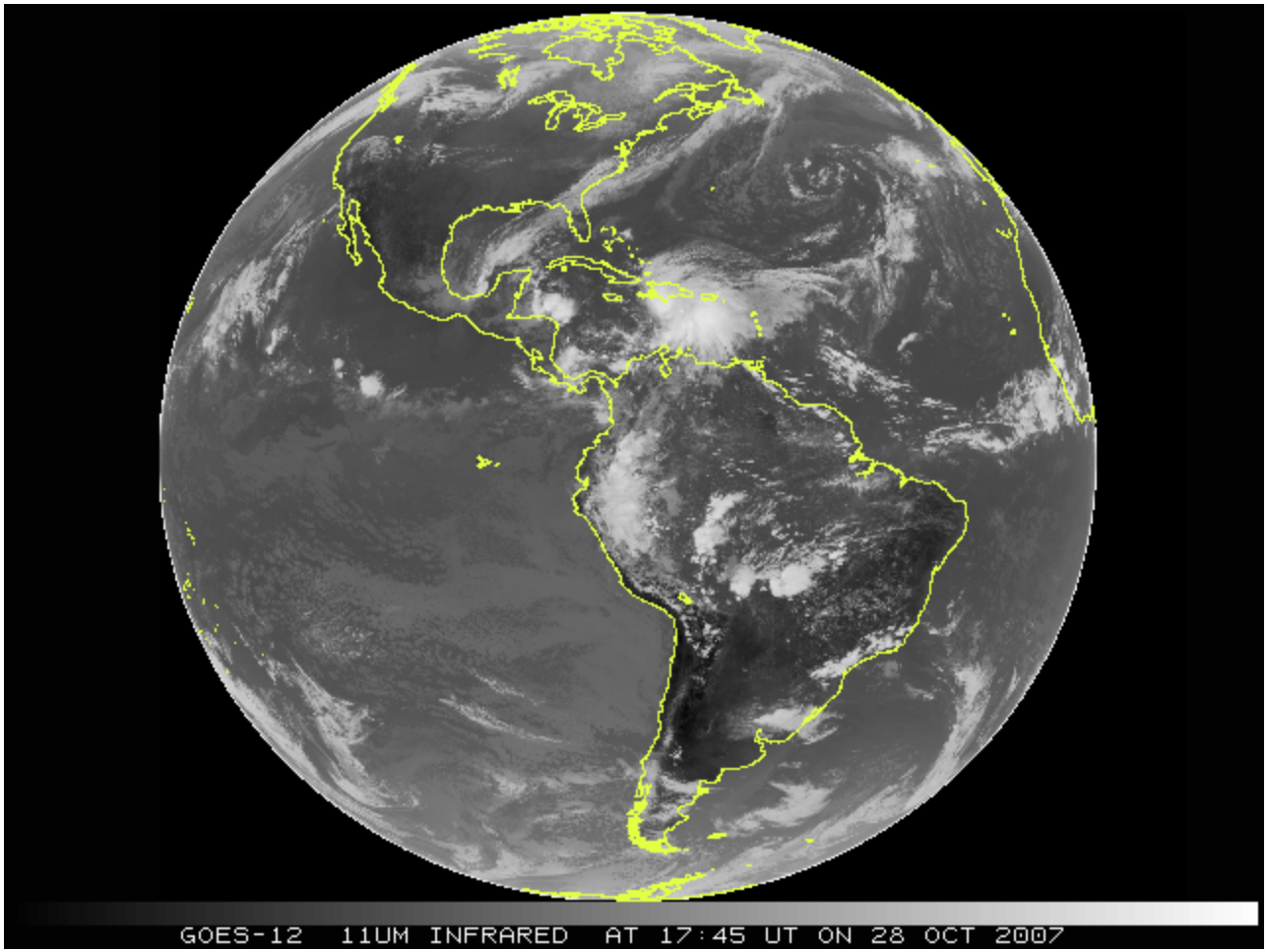
2007-10-31 at 1745 UT

GOES Visible



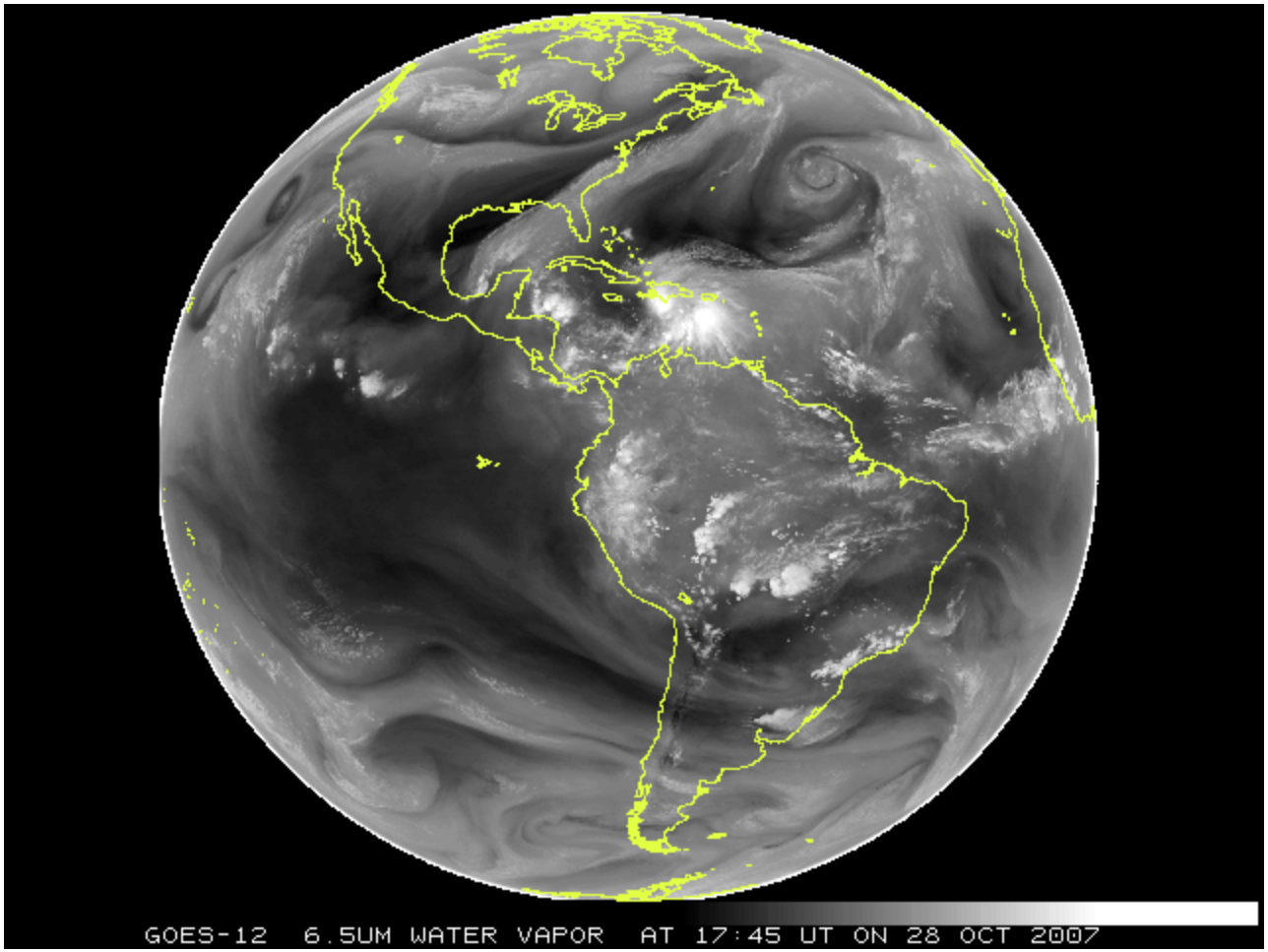
Animate: 3-hourly from 2007-10-28 1745 UT through 2007-10-31 1745 UT

GOES Longwave IR Window



Animate: 3-hourly from 2007-10-28 1745 UT through 2007-10-31 1745 UT

GOES Upper Level Water Vapor



Animate: 3-hourly from 2007-10-28 1745 UT through 2007-10-31 1745 UT

SST from "split window" approach

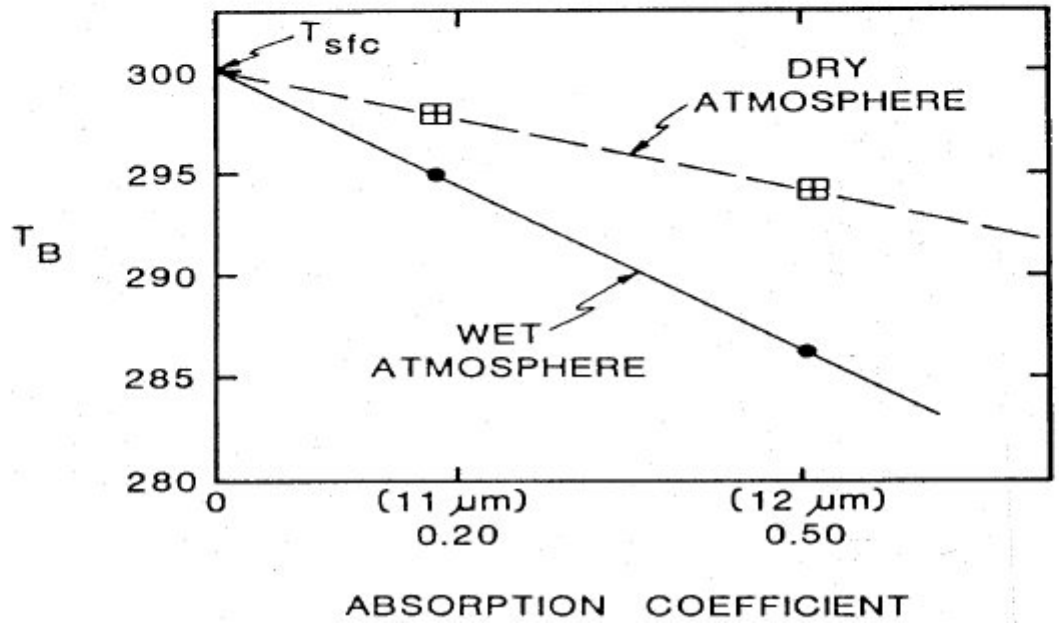
Moisture attenuation in atmospheric windows varies linearly with optical depth.

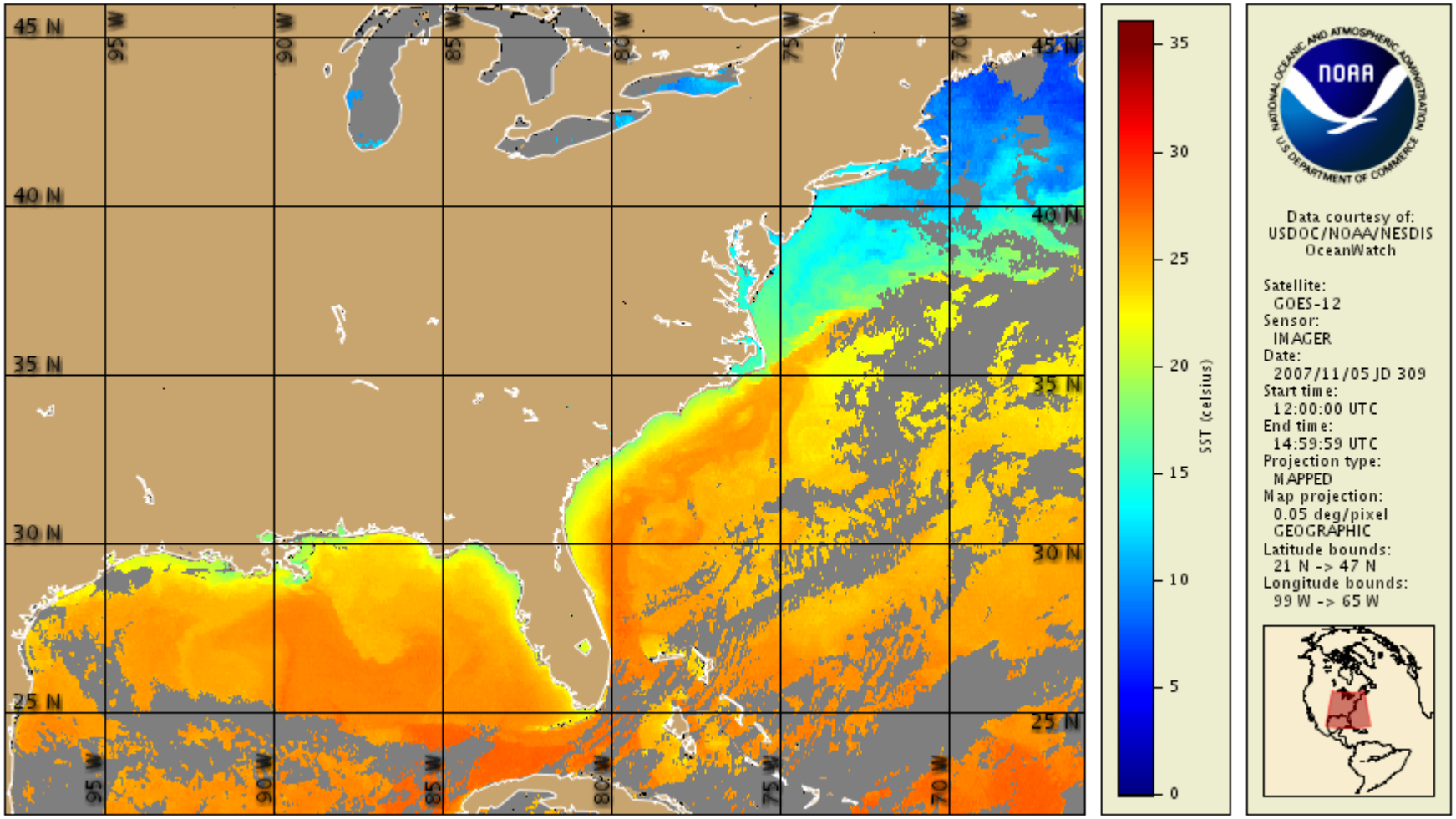
$$\tau_\lambda = e^{-k_\lambda u} = 1 - k_\lambda u$$

For same atmosphere, deviation of brightness temperature from surface temperature is a linear function of absorbing power. Thus moisture corrected SST can inferred by using split window measurements and extrapolating to zero k_λ

$$T_s = T_{bw1} + [\, k_{w1} / (k_{w2} - k_{w1}) \,] [T_{bw1} - T_{bw2}] \; .$$

Moisture content of atmosphere inferred from slope of linear relation.




45 N
40 N
35 N
30 N
25 N
95 W
90 W
85 W
80 W
75 W
70 W
35
30
25
20
15
10
5
0
SST (celsius)
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S DEPARTMENT OF COMMERCE
Data courtesy of:
USDOC/NOAA/NESDIS
OceanWatch
Satellite:
GOES-12
Sensor:
IMAGER
Date:
2007/11/05 JD 309
Start time:
12:00:00 UTC
End time:
14:59:59 UTC
Projection type:
MAPPED
Map projection:
0.05 deg/pixel
GEOGRAPHIC
Latitude bounds:
21 N -> 47 N
Longitude bounds:
99 W -> 65 W

NOAA/NESDIS OSDPD SST Algorithms

The NOAA Office of Satellite Data processing and Distribution generate sea surface temperature (SST) retrievals on an operational basis from the GOES-11 and 12 satellite Imagers. The algorithm retrieval schemes are based on Radiative Transfer Modeling (RTM), generating skin temperatures not bulk temperatures. The Imager channels are listed below.

Radiative-transfer-based SST retrieval algorithms are used to generate the GOES-11/12 SST retrievals. The form of the current GOES operational SST equation is:

$SST = a_0 + a_0?S + \Sigma_i (a_i + a_i?S)T_i$

where *i* is GOES-Imager channel number (2, 4, 5),
S = sec (satellite zenith angle) ? 1 and T*i* is channel brightness temperature in Kelvin.

Coefficients (for Kelvin brightness temperatures)
$a_0, a_0?, a_2, a_2?, a_4, a_4?, a_5, a_5?$

→ **GOES-11 (day)**
Two channel
Modeled RMS error = 0.68364262
-18.01 -6.52 0.0000 0.0000 3.3188 0.1466 -2.2588 -0.1174

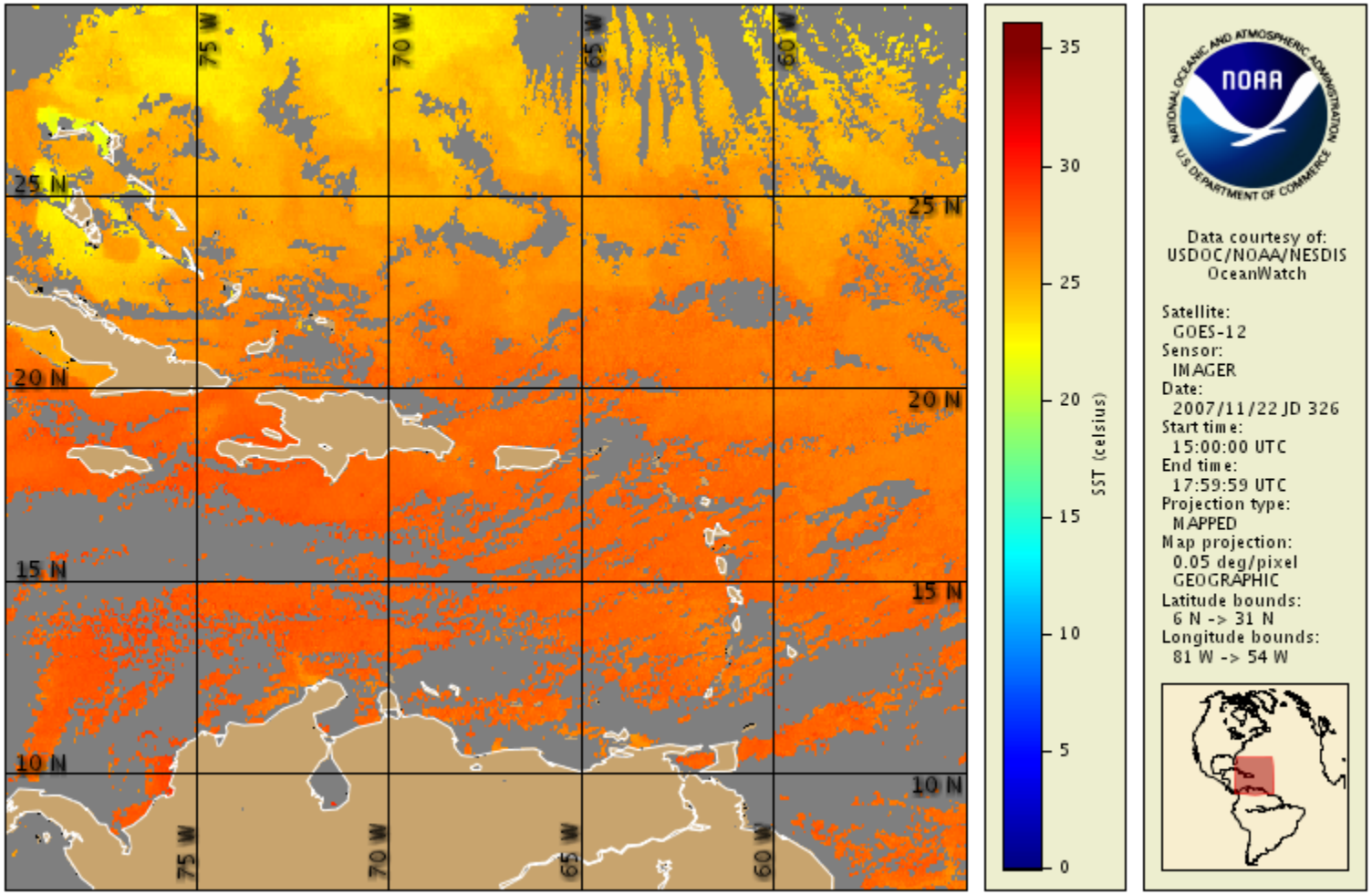
→ **GOES-11 (night)**
Three channel
Modeled RMS error = 0.30877404
-5.46 -2.93 0.9449 -0.0384 0.5698 0.3328 -0.4905 -0.2775

As shown in the table, channel 5 of the Imager on the GOES-12 platform is centered at 13.3 microns and is therefore not used in the SST retrieval. While SSTs can still be retrieved at night using the 3.9 and 11 micron channels (2 and 4), daytime retrievals are complicated by the contribution of reflected and scattered solar radiation to the channel 2 brightness temperature. Three extra steps are performed:

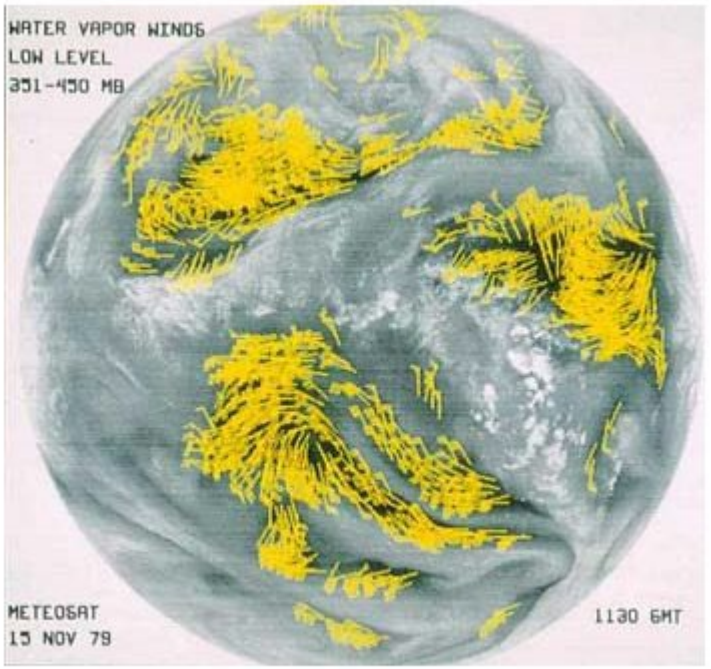
- the region affected by sun glint is estimated using NCEP model winds, the Cox and Munk (1954) slope distribution and the satellite-solar geometry;
- the clear-sky scattered solar radiation contribution is estimated for a typical value of aerosol optical depth;
- channel 2 brightness temperatures are adjusted to compensate for the solar contributions estimated in the previous steps, with the exception that sun glint corrections >1 deg. K are flagged as insufficiently reliable to be used for SST retrieval. SSTs are retrieved for the remaining clear-sky pixels using the adjusted channel 2 brightness temperatures along with the channel 4 data, using the same retrieval equation form described above.

→ **GOES-12 (day and night)**
-2.10, -1.15, 1.177, 0.073, -0.162, -0.069, 0.0, 0.0
(Coefficients for channel 5 are zero because channel 5 (13.3 ?m) is not used.)

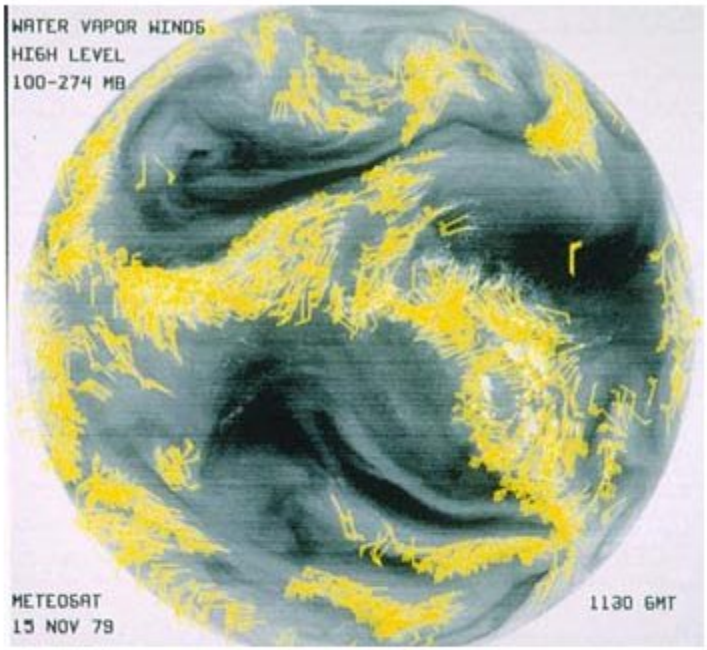
2007


75 W
70 W
65 W
60 W
25 N
20 N
15 N
10 N
SST (celsius)
35
30
25
20
15
10
5
0
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Data courtesy of:
USDOC/NOAA/NESDIS
OceanWatch
Satellite:
GOES-12
Sensor:
IMAGER
Date:
2007/11/22 JD 326
Start time:
15:00:00 UTC
End time:
17:59:59 UTC
Projection type:
MAPPED
Map projection:
0.05 deg/pixel
GEOGRAPHIC
Latitude bounds:
6 N -> 31 N
Longitude bounds:
81 W -> 54 W

Water vapor tracked “winds” from Meteosat during FGGE (the **F**irst Global Atmospheric Research Program (**G**ARP) **G**lobal **E**xperiment)



FGGE-Meteosat-winds-low.jpg

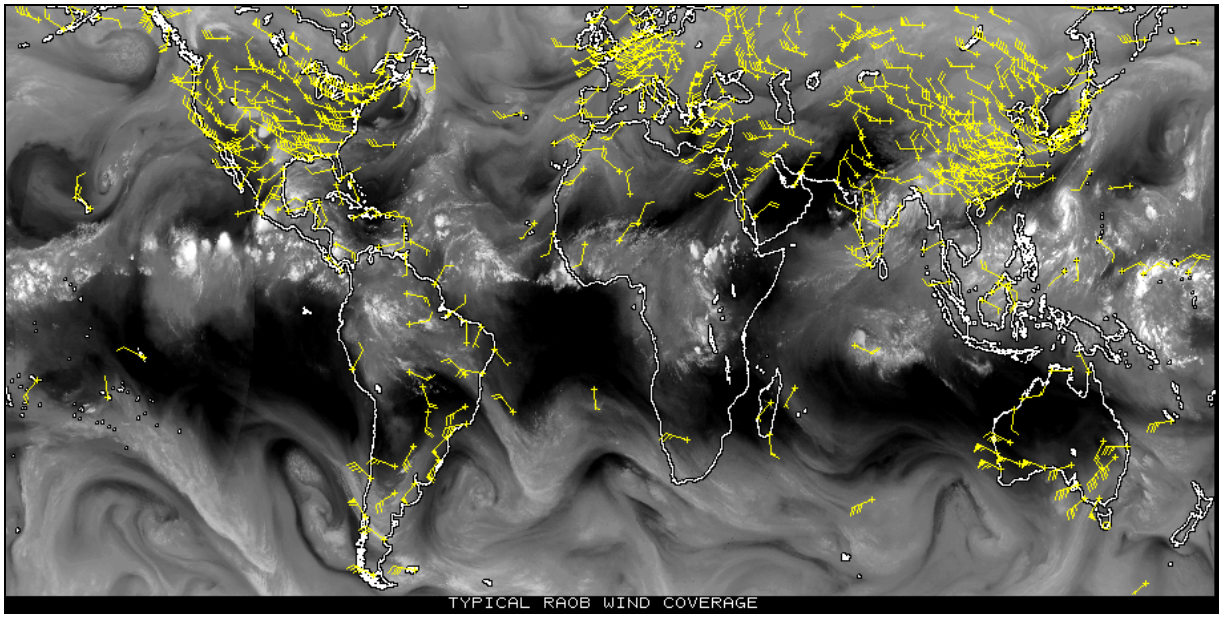


FGGE-Meteosat-winds.jpg

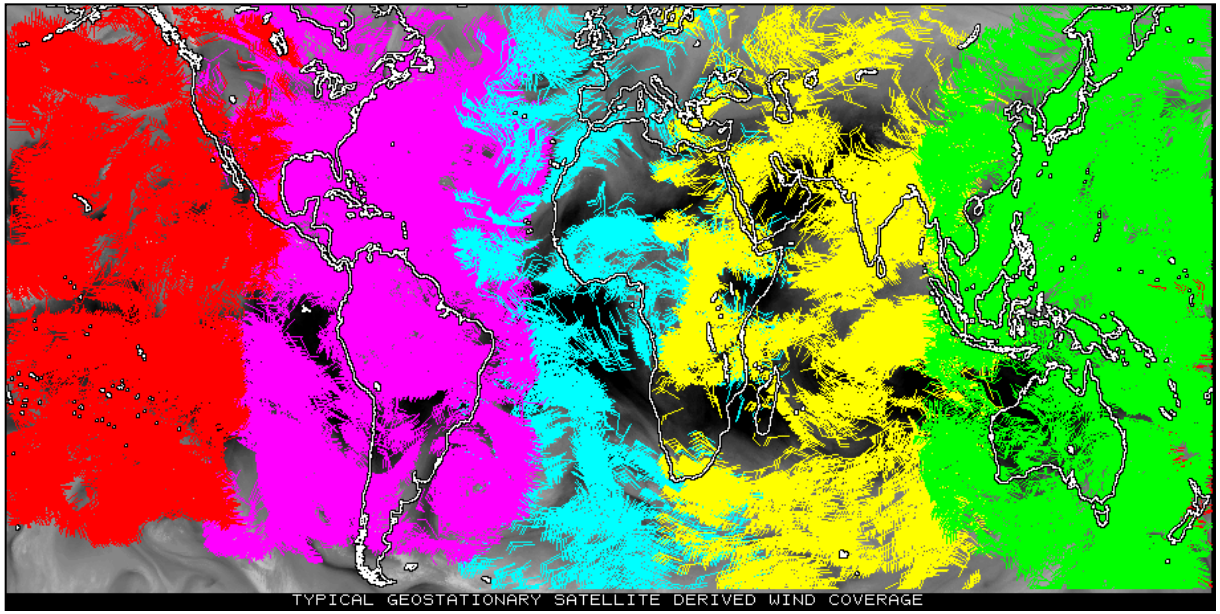
(15 Nov 1979)

Spatial coverage of wind observations

RAOB



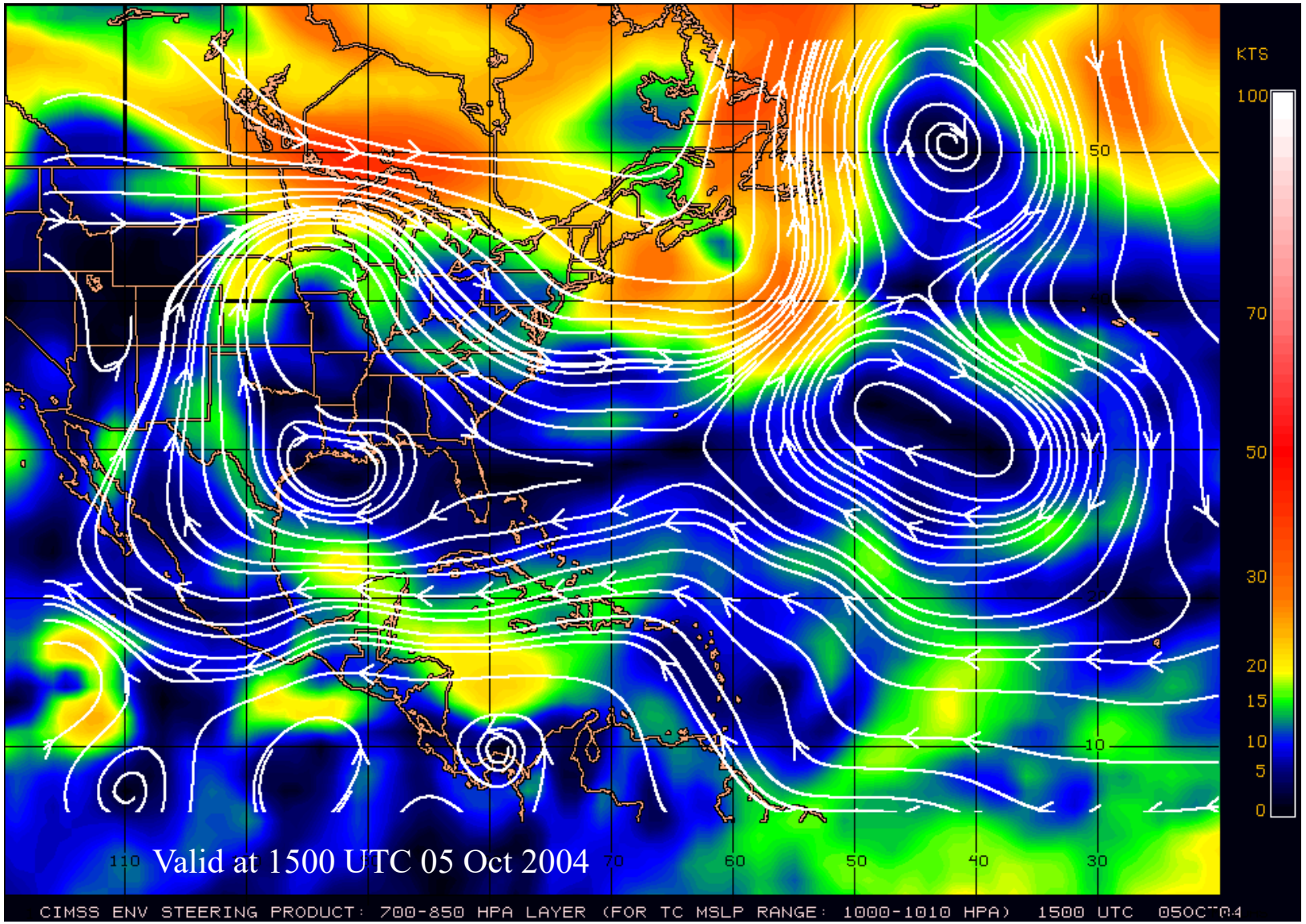
Satellite



12 UTC

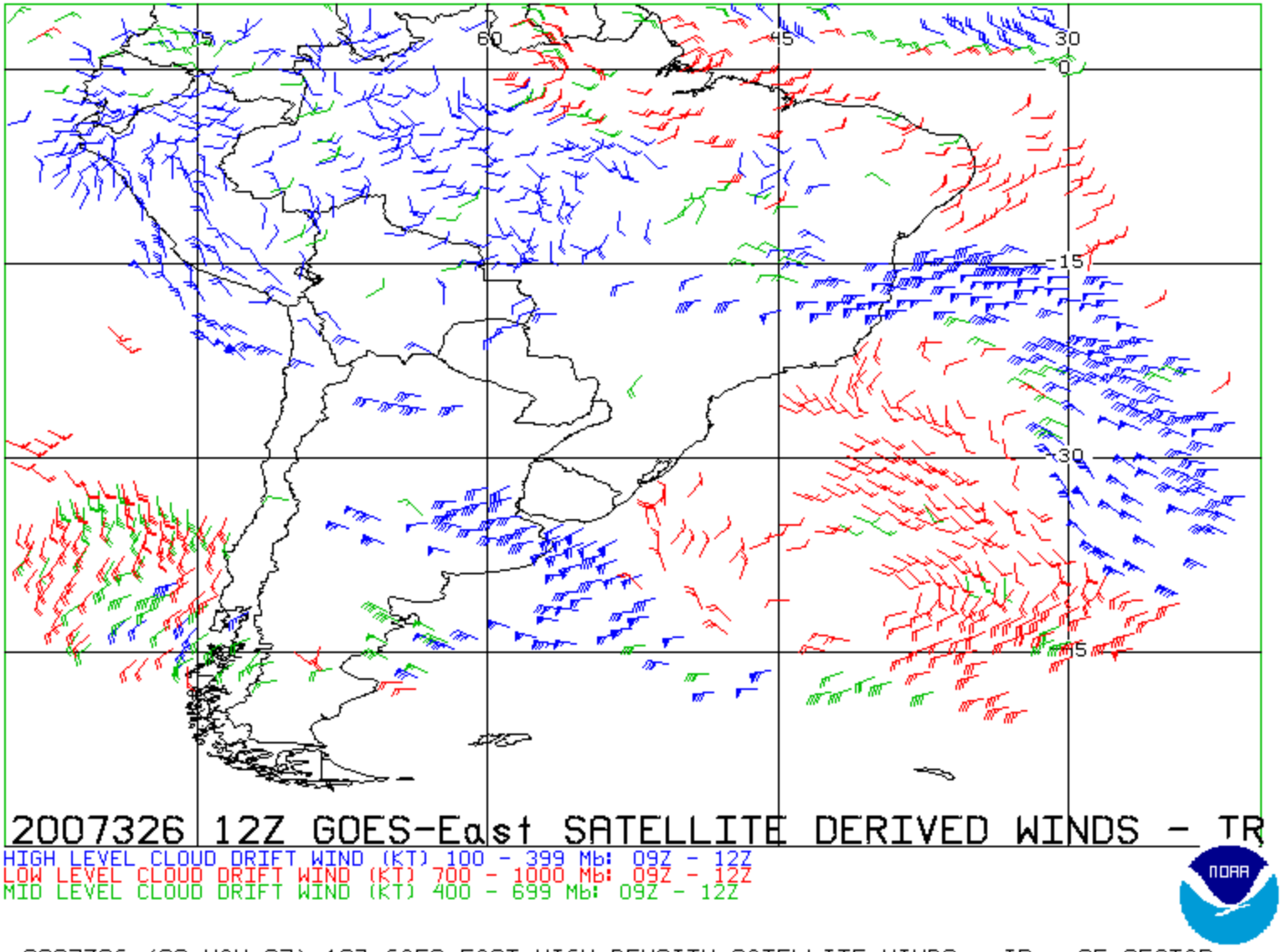
05 Oct 2004

Environmental steering current

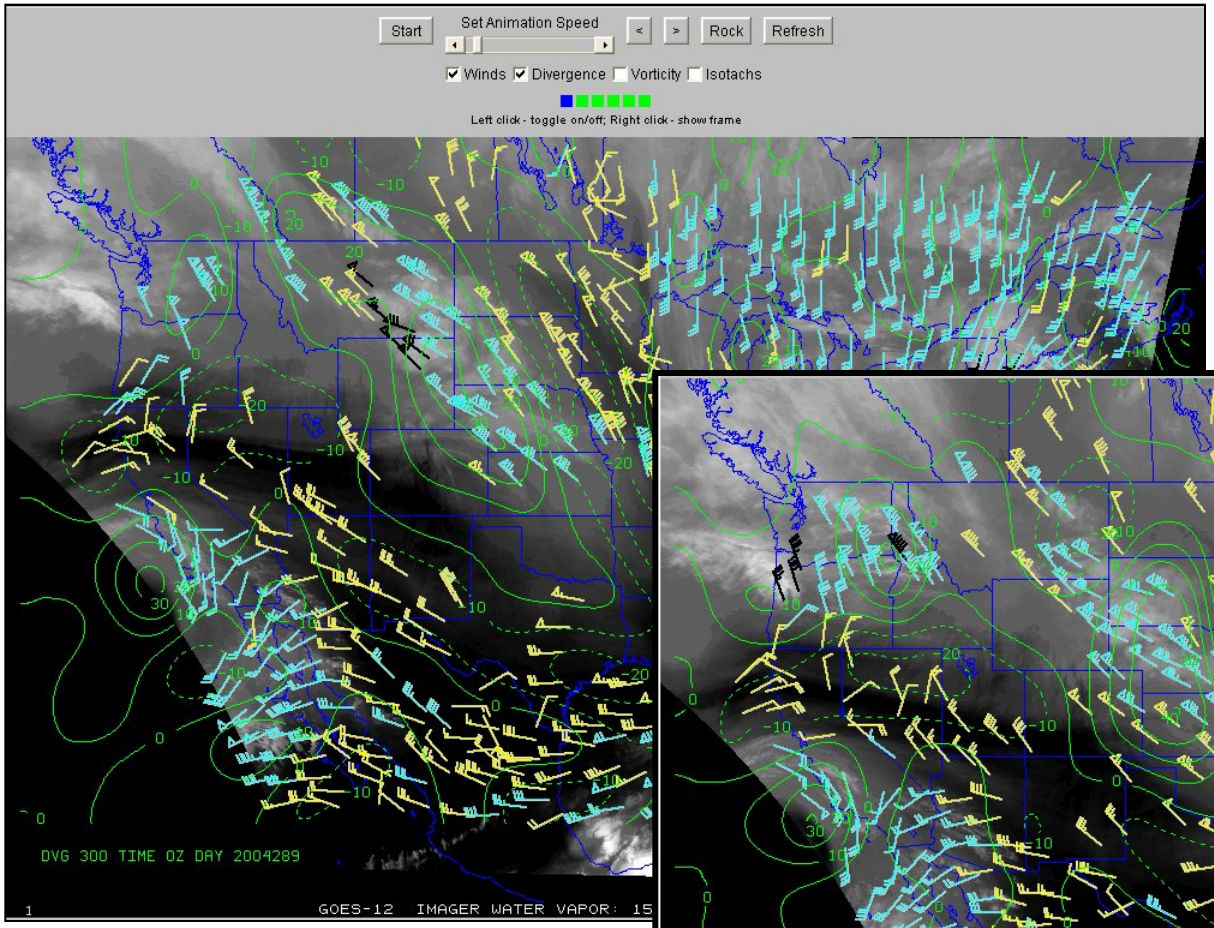


http://cimss.ssec.wisc.edu/tropic/real-time/atlantic/winds/winds-dlm.html

Operational (NOAA/NESDIS) GOES derived satellite winds

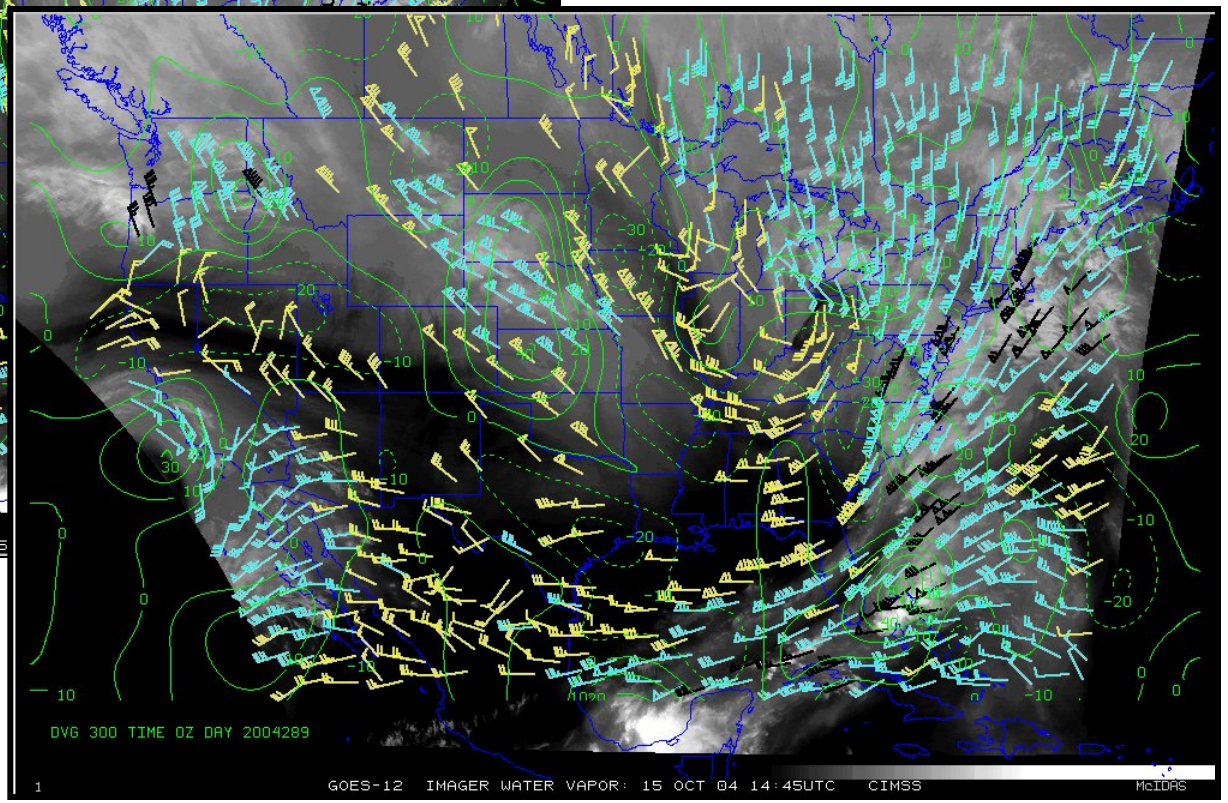


Satellite winds for dynamics diagnosis



Water vapor tracked wind analyses

From 1245 UTC to 1415 UTC on 15 Oct 2004



http://cimss.ssec.wisc.edu/mesoscale_winds/real.html

Precipitation estimates from satellite

NOAA Satellites and Information
National Environmental Satellite, Data, and Information Service

Satellite Services Division
Precipitation Products

DOC / NOAA / NESDIS / OSDPD / SSD /

Disclaimer and Privacy Policy

Coast Watch | Fire | OSEI | Precipitation | Sat Info | Snow & Ice | Tropical | Volcano | Winds | GIS

Mission Statement

Text and Graphic Products

Satellite Precipitation Estimates:
Most Recent
SPENES from the last 90 Days

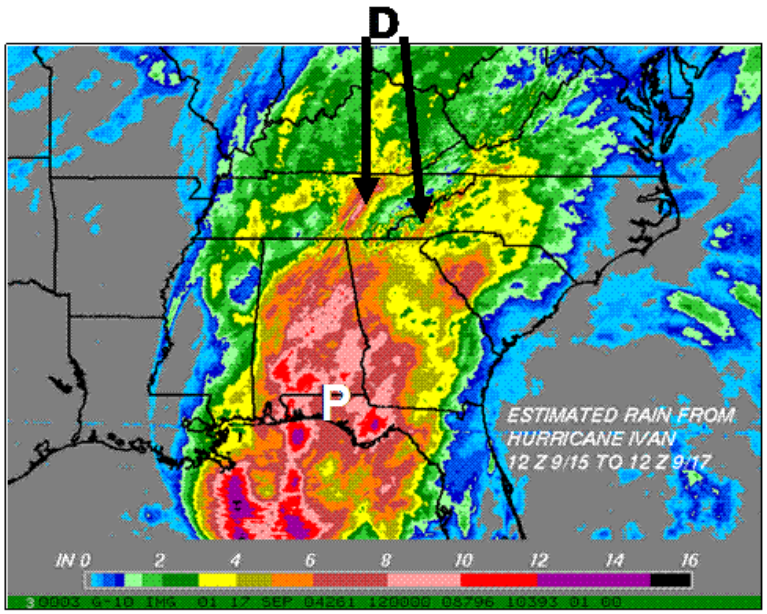
Graphic Products
Real Time Satellite Precipitation Graphics:
Most Recent
Graphics from the last 90 Days

More information about our Precipitation Products
The SSD Precipitation Program
Overview of Satellite Precipitation Estimates (810k PowerPoint)
Precipitation Summaries:
- 2002 (150k Adobe PDF)
- 2002 (725k WordPerfect)

Case Studies and Papers
Operational Significant Event Imagery --
- Hurricane Mitch (1998)
- Auto-Estimator Precipitation Estimates - Tropical Storm Allison

Abstracts --
- Brief Analysis of the 2001 - 2002 SAB Lake Effect Snow Estimates (pdf)

Hurricane Ivan

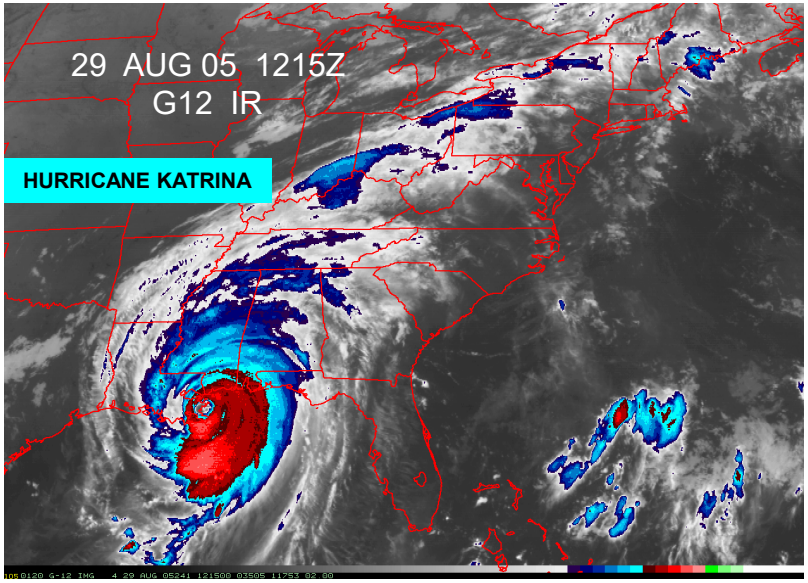


48 Hour Hydro-Estimator rainfall (inches) ending September 17, 2004, 1200 UTC; devastation in mountainous areas indicated by "D" and Florida Pan Handle by "P".

http://www.ssd.noaa.gov/PS/PCPN/

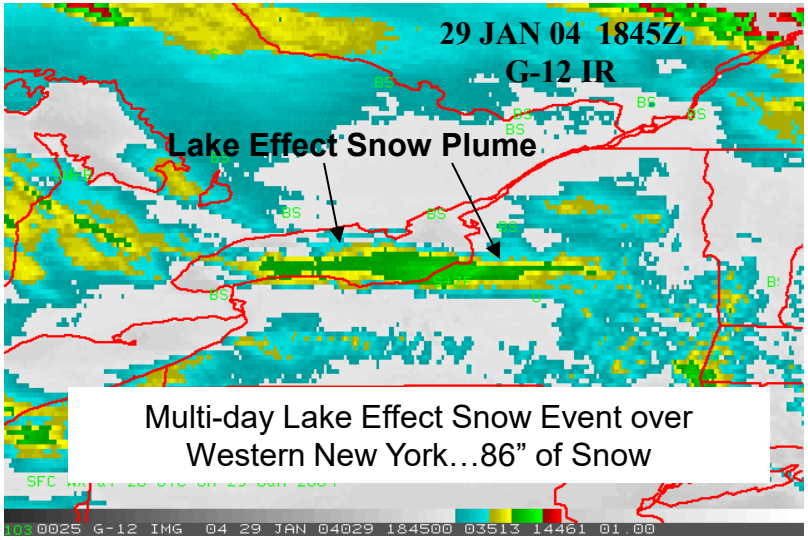
SATELLITE ANALYSIS BRANCH PRECIPITATION OPERATION

Updated 2007

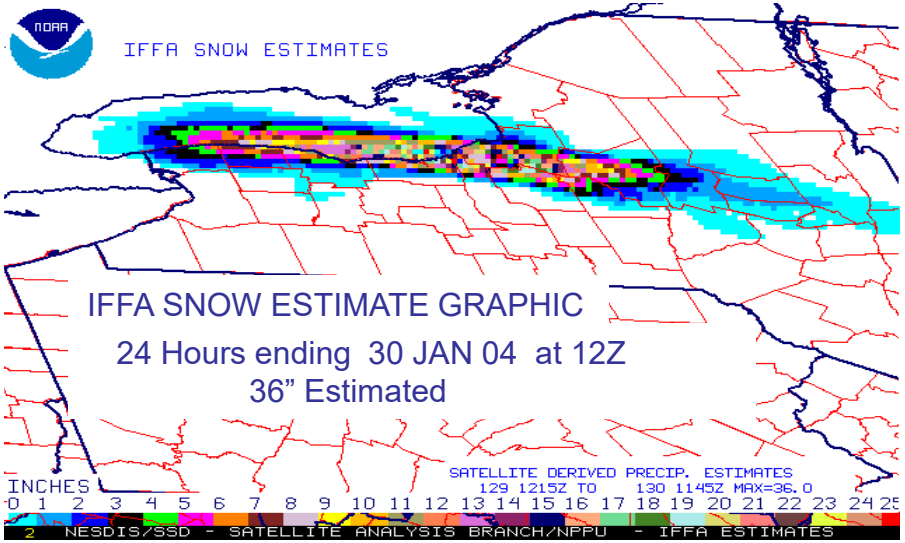


SATELLITE PRECIPITATION ESTIMATES..DATE/TIME 08/29/05 1045Z
SATELLITE ANALYSIS BRANCH/NESDIS---NPPU---TEL.301-763-8678
LATEST DATA USED: GOES-12 1015Z TEB
.
LOCATION...ALABAMA...MISSISSIPPI...LOUISIANA..
.
ATTN WFOS...MOB...JAN...LIX...LCH...
ATTN RFCS...SERFC...LMRFC...
.
EVENT...TROPICAL BANDS COMING ASHORE
.
SATELLITE ANALYSIS TRENDS...THE EYE OF THE TROPICAL SYSTEM IS PRESENTLY COMING ASHORE IN THE MISSISSIPPI DELTA AND ENHANCED BANDS OF HEAVY RAIN CONTINUE TO SPIRAL AND SLIDE NORTHWARD INTO THE S.E. LA AND MS COASTAL COUNTIES/PARISHES. A SIGNIFICANT BAND THAT HAD MOVED WESTWARD THRU THE LAKE PONTCHARTRAIN AREA HAS WARMED BUT RAIN RATES OF UP TO 1.3" PER HOUR WERE ASSOCIATED WITH IT. THE MAIN EYEWALL BAND SLIDING IN TOWARDS THE MS COAST HAS 1.5" TO 2.0" PER HALF-HOUR RAIN RATES AND WILL CONTINUE TO AGGRAVATE THIS AREA THAT HAS ALREADY RECEIVED AMPLE RAIN OVERNIGHT. CURRENT TOTALS OF UP TO 7.5" TO 1015Z IN THE DELTA REGION.
.
SEE NCEP HPC DISCUSSION AND QPF/S FOR FORECAST.
....NESDIS_SAB IS A MEMBER OF 12 PLANET....
.
SSD/SAB WEB ADDRESS FOR PRECIP ESTIMATES:
HTTP://WWW.SSD.NOAA.GOV/PS/PCPN/
...ALL LOWER CASE EXCEPT /PS/PCPN/

SPENES MESSAGE FOR HRCN KATRINA



Multi-day Lake Effect Snow Event over Western New York…86" of Snow



HISTORY OF IFFA/QPE OPERATION

- **1979 First Estimates – *Scofield/Oliver Convective Technique***
- **1983 - Fully Operational**
  - using McIDAS system – ***Interactive Flash Flood Analyzer (IFFA***)
  - SPENES messages on AFOS
- **1993 – NESDIS/SAB Collocated with NCEP/HPC, forming NPPU**
  - better QPF support
- **1996 - Estimate Graphics and SPENES messages on Internet**
  - SSD Web Page
- **1997 - Orographic Correction added**
  - for short-term estimates
- **2000 - Combined IFFA/Auto-Estimator Operation**
- **2002 – Hydroestimator – new version of Auto-Estimator**

SPENES Contents

- **Satellite Analysis and Trends**
- **Precipitation Estimates -** Manual (IFFA) or Automated (Hydroestimator)

Satellite Data Used:

GOES IR, VIS, WV

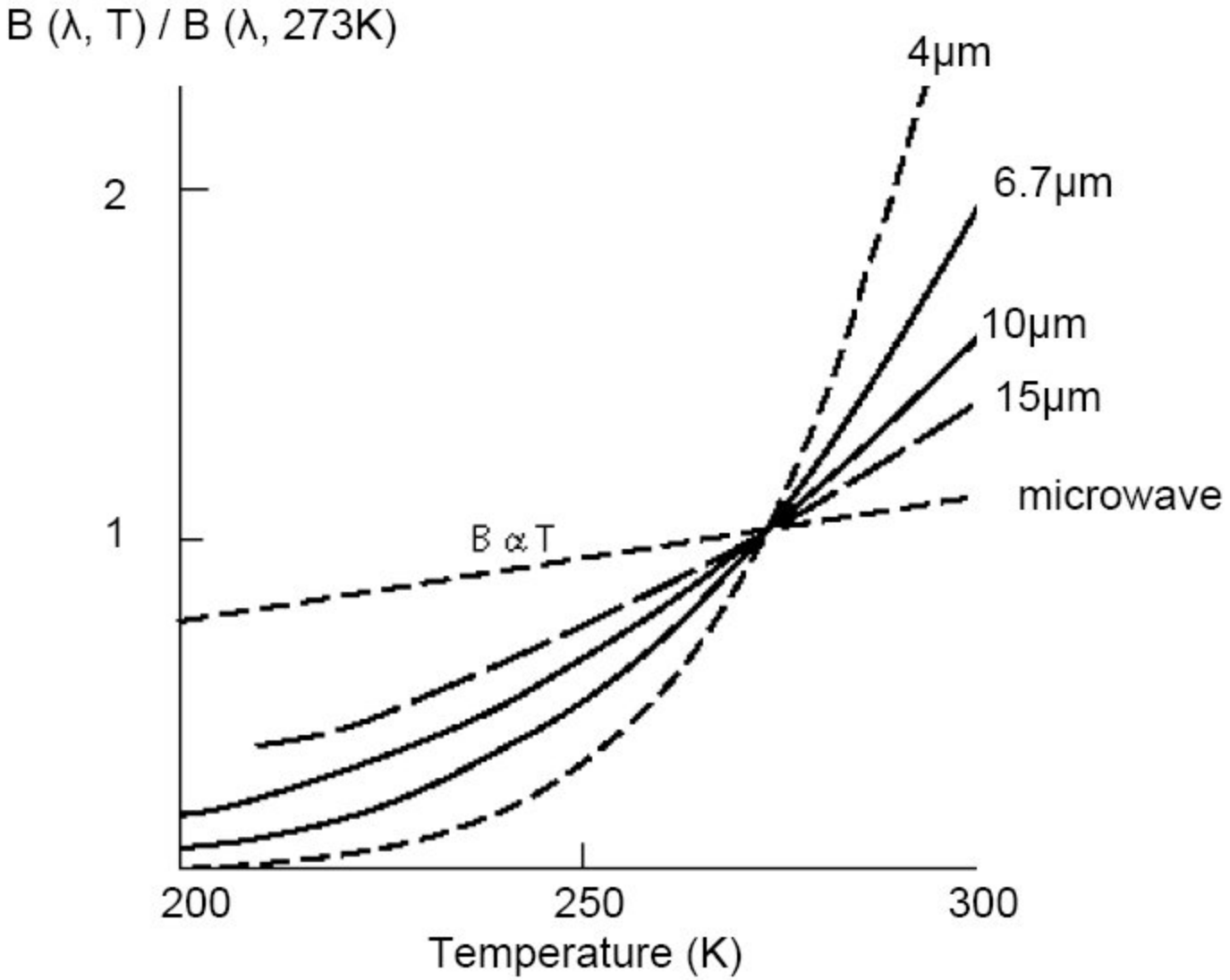
GOES Sounder and Imager Data/Derived Product Imagery (DPI)

GOES Satellite Winds

Microwave: DMSP SSM/I (rain rates and PW)
NOAA AMSU (rain rates and PW)
NASA TRMM (rain rates)
NASA AMSR-E (rain rates and PW)

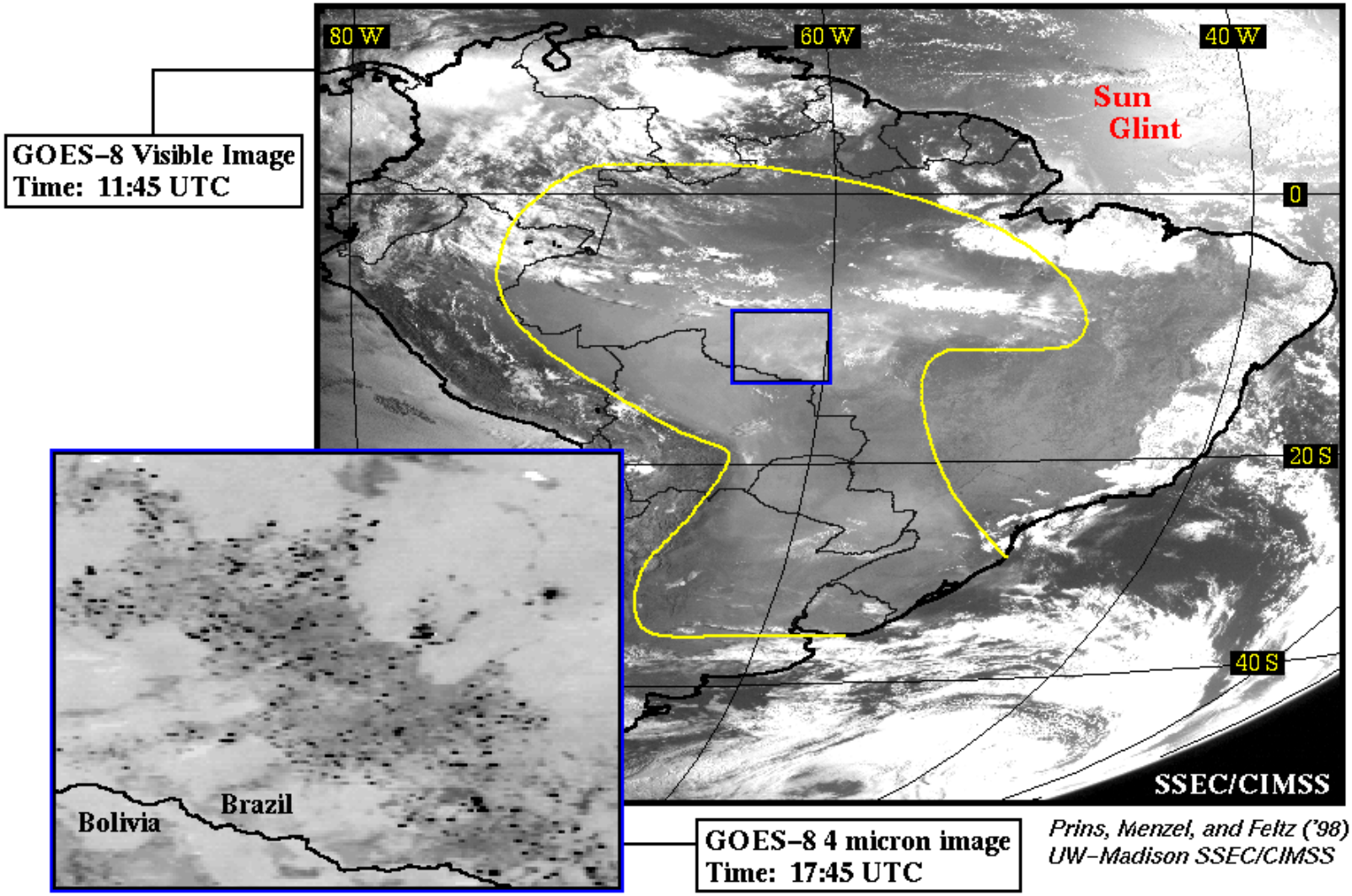
Shortwave window most sensitive for fire hot spots

Temperature Sensitivity of B(λ,T) for typical earth scene temperatures



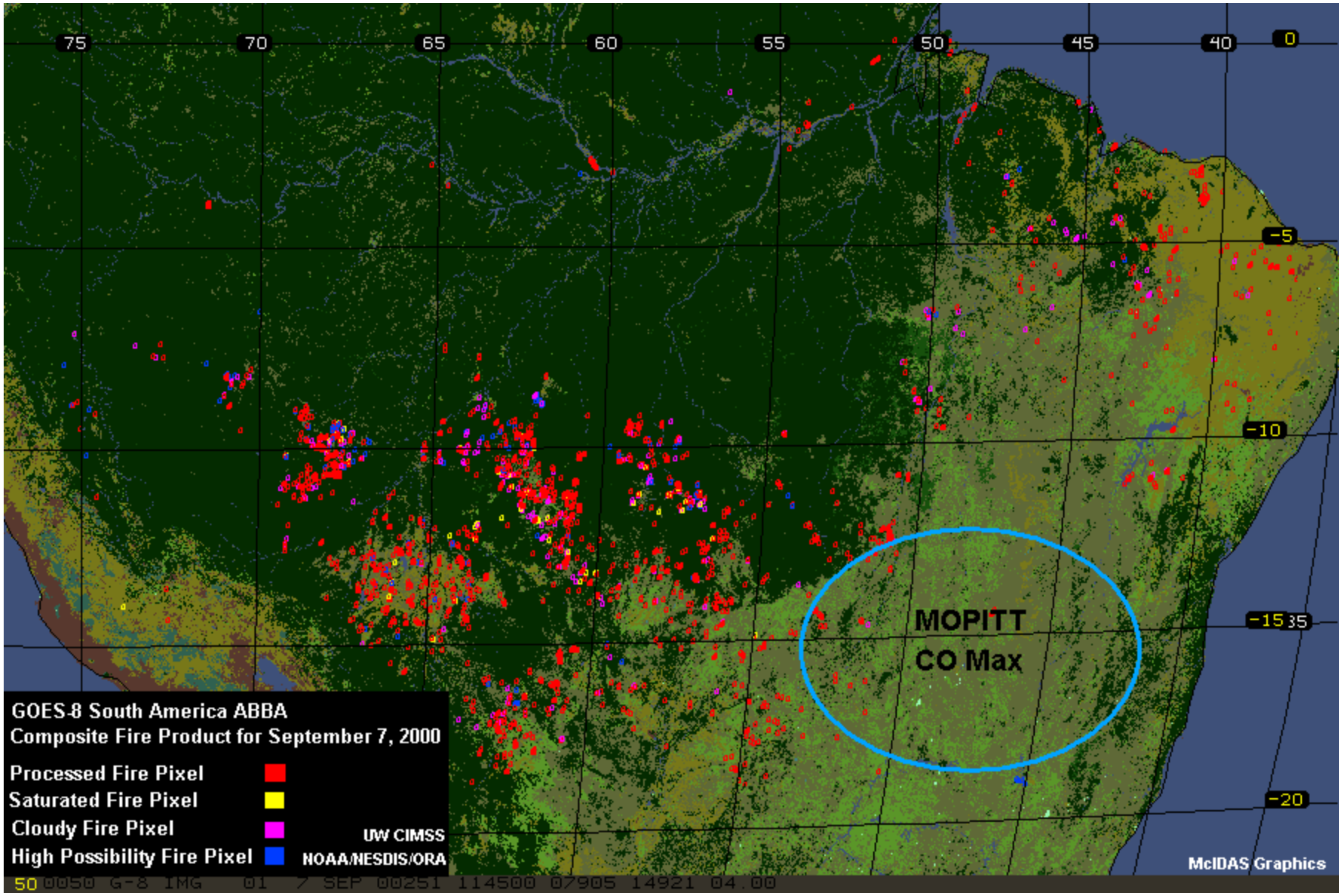
Smoke Pall and Fires Observed in GOES–8 Imagery

Date: 27–Aug–1997 **Smoke Coverage: ~ 6.0 million km^2**

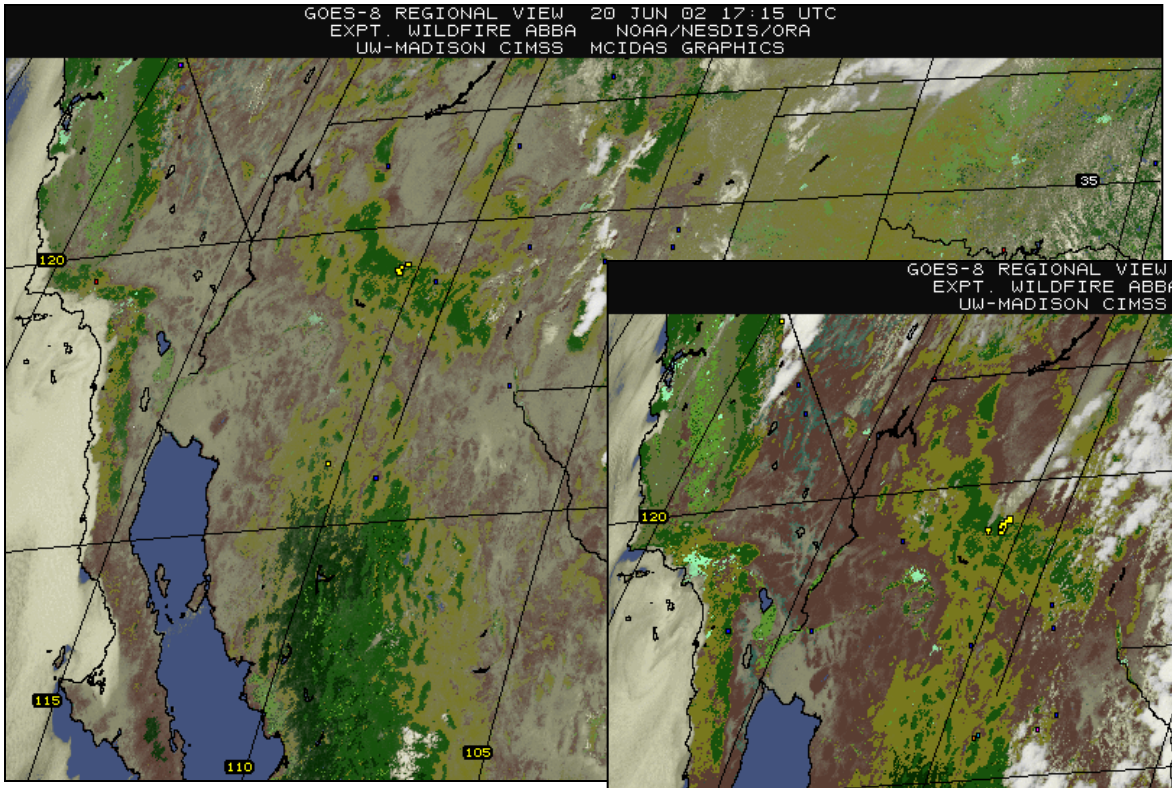


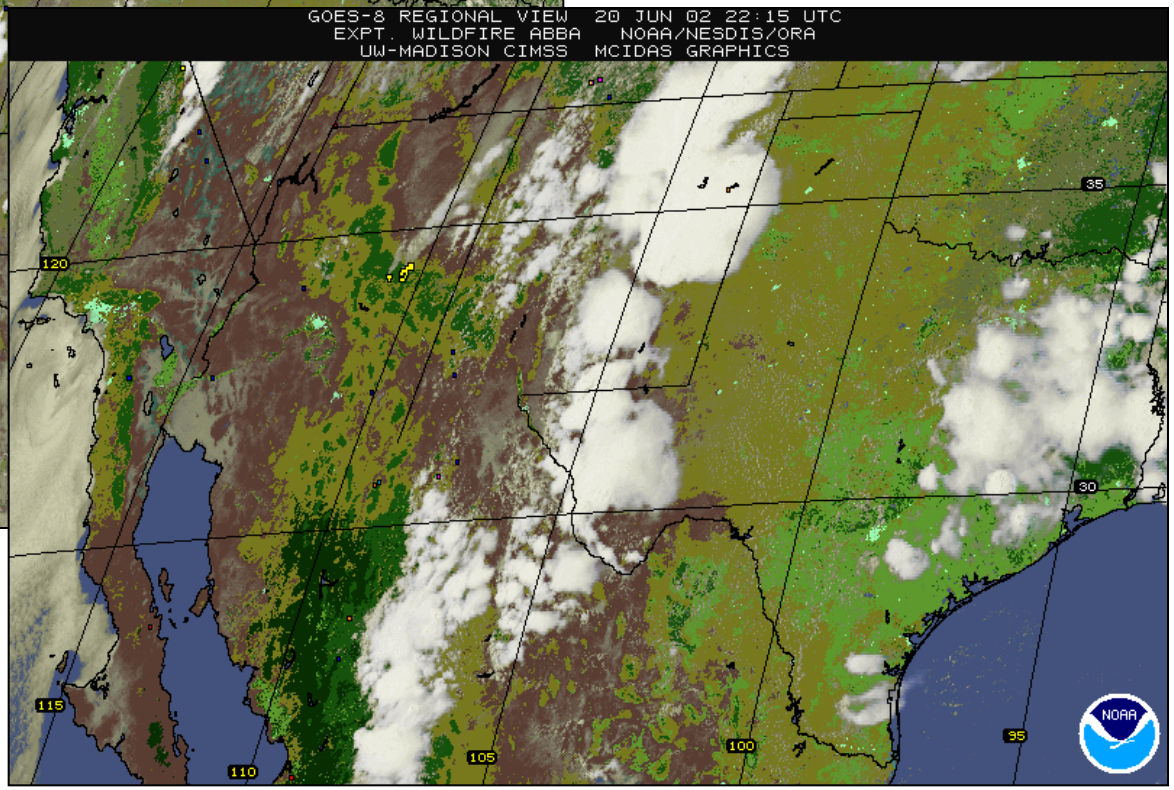
Prins, Menzel, and Feltz ('98)
UW–Madison SSEC/CIMSS

Atmospheric CO pattern and source (fires)



Fire detection





Arizona wildfires

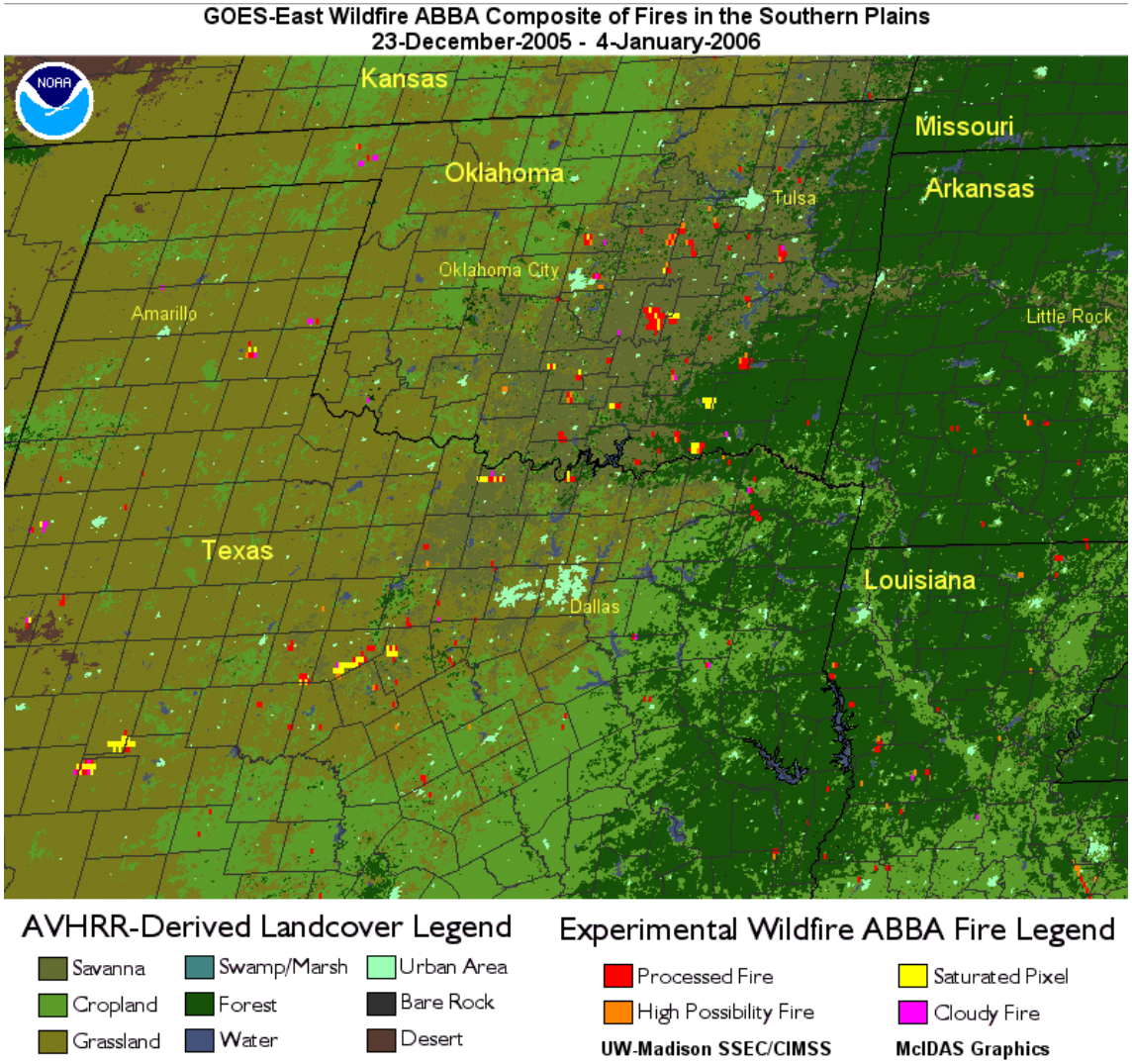
GOES-8 ABBA

1715 – 2215 UTC

20 Jun 2002

http://cimss.ssec.wisc.edu/goes/burn/abba.html

GOES WF_ABBA Monitors Wildfire Activity in Southern Plains

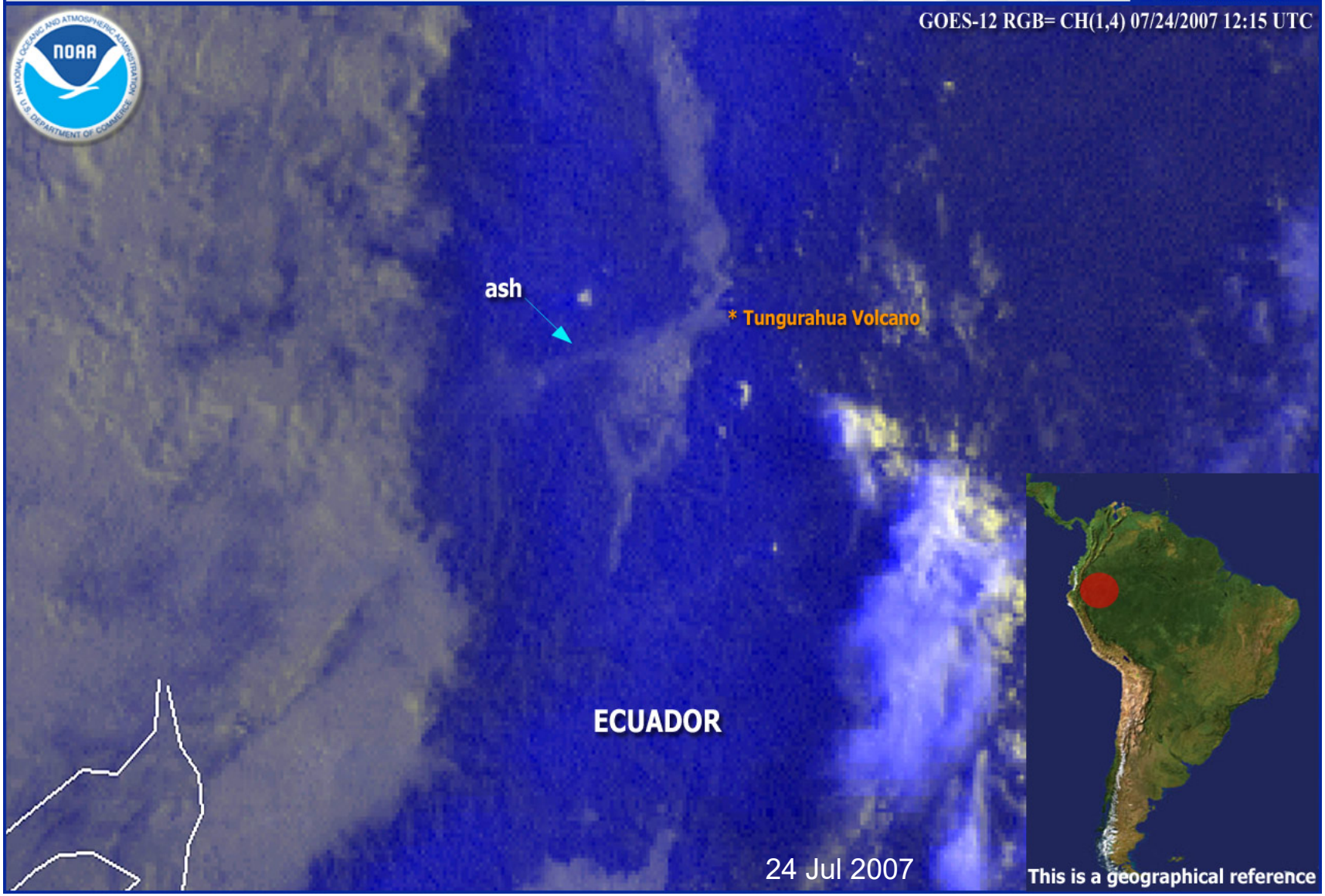


As of 04 January 2006, wildfires killed 5 people, destroyed at least 470 homes, and consumed over 600,000 acres in Oklahoma, Texas, and New Mexico.

(C. Schmidt, J. Brunner, and E. Prins)

This GOES Satellite imagery taken at 1215 UTC shows a plume of gases and ash from the eruptions of Tungurahua Volcano located at 1.47S, 78.4W in Ecuador. The ash estimated to approximately 16,480 feet is moving to the southwest.

Credit: NOAA

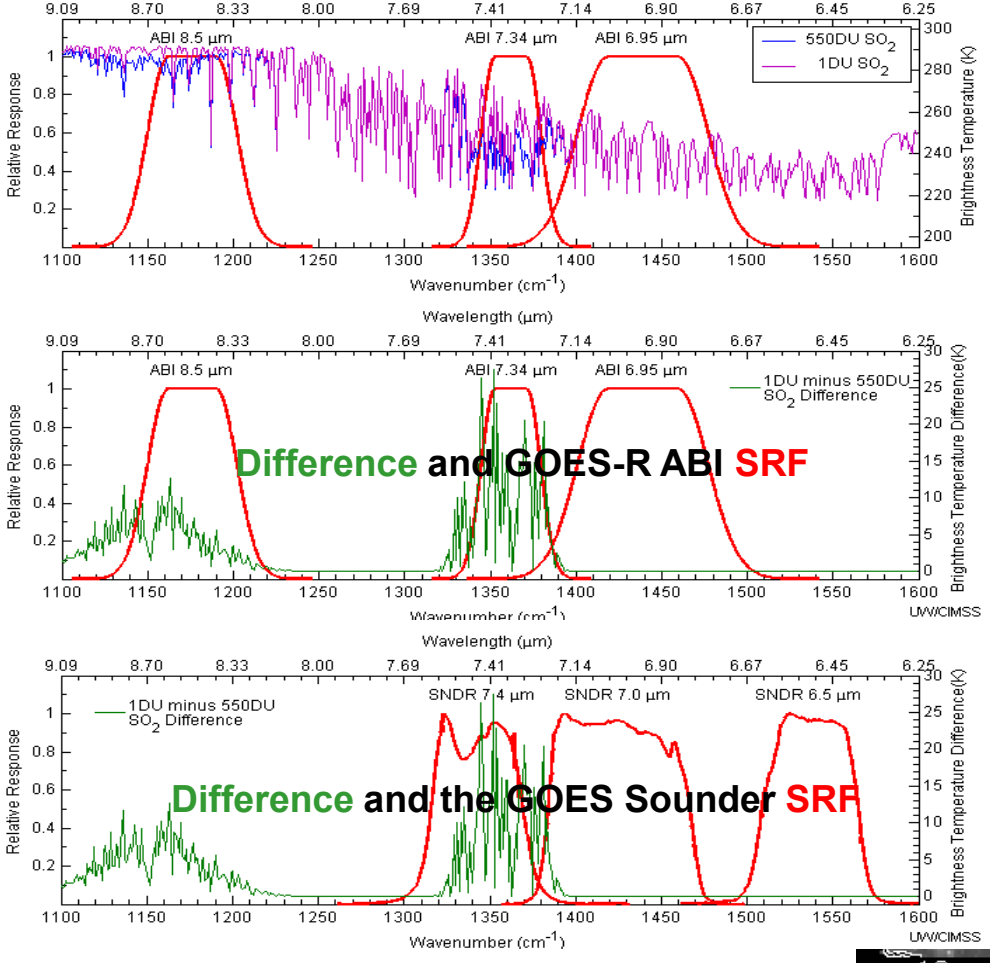


USING GOES-R TO HELP MONITOR UPPER LEVEL SO_2

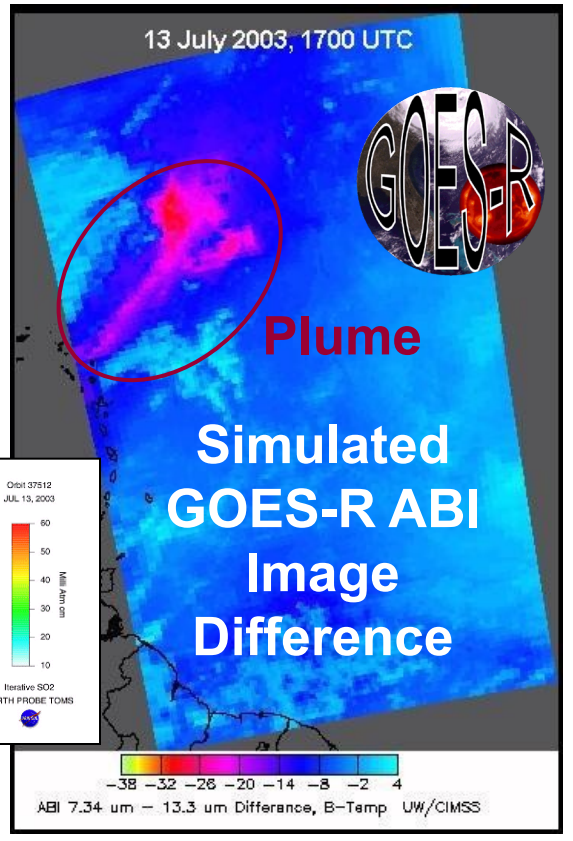
Anthony J. Schreiner*, Timothy J. Schmit#, Jun Li*, Gary P. Ellrod#, Mat Gunshor*

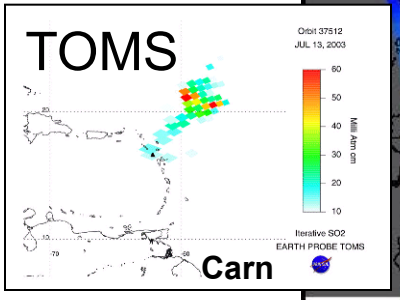
***CIMSS** **#NOAA/NESDIS**

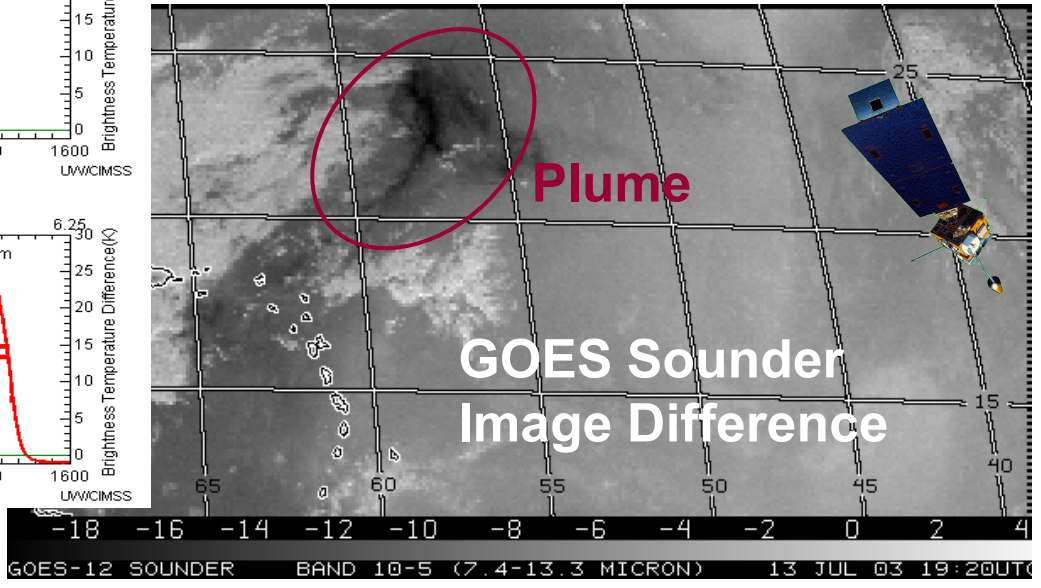
Simulated IR spectrums for "normal" and "SO_2 enriched" atmosphere and spectral response functions



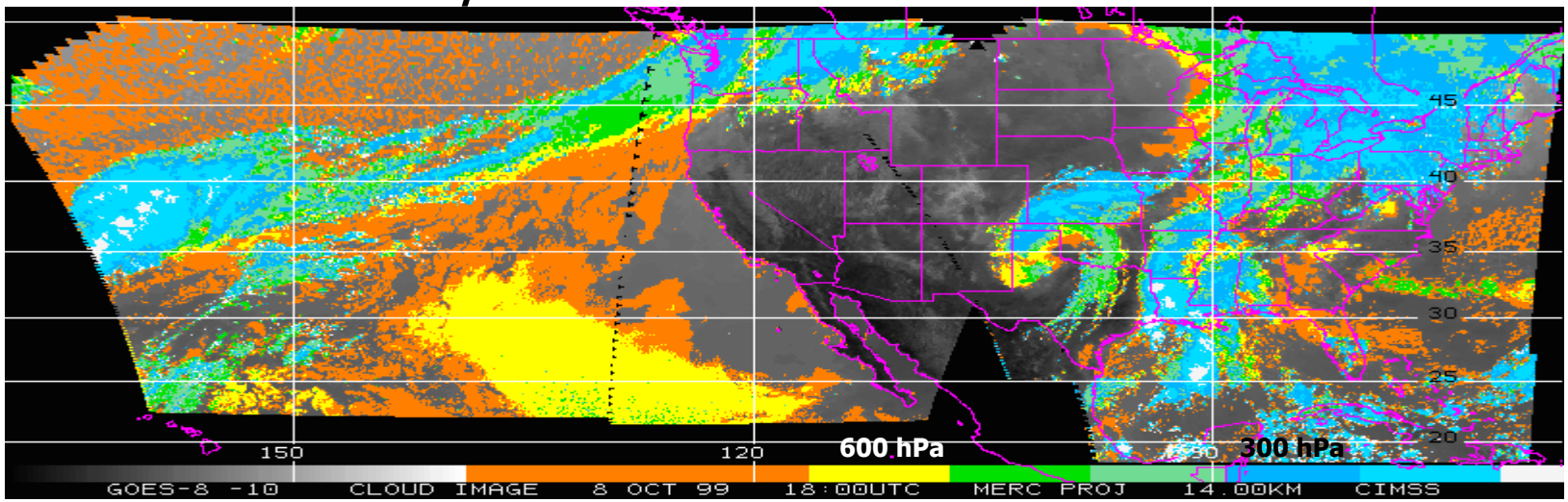
Detection of volcanic plumes



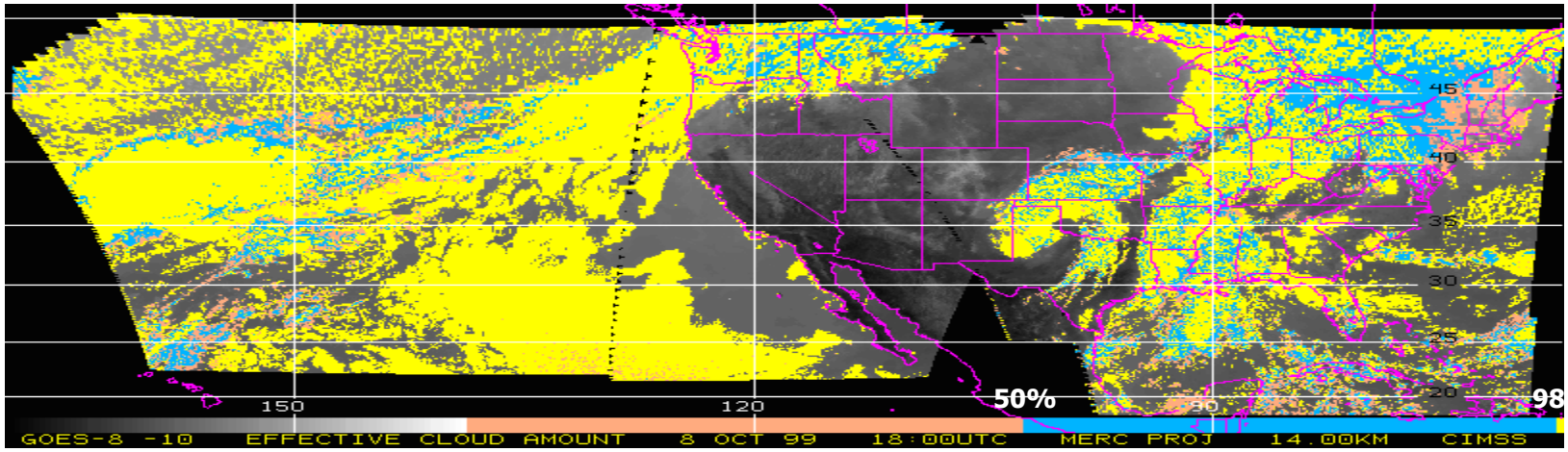




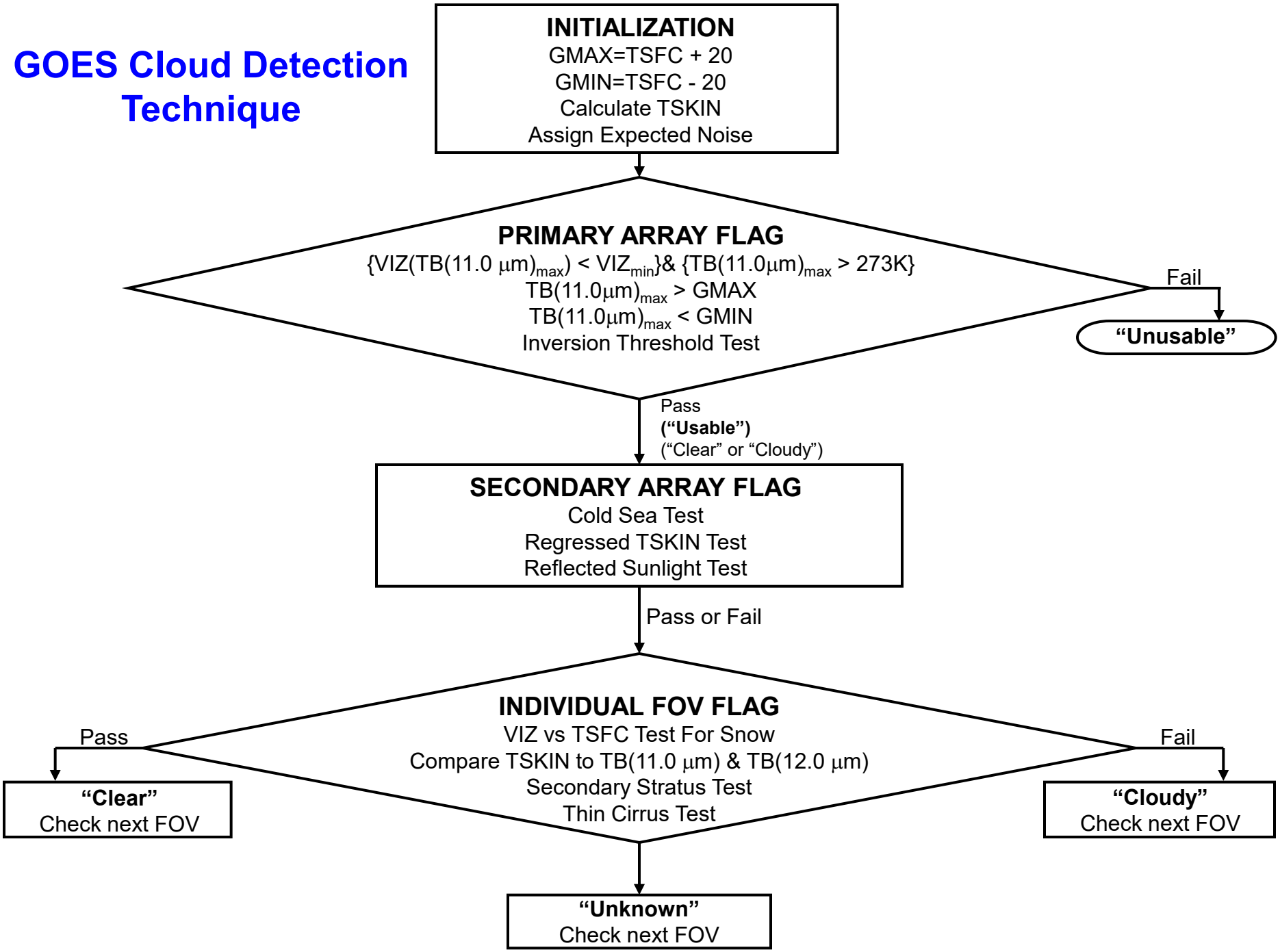
NOWCASTING/FORECASTING APPLICATIONS



- Combining both images can locate deep convection and major weather systems
- Thin clouds imply regions of radiational cooling



GOES Cloud Detection Technique



Review of the CO_2 Technique

- Use two CO_2 absorption intervals to specify a cloud height and amount

  Assumptions: cloud is opaque (infinitesimal thickness)
  emissivities of the two channels are the same

- The relationship used is (a version of the RTE)

$$R_\lambda - R_{\lambda cl} = \eta \varepsilon_\lambda \int_{P_s}^{P_c} \tau_\lambda \left(\frac{dB_\lambda}{dp} \right) dp$$

R_λ - measured radiance
$R_{\lambda cl}$ - observed radiance in the absence of clouds
η - cloud amount
ε_λ - emissivity
τ_λ - transmittance function
dB_λ/dp - the change of Planck radiance with respect to pressure

- Since there are two unknowns ($\eta\varepsilon$ and P_c) and one equation, a ratio is defined.

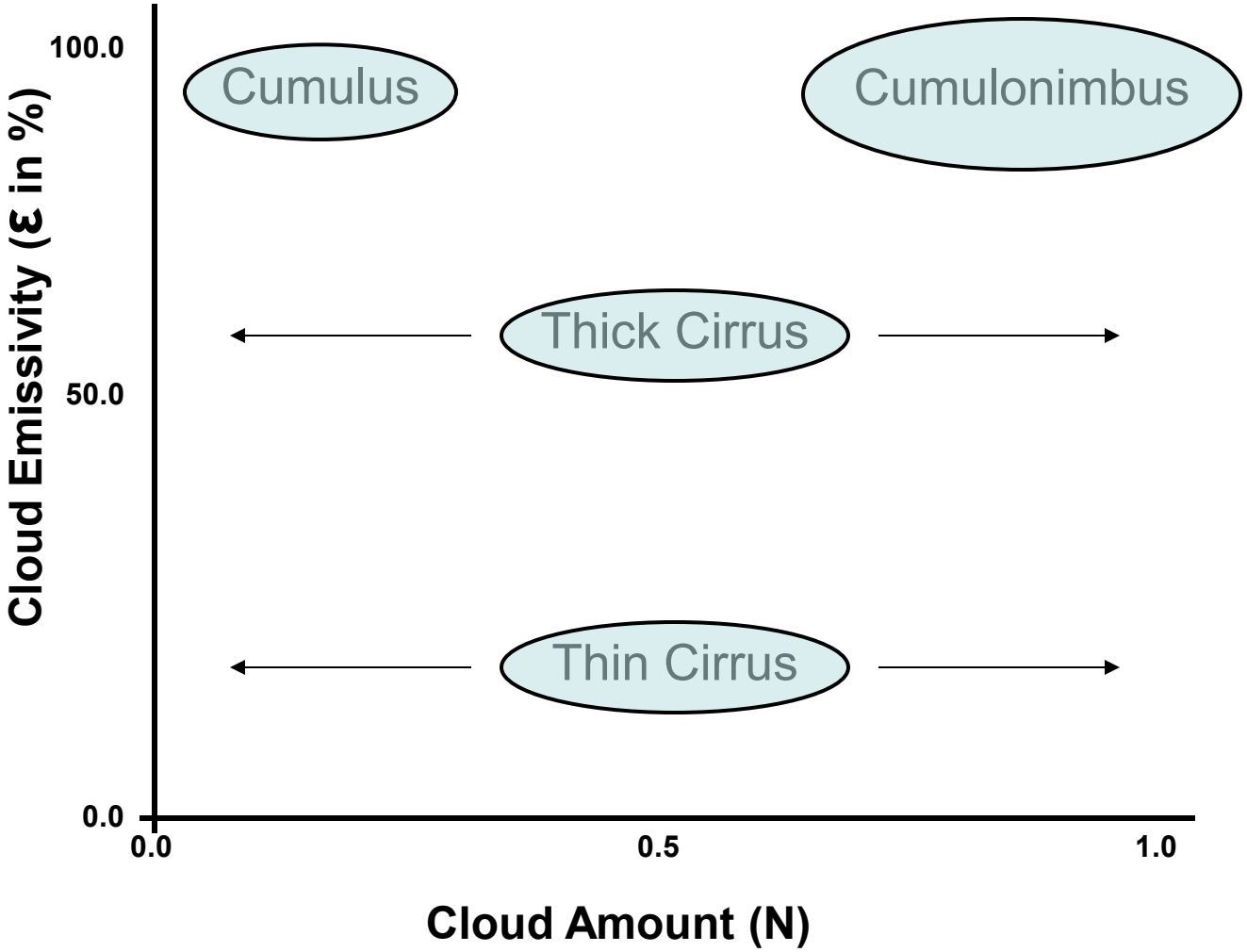
$$\frac{R_1 - R_{1cl}}{R_2 - R_{2cl}} = \frac{\int_{P_s}^{P_c} \tau_1 \frac{dB_1}{dp} dp}{\int_{P_s}^{P_c} \tau_2 \frac{dB_2}{dp} dp}$$

assume cloud amount, η, is the same;
emissivity, ε, of the cloud is the same for both spectral intervals

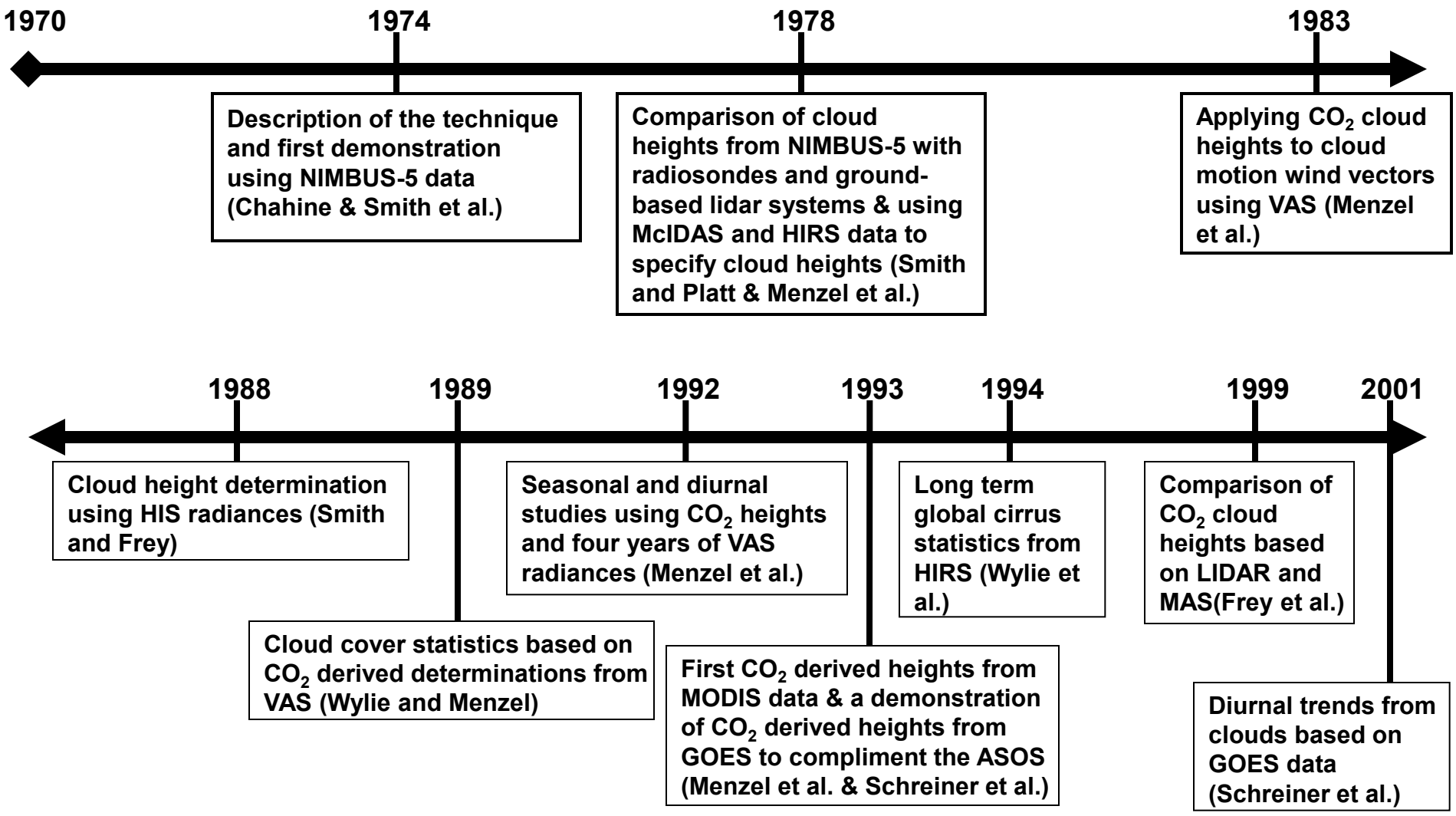
- Effective cloud amount, $\eta\varepsilon$, is calculated by solving the above equation for either spectral interval once Pc, pressure of the cloud, has been determined.

What is Effective Cloud Amount (Nε)?

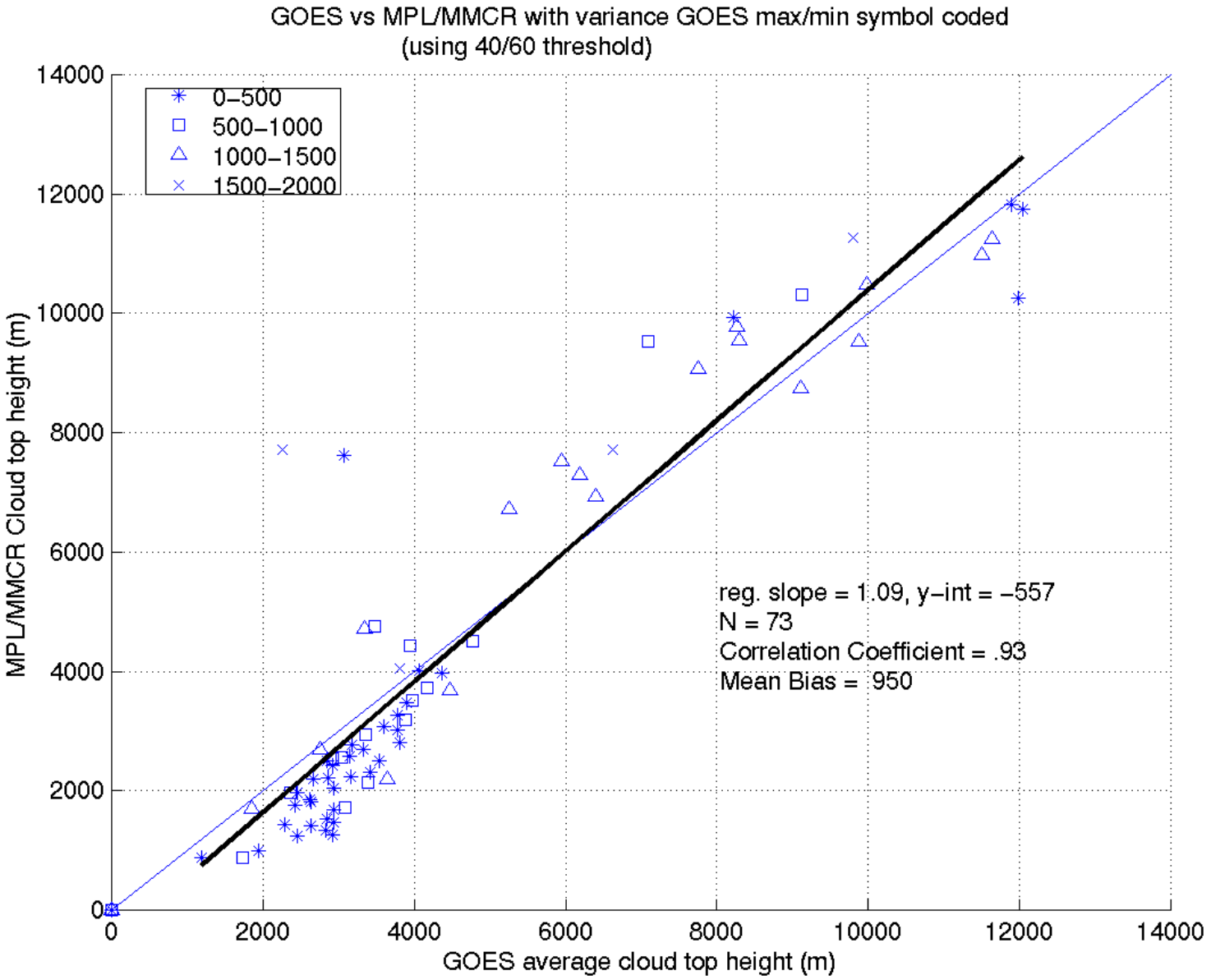
Effective cloud amount is the emissivity (ε) of a cloud times the fractional cloud cover (N) for a given field of view.



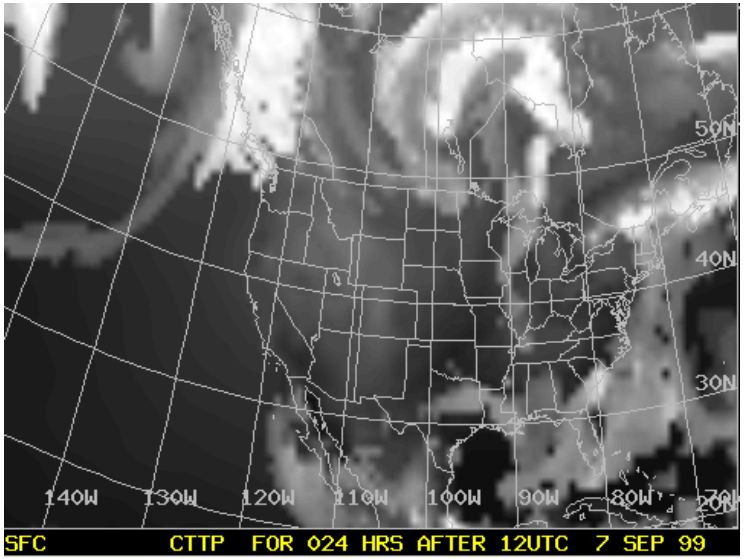
CO_2 Slicing Technique at CIMSS
A Historical Perspective



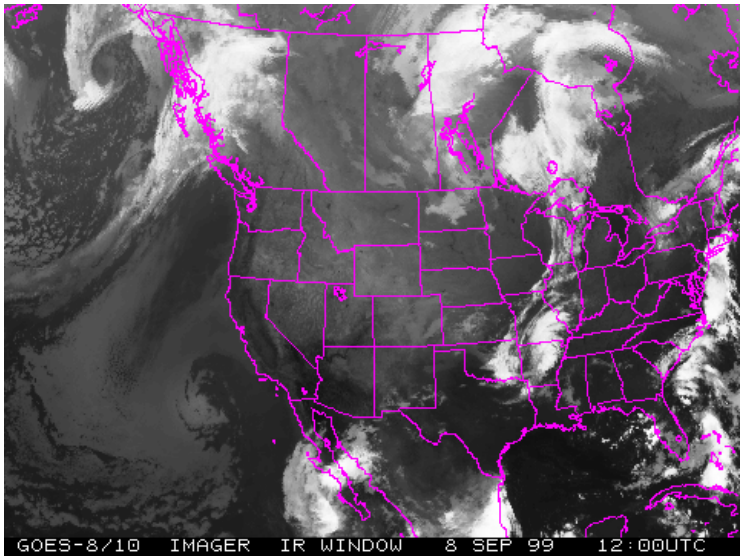
Comparison to MPL/MMCR at CART Site



GOES CLOUD PRODUCT & NWP MODELS (CRAS)

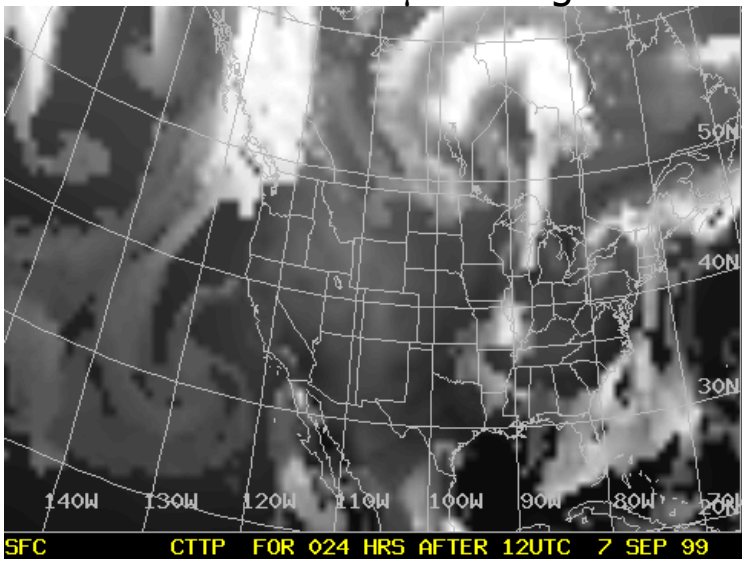


24 hr Forecast w/o Sat CP & PW



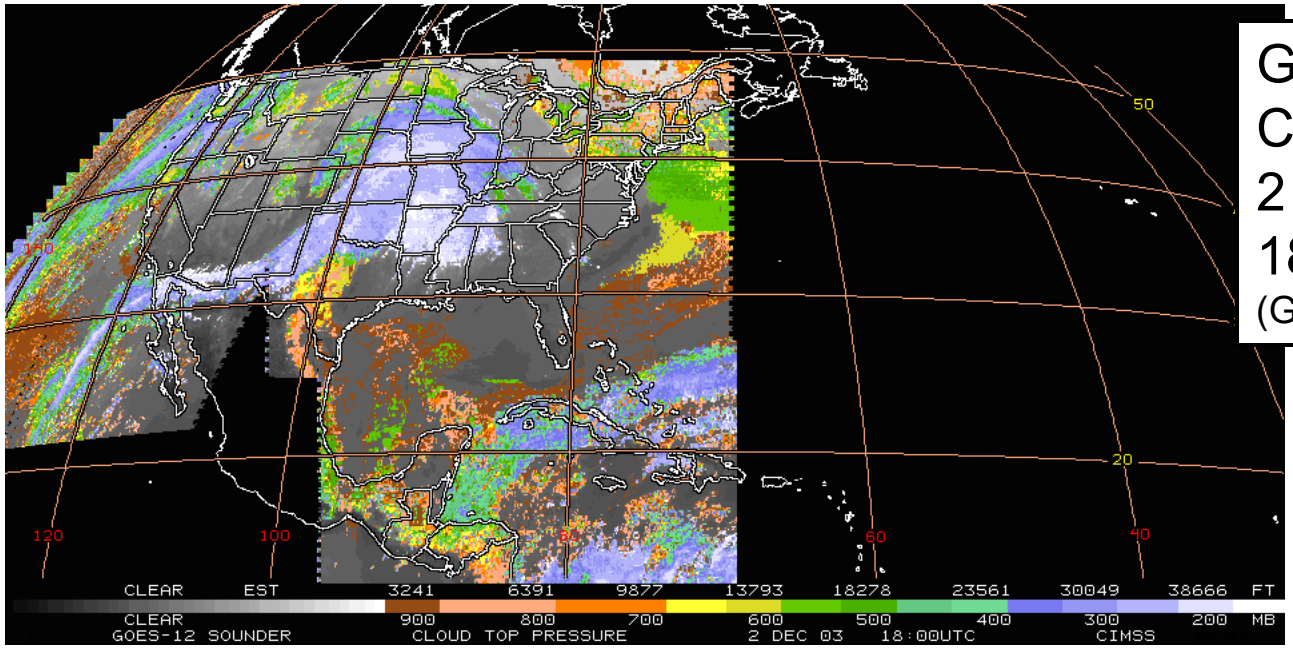
GOES-8 11μm Image

- The NWP model is initialized with Sat. CP & PW
- Prior to start of forecast, Sat. CP is inserted at 3 hourly intervals
- With Sat. data positive impact is seen over the eastern Pacific and central part of US

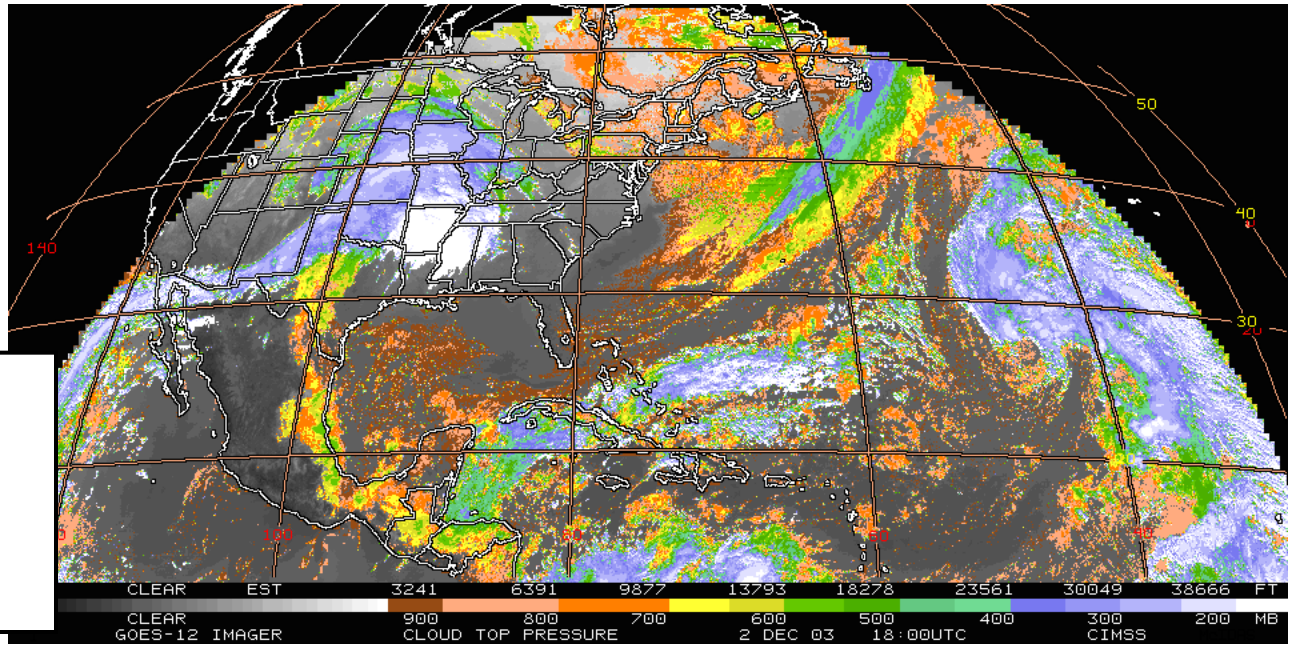


24 hr Forecast w Sat CP & PW

Sounder and Imager CTP comparison



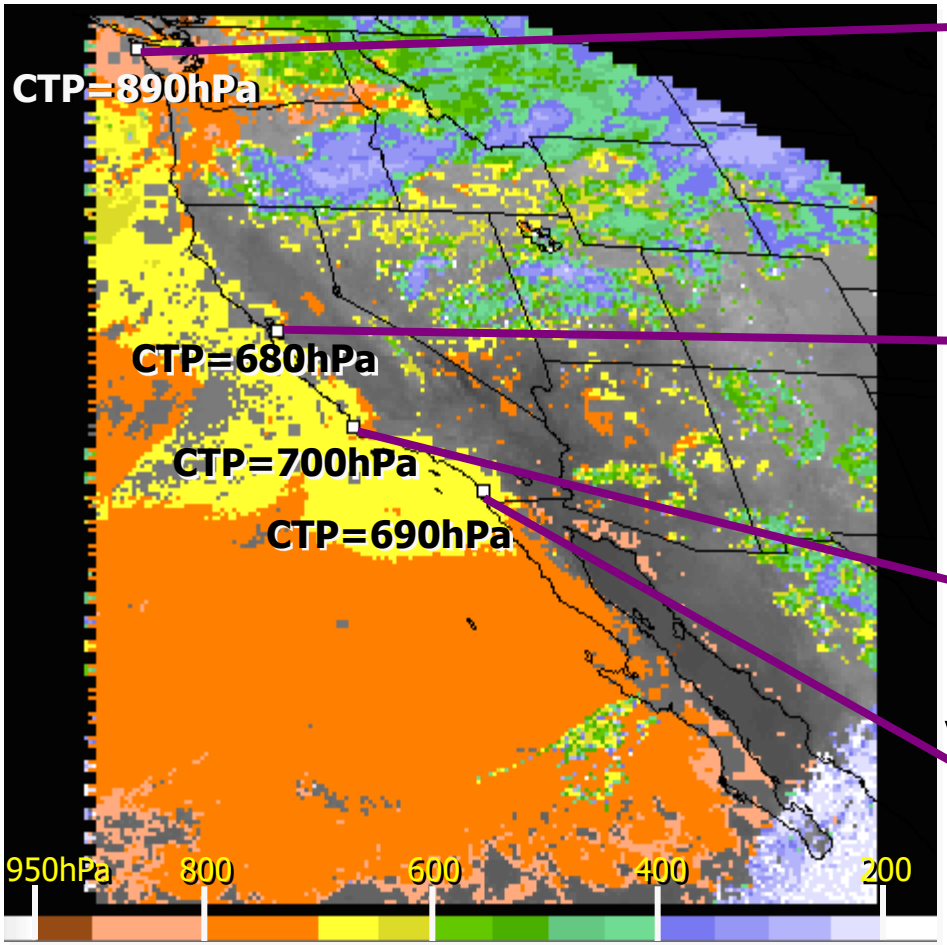
GOES-10/12 Sounder
Cloud Top Pressure
2 Dec 2003
18:00 UTC
(GOES-12 Imager Projection)



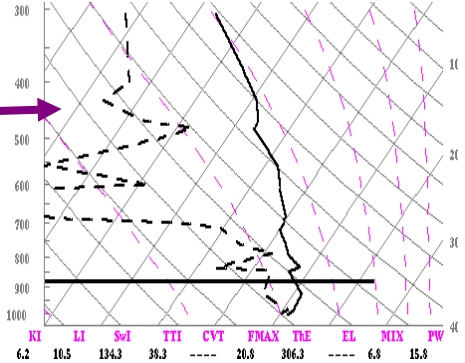
GOES-12 Imager
Cloud Top Pressure
2 Dec 2003
18:00 UTC

Data quality

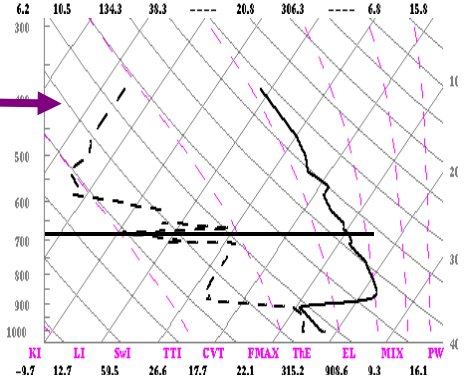
21 Sep 2000 12 UTC



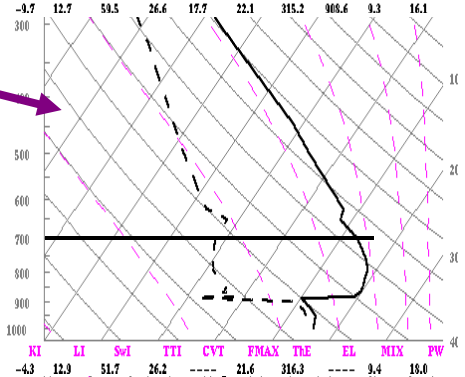
Quillayute, WA



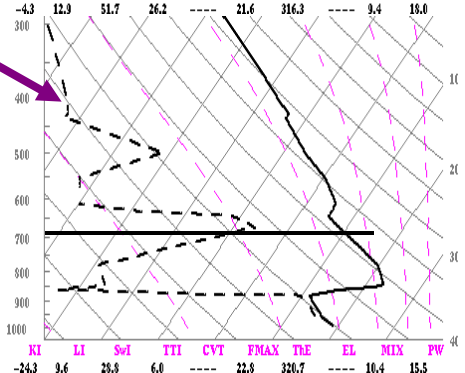
Oakland, CA



Vandenberg AFB, CA



Miramar, CA



The vertical resolution of the GOES Sounder is limited, especially at low levels.

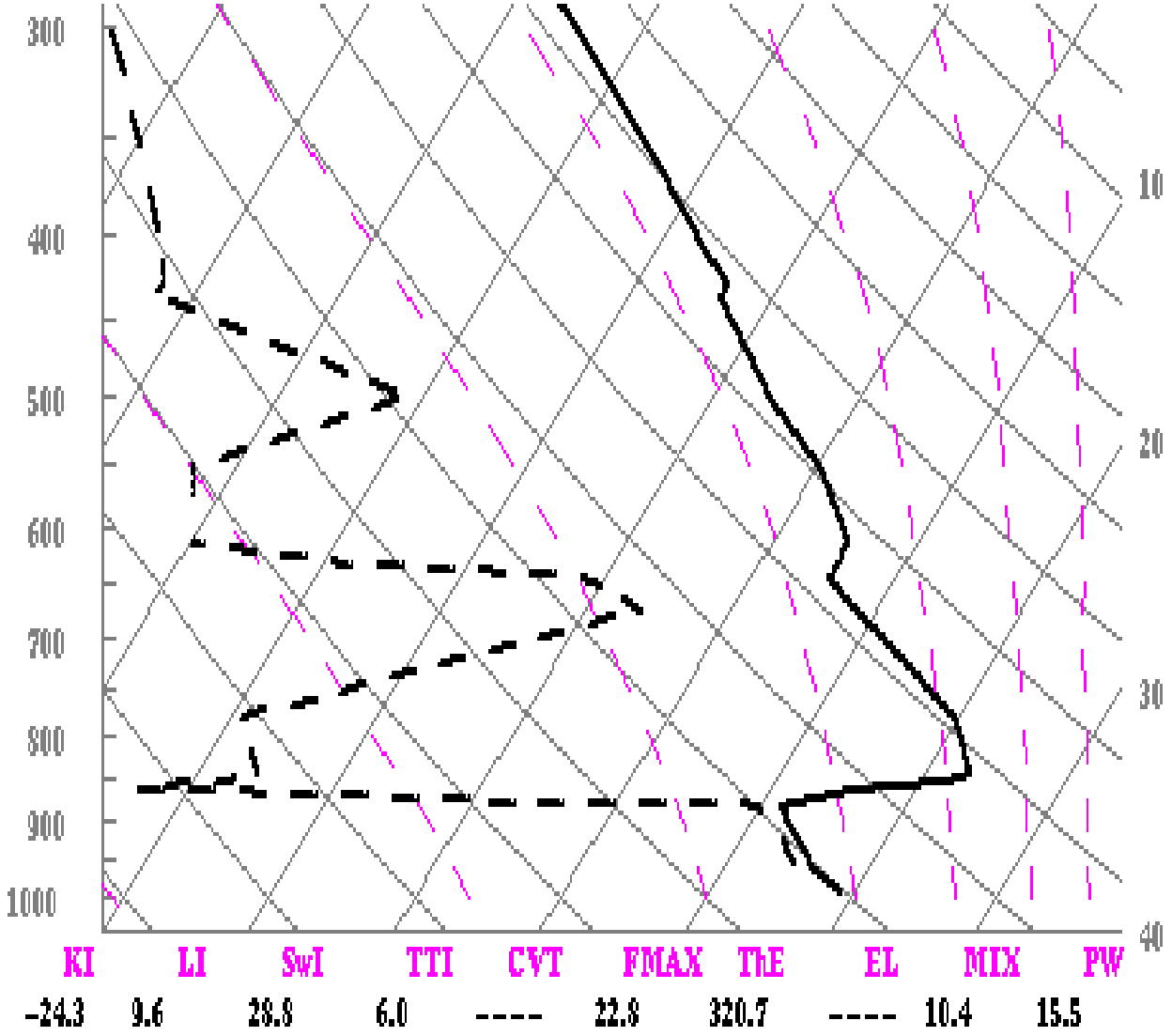
Define:

"Top/Down"

- Compare TB(11μm) with guess profile
- Assume no Inversions
- First level of agreement between TB(11μm) & profile is CTP

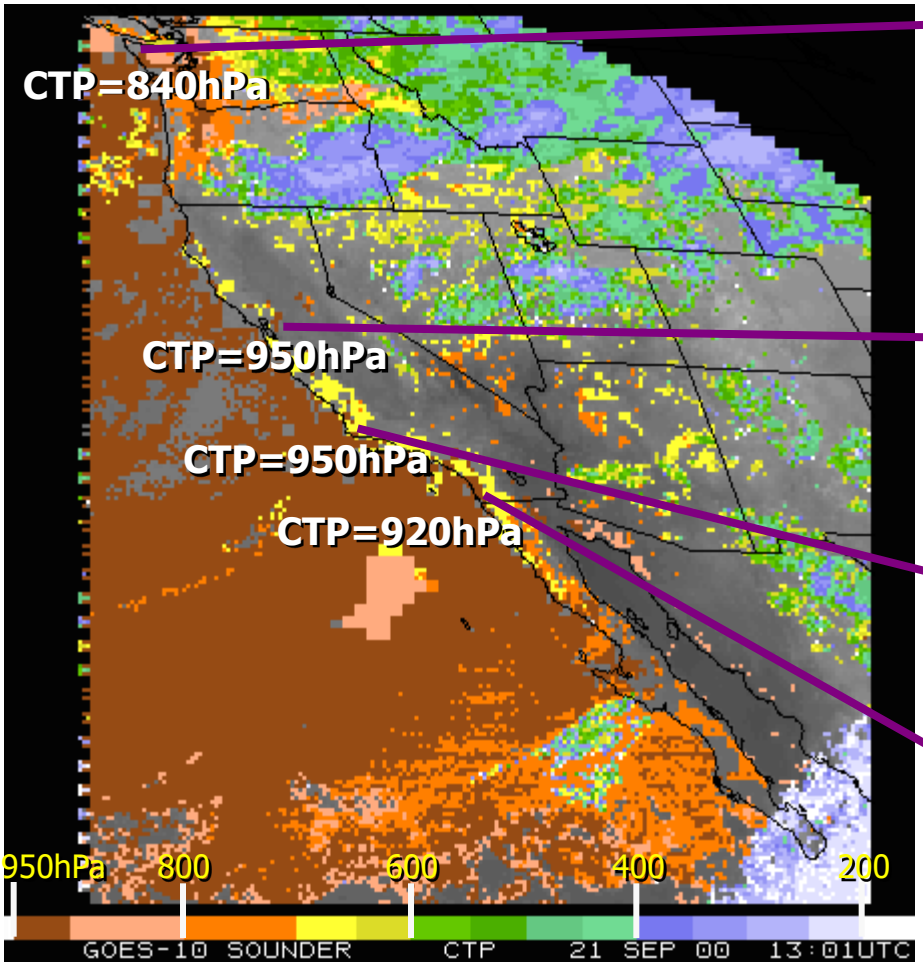
"Bottom/Up"

- Compare TB(11μm) with guess profile
- Find top of cloud:
  - Determine level of max change of TD Depression
  - Determine height of Temperature Inversion
  - First level of agreement between TB(11μm) & profile
- CTP assigned where one of these conditions exists & TB(11μm) is within "some window" of guess profile

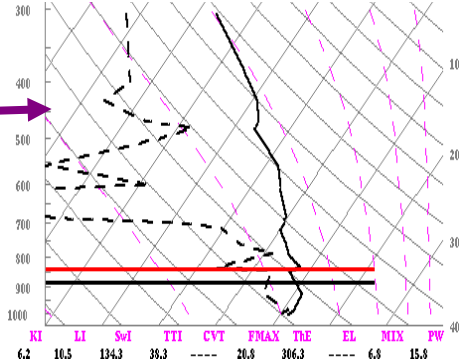


Results Using New Method

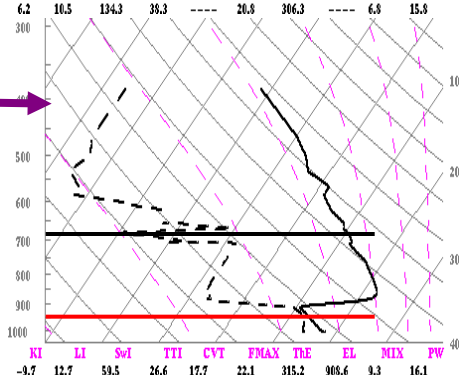
21 Sep 2000 12 UTC



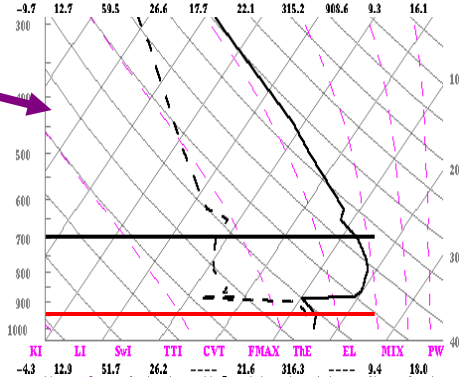
Quillayute, WA



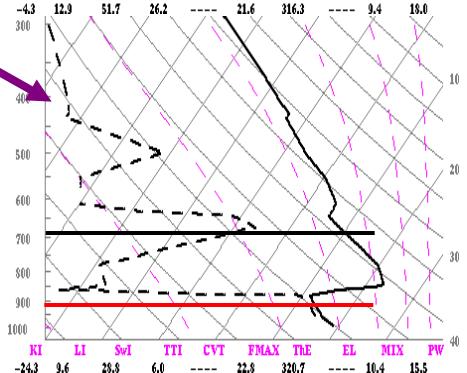
Oakland, CA



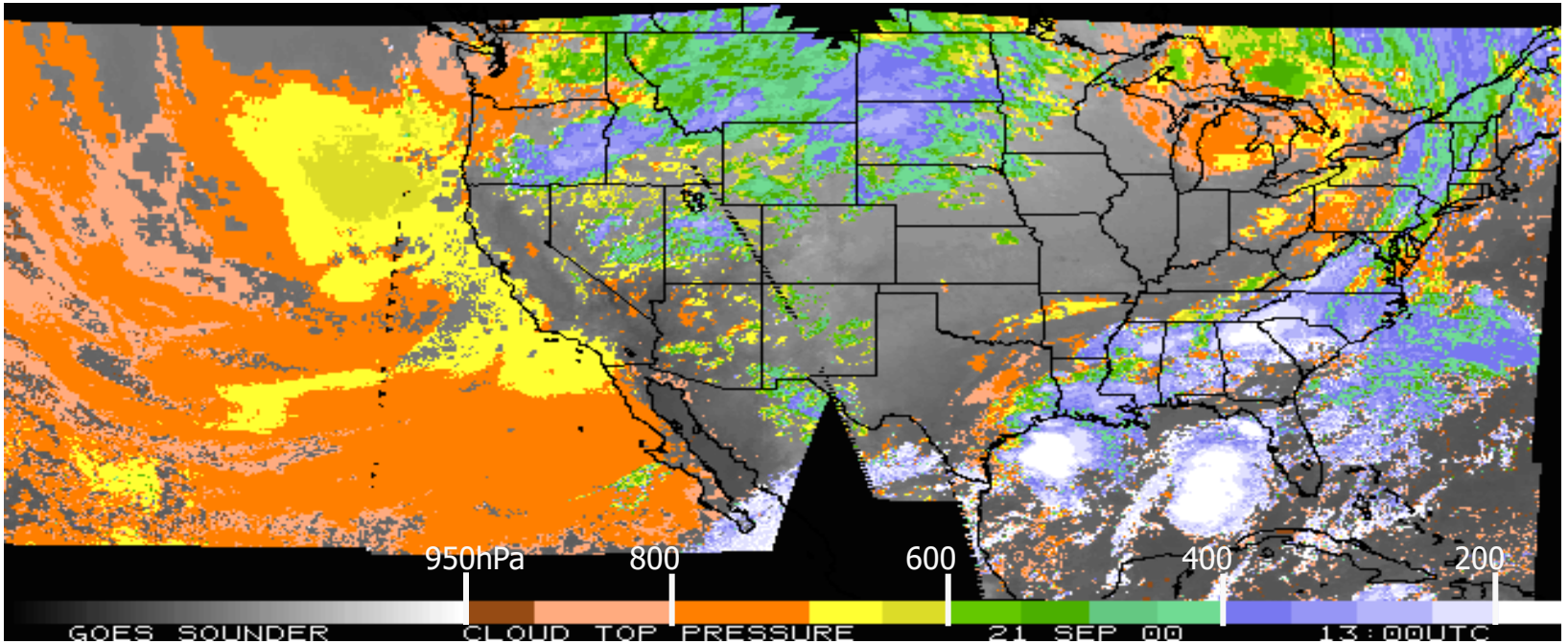
Vandenberg AFB, CA



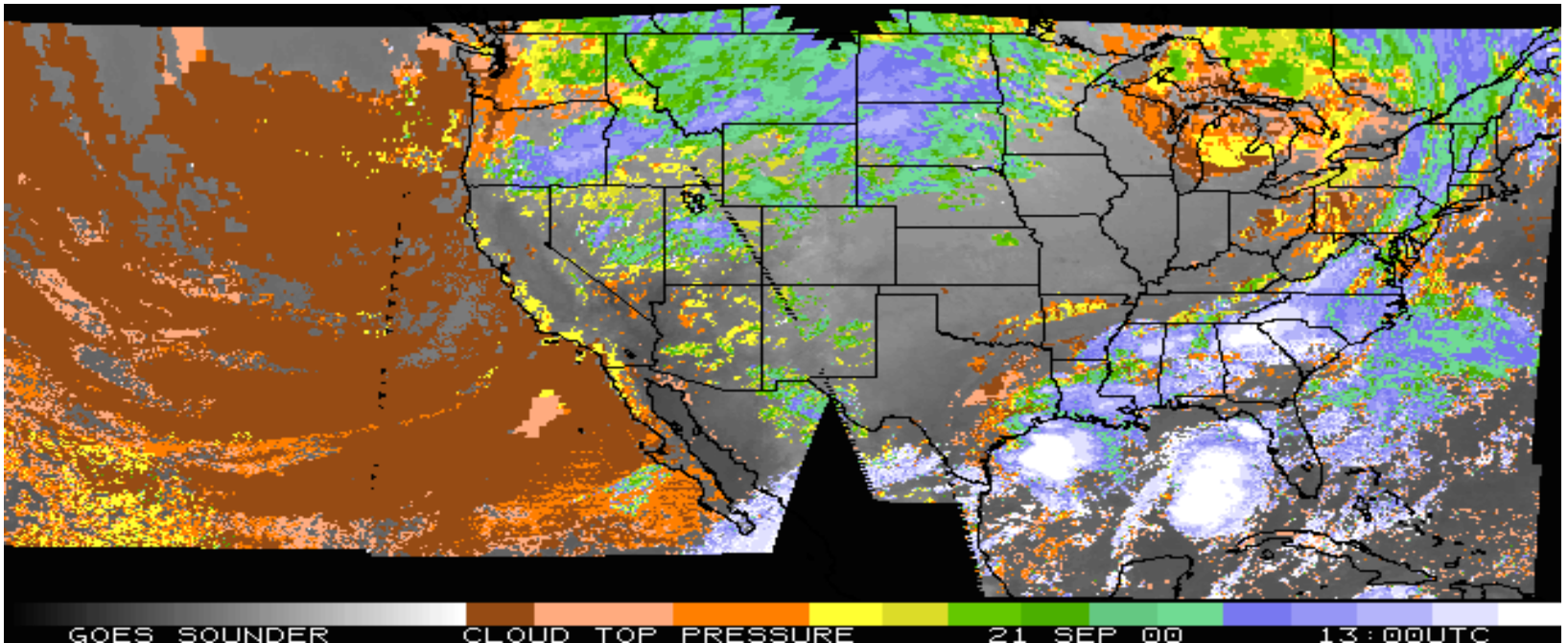
Miramar, CA



Application to the Eastern Pacific and Beyond

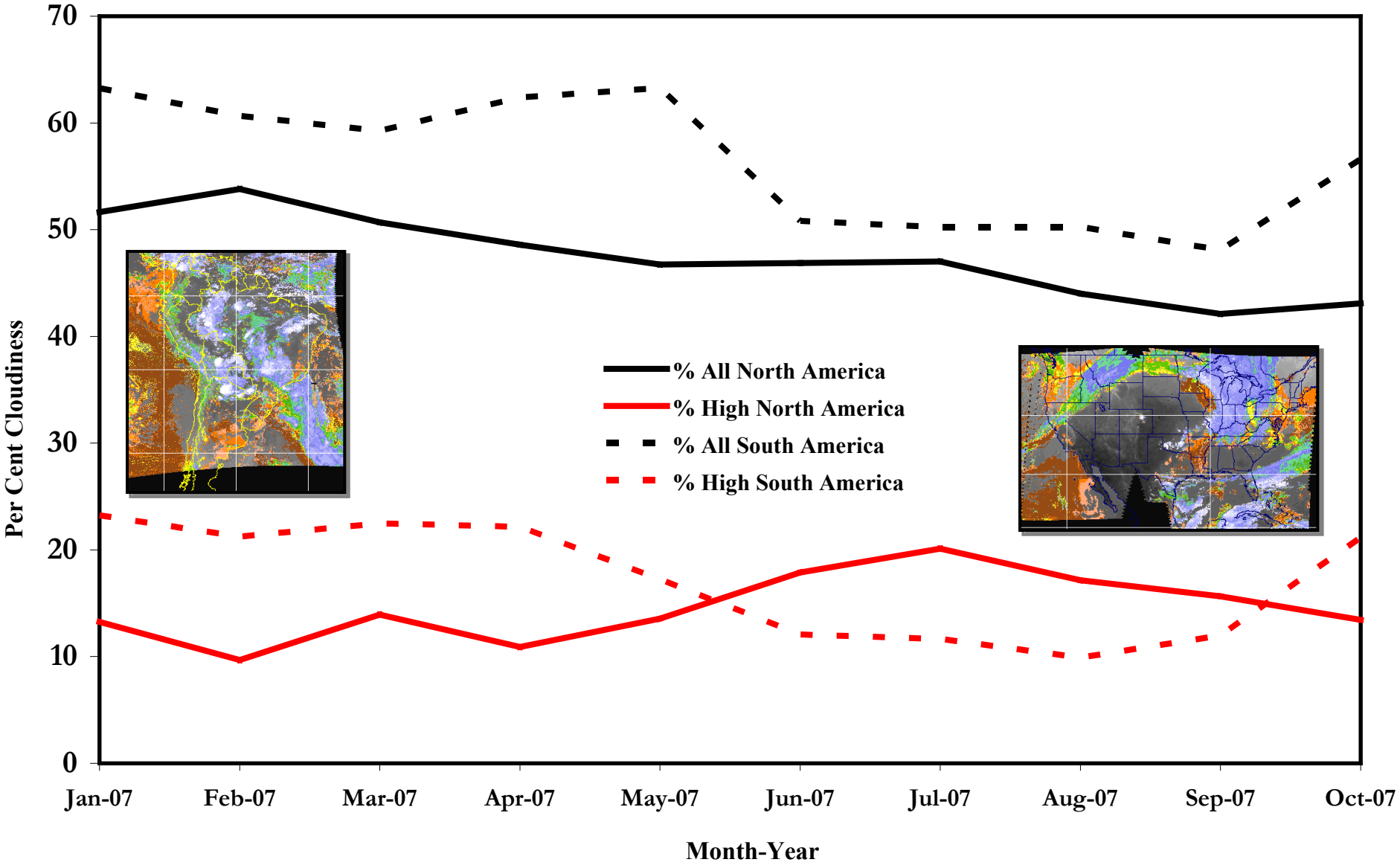


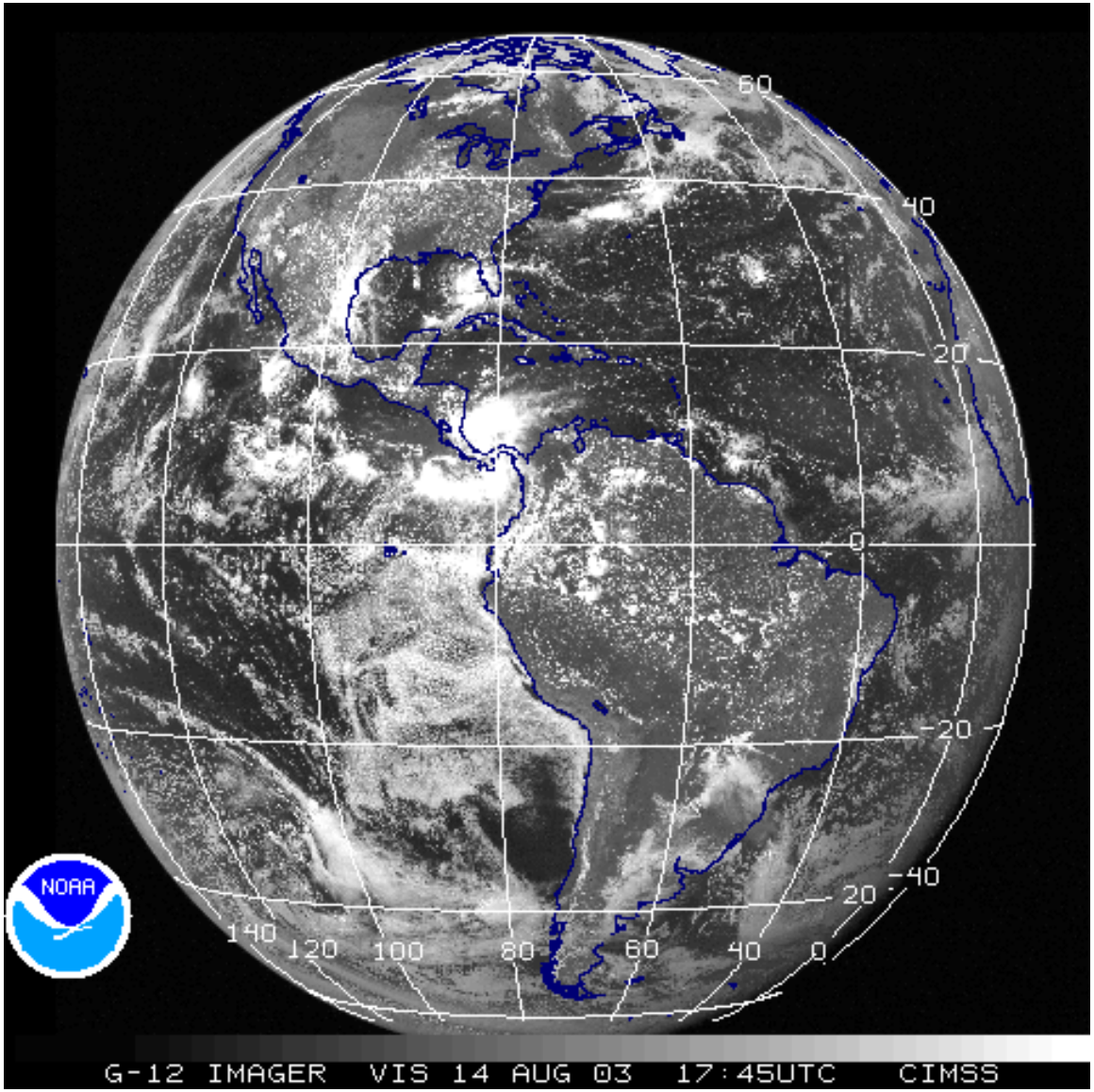
Old Method



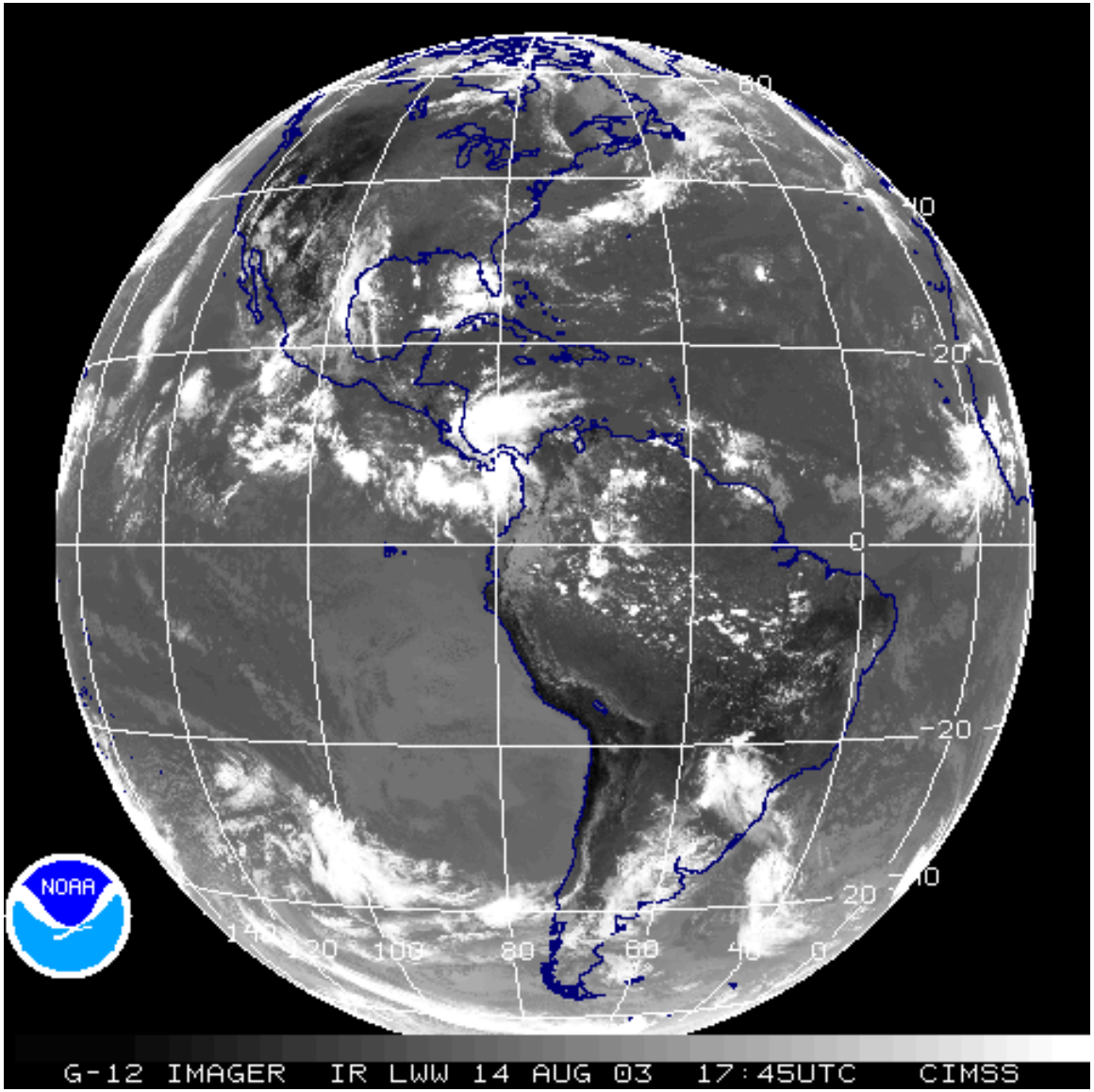
New Method

Monthly Changes in Cloudiness from GOES Sounder CTP DPI



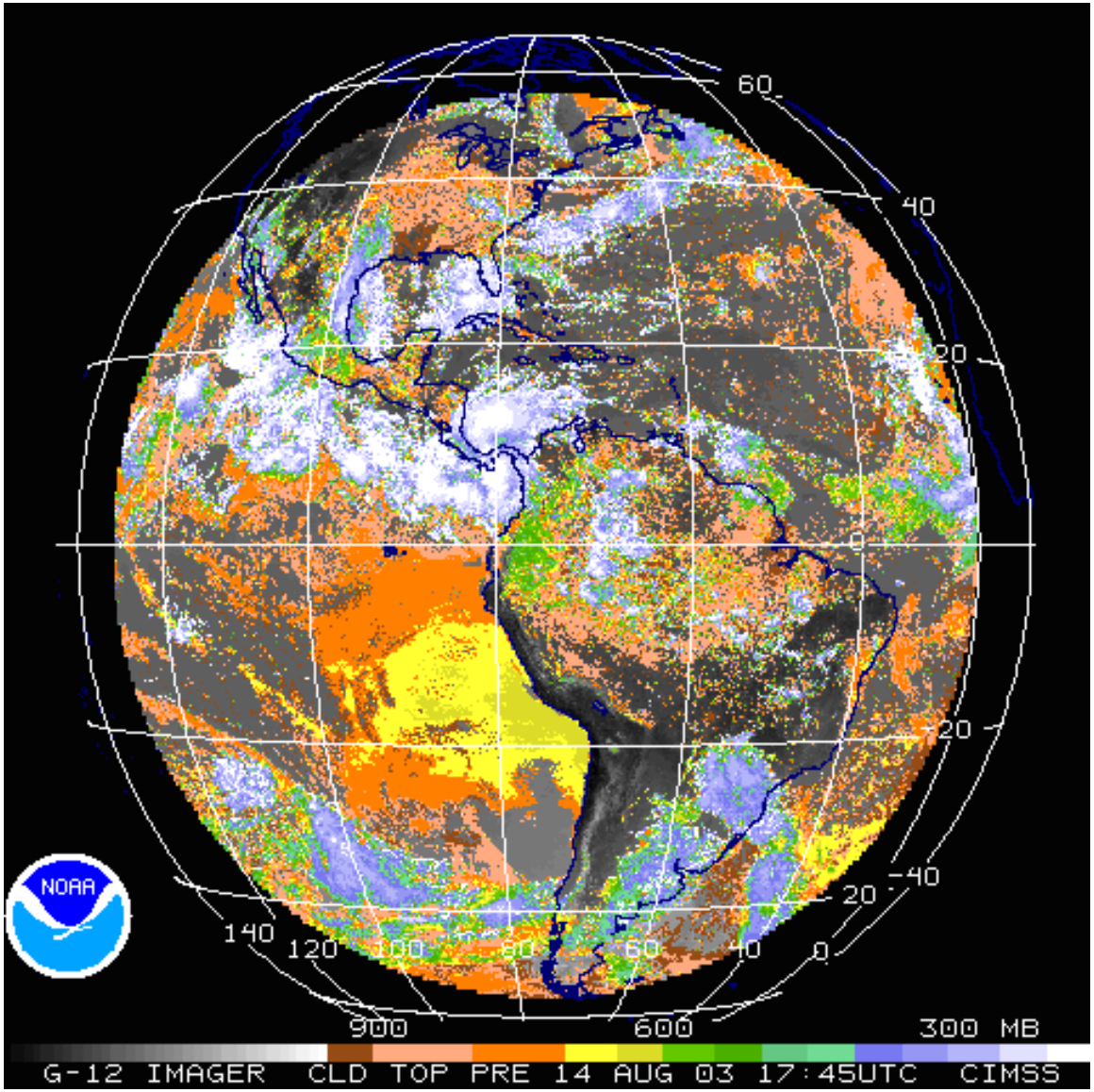


GOES-12 Imager, Visible

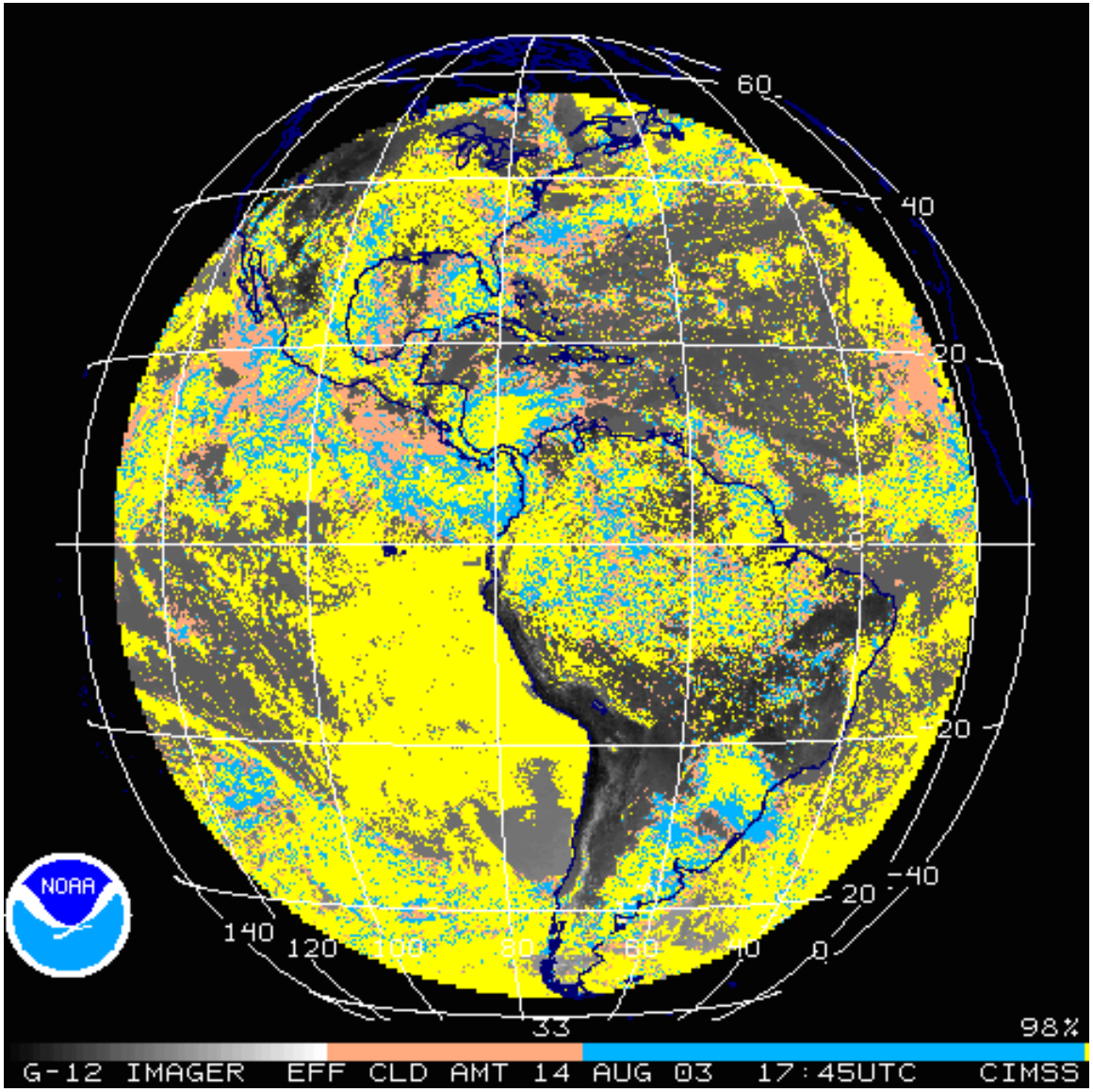


GOES-12 Imager, IR Window

Now hourly processing…



GOES-12 Imager, Cloud-Top Pressure



GOES-12 Imager, Effective Cloud Amount

Aspects of satellite applications: general to specific

Imagery (monitor [qualitative/quantitative], interpret)

Winds (measure motions)

Soundings (derive vertical profiles or quantities) [or imagery of]

Assimilation of above data into numerical models

Storm/cloud detection, synoptic interpretation, indicators of turbulence or instability, multi-spectral combinations ("true color" images; detection of fog, fire, smoke, volcanic ash, aerosols, snow, ice…)

Diagnostic wind fields (steering of tropical storms; synoptic dynamics)

Fields of total precipitable water, atmospheric stability