Guam NWS Polar Orbiter Direct Broadcast Applications Workshop

Volcanic Clouds and Sea Surface Temperatures

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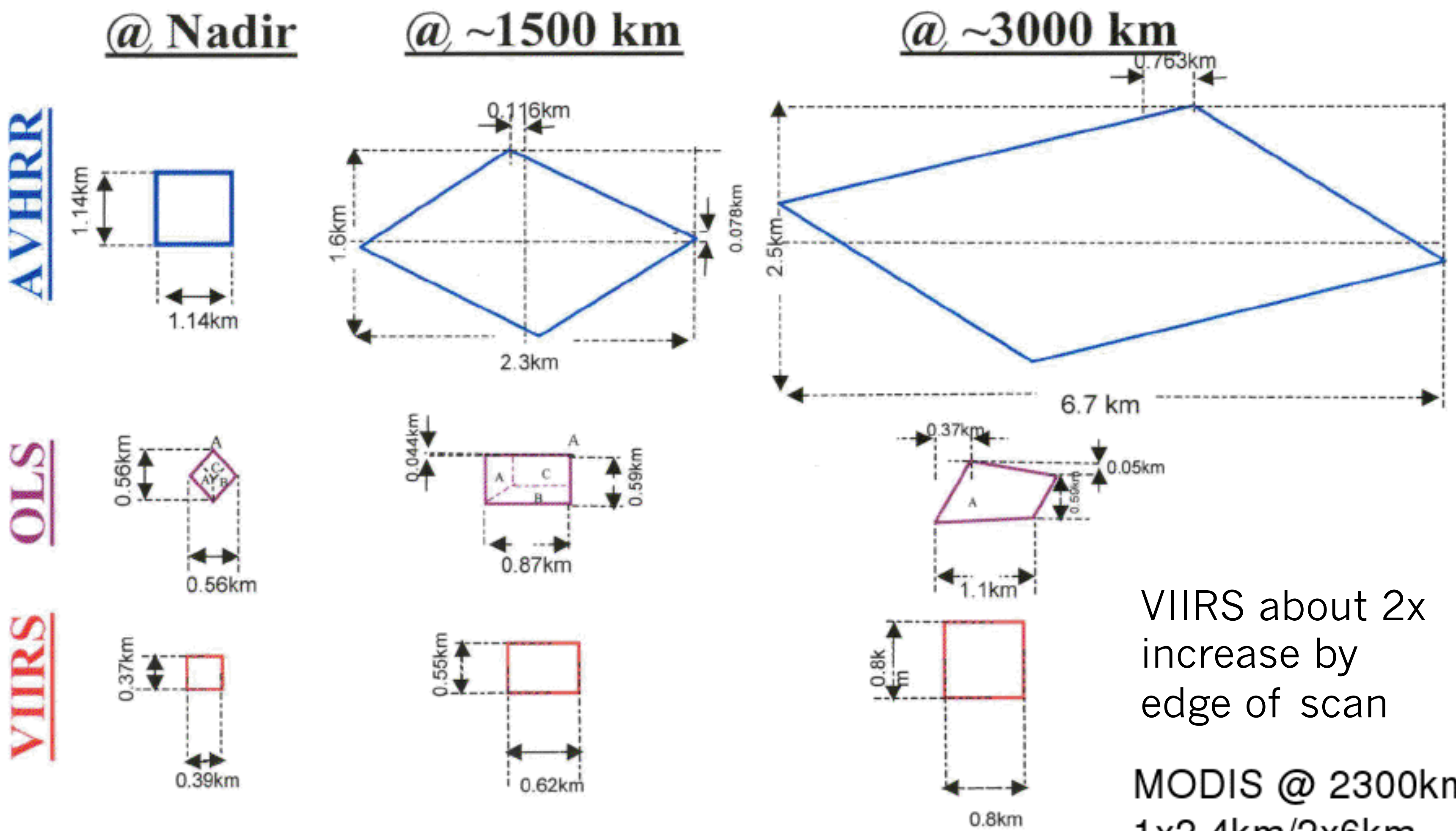
Cooperative Institute for Meteorological Satellites Studies (CIMSS)
Space Science and Engineering Center (SSEC)

16 and 19 April 2018

VIIRS Improvements From AVHRR: Geometric properties

Higher spatial resolution with reduced pixel growth



VIIRS about 2x increase by edge of scan

MODIS @ 2300km: 1x2.4km/2x6km


Identifying Hazardous Airspace in the Wake of Volcanic Eruptions

Michael J. Pavolonis
NOAA/NESDIS/STAR

Online video of Mike Pavolonis, presenting these slides at the American Meteorological Society JPSS Short Course, can be found at:

https://annual.ametsoc.org/2018/index.cfm/programs/short-courses-workshops/ams-short-course-using-jpss-data-products-to-observe-and-forecast-major-environmental-events/

Outline

1. Volcanic clouds and aviation
2. JPSS volcanic cloud remote sensing and aviation decision support
3. Advanced products and resources

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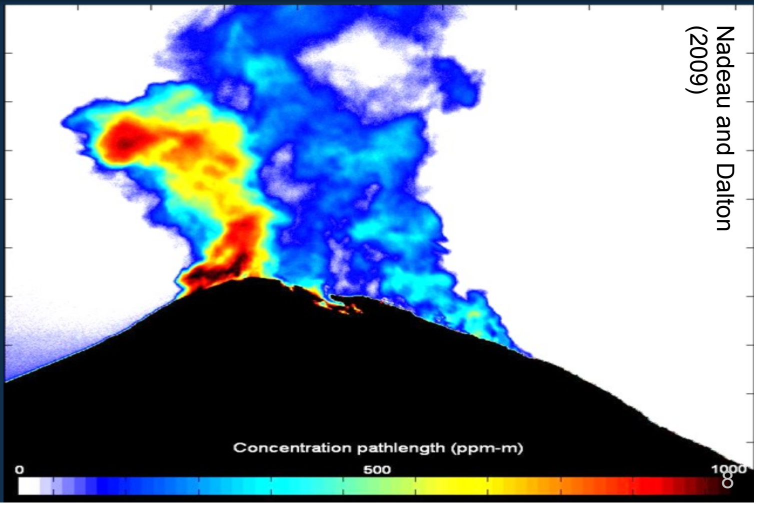
WHAT IS A VOLCANIC CLOUD?

1). Ash dominated volcanic plumes: Semi-transparent clouds dominated by volcanic ash. Lightning is sometimes present in these clouds.

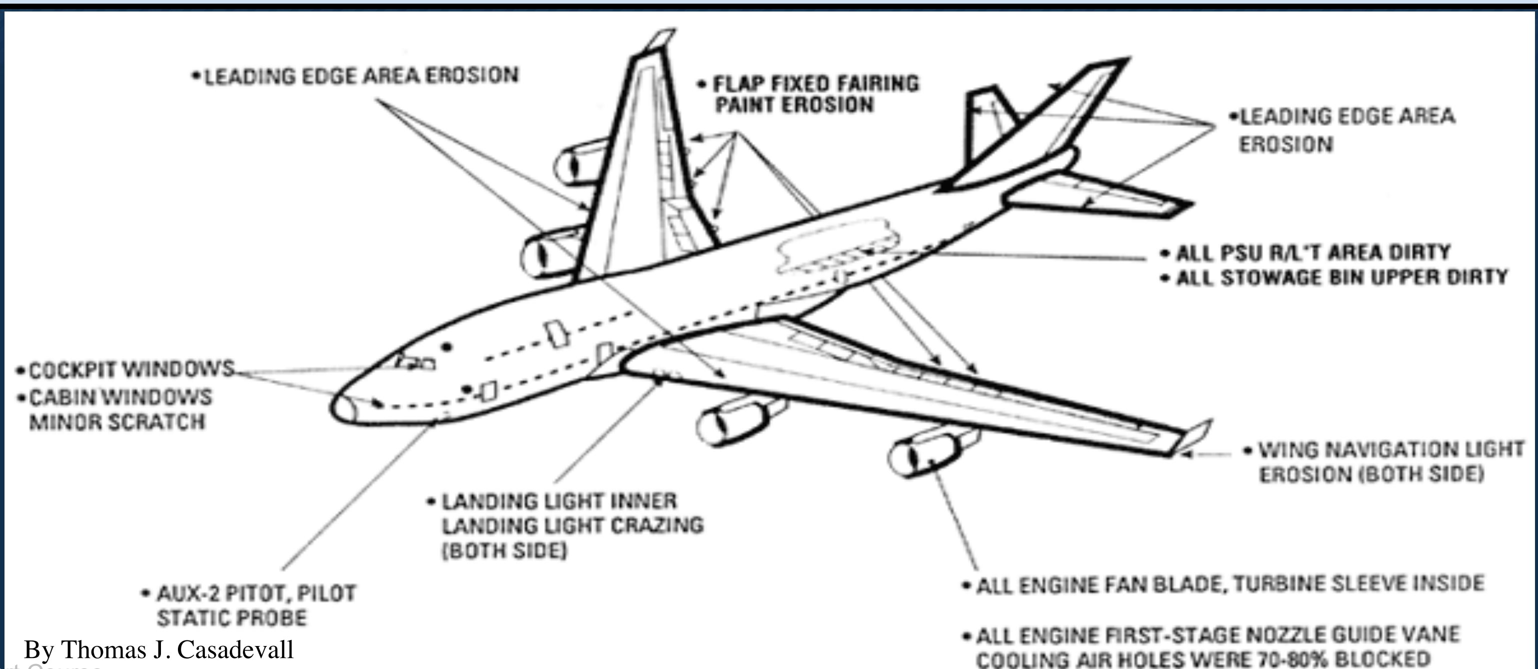
2). Ice topped umbrella clouds: These cloud are mostly observed during a major eruption. A spectral based volcanic ash signal is usually initially absent because the ash is encased in ice and/or the cloud is opaque. Lightning is often present in these clouds.

3). SO_2 clouds: Sulfur dioxide clouds that may or may not contain volcanic ash. Some eruptions produce large amounts of SO_2 and very little ash and vice-versa.



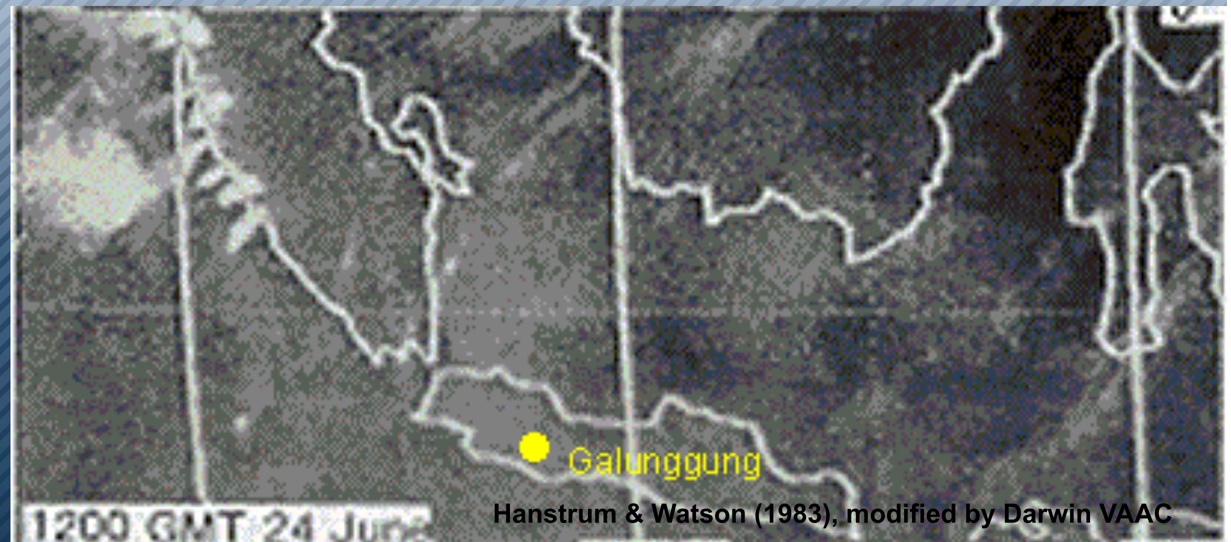
Volcanic Clouds and Aircraft

- ***Sand blasts cockpit wind screen, airframes, and flight surfaces***
- ***Clogs the pitot-static system (includes airspeed instrument)***
- ***Ingestion into air conditioning and cooling systems leads to contamination of electrical and avionics units, fuel and hydraulic systems, and cargo-hold smoke detection systems***
- ***Damages jet turbine engines (can lead to complete engine failure)***



By Thomas J. Casadevall

British Airways Flight 9, June 24, 1982



Hanstrum & Watson (1983), modified by Darwin VAAC

“Ladies and gentlemen, this is your captain speaking. We have a small problem. All four engines have stopped”
-Captain Eric Moody

KLM Flight-867, December 15, 1989


Credit: Gary Hufford


Joyce M. Warren

KLM Flight-867, December 15, 1989

- A similar in-flight emergency occurred in December of 1989 when a KLM jet encountered volcanic ash from Mount Redoubt just outside of Anchorage, AK.
- Power to all 4 engines was lost. Fortunately, the crew was able to re-start 2 engines after gliding down to 17,000 feet, narrowly avoiding disaster.
- The heavily damaged plane made an emergency landing in Anchorage. Aircraft are not certified to fly through volcanic ash so even when an aircraft flies through lower concentrations of ash that do not cause engine failure, the plane must be grounded and thoroughly inspected for damage.
- That process is very costly.

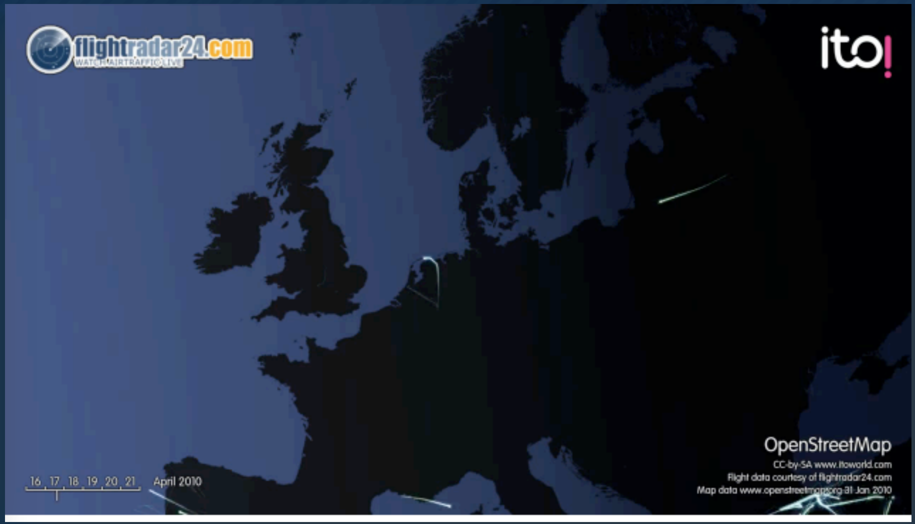
Economic Impacts of Volcanic Ash

April 2010

The Eyjafjallajökull Eruption:

- Nearly 100,000 canceled flights (50% of world's air traffic!)
- Airlines were losing $200 million/ day
- Total economic impact - $2 billion

Before Ash Event

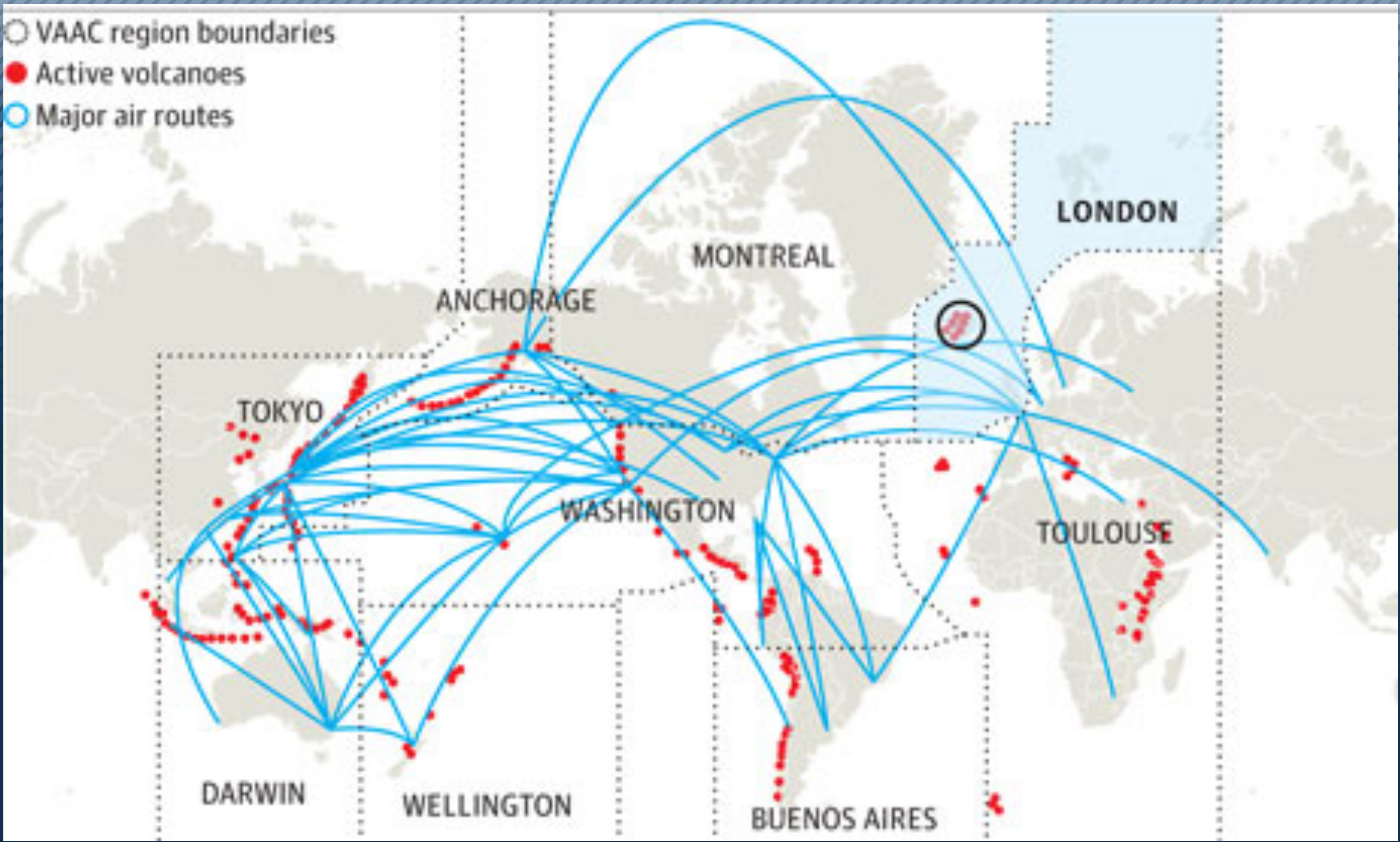


During Ash Event

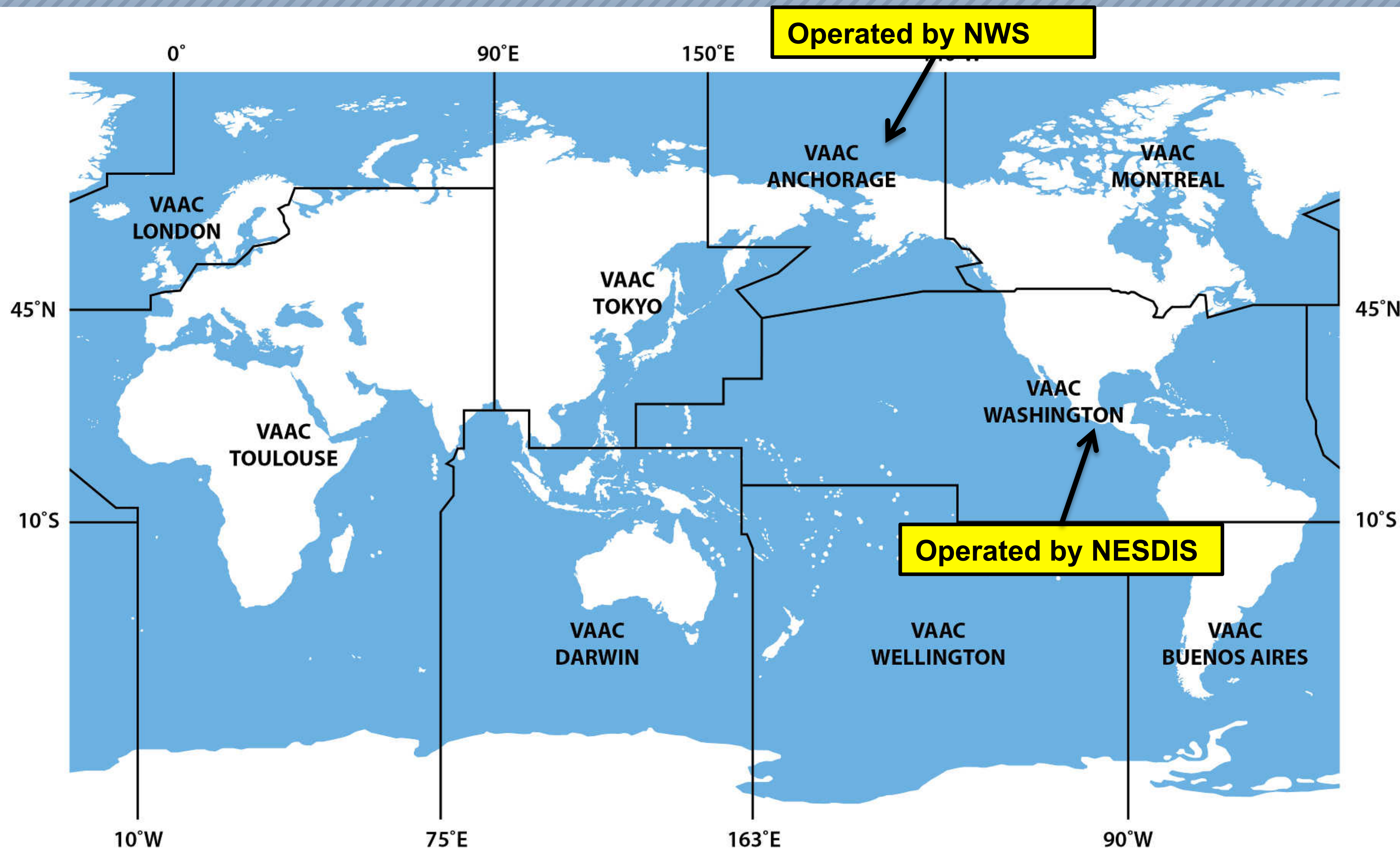
Economic Impacts of Volcanic Ash

- Even weak eruptions can be problematic for aviation if the volcano is a high mountain (e.g. Popo in Mexico City).
- There are on average 60 different volcanoes that erupt each year.
- There is usually at least one volcanic eruption per day.
- More than 10 per year will inject ash to 45,000 feet.
- The Smithsonian Global Volcanism Program database contains 1549 volcanoes
- Since 1976 an average of 2 aircraft encounters per year have occurred (most of them damaging)

Major Flight Routes



Volcanic Ash Advisory Centers (VAAC's)



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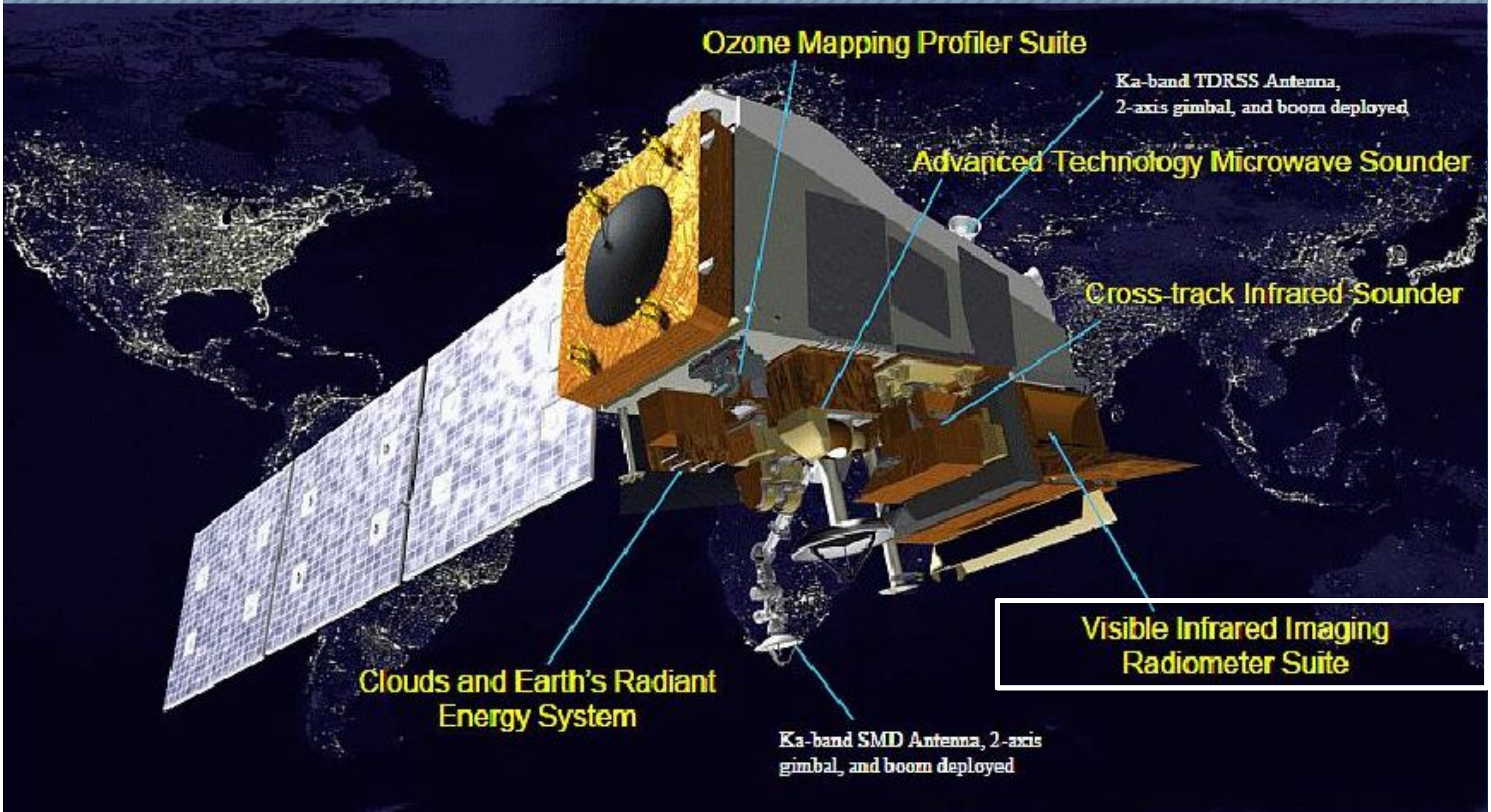
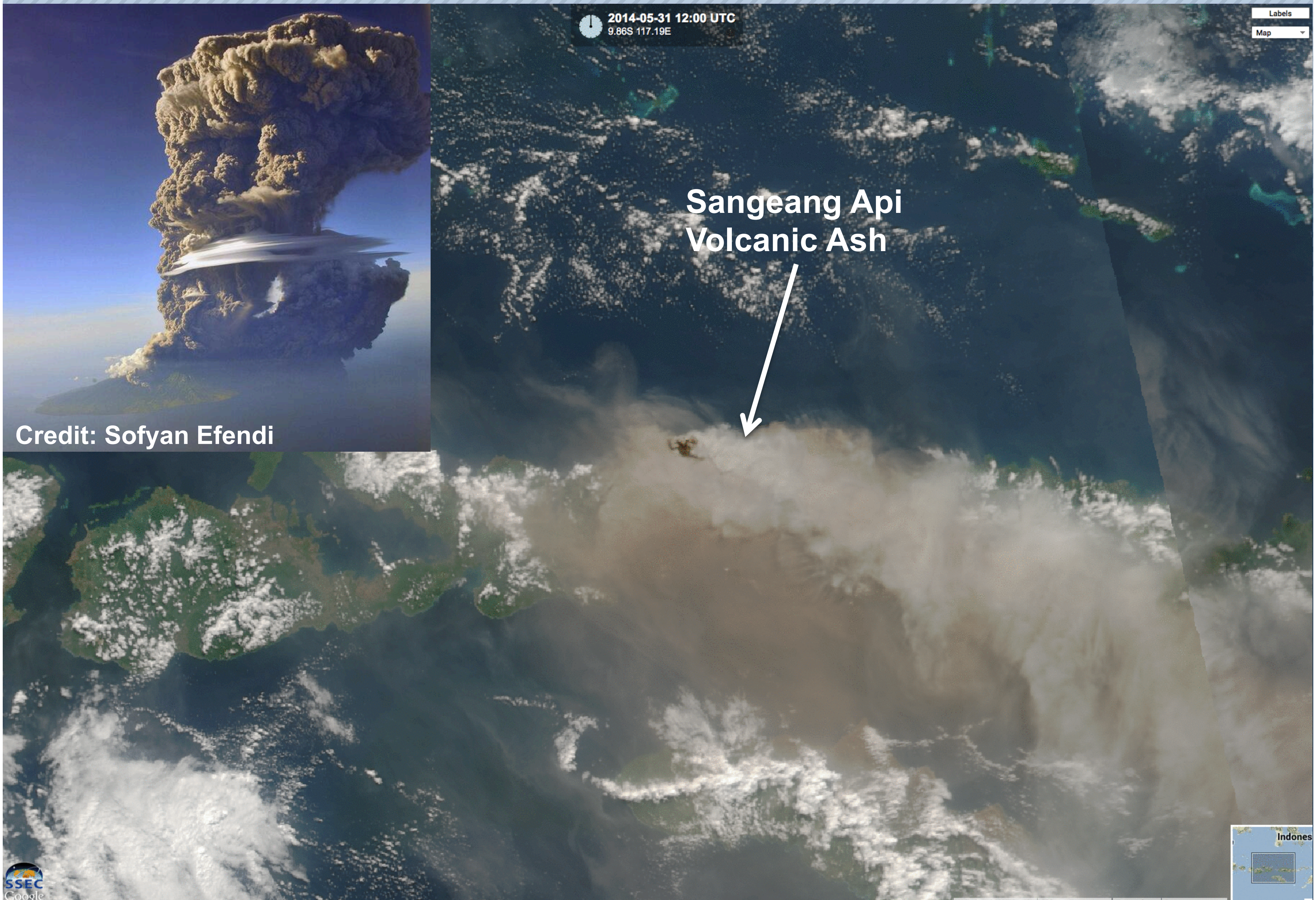
S-NPP/NOAA20 Instruments and Volcanic Clouds



Characteristics of Ash Cloud

Ash is more absorbing at visible wavelengths than meteorological clouds, so it will often appear brown in true color imagery if sufficient ash is present

VIIRS True Color Imagery

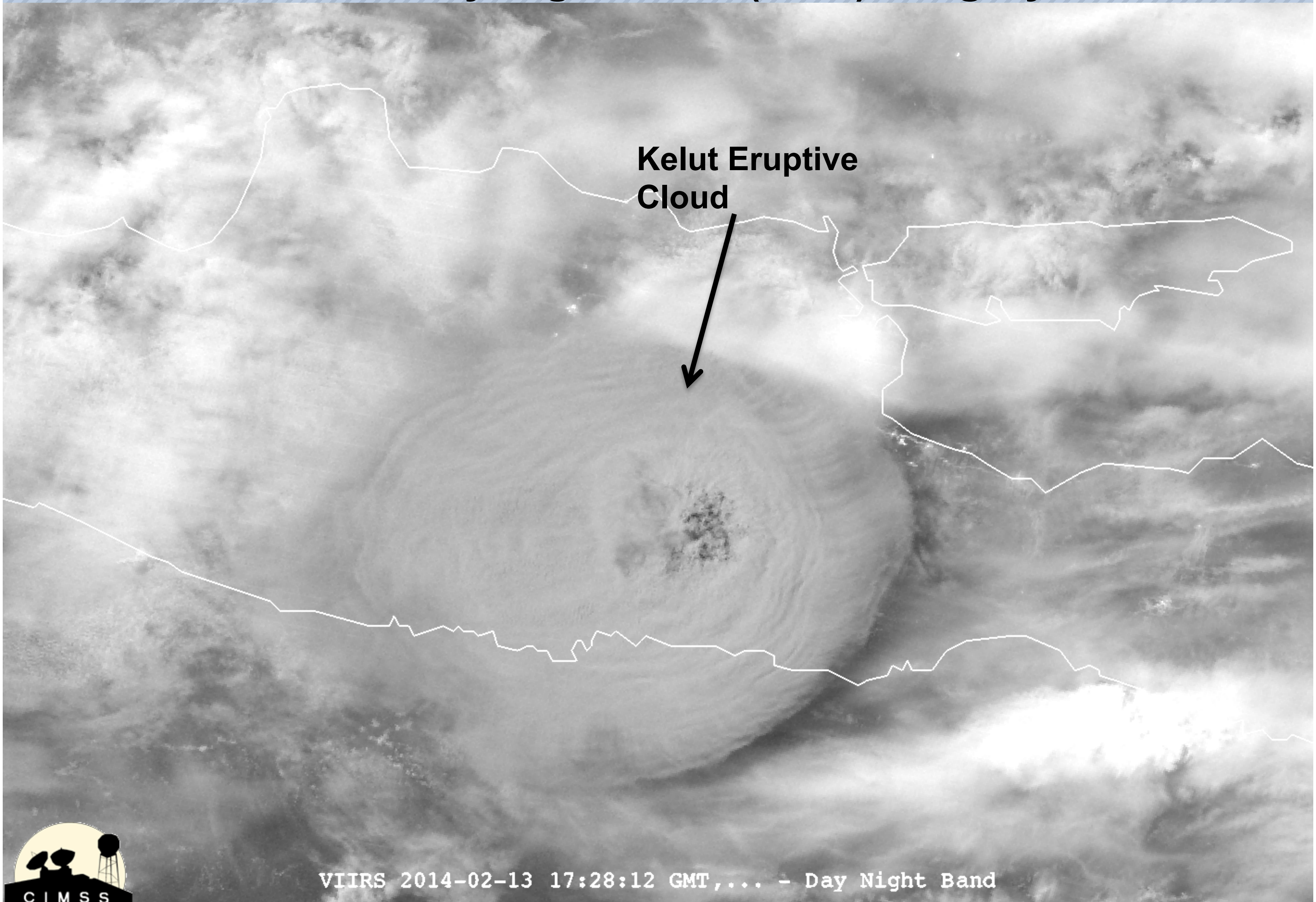


Credit: Sofyan Efendi

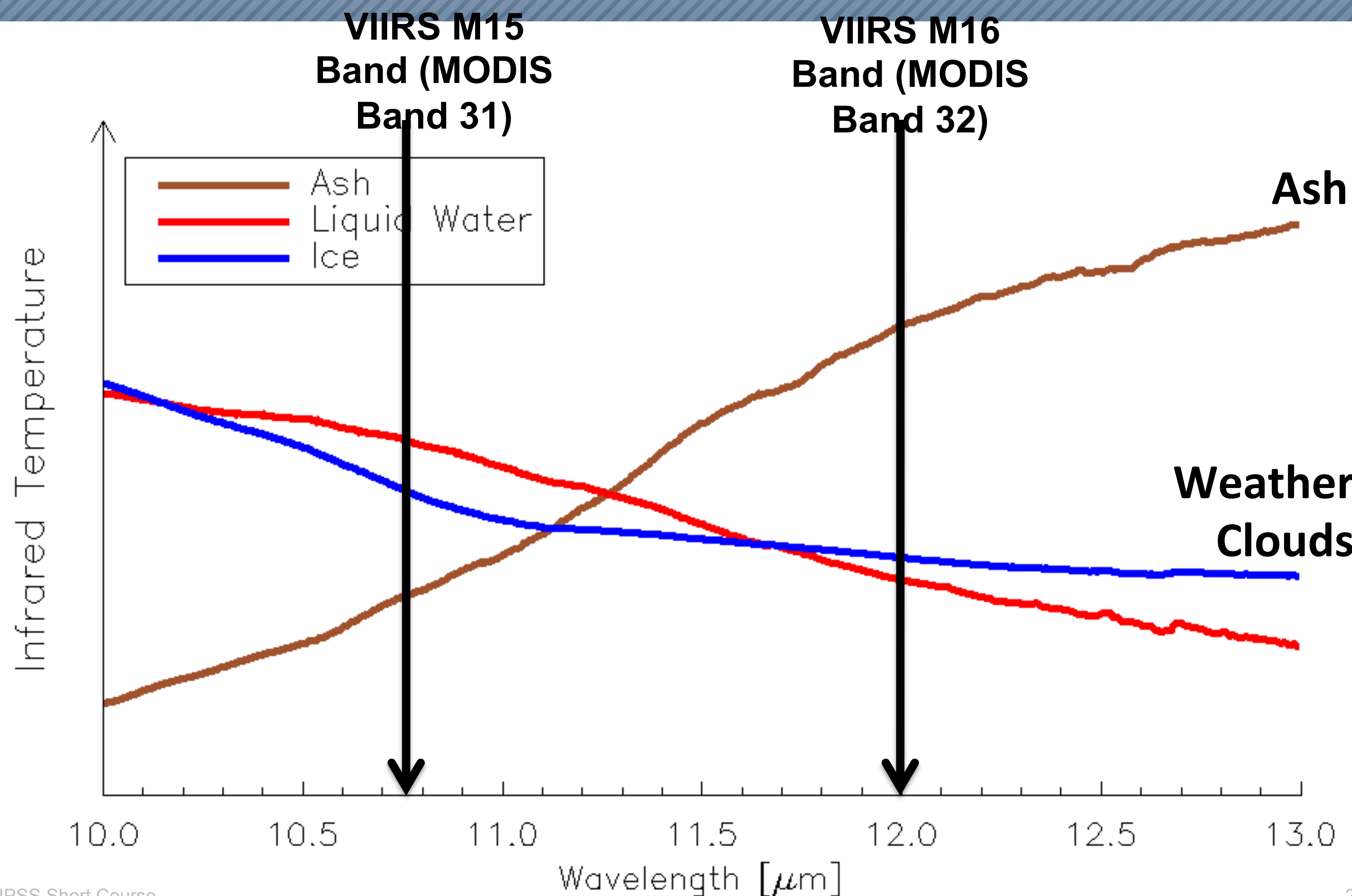
Characteristics of Ash Cloud

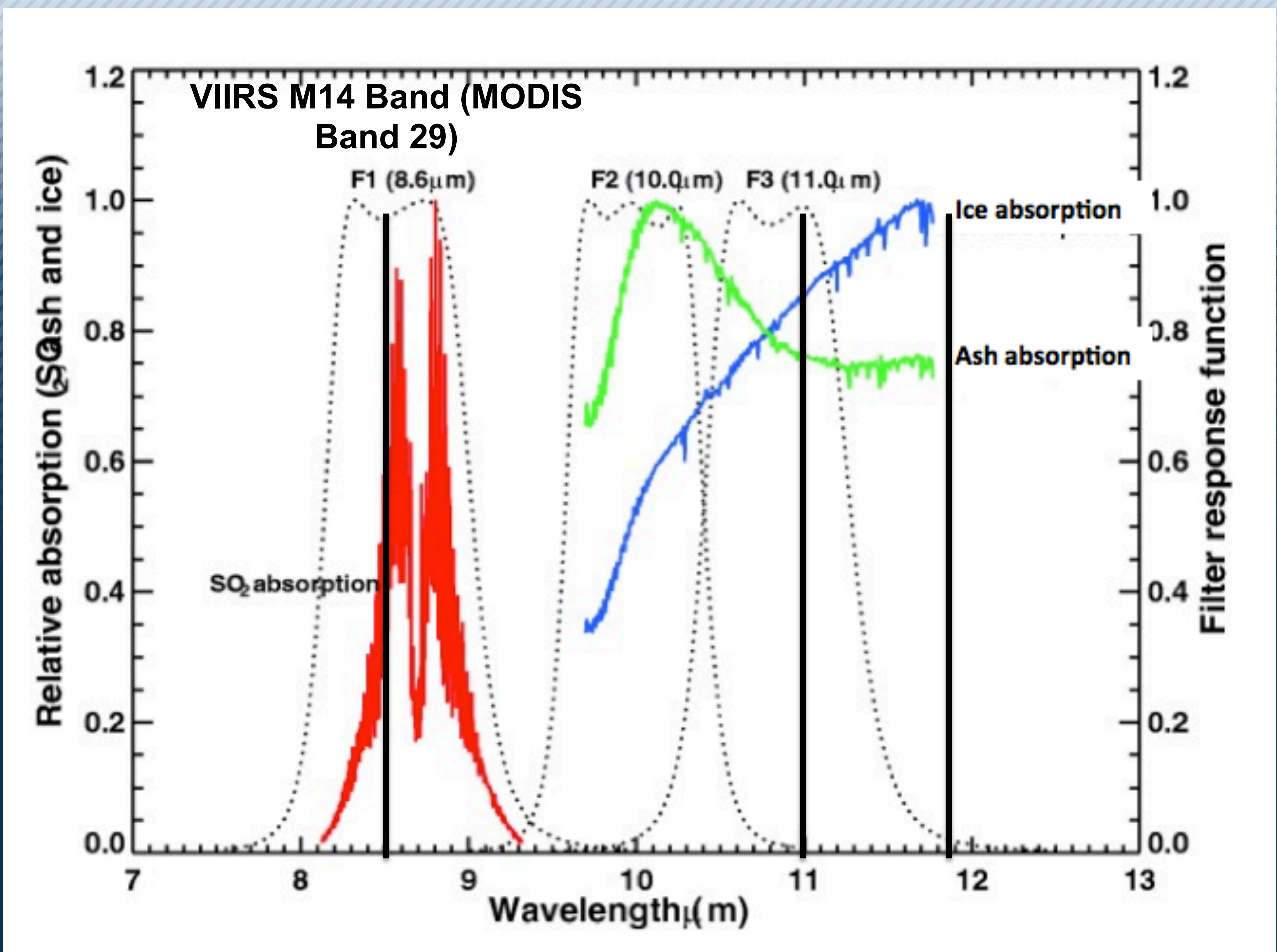
True color imagery is not available at night, but the presence of thick columns of ash can be inferred from the VIIRS Day/Night Band since ash absorbs more visible light than meteorological clouds

VIIRS Day/Night Band (DNB) Imagery



Infrared Based Volcanic Ash Detection

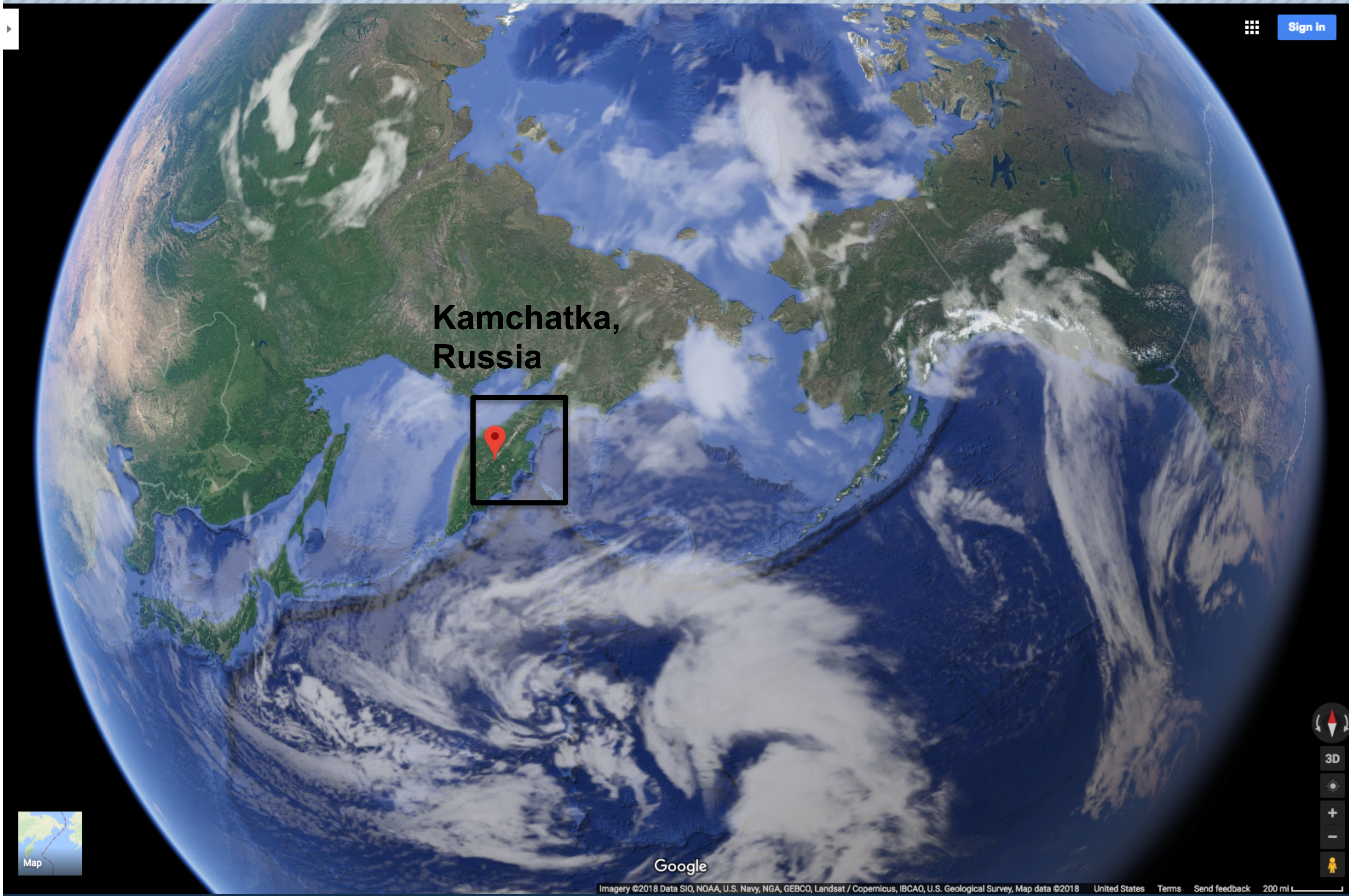




VIIRS M14 Band (MODIS Band 29)
F1 (8.6μm)
F2 (10.0μm)
F3 (11.0μm)
Ice absorption
Ash absorption
SO2 absorption
Relative absorption (SO2, ash and ice)
Filter response function
Wavelength (μm)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
7
8
9
10
11
12
13

RGB Creation

- Red: 12 µm – 11 µm brightness temperatures positive for ash
- Green: 11 µm – 8 µm brightness temperatures positive for sulphur dioxide (SO_2)
- Blue: 11 µm brightness temperatures – contributes most when warm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Russia
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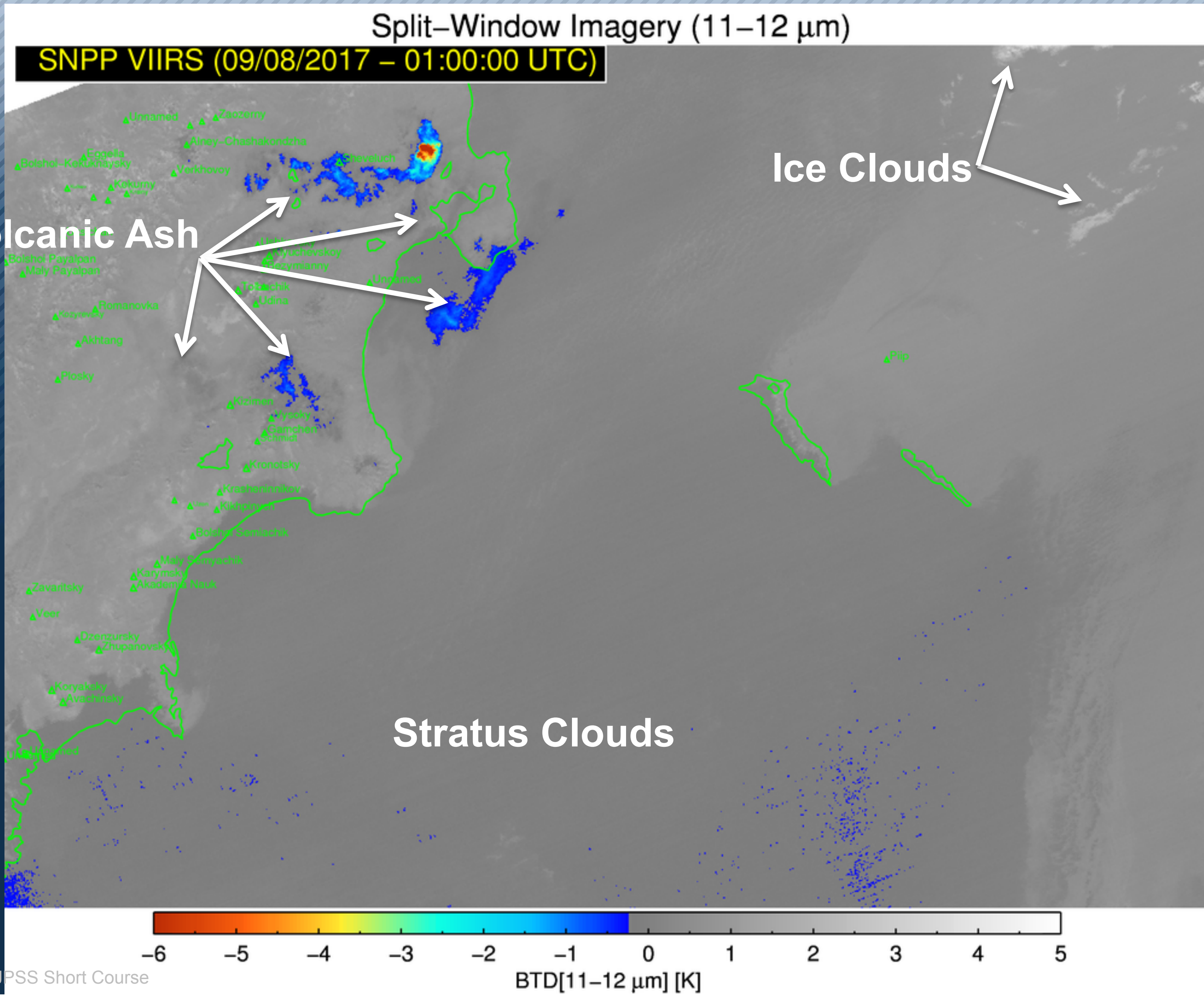
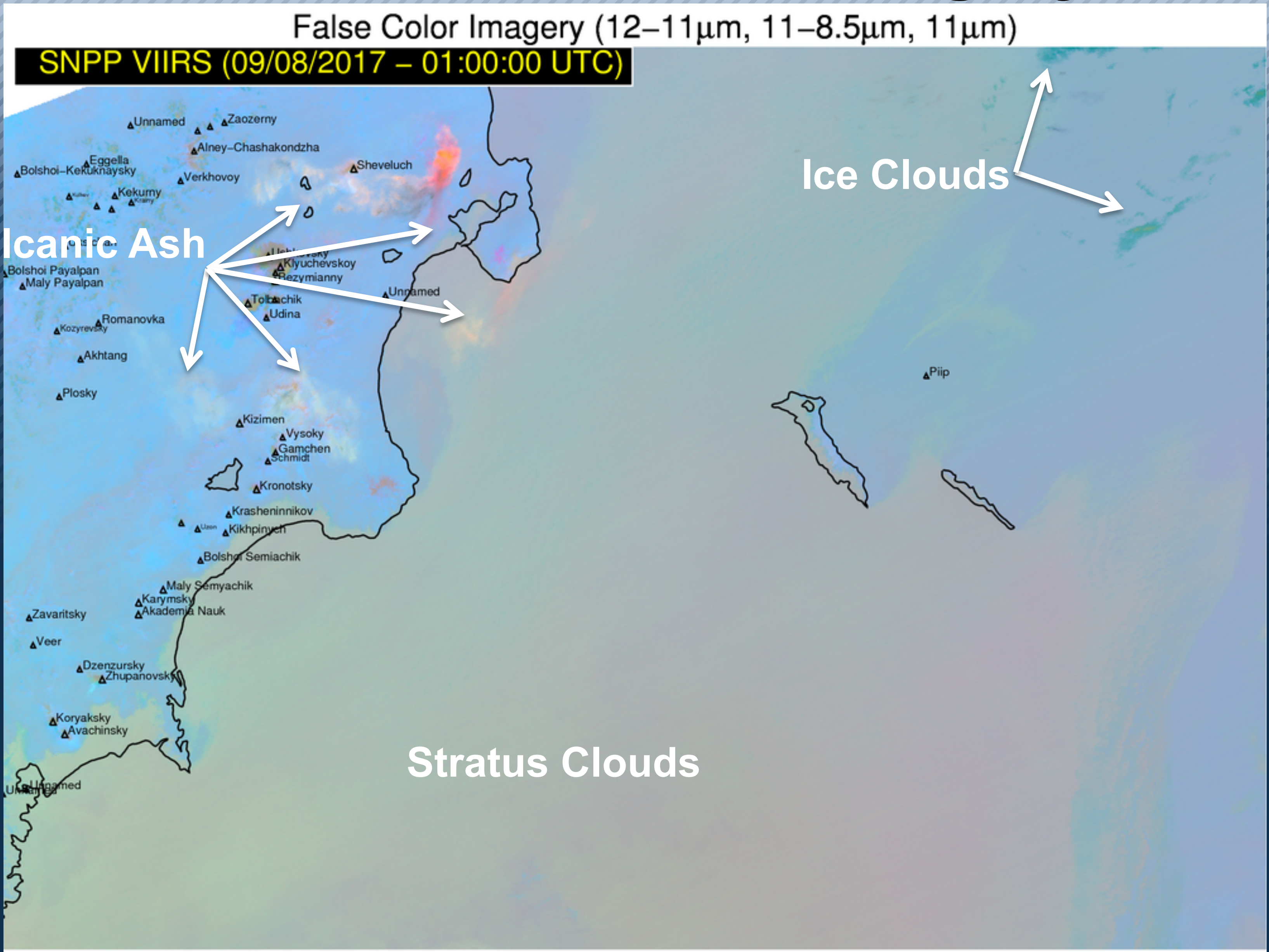
The "11 – 12 µm Split-window Brightness Temperature Difference (BTD)"



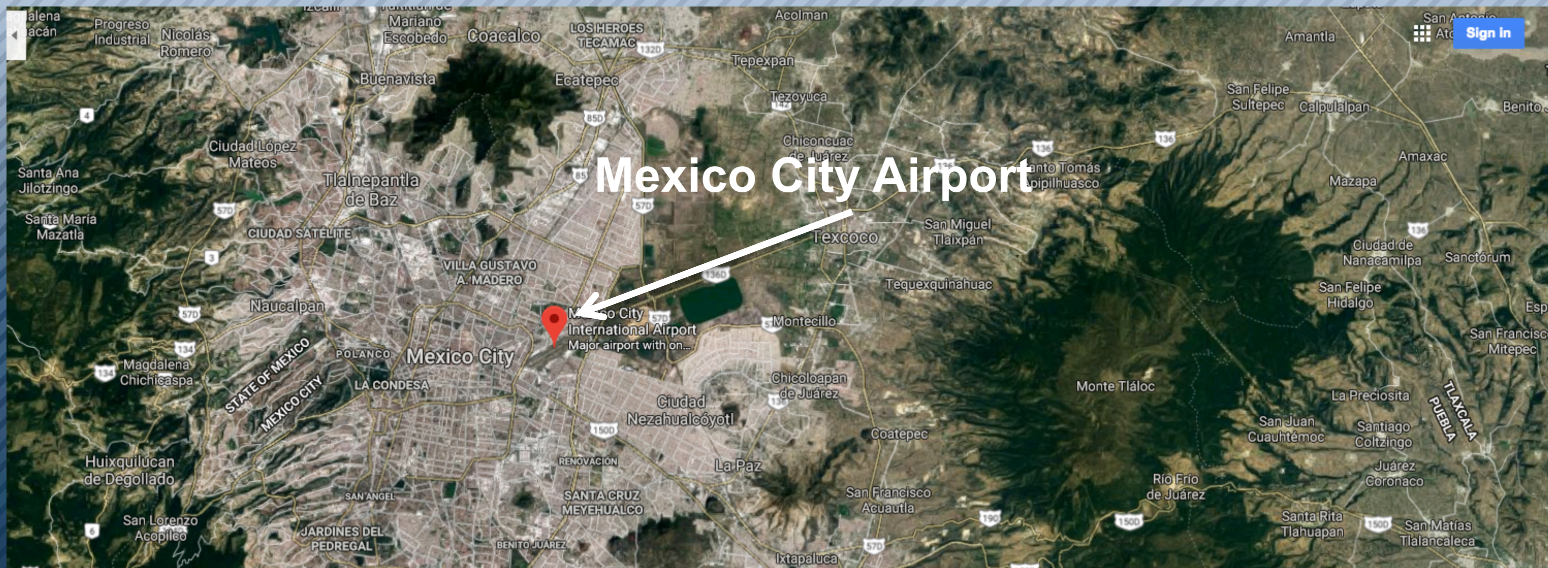
VIIRS False Color Imagery

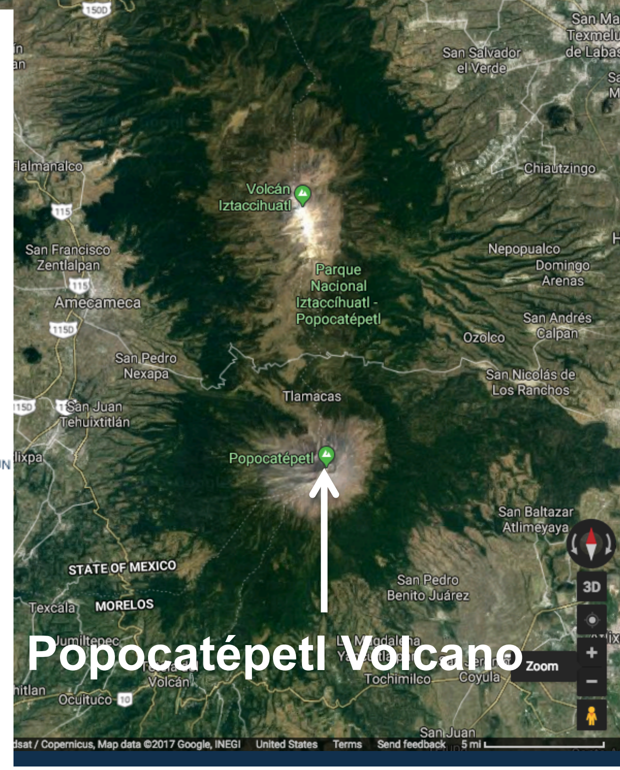


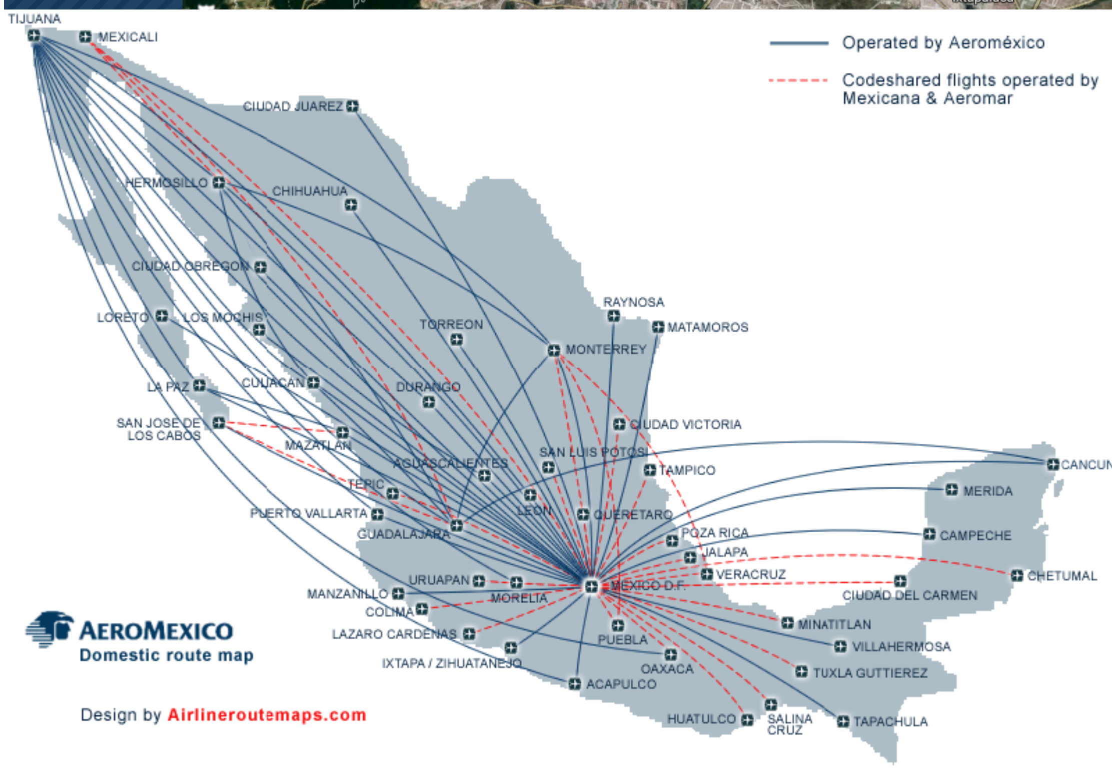
Volcanic ash: reddish
Volcanic ash + SO_2: reddish/yellowish

SO_2 with no ash: green

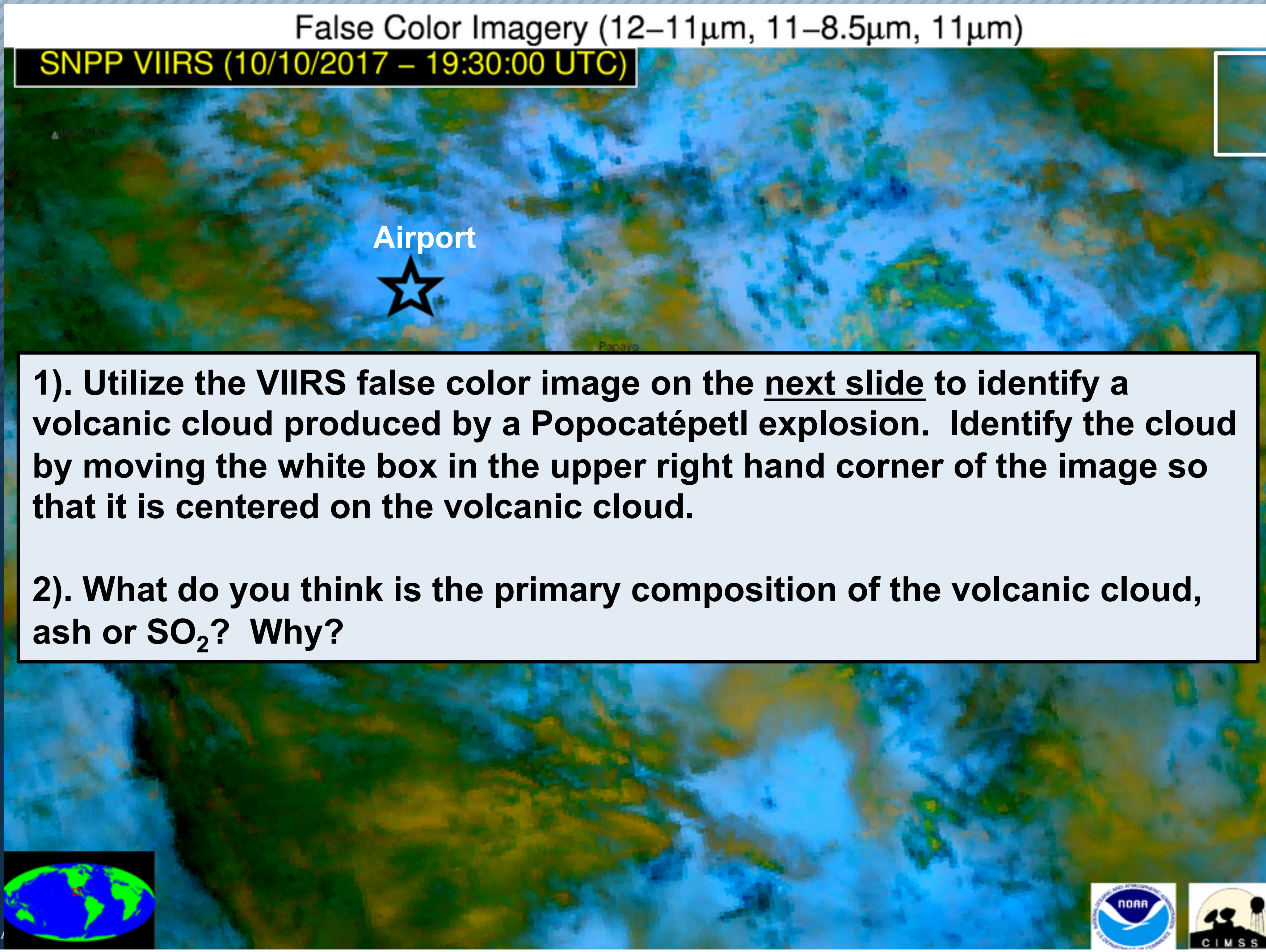
Exercise #1: Volcanic Emission Near Airport







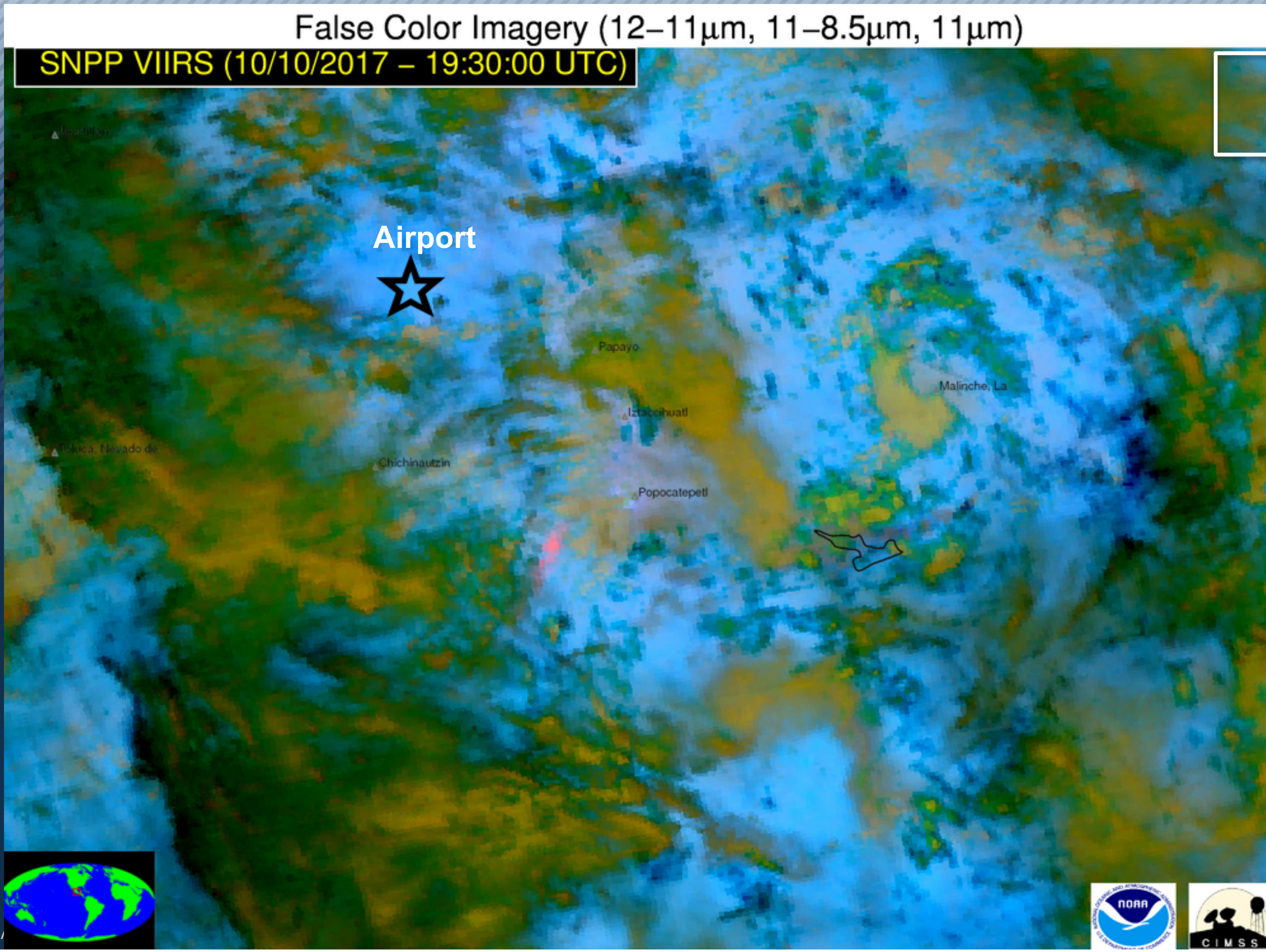
Exercise #1: Volcanic Emission Near Airport



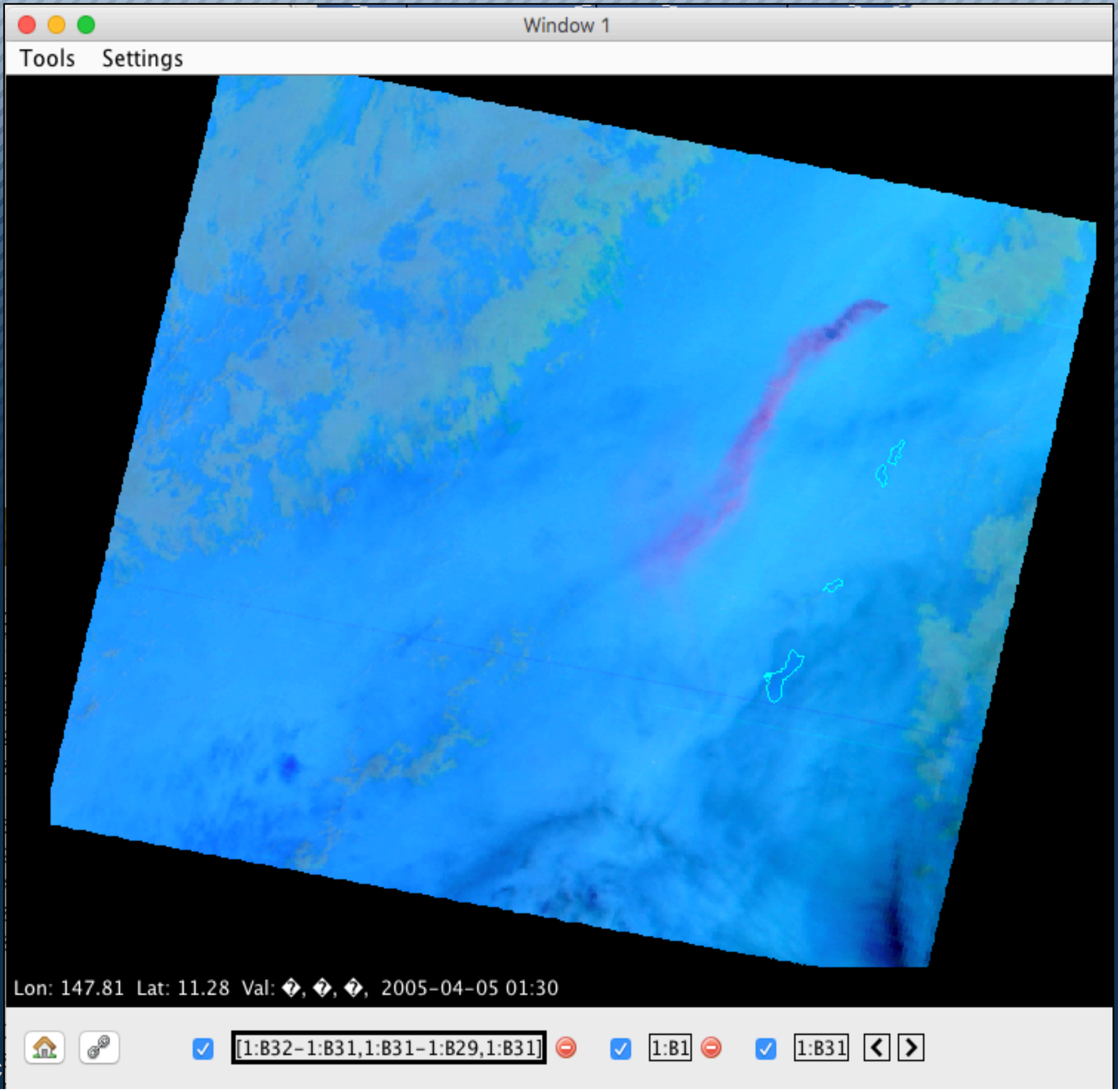
1). Utilize the VIIRS false color image on the <u>next slide</u> to identify a volcanic cloud produced by a Popocatépetl explosion. Identify the cloud by moving the white box in the upper right hand corner of the image so that it is centered on the volcanic cloud.

2). What do you think is the primary composition of the volcanic cloud, ash or SO_2? Why?

Exercise #1: Volcanic Emission Near Airport



Volcanic Eruption – Anatahan 2005



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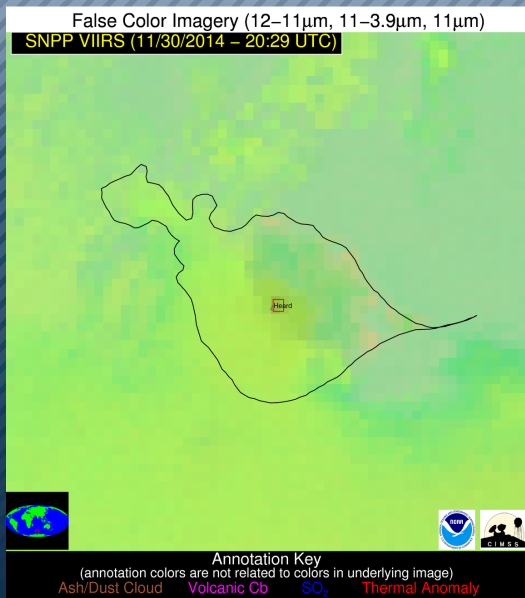
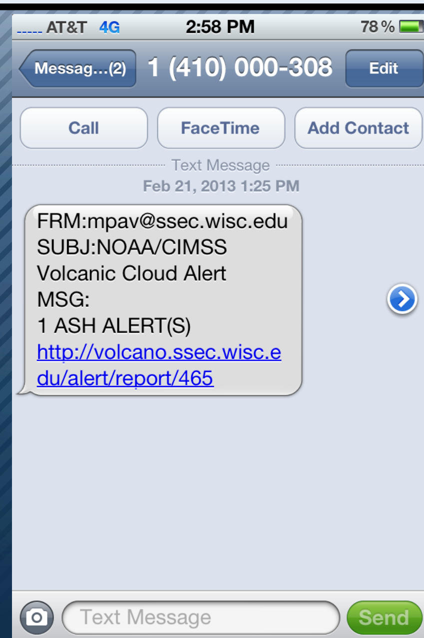
VOLcanic Cloud Analysis Toolkit (VOLCAT)

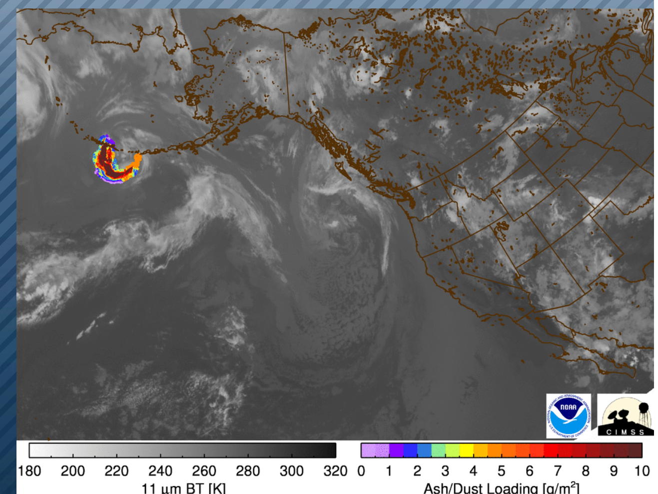
1). Unrest Alerts



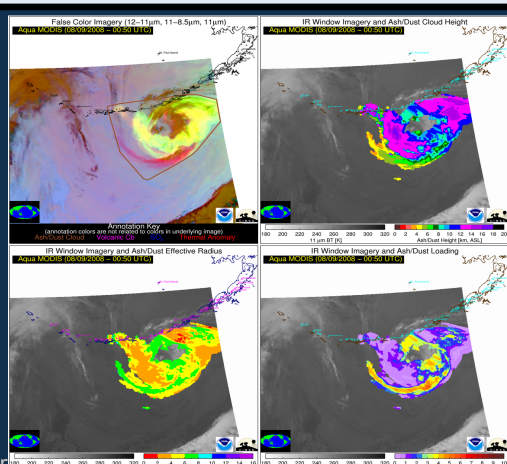
2). Eruption Alerts



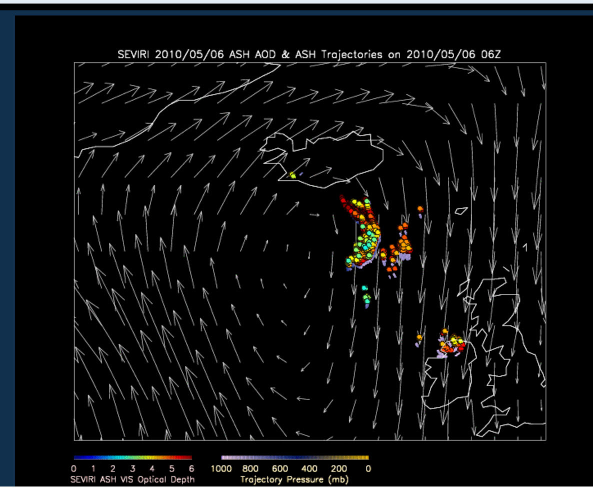
3). Volcanic Cloud Tracking



4). Volcanic Cloud Characterization

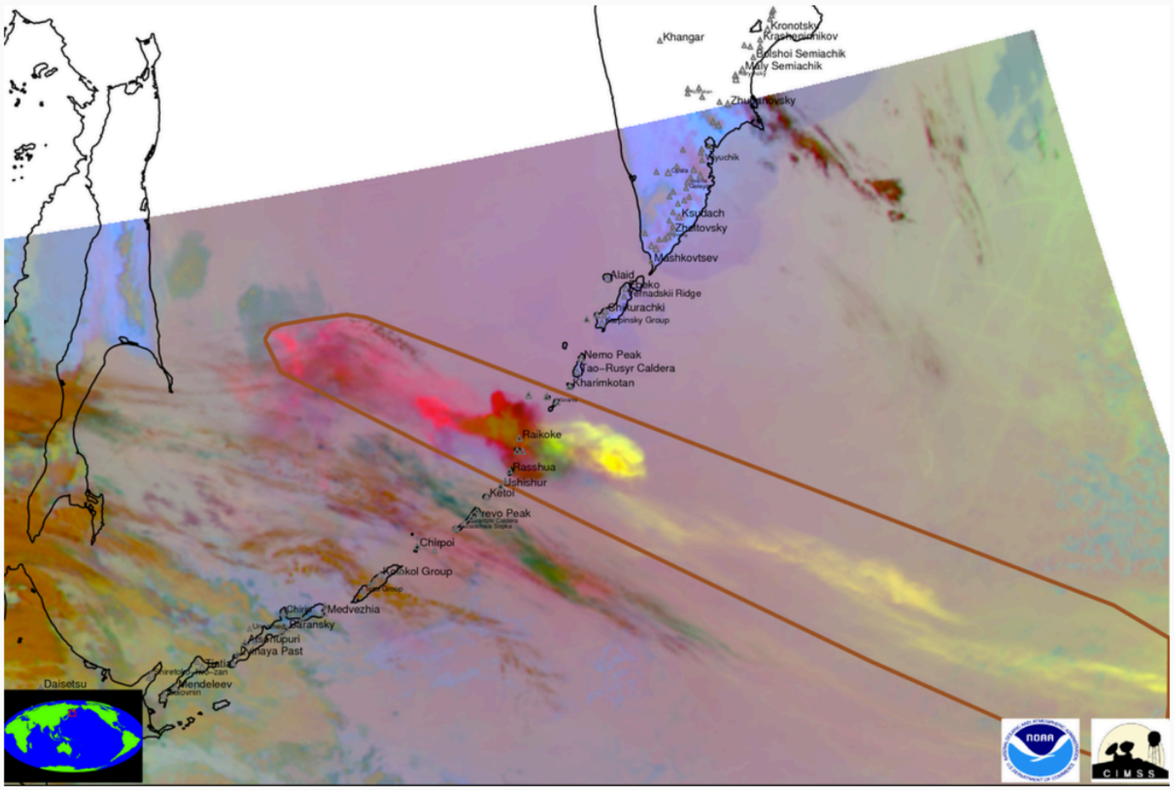


5). Dispersion Forecasting



Online Tutorials

Additional false color imagery



Example of obtaining plume composition information by using false color imagery with the 8.5 um channel.
This example is from the eruption of Sarychev Peak in June 2009. The ash plume is indicated by the brown polygon. To the west of Sarychev Peak, the ash plume has a magenta color, indicative of only volcanic ash. To the east the ash plume has more of a yellow color, indicitive of **both** ash and sulfur dioxide (the 8.5 um channel is sensitive the presence of sulfur dioxide). The appearance of volcanic ash appears the same day and night using this false color imagery.

https://volcano.ssec.wisc.edu/

New Polar Orbiter Direct Broadcast Satellite Data and Products From Direct Broadcast

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Space Science and Engineering Center (SSEC)
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ACSPO SST for Direct Broadcast

ACSPO

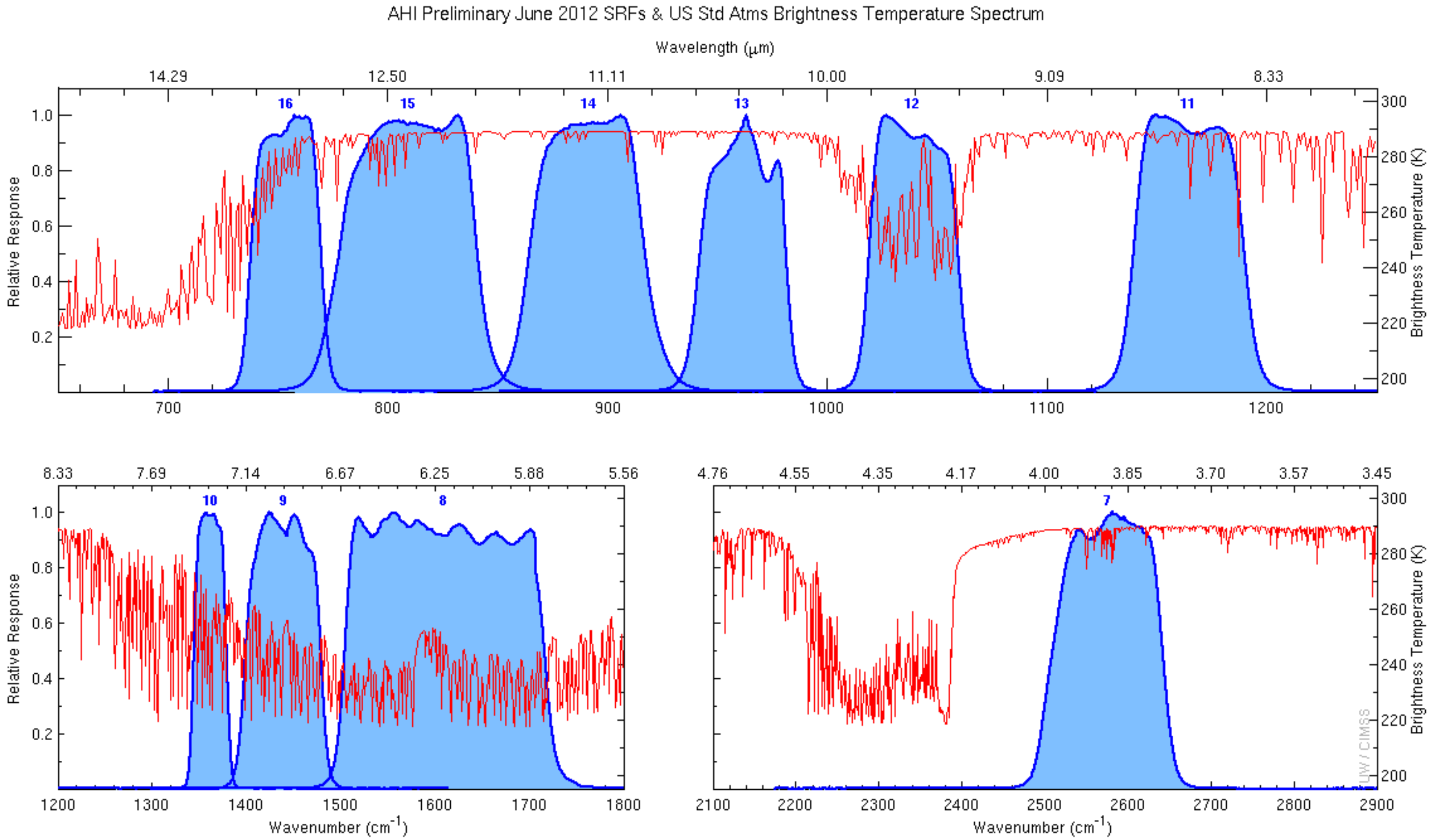
ACSPO (Advanced Clear-Sky Processor for Oceans) retrieves sea surface temperature from multispectral imager observations.

Heritage	Developed at NOAA/NESDIS/STAR by Alex Ignatov, John Sapper, John Stroup, and Yury Kihai.
Satellites/ Sensors	Suomi NPP VIIRS; NOAA-18/19 AVHRR; Metop-A/B AVHRR; Terra/Aqua MODIS.
Products	Sea surface temperature - Multiple views per day because same science algorithm applied to each instrument - Full imager spatial resolution
Features	• Multi-sensor common algorithm. • ACSPO is the official JPSS algorithm for SST.

Sea Surface Temperatures

- Simple Brightness Temperature Difference Algorithm
- "Split Window" technique
- Regression between
  - 11-12 µm BTDIF (MODIS bands 31 and 32)
    (VIIRS Bands M15 and M16)
  - 4 µm BTDIF too can be used
    - Must be careful in sunglint regions because of solar contamination
  - In essence, you are trying to correct for the lowering of the observed brightness temperatures by water vapor using the BTDIF between these two window channels

The IR channels on the AHI



AHI has many more bands than the MTSAT imagers.

MODIS Longwave Infrared Sea Surface Temperature (c5)

dBT <= 0.5

sst = a00 + a01*BT11 + a02*dBT*bsst + a03*dBT*(1.0/mu - 1.0)

dBT >= 0.9

sst = a10 + a11*BT11 + a12*dBT*bsst + a13*dBT*(1.0/mu - 1.0)

0.5 < dBt < 0.9

sstlo = a00 + a01*BT11 + a02*dBT*bsst + a03*dBT*(1.0/mu - 1.0)

ssthi = a10 + a11*BT11 + a12*dBT*bsst + a13*dBT*(1.0/mu - 1.0)

sst = sstlo + (dBT - 0.5)/(0.9 - 0.5)*(ssthi - sstlo)

where:

dBT = BT11 - BT12

BT11 = brightness temperature at 11 um, in deg-C

BT12 = brightness temperature at 12 um, in deg-C

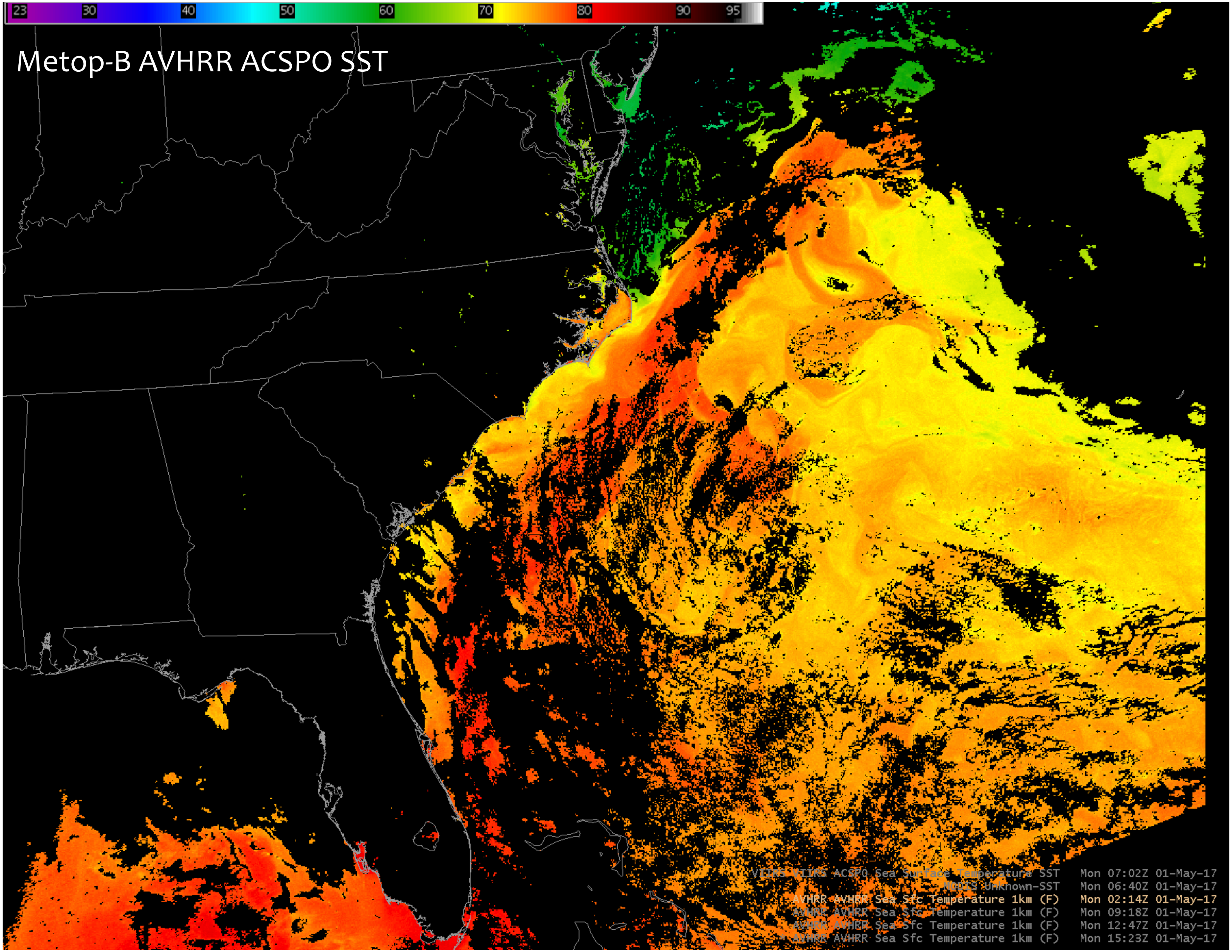
bsst = Either sst4 (if valid) or sstref (from Reynolds OISST)

mu = cosine of sensor zenith angle

a00, a01, a02, a03, a10, a11, a12, a13 derived from match-ups

Lower 48 Examples

* 1 May 2017
* All supported instruments from one day
  * Coverage – AWIPS display shows how good coverage can be with all instruments together
  * Consistency in products across instruments
  * There will be twice as much coverage on normal day (one orbit shown only)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MODIS Unknown-SST Mon 06:40Z 01-May-17
AVHRR AVHRR Sea Sfc Temperature 1km (F) Mon 02:14Z 01-May-17
AVHRR AVHRR Sea Sfc Temperature 1km (F) Mon 09:18Z 01-May-17
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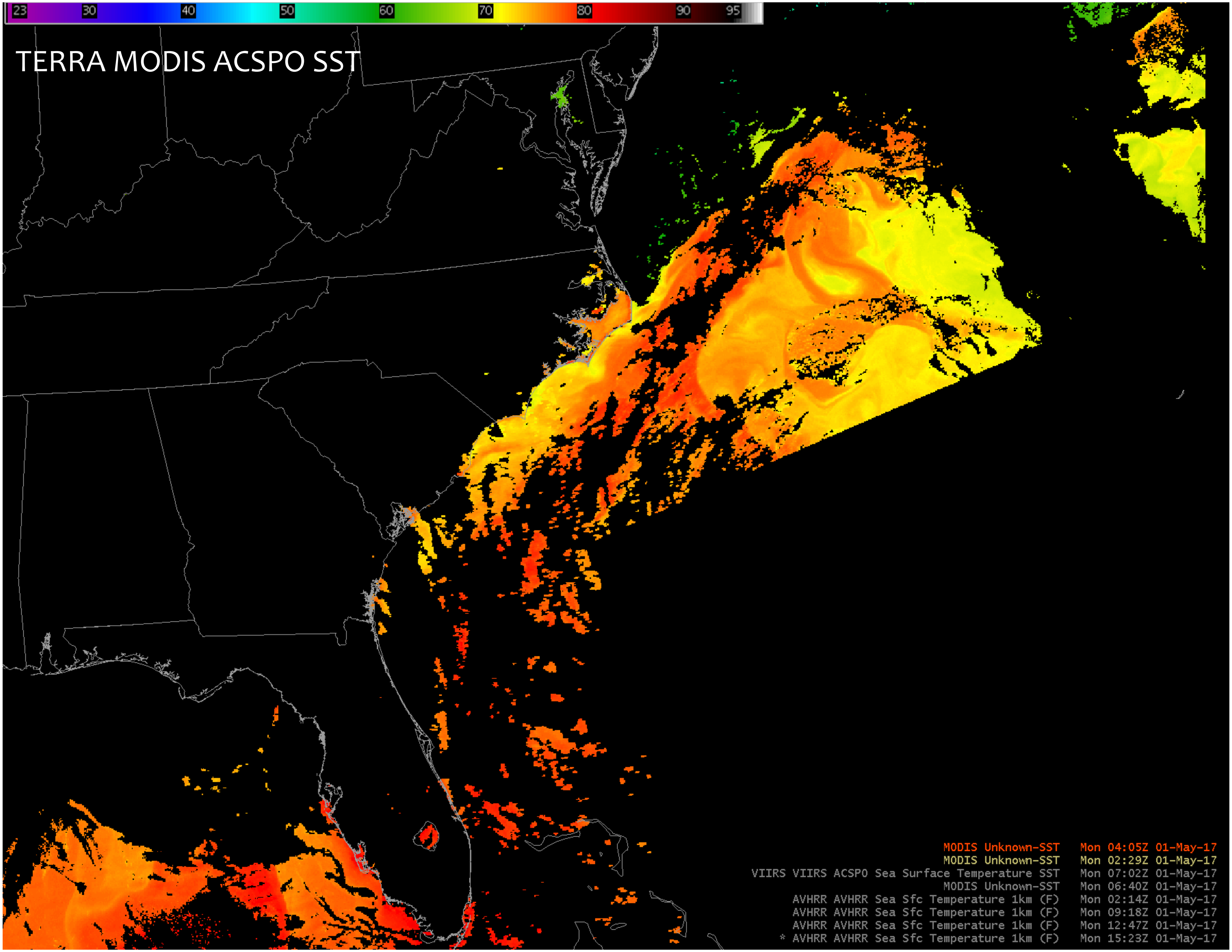

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VIIRS VIIRS ACSPO Sea Surface Temperature SST Mon 07:02Z 01-May-17
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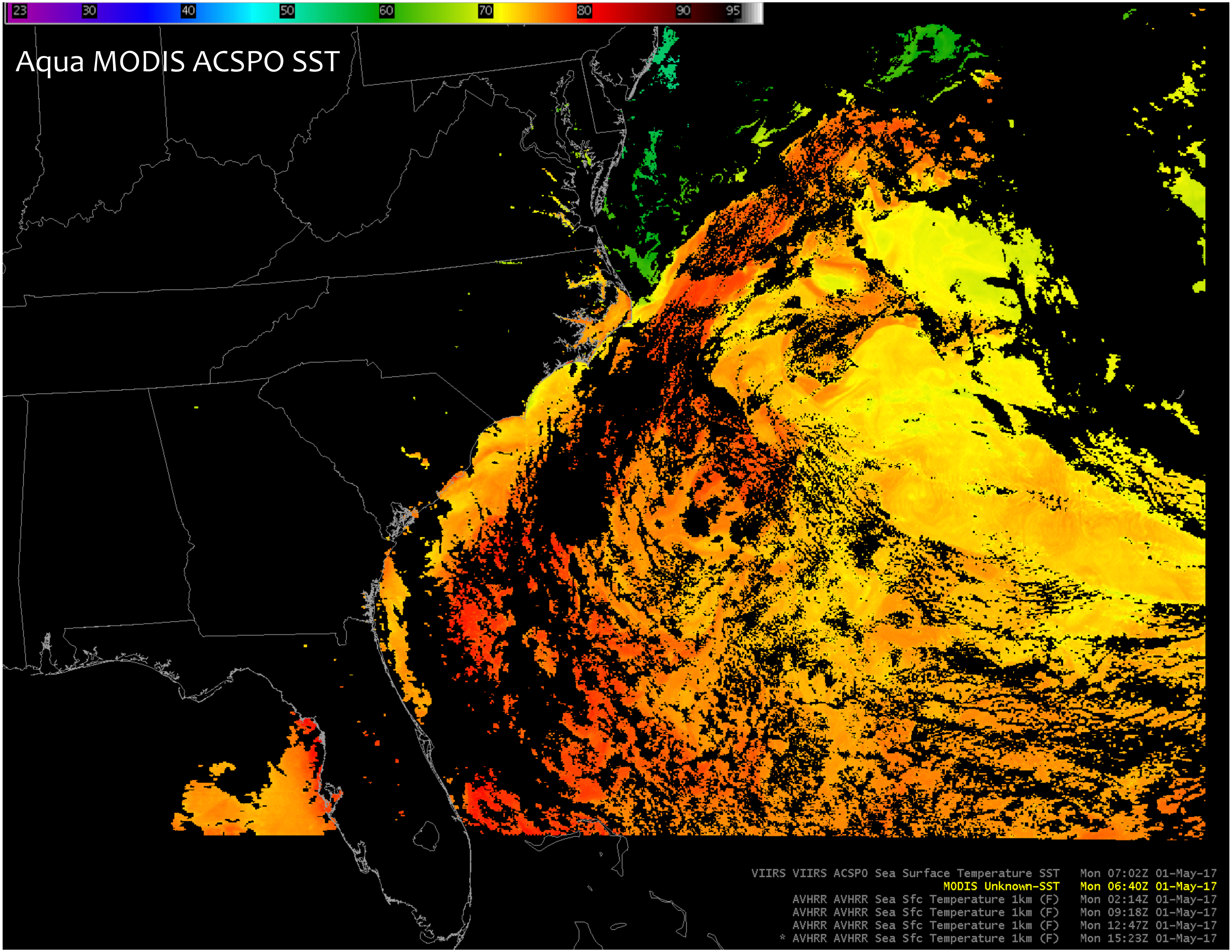
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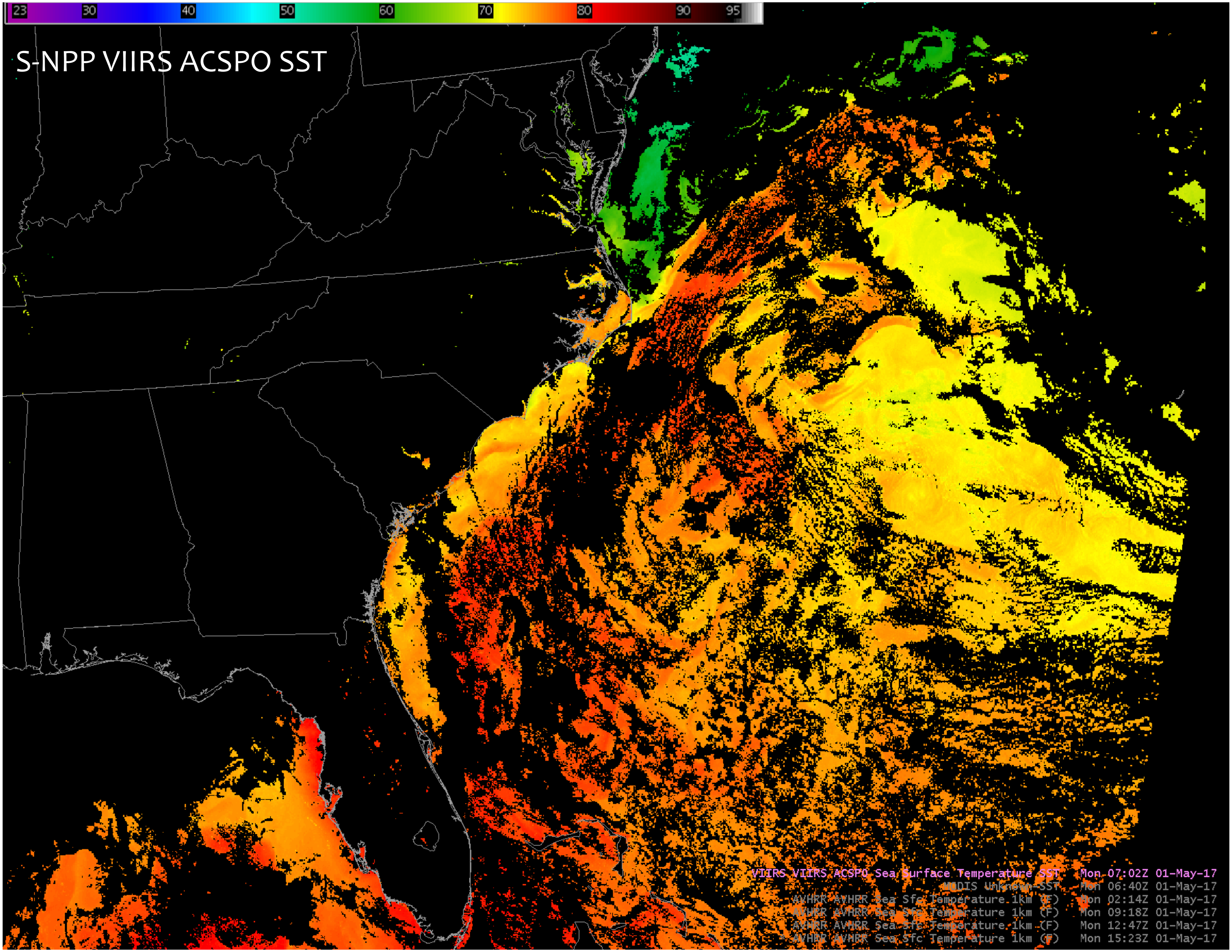

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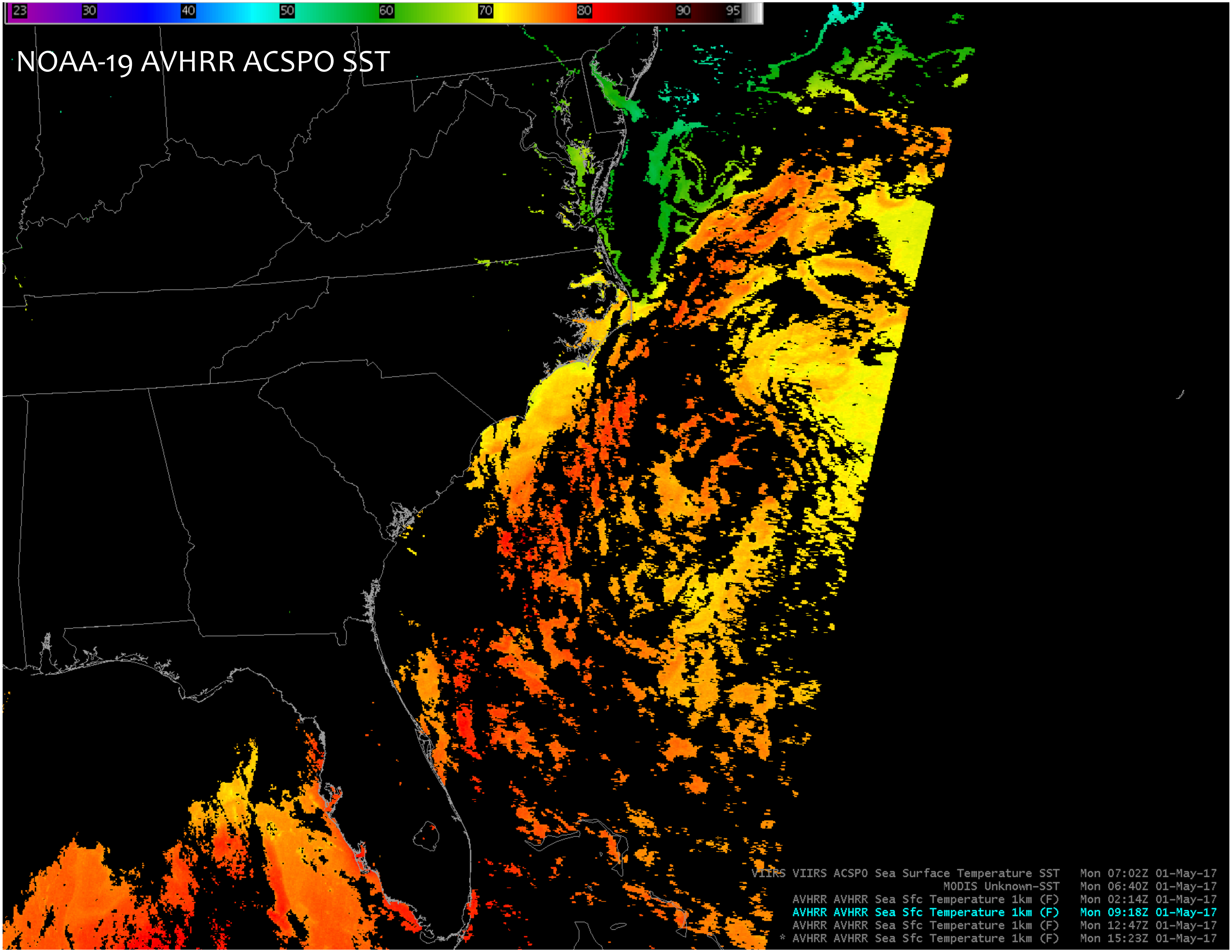
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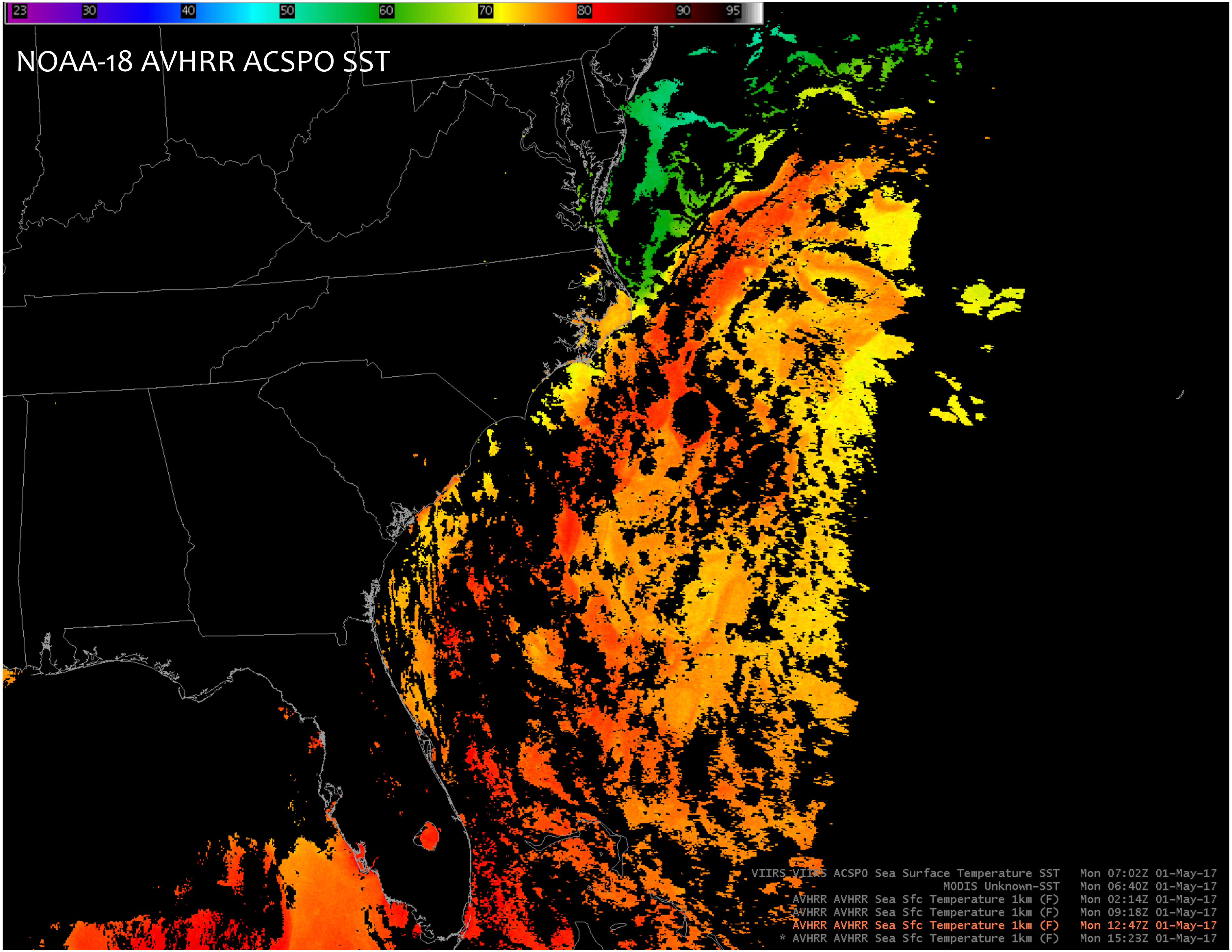
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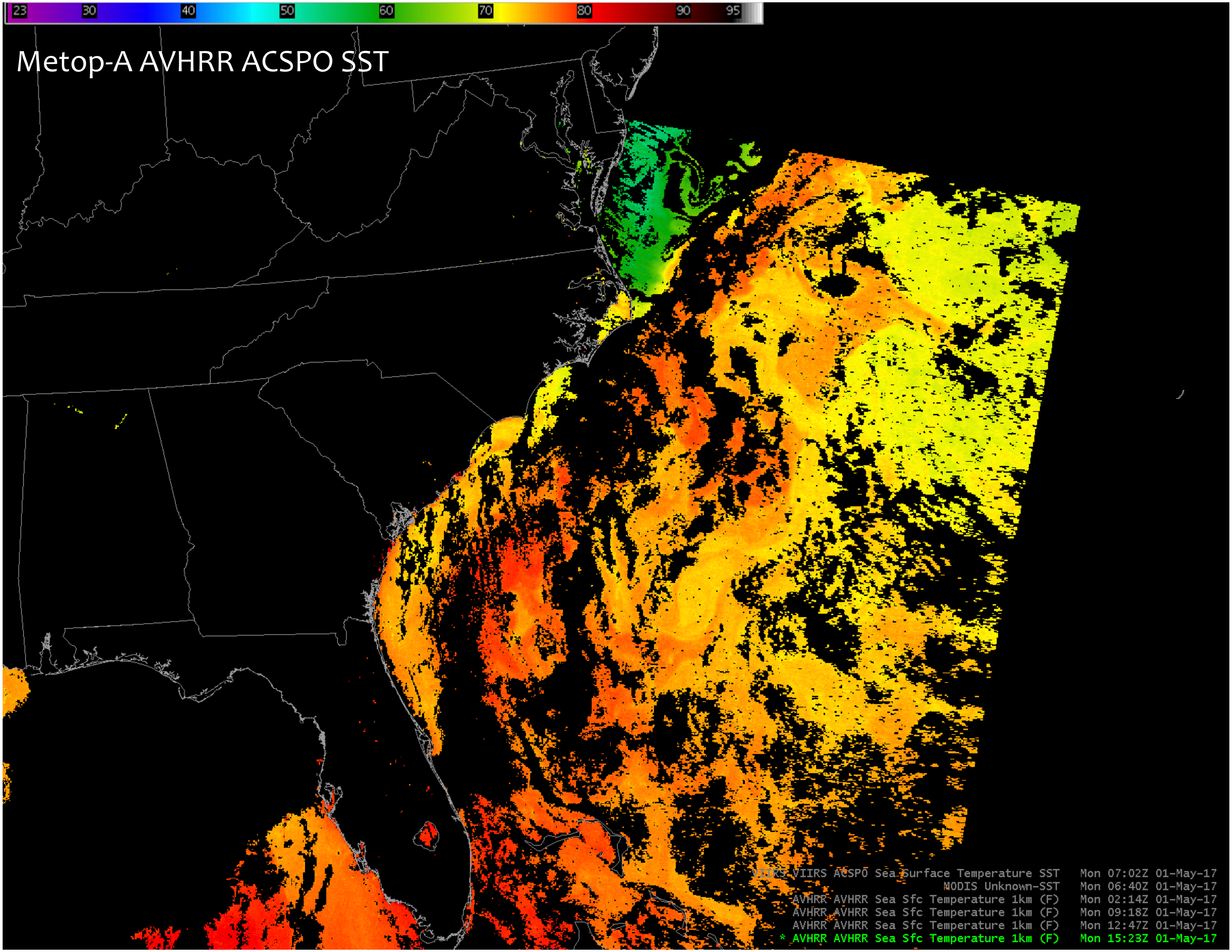
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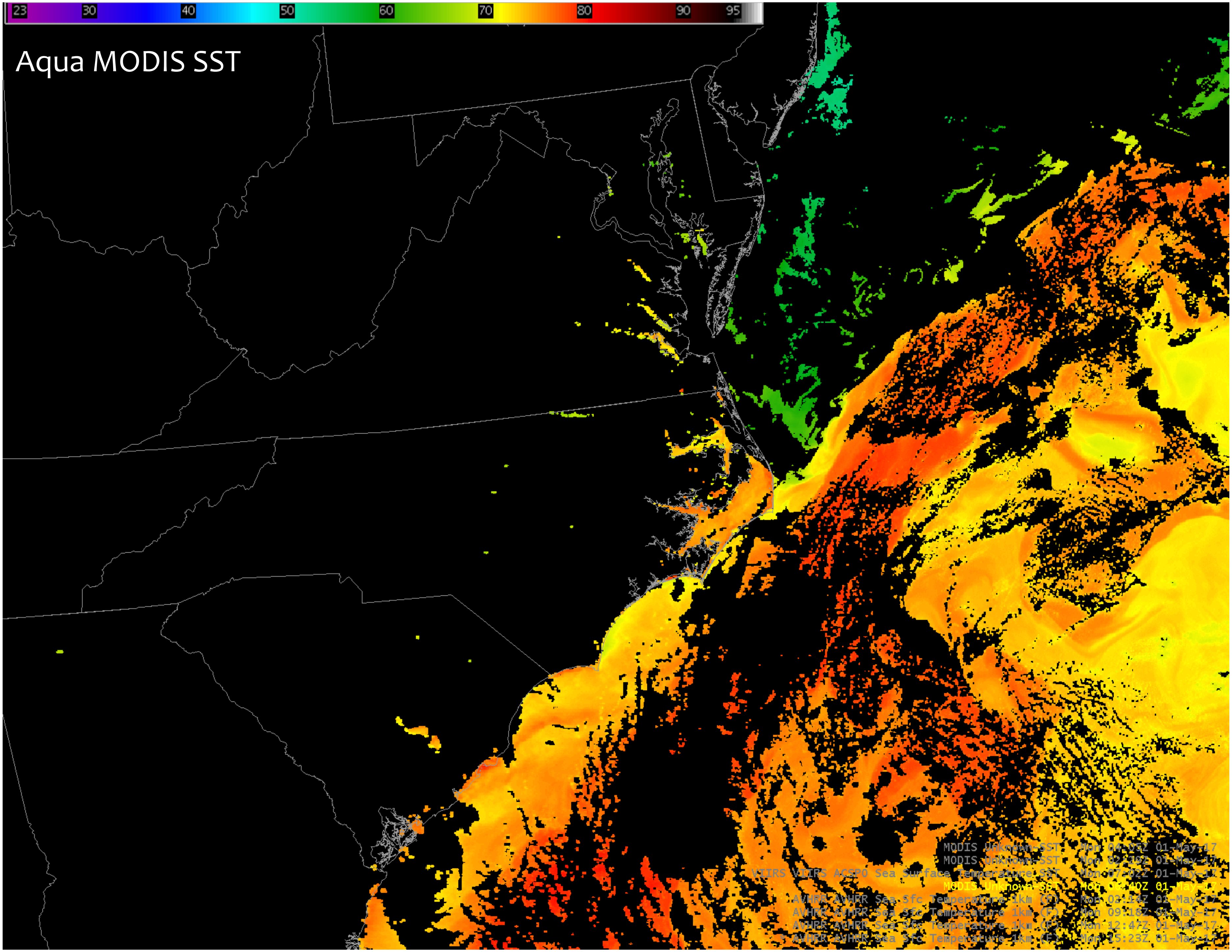
Coverage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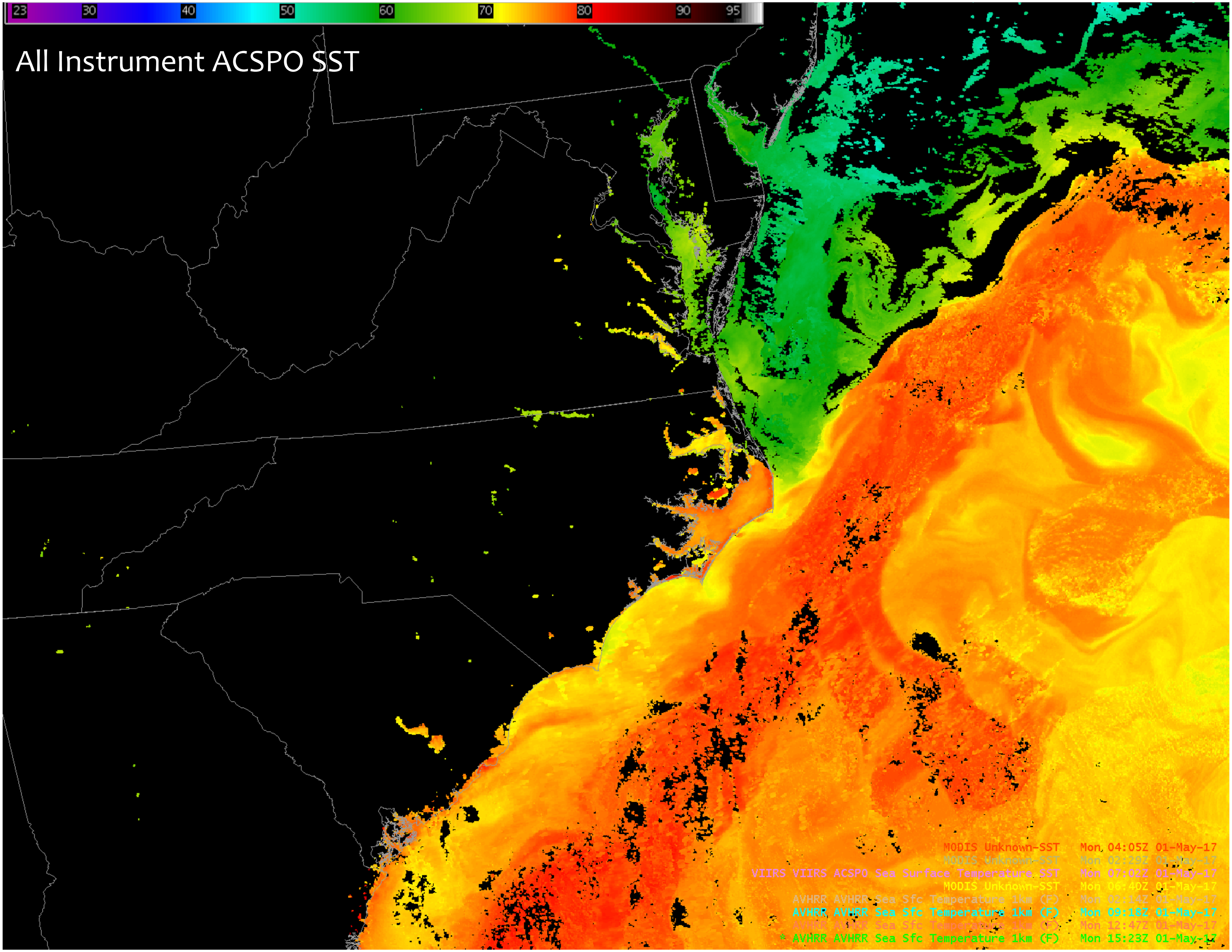
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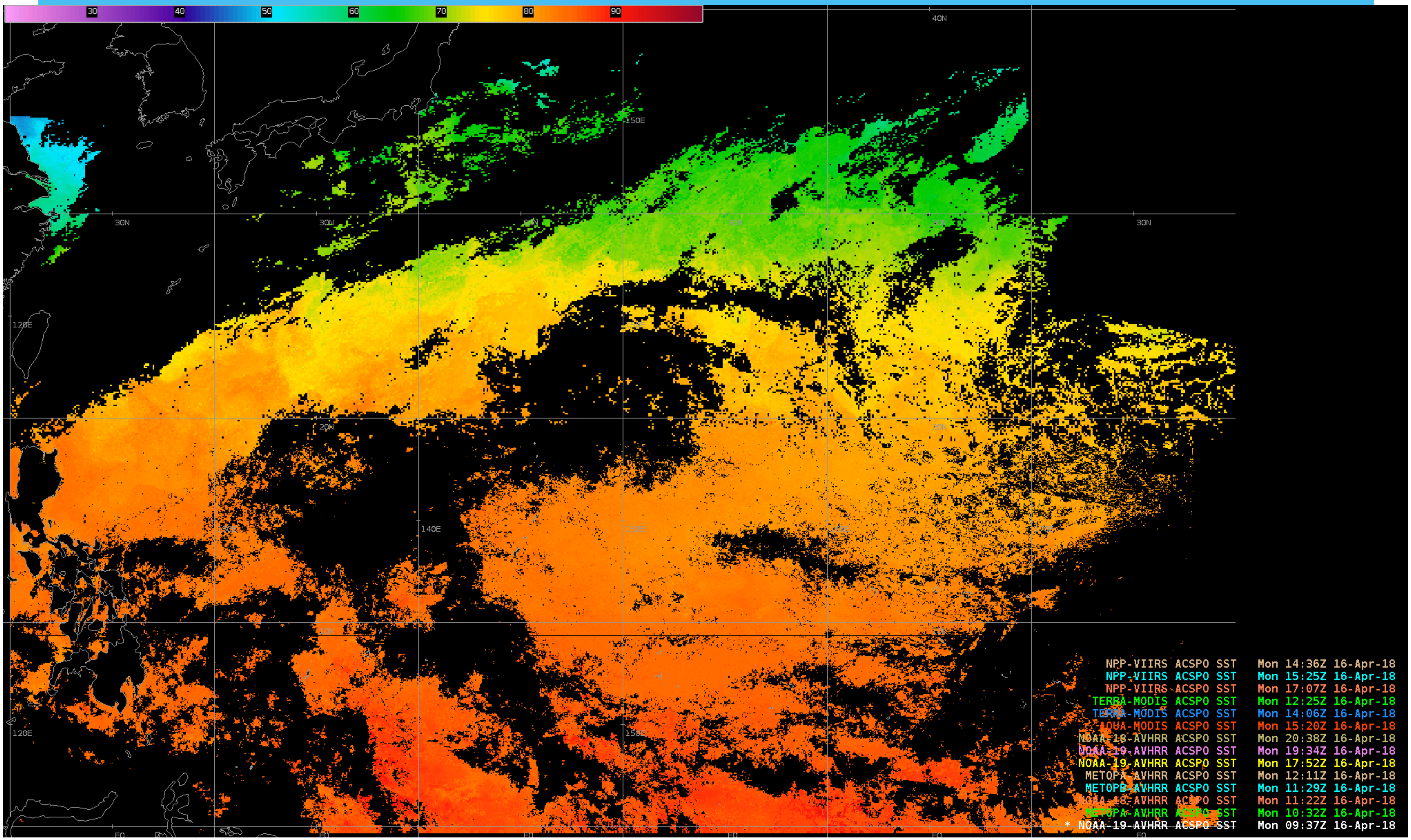
90
95
All Instrument ACSPO SST
MODIS Unknown-SST Mon 04:05Z 01-May-17
MODIS Unknown-SST Mon 02:29Z 01-May-17
VIIRS VIIRS ACSPO Sea Surface Temperature SST Mon 07:02Z 01-May-17
MODIS Unknown-SST Mon 06:40Z 01-May-17
AVHRR AVHRR Sea Sfc Temperature 1km (F) Mon 02:14Z 01-May-17
AVHRR AVHRR Sea Sfc Temperature 1km (F) Mon 09:18Z 01-May-17
AVHRR AVHRR Sea Sfc Temperature 1km (F) Mon 12:47Z 01-May-17
* AVHRR AVHRR Sea Sfc Temperature 1km (F) Mon 15:23Z 01-May-17

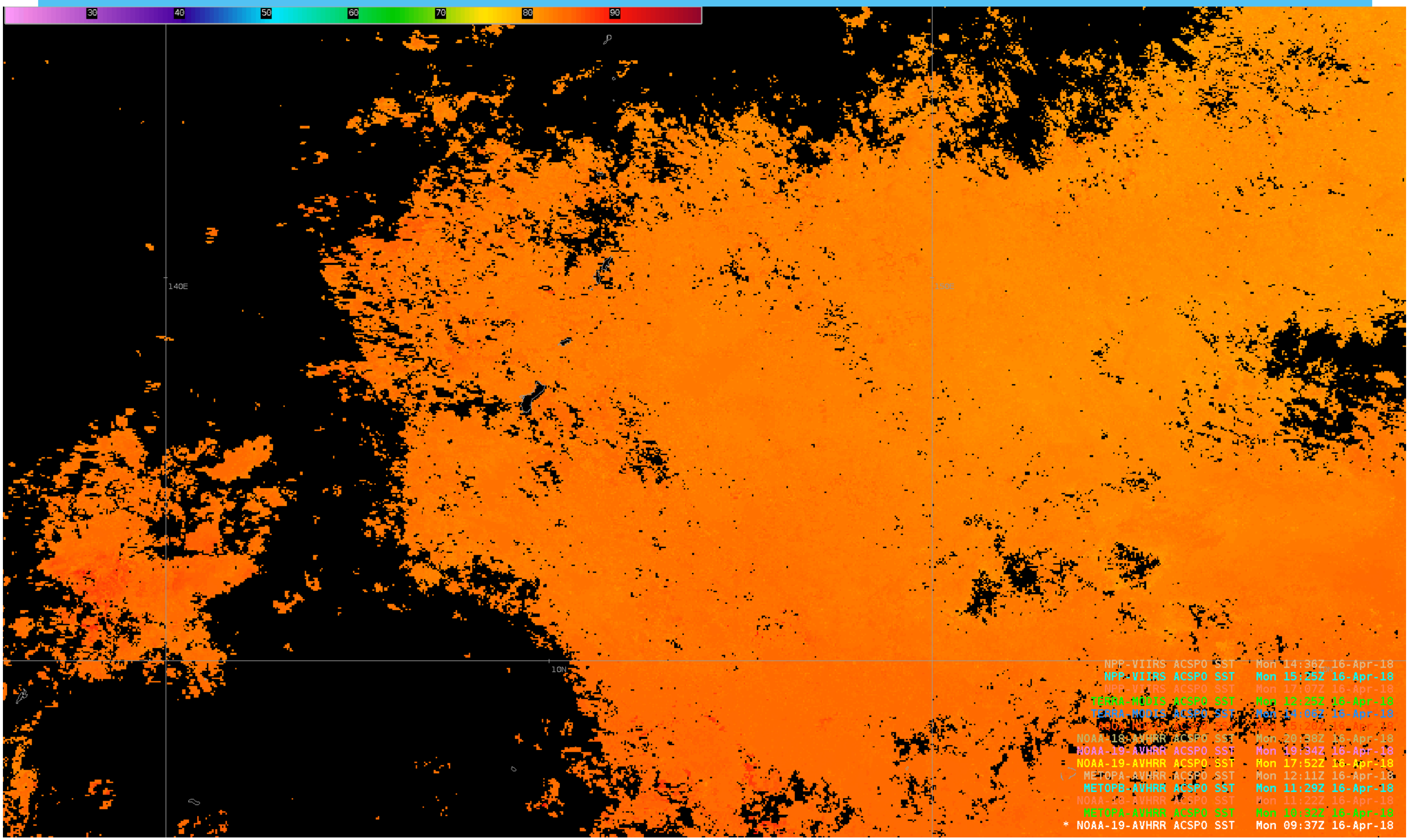
Guam NWS SSTs - 12 Hour Composite

16 April 2016 (14 overpasses)



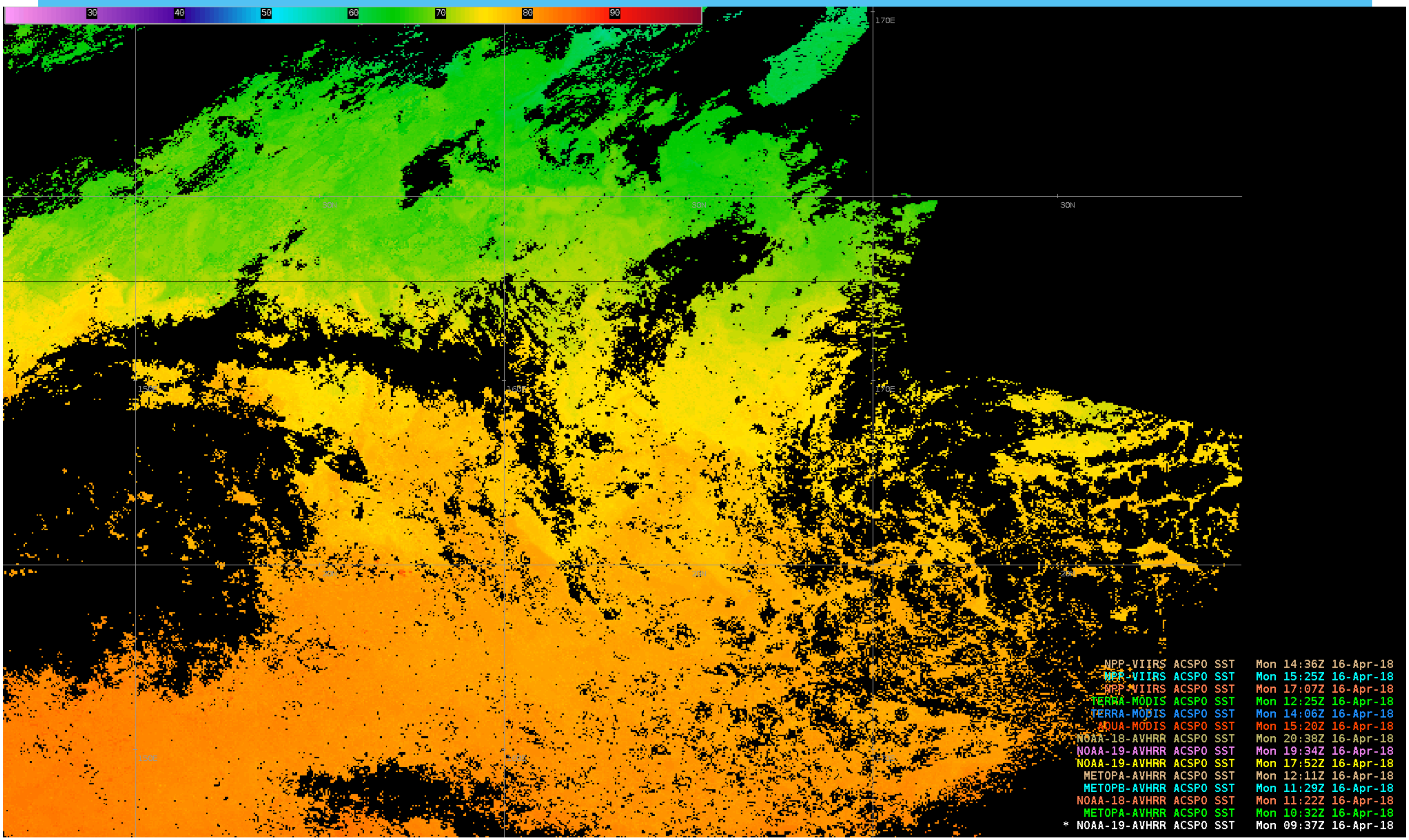
Guam NWS SSTs - 12 Hour Composite

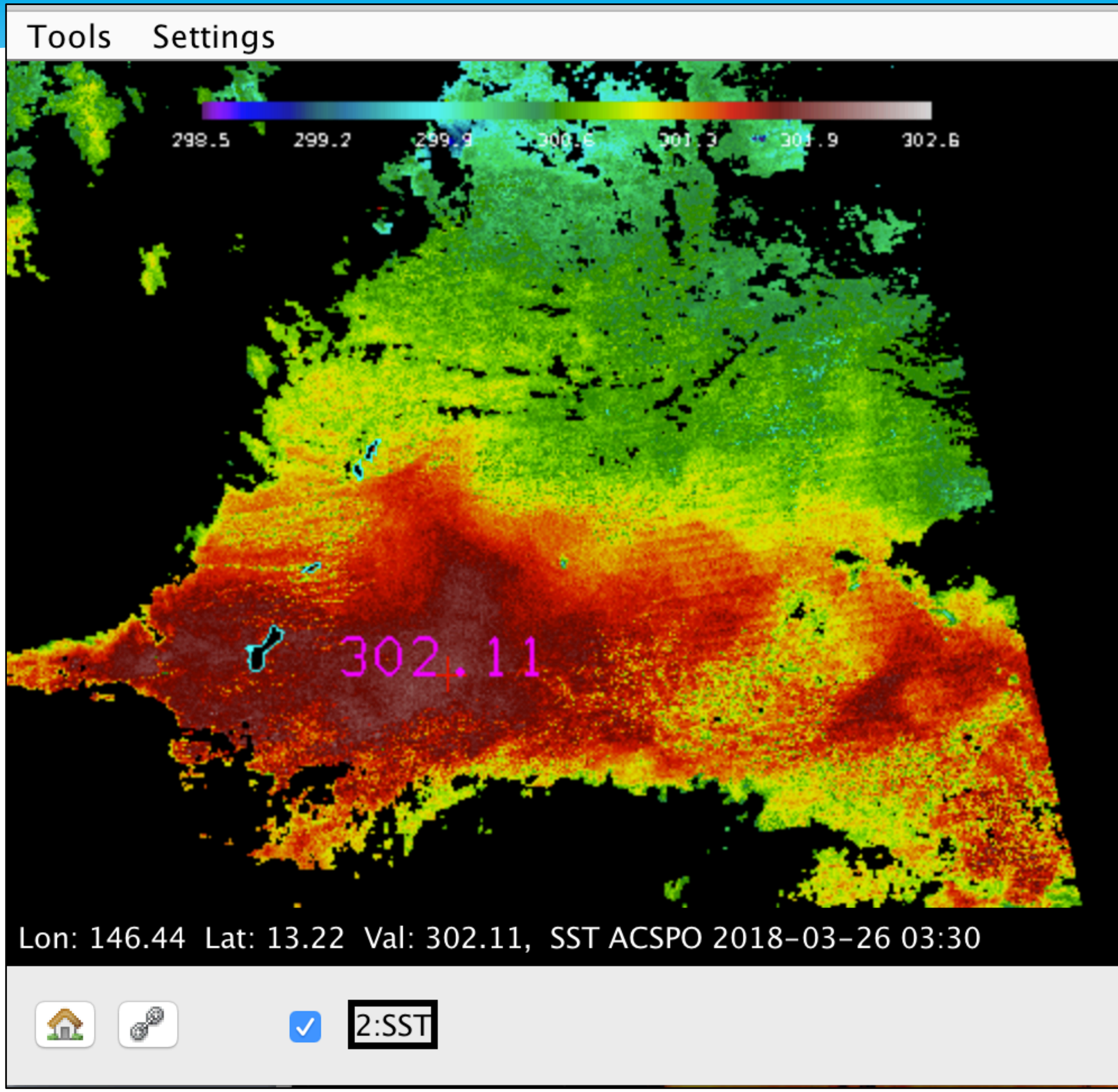
16 April 2016 (14 overpasses)



Guam NWS SSTs - 12 Hour Composite

16 April 2016 (14 overpasses)





Tools
Settings
298.5
299.2
302.6
302.11
Lon: 146.44 Lat: 13.22 Val: 302.11, SST ACSPO 2018-03-26 03:30
2:SST

Utility of SST for Guam?

- Tropical Cyclone development and intensity
- Low temperatures.
- Fishing?
- Other local applications?

Thank you.

Questions?

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