Satellite 101, Part 1

NOAA Coastwatch Satellite Course

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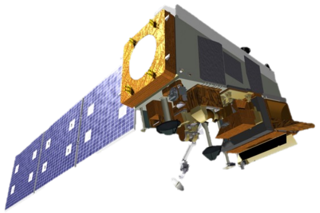
What is covered in this presentation



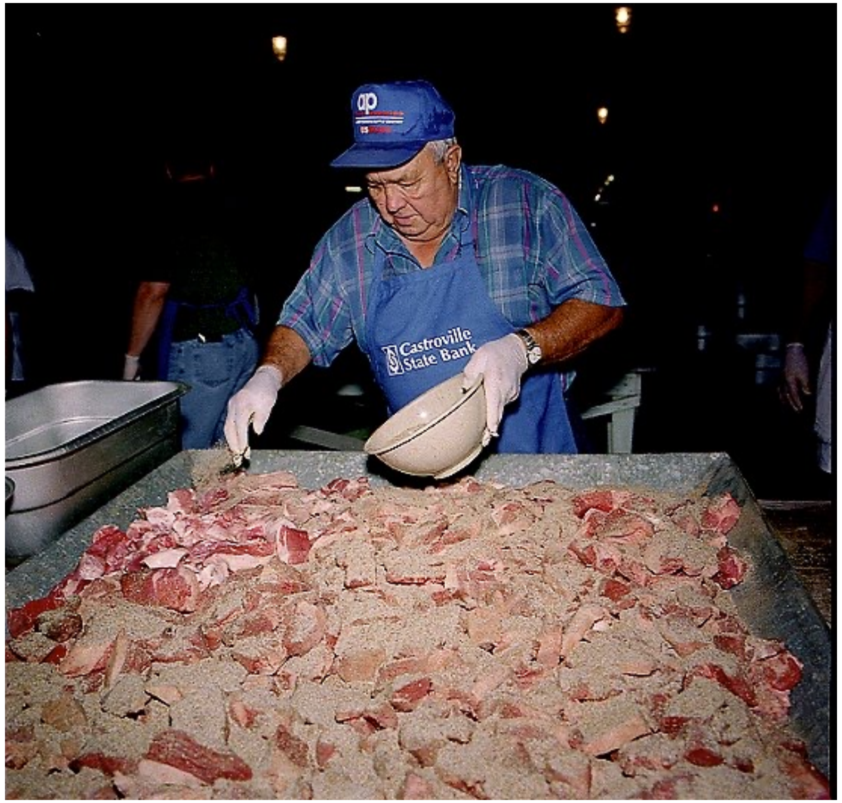
Part 1:

- Overview of available satellite products
- Different Types of Orbits
- Different Resolutions and Spatial Coverages
- Levels of Data Processing

Part 2:

- Types of Sensors and Measurements

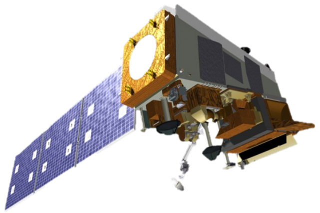
Sausage Making vs Sausages



What goes into making satellite products: EMR, wavelength bands, IOPs, radiances, atmospheric correction, lunar calibration, absorption spectra, cloud masks…

Using the data for your specific application

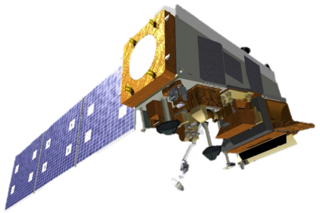
What oceanographic measurements are made by satellites?



- Sea Ice
- Sea Surface Temperature (SST)
- Sea Surface Height (SSH)
- Chlorophyll (ocean color)
- Rainfall
- Surface Vector Winds (SWV)
- Sea Surface Salinity

For how long?

What oceanographic measurements are made by satellites?

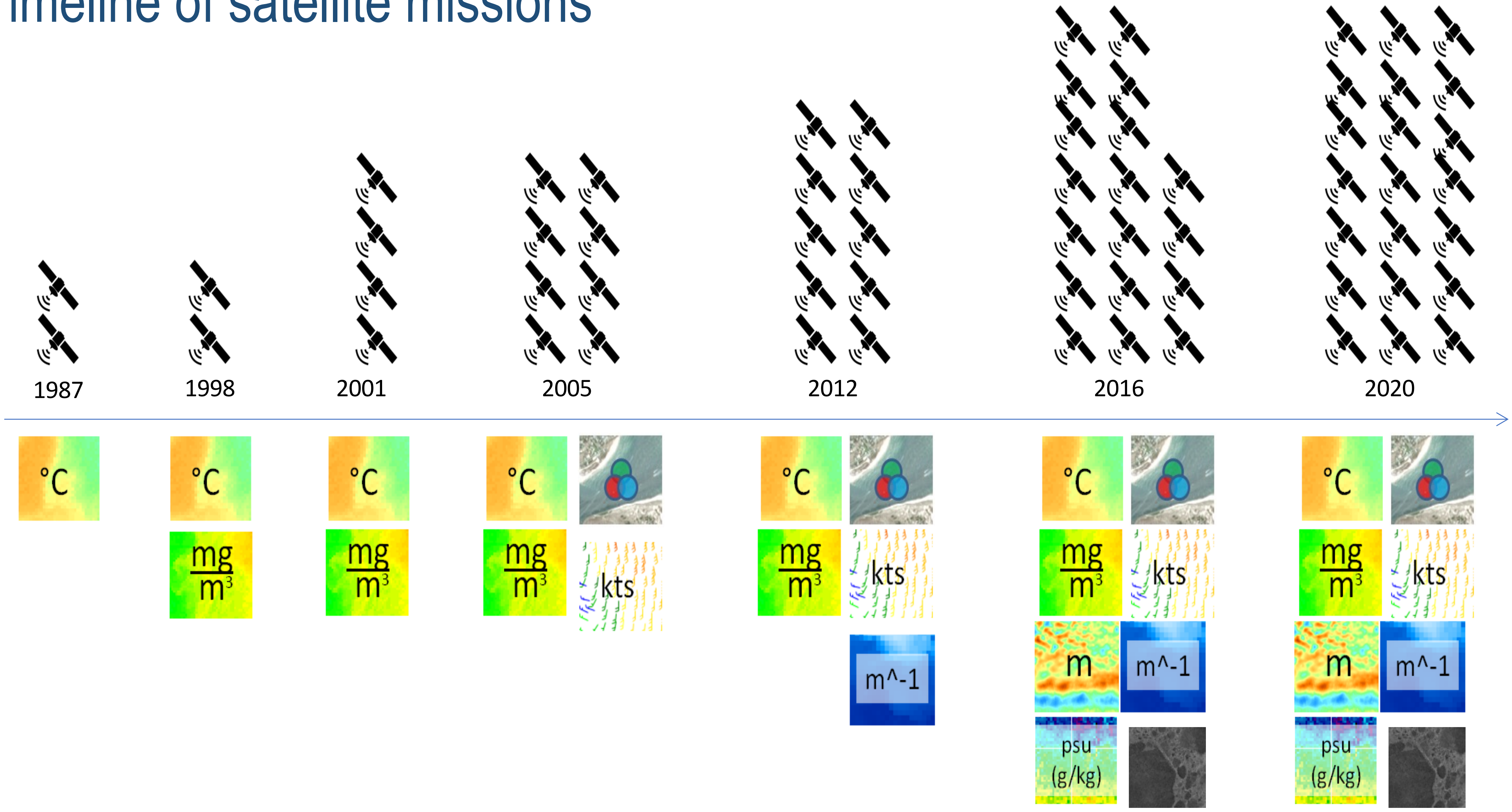


• Sea Ice	since 1978[1]
• Sea Surface Temperature (SST)	since 1981
• Sea Surface Height (SSH)	since 1992
• Chlorophyll (ocean color)	since 1997[2]
• Rainfall	since 1997
• Surface Vector Winds (SWV)	since 1999[3]
• Sea Surface Salinity	since 2011

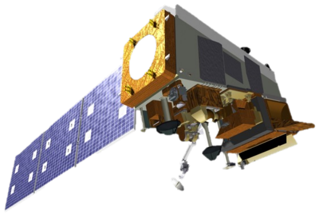
For many applications we want to know how the oceans are changing over time, so we need long timeseries of consistent measurements

[1]The *consistently processed* satellite passive microwave record of sea ice concentration begins in 1978, but other data extends to 1966.
[2]The continuous record of ocean color sensors extends back to 1997, but the CZCS mission flew from 1979-1986.
[3] Wind speed, without direction, dates back to 1988

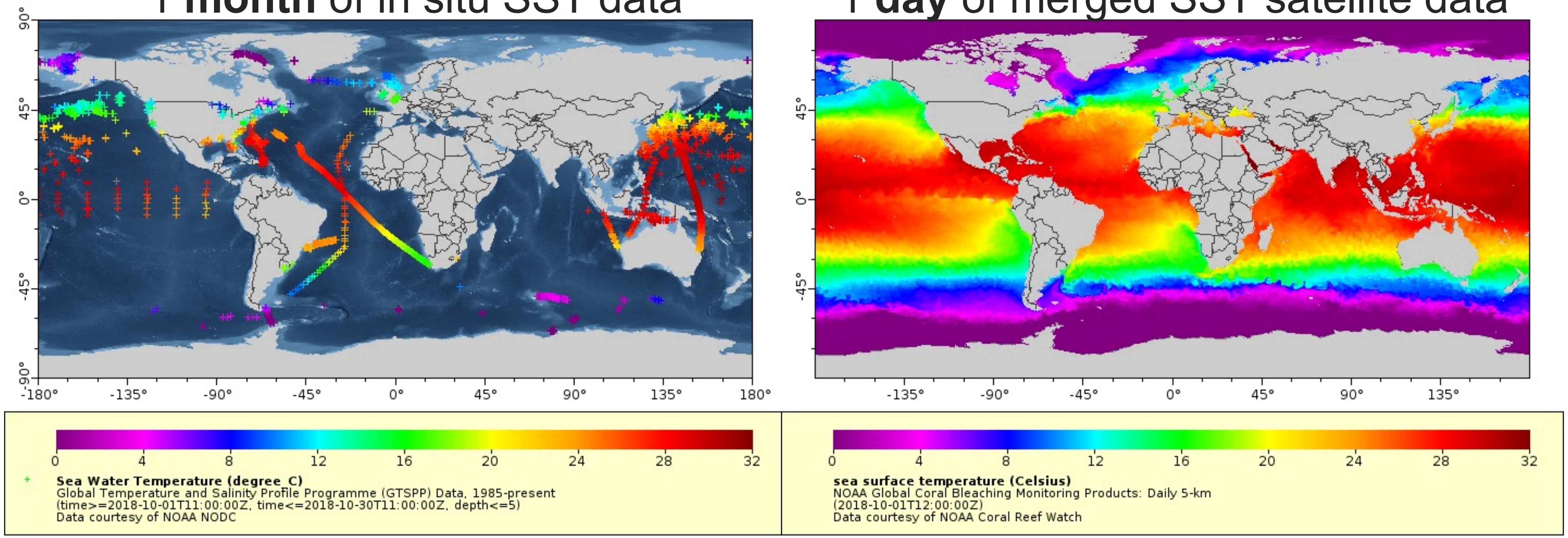
Timeline of satellite missions



Benefits of satellite data

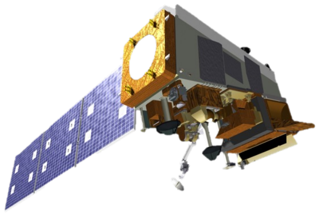


1 **month** of in situ SST data | 1 **day** of merged SST satellite data



- Satellite data provides observations of the ocean at temporal and spatial scales that are impossible to achieve with traditional in situ measurements
- Timeseries of satellite data make it possible to detect anomalous conditions and 'observe' past events

Satellite orbits



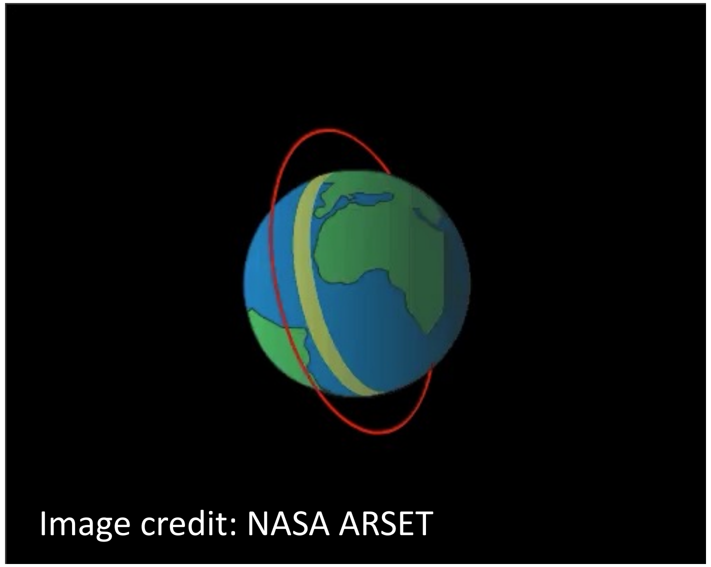


Image credit: NASA ARSET

Polar-orbiting satellites view most of the earth once a day

Altitude: 700-800 km

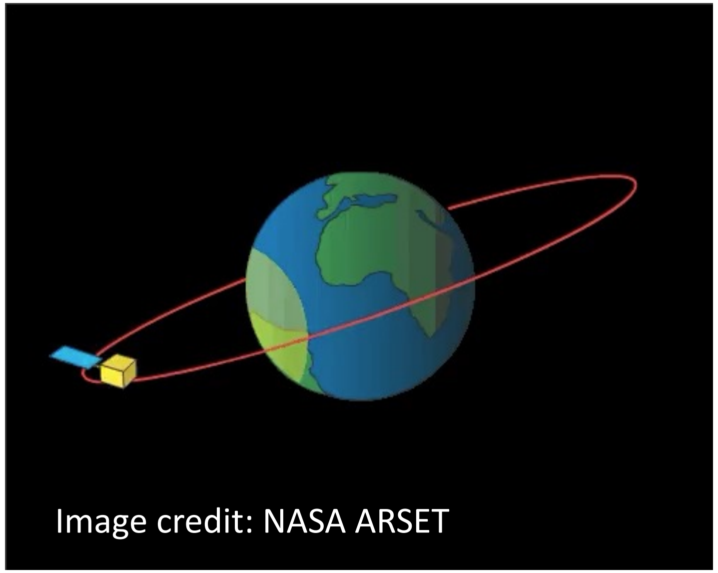


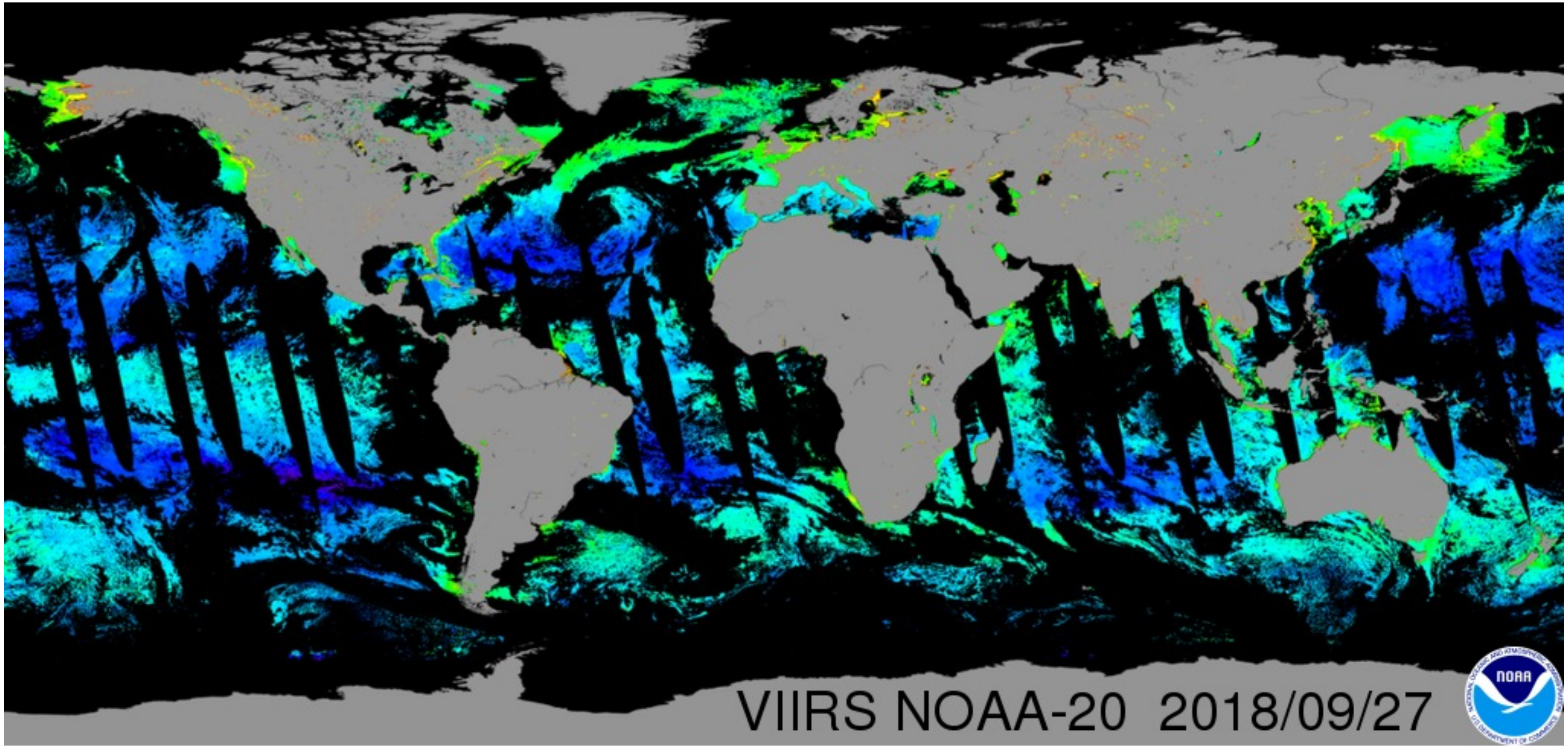
Image credit: NASA ARSET

Geostationary satellites view a limited region of the earth, but do so continuously throughout the day

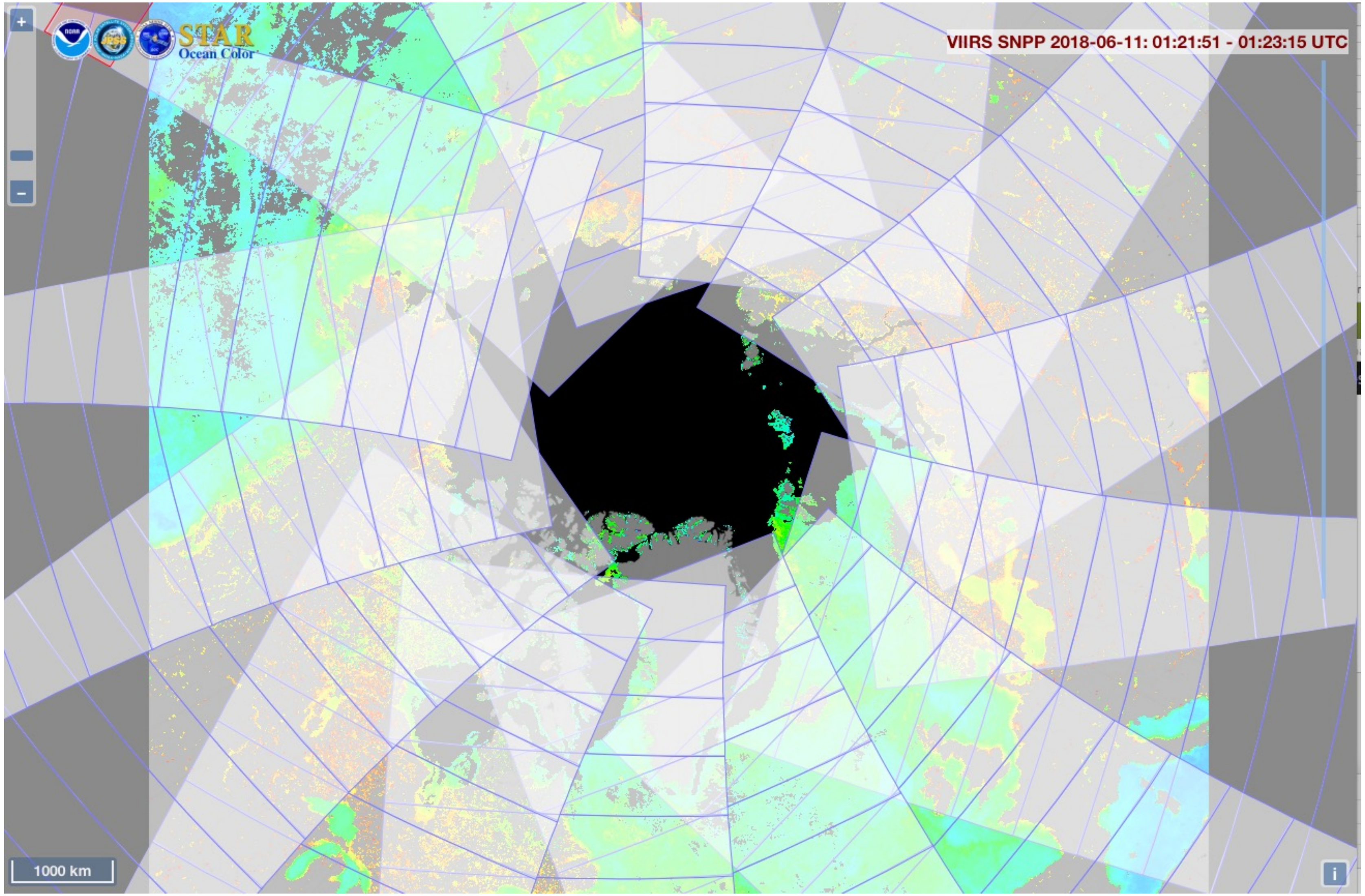
Altitude: 35,800 km

- Most oceanographic satellite measurements come from polar-orbiting satellites
- Some SST measurements are made from geostationary satellites
- South Korea has an ocean color sensor on a geostationary satellite

Polar Orbit



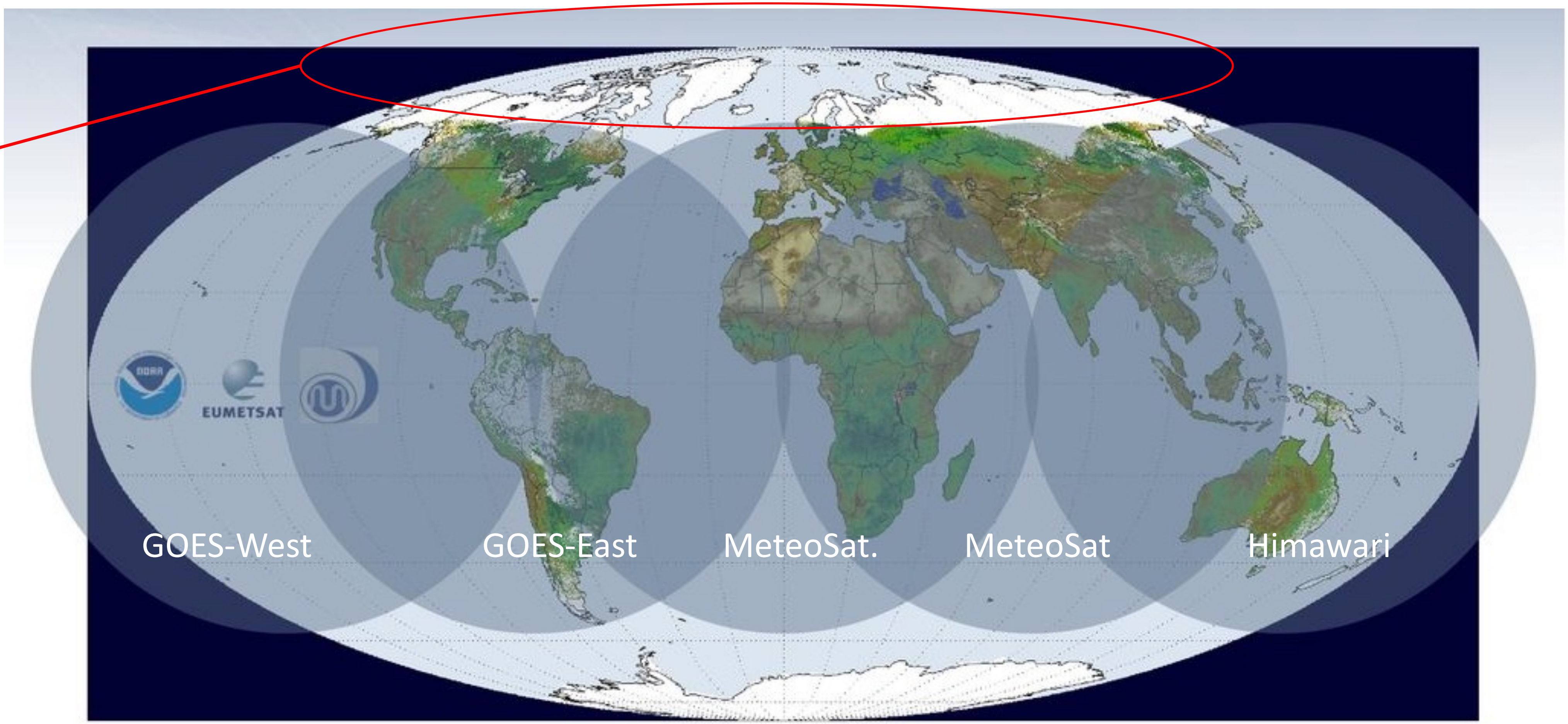
Polar Orbit



from https://www.star.nesdis.noaa.gov/sod/mecb/color/ocview/ocview.html

Geostationary coverage

Geostationary satellites aren't much use in polar regions!



GOES-West (US), GOES-East (US), MeteoSat x2 (Europe), Himawari (Japan)
-> 5 satellites for global coverage

Polar vs Geo Orbits

Polar

- Altitude: 700-800 km
- ~ 14 orbits a day
- Global coverage
- High spatial resolution (< 1 km)
- Low temporal resolution (≥ 1 day)

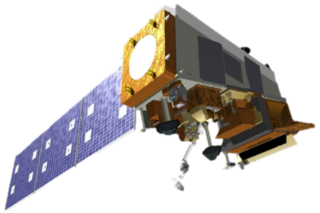
Geo

- Altitude: 35,800 km
- Poor coverage of the poles
- Regional coverage only
- Low spatial resolution (2-4 km)
- High temporal resolution (< hour)

Higher spatial resolution generally means lower temporal resolution, and vice-versa.

You can't have everything!

What Resolution?



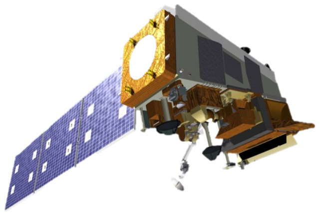
- **Spatial resolution** is the pixel size of the image. The resolution of oceanographic satellite products ranges from 250 m – 25 km.

- **Temporal resolution** is the amount of time that passes between subsequent images at the same point.

- **Spectral resolution** refers to how many bands the sensor has.

- **Swath width** refers to the width of the area observed by the satellite (polar-orbiting). Satellites with larger swath widths will take less time to acquire global spatial coverage.

High Spatial Resolution Satellites



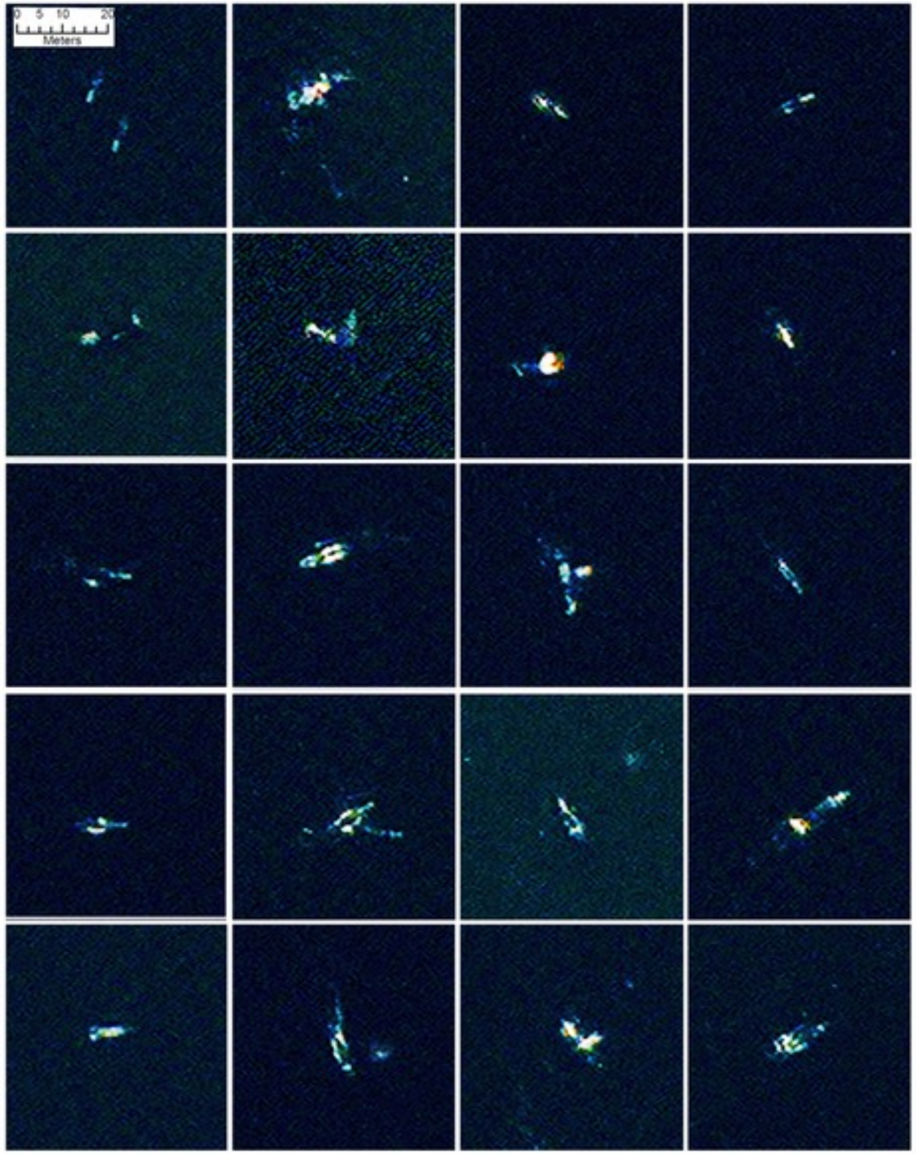
- There are a number of high spatial resolution imaging sensors, ~1-30 m, e.g. SPOT, QuickBird, IKONOS, OrbView-3, Hyperion, WorldView
- The trade-off is temporal resolution, and these sensors generally have very long repeat-times. Some don't have regular repeat times, but rather work on a system of scheduled, on-demand acquisitions.
- These data are generally better suited for land applications than for ocean applications.
- Most of the data has to be purchased, or is difficult to get a hold of.
- These data are generally not offered as part of this course.

Whales from Space

Figure 2. A selection of 20 comparable false colour image chips (bands 1-8-5) of probable whales found by the automated analysis.

"The WorldView2 satellite has a maximum 50 cm resolution and a water penetrating coastal band in the far-blue part of the spectrum that allows it to see deeper into the water column. Using an image covering 113 km^2, we identified 55 probable whales and 23 other features that are possibly whales, with a further 13 objects that are only detected by the coastal band."

Fretwell PT, Staniland IJ, Forcada J (2014) Whales from Space: Counting Southern Right Whales by Satellite. PLoS ONE 9(2): e88655. doi:10.1371/journal.pone.0088655
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0088655



Levels of Data

- Level 0: Raw data received from satellite, in standard binary form
- Level 1: Unprocessed data in sensor's geographic coordinates, containing calibration information
- Level 2: Derived geophysical variables atmospherically corrected and geolocated, but presented in sensor's geographic coordinates (granules). Also sometimes referred to as "along-track" data.
- **Level 3:** Derived geophysical variables mapped on uniform space-time grid scales. Spatial and temporal composites.
- **Level 4**: Model output or results from analyses of lower-level data e.g., variables derived from multiple measurements, like primary productivity or interpolation to provide cloud-free product

This course focuses primarily on level 3 and level 4 data

Temporal Composites

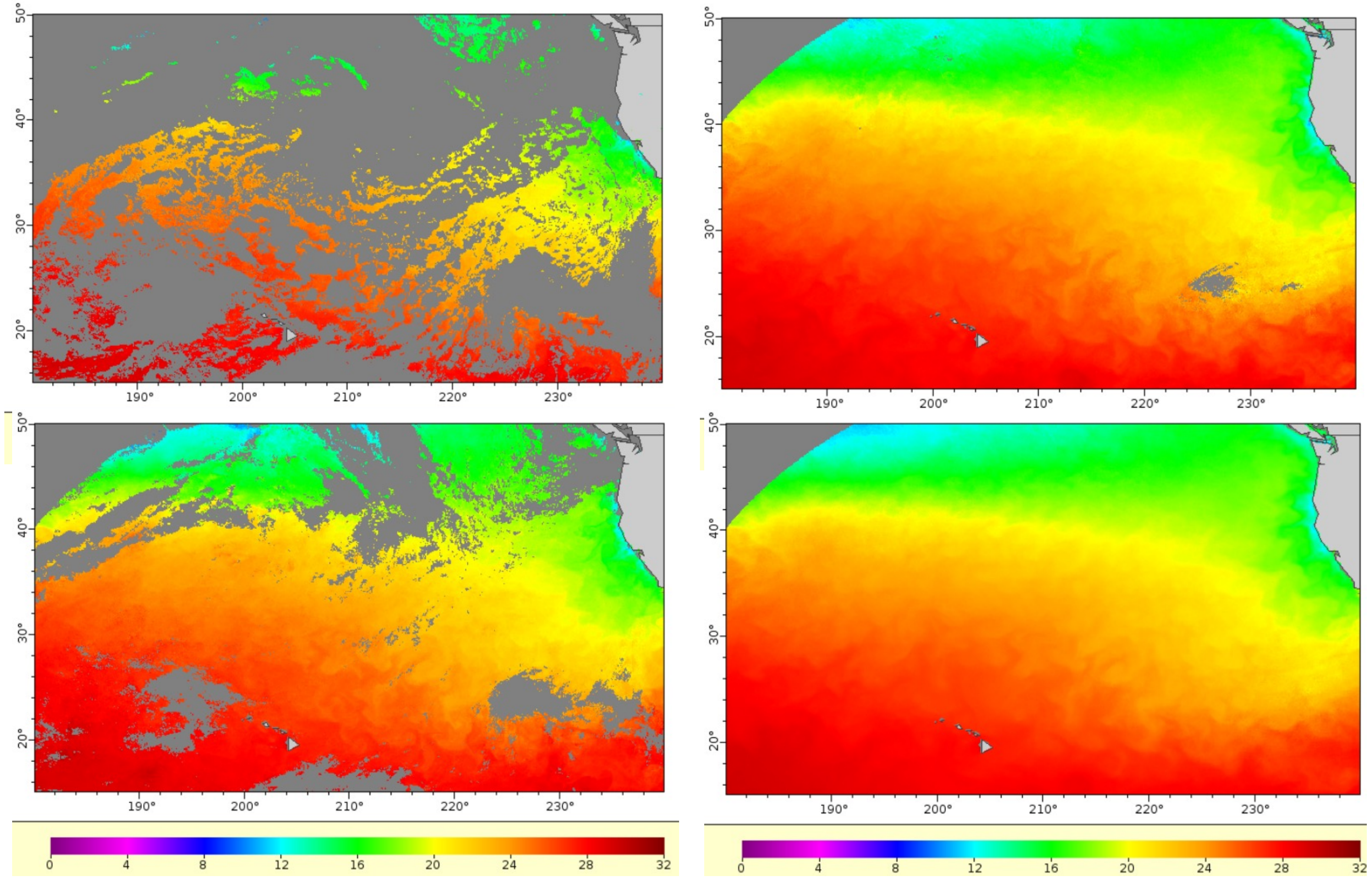
Composites product are the best way to deal with missing data due to cloud coverage

- **Level 3C**: Collated, or Temporal Composites
  Data from different time periods from the same sensor are collated together
  Example: Blending 7 (or 8) days of VIIRS Chl data into a weekly composite

- **Level 3S**: Super-collated or Blended Products
  Data from different time periods and different sensors are collated together.
  Example: Blending data from geostationary and polar-orbiting IR sensors

Example of Temporal Compositing

GOES West SST – September 2018



Sept 15 Hourly Image

Sept 12-18 Weekly Composite

Sept 15 Daily Composite

Sept Monthly Composite

Cloud Masking

- Cloud masks are necessary for measurements that can’t see through clouds, such as SST and ocean color
- Since cloud masks are usually made from visible imagery, cloud masks for nighttime retrievals of SST are less accurate than for daytime retrievals
- Different agencies and different satellite product producers use different cloud masks.

Anomaly Products and Climatologies

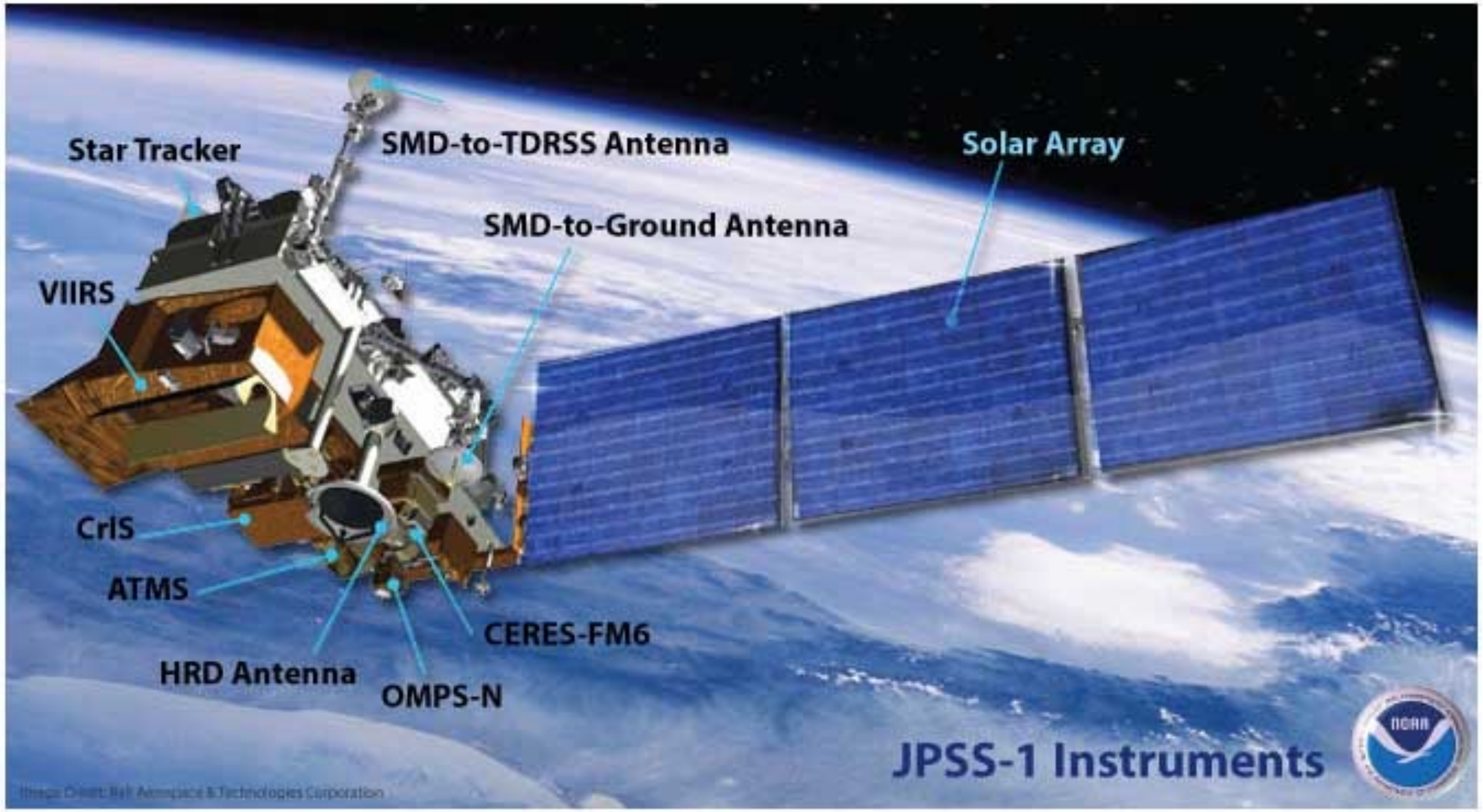
- For many applications an anomaly is more useful than the actual parameter. Anomalies are generated by subtracting a climatology of that parameter.

- We have a limited number of products with anomalies:

	MUR	NOAA Global Coral Bleaching	OSU SST and Chlorophyll Anomalies (MODIS)
Temporal Coverage	2002 - now	1985 - now	2003 - now
Temporal Resolution	Daily & Monthly	Daily	Monthly
Spatial Resolution	1 km	5 km	2 km, West Coast only
Products	SST	SST	SST and Chlorophyll
ERDDAP link	https://coastwatch.pfeg.noaa.gov/erddap/griddap/jplMURSST41anommday.graph	https://coastwatch.pfeg.noaa.gov/erddap/griddap/NOAA_DHW.graph?CRW_SSTANOMALY	https://coastwatch.pfeg.noaa.gov/erddap/griddap/osu2SstAnom.graph https://coastwatch.pfeg.noaa.gov/erddap/griddap/osu2ChlaAnom.graph

Satellite vs Sensor

VIIRS:
Visible
Infrared
Imaging
Radiometer
Suite



Some satellites are single-mission, carrying only one sensor, e.g. the SeaWiFS sensor on the GeoEye/OrbImage satellite. Other satellites have multiple sensors on them, as the JPSS satellites do. The same sensor can be on multiple satellites, ie VIIRS on SNPP and NOAA-20

US Satellite Agencies

NASA

National Aeronautic and Space Agency

Responsible for satellite research and development

NOAA

National Oceanic & Atmospheric Administration

Responsible for operational satellites for routine uses

Joint Polar Satellite System (JPSS):

a collaborative multi-satellite mission between NOAA and NASA

DOD

Department of Defense

Responsible for military satellites

NOAA CoastWatch Satellite Course - Narrated Presentations

- **Satellite 101 – Part 1**
- Satellite 101 – Part 2
- Fundamentals of Ocean Color
- Fundamentals of Sea-Surface Temperature
- Fundamentals of Altimetry, Wind and Salinity
- Introduction to ERDDAP
- What Dataset to Choose?
- Bringing Satellite Data into ARCGIS