Satellite Observations

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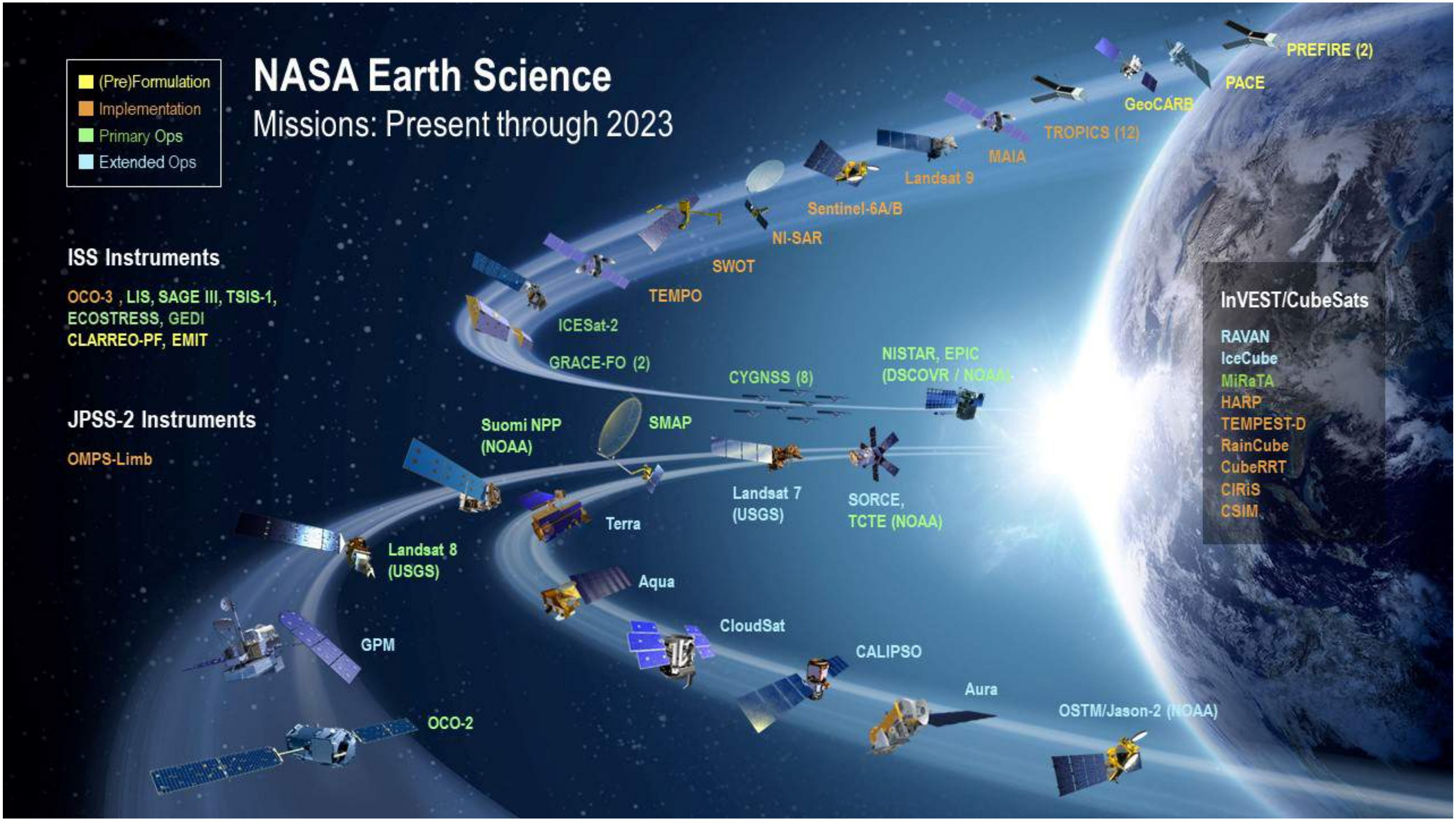
Outline

- Some of the satellite data sets in use by ECCO
- Issues related to satellite data use as constraints in the state estimates (e.g., defining errors, choosing products,…)
- Other data sets for possible future use
- Some upcoming satellite systems (GRACE Follow-On, SWOT,…)

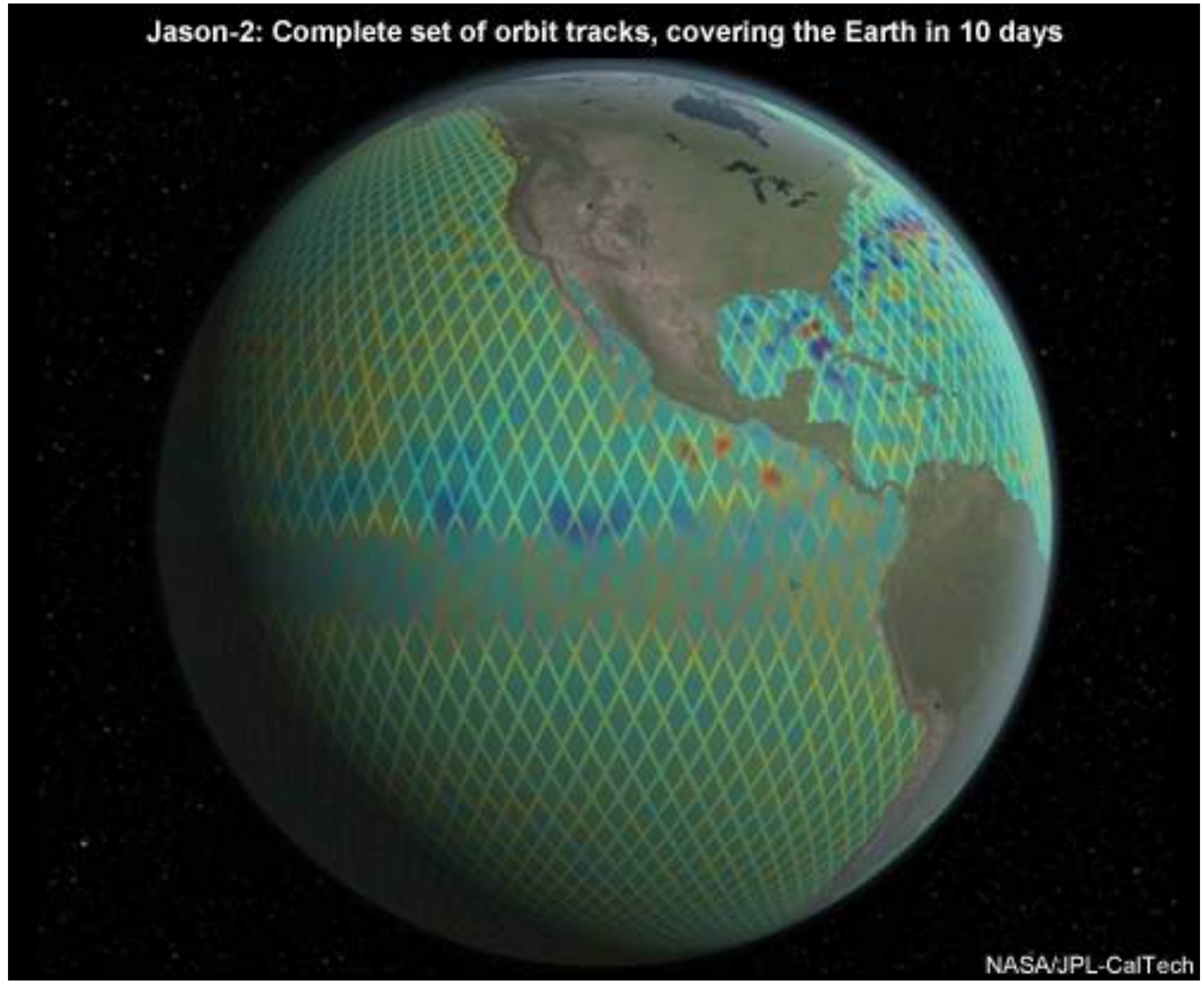
Observing the oceans from space…



Global coverage, fast repeat

Dependent on

- **Orbit types**
- **Instrument footprint**
- **Retrieval methods**

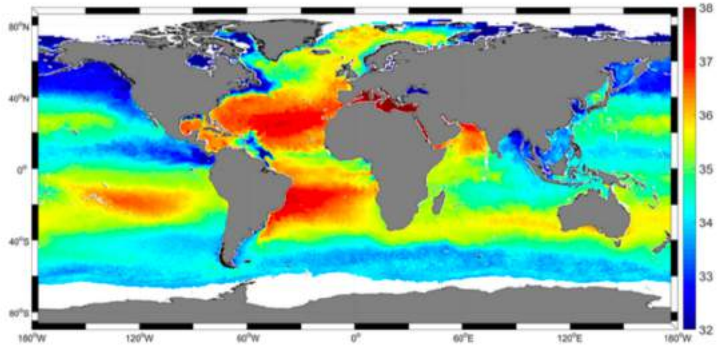


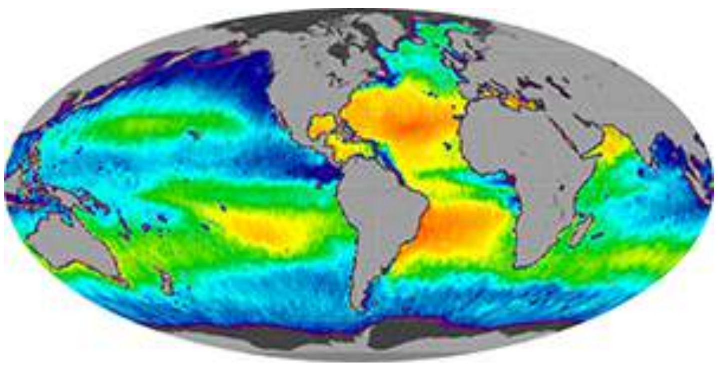
- **Aside from gravity missions, measurements restricted to "surface" variables**

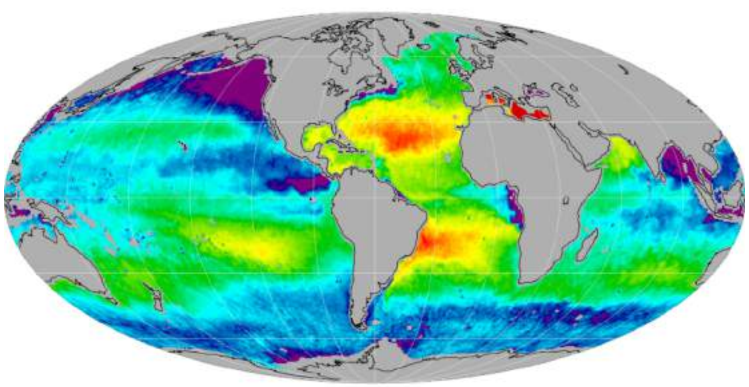
Current satellite data constraints

- Sea level altimetry
  - From TOPEX/Poseidon to current constellation of altimeters
- Space gravimetry
  - GRACE (Gravity Recovery And Climate Experiment) but also GOCE)
- Sea surface salinity
  - Aquarius
- Sea surface temperature
  - AVHRR
- Sea ice concentration (treated by Ian and An)

Sea surface salinity (SSS)







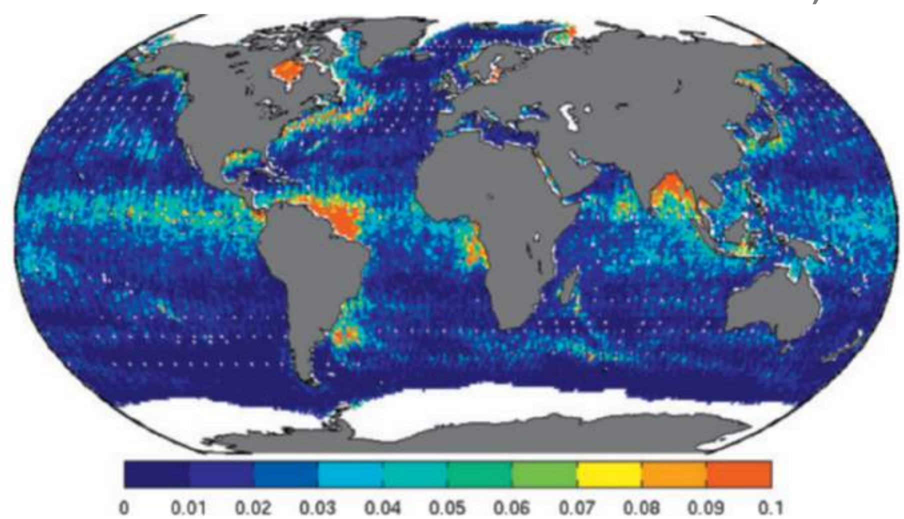
- **Soil Moisture Ocean Salinity (SMOS, 2009-present)**
- **Aquarius (2011-2015)**
- **Soil Moisture Active Passive (SMAP, 2015-present)**

(all available from different distribution centers)

Common retrieval issues

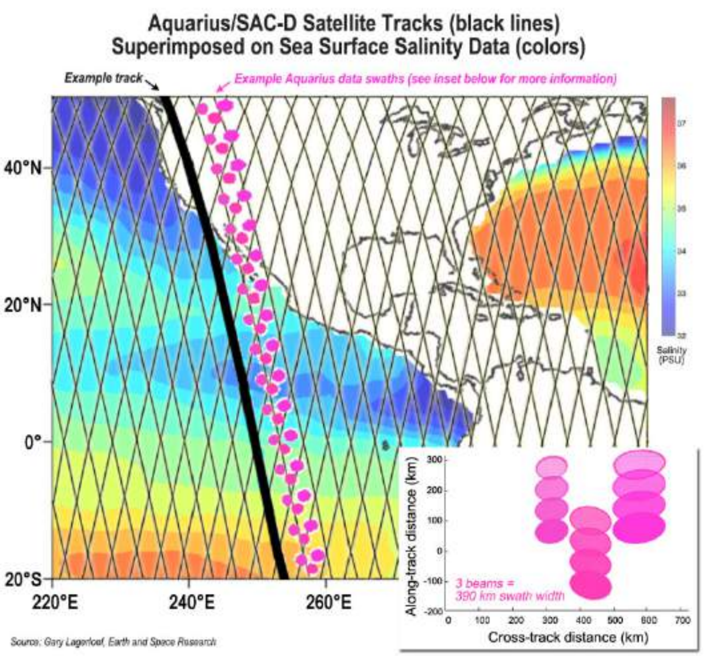
- Measuring skin vs. bulk properties

Vinogradova and Ponte (2012, J. Atmos. Oce. Tech.)



psu

- Weakly sampling and effects of temporal aliasing

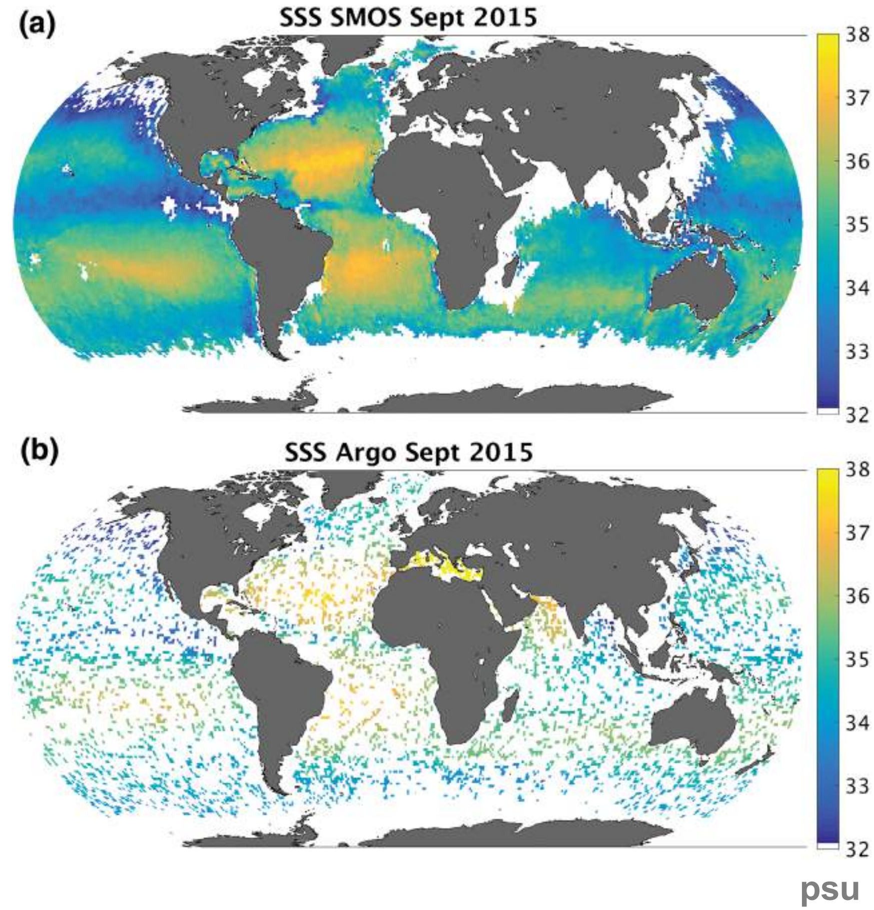


- Various footprints and horizontal sampling patterns

Valuable characteristics

- Good data coverage, even compared to Argo

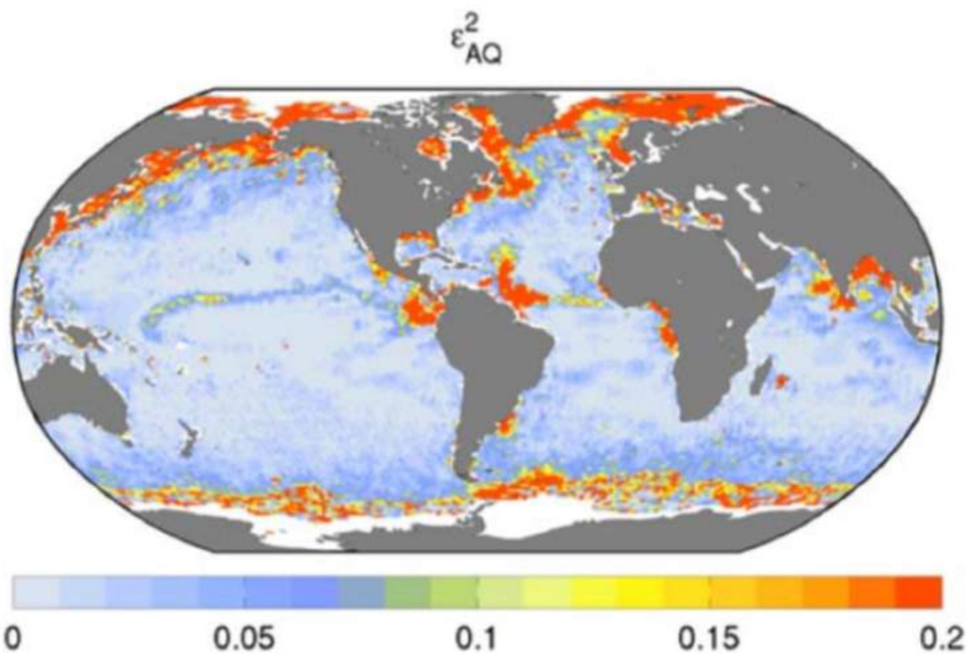
- Large footprint averages out short spatial scales

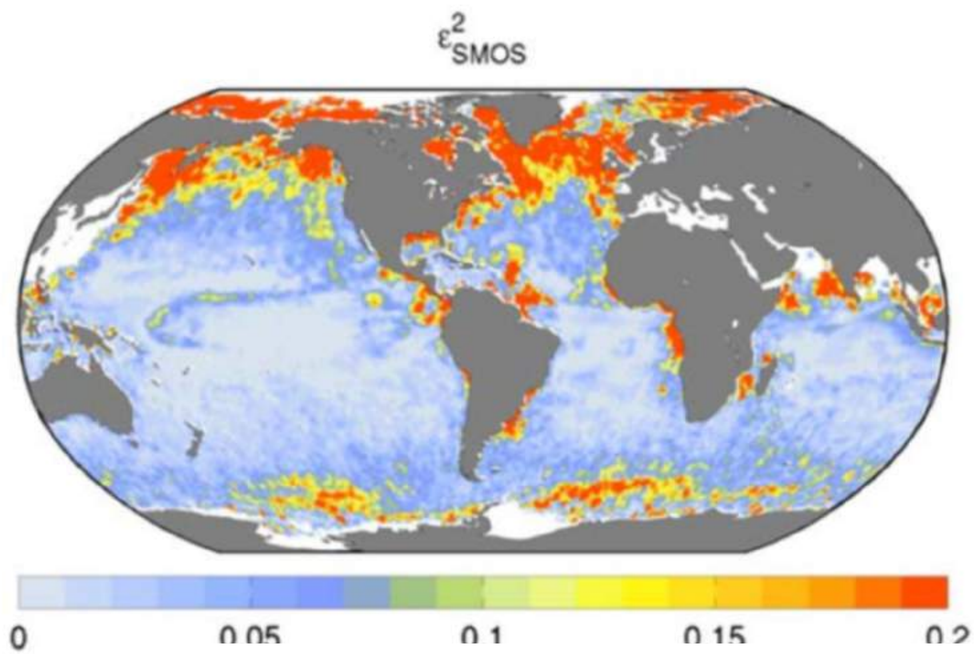


Srokosz and Banks (2019, Weather)

Estimating errors

- ➢ $D = s + d'$, $M = s + m'$, $var(d') = var(D) - cov(D,M)$

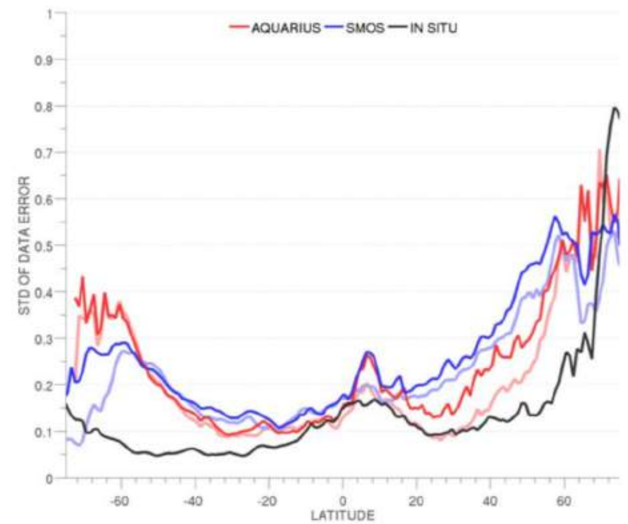




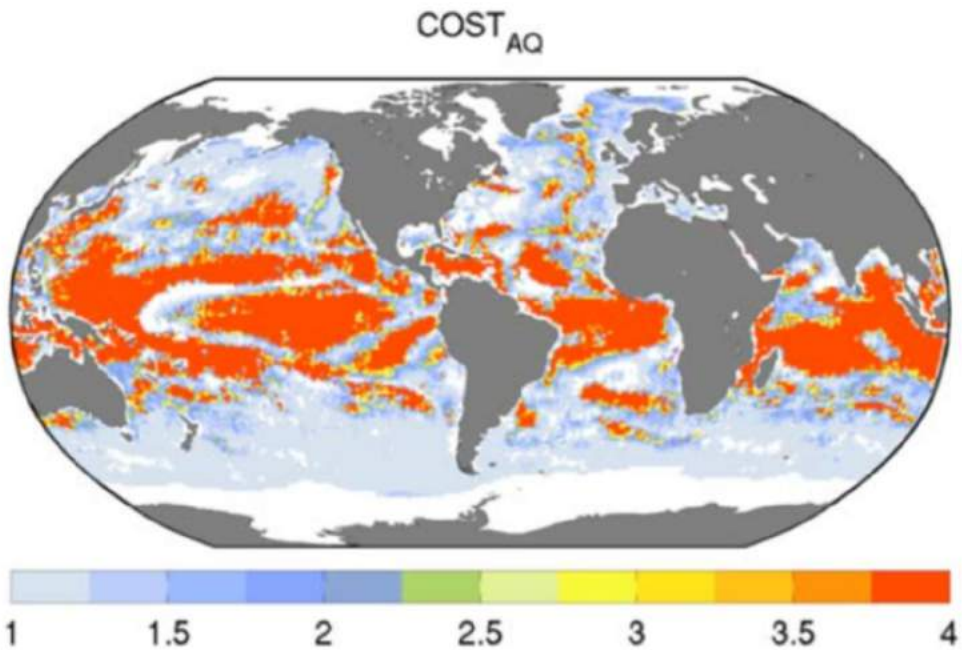
Vinogradova et al. (2014, J. Geophys. Res.)

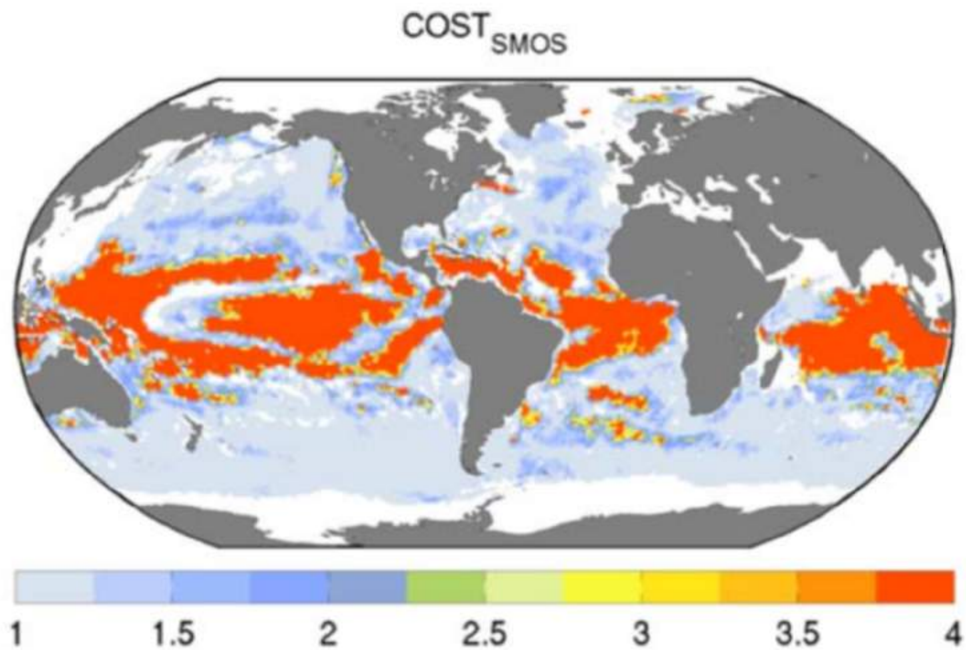
- ➢ 3-way collocation (when possible)
- ➢ Mean bias (e.g., compare to in situ)
- ➢ Assess against errors provided with data (when available)

- **Assess costs and the potential value as a constraint**



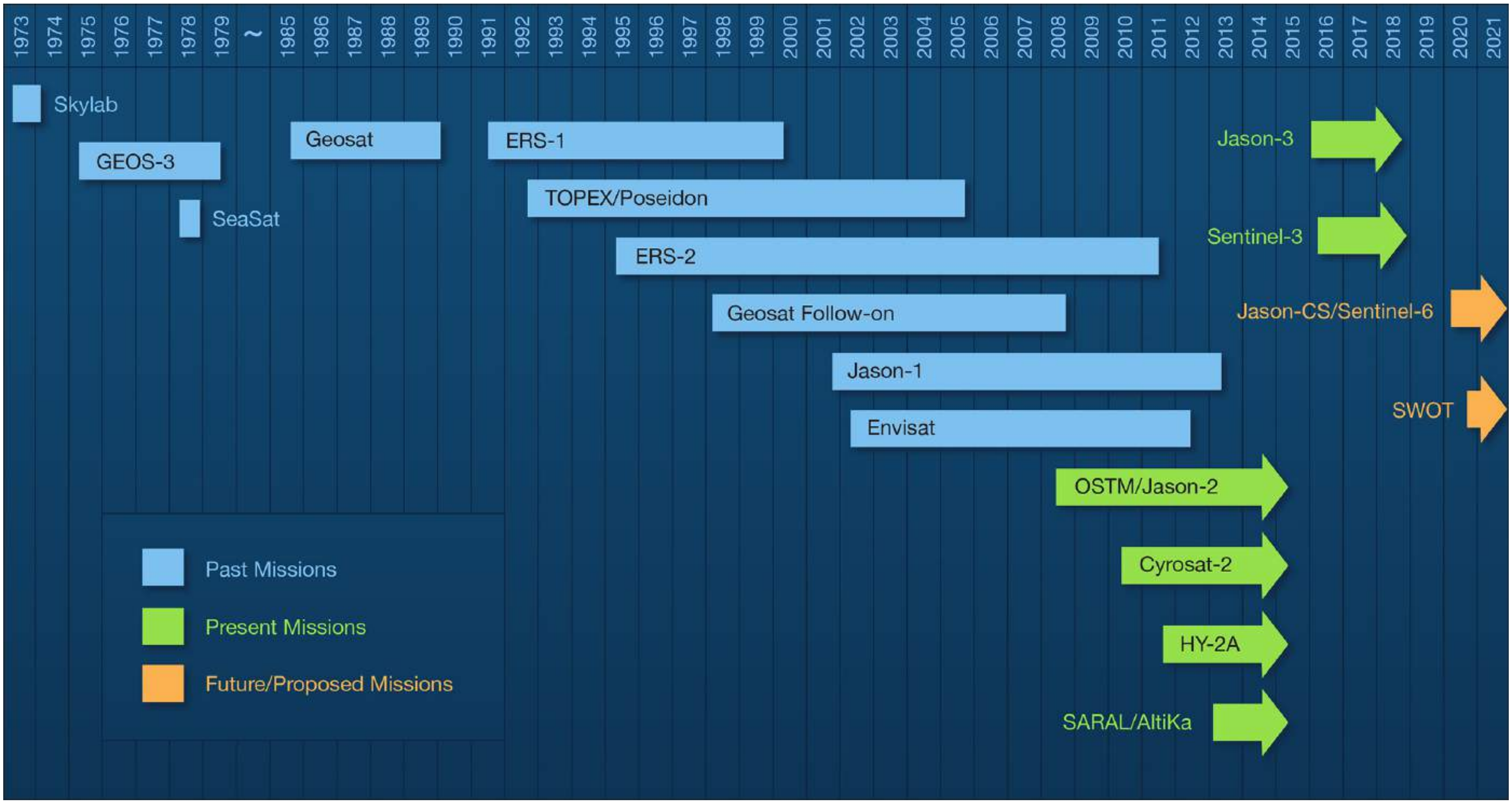
Vinogradova et al. (2014, J. Geophys. Res.)





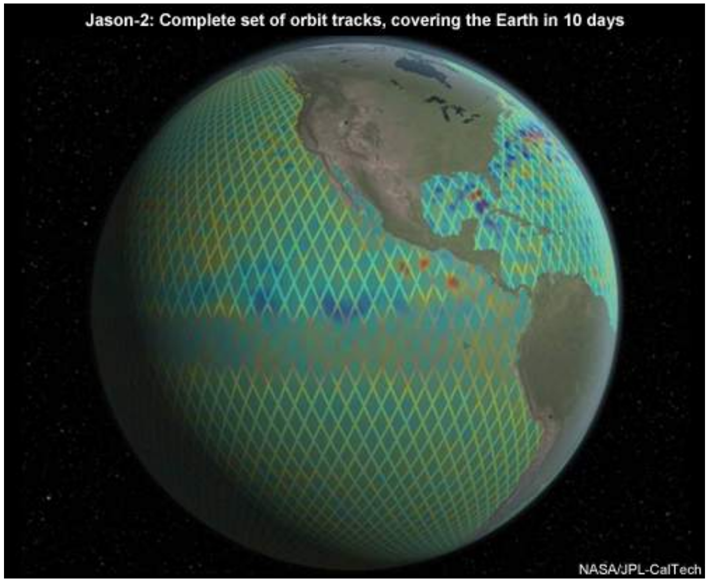
Satellite altimetry

➢ **From TOPEX/Poseidon to current constellation**



(courtesy of J. Benveniste)

Spatial coverage



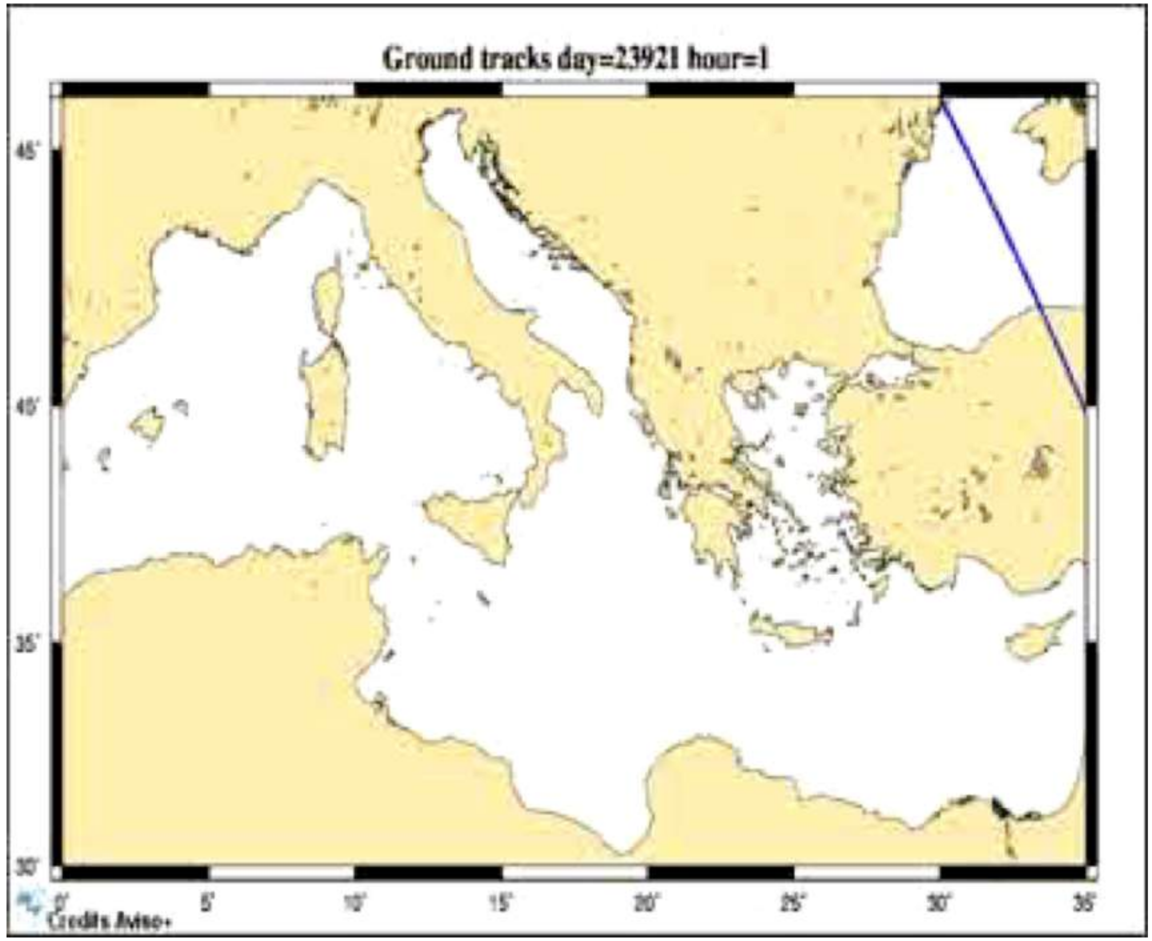
Ground tracks of 4 missions:

Jason-2

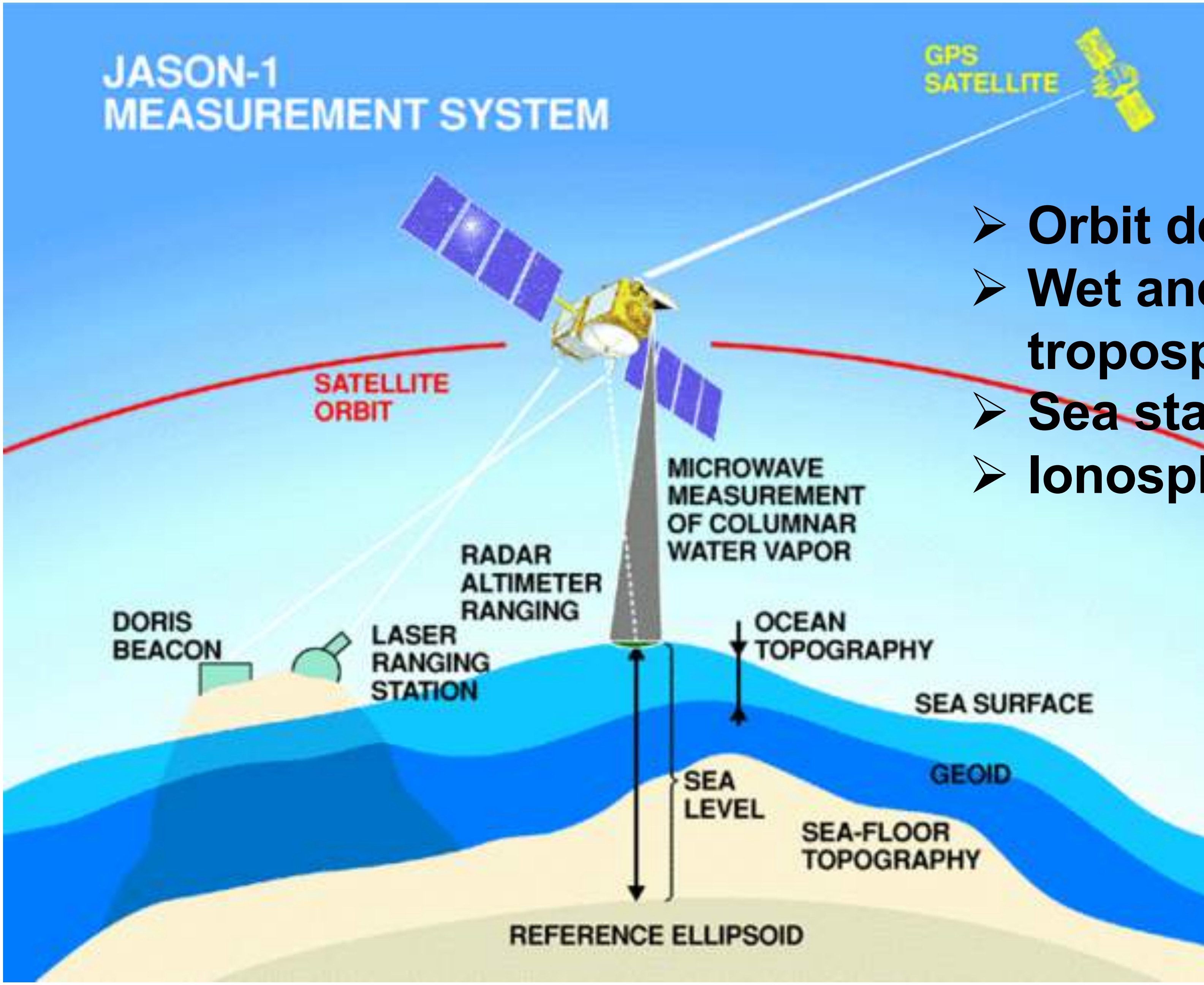
Cryosat-2

Saral/Altika

HY2A



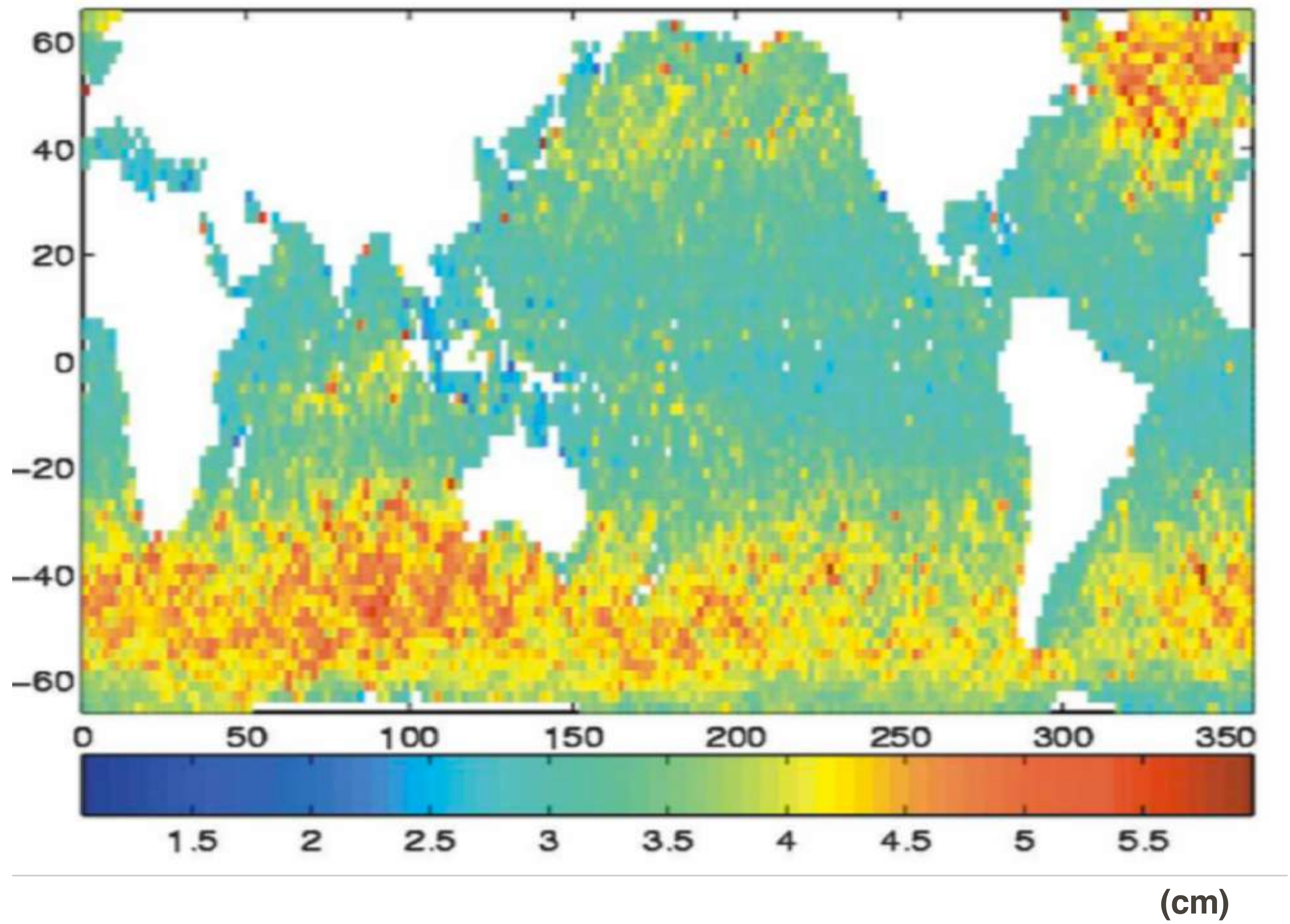
A complex measurement…



- Orbit determination
- Wet and dry tropospheric delay
- Sea state bias
- Ionospheric effects

Instrument noise

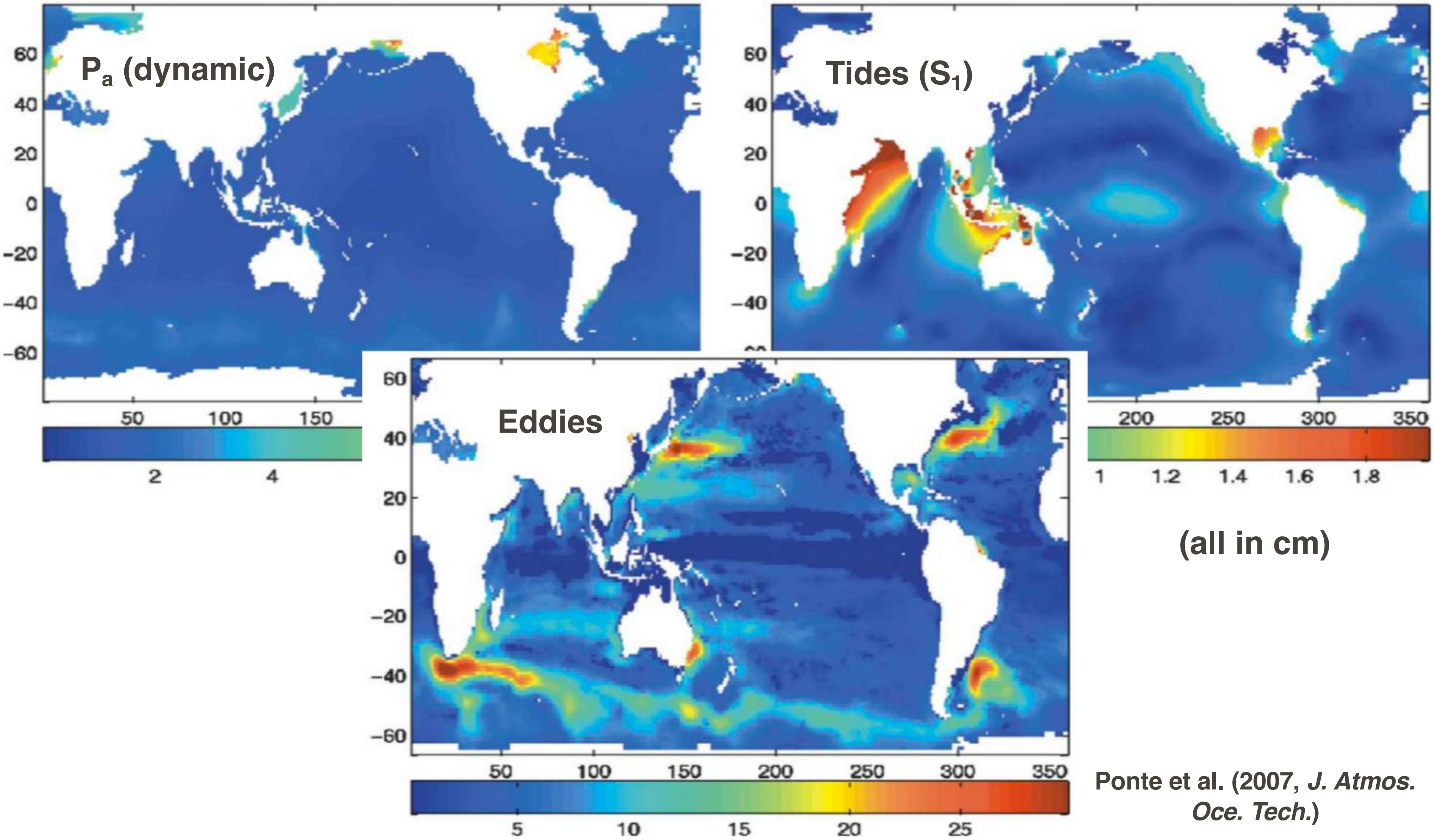
➢ **Leveraging a few months of tandem flight from TOPEX and Jason-1**



Ponte et al. (2007, *J. Atmos. Oce. Tech.*)

Representation noise

- **Dealing with signals not represented in models**



(all in cm)

Ponte et al. (2007, *J. Atmos. Oce. Tech.*)

Common issues

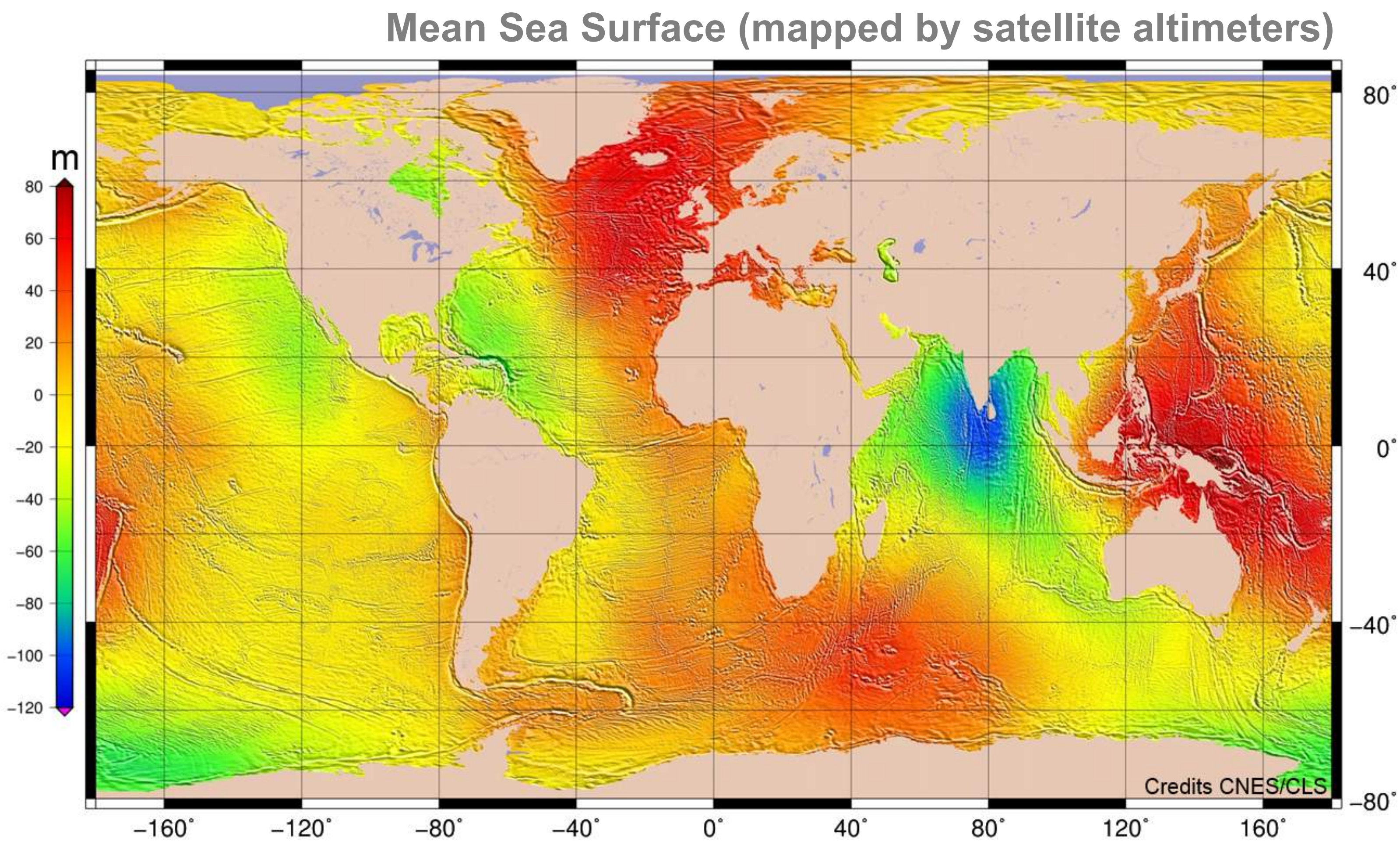
- Temporal aliasing (includes tidal and non-tidal signals)…typical repeat cycles of 10 days or longer

- Inhomogeneous spatial resolution (relatively finer along-track, coarse across-track)

- Poor coverage of coastal regions

- Static signals (largest is mean geoid)

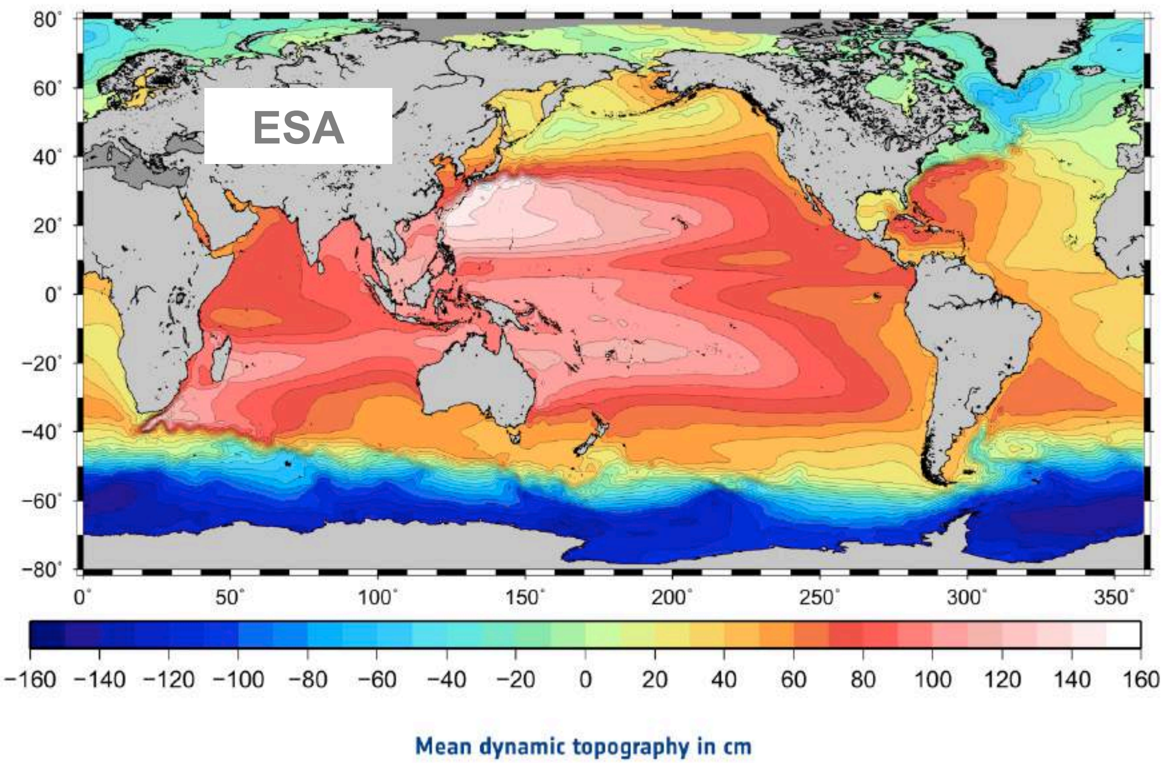
Anomalies vs. mean state



➢ **Separate constraints for time mean and anomalies from mean typically done**

Mean dynamic ocean topography (DOT)

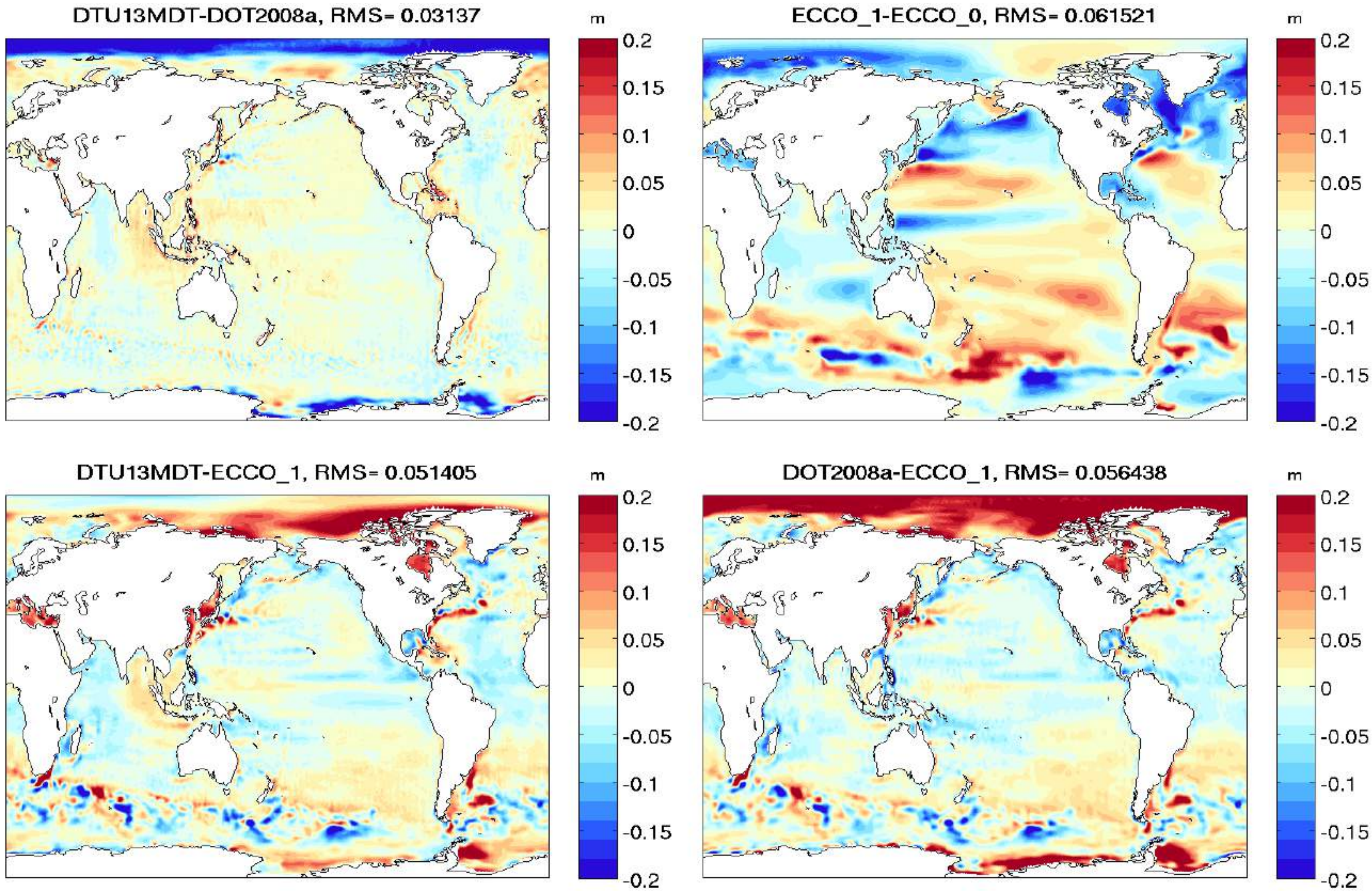
- **Usually obtained by subtracting estimate of marine geoid (GRACE/GOCE) from altimetric mean sea surface**



Some considerations:

- **Merging different spatial scales**
- **Omission errors**
- **Purely geodetic DOT**

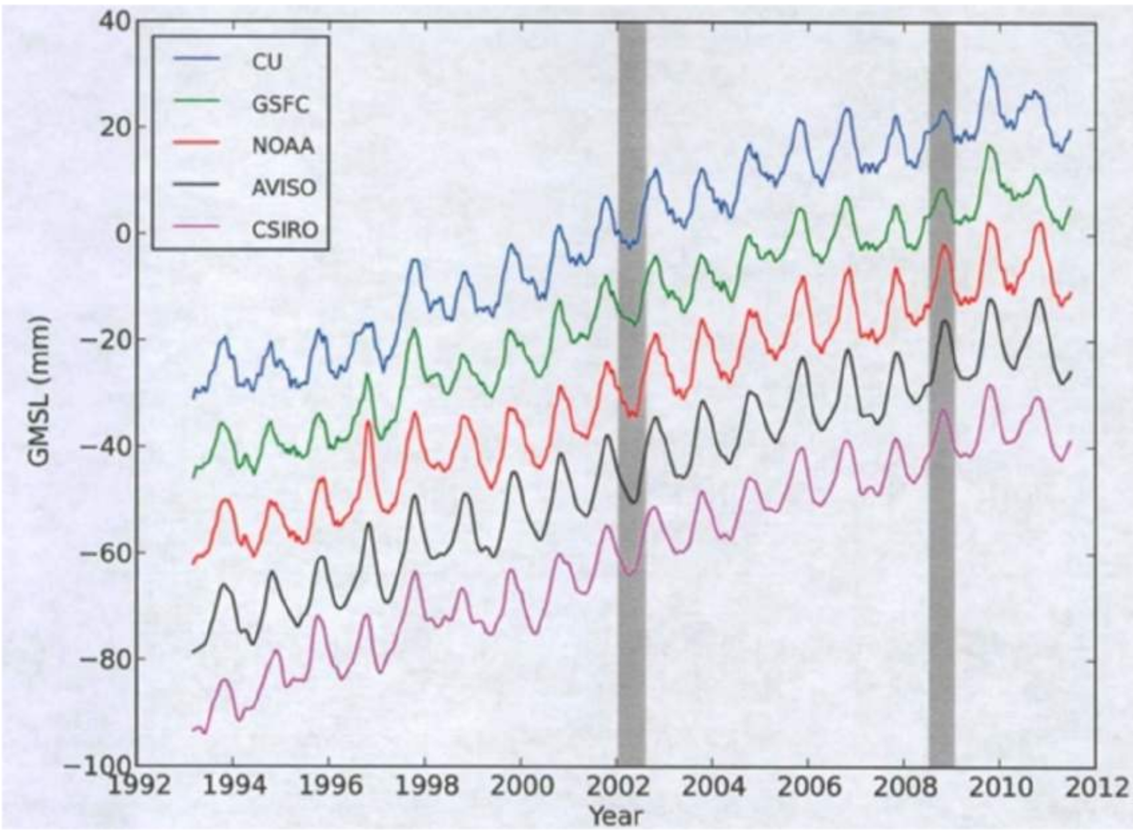
Comparing DOTs



- **Evolving estimates with accumulation of data**
- **Effects of constraints dependent on noise estimates**

Global mean sea level

- Average of GMSL curves from different centers (NOAA, AVISO, CSIRO)…spread gives measure of data noise



Masters et al. (2012, Marine Geodesy)

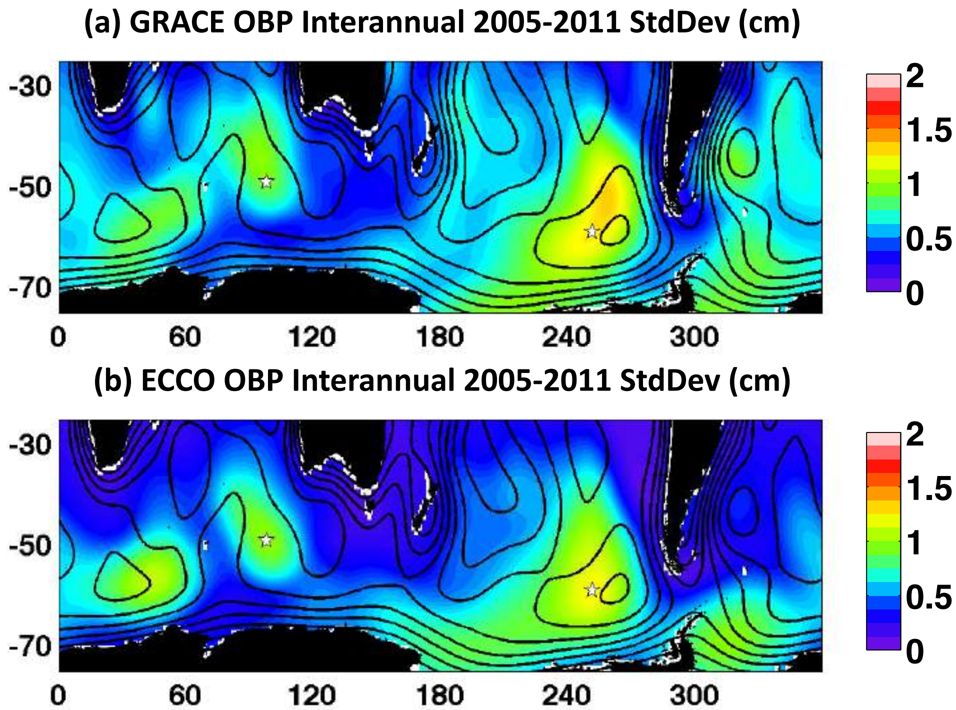
- Cost term based on sum of global mean steric height and net real freshwater fluxes

Space gravimetry

- Tracking changes in gravity field by microwave ranging between two satellites
- Complex retrieval of changes in ocean mass/bottom pressure
- Nominal monthly sampling at a few hundred km

(available from various processing centers, PO.DAAC @JPL)

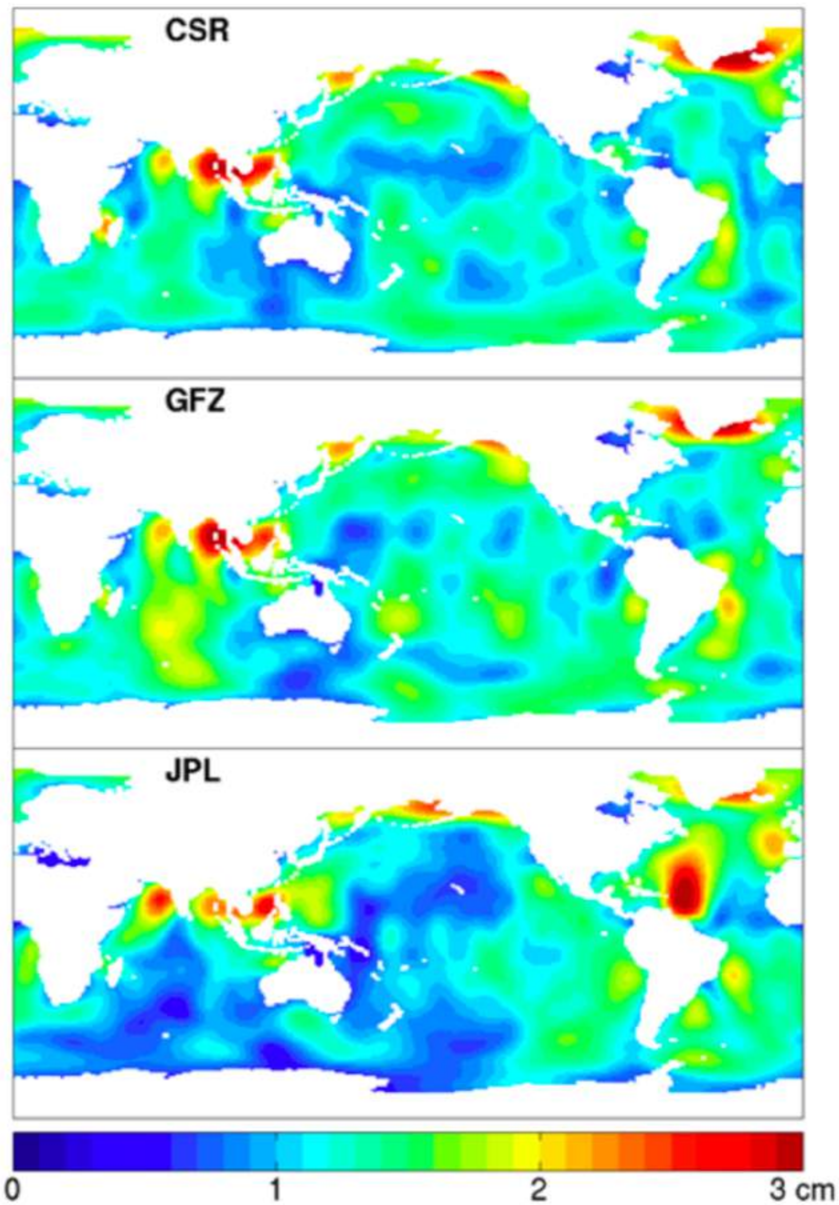
Constraining to GRACE

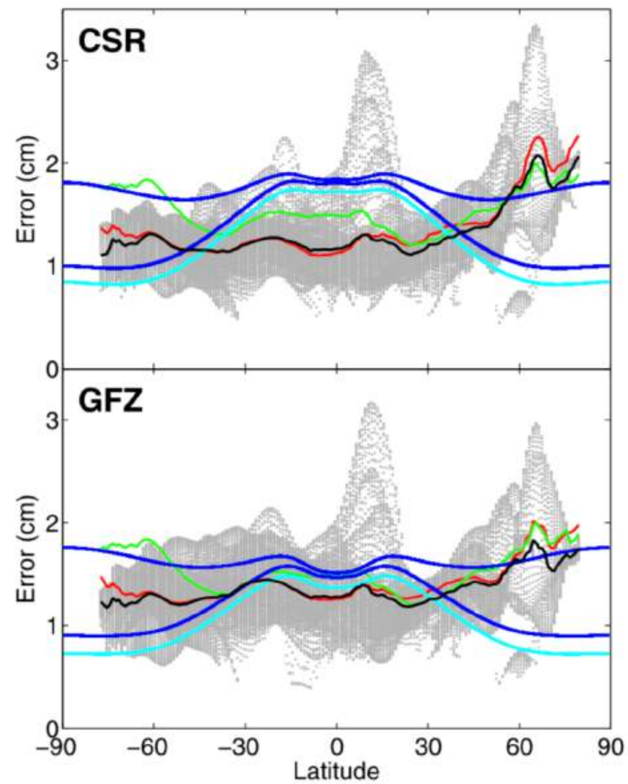


Ponte and Plecuch (2014, *J. Phys. Oceanogr.*)

- Different inversion methods
- Different temporal resolutions (submonthly fields available)

Error estimates

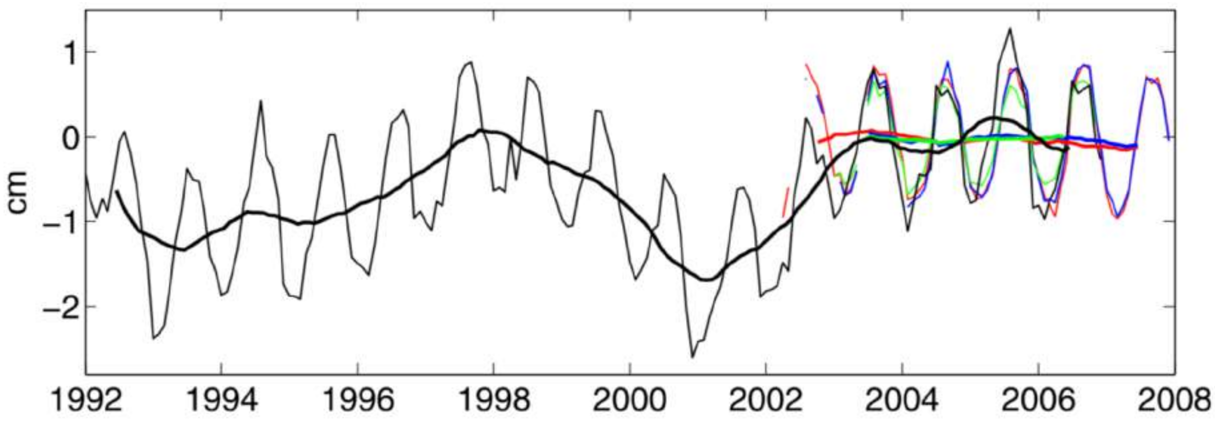




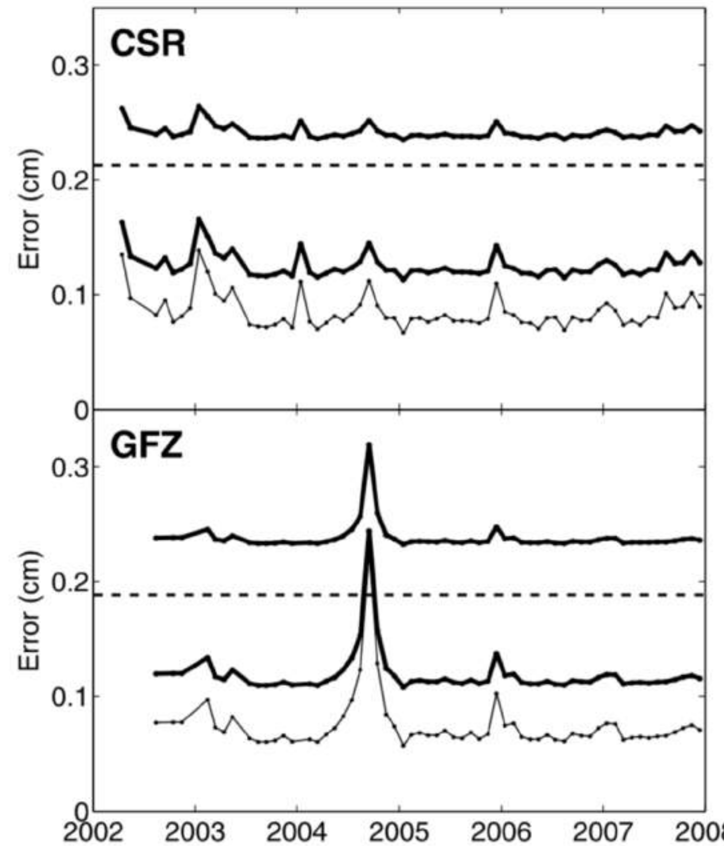
- Differences between model and various products
- Comparisons with errors provided by data centers

Quinn and Ponte (2008, *J. Geophys. Res.*)

Global mean bottom pressure

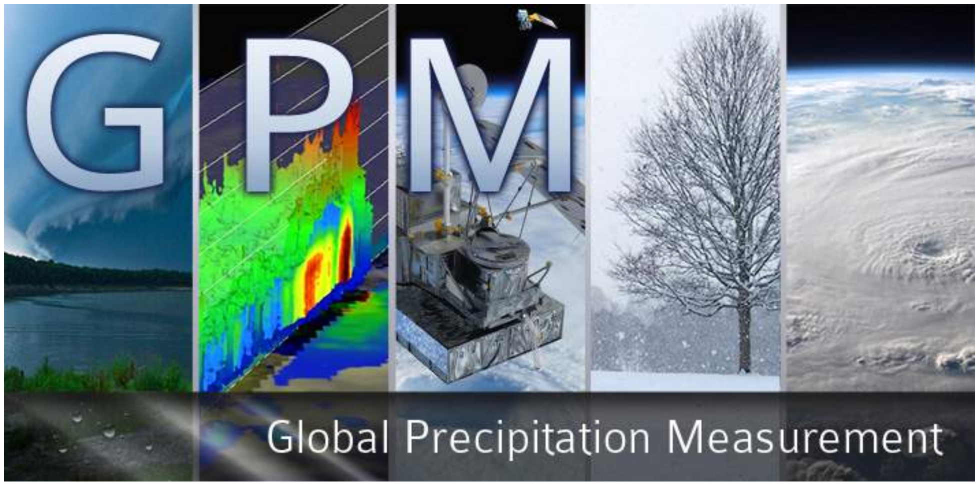


Quinn and Ponte (2008, *J. Geophys. Res.*)

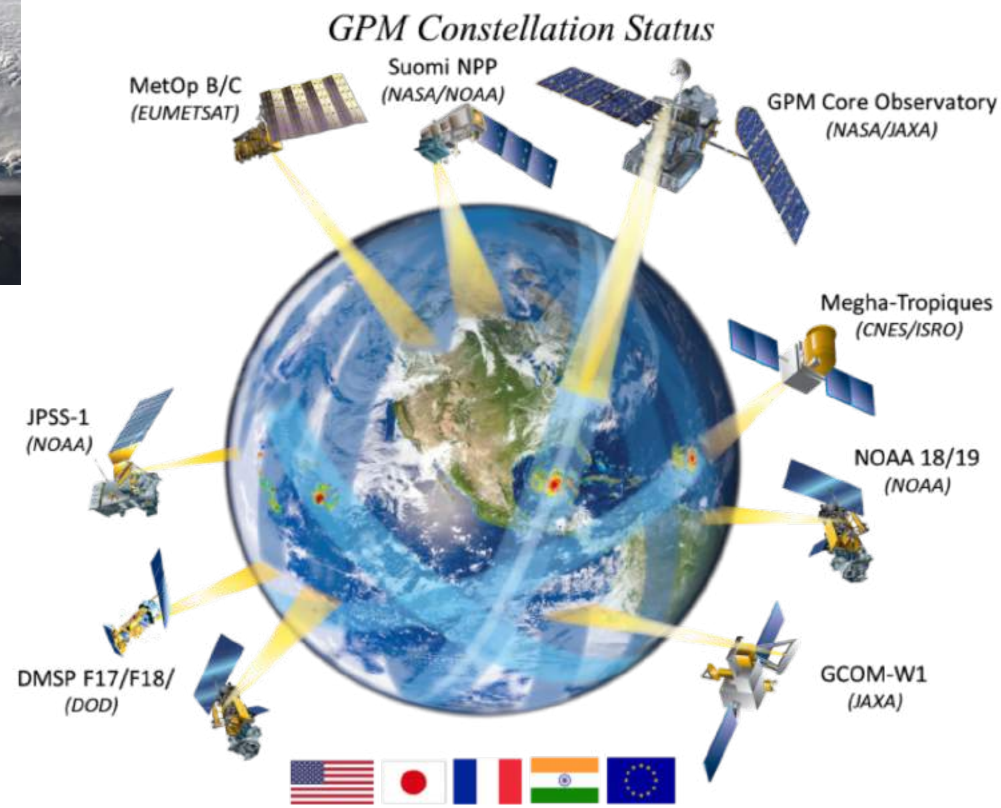


- Constraining global mean mass, net freshwater flux into ocean
- Remove global mean atmospheric pressure effects
- Similar treatment of errors (mixture of methods)

Some other satellite data sets

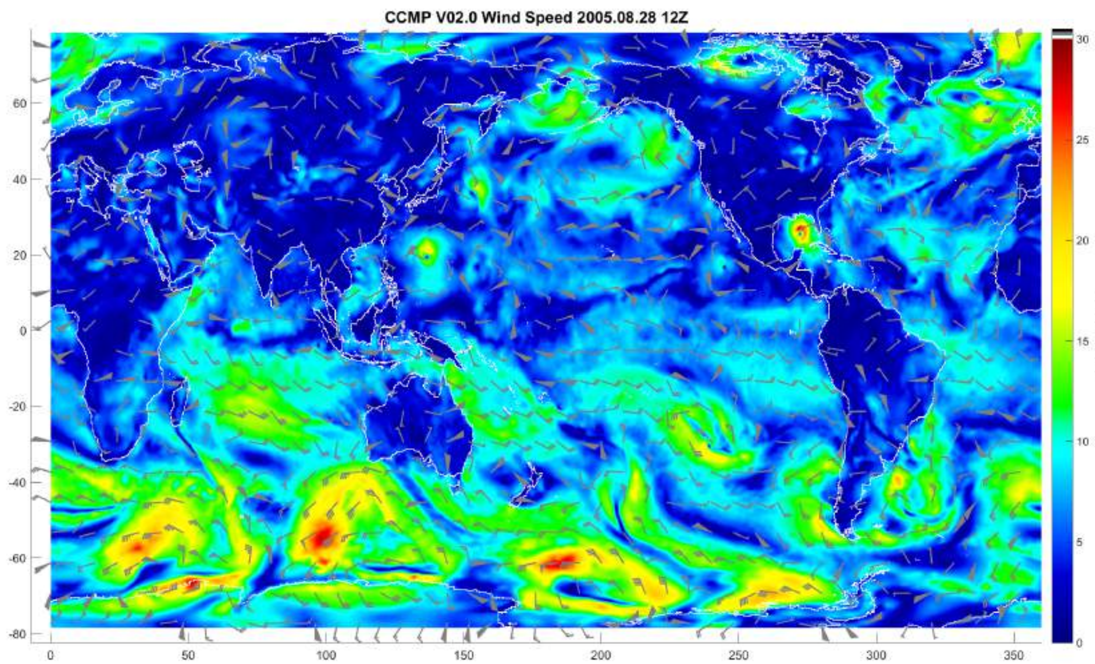


- Global coverage, 0.1º, daily, since 2014
- Constraining, validating a most uncertain forcing field



Some other satellite data sets

- Cross-Calibrated Multi-Platform (CCMP) gridded surface vector winds produced at Remote Sensing Solutions
- Combination of satellite-derived, in situ, and analyses winds, 6-hourly, 0.25ºx0.25º



OceanColor WEB

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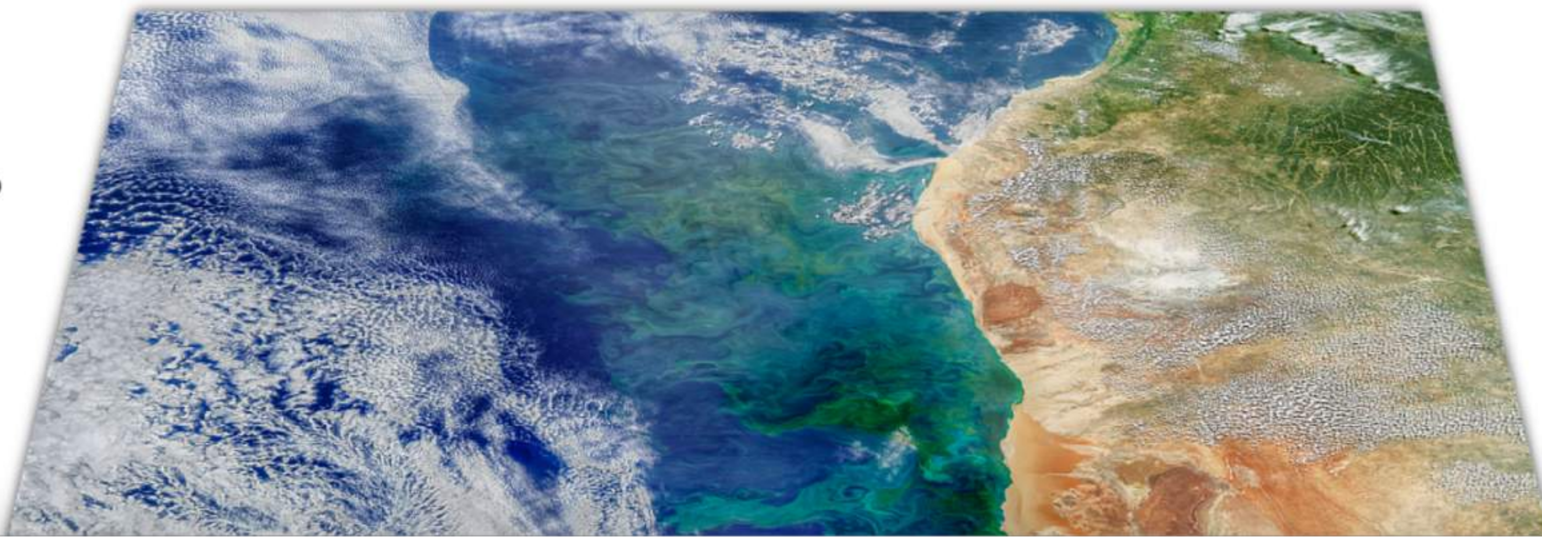
NASA's OceanColor Web is supported by the Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center. Our responsibilities include the collection, processing, calibration, validation, archive and distribution of ocean-related products from a large number of operational, satellite-based remote-sensing missions providing ocean color, sea surface temperature and sea surface salinity data to the international research community since 1996.

Ocean Color Feature

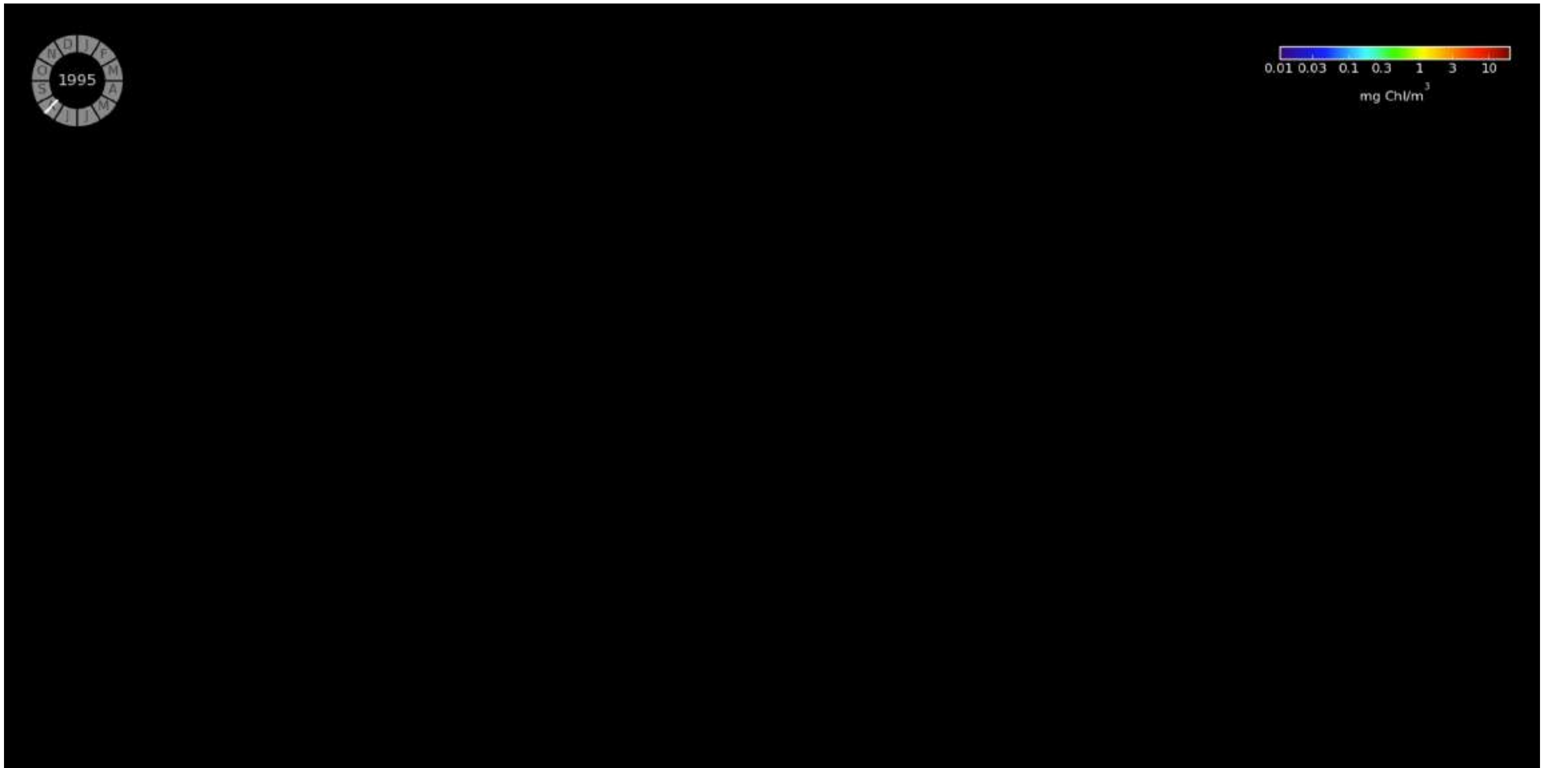
Benguela Upwelling Ecosystem

10 May 2019
13:05 UTC



Aqua
MODIS

https://oceancolor.gsfc.nasa.gov/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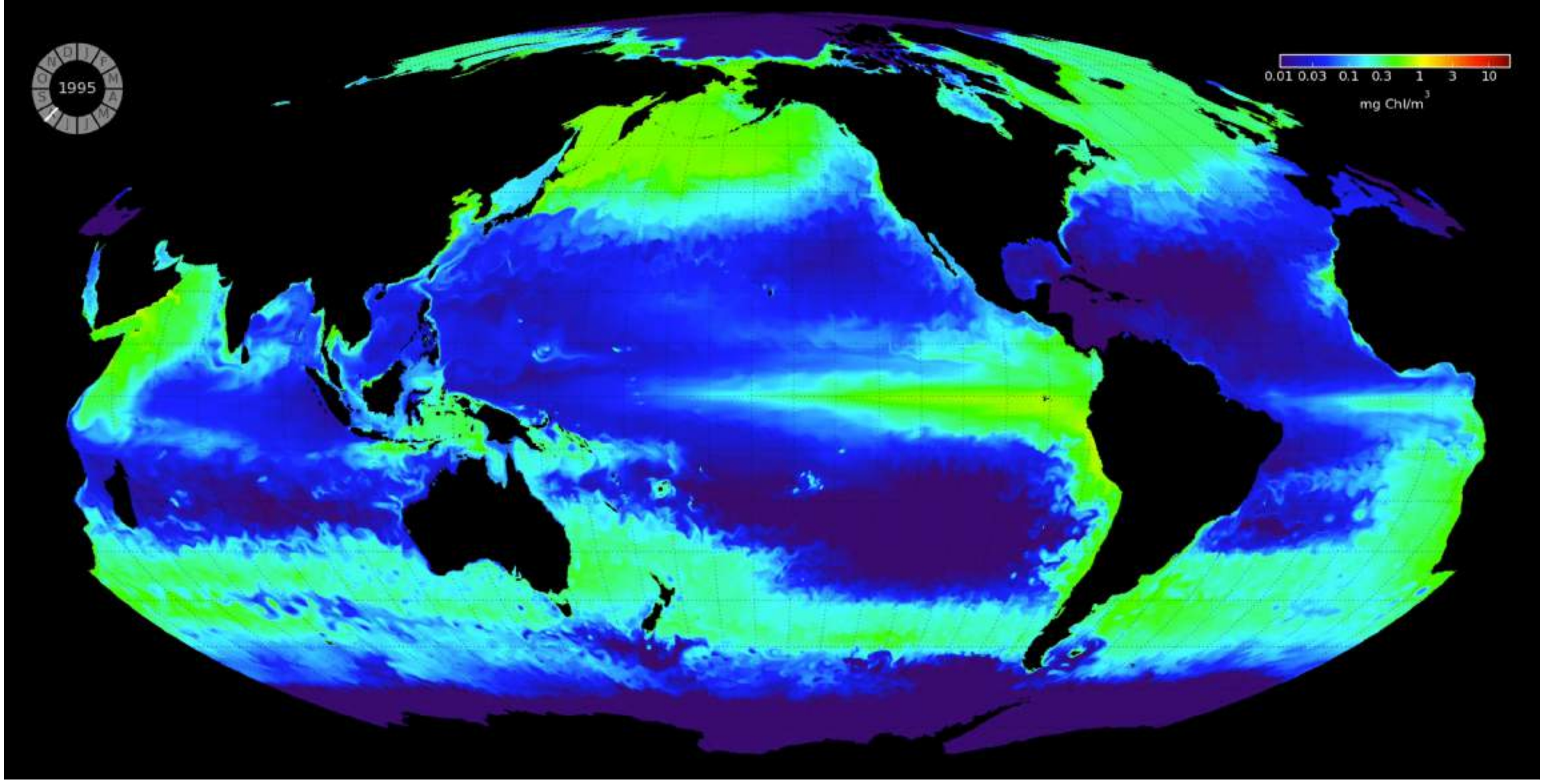
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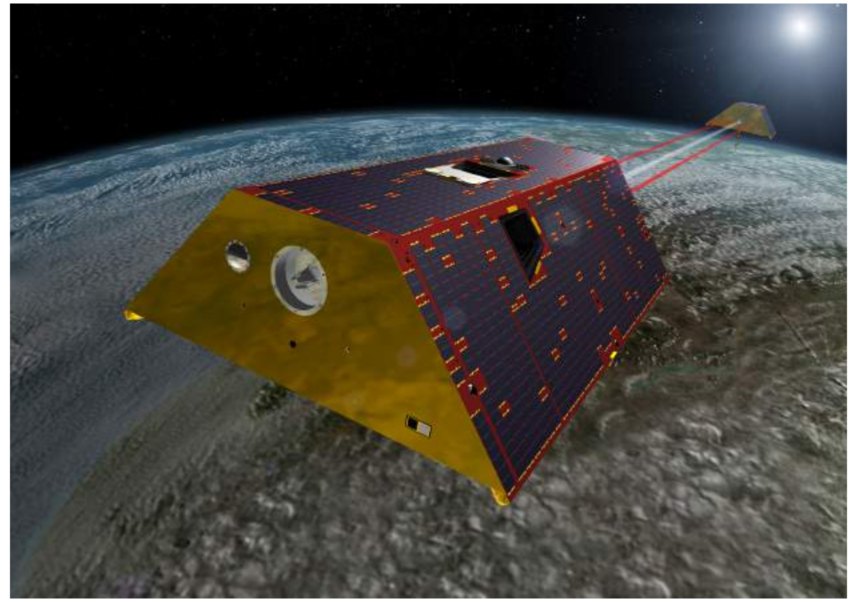
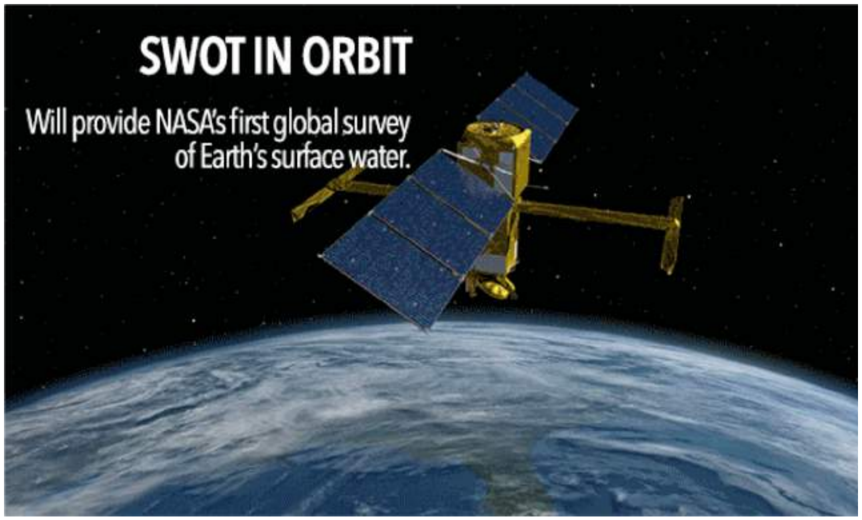
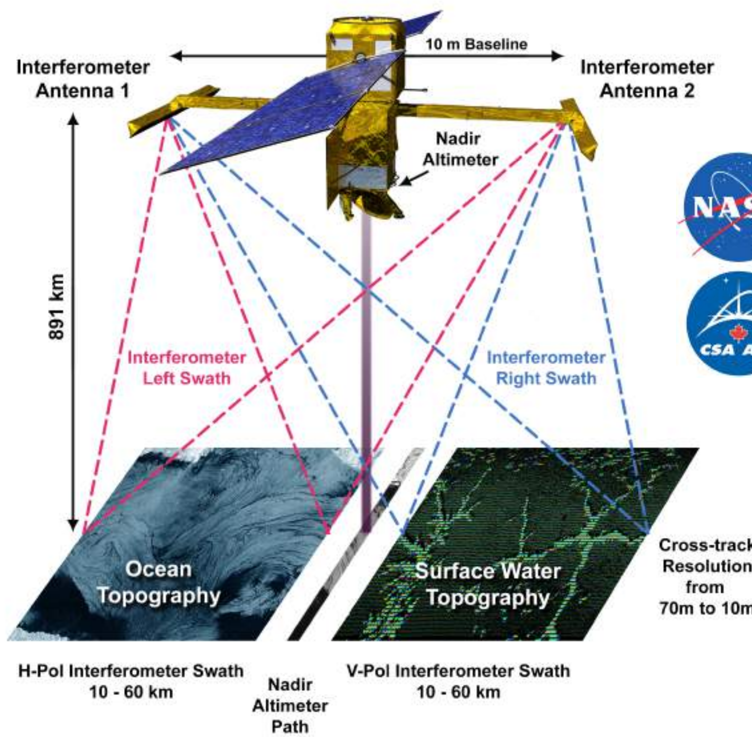
GRACE Follow-On



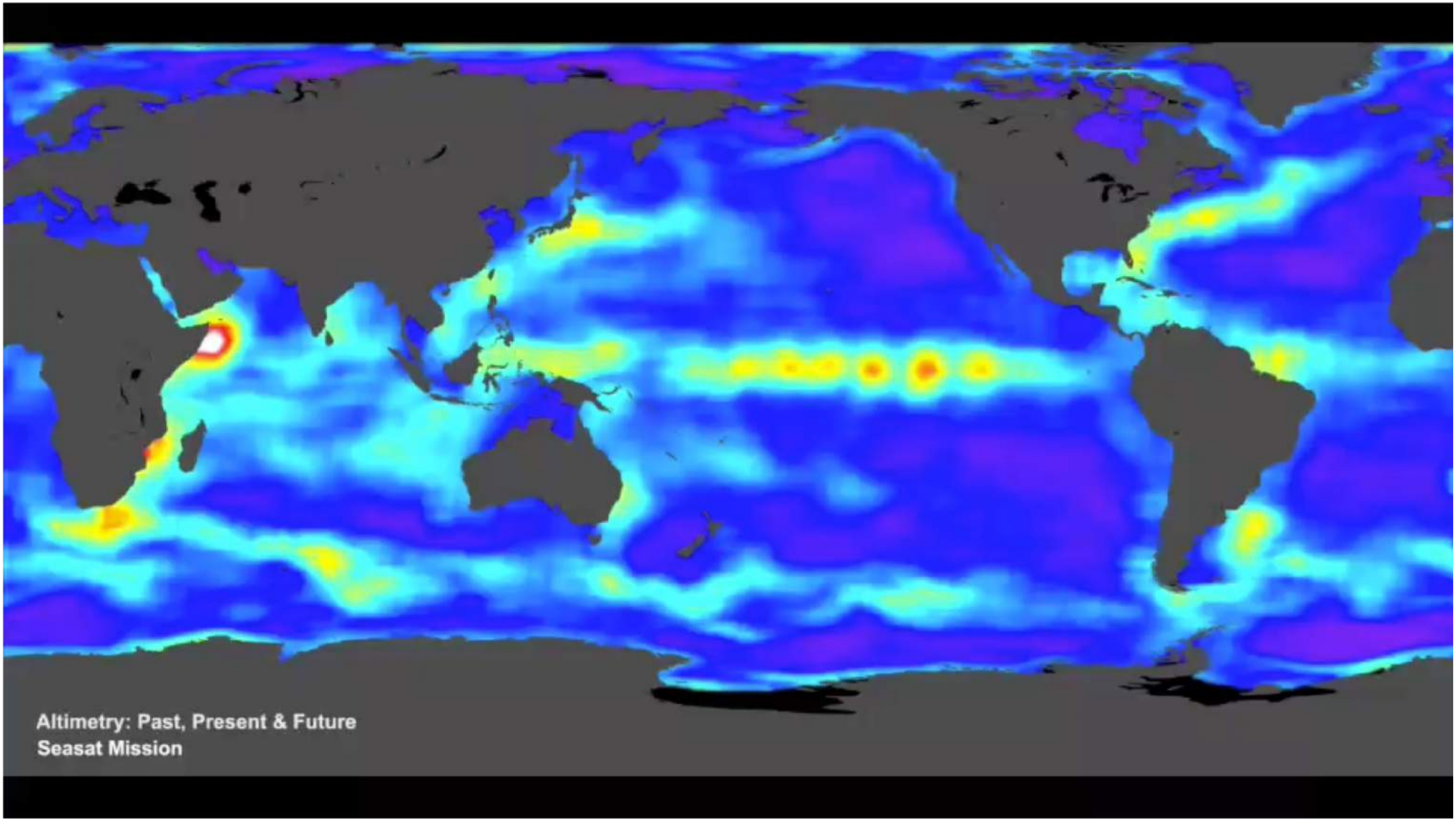
- Launched May 2018
- First data products about to be released
- Similar to GRACE design but includes experimental laser ranging system
- Continuing GRACE record of ocean bottom pressure, global mean ocean mass, land ice…

Surface Water Ocean Topography (SWOT)





- ➢ **Tentative launch date September 2021**
- ➢ **21-day repeat cycle, average revisit time ~10 days**
- ➢ **Resolving mesoscale and submesoscale (15 km)**
- ➢ **Better look at coastal regions**
- ➢ **Land hydrology…better river runoff**


Altimetry: Past, Present & Future
Seasat Mission

Summary

- Satellites offer global coverage and relatively fast repeat cycles for mostly surface variables but retrievals and sampling are complex

- Currently used data includes all altimetry, bottom pressure from GRACE, geodetically derived dynamic ocean topography, Aquarius, SST, ice concentration

- Assessment of errors, including representation errors, often difficult and subjective but essential for state estimation

- Data choices involve issues of consistency with model physics/forcing, quality, and convenience of use

- Keeping up with new data versions, new missions and incorporating more available data is a major challenge