Research Satellite Missions

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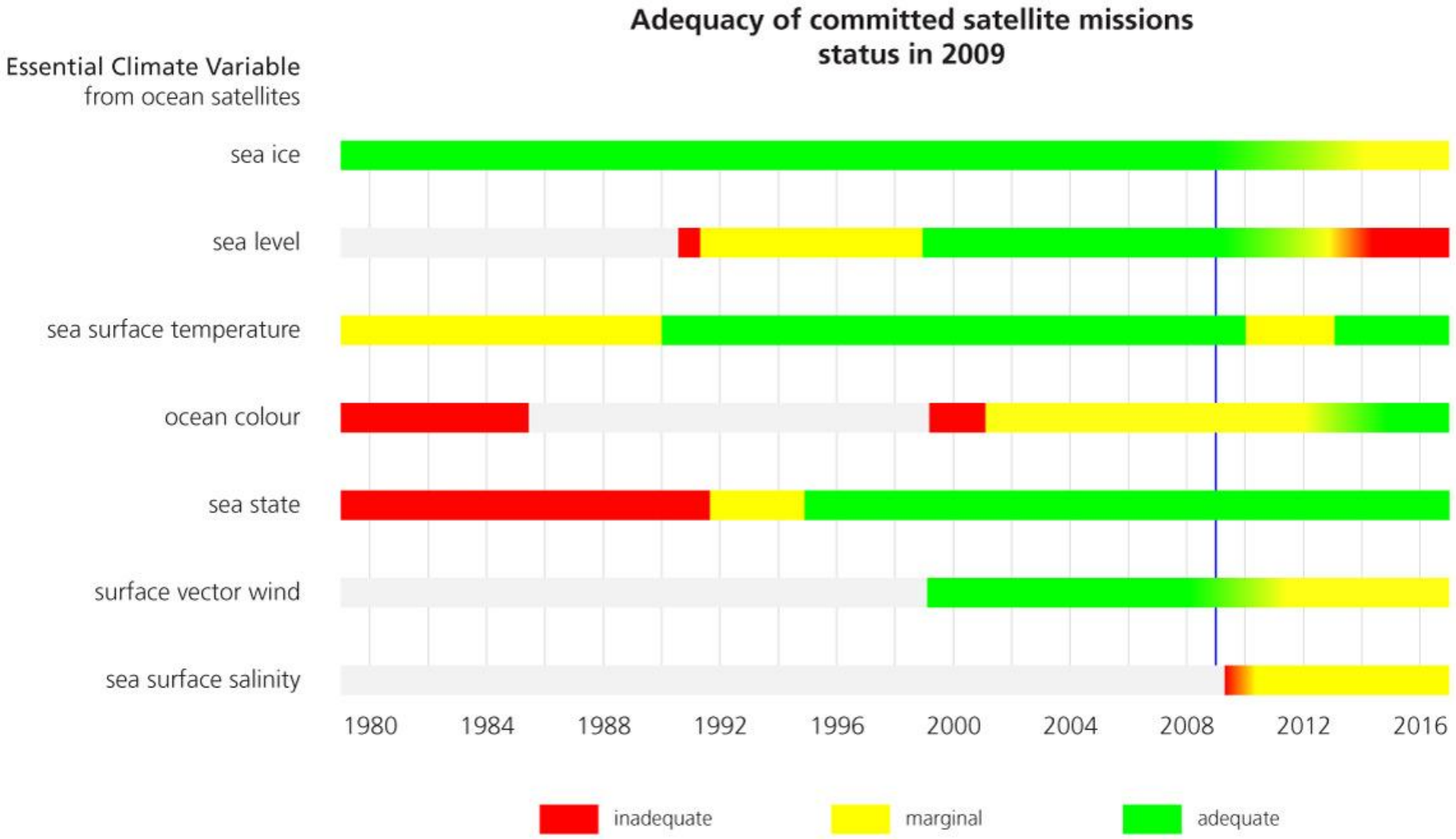
AND

COMMUNITY WHITE PAPERS

With special thanks to Josh Willis, JPL

24 Sept 2009


Adequacy of committed satellite missions status in 2009
Essential Climate Variable from ocean satellites
sea ice
sea level
sea surface temperature
ocean colour
sea state
surface vector wind
sea surface salinity
1980
1984
1988
1992
1996
2000
2004
2008
2012
2016
inadequate
marginal
adequate

Research Satellite Missions

Observing Seven GCOS Essential Climate Variables

- Sea Ice – Continue the climate record of sea ice coverage
  Research: sea ice thickness and dynamics.
- Sea level – Jason-series and polar orbiting altimeters continue the climate record; becoming sustained, systematic observations.
  Research: improved resolution and uncertainty for climate record.
- Sea Surface Temperature – Continue IR record, supplement with microwave.
  Research: more sophisticated blended products improve coverage, spatial/temporal resolution.
- Ocean Color – Continue record, fly climate-quality instruments
  Research: improved analyses enabled by sensitive, well-characterized instruments.
- Sea State – Improve coverage, common goals with other ECV observations
- Ocean Vectors Winds – ASCAT and QuikSCAT continue the climate record. Develop sustained, systematic observations.
  Research: constellation, improve spatial resolution, sensitivity.
- Sea Surface Salinity – Emerging ECV.
  Research: SMOS, Aquarius/SAC-D pathfinders to begin climate record.

Contributing Community White Papers (by ECV)

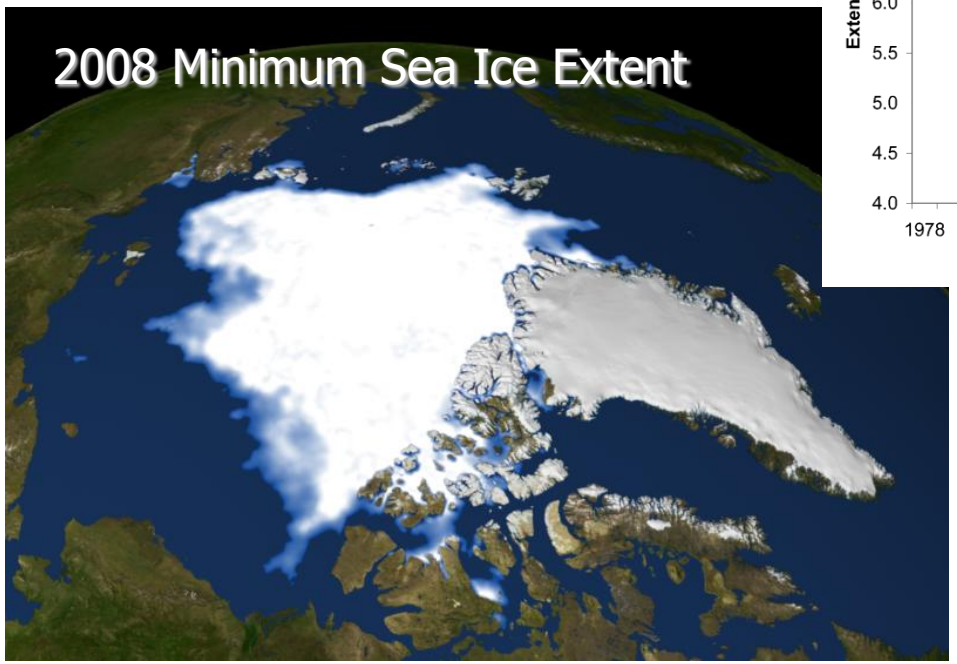
- *Kwok et al* – Combining satellite altimetry, time-variable gravity, and bottom pressure to understand the Arctic Ocean: A transformative approach
- *Fu et al* – The SWOT (Surface Water and Ocean Topography Mission: Spaceborne radar interferometry for oceanographic and hydrological applications
- *Donlon et al* – Successes and challenges for the modern sea surface temperature observing system
- *Le Quere et al* – Observational Needs of Dynamic Green Ocean Models
- *Swail et al* – Wave Measurements, needs and developments for the next decade
- *Bourassa et al* – Remote sensed winds and wind stresses for marine forecasting and ocean modeling
- *Lagerloef et al* – Resolving the global salinity field and variations by blending satellite and in situ observations

Other Contributing Community White Papers

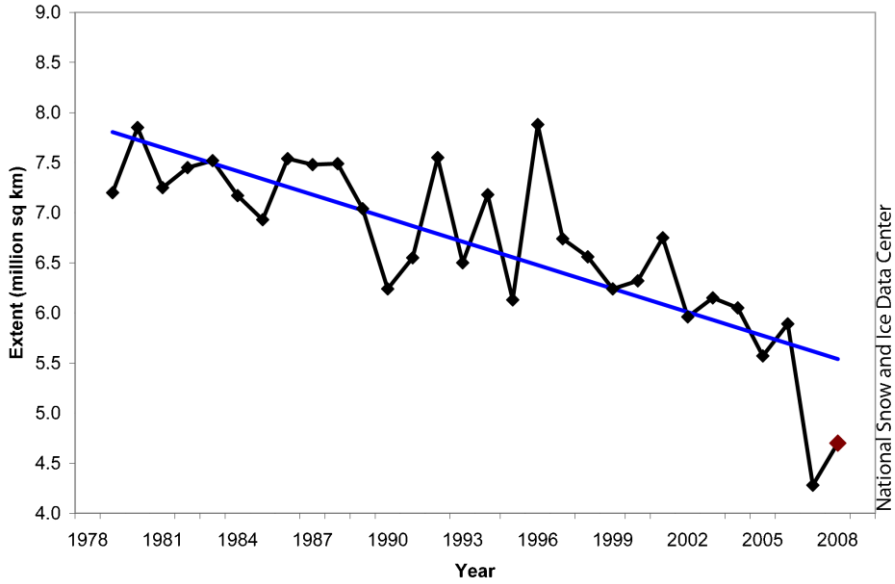
- *Breivick et al* - Remote sensing of sea ice
- *Wilson et al* - Ocean Surface Topography Constellation: The next 15 years in Satellite Altimetry
- *Scott et al* – Integrating satellite altimetry and key observations: what we've learned, and what's possible with new technology
- *Shum et al* - Geodetic Observations of ocean surface topography, ocean currents, ocean mass, and ocean volume change.
- *Cipollini et al* – The role of altimetry in coastal observing systems
- *Yoder et al* – The Ocean Colour Radiance Virtual Constellation (OCR-VC)

Sea Ice

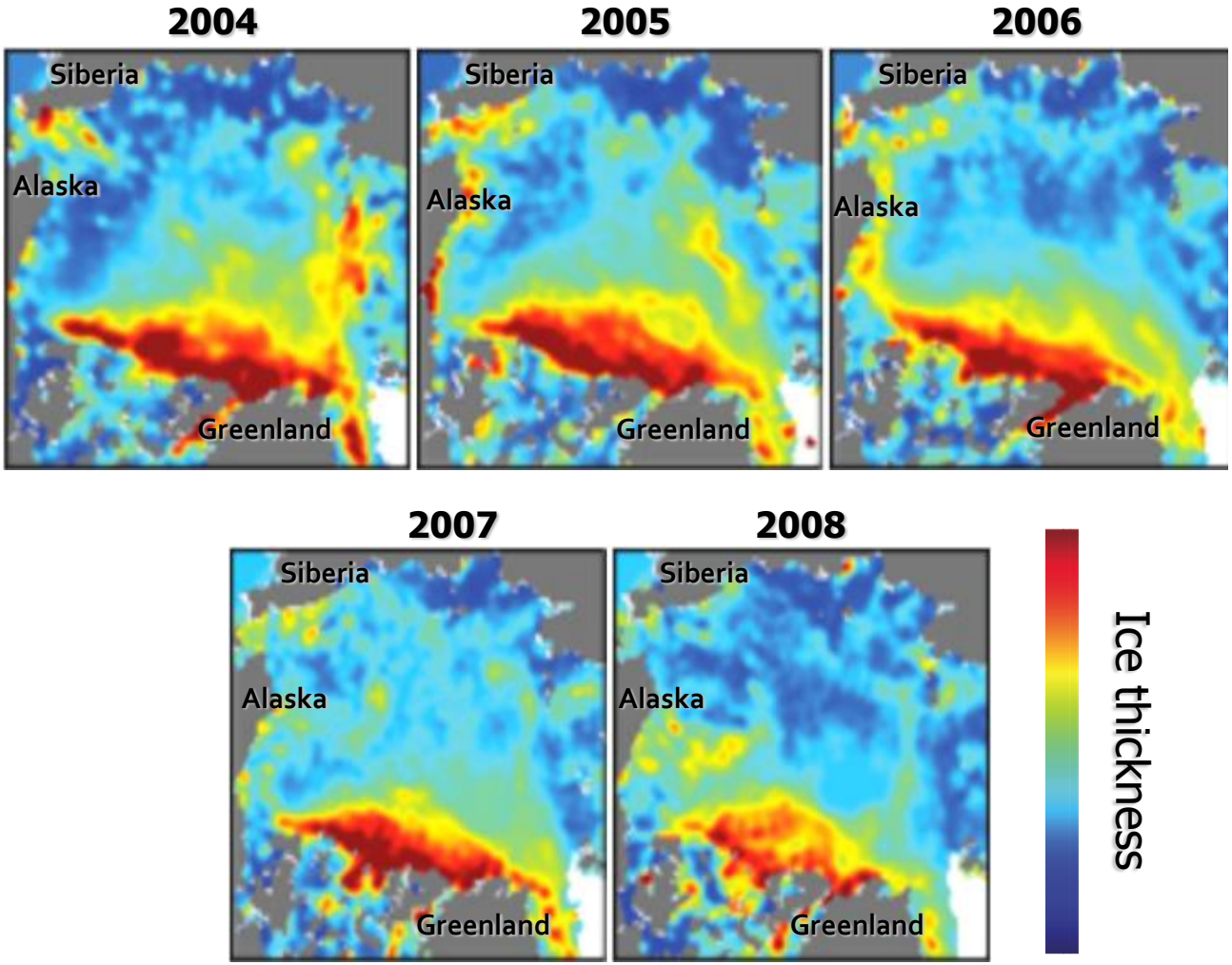
Past satellite observations focused on primarily on sea ice area and extent



Minimum Sea Ice Extent



Sea Ice Thickness

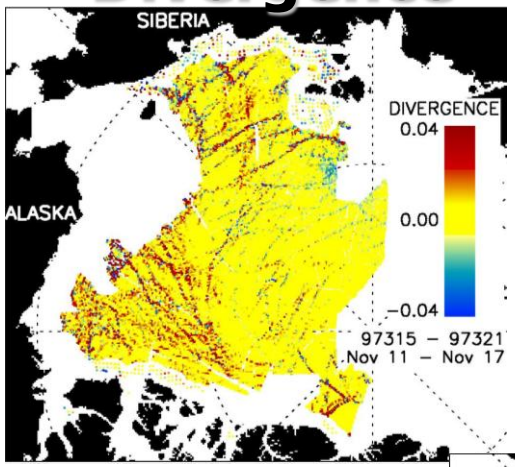


ICESat captures thinning of Arctic Ocean sea ice

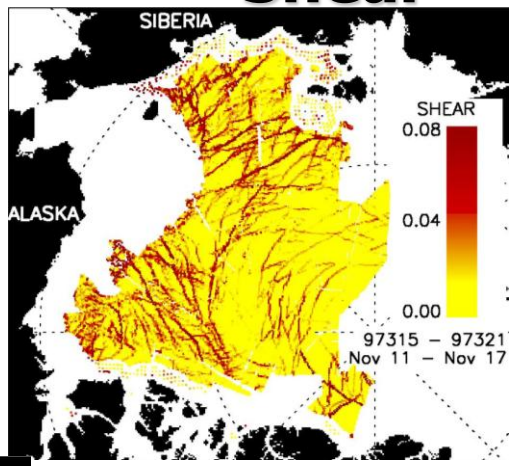
(Kwok et al., 2009)

Sea Ice Motion and Deformation

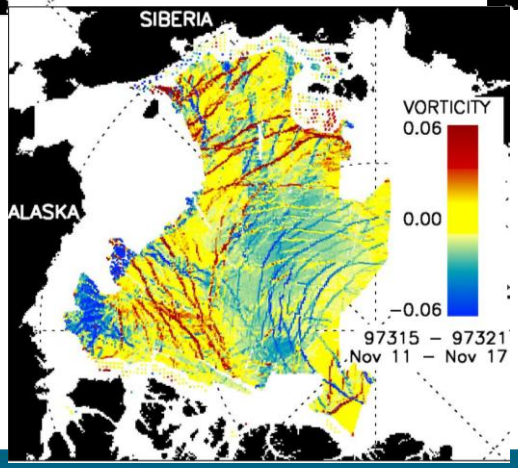
Divergence



Shear



Vorticity



High-resolution Synthetic Aperture Radar (SAR) reveals a dynamic ice cap

(Kwok. 2005)

Sea Ice

Upcoming sea ice missions

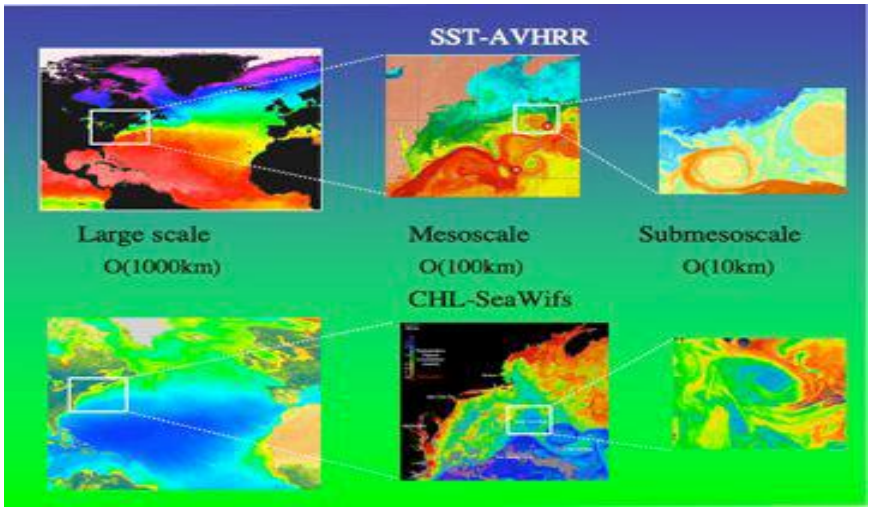
- ICESat-2 (Decadal Survey Mission) – follow-on to the ICESat-1 lidar mission that will provide records of sea ice freeboard and thickness of the Arctic and Antarctic.

- DesDynI (Decadal Survey Mission) – provide synthetic aperture imagery for derivation of fine-scale (5 km) sea ice motion and deformation.

- CryoSat-2 (ESA ice mission) – radar altimeter instrument for measurement of sea ice freeboard and thickness.

Sea Surface Height

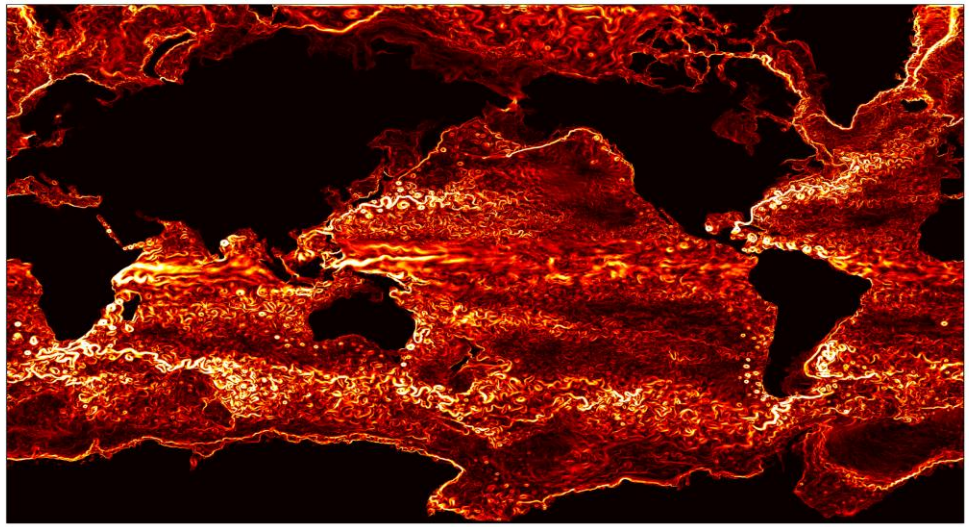
SST and ocean color reveal the submesoscale

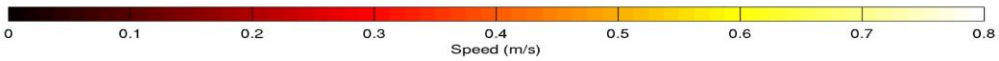


Kinetic Energy and Transport processes require 10-100 km resolution

High-resolution model shows ubiquity of submesoscale processes

Ocean current speed at 15 m depth from 1/16th ECCO2 integration

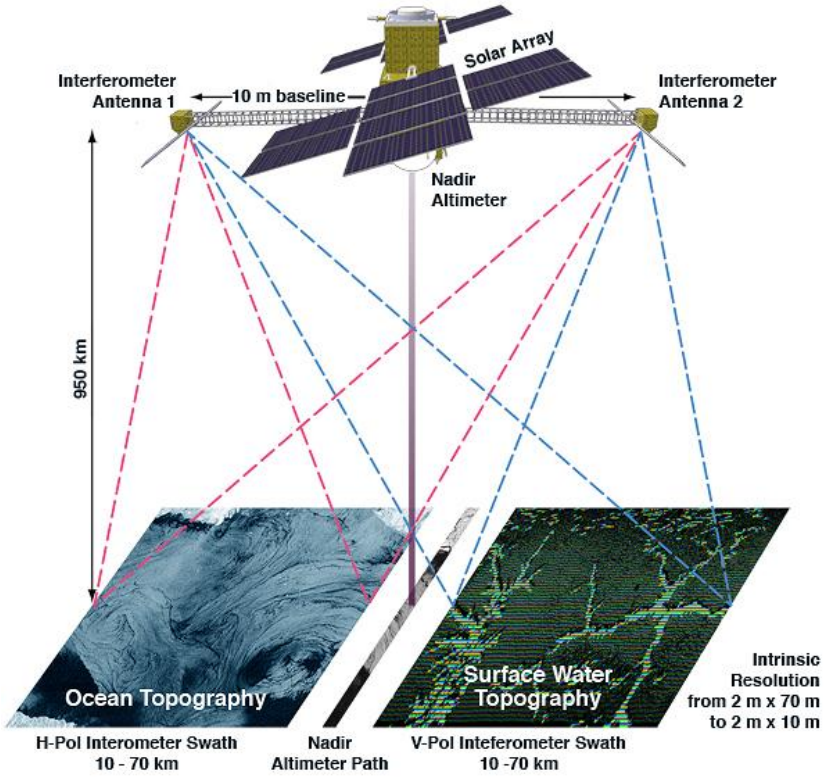




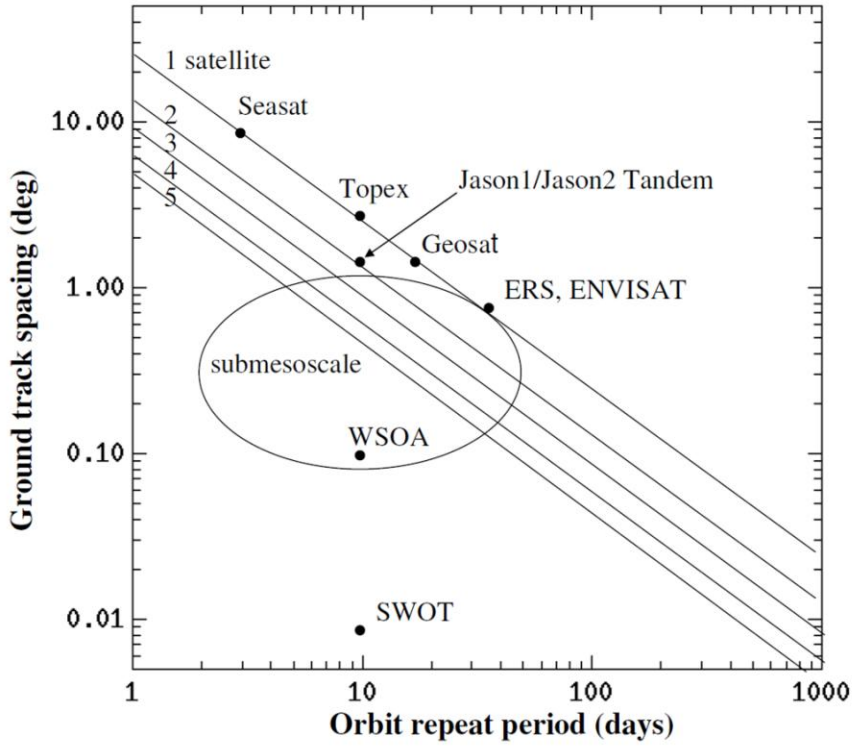
Surface Water and Ocean Topography (SWOT)

Radar Interferometry Wide-Swath Atlimetry Mission

Measurement configuration

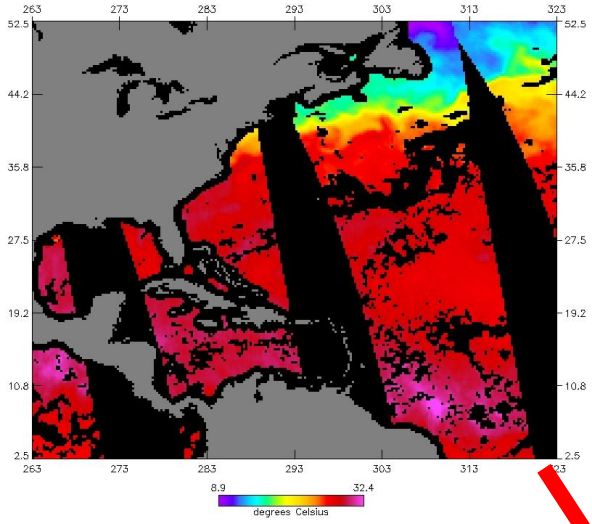


SWOT resolution is more powerful than 10 nadir altimeters combined



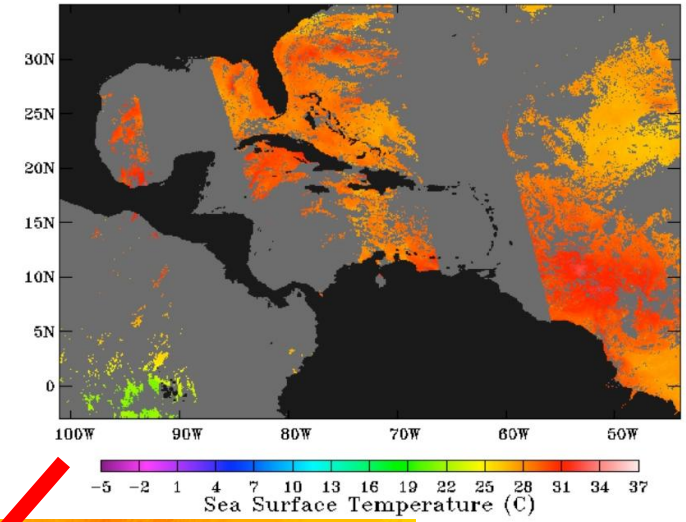
Sea Surface Temperature

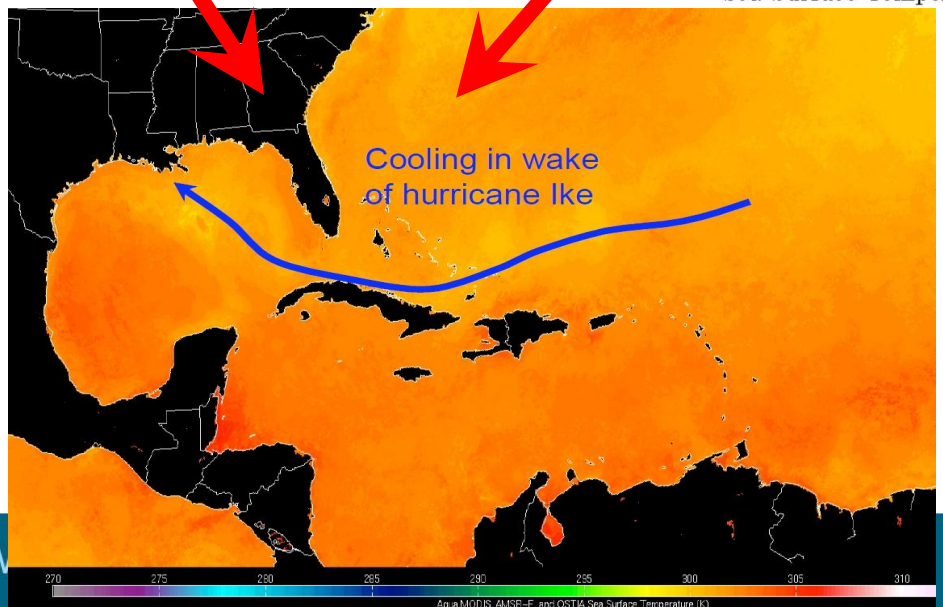
Microwave



+

Infra-Red

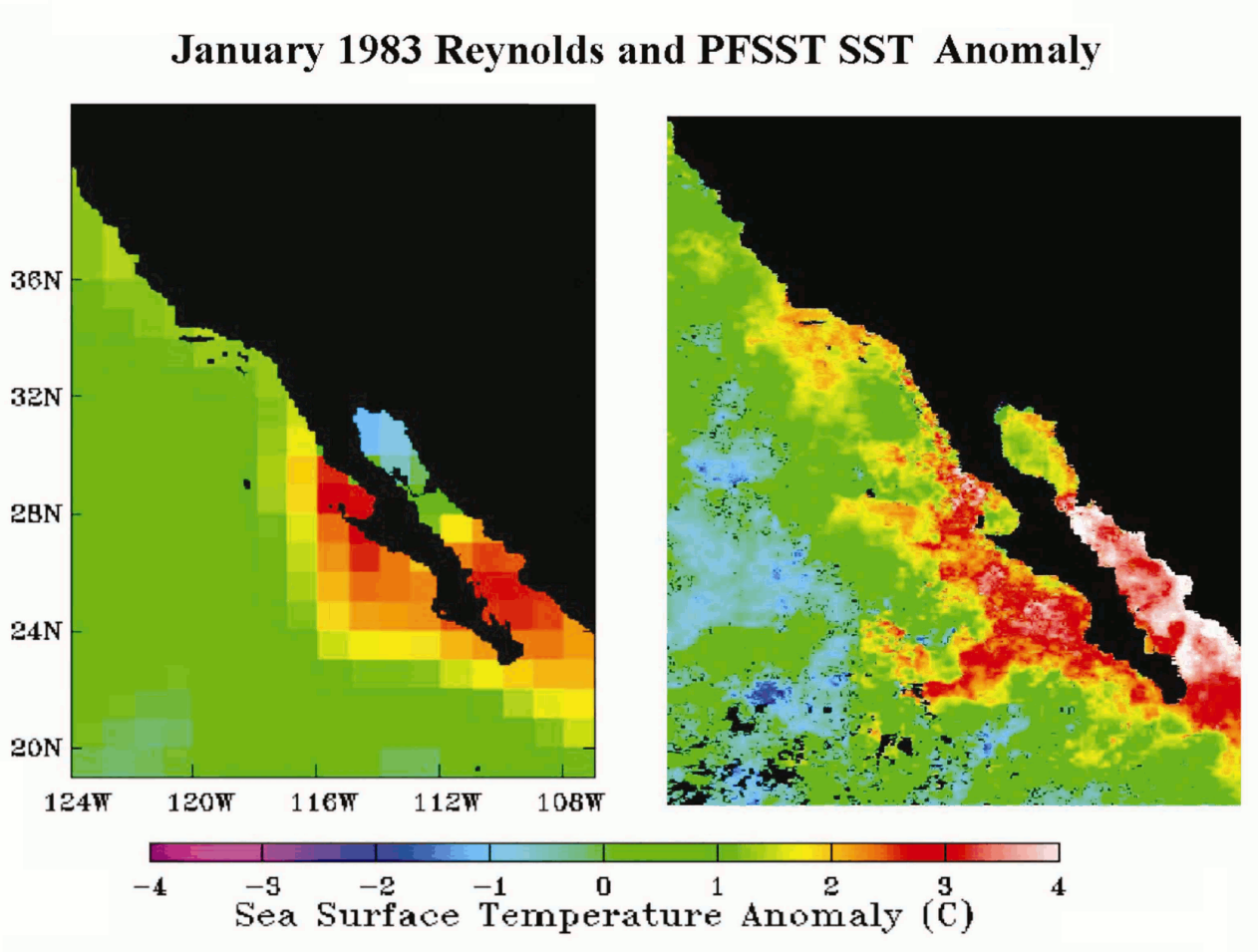




Combined MODIS & AMSR-E

For now, data from multiple satellites is need to estimate high-resolution SST

Sea Surface Temperature

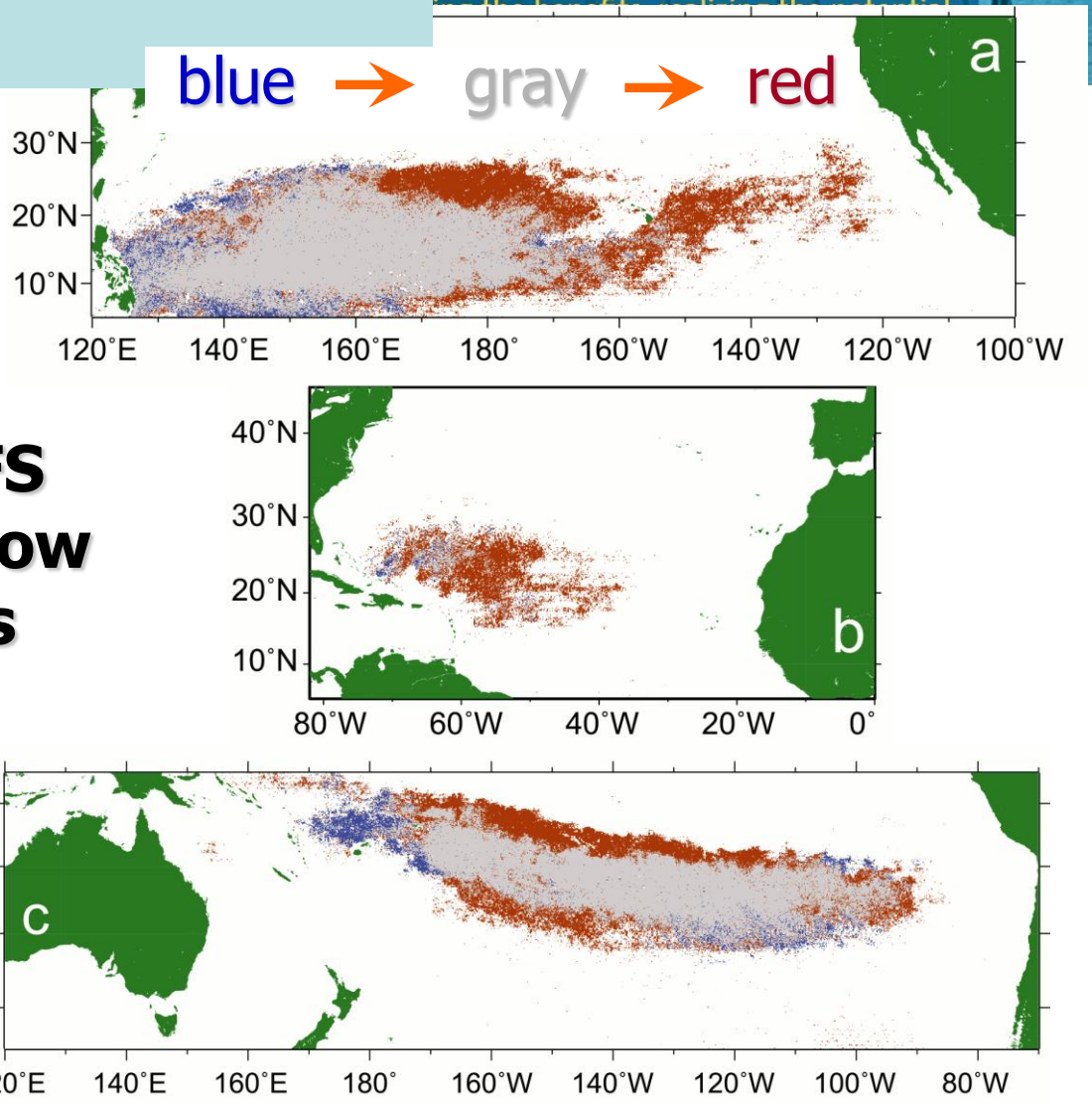


1-month average of AVHRR

Pathfinder Reprocessed

Reanalysis of satellite data back to 1981 reveals the '82-'83 El Nino in high resolution

Ocean Color



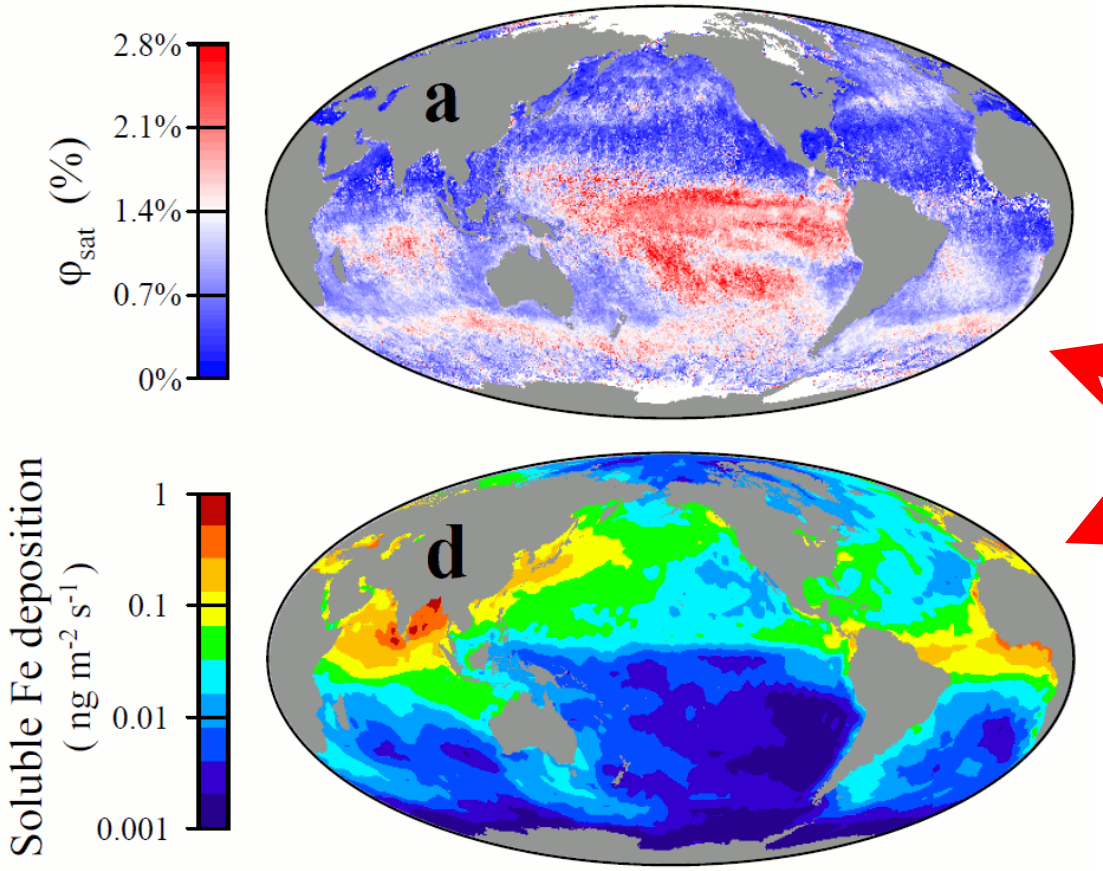
A decade of SeaWiFS shows expansion of low chlorophyll regions

Polovina et al. (2008)

1998/1999 Only	1998/1999 and 2005/2006	2005/2006 Only

Ocean Color

Adjusted Fluorescence



Correlation suggests a relationship with Iron limitation

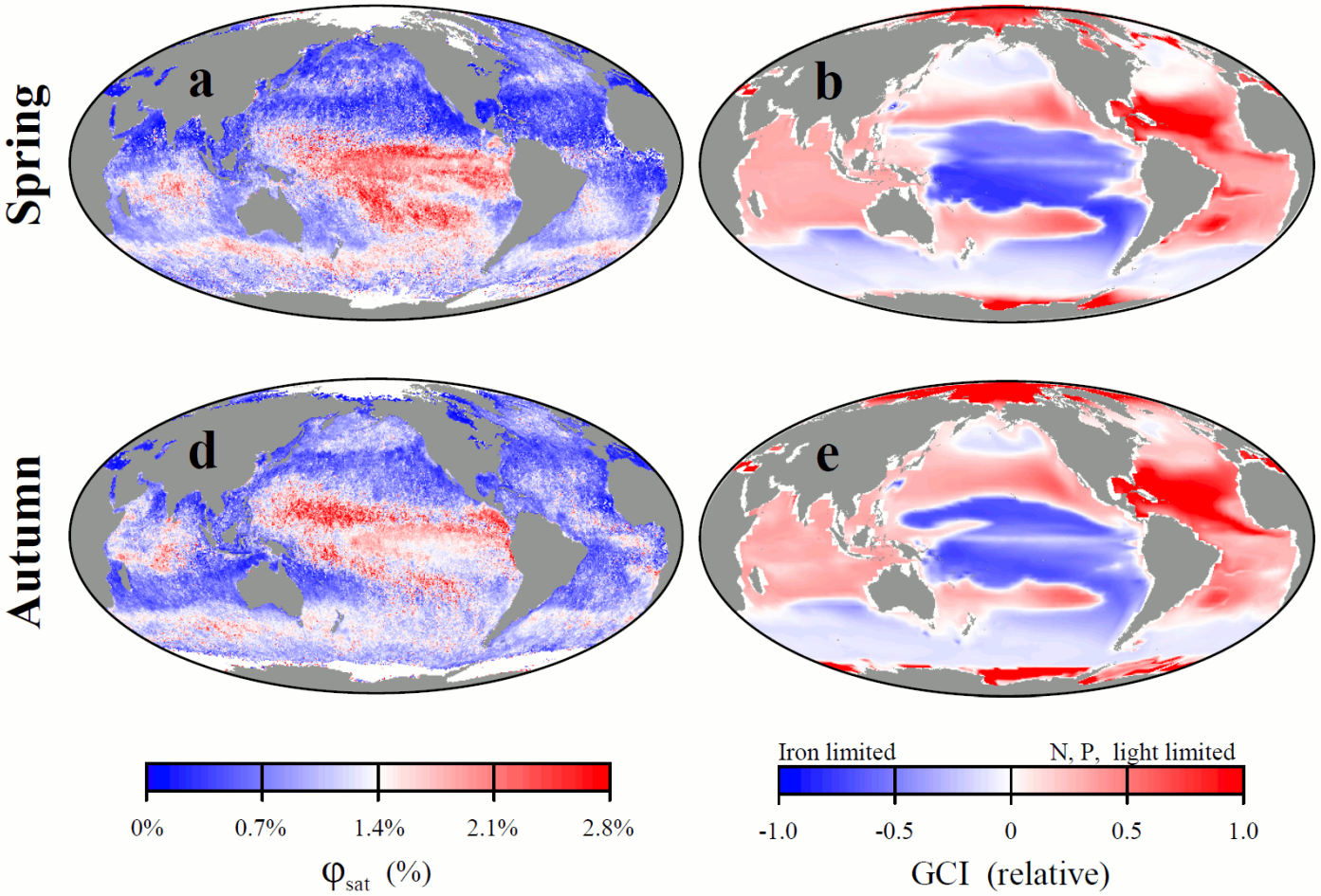
Behrenfeld et al. (2009)

Iron Deposition

Ocean Color

Adjusted Fluorescence

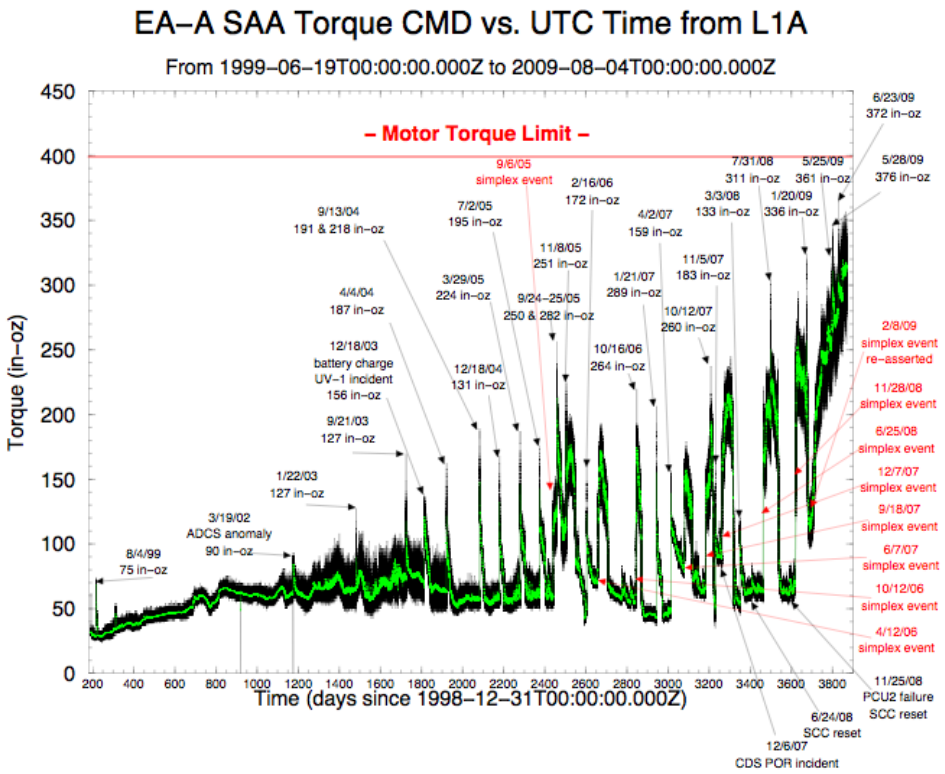
Modeled Iron Limitation



Models suggest a strong relationship between iron stress and fluorescence

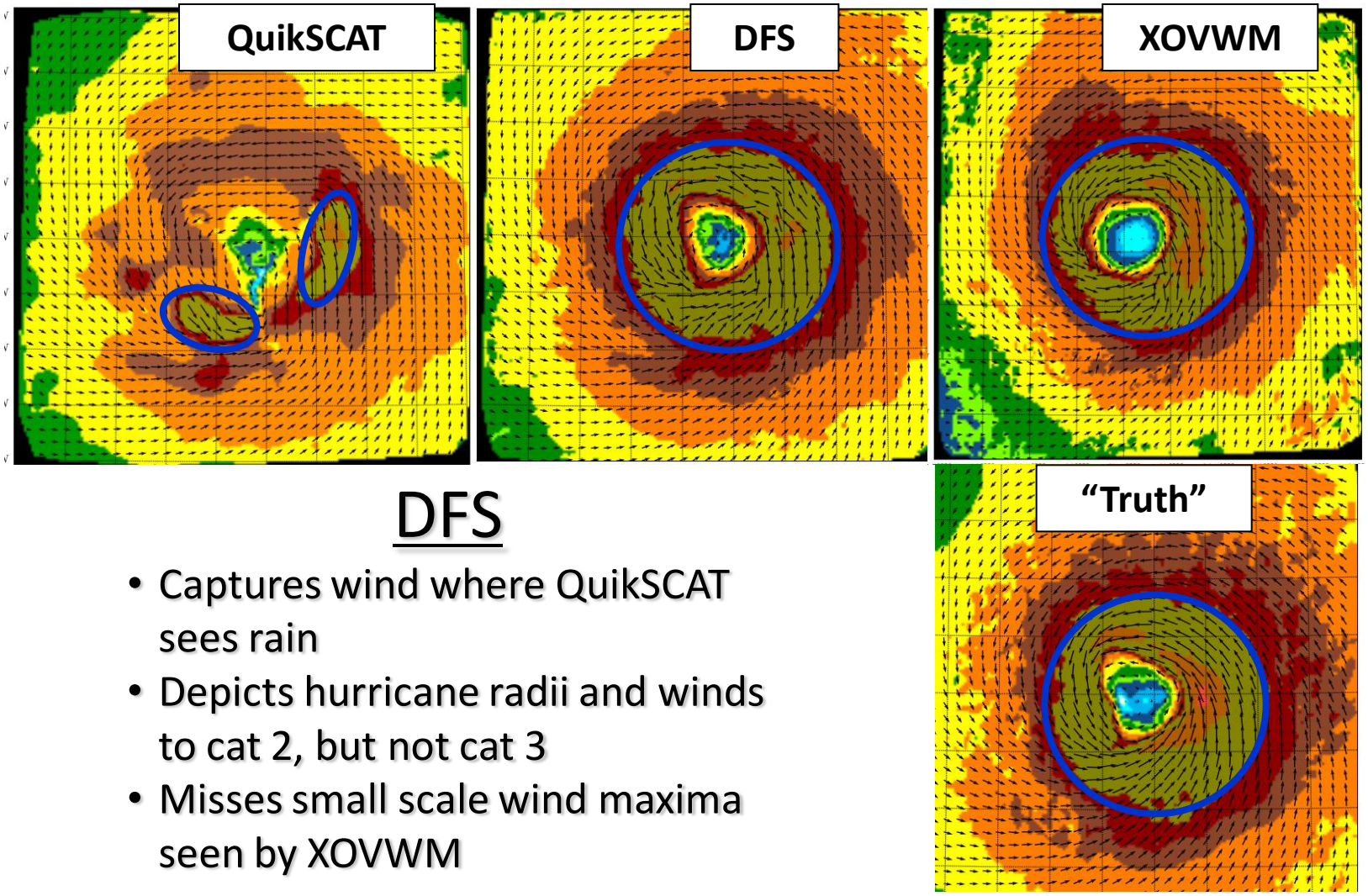
Behrenfeld et al. (2009)

QuikScat


EA–A SAA Torque CMD vs. UTC Time from L1A
From 1999–06–19T00:00:00.000Z to 2009–08–04T00:00:00.000Z
– Motor Torque Limit –
Torque (in–oz)
Time (days since 1998–12–31T00:00:00.000Z)
8/4/99 75 in–oz
3/19/02 ADCS anomaly 90 in–oz
1/22/03 127 in–oz
9/21/03 127 in–oz
12/18/03 battery charge UV–1 incident 156 in–oz
4/4/04 187 in–oz
9/13/04 191 & 218 in–oz
12/18/04 131 in–oz
3/29/05 224 in–oz
7/2/05 195 in–oz
9/6/05 simplex event
9/24–25/05 250 & 282 in–oz
11/8/05 251 in–oz
10/16/06 264 in–oz
2/16/06 172 in–oz
1/21/07 289 in–oz
4/2/07 159 in–oz
10/12/07 260 in–oz
11/5/07 183 in–oz
3/3/08 133 in–oz
7/31/08 311 in–oz
1/20/09 336 in–oz
5/25/09 361 in–oz
6/23/09 372 in–oz
5/28/09 376 in–oz
2/8/09 simplex event re–asserted
11/28/08 simplex event
6/25/08 simplex event
12/7/07 simplex event
9/18/07 simplex event
6/7/07 simplex event
10/12/06 simplex event
4/12/06 simplex event
11/25/08 PCU2 failure SCC reset
6/24/08 SCC reset
12/6/07 CDS POR incident

Dual Frequency (DFS) v. QuikSCAT, XOVWM

Simulated Retrievals based on Katrina (2005)



DFS

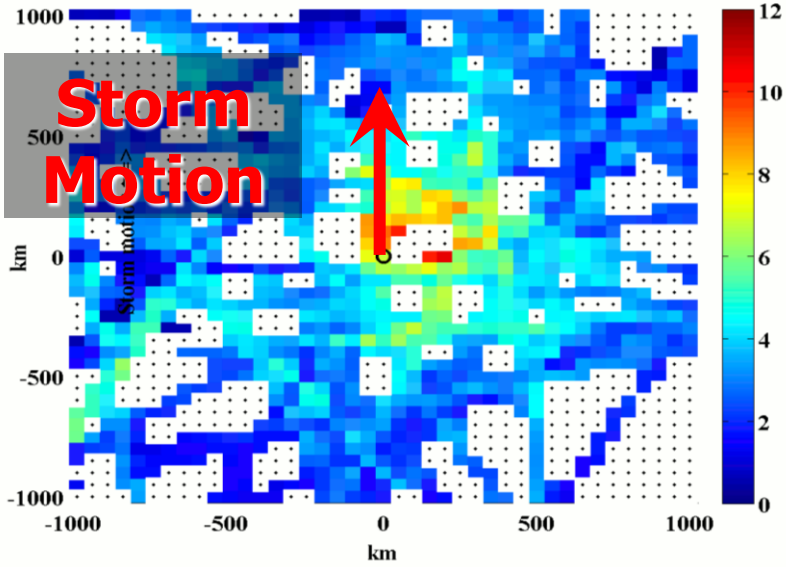
- Captures wind where QuikSCAT sees rain
- Depicts hurricane radii and winds to cat 2, but not cat 3
- Misses small scale wind maxima seen by XOVWM

Rodriguez et al., JPL

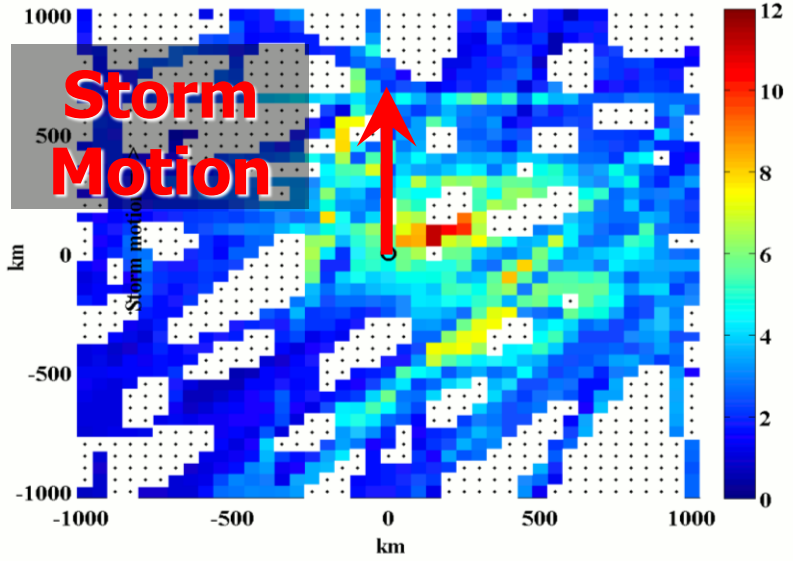
Sea State

Mean over Cat 3 storms and greater in the Western Pacific

2003



2005



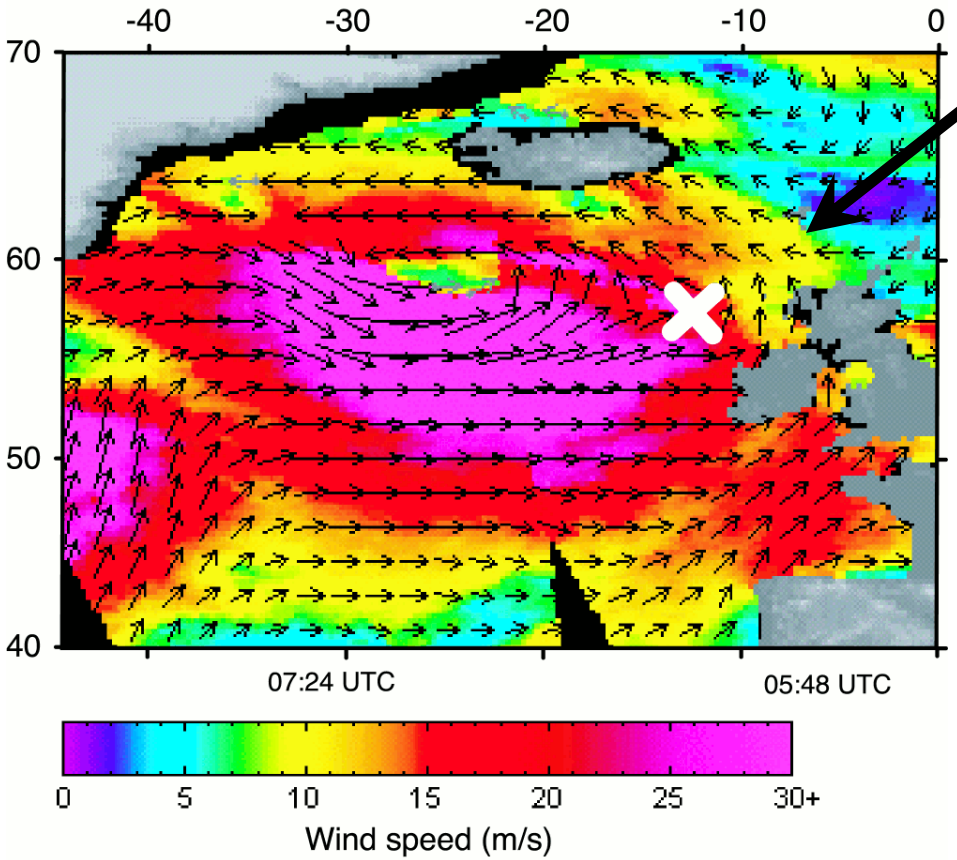
Altimeters provide surface wave height observations around Tropical Cyclones

Note wave intensification in right front quadrant

Callahan & Oslund (2009)

Sea State

QuikSCAT winds west of Scotland, 8 Feb 2000



RSS *Discovery* observes record wave height of 29.1 m (18.5 m H_s) on 8 Feb 2000

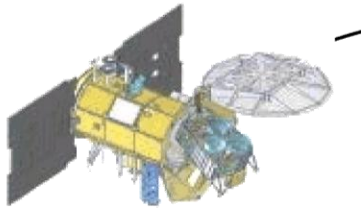
On Feb 9, direct overflight of TOPEX observed H_s of 10.5 m compared with 11.3 m from RSS *Discovery*

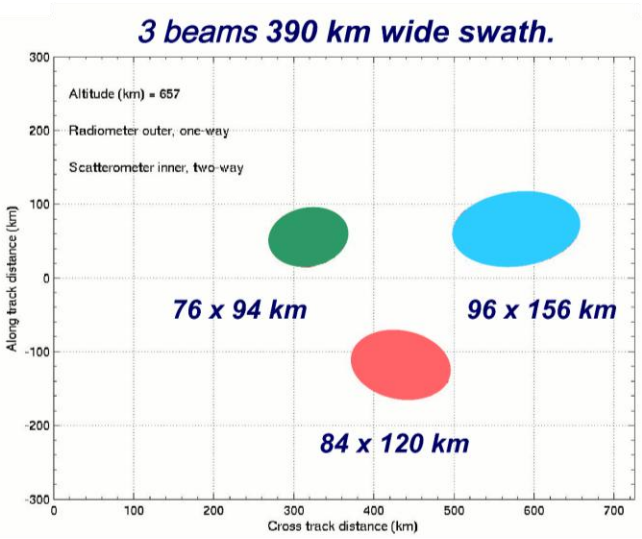
Holliday et al. (2006)

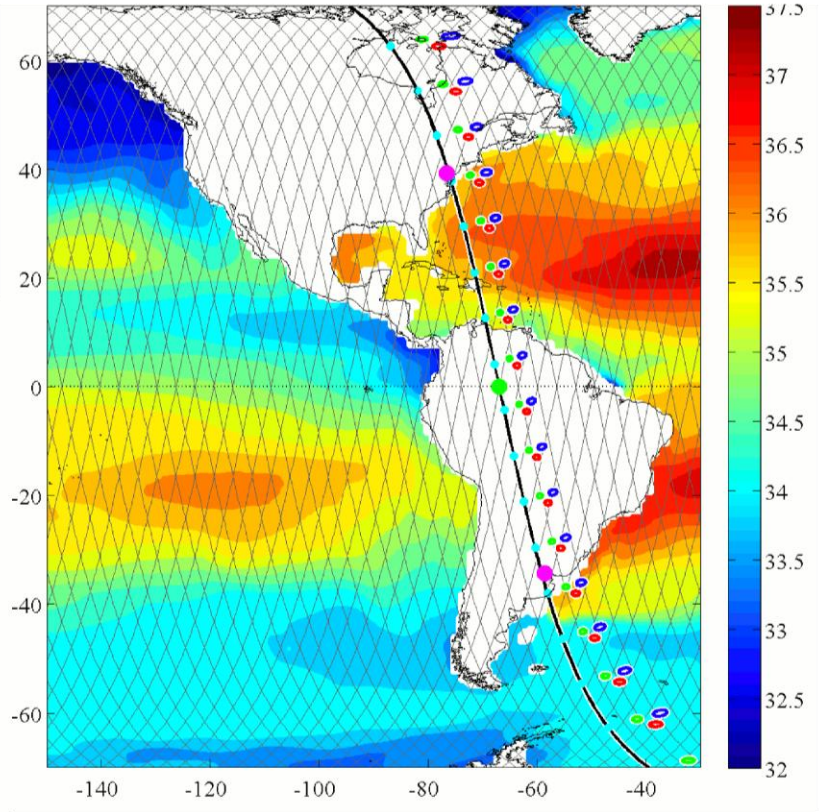
Sea State

- Multiple satellite altimeters are required to provide denser coverage and long-term, stable time series of repeat observations with high temporal resolution. (Covered by sea level recommendations)
- SAR wave measurements should be an important component of any future wave program (Covered by sea ice recommendation)
- High priority should be given to replacement of a Ku-band scatterometer capability in space for measurement of winds. (Covered by winds recommendation)

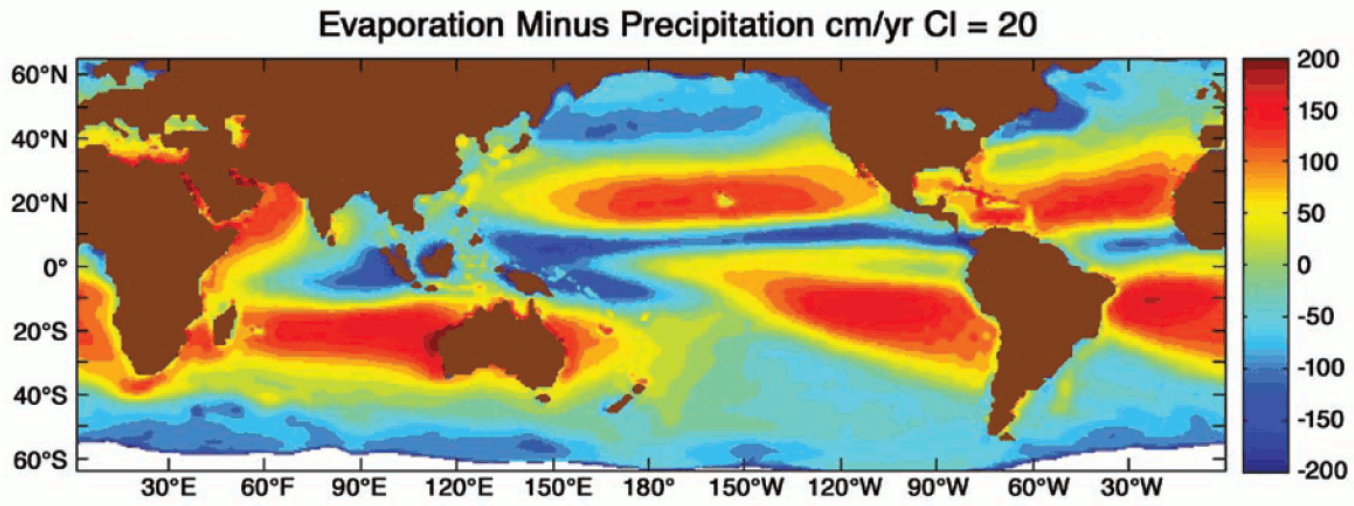
Sea Surface Salinity

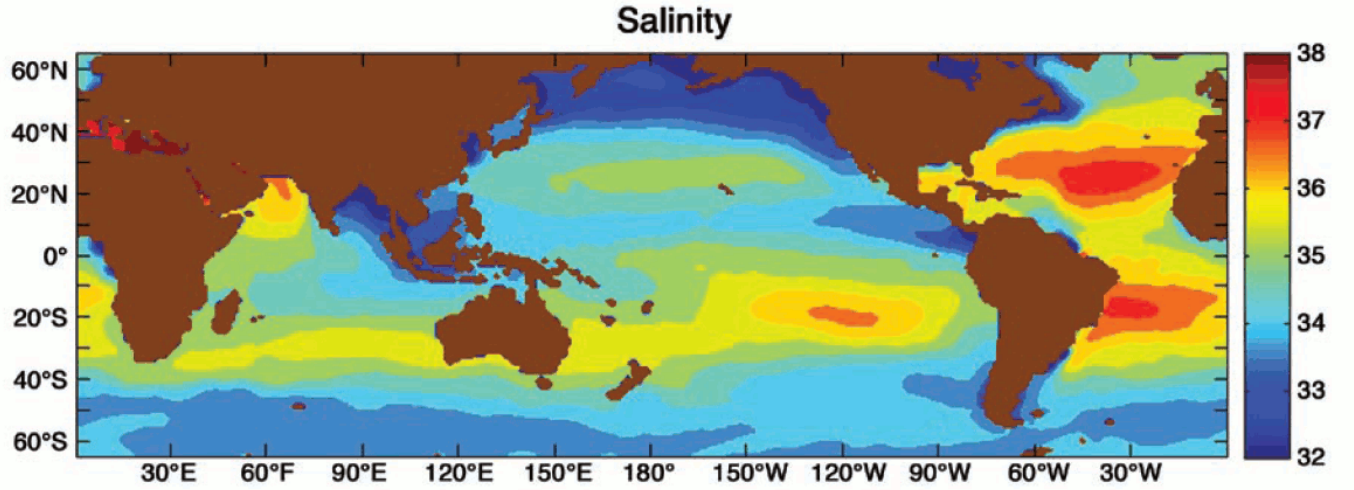






Sea Surface Salinity



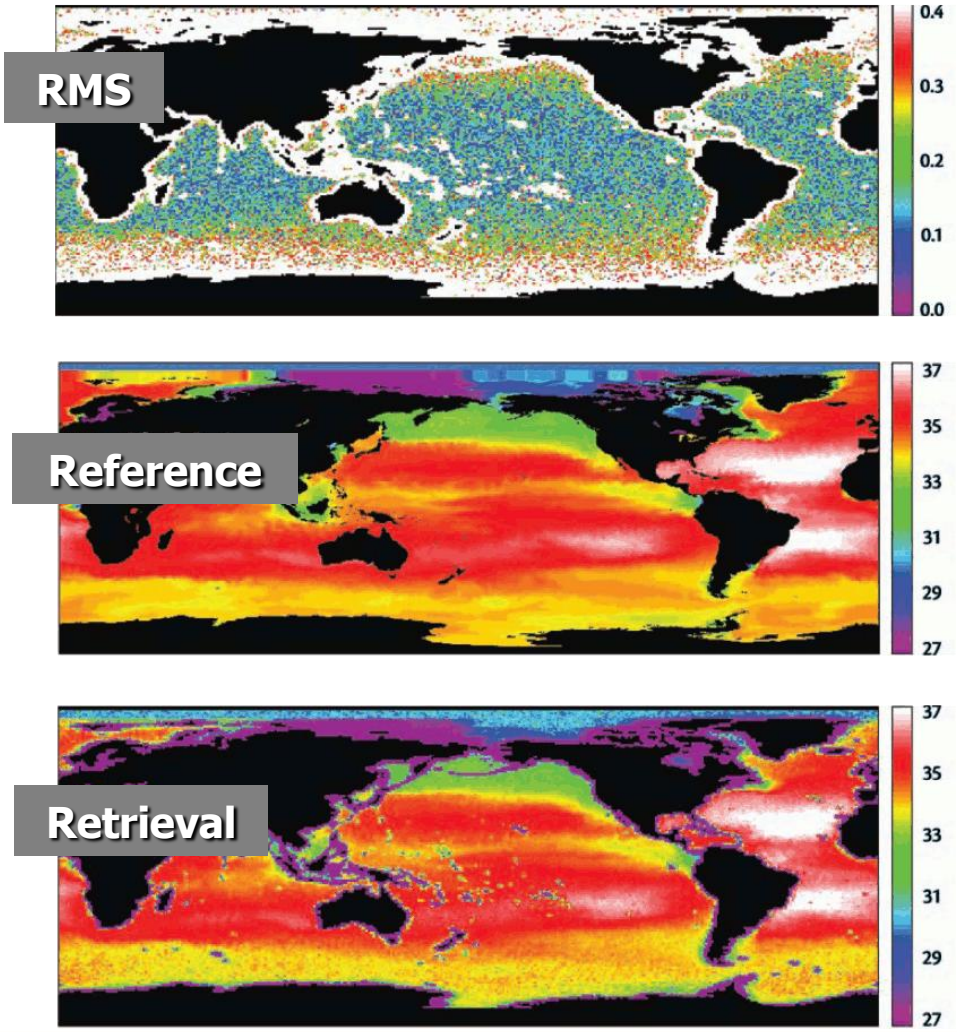


<u>Water Cycle</u>
Surface salinity observations will shed light on the global freshwater budget

Evap: Yu & Weller (2007) **Precip: GPCP** **Sal: WOA**

Sea Surface Salinity

Simulated Aquarius Observations



Averaging monthly and over 150 km scales, Aquarius is expected to have 0.2 PSU accuracy

Main Points/Recommendations

Research Satellite Missions will continue to contribute in a variety of ways to the sustained observation of oceanic Essential Climate Variables (ECVs). Future research and improved understanding of the climate record depends on the following:

1) Sea-Ice – Rapid changes in Arctic sea ice draw attention to the urgent need for sea ice missions for understanding of sea ice thickness and dynamics (e.g. Cryosat-2, Icesat-2, DesDynI)

2) Sea Level – Confirmation of future missions – for operations and research is urgently needed (e.g. Jason-series, Sentinel-series, SWOT)

3) SST - Donlon et al. CWP has a comprehensive set of recommendations for the SST observing system. Urgent attention to continuity of satellite microwave data is needed.

4) Ocean color recommendations may be offered in other plenary papers. However, acceleration of research missions (e.g. ACE) is needed.

5) Sea state research is enabled by success in meeting the sea ice, sea level, and wind recommendations.

Main Points/Recommendations (2)

6) Ocean Vector Wind – May suffer a decline of capability unless data from new satellites in available, calibrated and validated. Improved spatial/temporal resolution and sensitivity is needed. (eg. DFS on GCOM-W2, Post-EPS) This need is urgent, given the impending loss of QuikSCAT.

7) Sea Surface Salinity – A robust in situ observation program and research demonstrations of satellite data utility are required to make the most of near-term space assets. The opportunity is available to develop and possibly continue a global climate record for sea surface salinity (e.g. SMOS, Aquarius/SAC-D).