Satellite Microwave Observations of the Global Ocean

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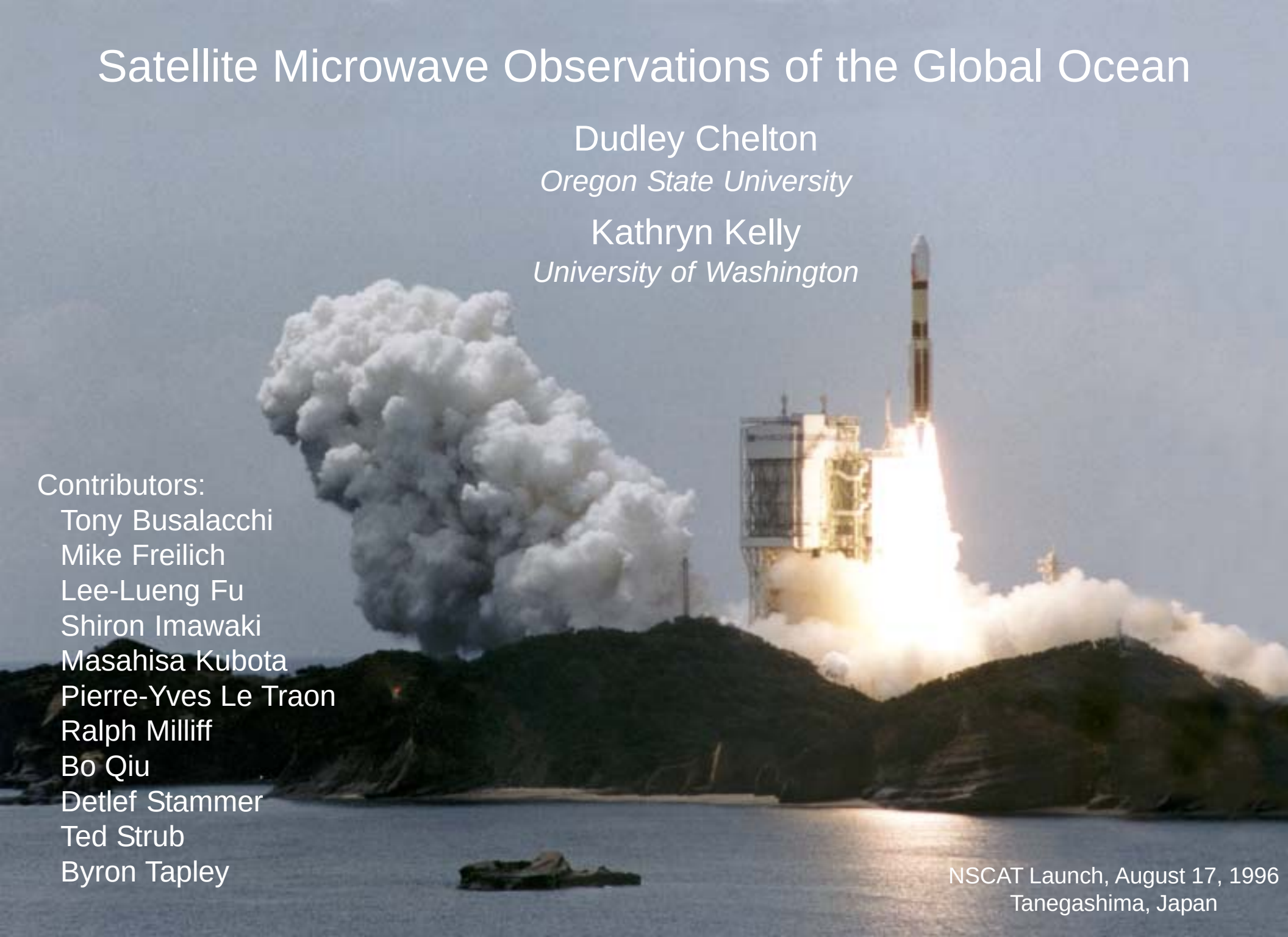
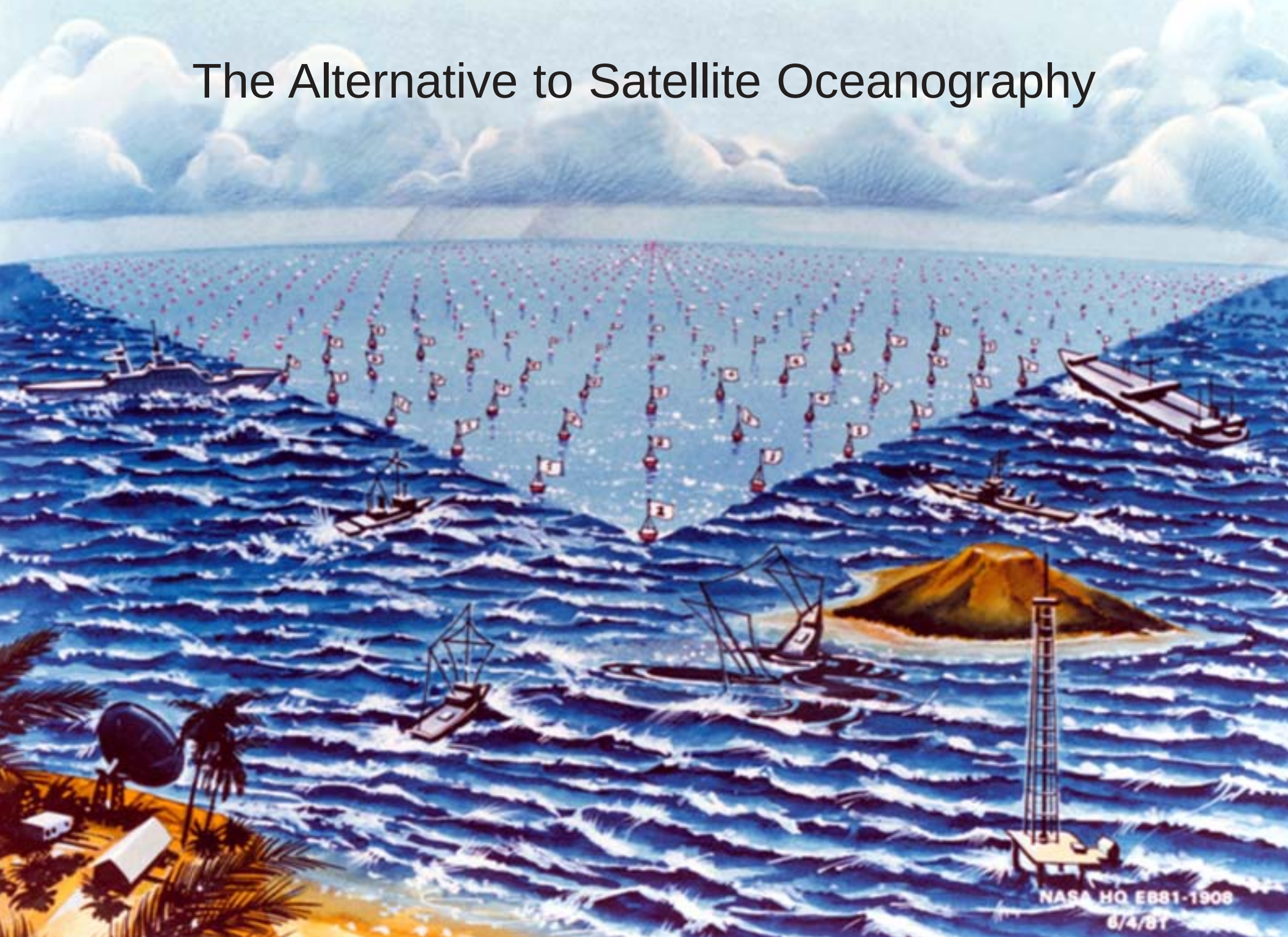
- Pierre-Yves Le Traon
- Ralph Milliff
- Bo Qiu
- Detlef Stammer
- Ted Strub
- Byron Tapley

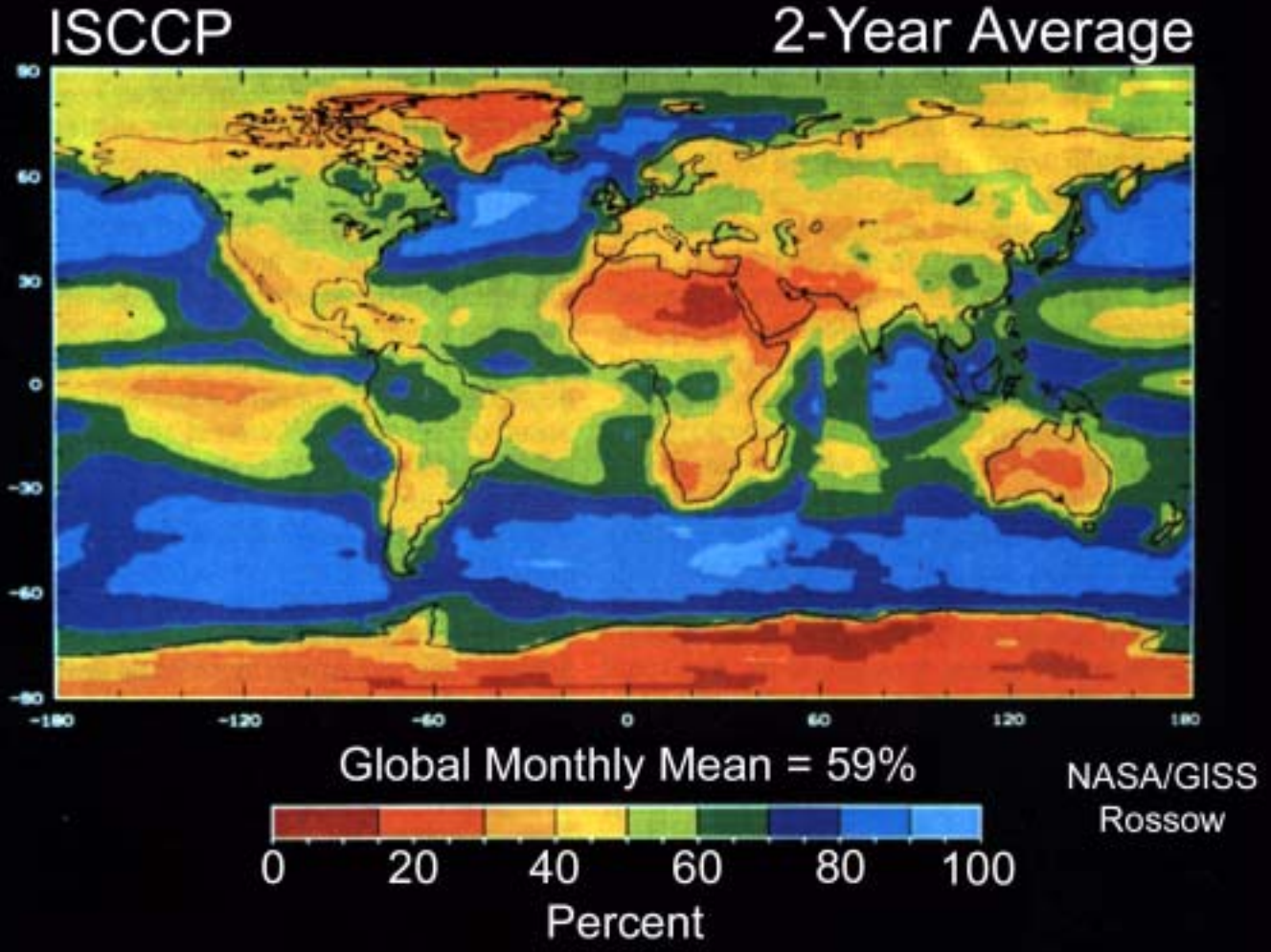


NSCAT Launch, August 17, 1996
Tanegashima, Japan

The Alternative to Satellite Oceanography

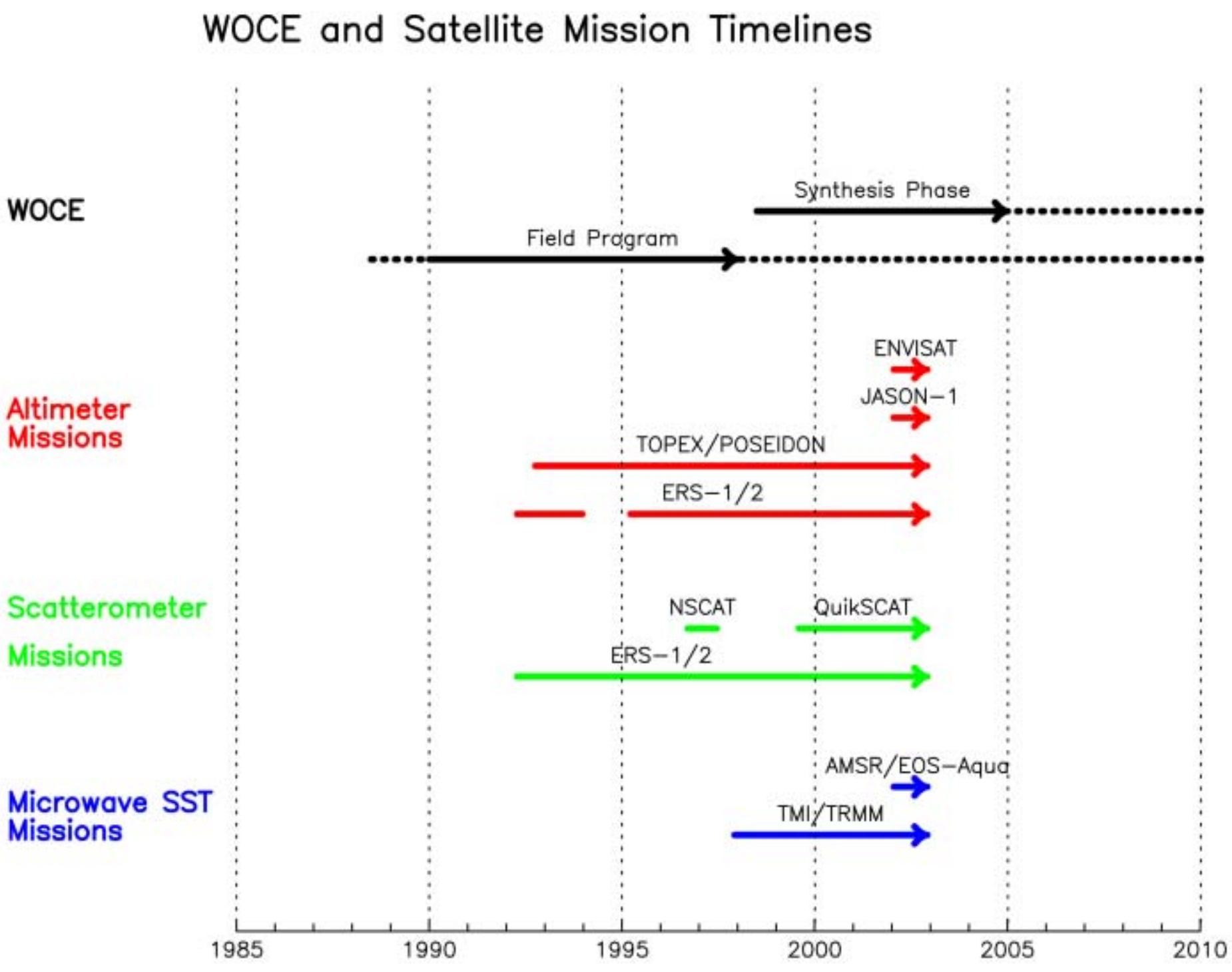


Cloud Amount

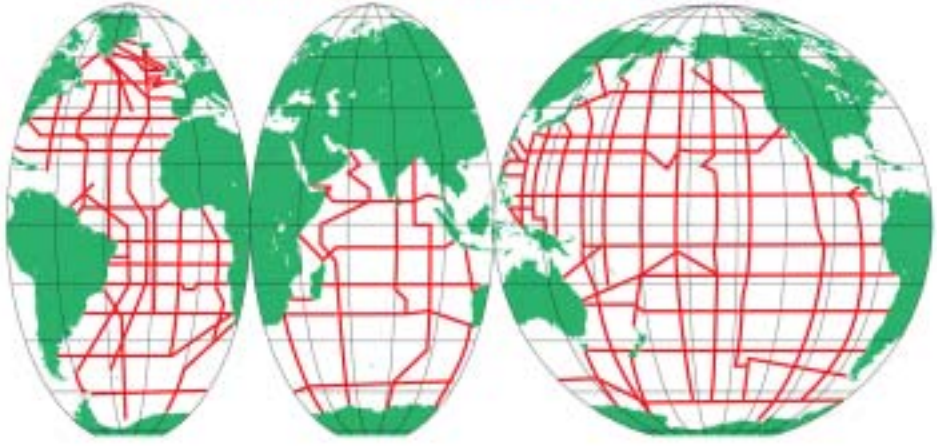


Microwave Sensors Most Relevant to WOCE:

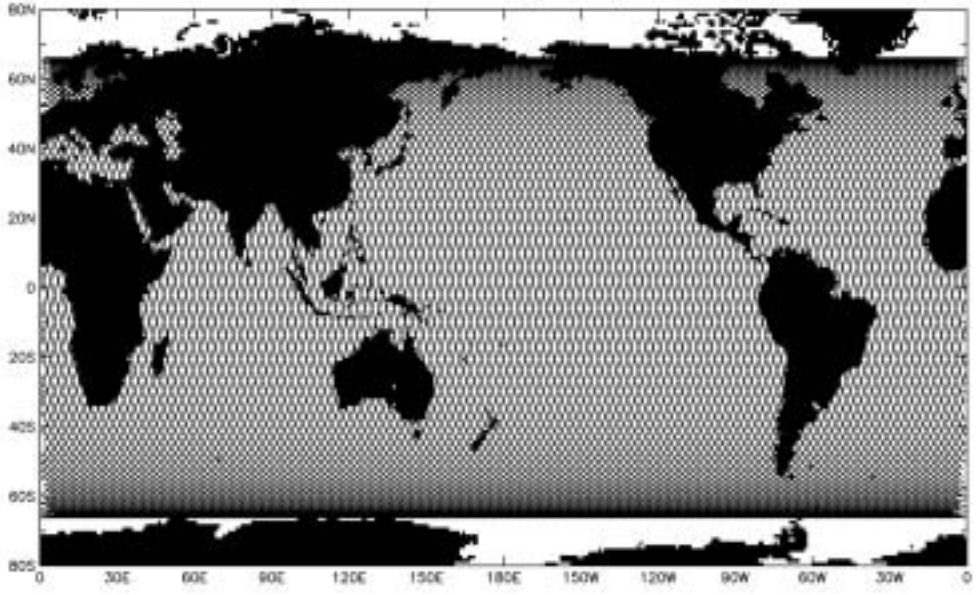
- *Altimeter Measurements of Sea Surface Height*
- *Scatterometer Measurements of Wind Stress*
- *Passive Microwave Radiometer Measurements of SST*


WOCE and Satellite Mission Timelines
WOCE
Synthesis Phase
Field Program
Altimeter Missions
ENVISAT
JASON−1
TOPEX/POSEIDON
ERS−1/2
Scatterometer Missions
NSCAT
QuikSCAT
ERS−1/2
Microwave SST Missions
AMSR/EOS−Aqua
TMI/TRMM
1985
1990
1995
2000
2005
2010

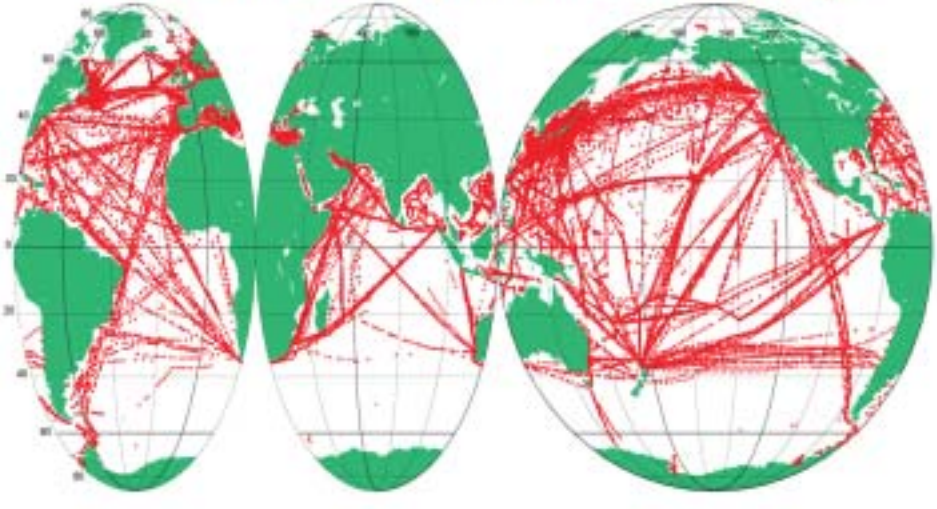
WOCE Hydrographic Survey Lines



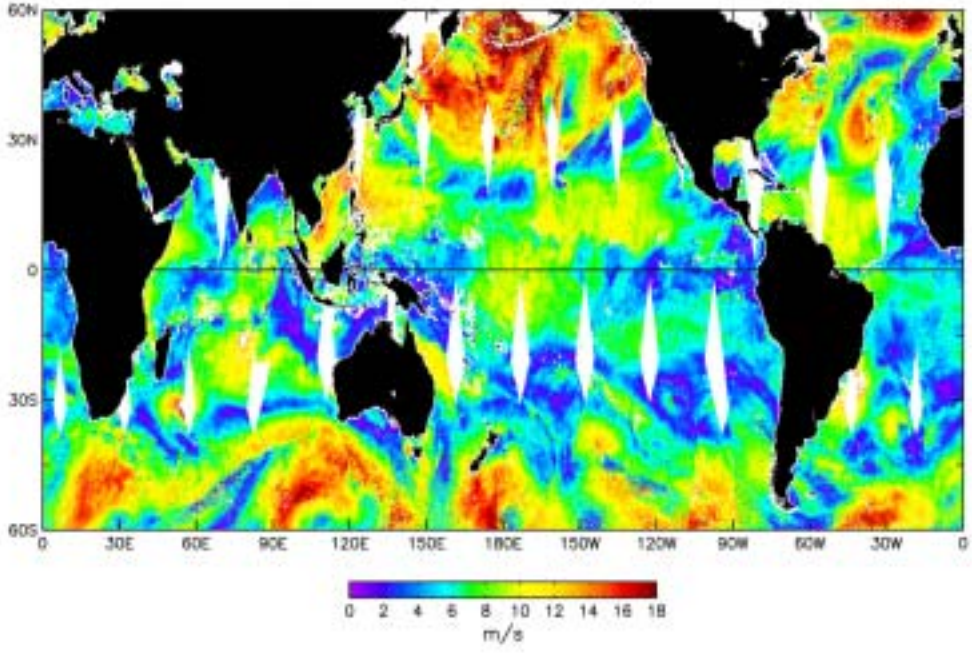
TOPEX/POSEIDON 10-Day Repeat Ground Track



Observations from Volunteer Observing Ships

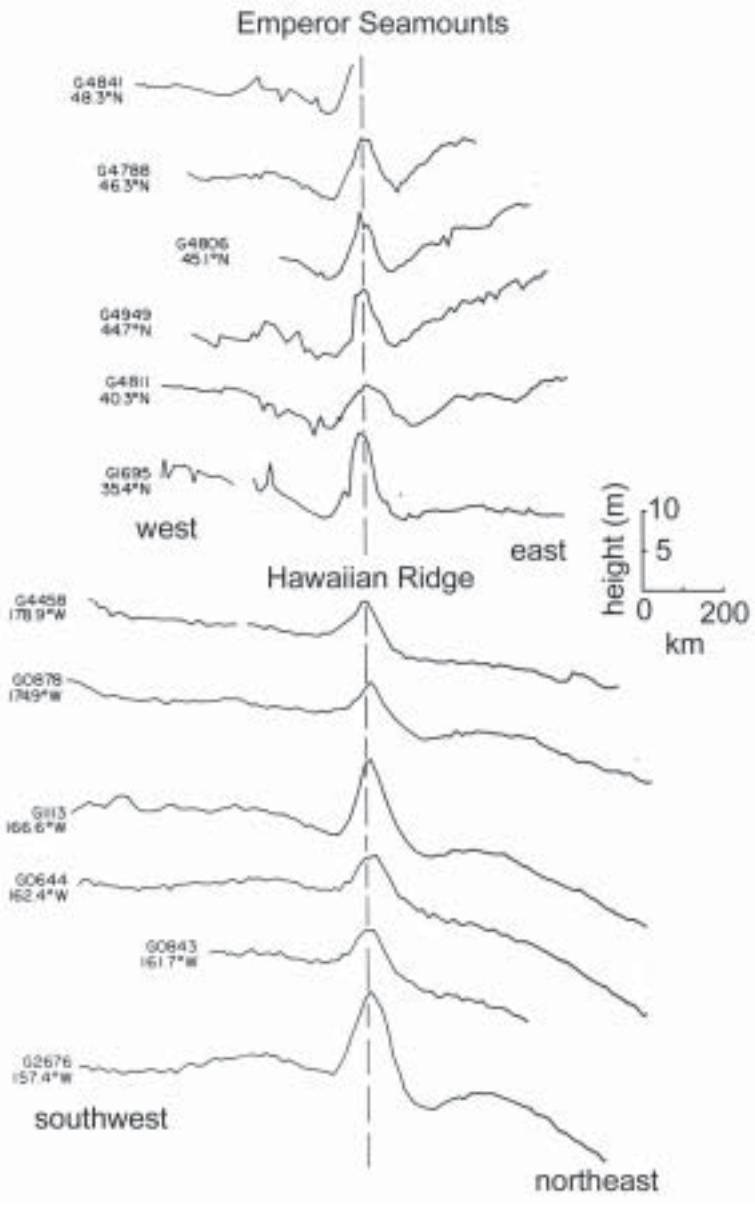


QuikSCAT Coverage in 24 Hours (1 February 2000)

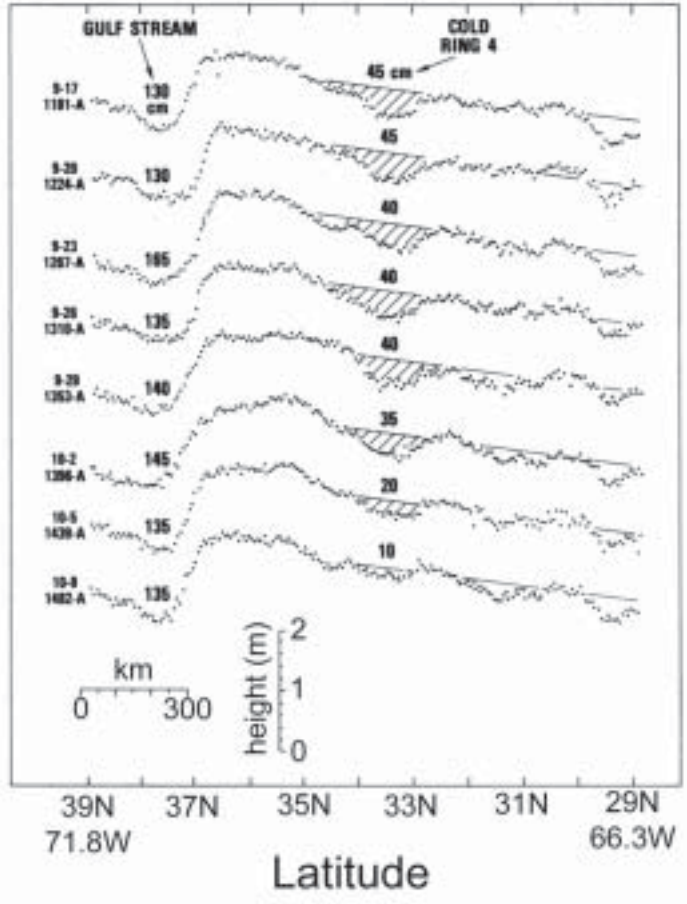


Satellite Altimetry in the Early 1980s

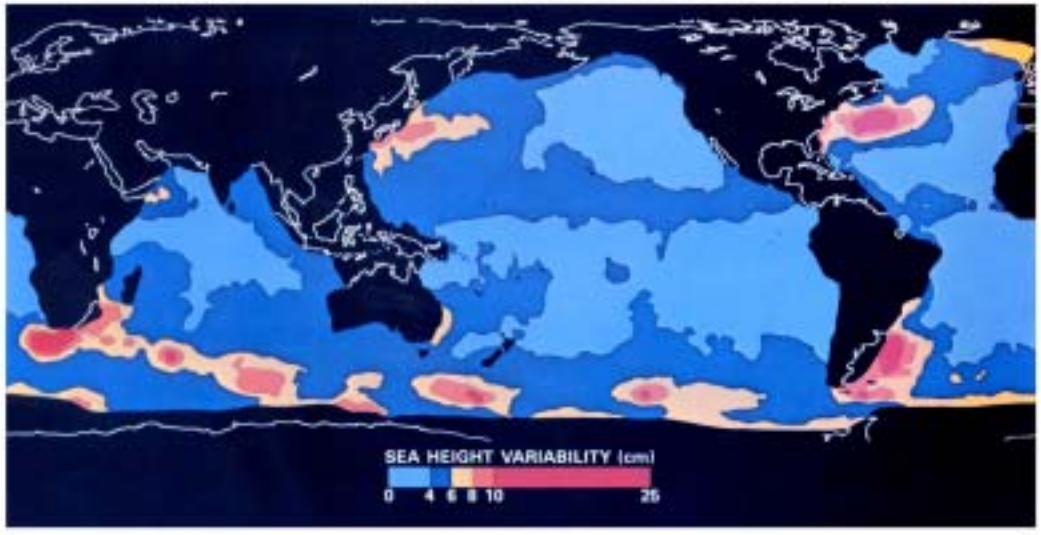
GEOS-3 Altimeter Measurements of SSH
(Watts, 1979)



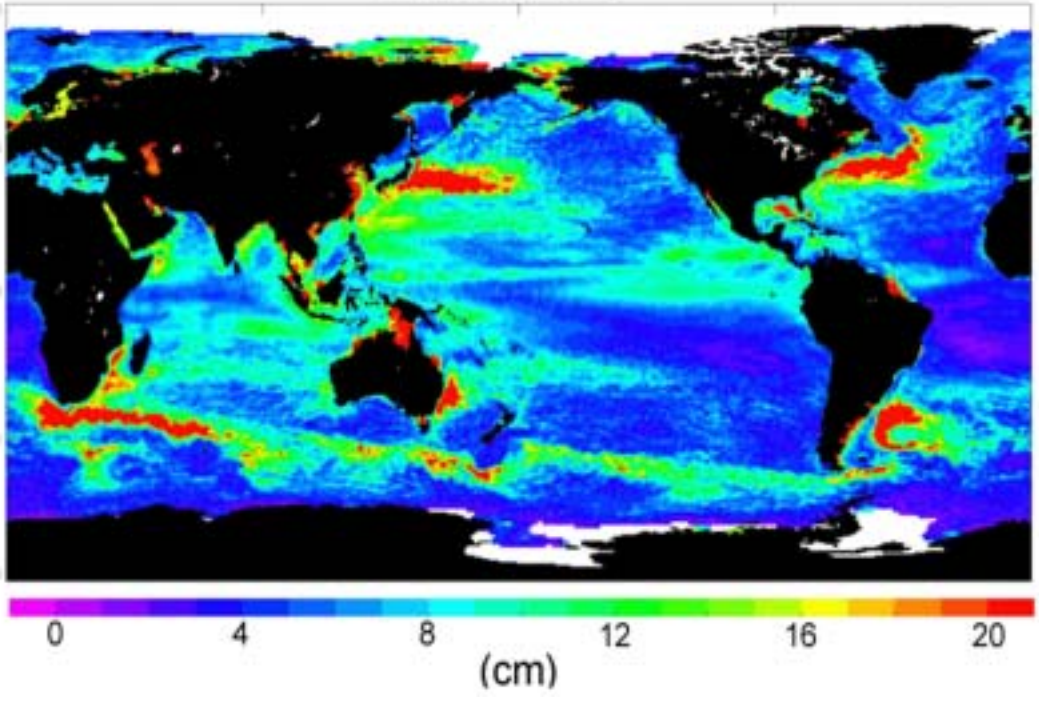
Seasat Altimeter Measurements of SSH
(Cheney and Marsh, 1981)



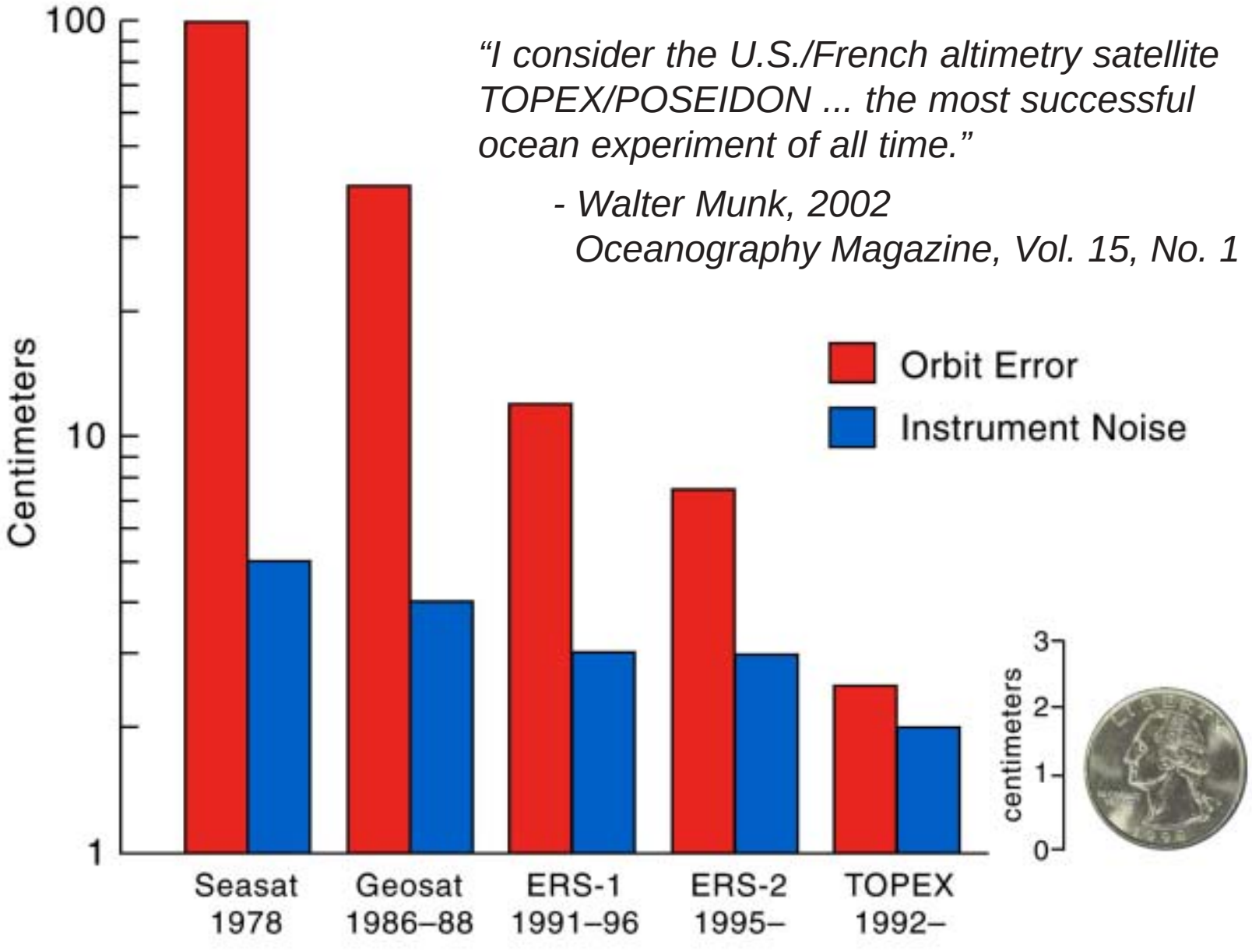
SSH Standard Deviation from 24 Days of Seasat Altimeter Data
(Cheney and Marsh, 1984)



SSH Standard Deviation from Combined T/P and ERS Altimeters
(Ducet et al., 2000)



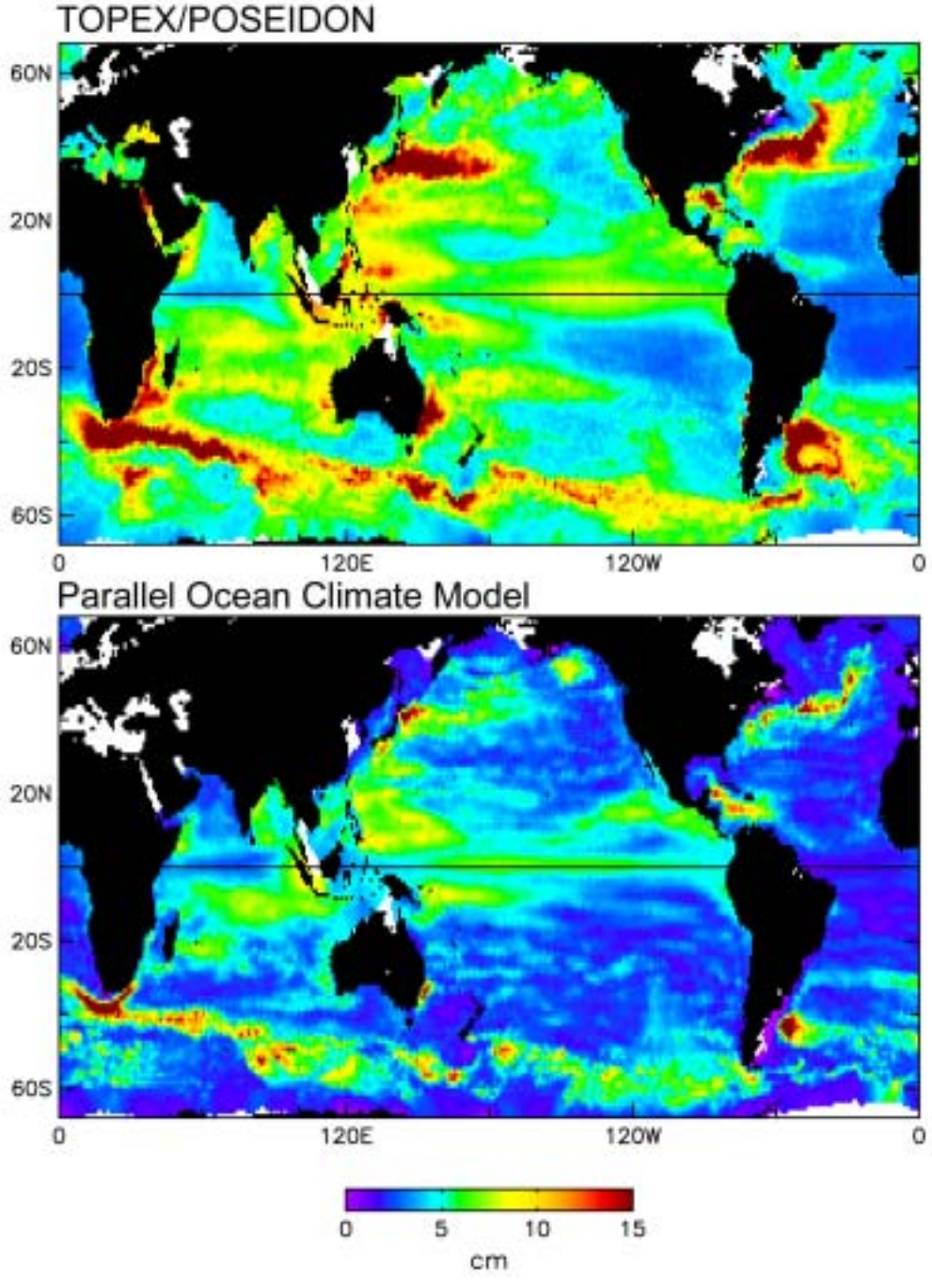
History of Satellite Altimeter Accuracy



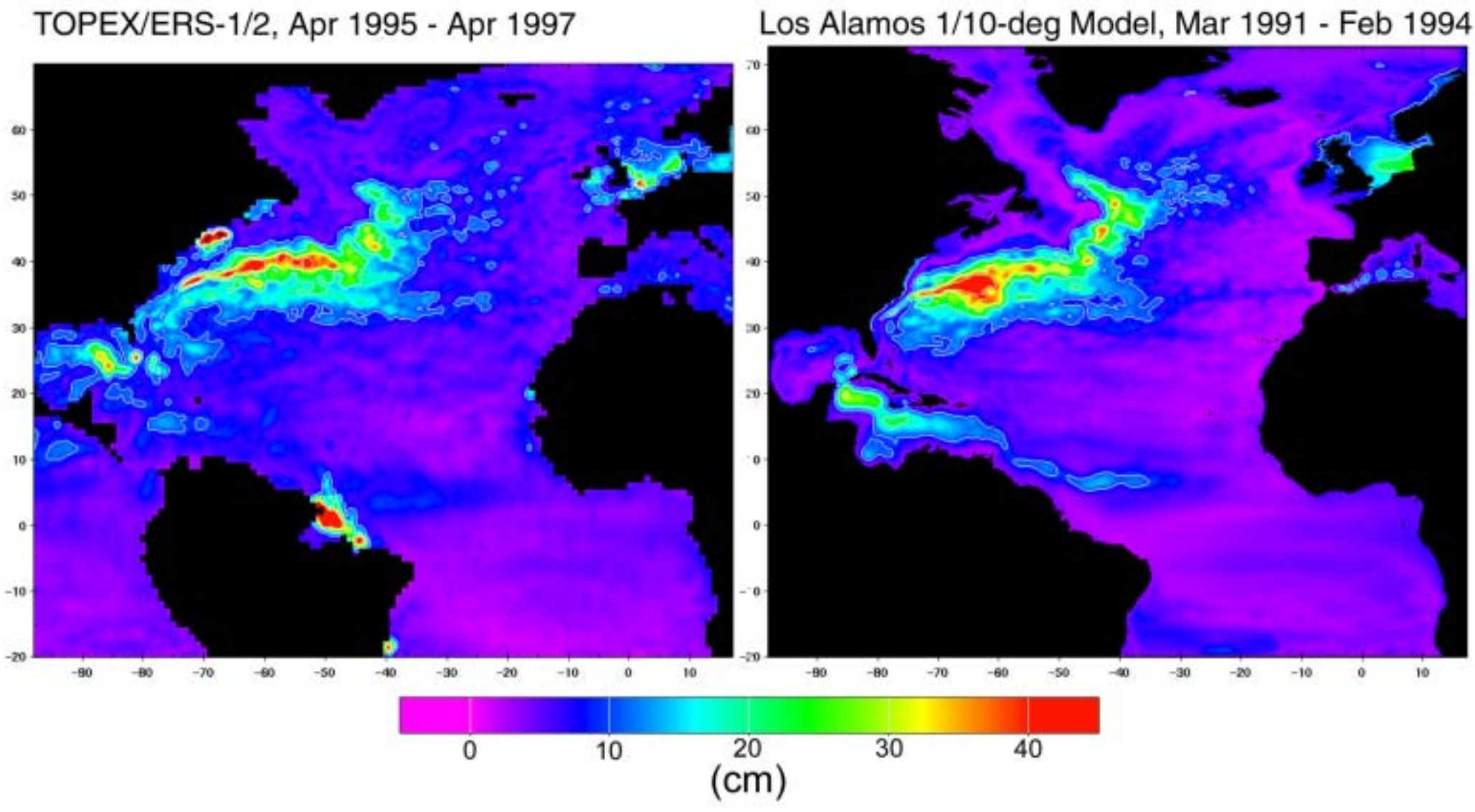
"I consider the U.S./French altimetry satellite TOPEX/POSEIDON ... the most successful ocean experiment of all time."

- Walter Munk, 2002
Oceanography Magazine, Vol. 15, No. 1

Standard Deviation of Nonseasonal SSH

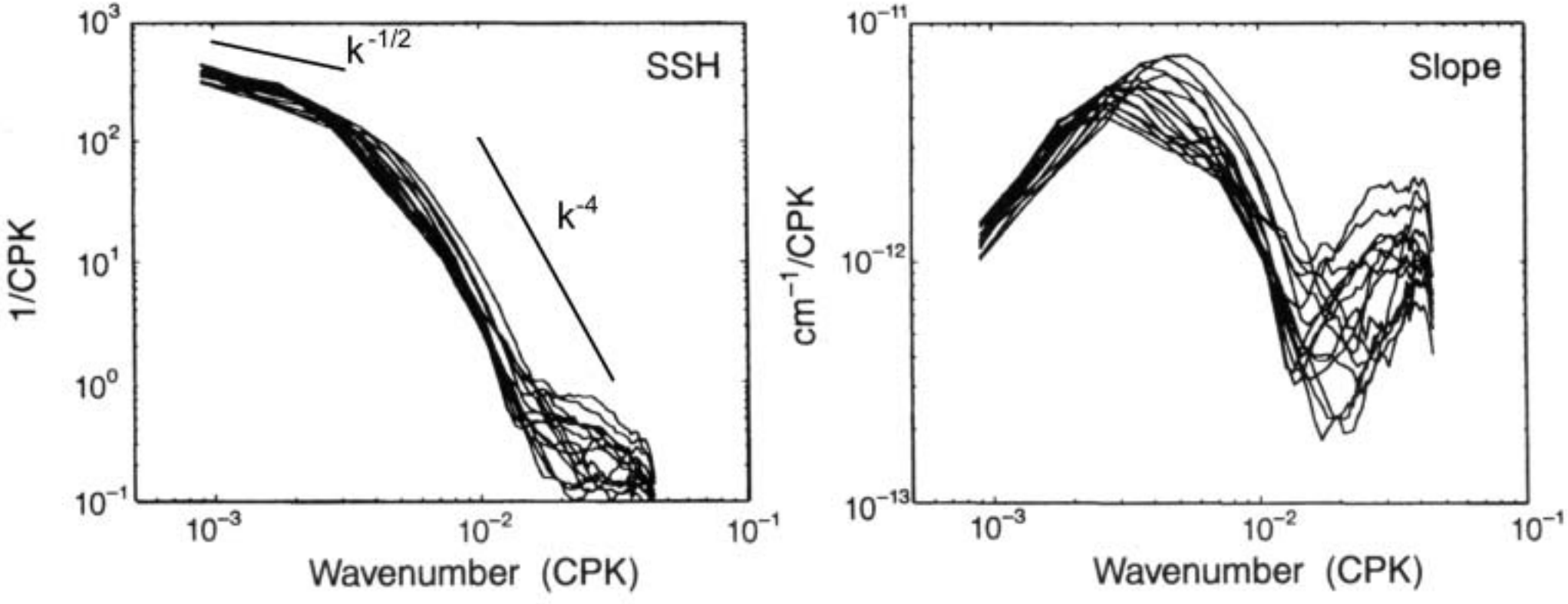


North Atlantic SSH Standard Deviation
(Smith et al., 2000)



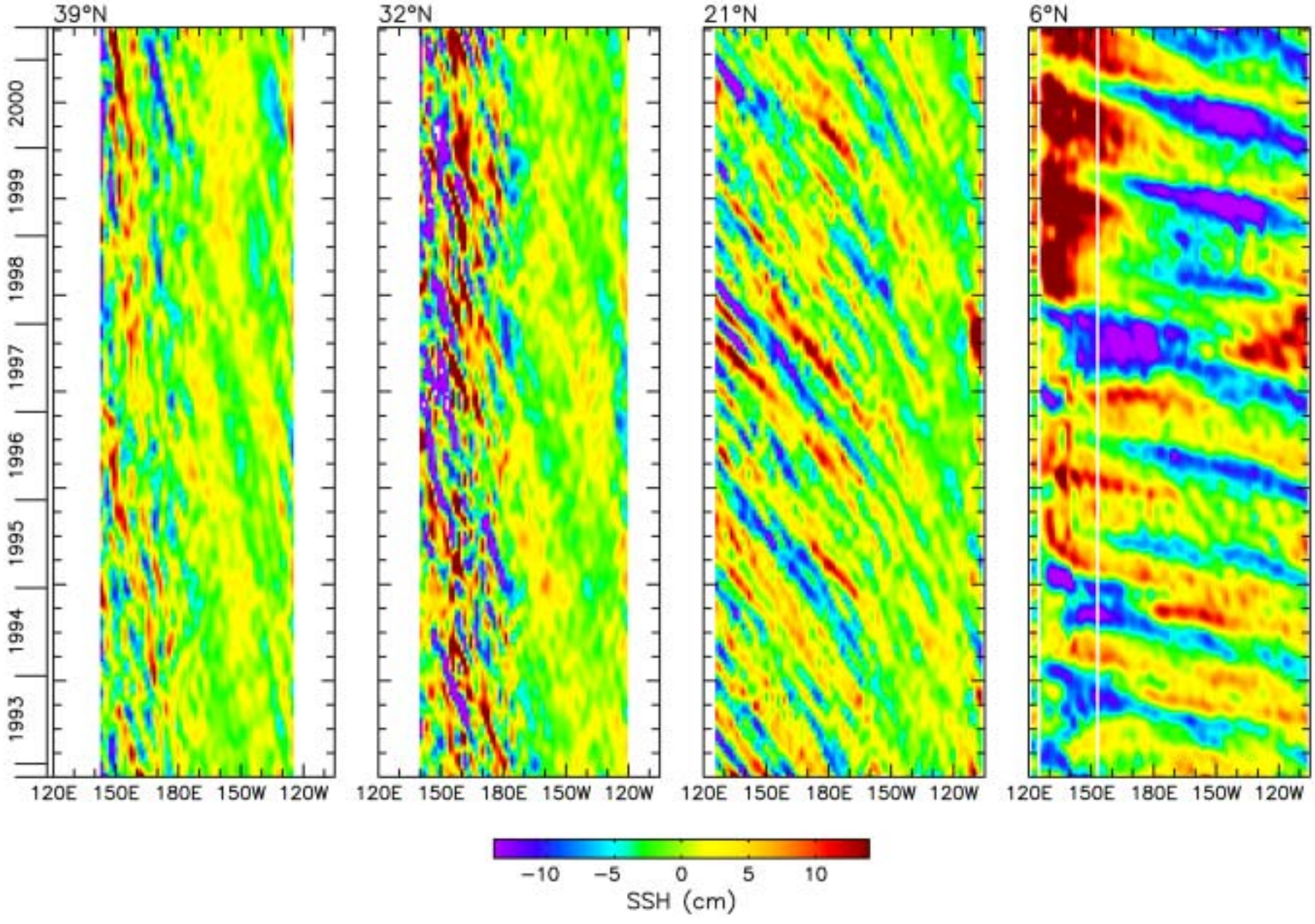
Along-Track Wavenumber Spectra from TOPEX

(Stammer, 1997)



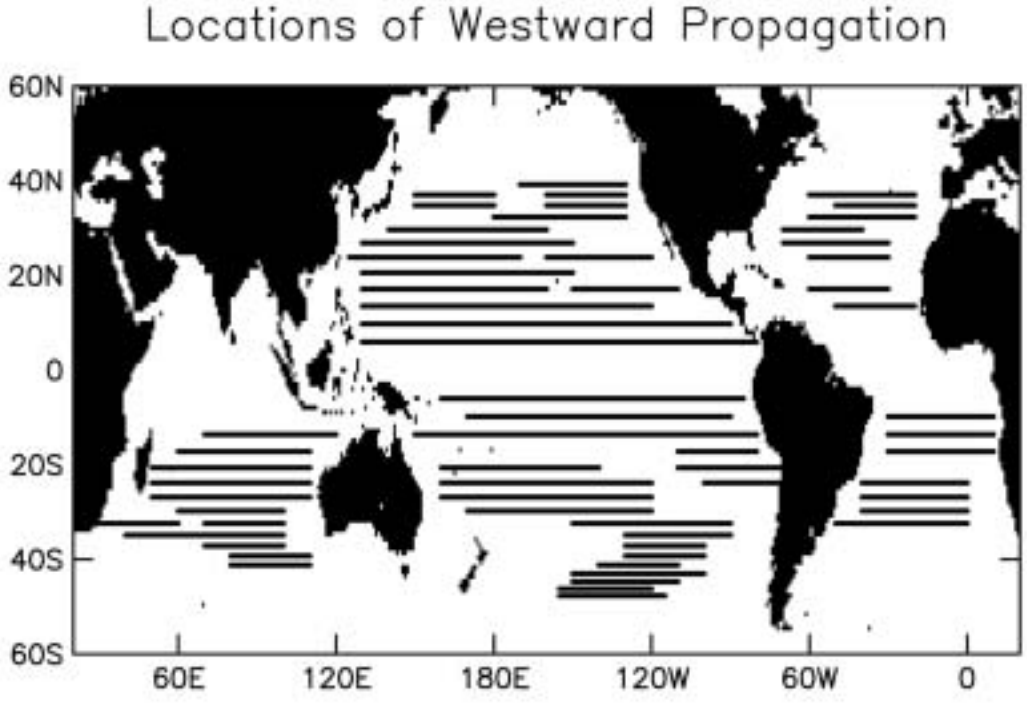
Time-Longitude Plots of SSH from TOPEX

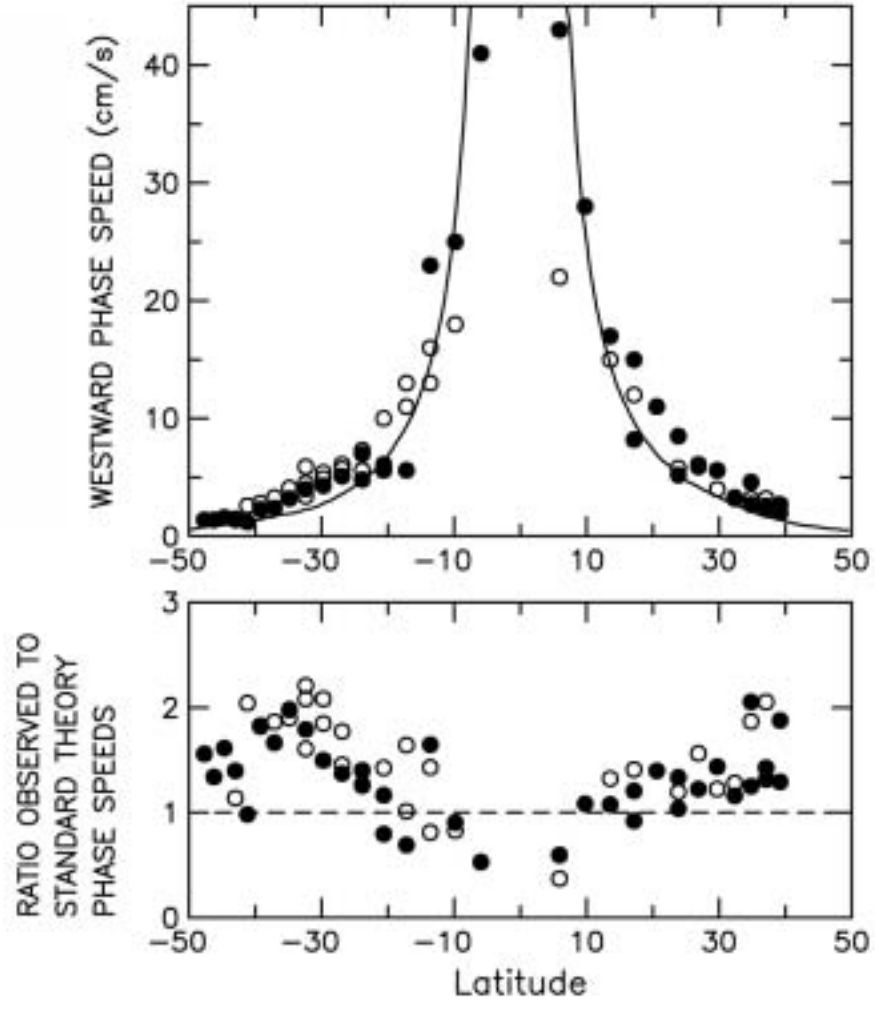
(Fu and Chelton, 2001)



Latitudinal Variation of Westward Phase Speeds from TOPEX/POSEIDON

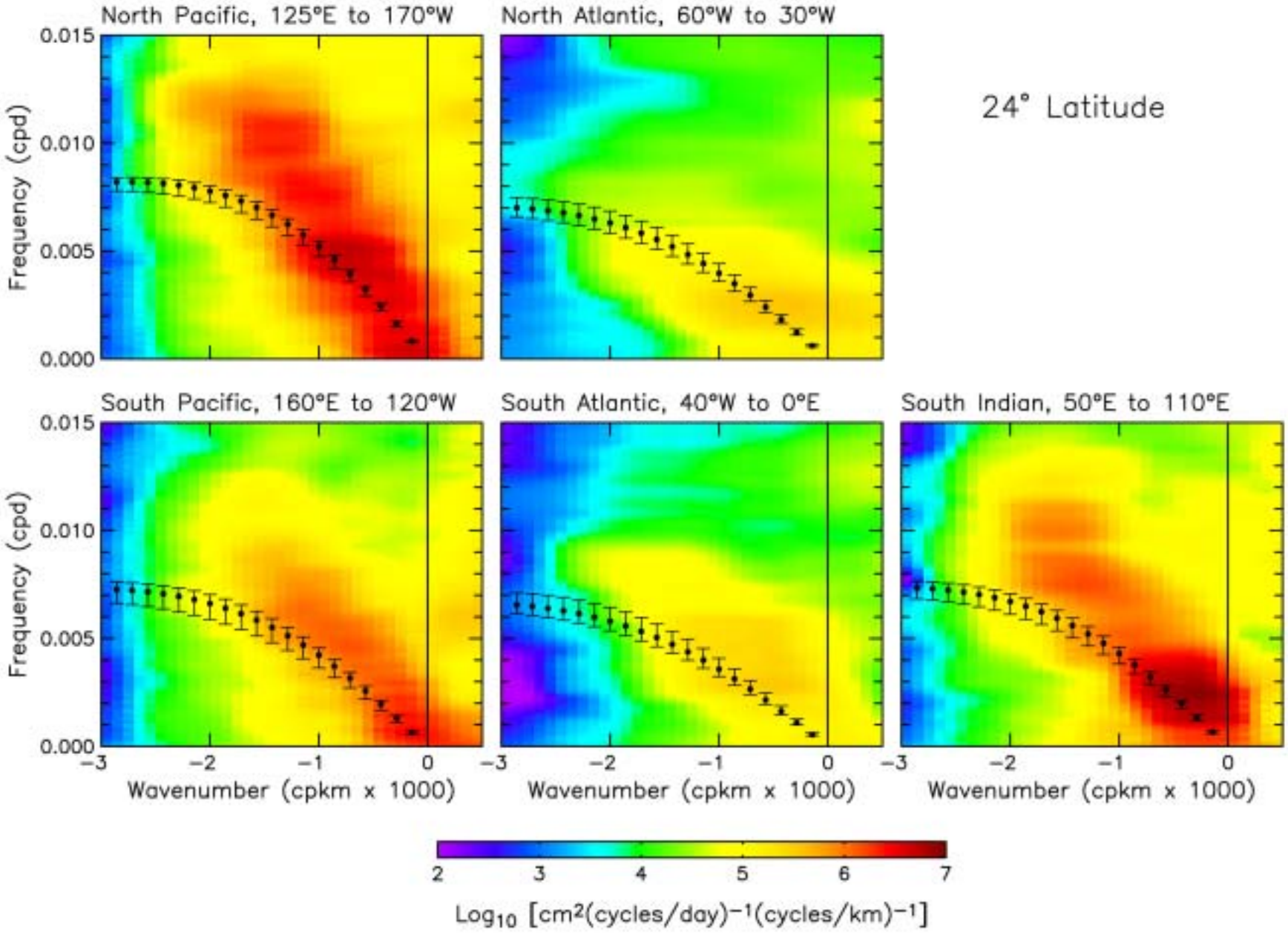
(Fu and Chelton, 2001)





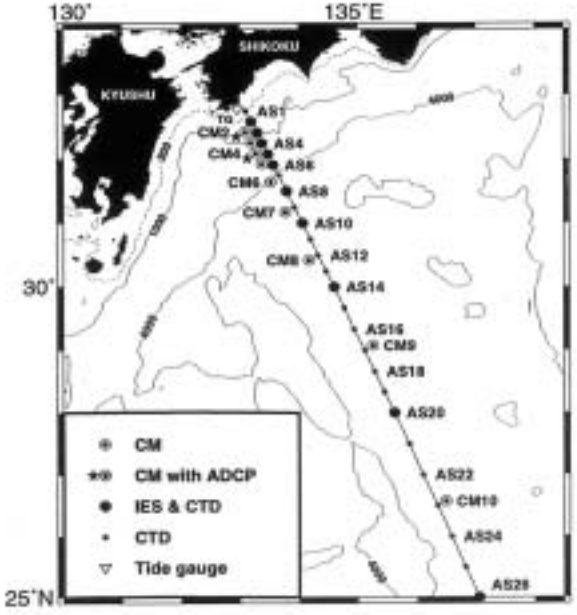
Zonal Wavenumber-Frequency Spectra of SSH

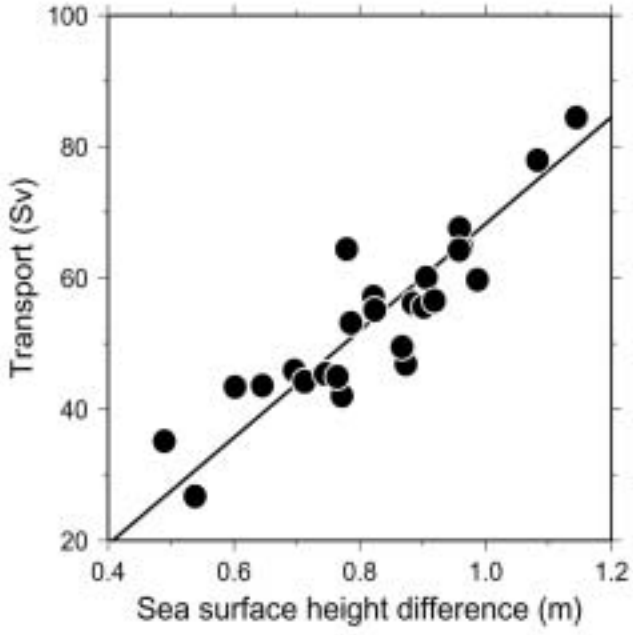
(Fu and Chelton, 2001)

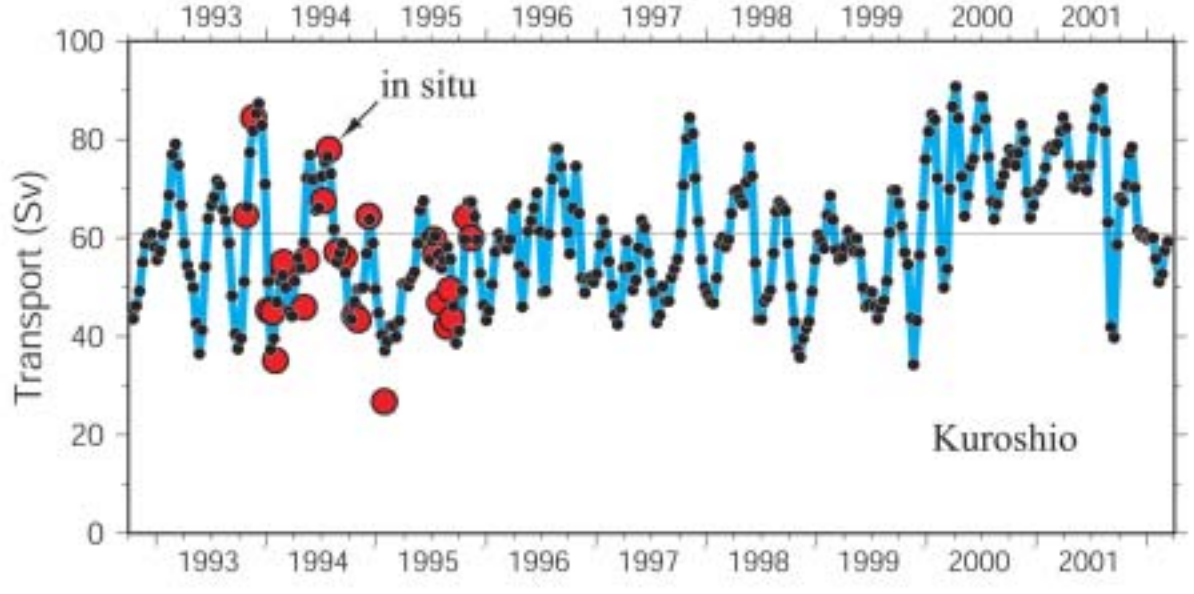


TOPEX/POSEIDON Estimates of Kuroshio Transport Variations

(Imawaki et al., 2001)

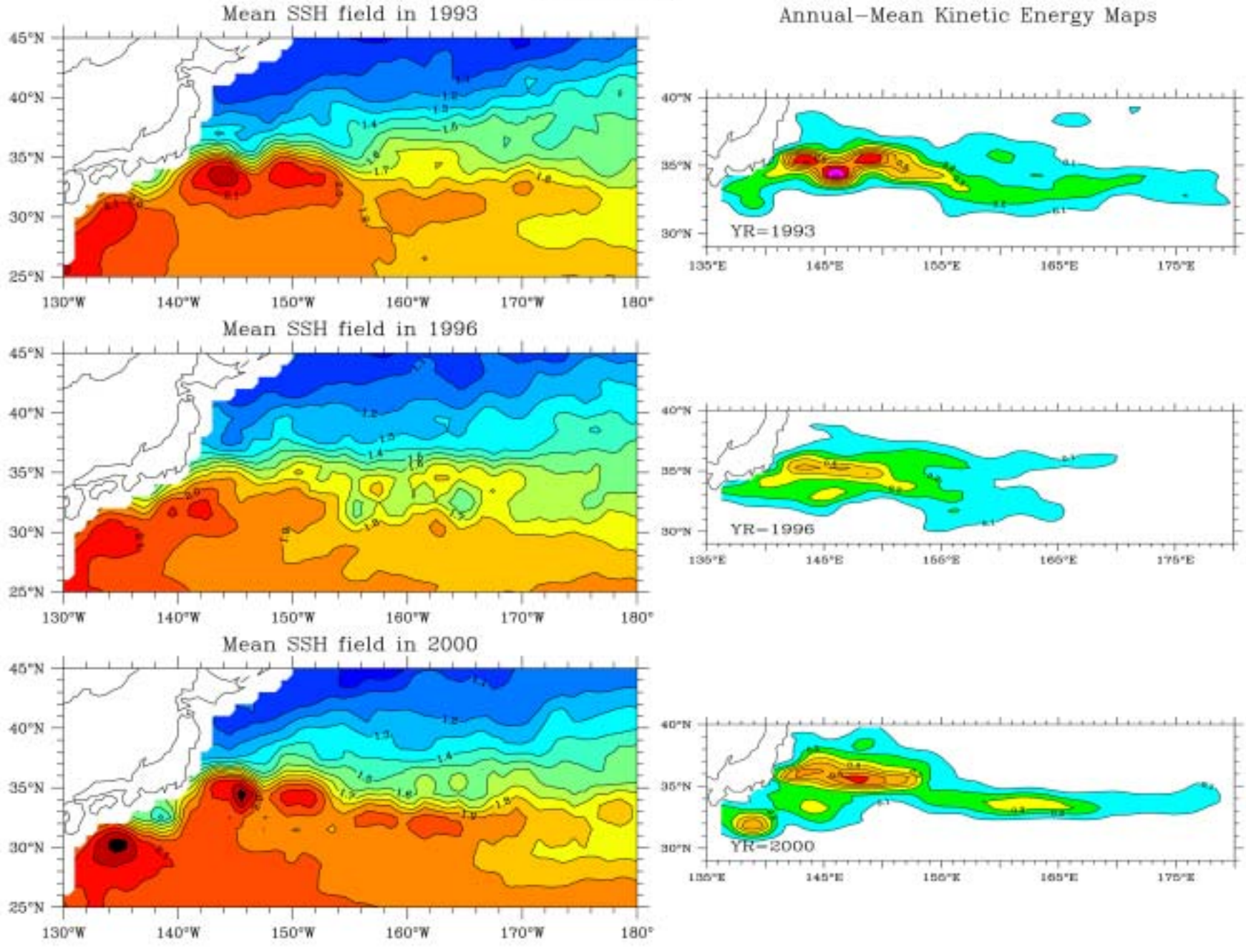




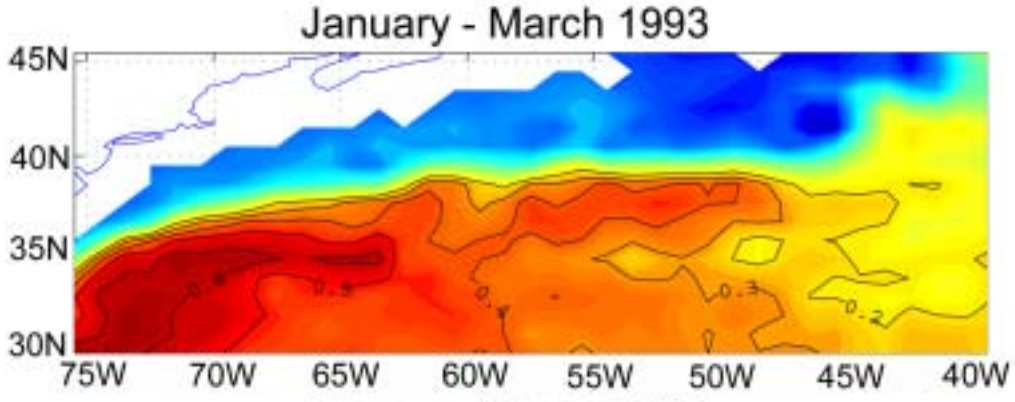


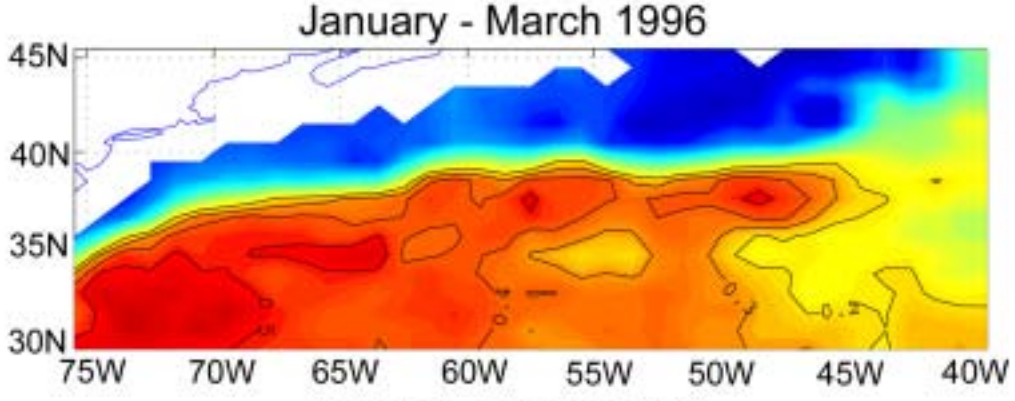
Variations in Zonal Penetration of the Kuroshio Extension

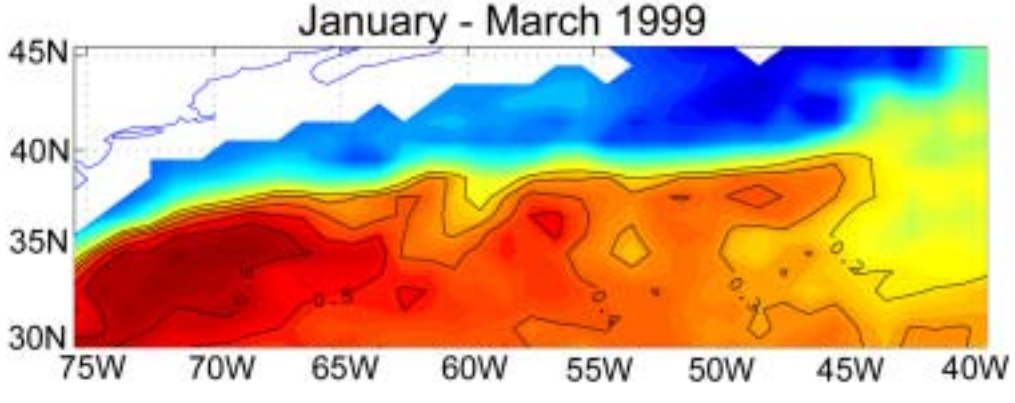
(Qiu, 2000)

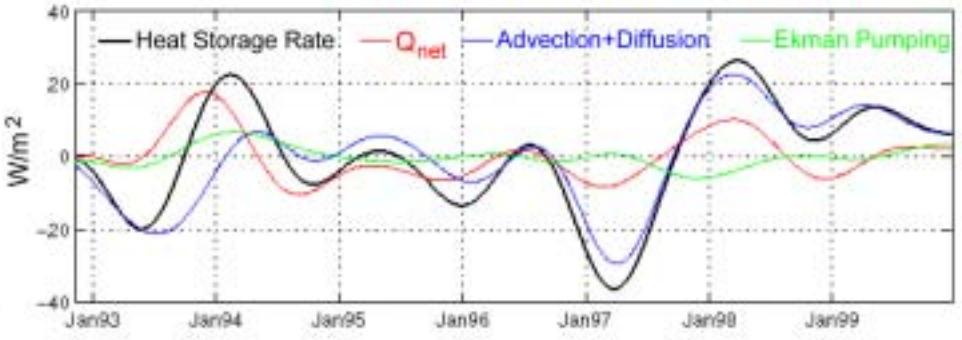


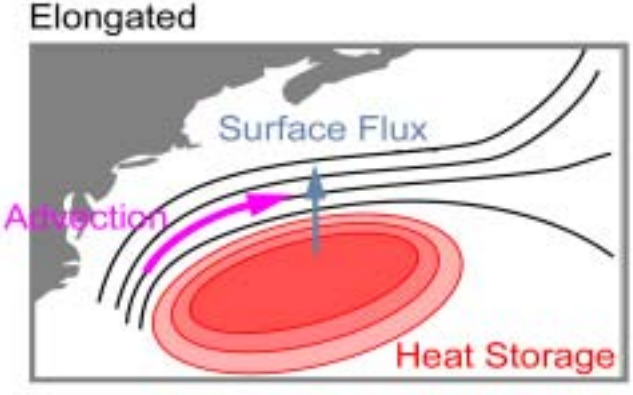
Variations in Heat Content of the Gulf Stream
(Dong and Kelly, 2002)

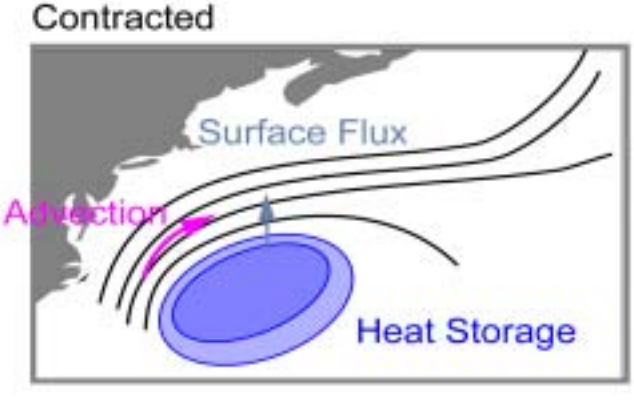






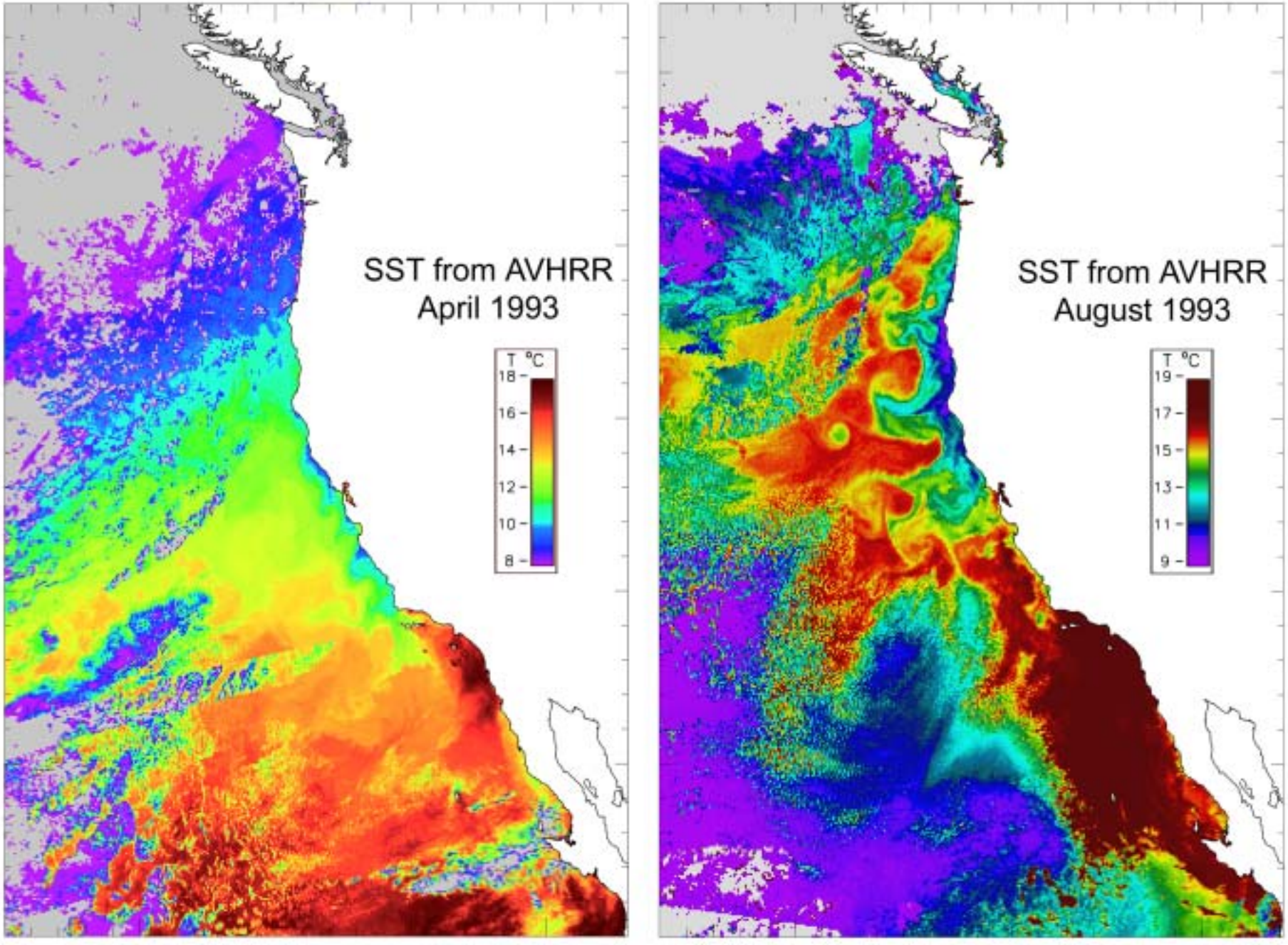






Seasonal Offshore Migration of the California Current

(Strub and James, 2000)



Seasonal Offshore Migration of the California Current

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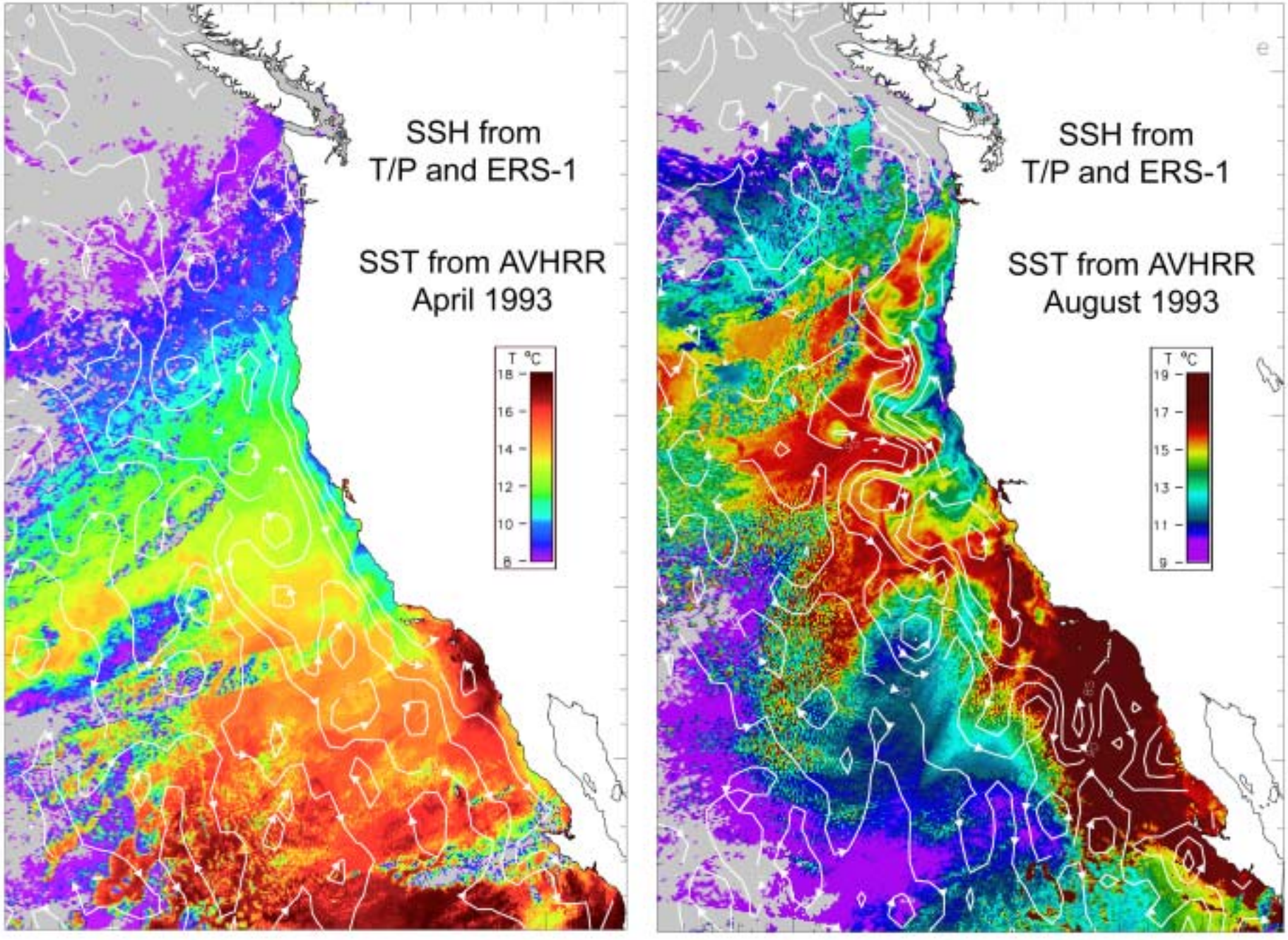
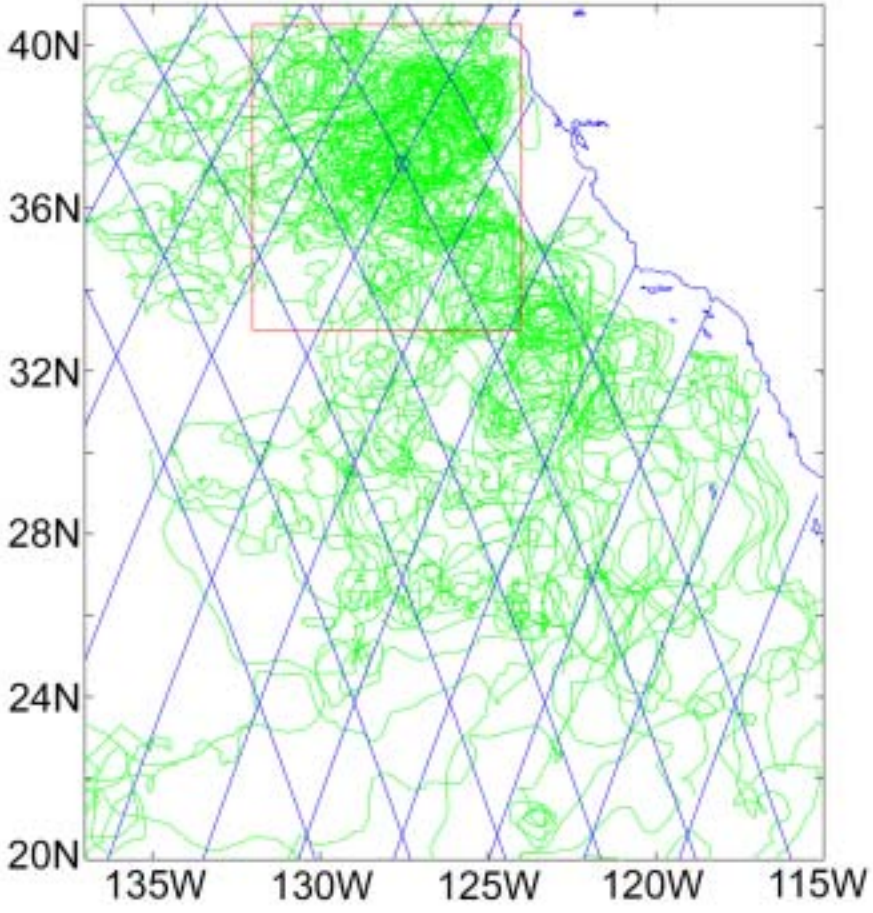
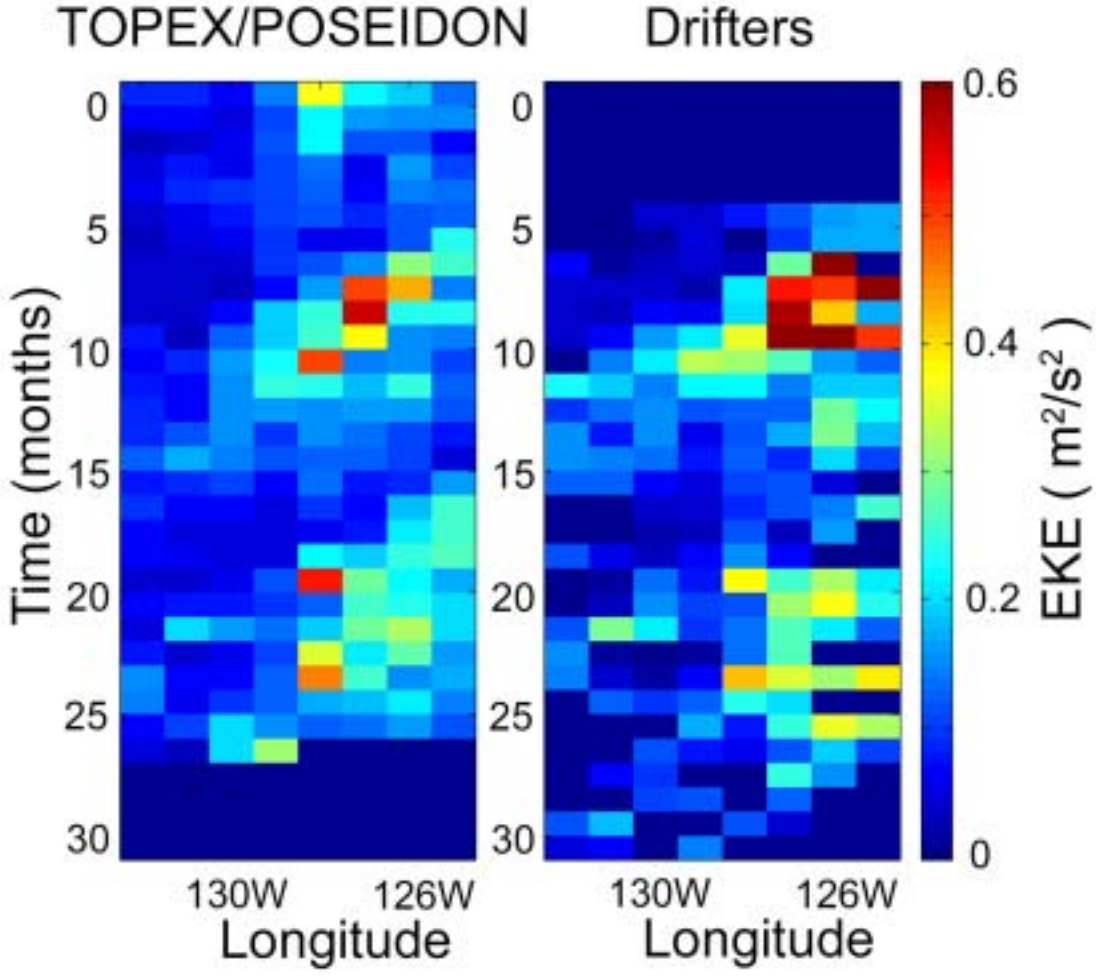


Eddy Kinetic Energy in the California Current from Altimetry and Drifters

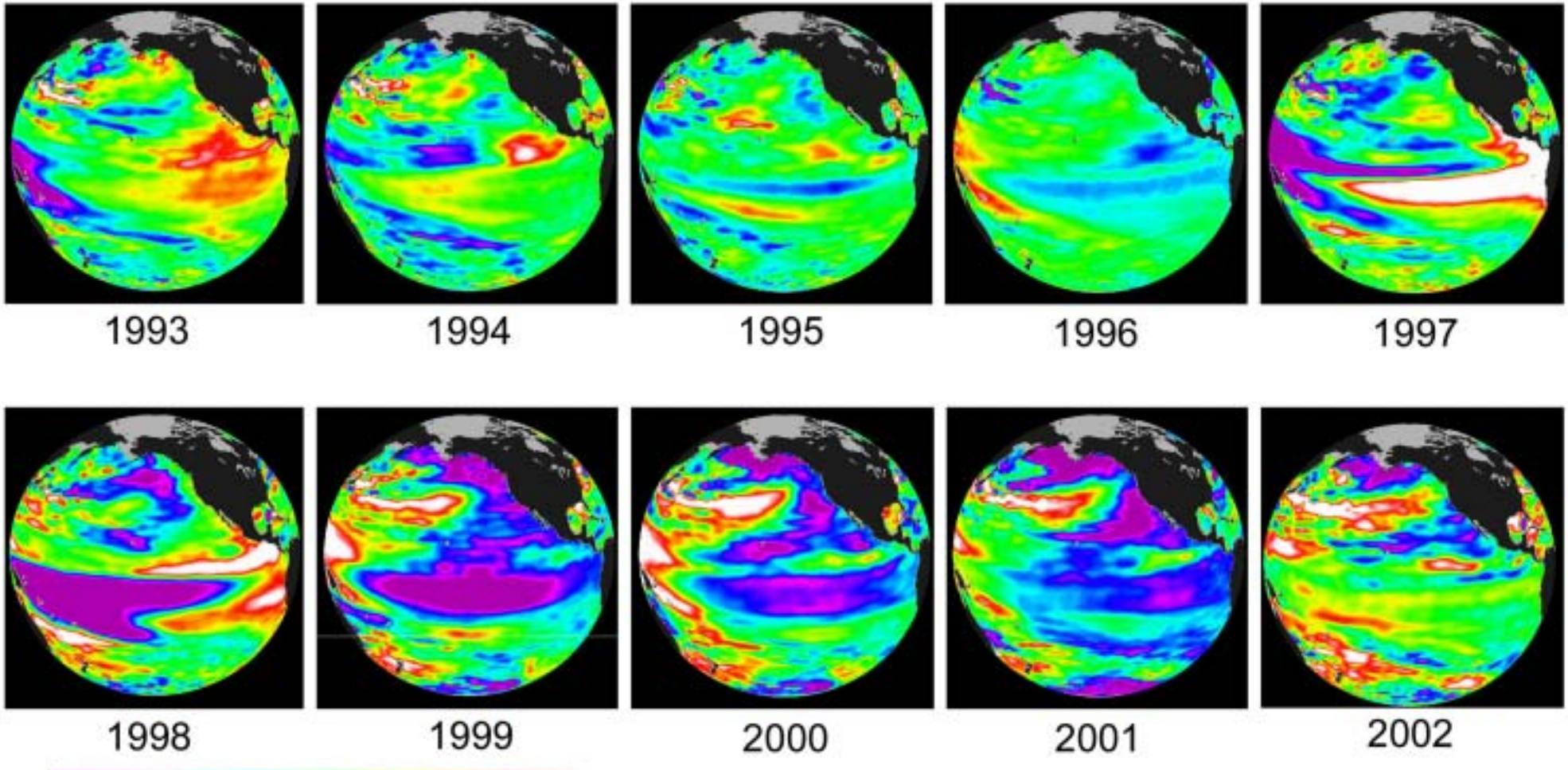
(Kelly et al., 1998)





Annual Averages of SSH from 10 Years of TOPEX/POSEIDON Data

(Courtesy of L.-L. Fu)

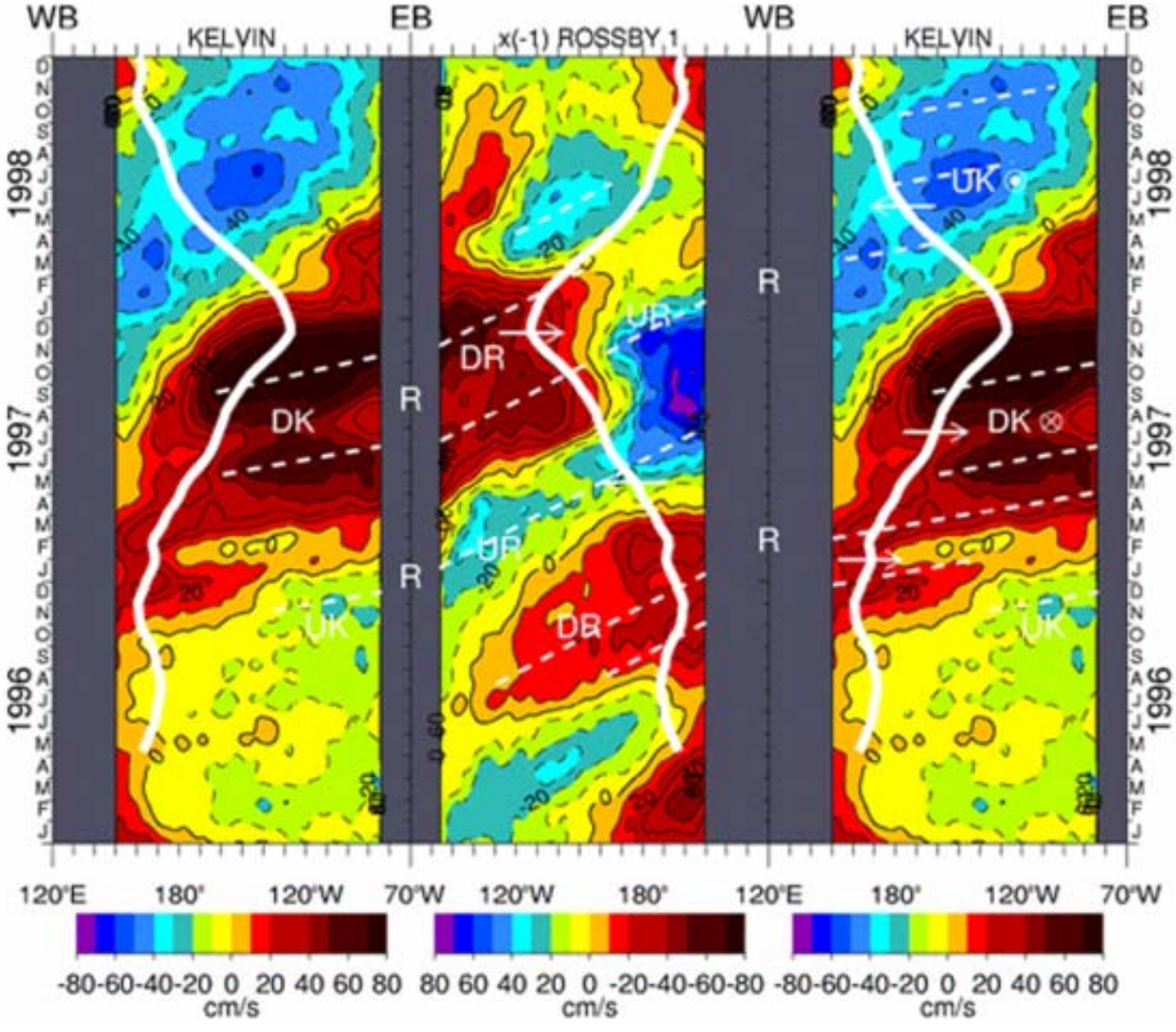


National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

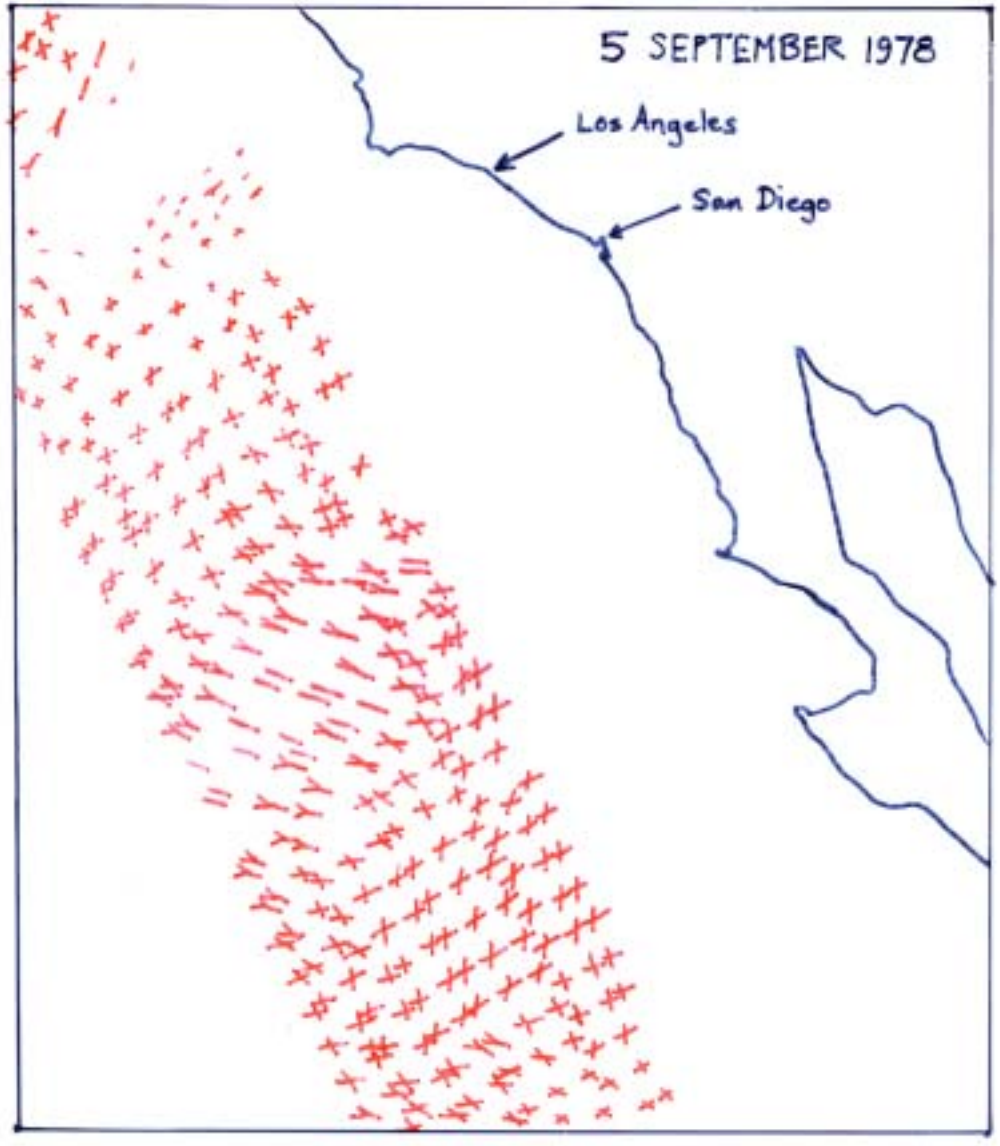
cnes

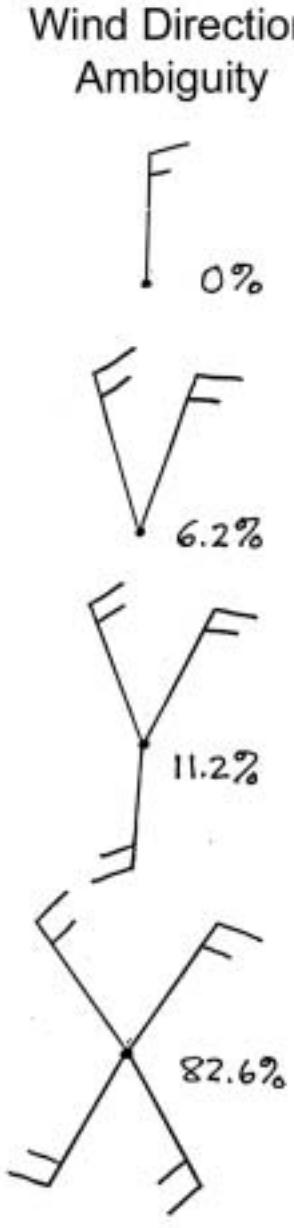
Investigation of ENSO Theories from TOPEX/POSEIDON Data

(Picaut et al., 2002)

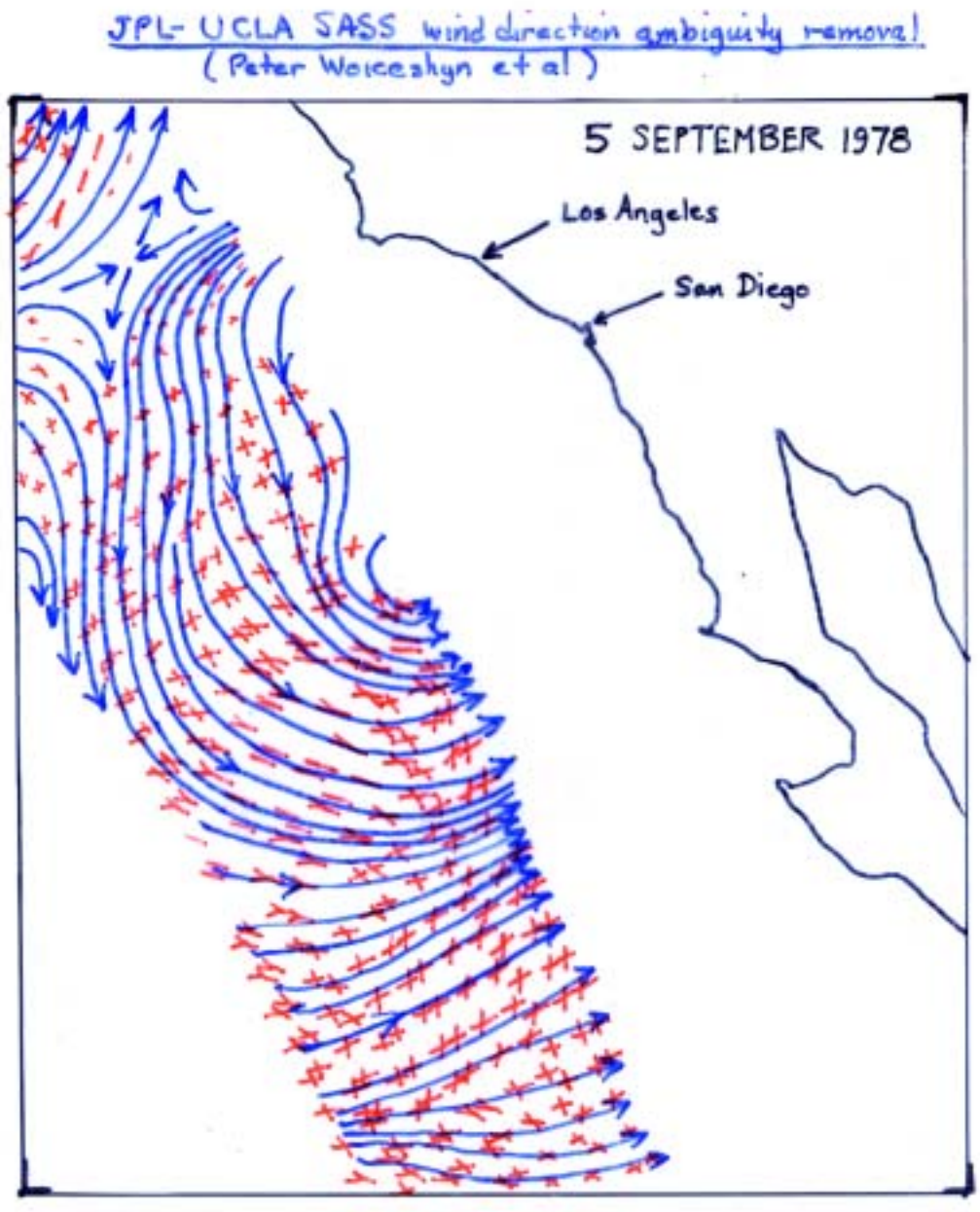


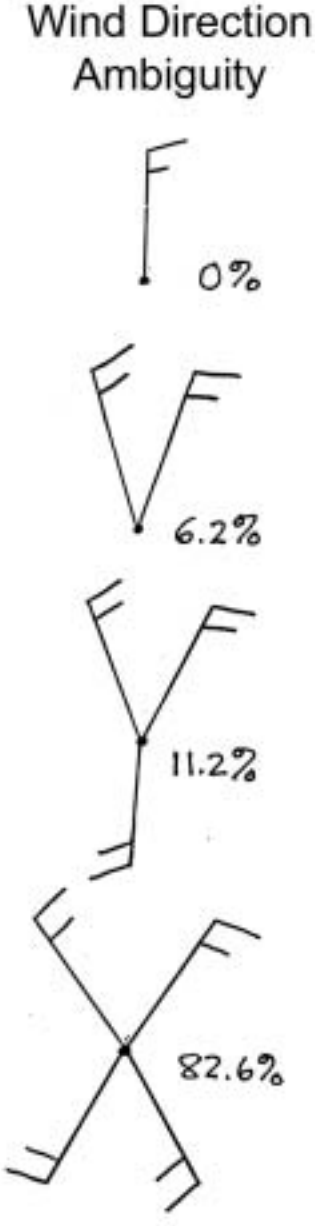
Seasat Scatterometer Measurements of Winds in Hurricane Norman

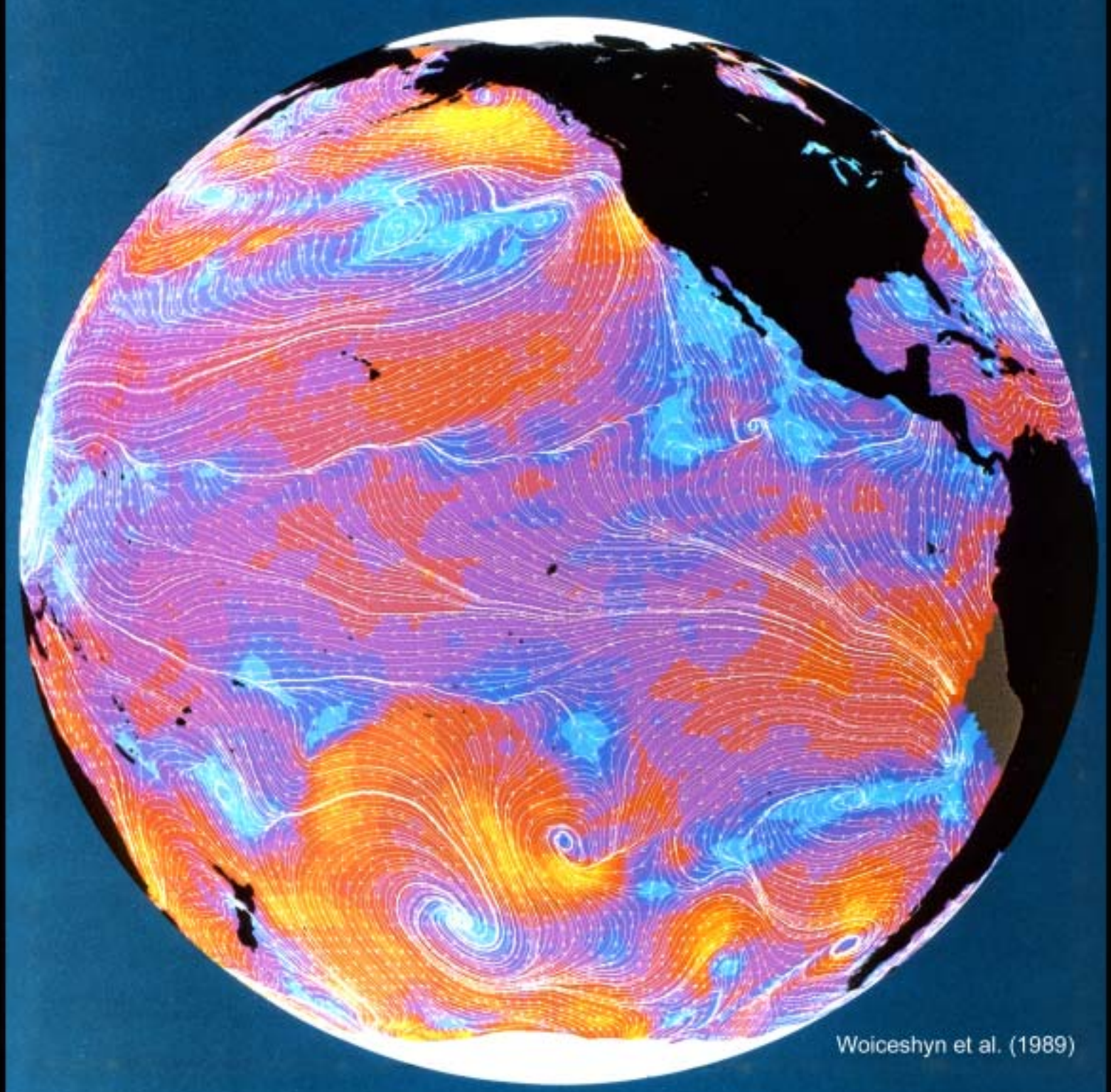




Seasat Scatterometer Measurements of Winds in Hurricane Norman

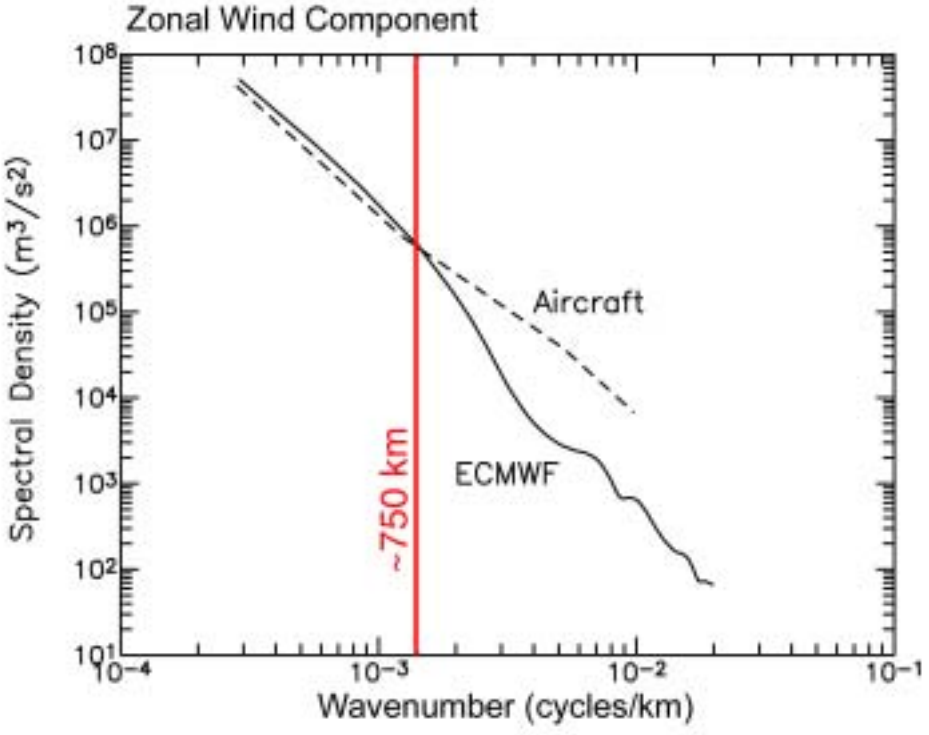


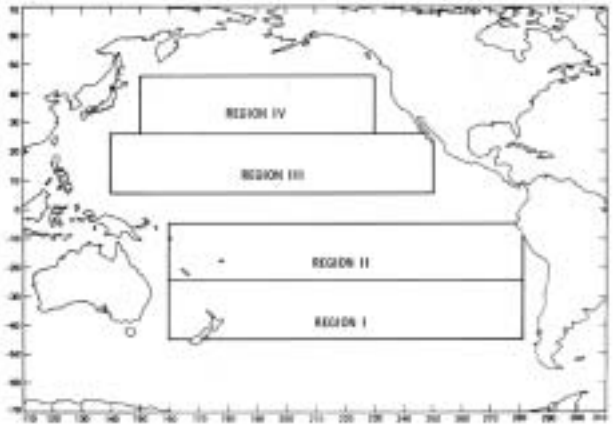


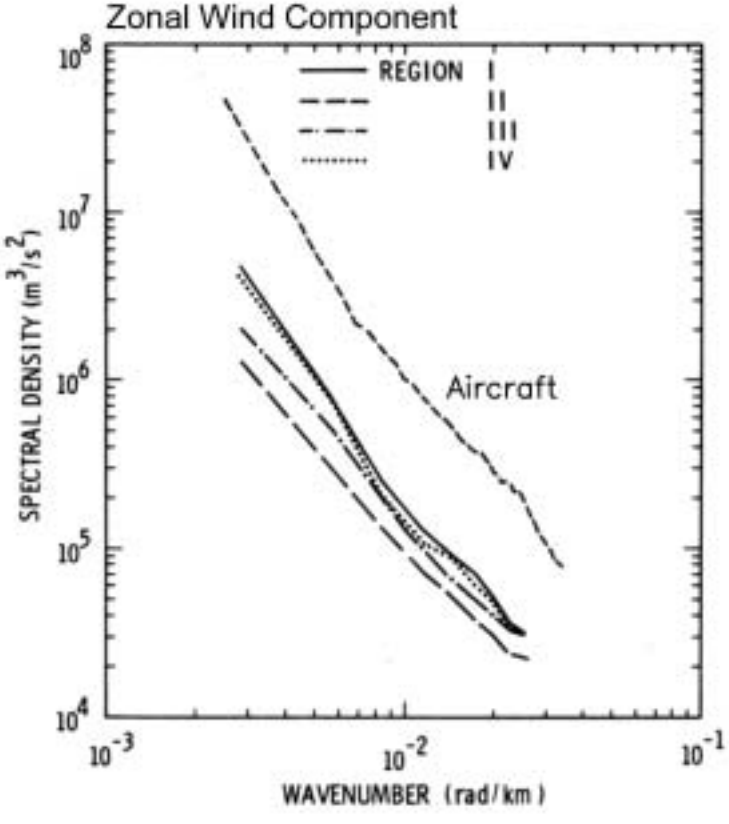

Woiceshyn et al. (1989)

Wavenumber Spectra of Near-Surface Winds

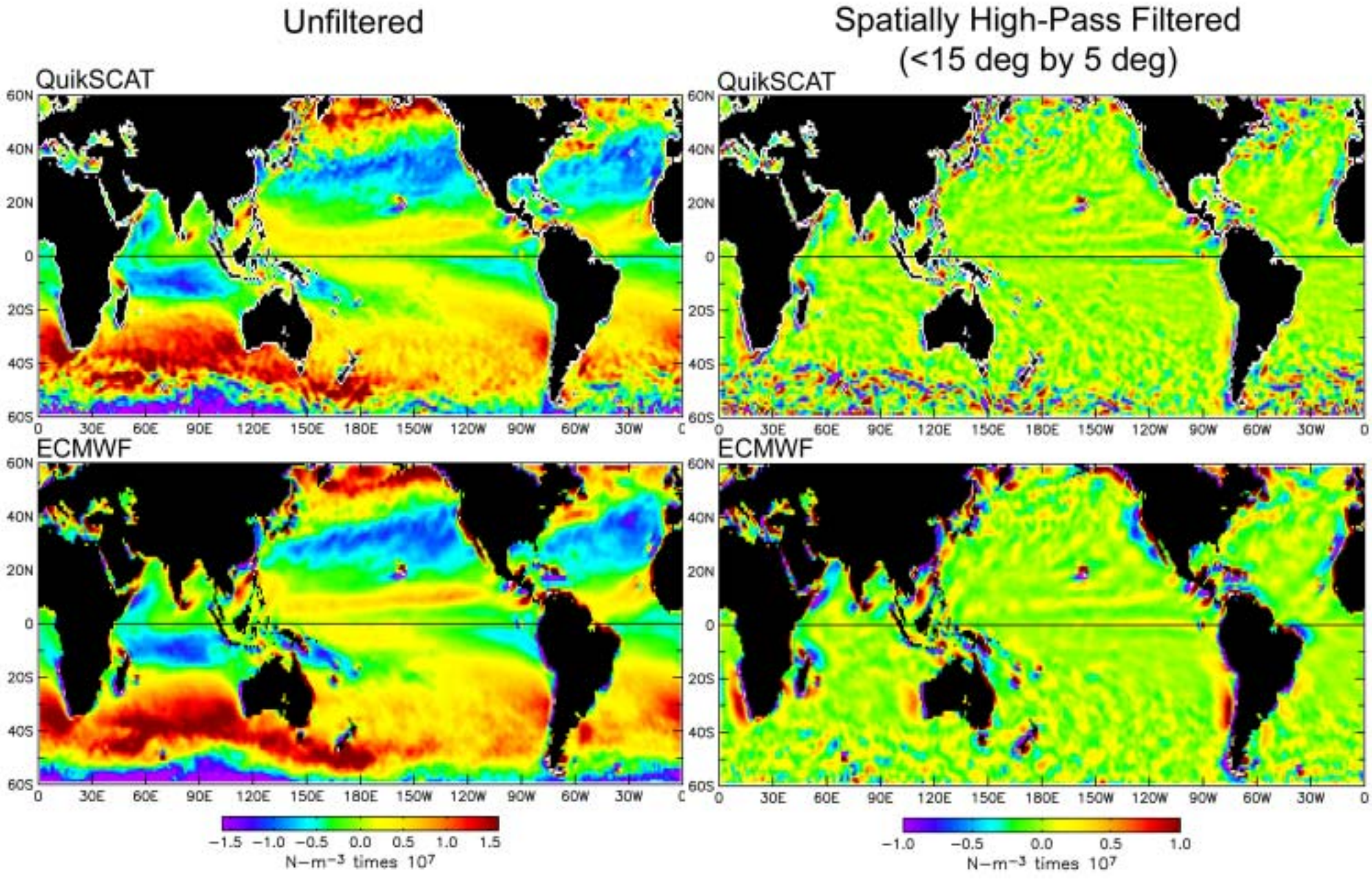
(Freilich and Chelton, 1986)





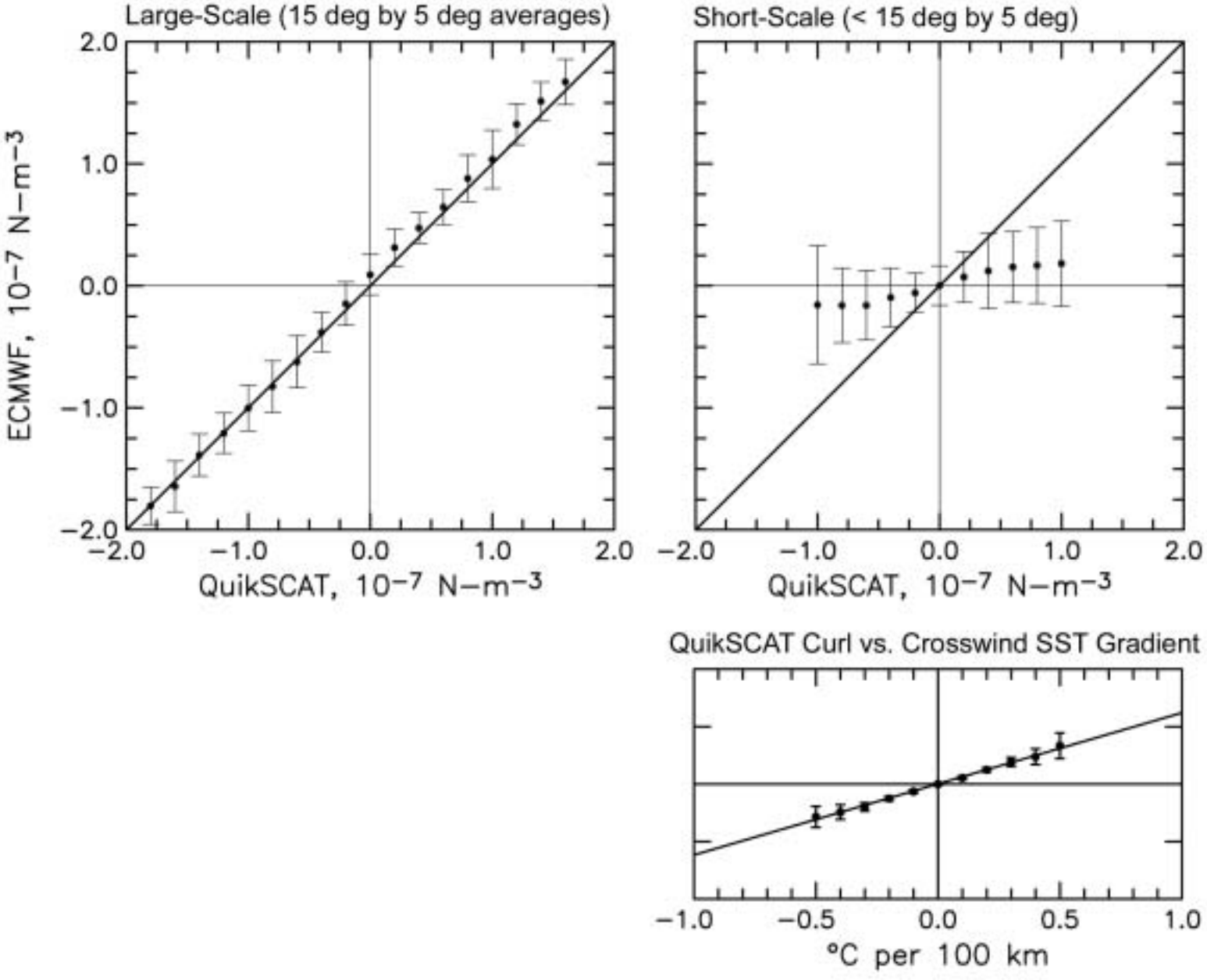


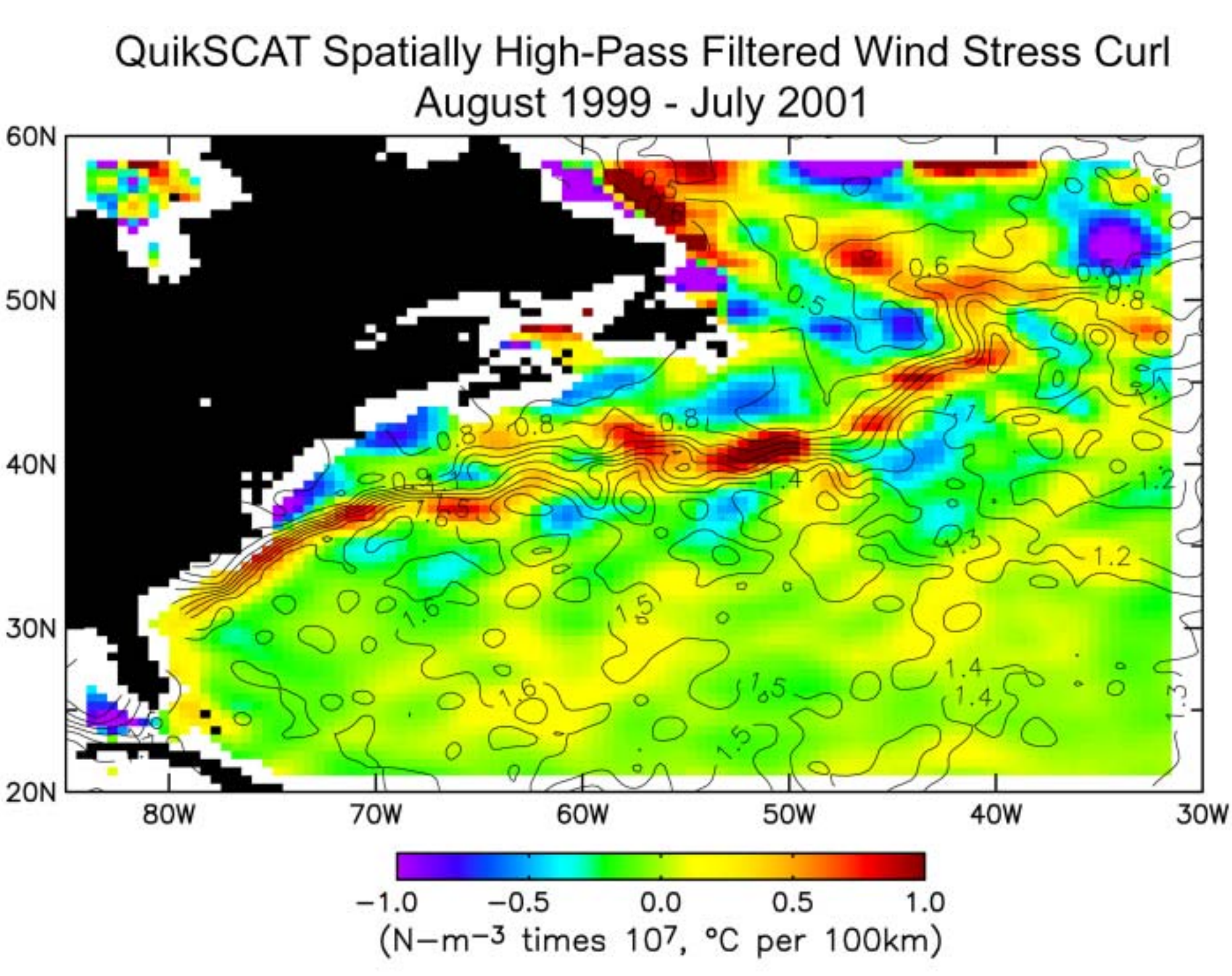
2-Year Average Wind Stress Curl (August 1999 - July 2001)



QuikSCAT versus ECMWF Wind Stress Curl

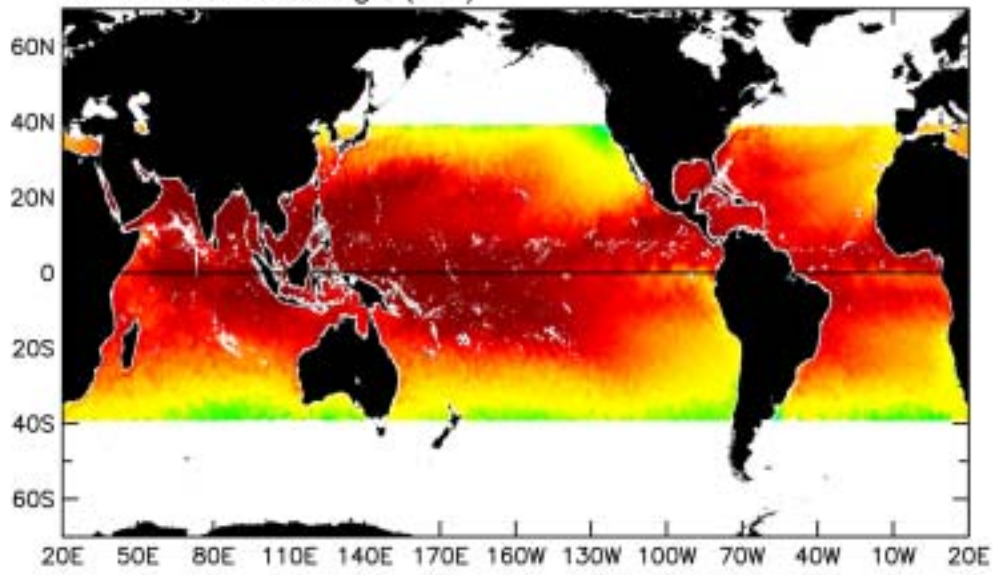
30°S–60°S, August 1999–July 2001



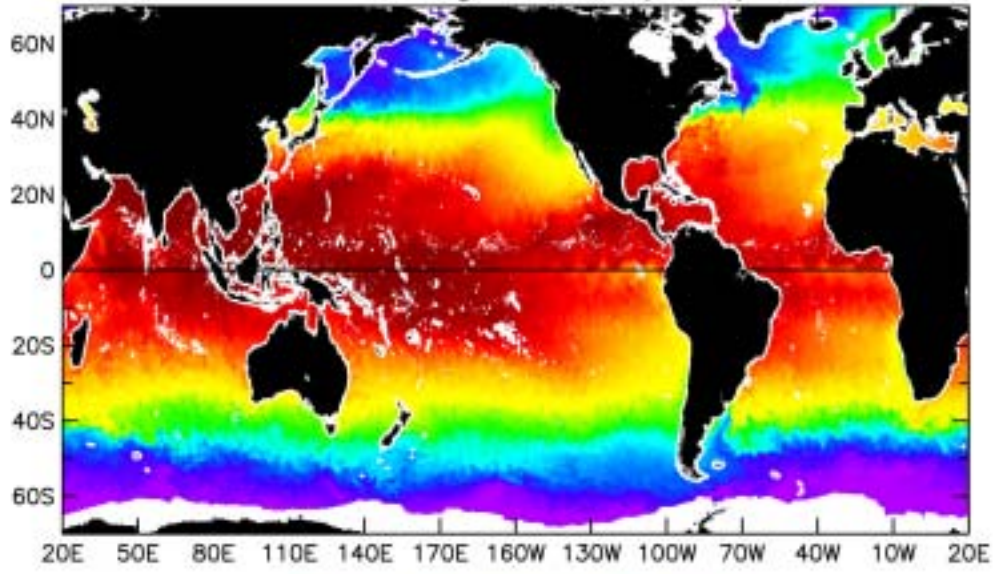

QuikSCAT Spatially High-Pass Filtered Wind Stress Curl
August 1999 - July 2001
60N
50N
40N
30N
20N
80W
70W
60W
50W
40W
30W
−1.0
−0.5
0.0
0.5
1.0
(N−m−3 times 107, °C per 100km)

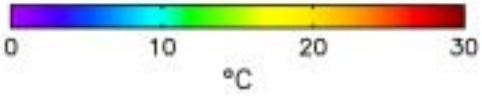
Satellite Microwave Measurements of SST
11-13 June 2002

TRMM Microwave Imager (TMI)

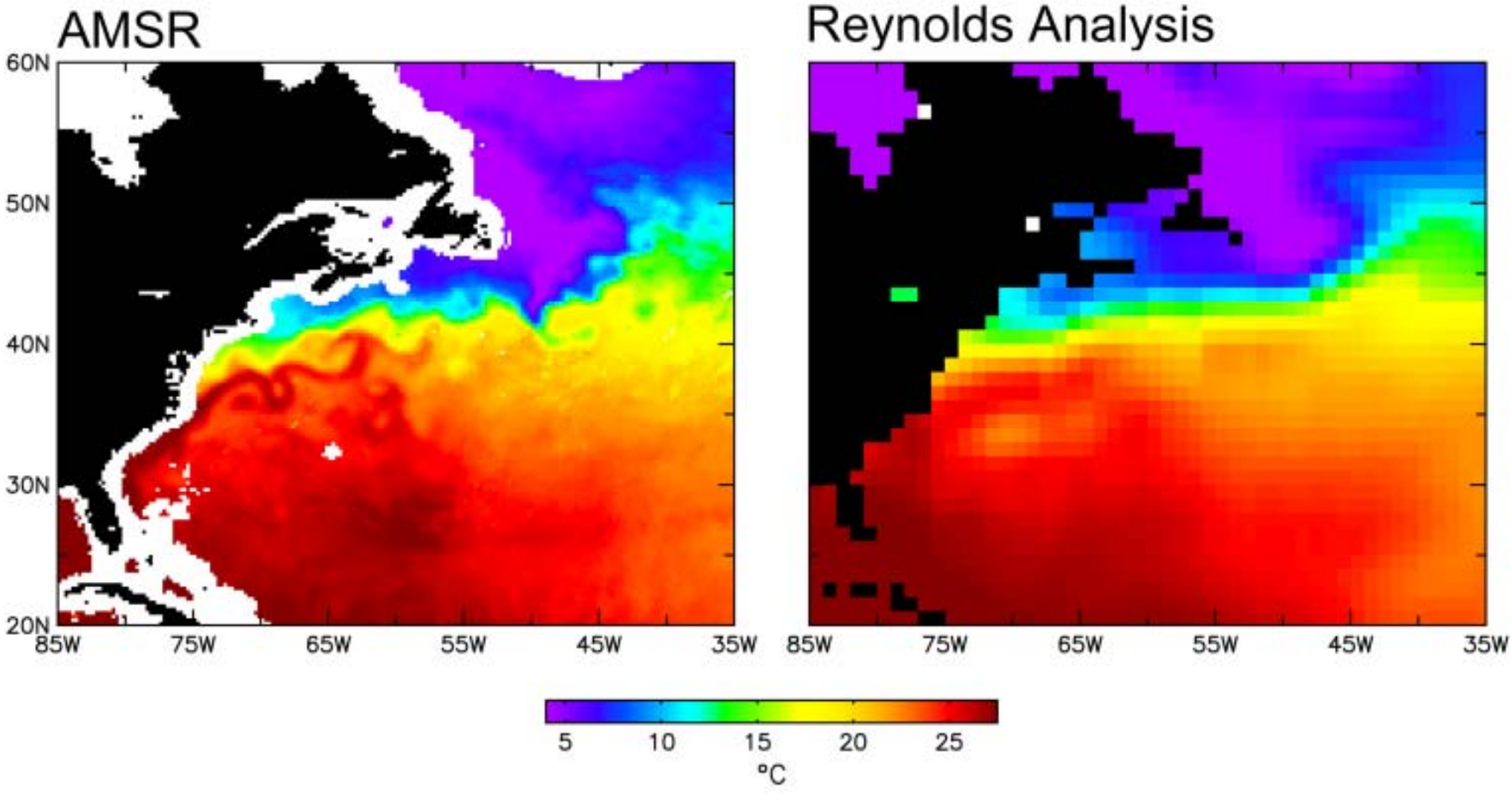


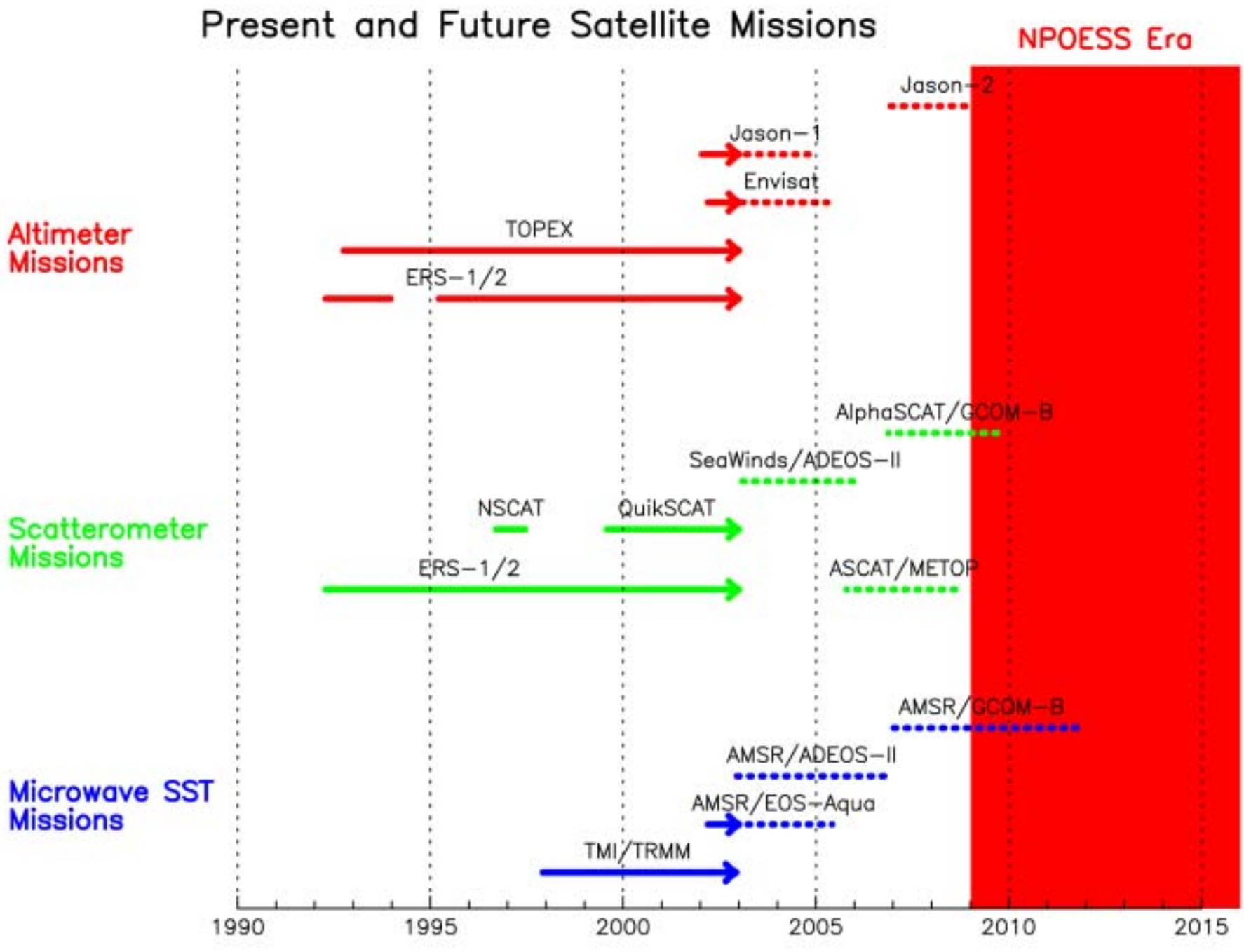
Advanced Microwave Scanning Radiometer (AMSR)





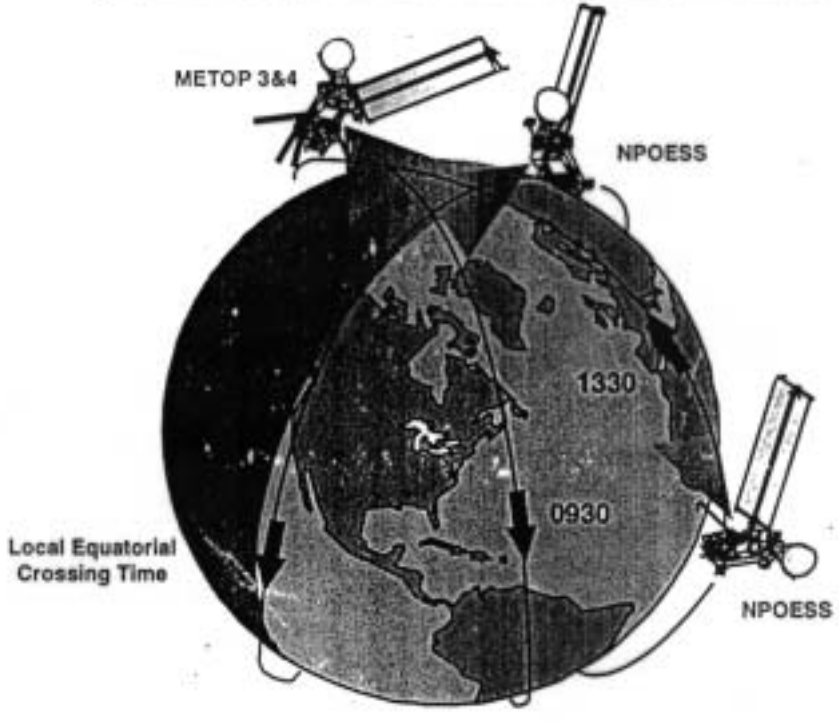
Sea Surface Temperature, 11-13 June 2002




Present and Future Satellite Missions
NPOESS Era
Jason-2
Jason-1
Envisat
Altimeter Missions
TOPEX
ERS-1/2
AlphaSCAT/GCOM-B
SeaWinds/ADEOS-II
NSCAT
QuikSCAT
Scatterometer Missions
ERS-1/2
ASCAT/METOP
AMSR/GCOM-B
AMSR/ADEOS-II
AMSR/EOS-Aqua
Microwave SST Missions
TMI/TRMM
1990
1995
2000
2005
2010
2015

NPOESS

National Polar-orbiting Operational Environmental Satellite System



A Tri-Agency, International Effort to Leverage and Combine Environmental Satellite Activities

Mission Statement

To provide a single, national, polar remote-sensing capability to acquire, receive and disseminate global and regional environmental data

To achieve National Performance Review (NPR) cost savings through the convergence of DoD and NOAA environmental satellite programs

To incorporate, where appropriate, technology transition from NASA's Mission to Planet Earth (MTPE)

A Symptom of the Concern About NPOESS

From the NPOESS Requirements Document, February 2000:

4.1.6.6.10 Surface Wind Stress (DOC/DoD). The frictional stress of the wind acting on the sea surface, causing it to move as a wind-drift current, and causing the formation of waves.

Systems Capabilities	Thresholds	Objectives
a. Horizontal Resolution	50 km	20 km
b. Mapping Accuracy	7 km	10 km
c. Measurement Range	0 to 50 N/m^2	0 to 50 N/m^2
d. Measurement Precision	2 N/m^2	1 N/m^2
e. Measurement Accuracy	± 2 N/m^2	± 1 N/m^2
f. Refresh	12 hours	12 hours

From the NPOESS Requirements Document, November 2002:

4.1.6.6.9 Global Sea Surface Wind Stress (DOC/DoD). The frictional stress of the wind acting on the sea surface, causing it to move as a wind-drift current, and causing the formation of waves. The requirements below apply under both clear and cloudy conditions.

Systems Capabilities	Thresholds	Objectives
a. Horizontal Cell Size	20 km	1 km
b. Mapping Uncertainty	5 km	1 km
c. Measurement Range	0 to 2 $N\ m^{-2}$	0 to 10 $N\ m^{-2}$
d. Measurement Precision	0.02 $N\ m^{-2}$	0.01 $N\ m^{-2}$
e. Measurement Accuracy	0.02 $N\ m^{-2}$	0.01 $N\ m^{-2}$
f. Refresh	8 hours	1 hour

Where is the Requirement for Wind Direction?!!

Conclusions

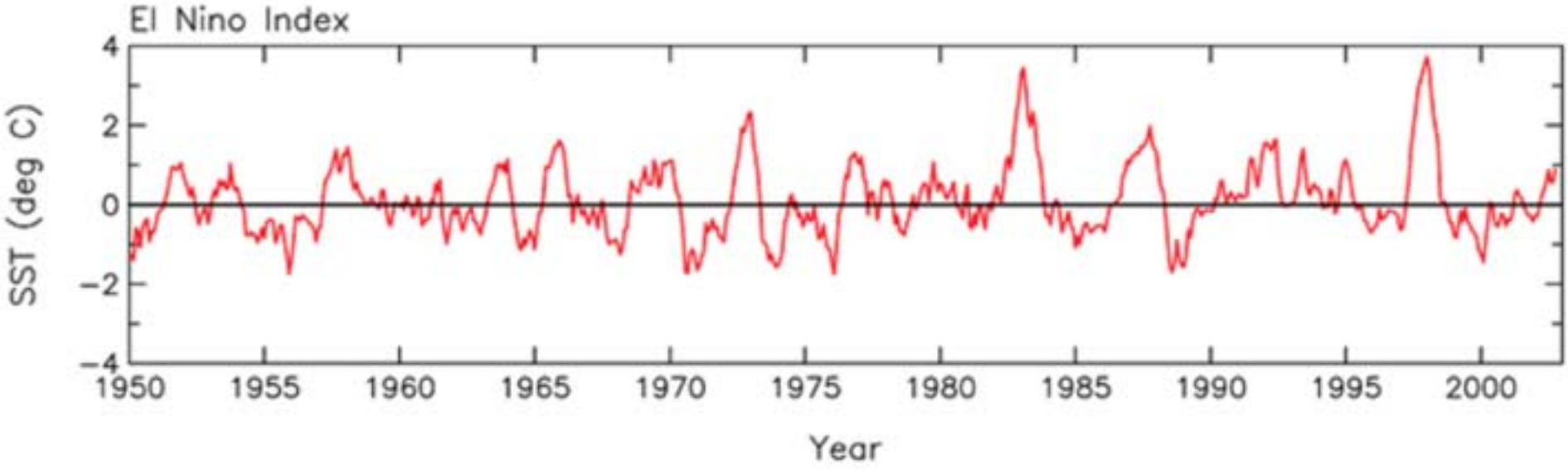
- *“Satellites constitute the most important technology innovation in modern times. ... The most important satellite contribution is not the instrument packages ... but the ability to sample the global ocean and to sample it adequately in x,y-space...”*

  - Walter Munk, 2002 (Oceanography Magazine, Vol. 15., No. 1)

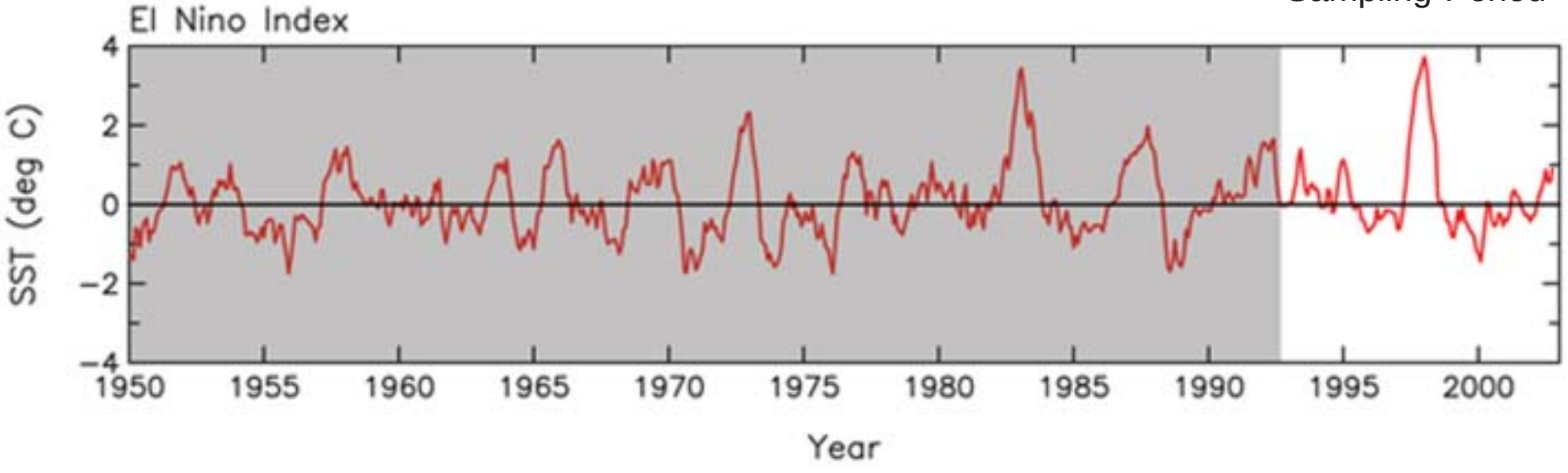
- *The unique global perspective, high spatial resolution, and frequent sampling provided by satellite observations are essential for observational studies of global ocean circulation.*

- *Satellite data provide the necessary forcing and observational constraints for accurate 4-dimensional modeling of the global ocean circulation.*

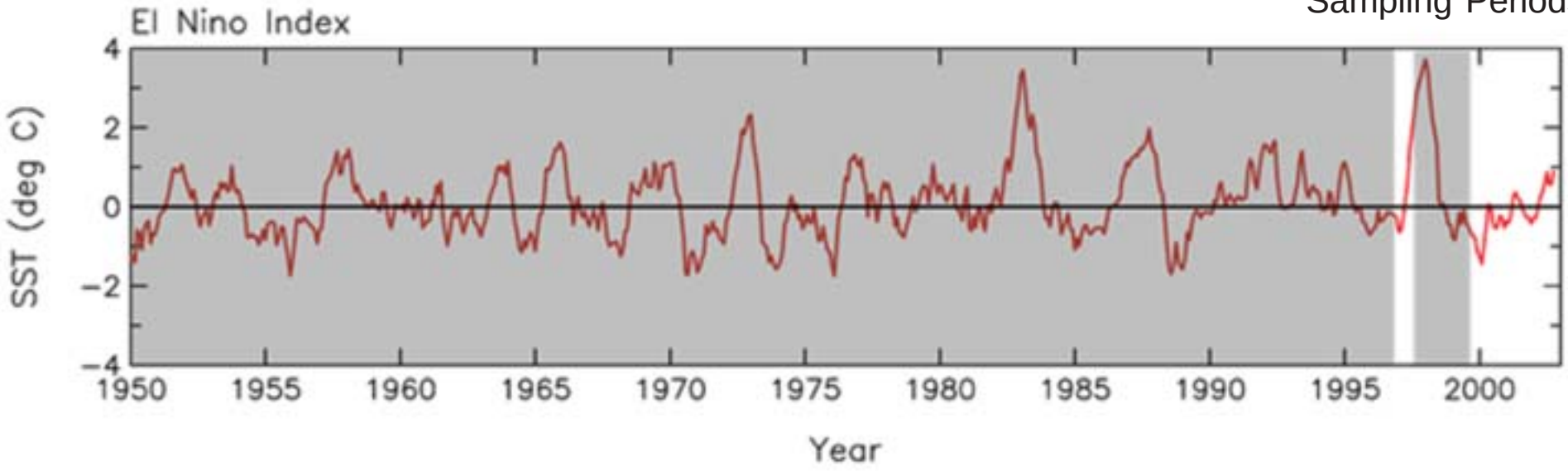
- *The 10-year TOPEX/Poseidon altimeter mission has demonstrated the need for highly accurate measurements and a long data record.*


El Nino Index
SST (deg C)
4
2
0
−2
−4
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year

TOPEX/POSEIDON
Sampling Period



NSCAT and QuikSCAT
Sampling Periods



Challenge for the Future:

Sustaining continuous records of high-quality satellite observations for climate research.

- Climate time scales are much longer than individual satellite missions.
- Satellite observations for ocean climate studies must therefore be acquired from operational satellite programs. (NPOESS???)
- The links between the oceans research community and the various national space agencies must be strengthened to assure the quality and long-term continuity of satellite observations.
- These links must be formalized soon...the time from conception to launch of a satellite instrument is about 10 years.