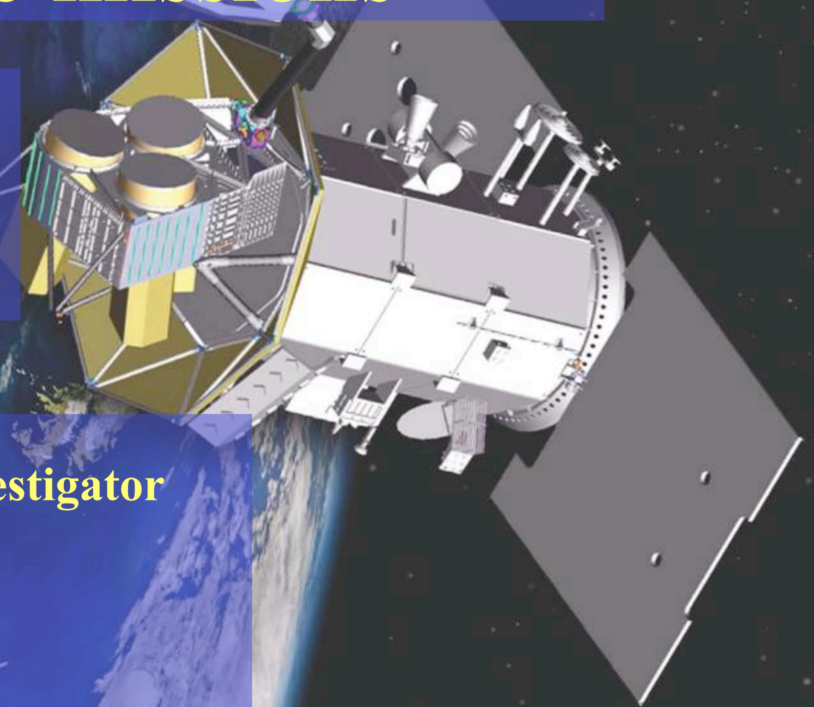
National Aeronautics and Space Administration

# Linking ocean circulation, the water cycle and climate: New science opportunities with salinity satellite missions

**OSTST Meeting**
**23 June 2008**
**Seattle**




**Gary Lagerloef**
***Aquarius* Principal Investigator**

**Jonathan Lilly (ESR)**
**Kathleen Dohan (ESR)**
**John Gunn (ESR)**

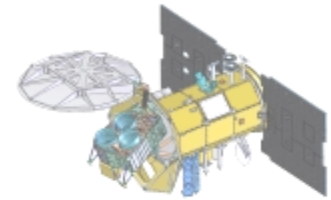

Understanding the Interaction Between Ocean Circulation, the Water Cycle, and Climate by Measuring Ocean Salinity

Aquarius/SAC-D

CONAE • GSFC • JPL

www.nasa.gov

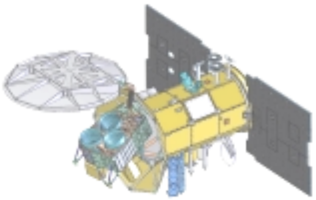
# Outline



1. Some information about the SMOS and Aquarius/SAC-D salinity missions

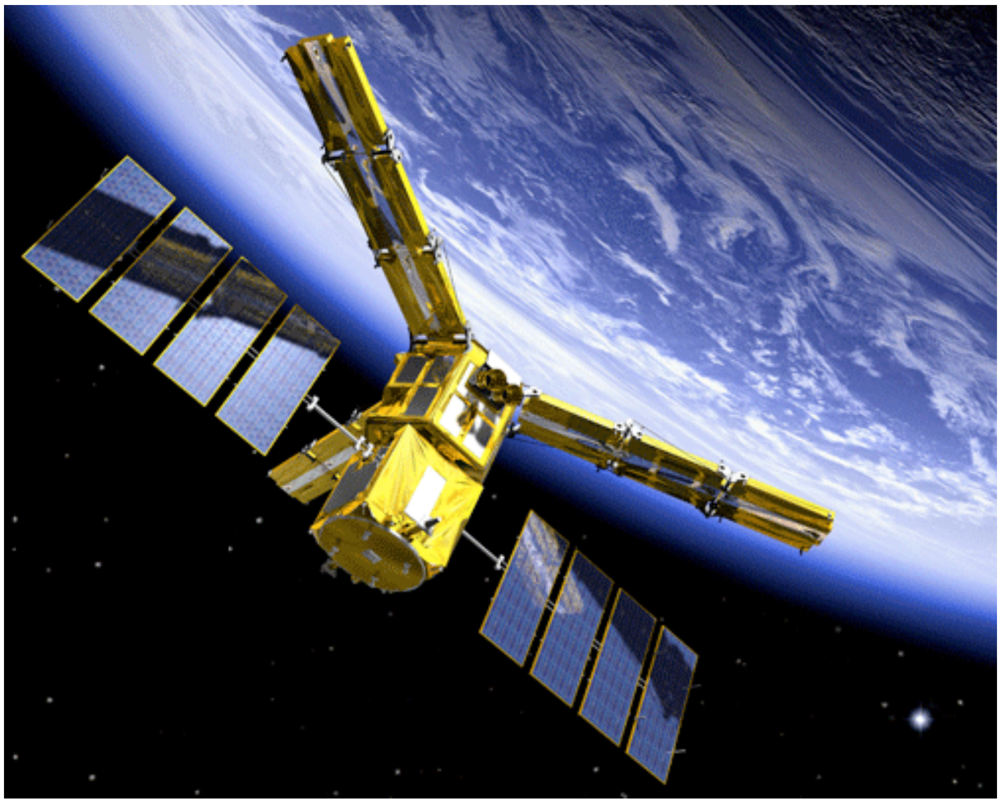
2. Some “big picture’ science

3. Preliminary salt balance estimates using surface currents and proxy  SSS data from Argo

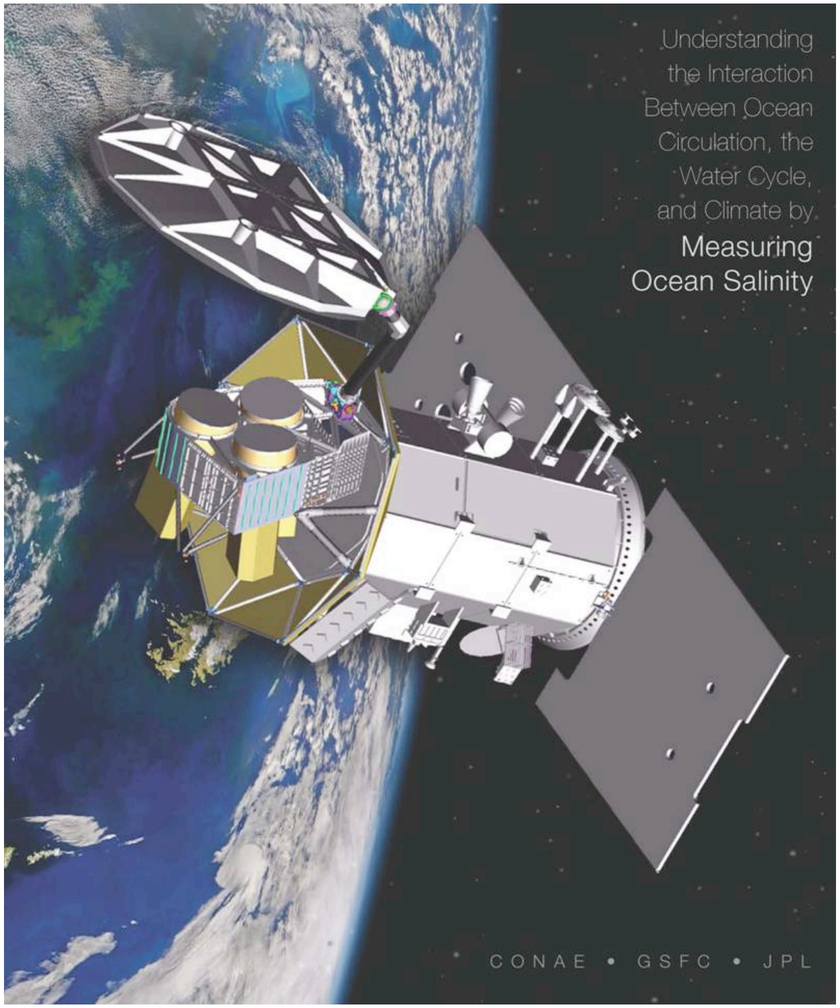


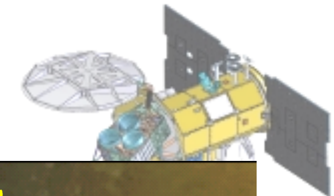
# Two Salinity Missions

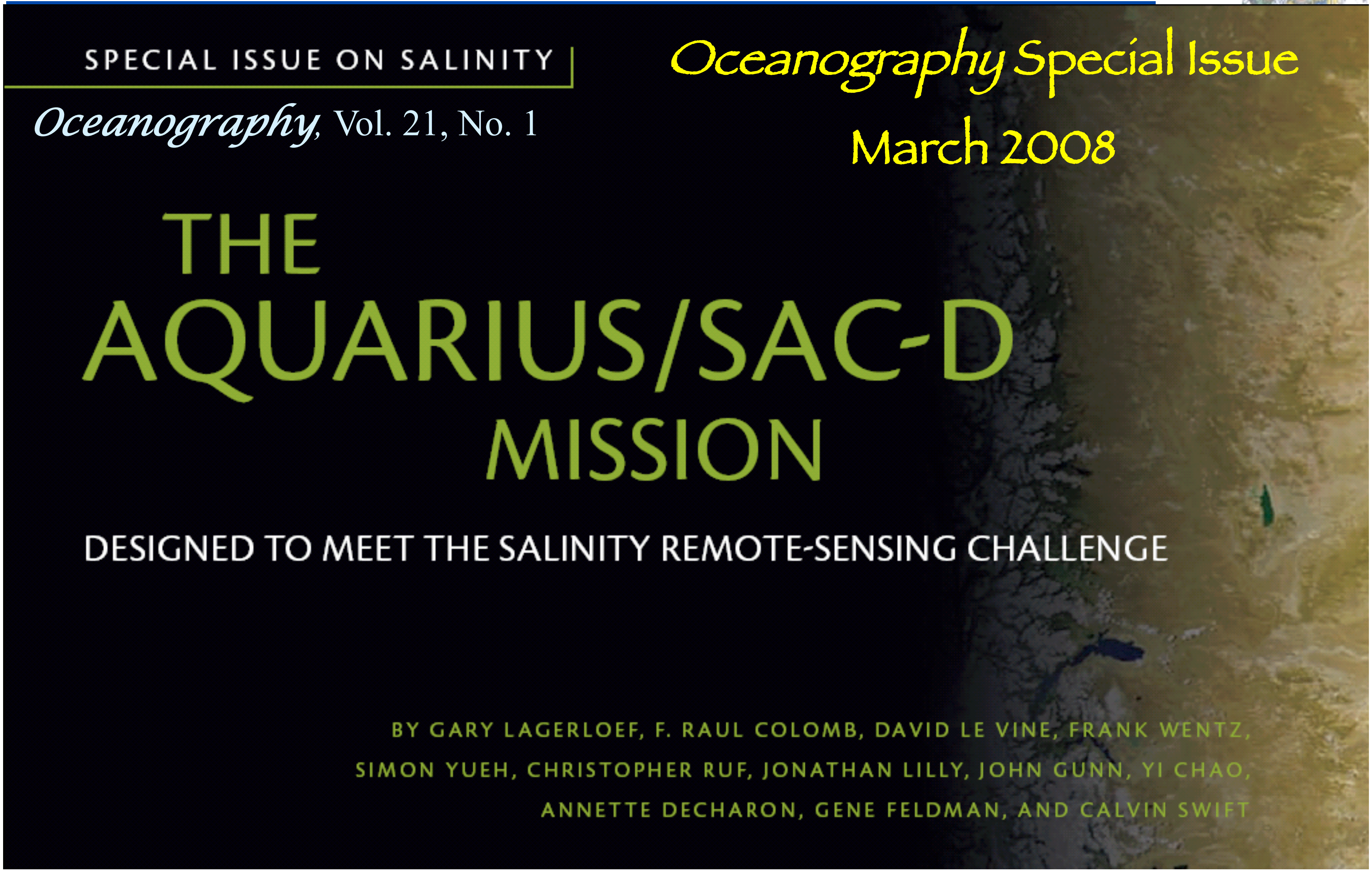
SMOS Lunch Fall 2009



Aquarius/SAC-D Lunch mid-late 2010






SPECIAL ISSUE ON SALINITY

*Oceanography*, Vol. 21, No. 1

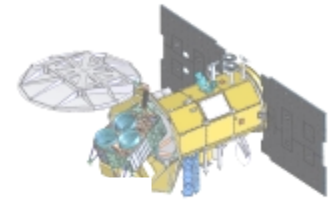
Oceanography Special Issue
March 2008

# THE AQUARIUS/SAC-D MISSION

DESIGNED TO MEET THE SALINITY REMOTE-SENSING CHALLENGE

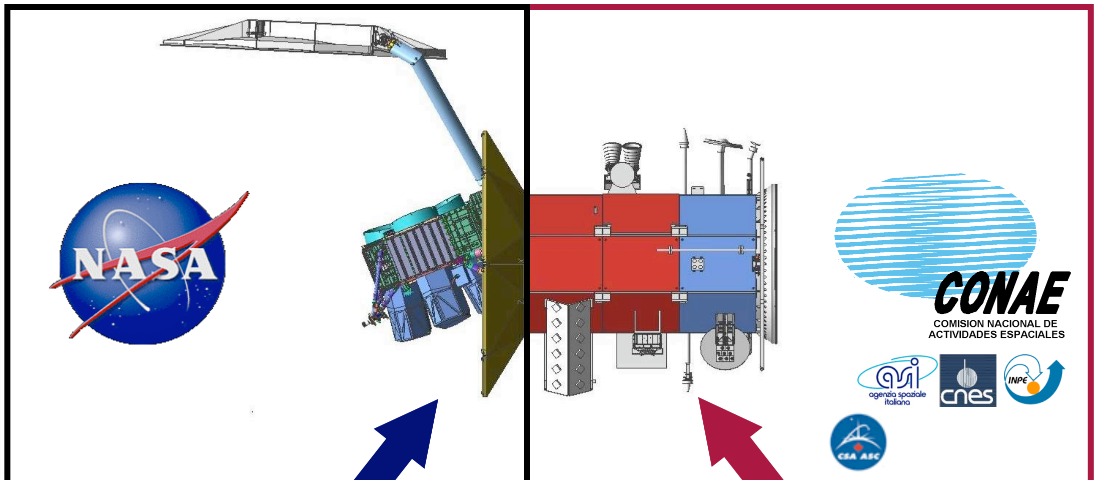
BY GARY LAGERLOEF, F. RAUL COLOMB, DAVID LE VINE, FRANK WENTZ, SIMON YUEH, CHRISTOPHER RUF, JONATHAN LILLY, JOHN GUNN, YI CHAO, ANNETTE DECHARON, GENE FELDMAN, AND CALVIN SWIFT

# Aquarius/SAC-D Observatory



## International Partnership between United States – Argentina

INVAP

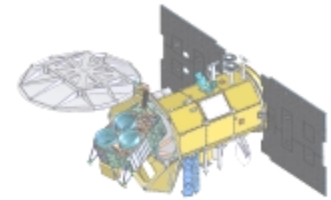




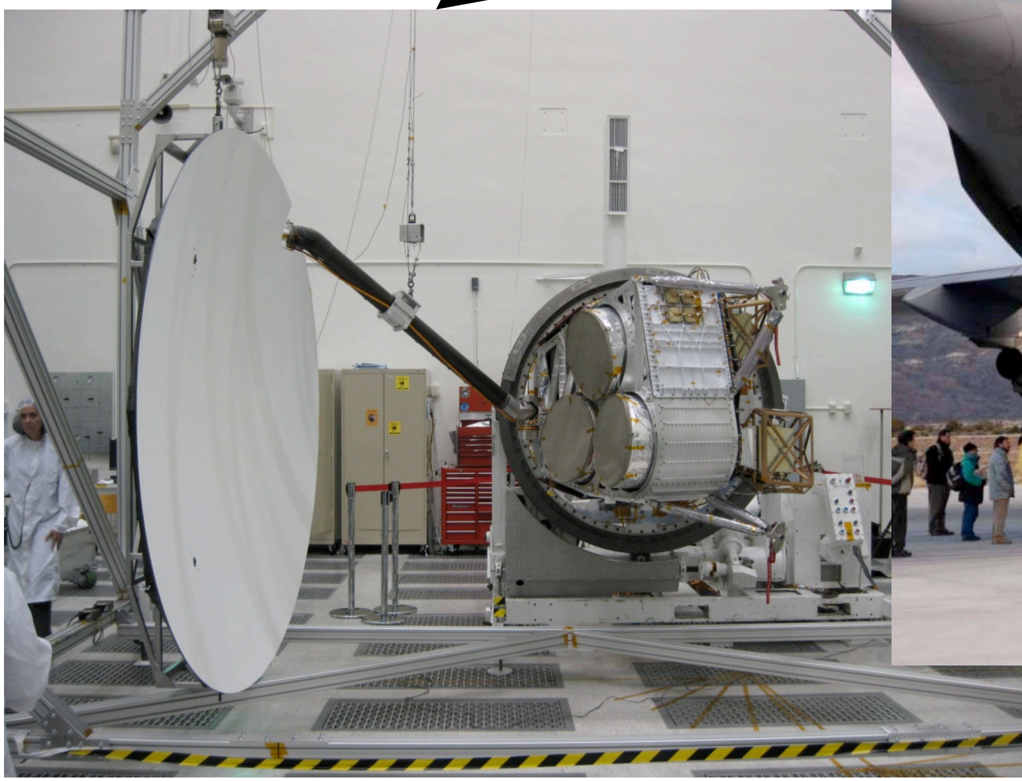
- Aquarius Salinity Microwave Instrument
- Launch Vehicle

- Service Platform and SAC-D Science Instruments
- Mission Operations & Ground System

# Aquarius Instrument Completed and Delivered



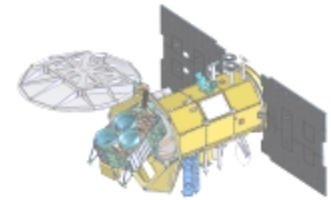
1. Deployment test complete (10 November 2008)
2. Arrival in shipping container to Bariloche Argentina (3 June 2009)



AQUARIUS/SAC-D

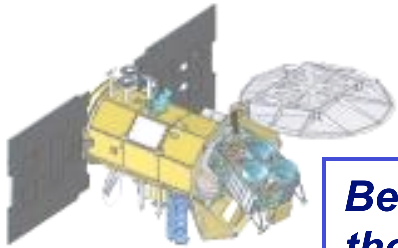
Salinity Satellite Mission

# Mission Design and Sampling Strategy



***Sun-synchronous exact repeat orbit***
***6pm ascending node***
***Altitude 657 km***

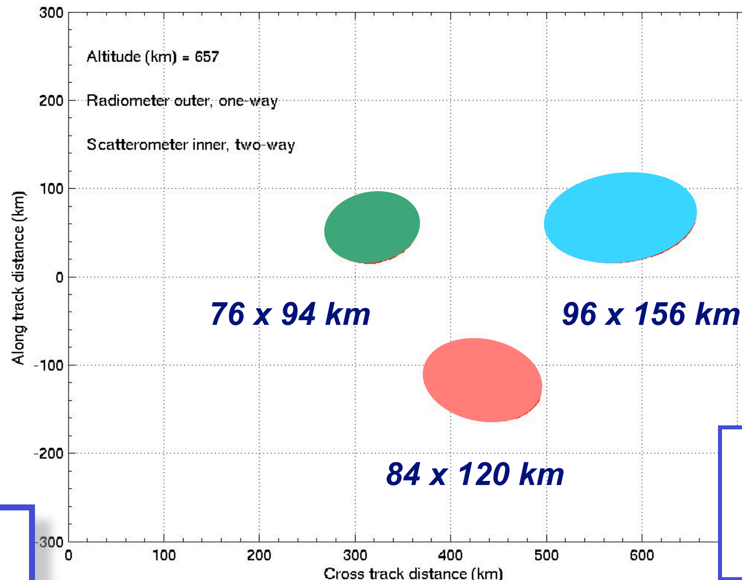
- ***Global Coverage in 7 Days***
- ***4 Repeat Cycles per Month***

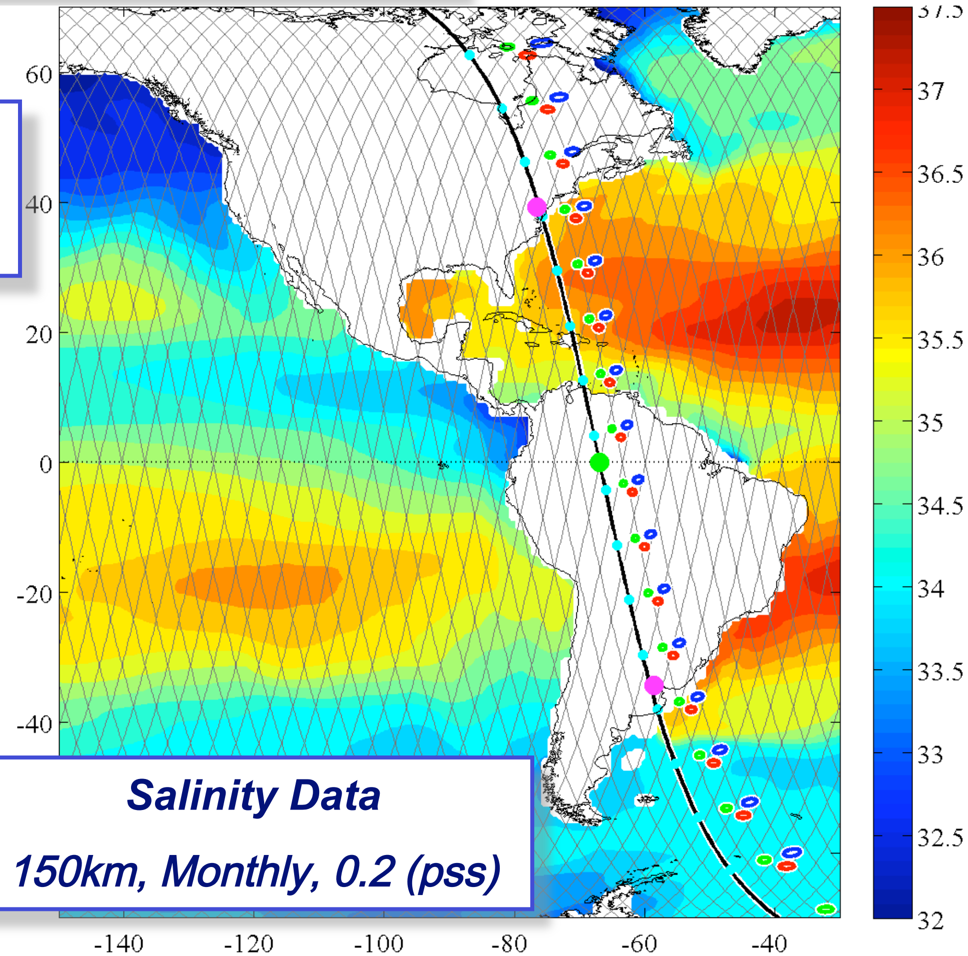


***Beams point toward the night side to avoid sun glint***

In Orbit Check out

***3 beams 390 km wide swath.***



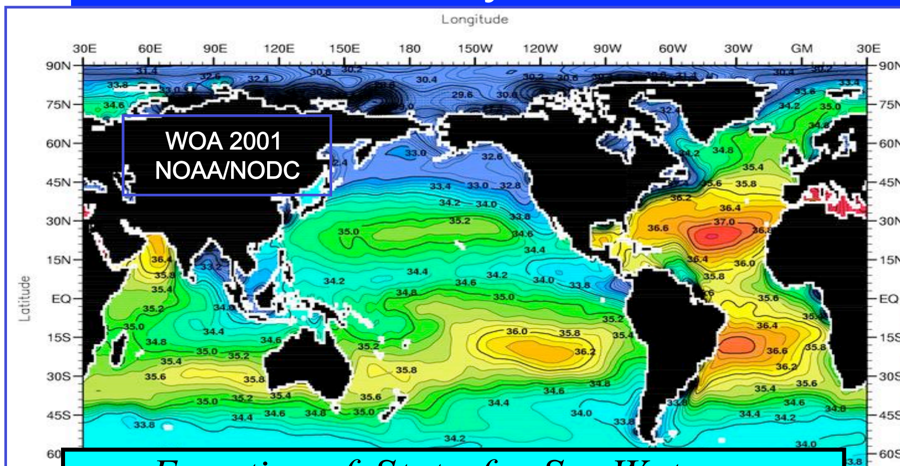

***Salinity Data***

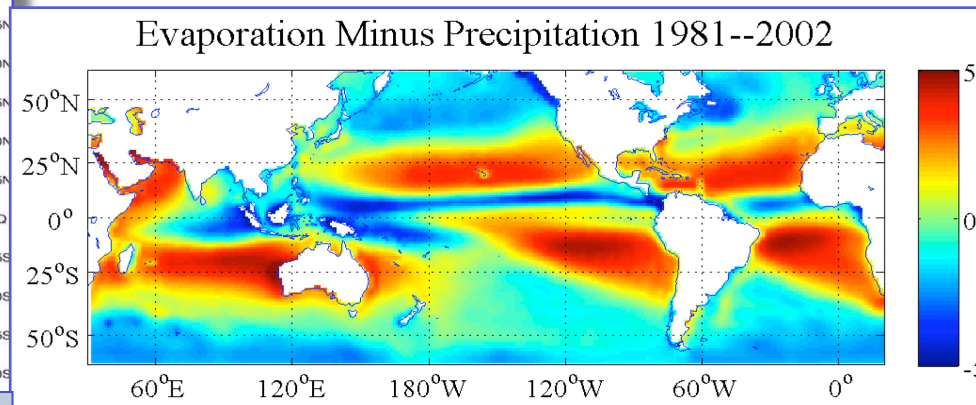
***150km, Monthly, 0.2 (pss)***

Launch 2010

# Aquarius Mission Science

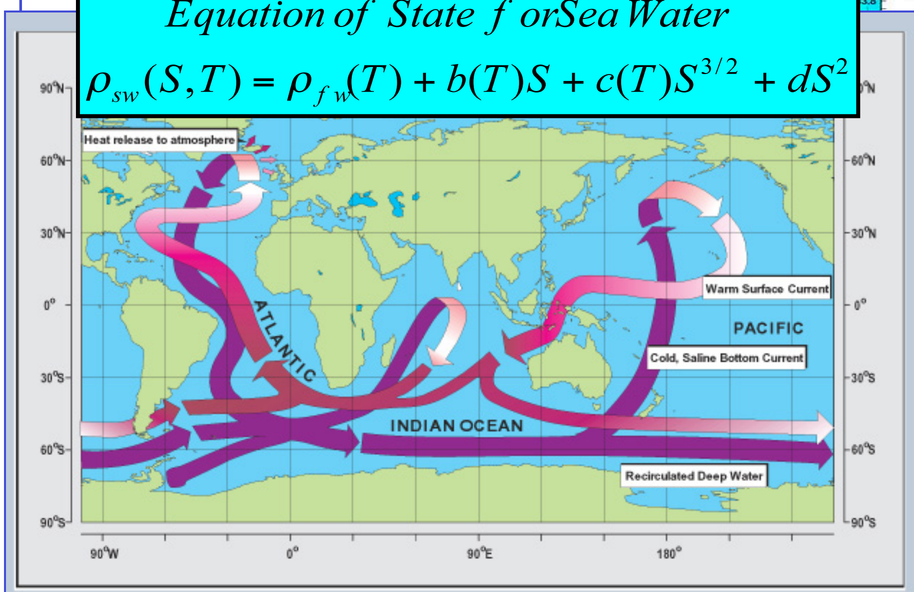
## Understanding the Interactions Between the Ocean Circulation, Global Water Cycle and Climate by Measuring Sea Surface Salinity




*Equation of State for Sea Water*

$$\rho_{sw}(S,T) = \rho_{fw}(T) + b(T)S + c(T)S^{3/2} + dS^2$$



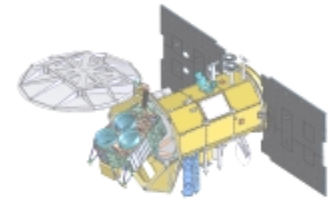

Global salinity patterns are linked to rainfall and evaporation

Salinity affects seawater density, which in turn governs ocean circulation and climate

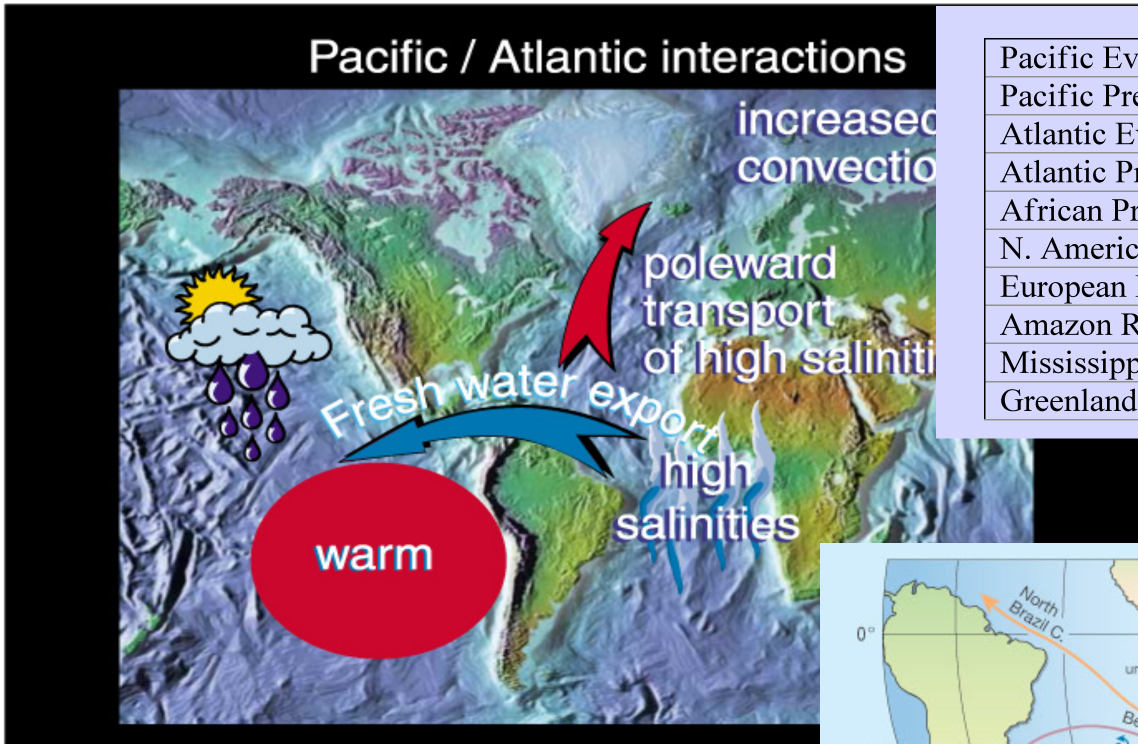
The higher salinity of the Atlantic sustains the oceanic deep overturning circulation

Salinity variations are driven by precipitation, evaporation, runoff and ice freezing and melting

# Salinity and Ocean Circulation



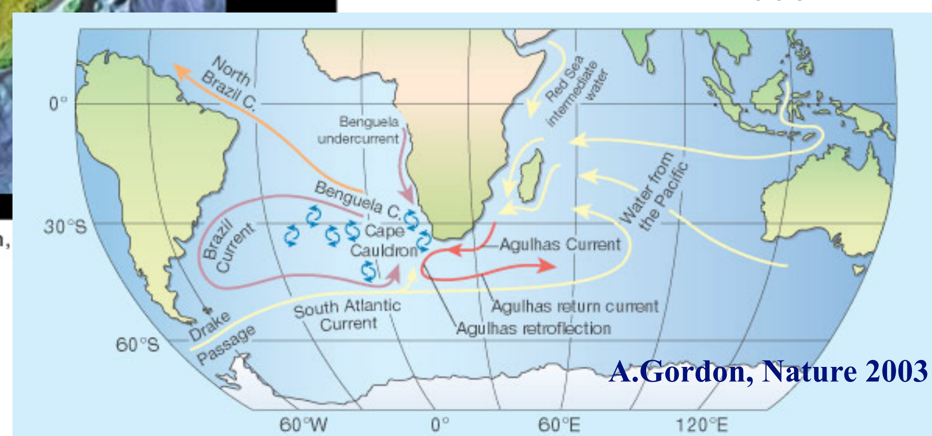
## An atmospheric freshwater conveyor and inter-basin salt exchanges help sustain the Atlantic salt balance that sustains the ocean conveyor




Mechanism of Pacific - Atlantic Interactions on multi-decadal time scales. From, 2001, 28, 538-542 **M. Latif, GRL 2001**

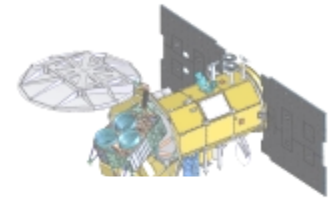
| | | |
|---|---|---|
| Pacific Evaporation | 212,655 km$^3$/yr | 6.74 Sv |
| Pacific Precipitation | 228,529 | 7.24 |
| Atlantic Evaporation | 111,085 | 3.52 |
| Atlantic Precipitation | 74,626 | 2.36 |
| African Precipitation | 20,743 | 0.66 |
| N. America Precipitation | 15,561 | 0.49 |
| European Precipitation | 6,587 | 0.21 |
| Amazon River Discharge | 6,000 | 0.19 |
| Mississippi River Discharge | 560 | 0.017 |
| Greenland Glacial Discharge* | 225 | 0.007 |

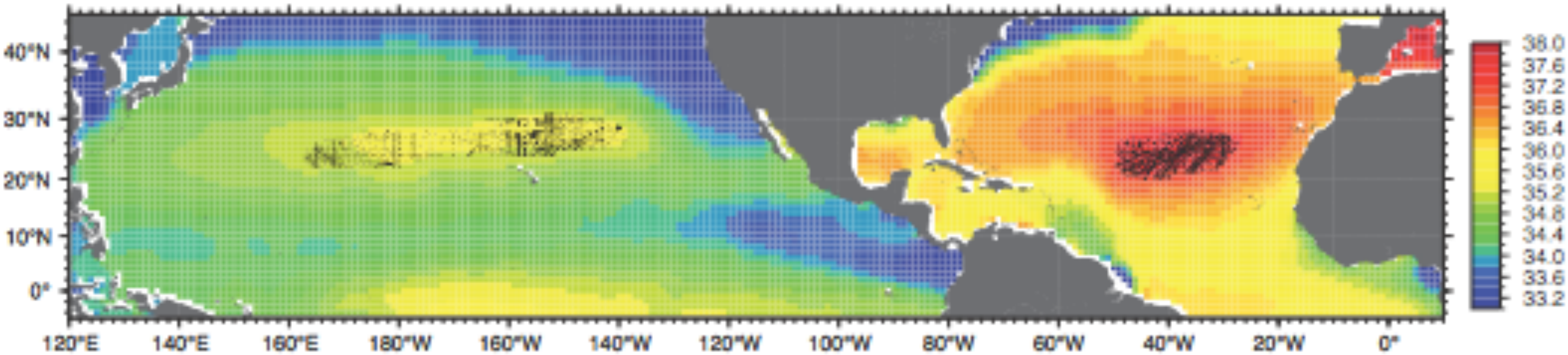
R.Schmitt, *Oceanography*, 2008

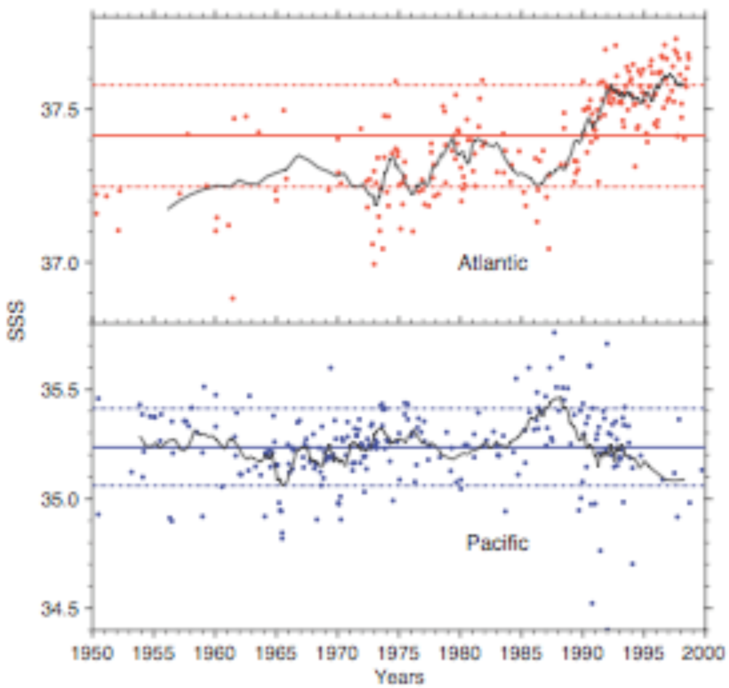


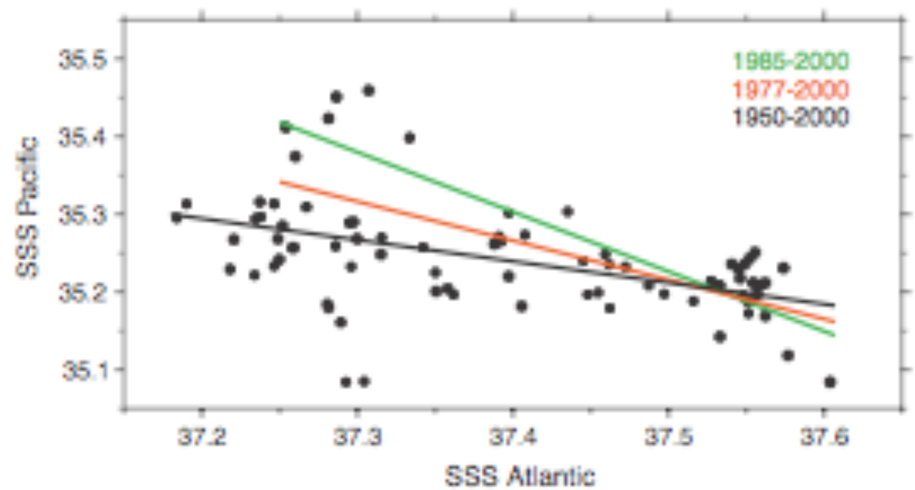

**A.Gordon, Nature 2003**

# Ocean Salinity Trends; Links to Water Cycle



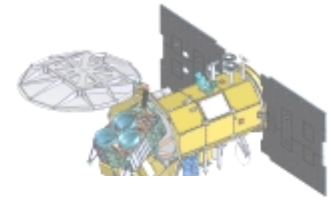


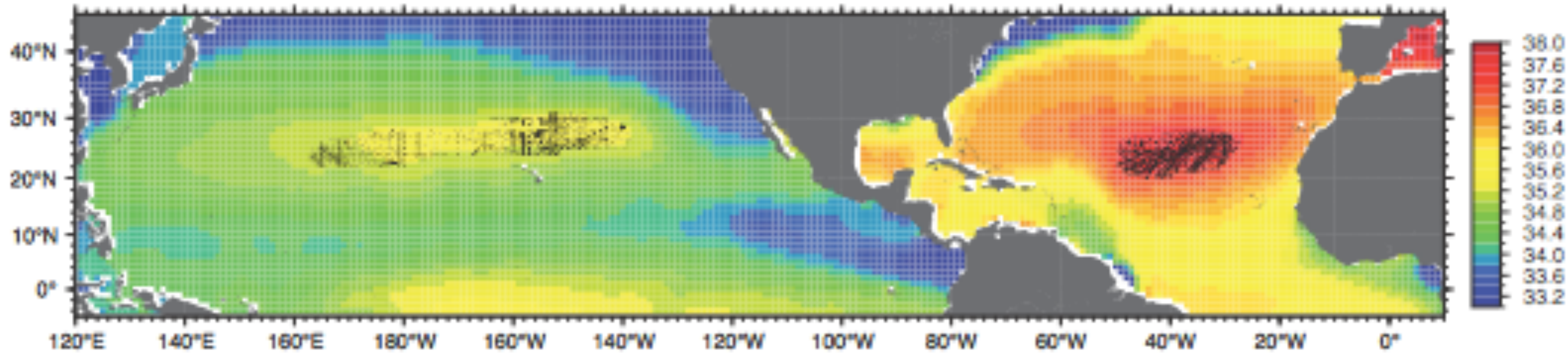



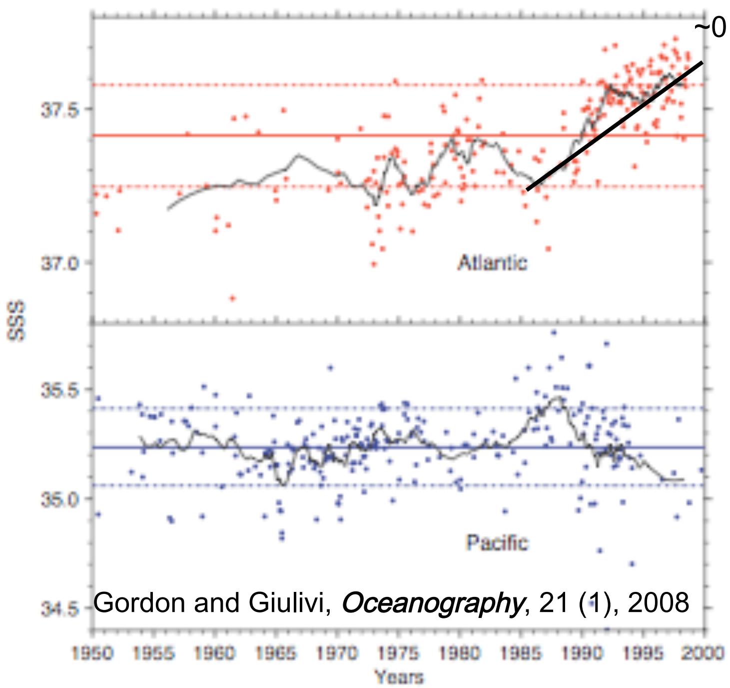




Gordon and Giulivi, *Oceanography*, 21 (1), 2008

# Ocean Salinity Trends; Links to Water Cycle





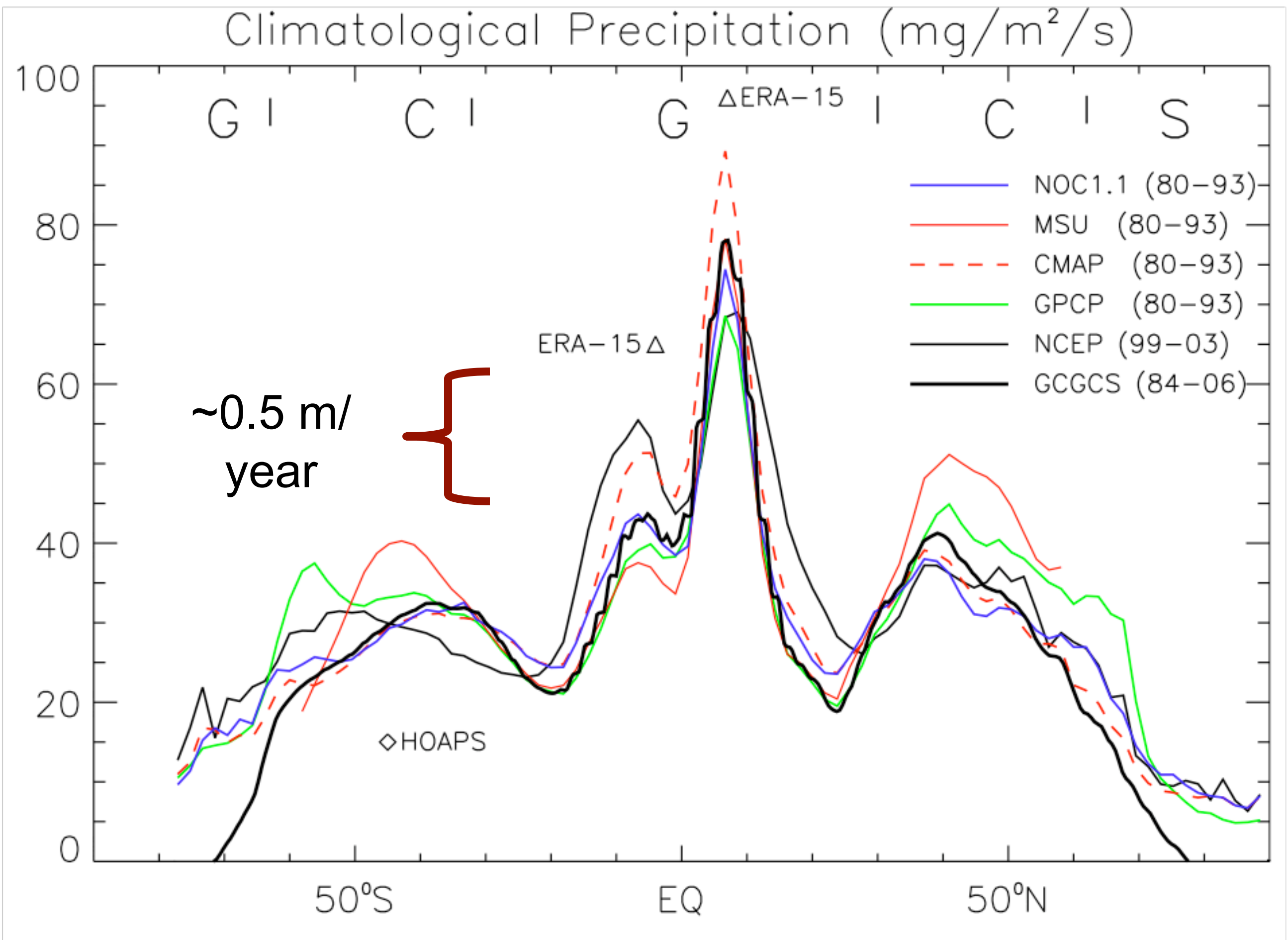

Gordon and Giulivi, *Oceanography*, 21 (1), 2008

Do these trends signify changes in the

- atmospheric branch of the hydrologic cycle?
- ocean circulation and salt transport?
- both ?

How well can we resolve either of these processes ?

# Uncertainty in the Global Precipitation Estimates




From Large and Yeager, 2008

The uncertainties in mean precipitation data sets are significant.

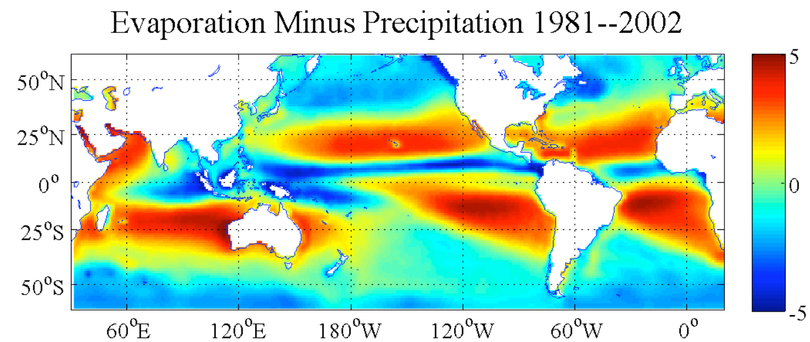
0.5 m/yr equates to 0.25 psu/yr for H=70m

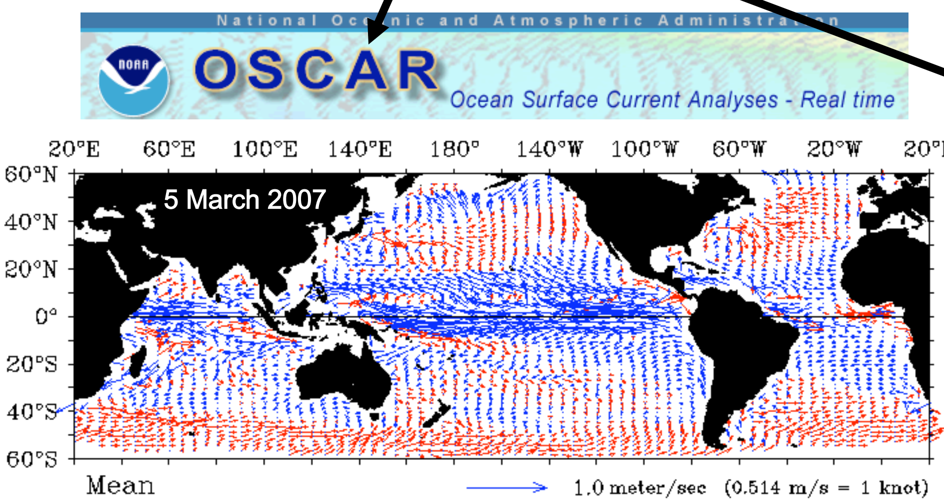
This is abut a factor of 10 greater than the observed SSS trends.

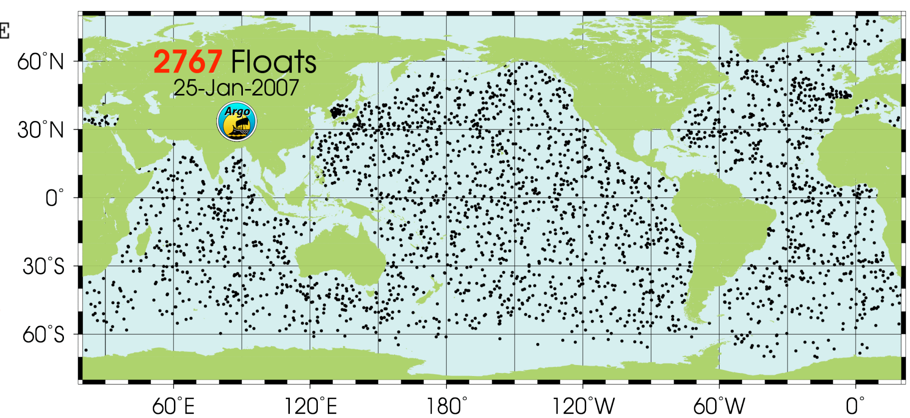
# The Remainder of this Talk

- To examine mean salt (SSS) advection and divergence
- Contrast with SST advection and divergence
- *Trial balance* with E-P net surface freshwater forcing

$U \cdot \nabla S \sim S(E-P)/H$

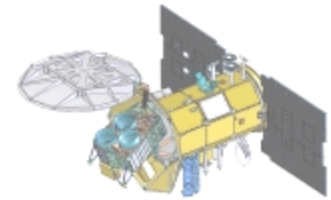


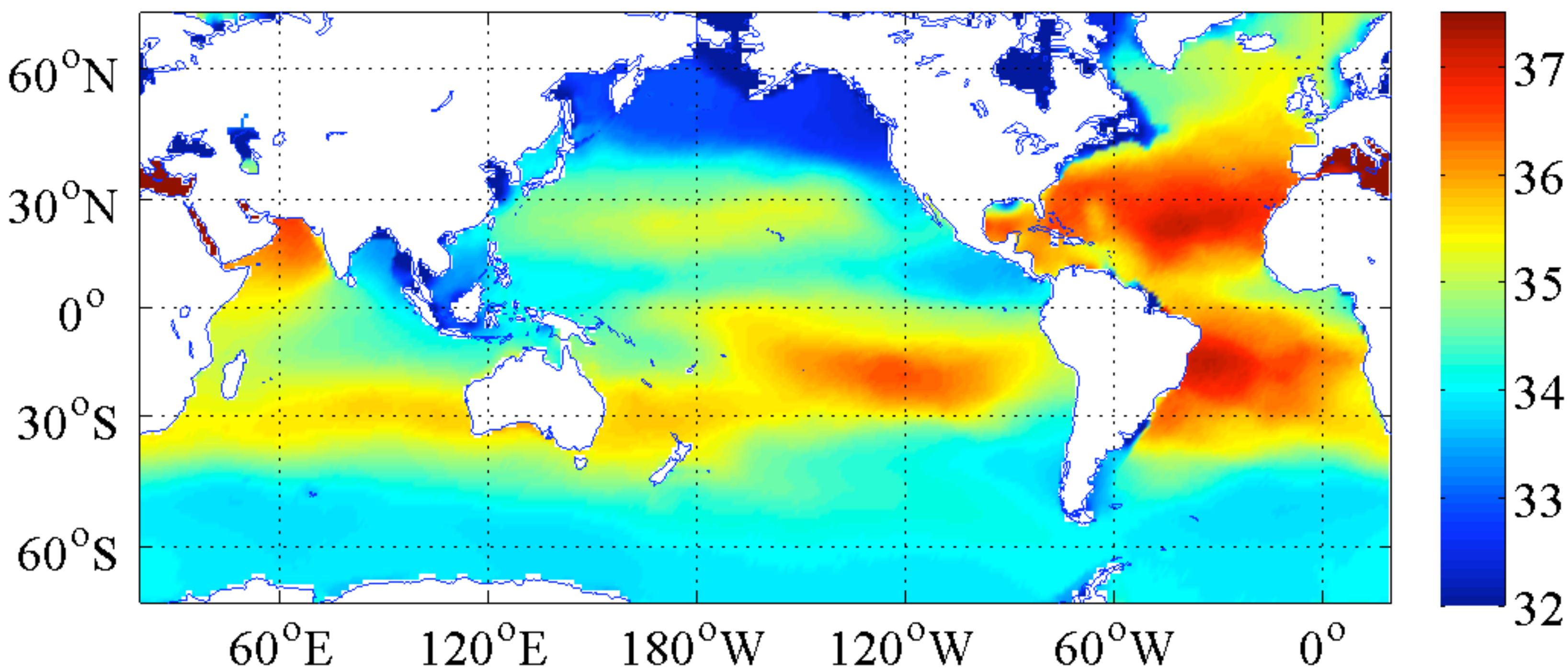




OSCAR = Geostrophic + Ekman @ 15m

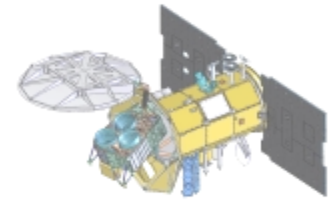
# Two Year Mean SSS from Argo Data

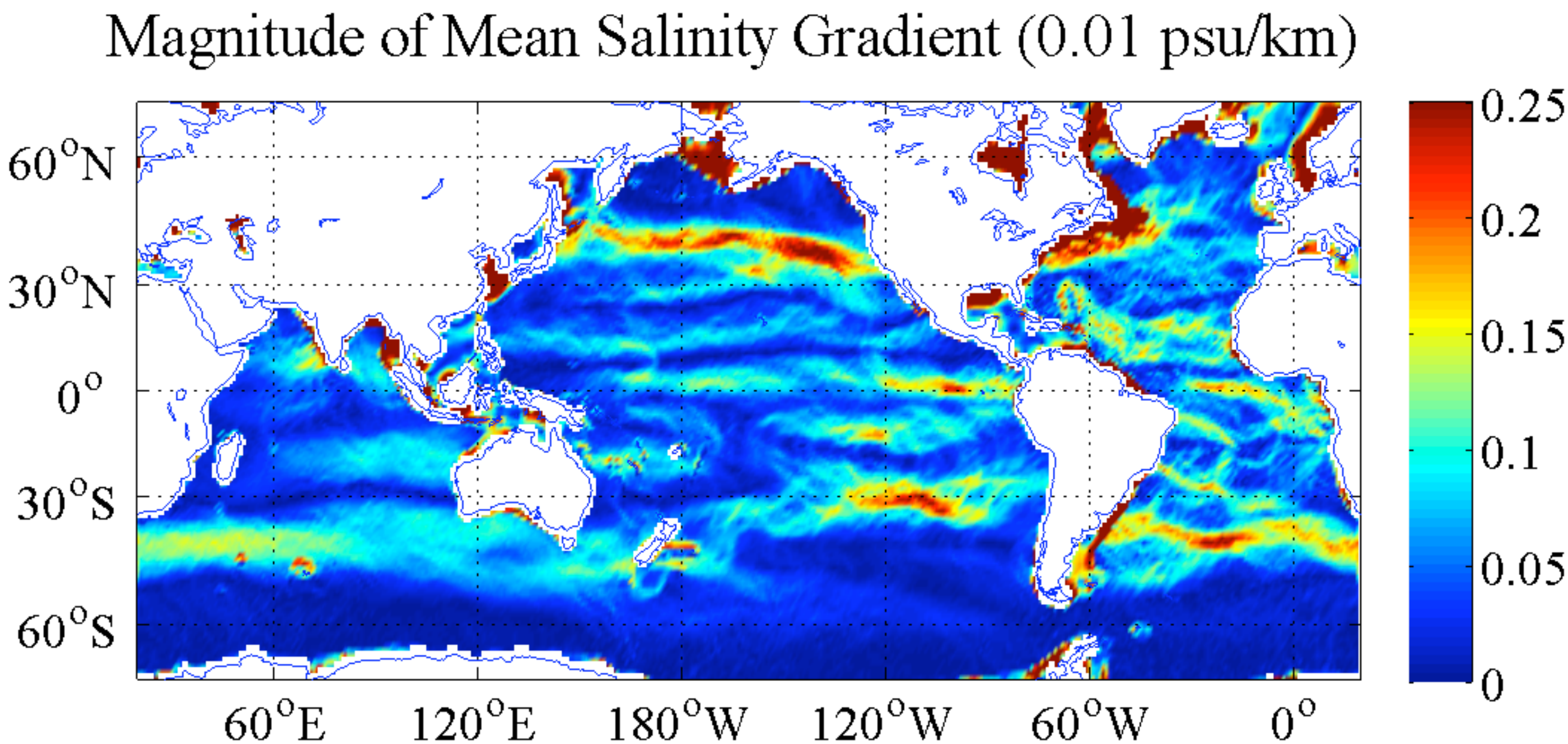


Mean Argo Sea Surface Salinity, 2006 & 2007

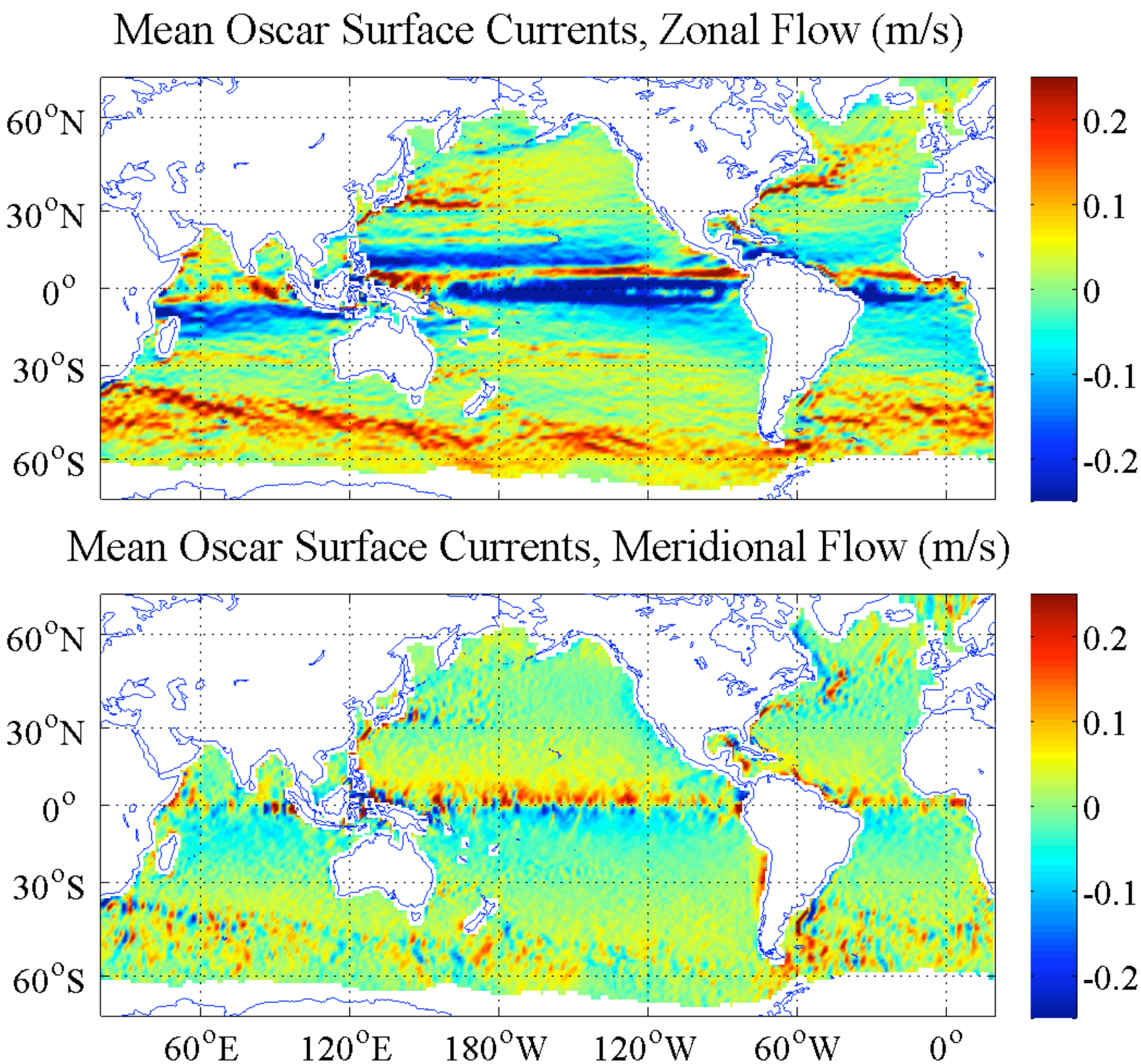


# Salinity Gradient Magnitude



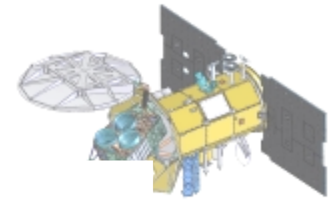


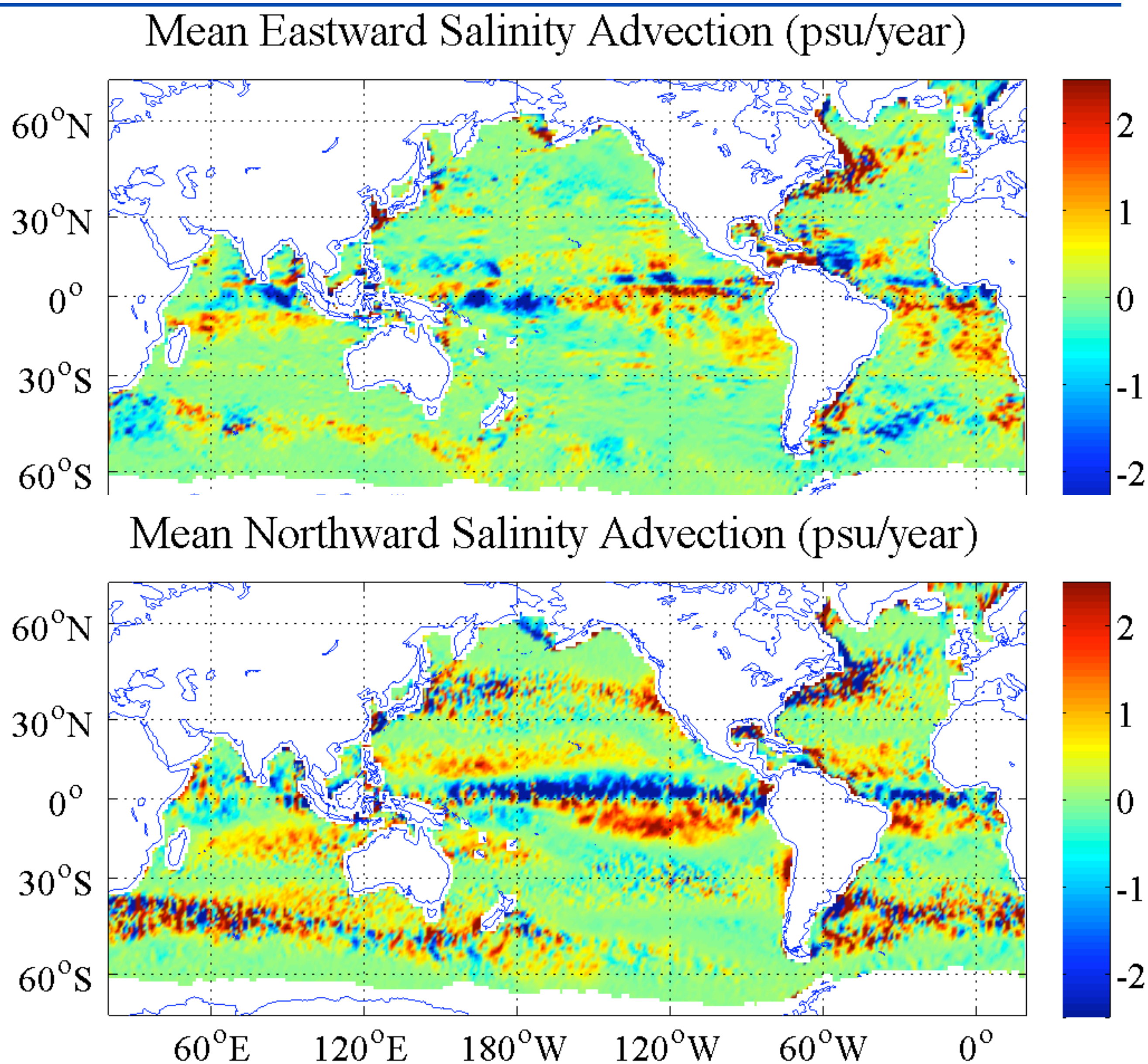
# Mean Velocity Components



AQUARIUS/SAC-D
Salinity Satellite Mission

# Salinity Advection Terms





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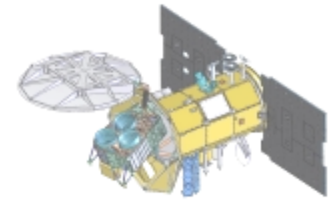
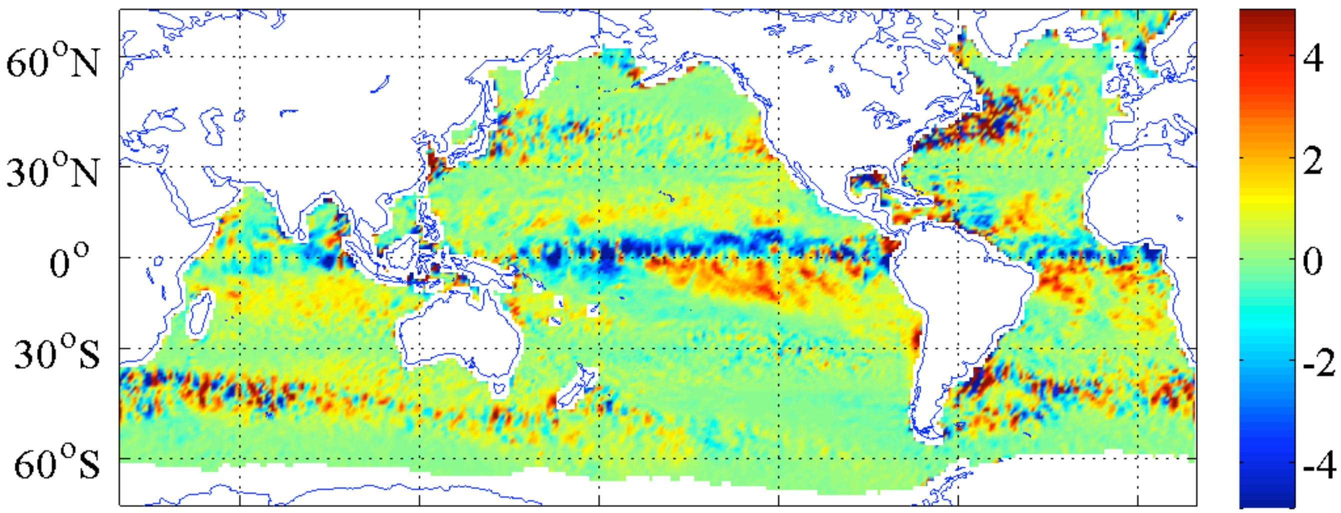


# Salinity Divergence Total

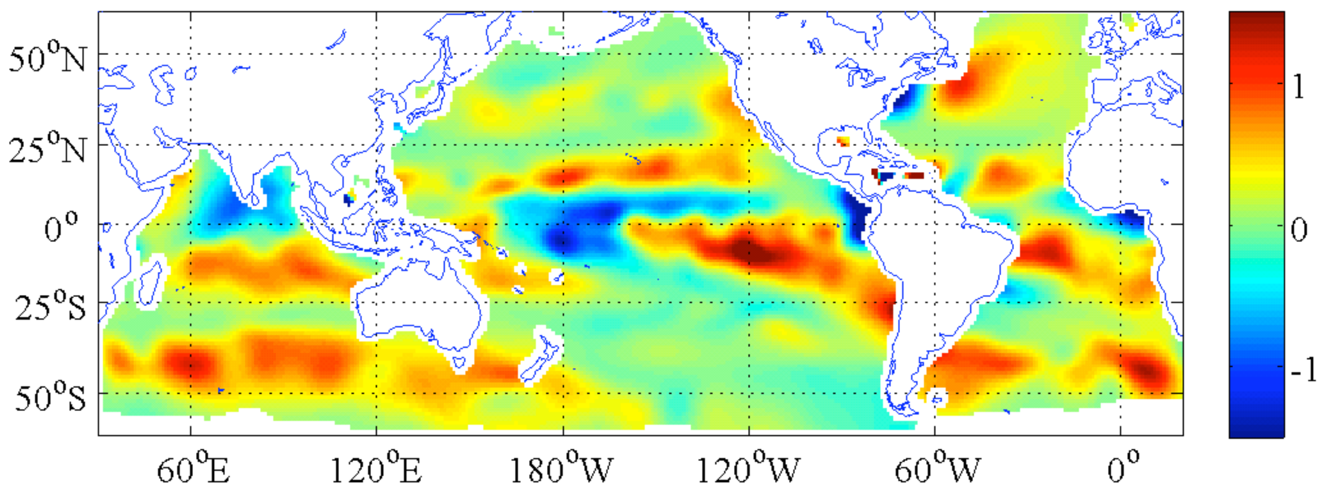
Mean Salinity Advection (psu/year)




U·∇S

psu · year$^{-1}$

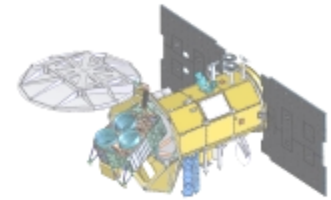
Salinity Advection 2005--2006



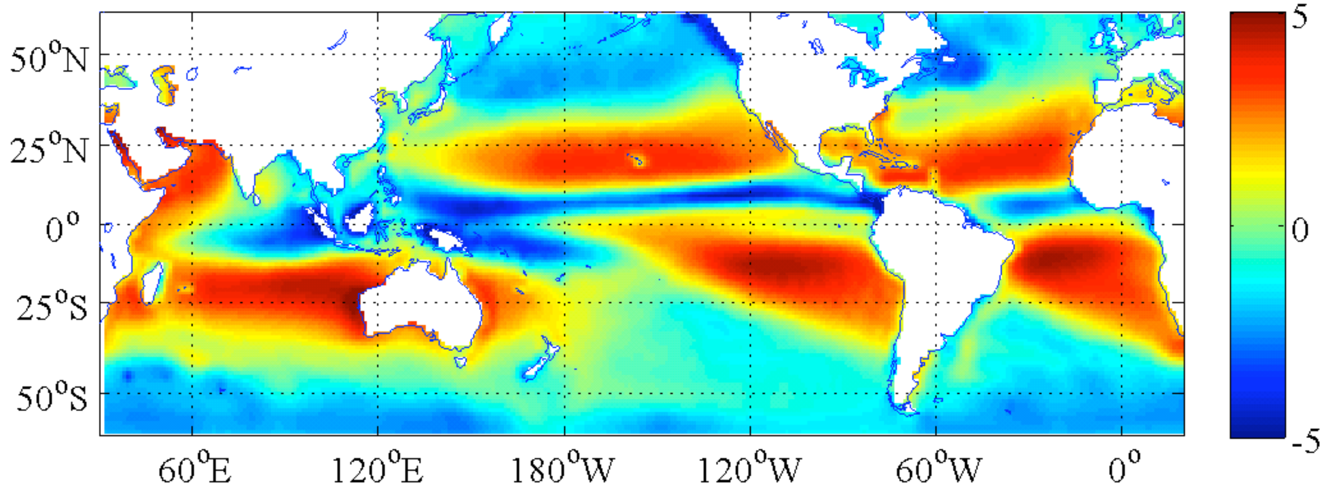

U·∇S

Smoothed

# Net Freshwater Flux



Evaporation Minus Precipitation 1981--2002

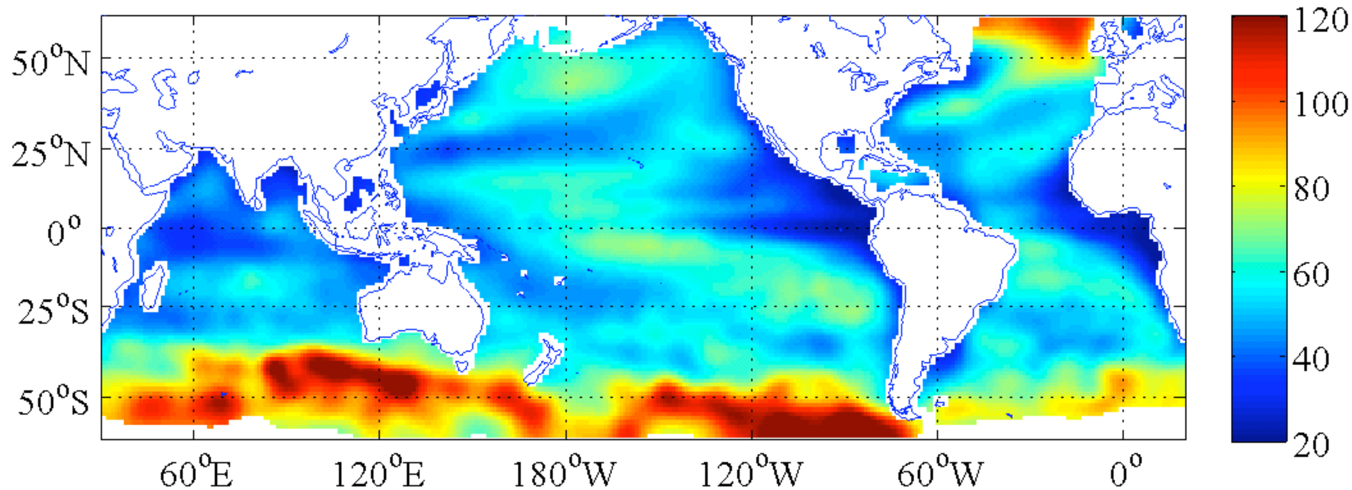



Precipitation (GPCP)

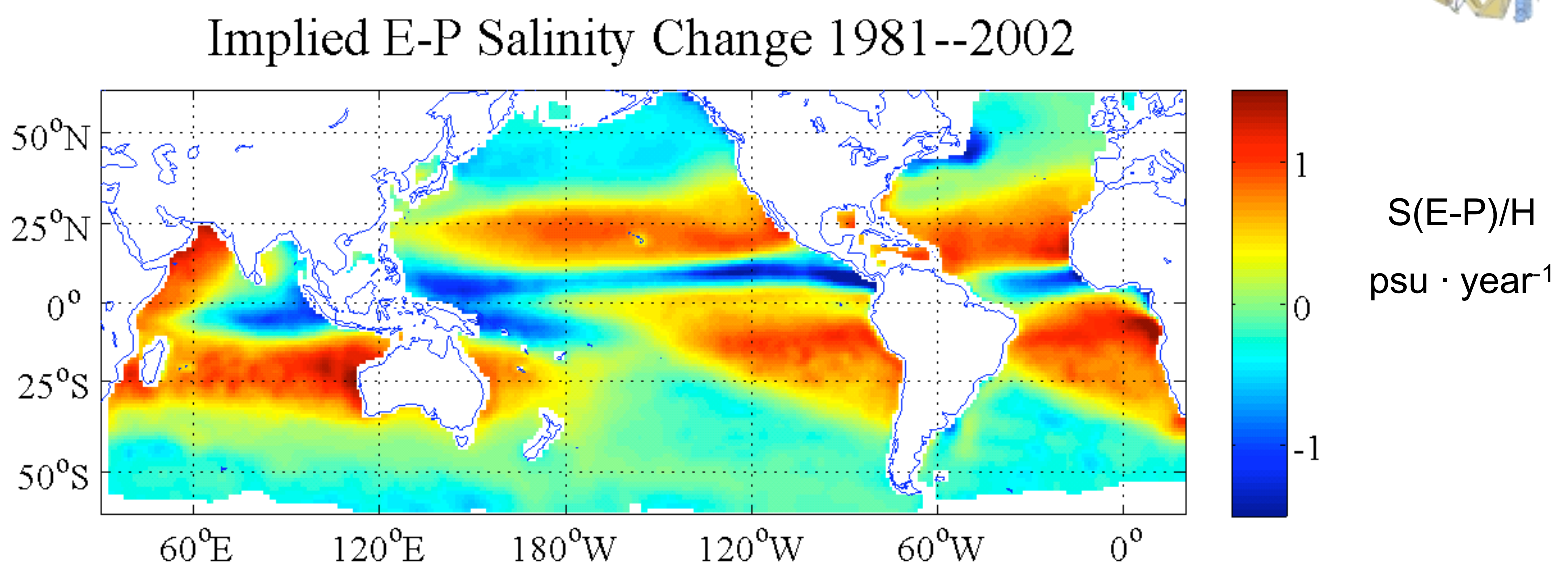
&

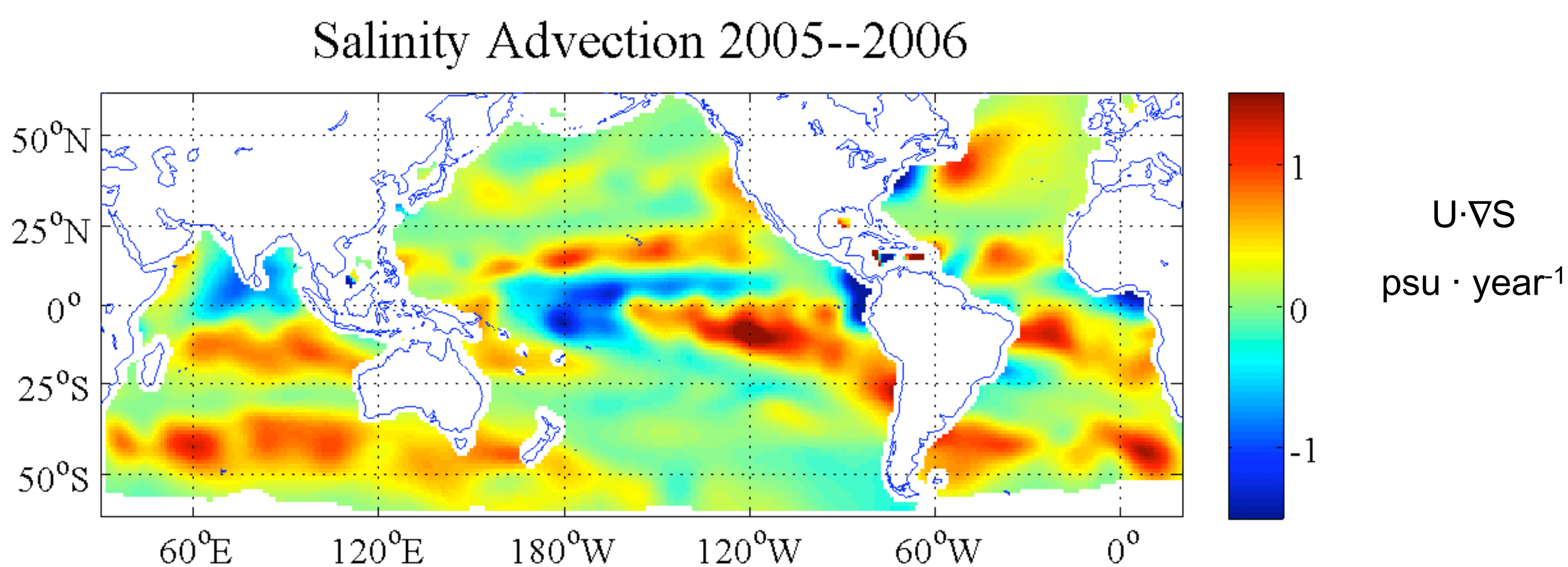
Evaporation (Lisan Yu, WHOI)

LODYC Climatological Mean Mixed Layer Depth



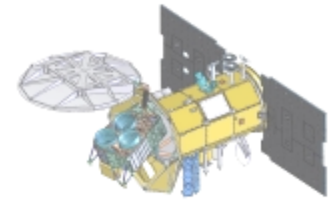
# Net flux vs Salinity divergence



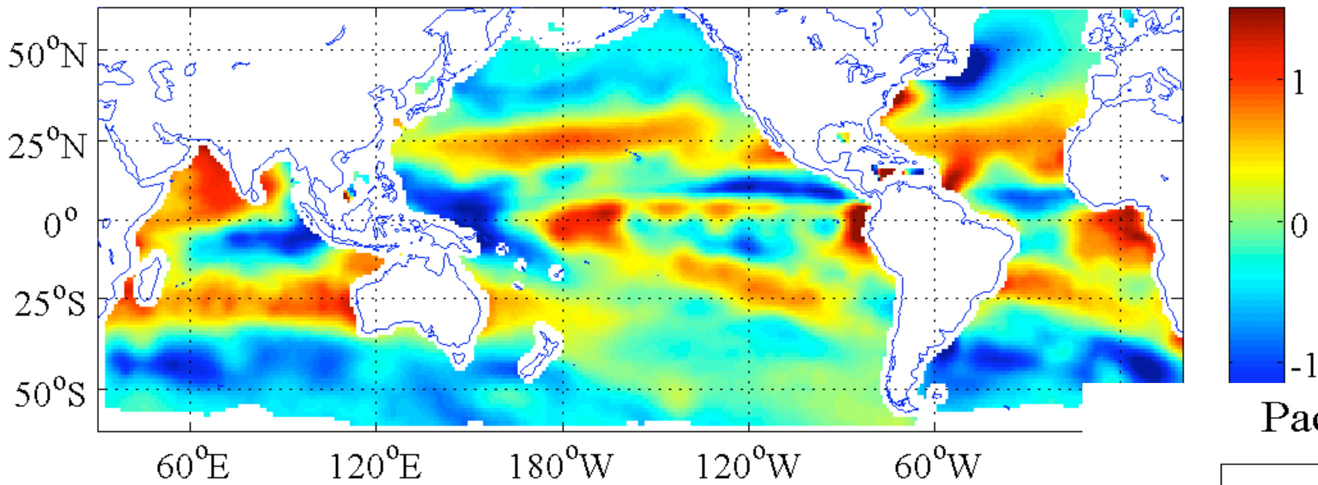



# Surface forcing minus advection

AQUARIUS/SAC-D
**Salinity Satellite Mission**



(E-P) Salinity Forcing Minus Salinity Advection

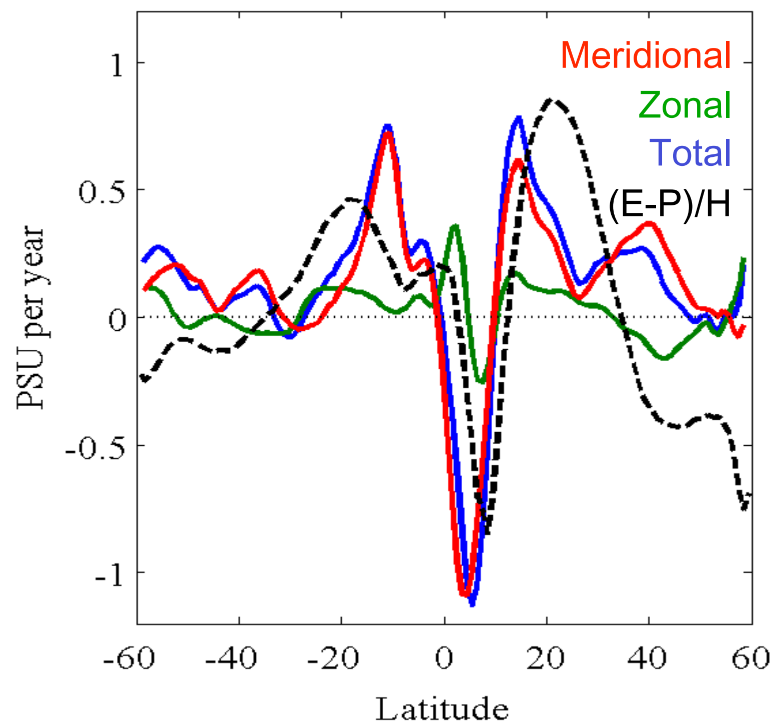



Latitudes of peak SSS divergence are shifted merdionally relative to peak E-P, causing zonal difference patterns.

Need to resolve vertical mixed layer processes

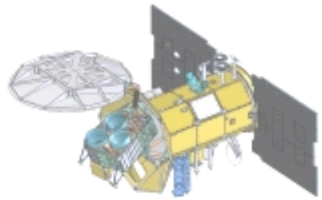
Climatic trends will consist of small differences between large numbers

Pacific Salinity Advection




G. Lagerloef, et al.
Plenary

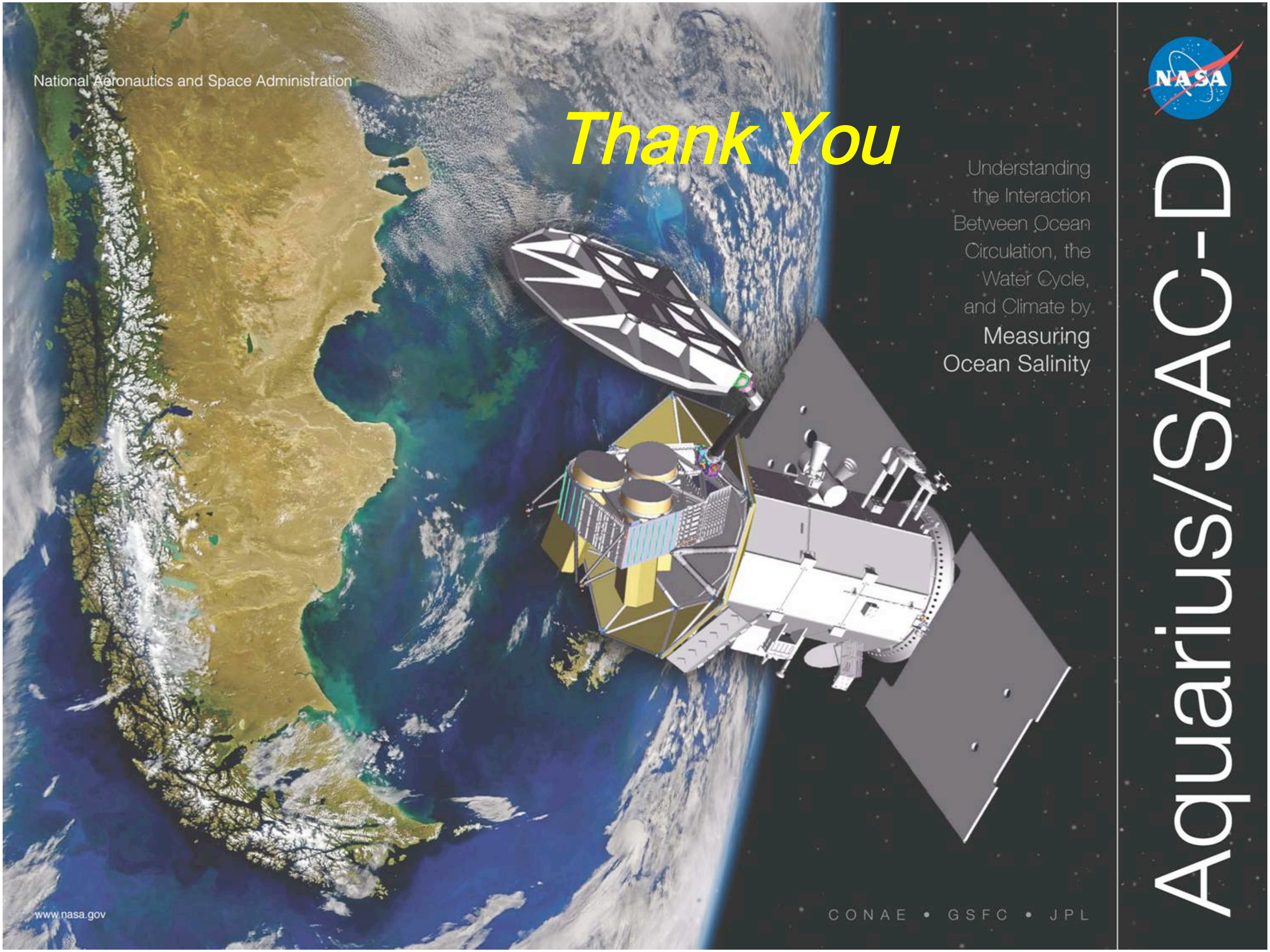
# Summary



The Aquarius science goal is to understand the links between ocean circulation, global water cycle and climate by measuring ocean surface salinity

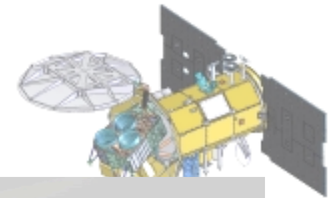
- Salinity trends can be linked to changes in both circulation and E-P forcing.
- Large uncertainties exist in precipitation data sets
- Salt advection is similar magnitude to E-P, but there are large differences.
- Satellite salinity and ocean surface topography data together form an important tool to investigate the uncertainties in the marine freshwater budget.

# Thank You


National Aeronautics and Space Administration
NASA
Understanding the Interaction Between Ocean Circulation, the Water Cycle, and Climate by Measuring Ocean Salinity
Aquarius/SAC-D
CONAE • GSFC • JPL
www.nasa.gov

AQUARIUS/SAC-D
Salinity Satellite Mission

# U.S. CLIVAR Salinity Working Group Proposed Control Volume Experiment



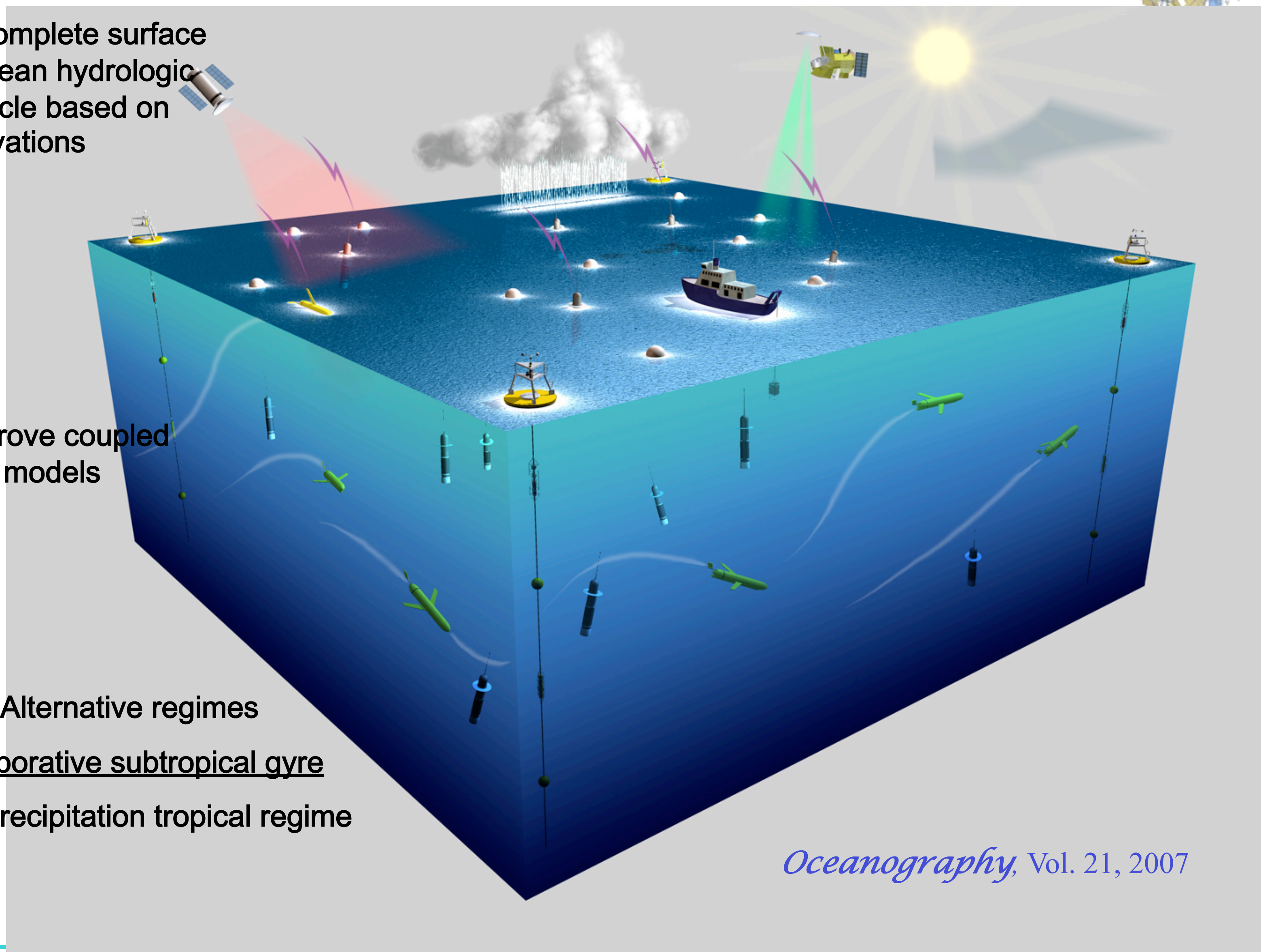
Constrain the complete surface atmosphere/ocean hydrologic [seasonal] cycle based on observations

Test and improve coupled climate models

Alternative regimes

•evaporative subtropical gyre

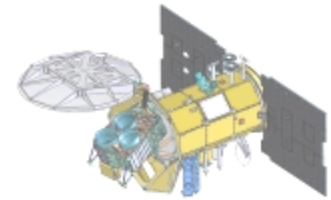
•high precipitation tropical regime



*Oceanography*, Vol. 21, 2007

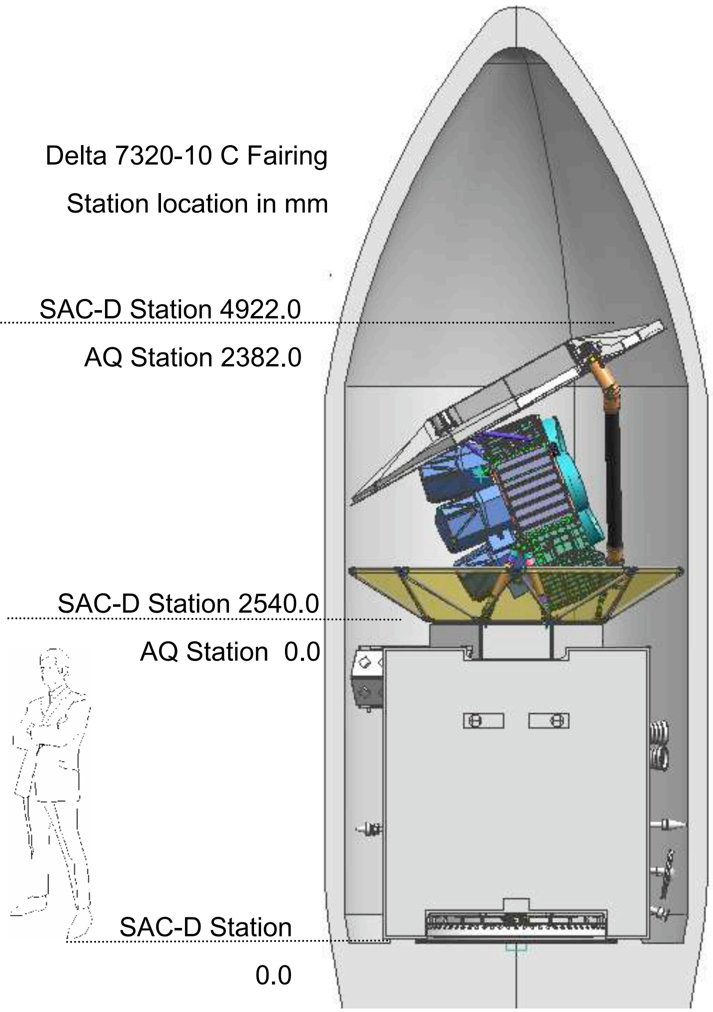
# AQUARIUS/SAC-D

## Salinity Satellite Mission

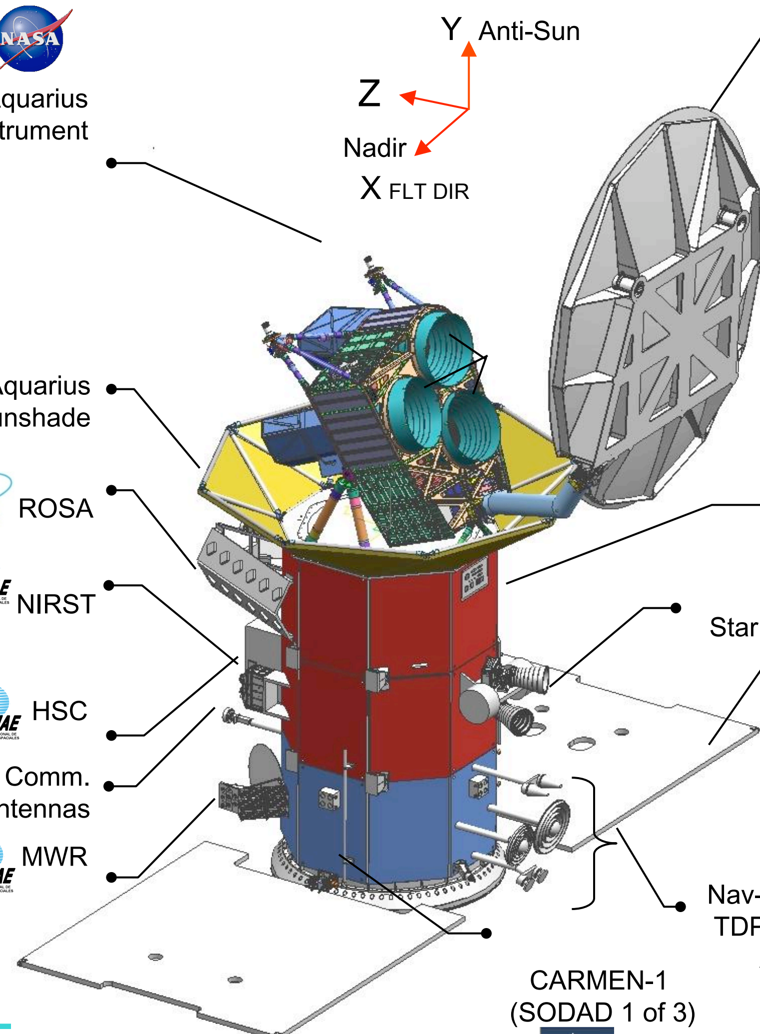


# Observatory Configuration

### Stowed Configuration

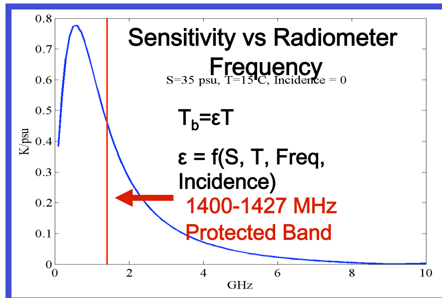


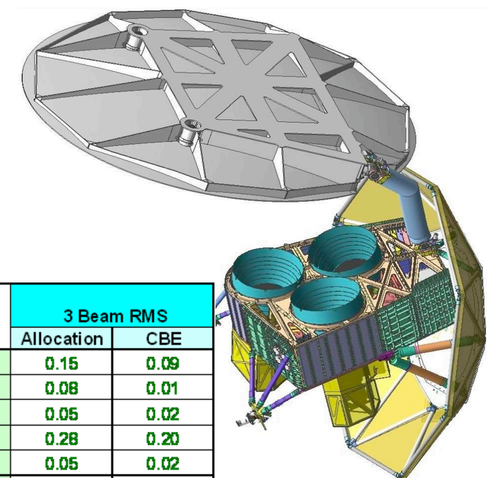

### Deployed Configuration



# The Aquarius/SAC-D Salinity Mission

**Aquarius/SAC-D will systematically observe the global surface salinity field for ≥3 years to achieve a monthly accuracy that will resolve the seasonal and interannual variability at 150 km scales.**



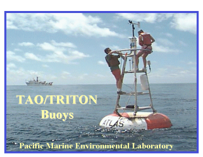
**Approach:**

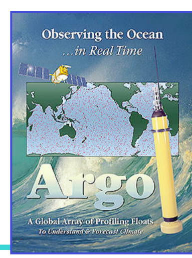
- Integrated L-band ultra-stable microwave radiometer-radar, 3 fixed beams, 390 km wide swath, 7-day repeat polar orbit
- Radar scatterometer is required to correct for wind roughness, the largest uncertainty error source
- Monthly averages to reduce measurement noise and achieve 0.2 psu RMS accuracy
- Three year baseline mission to resolve seasonal to interannual variability and robust mean field
- Independent calibration and validation from global *in situ* ocean observing system

| Error Sources | 3 Beam RMS Allocation | 3 Beam RMS CBE |
|---|---|---|
| Radiometer | 0.15 | 0.09 |
| Antenna | 0.08 | 0.01 |
| System Pointing | 0.05 | 0.02 |
| Roughness | 0.28 | 0.20 |
| Solar | 0.05 | 0.02 |
| Galactic | 0.05 | 0.004 |
| Rain (Total Liquid Water) | 0.02 | 0.01 |
| Ionosphere | 0.06 | 0.043 |
| Atmosphere - other | 0.05 | 0.02 |
| SST | 0.10 | 0.07 |
| Antenna gain near land & ice | 0.10 | 0.10 |
| Model Function | 0.08 | 0.07 |

| Brighness Temperature Error per Observation | Baseline Mission Allocation | Baseline Mission CBE |
|---|---|---|
| Total RSS (K) | 0.38 | 0.27 |
| Margin RSS (K) | 0.27 | |

| Latitude Range | Mean Sensitivity (dTv/dS) | Mean # Samples in 28 Days | Baseline Mission Monthly Salinity Error (psu) Allocation | Baseline Mission Monthly Salinity Error (psu) CBE |
|---|---|---|---|---|
| 0-10 | 0.756 | 10.9 | 0.15 | 0.11 |
| 11-20 | 0.731 | 11.3 | 0.16 | 0.11 |
| 21-30 | 0.671 | 12.1 | 0.16 | 0.12 |
| 31-40 | 0.567 | 13.5 | 0.18 | 0.13 |
| 41-50 | 0.455 | 15.9 | 0.21 | 0.15 |
| 51-60 | 0.357 | 20.3 | 0.24 | 0.17 |
| 61-70 | 0.271 | 30.2 | 0.26 | 0.18 |
| Global RMS (psu) | | | 0.20 | 0.14 |
| Margin RSS (psu) | | | 0.14 | |




G. Lagerloef, et al.
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