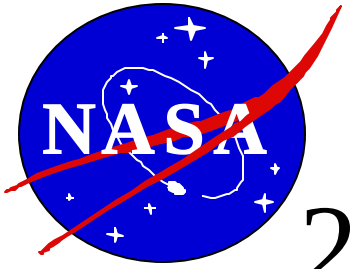


20,000 Leagues Under the Sea
Measuring the Deep Ocean in the 21st Century

Bill Emery and Waleed Abdalati

NASA HQ

Wash. DC

Measuring the Deep Ocean in the Past

- To appreciate the technologies we have available today it is useful to reflect on how the deep ocean was studied in the recent past.

- Ship surveys using hydrographic sampling supported by wires and winches have been the primary means of sampling the deep ocean.

- Some information has been made available from moored instruments but the majority of our information comes from ship surveys.

The Meteor Expedition

- One of the earliest expeditions dedicated to physical oceanography the Meteor Expedition covered the Atlantic Ocean in the mid 1920's.

Photo 19. The *Meteor* before conversion.

Hydrographic Sampling on the Meteor

- The main sampling system was a pair of hydrographic winches which made casts down to 5,000 m. Here is one such winch with George Wuest (helmet) and Albert Defant in the picture.

Typical Modern Research Vessel

- This is a model of the RV Franklin a research vessel operated by the Australian CSIRO Division of Marine Research.

Typical Modern RV Capabilities

- Modern RV are equipped with:

1. Excellent handling and station keeping (bow thrusters, dual propellors, stern thrusters, etc.
2. Excellent navigation GPS, LORAN
3. Excellent communications via VHF and satellite broadcast.
4. A variety of winches and support systems for collecting hydrographic data.
5. Acoustic systems for mapping the bottom, computing currents (AD CP) and communicating with moorings.
6. Good work space for constructing and deploying deep moorings.
7. Good food and accommodations.

Typical Bottle Samplers

Alternate Profiler Called the Batfish

Typical Current Meter Mooring

Limitations to Ship and Mooring Measurements

• Do not report realtime and data have to be brought back to shore and analyzed. This is particularly true of the moorings which may need to last a year or more.

• Ship time is expensive and so measurements are costly mainly due to the infrastructure of maintaining the research fleet.

• Failures are very difficult to compensate for and require additional ship time to correct.

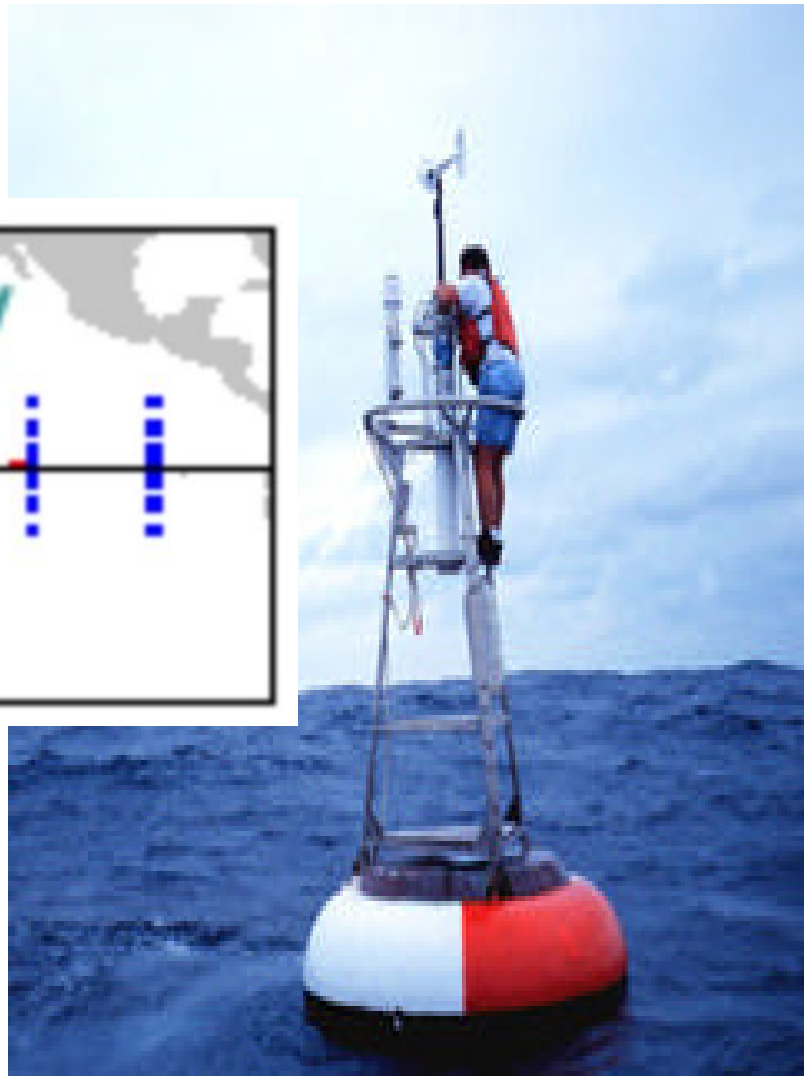
• Expense of maintaining the moorings or operating the ship makes it costly to make synoptic spatial surveys. As a result all ship sampling is only representative of the long term mean state.

Modern Open Ocean Sampling a System in Transition

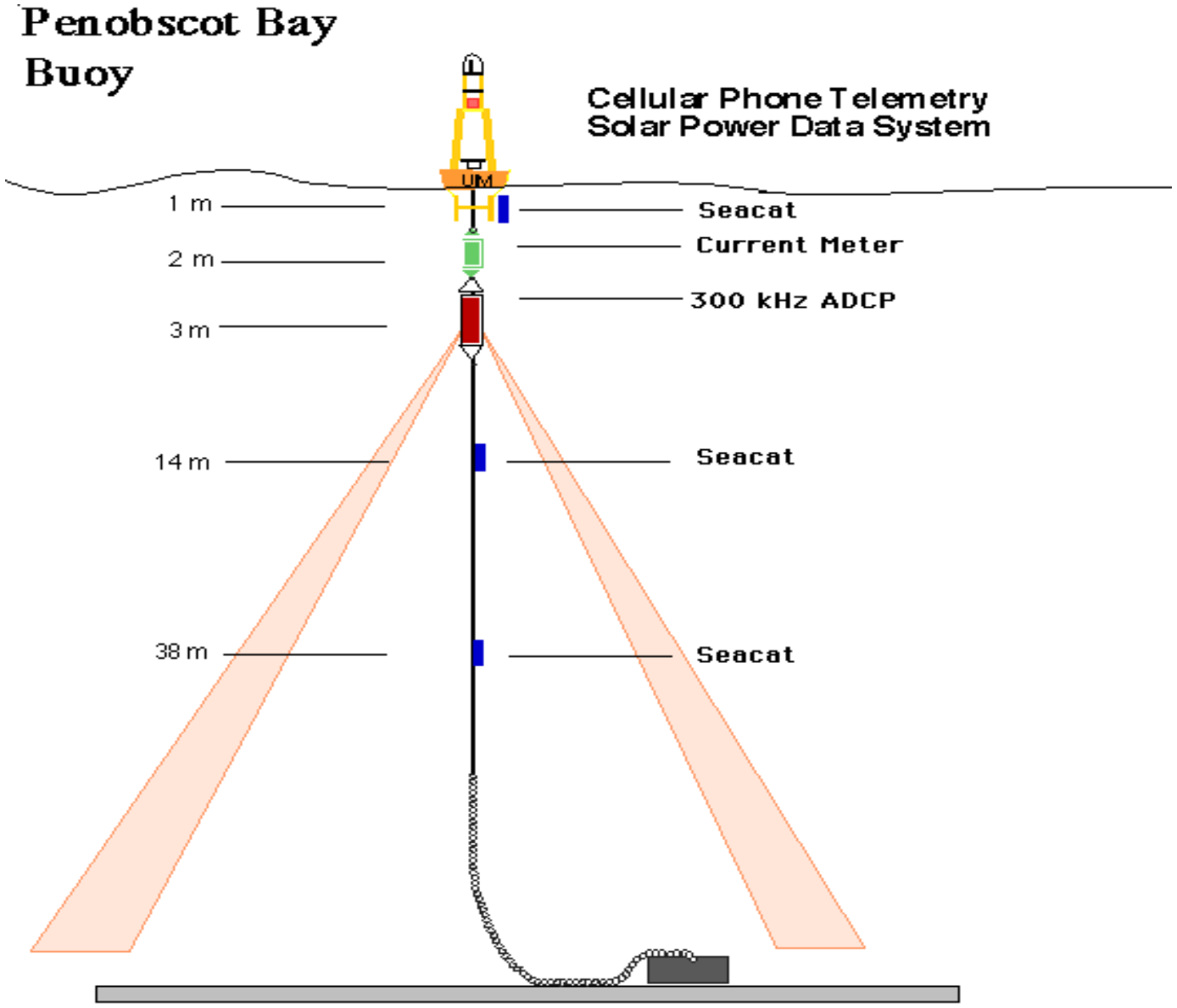
- What caused the big change in this observational system?

The advent of data collection systems from polar orbiting satellites that made it possible to report data in near realtime from autonomous platforms on the open ocean. Service ARGOS on the NOAA polar orbiting satellites were the initial suppliers of this service but now due to data rate limitations with this system there is a tendency to switch to GPS positioning and data collection which can handle a much wider bandwidth. Now we can interrogate and report data from a large number of platforms on the ocean all at the same time. This greatly enhances the ability of autonomous system to collect the data needed.

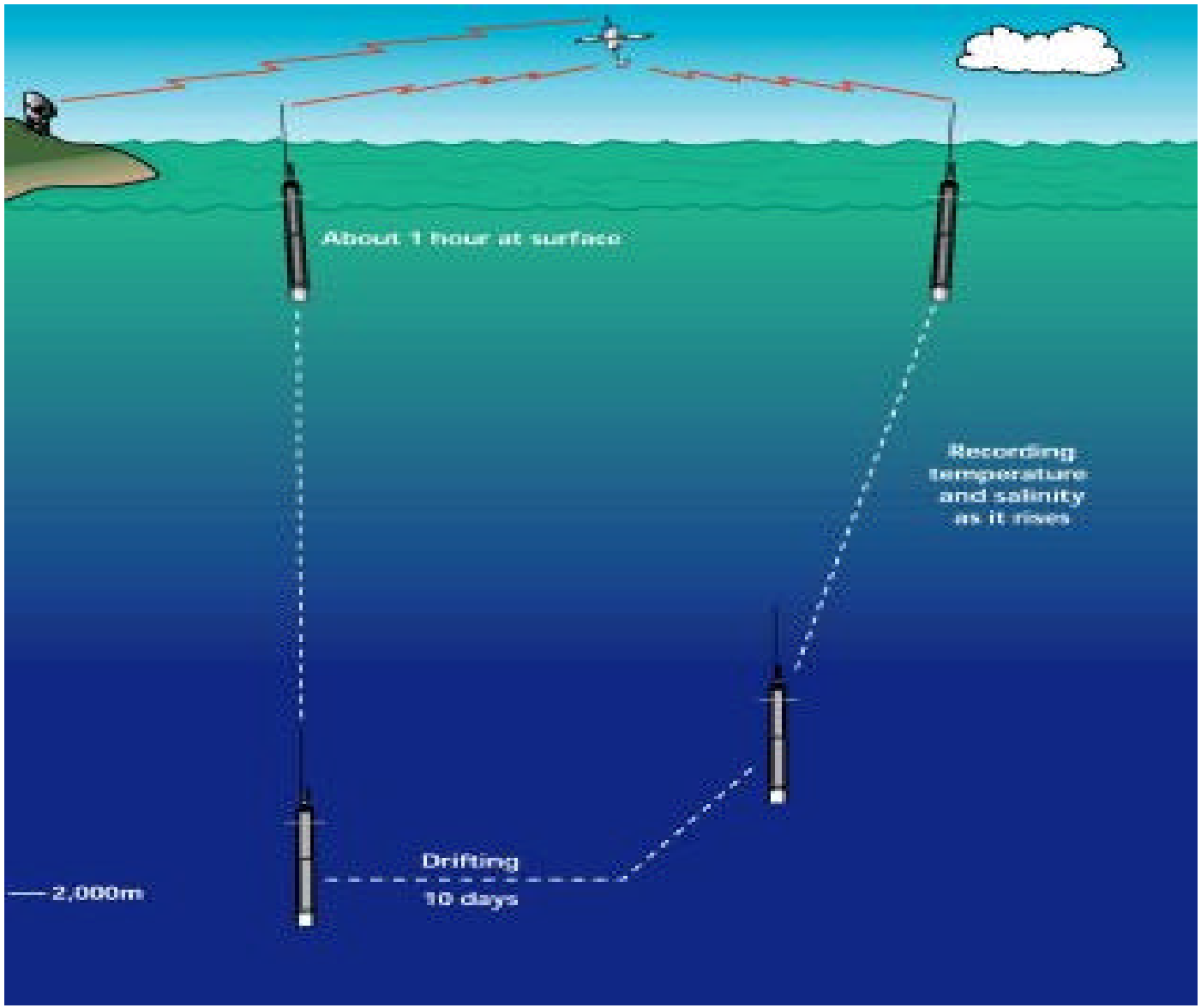
Deep Ocean Moorings Reporting in Realtime



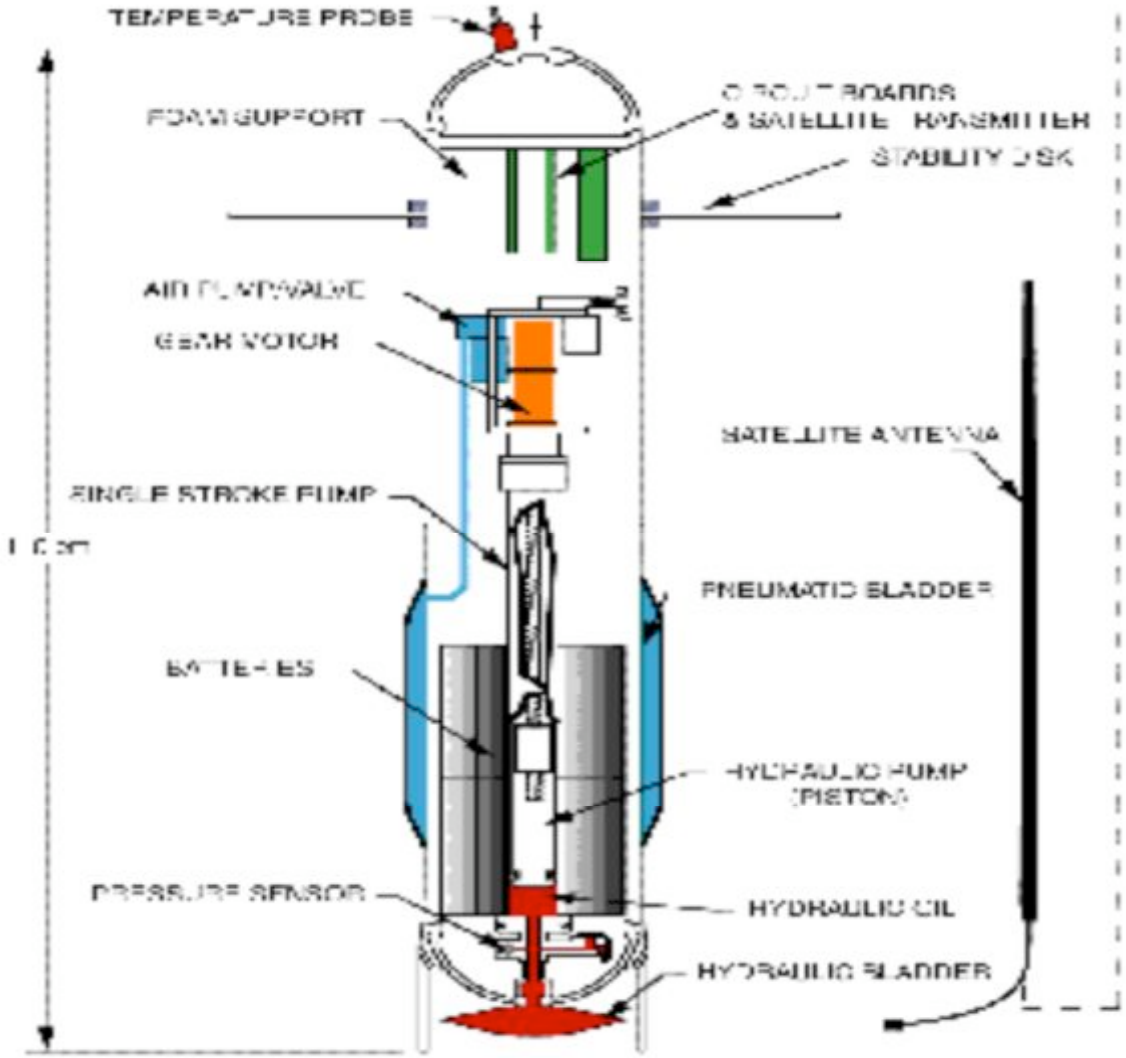
Coastal Buoys Provide Realtime Info to Mariners



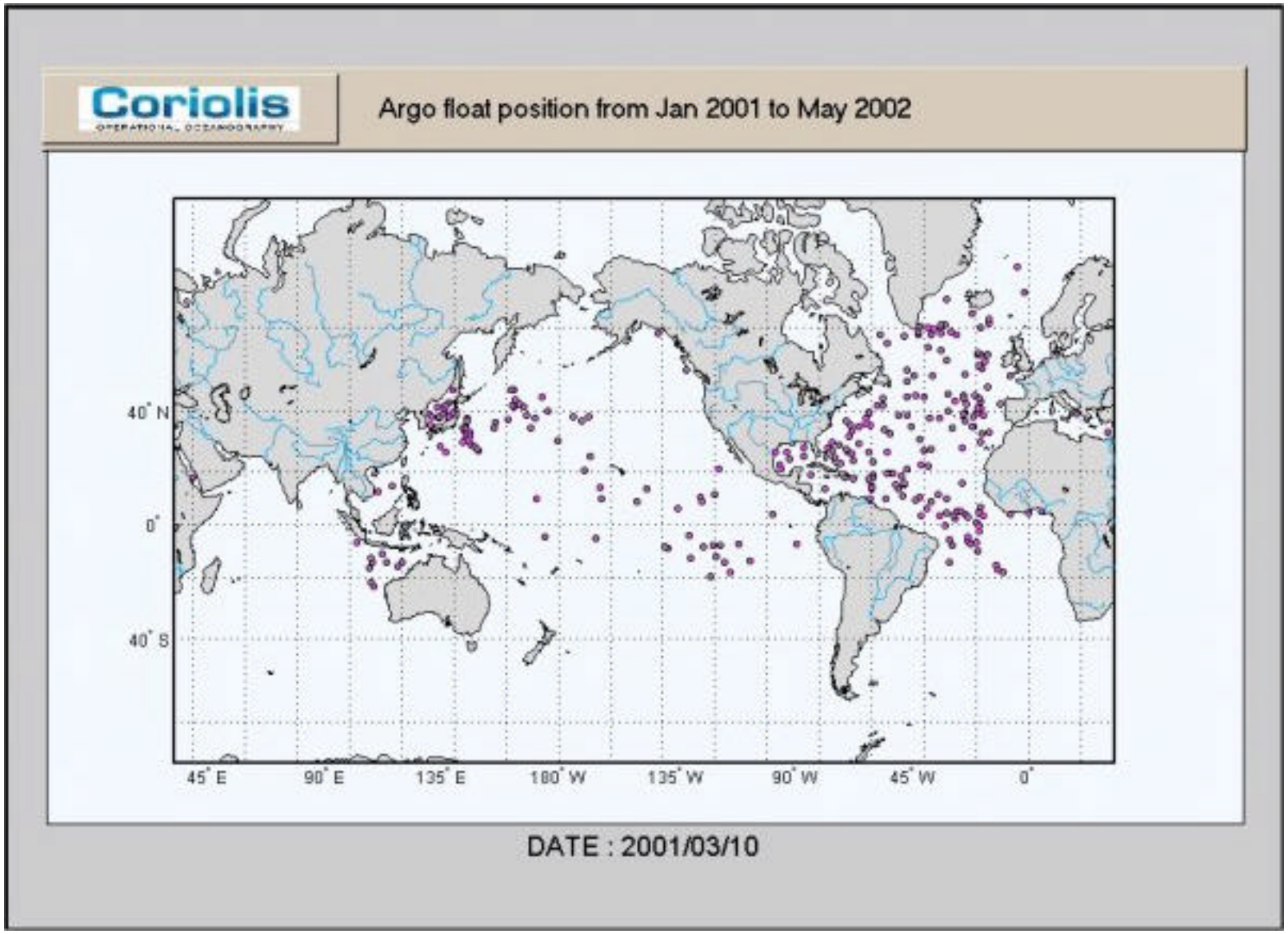
The ARGO Float System



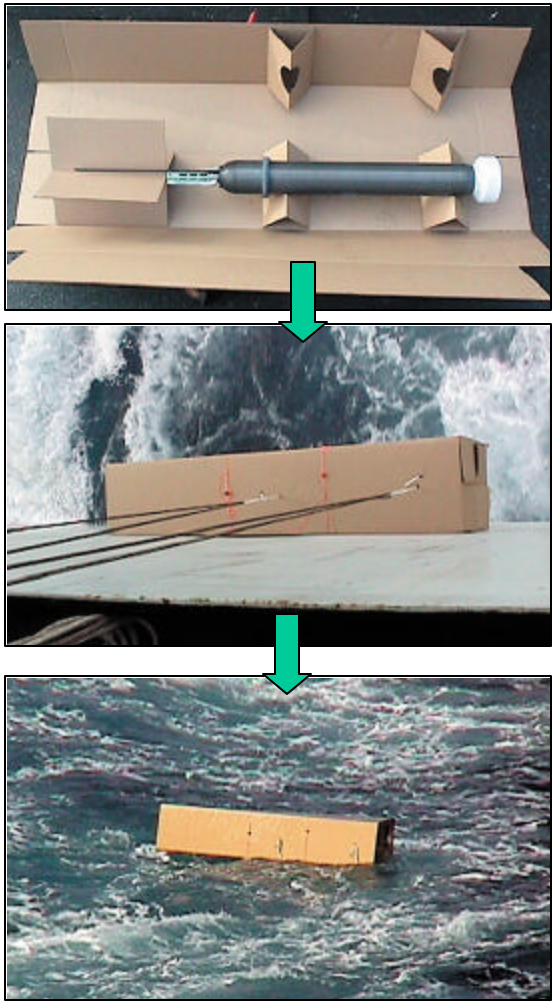
An ARGO Float

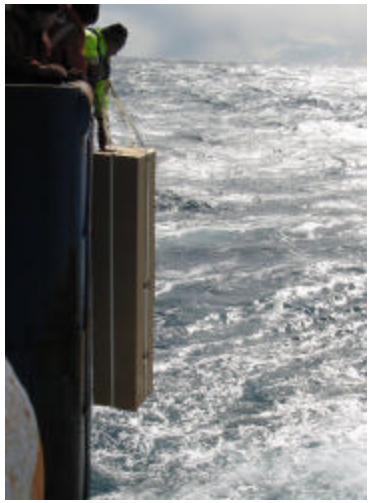


ARGO Float Geographic Distribution



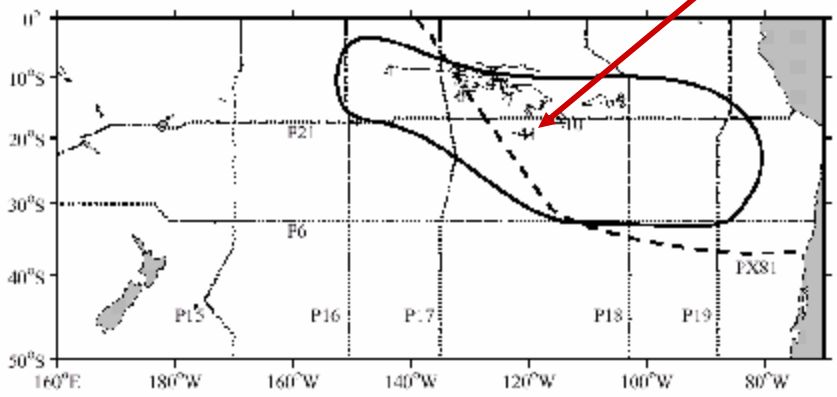
ARGO Deployment Strategies

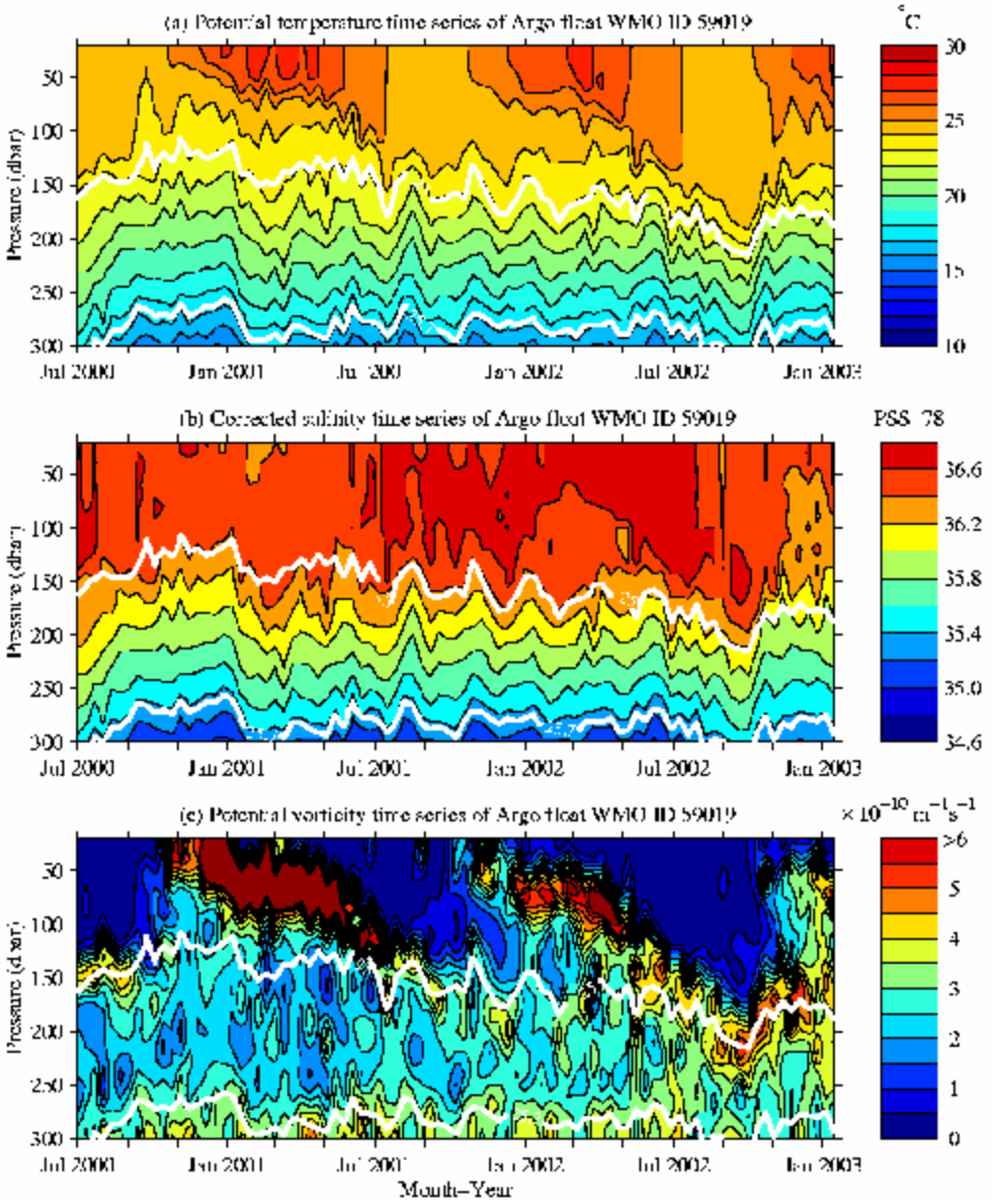




Water mass formation:

Argo floats, together with WOCE hydrographic cruises and High Resolution XBT/XCTD transects are used to describe South Pacific Eastern Subtropical Mode Water formation and decay (Wong and Johnson, 2003, In press).

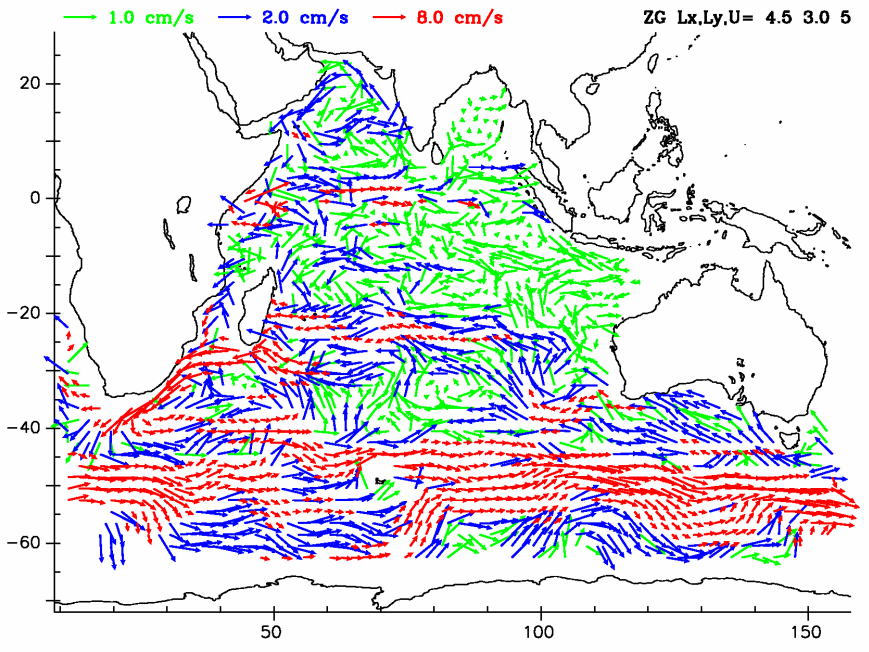


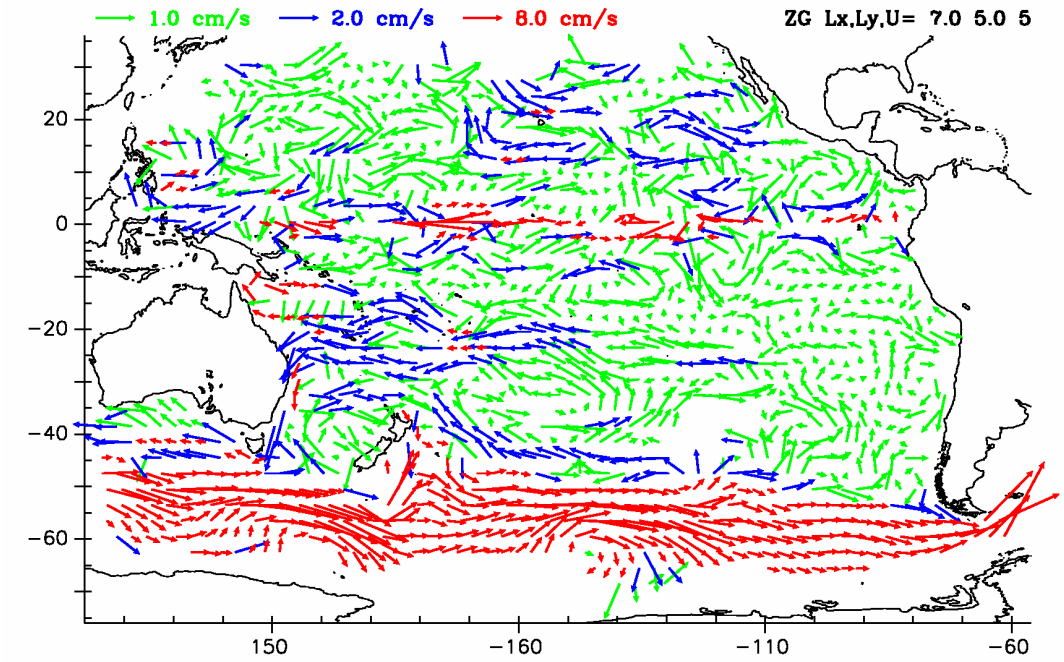


(Right) Time-series of T,S, PV from an Argo float near the formation region.

Ocean circulation (1):

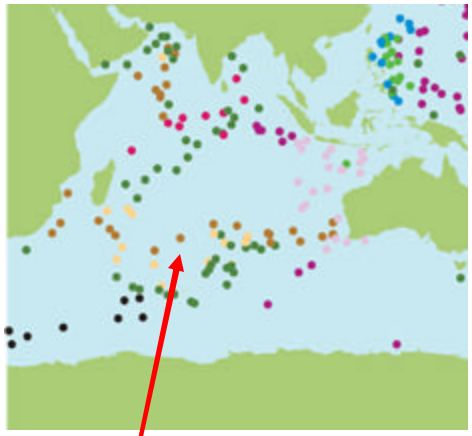
***Mean flow* - Pre-Argo floats at coarse spatial resolution are used to estimate mean circulation at 1000 m (Davis, 2003).**



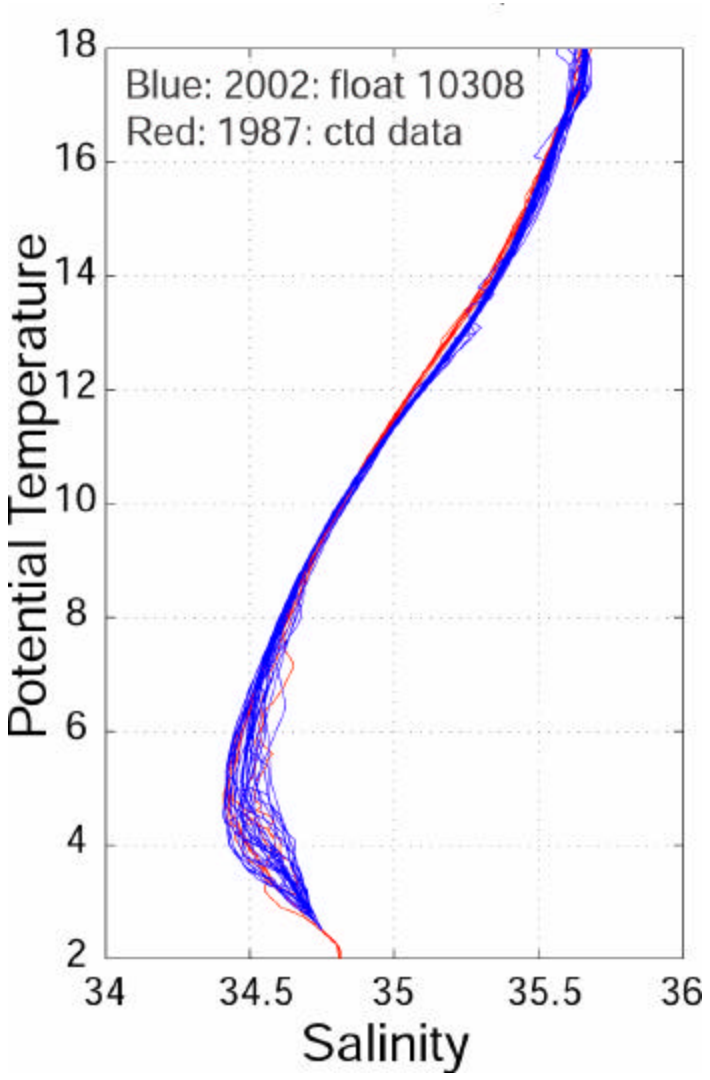


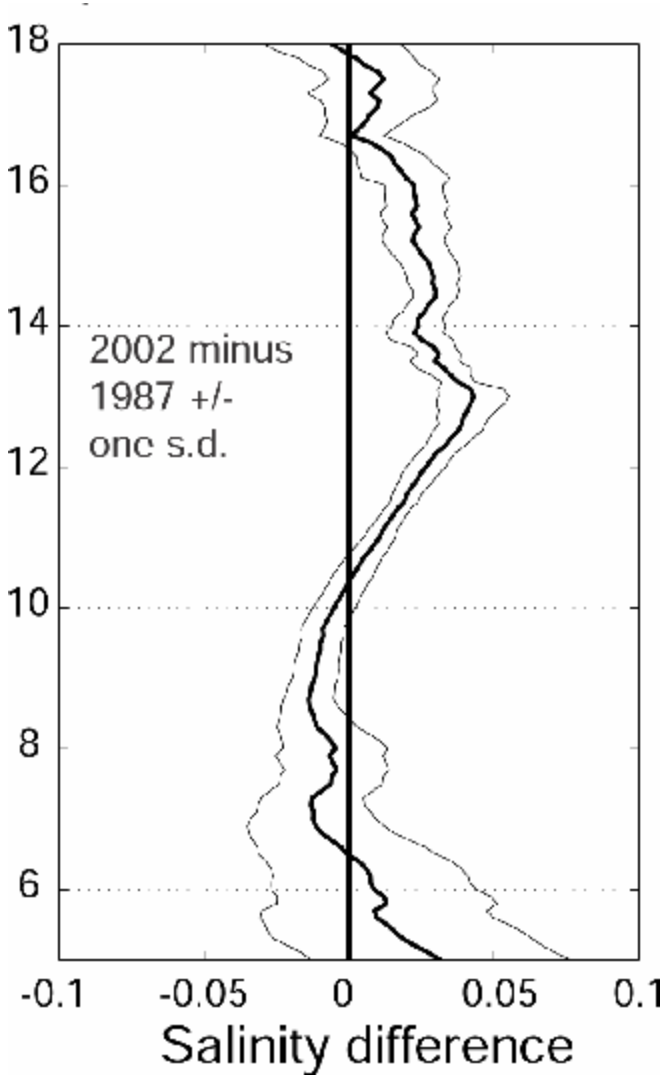
T/S variability in subducted waters:

A significant shift to higher thermocline salinity relative to 1987 data is seen in Argo floats and shipboard CTD casts (King, 2003).



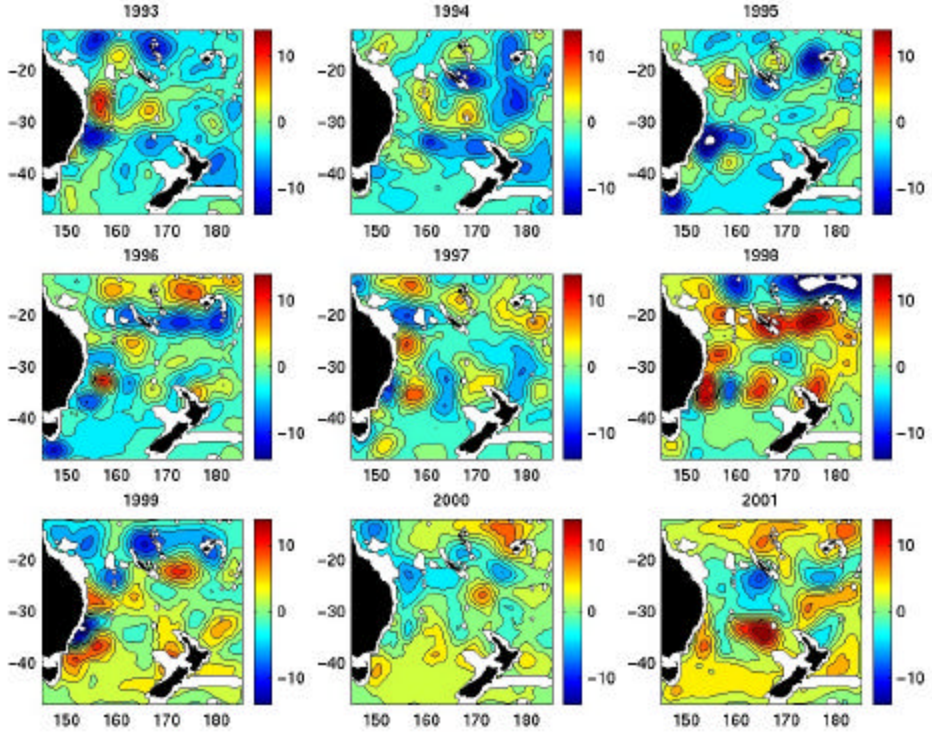
UK Argo floats at 30°S in Indian Ocean deployed one year ago.



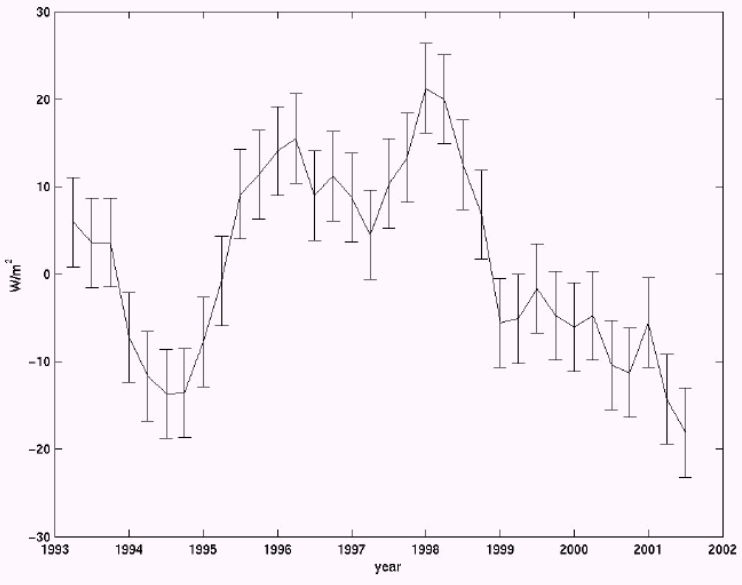


Argo and altimetry:

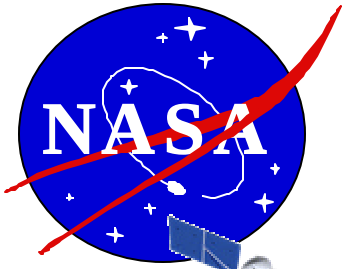
Combination of altimetry with profile data including Argo provides estimates of T(z), dynamic height, heat content (Willis, Roemmich, and Cornuelle, 2003).

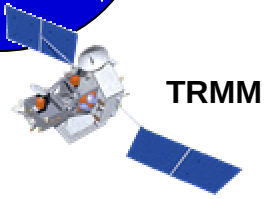


Annual means, 1993 - 2001, of dynamic height (0/800 dbar) in the Tasman Sea.



Interannual variability in heat gain by the ocean averaged over the Tasman Box region.





TRMM

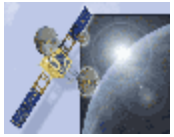
GRACE

Cloudsat

CALIPSO

Aqua

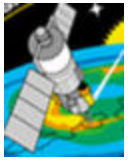
TOPEX

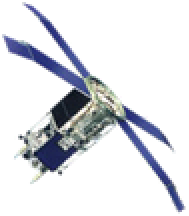


GIFTS

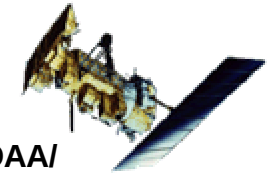
Landsat

Meteor/
SAGE



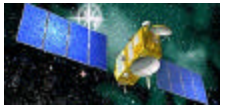


SeaWiFS

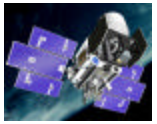


NOAA/
POESS

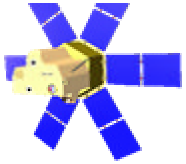
Terra



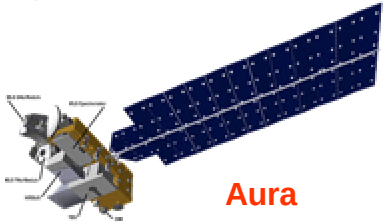
Jason



ICESat

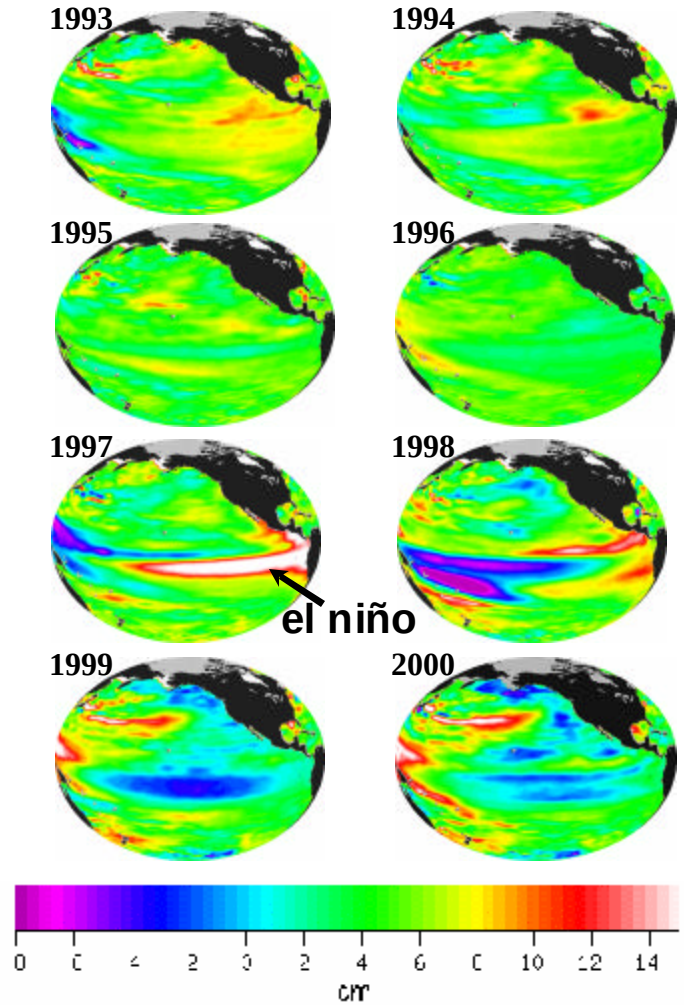


SORCE

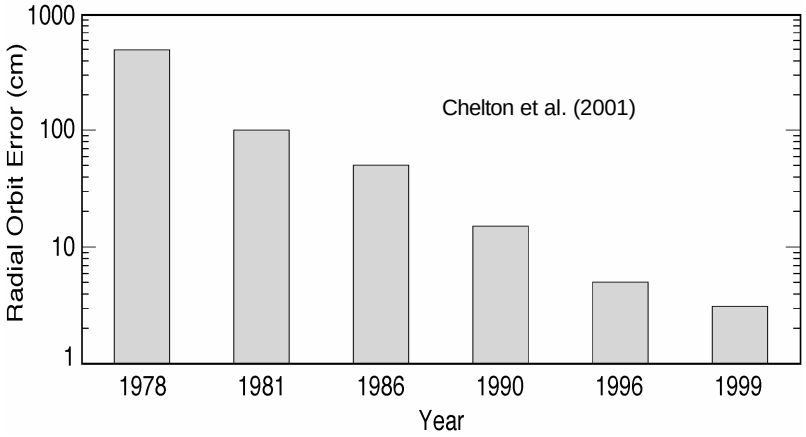


Aura

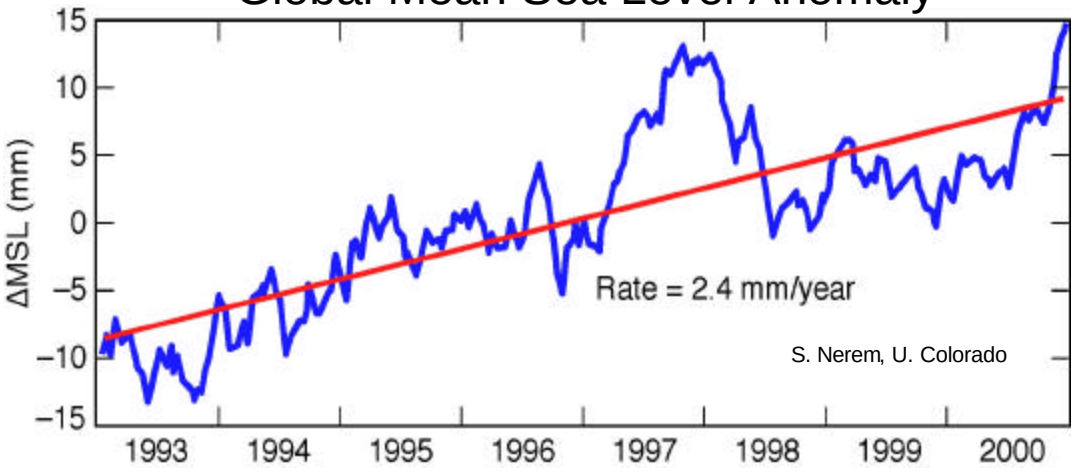
Yearly Averaged Anomalies of Ocean Surface Topography



Improvement in orbit accuracy



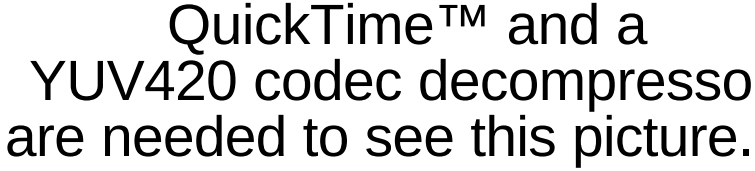
Global Mean Sea Level Anomaly



Satellites Produce Space/Time Series

97/98

ENSO

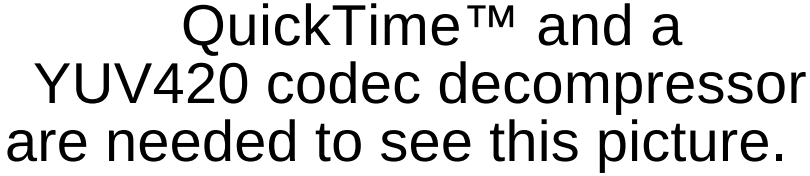


Satellites Produce Space/Time Series

Annual

Cycle of

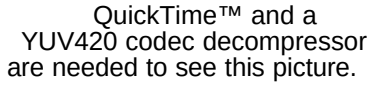
SST



Satellites Combined with Models

97/98

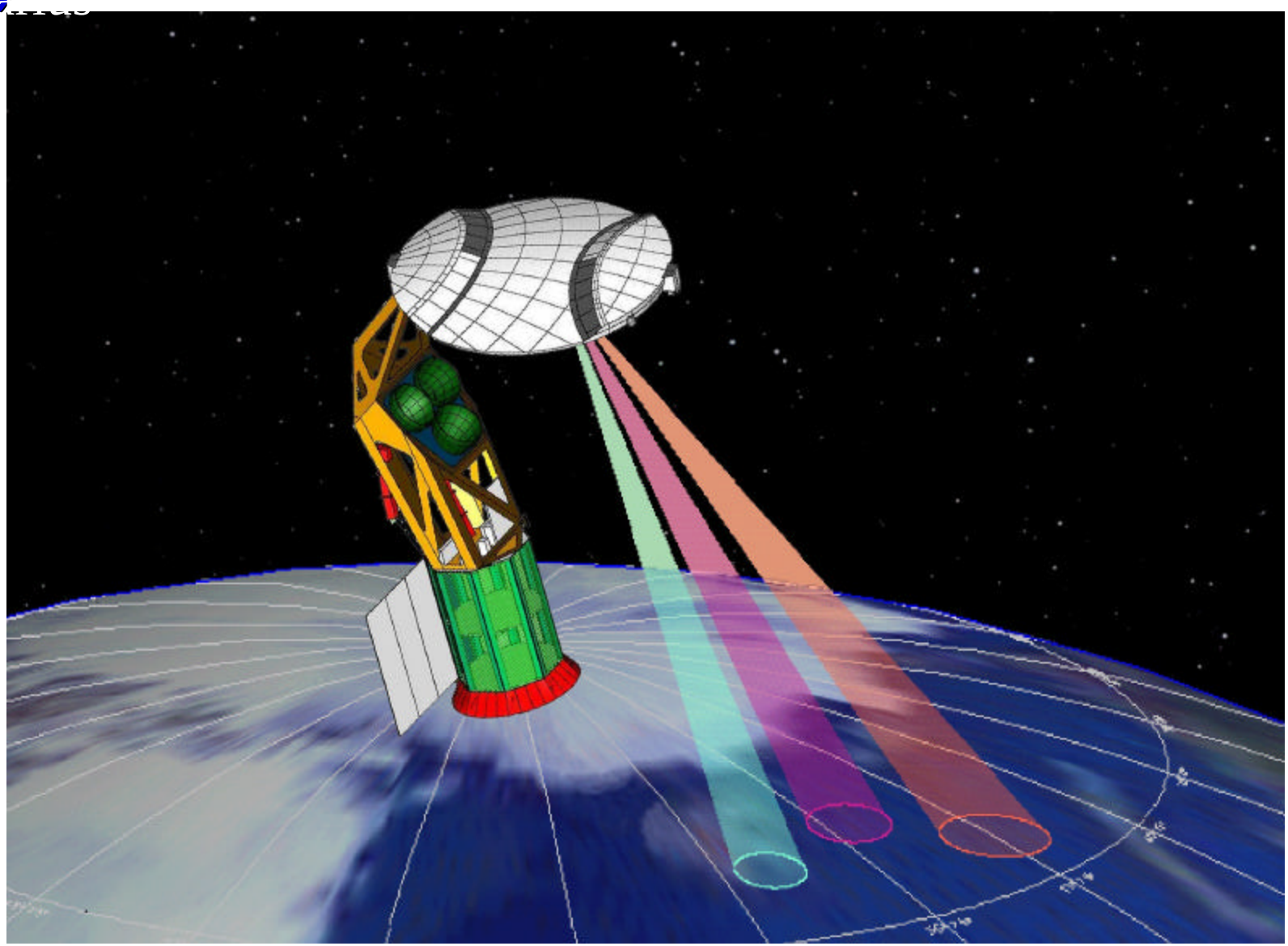
ENSO



Models Assimilate Satellite Altimetry and Produce High Resolution Realizations

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

The Aquarius Satellite Will Measure Surface Salinity



100 years of salinity measurements by ships

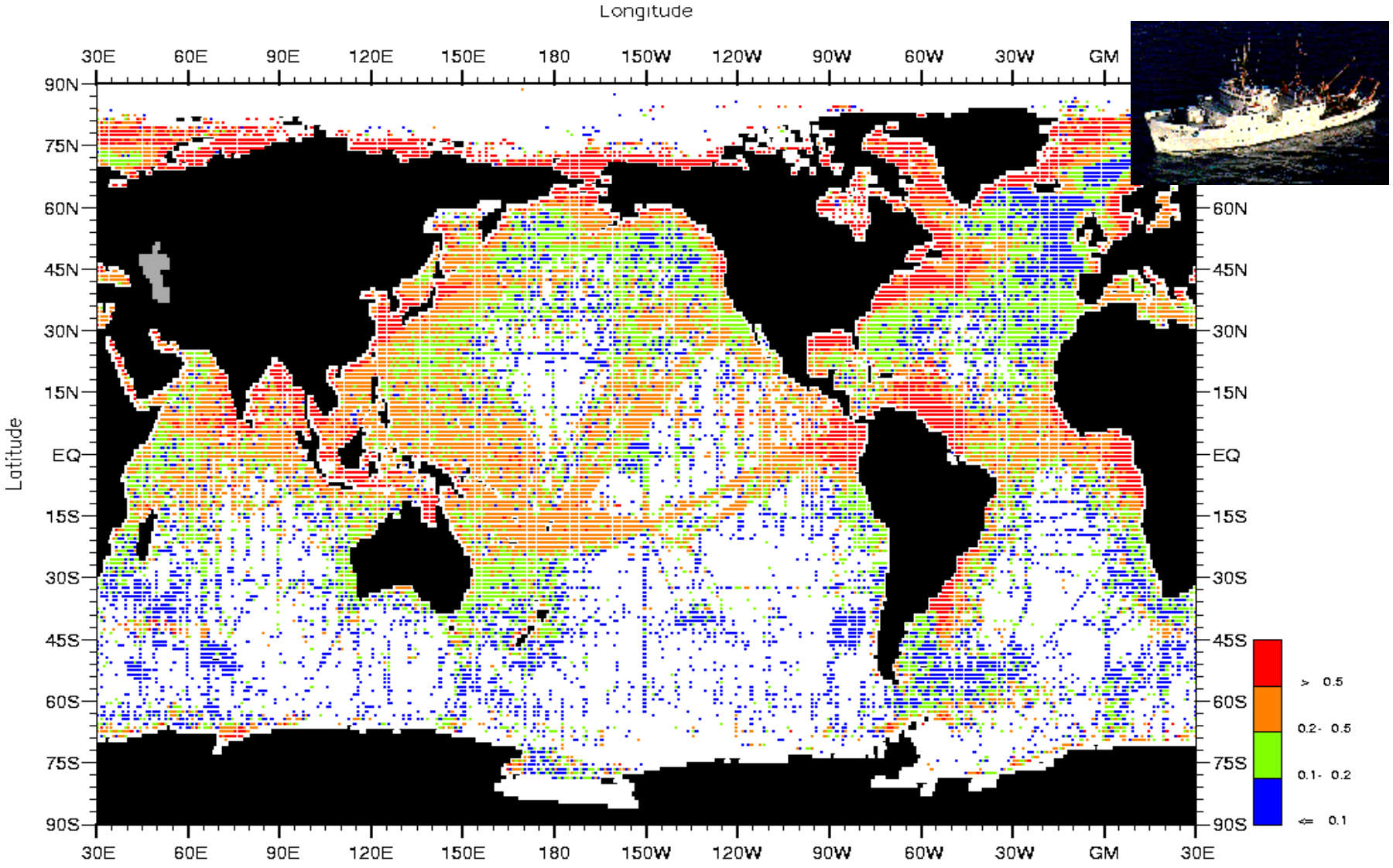
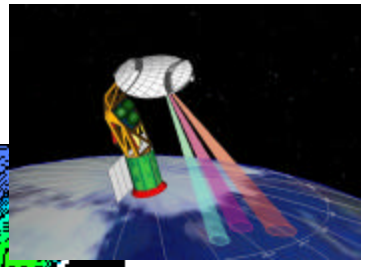


Fig. A4-1. Annual salinity (PSS) standard deviation at the surface .

One Week of Salinity Measurements from Space



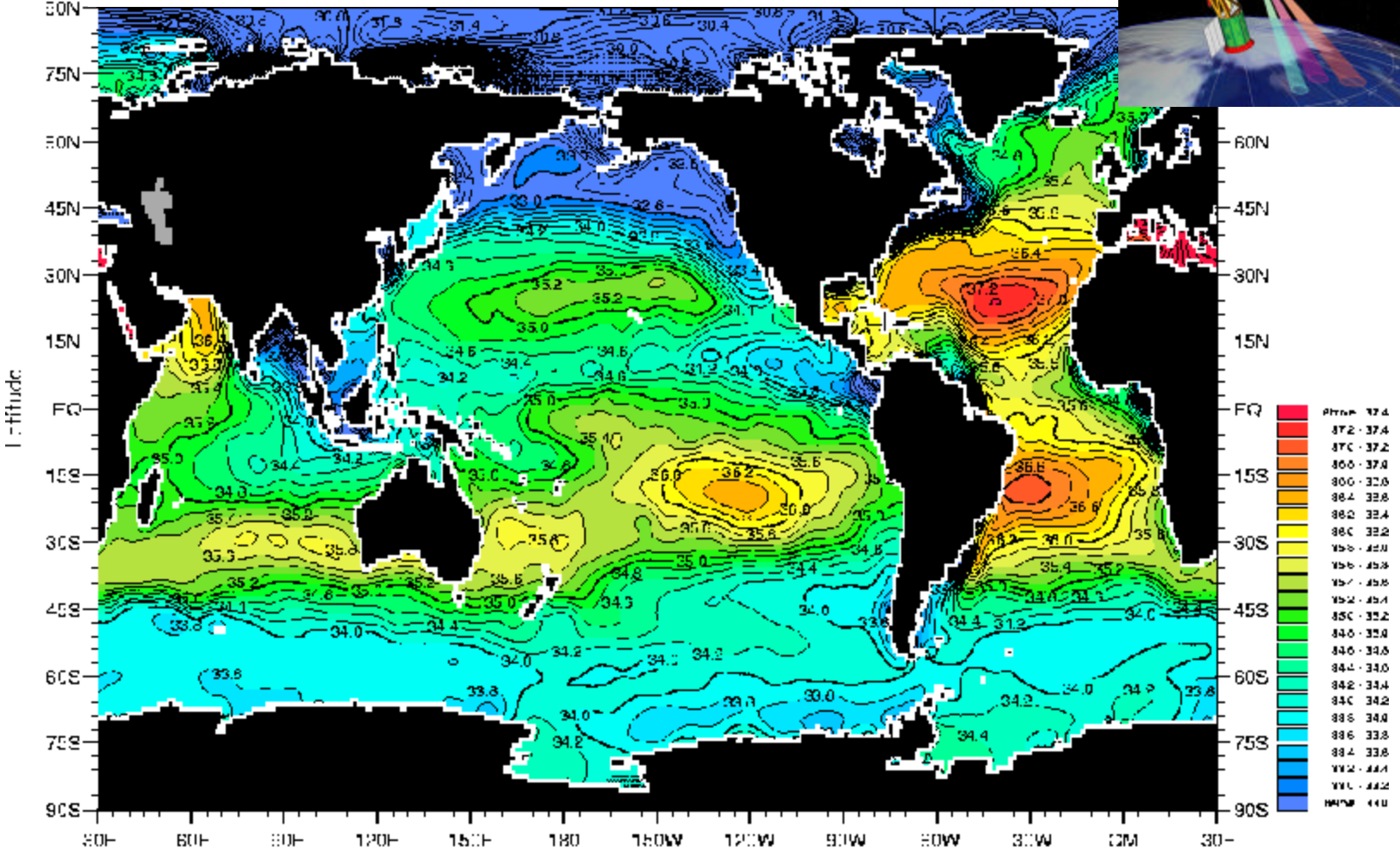
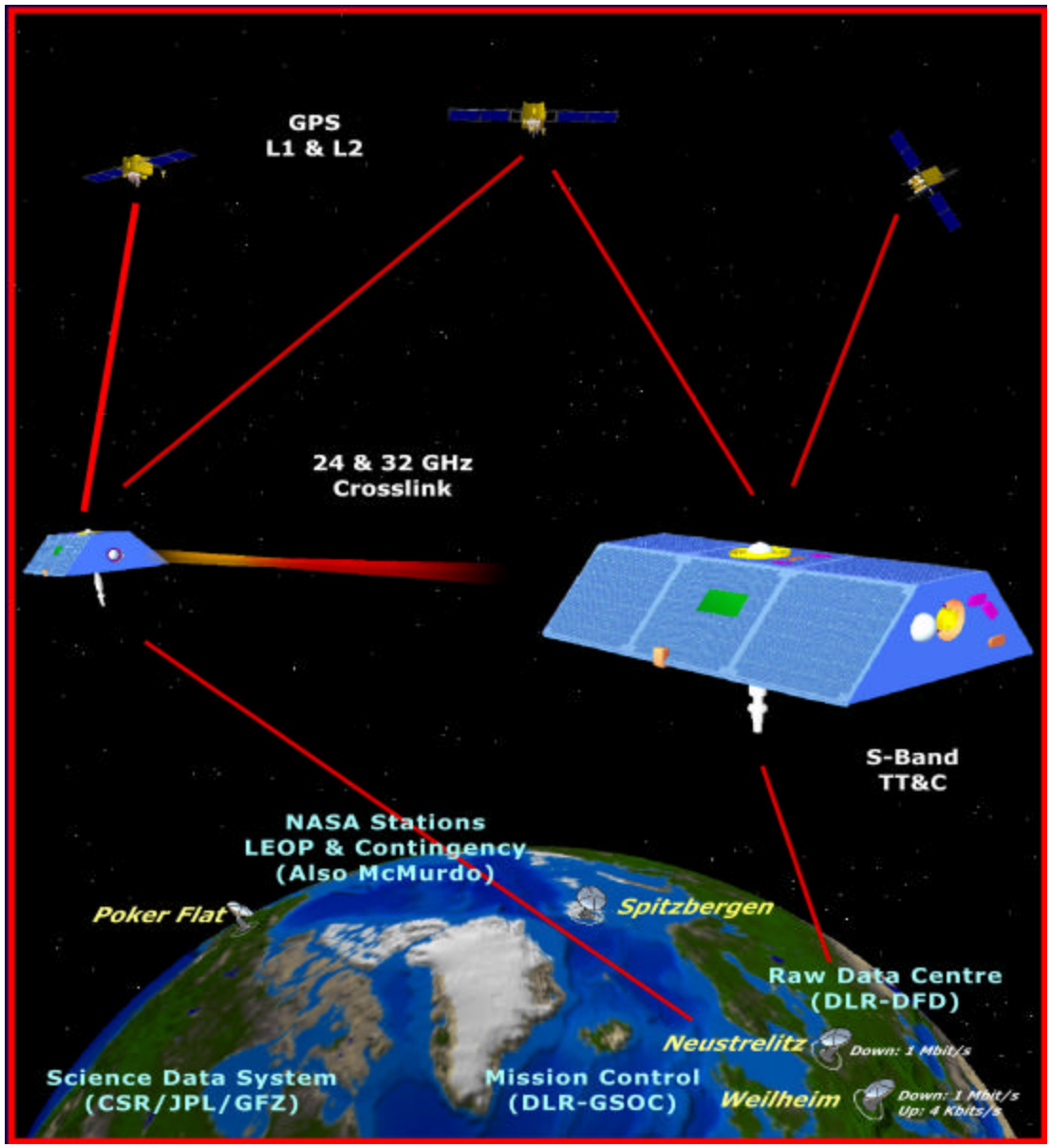


Fig. A2-1. Annual mean salinity (PSS) at the surface.

Minimum Value= 3.57 Maximum Value= 40.02 Contour nterva 3.20

Gravity Recovery and Climate Experiment (GRACE)



Science Goals

High resolution, mean & time variable gravity field mapping for Earth System Science.

- land surface water
- ice sheet mass changes
- ocean water mass movement
- atmospheric pressure
- any redistribution of mass

NASA's Vision of the Future in Oceanography