Observations of the Meridional Overturning Circulation (MOC) Above and Below the Ocean Surface

Peter C. Chu[1], Charles Sun[2], Chenwu Fan[1]

[1]Naval Postgraduate School, Monterey, CA93943

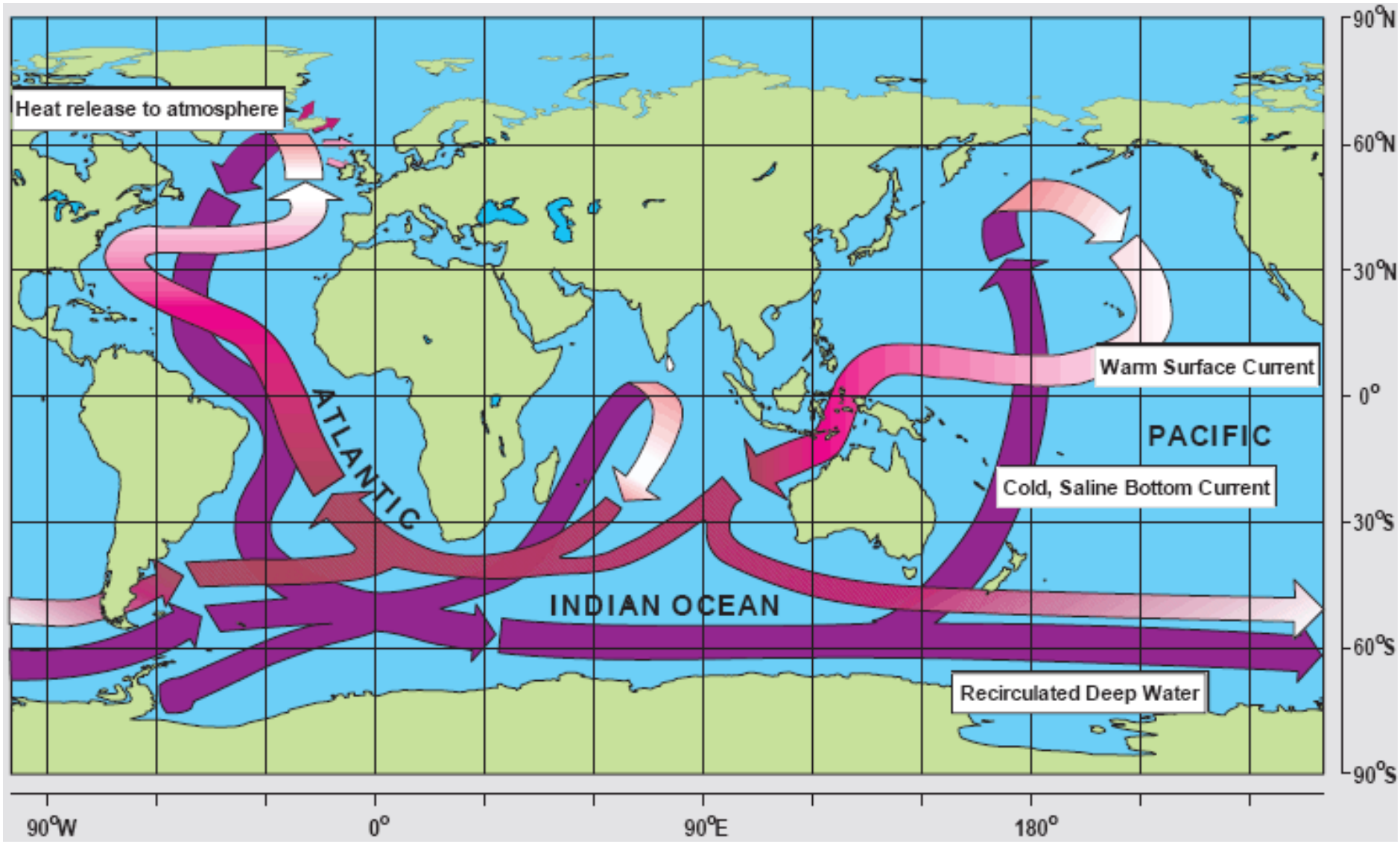
[2]NOAA/NODC, Silver Spring, MD 20910

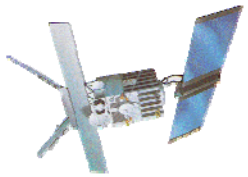
pcchu@nps.edu,

http://faculty.nps.edu/pcchu

tel: 831-656-3688, fax: 831-656-3686

Meridional Overturning Circulation (MOC)





How can we effectively use observational ocean data above and below the surface to detect MOC without distortion?

Objective

- Developing temporally varying 4D global gridded synoptic temperature, salinity, and velocity (STSV) dataset with temporal increment of one month

  →

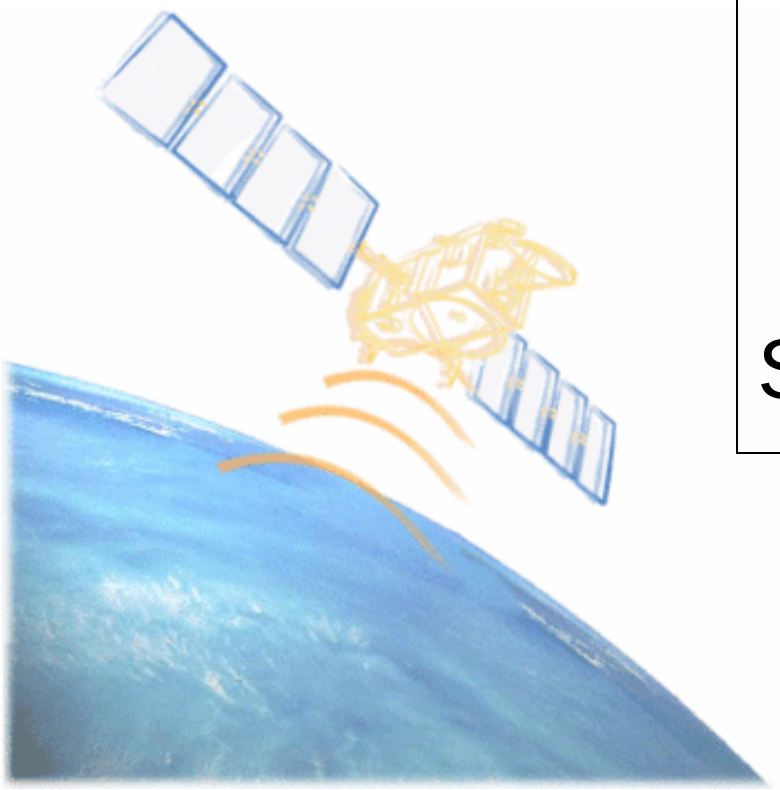
  Meridional Overturning Circulation (MOC)

  Heat Transport

  →

  Climate Change

Ocean Surface Velocity



Satellite Altimeters

(JASON-1, GFO, ENVISAT)

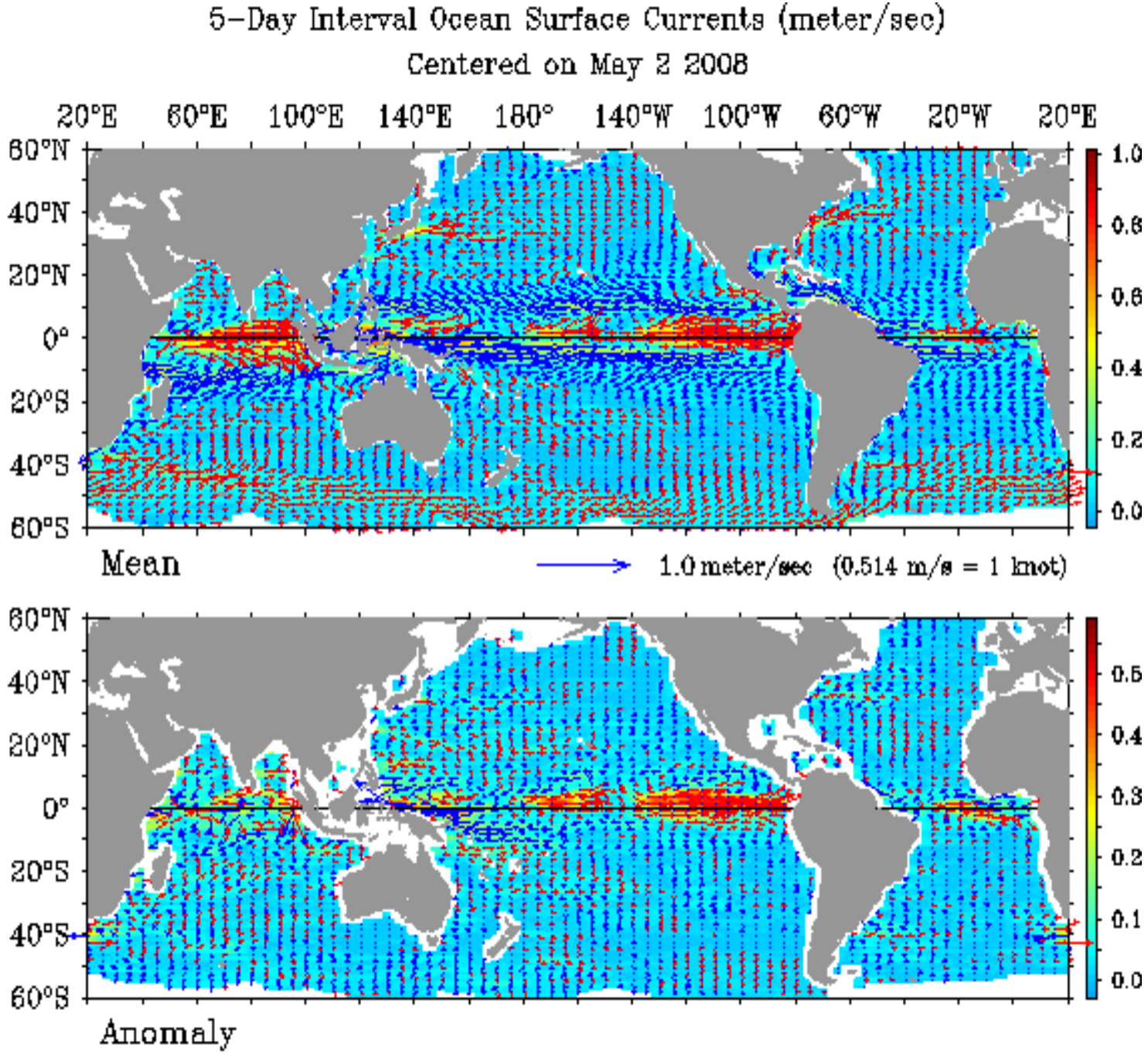
Scatterometer (QSCAT)

Ocean Surface Current Analyses – Realtime (OSCAR) Data

(1) Ocean Surface currents data available for whole world' oceans at www.oscar.noaa.gov

(2) Ocean Currents are computed from Sea Surface Height (SSH) data which is derived from satellite based altimeters JASON-1, GFO, Envisat and wind data which is derived from QUICKSCAT satellite

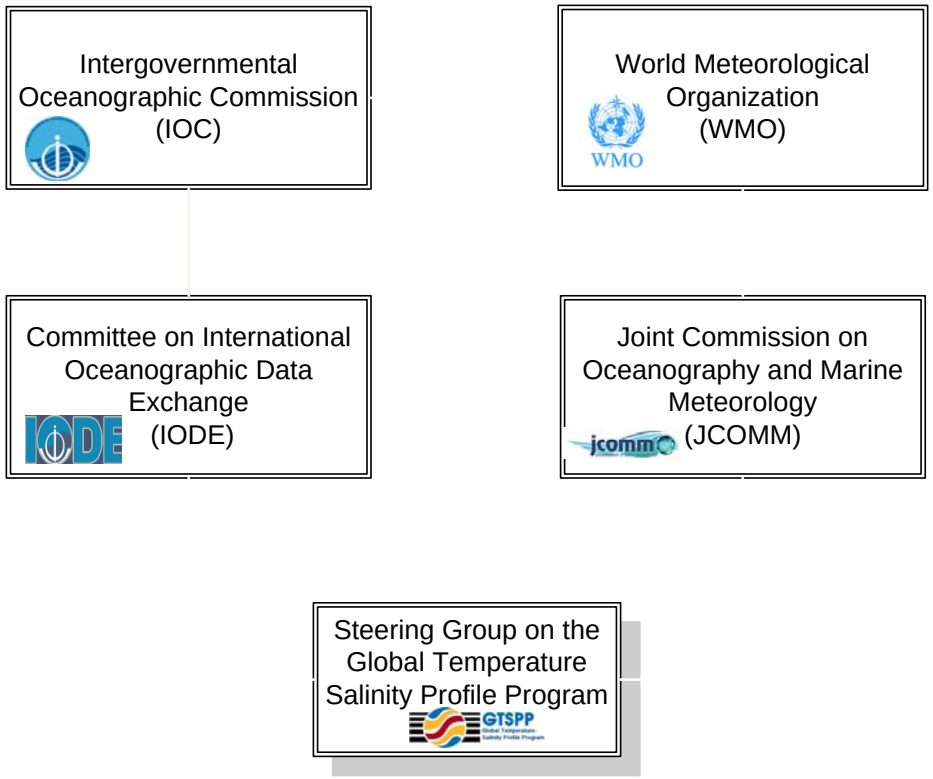
(3) Data continuously available every 5 days

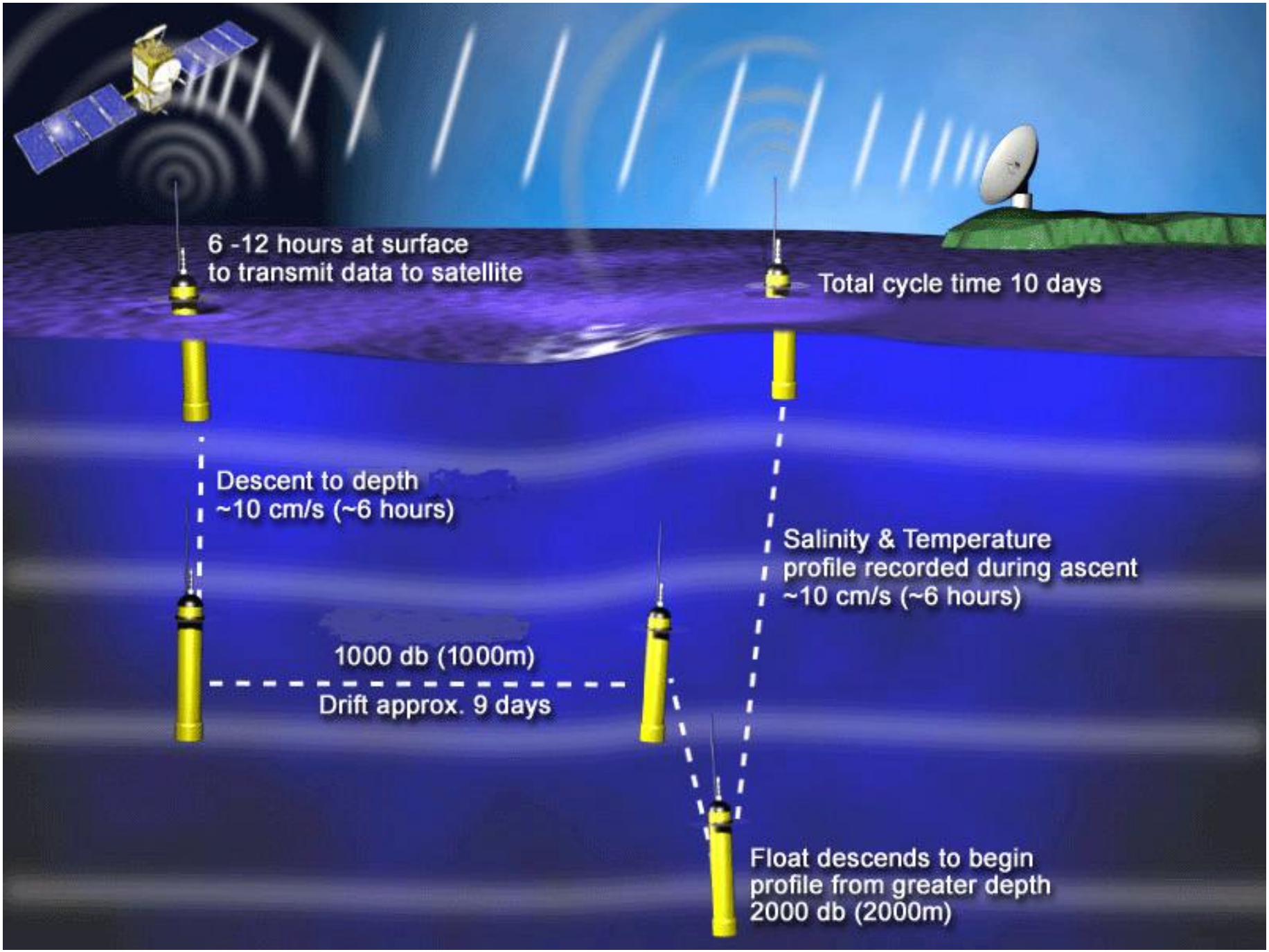

5-Day Interval Ocean Surface Currents (meter/sec)
Centered on May 2 2008
20°E
60°E
100°E
140°E
180°
140°W
100°W
60°W
20°W
20°E
60°N
40°N
20°N
0°
20°S
40°S
60°S
1.0
0.8
0.6
0.4
0.2
0.0
Mean
1.0 meter/sec (0.514 m/s = 1 knot)
0.5
0.4
0.3
0.2
0.1
0.0
Anomaly
NESDIS/NOAA
May 7 2008

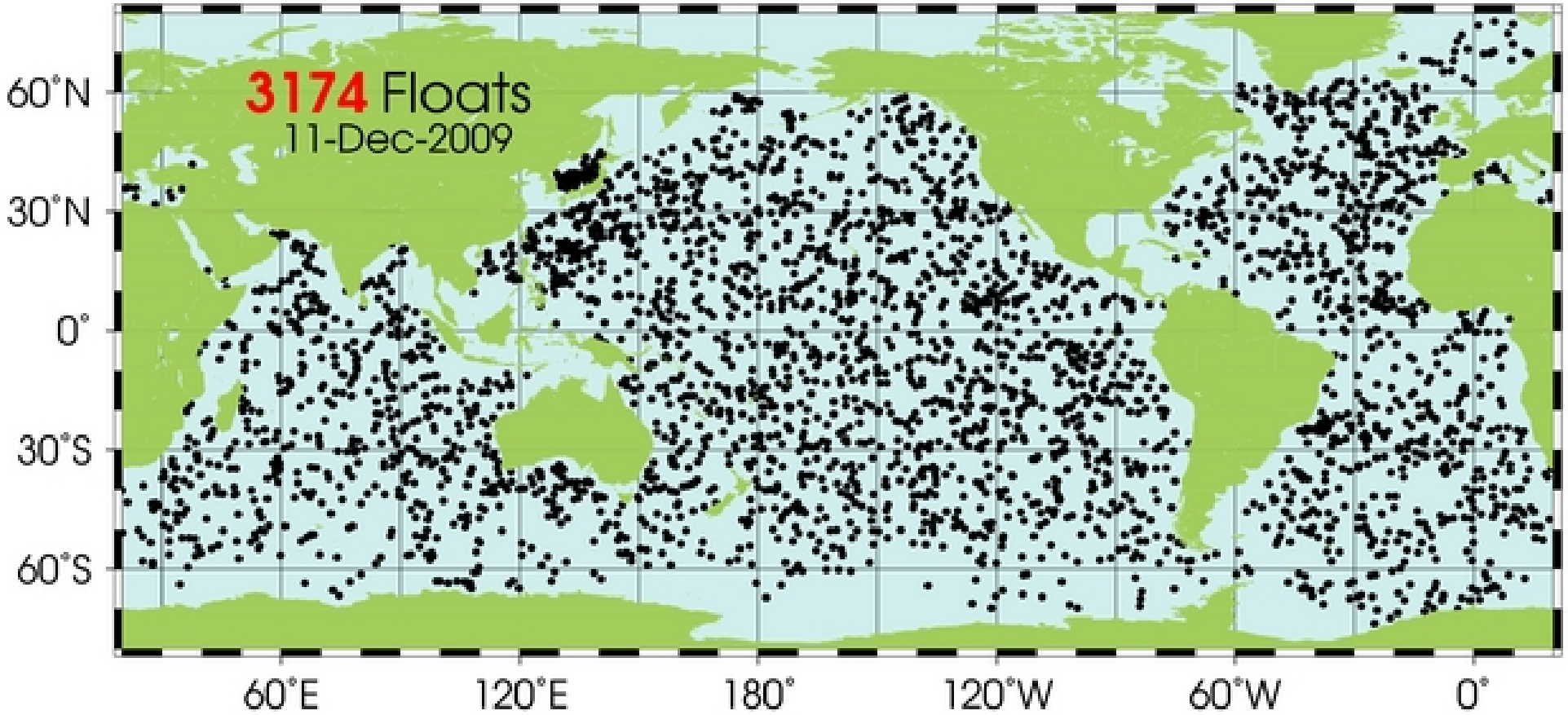
GTSPP

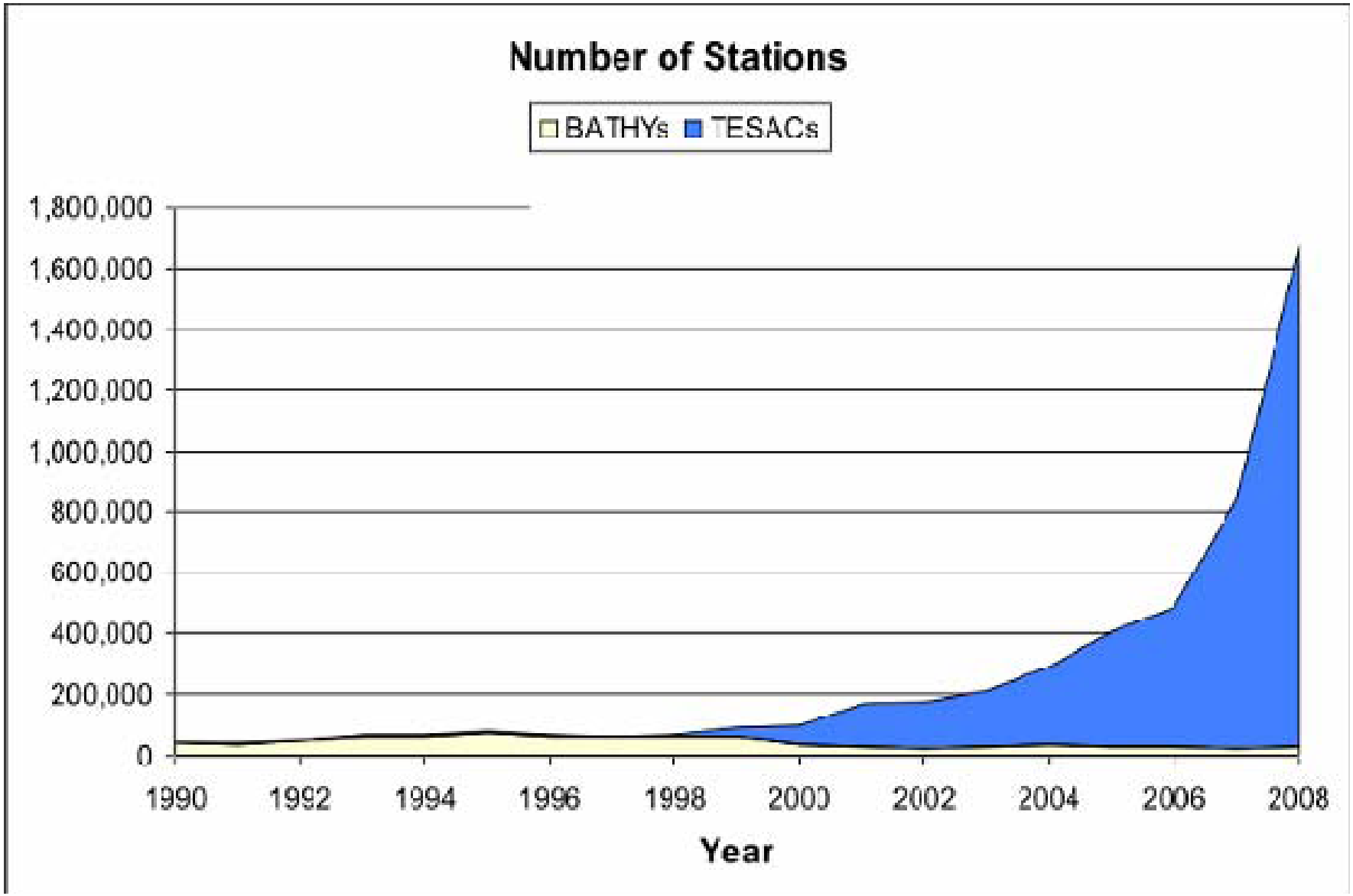
GTSPP = Global Temperature Salinity Profile Program

- GTSPP is a joint WMO-IOC program designed to provide improved access to the highest resolution, highest quality data as quickly as possible.
- GTSPP began as an official IODE pilot project in 1989.
- It went into operation in November 1990.



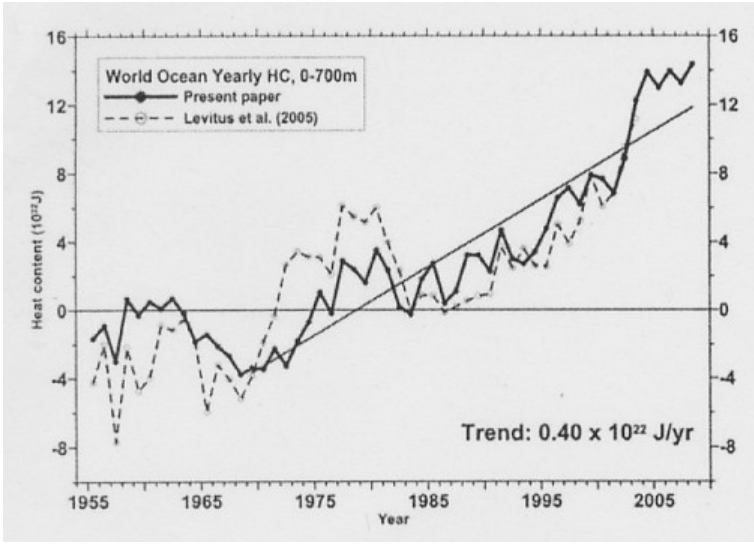

6 -12 hours at surface
to transmit data to satellite
Total cycle time 10 days
Descent to depth
~10 cm/s (~6 hours)
Salinity & Temperature
profile recorded during ascent
~10 cm/s (~6 hours)
1000 db (1000m)
Drift approx. 9 days
Float descends to begin
profile from greater depth
2000 db (2000m)


3174 Floats
11-Dec-2009
60°N
30°N
0°
30°S
60°S
60°E
120°E
180°
120°W
60°W
0°


Number of Stations
BATHYs
TESACs
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Year

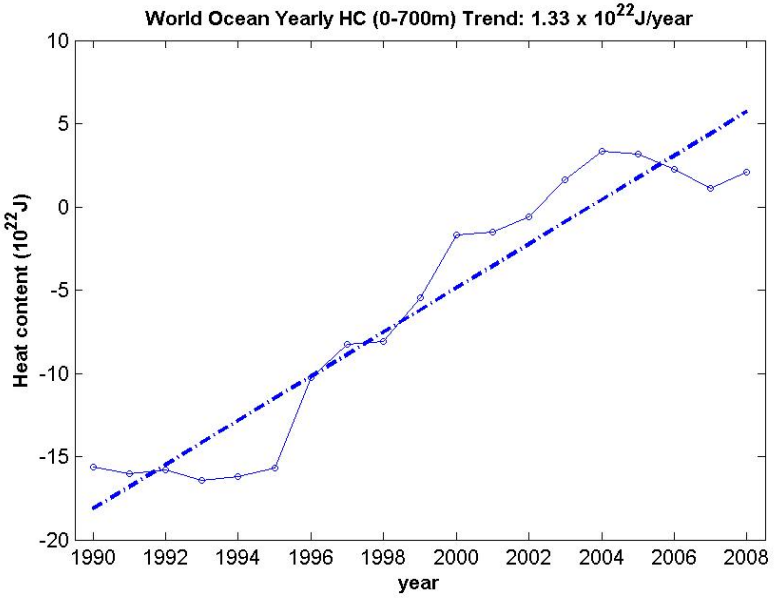
Trend of Upper Ocean (0-700 m) Heat Content

0.4 X 10^{22} J/yr
(1958-2008)
(Levitus et al.,GRL, 2009)
Without Argo data



1.3 X 10^{22} J/yr
(1990-2008)

With Argo data



Establishment of 4D global gridded synoptic temperature, salinity, and velocity (STSV) dataset

OSD
Spectral Representation

$$c(\mathbf{x}, z_k, t) = A_0(z_k, t) + \sum_{m=1}^{M} A_m(z_k, t)\ \Psi_m(\mathbf{x}, z_k),$$

Spatial Variability is represented by the basis functions

→ Vertical structure is preserved

Basis Functions (Closed Basin)

$$\triangle \Psi_k = -\lambda_k \Psi_k, \quad \Psi_k|_\Gamma = 0, \qquad k = 1, \ldots, \infty$$

$$\triangle \Phi_m = -\mu_m \Phi_m, \quad \frac{\partial \Phi_m}{\partial n}|_\Gamma = 0, \qquad m = 1, \ldots, \infty.$$

References

- Chu, P.C., L.M. Ivanov, T.P. Korzhova, T.M. Margolina, and O.M. Melnichenko, 2003a: Analysis of sparse and noisy ocean current data using flow decomposition. Part 1: Theory. Journal of Atmospheric and Oceanic Technology, 20 (4), 478-491.

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- These papers can be downloaded from:
- http://faculty.nps.edu/pcchu

Global 4D (T, S) Dataset

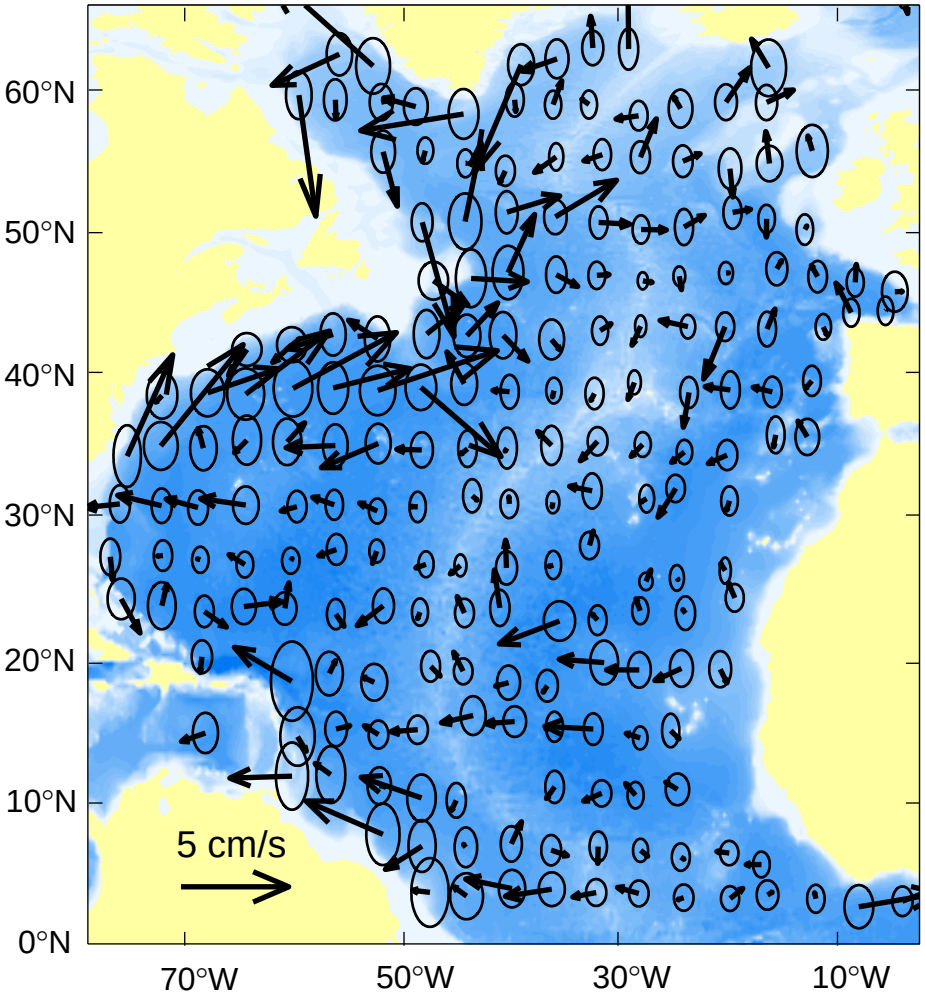
4D Velocity Data

Reference + Geostrophic

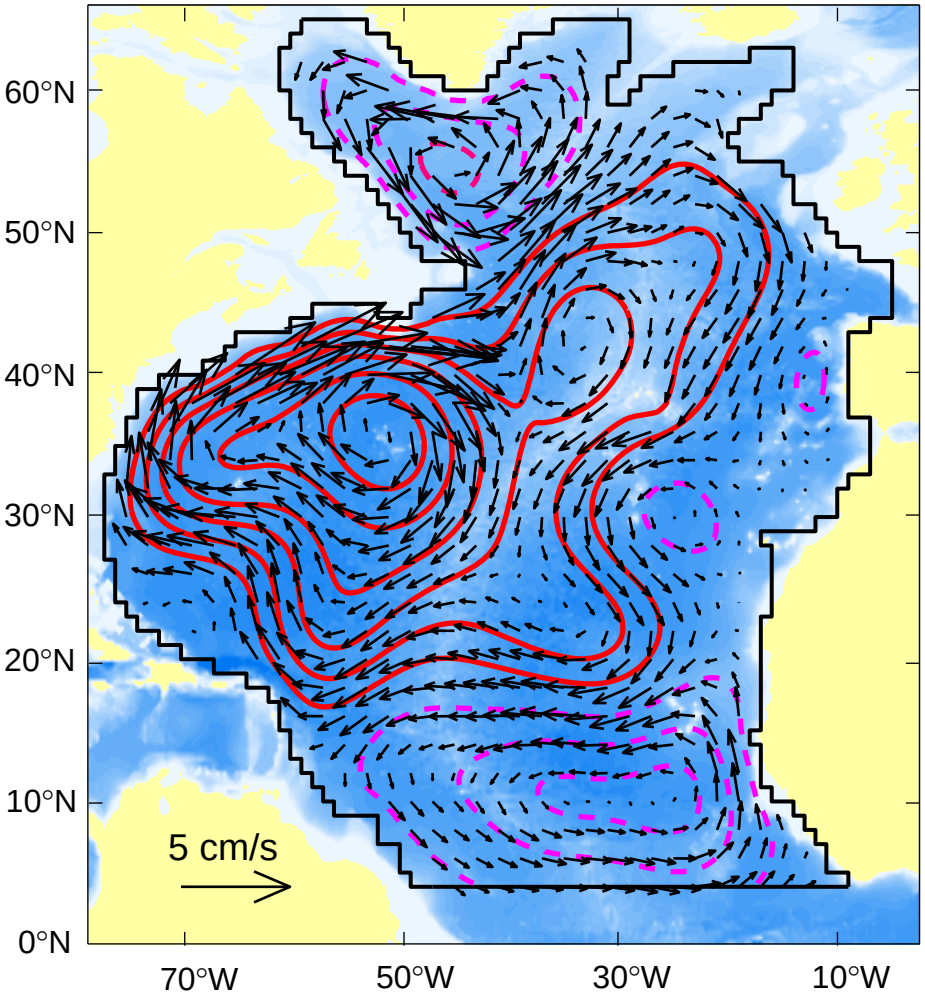
(T, S)

Circulations at 1000 m (March 04 to May 05) from Argo trajectory data

Bin Method



OSD



Meridional Overturning Streamfunction $\Psi(y, z)$

$$V(y, z) = \int v dx, \qquad W(y, z) = \int w dx$$

$$V = -\Psi_z \qquad W = \Psi_y$$

Conclusions

- (1) As technology advances, the MOC can be eventually observed by satellites, Argo drifters, …
- (2) It is important to establish 4D (T, S, **V**) data for climate research
- (3) The data shows faster upper ocean warming in the recent two decades (1990-2008)