Report
on the 6th
Annual System Review

NOAA/CPO Climate Observation Division

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Silver Spring

Bob Weller
Climate Working Group
Climate Observing System Council
Climate Observation Program

Mission
Build and sustain a global climate observing system that will respond to the long-term observational requirements of the operational forecast centers, international research programs, and major scientific assessments.

2008 Review
Focus on the in situ Ocean component with the theme of “Toward the Next Decade” – taking into account an international workshop OceanObs 09 planned for Venice in Sept 09, following up on OceanObs 99, and the white papers to be developed on facets of the obs system.

Additional context: discussions of a National Climate Service
Sustained Ocean Observations is a multinational effort in which the NOAA Climate Obs Program is a major player.

2008
The Plan

GCOS-92:
- Initial GOOS
- GEOSS Ocean Baseline
- UNFCCC Priority
- G8 Commitment

JCOMM is identified as the implementing agent for 21 specific actions.

Implement the ocean domain of GCOS-92:
JCOMM is identified as the implementing agent for 21 specific actions.
Initial Global Ocean Observing System for Climate
Status against the GCOS Implementation Plan and JCOMM targets

Total *in situ* networks **60%**
February 2008

- **87%** Surface measurements from volunteer ships (VOSclim)
- **100%** Global drifting surface buoy array
- **62%** Tide gauge network (GCOS subset of GLOSS core network)
- **81%** XBT sub-surface temperature section network
- **100%** Profiling float network (Argo)
- **43%** Repeat hydrography and carbon inventory

Milestones
- Drifters 2005
- Argo 2007

- **Reference time series** 24%
- **Global reference mooring network** 48%
- **Global tropical moored buoy network** 79%
- **58 sites**
- **25 moorings planned**
- **19 moorings planned**

Continuous satellite measurements of sea surface temperature, height, winds, and colour
Initial Objectives
How well are we doing? What else?

- Sea level to identify changes resulting from climate variability and change;
- Ocean carbon content every ten years and the air-sea exchange seasonally;
- Sea surface temperature and surface currents to identify significant patterns of climate variability;
- Sea surface pressure and air-sea exchanges of heat, momentum, and fresh water to identify changes in forcing function driving ocean conditions and atmospheric conditions;
- Ocean heat and fresh water content and transports to: (1) identify changes in the global water cycle; (2) identify changes in thermohaline circulation and monitor for indications of possible abrupt climate change; and (3) identify where anomalies enter the ocean, how they move and are transformed, and where they re-emerge to interact with the atmosphere; and
- Sea ice extent, concentrations, and thickness to identify changes resulting from, and contributing to, climate variability and change.
Discussion foci:

• Progress of the observing system over the past decade
• Combined use of satellite, in situ, and modeling techniques to observe the global ocean
• Scientific results, uncertainties, and present capabilities of the existing observing system
• Issues; gaps in the system; additional capabilities that are needed to reduce errors, improve scientific understanding, document change, and enable climate forecasting
The 2008 Annual System Review Agenda

- Session 1: OceanObs’09 -- Setting the Stage
  - Keynote: Ed Harrison -- OOPC

- Session 2: Ocean Circulation and Global Transport of Heat and Fresh Water
  - Chair: David Legler -- US CLIVAR

- Session 3: Biogeochemistry
  - Chair: Maria Hood – IOCCP

- Session 4: The Ocean’s Influence on Variability in Seasonal Temperatures, Precipitation, Sea Ice, and Extreme Events
  - Chair: Ed Sarachick -- UW

- Session 5: Rising Sea Level and the Ocean’s Storage of Heat
  - Chair: Kevin Trenberth NCAR

- Session 6: User Requirements and Applications
  - Chair: Ming Ji -- NCEP/OPC

- COSC Open Session
  - Program Planning and Budget
  - Climate Services: The Sustained Ocean Observing System as a Foundation Climate Service

- COSC Executive Session
  - Planning for in-depth project reviews
OceanObs09 - Conference Goals
Ed Harrison

1. Highlight the crucial role of the ocean observing system for understanding and predicting climate
2. Demonstrate the societal and economic benefits of the observing system
3. Make clear the challenge of completing and maintaining the core observing system
4. Identify new opportunities for increased capability, such as biogeochemical and ecosystem monitoring
5. Promote partnerships to sustain and advance development of the system into the 21st century
Session 2: Ocean Circulation and the Global Transport of Heat and Freshwater

surface currents, Ekman flow, Pacific inflow to Arctic, several talks on AMOC, low-lat S. Pac. WBC
CONCLUSIONS:
Combined drifter and altimeter derived velocity anomalies can be used to make regional, realistic, near real time maps of 15m ocean circulation.
Global, absolute sea level on 50km scale from combined data displays new circulation features.
OGCM solutions are most stringently tested with velocity fields derived from combined drifter and altimeter observations.
- follows slopes and ridges
  ... SLOWLY (a few cm/s – 8hrs for 1 mile)
- strong “eddie”s within that flow
- likes to stick to a depth contour .. MOSTLY
- takes more than 10-20-30 .. years to get back out!

Rebecca Woodgate
PACIFIC WATER
- nutrient rich
- source of heat and freshwater

- follows slopes a bit (and faster!), but also crosses basins
  ... in response to wind??
- eddies important again
- keeps nutrients high in the water
- takes 10 years or less to cross Arctic

Rebecca Woodgate
Session 2 – Ocean Circulation and the Global Transport of Heat and Freshwater - some thoughts

- Progress toward synthesis; not so focused on single technique
- Challenging the perspectives – role of the Arctic, connectivity of the Arctic, observing the Arctic, including ecosystems; role of the deep ocean, need to observe the deep ocean

- Potentially a broad conceptual framework
  - Surface currents, bndy currents, MOC, transport processes, storage monitoring
  - Observational quantification; observing prototypical sites/processes or every site
  - Parameterization or determination
  - Monitoring and production of indices
  - Model validation and verification
  - International partnerships
Session 3: Changing Ocean Biogeochemistry, Ocean Carbon Uptake, and Impacts on Ecosystems

Ship-based obs, inorganic carbon inventories, Air-sea CO2 flux, use of chlorofluorocarbon obs to constrain estimates of anthropogenic CO2 uptake, Ocean acidification, new sensors for Argo floats, coral reef watch, biogeochemical time series in the Bering strait
Global Survey is 60% complete with all measurements meeting or exceeding anticipated quality requirements.

Meridional sections in the Atlantic, Pacific and Indian oceans show that there are significant and measureable inorganic carbon changes in all three ocean basins over the last decade.
Comparison of crossover and overlap stations indicate the DIC data are good to +/- 1 µmol kg\(^{-1}\) and alkalinity data are good to +/- 2 µmol kg\(^{-1}\).
Ocean Acidification of the North American Continental Shelf

NACP Coastal Survey Cruise: 11 May - 14 June 2007

Distribution of the depths of the corrosive water (aragonite saturation < 1.0; pH < 7.75) on the continental shelf of western North America from Queen Charlotte Sound, Canada to San Gregorio Baja California Sur, Mexico.

On transect lines 5 and 6 the corrosive water reaches all the way to the surface in the inshore waters near the coast.

Feely et al. (2008)
Session 3: Changing Ocean Biogeochemistry, Ocean Carbon Uptake, and Impacts on Ecosystems – Some thoughts

- Rigor in the repeat carbon/hydro observations – such as the sections that cross and evidence of change
- A sense of urgency fueled by the acidification, potential ecosystems impacts and changes
- Challenges remaining in implementing surface pCO2 obs
- What observations are needed to address acidification, ecosystems impacts? How to monitor ocean ecosystems?

- Ships and the cost of repeat sections?
- A part of the Argo array trading off lifetime for more diverse sensors?
- The under-observed high latitudes
- The challenge of observing in coastal regions
- What are the interfaces between ecosystems management/monitoring and climate observation/prediction?
Session 4: The Ocean’s Influence on Seasonal Variability
(Temperature, Precipitation, Sea Ice, Extreme Events)

Global tropical moored buoy array,
salinity from space, global SST analyses,
US CLIVAR drought working group,
storage and movement of heat,
seasonal variability and trends in evaporation, global precip,
Arctic Sea Ice outlook as a pilot climate service product,
Arctic sea ice
Global SST – Reynolds and Chelton

- **GHRSSST has resulted in many high resolution SST products**
  - Differences in input data, grid resolution, analysis procedures
  - Important differences in analyzed SSTs and analysis resolution

- **The purpose here is try to identify analysis problems and determine which analyses are superior**
  - If an analysis resolution is set too fine, all you will get is noise
Satellite observations provide information of spatial / temporal variations.

In situ instruments (ships, buoys, atolls..) make direct measurements.

Merging improves quality of oceanic precip analysis.

Various merged / combined analyses (e.g. GPCP, CMAP, TRMM) present similar spatio-temporal variation patterns.
Problems in Existing Precip Data Sets

- Uncertainty in quantitative magnitude
- Inhomogeneity in Long-term time series
- Poor Quality over high latitudes
- Coarse Resolution in long-term data sets

Critical Elements Need to be Addressed for improved observation of oceanic precipitation

- In Situ Measurements
  buoys, ships, special field experiments ..

- Satellite Estimates
  new instruments, new technology, new networks

- Combining Information from Various Sources
  different satellites
  in situ & satellites
  precip & other parameters (e.g. moisture, temperature ..)
Session 4: The Ocean’s Influence on Seasonal Variability (Temperature, Precipitation, Sea Ice, Extreme Events) – some thoughts

• attempt at bringing together observing oceanic variability – SST, fluxes, salinity, sea ice – with user pull (drought, ice pack/Arctic change)

• A bit derailed by a focus on an observing element – tropical buoys – and their status (transition to NDBC, Indian ship time)

• There is more potential to be mined here
  – Lisan Yu’s evaporation product led to a dialog with atmospheric community
  - Storage and movement of heat (Trenberth) cross-checking ocean obs with surface flux – why not for freshwater using ocean salinity from Argo
Session 5: Rising sea level and ocean’s storage of heat

Global sea level rise from tide gauges, Satellite altimetry, ARGO float program, ARGO float sampling simulations, XBT obs, low-density XBT lines, ocean heat content 1955-2007, Deep ocean heat and freshwater storage
Observed rise at the upper limit of IPCC TAR projection that includes a “land-ice uncertainty”

Suggestion: NOAA Obs/Model Program to Improve Projections of Sea Level Rise

• Model projections don’t agree well with 15+ year altimeter record either globally or regionally
• Many elements already exist in NOAA or are heavily supported by NOAA, including Jason altimetry (a new NOAA operational responsibility), tide gauges, Argo floats, and modeling capabilities.
• Possible broad agency involvement: OAR, NESDIS, NOS
• Topic for OAR/NESDIS workshop in late September
Session 5: Rising sea level and ocean’s storage of heat – some thoughts

- Sea level – many examples of the need for careful consideration of observing capabilities (drift in altimeters, Argo float near surface obs problem)
- Sea level – pointing to the need to improve models and the essential role of obs
- XBTs – how does one make wise choices in long-lived networks, in pursuing data quality from systems not designed for climate (e.g. drop rate corrections); cautionary tales of different groups, of metadata needed to track corrections

- A clear target of the program – observation, understanding, better prediction of sea level rise – an index with clear societal translation and need
- Is this a focus for evaluation of all ocean temperature observations and the evolution of those observations?
Session 6: User Requirements/Applications

OSMC (Obs. Sys. Monitoring Center),
NCEP ocean data assimilation and forecasting,
Multi-decadal variability/predictability in GFDL models,
WCRP, IPCC
Data access - OSMC

3 areas of integration under OSMC

1. Climate platforms via realtime input from GTS
2. Climate archives (‘DACs’ and ‘GDACs’)
3. Climate products and data

- Open and easy access to data is critical
- Lowering the threshold for diverse users
- Metrics for success for Climate Obs Program?
Real Time Ocean Forecast System (RTOFS): A high resolution operational ocean forecast system for the Atlantic
• NCEP is a users, assimilating ocean data

• Is this a path for gridded products some users might want instead of raw data?
• How would one judge quality of such products?
• What is the dialog between NCEP and those doing the observations?
**Decadal Prediction**

Rosati

**Challenges with Ocean Initialization**

Many different global reanalysis products, and significant differences exist

**GSOP: Assessment of quality of ocean syntheses**

**Synthesis Evaluation Workshops (ECMWF 9/06; MIT 9/07)**

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**Tropical Upper Ocean T Anomalies (Upper 300 m)**

- Pacific ↔
- Indian →

**Balmaseda and Weaver**
• The need for model initialization
• The potential use of these models to guide ocean observing system design
  – Tropical ocean
  – Deep ocean data to constrain model drift
WCRP use/need of sustained global ocean observations

- Fundamental/basic research
- Process studies
- Parameterizations (e.g. CPTs)
- Monitoring (including assessment and attribution)
- (Re)Analysis
- Initialization of prediction
WCRP use/need of sustained global ocean observations

- Sea level rise
- Role of the ocean in predicting/forecasting drought/flood
- Abrupt climate change
- Tropical cyclones, storms, surges and other climate-related hazards
What else is needed?

- Greater synergy between in situ and space-based ocean observations
- Greater dialogue (i.e., requirements) between climate prediction and ocean observing components
- Systems approach to obs/fields
- A routine ocean state estimation activity inclusive of observational error estimates
- Sustained data/information delivery; plan for access and archival of ocean research observations
- Infrastructure to ensure climate quality, continuity, and reprocessing capabilities
Is decadal variability real?

Causes of decadal variability: artefact due to temporally changing observing system

Annual ocean heat content 0-700m relative to 1961-90 average

- Ishii et al 2006
- Willis et al 2004
- Levitus WOA
- ARGO problems
- XBT drop rate problems

Trenberth
Estimates of upper 700 m ocean heat content and SST. Domingues et al Nature 2008
Adaptation to climate change

- Assess vulnerability
- Devise coping strategies
- Determine impacts of possible changes
- Plan for future changes

Requires information
An Integrated Earth System Information System