Observational Oceanography II: *in-situ* Process Studies

+ Goals for the next decade

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With slides from Mike Patterson, Director of US CLIVAR

ECCO Summer School 2019 * Friday Harbor Laboratories
What are Observations used for?

From Lecture 1....

• Observations for mapping fields, initiating or nudging models
  ▪ Timely (available through the Global Telecommunication System (GTS) in near realtime)
  ▪ Geographically distributed in coherent array, with known uncertainty and quality

• Observations for validation
  ▪ Independent obs (e.g. not assimilated)
  ▪ High quality, of known uncertainty that is smaller than error of model.

• Observations for improving model physics, parameterizations and understanding of processes
  ▪ Oversampled, high quality observations (e.g. Process Studies)
How many errors can I have?

• Mistakes and Miscalculations
• Mean bias errors & Random uncertainty due to noise
• Systematic biases due to sampling issues
• Systematic biases due to field errors
• Systematic biases due to calibration errors, model physics errors, etc.
• Error in representation of a mean value by a spot observations.
Motivation for Process studies
Motivation for Process Studies

What are the key mechanisms and processes controlling the climate system? How are these modulated by large-scale variability and general circulation? *Improved understanding of these processes can lead to better predictability in the climate system.*

If this process cannot be resolved by model, can it be parameterized?

Does the parameterization improve the model state estimates & forecasts?

What are minimum observations/variables needed to resolve and monitor this process? *Improved monitoring of these processes can lead to better predictability in the climate system.*
About US CLIVAR

US Climate Variability and Predictability (CLIVAR) is a national research program with a mission to foster understanding and prediction of climate variability and change on intraseasonal-to-centennial timescales, through observations and modeling with emphasis on the role of the ocean and its interaction with other elements of the Earth system, and to serve the climate community and society through the coordination and facilitation of research on outstanding climate questions.

US CLIVAR research is currently supported by participating programs within five Federal agencies including the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Department of Energy (DOE), and the Office of Naval Research (ONR). A US CLIVAR Inter-Agency Group of program managers from these five agencies coordinates and targets funding and resources to support the research activities of the program. Four of these agencies, NASA, NOAA, NSF, and DOE sponsor the US CLIVAR Project Office to work with the SSC and its Panels in coordinating science planning, implementing research activities, communicating research advances and needs, and supporting international engagement and collaboration.
Panel Descriptions

Phenomena, Observations, and Synthesis Panel

The Phenomena, Observations, and Synthesis Panel’s (POS) mission is to improve understanding of climate variations in the past, present and future, and to develop syntheses of critical climate parameters while sustaining and improving the global climate observing system.

Predictability, Predictions, and Applications Interface Panel

The Predictability, Predictions and Applications Interface Panel’s (PPA) mission is to foster improved practices in the provision, validation and use of climate information and forecasts through coordinated participation within the U.S. and international climate science and applications communities.

Process Study and Model Improvement Panel

The Process Study and Model Improvement Panel’s (PSMI) mission is to reduce uncertainties in the general circulation models used for climate variability prediction and climate change projections through an improved understanding and representation of the physical processes governing climate and its variation.

Funding for US CLIVAR provided by

NASA  NSF  ONR  NOAA

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Consider getting on this panel!
BEST PRACTICES FOR PROCESS STUDIES

BY MEGHAN F. CRONIN, SONYA LEGG, AND PAQUITA ZUIDEMA

PROCESS STUDY “BEST PRACTICES”

• Modelers and observationalists should be integrated in the study from the planning stage onward.
• Integrated and synthesized datasets should be generated from the process study observations to provide model-comparable data that can be used as benchmarks for assessing and validating models. Furthermore, diagnostics shown in much-cited published figures should be provided in digital format as “synthesis products.”
• Broad use of the data should be encouraged through
  — open data policies;
  — centralized access to all components of the experiment; and
  — data archiving in a user-friendly format, and with sampling information (“metadata”) that is necessary for understanding the measurement.

Meghan Cronin was co-chair of the US CLIVAR Process Study and Model Improvement Panel from 2005-2008
Sonya Legg was co-chair of US CLIVAR PSMIP from 2007-2009
Paquita Zuidema was co-chair of US CLIVAR PSMIP from 2009-2011
US CLIVAR has also promoted the concept of Climate Process Teams (CPTs).


Climate Process Teams

For a decade and a half, US CLIVAR has promoted the concept of Climate Process Teams (CPTs). CPTs improve the fidelity of coupled climate models by facilitating the transfer of knowledge from observational and process-oriented research to the development of physical process representation in component ocean or atmosphere global climate models (GCMs). A CPT, as defined by US CLIVAR, is a:

funded multi-institutional project that assembles observation-oriented experimentalists, process modelers, process diagnosticians, theoreticians, and climate model developers from two or more modeling centers into a single project that focuses on a specific process or set of processes to assess model sensitivities to process uncertainties, establish observation and model metrics, and develop, test, and implement parameterization improvements.

NSF and NOAA have co-sponsored two rounds of CPT projects, with the latest projects completing in 2015/16.

In 2015, the US CLIVAR Process Studies and Model Improvement (PSMI) Panel organized a review of CPTs to assess the effectiveness and lessons learned from the CPT approach, main sources of errors/biases in models, opportunities for future model improvement, and potential payoff for future CPT projects. The review committee collected input through questionnaires of seven US modeling center and numerous observational programs, process studies, CPT projects, and US CLIVAR Working Groups, followed by an open community workshop held at NOAA GFDL in September 2015. The information collected informed a 2016 US CLIVAR White Paper.

Below are the key findings from the white paper, best practices for a CPT, and how best to propose a CPT project to the US CLIVAR funding agencies.
Process Studies vetted by the US CLIVAR panels:

**AMOC** – Atlantic Meridional Overturning Circulation Program (including SAMBA and OSNAP)

**CLIMODE** – CLivar Mode Water Dynamic Experiment

**DIMES** – Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean

**DYNAMO** – Dynamics of Madden Julian Oscillation

**EPIC** – Eastern Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System

**IASCLiP** – Inter-Americas Study of Climate Processes

**KESS** – Kuroshio Extension System Study

**NAME** – North American Monsoon Experiment

**SPURS** – Salinity Processes in the Upper Ocean Regional Study

**VOCALS** – VAMOS Ocean-Cloud-Atmosphere-Land Study
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Using data from historical process studies

• Learn about process studies by going to US CLIVAR website & process study website.

• Access data from process study website or from national data archive (e.g. NOAA’s NCEI, NASA’s EOSDIC & PODAAC, NSF’s NCAR EOL).

• Reach out to the process study PIs.
Kuroshio Extension System Study

The warm, northward-flowing waters of the Kuroshio western boundary current leave the Japanese coast to flow eastward into the North Pacific as a jet — the Kuroshio Extension. The Kuroshio Extension forms a vigorously meandering boundary between the warm subtropical and cold northern waters of the Pacific. A recirculation gyre exists to the south of the Kuroshio Extension. Another may exist to the north. This is also one of the most intense air-sea heat exchange regions on the globe, where the warm Kuroshio waters encounter the cold dry air masses coming from the Asian continent. The Kuroshio Extension system exhibits variations which strongly affect North American climate. Among the diverse fields that will benefit from this work are fisheries and climate research, and understanding storm tracks.

Understanding the processes that govern the variability of and the interaction between the Kuroshio Extension and the recirculation gyre is the goal of this study. Processes coupling the baroclinic and barotropic circulations will be examined by case studies of the local dynamical balances, particularly during strong meandering events. The mechanisms by which water masses are exchanged and modified as they cross the front will be characterized. The objective is to determine the processes governing the strength and structure of the recirculation gyres in relation to the meandering jet.

Science Highlights

KEO Surface Buoy

KEO mooring carries a suite of meteorological sensors to measure winds, air temperature, relative humidity, rainfall, and solar and longwave radiation.

https://uskess.whoi.edu/
Objectives:

1) To understand processes coupling the baroclinic and barotropic circulation and variability.
    
    Hypotheses: ...
    
    What’s needed: Density and velocity time series, with mesoscale resolution to calculate \( \frac{d}{dx}, \frac{d}{dy} \) and \( \frac{d}{dt} \) of density and velocity. Sufficient vertical resolution to quantify structure of upper-jet baroclinic front and the deep nearly barotropic fields. “Case-studies” of the local dynamical balances, particularly of large-amplitude events.

2) To determine and quantify cross-frontal exchange processes in the Kuroshio Extension.
    
    Hypotheses: ...
    
    What’s needed ...

3) To determine the processes that govern the strength and structure of the recirculation gyre – its position, elongation, stratification, and subtropical mode water formation within the gyre.
    
    ...

https://uskess.whoi.edu/
Oops! The 2004-2006 process study is done and links to the data on the static website are now broken!
The NCEI provides archival and access to oceanic, atmospheric, and geophysical datasets from the ocean’s bottom to the sun’s surface and from million-year-old ice cores to near-real-time satellite retrievals. Limited data from process studies/field campaigns are archived here. Visit https://www.ncei.noaa.gov/

From slide courtesy of Mike Patterson, US CLIVAR director
Searching on “KESS”, 3 clicks later get to:

**Ocean Climatology**

- World Ocean Database
- Global Temperature-Salinity
- Regional Climatologies
- Global Ocean Heat and Salt Content
- SST Climatologies (Pathfinder)

**Parameters and Data Types**

- Temperature
- Salinity
- Oxygen
- Nutrients
- Inorganic Carbon
- Particulate
- Phytoplankton
- Chlorophyll
- Profile Data
- Ocean Currents
- Sea Level
- Sea State / Wave Data
- Biological Data
- Satellite Data
- Ocean Acidification
- Ocean Color
- Video Data

**Project Data Sets**

- Coastal Data Center Projects
- Coastal Water Temperatures
- Joint Archive for Sea Level
- World Ocean Atlas / Database
- Ocean Carbon Data System
- Coastal Buoy Data Archive
- Global Ocean Currents
- Satellite Oceanography
- IOCDB Archive Data Portal

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**Bottom Pressure, Vertical Acoustic Round-Trip Travel Time, and Near-Bottom Currents Data**

This data set contains Current and Pressure-recording Inverted Echo Sounders (CP(ES)), as part of the Kuroshio Extension System Study (KESS) from 26 April 2004 to 25 June 2006 in the Kuroshio Extension east of Japan (NCEI Accession 0073269).

- Download Data:
  - HTTPS (download)
  - FTP (download)

These data are available through the File Transfer Protocol (FTP). You may use any FTP client to download these data.

**Distribution Formats**

- Original data format

**Ordering Instructions**

Contact NCEI for other distribution options and instructions.
Let’s see if we can get to the SPURS data....

**NASA Earth Observing System Data and Info Service (EOSDIS) and the Physical Oceanography Distributed Active Archive Center (PODAAC)**

NASA PO.DAAC preserves and provides access to NASA’s ocean and climate data. Data from NASA-sponsored process studies/field campaigns (e.g., SPURS) are archived here. Visit [https://podaac.jpl.nasa.gov/](https://podaac.jpl.nasa.gov/)
Searching on “SPURS” in PODAAC brings up 3 pages of data from SPURS-1 and SPURS-2. Notice nice organization of data in left bar!

SPURS (Salinity Processes in the Upper Ocean Regional Study) aimed to resolve key mechanisms responsible for near-surface salinity variation.
NCAR Earth Observing Laboratory

The EOL Data Archive provides archival and access to atmospheric, oceanographic, and other geophysical datasets from scientific process studies/field campaigns for which NCAR/EOL has provided data management support.

Visit https://www.eol.ucar.edu/all-field-projects-and-deployments

From slide courtesy of Mike Patterson, US CLIVAR director
Selecting a specific field project takes you to the list of accessible data sets by category, platform, data type, lead scientist, and institution.

Visit [https://www.eol.ucar.edu/all-field-projects-and-deployments](https://www.eol.ucar.edu/all-field-projects-and-deployments)

This example shows data from DYNAMO (Dynamics of Madden Julian Oscillation) process study that took place in the tropical Indian Ocean in 2011-2012.

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Air-Sea Fluxes with a focus on Heat and Momentum

Goals for 2030:
Gridded Air-Sea fluxes with 1-day random uncertainties of:
15 W m$^{-2}$ (5%) & 0.01 N m$^{-2}$ (5%)

And Biases less than:
5 W m$^{-2}$ & 0.005 N m$^{-2}$

For: 3-hourly at 25 km

Aspirational goal: 1-hrly at 10km
Need more than 10 essential ocean & climate variables to compute air-sea heat fluxes.

\[ Q_{\text{net}} = Q_{SW} - Q_{LW} - Q_{\text{lat}} - Q_{\text{sen}} \]
Air-Sea Fluxes with a focus on Heat and Momentum

Two Big Asks:

1. Improved space-based near-surface retrievals of surface humidity and air temperature.
2. Regionally distributed in situ network of flux observations, built around an expanded OceanSITES network of reference stations.
Improved space-based near-surface retrievals of surface humidity and air temperature.

**Improved vertical resolution and accuracy of temperature and humidity profiles.** This could be done for example by combining a 5-channel C- to Ka-band digital radiometer with a 50 and 183 GHz hyperspectral digital sounder.

Improved algorithms relating near-surface retrievals to surface humidity and air temperature.

Simultaneous retrievals of SST, surface wind speed and direction, and profiles of near-surface air temperature and humidity (as well as rain, water vapor, soil moisture, sea ice concentration).

![Diagram of heat flux equations](image)
(2) Regionally distributed in situ network of flux observations, built around an expanded OceanSITES network of reference stations.
Roadmap for Expansion of *in situ* Array

- Evaluate cross-platform, cross-product, & ocean vs. land-based comparisons to quantify uncertainties and improve best practices and model physics and parameterizations.
  - Ocean & Land Baseline Surface Radiation Network (BSRN)?
- Form an international Autonomous Surface Vehicles (ASV) expert group to coordinate data stream, evaluate data, and develop best practices and standardizations.
- Perform array design studies and pilot studies to raise Technical Readiness Levels for flux platforms.
- Improve bulk algorithms, including role of sea state, and parameterizations of albedo and emissivity.
- Improve coupling physics in NWP.

Roadmap for Optimization of Satellite Retrievals

- Improve resolution of satellite retrievals, time coincidence of remotely-sensed flux EOVs/ECVs, and algorithms relating retrievals to near-surface conditions.
- Improve parameterizations for transforming bulk EOV/ECV into bulk algorithm state variables.
Roadmap for Expansion of \textit{in situ} Array

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  - Ocean \& Land \textit{Baseline Surface Radiation Network (BSRN)}?
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- \textbf{Improve coupling physics in NWP}.

Roadmap for Optimization of Satellite Retrievals

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\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|c|}
\hline
\hline
\textbf{Bulk SST} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Skin Temperature} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Wind Speed and Direction} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Air Temperature} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Humidity} & Not met & Not met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Bulk Surface Currents} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Skin Surface Currents} & Not met & Not met & Adequate & & & & & & & & & & & \\
\hline
\hline
\textbf{Surface Longwave Radiation} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
\textbf{Albedo} & Partially met & Partially met & Adequate & & & & & & & & & & & \\
\hline
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