CLIVAR: CLIMATE & OCEAN
variability, predictability and change

WCRP Core Project on the
Ocean-Atmosphere System

Detlef Stammer & Annalisa Bracco (SSG co-chairs)

CLIVAR: CLIMATE & OCEAN variability, predictability and change

- Describe and understand the dynamics of the coupled ocean-atmosphere system,
- Identify processes responsible for climate variability, change and predictability,
- Develop - through the collection and analysis of observations - and apply models of the coupled climate system.
CLIVAR was established 20 years ago as one of the core-projects of the World Climate Research Programme, building on WOCE and TOGA,

The CLIVAR legacy includes the

- implementation and development of major multinational observing networks in all the ocean basins;

- development of ocean and climate re-analyses, bridging observations and modeling through data assimilation;

- development of ocean-climate models, initialized decadal climate predictions building on o&c reanalyses.
New CLIVAR Science

Long term objectives:

- Identify ocean and coupled climate processes that are critical for global and regional climate variability and change
- Identify temporal and spatial scales of climate predictability
- Quantify constraints on climate sensitivity, air-sea exchange and Earth’s energy budget / ocean heat content
- Quantify regional impacts of climate change in sea level, cryosphere and water cycle
- Quantify past/present/future ocean role in CO₂ uptake and links between climate and ocean ecosystems

New CLIVAR Science Plan will be released in 2016
Science Plan

TIMELINE

MAY 2016 - Draft posted on CLIVAR website and widely distributed (including WCRP, sister programmes) for comment/input

MAY/JUNE, 2016 - further refinement of Plan

MID/END JULY, 2016 - new draft (ICPO w/ editorial team) prepared and published on CLIVAR website and advertised on CLIVAR OSC website

SEPTEMBER 2016 - OSC - town hall for community input, comment

OCT/NOV - revisions to Plan based on OSC, produce camera-ready copy

DECEMBER 2016 - "final" Plan published
How CLIVAR works
Research Foci (RF): launched in 2015; focused limited-lifetime initiatives (5 years or less); topics of high priority in the climate research community that would benefit from enhanced international coordination.

- Decadal Climate Variability & Predictability
- Planetary Heat Balance & Ocean Heat Storage (with GEWEX participation)
- ENSO in a Changing Climate
- Eastern Boundary Upwelling Systems
- Regional Sea Level Change & Coastal Impacts (with CliC participation)
International cooperation is critical to grow the infrastructure that underpins all CLIVAR science:

- Climate and Ocean Process and Sustained Observations
- Global, Regionally Enhanced and Process Models
- Ocean Data, Synthesis and Assessment
- Capacity Development and Knowledge Exchange
Scientific progress

Organized around WCRP objectives

– Climate processes
– Climate predictability
– Climate sensitivity
– Regional impacts
– Ocean CO$_2$ uptake
Climate feedbacks and modes of coupled variability
Model representation of climate modes
The ocean’s role in climate variability at different timescales
Ocean energetic and mixing
Key Themes

- Storm tracks, jet streams and weather systems
- Tropical-extratropical interactions
- Coupled atmosphere-ocean feedbacks

Figure from Minobe et al. (2010) showing vertical velocity response in the Gulf Stream region.

Mesoscale eddy role in air-sea interactions
Ma et al., Scientific Reports, 2015
Impact of sharp SST front on European Blocking

20-year 0.5-degree resolution AGCM experiments.

Smoothing is just over the Gulf Stream region.

Sharp SST front (CONTROL): more frequent blocking than smoothed SST (SMOOTH)

O’Reilly, Minobe & Kuwano-Yoshida (2015 Clim Dyn)

PDFs of eddy-driven jet latitude

Significant difference

Sharp SST front causes larger probability of northern path of eddy driven jet

O’Reilly, Minobe, Kuwano-Yoshida & Woolings (in prep)

- High-res SST is important for high-res AGCM.
- Hires-MIP in CMIP6 is great resource for studies of mid-latitude air-sea interaction.
CLIMATE PROCESSES
RF ENSO in a changing climate

Need for:
• TPOS-type observations
• Continued/enhanced record
• Enhanced obs of Equatorial currents
• Equatorial atmospheric data
CLIMATE PROCESSES
Pacific and IO Region Panels: Plans for new experiment in the Indo-Pacific and Indonesian Throughflow (ITF)

- Large transports
- Complex pathways
- Modulation by ENSO/SPCZ
- Warm Pool Maintenance
- WBC

NPOCE (Northwestern Pacific Ocean Circulation Experiment): 2010-
China, US, Australia, Japan, Korea, Philippines, Indonesia, Germany

SPICE (Southwest Pacific International Circulation and Climate Experiment): 2008-2015, France, Australia, New Zealand, US, Fiji Islands
CLIVAR Pacific Region Panel working in coordination with TPOS2020 Western Boundary Task Team to determine the observational requirements, strategies and design plan for the region.
CLIMATE PROCESSES
Ocean Model Development Panel

- Ocean energetics, waves, mixing and parameterizations

- Coordinate Ocean-Ice Reference experiments
  - Evaluation, understanding, and improvement of ocean models
  - Investigation of mechanisms for seasonal, interannual, and decadal variability
  - Evaluation of robustness of physical mechanisms across models
  - Complements data assimilation / state estimation
    - bridges observations and modelling
    - ocean initial conditions for climate (decadal) prediction simulations.
CORE phase II (CORE-II) represents an experimental protocol for coupled ocean – sea-ice simulations forced with inter-annually varying prescribed atmospheric data.

CORE is recognized as the community standard for coordination of global ocean – sea-ice simulations.

Danabasoglu et al. (2014, Ocean Modelling)
Fig. 2 The time-mean AMOC stream function from 1960-2007 in depth/latitude space for the No Assimilation set of forced ocean model simulations. The NCAR-CORE forced ocean model simulation is included for comparison. Positive (negative) contours indicate clockwise (counter-clockwise) circulations, respectively. Bold line is the zero contour. Contour interval is 2 Sv.

Fig. 4 The standard deviation of the annual-mean, detrended stream function from 1960-2007 in depth/latitude space for the set of ocean reanalysis products. The NCAR-CORE forced ocean model simulation is included for comparison. Bold line corresponds to the 0.5 Sv contour. Contour interval is 0.25 Sv.

Karspeck et al., 2015
Goal:
• To evaluate the consistency among and strength/weakness of different ocean synthesis products
• To explore merit of ensemble ocean synthesis products
• To assess observational impacts

Examples of recent progress/applications:
• Initializations of S-I & decadal forecasts.
• Near real-time monitoring of ocean state (e.g., NOAA’s monthly Ocean Briefings).
• Improvement of data assimilation methods & practices.
• Utility of related tools for OSE & OSSE (e.g., TPOS2020)
• Ocean heat content & sea level changes (related to WCRP Grand Challenges)

Overview articles: Balmaseda et al. 2015, J. Oper. Oceanogr. + several articles in the same issue; Fujii et al. 2015, QJRM.
CORE-II Special Issue of Ocean Modelling

- North Atlantic and Atlantic meridional overturning circulation (AMOC)
  Part I: Mean states (Danabasoglu, Yeager, & Bailey),
  Part II: Interannual to decadal variability (Danabasoglu, Yeager, & Kim),

- Global and regional sea level (Griffies, Yin, Durack, & Goddard),

- Southern Ocean water masses, ventilation, and sea-ice (Downes, Farneti, Griffies, Marsland, & Uotila),

- Antarctic Circumpolar Current and Southern Ocean overturning circulation (Farneti, Downes, Griffies, & Marsland),

- Arctic Ocean and sea-ice (Wang, Ilicak, Gerdes, & Drange),
  Part I: Sea-ice and solid freshwater
  Part II: Liquid freshwater

- Arctic Ocean and sea-ice (Ilicak, Wang, Gerdes, & Drange),
  Part III: Hydrography and fluxes

- Pacific Ocean circulation and its variability (Tseng)

Ocean Data Assimilation in Support of Climate Applications: Status and Perspectives, D. Stammer, M. Balmaseda, P. Heimbach, A. Köhl, and A. Weaver
CLIMATE PREDICTABILITY

- Intra-seasonal to Interannual Variability, Predictability and Prediction
- Decadal Variability, Predictability and Prediction (multi-decadal variability and detection/attribution of changes)
- Extreme Weather and Climate and Ocean Extremes
Decadal Climate Variability and Predictability

DCVP RF

- Two focus areas:
  - **Atlantic Decadal Climate Variability and Predictability**: variations of ocean circulation systems (AMOC, gyres), related SST (AMV/AMO extratropical and tropical) and atmospheric (NAO/AO, blocking) variability; their interactions with land areas and other ocean basins.
  - **Pacific Decadal Climate Variability and Predictability**: decadal tropical SST variability (IPO); links to North Pacific ocean circulation and SST

- CLIVAR and WCRP are already engaged in observational, analysis and modeling research on these subjects.
- DCVP RF will draw on these activities but focusing on **process understanding**
“Drivers of Teleconnectivity” – Motivation

Regions where DCV is prominent (top figs) are globally teleconnected (bottom).

**Pacific**

**Atlantic**

**Southern Ocean**

Figure courtesy C. Deser (presented at the CLIVAR-ICTP International Workshop on Decadal Climate Variability and Predictability: Challenge and Opportunity Trieste, Italy 16-20 November 2015)
CLIMATE SENSITIVITY
RF CONCEPT-HEAT
Consistency between planetary energy balance and ocean heat storage

• K. von Schuckmann, K. Trenberth; joint with GEWEX

• Bringing together different climate research communities concerned with the energy flows in the Earth’s System to advance on the understanding of the uncertainties through budget constraints:

  - Atmospheric radiation
  - Ocean Heat Content
  - Earth’s surface fluxes (when, where, how much)
  - Climate variability and change
  - Data assimilation & operational services
  - Climate projection
  - Sea level
An imperative to monitor Earth’s energy imbalance

K. von Schuckmann¹,², M. D. Palmer³, K. E. Trenberth⁴, A. Cazenave⁵,⁶, D. Chambers⁷, N. Champollion⁶, J. Hansen⁸, S. A. Josey⁹, N. Loeb¹⁰, P.-P. Mathieu¹¹, B. Meyssignac⁵ and M. Wild¹²

Earth’s Energy Imbalance
Currently +0.5 to 1 Wm⁻²

Schematic representations of the flow and storage of energy in the Earth’s climate system and related consequences. a, EEI as a result of human activities. The global ocean is the major heat reservoir, with about 90% of EEI stored there. The rest goes into warming the land and atmosphere, as well as melting ice (as indicated). b, ‘Symptoms’ of positive EEI, including rises in Earth’s surface temperature, ocean heat content, ocean mass, global mean sea level, atmospheric temperature and moisture, drought, flooding and erosion, increased extreme events, and evaporation – precipitation (E–P), as well as a decrease in land and sea ice, snow cover and glaciers.
Five parallel, but interconnected, working groups:

1. An integrated approach to paleo time scale sea level estimates
2. Quantifying the contribution of land ice to near-future sea level rise
3. Causes for contemporary regional sea level variability and change
4. Predictability of regional sea level
5. Sea level science for coastal zone management

International Conference on Sea Level Change: New York University, July. 10 – 15, 2017
REGIONAL IMPACTS / CO₂ UPTAKE
RF on Eastern Boundary Upwelling Systems

• Identifying key **physical processes, similarities and differences** between EBUS
• Improving **model representation** of EBUS.
• Examining **biogeochemical interactions** and role in carbon and nutrient cycling
• **Understanding future variability**

In collaboration with IMBER and SOLAS
Challenge

- Analysis of downscaled climate models and reanalysis products
- Design of upwelling metrics
- Synthesis of existing physical and biogeochemical data
- Design of process-oriented numerical experiments for sensitivity study
- Exploration of EBUS water sources and their climate-scale variability
- Identification of nutrient and carbon sources in EBUS

Proposed activities

Figure 1: Sea surface temperature anomalies between an NCAR-CESM simulation and WOA data.
Climate and Ecosystem Predictability in the North Pacific
PICES Study Group in collaboration with CLIVAR

Study Group on *Climate and Ecosystem Predictability* (SG-CEP)

NEW STUDY GROUP
CLIMATE AND ECOSYSTEM PREDICTABILITY

WG27
Mechanisms

WG28
Ecosystem Indicators

WG29
Modeling

2015/16
SG Predictability

in collaboration with CLIVAR

2016/19
Joint CLIVAR/PICES
Climate & Ecosystem Predictability

S-CCME
Climate Projections on Fish
Dissemination

- Town halls: AGU Fall Meeting, Ocean sciences
- Session at major conferences
- Themed workshops (DCVP; Kuroshio, CLIVAR/WESTPAC)
- Training Schools
- Exchanges
CLIVAR Open Science Conference

“Charting the course for climate and ocean research”
18-25 September 2016, Qingdao, China

http://www.clivar2016.org/
Programme Overview

**September 2016**

17\(^{th}\) - 18\(^{th}\), 24\(^{th}\) : CLIVAR Panel Meetings

18\(^{th}\), 24\(^{th}\)-25\(^{th}\) : Early Career Scientists Symposium

19\(^{th}\)-23\(^{rd}\) : Open Science Conference

23\(^{rd}\), PM - 24\(^{th}\) : CLIVAR SSG Meeting

750 scientists from 66 countries submitted 936 abstracts

280 ECS applied for a place in the ECS Symposium
<table>
<thead>
<tr>
<th>Time</th>
<th>AM</th>
<th>PM</th>
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<tbody>
<tr>
<td>7:30</td>
<td>Registration &amp; Transport to QNLM</td>
<td>14:00 Plenary Session 1-Ocean Role in Climate</td>
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<tr>
<td>9:00</td>
<td>Shuttle bus from hotel to QNLM</td>
<td>15:30 Coffee/tea provided by QNLM</td>
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<tr>
<td>10:00</td>
<td>Opening Session</td>
<td>16:00 Parallel 1.1 - Energy Chairs: Karina von Schuckman, Matthew Palmer</td>
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<tr>
<td>11:00</td>
<td>Speech from Mayor of Qingdao, provided by QNLM</td>
<td>16:00 Parallel 1.2 - Carbon Chairs: Pedro Monteiro, Curtis Deutsch</td>
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<tr>
<td>11:30</td>
<td>Keynote 1 Speaker: Thomas Stocker</td>
<td>16:00 Parallel 1.3 - Water Chairs: Paul Durack, Sonia Seneviratne</td>
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<tr>
<td>12:15</td>
<td>Lunch in QNLM cafeteria</td>
<td>17:30 Transport to hotel Shuttle bus from QNLM to hotel</td>
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**Sep 19th – OSC**

*(in the Qingdao National Laboratory for Marine Science and Technology (QNLM)*)
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<thead>
<tr>
<th>AM</th>
<th>DAY 2</th>
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<th>DAY 5</th>
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<tbody>
<tr>
<td>Tuesday 20-Sep</td>
<td>Wednesday 21-Sep</td>
<td>Thursday 22-Sep</td>
<td>Friday 23-Sep</td>
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<tr>
<td>9:00 Plenary Session 2</td>
<td>9:00 Plenary Session 3</td>
<td>9:00 Plenary Session 4</td>
<td>9:00 Plenary Session 5</td>
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<tr>
<td><strong>Climate Variability and Predictability</strong>&lt;br&gt;Harry Hendon: Intraseasonal to Interannual&lt;br&gt;Rowan Sutton: Decadal&lt;br&gt;Kim Cobb: Centennial to Millennial</td>
<td>Understanding Ocean and Climate Processes&lt;br&gt;Raffaele Ferrari: Mixing and Stirring&lt;br&gt;Rym Msadek: Ocean and Climate Dynamics&lt;br&gt;Weidong Yu: Upwelling and Frontal Zones</td>
<td>The Ocean in a Warmer World&lt;br&gt;Clara Deser: Climate Modes&lt;br&gt;Anny Cazenave: Sea Level&lt;br&gt;Fan Wang: Boundary Currents</td>
<td><strong>Climate Information and Sustainable Development</strong>&lt;br&gt;Chair: Martin Visbeck&lt;br&gt;Keynotes: Jane Lubchenco&lt;br&gt;Tbc&lt;br&gt;Arame Tall</td>
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<tr>
<td><strong>Poster Session 1</strong></td>
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<td>12:00 Lunch</td>
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<td>12:30-13:00 Closing Ceremony</td>
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<td>14:00</td>
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<td><strong>Parallel 4.2 - Sea Level</strong>&lt;br&gt;Chairs: Aimee Slangen, Benoit Meyssignac</td>
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<td><strong>Parallel 2.2 – Decadal</strong>&lt;br&gt;Chairs: Paco Doblas Reyes, Yochanan Kushnir</td>
<td><strong>Parallel 3.2 - Ocean and Climate Dynamics</strong>&lt;br&gt;Chairs: Shosho Minobe, Matthew England</td>
<td>14:00</td>
<td><strong>Parallel 4.3 - Boundary Current Systems</strong>&lt;br&gt;Chairs: Sabrina Speich, Toshio Suga</td>
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<td><strong>Parallel 2.3 – Centennial</strong>&lt;br&gt;Chairs: Pascale Braconnot, Axel Timmermann</td>
<td><strong>Parallel 3.3 – Upwelling</strong>&lt;br&gt;Chairs: Enrique Curchitser, Mauricio Mata</td>
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<td>14:00</td>
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<td>SSG and Panel /RF meetings (Fri, Sat and Sun)</td>
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<tr>
<td>15:30 Coffee/tea</td>
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<td>16:00 Poster Session 2</td>
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<td>Keynote 2</td>
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<td>Wenju Cai</td>
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<td>Magdalena Balmaseda</td>
<td>Jennifer MacKinnon</td>
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<td><strong>Evening</strong></td>
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<td>19:00-21:00 Banquet</td>
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<td>Or 18:00-19:00 Townhalls 1,2,3</td>
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Early Career Scientist Symposium (ECSS)

The Early Career Scientists Symposium (ECSS) is a 3-day programme designed by, and for, early career scientists.

A unique opportunity for young scientists to interact and exchange ideas with their peers and senior scientists.

The ECSS will include career development workshops, while building lasting relationships and collaborations with colleagues from different countries.

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<tr>
<td>Opening session</td>
<td>Plenary session: Science Frontiers</td>
<td>YESS and the foundation of ECS organizations in climate science</td>
<td>Speaker: Gaby Langendijk</td>
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<tr>
<td>Introduction to the OSC</td>
<td>Working Groups on “Science Frontiers”</td>
<td>Science topics panel discussion</td>
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<td>Coffee/tea</td>
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<td>Lunch</td>
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<td>Closure</td>
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<tr>
<td>PM</td>
<td>Introduction to Working groups with short talks by Senior Scientists on OSC Daily themes</td>
<td>Working Groups on “Science Frontiers”</td>
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<td>Speakers: Pedro Monteiro; Pascale Braconnot; Mat England; Eric Guilyard</td>
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<td>Evening</td>
<td>Working Groups / PICO sessions</td>
<td>Working Groups presentations and plenary discussion</td>
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Early Career Scientists Symposium

- Hosted by FIO: 18, 23-24 Sept
- Unique opportunity for young scientists to interact and exchange ideas with their peers and senior scientists.
- Designed by and for the CLIVAR ECS community, jointly with YESS

Opportunities at the OSC
- Career development workshops
- Mentoring
Recent and planned CLIVAR capacity development activities

2015:
• CLIVAR-ICTP School on Ocean Climate Modelling: Physical and Biogeochemical Dynamics of Semi-Enclosed Seas” Ankara, Turkey, OMDP, EBUS, Sept 2015
• CLIVAR-ICTP Workshop on Decadal Climate Variability and Predictability, DCVP, ICTP, Nov 2015

Activities planned for 2016:
• CLIVAR-ICTP Advanced School on Earth System Modelling, IITM, Pune, India, July 2016
• ECSS, Qingdao, China, September 2016
• ICGPO summer intern from Kenya, August 2016
Challenges

• New ICPO director (ongoing search)

• Sustained funding for activities and Project Office
Modelling Challenges

- Improved representations of unresolved physics, e.g., mesoscale and submesoscale eddies
- Southern Ocean biases (e.g., heat and carbon uptake)
- Western boundary current separation
- Warm biases off the west coasts of continents (upwelling)
- Ocean physics and BGC interactions, e.g., Oxygen minimum zones
Observational Challenges

- Deep observations (e.g., deep-Argo),
- Continuous observations
- Full depth, basin-wide, AMOC and associated transports, including the Arctic Ocean
- Carefully-derived error estimates for observational data
- Expanded and improved paleo-climate data
New opportunities

IPCC Special Report on Oceans and Cryosphere
The End