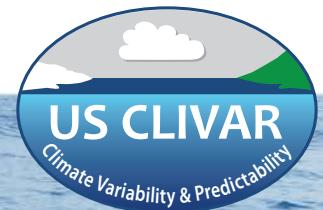




2019 US CLIVAR Summit Meeting Objectives and Outcomes

Tony Lee, SSC Chair



Meeting Objectives

The Panels at this meeting will consider **near-term implementation priorities** to make tangible progress in addressing **science goals** over the next year.

- Context – Update on US and International programs
- Special Science Sessions
 - Big Data & Machine Learning for Climate Science
 - Observing and Understanding the Arctic Ocean
- Panel Priorities – Review progress, identify gaps and opportunities
- Cross-Panel Interaction – Foster dialogue on topics of common interest
 - West Coast Ecological Forecasting (POS, PPAI, PSMI)
 - Subseasonal-to-Seasonal Prediction (PPAI, PSMI)
 - Seasonal-to-Decadal Prediction (PPAI, PSMI)
- Plan Implementation – Identify action items to advance US CLIVAR goals and research challenges

US CLIVAR Goals

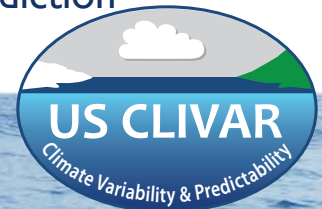
- 1) Understand the **role of the oceans** in climate variability on different time scales.
- 2) Understand the **processes** that contribute to climate change and variability in the past, present, and future.
- 3) Better **quantify uncertainties** in the observations, simulations, predictions and projections of climate variability and change.
- 4) Improve the **development and evaluation of climate simulations and predictions.**
- 5) **Collaborate with research and operational communities** that develop and use climate information.

US CLIVAR Goals

- 1) Understand the **role of the oceans** in climate variability on different time scales.
- 2) Understand the **processes** that contribute to climate change and variability in the past, present, and future.
- 3) Better **quantify uncertainties** in the observations, simulations, predictions and projections of climate variability and change.
- 4) Improve the **development and evaluation of climate simulations and predictions.**
- 5) **Collaborate with research and operational communities** that develop and use climate information.

Research Challenges

Decadal Variability & Predictability	Climate & Extreme Events	Polar Climate Changes	Climate & Carbon/Biogeochemistry
<ul style="list-style-type: none"> • Decadal modes of variability • Overturning circulation • Warming hiatus • Expanding tropics • Initialized predictions • Large ensembles 	<ul style="list-style-type: none"> • Tropical cyclones & hurricanes • Sea level variability, change, & extremes/coastal inundation • Heat waves/cold outbreaks • Drought • Heavy precip & floods 	<ul style="list-style-type: none"> • Arctic-subpolar gyre exchanges • Southern Ocean stratification & transport • Ocean-ice sheet & ocean-sea ice interactions • Arctic-midlatitude atmos. connections 	<ul style="list-style-type: none"> • Carbon cycle sensitivity • Coupled physical & biogeochemical processes • Marine ecosystem and fisheries response to climate variability & change
<ul style="list-style-type: none"> • Year 2 predictability • Stratosphere influences 	<ul style="list-style-type: none"> • East Coast sea level • S2S predictability of severe storms 	<ul style="list-style-type: none"> • Arctic Ocean observation needs • Sea ice prediction 	<ul style="list-style-type: none"> • West Coast marine prediction



US CLIVAR InterAgency Group

US funding agency program managers meet quasi-monthly to coordinate implementation of research activities in support of US CLIVAR goals.



NASA Physical Oceanography (Eric Lindstrom, Nadya Vinogradova-Shiffer)
NASA Modeling, Analysis & Prediction Program (David Considine)



NOAA Climate Variability & Predictability (Sandy Lucas)
NOAA Modeling, Analysis, Predictions & Projections (Dan Barrie, Annarita Mariotti)
NOAA Ocean Observations & Monitoring (David Legler, Jim Todd)



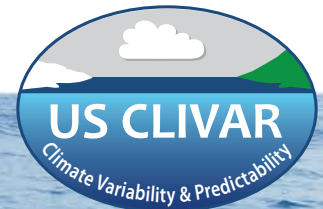
NSF Physical Oceanography (Mete Uz)
NSF Climate & Atmospheric Dynamics (Eric DeWeaver, Ming Cai)
NSF Arctic Natural Sciences (Xujing Jia Davis)



DOE Earth and Environmental System Modeling (Renu Joseph)



ONR Physical Oceanography (Scott Harper)
ONR Earth System Prediction Capability (Daniel Eleuterio)

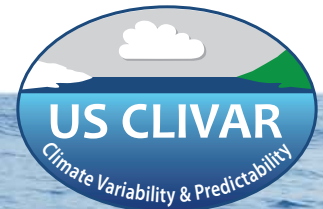


Near-term Panel Priorities

Phenomena, Observations, and Synthesis (POS) Panel

Advocates and leverages long-term climate monitoring and synthesis strategies to better document, understand, model, and predict climate variability

- Evaluate health of the ocean and atmosphere **observing systems for climate**
- Promote expansion of observations to climatically important but undersampled regions
 - **deep ocean**
 - **high latitudes**
 - **regional seas and coasts**
- Collaborate with coastal ocean research communities to study large-scale and coastal-scale climate interactions
 - **coastal sea level** of US East Coast
 - **ecological forecasts** along US West Coast
- Quantify **observational uncertainties**

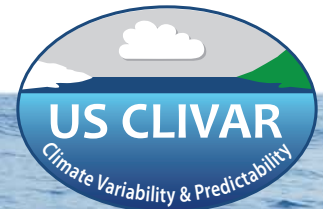


Near-term Panel Priorities

Process Studies & Model Improvement (PSMI) Panel

Aims to reduce uncertainties in 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

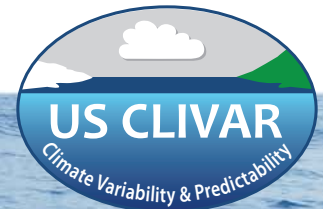
- Evaluate success and lessons of previous Climate Process Teams and **need for future CPTs**
- Provide **feedback on process studies** through webinar series, promoting best practices in data sharing and climate model engagement
- Expand focus on coupled processes, including **interaction with land, stratosphere, cryosphere, and biogeochemical processes**
- Evaluate the use of **new modeling capabilities**, such as eddy resolving ocean models and high-resolution atmospheric models, scale-aware parameterizations, coupled data assimilation, machine learning and AI applications



Near-term Panel Priorities

Predictability, Predictions, and Applications Interface (PPAI) Panel
Coordinates plans to understand predictability of the oceans and climate across time scales, advance climate predictions and projections, and quantify/communicate skill and uncertainty

- Help improve **S2S predictions** and information products
 - global-scale **teleconnection modes**
 - convection-permitting **regional modeling** to capture extremes
- Advance **decadal predictability and predictions**
- Close the substantial gaps between products offered by the climate modeling community and **needs of potential users**
- Coordinate efforts to **evaluate forecast uncertainty**



Highlights of 2018-2019 Program Implementation

- Celebrated **20th anniversary** and promoted program progress
 - Ocean Sciences Meeting Town Hall with International CLIVAR
 - Digital Yearbook and Anniversary Video providing online testimonials from current and past US CLIVAR IAG, SSC, and Panel members
 - Receptions for community at Ocean Sciences and Fall AGU Meetings
- Separate **panel meetings** in 2018 allowed development of **near-term research foci** and focused exploration of **implementation opportunities**
- Provided input for **TPOS2020 2nd Report** as well as **reviews of Tropical Atlantic and Indian Ocean Observing Systems**, and conducted external **review of US GO-SHIP Program**, joint with OCB
- Completed multi-year review of past and opportunities for **future Climate Process Teams**, with NOAA call and PSMI Fall AGU Town Hall in 2018 and interagency review /selection of new projects in 2019
- Exploring interface with **applications in**
 - **marine ecosystems/fisheries**
 - **coastal resilience** to sea level changes
 - **water resources** and use of S2S and multi-year predictions
 - **health impacts** of climate variability and change



Highlights of 2018-2019 Program Implementation

- Completed WGs on
 - **Arctic Change and Possible Influences on Mid-latitude Climate and Weather** (2015-2018)
 - **Changing Width of Tropical Belt** (2016-2019)
- Launched WGs on
 - **Large Initial Condition Earth System Model Ensembles** (2018-2021)
 - **Obs and Modeling of Water Isotopes in the Climate System** (2018-2021)
 - **Emerging Data Science Tools for Climate Variability and Predictability** (2019-2022)
 - **Mesoscale and Frontal-scale Ocean-Atmosphere Interactions** (2019-2022)
- Launched new Task Team on **Paleo-AMOC** (2018-2020)
- Organized Town Halls and panel-related **sessions at scientific conferences**
- Conducted expanded **webinar series** for *Variations*, POS, PSMI, US AMOC, and summer updates for WGs and Science Team



Open Community Workshops and Conferences



Ocean Mesoscale Eddy Interactions with the Atmosphere Workshop
17-18 February 2018 in Portland, Oregon



Bridging Sustained Obs & Data Assimilation in Advance of Next Gen TPOS
1-3 May 2018 in Boulder, Colorado



International AMOC Science Meeting
24-27 July 2018 in Miami/Coconut Grove, Florida



International Subseasonal to Decadal Prediction Conferences
17-24 September 2018 in Boulder, Colorado



International ENSO in a Warmer Climate Conference
16-18 October 2018 in Guayaquil, Ecuador



Sources and Sinks of Ocean Mesoscale Eddy Energy Workshop
12-14 March 2019 in Tallahassee, Florida



Sea Level Hotspots from Florida to Maine Workshop
23-25 April 2019 in Norfolk, Virginia



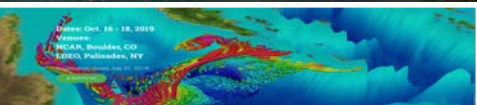
Atmos Convection & Air-Sea Interactions over Tropical Oceans Workshop
7-9 May 2019 in Boulder, Colorado



The Large Ensembles Workshop
24-26 July 2019 in Boulder, Colorado



Water Isotopes and Climate Workshop
1-3 October 2019 in Boulder, Colorado



CMIP6 Hackathon
16-18 October 2019 in Boulder, Colorado and Palisades, New York

Context

US CLIVAR operates in connection with US and international science programs and organizations that provide context for our work to plan, organize, and advocate for climate science.

International CLIVAR, WCRP, and IOC

- International global and basin panels
- CLIVAR research foci and WCRP grand challenges
- Projects: CMIP6, Coordinated Ocean-Ice Reference Experiments, Ocean Reanalysis Intercomparison Project, numerous process studies
- International science conferences: CLIVAR2016, Regional Sea Level (2017), ENSO (2018), Subseasonal to Decadal (2018), Ocean Obs '19



US Global Change Research Program

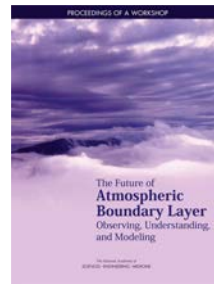
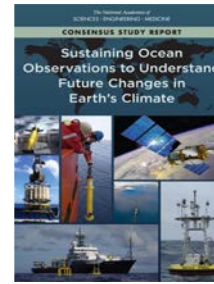
- Interagency Working Groups for Observations, Integrative Modeling, Advancing Science, Carbon Cycle, Water Cycle, Climate Change & Human Health
- National Climate Assessment and ongoing assessments (e.g., 2nd State of the Carbon Cycle Report, Climate and Health Assessment)



globalchange.gov

U.S. Global Change Research Program

Context



National Academy of Sciences

- Reports prioritizing research for Sustaining Ocean Observations (2017), Decadal Survey of Earth Science & Applications from Space (2018), Atmospheric Boundary Layer Obs, Understanding, & Modeling (2018)
- Upcoming studies: Future of the US Weather Enterprise (including S2S), Climate Intervention Strategies that Reflect Sunlight to Earth

Other Research Programs



- Internationally-organized observation programs, including TPOS2020, AtlantOOS, IndoOS, Arctic Observing Network, Southern Ocean Observing System, as well as GOSHIP, Argo (including deep and bgc), OceanSites, Global Drifter Program
- US science and agency programs: Ocean Carbon Biogeochemistry (OCB), Study of Environmental Arctic Change (SEARCH), NSF Arctic Natural Sciences, NSF Paleoclimate and Marine G&G, NOAA Southwest Fisheries Service
- International science programs: Polar Prediction Project (PPP), Past Global Changes (PAGES), North Pacific Marine Science Organization (PICES)



An Ocean of Opportunity

September 16-20, 2019
Hawai'i Convention Center

MISSION

The OceanObs'19 conference is a community-driven conference that brings people from all over the planet together to communicate the decadal progress of ocean observing networks and to chart innovative solutions to society's growing needs for ocean information in the coming decade.

Program Objectives

Information: how do we meet future user needs? And how can we better communicate among observing systems to deliver products for users that follow usability and other best practices across the globe?

Innovation: how can we spur innovation in observing technologies, products, and user services?

Integration: how can we balance user and operator needs, capabilities, and knowledge worldwide? And how can we improve sharing and access of capabilities internationally? How can different actors from academia, the public and private sector work together.

Governance: how can we improve ocean observing governance at the global and basin scale? How can we register commitments and deliver against agreed objectives?

OCEANOBS'19 BREAKOUT SESSIONS

Tuesday: Information: Sept 17

- + Blue Economy and Sustainable Development
- + Capacity Building
- + Climate Change and Variability
- + Ecosystem Health and Biodiversity
- + Global Observing System For Marine Debris
- + Integrated Ocean Observations I
- + Ocean, Weather and Climate Forecasting

Wednesday: Innovation: Sept 18

- + Community Building and Dialogue
- + Integrated Ocean Observations II
- + Modeling and Assimilation Innovation
- + Open Source Software Revolution
- + Observing Technology Innovation-Platform and Communications
- + Observing Technology Innovation-Sensor
- + UN Decade of Ocean Science for Sustainable Development

Thursday: Integration: Sept 19

- + Arctic Observing System
- + Data Integration with User Products
- + Governance Needs
- + Integrated Ocean Observations III
- + Ocean Best Practices
- + Traditional Knowledge Building
- + Uncertainty Quantification
- + UN Sustainable Development Goals

US CLIVAR Contributions to OceanObs'19 White Papers

“Atlantic Meridional Overturning Circulation: Observed Transport and Variability” led by Eleanor Frajka-Williams, co-author Shane Elipot (**POS**) and R. Perez (previously **POS**)

“Observational Needs for Improving Ocean and Coupled Reanalysis, S2S Prediction, and Decadal Prediction” led by Stephen Penny (**PSMI**), co-author Aneesh Subramanian (**POS**)

“Ocean observations to improve our understanding, modeling and forecasting of subseasonal-to-seasonal variability” led by Aneesh Subramanian (**POS**), co-author Maria Flatau (**PSMI**), Stephen Penny (**PSMI**)

“Ocean Reanalyses: Recent Advances and Unsolved Challenges” led by Andrea Sorto, co-author Stephen Penny (**PSMI**)

“A Sustained Ocean Observing System in the Indian Ocean for Climate Related Scientific Knowledge and Societal Needs” led by J.C. Hermes, co-author Aneesh Subramanian (**POS**), Tony Lee (**SSC co-chair**)

“Integrated Observations of Global Surface Winds, Currents, and Waves: Requirements and Challenges for the Next Decade” led by Ana Beatriz Villas Boas, co-author Aneesh Subramanian (**POS**)

“Satellite Salinity Observing System: Recent Discoveries and the Way Forward” led by Nadya Vinogradova (**IAG**), co-author Kyla Drushka (**POS**), Tony Lee (**SSC Chair**)

“Ship-Based Contributions to Global Ocean, Weather, and Climate Observing Systems” led by Shawn Smith, co-author Kyla Drushka (**POS**)

“Tropical Pacific Observing System” led by Neville Smith and William Kessler, co-author Yolande Serra (**POS**), Kris Karnauskas (**PSMI**), and Janet Sprintall (**PSMI**)

“The Tropical Atlantic Observing System” led by Gregory Foltz (**PSMI**), co-

author R. Perez (previously **POS**)

“Ocean Observations in Support of Studies and Forecasts of Tropical and Extratropical Cyclones” led by Ricardo Domingues, co-author Gregory Foltz (**PSMI**)

“Detecting Change in the Indonesian Seas” led by Janet Sprintall (**PSMI**)
“SMART Cables for Observing the Global Ocean: Science and Implementation” led by Bruce Howe, co-author Shane Elipot (**POS**)

“Sustaining Ocean Observations for Understanding and Predicting Climate Change: Old Problems, New Institutions” led by Robert Weller, co-author Dan Vimont (**both former SSC Chairs**)

“Observational Needs: Marine Ecosystem Modeling and Forecast. *Frontiers in Marine Science*”, lead author: Antonietta Capotondi (**PSMI**), co-author: Aneesh Subramanian (**POS**)

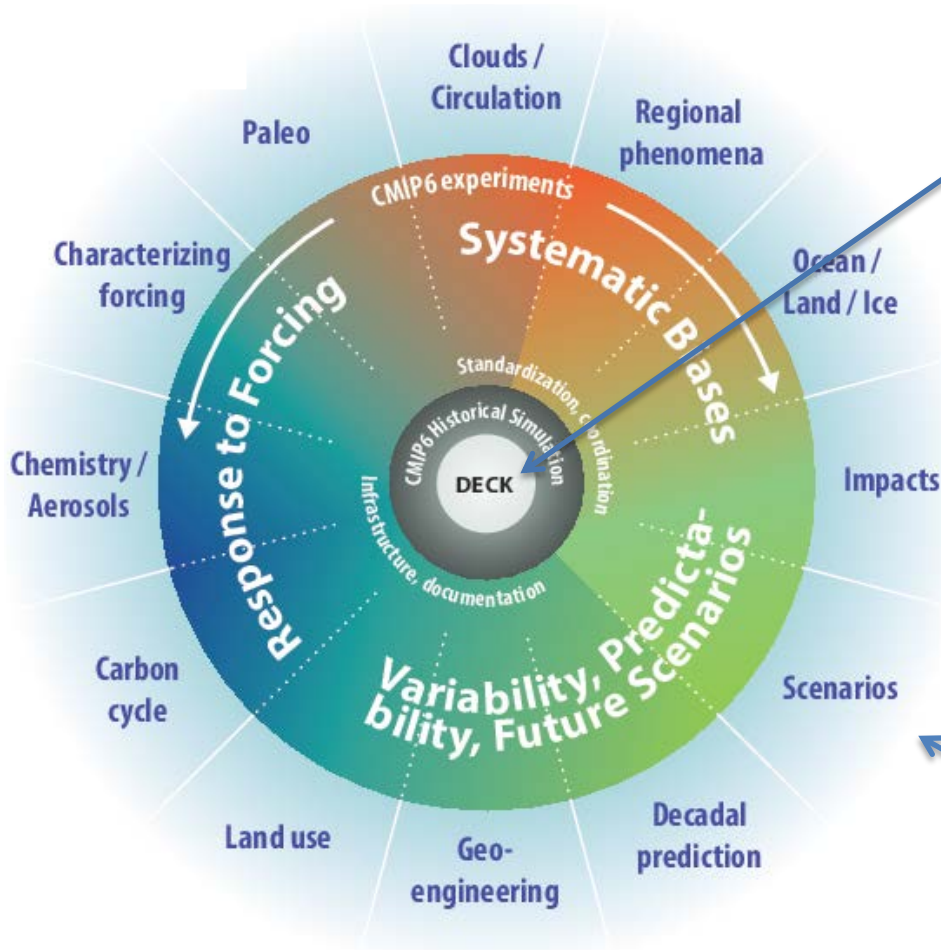
“More than 50 years of successful continuous temperature section measurements by the Global Expendable Bathythermograph Network, its integrability, societal benefits, and future”, lead author: Goni G.J., co-author: J. Sprintall (**PSMI**)

“Global perspectives on Observing ocean boundary current systems.”, lead author: Todd, R.E., co-author, J. Sprintall (**PSMI**)

“Putting It All Together: Adding Value to the Global Ocean and Climate Observing Systems With Complete Self-Consistent Ocean State and Parameter Estimates”, lead author: Patrick heimbach, co-author Christopher Piecuch (**POS**)

“Towards Comprehensive Observing and Modeling Systems for Monitoring and Predicting Regional to Coastal Sea Level”, lead author: Rui M. Ponte, co-author Christopher Piecuch (**POS**)

CMIP6: More Models, More Experiments, More Data



(1) Continuous experiments

DECK (entry card for CMIP)

- i. AMIP simulation (~1979-2014)
- ii. Pre-industrial control simulation
- iii. 1%/yr CO₂ increase
- iv. Abrupt 4xCO₂ run

CMIP6 Historical Simulation (entry card for CMIP6)

- v. Historical simulation using CMIP6 forcings (1850-2014)

(2) 26 CMIP-Endorsed MIPS

- 42 institutions/consortia have registered (CMIP5: 31 inst.)
- 101 models are registered (CMIP5: 59 models)
- 287 experiments defined; 102 tier 1 (CMIP5: 33; 14 tier 1 expts.)
- 10 – 50 PB of model output expected (CMIP5: ~2 PB)

CMIP6 Data Availability, AR6 Deadline, and Analysis Schedule

More than 28 days | More than 7 days | Less than 7 days

Number of 'datasets' [variables x (# of simulations)] from each model in support of each CMIP6 CMIP experiment.

model	# of experiments	1pctCO2	abrupt-4xCO2	amip	esm-hist	esm-piControl	esm-piControl-spinup	historical	piControl	piControl-spinup
# of models	118	21	21	20	5	5	1	21	22	2
AWI-CM-1-1-MR	4	120	120					600	50	
BCC-CSM2-MR	7	143	143	456	569	143		565	142	
BCC-ESM1	5	145	137	369				525	134	
CAMS-CSM1-0	5	140	140	141				65	75	
CESM2	6	923	857	540		1009		10868	964	
CESM2-WACCM	5	911	830	1388				2583	1002	
CNRM-CM6-1	5	383	1814	495				4061	301	
CNRM-ESM2-1	9	1946	1452	561	606	554	279	2945	576	273
CanESM5	6	1918	618		2864	293		10453	596	
E3SM-1-0	5	55	55	110				275	55	
EC-Earth3	2							1323	215	
EC-Earth3-Veg	5	197	197	145				231	218	
FGOALS-f3-L	1			267						
GFDL-AM4	1			69						
GFDL-CM4	5	347	412	281				383	506	
GFDL-ESM4	5	109	101		43	44			100	
GISS-E2-1-G	5	166	166	1840				1711	176	
GISS-E2-1-H	4	143	143					1430	152	
HadGEM3-GC31-LL	5	609	289	804				1324	339	
IPSL-CM6A-LR	6	707	8056	3363				22461	1800	390
MIROC6	5	109	109	930				1090	109	
MRI-ESM2-0	5	148	1816	475				859	161	
NESM3	1			1						
SAM0-UNICON	5	170	170	149				205	146	
UKESM1-0-LL	6	963	400	297	507			3347	350	

- Data holdings tracked for Deck, Historical, and Endorsed MIPS
- August 4 status for Deck/Historical runs: 25% of participating models ←
- Endorsed MIPS runs coming more slowly
- Challenges in meeting AR6 publication deadline of Dec. 31
- WCRP CMIP6 Analysis Workshop on Mar. 25-28 in Barcelona
- US CLIVAR-OCB organized CMIP6 Hackathon on Oct. 16-18 at NCAR/LDEO



2021 2030 United Nations Decade of Ocean Science for Sustainable Development

This Decade will provide a common framework to ensure that ocean science can fully support countries' actions to sustainably manage the Oceans and more particularly to achieve the 2030 Agenda for Sustainable Development.

Through stronger international cooperation, the Decade will bolster scientific research and innovative technologies to ensure science responds to the needs of society:

- A clean ocean where sources of pollution are identified and removed
- A healthy and resilient ocean where marine ecosystems are mapped and protected
- A predictable ocean where society has the capacity to understand current and future ocean conditions
- A safe ocean where people are protected from ocean hazards
- A sustainably harvested ocean ensuring the provision of food supply
- A transparent ocean with open access to data, information and technologies

Additional Context

With the new Administration and Congress in 2017, we anticipated shift in priorities and funding at agencies for climate research.

President Budgets for 2018, 2019, and 2020 have included reductions for climate and Earth system research at NASA, NOAA, and DOE, with across-the-board reductions for NSF.

Senate and House appropriations for 2018 and 2019 have held budgets steady.

US CLIVAR should continue to organize and implement community science activities to advance/accelerate progress on understanding, observing, modeling, and predicting climate variability across the range of timescales and to inform the application of climate information to address societal needs.

Plenary Agenda

Tuesday, August 6

Presenters

08:00	Welcome and meeting objectives	Mike Patterson & Tony Lee
08:30	International CLIVAR	Annalisa Bracco
09:00	Agency manager engagement	Agency Managers
10:00	Science Session: Big data and machine learning for climate science	Gudrun Magnisdottir, Kevin Reed, Aneesh Subramanian
	Introduction	Michael Pritchard
	Earth System Modeling 2.0: Toward accurate and actionable climate predictions with quantified uncertainties	Tapio Schneider
	Detecting climate signals with machine learning	Elizabeth Barnes
	Deep learning for pattern recognition in weather the climate science	Karthik Kashinath
13:15	Panel breakouts	
17:45	Science Session: Observing and understanding the Arctic Ocean	Tony Lee, Jamie Morison
	Overview of Arctic Ocean science	Jamie Morison
	A developing strategy for supporting the Arctic Regional component of GOOS	Sandra Starkweather
	Briefing of CLIVAR/CliC Northern Ocean Region Panel activities	Amy Solomon
	The Arctic-Subpolar North Atlantic state estimate (ASTE)	Patrick Heimbach

Plenary Agenda

Wednesday, August 7

Presenters

08:00 Panel breakouts continue

13:15 **West Coast ecological forecasting**

Introduction

Antonietta Capotondi

Overview of the US West Coast ecosystem modeling program

Pierre Damien

Integrating plankton models and observations

Jessica Luo

Local governments in Santa Barbara County as end users of ecological forecasts for climate adaptation planning

Monica Meyers

Discussion

Thursday, August 8

08:00 Panel business breakouts

10:30 Breakout reports

Panel Co-chairs

11:30 Conclusions and Next Steps

Tony Lee

12:00 Adjourn

Panel Breakouts (Tues pm-Thurs am)

Phenomena, Observations, and Synthesis (POS)

- East Coast sea level rise
- Uncertainty quantification
- Observing systems (Arctic, US GO-SHIP, SOCCOM, ocean-atmosphere boundary layer)
- Biogeochemistry
- Panel business

Process Study and Model Improvement (PSMI)

- Air-sea interaction
 - Opportunities and challenges of machine learning for model improvement
 - Subseasonal-to-Seasonal prediction
 - Seasonal-to-Decadal prediction
 - CMIP6 progress and improvements
 - Panel business
- (w/ PPAI)

Predictability, Predictions, and Applications Interface (PPAI)

- Big data/artificial intelligence/machine learning
- Arctic prediction
- Climate and health
- Panel business

Anticipated Outcomes

- **Progress on near-term panel priorities, explicitly considering uncertainty quantification across topics, and addressing program goals and research challenges regarding:**
 - Observing and analyses systems
 - Climate variations and impacts
 - Process study opportunities and feedback
 - Implementing process understanding in models
 - Predictability and prediction across timescales
 - Advancing the interface with applications, connecting prediction and communicating climate information
- **Recommendations to address:**
 - Challenges in applying big data and machine learning to climate and Earth system science
 - Observing and modeling to improve understanding and prediction of Arctic Ocean variability and change
 - Implementation strategy to advance framework for West Coast marine ecosystem prediction

Anticipated Outcomes

- **Specific action items and recommended implementation activities**
 - Working Groups (for focused actions with interagency appeal; only one new start in 2020)
 - Workshops and conferences (for broad community engagement)
 - Opportunities for students and early career scientists (e.g., training programs, hackathons)
 - Panel-organized sessions at scientific conferences (coordinating with Intl. CLIVAR)
 - Website content, esp. for accomplishments and core science activities
 - Webinars and editions of Variations
 - White papers and reports
 - Best practices articles, review papers, and special journal collections
 - Input for external requests and opportunities (e.g., NAS reviews, CMIP6/AR6, Ocean Obs '19)
- **Concise Summit Report**
 - To communicate with community and sponsoring agencies in timely manner
 - To emphasize key findings, discussion, and conclusions (presentations posted on website)
 - To list resulting recommendations and action items (with panelist leads) for coming year

Thank You and Enjoy Long Beach!

