



2018 CPO ESSM Workshop and ESSM Council Meeting Report

November 6 - 7, 2018

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10/19



Introduction

The November 2018 CPO Earth System Science and Modeling (ESSM) Workshop and ESSM Council Meetings brought together key CPO partners and stakeholders, both internal and external to NOAA, to discuss CPO's climate and Earth system research needs and opportunities, and partnership strategies over the next 1-5 years. This workshop had three focus areas: Climate research to enable societal resilience to extremes, Climate research to inform coastal and marine ecosystem management, and Linking observations to process understanding and model improvements.

All OAR labs participated in the workshop, emphasizing their core capabilities in research, observations, modeling, predictions and other applications. All NOAA line offices also participated in representing their major service requirements. Discussion on the unique role of CPO/ESSM competitive research programs, its future research needs and opportunities, and partnership strategy was in the context of advances in the broader external research community, core capabilities in OAR labs and service requirements from NOAA line offices.



The workshop key comments and high level recommendations include the following:

- 1.** The CPO/ESSM competitive research programs have been a key steward of foundational and transitional research in climate science and should continue to leverage the external community to expand NOAA's research capacity and expertise and develop the future talent pool for NOAA and the Nation.
- 2.** ESSM research priorities should be aligned with OAR and NOAA mission goals and complementary to the OAR lab core capabilities.
- 3.** ESSM should balance near-term research to address immediate needs and long-term discovery-minded research that advances understanding and capabilities.
- 4.** ESSM research should include a process-oriented approach to assess the mechanisms of predictability and model fidelity, including Climate Process Teams (CPTs) for model development.
- 5.** Pressing research needs for coastal and marine ecosystem management include understanding the predictability of climate regime shifts, improving Earth system models, improving prediction across scales, and assessing the skill and application of Earth system model predictions.
- 6.** Diverse NOAA groups of observations and modeling should work together to make the best use of observations in model development and prediction improvement and CPO can help facilitate and support the collaborations.

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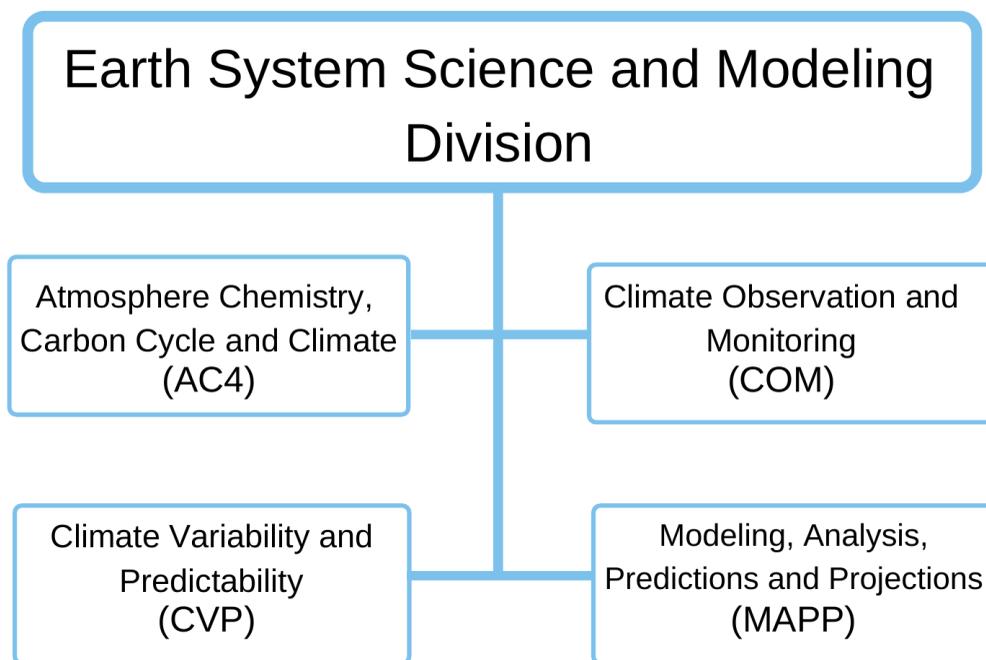
Acknowledgments

Thank you Courtney Byrd and Nicholas Komisarjevsky for the kind help and support in creating this report.

1. Background

NOAA's Climate Program Office (CPO) is the climate research arm of NOAA Oceanic and Atmospheric Research (OAR). CPO supports NOAA mission-driven climate research by working across NOAA and engaging the external community primarily through annual Federal Funding Opportunities. CPO's Earth System Science and Modeling (ESSM) Division consists of four programs: AC4 (Atmospheric Chemistry, Carbon Cycle and Climate), COM (Climate Observation and Monitoring), CVP (Climate Variability and Predictability) and MAPP (Modeling, Analysis, Predictions and Projections).

ESSM programs support climate and Earth system research to advance understanding, modeling, prediction and applications across multiple disciplines and timescales. The ESSM Council (which includes scientists from NOAA as well as the broader academic and international community) provides individual advice on ESSM science opportunities and strategies through consultation and information exchange.

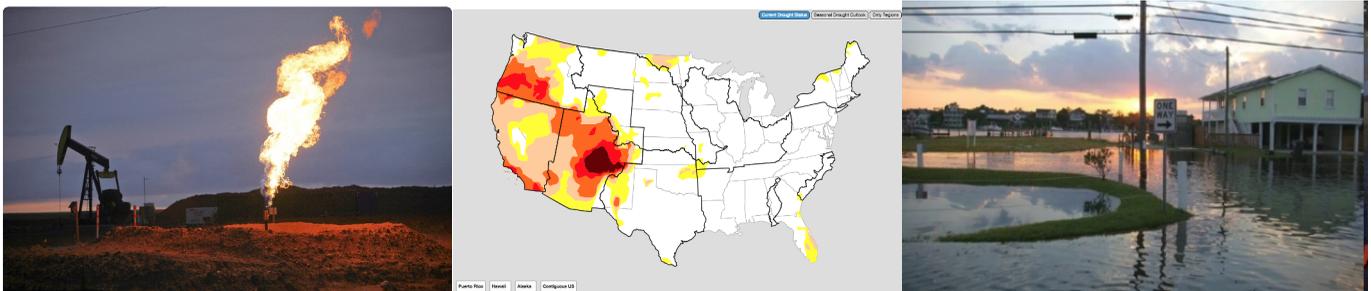


Workshop Objective

The **objective** of the 2018 CPO ESSM Workshop and ESSM Council Meeting was to bring together key CPO partners and stakeholders, both internal and external to NOAA, to discuss CPO's climate and Earth system research priorities and partnership strategies over the next 1-5 years. The discussions during the workshop were focused around the following **questions**:

- What can the external climate research community do to advance NOAA's climate mission? Similarly, what can NOAA labs, programs and centers offer to the external climate community?
- In terms of climate and Earth system research priorities, what is the unique role of CPO/ESSM competitive research programs considering the key climate science challenges and opportunities, the core capabilities and gaps in NOAA labs, programs and centers, and CPO's research program scope?
- What is the optimal strategy for CPO programs to facilitate coordination and partnerships within NOAA and with the external community?

This report is based on the presentations and discussions during the workshop and the ESSM Council meeting. The report will inform CPO's future climate and Earth system research opportunity and partnership strategies with the external community and NOAA labs, programs and centers.



2. Workshop key comments and recommendations

These comments and recommendations emerged from the workshop discussions and follow-up assessments by the ESSM Council, the workshop organizing committee and discussion leaders.

a. Key comments on the value of CPO research programs

CPO research programs have been a key steward of foundational and transitional research in climate science and associated disciplines over the last 30+ years. This role was played through curating independent and collaborative projects involving the external research community (mainly academic), OAR laboratories, and NOAA's Cooperative Institutes including international leadership in major field projects (e.g. TOGA COARE) that advanced science relevant to the NOAA mission. CPO led the establishment of the first inter-sectoral applied research programs that were the seed for the very successful RISAs precursor to the National Climate Assessment and standing projects such as NIDIS.

The unique contribution of CPO and ESSM competitive research and leadership is to leverage the external community to expand NOAA's research capacity and expertise and develop the future talent pool for NOAA and the nation through strategic partnerships. To be successful, grant programs must be aligned with NOAA's mission and be complementary to core NOAA Lab capabilities. Top caliber foundational research is also necessary to develop the climate intelligence knowledge that must underlie authoritative applications to meet societal needs. This includes providing scientific insight and data to a broad range of stakeholders that goes beyond decision makers and policymakers, and also includes the agents of quality of life and resilience from engineering societies, trade associations, industry, and others.

b. Recommendations for ESSM research priorities

1. Maintain and expand competitive research programs nurtured as an integral part of NOAA's research enterprise with goals of expanding the research capacity and expertise, leverage innovation and creativity outside of NOAA, and developing NOAA's future talent pool. More dedicated discussions or workshops with key partners are needed to explore paths forward.
2. To develop programs that balance research to address immediate needs with a commitment to long-term discovery-minded research necessary to acquire new understanding and predictive capability.
3. To achieve (1) and (2) by leveraging existing, as well as developing improved and more agile, relationships between research assets within NOAA and the external research community.

c. Recommendations for ESSM partnership strategies

There was substantial discussion on the needs and opportunities to expand and build partnerships among OAR Labs and programs and the external research community. One of the clear recommendations emerging from the workshop was the need to develop processes to facilitate the broad engagement of independent researchers with ongoing NOAA programs and initiatives.

One example is for CPO to facilitate collaborations between OAR scientists and independent researchers for evaluating biases in NOAA weather/climate models. There is a set of standard variables used for the model evaluations, yet less conventional measures of model performance, anchored on theoretical footing, could accelerate bias reductions in the NOAA climate models and model-based predictions. This type of effort is important because climate model output is heavily used for a number of OAR labs for their long-range predictions. ESSM could play a critical role in bringing fresh ideas from independent researchers to the powerful modeling expertise in NOAA Labs.

NOAA Labs could provide dedicated support to lab scientists to participate in research proposals. Other opportunities would be to fund visitors and graduate students through a fellowship program managed by ESSM or CPO. Providing the funding, instead of grants to faculty, will ensure that the University reach increases beyond CIs and their host institutions and trains NOAA's future workforce

d. Recommendations for CPO

The recommendations for CPO are not different from the recommendations for ESSM, albeit their scope is broader.

1. Fast support for competitive research as a currency of excellence, diversity and innovation. Recognize that the portfolio of CPO's research programs are uniquely positioned to lead in seamlessly transferring science to applications and provide quantitative science-vetted information to the public
2. Balance research readiness levels across programs so that foundational research is not undermined by short-term needs
3. Foster and nurture scientific exchange and effectiveness of collaborative research among different CPO programs
4. Develop assessment and evaluation processes to document research impact

3. Session Summaries

Session 1: Overviews and Panel Discussion

The session started with remarks from OAR and CPO leadership and an overview of ESSM grant programs including AC4, COM, CVP and MAPP. Two keynote presentations by Jean-Francois Lamarque (NCAR) and Dennis Lettenmaier (UCLA) provided an overview on major climate science challenges and opportunities and a historical view of CPO's engagement with the external research community.

A series of presentations from all OAR labs described their missions, core capabilities and gaps/needs. This input provided important context for discussions on the role of the external research community and the role of CPO research programs in advancing NOAA's mission.

A panel discussion underscored the value of engaging the external community, the role of CPO competitive research programs, and the importance of strategic partnerships.

Key points include:

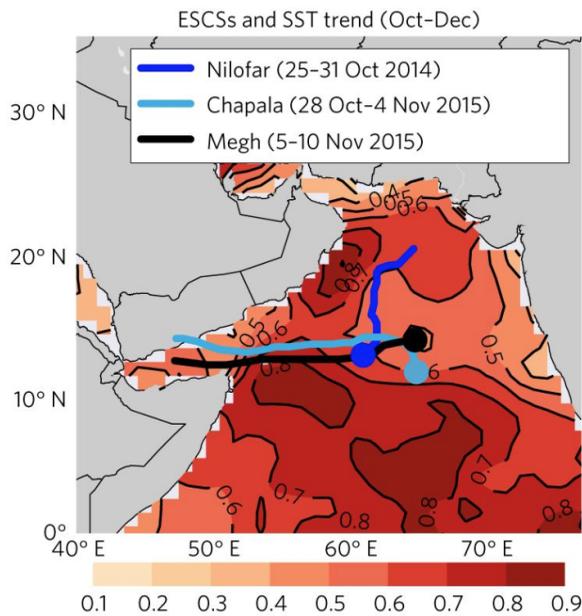
- OAR Labs and the Cooperative Institutes (CIs) sustain and advance NOAA's core capabilities in science, modeling, observations and applications.
- A lot of innovation and creativity exist in the broader research community outside of NOAA.
- The CPO/ESSM competitive research programs are important for NOAA and they have successfully engaged community experts in areas relevant to NOAA, including theory, field campaigns, and modeling. In so doing, NOAA leverages external expertise and develops new capabilities.

- The CPO grant programs should be aligned with OAR and NOAA mission goals and complementary to core NOAA Lab capabilities. Examples of past successes are numerous (e.g., field programs, Climate Process Teams (CPTs), Land Data Assimilation System (LDAS), Earth System Modeling, North American Multi-Model Ensemble (NMME), etc.). Those successful examples were built upon feasibility, uniqueness and gaps to be filled, with CPO/ESSM program managers proactively working with the NOAA Labs and centers to coordinate and facilitate community engagement.
- There is a need for a balance between short-term (3 years) research projects on problems with reachable solutions and long-term (5-10 years) projects on problems with enormous difficulties but profound societal importance.



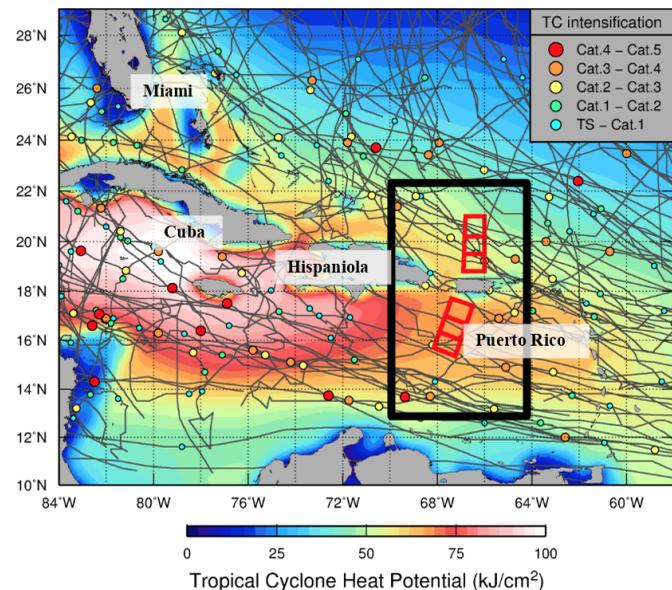
Session 2: Research to advance climate science and to enable societal resilience to extremes

The session started with several overview presentations from the application perspective including coupled human-natural systems, NWS Unified Forecast Model (UFS), and climate linkage to atmosphere composition. A science overview talk described ECMWF research on multi-scale predictability and model improvements. A set of short science presentations from GFDL, AOML, and ESRL/PSD highlighted OAR's core capabilities and research needs related to extremes, including process and predictability studies, modeling, data assimilation, attribution, and subseasonal-to-decadal prediction.



Increasing frequency of extremely severe cyclonic storms over the Arabian Sea

Murakami et al, 2017, Nature Climate Change



Underwater gliders are deployed during hurricane season to monitor the ocean over regions frequently affected by storms to improve ocean model initialization. NOAA PhOD underwater glider operations

Key Points:

- CPO/ESSM research priorities should continue to include a process oriented approach to predictability across time-scales that supports improving operational modeling and prediction.
- ESSM research priorities should balance the immediate need for improving the forecast and other applications “today” with a longer-term vision that requires a deeper understanding of mechanisms and processes associated with predictability that will improve or extend the time-scale of predictions “tomorrow.”
- Significant progress has been made to advance operational predictions and applications, but much of the foundational research that extends beyond the NOAA Labs and the CIs remains to be done. The workshop participants noted the importance of CPO/ESSM support for innovative modeling and hypothesis testing with a hierarchy of tools. This foundational research is important to understand the complex models and nature. Much of this work sits outside the NOAA labs and the CIs. CPO/ESSM’s role is to ensure that this work is designed and implemented in partnership with NOAA Labs and CIs to make progress.

The process of improving models and data assimilation systems has been long and slow. One of the most effective strategies in place today involves the so-called climate process teams (CPTs). These teams involve global modelers, process modelers, observationalists, theoreticians, multiple agencies and field campaigns. CPO has been leading the way in coordinating and supporting CPTs and ensuring that they work to improve the core NOAA models and prediction/projection systems.

Session 3: Climate research to inform coastal and marine ecosystem management

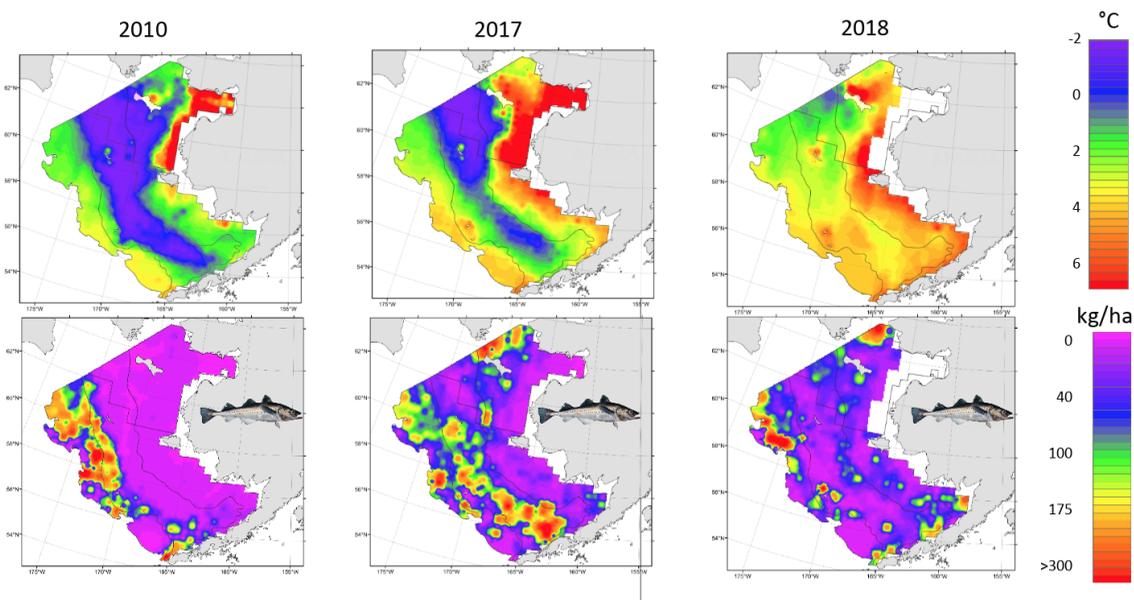
The session featured a dozen engaging talks, most of which summarized current NOAA activities and highlighted research needs from NOS and NOAA Fisheries. Topics included climate science needs and priorities for fisheries and ocean services, priorities for multiscale Earth system modeling for marine ecosystem applications, ocean acidification and biogeochemistry research, sea level rise and coastal inundation.

Recommendations

- Pressing research needs to inform coastal and marine ecosystem management were discussed, including (i) the challenge of improving Earth system models, (ii) the importance of “prediction across scales” for marine ecosystem and coastal management, (iii) the reality of using imperfect models to make better predictions, (iv) a process-oriented approach to assess the mechanisms of predictability, (v) an assessment of the skill and application of Earth system model predictions, and (vi) the important role of Climate Process Teams (CPTs) in model development.
- A key research challenge for marine ecosystem management revolves around the predictability of climate regime shifts. Presently, coupled models do not capture the amplitude or the timing of regime transitions well, if at all. Regime shifts are critical for the prediction of species migration and, most generally, understanding what is changing in the marine environment and why, how long present conditions will persist, and how marine and fishery managers should respond. Basin-scale changes associated with climate regime transitions are also important to coastal regions in terms of regional sea level rise, the frequency and amplitude of coastal flooding events, and coastal biology.

Recommendations Continued

- In general, the challenge of S2S predictions was noted as being of especially critical importance for coastal and marine ecosystem management. On longer time scales, projections with Earth system models are important for resilience and sustainability efforts, and for decisions such as rebuilding fisheries.
- There was considerable discussion on model resolution with many examples of the positive impact of both atmospheric and oceanic resolution – reduced biases in coastal regions, improved shelf-scale dynamics, etc. It was further noted that there are multiple techniques including high resolution global models, variable resolution models, regional models, and downscaling techniques.



Observed Eastern Bering Sea bottom trawl survey Mean bottom temperature and pollock CPUE. *Stevenson and Lauth, In revision Polar Biology; Data from Robert Lauth, Alaska Fisheries Science Center*

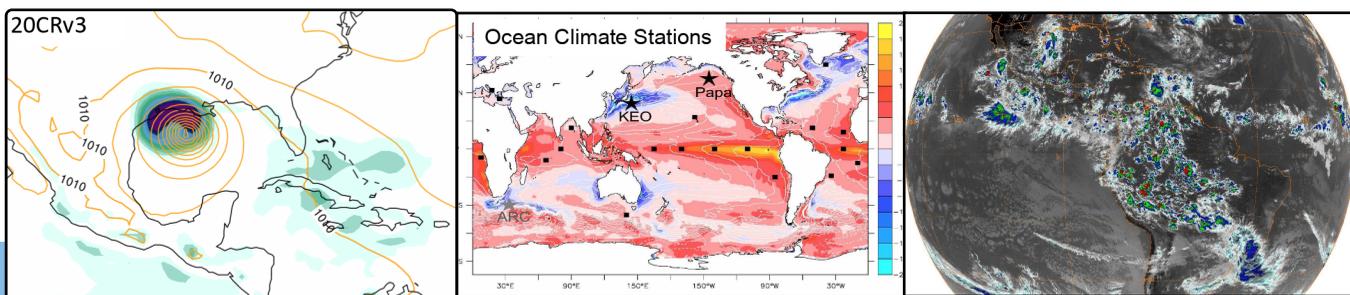
Session 4: Linking observations to process understanding and model improvements

The session opened with an overview presentation pointing out how a variety of observations including carbon and water isotopes can lead to better understanding of exchanges of water and carbon between the biosphere and atmosphere. A series of presentations from NOAA Labs, and programs showed the core observation capabilities and major challenges, including:

- Continuous long-term measurements of a range of advanced remotely sensed observations out to at least 2040 (JPSS).
- NCEI's role as the Nation's steward of environmental information;
- Expertise in observing and modeling land-atmosphere interactions exists at GSD, ARL, GMD, and other labs. Observations and modeling could be better coordinated.
- CarbonTracker and long-term measurements in global CH₄ and other trace gases (GMD).
- AOML's observations and monitoring of key ocean features, coastal environments and sea level changes could be useful for constraining meridional heat transport and for constraining and evaluating models.
- PMEL pointed out that some major challenges in global ocean dynamics include representing air-sea fluxes in global climate models, quantifying ocean heat and carbon uptake, and ocean acidification. Current marine ecosystem assessments do not include acidification and the effects of sea ice melting.
- GFDL discussed three ways of bringing models and data together: 1) observations can be used to diagnose model processes, 2) climate models can be evaluated by running them in weather forecasting mode, and 3) emergent constraints can be identified and used as model evaluation metrics. Process oriented metrics developed with CPO support were seen as a viable path for model improvement.

Key Points:

- Interactions between diverse Earth System components operating at different timescales in the climate system need to be considered rather than treating processes separately.
- Diverse NOAA groups of observations and modeling should work together to make best use of observations, especially those resulting from new technologies, in model development and prediction improvement.
- Diverse parts of NOAA collecting observations and developing models should work together to make best use of observations, especially those resulting from new technologies.
 - CPO could further enhance collaborations between observations and modeling groups.
 - NOAA OAR has a lot of expertise in observing and modeling land-atmosphere interactions, and this capability could be better coordinated with modeling by fostering collaborations.
- More observations are needed, including the carbon cycle, and the Argo floats. Long-term monitoring using continuous observations is needed to understand climate. In the 20th century physical, chemical and biological processes were considered separately, in the 21st century these processes and their interactions need to be considered jointly, a recurring theme for this session.



Appendix A: Workshop Agenda

Day 1 Morning: Session 1: OAR/CPO/ESSM Overviews and Panel Discussion

08:00: Coffee and refreshments

08:15: Welcome and around the room (Jin Huang)

8:30-10:00: (Chair: Jin Huang; Rapporteur: Nicholas Komisarjevsky)

- OAR remarks (Ko Barrett, 10 min)
- CPO overview (Wayne Higgins, 20 min)
- CPO/ESSM overview and the workshop introduction (Jin Huang, 20 min)
- Major climate science challenges and opportunities (Jean-Francois Lamarque, 20 min)
- Engaging the external research community: a historical view (Dennis Lettenmaier, 20 min)

10:00-10:20: Break

10:20-11:15: Short talks (Chair: Sandy Lucas; Rapporteur: Cody Sullivan)

- **OAR labs overviews (mission; core capabilities; gaps/needs):** AOML (Molly Baringer); ARL (Ariel Stein or Howard Diamond); ESRL/CSD (Tom Ryerson); ESRL/GMD (Jim Butler); ESRL/GSD (Stan Benjamin); ESRL/PSD (Robin Webb); GFDL (Yi Ming); GLERL (Phillip Chu); NSSL (Harold Brooks); PMEL (Chidong Zhang)

11:15 -12:30: Panel discussions (panelist remarks and participant interaction): Values of engaging the external community, role of CPO grants programs, and coordination/partnership strategies.

Panel members: Ana Barros (Lead), Chidong Zhang (PMEL), Yi Ming (GFDL), Roger Pulwarty (PSD), Jim Hurrell, Mike Patterson (USCLIVAR)

12:30-1:30 **Lunch** (Lobby outside of Spring Room)

Day 1 Afternoon: Session 2: Research to advance climate science and to enable societal resilience to extremes

1:30 -3:30: Presentations to highlight the key issues and relevance to CPO/ESSM

(Chair: Sukyoung Lee; **Rapporteur:** Nicholas Komisarjevsky and Cody Sullivan)

- **Application perspectives on climate research needs (15 min each)**
 - Climate intelligence for coupled human-natural systems from summit to sea (Ana Barros)
 - Upstream research to advance NWS Unified Forecast Model (Hendrik Tolman)
 - Climate linkage to atmospheric composition (wildfire, air quality) (Tom Ryerson)
- **Science overviews and pressing research needs (15 min each)**
 - Multi-scale predictability and model improvements (Magdalena Balmaseda)
- **NOAA core capabilities and major gaps (10 min each)**
 - Modeling of the Earth system (Yi Ming)
 - Subseasonal-to-seasonal-to-decadal prediction system (Andrew Wittenberg)
 - OSSE (Molly Baringer)
 - Interactions of aerosols and clouds (Graham Feingold)
 - Decadal predictabilities of extremes (Matt Newman)
 - Attributions of climate extremes (Martin Hoerling)

3:30-4:00: Break

4:00-5:00: Discussions on the pressing research needs, potential CPO/ESSM research priorities and partnership strategy (**Lead:** Ben Kirtman; **Rapporteur:** David Herring)

Day 2 Morning: Session 3: Climate research to inform coastal and marine ecosystem management

08:00: Coffee and refreshments

08:15-10:00: Presentations to highlight the key issues and relevance to CPO/ESSM

(Chair: Dan Barrie; **Rapporteur** Nicholas Komisarjevsky)

- **Application perspectives (15 min. for each talk)**
 - Climate science needs for Fisheries (Cisco Werner)
 - Climate science needs for Ocean Service (Mark Osler)
- **Science overviews and research needs (15 min. for each talk)**
 - Coupling at the ocean-atmosphere interface – boundary layer processes (Joellen Russell)
 - Advances in global Earth system predictions for marine ecosystem applications (Charlie Stock)
 - Towards a multi-scale Earth system model: challenges and opportunities (Enrique Curchitser)
 - Climate research for marine resources and ecosystem applications (Mike Alexander)
 - Ocean forecasts for marine resources management (Mike Jacox)

10:00– 10:30: Break

10:30-11:30: NOAA core capabilities and major gaps (10 min for each talk)

(Chair: Ken Mooney; **Rapporteur:** Cody Sullivan)

- Ocean Acidification Program (Dwight Gledhill)
- Ocean Carbon and BGC Argo (Rik Wanninkhof)

- Innovative observing technologies for studying the marine ecosystem (Chris Meinig)
- Climate and ocean ecosystem projections for fisheries management in Alaska (Anne Hollowed or TBD)
- GLERL (Philip Chu)
- Producing and providing climate intelligence related to coastal inundation (Billy Sweet)

11:30-12:30: Discussions on the pressing research needs, potential CPO/ESSM research priorities and partnership strategy (**Lead:** Jim Hurrell, **Rapporteur:** David Herring)

12:30-1:30: Lunch (Lobby outside of Spring Room)**12:30 – 1:30 ESSM Council and Organizing Committee Side Meeting:** to reflect the takeaways from the workshop so far; and to discuss the next steps to develop and disseminate the workshop report.

Day 2 Afternoon: Session 4: Linking observations to process understanding and model improvements (Chair: Monika Kopacz; **Rapporteur:** Cody Sullivan)

1:30-3:00: Short presentations to highlight NOAA existing observational and modeling capabilities, process studies and needs for their integrations (**10 min for each talk**)

- Introduction (Lori Bruhwiler, 5 min)
- JPSS (Mitch Goldberg)
- NCEI (Russell Vose)

- A multi-lab and integrated observation/modeling approach to improving understanding land-atmosphere interactions (Dave Turner and Tilden Meyer, 20 min)
- GMD (Jim Butler)
- AOML (Gustavo Goni)
- PMEL (Chidong Zhang)
- GFDL (Yi Ming)

3:00 – 3:00 Break

3:30- 4:30: Discussions on the pressing research needs, potential CPO/ESSM research priorities and partnership strategy (**Lead:** GMD/Lori Bruhwiler; **Rapporteur:** Nicholas Komisarjevsky)

4:30-4:45: Brief workshop summary and closing remarks (Jin Huang)

Appendix B: Council Members

1. Ana Barros (Duke University, Chair)
2. Magdalena Balmaseda (ECMWF)
3. Enrique Curchitser (Rutgers University)
4. Jim Hurrell (Colorado State University)
5. Ben Kirtman (University of Miami)
6. Young-Oh Kwon (Woods Hole Oceanographic Institution)
7. Sukyoung Lee (Penn State University)
8. Yi Ming (NOAA/GFDL)
9. Eric Williams (NOAA/ESRL)

Appendix C: ESSM Workshop Participants

Michael Alexander (ESRL/PSD)
Jennifer Saleem Arrigo (USGCRP)
Ana Barros (Duke University, Chair)
Lori Bruhwiler (ESRL/GMD)
Magdalena Balmaseda (ECMWF)
Ko Barrett (OAR)
Daniel Barrie (CPO)
Molly Baringer (AOML)
Stan Benjamin (ESRL/GSD)
Harold Brooks (NSSL)
Jim Butler (ESRL/GMD)
Philip Chu (GLERL)
Enrique Curchitser (Rutgers University)
Howard Diamond (ARL)
John Dunne (GFDL)
Graham Feingold (ESRL)
Rong Fu (UCLA)
Dwight Gledhill (Ocean Acidification)
Mitch Goldberg (NESDIS/JPSS)
Gustavo Goni (AOML)
David Herring (CPO)
Jim Hurrell (Colorado State University)
Martin Hoerling (ESRL/PSD)
Anne Hollowed (NOAA FISHERIES)
Mike Jacox (NOAA FISHERIES)
Ben Kirtman (University of Miami)
Nicholas Komisarjevsky (CPO)
Monika Kopacz (/CPO)
Young-Oh Kwon (Woods Hole Oceanographic Institution)
David Herring (CPO)
Wayne Higgins (CPO)
Paul Hirschberg (/CPO)
Jean-Francois Lamarque (NCAR)
Sukyoung Lee (Penn State University)
Jin Huang (/CPO)
Dennis Lettenmaier (UCLA)
Sandy Lucas (CPO)
Annarita Mariotti (CPO)
Gary Matlock (OAR)
Chris Meinig (PMEL)

Appendix C: ESSM Workshop Participants

Kenneth Mooney (CPO)

Yi Ming (GFDL)

John Murphy (NWS)

Matt Newman (ESRL/PSD)

Claudia Nierenberg (CPO)

Mark Osler (NOS)

Mike Patterson (USCLIVAR)

Roger Pulwarty (ESRL/PSD)

Emily Read (CPO)

Joellen Russell (University of Arizona)

Tom Ryerson (ESRL/CSD)

Emily Smith (CPO)

Ariel Stein (ARL)

Charlie Stock (GFDL)

Cody Sullivan (NOAA/OAR/CPO)

Bill Sweet (NOAA/OAR/CPO)

Hendrik Tolman (NWS)

Dave Turner (ESRL/GSD)

Russell Vose (NCEI)

Rik Wanninkhof

Robin Webb (ESRL/PSD)

Cisco Werner (NOAA FISHERIES)

Eric Williams (ESRL)

Andrew Wittenberg (GFDL)

Xubin Zeng (University of Arizona)

Chidong Zhang (PMEL)

Lihang Zhou (NESDIS)

Appendix D: ESSM Managers and Staff



Jin Huang
ESSM Division Chief



Annarita Mariotti
MAPP Program Director



Ken Mooney
AC4 Program Manager



Dan Barrie
MAPP Program Manager



Monika Kopacz
AC4 Program Manager



Courtney Byrd
MAPP Program Assistant



Virginia Selz
COM Program Manager



Amara Huddleston
MAPP Program Communications & Analyst



Sandy Lucas
CVP Program Manager

Appendix E: Acronyms

AC4: Atmospheric Chemistry, Carbon Cycle and Climate	MAPP: Modeling, Analysis, Predictions and Projections
AOML: Atlantic Oceanographic and Meteorological Laboratory	NCEI: National Centers for Environmental Information
ARL: Air Resources Laboratory	NESDIS: National Environmental Satellite, Data, and Information Service
CI: Cooperative Institute	NMME: North American Multi-Model Ensemble
COM: Climate Observation and Monitoring	NOS: National Ocean Service
CPO: Climate Program Office	NSSL: National Severe Storms Laboratory
CPT: Climate Process Team	NWS: National Weather Service
CSD: Chemical Sciences Division	OAR: Oceanic and Atmospheric Research
CVP: Climate Variability and Predictability	OSSE: Observation System Simulation Experiments
ECMWF: European Centre for Medium-Range Weather Forecasts	PME: Pacific Marine Environmental Laboratory
ESRL: Earth System Research Laboratory	PSD: Physical Sciences Division
ESSM: Earth System Science and Modeling	TOGA: Tropical Ocean-Global Atmosphere
GFDL: Geophysical Fluid Dynamics Laboratory	TOGA COARE: TOGA Coupled Ocean Atmosphere Response Experiment
GLERL: Great Lakes Environmental Research Laboratory	UFS: Unified Forecast System
GMD: Global Monitoring Division	USCLIVAR: US Climate Variability and Predictability
GSD: Global Systems Division	USGCRP: U.S. Global Change Research Program
JPSS: Joint Polar Satellite System	
LDAS: Land Data Assimilation System	



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