Request to US CLIVAR For Workshop Sponsorship

1. Requesting Panel, Working Group, or person/s:

Lei Wang (Purdue University)
Gang Chen (University of California, Los Angeles)
Jian Lu (Pacific Northwest National Laboratory)

2. Title of workshop or meeting:

Blocking and Extreme Weather in a Changing Climate

3. Venue:

UCAR Center Green, Boulder, CO
We also consider the NCAR Mesa Laboratory, Boulder, CO as an alternate option.

4. Dates:

Three days in late summer or fall 2023, depending on UCAR room availability;
Avoiding CESM workshop (June 12-15), CESM tutorial (likely August 7-11);
Avoiding major religious and cultural holidays.

5. Scientific Organizing Committee (include affiliations):

Confirmed
Lei Wang[*], co-chair (Purdue University)
Jian Lu, co-chair (Pacific Northwest National Laboratory)
Melissa Breeden[·] (NOAA PSL)
Gang Chen (University of California, Los Angeles)
Stephanie Henderson[*] (University of Wisconsin-Madison)
Veeshan Narinesingh[*] (Princeton University/NOAA GFDL)
Isla Simpson (NCAR)
Tim Woollings (University of Oxford)

6. Proposed attendees, include estimate number (indicate if open or by invitation):

We expect 80-100 scientists to participate (about 70 in-person with the rest participating remotely). The workshop will be *open* and will bring together scientists from several research communities that have interests and insights into atmospheric blocking and extreme weather events in a changing climate. We will be inclusive of attendees covering a spectrum of career level from grad students to early career scientists to senior faculty and scientists, and we will also be inclusive of all identities across race, gender, orientation, religion, etc. For example, we will be proactively reaching out to relevant Black and Latinx scientists to invite them to attend.

[·] Early Career Scientist

We would like to propose a three-day workshop consisting of oral sessions, poster sessions, and breakout group discussions dedicated to the open questions. The workshop will be held at a venue in the US and with international scope. The workshop aims to bring together specialists in the field of atmospheric, oceanic, and climate science that have interests and insights into blocking and associated extreme weather in a rapidly changing climate. Participants will include those already actively working on the physical processes of blocking and extreme weather, which has traditionally been a subset of the Atmospheric and Oceanic Fluid Dynamics community, together with scientists from the oceanography, air-sea interactions/coupling, remote sensing, climate modeling, paleoclimate, subseasonal to decadal prediction, climate feedback, and climate assessment communities. Since blocking is not only a key dynamical process leading to extreme weather events, but also a very complex phenomena with a range of different processes involved, we also aim to improve the communication of atmospheric blocking and weather extremes with the more general science community. The make-up of the steering committee is intended to reflect and access that broad audience. A list of potential invitees and participants can be found under item 10.

The proposed workshop will be of interest to US CLIVAR panels, including the Process Study and Model Improvement Panel and the Predictability, Predictions, and Applications Interface Panel. We have designed a draft agenda and break out room discussions to specifically address the relevant topics such as process-level understanding, model uncertainties, climate change projections, predictability, and improved representation of the physical processes in models.

7. Aims and objectives:

Atmospheric blocking often causes high-impact weather extremes such as heat waves, droughts, cold outbreaks, and floods in the mid-latitudes. However, the physical and dynamical processes involved in blocking and how blocking may respond to climate change are not yet well understood, which reduces our confidence in prediction on subseasonal to decadal timescales and projection into the century, hindering informed decisions and policy making in relation to climate mitigation and adaptation. Blocking, a complex phenomenon with a range of different processes involved, strongly interacts with other components of the climate system. This is an emergent subject as climate change may affect the frequency, duration, and geographic distribution of blocking and associated extreme weather events. More generally speaking, as the most recent IPCC report summarized (i.e., chapter 11.1), there is overall *low* confidence about future changes in the magnitude, frequency, and spatial distribution of large-scale atmospheric circulation patterns (including the persistent and quasi-stationary blocking patterns), which contributes to the changes in extremes.

On the other hand, human-caused climate change has altered the likelihood or severity of extreme weather events, especially those linked to heat. The past two years mark the hottest summer for many regions of the globe with record-shattering extreme heat waves. Moreover, compound extremes, referred to as simultaneous, concurrent, or coincident extremes, have been

becoming more frequent and better organized across different geographic regions, and may lead to larger impacts to human society and the environment than individual extremes alone. Due to the multifaceted linkages, compound events are often observed with a presence of blocking patterns. There has been a heated debate regarding the physical processes associated with the extremes, especially regarding the effects of large-scale circulation, such as those associated with blocking, on changes in extremes.

Certain regions are experiencing more pronounced impacts of these compound extreme weather events that are associated with blocking patterns. For example, from late June to early July 2021, driven by a strong blocking pattern fueled by upstream diabatic forcing released from the ocean, an unprecedented heatwave shocked the Pacific Northwest and Canada in the following couple of days, causing over 1,000 deaths as one of the most deadly extreme events in the region.

The dynamics of atmospheric blocking and weather extremes has been a major focus in the Large-Scale Atmospheric Circulation session, that the organizers here actively organized at the AGU fall meeting for the past five years. The momentum has been built up through a sequence of recent workshops including 2016 (2019) Blocking Workshop at University of Reading (Ludwig-Maximilians University), 2018 (2022) Storm Track Workshop at Stockholm (Saint-Pierre-d'Oléron, France), and 2019 Correlated Extremes workshop at Columbia University. This workshop is related to two recent US CLIVAR workshops - the 2013 Extremes workshop, which focused on evaluating whether current climate models produce extremes for the right reasons, and the 2015 Arctic-Midlatitude workshop, which focused on understanding the dynamical coupling between Arctic variability and mid-latitude weather. The proposed US CLIVAR workshop builds upon findings and recommendations of these previous workshops, and now aims to address an emerging research topic that requires experts from blocking, extremes, and climate variabilities work together. The main distinction for this proposed workshop is that **it aims to advance our process-level understanding of the connections between atmospheric blocking and extreme weather in a changing climate, and the connections and feedbacks of oceanic climate variability to blocking and extreme weather.** To achieve this goal, we aim to 1) synthesize the current understanding of blocking and extreme weather in a changing climate; 2) assemble scientists from different research communities enabling a dialogue among them; and 3) identify the most important gaps of knowledge, propose promising ways to move science forward, and create and promote the conditions for possible collaborations.

The proposed workshop will provide a platform for national and international conversation on this pressing, highly impactful issue (i.e., blocking) as both a weather and climate phenomenon. It also affords an avenue for more collaborative and synergistic effort on this important and challenging topic. In addition, the workshop will provide an opportunity for researchers to work towards agreeable definitions of atmospheric blocking as part of the scoped Blocking - Extreme - Model Intercomparison Project (BEMIP) – see more details in the draft agenda and deliverables.

8. Relevance and/or benefits to US CLIVAR:

This request is relevant to US CLIVAR because the workshop will cover but not be limited to these five topics: (1) key physical processes of blocking and extreme weather that contribute to climate variability and change in the past, present, and future; (2) the connections and feedbacks of oceanic climate variability such as ENSO, AMOC, NAO; (3) better uncertainty quantification of blocking and extreme weather in weather prediction and climate simulations; (4) evaluation and understanding of model simulations of blocking and extreme weather using a hierarchy of models; (5) an interdisciplinary collaboration with operational communities and stakeholders that develop and use climate information. All the five points address the Goal 1-5 listed in the Science Plan of US CLIVAR.

Specifically, US CLIVAR's science plan identifies climate and extreme events as one of the key research challenges, and ocean impacts climate extremes through its impacts on cyclogenesis and the large-scale atmospheric circulation. At the same time, prolonged blocking events may influence climate patterns and variability, such as blocking changing salinity patterns for high-latitude oceans by providing new moisture sources. Therefore, we identify atmospheric blocking as a key missing piece needed for making progress with these grand challenges envisioned by US CLIVAR, as well as an agent creating dialog among different research communities of US CLIVAR.

9. Format of meeting:

We would like to propose a three-day workshop consisting of oral sessions, poster sessions, and breakout group discussions dedicated to the open questions. The meeting will be in hybrid format with both in-person and virtual participants.

The workshop will have not only oral/poster presentations, but also discussions on important open questions in the field. We value and view this workshop as an important opportunity for community building, and networking and discussing potential collaborations. The workshop will consist of four components:

a. A small number synthesis talks on overarching themes
b. Poster sessions for attendees to present their ongoing research.
c. Break-out room discussions:
    i. Before the workshop, the organizers will reach out to participants to solicit questions or convertrosial aspects that are worth discussions.
    ii. During the workshop, the questions will be posted at the beginning to increase engagement. Moderators and rapporteurs will be assigned for each breakout room. Each breakout room will be tasked with deliverables, such as identifying gaps in existing knowledge, brainstorming ways forward, etc.
    iii. After the workshop, the organizers will follow up with participants to design actionable plans to complete some identified high-priority deliverables.

Preliminary Draft Agenda:
We sketch out a preliminary schedule with topics to be discussed. For each day, we will start with invited talks to give high-level summary, followed by contributed talks and posters. We will organize break-out room discussions for each day after presentations, each discussion will be tasked with addressing specific questions, which will be prepared by the organizing committee and distributed to the participants in advance of the workshop.

Day One:
Goal: Synthesized and diverse perspectives by invited and contributed presentations.
Topic: Atmospheric Blocking, Extreme Weather, and Their Relationships
Description:

- Review the current state of research on atmospheric blocking and extreme weather
- Key physical processes of blocking and extreme weather
- Blocking lifecycles
- Correlated and compound extreme weather events
- Different detection algorithms and metrics for blocking and extremes; Pros and Cons for each metric.
- Emerging field: the role of latent heating in the formation, maintenance, and decay of blocking and extreme weather

Break-out Room Tasks:

- Summarize the up-to-date physical and dynamical understanding as well as gaps of knowledge of blocking and extremes. Topics include but not limited to 1) conflict between linear vs nonlinear interpretation of blocking; 2) validity of the quasi-resonance mechanism as the mean wind changes under climate warming; 3) controversy on the role of Arctic amplification in more extreme wavy circulation. 4) lack of consistent framework for quantifying the feedbacks in blocking (e.g., from diabatic processes and via air-sea interaction).
- To put us on the same page in terms of diagnostic methods, we will identify a strategy for developing potential intercomparison project for Blocking and Extremes metrics; Discuss necessary steps and agree on the same datasets (reanalysis and climate model outputs).

Day Two:
Goal: Bringing dynamists and modelers together
Topic: Representation of Blocking and Extremes in Models
Description:

- Evaluation and understanding of model simulations of blocking and extreme weather using a hierarchy of models (e.g., ECMWF's IFS sub-seasonal reforecasts, climate models)
- Better uncertainty quantification of blocking and extreme weather in weather prediction and climate simulations

- Sensitivity of simulated blocks and extreme weather to the resolved diabatic heating by moist processes and cloud-radiative feedbacks
- An interdisciplinary collaboration with operational communities and stakeholders that develop and use climate information

Break-out Room Tasks:

- Assess the current capabilities and limitations for realistically simulating blocking and extreme weather events, especially in key regions. Topics include but not limited to dependence of model resolution, properly capturing realistic mean states, forecasting, parametrization of orographic drag, sub grid-scale processes, air-sea coupling, teleconnections, etc.
- Identify strategies to improve representations of blocking and extremes in climate models.

Day Three:

Goal: Assemble scientists from different research communities enabling a dialogue, and identify ways forward

Topic: Climate Variability and Climate Change

Description:

- Summary of discussions of the first two days
- Responses of blocking and associated extremes to Climate Change
- The connections and feedbacks of oceanic climate variability such as ENSO, AMOC
- Tropical Remote Drivers of Blocking and Extremes (e.g., MJO, ENSO)
- Midlatitude External Forcing (e.g., topography, SST fronts)

Break-out Room Tasks:

- Summarize the complex responses of blocking and extremes in a warming climate, and identify the key factors that control the overall number, the geographic distribution, intensity, and trend of blocking and extreme weather events.
- Assess the confidence level of the projected changes of blocking and extreme weather events in a warming climate in numerical models.
- Scientific organizing committee meeting to plan for the white-paper writing and to coordinate the proposed Blocking-Extreme-MIP project.

10. Tentative list of invited speakers/participants:

Early Career Scientists (# of female: 12, # of male: 11)

Blocking and Extreme Weather:
Seraphine Hauser (KIT, Germany)
Franziska Teuber (Mainz)
Marie Drouard (Universidad Complutense de Madrid, Spain)
Charlie Suitters (University of Reading)
Emily Neal (University of Chicago)

Valentina Castañeda (Purdue University)
Pragallva Barpanda (NOAA Physical Sciences Laboratory)
Sina Lenggenhager (University of Bern)
Momme Hell (Scripps Institution of Oceanography)
Packard Chan (University of Exeter)
Tyler Christopher Leicht (SUNY-Albany)
Lina Boljka (University of Bergen)
NuanLiang Zhu (University of Chicago)
Ebrahim Nabizadeh (Rice University)

Climate Extremes:
Daniel Steinfeld (ETH Zurich)
Andrew Winters (University of Colorado)
Colin Raymond (Columbia University)
Kai Kornhuber (Columbia University)
Orli Lachmy (Open University of Israel)
Rachel White (University of British Columbia)
Talia Tamarin-Brodsky (Massachusetts Institute of Technology)
Lenka Novak (Caltech)
Samuel J Smith (Indiana University Bloomington)

Mid-career to Senior Scientists (likely to attend)
Blocking:
Brian Hoskins (University of Reading)
Akira Yamazaki (Kyushu University)
Noboru Nakamura (University of Chicago)
Stephan Pfahl (Freie Universität Berlin)
Padrem Hassanzadeh (Rice University)
Anthony Lupo (University of Missouri)
James F. Booth and associates (CUNY City College)
Paolo Davini (CNR-ISAC)
Ben Harvey (University of Reading)
Hisahi Nakamura (University of Tokyo)
Patrick Martineau (JAMSTEC)

Extreme Weather:
Gary Lackmann (North Carolina State University)
Olivia Martius (ETH Zurich)
Christian Grams (Karlsruher Institut für Technologie)
Michael Wehner (Lawrence Berkeley National Laboratory)
Bradfield Lyon (University of Maine)
Paul Roundy (SUNY-Albany)
Edmund Chang (Stony Brook University)
Steven Cavallo (University of Oklahoma)

Andrea Lang (SUNY-Albany)
Lance F Bosart (SUNY-Albany)

Large-scale Circulations:
Tiffany Shaw (University of Chicago)
Paul O'Gorman (Massachusetts Institute of Technology)
Aditi Sheshadri (Stanford University)
Ed Gerber (New York University)
Kevin Grise (University of Virginia)
Paulo Ceppi (Imperial College)
Gina R Henderson (US Naval Academy)
Daniela Domeisen (ETH Zürich)
R. Saravanan (Texas A&M University)
David Thompson (Colorado State University)
Yutian Wu (Columbia University)
Volkmar Wirth and Michael Riemer (Johannes Gutenberg-University Mainz)

Climate Extremes and Impacts:
Noah Diffenbaugh (Stanford University)
L. Ruby Leung (Pacific Northwest National Laboratory)
Radley Horton (Columbia University)
Andrew W. Robertson (Columbia University)
Sonia Seneviratne (ETH Zürich)
Yi Ming (Boston University)
Haiyan Teng (Lawrence Berkeley National Labortory)
Dim Coumou (Vrije Universiteit Amsterdam)
Merce Casas Prat (Environment Canada)
Deniz Bozkurt (Universidad de Valparaiso)
James Renwick (Victoria Unviersity of Wellington)
Colin Zarzycki (Penn State University)
Deepti Singh (Washington State University)
Yannick Peings (University of California Irvine)

Modeling and Forecasting:
Mio Matsueda (University of Tsukuba)
Frederic Vitart (ECMWF)
Julian Quinting (Karlsruher Institut für Technologie)

Others potentially interested:
Not yet involved in blocking and extreme weather research, but working on very relevant topics
Large-scale dynamics: Walter Robinson (North Carolina State University); Rei Chemke (Weizmann Institute)
Climate dynamics: Sukyoung Lee (Penn State University); Nicole Feldl (University of California Santa Cruz)

Climate variability: Clara Desser (NCAR); Jen Kay (University of Colorado)
Ocean's influence on atmosphere: Robb Wills (University of Washington); Ping Chang (Texas A&M University)
Climate and Clouds: Nick Lutsko (University of California San Diego)
Hurricanes and extremes: Suzana Camargo (Columbia University)
Modeling: Ming Zhao (NOAA GFDL); Geradl Meehl, Brian Medeiros, Richard B Neale (NCAR)

11. Deliverables:

- Workshop Report that summarizes the state of the knowledge and gaps in understanding, and puts forward recommendations for future diagnostic/modeling activities, necessary observations, theoretical frameworks, and other ways forward
- Scope a new **Blocking - Extreme - Model Intercomparison Project (BEMIP).** As reviewed in Woollings et al 2018 from a previous Blocking workshop, the largest discrepancies among climatologies come from the different methodologies of blocking index and a lack of coordinated efforts to compare indexes using the same datasets and adhere to the same protocols. This discrepancy has severely limited our ability to reach consensus of blocking and extreme weather responses in a warming climate. Similar obstacles in the Atmospheric River research community were alleviated through the development of the Atmospheric River Tracking Method Intercomparison Project (ARTMIP). We will model after the success of the ARTMIP but focus on blocking and extreme weather. This proposed workshop can provide a critical and much-needed opportunity for experts to collaborate on this intercomparison project.
- Community information piece to be submitted to EOS or BAMS
- Initiate a review and synthesis paper

12. Approaches to address diversity, equity, and inclusion:

- In the drafting of the workshop proposal, we ensure all inputs from members are actively solicited and valued in the process of finalizing the request.
- We would proactively ensure the inclusion of scientists who are early-career and from under-represented groups in the organizing committee and as oral presenters.
    - The organizing committee membership reflects diversity, equity, and inclusion.
    - The determination of oral and poster presentations at the meeting reflects diversity, equity, and inclusion, where consideration would be given to diversity across scientific expertise, institutional affiliation, career stage, gender, race/ethnicity, and other demographic factors.
- During the workshop, we will organize network events for early career scientists. By fostering an intellectually stimulating, inclusive environment, we are helping early career scientists develop scientific identity and build confidence.
- Our meeting dates would avoid major religious and cultural holidays.
- We would promote the event by targeting under-represented groups to engage their awareness and participation.

- The meeting budget would include reduced registration fees and travel support opportunities for early career scientists and scientists from underrepresented racial and/or ethnic groups, further enabling their participation in the meeting.

13. Budget request from US CLIVAR:

We request support for meeting logistics and travel support for 6 organizers (nonlocal), 5 invited speakers, and 20 early career scientists. In particular, we request reduced registration fees and travel support opportunities for early career scientists and scientists from underrepresented racial and/or ethnic groups.

Travel for 31	$53,050
Catering for 70	9,321
A/V and Multimedia Services	5,000
Supplies and Processing Fees	2,000
Meeting and Travel Staff Time	5,926
Indirect Costs	7,831
Subtotal	83,128
Less registration revenue	-14,375
Total Request	$68,753

14. Other sources of funding:

Registration revenue: Estimated total of $14,375 based on in-person registration rate of $250; $125 for early career and underrepresented scientists and virtual rates of $200 and $100, respectively.

We will seek possible funding for European colleagues through European Research Council.