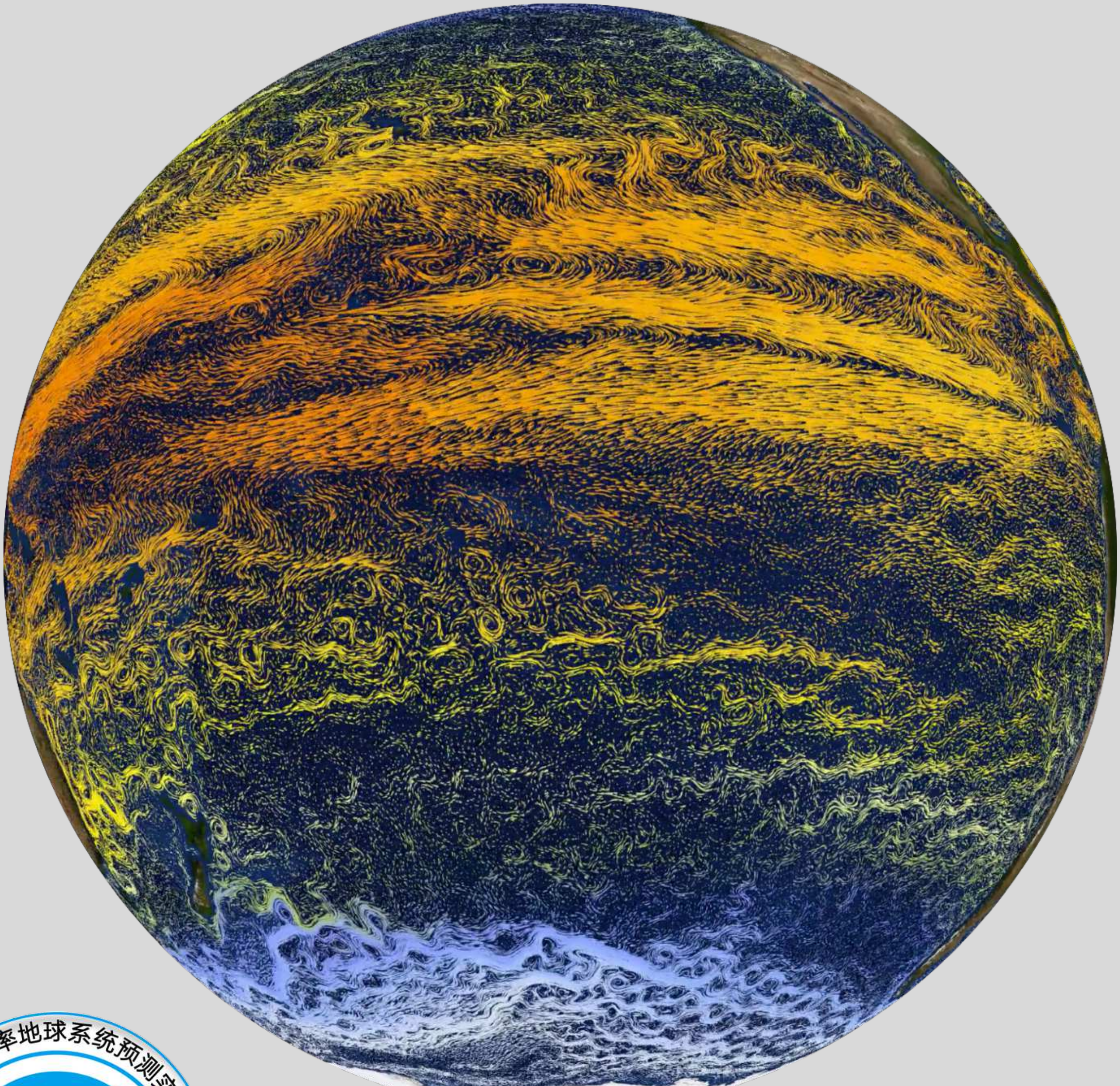
International Laboratory for High-Resolution Earth System Prediction (iHESP)



PROJECT OVERVIEW

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International Laboratory for High-Resolution Earth System Prediction (iHESP)

PROJECT OVERVIEW

国际高分辨率地球系统预测实验室

iHESP

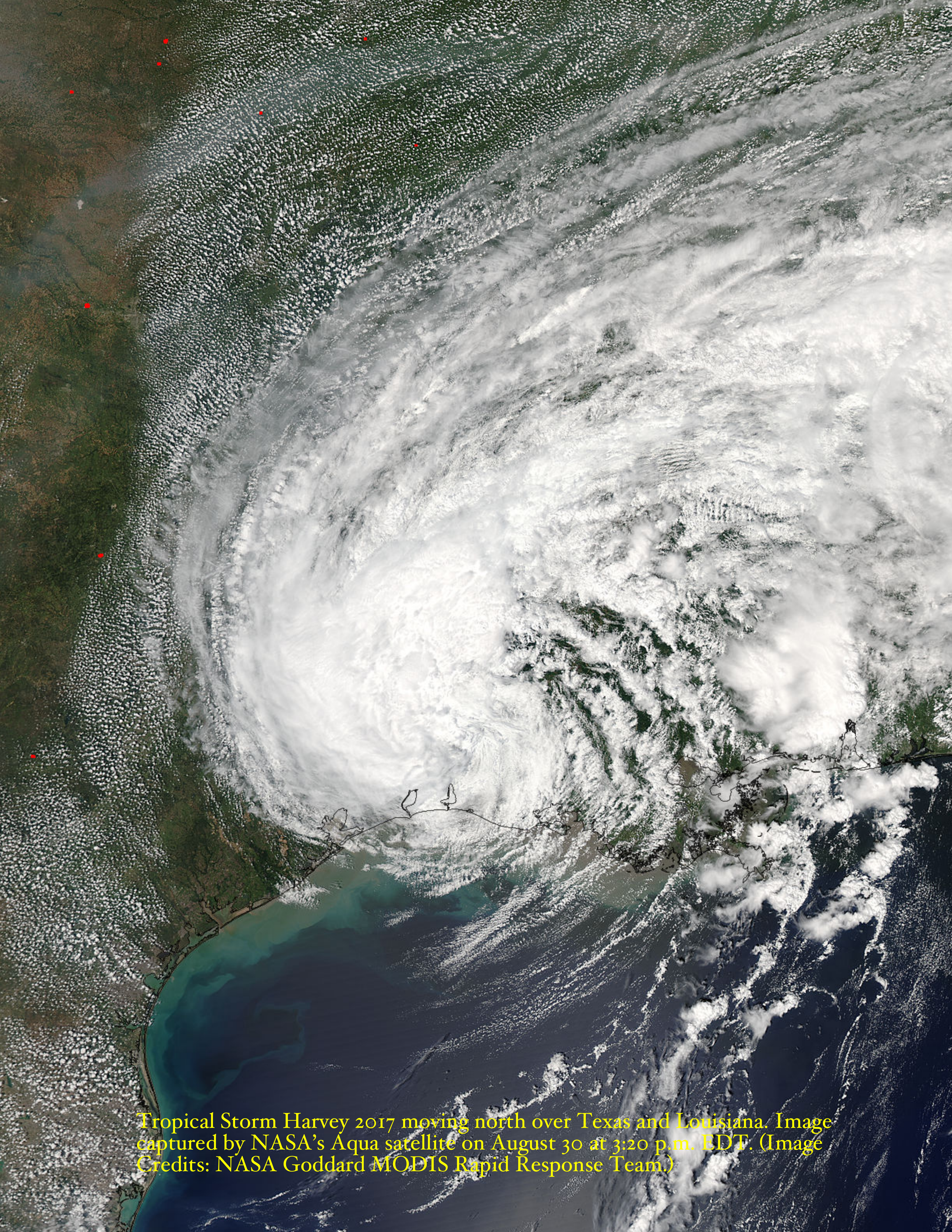
International Laboratory for High-Resolution Earth System Prediction

NCAR

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

A T M

Contents



Tropical Storm Harvey 2017 moving north over Texas and Louisiana. Image captured by NASA's Aqua satellite on August 30 at 3:20 p.m. EDT. (Image Credits: NASA Goddard MODIS Rapid Response Team.)

iHESP Project Overview

1 IMPETUS

There is a pressing need to develop a new advanced modeling framework for high-resolution[1] multiscale Earth system predictions. We have already seen that climate variations impact the likelihood and intensity of extreme weather, including tropical cyclones, heat waves, winter storms, droughts, floods, and coastal sea-level rise. Such events have profound effects on the well-being of humans, agriculture, energy use, industrial activity, marine ecosystems, and coastal sustainability, with economic impacts in the billions of dollars.

In order to address this need, the Qingdao Pilot National Laboratory for Marine Science and Technology (QNLM), Texas A&M University (TAMU), and the U.S. National Center for Atmospheric Research (NCAR) have been engaging in a discussion about a trilateral collaboration to establish the International Laboratory for High-Resolution Earth System Prediction (iHESP) since 2016. We believe that such an international collaboration is timely and has the potential to yield enormous social, economic, and environmental benefits, making it an extremely valuable effort for policymakers and stakeholders. We envision the new Laboratory will play a fundamental role in moving Earth system science and prediction forward by combining the expertise of these three renowned research institutions to pursue transformational efforts in the development and application of high resolution Earth system models.

2 INCEPTION

On November 17, 2017, a Memorandum of Agreement (MOA) for the establishment of iHESP was signed by QNLM, TAMU and NCAR (Figure 1). The overarching objective of iHESP is to accelerate efforts in: 1) high-resolution ocean and Earth system model development; 2) high-resolution ocean and Earth system simulation and prediction; and 3) advancing scientific understanding of interactions among different Earth system components across different space and time scales. iHESP begins its official operations in April 2019.

iHESP will address the urgent need to develop a new advanced modeling framework for high-resolution multiscale Earth system predictions. This new modeling framework and products that iHESP intends to develop will be critical to understanding and

[1] eddy-permitting / -resolving in the ocean and tropical cyclone (TC)-permitting resolution in the atmosphere.

Figure 1. iHESP MOA signing ceremony at QNLM, Qingdao, China in October, 2017.

developing solutions for risks associated with rapidly changing environmental conditions across the planet, including those associated with climate variability on seasonal to decadal time scales. The establishment of iHESP seeks to provide reliable information at both global and regional scales, taking full advantage of the combined expertise of three world-class institutions.

iHESP's founding principle is strong international collaboration and open science. Today, as innovative resources are actively exchanged among the global Earth science community at an unprecedented level, open science and collaborative innovation have become an important mode for international science and technology innovation and development. We expect that iHESP will quickly develop into a world-leading research center for Earth system modelling and prediction, through gathering high-caliber talents, pooling together complementary resources, and realizing innovative research. It is also expected that iHESP will work with such international programs and initiatives as Future Earth, the International Geosphere Biosphere Program (IGBP), and the World Climate Research Program (WCRP) to provide scientific guidance and management strategies for climate prediction.

The operating budget for the initial phase of the iHESP project, for the next five years from 2018 to 2023, is US $20M.

3 PARTNERS

The three key collaborating partners of iHESP are the Qingdao Pilot National Laboratory for Marine Science and Technology (QNLM), Texas A&M University (TAMU), and the U.S. National Center for Atmospheric Research (NCAR). Each of these institutions have respectively developed strong expertise and proven experience in high-resolution ocean modeling and global and regional Earth system modeling. iHESP will build on these existing strengths and foster international collaborations between scientists at the QNLM modeling laboratories and the modeling community in the US and other countries.

QNLM is China's first national laboratory in marine research, launched in 2015. Jointly supported by Chinese Central Government, Shandong Provincial Government and Qingdao Municipal Government, QNLM focuses on basic research, applied basic research and especially the development of cutting-edge technology. It has launched the world's fastest computing center for marine research, launched a fleet of research vessels including the famous manned submersible Jiaolong, and forged partnerships with a number of the world's renowned institutions, including Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia and TAMU and NCAR in the US.

Texas A&M University (TAMU) in College Station, Texas, USA, established in 1876, is the flagship school of the Texas A&M system. The fourth largest university in the US and the largest in Texas, it is one of only a few universities in the US to be designated a land grant, sea grant, and space grant university. TAMU is also one of a few universities in the US to have a college in Geosciences that encompasses a broad range of disciplines in Earth system sciences, including Oceanography, Atmospheric Sciences, Geology and Geophysics, and Geography, as well as the International Ocean Discovery Program (IODP) – a US National Science Foundation funded international marine research collaboration dedicated to advancing scientific understanding of the Earth through drilling, coring, and monitoring the subseafloor. Together, these academic departments and research centers have brought a wide range of talents and capabilities in Earth system science to TAMU, positioning it extremely well to deal with challenges in integrated Earth system science research. TAMU and its College of Geosciences have a long history of collaborating with Chinese universities and institutions.

NCAR, is one of world's premiere institutes in atmosphere and Earth system science. Established in 1960, NCAR's mission is to understand the behavior of the atmosphere and related Earth and geospace systems; to support, enhance, and extend the capabilities of the university community and the broader scientific community, nationally and internationally; and to foster the transfer of knowledge and technology for the betterment of life on Earth. NCAR is committed to the continued advancement of Earth system modeling, improved predictive capabilities, and more effective applications of these advances to societal needs. Through this new international laboratory, and in collaboration with the broader research community, NCAR will be able to accelerate its progress on these strategic objectives, thereby enhancing its ability to bring relevant and objective information to national and international decisions on mitigation, adaptation, resiliency, and sustainability.

In addition to the three main partners, iHESP seeks to develop collaborations with other modeling centers and institutes worldwide and participates in other international modeling projects that share the same vision with iHESP to advance Earth system modeling and prediction science.

4 SCIENTIFIC GOALS

The main focus of the initial phase of iHESP is on research and development for high-resolution Earth system model and key modeling technologies including large-scale high-efficiency parallel computing technology, data assimilation technology, visualization, big data analytics and mining.

The specific science goals of iHESP for the next five years are as follows.

- Assess and quantify the role of mesoscale ocean features, including fronts and eddies, and their interactions with the atmosphere and sea-ice in climate variability, predictability, and prediction by carrying out an unprecedented ensemble of present and future climate simulations at ocean-mesoscale-eddy-resolving and tropical cyclone (TC)-permitting resolutions in the ocean and atmosphere, respectively;

- Develop a new advanced modeling framework for high resolution regional and global Earth system predictions at sub-seasonal to decadal time scales by focusing on:
  - Improving or/and replacing the ocean component in NCAR's Community Earth System Model (CESM) with a new ocean model that has improved upper ocean mixing processes, including surface wave and tidal effects, as well as other unresolved small-scale dynamics,
  - Enhancing the CESM coupling software framework by developing a set of online nesting tools for dynamical downscaling through embedding regional-CESM (R-CESM) within global CESM, and

- Developing a new online coupled data assimilation capability for high-resolution regional and global Earth system models.

A central research question to be addressed is how the simulation of natural variability of the climate system depends on model resolution. In particular, how do multi-scale interactions arising from coupling the better resolved atmosphere and ocean models influence the low-frequency, large-scale behavior of the Earth system that has an important bearing on the predictable dynamics of the system? An understanding of the natural variability of the system is a necessary (but not sufficient) condition for establishing the predictability of the climate system and for addressing issues related to signal detection and attribution of anthropogenic climate change. A key outstanding question in climate prediction research that we will address is: Will enhanced model resolution improve interannual-to-decadal forecast skill and signal-to-noise characteristics? Other related scientific questions that will be addressed include: To what extent can the knowledge about climate variability and predictability gained from coarse resolution modeling studies carry over to the ocean eddy-resolving regime? And to what extent can the dynamical downscaling through embedding R-CESM within global CESM further improve assessment of regional impact of weather and climate extremes?

5 MAJOR OUTCOMES AND IMPACTS

iHESP is expected to produce results on a wide range of topics related to climate and Earth system modeling and prediction that will have high impacts on the broad research community for many years to come. These include:

- First complete set of high-resolution global CESM simulations, including an ensemble of climate projections, which can provide useful guidance for future climate projection and application research.

- High-resolution model output that will be used by a broad community for a wide range of multidisciplinary climate application studies, including impact of climate extremes, coastal sea-level rise, climate and agriculture, climate and infectious disease, climate and water resources;

- High-resolution CESM simulations designed for the high-resolution Model Intercomparison Project (HighResMIP) of the Coupled Model Intercomparison Project 6 (CMIP6), making CESM a participating member of the highResMIP;

- Unique contribution to CMIP6 DECK (Diagnostic, Evaluation and Characterization of Klima) and Decadal

Climate Prediction Project (DCPP) Model Intercomparison Project (MIP) experiments by providing the highest resolution output ever submitted;

- High-profile journal articles, including possibly a special volume dedicated to this project that will focus on the science and benefits of high-resolution global climate simulations.

In addition to the aforementioned numerical simulations using the high-resolution CESM, iHESP will advance the development of high-resolution Earth system modeling by delivering:

- A regional-CESM that couples Weather Research Forecasting (WRF) model, Regional Ocean Modeling System (ROMS) and Community Land-Surface Model (CLM) in the same coupling framework as in its global version - CESM, for higher resolution regional climate simulations, analysis and predictions,

- An integrated regional/global coupled system that embeds R-CESM within CESM using a new advanced coupling software – Intra-Component Driver Framework (ICDF) software – thereby providing a set of modeling tools for nesting higher resolution regional model components into coarse resolution global model components,

- A coupled data assimilation capability for both R-CESM and CESM that can be used to initialize high-resolution climate forecasts.

Similar to the high-resolution CESM simulations, these model software development efforts will be unprecedented in scope, enhancing modeling capability for high-resolution regional and global Earth system prediction at subseasonal-to-decadal (s2D) time scales. These new modeling capabilities will serve to open up new avenues for future collaborative research.

To maximize the broader impact of iHESP research, we will ensure that all products resulting from this collaborative research effort, including model software, data output and other deliverables (excluding project background IP and confidential information) will be made publically and freely available on basis of open access and appropriate terms of use through iHESP and/or institutional repositories and websites. We will make a concerted effort to coordinate and share our high-resolution simulations and process-based analyses with other similar modeling projects at an international level, such as the HighResMIP. By comparing our model results with other models, a robust assessment of the benefits of increased horizontal resolution for climate simulation can be made.
The cutting-edge research conducted at iHESP represents an important step in

closing the gap between climate and weather prediction by allowing climate model resolution to approach weather resolving scales. We expect that the research products generated by iHESP will contribute significantly to improving predictive skill of weather and climate extremes on time scales from days to seasons to decades. Given that weather and climate extremes affect every aspect of our society, providing more accurate and reliable predictive information about occurrence of extremes on these climate time scales can have enormous implication for mitigating risks to society and to ecosystems in the near-term (subseason to year) and for effective adaptation planning in the longer term (decade and longer). Therefore, the impact of new modeling and simulation technologies developed by iHESP will be long-lasting and far-reaching.

6 MANAGEMENT STRUCTURE

The iHESP's management structure comprises a Steering Committee (SC), Scientific Advisory Committee (SAC), and a Director who reports to the Steering Committee (Figure 2). The SC will be composed of seven (7) members: two (2) representatives each from QNLM, TAMU, and NCAR. The SC will be chaired by an independent third entity. The SC is responsible for review and selection of the five (5)-year scientific plan, annual work plan, and approval of the annual budget and the appointment of the Laboratory Director. The SC will make decisions through consensus. The SAC provides advice to the SC concerning the scientific elements of the program. The SAC is composed 4-8 external (non-Parties) members, including experts from relevant research fields and representatives from prestigious research institutions. All SAC members shall be agreed upon by SC. A list of Steering and Scientific Advisory Committee members can be found on the iHESP website at https://iHESP.tamu.edu. The iHESP main office is situated off campus at Texas A&M University in College Station, Texas. Partners are located at QNLM and NCAR.

7 MENTORING STRATEGIES

This five-year project will support 4 postdoctoral researchers and 2 graduate students each year. All the postdocs and students will be supported and managed through the iHESP main office at TAMU, but they can be mentored by scientists in other institutions. The primary goal of the postdoctoral mentoring program is to support overall development and advancement of researchers' professional and research skills, leading to greater scientific independence and career success. We will provide the postdoctoral researchers (and graduate students) with valuable experience in Earth system modeling and prediction studies. Specific steps are planned to support the

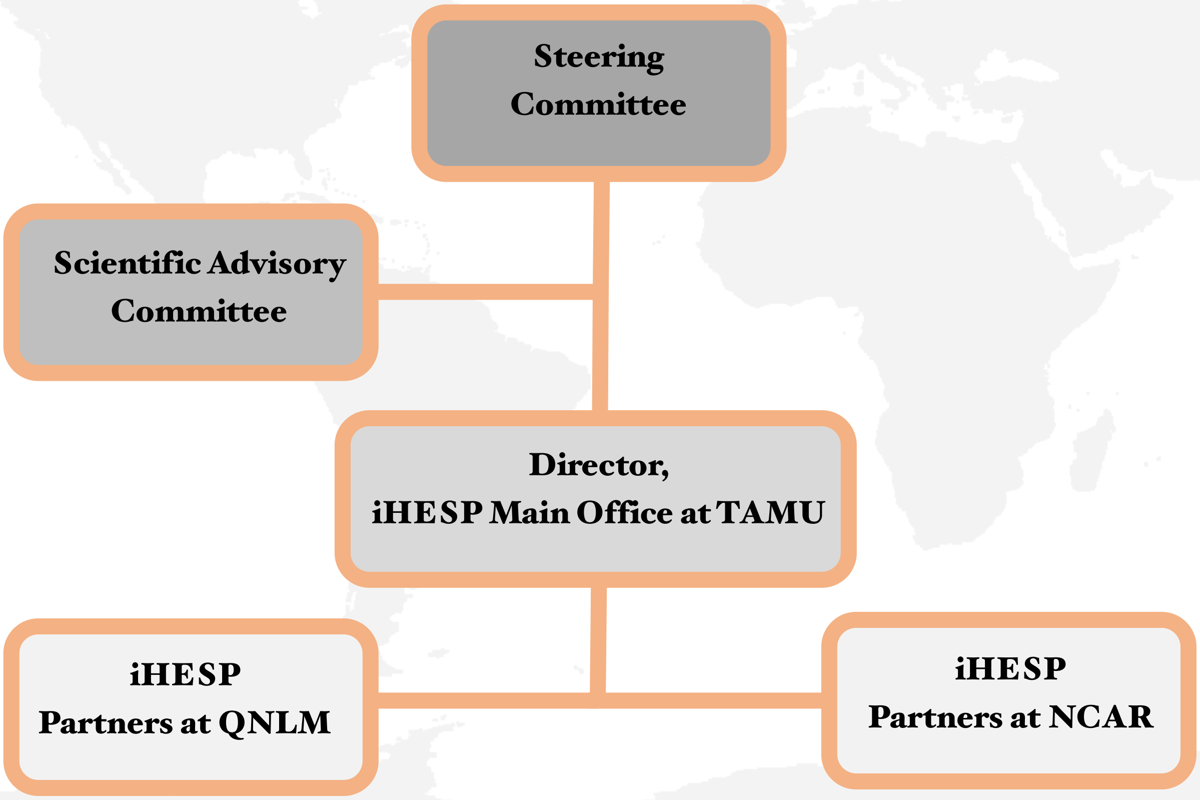


Fig.2 iHESP Management Structure.

overall success and growth of the postdoctoral researchers and graduate students. These include:

- Guiding young researchers in the preparation of an individual development plan that maps short and long-term research goals and career options;
- Cross-participation by all researchers in model development, integration, operation, and analysis;
- Ensuring collaboration among all postdoctoral researchers to maximize exposure to modeling methods in multiple disciplines;
- Encouraging co-authored journal articles;
- Participation in professional development seminars/workshops as they arise;
- Opportunities to network with visiting scholars through visiting speaker series;
- Travel to conferences each year, such as the American Geophysical Union Fall meetings, with the goal that the postdoctoral researchers present a poster or paper at the conference;
- Participation in weekly research group meetings, in which members will be expected to present their research regularly, and feedback and coaching will

be given to help all members to develop their communication and presentation skills.

8 CONCLUDING REMARKS

iHESP's goal is to advance challenging fundamental science and technology in Earth system modelling and prediction. Looking ahead, it is our sincere hope and firm belief that through our joint efforts to tackle the most fundamental problems in climate modeling and prediction research, iHESP will be playing a leading role in the advancement of Earth system science and prediction.

Acknowledgements

1. The image on the cover page is created by Mingkui Li, Ocean University of China. It shows sea surface temperature (SST) in color and ocean surface currents in flow-lines. The data is from a high-resolution CESM run.

2. The breaking wave image in the header is a cropped version of original image obtained from Wikipedia (https://en.wikipedia.org/wiki/Breaking_wave#/media/File:Large_breaking_wave.jpg)

iHESP

国际高分辨率地球系统预测实验室

international Laboratory for High-Resolution Earth System Prediction