NOAA Technical Memorandum NOS 34
NOAA Technical Memorandum NWS 02
NOAA Technical Memorandum OAR 02

UFS Coastal Applications Team - Water Quantity Marine Navigation Sub-Application Tiger Team: Report

Silver Spring, Maryland
June 2022

noaa **National Oceanic and Atmospheric Administration**

U.S. DEPARTMENT OF COMMERCE
National Ocean Service
National Weather Service
Oceanic and Atmospheric Research

National Ocean Service
National Weather Service
Oceanic and Atmospheric Research

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

The **National Ocean Service (NOS)** is one of six major divisions within the National Oceanic and Atmospheric Administration (NOAA), which is housed within the U.S. Department of Commerce. NOS is the nation's most comprehensive coastal agency with world-class expertise in science, technology, and management. Although NOS delivers a diverse suite of products and programs, the main mission areas are reflected in the three primary sections of its budget: Navigation, Observations, and Positioning; Coastal Science and Assessment; Ocean and Coastal Management and Services.

The **National Weather Service (NWS)** has played a key role in protecting American lives and properties for over a century. The timely provision of reliable weather, water, climate, and environmental information has supported the Nation's social and economic development. NWS offices in communities across the United States and its territories, supported by regional and national centers, provide the authoritative information needed by Americans, including national, regional, state, tribal, and local authorities, to plan, prepare, mitigate, and respond to natural and human-caused events.

Oceanic and Atmospheric Research (**OAR**) is a division of the National Oceanic and Atmospheric Administration (NOAA). OAR is also referred to as **NOAA Research**. NOAA Research is the research and development arm of NOAA and is the driving force behind NOAA environmental products and services aimed at protecting life and property and promoting sustainable economic growth. Research conducted by programs within NOAA and through collaborations outside NOAA, focuses on enhancing the understanding of environmental phenomena such as tornados, hurricanes, climate variability, changes in the ozone layer, El Niño/La Niña events, fisheries productivity, ocean currents, deep sea thermal vents, and coastal ecosystem health.

NOAA Technical Memorandum NOS 34
NOAA Technical Memorandum NWS 02
NOAA Technical Memorandum OAR 02

UFS Coastal Applications Team - Water Quantity Marine Navigation Sub-Application Tiger Team: Report

Greg Seroka (NOAA/NOS/OCS) (Overall Co-Lead)
John Kelley (NOAA/NOS/OCS) (Overall Co-Lead)
Joe Sienkiewicz (NOAA/NWS/NCEP/OPC) (NWS Co-Lead)
Charles Seaton (CRITFC) (Academic Co-Lead)
Eric Anderson (Colorado School of Mines) (Academic Co-Lead)
Allison Allen (NOAA/NWS/AFS)
Cristina Forbes (USCG-SAR)
Ayumi Fujisaki-Manome (U. of Mich./CIGLR, NOAA/OAR)
Kevin A. Haas (Georgia Tech)
Carolyn Lindley (NOAA/NOS/CO-OPS)
Dan Roman (NOAA/NOS/NGS)
Neil Weston (NOAA/NOS/OCS)

June 2022

noaa **National Oceanic and Atmospheric Administration**

U. S. DEPARTMENT OF COMMERCE
Gina M. Raimondo
Secretary

National Oceanic and Atmospheric Administration Dr. Richard Spinrad
Under Secretary

National Ocean Service
Nicole LeBoeuf
Assistant Administrator

Oceanic and Atmospheric Research
Dr. Cisco Werner
Acting Assistant Administrator

National Weather Service
Ken Graham
Assistant Administrator

NOTICE

Mention of a commercial company or product in this technical memorandum does not constitute an endorsement by NOAA. Use for publicity or advertising purposes of information from this publication concerning proprietary products or the tests of such products is not authorized.

Table of Contents

List of Table

Executive Summary

Following the Coast & Geodetic Survey Act of 1947, Hydrographic Services Improvement Act of 1998, and the International Convention for the Safety of Life at Sea (SOLAS) of 1974, NOAA National Ocean Service (NOS) and its partners have been providing forecast guidance of water levels, currents, and other environmental variables to support marine navigation since 2002. Presently, NOS has 15 local operational oceanographic forecast modeling systems. NOS and its partners continue to develop, evaluate, and implement operational oceanographic forecast modeling systems to provide forecast guidance for additional coastal, lake, and river areas within the U.S. and with greater accuracy. The existing forecast systems use a variety of different core 3D oceanographic models.

The Unified Forecast System (UFS) is a proposed community-based, coupled comprehensive Earth modeling system that is designed to incorporate NOS oceanographic forecast model core(s) into a simplified NOAA modeling suite. This simplification is intended to reduce the footprint of the number of NOAA models and thus reduce development, operations, and maintenance. The UFS Coastal Applications Team (CAT) - Water Quantity set up a marine navigation sub-application team to set the foundation for the selection of an oceanographic model(s) to be part of the UFS that supports the marine navigation community. This sub-application team performed the following tasks:

- Generated consensus user requirements for marine navigation and the Blue Economy.
  - The required priority user variables are the following: **water levels, surface water currents, sea and lake ice, and water temperature and salinity**. Other required user variables for marine navigation that were considered here and should be coordinated include winds and waves.
- Developed criteria for selecting oceanographic models, based on those user requirements and the UFS framework.
  - The UFS framework requires a **community model approach, coupling in the ESMF/NUOPC framework, and data assimilation in the JEDI framework**.
- Applied those criteria to select an initial list of oceanographic models for further consideration.
  - The initial list of recommended models is **FVCOM, ROMS, SCHISM, and MOM6**.
- Defined recommended skill assessment guidelines for future evaluation of the oceanographic models.
  - This future evaluation of the models will be performed by a separate independent team.

I. Background

Following the Coast & Geodetic Survey Act of 1947, Hydrographic Services Improvement Act of 1998, and the International Convention for the Safety of Life at Sea (SOLAS) of 1974, NOAA National Ocean Service (NOS) and its partners have been providing forecast guidance of water levels, currents, and other variables to support marine navigation since 2002. Presently, NOS has local operational oceanographic forecast modeling systems for Lake Erie, Lake Ontario, Lake Superior, Lakes Michigan/Huron, Gulf of Maine, New York Harbor, Delaware and Chesapeake Bays, St. Johns River, Tampa Bay, Northern Gulf of Mexico, San Francisco Bay, Columbia River, U.S. West Coast, and Cook Inlet.

NOS and its partners continue to develop, evaluate, and implement operational oceanographic forecast modeling systems to provide forecast guidance for additional coastal and lake areas within the U.S. and with greater accuracy. The existing forecast systems use different core 3D oceanographic models: Regional Ocean Modeling System (ROMS), Finite Volume Community Ocean Model (FVCOM), Princeton Ocean Model (POM), Semi-implicit Eulerian-Lagrangian Finite Element (SELFE), and Environmental Fluid Dynamics Code (EFDC).

The Unified Forecast System (UFS) is a proposed community-based, coupled comprehensive Earth modeling system that is designed to incorporate NOS oceanographic forecast model core(s) into a simplified NOAA modeling suite. This simplification is intended to reduce the footprint of the number of NOAA models and thus reduce maintenance, computer resources, documentation updates, algorithm development and implementation, and streamline upgrades to the models.

The focus of the UFS Coastal Applications Team (CAT) - Water Quantity is on the physical properties of the hydrodynamic models. The members on the team are from NOAA, the U.S. Coast Guard (USCG), and academic institutions. This report is a product from the marine navigation sub-application under the UFS CAT - Water Quantity with the goal to provide criteria for an objective selection of an oceanographic model(s) to be part of the UFS that supports the marine navigation community, i.e., products that will be used by the marine navigation community. The selected model(s) will have long-term, i.e. 10-15 years, implications for operational oceanography in the U.S.

II. Purpose of the Tiger Team

The UFS CAT - Water Quantity requested a marine navigation sub-application tiger team to generate consensus guidelines (i.e., metrics, criteria, and competing numerical oceanographic models) for a “model evaluation”. These guidelines will be presented to the UFS Steering Committee for recommendation on conducting a future “model evaluation”. A separate team that has yet to be defined will conduct that evaluation and selection process for the coastal/inland numerical oceanographic forecast model(s) used for the marine navigation sub-application in the Unified Forecast System (UFS).

III. User/Partner Requirements

NOAA and its partners have over the last few decades collected user requirements from the marine navigation and related communities. These communities included commercial and recreational mariners, port authorities, NWS and private forecasters, marine educators/researchers, search and rescue, manufacturers of marine navigational systems, and offshore wind energy operators. The International Hydrographic Organization (IHO) has also been collecting user requirements in order to create product standards (IHO S-1xx) to be used as part of a carriage suite on certain vessels that can be displayed on an Electronic Chart Display Information System (ECDIS).

The tiger team reviewed several user requirement documents and populated a table with the relevant items. (For more details, see the "Users + Requirements" tab in the spreadsheet here.) The tiger team then composed a list of the common user requirements needed for ongoing and future NOS models to provide forecast guidance supporting marine navigation and the Blue Economy (Table 1).

To support marine navigation in the waterways and ports of the U.S., mariners need forecast guidance of all the following variables: **water levels, surface water currents, sea and lake ice, and temperature and salinity.** Other required user variables for marine navigation that were considered here and should be coordinated include winds and waves.

Table 1. Common user requirements for oceanographic forecast modeling systems supporting marine navigation.

User Requirements	
Category of requirement	**Consensus/range of requirements**
Key user variables:	
Priority:	**Water levels** **Surface water currents** (top 25 m for navigation, top 1 m for SAR) **Sea and lake ice** (concentration, thickness, and velocity) **Temperature and Salinity** (density)
Consider:	Wind and atmospheric pressure, riverine, wave forcing, shorefast ice, ice pressure
User requirements:	
Forecast configuration:	
Forecast frequency, e.g. every 6 hours	6 hours
Forecast turnaround time, e.g. 2	Minimum 1 hour before forecast cycle deadline (NWS)

hours after 00z for 00z cycle	Before start of the next model forecast cycle (NOS)
Temporal resolution of output, e.g. every 6 minutes, 1 hour, 3 hours, etc.	At least hourly, optimally up to 6 minutes
Forecast range, e.g. f-006 to f120 hours	5 to 7 days, 14 days for planning (monthly/seasonal for lake/sea ice)
Reliability, e.g. 99.9% uptime	99-99.9%
Locations, e.g. generic seaport, bay, St. Lawrence R/Nova Scotia for SAR	Coastal ocean, Great Lakes, including ports, harbors, bays, and connecting channels and rivers, and islands/atolls in the Pacific (e.g. Hawaiian Islands and Guam) Arctic, Antarctic, Alaska, Northwest/Northeast Passages (for lake/sea ice)
Depth of currents, e.g. 4.5 m below surface for nav, top 1 m for SAR	Entire water column in order to provide currents at: 4.5 m below surface for navigation 0-1 m below surface for search and rescue
Horizontal resolution, e.g. 50 m channel/nearshore, coarser offshore	10 m in rivers, 10s of m in shipping channels, 30 m for sea ice, 50 m-1km in inlets/bays, lakes, <=2 km around small islands, 5 km in open ocean (1 km for surface currents in EEZ) Represents these structures: levees, piers, offshore wind farms
Deterministic and/or probabilistic forecast guidance?	Definitely deterministic, interest in probabilistic
To what datum(s) do the products need to be referenced?	Vertical: chart datum (e.g. NOAA: MLLW, LWD for Great Lakes), Horizontal: WGS84
Accuracy (acceptable error):	
Water level accuracy	15 cm (0.5 ft) based on ~2003 estimates of pilots' needs for under keel clearance; for time of high water and time of low water, 0.5 hr (assist in selecting port arrival/departure times)
Surface current accuracy	Speed: 26 cm/sec (0.5 kt); time of max flood or ebb 30 min; for slack water times, 15 min Direction: 22.5 degrees provided current speed is not less than 26 cm/s (0.5 kt) (values based on pilots' needs for maneuvering in ports and dredged channels) For USCG SAR: 0.1 m/sec / 10 degrees
Sea and lake ice accuracy	Depth/thickness 10 cm, concentration 10%, extent 10%, motion .25km/day / 10 degrees
Water density, salinity, and temperature accuracy	Desired accuracy of a forecast of a ship's draft is to the nearest 7.5 cm: for vessel draft of 15.25 m (50 ft) (largest existing around 2003) and acceptable error in draft of 7.5 cm, acceptable error X is 3.5 psu for

	salinity and 7.7C for water temperature
Product formats:	S-100/HDF5, GRIB2, Web mapping services, GIS compatible files, NetCDF, SHEF; documentation describing files
Display systems:	Have ability to overlay forcing information together on graphical interface (e.g. winds over ice); follow (S-100) portrayal rules, such as cell and other mobile devices, Portable Pilot Units (PPU), Electronic Chart Systems, and ECDIS.

IV. Model Candidates and General Pros and Cons

These are the model candidates considered by the tiger team:

- Finite Volume Community Ocean Model (FVCOM)
- Regional Ocean Modeling System (ROMS)
- Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM)
- ADvanced CIRCulation model (ADCIRC) (3D)
- Modular Ocean Model 6 (MOM6)
- BLUElink OceanMAPS (Australian global model)
- Relocatable Ocean Atmosphere Model (ROAM)/Sparse Hydro Ocean Code (SHOC) (Australian high resolution model)
- Nucleus for European Modelling of the Ocean (NEMO)

The model candidates listed above were selected primarily based on their present use in Research to Operations to Research (R2O2R) by NOS and NOAA labs, and on their output used by U.S. Coast Guard (USCG) Search and Rescue (SAR). The tiger team placed significant emphasis on the UFS's purpose of being a **community-based and coupled modeling system following the Earth System Modeling Framework (ESMF), with a data assimilation system following the Joint Effort for Data Assimilation Integration (JEDI) framework**. We also considered NOAA's commitment via past and present long term funding.

Based on NOAA experience over 20 years with evaluation, testing, and operations, the following R2O2R topics were considered for assessment:

- coupling
- data assimilation
- operational readiness
- geographic coverage/capability
- model characteristics
- developer support

This assessment consisted of documenting pros and cons for the models for each of the above topics based on NOAA/USCG experience and reports. (For more details, see the tables here.)

The tiger team reviewed the pros and cons for each model and for each topic and produced a summary assessment (Table 2).

Table 2. Summary assessment of model pros and cons

	Coupling	Data assimilation	Operational readiness	Geographic coverage/ capability	Model characteristics	Developer support
FVCOM	NUOPC caps written or being written; CICE is	Optional SST/SSH DA module included.	Running operationally on WCOSS by	Unstructured mesh with triangular	Limitations on simulating vertical T	Long-standing funding commitment from

	old and coupled internally	(Nudging, OI, EnKF, RRKF, EnSRF, ETKF); DA not operational	NCEP	elements	structure	NOS base funds; Latest user manual from 2013
ROMS	NUOPC caps written or being written; structured grid may be future concern	4DVAR, work on JEDI	Running operationally on WCOSS by NCEP, but 2k+ GOTO statements in ARPACK	Structured grid	Some bias with temperature and salinity performance in estuaries	Long-standing funding commitment from NOS base funds; not managed within GIT
SCHISM	NUOPC caps written or being written	DA in active development	Running operationally in Taiwan, New Zealand	Unstructured mesh with triangular and quad elements	Flexible time stepping, mixed higher/lower order transport methods	Not a consistent funding commitment from NOAA base funds
ADCIRC (3D)	More work for 3D NUOPC	Just bias correction for water levels; none for currents, T/S	Unaware of operational 3D ADCIRC; 700+ GOTO statements	Unaware of 3D ADCIRC for areas of interest	Unaware of 3D baroclinic performance/ accuracy	Not a consistent funding commitment from NOAA base funds; code not fully open source
MOM6	NUOPC caps written or being written; structured grid may be future concern	Ability to interface with CESM coupled DA, work on JEDI; DA not operational	Proposed to be included in UFS	Proposed to have regional capabilities; NCEP/EMC plan to use MOM6 for global and regional (hurricane) operational applications.	Not being applied operationally within NOAA	GIT, international community
BLUElink OceanMAPS	Doesn't use NUOPC	FGAT (first guess at appropriate time) and Ensemble OI (EnOI) for DA; no planned work on JEDI	Running operationally in Australia	Global model with coastal applications; structured grid	Good for currents, Australian Navy likely uses T/S and water levels	No direct links to code
ROAM/SHOC	Doesn't use NUOPC	FGAT (first guess at appropriate time) and Ensemble OI (EnOI) for DA; no planned work on JEDI	Running operationally in Australia	Can be deployed in any area of interest with any desired resolution; structured grid	Good for currents, Royal Australian Navy uses 3D T/S fields for improving sonar range prediction. ROAM initialized with OceanMAPS.	SHOC code available on GitHub. Code for ROAM deployment system not available.
NEMO	Doesn't use NUOPC	DA via ASM, includes velocity DA; no planned work on JEDI	Running operationally in Canada, included in NOAA's regionalized NMME	Nested 2-way coupling (AGRIF) allows refinement in structured mesh	Research level demo of good performance at harbor scale (100 m); wetting/drying just recently introduced	SVN, not GIT

Key:
Meets or exceeds readiness for capability
Some capability but effort required for readiness
Capability in planning only or otherwise insufficiently ready

Acronyms:
CICE: Los Alamos Sea Ice Model, sometimes referred to as the Community Ice CodE
DA: Data Assimilation
3D: 3-dimensional
FGAT: First Guess at Appropriate Time
EnKF: Ensemble Kalman Filter
RRKF: Reduced Rank Kalman Filter
EnSRF: Ensemble Square Root Filter
ETKF: Ensemble Transform Kalman Filter
OI: Optimal Interpolation
ARPACK: ARnoldi PACKage
JEDI: Joint Effort for Data assimilation Integration
NMME: North American Multi-Model Ensemble
NUOPC: National Unified Operational Prediction Capability
NUOPC cap: lightweight software layer that sits on top of model code
CESM: Community Earth System Model
AGRIF: Adaptive grid refinement in Fortran
ASM: Apply assimilation increments
SVN: Apache Subversion

V. Recommendations to Model Evaluation Committee

The tiger team provided two recommendations to the model evaluation committee:

1. Based on Table 2 that outlines the pros/cons for each model and user requirements, the tiger team recommends the following models to be evaluated by the model evaluation committee:
   - **FVCOM**
   - **ROMS**
   - **SCHISM**
   - **MOM6**

   Emphasis was placed on applying these models to coastal waters, getting them ready for operations, documentation, code repository availability, data assimilation proven in operations, large community support, and coupled NUOPC readiness.

2. Based on user requirements, community needs, past model evaluations, and model pros/cons (e.g. coupling, data assimilation, etc. needed), the tiger team recommends the consensus guidelines for model evaluation/skill assessment given in Table 3 below. (For more details, see the "Skill Assessment Guidelines" tab in the spreadsheet here.)

   To support marine navigation in the waterways and ports of the U.S., mariners need forecast guidance of all the following variables: **water levels, surface water currents, sea and lake ice, and temperature and salinity.** Other required user variables for marine navigation that were considered here and should be coordinated include winds and waves.

Table 3. Consensus guidelines for model evaluation/skill assessment of oceanographic forecast modeling systems supporting marine navigation.

Skill Assessment Guidelines	
Category of requirement	**Consensus/range of requirements**
Model setup:	
Which version of the model?	Latest stable and documented version
Who sets up and runs the simulations?	Independent NOAA-led team, possible structure as was done for Next Generation Global Prediction System (NGGPS) (NGGPS Dycore Test Group for FV3 vs MPAS)
Compute platform, i.e. cloud or on premise?	HPC (NOAA RDHPCS or HPC on cloud): on a supercomputer using a close-to-latest version of a conventional multi-core processor
Temporal resolution	Model output should be at least hourly, up to 6 minutes if possible
At what vertical/horizontal	Horizontal: 10 m in rivers to 5 km in open ocean/lakes

resolution to run the models?	Vertical: resolve navigable water column, including 0-1 m and 0-4.5 m below surface
Adaptability to forcing, e.g. updates to HRRR, or new atmospheric model (e.g. RRFS)?	Should be usable in the ESMF framework Able to be coupled to different atmospheric models, hydrology model, wave model, open ocean model, cryosphere model
Run deterministically and probabilistically?	Priority deterministic, probabilistic if possible
Level of difficulty in setup of model and diagnosing issues/failures - quantify?	Assess to see if it has good descriptive logs Assess to see if it has good instructions for developing grid and running model Subjective evaluation of code for above
Use data assimilation?	Yes, data assimilation (JEDI)
Which types of simulations, i.e. tidal, hindcast, and semi-operational nowcast/forecast runs?	Astronomical tide only run Hindcasts for specified length of time for stability (e.g. 3 months-years) Historical cases (USCG SAR events, navigational events, storms) Benchmark tests for scalability and performance 15-30 day semi-operational nowcast/forecast run
Time period:	
What should be the hindcast period/length?	Minimum 1 year for hindcasts
Locations:	
What should be the geographic coverage for regional models?	Great Lakes (non-tidal) High tidal range locations Gulf of Mexico/U.S. East Coast U.S. West Coast/Pacific islands Alaska Arctic
Observations for validation:	
What type of water level observations should be used for validating the models?	NWLON, PORTS, USGS, IOOS gages, USACE, Env Canada stations
What type of water current observations should be used for validating the models?	ADCPs, HF Radar, drifting buoys, USACE, USGS
What type of ice observations should be used for validating the models?	NIC ice coverage, thickness; satellite radar data; in situ (e.g. USCG, GLERL, buoys)
What type of temperature/salinity observations should be used for	NDBC/IOOS buoys, NWLON, PORTS, USGS, Env Canada stations, SST/SSS analyses (mostly satellite)

validating the models?	
Variables to assess:	
Water level	Magnitude of the water level at all times and locations for under-keel clearance; The time periods and amplitudes of high and low water for under-keel clearance
Currents	Assess full navigable water column currents where observations are available, with a focus on top 4.5 m and 0-1 m (for USCG SAR): the speed and direction of the currents at all times and locations, but especially at channel junctions only for navigation and especially in coastal waters for SAR, for maneuvering (the direction is computed only for current speeds above ½ knot); -the times, amplitudes, and directions of the maximum flood and ebb currents (for navigation, e.g. maneuvering); -the start times and end times of slack water (slack water is defined as by a current speed of less than ½ knot) before flood and ebb at all locations, but especially at channel junctions for planning turns in confined areas, for navigation
Sea and lake ice	Assess ice coverage/concentration and thickness, and possibly ice velocity and ice pressure
Salinity/Temperature (Density)	Assess full navigable water column density where observations are available, with a focus on top layer: water density, since it contributes to buoyancy, for under-keel clearance and cargo loading capacity. Density is usually defined in terms of salinity and temperature
Accuracy (acceptable error):	
Water level	15 cm (0.5 ft) based on ~2003 estimates of pilots' needs for under keel clearance; for time of high water and time of low water, 0.5 hr (assist in selecting port arrival/departure times)
Surface currents	Speed: 26 cm/sec (0.5 kt); time of max flood or ebb 30 min; for slack water times, 15 min Direction: 22.5 degrees provided current speed is not less than 26 cm/s (0.5 kt) (values based on pilots' needs for maneuvering in ports and dredged channels) For USCG SAR: 0.1 m/sec / 10 degrees
Sea and lake ice	depth/thickness 10 cm, concentration 10%, extent 10%, motion .25km/day / 10 degrees
Water density, Salinity, and Temperature	Desired accuracy of a forecast of a ship's draft is to the nearest 7.5 cm: for vessel draft of 15.25 m (50 ft) (largest existing around 2003) and

	acceptable error in draft of 7.5 cm, acceptable error X is 3.5 psu for salinity and 7.7C for water temperature
Metrics:	
Water level; Surface water currents; Water density, Salinity, and Temperature	RMSE/SD Correlations for timing of peaks and lags Series Mean (SM) for how well model reproduces obs mean; Central Frequency (CF) for how often error (error = predicted - obs or tide) is within acceptable limits; Positive Outlier Frequency (POF) and NOF for how often nowcast/forecast is higher than obs; Maximum Duration of Positive Outliers (MDPO) and MDNO for whether there are long periods when model overpredicts; Worst case Outlier Frequency (WOF) for when obs water level turns out to be low but model erroneously predicted much higher water level (and astro tide is thus best used) Target frequencies: CF(X) >= 90%; POF(2X) and NOF(2X) <=1%; WOF(2X) <= 0.5% for water levels, where X is acceptable error magnitude Target duration of errors: MDPO(2X) and MDNO(2X) <= L, where L is time limit or maximum allowable duration
Sea and lake ice	For lake-wide mean coverage/thickness: MAE, RMSE, and Normalized RMSE; For pixel-to-pixel evaluation: Proportion Correct, Frequency Bias Index, Probability of Detection (hit rate), Probability of False Detection (false alarm rate); Short-term ice forecasts: whether it outperforms 'persistence forecast' or 'normal-year forecast' (pass) or not (fail); Arctic sea ice (large body): Modified Hausdorff Distance approach (Dukhovskoy et al. 2015, JGR doi:10.1002/2015JC010989) (not as applicable to coastal ice that forms here and there); threat score.
Performance:	
Assess scalability/computational burden and performance of model, WCOSS compatibility/feasibility of deployment	Configurations must be same or as similar as possible across simulations/models tested for scalability, performance, and accuracy. For benchmark simulations, performance should be measured as the number of processors needed to reach an operational speed requirement – using a workload sized to represent model domains today and in the near future. Scalability should be measured as strong scaling efficiency running on high numbers of processor cores with workloads planned to be in operational use in 5 years.
Archive:	Archives of the evaluation simulations should be saved for 2 years after the completion of the evaluation.

The tiger team noted that the on-demand deployability for any geographic area of ROAM/SHOC should be a feature that future versions of the selected models should strive to incorporate.

Acknowledgements

The tiger team would like to thank the following people for providing their thoughtful input that contributed to this report:

- Mikhail Entel (BOM)
- Emlyn Jones (CSIRO)
- Avichal Mehra (NOAA/NWS/EMC)
- Saeed Moghimi (NOAA/NOS/OCS)
- Zizang Yang (NOAA/NOS/OCS)
- Aijun Zhang (NOAA/NOS/CO-OPS)

References

https://drive.google.com/drive/folders/1ES5Vwd4LHNpDB8WAtCVl9RyQSePeBKqV?usp=sharing