Ongoing efforts at NOAA to develop a global ocean Observing System Simulation Experiment (OSSE) capability

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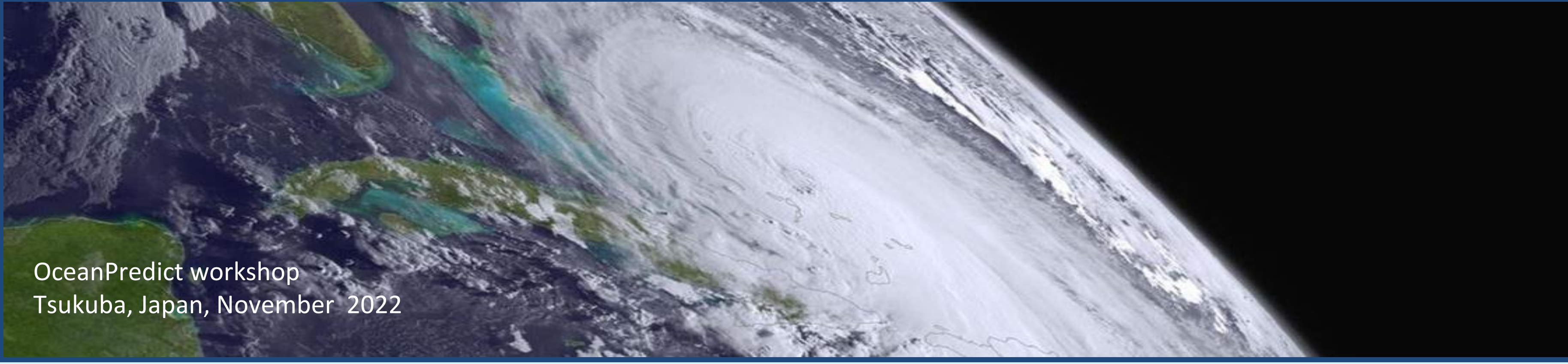


OceanPredict workshop
Tsukuba, Japan, November 2022

Outline

- Motivation for observing system impact studies
- Introduction to the NOAA Quantitative Observing System Assessment Program (QOSAP)
- Current capabilities under QOSAP
- Path forward towards building an ocean OSSE/OSE system

Today’s modeling and observing systems capabilities: Observing System Experiments (OSEs)

- Can we do better? - Optimize use of current observations in current modeling systems
  - Enhanced data assimilation strategies
  - More realistic characterization of observations
  - Management of large volume of data
  - Timeliness for model upgrades

- Can we leverage existing observations not currently utilized?
  - Driven by requirements and priorities
  - Investment in personnel and HPC resources

Looking ahead and simulating the future: Observing System Simulation Experiments (OSSEs)

- Costs of developing, deploying and maintaining new space-based architectures typically exceed $100-500 million/instrument
- Need to provide quantitative information on the impact of proposed observing systems in the next planned generation of numerical weather prediction systems
- Help inform major decisions by evaluating the impact of alternative mix of current and/or proposed instruments for better understanding and prediction of Earth Systems
- OSSE studies provide an ideal platform for this
  - Analyze tradeoffs (coverage, resolution, accuracy and data redundancy)
  - Optimize data assimilation and modeling strategies

Cost-benefit analysis for better planning and decision making

Realism and interpretation of OSSE results

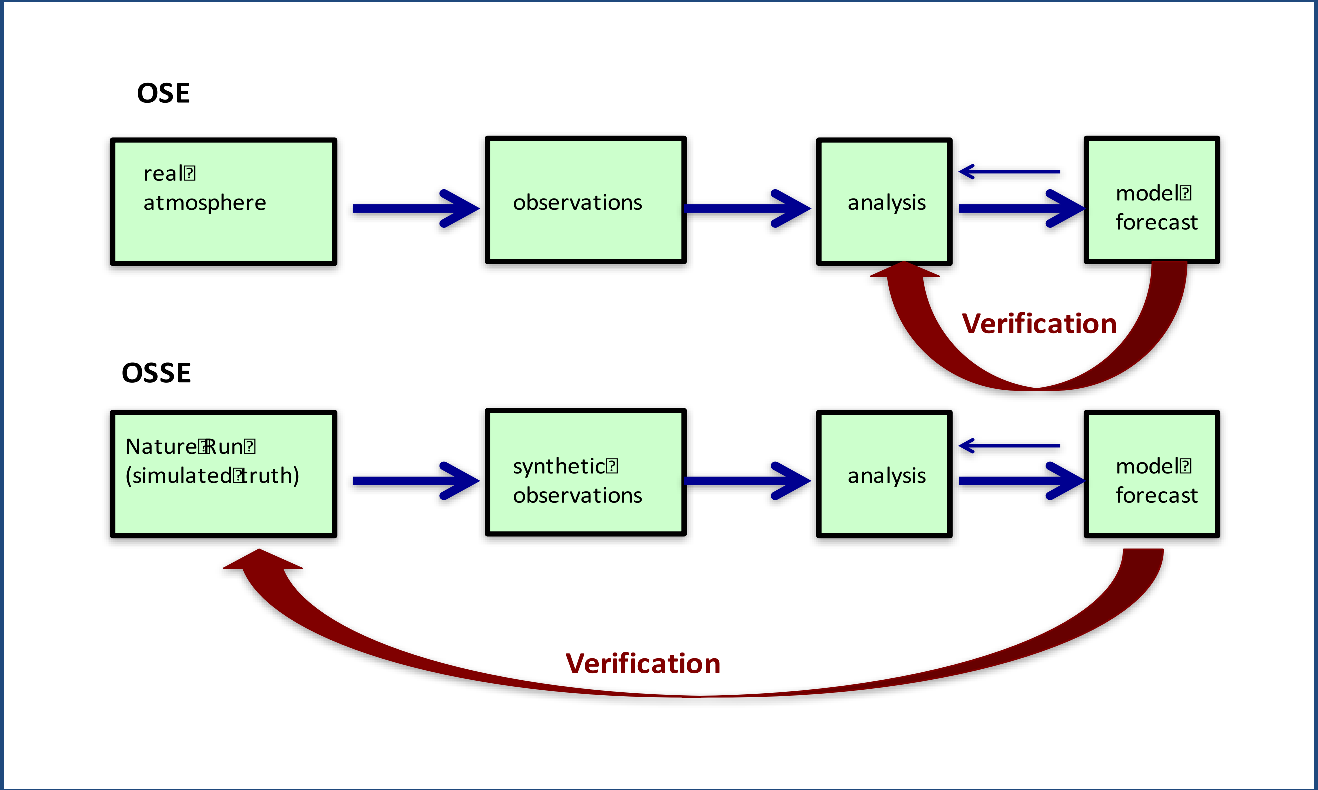
- Will the study be completed in time to be useful?
- Is the predictability of the forecast model realistic?
- Are the coverage and error characteristics of simulated observations realistic?
- Are the forecast accuracy of the model and impacts of existing observing systems in the OSSE comparable to the real world?
- Have the limitations of the OSSE system been determined? (Conclusions should not be drawn beyond these limitations)

Are the costs of observing system deployment justified by the benefits?

Challenges

- Computer power
- Breadth of information (a lot of pieces in play)
- Resilience of the overall observing system
- Statistics vs. individual weather events
- Choosing the right verification metrics

OSE (real) vs. OSSE (simulated)



The truth is unknown

The truth is known

QOSAP Program

- Costs of developing, deploying and maintaining new space-based architectures typically exceed $100-500 million/instrument.
- Need to provide quantitative information on the impact of proposed observing systems for the next planned generation of numerical weather prediction systems.
- Established in 2014 as a NOAA Program, with the primary objective of increasing the use of quantitative assessments for proposed changes to the global observing system.
- Replaced the earlier Observing System Simulation Experiment (OSSEs) Testbed.
- Program based at OAR (NOAA research) with representatives from all the NOAA Line Offices.
- Primary quantitative assessment tools used by QOSAP are Observing System Simulation Experiments (OSSEs) and Observing System Experiments (OSEs).

QOSAP Functions

- Maintain/develop/update NOAA “OSSE/OSE ready” capabilities for environmental applications.
- Provide recommendations to the Observing Systems Committee / NOAA Observing Systems Council (OSC/NOSC) for changes to the configuration of NOAA’s observing systems and overall portfolio to maximize the benefit to NOAA and its constituents.
- Work with NOAA Line Offices conducting OSE/OSSEs to follow the NOSC Impact Assessment Framework Memo “Guidance on the Process to Define, Design, Execute, Review & Report on Observing Systems Value and Impact Assessments”, of March 22, 2018.
- Conduct comprehensive assessments as requested by the different NOAA Line Offices through funded projects after a case-by-case consideration.
- Participate in relevant working groups and committees regarding quantitative assessments.
- Help inform major decisions by evaluating the impact of alternative mix of current and/or proposed instruments for better understanding and prediction of Earth Systems.

Current capabilities under QOSAP

- Global Atmospheric OSSE/OSE systems
  - NASA and ECMWF nature runs; NOAA FV3GFS model
- Hurricane OSSE/OSE system under development
  - High-resolution ECMWF nature run; HWRF (HAFS) model
- Framework for nowcasting applications
  - Deep neural network (DNN)
  - Exploring use of high-resolution ECMWF NR
- Implementation of current capabilities on Cloud/AWS environment
- Initial discussions to build a Space Weather OSSE-type capability
- Initial work towards building an ocean OSSE/OSE system
  - Ultimately, add fisheries & marine ecosystems component
- Potential new initiatives identified by the Line Offices
  - Fire, air quality, flooding, atmospheric rivers
  - Sampling strategies; tradeoff studies for field-campaign applications

Consolidated Observing Systems Simulator (COSS)

Agile, NR model agnostic

DWL/LIPAS for 3D winds in collaboration with KNMI

Process Input Data

COSS

Simulation type

- Perfect observations
- Error addition

- FV3GFS Global OSSE system calibrated with two different NR (G5NR and ECO1280)
- Hurricane OSSE system under development

Conventional Observations

- ECO1280
- G5NR

Radiances

- CRTM
  - G5NR
    - Clear-Sky
  - ECO1280
    - Clear-Sky
    - All-Sky

Aircraft Observations

- Aircraft Reports
  - ECO1280
  - G5NR

AMV Observations

- ECO1280
- G5NR

GNSS-RO

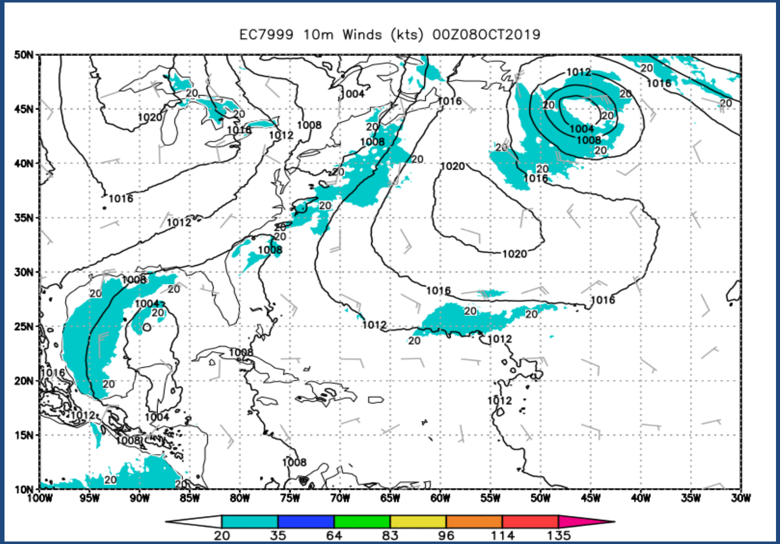
- Refractivity/Bending
  - ECO1280
  - G5NR

Current NOAA global OSSE system

- ECMWF ECO1280 (~ 9km) nature run
  - Based on the ECMWF operational configuration between November 2016 – July 2017
  - 14 months: 00 UTC Sep 30, 2015 – Nov 30, 2016.
- QOSAP COSS package to generate error-added observations.
- Simulated conventional, RO profiles and MW/IR radiances under cloudy conditions.
- Ongoing efforts to incorporate 3D active and passive winds from space.
  - Doppler Wind Lidar observations in collaboration with EUMETSAT/KNMI – completed
  - 3D passive Atmospheric Motion Vector winds (tracking moisture features)
- OSSE system calibrated with the NOAA's global data assimilation and forecast system
  - October-November with observing architecture operational in 2015.
  - **June-July with observing architecture operational in 2020 – used for many OSSE assessments**

Hurricane OSSE System

ECMWF ECO7999; 1.4 km resolution NR



- **Season 1**: 1 November 2018 00 UTC — 1 March 2019 00 UTC
- **Season 2**: 1 August 2019 00 UTC — 1 November 2019 00 UTC

Storm from the nature run has been selected

- High temporal resolution (**15 minute**) output
- Late October storm forming out of the Central American gyre
- Tracks north into Gulf of Mexico strengthening before **landfall** in Florida
- Crosses into Atlantic up eastern seaboard
- Timeline:
  - Genesis: 00Z October 09
  - Peak Intensity: 15Z October 13
  - Landfall: 12Z October 14
  - Atlantic Re-emerge: 03Z October 15
  - Dissipation: 18Z October 17
  - **Total time: ~8.5 days**

This research used resources of the Oak Ridge Leadership Computing Facility, which is a DOE Office of Science User Facility supported under Contract DE-AC05-00OR22725.

Wedi et al. 2020: A Baseline for Global Weather and Climate Simulations at 1 km Resolution; Journal of Advances in Modeling Earth Systems, 12, https://doi.org/10.1029/2020MS002192.

Building an ocean OSSE capability

- High interest from the ocean modeling community
- Synergism with OceanPredict and SynObs
- Enables enhanced leveraging
  - Optimization of observing system design, targeting techniques, trade-offs
  - Impact of current and proposed in-situ/satellite observations
- Longer-term plans for an ocean-fisheries OSSE
  - Identify requirements, biological and physical variables to be measured
  - Ocean-Ecosystems, 3-step process?
    - Physics, circulation
    - Biological, chemistry
    - Fish and other marine ecosystems

In coordination with Eric Bayler (NOAA)

Requirements for an ocean nature run

- Global, ~ 1 km resolution
- Ocean-atmosphere-waves-cryosphere (sea-ice)
- 10-year run to capture climate variability
- Significant amount of HPC resources (execution and storage)
- Potential use of NASA's nature run as a starting point?

Next Steps

- Generation/Validation of an ocean global nature run
- Simulator – extend COSS to ocean observations
- Build OSSE system and calibrate the system
- Initial quantitative assessments
    - Global
    - Tropical cyclones
    - Arctic

Questions?