Theme 1: Operational Oceanography: Past, Present, and Future

From weather to ocean prediction: an historical and assessment viewpoint

Pinardi, Nadia [1], Lermusiaux, Pierre[2], Coppini, Giovanni[3], De Mey-Fremaux, Pierre[4], Fratianni, Claudia[5], Huthnance, John[6], Navarra, Antonio[7], Preller, Ruth[8], Tibaldi, Stefano[7], Manzella, Giuseppe[9], Moussat, Eric[10], Lyubartsev, Vladislav[7], Sepp-Neves, Antonio[1], Trotta, Francesco[1], Simoncelli, Simona[5] [1]University of Bologna, Bologna, Italy [2]MIT, Boston, USA [3]CMCC, Lecce, Italy [4]LEGOS, Toulouse, France [5]INGV, Bologna, Italy [6]Proudman Oceanographic Laboratory, Liverpool, UK [7]CMCC, Bologna, Italy [8]Naval Research Laboratory, Mississippi, USA [9]ETT-Solutions, Genoa, Italy [10]IFREMER, Brest, France nadia.pinardi@unibo.it

This paper reviews the historical development of concepts and practices in the science of ocean prediction. It starts from a short presentation of key concepts and then presents the first meteorological forecasting experiment in the 50s, followed by the extension to wind waves and continuing with tidal and storm surge predictions to arrive at the first successful ocean mesoscale forecast in 1983. The scientific and technological developments that made accurate ocean predictions possible are connected with the gradual understanding of the importance of the oceanic mesoscales and their inclusion in the numerical models. Ocean forecasting developed first at the regional open ocean level, later progressing to global and coastal scales. Recent developments and future best practices for operational ocean forecasting, probabilistic forecasting and risk assessment will be discussed including the assessment of the forecasting and analysis system from end-user products.

Presentation Format: Oral Session

Keywords: Evolution - Operational Oceanography strategy, funding & sustainability, Evolution - Scientific, economic and societal requirements of Operational Oceanography, Models - Current scientific challenges of ocean modelling, Systems - Ocean Prediction Systems types (forecasting, analysis, scales, assessment, regions, ecosystem, ice, wave, etc.), Systems - Prediction system performance & evaluation

Presenter:
Nadia Pinardi
University of Bologna
Bologna, Italy
nadia.pinardi@unibo.it

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Next generation operational global ocean forecasting for Australia

Brassington, Gary[1], Oke, Peter[2], Sakov, Pavel[3], Divakaran, Prasanth[4], Huang, Xinmei[4], Zhong, Aihong[4], Velic, Mirko[4], Freeman, Justin[4], Fiedler, Russell[2], Chamberlain, Matt[2], Hogg, Andy[5], Kiss, Andrew[5] [1]Bureau of Meteorology, Syney, Australia [2]CSIRO, Hobart, Australia [3]Bureau of Meteorlogy, Hobart, Australia [4]Bureau of Meteorology, Melbourne, Australia [5]Australian National University, Canberra, Australia gary.brassington@bom.gov.au

The Bureau of Meteorology has delivered operational ocean forecasts since 2007 underpinned by the Ocean Model, Analysis and Prediction System (OceanMAPS) developed through the Bluelink projects, a collaboration of the Royal Australian Navy, Bureau of Meteorology and CSIRO. The current forecast system, OceanMAPS version 3 is based on a near-global Modular Ocean Model version 4p1 with 1/10 x 1/10 degree resolution and 51 vertical levels which resolves the low-wavenumber spectrum of the mesoscale circulation. An ensemble optimal interpolation method is applied, based on the software ENKF-C, to assimilate along-track satellite altimetry, satellite SST and in situ profiles on a 3-day cycle. Three time-lagged forecast systems provide a multi-cycle ensemble that provides guidance on forecast uncertainty. An overview of the current system and recent improvements will be presented including upgrades to Modular Ocean Model version 5, bulk fluxes, new observing platforms and atmospheric forcing.
 A next generation global ocean forecast system (OceanMAPS version 4) is under development with a target for operationalization in 2019/20. This includes: a new fully global ocean sea-ice model and an ensemble Kalman filter (EnKF) data assimilation system. The global ocean sea-ice model is being developed through a collaboration with the Australian Universities and is based on the Modular Ocean Model version 5, CICE 5.1 and OASIS3-MCT. The ocean model features a 1/10 degree Mercator/tri-polar grid and 75 vertical levels which has been optimised for the observed baroclinic variability with a 1.1 m top cell and a maximum vertical cell of 198 m. The sea-ice model includes EVP dynamics and a ridging scheme with 5 thickness categories. The model has been extensively evaluated via repeat year forcing and JRA-55 forced integrations. The EnKF is configured as a 96-member ensemble with a 3-day update cycle and an inflation capped at 3%. Observations are asynchronously assimilated with satellite SST assimilated every 6 hrs, satellite altimetry every 24 hrs and vertical profiles assimilated every 3 days. This system uses 9 kSU/cycle and has a storage per cycle of up to 7 TB with a full restart of 2.8 TB. A two year hindcast has been completed that demonstrates reduced mean absolute error between 7% and 30% of the ocean state, reduced bias as well as probabilistic products. The results of the hindcasts and progress toward operationalisation will be presented.

Presentation Format: Oral Session

Keywords: Systems - Prediction system performance & evaluation, DA - Ensemble data assimilation, Systems - Research-to-operations delivery chain, Models - Ocean model configurations,

Presenter:
Gary Brassington
Bureau of Meteorology
Syney, Australia
gary.brassington@bom.gov.au

U.S. navy Forecasting Developments

Hogan, Patrick[1], Metzger, E. [1], Rowley, Clark[1], Barton, Neil[1], Frolov, Sergey[1], Smedstad, Ole Martin[1], Thoppil, Prasad[1]
[1]Naval Research Laboratory, Stennis Space Center, USA patrick.hogan@nrlssc.navy.mil

The Global Ocean Forecast System (GOFS) is the U.S. Navys real-time global prediction system. GOFS 3.1 is the present operational capability, which was declared operational on 07 November 2018 with these new capabilities relative to GOFS 3.0: a) increased vertical resolution (41 vs. 32 layers) to better resolve the upper ocean, b) two-way coupling between HYCOM and the Los Alamos-developed Community Ice CodE (CICE), and c) improved synthetic profile projection into the ocean interior (known as Improved Synthetic Ocean Profiles (ISOP). The higher vertical resolution in the upper ocean was designed to better represent mixed layer processes, ISOP to more accurately project surface information into the ocean interior, and CICE to provide improved physics and rheology for better sea ice concentration, thickness and drift forecasts.

The GOFS provides the Navy with a first look of the three dimensional ocean environment anywhere, anytime across the global ocean. These environmental fields are used to provide real time predictions of derived acoustic parameters including sound speed and sonic layer depth. In addition, the GOFS provides boundary conditions for higher resolution regional/coastal models. Ocean forecasts are also valuable for tactical planning, optimum track ship routing, asset deployment, search and rescue operations, long-range weather prediction, and the location of high current shear zones. GOFS also provides forecasts of sea ice extent and thickness in the Arctic and Antarctic. The sea ice environment in the Arctic Ocean has become increasingly important for strategic and economic reasons over the past decade given the diminishing trend in year-to-year sea ice extent and thickness and the potential summertime opening of the Northwest Passage and Siberian sea routes. Fractures, leads and polynya forecasts are also valuable to the naval submarine community.

GOFS 3.5, which is scheduled to be transitioned to operations in 2019, is similar to GOFS 3.1 except that the horizontal grid resolution is 1/25 and the system includes tidal forcing. GOFS 3.5 will provide boundary conditions for even higher resolution coastal models, and serve as the backbone of a globally relocatable ocean nowcast/forecast capability that will address the need for littoral or deep water support anywhere in the world and, at 1/25 resolution, without the need for most intermediate regional models. A coupled ocean-atmosphere-ice system is also being developed and transitioned, called the Navy Earth System Prediction Capability (ESPC). Navy ESPC includes both a deterministic and ensemble forecast capability. For the presentation, we will provide a technical description of the GOFS and ESPC systems, including verification and validation as well as derived products.

Presentation Format: Oral Session

Keywords: Systems - Implementation of Ocean Prediction Systems, Systems - Prediction system performance & evaluation, Systems - Research-to-operations delivery chain, Systems - Coupled systems, Systems - Prediction system validation/ intercomparisons

Presenter:
Patrick Hogan
Naval Research Laboratory
Stennis Space Center, USA
patrick.hogan@nrlssc.navy.mil

Development of the Canadian Operational Network of Coupled Environmental Prediction Systems (CONCEPTS): past, present, future

Davidson, Fraser[1], Smith, Gregory[2], Ritchie, Hal[3], Lu, Youyu[4], Scantland, Normand[5], Couet, Martin[6], Pellerin, Pierre [2], Lontoc-Roy, Melinda[7], Burnie-Gardiner, Chris[8], Bernier, Natacha[2], Bouchet, Veronique [2], Joseph, Helen[9] [1]Fisheries and Oceans Canada, St. John's, Canada [2]Environment and Climate Change Canada, Dorval, Canada [3]Environment and Climate Change Canada, Halifax, Canada [4]Fisheries and Oceans Canada, Halifax, Canada [5]Department of National Defence, Halifax, Canada [6]Department of National Defense, Ottawa, Canada [7]Fisheries and Oceans Canada, Ottawa, Canada [8]Canadian Coast Guard, Ottawa, Canada [9]HCJ Consulting, Dalkeith, Canada Fraser.Davidson@dfo-mpo.gc.ca

Herein we describe the progress from idea and motivation to the implementation of sustained research, development and operations of ocean prediction systems under the Canadian Federal Government CONCEPTS initiative. Currently this MOU initiative includes Fisheries and Oceans Canada, Environment and Climate Change Canada and National Defense and the Canadian Coast Guard. This initiative maintains and evolves operational ocean and ice prediction systems within a seamless environmental prediction framework with sustained research, development and operational efforts. We present some of the key decisions, and strategies made with respect to collaborations, modeling, data assimilation and international partnerships including Mercator-Ocean and GODAE OceanView as well as key advances made over the last 10 years. Finally we provide a Canadian perspective on the evolution of ocean prediction in Canada as well as future global trends, opportunities and challenges in operational oceanography.

Presentation Format: Oral Session

Keywords: Evolution - End to end operational oceanography systems, Systems - Research-to-operations delivery chain, Evolution - Future perspective and new frontiers in Operational Oceanography, Applications - Capacity building, Evolution - Operational Oceanography strategy, funding & sustainability

Presenter:
Fraser Davidson
Fisheries and Oceans Canada
St. John's, Canada
Fraser.Davidson@dfo-mpo.gc.ca

Abstract ID: 3615646

Status and future of operational oceanography in Denmark

Korabel, Vasily [1] [1]DMI, Copenhagen, Denmark v.korabel@gmail.com

 Coastal ocean forecasting is essential for the safety and development of coastal communities. Denmark, being located in the North Sea - Baltic Sea transition zone, is exposed to mid-latitude storm surges and dependent on general oceanographic knowledge. The society on Greenland, a part of the Kingdom of Denmark, is steered by met-ocean conditions, and especially sea ice.

The Danish Meteorological Institute (DMI) is a leading oceanographic center in Europe, providing operational products and services for the Baltic/North Seas, and Greenland, such as storm surge sea levels, wave and ice forecasts, oil spill modeling, oceanographic and hydrographic conditions, etc. This presentation will provide a status of operational oceanography development at DMI. Focusing on the ongoing Copernicus project, we will address the challenges that current coastal models face in the region such as resolving the sub-mesoscale eddies and modeling the water exchange between the complex sub-domains. We will discuss the potential roadmap for the developing the next-generation forecasting systems for European Seas based on the unified ocean-ice-ecosystem Nemo-based models. With the new emerging components of the European Ocean Observing system, the new models will be build upon the capabilities of using new observations through data assimilation and integrating them into better products for end users.

Presentation Format: Oral Session

Keywords: Applications - Ocean products for scientific, economic and societal use, DA - Data assimilation applications, Models - Current scientific challenges of ocean modelling, Models - Downscaling, Evolution - End to end operational oceanography systems

Presenter:
Vasily Korabel
DMI
Copenhagen, Denmark
v.korabel@gmail.com

Operational Oceanography in the China seas: Past, Present and Future

LIU, GUIMEI[1] [1]NMEFC, BEIJING, CHINA LIUGM@NMEFC.CN

The primary functions of the National Marine Environmental Forecasting Center(NMEFC) are marine environmental forecasting, marine disaster forecasting and warning, and operational management.Over the past 50years, NMEFC has published numerous marine forecasting products regarding ocean waves, storm surges, tsunamis, red tides, sea ice, ocean currents, sea temperature and El Nio patterns. Since 1960s, the operational oceanography forecastingproducts weremainly based on empirical forecast and statistical forecastmethod.In recent years, NMEFC has started to develop state-of-art ocean forecasting systems fromregional to global ocean.Theoperational oceanography forecastingsystemin the China seasincludestheNorthwest Pacific model, the East China Sea model, the South China Sea model andtheBohai model, with resolutions from 1/20to 1/60. Meanwhile, real-time data assimilation system has been developed, which can assimilate the Argo buoysdata, satellite remote sensing Sea Surface Temperature (SST) and Sea Level Anomalous (SLA) data, and so on. The operational oceanography forecasting system providesocean element products, such as sea temperature, salinity, currents, etc., andalsoprovide ocean service products, including search and rescue, oil spill, ecological forecast and so on. Based on the system, meso-scale forecasting products, includingmeso-scaleeddy, oceanic frontand thermocline, havealready been derived. Currently, the interpretation of numerical forecasting products and a newintelligent gridded forecasting products in the China seasare developing.

Presentation Format: Oral Session

Keywords: Applications - Search and rescue, Applications - Oil & gas industries, Applications - Disaster & risk management, Models - Current scientific challenges of ocean modelling, Models - Ocean model configurations

Presenter:
GUIMEI LIU
NMEFC
BEIJING, CHINA
LIUGM@NMEFC.CN

Programmatic Overview of NOAA's National Ocean Service Coastal Modeling Portfolio (Activities, Performance, Challenges, and Opportunities)

Zhang, Aijun[1], Urizar, Cristina[1], Lindley, Carolyn[1], Burke, Pat[1], Bradley , Paul [2], Myers, Edward[3], Powell, Julia[3], Saraf, Neeraj[3], Snowden, Derrick[4], White, Stephen[5] [1]NOAA/NOS/COOPS, Silver Spring, USA [2]NOAA?NOS/COOPS, Silver Spring, USA [3]NOAA/NOS/OCS, Silver Spring, USA [4]NOAA/NOS/IOOS, Silver Spring, USA [5]NOAA/NOS/NGS, Silver Spring, USA aijun.zhang@noaa.gov

Real-time marine forecast products based on numerical ocean models are a powerful tool serving a variety of uses, such as marine navigation planning for port operations, harmful algal bloom forecasting and tracking, coastal hazard response, and emergency search and rescue. Advances in data acquisition technology, ocean dynamics, numerical schemes and visualization tools have made marine forecasting forecasts more accurate and reliable and the dissemination of operational model products and decision support services more timely and accessible.
 Guided by NOAA Unified Modeling principles, NOS collaborates with cross-agency and Federal partners, and extramural partners from academia and the local maritime community to transition research models to operations. A unified modeling framework and standards are also leveraged to facilitate these transitions. The goal of NOS Coastal Modeling Program[1] Over the next 10 years intends to provide complete coverage of the continental U.S, the Great Lakes , Hawaii, Alaska, and its territories to establish the necessary national operational infrastructure via an end-to-end framework that will provide timely and reliable forecast information to inform decision making for multiple applications. This presentation will provide an overview of NOS modeling portfolio, a pathway to transition research models and applications to operations, and an overview of challenges with developing a cohesive modeling framework. In late FY19, NOS will be sponsoring an external community workshop to inform this strategy and address some these challenges.

Presentation Format: Oral Session

Keywords: Systems - Ocean Prediction Systems types (forecasting, analysis, scales, assessment, regions, ecosystem, ice, wave, etc.), Evolution - Future perspective and new frontiers in Operational Oceanography, Models - Future trends in ocean modelling, DA - Data assimilation applications, Evolution - Operational Oceanography strategy, funding & sustainability

Presenter:
Aijun Zhang
NOAA/NOS/COOPS
Silver Spring, USA
aijun.zhang@noaa.gov