Wave Modelling System Implementation

Date

Authors

Guilherme Franz

Ligia Pinto

Isabella Ascione

Rodrigo Fernandes

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Summary

The implementation of operational wave modelling forecasting systems for the Portuguese Coast and South West French Coast are presented in this report. The system will provide wave forecasting data to verify the appropriate conditions and best locations to deploy floating barriers to contain oil spills in emergency situations, reducing the risk of oil leakage. Wave models with the physics appropriate to shallow waters, as well as to the current-wave interactions, have been implemented. A downscaling approach has been followed to consider the swell generated in the North Atlantic into the regional and local high resolution models. Wind forcing from a global atmospheric model has been used to simulate the waves generated in the North Atlantic. High resolution atmospheric models have also been used to properly simulate the waves generated by the local wind in the the Tagus Estuary (Portugal) and La Rochelle Bay (France) models.

1. Introduction

The wind-generated waves can affect the effectiveness of floating barriers used to contain oil spills at sea, also known as booms. Operational wave modelling forecasting systems can help to verify the appropriate conditions and best locations to deploy these barriers in emergence situations, reducing the risk of oil leakage. These systems are based in wave models that consider the physical processes behind the generation, propagation and dissipation of the waves along the ocean, shelf seas and coastal waters.

As the wind is the driving force for the wave's generation, the quality of the wave models results is directly related with the quality of the wind used as input. Atmospheric models are needed to provide the correct inputs, with adequately spatial resolution. When a large area is simulated, as the North Atlantic, the results from the Global Forecast System (GFS) with 0.5° resolution can be used. However, when the goal is to simulate smaller confined areas as estuaries or bays, a model with more resolution is necessary to properly represent the wind changes due to local topography.

The waves generated in storms can travel thousands of kilometres along the ocean. The European Atlantic Coast is frequently reached by waves generated in storms a long distance away in the western North Atlantic. The waves generated in a distance storm, called swell, are regular and long-crested, while the waves generated by the local wind, called wind sea, are irregular and short-crested.

As the waves propagate into coastal waters, the interactions with the bottom and the shorelines become important. Thus, high spatial resolutions wave models are needed to properly represent the bottom topography and land boundaries. However, the computational cost or, in other words, the time spent by a numerical model to calculate a defined period, is directly proportional to the spatial resolution. Thereby, refined models to large areas are time consuming and infeasible for operational forecasting systems. A downscaling approach can properly represent the swell propagation from the ocean scale models, with low resolutions, to the coastal waters models, with high resolutions, in a feasible time.

In the coastal waters, the currents can become important to the growth and decay of waves. A hydrodynamic model can provide the currents and water level to wave models, with an adequately spatial and time resolution. In the other hand, waves can produce currents, particularly in the surf zone. Thus, wave models can provide the wave parameters to the hydrodynamic model. In the early 90s, the improvement of the computers made possible the development of advanced spectral models, known as third-generation models. These models solve the spectral action balance equation and can solve the wave`s propagation in the presence of currents, as action density is conserved.

MARETEC research team (www.maretec.org) has implemented, since 2004, an operational wave forecasting system for the North Atlantic and Portuguese Coast (http://maretec.mohid.com/ww3) based in the model WAVEWATCH III (version 2.22). WAVEWATCH III model has been developed at the Marine Modelling and Analysis Branch (MMAB) of the Environmental Modelling Centre (EMC) of the National Centres for Environmental Prediction (NCEP). However, the version 2.22 is valid only for modelling waves in deep waters. Recently, a new version of WAVEWATCH III (version 3.14) has been released, with the physics adequate for the shallow waters. New tools are being developed to update the MARETEC´s operational wave forecasting system to the last version of WAVEWATCH III.

The wave model SWAN was developed to be an extension of the deep water third-generation wave models, which include shallow water processes formulations for dissipation due to bottom friction, triad wave-wave interactions and depth-induced breaking (The Swan team, 2013). SWAN is developed at Delft University of Technology and is probably the most used wave model for shallow waters. This model has already been implemented by MARETEC team in the Portuguese Coast and Tagus Estuary and the results obtain with this model will be compared with the last version of WAVEWATCH III.

2. Wave System Setup

2.1. Multi-Grid

A downscaling approach was followed in the wave modelling system implementation to properly represent the propagation of waves generated in the North Atlantic into the Coast of Portugal and France, specifically in La Rochelle Bay. The grid resolutions range from approximately 50 km in the North Atlantic domain to 400-200 m in the last domains (La Rochelle and Tagus Estuary). To avoid numerical instabilities, the resolution between the father and son grids were improved at most five times. Below, a scheme and figures of the different domains and their bathymetry are presented.

- I. North Atlantic (Figure 1)
  - II. South West Europe (Figure 2)
    - III. Portugal (Figure 3) and La Rochelle-Level 1 (Figure 4)
      - IV. Portugal Central (**Error! Reference source not found.**)
        - V. Tagus Estuary (**Error! Reference source not found.**)
      - IV. La Rochelle-Level 2 (Figure 5)
        - V. La Rochelle-Level 3 (Figure 6)

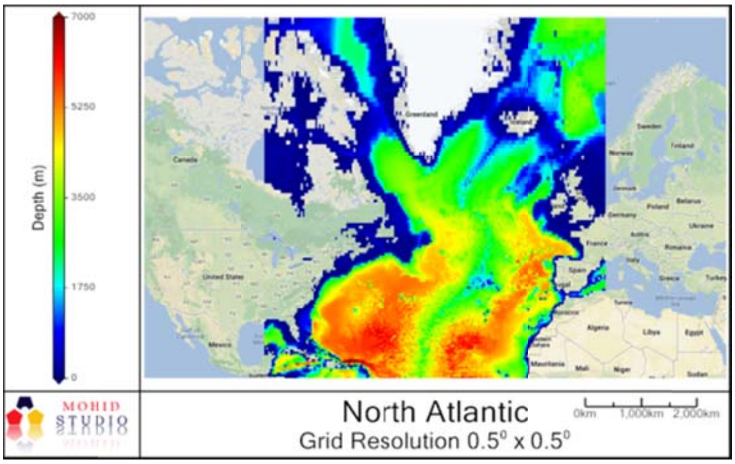

Figure 1 – North Atlantic grid

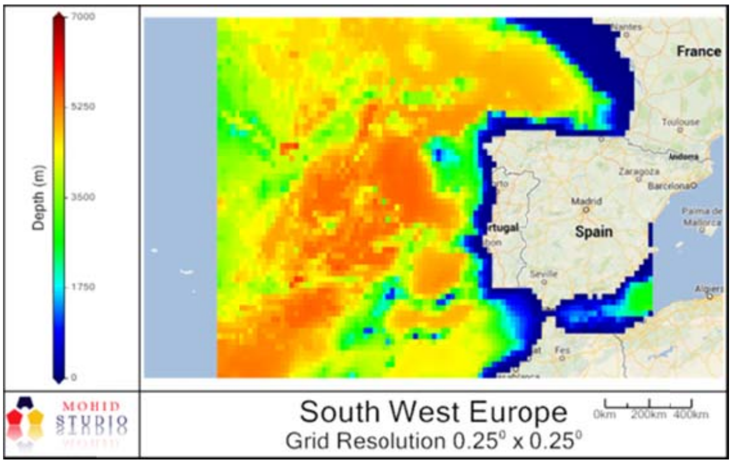

Figure 2 – South West Europe grid

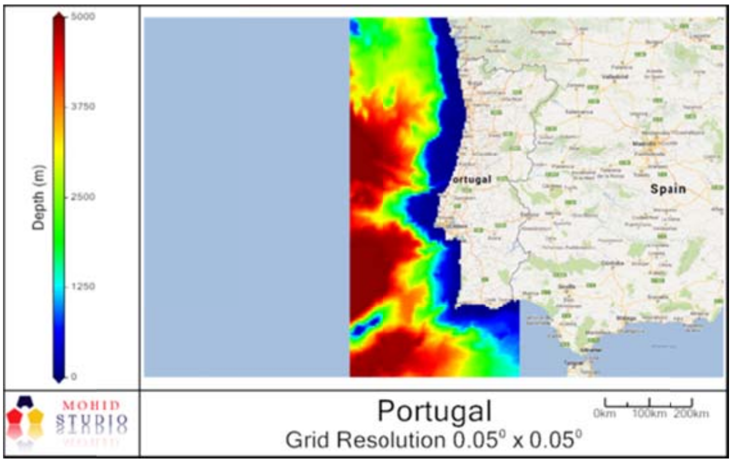

Figure 3 – Portugal grid

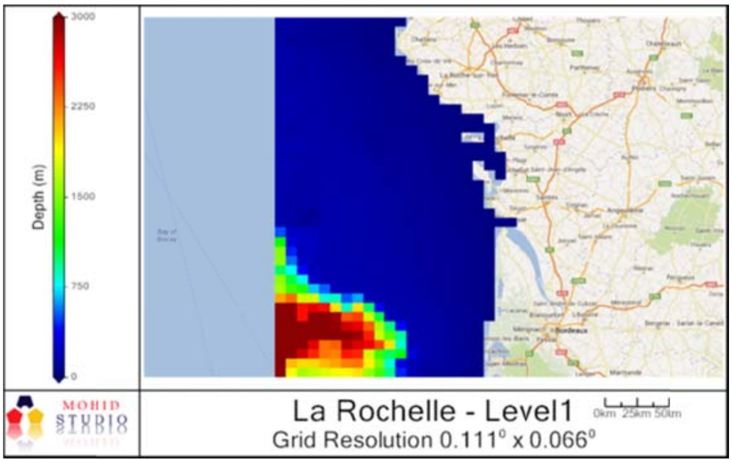

Figure 4 – La Rochelle - Level1 grid

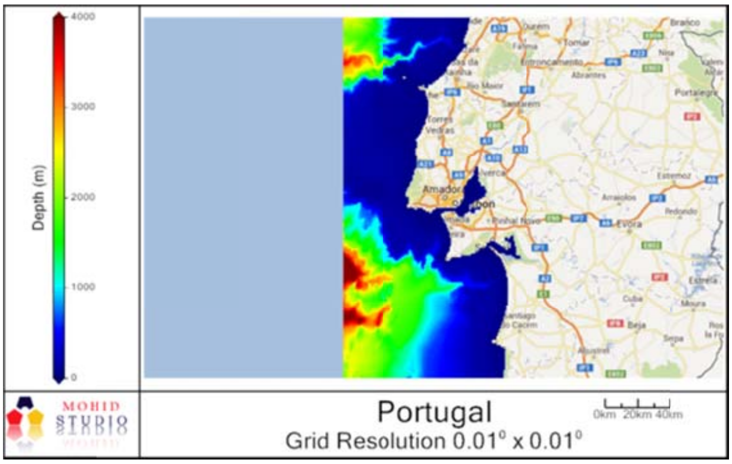

Figure 5 – Portugal Central grid

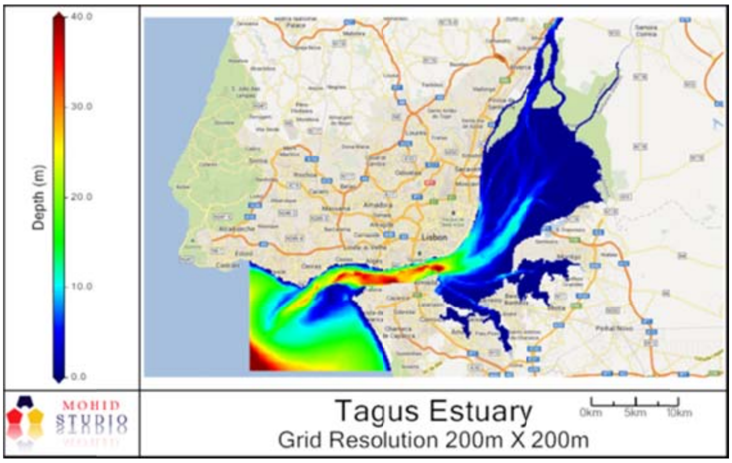

Figure 6 – Tagus Estuary grid

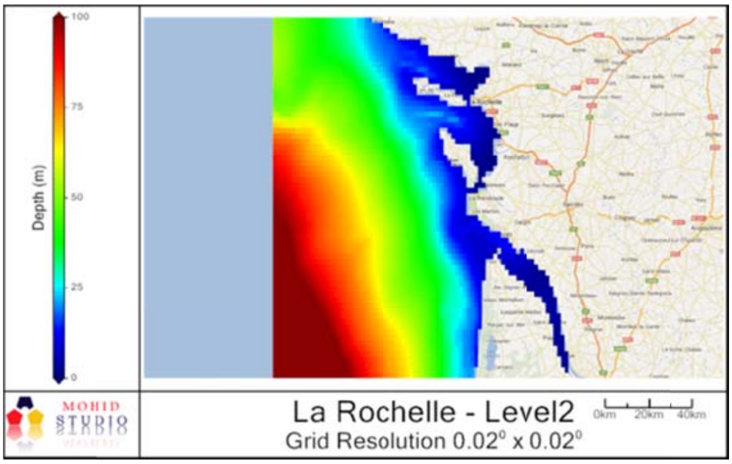

Figure 7 – La Rochelle - Level2 grid

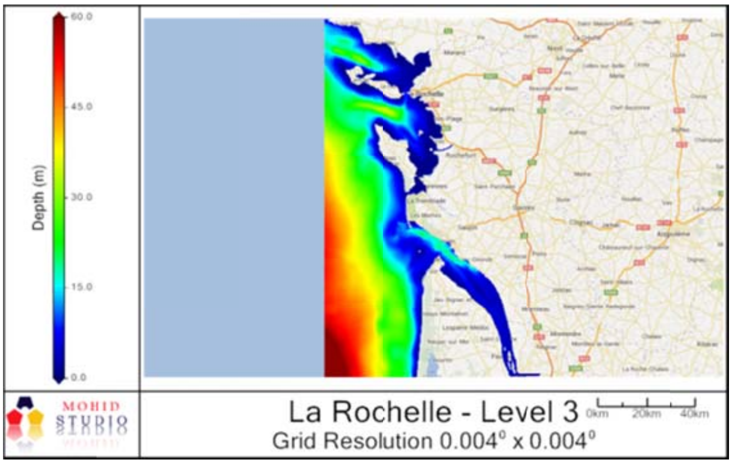

Figure 8 – La Rochelle - Level 3 grid

2.2. Wind Forcing

The wind forcing for the wave modelling systems is provided for the North Atlantic by the Global Forecast System (GFS) from the National Oceanic and Atmospheric Administration (NOAA). GFS has a resolution of about 50 km x 50 km. This resolution is not adequate to represent the wind near coast or in inner areas affected by the local topography. Thus, the wind forcing in the domain of the Tagus Estuary is provided by the Weather Research and Forecasting (WRF) model, implemented with nested grids with a 9 km x 9 km spatial step for Portugal and a 3 km x 3 km spatial step in a square domain with approximately 200 km x 200 km in an area centred in Lisbon (Trancoso, 2012). Initial and boundary conditions to WRF are provided by GFS. Similarly, the wind forcing for La Rochelle Bay (Level 2 and 3) is provided by MeteoFrance with a grid resolution of 2.5 km x 2.5 km.

2.3. Water Level and Currents

The water level and currents are provided by the MOHID Hydrodynamic Model. The MOHID water modelling system (www.mohid.com) was first developed by MARETEC team. MOHID has been in continuous evolution to stay updated in the state of the art in different areas of modelling concern, with the collaboration of enterprises, consultants, universities and students of different countries. The influence of the water level variations and currents are more important in shallow areas near the coast. Thus, their effects will be studied mainly in the Tagus Estuary and La Rochelle (Level 3) domains.

2.4. Preliminary Results

Some preliminary results of the wave model for the Tagus estuary and La Rochelle obtained with WAVEWATCH III (version 2.22) coupled with SWAN model are shown in the Figure 10 to Figure 12.

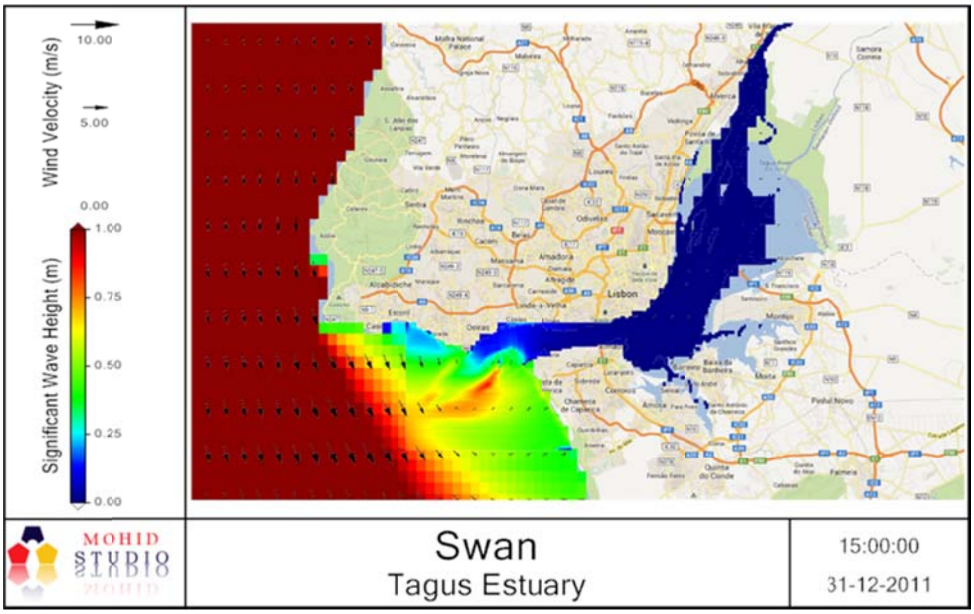

Figure 9 – Map of significant wave height and wind velocity for the Tagus estuary area

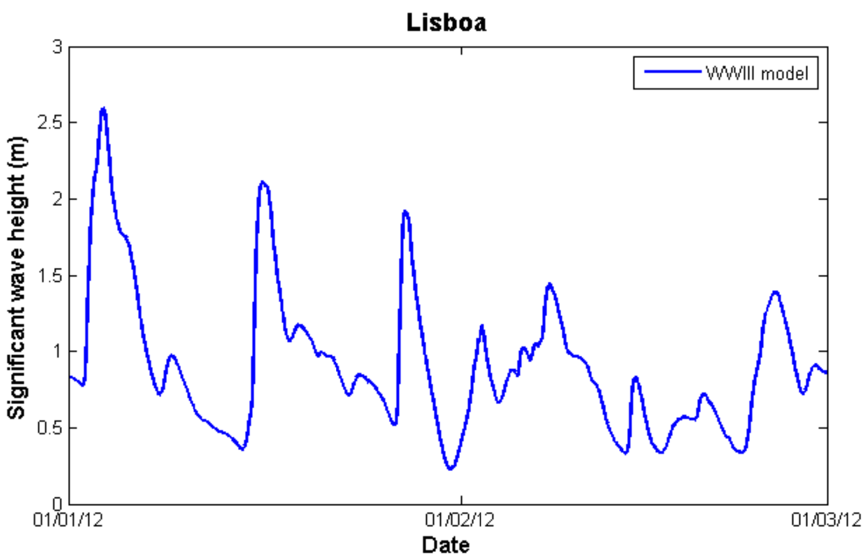

Figure 10 – Timeseries of significant wave height obtained with the wave model for the Lisbon harbor station

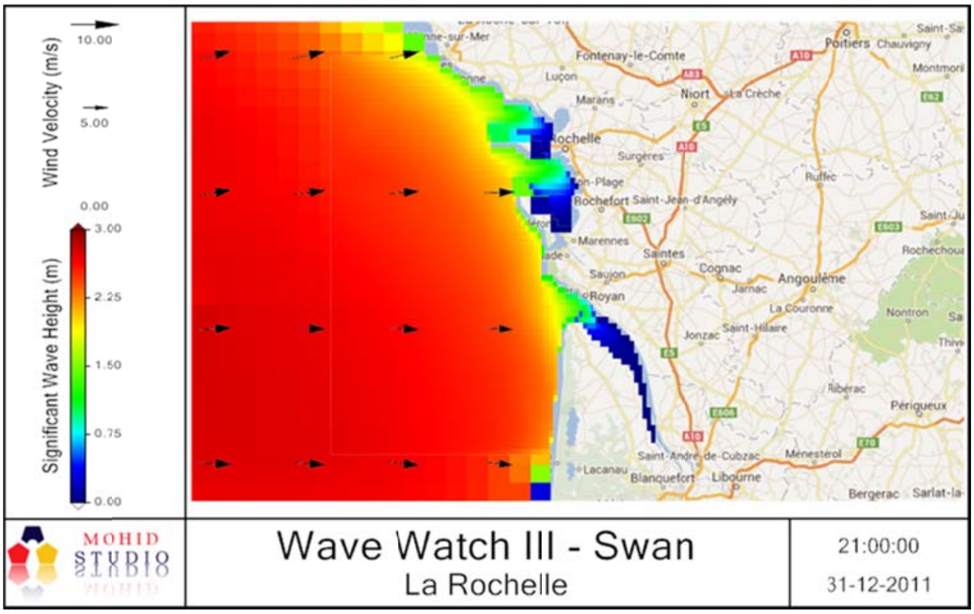

Figure 11 – Map of significant wave height and wind velocity for the la Rouchelle area

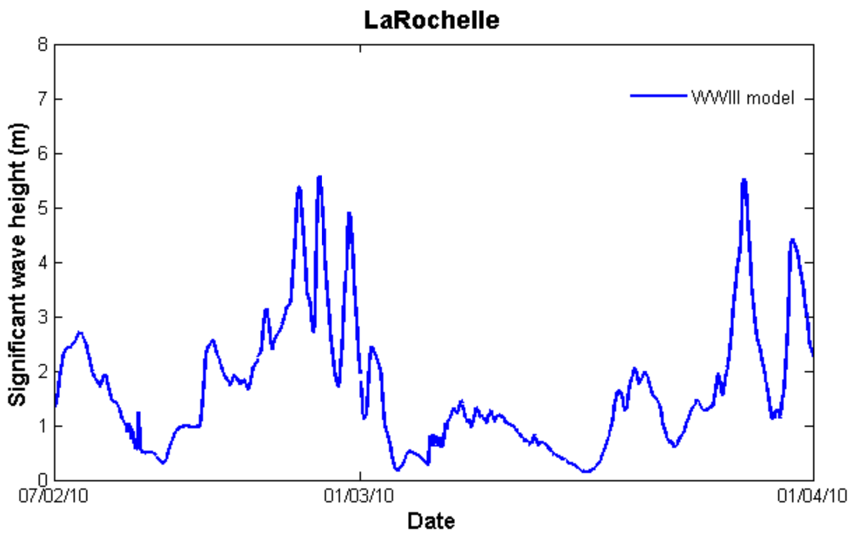

Figure 12 – Timeseries of significant wave height obtained with the wave model for La Rochelle station

2.5. Validation Period

The year of 2012 is the period chosen for the wave modelling system validation in the Portuguese Coast and Tagus Estuary due to the best wave data available. In La Rochelle Bay there is no data available for this period and the validation period chosen is the year of 2010. In Table 1 is presented the location of the wave buoys that will be used in the wave modelling system validation and the period with available data.

	Latitude	Longitude	Data period
Leixões	41.316667º	-8.983333º	01/02/2008 -
Lisbon harbor	38.620833º	-9.384833º	01/01/2011 -
Sines	37.921111º	-8.928889º	01/02/2008 -
Faro	36.904722º	-7.898333º	01/02/2008 -
La Rochelle	45.840333º	-1.813667º	01/01/2010 - 1/4/2011

Table 1 – Wave buoys used in the wave modelling system validation

Figure 13 – Wave buoys location in the Portuguese Coast

Figure 14 – Wave buoy location in La Rochelle Bay

The main objectives of the wave modelling system validation is to show the ability of the wave model to represent waves near the coast, in particular the capacity of the model to represent the wave variability trends with the least possible error. During the validation will be given less emphasis to the representation of extreme scenarios (high waves), since in these cases the application of oil boom is unfeasible.

2.6. Automatic Running Tool

To turn the wave modelling system operational it will be necessary to adapt the Automatic Runninc Tool (ART) currently used in the MARETEC for the operational wave forecasting system. This software tool has been initially designed to allow automatic simulations of MOHID water modelling applications, but is now evolving to a wider system, allowing to run MOHID land (watershed modelling) and to run WW3 wave modelling system. ART can be used to run historic periods or in nowcast / forecast mode.

This software system is responsible for:

a) preparation and configuration of model inputs, including downloading, extraction, glueing and interpolation of boundary and initial conditions;

b) running model simulations;

c) backup & storage of output results

d) generation of maps and timeseries based numerical results obtained

e) sending emails controlling the evolution of the system.

In the future, atmospheric model WRF will also be available to run using ART.

Acknowledgments

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Bibliography

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