Polar COAWST

Coupled Atmosphere (Land)–Ocean–Sea Ice–Wave–Sediment Transport Modeling System for Polar Regions

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Outline

• Introduction

• COAWST

• Polar COAWST
  • Working Groups
  • Polar COAWST Components
  • Polar COAWST Full Coupling System
  • Status of Polar COAWST
  • Preliminary Results

• Summary and Plans
Based on the COAWST (the Coupled Ocean – Atmosphere – Wave – Sediment Transport modeling system), the POLAR COAWST modeling system is being developed by a team of researchers at The Ohio State University (OSU), New York University (NYU), Old Dominion University (ODU) and North Carolina State University (NCSU) to model the multi-disciplinary processes impacting atmosphere, land, ocean, sea ice, wave and interactions between them in the polar regions, and to simulate climate changes of Antarctica and the Arctic.

The Polar COAWST component models:

1. The polar version of the Weather Research and Forecasting atmospheric model (with Noah and CLM land model) (Polar WRF; Bromwich et al. 2013; Hines et al. 2015)
2. The ROMS ocean model
3. The Budgell sea ice model in ROMS or the Los Alamos sea-ice model (CICE)
4. The SWAN (Simulating WAves Nearshore) wave model

The models are coupled through the flux coupler, Model Coupling Toolkit (MCT).
COAWST: A Coupled-Ocean-Atmosphere-Wave-Sediment Transport Modeling System

COAWST Modeling System

To better identify the significant processes affecting our coastlines and how those processes create coastal change we have developed a Coupled Ocean – Atmosphere – Wave – Sediment Transport (COAWST) Modeling System, which is integrated by the Model Coupling Toolkit to exchange data fields between the ocean model ROMS, the atmosphere model WRF, the wave model SWAN, and the sediment capabilities developed as part of the Community Sediment Transport Modeling Project.

John Warner
US Geological Survey, Woods Hole, MA

http://woodshole.er.usgs.gov/operations/modeling/COAWST/index.html
COAWST Modeling System

**COAWST**
Coupled Ocean – Atmosphere – Wave – Sediment Transport

Modeling System to investigate the impacts of storms on coastal environments.

C = Coupled
O = Ocean
A = Atmosphere
W = Wave
ST = Sediment Transport

**MCT**
v 2.6.0

**ROMS**
syn 797

**WRF**
v 3.7.1

**SWAN**
v 41.01AB
[http://vlm089.citg.tudelft.nl/swan](http://vlm089.citg.tudelft.nl/swan)

**CSTMS**

USGS

COAWST- Ice → Polar COAWST
COAWST

OCEAN

ATMOSPHERE

WAVE

USGS
Polar COAWST Working Group

- The Ohio State University (OSU)
- Old Dominion University (ODU)
- New York University (NYU)
- North Carolina State University (NCSU)
Polar COAWST Components

1. Atmosphere model
   Polar WRF (Land: Noah or CLM)

2. Ocean model
   ROMS

3. Sea ice model
   Budgell or CICE

4. Wave model
   SWAN

The flux coupler:
   Model Coupling Toolkit (MCT) under COAWST frame.
Atmosphere Model: Polar WRF

(Version 3.1 - 3.7.1, http://polarmet.osu.edu/PWRF/)

Developed and maintained by the Polar Meteorology Group

- The key modifications for Polar WRF are:
  - Optimal turbulence (boundary layer) parameterization
  - Implementation of a comprehensive sea ice description in the Noah LSM
  - Improved treatment of heat transfer for ice sheets and revised surface energy balance calculation in the Noah LSM
  - Improved cloud microphysics for polar regions

- Model evaluations of Polar WRF simulations have been performed in the Arctic and Antarctica

- Polar WRF is used by forecasters as part of the National Science Foundation sponsored Antarctic Mesoscale Prediction System.

- Polar WRF is used by more than 250 users for polar region climate change simulation and weather system modeling
Regional Ocean Modeling System (ROMS) is a free-surface, terrain-following, primitive equations ocean model widely used by the scientific community for a diverse range of applications.

The model is developed and supported by researchers at the Rutgers University, University of California Los Angeles and contributors worldwide.
The sea-ice component of ROMS, Budgell sea ice model is a combination of the elastic-viscous-plastic (EVP) rheology and simple one-layer ice and snow thermodynamics with a molecular sublayer under the ice. It is tightly coupled, having the same grid (Arakawa-C) and timestep as the ocean and sharing the same parallel coding structure for use with MPI or OpenMP.

The Budgell sea ice model is used in the current version of Polar COAWST.
The Los Alamos sea ice model (CICE) is the result of an effort to develop a computationally efficient sea ice component for use in fully coupled, atmosphere-ice-ocean-land global climate models.

CICE was used in several of the climate models contributing to the Fourth and Fifth Assessment Reports of the Intergovernmental Panel on Climate Change. The CICE can be used in global climate modeling and in standalone mode for sea ice simulations.

CICE will be coupled to Polar COAWST in the future.
Wave Model: SWAN

SWAN (Simulating WAves Nearshore) is a third-generation wave model, developed at Delft University of Technology, that computes random, short-crested wind-generated waves in coastal regions and inland waters.

SWAN accounts for the following physics:

- Wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-stationary depth.
- Wave generation by wind.
- Three- and four-wave interactions.
- Whitecapping, bottom friction and depth-induced breaking.
- Dissipation due to aquatic vegetation, turbulent flow and viscous fluid mud.
- Wave-induced set-up.
- Propagation from laboratory up to global scales.
- Transmission through and reflection (specular and diffuse) against obstacles.
- Diffraction.

http://swanmodel.sourceforge.net/
Exchanged Fields between Polar WRF, ROMS, Sea Ice and Wave

WRF-ROMS(Sea ice)-SWAN

ATMOSPHERE
Polar WRF
(Land: Noah or CLM)

MCT
Uwind, Vwind, Patm, RH, Tair, cloud, rain, evap, SWrad, Lwrad LH, HFX, Ustress, Vstress

MCT
H_{wave}, L_{wave}, T_{psurf}, Z_0

MCT
U_{wind}, V_{wind}

OCEAN SEA ICE
H_{wave}, L_{mwave}, L_{pwave}, D_{wave}, T_{psurf}, T_{mbott}, Q_b, Diss_bot, Diss_{surf}, Diss_{wcap}, U_{bot}

WAVE
u_s, v_s, \eta, bath, Z_0

Sea ice and Wave?
Exchanged Fields between Polar WRF, ROMS, Sea Ice and Wave

WRF-ROMS-CICE-SWAN

ATMOSPHERE

Polar WRF
(Land: Noah or CLM)

MCT

Uwind, Vwind, Patm, RH, Tair, cloud, rain, evap, SWrad, Lwrad
LH, HFX, Ustress, Vstress

SEA ICE

CICE

MCT

Sea Ice to OCN
merged momentum flux

OCN to Sea Ice
ocean currents, SST

OCEAN

MCT

H_{wave}, L_{mwave}, L_{pwave}, D_{wave}, T_{surf}, T_{mbott}, Q_{b},
Diss_{bot}, Diss_{surf}, Diss_{wcap}, U_{bot}

WAVE

MCT

u_s, v_s, \eta, \text{bath}, Z_0

Uwind, Vwind

Los Alamos National Laboratory

Research Computer

Simulating Waves Nearshore

ROMS

Exchanged Fields between Polar WRF, ROMS, Sea Ice and Wave
Exchanged Fields between ROMS, Sea Ice and Polar WRF

WRF-ROMS-CICE

ATM to OCN
- surface pressure
- merged momentum flux
- mean net longwave
- banded shortwave radiation
- precipitation
- sensible heat flux

OCN to ATM

OCN to Sea Ice
- ocean currents, SST

Sea Ice to OCN
- merged momentum flux

Sea Ice to ATM
- ice fraction, masking information

ATM to Sea Ice
- wind, stress
- lowest level temperature
- specific humidity
- lowest height, radiation
- derived air density

ROMS

Sea Ice

CICE
Polar WRF has been run for multiple years in COAWST framework.

ROMS with sea ice has been run for 8 years in COAWST framework with forcing from ERA-Interim.

Developing Polar WRF, ROMS and Sea ice coupling system for Antarctic region:

1. Polar WRF, ROMS, and Sea ice at the same resolution (10 km)
2. Polar WRF at 40km, ROMS at 10km

Updating Polar COAWST to current COAWST version 3.2.

Issue: SCRIP (A Spherical Coordinate Remapping and Interpolation Package) at polar region.
Results

ROMS with sea ice after 4 simulated years in COAWST framework.

Simulated fractional sea ice
Atmospheric forcing from ERA-Interim
Summary and Future Work

For Polar WRF coupled to ROMS with Budgell sea ice, we still have issues with the interpolation weights (SCRIP) in COAWST version 3.1 framework.

Update Polar COAWST in COAWST version 3.2 framework, and fix interpolation weight issues.

Use new version of Polar COAWST to run the test case

1. Polar WRF, ROMS, and Sea ice at the same resolution (10 km)
2. Polar WRF at 40km, ROMS at 10km (monthly run)