RESEARCH AREA NO.:  3
THEME NO.:  10

TITLE:  Contributions to Arctic System Modeling

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COLLABORATORS AND ROLES:

C. Deal (IARC):  Marine ecosystem model development
M. Jin (IARC):  Marine ecosystem model implementation
G. Gibson (IARC):  Marine biogeochemical modeling
E. Watanabe (JAMSTEC):  High-resolution Arctic Ocean modeling
H. Park (JAMSTEC):  Land surface modeling
BACKGROUND:

• Arctic System Modeling is an emphasis of the IARC Strategic Plan, and IARC has facilitated community planning through workshops and a published science plan.

• Various modeling activities are underway in JICC themes, providing potential contributions of component models for an Arctic System Model.
OBJECTIVES:

The goal of Arctic System Modeling is to produce a modeling framework for the Arctic region, enabling investigations of Arctic climate variability and change as well as their potential impacts on humans, ecosystems and the global system.

Specific goals of the JICC Theme 10:

• Contribute to development of Arctic System Model, with emphasis on modules for
  -- marine biochemistry
  -- terrestrial surface/hydrology
  -- Arctic ocean/sea ice

• Develop and test component modules with observational data

• Use models to assess interactions between different components of the Arctic system
METHODOLOGY:

• Follow implementation plan of Arctic System Modeling based on IARC ASM Report (2010)

• Modify existing IARC and JAMSTEC model components to conform with ASM modularity

• Implement JAMSTEC/IARC modules in widely used earth system models
Framework for an Arctic System Modeling activity

(IARC report -- co-authored by Roberts et al., )
The three primary JAMSTEC/IARC modeling emphases:

- marine biochemistry/ecosystems
- land surface/hydrology
- Arctic Ocean/sea ice (high-resolution)
ACTIVITIES FOR PAST YEAR:

Marine

• Implementation of IARC marine biogeochemistry in Community Earth System Model (released in mid-2013)

• Testing and improvement of new ocean mixing scheme in CESM/POP-CICE ecosystem model, including a lead-dependent brine rejection parameterization

• Implementation of DMS (DiMethyl Sulfide) module in the global CICE model
IARC/LANL POP-CICE DMS ecosystem model results suggest that ice algae are an important source of seawater DMS, particularly in the Bering Sea in April and in shelf seas surrounding the Arctic Ocean in May. Ice algal DMSP (the DMS precursor) export from sea ice is key.

Simulated surface seawater DMS concentrations for year 2000 with (upper) and without (lower) sea ice biogeochemistry (BGC) (i.e., no ice algae and DMS(P) production in sea ice).
IARC/LANL model results show higher surface seawater DMS concentrations in low ice years, (most significantly off the north coast of Russia where the simulated sea ice concentration decreased by >50%), suggesting enhancement of DMS emissions in a warming Arctic.

Comparison of observed (black) and simulated mixed-layer depth along tracks of Ice-Tethered Profilers (IPTs)

control simulation vs. new mixing parameterization
ACTIVITIES FOR PAST YEAR:

*Terrestrial*

- Paper published on relationships between simulated permafrost, snow cover and sea ice (*Park et al., 2013, Polar Science*)
- Paper on land-atmosphere-ocean variations over western North America and eastern Asia published (Walsh et al., 2013, *Polar Science, IARC* special issue)
- Paper submitted on the effect of snow depth on pan-Arctic permafrost thermal regimes (*Park et al., 2014, Env. Res. Lett.*, in review)
Russian permafrost temperatures at 10 m depth: Observed vs. Simulated (CHANGE model)
Permafrost temperature changes at 3.6 m when snowfall is increased by 30% (UP) or decreased by 30% (DN)
Active Layer Thicknesses, departure from mean:
Simulated (black) vs. Observed (red)
SUMMARY:

Main JICS contributions to Arctic System Modeling have been:

• Arctic marine ecosystem module implemented in the widely used Community Earth System Model

• Simulations of Arctic Ocean primary productivity and dimethyl sulfide (DMS) processes

• Arctic terrestrial simulations addressing interactions between soil state, snow cover, temperature and trace gas fluxes

• Previous years (E. Watanabe): High-resolution simulations of Arctic Ocean/sea ice, with focus on role of eddies in transports from the shelf seas to the deep basins