# Forecasting future sea ice conditions in the MIZ: a Langrangian approach

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## LONG-TERM GOALS

1- Determine the source regions for sea ice in coastal zones using back trajectories calculated from satellite-derived sea ice drift, based on work by Maslanak et al. 1995, Emery et al. 1997a, Meier et al. 2000, Tschudi et al. 2010.

2- Assess whether the source region of sea ice melting in peripheral seas in the GCMs participating in the IPCC AR5 and regional sea ice models agree with observed source region patterns from the satellite-derived dataset.

3- Compare Lagrangian ice trajectories in model and satellite datasets.

4- Repeat this analysis for 4 critical climate horizons: a base period (1979-2000), the most recent decade when transition to a new sea ice regime occurred (2001-2010), and two projection periods in the 21$^{st}$ Century (mid and late 21$^{st}$ century).

## OBJECTIVES

1- Reduce uncertainties in future sea ice extent prediction from climate model participating in CMIP5. These include temporal evolution and geographical distribution of sea ice.

2- Improve our understanding of the strength and/or limitation of GCM's predictions of the future ice edge position.

3- Identify limitations in the ability of GCMs to simulate source regions for sea-ice being advected into MIZs and thus provide guidance for developing more reliable forecasts of the future sea ice edge evolution.

4- Quantify GCM biases in the balance of thermodynamically formed, in situ, ice production or loss and advection.

## APPROACH

**Bruno Tremblay**, McGill University and Lamont Doherty Earth Observatory of Columbia University.
**Stephanie Pfirman**, Barnard College, Columbia University and LDEO of Columbia University

**Robert Newton**, LDEO of Columbia University
**Walt Meier**, National Snow and Ice Data Center

We will use satellite-derived and climate model sea-ice drift to produce backward trajectories of sea ice from the marginal ice zone and all peripheral seas. The back trajectories will start just before the melt season and will extend to the beginning of the floe's life when first formed. Analysis of source regions for sea ice melting in the peripheral seas and within the marginal ice zone will be performed from both observed and modeled datasets. In the case of observed drift, sea ice age will also be calculated at each position of the back trajectories. For the simulated drift, we will calculated the sea ice thickness (mean and amount from each different ice thickness category available).

Development of code to interpolate the observed velocity field on the exact latitude/longitude location of the Lagrandian trajectories will be developed. In the case of model data, we will interpolate the sea ice concentration, thickness and velocity onto the same EASE grid on which the satellite derived data is calculated. Once this is done, the same interpolation routine will be used as for the observed data.

## WORK COMPLETED

We will compare back trajectories and source regions for sea ice transported to the marginal ice zone from simulated drift and satellite drifts. The simulated drifts are from a selection of climate models participating in CMIP5 and satellite drift comes from passive microwave retireval. This analysis will be done for 4 different time periods: the late 20$^{th}$ century, the early 21$^{st}$ century, the mid 21$^{st}$ century and the late 21$^{st}$ century. Strengths and biases of the models will be identified.

We will add features to the Ice Tracker program of Chuck Fowler (U of Colorado) and host it on the NSIDC web site. The new site capabilities will include the posibility to track many ice floes in forward or backward trajectory mode, as well as store the ice age, air temperature and other diagnostics at the point location of the trajectory.

## RESULTS

See section above.

## IMPACT/APPLICATIONS

The validation of climate models against Lagrangian back trajectories will provide a new lens to assess global climate models strengths and biases. In particular, comparing the source region for sea ice populating the marginal ice zone and peripheral seas during the summer melt season from observations and GCMs will help reduce uncertainties in projections of future sea ice extent.

## RELATED PROJECTS

**World Wildlife Fund, 30K, *Sea ice extent across the Canadian Arctic,* 09/2012 – 12/2012.**

Evaluation of global climate models participating in CMIP5 for the timing of melt onset, freeze-up, end of winter snow depth and ice thickness within the Canadian Arctic Archipelago (CAA). We will produce spatial distribution of the above quantities from all CMIP5 climate models for today's climate, mid 21$^{st}$ century and end of the 21$^{st}$ century. The analysis will be repeated with a high resolution (4km) coupled ice-ocean model of the pan-Arctic (MITgcm) forced with atmopsheric field from the global version of the MITgcm for the same time intervals. The goal is to characterize the more likely geographical pattern of the sea ice retreat within the CAA in the next century. These analysis will serve for planning activities of WWF in terms of sea-ice dependent species and loss of habitat.

**Environment Canada, Grant and Contribution, 35K/year, *Sea ice dynamics within the Canadian Arctic Archipelago*, 06/2011 – 05/2014**.

Development of a sea ice dynamic model with tensile strength included. The presence of landfast sea ice in the Arctic and sea ice arches in narrow passages of the archipelago are clear indications of the presence of tensile strength of sea ice at finer spatial scales. The completion of this work will yield a model that is both applicable to the Arctic proper and the narrow passage of the Canadian Archipelago.

**Indian and Northern Affairs, Beaufort Region Environmental Assessment, *The development of efficient sea ice implicit solver for viscous-plastic sea ice model,* 35K/year, 06/2011 – 05/2015**.

Development of new preconditionners for the GMRES component of our Jaobian Free Newton Krylov solver for the momentum of sea ice. Parallelization of the model. Implementation of the model in the Los Alamos CICE model.