Adjoint sensitivities of sub-ice shelf melt rates to ocean circulation under Pine Island Ice Shelf, West Antarctica

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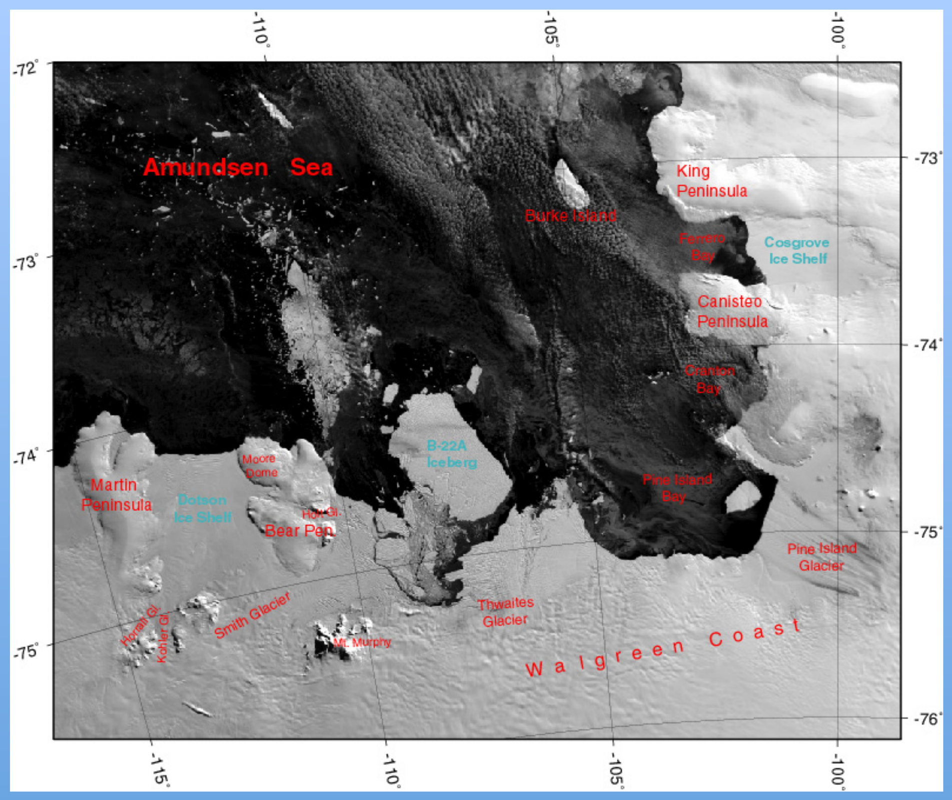
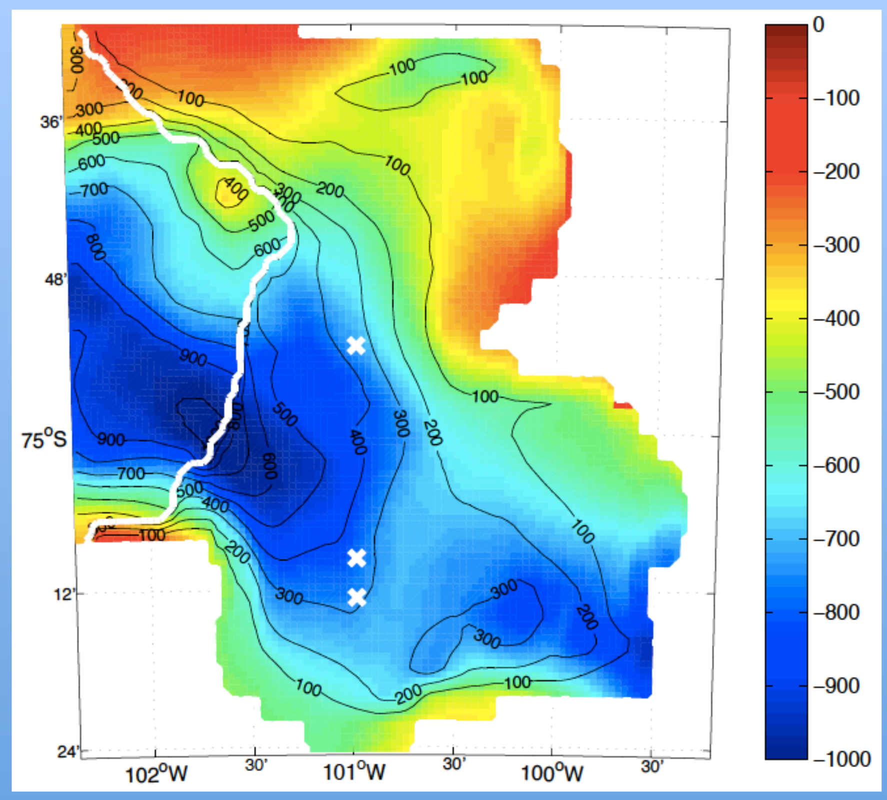
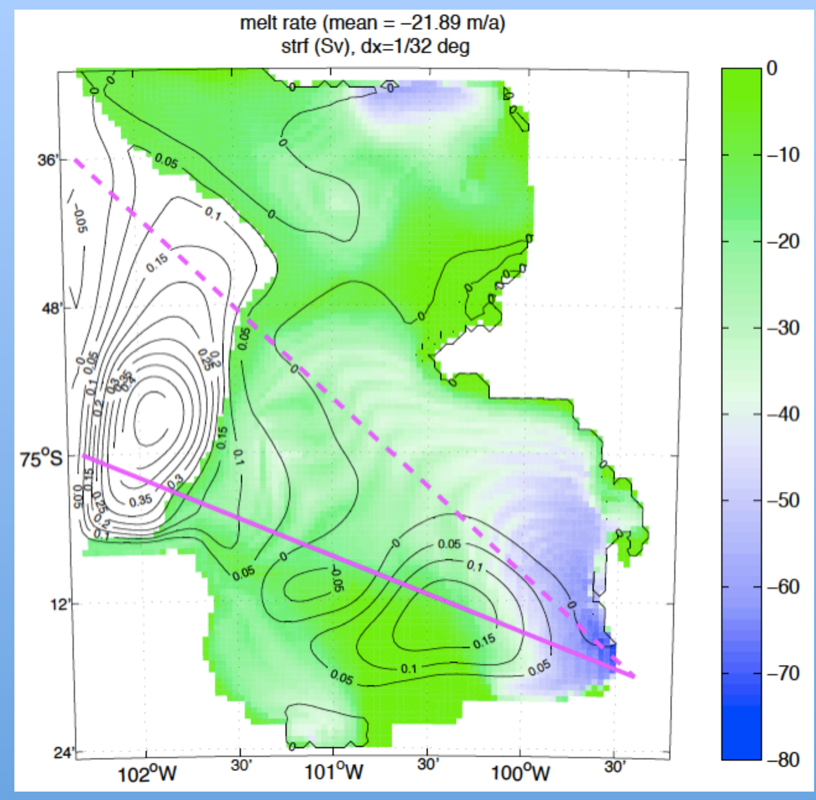


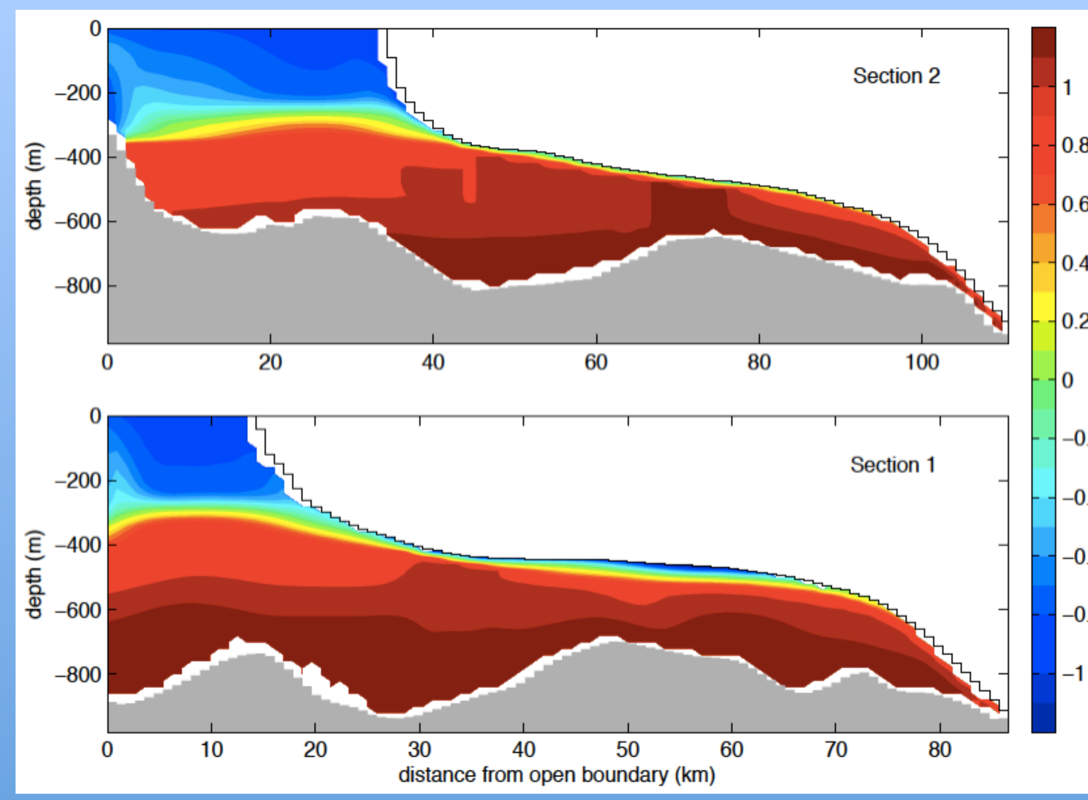
Pine Island Glacier & Ice Shelf in the Amundsen Sea Embayment, West Antarctica



Bed rock bathymetry (color, in meters), and water column thickness (contours), in intervals of 100 m) of the 900±30 m horizontal resolution model. The white contour indicates the ice edge.



Mean melt rate (in color, in m/a) and vertically integrated stream function (contours, in intervals of 0.05 Sv, 1). The cyan lines show the location of Section 1 (solid) and Section 2 (dashed).



Potential temperature profile(in ◦C) along Section 1 (solid line) and Section 2 (dashed line).

GOAL

We investigate the sensitivity of sub-ice shelf melt rates under Pine Island Ice Shelf, West Antarctica, to changes in the oceanic state .

APPROACH

We use an adjoint ocean model that is capable of representing the flow in sub-ice shelf cavities. The adjoint is based on algorithmic differentiation (AD) of the Massachusetts Institute of Technology's ocean general circulation model (MITgcm; see http://mitgcm.org). It was extended by adding into the AD process the corresponding sub-ice shelf cavity code, which implements a three-equation thermodynamic melt rate parameterization to infer heat and fresh water fluxes at the ice shelf-ocean boundary [Losch, 2008]. The domain is the immediate surrounding of the Pine Island Ice Shelf (PIIS) in the Amundsen Sea Embayment, covering an area between roughly 74◦3'S and 75◦2'S, and 102◦2'W and 99◦1'W, and with an open boundary to the West. Its horizontal resolution is 1/32°, corresponding to 900 m cell width. Bathymetry and hydrography are from Timmermann et al. [2010] and Jenkins et al. [2010].

RESULTS

The inferred sensitivities reveal dominant time scales of 30 to 60 days over which the shelf exit is connected to the deep interior via advective processes. They exhibit rich three-dimensional time-evolving patterns that can be understood in terms of a combination of the buoyancy forcing by the inflowing water masses, the cavity geometry, and the effect of rotation and topography in steering the flow in the presence of prominent features in the bedrock bathymetry. Dominant sensitivity pathways are found over a sill, as well as ``shadow regions'' of very low sensitivities.

CONCLUSIONS

The high degree of spatial variability, with regions exhibiting large sensitivities in the vicinity of others with little apparent sensitivities have important implications for observation and monitoring. To the extent that these spatial patterns are robust they provide valuable information for guiding observational campaigns, e.g. for under-ice shelf instrument deployment, or the determination of suitable drilling positions on the ice shelf for hydrographic instrument lowering. We advocate that studies such as this should be extended and considered in the mix of decision-making tools for observing system design.

REFERENCE

- Heimbach, P. and M. Losch, 2011: Adjoint sensitivities of sub-ice shelf melt rates to ocean circulation under Pine Island Ice Shelf, West Antarctica. *Annals Glaciol.*, submitted.
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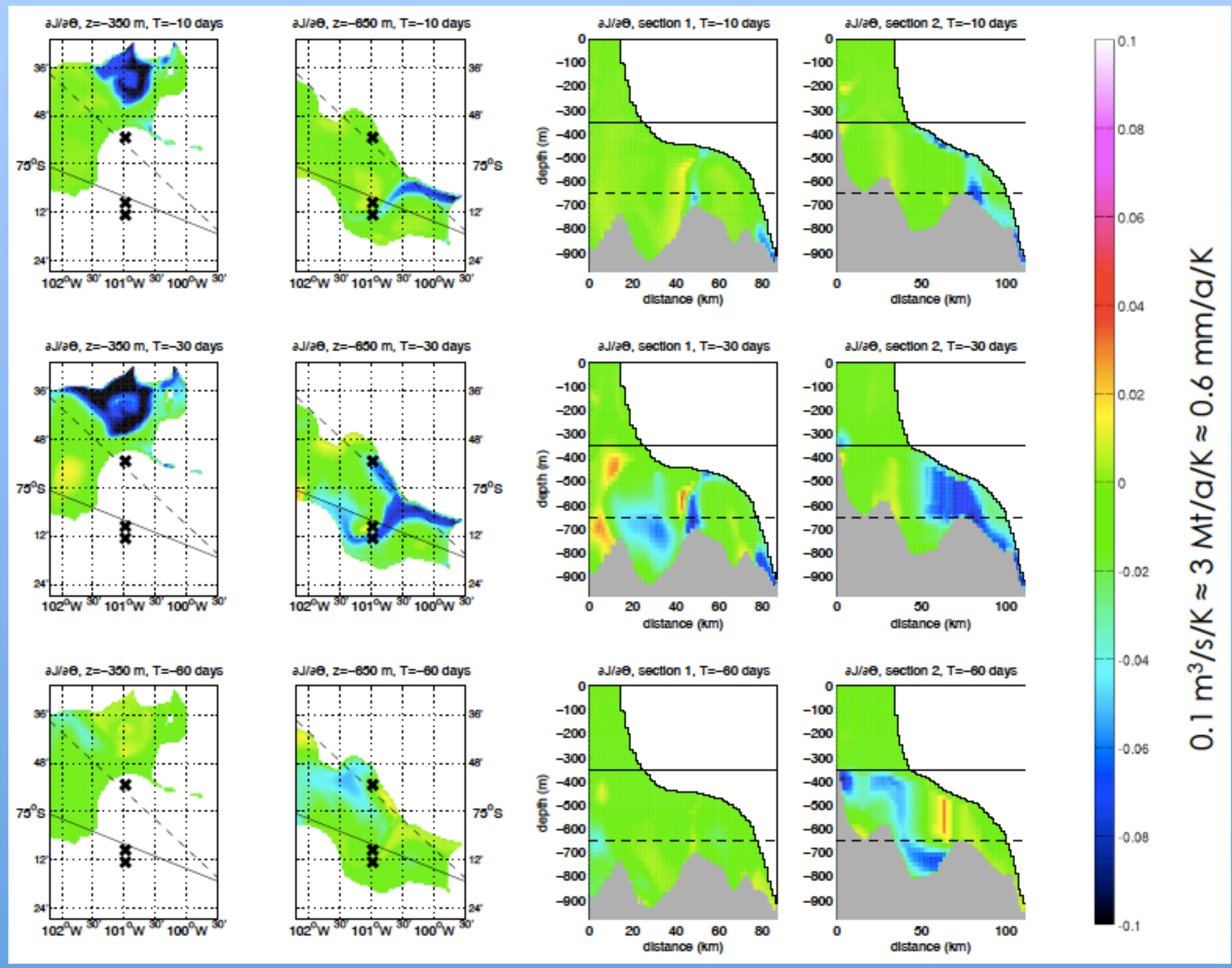

Adjoint sensitivities $\delta^{*}T = (\partial J/\partial T)^{T}$ at $t = \tau_f - 10$ days, −30 days, and −60 days (back in time). Horizontal slices at z = −350 m and z = −650 m on the left hand side, vertical sections on the right hand side. The solid lines in the horizontal slice plots indicate section 1 (right-center), the dashed lines section 2 (far right). The solid and dashed lines in the vertical section plots indicate the positions of the horizontal slices. Units are in $m^3\,s^{-1}\,K^{-1}$, with $0.1\ m^3\,s^{-1}\,K^{-1} \approx 3\ Mt\,a^{-1}\,K^{-1} \approx 3\ mm\,a^{-1}\,K^{-1}$.

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