Ocean variability contributing to basal melt rate near the ice front of Ross Ice Shelf, Antarctica

Laurie Padman
I. Arzeno, R.C. Beardsley, R. Limeburner, B. Owens,
S.R. Springer, C.L. Stewart, M.J.M. Williams
+ G. Moholdt, H.A. Fricker, M.S. Dinniman, S.L. Howard

Sponsored by NSF & NASA
Focus of talk
Basal melt in the Ross Ice Shelf Frontal Zone (ISFZ)

Arzeno et al. (2014; JGR-Oceans)
Moholdt et al. (in revision; JGR-ES)
Horgan et al. (2011; JGR-Oceans)
Stern et al. (2013; JGR-Oceans)
Explain “high” melt rate ($M_b$) near RIS front

Moholdt et al. [in revision]
Lagrangian analysis of ICESat

Horgan et al. [2011]
Ocean melt modes: Focus on Mode 3

Graphic courtesy of Mike Craven
Modeled $M_b$

Entire RIS

Mean $M_b \sim 0.25 \text{ m a}^{-1}$
Melt rate is seasonal; highest in summer (JFM)

Average $M_b$ (m a$^{-1}$) for entire RIS, and ISFZ* only

* ISFZ defined as within 30 km of ice front
Why seasonal? (1) Polynya insolation

Polynya net surface heat flux (W/m²)

Ross Polynya

ISFZ
Why seasonal? (2) Southward flow of MCDW

Bathymetry

Summer

Winter
Cross-ice-front hydrographic contrasts

- **Summer**
  - Polynya ISFZ

- **Winter**
  - Pot. Temp
  - Salinity
  - Pot. Density
What we know from satellites

‘High’ annual-average $M_b$ near ice front

ISFZ melt ~40% of total RIS melt

Inferred from models

Melt near an ice front is seasonal

Upper-ocean heat in Ross Polynya in summer due to insolation + increased southward MCDW transport
Speculation

Mode 3 melt is more responsive to annual variability of forcing than Mode 1 (grounding-line melt)

Rapid ice-front thinning & retreat driven by enhanced Mode 3 melt would accelerate dynamic ice loss

⇒ Climatological changes in summer ocean and sea-ice state in the Ross Polynya may affect dynamic ice loss

Now we want ...

*In situ* evidence for Mode 3 melt and seasonality

Improved understanding of processes determining seasonality, to better represent ISFZ melt in future climate states

*Do we even know the sign of expected Mode 3 melt rate change?*
In situ measurements

ANDRILL: Coulman High sites
Sub-ice-shelf hydrography
Time series measurements

AWS
AWS
GPS
Moorings
$M_b$ from mooring

Ocean heat flux

$$Q_O = \rho_w C_p C_H u^* \Delta T$$

Where

$$u^* = C_D^{1/2} |u|$$

To get $M_b$, equate $Q_O$ to latent heat, with correction for through-ice conduction (\sim 20\%)
VM-2 (model)

Summer
Warm, low $|u|$  

Winter
Cold, high $|u|$  

Tides change $M_b$ time dependence and average
Model output (no tides)

Highest $M_b$ at this site is in winter, not summer, since extra $|u|$ dominates over reduced $\Delta T$. 

2 y @ 5-day averages

6 mo @ 4-h averages
Weather-band (period of days) variability is **not** correlated with local winds:

⇒ Eddies and/or topographic-trapped waves along the ice front

Strength of these processes depends on density gradients: cross-front, and vertical:

⇒ These change with stratification in Ross Polynya and buoyant meltwater fluxes to and within the ISFZ
Summary (Ross ISFZ basal melt rate $M_b$)

‘High’ $M_b$ near ice front ($\sim 2$ m a$^{-1}$ cf <0.3 m a$^{-1}$ overall)

ISFZ melt $\sim 40\%$ of net RIS melt

Seasonal cycle of warm upper-ocean water near the ice front; insolation + MCDW southward advection

But ...

$M_b$ depends on high-frequency ocean variability (tides, eddies, frontal instabilities) with energy that is out of phase with upper-ocean $T$; $\Rightarrow$ more complex $M_b(t)$ signal

Implies sensitivity to interactions between atmosphere, ocean, ice shelf and sea ice at short time and space scales
Thank you
End formal talk
Moholdt et al. [in revision]
Lagrangian analysis of ICESat
Annual cycle: 5-day averages

No Tides

Tides
Summer (2004/05) only: 4-h averages

No Tides

Tides
Summary (Ross ISFZ melt)

‘High’ melt rate near ice front (~2 m a\(^{-1}\) cf <0.3 m a\(^{-1}\) overall)

ISFZ melt ~40% of net RIS melt

Seasonal cycle as warm upper-ocean water gets to ice front; insolation + MCDW southward advection

Dependence on tides (~50%) and ‘weather-band’ (~50%)

W-B appears to be ‘frontal instability’, not local wind forcing, and so depends on ocean stratification differences between Ross Polynya water and water under ISFZ

Implies sensitivity to interactions between atmosphere, ocean, ice shelf and sea ice