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

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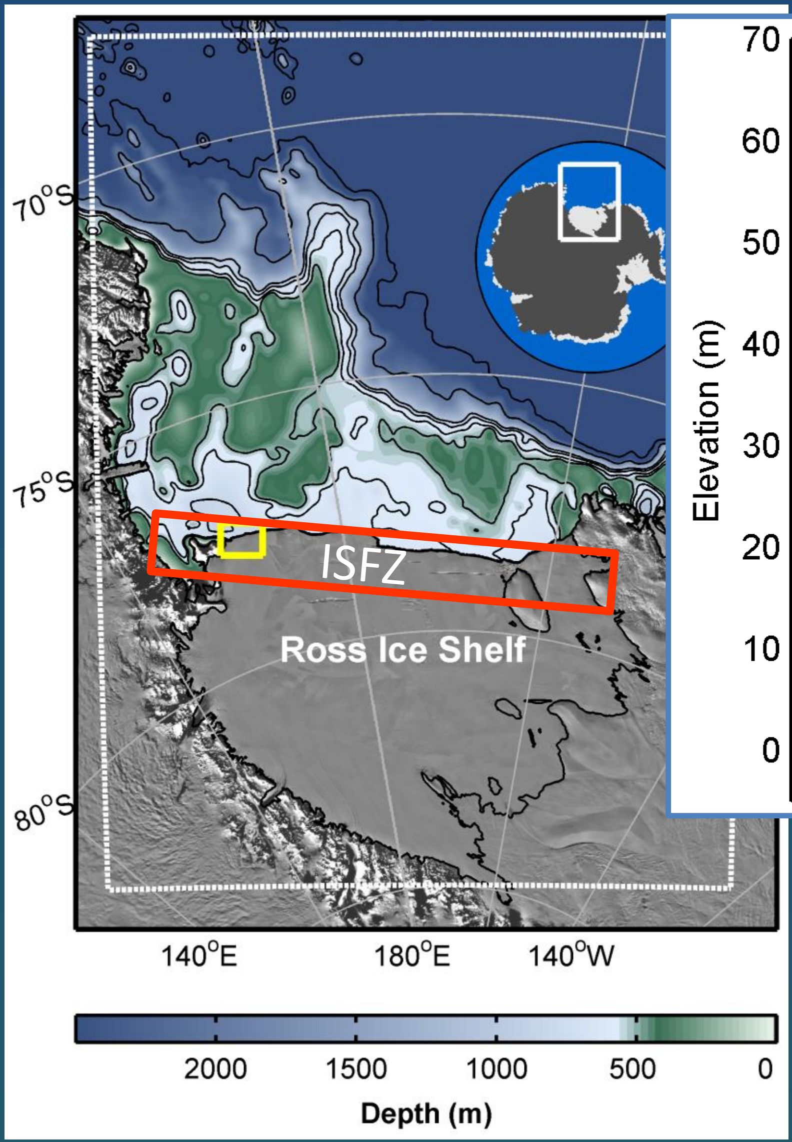
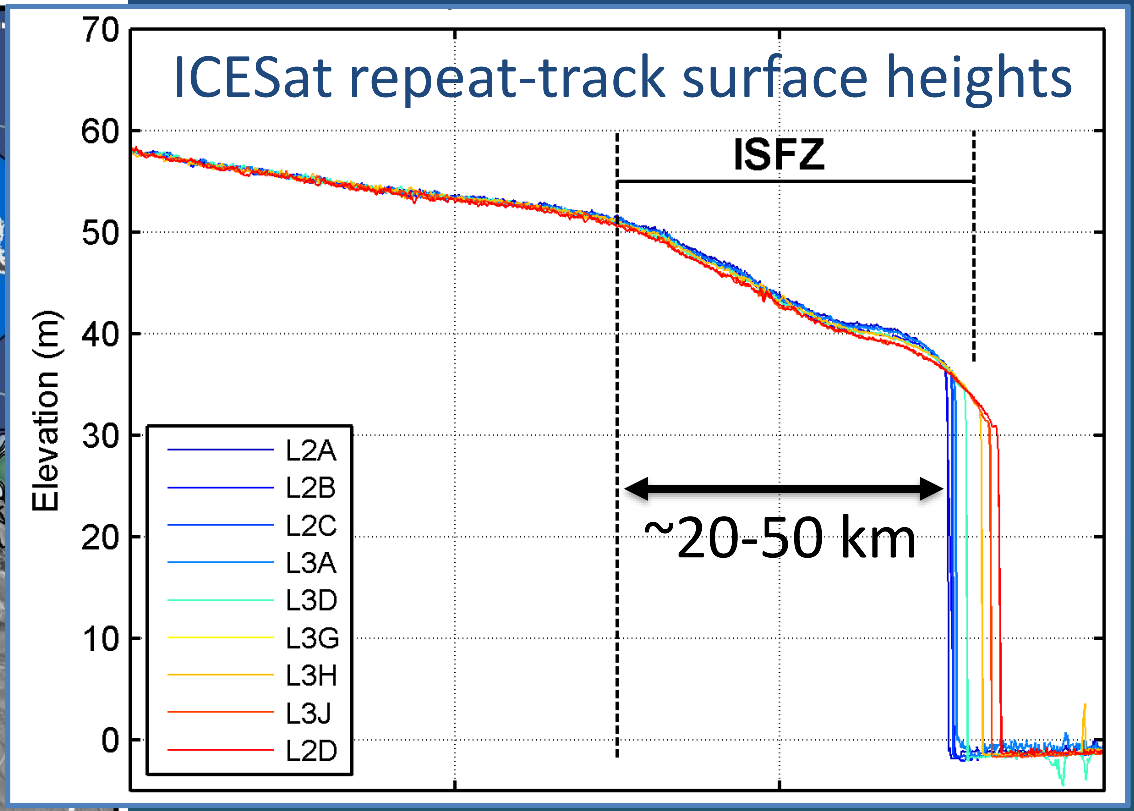
Sponsored by NSF & NASA

Focus of talk

Basal melt in the Ross Ice Shelf Frontal Zone (ISFZ)





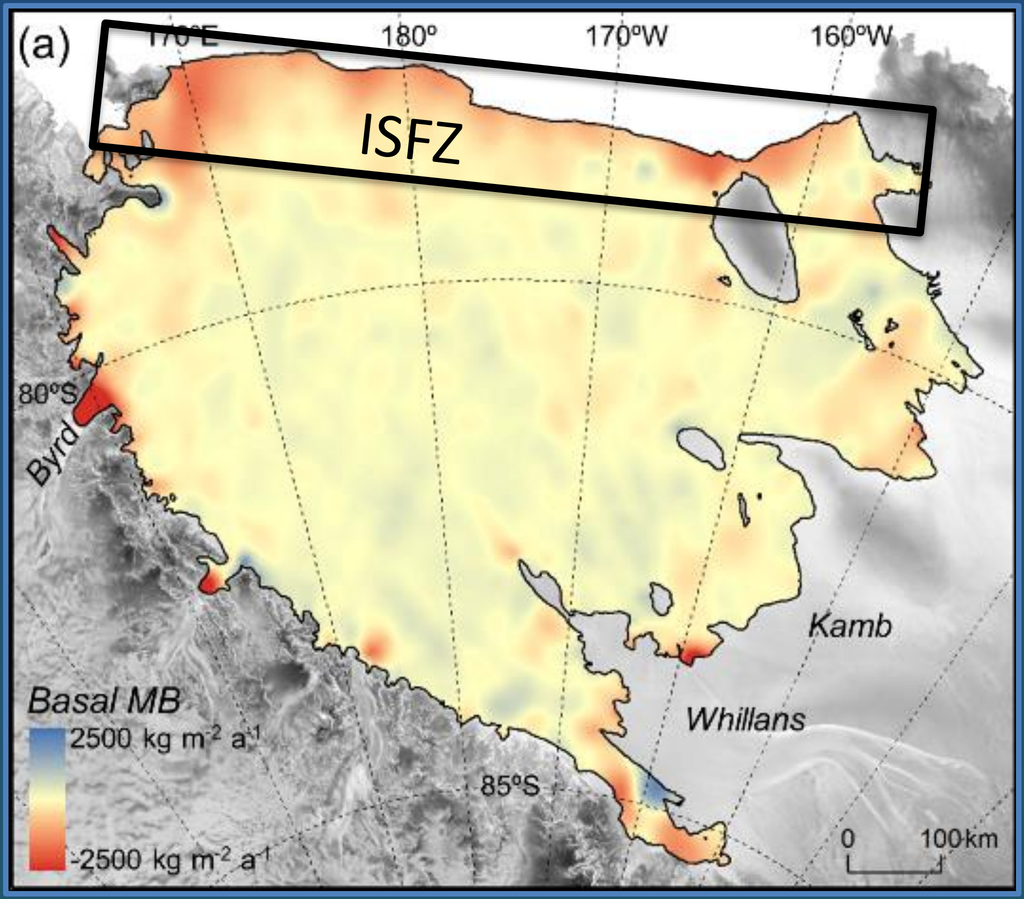
Arzeno et al. (2014; *JGR*-Oceans)

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



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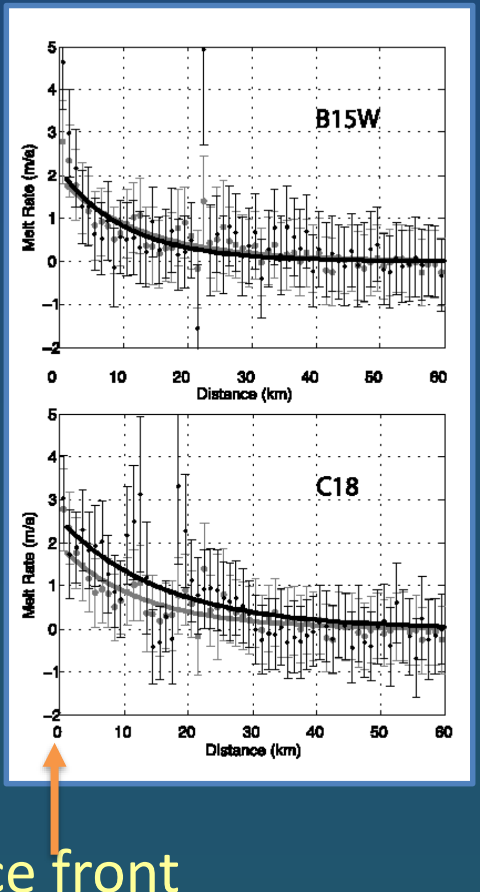
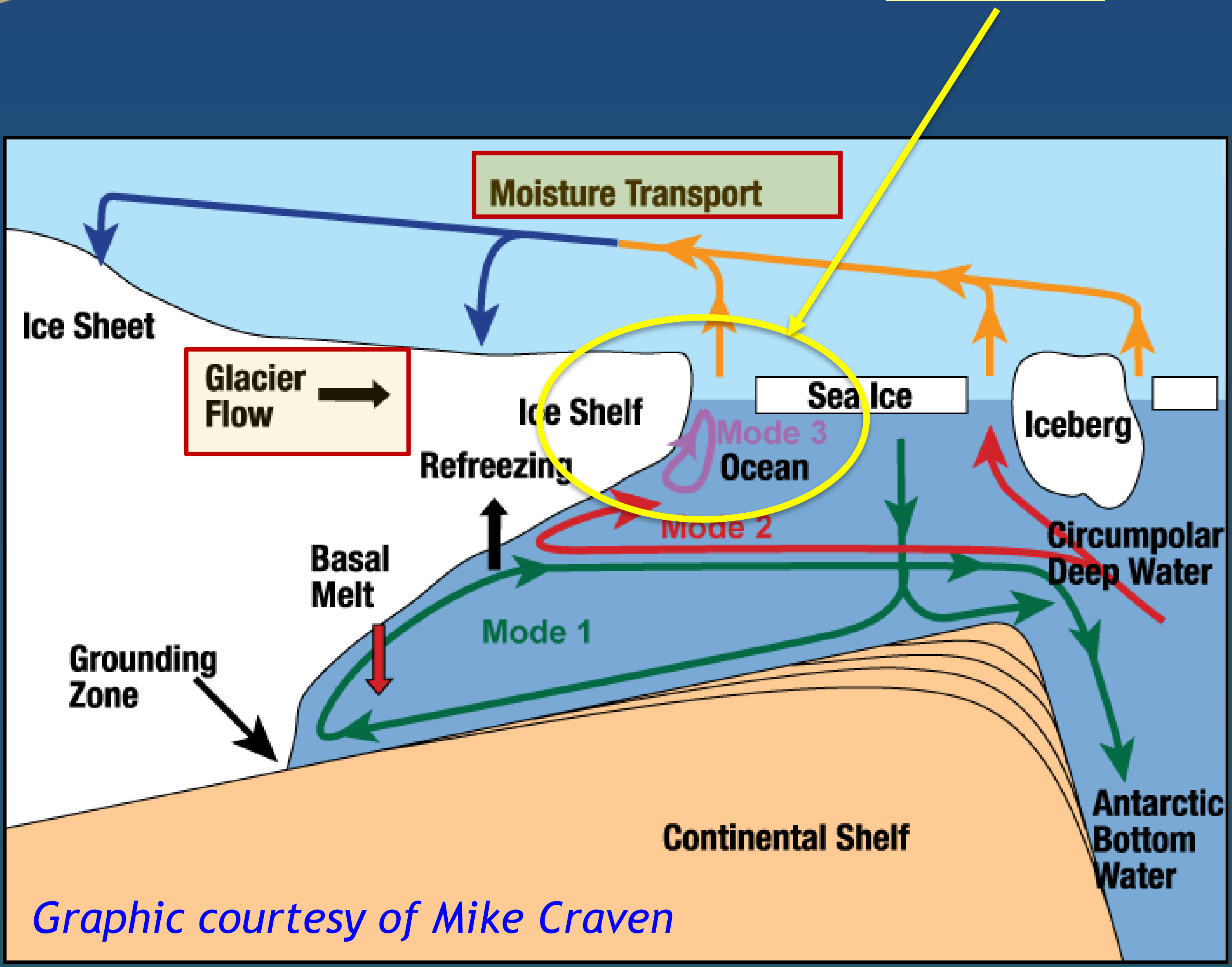


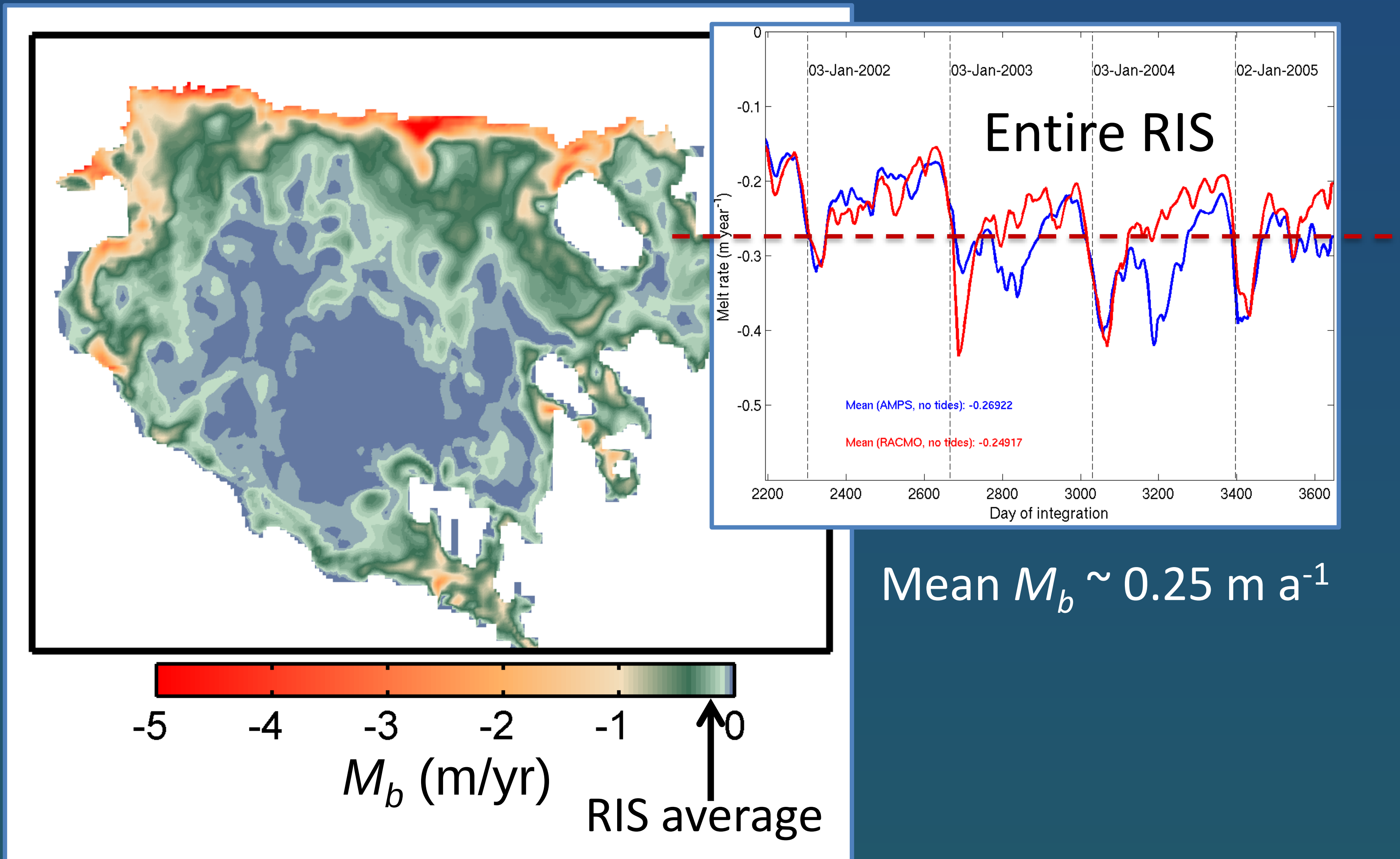
Horgan et al. [2011]

Ocean melt modes: Focus on Mode 3



Graphic courtesy of Mike Craven

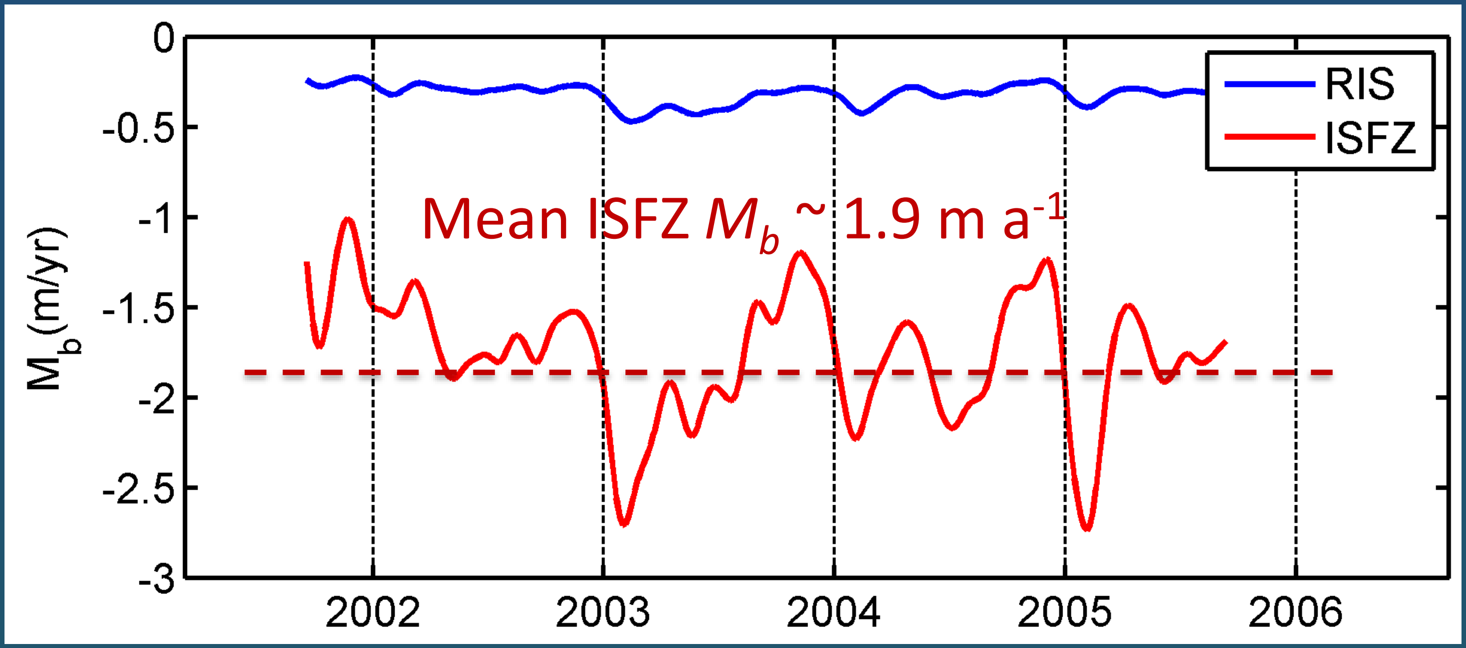
Modeled M_b



Mean M_b ~ 0.25 m a^{-1}

Melt rate is seasonal; highest in summer (JFM)

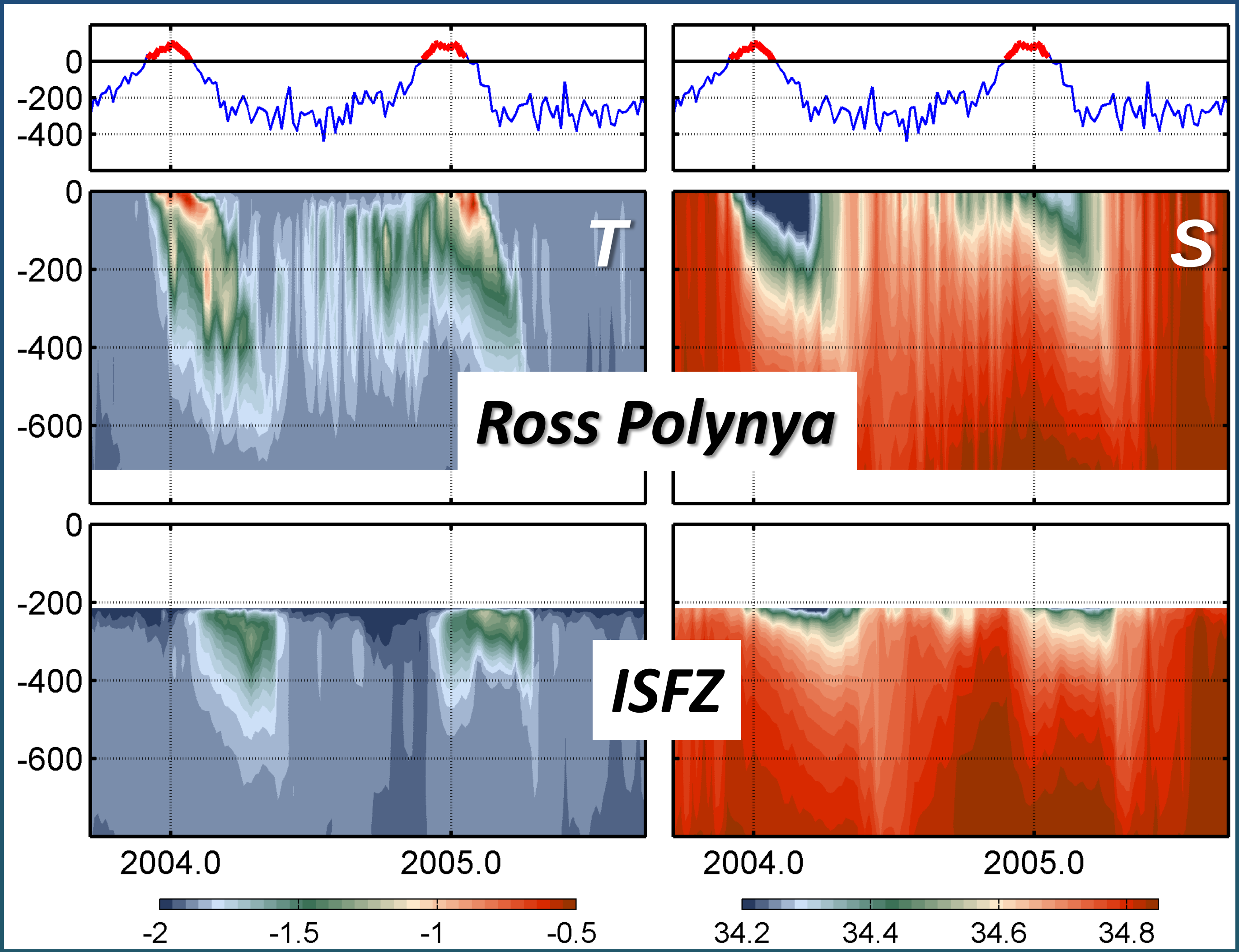
Average M_b ($m\ a^{-1}$) for entire RIS, and ISFZ* only



More melt

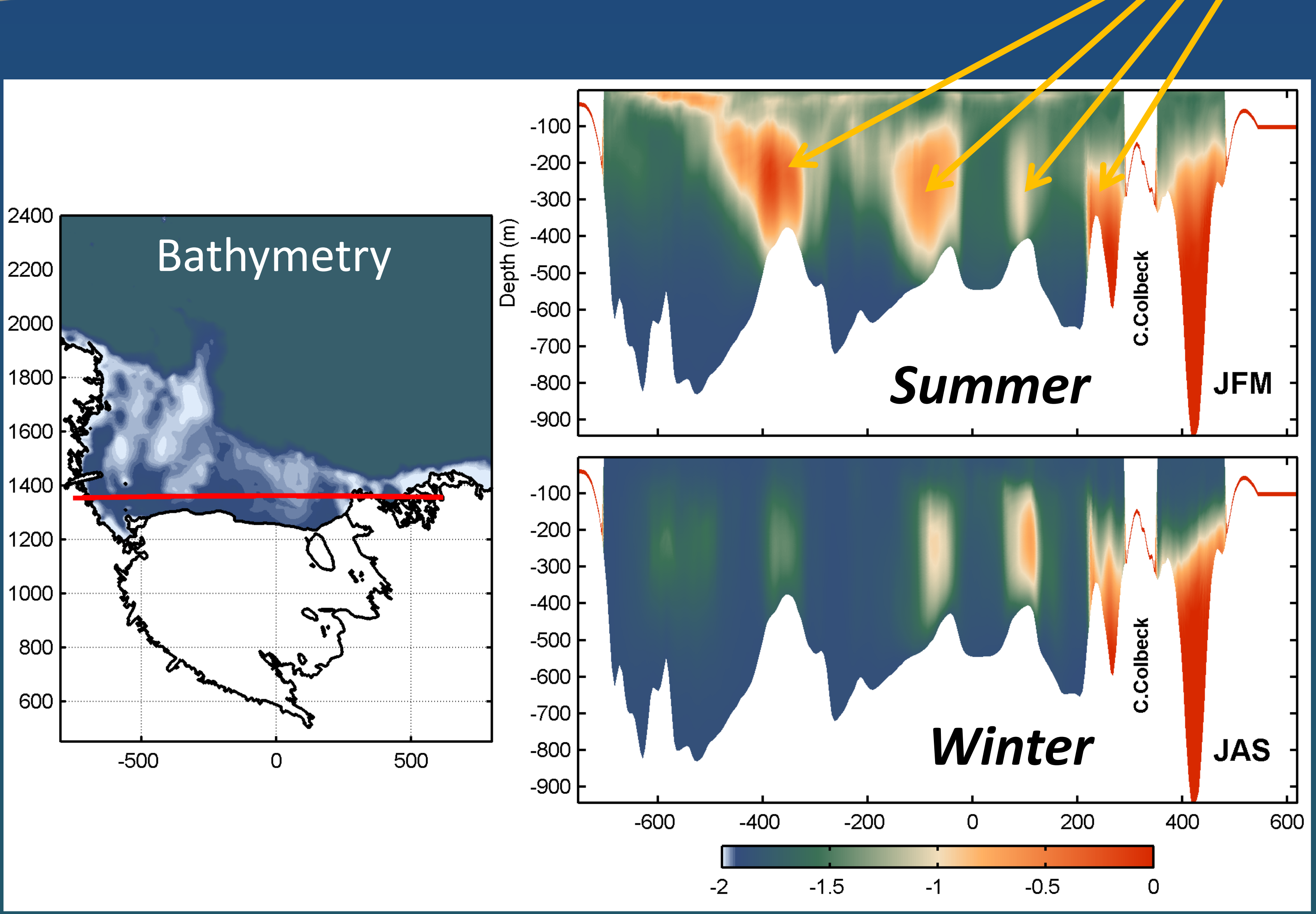
* ISFZ defined as within 30 km of ice front

Why seasonal? (1) Polynya insolation

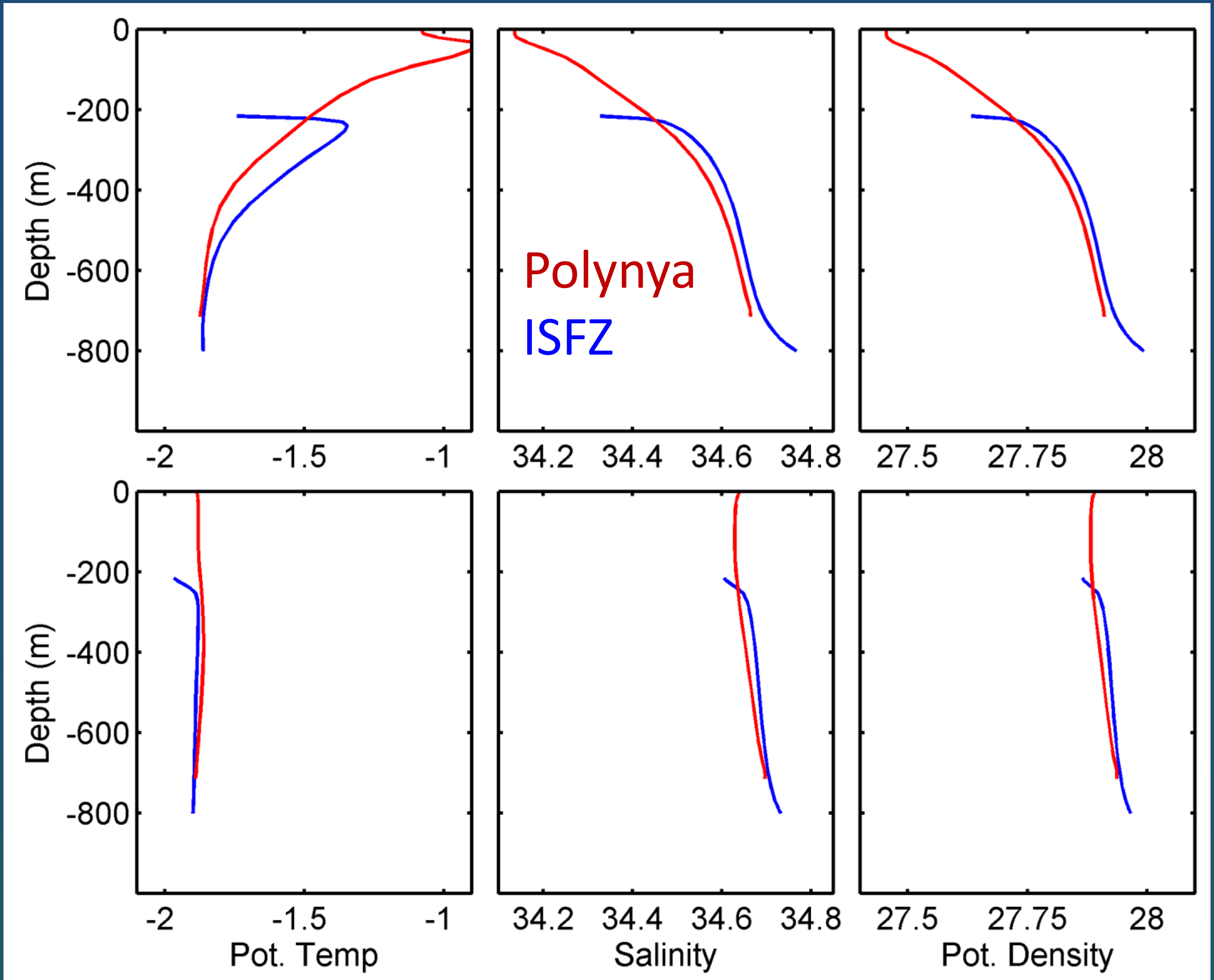


Polynya net surface heat flux (W/m^2)

Why seasonal? (2) Southward flow of MCDW



Cross-ice-front hydrographic contrasts



Summer

Winter

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 <u>summer</u> ocean and sea-ice state in the Ross Polynya may affect dynamic ice loss

Now we want …

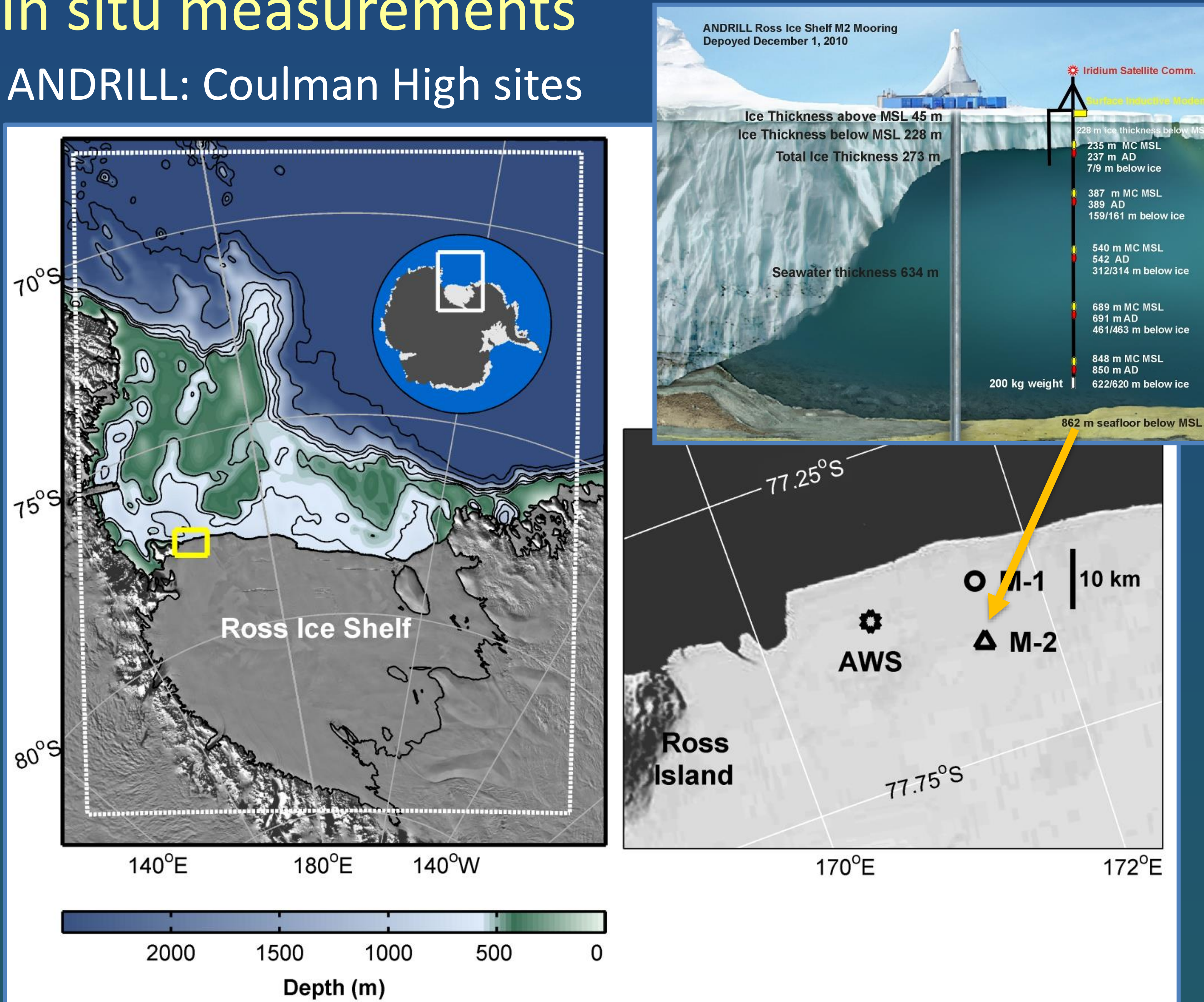
<u>In situ</u> evidence for Mode 3 melt and seasonality

Improved understanding of <u>processes</u> determining season-ality, to better represent ISFZ melt in future climate states

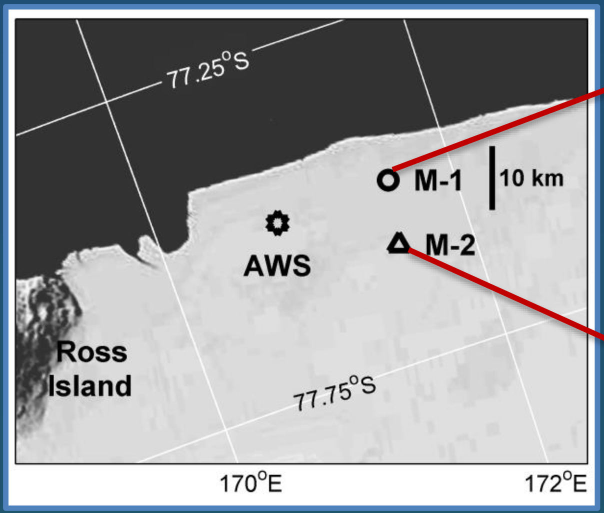
Do we even know the <u>sign</u> of expected Mode 3 melt rate change?

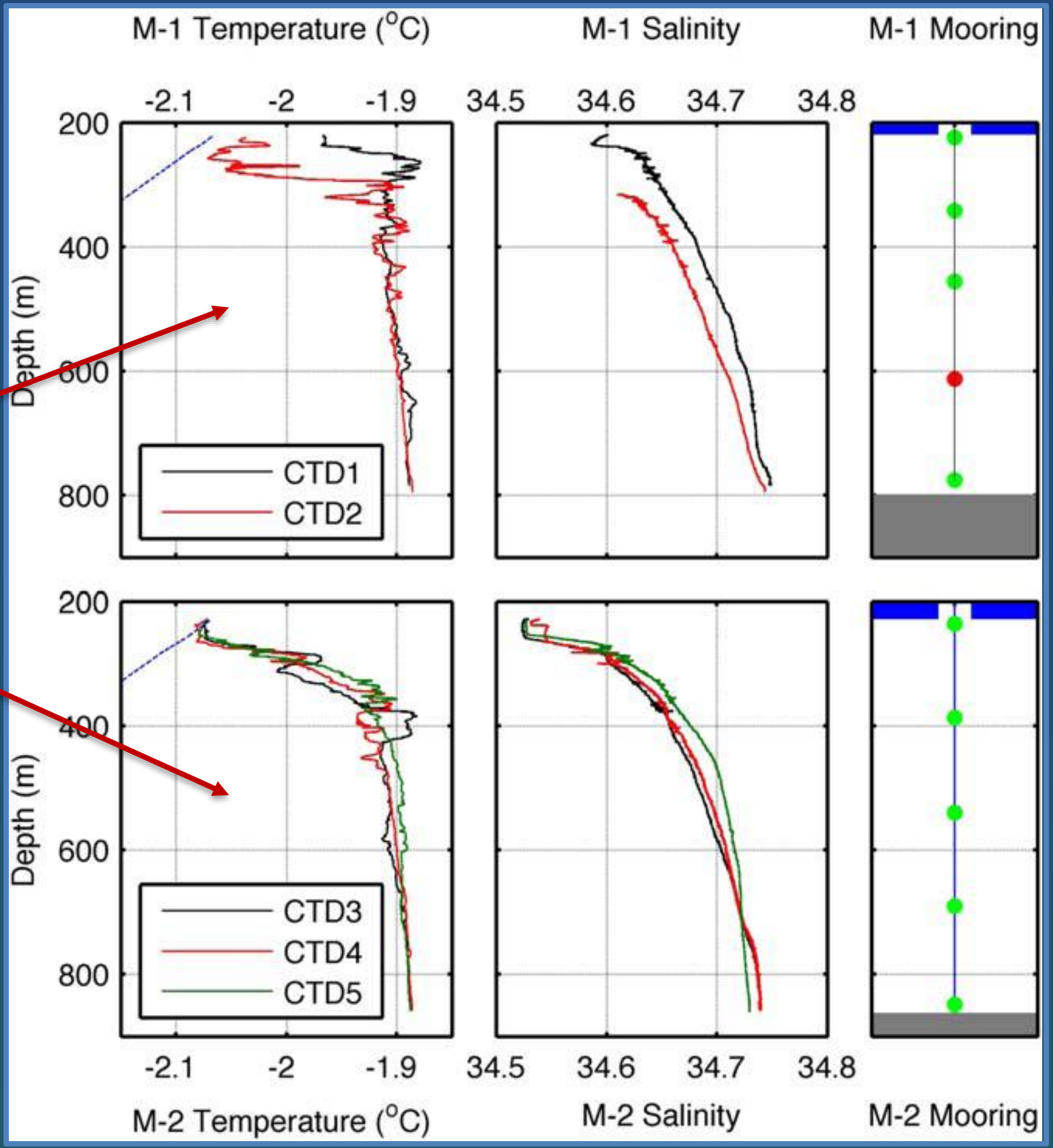
In situ measurements

ANDRILL: Coulman High sites

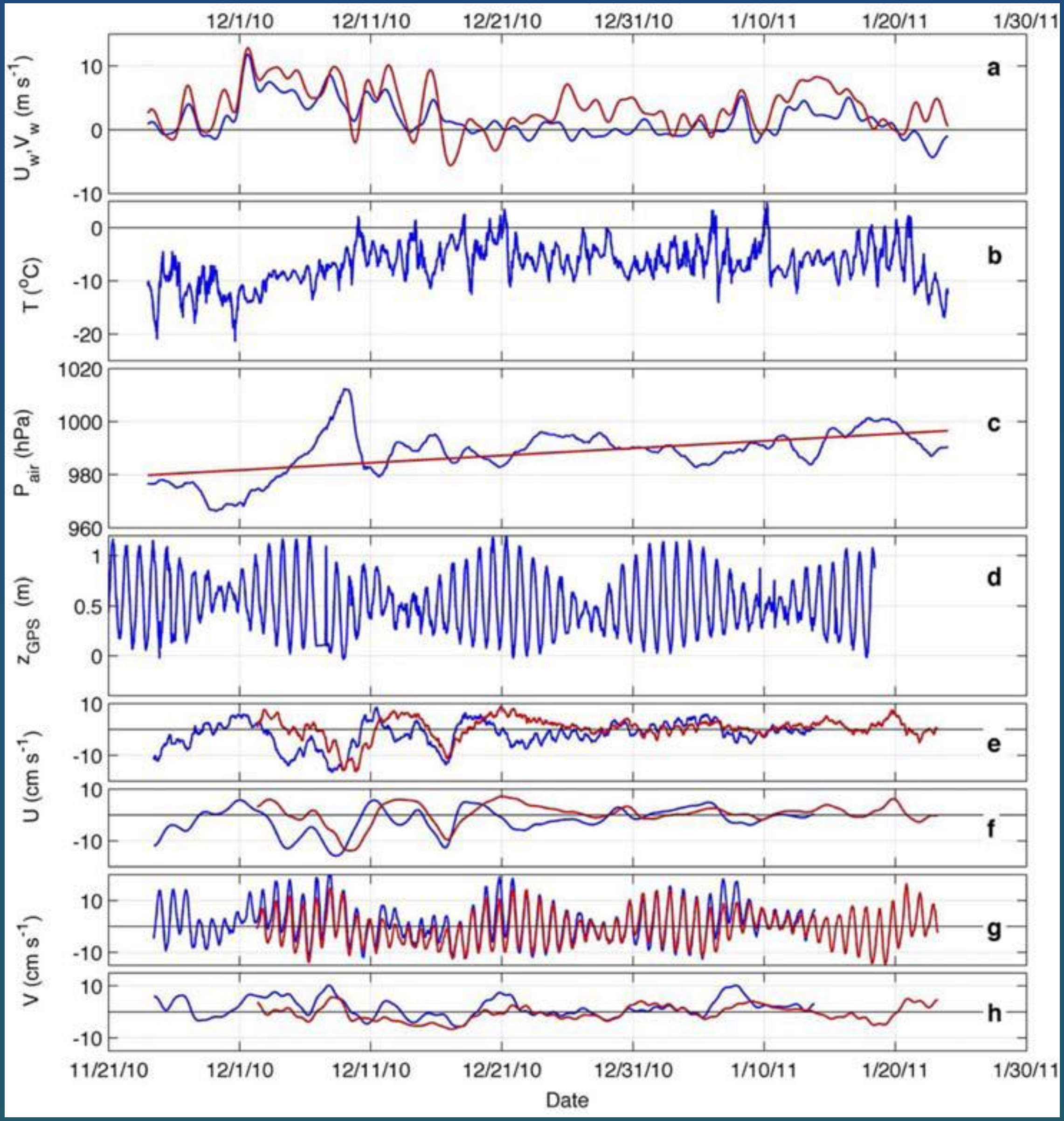


Sub-ice-shelf hydrography





Time series measurements



AWS

AWS

GPS

Moorings

M_b from mooring

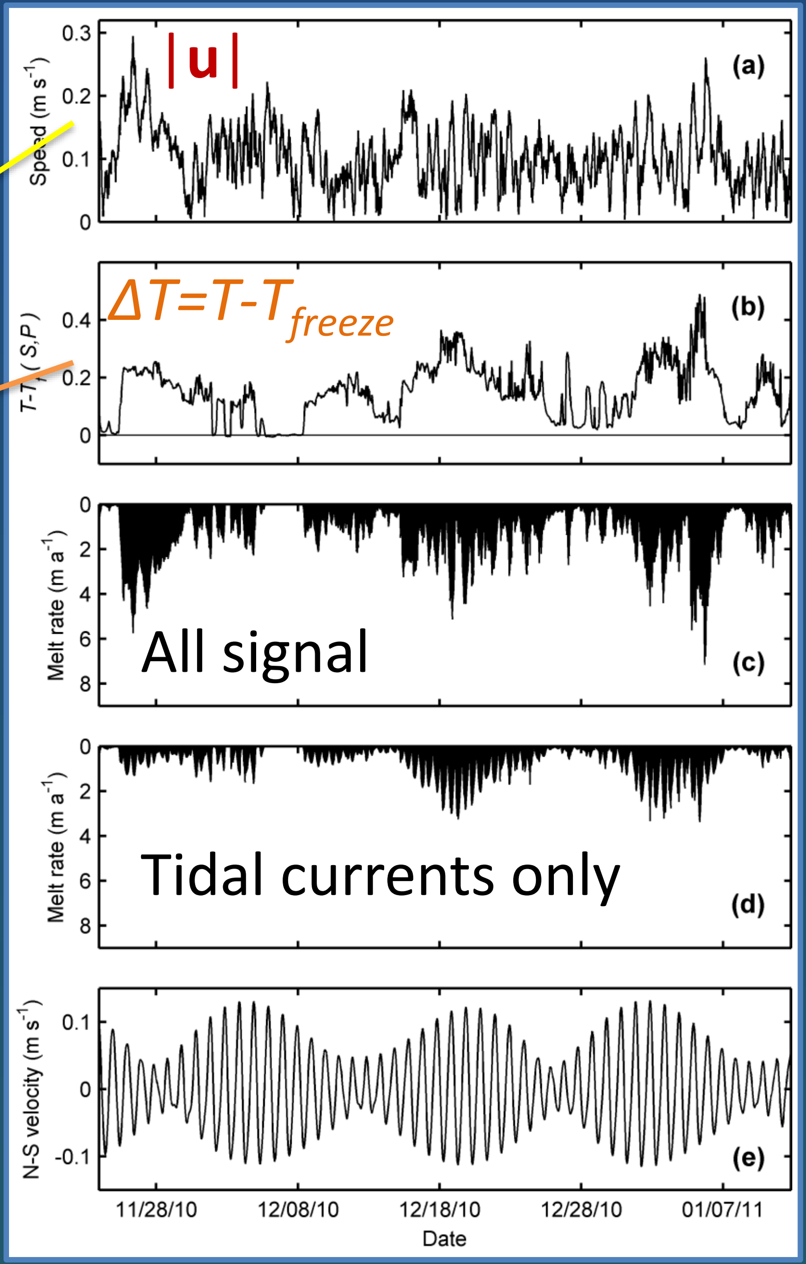
Ocean heat flux

$$Q_O = \rho_w C_p C_H u_* \, \Delta T$$

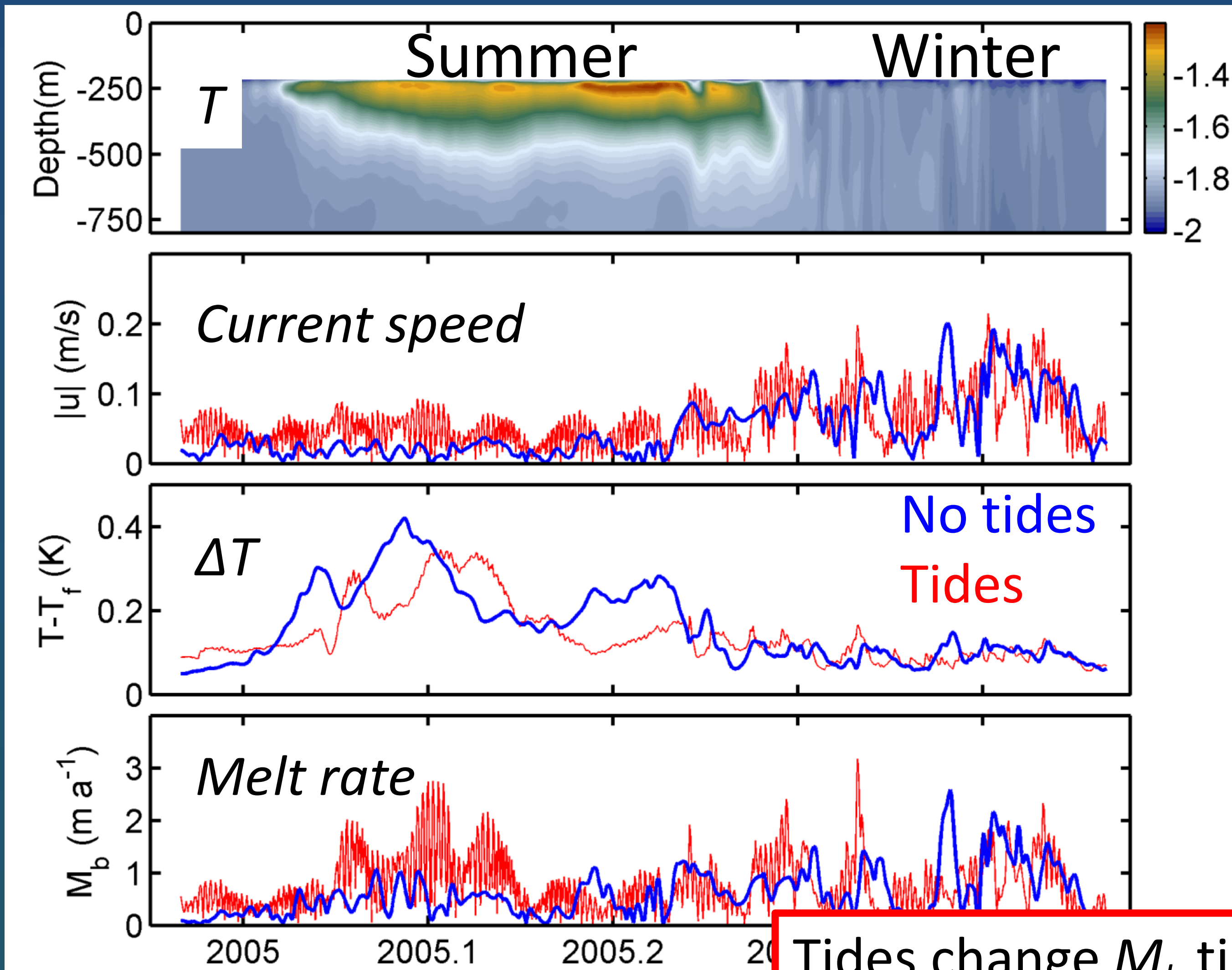
Where

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

To get M_b, equate Q_O to latent heat, with correction for through-ice conduction (~20%)



VM-2 (model)



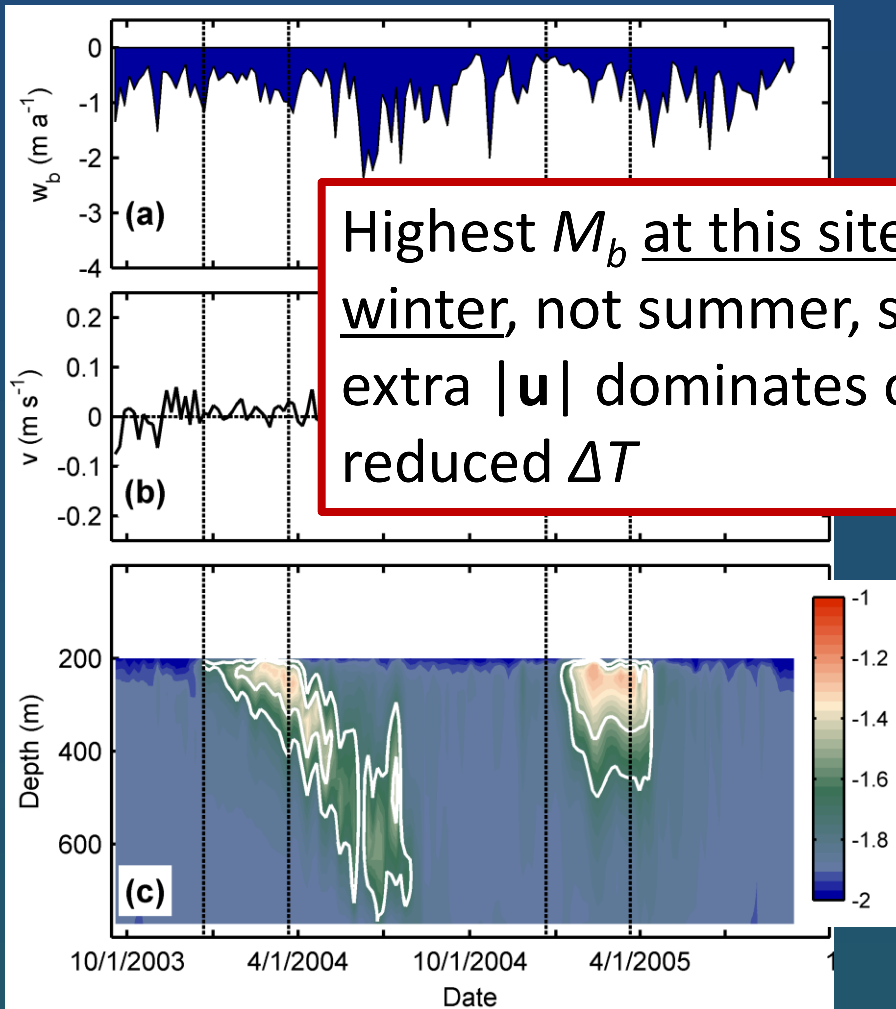
Summer
Warm, low |**u**|

Winter
Cold, high |**u**|

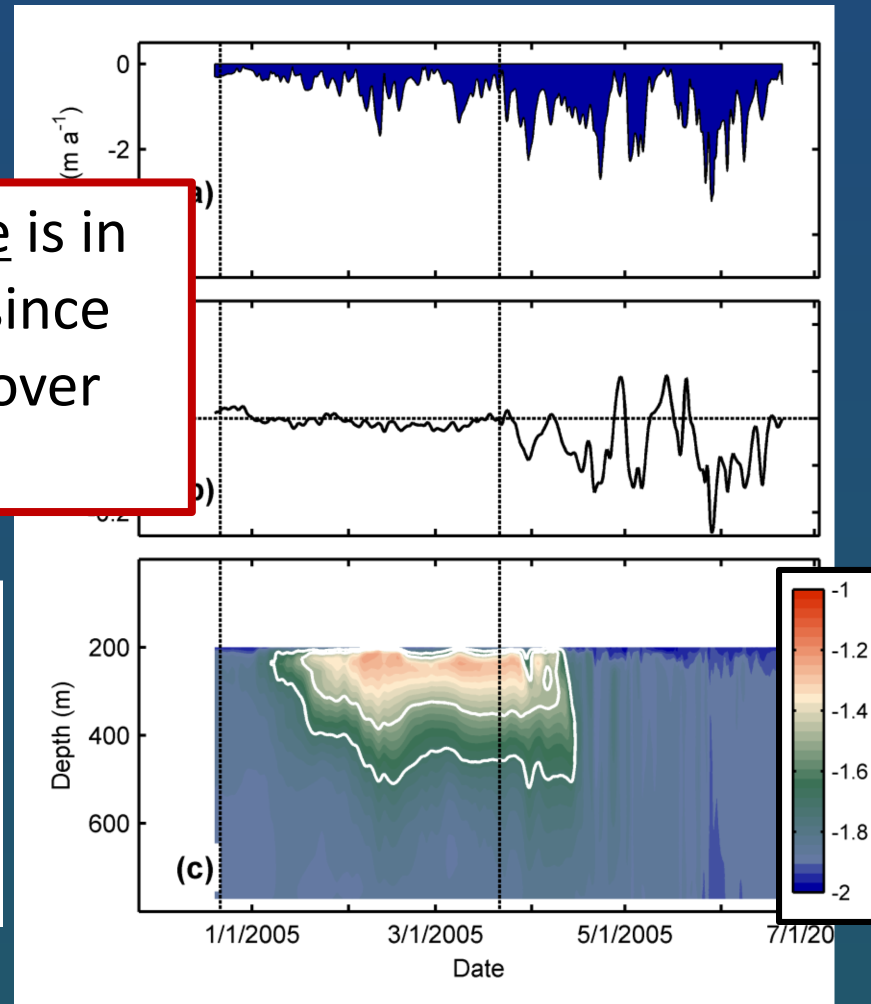
Tides change M_b time dependence and average

Model output (no tides)

Highest M_b at this site is in winter, not summer, since extra |**u**| dominates over reduced ΔT



2 y @ 5-day averages



6 mo @ 4-h averages

Not shown

Weather-band (period of days) variability is <u>not</u> 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 (~2 m a^{-1} cf <0.3 m a^{-1} overall)

ISFZ melt ~40% of net RIS melt

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

But …

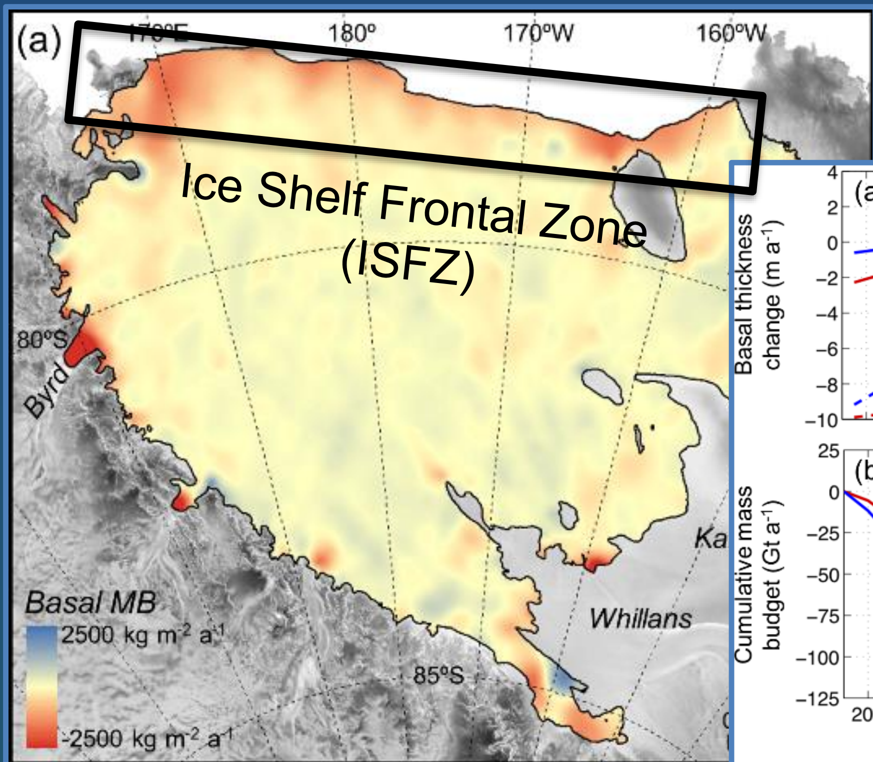
M_b depends on high-frequency ocean variability (tides, eddies, frontal instabilities) with energy that is out of phase with upper-ocean T; => more complex $M_b(t)$ signal

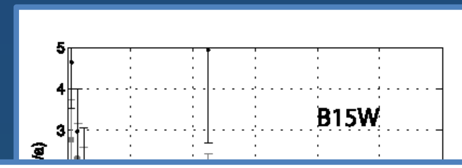
Implies sensitivity to interactions between atmosphere, ocean, ice shelf and sea ice at short time and space scales

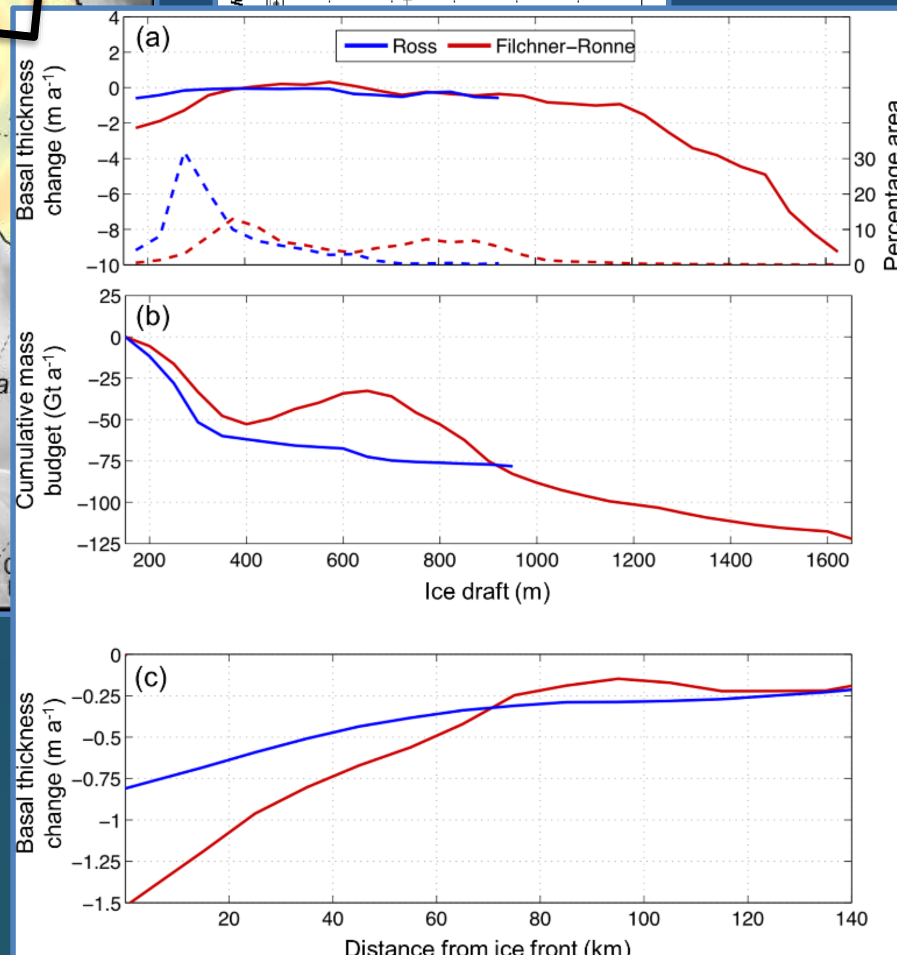

Thank you

End formal talk

Explain high melt rates near RIS front







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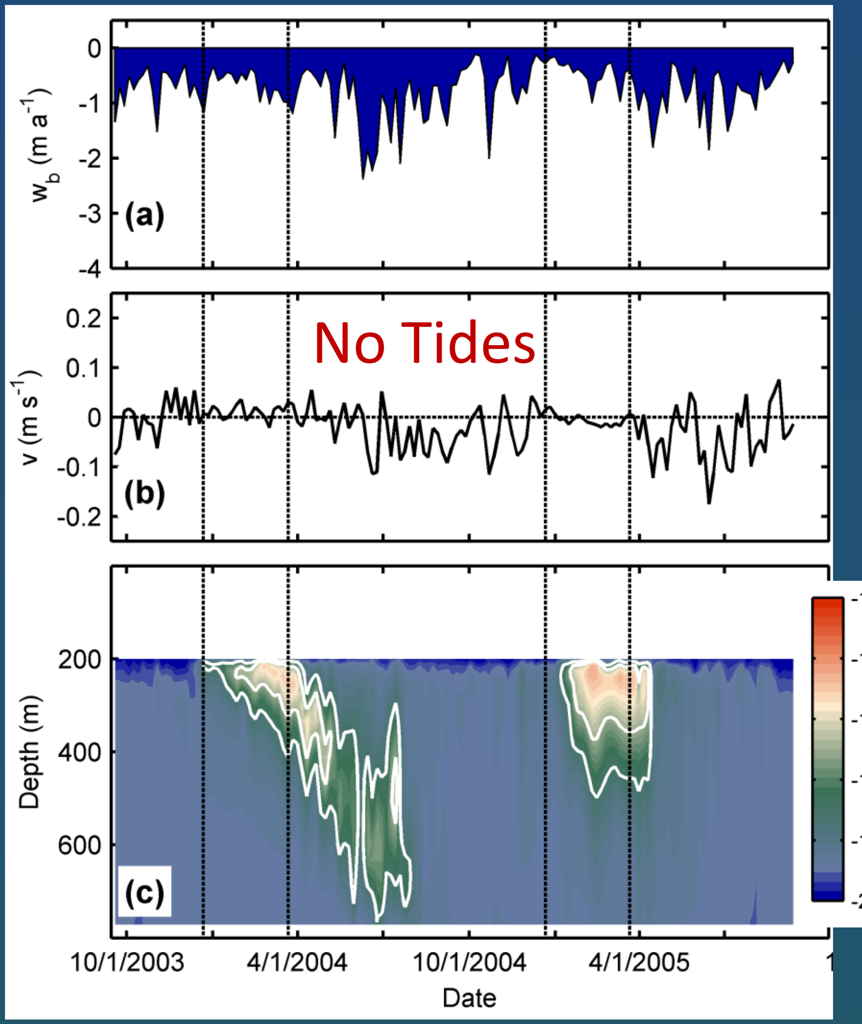
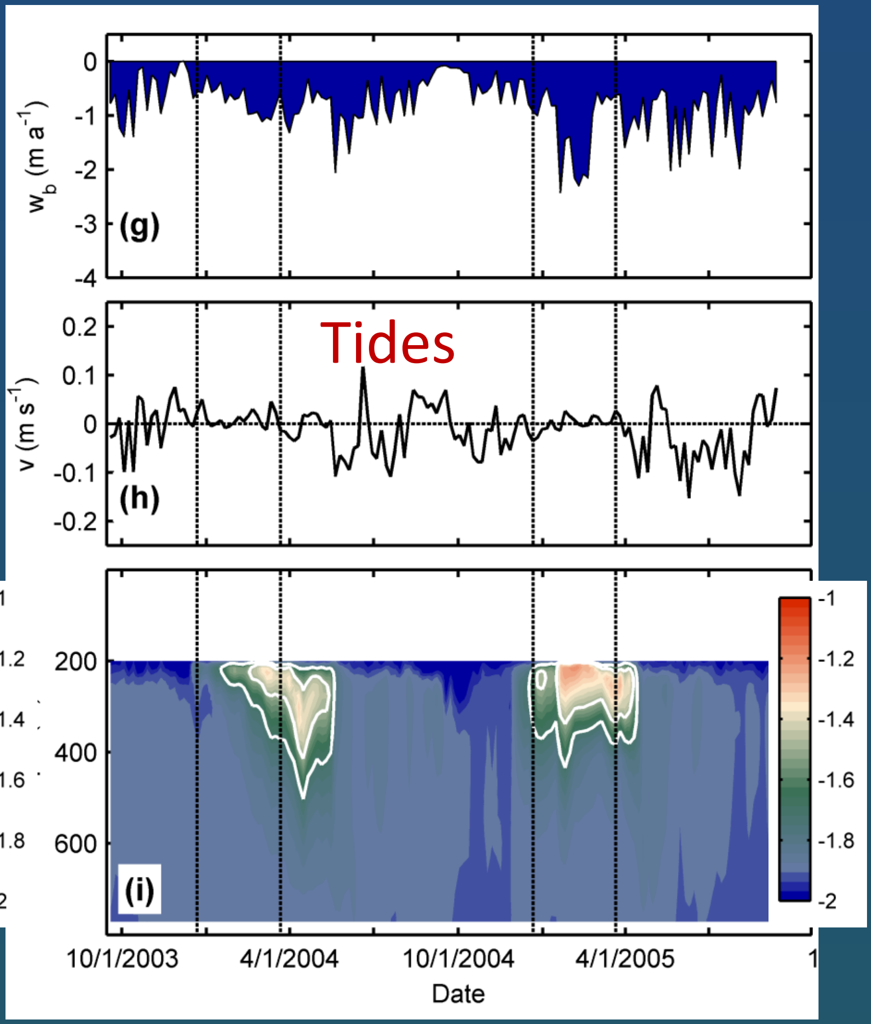
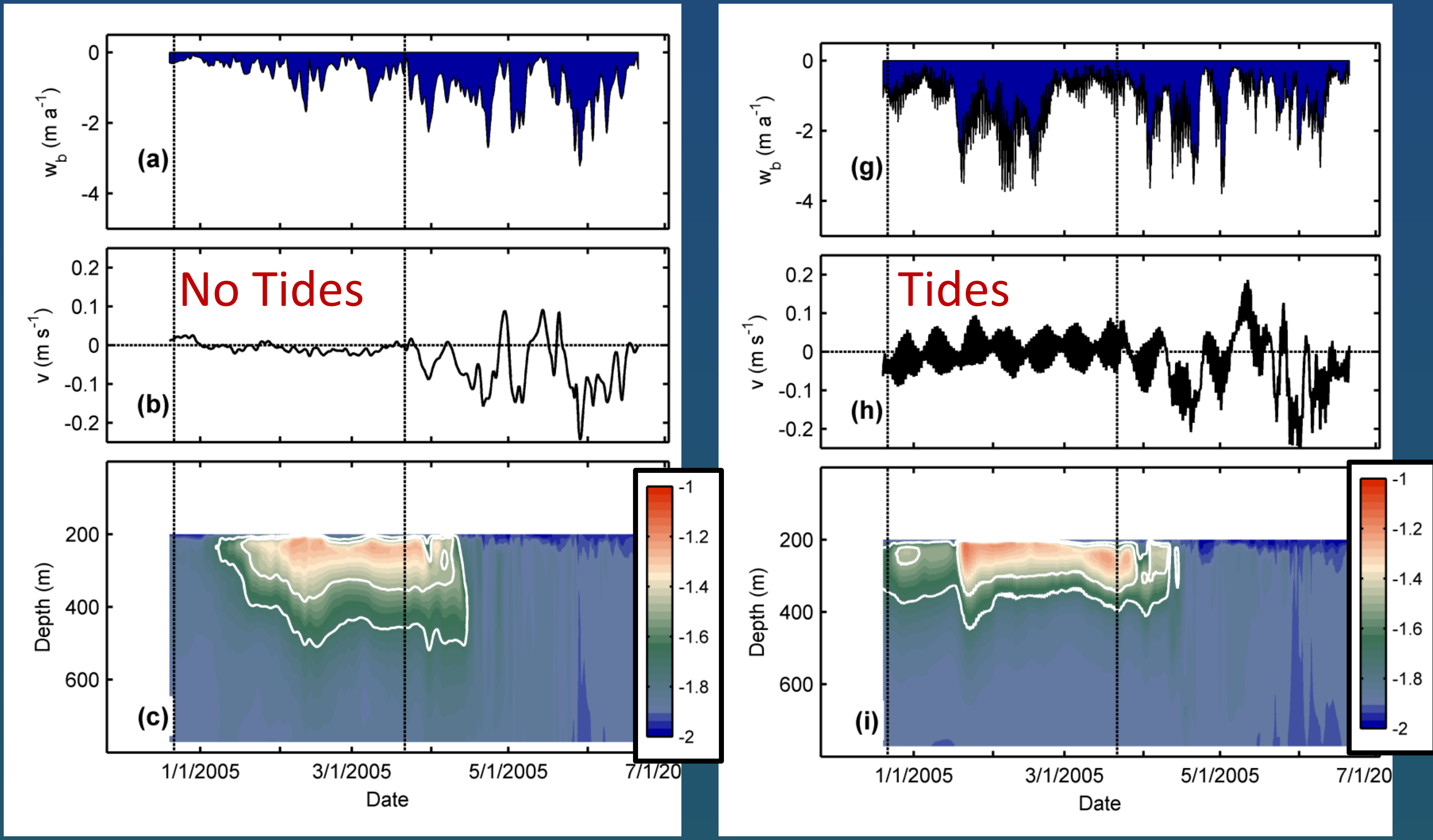
Annual cycle: 5-day averages





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



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