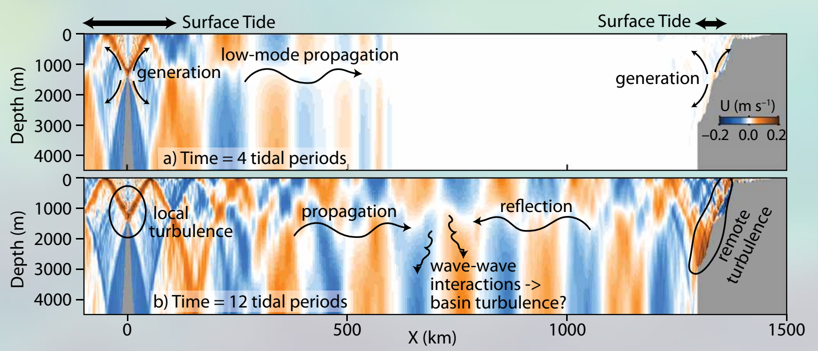
Tasmania internal tide experiment: Reflection from the slope

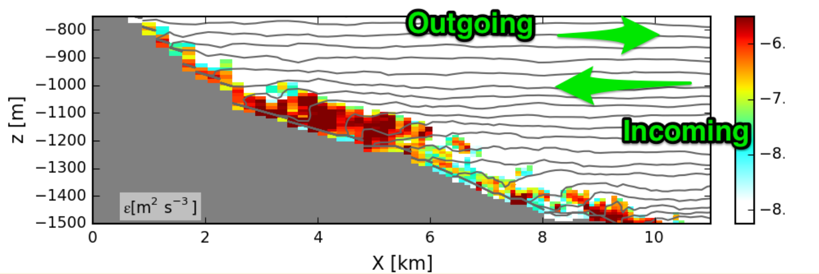
Jody Klymak
University of Victoria
February 17, 2016



Harper Simmons, Shaun Johnston, Zhongxiang Zhao, Rob Pinkel, Matthew Alford, Jennifer MacKinnon, Jonathan Nash, Dmitry Brazhnikov, Sam Kelly, Amy Waterhouse, Nicole Jones

Experiment Goal

Turbulence due to continental slope



- Parameterize dissipation, $D = F_{in} - Fout$ as function of F_{in} (not trivial).
- But more basic: how to disentangle F_{in} from F_{net}?

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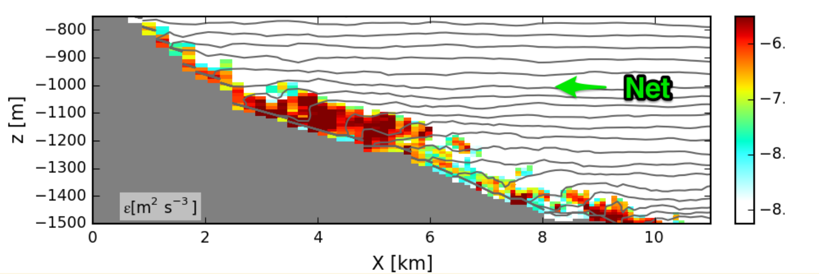

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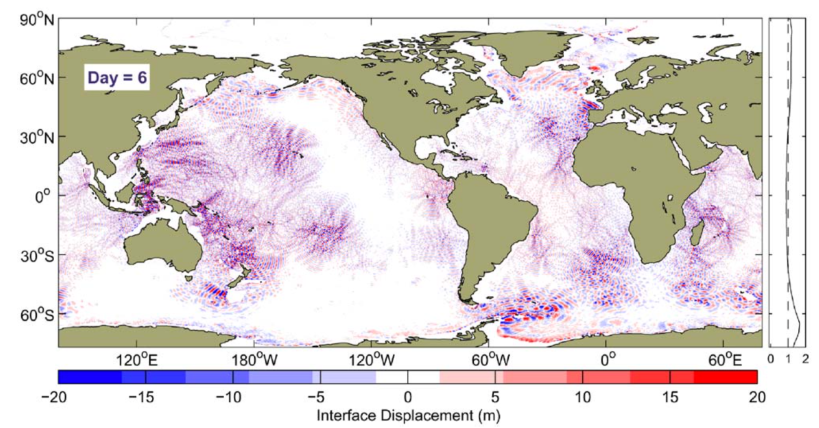
TTide: Tasmania Internal Tide Experiment



Simmons et al 2004

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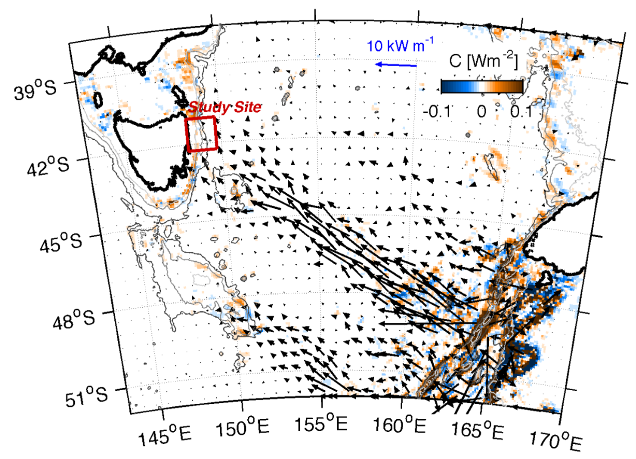

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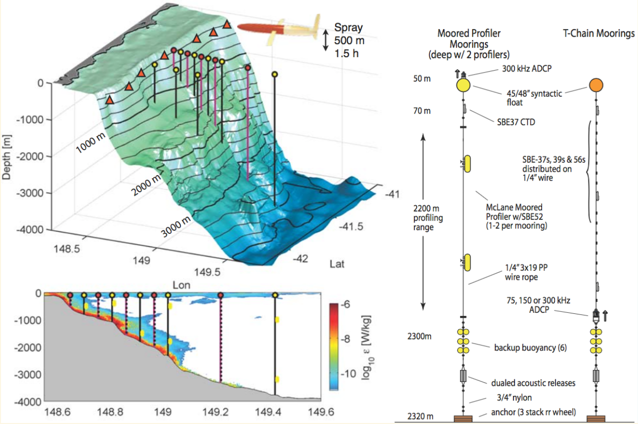
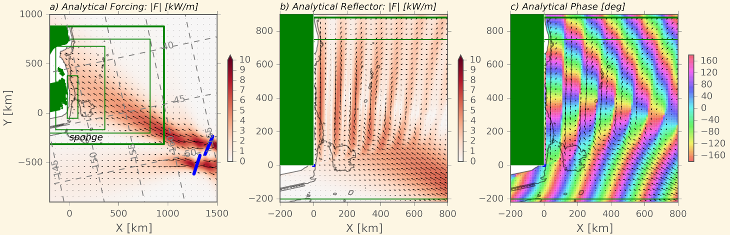
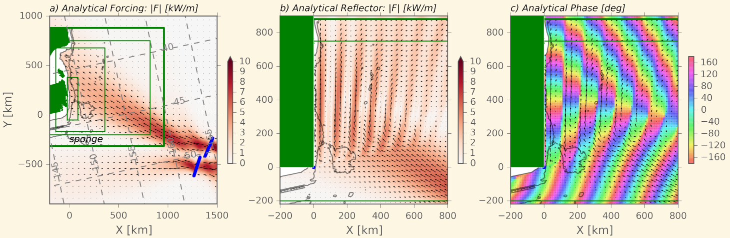


Setup



- MITgcm (hydrostatic, Klymak and Legg 2010 dissipation)
- Analytical M_2, mode-1, forcing meant to represent Macquarie Ridge
- Central region 1 km x 1 km, telescope around this.
- sponge forcing and absorbers

Simple Response?

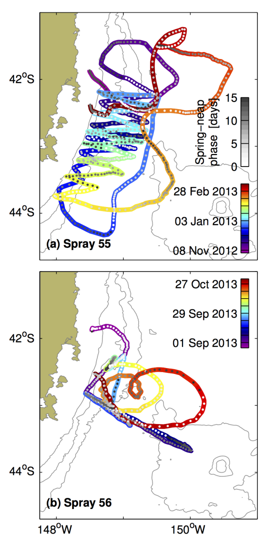


- Standing wave cross-slope ($k_x = cos(30)k_r$)
  - beam at about 30 degrees to wall.
  - 180 degree phase reversal at 50 km, 150 km, 250 km etc.
- Propagating wave along-slope ($k_y = sin(30)k_r$)
- Slight curvature due to the spherical spreading of the incoming wave.

Gider Survey

Shaun Johnston & Dan Rudnick, SIO

- *Johnston et al, 2015, JPO*
- Nov 12-Feb 13, Sep 13- Oct 13
- measured CTD and velocity
- Estimated tidal amplitudes for u, v, and η
- Used gliders as antennae to separate incoming from outgoing, by fitting two plane waves over observed amplitudes and phases



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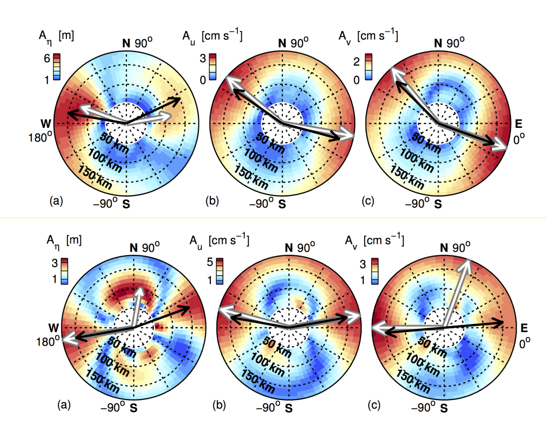
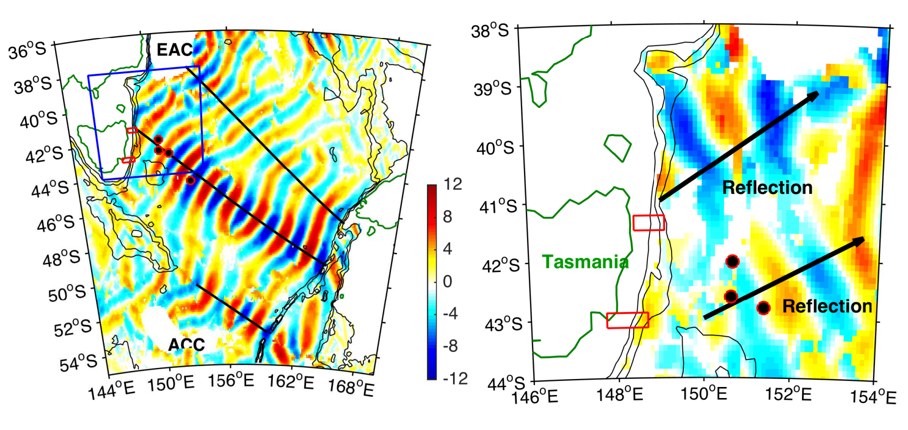


- Two missions, fits: η, u, and v
- incoming towards NW
- reflection ENE
- Consistent with gross expectation

Altimetry Observations

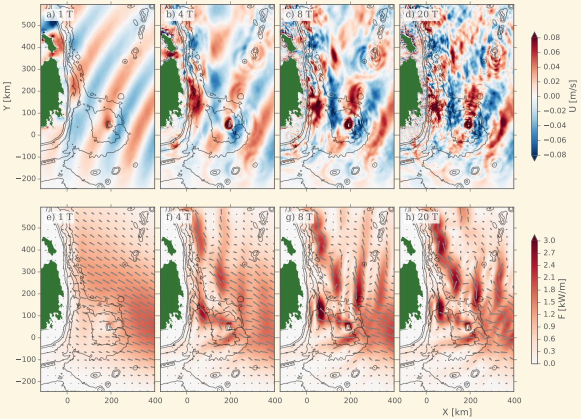
Zhonxiang Zhao, APL/UW & Matthew Alford, SIO



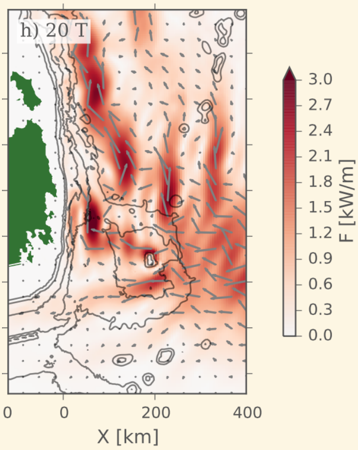
- Analyze altimeter tracks
- Decompose locally into two plane waves
- Note reflection "split"

Response

MITgcm; realistic bathymetry



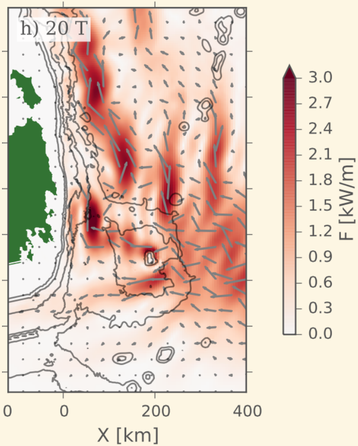
Points



Model gives some guidance as to what is happening here:

- Tasman Rise diffracts incoming energy
  - Localized energy: hard to do plane-wave fits
  - We don't *know* what the incoming flux is
- There is a strong super-inertial BT/BC slope wave that redistributes energy along shelf.

Points



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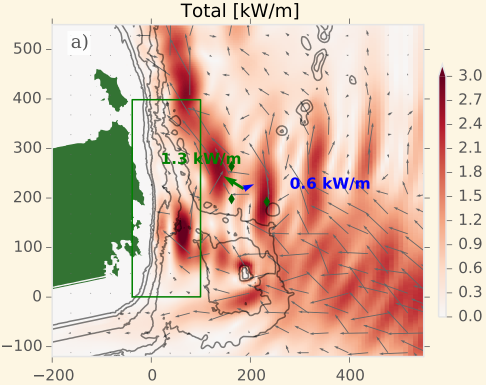
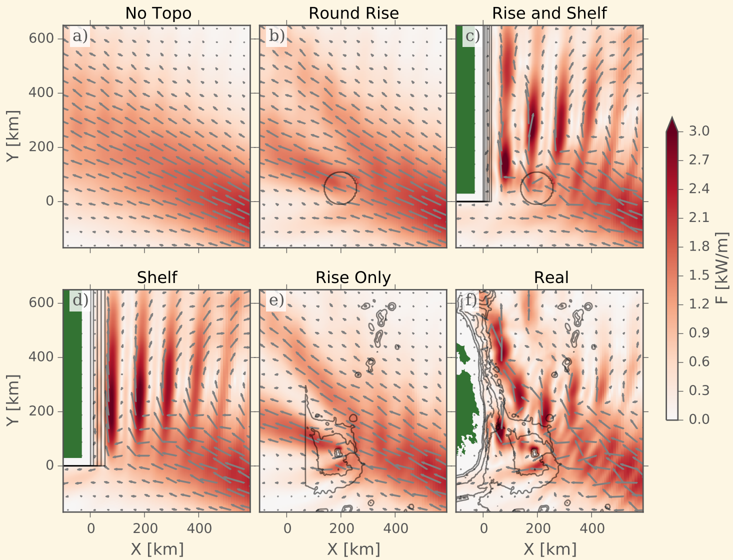
Two-waves: mooring

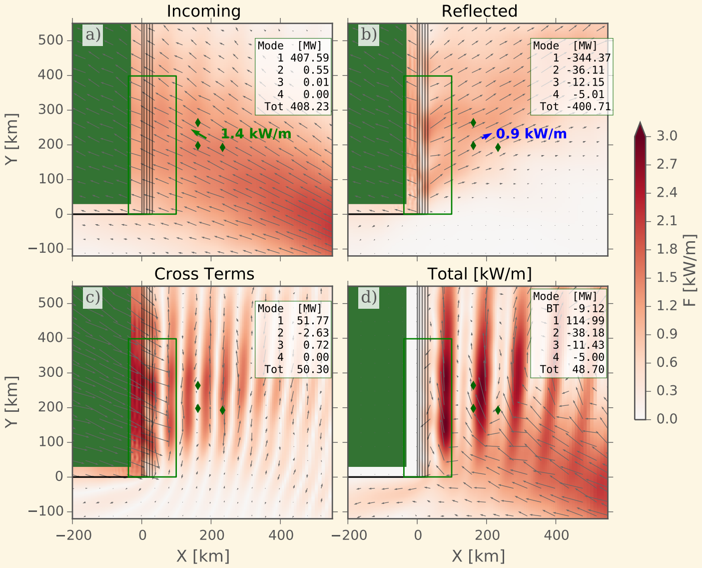


- Two-wave plane fit
- $F_{in} = 1.3\ kW/m$, $F_{out} = 0.6\ kW/m$
- $D > 0.5F_{in}$!
- Do we believe this (hint: no, below we will show $D \approx 0.25F_{in}$).

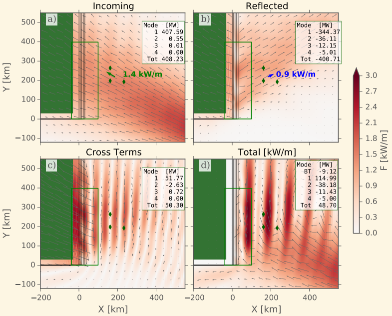
Incoming versus outgoing: Simplified Geometries



Incoming versus outgoing: Simple Shelf



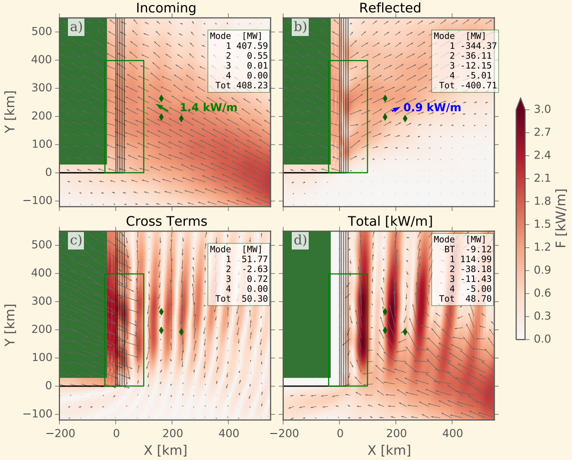
Incoming vs Outgoing



$$u_1^t(x,y) = u_1^i + u_1^r$$
$$v_1^t(x,y) = v_1^i + v_1^r$$
$$p_1^t(x,y) = p_1^i + p_1^r$$

$$F_{u1}^t = \overbrace{u_1^i p_1^i}^{Incoming} + \overbrace{u_1^r p_1^r}^{Reflected} + \overbrace{u_1^i p_1^r + u_1^r p_1^i}^{Cross\ \ Terms}$$
$$F_{v1}^t = \overbrace{v_1^i p_1^i}^{Incoming} + \overbrace{v_1^r p_1^r}^{Reflected} + \overbrace{v_1^i p_1^r + v_1^r p_1^i}^{Cross\ \ Terms}$$

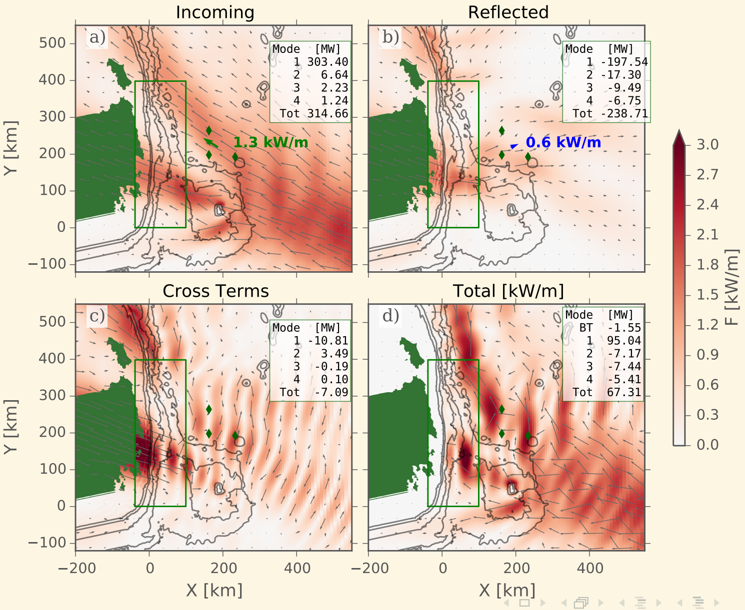
Incoming vs Outgoing: Simple shelf



- In: +408 MW
- Cross: + 50 MW
- Out: -400 MW
- Diss: 50 MW = 11%

(Note: slight energy imbalance – 58 vs 50 MW – because "Incoming" energy fluxes are inaccurate over shelf.)

Incoming vs Outgoing: Realistic



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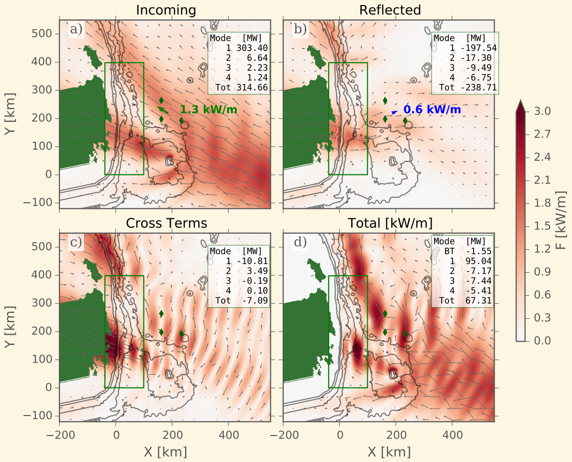
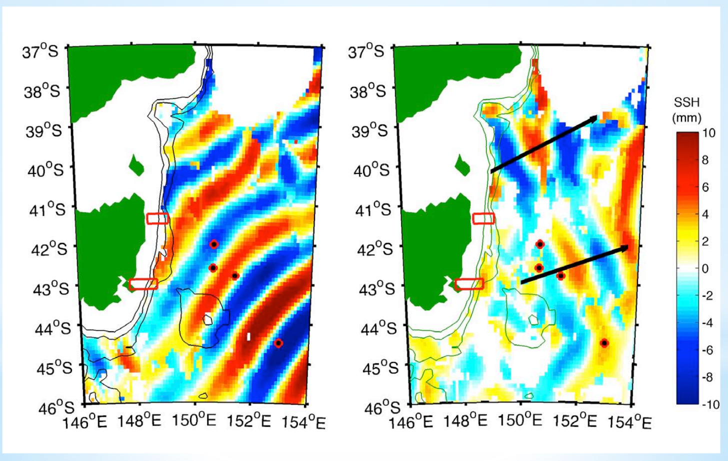


- In: +314 MW (vs +408 MW w/o Tasman Rise)
- Cross: - 7 MW
- Out: -238 MW
- Diss: 67 MW = 22% (vs 40% if we assumed Tasman Rise didn't matter)

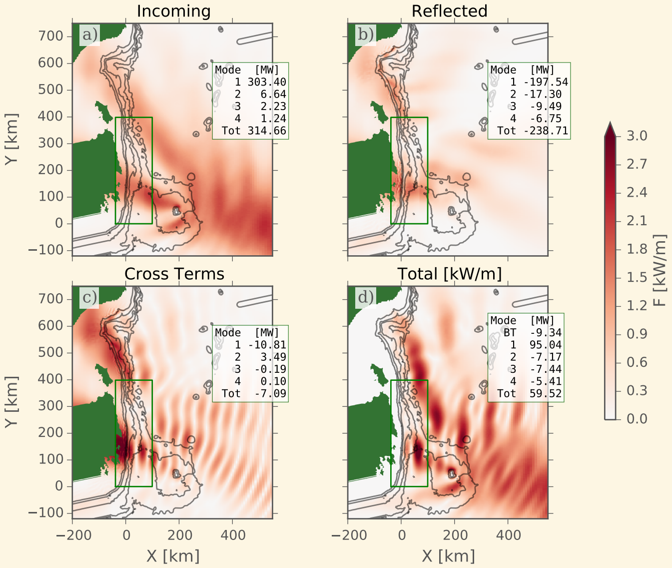
(Note: slight energy imbalance – 69 vs 67 MW – because "Incoming" energy fluxes are inaccurate over shelf.)

Diffraction: Altimeter estimates

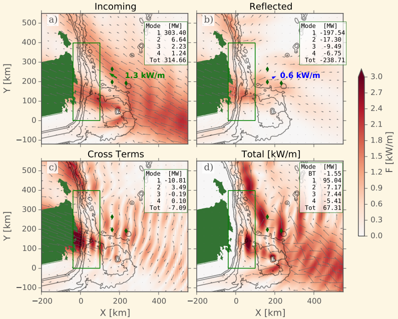


- Z. Zhao Altimeter measurements..

Diffraction: Model



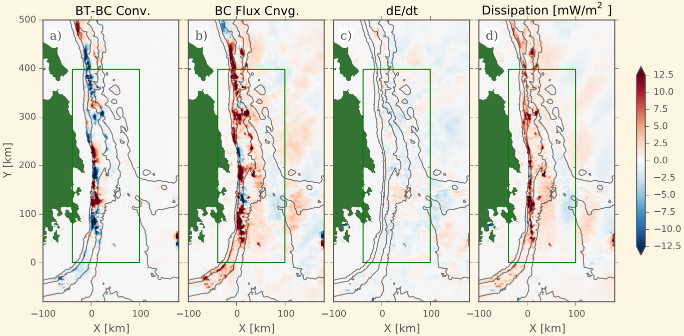
Incoming versus outgoing: Realistic



- Mooring:
  $(1.3 - 0.6)/1.3 \;\; [\mathrm{kW\,m^{-1}}] = 53\%$
- Model Mode 1 only:
  $(303 - 207)/303 \;\; [\mathrm{MW}] = 30\%$
- Model Total: $69/315 \;\; [\mathrm{MW}] = 22\%$

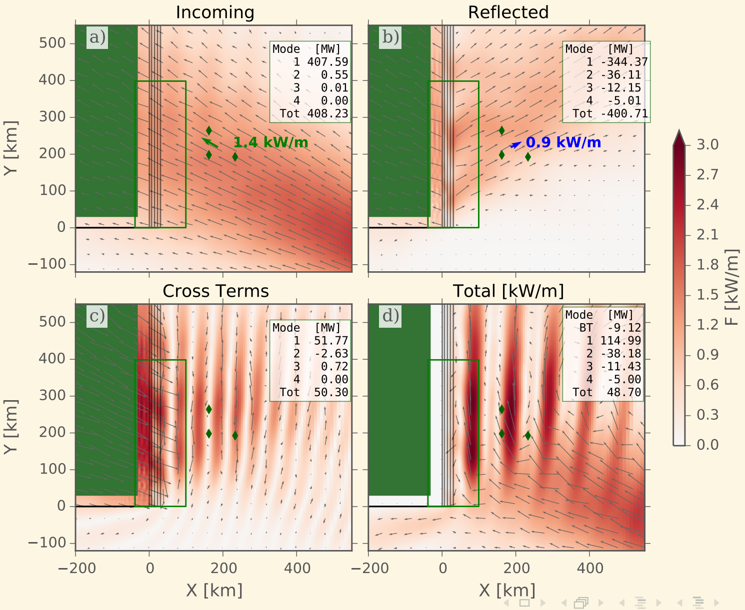
Slope Wave

Vertically integrated energy budget



- Alternating BT/BC conversion.
- $\lambda \approx 100$ km

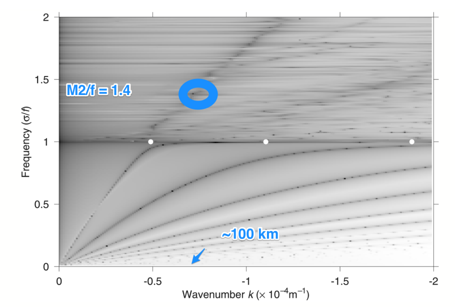
Slope Wave



Incoming
Reflected
Cross Terms
Total [kW/m]
a)
b)
c)
d)
Mode [MW]
1 407.59
2 0.55
3 0.01
4 0.00
Tot 408.23
1.4 kW/m
Mode [MW]
1 -344.37
2 -36.11
3 -12.15
4 -5.01
Tot -400.71
0.9 kW/m
Mode [MW]
1 51.77
2 -2.63
3 0.72
4 0.00
Tot 50.30
Mode [MW]
BT -9.12
1 114.99
2 -38.18
3 -11.43
4 -5.00
Tot 48.70
Y [km]
X [km]
F [kW/m]

Slope Wave

Dale et. al. 2001: Super-inertial shelf waves



- *Not* freely-propagating (forced)
- "Near-resonant" waves depend on shelf geometry.

Slope Wave

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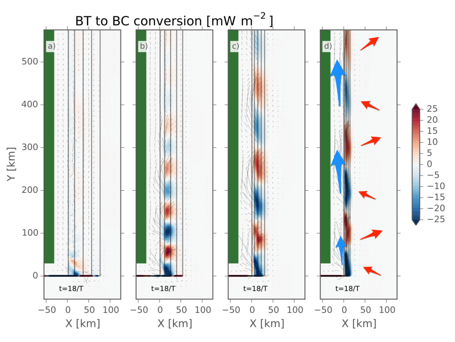

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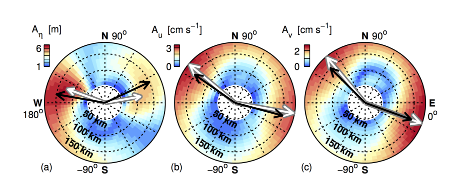
Summary

What have we learned about internal tide?

1. Two-wave solution good first step, but hard to use to get net flux (dissipation)
2. Significant diffraction around Tasman Rise.
3. Super-inertial slope waves redistribute energy along slope.

Complex incoming field and complex reflection implies difficult to quantify reflection experimentally.



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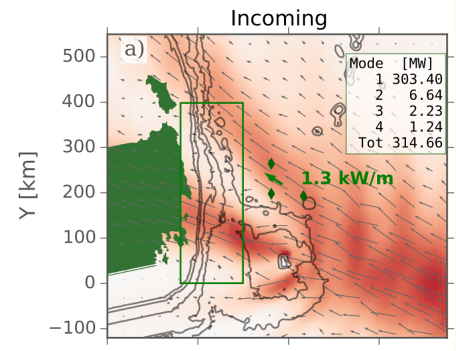

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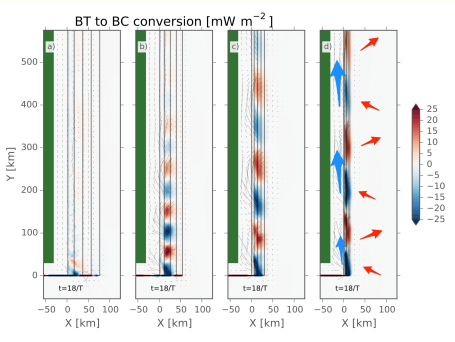

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