Tasmania internal tide experiment: Preliminary modeling

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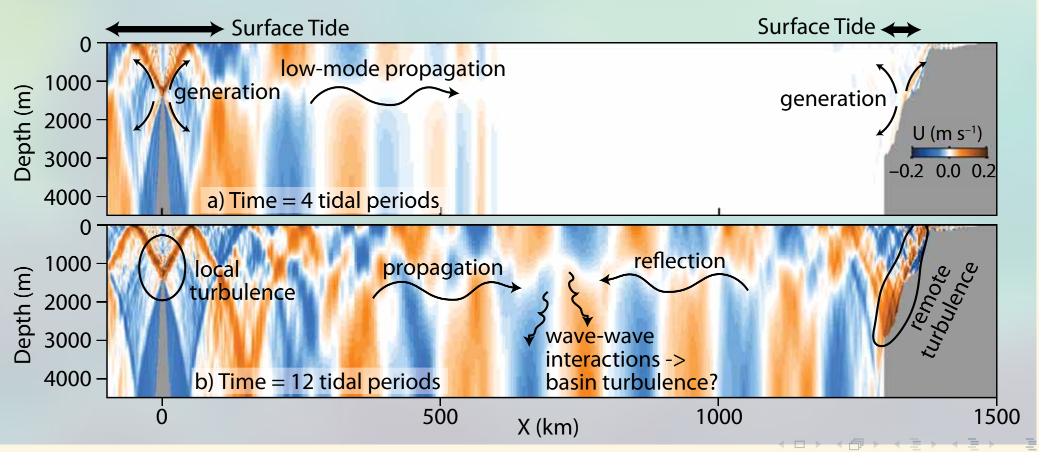
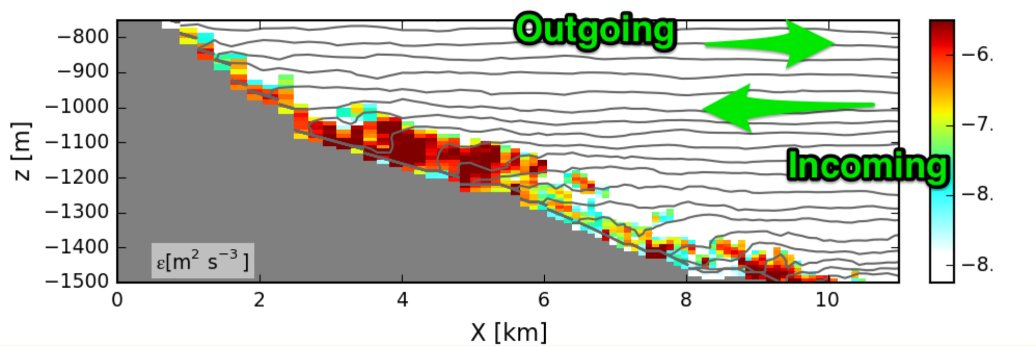
University of Victoria
June 26, 2015



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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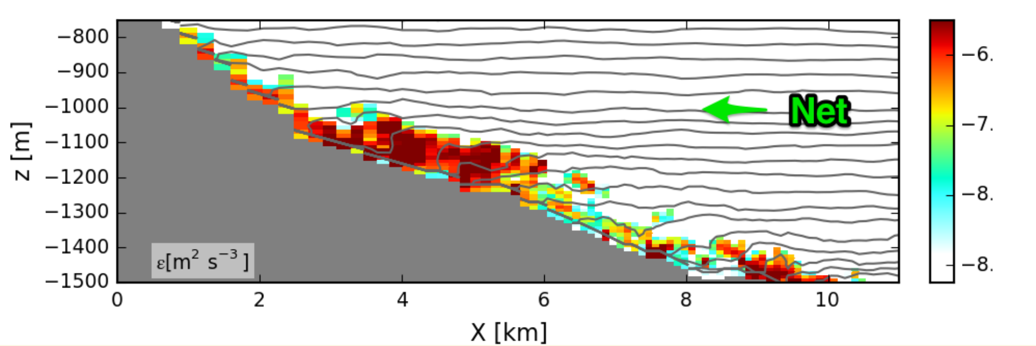

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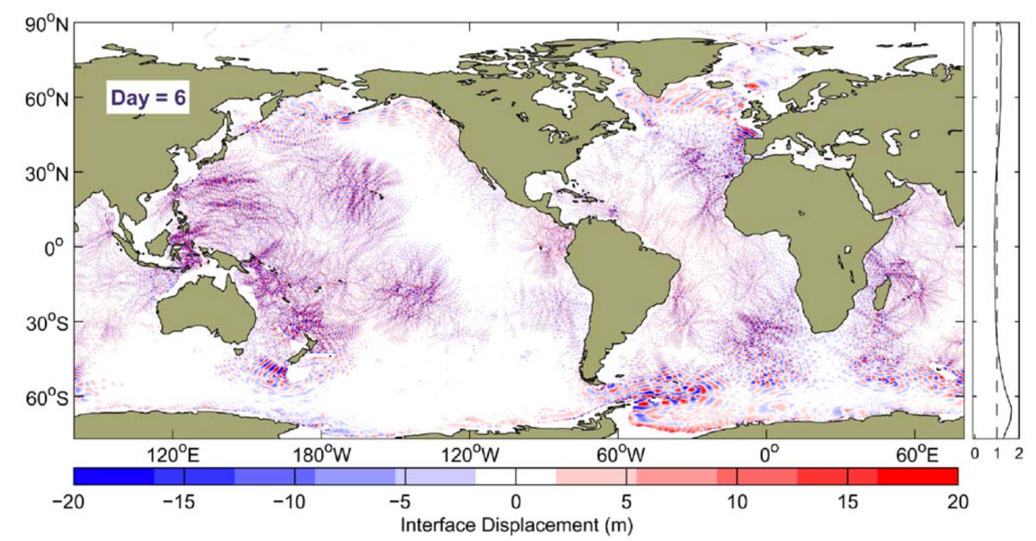
TTide: Tasmania Internal Tide Experiment



Simmons et al 2004

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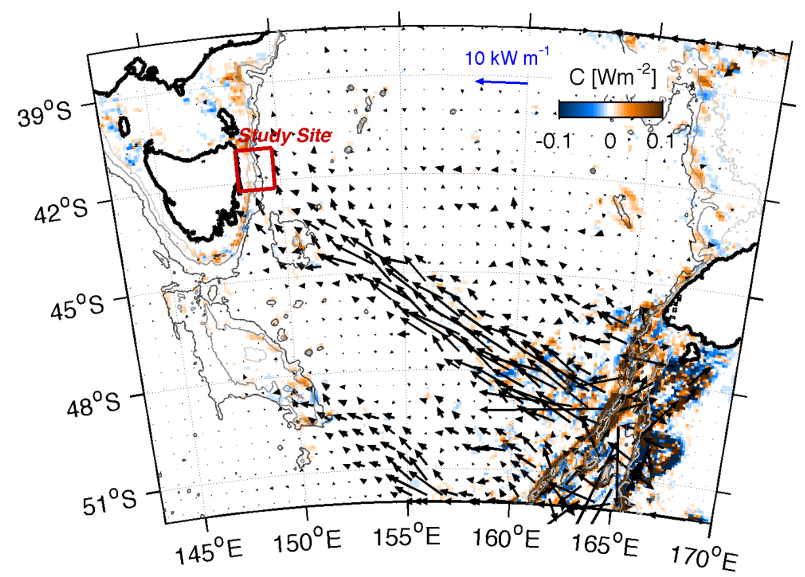

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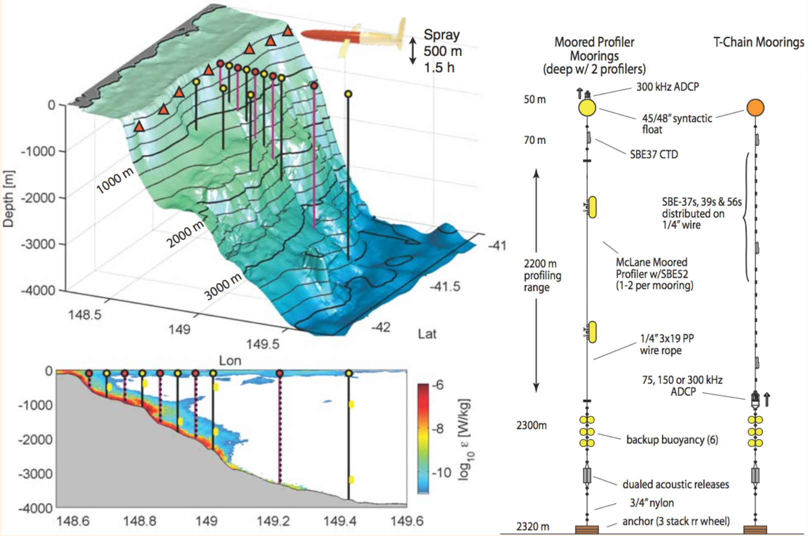
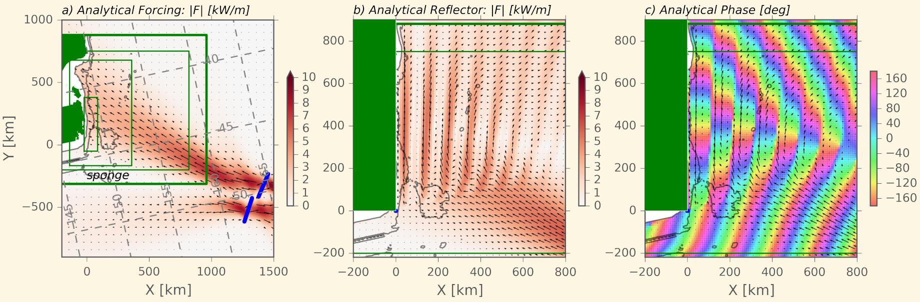
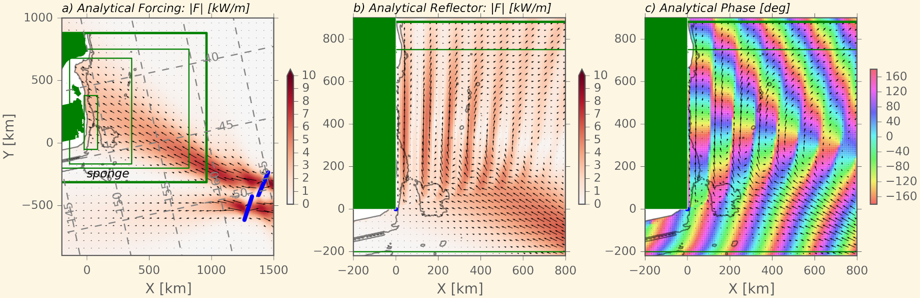


Setup



- 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

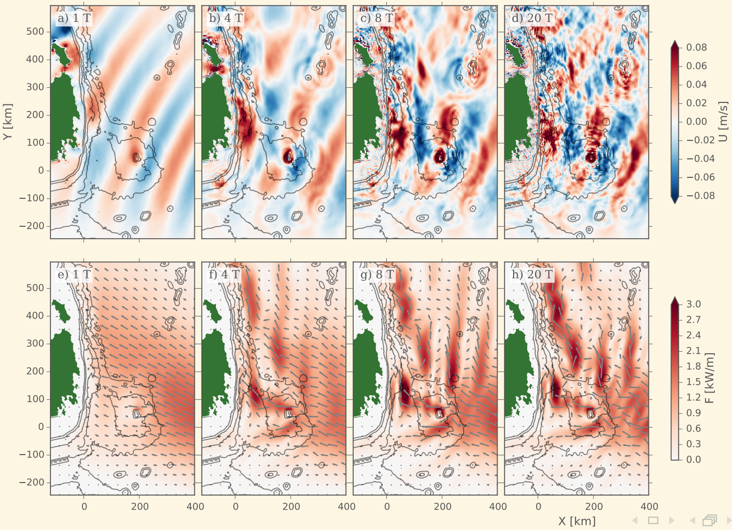
Simple Response?



- 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.

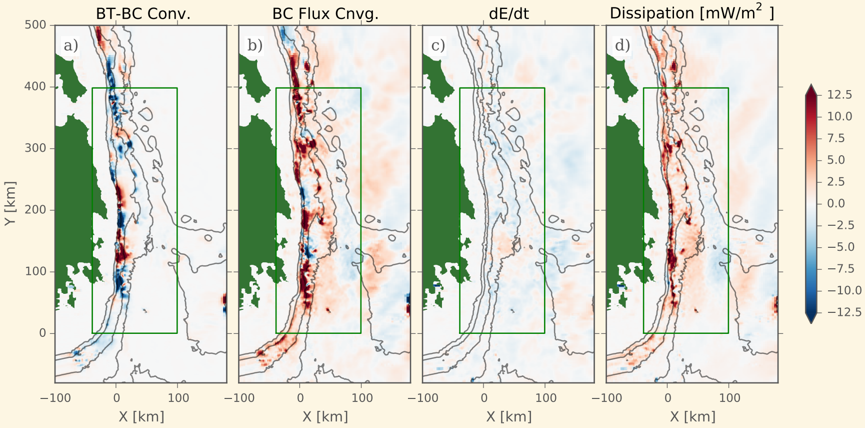
Response

MITgcm; realistic bathymetry

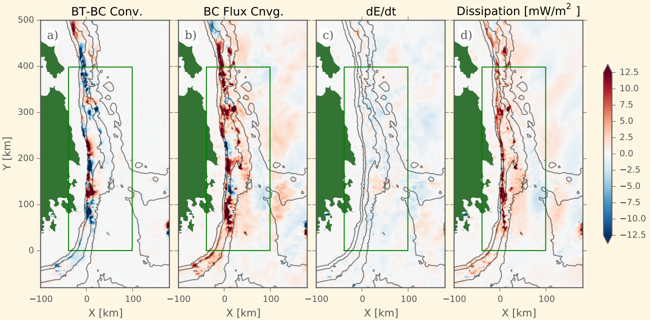


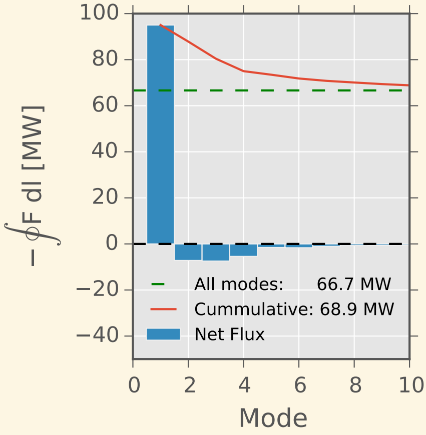
Response

Energy Budget (Depth-integrated; tidally averaged)

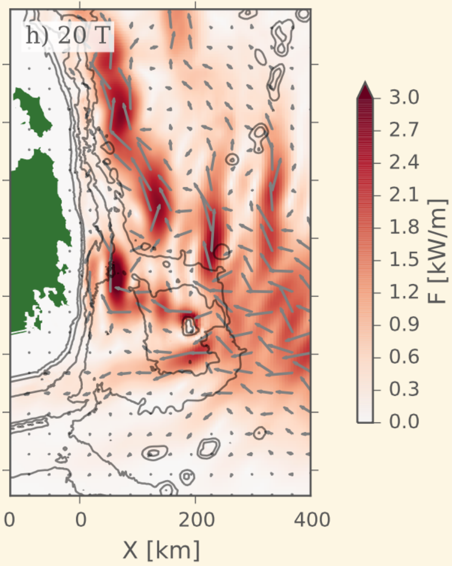


Net Energy Budget





Points



- Tasman Rise diffracts incoming energy
  - Localized energy: hard to do plane-wave fits
  - We don't *know* what the incoming flux is
- Reflectivity is somewhat less than 2-D reflectivity estimates
- There is a strong super-inertial BT/BC slope wave that redistributes energy along shelf.

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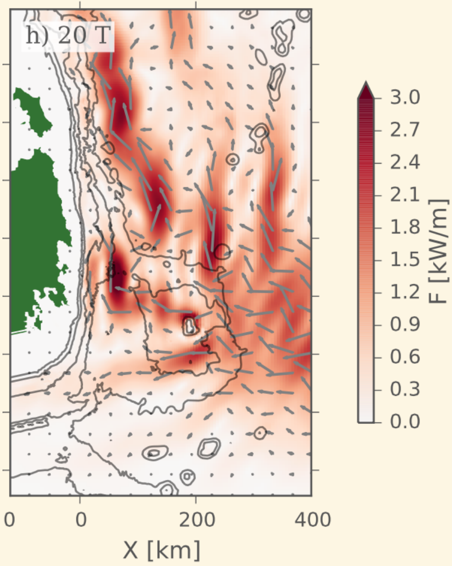

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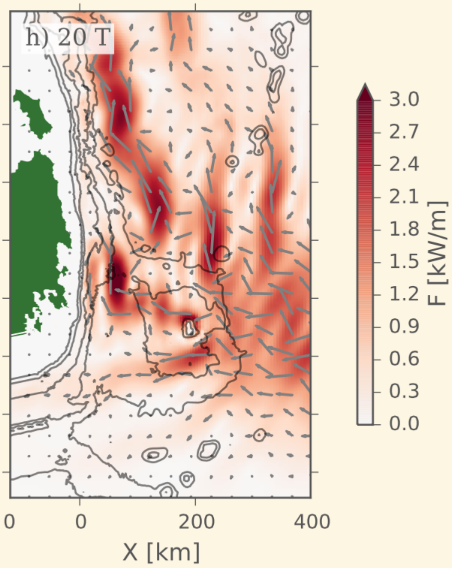

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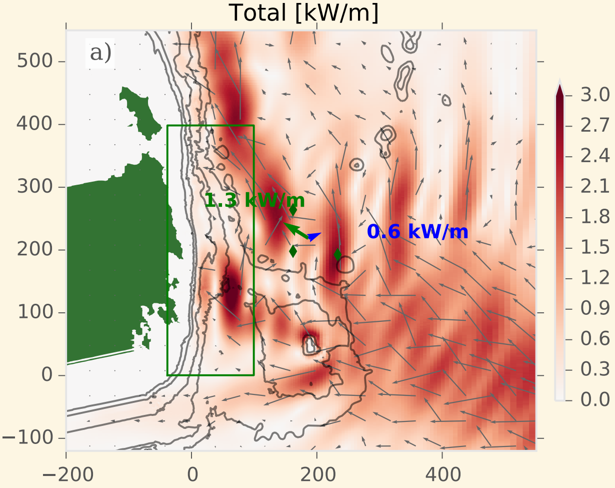
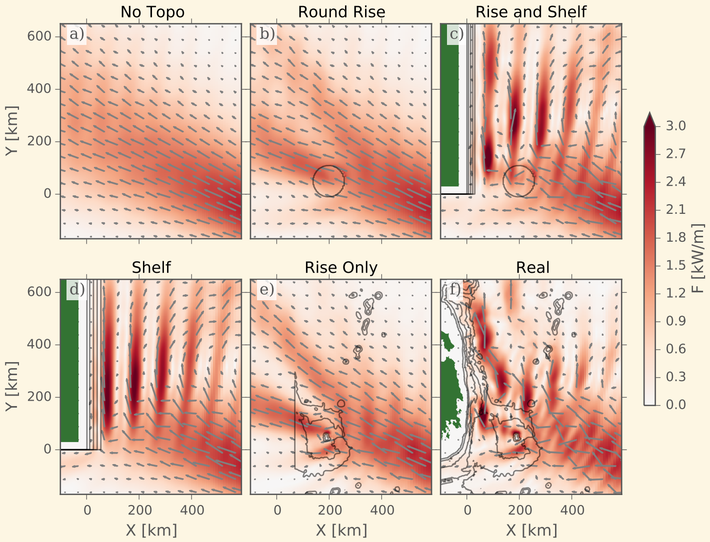
Two-waves: mooring

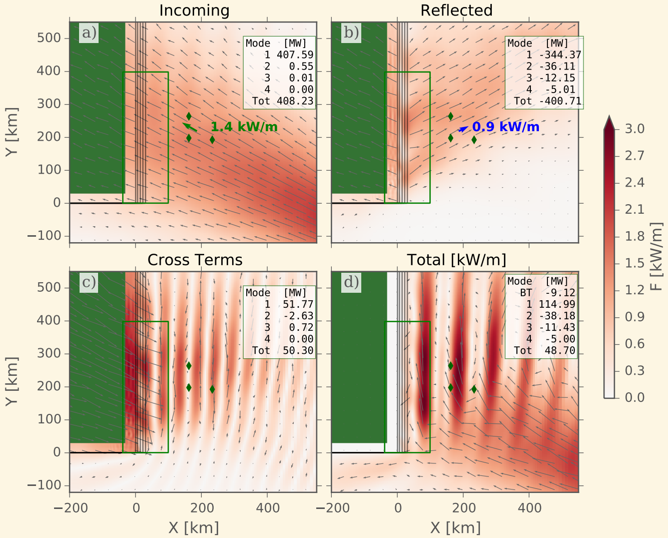


- Two-wave plane fit
- $F_{in} = 1.3\ kW/m$, $F_{out} = 0.6\ kW/m$
- $D > 0.5F_{in}$!
- Do we believe this (hint: no, below we will show $D \approx 0.25F_{in}$).

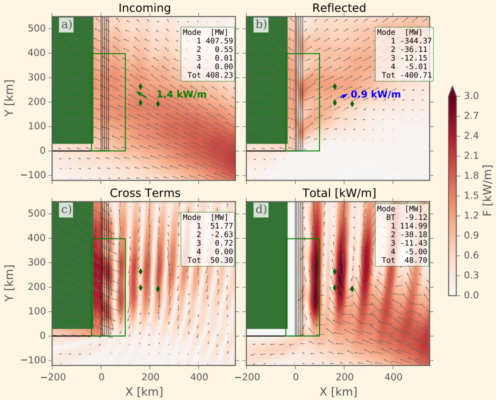
Incoming versus outgoing: Simplified Geometries



Incoming versus outgoing: Simple Shelf



Incoming vs Outgoing



$$
\begin{aligned}
u_1^t(x,y) &= u_1^i + u_1^r \\
v_1^t(x,y) &= v_1^i + v_1^r \\
p_1^t(x,y) &= p_1^i + p_1^r
\end{aligned}
$$

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

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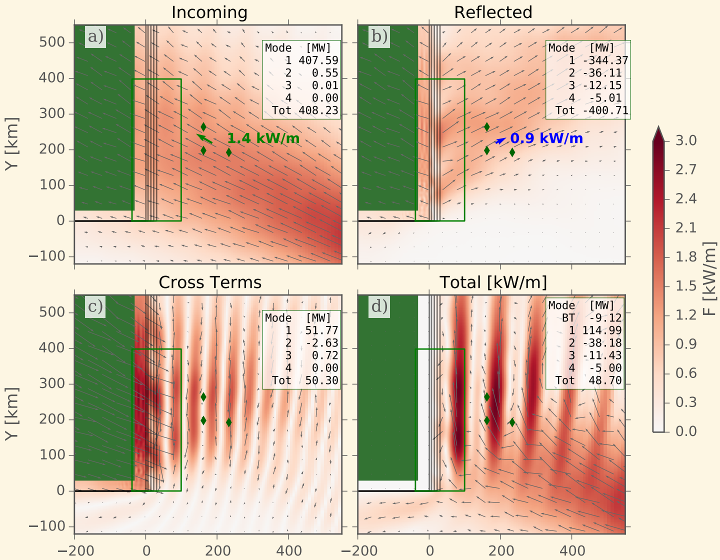
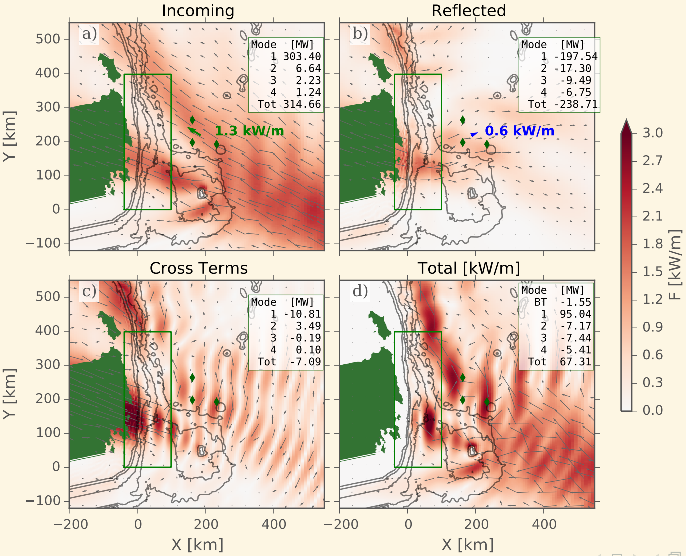


- In: +408 MW
- Cross: + 50 MW
- Out: -400 MW
- Diss: 50 MW = 11%

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

Incoming vs Outgoing: Realistic



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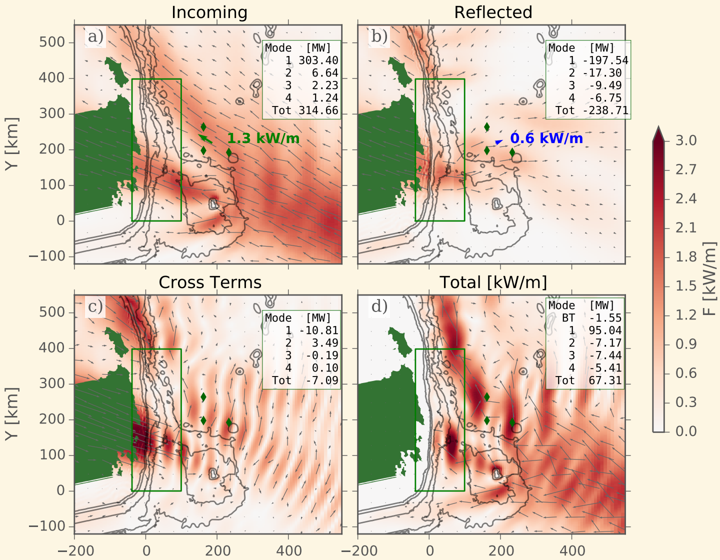
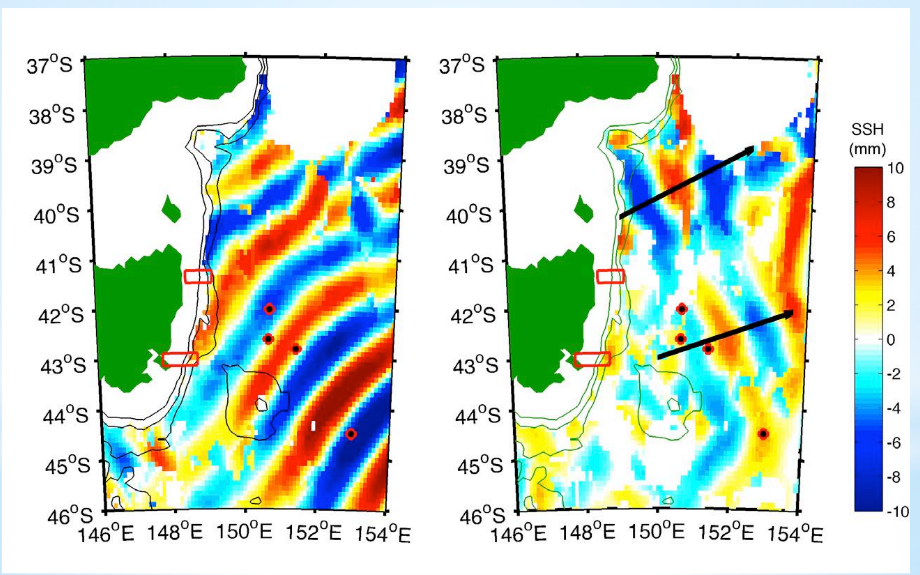


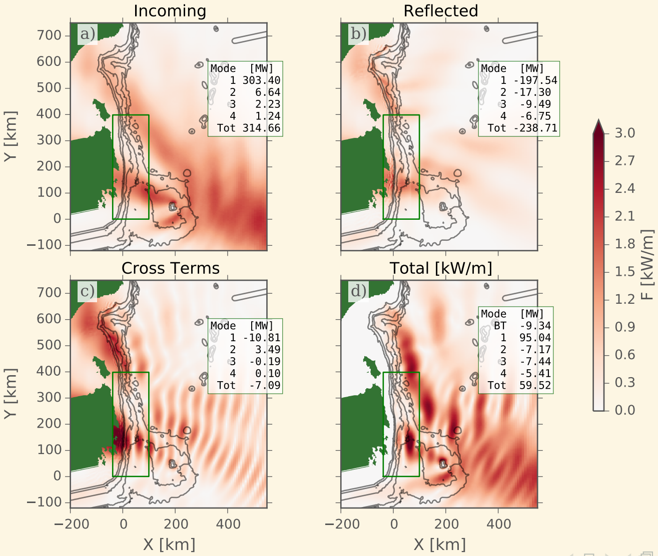
- In: +314 MW (vs +408 MW w/o Tasman Rise)
- Cross: - 7 MW
- Out: -238 MW
- Diss: 67 MW = 22% (vs 40% if we assumed Tasman Rise didn't matter)

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

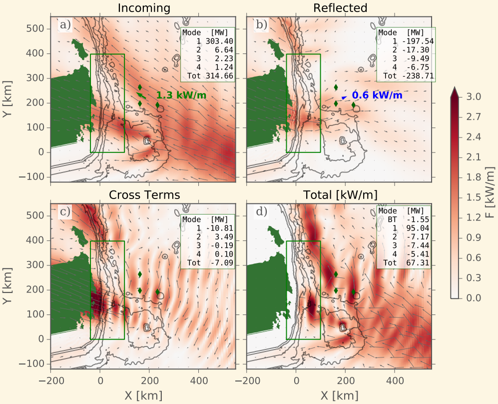
Diffraction: Altimeter estimates



Diffraction: Model



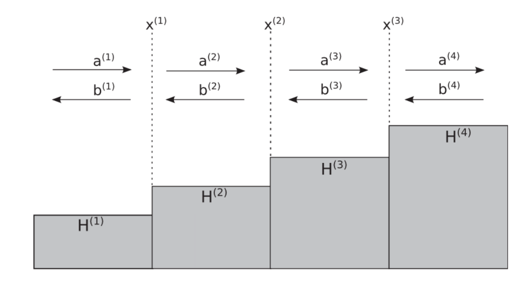
Incoming versus outgoing: Realistic

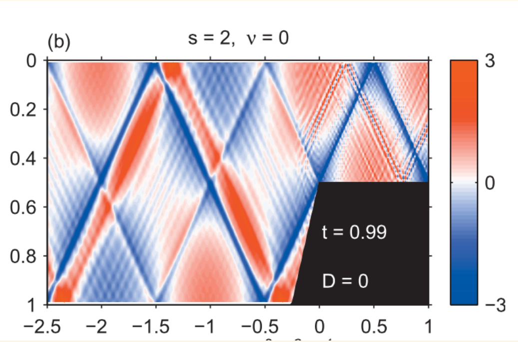


- Mooring: $(1.3 - 0.6)/1.3 \quad [\mathrm{kW\,m^{-1}}] = 53\%$
- Model Mode 1 only: $(303 - 207)/303 \quad [\mathrm{MW}] = 30\%$
- Model Total: $69/315 \quad [\mathrm{MW}] = 22\%$

Linear Model?

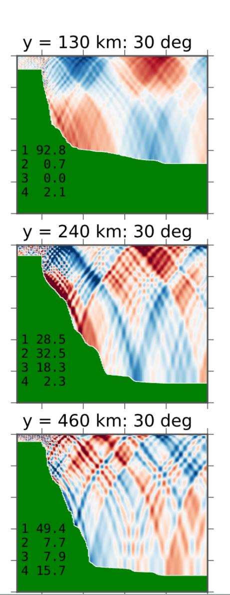
Kelly et al 2010

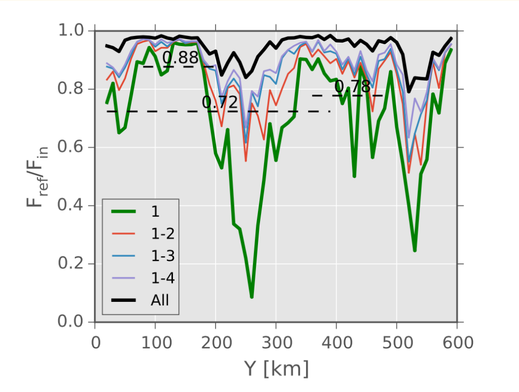




- Can calculate linear response to mode-1 forcing
- 2-D slices
- Can accommodate angular incidence.

Linear Model?

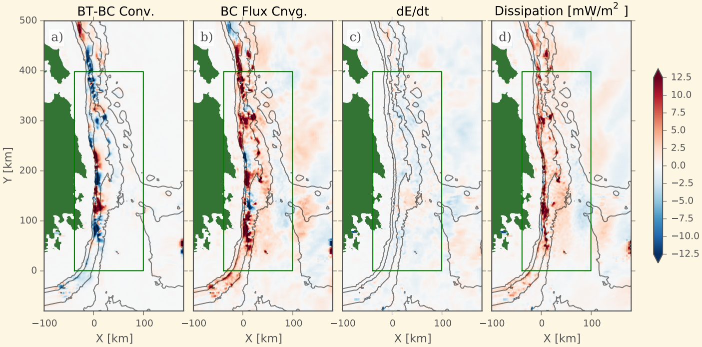




- Model: 70% reflected in mode-1
- Linear Calc: ≈ 80%
- Some three-dimensionality

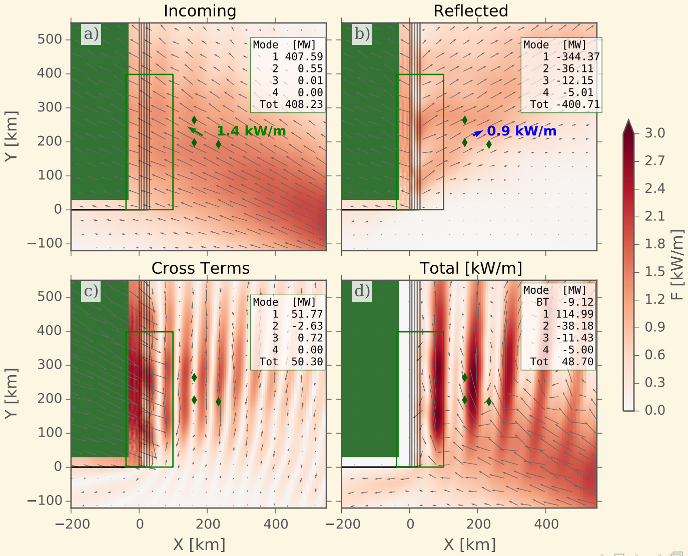
Slope Wave

Vertically integrated energy budget



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

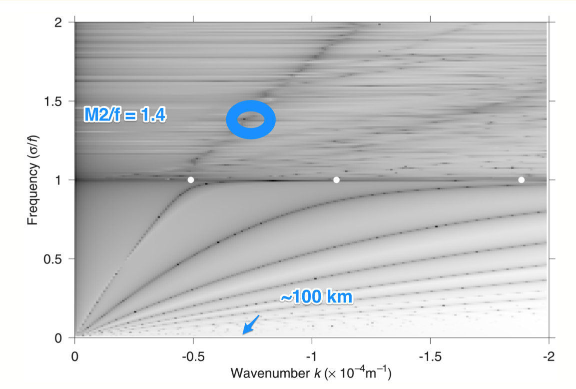
Slope Wave



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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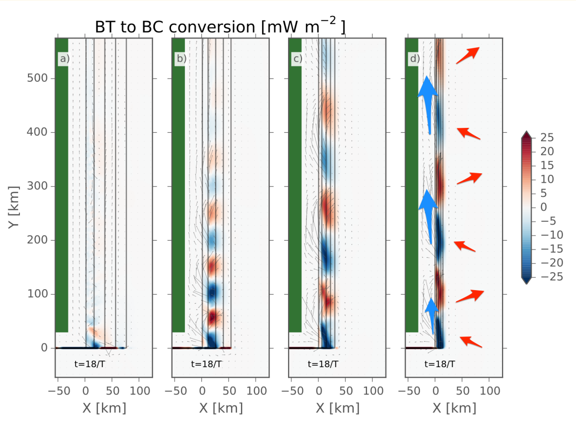

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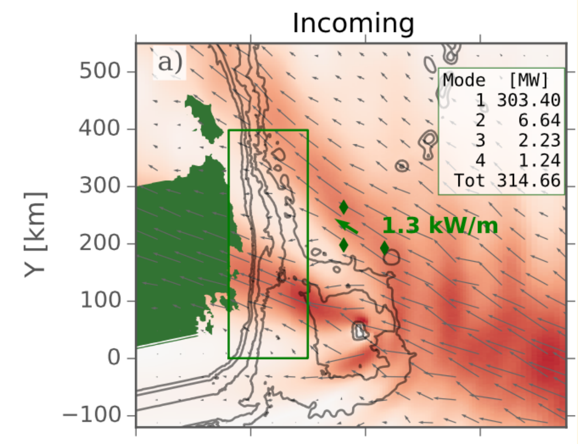
Summary

What have we learned about internal tide?

1. Significant diffraction around Tasman Rise.
2. Two-dimensional model captures some of the reflection.
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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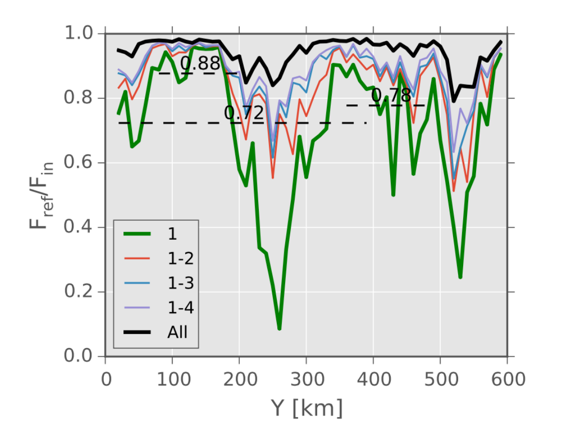

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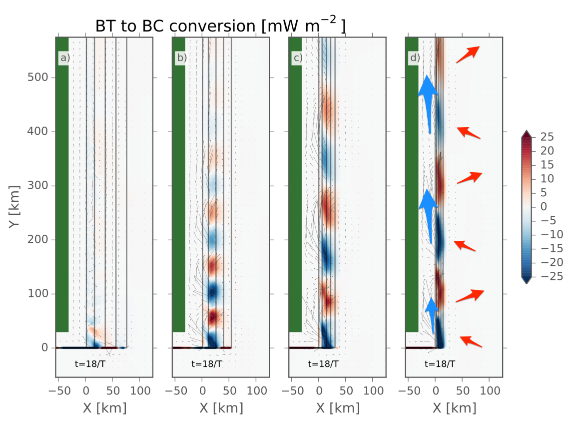

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