Using high-resolution simulations of South Georgia and New Zealand to assess orographic drag parametrization schemes

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Key Issues

- **NWP and Climate predictions are highly sensitive to the tuning of drag parametrization schemes, yet these remain crude and unconstrained.**
- **Mountains don’t move, but the drag processes are complex, intermittent and can be highly nonlinear.**
- **Drag from small mountainous islands may account for the missing drag in GCMs**.

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Aims

- Use high resolution model simulations to understand:
  - Processes responsible for drag e.g. role of mountain waves vs low-level drag process such as flow blocking and mountain wakes
  - How well do orographic drag parametrization schemes represent the drag?
  - Are the surface pressure drag and momentum fluxes predictable?
  - How do drag schemes behave across different resolutions?
- Use simulations of observed cases from observational campaigns to validate the simulations
- Focus on southern hemisphere mountainous islands:
  - Have concentrated on South Georgia Island (SG-WEX)
  - Now beginning to consider New Zealand (DEEPWAVE)

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SG-WEX Methodology

- Run 1-month simulations to generate statistical properties of gravity waves, wakes, pressure drag and momentum fluxes
  - Austral winter (deep GW propagation). July 2013.

- Compare results at high (1.5km) resolution with no drag parametrization, with lower (15km) resolution simulations.
  - Can the missing pressure drag and momentum fluxes at low resolution be represented by a parametrization scheme?

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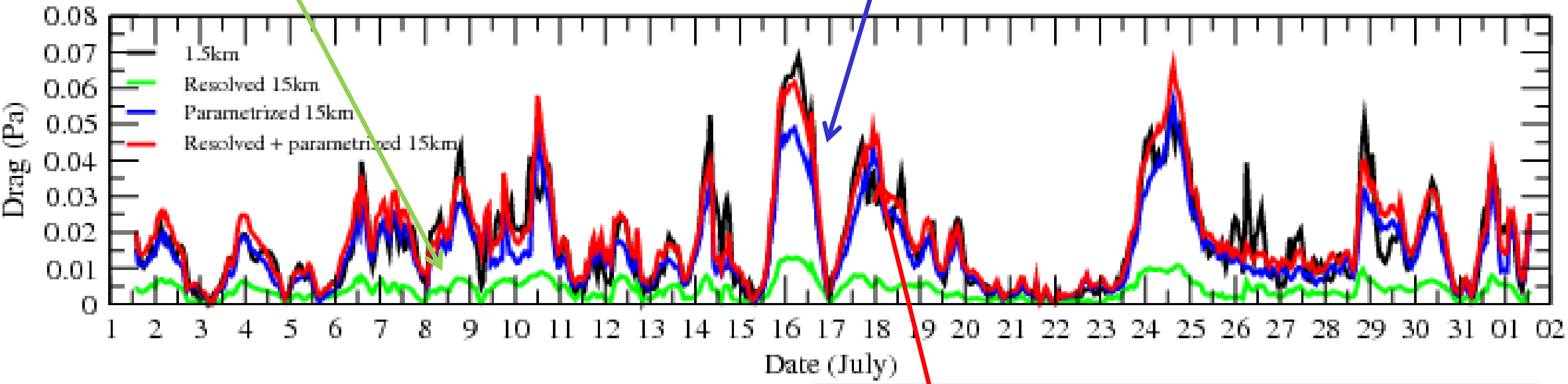
Resolved and parametrized drag at coarse resolution

•The drag is under-resolved on 15km grid

•Results suggest that enhancement of the drag, when flow is perpendicular to the sub-grid mountains, is under-represented by the parametrization scheme.

•Rectifying this in the parametrization scheme gives parametrized drag which is well correlated with drag in 1.5km simulation



Sum of resolved and parametrized drag in 15km simulation agree very well with 1.5km drag!

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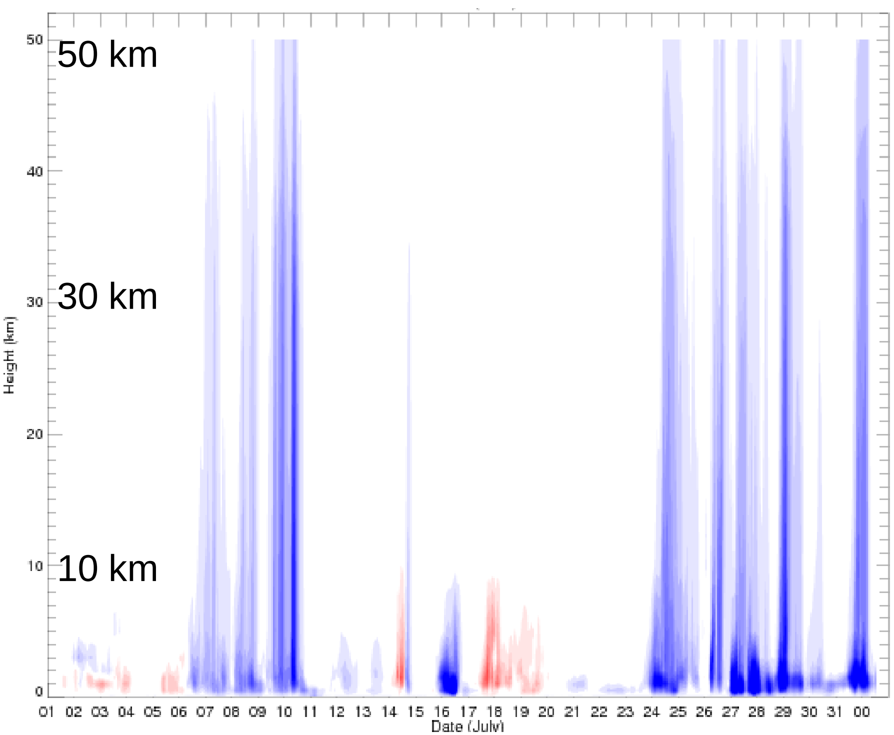
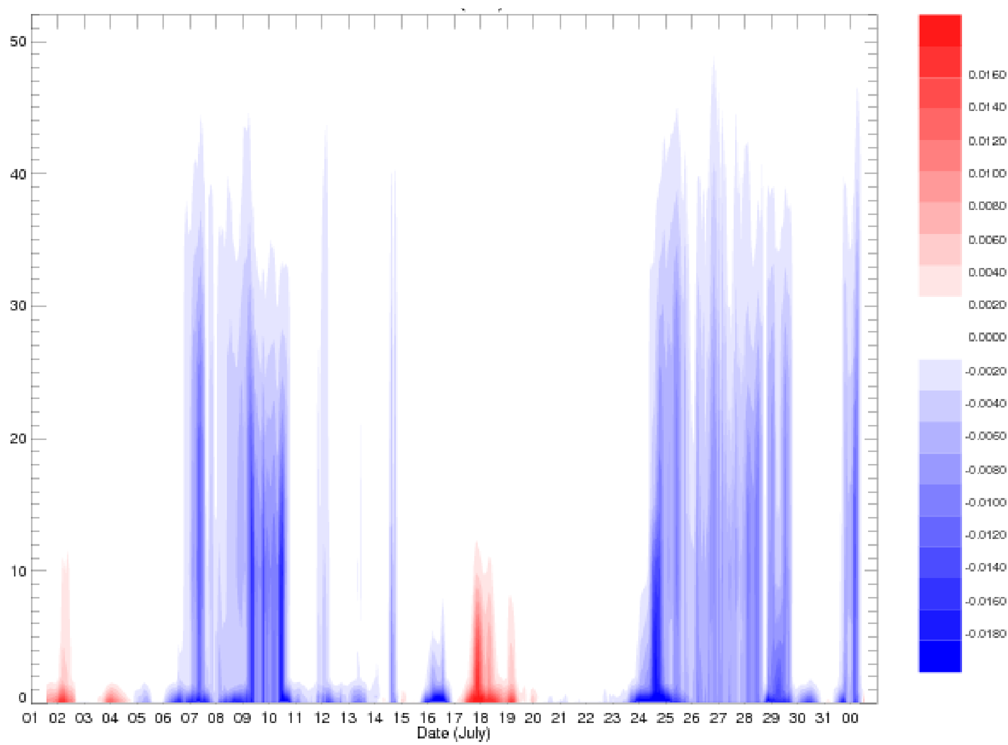
Parametrized vs resolved momentum fluxes

1.5km: resolved fluxes



15km: parametrized+resolved fluxes



- Momentum fluxes at coarse resolution compare well with those at high resolution
    - Greater intermittency and deeper wave propagation at high resolution

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DEEPWAVE simulations

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- Now considering broader mountain ranges than South Georgia
- Repeat methodology for some DEEPWAVE cases
  - Deep simulations with lid at 78 km
  - ENDGame dynamical core
- Nested simulations with a range of grid spacings
  - 2, 4, 8, 20 and 40 km.
  - Selected case studies driven by series of N512 global forecasts
- Would like to:
  - Use DEEPWAVE measurements (e.g., lidar) to validate (or otherwise!) the simulations
  - Compare simulations with results from other models

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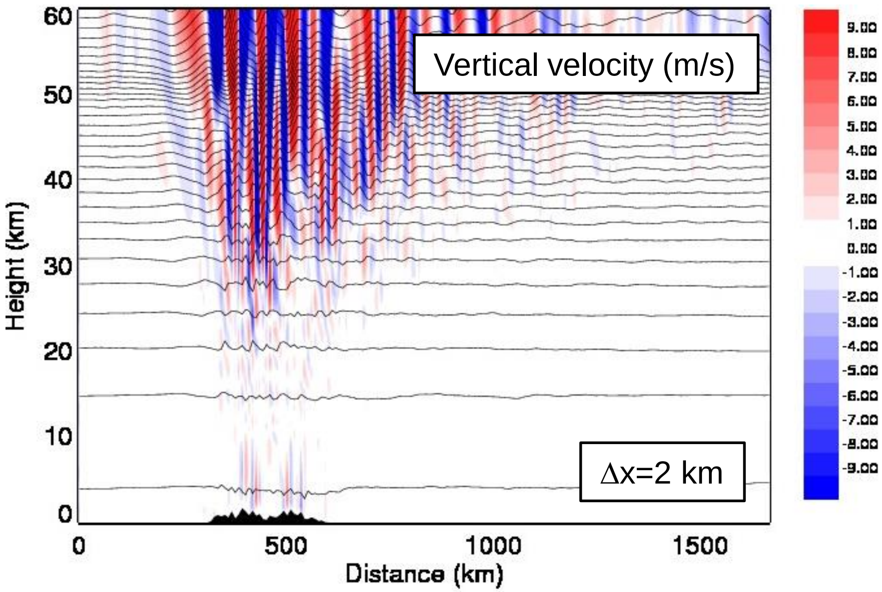
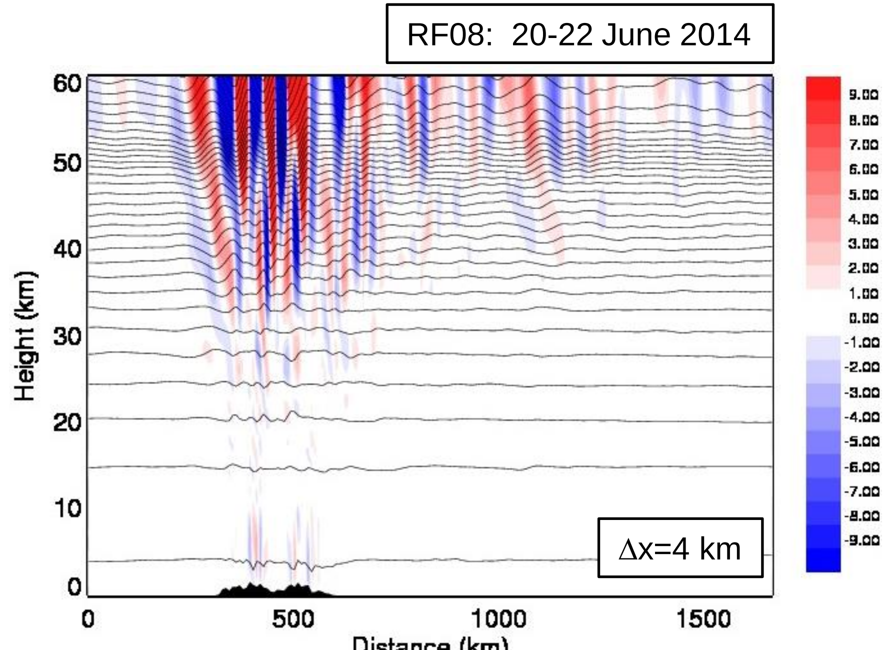
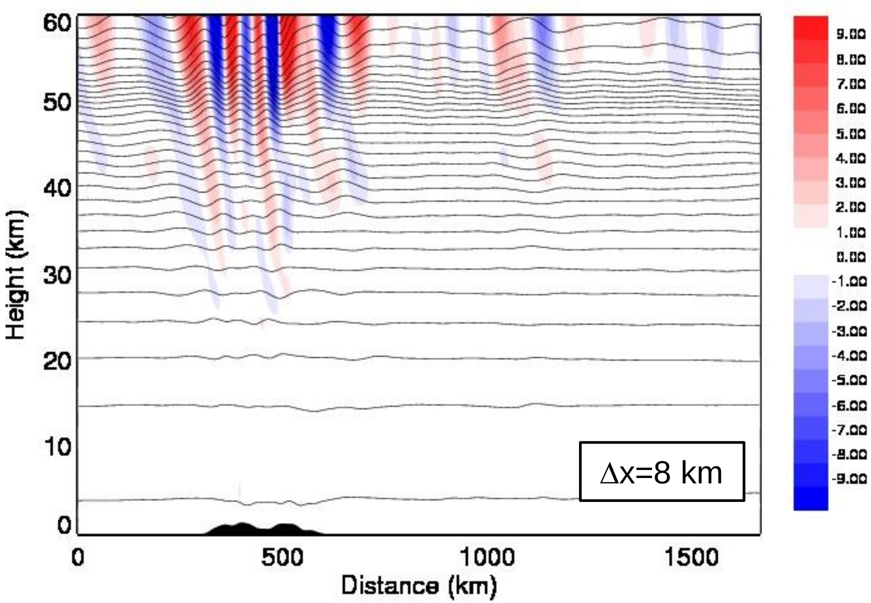
DEEPWAVE simulations for 20-22 June 2014

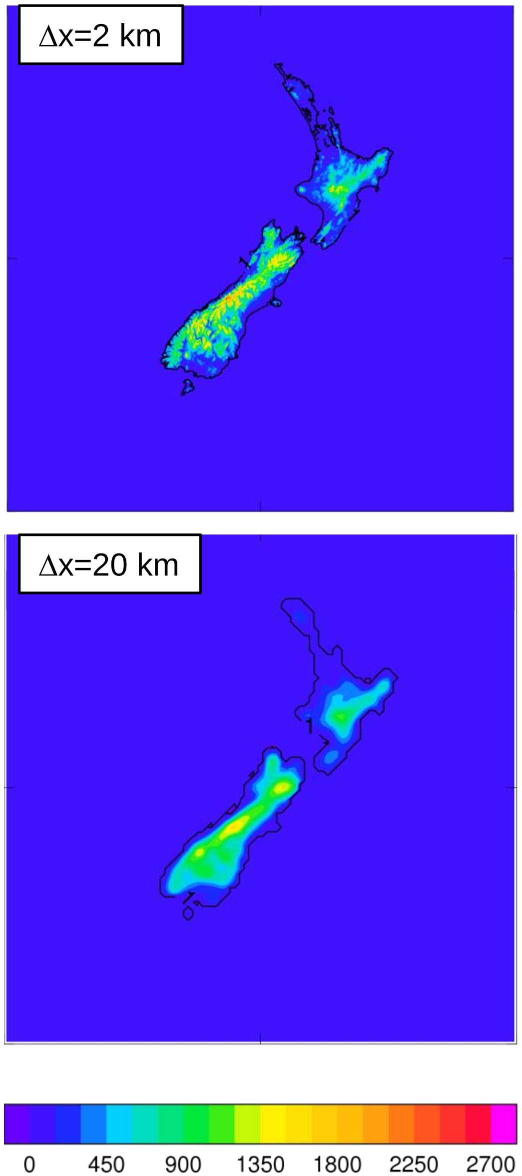


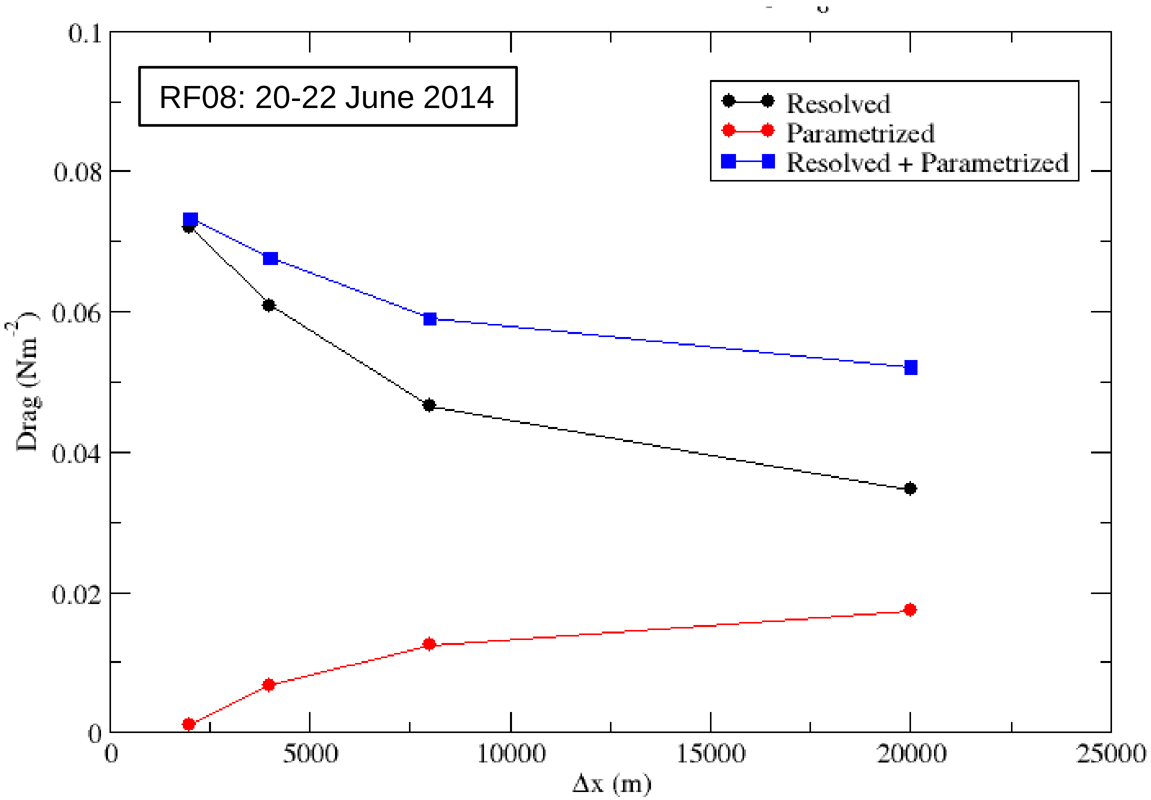




- Resolved mountain waves in initial DEEPWAVE simulations show a clear resolution sensitivity
- Mountain wave amplitude decreases monotonically with increasing grid length

How does drag vary with resolution for New Zealand?





- Extent to which total (resolved + parametrized) drag varies with resolution appears to be case dependent.

- Why is this?

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Conclusions: South Georgia

- Simulations suggest mountain-wave momentum fluxes penetrate high into the stratosphere and mesosphere.
- The high drag / momentum flux episodes are intermittent.
- A simple parametrization scheme, *when suitably tuned*, can represent the variation in low-level drag and momentum flux well.
- The drag and momentum fluxes are deterministic, at least for *relatively simple orography.*
- Paper just published in QJRMS:

Vosper (2015). DOI: 10.1002/qj.2566

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Further work: DEEPWAVE

- How are the resolved and parametrized waves represented at different resolutions?
  - Which parts of the GW spectra are resolved?
- Will the South Georgia GWD parametrization results hold for the much broader NZ mountain barrier?
- Simulations need to be validated against observations!
- What is the impact of NZ on the large scale flow?
- Questions:
  - Which cases to focus on?
  - Are others interested in collaborating, e.g., perhaps through model intercomparisons?

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