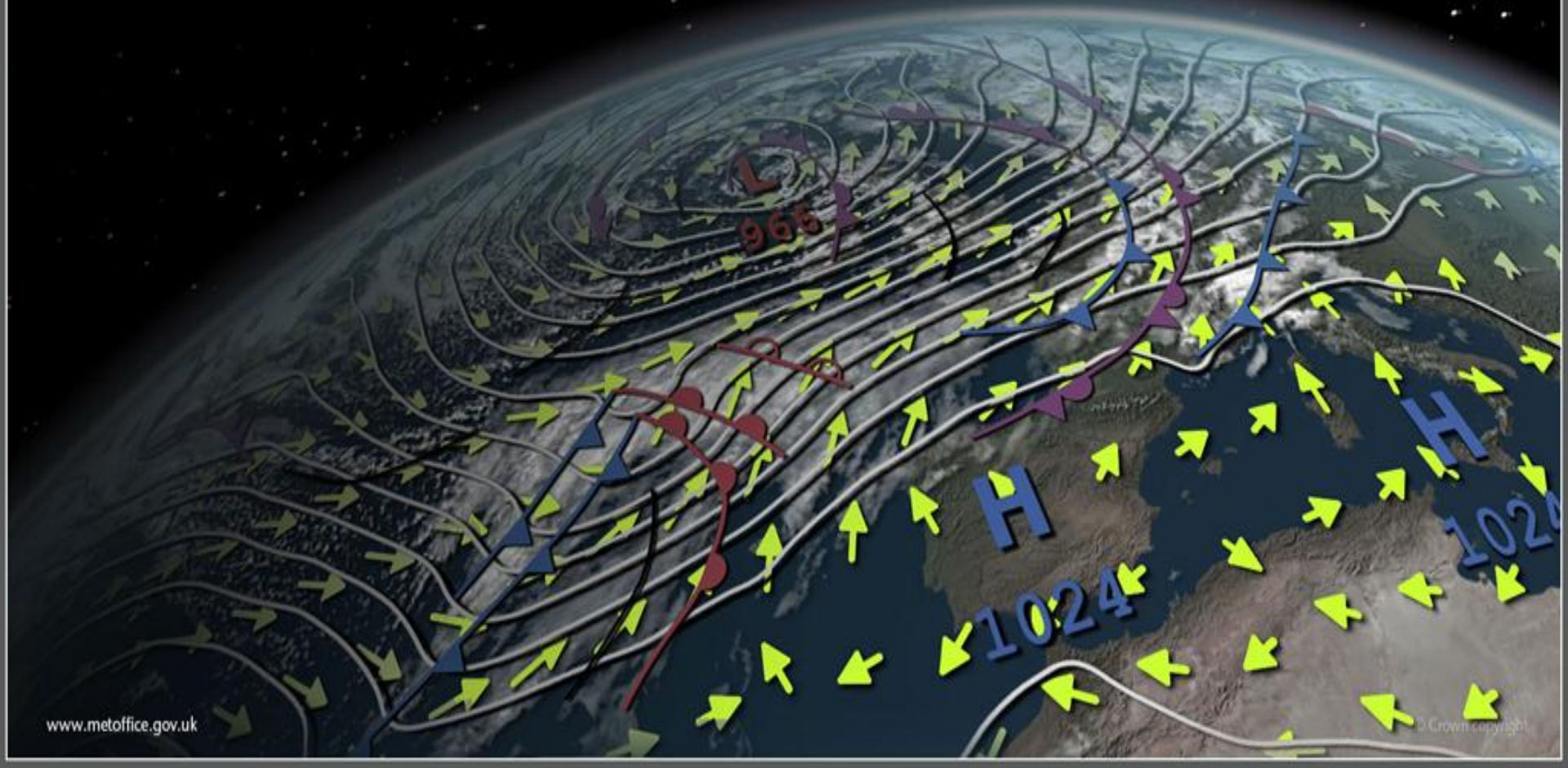
Orographic processes in polar regions

Simon Vosper and Andy Elvidge, Met Office

YOPP Workshop, Exeter. 09-10 November, 2015



Motivation

- Despite decades of research orographic processes are still poorly represented in global NWP and climate models.
  - NWP and climate predictions are highly sensitive to the tuning of drag parametrization schemes, yet these remain crude and unconstrained.
  - There is a need to better understand how well drag is represented in GCMs
- Currently models typically only parametrize orographic drag. Other sub-grid orographic processes have particular importance in polar regions, across timescales:
  - Wake effects, foehn, orographic enhancement of clouds and precipitation
- Arctic and Antarctic mountain ranges are a major source of orographic drag e.g. Antarctic coastal range, Scandinavia, Greenland, Alaska Range
  - Recent Met Office NWP performance at high latitudes has been a cause for concern.

Motivation contd.

- Polar regions lend themselves to unique orographic processes and impacts, presenting challenges to understanding and model representation
  - Strong mean zonal winds + orography:

    Major sources of gravity waves, often deep-propagating → polar stratospheric clouds

    'Extreme' weather e.g. Greenland tip jets → maritime hazard, implications for ocean circulation
  - Ice sheets + orography:

    Density driven katabatic winds → sea ice advection, impacts on deep water generation

    Foehn warming → ice shelf and glacial melt
  - Complex scale interactions:

    E.g. Large-scale katabatic flows across Greenland interact with smaller scale flows over coastal mountain range

Some recent progress

- **Orographic drag:**
  - High resolution models being used to assess behaviour of drag across range of resolutions
  - Focus on southern hemisphere mountainous island barriers - New Zealand, South Georgia Island – 'SGWEX'
- **Orographic enhancement of precipitation:**
  - Rain gauge observations used to assess sensitivity of orographic precip to horizontal resolution and develop a new parameterization – Smith et al., 2015, QJRMS, submitted
- **Wake effects and foehn:**
  - Observations and high resolution modelling of foehn winds and warming over the Antarctic Peninsula – 'OFCAP'
  - Antarctic Peninsula used as a natural laboratory to quantify leeside warming mechanisms
  - SGWEX

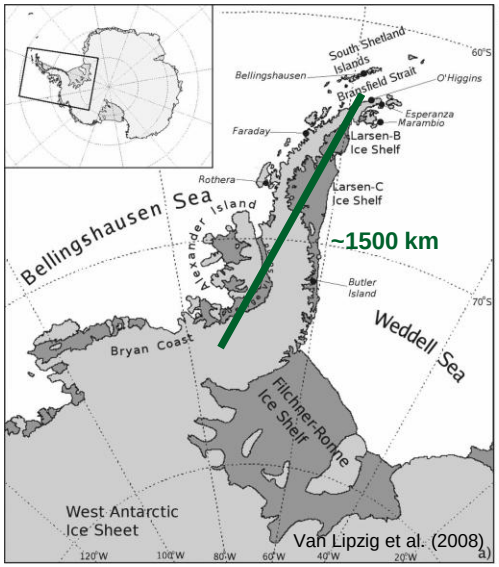
Mountains: Observations are limited! Polar mountains: Really limited!

Use high resolution simulations to represent the "truth".

Foehn winds and warming on the Antarctic Peninsula

OFCAP (Orographic Flows and Climate of the Antarctic Peninsula)

My PhD project, with Ian Renfrew, UEA

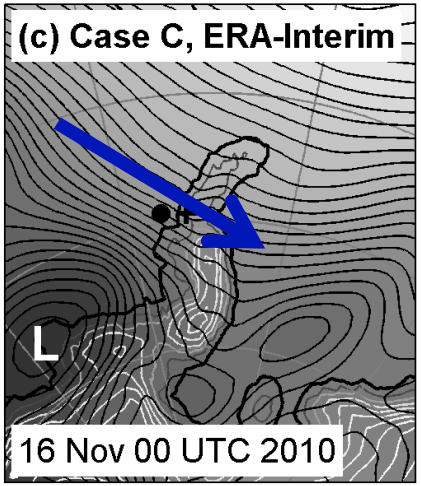


The Antarctic Peninsula

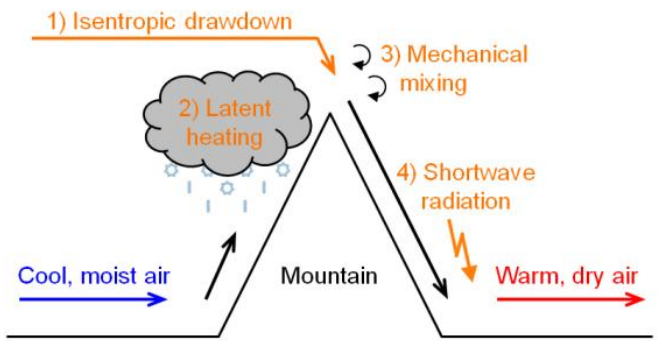
Long, high level ridge (mostly >1500m)

Within SH jet stream

Ice shelves on east coast



FOEHN WARMING MECHANISMS



University of East Anglia

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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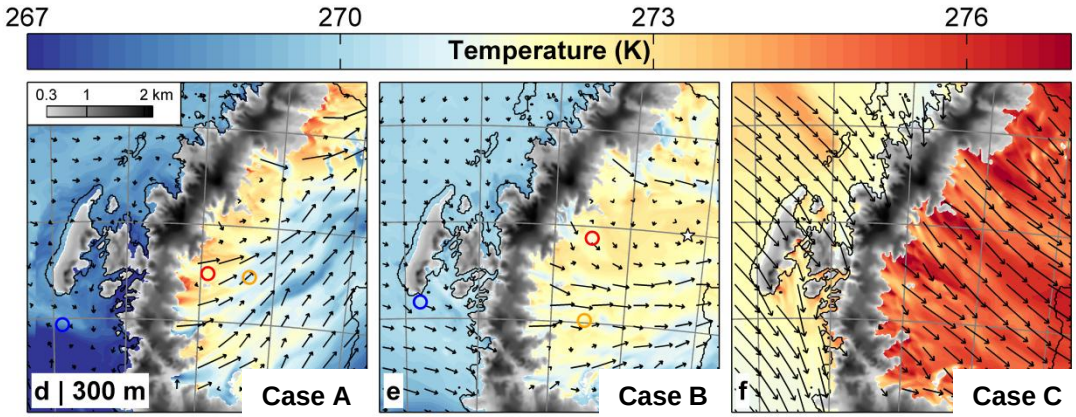
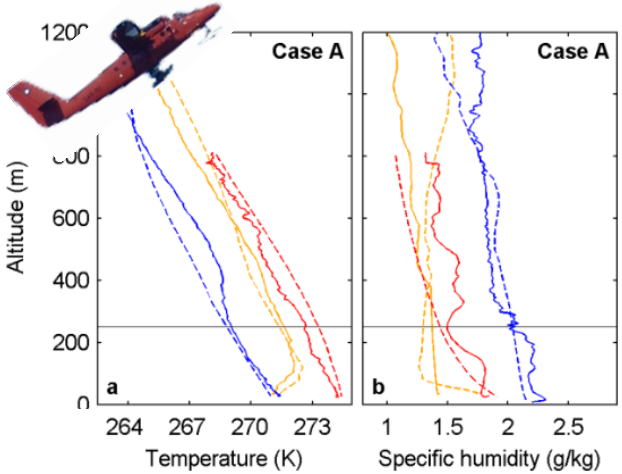
(Elvidge et al., 2015, BAMS)



Near surface temperature, MetUM 1.5 km

OFCAP field campaign: BAS's MASIN (instrumented Twin Otter aircraft)



Solid = obs

Dashed = MetUM 1.5km

UPWIND

DOWNWIND

FURTHER DOWNWIND

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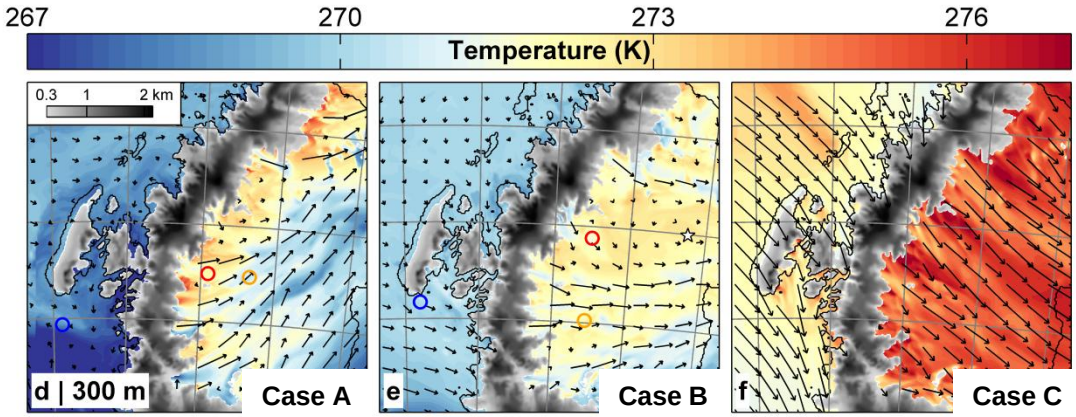
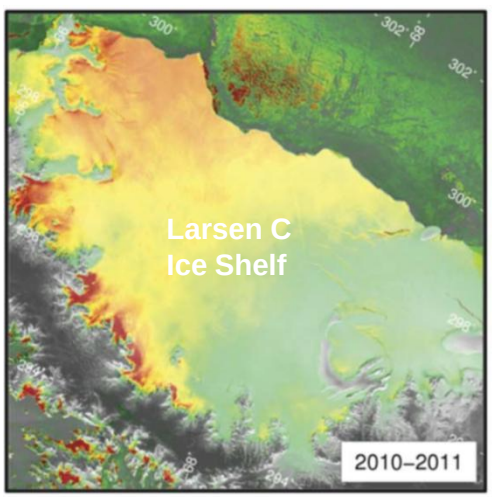
(Elvidge et al., 2015, BAMS)





Surface melt duration from satellite SAR backscatter data (Luckman et al., 2014, Antarctic Science)

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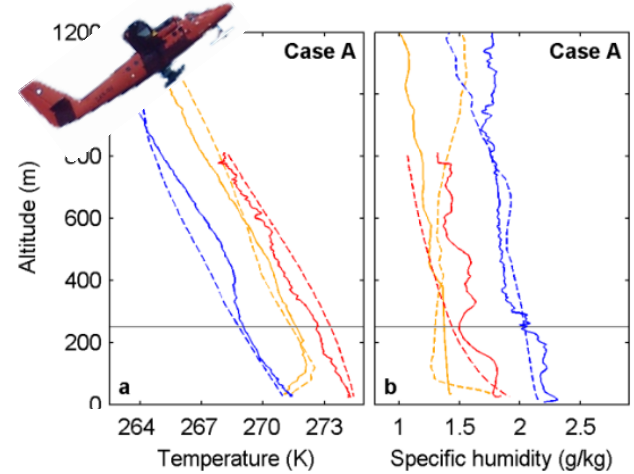

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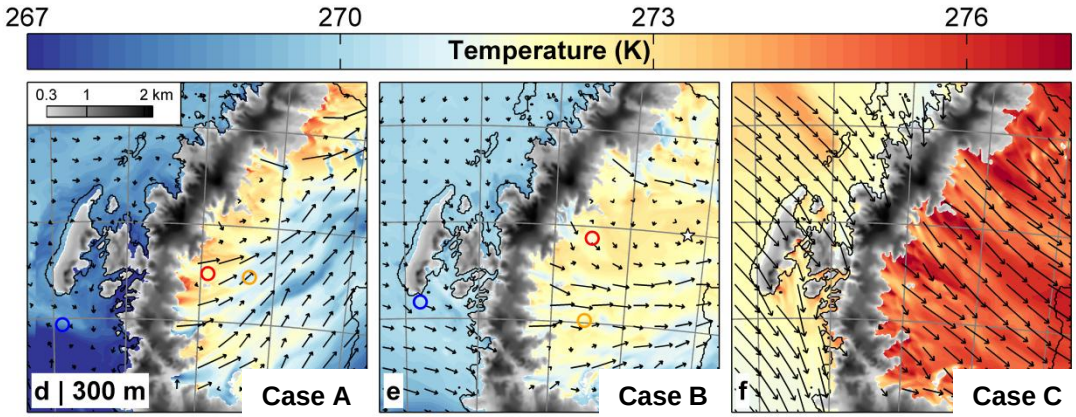

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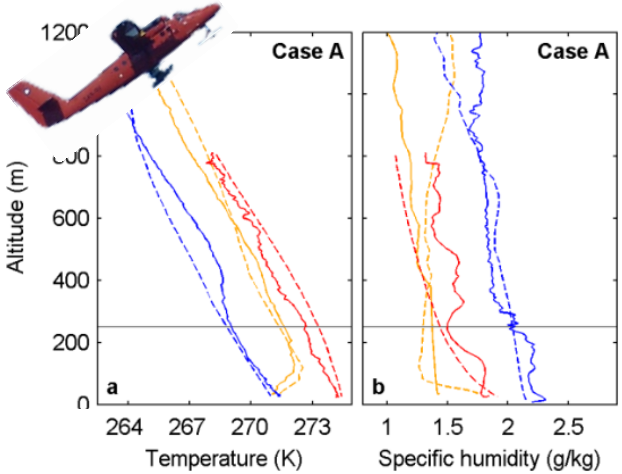

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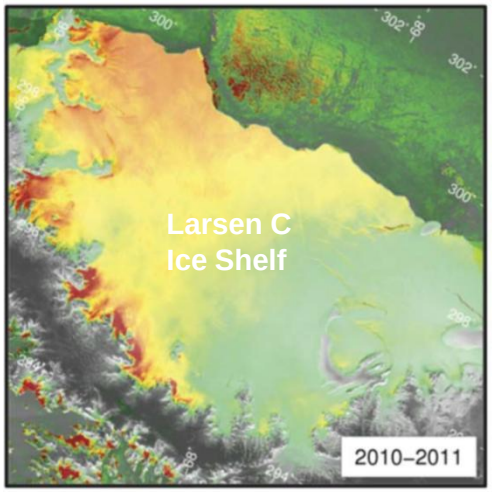

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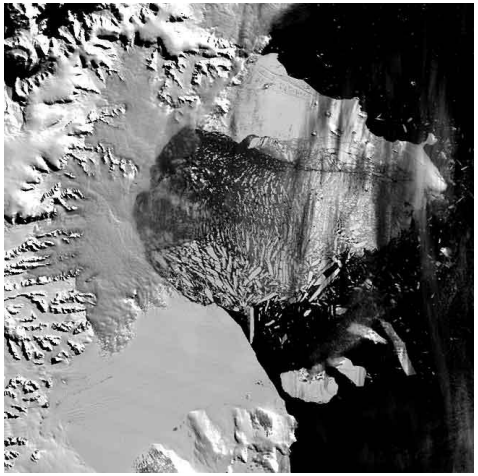


Larsen B collapse, 2002

South Georgia Wave Experiment (SG-WEX)

UK Universities: Bath and Leeds + British Antarctic Survey and Met Office

What is the nature, variability and influence of GWs generated by South Georgia?

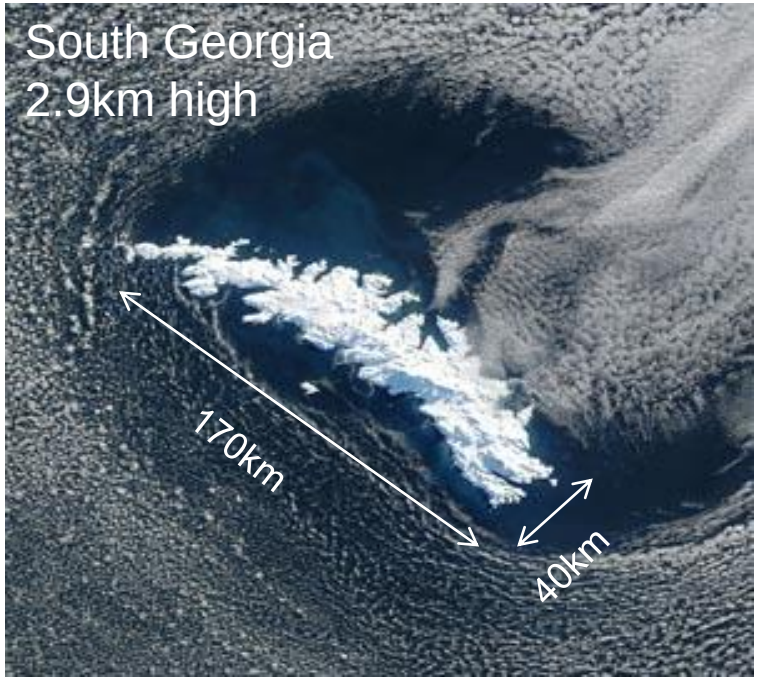
Observations

- Two radiosonde campaigns
- Satellite measurements across South Atlantic
- First S. Georgia atmospheric radar, measuring GWs up to mesosphere

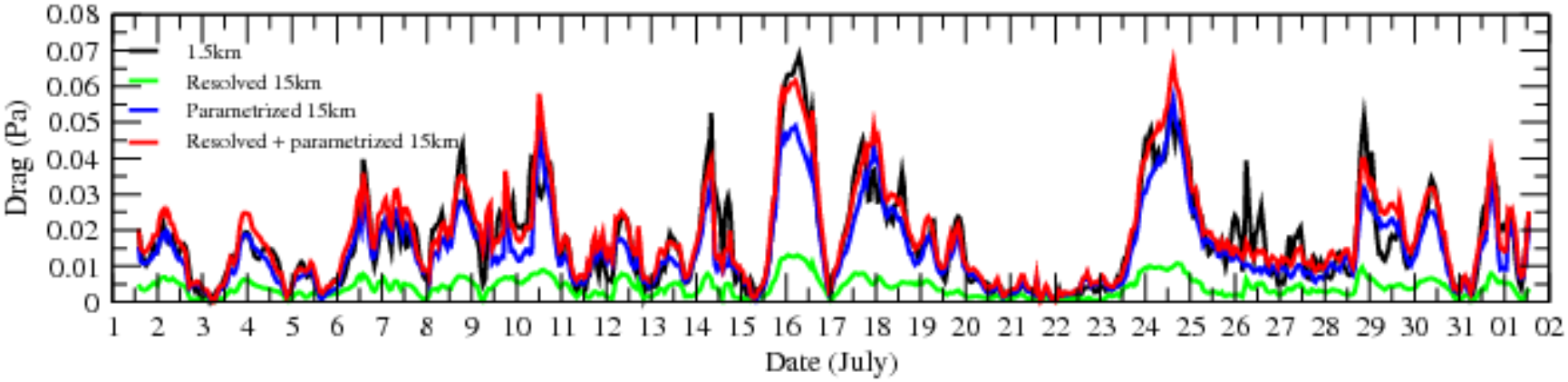
Modelling

- MetUM 15 km, 1.5 km

Recent studies of drag over South Georgia (Vosper, 2015, QJRMS)

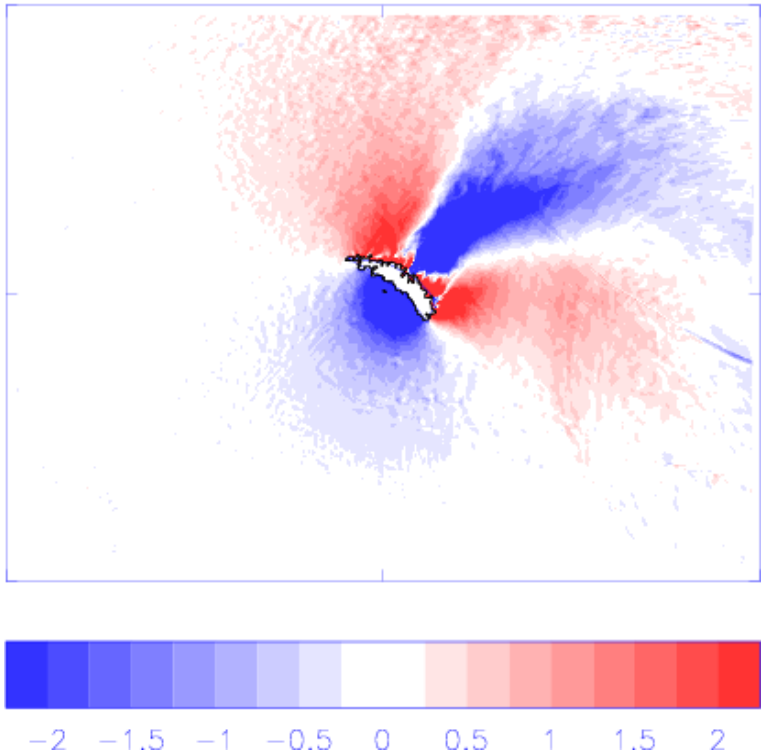


- One-month limited area simulations at 1.5km and 15km resolution.
- Drag is under-resolved on 15km grid
- Parametrized drag correlates well with drag in 1.5km simulation
- **Sum of resolved and parametrized drag in 15km simulation agrees well with 1.5km drag.**

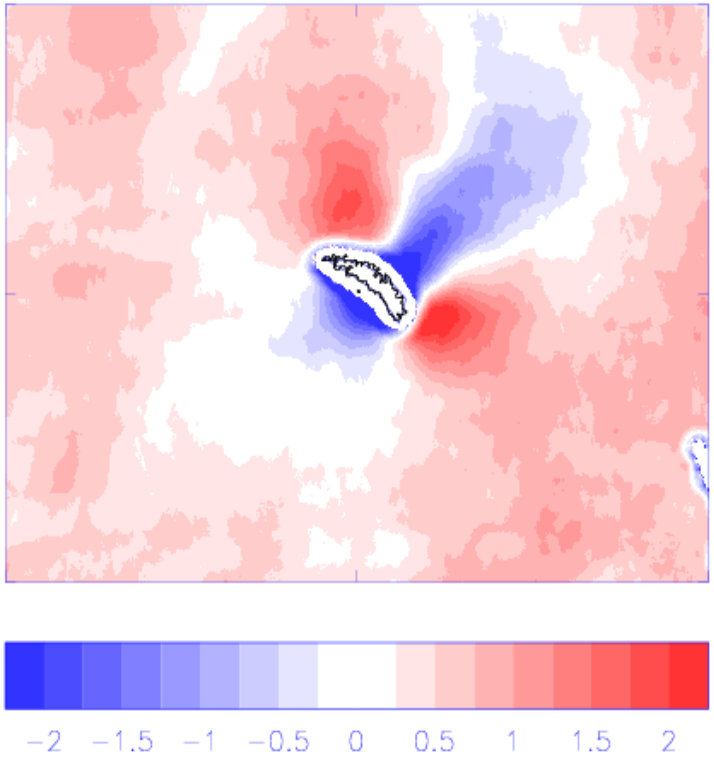


South Georgia: Local wake effects

Model (UM Δx=1.5km)



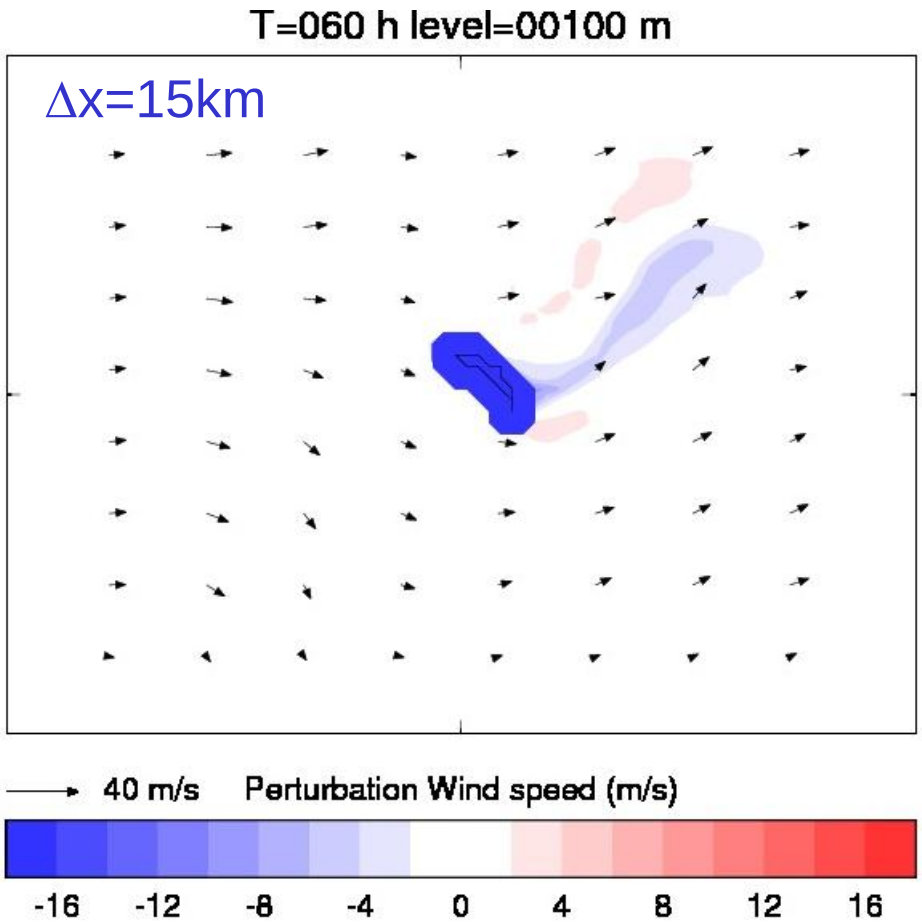
ASCAT – ERAi

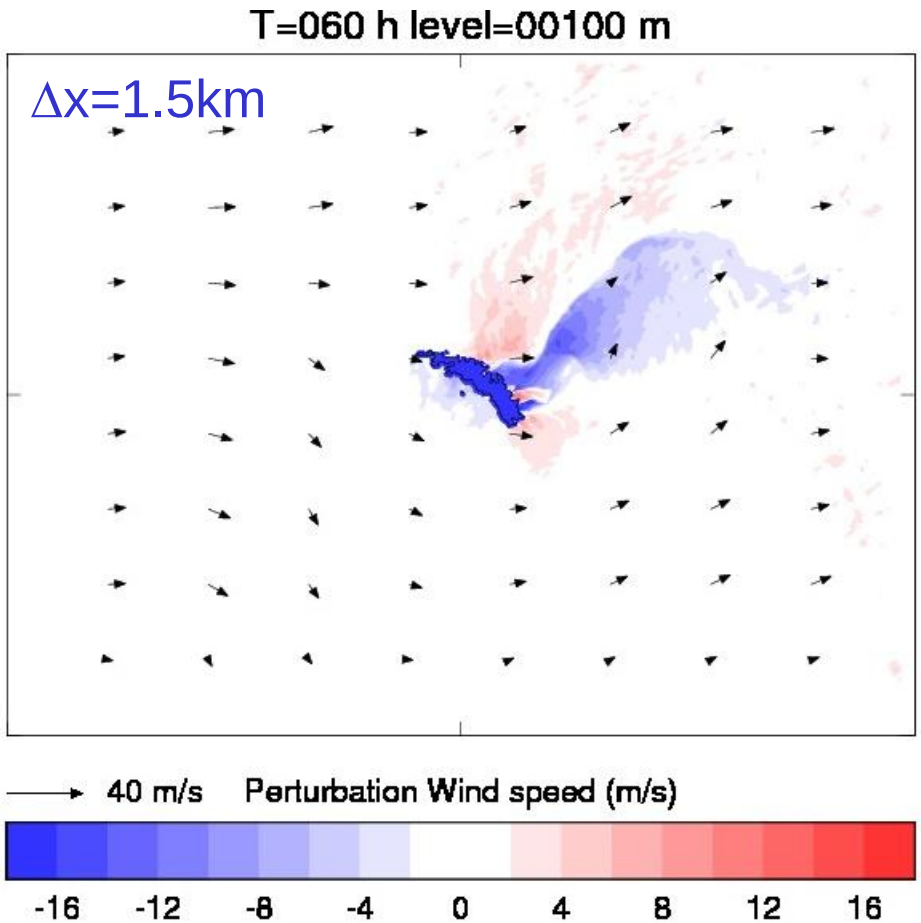


- Model predicts clear wake signal in lee of island in mean 10 m winds
- Satellite scatterometer winds show similar pattern

(John Hughes, Univ. Leeds)

To what extent can a drag parametrization produce the correct local flow response?





Implications for YOPP

YOPP observations and output will help support:

- Improved understanding of orographic effects and their impacts in the polar regions:
  - Complex flow dynamics of drag processes: flow blocking and gravity wave generation
  - Gravity wave breaking and clear air turbulence
  - Orographic enhancement of cloud and precipitation
  - Foehn and wake effects and their influence on surface exchange
  - Scale interactions
- Parameterization development
  - Drag
  - Cloud and precipitation
  - Foehn warming?
- Validation and development of high resolution models

YOPP observations: some ideas

What kind of observations?

Multilevel flights extending high above mountains:

- Drag: GWs and momentum fluxes
- GW breaking and clear air turbulence
- Orographic clouds and precipitation

Low level flights downwind of mountains + surface obs + sondes:

- Wake effects and foehn

Where?

Isolated islands / peninsulas provide natural laboratories for investigation of orographic processes – easier, ‘un-muddied’ characterisation of orographic forcing and subsequent flow response

- Svalbard, Iceland, Southern tip of Greenland, Antarctic Peninsula, S. Georgia

On the other hand... Observations over more complex orography would help guide research and test models

- Alaska, Greenland

Met Office

Thanks for listening

Questions/Discussion?