Enhanced wind variability in the orographic gravity wave parameterisation and its influence on dynamics

EGU general assembly 2021, AS1.14 Internal Gravity Waves

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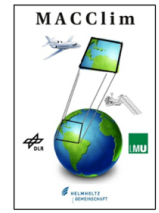



26 April 2021





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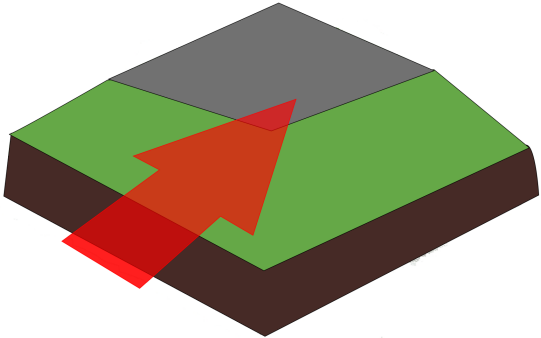
DLR



1 Introduction



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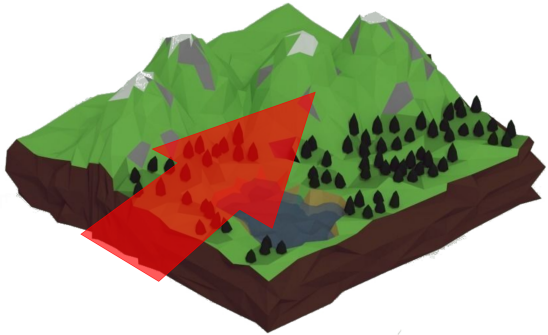

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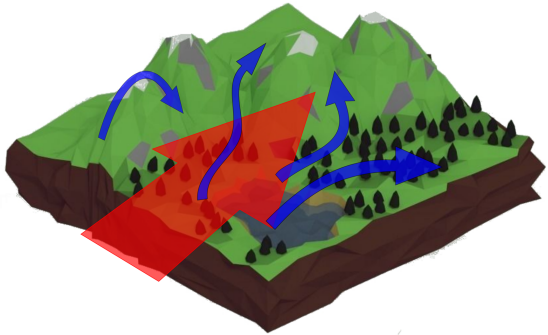

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$\Rightarrow$ Loss of variability in parameterisation (but that cannot be resolved)



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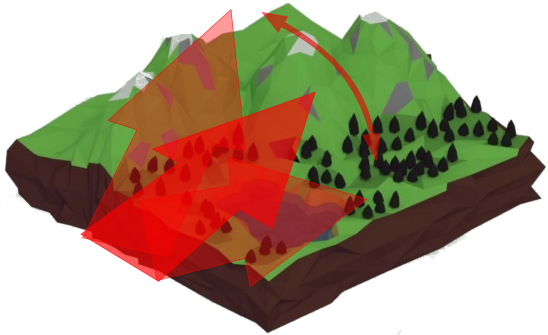

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$\Rightarrow$ Stochastic modification of low-level wind direction when used in SSO application



2 OGW scheme modification

original low-level wind velocity:

$$vel_o = \sqrt{u_{low-o}^2 + v_{low-o}^2} \tag{1}$$

original low-level wind direction:

$$dir_o = 2\pi - acos\left(\frac{u_{low-o}}{vel_o}\right) \quad \text{if } v_{low-o} < 0 \tag{2}$$

$$dir_o = acos\left(\frac{u_{low-o}}{vel_o}\right) \quad \text{if } v_{low-o} > 0, \tag{3}$$

u_{low-o}, v_{low-o}: original wind in meridional and latitudinal direction



OGW scheme modification

n: normally distributed random number
$\mapsto$ to stochastically modify wind direction for use on subgrid-scale

New modified wind direction:

$$dir_m = dir_o - \left[\frac{\pi}{4} + \left(n \cdot \frac{\pi}{2}\right)\right] \tag{4}$$

$\Rightarrow$ New modified meridional and latitudinal winds:

$$u_{low-m} = vel_o \cdot cos(dir_m) \tag{5}$$

$$v_{low-m} = vel_o \cdot sin(dir_m) \tag{6}$$



Parameters settings

- $Mean(n) = 0.5$ ($n = 0.5 \mapsto$ no wind deflection)
- $Std(n) = 0.2$ (determines probability of large and small wind deflection)
  $\mapsto$ Standard deviation of wind angle: 11.5°
  $\mapsto$ The angle change exceeds 45° in about 1% of the cases
- Parameters chosen to generate 'modest' changes

$\Rightarrow$ **SSO wind direction modification leads to changes in launching and propagation properties of OGWs**

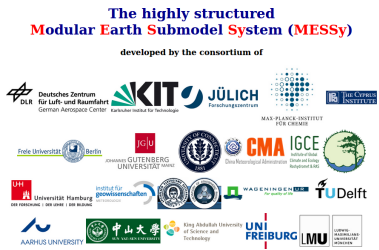


3 Simulation

General Circulation Model

- EMAC (ECHAM MESSy Atmospheric Chemistry Jöckel et al., 2010, 2016)
- MESSy: Modular Earth Submodel System: `www.messy-interface.org`
- sub-grid scale orography parameterisation including orographic gravity waves by Lott and Miller (1997); Lott (1999) $\mapsto$ MESSy submodel OROGW.







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Simulation setup

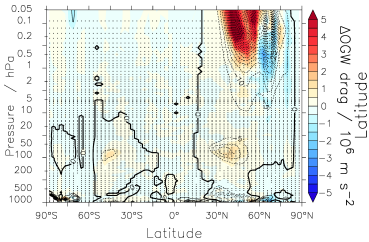
- ref: reference simulation
  dt1: sensitivity simulation with modified OGW scheme
- no chemistry, free-running (E5 setup)
- T42L90MA $\sim$ 2.8°x2.8°, 90 layers in the vertical
- SSTs and the SICs prescribed - 1995-2004 (HadISST) (Rayner et al., 2003)
- prescribed GHG concentrations; ozone from Fortuin and Kelder (1998)
- 'nudged' QBO
- 60 years simulations, including 10 years spin-up



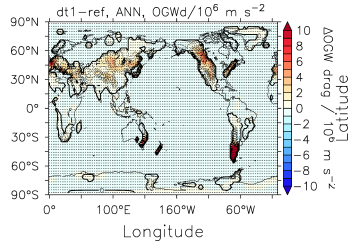
4 Orographic gravity wave drag changes

4.1

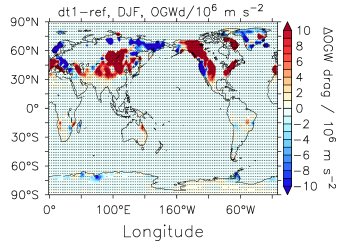
zonal mean



100hPa



0.1hPa

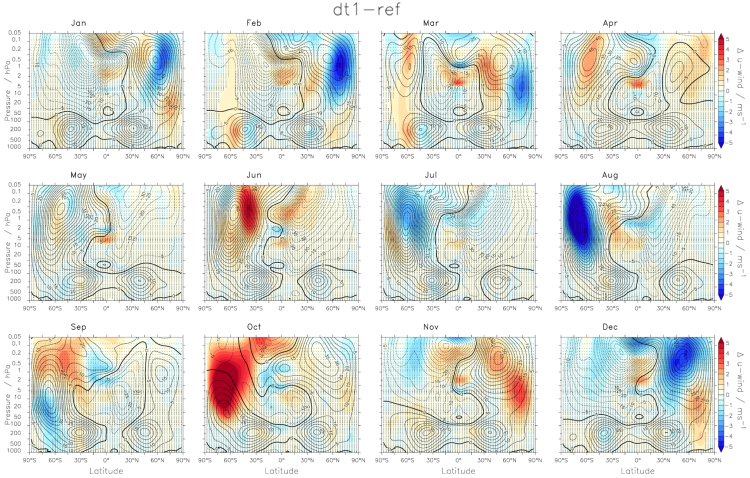


- Changes in OGWD in zonal mean and particular regions
- Most differences are not significant

⇒ Do these changes have an impact on temperatures and dynamics?



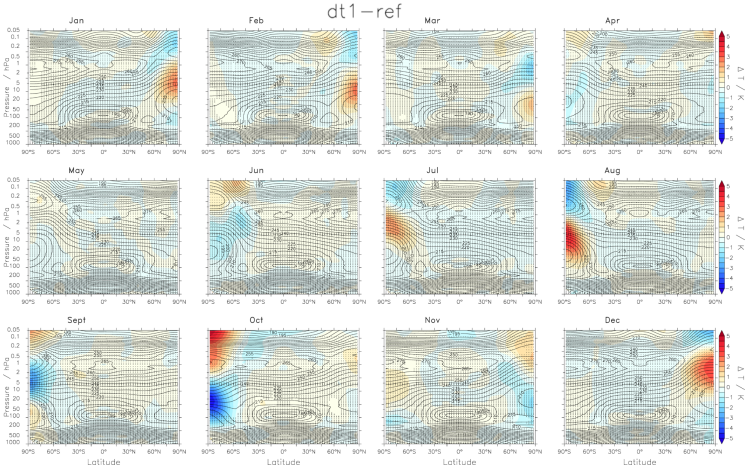
Monthly zonal wind differences



- Significant Antarctic polar vortex
  - deceleration in August
  - acceleration in October
- February, March, April: Wind enhancement in SH
- Barely any significant differences in the NH, but some deceleration from Dec-Mar



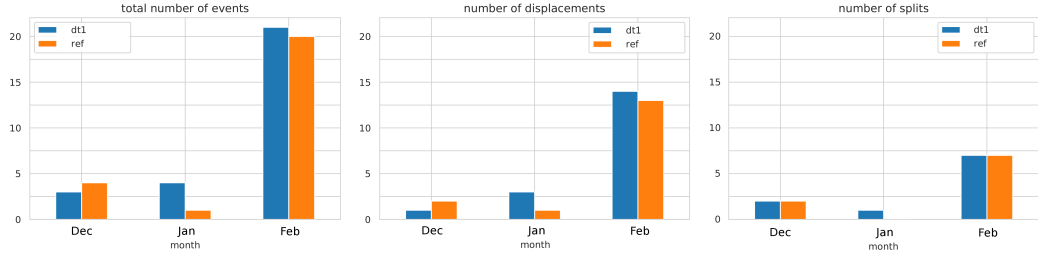
Monthly temperature differences



- Significant SH polar temperature changes in August and October $\mapsto$ corresponding to the polar vortex changes
- Temperature increase in December in NH



4.2 Sudden Stratospheric Warmings in NH

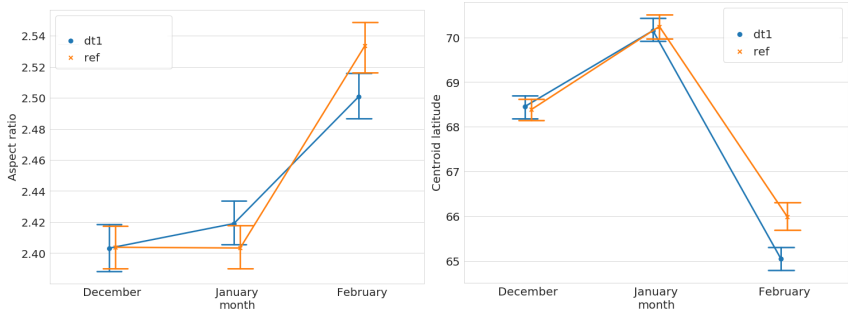


(detection method following Seviour et al., 2013)

- Slight enhancement of SSWs (but barely significant)
- models underestimate SSW frequency mainly in Jan and Feb (see Kim et al., 2017)
  $\Rightarrow$ slight improvement
- mainly due to more diplacements



Polar vortex structure in NH

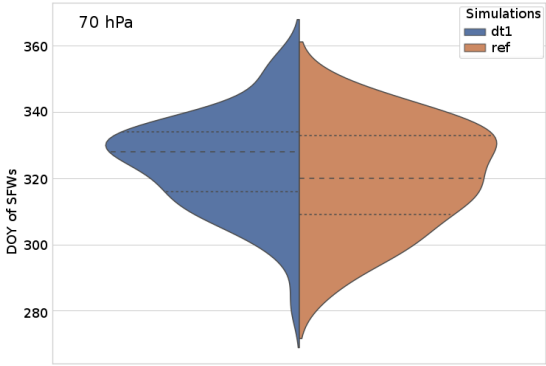


- Smaller aspect ratio and lower centroid latitude in February
- Significant change of vortex geometry average in February

⇒ Only small SSW changes maybe because some criteria was not met



Final warming date in SH at 70 hPa



- mean day ∼350 in ERA-Interim (de la Cámara et al., 2016)
- mean day 320 in ref
  mean day 325 in dt1

⇒ Some improvement of final warming date (more stable vortex?)



5 Conclusions

- Physically sensible stochastic random modification of wind direction from model grid scaale to subgrid scale in OGW scheme
- Thereby caused OGWD changes lead to
  - significant changes in monthly winds and temperatures
  - slight enhancement of SSWs, and vortex geometry changes
  - backward shift of final warming date (more stable SH polar vortex)

$\Rightarrow$ Some model biases (temps, winds, vortex stability,...) may be alleviated with this measure

Outlook

- Analyse wind/GW flux variability in comparison to reanalyses/observations (to constrain model)
- Refine modification (red noise, orography-dependence,...)
- Impose random change also on wind speed to allow gusts
- Analysis of impact on middle and upper atmosphere



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DLR



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