Further developments to parameterized orographic drag in CAM

Julio Bacmeister, Peter Lauritzen, Patrick Callaghan, Jerry Olson AMP
Overview

- Background
- Anisotropic/blocking scheme description
- Results
  - AMIP results
    - Isotropic vs Ridge schemes
    - TMS vs no-TMS
  - CAPT
- Future work
Ridge-based orographic drag scheme

- Anisotropy
- Low-level processes (blocking)
- Multiple ridges

- Soon: trapped lee waves from meso-γ ridges (L<20km)
Subgrid variance may not be a good way to diagnose forcing for orographic gravity waves.

Cross-sections with approximately equal variances.
Most models smooth topography. What should be parameterized, e.g.: Figure above – green arrow or black arrow? What about blue arrows?
Feature-based ridge identification

- Smooth (Bandpass) topography (scale $\sim L_s$)
- Calculate variances of mean cross-sectional profiles at 16 different orientations on $L_a \times L_a$ domains
- Maximum 1D vs 2D variance determines “ridge” angle

Outputs
- Orientation
- Ridge height (different from std. dev. of topo)
- Geographically-based estimate of “effgw_oro”
- Estimate of ridge width
- “quality” ratio of 1D/2D variance
Feature-based ridge identification

Feature scale
~125km

Plotted over raw 3km topography data
Feature-based ridge identification

Feature scale
\(~125\text{km}\)

Plotted over unresolved topography:
Raw-Smooth(180\text{km})
Feature-based ridge identification
Blocking, low-level turning
(follows Scinocca & McFarlane 2000)

i – vertically propagating waves \( \partial_z \tau \) via saturation

ii - downslope wind layer \( \partial_z \tau \sim (\tau_{dsw} - \tau_{sat}) / H_{dsw} \); \( \tau_{dsw} = \alpha \tau_{sat} \)

iii – low-level flow turning \( \partial_z \tau \sim U^2 \)
AMIP runs 1/1979-1/2000

- FV 0.9x1.25 (Ridge Scheme is ready for SE as well)
- 8 runs
  - Default GW scheme (4): CAM5.4/CLUBB; TMS/No-TMS
  - Ridge-based scheme(4): CAM5.4/CLUBB; TMS/No-TMS
- A PI-1850 coupled run has started with Ridge-based scheme, CLUBB, No-TMS. 20-years done

- All use GTOPO30 not GMTED due to apparent errors in GMTED over Antarctic Peninsula
DJF Zonal mean winds (CAM5.4)

Isotropic GWD

Ridge-based GWD

Ridge-based GWD w/out TMS

CAM5.4

f.15b03.FAMIP.f09_g16.test00 (yrs 1980–1999)

f.15b03.FAMIP.f09_g16.RD04 (yrs 1980–1999)

f.15b03.FAMIP.f09_g16.RD06 (yrs 1980–1999)

ERA40

Zonal wind m/s

Pressure (mb)

Height (km)

Pressure (mb)

Height (km)

Pressure (mb)

Height (km)
JJA Zonal mean winds (CAM5.4)

**Isotropic GWD**

**Ridge-based GWD**

**Ridge-based GWD w/out TMS**

**JJA**

ERA40
Zonal mean GW zonal wind tendencies

Isotropic GWD

Ridge-based GWD
w/out TMS

DJF

JJA
Annual mean wind stress (CAM5.4)

Isotropic GWD

Surface stress mean = 0.07 N/m²

LARGE-YEAGER

f015b0.FAMIP.f09_g16.test00 - LARGE-YEAGER

Surface stress mean = -0.00 N/m²

Ridge-based GWD w/out TMS

Surface stress mean = 0.07 N/m²

LARGE-YEAGER

f015b03.FAMIP.f09_g16.RDG06 - LARGE-YEAGER

Surface stress mean = -0.00 N/m²
• Ridge based scheme improves SH without detrimental effects on NH
• Overall improvements in wind-stress

• With CAM-CLUBB – more mixed results
More effects of Turbulent Mountain Stress (TMS)
Annual mean 2m Temperatures

**CAM5.4 Isotropic GWD**

- Min = 217.00 Max = 310
- 2-meter Temp (land) mean = 285.91

**CAM5.4 Ridge-based GWD w/out TMS**

- Min = 219.41 Max = 303.6
- 2-meter Temp (land) mean = 285.91

**f.e. FAMIP.109_g16.test00 - IPCC/CRU**

- Mean = -0.13
- RMSE = 1.69

**f.e. FAMIP.109_g16.RDG06 - IPCC/CRU**

- Mean = -12.77
- RMSE = 1.60
Annual mean 2m Temperatures

CLUBB+Isotropic GWD

2-meter Temp (land)  mean = 285.91

Min = 217.99 Max =

CLUBB+Ridge-based GWD w/out TMS

2-meter Temp (land)  mean = 285.91

Min = 219.41 Max = 303.1

f.015b03ch.FAMIP.09_f09.CLB00 - IPCC/CRU

mean = 0.25  rmse = 2.11

Min = -12.50 Max =

f.015b03ch.FAMIP.09_f09.CLB-RDG00 - IPCC/CRU

mean = 0.13  rmse = 2.05

Min = -9.95 Max = 9.95
Annual mean 2m Temperatures (coupled runs)

CLUBB+Ridge-based GWD

CLUBB+Isotropic GWD

b.e15.B1850G.f09_g16.new_mountain_wave.28 (yrs 2-20)

2-meter Air Temp mean = 285.83 K

ANN

Min = 217.34 Max = 301.85

CLUBB+Ridge-based GWD w/out TMS

b.e15.B1850G.f09_g16.pi_control.28 (yrs 2-20)

2-meter Air Temp mean = 285.93 K

Min = 216.04 Max = 302.38

CLUBB+Isotropic GWD

b.e15.B1850G.f09_g16.new_mountain_wave.28 - b.e15.B1850G.f09_g16.pi_control.28

mean = -0.10 rmse = 0.57 K

Min = -5.97 Max = 8.43
DJF 10m Winds

Ridge-based GWD including TMS

Ridge-based GWD w/out TMS

Courtesy of Marcus Löfverström
JJA Precipitation

CAM5.4 w/ Isotropic GWD

*including TMS*

CAM5.4 w/Isotropic GWD

*w/out TMS*
- TMS may lead to biases in 10m, 50m winds
- TMS exacerbates JJA Rocky Mtn precip bias
- TMS could contribute to warm bias in central US

- Forecasts initialized from ERA-I reanalyses
- 4-times per day 00,06,12,18Z run for 15 days
January mean 900-700 hPa wind-speed errors at day 3 00Z Validated against ERA-I

Change in error w and w/out Ridge based scheme

Yellow-red $\rightarrow$ improvement with Ridge-based scheme
January mean 900-700 hPa wind-speed errors at day 3 00Z

Validated against MERRA

Change in error w and w/out Ridge based scheme
January mean NH anomaly correlation in Zonal wind

U at 200 hPa

U at 800 hPa

- CAM5.4
- CAM5.5 (CAM-CLUBB)
- Isotropic GWD +TMS
- Ridge GWD +TMS
- Ridge GWD -TMS
Future work

- Diagnose momentum processes in CAM
  - Low-level flow parameterization in Ridge GW
  - Lee-waves/retune TMS/Beljaars
  - Momentum mixing in CLUBB
  - Sub-cycle drag processes
  - Comparisons with $U$, $V$ in radiosonde data
  - DART
- WACCM simulation to see effects of Ridge GW on SSWs
- Anisotropic TMS
- Topography data set quality control (e.g. missing Antarctic Peninsula in GMTED)
- *Couple to microphysics (w/ Xiaohong Liu)*
gtopo30
Rectangle shows approximate layout of map in slide #3
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Antarctic Peninsula 100 m Digital Elevation Model
Derived from ASTER GDEM  National Snow and Ice Data Center

http://nsidc.org/data/docs/agdc/nsidc0516-cook/