Environment and Climate Change Canada | Environnement et Changement climatique Canada

Canada

WGNE* Drag Project:

Importance of and uncertainties in parametrizations of surface drag and momentum exchanges in weather and climate models

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with contributions from

WGNE Drag Project participants

** WGNE = Working Group on Numerical Experimentation*
http://www.wmo.int/pages/about/sec/rescrosscut/resdept_wgne.html

2016 SPARC Gravity Wave Symposium
16-20 May 2016
State College, PA, USA

SPARC Stratosphere-troposphere Processes And their Role in Climate

WMO OMM

WCRP World Climate Research Programme

WWRP World Weather Research Programme

WGNE's mission

http://www.wmo.int/pages/about/sec/rescrosscut/resdept_wgne.html

Co-chairs: Keith Williams (UKMO) and AZ (ECCC)

Working Group on Numerical Experimentation

- *Jointly established by the **WCRP** and the WMO Commission for Atmospheric Sciences (**CAS**)*
- *Responsibility of fostering the **development of** atmospheric circulation **models** for use in **weather** prediction and **climate** studies on all time scales and diagnosing and resolving shortcomings.*

A distillation of the Terms of Reference…..

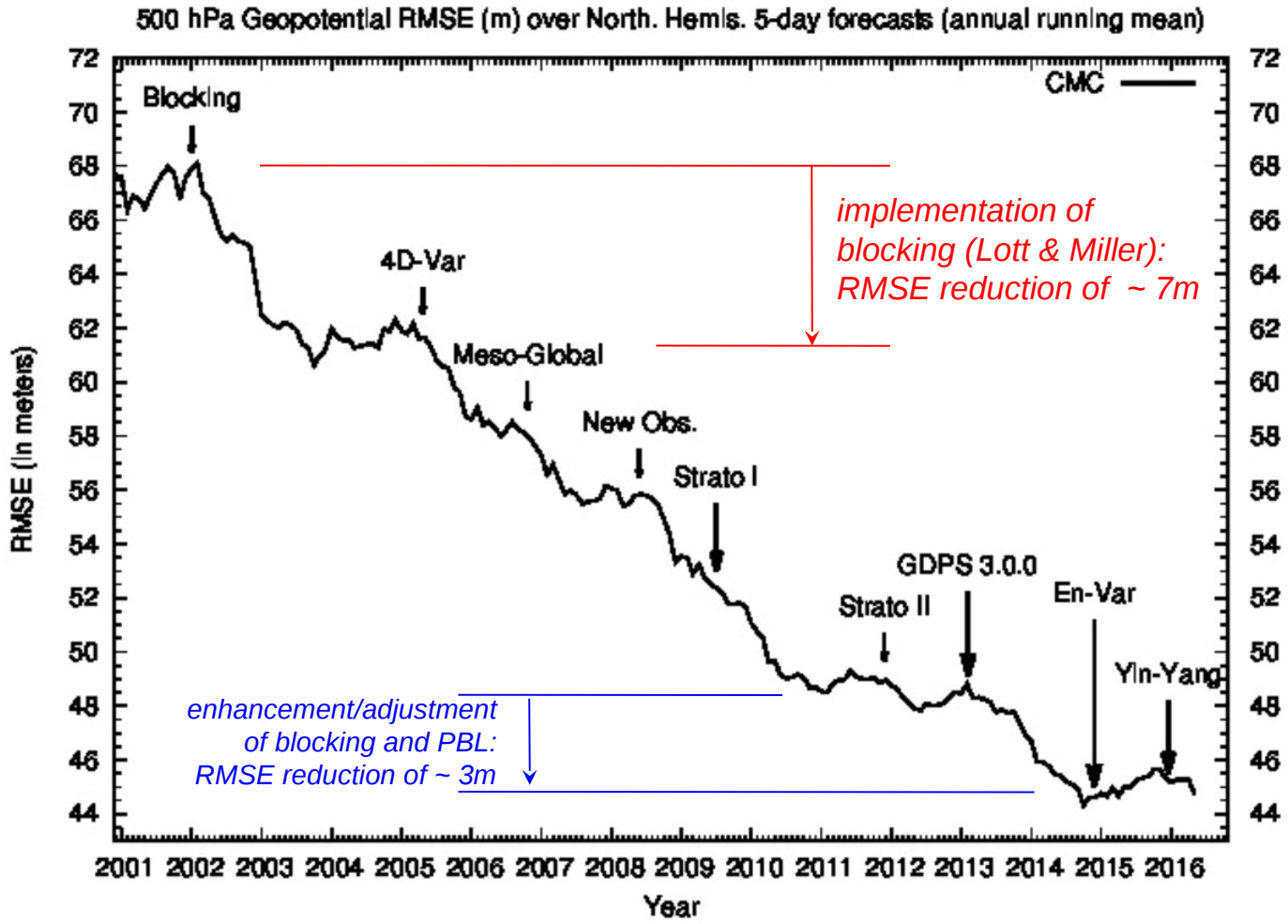
- *Advice, liaison*
- *Co-ordinated experiments*
- *Workshops, publications, meetings*

Some ongoing projects

- *MJO-Task Force (improve representation of MJO in weather & climate)*
- *Aerosol Project (assess importance of aerosols in weather & climate)*
- ***Drag Project** (inter-comparison of momentum budgets) co-led by Julio Bacmeister (NCAR) and AZ (ECCC)*

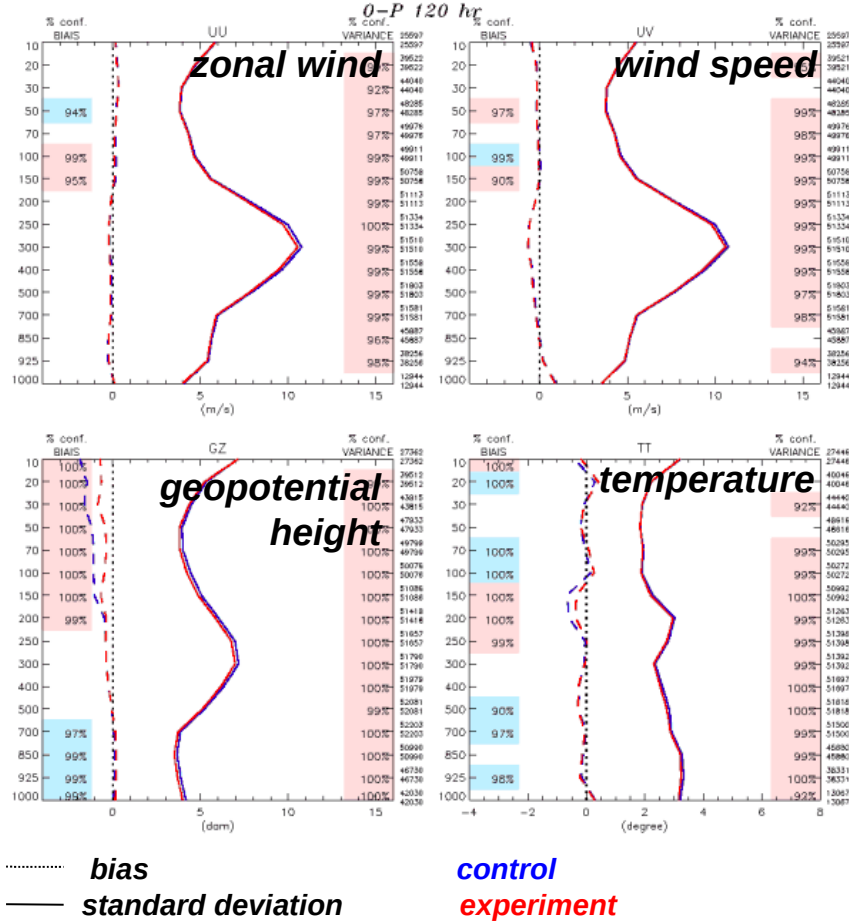
Motivation for WGNE Drag Project:
importance/impact of parametrization of orographic processes

Example: Impact of orographic blocking in the Canadian global model



Motivation for WGNE Drag Project:
importance/impact of parametrization of orographic processes

verification against radiosondes
DJF 2014-15 - N. Hemisphere – day 5



Example of improvements from a recent successful upgrade of the Canadian GDPS:

Control

Global system that was operational up to 15 Dec 2015

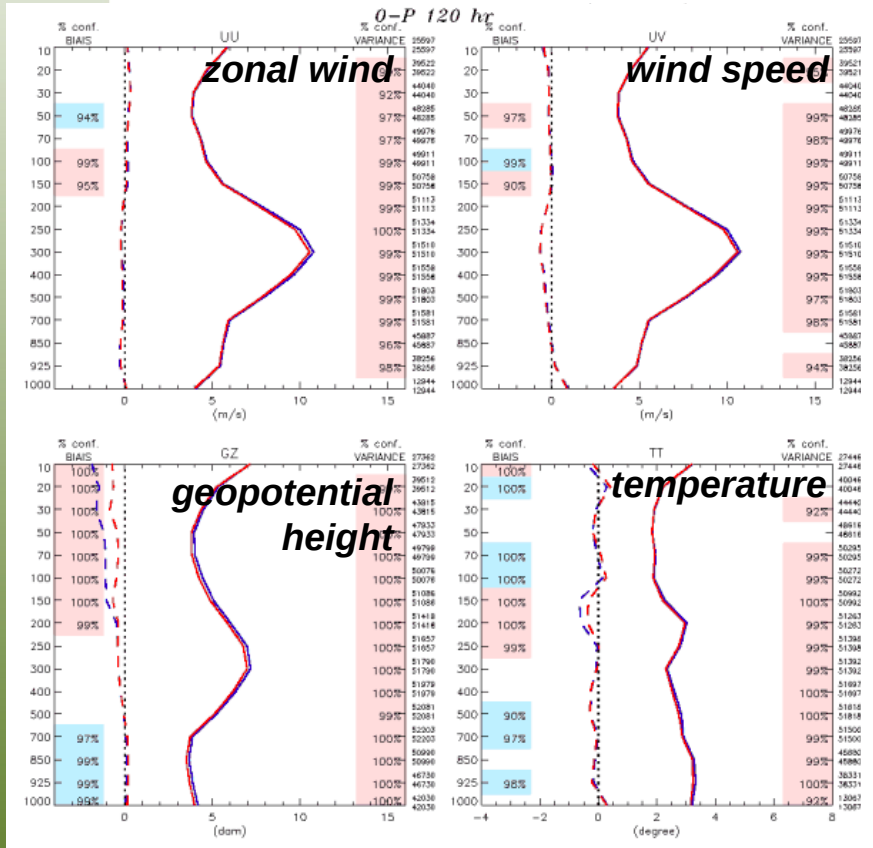
Experiment

New global system, including

- *Yin-Yang grid*
- *improvements to the trajectory calculations in the semi-lag scheme*
- *updates in the data assimilation (e.g. new data: ATMS, CrIS, GPS; and inter-channel correlations for all infrared and microwave radiances*
- *became operational on 15-Dec-2015*

Motivation for WGNE Drag Project:
importance/impact of parametrization of orographic processes

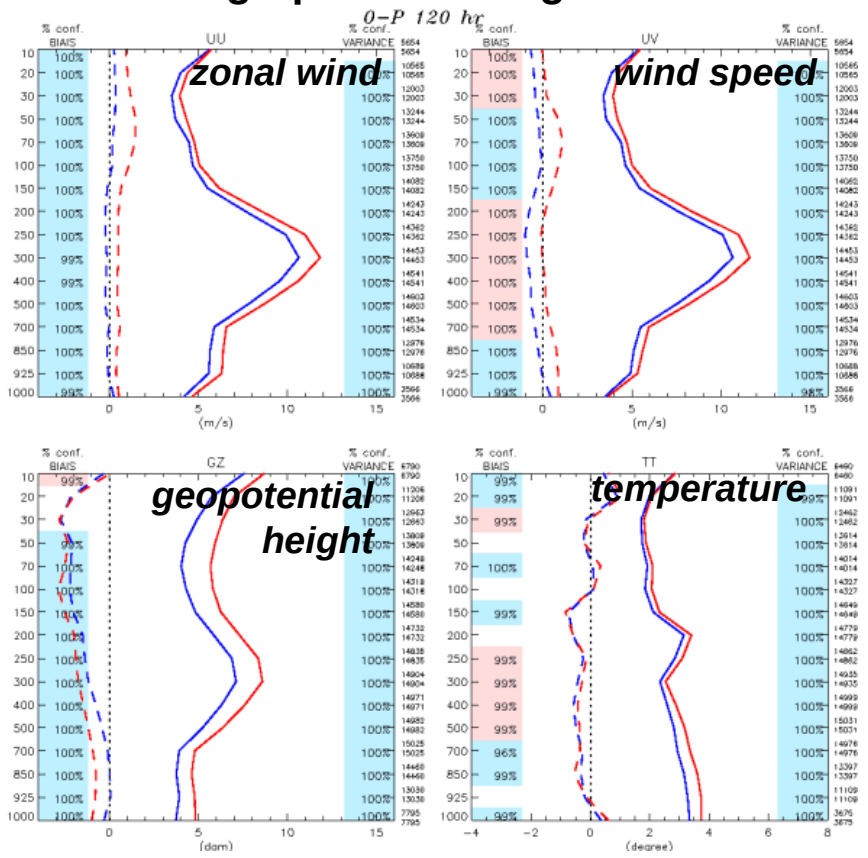
Dec 2015 GDPS upgrade



bias
standard deviation

control
experiment

Sensitivity test:
turning off the orographic blocking scheme



control: operational settings
experiment: no blocking

WGNE Drag Project design

Field to be compared: **surface stress***

$$\vec{\tau} = (\tau_x, \tau_y)$$

In a typical forecast model, it is partly resolved and partly parametrized:

$$\begin{aligned} \vec{\tau} &= \vec{\tau}^{res} + \vec{\tau}^{phy} \\ \vec{\tau}^{res} &= p_s \vec{\nabla} h = \text{resolved orographic stress} \\ \vec{\tau}^{phy} &= \text{subgrid (physics) stress} \end{aligned}$$

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* *Surface stress* = force parallel to the surface, per unit area, as applied by the wind on the earth's surface (land or water).

WGNE Drag Project

Main goal: compare the **parametrized** or physics component of this surface stress, i.e. the stress from parametrizations such as the planetary boundary layer (**PBL**) and the subgrid orographic (**SGO**) schemes.

$$\vec{\tau}^{phy} = \vec{\tau}^{pbl} + \vec{\tau}^{sgo}$$

$$\vec{\tau}^{pbl} = \text{stress from PBL scheme}$$

$$\vec{\tau}^{sgo} = \text{stress from subgrid orographic scheme(s)}$$

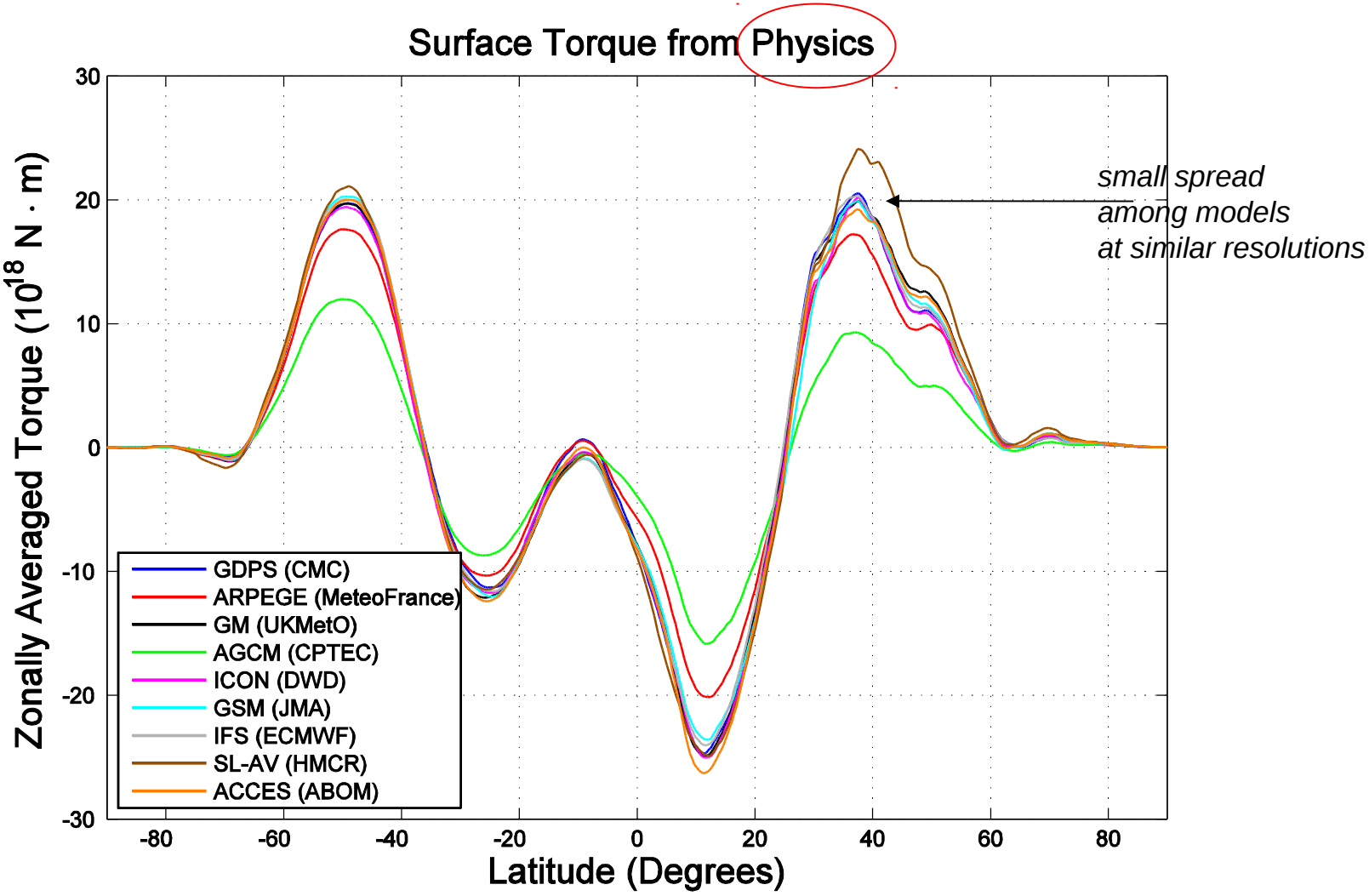
Basic output requested: x- and y-components of the parametrized stress, in units of N/m2, averaged over the 1st day (24h) of a month of forecasts. The months proposed were Jan and Jul 2012.

WGNE Drag Project

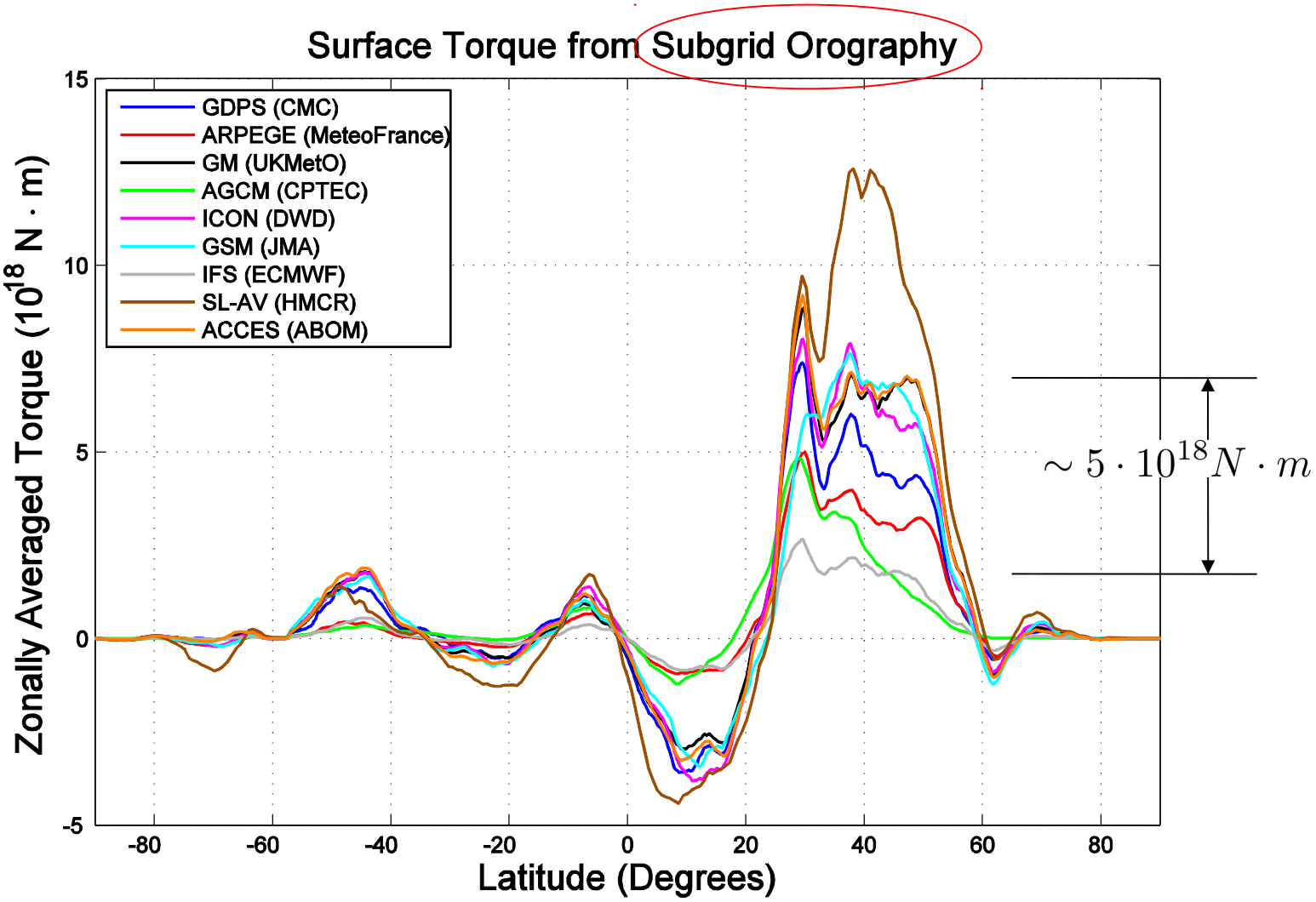
Table 1: Participating models

model name	resolution	center	stress components provided
GDPS	25km	CMC	pbl, gwd, blc, res
ARPEGE	10-60km	Meteo-France	pbl, sgo
GM	25km	UK MetOffice	pbl, sgo
IFS	15km	ECMWF	pbl, sgo, res
GSM	20km	JMA	pbl, lgw, sgw, res
ACCESS	40km	Australian BOM	pbl, gwd, blc
AGCM	45km	CPTEC	pbl, gwd, res
AGCM-2	45km	CPTEC	pbl, gwd, res
SL-AV	80km	HMCR	pbl, sgo
CAM-5	100km	UCAR	pbl, gwd, tms
ICON	13km	DWD	pbl, sgo, res

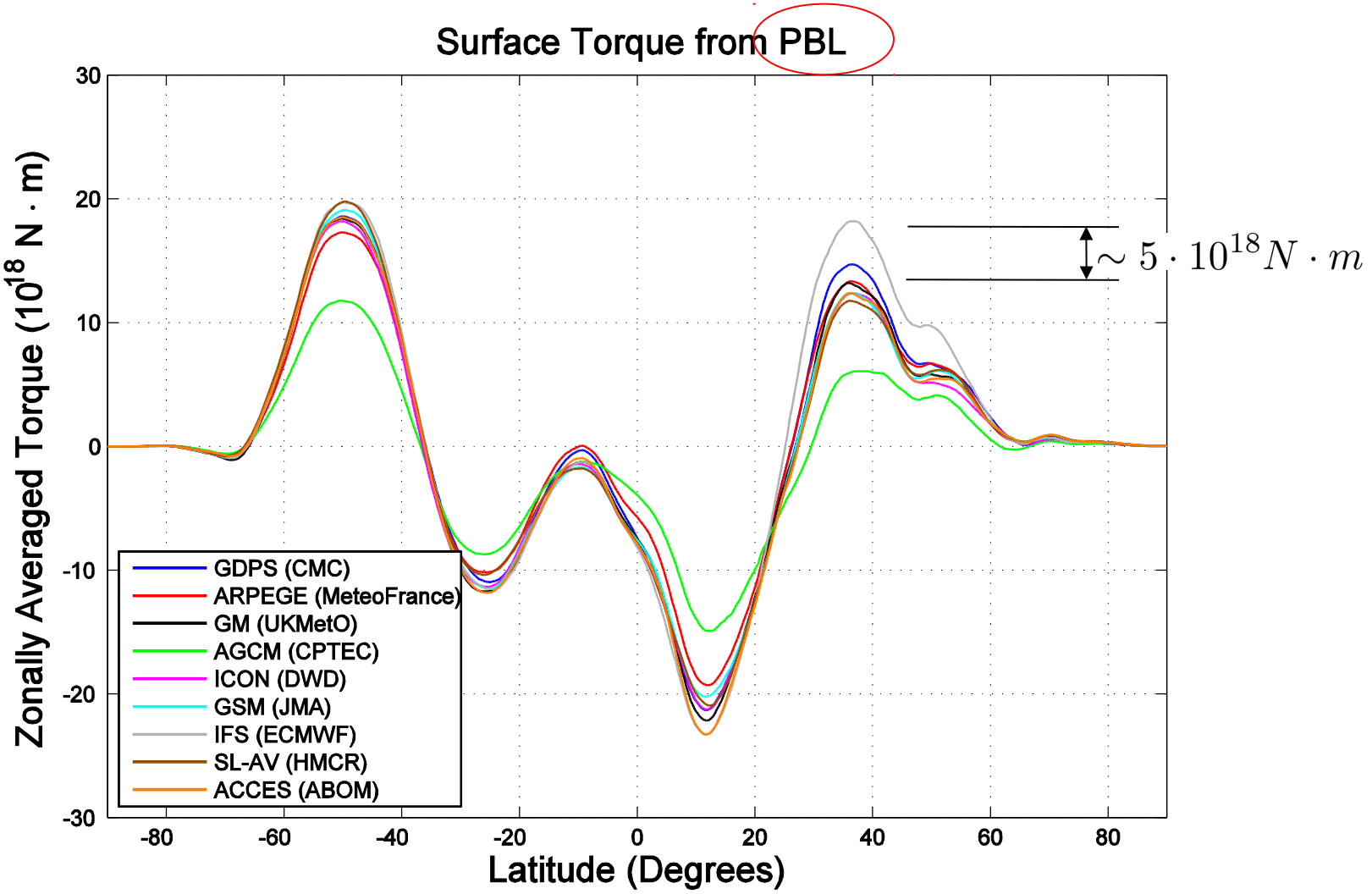
Comparison of averaged surface torque components Jan 2012



Comparison of averaged surface torque components Jan 2012



Comparison of averaged surface torque components Jan 2012



WGNE DRAG-project: inter-comparison of stress fields

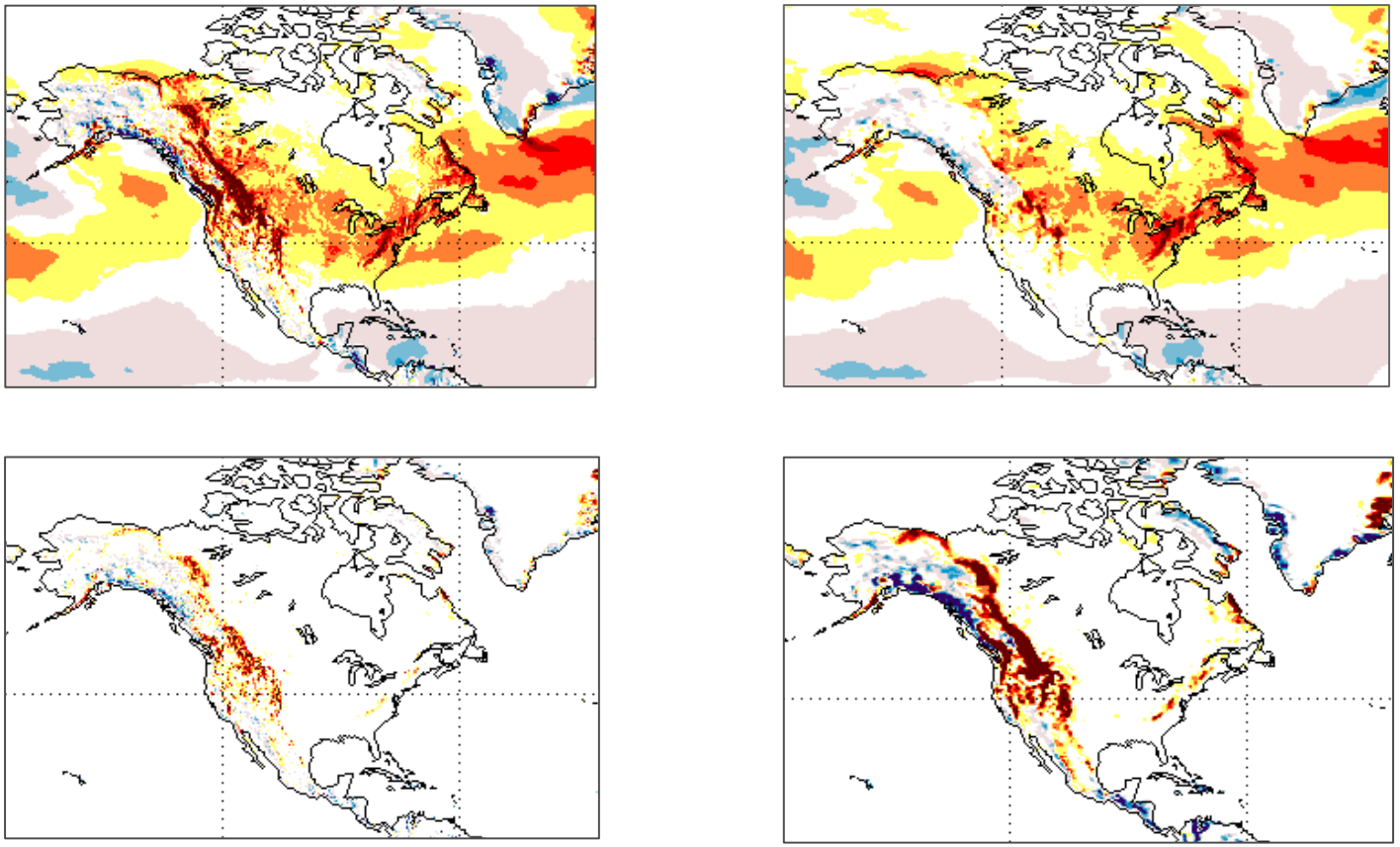
u-component of stress – Jan 2012 – 06-12h average

IFS (ECMWF)

UM (UKMetO)

PBL

SGO



PBL versus SGO surface stress: distinct dependency w.r.t. static stability

- *surface stress due to turbulence (PBL) usually weaker under stable conditions*
- *depth/height of the blocked layer (SGO) usually larger in statically stable cases*

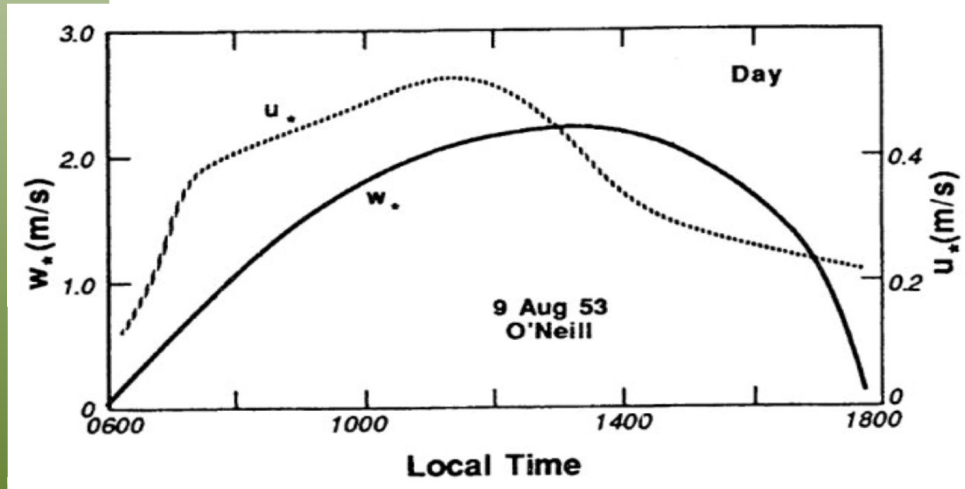
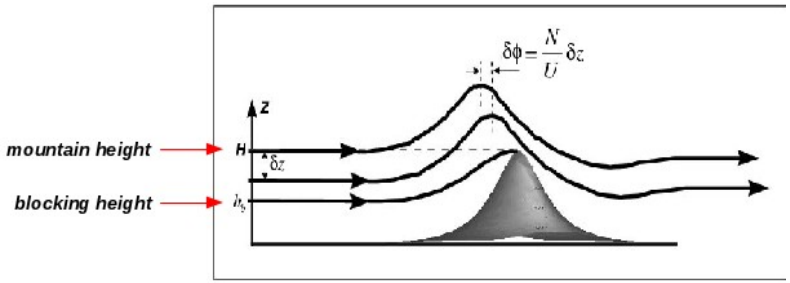


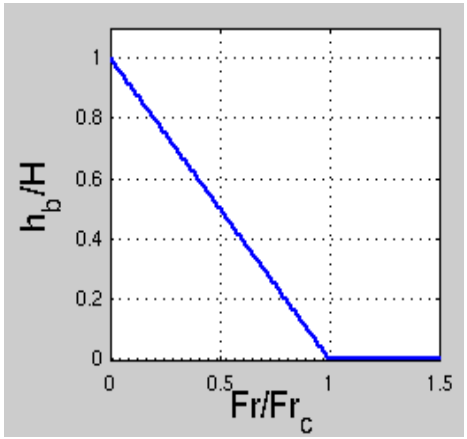
Fig 4.1 from "An Introduction to Boundary Layer Meteorology" by Roland B. Stull: Sample variations of fiction velocity u* and Convective scaling velocity w* with time, for the O'Neil (Nebraska) Field programs.

SGO blocking height



Based on Lott & Miller F1997: for constant buoyancy *N* and incident wind *U*:

$$h_b \sim H \cdot \max(0, 1 - Fr/Fr_c)$$



where:

H = subgrid mountain height

Frc = 2

$$Fr = \frac{U}{NH}$$

Numerical issues to be considered: sensitivity to ancillary fields

Sensitivity to the details in the generation of ancillary fields:

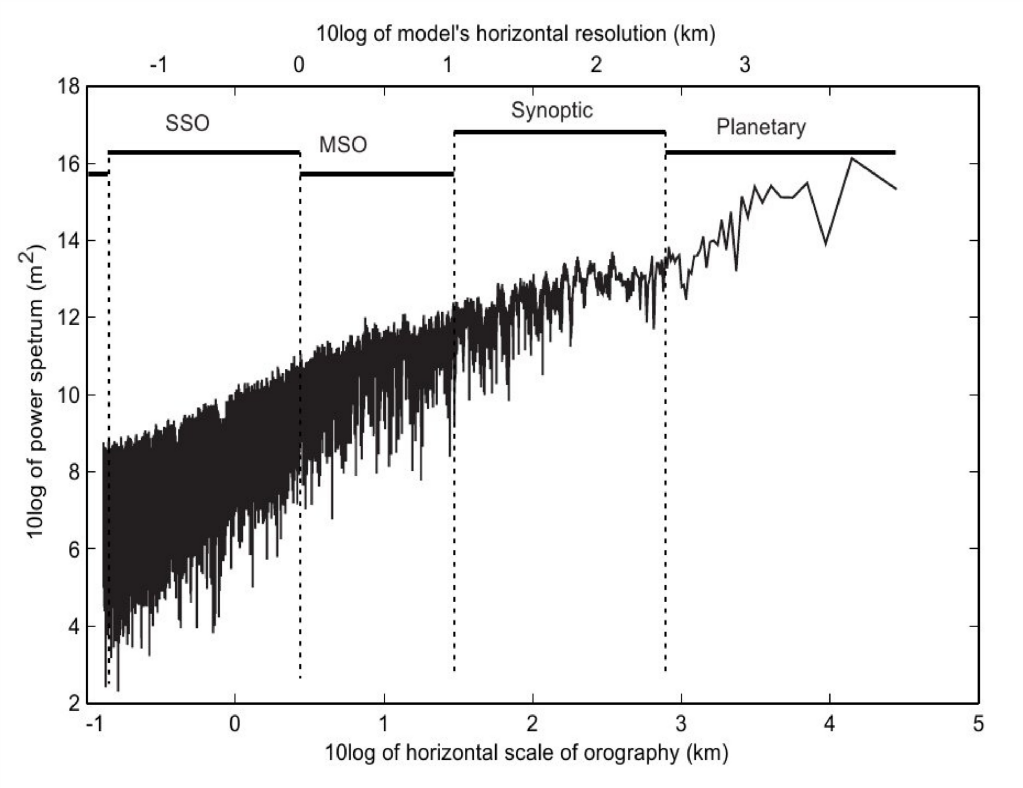
- *choice and quality control of topography database*

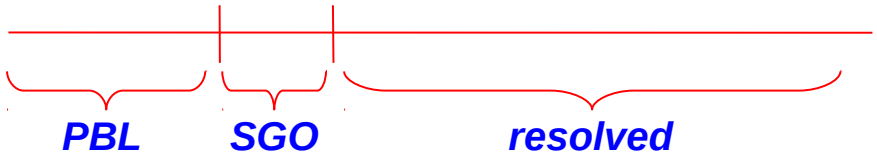
- *separation of scales*
  - *resolved vs subgrid-scale*
  - *filtering of resolved topo*
  - *partition of subgrid-scales*

  SGO: 5km to resolved
  PBL: unresolved and < 5km

- *algorithms for subgrid fields*
  - *effective roughness length or orography variance for PBL*
  - *elliptical mountain parameters for SGO*

Fig 2.2 from Rontu 2007: One-dimensional power spectrum of global orography cross-section along the latitude 45 N, based on STRM 3" data.



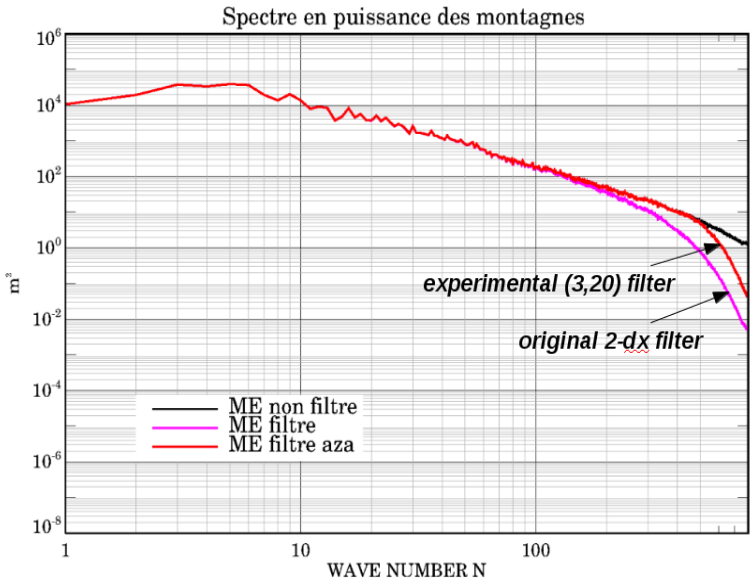


Numerical issues to be considered: sensitivity to ancillary fields

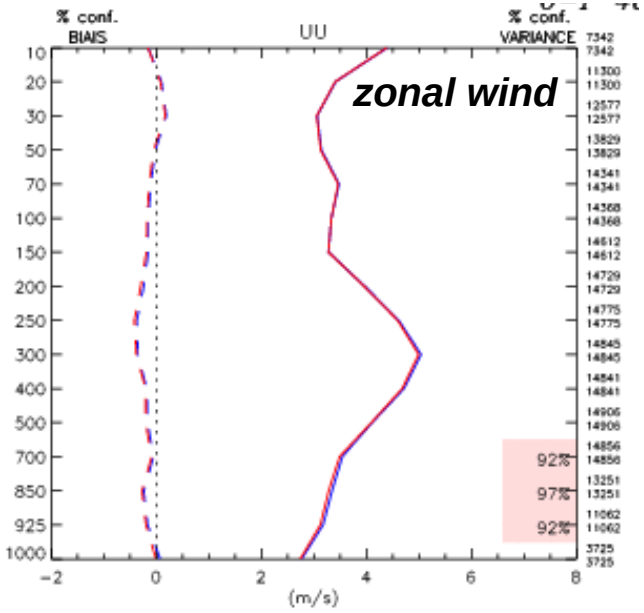
Sensitivity tests using the Canadian GDPS and two distinct resolved topography fields:

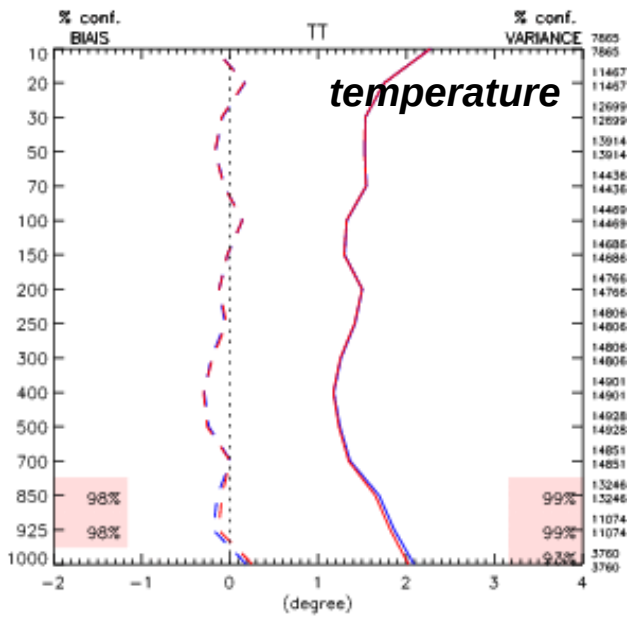
control*: using the operational topography filter*

experiment*: using a "less aggressive" filter (i.e. less smoothing)*



verification against radiosondes: DJF 2015 N. Hemisphere day 2



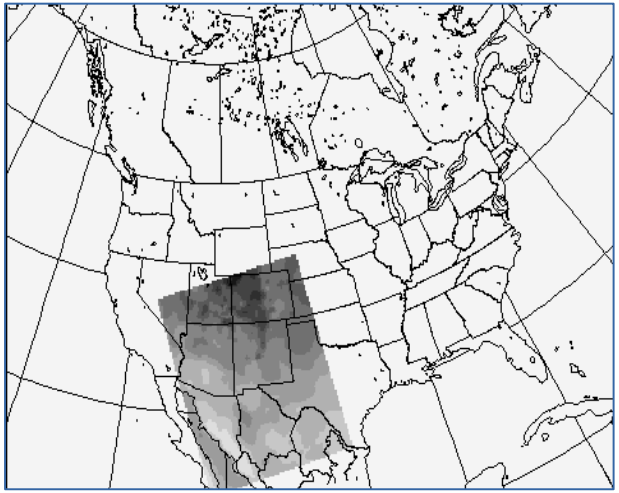


Numerical issues to be considered: sensitivity of schemes to vertical discretization and to tuning parameters (e.g. critical values)

Limited area experiment:

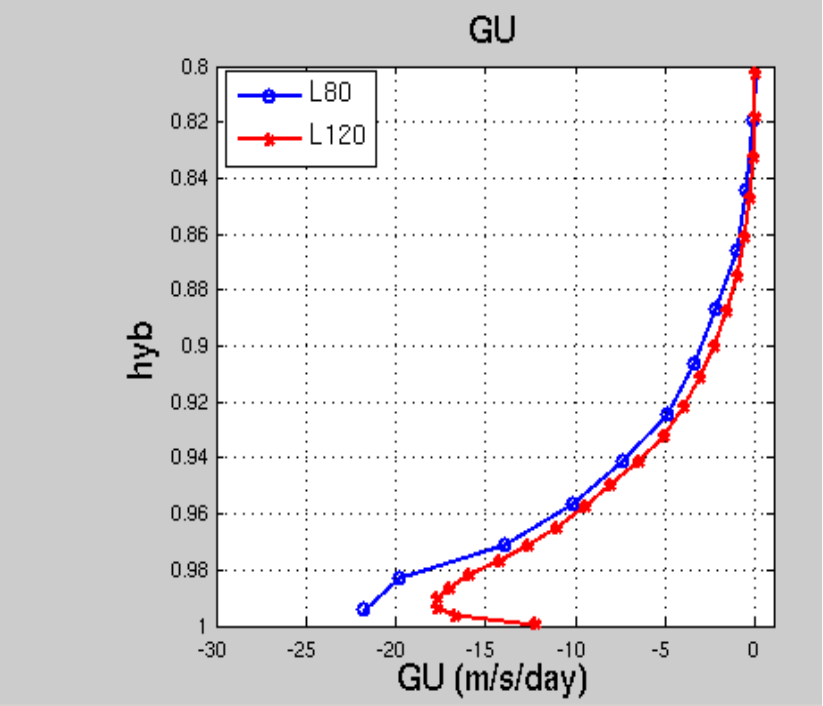
- N. America south-west sub-domain
- analysis: 15-Feb-2011 00Z
- 12-h simulation

Comparison of mean* profiles of
SGO tendency for zonal wind



***control**: operational vertical grid*

***experiment**: new vertical grid, with enhance vertical resolution in the boundary layer*



Summary of the project so far

- Atmospheric circulation in numerical models is **very sensitivity to the representation of surface drag** (and momentum transfer in general)
- **Large uncertainty in the partition** of stress between distinct processes over orography (PBL versus SGO)
- Sensitivity to “numerical” details, e.g.
  - *how **ancillary data** are generated*
  - ***resolution issues**, e.g. definition of “resolved” versus “unresolved”; and sensitivity of schemes to horizontal and vertical discretization*
  - *how the **model dynamics** responds to parametrized forcings*
- **New guidance needed** to clarify the above issues, e.g.
  - *new theoretical insights*
  - *new observational data or better use of existing data*
  - *numerical experiments (e.g. high resolution simulations)*
  - *further collaboration (e.g. inter-comparison projects, bringing together NWP and climate modellers)*

Recent work, future activities and collaboration

Recent papers

- ***Sandu*** *et al. 2015: Impacts of parameterized orographic drag on the Northern Hemisphere winter circulation, JAMES*
- ***Vosper*** *2015: Mountain waves and wakes generated by South Georgia: implications for drag parametrization*

Upcoming events

- ***ECMWF workshop****: Drag processes and their links to large-scale circulation. Reading, UK, Sep 2016 (co-sponsored by WCRP, WWRP, WGNE, SPARC, GEWEX)*
- ***WGNE workshop on Systematic Errors****: Montreal, Canada, June 2017 (please stay tuned!)*
- ***WCRP Modelling Summit****: UKMO, Exeter, UK, October 2017*

Collaboration

- ***CMIP6****: output to include surface stress components*
- ***WGNE*** *and* ***SPARC*** *(and other groups): hopefully extend collaboration and consider coordinated workshops / symposiums on themes related to representation of momentum exchanges in models*

Potential topics for future WGNE-SPARC coordinated activities

Potentially common theme, based on issues raised by Drag Project and some talks from SPARC symposium:

Representation of effects/disturbances generated by complex terrain/orography

- *resolved versus parametrized (dynamics-physics coupling)*
- *interaction with other parametrized processes (e.g. turbulence)*
- *guidance from theoretical studies, high-resolution simulations and observations*

Coordinated activities (e.g. intercomparison studies, workshops, etc.) might benefit from bringing together different communities and expertises:

- *experts in boundary layer turbulence and orographic waves*
- *from NWP to climate scales*
- *developers of dynamical core and physical parametrizations*
- *modelling versus observations*

Of special interest for WGNE*:*

Focus on common/systematic model errors across scales...

Thank you