Environment and Climate Change Canada
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Activities at CMC to reduce systematic errors in the GEM model

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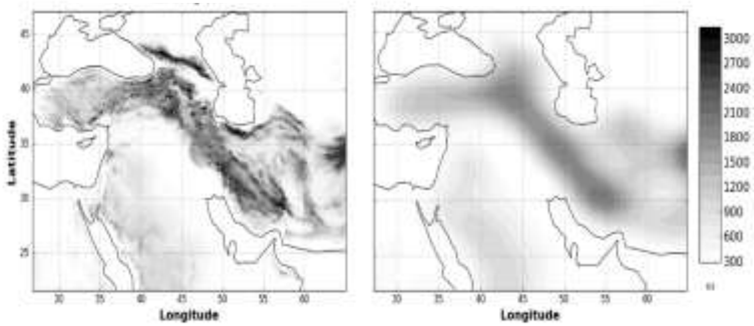
But first… some publicity!

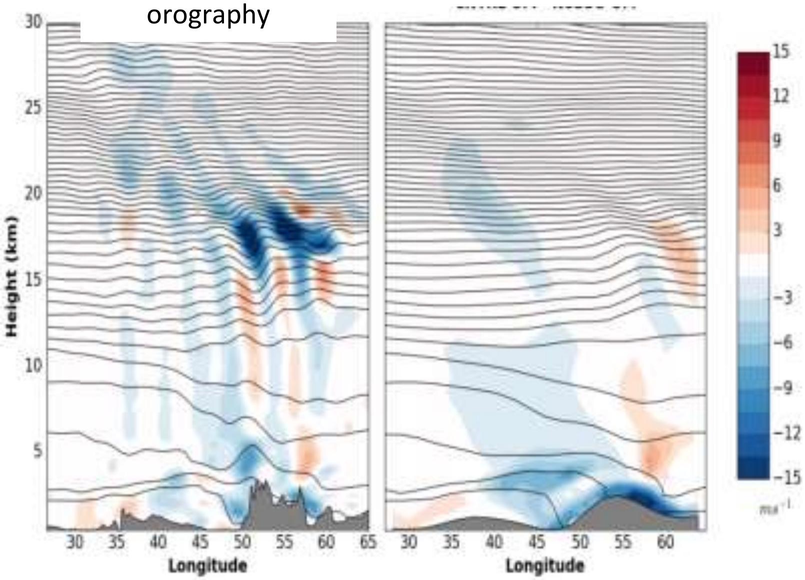
COnstraining ORographic Drag Effects (**COORDE**)

High resolution orography | Low resolution orography



Plot shows the impact on the zonal winds from small-scale resolved orography (left) and parametrized orographic drag (right) in the Met Office UM

Impact of resolved orography | Impact of parametrized orographic drag



van Niekerk et al. (2018), JAMES

Understanding the effects of resolved and parametrized orographic drag through the ***COORDE***-nation of different modeling groups.

Aims:

- Expose differences in orographic drag parametrization formulation between models
- Understand impacts of differences in orographic drag parametrizations for modelled circulation
- Use high resolution simulations to quantify drag from small-scale orography, typically unresolved in models used for climate/seasonal projections, in order to evaluate orographic drag parametrizations
- Understand differences in resolved and parametrized orographic drag across models

Potential participants currently include: Environment Canada, DWD, CMA, NOAA/NCEP, KIAPS, Meteo-France, Met Office and ECMWF.

Contact Annelize.vanNiekerk@MetOffice.gov.uk and irina.sandu@ecmwf.int for more information or if you are interested in participating

"Now back to our regularly scheduled programme…"

Some aspects of a recent R&D project at CMC, of possible interest for WGNE

Main goal was to improve forecast skill while

- *diagnosing the cause and reducing some of the known systematic errors*
- *increasing the model resolution (horizontal and/or vertical)*
- *trying to "unify" the physics packages used by the low and high-resolution systems*

The approach used involved

- *challenging the model across resolutions/scales*
- *developing parametrizations less sensitive to vertical resolution*
- *imposing conservation principles (e.g. mass, momentum, energy, water)*
- *participating in (and benefiting from) international projects*
- *expanding R&D strategies*

Development Strategies

(slide kindly provided by Ron McTaggart-Cowan, RPN/ECCC)

Cost / Turnaround Time / Complexity

- Single Column Model
- Small LAM Case Study
- Full Model Case Study
- Tendency Diagnostics
- Reduced Res. Sequence
- Full Res. Sequence
- MHEEP
- Reduced Res. Cycle
- Full Res. Cycle

- To help us focus on specific physical processes, we used a hierarchy of models and configurations in C&P
- Investigations often move back and forth between complex and simpler frameworks
- The use of reduced resolution forecasts and cycles is a common approach that seems essential given limited resources
- Evaluation techniques in C&P include:
  - Standard upper air and surface scoring
  - Comparison with obs, gridded retrievals, climatologies, cyclone tracking datasets
  - Expert evaluation of cases/systematic behaviours
  - Assessment of parameterization tendencies
  - Participation in intercomparison projects

Model **H**ydrological and **E**nergy Budget **E**valuation **P**roject

(slides kindly provided by Paul Vaillancourt, RPN/ECCC)

Objective:

- evaluate the mean state of all components of the hydrological cycle as well as surface and top of atmosphere energy budgets

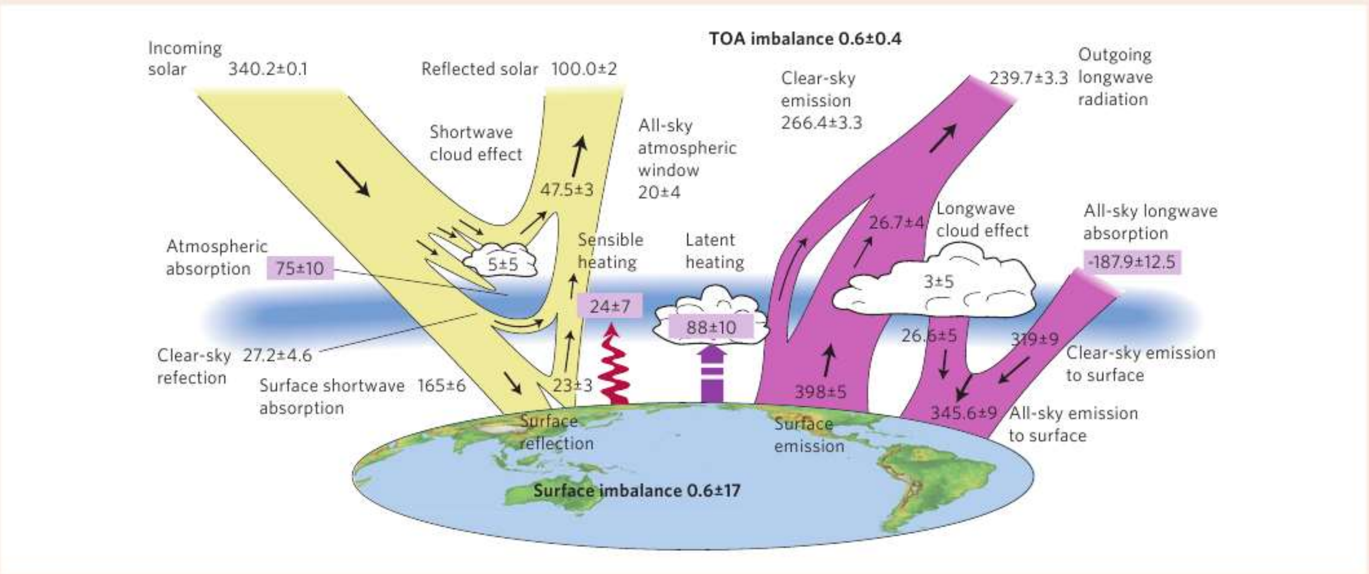


Figure B1 | The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2}. Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance.

Climatologies:
Trenberth et al. 2009
Stephens et al. 2012
Stephens et al. 2015
Wild et al. 2015

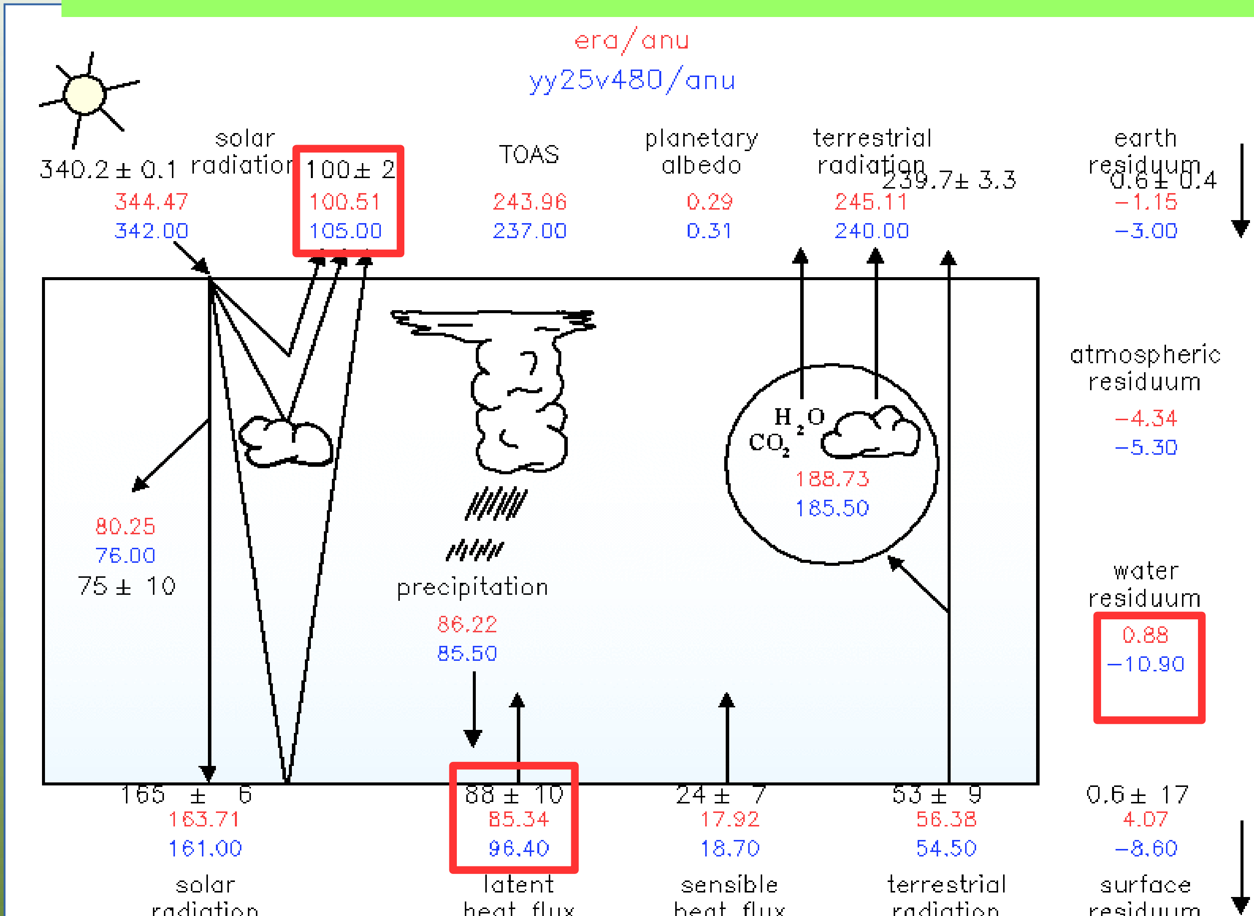
MHEEP - protocol

- Run four 13-month 25km free runs (year 2009), starting from MSC analyses staggered by 1day+6 hours.
- Daily SST and sea-ice fraction from MSC analyses.
- Ensemble annual/seasonal means are produced for:
  - TOA and SFC radiative fluxes
  - Latent/Sensible heat SFC fluxes
  - PR, precipitable water, liquid water path, cloud fraction
- Compare to ...

MHEEP – evaluation datasets

Variable	Source 1 – obs/anal	Source 2 - reanalysis	Source 3 - climatologies
Precipitation	Global Precipitation Climatology Project (provided by the NOAA/OAR/ESRL PSD)	ERA-interim	Trenberth/Stephens/Wild
Precipitable water	Multi-Sat Merged Monthly 1-deg (Remote Sensing Systems sponsored by NASA)	ERA-interim	
Liquid water path	Monthly SSMIS (Remote Sensing Systems sponsored by NASA)	ERA-interim	
Cloud fraction	Combined Cloudsat-Calipso (Kay and Gettelman 2009)	ERA-interim	Trenberth/Stephens/Wild
Latent/Sensible heat flux	Woods Hole OAFLUX	ERA-interim	Trenberth/Stephens/Wild
TOA and Surface SW and LW fluxes	CERES-EBAF-3B / ERA-interim (NASA)	ERA-interim	Trenberth/Stephens/Wild

MHEEP – summary graphs



Summary graph of global annual means
Black: Stephens et al. 2012 climatology
Red: ERA-int for 2009. Blue: MHEEP control runs

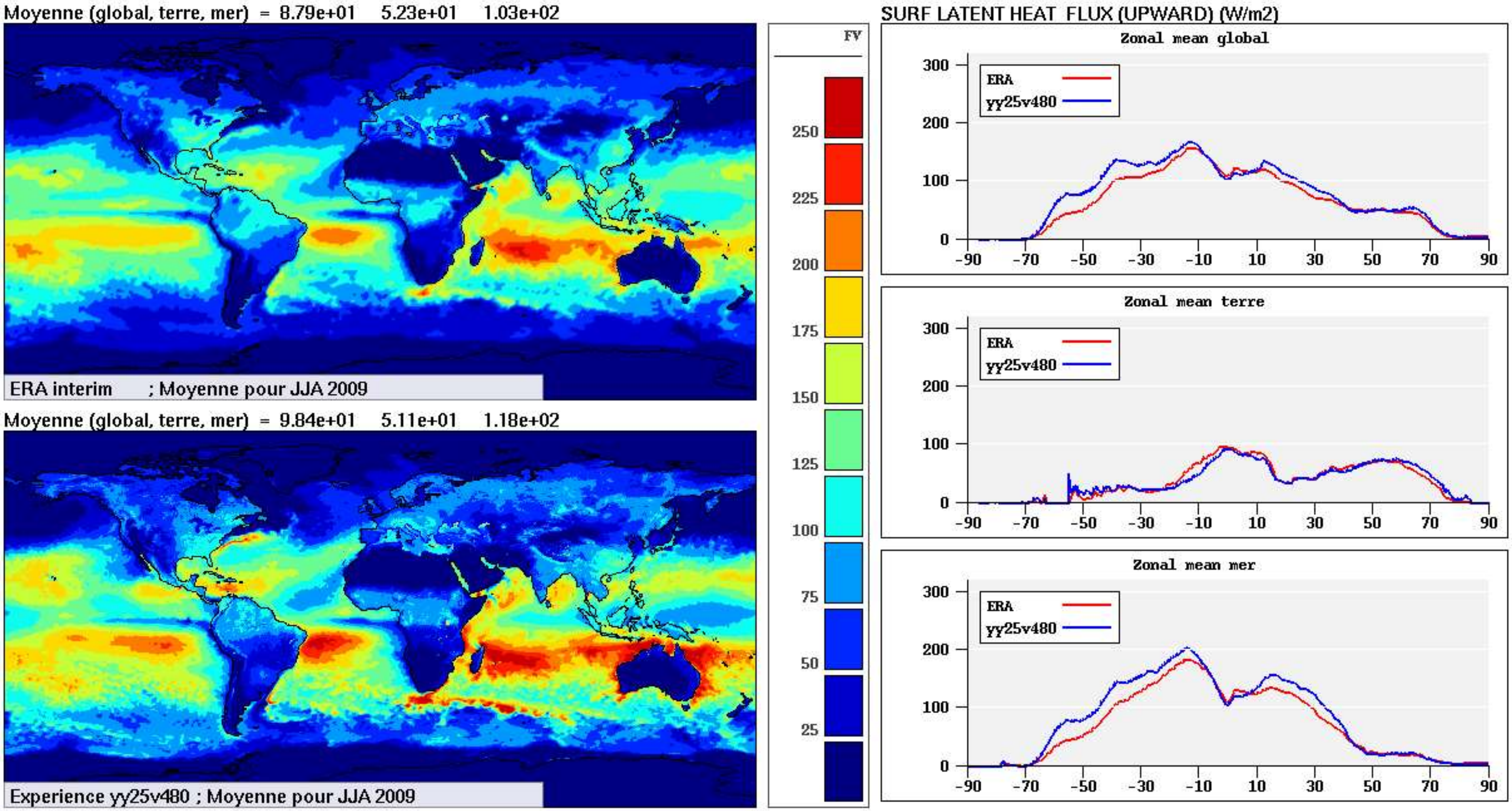
Main problems identified:

Water residuum: large imbalance between evaporation & precipitation.

Latent heat fluxes: Largest error in the energy budget.

Solar radiation fluxes: Over-estimate of planetary albedo and under-estimate of SW flux at surface.

Maps and zonal means: JJA-2009 means of latent heat surface fluxes (W/m2)



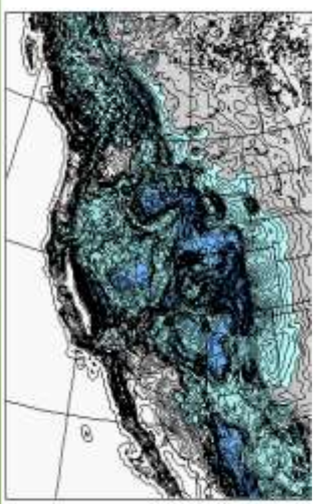
Top right: **ERA interim**
Bottom right: **operational model** GDPS

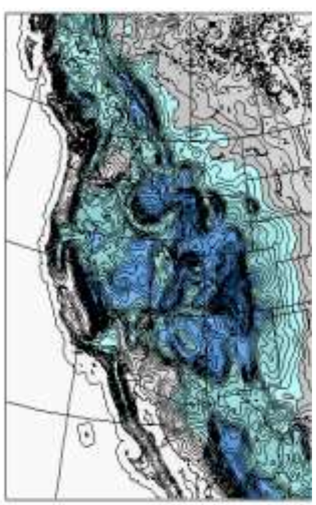
Zonal means (global, land, ocean)
ERA versus **Model**

Topography:
"To filter or not to filter?"

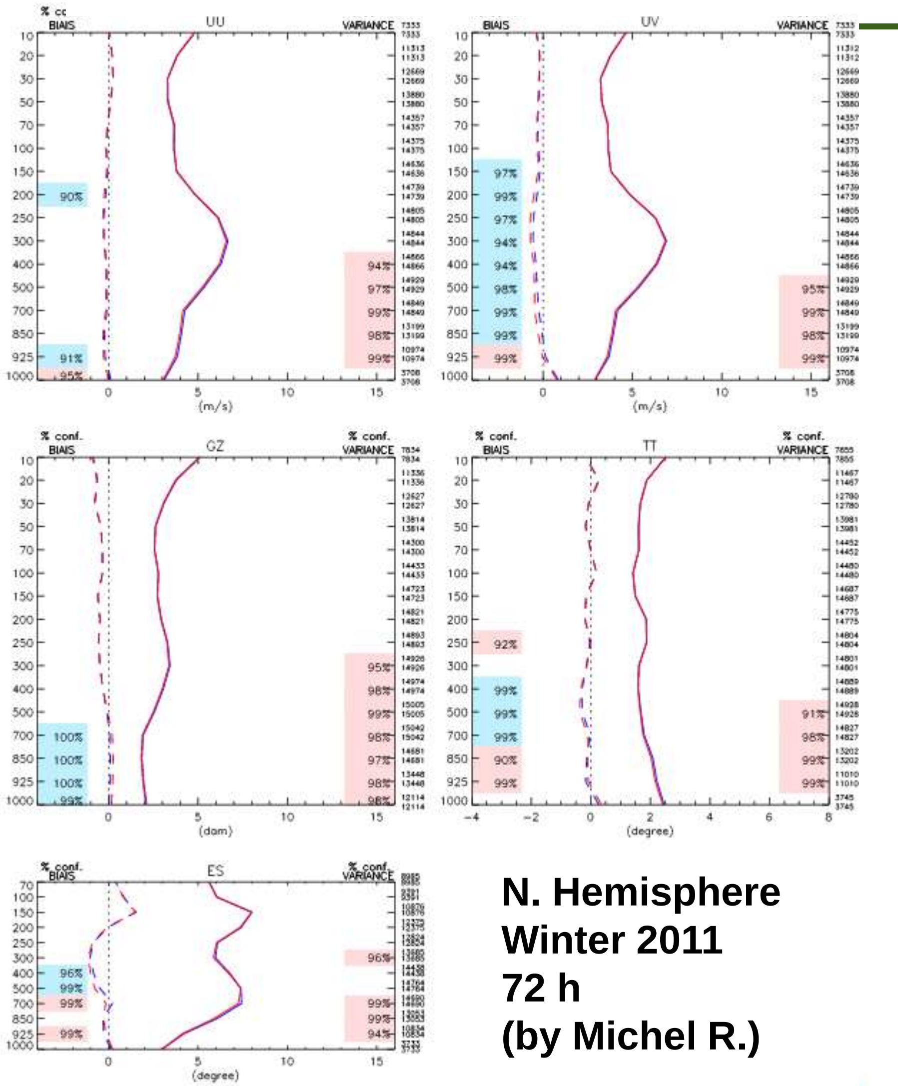
Scores against radiosondes
Sensitivity test
GDPS-25m: (oper) filtered ME
GDPS-25km: non-filtered ME

- in early stages of the project, we realized that the topography **filter** currently used is probably "**too aggressive"**, leading to an excessively smoothed topography
- sensitivity tests revealed that removing the filter (or possibly using a sharper filter) could improve the quality of forecasts



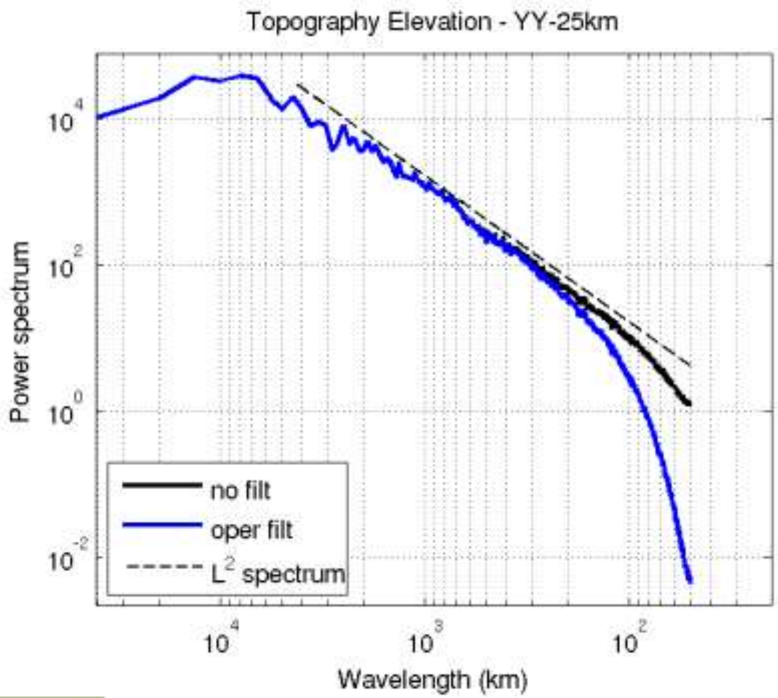


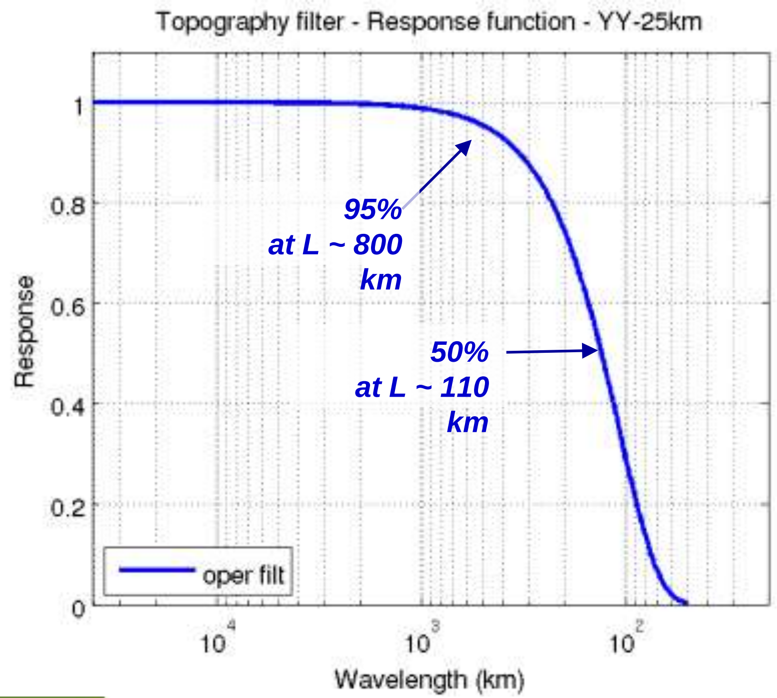
non-filtered ME (oper) filtered ME



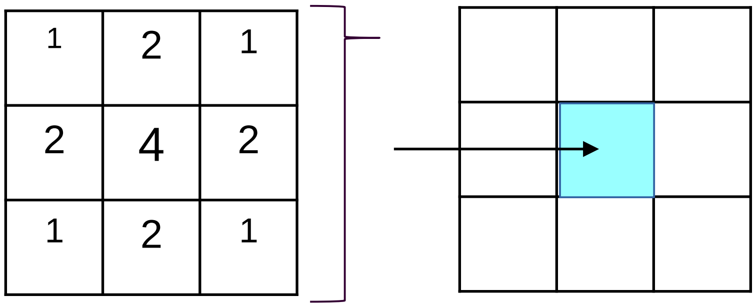
N. Hemisphere
Winter 2011
72 h
(by Michel R.)

Canada





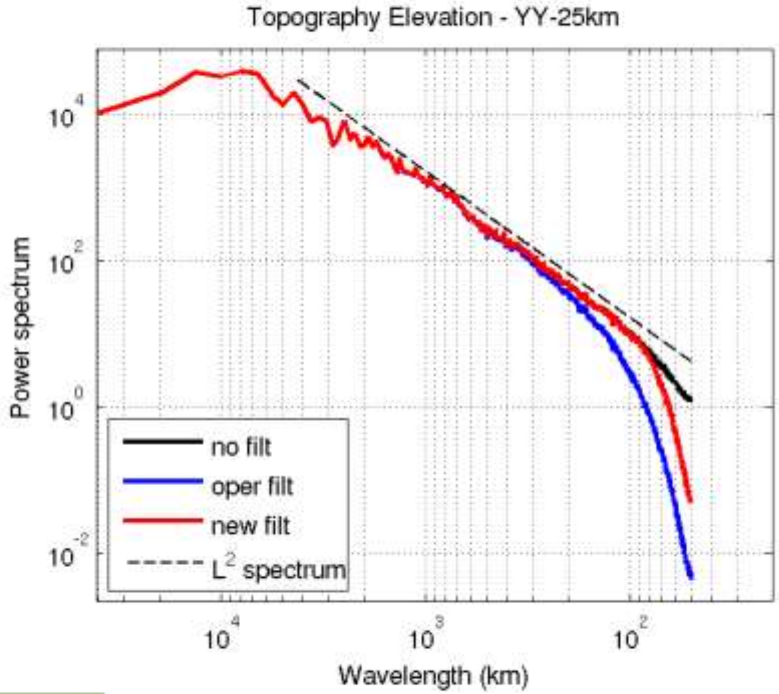
- The operational filter (sometimes referred to as the "**2-dx filter**") uses a simple 9-point-average of near-neighbor values, with weights indicated in the diagram below:

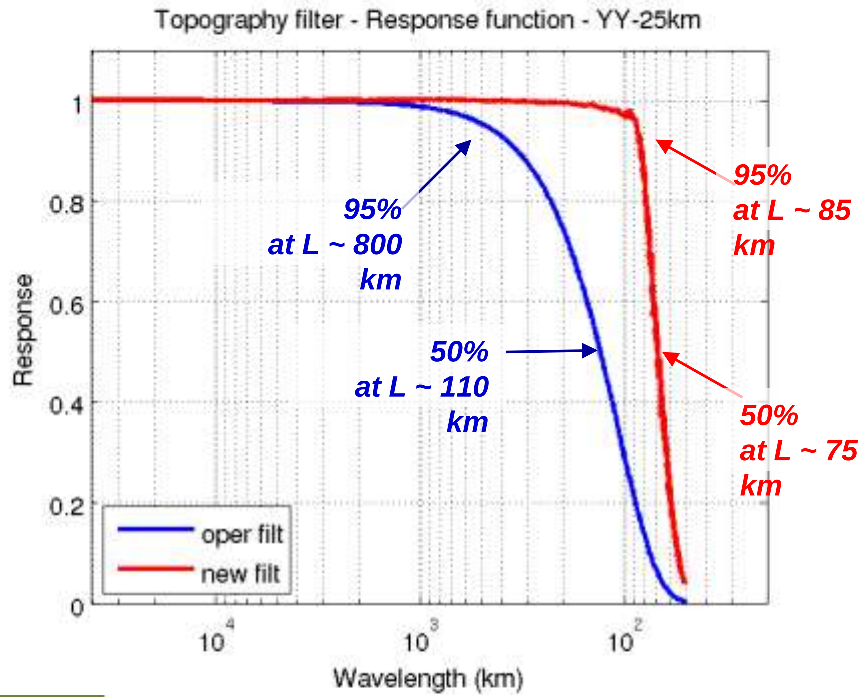


filter weights

- The primary goal of the filter was to eliminate wavelengths of size 2-dx (where dx is the grid spacing), but the filter weights are such that even wavelengths **up to 30-dx are affected**.

- In the case of the operational GDPS-25km, this implies a 50% loss in amplitude at ~110 km, and **5% loss at ~800 km**.





- A **new topography filter** is now available in **GenPhysX**. It is also a N-point-average filter, inspired by the so-called "*topography digital filter*" previously used (in older versions of GEM) for GU grids, to eliminate topography anisotropies near the poles.
- The new filter comes with 2 adjustable parameters that allow the user to control
  (a) its **sharpness** and
  (b) the **wavelength** at which the amplitude should be reduced by **50%**
  - In the example on the left, still for the operational GDPS-25km, the new filter gives 50% amplitude at 3x25km = 75km, and reaches **95% at ~85 km** (instead of the 800 km of the operational filter).

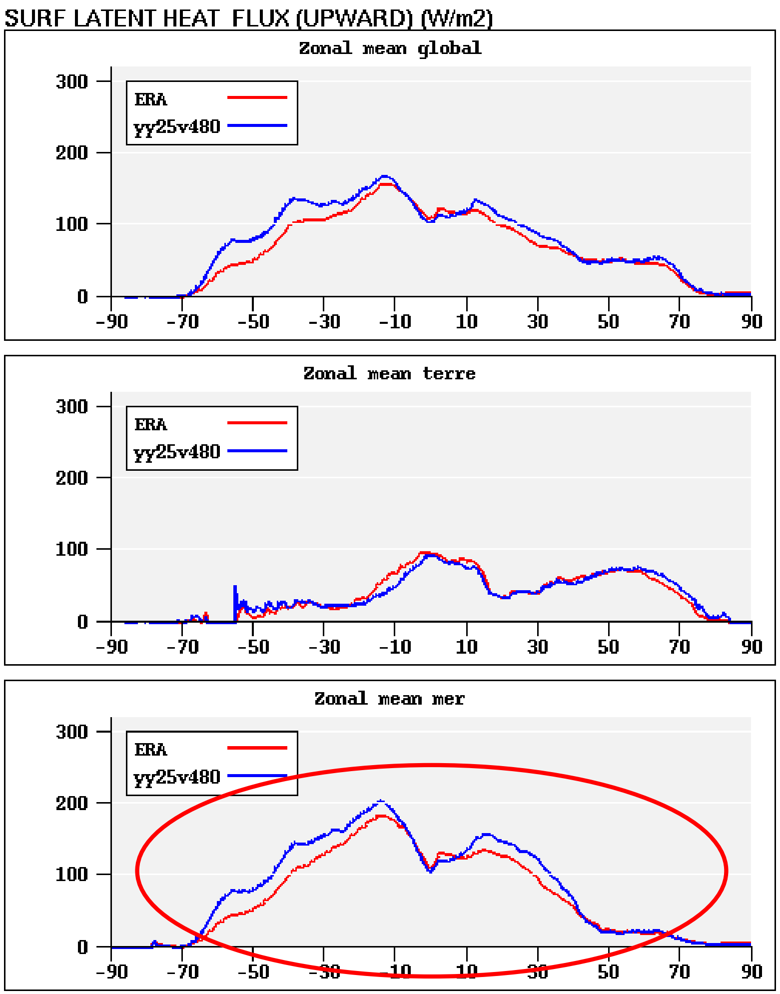
Selected results, combining all model changes*

* Mainly changes/improvements in parameterizations, e.g.

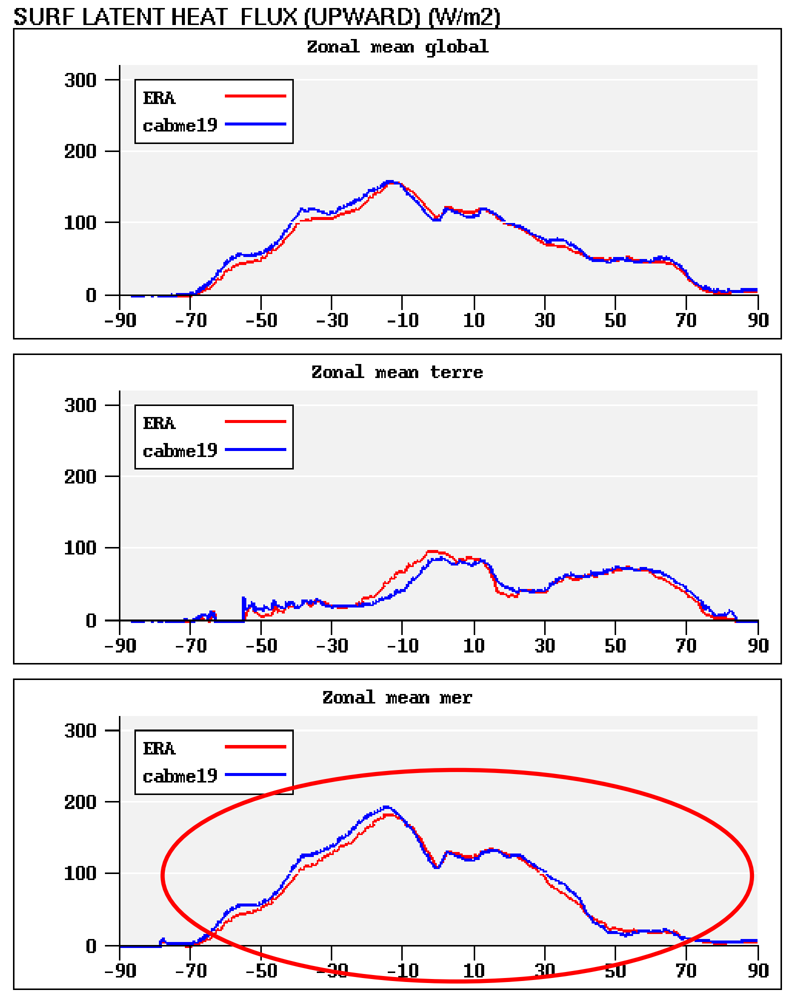
- *revised or new **deep/mid-level/shallow convection** schemes (all following a "mass-flux" formulation, and based on Kain-Fritsch approach)*
- *energy and water conservation imposed in **gridscale condensation** scheme*
- *revised **PBL** scheme (code refactored, new mixing length, improved treatment of BL clouds, dissipative heating included, updates in surface-layer calculations for improved coupling under strongly stable conditions)*
- *improved **orographic blocking** scheme (code refactored to reduce sensitivity to vertical resolution, dissipative heating included, new ancillary fields)*
- *updated **radiative transfer** scheme (including new climatologies for ozone, greenhouse gases, and land-surface emissivity)*

Zonal means of JJA-2009 means of latent heat surface fluxes (W/m2)

ERA versus Operational model



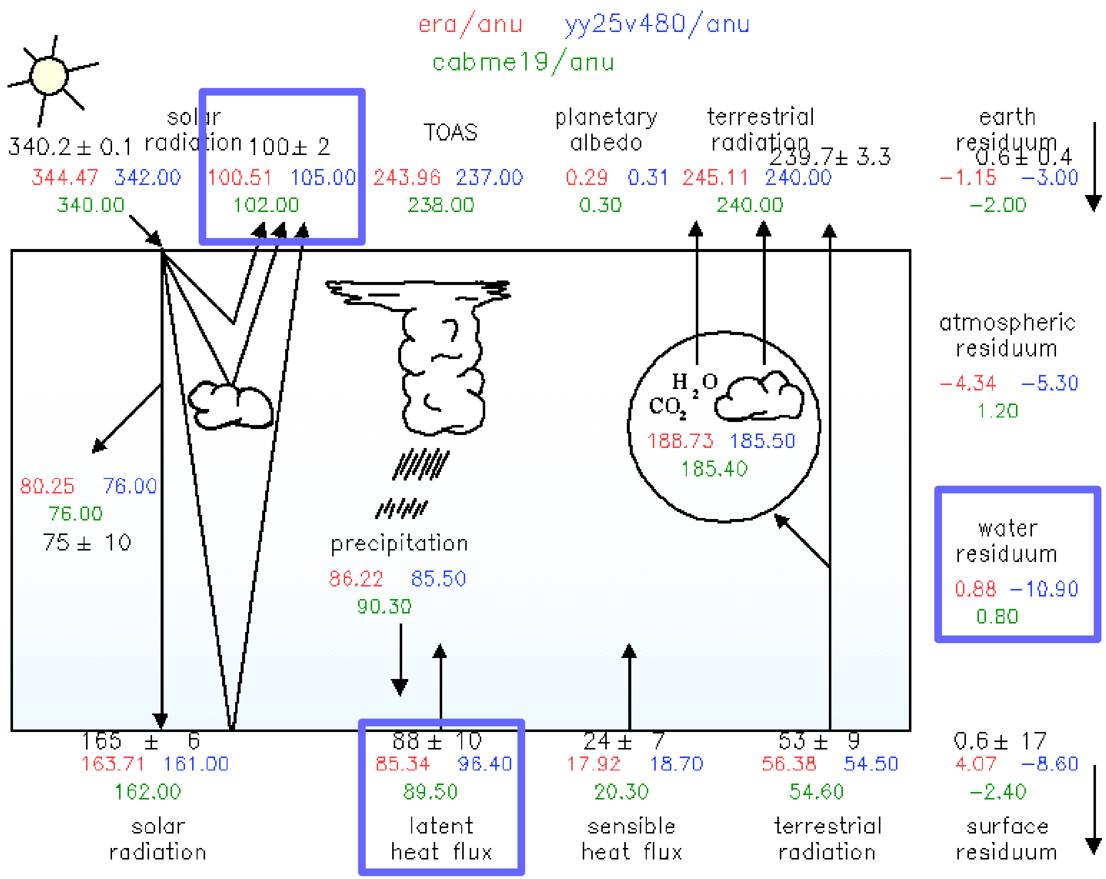
ERA versus Experimental model



MHEEP

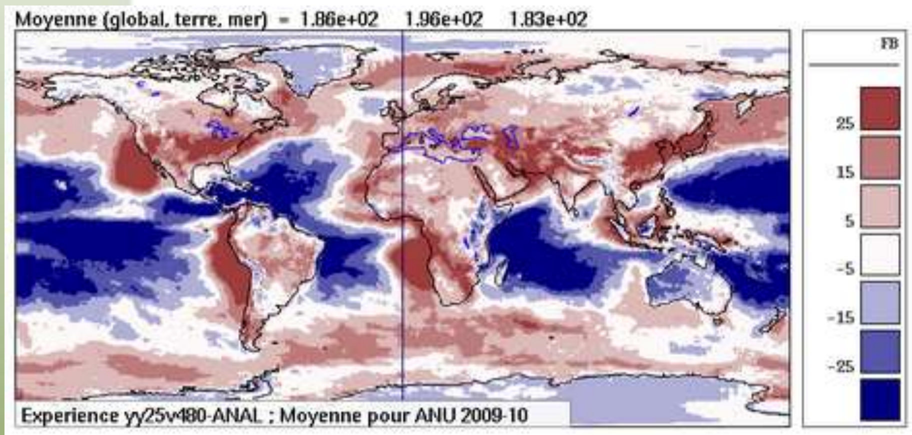
latest config vs GDPS-ops-ctl

ERA
OPER model
EXPE model

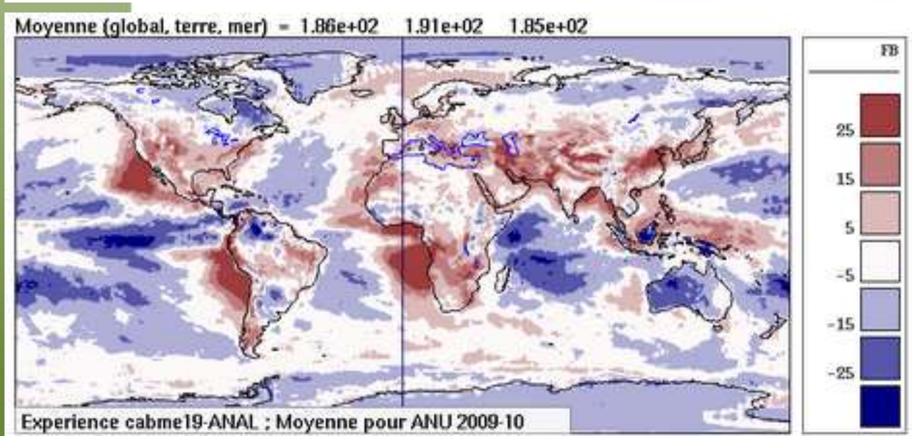


MHEEP

improvements in **SW flux at sfc**



annual mean of
OPER model *minus* **CERES obs**

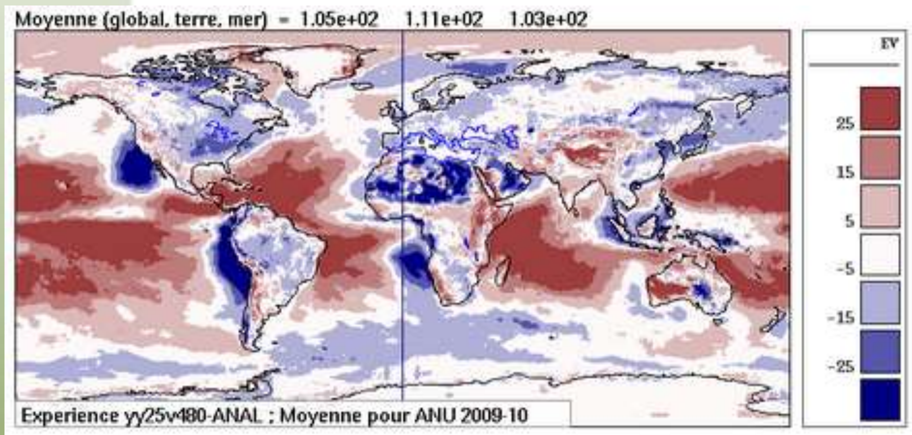


annual mean of
EXPER model *minus* **CERES obs**

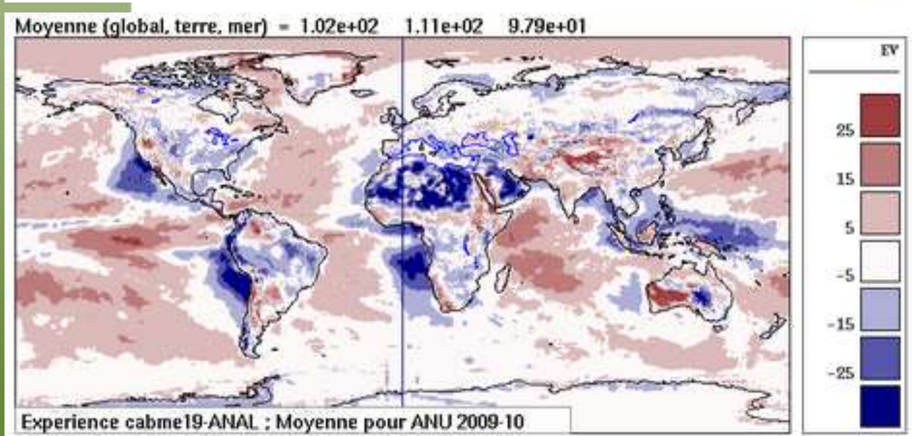
W m-2

MHEEP

improvements in **SW flux at TOA**



annual mean of
OPER model *minus* CERES obs

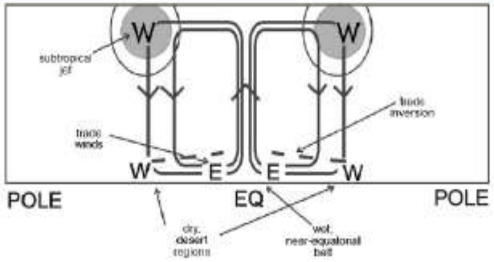


annual mean of
EXPER model *minus* CERES obs

W m-2

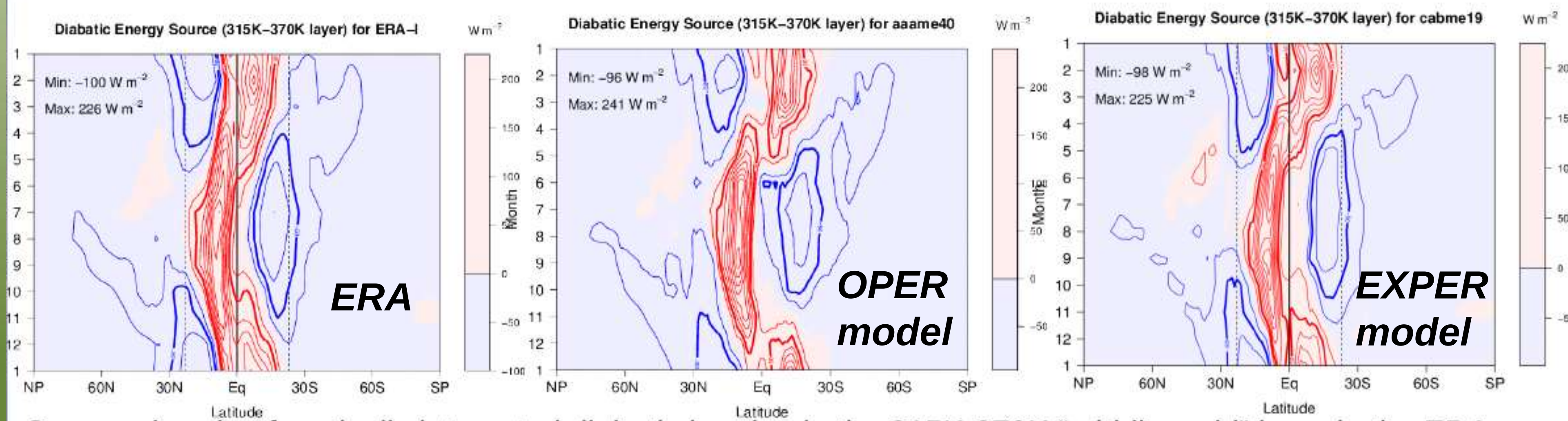
Strength of the Hadley Cells

(slide kindly provided by Ron McTaggart-Cowan,RPN/ECCC)



Schematic of Hadley cells (MIT).

- The Hadley Cells are thermally direct mean meridional circulations that are driven by latent heat release in the intertropical convergence zone
- Diabatic heating rates are transformed to vertical mass flux in isentropic coordinates to estimate the circulation strength
- The amplitude, structure and seasonal cycle of Hadley cells is improved the C&P physics and conservation configuration

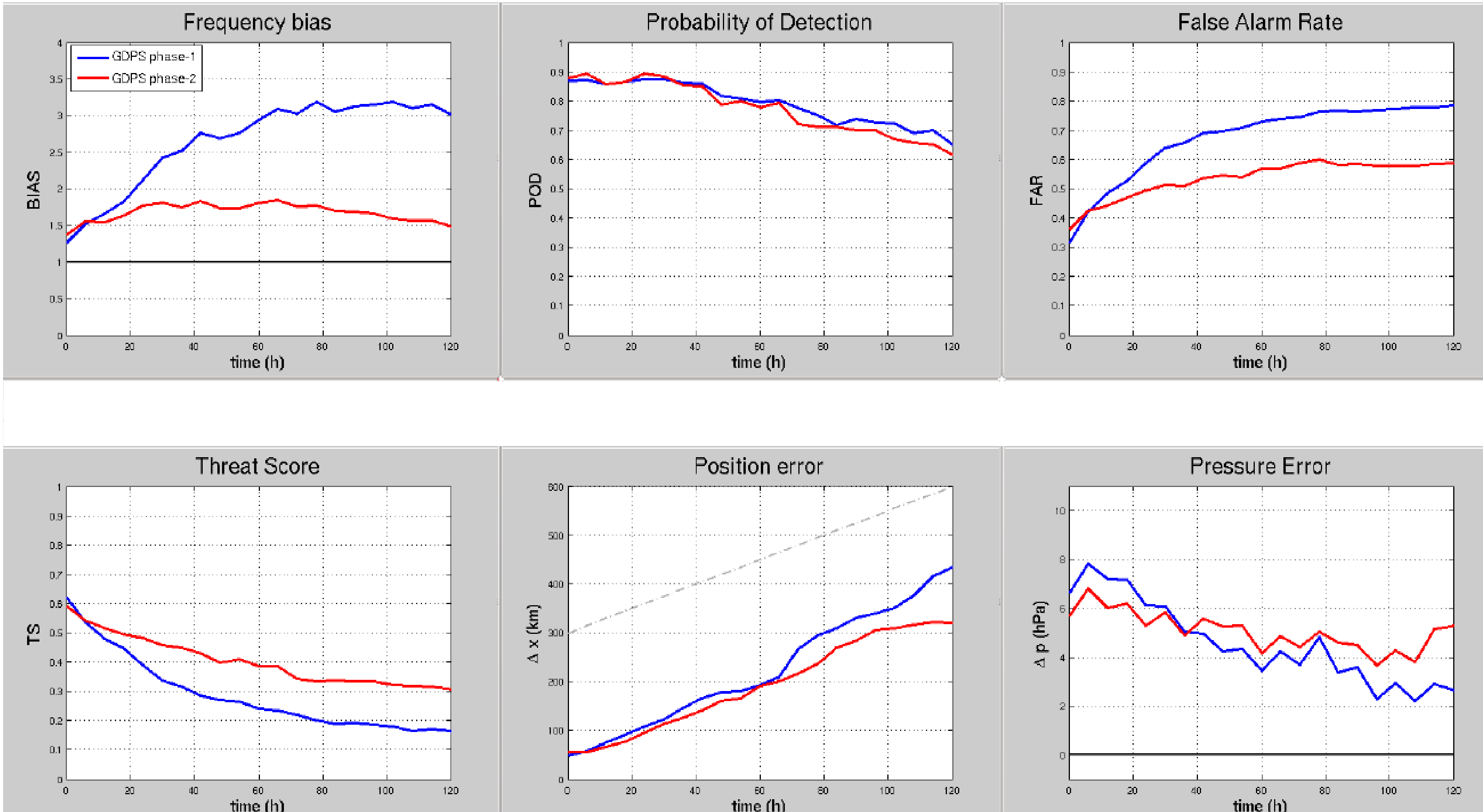


Seasonal cycle of vertically integrated diabatic heating in the 315K-370K "middleworld" layer in the ERA-Interim analysis (left), an operationally configured control (middle) and a recent configuration (right).

Impact on Tropical Cyclone forecasts

Operational versus **experimental** model

Verification against best tracks, averages over Summer 2016

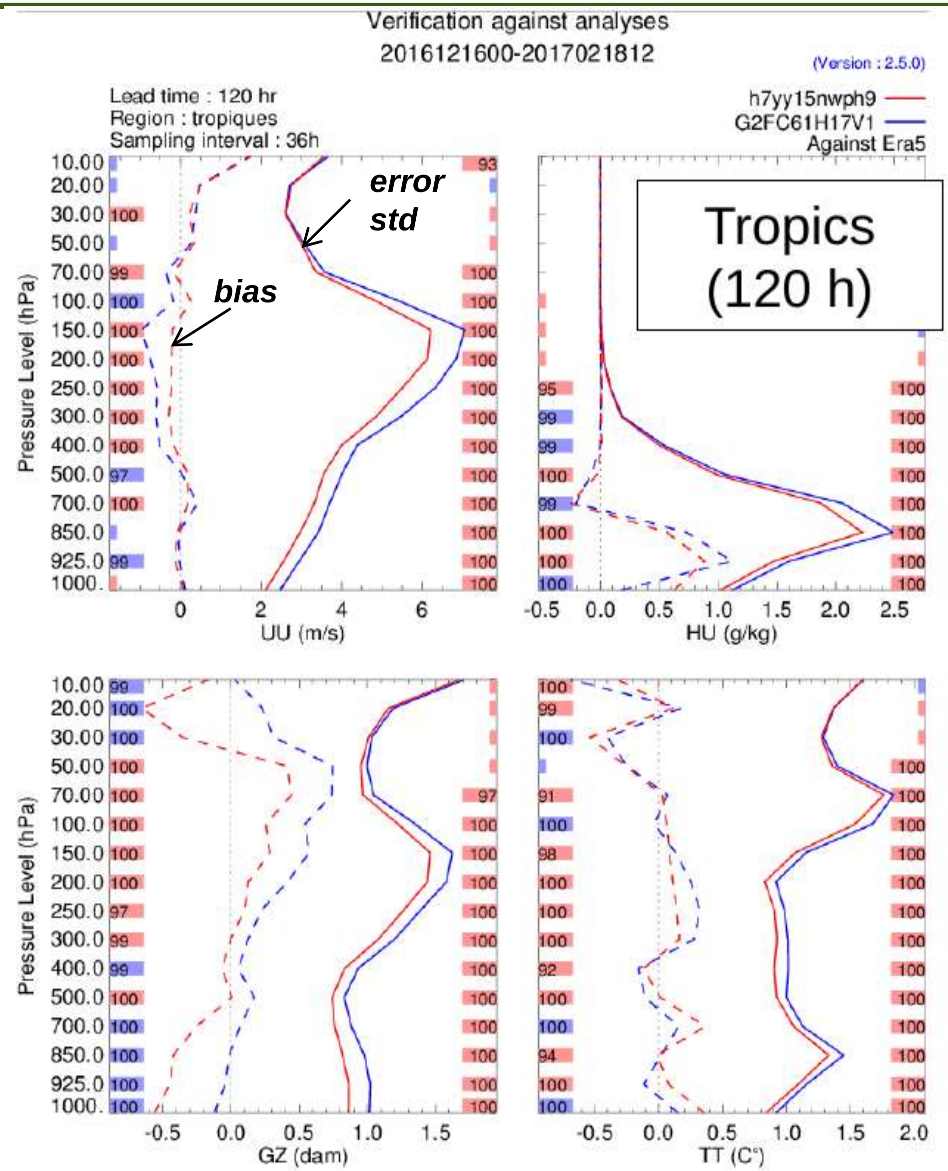


Tropical evaluation against ERA5

Operational versus **experimental** model

Zonal Wind

Geopotential height



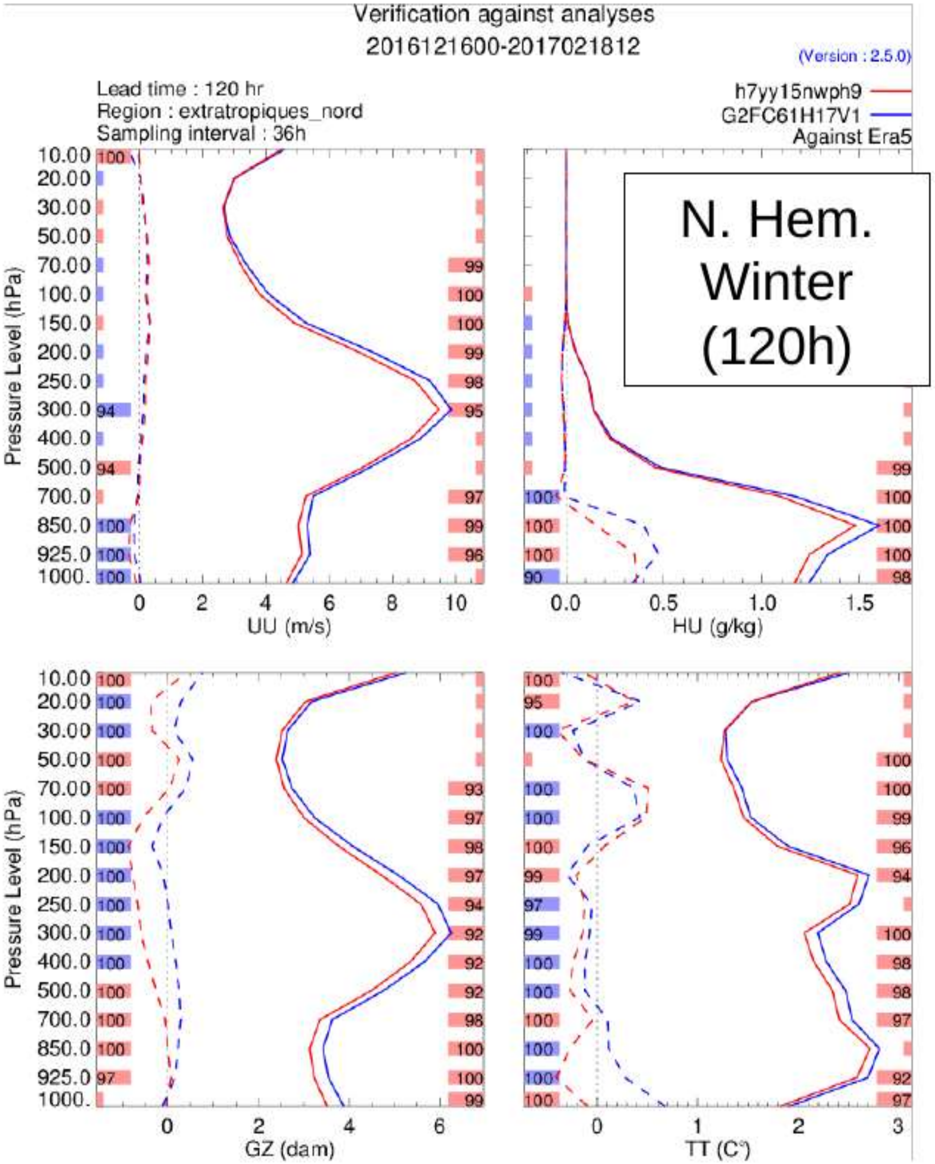
Specific humidity

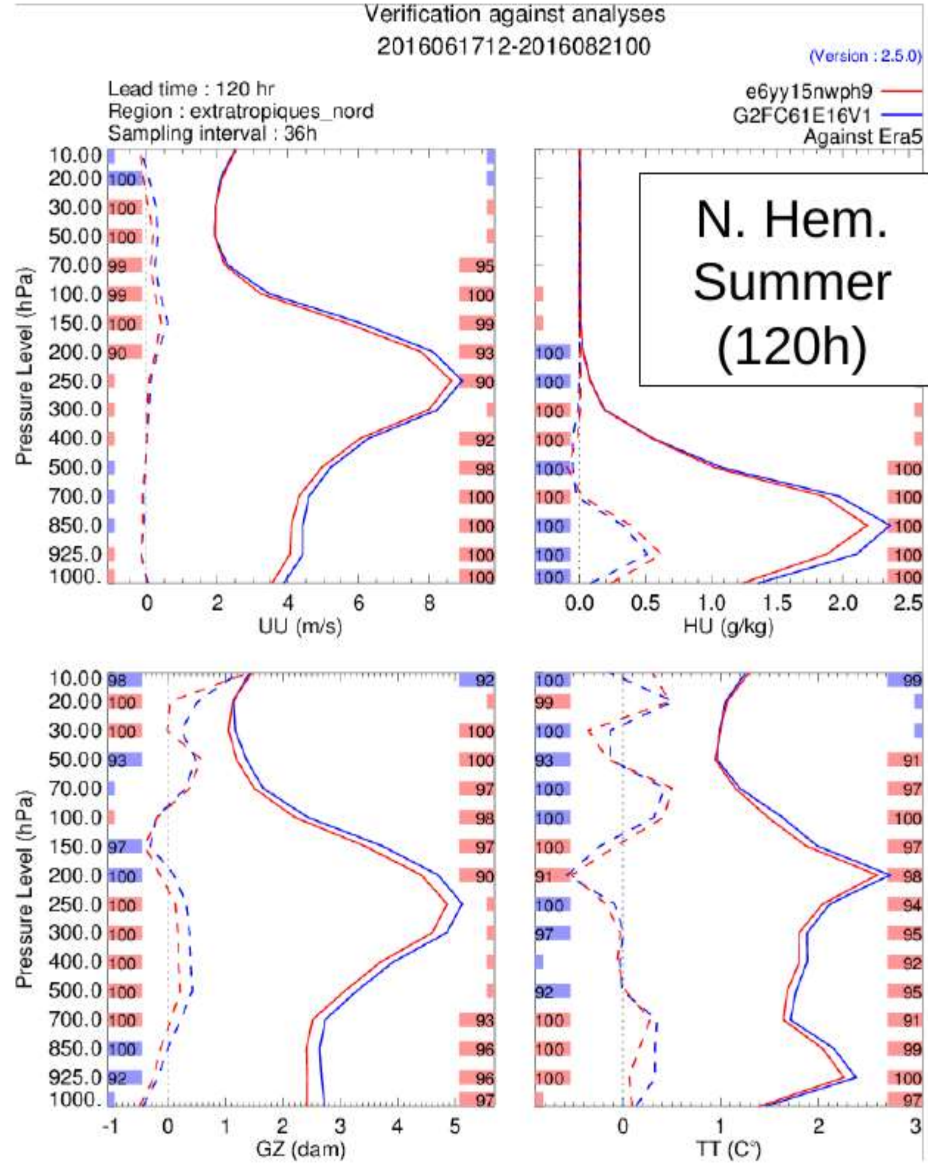
Temperature

Canada

Extratropical Evaluation Against ERA5

Operational versus **experimental** model

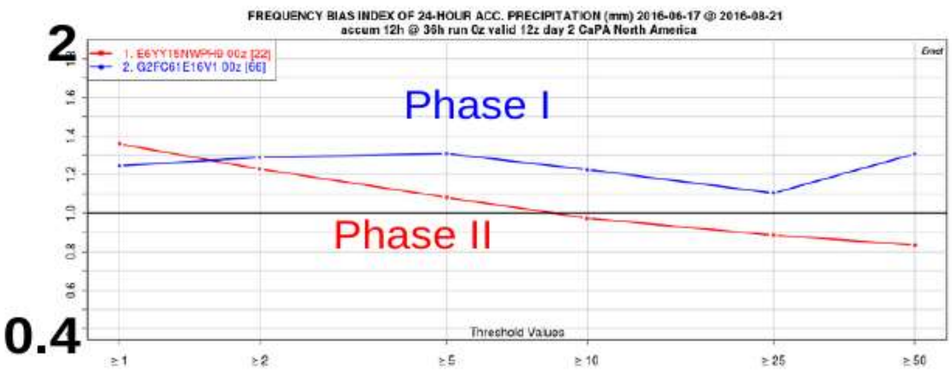




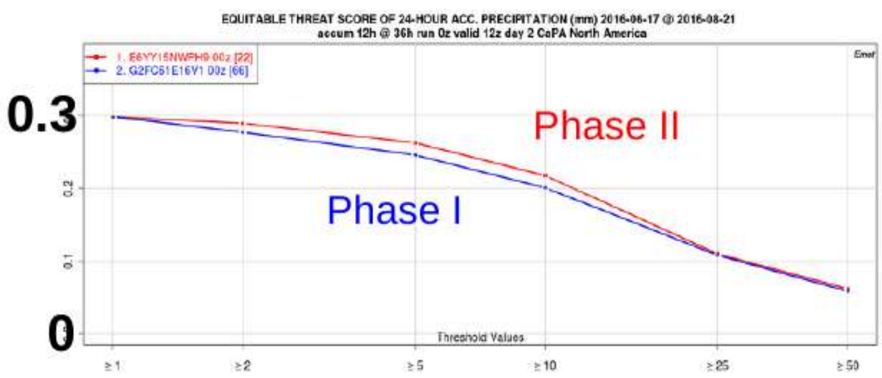
Impact on precipitation over N. America

Operational versus **experimental** model

Frequency Bias Index



Equitable Threat Score



Precipitation Bias and ETS,
24h accumulation
(12-36h lead time)

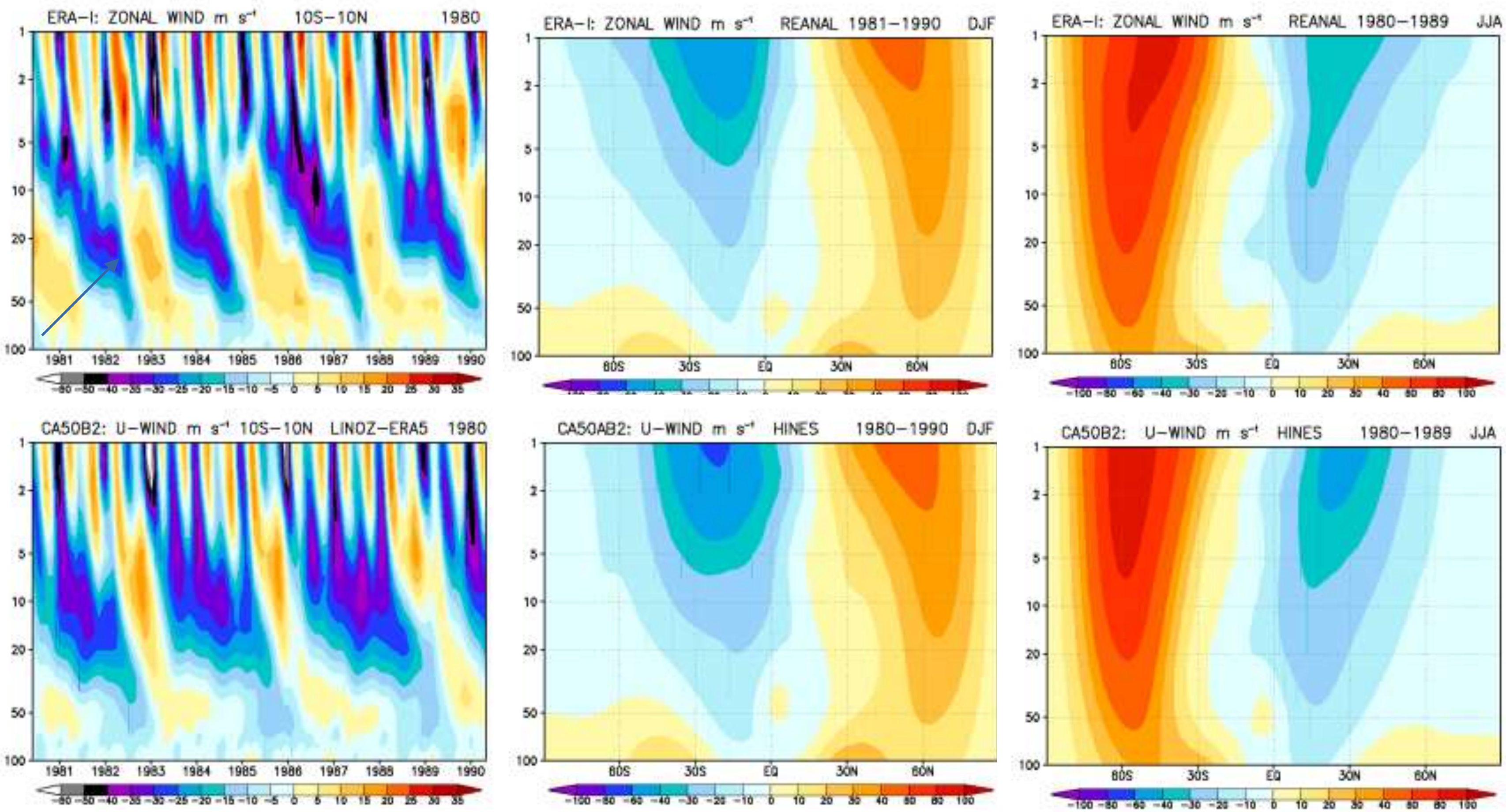
Canada

Evaluation of multi-year means and QBO

(slide kindly provided by Jean de Grandpré and Irena Ivanova, ARQI/ECCC)

- Comparison of 10-yr model runs (1981-1990, prescribed SST) against reanalyses (Era-Interim).

	U-Wind 10S-10N 10-yr Time Series	DJF U-Wind 10-yr mean	JJA U-Wind 10-yr mean
ERA Interim			
EXP model			



Merci