"Modernisation des paramétrisations de la physique atmosphérique des modèles de PNT canadien"

Partie I: Introduction, stratégie de développement et description des changements aux schémas de transfert radiatif et de convection.

15 janvier 2020

Paul Vaillancourt
RPN-A, ECCC

Le projet “Modernisation des paramétrisations de la physique atmosphérique des modèles de PNT canadien”

- A débuté en 2014 pour faire face aux irritants suivants:
  - Surestimation significative de l’évaporation sur les océans
  - Surestimation de la précipitation du modèle régional
  - Schéma de convection restreinte non conservatif dans le SGPD
  - Surestimation significative du nombre de tempêtes tropicales
  - Seul centre opérationnel à ne pas paramétrer le transport de momentum par la convection
  - Seul centre opérationnel à ne pas paramétrer la “convection élevée”
  - Seul centre opérationnel à ne pas avoir son premier niveau modèle entre 5-10m (premier niveau à 20m)
  - Ensemble de paramétrage différent pour chaque système (2.5,10,15,25,39km)

Le projet "Modernisation des paramétrisations de la physique atmosphérique des modèles de PNT canadien"

Le groupe de physique de l'atmosphère de RPN-A a reçu le mandat d'attaquer ces problèmes de façon intégrée et pour tous les systèmes de prévision numérique, sans trop de contrainte sur la durée du projet…

Cela a permis de formuler des objectifs ambitieux :

- Moderniser la physique:
  - Éliminer options non physiques, créer nouveaux schémas, nouvelles options, recoder
  - Rendre les paramètres libres plus physiques et "state dependent"
  - Augmenter cohérence, améliorer communication entre les schémas
- Améliorer le budget globale d'énergie et le cycle hydrologique
- Augmenter la résolution horizontale et verticale et abaisser le premier niveau modèle à 10m
- Moderniser la stratégie de développement
- Physique unifiée pour tous les systèmes

Merci à tous les contributeurs!

- Recherche-RPN:

R. McTaggart-Cowan (chef de projet), A. Zadra, P. Vaillancourt, D. Paquin-Ricard, J. Milbrandt, H. Barker, J. Yang, Michel Roch, L. Separovic, C. Girard, S. Chamberland, S. Heilliette, M. Charron , B. Cassati, C. Jouan

- CMC-Développement:

A. Patoine, S. Corvec, F. Lemay, N. Gasset

- Division Qualité de l'air :

J. DeGrandPré, I. Ivanova

- Division Climat:

J. Cole, J. Li

Aperçu des composantes modifiées:




Radiative Transfer (PV)	minor changes/minor impacts
Shallow Convection (PV)	new/major impacts
Deep Convection (PV/RMC)	major changes/major impacts
Elevated Convection (RMC)	new/major impacts
Surface (AZ/RMC)	minor changes/major impacts
Surface Layer (AZ)	minor changes/major impacts
Blocking / Gravity Wave Drag (AZ)	minor changes/major impacts
Boundary Layer (AZ)	major changes/major impacts
Gridscale Condensation	minor changes/minor impacts

Autres: Résolution horizontale et verticale, conservation de la physique et de la dynamique (AZ/RMC)

Note: Environ 2 ans de travail ont été nécessaire pour comprendre et maîtriser la sensibilité à la position des niveaux dans la verticale (1er niveau en particulier). Même chose pour comprendre comment réduire les flux de chaleur latente.

Plan de la Partie I:

1) Introduction

2) Stratégie de développement / Transfert technologique

3) Quelques résultats “finaux” (pourquoi 3 séminaires!!)

4) Protocole “MHEEP” et résultats avec config initiale

5) Quoi de neuf pour le transfert radiatif

6) Quoi de neuf pour la convection: Partie 1/2

7) MHEEP: résultats avec config finale

Development Strategies

Cost / Turnaround time / Complexity

Single Column Model	[>10^3; 0.1h]
Small LAM Case Study	
Full Model Case Study	
Tendency Diagnostics	
Reduced Res. Sequence	[>100; 24h]
Full Res. Sequence	[< 100; 50h]
MHEEP	[< 100; 75h]
Reduced Res. Cycle	[5-10]
Full Res. Cycle	[< 5; 700h]

for GDPS: #of exps; hr/exp]

- We used a hierarchy of models and configurations
- Investigations often move back and forth between complex and simpler frameworks
- The use of reduced resolution forecasts and cycles (e.g. 25km for GDPS instead of target 15 km) is a common approach that seems essential given limited resources
- Evaluation techniques include:
  - Standard upper air and surface scoring
  - Comparison with obs, external re-analyses, gridded retrievals, climatologies, cyclone tracking datasets
  - Expert evaluation of cases/systematic behaviours
  - Assessment of parameterization tendencies
  - Participation in intercomparison projects

Quelques mots sur le processus de transfert technologique...

- < Sept 2018: Chaque groupe prépare une série de scores “standards” pour démontrer l’impacts des changements proposés
- Septembre 2018: présentations de résultats finaux sur les différentes composantes(atmosphère, océan-glace, assimilation...) proposées pour les cycles finaux. Décision sur la composition des cycles finaux.
- Oct-Déc 2018: Cycles finaux (cycles d’assimilation de 2.5 mois d’été et 2.5 mois d’hiver)
- Passe parallèle (nouveau système vs système ops en temps réel) de février-juin 2019. Évaluation objective (scores) et évaluation par les MT.
- Implantations opérationelles le 3 juillet 2019 du SGPD, SRPD et SRPE ...

Quelques résultats pour justifier 5 ans de travail et 3 séminaires...

Résultats complets:

Notes technique pour les implantations du CMC de juillet 2019:

Système global de prévision déterministe (SGPD): Passage de la version 6.1.0 à la version 7.0.0
https://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/tech_notes/technote_gdps-700_f.pdf

Système régional de prévision déterministe (SRPD): Passage de la version 6.00 à la version 7.00
https://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/tech_notes/technote_rdps-700_f.pdf

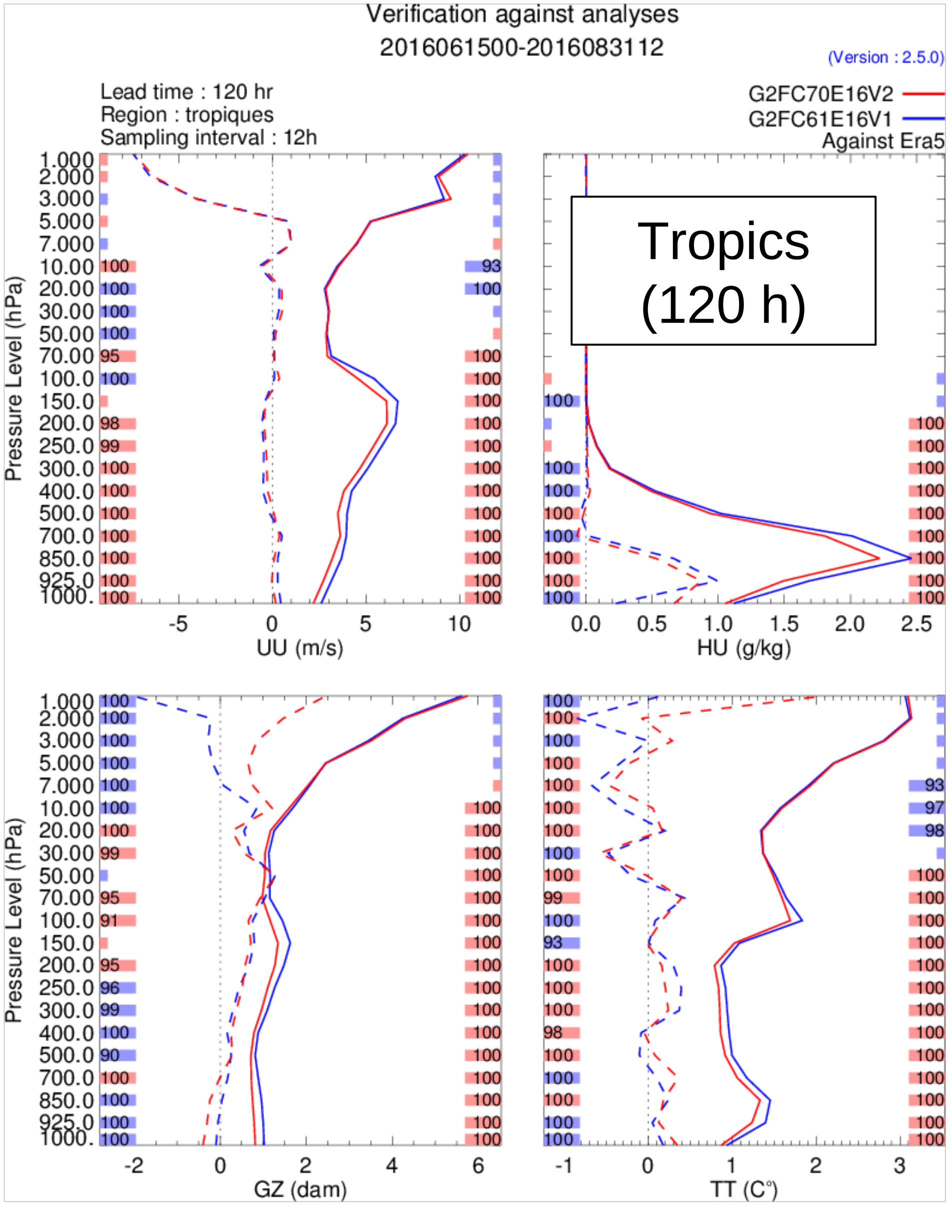
Système régional de prévision d'ensemble (SRPE): Version 3.0.0
https://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/tech_notes/technote_reps-300_20190703_f.pdf

Publications:

McTaggart-Cowan, R., P.A. Vaillancourt, A. Zadra, S. Chamberland, M. Charron, S. Corvec, J. Milbrandt, D. Paquin-Ricard, A. Patoine, M. Roch, L. Separovic, J. Yang, 2019: Modernization of Atmospheric Physics Parameterization in Canadian NWP. Journal of Advances in Modeling Earth Systems

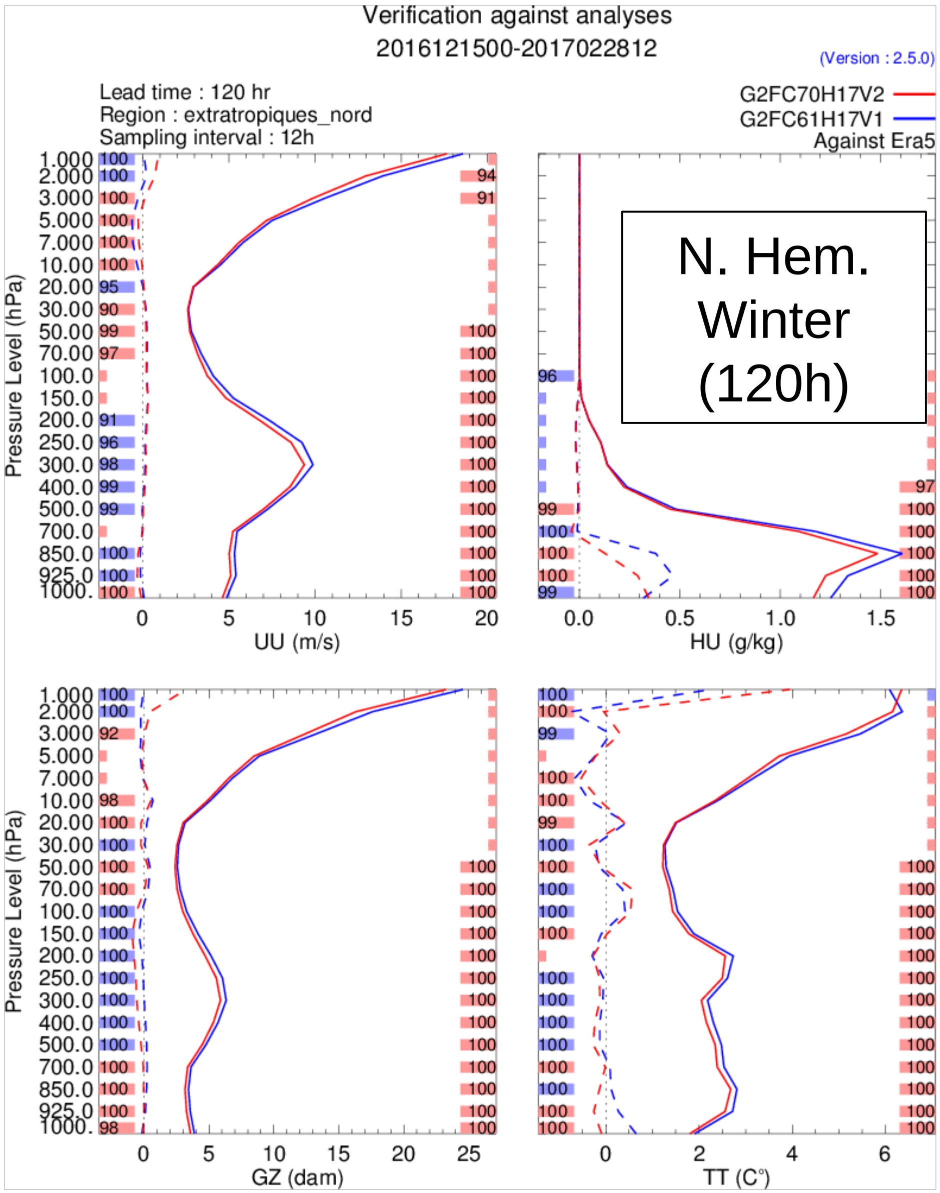
McTaggart-Cowan, R., P.A. Vaillancourt, A. Zadra, L. Separovic, S. Corvec, D. Kirshbaum, 2019: A Lagrangian Perspective on Parameterizing Deep Convection. Monthly Weather Review.

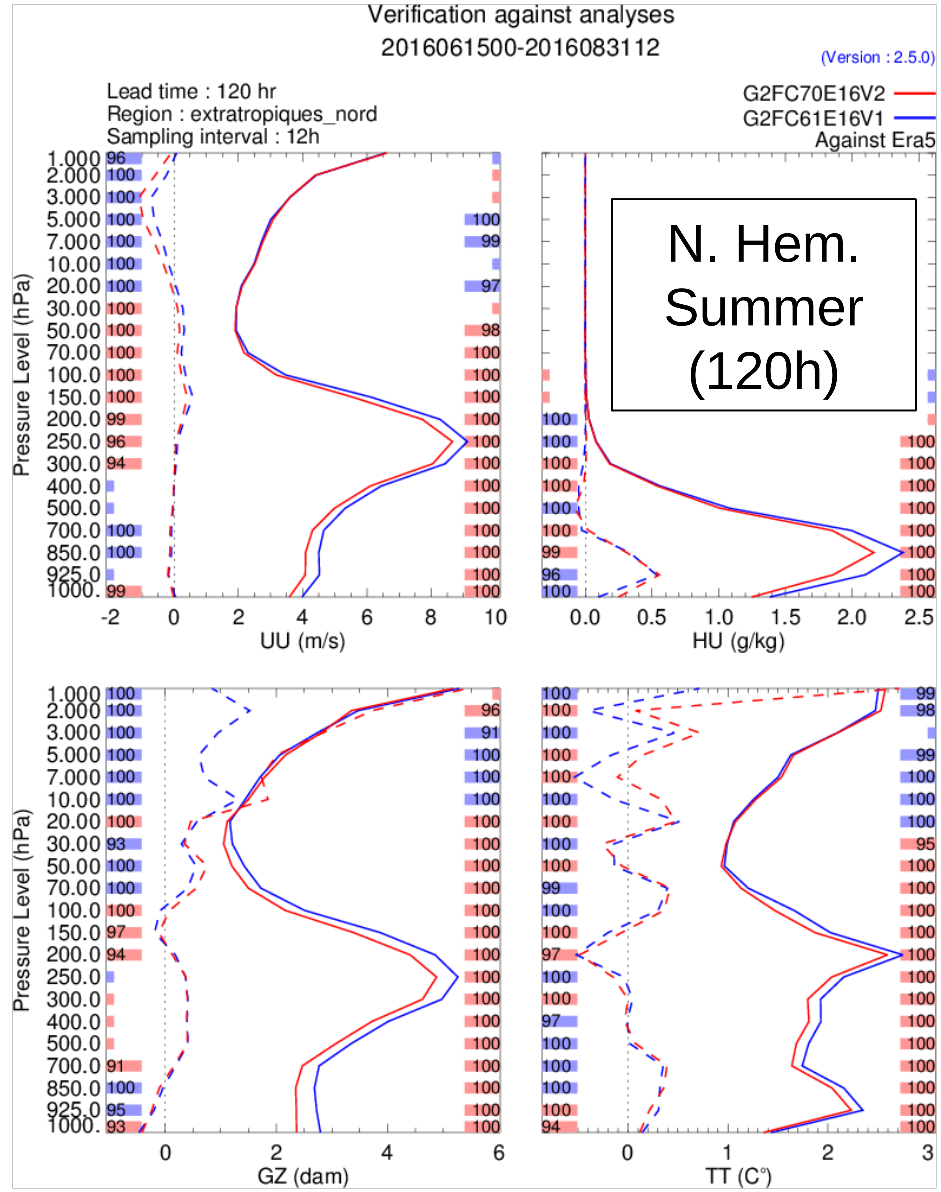
Scores du SGPD sur les Tropiques contre ERA5 pour cycles finaux d’été 2016:



Comparaison des prévisions en altitude du SGPD-7.0.0 (en rouge) et du SGPD-6.1.0 (en bleu) contre réanalyse d’ERA5. L’écart-type (lignes continues) et le biais(valeurs prévues moins valeurs observées; lignes pointillées) sont indiqués pour le vent zonale (UU), l’humidité spécifique (HU), la hauteur du géopotentiel (GZ), la température (TT). Ces scores sont produit a partir de 150 cas pour chaque saison.Les boites de couleurs à gauche (à droite) de chaque graphique indiquent le degré de signifiance statistique du biais (écart-type). Les boites rouges (bleus) indiquent que la version 7.0.0 a donné un biais inférieur (supérieur) ou un écart-type moins (plus) élevé que la version 6.1.0 avec un niveau de confiance au-dessus de 90 %. S’il n’y a pas de boite de couleur, les résultats des 2 expériences ne sont pas significativement différentes d’un point de vuestatistique.

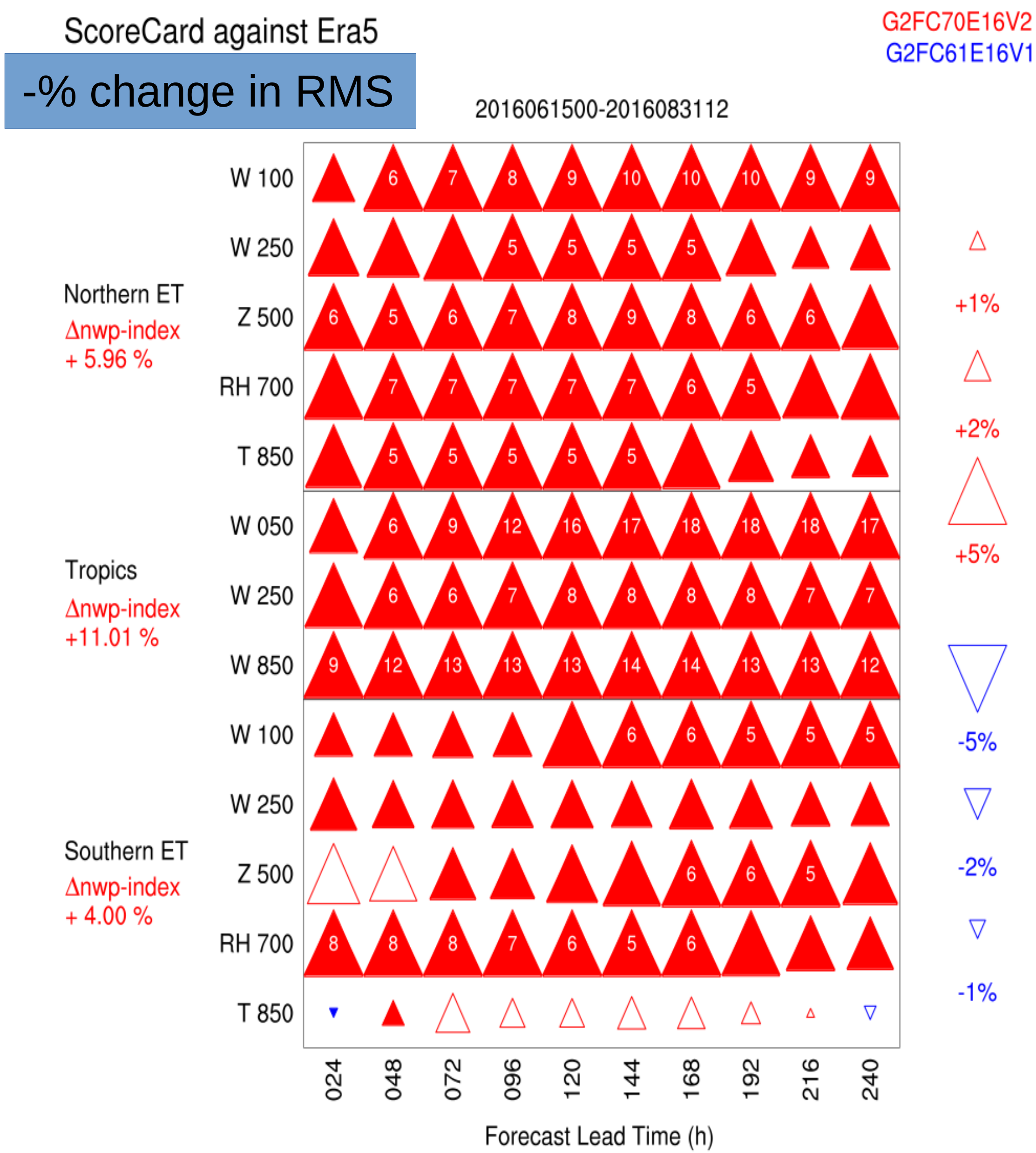
Scores du SGPD sur les Extra-Tropiques Nord contre ERA5 pour cycles finaux:





<u>Attention:</u> les échelles varient...

Résumé des scores du SGPD contre ERA5 pour cycles finaux d’été 2016:



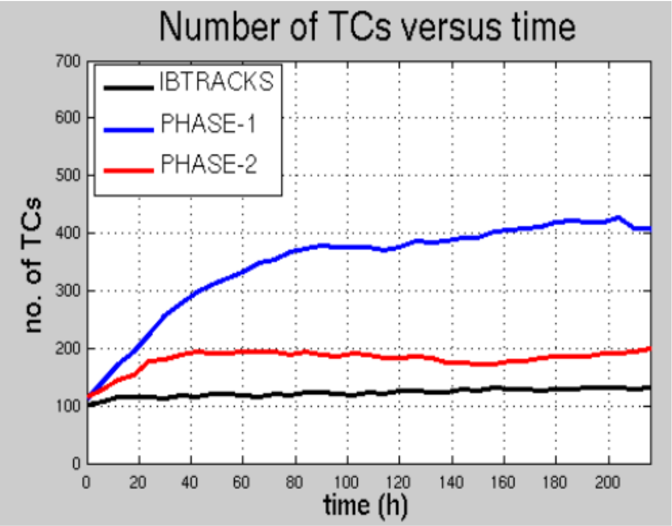
Résumé des scores de vérification des prévisions globales (pour des prévisions allant de 24h à 240h et pour des niveaux de 850hPa à 100hPa) contre réanalyses ERA5 en termes de pourcentage de changement de l’erreur quadratique moyenne (EQM)du SGPD-7.0.0 versus le SGPD-6.1.0.Les triangles rouges (bleus) indiquent une amélioration (détérioration) et les triangles remplis indiquent que les différences sont statistiquement significatives(selon une méthode de bootstrap). La taille des triangles représente l’amplitude du changement en pourcentage comme le montre la légende à droite. Les changements supérieurs à 5% sont indiqués dans les triangles. Les étiquettes de gauche indiquent la variable et le niveau de pression(hPa). W = vitesse du vent, Z = hauteur du géopotentiel, RH = humidité relative, T=température

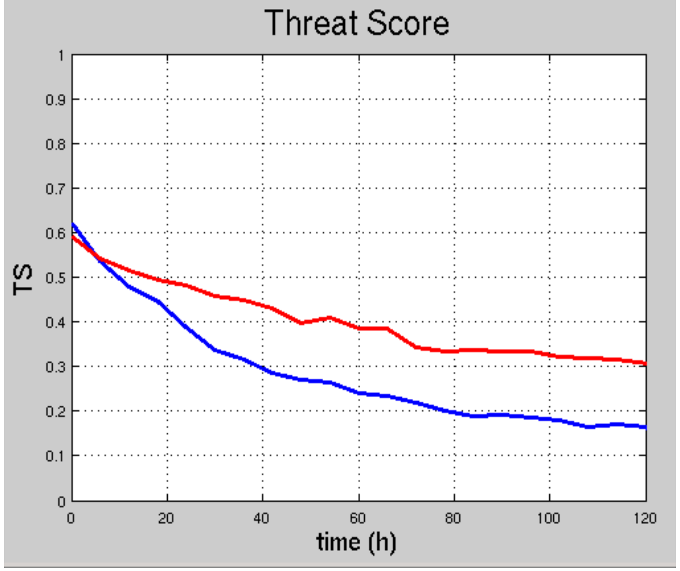
Tropical Cyclones (TCs)

- The global and regional operational models are infamous for their over-development of tropical cyclones

- The improved representation of the tropical environment yields a large reduction in false alarms.

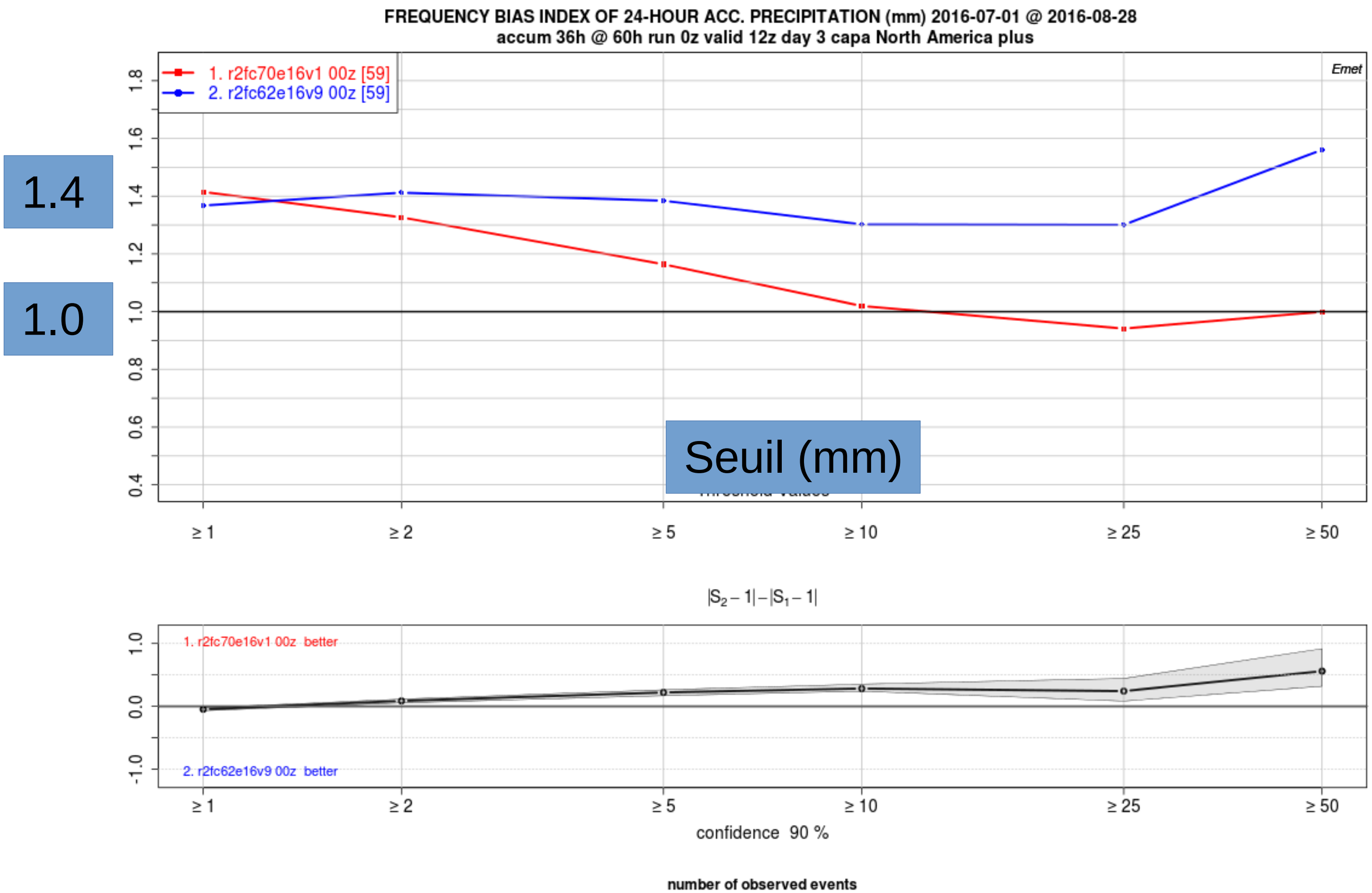
- The improved threat score indicates that the hit rate is not negatively affected: true TCs remain while many spurious events are eliminated.





Tropical cyclone tracking results in terms of TC count (top) and threat score (bottom) for GDPS Phase-I (blue) and proposed Phase-II (red) models. The International Best Track Archive (IBTrACS; Knaff et al 2013) is used as the reference for evaluation.

Diminution de la précip du SRPD 7.0.0



Cycles finaux été:
1 juillet 2016-
28 aout 2016
Domaine: Am. du Nord
Échéance: 36-60h

Biais de fréquence d'accumulation de précipitations (fréquence des prévisions divisée par la fréquence des observations) sur 24h. Vérification de la version 7.0.0 (en rouge) et de la version 6.0.0 (en bleu) du SRPD contre les observations ayant passé le QC de Capa Pour chaque comparaison, la différence entre les deux expériences (rouge moins bleu) est indiquée dans la partie inférieure du panneau, où les zones en gris représentent l'intervalle de confiance de 90%

New tool in our development strategy:
Model Hydrological and Energy Budget Evaluation Project (MHEEP)

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

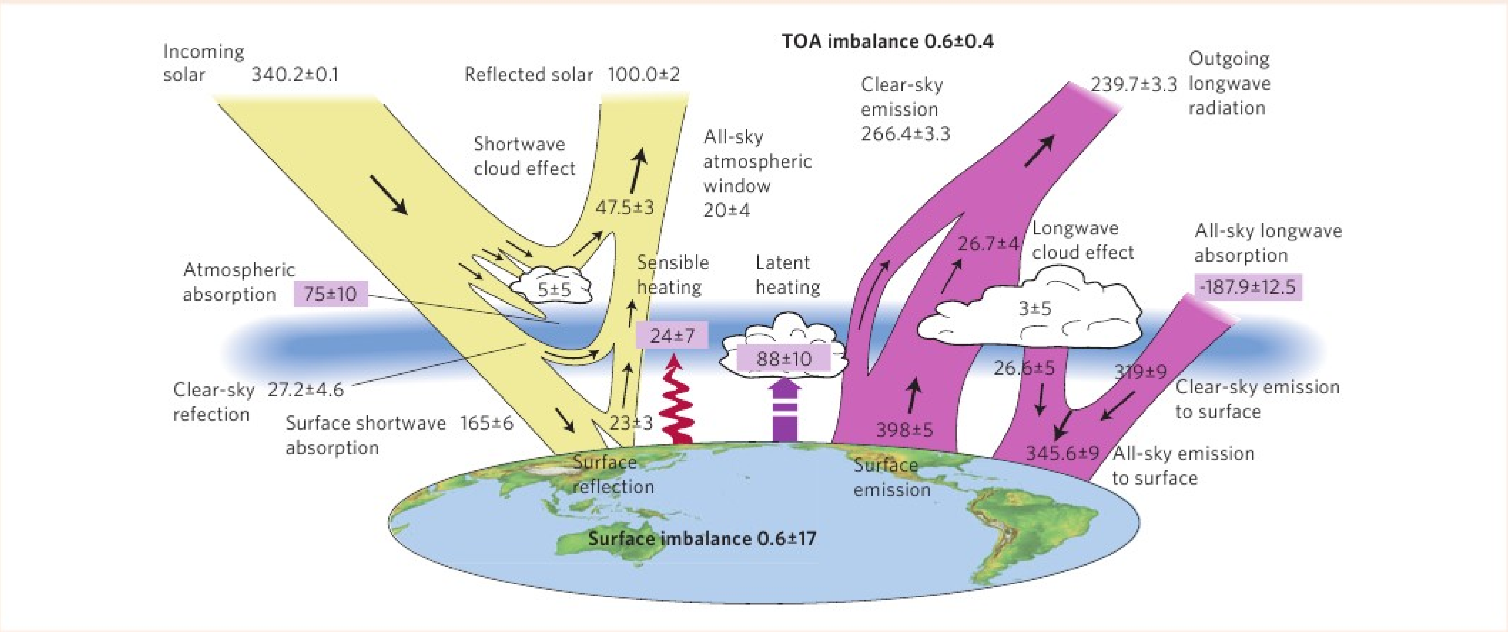


Figure B1 | The global annual mean energy budget of Earth for the approximate period 2000–2010. All fluxes are in Wm^{-2}. Solar fluxes are in yellow and infrared fluxes in pink. The four flux quantities in purple-shaded boxes represent the principal components of the atmospheric energy balance.

Climatologies:

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

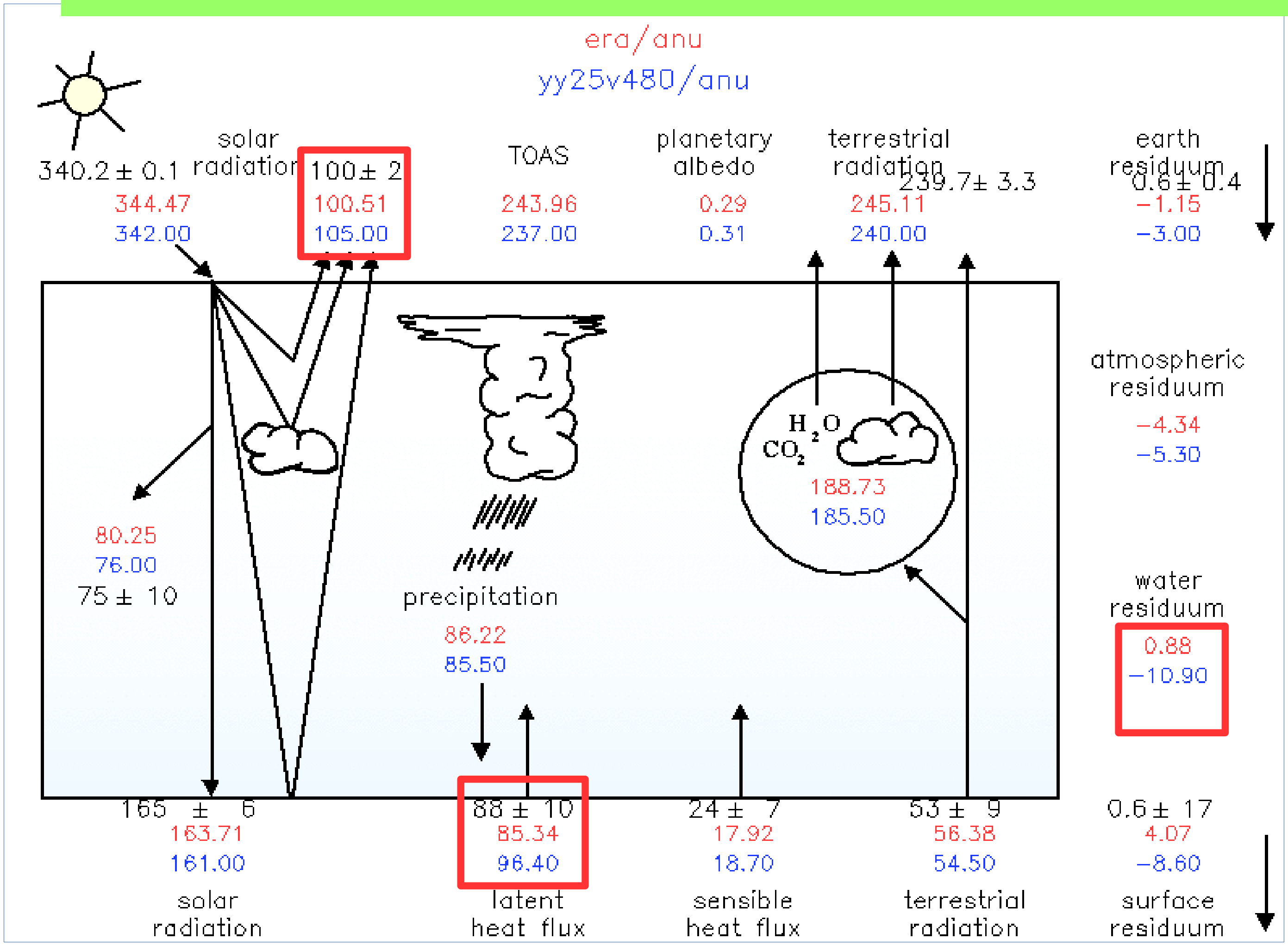
MHEEP - protocol

- Run four 13-month 25km free runs (year 2009), starting from CMC analyses staggered by 1day+6 hours.
- Daily SST and sea-ice fraction from CMC 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 – global gridded obs/anal	Source 2 - reanalysis	Source 3 - climatologies
Precipitation	Global Precipitation Climatology Project	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



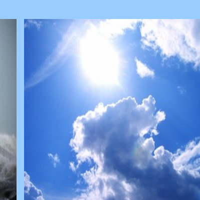
<u>Summary graph of global annual means</u>
Black: Stephens et al. 2012 climatology Red: ERA-int for 2009.
Blue: MHEEP control runs of old model

<u>Main problems identified:</u>

<u>Water residuum:</u> large imbalance between evaporation and precipitation.

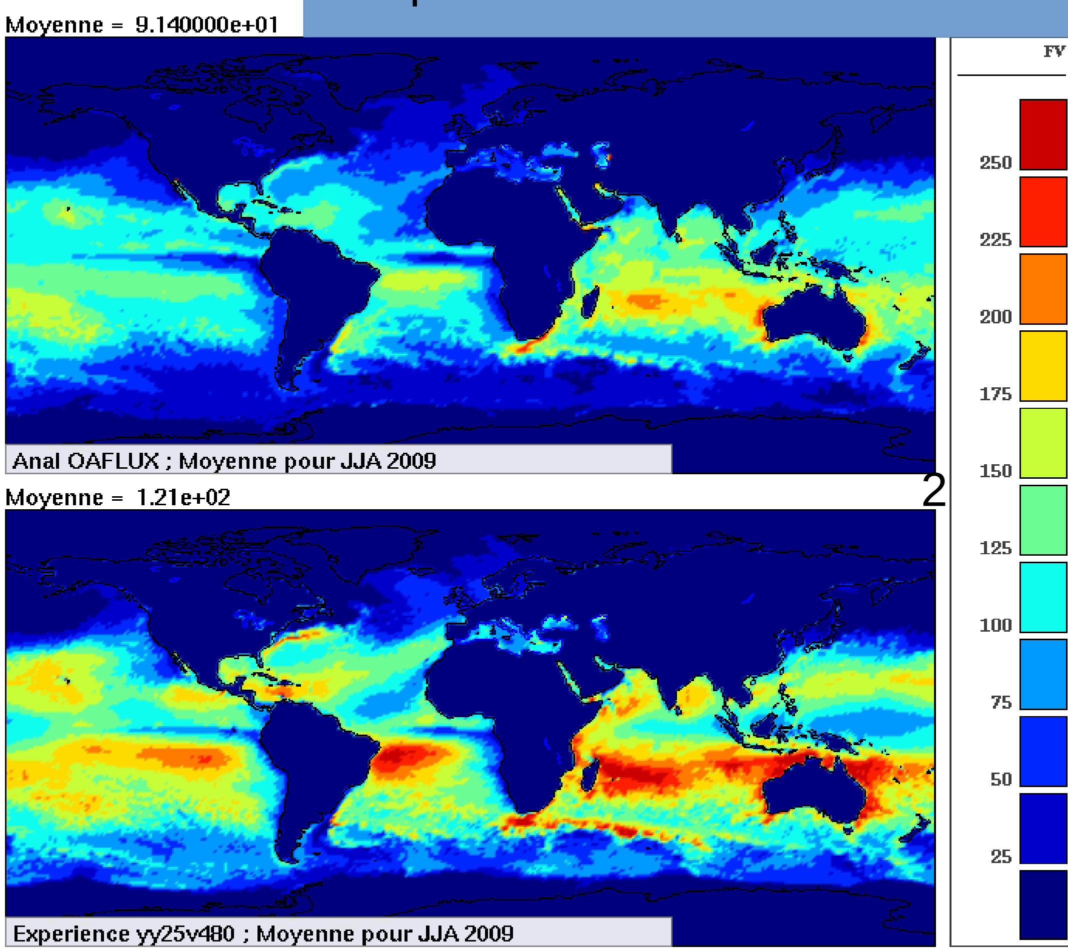
<u>Latent heat fluxes:</u> Largest error in the energy budget.

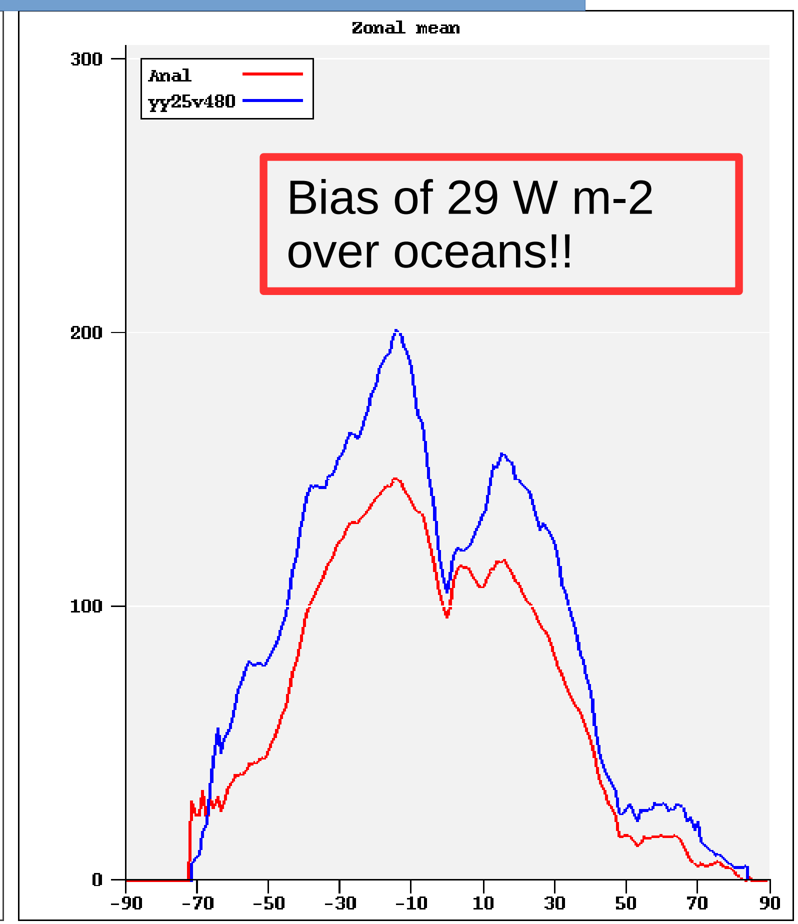
<u>Solar radiation fluxes:</u> Over-estimate of planetary albedo and under-estimate of SW flux at surface.



MHEEP – lots of maps!

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

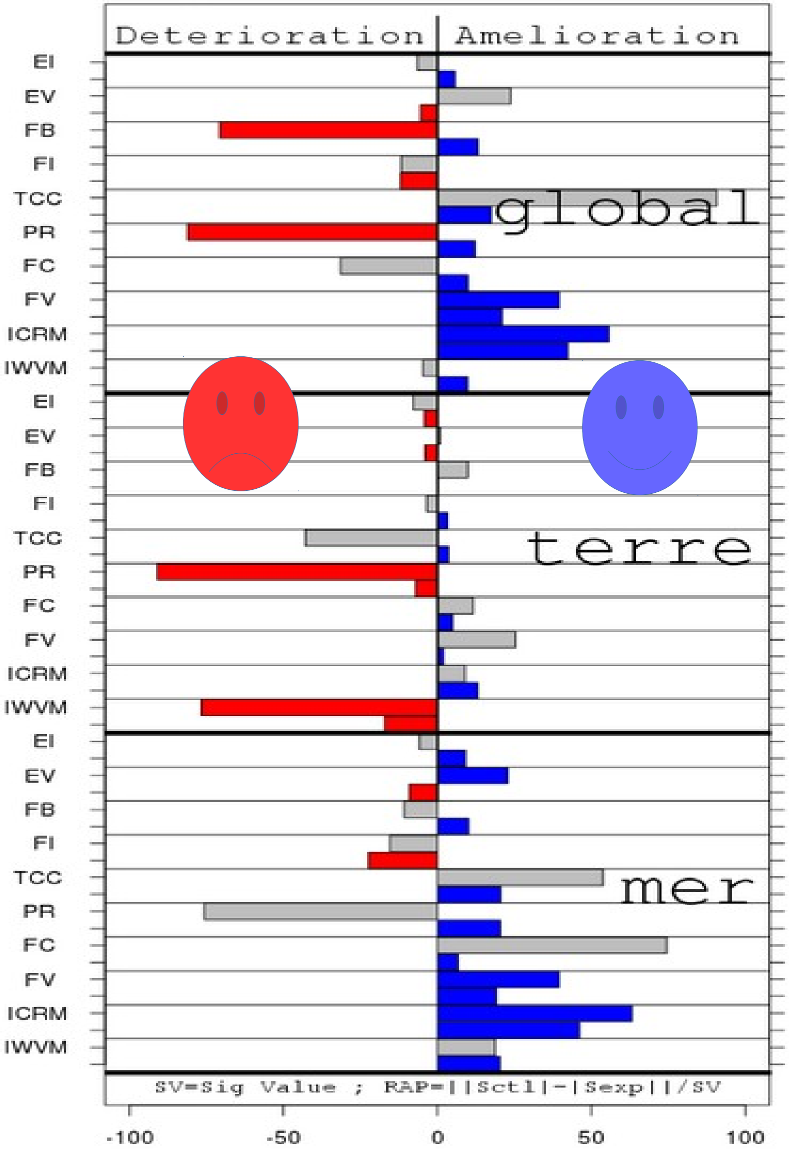




Top right: Source1: Oaflux product
Bottom right: GDPS ops-ctl

Zonal means. Red: source 1.
Blue: model

MHEEP – histo-synthèse



Is EXP2 better than EXP1 ?

- For each variable calculate bias and rms against Sources 1 and 2 for globe/land/oceans
- Compare change in score to subjective threshold to determine if significant
- Calculate relative change in “score”

Cabme04 against Control (GDPS-OPS)

Note: cabme04 first config to give satisfactory results both in Mheep and forecast series.

Radiative transfer in GEM: brief history

- before 2009:
  - all CMC operational systems used the simple **broad band** RT scheme called NEWRAD (SW: Fouquart and Bonnel, 1980; LW: Garand, 1983)
- 2003-2008:
  - Imported and adapted **CKD** (Correlated K Distribution) scheme of Li&Barker(2005) developed at cccma
- 2009-2011:
  - implemented CCCMARAD in all CMC operational systems
- 2010-2018: updated CCCMARAD ==> <u>CCCMARAD2</u>
- 2019 – : implemented CCCMARAD2

Cccmarad2: What's new

- From cccma :
  - improved treatment of water vapor continuum
  - new: absorption of SW by methane
  - 3D treatment of trace gases (instead of constant)
  - new option for effective solar path length
  - modifications to band intervals
  - revision of ozone cross sections for absorption
  - allows surface emissivity < 1

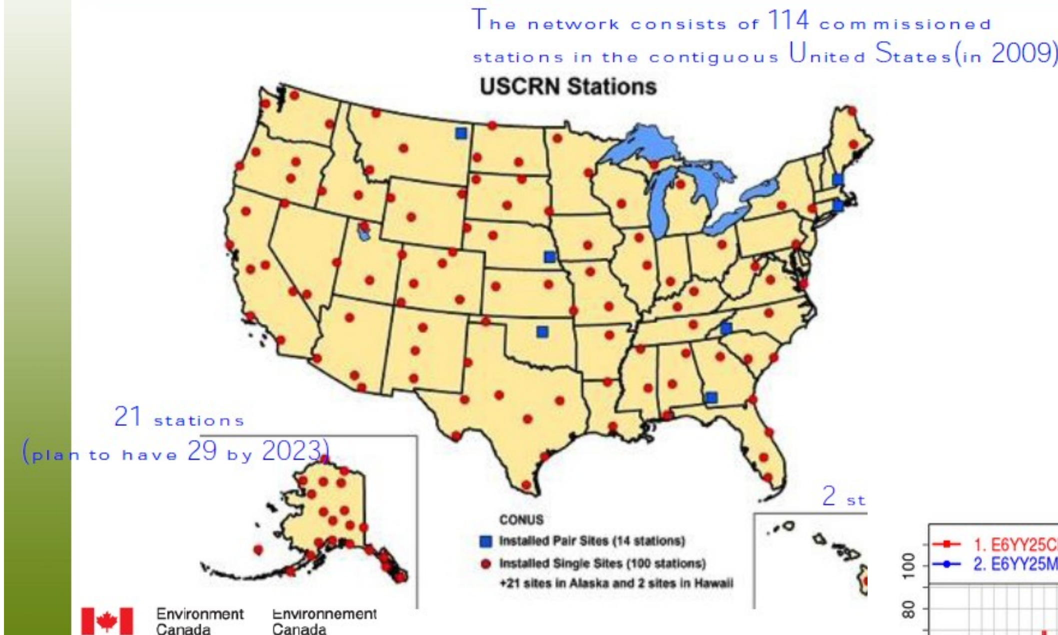
Note: we have not implemented cccma's approach to cloudy-sky RT

Cccmarad2: What's new

- From us:
  - updated solar constant (1367 ==> 1361 W/m2)
  - Use “normalized” 3D trace gas monthly climatologies (CH_4,N_2O,CFC11,CFC12) produced with “Linoz”
  - Automatic adjustment of background GHG concentrations for simulated year(1950-2016)
  - new 3D ozone monthly climatology built from ERA5+Haloe
  - broadband monthly climatological surface emissivity for ISBA soil/veg built by S. Heilliette from MODIS and Bo-Hui Tang et al. (2011)
  - improved cloud-radiation interaction for MP schemes (use provided effective radii)

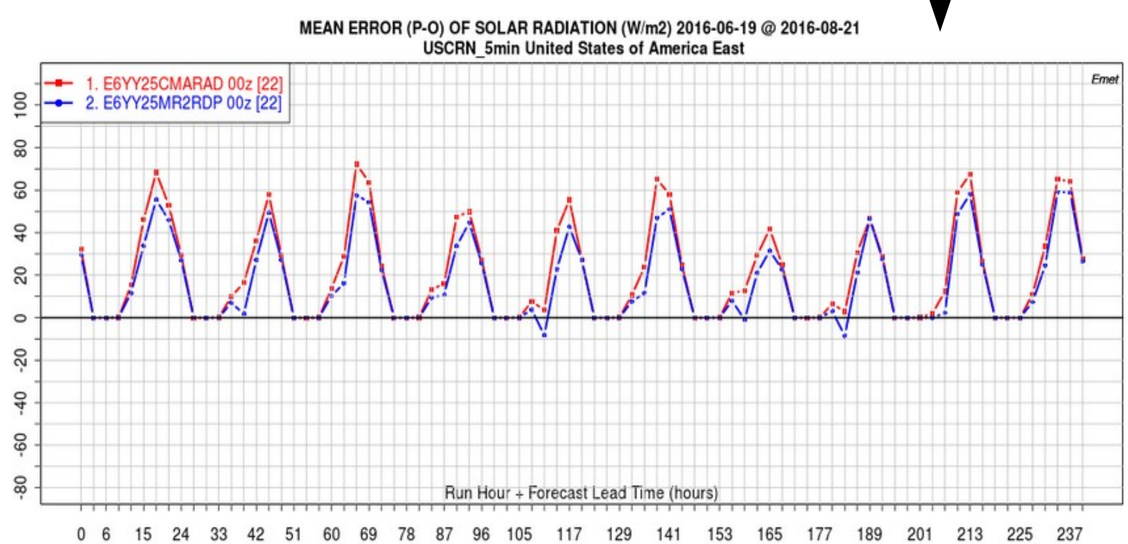
Cccmarad2: impacts

USCRN - network with 137 stations



Blue: cccmarad2

Reduction in SW bias of 12 W m-2 at local noon

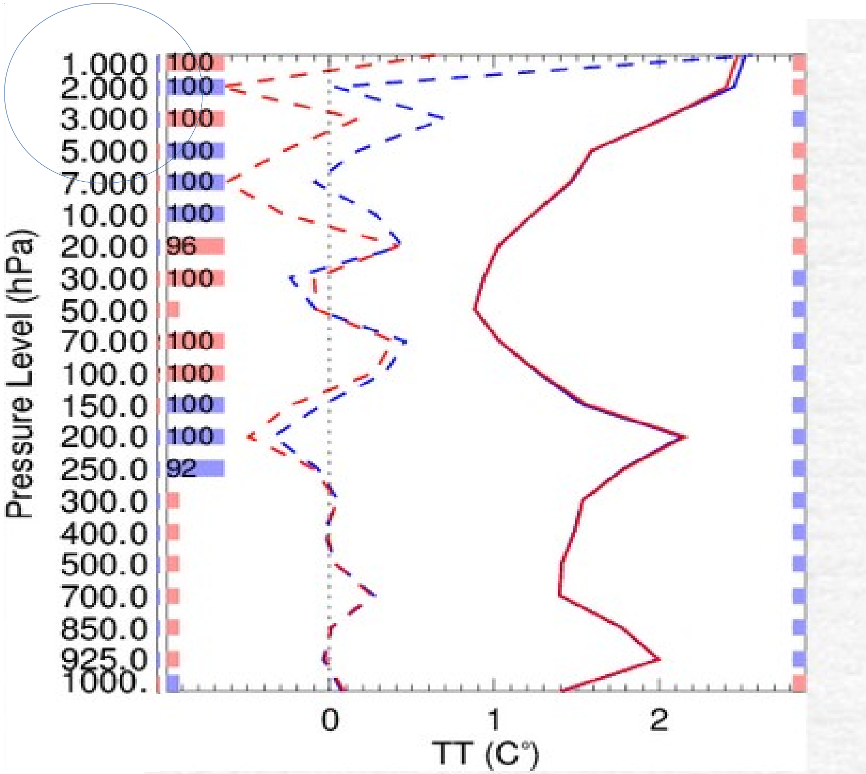


<u>New in EMET: USCRN stations</u>

SW flux,met obs, soil temperature and moisture...

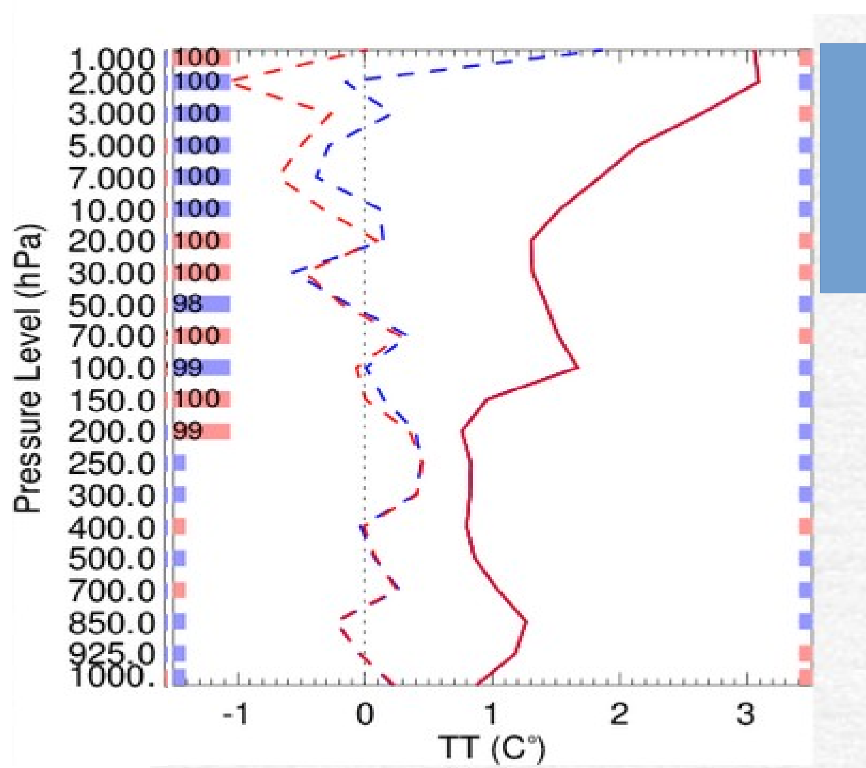
Cccmarad2: impacts

- Minor improvements in SW surface and top of atm fluxes
- Neutral arcad/verdict impacts in troposphere
- Impacts on TT in strato/meso (degradations above 2 hPa)



VERDICT – extratropics-N – 96hr

RED: cccmarad1 Blue: cccmarad2

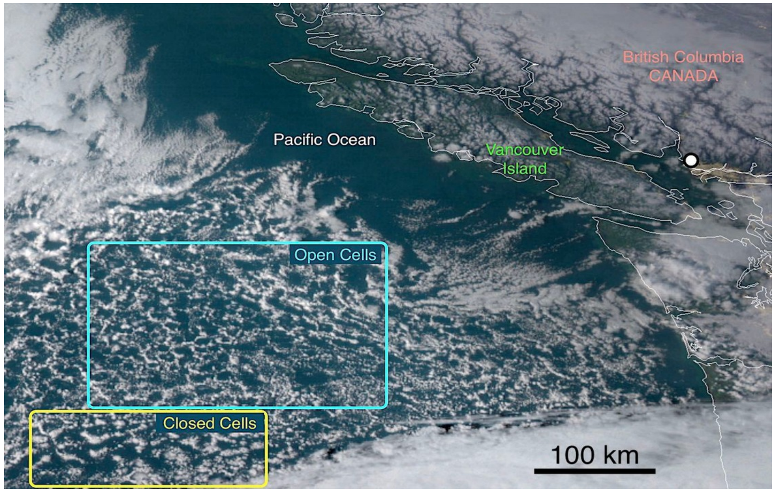


Against ERA5

VERDICT – tropics – 96hr

RED: cccmarad1 Blue: cccmarad2

Convection: remarques générales



- Aux résolutions ciblées dans ce projet, 2.5-40km, paramétriser la convection reste essentiel.
- En réponse aux irritants énumérés précédemment:
  - Éliminer le schéma ktrsnt_mg
  - Utilise l’approche “mass flux” pour tous les types de convection
  - Nouveaux schéma de convection restreinte et convection “élevée”
  - Priorité à la convection profonde
  - Transport de momentum pour tous les types de convection

Note: En pratique, les paramétrages de convection jouent un rôle important pour contrôler les problèmes de tempête de point grille qui résultent de la rétro-action positive entre la dynamique (vitesse verticale) et le schéma de nuage.

Convection parametrization: components (e.g. deep)

1) Triggering:

- Test updraft source layers (USL) from bottom *3500m*
- USL: *60hPa* thick mixed layer
- Lift USL, determine LCL properties (Z,T,Q,M,U,V)
- <u>Is perturbed parcel buoyant at LCL ?</u>

$$T_P(LCL)+\delta T > T_{env}(LCL)$$

$$\delta T = 4.64(W_{env} - W_T)^{(1/3)}$$

W_T: Triggering threshold

Is $\delta T > 0$?

2) Updraft (Downdraft):

- Guess initial cloud base mass flux
- Solve for updraft velocity
- Solve for ϵ, δ, M
- Solve updraft properties
- **Cloud thickness > 3000m** (finalize trigger).
- (Repeat similar procedure for downdraft)
- Calculate adjusted env variables

3) Closure (scaling):

- Reduce CAPE by 90% within ***convective adjustment timescale*** (τ_c)
- CAPE : convective available potential energy

$$CAPE = \int_{LCL}^{CTL} \frac{(\theta_e^u - \bar{\theta}_{es})}{\bar{\theta}_{es}}$$

- Iterative procedure to:
  - re-scale mass fluxes,
  - re-calculate $\bar{\psi}$
  - Recalculate CAPE

Lots of internal parameters were fixed.
Tried to make several of them state dependent.

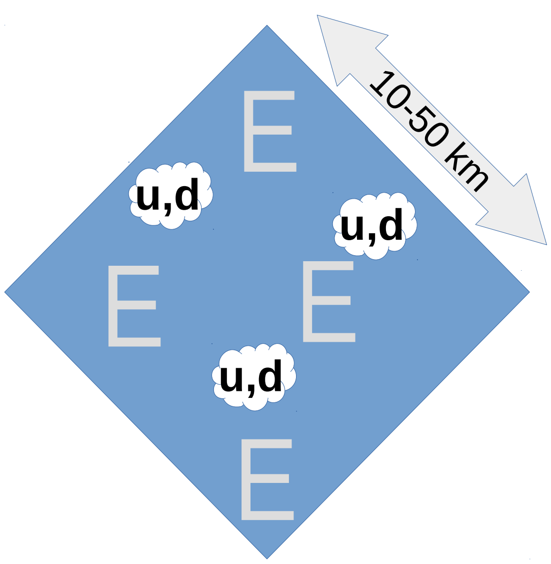
Convection: mass flux approach basics

The effect of convection (sub-grid scale transport) on the grid mean of a variable ψ :

$$\frac{\partial \psi}{\partial t} = \frac{\partial F_\psi}{\partial p}$$

$$F_\psi = (\overline{w'\psi'}) = M(\psi - \psi')$$

<u>The grid is decomposed into three parts; updraft, downdraft and environment.</u> Assuming that the cloud fraction is small, the following approximation is obtained:



$$F_\psi = F_{\psi u} + F_{\psi d}$$

$$\frac{\partial \psi}{\partial t} = \frac{\partial [\overbrace{M^u(\psi - \psi^u)}^{updraft} + \overbrace{M^d(\psi - \psi^d)}^{downdraft}]}{\partial p}$$

$\partial \psi / \partial t$: tendency

M^u, ψ^u: updraft variables

M^d, ψ^d: downdraft variables

5 unknowns/equations
+ mass conservation
(env mass flux)

Convection: mass flux approach basics

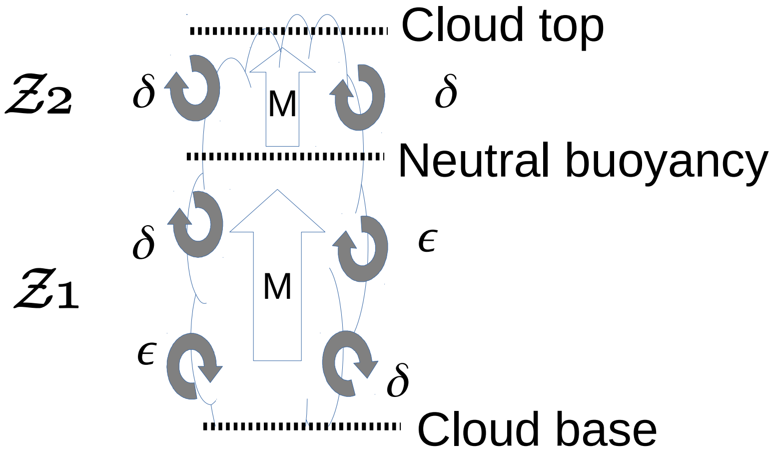
Assuming steady state plumes, the cloud exchanges mass with the environment through detrainment (δ) of cloud mass and entrainment (ε) of environmental air. The mass flux equation for the cloud/updraft is :

M = ρ A W ;
[M] = Kg s-1

$$\frac{1}{M_u}\frac{\partial M_u}{\partial p} = \epsilon_u - \delta_u$$

$$[\delta, \epsilon] = Pa^{-1}$$

$$\frac{\partial \psi_u}{\partial p} + \epsilon_u(\psi_u - \psi) = S_u$$



In KF, entrn/detrn rates are determined by a i) constant inflow of air into updraft (prop. to radius) and ii) a *buoyancy sorting mechanism*, which determines fraction of mixed air that is positively or negatively buoyant.

Similar for downdraft but upside down… from level of free sink down to forced detrainment layer.

Deep convection: What's new in kfc2?

- Updraft radius is reduced from 1500m to 1250m over oceans *(improved cloud top heights)*
- State-dependent convective adjustment timescale *(eliminate some too strong precip events)*
- State-dependent triggering thresholds over oceans
- Adjusted convective triggering thresholds over land
- Downdraft detrainement layer increased to 6000Pa *(improved near sfc HU)*
- Triggering is re-evaluated every timestep rather than every convective timescale
- Minimum cloud depth threshold reduced to 3000m for coherence with shallow
- **Implemented Convective Momentum Transport (CMT)**

Convective Momentum Transport in mass flux schemes

Two mechanisms contribute to the exchange of momentum between the cloud and its env: mass exchange via (ϵ_u, δ_u) and a horizontal pressure force

$$\frac{\partial v_u}{\partial p} + \epsilon_u (v_u - v) = \frac{F_P^u}{M_u}$$

For v component of in-updraft horizontal wind

1) Gregory et al. (1997) proposed to approximate pressure force as proportional to mass flux and environmental shear:

$$F_P^u = C M^u \frac{\partial v}{\partial p}$$

where C is a tuning constant (C=0.7)

2) The pressure force can also be represented as a function of the difference in velocity between the cloud and its env (drag) **or equivalently** as an enhanced entrainment rate in the updraft (pre-ECMWF-Cy40r3 approach):

$$F_P^u = \Lambda(p)(v_u - v)$$
$$\epsilon^u = \epsilon^u + \Lambda \quad ; \quad \delta^u = \delta^u + \Lambda$$
$$\Lambda = \lambda \delta_u$$
$$(\lambda = 2. \quad \text{in anvil and} \quad \lambda = 0. \quad \text{elsewhere})$$

This method was implemented

CMT: remarks

- These approaches are highly empirical (weak theoretical basis according to Romps 2012) and designed for un-organized convection.

- R&D is necessary to better represent this process, for organized convection in particular. But, consider the impact...

Note: With both approaches, maximum tendency on winds is obtained if tuning constant (C or λ) = 0. The pressure force relaxes the cloud momentum and environmental momentum toward one another, and therefore reduces tendencies.

CMT: Forecast performance (deep only)

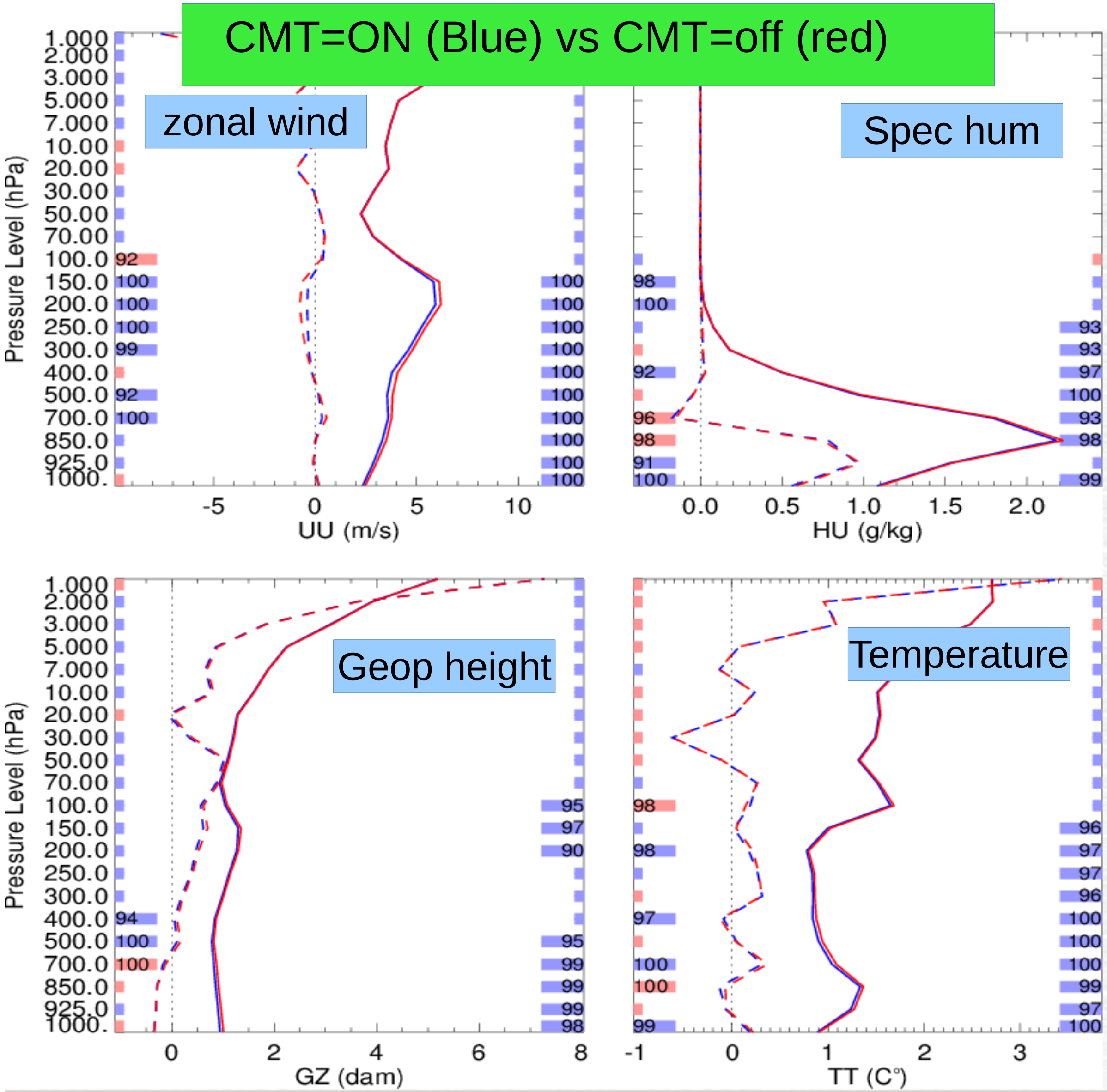


Figure: Profiles of bias(dash) and standard deviation of <u>error against ERA5</u> for 120h progs over JASO 2018 for <u>tropics</u>. Shading denotes stat significance. Color of shading denotes exp with best score.

Significant improvements for all variables in the Tropics.

Improvemnts amplify with cmt of shallow and mid

CMT: Sensitivity (w/r to λ=2)

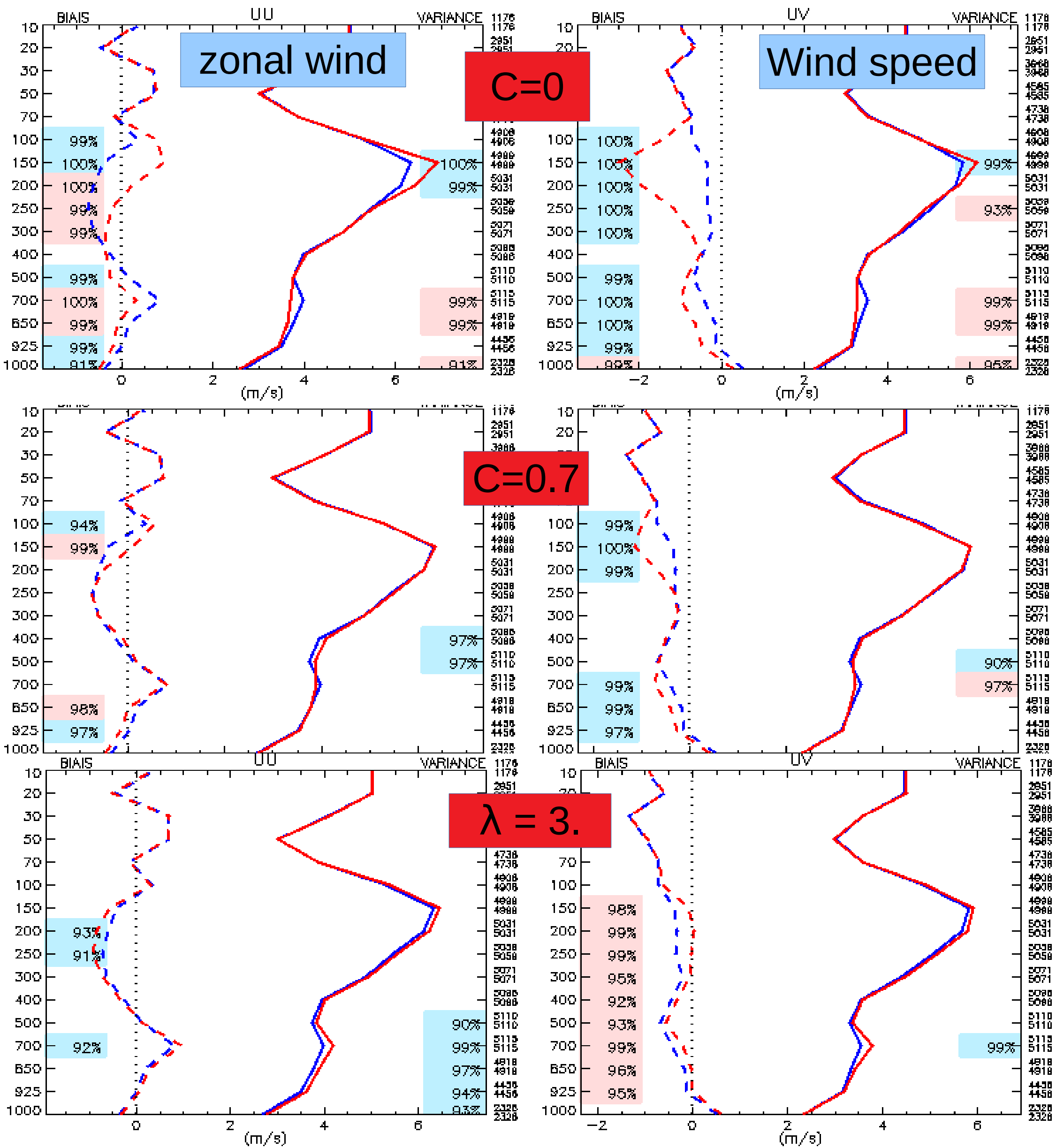


Figure: Profiles of bias(dash) and standard deviation of error against Radiosondes for 120h progs over JASO 2018 for tropics. Blue curves: ctl with op CMT. Red curves: experiments

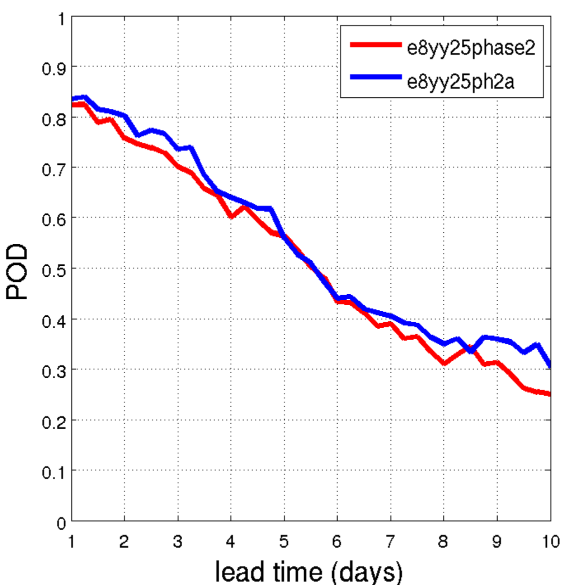
Results are quite sensitive to tuning parameter. Tendency on winds is strongest with C=0 or λ=0.

Not shown:
Significant regional variations, which we would like to exploit...

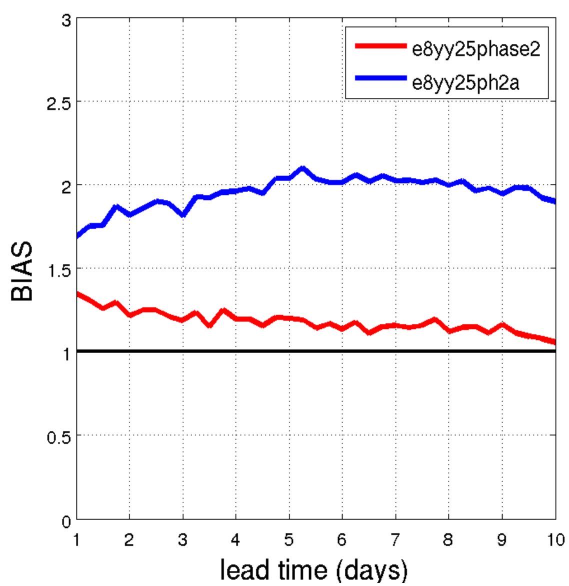
CMT: impact on tropical cyclones

<u>TC tracking:</u>

- 84 integrations from 29 June 2018 - 31 October 2018. 65 TCs were observed during this period.
- Tracking algorithm based on thresholds on relative vorticity, winds, geopotential thickness and baroclinicity.
- Observed TCs taken from v04 of IBTRACKS (Knapp et al., 2010)
- Standard categorical scores are calculated from counted hits, false alarms and misses.



Probability of detection



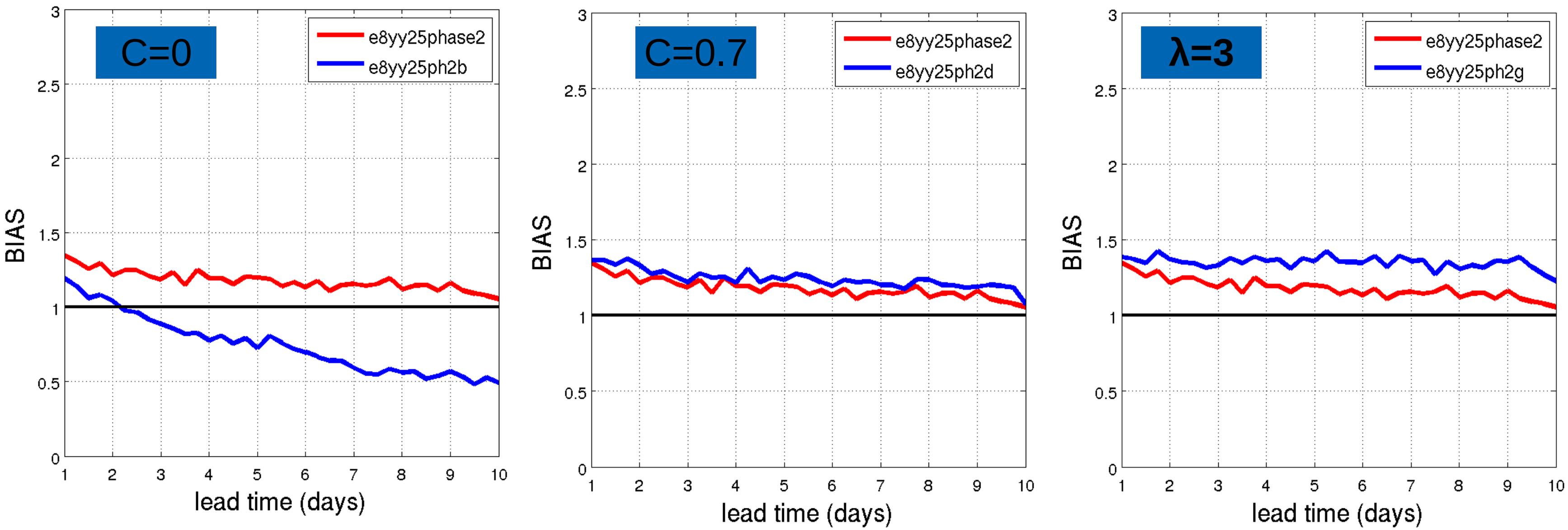
Bias=# of model TCs / # observed TCs

Blue curves: CMT=OFF
Red curves: CMT=ON
Results for <u>all basins</u>.
Not shown: significant regional variations

Major reduction of False Alarms, In particular for West Pacific.

CMT: impact on tropical cyclones

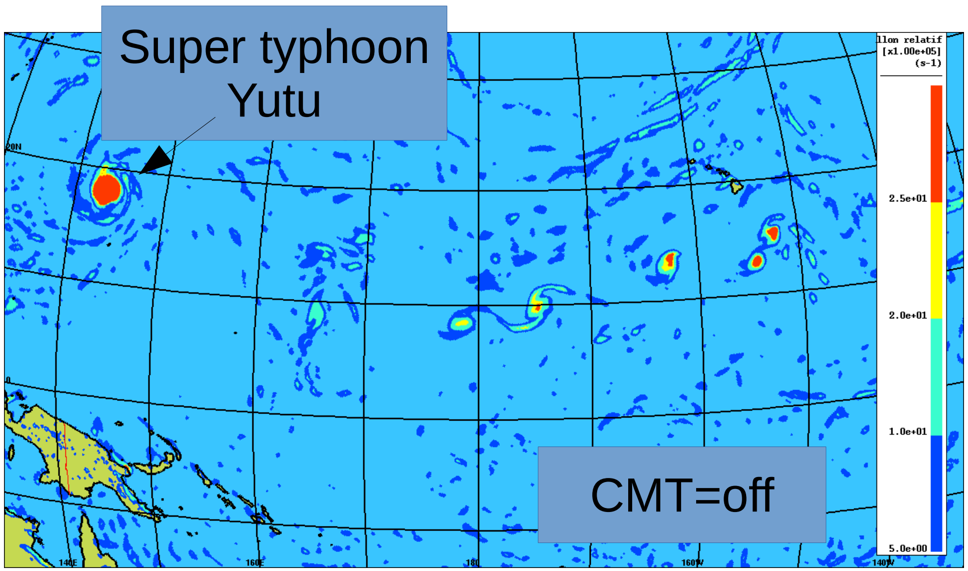
Sensitivity of frequency Bias to tuning parameters

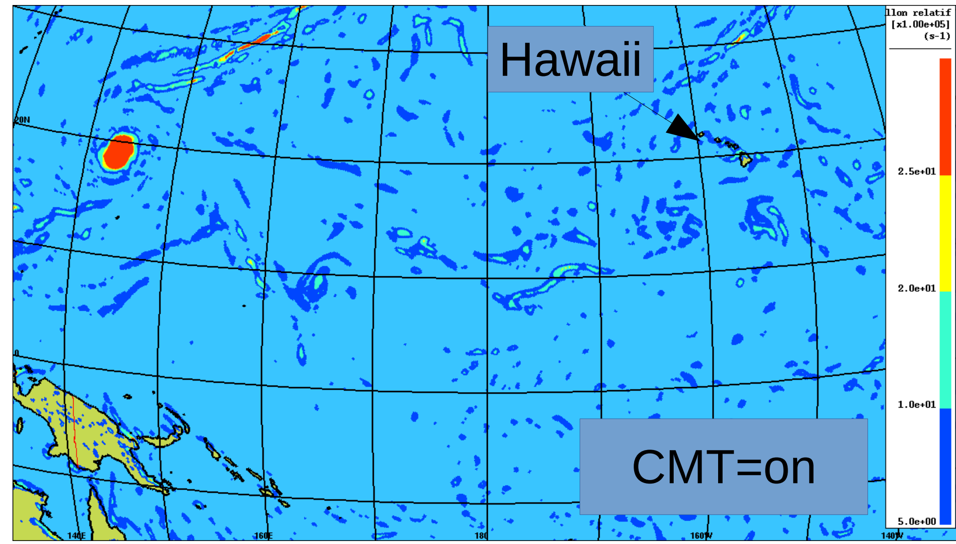


Bias=# of model TCs / #observed TCs

Again, results are quite sensitive to tuning parameter and significant regional variations are found.

CMT: impact on tropical cyclones





Relative vorticity field at 850 hPa for 90h forecast initialized from 20181022 12 UTC

One observed super typhoon (Yutu) is present in both solutions.
Our TC tracking algorithm identifies 3 false alarms south and south west of Hawaii when CMT=off (left). When CMT=on, both structure and amplitude of vorticity is significantly impacted. Why?

New shallow convection scheme:

Based on Bechtold et al. (2001) but updated, see McTaggart-Cowan et al. (2019).

1) Triggering:

- Test updraft source layer (USL) from **bottom *60hPa*** thick mixed layer
- **Simplified** estimate of temperature perturbation added to mixed parcel:

$$T_P(LCL)+\delta T \;>\; T_{env}(LCL)$$

$$\delta T = 0.2\,K$$

2) Updraft:

- turbulent mixing: **simplified** representation of entrainment and detrainment (ϵ, δ)
- updraft depth must be between 500 and 3000m
- **no downdraft, no precipitation**

3) Closure (direct):

- quasi-equilibrium with PBL forcing is assumed
- cloud base mass flux is directly calculated from increase in moist static energy in PBL.
- adjustment timescale = timestep

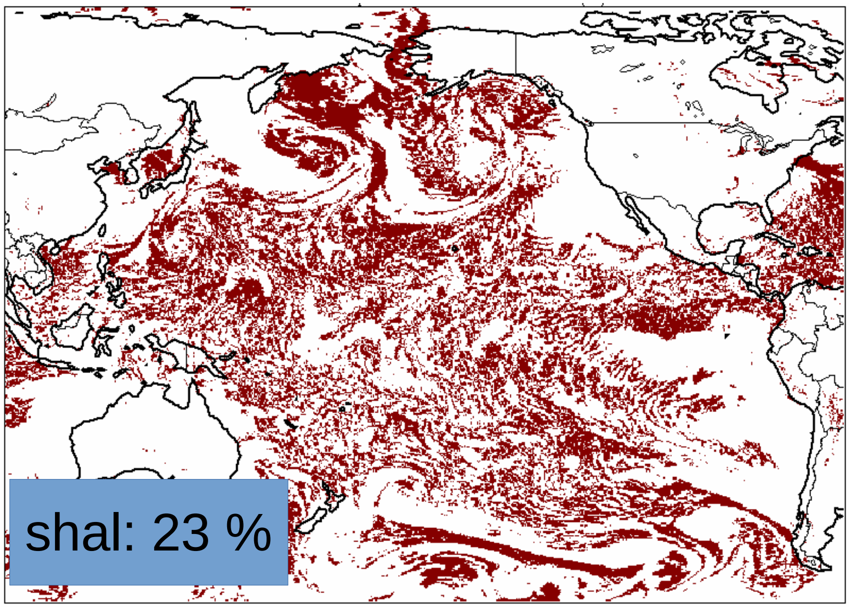
New shallow convection scheme:

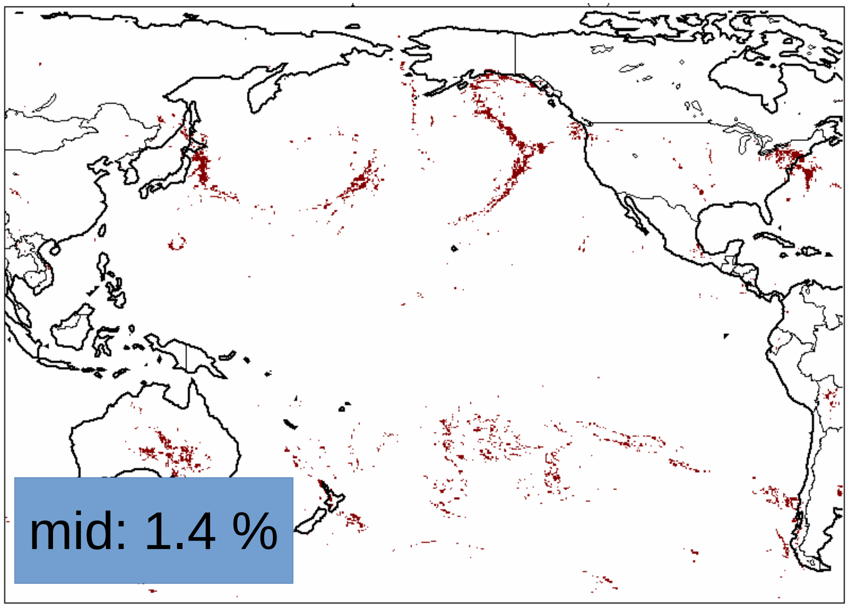
- New closure option (bkf_closures = equilibrium)
  - Eliminate integrated moist static energy below cloud base generated by all other processes within timestep
  - Ref: ECMWF IFS documentation
- New detrainment options (bkf_detrains):
  - Derooy10: DeRooy and Siebesma(2010)
  - Cuijpers95: Cuijpers (1995) : constant detrainement
- New entrainment options(bkf_entrains):
  - Bechtold08: Bechtold et al. (2008)
  - Derooy11: DeRooy et al. (2011)
  - Siebesma03: Siebesma et al. (2003): inversely proportional to Z

We chose simplest possible approach.

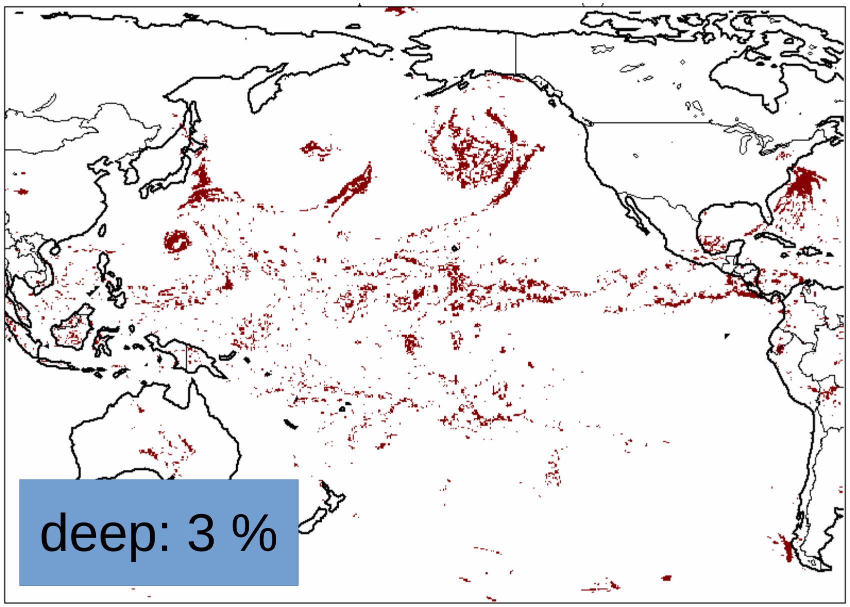
Convection: which scheme is active and where?

Example from 120hr forecast valid on 20181027-12UTC



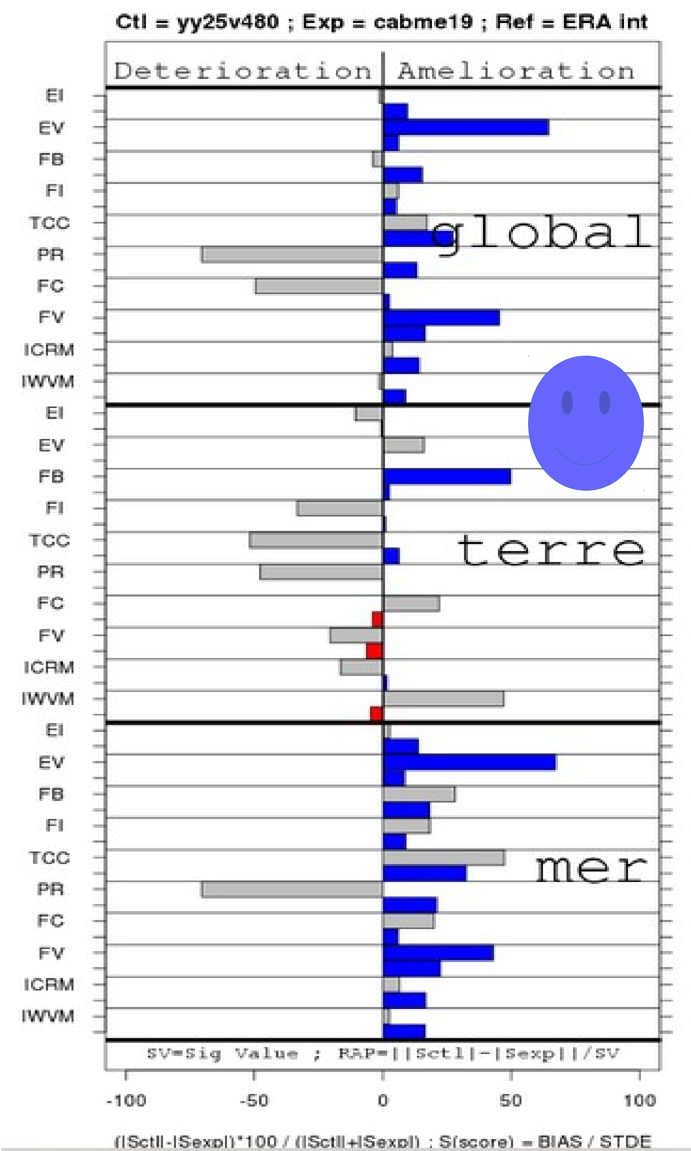


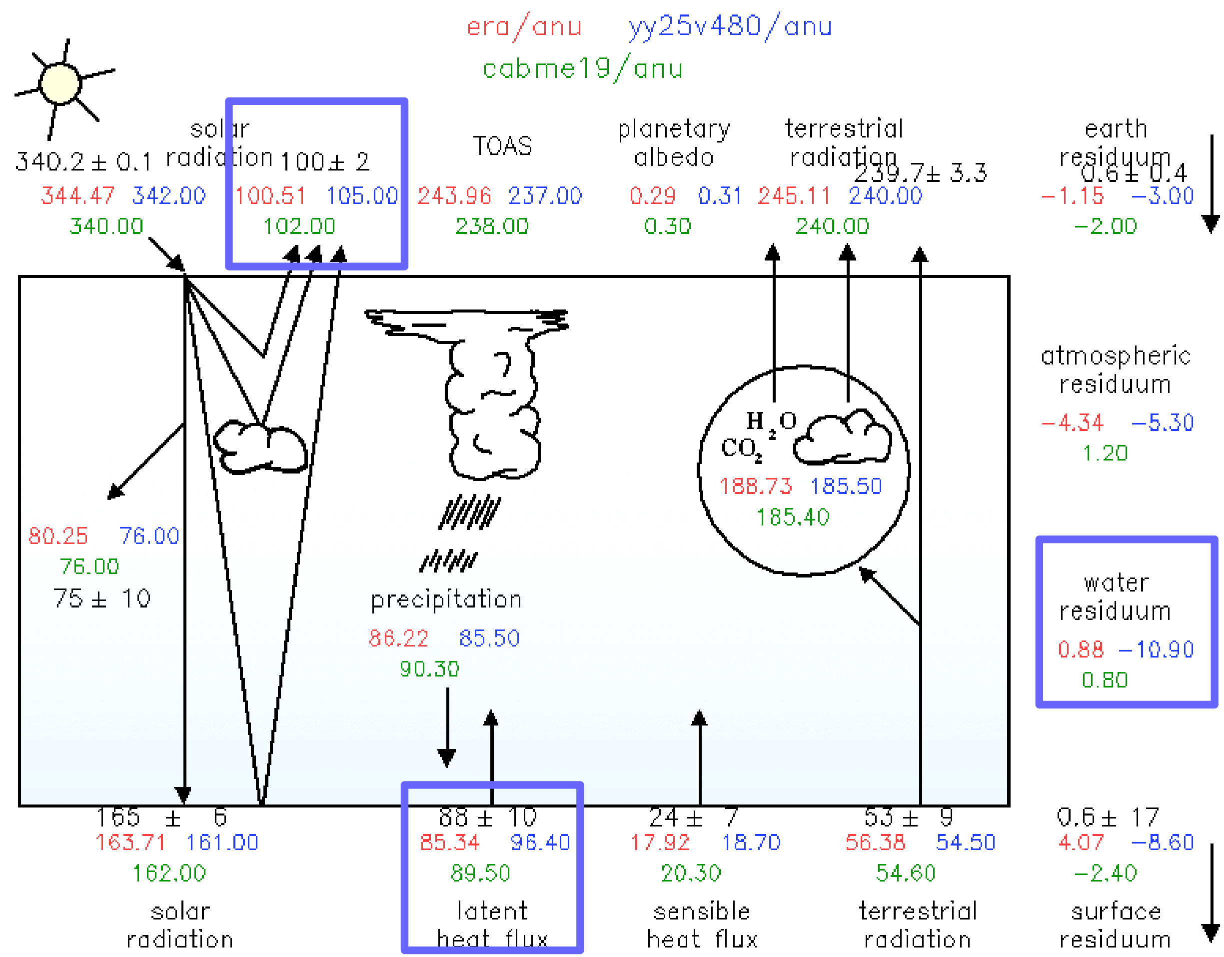
The mean activity frequency shown is for this Pacific zoom but it is typical of the global mean. How realist is that?



MHEEP

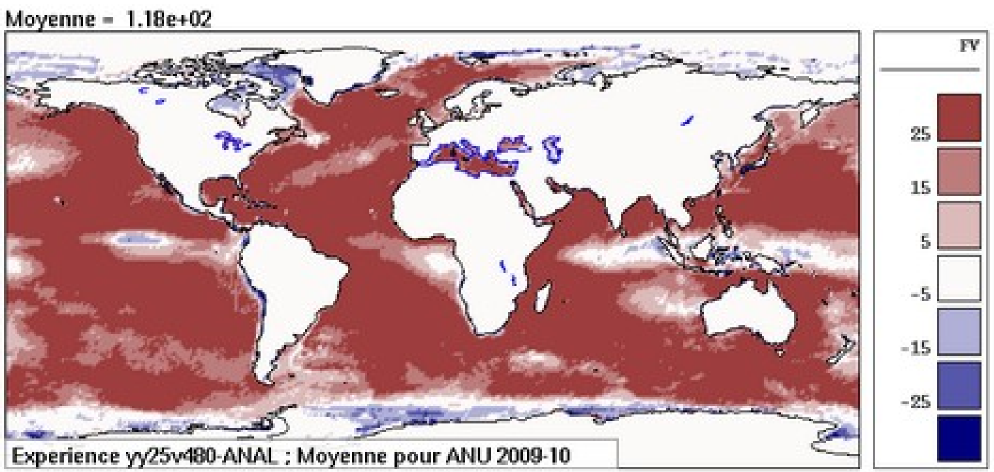
Quasi-final config(green) vs GDPS-ops-ctl(blue)



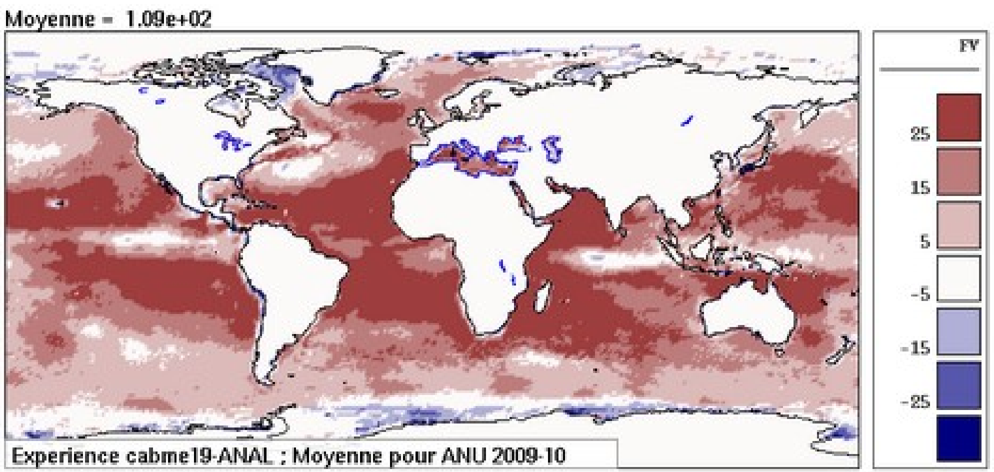


MHEEP

improvements in latent heat fluxes(FV)



TOP: GDPS-ops annual mean of FV – OAFLUX analysis



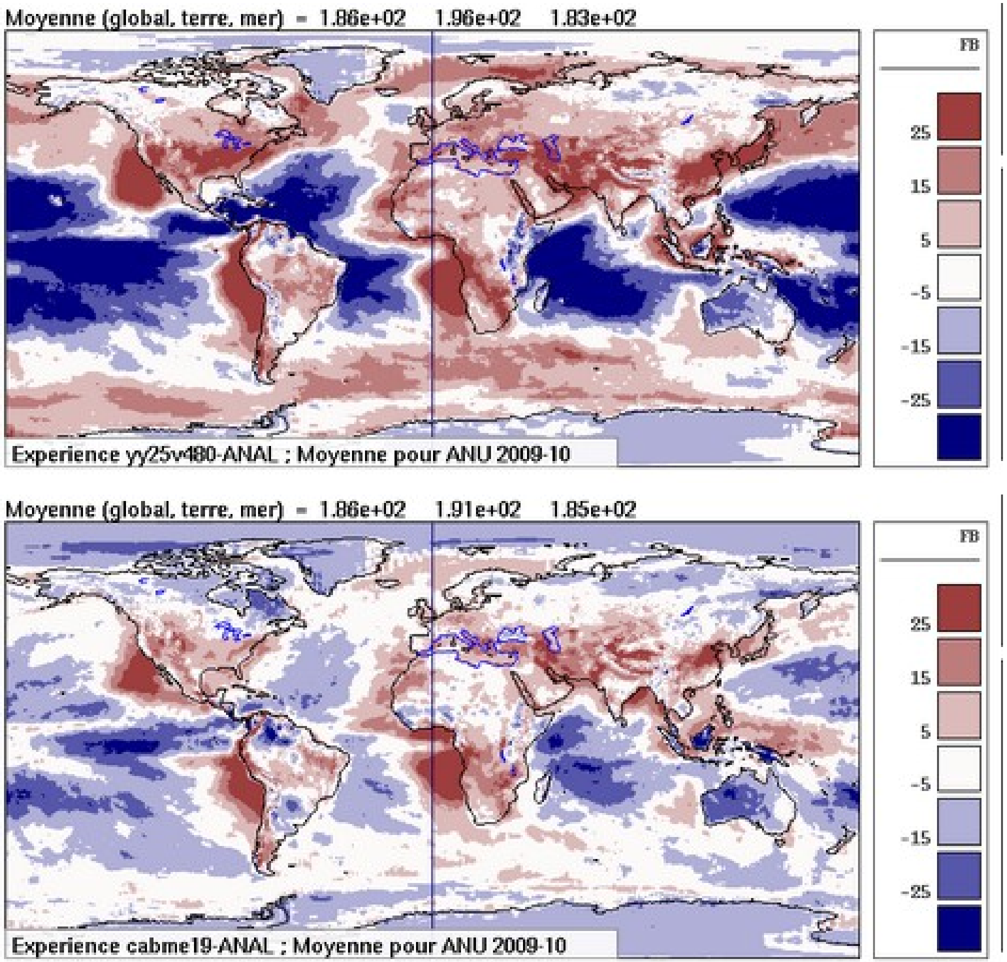
Bottom: CABME19(new) annual mean of FV –OAFLUX analysis

Comment…?

Bias in W m-2

MHEEP

improvements in SW flux at sfc (FB)



TOP: GDPS-ops annual mean of FB – CERES obs

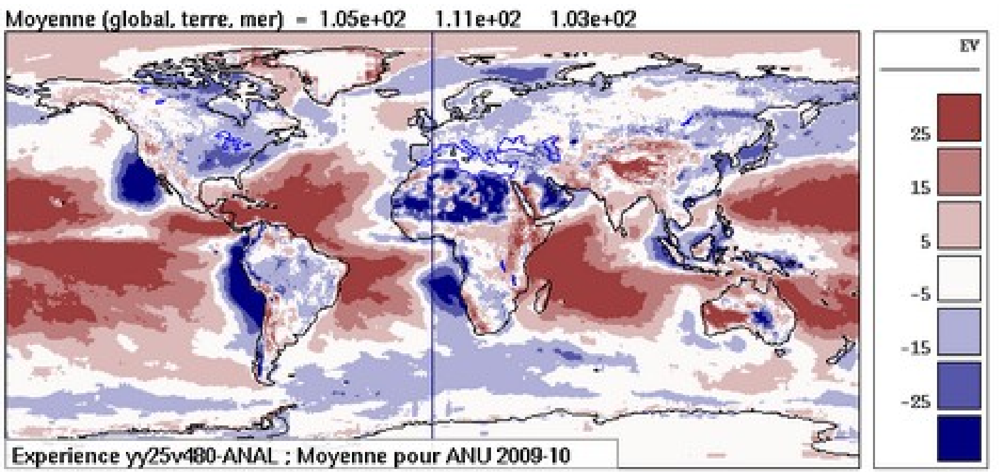
Bottom: CABME19(new) annual mean of FB –CERES obs

Why: combination of changes to radiation scheme, cloud cover and liquid water path

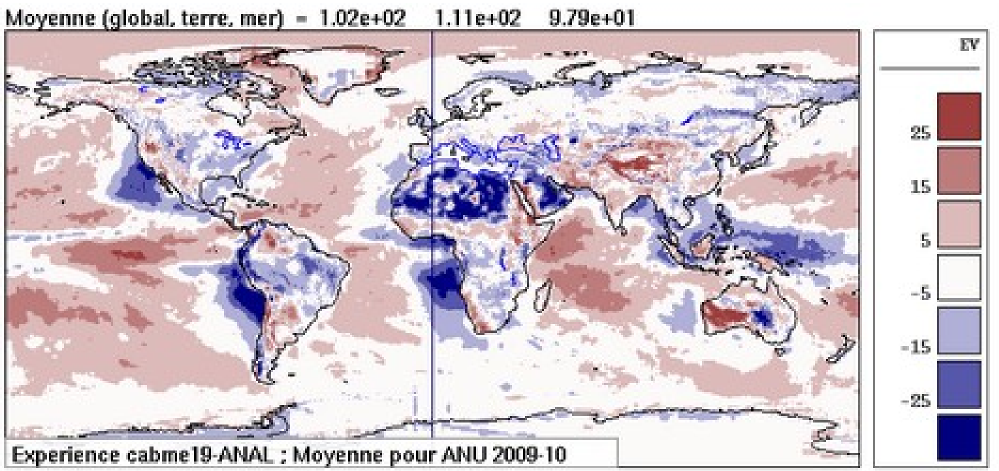
Bias in W m-2

MHEEP

improvements in SW flux at TOA (EV)



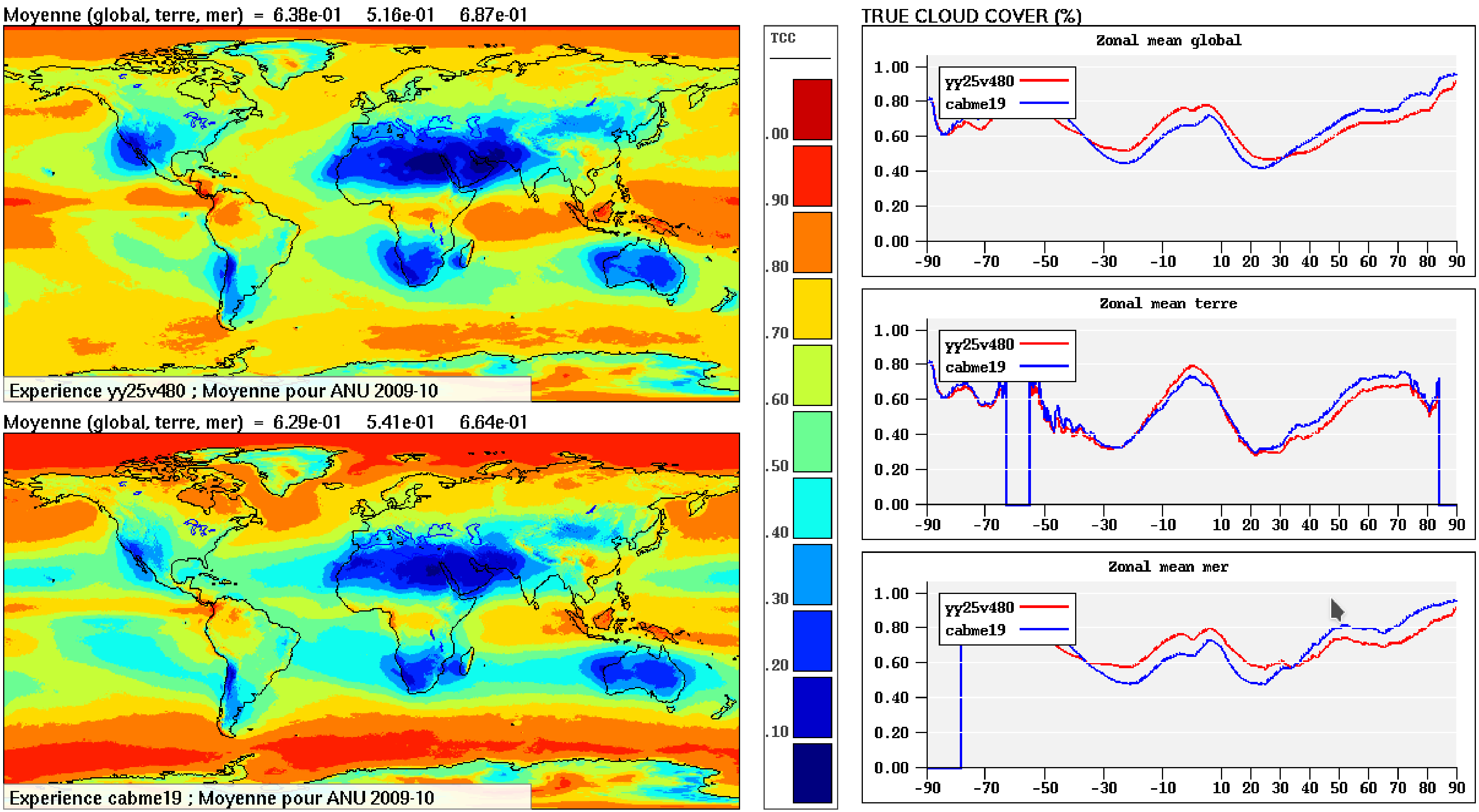
TOP: GDPS-ops annual mean of EV – CERES obs



Bottom: CABME19(new) annual mean of EV –CERES obs

Bias in W m-2

MHEEP: cloud cover



Top left or red curve (old model), bottom left or
blue curve (New model) annual mean Cloud cover (TCC)

Irritants en 2020:

- Vérification des nuages (ordre 0, 1, 2…)
- Probablement trop diminué TCC sur les océans
- Manque de nuages sur terre en général
- Forêts tropicales: flux, précip et nuages
- Structure de la précipitation sur les océans
- Intensité des cyclones tropicaux trop faible
- Stratocumulus près des côtes de Californie, Péru, Namibie, Iles Canaries
- Schéma microphysique (SRPD, SGPD...)

EXTRA

Convection in GEM:
brief history

Global

1998-2006 100km	2006 33km	2013 25km	2019 15km

- Deep- Kuo
  Shal- none
- Deep- Kain and Fritsch
  Shal- KuoTrans_mg
- Deep- KFC2
  Shal- Bechtold(KF+mods)
  Elevated- (KF+mods)

<u>All three schemes use mass flux approach</u>

Regional

1998 24km	2004 15km	2010 10km	2019 10km

- Deep- Fritsch-Chappell
  Shal- KuoTrans
- Deep- Kain and Fritsch
  Shal- KuoTrans
- Deep- KFC2
  Shal- Bechtold(KF+mods)
  Elevated- (KF+mods)

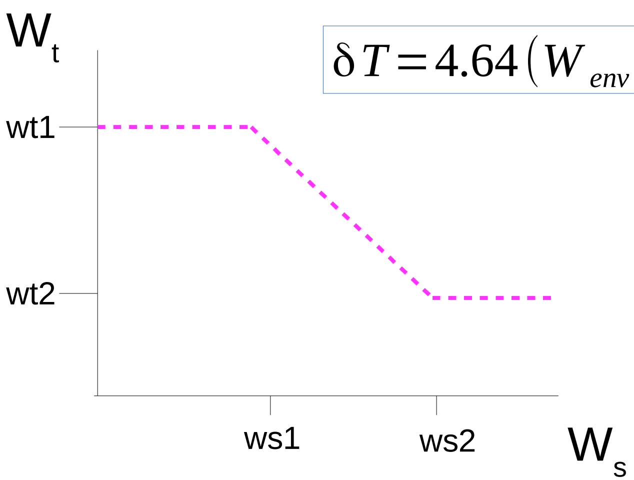
Deep convection: What's new in kfc2?

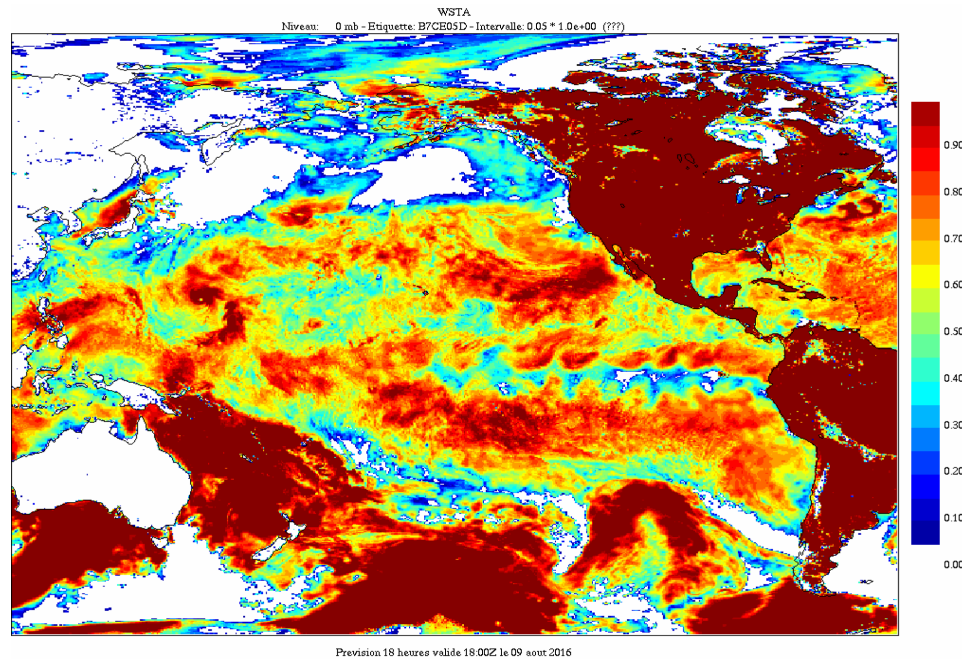
- State-dependent triggering thresholds over oceans,
- Function of pbl turbulent velocity scale - Ws

(kfctrigw = ws1,ws2,wt1,wt2)

(kfctrigw = .5, 1. ,0.07 ,0. in GDPS)

$$\delta T = 4.64 \left(W_{env} - W_T \right)^{(1/3)}$$





Ws m/s

NOTE: when possible(no degradations) we replaced empirical parameters with more dynamical/physical functions.

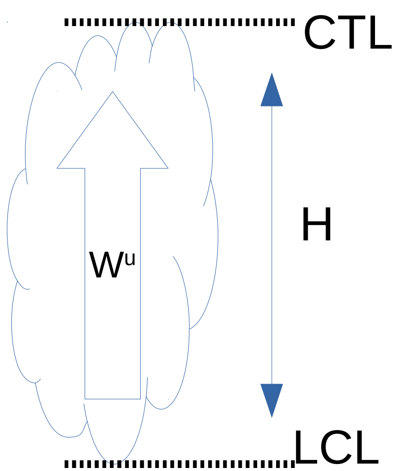
KFCTRIGW replaces constant threshold of .01 m/s over tropical oceans

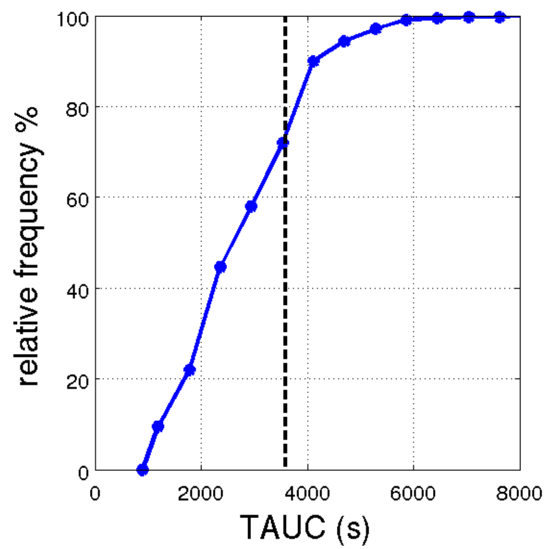
Deep convection:
What's new in kfc2?

- Convective adjustment timescale proportional to convective turnover time (deep_timeconv=bechtold09)

$$\tau_c = \alpha H / \overline{W^u}$$

$$\alpha = 4$$





Relative frequency of TAUC for GDPS.
70% of points have TAUC < 3600s

Impact:

- Neutral in sfc scores
- Minor improvements in arcad/verdict scores
- Eye-balling shows improved PR structure and **reduced grid-point storms**

NOTE: replaces constant 3600s for GDPS and 2700s for RDPS
To be used with deep_timerefresh=1p