Various aspects of what we can and would like to represent with ECMWF moist physics:

DYMECS project; Stein T, R. Hogan et al, BAMS 2015: "believe 1 km resolution enough, all remaining issues go away by further cranking up resolution => 200 m best but still sensitivity to mixing length

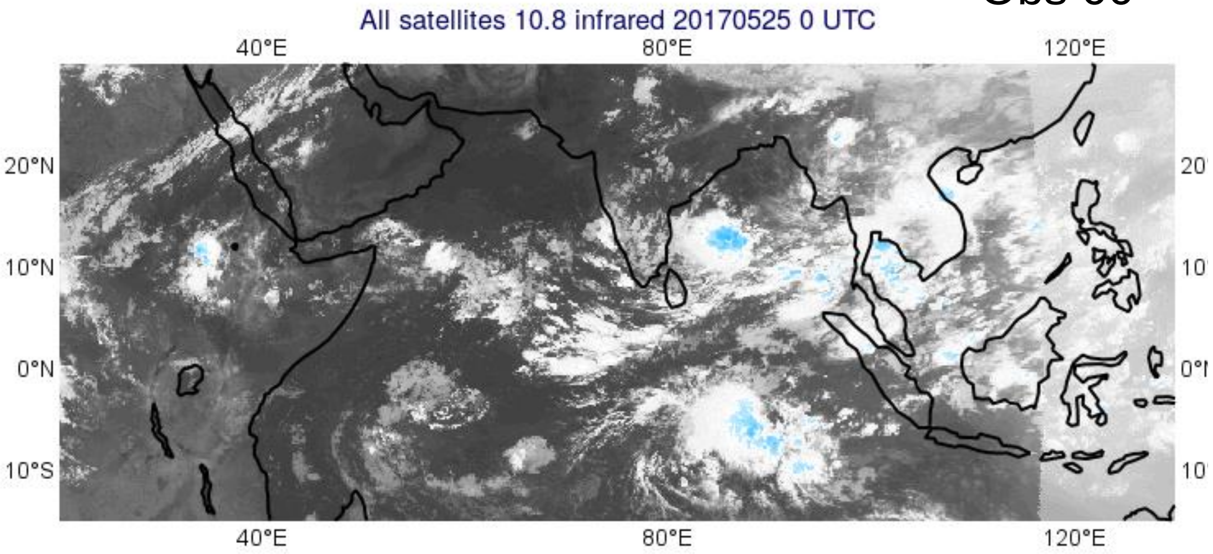
Yano et al. BAMS 2017/18: Is increase in resolution leading to better forecasts? Can't say yet but probabilistic approach and turbulence research with robust numerics needed

GEWEX convection permitting climate workshop, Prein Rasmussen, Stephens 2016: so far focus on precip extremes, uncertainties of CPMs could not be properly assessed, main benefits: reducing uncertainty in convective storms, gravity waves, terrain;, better representation of hydrolog. Processes (snowpack, orographic precip)

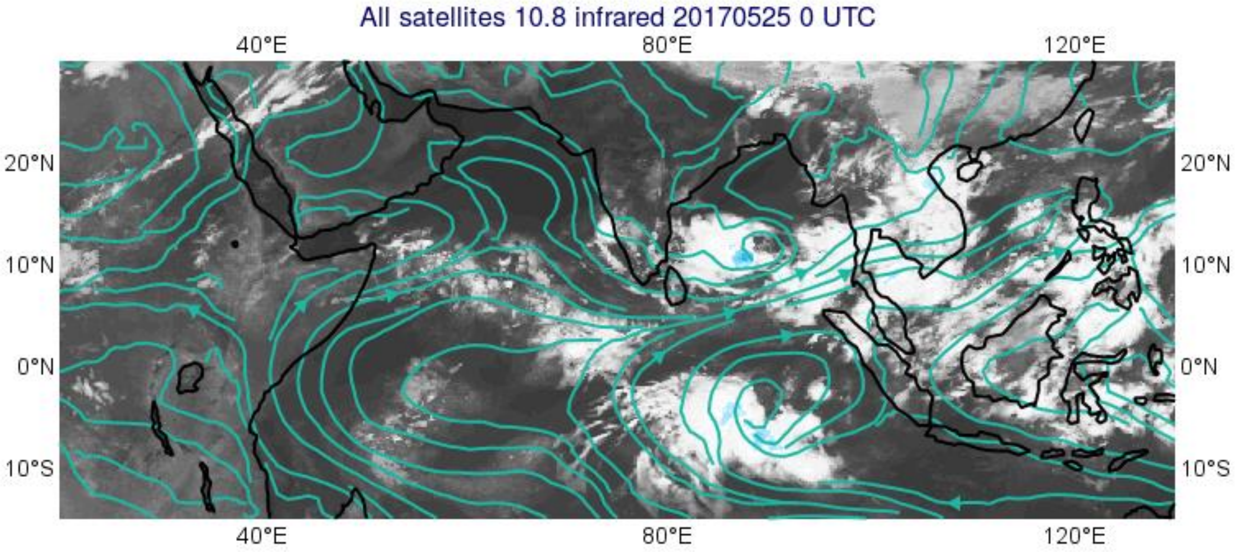
Peter Bechtold and colleagues

Large-scale waves and diurnal cycle

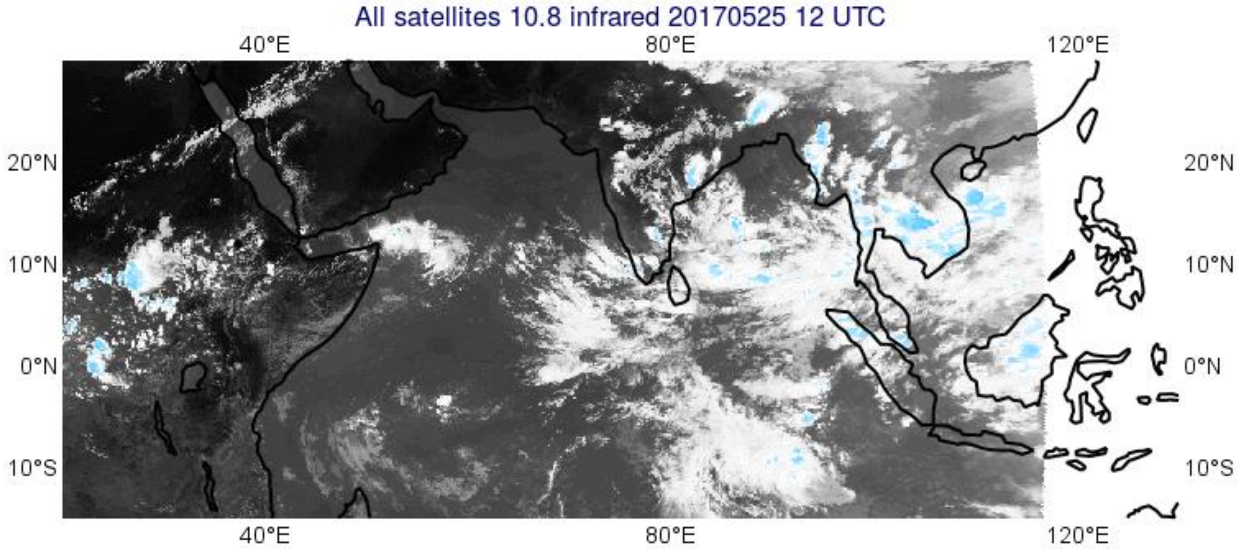
Obs 00



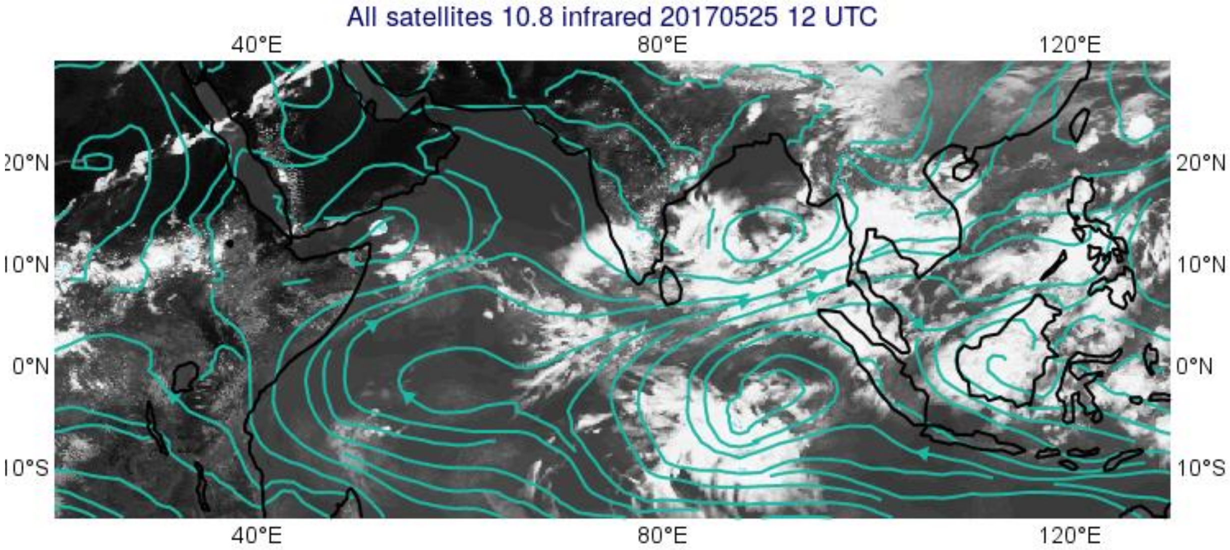
SIM 00



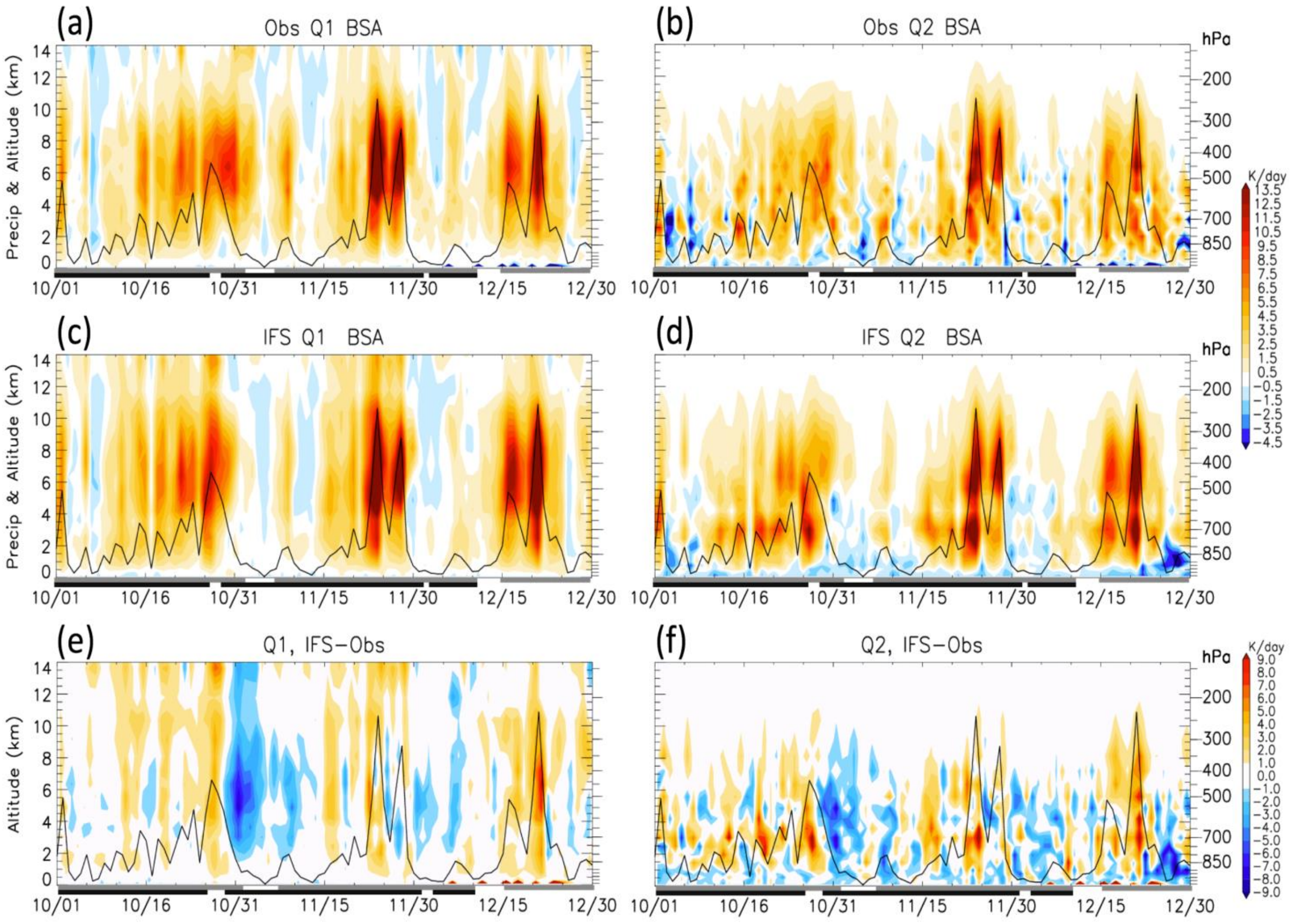
Obs 12

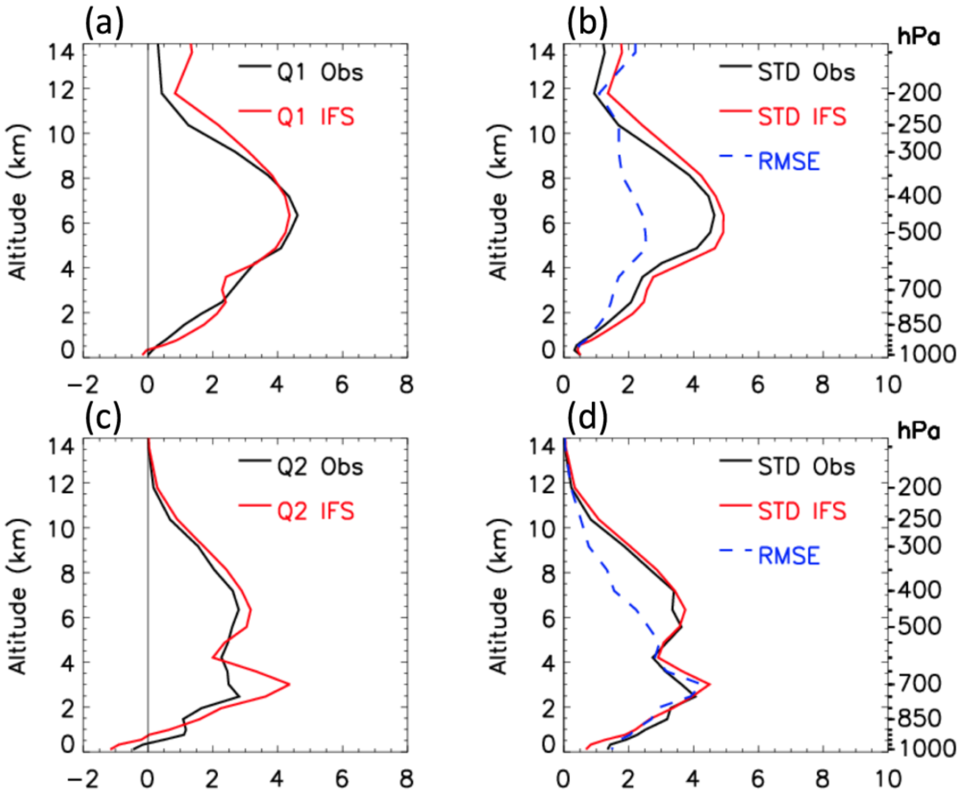


SIM 12



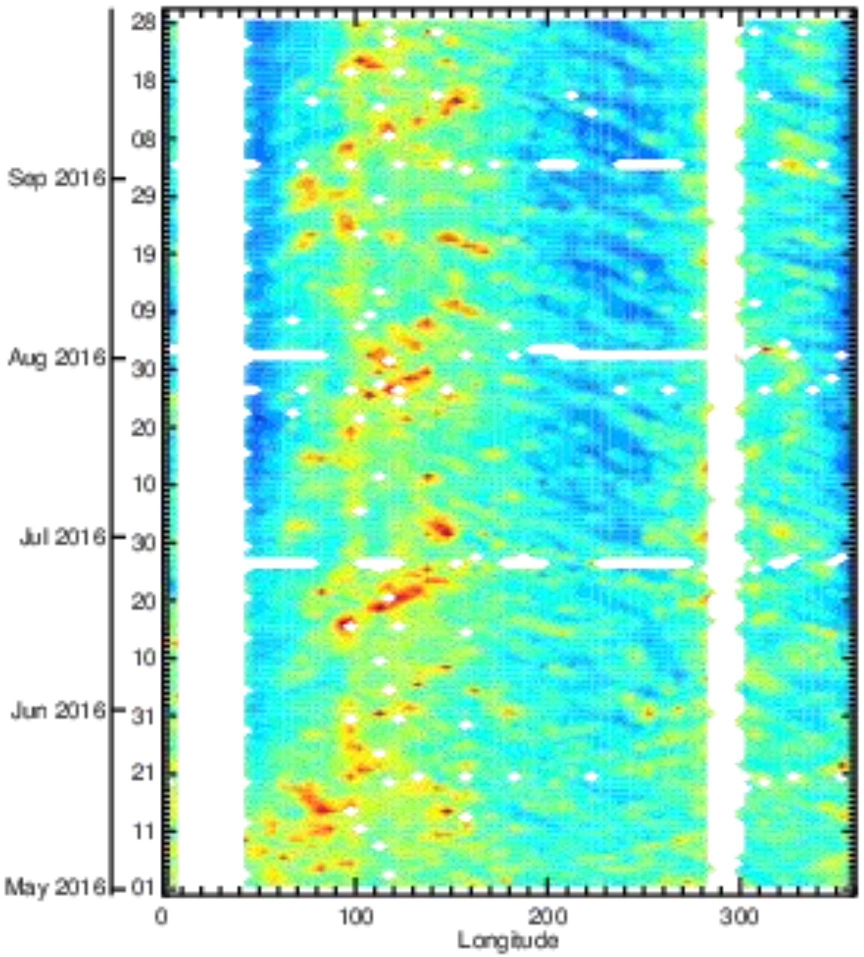
Updraught glaciation/melting level revisions, comparison with heating rates from DYNAMO

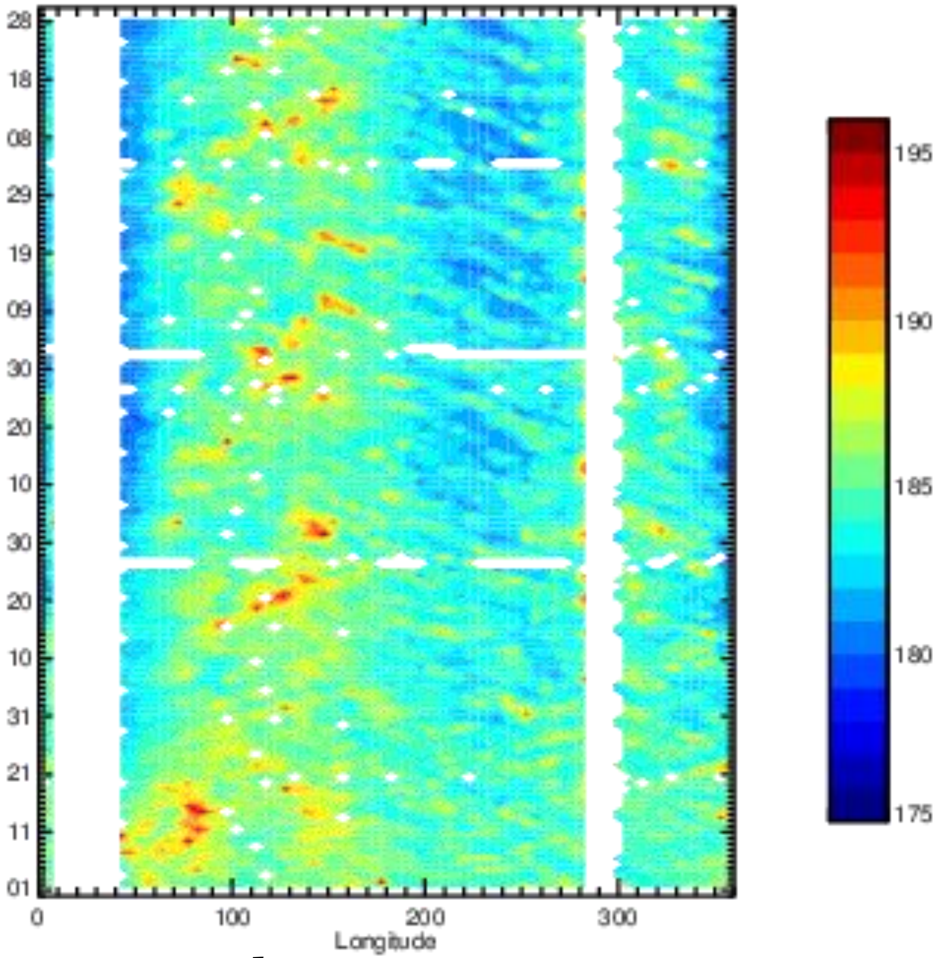




J.-E Kim et al. 2017, JAS

Tropical large-scale waves in observations and short-range forecasts: Microwave brightness temperatures - SAPHIR (sensitive to ice)

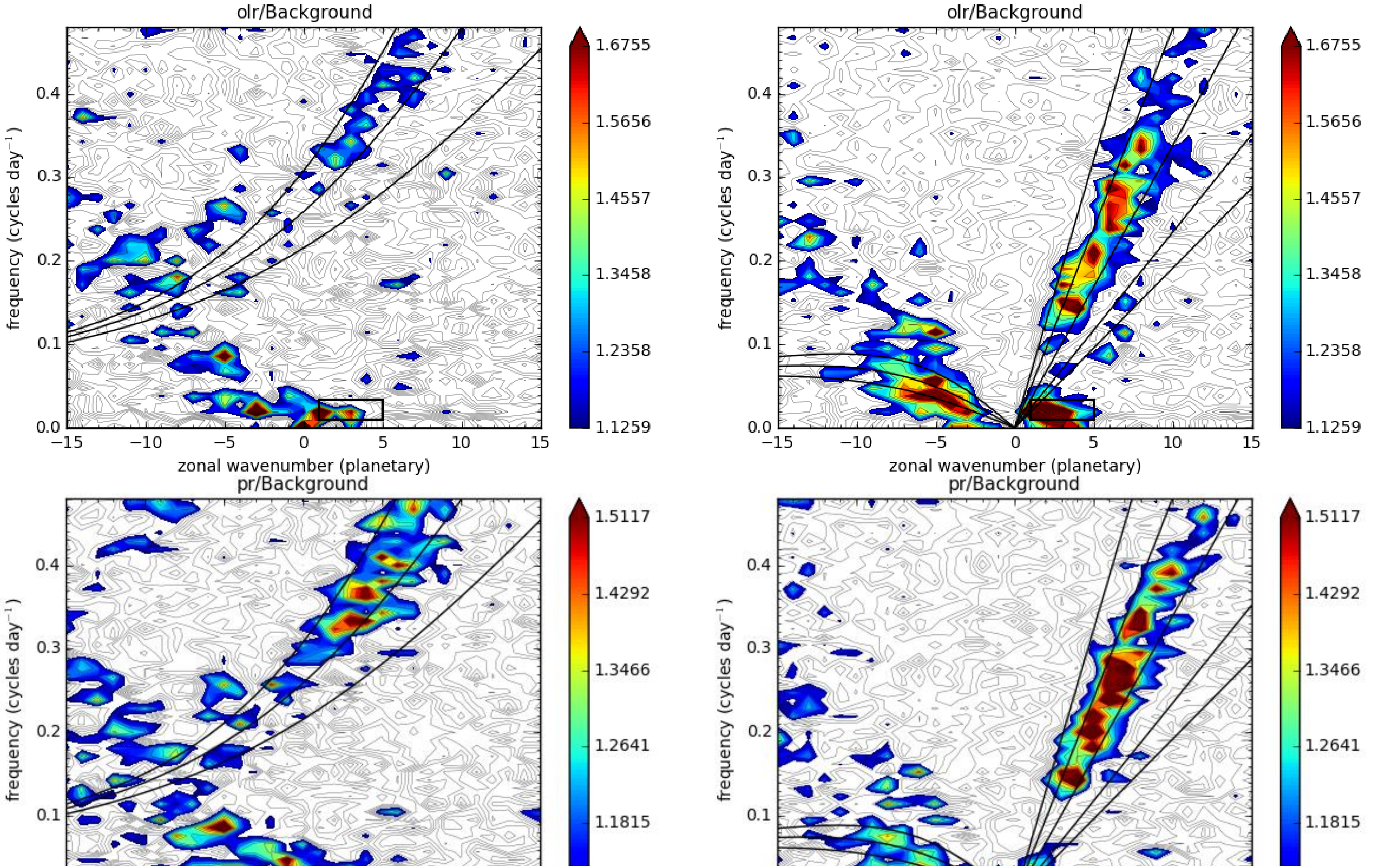




$$q_{r,s} = 10^{-3}\,\rho^{-1}\left(a_{r,s}F_{r,s}\right)^{b_{r,s}}$$

Courtesy A. Geer, P. Chambon and K. Lonitz

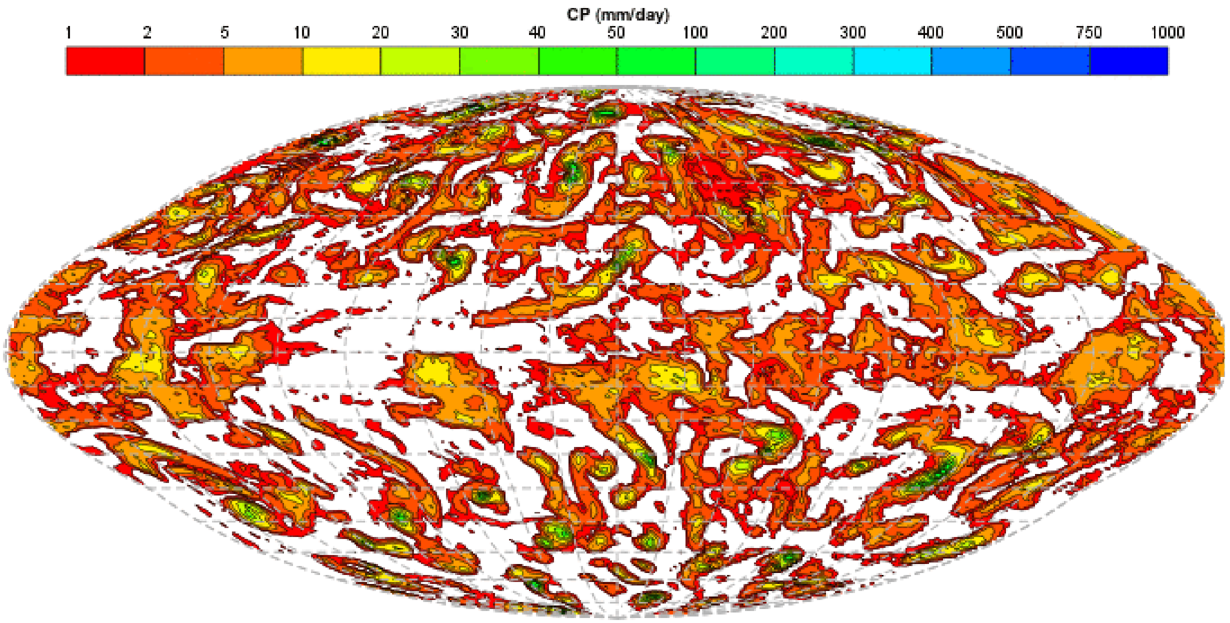
Wavenumber Frequency Spectra OLR and Precipitation

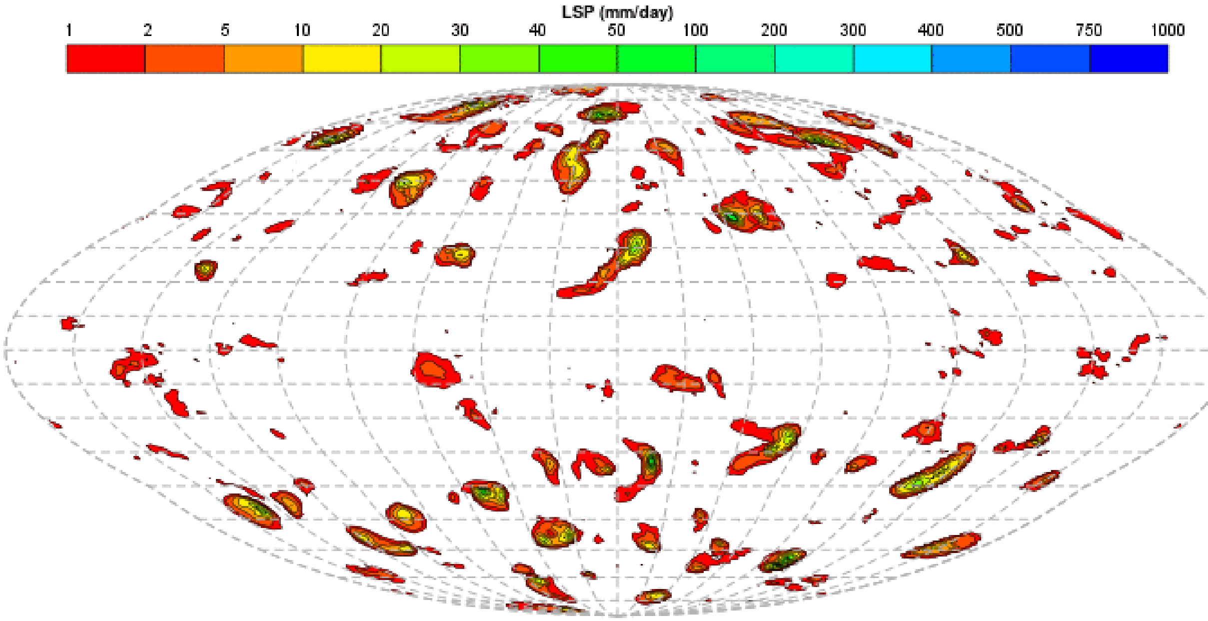


software courtesy M. Herman

Dias J. et al. comparison Obs GFS and IFS, 2017/18 MWR in preparation

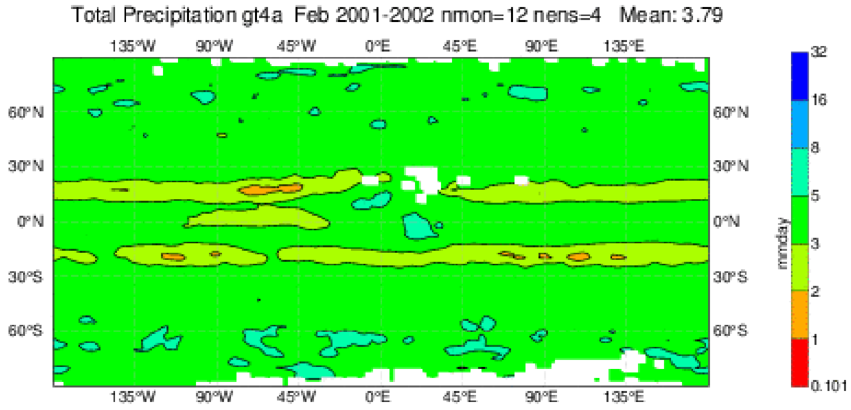
AQUA Planet with cst SST=30C, sun over equator, Cy43r3, Tl255: CP & LSP



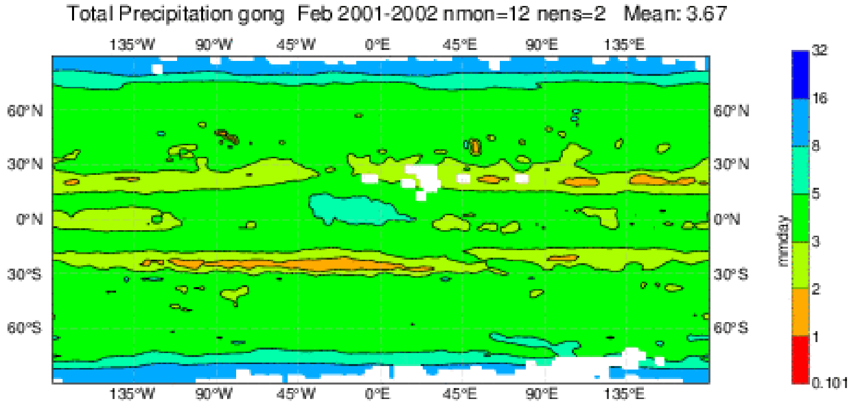


AQUA Planet with cst SST=30C, sun over equator: Mean Precipitation

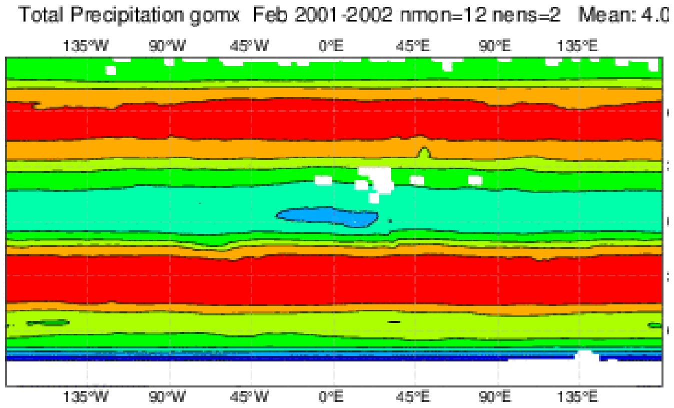
Base dx=80 km



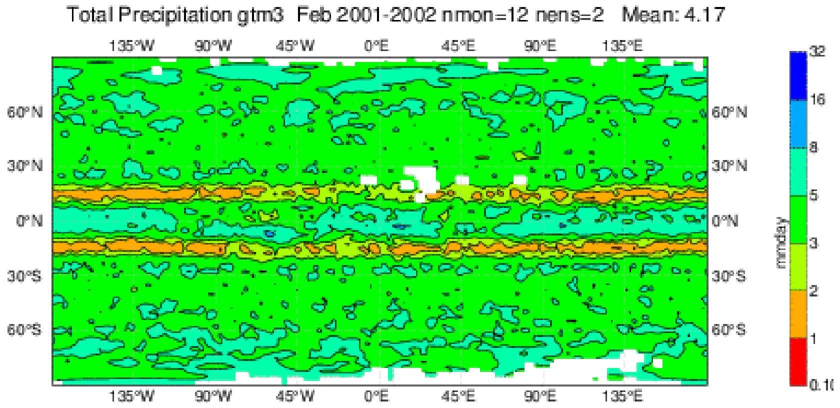
Small Planet: R/8 Cor*8



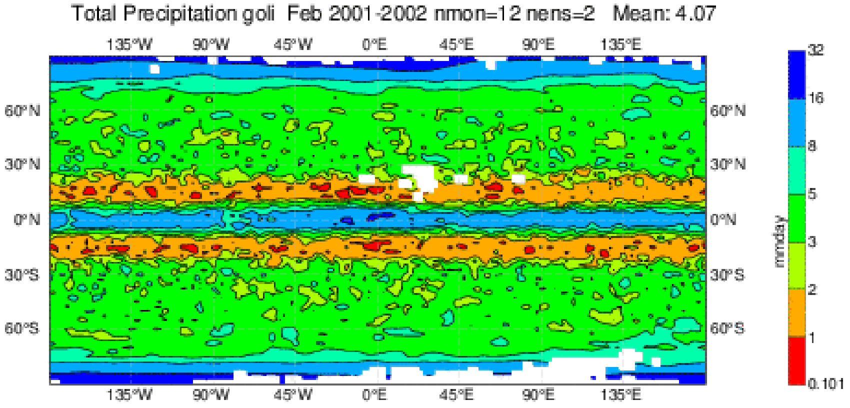
Small Planet: R/10



No deep

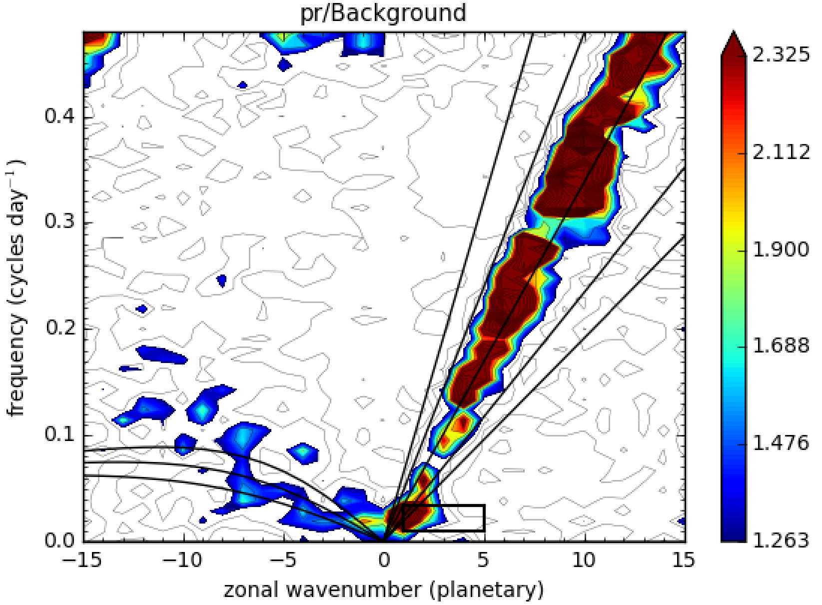


Small Planet: R/8 Cor*8 No Deep

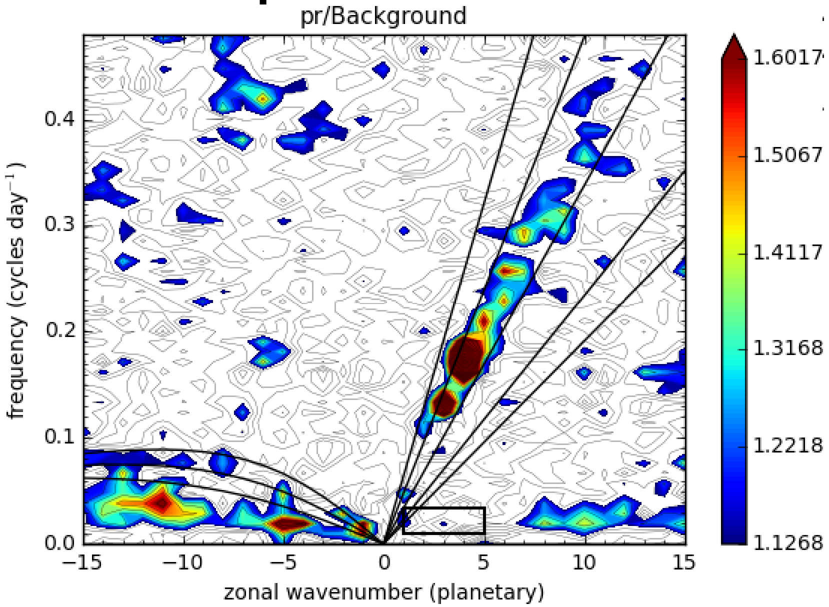


AQUA Planet with cst SST=30C, sun over equator: Precip spectra

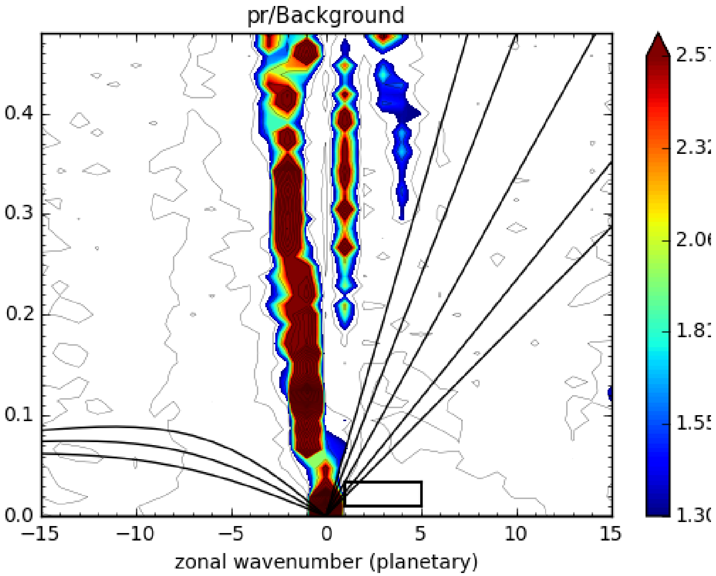
Base dx=80 km



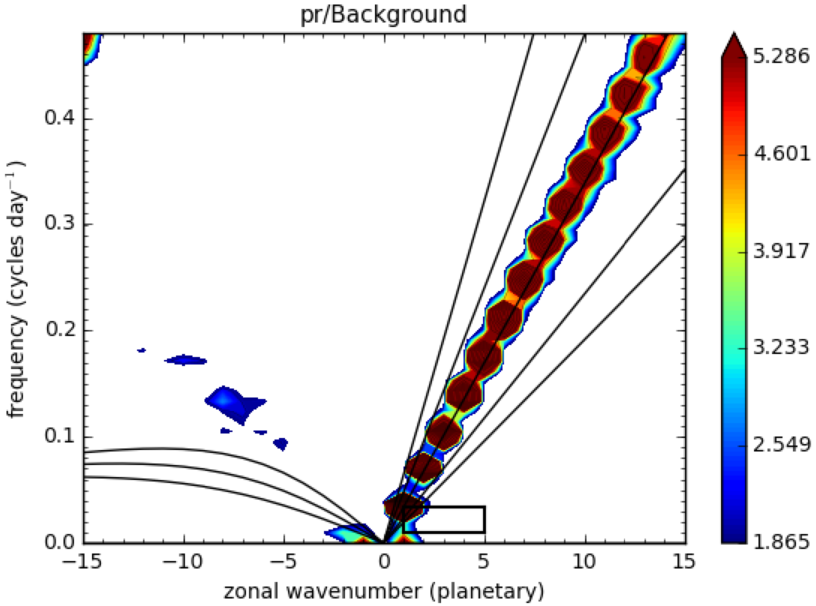
No deep



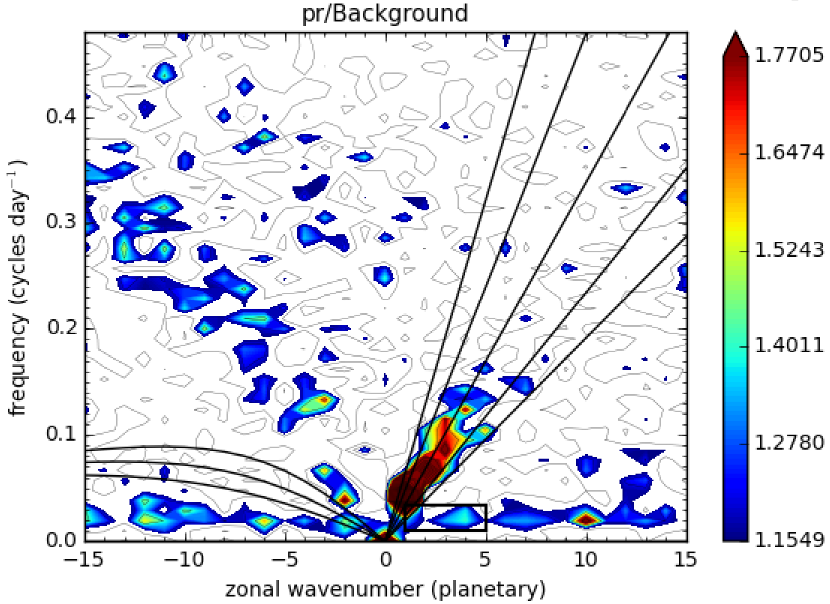
Small Planet: R/10



Small Planet: R/8 Cor*8

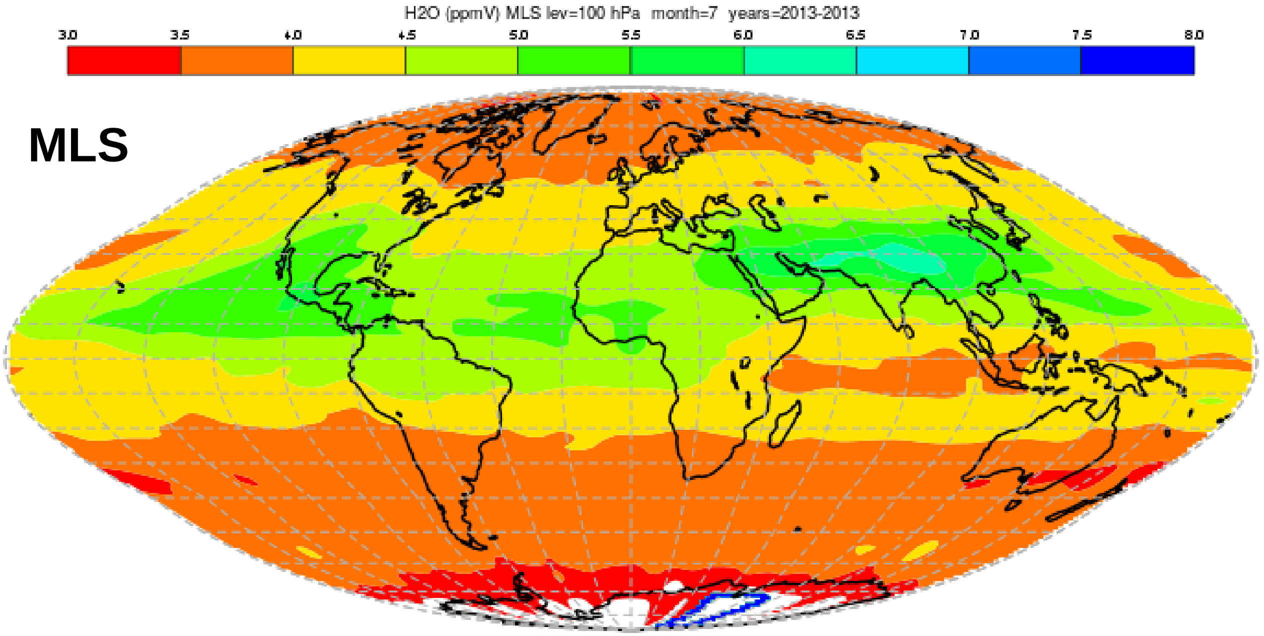


Small Planet: R/8 Cor*8 No Deep

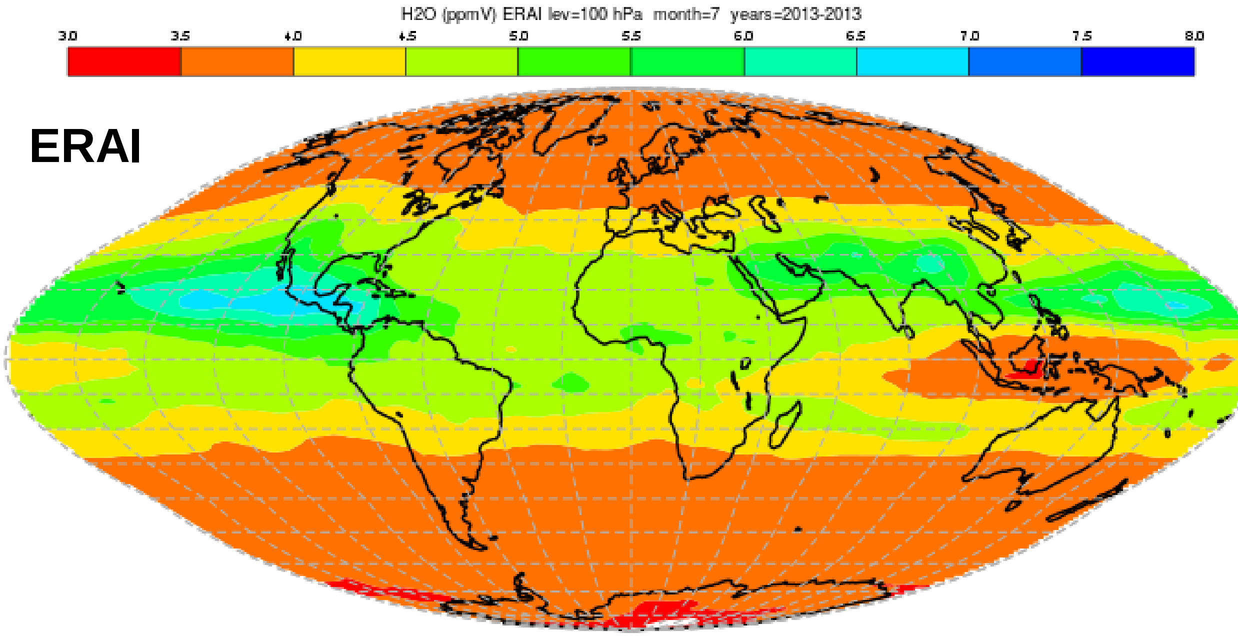


Stratospheric H2O and convection JA2013 100 hPa

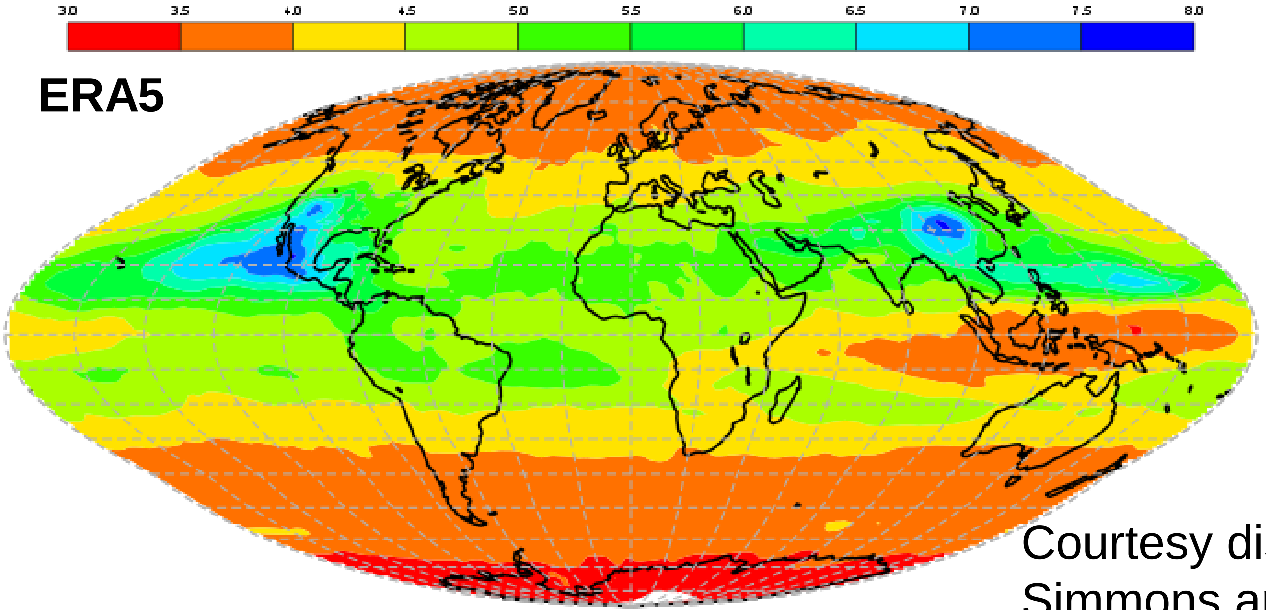
MLS



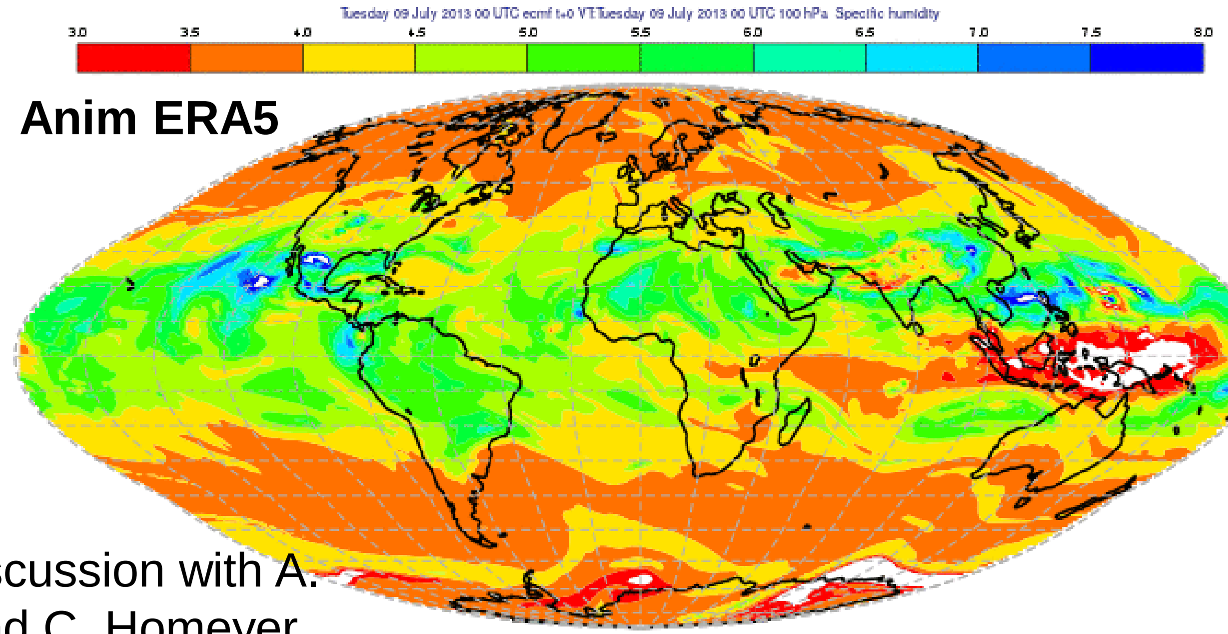
ERAI



ERA5



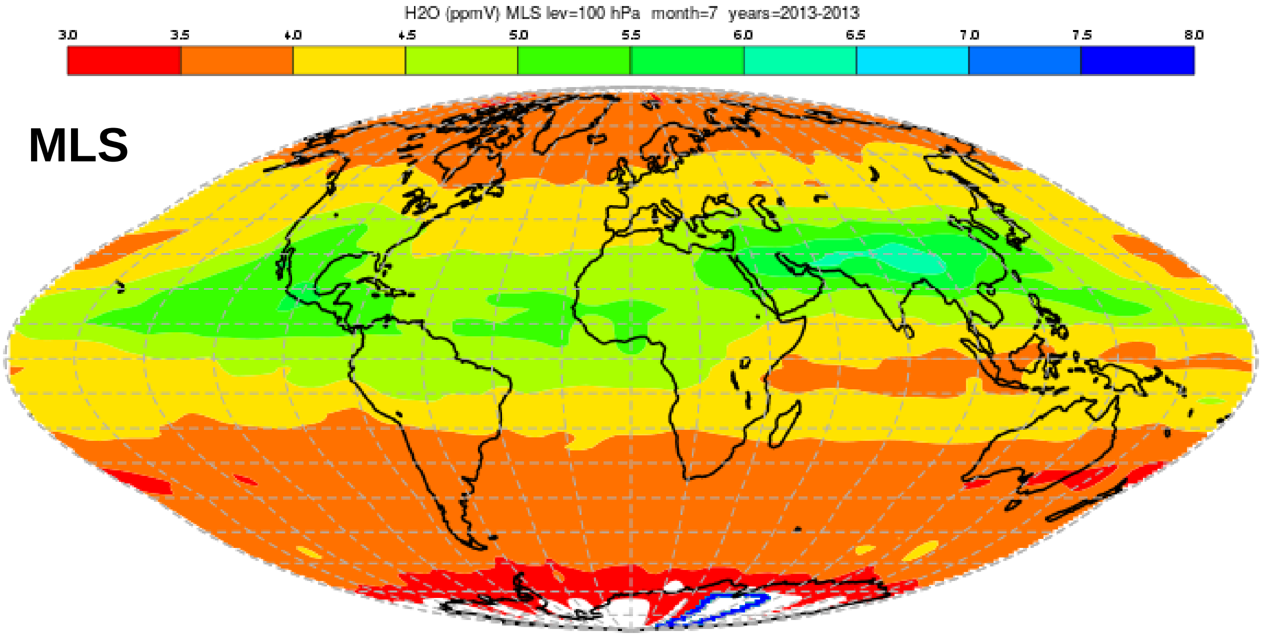
Anim ERA5

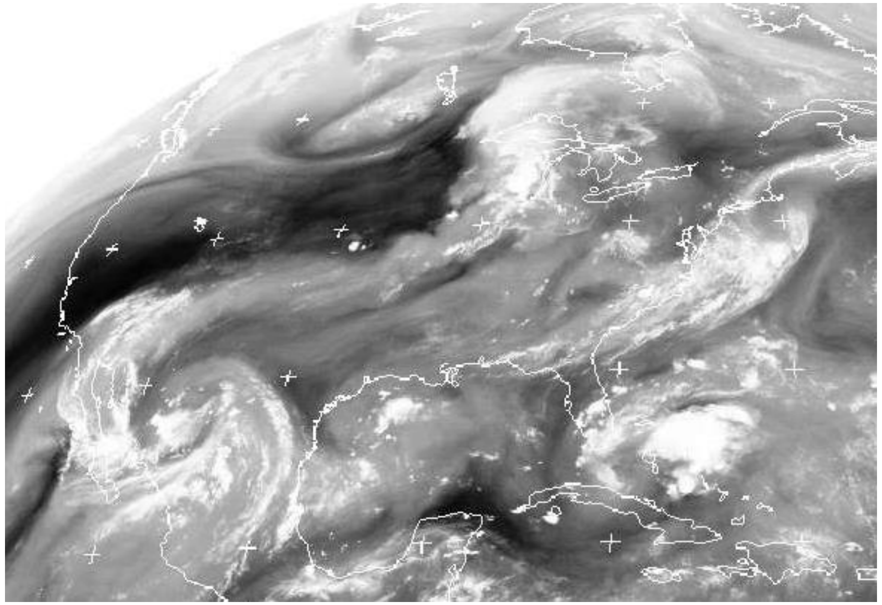


Courtesy discussion with A. Simmons and C. Homeyer

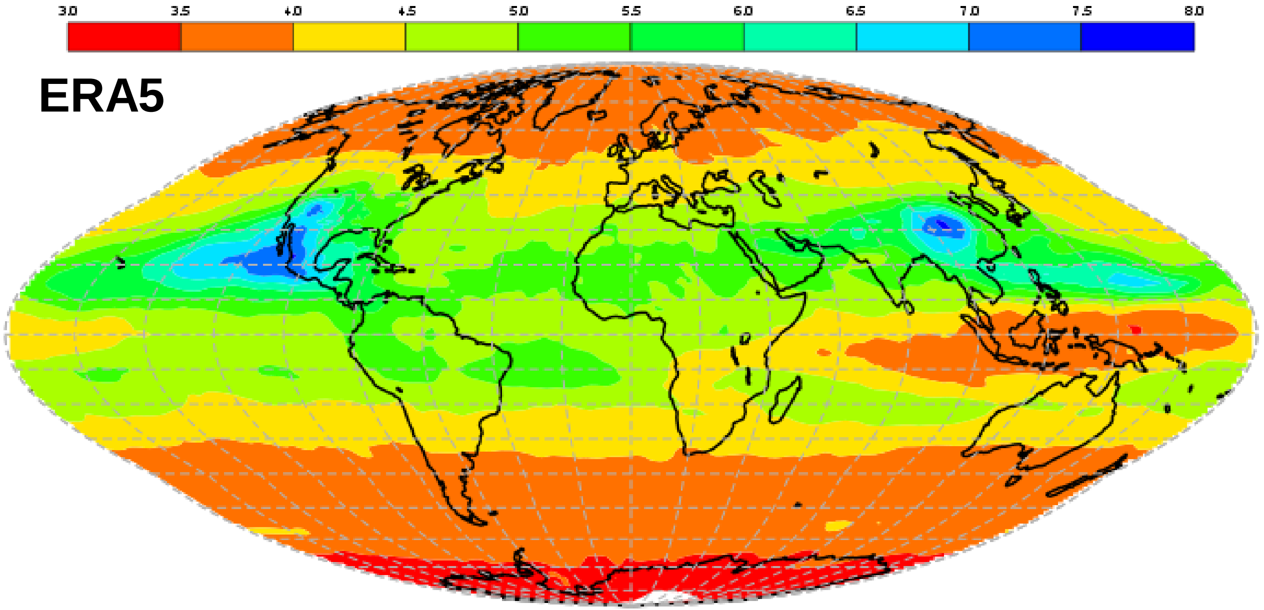
Stratospheric H2O and convection JA2013 100 hPa

MLS

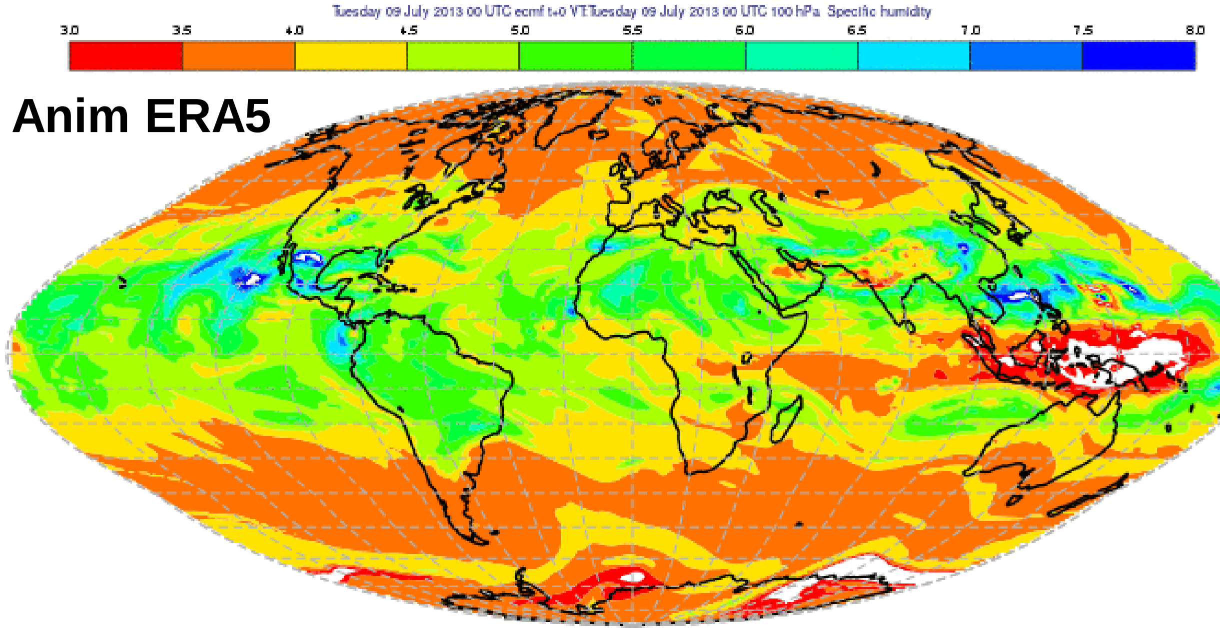




ERA5



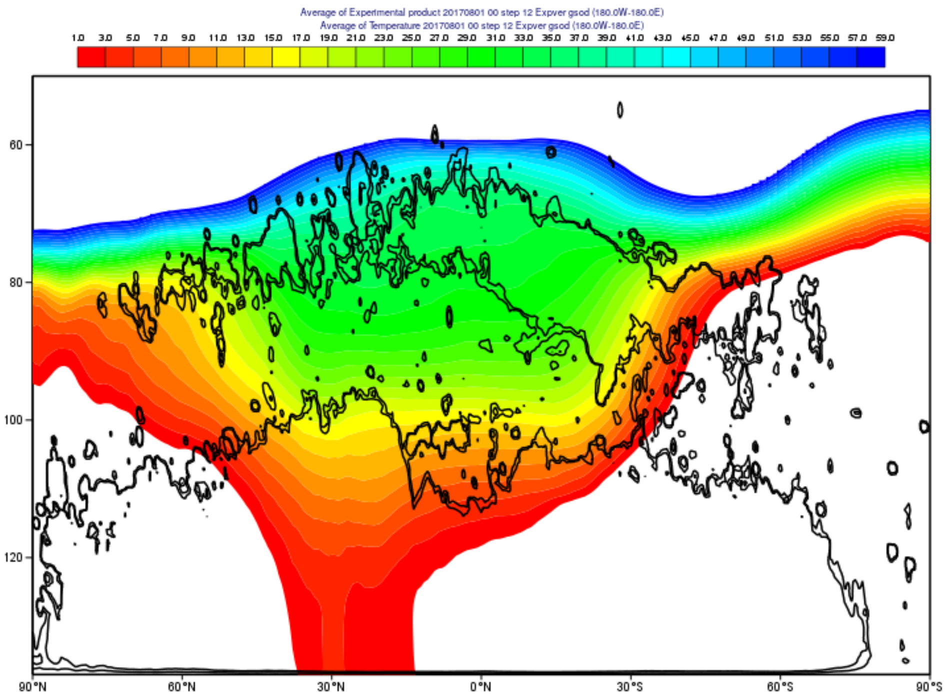
Anim ERA5

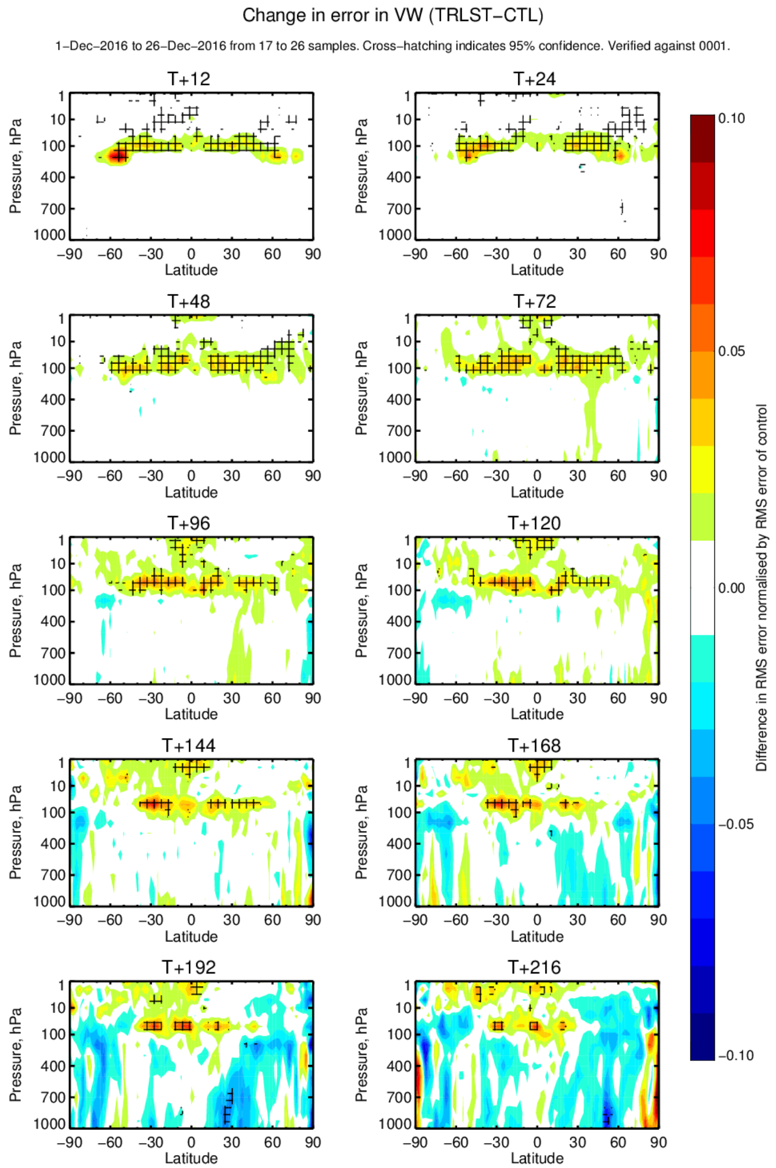


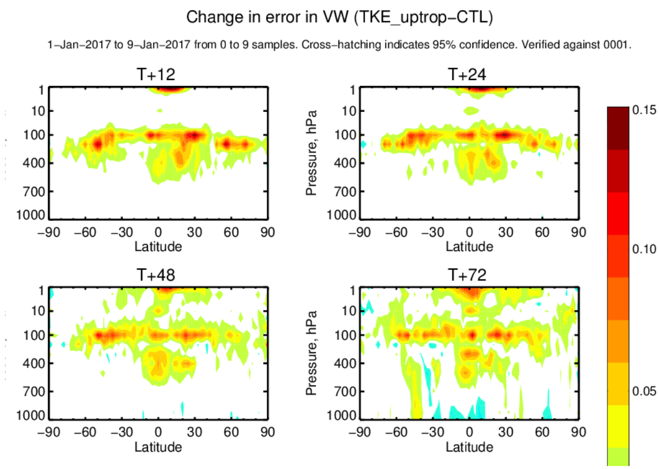
Issues in upper tropo/lower stratosphere: gravity wave breaking, diffusion, resolution?

Stratospheric group: I. Polichtchouk, R. Hogan, S. Malardel, N. Wedi, M. Diamantakis, I. Sandu, A. Beljaars, T. Stockdale, M. Rennie, E. Holm, L. Isaksen, F Vana, B Ingleby, A. Simmons, A. Bozzo, J. Flemming+ Satellite section

Zonal mean Theta-300 K, Mix. Coeff







experimental version with TKE above 500 hPa with E. Bazile

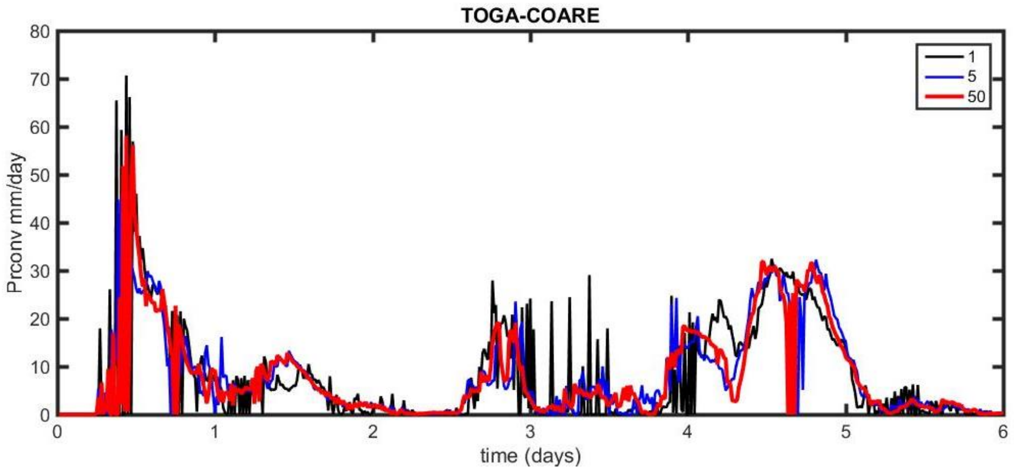
Very recent: progress shown by M. Diamantakis and F. Vana in using higher-order SL DP interpolation for wind, T. Stockdale in using 200 m vertical resolution

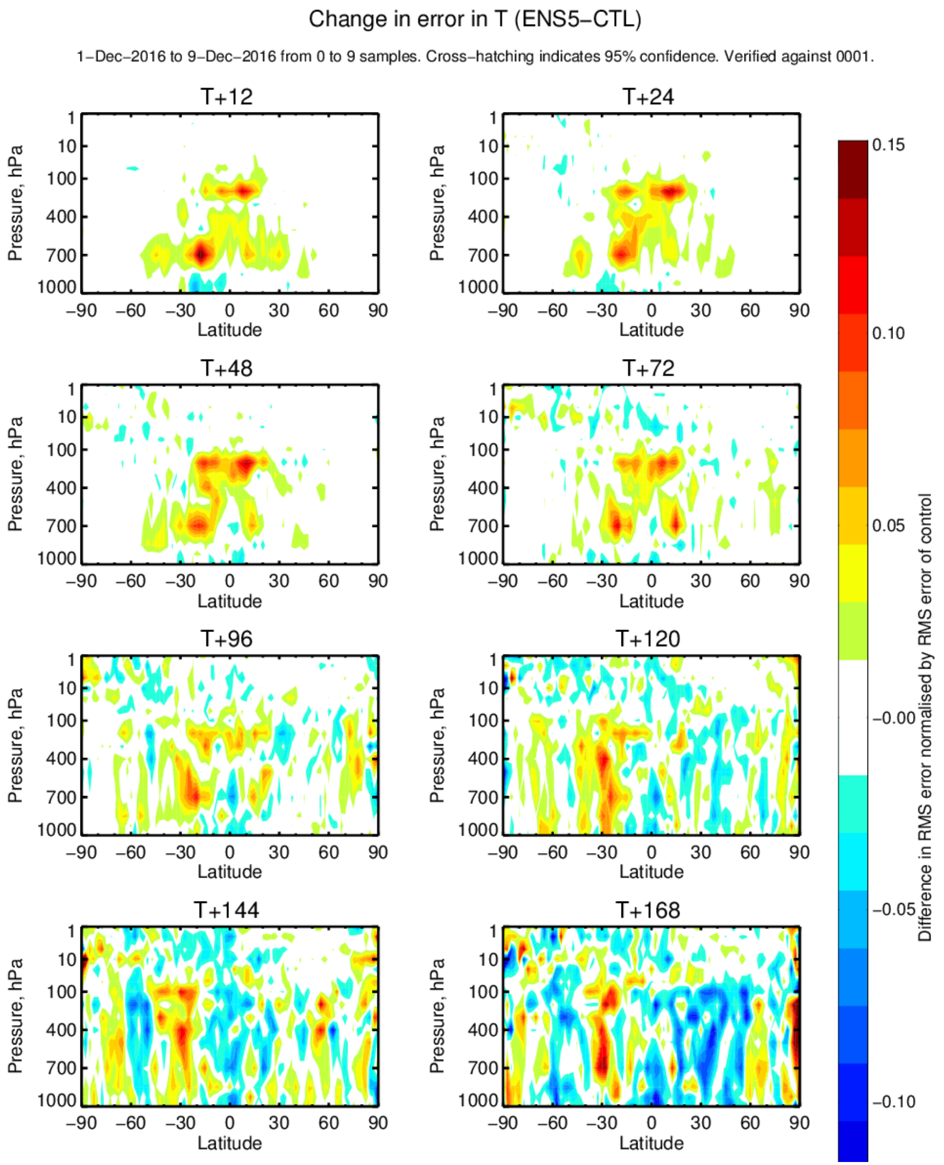
K-diff short tails above lapse rate tropopause Cy45r1

Does a Cumulus ensemble (based on entrainment) improve on biases at tropopause and trade wind inversion?

$$\varepsilon = \varepsilon_0 (1 + r); \quad r \in [-0.15, 0.15]$$

"full=trigger+ascent+closure" by calling whole convection n-times and averaging





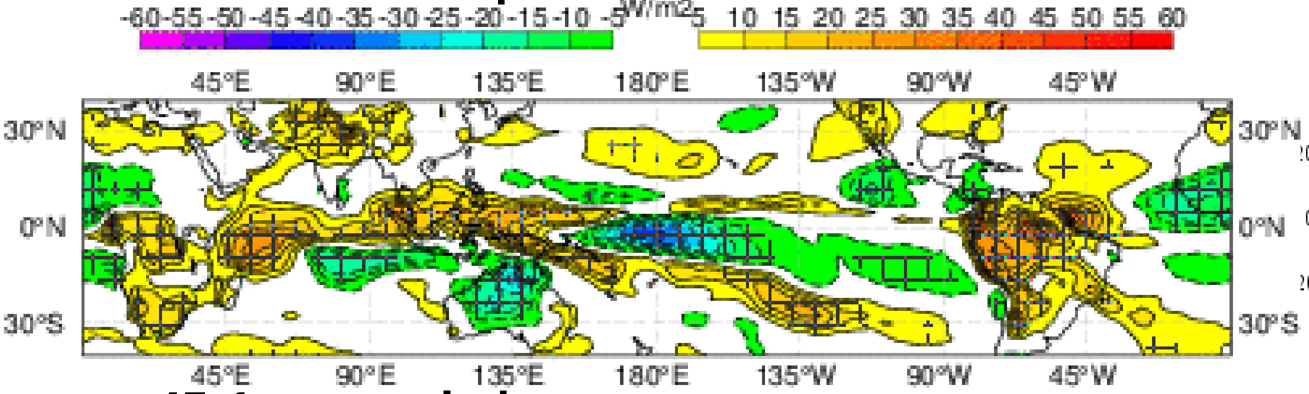
ECMWF

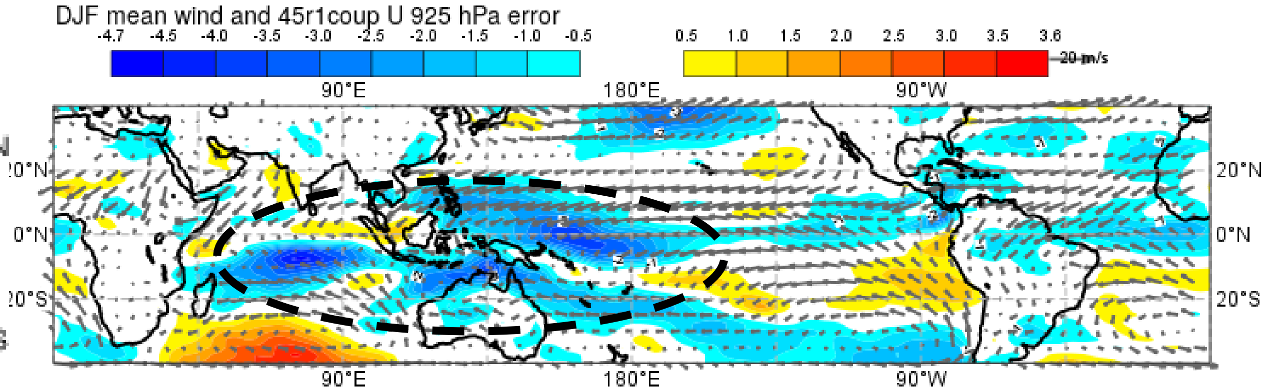
Systematic wind and OLR/Precip errors in coupled simulations

OLR – CERES-Ebaf annual 2000-2004

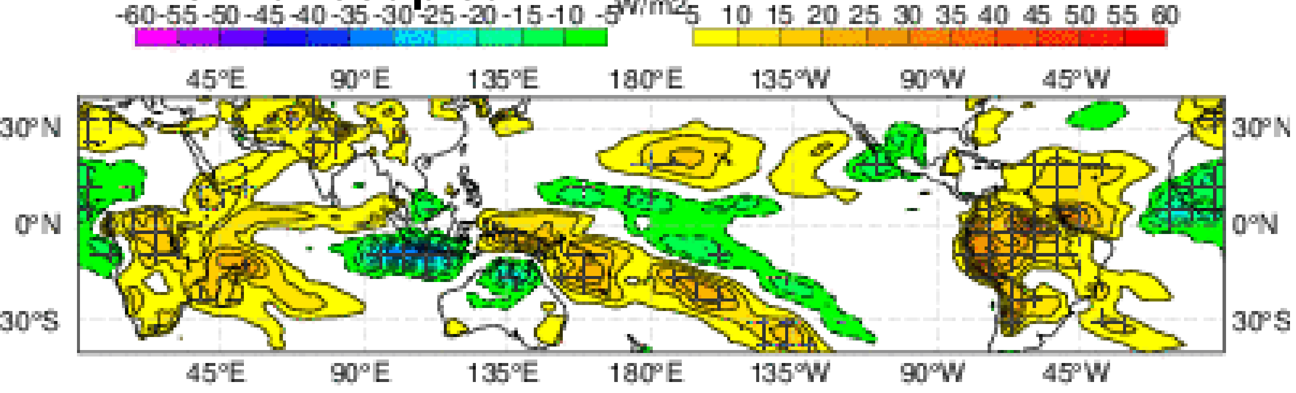
U 925 hPa – ERA5 DJF 2000-2004

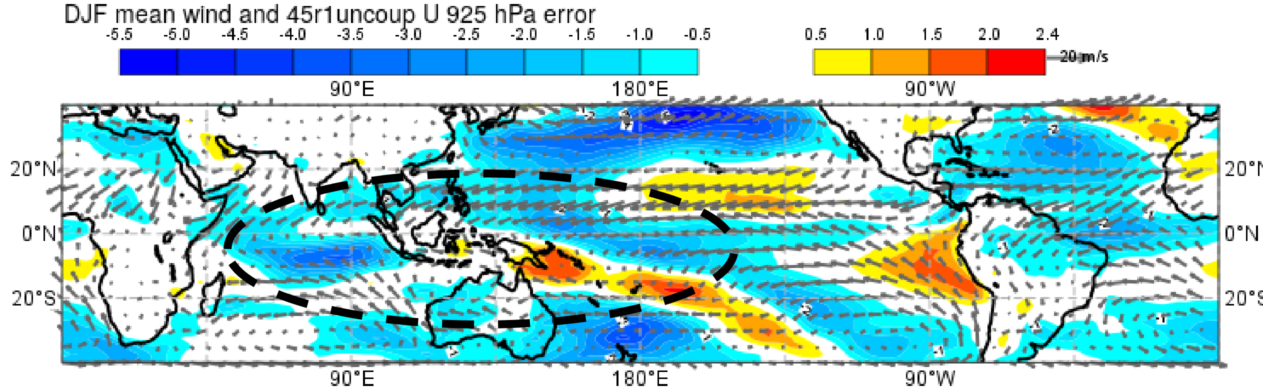
45r1 Tl255 coupled 0.025° Ocean



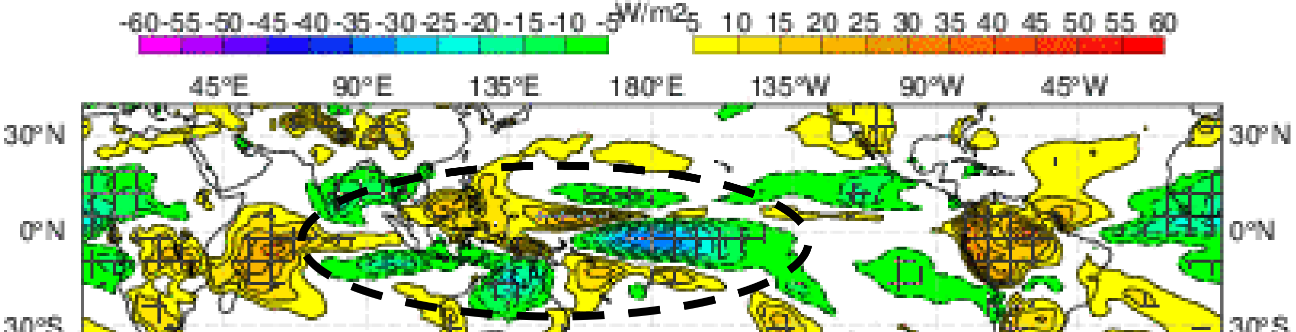


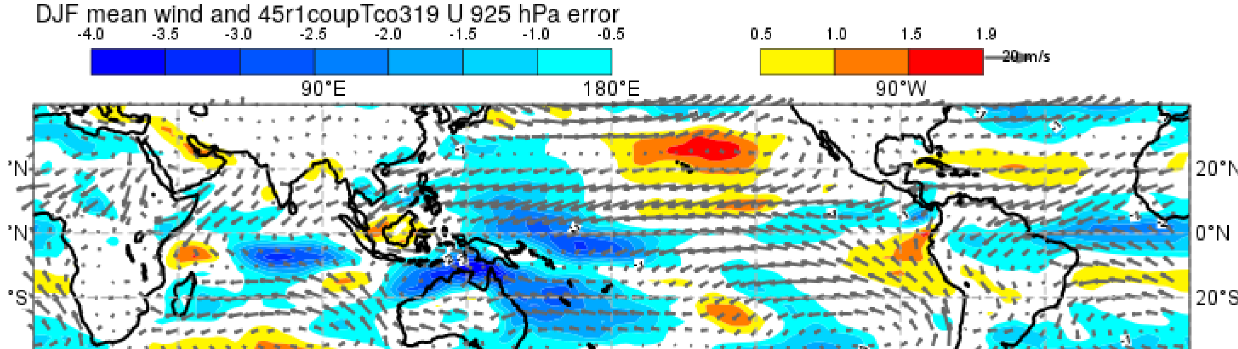
45r1 uncoupled



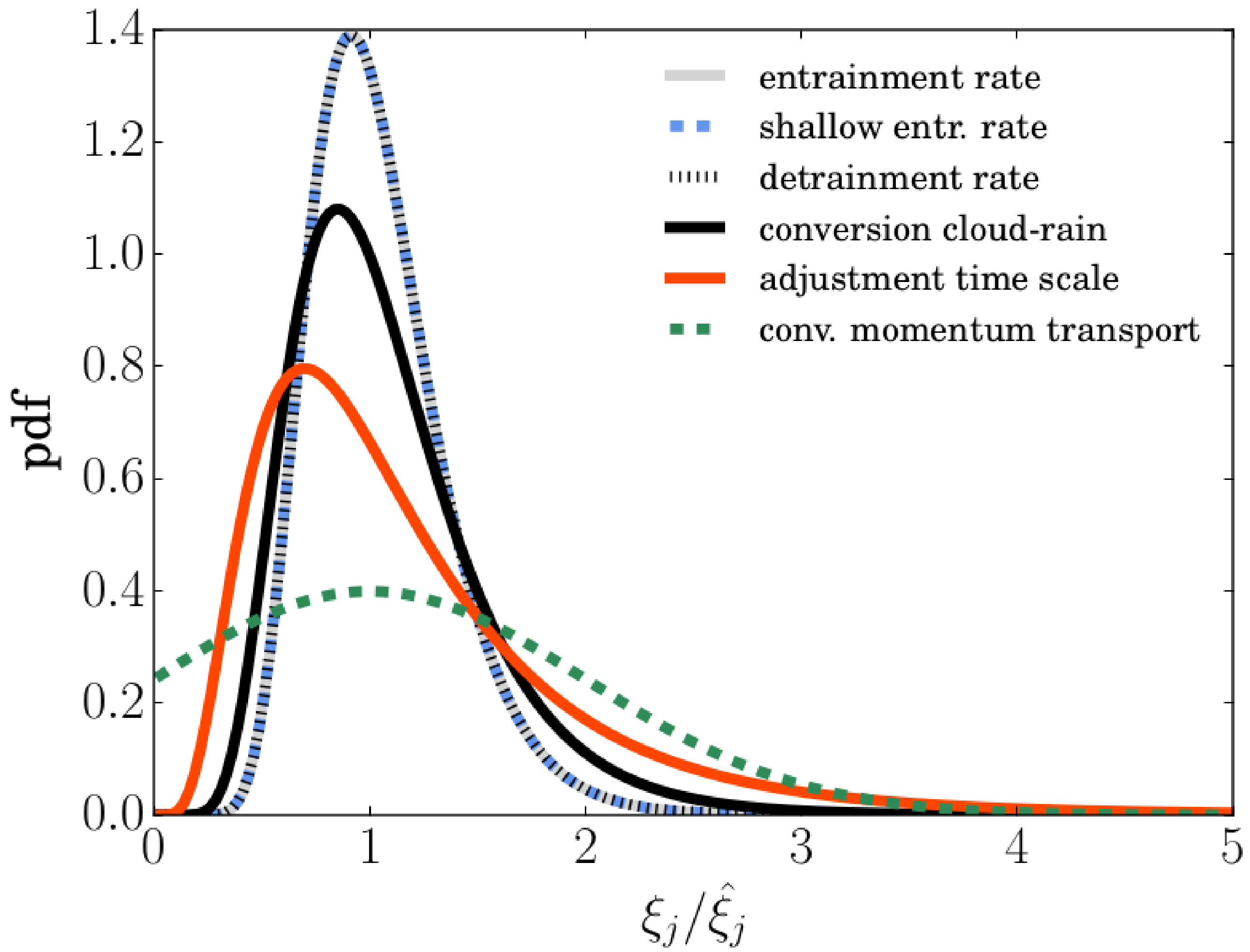


45r1 TCo319 coupled 0.025° Ocean





Ensemble and perturbed physics: Perturbed parameter distributions



Ollinaho et al. 2017, QJRMS
Leutbecher et al. 2017, QJRMS

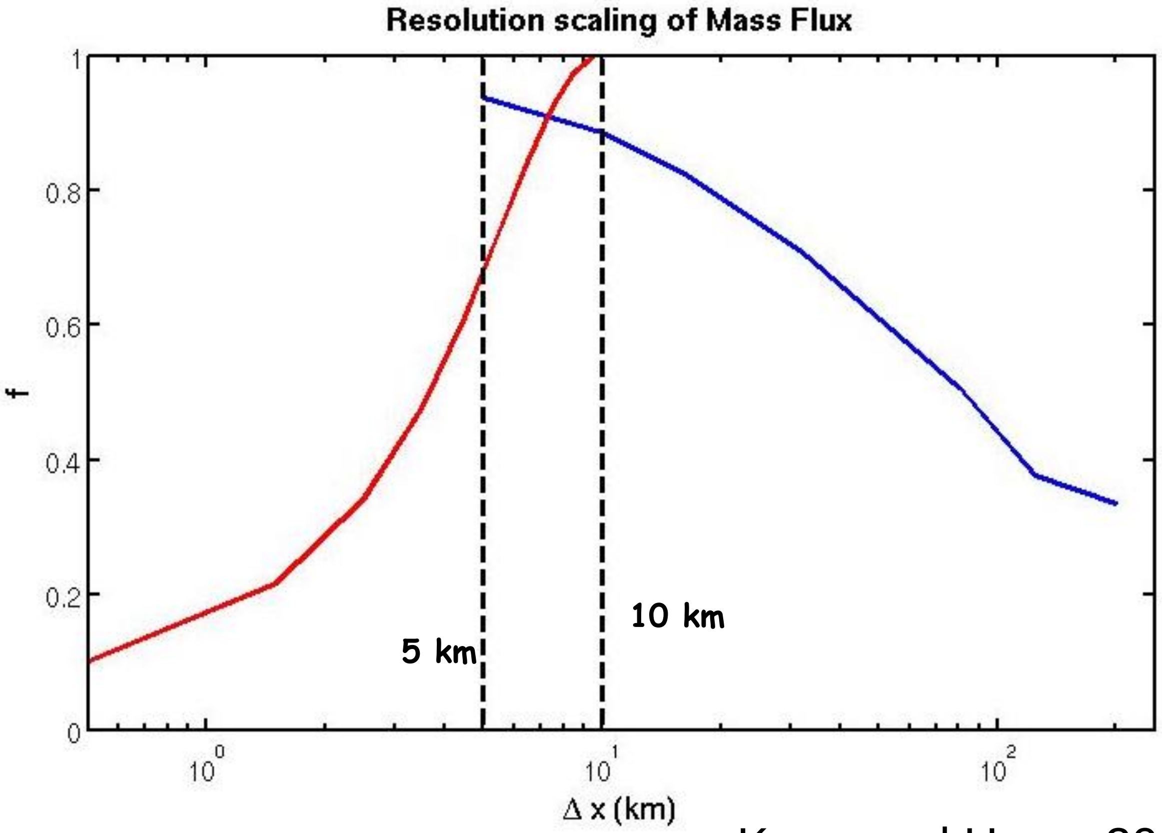
Ensemble is successful cause spatial-temporal varying perturbation pattern

Resolution scaling for deep convection

$$\overline{\omega'\Phi'} = \overline{\omega\Phi} - \bar{\omega}\bar{\Phi}$$

$$= \sigma(1-\sigma)\left(\bar{\omega}^c - \bar{\omega}^e\right)\left(\bar{\Phi}^c - \bar{\Phi}^e\right)$$

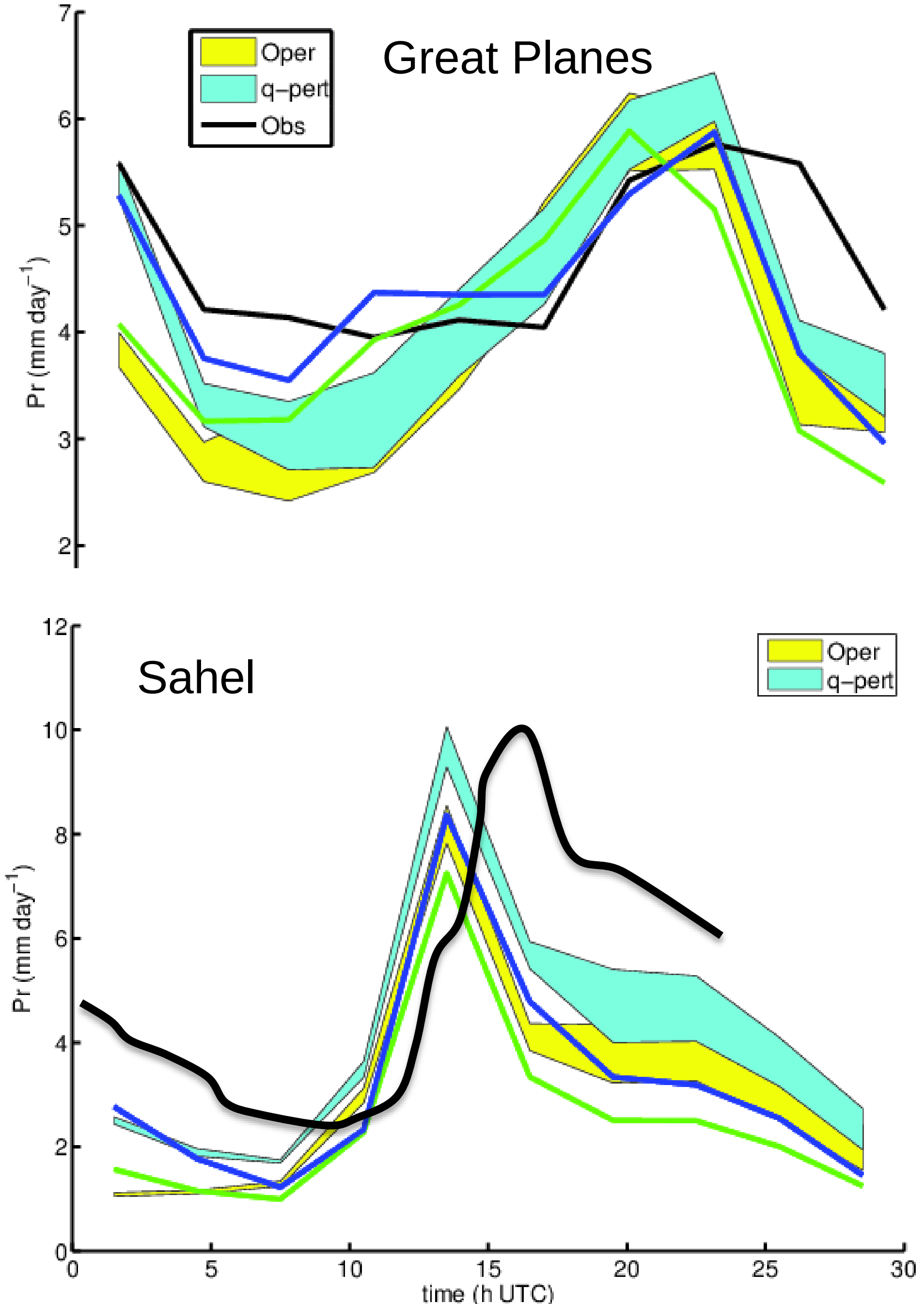
$$\cong \sigma\bar{\omega}^c\left(\bar{\Phi}^c - \bar{\Phi}\right) = -\frac{1}{g}M^c\left(\bar{\Phi}^c - \bar{\Phi}\right) \quad f(\Delta x)$$



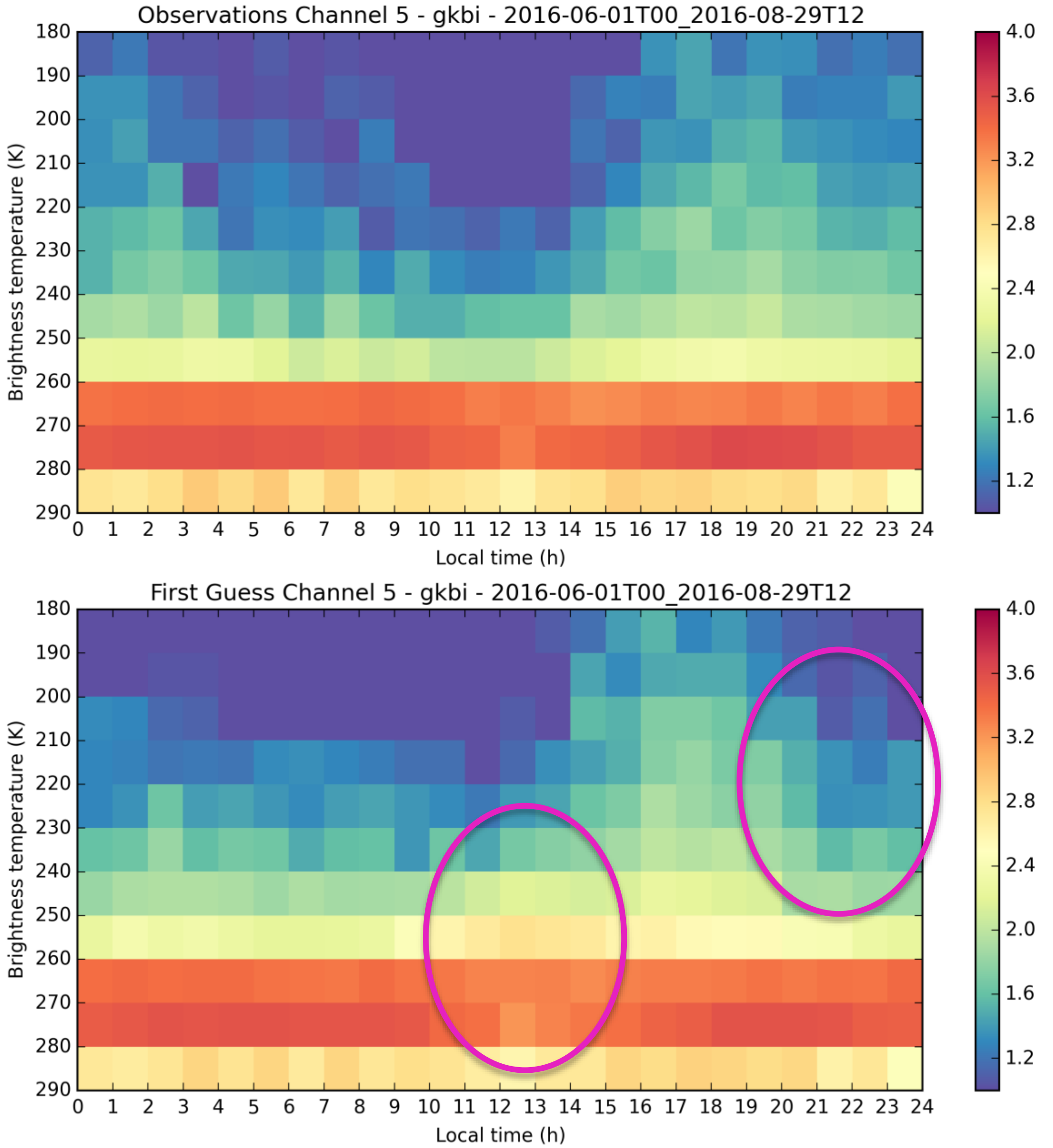
Developed in collaboration with Deutsche Wetterdienst and ICON model

Kwon and Hong, 2016 MWR; Grell and Freitas, 2014 Atm.Chem.Phys independently developed very similar relations

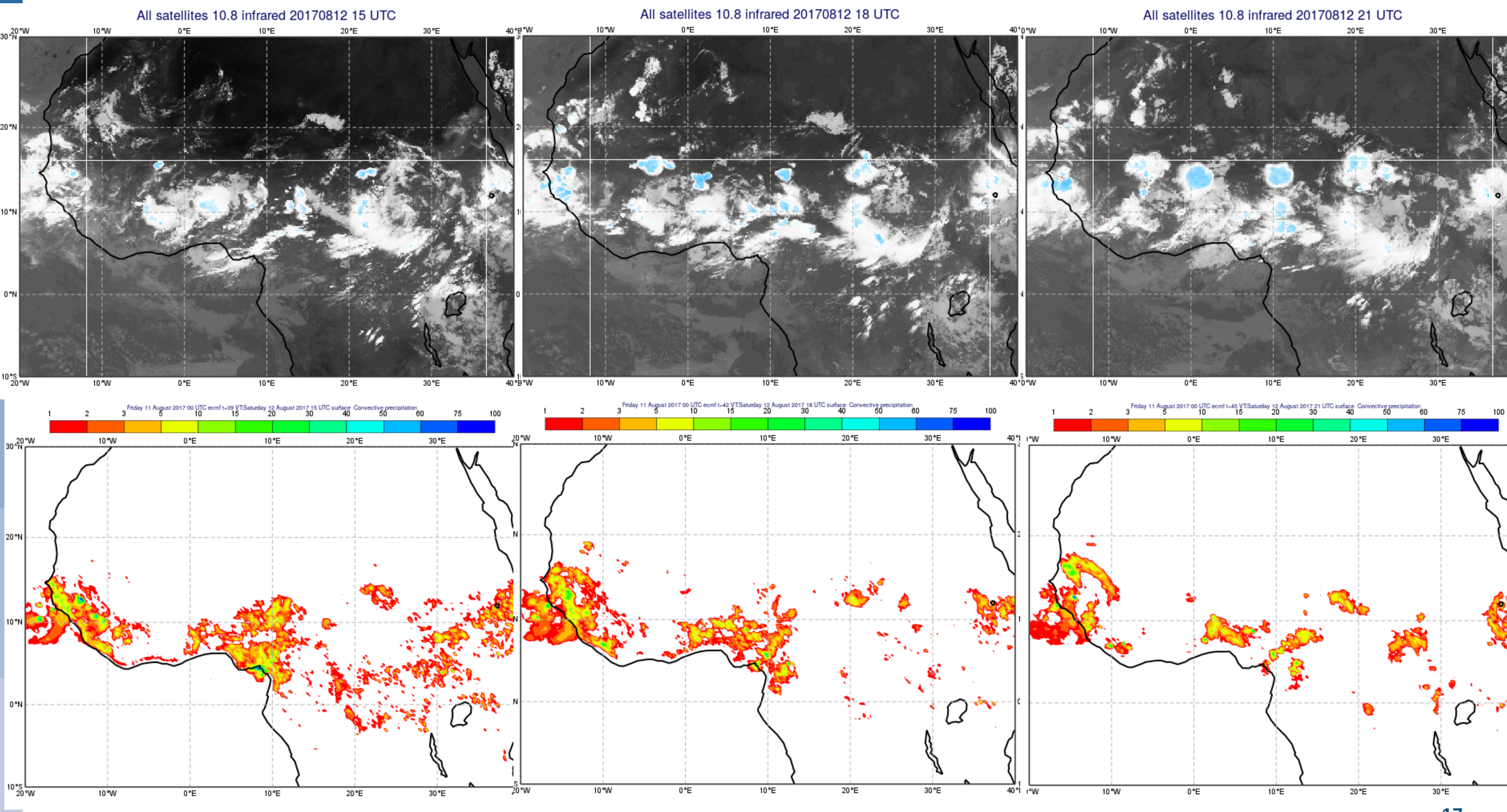
Major bias in night-time convection over land and uncertainty (Sahel)



SSMIS channel 6 Obs and First Guess JJA2016

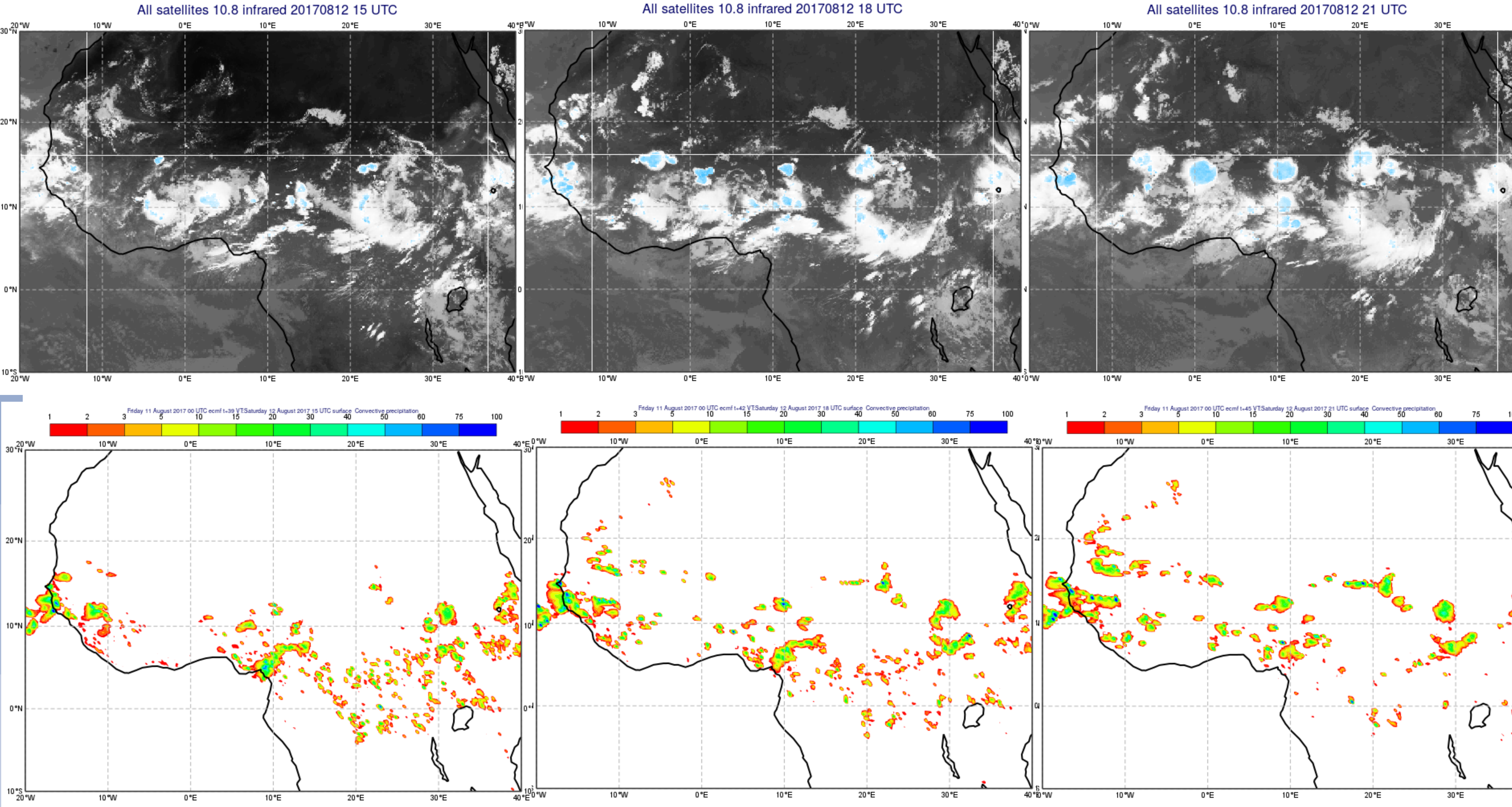


courtesy A. Geer



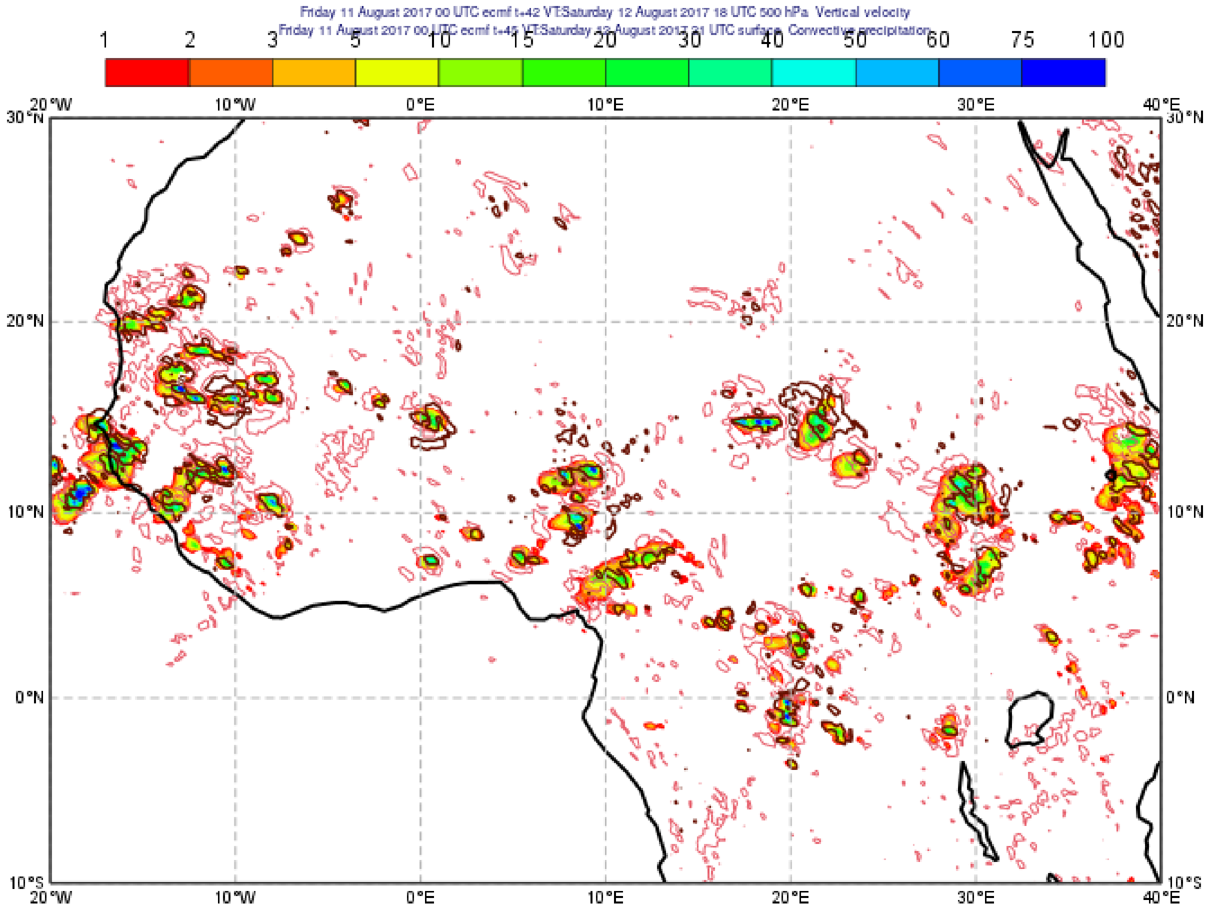
All satellites 10.8 infrared 20170812 15 UTC
All satellites 10.8 infrared 20170812 18 UTC
All satellites 10.8 infrared 20170812 21 UTC
Friday 11 August 2017 00 UTC ecmf t+39 VT:Saturday 12 August 2017 15 UTC surface Convective precipitation
Friday 11 August 2017 00 UTC ecmf t+42 VT:Saturday 12 August 2017 18 UTC surface Convective precipitation
Friday 11 August 2017 00 UTC ecmf t+45 VT:Saturday 12 August 2017 21 UTC surface Convective precipitation

TCo1999

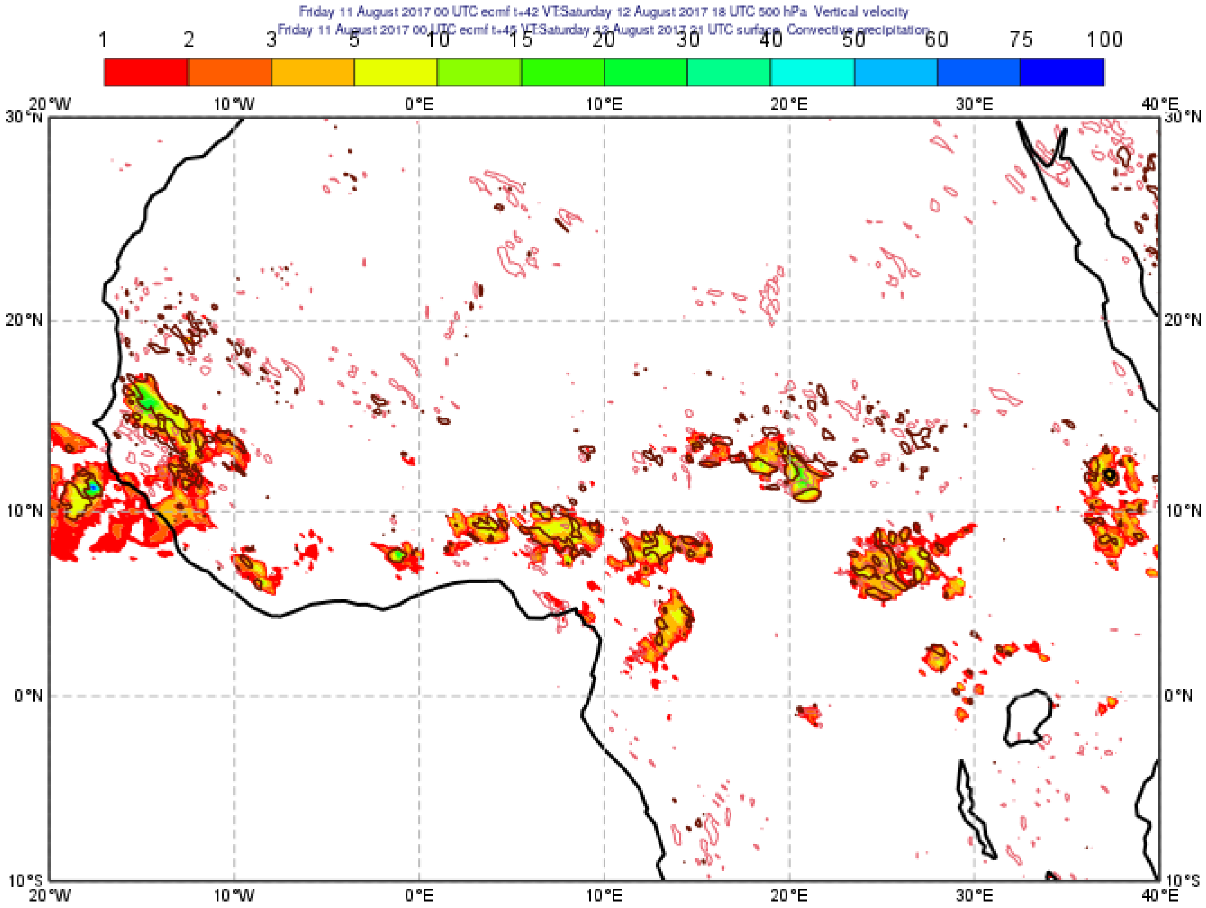


TCo1999 no deep

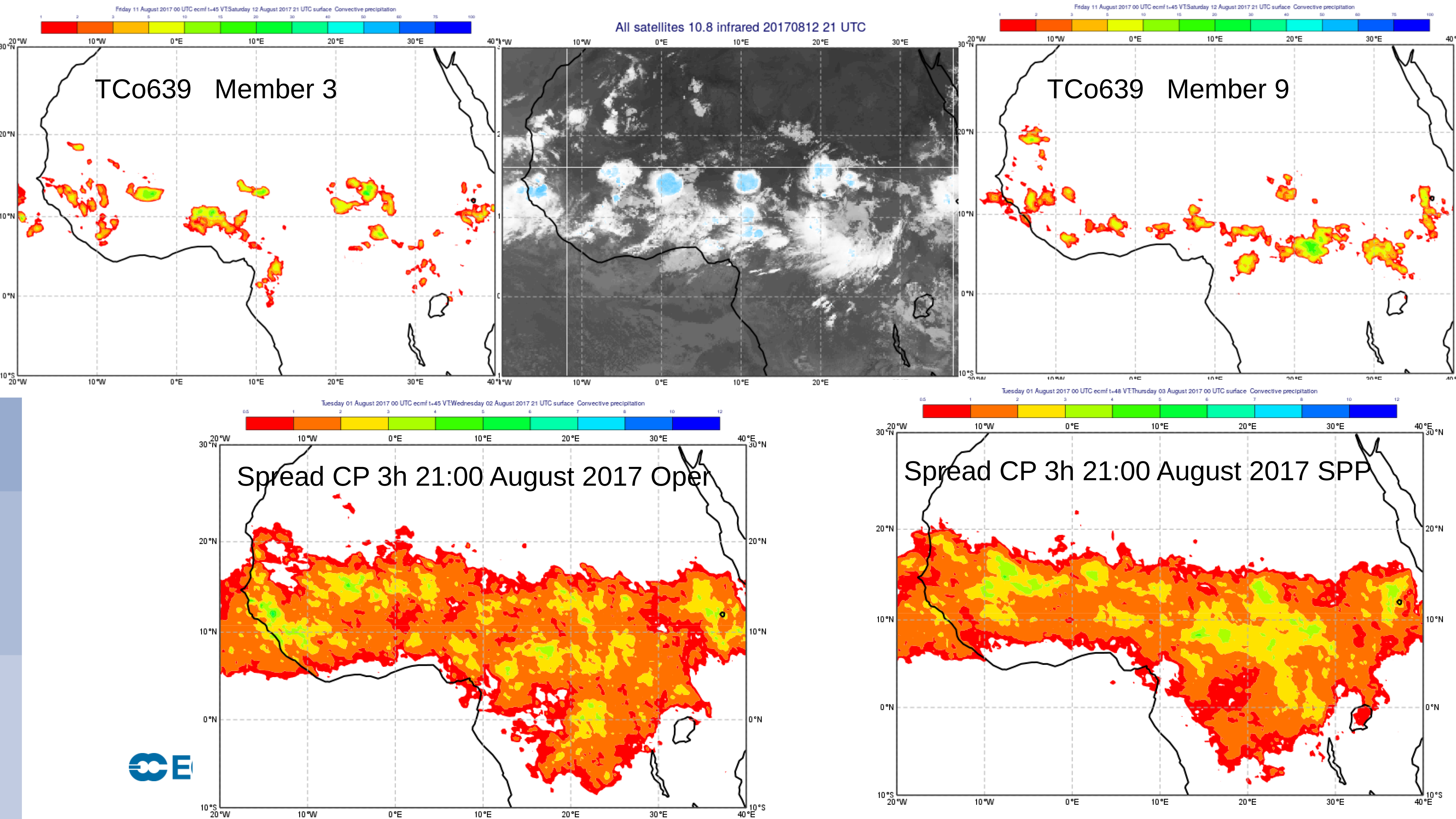
TCo1279 3h Precip and W 500 hPa (+5 cm/s –3 cm/s)



No deep



Oper


Friday 11 August 2017 00 UTC ecmf t+45 VT:Saturday 12 August 2017 21 UTC surface Convective precipitation
TCo639 Member 3
All satellites 10.8 infrared 20170812 21 UTC
Friday 11 August 2017 00 UTC ecmf t+45 VT:Saturday 12 August 2017 21 UTC surface Convective precipitation
TCo639 Member 9
Tuesday 01 August 2017 00 UTC ecmf t+45 VT:Wednesday 02 August 2017 21 UTC surface Convective precipitation
Spread CP 3h 21:00 August 2017 Oper
Tuesday 01 August 2017 00 UTC ecmf t+48 VT:Thursday 03 August 2017 00 UTC surface Convective precipitation
Spread CP 3h 21:00 August 2017 SPP

Convection-Dynamics: Mass flux (A)dvection to be done by explicit dynamics

with **Sylvie Malardel**, earlier work by N. Wedi; Kuell, A. Gassmann and Bott 2007

$$\left.\frac{\partial \bar{\psi}}{\partial t}\right|_{conv} = g\frac{\partial}{\partial p}\left[M^u(\psi^u - \bar{\psi}) + M^d(\psi^d - \bar{\psi})\right] + S; \quad \bar{M} = M^u + M^d + M^{env} = 0$$

$$\left.\frac{\partial \bar{\psi}}{\partial t}\right|_{conv} = g\frac{\partial}{\partial p}\left[M^u\psi^u + M^d\psi^d\right] - g\frac{\partial(M^u + M^d)}{\partial p}\bar{\psi} + S + A$$

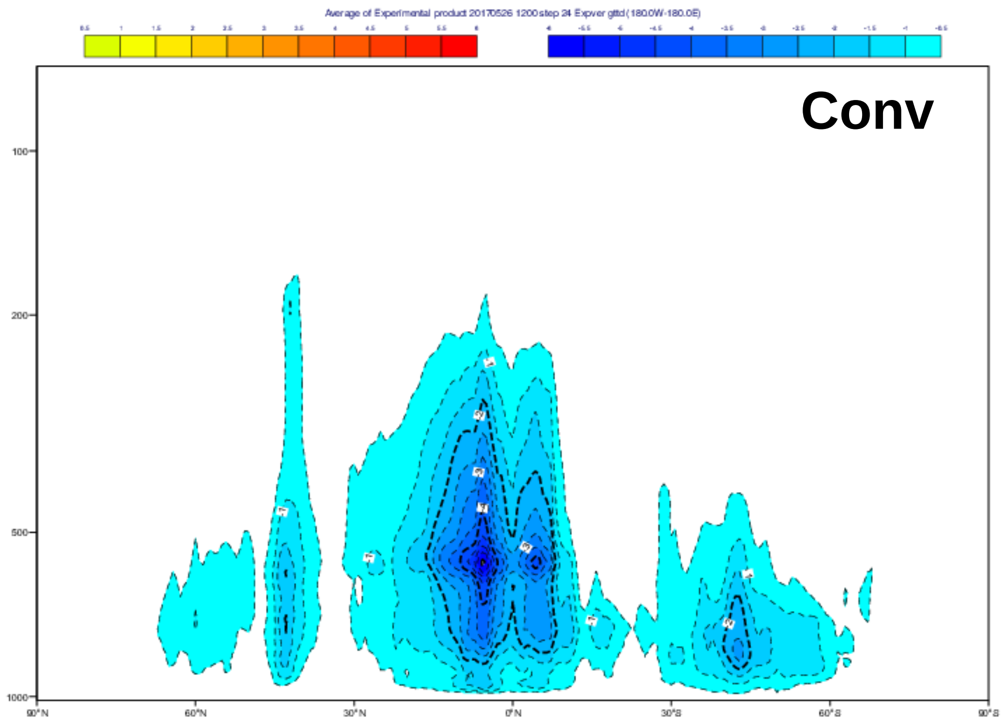
$$A = -g(M^u + M^d)\frac{\partial \bar{\psi}}{\partial p} = \omega\frac{\partial \bar{\psi}}{\partial p}; \quad Div[s^{-1}] = -g\frac{\Delta M}{\Delta p}$$

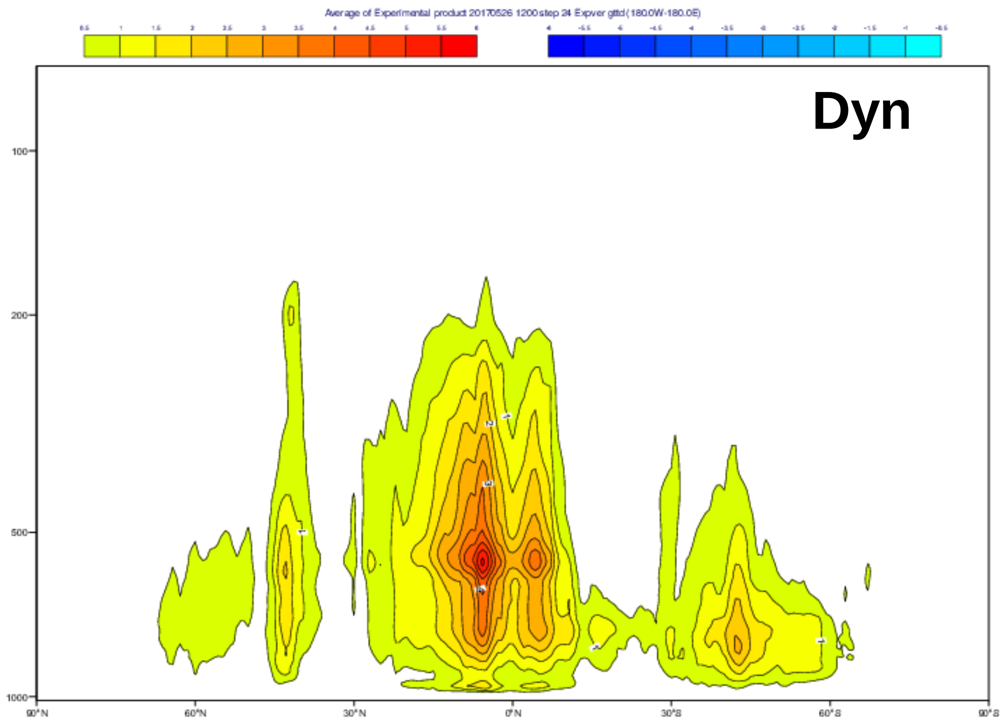
$$\Delta p = p_{k+1/2} - p_{k-1/2}$$

Difficulty: (1) Term A computed differently in Physics and SL dynamics: non-conservation (abandoning flux form, different time levels)

(2) Coupling with microphysics

Change in T Budgets, how much of total is **A** doing ?





Coupling to Dynamics

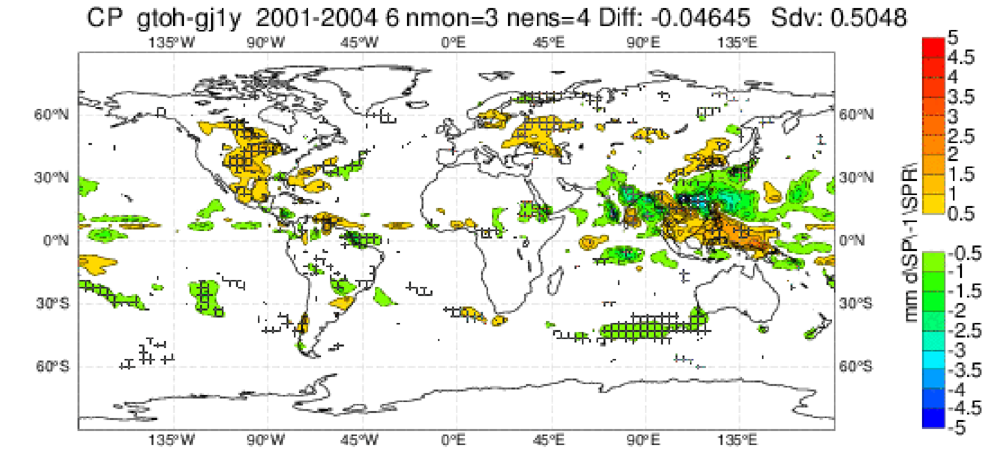
	REF	NEW
Continuity equation	$\frac{\partial \bar{\rho}}{\partial t} = -\nabla.(\bar{\rho}\bar{u})$	$\frac{\partial \bar{\rho}}{\partial t} = -\nabla.(\bar{\rho}\bar{u}) + \left[-\frac{\partial M}{\partial z}\right]$

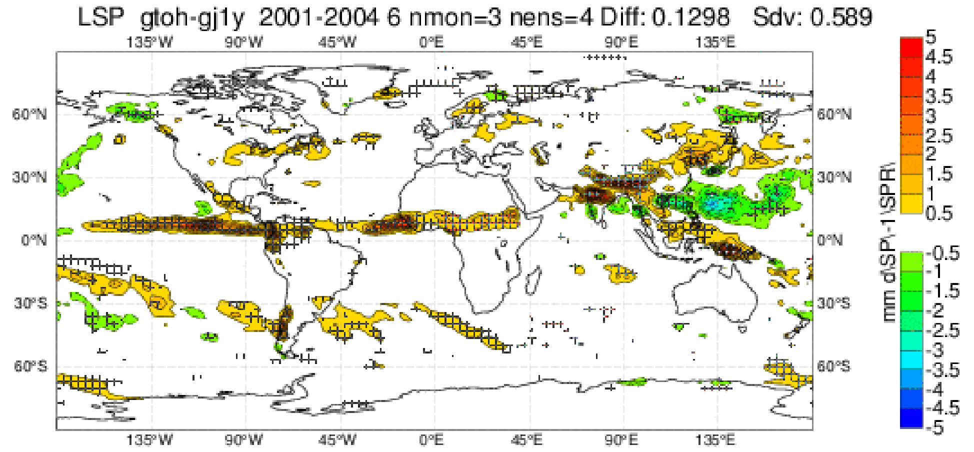
from which follows in IFS new (diagnostic values) for advection velocities ω, η°

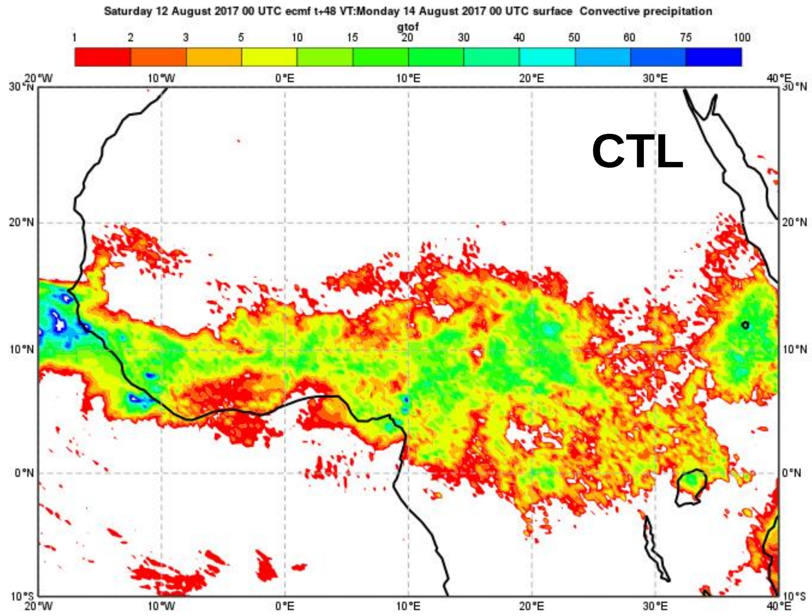
Sylvie Malardel

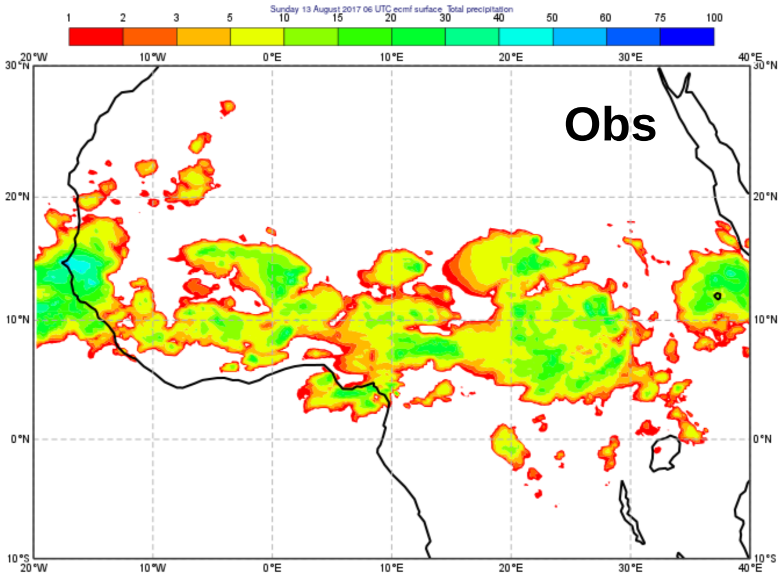
ECMWF

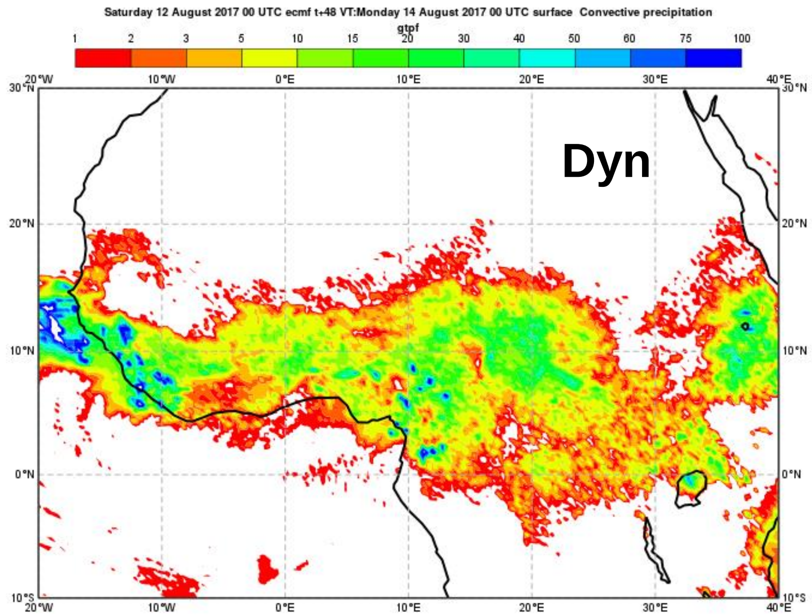
Mass flux subsidence in Dynamics: preliminary impact on climate











ECMWF

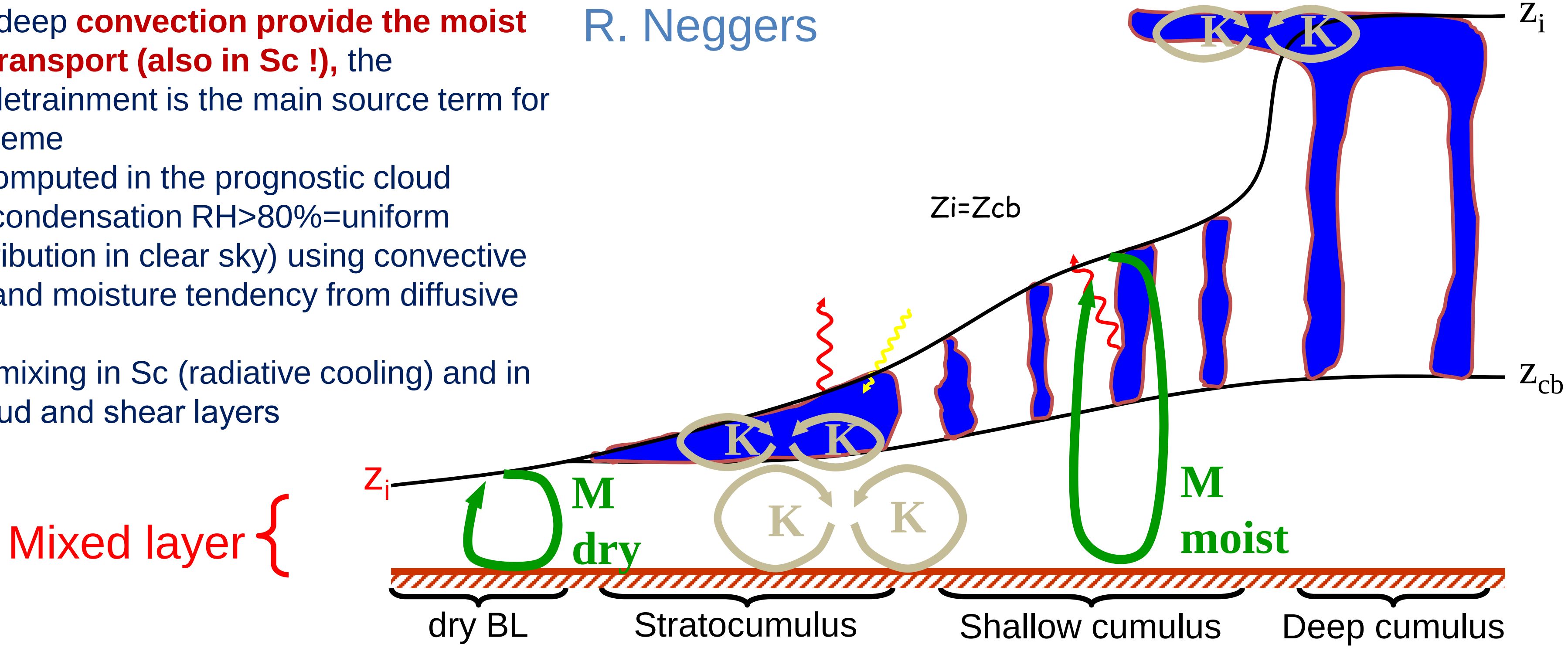
Subgrid vertical transport, mixing and condensation

Towards a more consistent and simple dual (dry+moist) mass flux + K-turb diffusion + cloud treatment

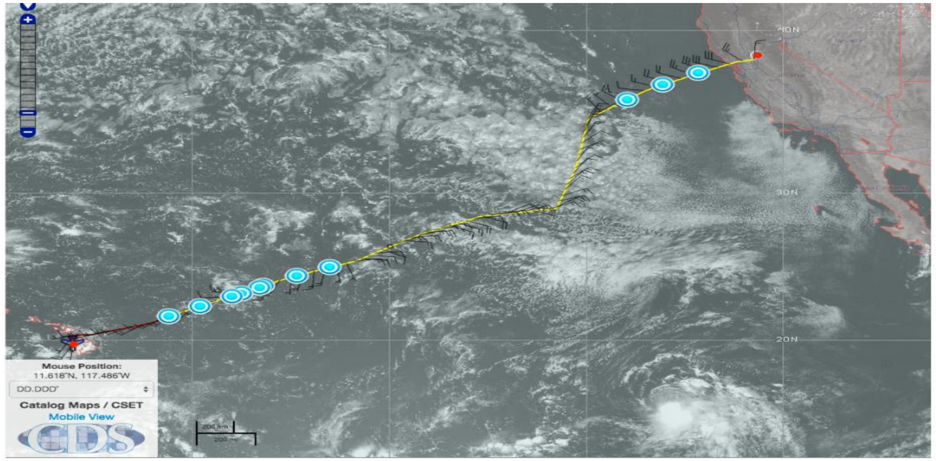
- "Diffusion scheme" does K-diffusion in moist conserved variables +dry mass flux
- The convective boundary-layer height Zi and/or cloud base Zb are determined by the same test parcel as in the shallow convection
- Shallow and deep **convection provide the moist convective transport (also in Sc !),** the condensate detrainment is the main source term for the cloud scheme
- Clouds are computed in the prognostic cloud scheme (for condensation RH>80%=uniform humidity distribution in clear sky) using convective detrainment and moisture tendency from diffusive mixing
- Additional K-mixing in Sc (radiative cooling) and in 'elevated' cloud and shear layers

with I. Sandu, M. Ahlgrimm., P. Lopez., R. Forbes

based on earlier implementations by M. Koehler, A. Beljaars, R. Neggers



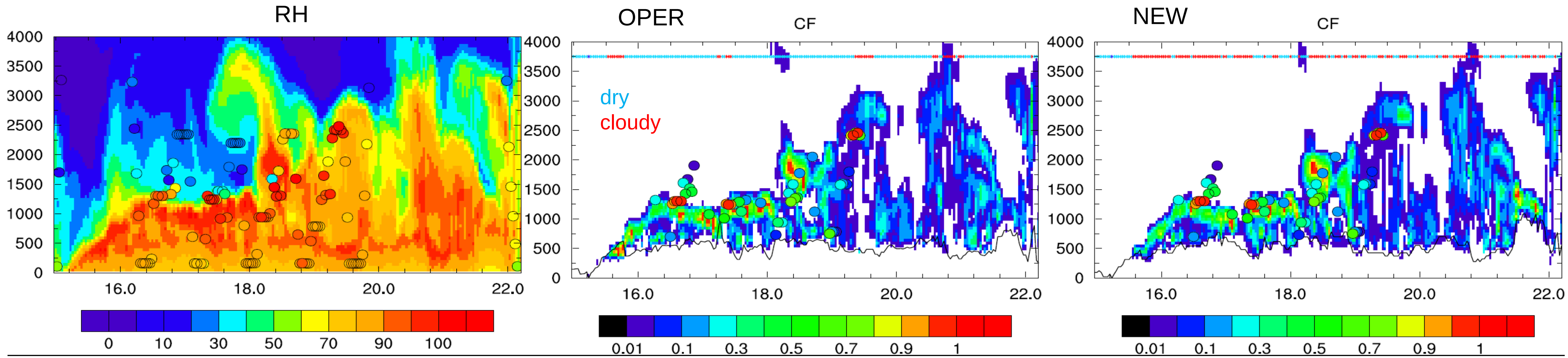
Evaluating forecasts against observations



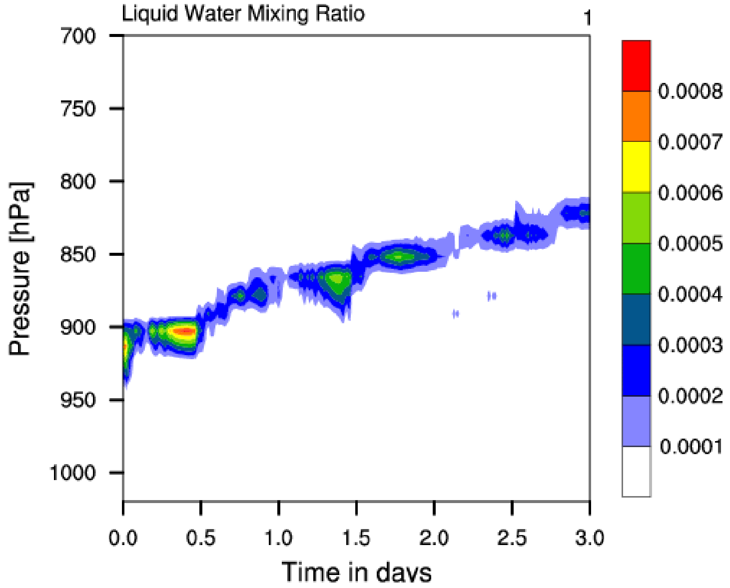
One of the flights during CSET

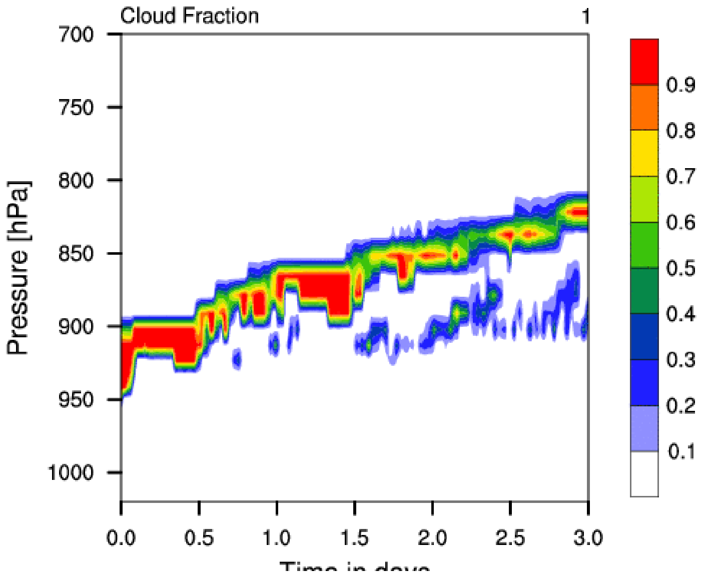
CSET, the Cloud System Evolution in the Trades
– July/August 2015 (University of Washington and Miami)

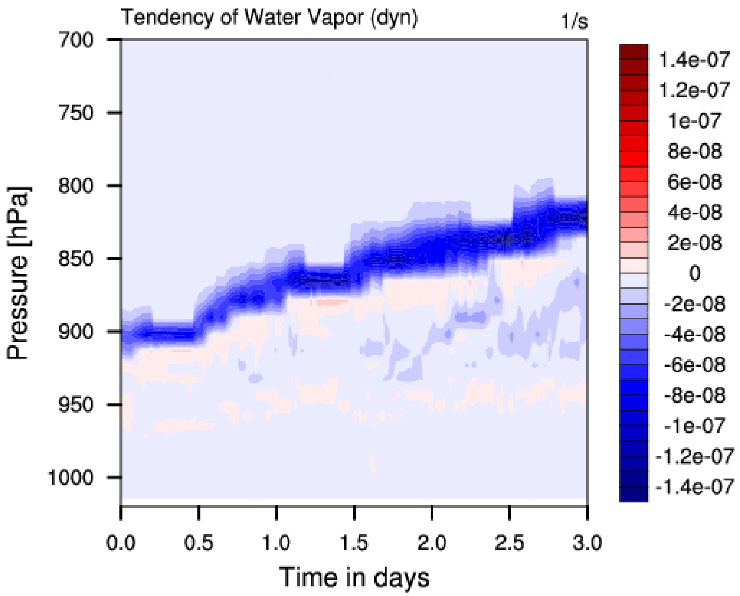
NARVAL (Next-generation Aircraft Remote sensing for Validation Studies)
– MPI-M (Dec 2013/Jan 2014)

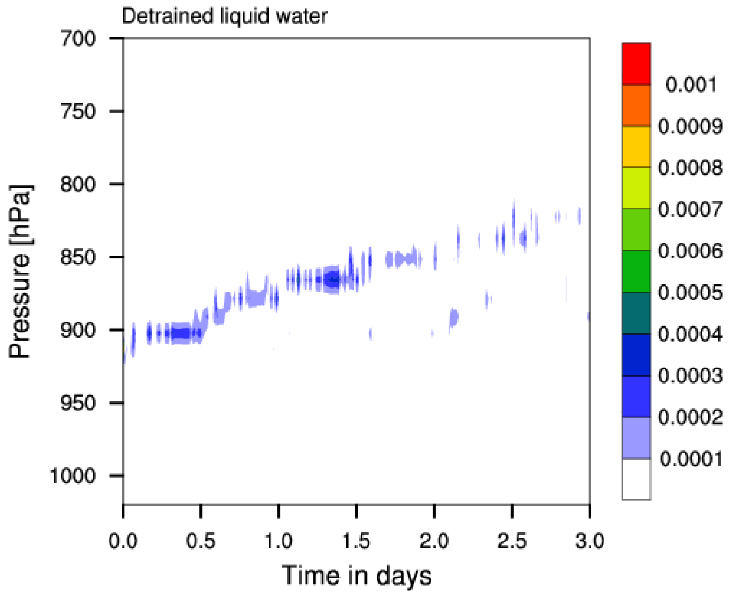


Is convection able to handle top entrainment and transitions? Coupling with cloud scheme (evaporation)

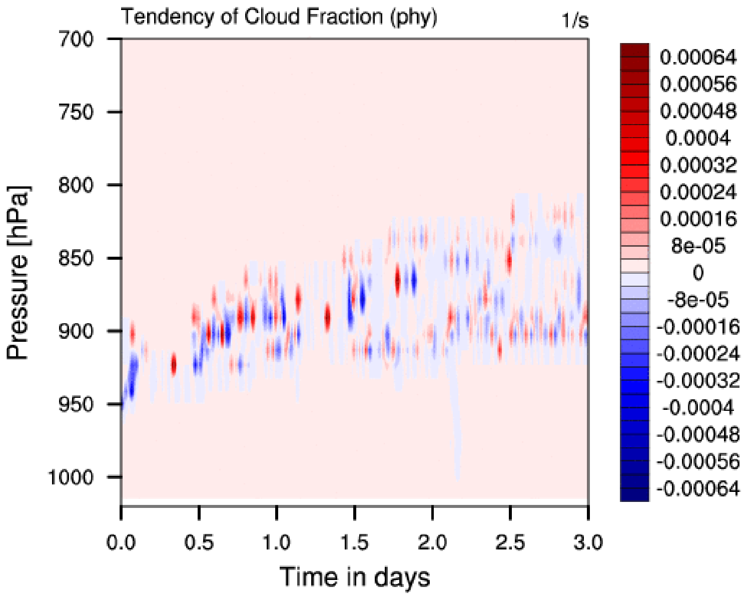








ME



Difficulties: Balance of processes, numerics of inversions

See also Lenderink and Holtslag (2000), Lock (2006), Beljaars (2016)

Summary of issues we want/need to improve on

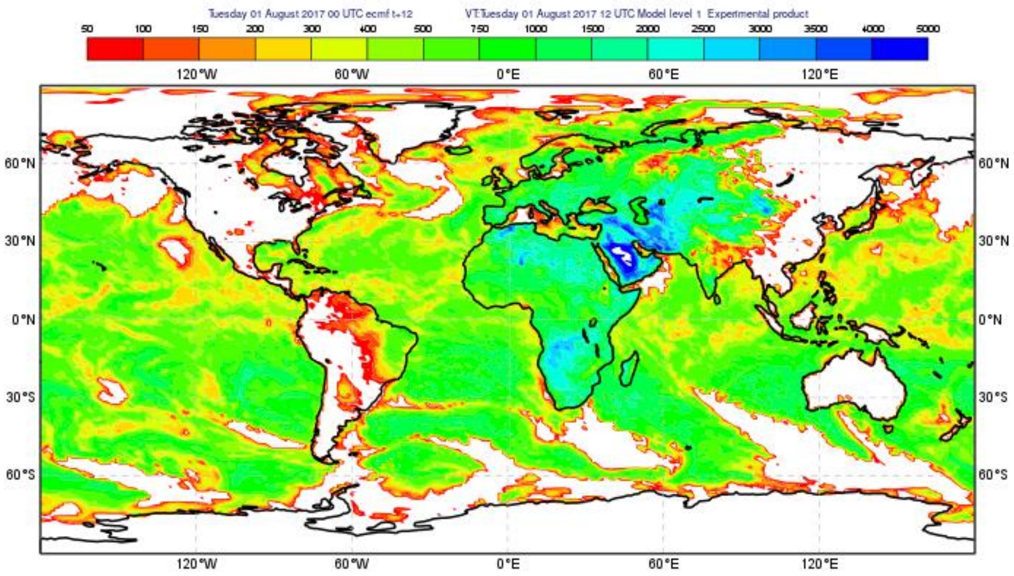
- Propagation/organisation of mesoscale convective systems (especially during night)
- Lower Stratosphere: cold bias and downward propagation of QBO signal (Kelvin wave filtering), convective overshoots
- Microphysics for microwave data assimilation
- Boundary-layer cloud formulation
- Biases in West Pacifc Precip/wind in relation with ocean coupling

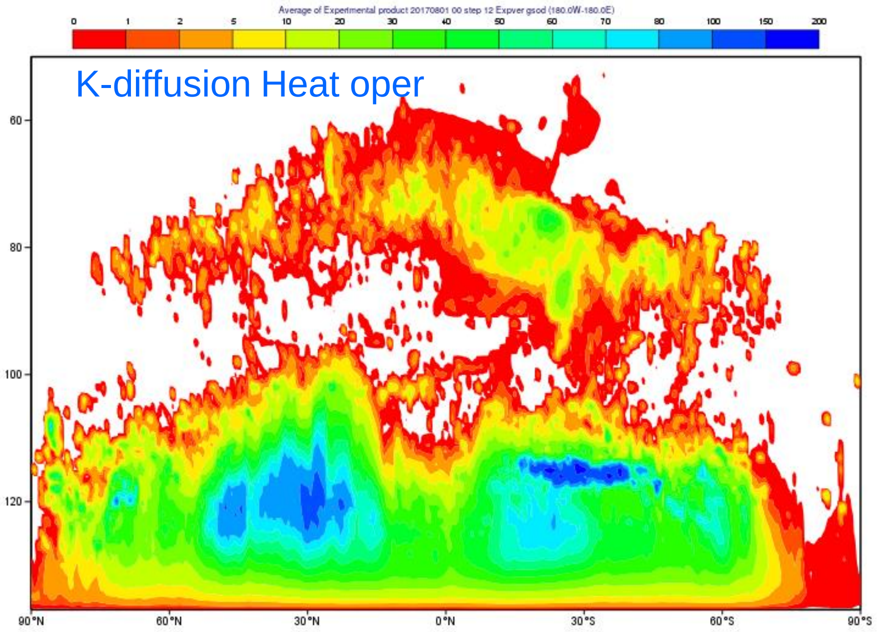
Some pathways

- Ensemble formulation absolutely needed, SPP; additional ensemble formulation in convection only brings potential limited benefit
- work on diffusion/numerics in stratosphere (free shear layers)
- Graupel (convection) might be needed for data assimilation
- Representing oceanic Cu/Sc with mass flux source or diffusion(K, TKE etc)+statistical cloud scheme
- Physics- dynamics coupling

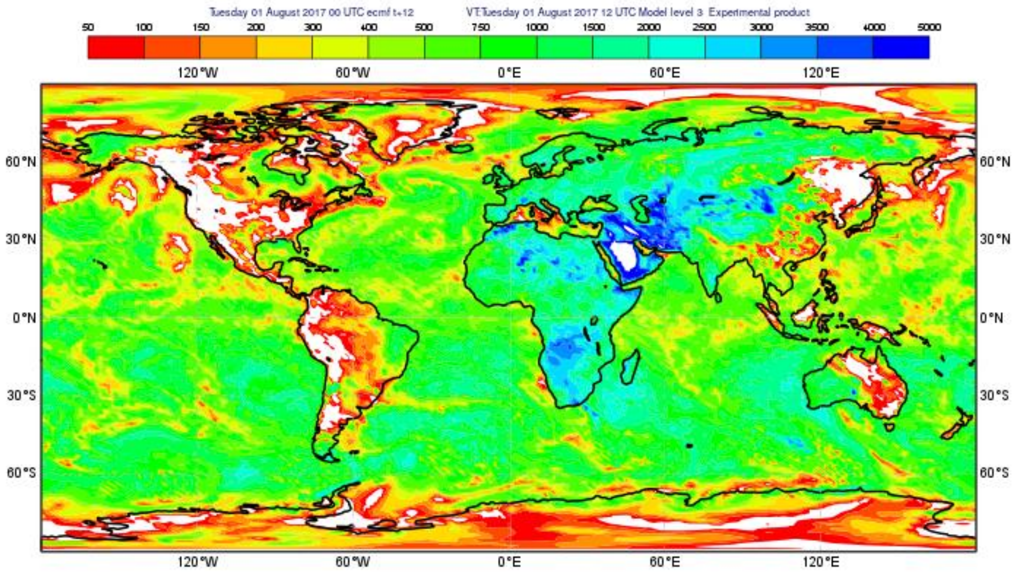
Coupling (experimental) diffusion code and TKE: collaboration with Meteo France (E. Bazile)

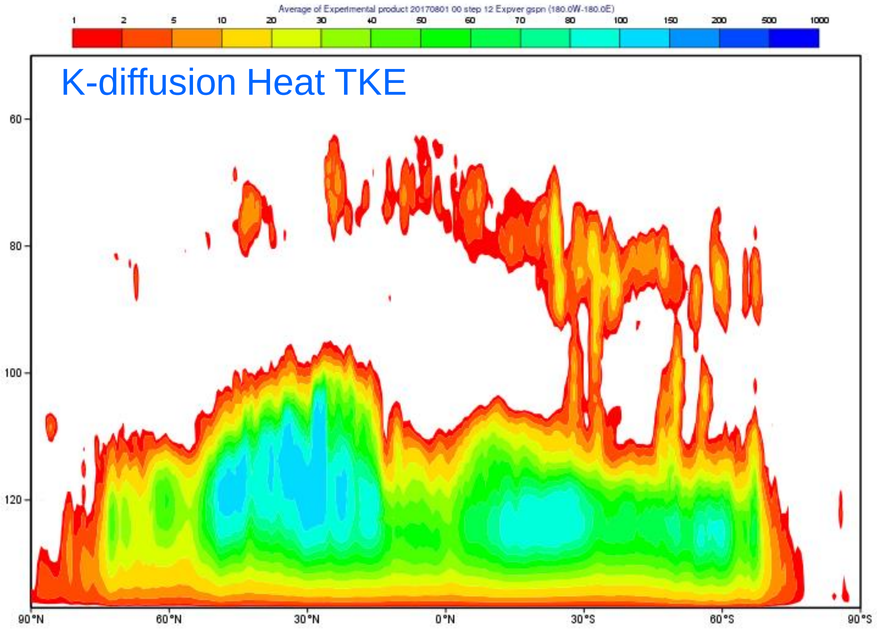
PBL height (m) oper unstable



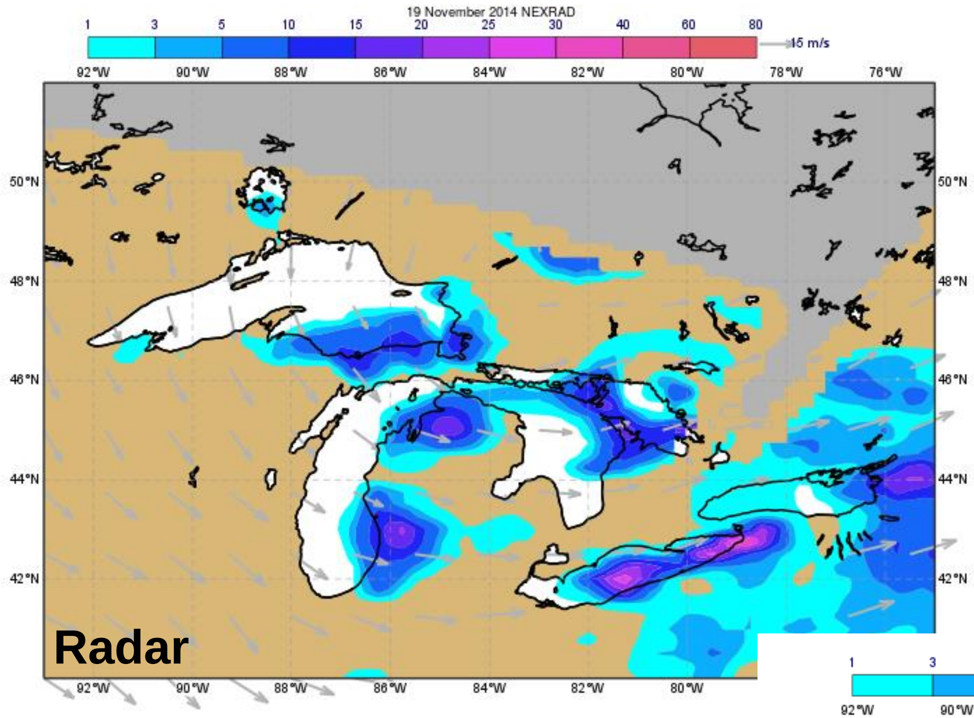


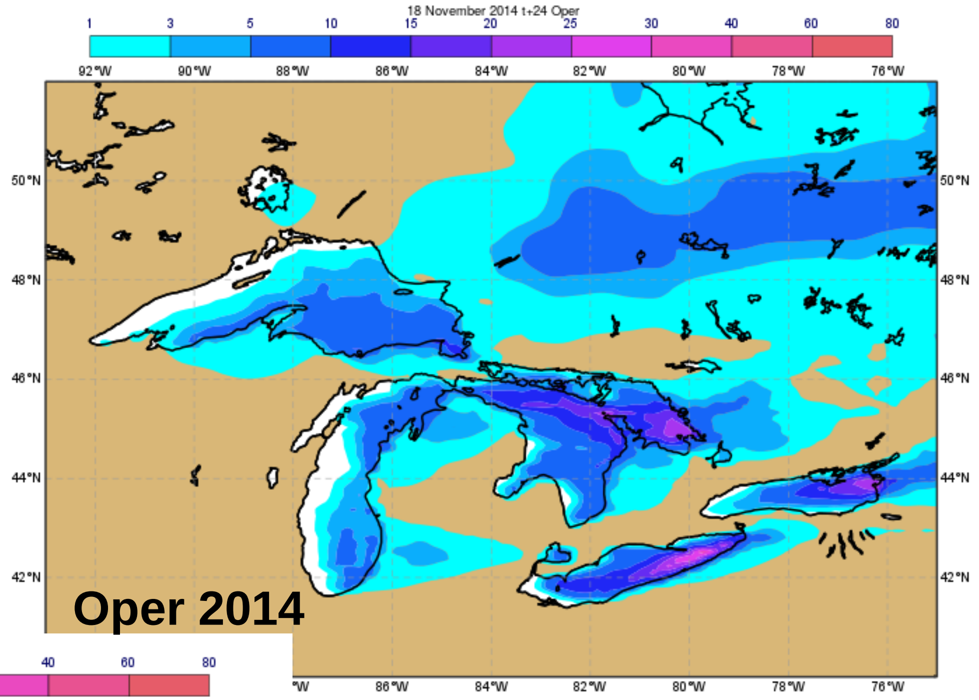
PBL height (m) TKE diag MeteoFrance

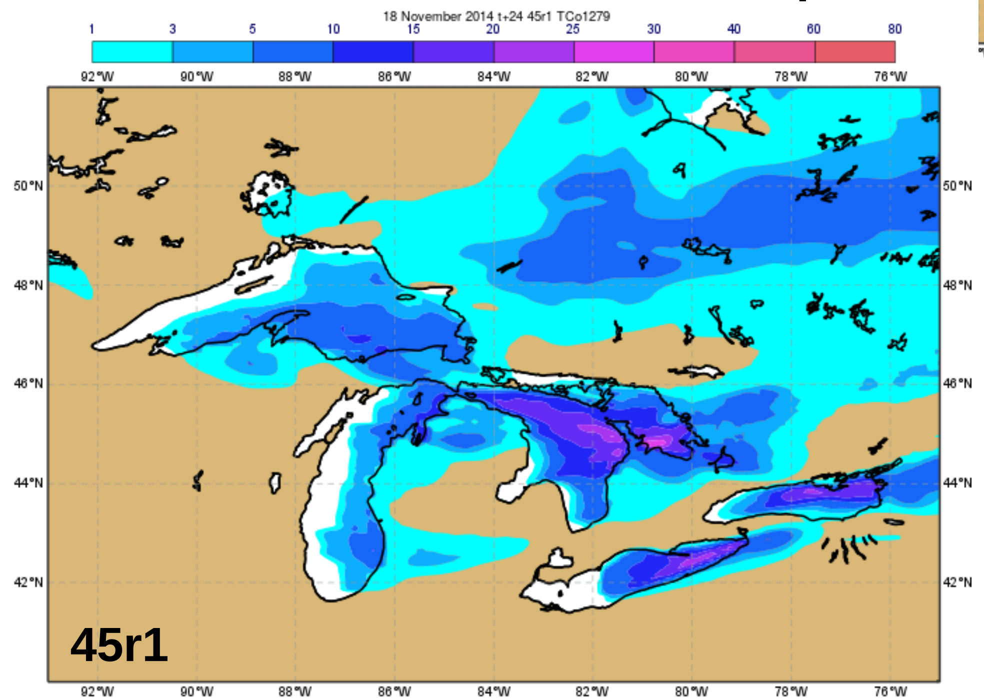


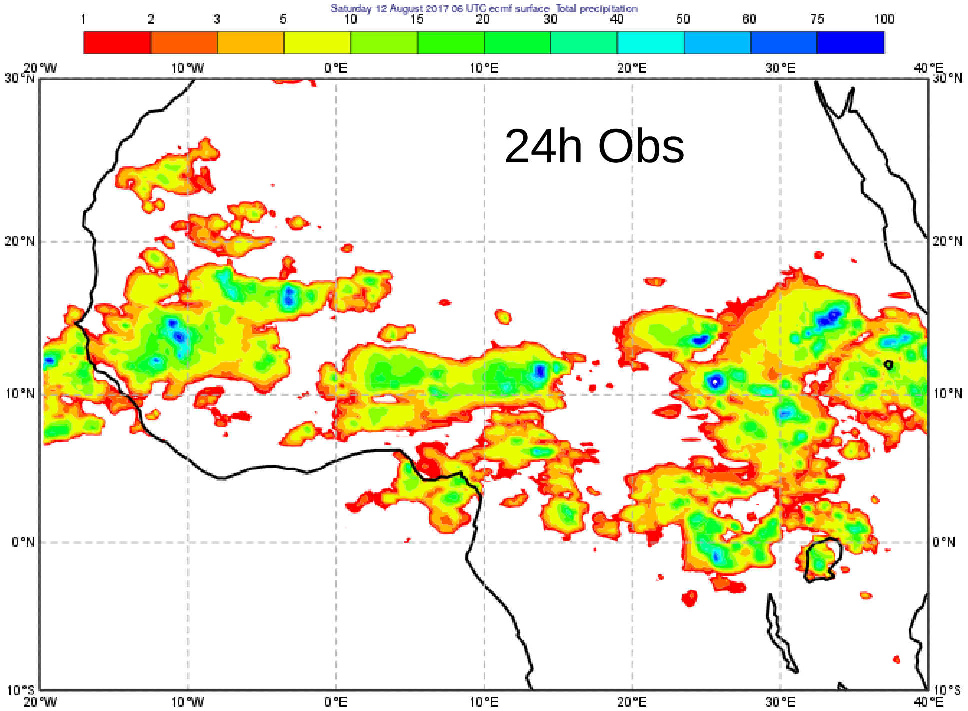


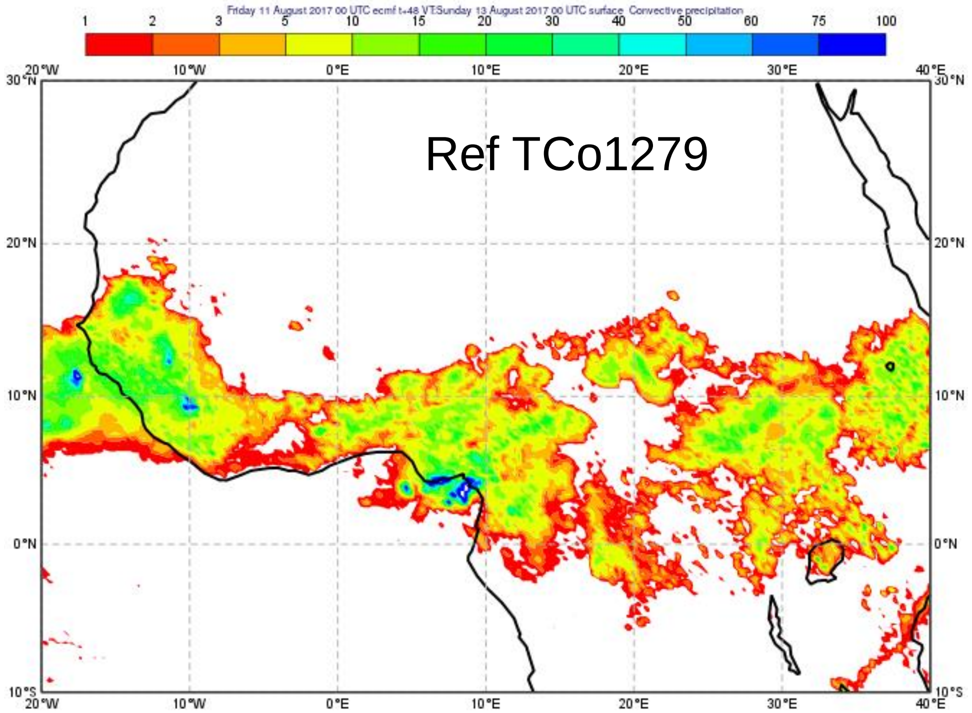
Wintery lake convection -snow

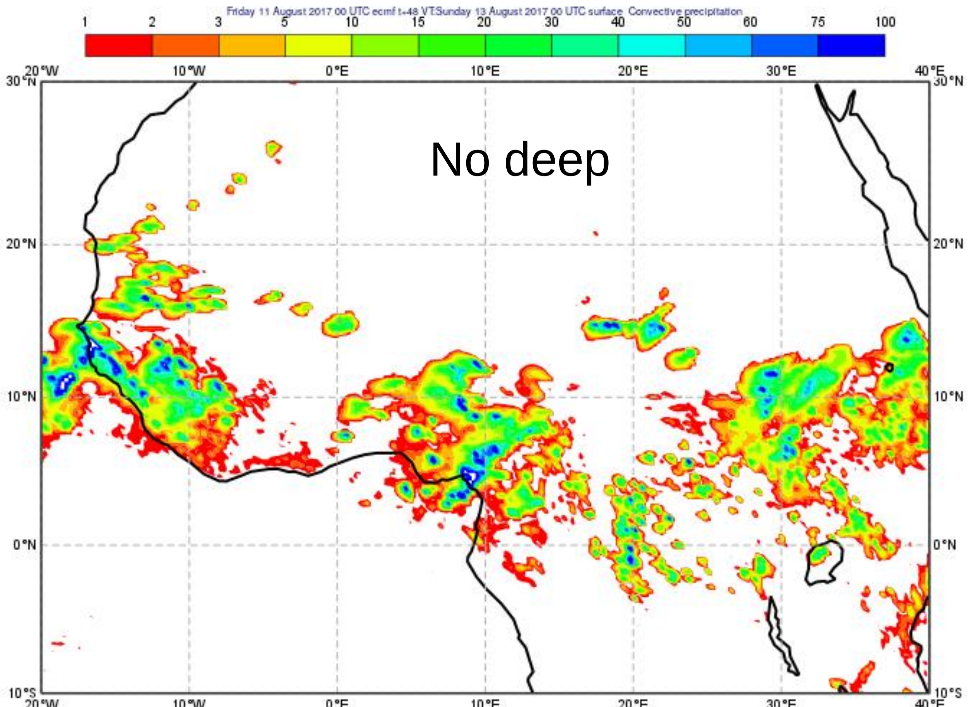




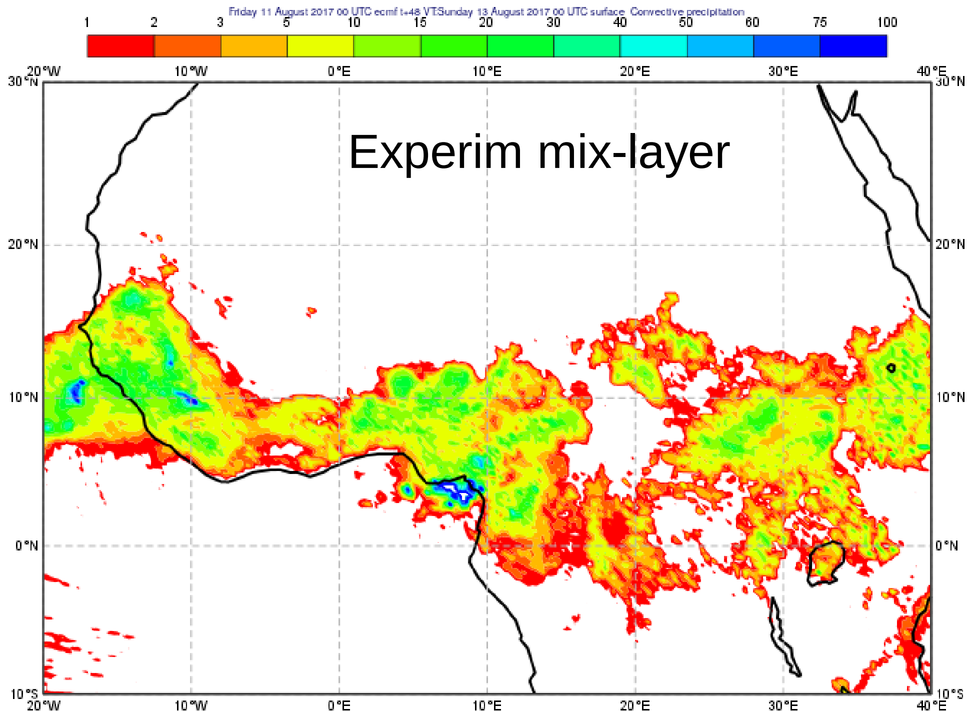



Saturday 12 August 2017 06 UTC ecmf surface Total precipitation
24h Obs


Friday 11 August 2017 00 UTC ecmf t+48 VT:Sunday 13 August 2017 00 UTC surface Convective precipitation
Ref TCo1279

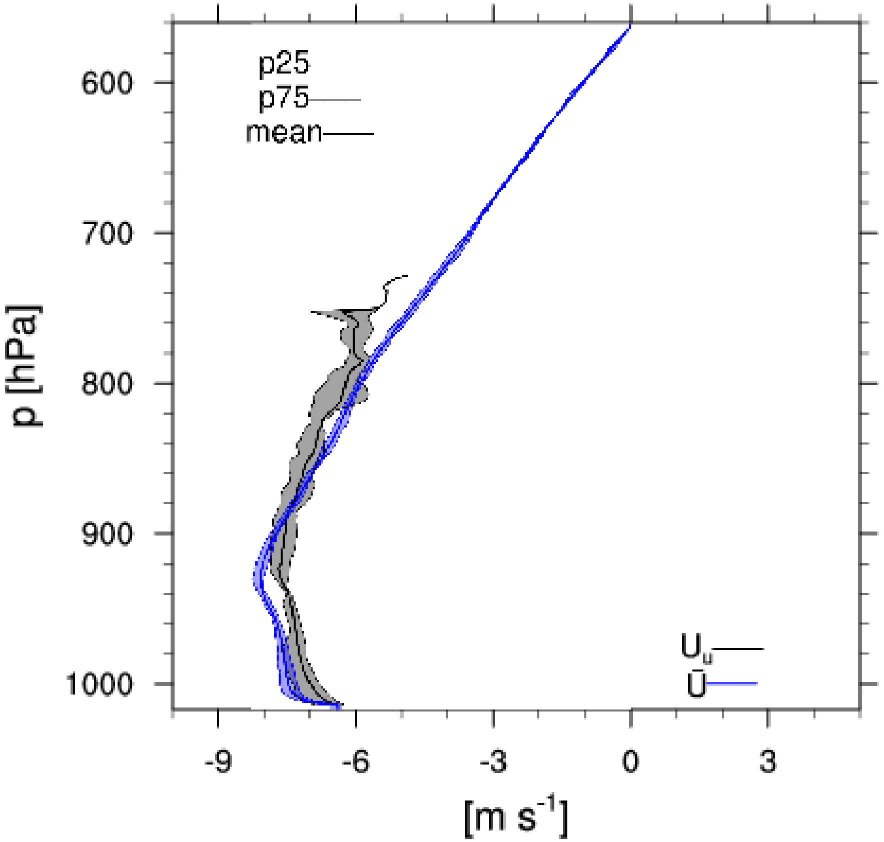

Friday 11 August 2017 00 UTC ecmf t+48 VT:Sunday 13 August 2017 00 UTC surface Convective precipitation
No deep

EATHEI

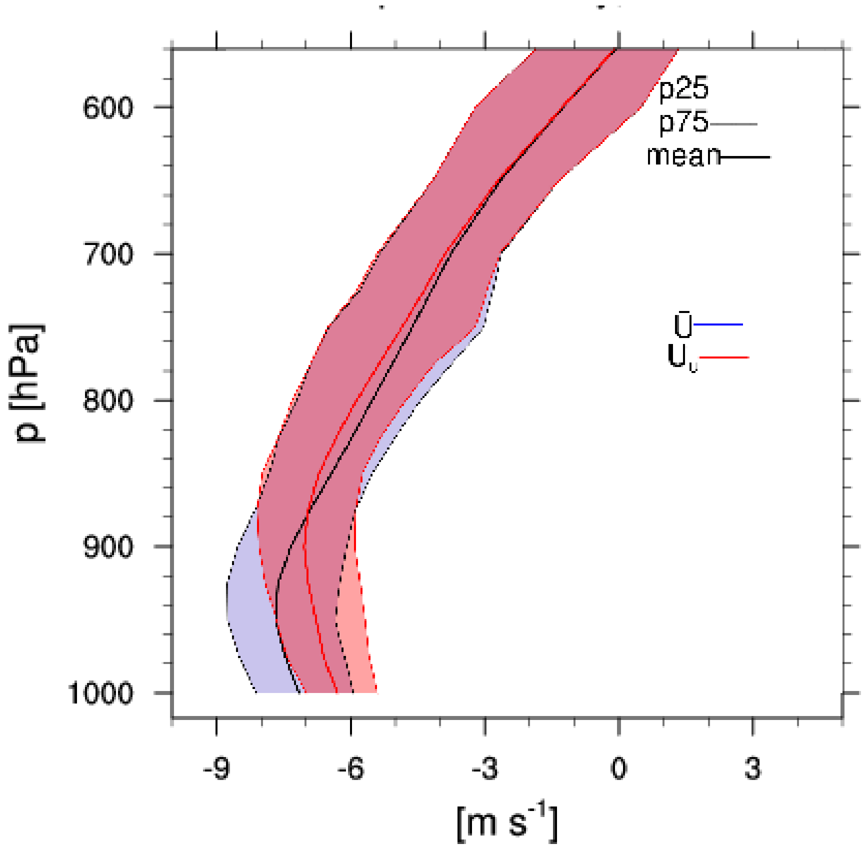

Friday 11 August 2017 00 UTC ecmf t+48 VT:Sunday 13 August 2017 00 UTC surface Convective precipitation
Experim mix-layer

Revisiting the convective momentum transport: shallow convection

RICO: LES

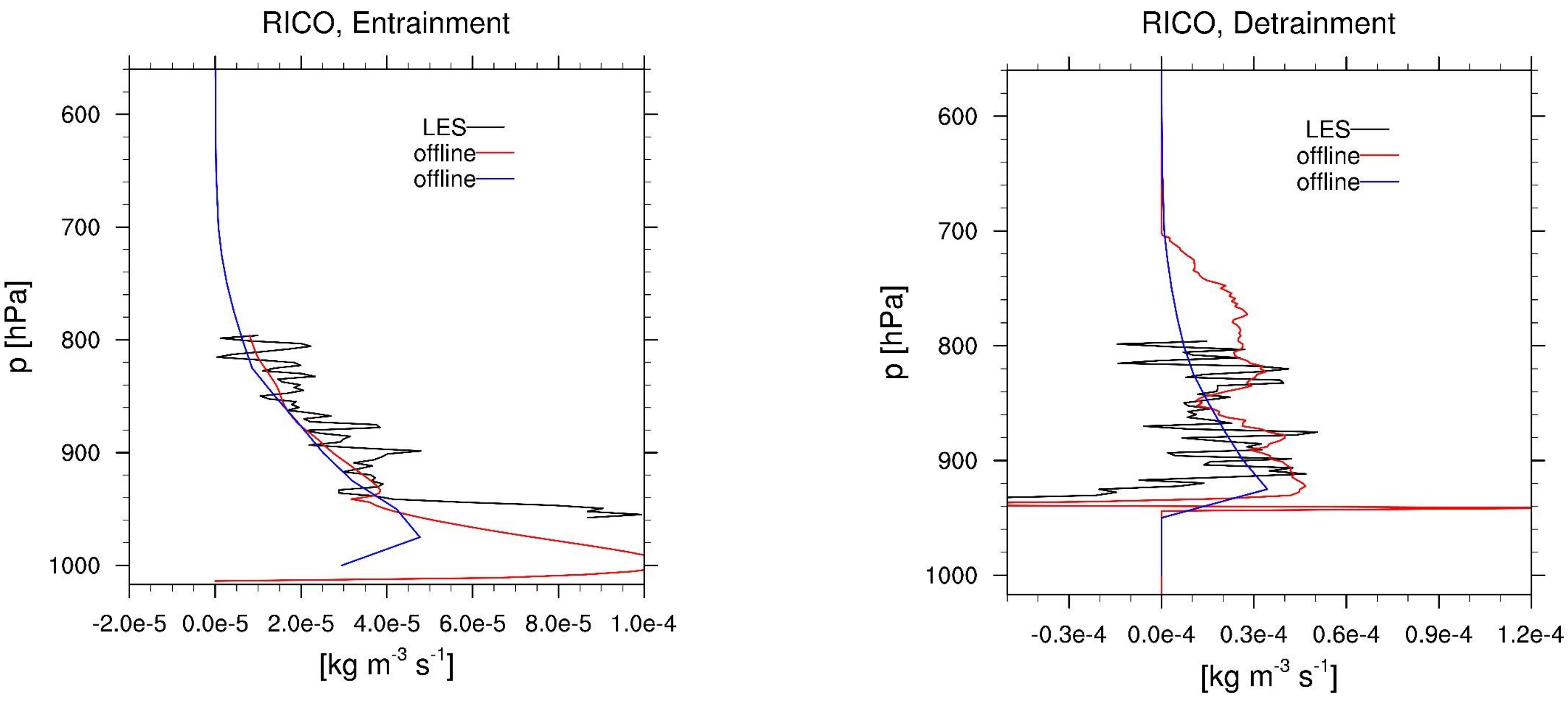


IFS: 16-28.12 2008 RICO domain



Schlemmer et al. 2017 JAMES

Revisiting the convective momentum transport: shallow convection



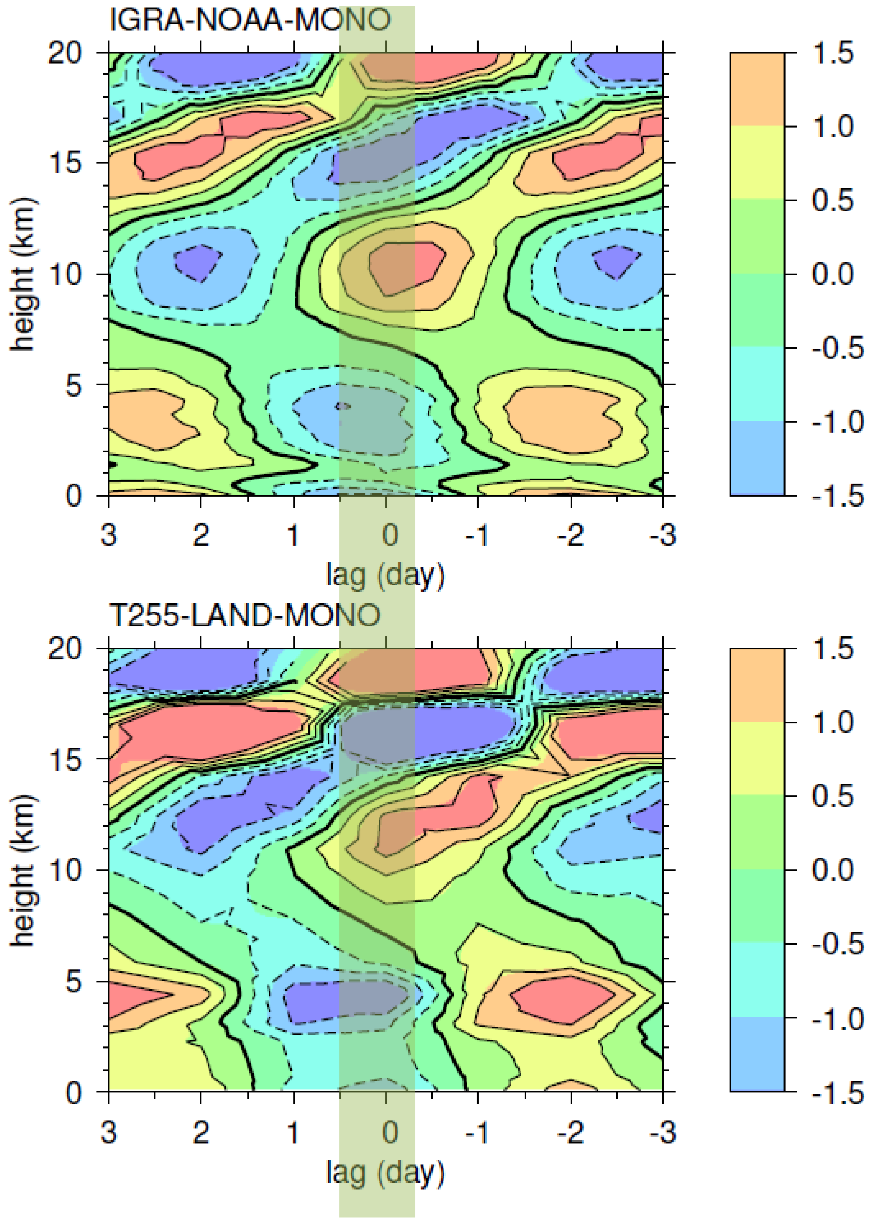
LES (black) IFS IFS formula with LES data

Kelvin waves: vertical structure

At z~10 km, warm anomaly and convective heating are in phase, leading to :

- the conversion of potential in kinetic energy = αω
- The generation of potential energy = N Q

- For inertia gravity waves, horizontal phase and group speed have same sign, but opposite sign for vertical propagation



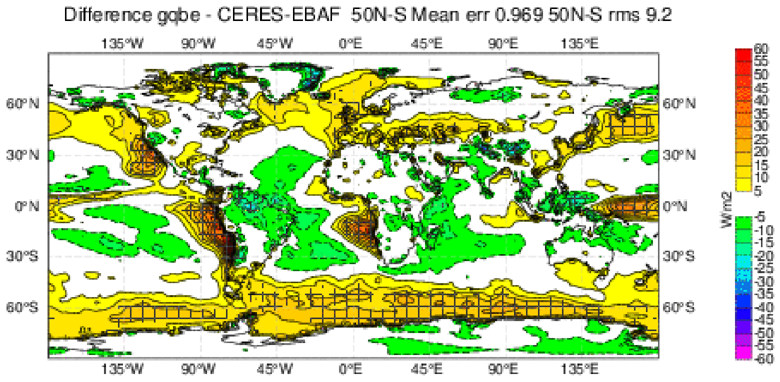
M. Hermann, Z Fuchs, D. Raymond, P. Bechtold (JAS 2016) , see also G. Shutts (2006, Dyn. Atmos. Oc.)

ECMWF

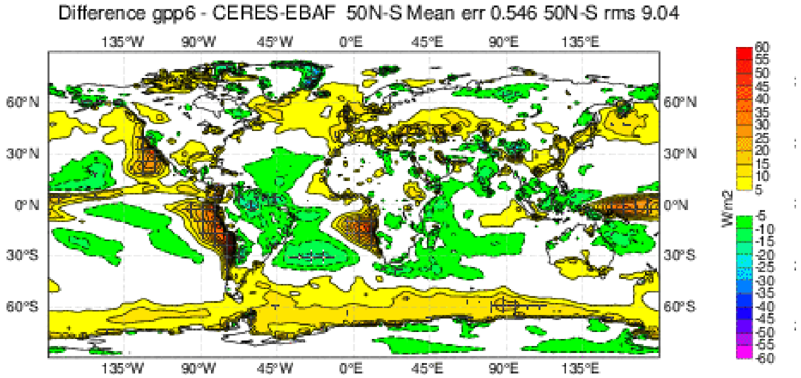
Improving the SW radiation biases:

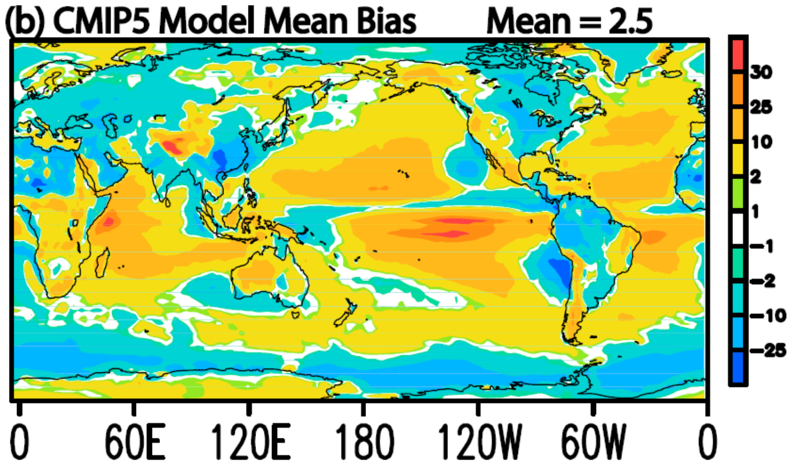
Focus: Storm tracks and Sc regions not reflective enough, trades and transition too reflective

Cy43r1

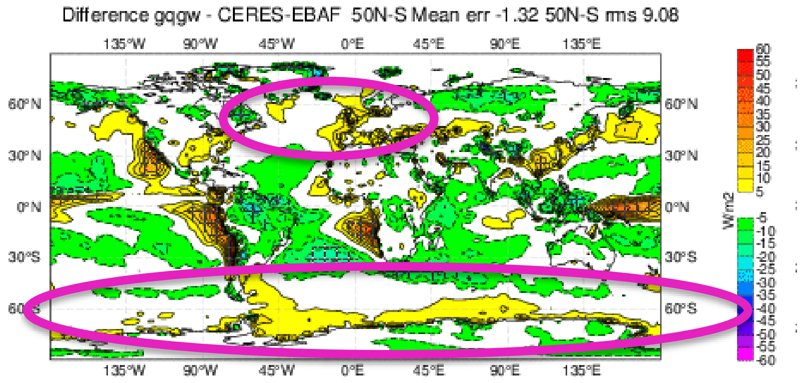


Adding 0- -38C mixed phase, snow, rain detrain, liquid phase only for shallow





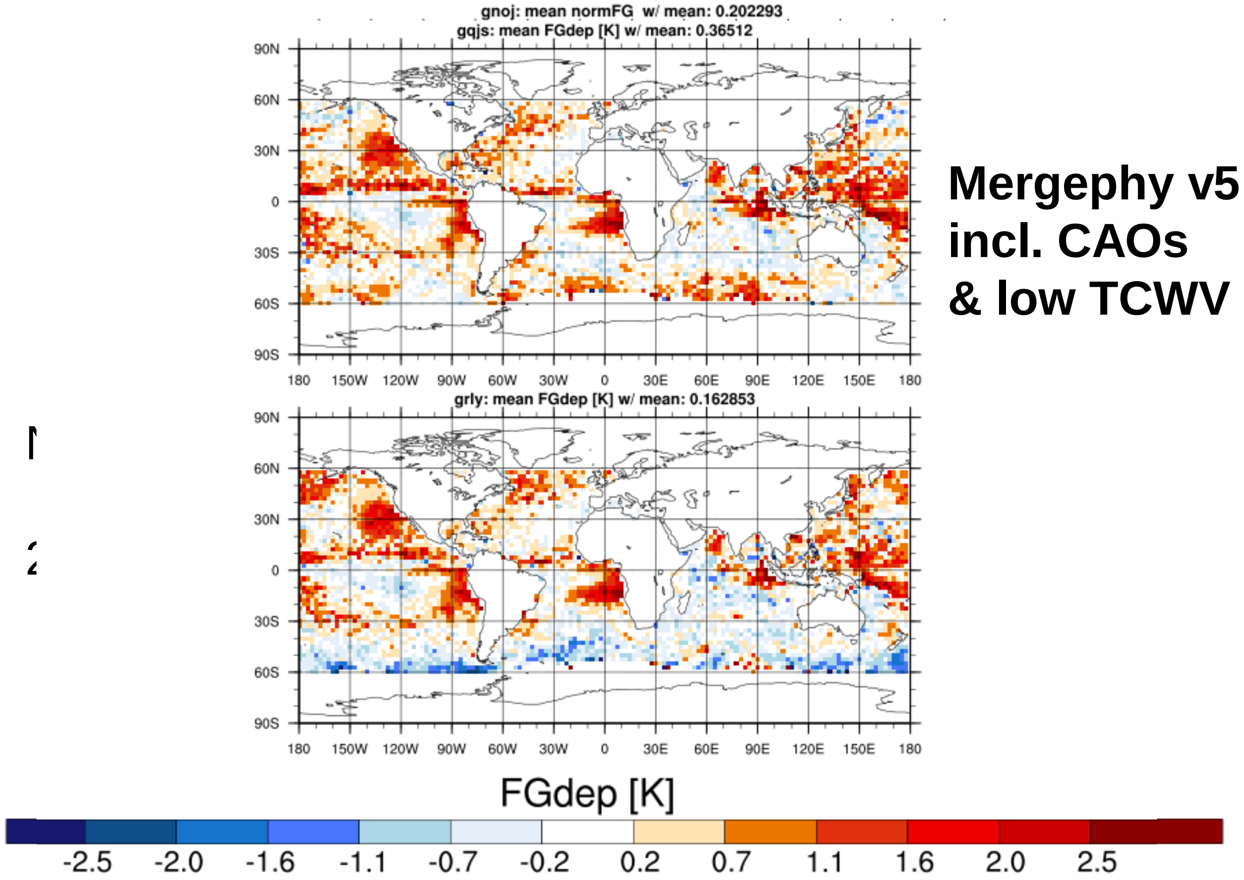
for Cy45r1 merged physics: cloud+conv



ECMWF

Assessing the SH biases through microwave first-guess departures

Total FG departures



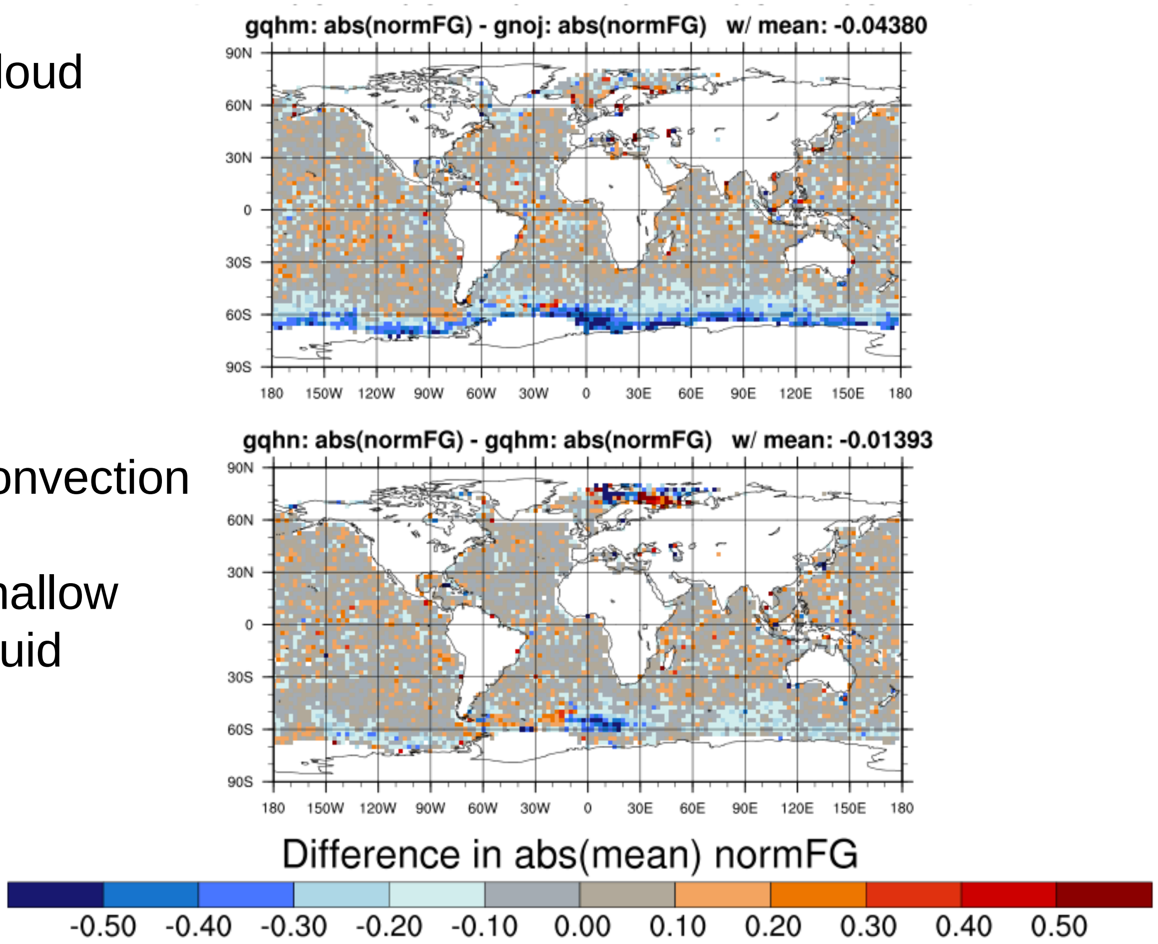
Mergephy v5 incl. CAOs & low TCWV

FG departure changes by contribution

Cloud

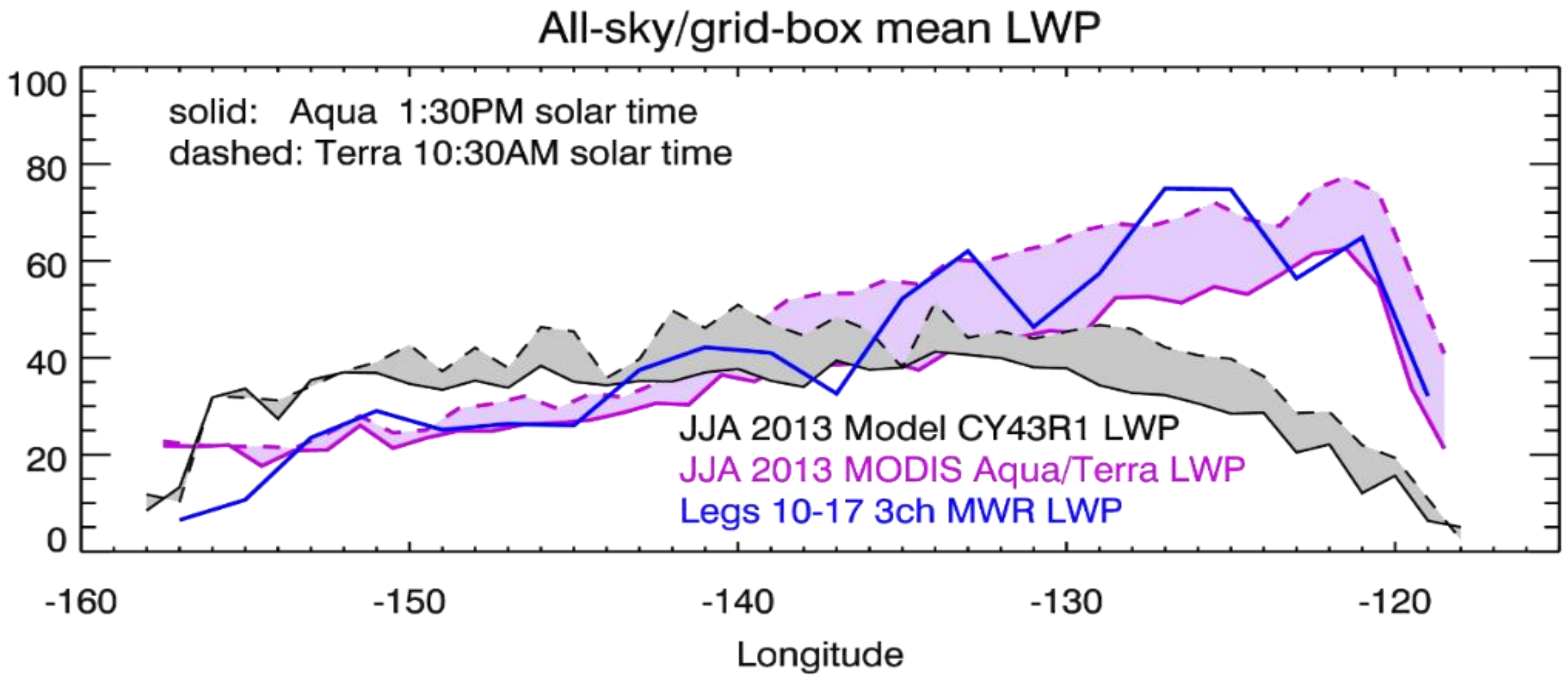
Convection

Shallow liquid



courtesy K. Lonitz

Assessing the SW radiation biases through complementary Satellite and ground-based data

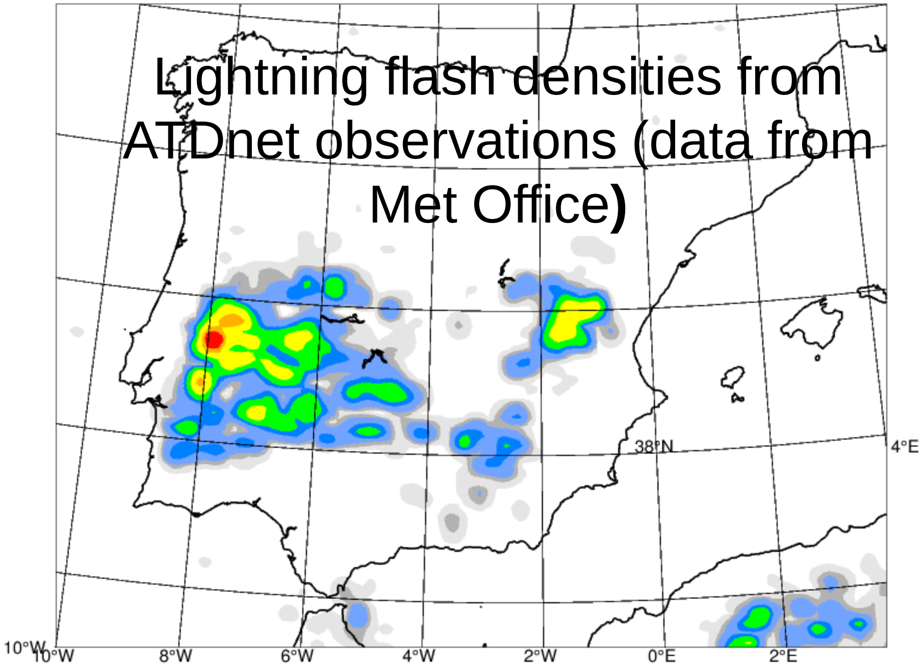


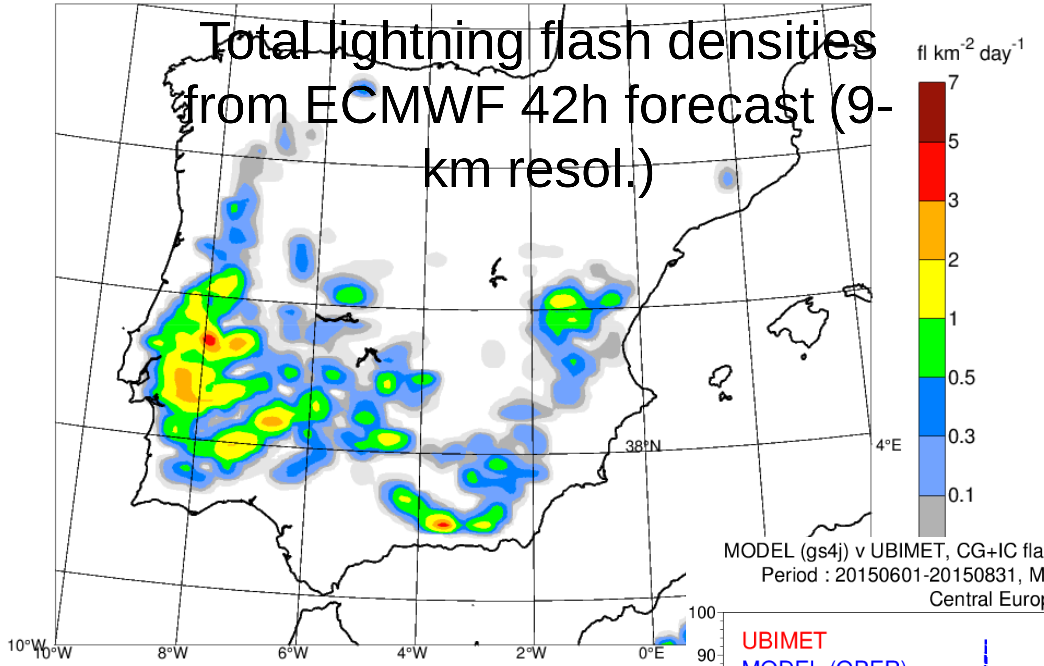
courtesy M. Ahlgrimm

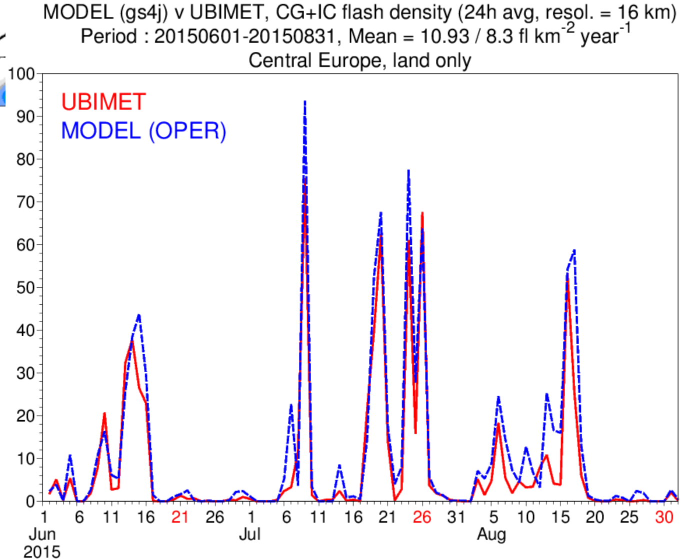
Forecasting Lightning

P. Lopez, 2016 MWR

In the model, total (CG+IC) lightning flash densities are diagnosed from CAPE, convective hydrometeor contents and convective cloud base height.







6h-avg lightning flash densities valid 17/06/2017 18 UTC: Portugal Fire

a 50% detection efficiency for ATDnet sensors (mainly cloud-to-ground flashes) has been assumed