Cumulus parametrization: a global NWP perspective and challenges in the tropics

Austr. Bureau of Meteor. : For tropical cyclones and MJO it is gold standard

Meteo Suisse: over Alps limited area 5 and 1 km better precip but over flat terrain EC is reference

Meteo France: often very realistic tropical convection but African squall line propagation can be odd

DWD, UK MetOffice: Diurnal cycle still too early, convective gusts

Singapore Met. Service: better structure (extremes) with 1 km models vs EC, but very difficult to control popcorn vs squall line features near Equator

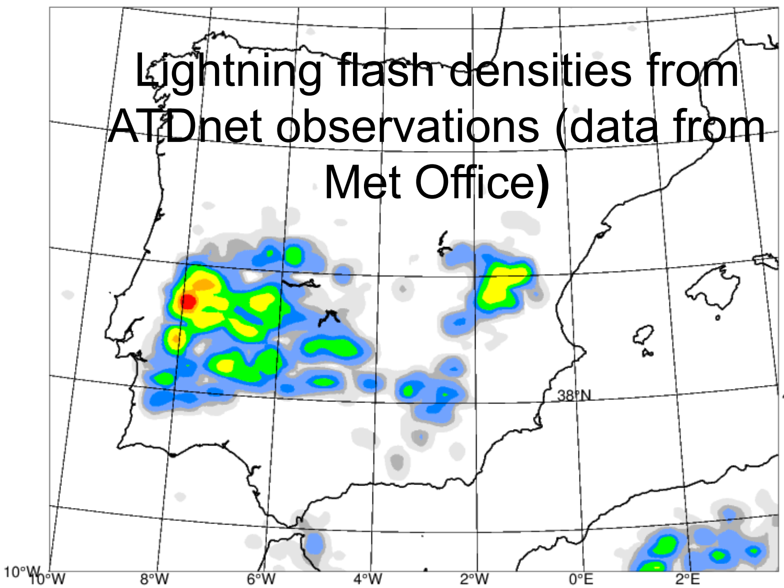
ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

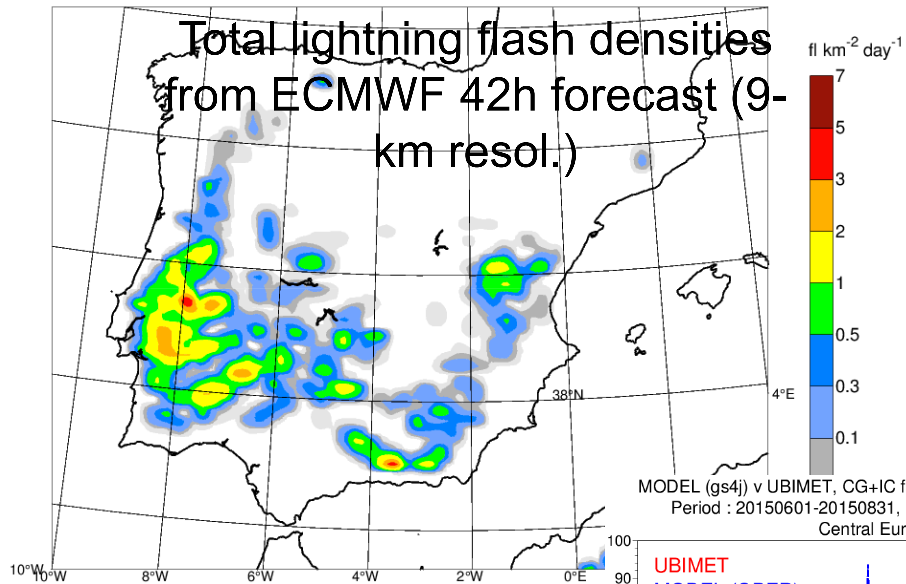
Peter Bechtold and colleagues

Forecasting Lightning

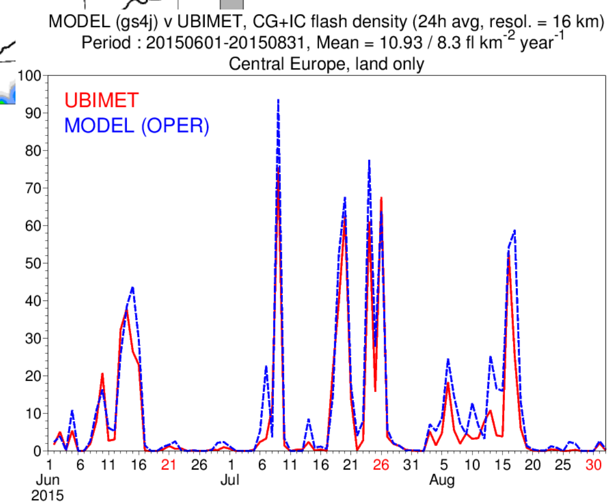
P. Lopez, 2016 MWR

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



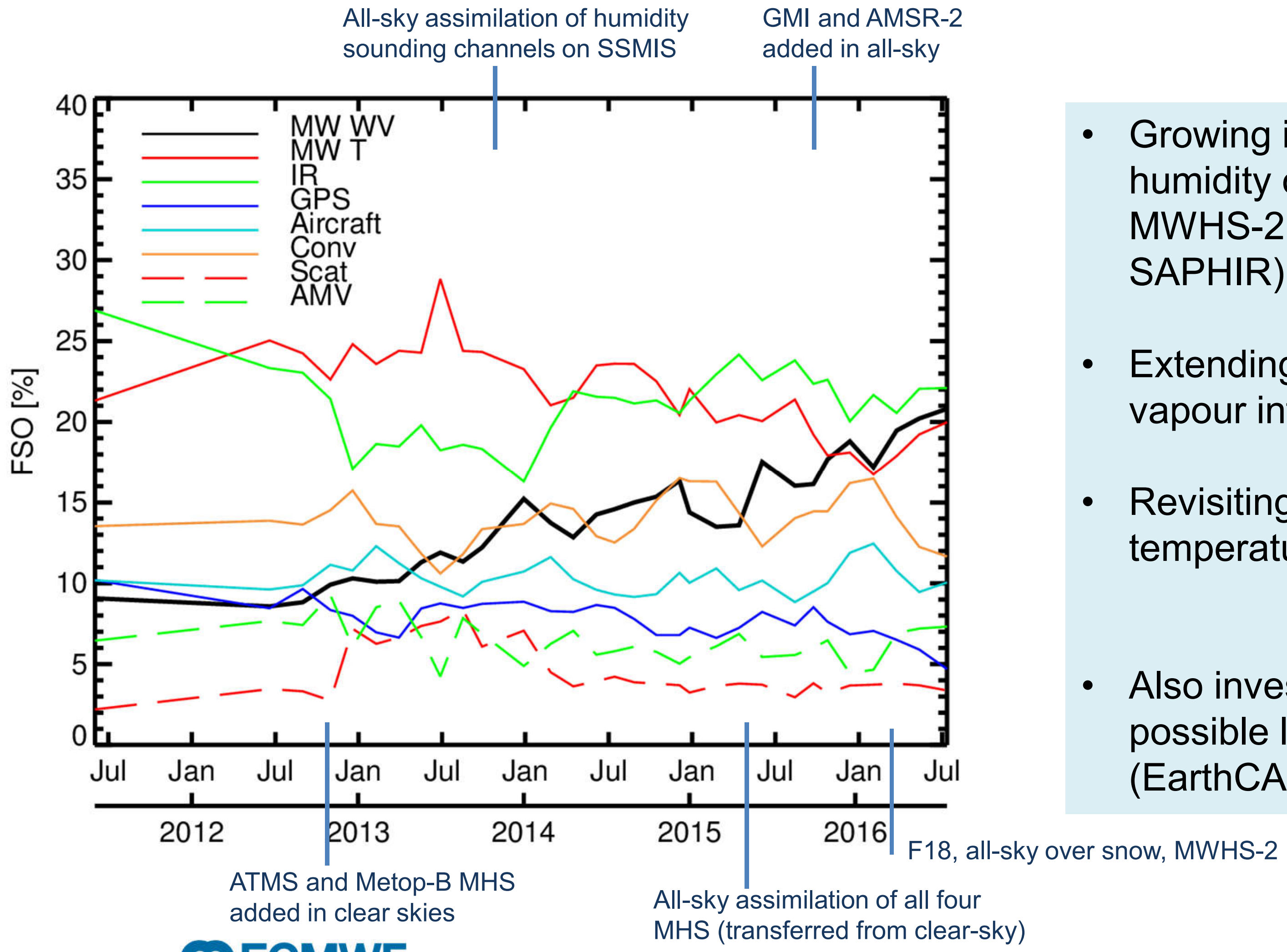


6h-avg lightning flash densities valid 17/06/2017 18 UTC: Portugal Fire



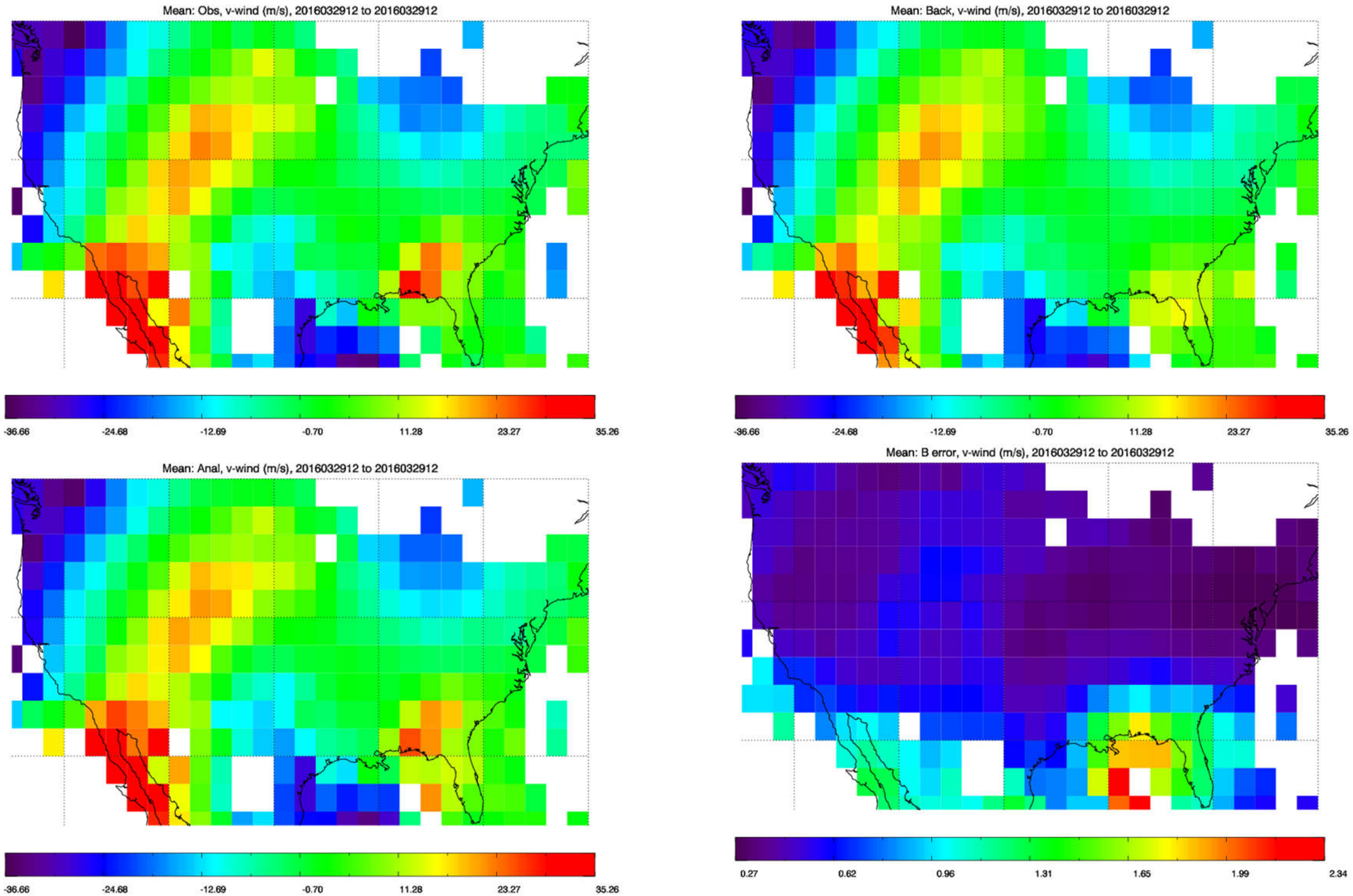
a 50% detection efficiency for ATDnet sensors (mainly cloud-to-ground flashes) has been assumed

Observation changes: the rise of all-sky!



- Growing importance of microwave humidity observations (MHS, ATMS, MWHS-2, SSMIS, AMSR2, GMI, SAPHIR).
- Extending this to infrared water vapour information.
- Revisiting all-sky microwave temperature observations.
- Also investigating radar, lidar, and possible lightning observations (EarthCARE, Aeolus, GOES-R, MTG).

Data assimilation: example of “convective” V-wind Obs & first guess

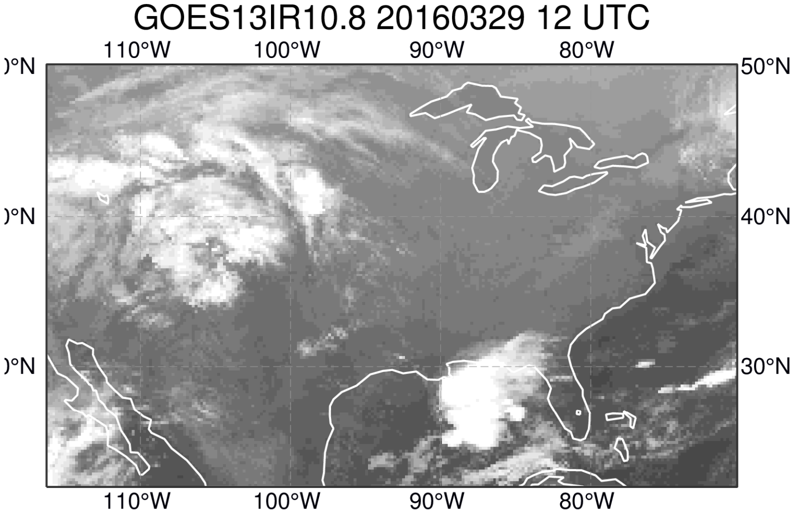


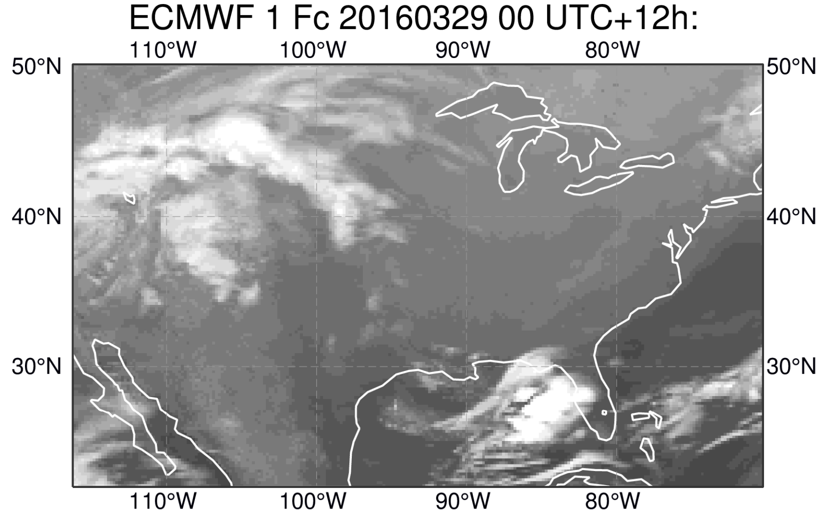
ECMWF

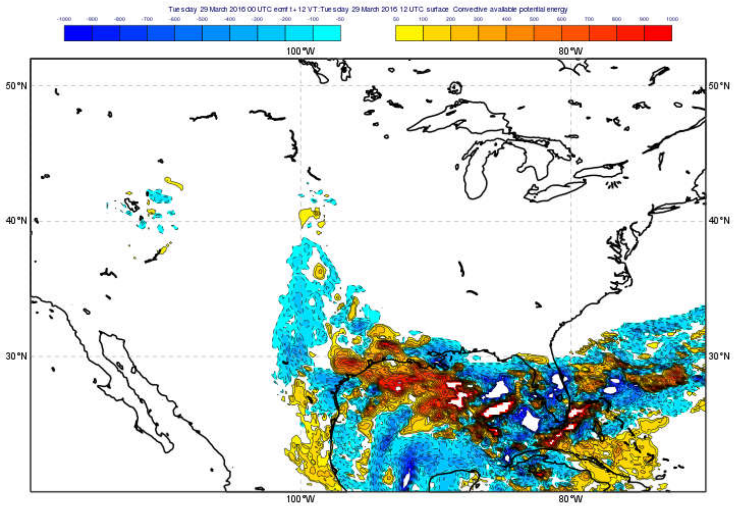
4DVarAnalysis (trajectory+TL evolved increment) able to correct the background (lack of convection) due to available aircraft Obs and background error statistics

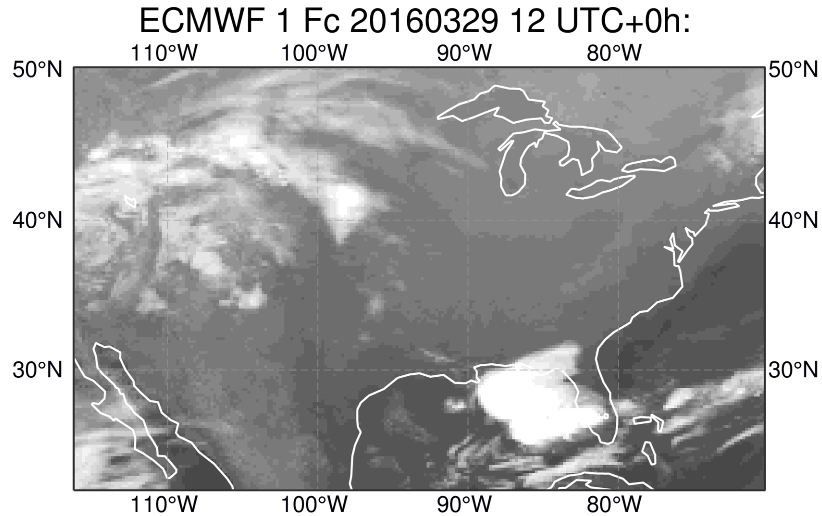
courtesy Mike Rennie

Data assimilation: “convective” analysis increments





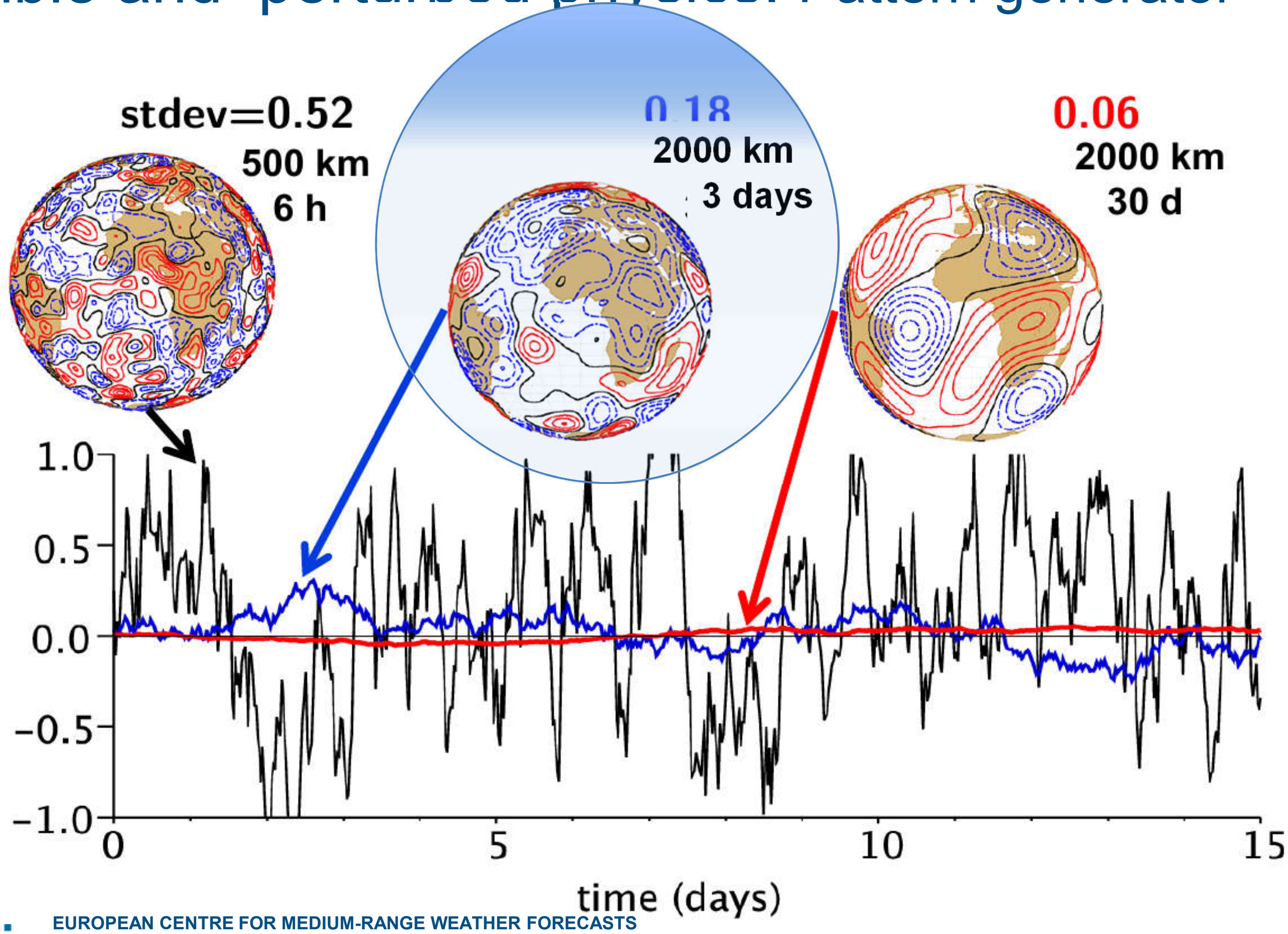




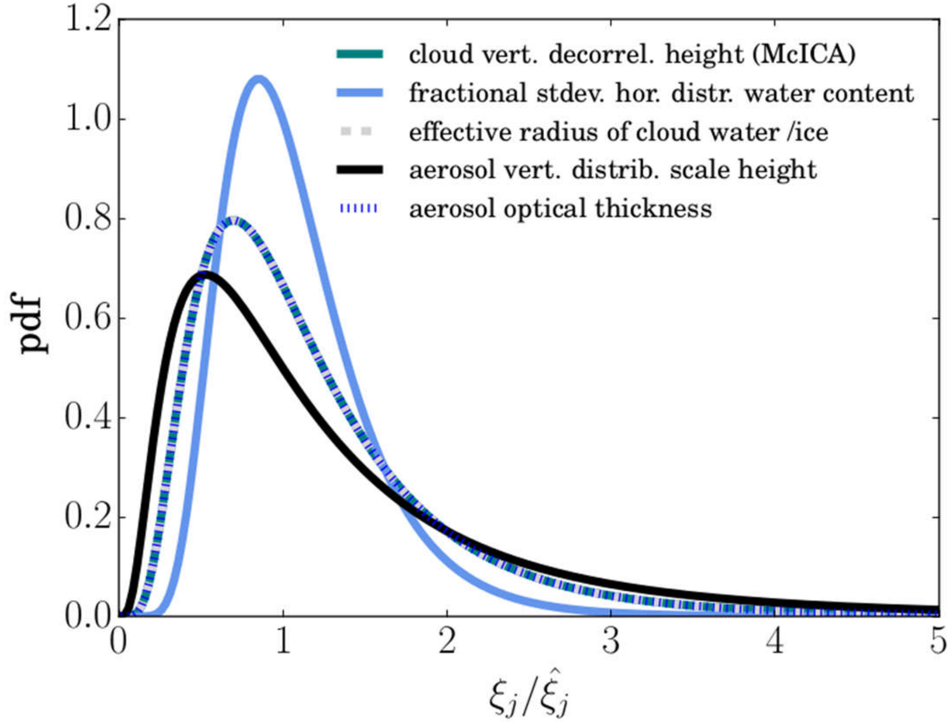
ECMWF

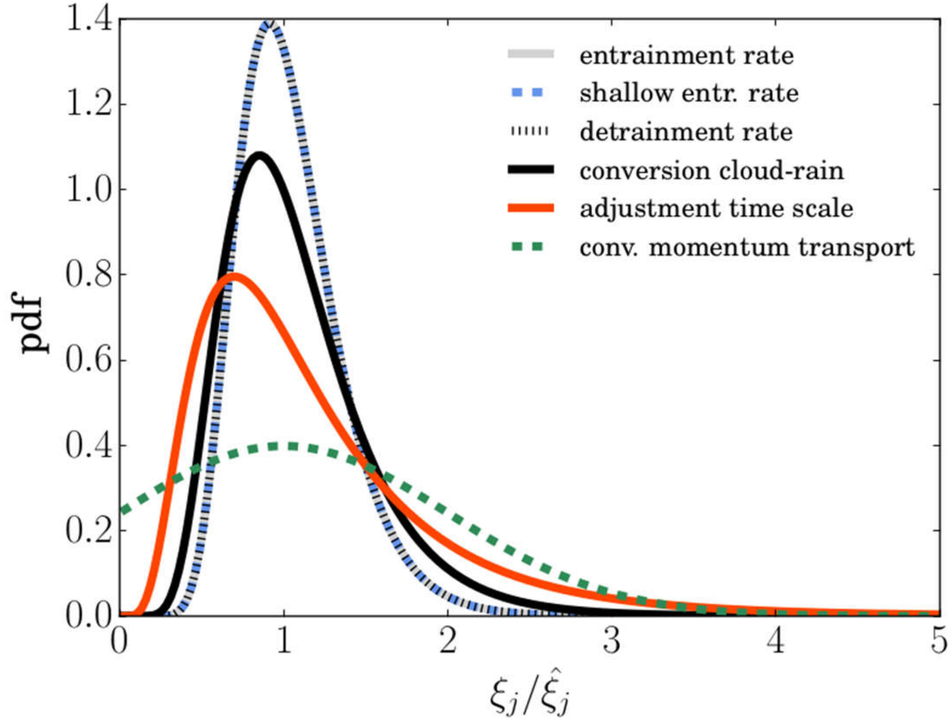
Slight change in large-scale conditions (CAPE/CIN) in analysis and convection is produced with right intensity and produces the 20 m/s outflow

Ensemble and perturbed physics: Pattern generator



Ensemble and perturbed physics: Perturbed parameter distributions



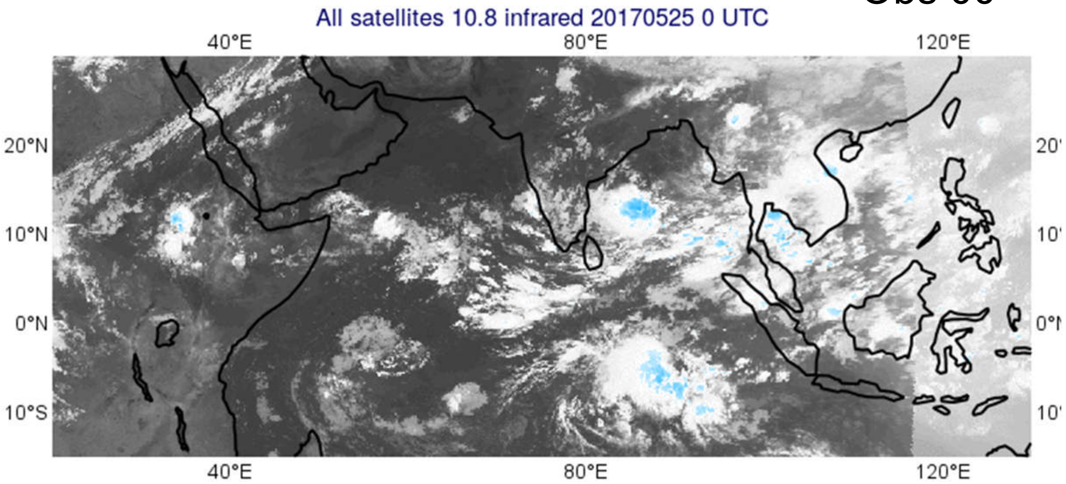


Ollinaho et al. 2017, QJRMS
Leutbecher et al. 2017, QJRMS

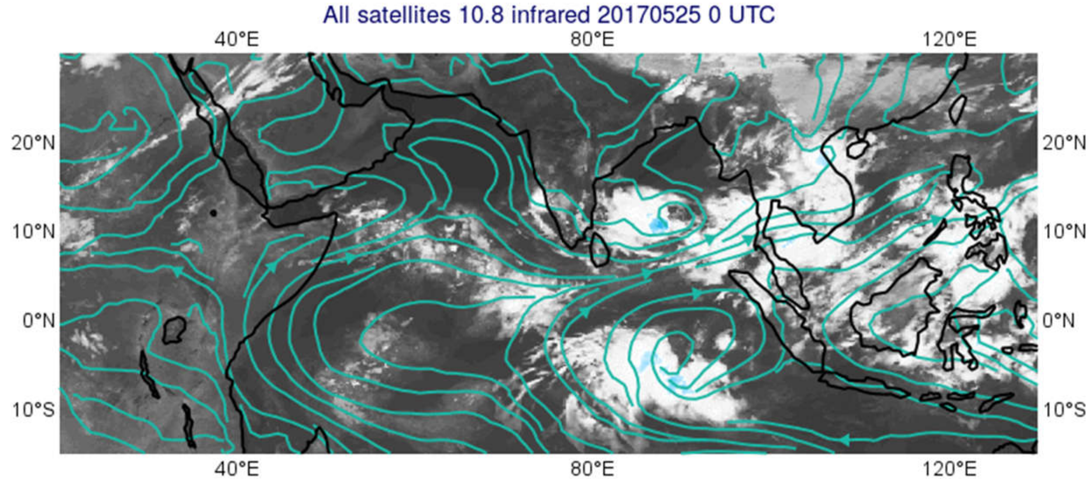
Overall estimation of upgradient momentum transport confirmed by work of P.Tullich and Wen Xiabao

Large-scale waves and diurnal cycle

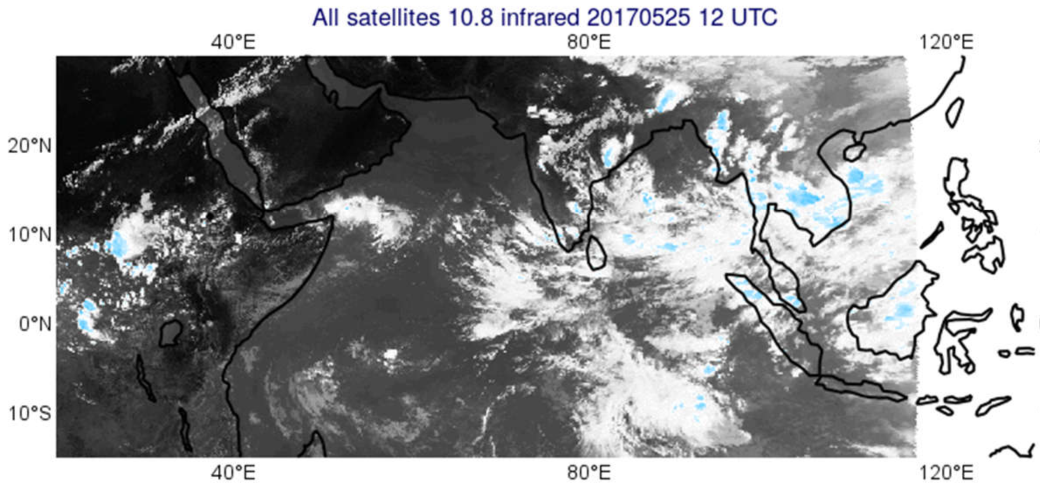
Obs 00



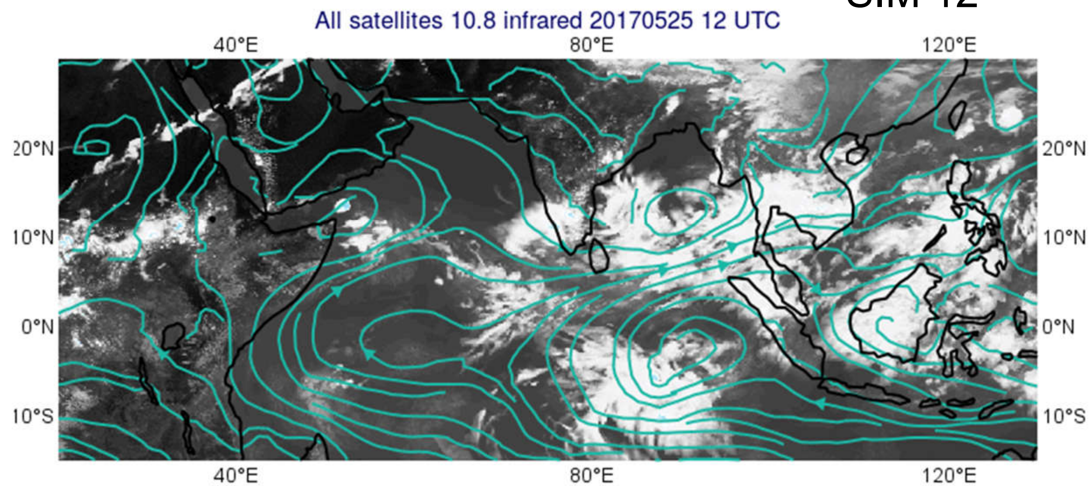
SIM 00



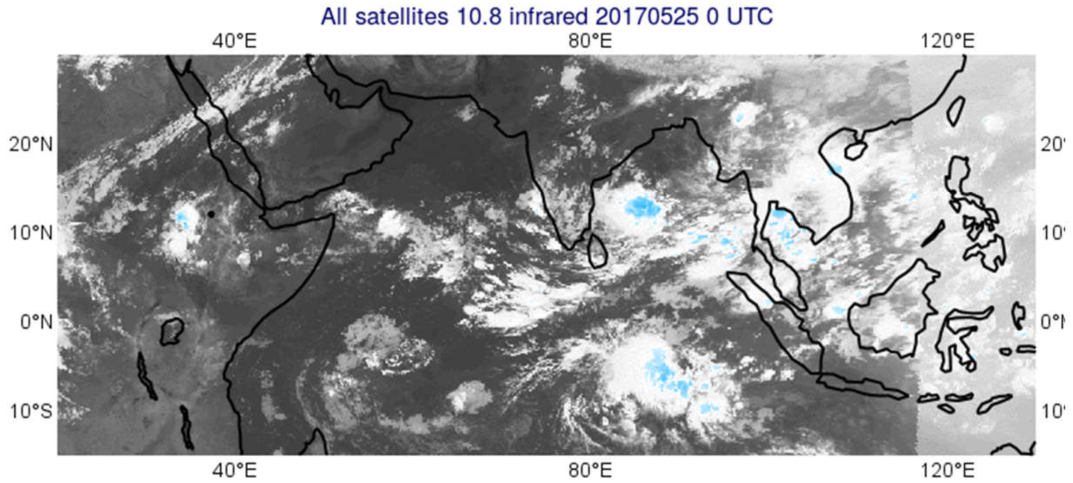
Obs 12

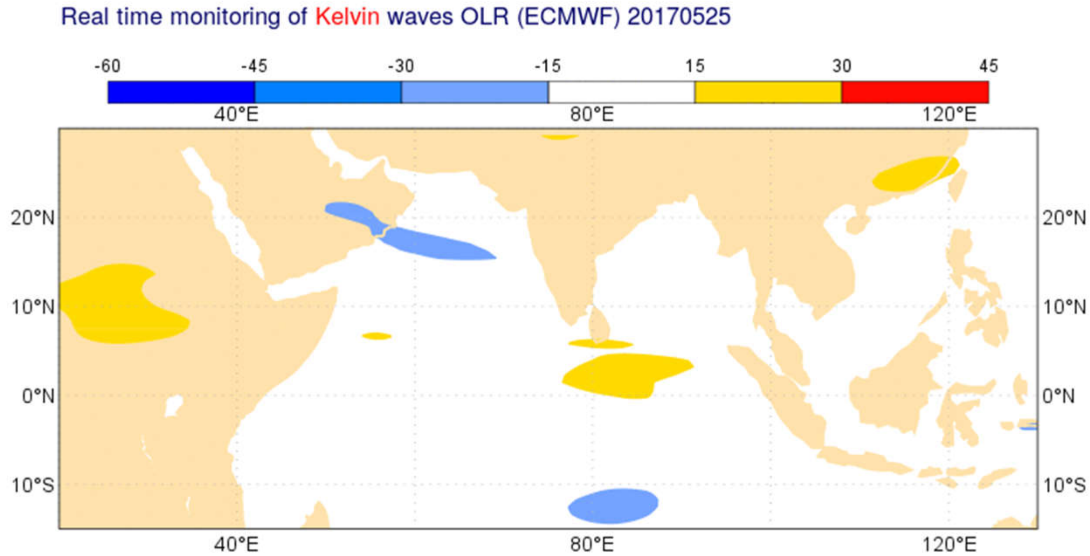


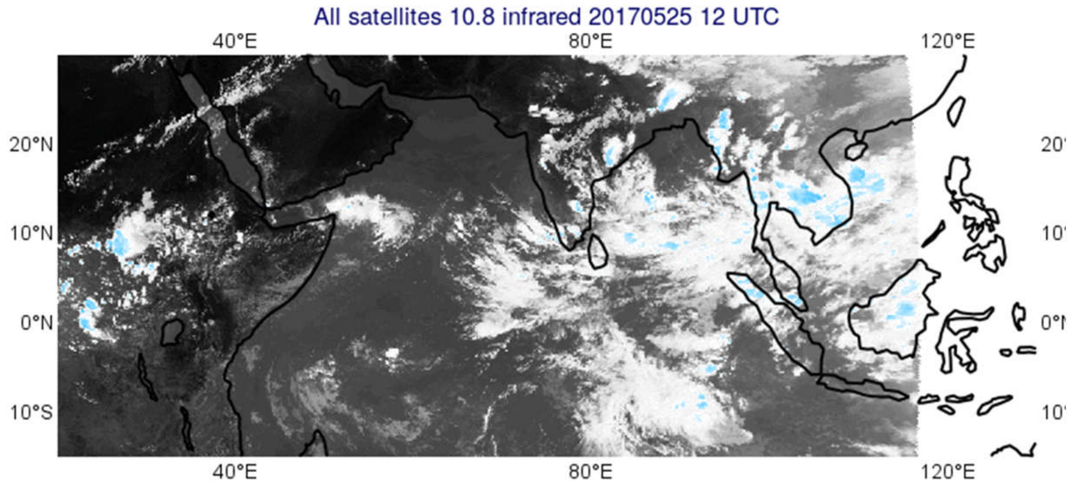
SIM 12

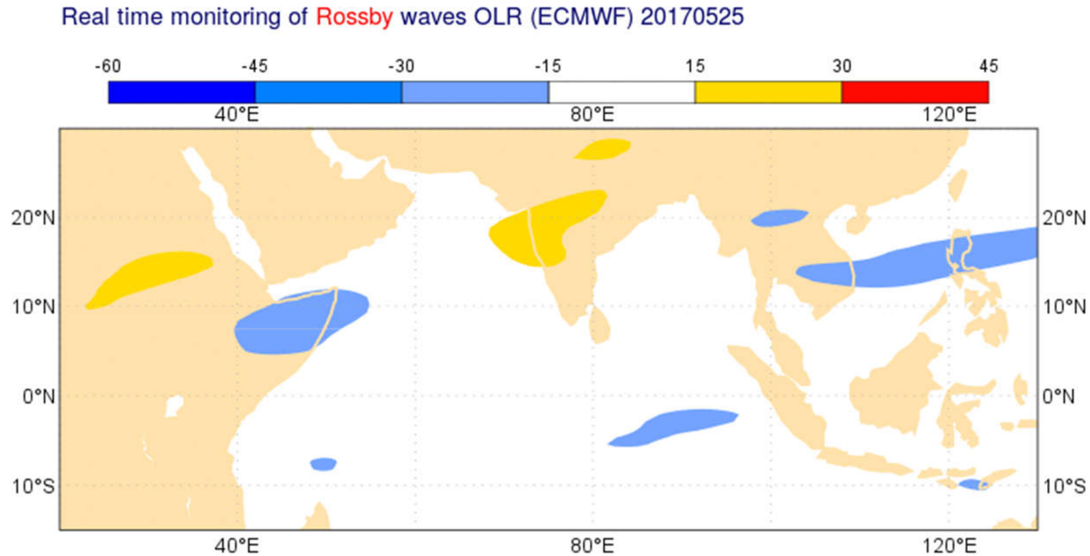


Tropical large-scale waves

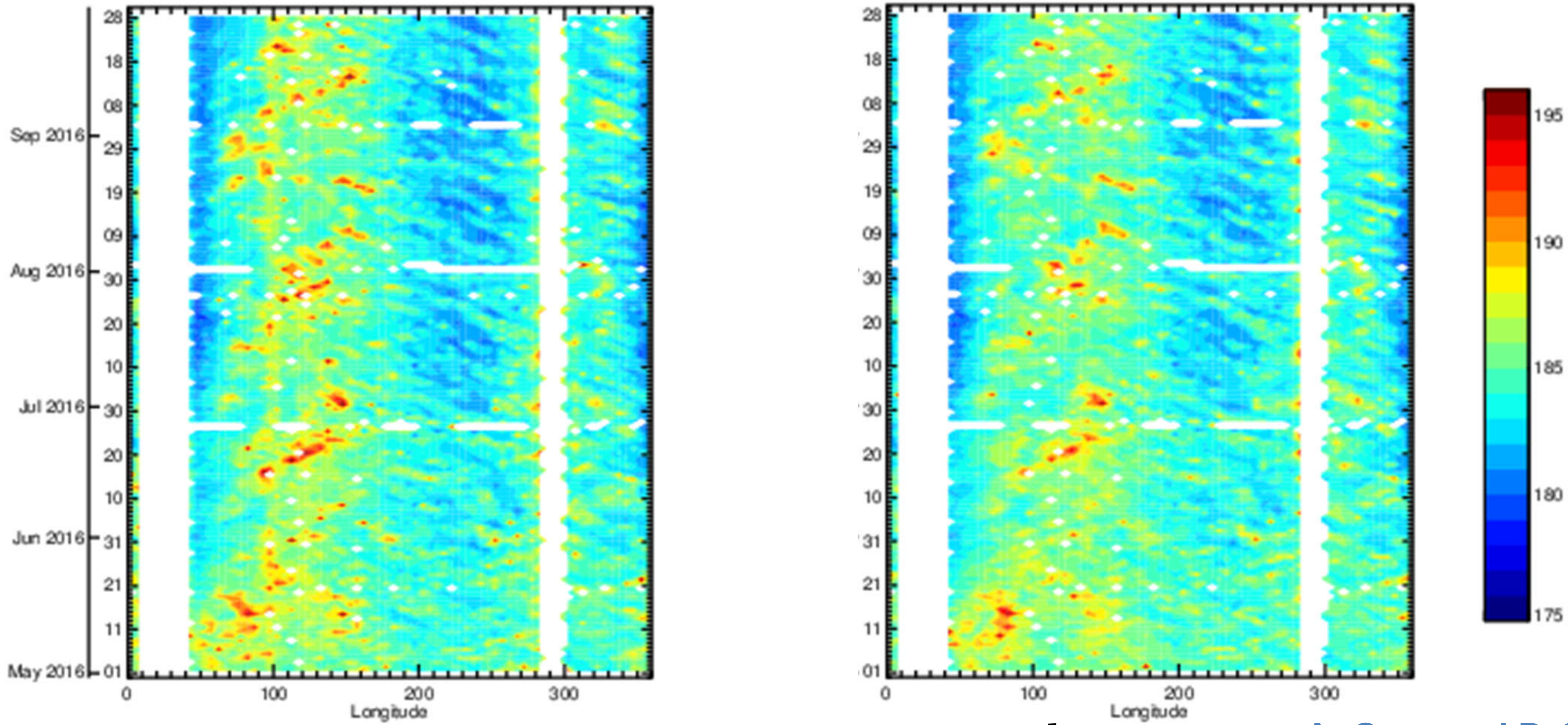








Tropical large-scale waves in observations and short-range forecasts: Microwave brightness temperatures - SAPHIR (sensitive to ice)

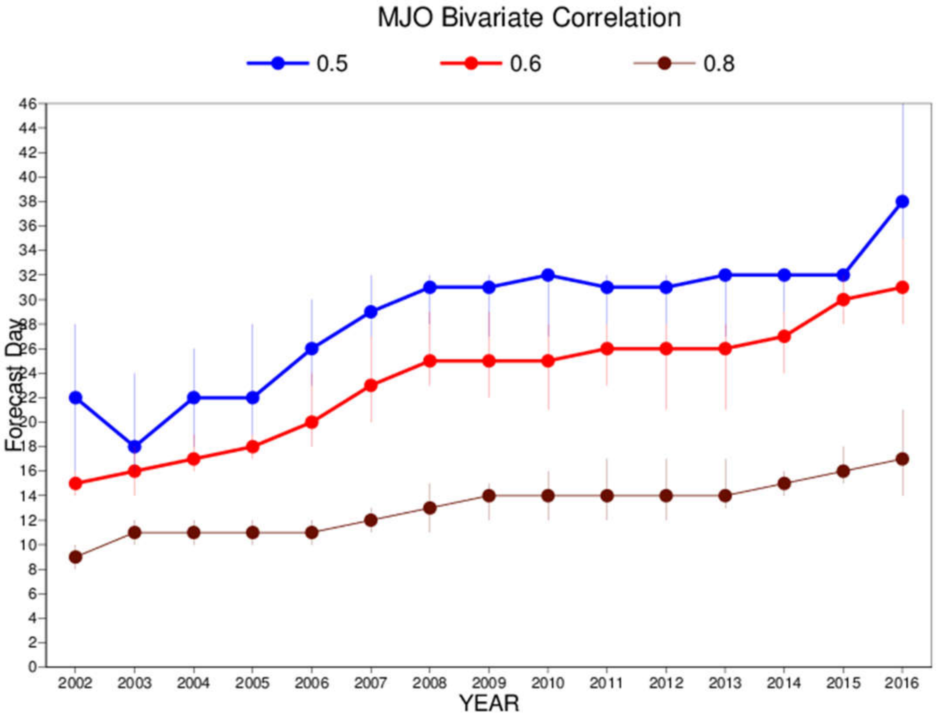


A. Geer and P. Chambon

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

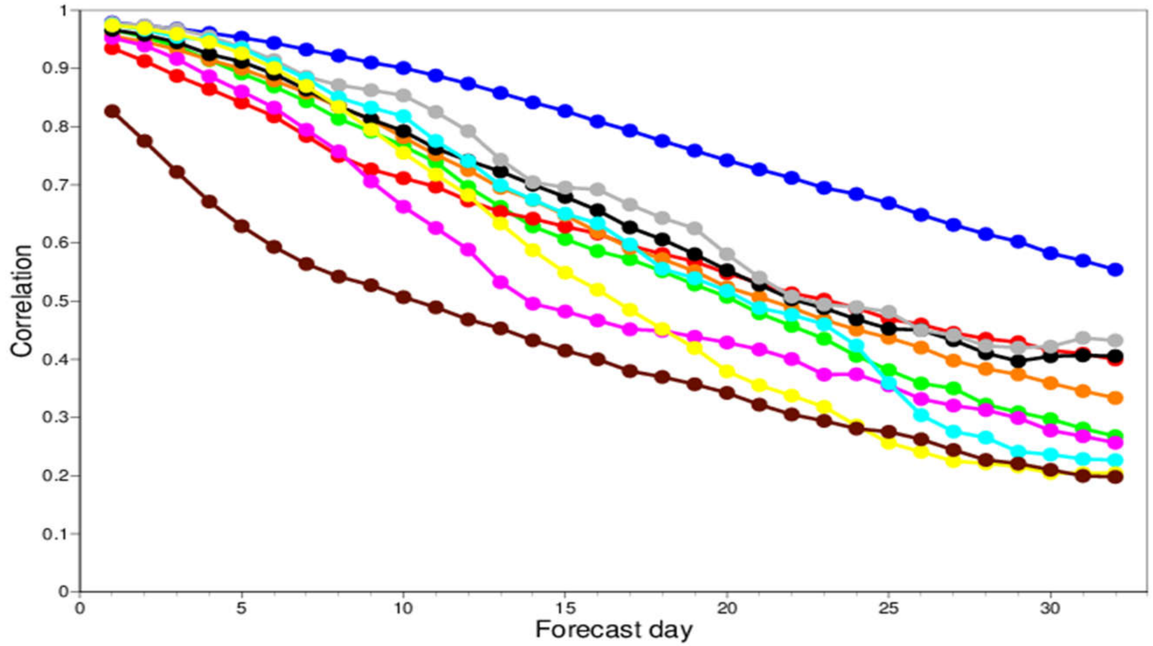
Predictability of the MJO: as measured from reforecasts and bi-variate correlation EOF (wind 850, 200 hPa, OLR)

Evolution of the IFS skill



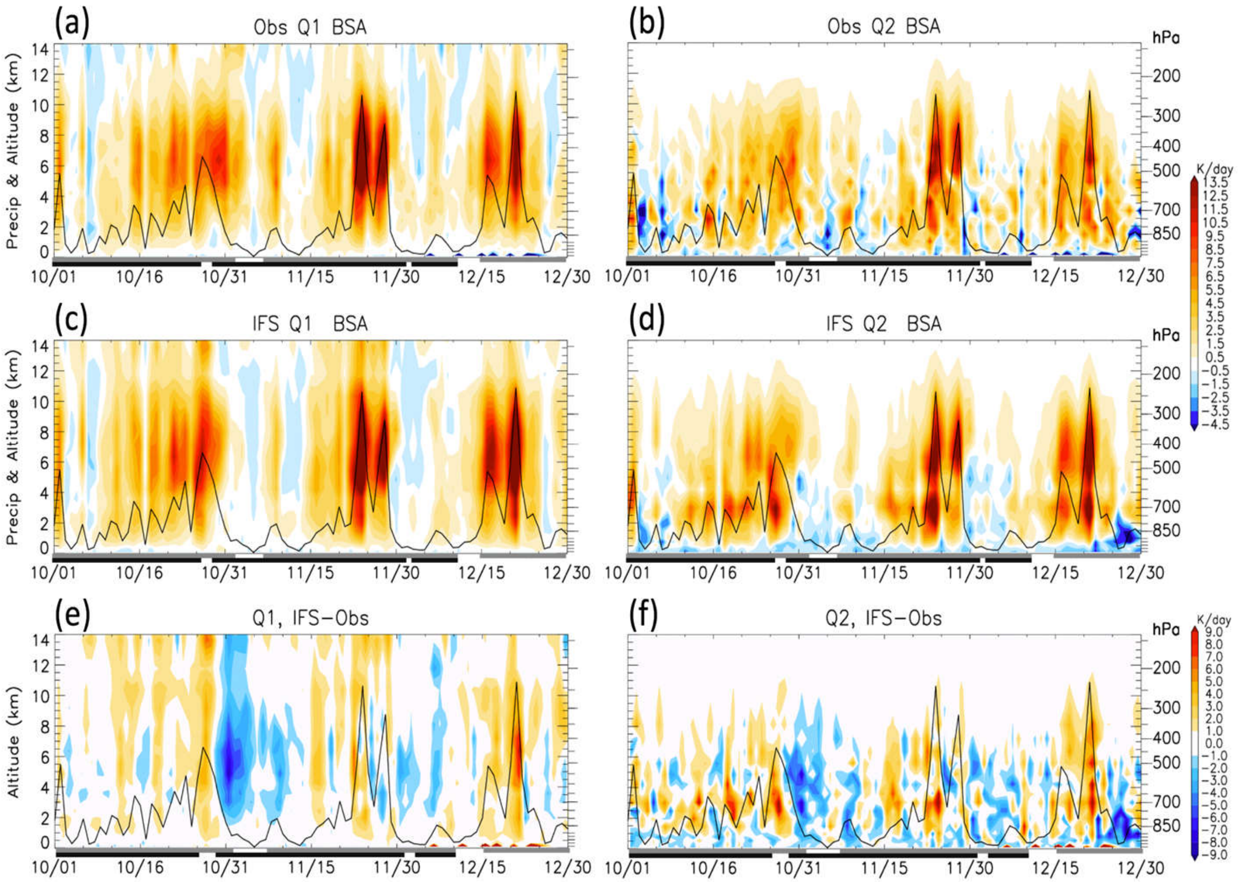
Multi-model from S2S database

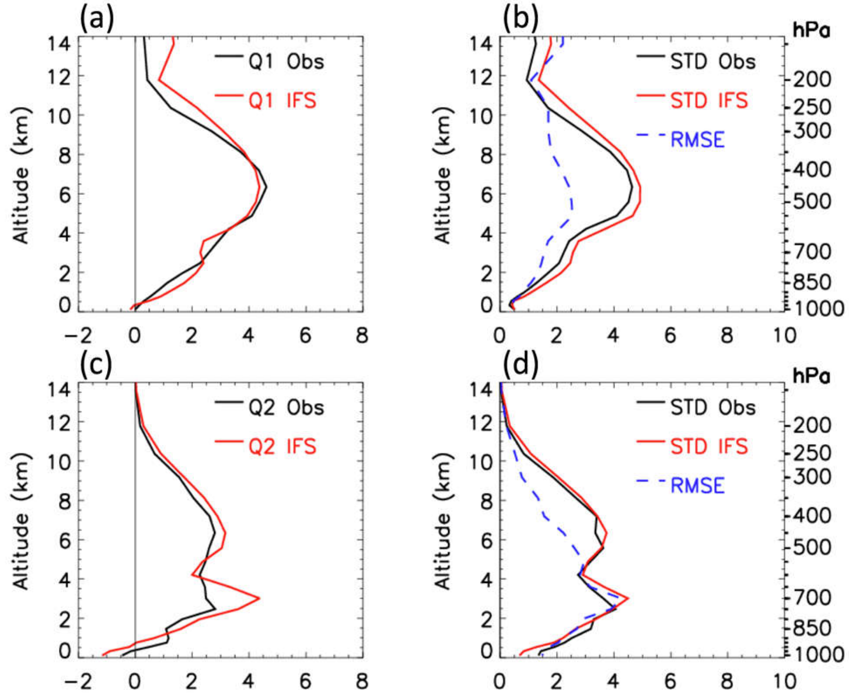
IFS



F. Vitart

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

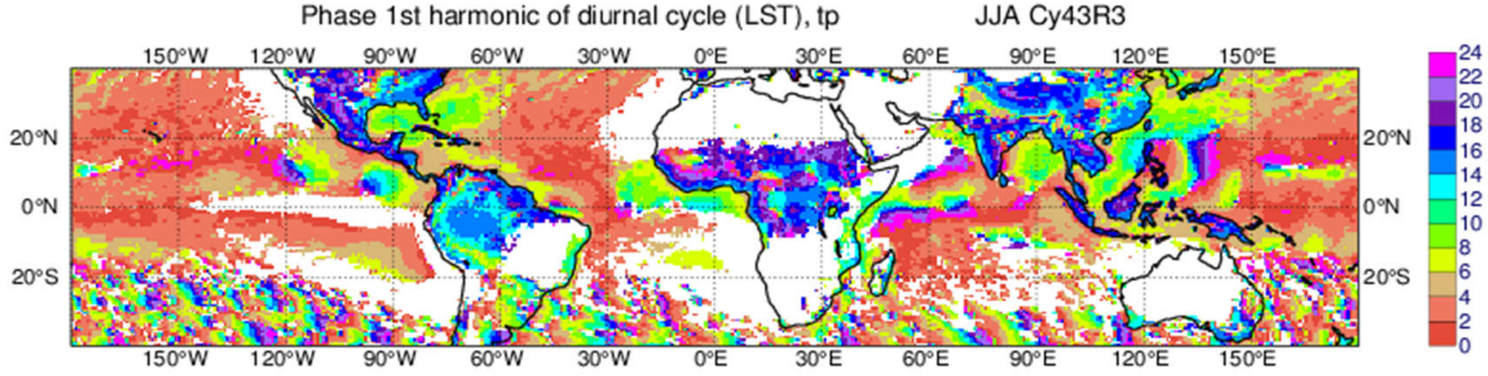


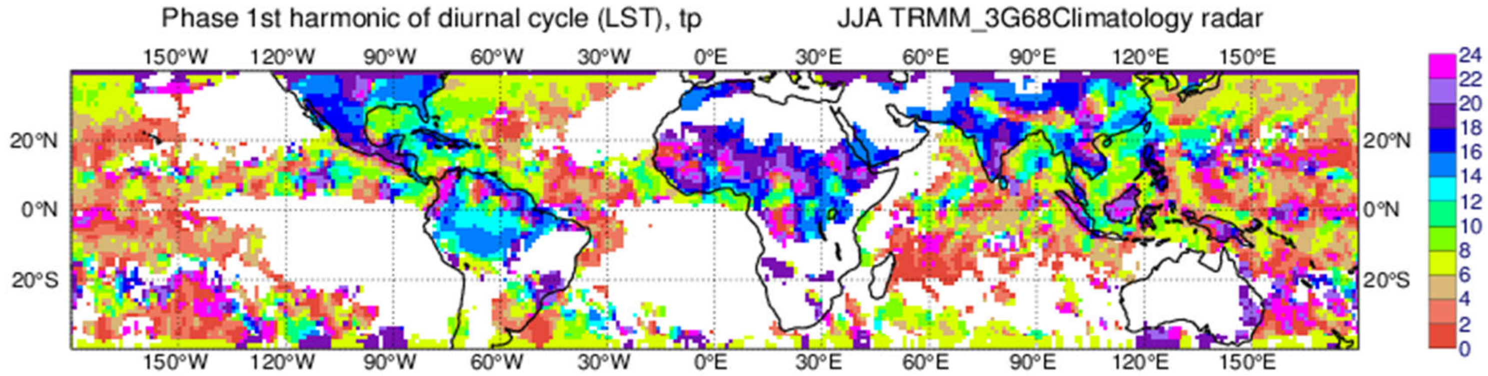


J.-E Kim et al. 2017, JAS

Diurnal cycle:

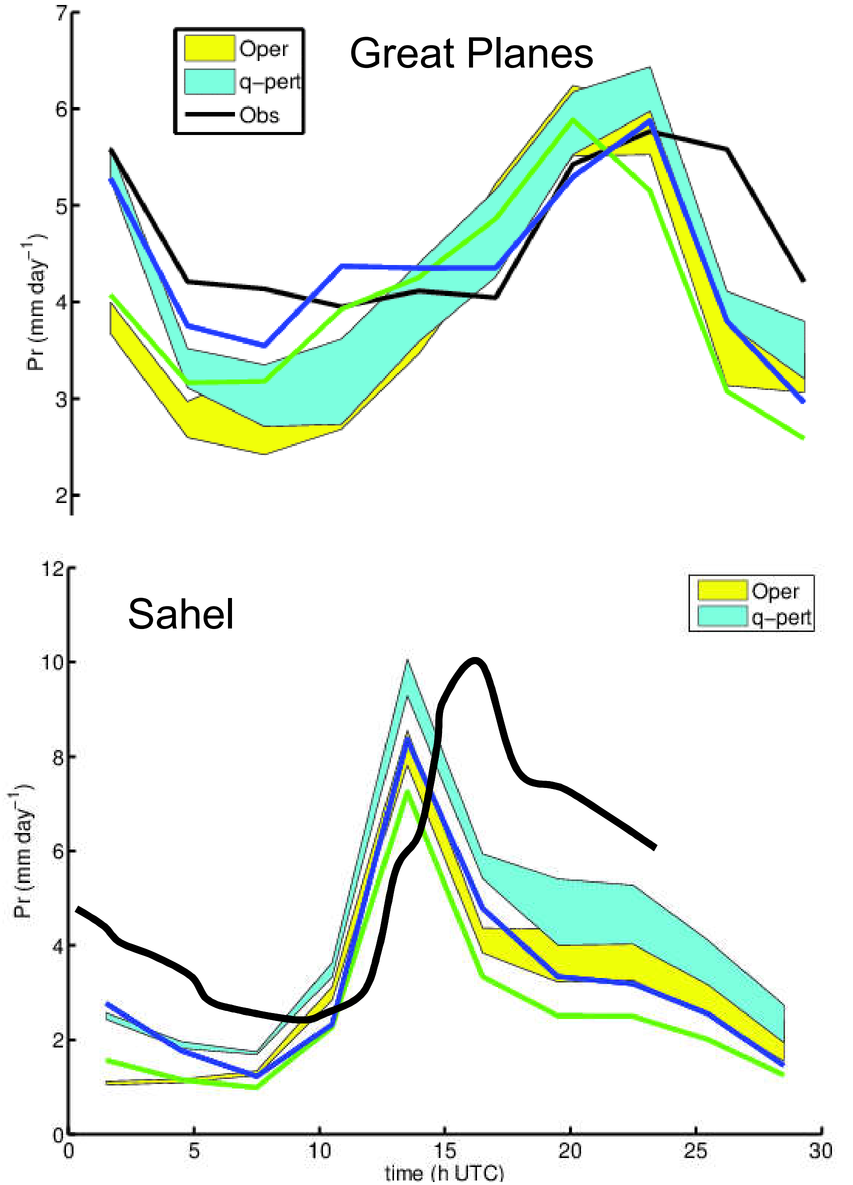
looks good globally for Precipitation peak (LST) but ….



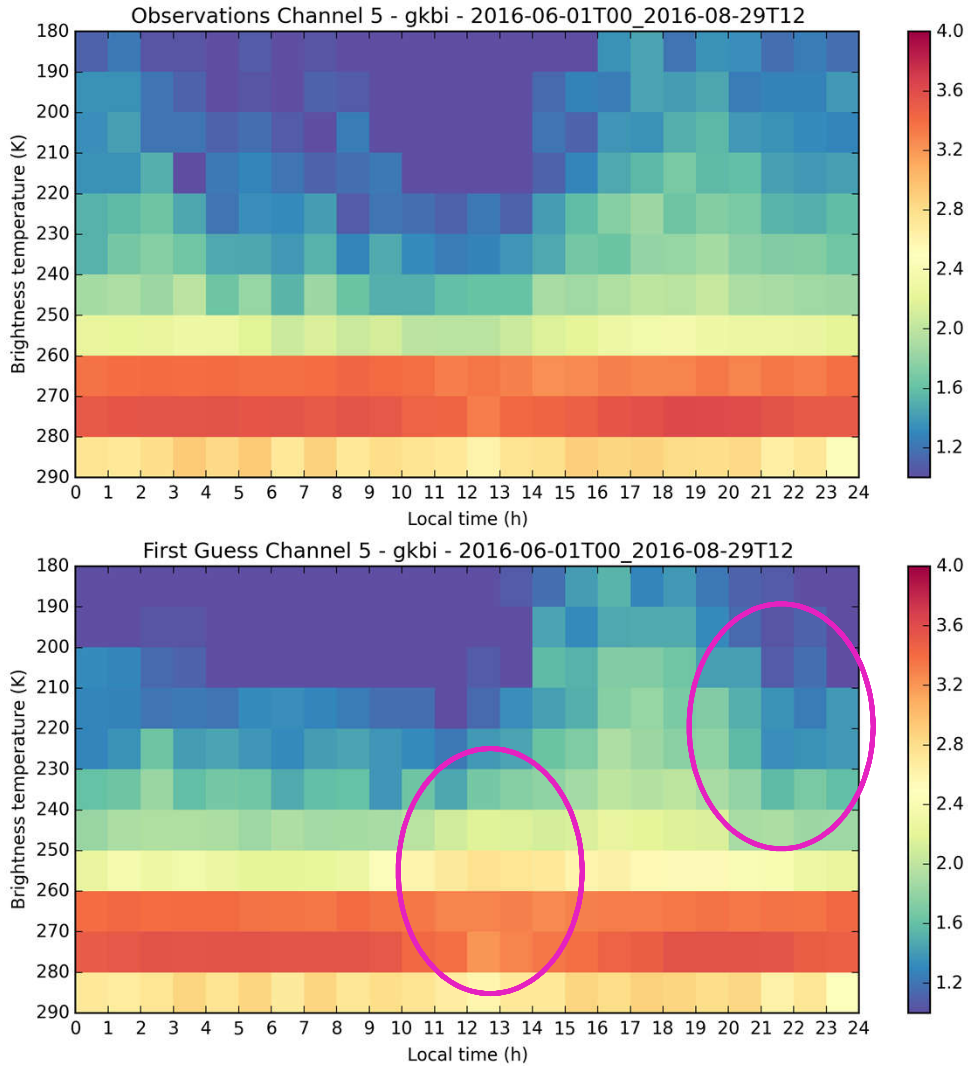


Bechtold et al. (2014)

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



SSMIS channel 6 Obs and First Guess JJA2016



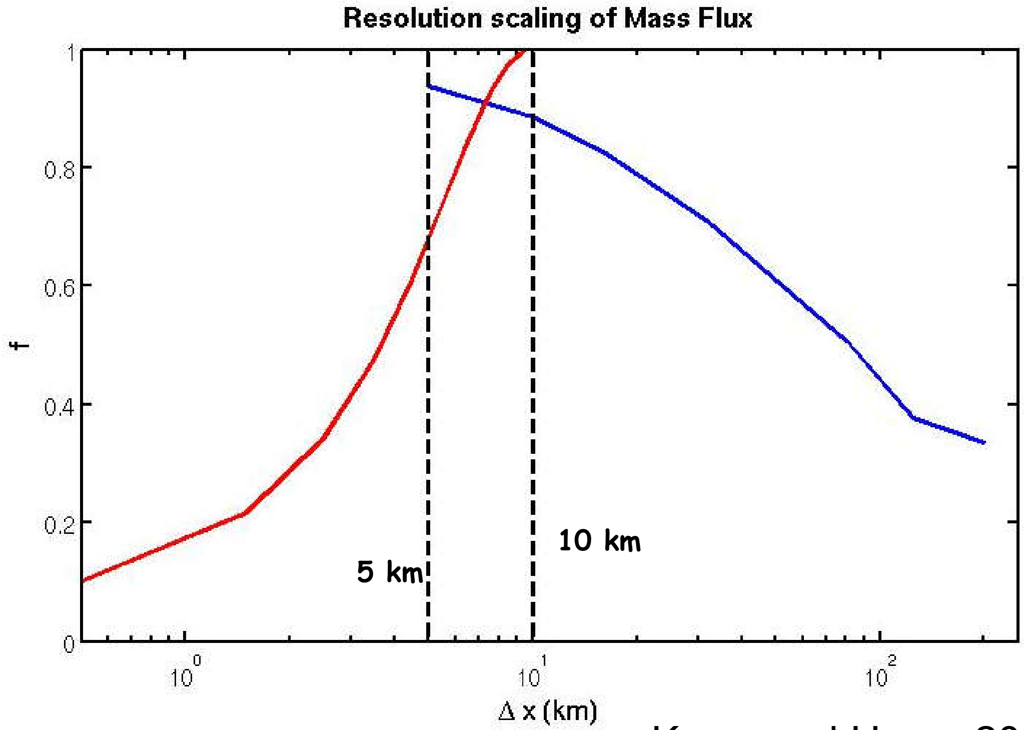
courtesy A. Geer

Resolution scaling for deep convection

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

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

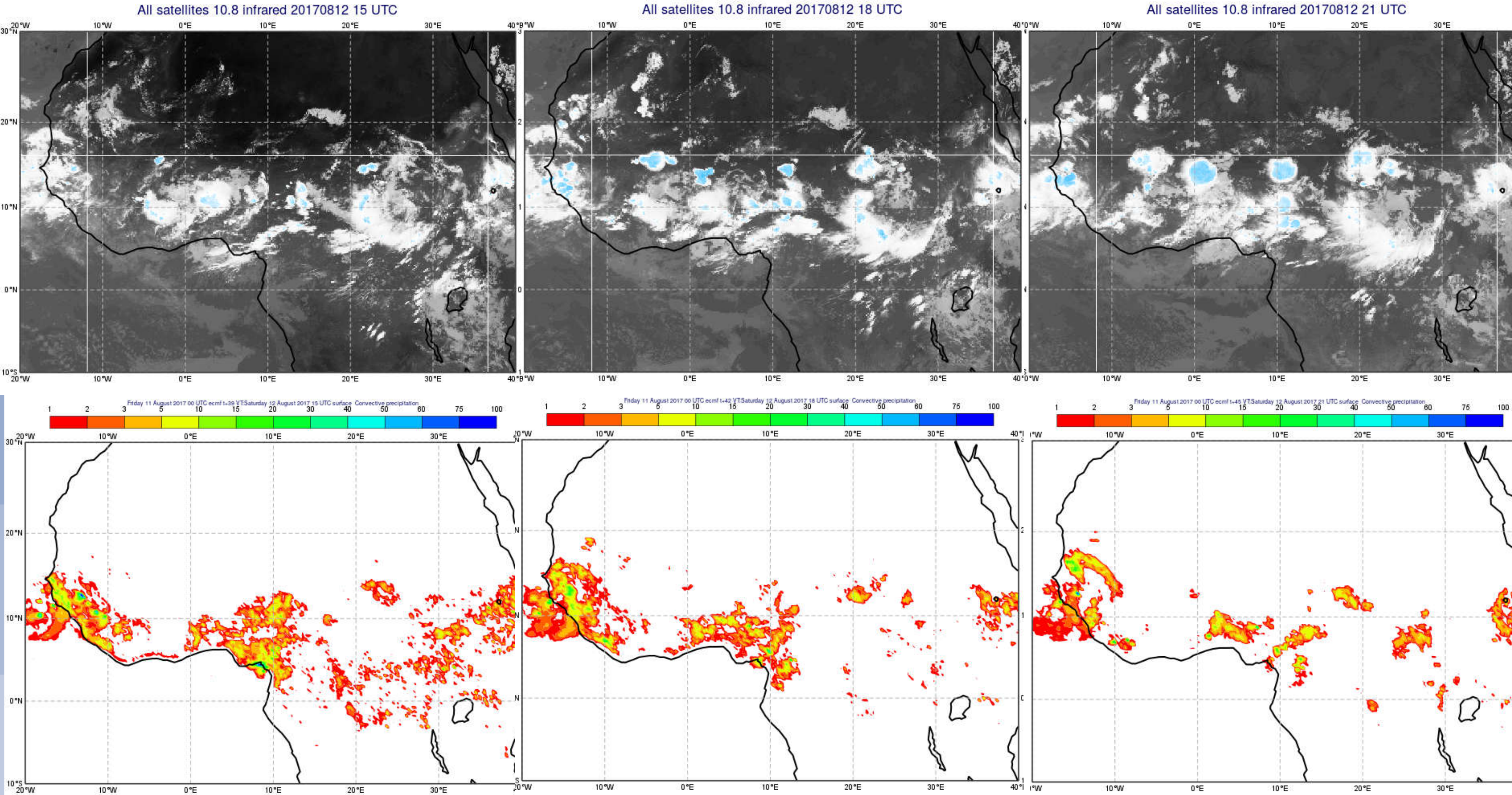
$$\cong \sigma\bar{\omega}^c\left(\bar{\Phi}^c - \bar{\Phi}\right) = -\frac{1}{g}M^c\left(\bar{\Phi}^c - \bar{\Phi}\right) \quad f(\Delta x)$$



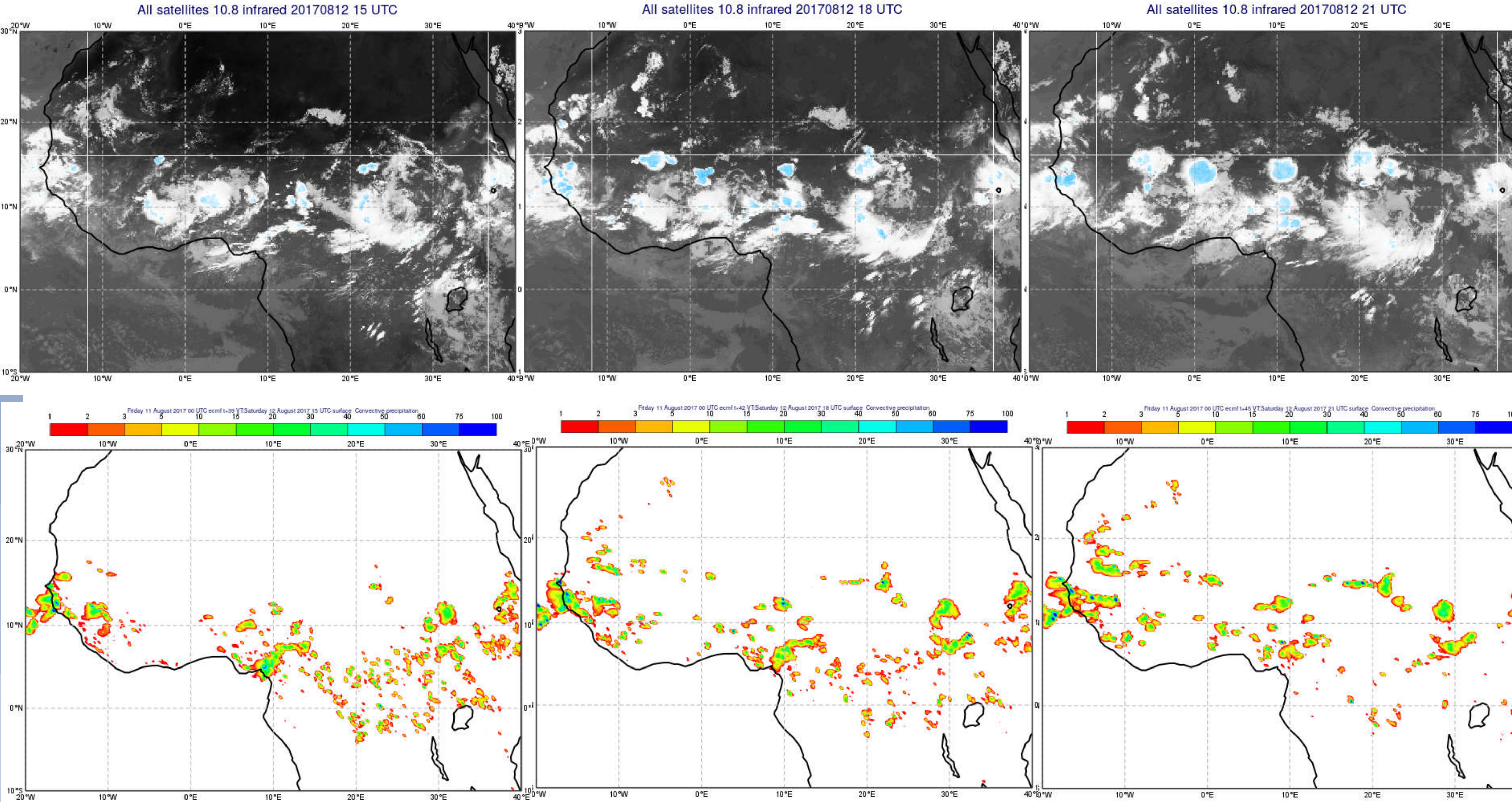
Developed in collaboration with Deutsche Wetterdienst and ICON model

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

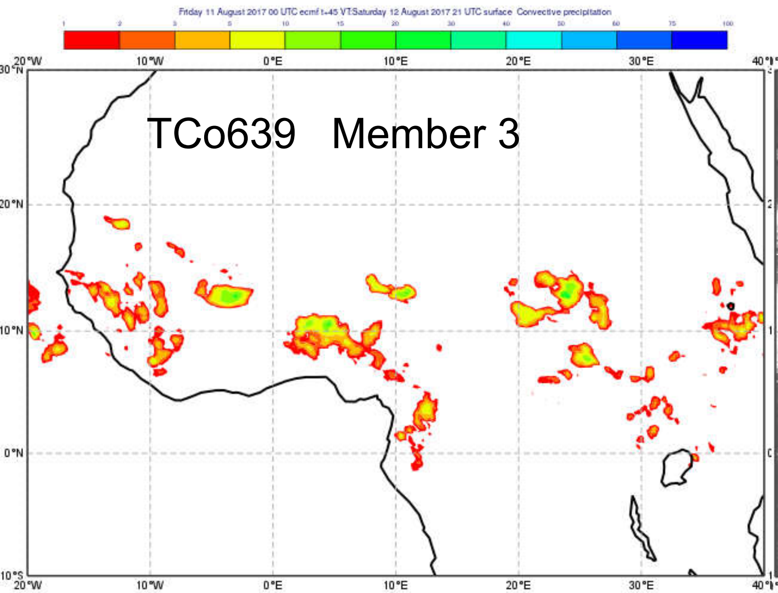
ECMWF

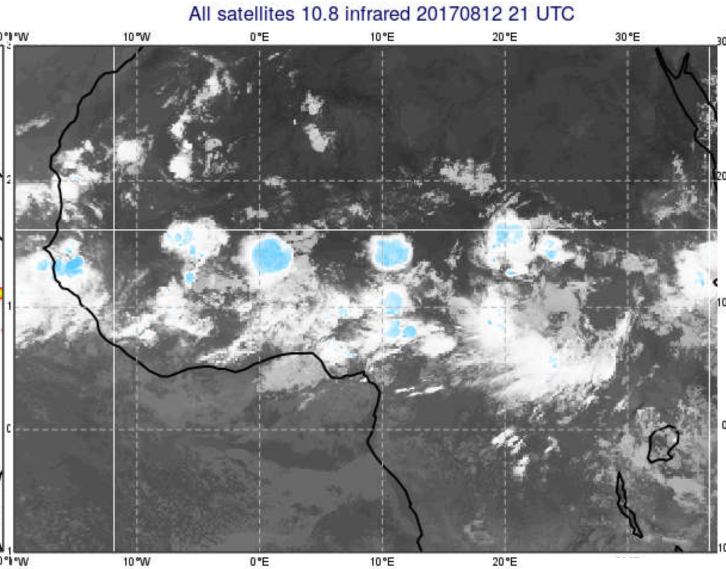

All satellites 10.8 infrared 20170812 15 UTC
All satellites 10.8 infrared 20170812 18 UTC
All satellites 10.8 infrared 20170812 21 UTC

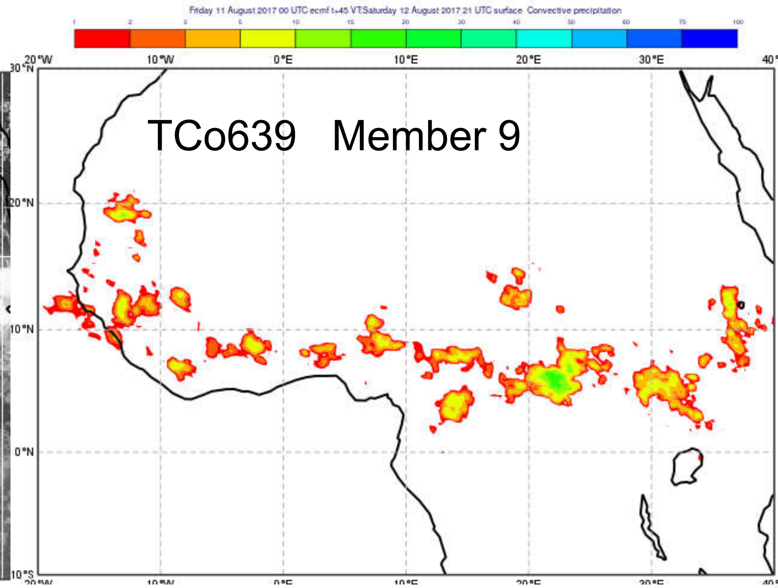
TCo1999

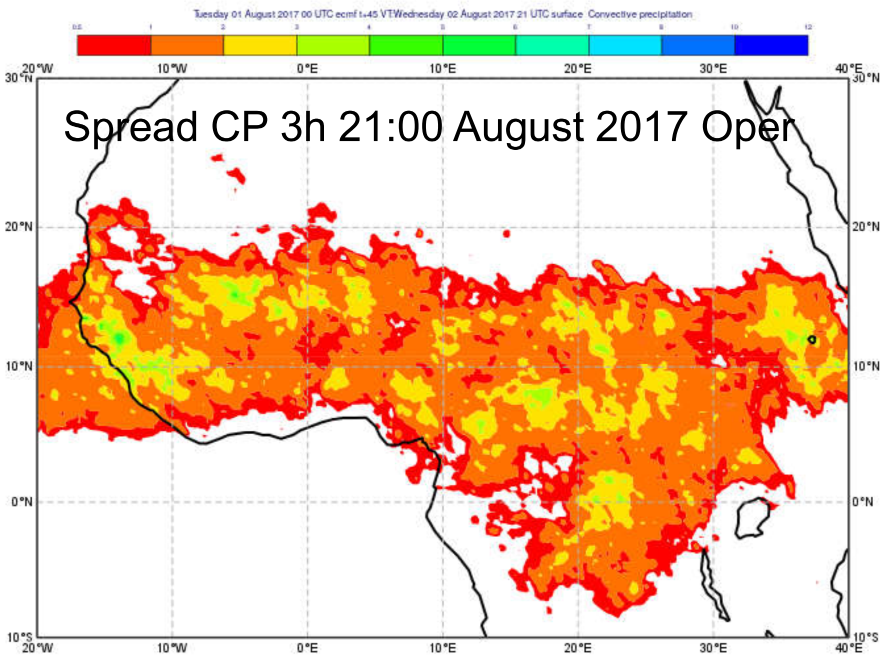


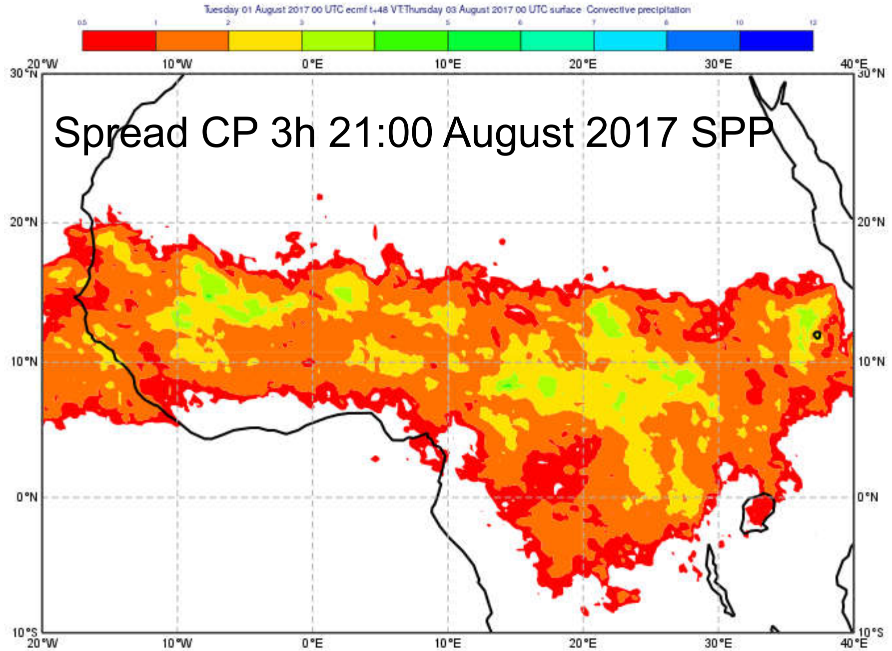
TCo1999 no deep


Friday 11 August 2017 00 UTC ecmf t+45 VT:Saturday 12 August 2017 21 UTC surface Convective precipitation
TCo639 Member 3

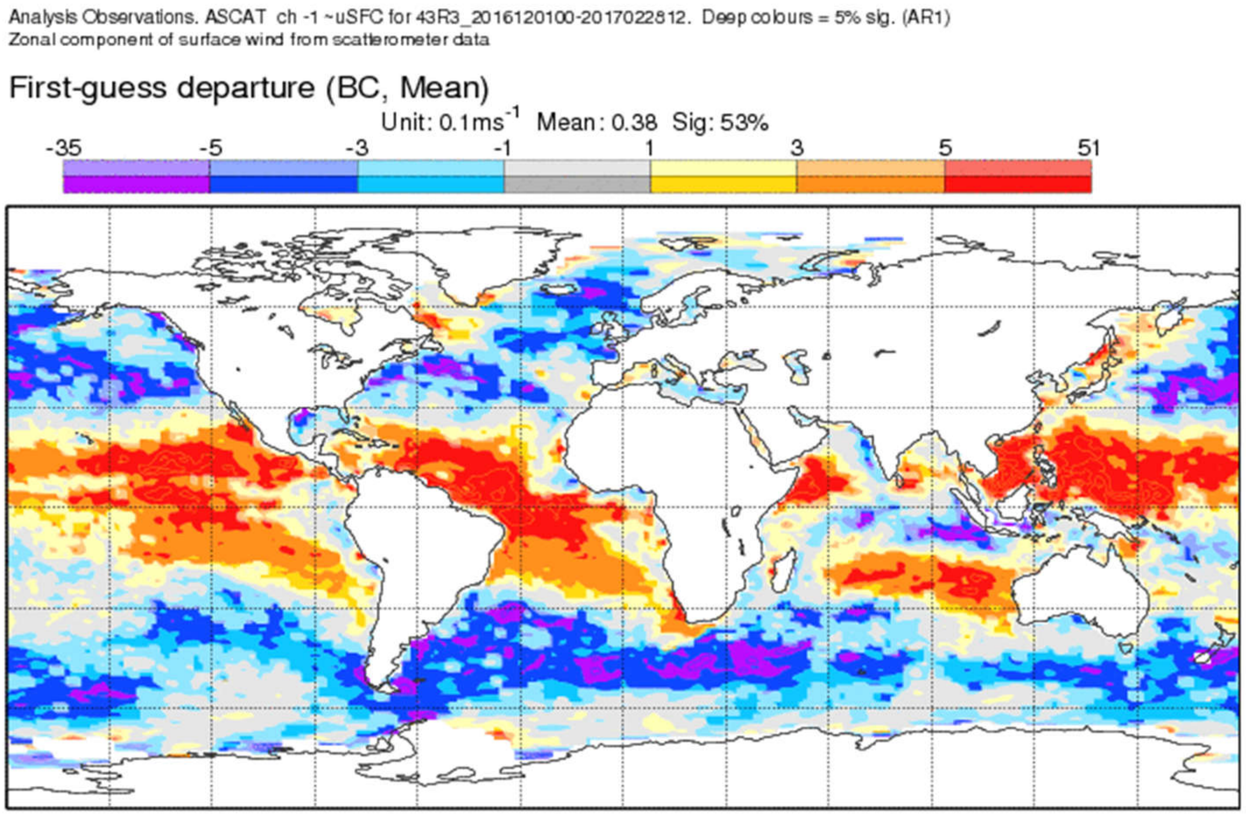

All satellites 10.8 infrared 20170812 21 UTC


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

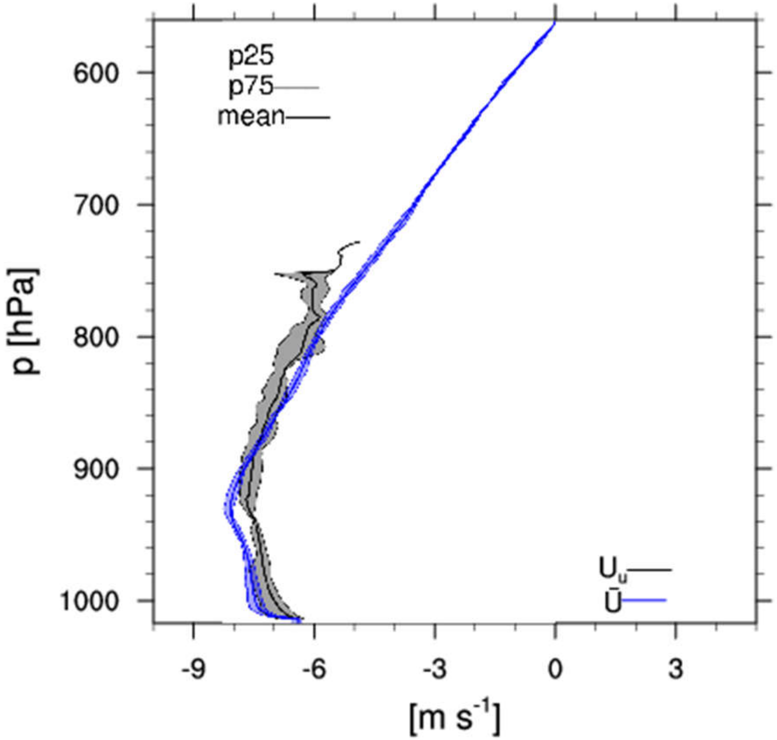

Tuesday 01 August 2017 00 UTC ecmf t+48 VT:Thursday 03 August 2017 00 UTC surface Convective precipitation
Spread CP 3h 21:00 August 2017 SPP

Tropical and subtropical low-level wind biases:
First-guess departures against scatterometer

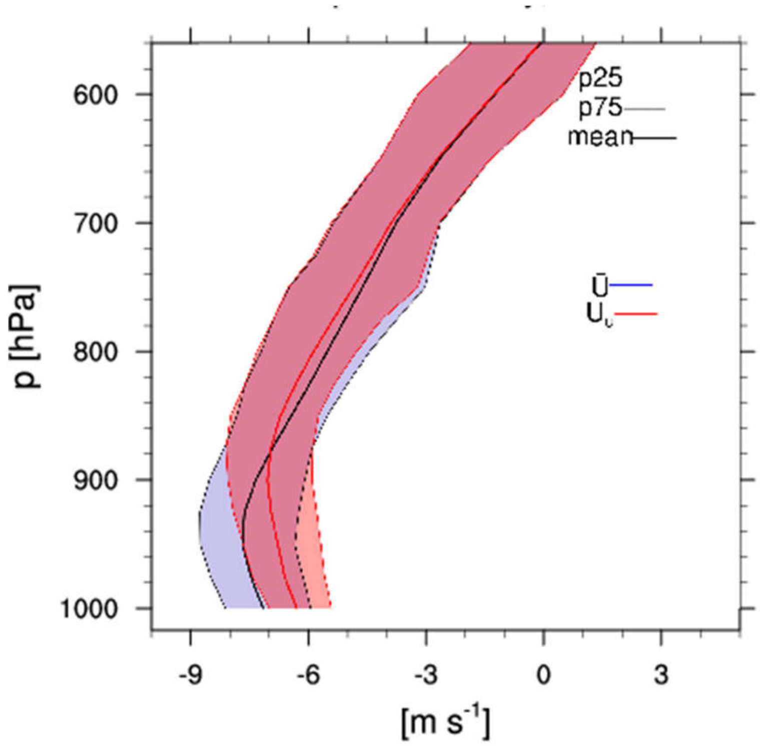


Revisiting the convective momentum transport: shallow convection

RICO: LES

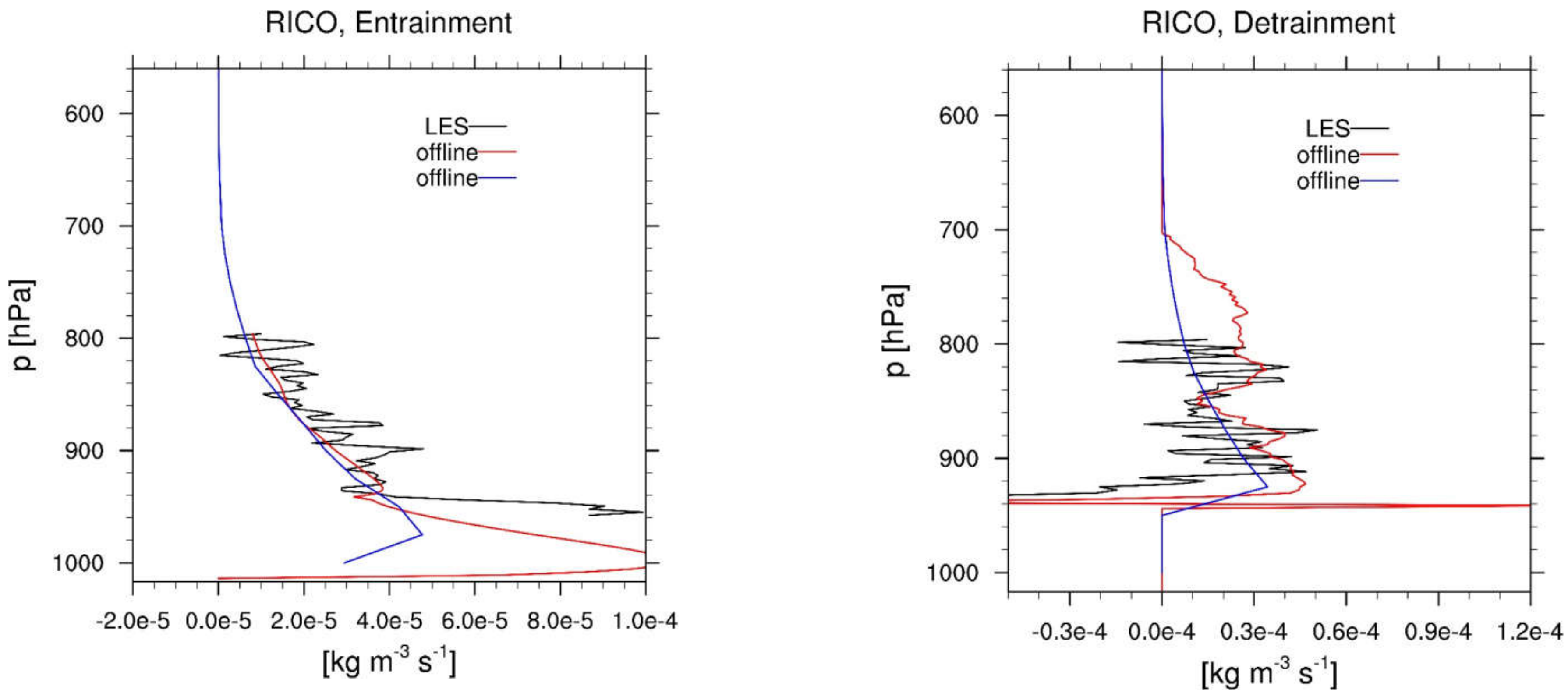


IFS: 16-28.12 2008 RICO domain



Schlemmer et al. 2017 JAMES

Revisiting the convective momentum transport: shallow convection

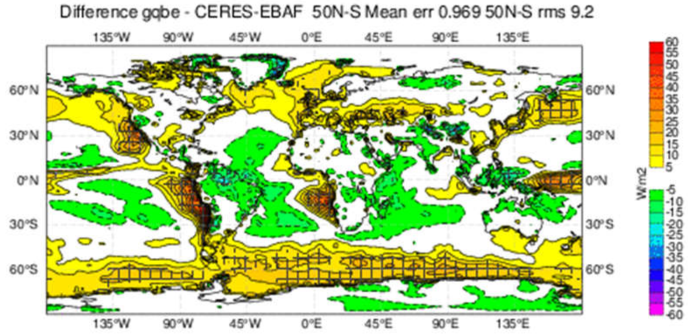


LES (black) IFS IFS formula with LES data

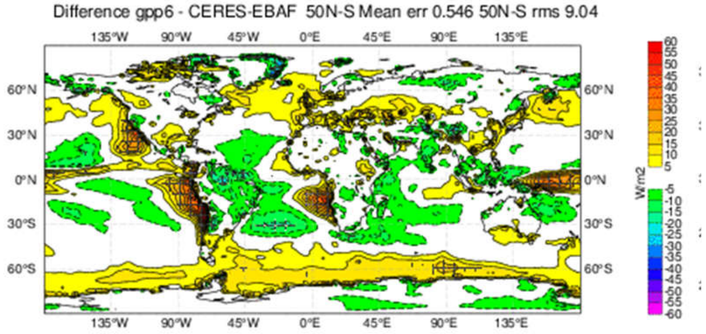
Improving the SW radiation biases:

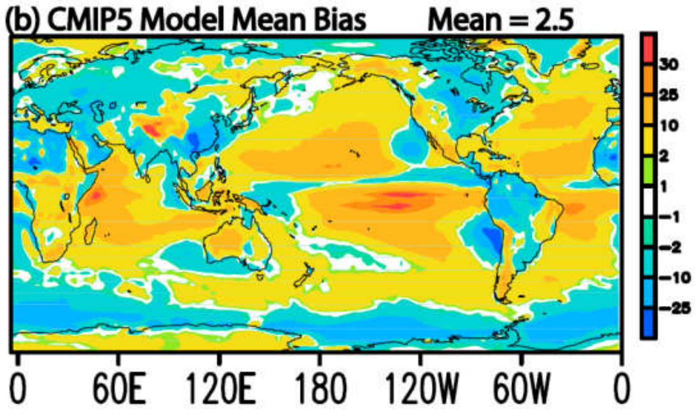
Focus: Storm tracks and Sc regions not reflective enough, trades and transition too reflective

Cy43r1

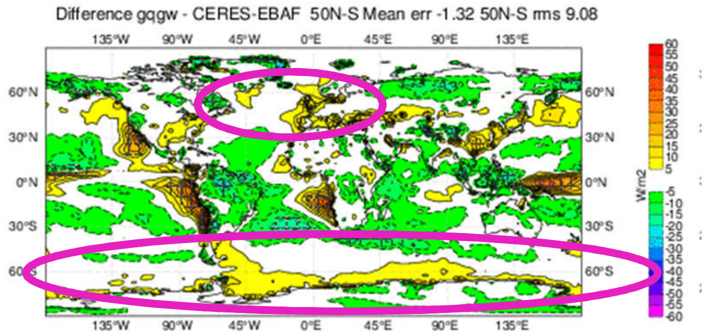


Adding 0- -38C mixed phase, snow, rain detrain, liquid phase only for shallow





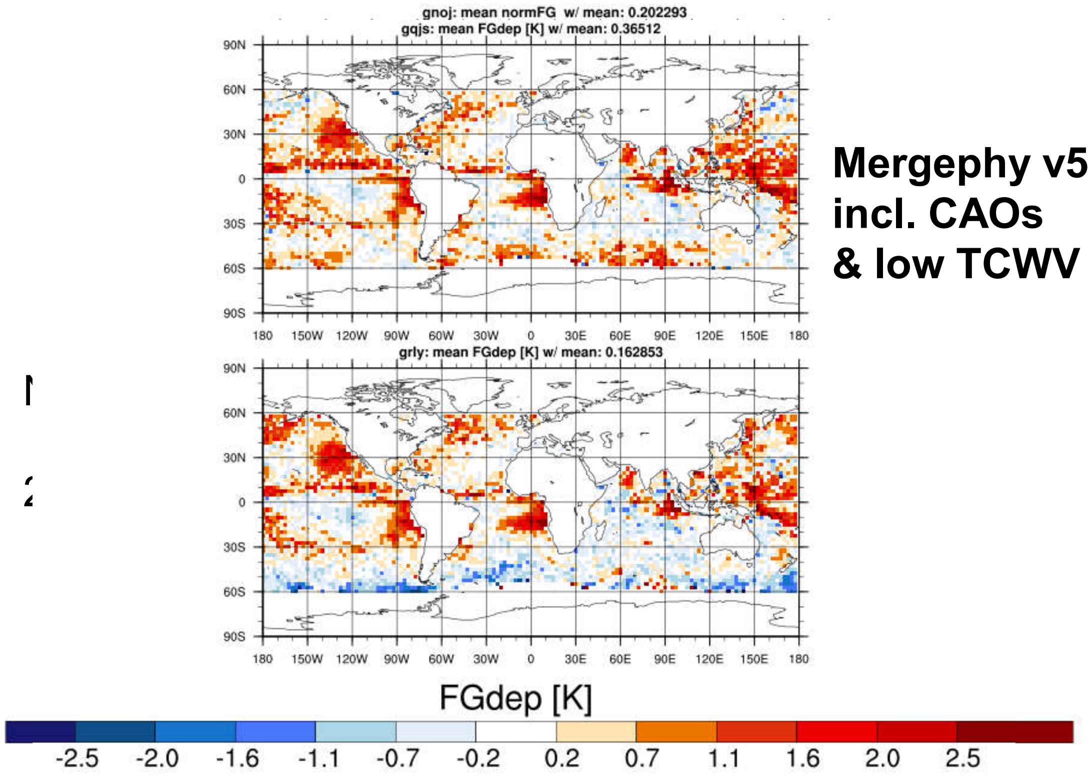
for Cy45r1 merged physics: cloud+conv



ECMWF

Assessing the SH biases through microwave first-guess departures

Total FG departures



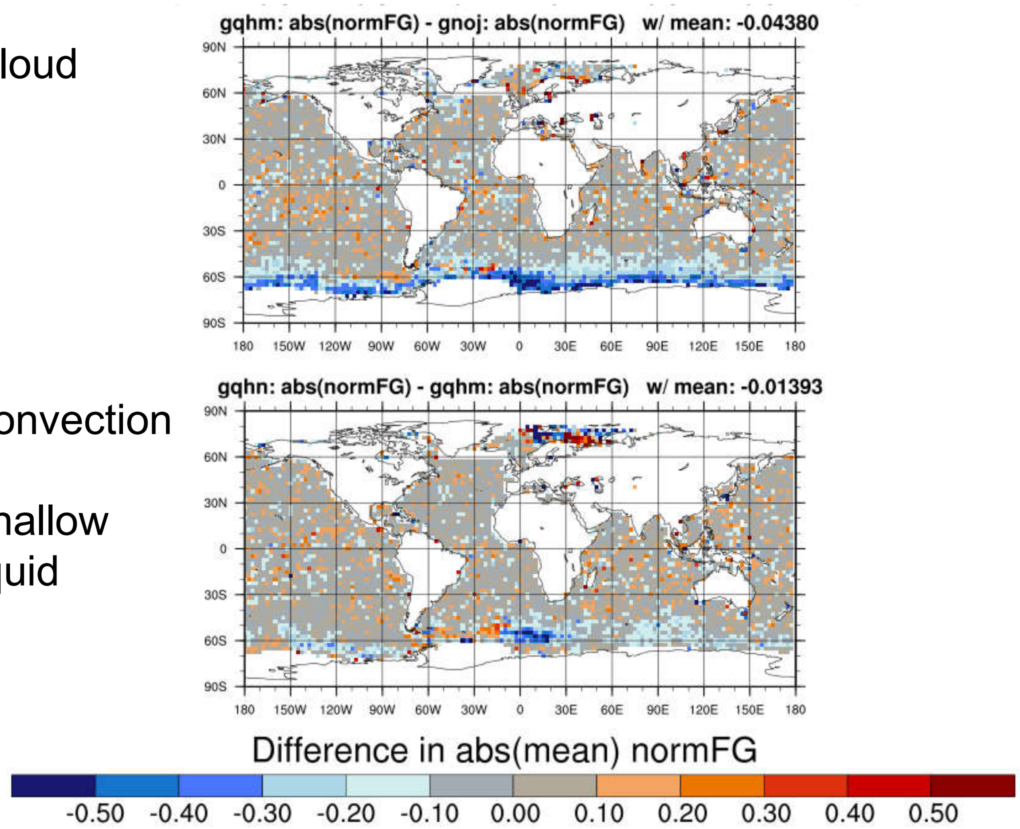
Mergephy v5 incl. CAOs & low TCWV

FG departure changes by contribution

Cloud

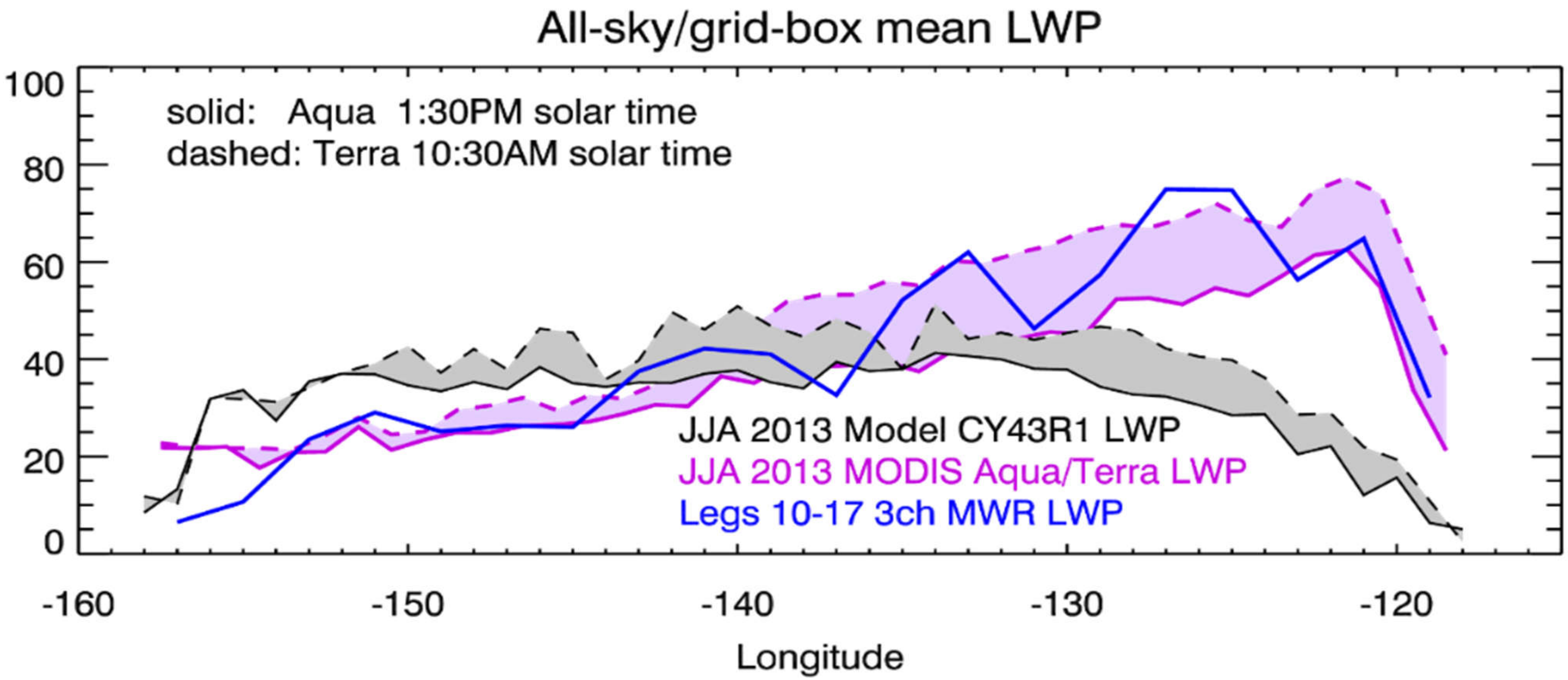
Convection

Shallow liquid



courtesy K. Lonitz

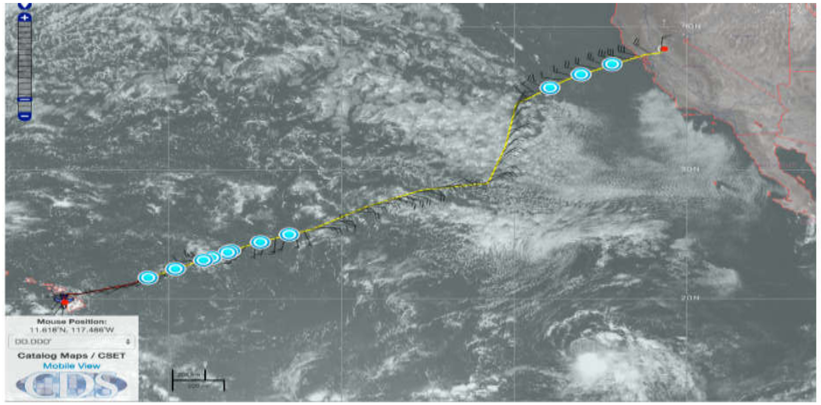
Assessing the SW radiation biases through complementary Satellite and ground-based data



courtesy M. Ahlgrimm

Evaluating forecasts against observations

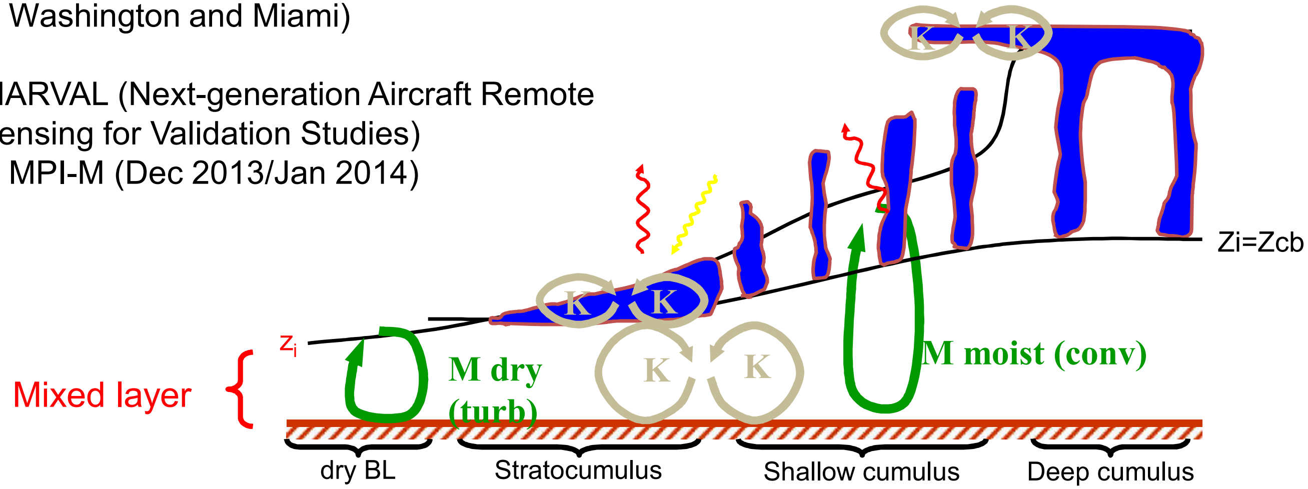
together with Irina S, Maike A., Philippe L., Richard F.



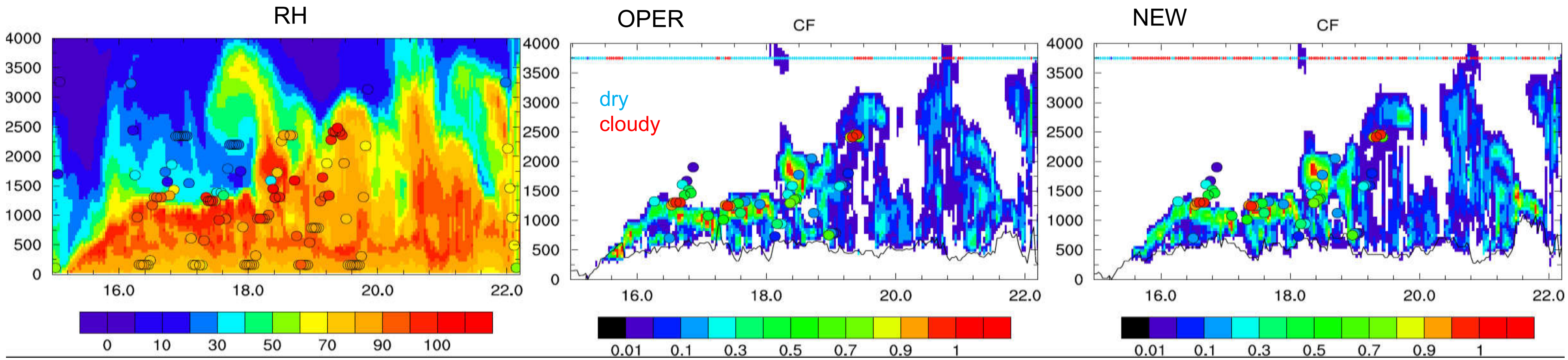
One of the flights during CSET

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)

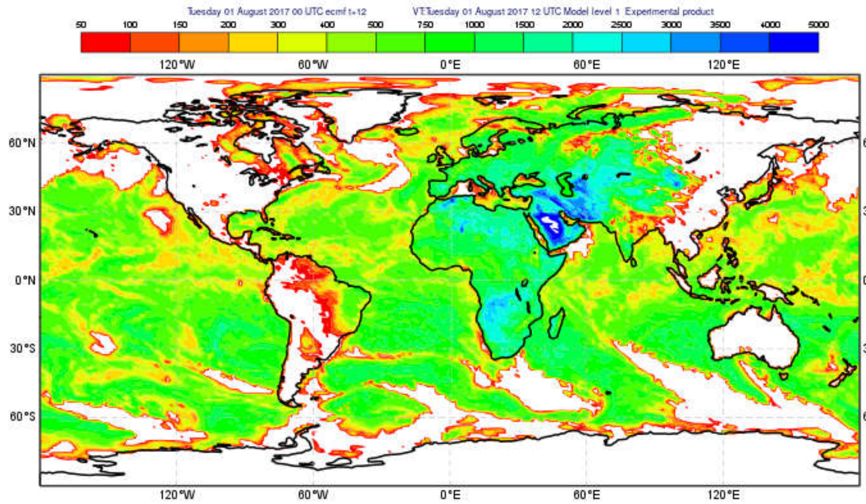


Towards a more unified turbulence, convection, cloud interaction

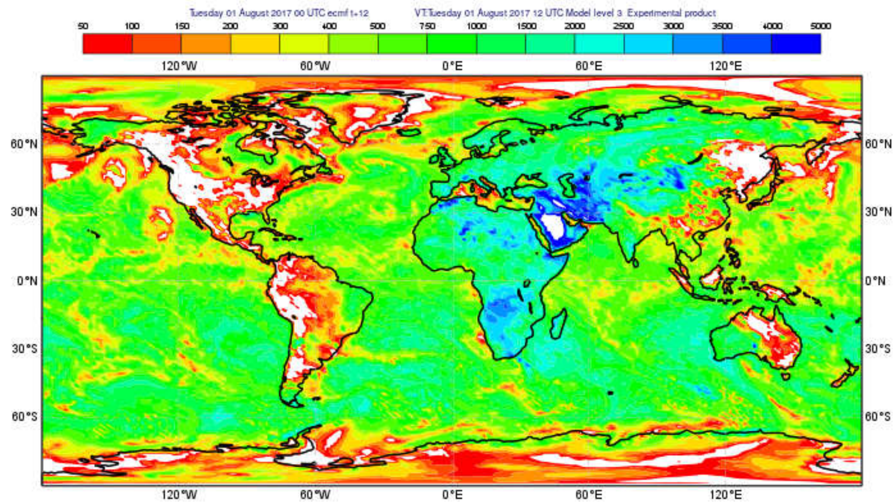


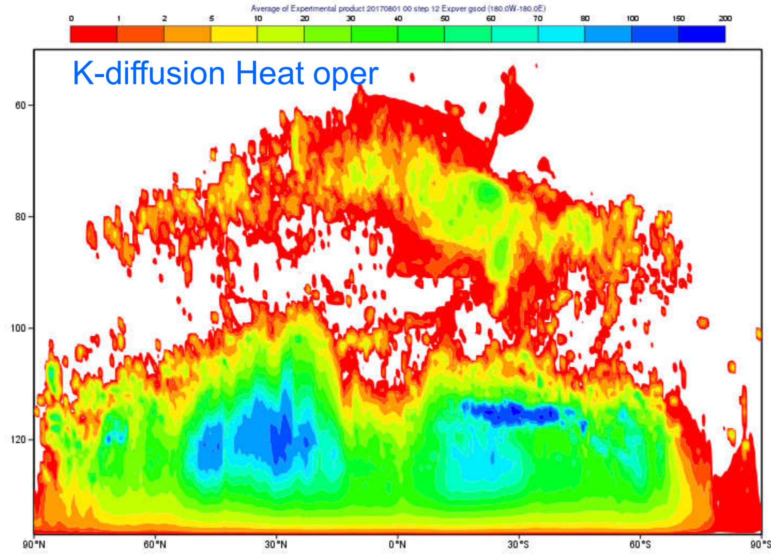
Coupling (experimental) diffusion code and TKE: collaboration with Meteo France (E. Bazile)

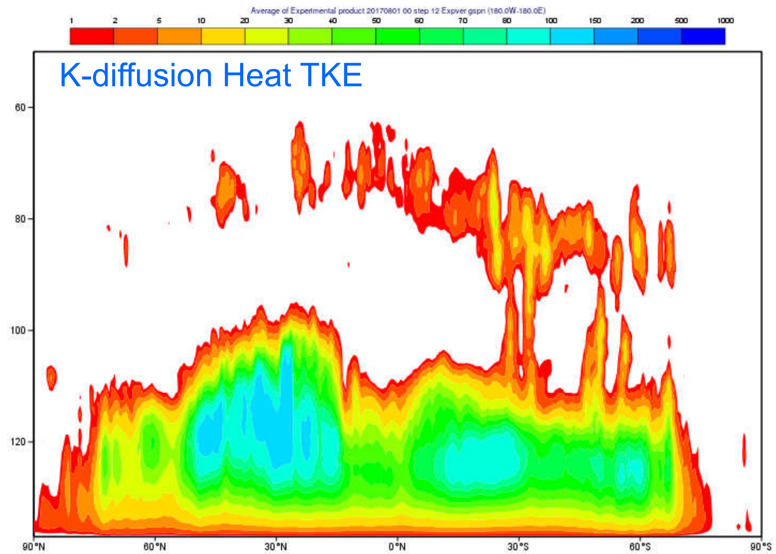
PBL height (m) oper unstable



PBL height (m) TKE diag MeteoFrance







Summary

- Most important is to get tropical winds/large-scale waves right, with still the largest potential for monthly and sub-seasonal predictability

- Addressing model biases in coupled system is top challenge, also propagating night-time mesoscale convective systems

- Good description of microphysics is necessary to assimilate advanced satellite observations (radiances) and reduce model radiation biases

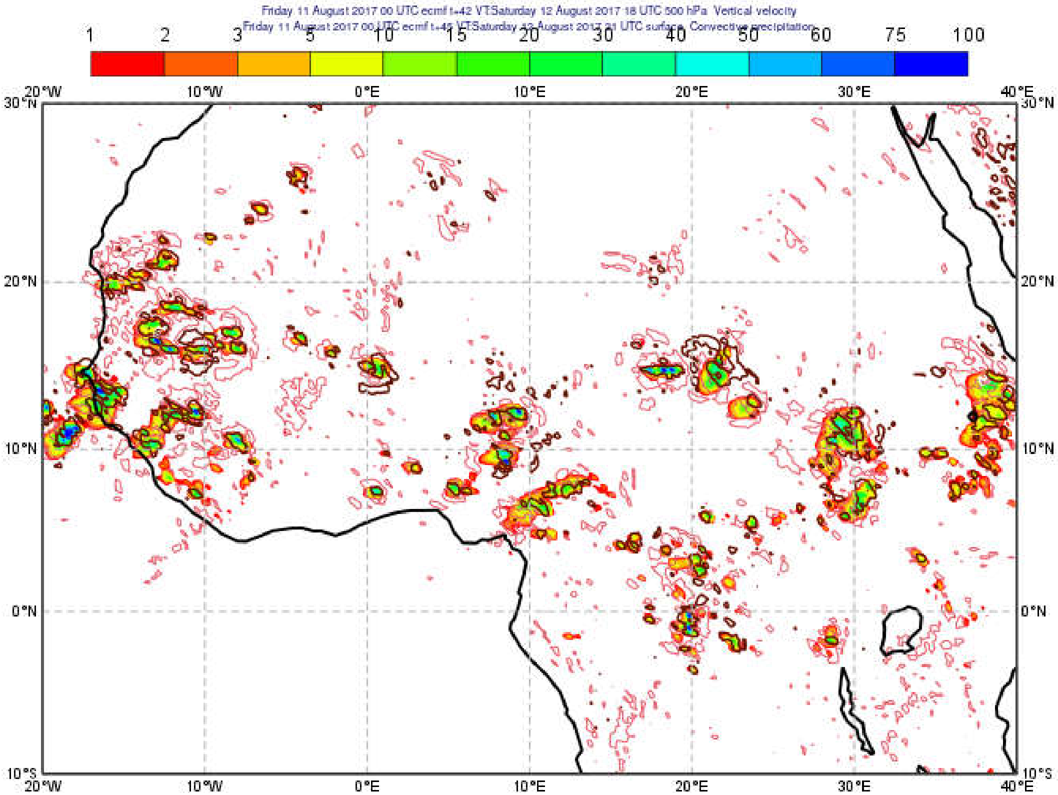
- Ensemble based method is crucial, including a physically based representation of model uncertainty

- Trade wind and subtropical cloud transition regions still show wind/cloud biases, convective momentum transport seems ok and mainly downgradient, but what about strong shear Sc (East Pacific)?

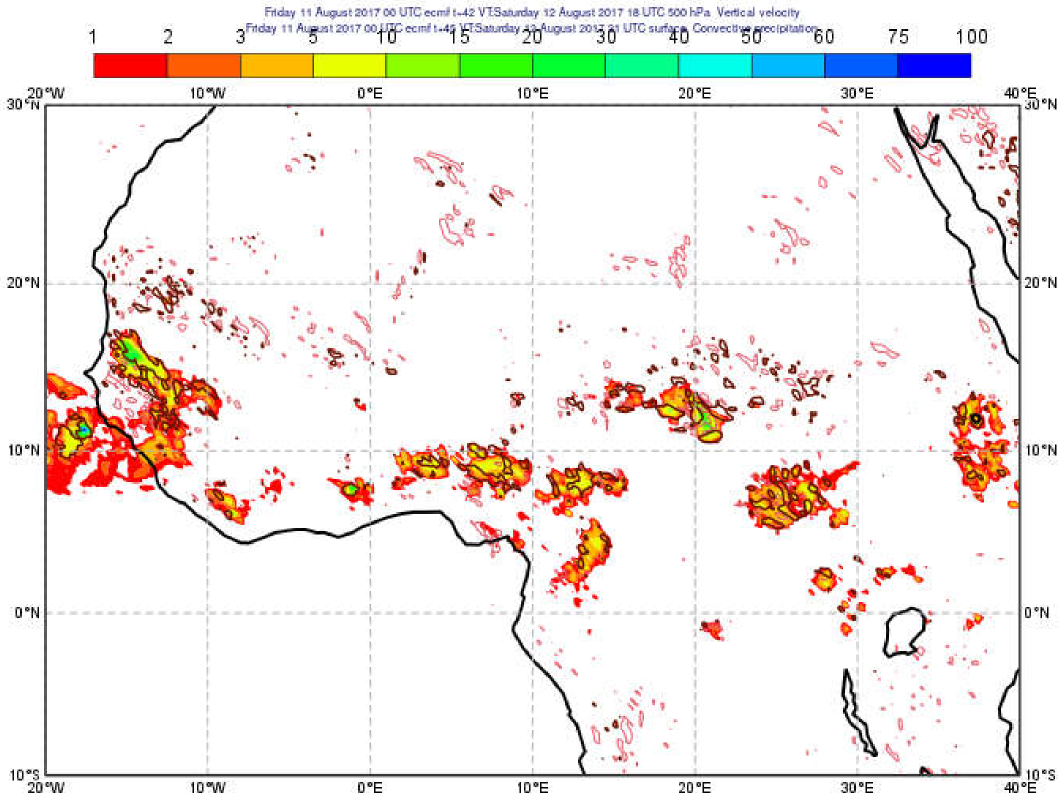
- Evaluating convective mass source in continuity equation (S. Malardel), continue PBL revision

- What do you expect from 1 km global models in tropics? Popcorn vs squall lines/outflow. What do you expect from massive multi-plume schemes with (Markov chain) memory? What do you expect from Super/Ultra parametrization? And what from multi-grid, non-local column methods?

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



No deep



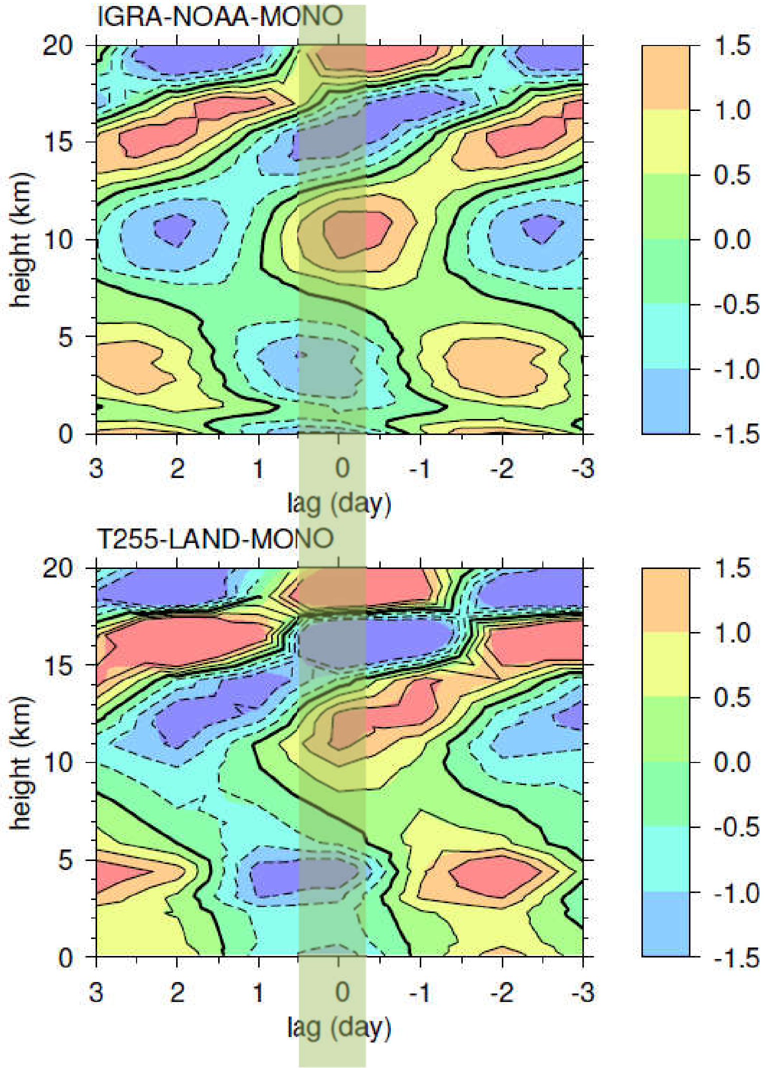
Oper

Kelvin waves: vertical structure

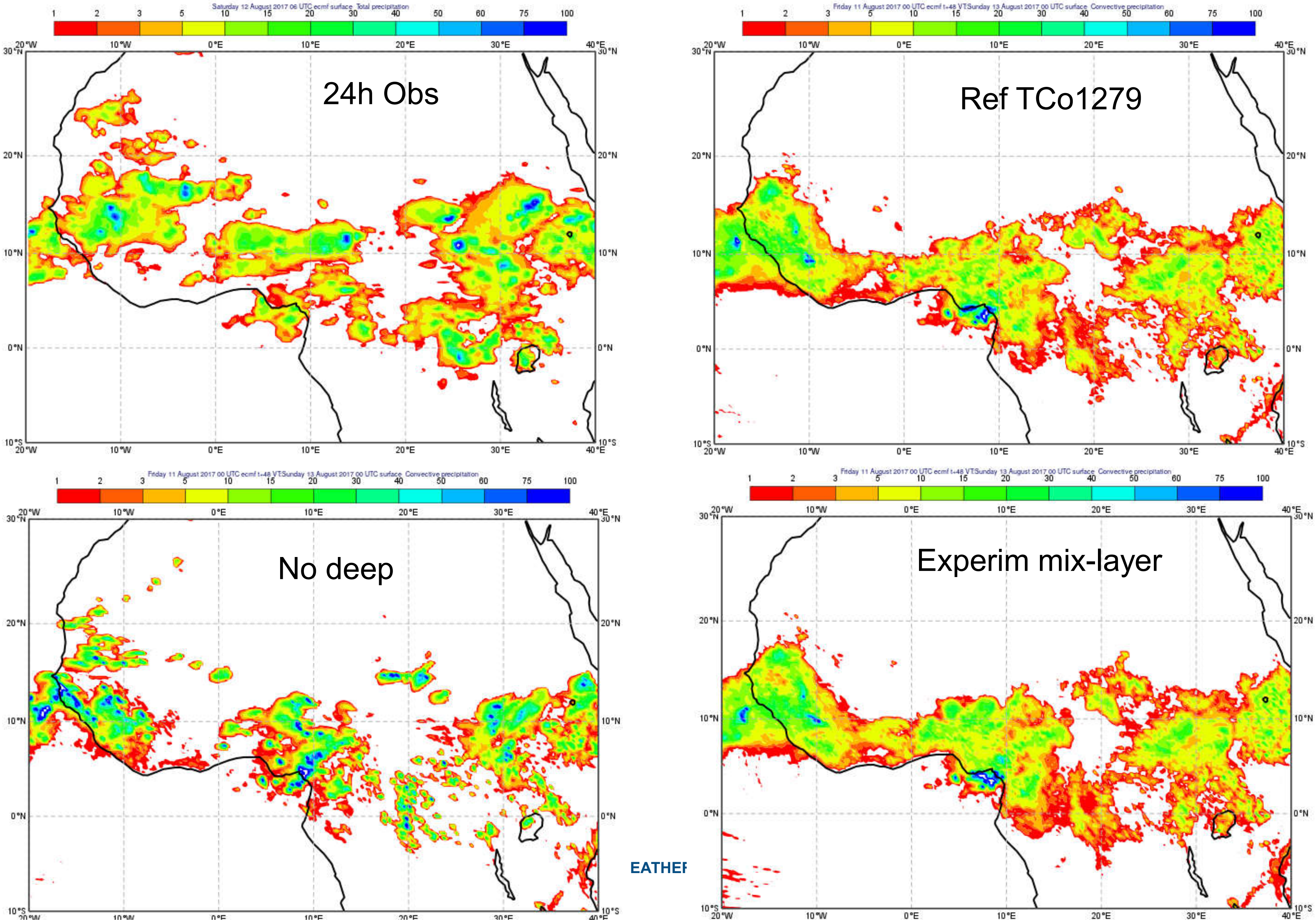
At z~10 km, warm anomaly and convective heating are in phase, leading to :

- 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.)


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
No deep
Experim mix-layer

EATHEF