35 years old or forever young?
Part I Aspects with the convection in the IFS now and in the ERA6

Peter Bechtold, Rheinmünster

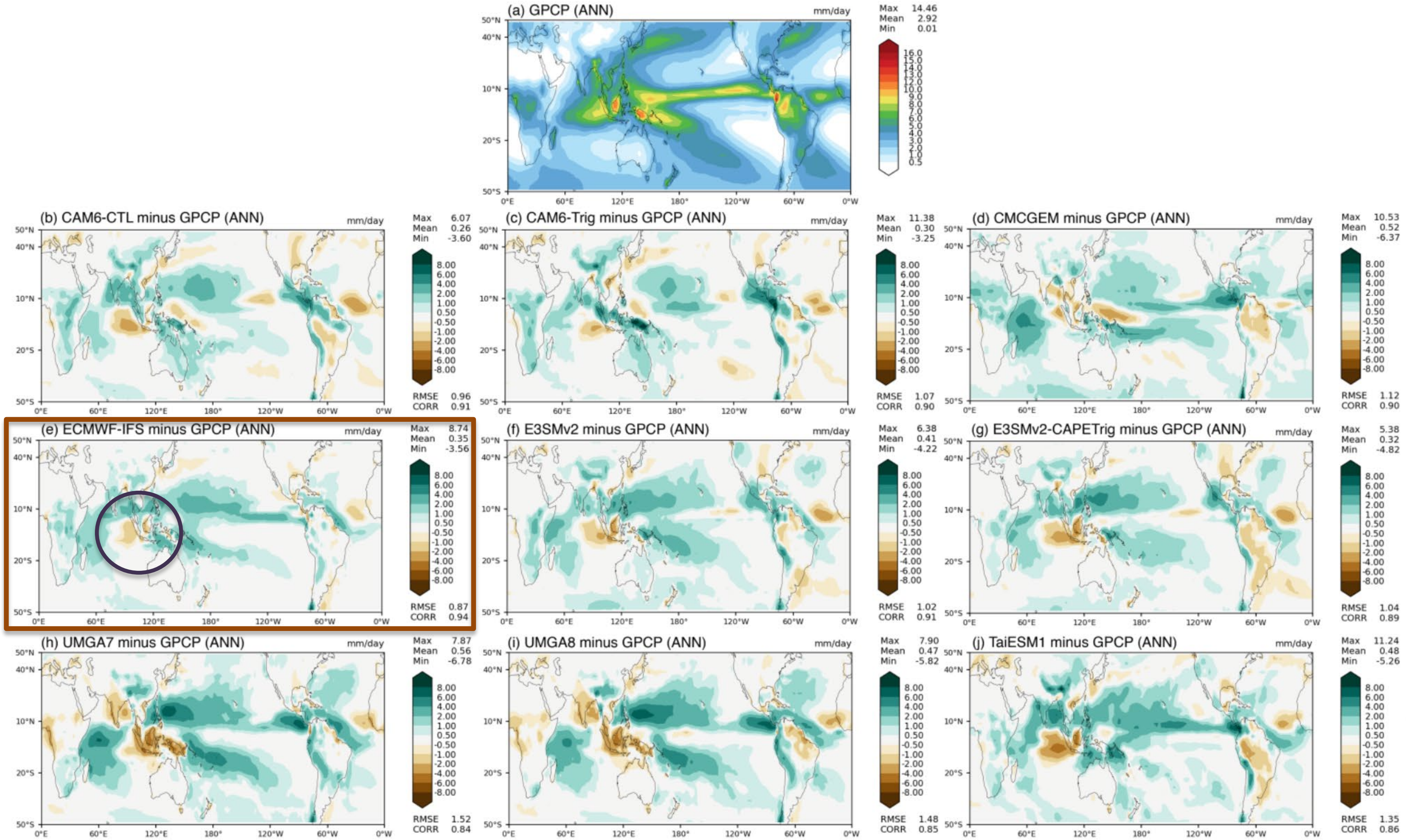
grateful to my colleagues, retrospectively to A. Beljaars, P. Bougeault, JF Geleyn, M. Miller, A. Simmons, to predecessors (M. Tiedtke, D. Gregory, C. Jakob)
and **ICON** (G. Zängl, M. Ahlgrimm, M. Köhler) and **Arpège** (Y. Bouteloup, E. Bazile, P. Marquet, J.M. Piriou) for making this possible

GASS diurnal cycle experiment: precip mean climate-GPCP uncoupled

Something general across models ???
IFS 47r3

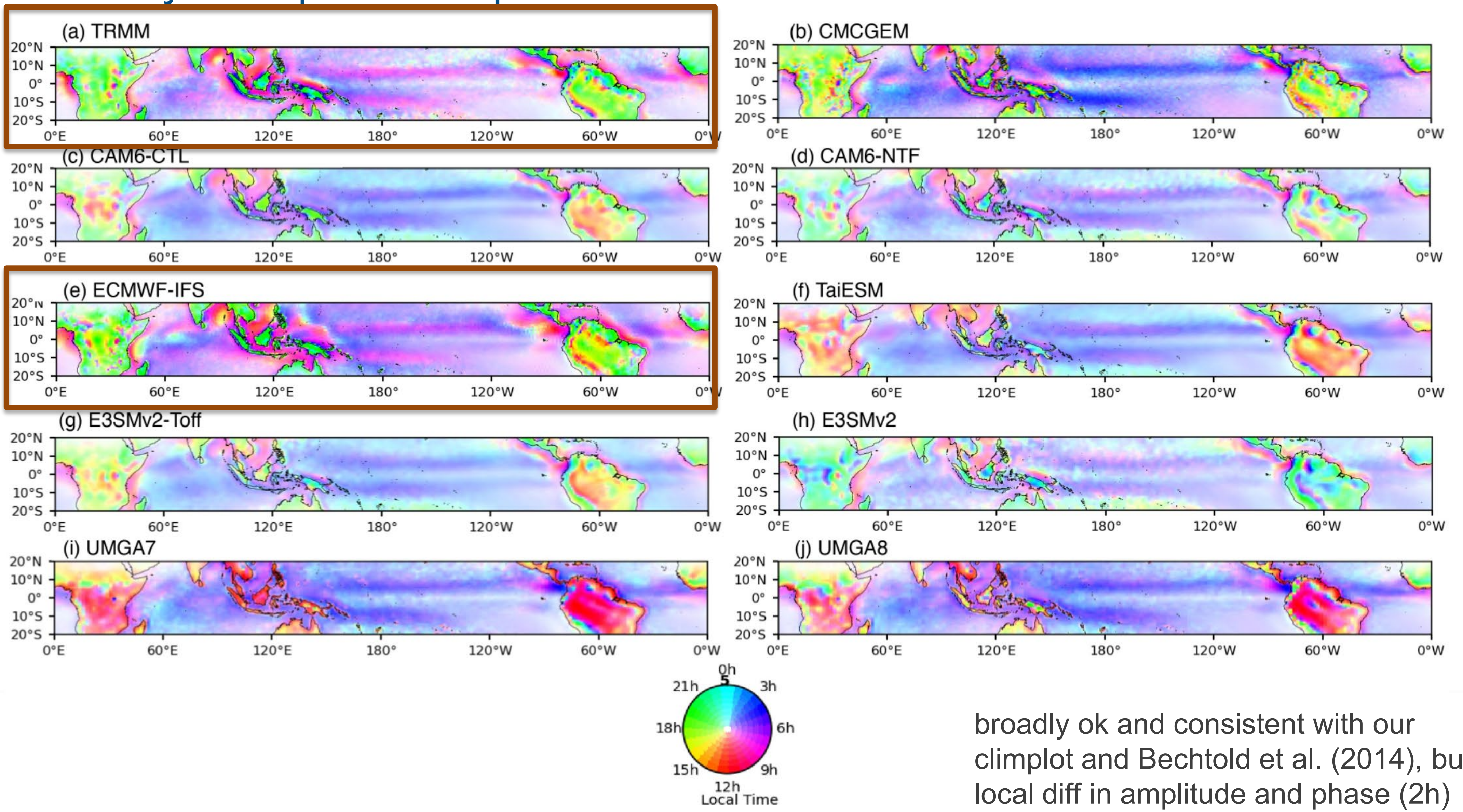
See Tao-Chen, Shaocheng Xie presentation in Monterey this summer

For wind SST effect see M. Mayer et al. 2022, ECMWF Tech Memo



GASS diurnal cycle experiment: phase

See also Tao-Chen, Shaocheng Xie presentation in Monterey this summer



broadly ok and consistent with our climplot and Bechtold et al. (2014), bu local diff in amplitude and phase (2h)

Convective fluxes

Resolution scaling: allowed without changing equations? Linear vs non-linear

DWD (G. Zängl)

$$\overline{\rho w' \psi'} = M_{\mathrm{up}} \left(1 - \frac{w_{\mathrm{env}}}{w_{\mathrm{up}}}\right) (\psi_u - \overline{\psi}) = M_{\mathrm{up}} \alpha_{\mathrm{x}} (\psi_u - \overline{\psi})$$

see Malardel&Bechtold QJRMS (2019)

Closure: CAPE+moisture advection

$$M_{\mathrm{base}} = M^{\star}_{\mathrm{base}} \frac{\mathrm{PCAPE}' + \mathrm{QCV} - \mathrm{PCAPE}_{\mathrm{bl}}}{\tau} \frac{1}{\int_{z_{\mathrm{base}}}^{z_{\mathrm{top}}} \frac{g}{\bar{T}_{\mathrm{v}}} M^{\star} \left(\frac{\partial \bar{T}_{\mathrm{v}}}{\partial z} + \frac{g}{c_p}\right) \mathrm{d}z}; \qquad M_{\mathrm{base}} \geq 0$$

$$\mathrm{QCV} = -\alpha_{\mathrm{qcv}} L_{\mathrm{vap}} \tau_c \frac{1}{g\ H} \int_{p_{\mathrm{surf}}}^{60\mathrm{hPa}} \left(\frac{\bar{q}}{\bar{q}_{\mathrm{sat}}}\right) \frac{\partial \bar{q}_{\mathrm{v}}}{\partial t}\Big|_{\mathrm{adv}} dp; \qquad \alpha_{\mathrm{qcv}} = 0.8$$

see T. Becker, Bechtold, I. Sandu QJRMS (2021)

Coupling convection and cloud scheme (liquid/ice & rain/snow)

Conv detrain= cloud Source: condensate, rain/snow

Conv Subsidence done in cloud scheme!!= implicit evaporation

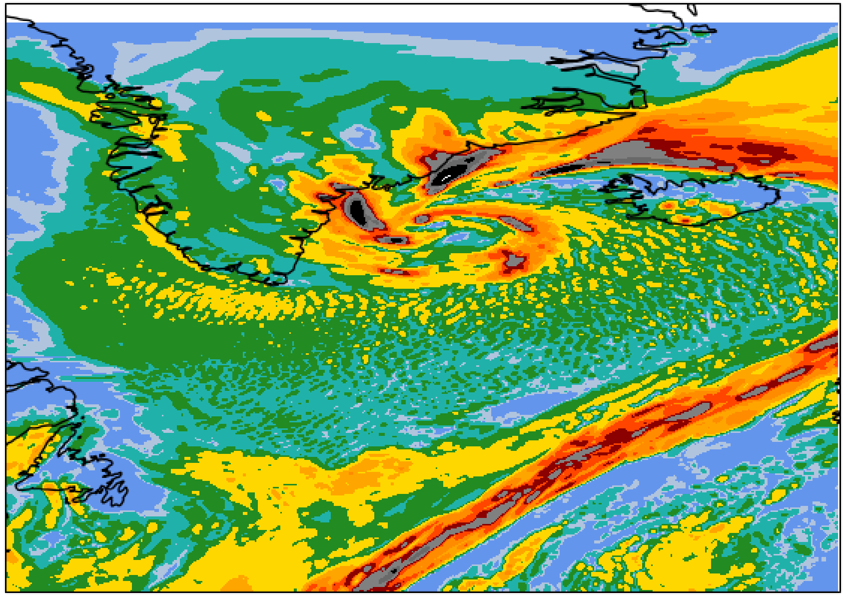
$$\left(\frac{\partial \bar{l}}{\partial t}\right)_{\mathrm{cu}} = g\frac{\partial}{\partial p}[M_{\mathrm{up}}l_{\mathrm{up}} - (M_{\mathrm{up}} + M_{\mathrm{down}})\bar{l})] = D_{\mathrm{up}}l_{\mathrm{up}} - g\frac{\partial}{\partial p}[(M_{\mathrm{up}} + M_{\mathrm{down}})\bar{l}]$$

$$\left(\frac{\partial \bar{r}}{\partial t}\right)_{\mathrm{cu}} = g\frac{\partial}{\partial p}[M_{\mathrm{up}}r_{\mathrm{up}} - (M_{\mathrm{up}} + M_{\mathrm{down}})\bar{l})] = D_{\mathrm{up}}r_{\mathrm{up}} - g\frac{\partial}{\partial p}[(M_{\mathrm{up}} + M_{\mathrm{down}})\bar{r}]$$

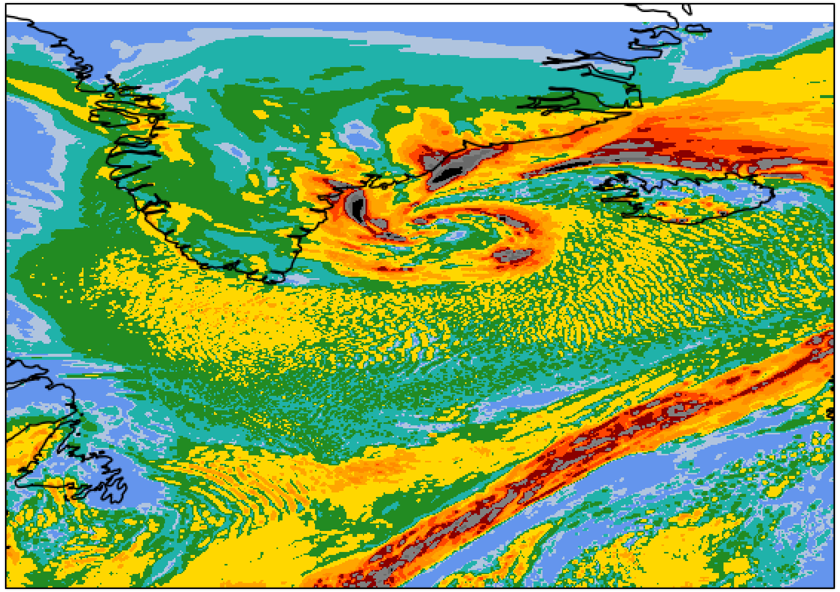
- *Note: above form is valid only for cloud species as it is assumed E=entrainment=0*
- *For rain/snow detrainment, we can increase this term to a fraction of the actual convective rain/snow production, then also radiation will see much more convective snow*

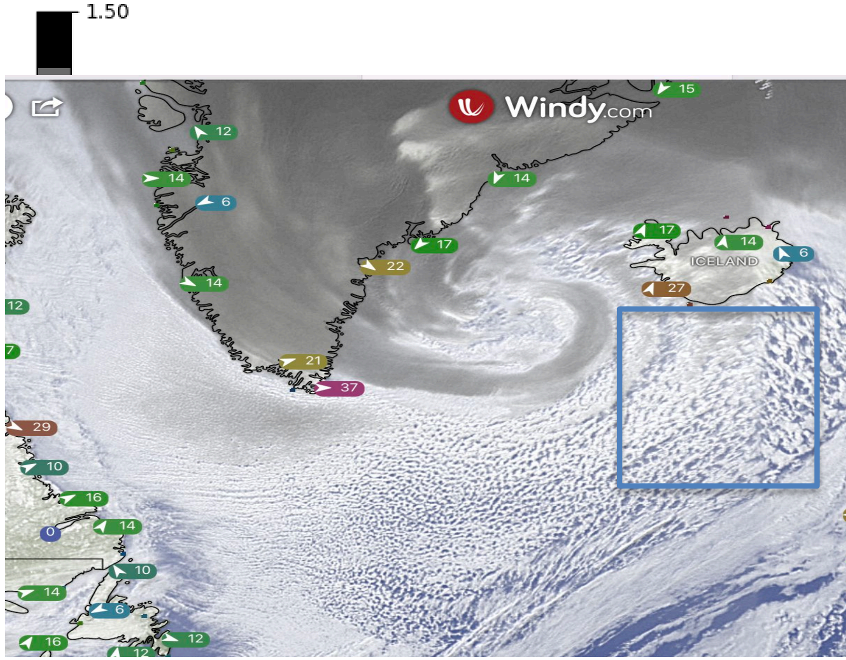
Convective organisation in cold air outflow 20220207 15 UTC mit Maike Ahlgrimm

Total column water, Oper 9 km

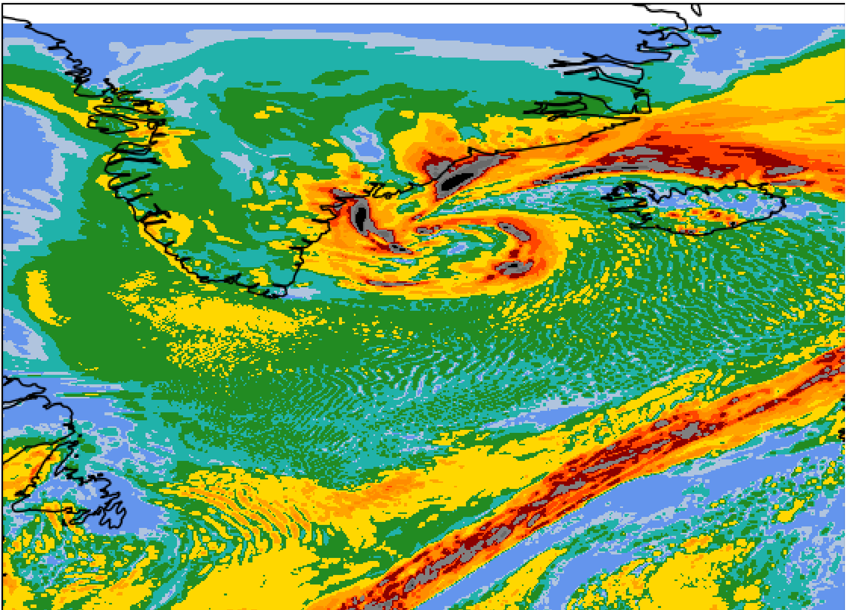


Total column water, 4 km

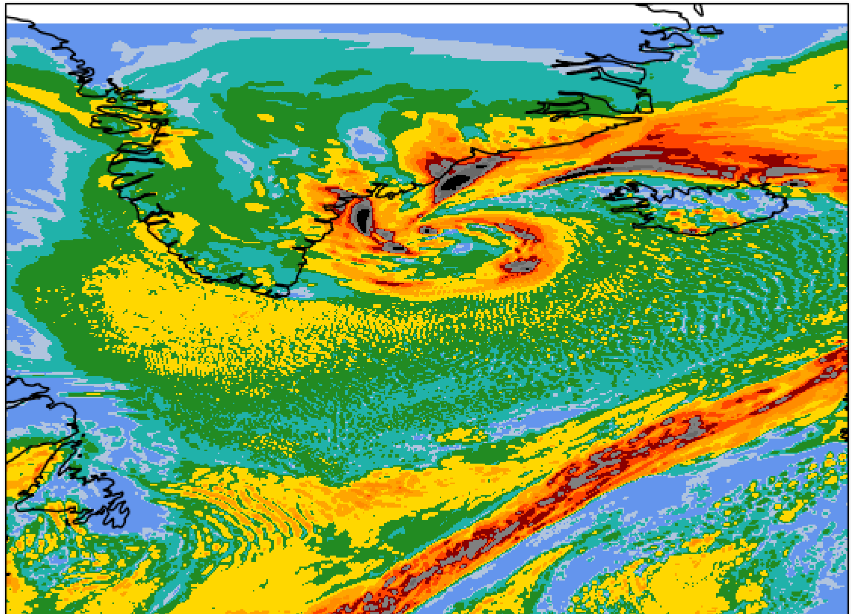




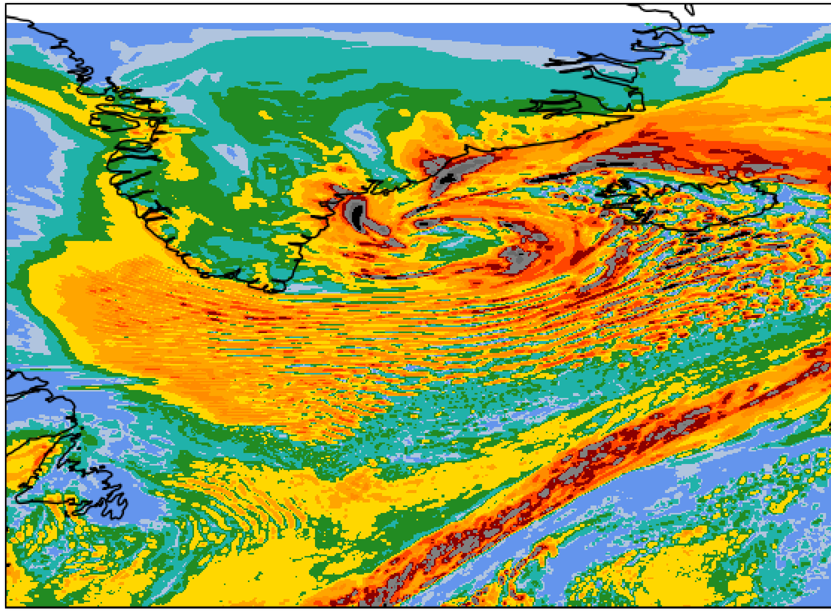
Total column water, CFL=1



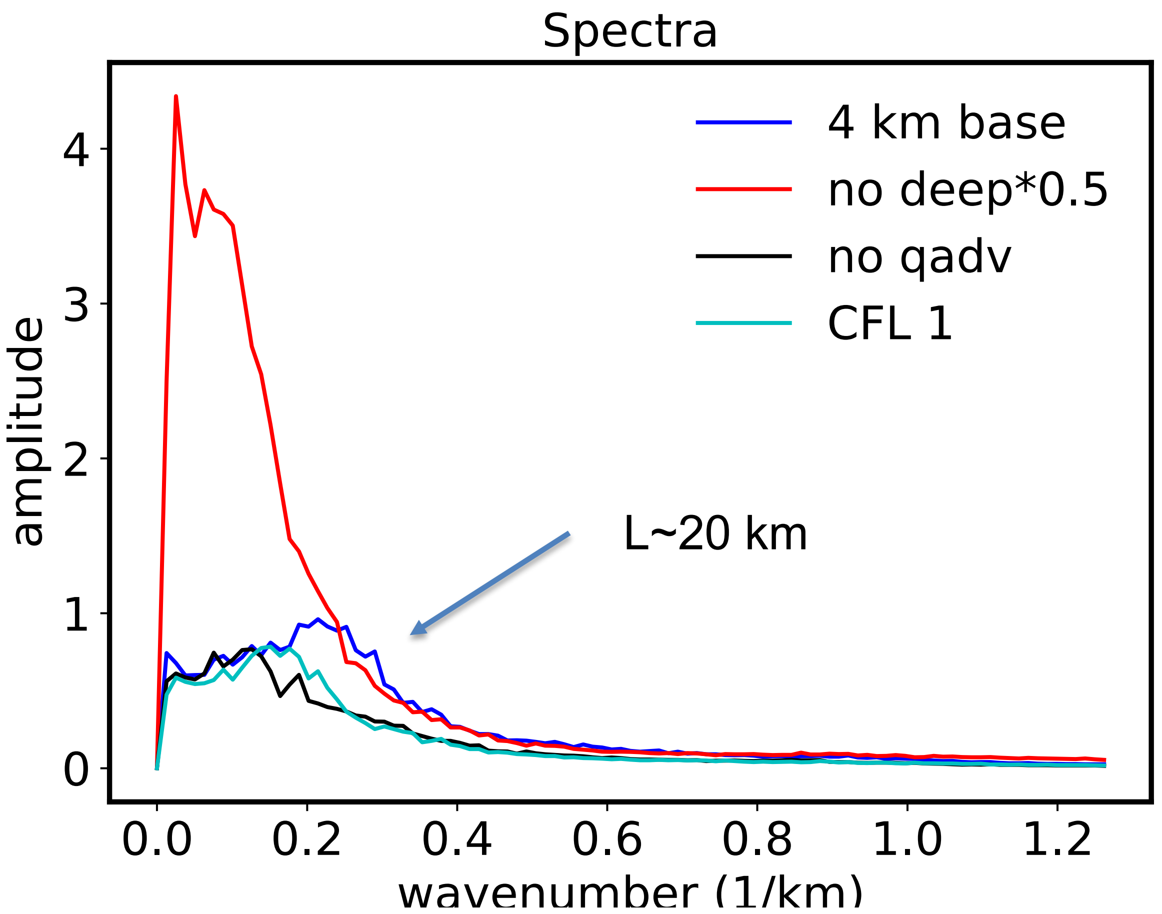
Total column water, no qadv



Total column water, no deep



over window south of Iceland

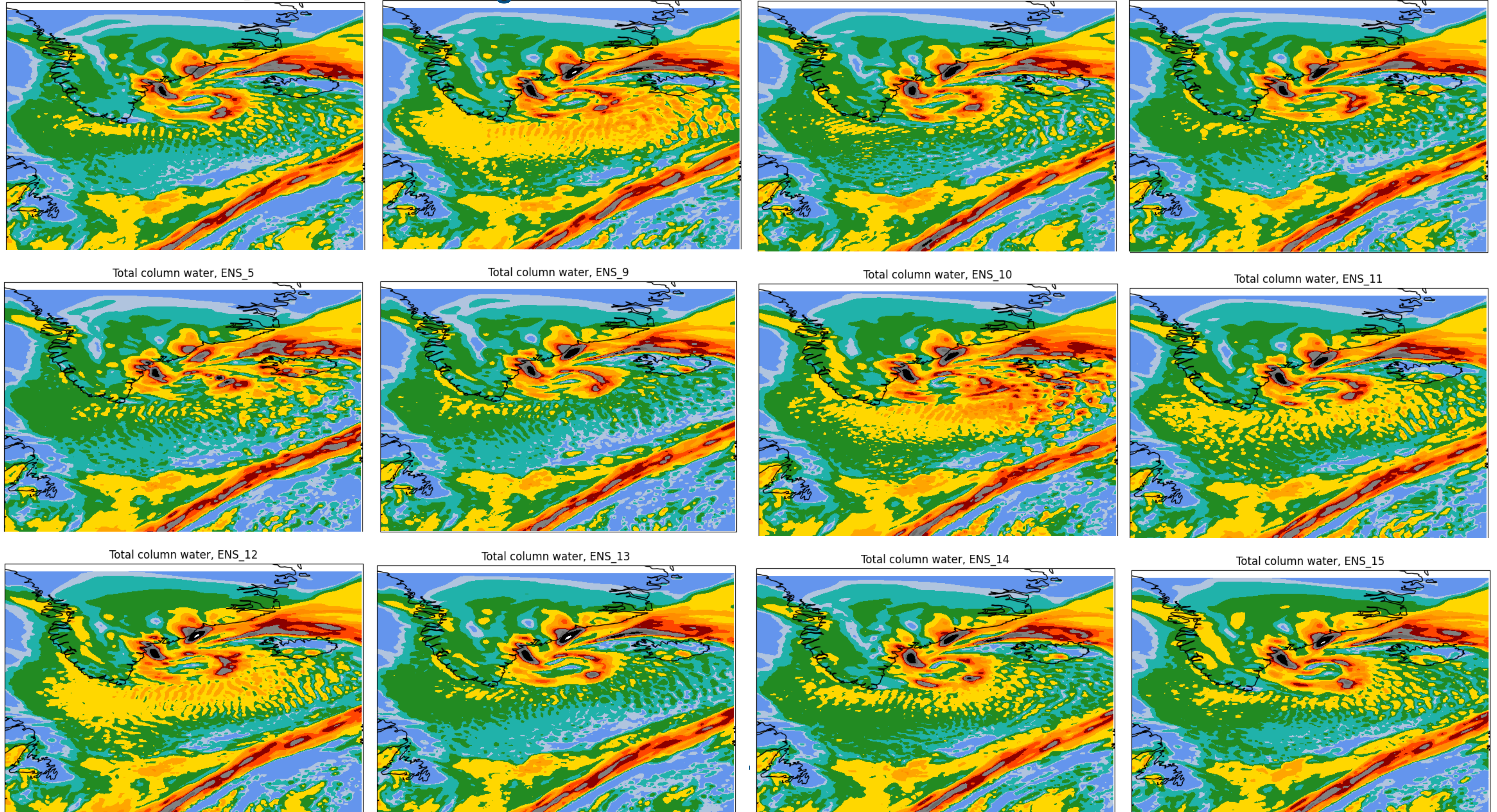


Making convection more intense-> smaller scales

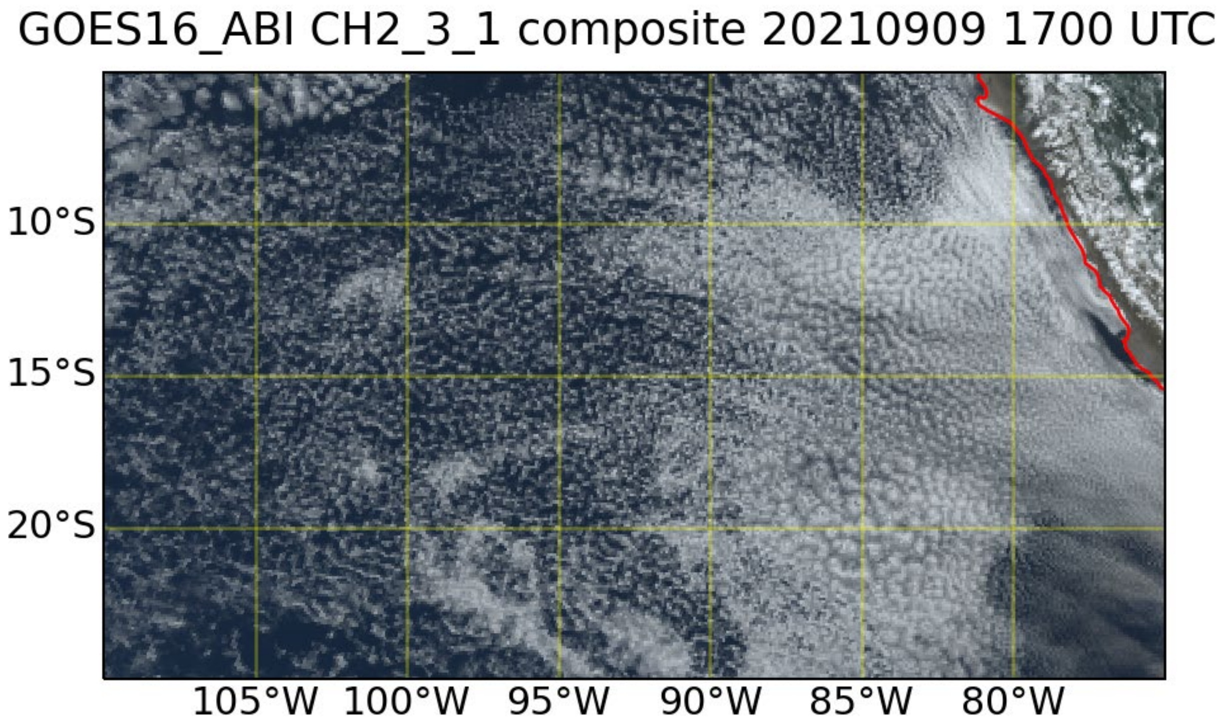
Switching off -> too intense, also larger scales affected

SPP Conv

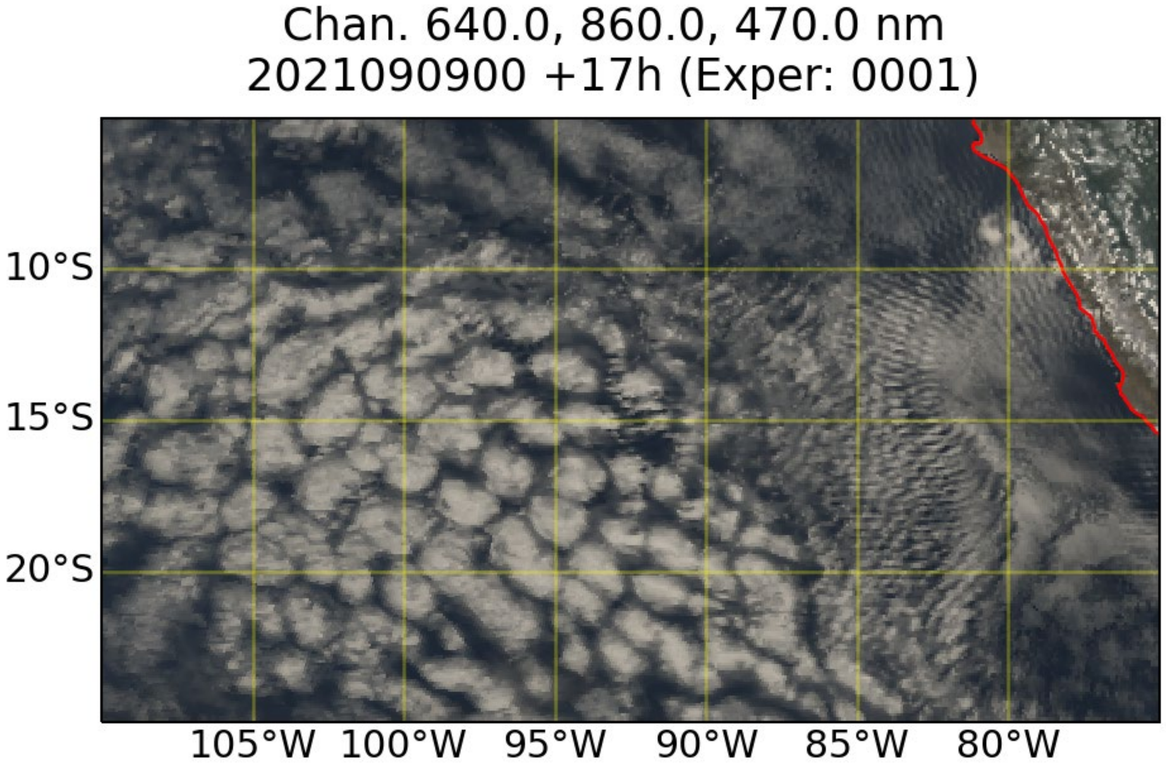
Convective organisation in cold air outflow 20220207 15 UTC



Evaluation of IFS+RRTOV/MFASIS solar reflectances vs GOES16: South Tropical Pacific trade-wind, Peru (P. Lopez et al. ECMWF Tech Memo 892)



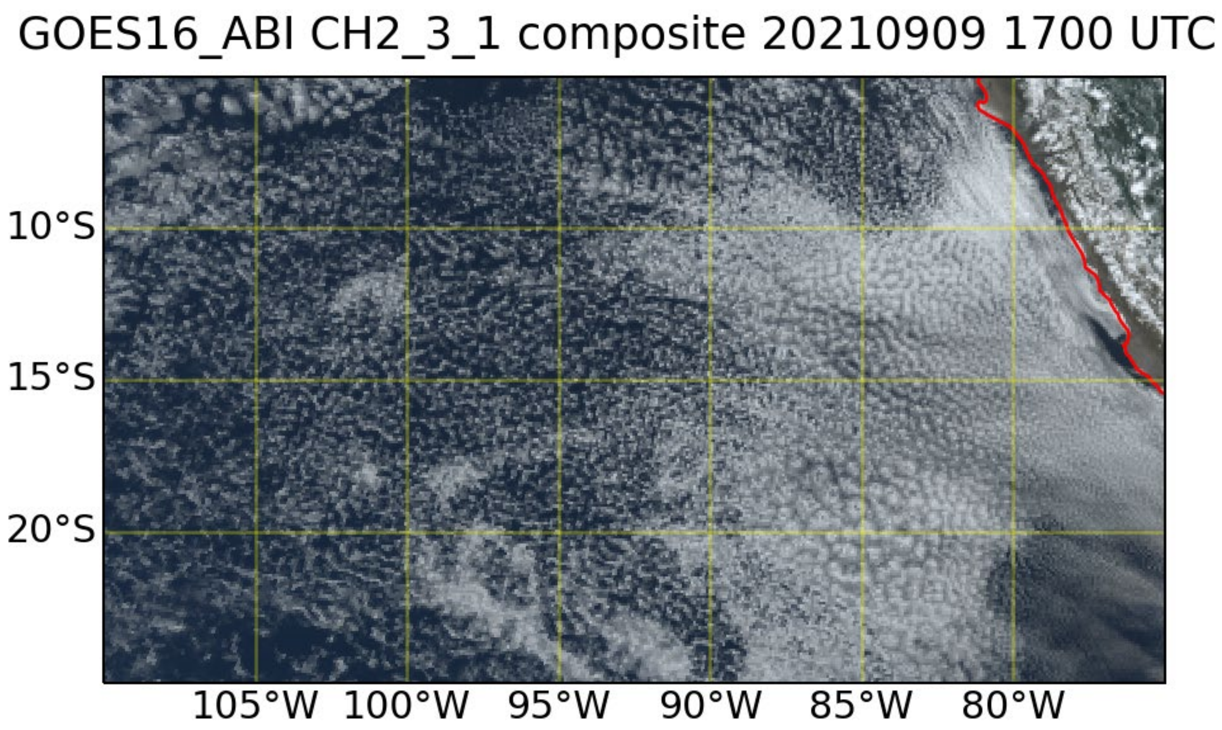
GOES-16 ABI (0.47, 0.64 & 0.86 μm)



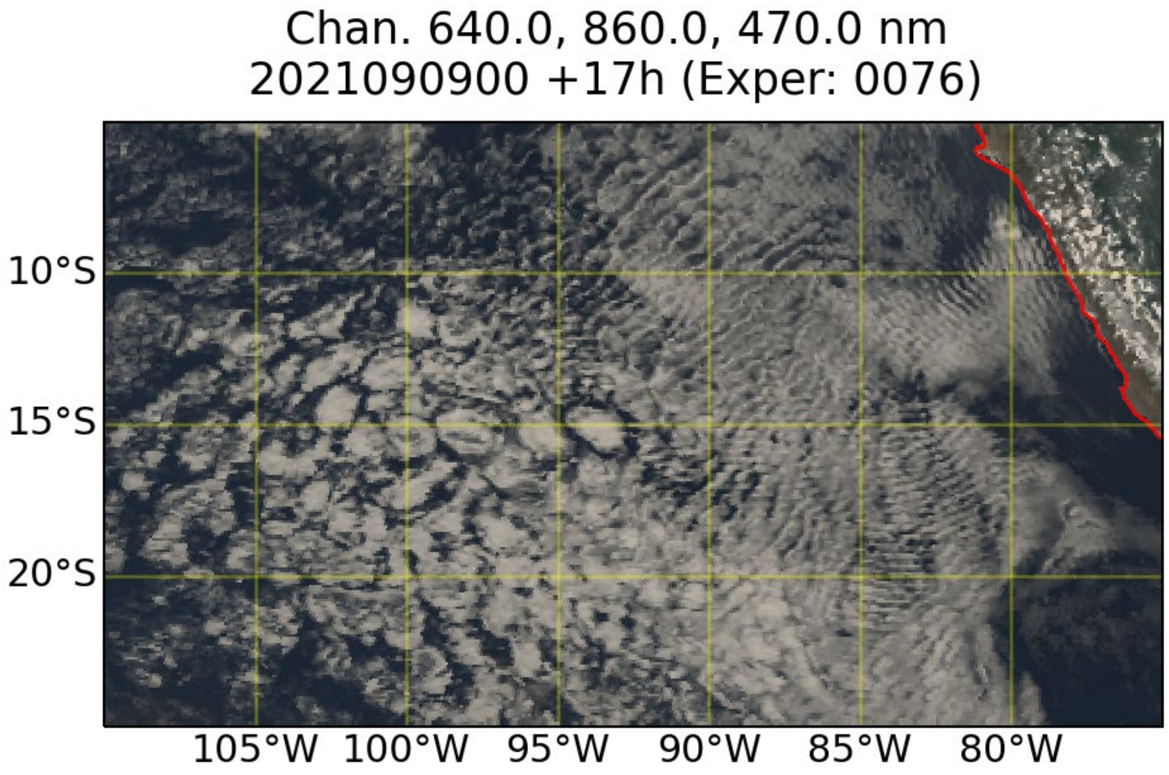
CY47R1

- With CY47r1, IFS produced far too large low-level trade-wind cloud clusters compared to GOES-16 obs.
- Closed-cells in the IFS, but open-cells in satellite obs.

Evaluation of IFS+RRTOV/MFASIS solar reflectances vs GOES16: South Tropical Pacific trade-wind, Peru



GOES-16 ABI (0.47, 0.64 & 0.86 µm)

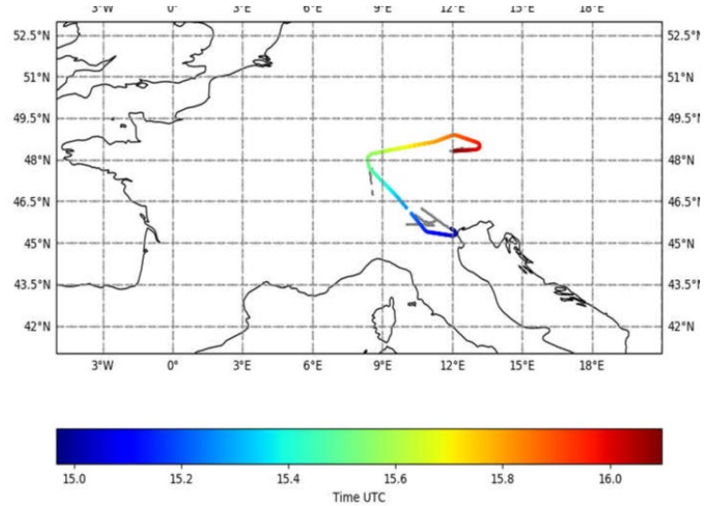


CY47R3

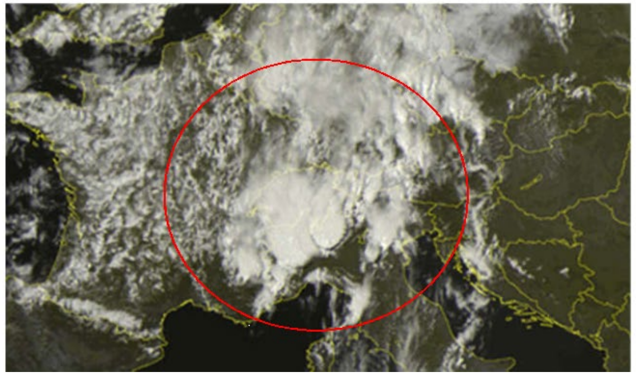
- With CY47r3, trade-wind low-level cloud clusters tend to be smaller, thus closer to GOES-16 obs.

- However, most cloud clusters are still too large.

Improvements, also for ERA6
convective overshoot and water vapor (Konstantin Krüger, Andreas Schäfler DLR)

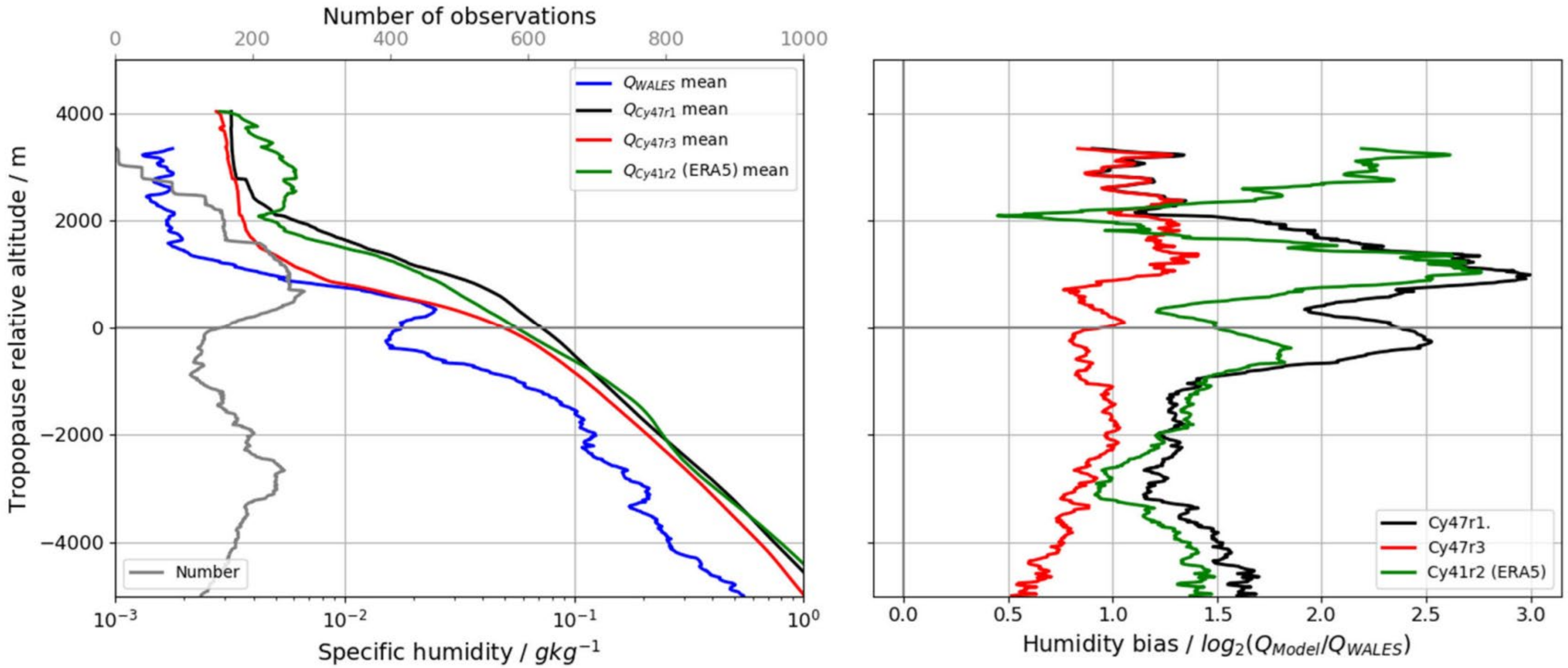


Active convection in northern Italy/ Alps



Case study of an active convection case (8th July 2021)

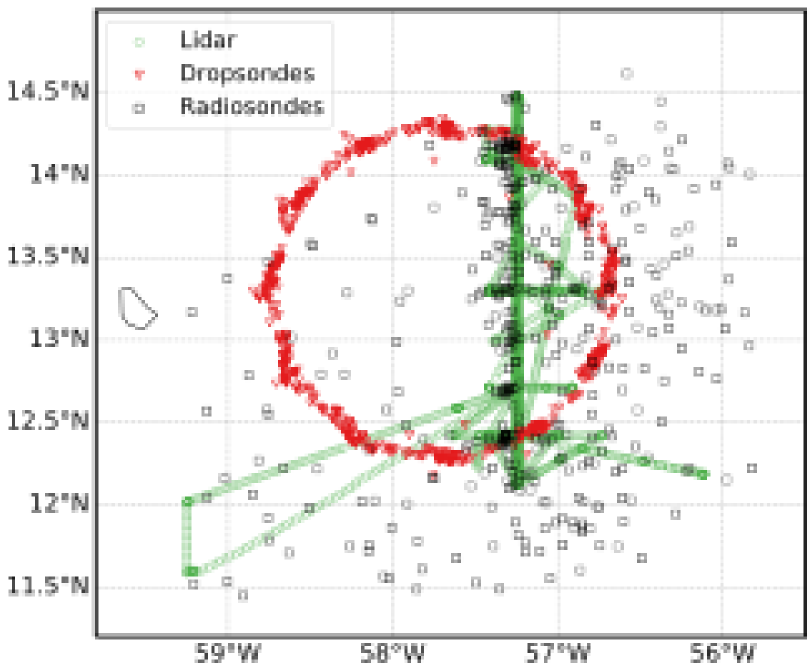
Average profiles of specific humidity (left) and bias (right) for the entire flight



- Bias significantly reduced in Cy47r3
- LMS bias very similar for ERA5 and Cy47r1

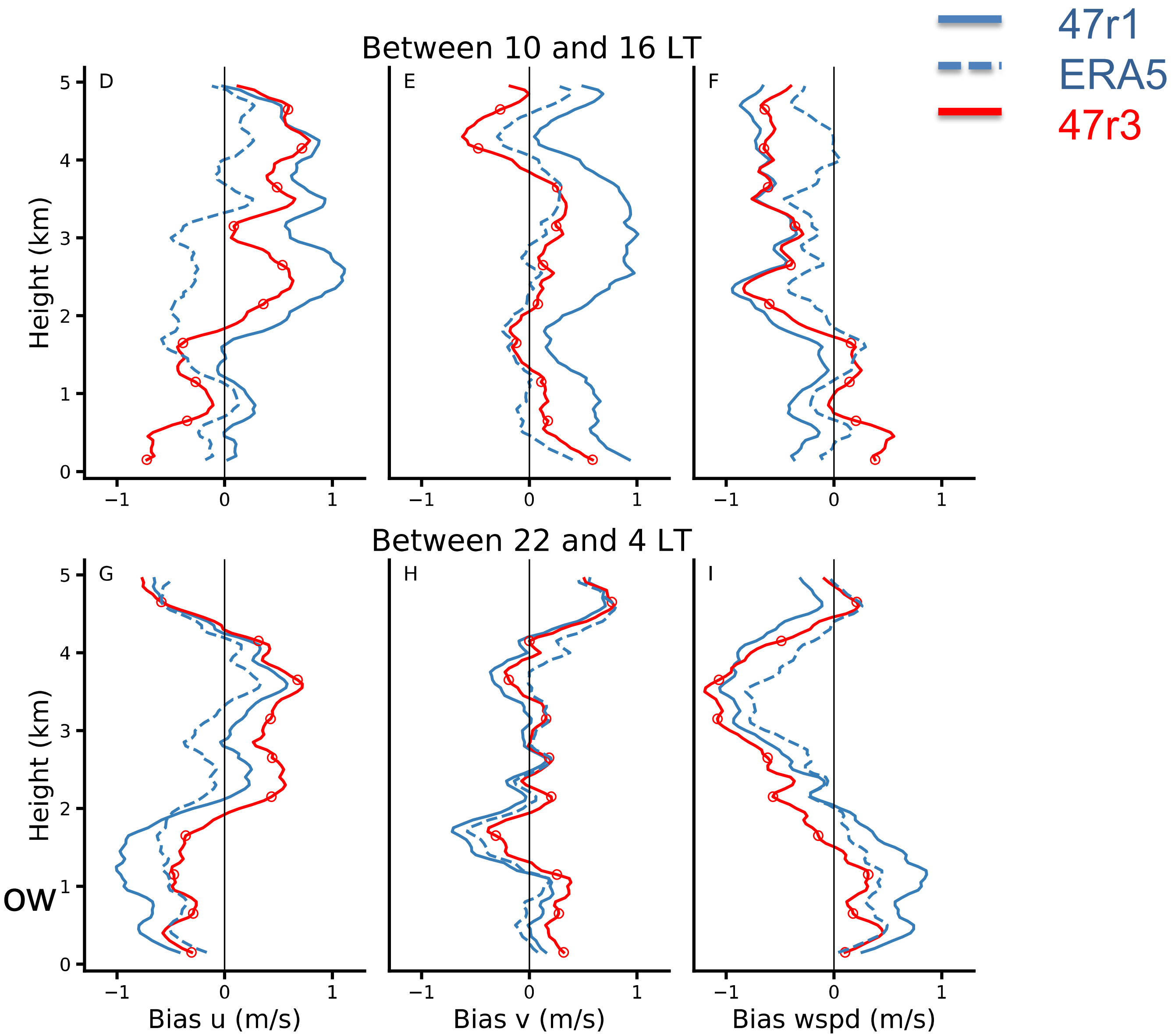
Overshoot correction suggested by G. Zängel DWD

Influence of model physics (Cy47r3) on subtropical winds EUREC4A



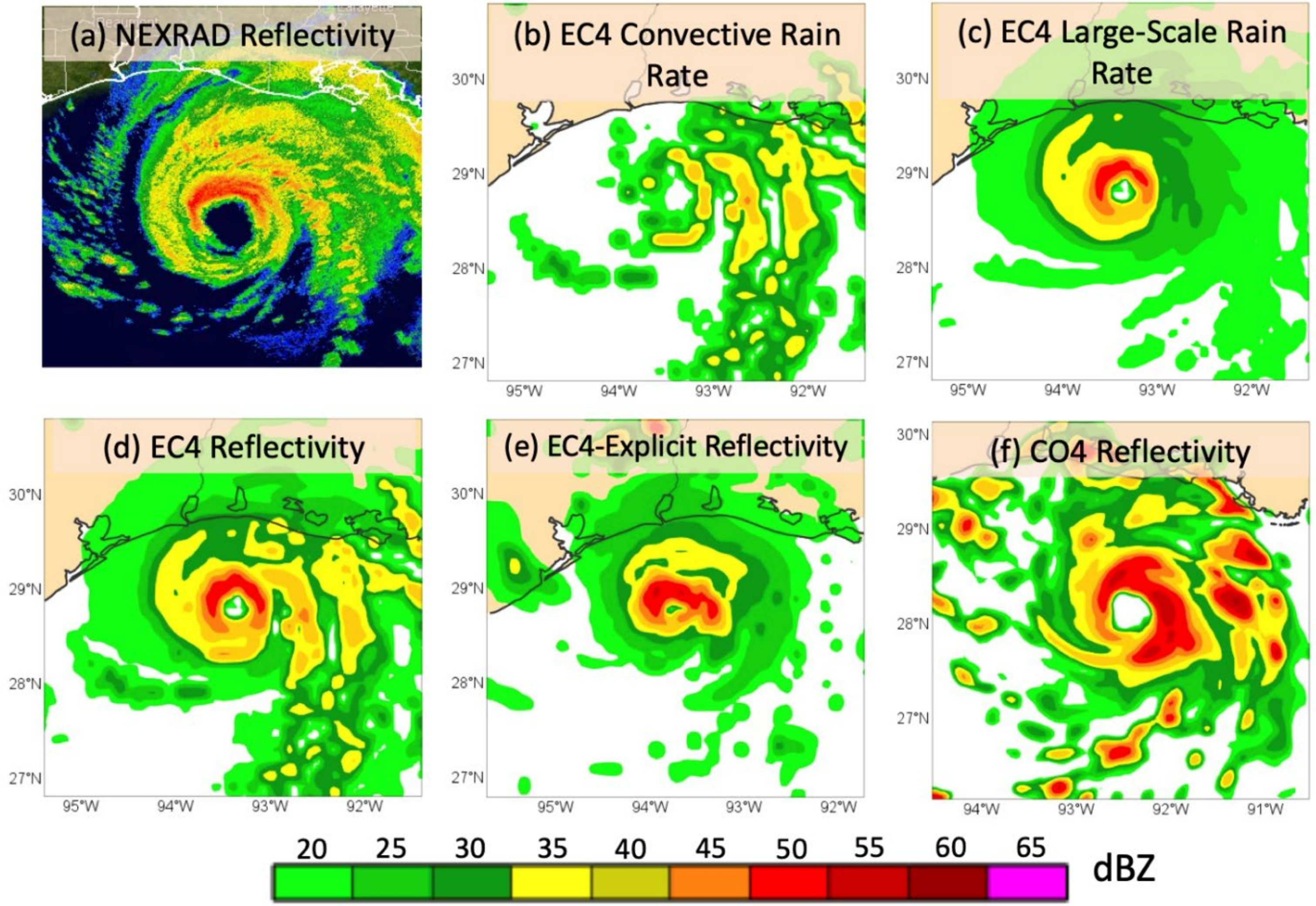
Savazzi et al. 2022, Atmos Chem Phys

see also Schlemmer et al. 2017, JAMES

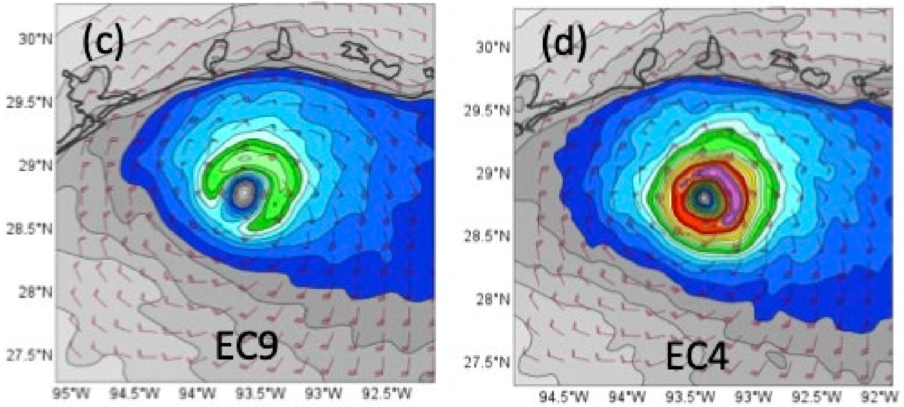


Lessons: need to look at diurnal scales, low-level flow (errors) dependent on free (deep) atmospheric tropical circulation (Hadley/Walker cell)

Convection and tropical cyclones (e.g. Laura 27 August 2020)



4 km resolution/scaling generally good (see also INCITE project Inna, DestinE experimentation), 9 km still too weak. Effect of convective heating in eyewall and strong low-level and weak mid-level inflow (spiraling arms) of θ_e and angular momentum



Majumdar S., L. Magnusson, P. Bechtold, J.-R. Bidlot, J. Doyle, MWR 2022 (submitted)

Vortex sensitivity to convective heating/stabilisation

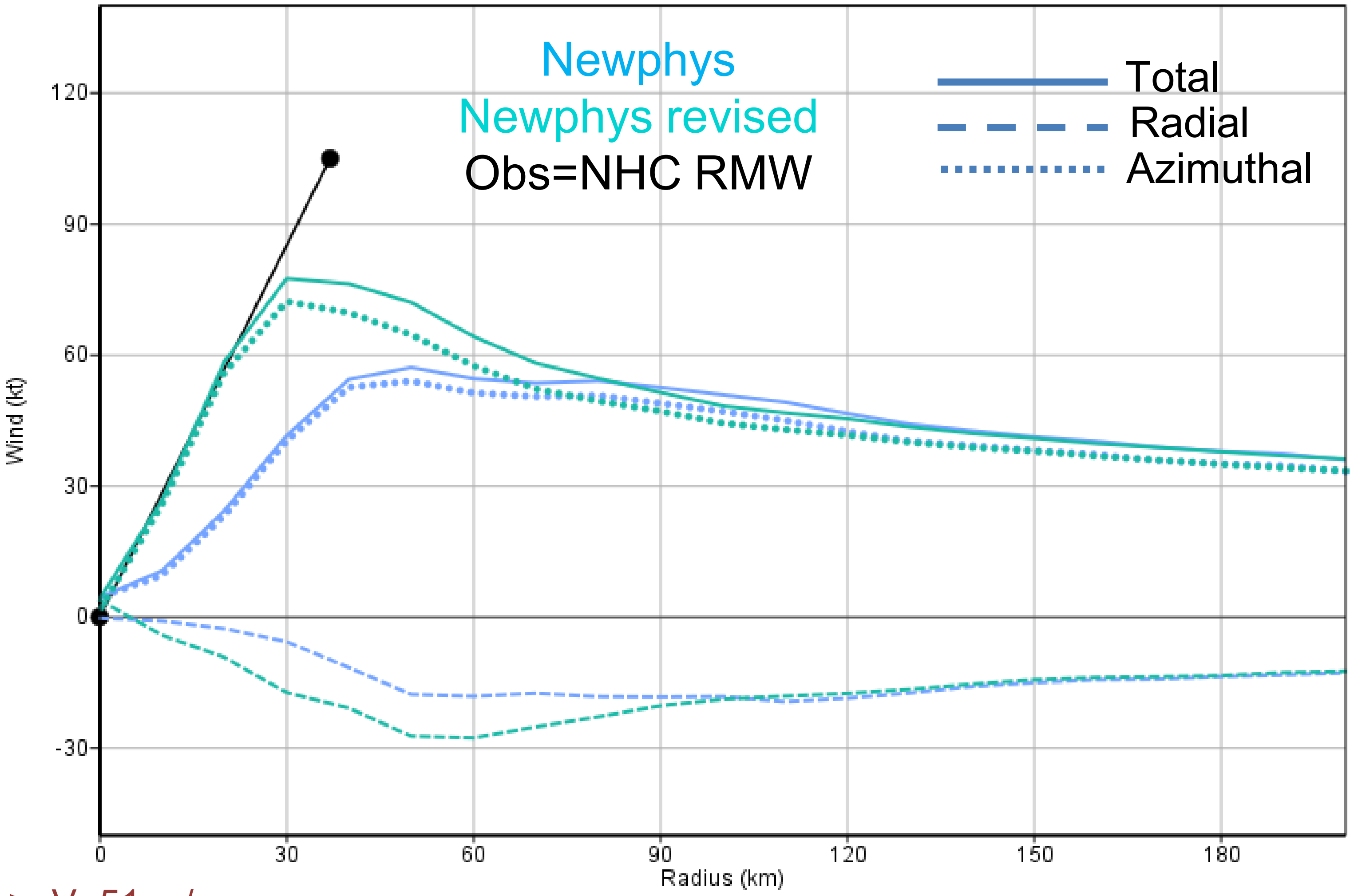
Large+weaker vortex vs smaller+stronger vortex

For Vortex dynamics= perturbation buoyancy force (pushing inward) vs pressure force (pushing outward) in thermal/gradient wind balance

maximum intensity just above PBL, see Emanuel&Rotunno 2011, Montgomery&Smith 2016, Makarieva&Nefiodov 2021

$$(T_{pbl} - T_0)C_p \frac{1}{\theta_e}\frac{\partial \theta_e}{\partial r} = -\frac{V^2}{r}$$

Azimuthally averaged radial profiles of 10 m wind



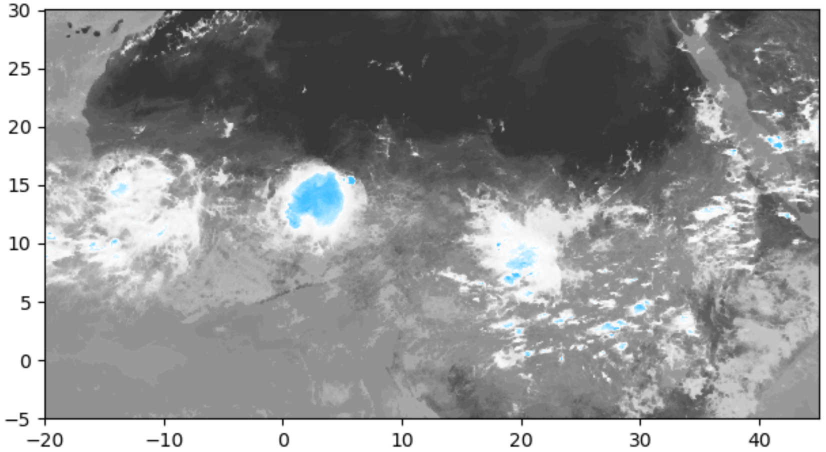
courtesy: Sharan Majumdar

28.5C -83C 345K 8K/150 km (9 km) =>. V=51 m/s

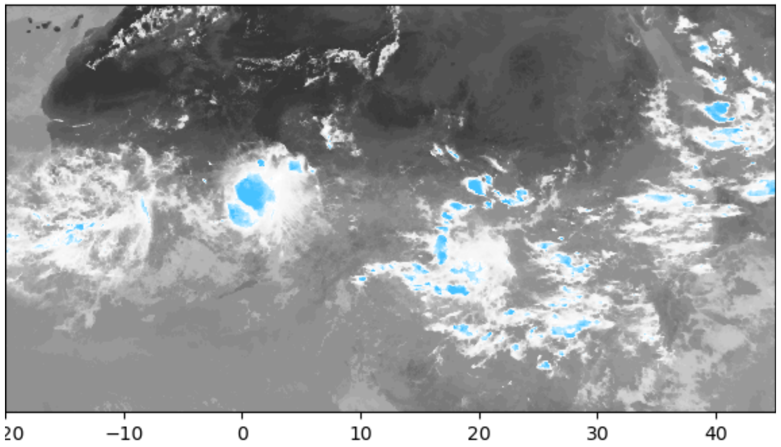
12K/150 km (4.5 km) => V=62 m/s @850 hPa

African squall lines & Easterly waves 20220804

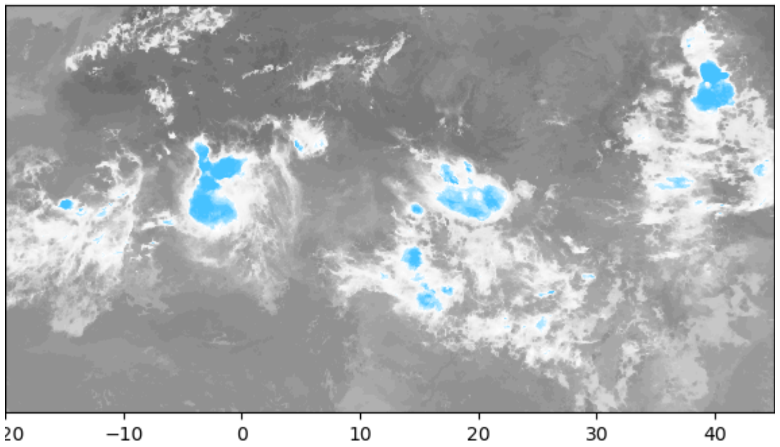
12UTC



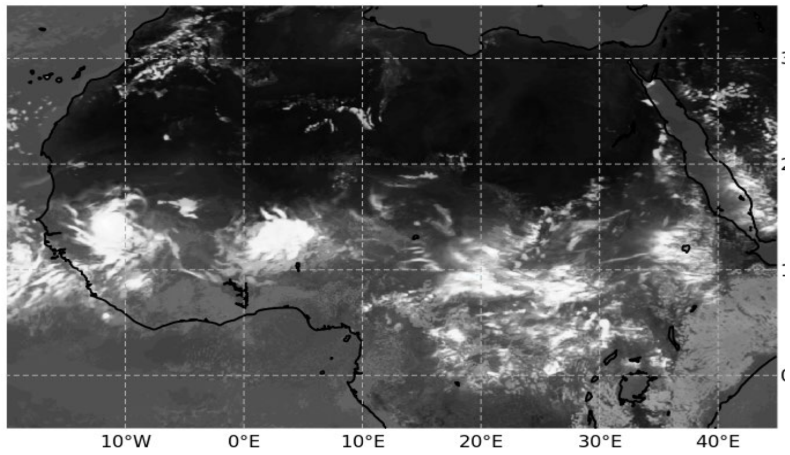
15 UTC



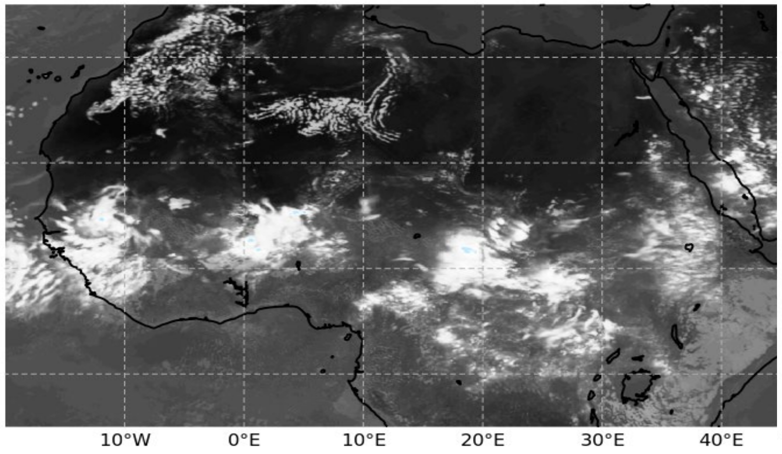
21 UTC. Obs *Josef Schröttele*



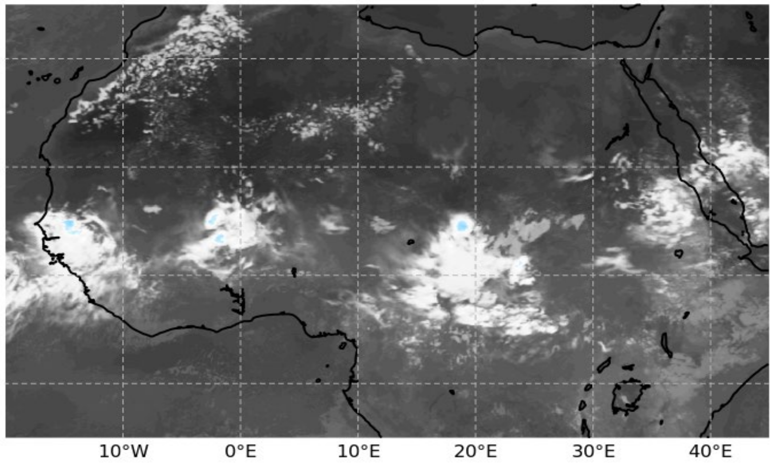
12UTC



15 UTC

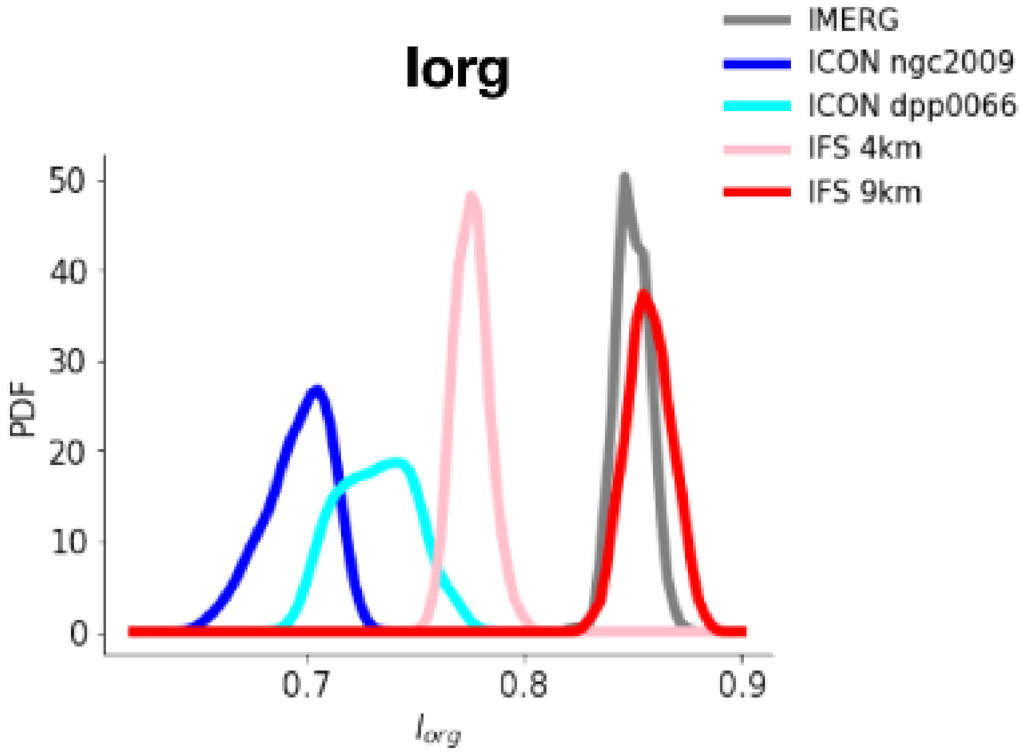


21 UTC Forecast

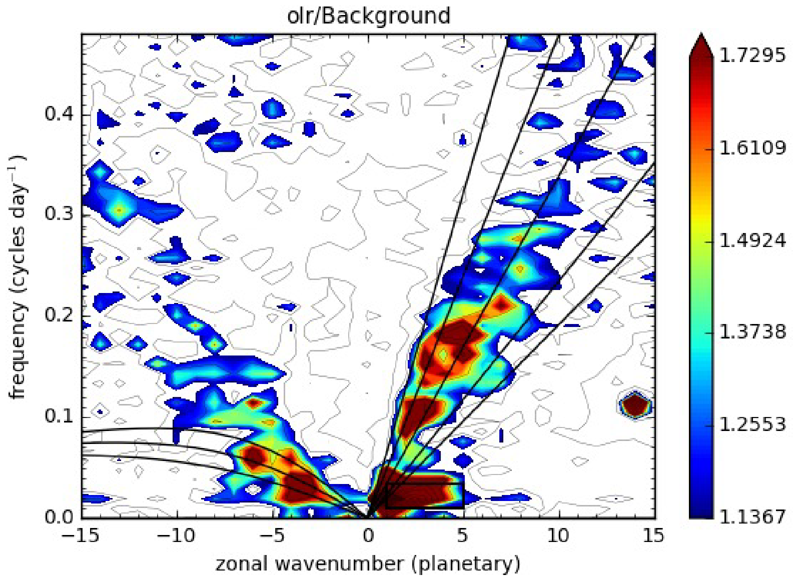


Westerly propagation and maintenance during nighttime transition mostly but not always achieved with 47r3 moisture advection

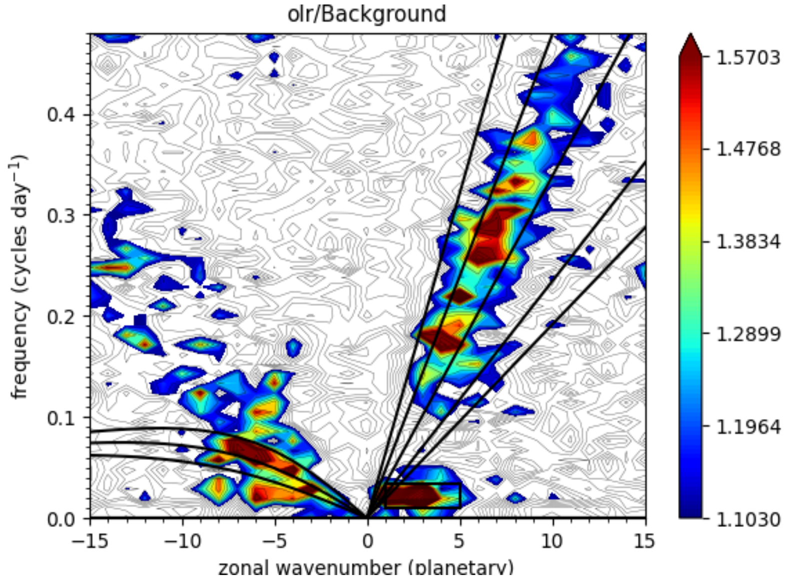
Organisation and waves always good?, what can happen? and why tendency to smaller scales when going to more “resolved”



from NEXTGEMS by Jiawei Bao (MPI Hamburg)



NOAA

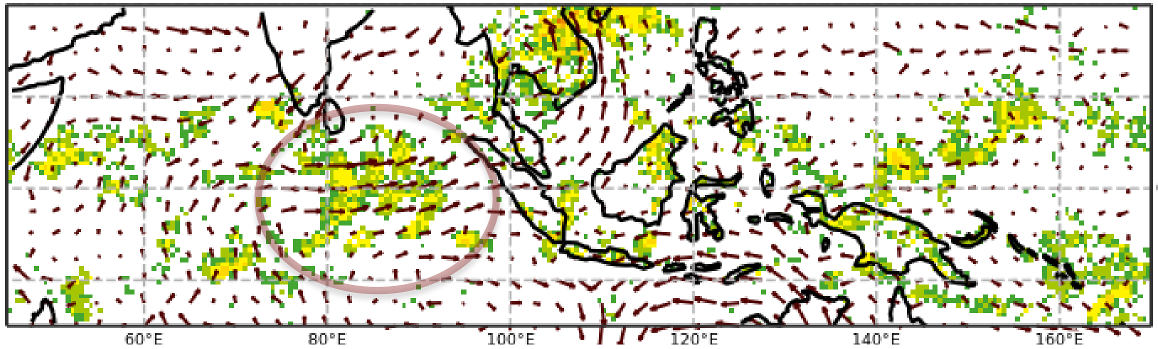


IFS climate

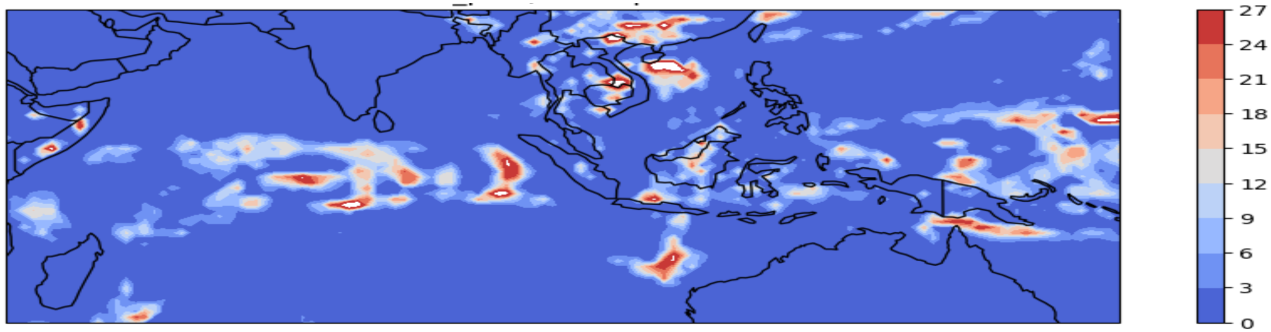
1-day filtered

Inertia-gravity waves vs convergence forcing/response

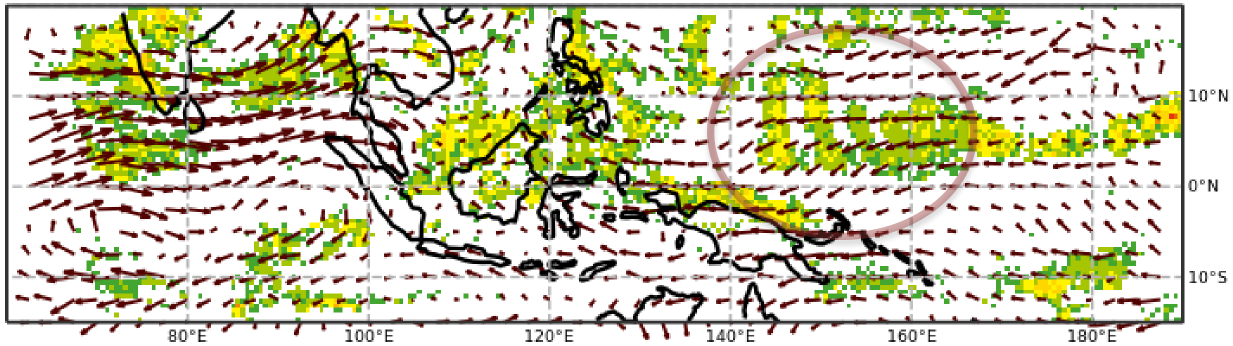
IFS 20220428 12+72h TP 3h uv 700 hPa

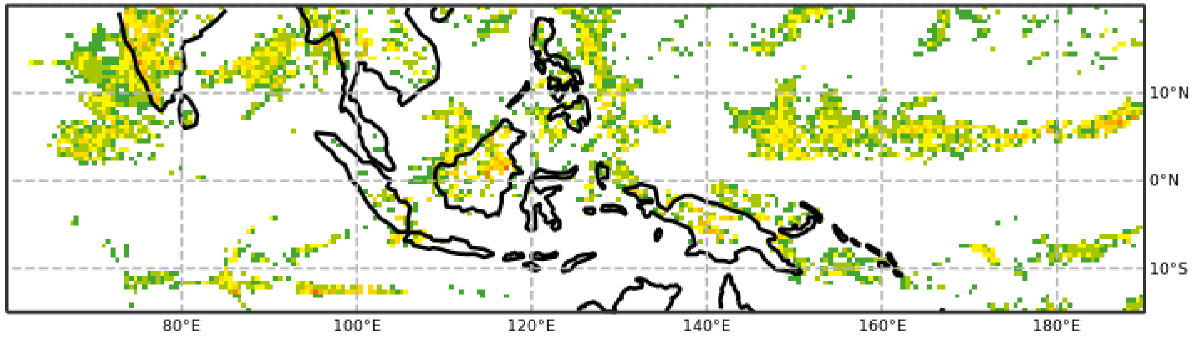


ICON/DWD Maike Ahlgrimm



IFS 20220803 00+748hTP 3h uv 700 hPa





$N = 0.02 - 0.04\ s^{-1}$ $\varpi \sim 2\pi/10800$ s

u=10-20 m s^{-1} ;v=0; Lx~600 km k= 2π/ Lx; m= 2π/ Lz

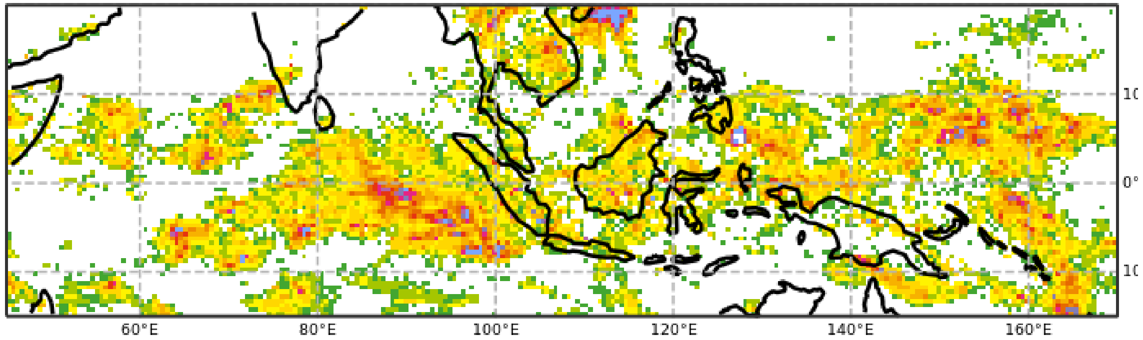
=> **$\tilde{c}$=c-u=55 m s^{-1} ; Lz~10 km**

wave limit on how fast but not on how slow

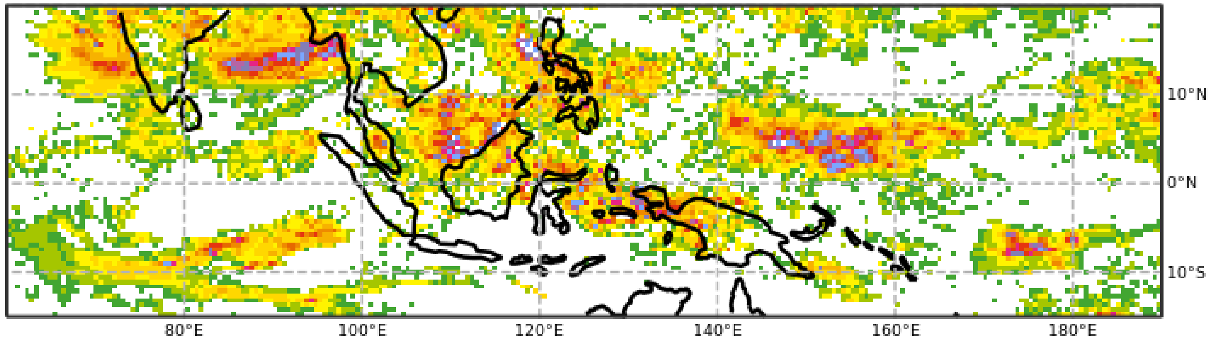
$$f^2 < \tilde{\omega}^2 < N^2 \qquad m^2 = \frac{k^2 N^2}{\tilde{\omega}^2} = \frac{N^2}{\tilde{c}^2}$$

Robust gravity wave vs convergence forcing/response

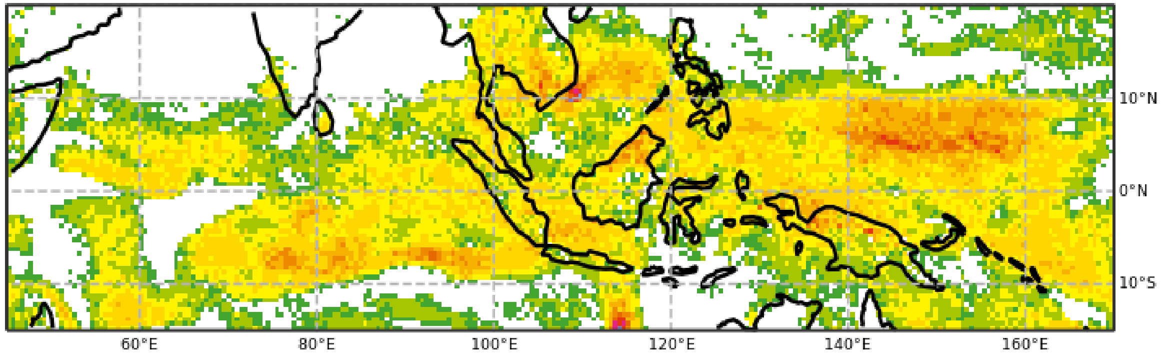
GPM 24h (mm) 20220430



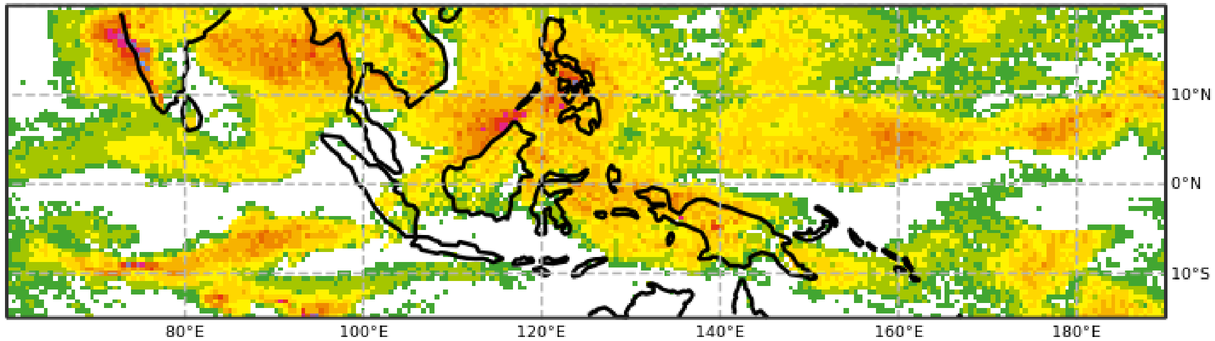
GPM 24h (mm) 20220804



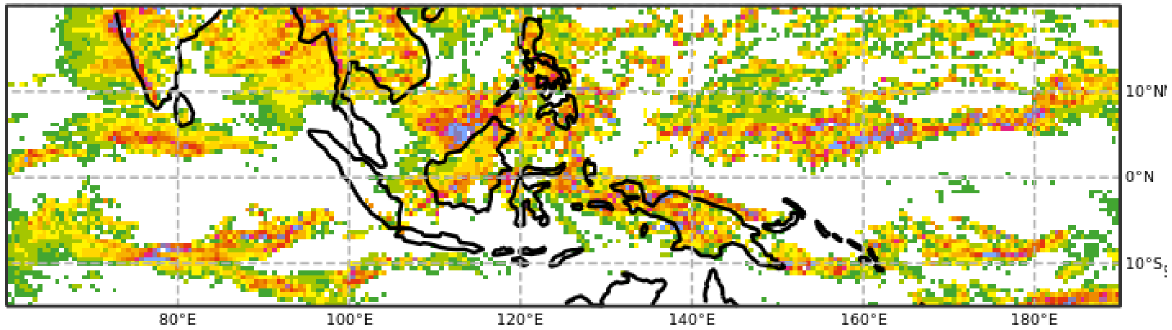
Oper 20220428+72h



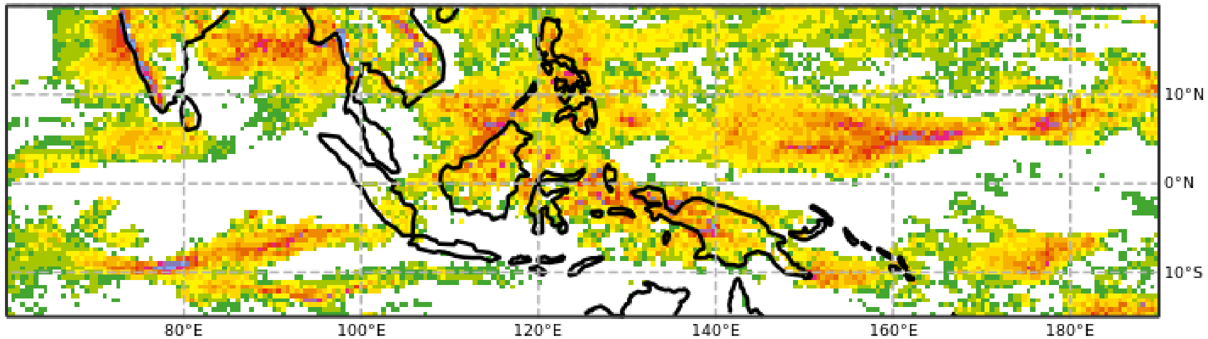
Oper 20220803+48h



80% Mu in dynamics 20% in conv 20220428+72h. 20220803+48



reduced downdraught and scaled with satfr 20220803+48h



Exp look 'good", but ... too sharp convergence, too warm, dry bias at equator and mjo problems

What else "helps" against GWs

- Noise (see also explicit)
- Stochastic Parameter Perturbations; GWs in 50 % of ensemble members only