Improving the representation of convective precipitation in ECMWF's Integrated Forecasting System for the nextGEMS project

Tobias Becker, Peter Bechtold, Richard Forbes, Irina Sandu, Thomas Rackow, Xabier Pedruzo and Inna Polichtchouk

Research Department, ECMWF, Reading, UK & Bonn, Germany

Alexander von Humboldt Stiftung/Foundation

The Challenge

- **mean precipitation** over NH Pacific ITCZ (5-10°N) strongly overestimated in storm-resolving nextGEMS Cycle 2 simulations with the IFS when deep convection parametrization is switched off (Deep Off)
- **precipitation intensity** strongly overestimated with Deep Off and strongly underestimated with Deep On
- **no resolution dependence** in Deep Off simulations at 9 and 4.5 km, with only minor improvements at 2.9 km

  ➔ we perform sensitivity study at 9 km to understand underlying problems and find best setup for higher resolutions

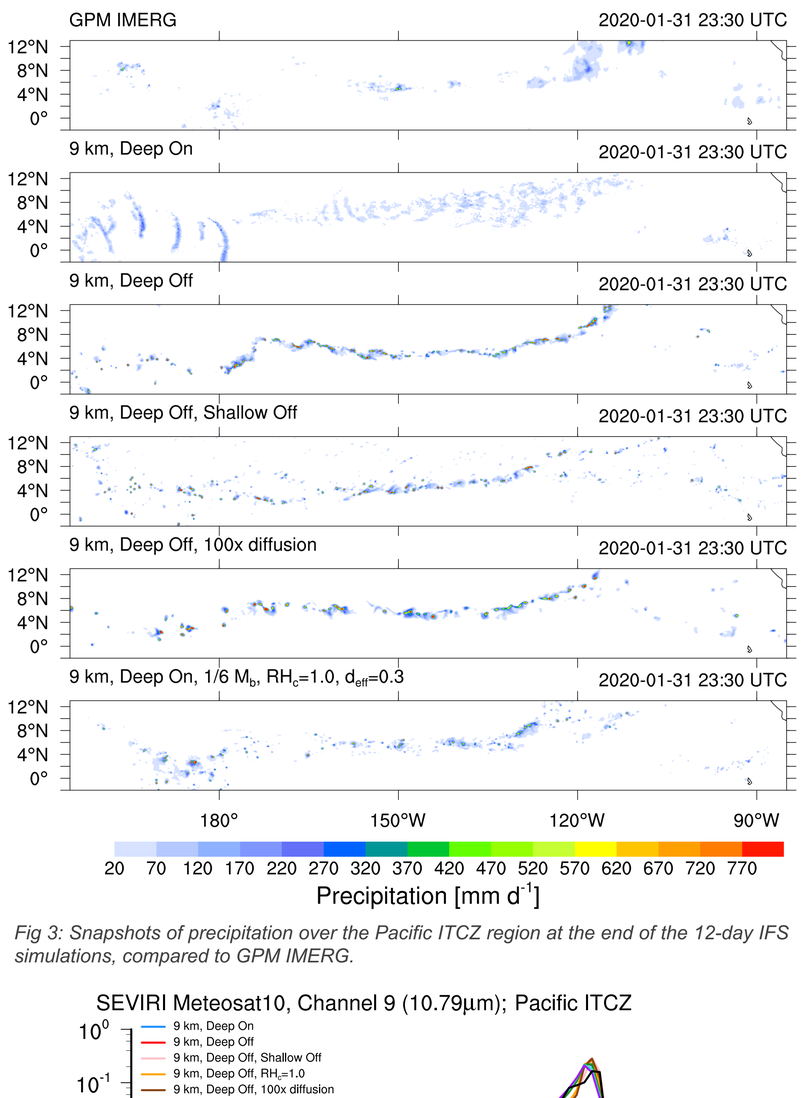

Fig 3: Snapshots of precipitation over the Pacific ITCZ region at the end of the 12-day IFS simulations, compared to GPM IMERG.

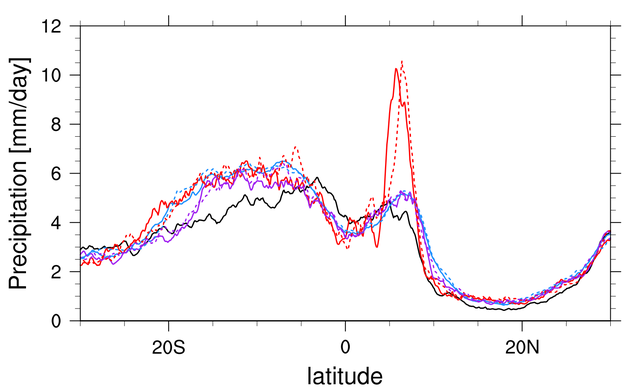

Fig 4: PDF of cloudy brightness temperatures over the Pacific ITCZ, using the satellite simulator tool for SEVIRI Meteosat 10, Channel 9 (10.79 µm) in the IFS simulations and comparing against GOES 15, Channel 4 (10.7 µm).

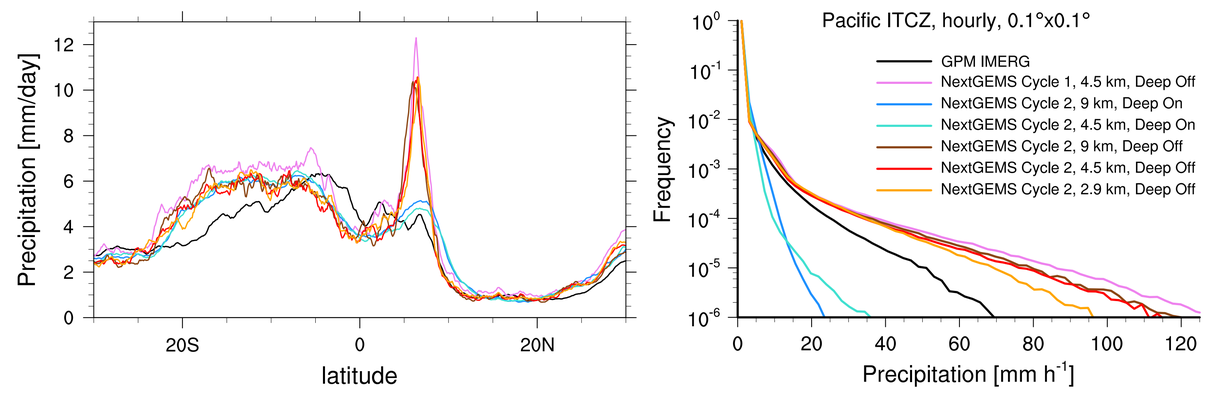

Fig 1: Zonal mean precipitation (left) and probability density function of hourly precipitation over the Pacific ITCZ (13˚N-2˚S,155˚E-85˚W), conservatively interpolated to a 0.1˚x0.1˚ grid (right), in the storm-resolving nextGEMS Cycle 1 & 2 simulations with the IFS. Results are shown for January 2020 (simulation day 2-12), relative to the satellite retrieval GPM IMERG.

Sensitivity Experiments

- **Shallow Off** – *switching both deep and shallow convection scheme off:*
  - slightly less ITCZ precipitation but therefore strong degradation w.r.t. temperature and specific humidity at the top of the boundary layer
- **100x diffusion** – *increasing spectral diffusion (of u, v, w, t and p_s) by factor of 100:*
  - less extreme precipitation and slightly larger convective cells but no improvements w.r.t. zonal mean precipitation
- **RH_c=1.0** – *increasing RH threshold at which hydrometeors can evaporate:*
  - slightly less extreme precipitation but no improvements w.r.t. zonal mean precipitation
- **1/6 M_b** – *decreasing cloud base mass flux by 1/6 (as would be used at 700 m resolution):*
  - precipitation intensity matches GPM IMERG, except for weak precipitation (<1 mm h^{-1}), which is too frequent
  - mean precipitation close to GPM IMERG over NH Pacific ITCZ but zonal mean precipitation still overestimated over SH tropics
  - mid-troposphere slightly too cold
  - cloud top height lower than with Deep Off and thus closer to GOES 15
- **d_{eff}=0.3** – *detraining 30% of hydrometeors produced by convection scheme to microphysics*
  - more low and mid-level clouds than in all other simulations and thus closer to GOES 15
- **revised physics package for storm-resolving scales (1/6 M_b, RH_c=1.0, d_{eff}=0.3):**
  - realistic zonal mean precipitation and realistic precipitation intensities
  - realistic spatial pattern of precipitation even though convective systems are too small, meaning that mesoscale convective systems like squall lines are not represented well
  - realistic vertical distribution of cloud but lower troposphere slightly too cold

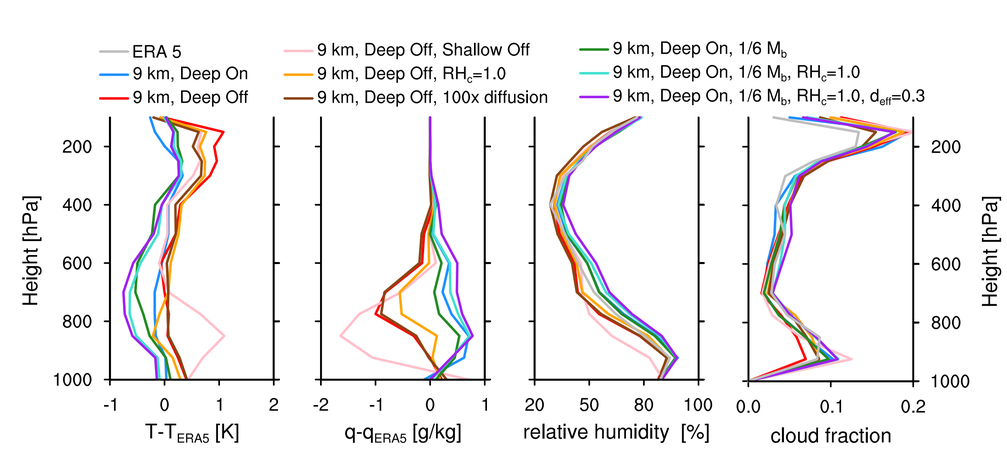

Fig 5: Mean vertical profiles over the Pacific ITCZ region, relative to the mean ERA 5 profile, which is subtracted for temperature and specific humidity.

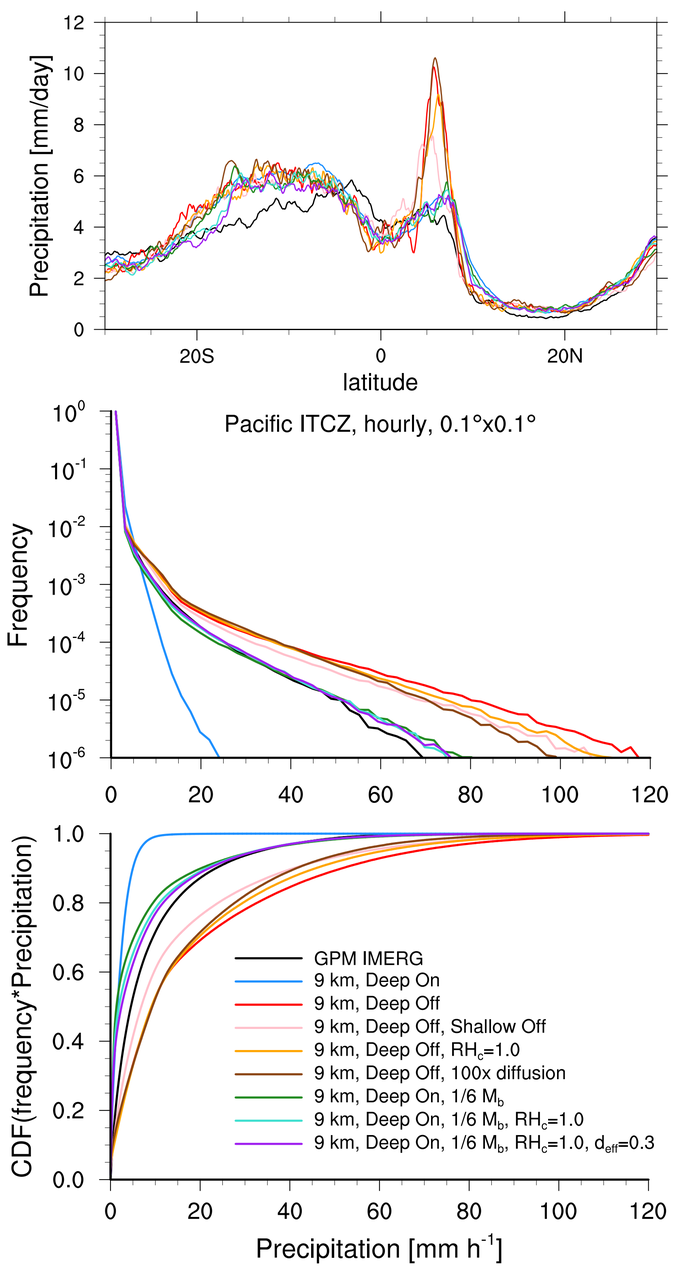

Fig 2: Top & mid: Same as Fig.1 but for the sensitivity experiments at 9 km resolution. Bottom: Cumulative density function of frequency times rainfall amount over the Pacific ITCZ region.

Fig 6: Same as Fig. 1 and Fig. 2 but comparing results at 9 and 4.5 km resolution.

Conclusions

- Global storm-resolving simulations (at 2.9 – 9 km) with Deep Off face the problem that processes critical for deep convection are underresolved, e.g., horizontal mixing of convective updrafts with their environment and vertical mixing prior to the triggering of convection.
- As a consequence, mean precipitation and precipitation intensity are overestimated over the Pacific ITCZ.
- With the proposed revisions to the moist physics for storm-resolving scales, the characteristics of precipitation (zonal mean, intensity and spatial pattern) are more realistic, as well as low and high clouds. These improvements are also apparent at higher resolutions.
- Skill scores can compete with the operational IFS version (unlike with Deep Off which shows big degradations).
- A remaining problem is that both with Deep Off and the revised physics, deep convective structures are too small and larger mesoscale convective systems like squall lines often cannot to be represented realistically.