Strategies to forecast extreme precipitation events from GFS and GEFS

Parameterization and Analyses group

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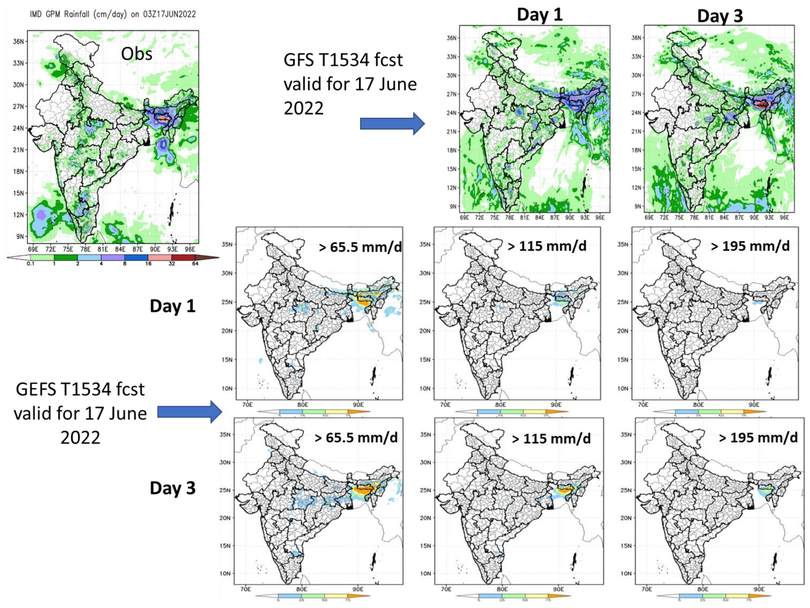
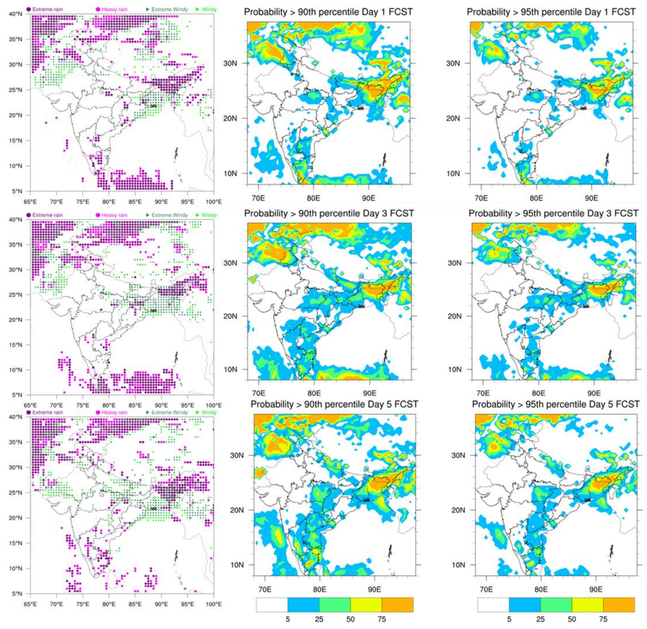
GFS and GEFS based forecast diagnostics for predicting extreme rainfall events

First column shows the percentile forecast from GFS T1534, the second and third column show the probability of exceeding the 90th and 95th percentile rainfall for the Day 1, 3 and 5 forecast valid for 17 June 2022.

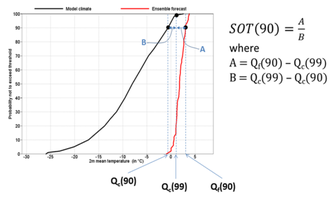
Extreme rainfall event on 17th June 2022

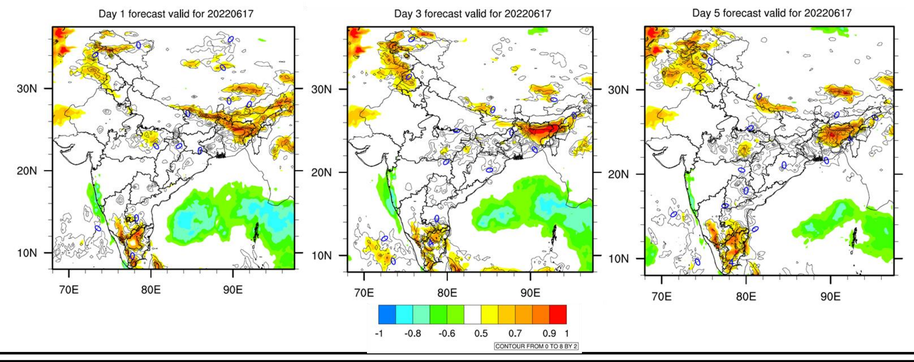




The Extreme Forecast Index (EFI, shaded) and Shift of Tails (SOT, contours) of rainfall for Day 1, 3, and 5 forecast valid for 16 June 2022. The EFI shows the likelihood of unusual (0-5-0.8) weather and very unusual (> 0.8) weather to occur. The SOT gives an indication of how extreme the event is with respect to the 99th quantile of the model climatology. These products are obtained from the GEFS forecast and its climatology (2013-2021 JJAS).

$$EFI = \frac{2}{\pi}\int_0^1 \frac{p - F(p)}{\sqrt{p(1-p)}}\,dp$$





Model development activity in GFS

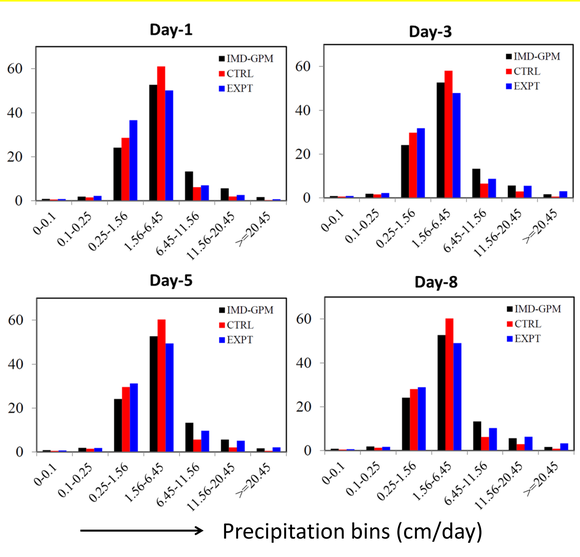
GFS T1534 with L128 hybrid levels

The higher number of vertical levels near the surface in L128 compared to L64 gives the reduced lowest model level height of around 20m than 45m in L64 in the GFS T1534 model. The model top level is increased from 0.27 hPa (~54 km) in L64 to 0.01 hPa (~80 km) in L128.

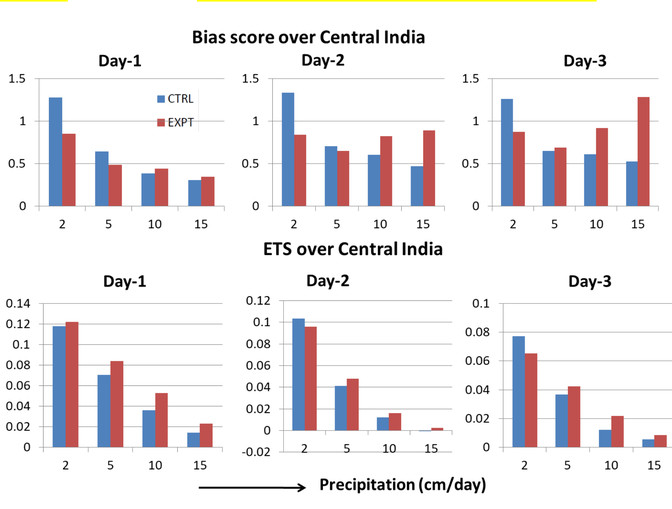
CTRL: T1534 with L64 levels, EXPT: T1534 with L128 layers

Model forecast run carried out for JJAS 2020 season

Rainfall PDF (%) over CI during JJAS 2020



Skill score over CI



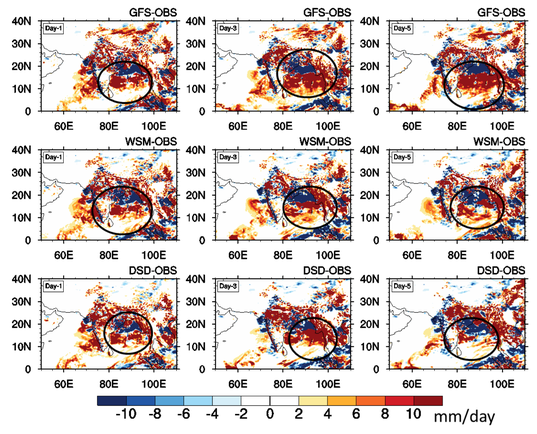
Improved parameterization constrained by observation

- Most of the model represents the particle by an exponential fit of the form- $N(D) = N_0 e^{-\lambda D}$ where N_0 is the intercept, λ is the slope and D is the diameter of the particle.
- The rates of several microphysical processes (e.g., vapor deposition and riming) are dependent on specification of N_0,
- The choice of N_0 remains problematic for microphysical scheme whether a constant value (Lin et al. 1983). or variable (Reisner et al. 1998). But most of the microphysical schemes assume N_0 is constant.
- WSM6 also assume that rain, graupel and snow are exponential distribution with constant intercepts N_0 .

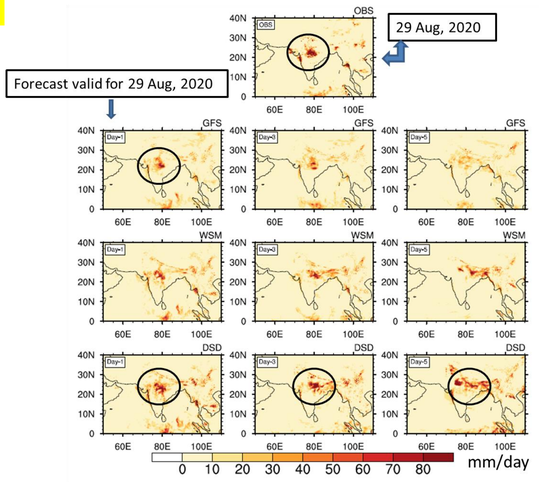
- Analysis of CAIPEEX data shows that N_0 and λ are co-related (Patade et al. 2015;).
- Also it varies with temperature which is not consistent with assumption that N_0 is constant.
- There appears to be a nearly linear relation between $\log(\lambda)$ and $\log(N_0)$, i.e. of the form **$\log(N_0)$ = alpha + beta $\log(\lambda)$** whose slope beta is **2.033** (using 2011 CAIPEEX data)
- The point is that, instead of assuming that **N_0 is constant which is not consistent with the CAIPEEX analyses**, we can instead replace this assumption with the relation **$N_0 = C\ (\lambda)^{2.033}$**, and then when the model produces a mixing ratio q, we can input it to the scheme and calculate the corresponding value of lambda using: **$q = a\ (C\ (\lambda)^{2.033})\ \Gamma(b+1) / \lambda^{(b+1)}$**

where a and b are the coefficient and exponent of the density relation that gives the mass of a hydrometeor of diameter D as **$M = aD^b$**

Bias (mm/day) valid for 13th Sept 2021



Heavy Rainfall over Bhopal, Central India (20200829)



GFS T1534 with TCO grid

Conventional Spectral grid:

- **Not scalable**
- **I/O**
- **Artificial diffusion damping**
- **Negative tracer**

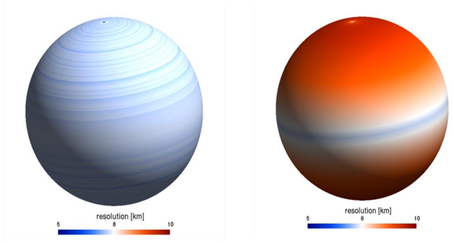
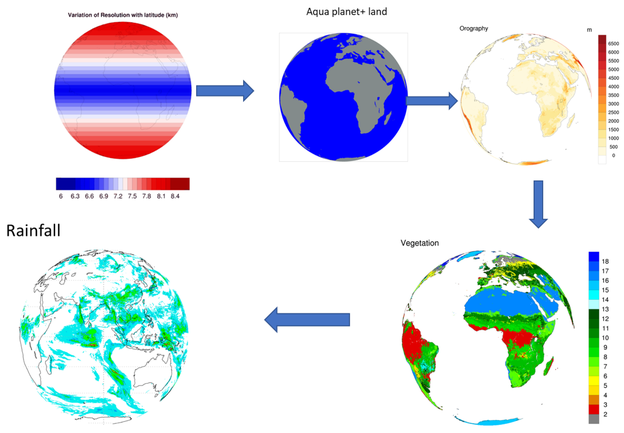


Figure (adopted from ECMWF News Letter 146) demonstrates that the octahedral mesh (right) has a locally more uniform dual-mesh resolution than the mesh (left).

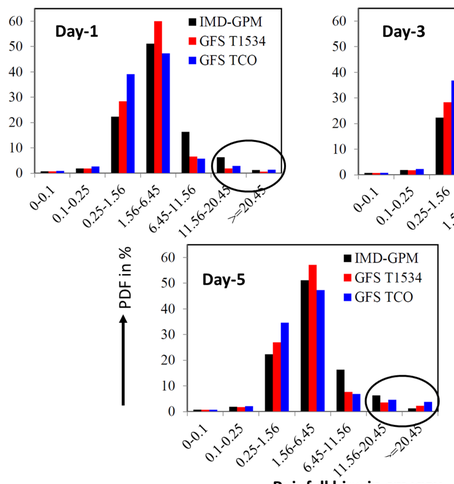
Numerical simulation of an idelaised baroclinic instability, conducted using IFS model on both the mesh showed the octahedral grid results in higher accuracy and substantially reduced unphysical flow distortions accuracy mainly as the approach depends on the underlying mesh which defines the shape of the elementary volumes around which the computations are made (ECMWF New Letter, No. 146, 2015).

Sequence of IITM HGFM Development

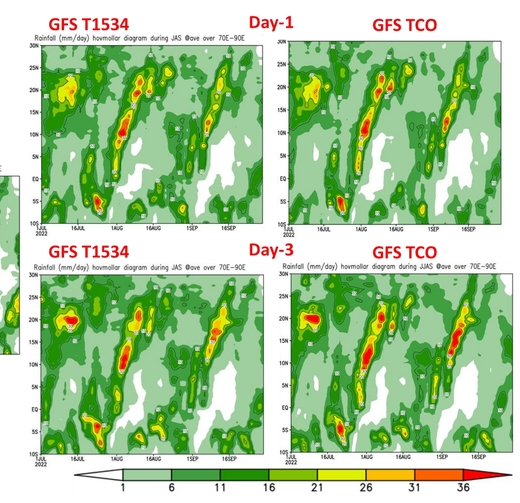


Link for a film on the development of the model https://youtu.be/dxacESa28bY

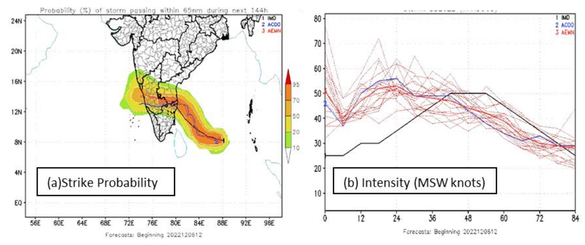
Rainfall PDF (%) over All India landmass



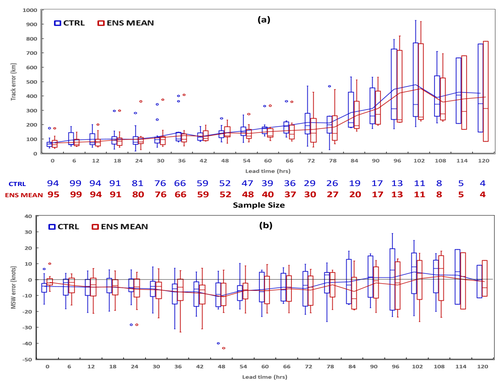
Rainfall (mm/day) Hovmollar diagram averaged over 70E-90E



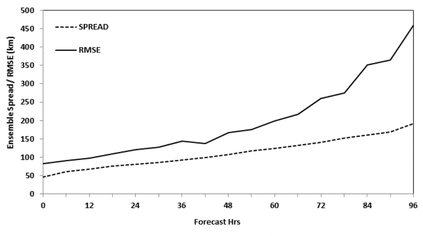
Probabilistic Prediction of Cyclones



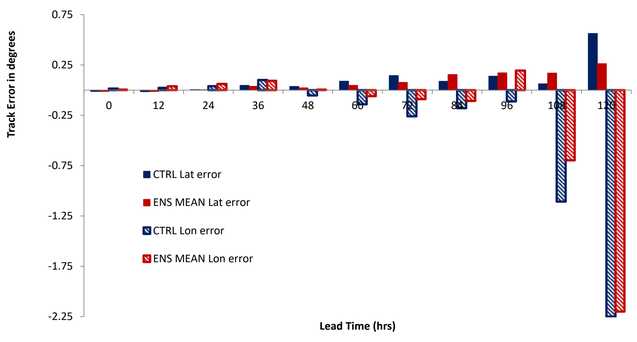
a) Strike probability b) Intensity in terms of MSW (kts) for cyclone Mandous (Dec 2022) for IC: 2022120612



Track error (km) b) Intensity error (kts) for cyclones during year 2020-2021



Ensemble spread and RMSE (km) for cyclones during 2020-21



Directional track error in degrees. Positive (negative) latitudinal error indicates northward (southward) bias and positive longitudinal error indicates eastward bias and vice versa.

Extreme rainfall event on 22nd August 2022