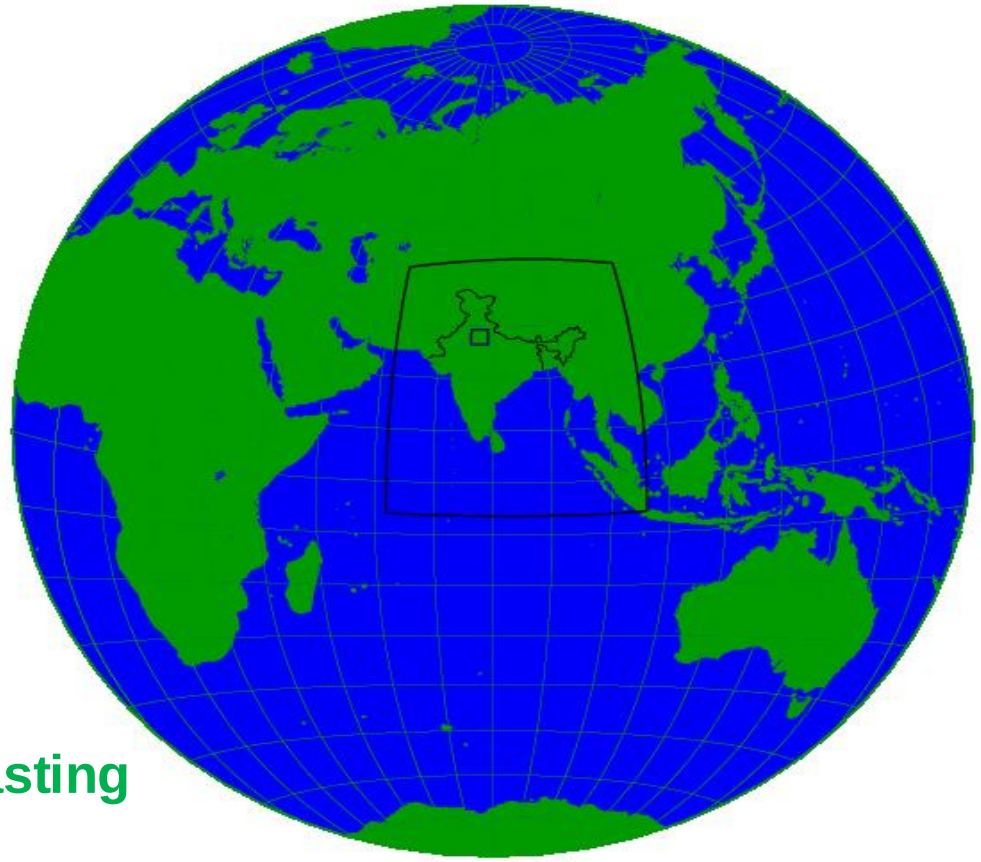
Status of RAL3 related activities at NCMRWF

Saji Mohandas
A. Jayakumar
T.J. Anurose
Mansi Bhowmick
Niranjan Kumar
Sukhwinder Kaur
V. Reddy
K.S. Apsara
Rose Raphel

National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences



Ministry of Earth Sciences

NCUM-R(~4km): History of science changes and experiments

Experiment	Description	RMED Tickets	Details
RAL3.0	CASIM+BM schemes @UM12.0	#83, #111, #192	Introduced new schemes, double moment microphysics (CASIM) and Bimodal (BM) cloud fraction generation.
RAL3.1	Radar hole fix @UM12.0	#375	In extreme rainfall, the model radar reflectivity suddenly drops causing holes, solved by applying a CFL limit on CDNC conversion rates.
RAL3.2	Hot spot fix @UM13.0	#311	Fix for a one time-step sudden extreme surface warming by enabling interactive buoyancy calculations in surface exchange terms.
RAL3.2+DSD	Radar hole fix 2 @UM13.0	#478	Due to ice melting by the unusual temperature profiles leading to broader DSD in the lower levels, resolved by measures to control the PSDs.
RAL3.2.4	RMED #504.4 @UM13.0	#479, #460, #471, #473	Multiple science changes affecting DA cycling, monotonicity scheme choice, washout of murk, and CASIM-consistent radiative scheme for radar hole fix 2.
RAL3.3	Proposed version @UM13.5	RAL3.2.4+#604, #605	Proposed testing with bugfixes to visibility diagnostics and correcting wind gust diagnostics

- RAL – UM Regional Atmosphere and Land versions, CASIM – Cloud AeroSol Interacting Microphysics
- RMED – Regional Model Evaluation and Diagnostics, DSD – Drop Size Distribution,
- PSD – Particle Size Distribution, DA – Data assimilation, UMnnn – Unified Model versions

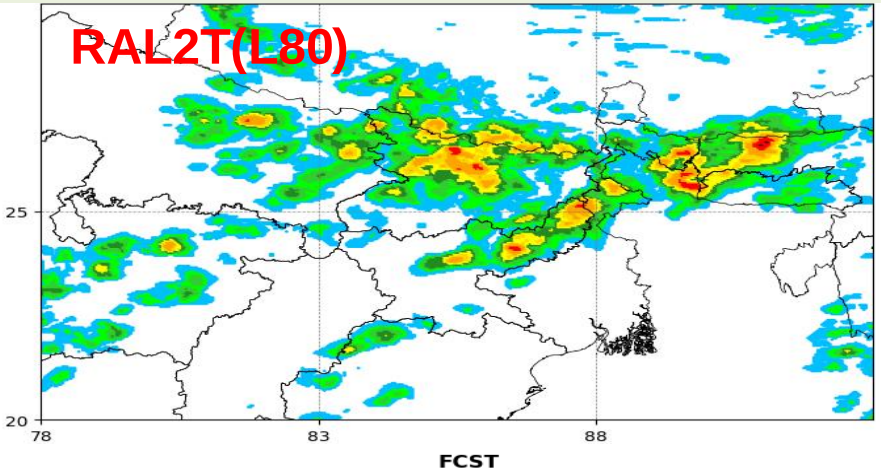
RAL3 package testing and tuning of Lightning Scheme

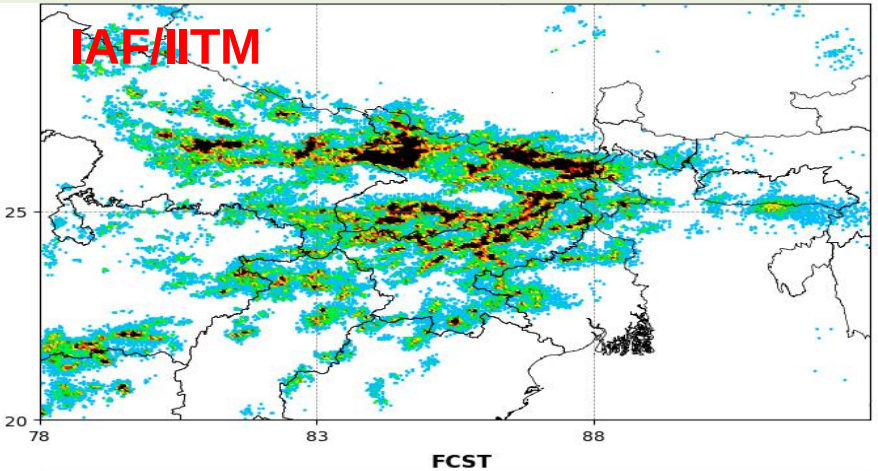
- **NCUM-R (~4km) was upgraded from RAL2 to RAL3.0 from 1 October 2022.**
- Significant improvement in precipitation distribution.
- Tuning of the McCaul scheme was carried out with the objective of increase in coverage and ability to predict intense hotspots – though compromising with some amount of overprediction and false alarms over some other locations.

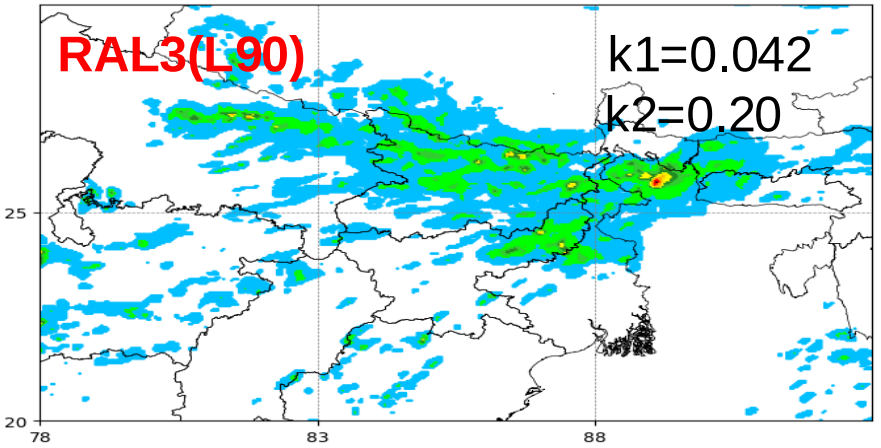
LIGHTNING FLASH COUNTS
IC: 25 JUNE 2020

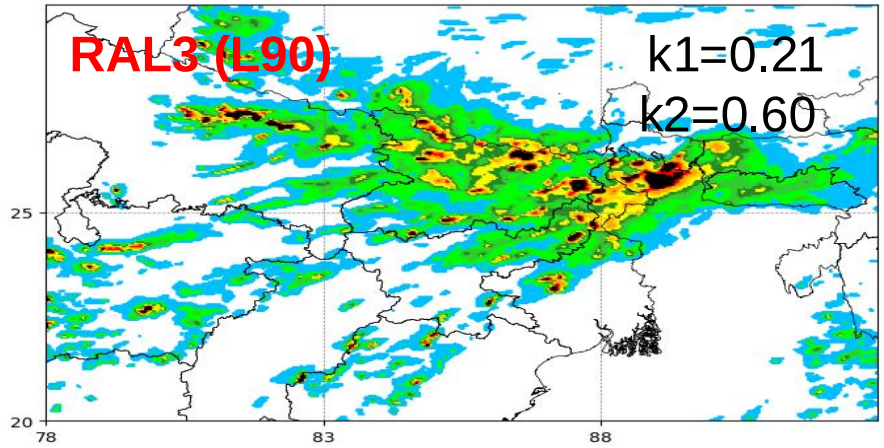
DAY-1 FORECASTS

Intensity is better captured in RAL3 by k1 x 5 times & k2 x 3 times









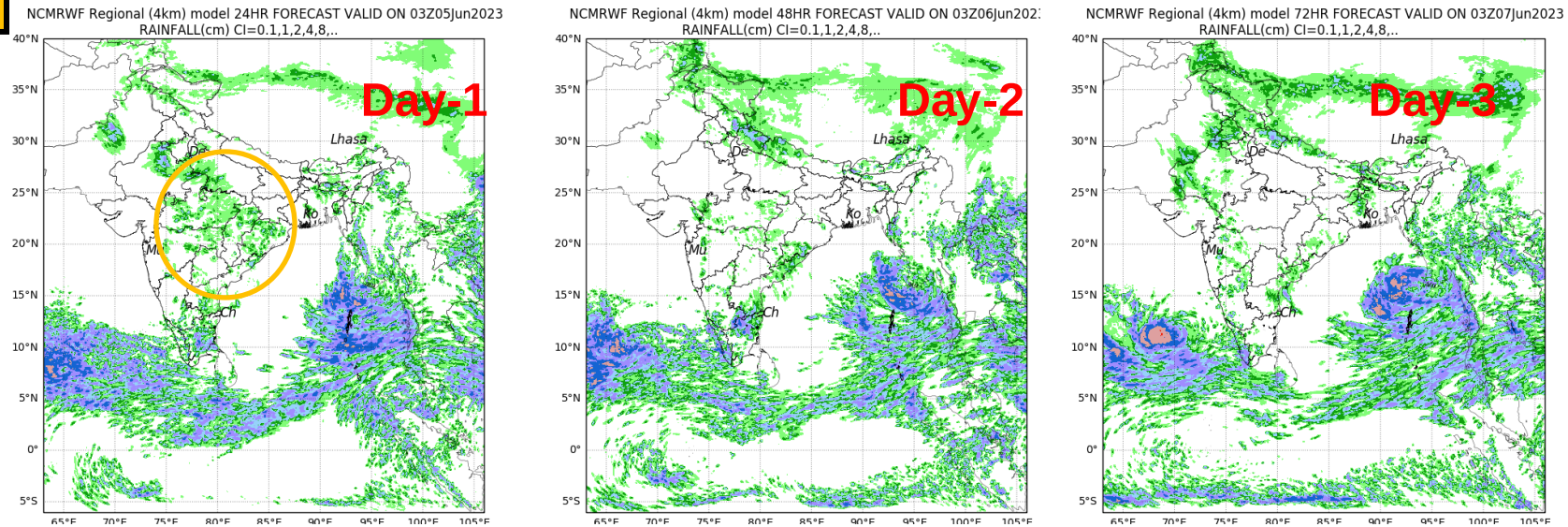
NCUM-R upgraded to RAL3.1 on 1 December 2023

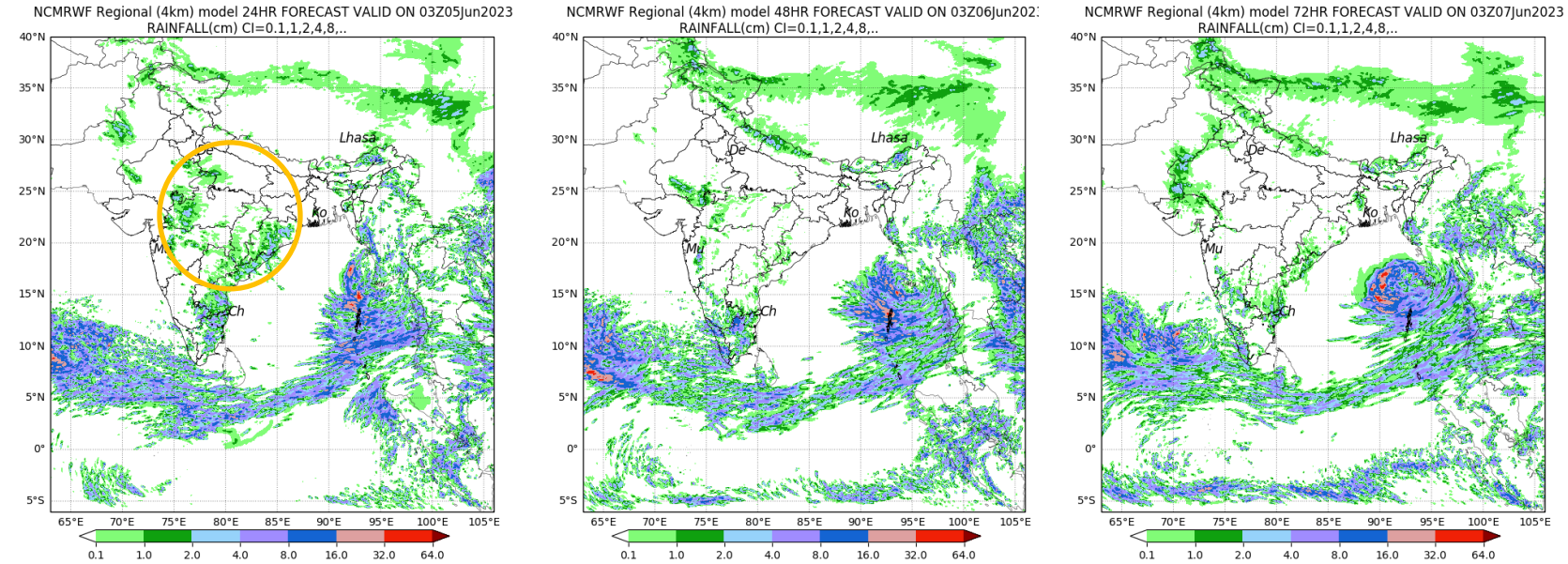
RAL3.0 vs RAL3.1

IC: 04 June 2023

(RAL3.0)

(RAL3.1)



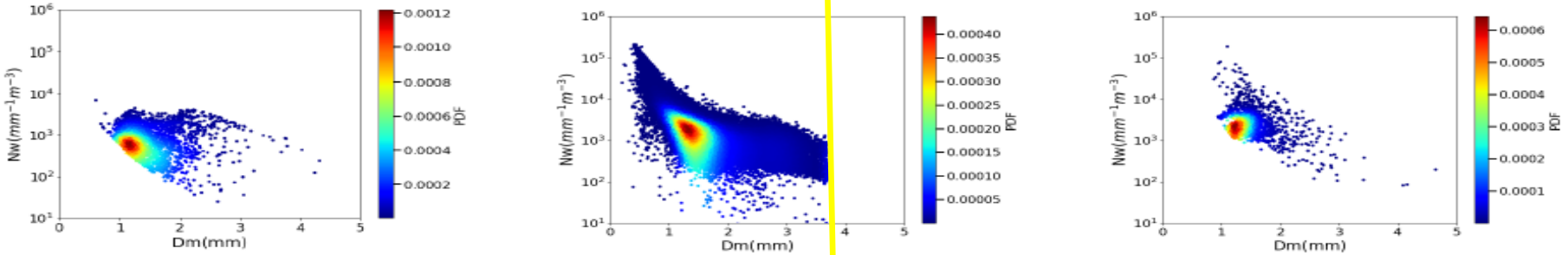


RAL3.1 produced slight reduction in the light rainfall distribution and minute increment in blobbiness compared to RAL3.0

Algorithm to separate the convective and stratiform precipitation amount was deviced.
New diagnostics: Dm- Mass weighted mean diameter & Nw- Normalised number concentration

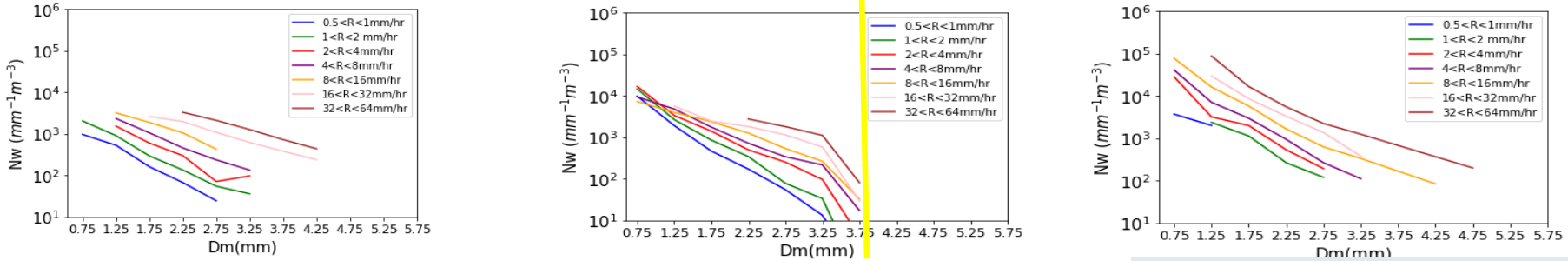
DSD Characterstics from observations (JWD & GPM-DPR) and Model

PDF of Nw vs Dm from observation and NCUM-R (~4km) model for monsoon convective-stratiform mixed precipitation over Tuljapur (rain shadow region in Western Ghat)



(a) JWD (b) NCUM-R (c) GPM

Nw vs Dm distribution for different rain rate intervals



RAL3.1 is better able to predict the DSD characteristics of low to middle sized drop.
Unlike GPM ,the model is overestimating Nw significantly in lower rainrate intervals.
There is a underestimation in predicting the higher sized drops followed by the truncation of drops (Dmax=3.75 mm) **(ticket #375)**

Apsara et al. (2024) under review

Testing of RAL3.3

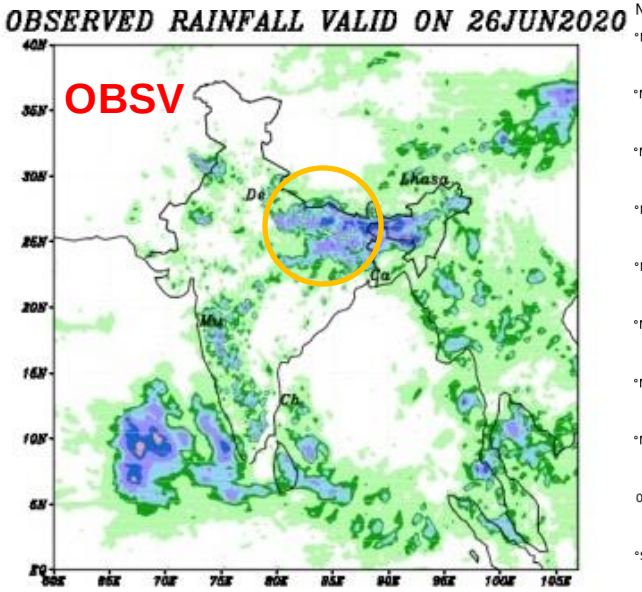
Precipitation

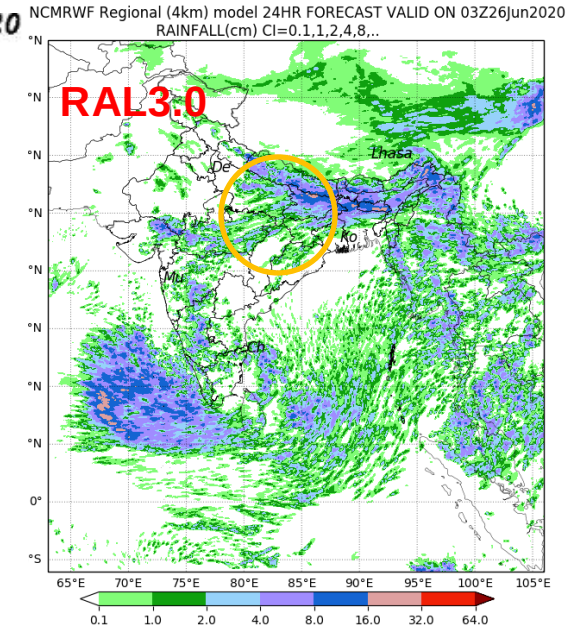
IC: 20200625

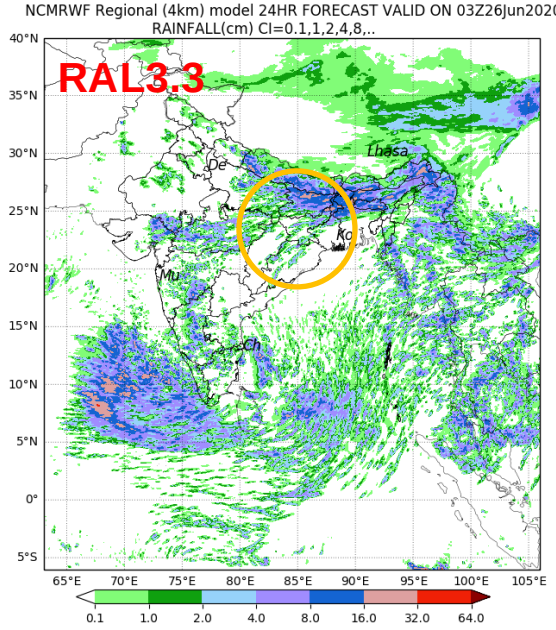
- RAL3.0 Operational from 1 October 2022
- RAL3.1 Operational from 1 December 2023

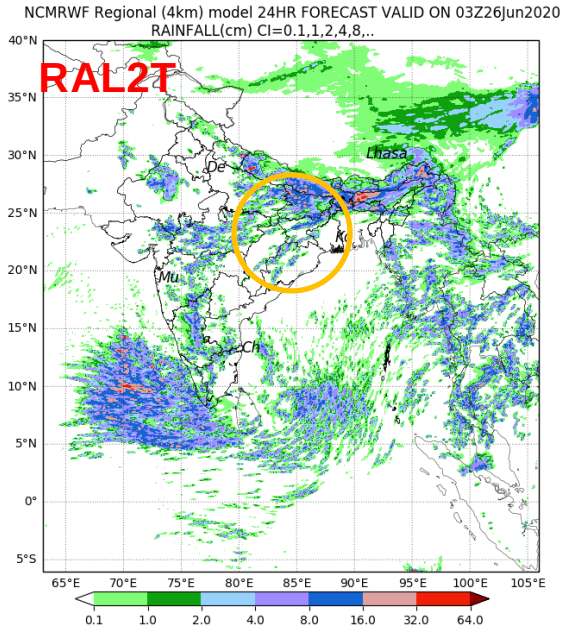
Differences in RAL3.3 w.r. to RAL3.0/RAL3.1

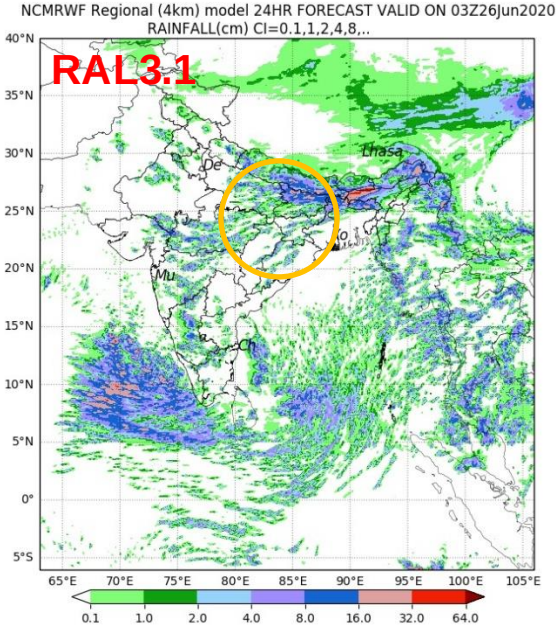
- Slightly large light rainfall distribution in RAL3.3 compared to RAL3.1, better matching with RAL3.0



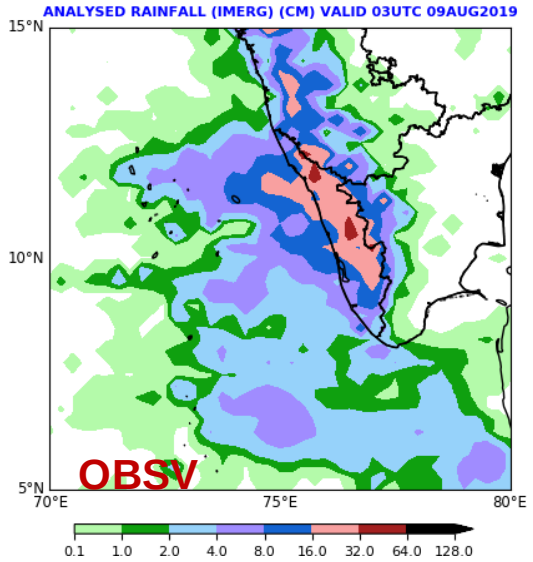


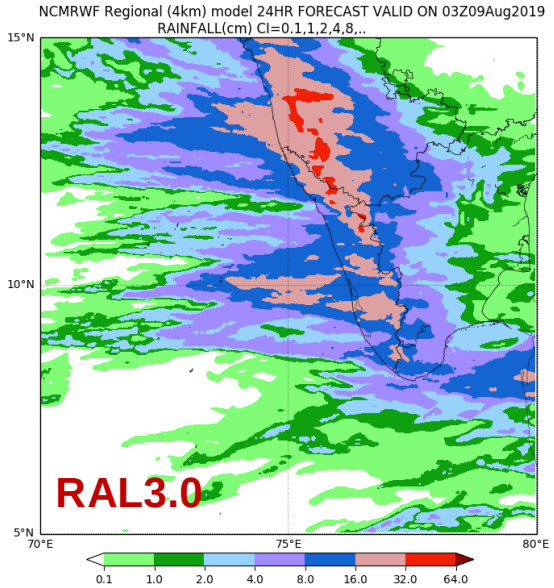


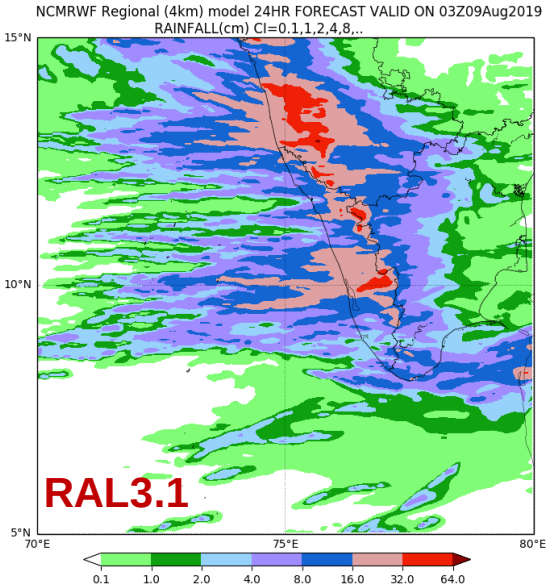


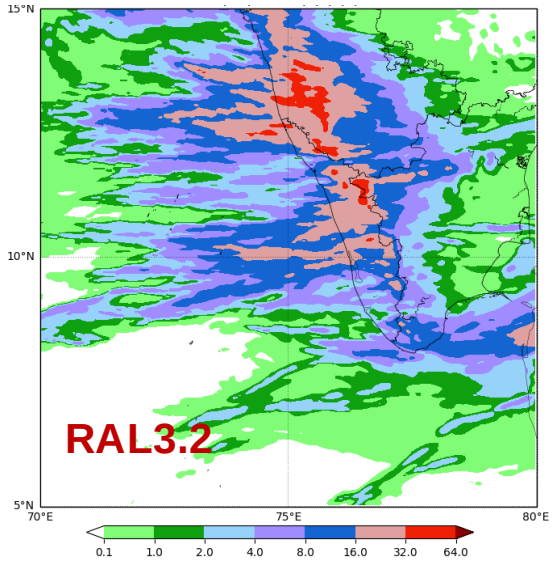


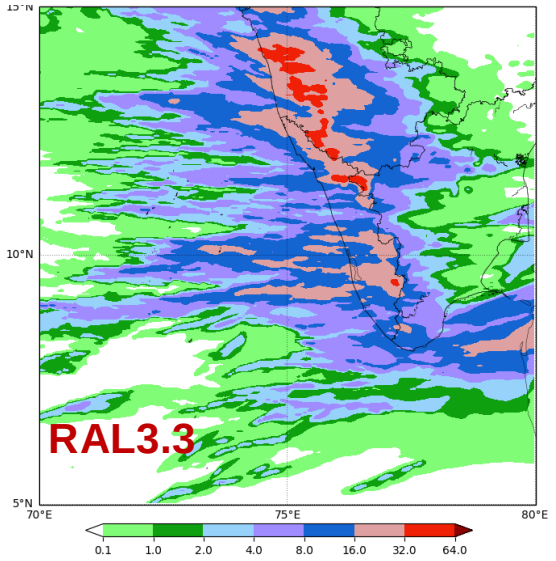
Kerala Flood : Day-1 Rainfall Valid for 003Z 09 Aug 2019







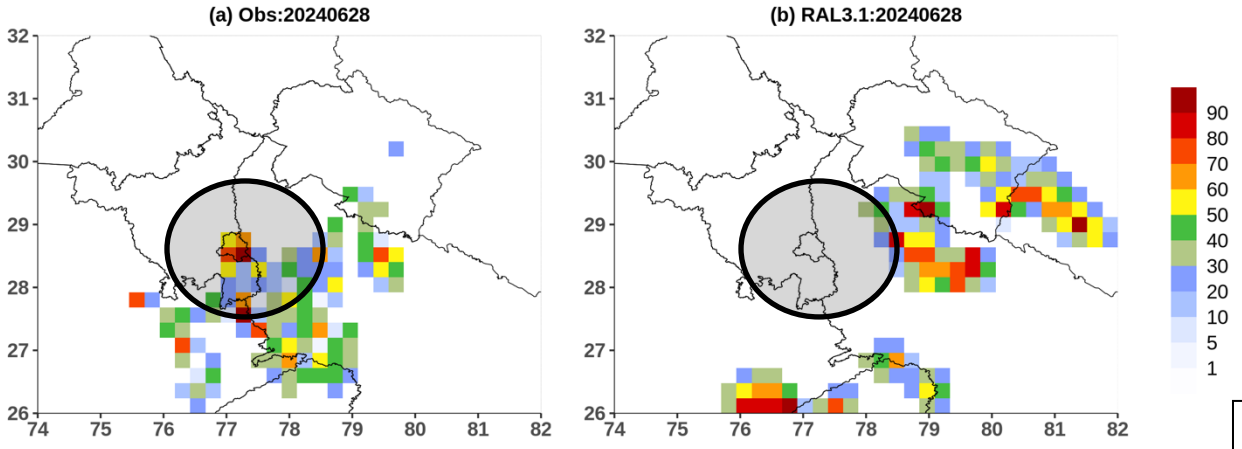




Increased coverage of rainfall intensity over Kerala for all RAL experiments compared to RAL3.0.

Impact of radar hole fix 2 in RAL3.3 is reducing the central Kerala rainfall peaks, though north Kerala part of rainfall patch is better simulated.

RAL3.1



CRA Threshold=20mm/day

	Obs	Fcst
Gridpoints>= 20 mm/day	108	129
Average Rain Rate (mm/day)	37	41.7
Maximum Rain (mm/day)	208.9	112.1
Rain Volume (km^3)	2.7	3.6

	Original	Shifted	Shift.Rotation
RMSE(mm/day)	39.51	37.79	NA
Correlation coefficient	-0.28	-0.17	NA

Error Decomposition:

Displacement Error 8.51 %
Volume Error 1.78 %
Pattern Error 89.71 %
Rotation Error NA %

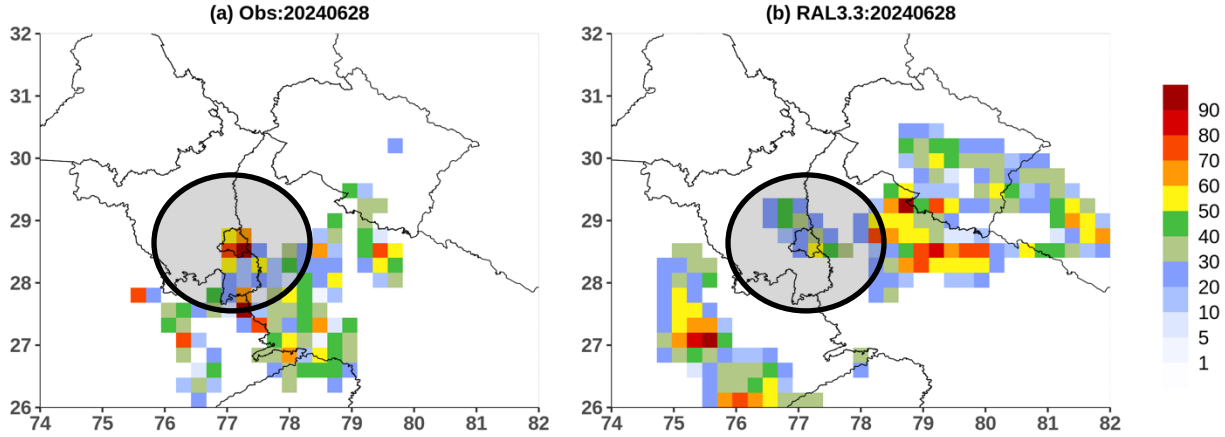
Location Error (x, y, Angle)= 0.2 , 0 , NA

RAL3.3 vs. RAL3.1 EVALUATION

28 JUNE 2024 (CRA ANALYSIS)

DAILY PRECIPITATION (mm/day)

RAL3.3



CRA Threshold=20mm/day

	Obs	Fcst
Gridpoints>= 20 mm/day	108	186
Average Rain Rate (mm/day)	37	37.2
Maximum Rain (mm/day)	208.9	96
Rain Volume (km^3)	2.7	4.7

	Original	Shifted	Shift.Rotation
RMSE(mm/day)	34.34	33.12	NA
Correlation coefficient	-0.16	-0.07	NA

Error Decomposition:

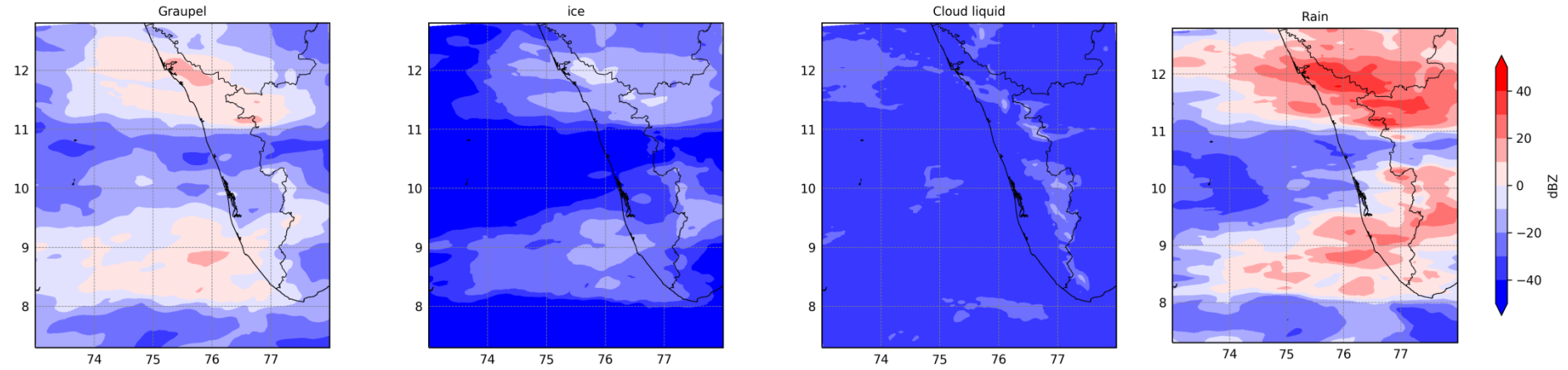
Displacement Error 6.93 %
Volume Error 6.97 %
Pattern Error 86.1 %
Rotation Error NA %

Location Error (x, y, Angle)= 0.2 , 0.2 , NA

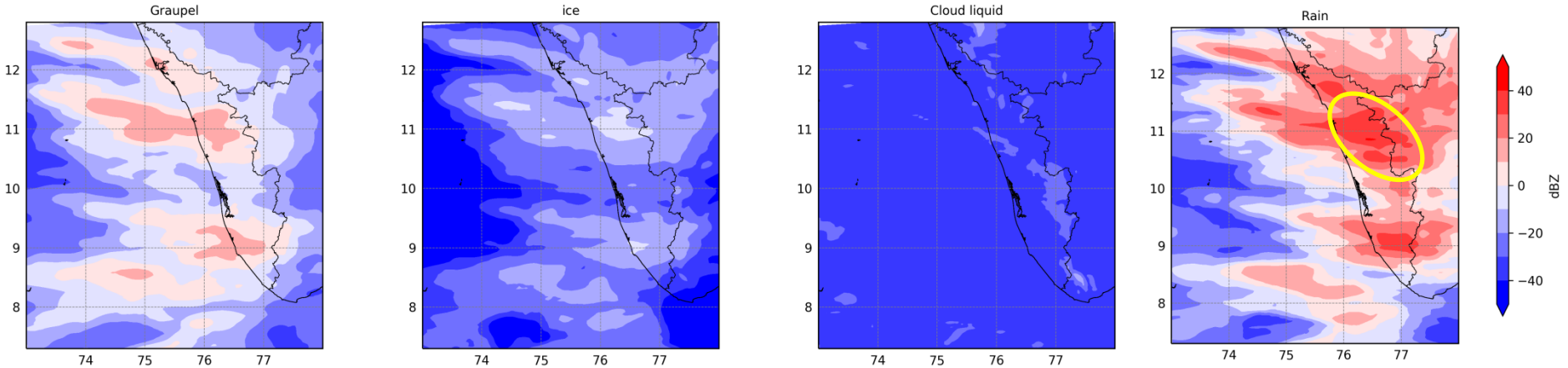
Overall slightly better performance in RAL3.3 compared to RAL3.1.
(except that the volume Error is high in RAL3.3)

Time averaged reflectivity for 2019 Kerala flood episode (Day-2 fcst, 18-24 Z, 8th Aug 2019)

RA3.1 **Graupel (6-8km)** **Ice (6-8km)** **Liquid cloud (1-3km)** **Rain(1-3km)**



RA3.3



Deep convective systems formed over central Kerala are predicted well by RAL3.3 compared to RAL3.1.

Rainfall is preceded by the higher amount of graupel in RAL3.3, while higher contribution of LWC is found in RAL3.1. Rainfall observed in the GPM is generally consistent with the Reflectivity in RAL3.3.

(***See convective session talk by Jayakumar)

Monthly Mean comparison
RAL3.1 vs. RAL3.3

30 days runs with IC: 15 June – 14 July 2024

Cell Stats (All India): DAILY PRECIPITATION

DAILY FLASH COUNTS (ocean masked)

Day-1

Increase in lower thresholds

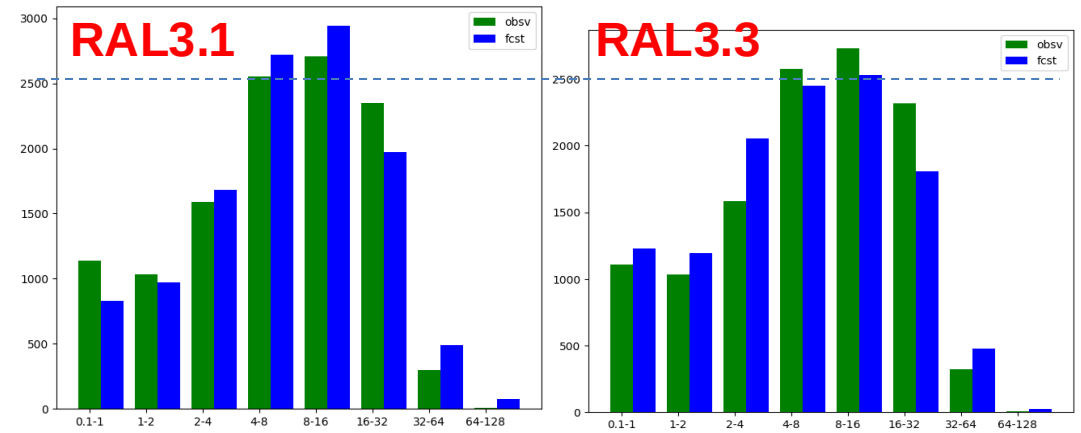
Decrease in higher thresholds

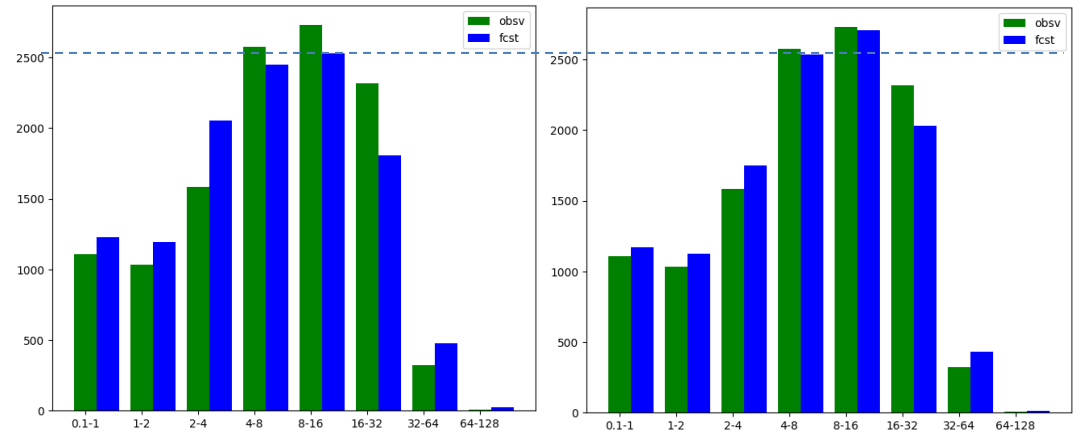
Day-2

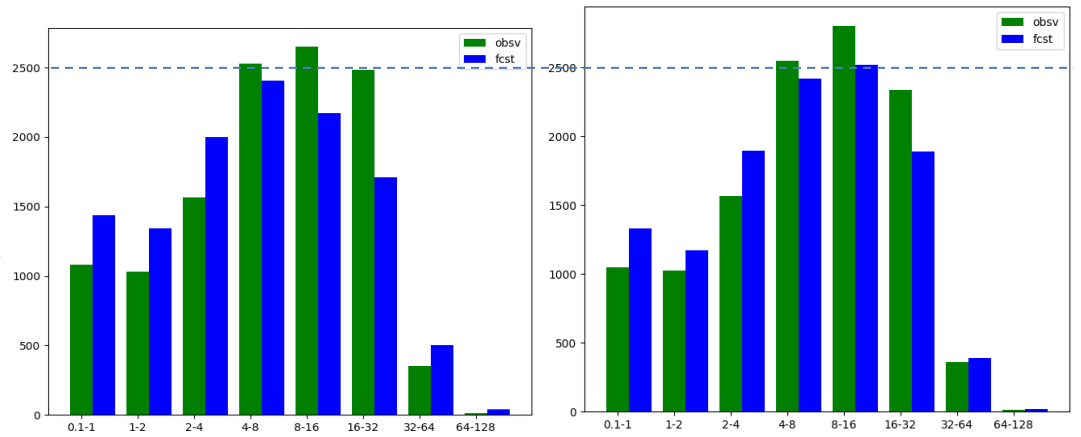
Lightning shows increased frequency in RAL3.3

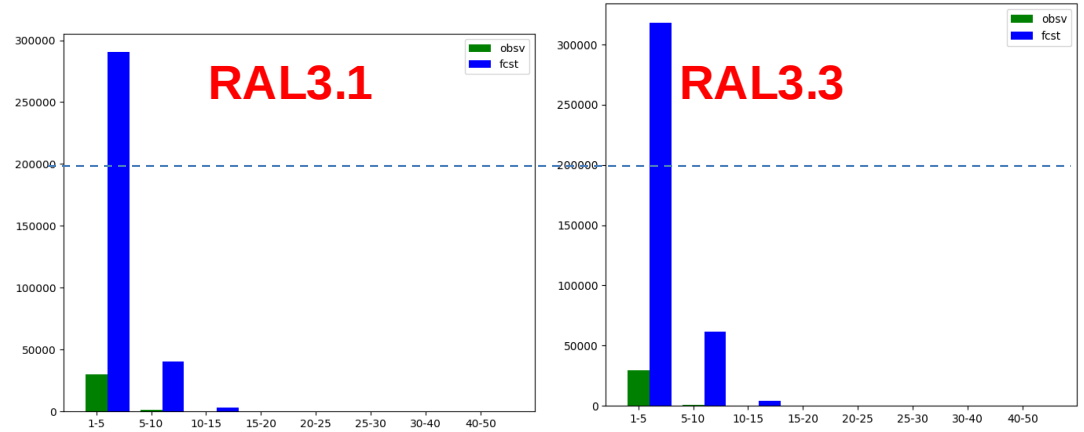
Day-3

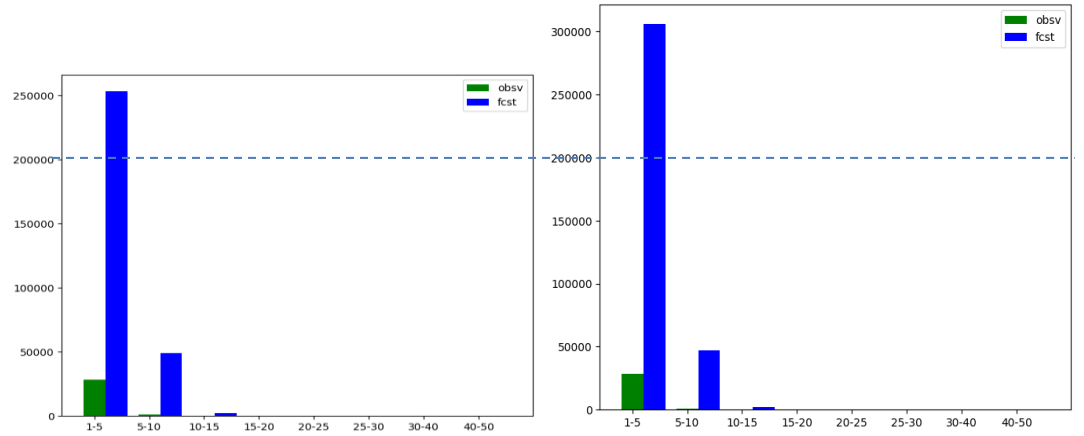
OVERALL BETTER MATCH WITH RAL3.3 COMAPRED TO RAL3.1

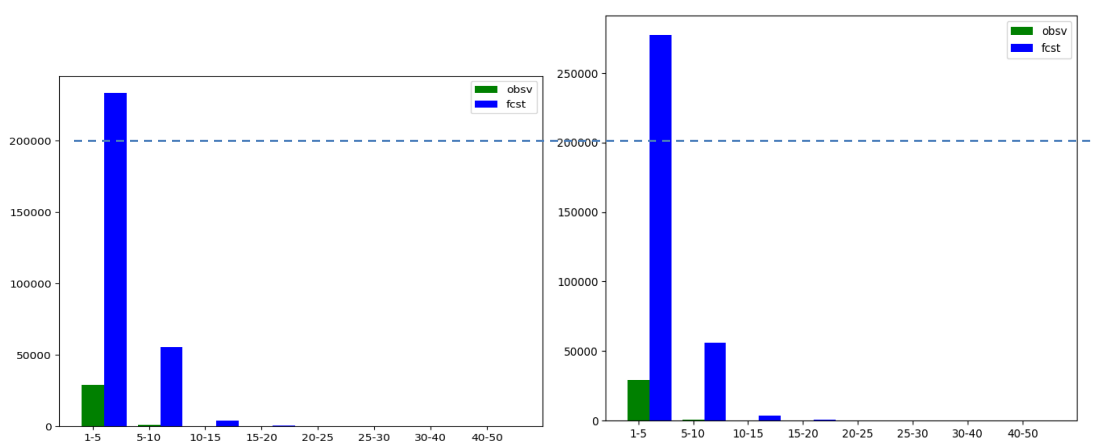








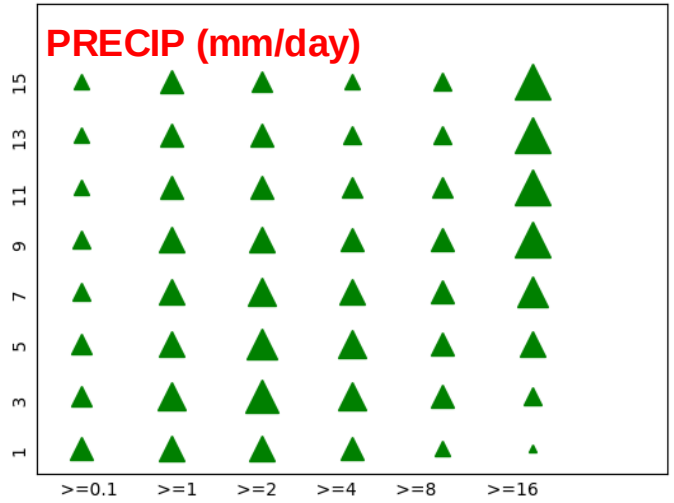




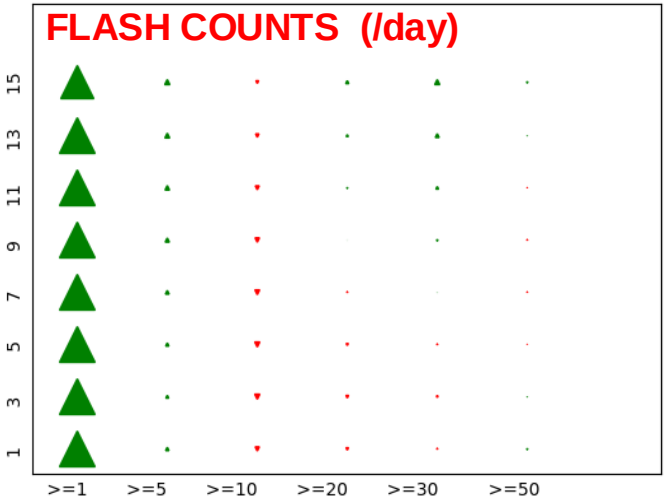
FSSDIF (RAL3.3 – RAL3.1) TOTAL PRECIPITATION AND LIGHTNING FLASH COUNTS

24HR

FSSDIF (THRESH, WIDTH) max/min=0.038103/0.007473 RAL3p3-RAL3p1

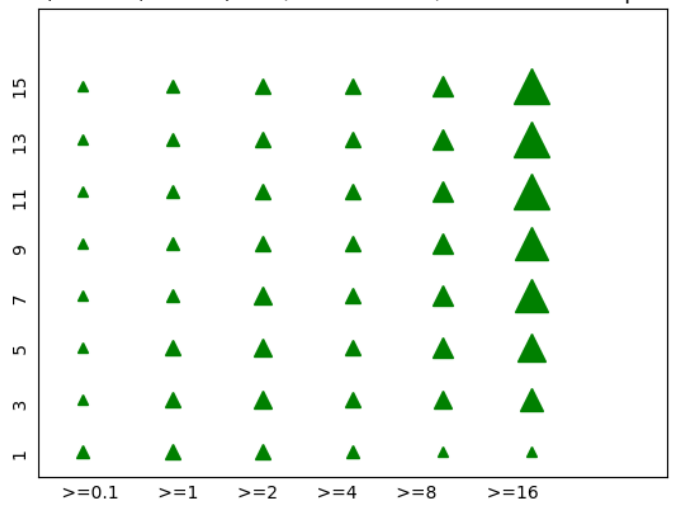


FSSDIF (THRESH, WIDTH) max/min=0.00872/-0.0012597 RAL3p3-RAL3p1

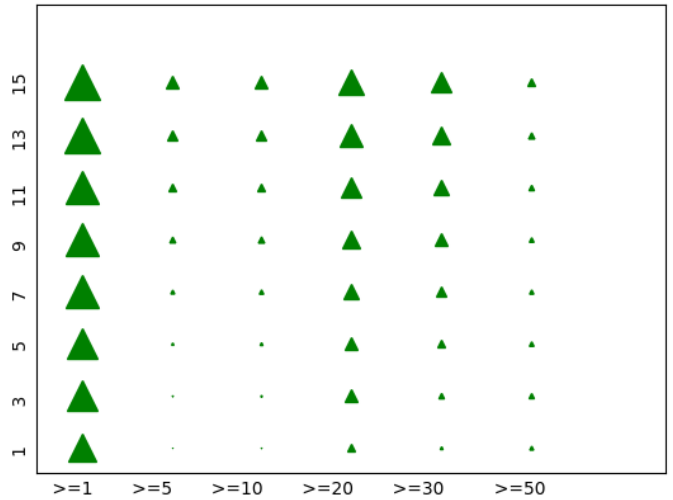


48HR

FSSDIF (THRESH, WIDTH) max/min=0.06775/0.017175 RAL3p3-RAL3p1

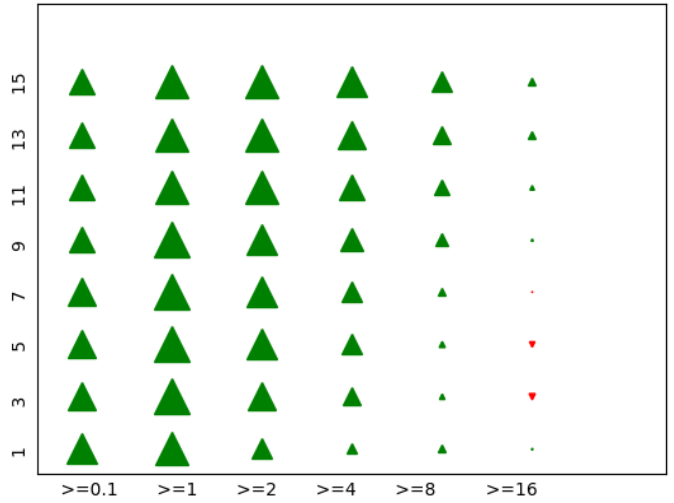


FSSDIF (THRESH, WIDTH) max/min=0.008272/9.9e-05 RAL3p3-RAL3p1

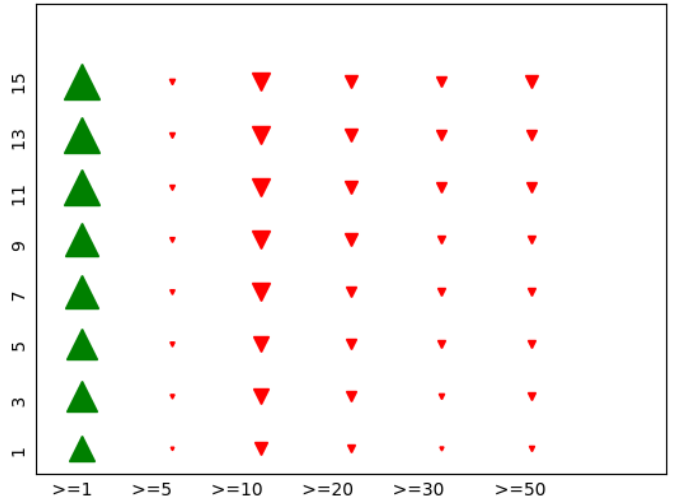


72HR

FSSDIF (THRESH, WIDTH) max/min=0.038416/-0.006735 RAL3p3-RAL3p1



FSSDIF (THRESH, WIDTH) max/min=0.012421/-0.0060701 RAL3p3-RAL3p1



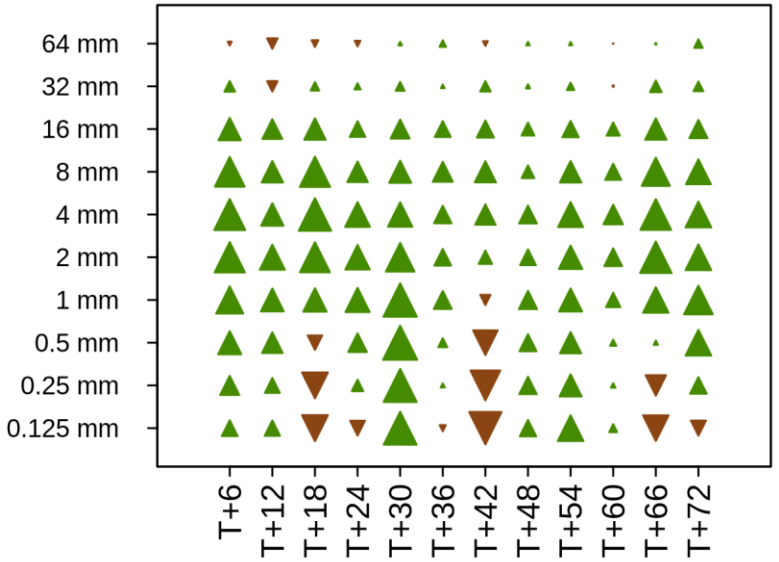
OVERALL POSITIVE IMPACT FOR RAL3.3 COMPARED TO RAL3.1

SIX HOURLY FRACTION SKILL SCORES AND BIAS

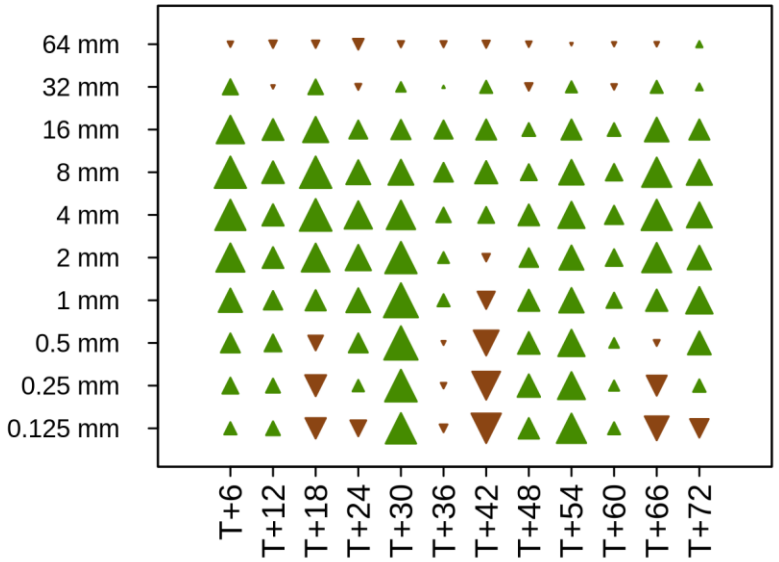
PRECIPITATION (mm/6-hour)

BIAS

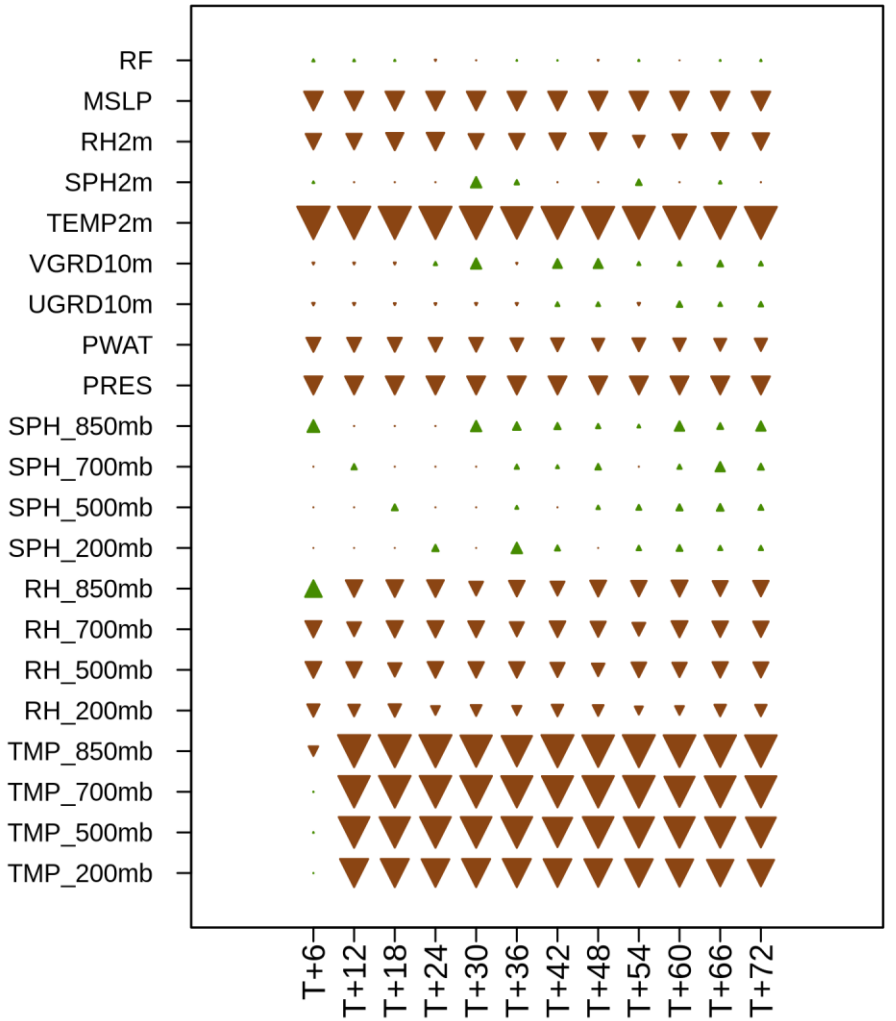
RAL3.3-RAL3.1 (FSS) at 1 grid length



RAL3.3-RAL3.1 (FSS) at 4 grid length



RAL3.3-RAL3.1(BIAS)



Fractions Skill Score (FSS) 6-hourly precipitation shows overall improvement except for the highest threshold

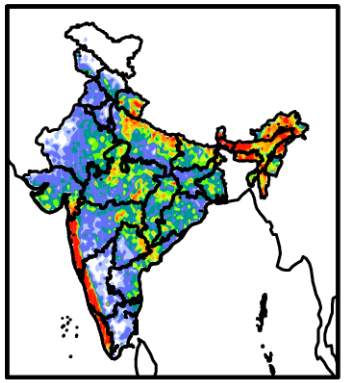
Absolute value of bias over Indian land region shows generally reduction in bias for RAL3.3 for all parameters.

RAL3.3 vs. RAL3.1 EVALUATION

(15 JUNE 2024 TO 14 JULY 2024)

DAILY PRECIPITATION (mm/day)

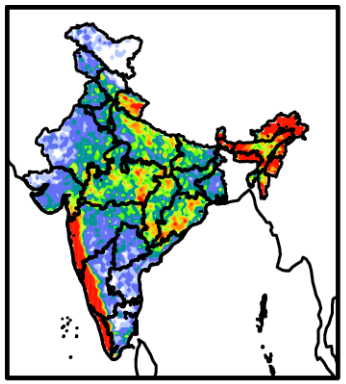
(a) IMD_MSG



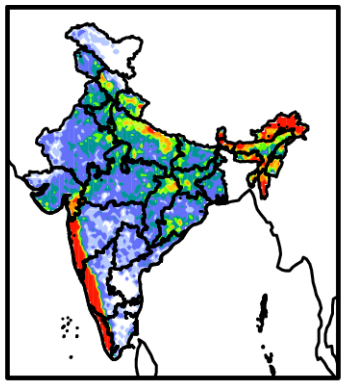
Observed and Model Forecast
Moderate Rain (>15.6mm/day)
(JJ 2024)

More frequency of moderate rainy days in RAL3.3 w.r. to RAL3.1.

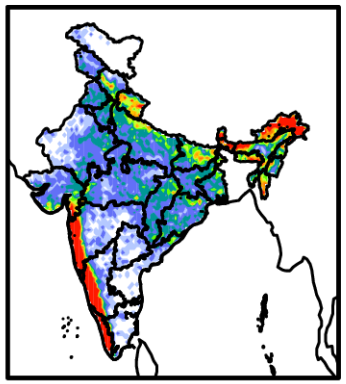
(b) RAL3.1: Day01



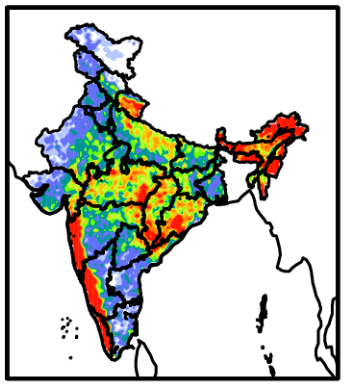
(c) RAL3.1: Day02



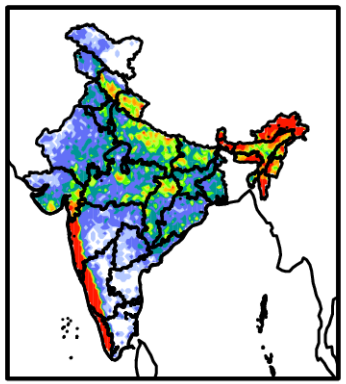
(d) RAL3.1: Day03



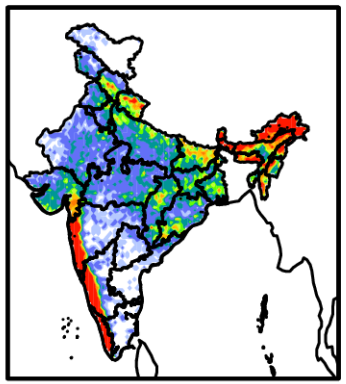
(e) RAL3.3: Day01

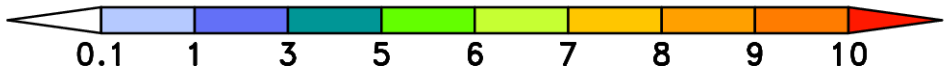


(f) RAL3.3: Day02

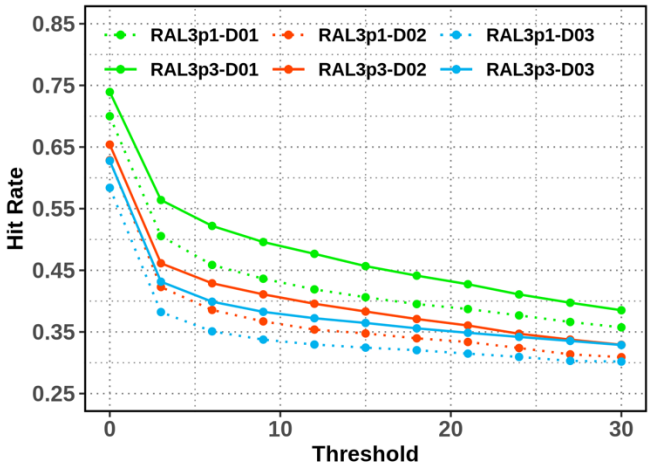


(g) RAL3.3: Day03

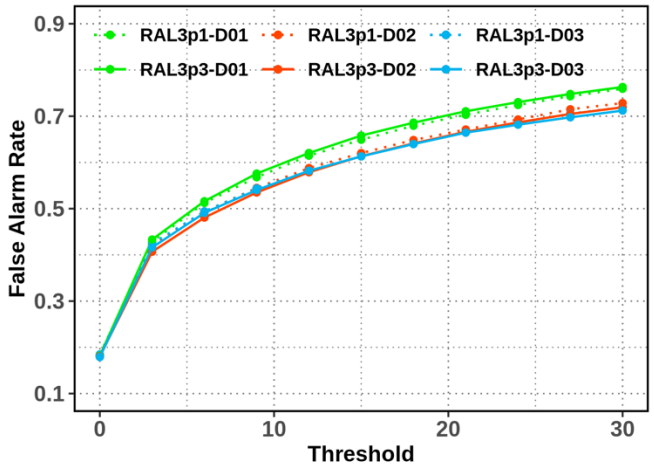




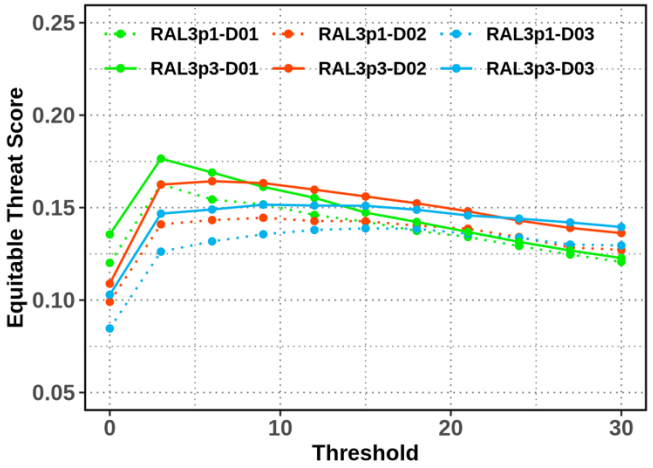
(a) POD



(b) FAR



(c) ETS

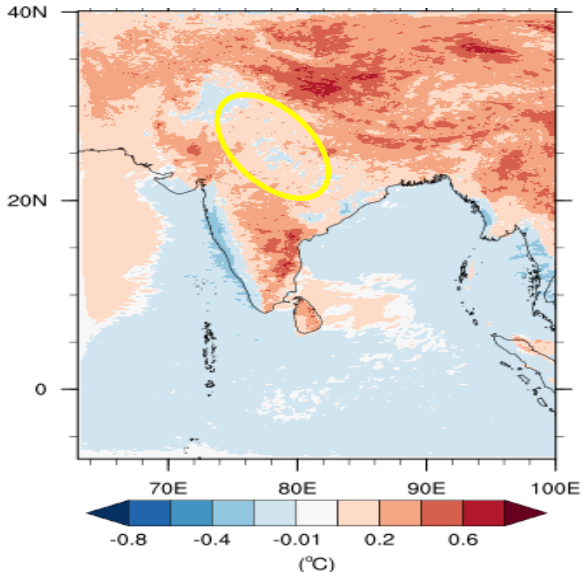


Increased rainy days frequency.

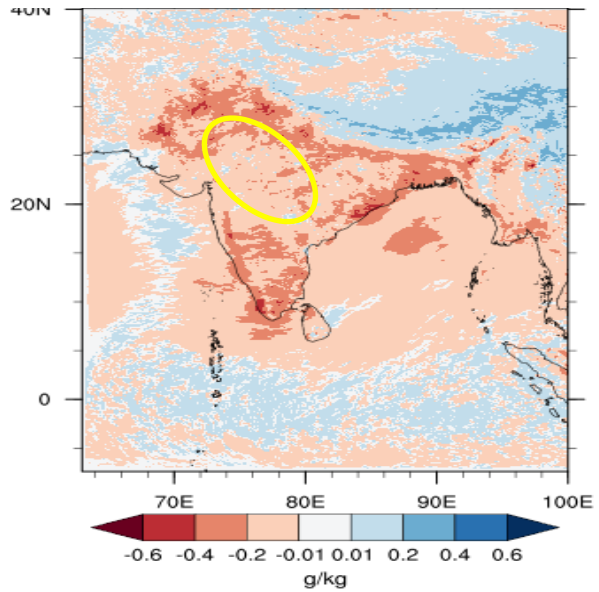
Improved POD, FAR and ETS for RAL3.3 compared to RAL3.1

ANOMALY (RAL3.3-RAL3.1) (15 June – 14 July 2024)

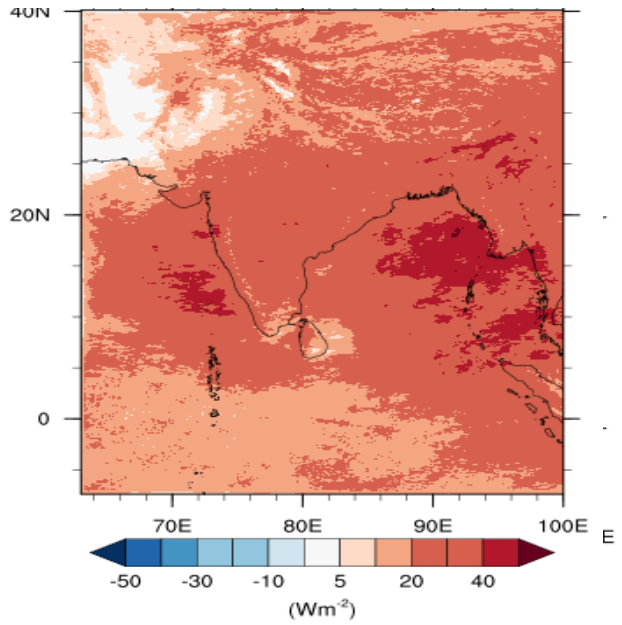
T1.5M



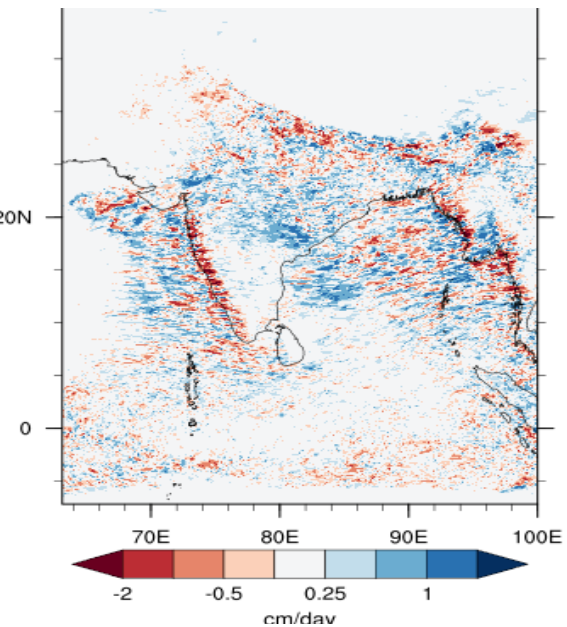
SPH1.5M



DSWF

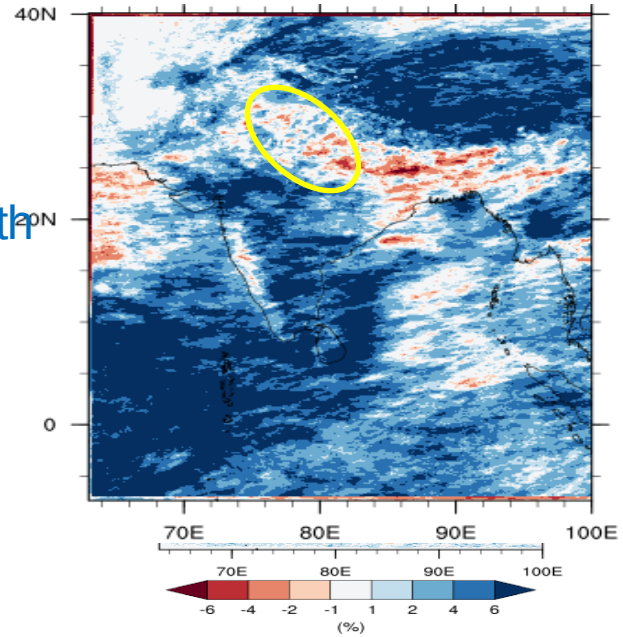


RAIN

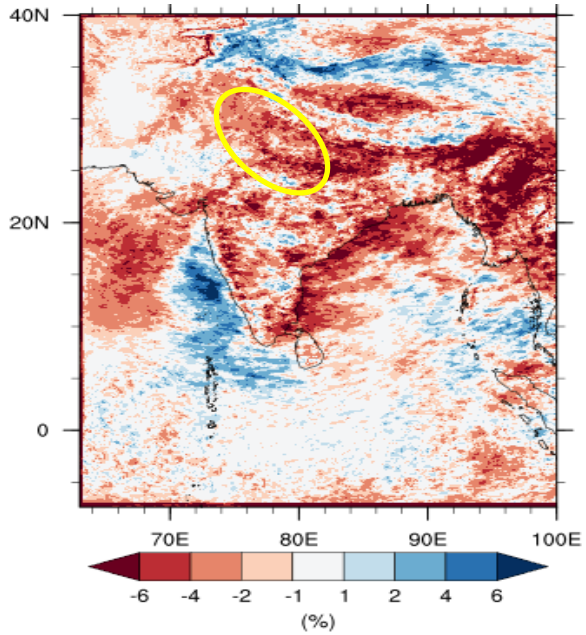


- Cooling over Indo-Gangetic Plains for RAL3.3.
- Drier surface humidity in RAL3.3
- Reduced high cloud fraction over IGP, Increase over south India.
- Reduced medium and low cloud fraction
- Dry rainfall anomalies over western coast and positive anomalies over IGP.

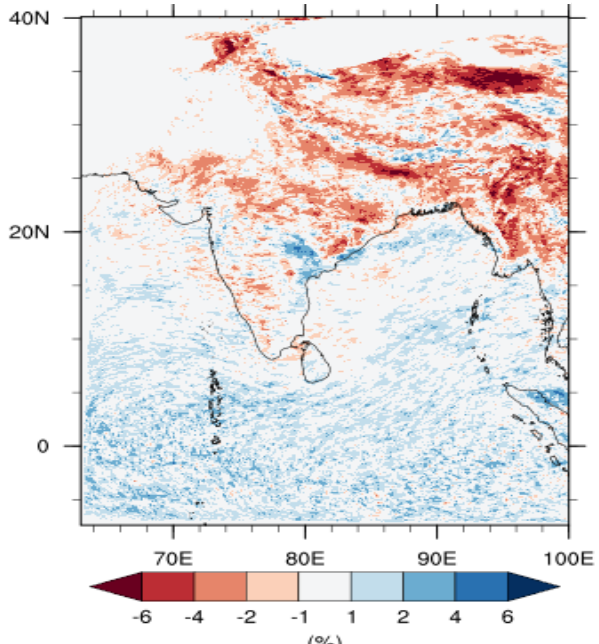
HCLD



MCLD

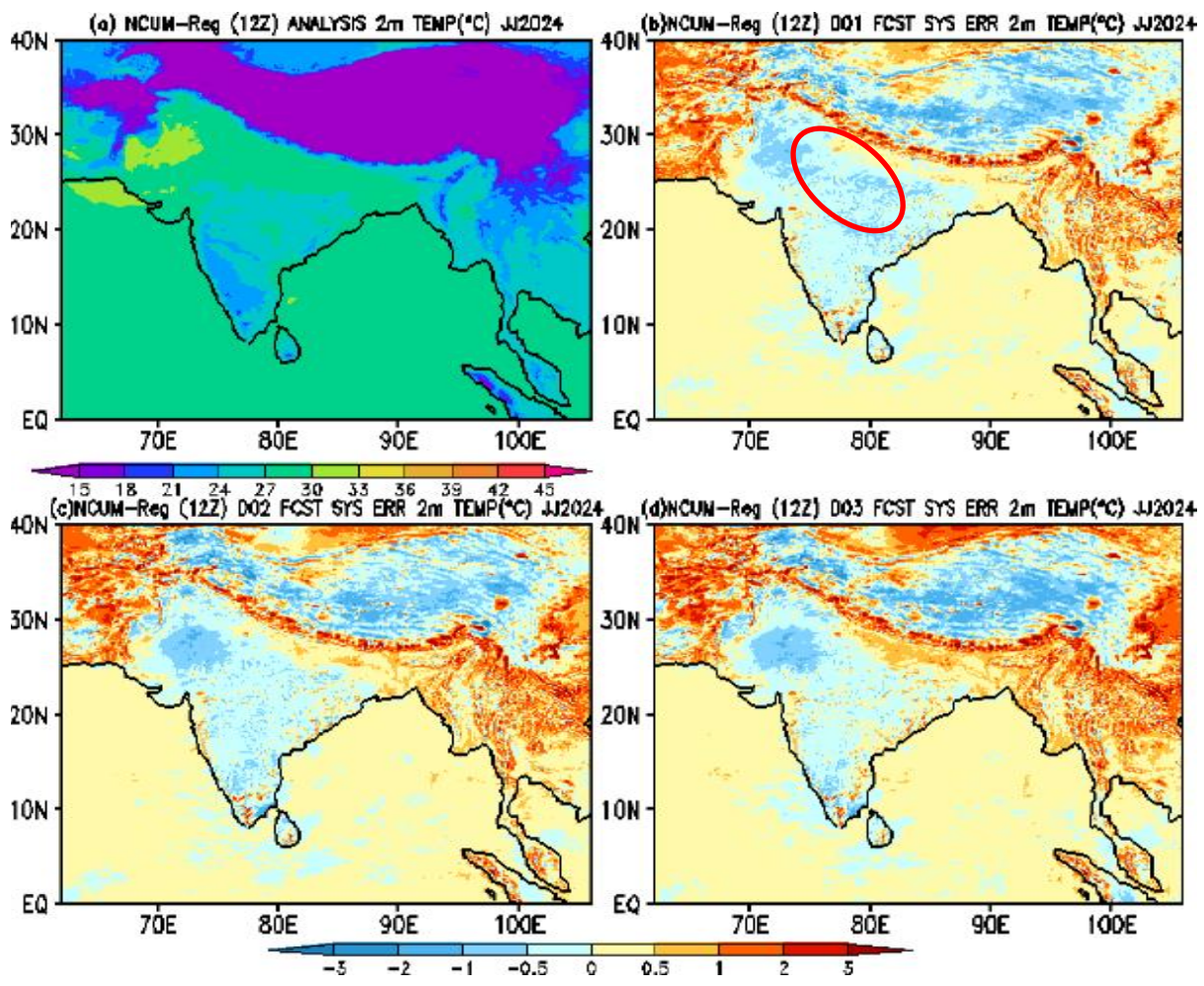


LCLD

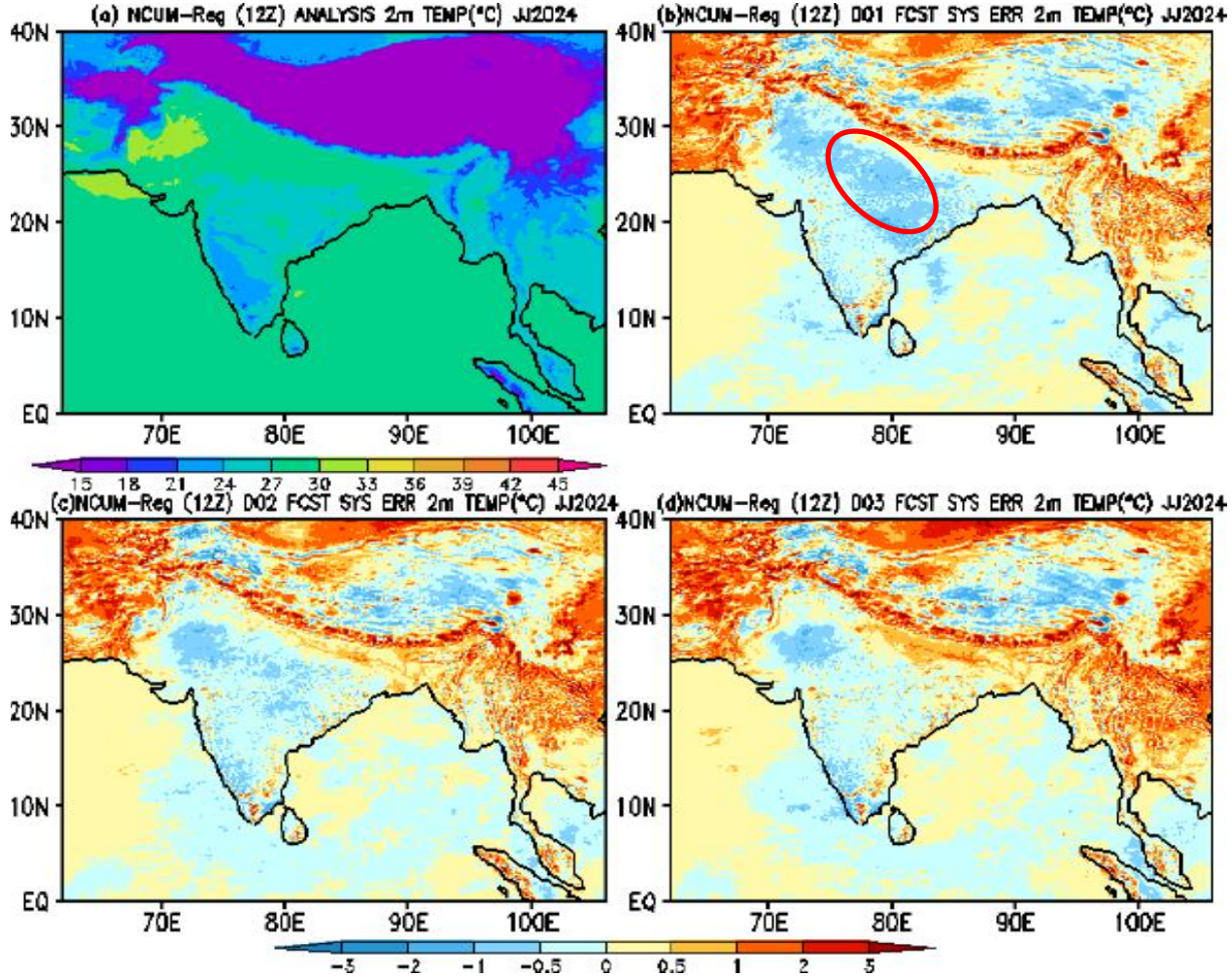


SYSTEMATIC ERRORS (1.5M TEMPERATURE)

RAL3.1



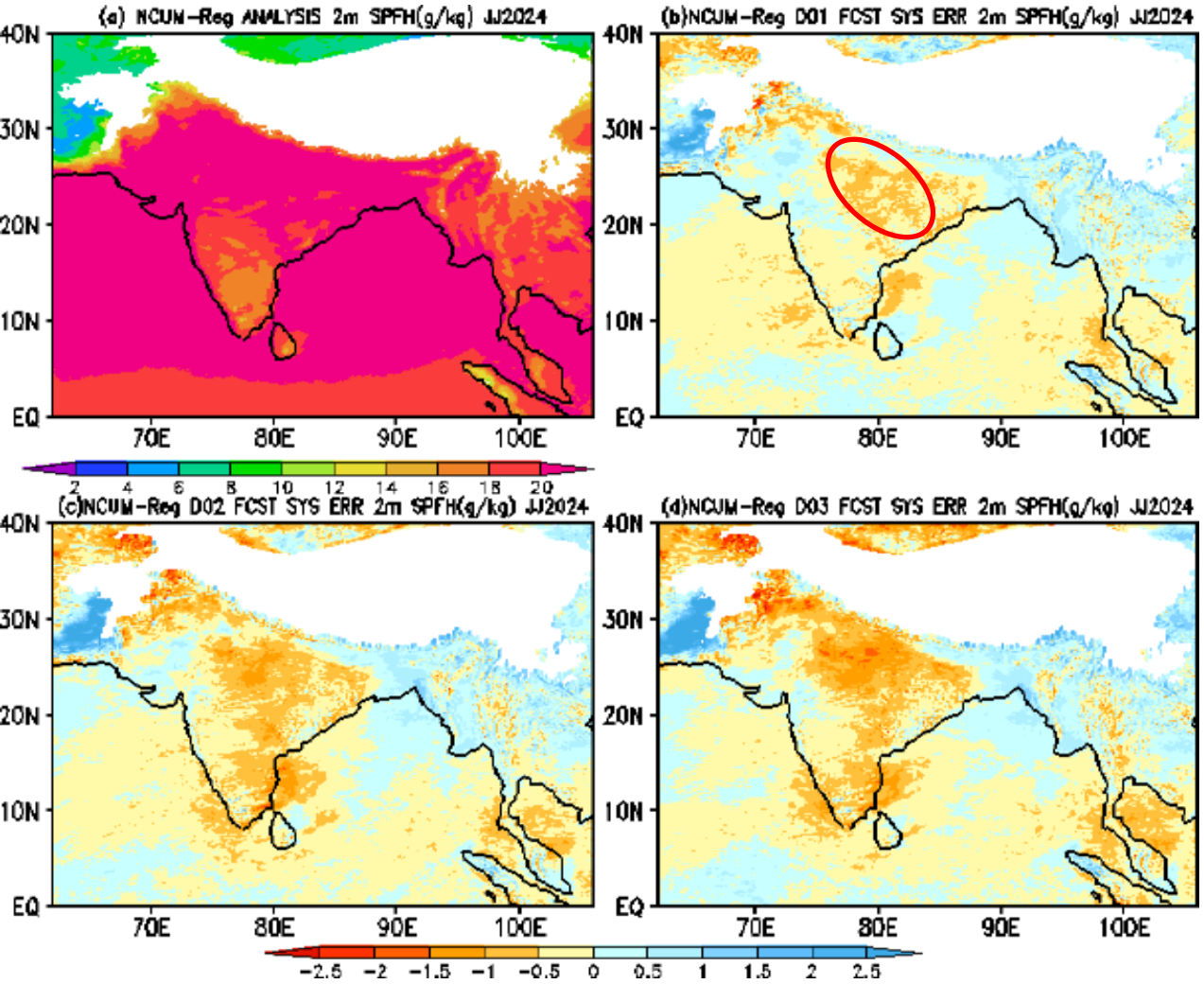
RAL3.3



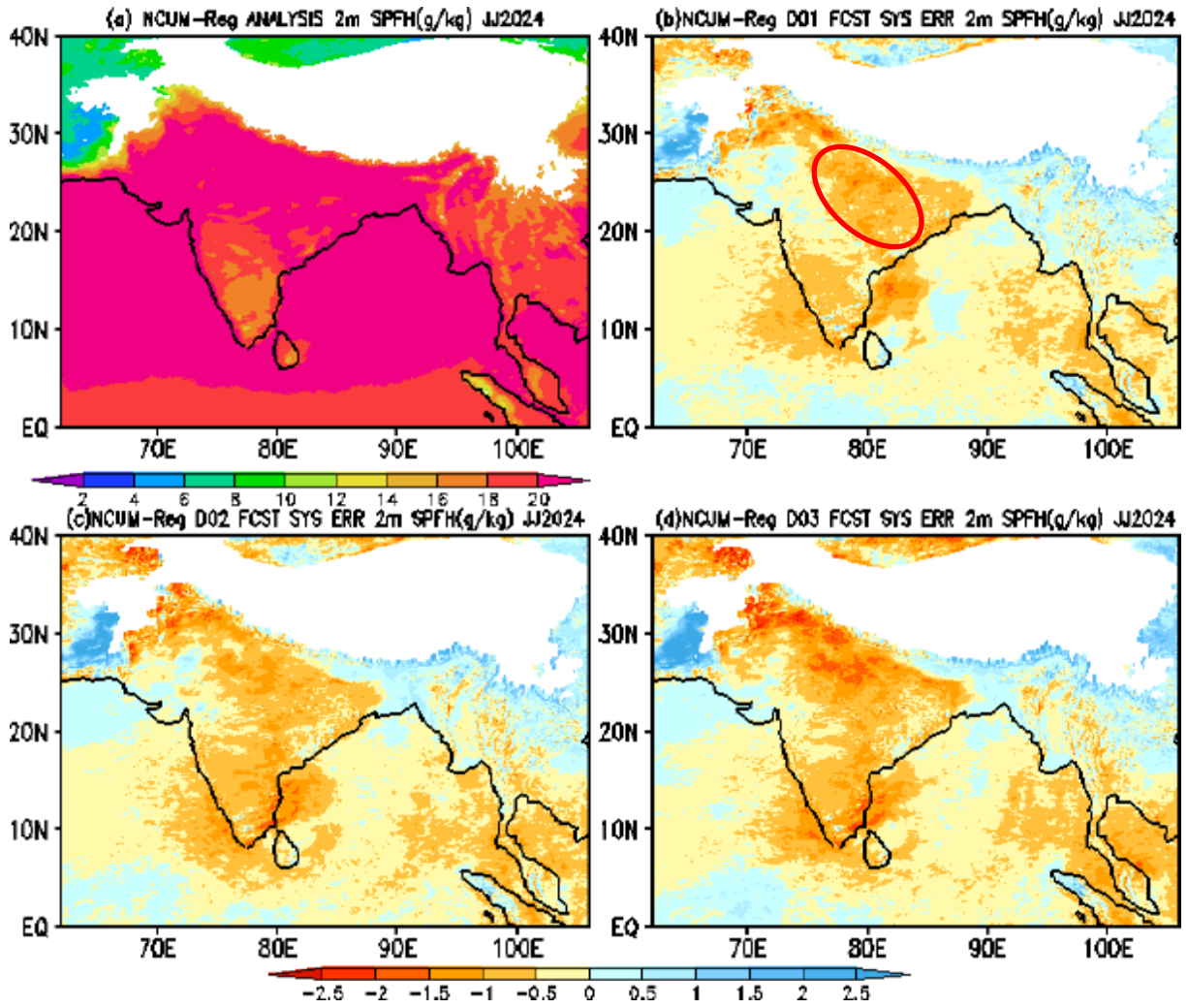
Enhanced cold bias over IGP for RAL3.3 compared to RAL3.1.
Maximum impact on Day-1, while Day 2 & 3 impact is significantly reduced.

SYSTEMATIC ERRORS (1.5M SPEC. HUMIDITY)

RAL3.1



RAL3.3



Enhanced dry bias over IGP in RAL3.3 compared to RAL3.1.

Maximum impact on Day-1, while increased dryness is shown with lead time in RAL3.3 compared to RAL3.1 on Day-3.

SCORE CARD

- ✓ Current operational version of NCUM-R, ‘RAL3.1’ has reduced light rain distribution compared to RAL3.0, but has slightly more realistic frequency distribution of PSD with respect to Disdrometer observations (improved medium dropsize distribution).
- ✓ However, RAL3.1 has been found to have a number of limitations in PSD, like (1) overestimation of mean number concentration significantly in lower rainrate intervals (2) underestimation in predicting the higher size drops.
- ✓ RAL3.3 works well with localised, convectively driven extreme rainfall events with enhanced generation of graupel and ice particles implying improved mixed-phase and warm-rain processes.
- ✓ However, there is a large scope for improvement in the ice processes in the case of more dynamically driven large-scale extreme events (as shown by Jayakumar’s presentation).
- ✓ RAL3.3 shows cold and dry surface anomalies over IGP in comparison to RAL3.1, and reduced mid-layer clouds. Regions of increased high clouds correspond to warm surface anomalies apparently due to Green house effect.
- ✓ Overall, RAL3.3 shows improved performance compared to RAL3.1.

Convective Scale Modelling : Future plans

- Science testing and possible upgradation of NCUM-R to RAL3.3
- RMED works related to CASIM microphysics, cloud and lightning
- DM-Chem development with improved effects of Irrigation, full chemistry, mineral dust and aerosol data assimilation
- High resolution updated ISRO and any new LuLc datasets will be tested for LAMs.
- Urban modeling for multiple cities (Bhubaneswar, Mumbai, Kolkata, etc.)
- Development of Regional Coupled system (2km/1.5km)

***See presentation by Anurose (Urban scale modelling session) on DM-Chem

Questions?