



***NMRF/VR/FEB/2021***



**VERIFICATION REPORT**

**NCUM Global Model Monthly Verification for  
February 2021**

**S. Karunasagar, Harvir Singh, Saji Mohandas, A. Jayakumar, K. Niranjan Kumar,  
and Raghavendra Ashrit**

**March 2021**

**National Centre for Medium Range Weather Forecasting  
Ministry of Earth Sciences, Government of India  
A-50, Sector-62, NOIDA-201 309, INDIA**

## Data control sheet

<b>1</b>	Name of the Institute	National Center for Medium range weather Forecasting
<b>2</b>	Document Number	
<b>3</b>	Date of Publication	March 2021
<b>4</b>	Title of the document	NCUM Global Model Monthly Verification for February 2021
<b>5</b>	Type of the document	Research Report
<b>6</b>	Number of pages, figures and Tables	30 pages and 21 figures
<b>7</b>	Authors	S. Karunasagar, Harvir Singh, Saji Mohandas, A. Jayakumar, K. Niranjan Kumar and Raghavendra Ashrit
<b>8</b>	Originating Unit	National Centre for Medium Range Weather Forecasting (NCMRWF), A-50, Sector-62, NOIDA201 309, India
<b>9</b>	Abstract	This report presents the verification summary of the NCMRWF Global Unified Model (NCUM hereafter) forecasts for February 2021 over India. Firstly, the monthly mean analysis and anomalies in the winds at four levels (850, 700, 500, and 200 hPa) are presented. The anomalies are computed against the ERA-5 climatology (1979-2018). This section is followed by systematic errors in the forecast winds, temperature, and relative humidity at 850, 700, 500, and 200hPa levels. Additionally, systematic errors are presented for Temperature & Specific Humidity at 2m height, Winds at 10m height and column integrated precipitable water (PWAT). The systematic errors in model forecasts are computed against its own analysis. Special attention is given to verify significant weather events of the month. During February 2021, dense fog conditions are noted on multiple days. Verification is presented for the visibility forecasts, specifically over the Indira Gandhi International (IGI) Airport-T3 in Delhi, based on the Delhi Model (DM 330m). These forecasts have been communicated to IMD as part of FDP-Winter Fog and Visibility activity
<b>10</b>	References	
<b>11</b>	Security classification	Unrestricted
<b>12</b>	Distribution	General

<b>Sl. No.</b>		<b>Page No.</b>
I	Introduction	4
1.	Highlights	5
2	Mean and anomaly of winds at 850 and 700 hPa	6
2	Mean and anomaly of winds at 500 and 200 hPa	7
3	Systematic errors in upper air variables	
	(a) 850 hPa winds	8
	(b) 700 hPa winds	9
	(c) 500 hPa winds	10
	(d) 200 hPa winds	11
	(e) 850 hPa Temperature	12
	(f) 700 hPa Temperature	13
	(g) 500 hPa Temperature	14
	(h) 200 hPa Temperature	15
	(i) 850 Relative Humidity	16
	(j) 700 hPa Relative Humidity	17
	(k) 500 hPa Relative Humidity	18
4	Systematic errors in surface variables	
	(a) 10m –winds	19
	(b) 2m – Temperature	20
	(c) Column integrated PWAT	21
	(d) 2m- Specific humidity	22
5	Verification of Rainfall Forecasts	
	(a) Mean and mean error	23
6	Rainfall Categorical scores for NCUM	24
7	Tmin Categorical scores for NCUM	25
II	<b>Special Weather Events of the Month and Highlights</b>	26
	Verification of Visibiity	27
	<b>Annexure: Verification against Radiosonde</b>	
	Table.1 & 2. Geopotential Height at 850 and 500 hPa	28
	Table. 3 &4. Temperature at 850 and 500 hPa	29
	Table. 5 & 6. Wind at 850 and 500 hPa	30

# I. Introduction

This report presents the verification summary of the NCMRWF Global Unified Model (NCUM hereafter) forecasts for February 2021 over India. The operational unified global model NCUM runs twice a day at NCMRWF with a horizontal grid resolution of 12km and 70 vertical levels reaching up to 80 km height and provides weather forecast for the next ten days. However, the forecasts based on 00UTC initial conditions up to Day-5 are considered in this report. The verification is carried out at daily intervals (Day-1, Day-2, etc., up to Day-5) against the model analysis for the near-surface, lower, and upper tropospheric variables.

Firstly, the monthly mean analysis and anomalies in the winds at four levels (850, 700, 500, and 200 hPa) are presented. The anomalies are computed against the ERA-5 climatology (1979-2018). This section is followed by systematic errors in the forecast winds, temperature, and relative humidity at 850, 700, 500, and 200hPa levels. Additionally, systematic errors are presented for Temperature & Specific Humidity at 2m height, Winds at 10m height and column integrated precipitable water (PWAT). The systematic errors in model forecasts are computed against its own analysis.

Verification of daily rainfall forecasts (24hr accumulated rainfall valid at 03UTC) is based on the 0.25 x0.25 grid merged (Satellite+Gauge) IMD-NCMRWF rainfall analysis. Verification of daily Temperature forecasts (Tmax and Tmin) is carried out against the IMDs daily observed gridded (0.5 x 0.5) Tmax and Tmin data. Categorical verification scores are presented for both temperature and rainfall for February 2021. The scores include Frequency Bias (BIAS Score), Probability of Detection (POD), False Alarm Ratio (FAR), Critical Success Index (CSI), Peirce's Skill Score (PSS), and Symmetric Extremal Dependency Index (SEDI).

Special attention is given to verify significant weather events of the month. During February 2021, dense fog conditions are noted on multiple days. Verification is presented for the visibility forecasts, specifically over the Indira Gandhi International (IGI) Airport-T3 in Delhi, based on the Delhi Model (DM 330m). These forecasts have been communicated to IMD as part of FDP-Winter Fog and Visibility activity.

At the end of the document, in the Appendix, statistics are tabulated for verification carried out against the radiosonde observations over India. The Mean error, RMSE and Correlation are presented for Geopotential height, Temperature and winds at two levels (850 and 500 hPa) for all lead times from day-1 to Day-10.

Some important highlights of the entire evaluation of NCUM forecasts during February 2021 and related biases are given below. These highlights are compiled from the Figures given below.

# 1. Highlights

## 1. Mean Analysis & anomaly winds (850, 700, 500 and 200 hPa):

- The mean 850 hPa winds feature (a) cyclonic gyre over eastern equatorial Indian Ocean (b) northwesterlies over Indo-Gangetic Plains (IGP) and (c) easterlies over Bay of Bengal and Arabian Sea. The wind anomaly circulation indicates stronger than normal flow during February 2021. **(Figures 1)**.
- The mean 700 hPa wind has (a) and (b) extend from 850 hPa level and a cyclonic gyre is prominent over the Arabian Sea. The wind anomaly shows stronger than normal flow associated with (a) and (b). Additionally, the anomaly shows stronger westerlies (>6m/s) over Arabian Sea and Bay of Bengal. **(Figures 1)**.
- The mean 500 and 200 hPa winds show strong westerly flow over northern parts of the domain. The anomaly flow suggests weaker than normal strength of the flow at 500 and 200 hPa over northern India and SW Asia. Over peninsular India, the southwesterly flow (500 hPa) was stronger than normal. **(Figure 2)**.

## 2. Systematic errors in winds, temperature & moisture fields:

- At 850 hPa northwesterly bias (>3m/s) is prominent over west coast of India in Day-1 which is prominent and widespread over NE Arabian Sea. Northeasterly bias over SE Coast of India, Easterly bias over Bay of Bengal and westerly bias over western Indian Ocean south of equator are prominent **(Figure 3)**. Similar biases are evident near the surface **(10m winds; Figure 14)**
- At 700 hPa the systematic errors tend to very noisy. Notable features are westerly bias over western Indian Ocean just south of the equator and cyclonic anomaly circulation over Arabian Sea. **(Figure 4)**
- At 500hPa, westerly bias over IGP, easterly bias over peninsular, Arabian Sea and Bay of Bengal and westerly bias over eastern Indian Ocean south of the equator are prominent. **(Figure 5)**.
- At 200 hPa widespread easterly bias can be seen with strong bias over central India, Arabian Sea and adjoining Africa and eastern equatorial Indian Ocean. **(Figure 6)**.
- The systematic errors in forecast temperatures at 850, 700 hPa levels feature strong warm bias (>0.5 to 2°C) over the Indian subcontinent, while cold bias is noticed in the upper troposphere (200hPa), except over central Asia. The bias more pronounced with forecast lead times **(Figures 7-10 and Figure 15)**.
- Systematic errors in forecast relative humidity at 850 hPa (& near surface) show strong dry bias over India and wet bias over neighboring seas. However, at higher levels wet bias over Indian landmass is prominent. Dry bias is also reflected in PWAT and specific humidity at 2m height **(Figures 11-13, 16-17)**

## 3. Verification Scores for Rainfall and minimum Temperature:

- The rainfall activity (>50mm/day) is mainly observed over hilly regions of J & K and Himachal region which is overestimated by the model. Rainfall over central India (>10mm/day) is also overestimated. **(Figure 18)**.
- The forecast skill is reasonable in predicting rainfall events of low intensity (<3mm/day) where the PSS values are > 0.3. For rainfall events of higher intensities (>6mm/day etc.) the PSS values are lower than 0.3. **(Figure 19)**.
- Tmin forecast verification during February 2021 is relatively poor, with PSS values lower than 0.3 at all lead times. **(Figure 20)**.

## 2. Mean and anomaly of winds:

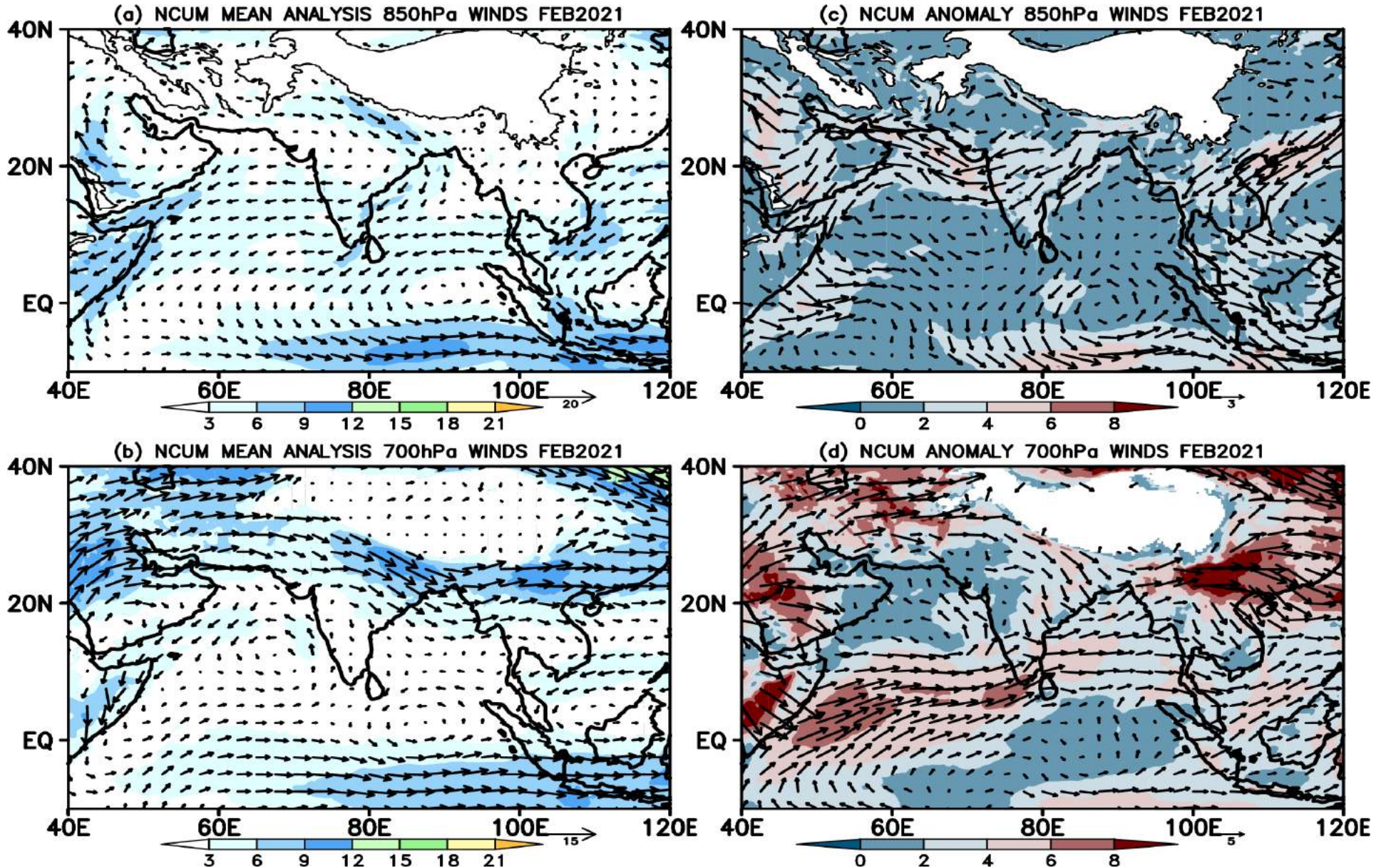


Figure 1. Mean winds at (a) 850 hPa and (b) 700 hPa in the NCUM Analysis during February 2021. Right panels show the anomaly circulation at (c) 850 hPa and (d) 700 hPa.

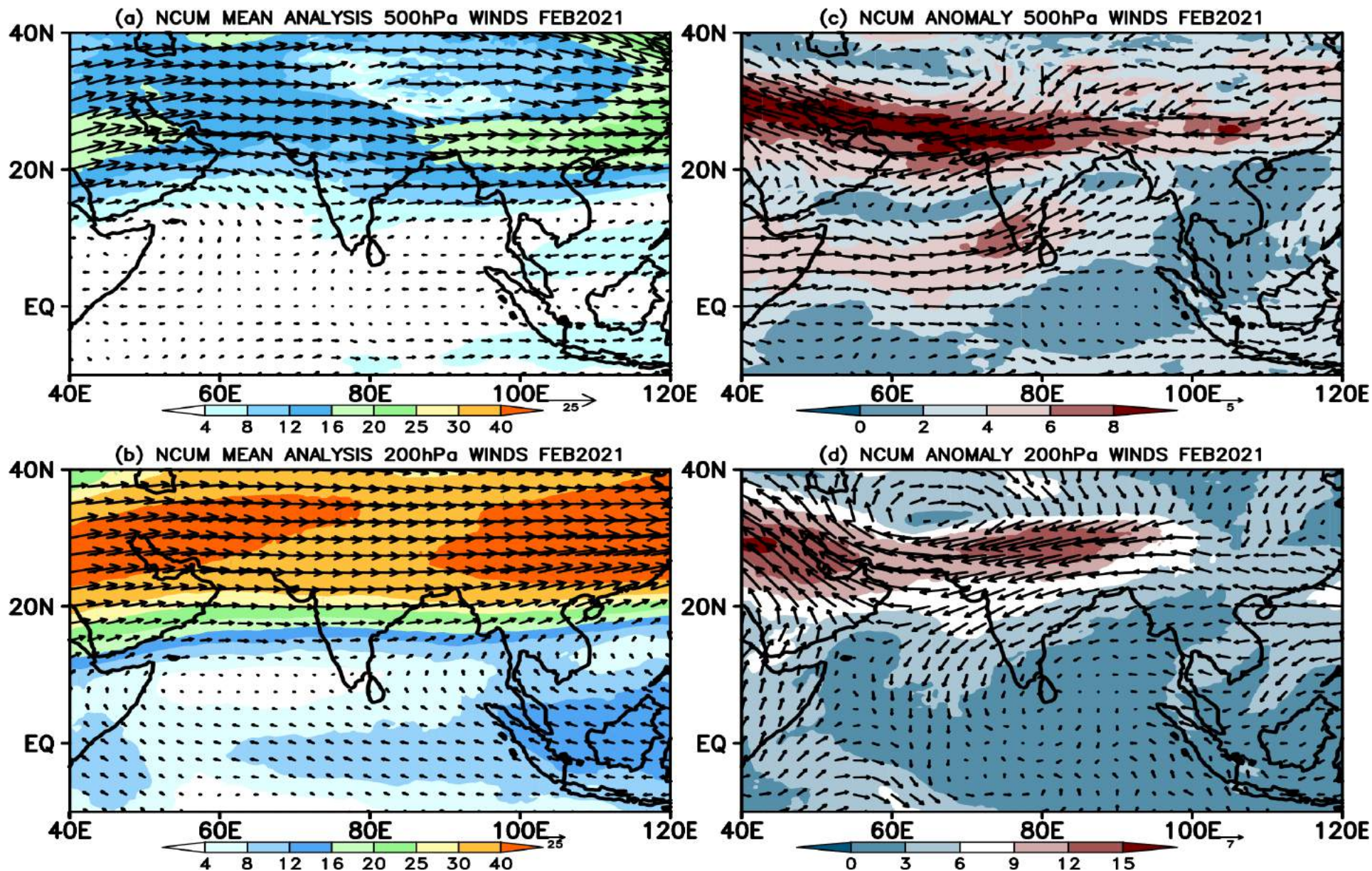


Figure 2. Mean winds at (a) 500 hPa and (b) 200 hPa in the NCUM Analysis during February 2021. Right panels show the anomaly circulation at (c) 500 hPa and (d) 200 hPa.

### 3. Systematic errors in Upper air variables:

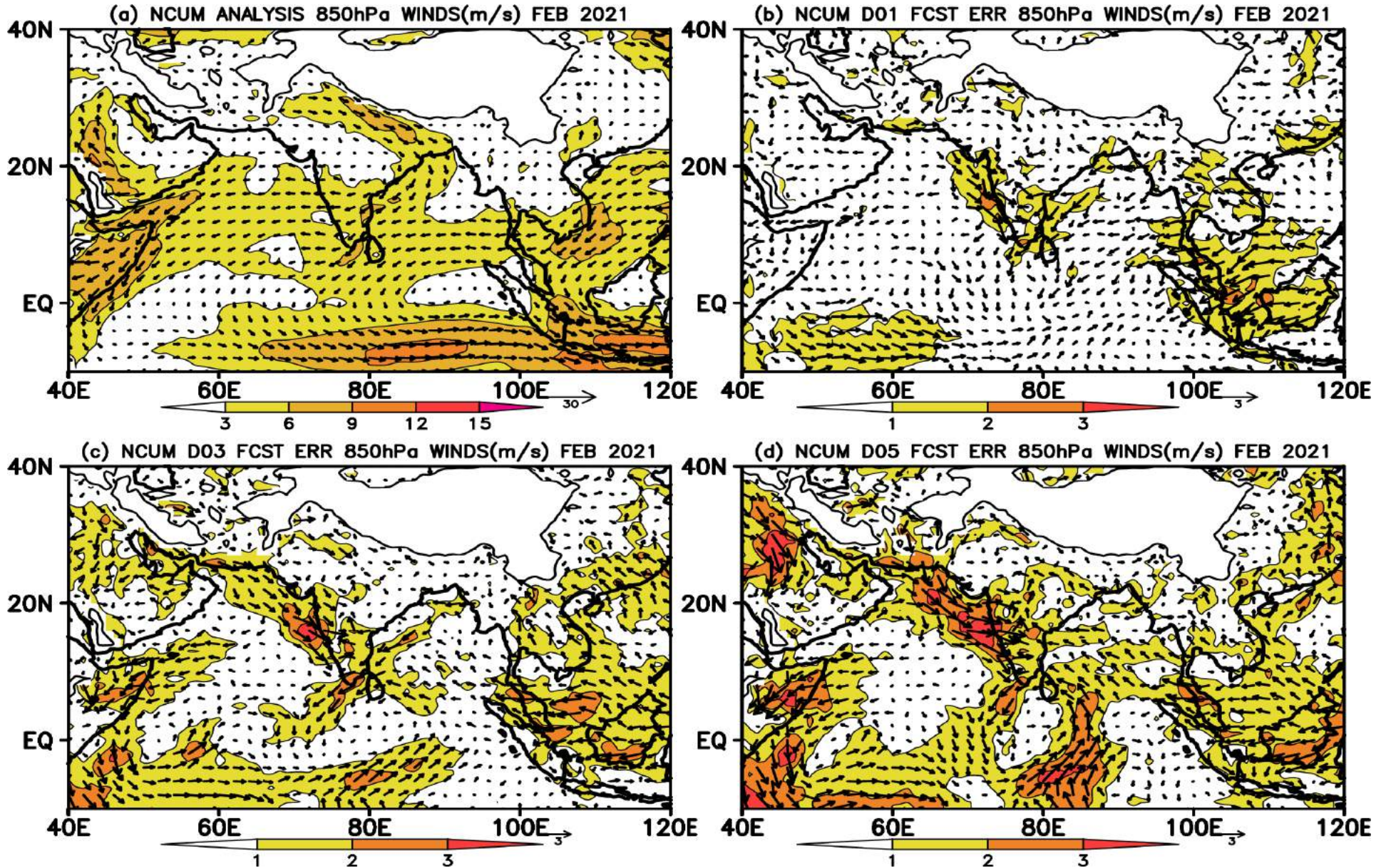


Figure 3. (a) Mean winds at 850 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021



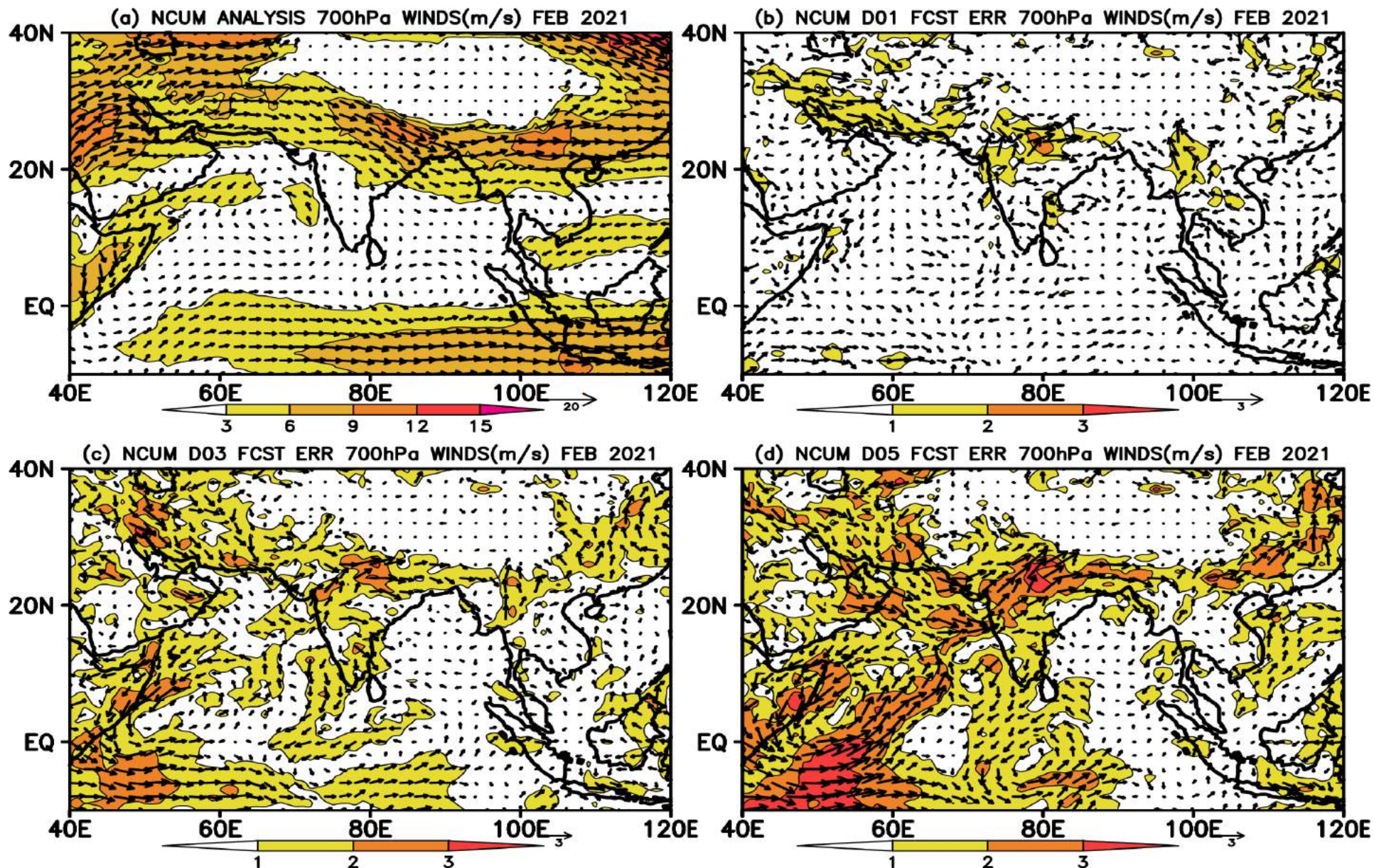


Figure 4. (a) Mean winds at 700 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

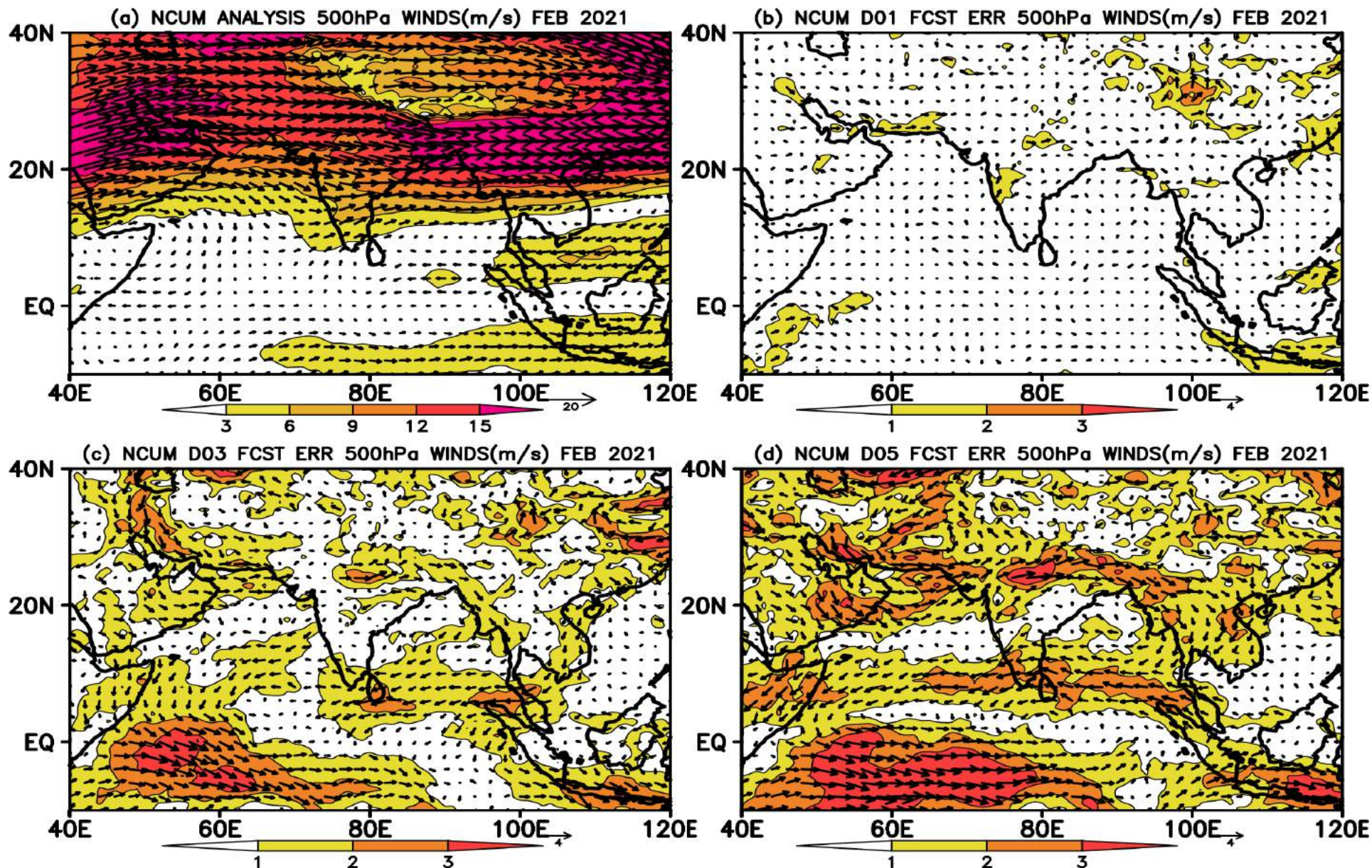


Figure 5. (a) Mean winds at 500 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

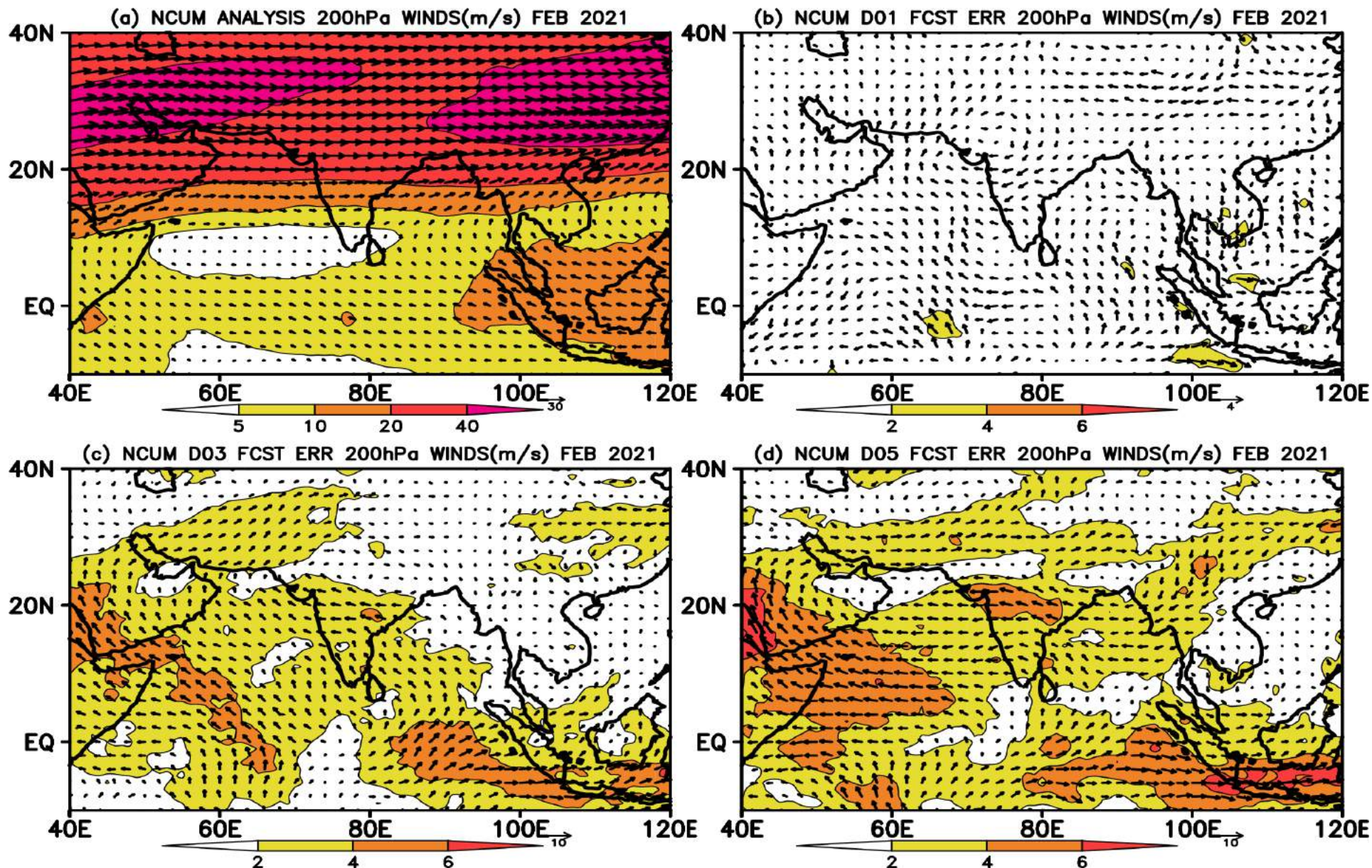


Figure 6. (a) Mean winds at 200 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

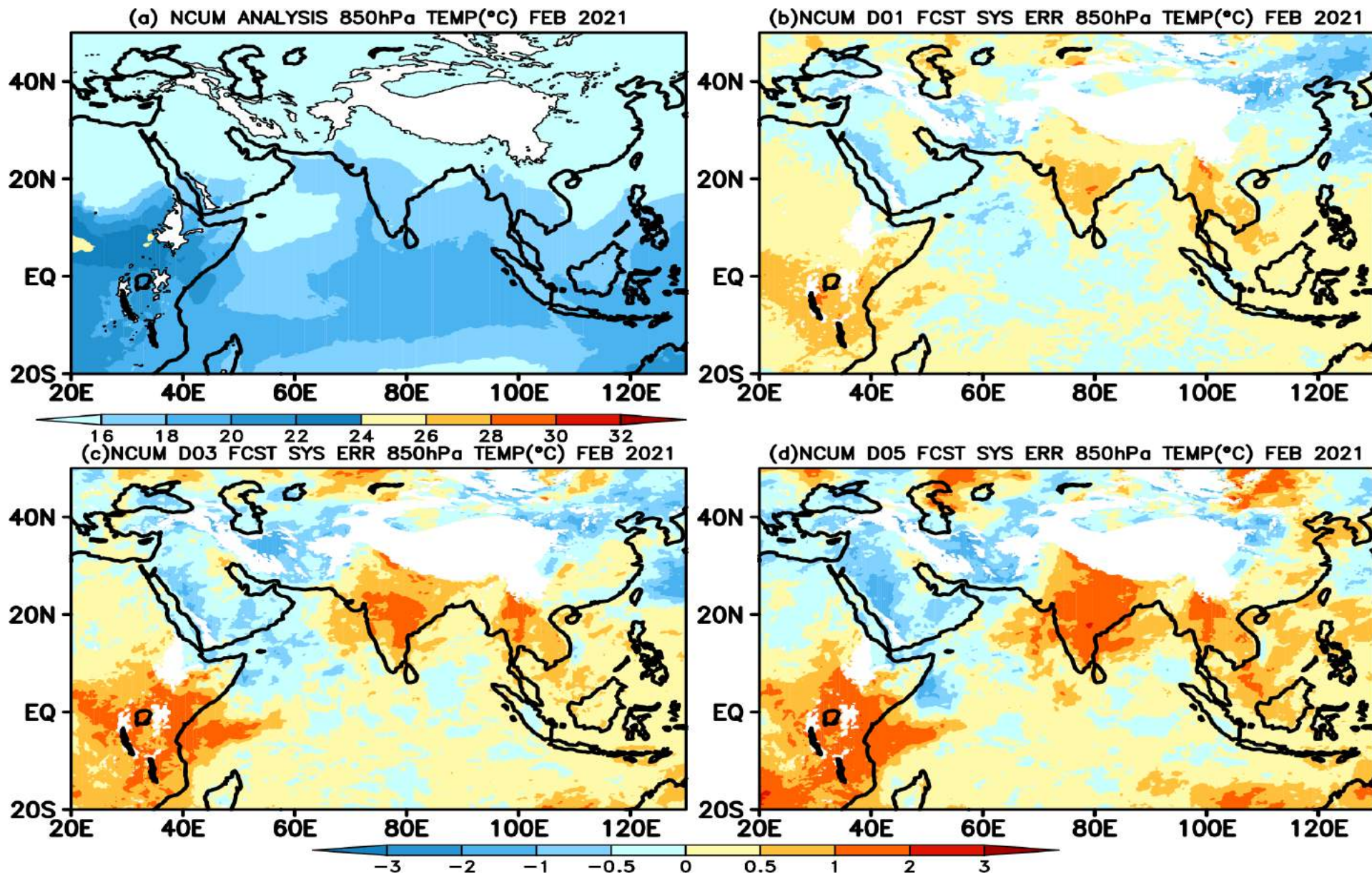


Figure 7. (a) Mean Temperature at 850 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

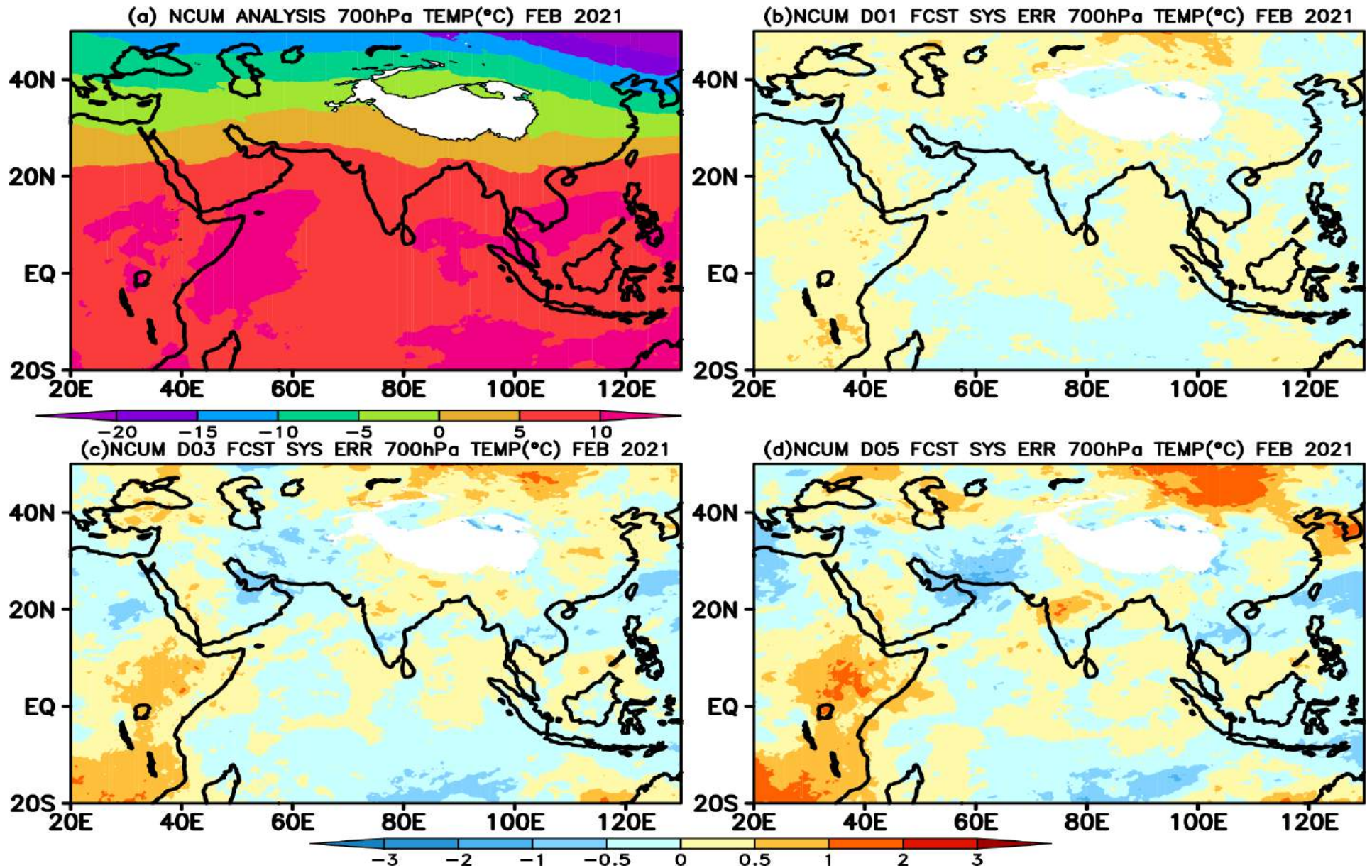


Figure 8. (a) Mean Temperature at 700 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

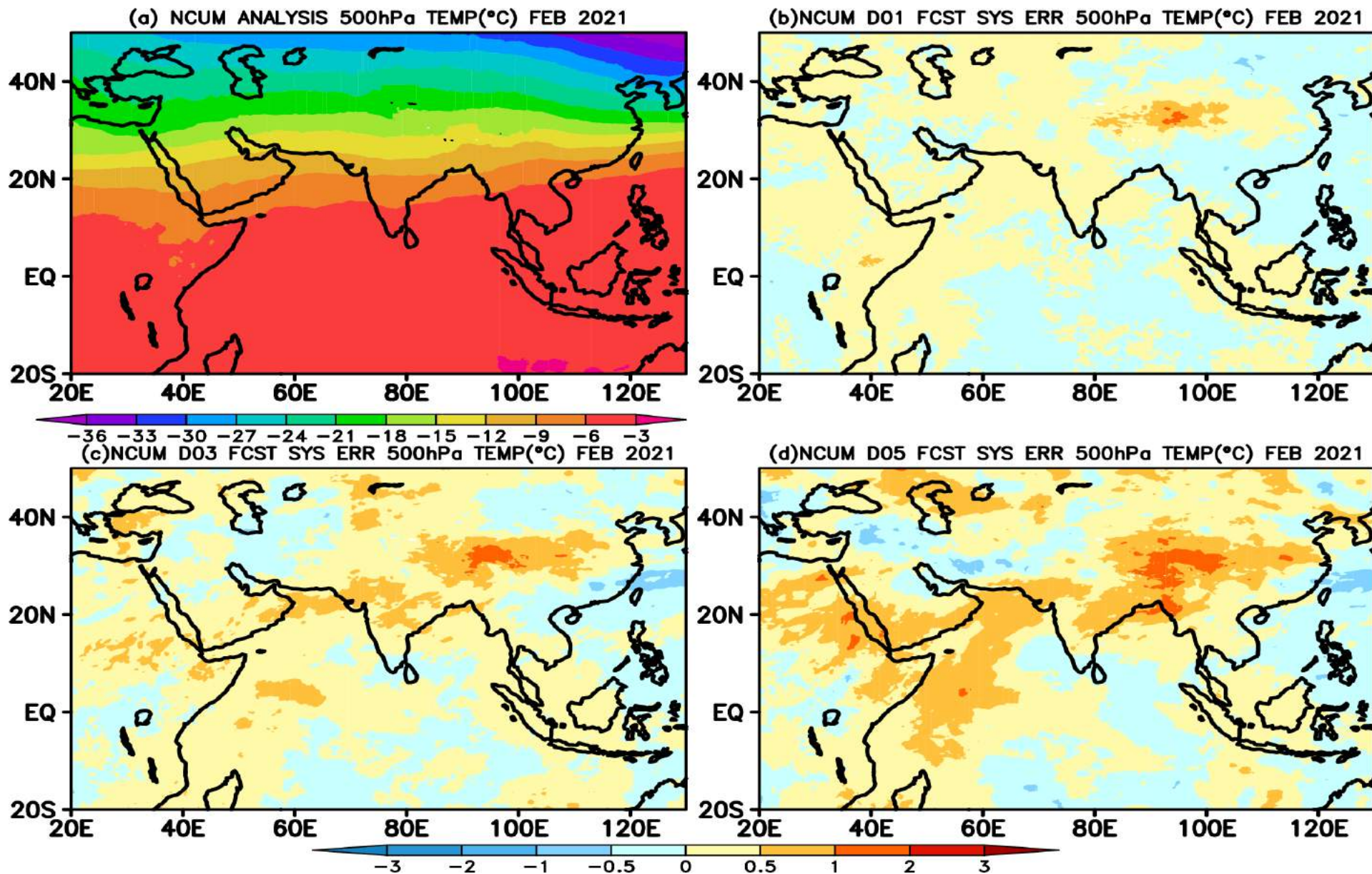


Figure 9. (a) Mean Temperature at 500 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

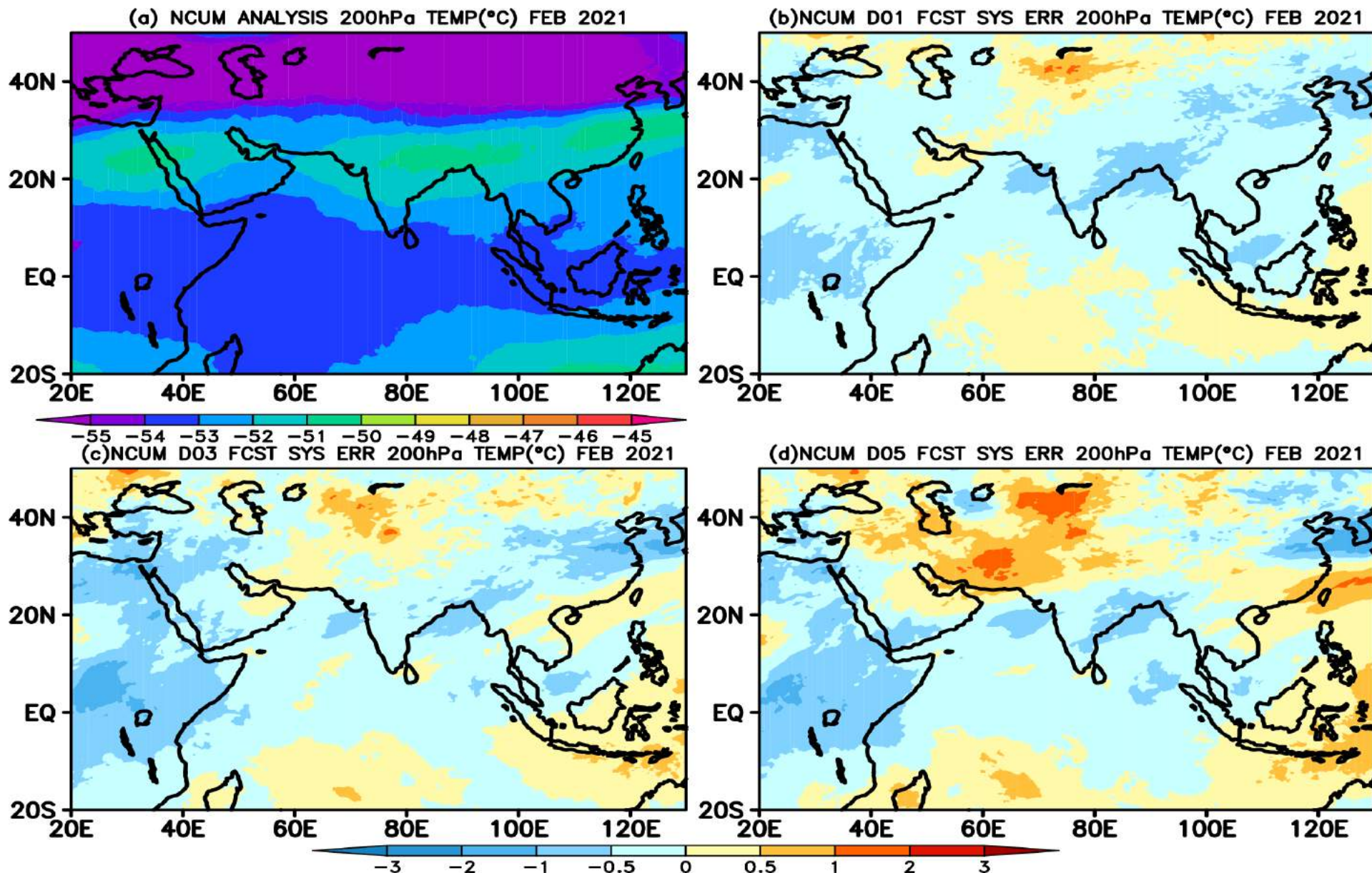


Figure 10. (a) Mean Temperature at 200 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

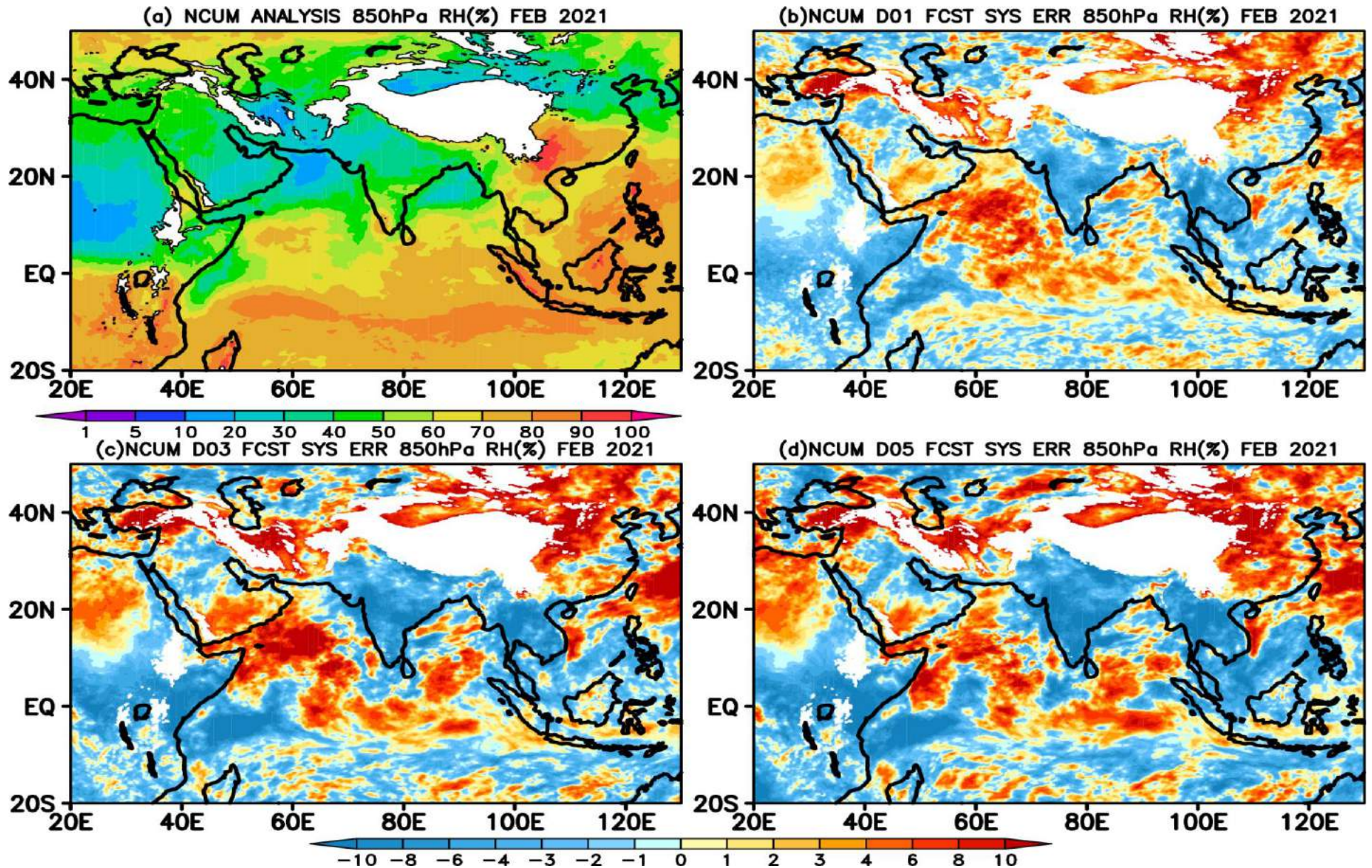


Figure 11. (a) Mean Relative Humidity at 850 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021



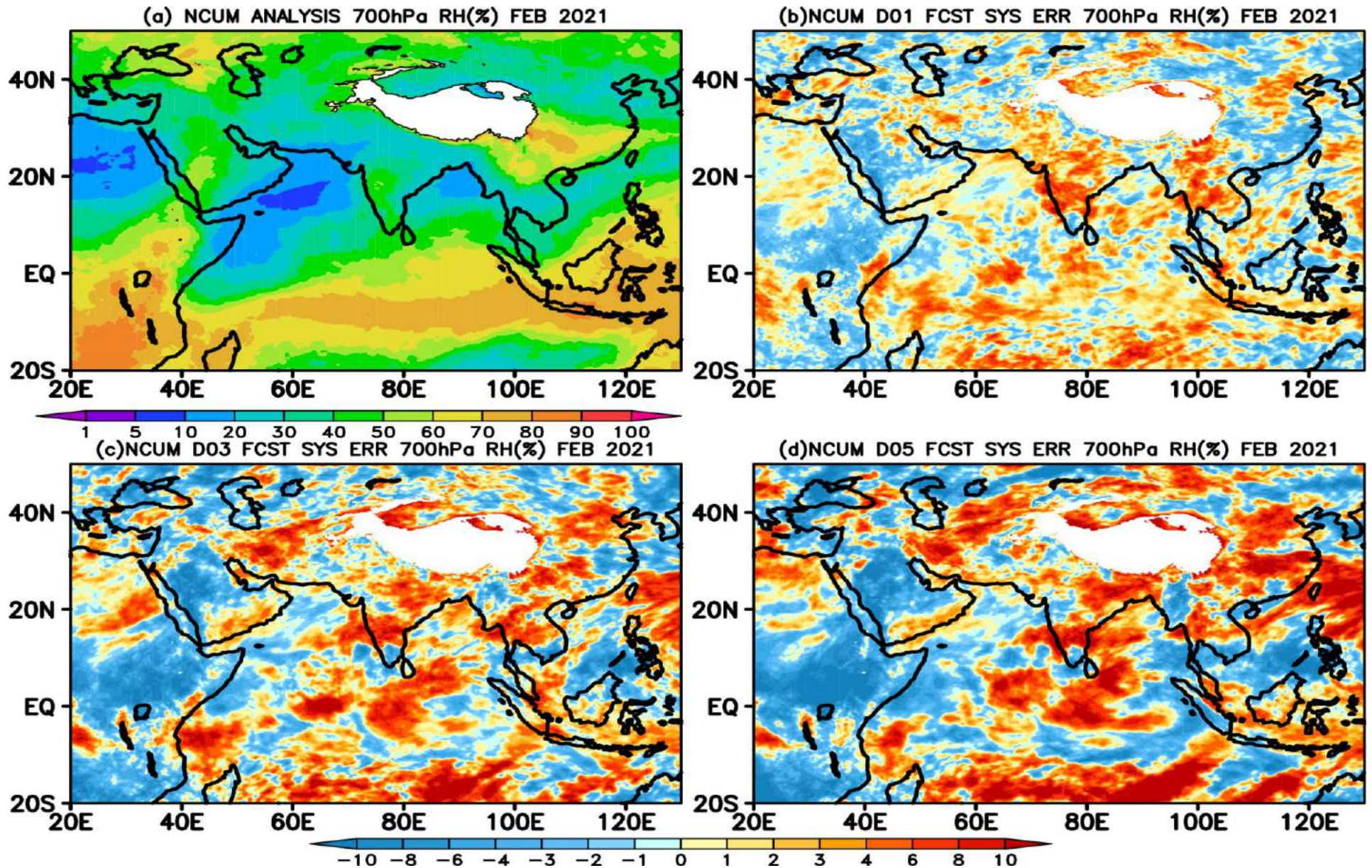


Figure 12. (a) Mean Relative Humidity at 700 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

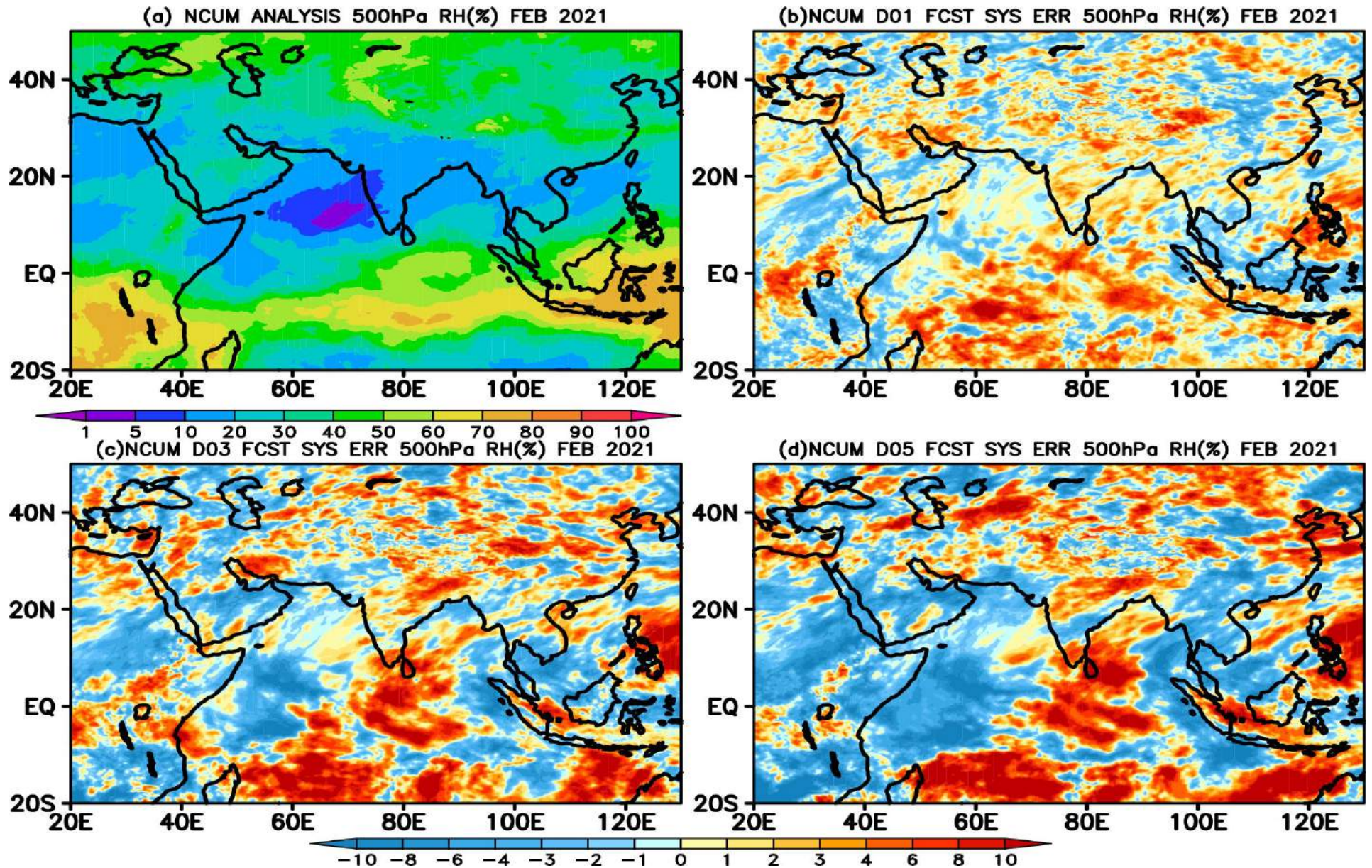


Figure 13. (a) Mean Relative Humidity at 500 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

#### 4. Systematic errors in surface variables

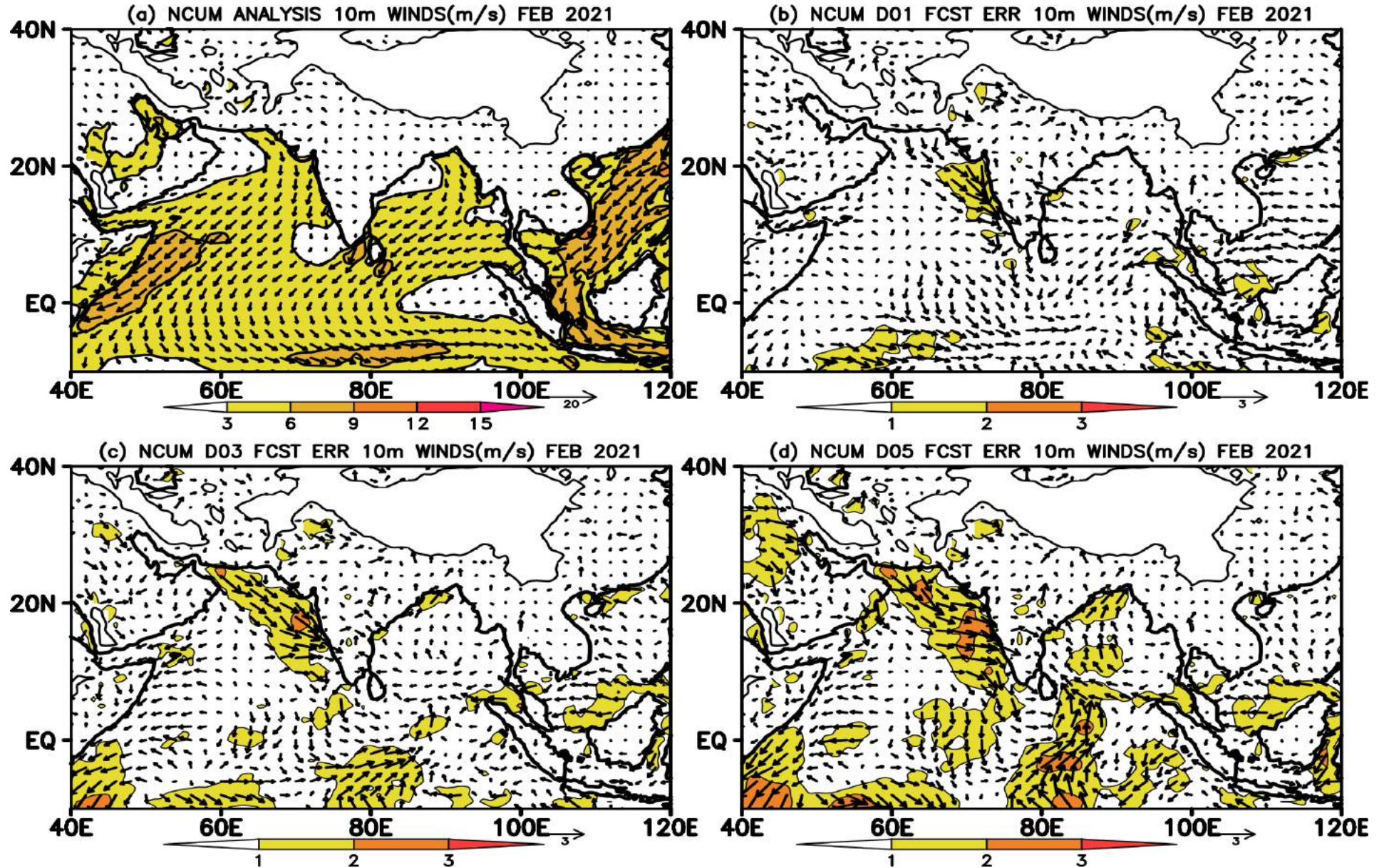


Figure 14. (a) Mean winds at 10m height and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

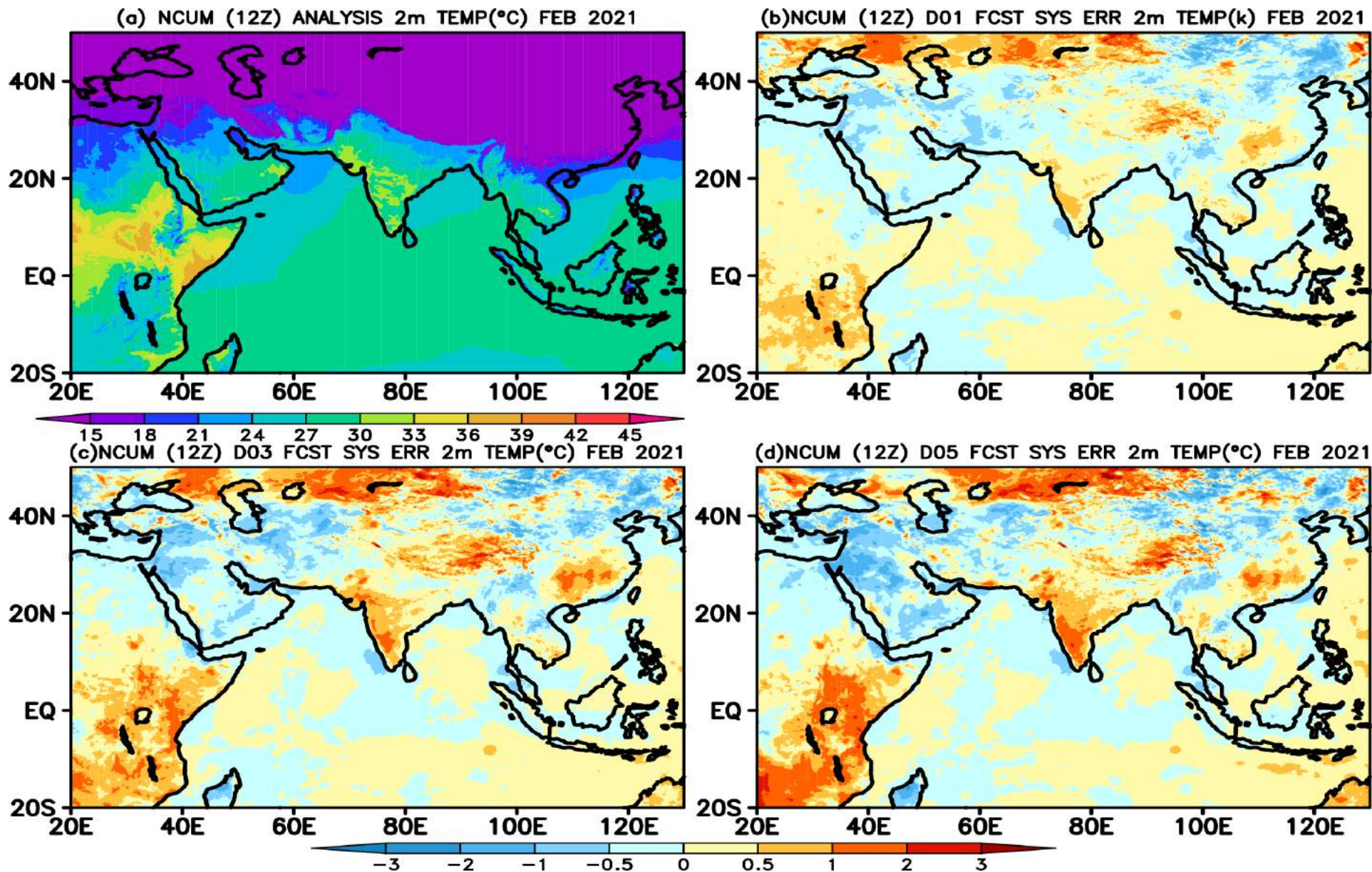


Figure 15. (a) Mean Temperature at 2mt height and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

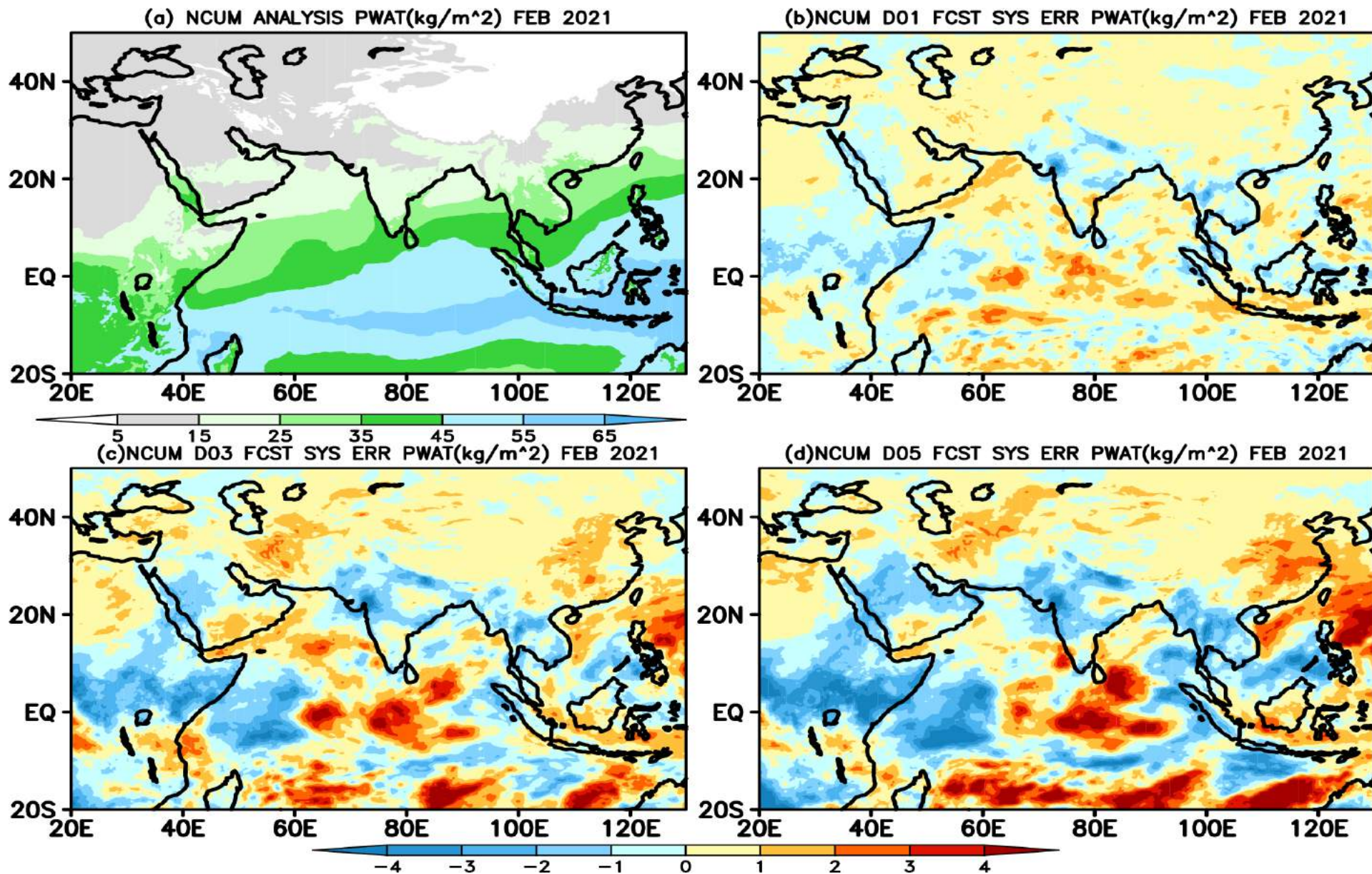


Figure 16. (a) Mean precipitable water content (PWAT) up to model levels and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

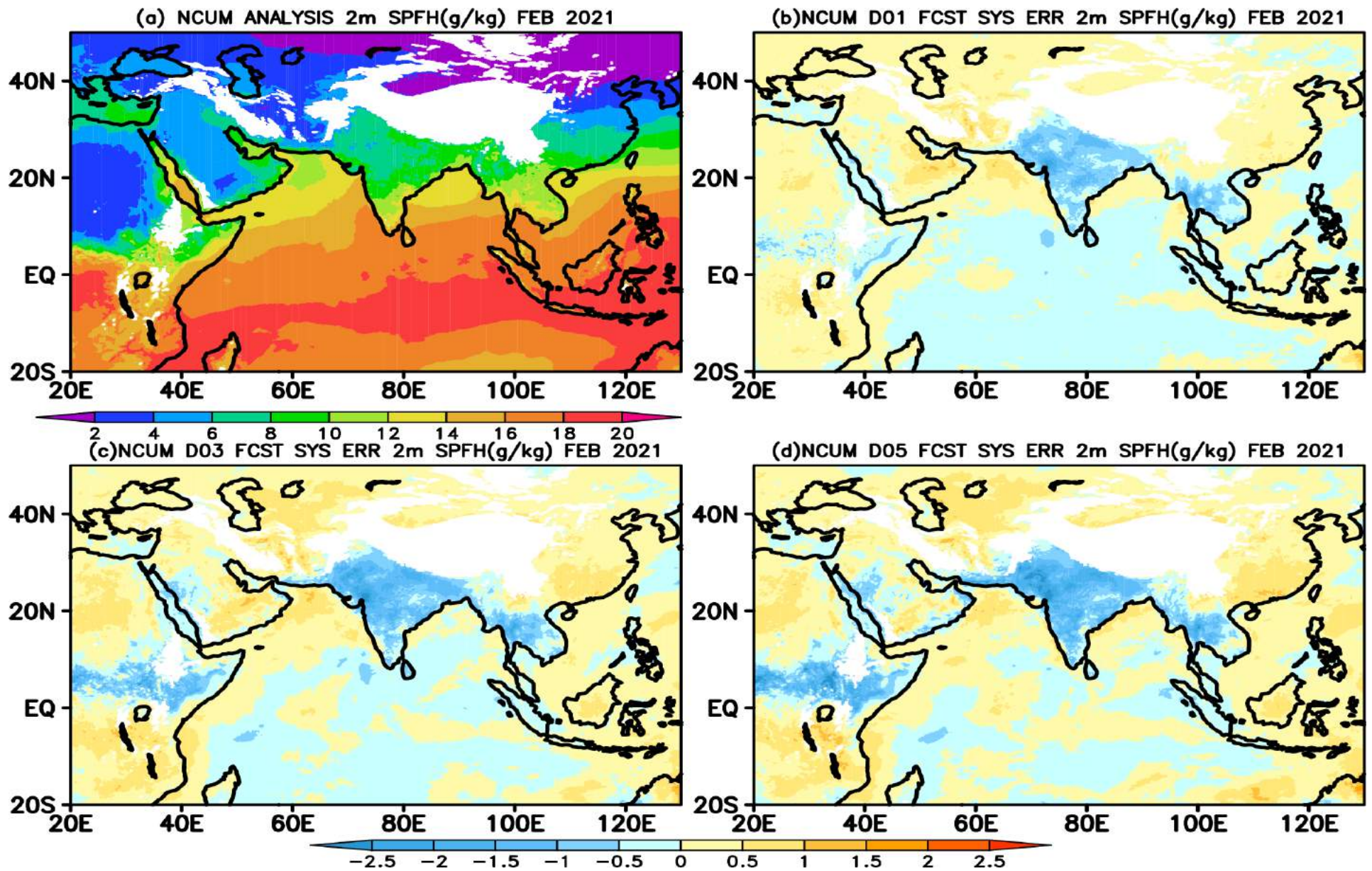
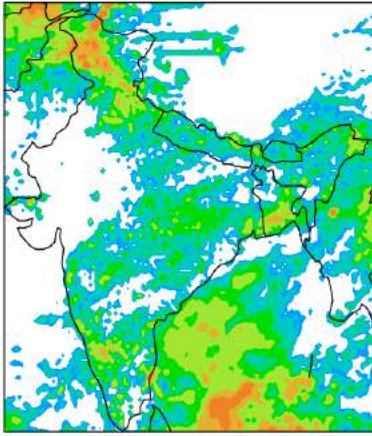


Figure 17. (a) Mean specific humidity and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during February 2021

## 5. Verification of Rainfall Forecasts

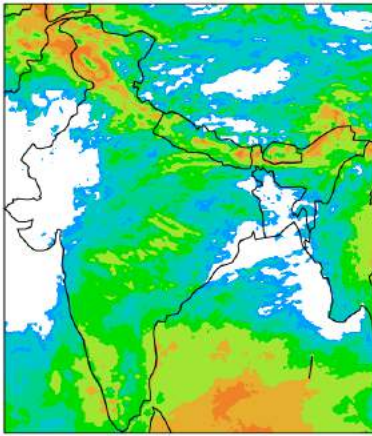
(a) Sat+Gauge



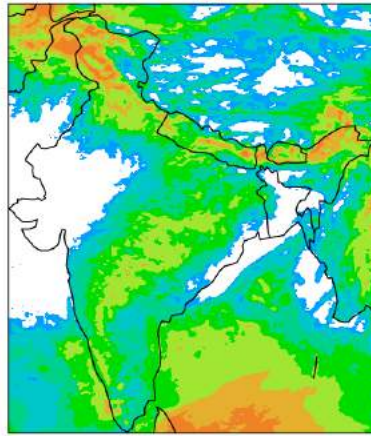
Observed and Model Forecast  
Accumulated Rainfall (mm/day)  
(FEB 2021)



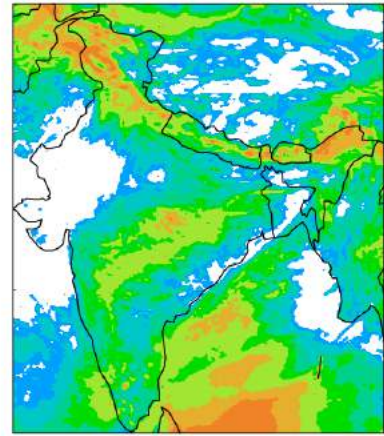
(b) NCUM:Day-1



(c) NCUM:Day-3

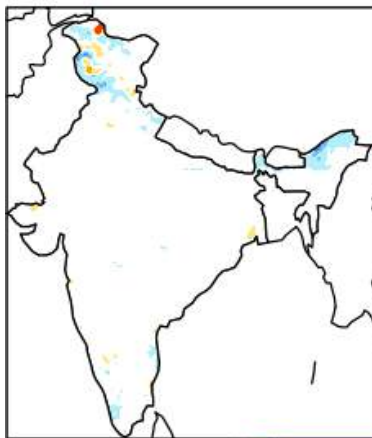


(d) NCUM:Day-5

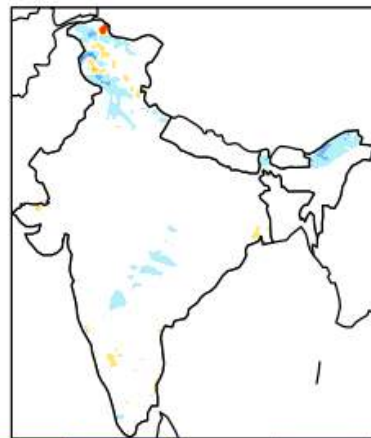


me(mm): FCST Rainfall (FEB 2021)

NCUM:Day-1



NCUM:Day-3



NCUM:Day-5

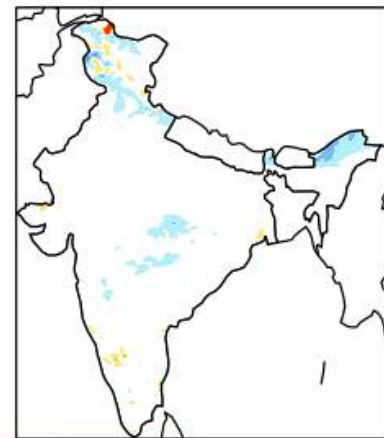
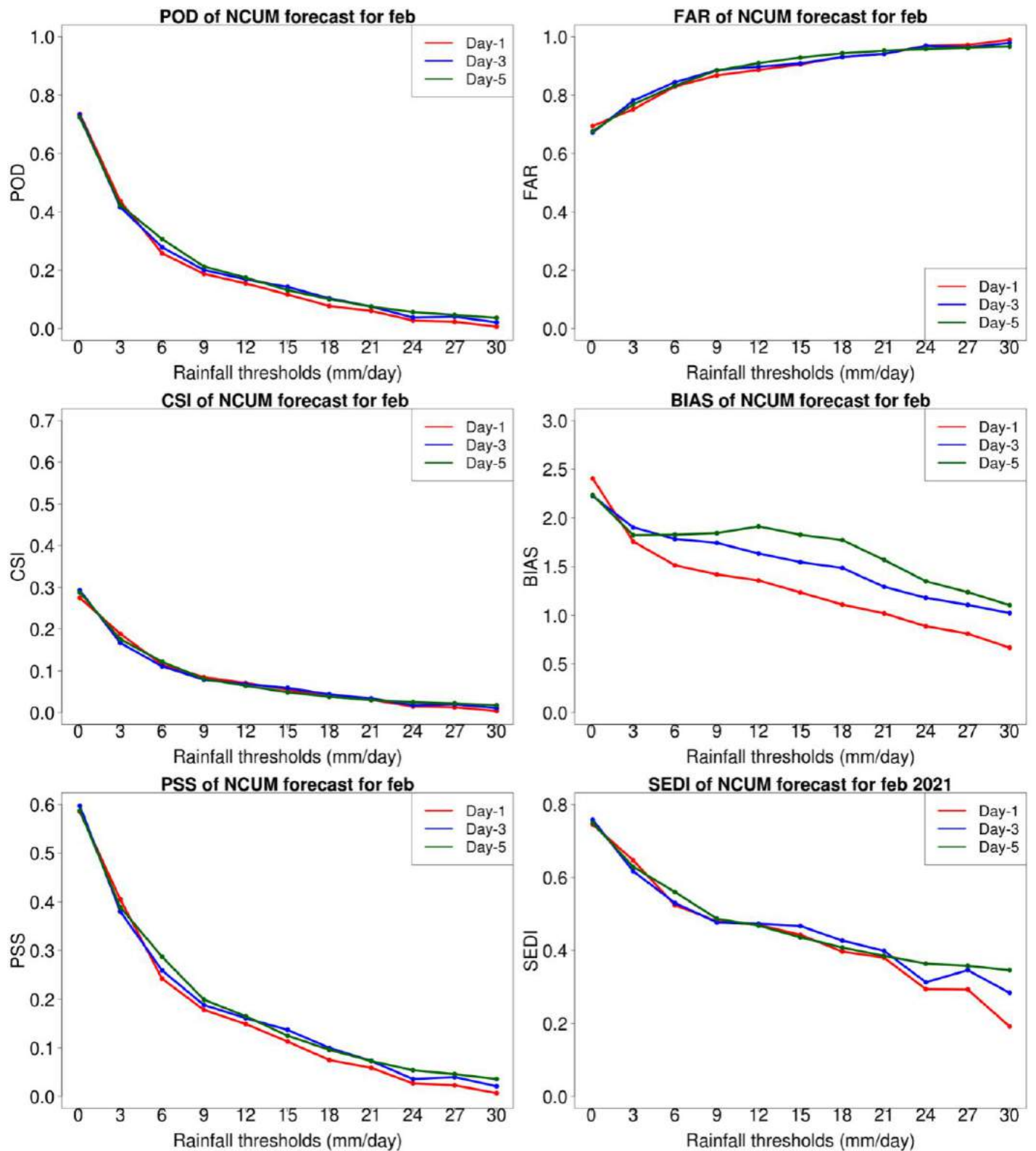


Figure 18. Accumulated February rainfall in (a) Observations and (b) Day-1 (c) Day-3 and (d) Day-5 forecasts. Bottom panels (e), (f) and (g) show Mean Error (ME) in Day-1, Day-3 and Day-5 forecasts respectively.

## 6. Rainfall Categorical scores for NCUM



**Figure 19. Categorical all India Rainfall scores POD (top left), FAR (top right), CSI(middle left), BIAS (middle right), PSS (bottom left) and SEDI (bottom right).**



## 7. Tmin categorical Scores for NCUM:

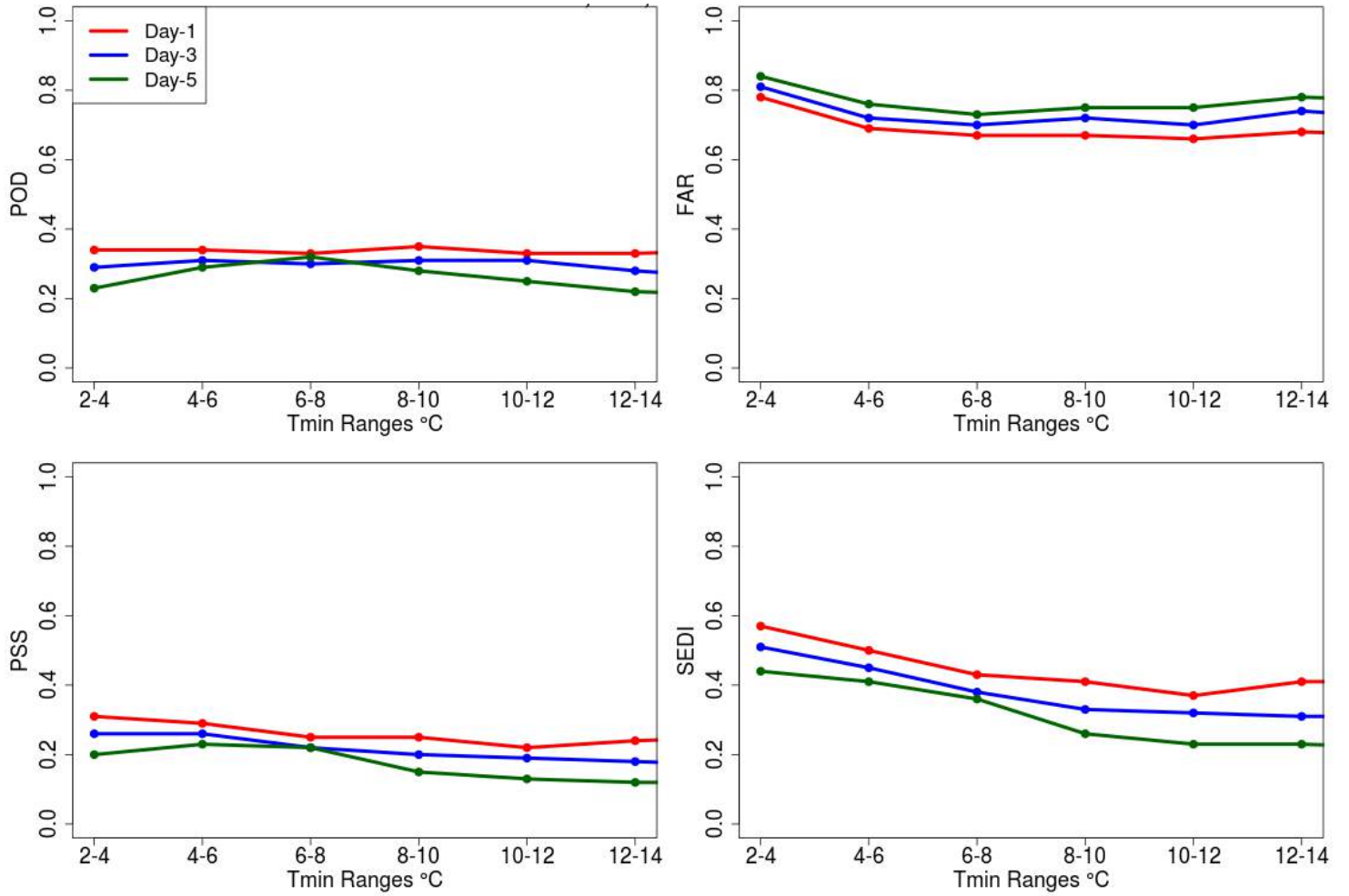
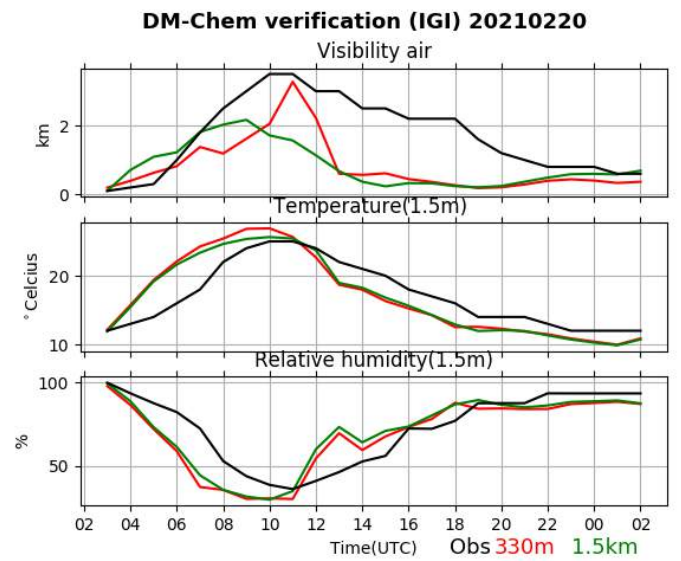
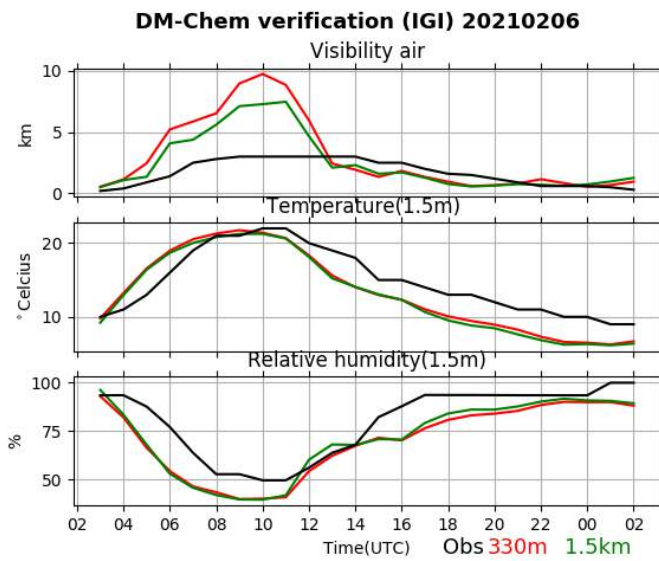
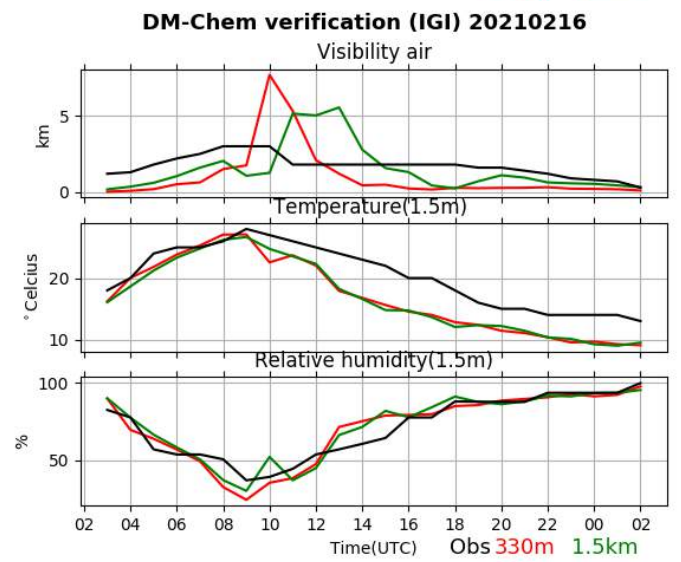
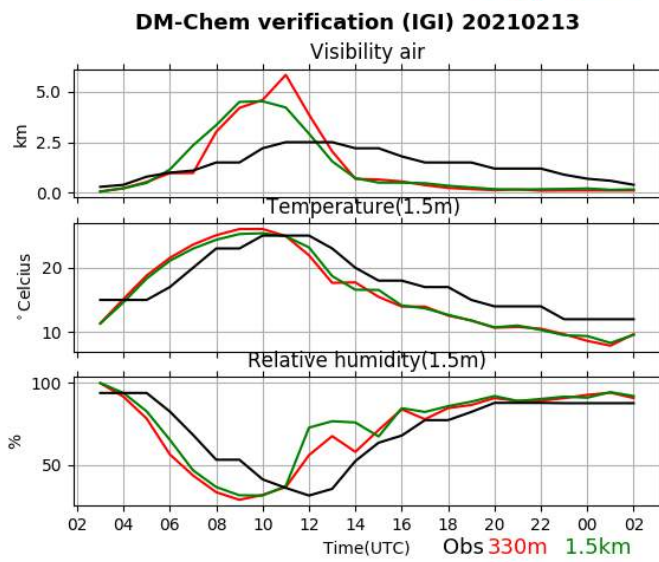
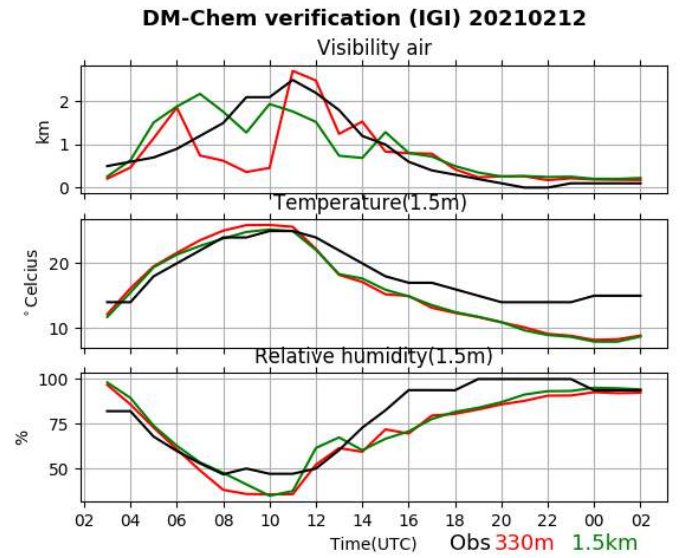
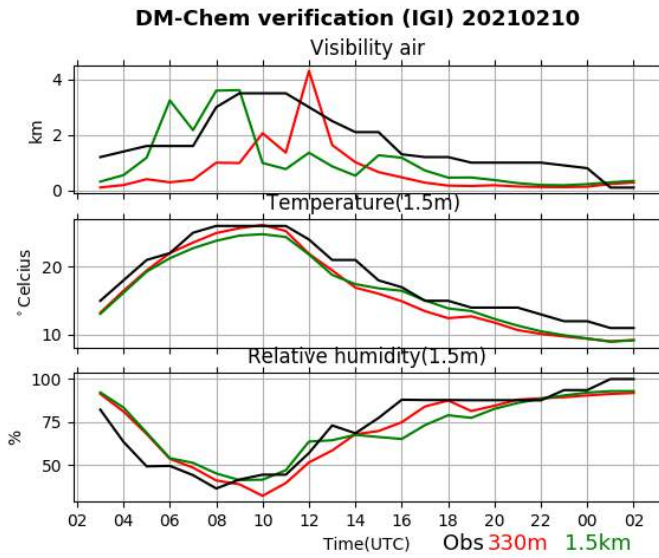


Figure 20. Categorical all India Tmin scores POD (top left), FAR (top right), PSS (bottom left) and SEDI (bottom right).

## II. Special Weather Events of the Month

### Verification of Visibility:

- Fog is one of the major weather events during winter over the Northern part of India, particularly Delhi. Dense to very dense fog conditions observed at isolated places during February over Delhi. The visibility verification has been carried out over Indira Gandhi International (IGI) Airport using NCMRWF Delhi models with 1.5 km and 330mtrs horizontal resolutions. Here we also showed diurnal variability of temperature and humidity during some special fog event days.
- The model forecasts are able to predict the low visibility conditions during the late hours and early hours of the day.
- Some mixed results are also noticed either over predicting or under predicting the visibility. Specifically, the overprediction of low-visibility conditions is noted when the surface temperatures are lower than the observations (Figure 21).



**Figure 21. Observed and forecast Visibility, Temperature and Relative Humidity over IGI-T3 on 10<sup>th</sup>, 12<sup>th</sup>, 13<sup>th</sup>, 16<sup>th</sup>, 06<sup>th</sup> and 29<sup>th</sup> February 2021.**

## Annexure: Verification against Radiosonde

**TABLE.1 INDIAN REGION VERIFICATION AGAINST RADIOSONDES**

**850 HPA GEOPOTENTIAL HEIGHT FEBRUARY 2021**

FORECAST PERIOD (HOURS)	MEAN ERROR 00GMT	RMSE 00GMT	CORRELATION 00GMT
24	1.1309	9.3461	0.6451
48	-0.2661	9.4955	0.7233
72	-0.9202	9.7388	0.7408
96	-1.2470	10.6195	0.6644
120	-3.0543	11.7078	0.6845
144	-3.8934	12.7379	0.6223
168	-5.6604	13.5585	0.6828
192	-7.8108	14.5820	0.6717
216	-8.6367	15.5316	0.6755
240	-7.7314	19.1404	0.6951

**TABLE.2 INDIAN REGION VERIFICATION AGAINST RADIOSONDES**

**500 HPA GEOPOTENTIAL HEIGHT FEBRUARY 2021**

FORECAST PERIOD (HOURS)	MEAN ERROR 00GMT	RMSE 00GMT	CORRELATION 00GMT
24	-15.1627	45.5151	0.5762
48	-15.3467	45.9296	0.7819
72	-14.7029	46.7930	0.8026
96	-14.0355	46.9394	0.7614
120	-16.1462	48.5151	0.7974
144	-15.7937	49.5036	0.7923
168	-18.2848	51.3674	0.7654
192	-21.8530	55.4308	0.7576
216	-23.4595	56.8821	0.7623
240	-22.1076	58.0368	0.7154

**TABLE.3 INDIAN REGION VERIFICATION AGAINST RADIOSONDES**

<b>850 HPA TEMPERATURE</b>				<b>FEBRUARY 2021</b>
FORECAST PERIOD	MEAN ERROR	RMSE	CORRELATION	
(HOURS)	00GMT	00GMT	00GMT	
24	-0.0771	1.3673	0.7272	
48	0.1229	1.4206	0.8102	
72	0.2923	1.5160	0.7927	
96	0.4672	1.6559	0.7340	
120	0.5606	1.7891	0.7397	
144	0.6248	1.8206	0.7559	
168	0.7413	1.9642	0.7042	
192	0.7303	1.9946	0.7123	
216	0.7467	2.1906	0.7130	
240	0.8136	2.2285	0.7244	

**TABLE .4 INDIAN REGION VERIFICATION AGAINST RADIOSONDES**

<b>500 HPA TEMPERATURE</b>				<b>FEBRUARY 2021</b>
FORECAST PERIOD	MEAN ERROR	RMSE	CORRELATION	
(HOURS)	00GMT	00GMT	00GMT	
24	-0.3213	1.4464	0.7849	
48	-0.1852	1.5116	0.8229	
72	-0.0822	1.5750	0.8588	
96	0.0038	1.6006	0.8013	
120	-0.0480	1.7570	0.8513	
144	0.0368	1.8309	0.8430	
168	0.0064	2.0988	0.7997	
192	-0.1389	2.2999	0.7821	
216	-0.3392	2.4801	0.7778	
240	-0.5880	2.8194	0.6593	

**TABLE.5 INDIAN REGION VERIFICATION AGAINST RADIOSONDES**

850 HPA WIND			FEBRUARY 2021		
FORECAST PERIOD		MEAN SPEED ERROR		RMSWVE	
(HOURS)	00GMT	00GMT			
24	-0.1050	3.6360			
48	0.0467	3.8533			
72	0.0203	4.0833			
96	0.0051	4.1507			
120	0.0018	4.2649			
144	-0.0299	4.4864			
168	-0.1368	4.6844			
192	-0.0659	4.9231			
216	0.0359	5.2033			
240	-0.1722	5.2884			

**TABLE.6 INDIAN REGION VERIFICATION AGAINST RADIOSONDES**

500 HPA WIND			FEBRUARY 2021		
FORECAST PERIOD		MEAN SPEED ERROR		RMSWVE	
(HOURS)	00GMT	00GMT			
24	-0.5957	3.9207			
48	-0.5154	4.3452			
72	-0.6332	4.7531			
96	-0.3452	5.1796			
120	-0.2577	6.1056			
144	-0.3199	6.6720			
168	-0.1789	6.9444			
192	0.1036	7.5820			
216	0.2476	8.3975			
240	0.3918	10.1356			