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**VERIFICATION REPORT**

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

**S. Karunasagar, Harvir Singh and Raghavendra Ashrit**

**May 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

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9	Abstract	This report presents the verification summary of the NCMRWF Global Unified Model (NCUM hereafter) forecasts for April 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 200 hPa levels. Additionally, systematic errors are presented for Temperature & Specific Humidity at 2m height and Winds at 10m height along with column integrated precipitable water (PWAT). Special attention is given to verify significant weather events of the month. During April 2021, there were 9 westerns disturbances and few heat wave conditions also prevailed over northern parts of India. These events have been verified and presented.
10	References	
11	Security classification	Unrestricted
12	Distribution	General

## Table of Contents:

Sl. No.		Page No.
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	Tmax Categorical scores for NCUM	25
8	Verification against Radiosonde	
	a. Geopotential Height at 850 and 500 hPa	26
	b. Temperature at 850 and 500 hPa	27
	c. Wind at 850 and 500 hPa	28
II	<b>Special Weather Events of the Month and Highlights</b>	29 – 34
	<b>References</b>	35

# I. Introduction

This report presents the verification summary of the NCMRWF Global Unified Model (NCUM hereafter) forecasts for April 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 Hersbach et al., (2020) 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 (Mitra et al. 2009, 2013). 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 (Srivastava et al 2009). Categorical verification scores are presented for both temperature and rainfall for April 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), which are described in standard text books (Wilks, 2011, Jolliffe and Stephenson, 2012), and new Symmetric Extremal Dependency Index (SEDI) (Stephenson et al 2008, Ashrit et al 2015, Sharma et al 2021) suitable for rare and extreme events.

Further, the verification is carried out against the radiosonde observations over India. The 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.

Special attention is given to verify significant weather events of the month. During April 2021, the WD's activity is much higher than normal like in March. In addition, heat wave conditions also formed over northern parts of India. Verification is presented for active WD's and heat wave conditions.

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

## 1. Highlights

- The wind anomaly at 850hPa shows an anomalous cyclonic flow over Arabian Sea. Whereas, anomalous flow from east to west over northern BOB and west to east flow over southern BOB. At 700 hPa, a strong northwesterly anomalous flow ( $>6\text{m/s}$ ) is noticed along the foot hills of Himalayas and IGP. In addition, the extended anomalous anti-cyclonic flow ( $>6\text{m/s}$ ) is noticed over core monsoon region to southern parts of India. In the upper levels at 200 hPa the anomalous cyclonic flow over northwestern parts of India and anti-cyclonic flow over China is an evident (**Figures 1-2**).
- At 850 hPa and 700 hPa, the bias in wind indicating a south-easterly flow over the BOB and strengthening with lead times. The northwesterly bias ( $>3\text{ms/}$ ) at 2m height and 850 hPa is noticed along the south-west coast of India. While at 700hPa a westerly bias is noted over Arabian Sea. At 500hPa, enhanced westerly bias in the equatorial Indian Ocean and south easterly bias over BOB is noted. At 200 hPa, a strong easterly bias ( $>6\text{m/s}$ ) over western Indian Ocean is noticed. Similarly, the northeasterly bias is noticed over northeastern parts of India (**Figures 3-6 and Figure 14**).
- The warm bias in temperature over the Indian subcontinent is noticed from surface to mid-troposphere while cold bias is noticed in the upper troposphere (200hPa). However, the warm bias is noticed over Pakistan and adjoining region. The bias is prominent with forecast lead times (**Figures 7-10 and Figure 15**).
- A wet (*dry*) bias in humidity over the Arabian Sea (*Indian landmass*) is noticed near the surface. However, at higher levels wet bias over Indian landmass is prominent. (**Figures 11-13 and Figure 17**)
- Model forecasts indicate the rainfall patterns and intensities are in agreement with observations over the north-eastern parts of India, along the foot hills of Himalayas and southern peninsular India and coastal region of Andhra Pradesh and the wide spread of rainfall is also noticed over central parts of India (**Figure 18 (a-d)**). However, the model forecasts are over predicting the intensity of rainfall over the above regions (**Figure 18 (e-g)**).
- Various statistical scores are computed to assess the NCUM mode skill in predicting the rainfall. The forecast skill is reasonable in predicting rainfall events of low intensity ( $<6\text{mm/day}$ ) where the PSS values are  $> 0.3$  and POD values are  $>0.4$ . For rainfall events of higher intensities ( $>6\text{mm/day}$  etc.), the PSS values are lower than 0.3. (**Figure 19**).
- Tmax forecast verification during April 2021 is relatively poor, with PSS values lower than 0.3 at all lead times. However, the model skills are good for 38-42°C (**Figure 20**).

## 2. Mean and anomaly of winds:

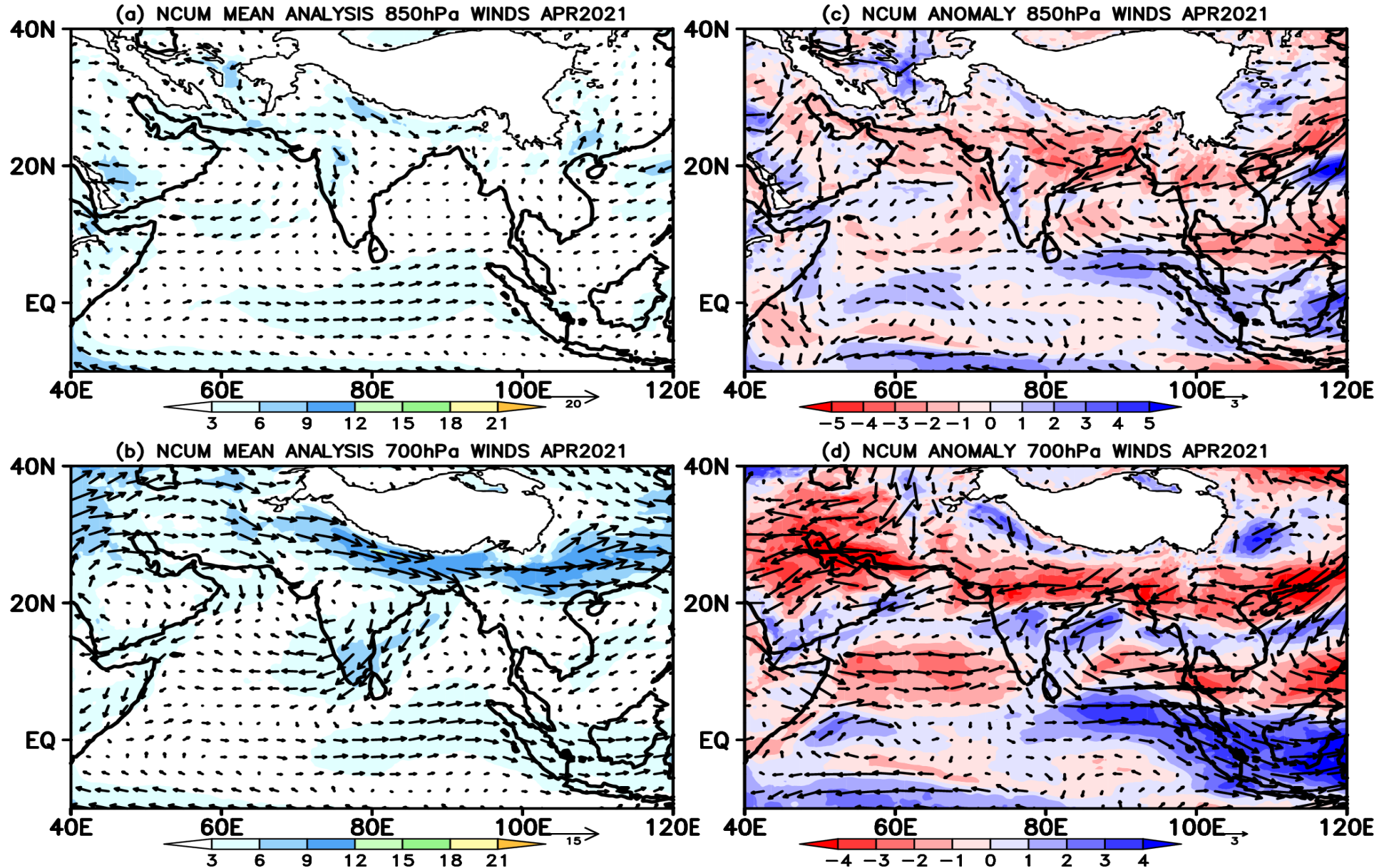


Figure 1. Mean winds at (a) 850 hPa and (b) 700 hPa in the NCUM Analysis during April 2021. Right panels show the anomaly circulation at (c) 850 hPa and (d) 700 hPa.

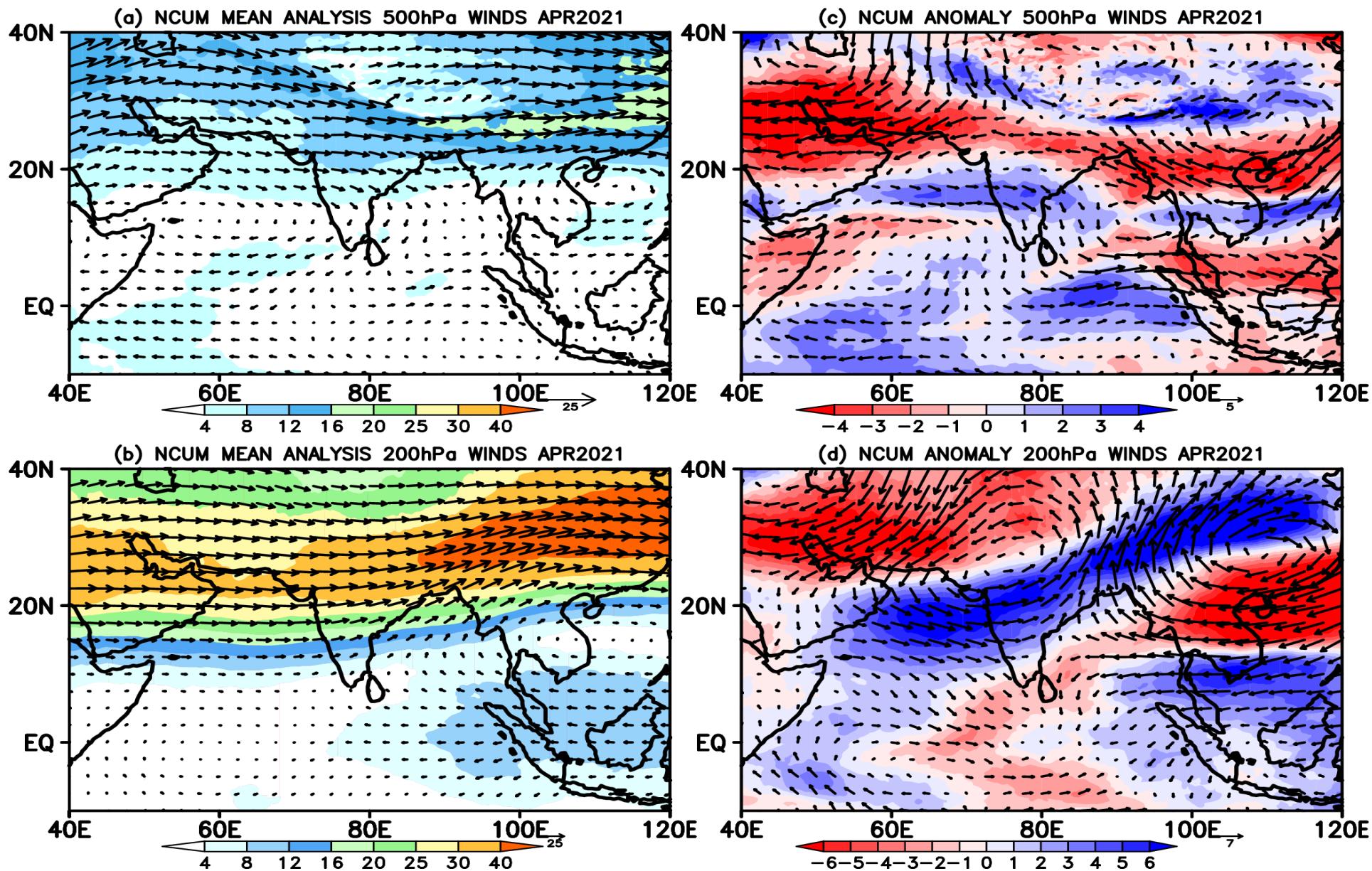


Figure 2. Mean winds at (a) 500 hPa and (b) 200 hPa in the NCUM Analysis during April 2021. Right panels show the anomaly circulation at (c) 500 hPa and (d) 200 hPa.

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

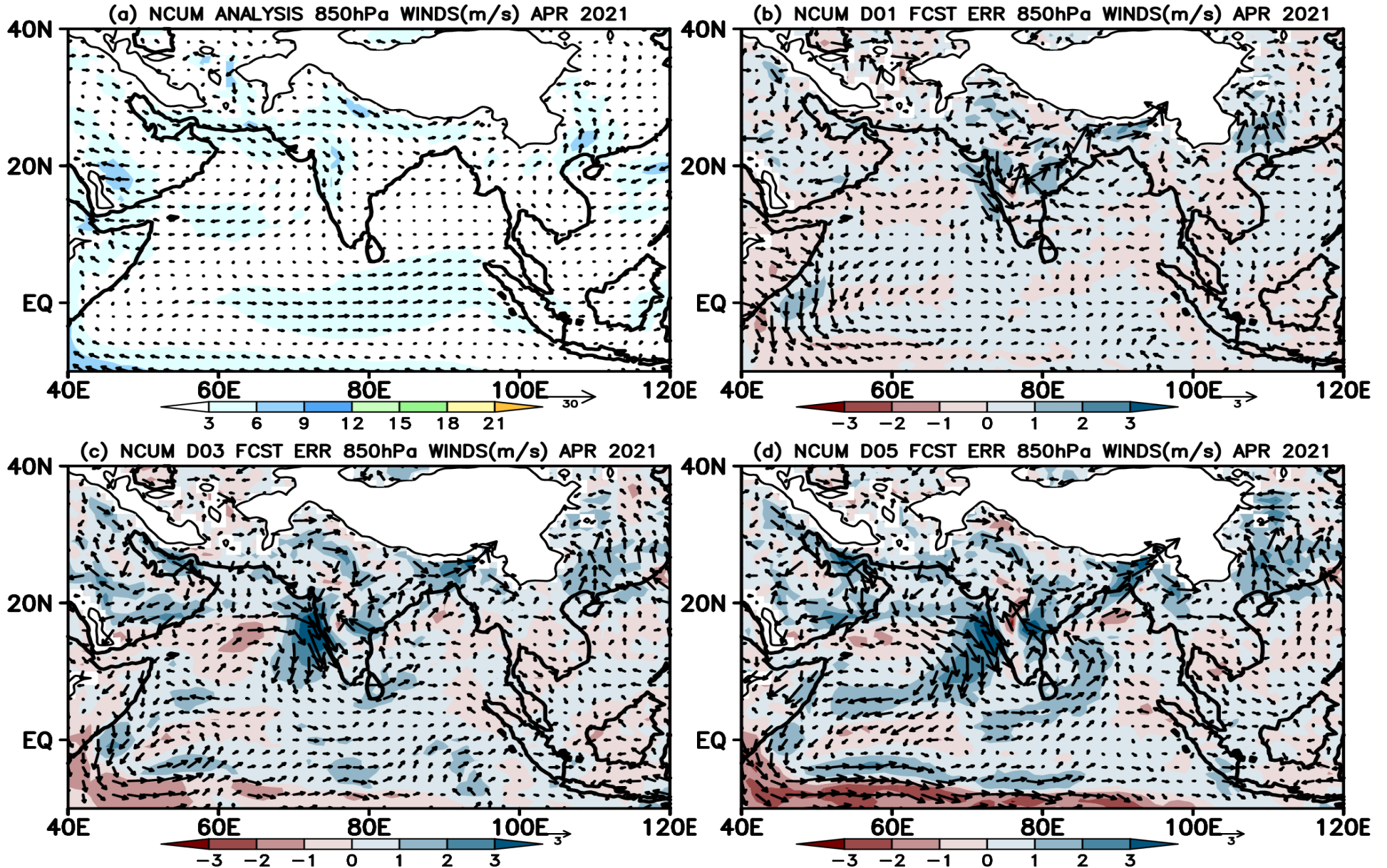


Figure 3. (a) Mean winds at 850 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021



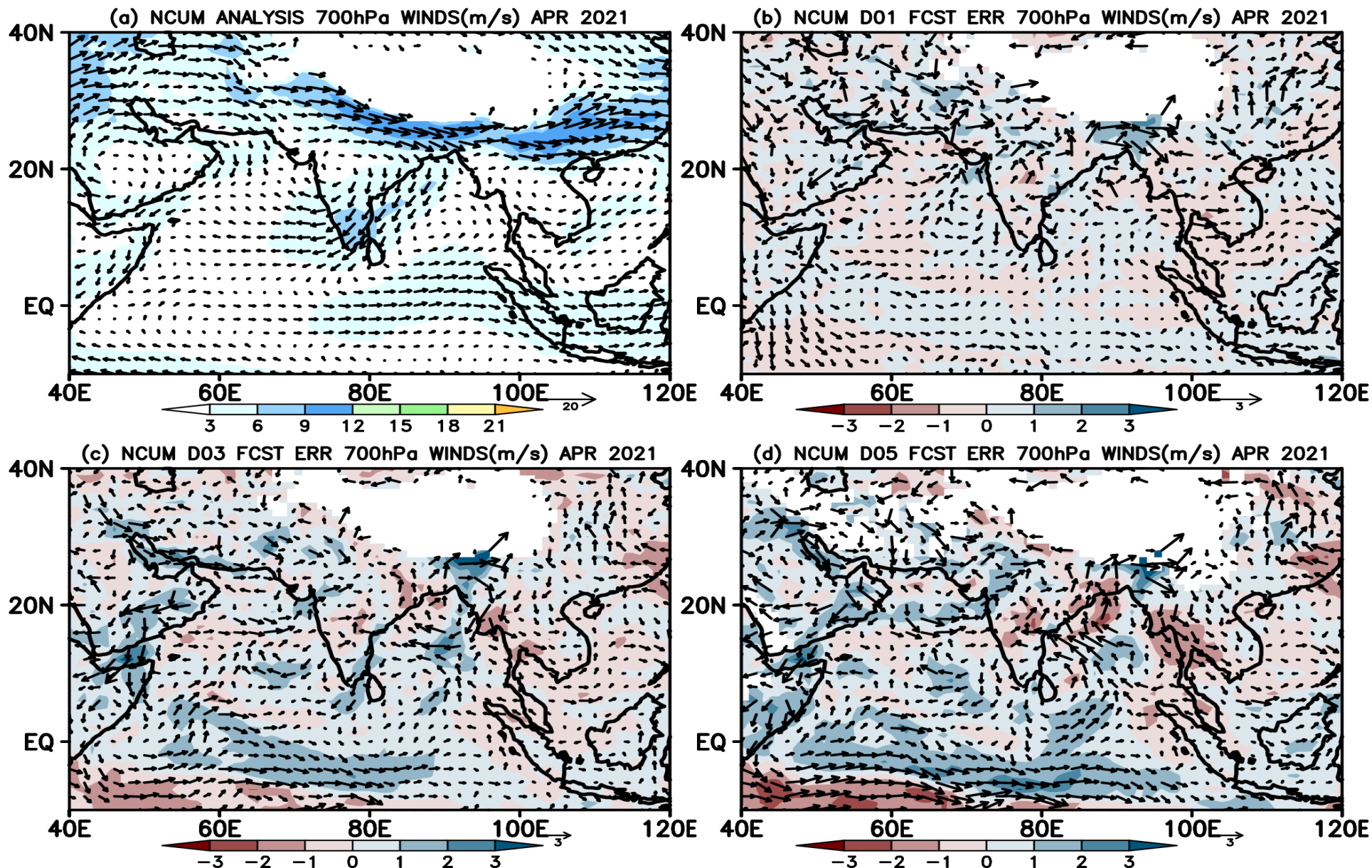


Figure 4. (a) Mean winds at 700 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

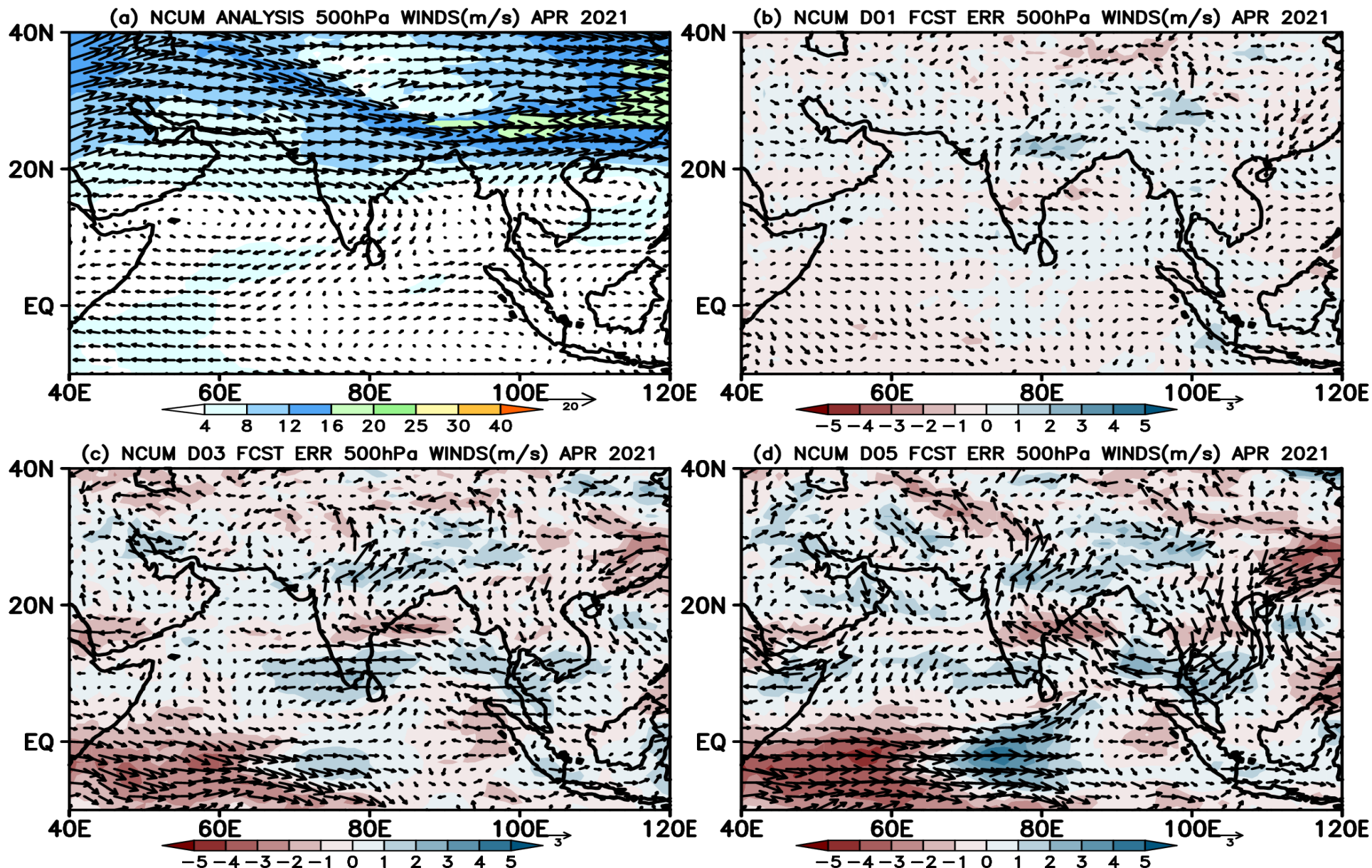


Figure 5. (a) Mean winds at 500 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

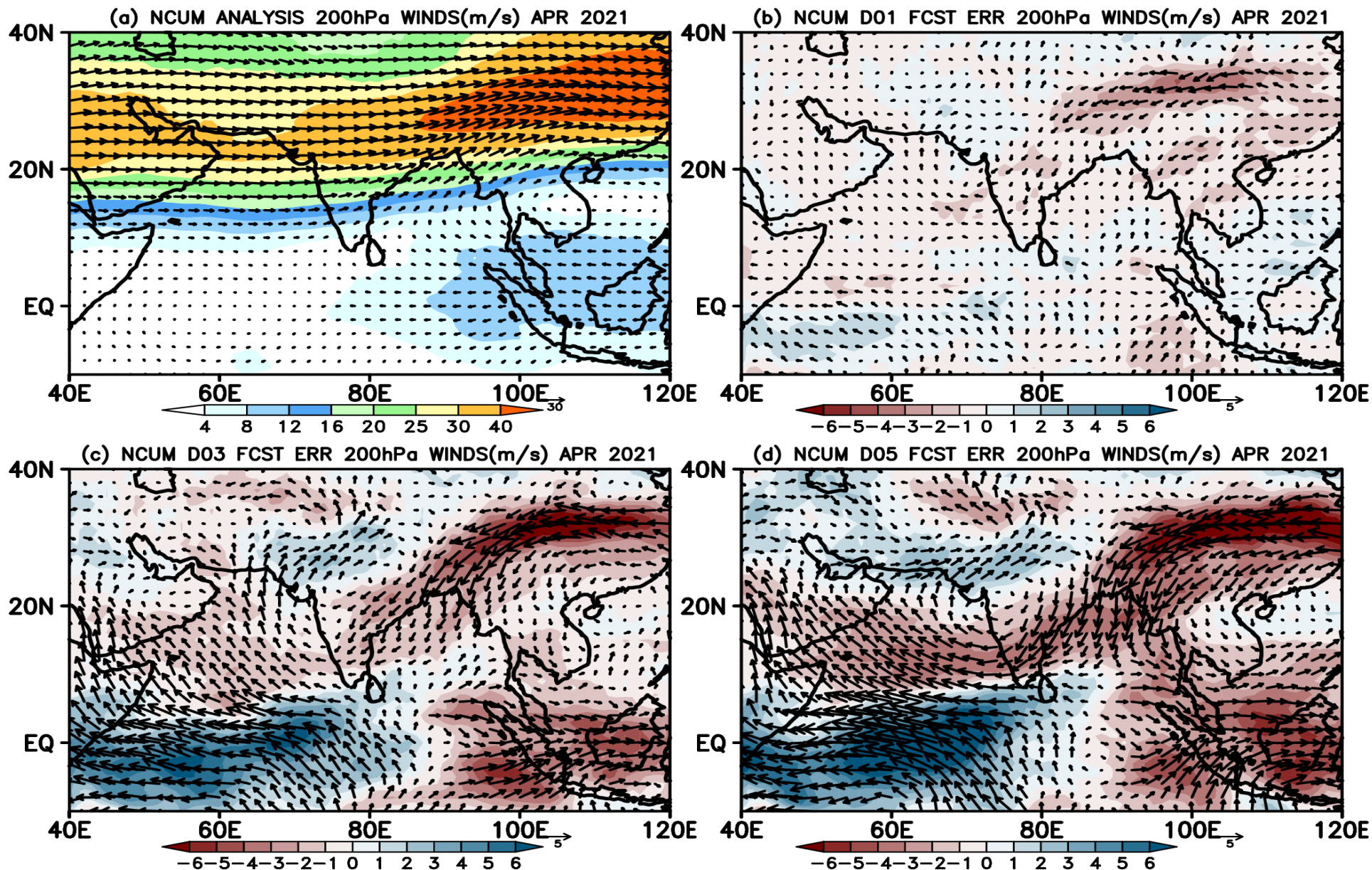


Figure 6. (a) Mean winds at 200 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

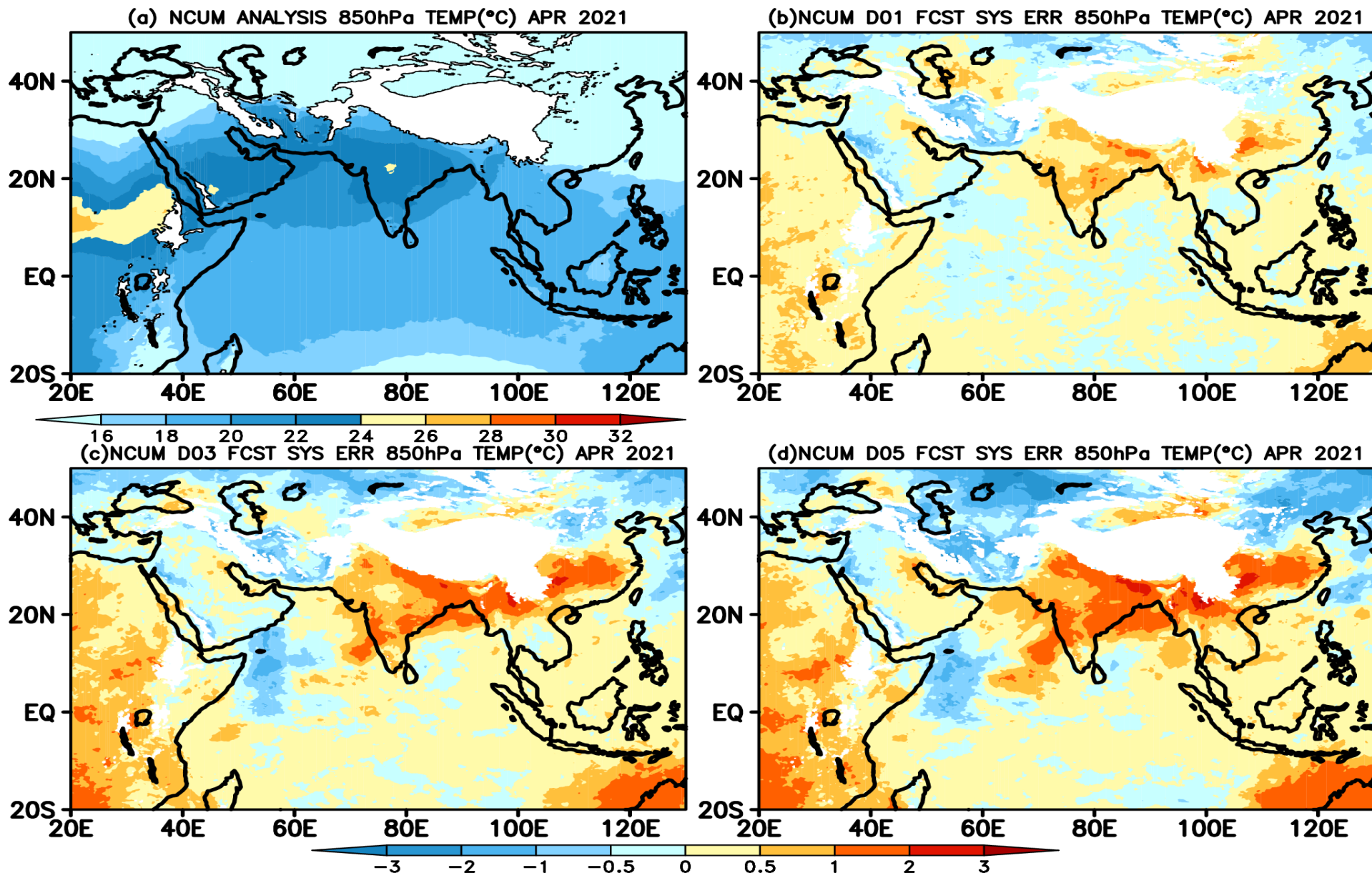


Figure 7. (a) Mean Temperature at 850 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

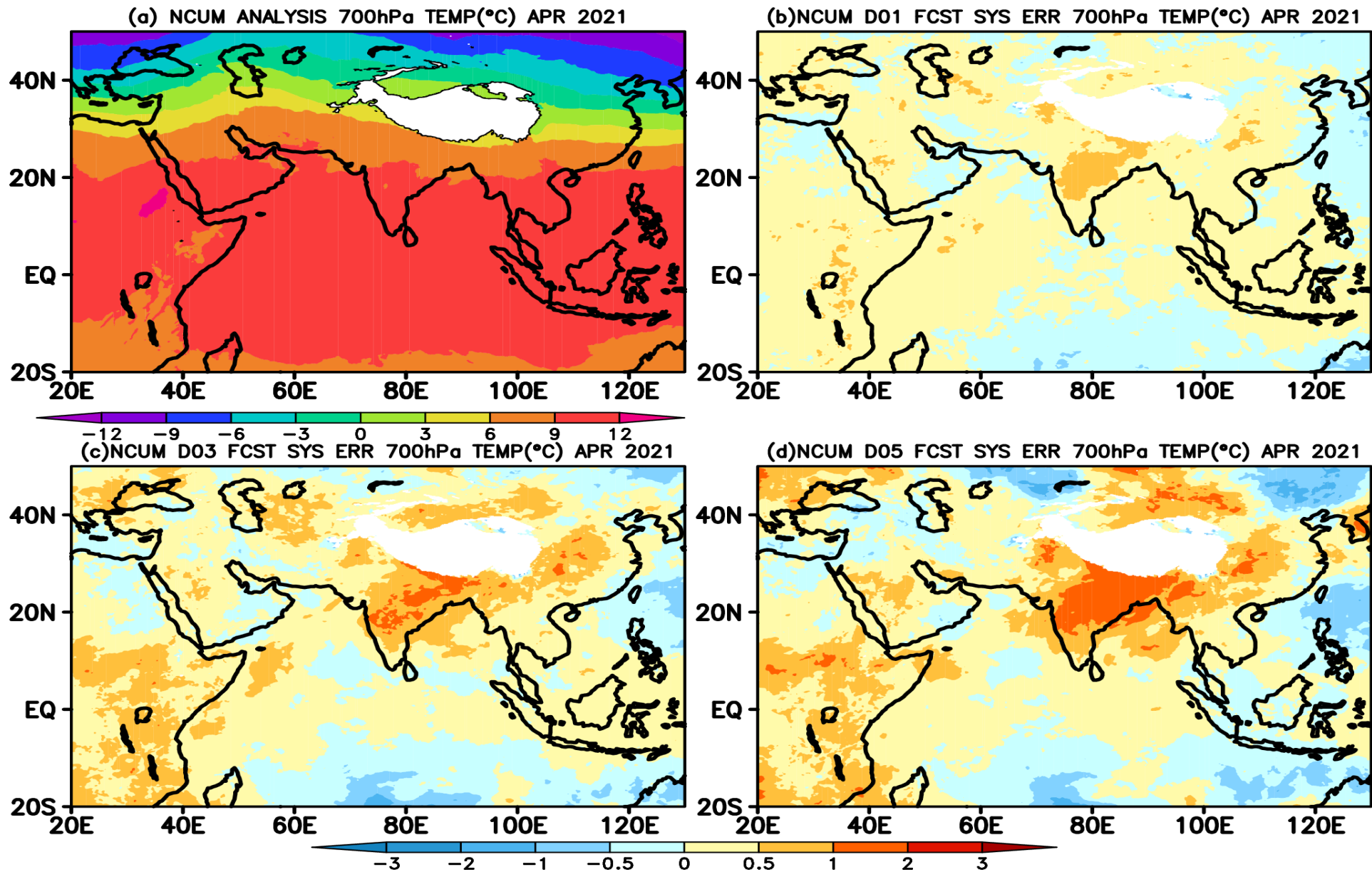


Figure 8. (a) Mean Temperature at 700 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

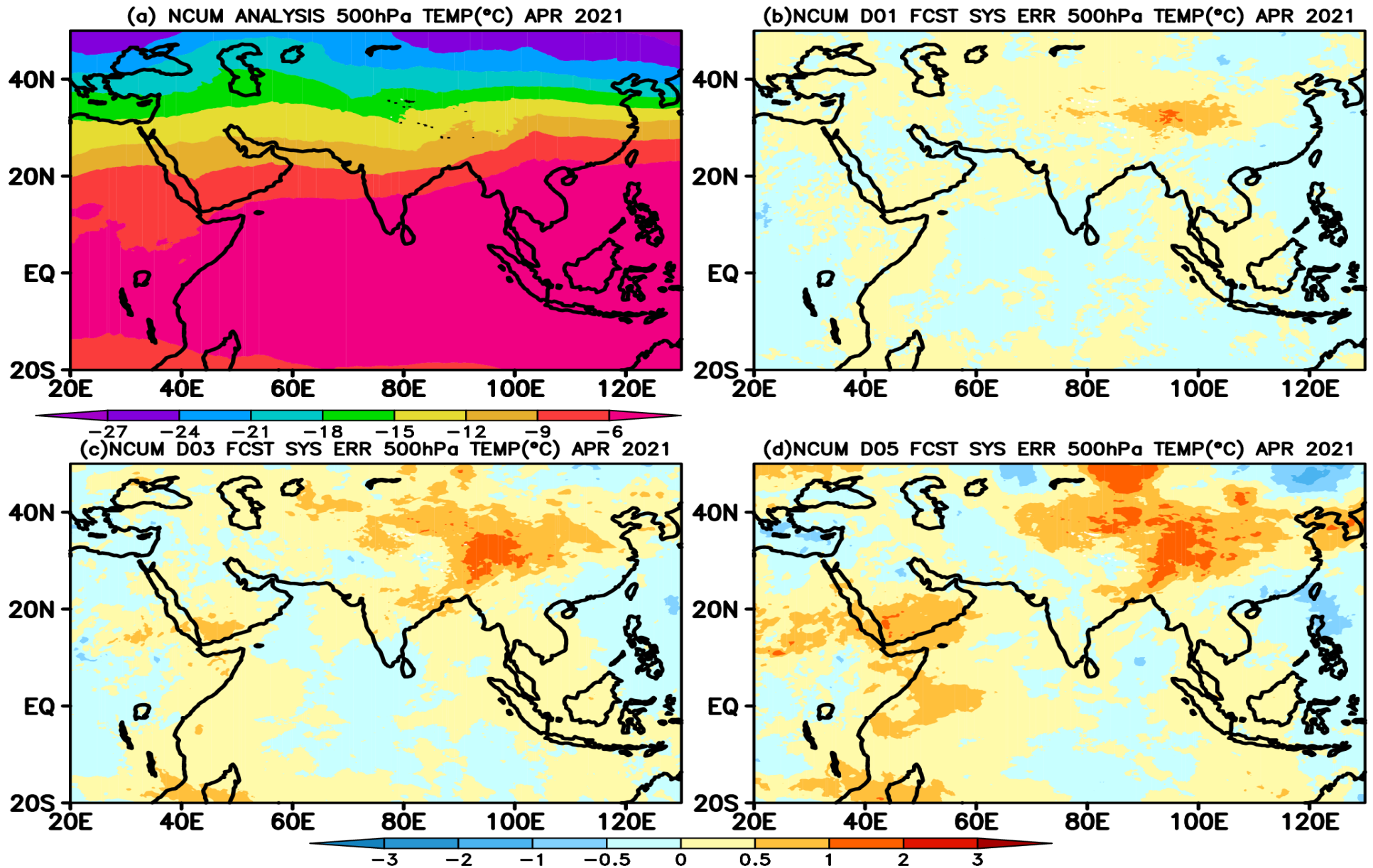


Figure 9. (a) Mean Temperature at 500 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

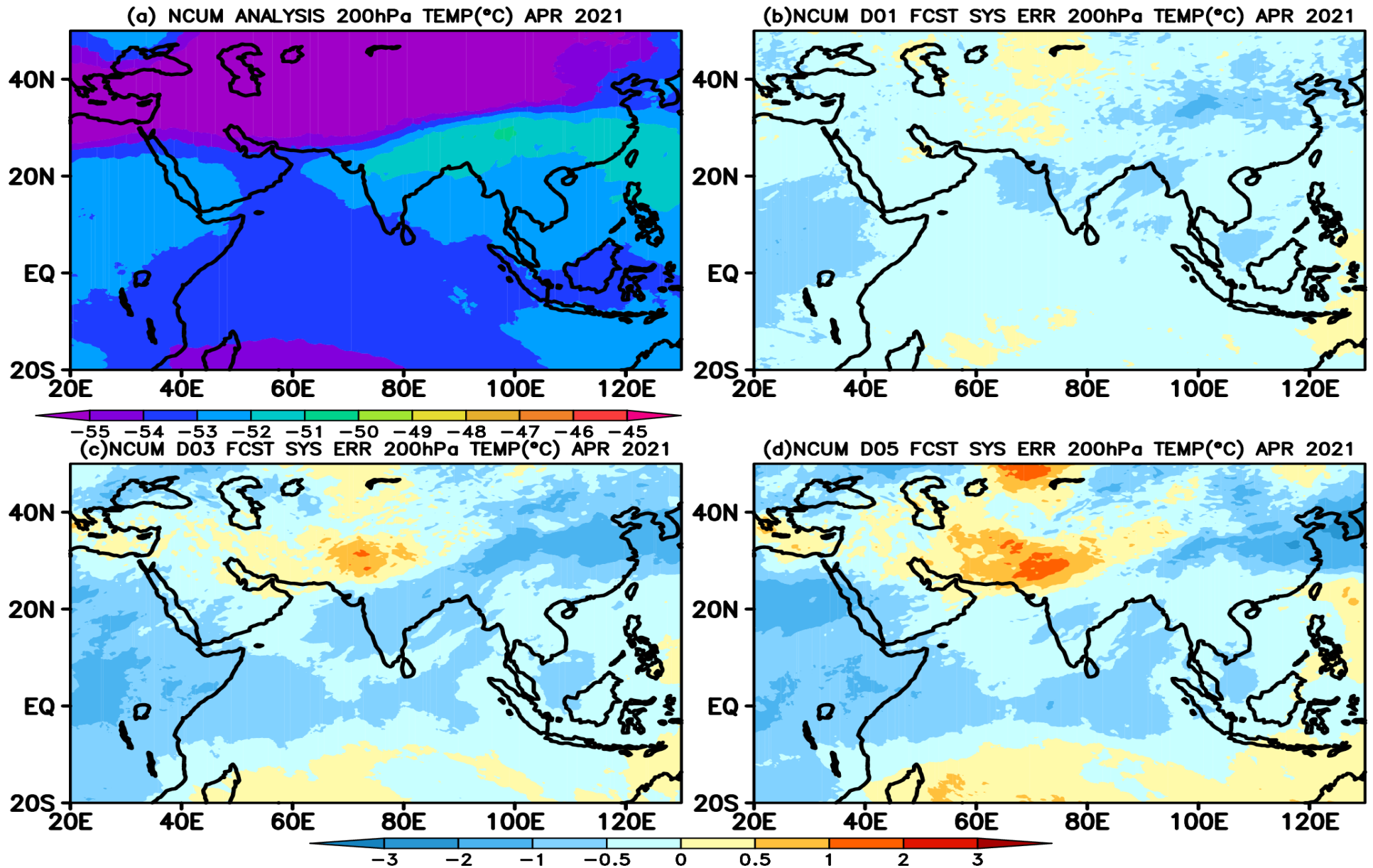


Figure 10. (a) Mean Temperature at 200 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

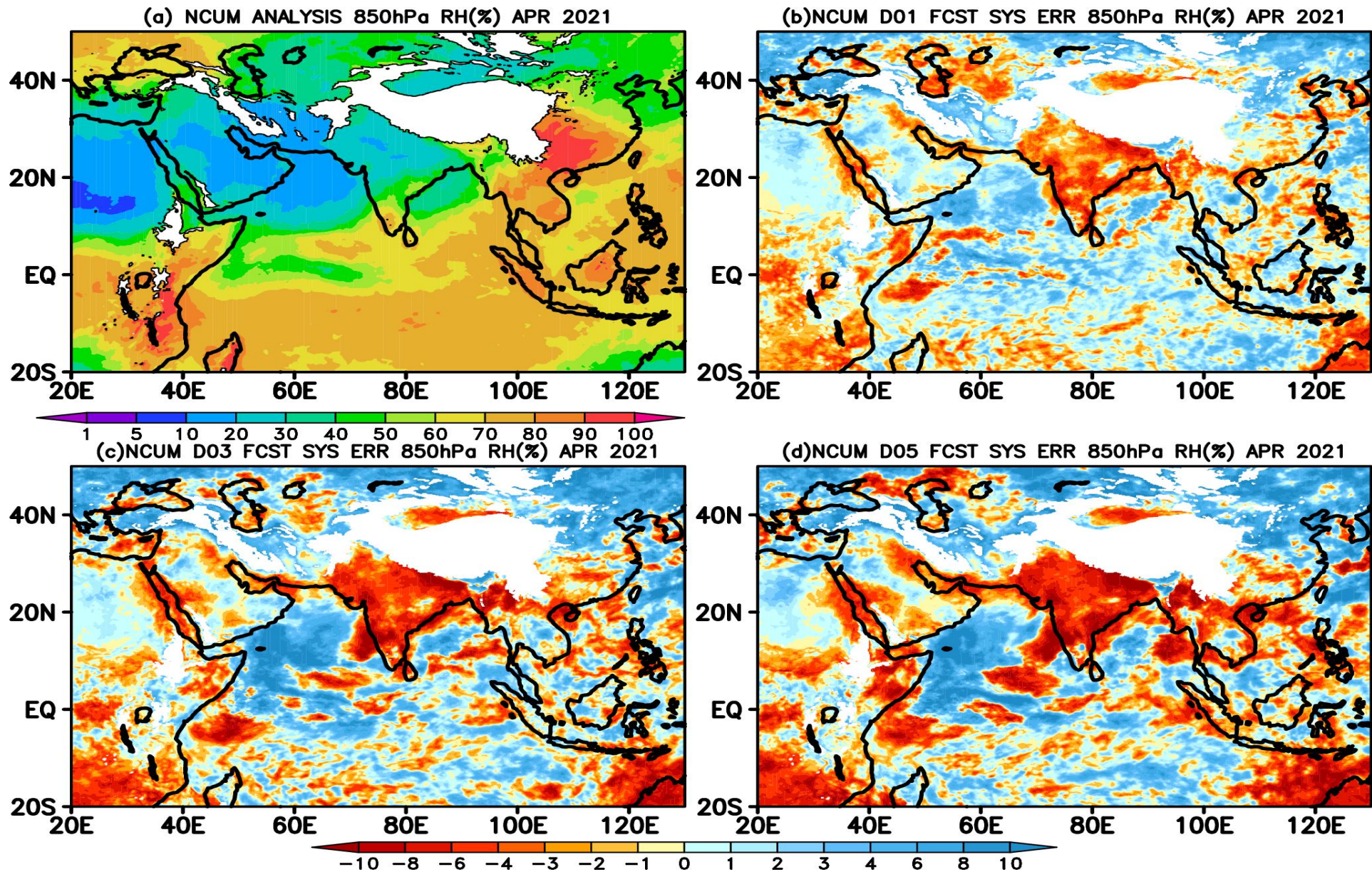


Figure 11. (a) Mean Relative Humidity at 850 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021



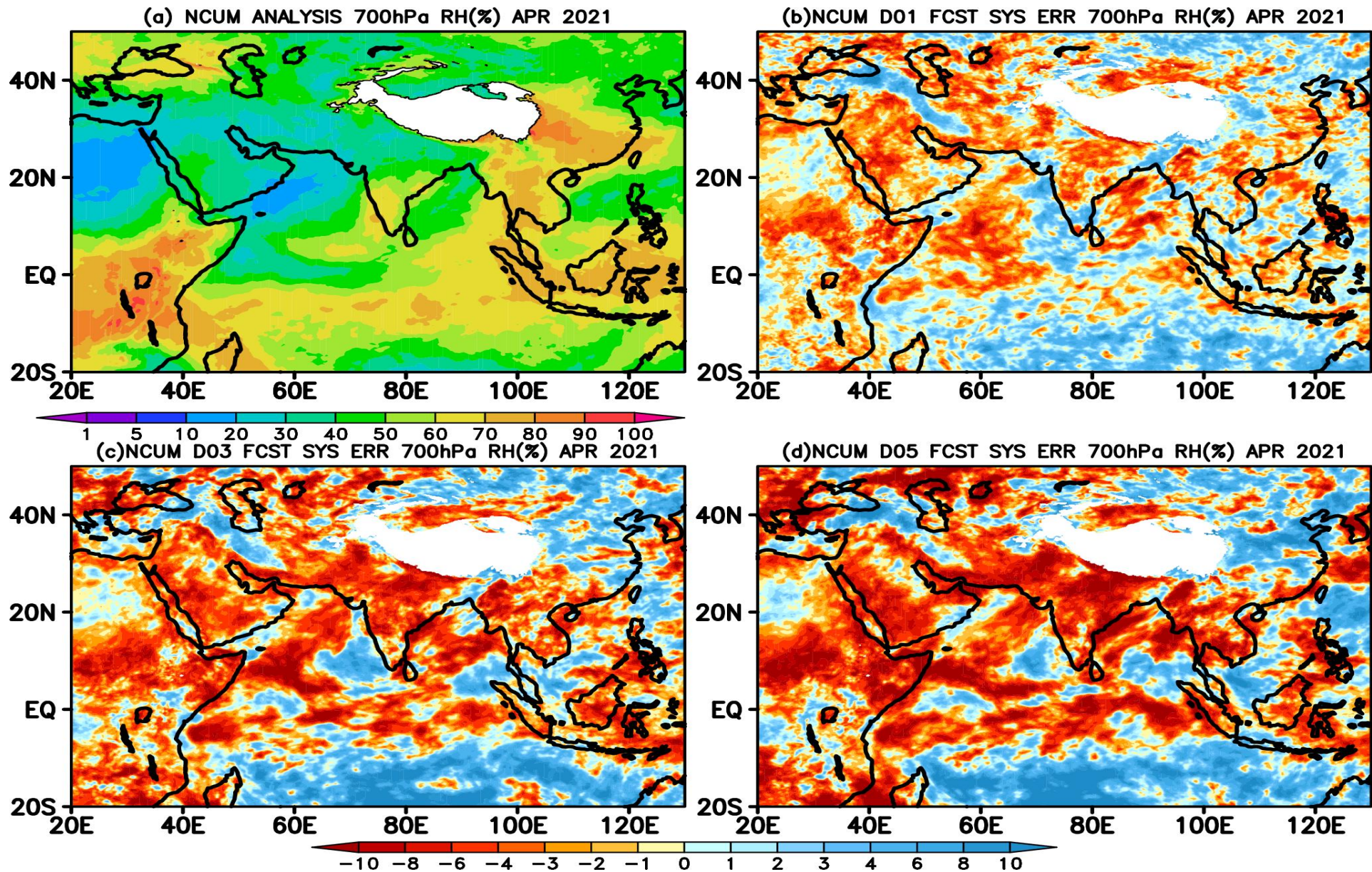


Figure 12. (a) Mean Relative Humidity at 700 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

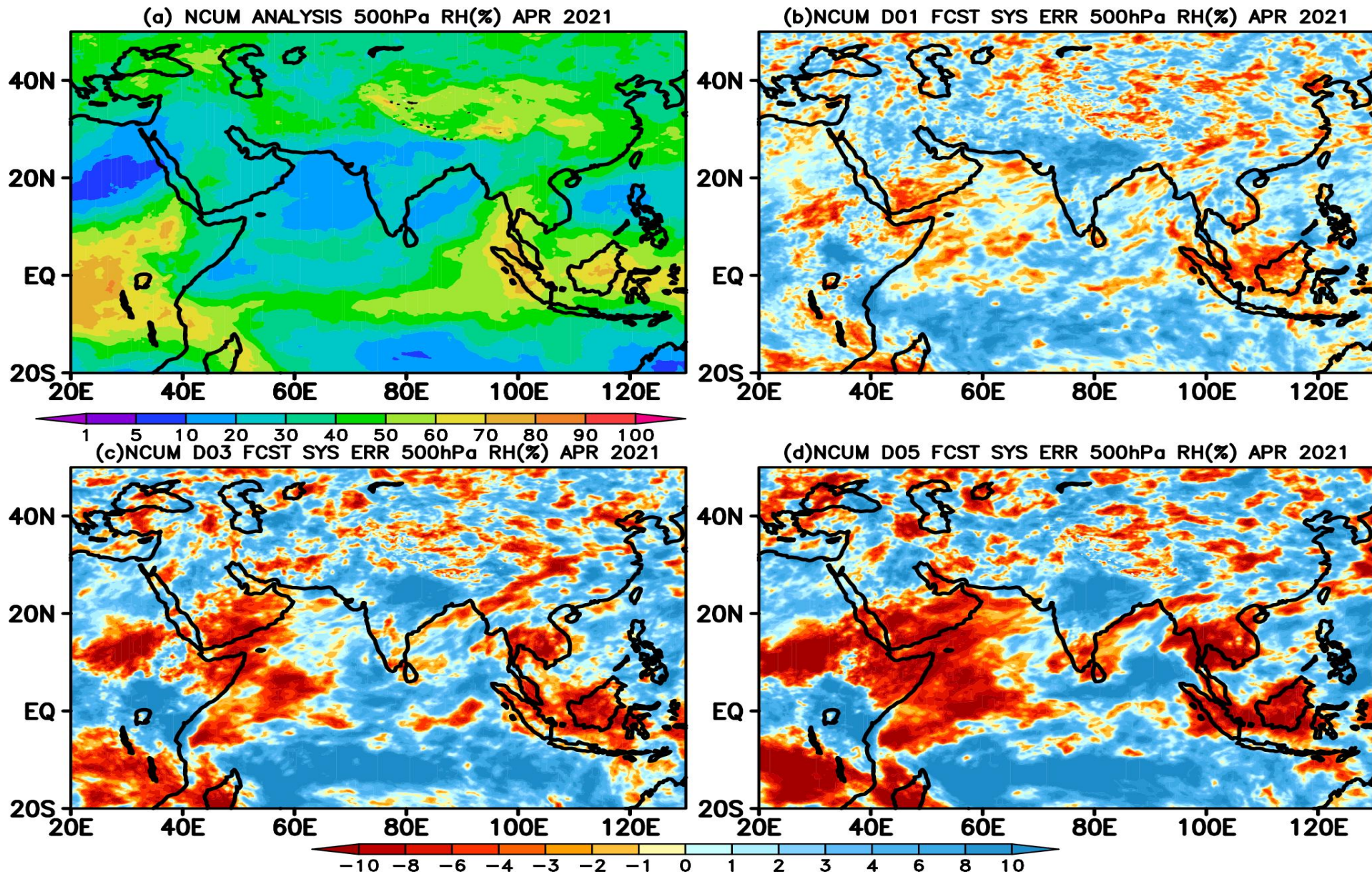


Figure 13. (a) Mean Relative Humidity at 500 hPa and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

#### 4. Systematic errors in surface variables

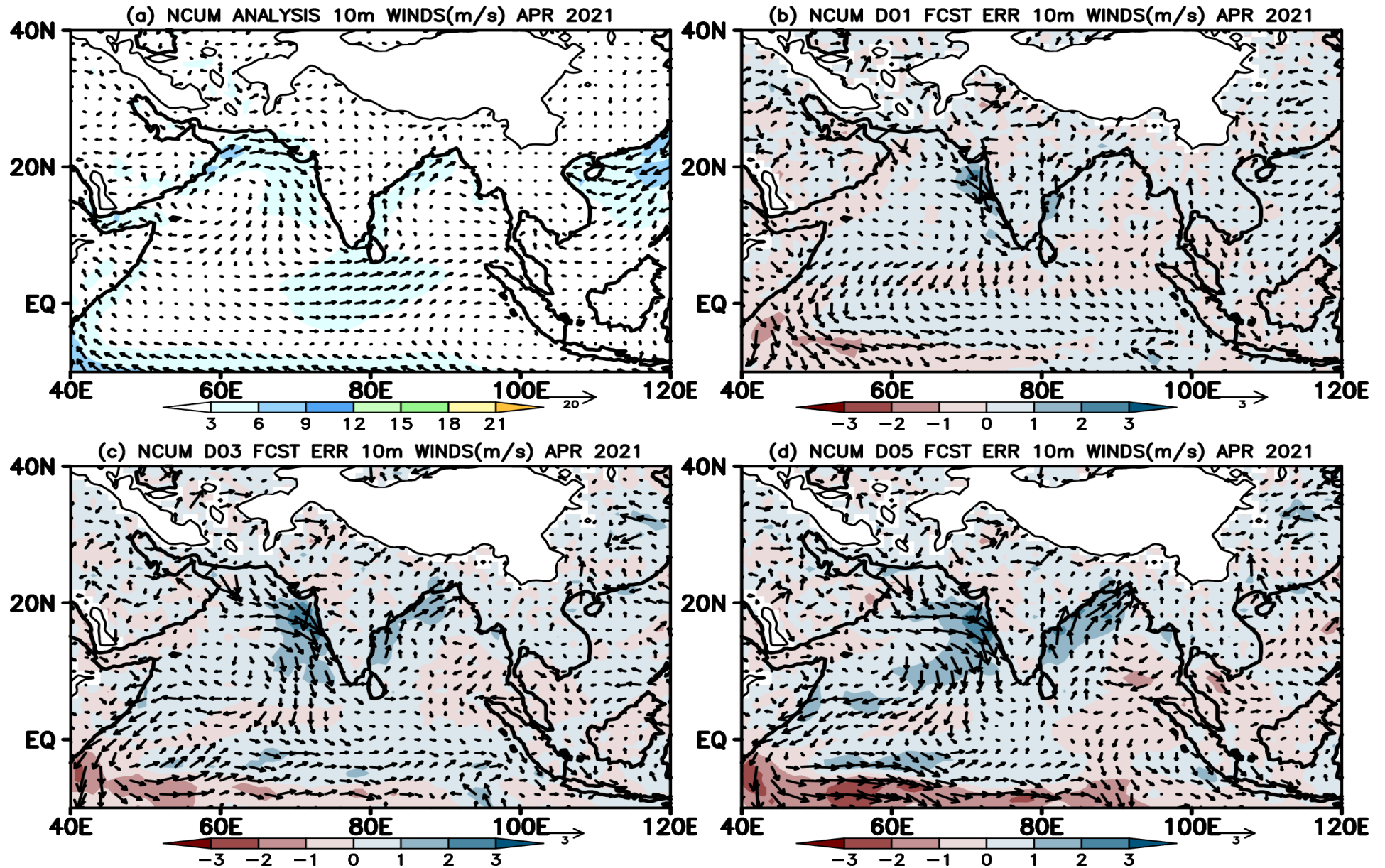


Figure 14. (a) Mean winds at 10m height and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

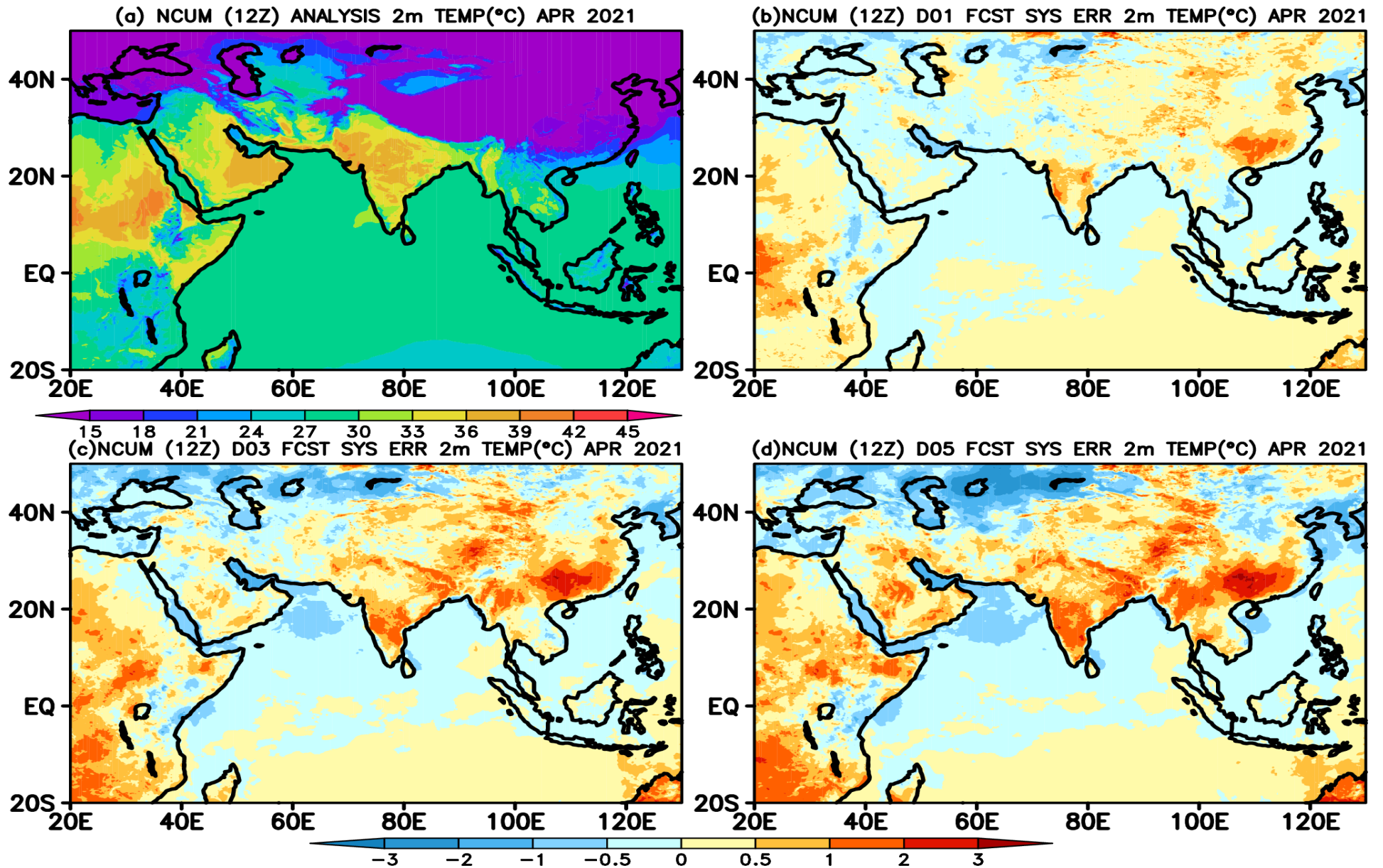


Figure 15. (a) Mean Temperature at 2mt height and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

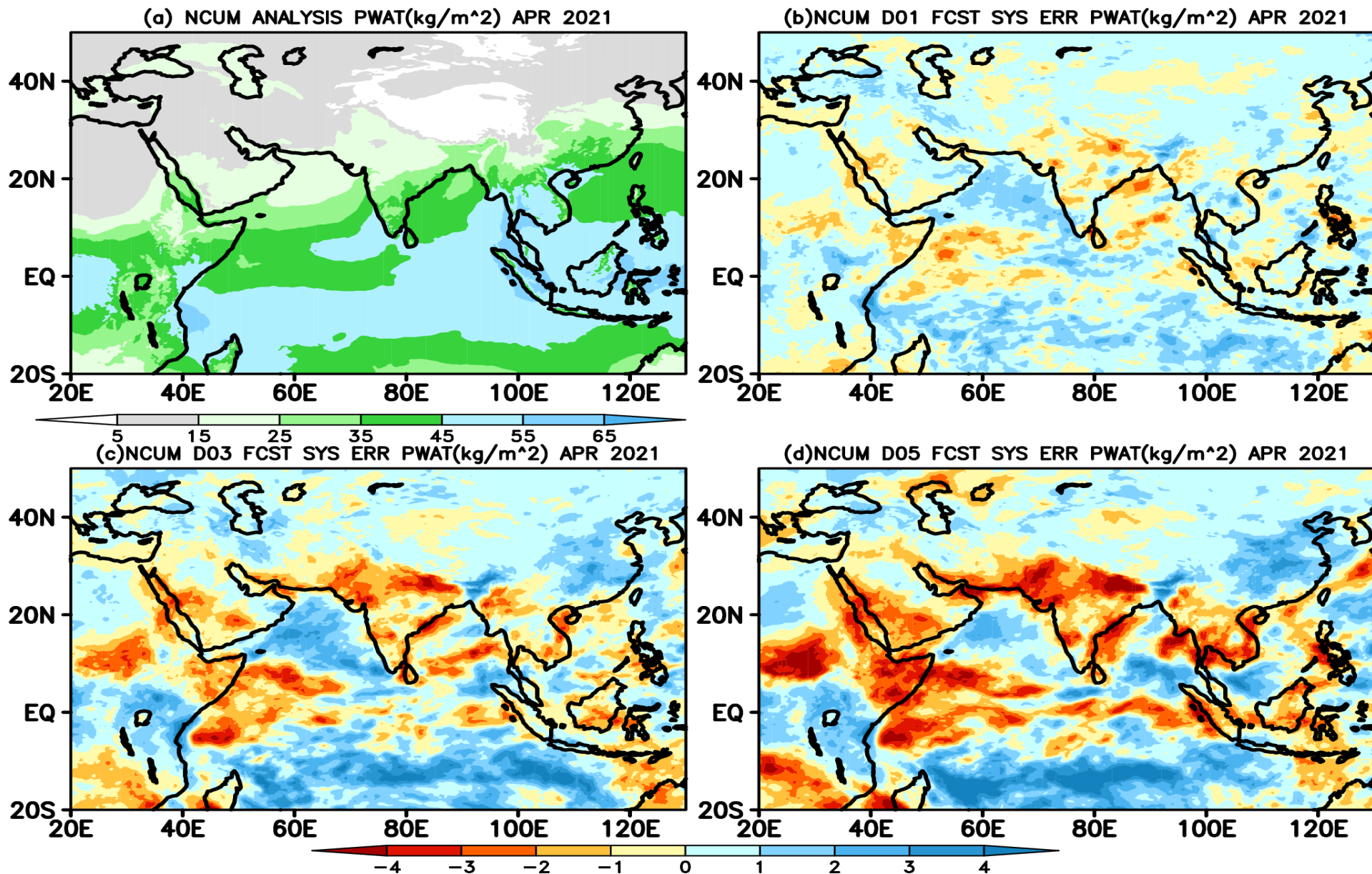


Figure 16. (a) Mean precipitable water content (PWAT) up to model levels and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

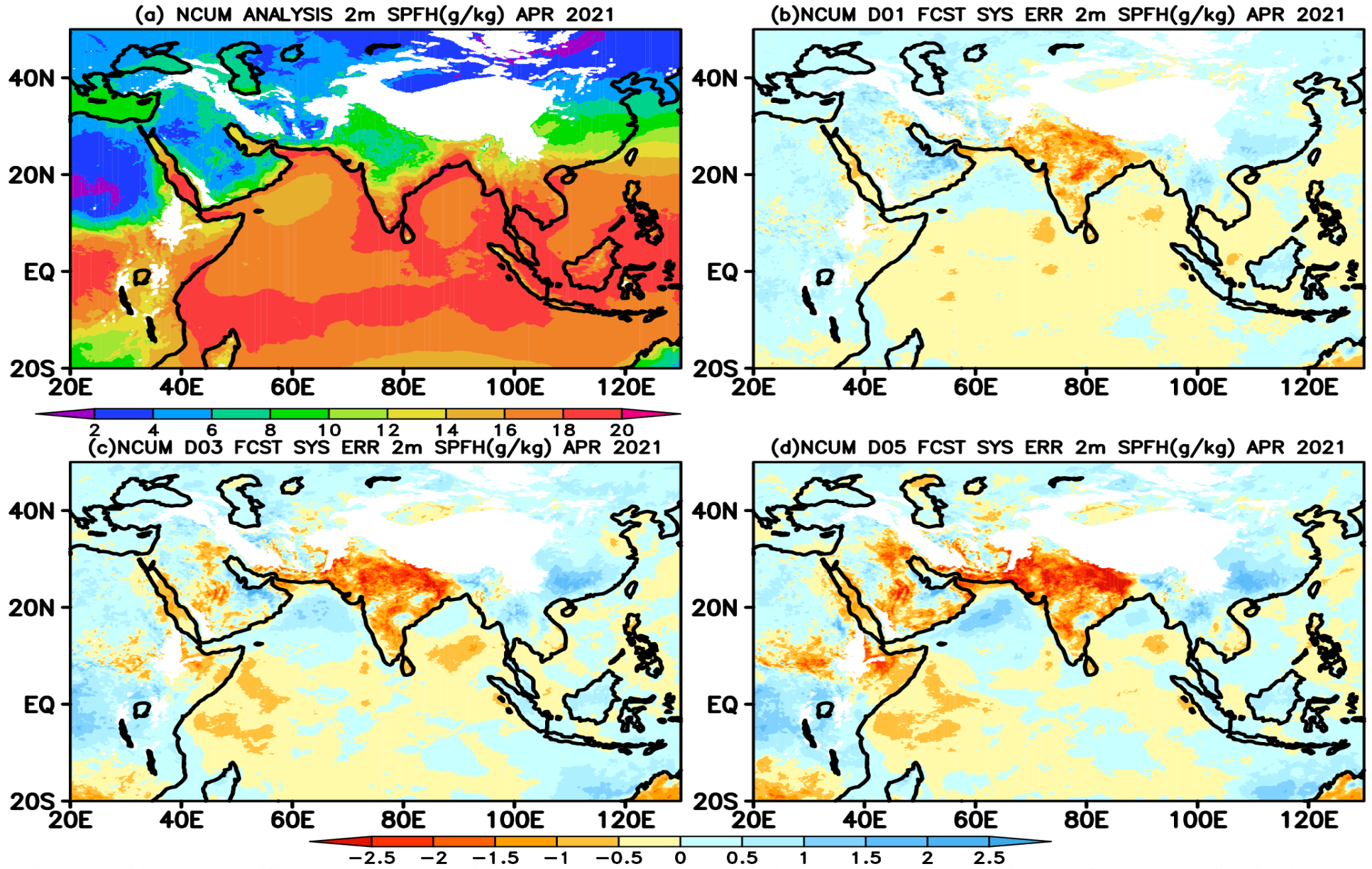


Figure 17. (a) Mean specific humidity at 2m height and systematic errors in (b) Day-1 (c) Day-3 and (d) Day-5 forecasts during April 2021

## 5. Verification of Rainfall Forecasts

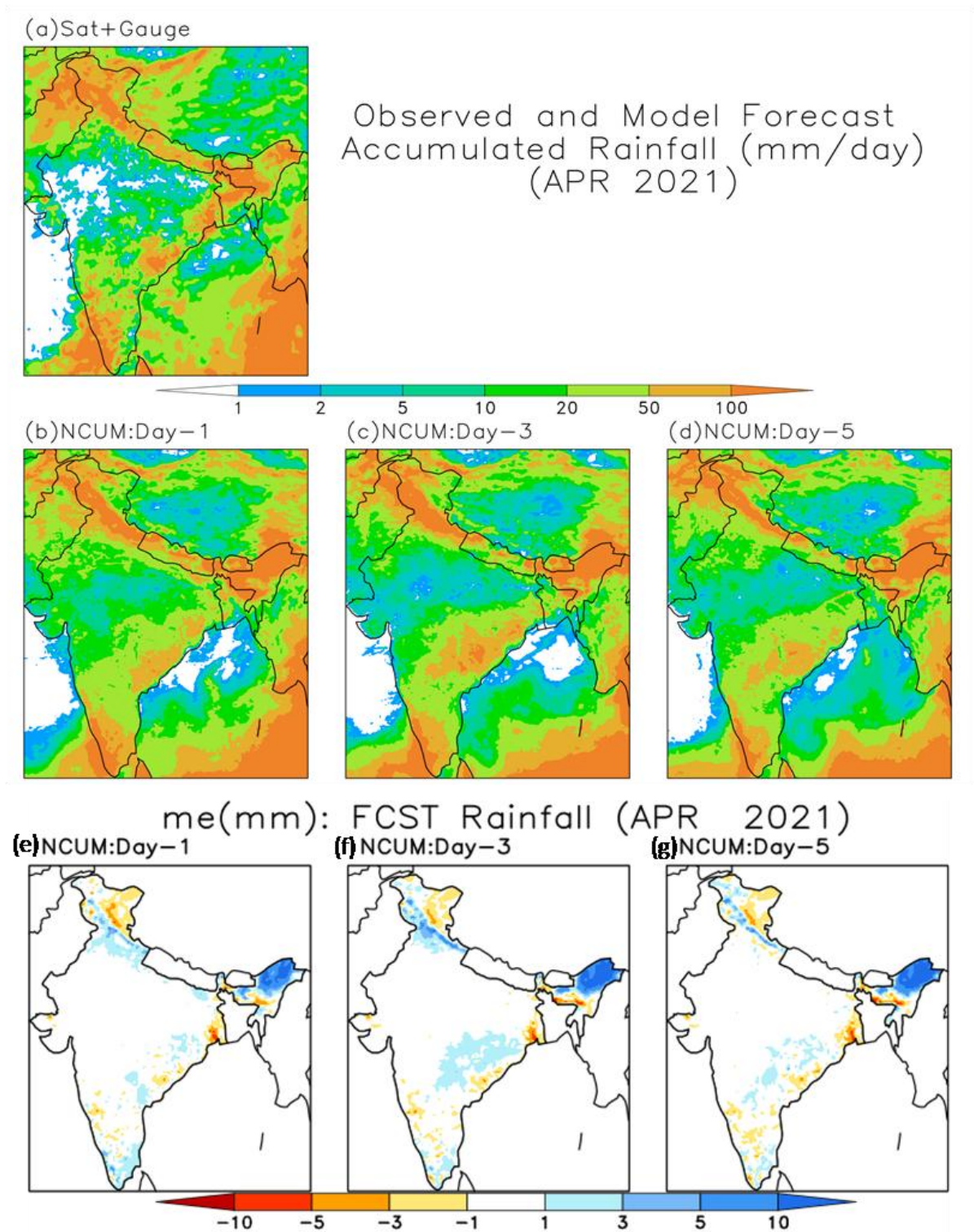


Figure 18. Accumulated April rainfall in (a) Observations and (b) Day-1 (c) Day-3 and (d) Day-5 forecasts. Bottom panels (e), (f) and (g) show Mean Error (ME) in Day-1, Day-3 and Day-5 forecasts respectively.

## 6. Rainfall Categorical scores for NCUM

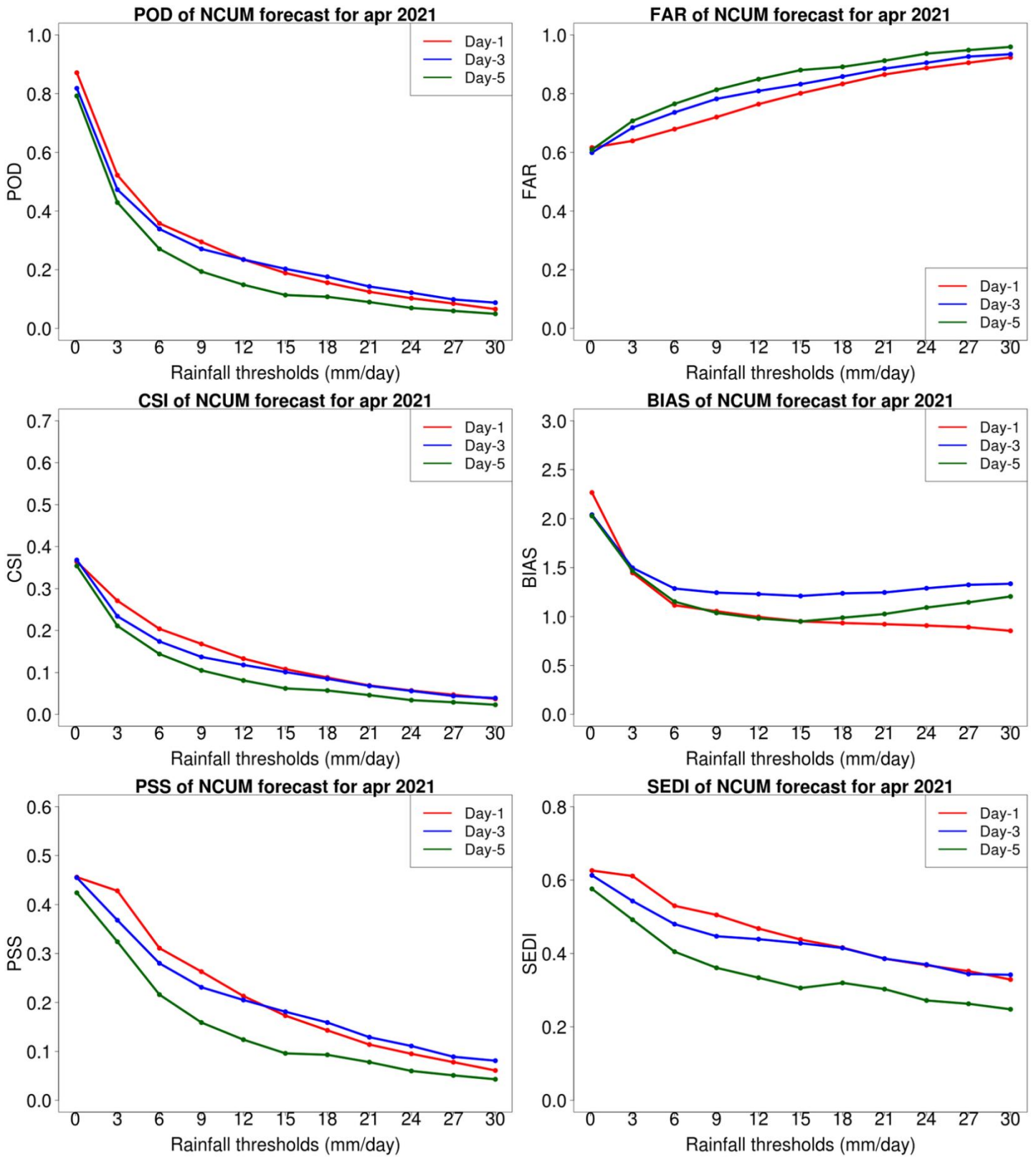
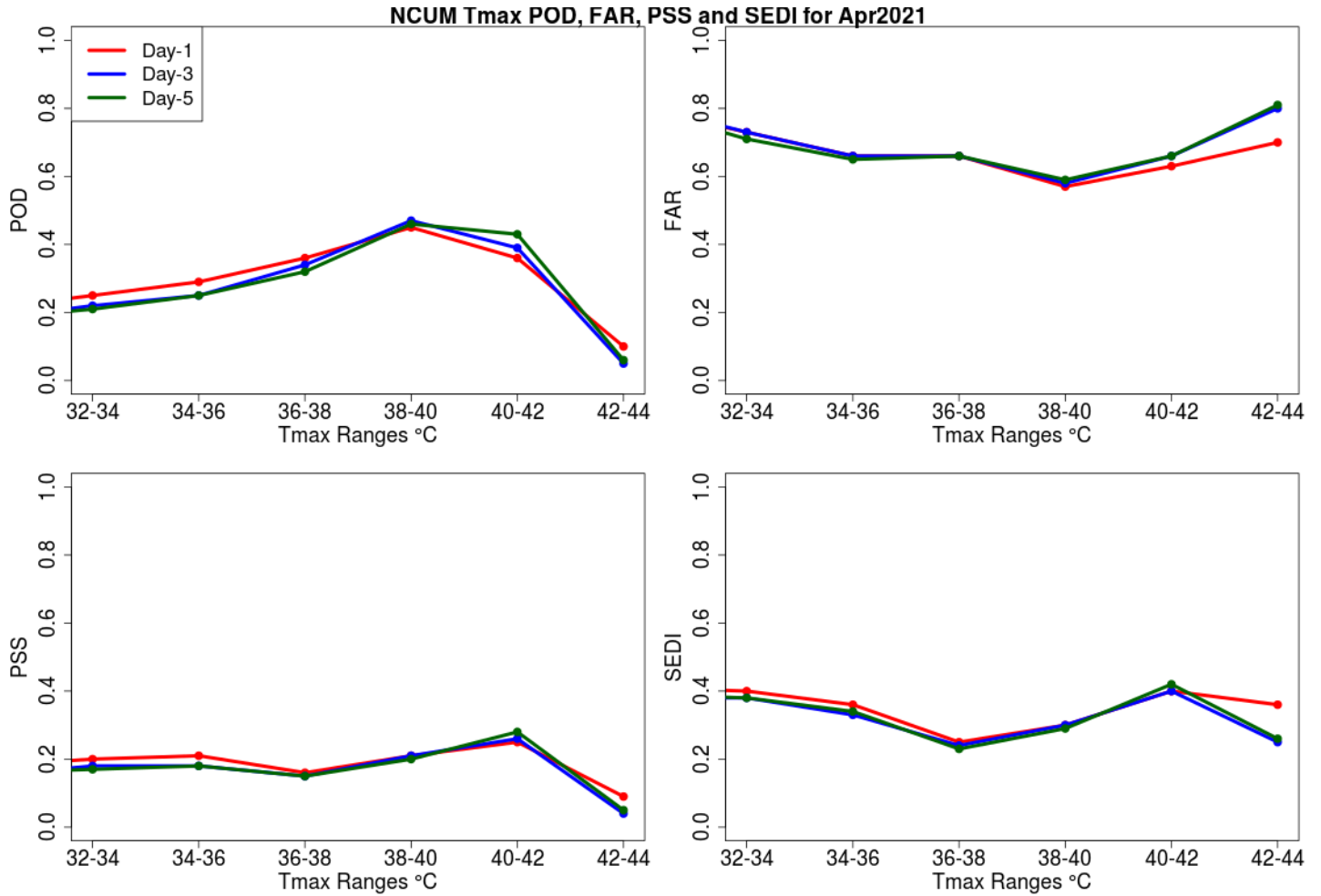


Figure 19. Categorical all India Rainfall scores POD (top left), FAR (top right), CSI(middle left), BIAS (middle right), PSS (bottom left) and SEDI (bottom right).



## 7. Tmax categorical Scores for NCUM:



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

## 8. Verification against Radiosonde

### a. GEOPOTENTIAL HEIGHT VERIFICATION AGAINST RADIOSONDES OVER INDIAN REGION

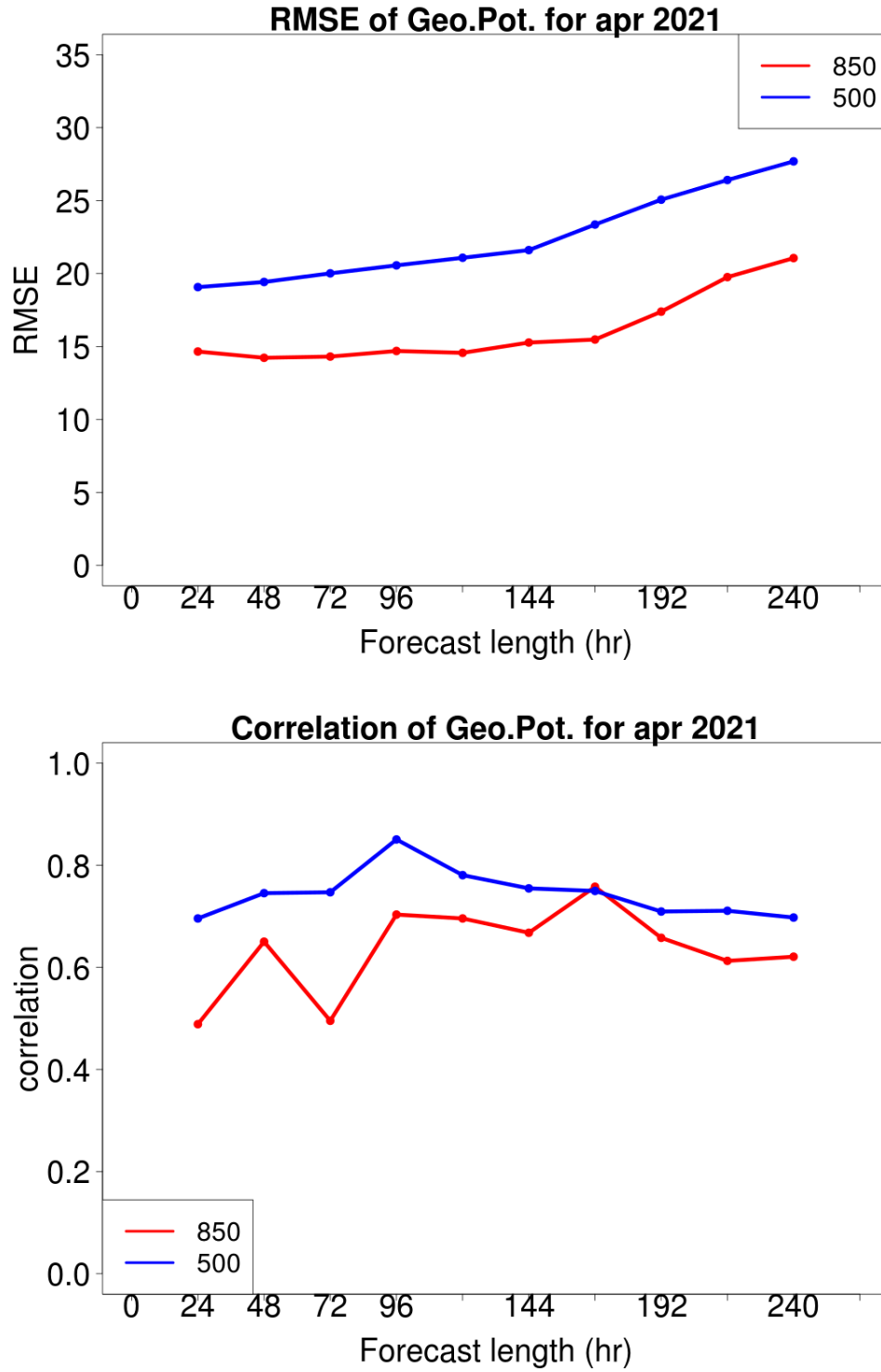
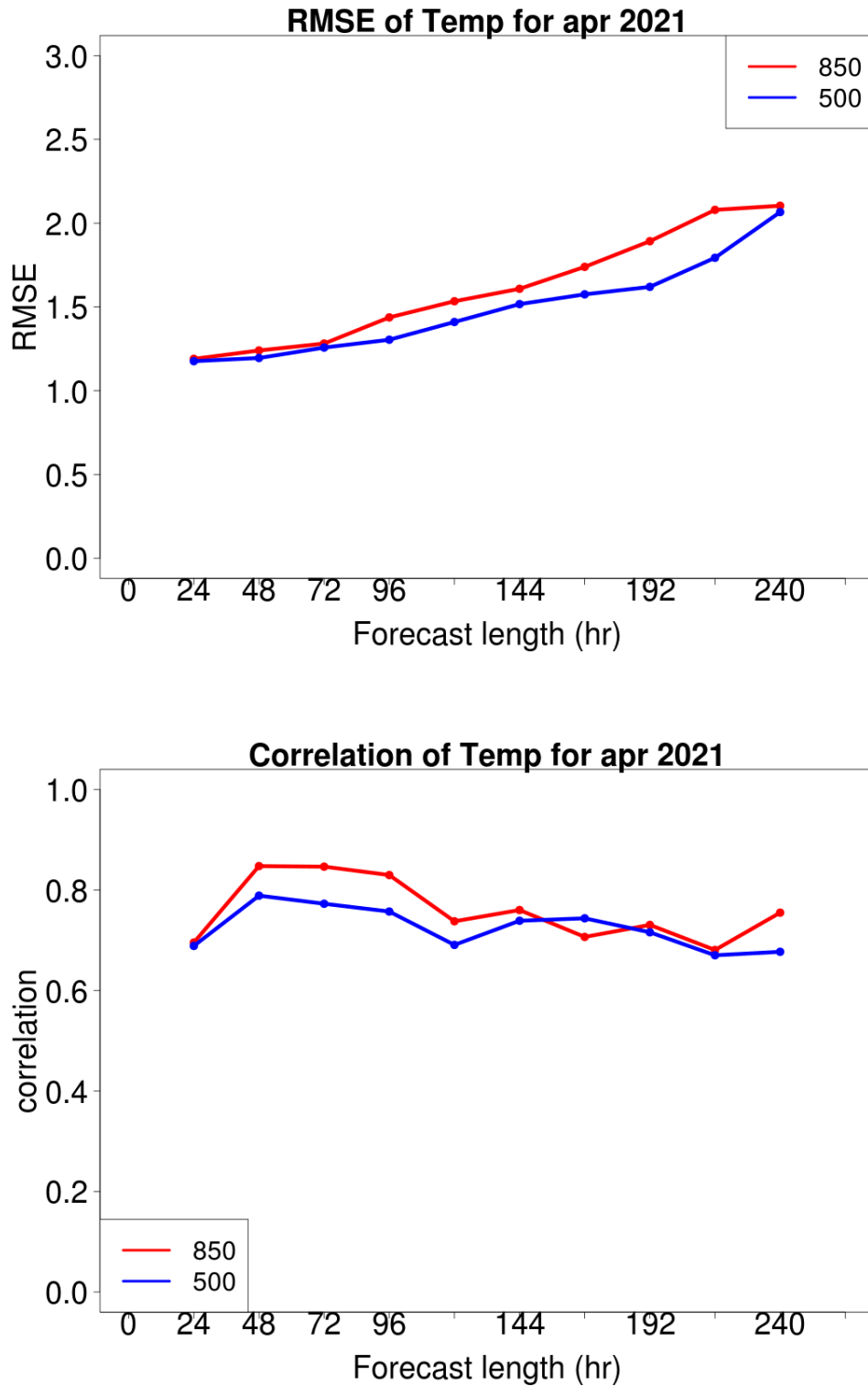


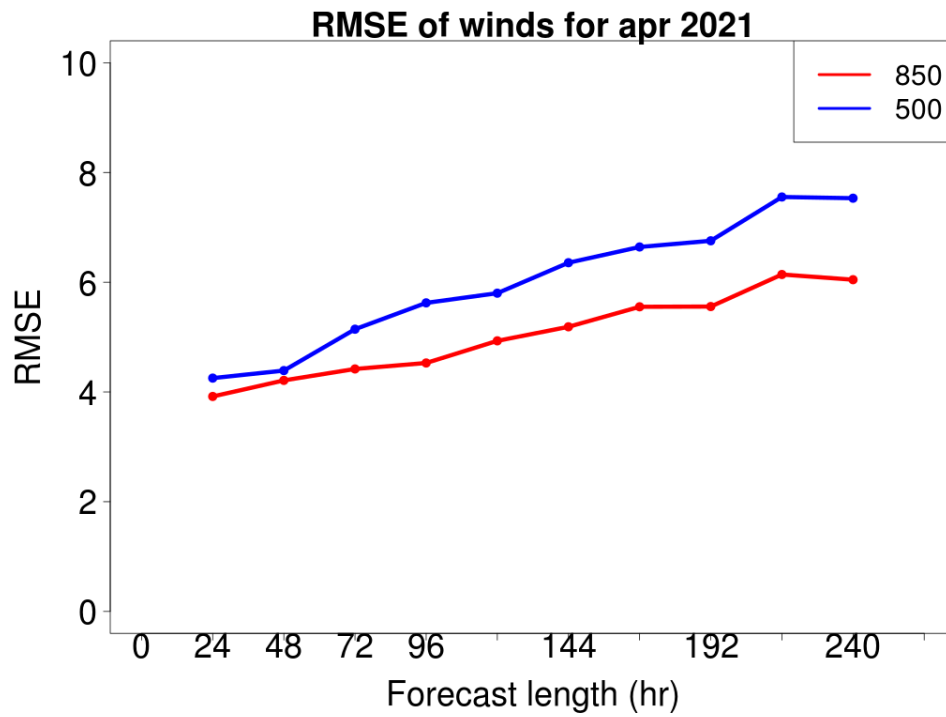
Figure.21. RMSE (upper panel) and Correlation (bottom panel) of geopotential height over Indian region during April 2021

**b. TEMPERATURE VERIFICATION AGAINST RADIOSONDES OVER INDIAN REGION**



**Figure.22. RMSE (upper panel) and Correlation (bottom panel) of Temperature over Indian region during April 2021**

**c. WIND VERIFICATION AGAINST RADIOSONDES OVER INDIAN REGION**



**Figure.23. RMSE of wind over Indian region during April 2021.**

## II. Special Weather Events of the Month

In this report, we have further evaluated model skill for some specific weather events during the month of April 2021

### Western Disturbances:

The western disturbance activity in the month of April was higher than normal. There were 9 WD's formed against the normal of 4 to 5 WD's. Out of 9, two active WD's are presented in this report.

- The analysis on 17 April 2021 (**Figure. 24**) depicts the presence of WD activity over north-western parts of India. The model is able to predict the WD and its associated rainfall (**Figure. 25**) in all forecast lead times.
- The model is able to predict the WD on 23 April 2021 (**Figure. 26**) over north-western side of Punjab and adjoining area up to Day-4. The intensity of the trough is weaker in Day-5 forecast lead times. The similar skill is an evident in Rainfall (**Figure. 27**)

### Heat wave:

- Heat wave conditions ( $>40^{\circ}\text{C}$ ) in the month of April is occasional and for shorter periods. The major cause for this is the presence of wet spells over northern parts of India due to the abnormal presence of WD's than normal. Model forecasts (**Figure, 28**) are able to predict the heat wave pockets over northern region of India up to 120 Hrs (Day-5) ahead. However, none of the model forecasts were predicted the peak value of the Temp ( $>42^{\circ}\text{C}$ ) over northwestern parts of India.

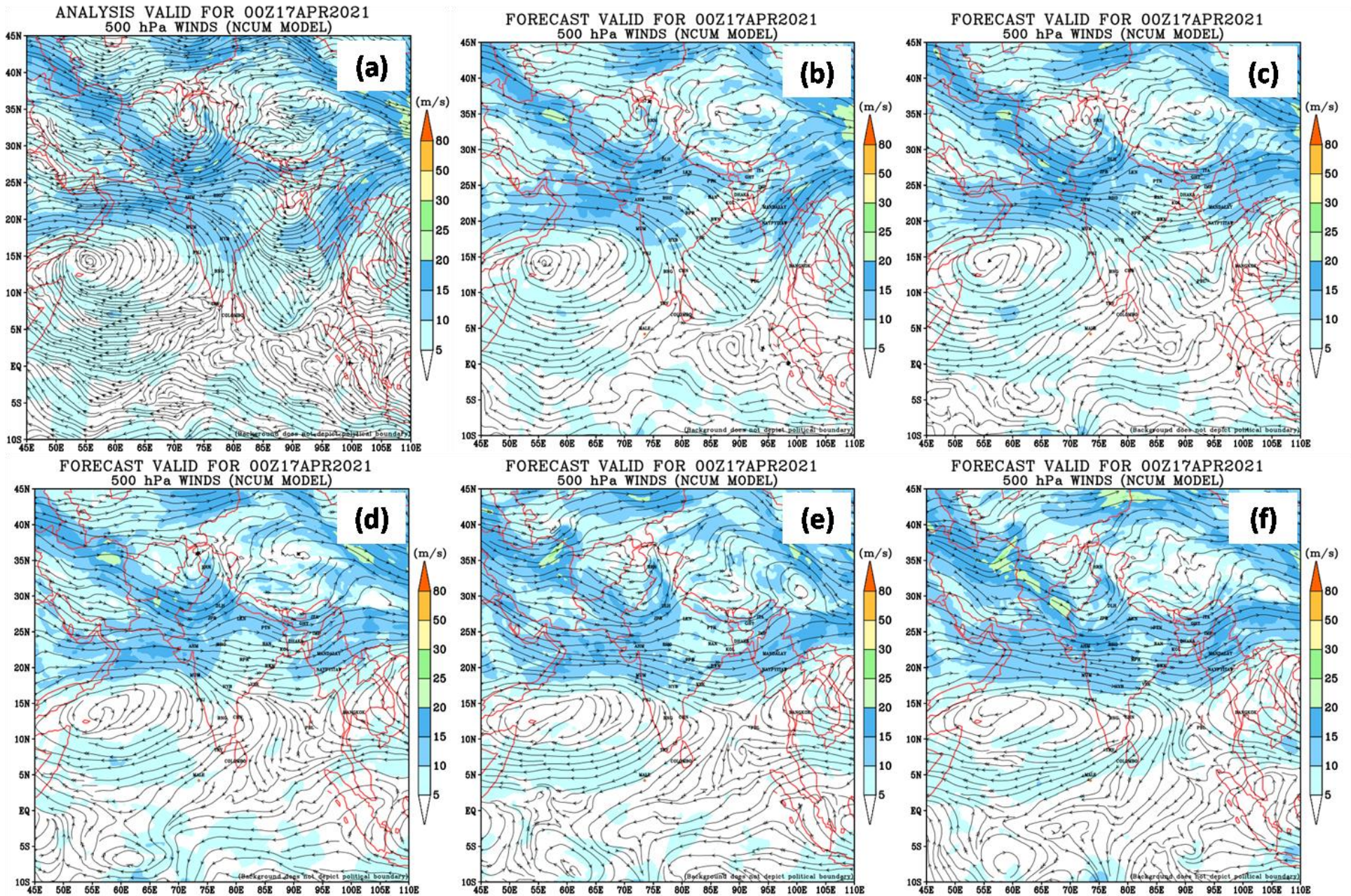


Figure 24. Winds (m/s) at 500 hPa in (a) Analysis (b) Day-1 (c) Day-2 (d) Day-3 (e) Day-4 and (f) Day-5 forecasts valid on 17 April 2021

OBS & NCUM RAINFALL(cm) FCST FOR 03Z17Apr2021

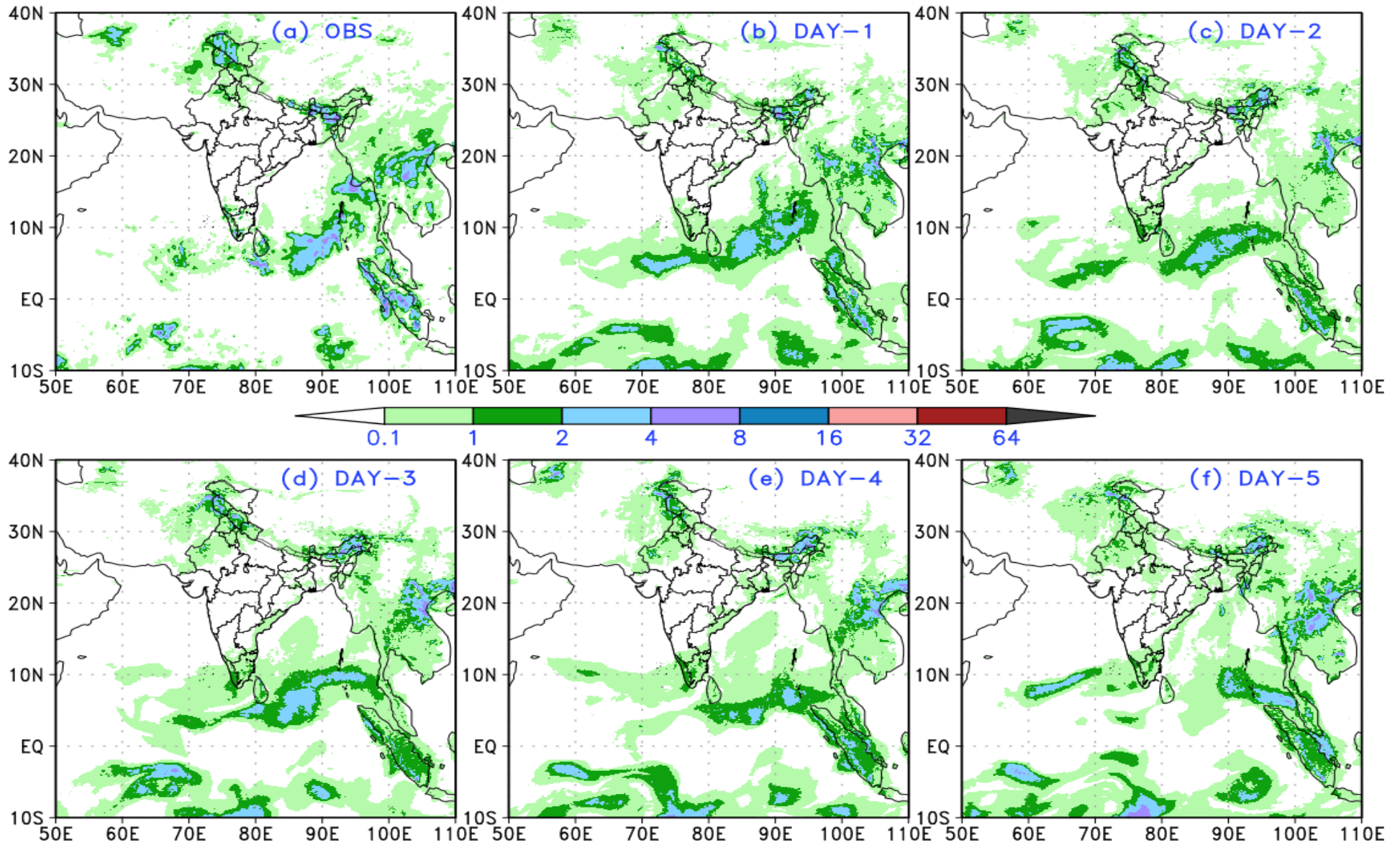


Figure 25. Rainfall on (a) Observation (b) Day-1 (c) Day-2 (d) Day-3 (e) Day-4 and (f) Day-5 forecasts of NCUM valid on 17 April 2021

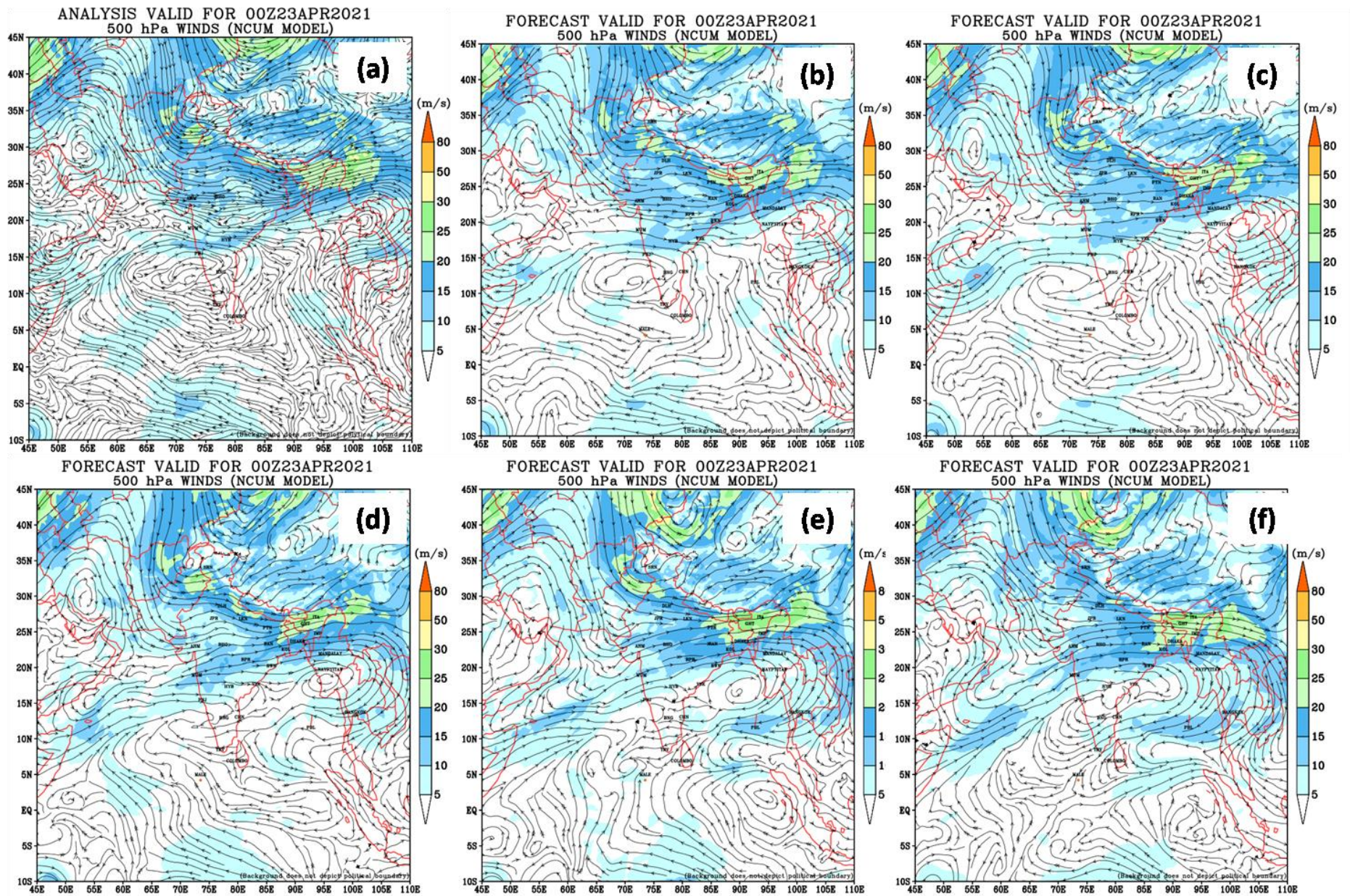


Figure 26. Winds (m/s) at 500 hPa in (a) Analysis (b) Day-1 (c) Day-2 (d) Day-3 (e) Day-4 and (f) Day-5 forecasts valid on 23 April 2021



OBS & NCUM RAINFALL(cm) FCST FOR 03Z23Apr2021

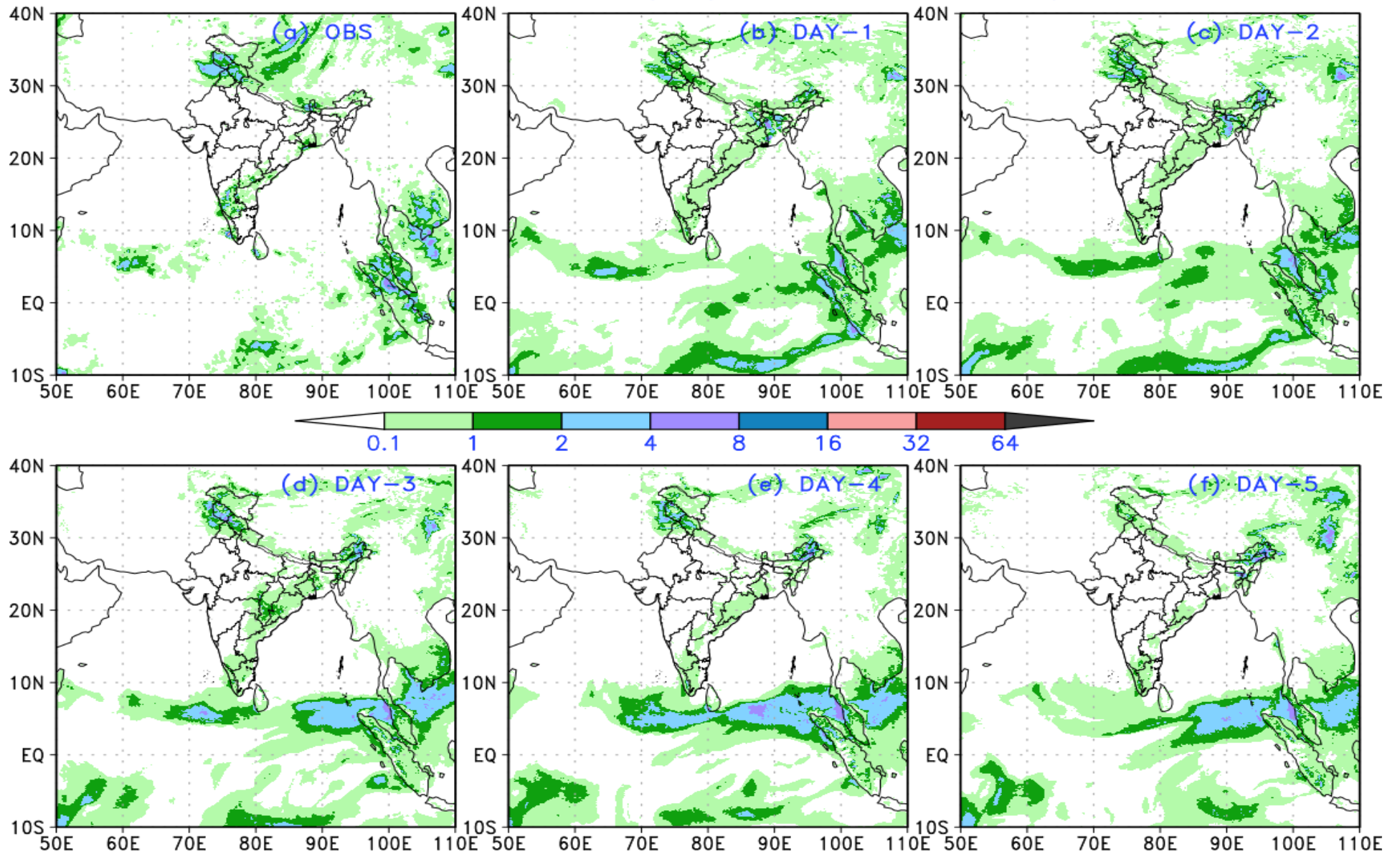
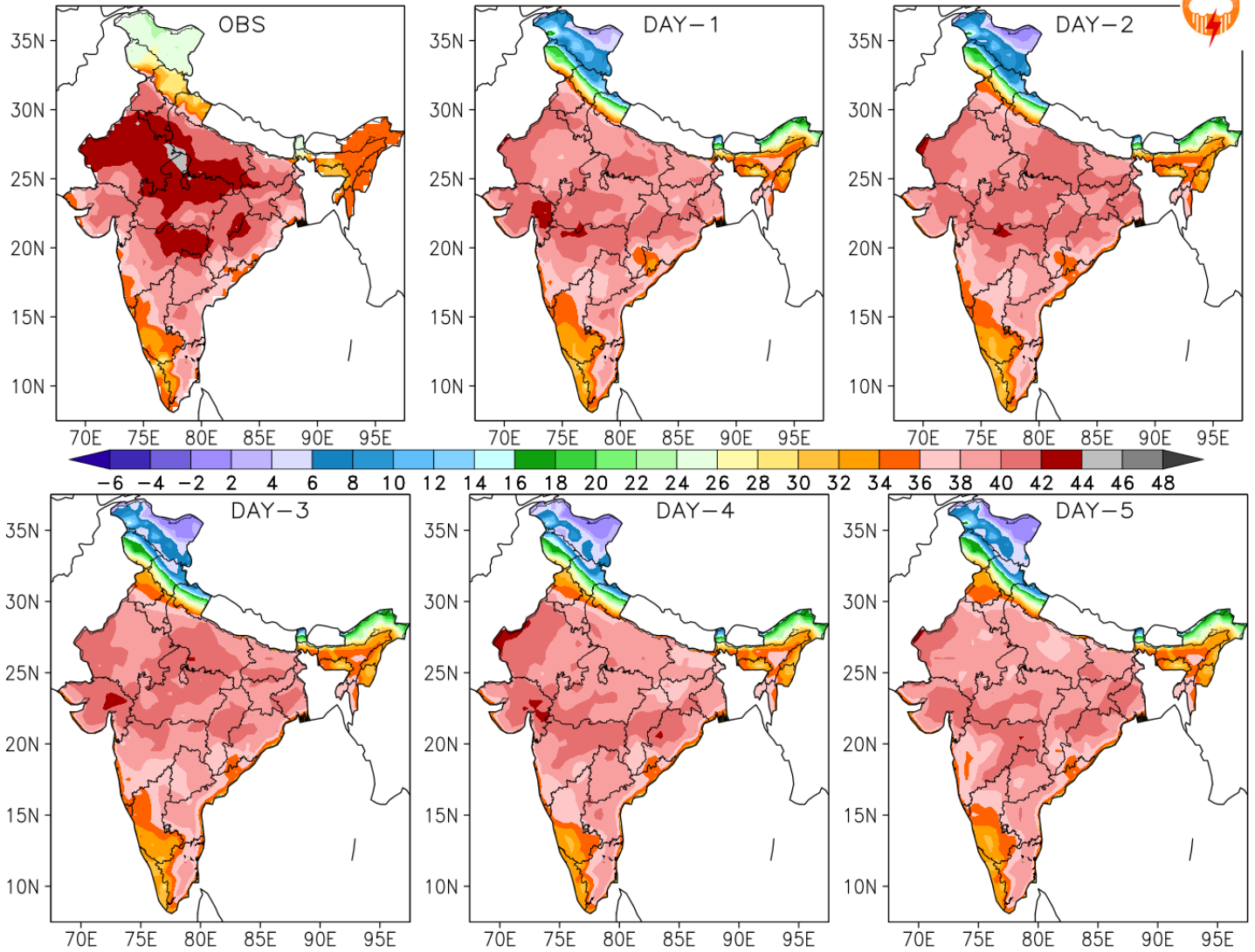


Figure 27. Rainfall on (a) Observation (b) Day-1 (c) Day-2 (d) Day-3 (e) Day-4 and (f) Day-5 forecasts of NCUM valid on 17 April 2021

IMD OBS, NCUM FCST TMAX (°C) 20210428



**Figure 28. Maximum Temperature(<sup>0</sup>C) from (a) IMD-observations (b) Day-1 (c) Day-2 (d) Day-3 (e) Day-4 and (f) Day-5 forecasts of NCUM on 28 April 2021**

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