"EVALUATION OF INSAT-3DR SOUNDER DERIVED ATMOSPHERIC TEMPERATURE RETRIEVALS OVER INDIA USING AIRS, COSMIC-2,HIGH-RESOLUTION ECMWF (EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTING) ERA-5 ANALYSES PRODUCTS AND RADIOSONDE MEASUREMENTS"
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OBJECTIVES

- INSAT-3DR Sounder Temperature profiles were compared with AIRS and ERA5 (Model reanalysis) data retrievals over the Indian region

- The temperature profiles for INSAT-3DR Sounder are collected with 12 IMD RadioSonde (Ground Data) observations over the Indian subcontinent

- INSAT-3DR Sounder Temperature profiles were compared with COSMIC-2 (Satellite Data) data retrievals over the Indian region

INTRODUCTION

- Atmospheric temperature plays an important role in our global climate change and also plays an important role in deciding the thermodynamic state of the atmosphere. Temperature deals with many biological- and physical processes between the earth's surface and the atmosphere including respiration and photosynthesis. It is regulating the heat and vapour exchange between the earth's surface and surrounding the atmosphere

- Atmospheric temperature varies in time as well as in space both vertically and horizontally throughout the atmosphere. However, atmospheric temperature profiles are essential for meteorological research. Notably, accurate and stable long-term observations of the vertical structure of atmospheric temperature are crucial for climate change monitoring

INTRODUCTION

- The main source of atmospheric temperature measurement data is the Radiosonde observations are a key data set in operational weather forecasting and upper-air climate research. Radiosonde observations have been used as "ground truth" for calibration and validation of satellite temperature retrievals. Radiosonde are launched only twice (00 and 12 UTC) per day during operation, and their spatial distribution is inhomogeneous with a relatively low density, especially over oceans, deserts, and polar regions

- In contrast to Radiosonde observations, satellite observations provide the measurements of atmospheric properties globally, including oceanic regions with more spatial- and temporal resolution. The accuracy and vertical resolution are the only cause of concern in satellite observations. Despite their limitations, satellite observations are complementary and very important for severe weather conditions where frequent observations are required

INTRODUCTION

- In this context, the launch of the Indian National Satellite System (INSAT-3DR) on 8 September 2016, launched by ISRO has gained a lot of significance due to its geostationary transfer orbit which provides vertical profiles with high temporal resolutions. It is restricted to India unlike the aforementioned satellites. The continuous observations of vertical profiles from the INSAT-3DR satellite plays an important role in numerical weather prediction over India and Monitor the earth's surface, carry out oceanic observations and also provides data dissemination capabilities.

INTRODUCTION

- In this study, we focus on the assessment of the quality of INSAT-3DR retrievals of temperature profiles; we conduct validation studies using 12 India Meteorological Department (IMD) RadioSonde observations, AIRS retrievals, Era-5 and COSMIC-2 data over the India region

- In doing so, INSAT-3DR temperature retrievals obtained from the routine application of the sounder data processing algorithm installed in the Multi-Mission Meteorological Data Processing System (MMRDPS), New Delhi, are taken and compared to IMD RadioSonde observations, Cosmic-2, Era5 and AIRS retrievals. This study intends to provide insights into what factors should be considered and where improvements might be made for better retrieval of atmospheric temperature profiles

INSAT-3D/3DR IMAGER CHANNEL SPECIFICATIONS

| Ch No	Ch ID	Channel Name	Spectral Range (μm)	Resolution (km)
1.	VIS	Visible	0.55-0.75	1.0
2.	SWIR	Short Wave Infrared	1.55-1.70	1.0
3.	MIR	Medium Wave Infrared	3.7-3.9	4.0
4.	WV	Water Vapour	6.5-7.1	8.0
5.	TIR 1	Long Wave Infrared	10.3-11.3	4.0
6.	TIR 2	Split	11.5-12.5	4.0

INSAT-3D SOUNDER CHANNELS CHARACTERSTICS

Detector	Ch No	λ_c (µm)	ϑ_c (cm^{-1})	NEΔT @300K	Principal absorbing gas	Purpose
Long Wave	1	14.67	682	0.17	CO_2	Stratosphere temperature
	2	14.32	699	0.16	CO_2	Tropopause temperature
	3	14.04	712	0.15	CO_2	Upper-level temperature
	4	13.64	733	0.12	CO_2	Mid-level temperature
	5	13.32	751	0.12	CO_2	Low-level temperature
	6	12.62	793	0.07	Water vapour	Total precipitable water
	7	11.99	834	0.05	Water vapour	Surface temp., moisture
Mid Wave	8	11.04	906	0.05	Window	Surface temperature
	9	9.72	1029	0.10	Ozone	Total ozone
	10	7.44	1344	0.05	Water vapour	Low-level moisture
	11	7.03	1422	0.05	Water vapour	Mid-level moisture
	12	6.53	1531	0.10	Water vapour	Upper-level moisture
Short Wave	13	4.58	2184	.05	N_2O	Low-level temperature
	14	4.53	2209	.05	N_2O	Mid-level temperature
	15	4.46	2241	.05	CO_2	Upper-level temperature
	16	4.13	2420	.05	CO_2	Boundary-level temperature
	17	3.98	2510	.05	Window	Surface temperature
	18	3.76	2658	.05	Window	Surface temp., moisture
Visible	19	0.695	14367	-	Visible	Cloud

OPERATIONAL SCENARIO OF INSAT-3D/3DR

INSAT Series	Temporal Resolution
3D-Imager (6 Channels)	½ hourly (xx00 &xx30 UTC)
3D-Sounder (19 Channels)	1½ hourly (Two times region-B) & Hourly (Three times region-A)
3DR-Imager (6 Channels)	½ hourly (xx15 & xx45 UTC)
3DR-Sounder (19 Channels)	Hourly (Three times region-A) & 1½ hourly (Two times region-B)

Sounder Observation Area

A (6 x 5)

B
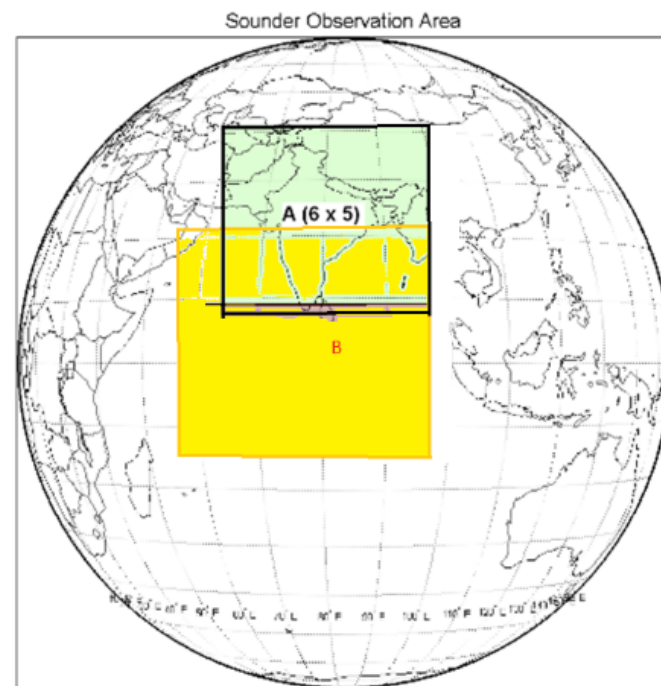
Sector-A
0000UTC-INSAT-3D
0100UTC-INSAT-3D
0200UTC-INSAT-3D
0300UTC-INSAT-3DR
0400UTC-INSAT-3DR
0500UTC-INSAT-3DR

Sector-B
0000UTC-INSAT-3DR
0130UTC-INSAT-3DR

0300UTC-INSAT-3D
0430UTC-INSAT-3D

Then this cycle will be repeated on six hourly basis.

DATA DESCRIPTION (INSAT-3DR)

- INSAT-3DR carries an 18-channel infrared sounder (+ visible channel) for atmospheric profiles of temperature and humidity. The algorithm is designed to retrieve the vertical profiles of atmospheric temperature and moisture in the atmosphere from the clear-sky infrared radiances in different absorption bands of the sounder. The atmospheric profile retrieval algorithm for INSAT-3DR Sounder is a two-step approach

- The first step includes the generation of accurate hybrid first guess profiles using a combination of statistical regression retrieved profiles and model forecast profiles. The second step is the nonlinear physical retrieval to improve the resulting first guess profile using the Newtonian iterative method (Thapliyal et al., 2017)

DATA DESCRIPTION (INSAT-3DR)

- The retrieved parameters from the INSAT-3DR sounder are generated as part of Level-2B files in HDF5 format. Vertically the retrievals are carried out at 40 pressure levels at a horizontal spatial resolution of 10 km and temporal resolution of 30 minutes. For spatiotemporal collocation, each pixel is identified with specific latitude, longitude and time. The latter is obtained from the scan time product in the L2B file

- In the present study, we used temperature profiles retrieved from INSAT-3DR sounder level-2 physical retrieval during the 1 year, 1st January 2021 to 31st December 2021 at 00 and 12 UTC were utilized for day-to-day comparison

DATA DESCRIPTION (AIRS)

- AIRS is one of the payloads on the National Aeronautics and Space Administration (NASA) Aqua satellite (Parkinson 2003). It is a polar sun-synchronous orbit revolving at an altitude of 705 km from the earth's surface with an orbital period of 98.99 min

- The Aqua spacecraft crosses the equator twice a day, once going north (ascending) at 1:30 P.M local time (daytime) and going south (descending) at 1:30 A.M local time (night times) in a sun-synchronous, near-polar orbit with an inclination of 98.2°

- It is a high spectral sounder with 2378 channels measuring the IR radiances at wavelengths in the range of 3.7–15.4 µm with a swath of 1650 km and a horizontal spatial resolution of 13.5 km at nadir (Aumann et al. 2003)

DATA DESCRIPTION (AIRS)

- The AIRS instrument is accompanied by two atmospheric-sounding instruments, the Advanced Microwave Sounding Unit-A (AMSU-A), and the Humidity Sounder for Brazil (HSB). AIRS has been collecting data with global coverage since 2002 and provides twice-daily profiles of temperature, pressure, water vapour and other atmospheric gases

- The AIRS data, the spatial resolution of 1° longitudinal and 1° latitudinal (Tian and Waliser 2014) at 24 pressure levels for temperatures from 1000 to 1 hPa. The AIRS retrievals of the latest Version 6 data product were released in January 2013 with several improvements from Version 5, including a new first-guessing approach, improved cloud-clearing algorithm, additional quality control fags, and measures of uncertainty (Susskind et al. 2003, 2006; Blackwell 2005)

- For the present study, we used the level 3 version 6 atmospheric temperature profiles pressure levels (1000, 925, 850, 700, 600, 500, 400, 300, 250, 200, 150, and 100 hPa) over the Indian region show during the period 1st January 2021 to 31st December 2021 around 01:30 India Standard Time (IST). AIRS data (V6, L3) were obtained from https://airs.jpl.nasa.gov/data/get_data

DATA DESCRIPTION (ERA5)

- INSAT 3DR sounder observations are also validated with ECMWF Reanalysis (ERA-5) product (Hans et al., 2020)

- ERA5 data temperature is downloaded from the Copernicus Climate Change Service Climate Data Store at 0.250 x0.250 spatial and 1-hour temporal resolution at 37 vertical pressure levels

- (https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-pressure levels?tab=overview)

DATA DESCRIPTION (COSMIC-2)

- Profiles of temperature, pressure and water vapour partial pressure from the COSMIC-2 mission (operational Level-2 product) are used for the validation of INSAT 3DR sounder observations. These profiles are provided from the surface or a lower altitude (varies) to 60 km altitude on a computational grid of 795 levels spaced uniformly at 50 m up to a height of 20 km and 100 m beyond 20 km. The data for the COSMIC-2 Level 2 products are available from https://www.tacc.cwb.gov.tw

- High-resolution ECMWF gridded analyses data, that are collocated with COSMIC-2 data files (https://www.tacc.cwb.gov.tw) are also used for validation purposes

DATA DESCRIPTION (RADIOSONDE)

- Upper-air temperature, pressures, humidity, and wind observations have been made by balloon-borne Radiosonde instruments for the past 7 decades and have had important applications in weather prediction, upper-air climate research, satellite data calibration and validation, etc

- The accuracy of the Radiosonde data is significantly affected by the sensor design, calibration, data processing and contamination. The uncertainty in the sonde measurements is especially very large in the upper parts of the troposphere owing to its dry and cold conditions

- This dataset provides the vertical profiles of temperature at standard levels (including the surface level and 1000, 920, 850, 700, 600, 500, 400, 350, 300, 250, 200, 150, and 100 hPa) and at significant levels. In the present study, the quality-checked RadioSonde data obtained from India Meteorological Department (IMD) 12 stations at different RadioSonde locations over the Indian subcontinent

DATA DESCRIPTION (RADIOSONDE)

- These observations are taken routinely at synoptic hours, 00 and 12 UTC, over various meteorological observatories. This dataset includes temperature, geopotential height, dew point depression, wind direction and wind speed at 22 mandatory pressure levels
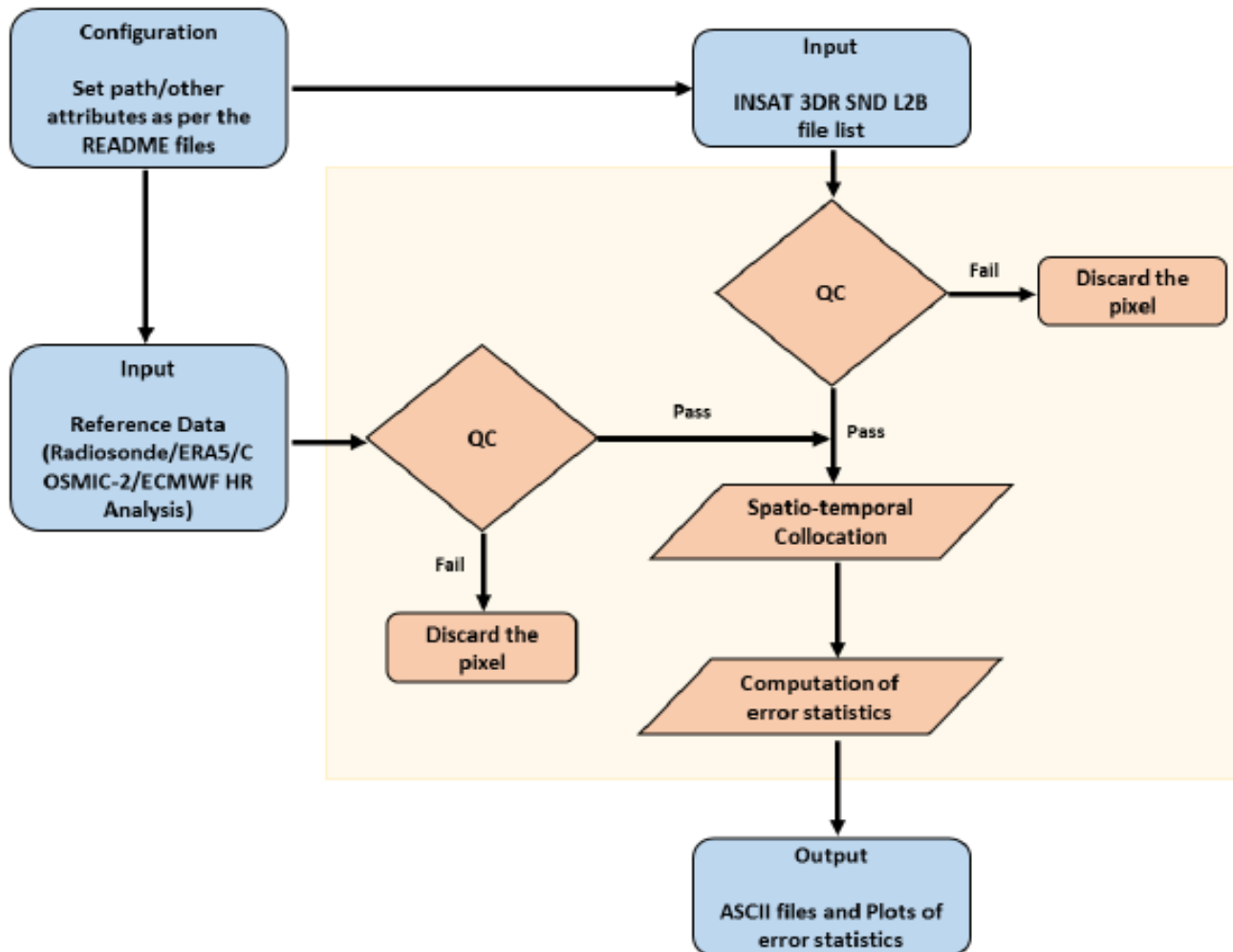
SELECTED IMD RADIOSONDE STATIONS & LOCATIONS

STATION	INDEX NO	LATITUDE	LONGITUDE
SRINAGAR (SRN)	42,027	34.3	74.48
NEW DELHI (NDL)	42,182	28.48	77.12
BHOPAL (BHP)	42,667	23.14	77.25
BHUBANESHWAR (BWN)	42,971	20.15	85.49
JAIPUR (JIP)	42,348	26.49	75.49
GOA (GOA)	43,192	15.29	73.49
CHENNAI (MDS)	43,297	12.99	80.18
PORTBLAIR (PBL)	43,333	11.39	92.44
AMINI (AMN)	43,311	11.30	72.11
BANGALORE (BNG)	43,295	12.58	77.35
MUMBAI (BMB)	43,003	19.10	72.85
JADGALPUR (JDG)	43,041	19.40	82.20

METHODOLOGY

- **The domain of validation** Spatial coverage of INSAT 3DR sounder in terms of Latitude and Longitude. i.e. **50-103⁰E** longitude and 15⁰S to 43⁰N latitude

- **Period of validation** Initial validation is performed for one year from 1st January 2021 to 31st December 2021

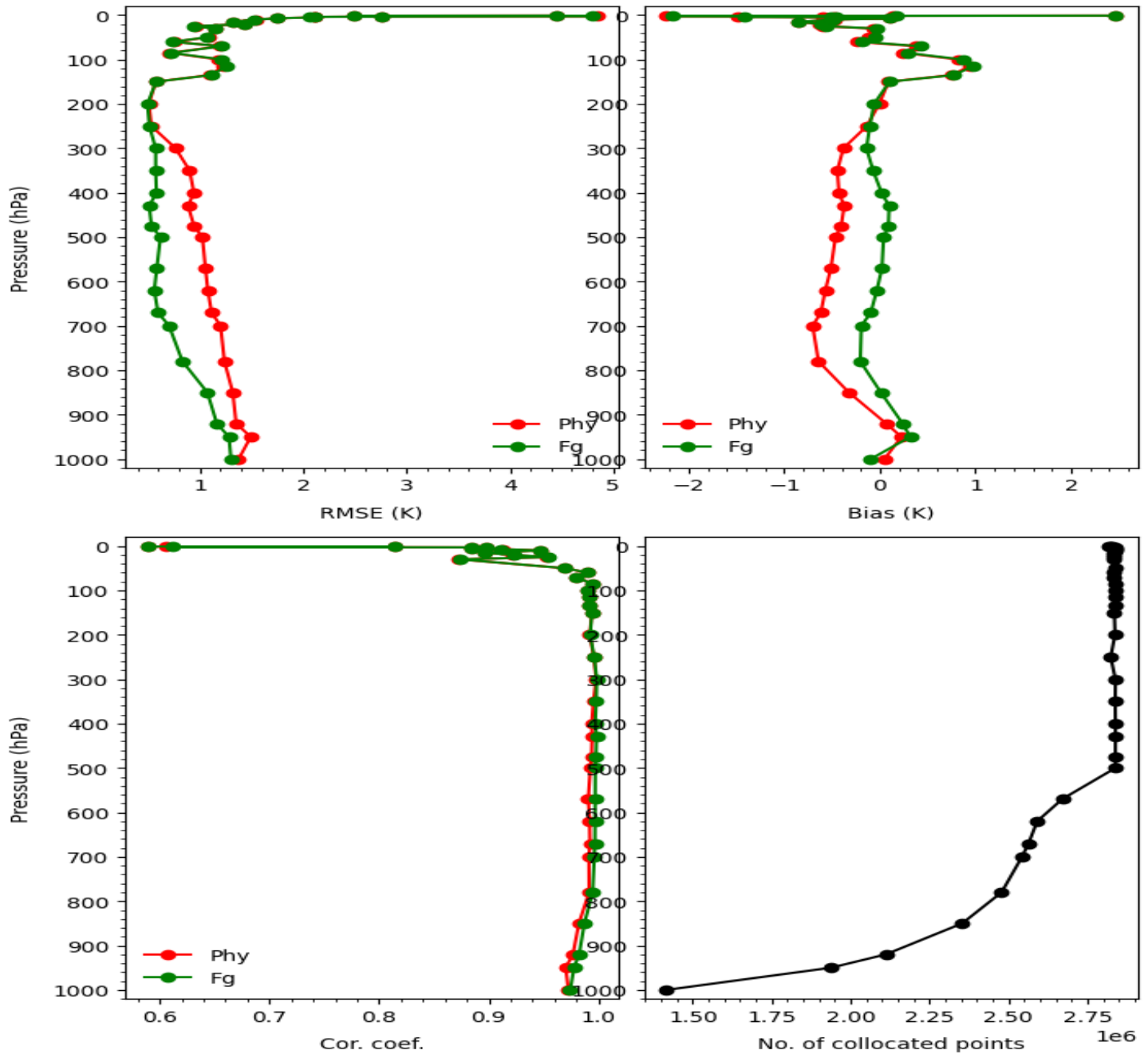# VALIDATION PROCEDURE FOR INSAT-3DR SOUNDER PRODUCTS OF TEMPERATURE
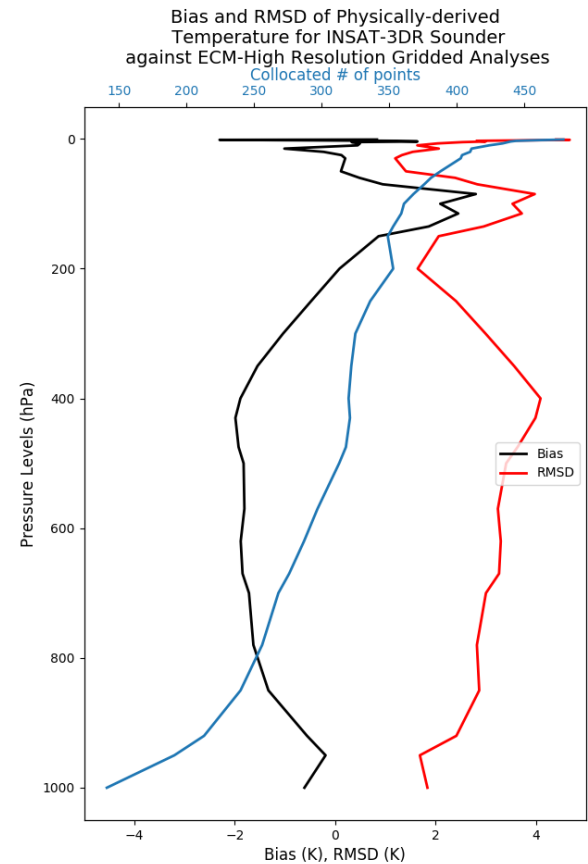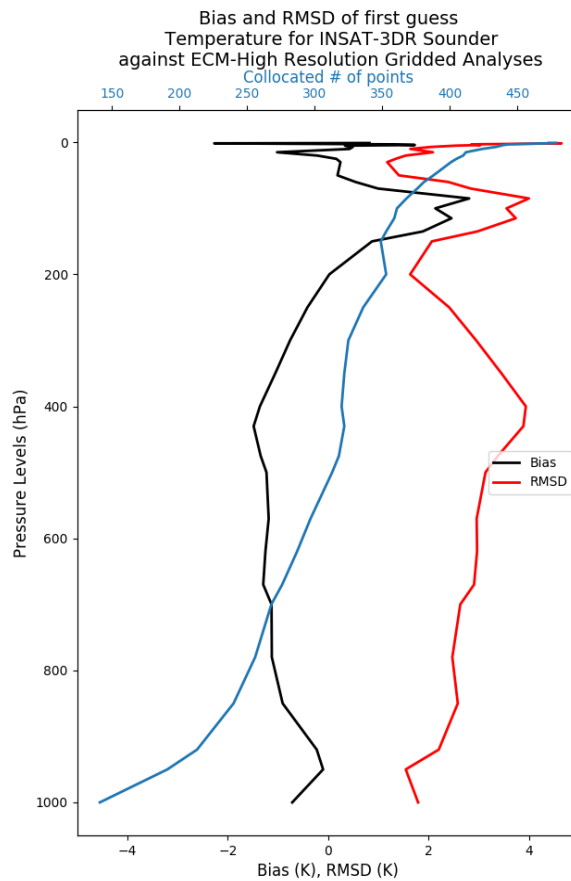
FINAL COMPUTATION (JAN – DEC 2021)

Reference Data (RadioSonde, ERA-5), AIRS and COSMIC-2

INSAT 3DR Sounder data

Selection of Co-located points (Spatial and temporal colocation)

Statistics and plots (RMSE/CC/BIAS)
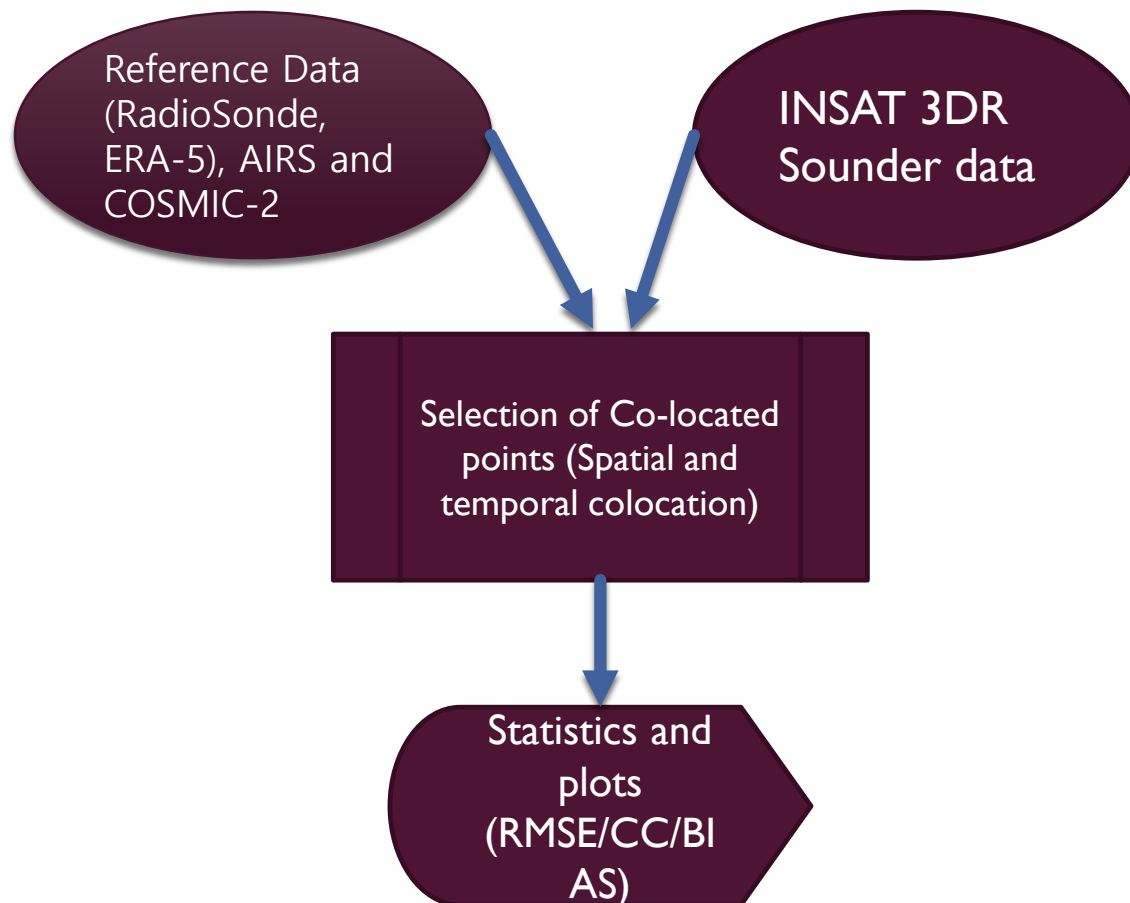
Error statistics in Temperature

INSAT 3DR SOUNDER VS COSMIC-2

There is no difference between 1st guess temperature and physically retrieved INSAT 3DR Algorithm in terms of bias and RMSE at the lower level the RMSE is 2 to 3 k, However it slightly degraded at 400 hpa and bias minimum at lower level but some significance has been above 200hpa

Bias and RMSD of first guess Temperature for INSAT-3DR Sounder against ECM-High Resolution Gridded Analyses

Bias and RMSD of Physically-derived Temperature for INSAT-3DR Sounder against ECM-High Resolution Gridded Analyses

VALIDATING INSAT-3DR ATMOSPHERIC TEMPERATURE RETRIEVALS OVER INDIA USING AIRS & ERA-5
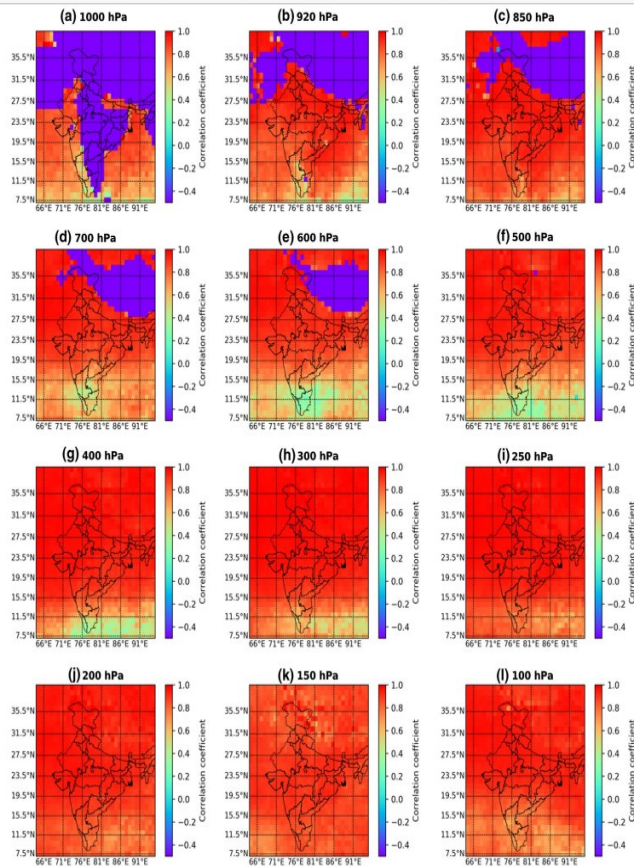
Spatial distribution of the correlation coefficient between INSAT-3DR Sounder and AIRS temperature profiles at different pressure levels from 1000 to 100 hPa during 2021 over the Indian region
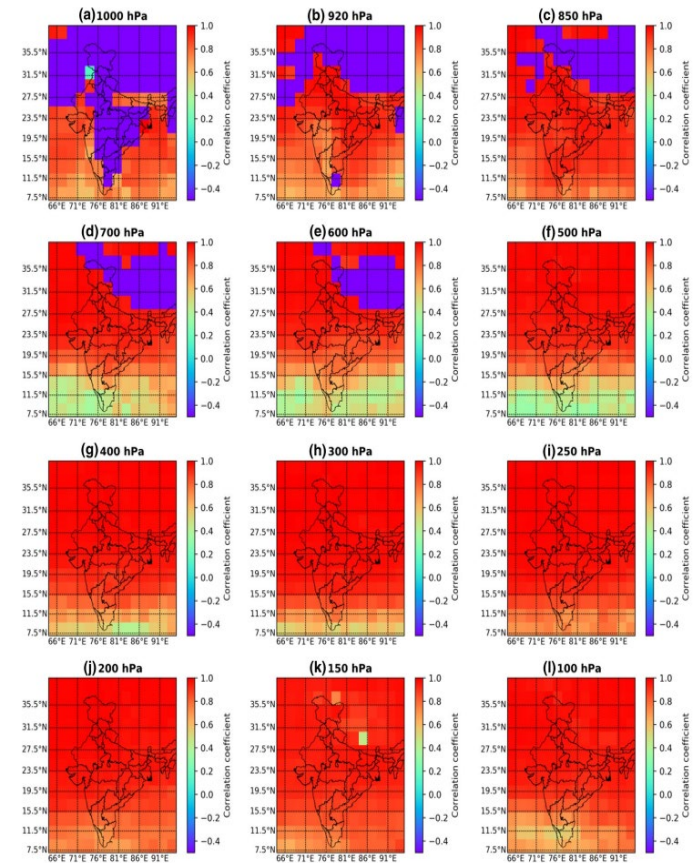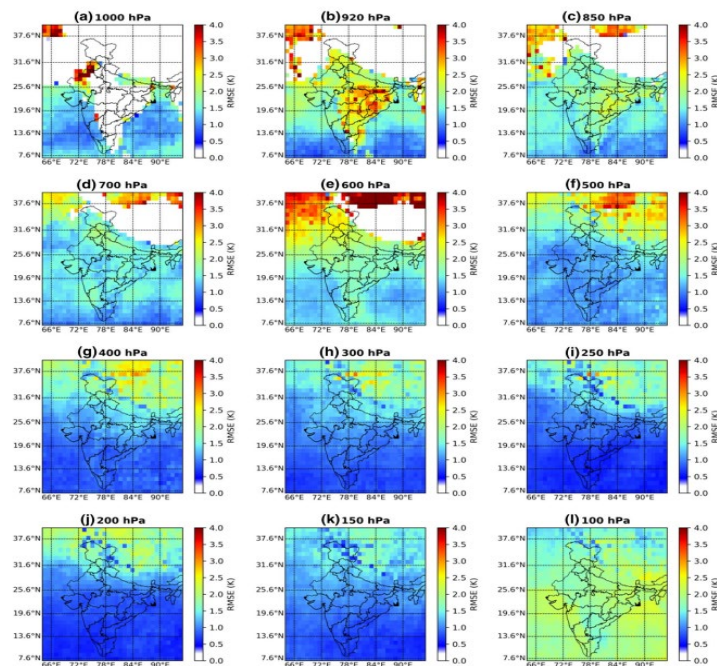
Spatial distribution of the correlation coefficient between INSAT-3DR Sounder and ERA-5 (ECMWF- Model Reanalysis) temperature profiles at different pressure levels from 1000 to 100 hPa during 2021 over the Indian region
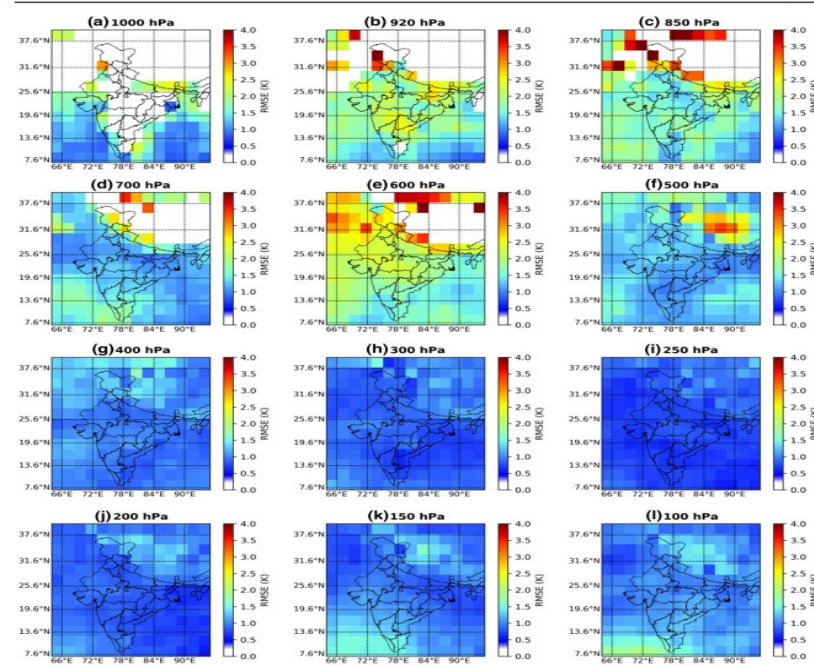
VALIDATING INSAT-3DR ATMOSPHERIC TEMPERATURE RETRIEVALS OVER INDIA USING AIRS & ERA-5


Spatial distribution of temperature (K) RMSE between the INSAT-3DR and AIRS at different pressure levels from 1000 to 100 hPa over the Indian region for the year 2021

Spatial distribution of temperature (K) RMSE between the INSAT-3DR and ERA-5 at different pressure levels from 1000 to 100 hPa over the Indian region for the year 2021
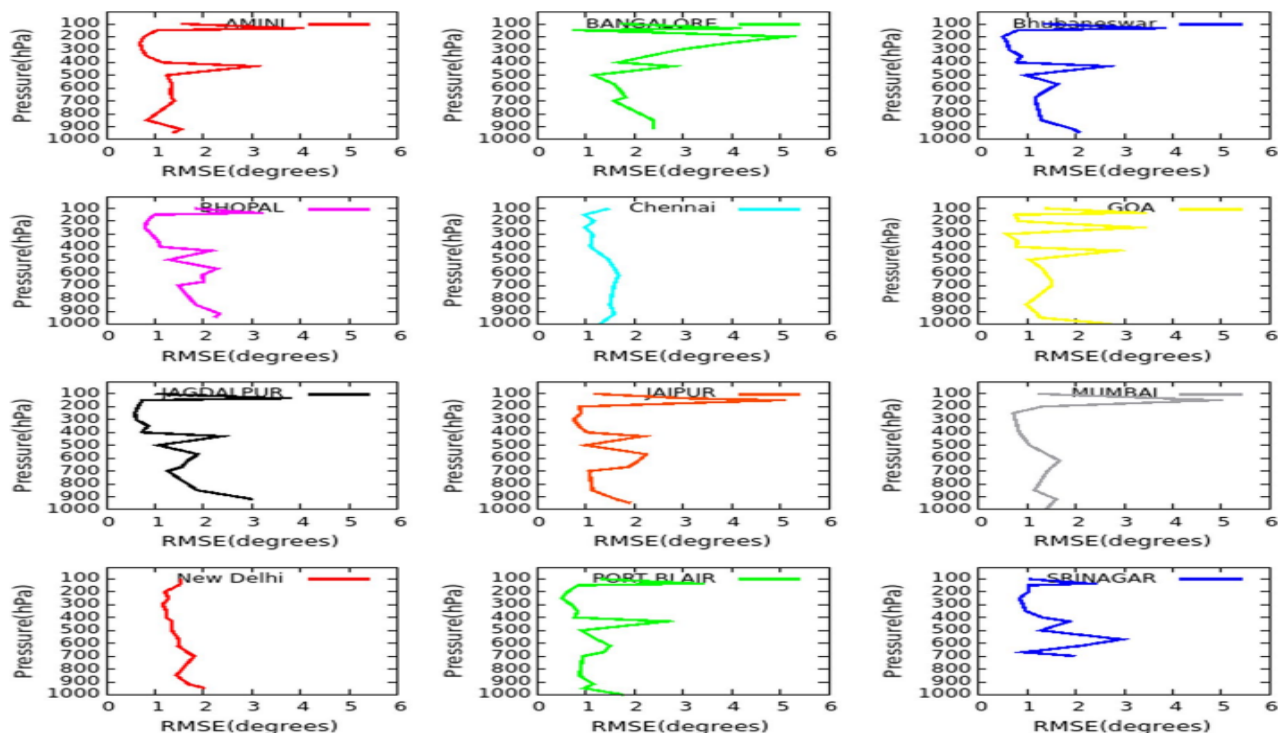
VALIDATING INSAT-3D ATMOSPHERIC TEMPERATURE RETRIEVALS OVER INDIA USING RADIOSONDE
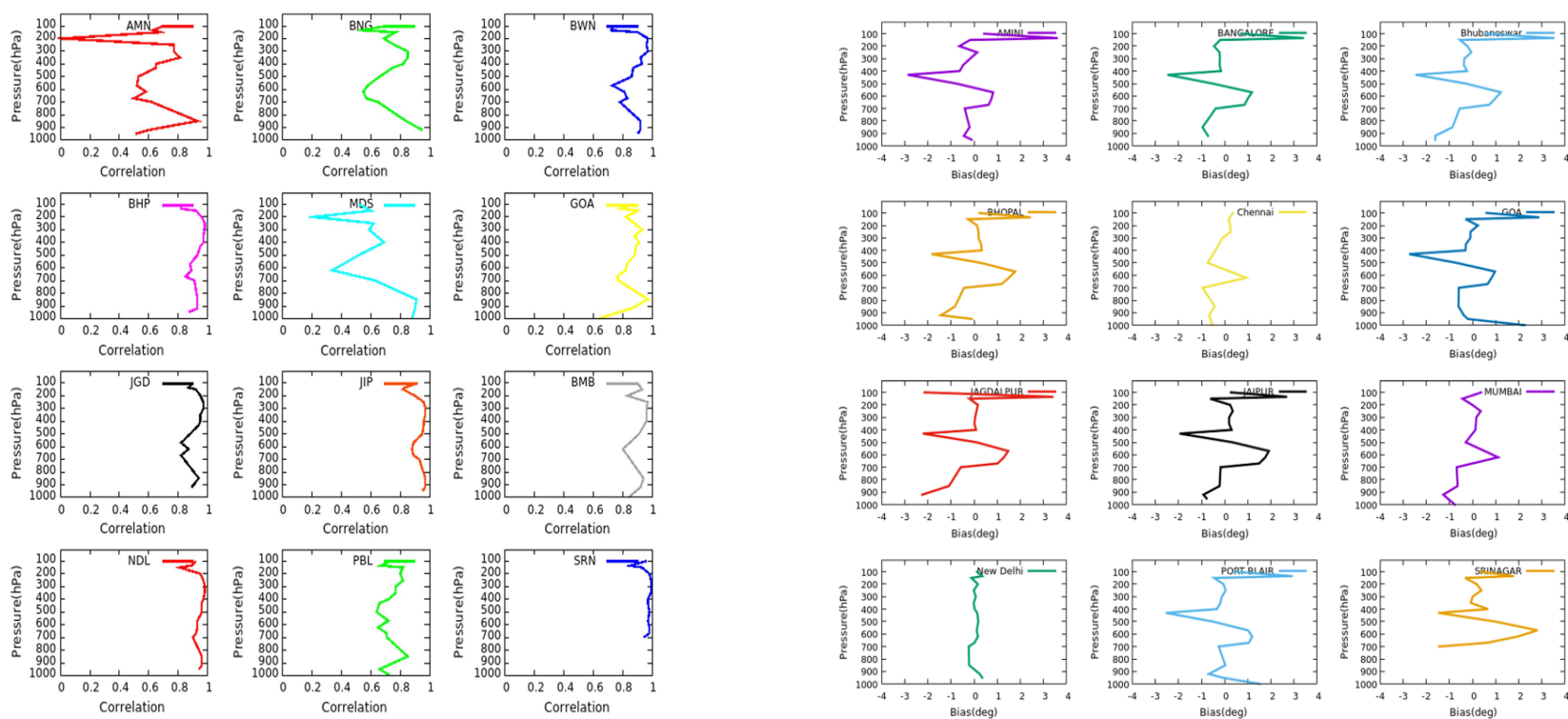
Correlation coefficient obtained in temperature at different pressure levels between INSAT-3DR with different RadioSonde stations over India during the period January to December 2021

BIAS obtained in temperature at different pressure levels between INSAT-3DR with different RadioSonde stations over India during the period January to December 2021

VALIDATING INSAT-3DR ATMOSPHERIC TEMPERATURE RETRIEVALS OVER INDIA USING RADIOSONDE

RMSE obtained in temperature (°C) at different pressure levels between INSAT-3DR with different RadioSonde stations over India during the period 2021

CONCLUSIONS AND FUTURE SCOPE

- The results show that INSAT-3DR temperature retrievals over land are a good agreement with AIRS/Radiosonde/COSMIC-2 and ERA-5 products other than over the ocean. The overall accuracy of retrieved temperature profiles correlation coefficient values more than 0.8, bias 0.6 °C and RMSE 2-3°C (approx) at each pressure level, except above 300 hPa at all stations shows 4 °C, respectively

- INSAT-3DR temperature retrievals at each pressure level from 1000–100 hPa show very good agreement with AIRS and ERA-5 over the Indian regions during the period 2021

- The INSAT-3DR was able to show a good correlation coefficient over a land region (>0.8) at all pressure levels from 1000–100 hPa than the ocean region around (>0.7) comparison with AIRS and ERA-5 temperature retrievals over India region

CONCLUSIONS AND FUTURE SCOPE

- The degradation performance showing over the ocean region might be attributed to improper bias correction coefficient for brightness temperature before physical retrievals and also may be due to difficulties of the cloud clearing over the coastal and ocean regions

- The retrieval results presented in the paper reflect the overall performance of retrieval scheme for accurate level temperature profile observations. There is a need for further improvements in the processing or retrieval scheme in order to improve the accuracy of retrievals. To have high quality of retrievals both, the retrieval scheme and the NWP system (first guess) should be well performed. Image navigation, calibration and radiance bias correction coefficients, all are important issues which affect retrieval performance. Therefore, it is important to make continuous effort to improve its quality

CONCLUSIONS AND FUTURE SCOPE

- A superior transmittance model even on future versions may also improve results. However, in future, the present work would be extended to use the bias corrected retrievals covering various seasons with more sample data and geographical regions over the Indian sub-continent to provide the reasonable interpretation and quantitative benefit to NWP

- The high temporal information available from INSAT-3DR sounder profiles can be used in weather forecasting and nowcasting applications. It will be used in the data assimilation system to study the impact of the data on various weather phenomena like cyclone tracks, rainfall forecasts, and monsoon features over India

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Dhanyawad aur Namaste