AOMSUC-15 FYSUC-2025
FIFTEENTH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE
THE JOINT 2025 FENGYUN SATELLITE USER CONFERENCE

Impact of FY-3D MWTS-2 Assimilation on Operational Rainfall Forecasts in an East African NWP System

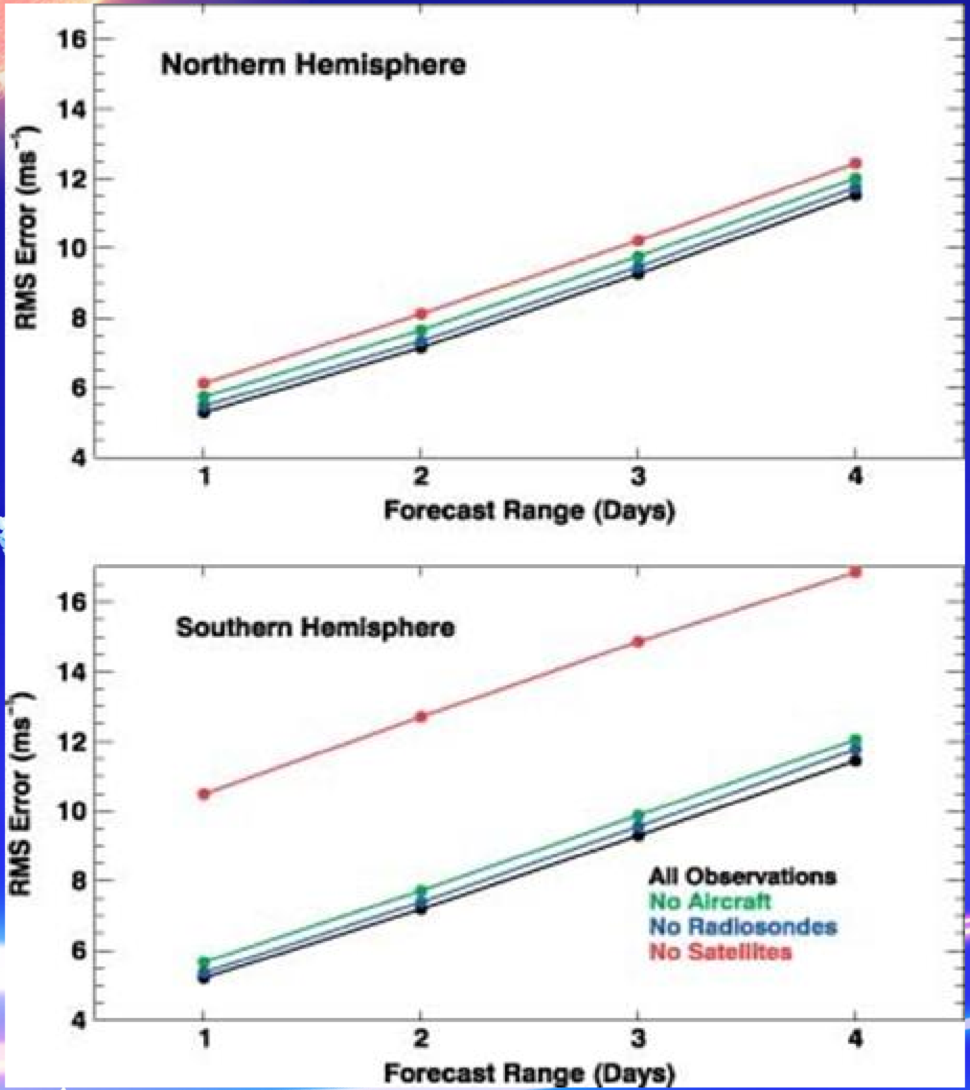
Othoo Phinous Okoth
PhD Student, NUIST, China
Principal Meteorologist, KMD

1. INTRODUCTION

- East Africa’s heterogeneous topography, coupled with its complex tropical dynamics, present significant operational challenges for local weather modelling.
- For instance, in April and May 2024, unprecedented heavy rainfall resulted in severe flooding across 33 of Kenya's 47 counties.
- This disaster led to over 300 fatalities, displaced approximately 300,000 people, and caused extensive damage to infrastructure.
- East African nations are allocating up to 9% of their national budgets to managing climate extremes, with losses averaging 2% to 5% of GDP.

1. INTRODUCTION

- Events around 1-4 November 2023.
- National Disaster Declared- Kenya.
- Extensive Infrastructural damage.



Effect of Incorporation (exclusion) of observational platforms on Forecast Errors of the IFM's 500 hPa geopotential height RMSE change relative to no sounders from day 1 to day 5 over NH and SH.

- Meteorological satellites are critical in regions where conventional data is either inadequate or lacking, such as over the Southern Hemisphere (East Africa), and remote lands.

ECMWF's Integrated Forecasting System; (Duncan et al. 2021).

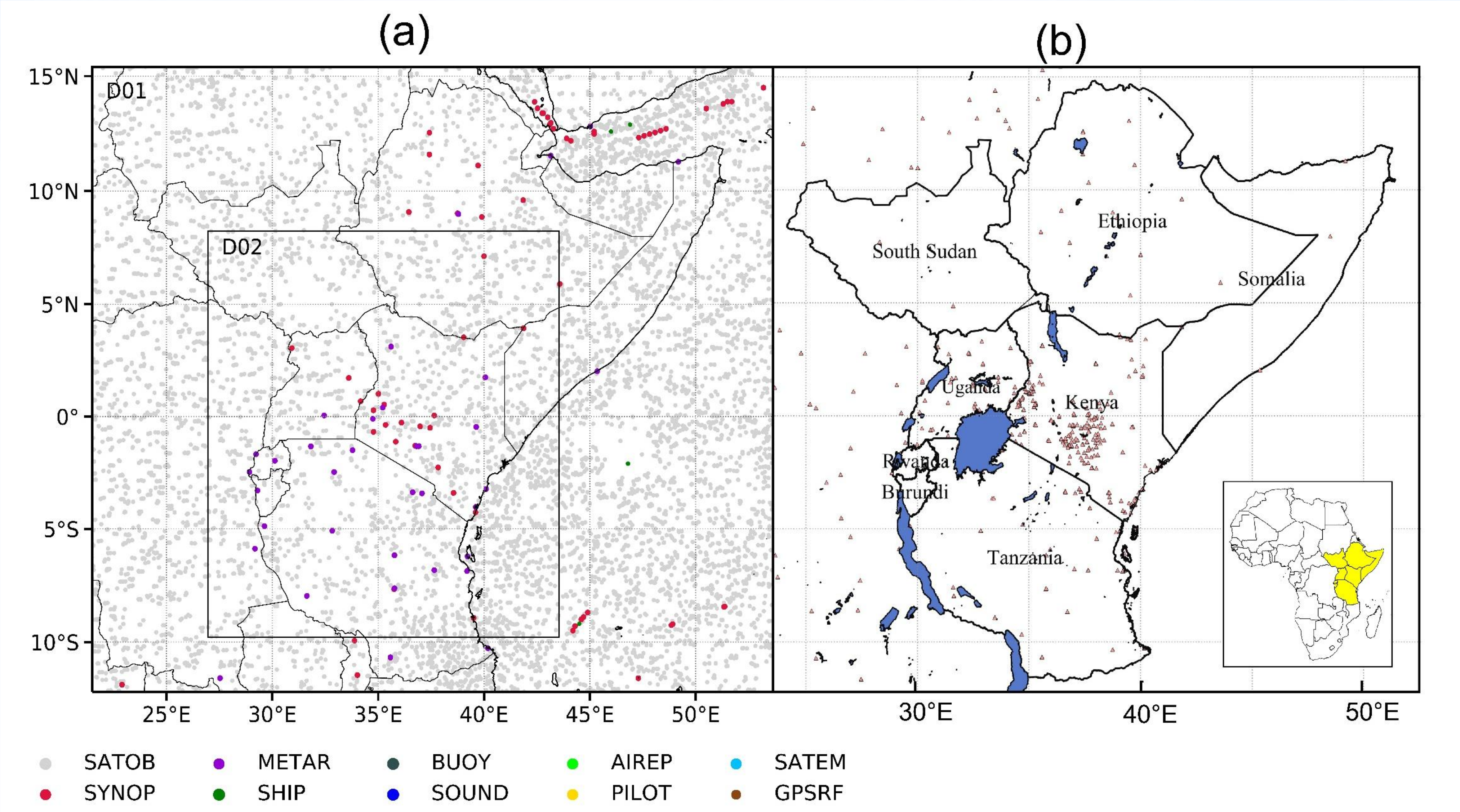
Challenges for NWP over EA

- East Africa's *sparse* observation network and data gaps exacerbate existing NWP challenges.
- Radiance Data Assimilation in East Africa remains largely unexplored and needs evaluation in operational Limited Area Models (LAMs) for robustness.
- Despite satellite data contributing ~80% of global NWP inputs, most East African NMHSs are still in the early stages of implementing radiance assimilation within their data assimilation frameworks.

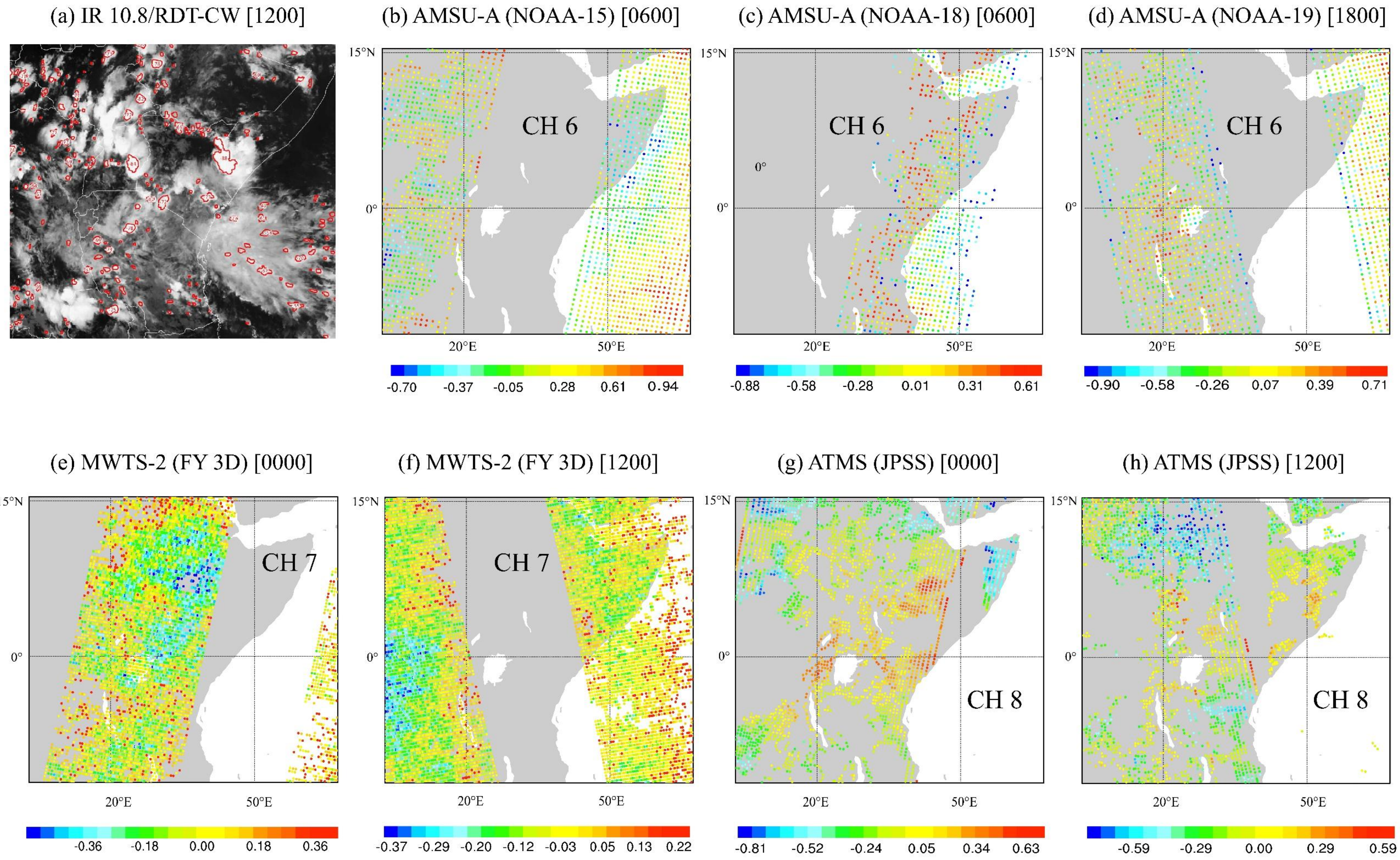
Main Objective

- To quantify incremental benefits to operational NWP LAM over East Africa through the assimilation of FY-3D's MWTS-2 instrument, as contrasted against experiments utilizing legacy microwave radiances from AMSU-A and ATMS instruments aboard NOAA/JPSS satellites.

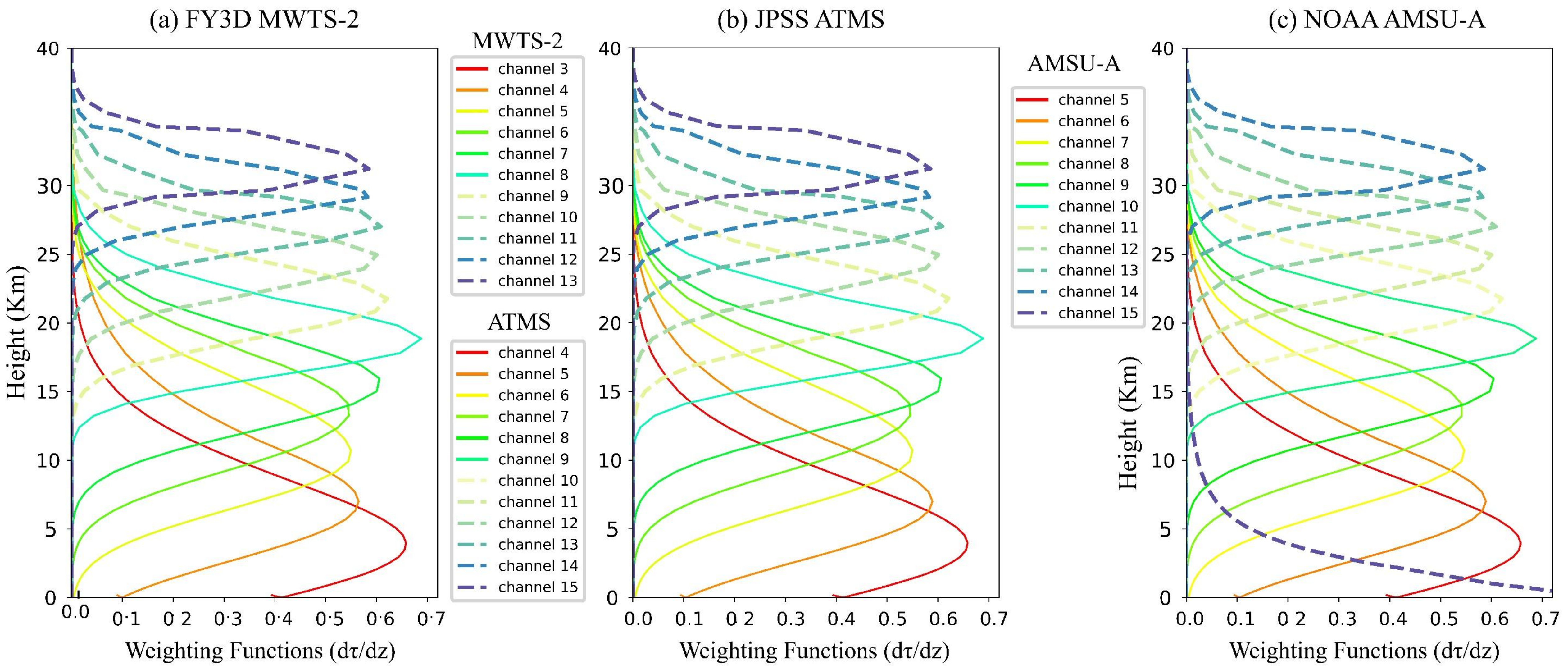
2. THE DOMAIN; OBSERVATION NETWORK



(a): The model domain configuration (Domain 1: 300 x 260 grids, Domain 2: 463 x 505 grids). Circular markers are NCEP ADP PREPBUFR observations valid at 1200UTC on 01 November 2023. Observations are plotted according to the legend order. (b): The geo-political setting of the study area. The triangular markers are Synop reports from NMHSs within the study domain.



(a) IR 10.8/RDT-CW [1200]
(b) AMSU-A (NOAA-15) [0600]
15°N
0°
20°E
50°E
CH 6
-0.70 -0.37 -0.05 0.28 0.61 0.94
(c) AMSU-A (NOAA-18) [0600]
15°N
0°
20°E
50°E
CH 6
-0.88 -0.58 -0.28 0.01 0.31 0.61
(d) AMSU-A (NOAA-19) [1800]
15°N
0°
20°E
50°E
CH 6
-0.90 -0.58 -0.26 0.07 0.39 0.71
(e) MWTS-2 (FY 3D) [0000]
15°N
0°
20°E
50°E
CH 7
-0.36 -0.18 0.00 0.18 0.36
(f) MWTS-2 (FY 3D) [1200]
15°N
0°
20°E
50°E
CH 7
-0.37 -0.29 -0.20 -0.12 -0.03 0.05 0.13 0.22
(g) ATMS (JPSS) [0000]
15°N
0°
20°E
50°E
CH 8
-0.81 -0.52 -0.24 0.05 0.34 0.63
(h) ATMS (JPSS) [1200]
15°N
0°
20°E
50°E
CH 8
-0.59 -0.29 0.00 0.29 0.59



Weighting function peaks for (a) MWTS-2, (b) temperature-sensitive ATMS channels and (c) AMSU-A. Solid lines represent assimilated channels, while dotted lines indicate excluded channels. Channels 1–2 of MWTS-2, 1–3 of AMSU-A and 1-4 of ATMS are omitted. NOAA in (c) include NOAA 15/18/19 satellites.

3. METHODS

- The study employs 6-hour cycling experiments over a 15-day period using WRF's 3DVar for clear-air radiance data assimilation, incorporating parameterization schemes tailored for East Africa.
- The assimilation process adjusts length scales, variances, and region-specific background error covariance parameters, optimizing the use of observational data for East Africa, with data thinning applied to improve computational efficiency.

Experiment	Assimilated Observations
NoDA	None
CNTRL	GTS
NMS	GTS + AMSU-A + ATMS
FY_NMS	GTS + AMSU-A + ATMS + MWTS-2

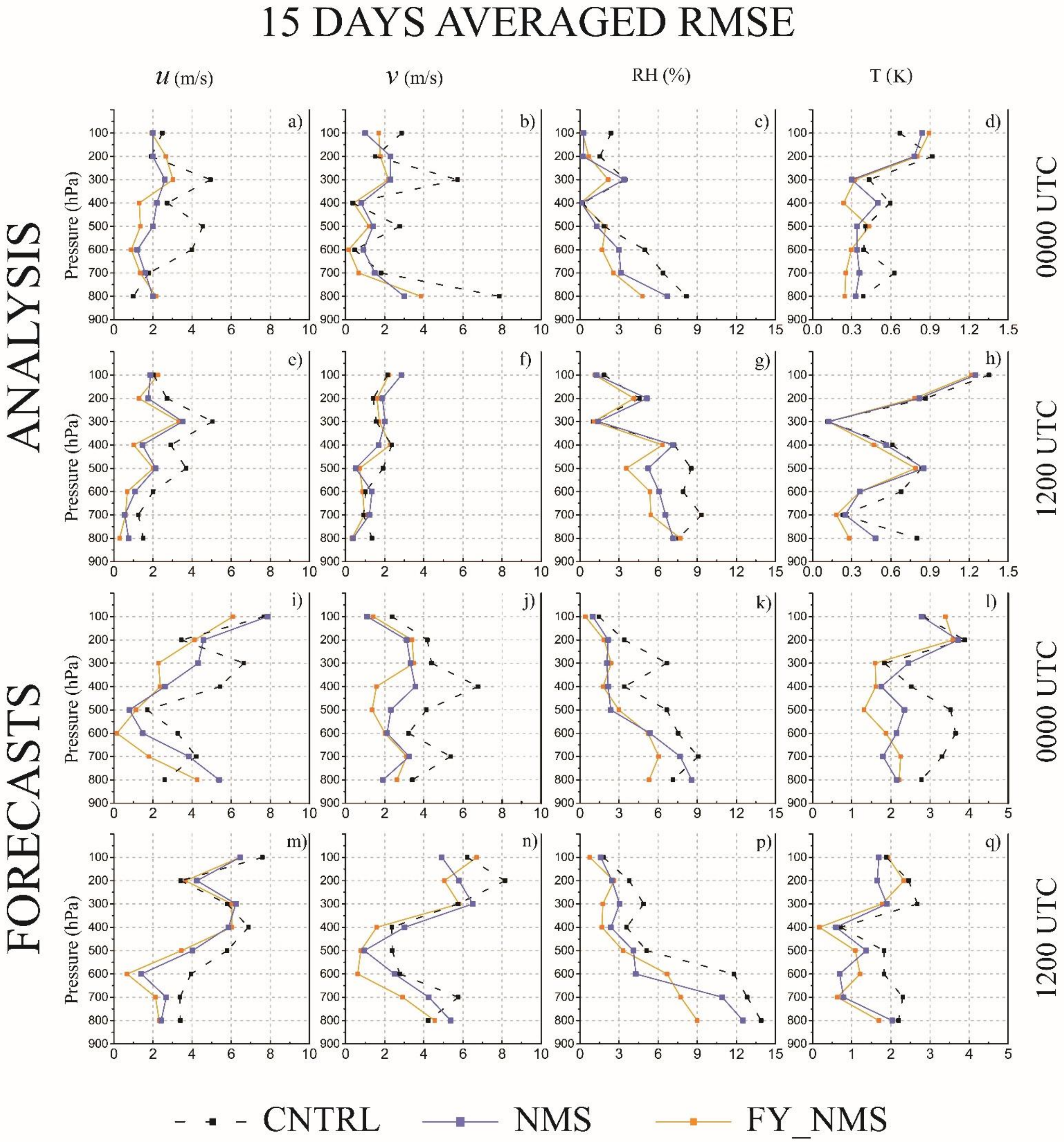
Model Evaluation:

RMSE, FSS, TS, ETS

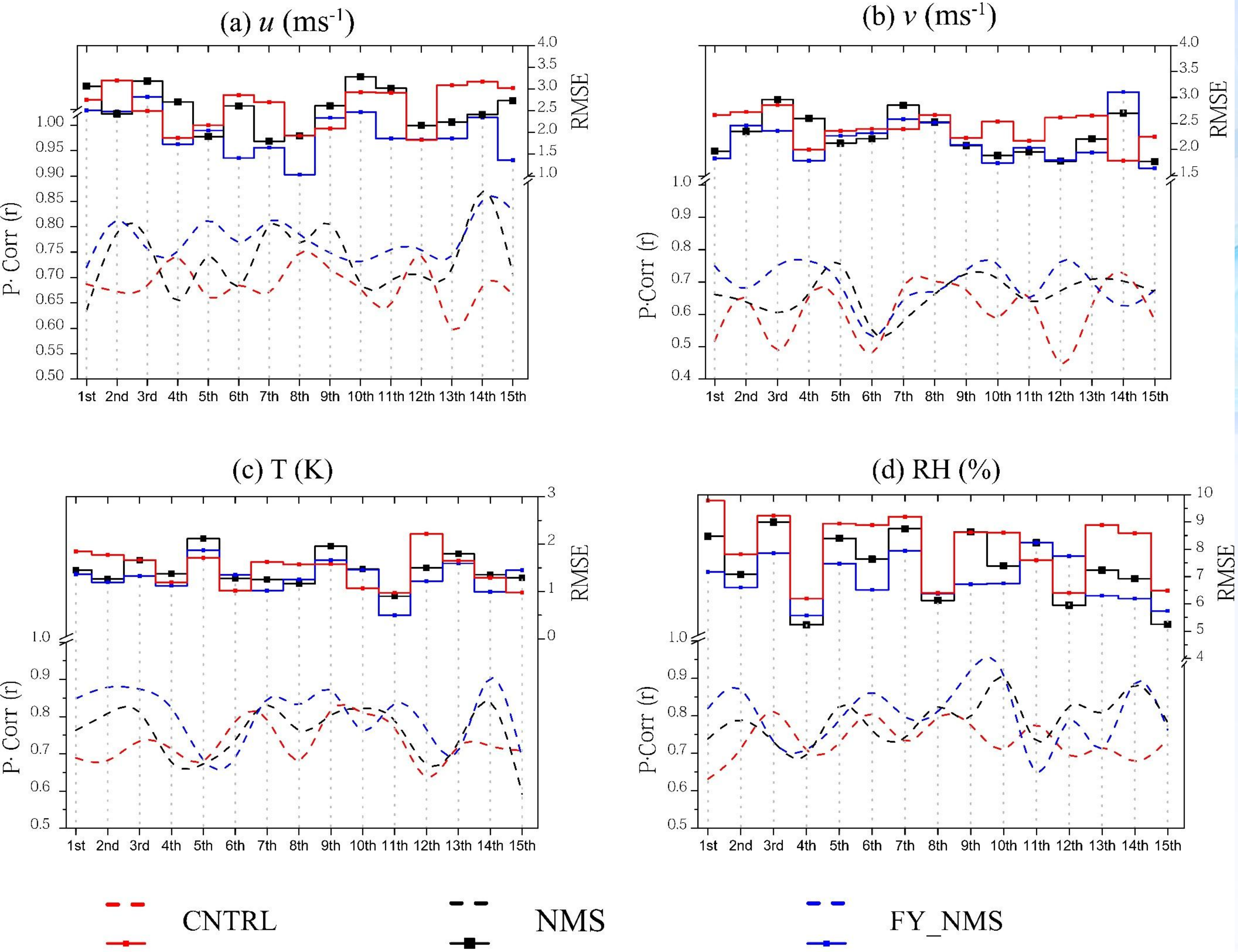
4. RESEARCH FINDINGS

(a) Error Reduction and Skill Metrics

Against ERA5

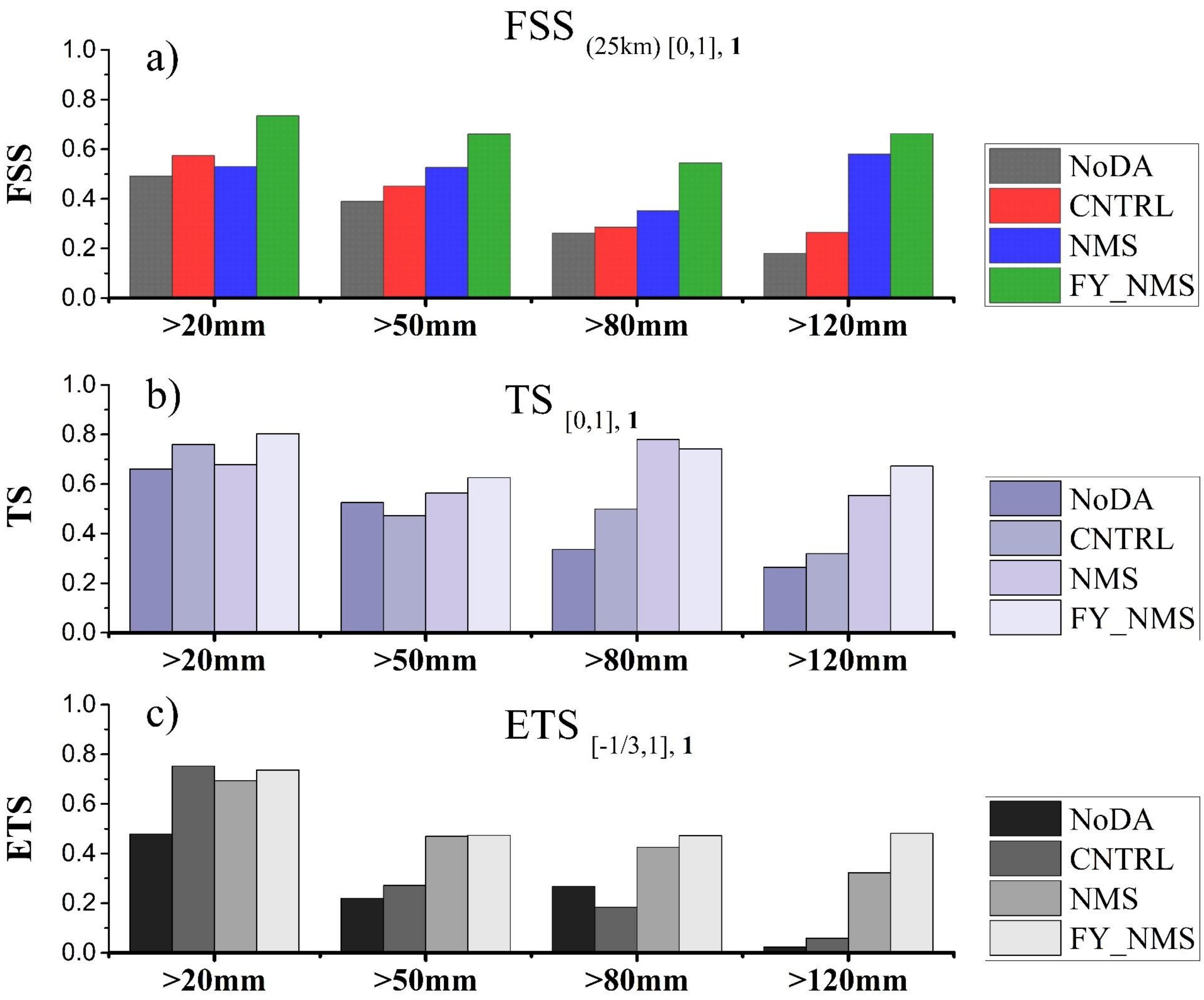


- Analysis RMSE differences between CNTRL and the radiance experiments are larger in the mid-troposphere (700-600 hPa) for u, v, and T, and in the lower levels (800-750 hPa) for RH, particularly at 0000 UTC.
- FY_NMS 12 h wind profile (u, v) forecasts attain close agreement with the reference data in the mid-tropospheric layers to the lower stratosphere, and in the lower to mid-troposphere for RH profile, with temperature improvements traversing the whole atmospheric column.



FY_AMS RMSE is smaller in at least 10 out of the 15 days for all the variables.

The temporal patterns place highest (lowest) r (RMSE) scores for all variables where AMS and FY_AMS curves are in phase.



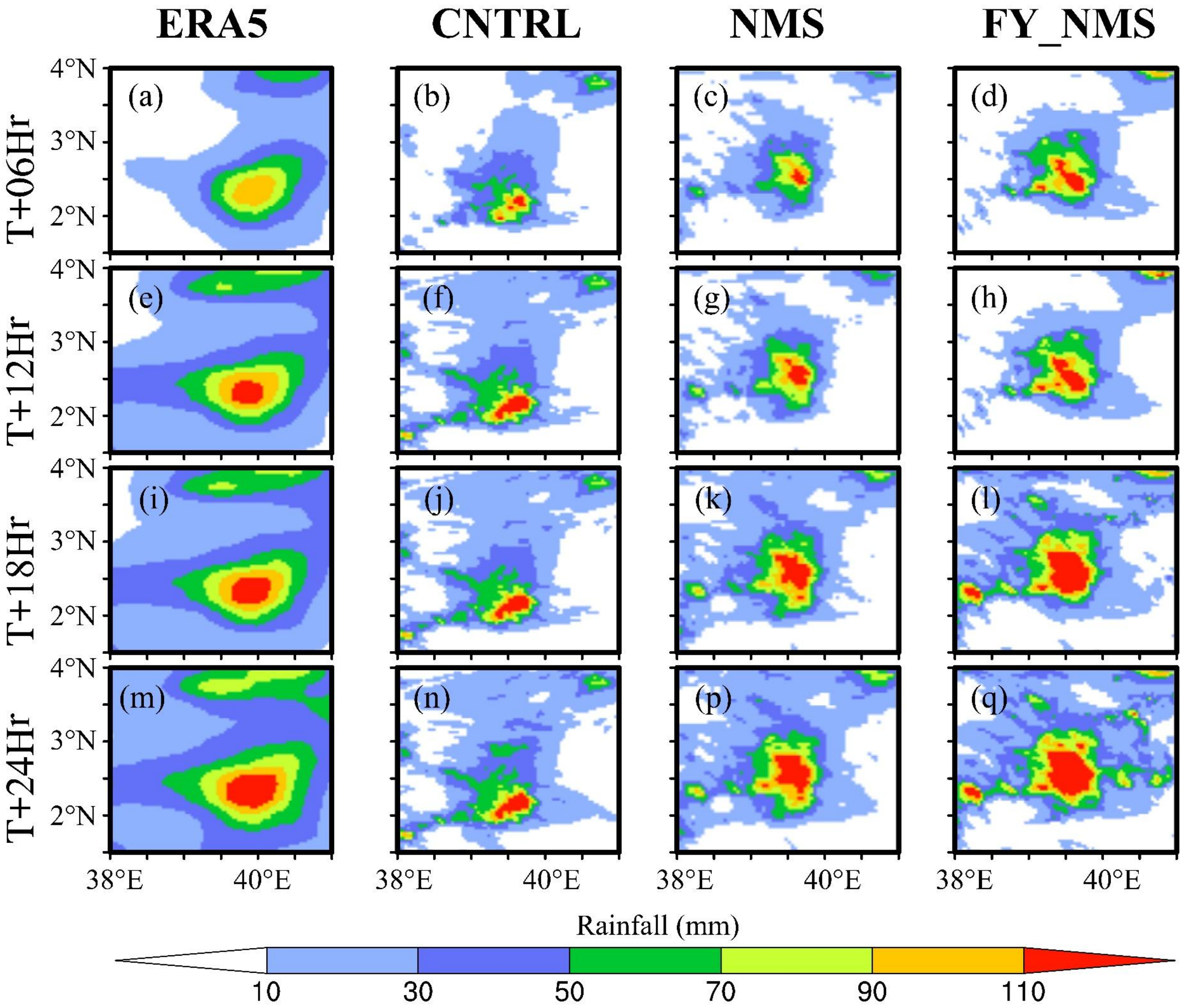
- ❖ The Histograms of rainfall metrics scores show improved skill across >50 to >120mm rainfall thresholds for the NMS and most notably, for FY_NMS.
- ❖ The distinction between NMS and FY_NMS is more evident in FSS, underscoring the unique analytical capability of neighborhood techniques to reduce the double penalty effect in rainfall assessment.

4. RESEARCH FINDINGS

(b) Mandera Rainfall Case

(b) Mandera Rainfall Case

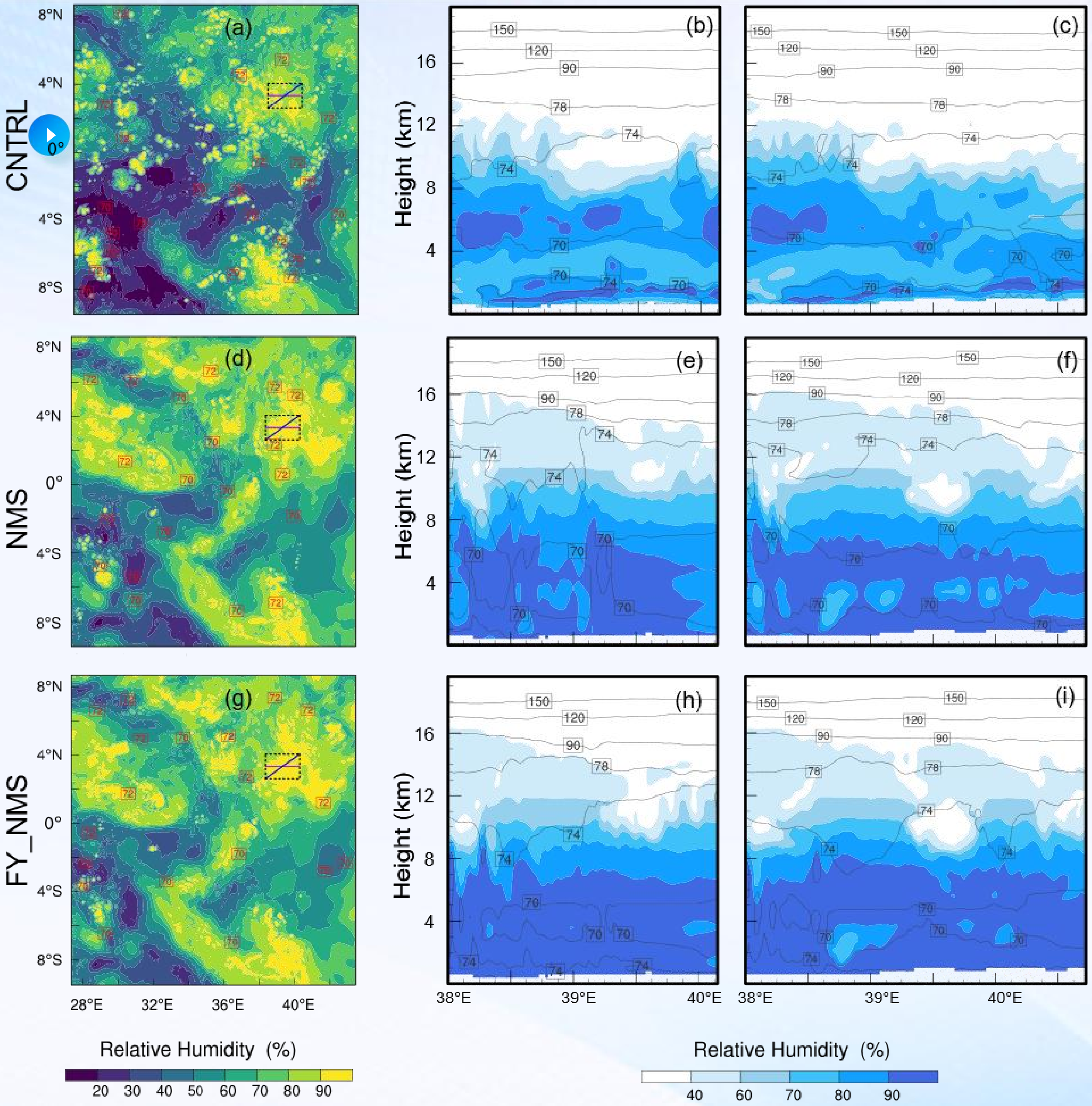
- The impact of MWTS-2, AMSU-A and ATMS radiances from FY-3D, NOAA-15/18/19 and JPSS satellites, respectively, is assessed by a case of a high intensity rainfall event in the neighborhood of Mandera (the areas bounded by 0.5° N, 38° E to 4° N, 42° E) on 2 November 2023.
- Climatologically, the semi-arid region is prone to erratic storms during dry to wet seasonal transition phase such as the case under review.
- Within 24-72 hours, some stations within the area (Wajir, Mandera) received in the upwards of 35% of their Annual Long Term Means of precipitation.



- FY_AMS's T+{h}: (h=12,18,24) rain rates, evaluated against ERA5 and validated against in-situ actuals, approach ERA5 spatio-temporal pattern.
- The accurate triggering of upper air thermal and dynamic adjustments is a consequential precursor to the improved T+12-24h rainfall skill in the radiance experiments.

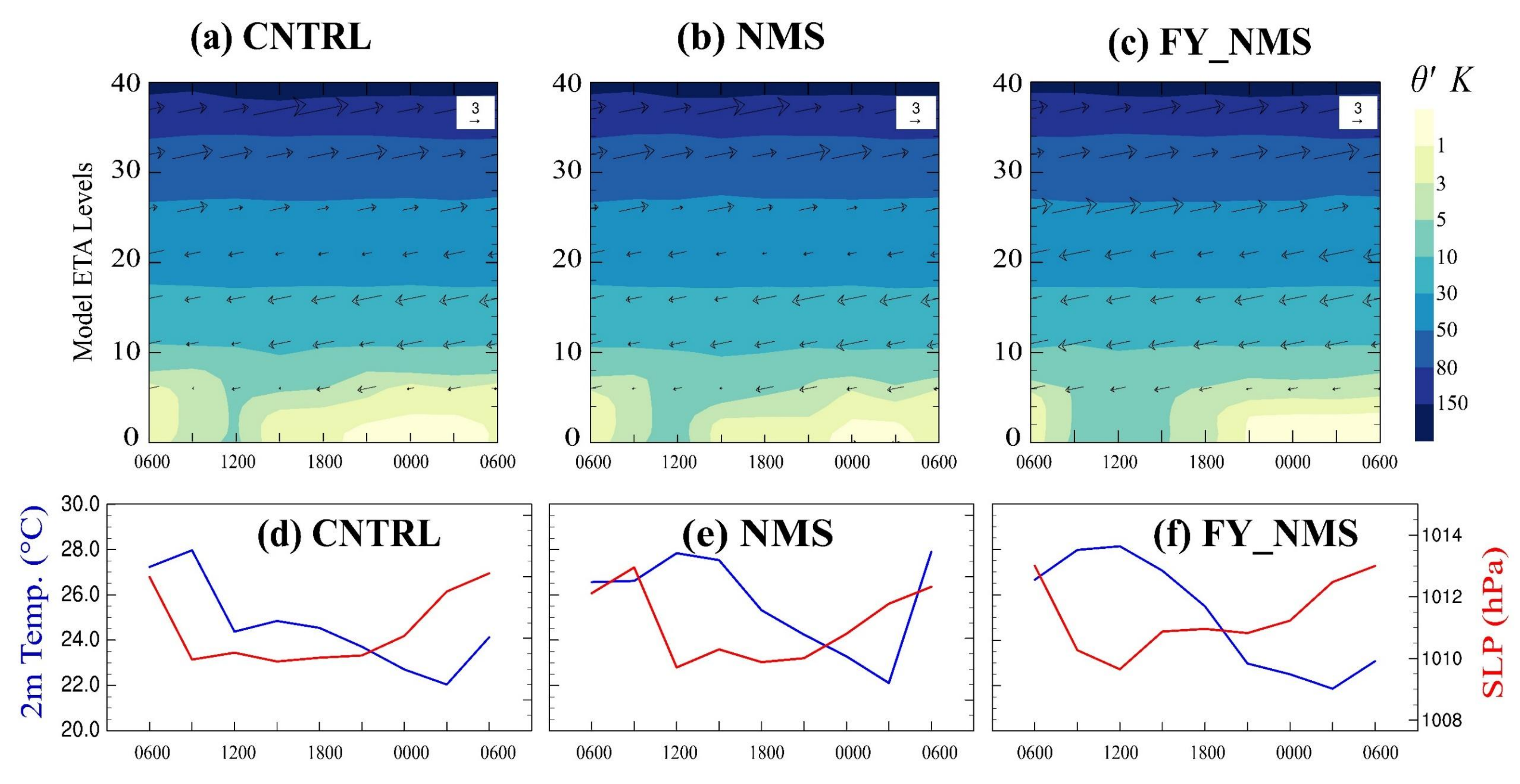
(b) Mandera Rainfall Case

- We examine the spatial structure along two cross-sectional planes to assess the impact of data assimilation on relative humidity (RH) and equivalent potential temperature (θ_e) analysis fields during the convectively active afternoon of 2 November 2023 at 1200 UTC.
- Equivalent potential temperature (θ_e) represents the total energy of an air parcel, making it a crucial indicator of atmospheric stability and convection potential.



- ❑ Assimilation of AMSU-A and ATMS radiances enhances RH between ~700–450 hPa and near the surface, while FY_NMS produces near-saturated humidity (>90%) across the transect from the surface to 7 km, with isolated convective cells extending above 12 km.

- ❑ The closed 70° C isenthalpic surfaces are near the ground and closer in NMS experiment, signifying a more buoyant atmosphere and a mixed phase supercell system in NMS experiment.



- CNTRL shows weak low-level warming and persistently low SLP, indicative of evaporative cooling and early weak inversion formation. NMS produces a brief θ′ spike (>5 K) due to rapid T_2 rise and SLP fall around 1200 UTC.
- FY_NMS corrects these biases - showing stronger low-level instability (θ′ = 5–10 K), SLP minima/T_2 maxima between 0900–1500 UTC, and enhanced vertical mixing at lower levels, consistent with peak precipitation timing.

5. CONCLUSION

- Assimilation of FY-3D MWTS-2 radiances introduced additional mid-tropospheric temperature weighting which refined tropospheric thermodynamic structures in analysis, correcting biases in temperature, RH, and stability profiles critical for convective initiation.
- FY_NMS experimental configuration demonstrated superior temporal-vertical consistency in θ′, SLP, and RH evolution, accurately reproducing diurnal convective phases and aligning rainfall timing and intensity with ERA5 reanalysis.
- The integrated assimilation framework provided enhanced vertical sensitivity and temporal coverage over a data-sparse tropical domain, establishing a benchmark for operational radiance data assimilation in East Africa’s complex convective environment.

Othoo, P. O, Y. D. Chen, W. Y. Yang, et al., 2025: Assimilation of MWTS-2, ATMS, and AMSU-A radiances for rainfall forecast in an operational East African NWP system. J. Meteor. Res., 39(5), 1–19, https://doi.org/10.1007/s13351-025-5035-z.

phyn.okoth@gmail.com

THANK YOU