

# Investigating the Radiative Impact of Saharan Dust Aerosols on Medium Range Forecasts for African Easterly Waves in the Unified Forecast System

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# OUTLINE

- 1 BACKGROUND AND MOTIVATION
- 2 UFS EXPERIENCE and EXPERIMENTAL DESIGN
- 3 RESULTS
- 4 DISCUSSION AND FUTURE WORK
- 5 UFS FEEDBACK



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# 1. BACKGROUND AND MOTIVATION

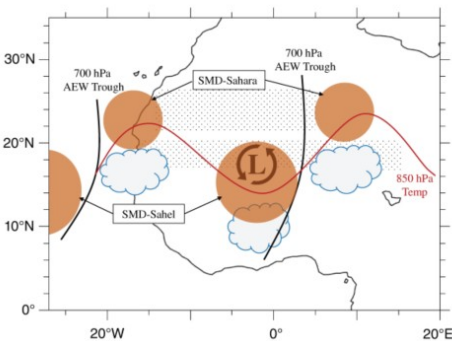
**African Easterly Waves (AEWs)** are synoptic-scale disturbances that form over sub-Saharan Africa during the West African Monsoon season and are the primary precursor for Atlantic tropical cyclones (Russel et al, 2017).



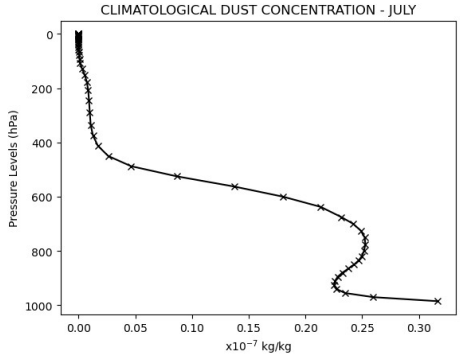
Semunegus et al. (2017)

Li and Sokolik (2018) point out that **dust** (a natural aerosol with average diameter between 0.1-100µm) is **one of the most abundant aerosols on the Earth**, which main source is the **Sahara Desert** (Bullard and Livingstone, 2009).

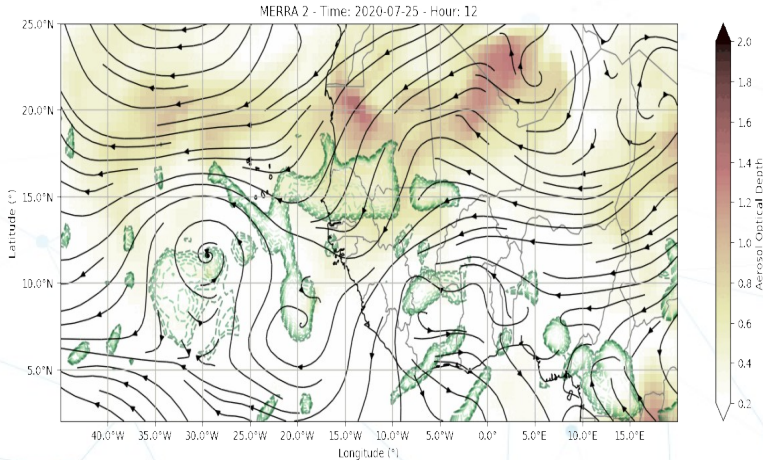
In addition, during the boreal summer, the dusty **Saharan air layer is vertically extended from 850 to about 500 hPa**, and more westward propagation of dust is enhanced. This behavior is mainly due to atmospheric features, such as low-level jets (**LLJs**), African easterly waves (**AEWs**), etc. (Grogan et al, 2017; Pu and Jin, 2021; Yu et al, 2021).



Grogan and Thorncroft (2018)



# 1. BACKGROUND AND MOTIVATION



Temporal evolution of Wind Circulation at 700 hPa (streams), precipitation greater than 1 mm/hr (green contours), and AOD 550nm (shaded) for the period of July 25<sup>th</sup> - 28<sup>th</sup> of 2020. Data: MERRA2.

- African Easterly Waves (AEWs) are an **essential part of the dynamics of northwestern Africa** and **plays an important role in the development of precipitation** over Western Africa, the Tropical Atlantic region, and the Caribbean.
- *Our main goal is to evaluate how the increase of dust content in the atmosphere can affect the characteristic and properties of the AEWs.*

# 2. UFS EXPERIENCE and EXPERIMENTAL DESIGN



```
cwbschuler@cheyenne1:~/glade/scratch/cwbschuler/ufs-srweather-app> ls
build ERRATA.md jobs README.md ufs_srweather_app_meta.h.in
CMakeLists.txt etc lib rename_model.sh ufs_srweather_app.settings.in
devbuild.sh exec LICENSE.md scripts
devclean.sh Externals.cfg manageExternals share versions
docs include modulefiles src
environment.yml input_model_data parm tests
```

A screenshot of the UFS Short-Range Weather App Users Guide search page. The page has a blue header with the title "UFS Short-Range Weather App Users Guide" and the version "release/public-v2.1.0". Below the header is a search bar. The main content area is dark grey and contains a table of contents with 14 items. At the bottom of the page is a logo for "SUPER ORBITAL" and a text box that says "SuperOrbital: Partnering with you to deliver mission-critical projects on Kubernetes. Learn more!".

UFS Short-Range Weather App Users Guide  
release/public-v2.1.0

Search docs

1. Introduction
2. Quick Start Guide
3. Container-Based Quick Start Guide
4. Building the SRW App
5. Running the SRW App
6. SRW Application Components
7. Input and Output Files
8. Limited Area Model (LAM) Grids: Predefined and User-Generated Options
9. Workflow Parameters: Configuring the Workflow in `config.yaml` and `config_defaults.yaml`
10. Rocoto Introductory Information
11. Workflow End-to-End (WE2E) Tests
12. Graphics Generation
13. FAQ
14. Glossary

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Ad by EthicsAds

» UFS Short-Range Weather App Users Guide

## UFS Short-Range Weather App Users Guide

- 1. Introduction
  - 1.1. How to Use This Document
  - 1.2. Prerequisites for Using the SRW Application
    - 1.2.1. Background Knowledge Prerequisites
    - 1.2.2. Software/Operating System Requirements
  - 1.3. SRW App Components Overview
    - 1.3.1. Pre-Processor Utilities and Initial Conditions
    - 1.3.2. Forecast Model
    - 1.3.3. Unified Post-Processor (UPP)
    - 1.3.4. METplus Verification Suite
    - 1.3.5. Visualization Example
    - 1.3.6. Build System and Workflow
  - 1.4. Code Repositories and Directory Structure
    - 1.4.1. Hierarchical Repository Structure
    - 1.4.2. Directory Structure
    - 1.4.3. Experiment Directory Structure
  - 1.5. User Support, Documentation, and Contributions to Development
  - 1.6. Future Direction
- 2. Quick Start Guide
  - 2.1. Install the HPC-Stack
  - 2.2. Building and Running the UFS SRW Application
- 3. Container-Based Quick Start Guide
  - 3.1. Download the Container
    - 3.1.1. Prerequisites:
    - 3.1.2. Working in the Cloud or on HPC Systems
    - 3.1.3. Build the Container
    - 3.1.4. Allocate a Compute Node
    - 3.1.5. Start Up the Container
  - 3.2. Download and Stage the Data
  - 3.3. Generate the Forecast Experiment
    - 3.3.1. Activate the Regional Workflow
    - 3.3.2. Configure the Workflow
    - 3.3.3. Generate the Workflow



# 2. UFS EXPERIENCE and EXPERIMENTAL

## DESIGN SETUP

### Period:

2020-07-24T00:00 to 2020-07-30T00:00

### Initialization data source:

**GFS (0.5°x0.5°) / every 6 hrs**

**MERRA-2 CLIM. AEROSOL (0.625°x0.5°)**  
(iaer from 5111 to 1111)

### Domain and grid spacing:

LatLon Projection scheme

Resolution of 25 km

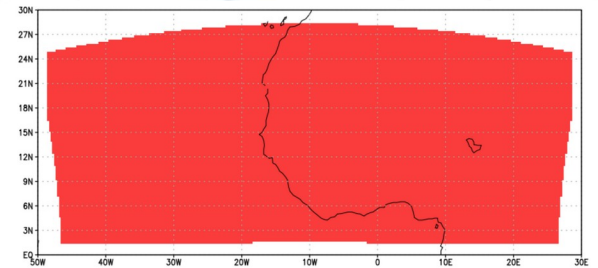
328 x 120 points, centered at 10°W and 15°N

GRID\_GEN\_METHOD: ESGgrid

\* Dust  
Dust aerosol is represented with 5 bins that correspond to dry size ranges (in  $\mu$ ) and densities ( $\text{kg}/\text{m}^3$ ):

bin	1	2	3	4	5
radius	0.73	1.4	2.4	4.5	8.0
radius lower	0.1	1.0	1.8	3.0	6.0
radius upper	1.0	1.8	3.0	6.0	10.0
density	2500	2650	2650	2650	2650

```
"AEW_GRID_LATLON_25km":  
GRID_GEN_METHOD: "ESGgrid"  
ESGgrid_LON_CTR: -10.0  
ESGgrid_LAT_CTR: 15.0  
ESGgrid_DELX: 25000.0  
ESGgrid_DELY: 25000.0  
ESGgrid_NX: 328  
ESGgrid_NY: 120  
ESGgrid_PAZI: 0.0  
ESGgrid_WIDE_HALO_WIDTH: 6  
DT_ATMOS: 40  
LAYOUT_X: 16  
LAYOUT_Y: 10  
BLOCKSIZE: 6  
QUILTING:  
  WRTCMP_write_groups: 1  
  WRTCMP_write_tasks_per_group: 32  
  WRTCMP_output_grid: "regional_latlon"  
  WRTCMP_cen_lon: -10.0  
  WRTCMP_cen_lat: 15.0  
  WRTCMP_lon_lwr_left: -48.5  
  WRTCMP_lat_lwr_left: 1.5  
  WRTCMP_lon_upr_right: 28.5  
  WRTCMP_lat_upr_right: 28.5  
  WRTCMP_dlon: 0.25  
  WRTCMP_dlat: 0.25
```



# 2. UFS EXPERIENCE and EXPERIMENTAL

## DESIGN

### Physic Suite: GFS v16

	GFS v16
Radiation (SW/LW)	RRTMG
Microphysics (MP)	GFDL
Boundary Layer (PBL)	TKE-EDMF
Surface Layer (SL)	GFS
Gravity Wave Drag (GWD)	None
Land Surface Model (LSM)	Noah
Deep Convection (DCU)	Sa-SAS
Shallow Convection (SCU)	sa-MF
Lake Model (LM)	NSST

### Two Simulations

1. **CONTROL (CTRL)**: UFS experiment with the original aerosols (dust) concentration from MERRA-2.
2. **DUSTY\_EXP (DU\_EXP)**: UFS experiment with eight times the original Dust concentration (“simulating an extreme event”).



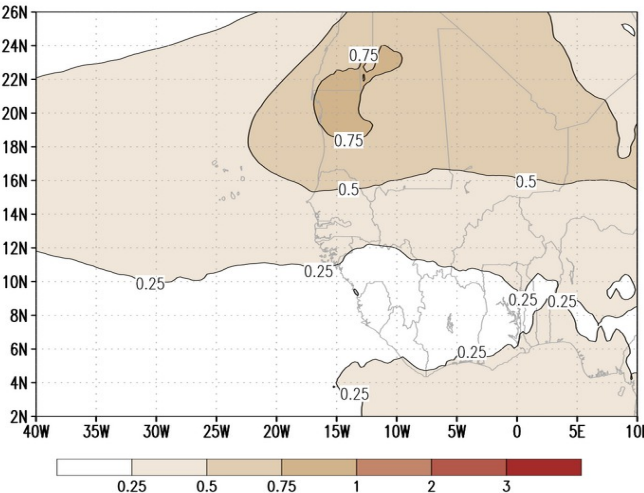
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# 3. RESULTS: Aerosol Optical Depth (AOD)

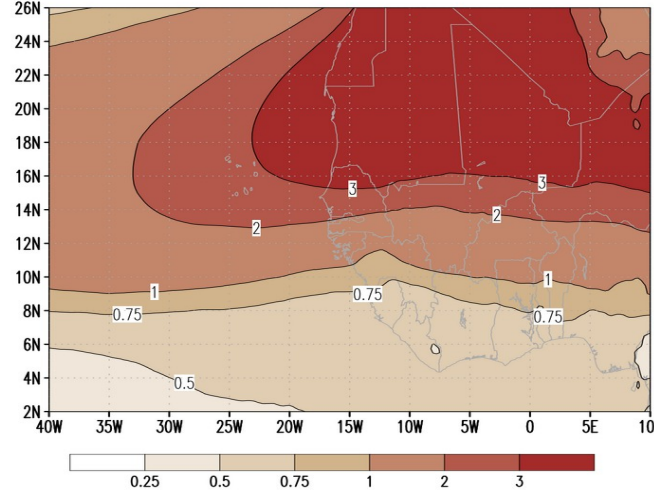
550nm

### CTRL



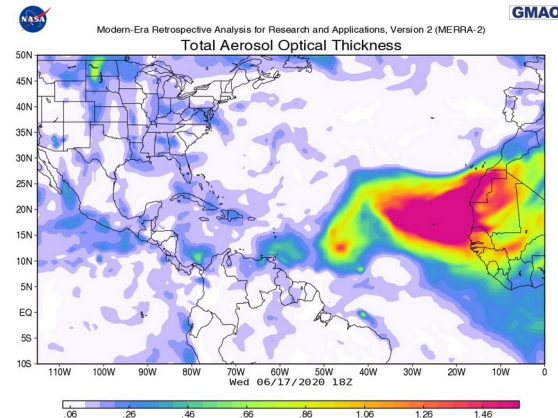
AOD for the CTRL simulation (Average over the period July 24<sup>th</sup> – 28<sup>th</sup> of 2020)

### DU\_EXP



AOD for the DU\_EXP simulation (Average over the period July 24<sup>th</sup> – 28<sup>th</sup> of 2020)

### REFERENCE



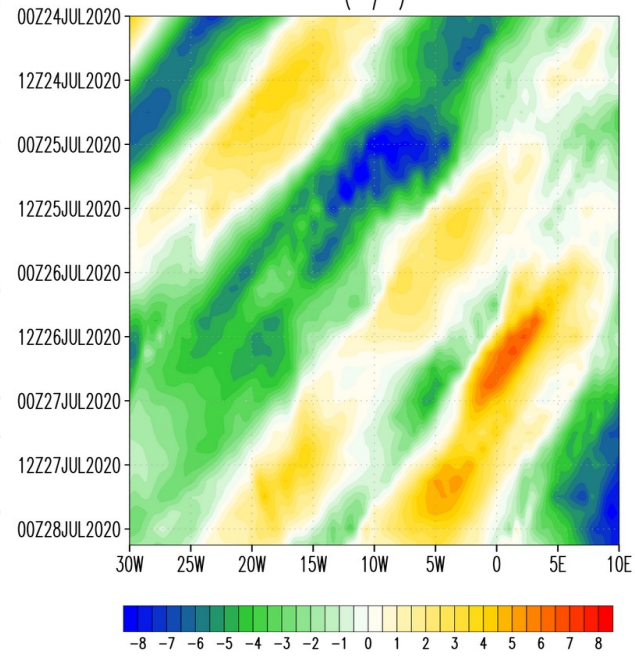


### 3. RESULTS: MERIDIONAL WIND AT 700hPa

Hovmoller Diagram for meridional wind at 700 hPa for both experiments. Average from 10°N-20°N.

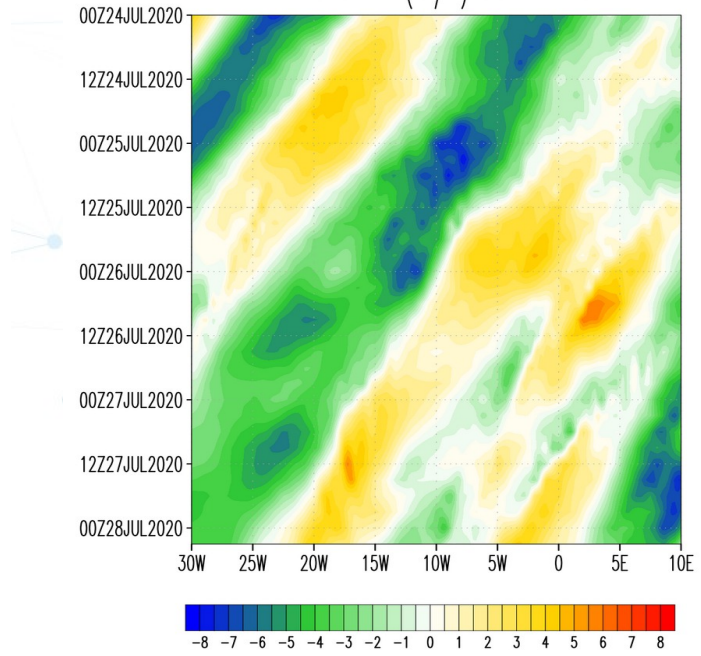
#### CTRL

DUx1 - V(m/s) at 700hPa



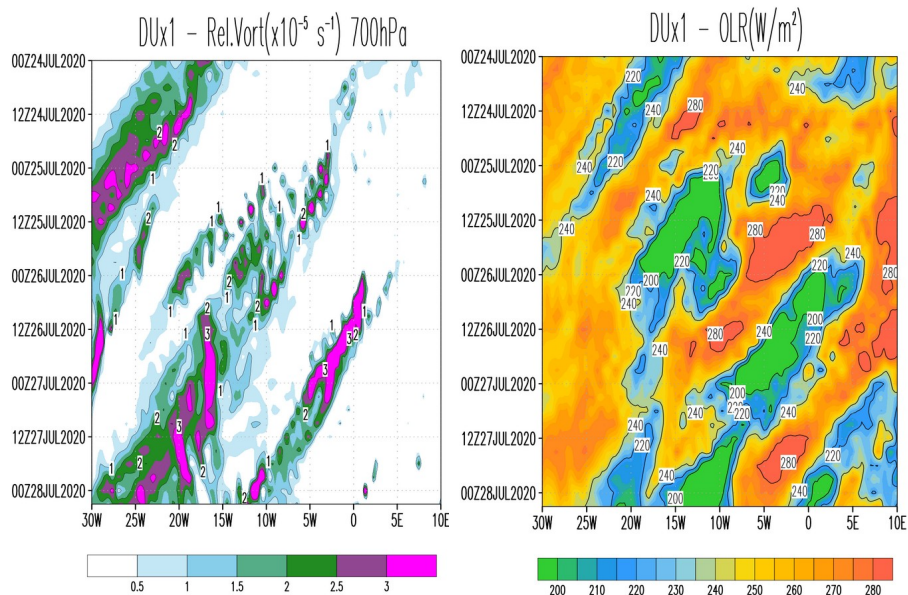
#### DU\_EXP

DUx8 - V(m/s) at 700hPa



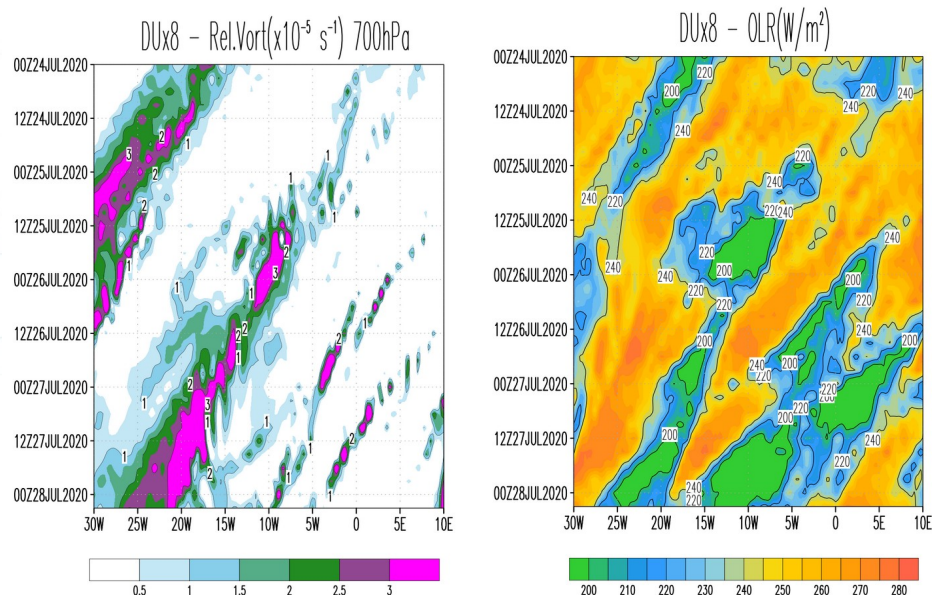
### 3. RESULTS: RELATIVE VORTICITY AT 700hPa and OLR

**CTRL**



Hovmöller Diagram ( $10^{\circ}\text{N}$ - $20^{\circ}\text{N}$ ) of cyclonic vorticity at 700hPa and Outgoing Longwave Radiation (OLR) for the CTRL experiment

**DU\_EXP**

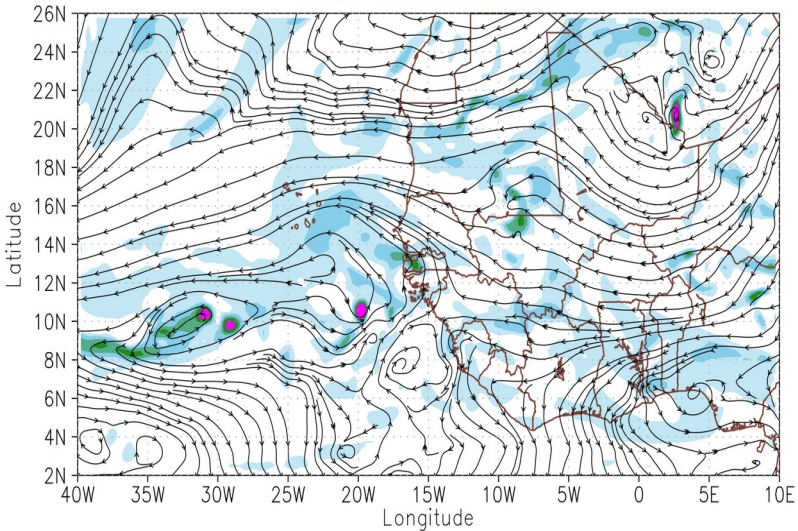


Hovmöller Diagram ( $10^{\circ}\text{N}$ - $20^{\circ}\text{N}$ ) of cyclonic vorticity at 700hPa and Outgoing Longwave Radiation (OLR) for the DU\_EXP experiment

# 3. RESULTS: WIND CIRCULATION AND CYCLONIC VORTICITY AT 700hPa

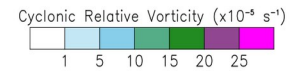
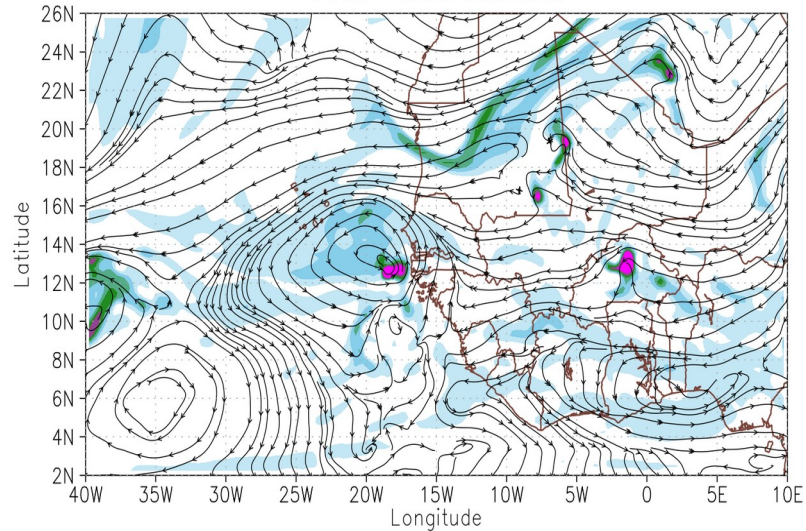
**CTRL**

DUx1 15Z27JUL2020



**DU\_EXP**

DUx8 15Z27JUL2020

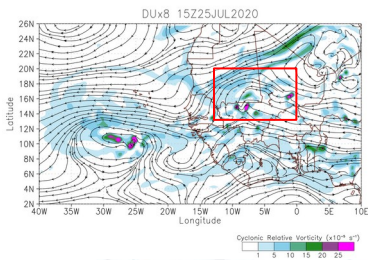




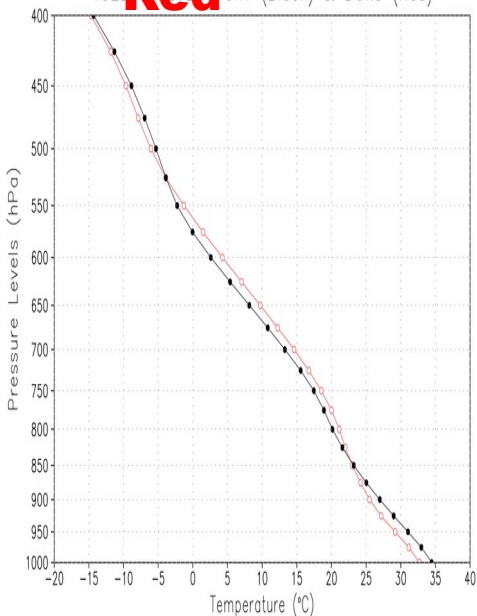
# 3. RESULTS: VERTICAL PROFILE OF TEMPERATURE

CTRL in Black and DU\_EXP in

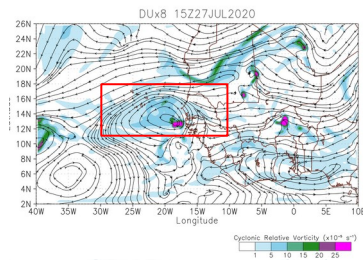
15Z25JUL2020 DUx1 (Black) & DUx8 (Red)



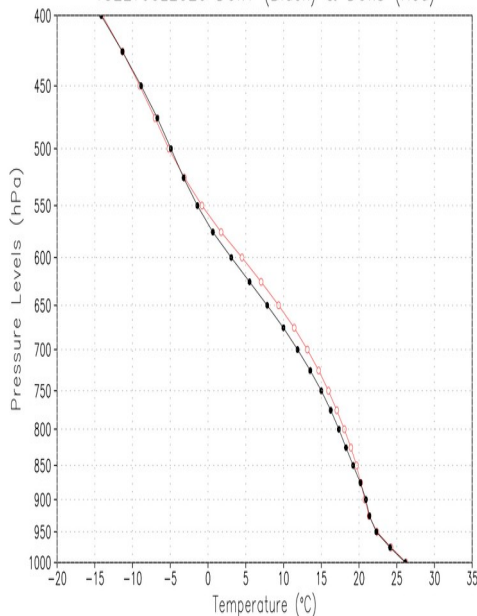
Average over 13°N-20°N  
and 15°W-0° for July 25<sup>th</sup>  
15Z, 2020



15Z27JUL2020 DUx1 (Black) & DUx8 (Red)

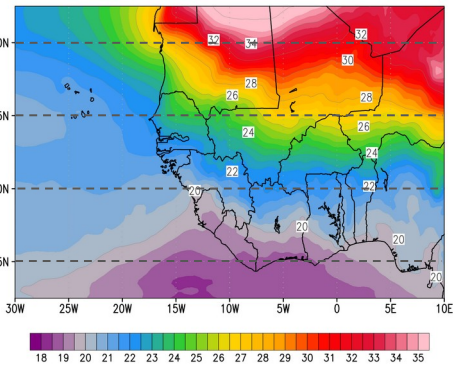


Average over 11°N-18°N  
and 30°W-10°W for July  
27<sup>th</sup> 15Z, 2020



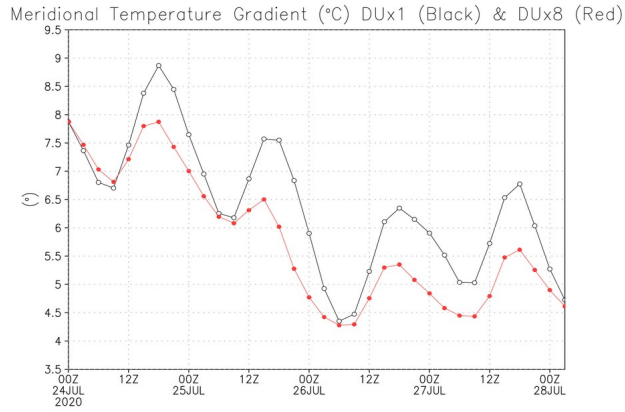
# 3. RESULTS: MERIDIONAL DIFFERENCE OF TEMPERATURE (1000-850hPa) and WIND DIFFERENCES

**CTRL**  
TMPave(1000-850hPa)



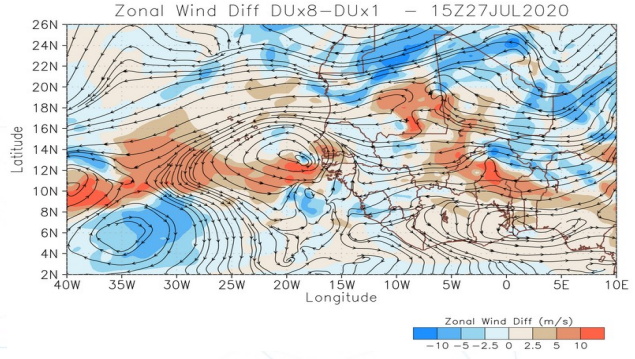
Spatial distribution of the Temperature (°C) in the lower troposphere (average from 1000-850hPa) over tropical northwestern African region.

**CTRL in Black and DU\_EXP in Red**

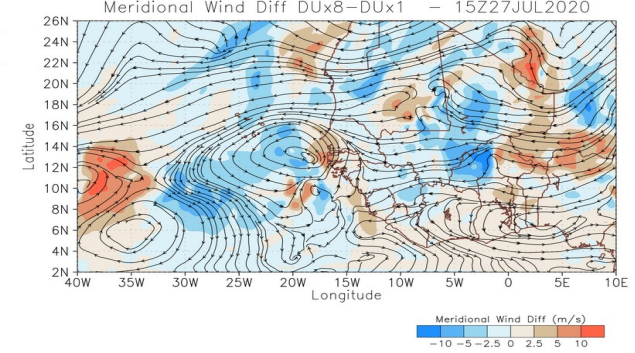


Temporal evolution of the meridional temperature gradient (difference between the north and south section) for the CTRL and DU\_EXP experiments.

**ZONAL WIND DIFF. AT 700hPa (DU\_EXP - CTRL)**



**MERIDIONAL WIND DIFF. AT 700hPa (DU\_EXP - CTRL)**





# 4. PRELIMINARY RESULTS AND FUTURE WORK

- Idealized UFS experiments were conducted. The dusty experiment exhibit the following features:
  - The wave structure looks “more defined” in the dusty experiment (DU\_EXP), especially once the AEW is over the ocean.
  - More cyclonic vorticity along the AEW identified initially on July 24<sup>th</sup>. However, it is not necessary the case for the wave initialized on July 26<sup>th</sup>.
  - Generated less meridional temperature gradient in the lower troposphere, which led to less westward wind and a more meandering circulation.
  - Colder (warmer) temperatures are seen at the levels of 1000-850 hPa (850-550hPa). Once the wave is over the Atlantic ocean, there is no significant temperature differences in the lower troposphere.
- More realistic UFS simulations will be conducted in the future.



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# 5. UFS FEEDBACK

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- CODEFEST is a very effective way to spin-up. The EPIC team helped to solve technical issues via zoom virtual room.
- The Users Guide provides detailed information covering many specific aspects. However, the Quick Start section can be further improved. Tutorials are needed for compiling/working in the cloud (AWS).
- Some python and bash scripts could be improved or updated.
- It would be helpful to provide the guidance on how to speed up the run in the Frequently Asked Questions (FAQ) section. For instance, by changing the LAYOUT\_X and LAYOUT\_Y numbers.



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**THANK YOU**



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