TAMS: A **T**racking, Classifying, and Precipitation-Assigning **A**lgorithm for **M**esoscale **C**onvective **S**ystems in Simulated and Satellite-Derived Datasets

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Acknowledgments: **WCO3**, **Irene Kruse**, **Adrian Tompkins**, **Zachary Moon** (TAMS co-developer), **NCAR-MMM**

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Outline

1. Overarching description of TAMS
2. Research Applications:
   - ❑African Easterly Waves and Tropical Cyclone Genesis
   - ❑Nocturnal Offshore Convection: The Role of the West African Monsoon and Land Breeze during CPEX-CV
   - ❑MCS Intercomparison Study
3. Summary

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Tracking Algorithm for Mesoscale Convective Systems

TAMS

Identification

↓

Tracking

↓

Classification

↓

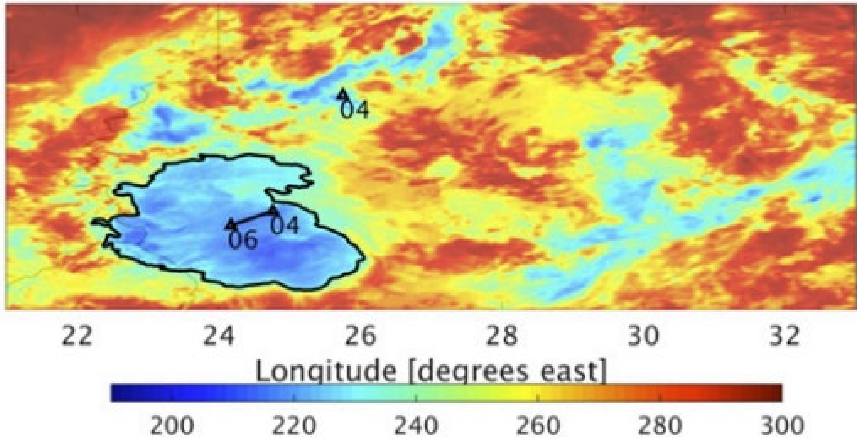
Precipitation assignment

Tracking Mesoscale Convective Systems that are Potential Candidates for Tropical Cyclogenesis

KELLY M. NÚÑEZ OCASIO, JENNI L. EVANS, AND GEORGE S. YOUNG

Department of Meteorology and Atmospheric Science, The Pennsylvania State University, University Park, Pennsylvania

(Manuscript received 15 March 2019, in final form 15 November 2019)



Núñez Ocasio et al. 2020a

Overall identification criteria:

- 235 K cloud temperature threshold
- 235 K areas have an embedded 219 K area(s) >= 4,000 km^2
- Contour shape (independent of satellite grid)

Tracking Algorithm for Mesoscale Convective Systems

TAMS

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FEBRUARY 2020 NÚÑEZ OCASIO ET AL. 655

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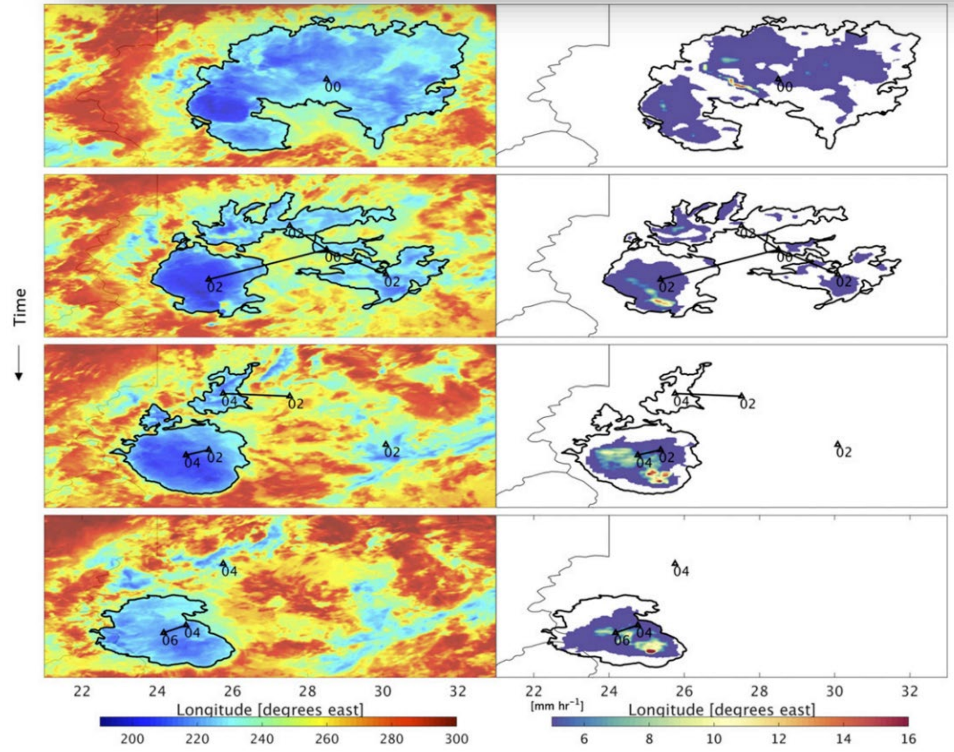

Núñez Ocasio et al. 2020a

Overall tracking steps:

- Cloud areas of the current image are compared to all the CEs from the next two available images
- Overlap method and cloud projection in the *x* direction
- MCS family
  - Recalling/recursive function

Tracking Algorithm for Mesoscale Convective Systems

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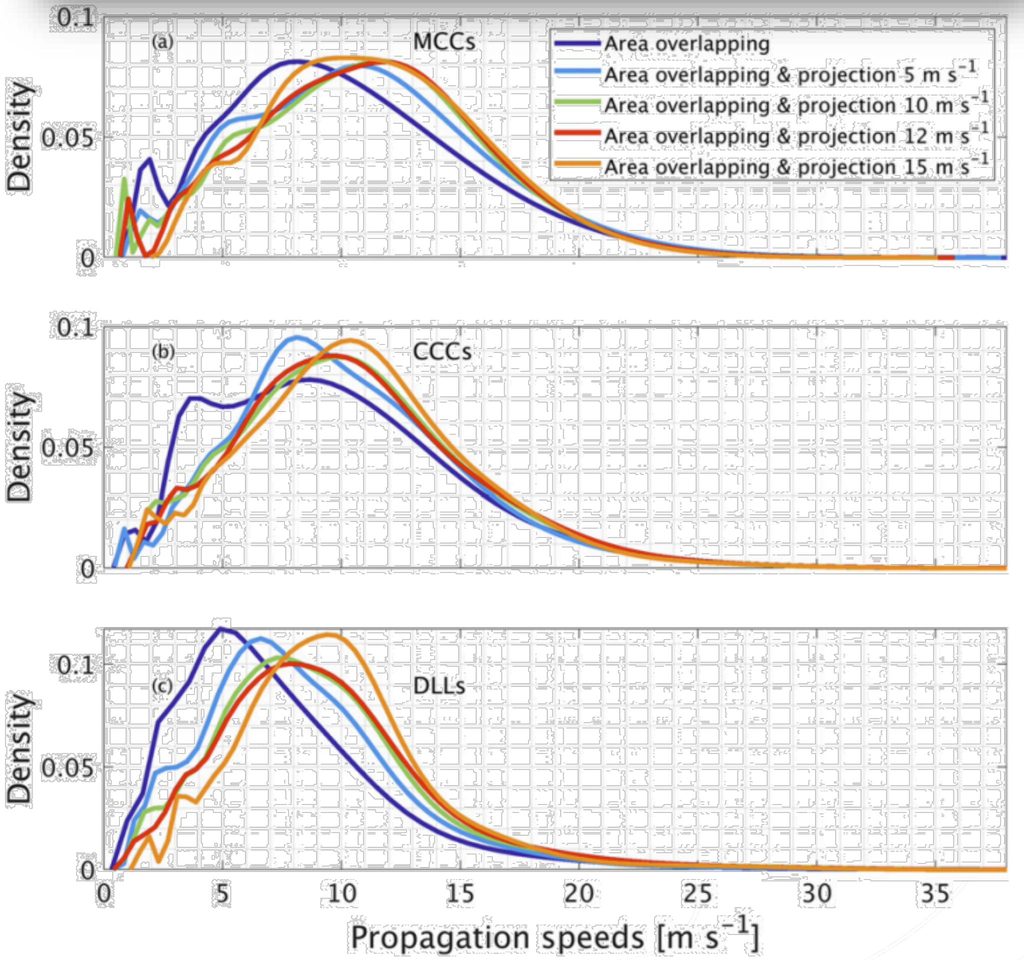

Area-overlapping technique with no projection underestimates the real propagation speed of MCSs over Africa

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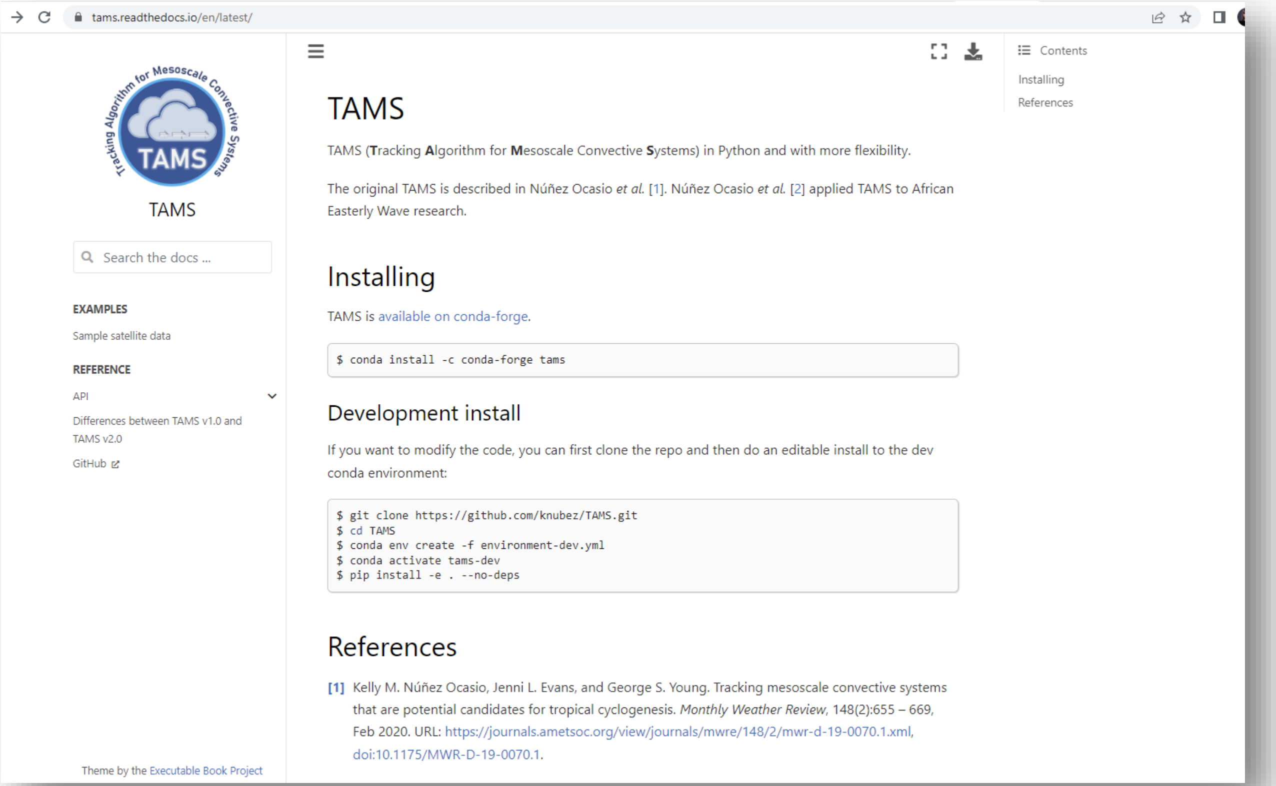
TAMS (v2.0): Package & Website

- User-friendly, open-source, & publicly available
- Install with pip or conda/mamba
- Conda environment recommended
- Grid-independent identification and tracking (satellite and model data)
- TAMS is also able to assign rain (or any other variable) to each object (cloud element or MCS)
- Output format: GeoPandas GeoDataFrame


tams.readthedocs.io/en/latest/

Tracking Algorithm for Mesoscale Convective Systems

TAMS

Search the docs ...

EXAMPLES

Sample satellite data

REFERENCE

API

Differences between TAMS v1.0 and TAMS v2.0

GitHub

Theme by the Executable Book Project

Contents

Installing

References

TAMS

TAMS (**T**racking **A**lgorithm for **M**esoscale Convective **S**ystems) in Python and with more flexibility.

The original TAMS is described in Núñez Ocasio *et al.* [1]. Núñez Ocasio *et al.* [2] applied TAMS to African Easterly Wave research.

Installing

TAMS is available on conda-forge.

```
$ conda install -c conda-forge tams
```

Development install

If you want to modify the code, you can first clone the repo and then do an editable install to the dev conda environment:

```
$ git clone https://github.com/knubez/TAMS.git
$ cd TAMS
$ conda env create -f environment-dev.yml
$ conda activate tams-dev
$ pip install -e . --no-deps
```

References

[1] Kelly M. Núñez Ocasio, Jenni L. Evans, and George S. Young. Tracking mesoscale convective systems that are potential candidates for tropical cyclogenesis. *Monthly Weather Review*, 148(2):655 – 669, Feb 2020. URL: https://journals.ametsoc.org/view/journals/mwre/148/2/mwr-d-19-0070.1.xml, doi:10.1175/MWR-D-19-0070.1.

Núñez Ocasio and Moon 2023 (*in prep*)

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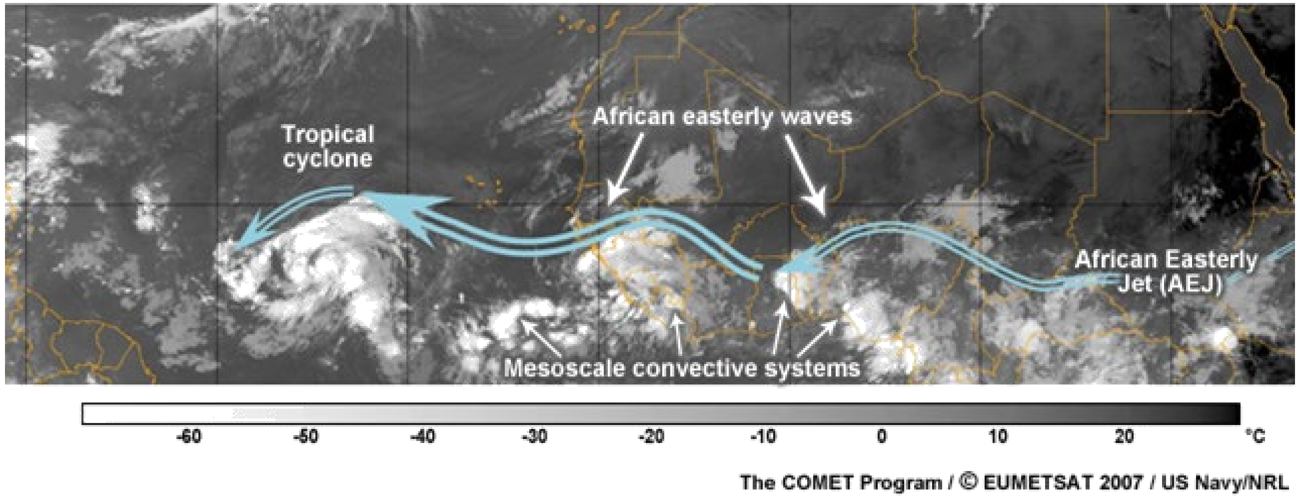
Motivation

- 90% of Sahelian rainfall events produced by MCSs
- MCSs over Africa are intrinsically related to AEW growth and propagation
- MCSs are modulated by AEWs that become tropical cyclones



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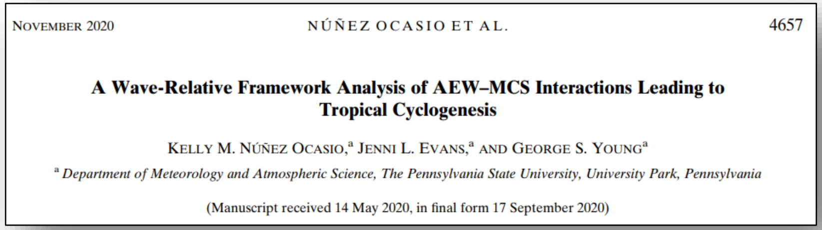
African Easterly Waves-MCS Systems & TC Genesis


NOVEMBER 2020 NÚÑEZ OCASIO ET AL. 4657

A Wave-Relative Framework Analysis of AEW–MCS Interactions Leading to Tropical Cyclogenesis

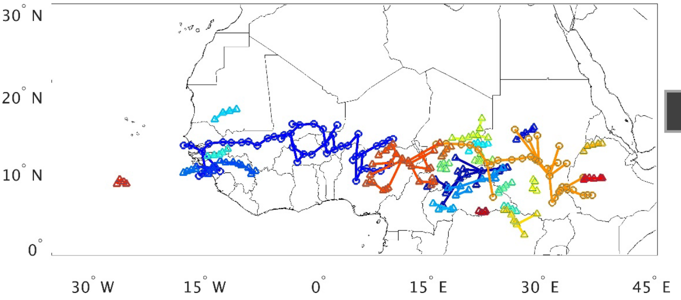
KELLY M. NÚÑEZ OCASIO,[a] JENNI L. EVANS,[a] AND GEORGE S. YOUNG[a]

[a] *Department of Meteorology and Atmospheric Science, The Pennsylvania State University, University Park, Pennsylvania*

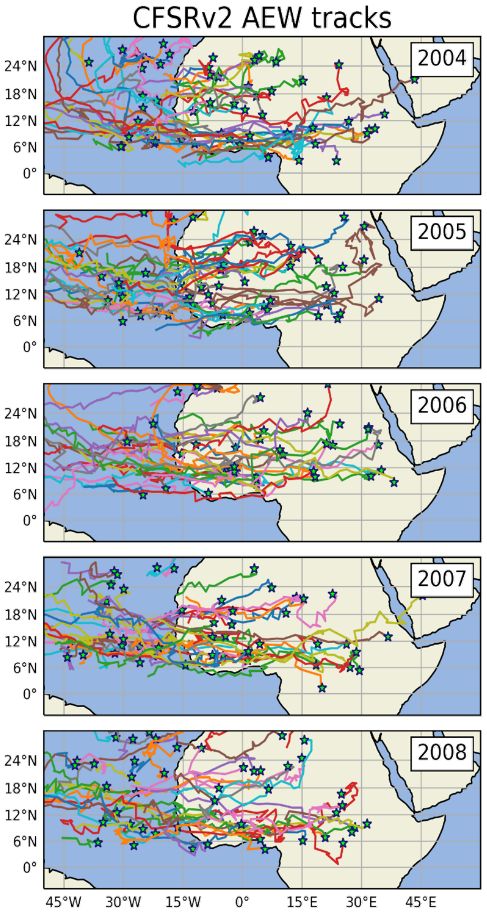
(Manuscript received 14 May 2020, in final form 17 September 2020)

Tracking Algorithm for Mesoscale Convective Systems

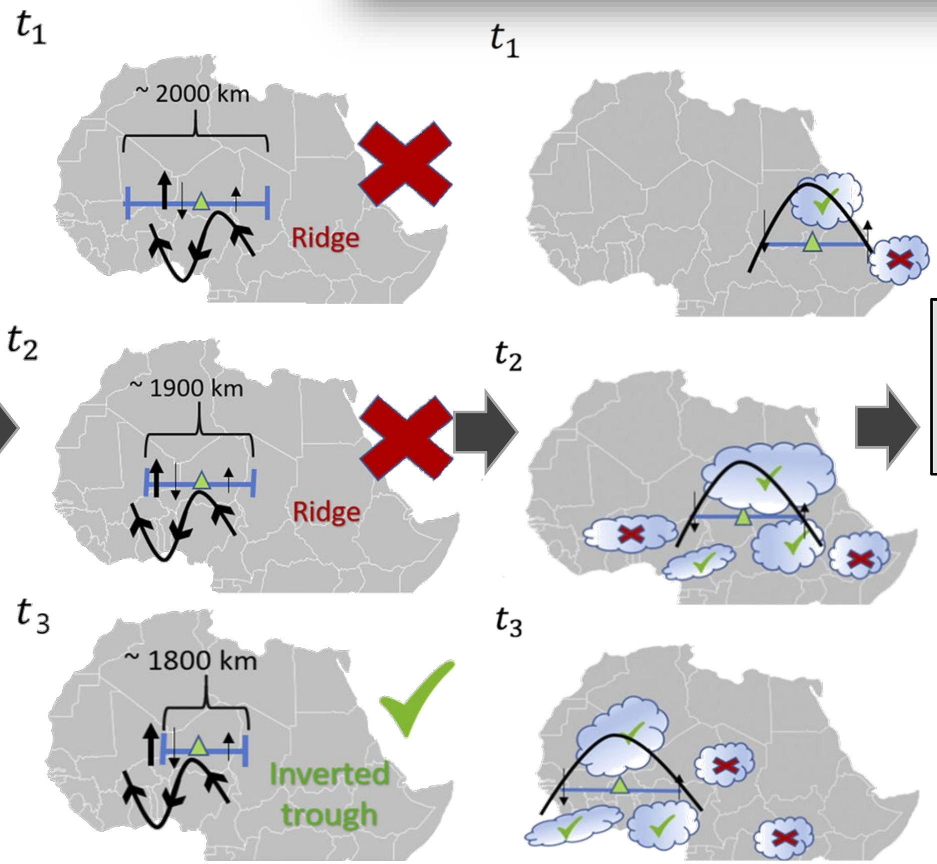
TAMS



Núñez Ocasio et al. 2020a



Brammer et al. 2018



Dataset of AEW-MCS systems

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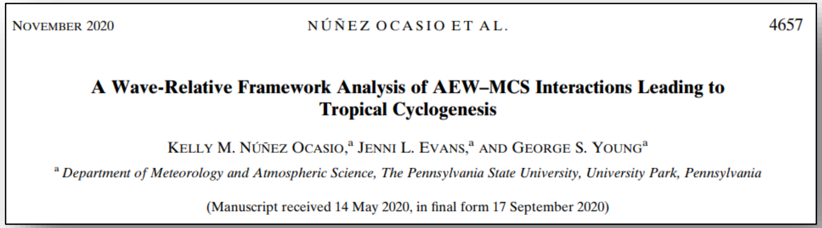
African Easterly Waves-MCS Systems & TC Genesis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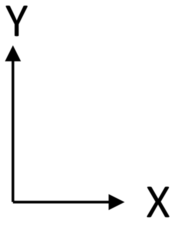
(Manuscript received 14 May 2020, in final form 17 September 2020)

MCSs of Developing AEWs independent of the zonal phasing (longitude), are latitudinally in phase with the AEW trough

t_1

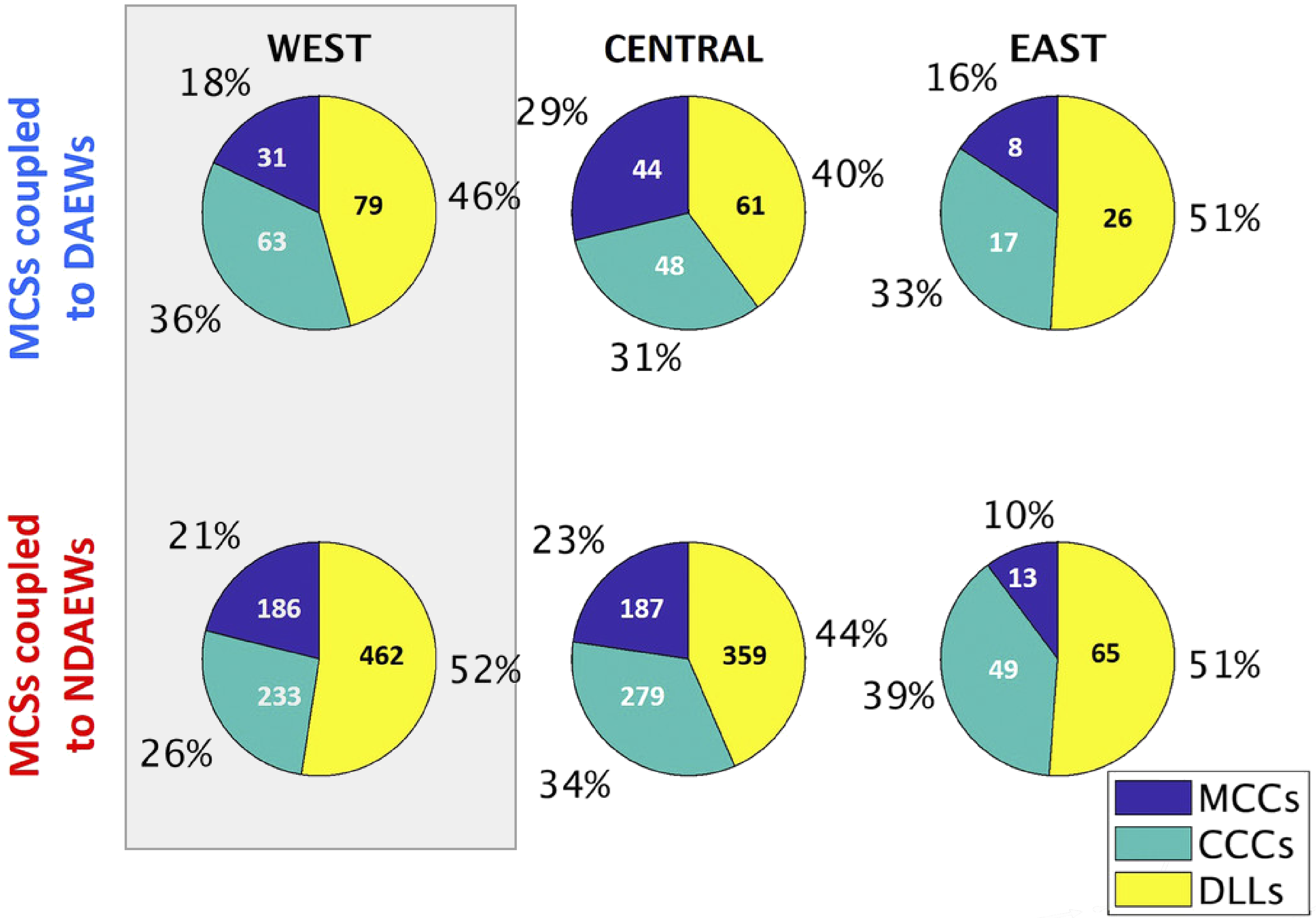
Developing AEW-MCS systems

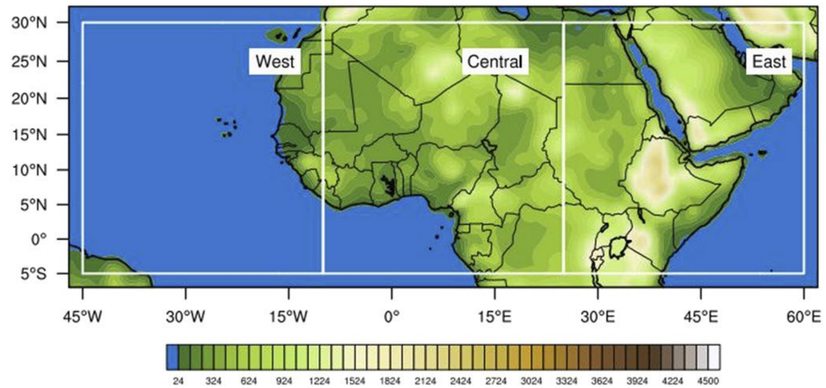
Non-developing AEW-MCS systems



Núñez Ocasio et al. 2020b

DAEWs have a larger fraction of organized MCSs over Central and West than NDAEWs





Núñez Ocasio et al. 2020b

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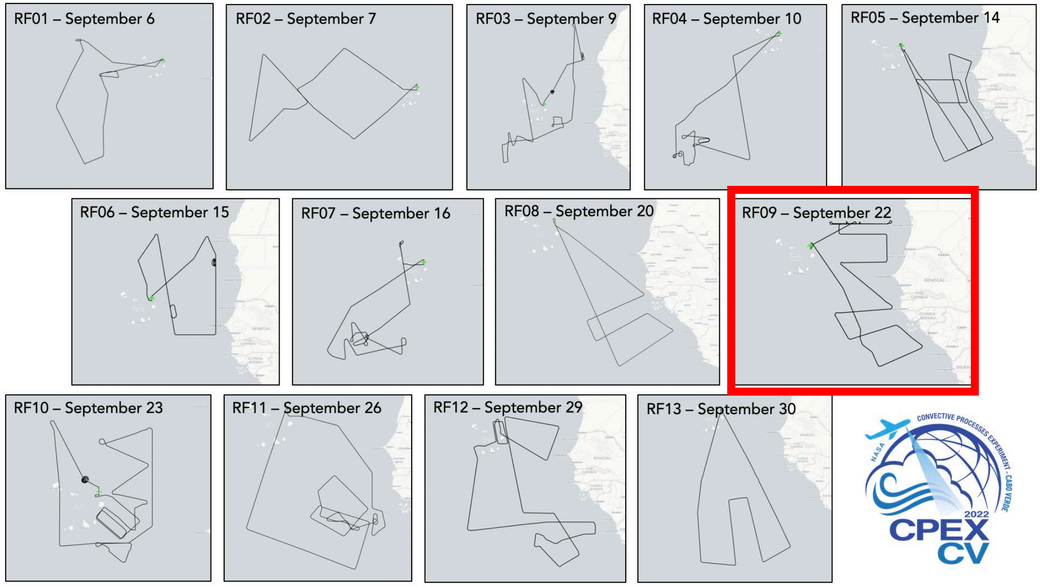
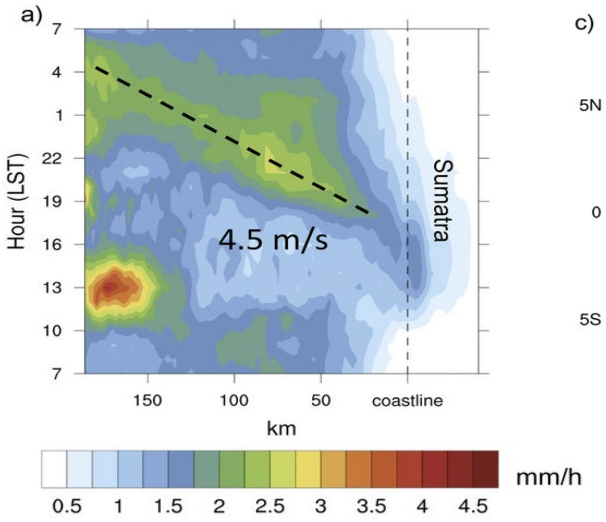
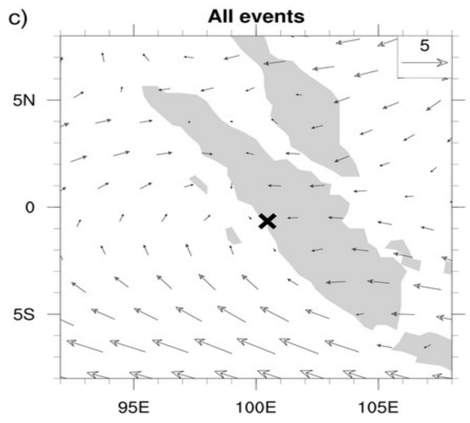
NASA
Convective Processes Experiment – Cabo Verde



Mechanisms proposed that support & initiate Nocturnal Offshore Convection

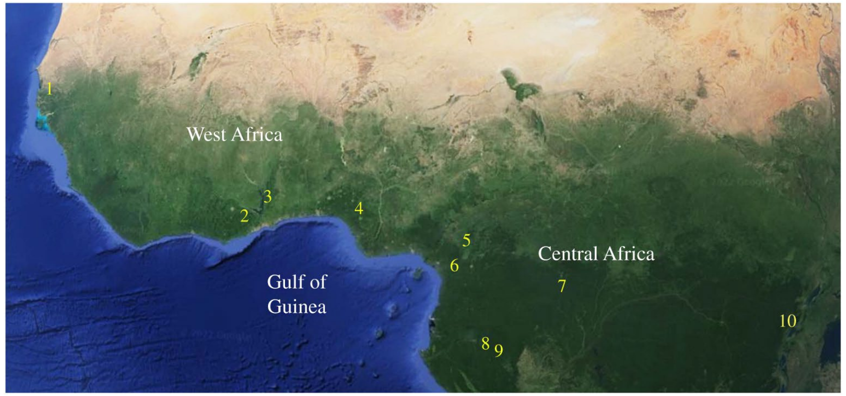
1) Low-level convergence, resulting from the interaction of the **land breeze** and **background low-level westerlies**



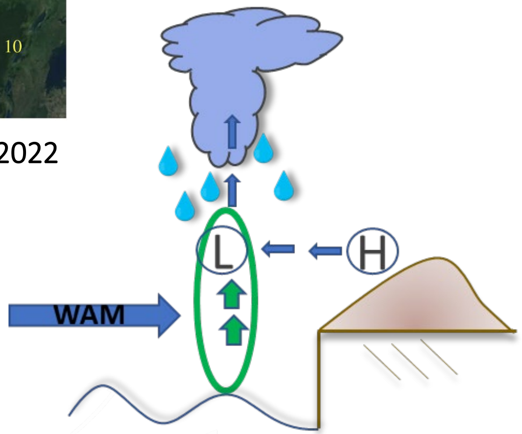


Figures from Bai et al. 2021

2) **Gravity waves** forced by the heat source of the diurnal mixed layer (Mapes 2003a,b)



Map from Akpo 2022



- Similar results for Borneo (Houze et al. 1981)
- Similar low-level convergence has also been found over South China (Park et al. 2011) and East Asia (Ohsawa et al. 2001)

Mechanisms proposed that support & initiate Nocturnal Offshore Convection

- Recent work by Peatman et. al 2023 suggests that both **gravity waves *and* land breeze can be responsible for offshore propagation**
- **Gravity waves mainly triggered isolated rainfall**
- **Offshore-propagating density currents (either due to the land breeze and/or cold pools).** The motion of this offshore density current coincides with the squall line propagating offshore.
- They highlight the fact that even with high-resolution modeling it is difficult to distinguish between land breeze and cold pools

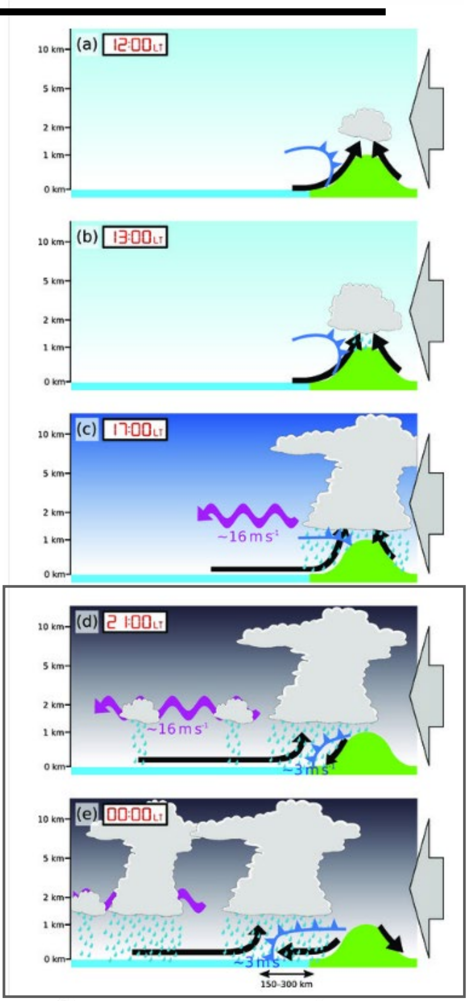
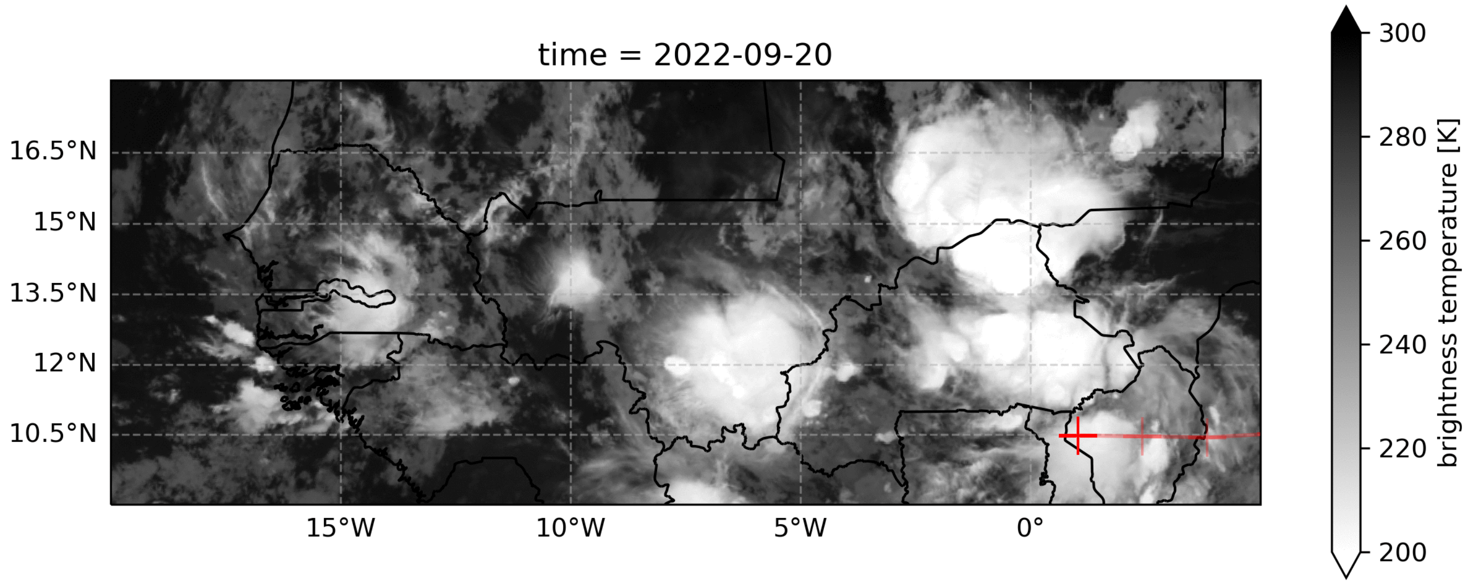


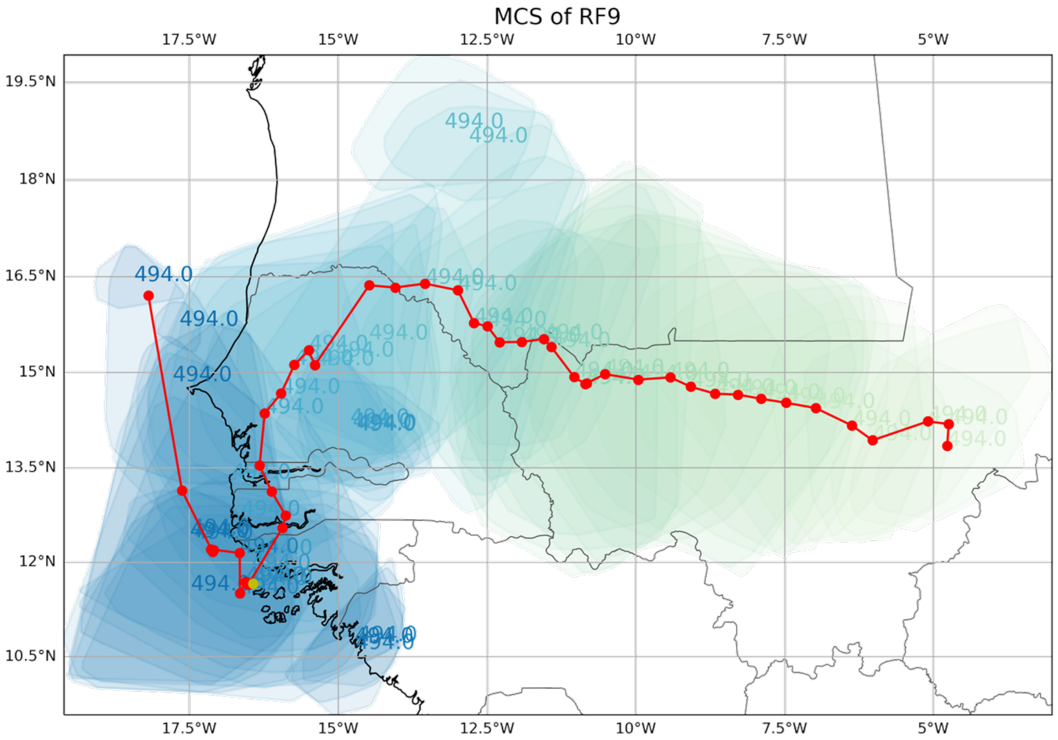
Figure from Peatman et al. 2023

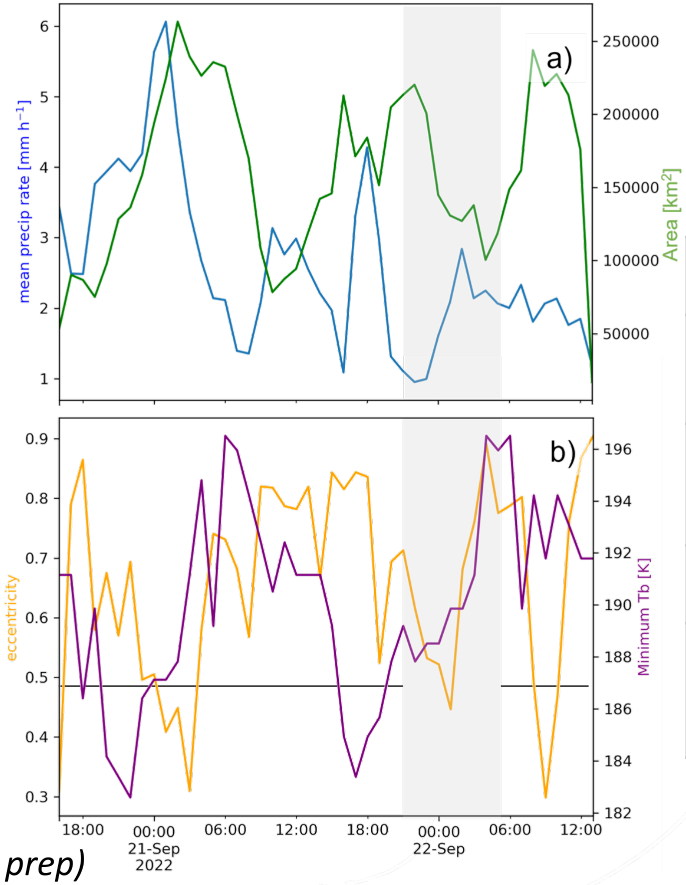
RF9: Evolution & Observations of Nocturnal Offshore Convection



Núñez Ocasio et al. 2023 *(in prep)*

RF9: Evolution & Observations of Nocturnal Offshore Convection

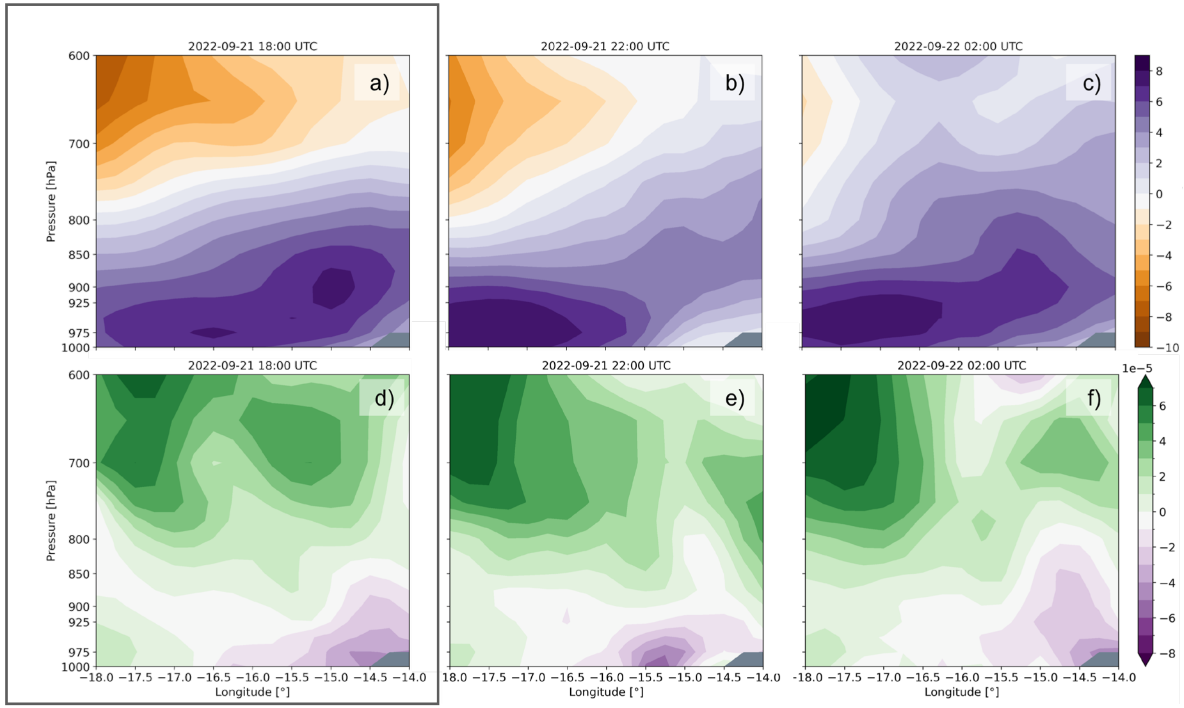


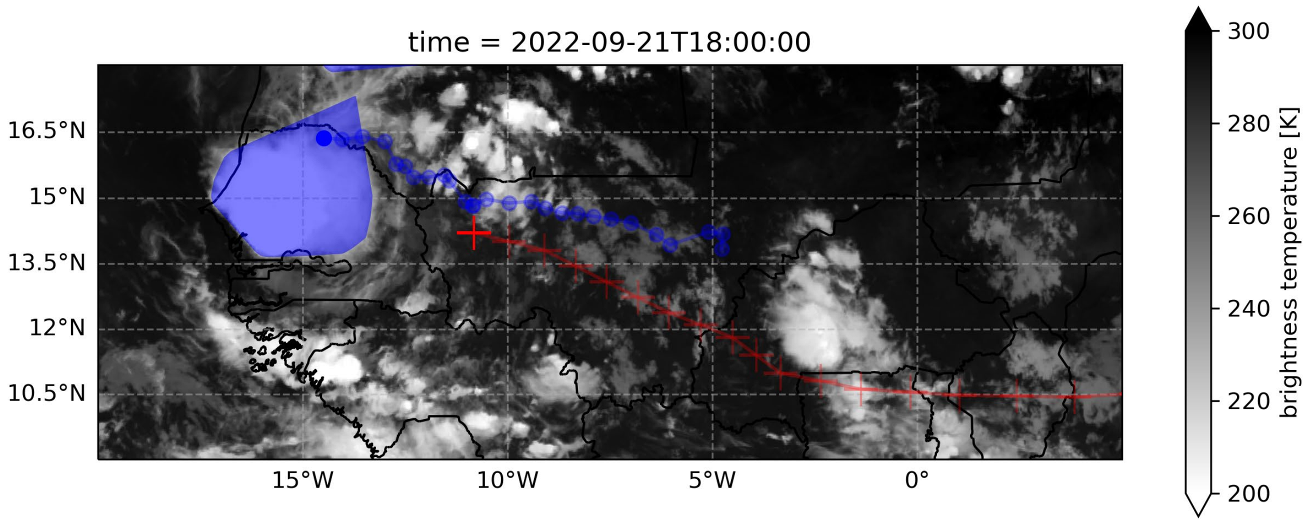


Núñez Ocasio et al. 2023 *(in prep)*

Initiation	2022-09-20 16:00:00 UTC
Geo center crosses over	2022-09-22 05:00:00 UTC
Termination	2022-09-22 13:00:00 UTC
Duration	45 hours
Classification	Mesoscale Convective Complex

RF9: Night of September 21st, 2022



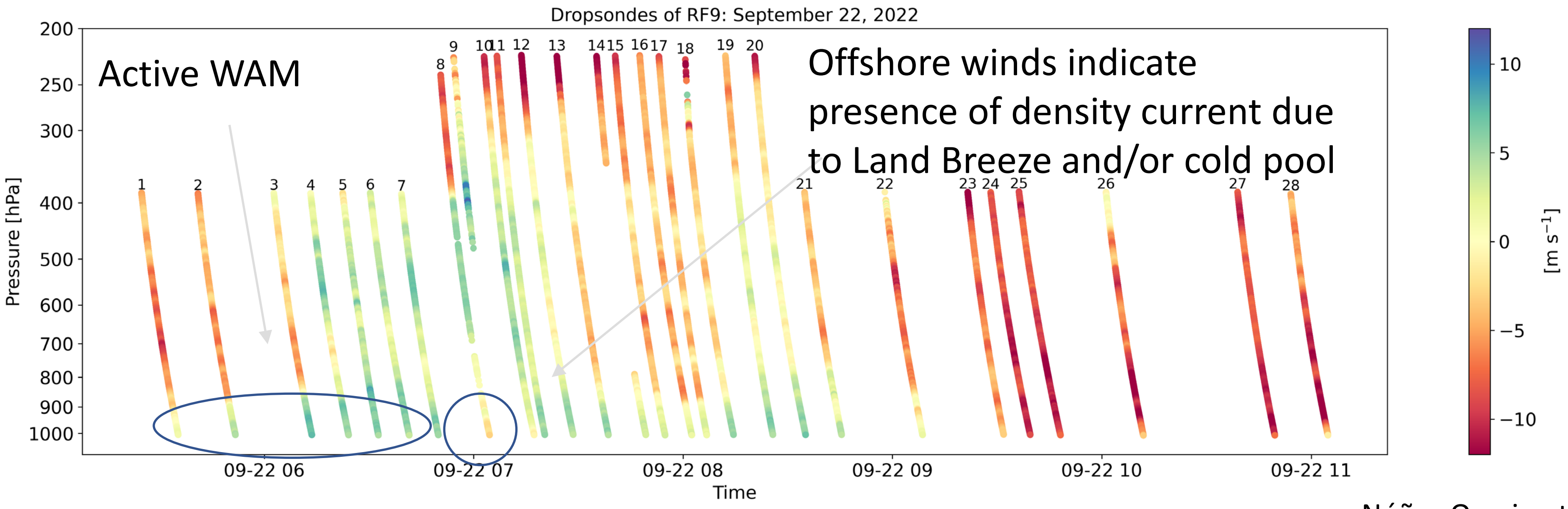


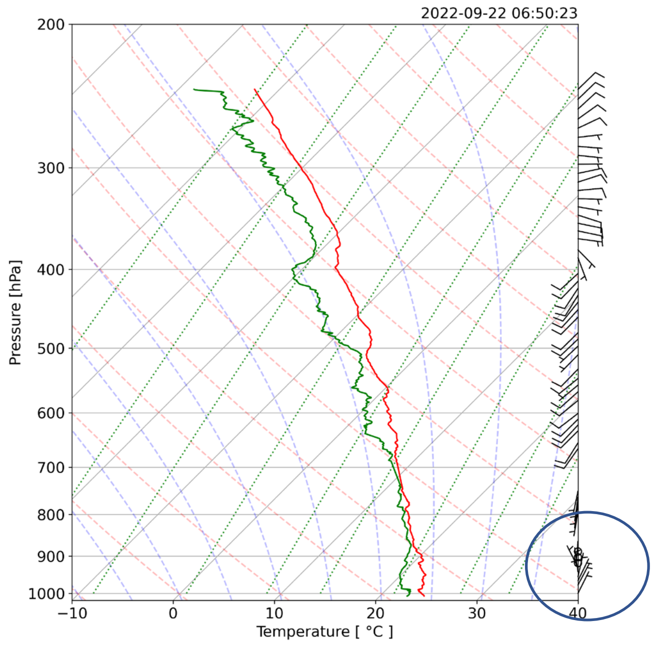
Núñez Ocasio et al. 2023 *(in prep)*

Reanalysis evidence of both LB (propagating offshore with a maximum at 2022-09-21 22:00 UTC and WAM retracting from coast

RF9: Evolution and Observations of Nocturnal Offshore Convection

- West African Monsoon and Land Breeze Observation

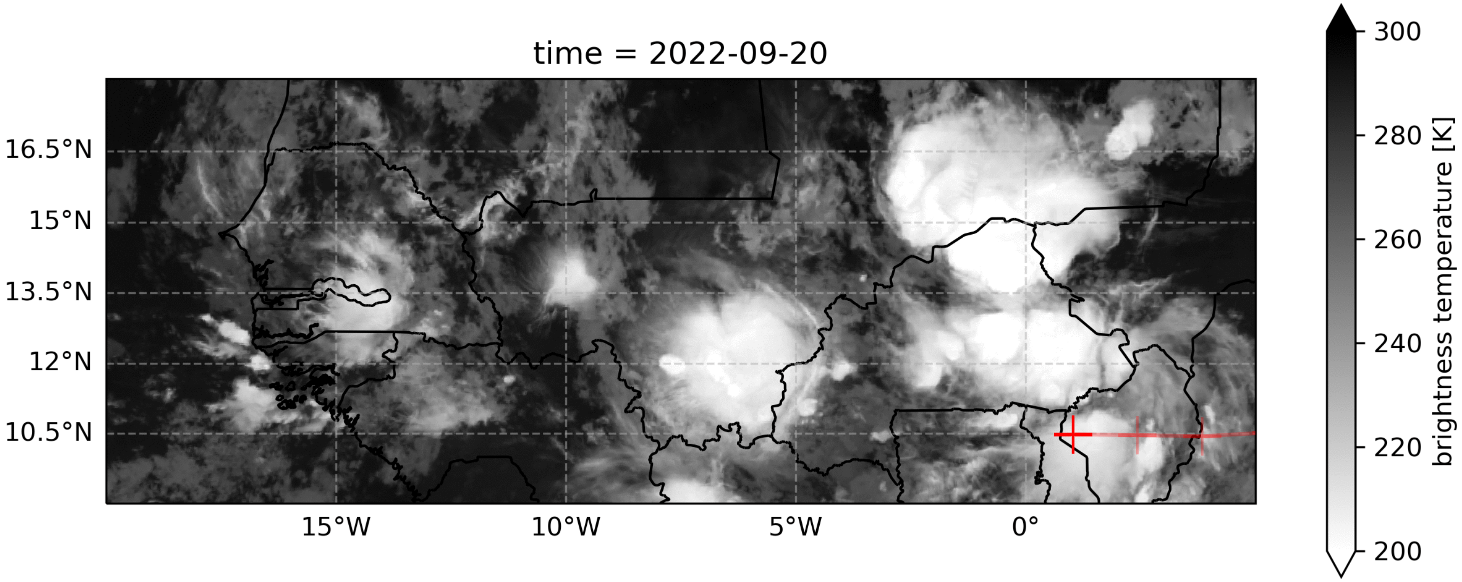


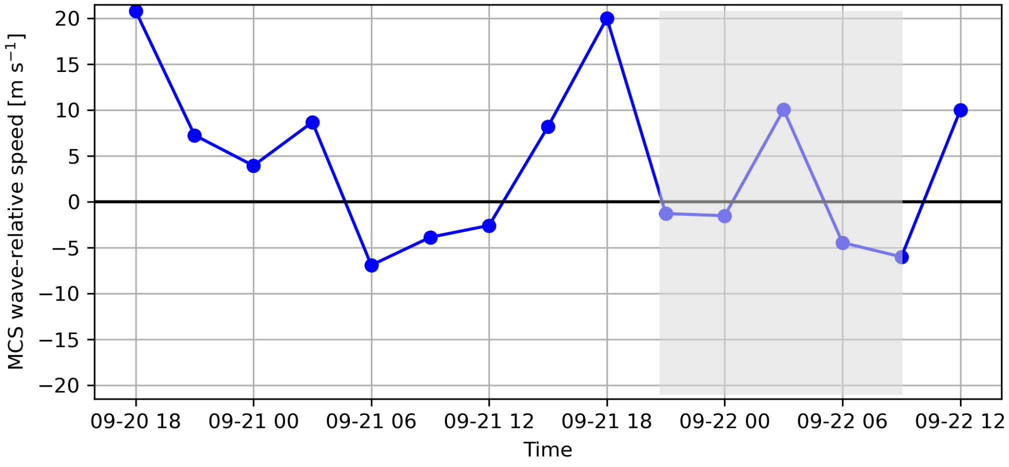


Núñez Ocasio et al. 2023 *(in prep)*

Observational evidence via dropsonde observations of both LB and WAM

Research Flight 9: The role of the AEW





Núñez Ocasio et al. 2023 *(in prep)*

- Temporary separation of MCS from AEW close to the coast and decrease in propagating speed of the MCS relative to wave indicate a change from AEW-supported propagation to offshore-supported propagation due to coastal mechanisms (density current form LB and/or cold pool)

- MCS speed and position relative to wave are significantly different across developing and non-developing systems (Núñez Ocasio et. al 2020)

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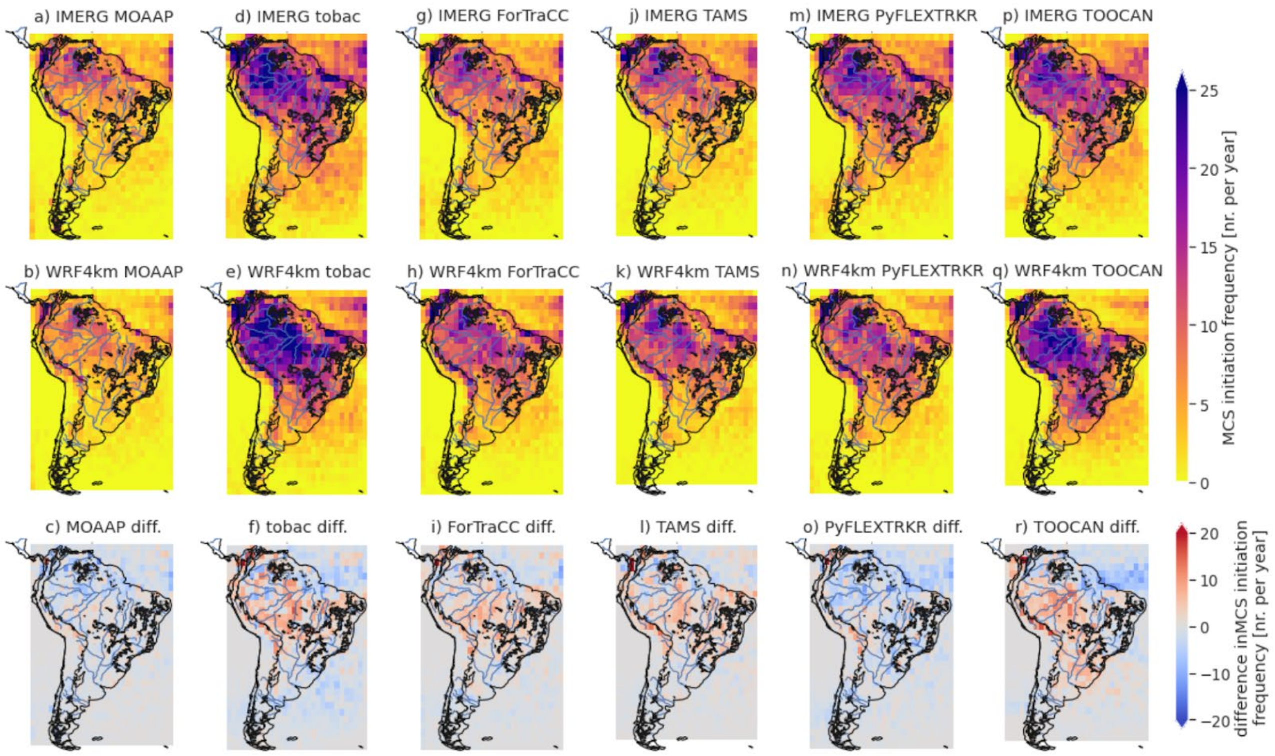
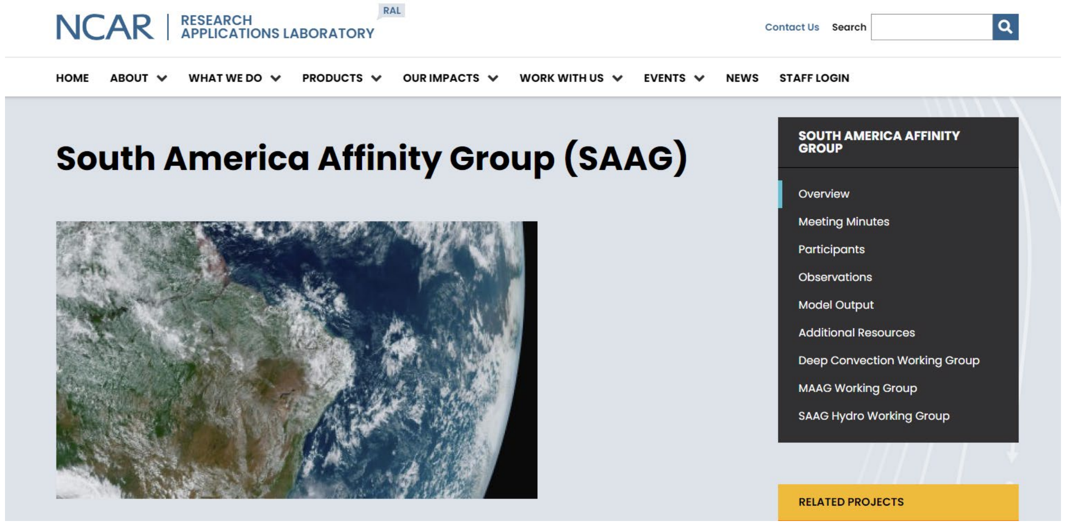
A Multi-MCS-Tracking Intercomparison Study for MCSs over South America



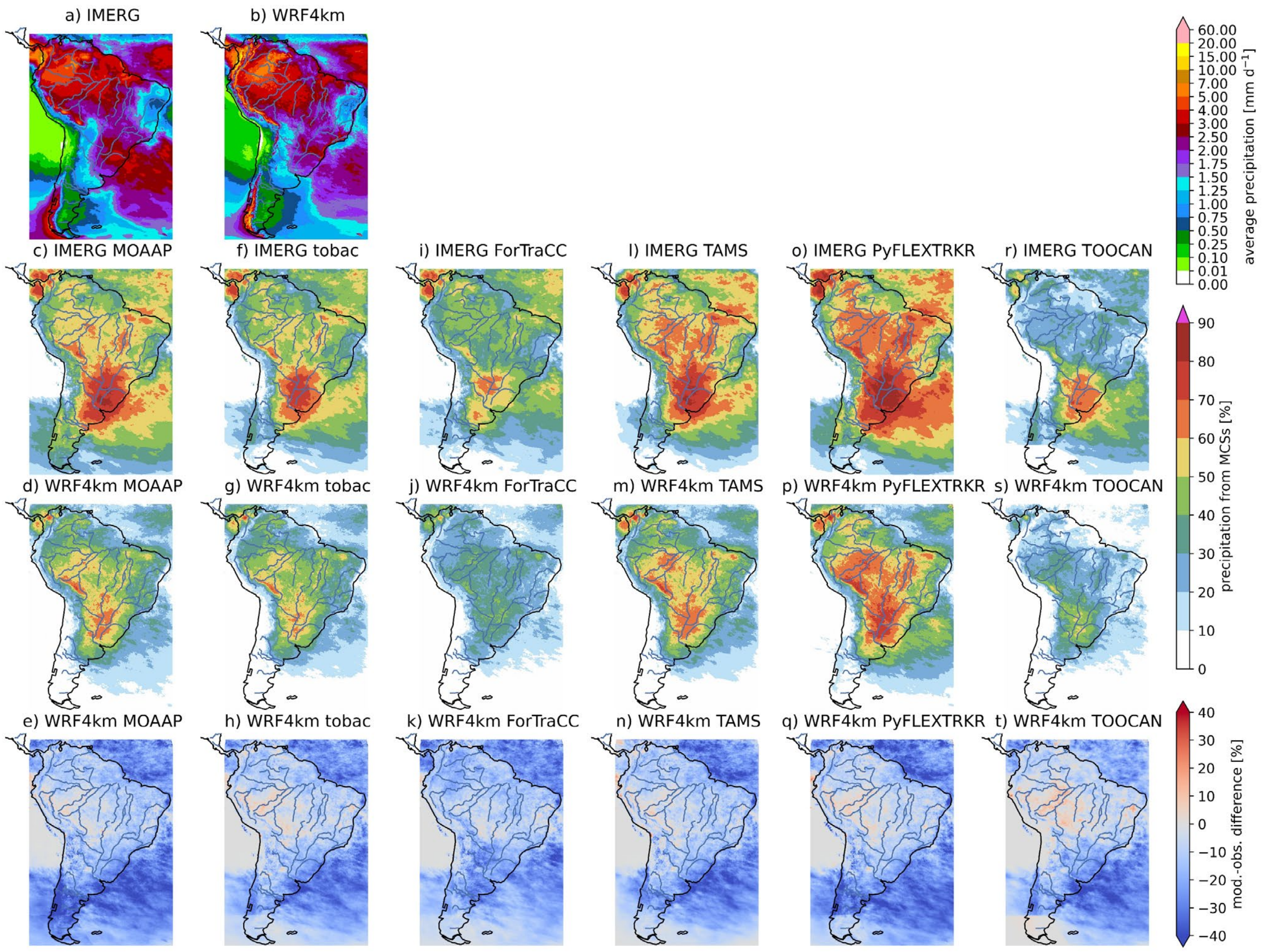
MOAAP **tobac** **ForTraCC** TAMS **PyFLEXTRKR** **TOOCAN**

Prein et al. 2023 *(in review)*



The evaluation of simulated MCS characteristics is less impacted by the tracker formulation and all trackers agree that the kilometer-scale model can capture MCS characteristics well across different South American climate zones.

MCS frequency differences can be large and vary in sign in many regions.



MOAAP **tobac** **ForTraCC** Tracking Algorithm for Mesoscale Convective Systems TAMS **PyFLEXTRKR** TOOCAN

Prein et al. 2023 *(in review)*

- Applying different trackers results in a wide range of MCS to total precipitation fractions with PyFLEXTRKR showing the largest contributions and TOOCAN and ForTraCC showing the smallest.

- There is also an agreement among trackers that the simulations are underestimating the fraction of precipitation from MCSs over large parts of the study region.

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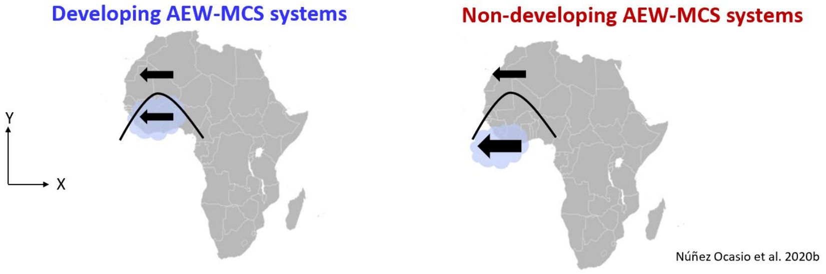
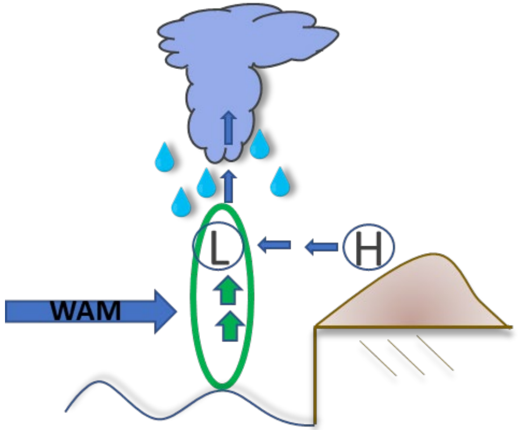
Summary





- TAMS is a grid-independent and open-source tracker that have been use to study AEW-MCS interactions as it considers shear propagation (TAMS is grid independent and is an open source tool)

knubez

- African Easterly Wave and Tropical cyclogeneses

- WAM-LB mechanism: Over western Africa this mechanism can support and maintain offshore convection, observational evidence and reanalysis does not support convective initiation from it
- MCS Intercomparison Study: The tracker formulation has substantial impacts on MCS characteristics such as frequency, size, duration, and MCS contribution to total precipitation

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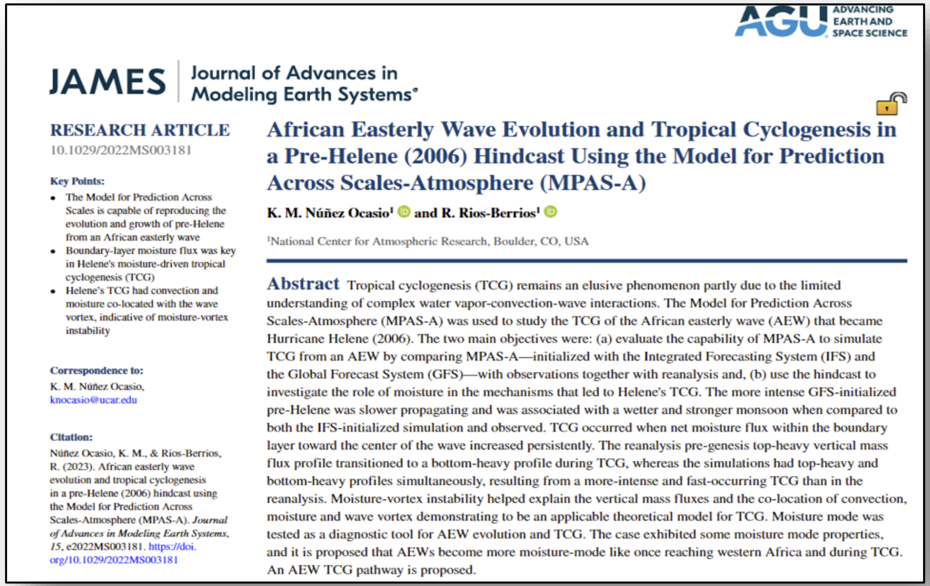
MPAS DATA: 15-km horizontal grid global simulations post-processed



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RESEARCH ARTICLE
10.1029/2022MS003181

Key Points:

- The Model for Prediction Across Scales is capable of reproducing the evolution and growth of pre-Helene from an African easterly wave
- Boundary-layer moisture flux was key in Helene's moisture-driven tropical cyclogenesis (TCG)
- Helene's TCG had convection and moisture co-located with the wave vortex, indicative of moisture-vortex instability

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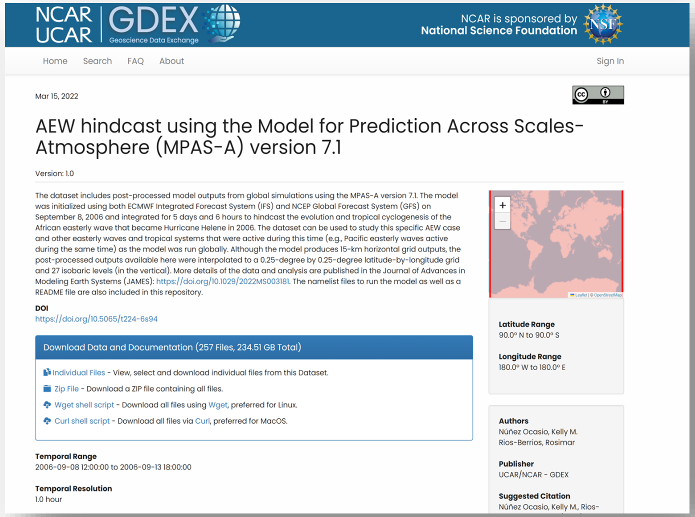
Citation:
Núñez Ocasio, K. M., & Rios-Berrios, R. (2023). African easterly wave evolution and tropical cyclogenesis in a pre-Helene (2006) hindcast using the Model for Prediction Across Scales-Atmosphere (MPAS-A). *Journal of Advances in Modeling Earth Systems*, *15*, e2022MS003181. https://doi.org/10.1029/2022MS003181

African Easterly Wave Evolution and Tropical Cyclogenesis in a Pre-Helene (2006) Hindcast Using the Model for Prediction Across Scales-Atmosphere (MPAS-A)

K. M. Núñez Ocasio[1] and R. Rios-Berrios[1]

[1]National Center for Atmospheric Research, Boulder, CO, USA

Abstract Tropical cyclogenesis (TCG) remains an elusive phenomenon partly due to the limited understanding of complex water vapor-convection-wave interactions. The Model for Prediction Across Scales-Atmosphere (MPAS-A) was used to study the TCG of the African easterly wave (AEW) that became Hurricane Helene (2006). The two main objectives were: (a) evaluate the capability of MPAS-A to simulate TCG from an AEW by comparing MPAS-A—initialized with the Integrated Forecasting System (IFS) and the Global Forecast System (GFS)—with observations together with reanalysis and, (b) use the hindcast to investigate the role of moisture in the mechanisms that led to Helene's TCG. The more intense GFS-initialized pre-Helene was slower propagating and was associated with a wetter and stronger monsoon when compared to both the IFS-initialized simulation and observed. TCG occurred when net moisture flux within the boundary layer toward the center of the wave increased persistently. The reanalysis pre-genesis top-heavy vertical mass flux profile transitioned to a bottom-heavy profile during TCG, whereas the simulations had top-heavy and bottom-heavy profiles simultaneously, resulting from a more-intense and fast-occurring TCG than in the reanalysis. Moisture-vortex instability helped explain the vertical mass fluxes and the co-location of convection, moisture and wave vortex demonstrating to be an applicable theoretical model for TCG. Moisture mode was tested as a diagnostic tool for AEW evolution and TCG. The case exhibited some moisture mode properties, and it is proposed that AEWs become more moisture-mode like once reaching western Africa and during TCG. An AEW TCG pathway is proposed.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Mar 15, 2022

AEW hindcast using the Model for Prediction Across Scales-Atmosphere (MPAS-A) version 7.1

Version: 1.0

The dataset includes post-processed model outputs from global simulations using the MPAS-A version 7.1. The model was initialized using both ECMWF Integrated Forecast System (IFS) and NCEP Global Forecast System (GFS) on September 8, 2006 and integrated for 5 days and 6 hours to hindcast the evolution and tropical cyclogenesis of the African easterly wave that became Hurricane Helene in 2006. The dataset can be used to study this specific AEW case and other easterly waves and tropical systems that were active during this time (e.g., Pacific easterly waves active during the same time) as the model was run globally. Although the model produces 15-km horizontal grid outputs, the post-processed outputs available here were interpolated to a 0.25-degree by 0.25-degree latitude-by-longitude grid and 27 isobaric levels (in the vertical). More details of the data and analysis are published in the Journal of Advances in Modeling Earth Systems (JAMES): https://doi.org/10.1029/2022MS003181. The namelist files to run the model as well as a README file are also included in this repository.

DOI
https://doi.org/10.5065/t224-6s94

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- Zip File - Download a ZIP file containing all files.
- Wget shell script - Download all files using Wget, preferred for Linux.
- Curl shell script - Download all files via Curl, preferred for MacOS.

Temporal Range
2006-09-08 12:00:00 to 2006-09-13 18:00:00

Temporal Resolution
1.0 hour

Latitude Range
90.0° N to 90.0° S

Longitude Range
180.0° W to 180.0° E

Authors
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Publisher
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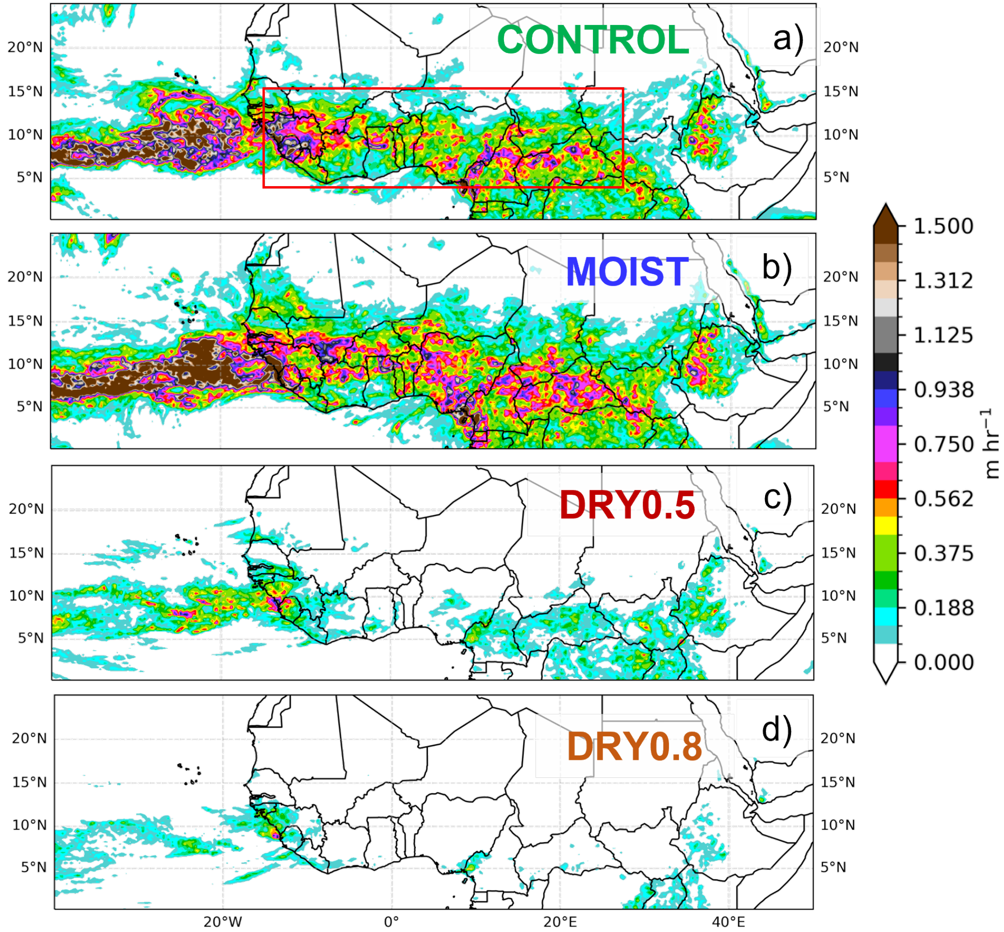
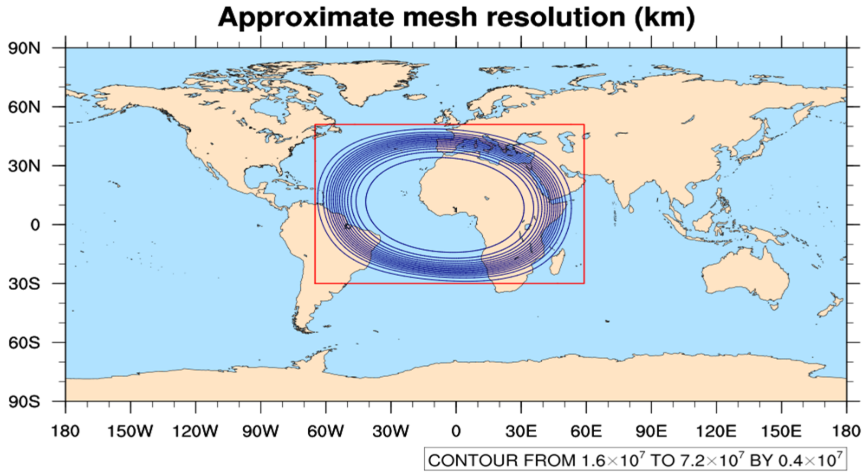
Moisture Sensitivity of MCSs over Tropical Africa and Eastern Atlantic



Núñez Ocasio et al. 2023 *(in review)*



- Initialization at 1200 UTC September 8, 2006: ERA5
- Limited area MPAS with a 15-3km variable mesh, 55 vertical levels, explicitly resolved deep convection
- Four moisture-sensitivity experiments altering initial and hourly lateral boundary RH at each pressure level
  1. CONTROL
  2. MOIST: 20%
  3. Dry: 50%
  4. Dry: 80%

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Tracking Algorithm for Mesoscale Convective Systems

TAMS

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