This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

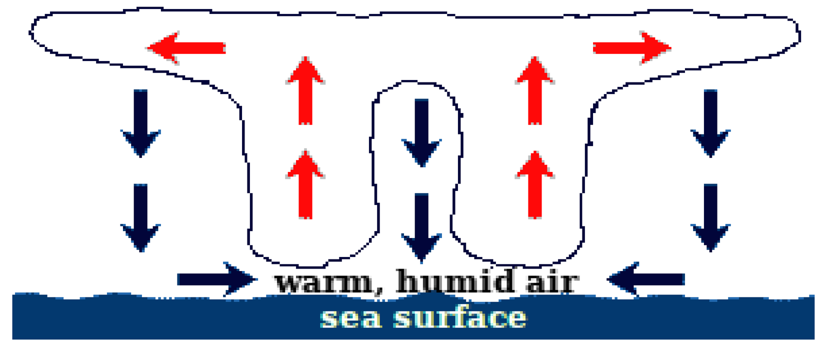
Identifying the origin of precipitation moisture within the tropical cyclones outer radius in the North Atlantic basin

Albenis Pérez-Alarcón[1,2], Patricia Coll-Hidalgo[1], José C. Fernández-Alvarez[1,2], Rogert Sori[1], Ricardo M. Trigo[3,4], Raquel Nieto[1], Luis Gimeno[1]

[1]*Environmental Physics Laboratory, Universidade de Vigo, Spain.* [2]*Departamento de Meteorología, InSTEC, Universidad de la Habana, Cuba.* [3]*Instituto Dom Luiz, Universidade de Lisboa, Portugal.* [4]*Departamento de Meteorologia, Universidade Federal do Rio de Janeiro, Brazil.*

Background

- The main fuel for tropical cyclones (TCs) is the release of latent heat derived from the condensation of water vapor [1].



- TC precipitation is mainly a product of the secondary circulation transporting moisture inward [2].
- Understanding the precipitation origin during the passage of TCs is important to significantly aid in disaster mitigation and risk analysis.

Objectives

This study applies a Lagrangian approach

- to identify the moisture sources for the precipitation within the area enclosed by the outer radio of TCs during the genesis, lifetime maximum intensity (LMI) and dissipation stages in the North Atlantic basin.
- to identify the changes in the moisture sources pattern during rapid intensification and after the extratropical transition.

Data and Models

HURDAT2 US NHC

TCSize EPhysLab

TROVA EPhysLab

FLEXPART

ERA-INTERIM reanalysis ECMWF

- In FLEXPART simulations, the atmosphere was homogeneously divided into approximately 2 million air parcels.
- The study period was set from 1980 to 2018.

Lagrangian moisture tracking

We only backtracked up to 10 days parcels that precipitated within the area enclosed by the outer radius of TCs. Precipitating parcels were filtered as those in which the specific humidity decrease in more than 0.1 g/kg [3].

According to Stohl and James [4], the moisture changes along the atmospheric parcel trajectory are controlled by gains, through evaporation from the environment (e), or losses, through precipitation (p), of specific humidity (q),

$$(e-p) = m\frac{dq}{dt} \quad (1)$$

where m is the mass of each parcel, assumed to be constant.

To gain an objective picture of the origin of moisture that contributed to the final precipitation over the target region, Sodemann et al. [5] proportionally discounted the precipitation in route to all previous moisture uptake

$$\triangle q_j' = \triangle q_j + \triangle q_i \frac{\triangle q_j}{\sum_{k=i}^{j} \triangle q_k} \quad (2)$$

where i denotes the parcel position at time t_i and j represents the parcel position at time t_{i-6}, t_{i-12}, ..., t_{i-240}. By amassing the final moisture changes ($\triangle q_j'$) of all the parcels over area A, the total moisture uptake (MU) was estimated as follows:

$$MU = \frac{m\sum_{k=1}^{N} \triangle q_k'}{A} \quad (3)$$

where N denotes the number of parcels residing over A.

Changes in moisture sources

during rapid intensification

- The summed contribution from the WNATL, TNATL, CS, GoM and terrestrial source CA accounting for 85.4% of total precipitation moisture gained by TCs during rapid intensification (RI)
- On average, the moisture uptake within 2000 km from the TC centre was approximately two times higher during the rapid intensification than during the slow intensification (SI) process.
- The moisture uptake from remote sources (more than 2500 km from the TC centre) was similar for RI and SI processes.

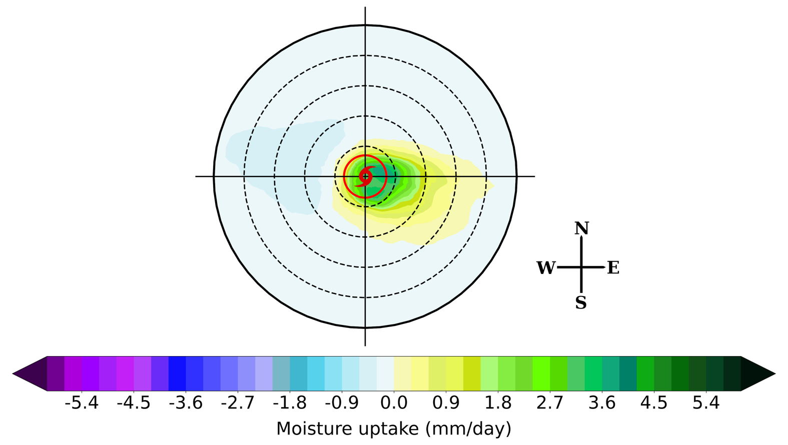


Figure 1. Spatial differences between the moisture uptake (mm/day) under rapid and slow intensification over a polar grid of 100-km radius × 4° azimuth polar grid out to 5000 km from the cyclone centre. The marker denotes the cyclone centre. The red circle represents the average outer radius of TCs and the black dashed circles illustrate the radial distance at a 1000 km step from the storm centre.

Local moisture uptake could be considered as a key factor for RI, but further studies are required to confirm this hypothesis.

Changes in moisture sources

during extratropical transition

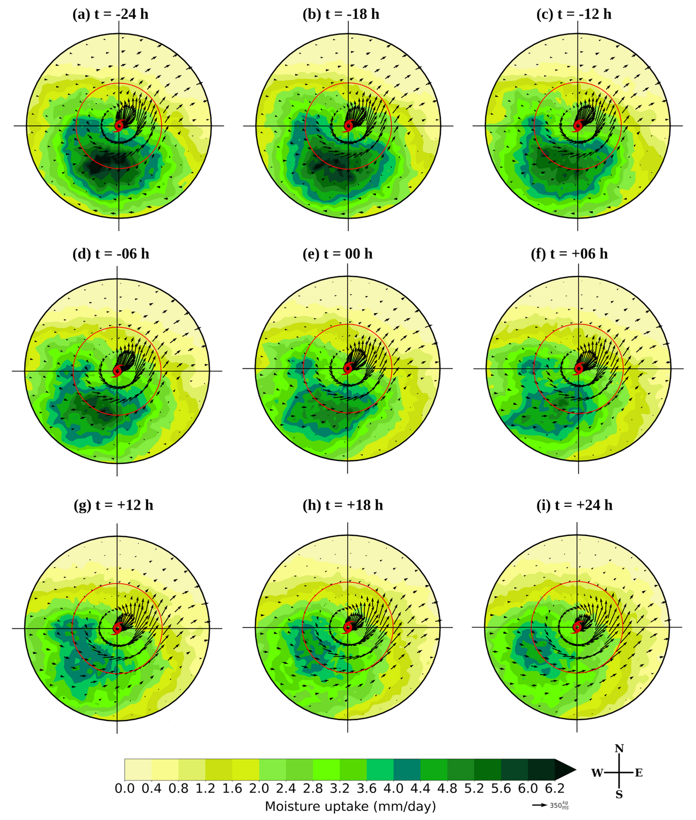


Figure 2. Mean moisture uptake for TCs precipitation by applying a TC-centric methodology. The average vertically integrated moisture flux is plotted in arrows. The red solid circle shows the mean size of TCs (900–1000 km) for each 6-hourly time step, and the solid black circle represents the 2000 km radial distance from the TC centre.

- The moisture was predominately originated from the south and southwest sectors during PRE-extratropical transition (ET) and from the southwest-west during POST-ET [8].

Moisture sources during genesis, LMI and dissipation phases

- The moisture sources pattern exhibited a north-south split around 10ºN, coinciding with the mean position of the Intertropical Convergence Zone (ITCZ) during the boreal summer.
- The highest moisture contribution (∼39%) during the genesis and LMI was from the tropical Atlantic Ocean north of ITCZ, including ∼11% from the Caribbean Sean and ∼6% from the Gulf of Mexico, followed by the western NATL (WNATL) with ∼23.8% and eastern subtropical NATL (ESNATL) with ∼16.6%.
- ∼10% of moisture was from the Atlantic Ocean south of ITCZ and ∼2% from the Eastern Pacific Ocean (EPAC) during genesis and LMI **[6]**.

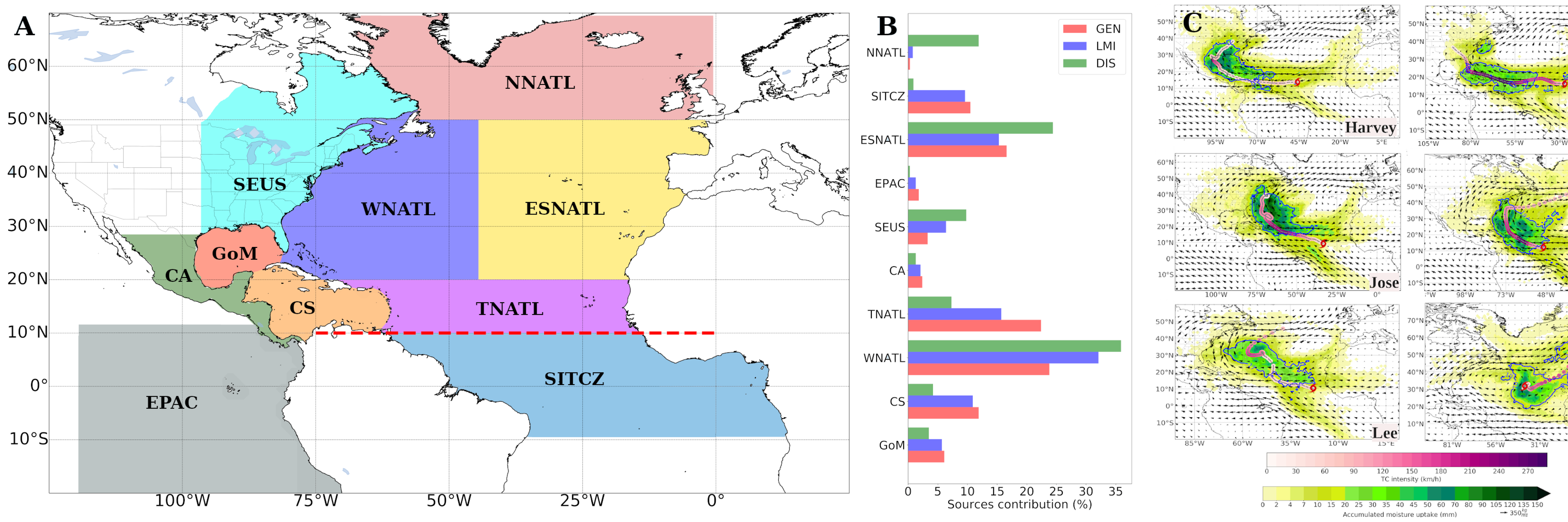


Figure 3. (**A**) Sources regions. (**B**) Moisture contribution for the precipitation of TCs during the genesis (GEN), lifetime maximum intensity (LMI) and dissipation (DIS) stages. The dashed red line denotes the mean position of the Intertropical Convergence Zone (ITCZ) during the summer in the North Hemisphere. (**C**) Moisture uptake pattern along the track of major hurricanes in the 2017 TC season. The average vertically integrated moisture flux is plotted in arrows.

- During the dissipation phase, the moisture sources shifted poleward as TCs moved, with the highest moisture support (∼60.3%) from the subtropical north Atlantic Ocean (WNATL + ESNATL) and ∼11.2% from the NATL north of 50ºN (NNATL).
- The highest moisture uptake generally occurred within 3-5º from the TC trajectory **[7]**.

Conclusions

- The highest moisture uptake was from sources close to TCs positions and was weak from remote sources.
- Local evaporation cannot fully explain the precipitation amounts of TCs, highlighting the role of the secondary circulation in the moisture transport inward.
- This work provides new insights into the TCs' climatology in the NATL basin.
- These findings can also be used as a reference to understand future changes in the origin of precipitation moisture for TCs precipitation under different climate change scenarios.

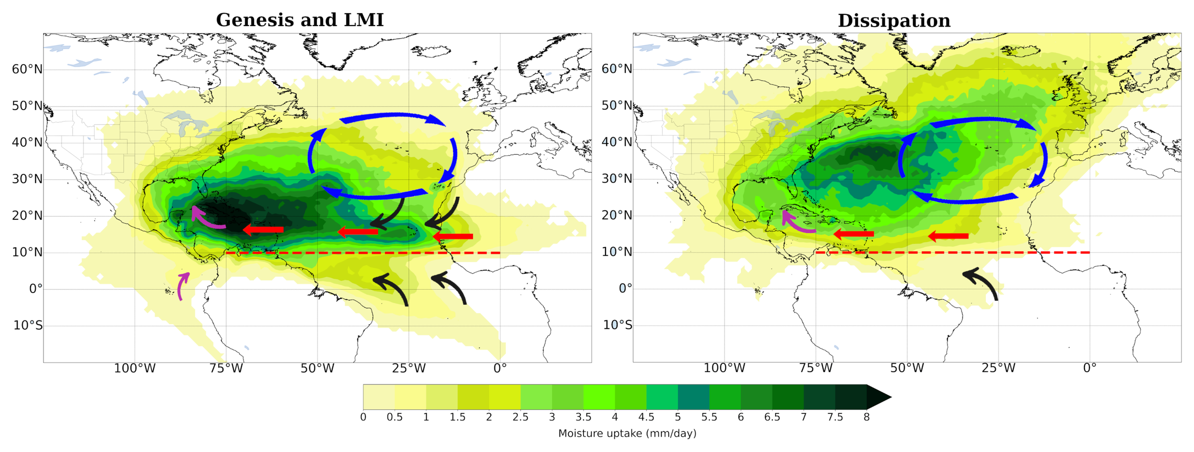


Figure 4. Spatial location of moisture sources for TC precipitation. The blue arrows denotes the North Atlantic Subtropical high, black and red arrows illustrate trade and easterly winds, respectively. Purple arrows shows the Caribbean Low-level jet and CHOCO jet.

References

[1] Emanuel et al. (2004). *J. Atmos. Sci.*, 61, 843–858. doi:10.1175/1520-0469(2004)061<0843:ECOTCI>2.0.CO;2

[2] Montgomery and Smith (2017). *Annu. Rev. Fluid. Mech.*, 49, 541–574. doi:10.1146/annurev-fluid-010816-060022

[3] Läderach and Sodemann (2016). *Geophys. Res. Lett.*, 43, 924– 933. doi:10.1002/2015GL067449

[4] Stohl and James (2005). *J. Hydrometeorol.*, 6, 961–984. doi: 10.1175/JHM470.1

[5] Sodemann et al. (2008). *J. Geophys. Res.*, 113, D03107. doi:10.1029/2007JD008503

[6] Pérez-Alarcón et al. (2022). *J. Hydrometeorol.*, 23(3), 457–472. doi:10.1175/JHM-D-21-0117.1

[7] Pérez-Alarcón et al. (2022). *J. Geophys. Res. Atmos.*, 127, e2021JD035554. doi:10.1029/2021JD035554

[8] Pérez-Alarcón et al. (2023). *Geophys. Res. Lett.*, 50 (7), e2022GL102120. doi:10.1029/2022GL102120

Contact Information

Corresponding Author Albenis Pérez-Alarcón

Edificio Campus da Auga. Universidade de Vigo, Campus Sur. Rúa Canella da Costa da Vela 12, 32004 Ourense, Spain

Email albenis.perez.alarcon@uvigo.es

Web https://ephyslab.uvigo.es/

Acknowledgements

We acknowledge support from PhD grants (UVigo and Xunta de Galicia), Portuguese Science Foundation, Ramón y Cajal postdoctoral fellowship, SETESTRELO project, and computing resources and technical support from CESGA and RES. Travel expenses were partially covered by the Travel Award sponsored by Atmosphere, an open access journal published by MDPI.

EPhysLab Universidade de Vigo Universidad de La Habana