Objectives and approaches used in moisture transport studies in EPhyLab at the University of Vigo.

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The authors acknoledge the support from
EXMERISK PROJECT (TED2021-129152B-C43)
MCIN/AEI y Unión Europea NextGenerationEU/ PRTR)

Environmental Physics Laboratory (EPhysLab)

What is EPhysLab?

- It is a multidisciplinary research group of the University of Vigo, established in 2002.
- It is formed of researchers in both **Atmospheric** and Oceanic Physics, and Computer Engineering
- It is a “Competitive Reference Group of the Xunta de Galicia” since 2006.

Environmental | Physics | Laboratory
EPhysLab

The EPhysLab group during the last decades has put its effort and resources to understand better the source-sink moisture relationships around the globe and the meteorological systems involved.

Researchers focussed on the hydrological cycle and atmospheric processes

https://ephyslab.uvigo.es/moisturetransport/index.php/Group

Staff

Dr. Luis Gimeno

P.I.

Dr. Raquel Nieto

P.I.

- Dr. Rogert Sori, Senior Scientist, EPhysLab-UVigo.
- Dr. Milica Stojanovic, Senior Scientist, EPhysLab-UVigo .
- Dr. Jorge Eiras-Barca, Senior Scientist, CUD-UVigo, Marin, Spain.

- Dr. Albenis Pérez-Alarcón, Post-Doc Scientist EPhysLab-UVigo , now at CGUL-IDL, University of Lisbon.
- Dr. José Carlos Fernández-Alvarez, Post-Doc Scientist, Galicia Supercomputing Center (CESGA), Santiago de Compostela, Spain.
- Dr. Luis Gimeno-Sotelo, Post-Doc Student at EPhysLab-UVigo.

- Patricia Coll-Hidalgo, Ph.D. Student at EPhysLab-UVigo.
- Gleisis Álvarez-Socorro, Ph.D. Student at EPhysLab-UVigo.
- Yiying Wang, Ph.D. Student at EPhysLab-UVigo.
- Jakob Ernst, Ph.D. Student at EPhysLab-UVigo.

Former Collaborators:

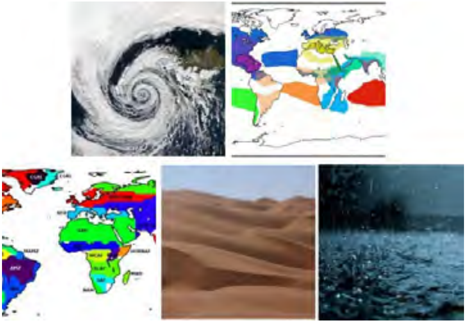
- Dr. Ricardo M. Trigo, Senior Scientist at University of Lisbon, Portugal.
- Dr. Anita Drumond, Senior Post-Doctoral Researcher at USP, Sao Paulo, Brazil.
- Dr. Alexandre Ramos, Senior Scientist at Karlsruhe Institute of Technology (KIT), Germany.
- Dr. Ana M. Durán-Quesada, Senior Scientist at Costa Rica University, Costa Rica.
- Dr. Marta Vázquez, Senior Scientist, EPhysLab-UVigo.

- 3 Senior Researchers
- 3 Postdoc
- 4 PhD Students

Main research topics

https://ephyslab.uvigo.es/moisturetransport/

1. Meteorological systems
2. Global moisture sources
3. Regional moisture sources
4. Droughts and extreme precipitation
5. Moisture sources in the future



EPhysLab has also led reviews on moisture transport

Gimeno L, Stohl A, Trigo RM, Dominguez F, Yoshimura K, Yu L, Drumond A, Durán-Quesada AM, Nieto R (2012), Oceanic and terrestrial sources of continental precipitation, Rev. Geophys., 50, RG4003, doi:10.1029/2012RG000389

Gimeno L, Vázquez M, Eiras-Barca J, Sorí R, Stojanovic M, Algarra I, Nieto R, Ramos AM, Durán-Quesada AM, Dominguez F (2020) Recent progress on the sources of continental precipitation as revealed by moisture transport analysis, Earth Science Reviews 201 https://doi.org/10.1016/j.earscirev.2019.103070

Gimeno,L., Eiras-Barca, J., Durán-Quesada, A.M., Domínguez, F., van der Ent, R., et al. (2021) The residence time of water vapour in the atmosphere, Nature Reviews Earth & Environment. https://doi.org/10.1038/s43017-021-00181-9

Research topics: Lagrangian models

The trajectory-based (Lagrangian) methods have been widely used in EPhysLab to investigate the atmopsheric moisture transport

FLEXPART-ERA-I

FLEXPARTv9.0

- 2 million air parcels
- Global simulations
- Period: 1980-2018
- Input H resolution: 1^0
- Input V resolution: 61 levels
- Output: binary files

FLEXPART-ERA5

FLEXPARTv10.4

- 30 million air parcels
- Global simulations
- Period: 1980-2023
- Input H resolution: 0.5^0
- Input V resolution: 137 levels
- Output: binary files

FLEXPART-WRF

FLEXPART-WRFv3.3.2

- Depending on WRF config
- Regional simulations
- Depending on the study goals
- Input H resolution: WRF
- Input V resolution: WRF
- Output: binary files

The moisture transport analysis provided by these datasets have been fully validated.

Fernández-Alvarez, J.C., Vázquez, M., Pérez-Alarcón, A., Nieto, R., Gimeno, L. (2023) Comparison of Moisture Sources and Sinks Estimated with Different Versions of FLEXPART and FLEXPART-WRF Models Forced with ECMWF Reanalysis Data, Journal of Hydrometeorology, https://doi.org/10.1175/JHM-D-22-0018.1

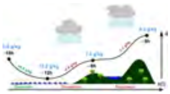
The most up-to-date simulations (FLEXPART-ERA5) are described on Zenodo

Vázquez, M., Alvarez-Socorro, G., Fernández-Alvarez, J. C., Nieto, R., Gimeno, L. (2024). Global FLEXPART-ERA5 simulations using 30 million atmospheric parcels since 1980 [Data set]. Zenodo. https://doi.org/10.5281/zenodo.13682647

Lagrangian moisture tracking approaches

They are based on the Lagrangian water budget equation from Stohl and James (2004,2005)

$$(e - p) = m\frac{dq}{dt} \approx m\frac{\triangle q}{\triangle t}$$



- **From Sodemann et al. (2008)**

The precipitation en route is discounted from all previous moisture uptakes

$$\triangle q_j' = \triangle q_j + \triangle q_i \sum_{k=t_{end}}^{i-6} \frac{\triangle q_j}{\triangle q_k}$$

By amassing the final moisture changes of all the parcels over the area A, the total moisture uptake (MU) was estimated

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

- **From Stohl and James (2004, 2005)**

Considering the $(e - p)$ contribution from all particles at every grid position, the total surface freshwater flux can be computed

$$E - P = \frac{m \sum_{k=1}^{N} (e - p)_k}{A}$$

- $E - P > 0$ Source region
- $E - P < 0$ Sink region

Stohl, A., and P. James (2004). Journal of Hydrometeorology, 5(8), 656–678. https://doi.org/10.1175/1525-7541(2004)005<0656:ALAOTA>2.0.CO;2

Stohl, A., and P. James (2005). Journal of Hydrometeorology, 6(12), 961–984. https://doi.org/10.1175/JHM470.1

Sodemann, H., C. Schwierz, and H. Wernli (2008). Journal of Geophysical Research, 113, D03107, doi:10.1029/2007JD008503.

Moisture tracking tools

- TROVA
- LATTIN

TRansport Of water VApor

Tracking approaches

It is developed in Python and Fortran to study moisture sources and sinks

1. Stohl and James (2004, 2005) - forward and backward mode
2. Sodemann et al. (2008) - Modified threshold values

Fernández-Alvarez, J.C.; Pérez-Alarcón, A.; Nieto, R.; Gimeno, L. (2022). TROVA: TRansport Of water VApor. SoftwareX, 20, 101228, https://doi.org/10.1016/j.softx.2022.101228

Moisture tracking tools

- TROVA
- LATTIN

LATTIN

Lagrangian Atmospheric moisTure and heaT trackINg

Lagrangian **A**tmospheric mois**T**ure and hea**T** track**IN**g

Tracking approaches

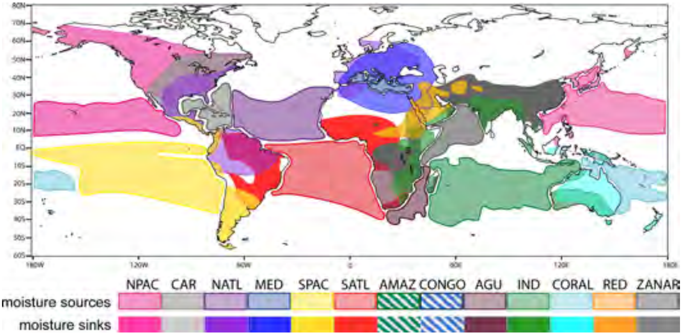
It is developed in Python and Fortran to study moisture sources and sinks

1. Stohl and James (2004, 2005) backward mode
2. Sodemann et al. (2008)
3. Freme and Sodemann (2019)
4. Keune et al. (2022)
5. P´erez-Alarc´on et al. (2022)

It also includes heat tracking approaches

Pérez-Alarcón, A.; Fernández-Alvarez, J.C.; Nieto, R.; Gimeno, L. (2024). LATTIN: A Python-based tool for Lagrangian atmospheric moisture and heat tracking. Software Impacts, 20, 100638. https://doi.org/10.1016/j.simpa.2024.100638

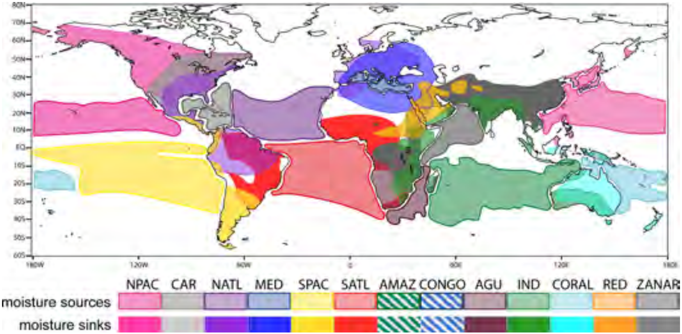
Primary result



- **One of the primary results from EPhsLab studies was identifying the continental sinks based on a forward integration from the main oceanic sources.**

Gimeno, L., Drumond, A., Nieto, R., Trigo, R.M., Stohl, A. (2010) On the origin of continental precipitation, Geophysical Research Letters, 37. https://doi.org/10.1029/2010GL043712

Primary result

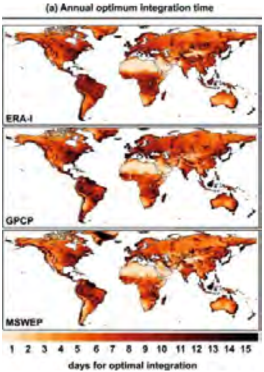


- **This study was highlighted as one of the most important geophysical papers published in 2010 by the AGU (3rd August EOS issue), and a feature paper of EOS was published (Gimeno et al., 2011) by invitation of the editors.**

Gimeno et al. (2011). A Close Look at Oceanic Sources of Continental Precipitation, Eos, 92(23), 193-200

Resulting datasets

- A database of Optimal Integration Times for Lagrangian studies of atmospheric moisture sources and sinks



Nieto, R., Gimeno, L. (2019) A database of optimal integration times for Lagrangian studies of atmospheric moisture sources and sinks. Sci Data 6, 59. https://doi.org/10.1038/s41597-019-0068-8

Resulting datasets

- A database of contributions of major oceanic and terrestrial moisture sources on continental daily extreme precipitation

Specifications Table

Subject	Climatology
Specific subject area	Extreme precipitation, moisture transport, climate change
Type of data	NetCDF data files
How data were acquired	Post-processing of the FLEXPART Lagrangian particle dispersion model outputs
data format	analysed
Parameters for data collection	3D (time, longitude, latitude)) ((E − P < 0)) data with 0.5°x0.5° horizontal resolution achieved daily for the period 1980–2018 considering at every grid point only the Peak Precipitation Month.
Description of data collection	The data was obtained by post-processing FLEXPART model global outputs.
Data source location	Institution: University of Vigo City/Town/Region: Ourense Country: Spain Primary data sources: ECMWF ERA-Interim reanalysis data (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era-interim)
Data accessibility	With the article and in http://dx.doi.org/10.17632/kgvvvx77h8.1
Related research article	Vázquez M., Nieto R., Liberato M.L.R., Gimeno L. (2020) Atmospheric moisture sources associated with extreme precipitation during the peak precipitation month. Weather and Climate Extremes, 30, 100,289. https://doi.org/10.1016/j.wace.2020.100289

Vázquez ,M., Nieto, R., Liberato, M.L.R., Gimeno, L. (2021) A data base of contributions of major oceanic and terrestrial moisture sources on continental daily extreme precipitation, Data in Brief, Vol. 35, 106830. https://doi.org/10.1016/j.dib.2021.106830

Resulting datasets

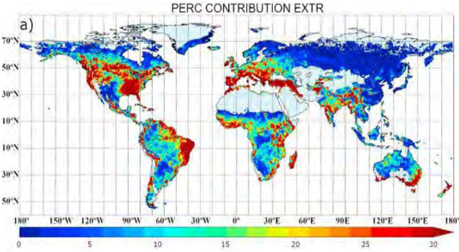
- A database of Global FLEXPART-ERA5 simulations using 30 million atmospheric parcels since 1980

Vázquez, M., Alvarez-Socorro, G., Fernández-Alvarez, J. C., Nieto, R., & Gimeno, L. (2024). Global FLEXPART-ERA5 simulations using 30 million atmospheric parcels since 1980 [Data set]. Zenodo. https://doi.org/10.5281/zenodo.13682647

Results

EPhysLab has investigated...

- extreme precipitation events
- occurrence of droughts



Percentage of contribution from the preferred moisture source for extreme events.

Weather and Climate Extremes 30 (2020) 100289

Contents lists available at ScienceDirect

Weather and Climate Extremes

journal homepage: http://www.elsevier.com/locate/wace

Atmospheric moisture sources associated with extreme precipitation during the peak precipitation month

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[b] Instituto Dom Luiz, Universidade de Lisboa, 1749-016, Lisboa, Portugal

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ARTICLE INFO

Keywords:
Extreme precipitation
Global moisture sources
Lagrangian analysis

ABSTRACT

Understanding moisture transport is crucial for understanding continental precipitation and extreme precipitation events, which are expected to become substantially more frequent under global warming conditions. In this work, the influence of major global moisture sources on extreme continental precipitation during the peak precipitation month is estimated and compared with climatological patterns. The results show a general change in the pattern of contribution of the primary source of precipitation (the source with the highest contribution) during extreme precipitation events. Most primary sources show a general reduction in their area of influence and a notable reduction in their contribution to the total precipitation.

1. Introduction

Extreme events have been an issue of interest in communities worldwide due to their important socioeconomics impacts. The number of flood events in several regions has risen over recent decades (Paprotny et al., 2018), as have the economic losses associated with these events (EASAC, 2018; Willner et al., 2018); these trends are expected to continue in the future (Roudier et al., 2016). The changes observed in extreme events show geographical variability, with observed increases in heavy precipitation events over most continental areas (IPCC et al., 2013). The effects of extreme precipitation events on society are evident and diverse. Although these events can produce natural disasters such as landslides and floods (Tichavský et al., 2019), which have potentially negative implications for crop yields, migration or energy systems (IPCC et al., 2014), several communities are highly dependent on the occurrence of extreme events for their water resources (Paltan et al., 2017). These uneven implications indicate that it is crucial to better understand the factors that influence the occurrence of extreme events to be able to predict them and allow communities to adapt to their possible consequences.

The effects of global warming have modified global rainfall patterns. However, the changes in observed and expected precipitation show high geographical and temporal variability (Adler et al., 2018; Nguyen et al., 2018; Pendergrass et al., 2017). Associated with higher temperatures, the water holding capacity of the atmosphere increases according to the Clausius-Clapeyron (C-C) relationship, in which the expected increase in water holding capacity is 7% per degree temperature increase (Trenberth et al., 2003). Therefore, an intensification of precipitation is expected. A global mean precipitation pattern cannot be estimated by scaling the C-C relationship; however, extreme precipitation events have a more consistent global relationship (Held and Soden, 2006; Trenberth, 2011). Both observed and predicted extreme events increase under global warming more than mean precipitation (e.g., Myhre et al., 2019; Donat et al., 2016; Papalexiou and Montanari, 2019). For example, according to Myhre et al. (2019), the occurrence of extreme precipitation events would double for each degree of temperature increase if historical trends continue. In general, this behaviour could be caused by the fraction of water vapor converted into rain during such events. During extreme precipitation events, most of the water vapor is precipitated out and, due to the higher moisture availability predicted by the C-C relationship, the upper percentile precipitation is expected to scale with temperature (Allen and Ingram 2002; Pall et al., 2007). However, important latitudinal differences in the response of extreme precipitation events to global warming were observed. These discrepancies are mostly derived from a dynamical contribution (O'Gorman and Schneider, 2009), as vertical motion is significantly relevant to the occurrence of extreme events (Duffy et al., 2020; Li and O'Gorman, 2020).

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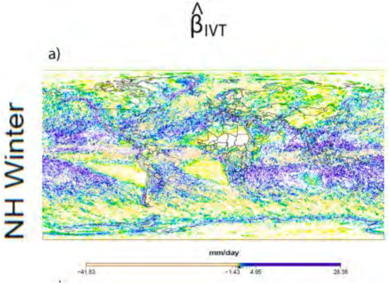
https://doi.org/10.1016/j.wace.2020.100289
Received 29 June 2020; Received in revised form 15 October 2020; Accepted 5 November 2020
Available online 10 November 2020
2212-0947/© 2020 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

M. Vázquez, R. Nieto, M.L.R. Liberato, L. Gimeno (2020) Atmospheric moisture sources associated with extreme precipitation during the peak precipitation month, Weather and Climate Extremes, Vol. 30, 100289; DOI: https://doi.org/10.1016/j.wace.2020.100289

Results

EPhysLab has investigated...

- extreme precipitation events
- occurrence of droughts



Spatial patterns of the significant values of the estimated coefficient that represents the influence of IVT on maximum precipitation according to the GEV analysis (95% confidence level), for Northern Hemisphere Winter (December–February) for the period 1981–2020.

Weather and Climate Extremes

Where does the link between atmospheric moisture transport and extreme precipitation matter?

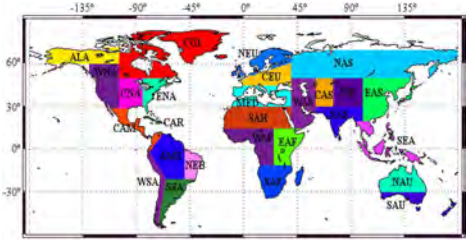
Luis Gimeno-Sotelo, Luis Gimeno

Gimeno-Sotelo, L., & Gimeno, L. (2023). Where does the link between atmospheric moisture transport and extreme precipitation matter?. Weather and Climate Extremes, 39, 100536.

Results

EPhysLab has investigated...

- extreme precipitation events
- occurrence of droughts



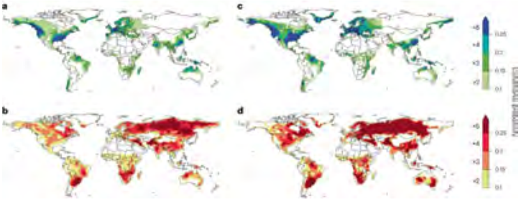

LINKING ANOMALOUS MOISTURE TRANSPORT AND DROUGHT EPISODES IN THE IPCC REFERENCE REGIONS

Drumond, A., Stojanovic, M., Nieto, R., Vicente-Serrano, S.M., Gimeno, L. (2019) Linking Anomalous Moisture Transport and Drought Episodes in the IPCC Reference Regions, Bulletin of the American Meteorological Society, 10(8), 1481–1498. https://doi.org/10.1175/BAMS-D-18-0111.1

Results

EPhysLab has investigated...

- extreme precipitation events
- occurrence of droughts




nature water

Article

Unravelling the origin of the atmospheric moisture deficit that leads to droughts

Received: 11 May 2023
Accepted: 21 December 2023
Published online: 6 February 2024
Check for updates

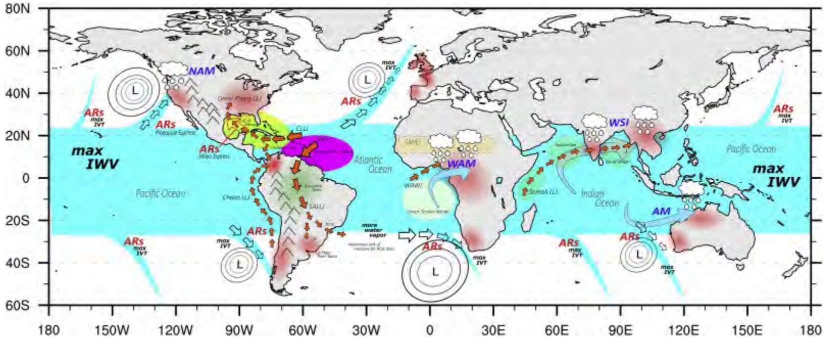
Luis Gimeno-Sotelo, Rogert Sorí, Raquel Nieto, Sergio M. Vicente-Serrano & Luis Gimeno

Drought is one of the most catastrophic natural hazards, and precipitation plays a major role in the development and intensification of drought events. The amount of precipitation resulting from humidity transported from a given moisture source can be key in revealing the origin of the atmospheric moisture deficit underlying drought occurrence. Here this study demonstrates, for the first time, the predominant role of moisture transport deficit in drought genesis. In most land areas, the estimated conditional probability of drought given an equivalent moisture deficit received either from the ocean or from the continents is higher than 10%. This probability is over 15% in the regions where the main atmospheric moisture transport mechanisms are active and over 20% in some hotspot regions, such as central-east North America, south-east South America and east Europe, where lower incoming moisture is almost synonymous with drought occurrence. Our results indicated that the contribution deficit of the dominant moisture source to the precipitation of a region could improve the predictability of droughts, with enormous hydrological, socioeconomic and environmental implications.

Gimeno-Sotelo, L., Sorí, R., Nieto, R. Vicente-Serrano S. and Gimeno L. Unravelling the origin of the atmospheric moisture deficit that leads to droughts. Nat Water 2, 242–253 (2024). https://doi.org/10.1038/s44221-023-00192-4

Weather Systems

EPhysLab has also investigated the moisture transport mechanisms associated with different weather systems



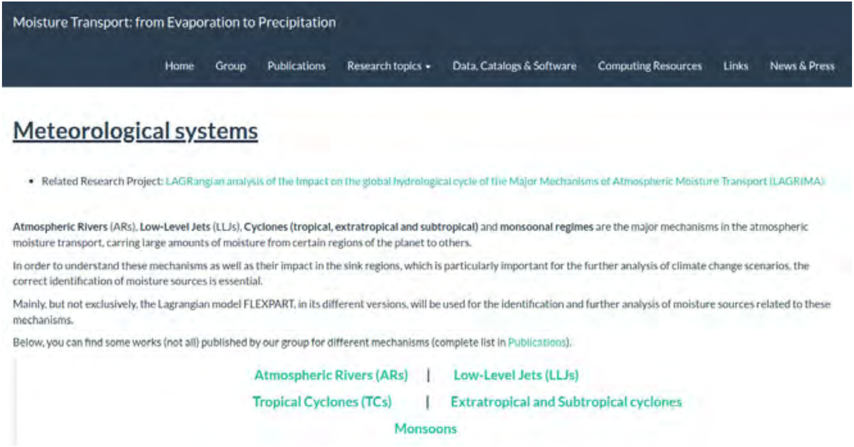
Major mechanisms of moisture transport at the global scale [from Gimeno et al. (2020)]

- Atmospheric rivers
- Low Level jets
- Tropical Cyclones
- Monsoons
- Extratropical and Subtropical cyclones

Gimeno et al. (2020) Recent progress on the sources of continental precipitation as revealed by moisture transport analysis, Earth Science Reviews 201 https://doi.org/10.1016/j.earscirev.2019.103070

The list of articles related with these studies can be found at

https://ephyslab.uvigo.es/moisturetransport/index.php/Meteorological_systems



Weather Systems and Mechanisms: Atmospheric Rivers

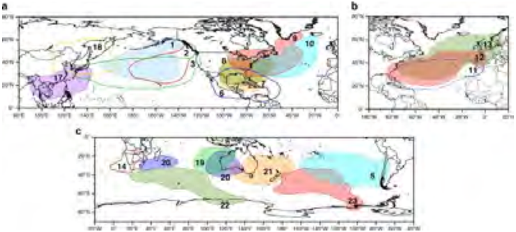

JGR Atmospheres

Changes in Moisture Sources of Atmospheric Rivers Landfalling the Iberian Peninsula With WRF-FLEXPART

Significant increase of global anomalous moisture uptake feeding landfalling Atmospheric Rivers

Atmospheric rivers moisture sources from a Lagrangian perspective

1. Fernández-Alvarez et al. (2023)
2. Algarra et al., (2020)
3. Ramos et al., (2016)



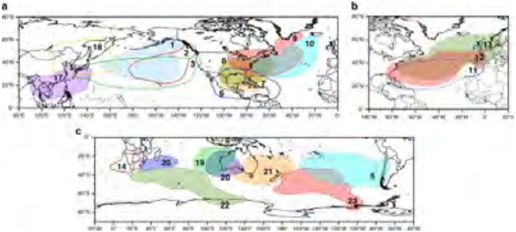
Fernández-Alvarez, J.C., Pérez-Alarcón, A., Eiras-Barca, J., Ramos, A.M., Rahimi-Esfarjani, S., Nieto, R., Gimeno, L. (2023). Changes in moisture sources of atmospheric rivers landfalling the Iberian Peninsula with WRF-Flexpart, Journal of Geophysical Research: Atmospheres, doi: 10.1029/2022JD037612

Algarra, I., Nieto, R., Ramos, A.M., Eiras-Barca, J., Trigo, R.M., Gimeno, L. (2020). Significant increase of global anomalous moisture uptake feeding landfalling Atmospheric Rivers, Nature Communications 11, 5082, https://doi.org/10.1038/s41467-020-18876-w

Ramos, A.M., Nieto, R., Tomée, R., Gimeno, L., Trigo, R.M., Liberato, M.L.R., Lavers, D.A. (2016) Atmospheric rivers moisture sources from a Lagrangian perspective, Earth System Dynamics, 7, 371-384

Weather Systems and Mechanisms: Atmospheric Rivers

1. Fernández-Alvarez et al. (2023)
2. Algarra et al., (2020)
3. Ramos et al., (2016)



Key Points

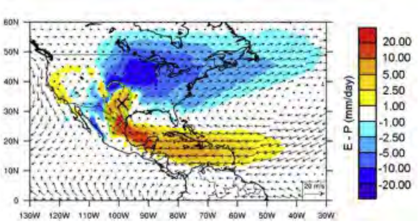
1 It is projected a northward shift of the main moisture source regions for AR in the IP in summer and fall, being particularly noticeable by the end of the 21st century.

2 It is found an enhanced evapotranspiration rates in association with landfalling atmospheric river events.

3 The major climatological areas for the anomalous moisture uptake extend along the subtropical North Atlantic, from the Florida Peninsula to each sink region.

Weather Systems and Mechanisms: Nocturnal Low Level Jets

- Algarra et al. (2019)



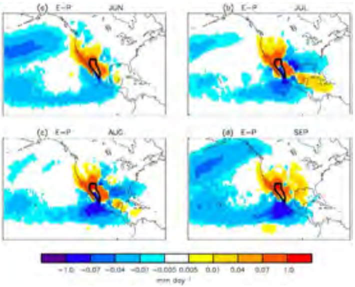
Key Points

- It is provided the location of the main moisture sinks and sources associated with each LLJ.
- Changes between days of jet and no-jet are reported geographically in terms of evaporation and precipitation.
- A brief appointment is done in terms of water scarcity and the association with the LLJs occurrence.

Algarra, I., Eiras-Barca, J., Nieto, R., Gimeno, L. (2019) Global climatology of nocturnal low-level jets and associated moisture sources and sinks, Atmospheric Research 229, 39-59. doi:10.1016/j.atmosres.2019.06.016

Weather Systems and Mechanisms: Monsoons

- Ordoñez et al. (2019)




Earth System Dynamics
EGU

Climatological moisture sources for the Western North American Monsoon through a Lagrangian approach: their influence on precipitation intensity

1 Introduction

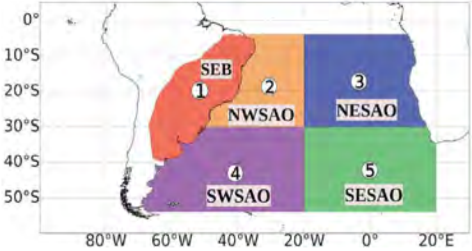
Key Points

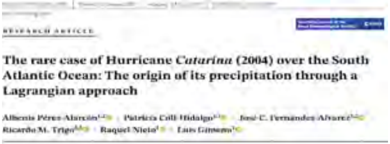
- During the wet season, the western North American monsoon region itself is on average the main evaporative source, followed by the Gulf of California.
- Moisture transport from the Caribbean Sea and the Gulf of Mexico is found to influence regional-scale rainfall during the monsoon peak

Ordóñez et al. (2019) Climatological moisture sources for the Western North American Monsoon through a Lagrangian approach: their influence on precipitation intensity, Earth System Dynamics 10, 59-72, doi: https://doi.org/10.5194/esd-10-59-2019

Weather Systems and Mechanisms: Subtropical Cyclones

These studies are focused on the South Atlantic basin




RESEARCH ARTICLE

The rare case of Hurricane *Catarina* (2004) over the South Atlantic Ocean: The origin of its precipitation through a Lagrangian approach

Albenis Pérez-Alarcón | Patricia Coll-Hidalgo | José C. Fernández-Alvarez | Ricardo M. Trigo | Raquel Nieto | Luis Gimeno


RESEARCH ARTICLE

Quantifying the related precipitation and moisture sources in the lifecycle of subtropical cyclones in the South Atlantic basin

Albenis Pérez-Alarcón | Patricia Coll-Hidalgo | José C. Fernández-Alvarez | Rogert Sorí | Rosmeri Porfírio da Rocha | Michelle Simões Reboita | Raquel Nieto | Luis Gimeno

Key Points

The analysis highlights the role of external sources in moisture support.

∼42 %–47 % of the moisture that reached the SCs precipitates

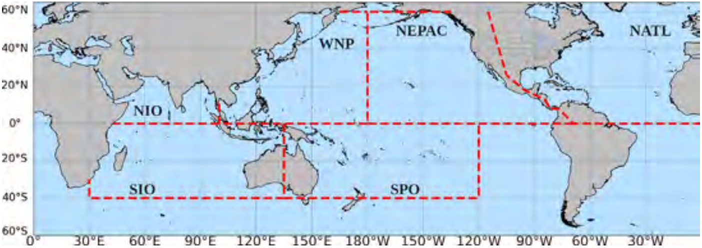
The northwestern SAO is the principal moisture source for SCs, with a quasi-constant contribution along the year.

Pérez-Alarcón, A. et al. (2023). The rare case of Hurricane Catarina (2004) over the South Atlantic Ocean: The origin of its precipitation through a Lagrangian approach. Q. J. R. Meteorol. Soc., 149 (752), 1038–1055. doi:10.1002/qj.4452

Pérez-Alarcón, A. et al. (2024). Quantifying the related precipitation and moisture sources in the lifecycle of subtropical cyclones in the South Atlantic basin. Q. J. R. Meteorol. Soc., 150(762), 2765–2782. doi:10.1002/qj.4734

Weather Systems and Mechanisms: Tropical Cyclones

Moisture sources for tropical cyclones has been investigated in each of the ocean basins



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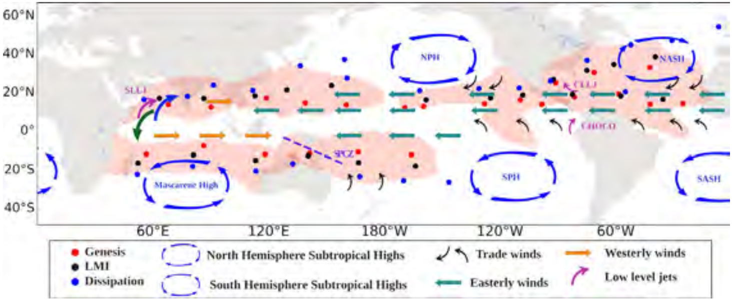


Schematic representation of moisture sources and transport mechanisms

Key Points

The moisture transport is controlled by the characteristic of the atmospheric circulation in each basin.

Hurricanes category 1 and 2 gained more moisture to produce precipitation than in any other stage of development.

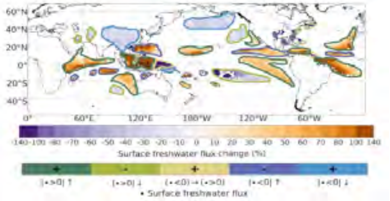
RI TCs gained more moisture from local sources than those undergoing slow intensification (SI). Total MU was approximately three times higher during RI than SI.

Tropical cyclones gained the highest amount of moisture from sources within 3–5° from their pathways (NATL basin).

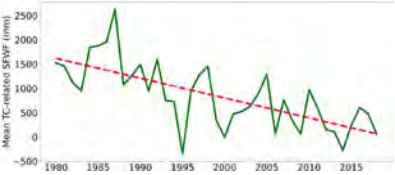
The moisture was predominately originated from the south and southwest sectors during PRE-extratropical transition (ET) and from the southwest-west during POST-ET in the NATL basin

Weather Systems and Mechanisms: Tropical Cyclones

Impacts of tropical cyclones on the global water budget



Surface freshwater fluxes anomalies in (%) during TCs.



Annual global TC-related surface freshwater flux (SFWF) and the dashed red line shows its statistically significant (p<0.05)

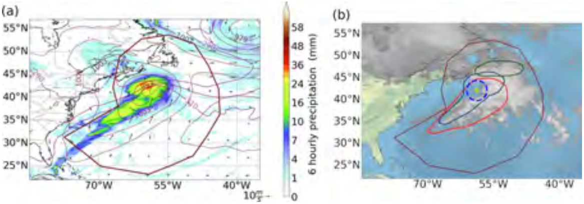

ARTICLE

Impacts of tropical cyclones on the global water budget

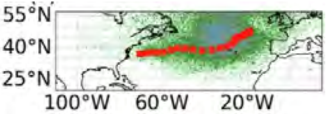
Pérez-Alarcón, A., Coll-Hidalgo, P., Fernández-Alvarez, J.C. et al. Impacts of tropical cyclones on the global water budget. npj Clim Atmos Sci 6, 212 (2023). https://doi.org/10.1038/s41612-023-00546-5

Weather Systems and Mechanisms: ExtraTropical cyclones

Moisture sources for extratropical cyclones has been investigated in the North Atlantic ocean basin



ETC shape modelling for the EC02902 case on February 8, 2002, at 1200 UTC over the North Atlantic (NATL) basin.



Moisture uptake for a radius target region over the entire lifecycle,ranging from March 21 at 0600 UTC to March 27 at 0000UTC

Coll-Hidalgo, P., Gimeno-Sotelo, L., Fernández-Alvárez, J.C. Nieto, R. and Gimeno, L.. North Atlantic Extratropical Cyclone Tracks and Lagrangian-Derived Moisture Uptake Dataset. Sci Data 11, 1258 (2024). https://doi.org/10.1038/s41597-024-04091-5

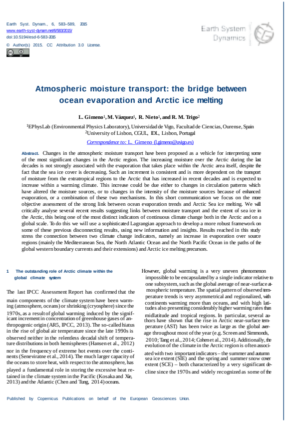
Key Points

In this study, we present a database for North Atlantic ETC tracks and a Lagrangian-Derived Moisture Uptake Dataset, both of which are derived from dynamically downscaled ERA5 reanalysis data. We provide moisture parameters such as the total moisture uptake and its vertical distribution by layer, and shapefiles of ETC structures, to facilitate further studies in this area. Our data have been thoroughly validated to ensure that the storm tracks and their characteristics are accurately represented in the model without distortion. Additionally, we conduct a series of experiments to demonstrate the rigour and quality of the methods employed to generate the data.

Other results from EPhysLab

Several regional studies have also been performed.

- Polar Regions
- River basins
- Moisture sources for Continental Climate Regions
- Ecoregions


Earth Syst. Dynam., 6, 583–589, 2015
www.earth-syst-dynam.net/6/583/2015/
doi:10.5194/esd-6-583-2015

Earth System Dynamics

Atmospheric moisture transport: the bridge between ocean evaporation and Arctic ice melting

L. Gimeno[1], M. Vázquez[1], R. Nieto[1], and R. M. Trigo[2]
[1]EPhysLab (Environmental Physics Laboratory), Universidad de Vigo, Facultad de Ciencias, Ourense, Spain
[2]University of Lisbon, CGUL, IDL, Lisbon, Portugal
Correspondence to: L. Gimeno (l.gimeno@uvigo.es)

Abstract. Changes in the atmospheric moisture transport have been proposed as a vehicle for interpreting some of the most significant changes in the Arctic region. The increasing moisture over the Arctic during the last decades is not strongly associated with the evaporation that takes place within the Arctic area itself, despite the fact that the sea ice cover is decreasing. Such an increment is consistent and is more dependent on the transport of moisture from the extratropical regions to the Arctic that has increased in recent decades and is expected to increase within a warming climate. This increase could be due either to changes in circulation patterns which have altered the moisture sources, or to changes in the intensity of the moisture sources because of enhanced evaporation, or a combination of these two mechanisms. In this short communication we focus on the more objective assessment of the strong link between ocean evaporation trends and Arctic Sea ice melting. We will critically analyse several recent results suggesting links between moisture transport and the extent of sea ice in the Arctic, this being one of the most distinct indicators of continuous climate change both in the Arctic and on a global scale. To do this we will use a sophisticated Lagrangian approach to develop a more robust framework on some of these previous disconnecting results, using new information and insights. Results reached in this study stress the connection between two climate change indicators, namely an increase in evaporation over source regions (mainly the Mediterranean Sea, the North Atlantic Ocean and the North Pacific Ocean in the paths of the global western boundary currents and their extensions) and Arctic ice melting precursors.

1 The outstanding role of Arctic climate within the global climate system

The last IPCC Assessment Report has confirmed that the main components of the climate system have been warming (atmosphere, oceans) or shrinking (cryosphere) since the 1970s, as a result of global warming induced by the significant increment in concentration of greenhouse gases of anthropogenic origin (AR5, IPCC, 2013). The so-called hiatus in the rise of global air temperature since the late 1990s is observed neither in the relentless decadal shift of temperature distributions in both hemispheres (Hansen et al., 2012) nor in the frequency of extreme hot events over the continents (Seneviratne et al., 2014). The much larger capacity of the oceans to store heat, with respect to the atmosphere, has played a fundamental role in storing the excessive heat retained in the climate system in the Pacific (Kosaka and Xie, 2013) and the Atlantic (Chen and Tung, 2014) oceans.

However, global warming is a very uneven phenomenon impossible to be encapsulated by a single indicator relative to one subsystem, such as the global average of near-surface atmospheric temperature. The spatial pattern of observed temperature trends is very asymmetrical and regionalized, with continents warming more than oceans, and with high latitudes also presenting considerably higher warming rates than midlatitude and tropical regions. In particular, several authors have shown that the rise in Arctic near-surface temperature (AST) has been twice as large as the global average throughout most of the year (e.g. Screen and Simmonds, 2010; Tang et al., 2014; Cohen et al., 2014). Additionally, the evolution of the climate in the Arctic region is often associated with two important indicators – the summer and autumn sea ice extent (SIE) and the spring and summer snow cover extent (SCE) – both characterized by a very significant decline since the 1970s and widely recognized as some of the

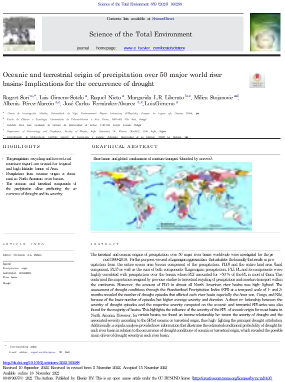
Published by Copernicus Publications on behalf of the European Geosciences Union.

Gimeno et al. (2015) Atmospheric moisture transport: the bridge between ocean evaporation and Arctic ice melting, Earth System Dynamics, 2, 583-589. doi:10.5194/esd-6-583-2015

Other results from EPhysLab

Several regional studies have also been performed.

- Polar Regions
- River basins
- Moisture sources for Continental Climate Regions
- Ecoregions


Science of the Total Environment 859 (2023) 160288

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Oceanic and terrestrial origin of precipitation over 50 major world river basins: Implications for the occurrence of drought

Rogert Sorí [a,*], Luis Gimeno-Sotelo [a], Raquel Nieto [a], Margarida L.R. Liberato [b,c], Milica Stojanovic [a,d], Albenis Pérez-Alarcón [a,e], José Carlos Fernández-Alvarez [a,e], Luis Gimeno [a]

[a] Centro de Investigación Mariña, Universidade de Vigo, Environmental Physics Laboratory (EPhysLab), Campus As Lagoas s/n, Ourense 32004, Spain
[b] Escola de Ciências e Tecnologia, Universidade de Trás-os-Montes e Alto Douro, 5001-801 Vila Real, Portugal
[c] Instituto Dom Luiz, Faculdade de Ciências da Universidade de Lisboa, 1749-016 Campo Grande, Portugal
[d] Department of Meteorology and Geophysics, Faculty of Physics, Sofia University "St. Kliment Ohridski", 1164 Sofia, Bulgaria
[e] Departamento de Meteorología, Instituto Superior de Tecnologías y Ciencias Aplicadas, Universidad de La Habana, 10400 La Habana, Cuba

HIGHLIGHTS

- The precipitation recycling and terrestrial moisture export are crucial for tropical and high latitudes basins of Asia.
- Precipitation from oceanic origin is dominant in North American river basins.
- The oceanic and terrestrial components of the precipitation allow attributing the occurrence of drought and its severity.

GRAPHICAL ABSTRACT

River basins and global mechanisms of moisture transport (denoted by arrows).

ARTICLE INFO

Editor: Fernando A.L. Pacheco

Keywords:
Precipitation origin
Lagrangian precipitation
River basins
Drought

ABSTRACT

The terrestrial and oceanic origins of precipitation over 50 major river basins worldwide were investigated for the period 1980–2018. For this purpose, we used a Lagrangian approximation that calculates the humidity that results in precipitation from the entire ocean area (ocean component of the precipitation, PLO) and the entire land area (land component, PLT) as well as the sum of both components (Lagrangian precipitation, PL). PL and its components were highly correlated with precipitation over the basins, where PLT accounted for >50 % of the PL in most of them. This confirmed the importance assigned by previous studies to terrestrial recycling of precipitation and moisture transport within the continents. However, the amount of PLO in almost all North American river basins was highlighted. The assessment of drought conditions through the Standardized Precipitation Index (SPI) at a temporal scale of 1- and 3-months revealed the number of drought episodes that affected each river basin, especially the Amazon, Congo, and Nile, because of the lower number of episodes but higher average severity and duration. A direct relationship between the severity of drought episodes and the respective severity computed on the oceanic and terrestrial SPI series was also found for the majority of basins. This highlights the influence of the severity of the SPI of oceanic origin for most basins in North America. However, for certain basins, we found an inverse relationship between the severity of drought and the associated severity according to the SPI of oceanic or terrestrial origin, thus highlighting the principal drought attribution. Additionally, a copula analysis provided new information that illustrates the estimated conditional probability of drought for each river basin in relation to the occurrence of drought conditions of oceanic or terrestrial origin, which revealed the possible main driver of drought severity in each river basin.

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http://dx.doi.org/10.1016/j.scitotenv.2022.160288
Received 10 September 2022; Received in revised form 5 November 2022; Accepted 15 November 2022
Available online 18 November 2022

Sorí et al. (2023) Oceanic and terrestrial origin of precipitation over 50 major world river basins: Implications for the occurrence of drought, Science of The Total Environment, Vol. 859, Part 2; DOI: 10.1016/j.scitotenv.2022.160288

Other results from EPhysLab

Several regional studies have also been performed.

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- River basins
- Moisture sources for Continental Climate Regions
- Ecoregions

Nieto et al. (2014), A catalog of moisture sources for continental climatic regions, Water Resour. Res., 50, 5322–5328, doi:10.1002/2013WR013901.

Other results from EPhysLab

Several regional studies have also been performed.

- Polar Regions
- River basins
- Moisture sources for Continental Climate Regions
- Ecoregions


remote sensing

Article

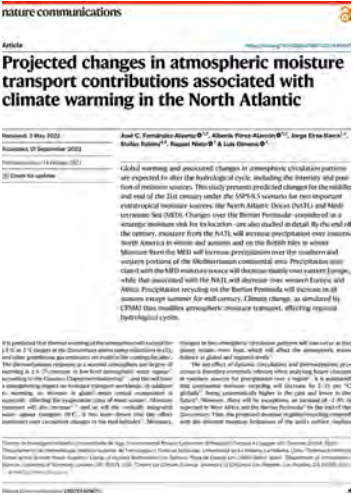
Vegetation Greenness Sensitivity to Precipitation and Its Oceanic and Terrestrial Component in Selected Biomes and Ecoregions of the World

Stojanovic et al. (2023) Vegetation Greenness Sensitivity to Precipitation and Its Oceanic and Terrestrial Component in Selected Biomes and Ecoregions of the World, Remote Sensing, 15 (19), 4706. https://doi.org/10.3390/rs15194706

Moisture sources in the future

Investigating future changes in moisture sources contributions has been addressed for the first time in EPhysLab

Moisture sources in the future


nature communications

Article

Projected changes in atmospheric moisture transport contributions associated with climate warming in the North Atlantic

Investigating future changes in moisture sources contributions has been addressed for the first time in EPhysLab

- FLEXPART-WRF has been used to simulate future changes in moisture transport contributions in the North Atlantic in the context of global warning

Fernández - Alvarez, J.C.; Pérez-Alarcón, A.; Eiras-Barca,J.; Rahimi, S.; Nieto, R.; Gimeno, L. (2023). Projected changes in atmospheric moisture transport contributions associated with climate warming in the North Atlantic. Nature Communications volume, 14, 6476. https://doi.org/10.1038/s41467-023-41915-1

Moisture sources in the future

Earth Systems and Environment
https://doi.org/10.1007/s41748-024-00532-8

ORIGINAL ARTICLE

Future Changes in the Contribution of Gulf of Mexico-Caribbean Sea Moisture Source: Impacts on Regional Precipitation Patterns

José C. Fernandez-Alvarez[1,2,3] · Gleisis Alvarez-Socorro[1] · Ana María Durán-Quesada[4] · Raquel Nieto[1,2] · Luis Gimeno[1,2]

Received: 3 July 2024 / Revised: 12 November 2024 / Accepted: 20 November 2024

Abstract
Central America (CA) and the eastern United States (US) is a region with a significant contribution from the Gulf of Mexico-Caribbean Sea (GM_CS) moisture source. In the context of climate change, sink patterns associated with this source may change implying significant changes in this region. Hence, this study determined future changes in the contributions to precipitation (PCs) associated with GM_CS. So, a dynamic downscaling methodology was considered using the regional climate model WRF-ARW and FLEXPART-WRF, forced with the CESM2 climate model. Specifically, a decrease in the GM_CS contribution in the CA region was projected for all seasons considered, showing a southward shift in the contribution pattern. Additionally, the sink pattern was projected to increase, but the area was projected to decrease, mainly by the end of the century, except in the autumn. In addition, for the southeastern US region, an increase in PCs in spring and autumn was projected for end-century, but a decrease in PCs by more than 40% in the summer months was projected. However, for the northeastern US, changes in PCs were amplified for both the mid- and end-century relative to the southeastern US region, with an increase projected for most periods, except for a slight decrease in the summer of 10%.

Keywords Climatic Models · Dynamic Downscaling · Future Changes · Moisture Source · Precipitation

1 Introduction

Investigating future changes in moisture sources contributions has been addressed for the first time in EPhysLab

- FLEXPART-WRF has been used to simulate future changes in moisture transport contributions in the North Atlantic in the context of global warning

Fernández-Alvarez, J.C., Alvarez-Socorro, G., Durán-Quesada, A.M., Nieto, r. and Gimeno L. Future Changes in the Contribution of Gulf of Mexico-Caribbean Sea Moisture Source: Impacts on Regional Precipitation Patterns. Earth Syst Environ (2024). https://doi.org/10.1007/s41748-024-00532-8

Moisture sources in the future


ORIGINAL ARTICLE

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES

Projected changes in moisture sources and sinks affecting the US East Coast and the Caribbean Sea

Jorge Eiras-Barca[1,2] | José Carlos Fernández-Alvarez[1,2,4] | Gleisis Alvarez-Socorro[1] | Stefan Rahimi-Esfarjani[5] | Pedro Carrasco-Pena[2] | Raquel Nieto[1,2] | Luis Gimeno[1,2]

Abstract

This study uses a combination of the FLEXPART Lagrangian dispersion model with the Weather Research and Forecasting (WRF) mesoscale Eulerian model (FLEXPART-WRF) to analyze the expected mid- to late century changes in the moisture sources and sinks of the North American East Coast (ENA) and the Gulf of Mexico (GM), as well as their most relevant abrupt moisture transport events: atmospheric rivers (ARs) and low level jets of the Great Plains (GPLLJ) and the Caribbean (CLLJ). Both the ENA and GM are expected to increase in importance as moisture source regions over the century, both overall and in their contributions to the ARs and both LLJs. A notable increase in the intensity of the GPLLJ and CLLJ moisture sources is also observed. All of these behaviors are neither spatially nor temporally homogeneous and need to be analyzed in a seasonal context. Likewise, the most relevant signs of change are practically all observed by the end of the century. Other noteworthy behaviors are also observed, including an increase in humidity associated with landfalling atmospheric river events in the winter months, or a notable latitudinal shift of the CLLJ's area of influence. These findings are best understood within the context of an observed increase in both continental precipitation and sea surface temperature.

KEYWORDS
CMIP6, FLEXPART-WRF, moisture sources, moisture transport

INTRODUCTION

Investigating future changes in moisture sources contributions has been addressed for the first time in EPhysLab

- FLEXPART-WRF has been used to simulate future changes in moisture transport contributions in the North Atlantic in the context of global warning

Eiras-Barca, J., Fernández-Alvarez, J. C., Alvarez-Socorro, G., Rahimi-Esfarjani, S., Carrasco-Pena, P., Nieto, R., & Gimeno, L. (2025). Projected changes in moisture sources and sinks affecting the US East Coast and the Caribbean Sea. Ann NY Acad Sci., 1–19. https://doi.org/10.1111/nyas.15289

Moisture sources in the future

Key Points

By the end of the century, moisture from the NATL will increase precipitation over eastern North America in winter and autumn and on the British Isles in winter.

Moisture from the MED will increase precipitation over the southern and western portions of the Mediterranean continental area. Precipitation associated with the MED moisture source will decrease mainly over eastern Europe, while that associated with the NATL will decrease over western Europe and Africa.

Precipitation recycling on the Iberian Peninsula will increase in all seasons except summer for mid-century.

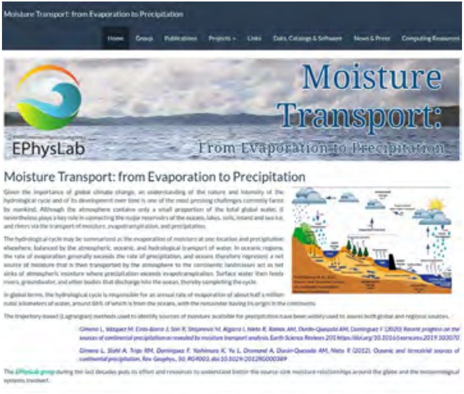
The Gulf of Mexico- Caribbean Sea (GM_CS) is expected to increase in importance as moisture source regions over the century for Eastern North America, both overall and in their contributions to the ARs and both LLJs. A notable increase in the intensity of the GPLLJ and CLLJ moisture sources is also observed.

A decrease in the GM_CS contribution in the Centro America region was projected for all seasons considered, showing a southward shift in the contribution pattern.

EPysLab in numbers

Scientific results linked to moisture transport

- Doctoral Thesis: 11
- Master Thesis: 3
- Publications: 161



https://ephyslab.uvigo.es/moisturetransport/

Current research topics

- Changes in the moisture sources' contribution to tropical cyclones, droughts, and extreme precipitation in the European and American regions under global warming.
- Quantifying the moisture transport anomalies during compound drought and heat wave events in the Iberian Peninsula
- Deficit of moisture transport and its linkages with droughts in the Central and South America and Caribbean regions.
- Moisture transport and associated mechanims for extreme precipitation events in South America.
- Impacts of moisture transport on major continental floods.
- Continuous improvements of LATTIN's features and capabilities

Research Projects

All of the EPhysLab studies has been associated with research projects

- **Present and future climate humidity transport over Central and South America: Mechanisms, extremes and attribution of changes. Funded by Xunta de Galicia (Grant: ED431F-2024/03), Spain**
- **High-resolution assessment of North Atlantic moisture transport in current climate and CMIP-6 future projections. Funded by Ministerio de Ciencia, Innovaci´on y Universidades (Grant: PID2021-122314OB-I00), Spain**
- LAGRangian analysis of the Impact on the global hydrological cycle of the Major Mechanisms of Atmospheric Moisture Transport (LAGRIMA). Funded by Ministerio de Econom´ıa y Competitividad. (Grant: RTI2018-095772-B-I00), Spain
- Moisture Tranport (TRAMO). Funded by Ministerio de Econom´ıa y Competitividad. Spain.
- Droughts and Moisture Transport (SETH)
- Moisture Sources for Continental Climatic Regions (CCRs)
- Atmospheric moisture transport, the bridge between ocean evaporation and Arctic Sea ice melting (EVOCAR)

EPhysLab is contributing to the **"Moisture tracking intercomparison project".**

Objectives and approaches used in moisture transport studies in EPhyLab at the University of Vigo.

Environmental Physics Laboratory, Centro de Investigación Mariña, Universidade de Vigo, Spain