EXTREME PRECIPITATION EVENTS IN THE MEDITERRANEAN AREA

A CONTRASTING LAGRANGIAN AND EULERIAN APPROACH FOR MOISTURE EVAPORATION SOURCES IDENTIFICATION

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What is a Heavy Precipitation Event (HPE)?

These occasional episodes can result in **more than 200 mm** of rainfall in **less than 24 h**. This phenomena led to **flash floods** which are a major environmental problem causing **social and economic losses**.

The **main cause** in the generation of HPEs is the **contrast between the warm and moist air with a low-pressure system**. Moreover, **orography** also plays a very important role.

For the Mediterranean region, most cases occur in **autumn**, due to the **combination** of a southward displacement of **the jet stream** with the **warm sea surface temperature**. Jet stream displacement can result in complex structures such as **Atlantic lows** or **cut-o-lows.**

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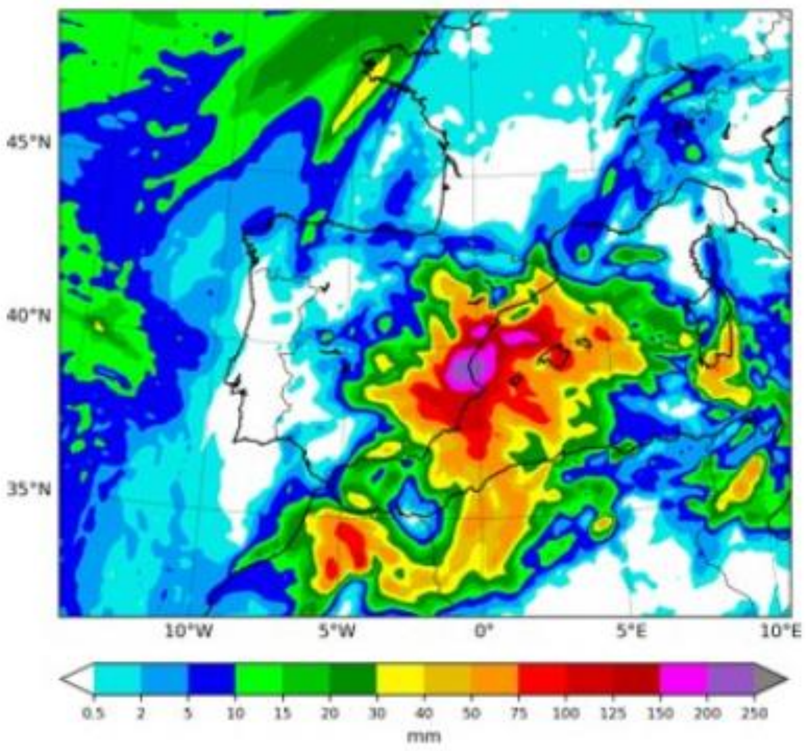
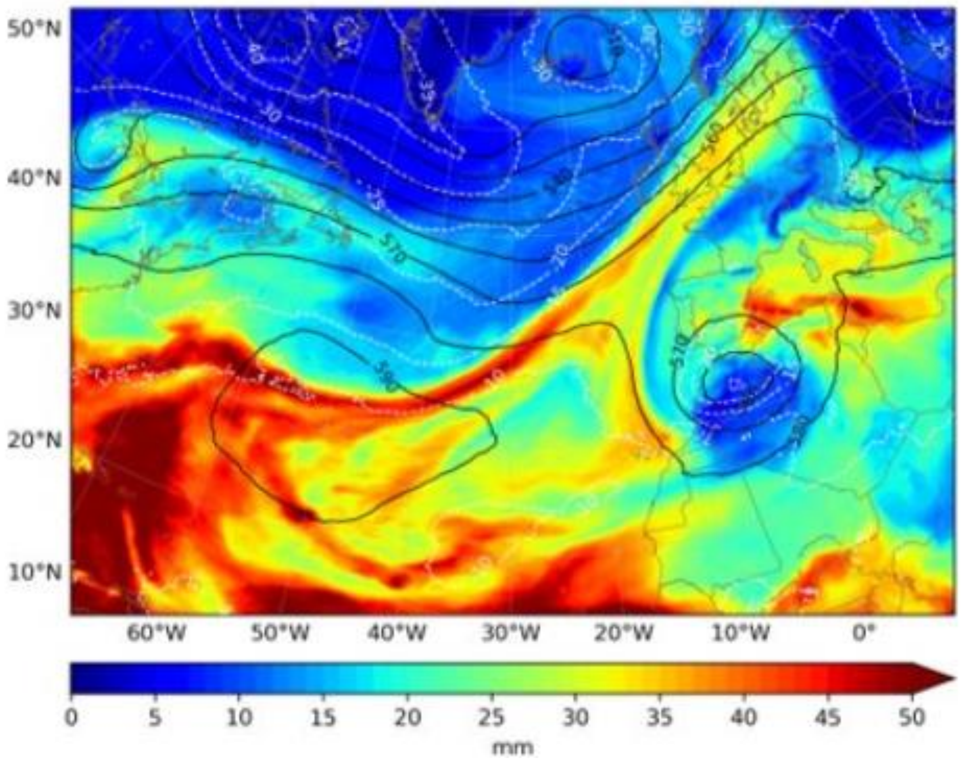
Study Case: October 1982

On the 20 October 1982 a **cold-core cut-off low** originated from an Atlantic trough, was centred aloft over Morocco. The **instability** and the emergence of **dynamic forcing** favour the **occurrence of upward air motions** in the SE Spanish area.

The cyclone consisted of **an extensive low-pressure system** with centre over Algeria, which organized a relatively **warm and very humid easterly flow**, producing **extreme precipitations** over SE Spanish and especially over the region of Valencia, with **maximum precipitation rates around 250 mm.**

Study Case: October 1982





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Objetive

Our goal is to **determine the source of humidity masses** contributing to this extreme precipitation event through a Lagrangian analysis and also, to **compare** the reliability of this method with a new Eulerian tracer method, Insua-Costa and Miguez-Macho [2018].

This innovative ***Eulerian tool*** can **tag and follow a moisture cell** from an initial position until it leaves the domain simulation, making it possible to **determine the contributing fraction** of a considered vapor source **to the final precipitation event.**

In contrast, the ***Lagrangian models*** allow us to **obtain retro-trajectories** giving us information about the **precise location where humidity comes from**.

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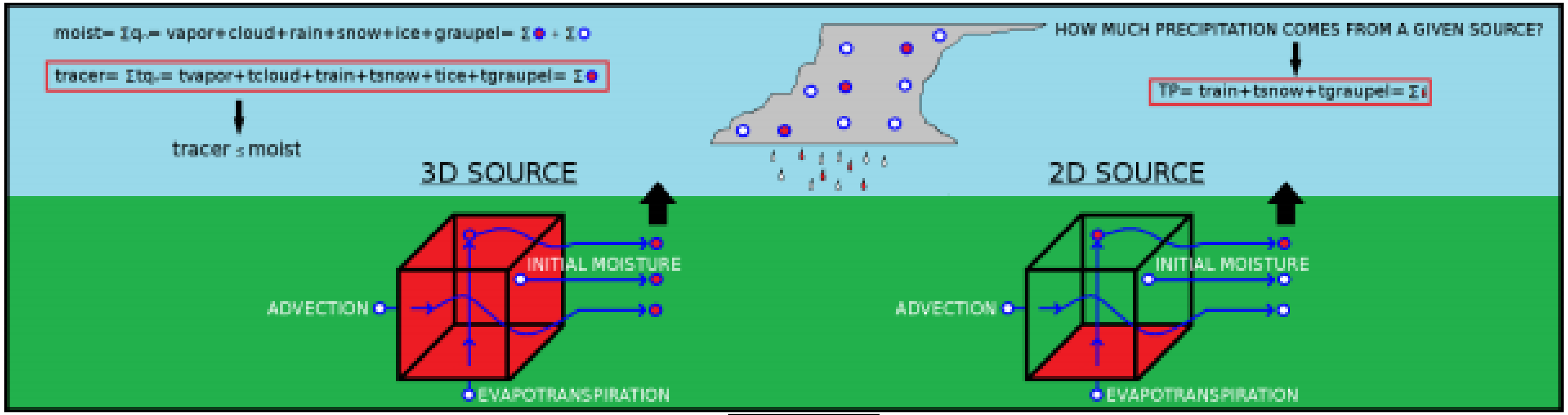
Eulerian Approach

The Weather Research Forecast model (WRF) can be coupled with a **Water Vapor Tracer (WVT)** tool to analyse the **sources of the water vapor**. This tool is **currently regarded** as the **most accurate** to **estimate** in great detail **the contribution** of the considered source **to total precipitation** at any point in a given model grid.



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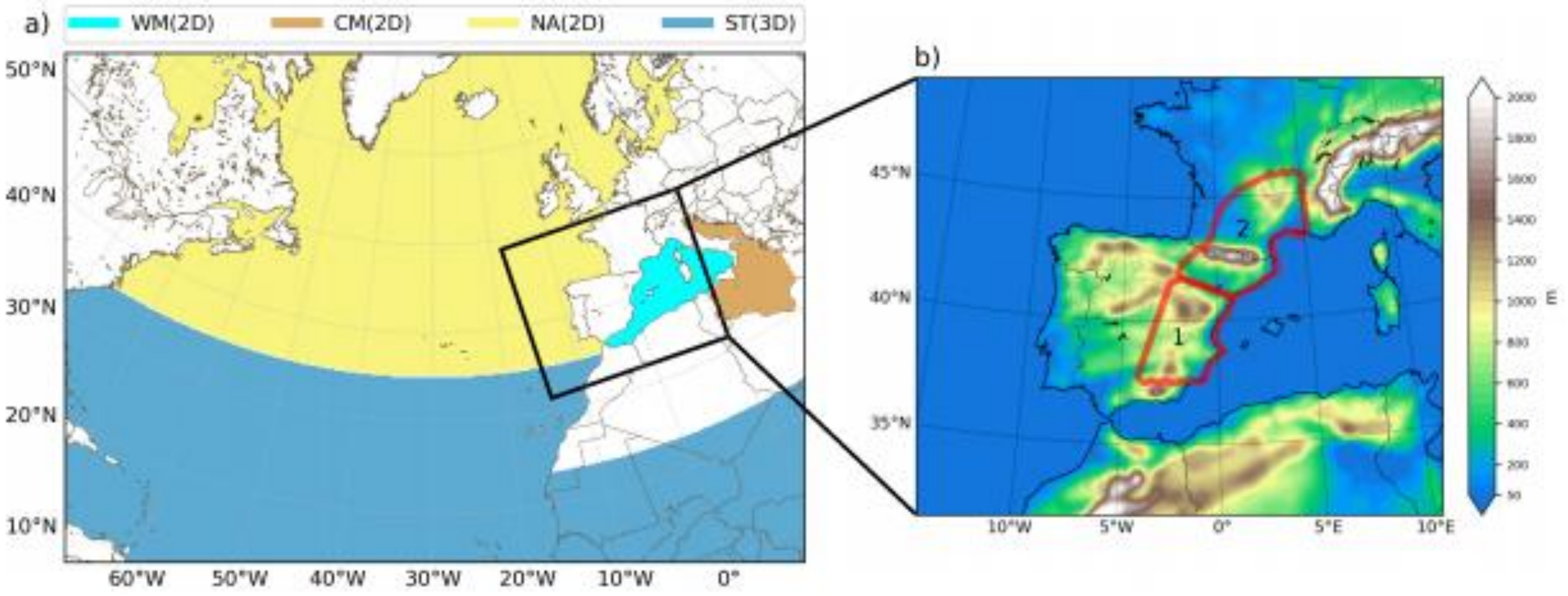
Tagged areas



(a) Simulation domain and moisture sources considered: Western Mediterranean (light blue), Central Mediterranean (brown) and North Atlantic (yellow) two-dimensional sources and tropical and subtropical three-dimensional source (dark blue). (b) Domain for precipitation analysis. The areas highlighted in red are the most affected by the October (1).

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Lagrangian Approach

To **determinate the main sources** of the Western Mediterranean Regions extreme precipitations, **atmospheric transport simulations** are carried by using the **FLEXPART-WRF model**. As a first approximation, evaporation areas are estimated by the **E-P balance** developed and validated by Stohl and James, 2004.

$$dq = \frac{q(t_{i+1}) - q(t_i)}{t_{i+1} - t_i} \rightarrow e - p = mdq \rightarrow E - P \approx \frac{\sum_{k=1}^{K}(e-p)}{A}$$

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Lagrangian Approach

To quantify moisture sources for heavy precipitation events, Sodemann's Lagriangian diagnostic was used. It takes into account **humidity changes in every single air cell**, supposing that a **positive moisture exchange come from evaporation**, and **weighted all of them along time**.

The importance of each positive uptake **is higher the closer to the precipitation region it is**, in terms of time.

Because changes above PBL could be due to a bad vertical and horizontal mixing resolution, a **1,5 factor is adopted for the PBL height** to smooth the error made selecting just those particles right below it.

FLEXPART-WRF simulation

We run **4 million** particles over the area $\mathbf{90°}\boldsymbol{W} - \mathbf{60°}\boldsymbol{E}$ **and** $\mathbf{3°}\boldsymbol{S} - \mathbf{55°}\boldsymbol{N}$

Then, we select particles over precipitation area $\mathbf{9°}\boldsymbol{W} - \mathbf{5°}\boldsymbol{E}$ **and** $\mathbf{33°}\boldsymbol{N} - \mathbf{43°}\boldsymbol{N}$ for the **19 October 00UTC to 21 October 21UTC .**

$\boldsymbol{E} - \boldsymbol{P}$ **balance values** are calculated for this area and time with a resolution of $\mathbf{1°} \times \mathbf{1°}$, selecting those **particles such** $\boldsymbol{E} - \boldsymbol{P} < -\mathbf{2}\boldsymbol{mm}/\mathbf{3}\boldsymbol{h}$ **sub-areas.** Furthermore $\mathbf{dq/dt} < -\mathbf{0.06gkg^{-1}}/\mathbf{3}\boldsymbol{h}$. $\mathbf{50.000}$ ***particles*** were tracked backward in time.

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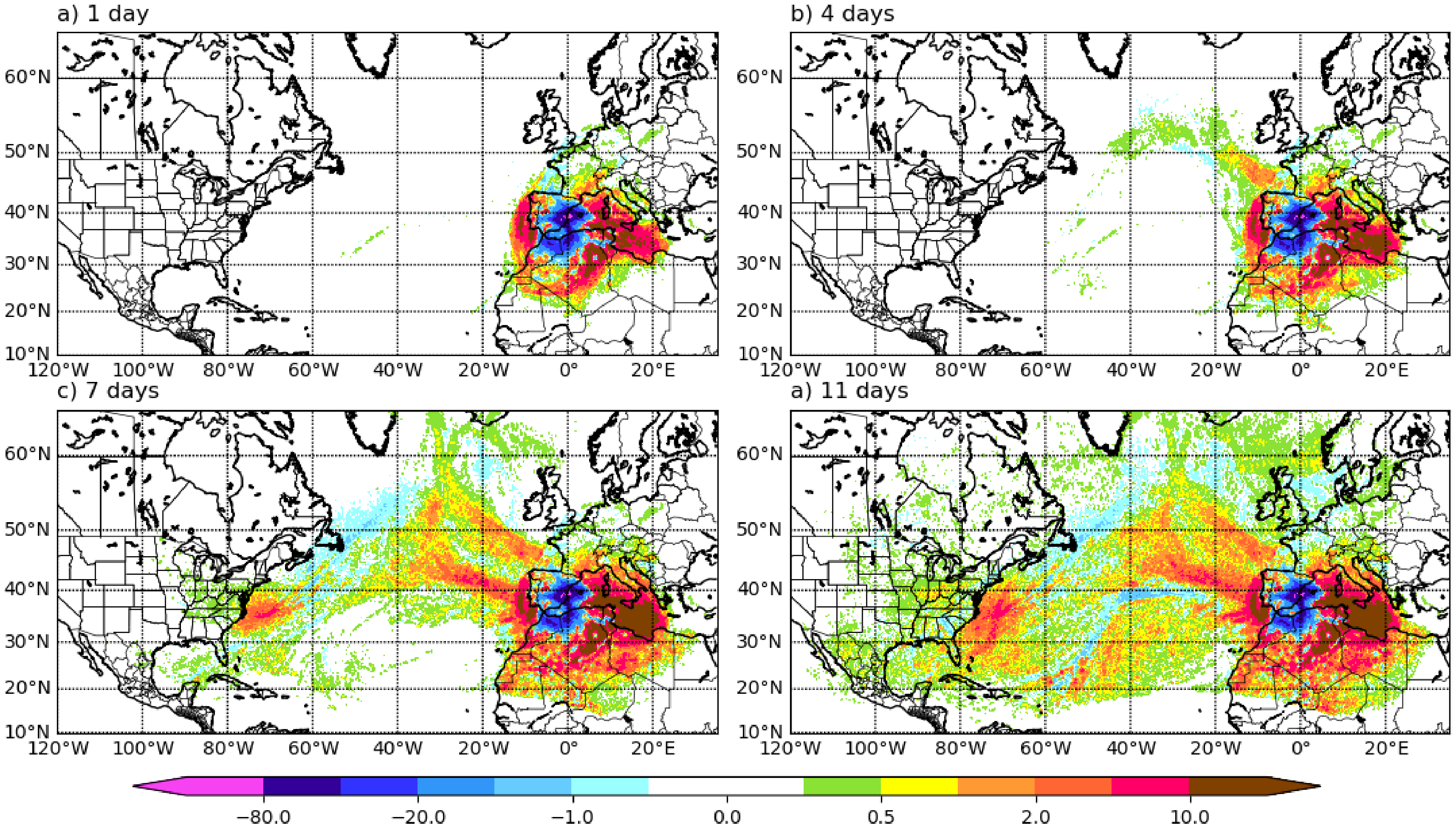
Temporal E-P balance evolution

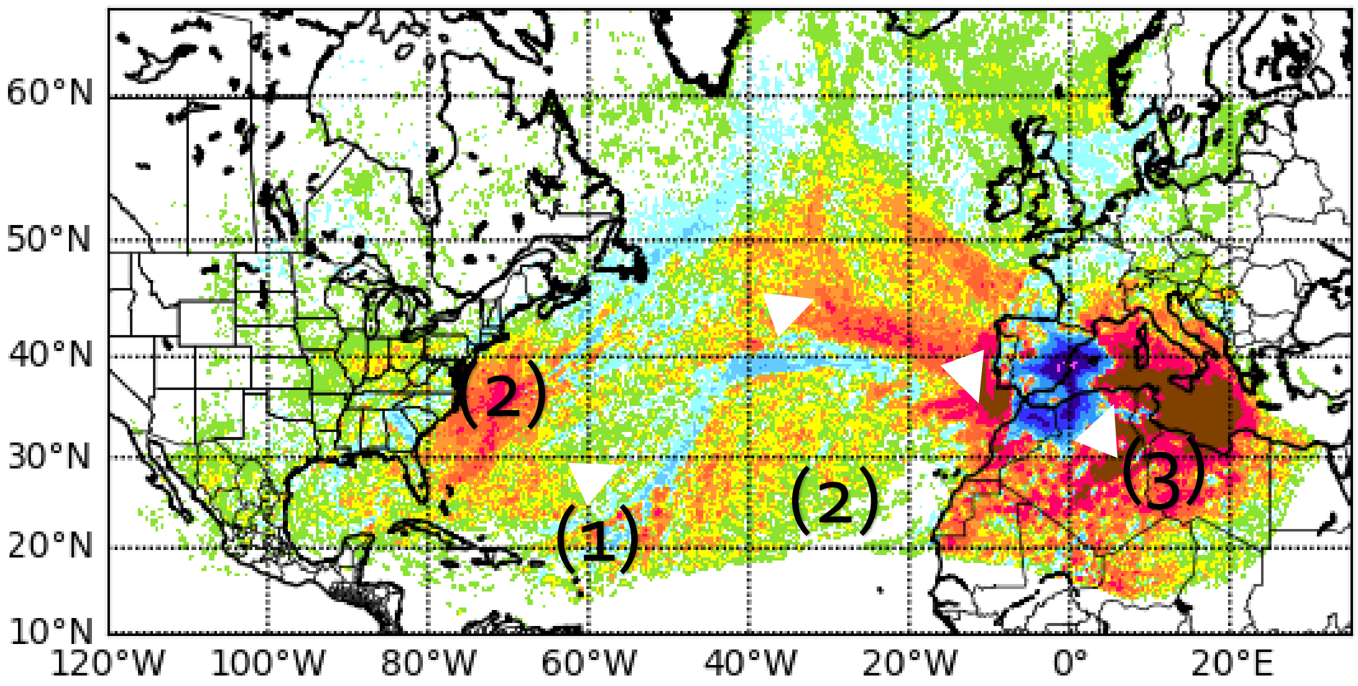


Maximum accumulated precipitation peak is reached after **72 hours, corresponding to October 21.**

A general view reveals the main moisture sources are the **Mediterranean sea, east American coast** and **the Atlantic ocean**.

Temporal E-P balance evolution

The target of particles follows the real atmospheric situation. The **moisture uptake** takes place at **both sides** of the **blue atmospheric river** along the Atlantic Ocean (2). Effective transport **crosses Atlantic ocean** from Caribbean and Subtropical regions (1) to Mediterranean area (3).



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Comparison Eulerian vs. Lagrangian

By applying Sodemann's moisture attribution method we find the following relative percentages of contribution for the same four tagged sources. Besides, Sahara region was also tagged:

	Lagrangian Method	Eulerian Method
WMED	20,80	19,14
CMED	17,79	18,28
NATL	13,58	14,89
TROP	5,26	31,02
SAHA	20,88	--

Table 1: Relative contribution (%) of the considered humidity sources to the October precipitation event. First column correspond to data obtained through Lagrangian below 1.5 PBL height, while second column correspond to Eulerian methodology.

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Comparison Eulerian vs. Lagrangian

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Most relative calculated percentages match for both methodologies.

However, relative humidity reported by **Lagrangian approach is six times smaller** than relative humidity reported by **Eulerian approach** for **Tropical region**.

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Comparison Eulerian vs. Lagrangian

	Lagrangian Method	Eulerian Method
TROP	5,26	31,02

This **difference** can be explained because the **residence time** for this particular region.

10-14	10-15	10-16	10-17	10-18	10-19	10-20	10-21

Residence time for particles originated in **Tropical área.**

Most of particles selected **precipitate before** HPE. This fact explains the **low percentage** atributed to Tropical source.

Mean time for **positive uptakes.**

Mean time for **tropical particles precipitation.**

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Conclusions

Lagrangian method can estimate the **same percentages** calculated by Eulerian approach **for most of humidity sources**. In case Tropical region, Lagrangian method can explain the observed mismatch due to the residence time.

We can conclude that both methods can replicate the same event. However, results should be read carefully and evaluate both methods for each case.

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