EGU LEONARDO CONFERENCE - Ourense 2016

Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events

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Major Mechanisms of Atmospheric Moisture Transport and Their Role in Extreme Precipitation Events

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Annu. Rev. Environ. Resour. 2016. 41:117–41

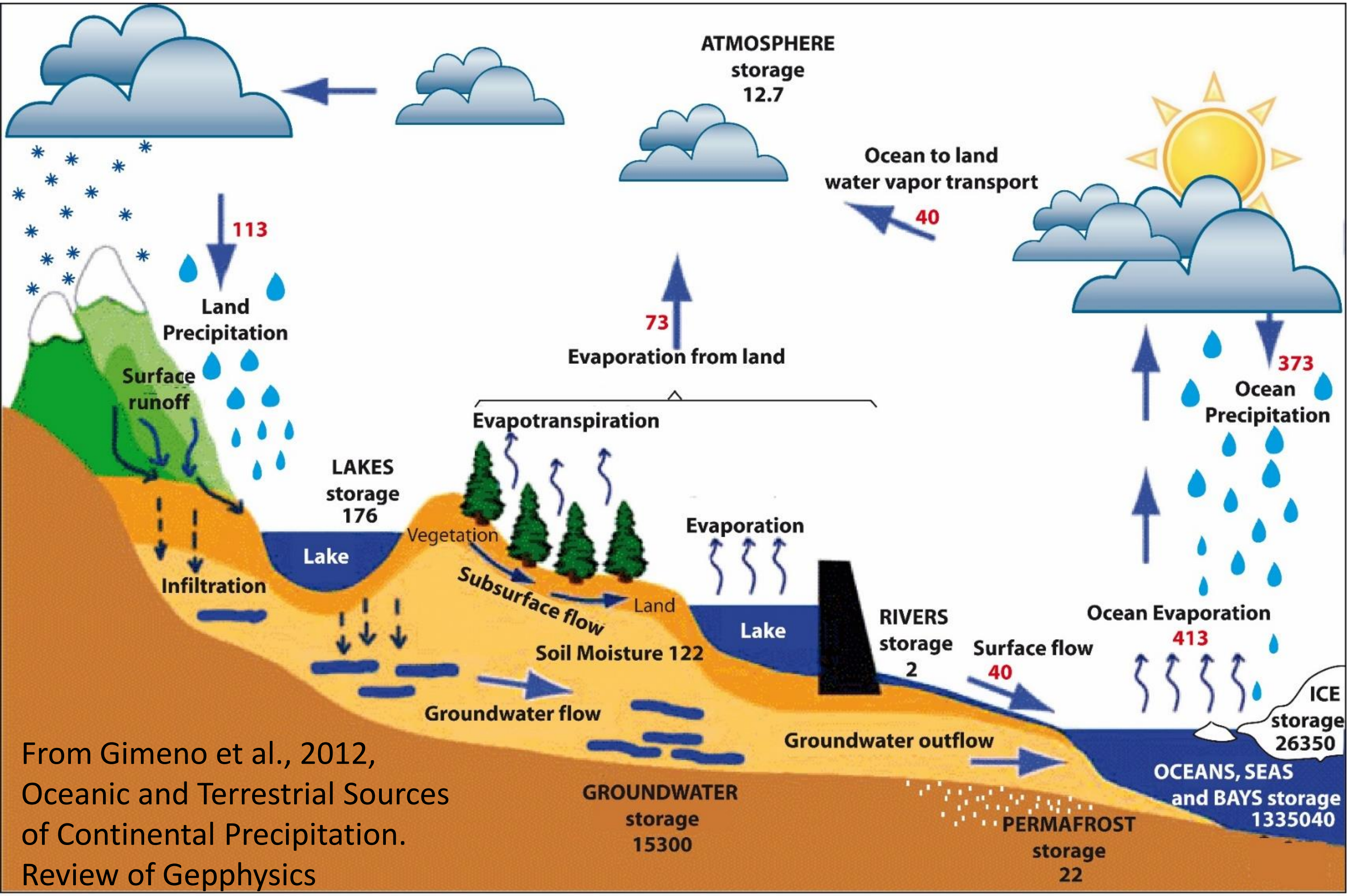
First published online as a Review in Advance on July 6, 2016

The *Annual Review of Environment and Resources* is online at environ.annualreviews.org

This article's doi:
10.1146/annurev-environ-110615-085558

PUBLISHED LAST WEEK on-line (20 October)
Print version November

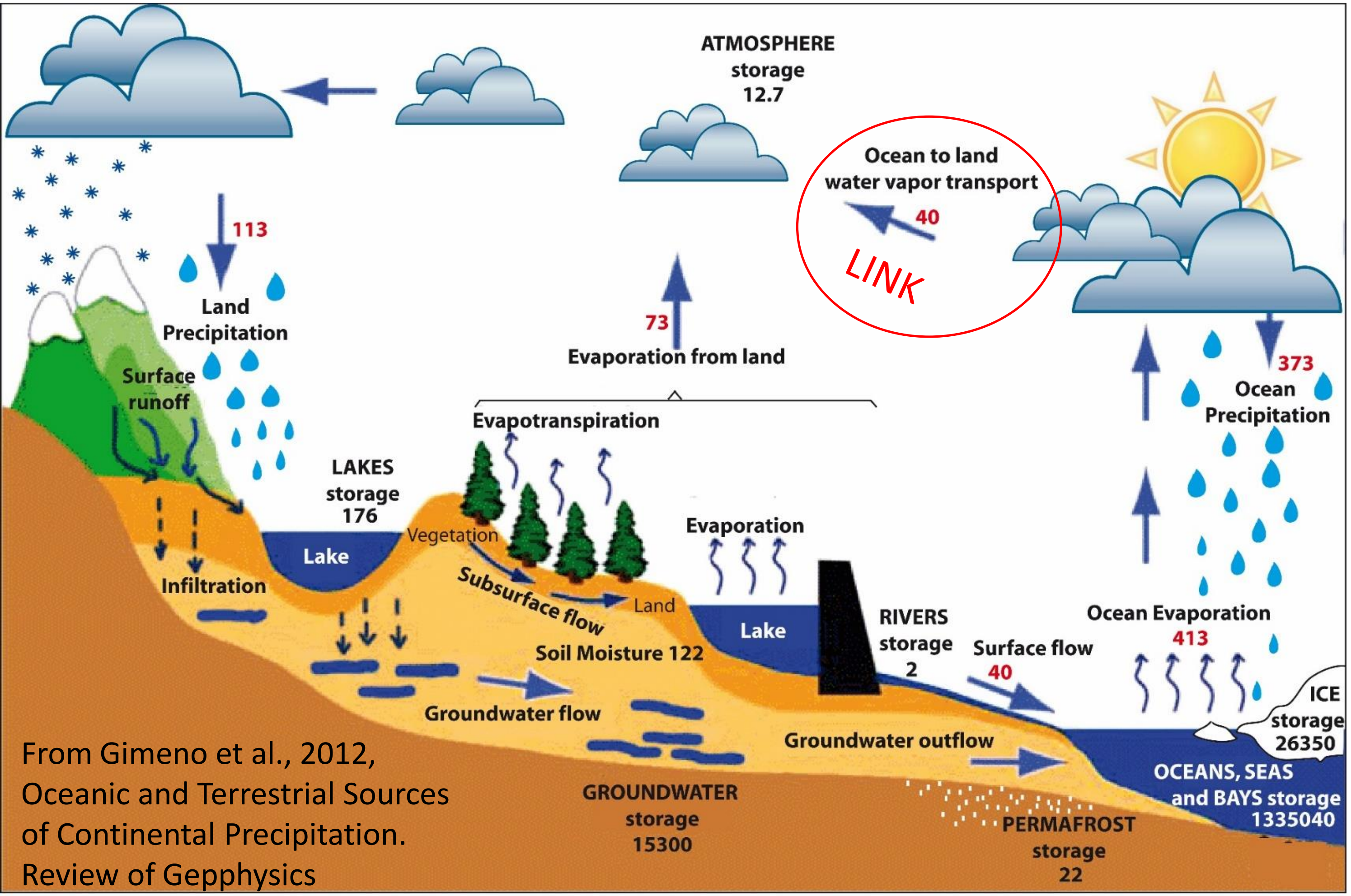
Each of the main components of the hydrological cycle plays a major role in the global climate system.



From Gimeno et al., 2012,
Oceanic and Terrestrial Sources
of Continental Precipitation.
Review of Gepphysics

From the perspective of climate change and variability, it is of the utmost importance to obtain the best possible understanding of both the intensity of the hydrological cycle and its evolution over time.

Understanding the processes governing the evaporation of water from the oceans and the transport of atmospheric moisture is particularly important, as is understanding the effects of each of these processes on the hydrological cycle — all within the context of the current paradigm of global climate change.



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The **transport of moisture** from the **oceans to the continents** is the primary component of the atmospheric branch of the water cycle,

and forms the **link** between evaporation from the ocean and precipitation over the continents

Physical processes behind transport of moisture → improve rainfall forecast

Role of anomalies in the transport of moisture → extreme drought or intense precipitation

Two large-scale dynamical/meteorological structures play important roles in the transport of moisture:
ARs and **LLJs**

The transport of moisture by both is connected to monsoonal regimes and
to other important natural hazards

Low-level jet (LLJ) systems → at globally scale, described in several regions

↓

LLJs appears during the **active phases of monsoon regimes**

Atmospheric rivers (ARs) → mostly confined to extratropical regions

Overall, the contributions of ARs and LLJs to total precipitation at the regional scale are now better quantified and are likely to be larger than previously considered.

One of our aims here is to unify our understanding of these processes at regional and global scale:

2 talks LLJs : L18 and L19 **10 talks ARs : L20 - L29** **&** **5 posters ARs : P39 – P43**

BUT, what about the **anomalies** of moisture transport ?

There is degree of uncertainty concerning the mechanisms involved in the anomalies seen during precipitation extremes and their consequences (i.e., drought or flooding).

Drought → significantly less moisture available than normal for long periods persistence: could be due in part to a lack of transport to the continents

Extreme rainfall and floods → large amounts of water vapor convergence

In this review paper we focused on this two major mechanisms of atmospheric moisture transport and discuss their roles in extreme hydrometeorological events (droughts and flooding) at the global scale

What is an AR?

The Atmospheric Rivers (ARs) are one of **the most important meteorological structures** that **provide** for most of the long distance **moisture transport**, accounting for 95% of meridional water vapor flux at 35º latitude.

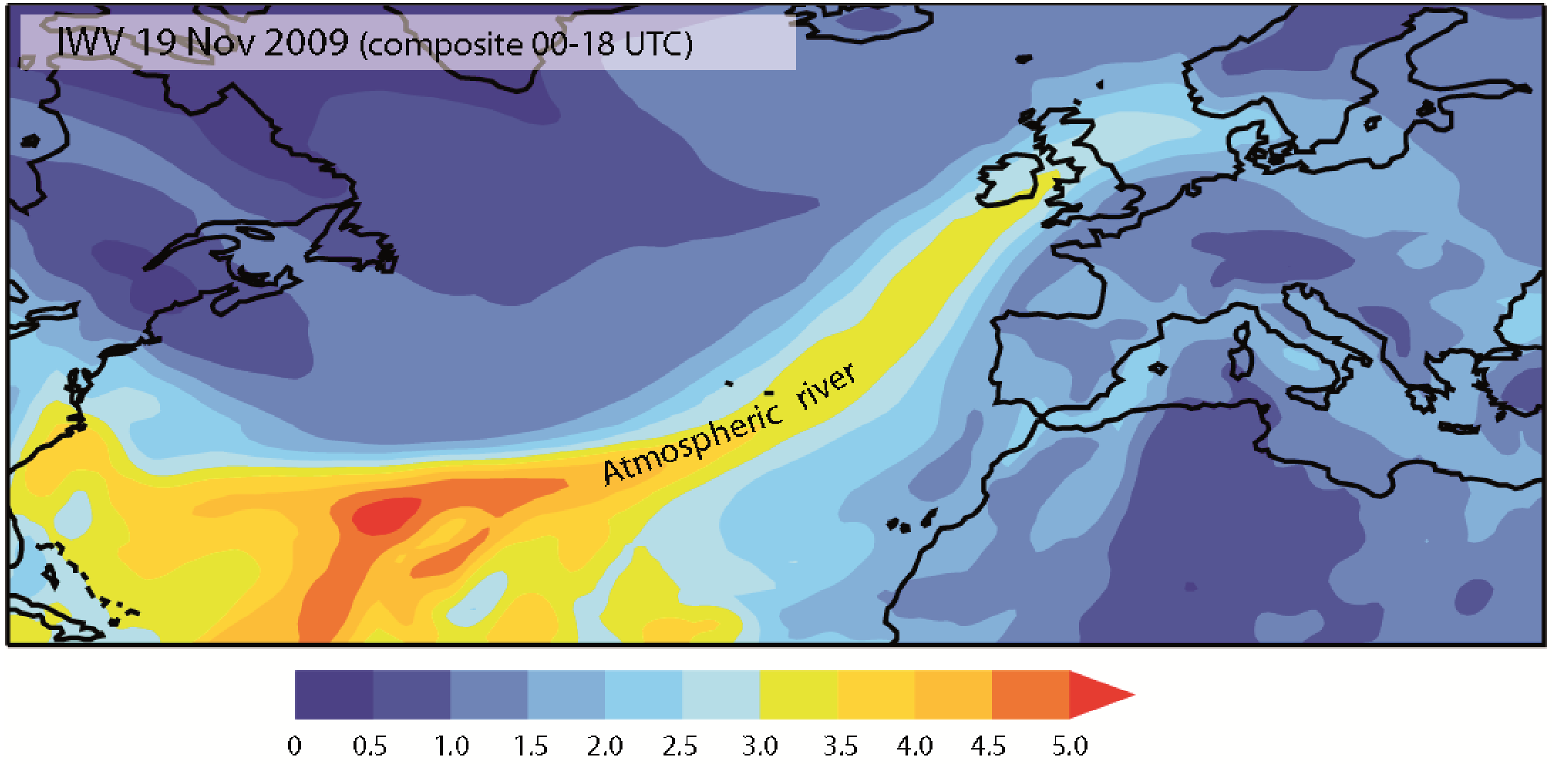


Figure from:
L Gimeno, R Nieto, M Vazquez and D Lavers (2014)
Atmospheric Rivers: a mini review.
Frontiers in Earth Science.
doi: 10,3389/feart.2014,00002

What is an AR?

These transient filamentary regions occur within the warm conveyor belt (WCB) of **extratropical cyclones**, and are characterized by **high water vapor content** and **strong low level winds**.

A typical AR **resides within the WCB** in the pre-cold-frontal region of an extratropical cyclone.

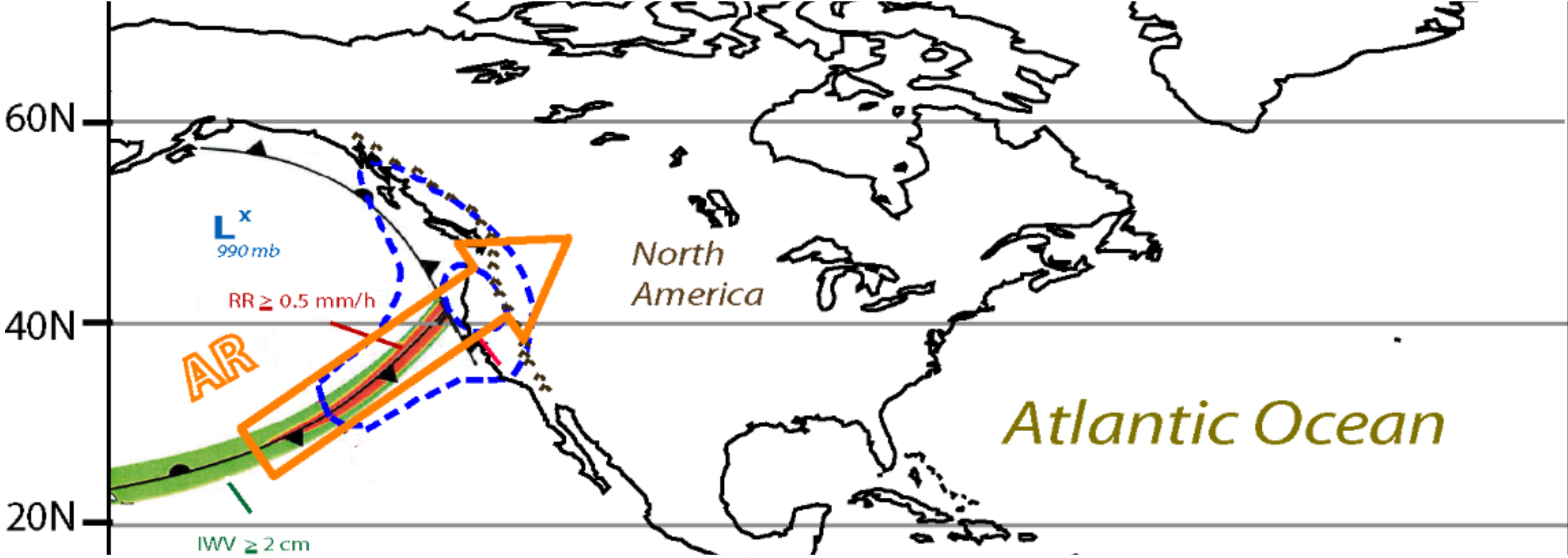


Figure adapted from Gimeno et al. 2016, Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events. Annual Review of Environmental and Resources.

Methods to Identify ARs

There are two traditional approaches used to detect ARs:

(i) by using Integrated Water Vapor (IWV)

(ii) by using Vertically Integrated horizontal water vapor Transport (IVT)

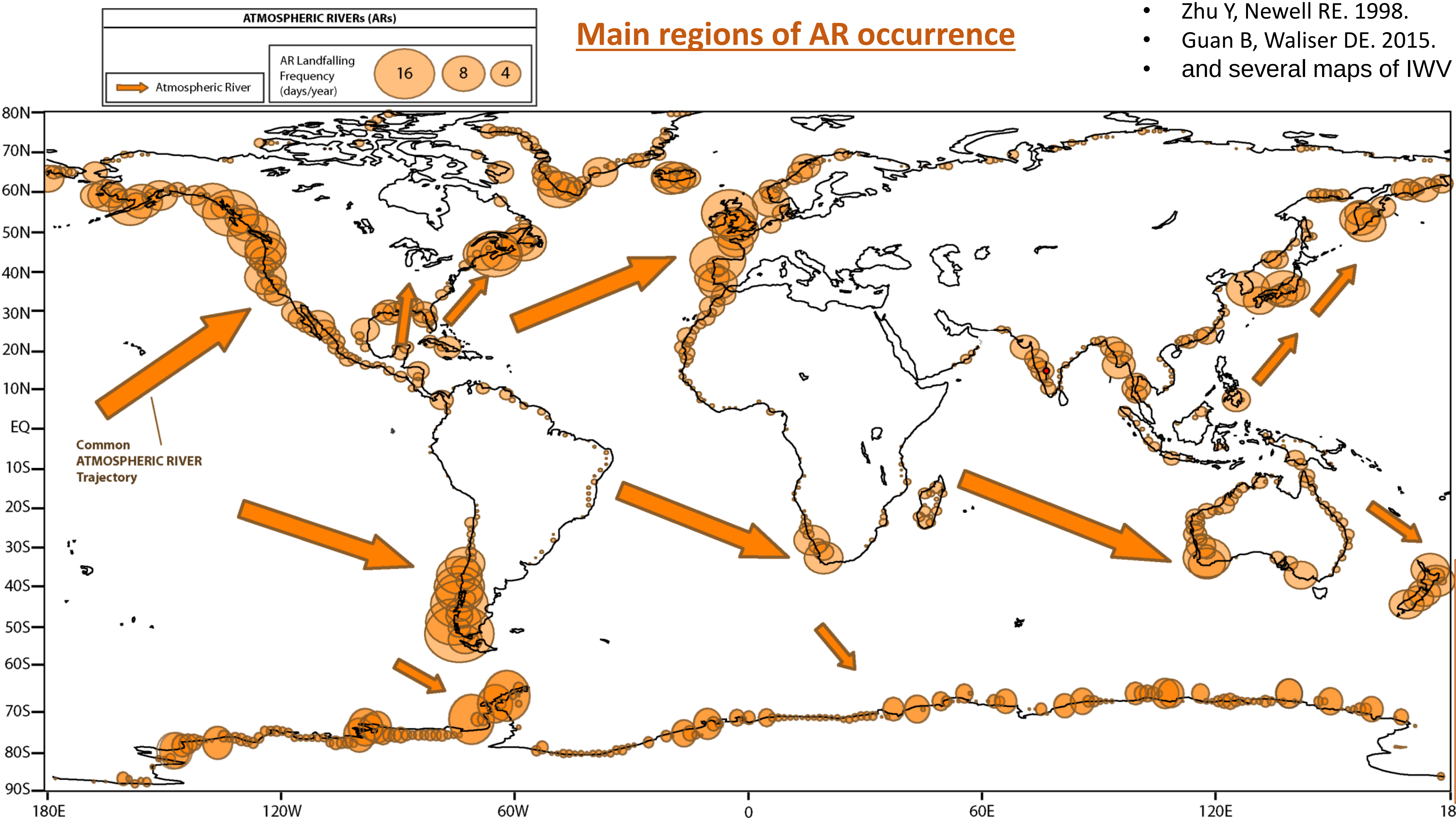
(iii) but also Water Tracers or particle Trajectories

Of course they will be explained along the following session

A Climatology view of ARs

Main regions of AR occurrence

Figure is based on:
- Zhu Y, Newell RE. 1998.
- Guan B, Waliser DE. 2015.
- and several maps of IWV composites.



Typically 3-5 ARs in each Hemisphere by day

Averaged duration: 20-40h

Figure adapted from Gimeno et al. 2016, Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events. Annual Review of Environmental and Resources.

What is a LLJ?

There are **wind corridors of the lower atmosphere**,
and they **carry** much of the **moisture** transport **from low to high latitudes** or **from warm oceans toward continents**.

They are a **warm-season** phenomenon.

Coastal LLJs: are generally in geostrophic balance and associated with topography and with daily cycles of land–sea contrast.

Inland LLJs: are generally driven by topographic and/or inertial effects or may result from secondary circulations associated with upper-level flows.

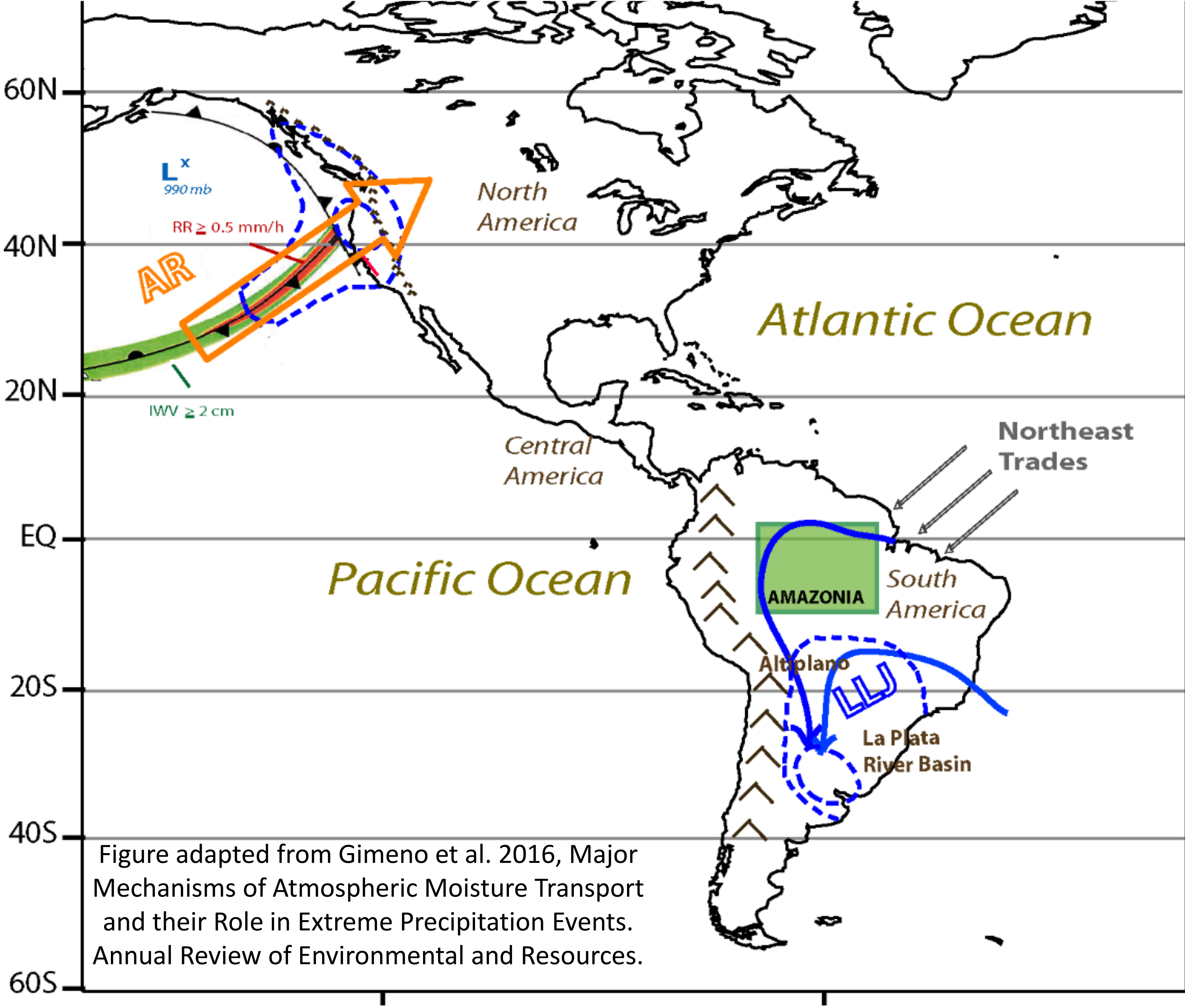


Figure adapted from Gimeno et al. 2016, Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events. Annual Review of Environmental and Resources.

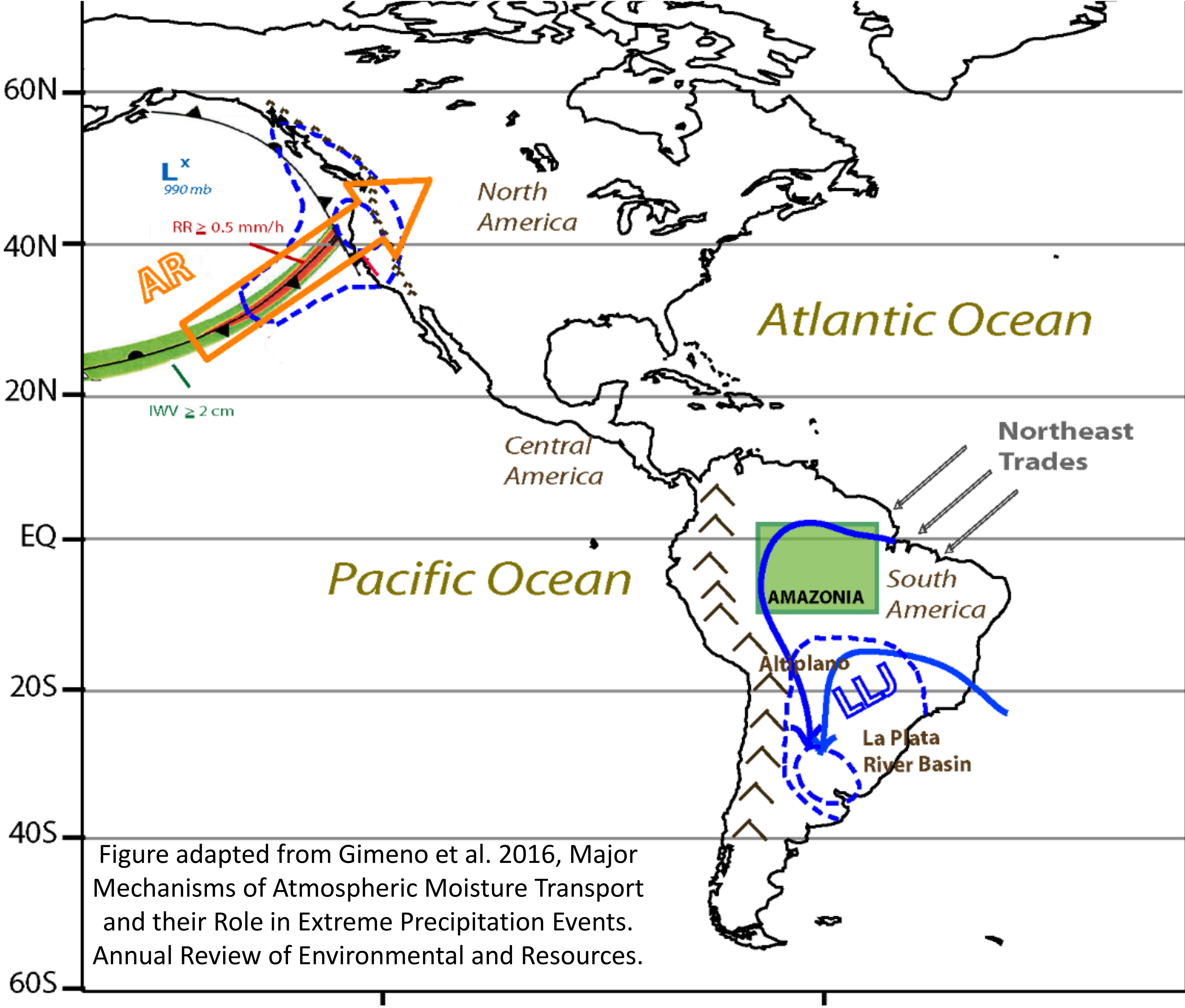
Topography may **influence** the **behavior** of an inland jet in different ways:

Several LLJs are the result of **channeling through gaps in the terrain via the Bernoulli effect** → Iran LLJ.

Barrier jets flow **parallel to the topography** and often result from geostrophic adjustment →

→South American LLJ east of the Andes.

The **most commonly studied** LLJs are those that achieve their maximum strength at **night** → Nocturnal LLJ



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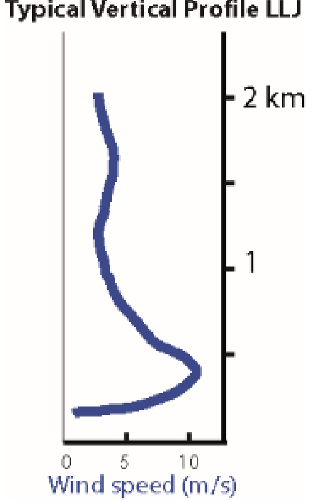
Methods to Identify LLJs

NLLJs tend to have maxima near local midnight,
with the height of the jet core ranging from 300 to 600 m above ground level (AGL)

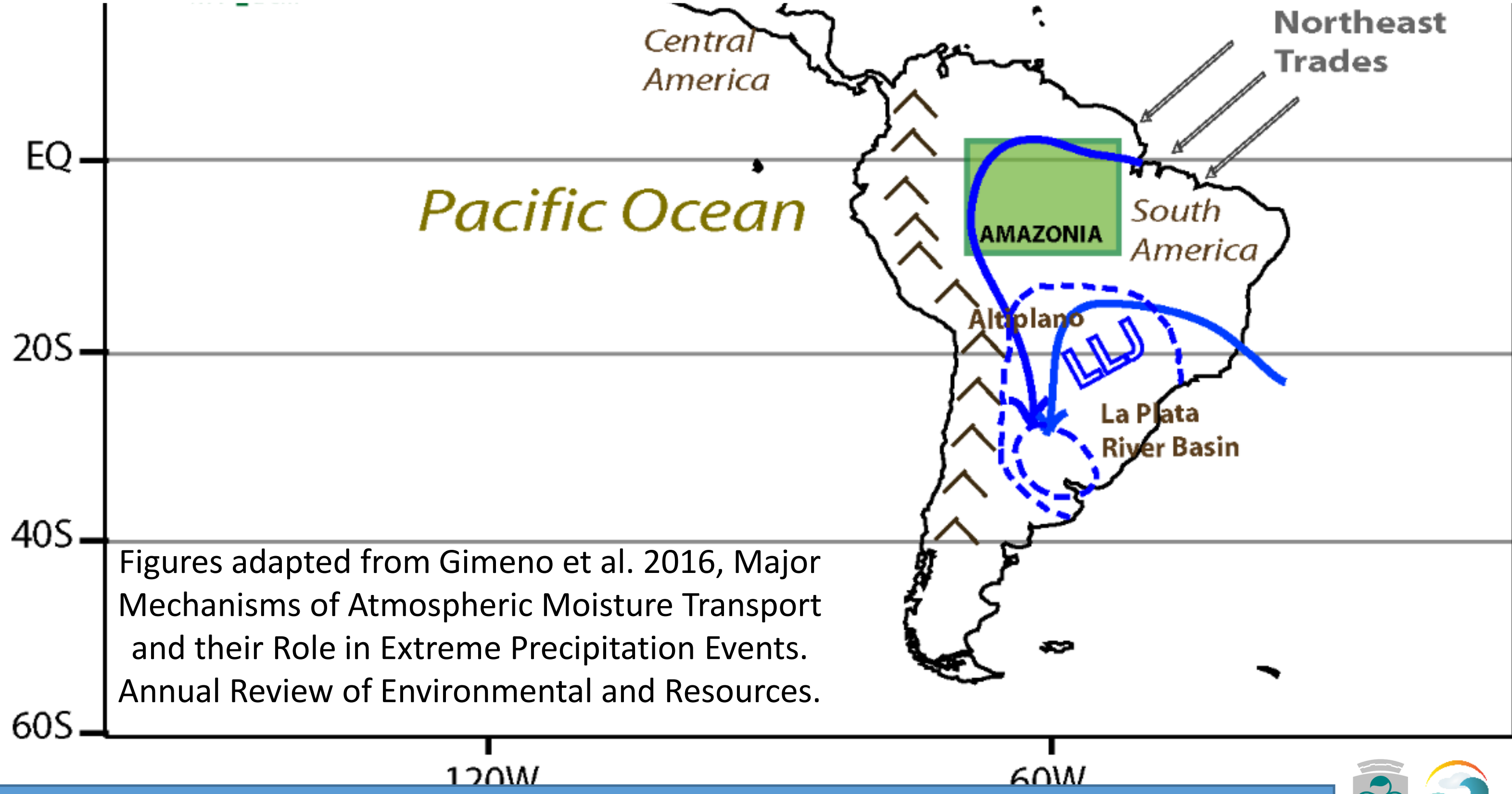


The lack of data at high temporal and spatial resolutions means that the proper study of NLLJs remains a particular challenge.

Few exceptions:

Great Plains of North America

South American LLJ (SALLJ)

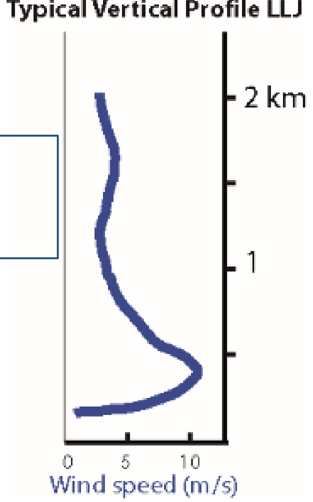


Figures adapted from Gimeno et al. 2016, Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events. Annual Review of Environmental and Resources.

Rife et al. (2010). Global distribution and characteristics of diurnally varying low-level jets. *J. Clim.* 23:5041–64

Characterized NLLJs over the entire planet using an objective method with reanalysis data

Methods to Identify LLJs



Rife et al. (2010). Global distribution and characteristics of diurnally varying low-level jets. *J. Clim.* 23:5041–64

Characteristics of NLLJs over the entire planet using an objective method with downscaled reanalyzed data

The NLLJ index was proposed based on the vertical structure of the temporal variation of the wind.

$$NLLJ = \lambda\,\varphi\,\sqrt{[(u_{00}^{L1} - u_{00}^{L2}) - (u_{12}^{L1} - u_{12}^{L2})]^2 + [(v_{00}^{L1} - v_{00}^{L2}) - (v_{12}^{L1} - v_{12}^{L2})]^2}$$

$$\lambda = \begin{cases} 0, & ws_{00}^{L1} \leq ws_{12}^{L1} \\ 1, & ws_{00}^{L2} > ws_{12}^{L2} \end{cases}$$

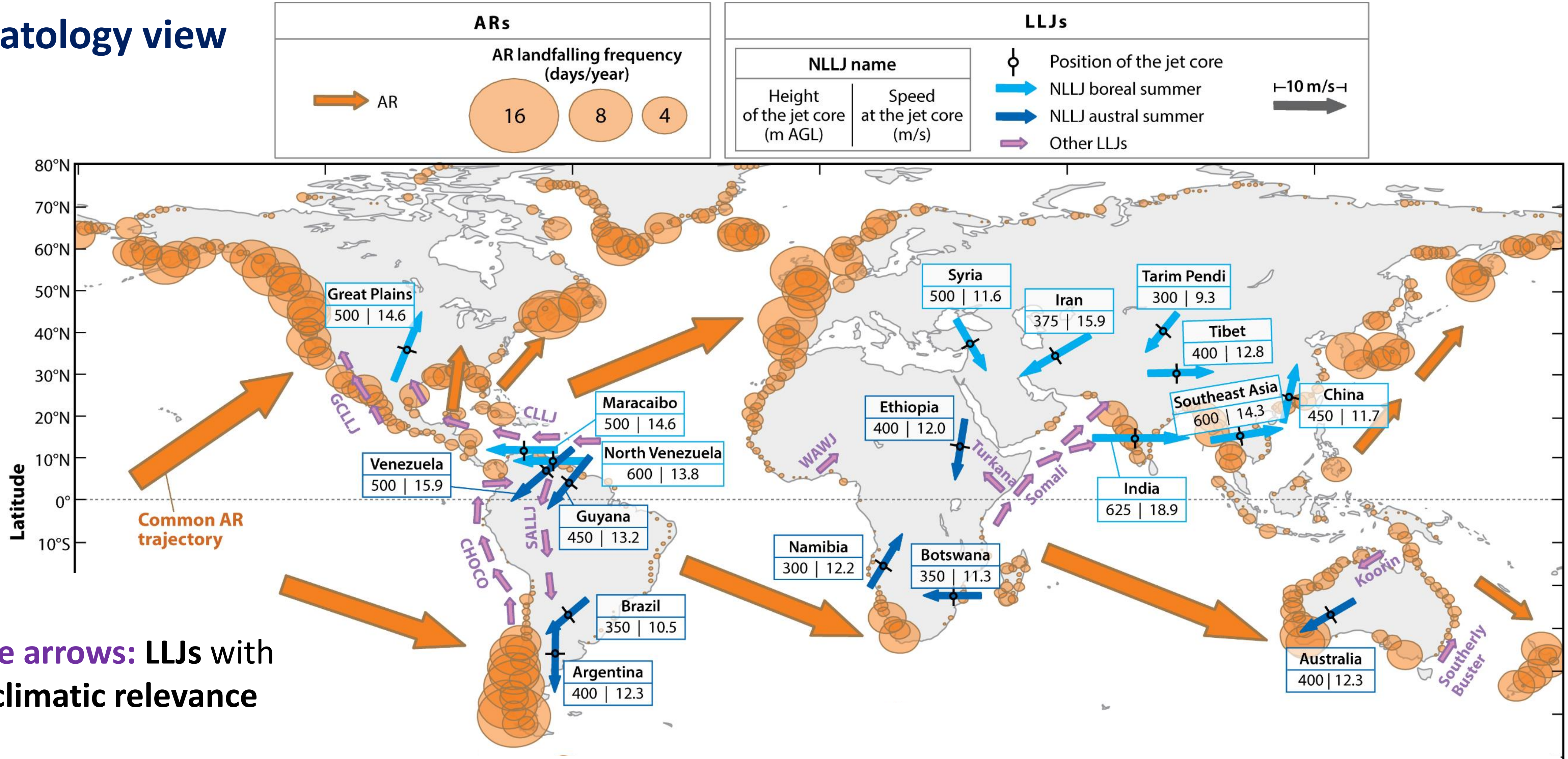
$$\varphi = \begin{cases} 0, & ws_{00}^{L1} \leq ws_{00}^{L2} \\ 1, & ws_{00}^{L1} > ws_{00}^{L2} \end{cases}$$

2 criteria:

- λ : winds (ws) at 500 m AGL (near jet level) stronger at local midnight (00) than at local noon (12),
- φ : wind speed (ws) at the core of the jet (500 m AGL, L1) stronger than that at a higher level (4 km AGL, L2)

18 NLLJs

A Climatology view of LLJs



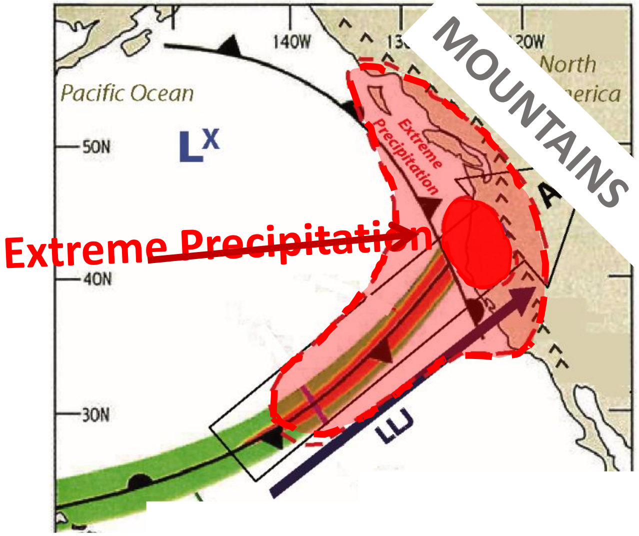
Purple arrows: **LLJs** with **high climatic relevance**

Blue arrows:
locations of **summer NLLJs**
(Rife et al 2010)

From Gimeno et al. 2016,
Major Mechanisms of Atmospheric Moisture Transport and their Role in Extreme Precipitation Events. Annual Review of Environmental and Resources.

Impact of Landfalling ARs

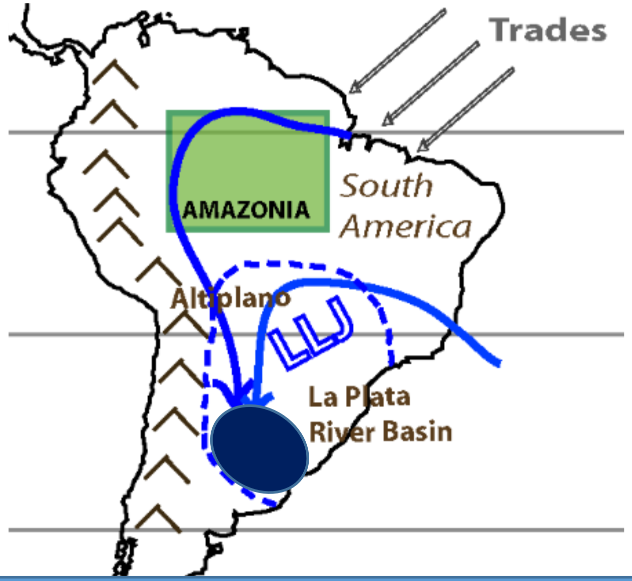
When a vapor-rich AR with strong horizontal winds encounters **mountainous terrain**, the **AR is forced upwards**, at which point orographic enhancement of rainfall can occur producing **extreme precipitation events and catastrophic flooding**

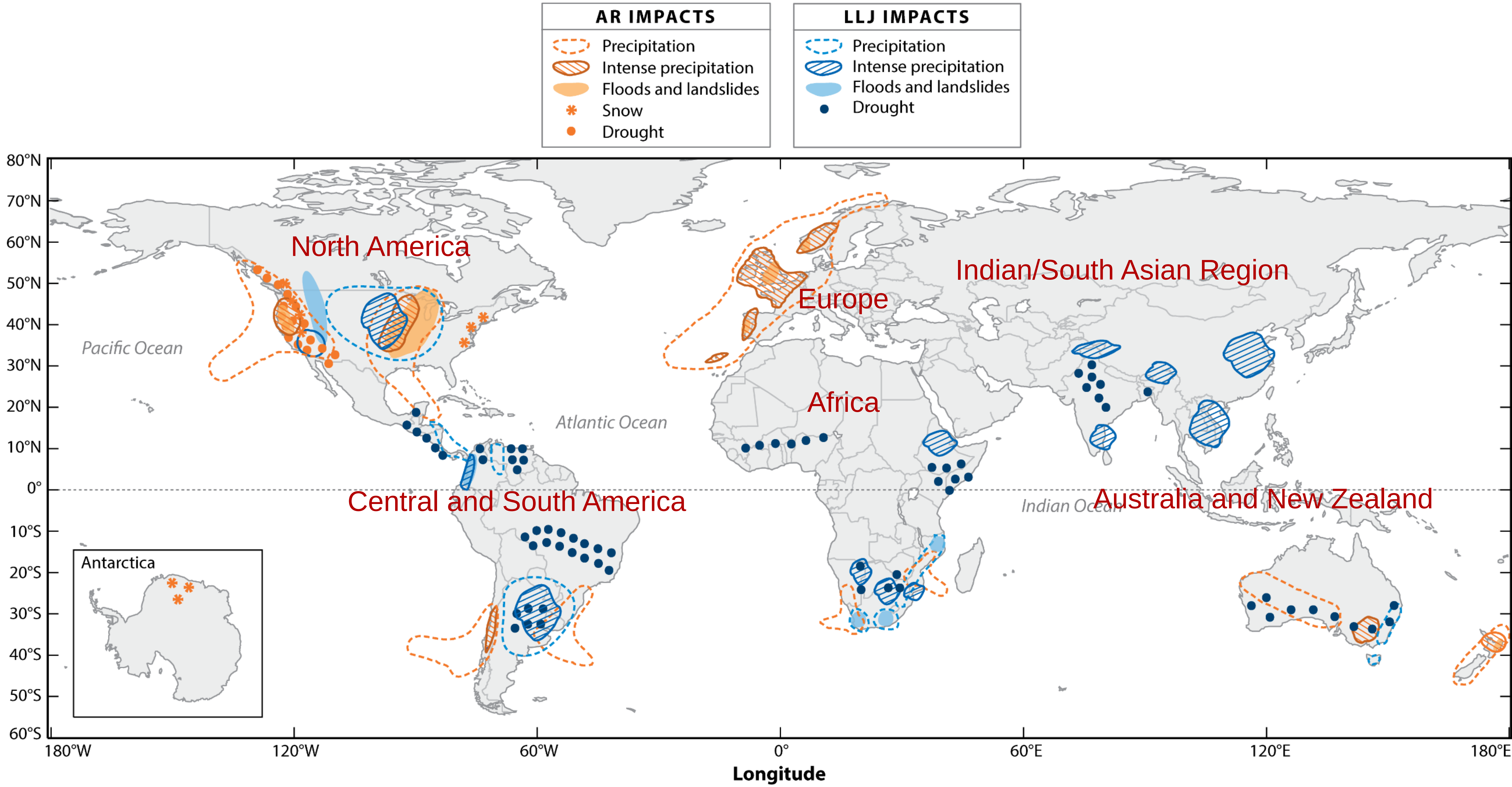


Other processes such as **synoptic** and **mesoscale systems** can play an important role in the intensification of precipitation via the associated convective motion, and **mesoscale frontal waves** can modify the stability or the duration of ARs.

Impact of LLJs

Link: **NLLJs** and **rainfall in different regions**, such as in the Great Plains, South America, Africa, India, and the western Pacific.





Gimeno L, et al. 2016.

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Thanks!

Graciñas