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The Relationship between Warm Conveyor Belts, Tropical Moisture Exports and Atmospheric Rivers

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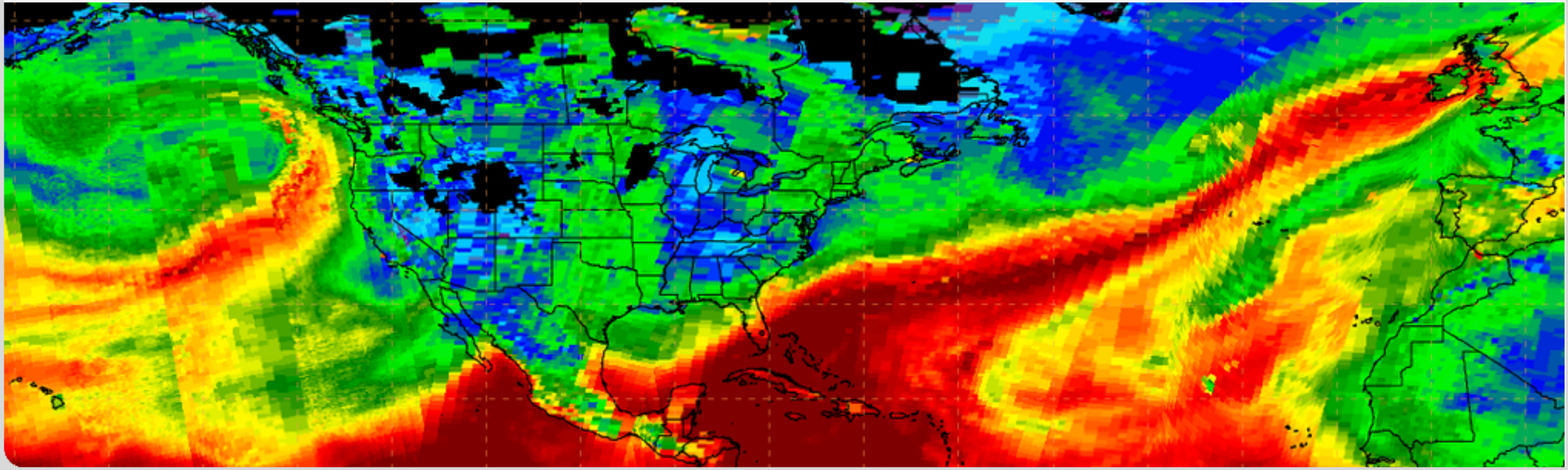
INSTITUTE OF METEOROLOGY AND CLIMATE RESEARCH



Introduction

- Many different concepts for meso- to synoptic-scale filamentary features of enhanced moisture content/transport, clouds and precipitation.
- These include **Warm Conveyor Belts (WCBs)**, Moisture Conveyor Belts, Moisture Bursts, **Atmospheric Rivers (ARs)**, **Tropical Moisture Exports (TMEs)**, Tropical Plumes and Tropical Intrusions.
- Different concepts emphasize different meteorological aspects.
- Some with clear objective identification criteria, others defined more loosely
- Boundaries between concepts are not sharp, leading to coincidences in time and space or temporal succession.
- Different features show differing geographical, seasonal and inter-annual variations.
- **There appears to be some confusion in the community about each concept's specific definition, purpose and usefulness!**

Objectives

- Systematically clarify and quantify the relationships between ARs, TMEs and WCBs using objective identification methods
- Provide global climatologies of all three concepts
- Assess their seasonality
- Examine overlaps in time and space

Data

- ERA-Interim re-analysis data
- 6-hourly data during period 1979–2014
- Interpolated to 1°x1° grid with 60 vertical levels
- Use Lagranto for trajectory computations (WCBs & TMEs)
- IWV = vertically integrated water vapour
- IVT = vertically integrated water vapour transport

Definition WCB

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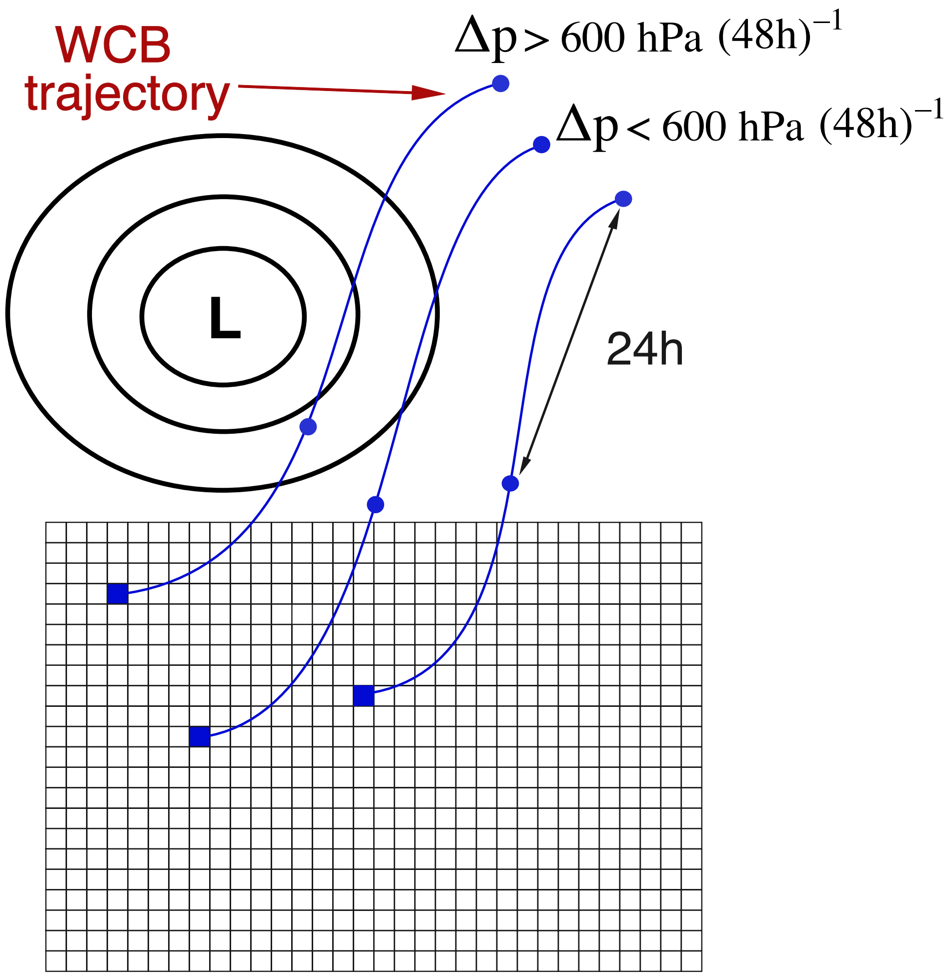
- Long history
- Definition goes back to *Wernli & Davies (1997)*
- WCB = trajectories ascending at least 600-hPa within 2 days
- Typically in the vicinity of extratropical cyclones
- Recent climatologies (e.g. *Madonna et al. 2014*)



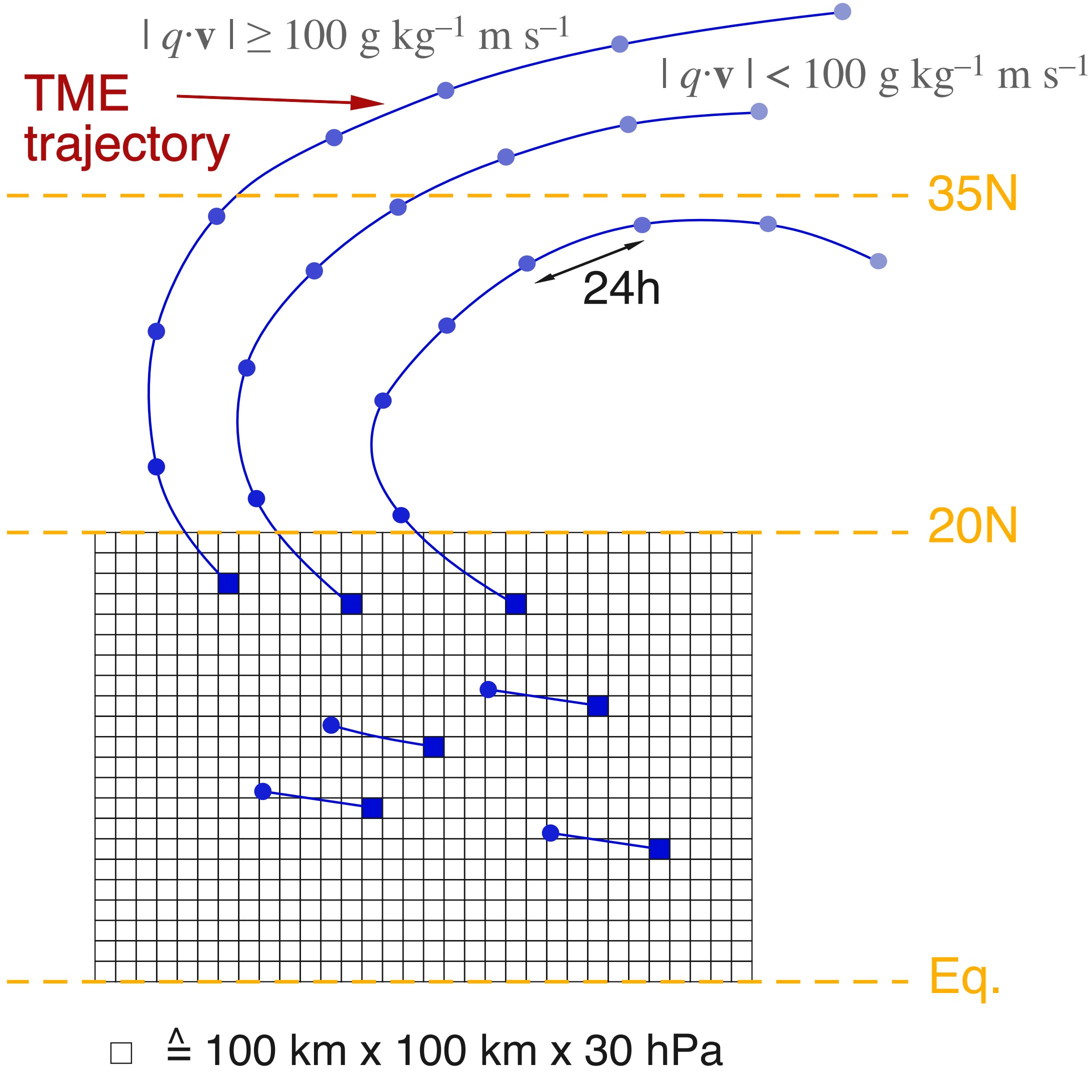
□ ≙ 80 km x 80 km x 20 hPa

from Wernli & Knippertz (2018), Chapter 3.2 in new Springer book:

Atmospheric Rivers: Two Decades of Research, by M. F. Ralph, M. Dettinger, J. J. Rutz, and D. E. Waliser (Eds.)"

Definition TME

- Definition goes back to *Knippertz & Wernli (2010)*
- Origin in tropics (20°S–20°N)
- Need to cross 35° latitude after <7 days
- Water vapor flux of at least 100 g kg^{-1} m s^{-1} poleward of 35° latitude
- No ascent criterion, no vertical integration
- Recent climatology (e.g. *Knippertz et al. 2013*)



from Wernli & Knippertz (2018)

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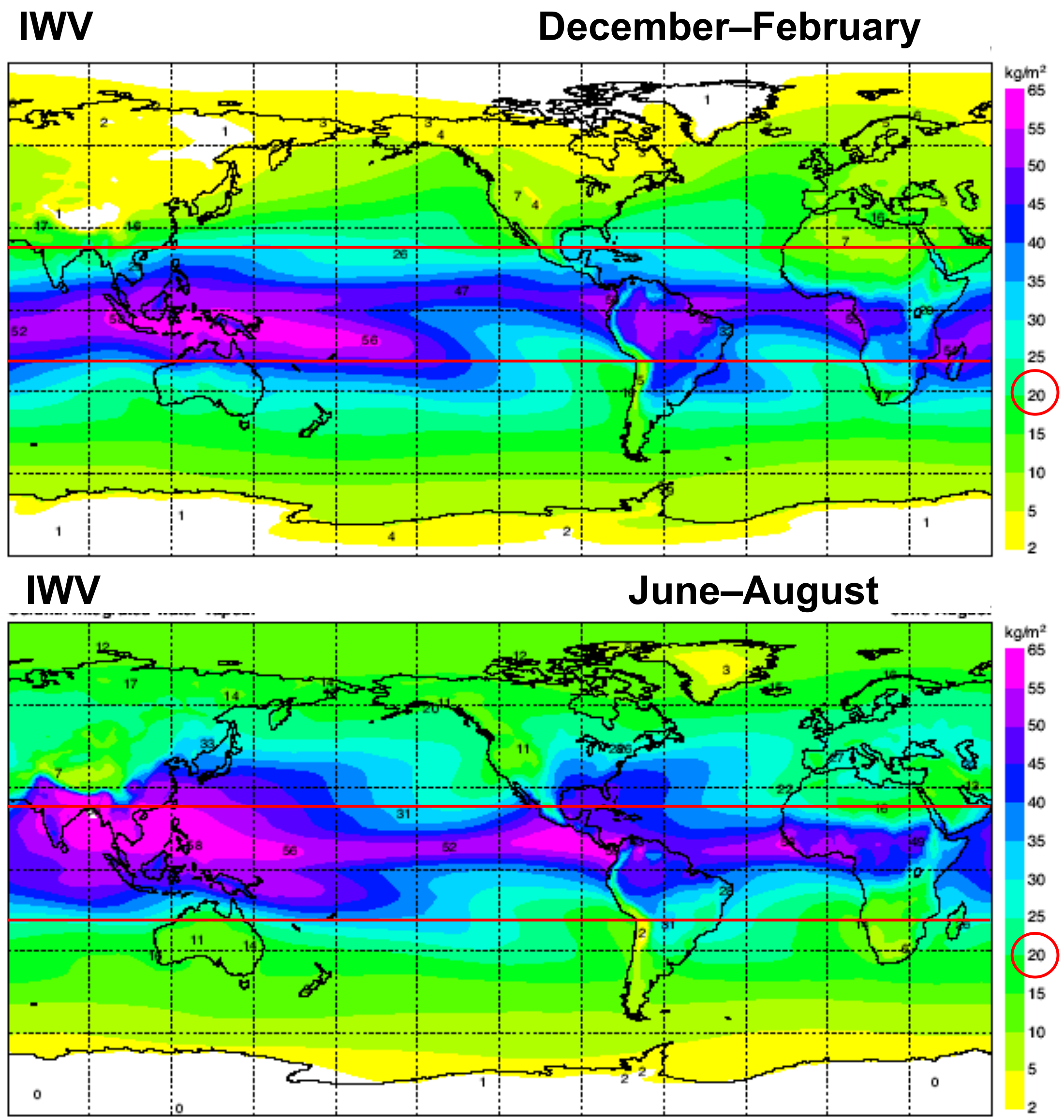
Definition AR

- Despite the popularity of the concept, no widely accepted definition.
- Eulerian approach
- 2-dimensional objects poleward of 20° latitude
- Criteria
  – IWV > 20 kg m^{-2} (=20 mm)
  – IVT > 250 kg m^{-1} s^{-1}
  – Length ≥ 2000 km
- ARs are synoptic-scale but not necessarily filamentary features



from ERA40 atlas

Example case

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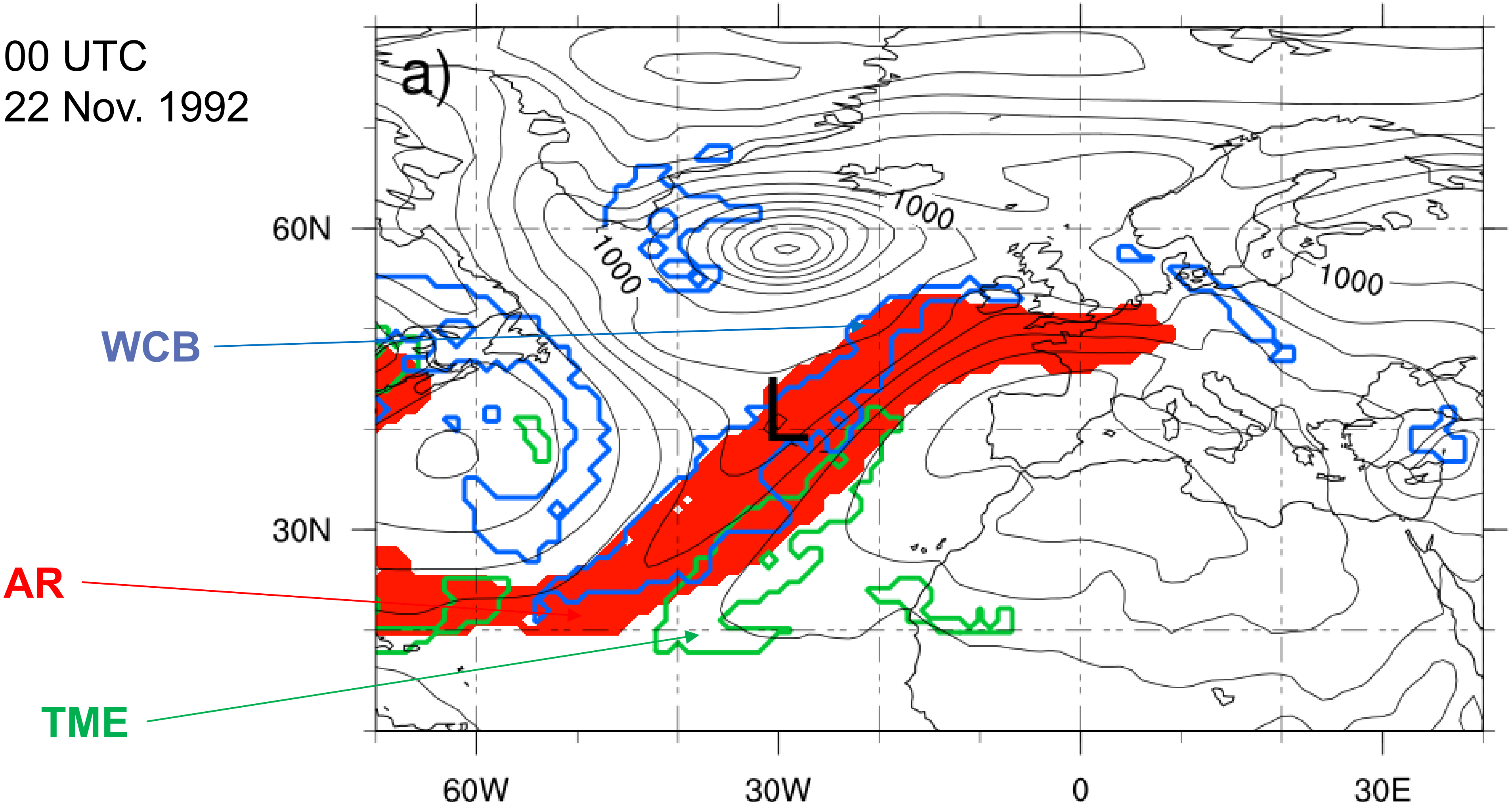
00 UTC
22 Nov. 1992



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Example case

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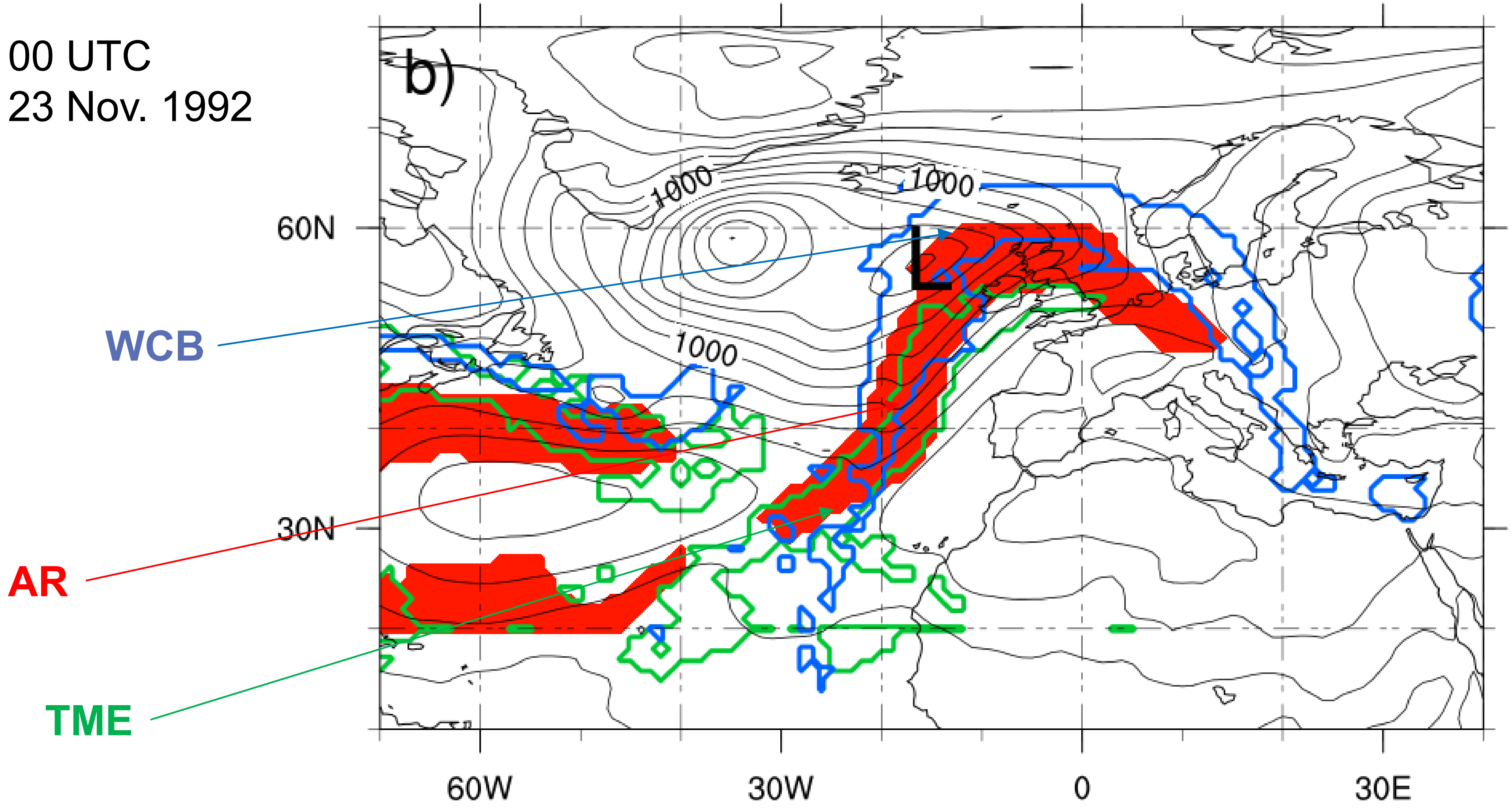
00 UTC
23 Nov. 1992



from Wernli & Knippertz (2018)

Example case

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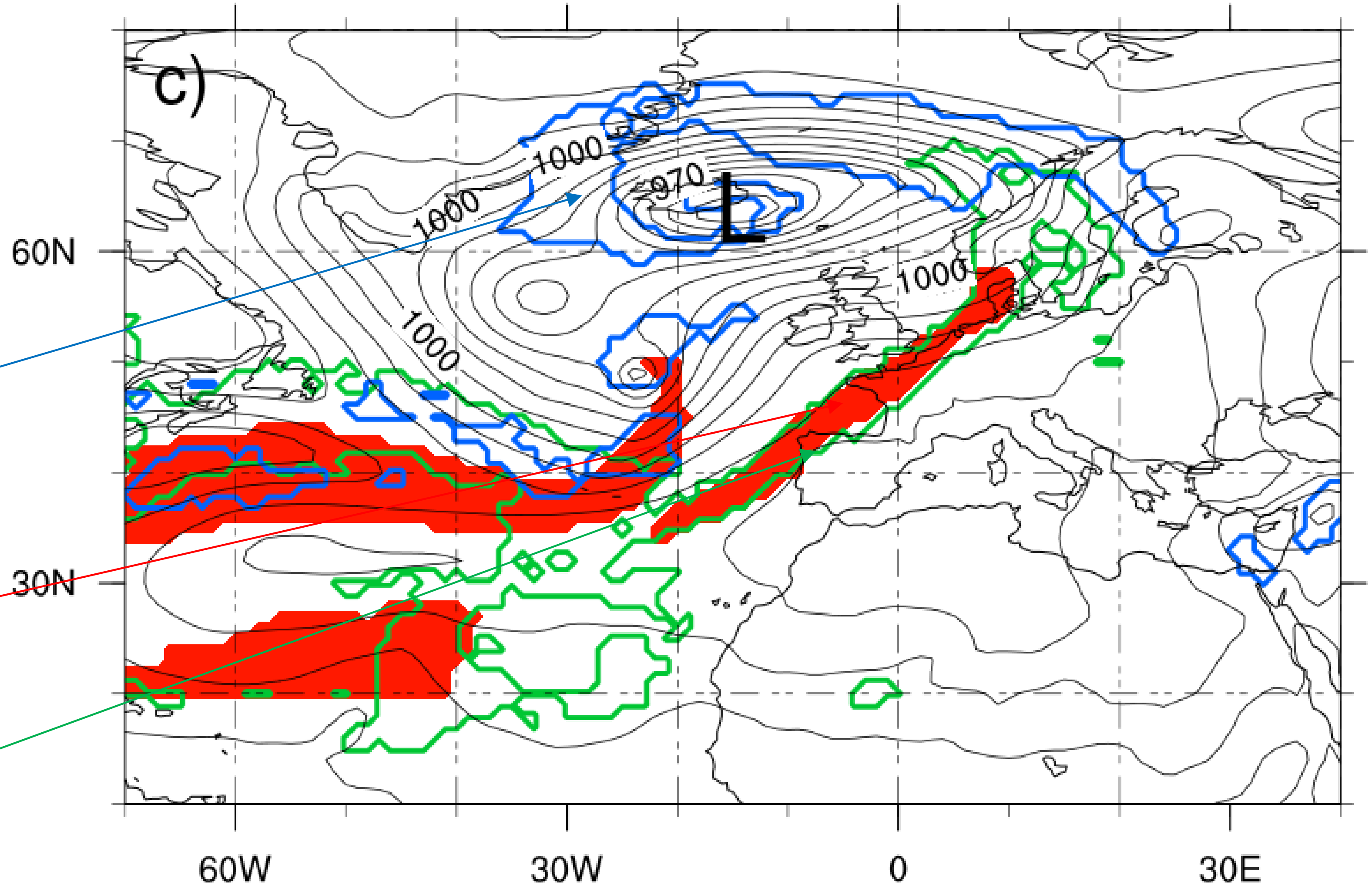
00 UTC
24 Nov. 1992

WCB

AR

TME



from Wernli & Knippertz (2018)

Climatology: WCBs

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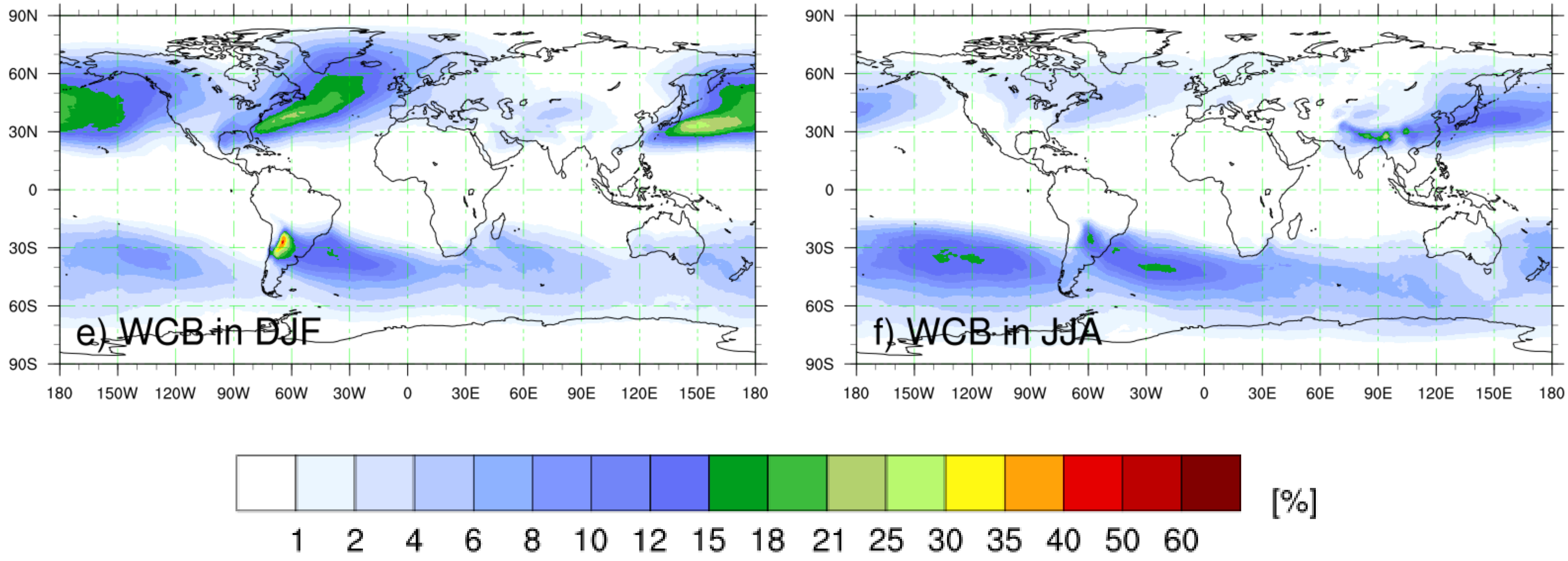
December–January **June–August**



from Wernli & Knippertz (2018)

- Clear relationship to winter stormtracks
- Orographic lifting (Andes, Himalayas)
- Secondary maximum: summertime SH, Meiyu-Baiu front

Climatology: ARs

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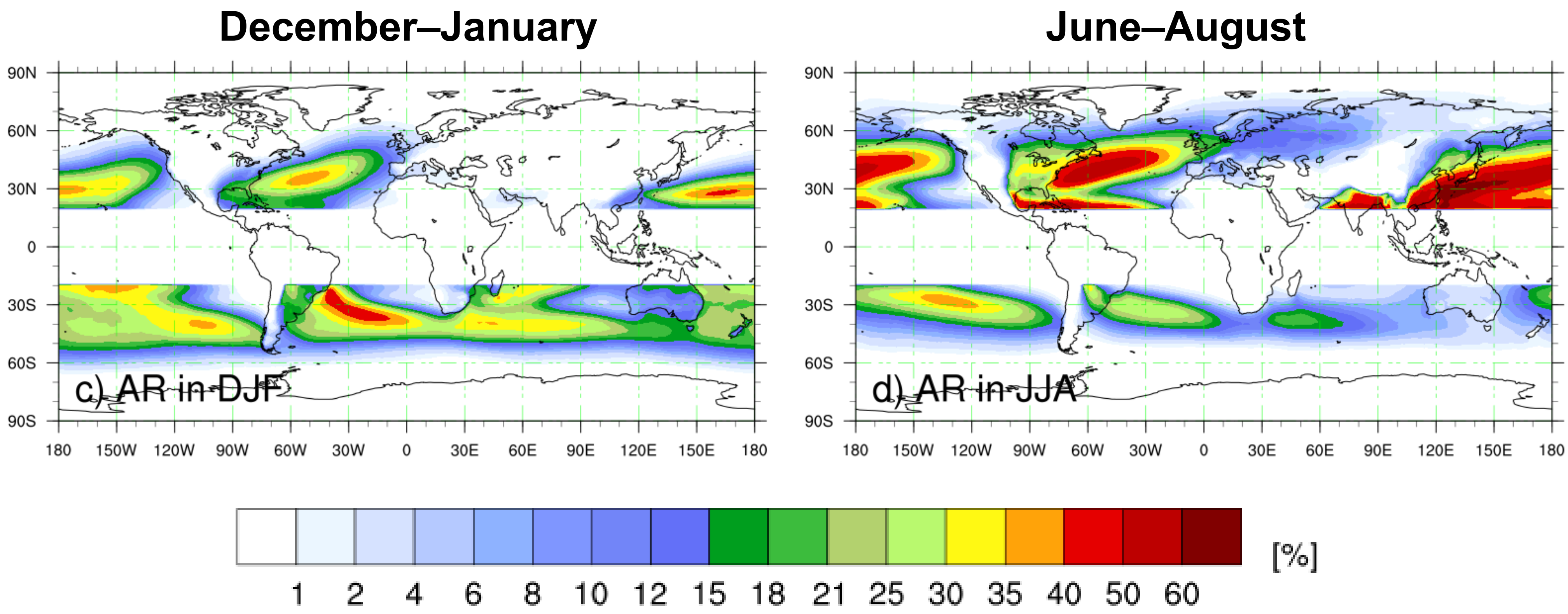
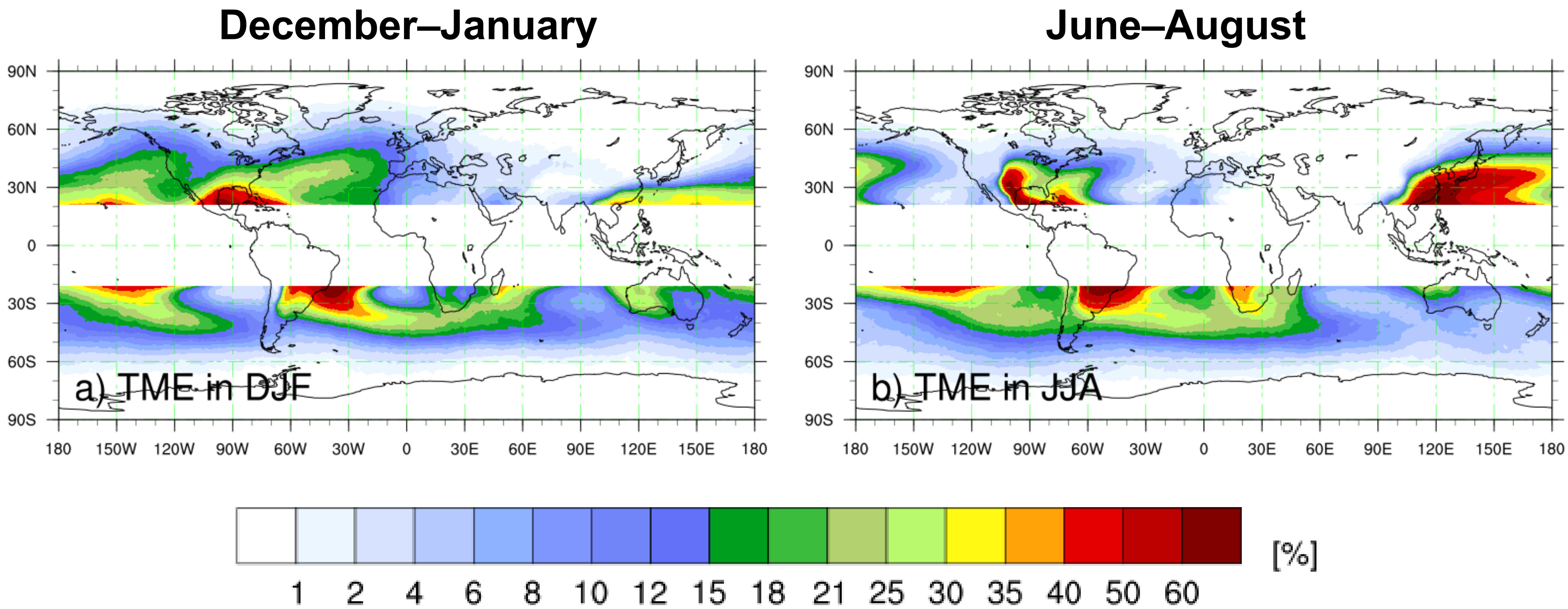


from Wernli & Knippertz (2018)

- Activity generally enhanced in summer
- Frequent ARs just north of 20°N in NH summer (e.g. monsoons)
- More confined to ocean than WCBs

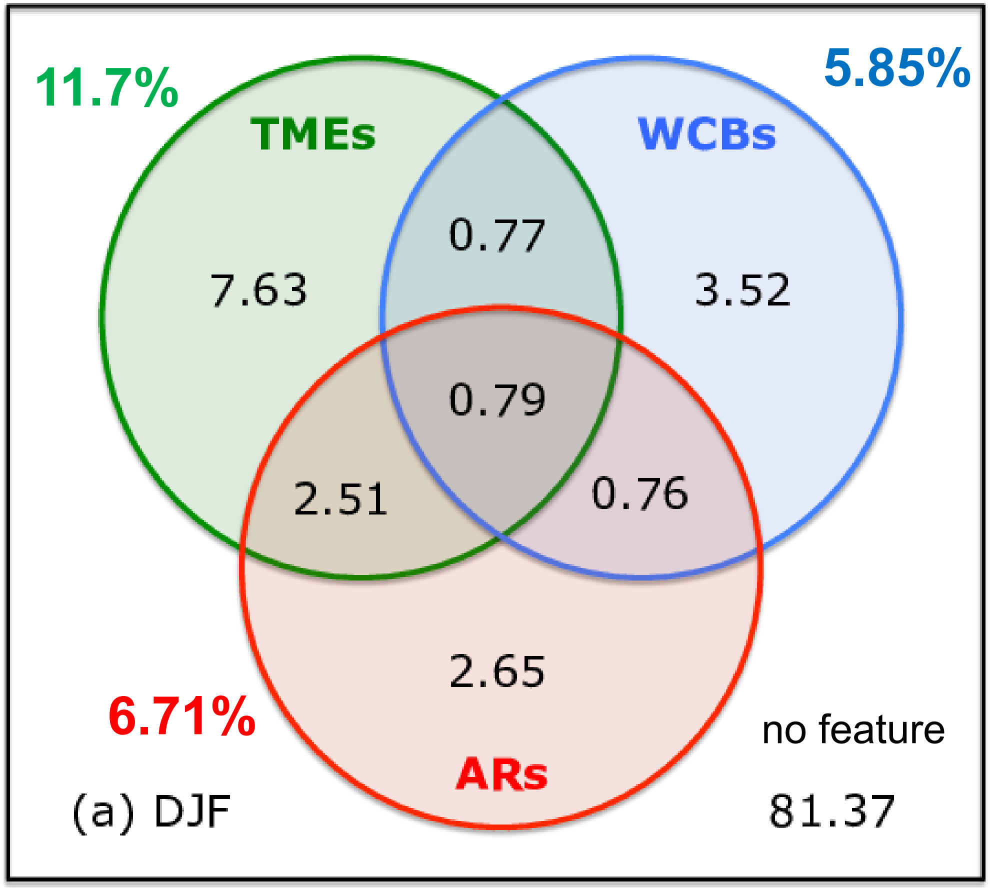
Climatology: TMEs



from Wernli & Knippertz (2018)

- Activity more confined to low latitudes
- Marked seasonal cycle in NH, much less in SH
- Clear global maximum Meiyu-Baiu front

Area overlap statistics



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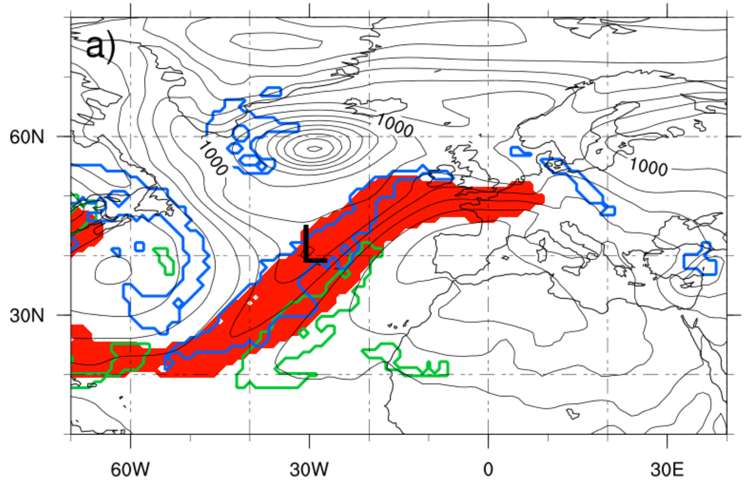
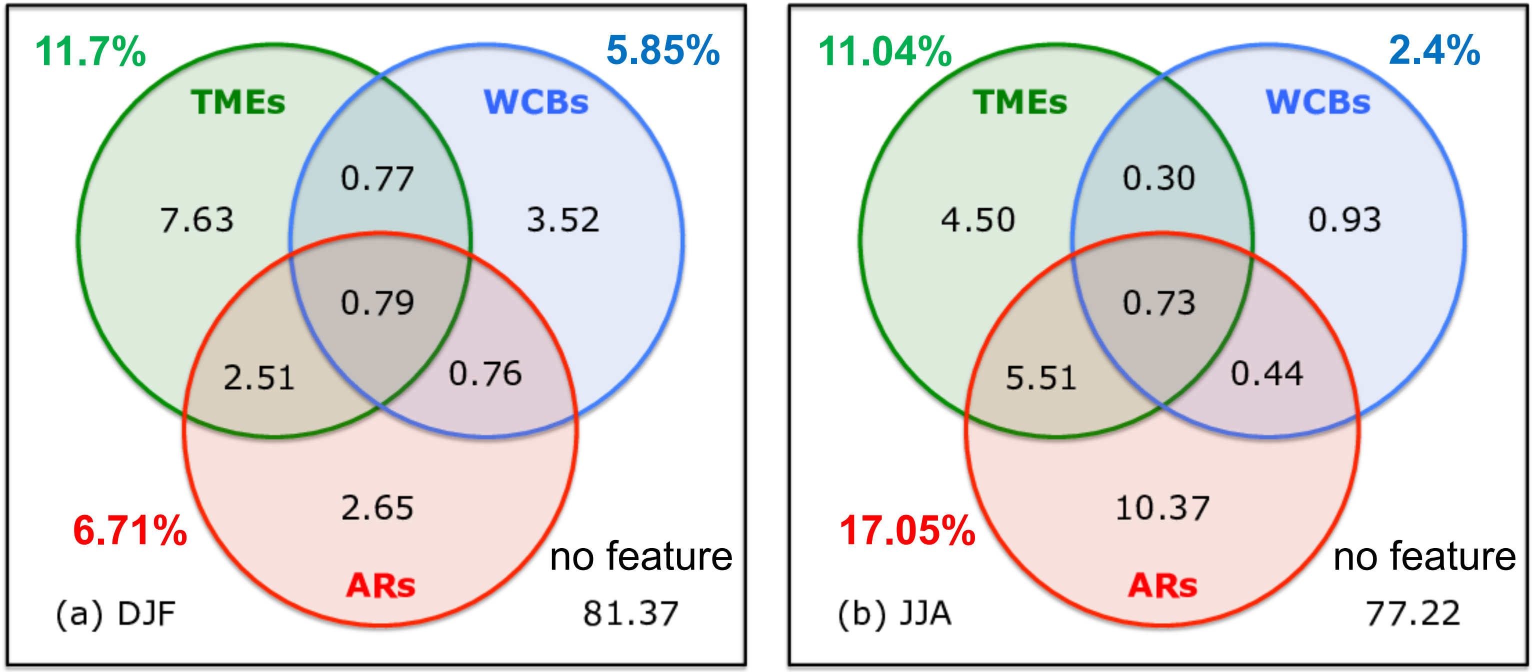


- Features often occur in isolation
- Many AR-TME coincidences
- Winter WCBs are most “independent”, as ascent depletes moisture

Seasonality of overlaps



from Wernli & Knippertz (2018)

- Seasonal cycle
  – TMEs stable
  – ARs NH summer maximum
  – WCBs NH winter maximum
- Even more AR-TME coincidences in NH summer

Conclusions

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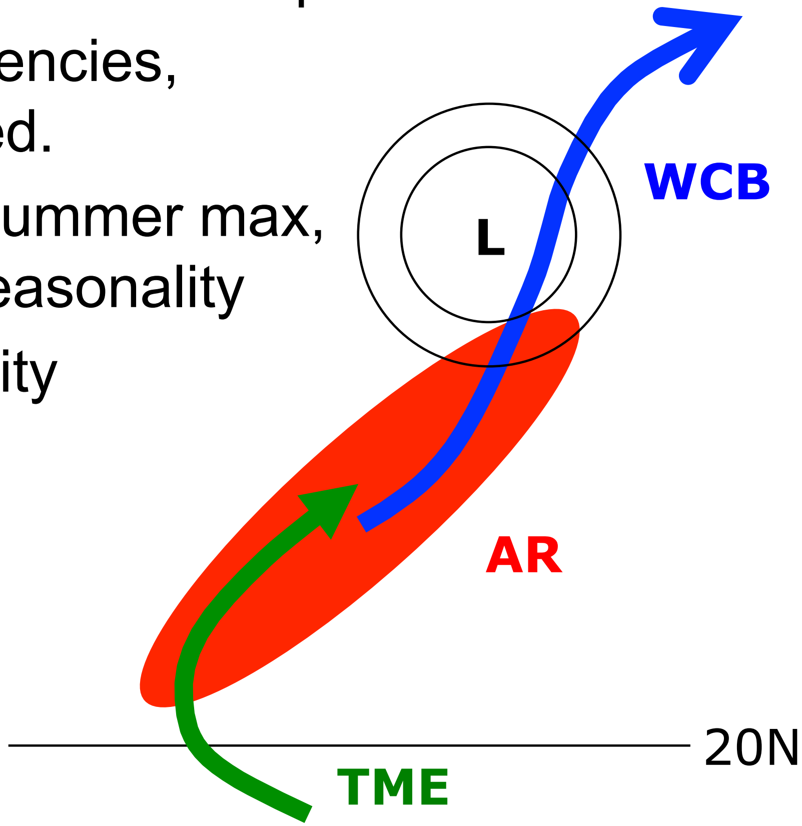
- First ever systematic comparison of WCBs, ARs & TMEs.
- Features are related but must not be used as synonyms.
- They focus on different aspects of moisture transport.
- Overall comparable occurrence frequencies, but overlap in space and time is limited.
- Asynchronous seasonality: ARs NH summer max, WCBs NH winter max, TMEs weak seasonality
- AR and TME more sensitive to humidity (most overlap), but many ARs not rooted in tropics
- WCB more sensitive to baroclinicity
- WCB ascent & rain-out limits poleward reach of ARs and TMEs



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