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DIPARTIMENTO DI SCIENZE DELLA TERRA "ARDITO DESIO"

Heavy precipitation over northern Italy and atmospheric rivers in the Mediterranean

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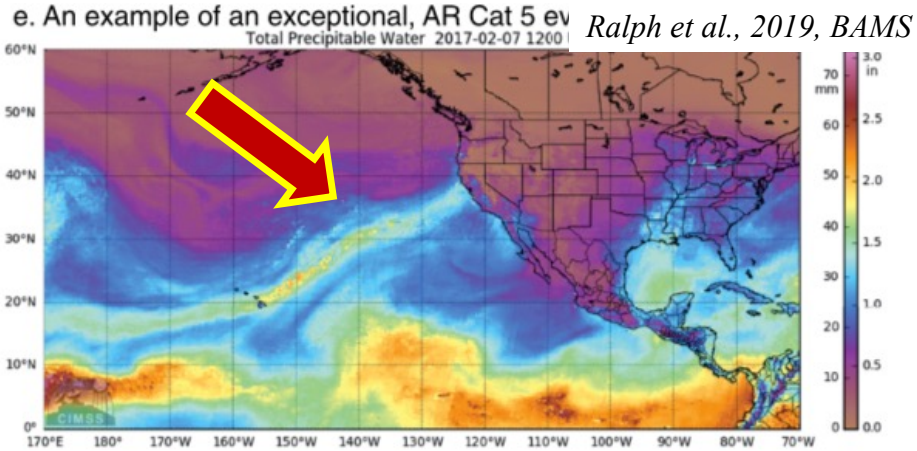
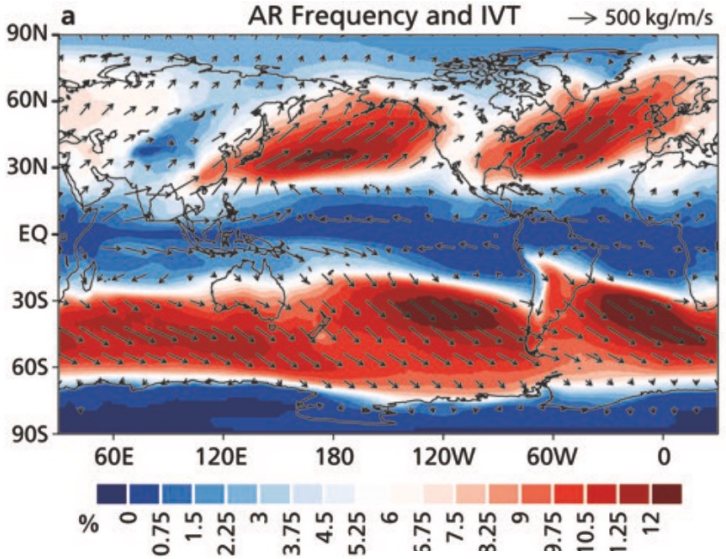
Acknowledgments: M. M. Miglietta[2], V. Levizzani[2], M. Vercellino

[1]Univ. Milan; [2]CNR - ISAC, Bologna; [3]CETEMPS/Univ. L'Aquila; [4]ARPAE; [5]Regional Civil Protection Agency - Abruzzo Region

ATMOSPHERIC RIVERS

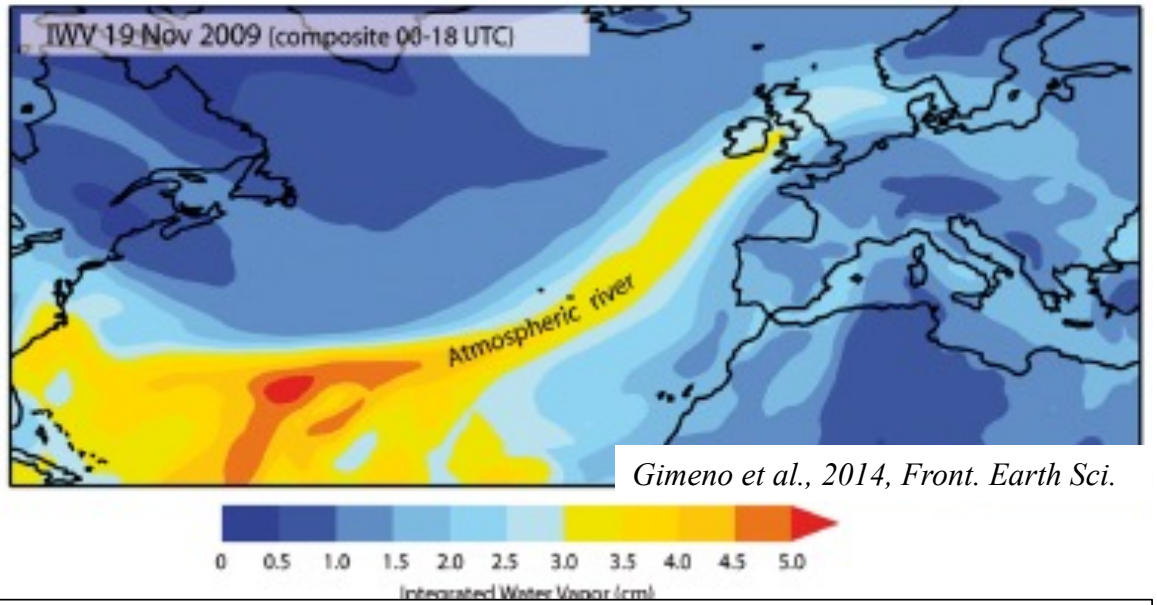


Ralph et al., 2019, BAMS



Guan & Waliser, 2015, JGR

ATMOSPHERIC RIVERS OVER EUROPE



Gimeno et al., 2014, Front. Earth Sci.

North Atlantic: *Stohl et al., 2008; Knippertz and Wernli, 2010; Ramos et al. 2016; Dacre et al., 2015; Brands et al., 2017*

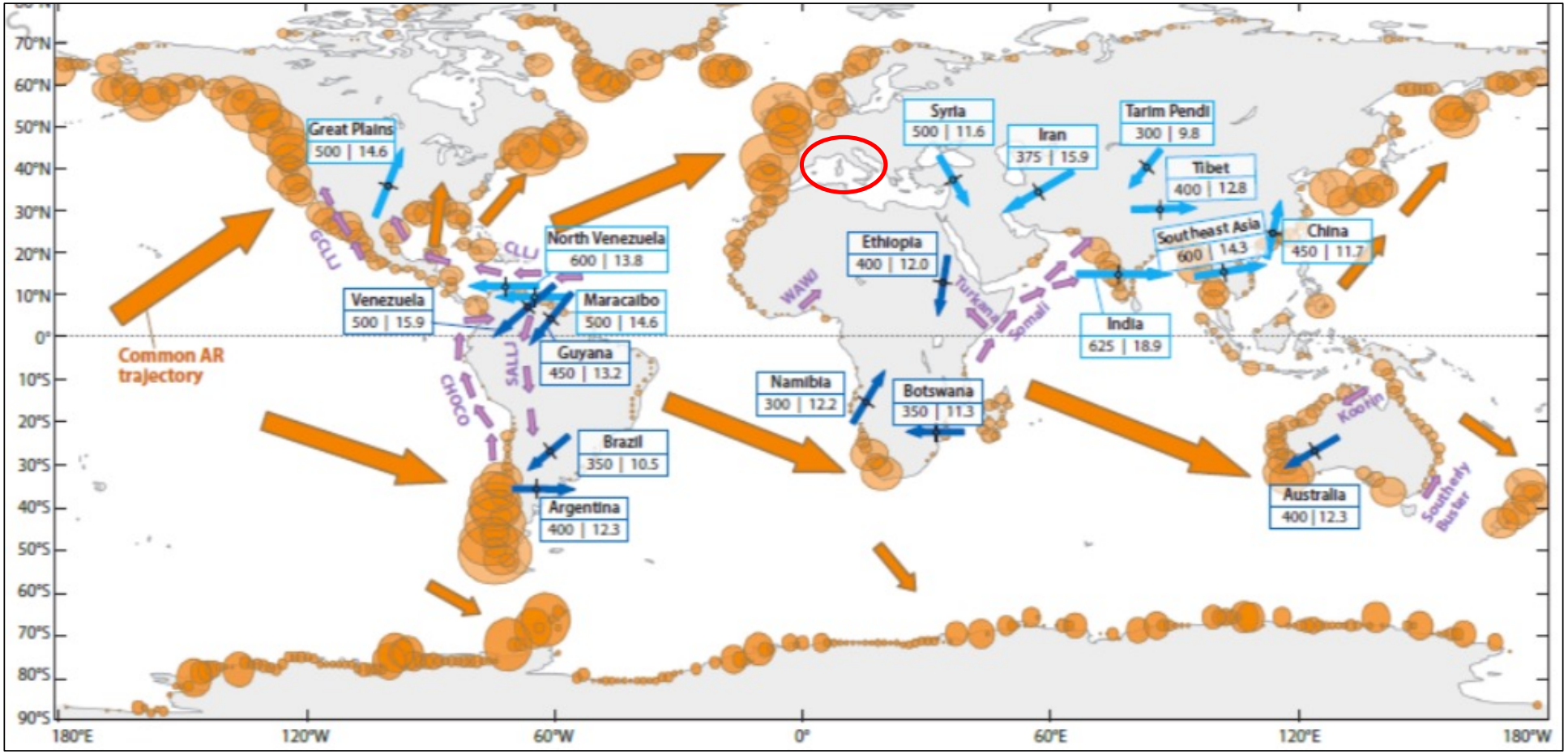
Scandinavian Peninsula: *Sodemann and Stohl, 2013; Benedict et al., 2019*

Iberian Peninsula: *Liberato et al., 2012; Ramos et al., 2015; Eiras-Barca et al., 2016*

Inland penetration in Central Europe: *Rossler et al., 2014; Inoita et al., 2020*

UK e France: *Lavers et al., 2011; Lavers and Villarini, 2013; Lu et al., 2013; Browning , 2018; Doiteau et al., 2021*

AR LANDFALL



Gimeno et al., 2016, Annu. Rev. Env. Res.

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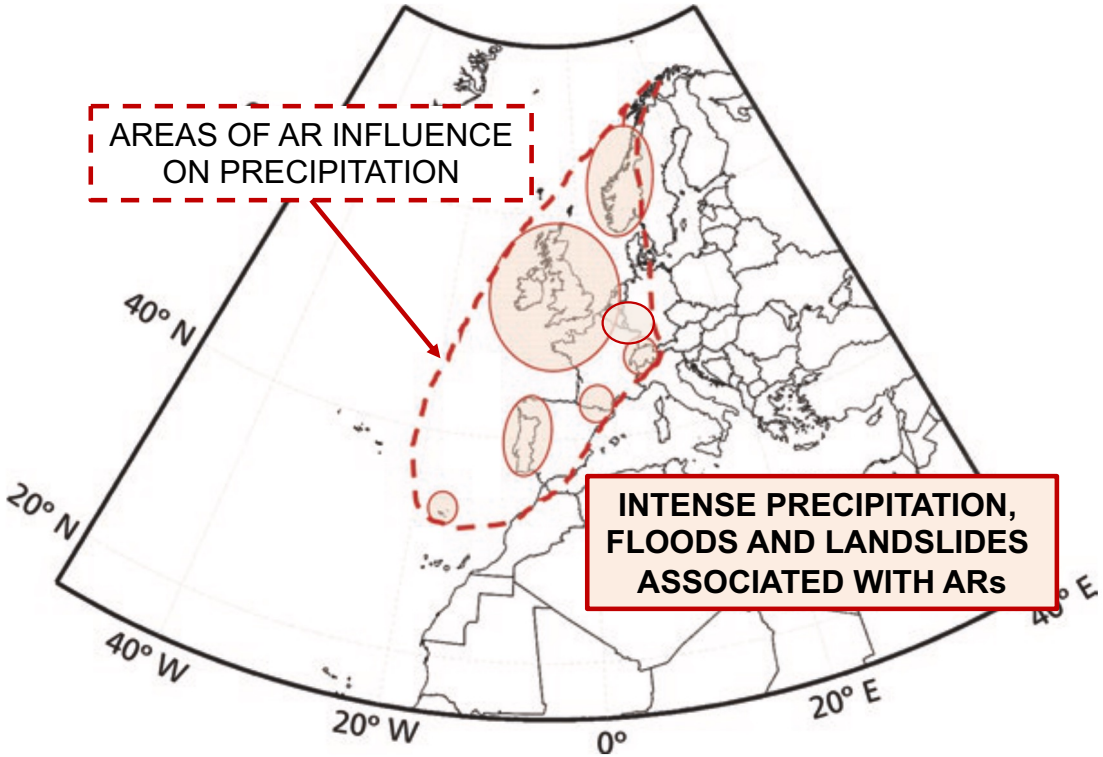
AR & PRECIPITATION - Europe



Adapted and updated from Gimeno et al. 2016

- In Western Europe ARs are responsible for 20-30% of all precipitation
- Strong seasonality (storm track)

Increasing interest in extreme events

- Strong relationship between ARs and annual maximum precipitation days in W-Europe coasts
- The strongest AR-AM connection is found in mountainous areas, mainly in fall and winter
- Striking inland impacts (more inland penetration compared to the US)

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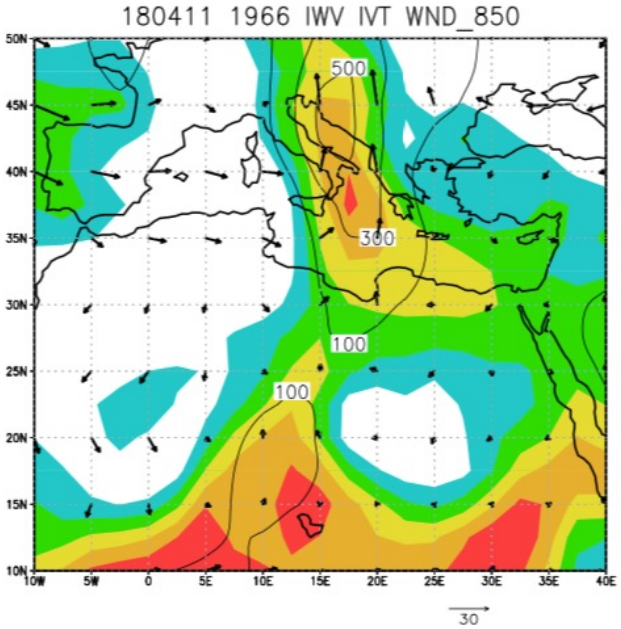
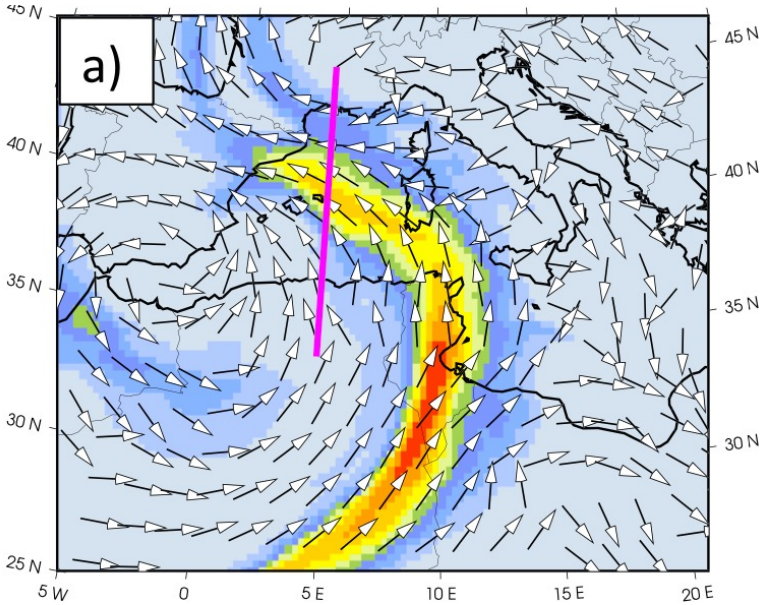
AR in the W-MEDITERRANEAN

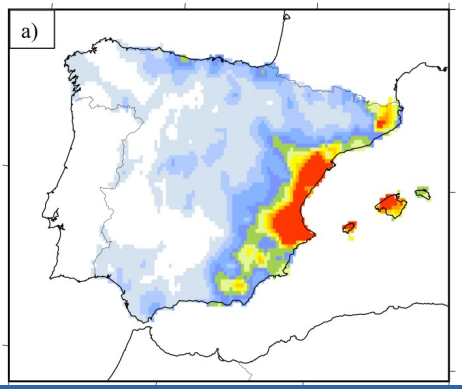
Suggesting the presence of an AR during the 1966 Florence flood



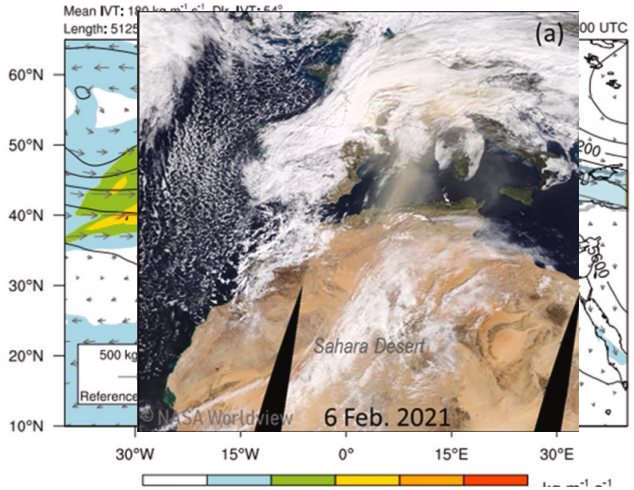
Krichak et al., 2016
Malguzzi et al., 2006
Buzzi et al., 2014

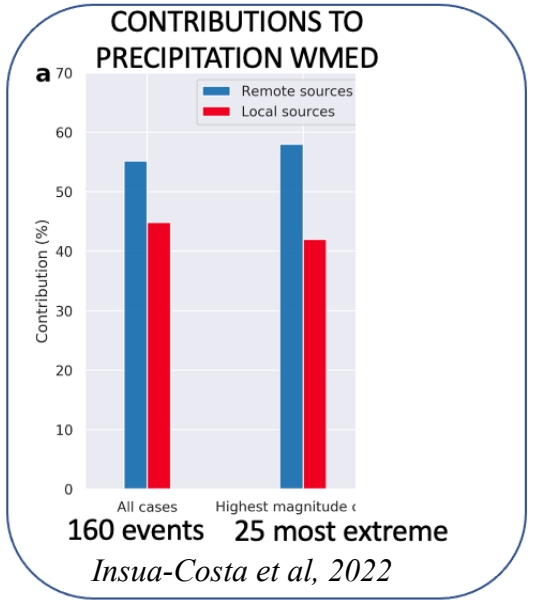


Lorente-Plazas et al, 2019



Francis et al, 2022





Insua-Costa et al, 2022

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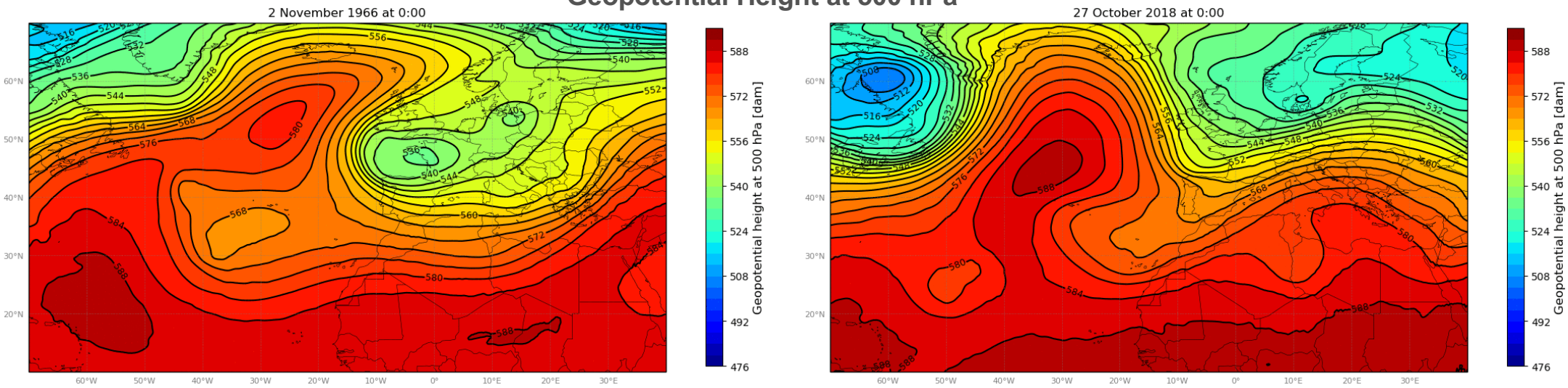
THE TWO “CENTURY FLOODS”

1966 FLOOD

2018 "VAIA" STORM



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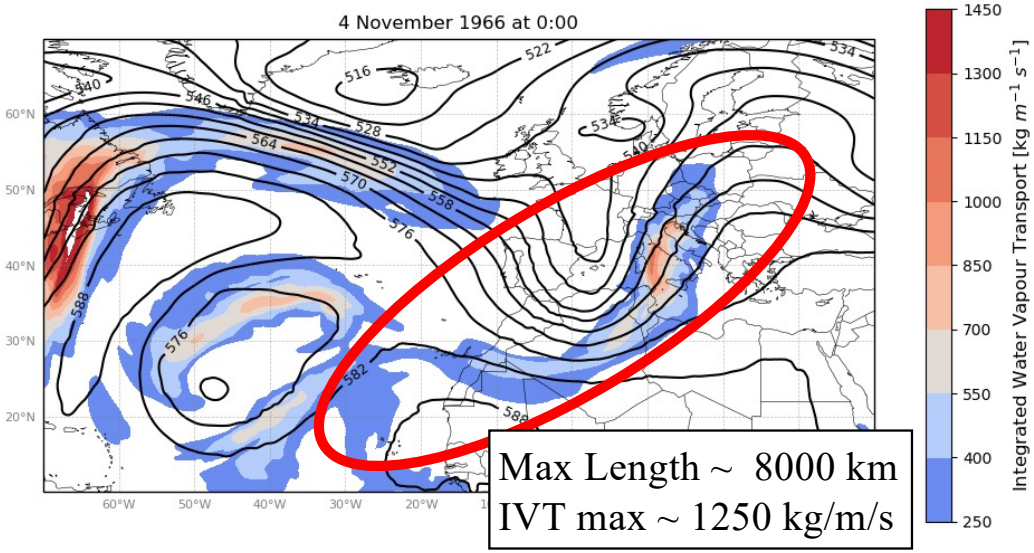
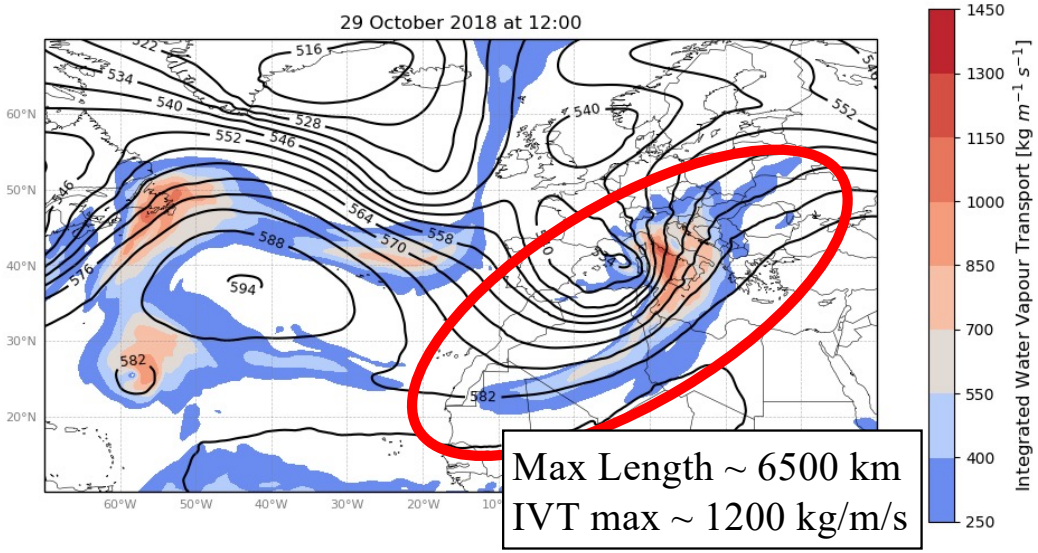
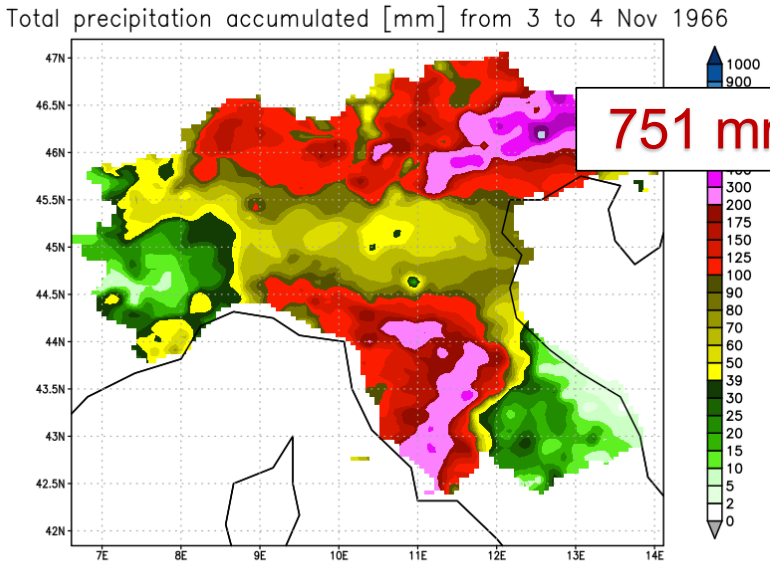
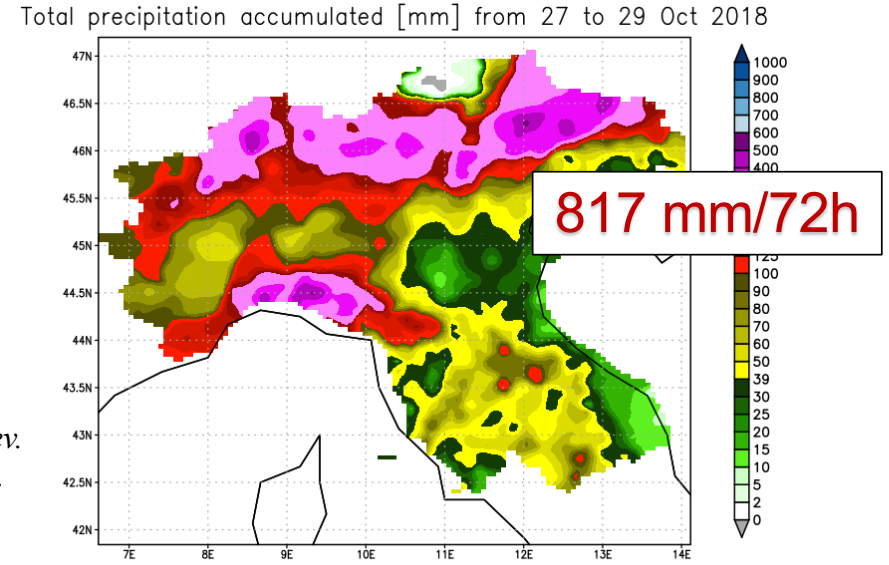






ArCIS database
Rainfall
1960-2024

Davolio et al, 2020, Mon. Wea. Rev.
Giovannini et al, 2021, Atm. Res.
Sioni et al, 2023, Atm. Res.



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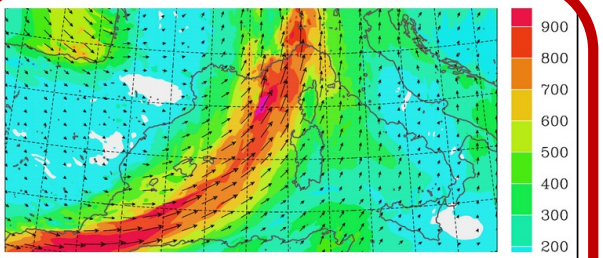
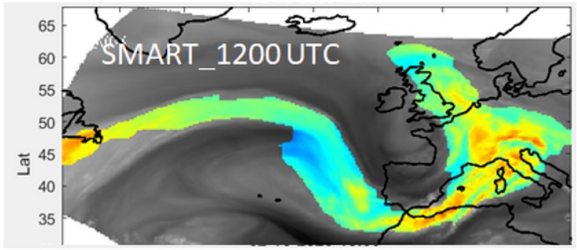
ARMEX

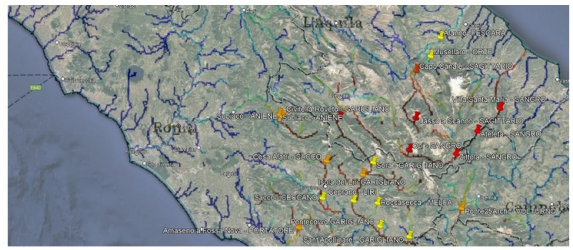
*Exploring **A**tmospheric **R**ivers in the **M**editerranean and their connection with **EX**treme hydrometeorological events over Italy: observation, modelling and impacts*



Meteorological modelling and analysis



Satellite monitoring and observations



Hydrological modelling and analysis

https://sites.google.com/view/armexproject

AIM:

- conduct a climatological analysis
- define AR characteristics and their impact in the mesoscale mechanisms of heavy precipitation
- reveal the hydrological impact of landfalling AR in several basins of different characteristics

TOWARDS A CLIMATOLOGY: ATMOSPHERIC RIVER DETECTION

Guan & Waliser (2015) algorithm with some adaptation for the Mediterranean

IVT Integrated Vapour Transport

i) IVT thresholds: IVT > 85-percentile
IVT > 250 $kgm^{-1}s^{-1}$

i) length > 2000 km

ii) aspect ratio > 2

AR Selection:

Target area: North/Central Italy

Origin area: outside the Mediterranean

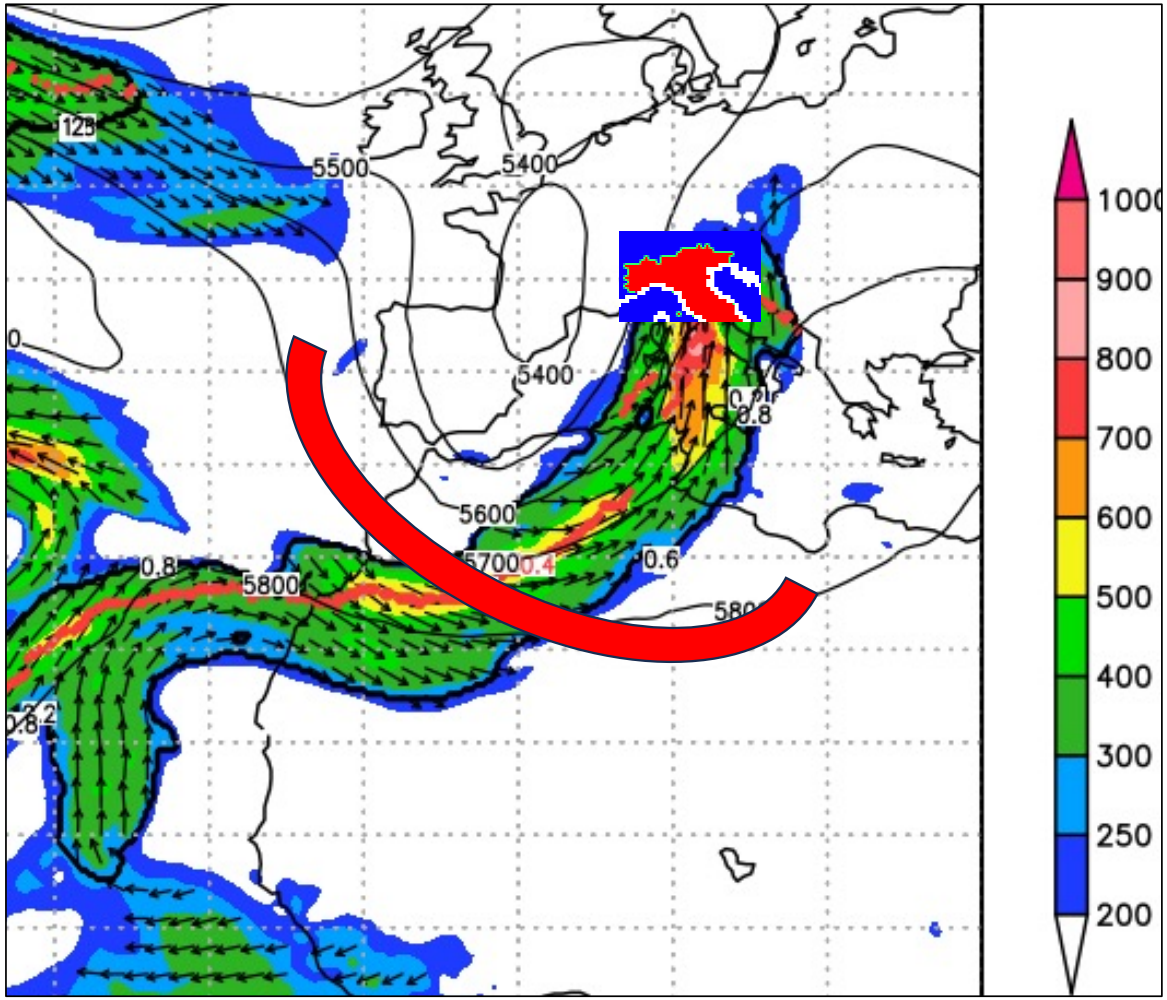
$IVT_y > 0$

Duration: at least 12 hours

MAX IVT over the sea, close to the target area

DATASETS:

ERA5 reanalysis (IVT) and ArCIS (1961-2024)



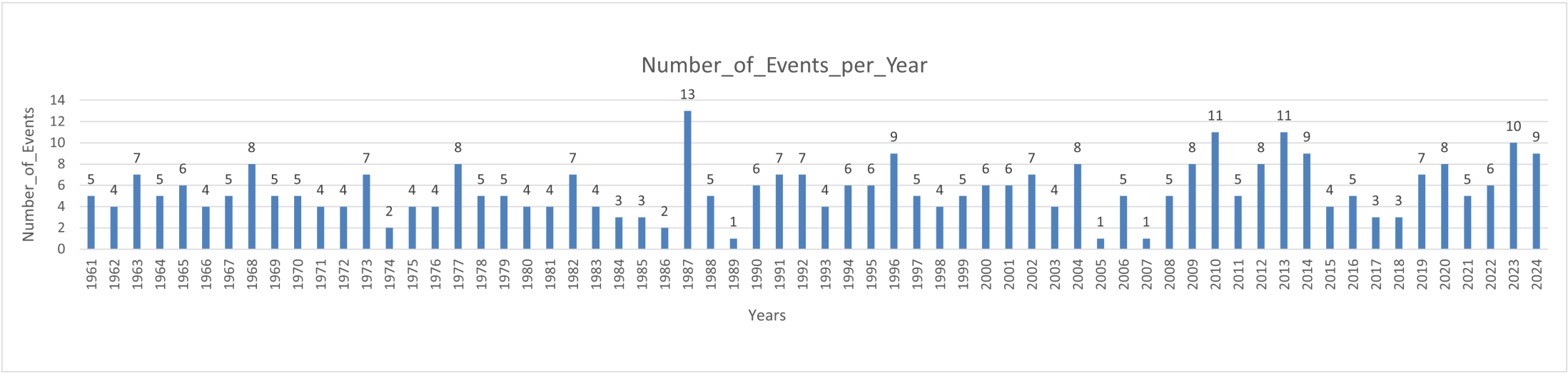
GUAN&WALISER ALGORITHM (adapted to the Med)

ERA5 1950-2024

IDENTIFICATION OF MOST INTENSE AR AFFECTING N-ITALY

MOST INTENSE EVENTS OVER N-ITALY

ARCIS RAINFALL 1961-2024



357 AR identified, on average 5.6 AR events per year

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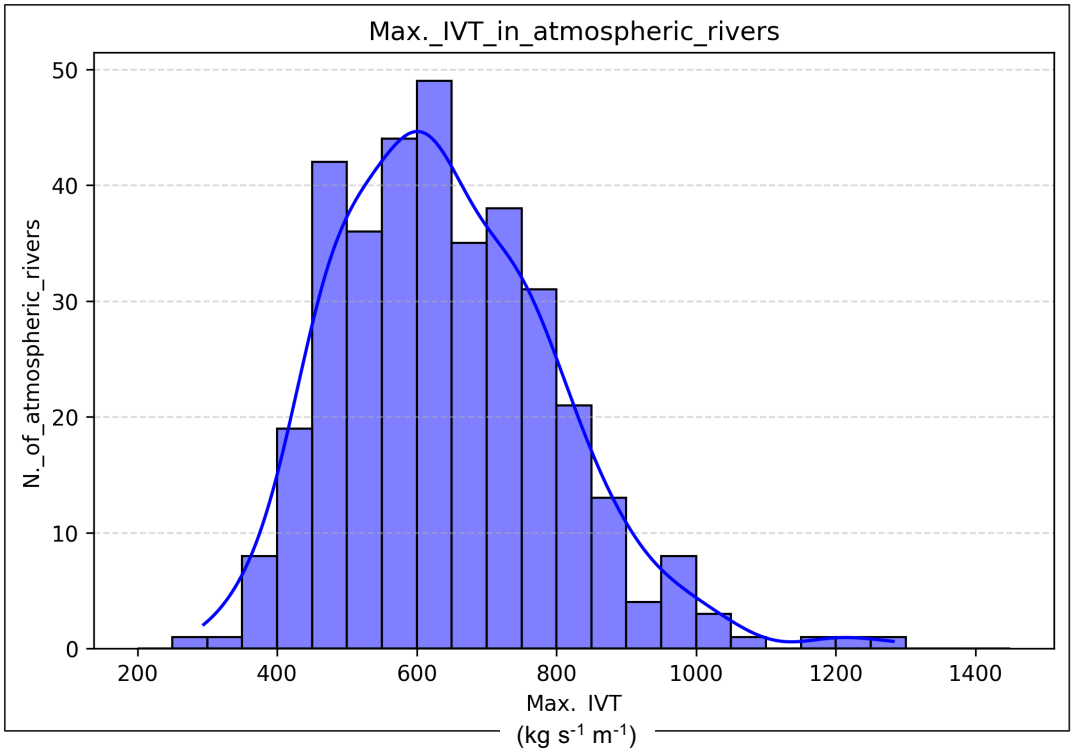
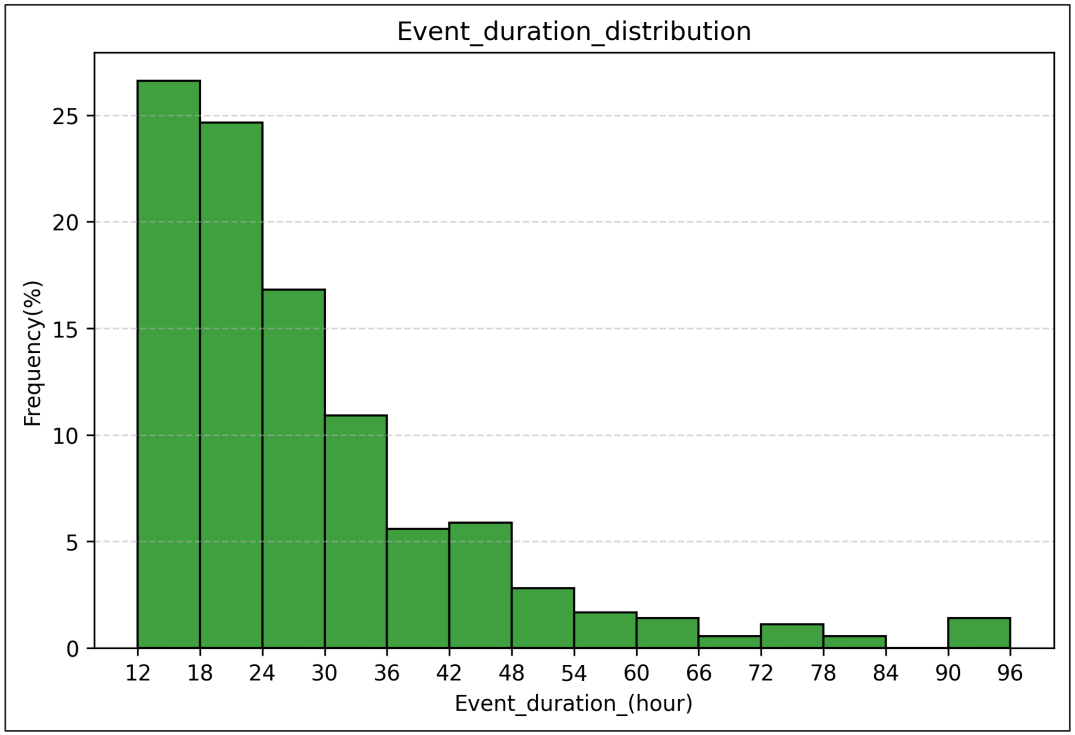
AR INTENSITY & DURATION





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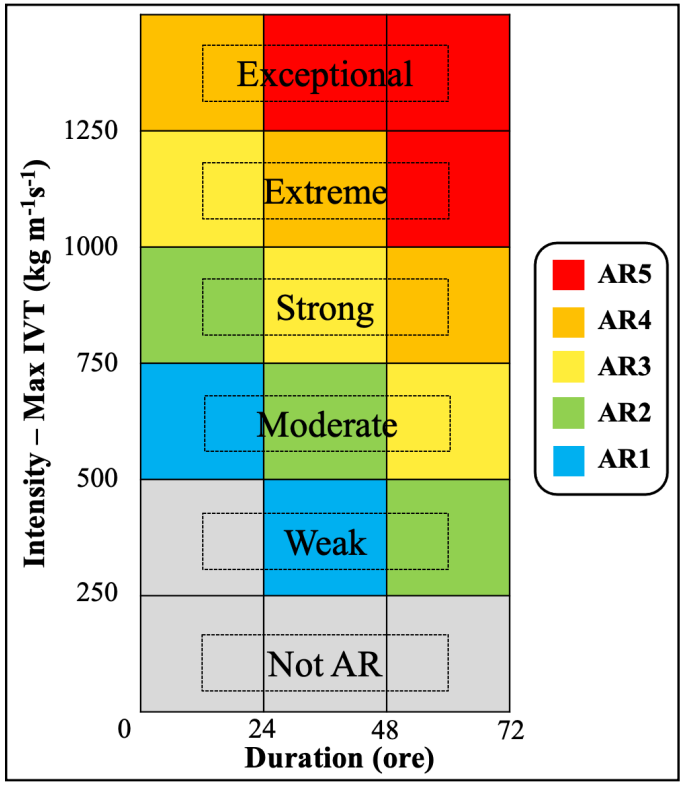
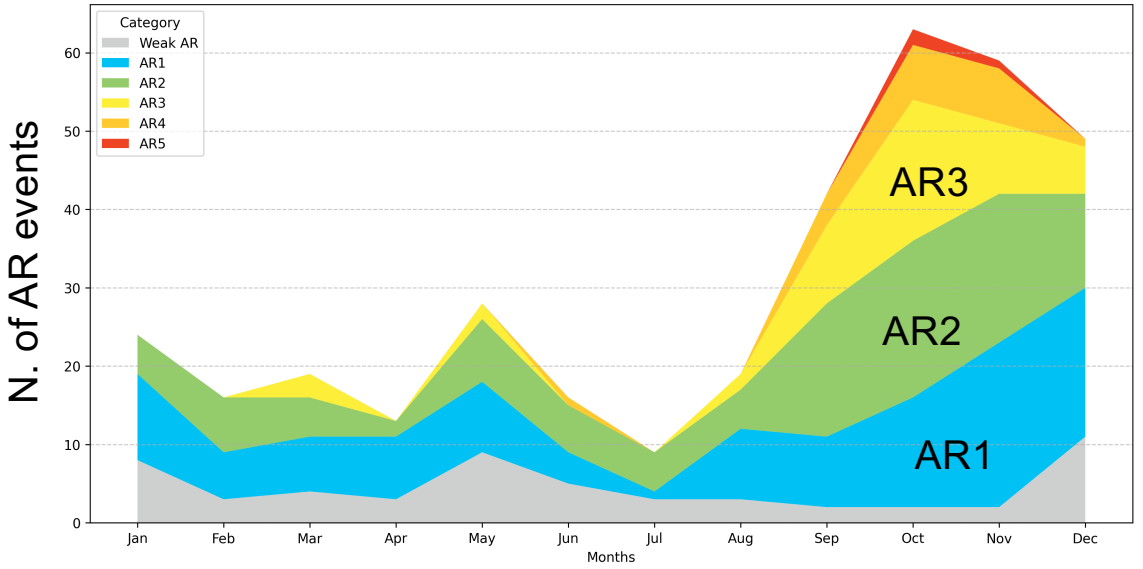
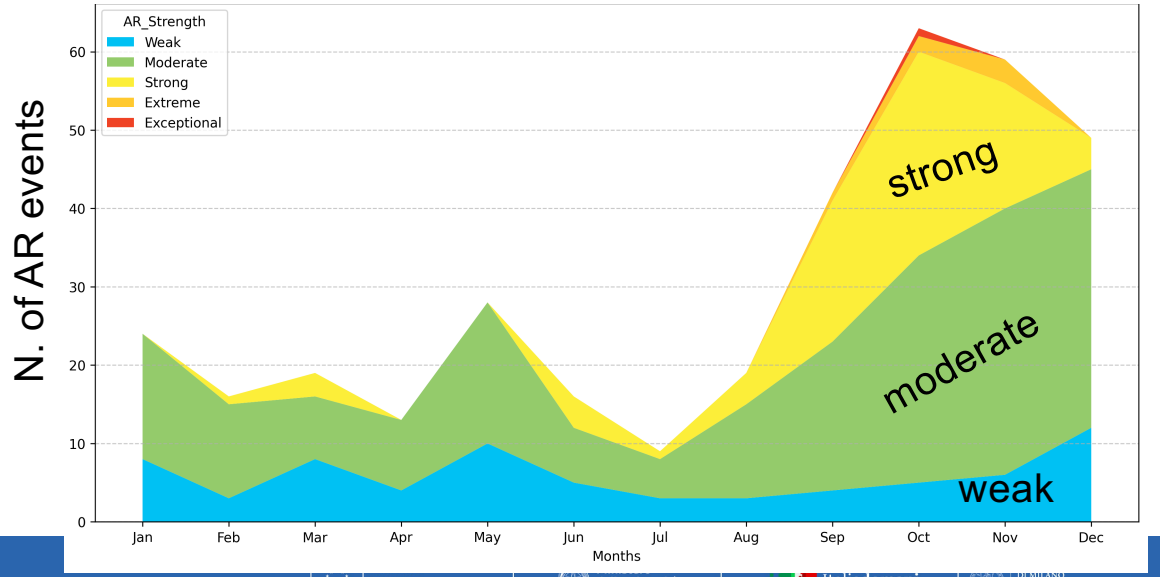
AR CATEGORIES AND SEASONAL DISTRIBUTION



Ralph et al., 2019



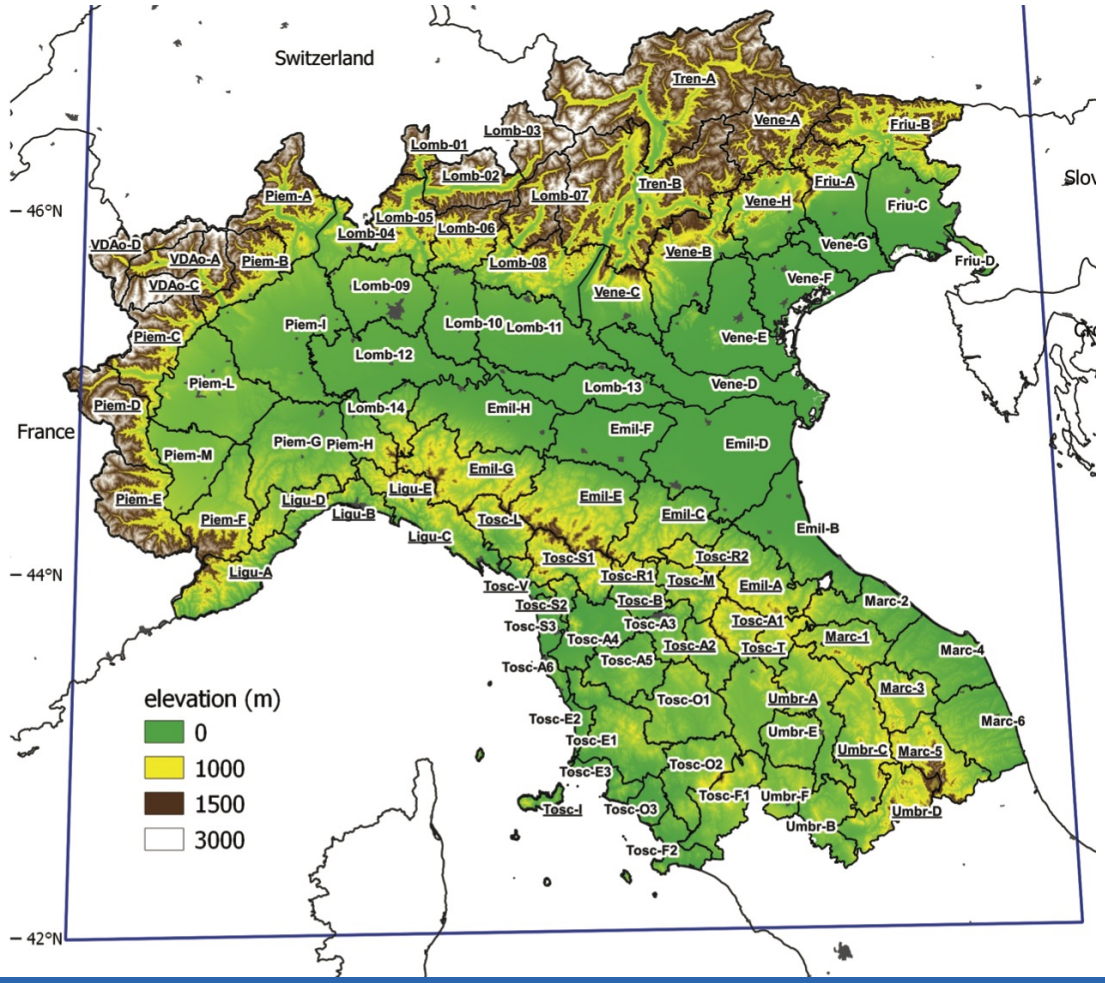


AR vs PRECIPITATION

- Daily precipitation aggregated over 94 warning-areas
- Mean area extension 1750 km^2
- **Extreme Precipitation Event (EPE)**: day with daily precipitation greater than 99th percentile (wet days only) across one or more warning areas

Grazzini et al., 2019, 2021

ITALIAN CIVIL PROTECTION WARNING AREAS



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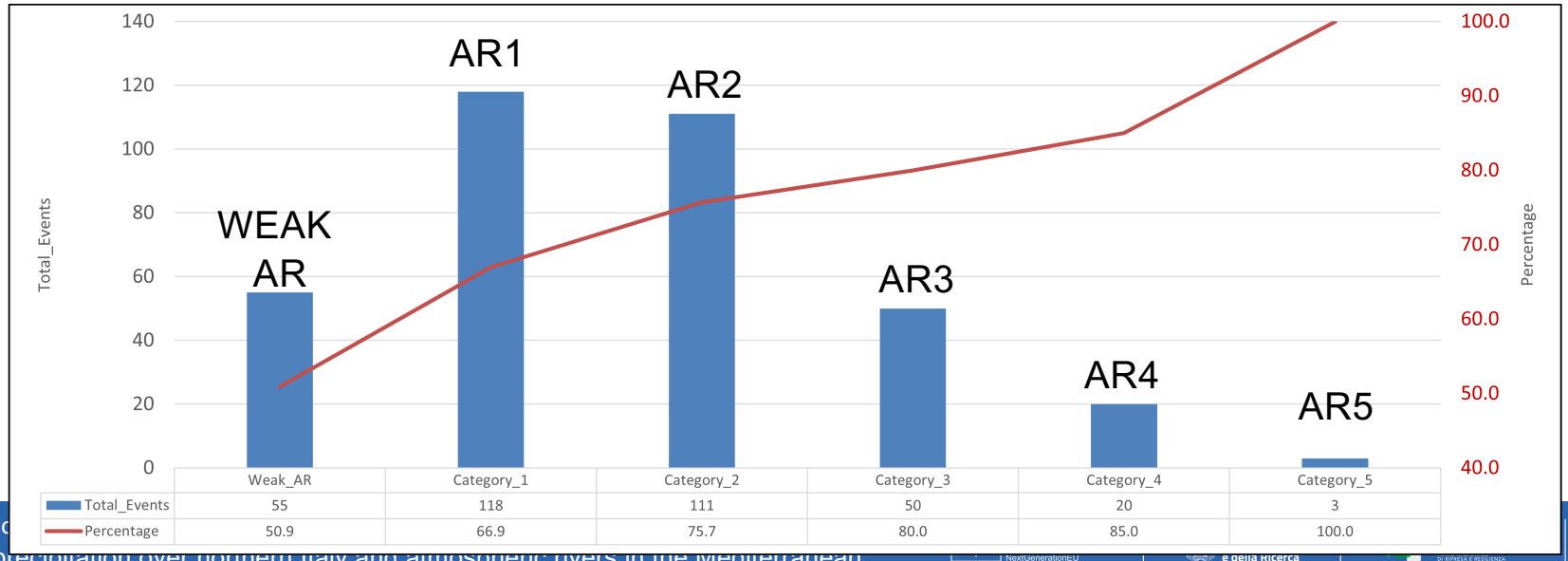
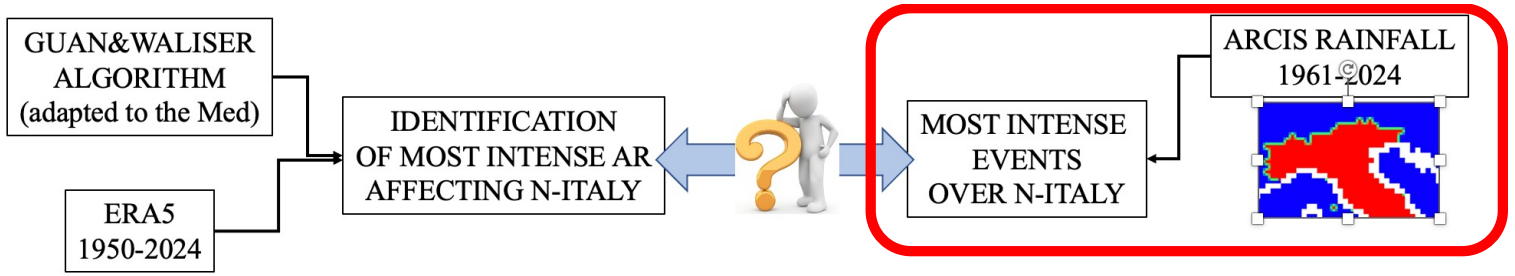
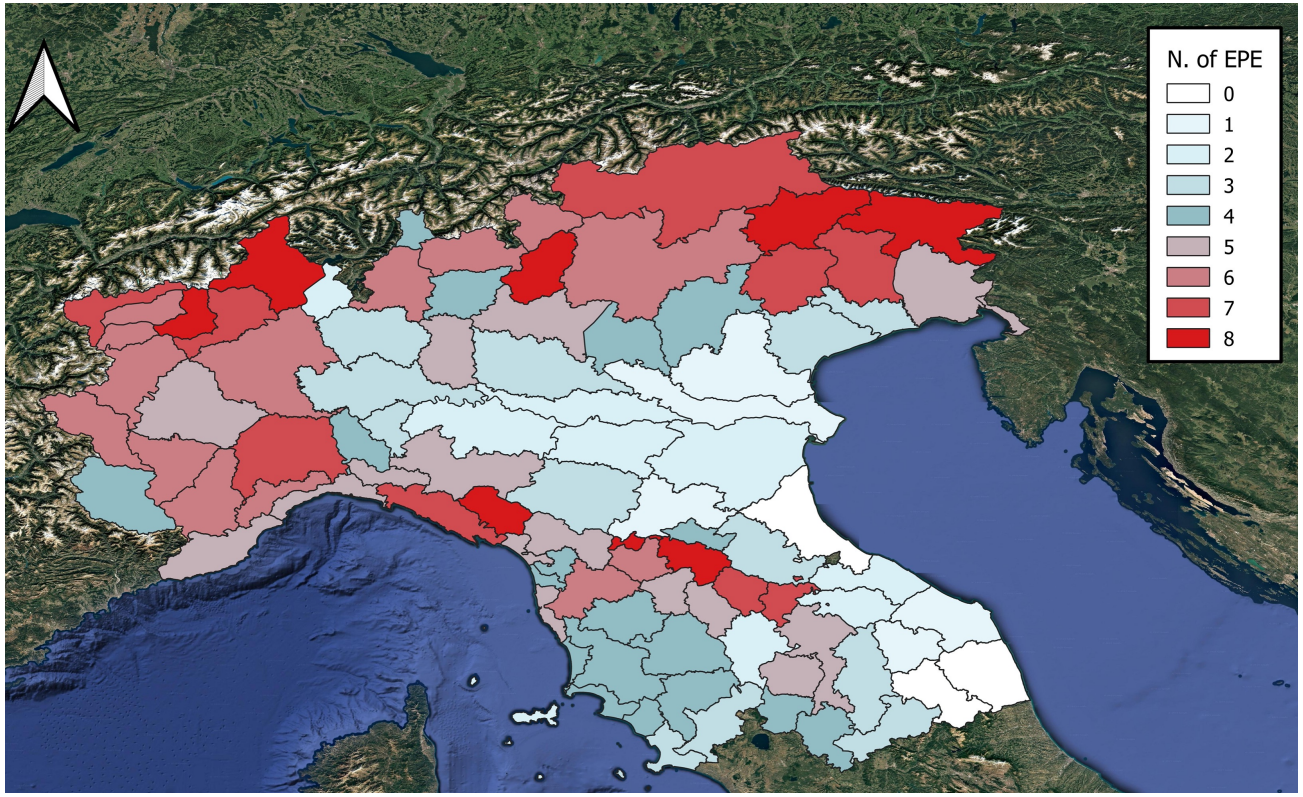
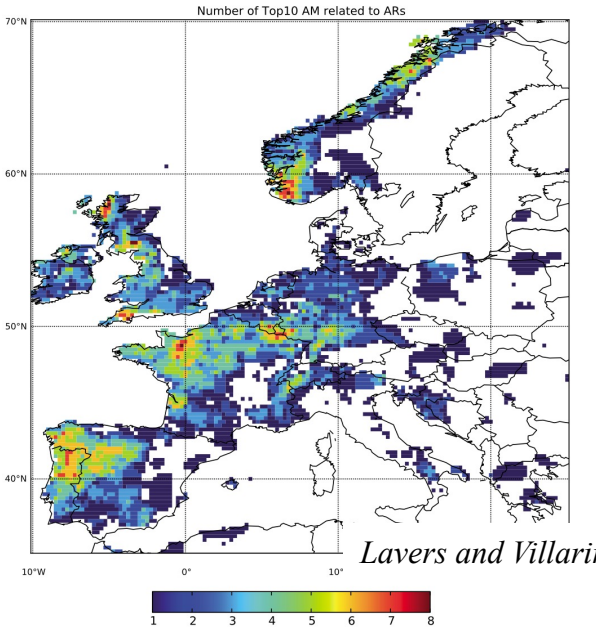
CATEGORY	N. of AR	N. of ARs associated with EPE	% of ARs associated with EPE
WEAK AR	55	28	51%
AR1	118	79	67%
AR2	111	84	76%
AR3	50	40	80%
AR4	20	17	85%
AR5	3	3	100%







Top 10 EPE associated with an AR



Lavers and Villarini, 2013

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EXPLORING PREDICTABILITY OF EPE and AR at MONTHLY TIME SCALE

Vaia storm event

25–31 Oct 2018, weekly anomalies

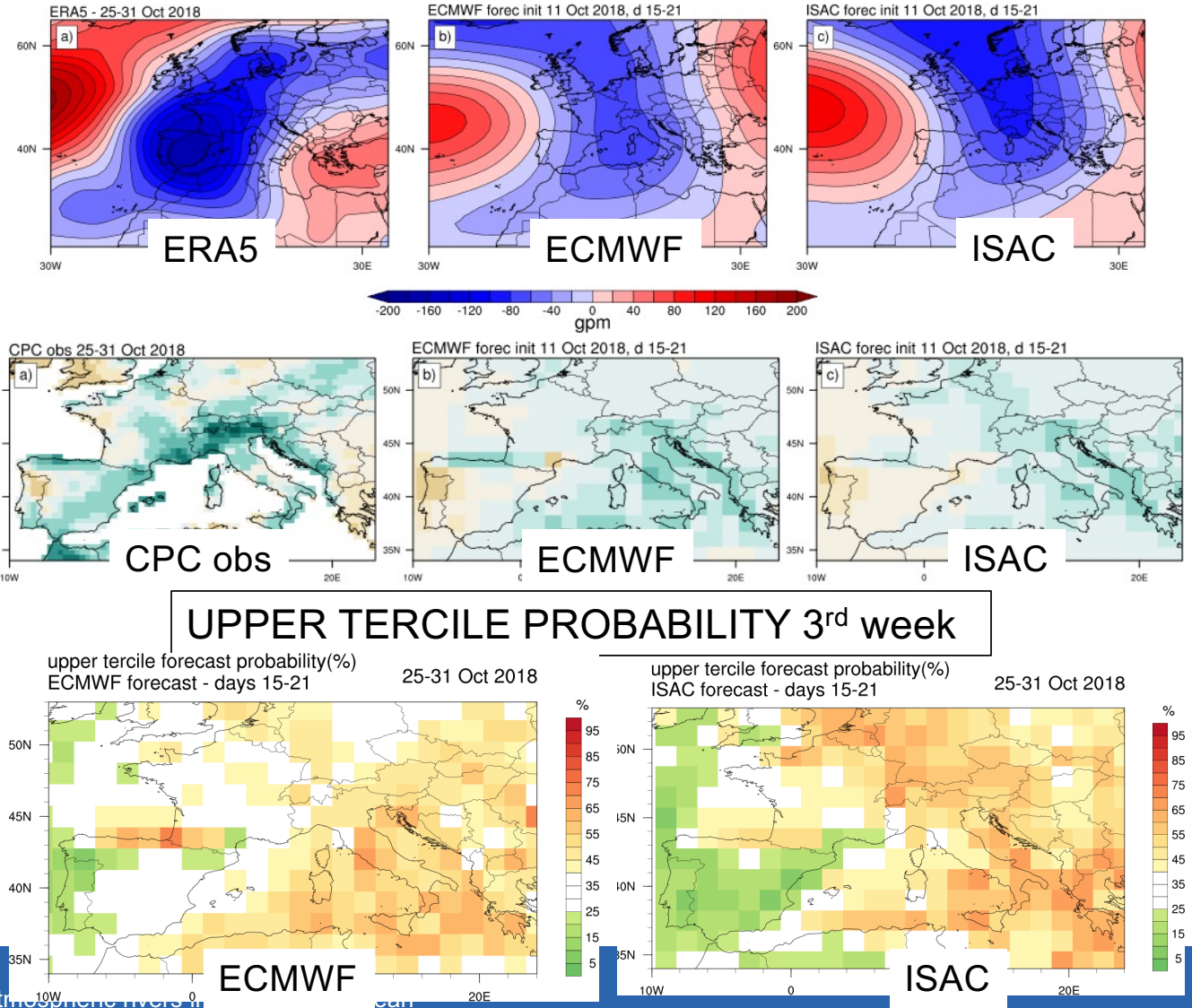
- **ERA5**: z500 (gpm)
- **CPC**: precipitation (mm/d)
- reference climate 1998–2017 (20 y)

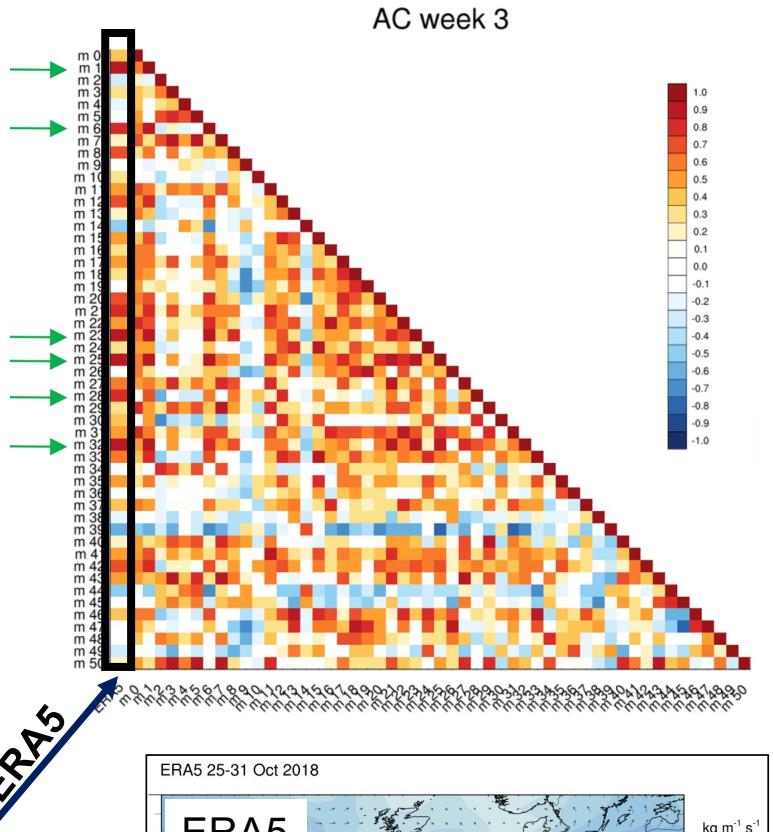
ECMWF ensemble forecast

- initialized: 11 Oct 2018 (operational)
- 51 members, perturbed
- reference climate: 11-member ensemble reforecasts, 1998–2017 (20 y)

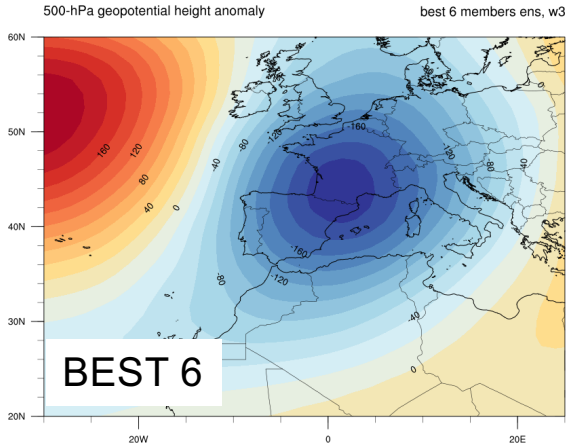
CNR-ISAC ensemble forecast

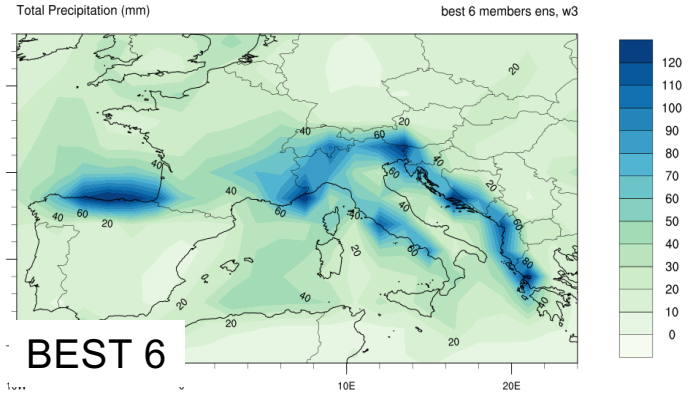
- initialized: 11 Oct 2018 (hindcast, ERA5)
- 41 members, lagged/perturbed
- reference climate: 8-member ensemble reforecasts, 2001–2020 (2018 removed, 19 y)



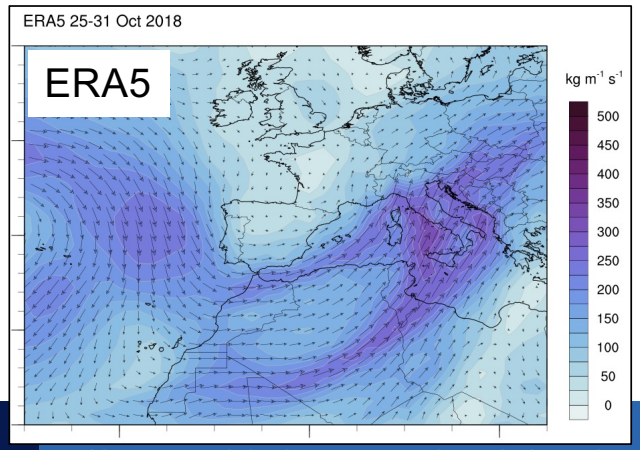


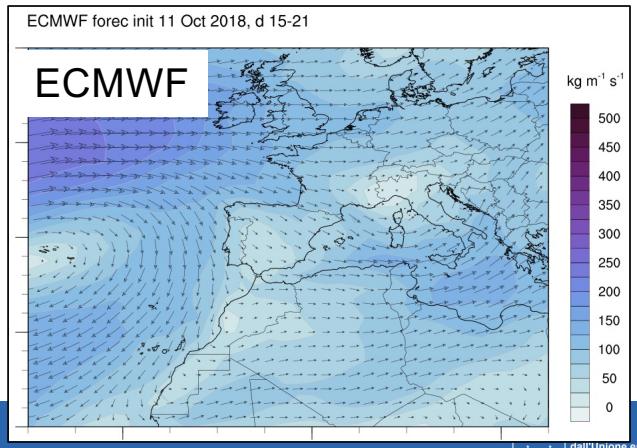
Extract the best (6) members higher anomaly correlation with ERA5 at week 3

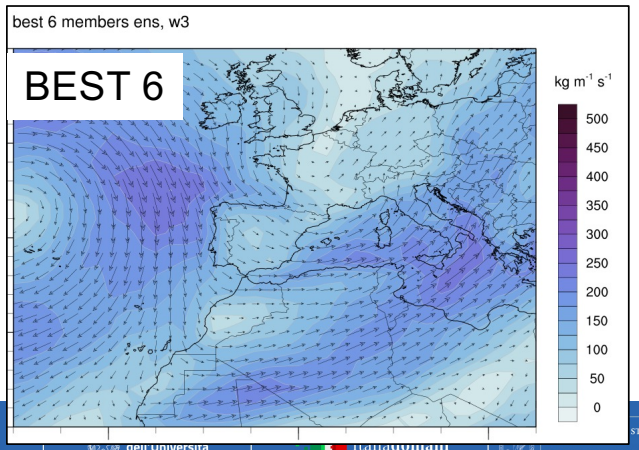




Why are they good? What happened upstream before?

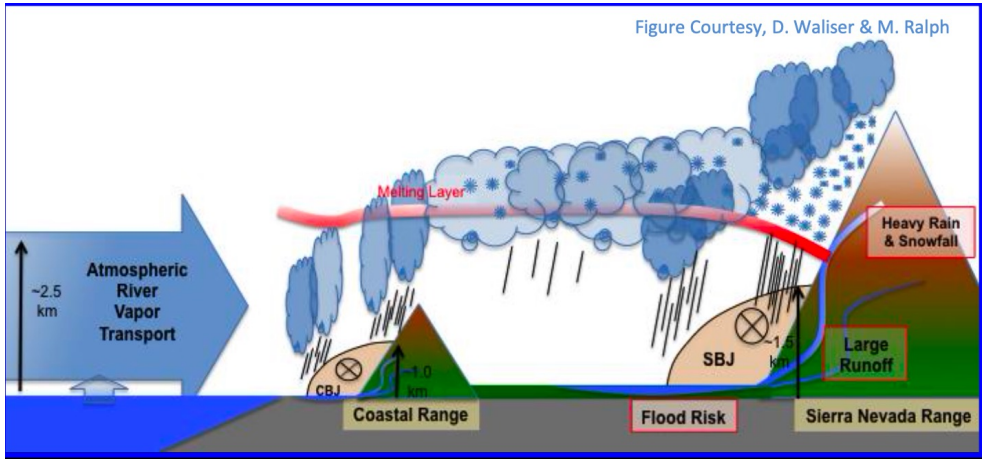






CONCLUSIONS

- Climatology: relevance of AR and connection with EPE
- Case study approach:
  - The AR may turn an ordinary intense rainfall event into a devastating flood
  - Mechanism of orographic precipitation
  - Local hydro-meteo impacts, forecasting at different time-scales



FUTURE PERSPECTIVES

- Connecting EPE to AR
- Exploring mechanisms associated with convection
- Extend the study to other Med areas

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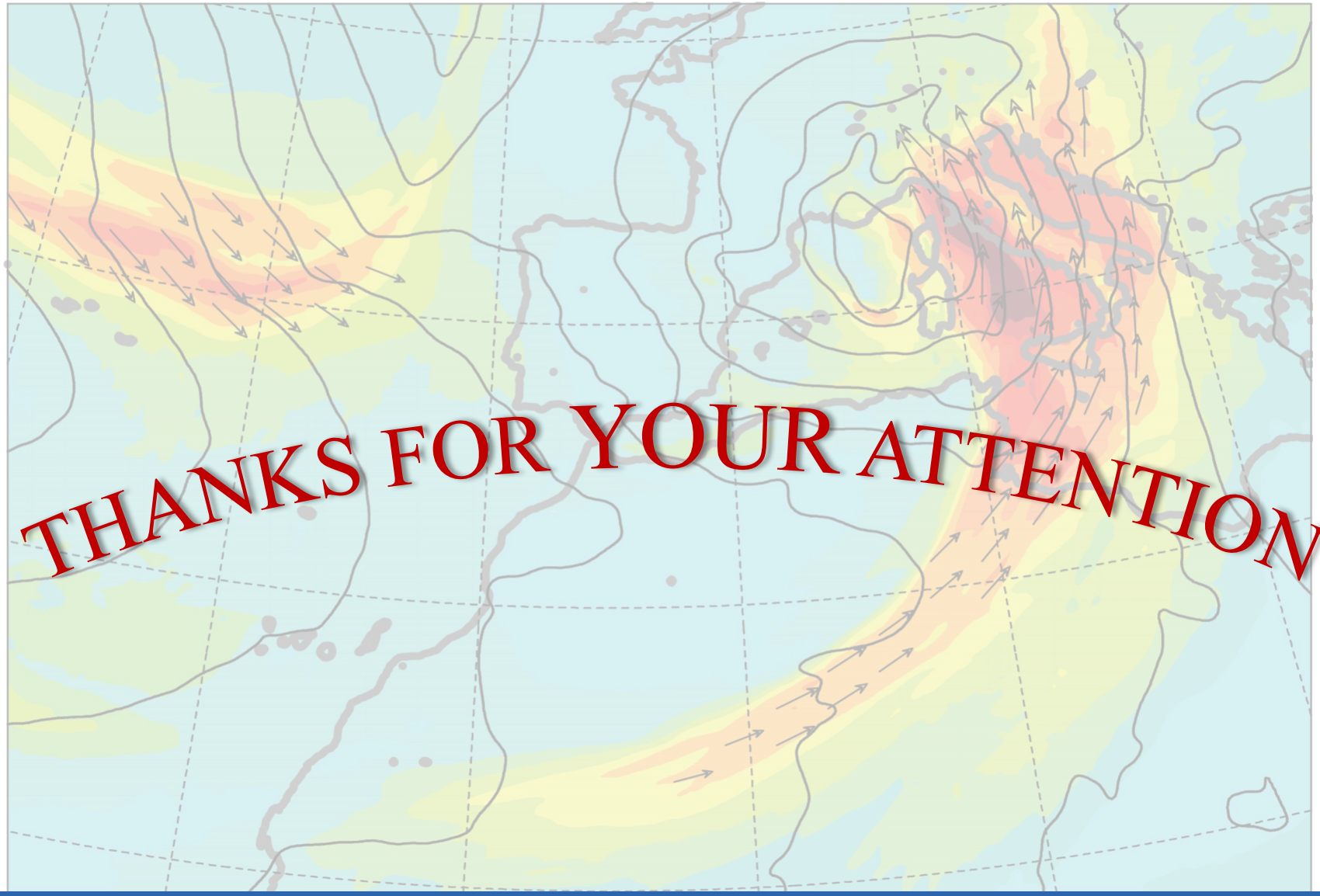

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