Seminari UniBO – ISAC
21 aprile 2023

Fenomeni responsabili di eventi intensi nel Mediterraneo a diverse scale: atmospheric rivers, cicloni e sistemi convettivi

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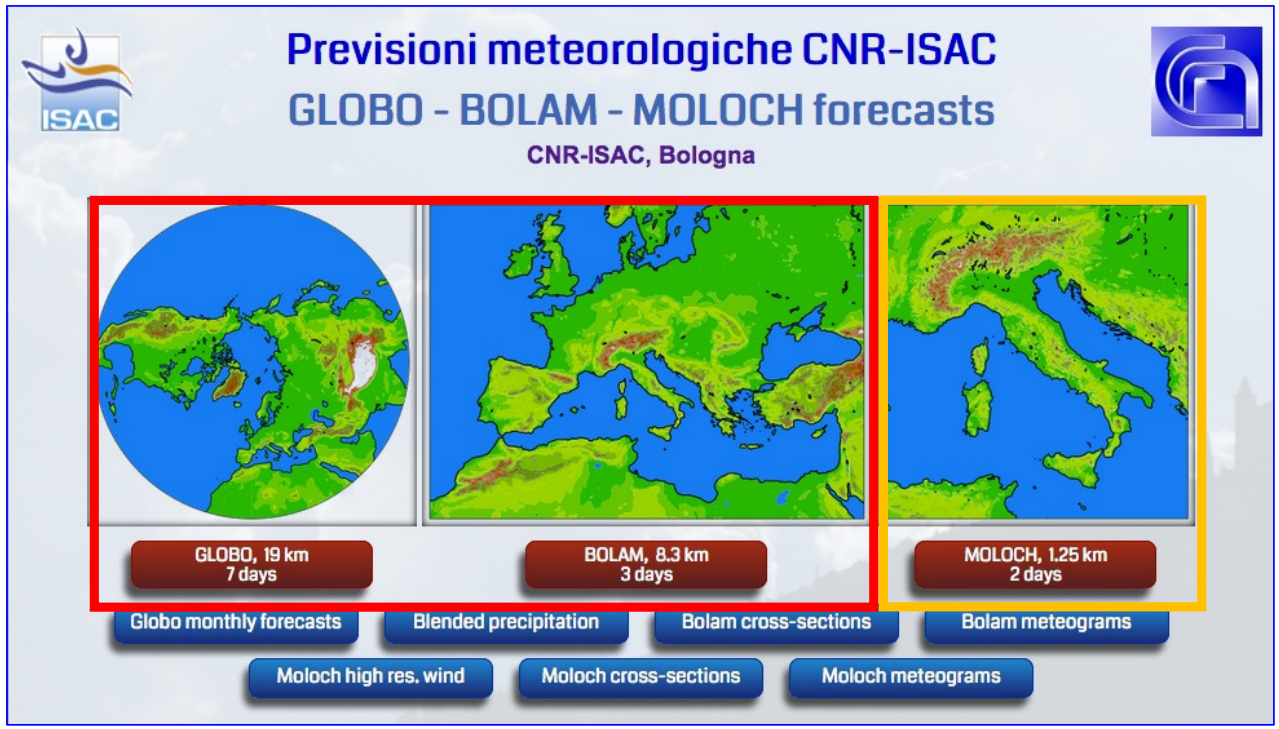


OPERATIONAL NWP at CNR-ISAC

http://www.isac.cnr.it/dinamica/projects/forecasts

IC: GFS Analysis

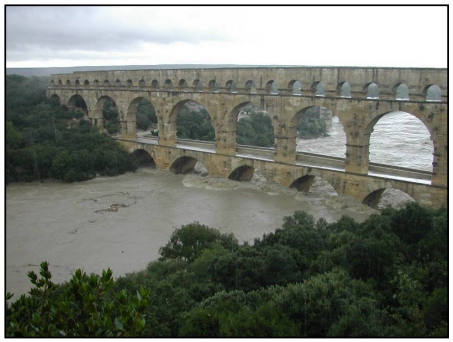
Buzzi et al., 1994 Met. Atm. Phys.
Malguzzi et al., 2011 Wea. Forec.

BOLAM: primitive equations, hydrostatic, parameterized convection (Kain-Fritsch)
GLOBO: grid-point hydrostatic general circulation model on a uniform mesh in geographic coordinates on the sphere

MOLOCH: non-hydrostatic, fully compressible, convection permitting

Malguzzi et al., 2006 J. Geoph. Res.

The climate change manifests itself through modification of meteorological phenomena, often leading to extreme events.
Extreme precipitation main trigger for natural disasters and one of the most costly and dangerous natural hazards.

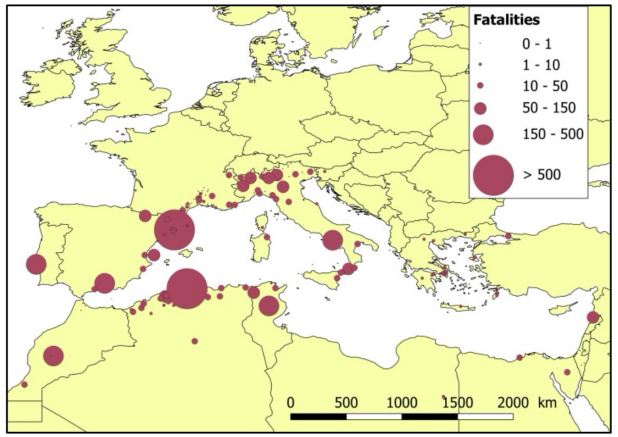


Better knowledge of meteorological dynamics and physical mechanisms associated with regional extreme precipitation:

→ Identify ways for improving predictability, increasing resilience and mitigate adverse impacts and risks

→Identify, describe and interpret future local changes in a particularly exposed and vulnerable region

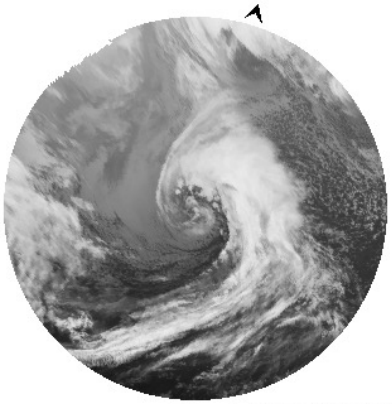
→Assess that the models are able to represent physical processes, to be confident in RCM projections

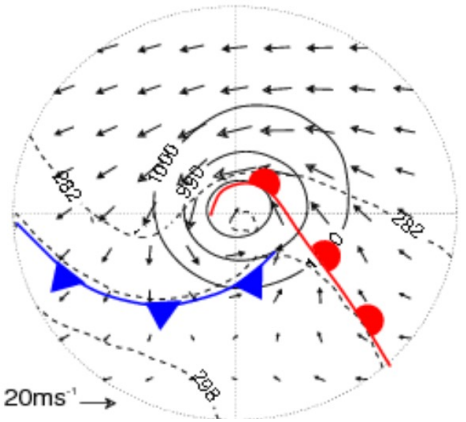


Flood fatalities 1940-2015
Gaume et al, 2016

FRAMEWORK

Increase of precipitation extremes (intensity, frequency and severity) in observation and projections at global scale





Precipitation extremes:

→ **dynamic processes**: determine the location

Multi-scale weather systems that gather and transport moisture to feed precipitation, provide uplift

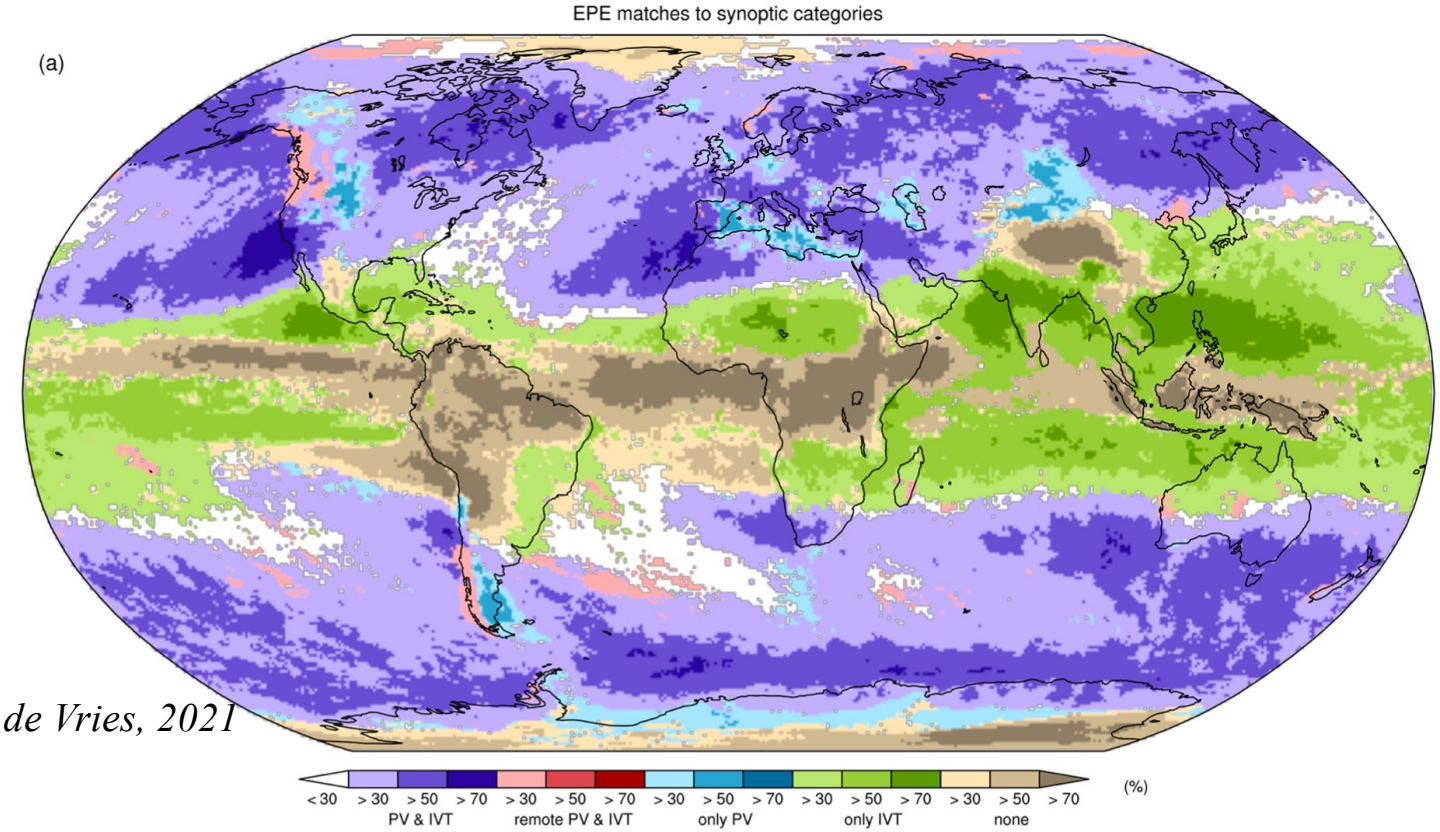
→ **thermodynamic processes**: determine the intensity

moisture, condensation, precipitation

Thermodynamic contribution of GW: Warmer air is capable of holding more moisture, available to rainstorm. This would lead to a spatially homogeneous increase of EP

Dynamic contribution of GW: changes in circulation and moisture transport pathways. This modifies regional responses, amplifying or weakening depending on the region

TWO KEY LARGE-SCALE PROCESSES FOR EPEs



de Vries, 2021

Rossby Wave Breaking (RWB)

↓

Potential Vorticity (**PV**) streamer

↓

Favours cyclogenesis

Reduces stability and favours ascent

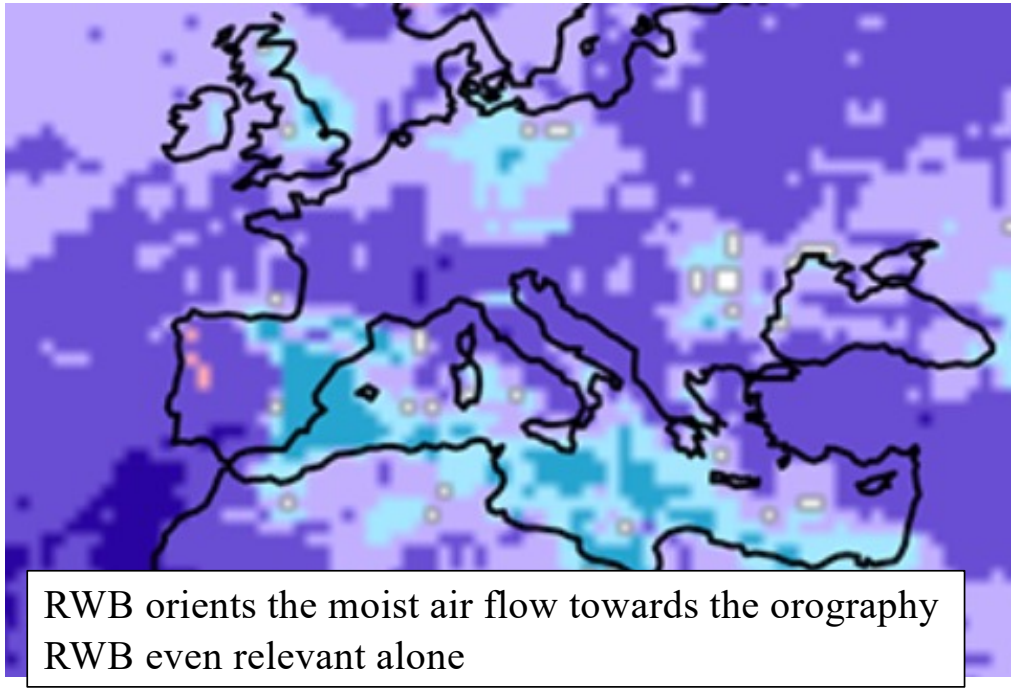
Enhances moisture transport

Intense Moisture Transport

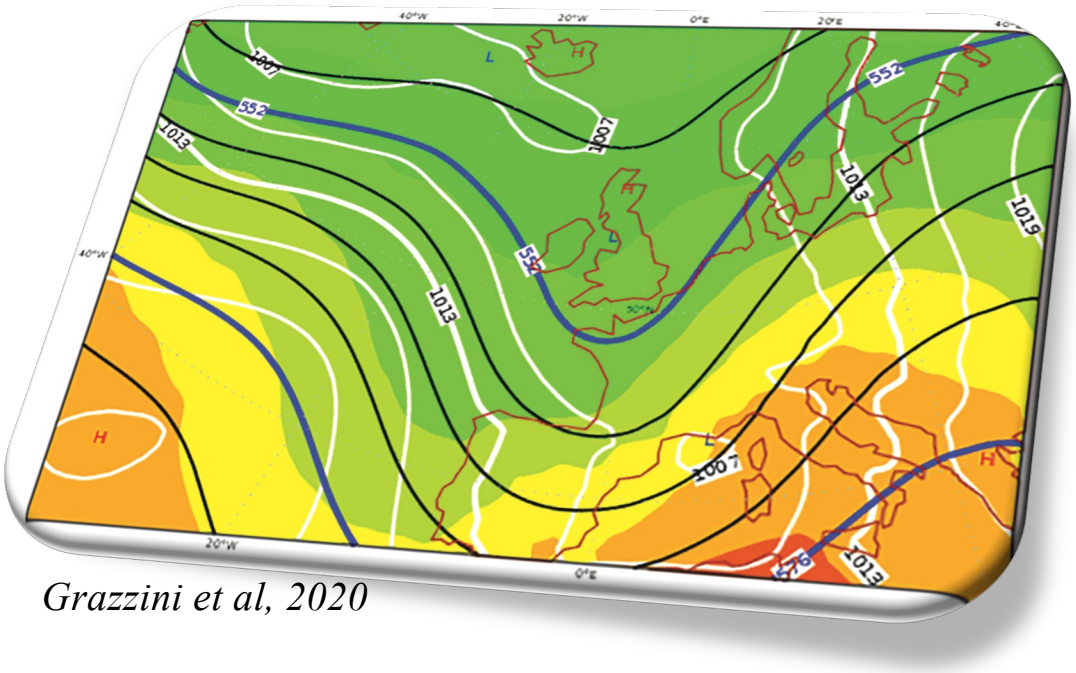
↓

Integrated Vapour Transport (IVT)

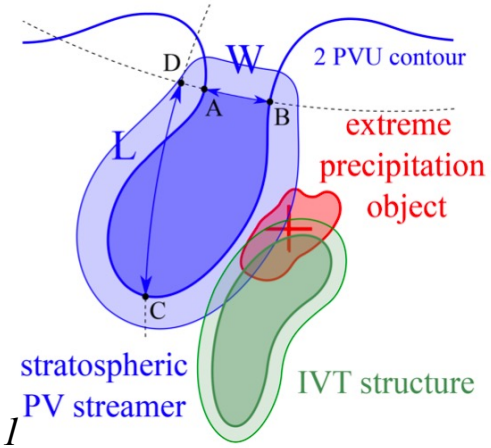
Precipitation volume increases with PV streamer intensity (strength of WB) and IVT max
but IVT is a constraint, thus crucial for EPE severity



RWB orients the moist air flow towards the orography
RWB even relevant alone

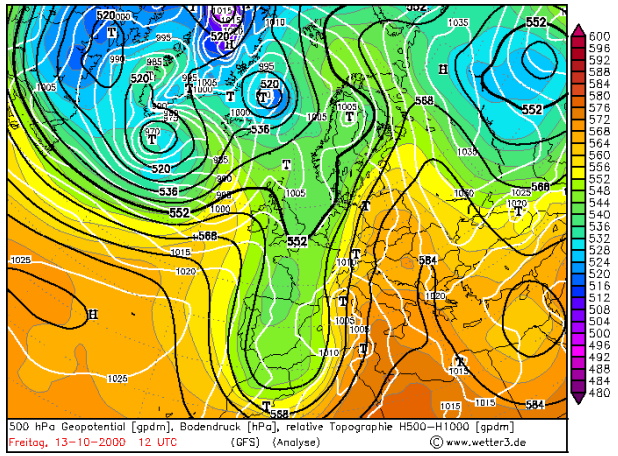


Grazzini et al, 2020

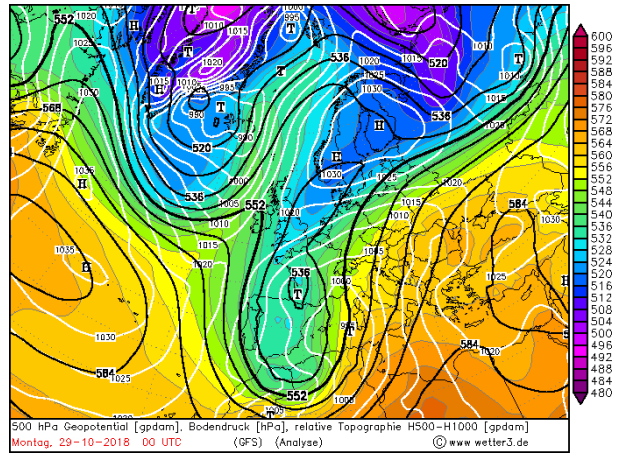


de Vries, 2021

Piedmont flood 2000



Vaia storm 2018



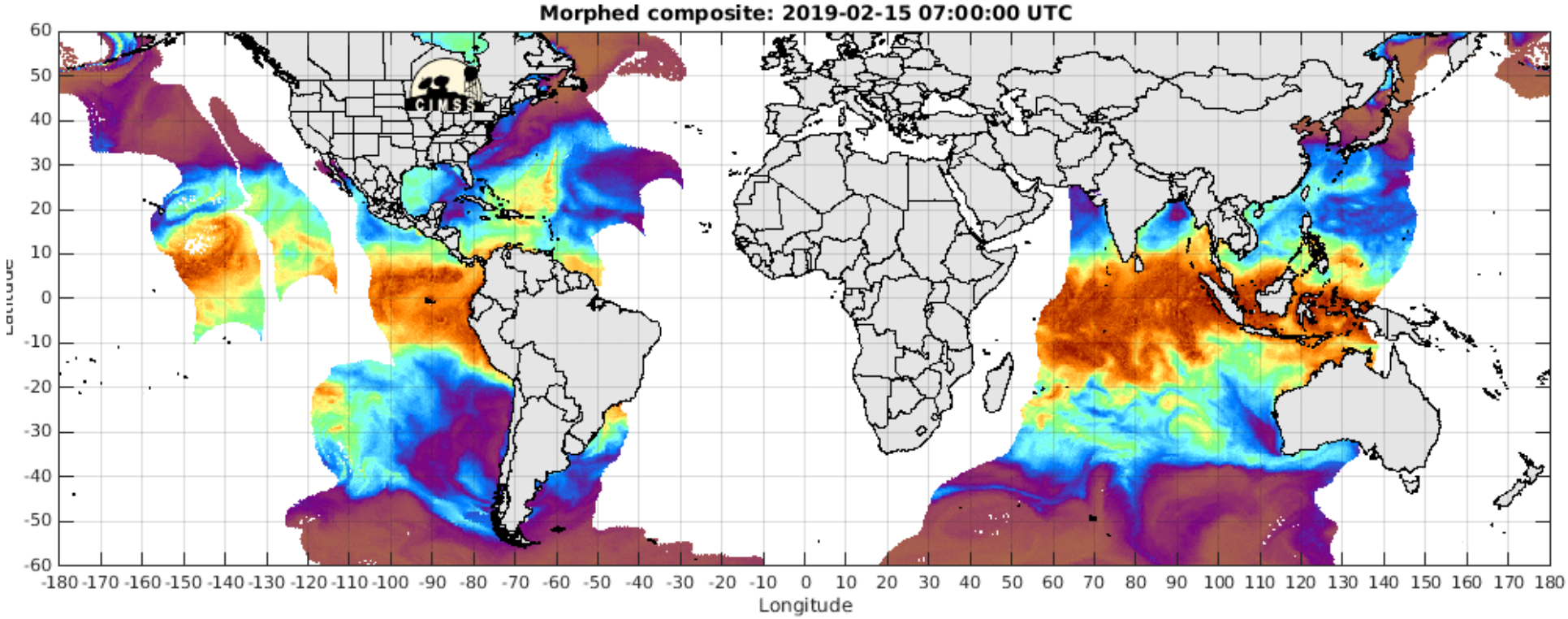
HEAVY (EXTREME) PRECIPITATION REQUIRES TWO INGREDIENTS: MOISTURE AND LIFTING

(1)
ATMOSPHERIC RIVERS

(2)
MEDITERRANEAN CYCLONES

(3)
MESOSCALE CONVECTIVE SYSTEMS

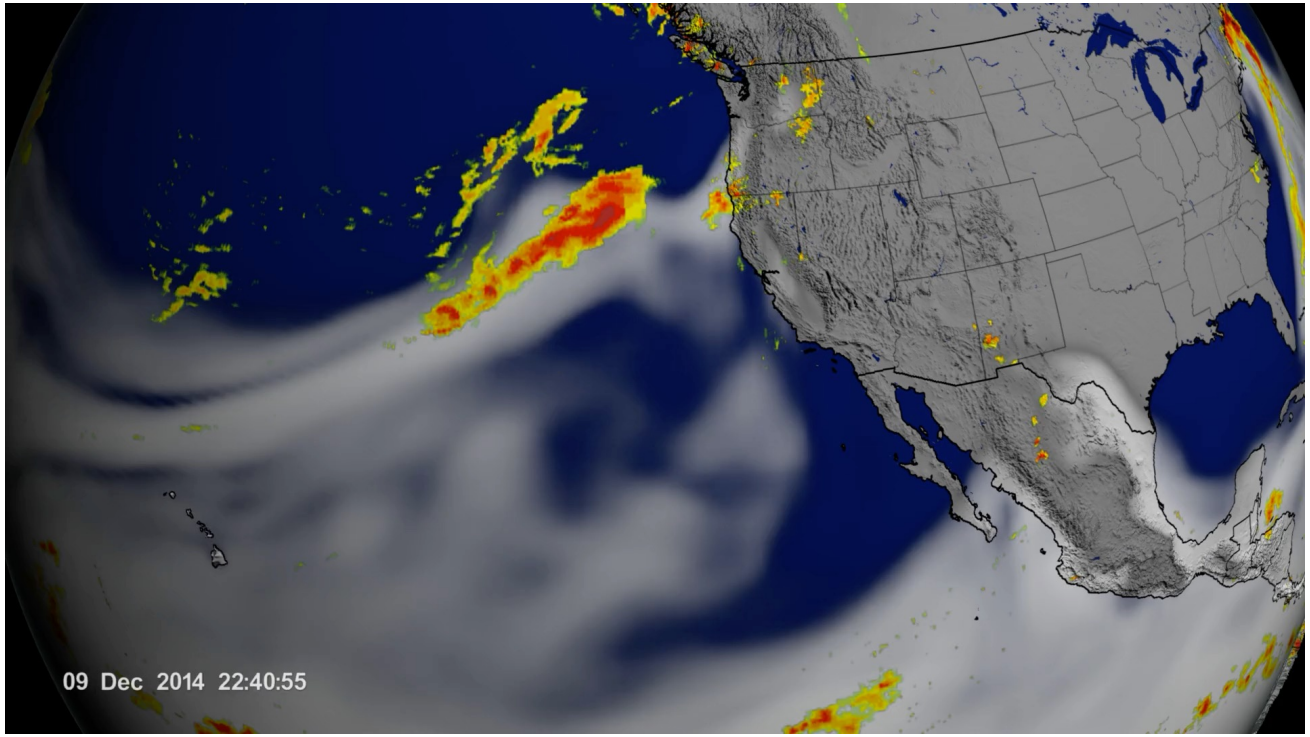
ATMOSPHERIC RIVERS

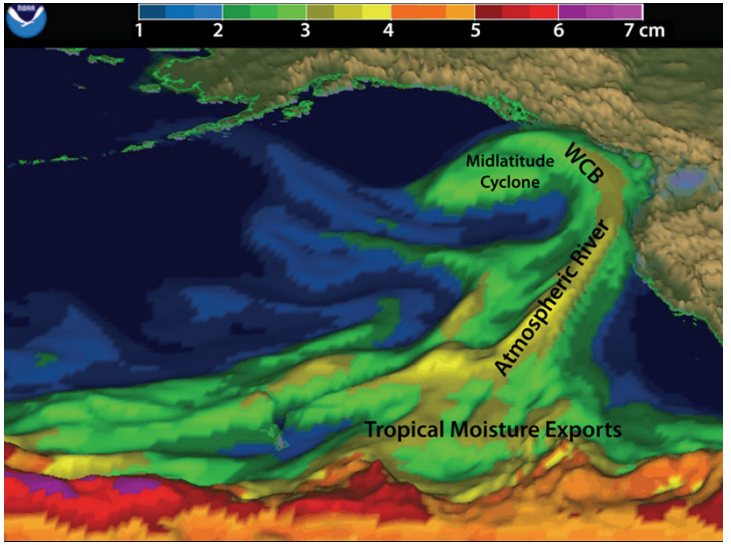


(*AMS Glossary of meteorology*)

"**Atmospheric River** (AR) is a **long, narrow, and transient corridor** of strong horizontal water vapour transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone"

"Atmospheric rivers **frequently lead to heavy precipitation** where they are forced upward—for example, by mountains or by ascent in the warm conveyor belt".





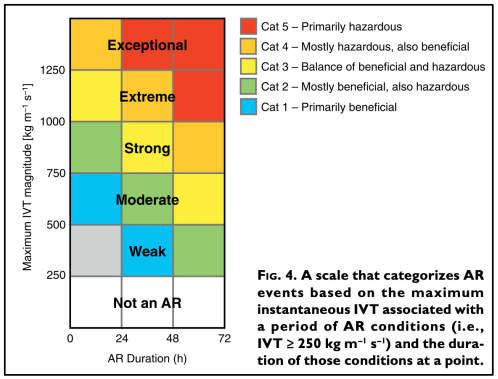
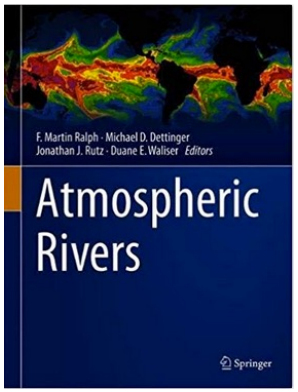
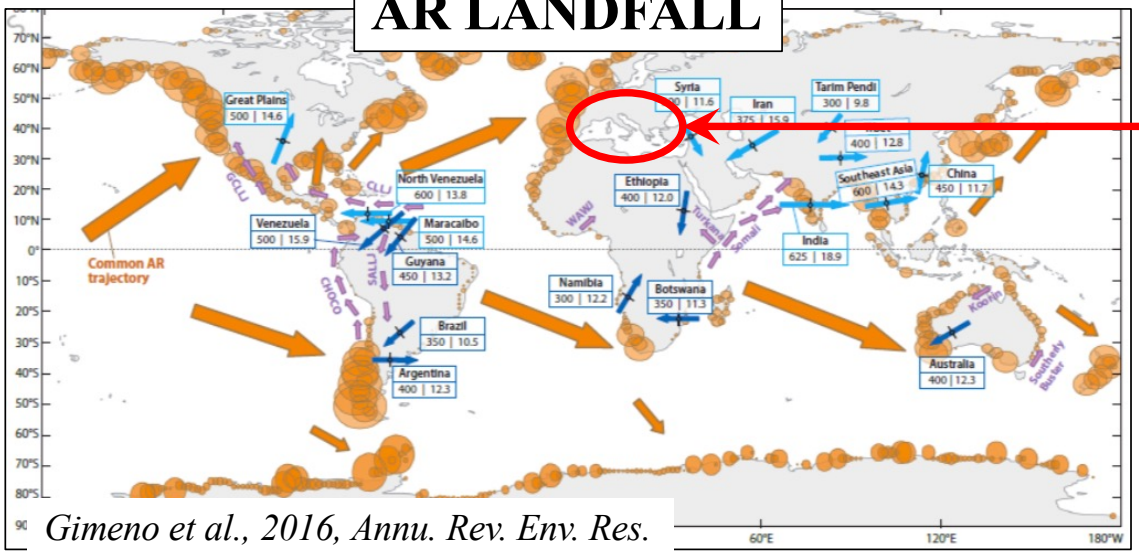


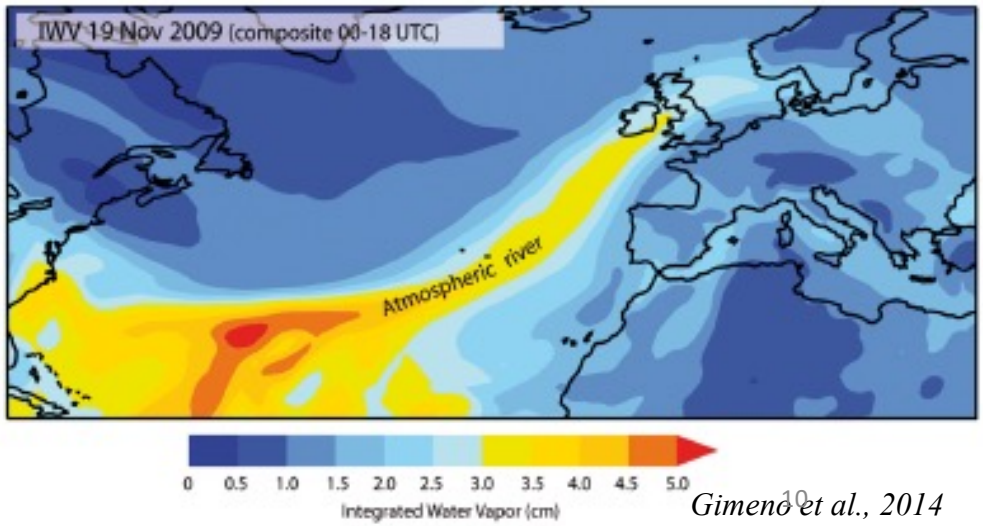
FIG. 4. A scale that categorizes AR events based on the maximum instantaneous IVT associated with a period of AR conditions (i.e., IVT ≥ 250 kg m⁻¹ s⁻¹) and the duration of those conditions at a point.



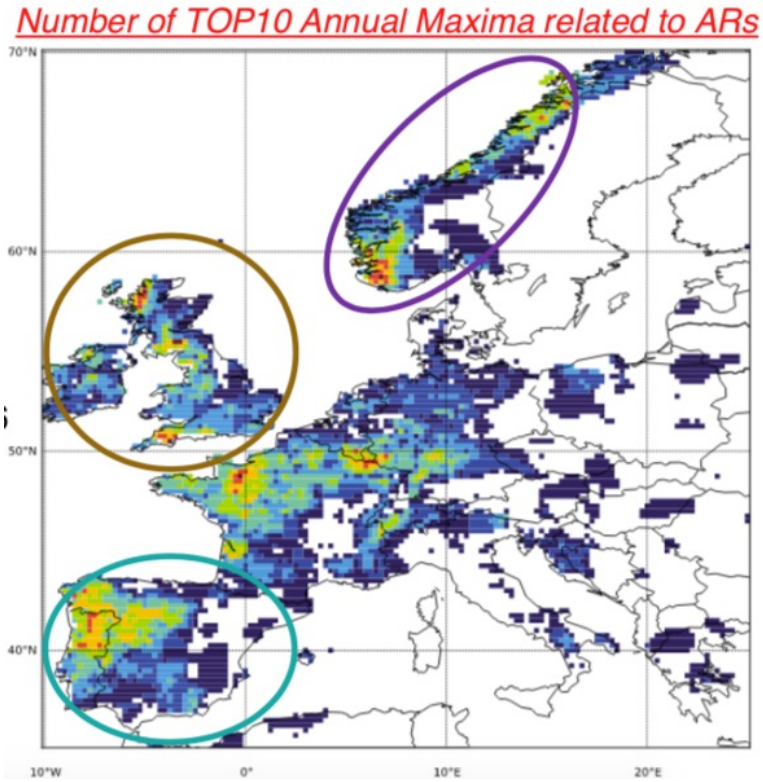
AR LANDFALL



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

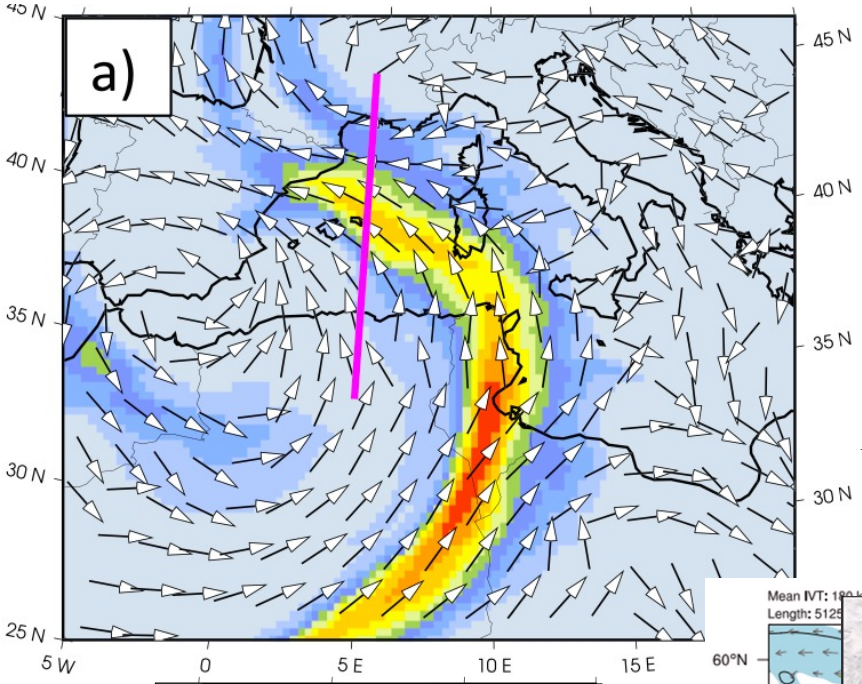


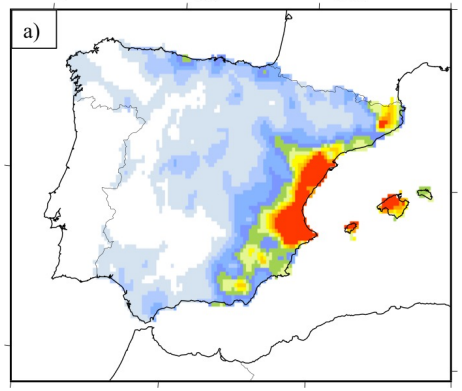
Gimeno et al., 2014

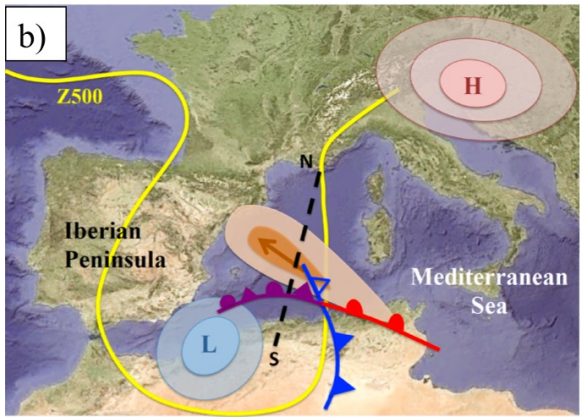


Lavers and Villarini, 2013

AR in the W-MED

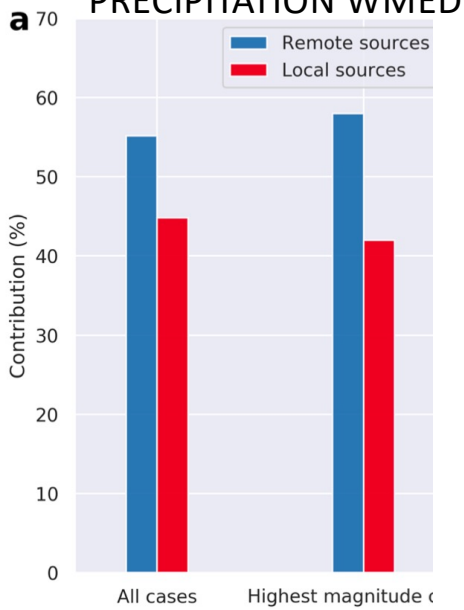






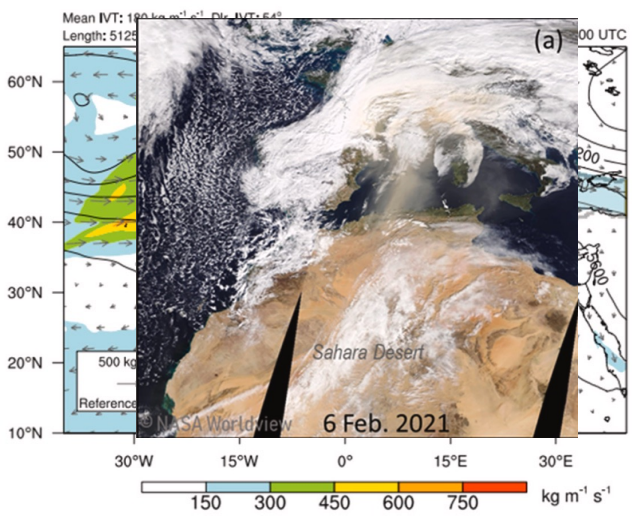
Lorente-Plazas et al, 2019

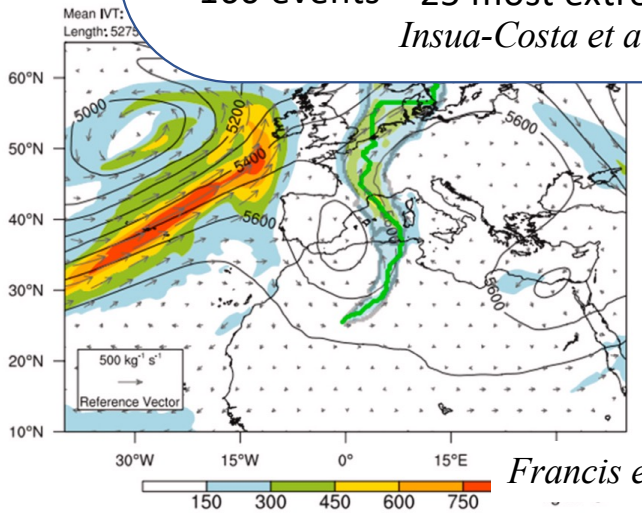
CONTRIBUTIONS TO PRECIPITATION WMED



160 events 25 most extreme

Insua-Costa et al, 2022



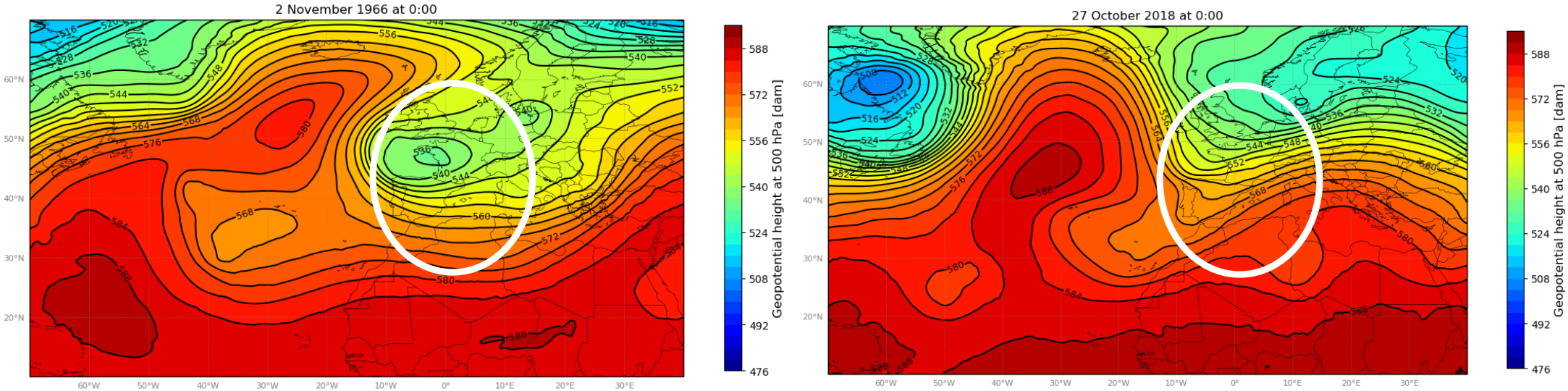


Francis et al, 2022

THE TWO “CENTURY FLOODS”

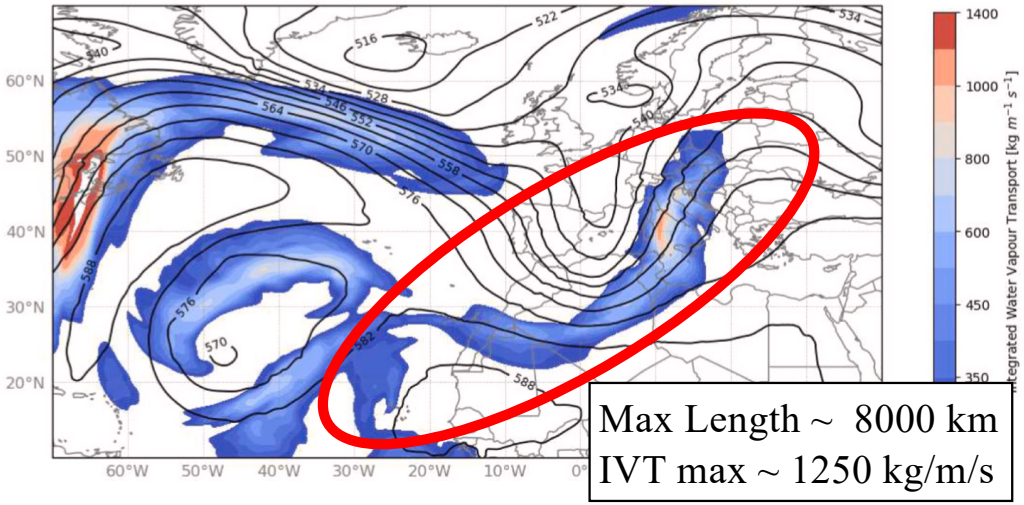
1966 FLOOD

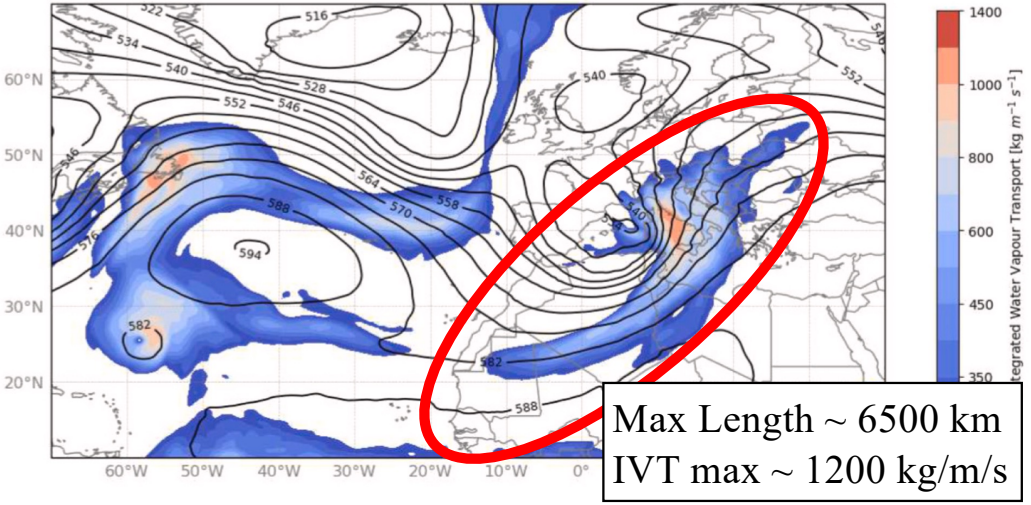
2018 "VAIA" STORM



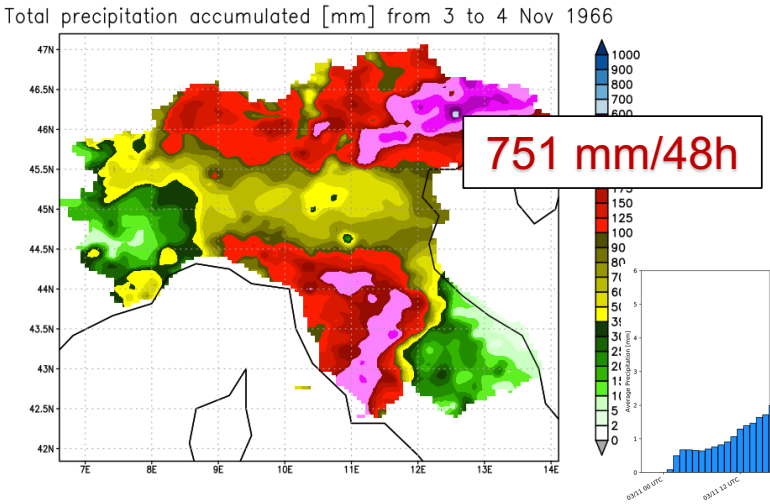
Geopotential Height at 500 hPa

Sioni et al, 2023

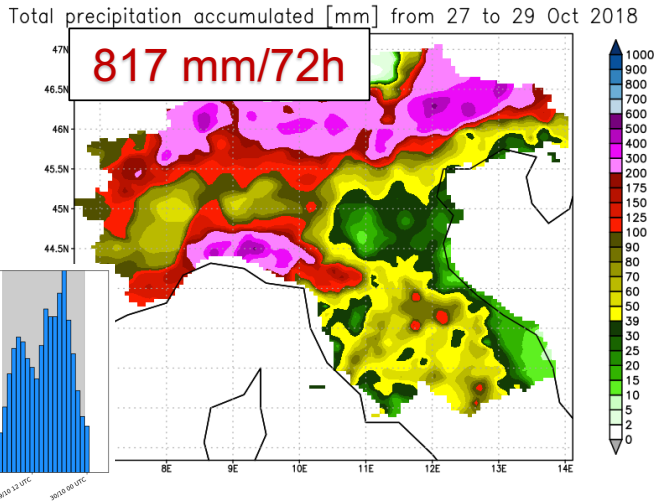




IVT max. ~ 1.2×10^3 kg/m/s → AR Discharge ~ 5×10^7 kg/s Po river flood-discharge: ~ 1.0×10^7 kg/s

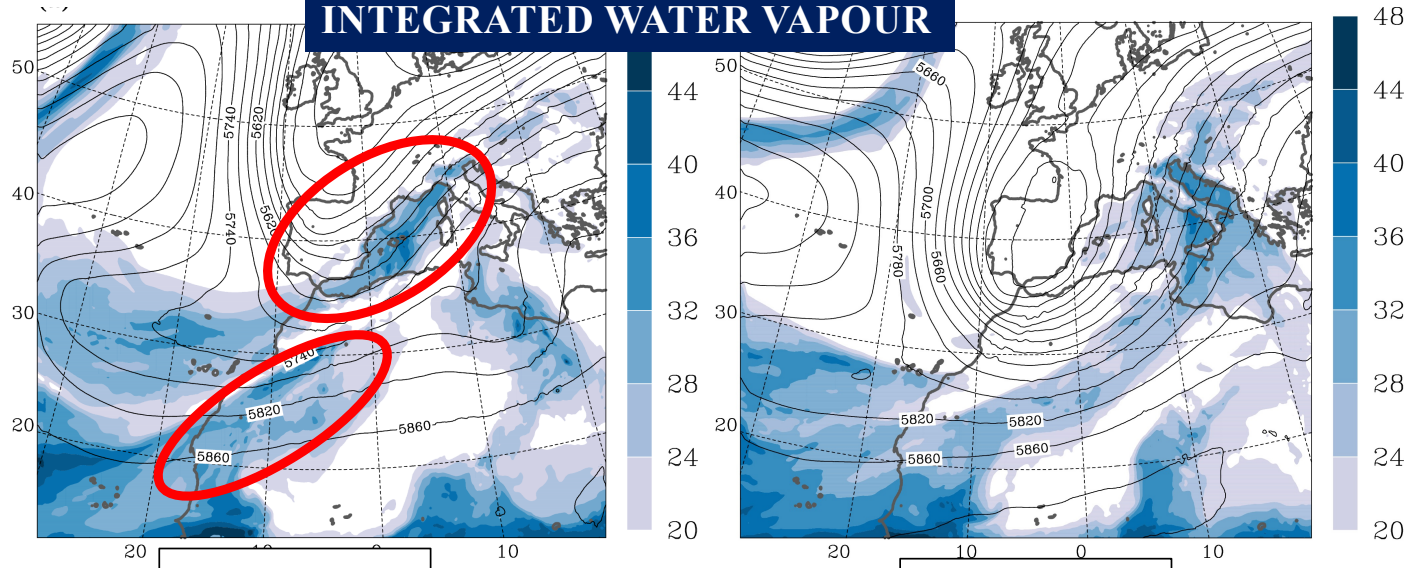


ArCIS database
Rainfall
1961-2022



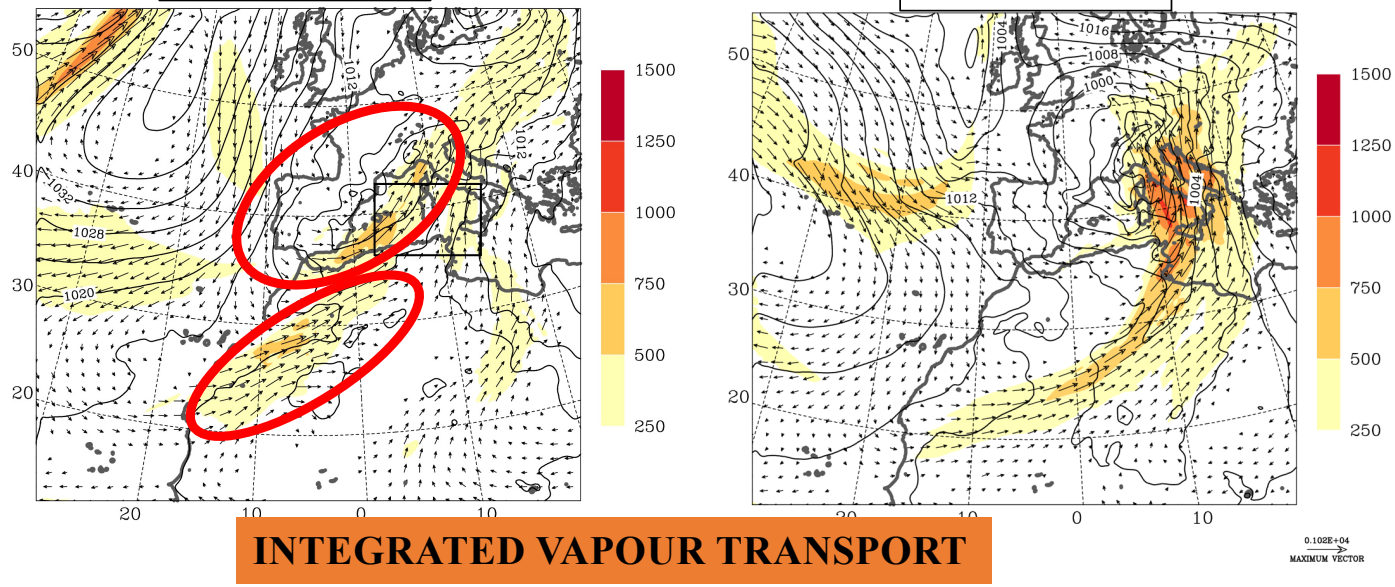
Davolio et al, 2020; Giovannini et al, 2021; Sioni et al, 2023

INTEGRATED WATER VAPOUR

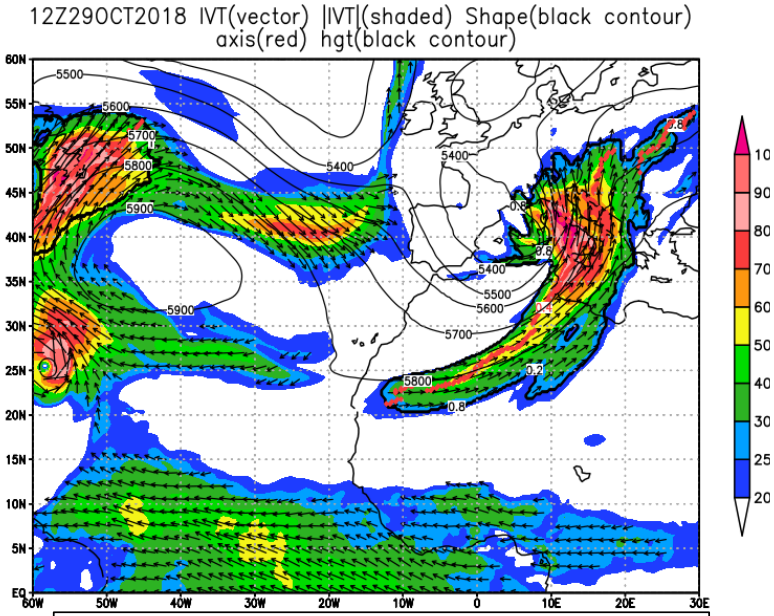


27 Ottobre

29 Ottobre



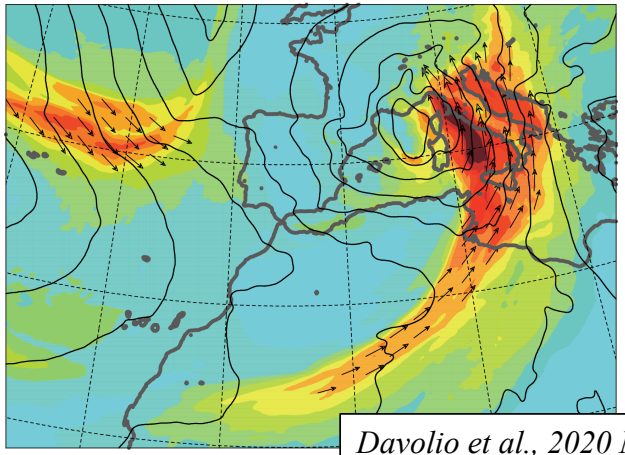
INTEGRATED VAPOUR TRANSPORT



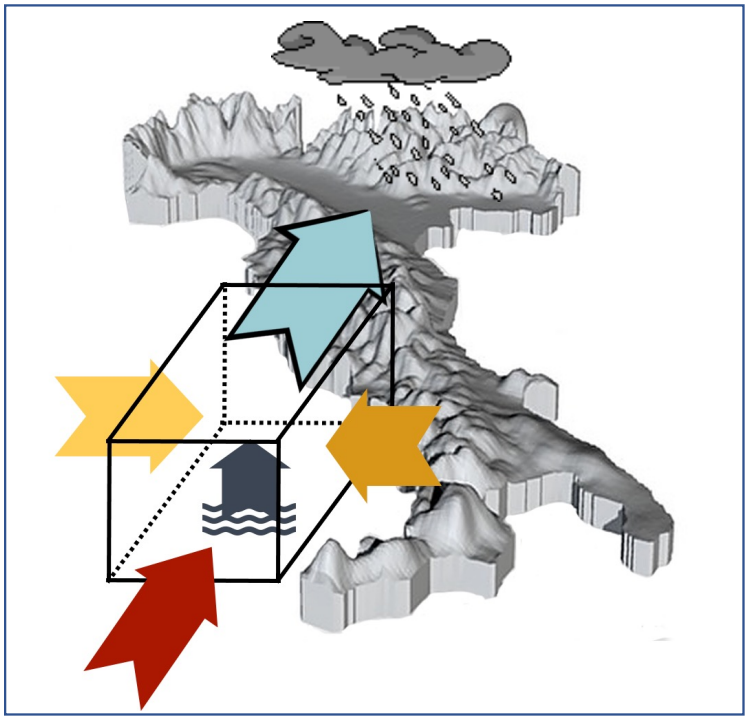
Algoritmo di **detection**
adattato per il Mediterraneo

Guan and Waliser (2015, 2019)

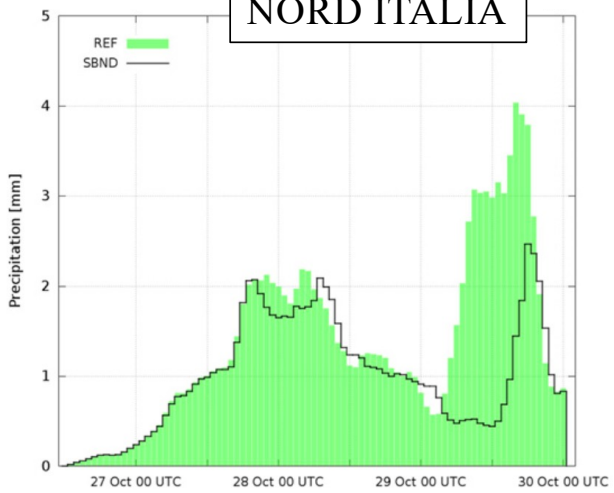
CONTRIBUTO DELL'ATMOSPHERIC RIVER ALLE PRECIPITAZIONI



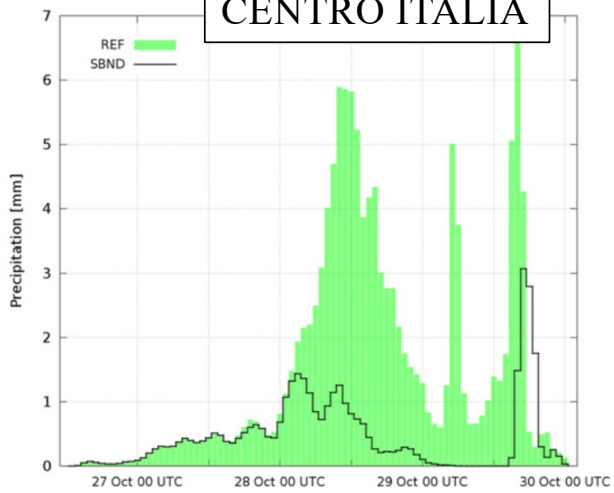
Davolio et al., 2020 Mon. Wea. Rev.



NORD ITALIA



CENTRO ITALIA

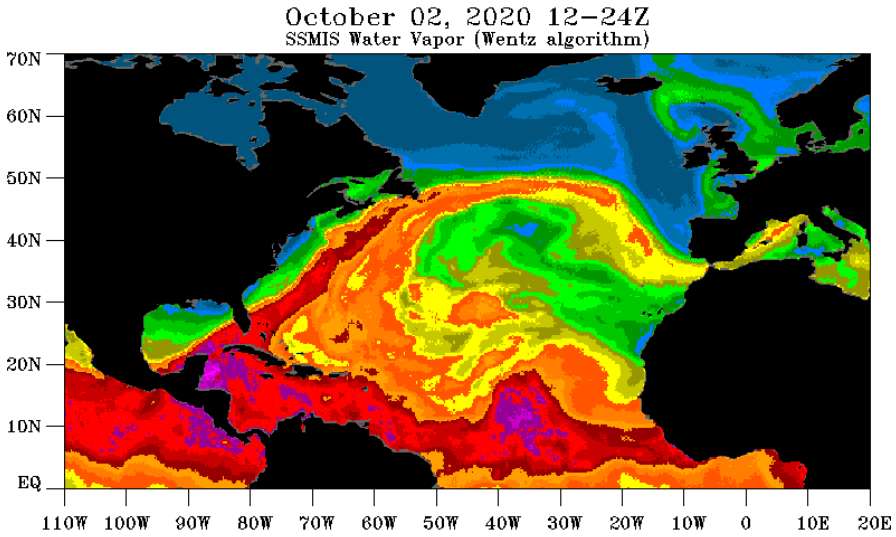


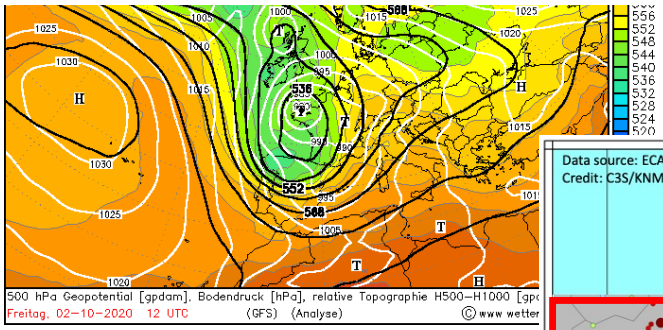
Esperimenti numerici di *sensitivity*

In generale negli eventi analizzati l'**Atmospheric River**

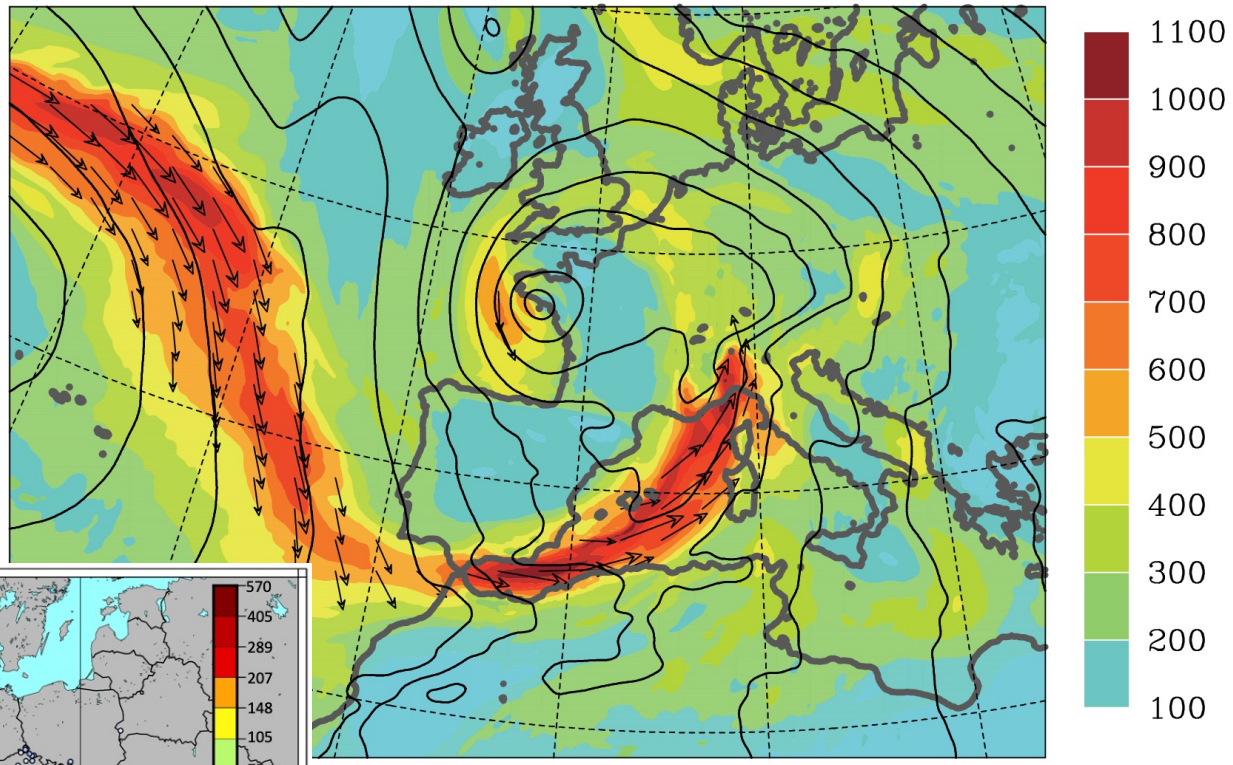
- riveste un ruolo fondamentale nell'alimentare le precipitazioni
- è ulteriormente alimentato dall'evaporazione dal mare e/o da convergenza locale
- penetra l'orografia degli Appennini e raggiunge l'arco alpino
- sul nord-est rilevante anche il trasporto dello Scirocco
- sul Mediterraneo si connette alla circolazione del ciclone (WCB)

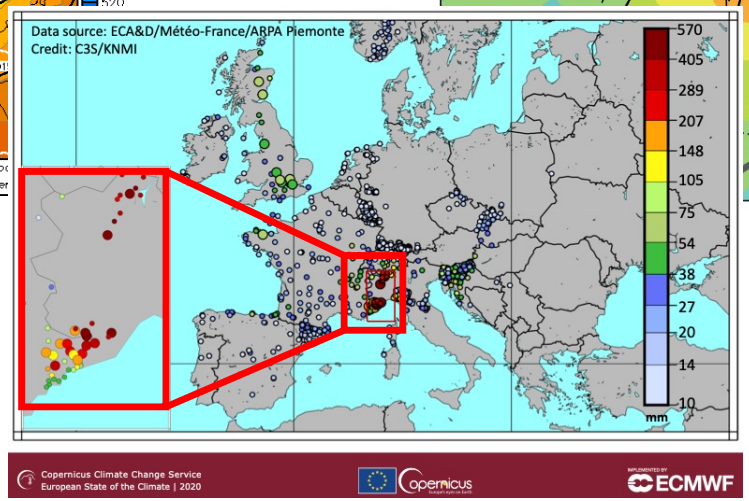
TPW – SSMI composite





ATMOSPHERIC RIVER – 2020/10/02
Integrated Vapour Transport (kg/m/s)





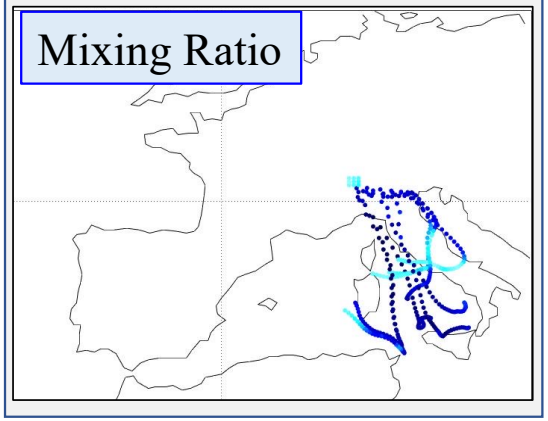
Copernicus Climate Change Service
European State of the Climate | 2020
Copernicus
ECMWF

MOISTURE SOURCES → 48-h Backtrajectory

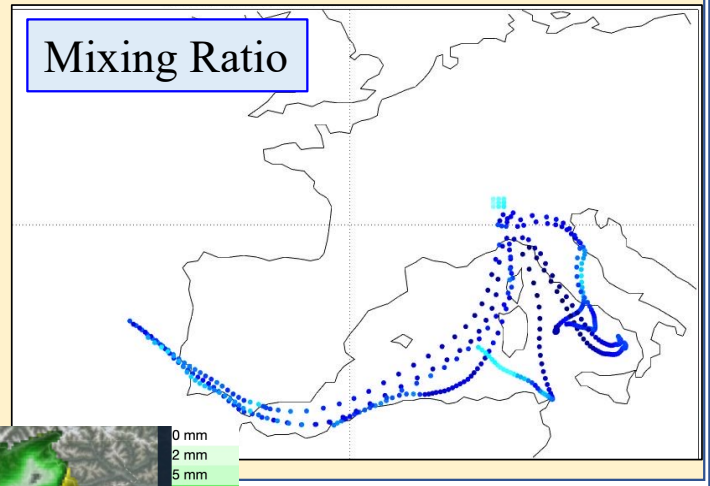
arriving at 00 UTC, 03 October

HYSPLIT AIR RESOURCES LAB

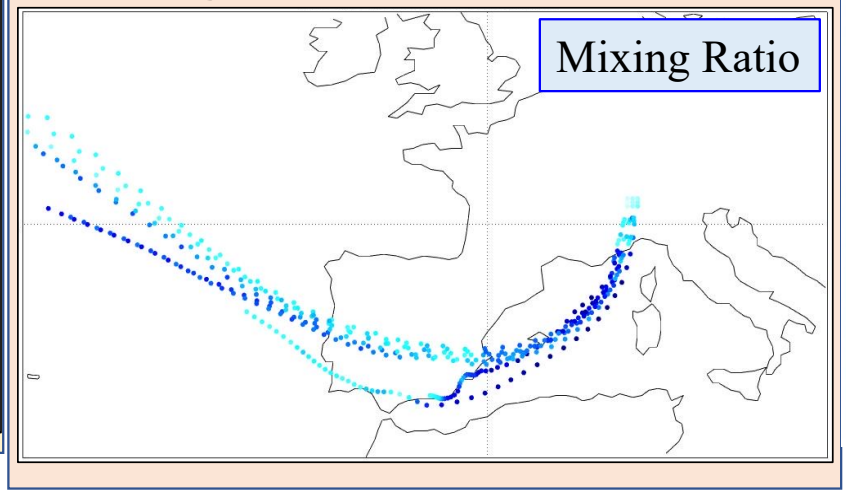
arriving at **2500 m**

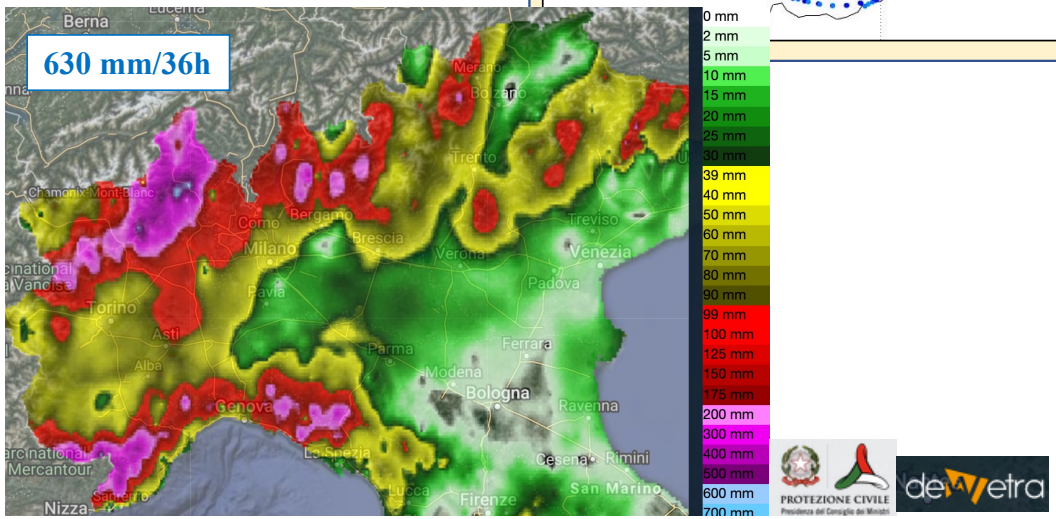


arriving at **3000 m**

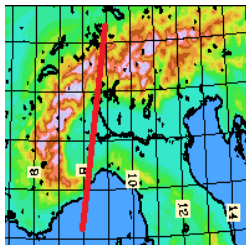


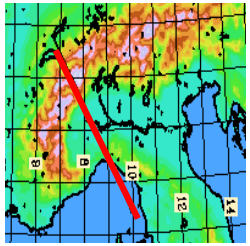
arriving at **4000 m**

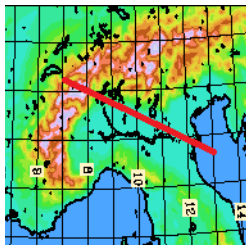


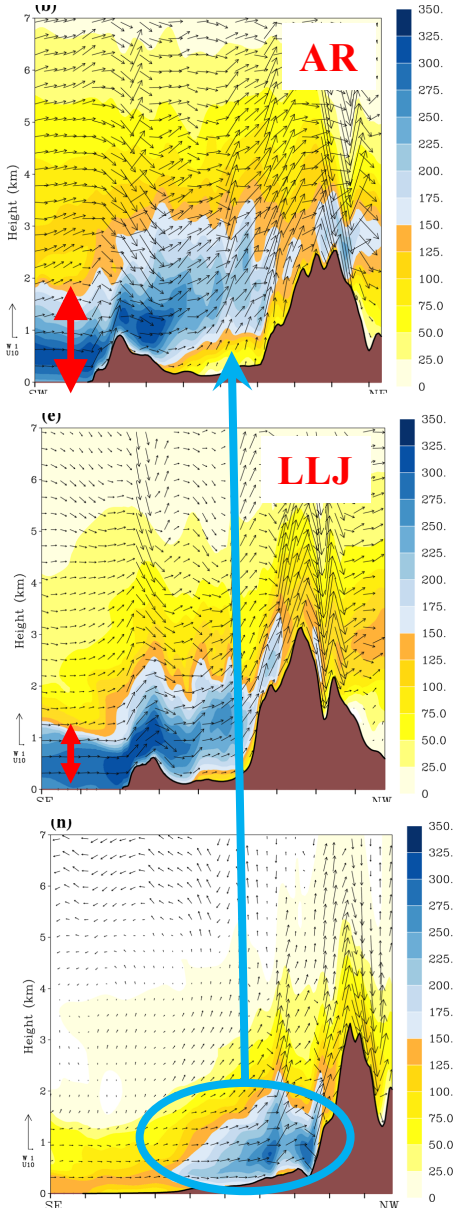


WV FLUX

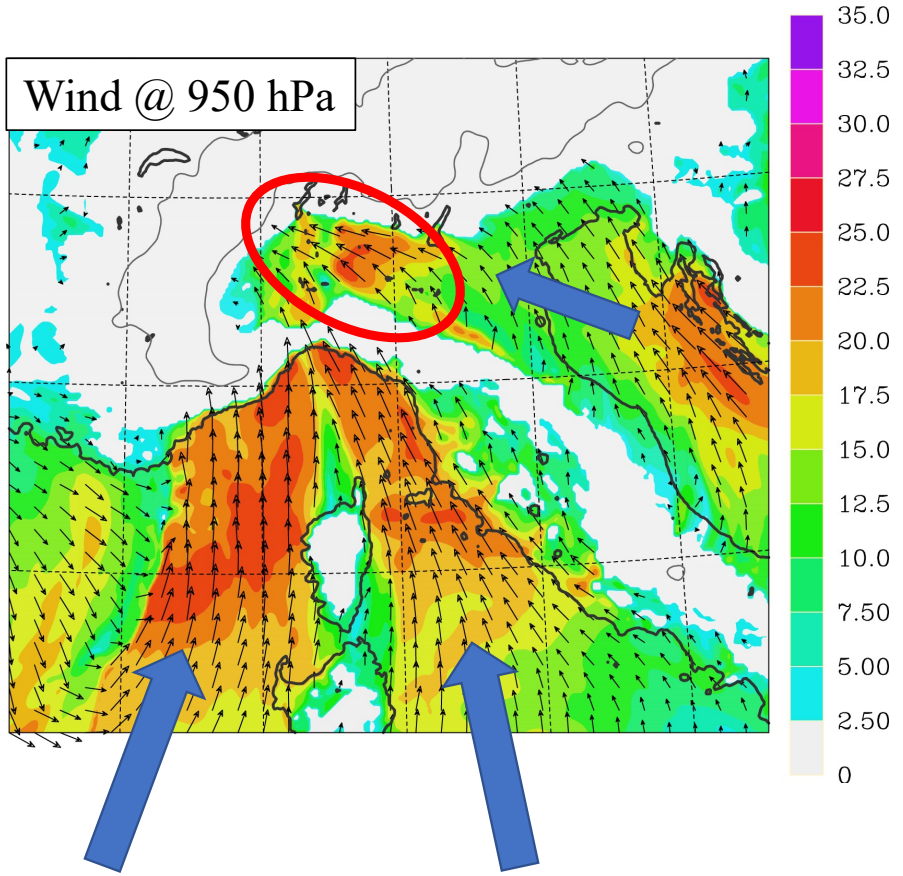








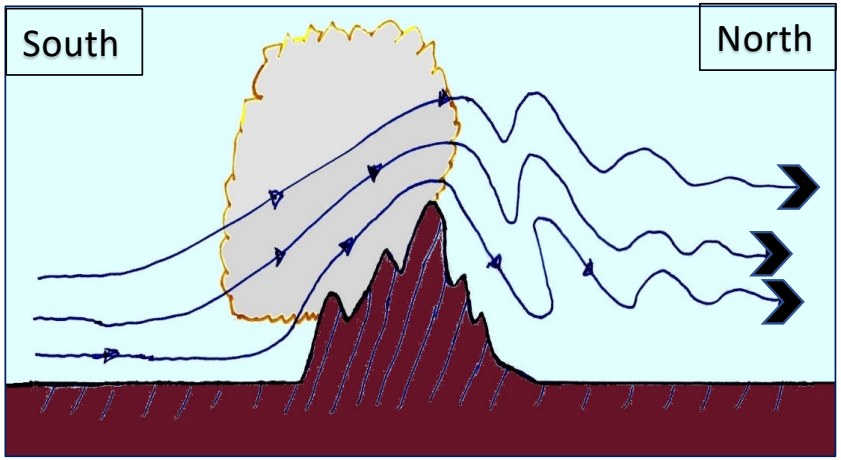
HIGH-RESOLUTION SIMULATIONS for MESOSCALE ANALYSIS - MOLOCH -



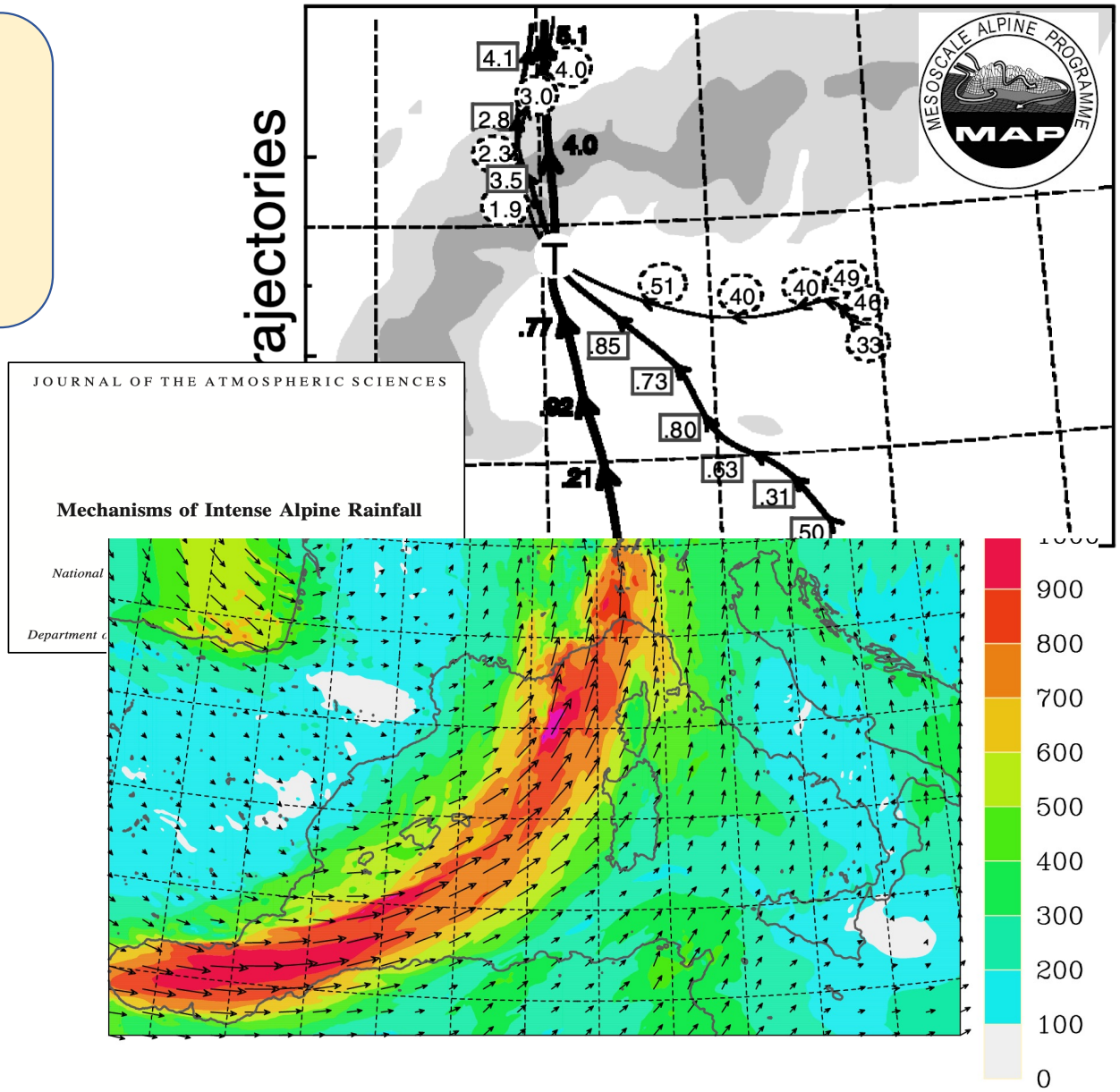
THE AR MAY TURN AN ORDINARY INTENSE RAINFALL EVENT INTO A DEVASTATING FLOOD

Davolio et al, 2023

Nearly neutral flow
Max precip efficiency
Embedded convection



Courtesy A. Buzzi

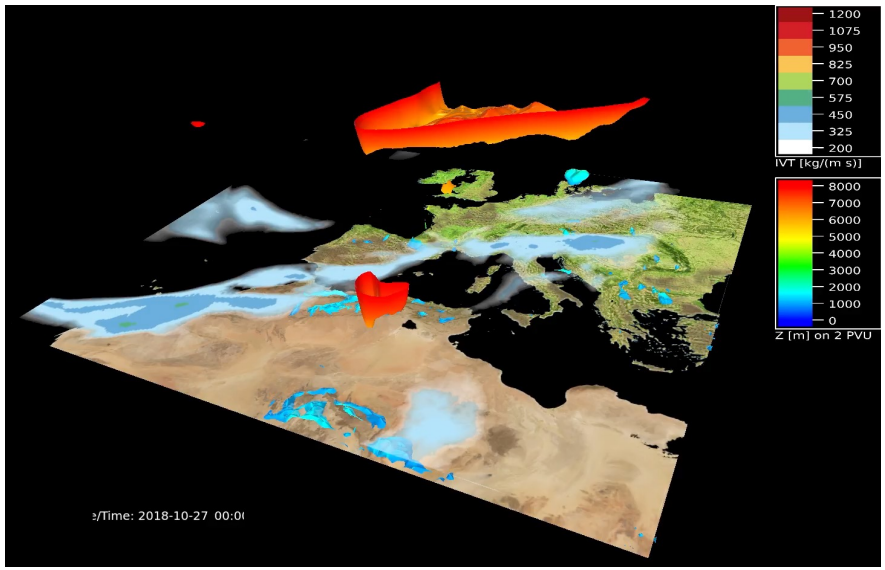


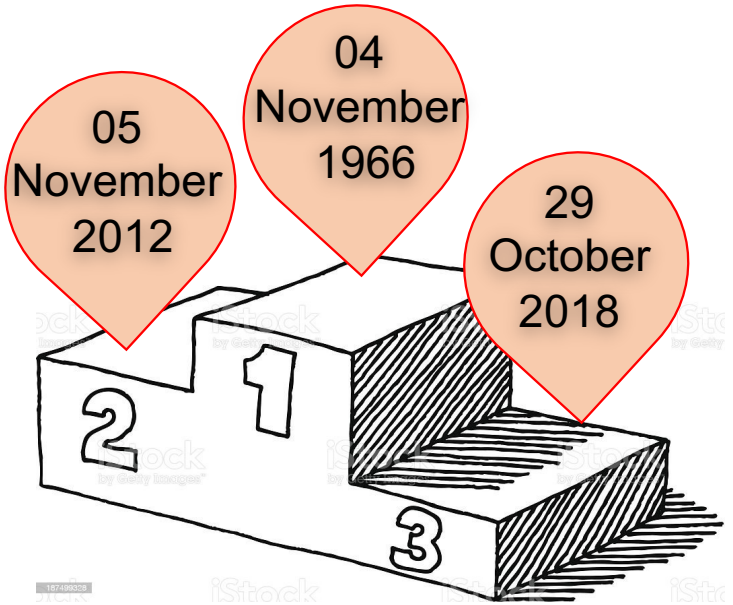
PROSPETTIVE ... WORK IN PROGRESS ... PROPOSTE TESI

ALGORITMO GUAN&WALISER → ADATTAMENTO AL MEDITERRANEO → ERA5 1950-2020 → ATMOSPHERIC RIVER PIU' INTENSI SULL'ITALIA → PRECIPITAZIONI ???

Atmospheric River

Ciclone Mediterraneo





→ Altri Eventi
→ Ghicciai NE ?

2) MEDITERRANEAN CYCLONES

Petterssen,1956

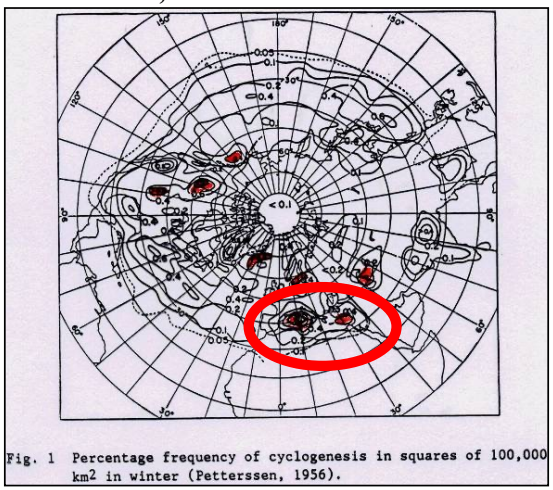
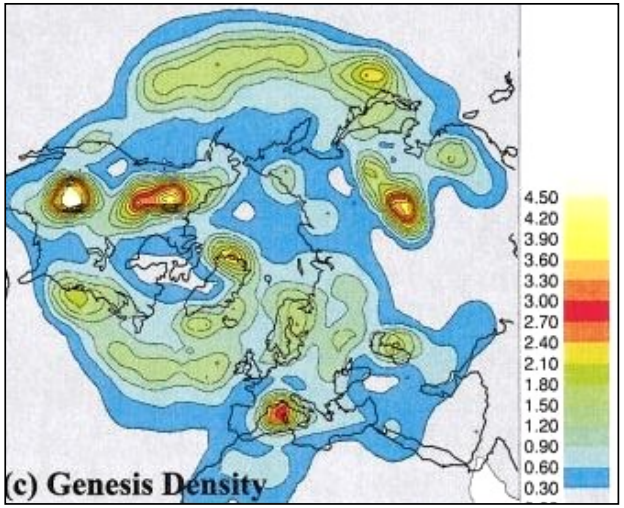
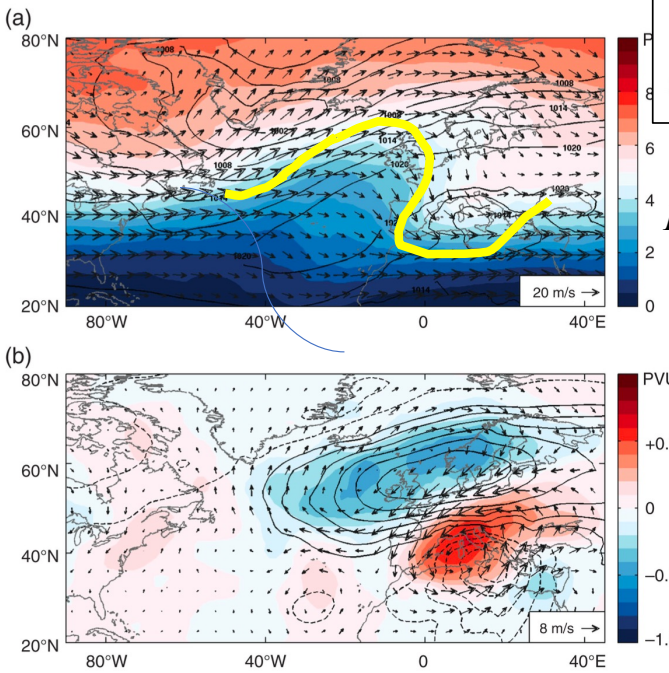


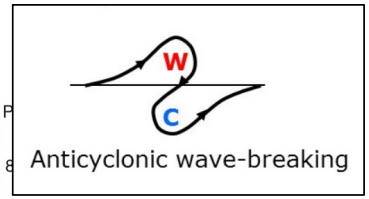
Fig. 1 Percentage frequency of cyclogenesis in squares of 100,000 km² in winter (Petterssen, 1956).

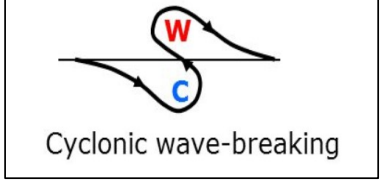
Hoskins and Hodges, 2002



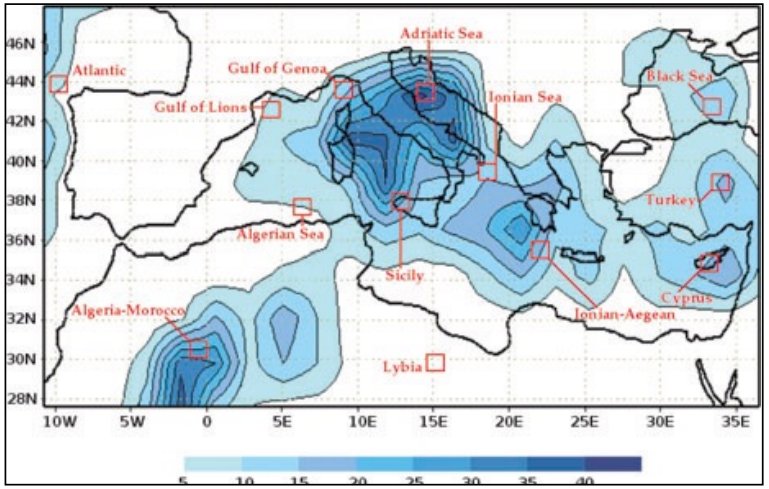


Raveh-Rubin and Flaounas, 2017

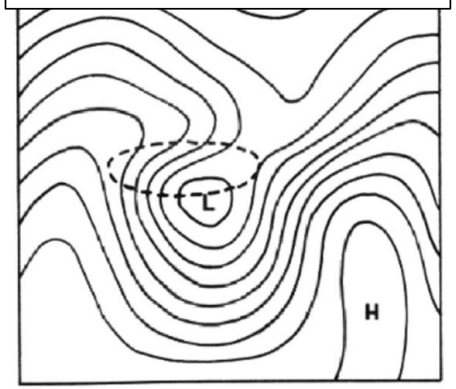




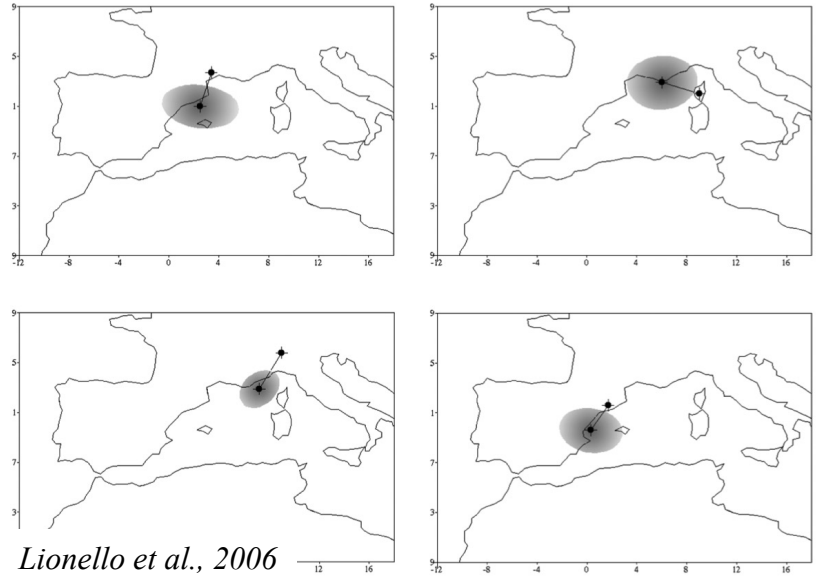
Homar et al., 2006



Orographic cyclogenesis



Buzzi et al et al., 2020



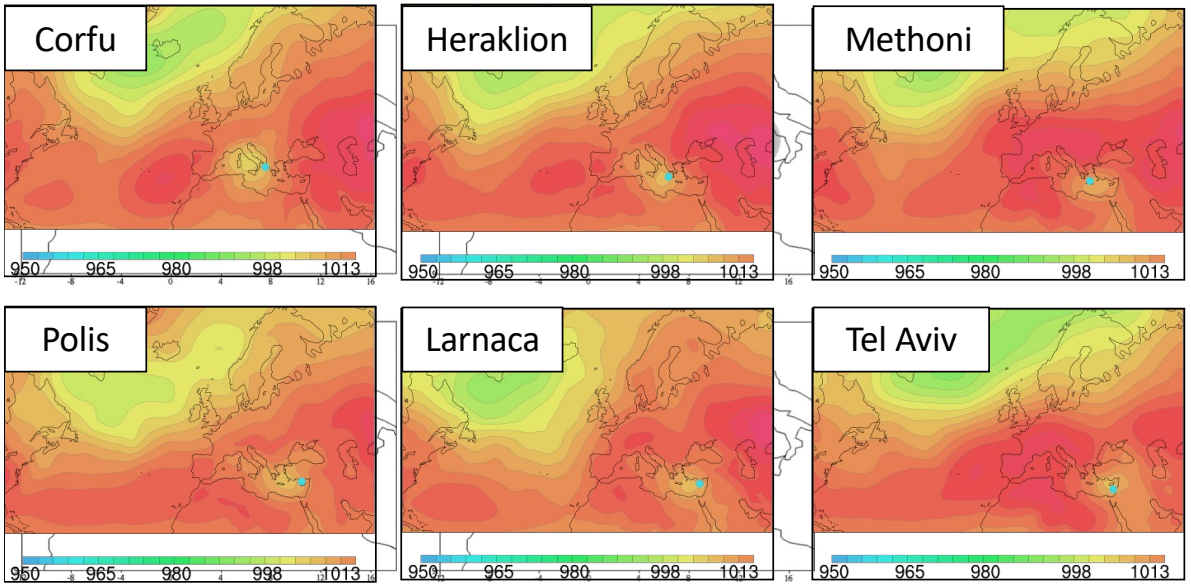
Lionello et al., 2006

Mediterranean cyclones & extreme precipitation

90% of HPE in the W-Med are associated with cyclones of diverse intensity (Jansa, 2001)

Cyclones contribute 60% to 90% of the regional extreme rainfall

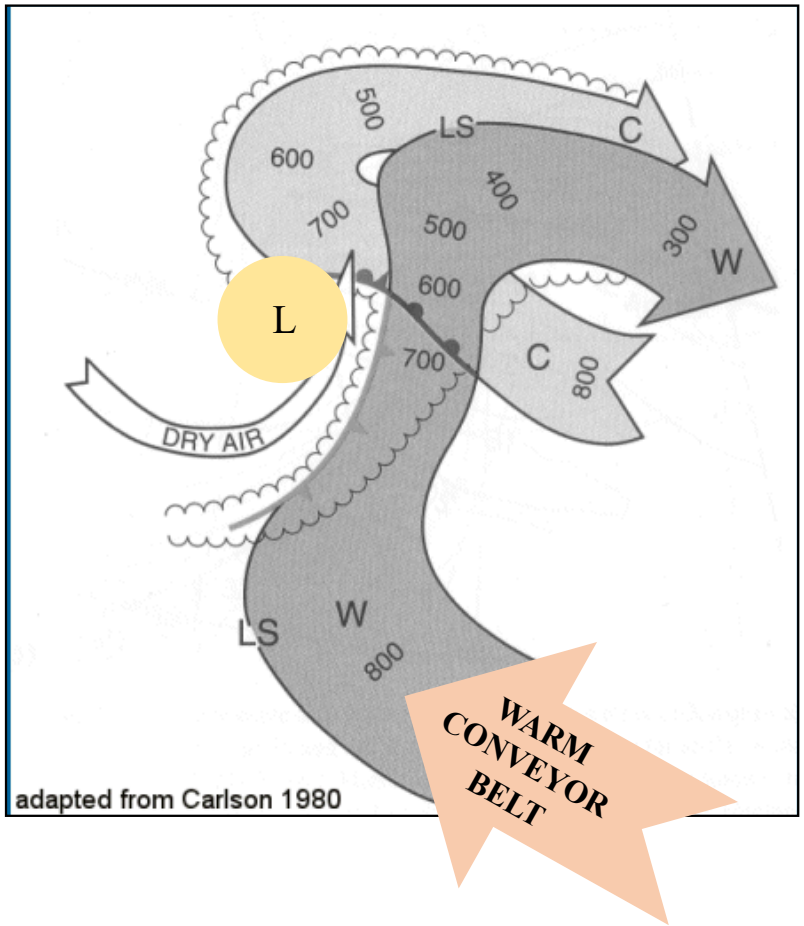
Both weak and intense cyclones are capable of producing high precipitation (Flaounas, 2018)

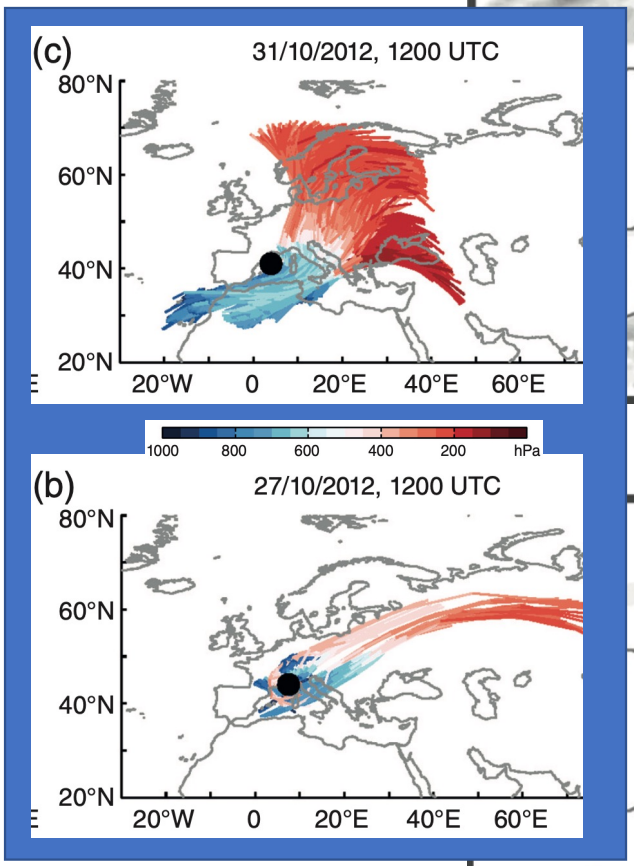


Lionello and Reale, 2010

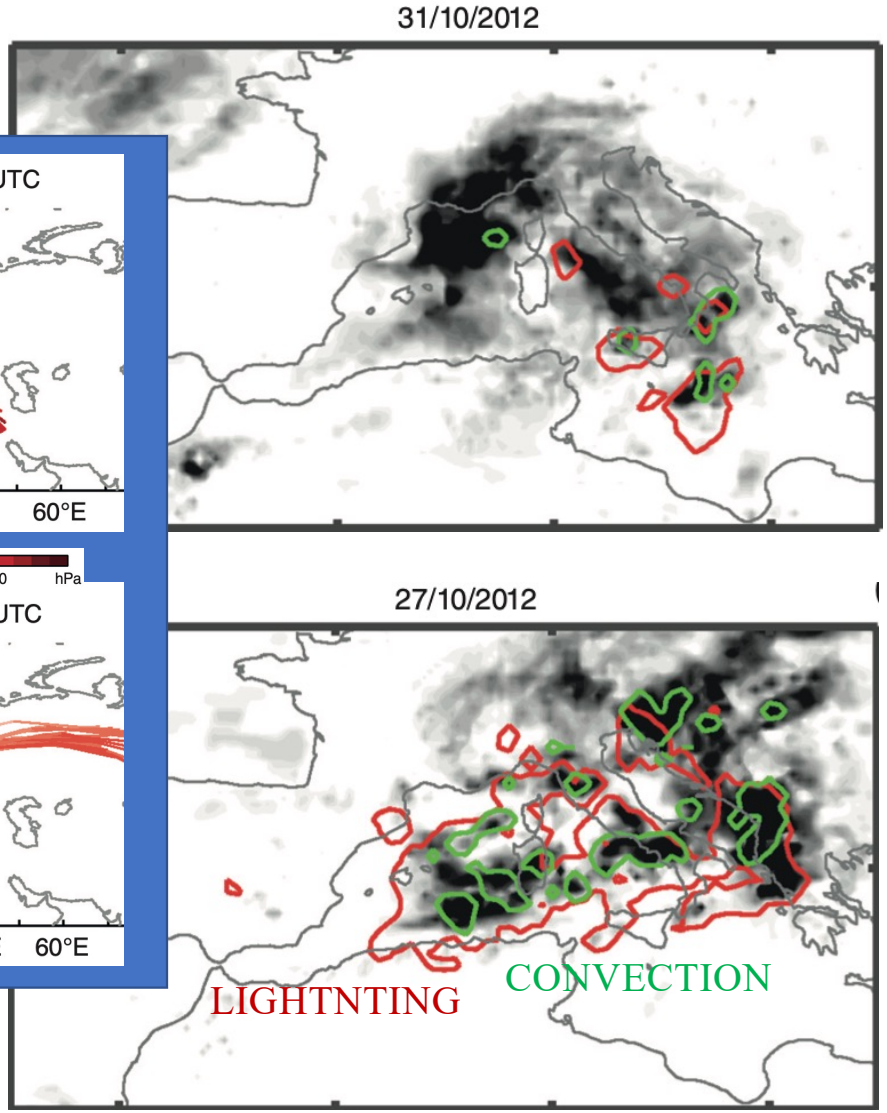
Most of the floods were related to the presence of a cyclone **able to organize properly the low-level warm and moist flow** promoting deep convection or feeding the precipitating system especially in region with steep orography

MEDCYCLONES AND RAINFALL
Airflow and convection

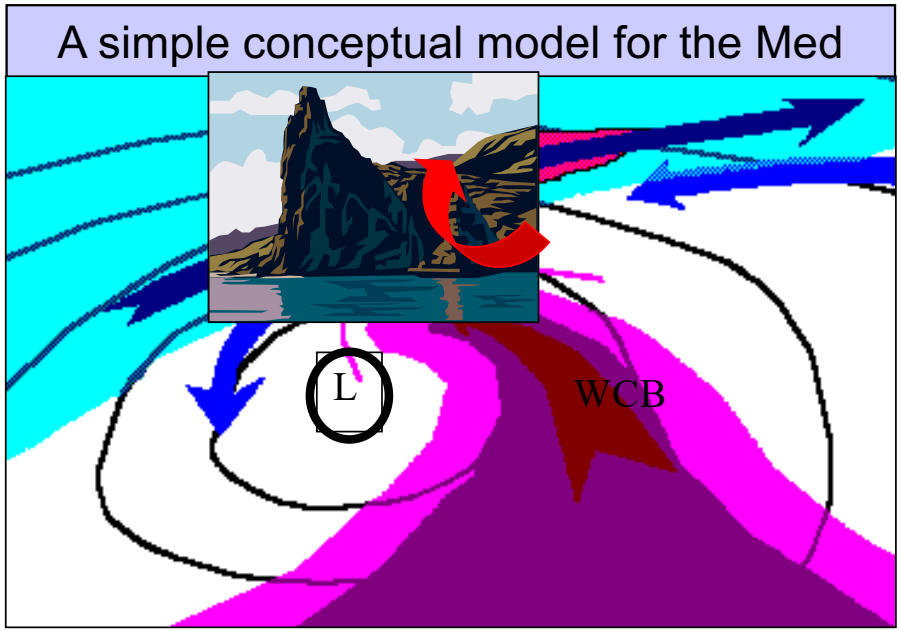




Flaounas et al, 2016



HEAVY PRECIPITATION AND CYCLONE LOCATION

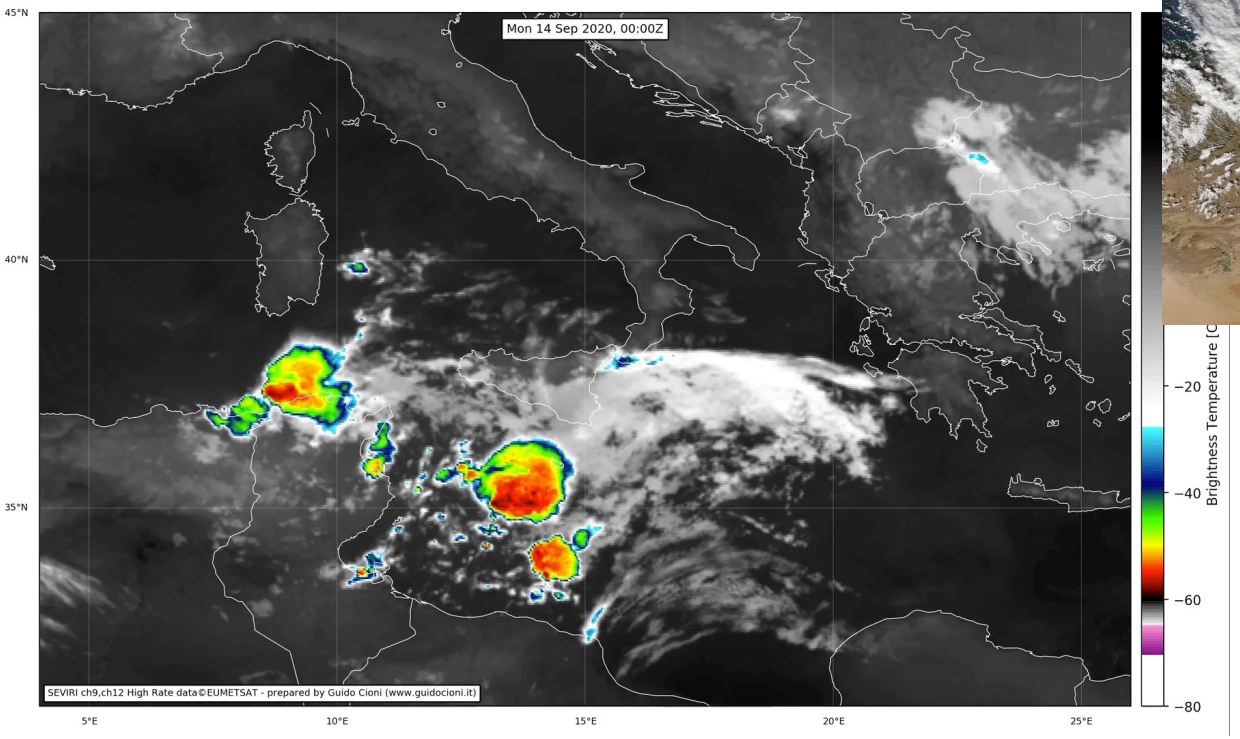


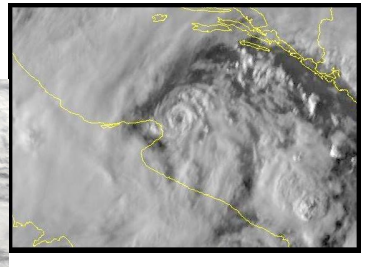
Jansa, 2001
Courtesy A. Buzzi

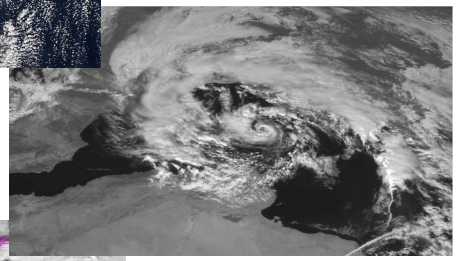
By adding a mountain a the end of the WCB can largely enhance precipitation, especially in cases of nearly neutral moist lapse rate.

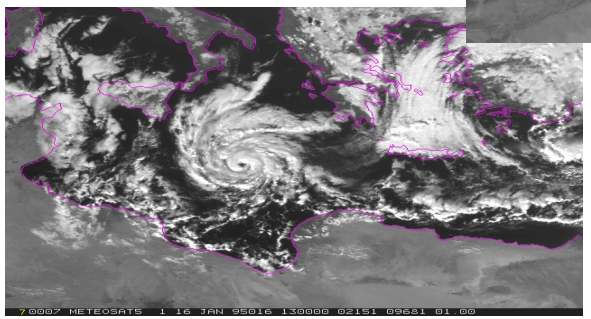
MEDICANES – MEDIterranean hurriCANES

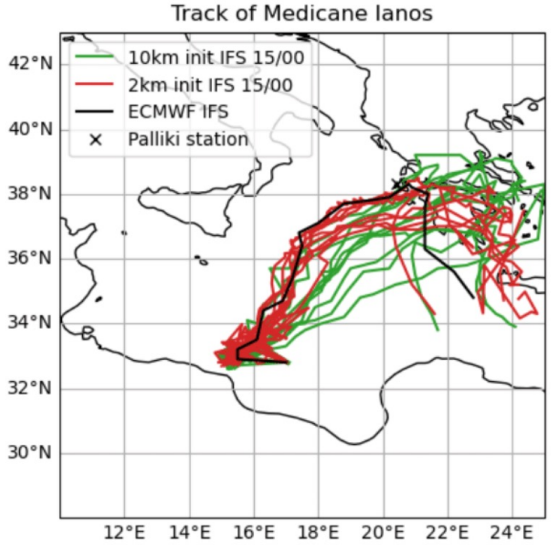
Ianos 15-17 Sep 2020
Cat. 2 hurricane
Extreme precipitation 645 mm/24 in Cefalonia

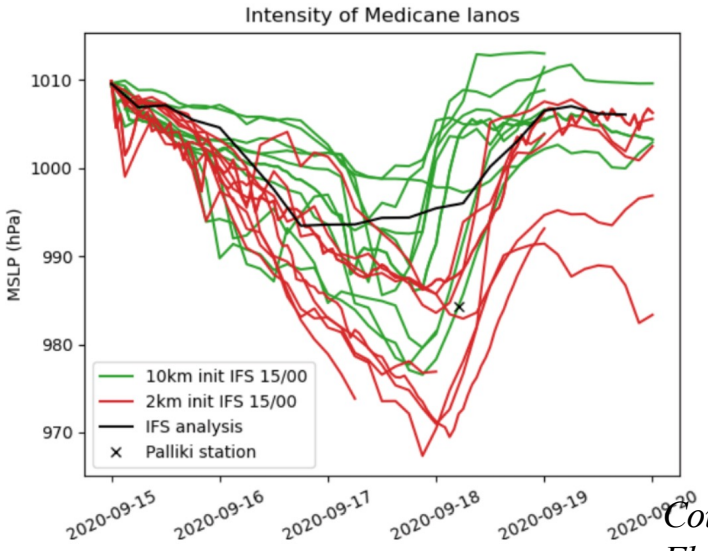






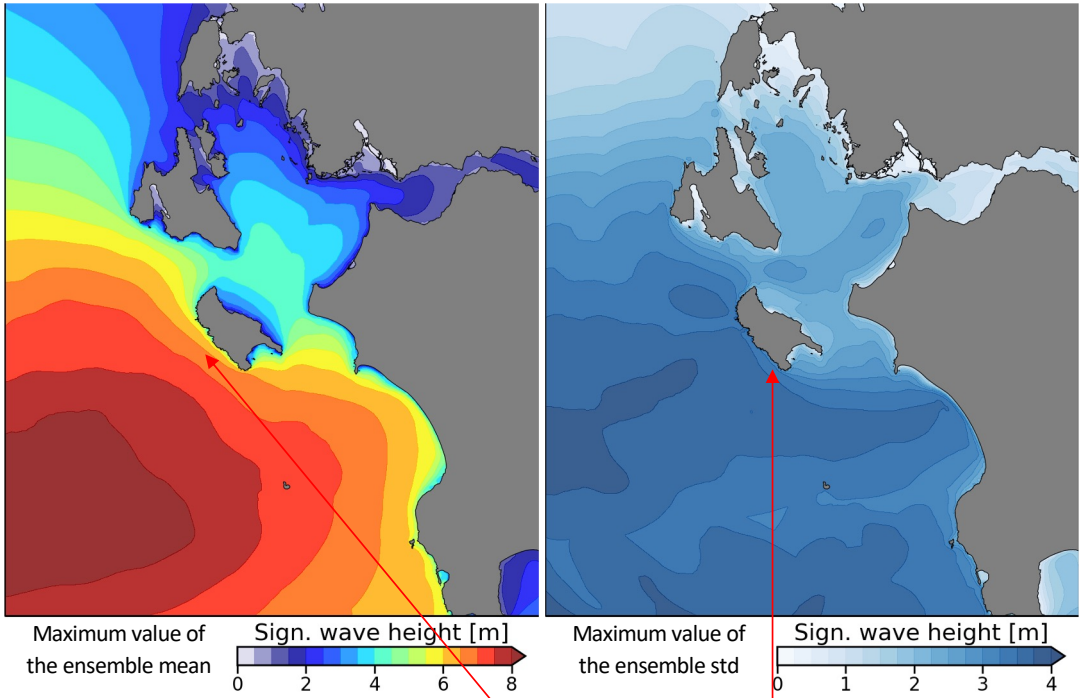


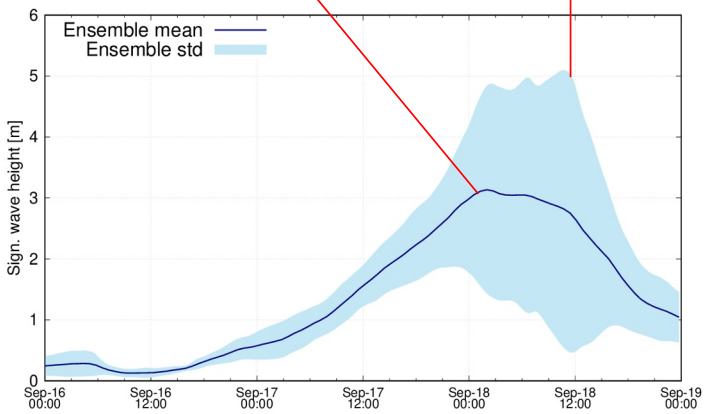




Courtesy
Florian Pantillon

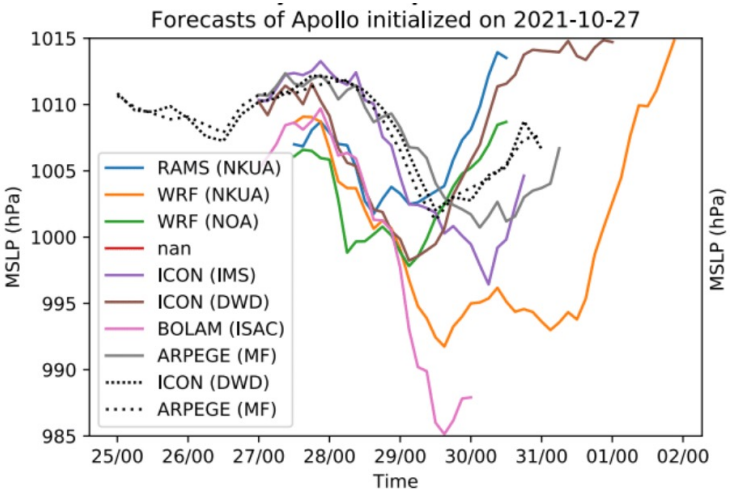
PREVISIONE
IMPATTI
PROCESSI

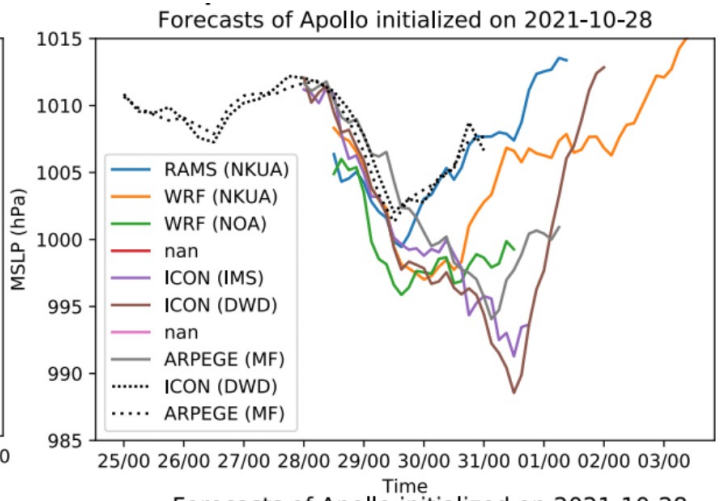


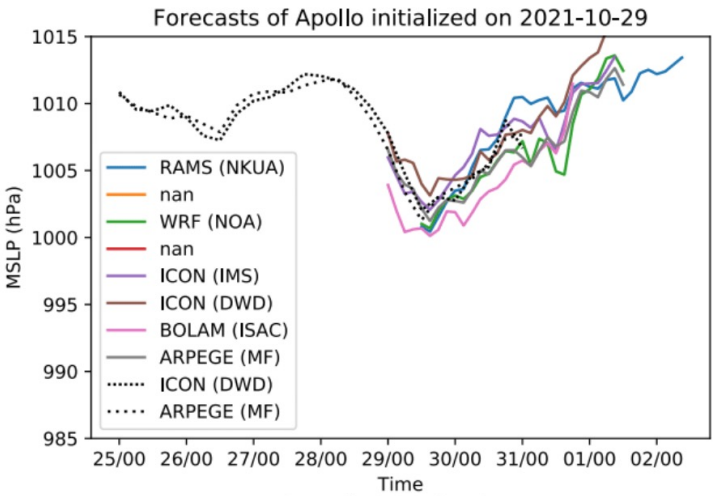


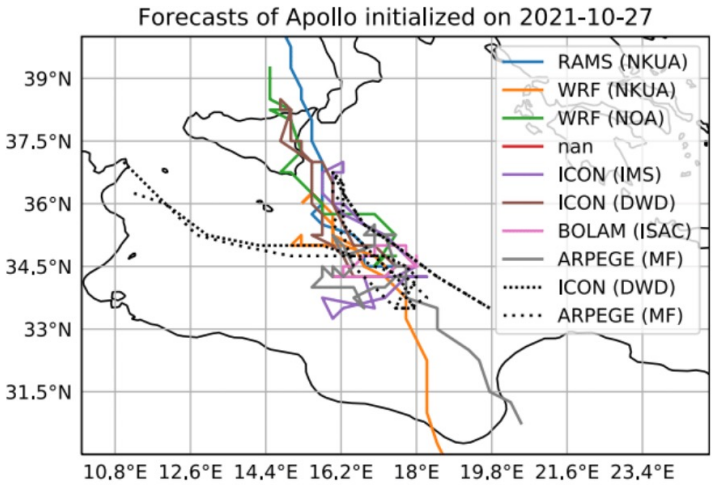
Courtesy
Marco Bajo

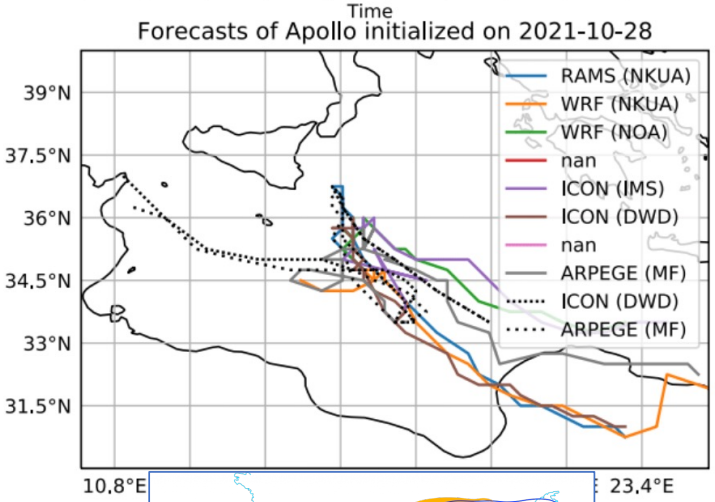
"MEDICANE APOLLO" – 27-29 Ottobre 2021

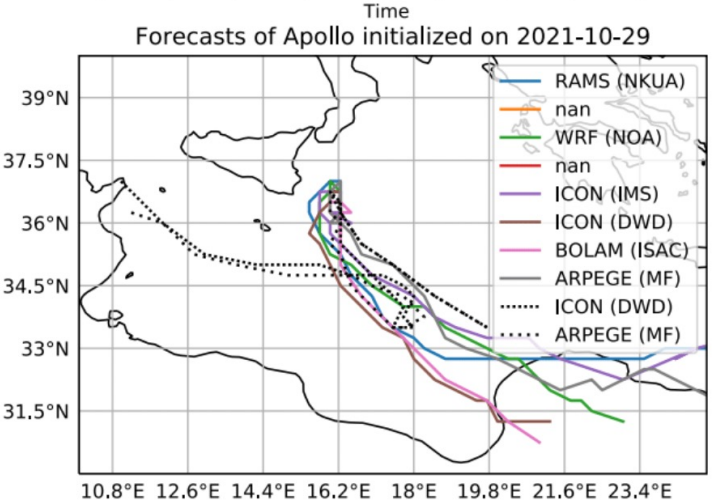


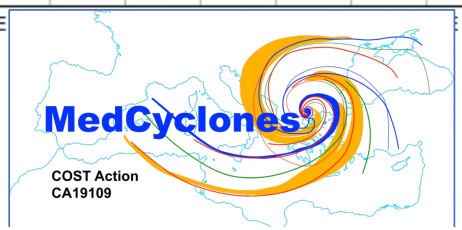










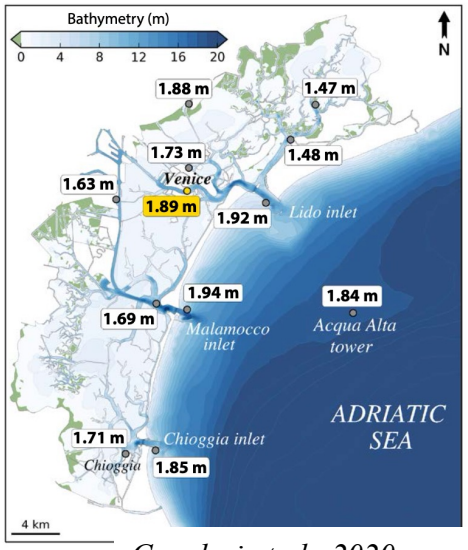


IMPATTO DEI CICLONI MEDITERRANEI: VENTO E STORM SURGE

Vento: in prossimità di un ciclone molto intenso, dove i gradienti di pressione sono grandi, si generano forti venti → Legame diretto tra intensità del ciclone e del vento
La complessa topografia del Mediterraneo gioca un ruolo fondamentale nell'intensificare localmente questi fenomeni (Bora, Maestrale, Scirocco, etc)

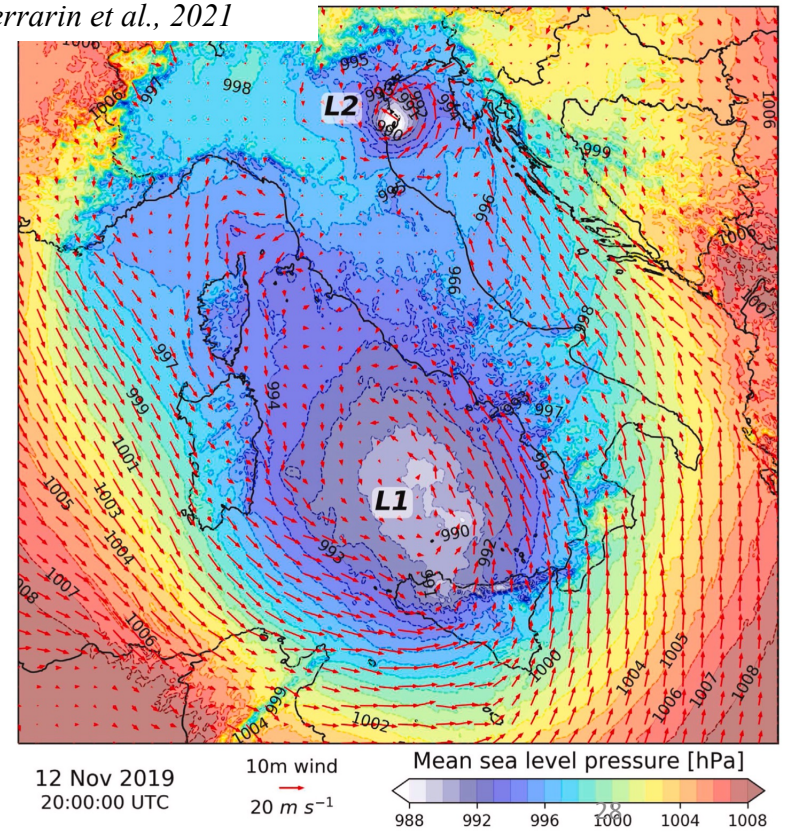
Onde e storm surge:

i) la posizione del ciclone può determinare un lungo fetch favorevole alle onde;
ii) la sua intensità favorisce forti venti che accumulano acqua (maggiormente per bacini shallow);
iii) effetto barometrico inverso

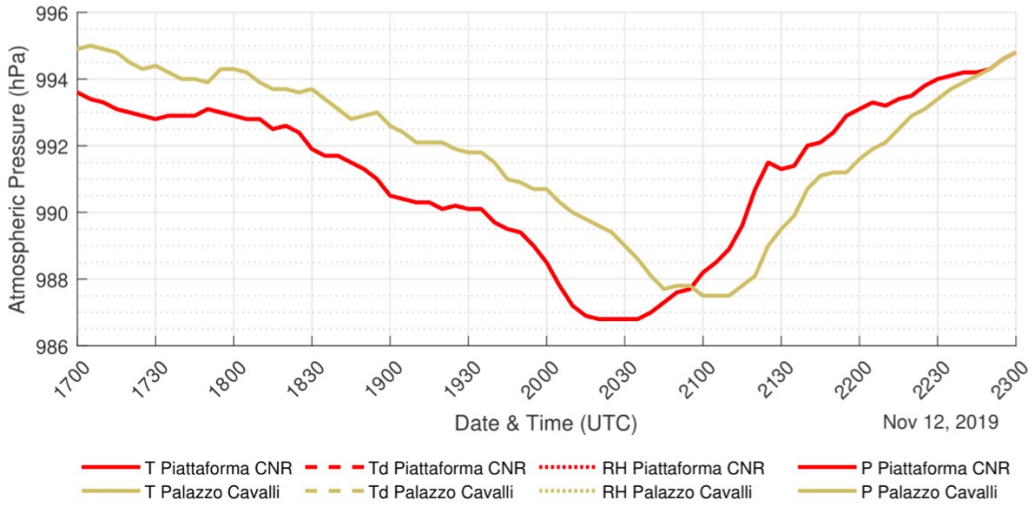


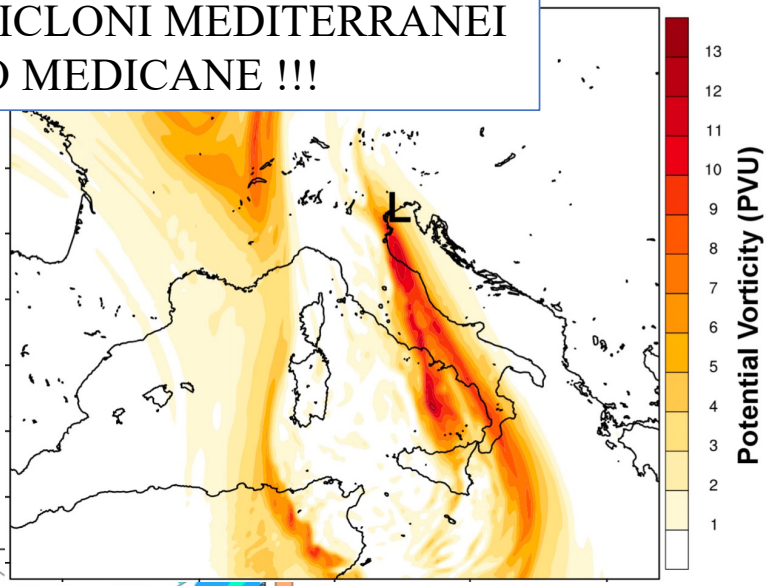
Cavaleri et al., 2020

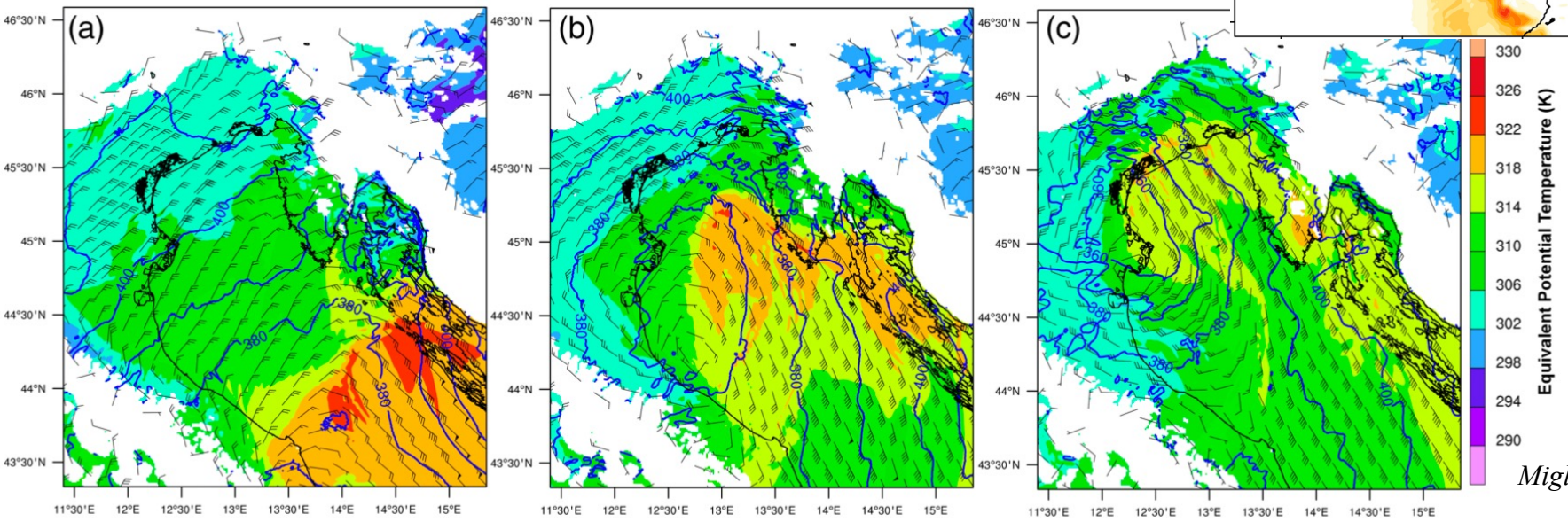
Ferrarin et al., 2021



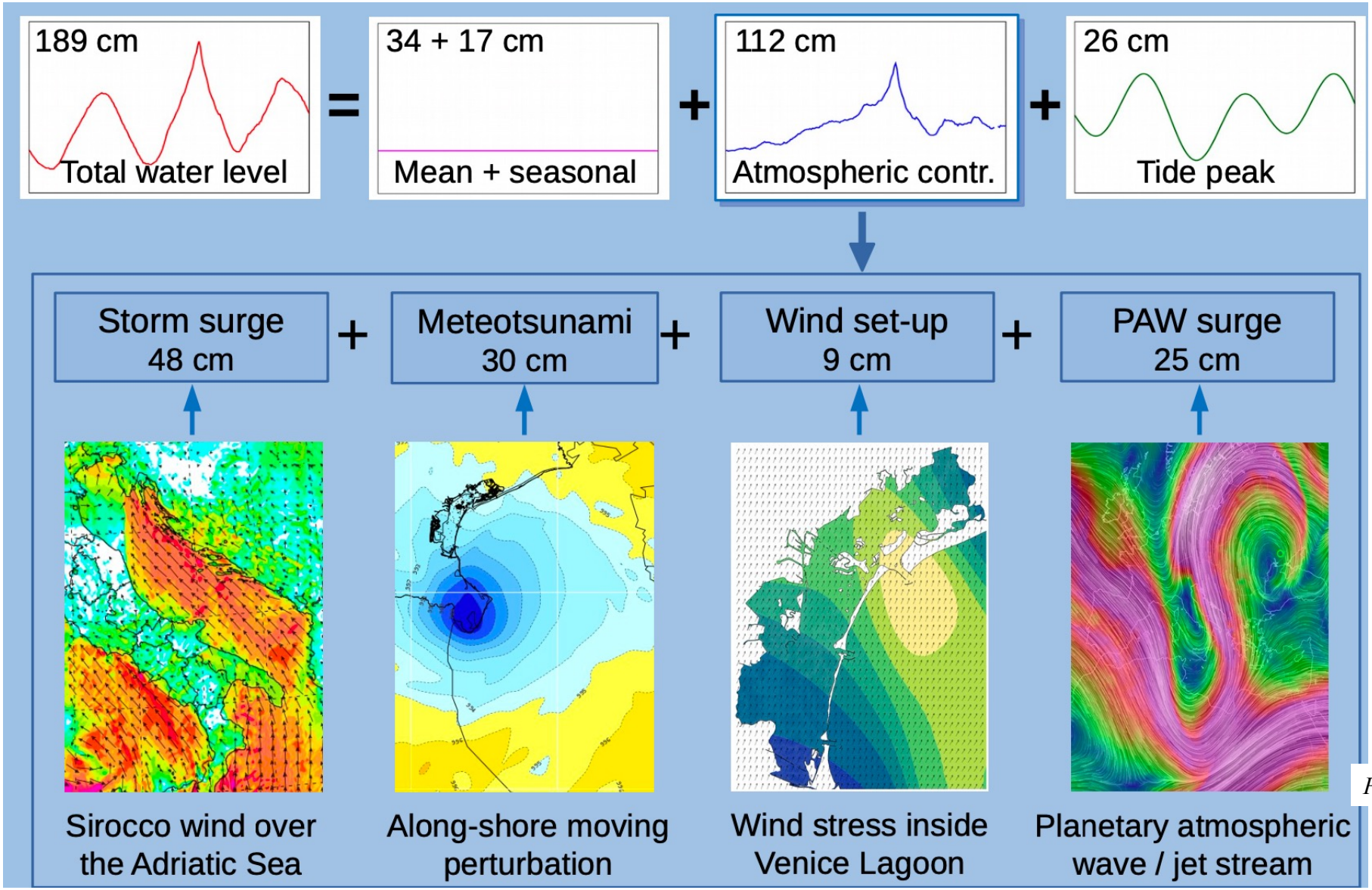
NON TUTTI I CICLONI MEDITERRANEI SONO MEDICANE !!!







Miglietta et al., 2023

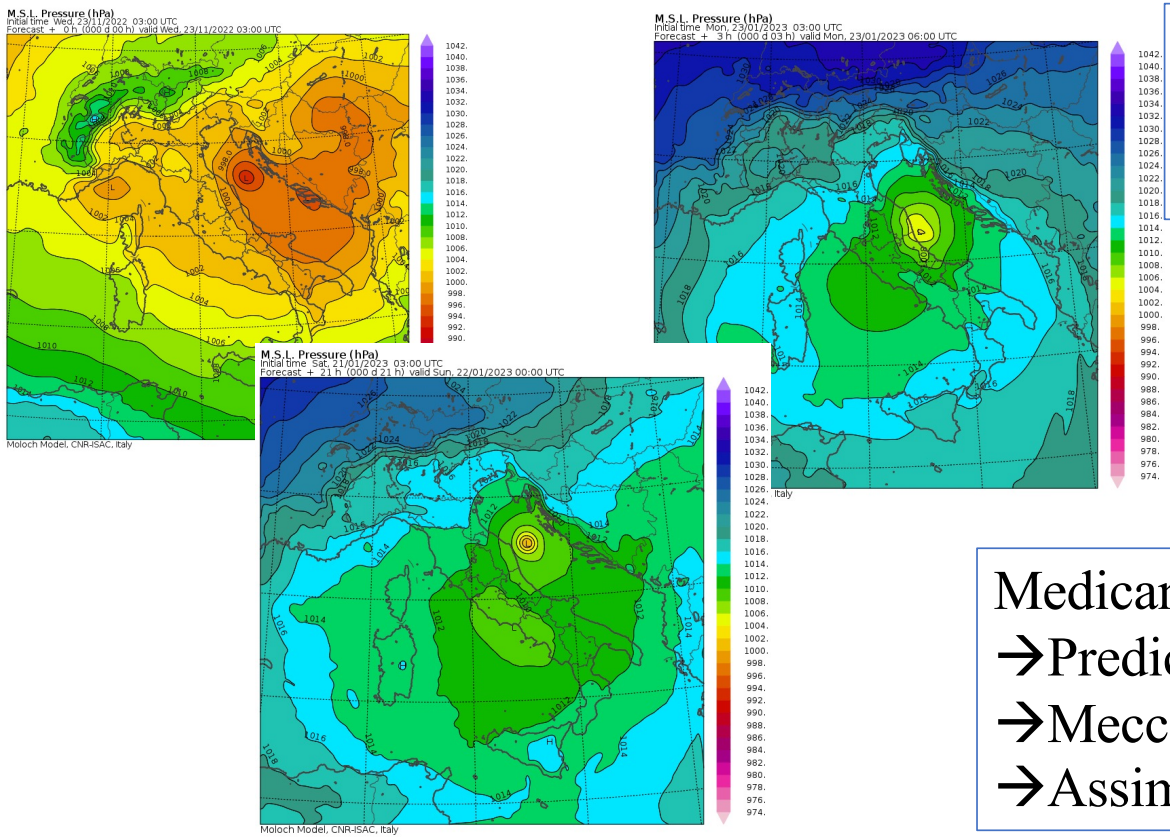


Ferrarin et al., 2021

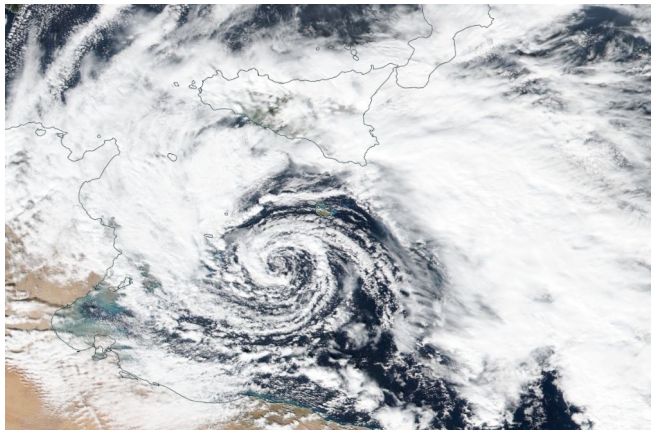
PROSPETTIVE ... WORK IN PROGRESS ... PROPOSTE TESI

MedCyclones
COST Action
CA19109

Casi studio collettivi: simulazioni e/o diagnostica
Best tracks database to be exploited
Opportunità di STSM

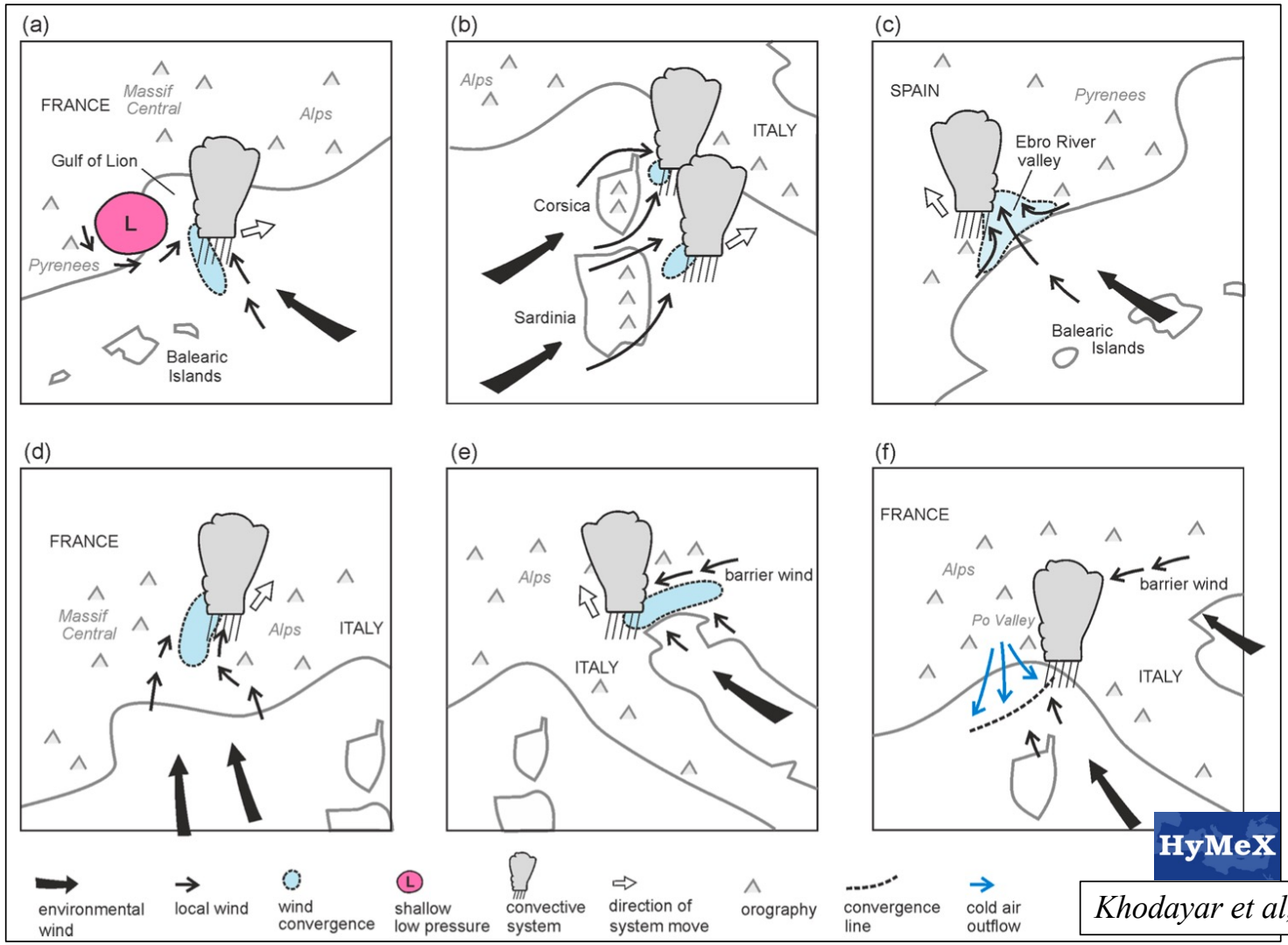


Small-scale cyclones in the Adriatic
→ Process study
→ Impacts

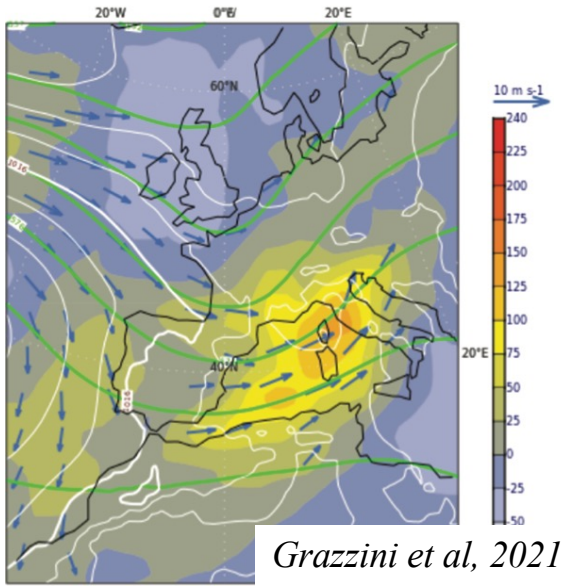


Medicane recenti:
→Prediciilità
→Meccanismi
→Assimilazione dati

MESOSCALE CONVECTIVE SYSTEMS



Khodayar et al, 2022

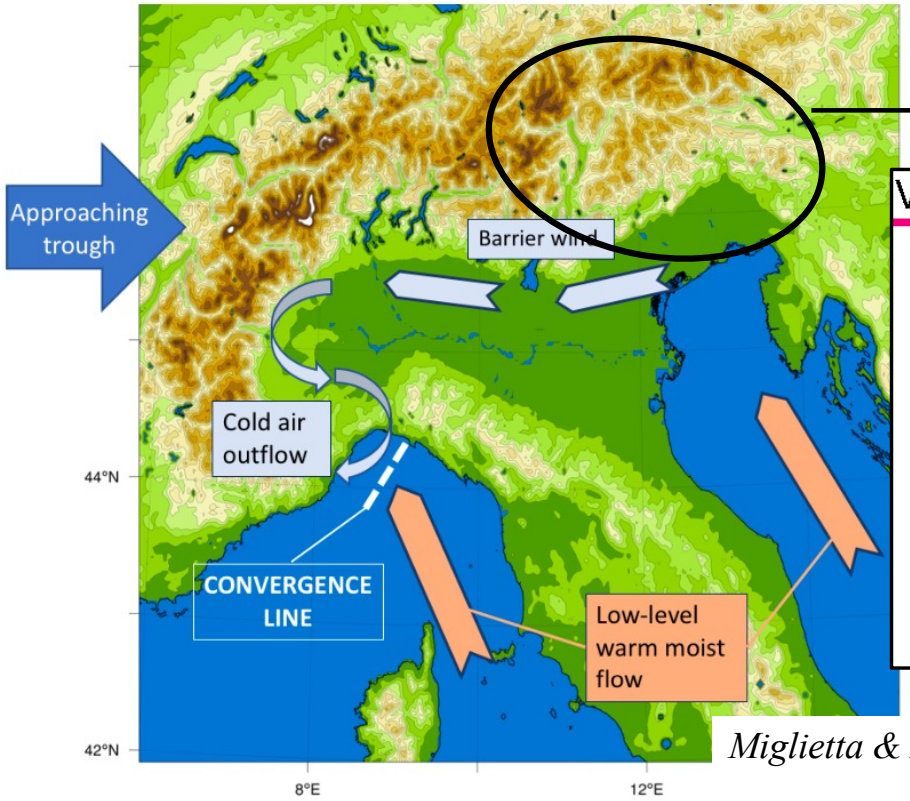


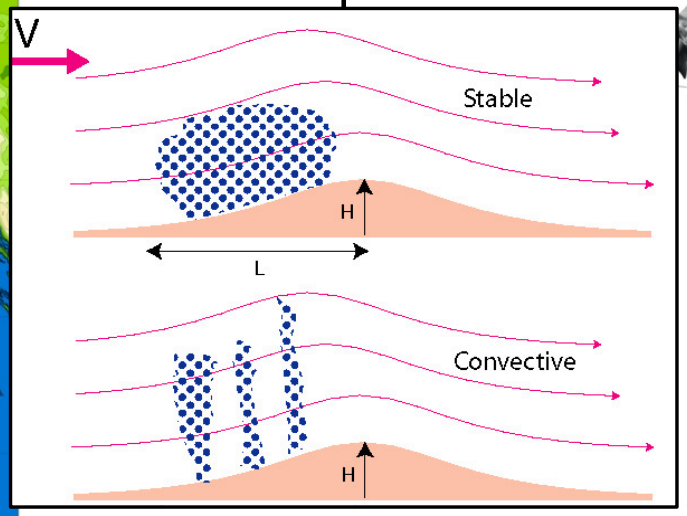
Grazzini et al, 2021

From the large scale

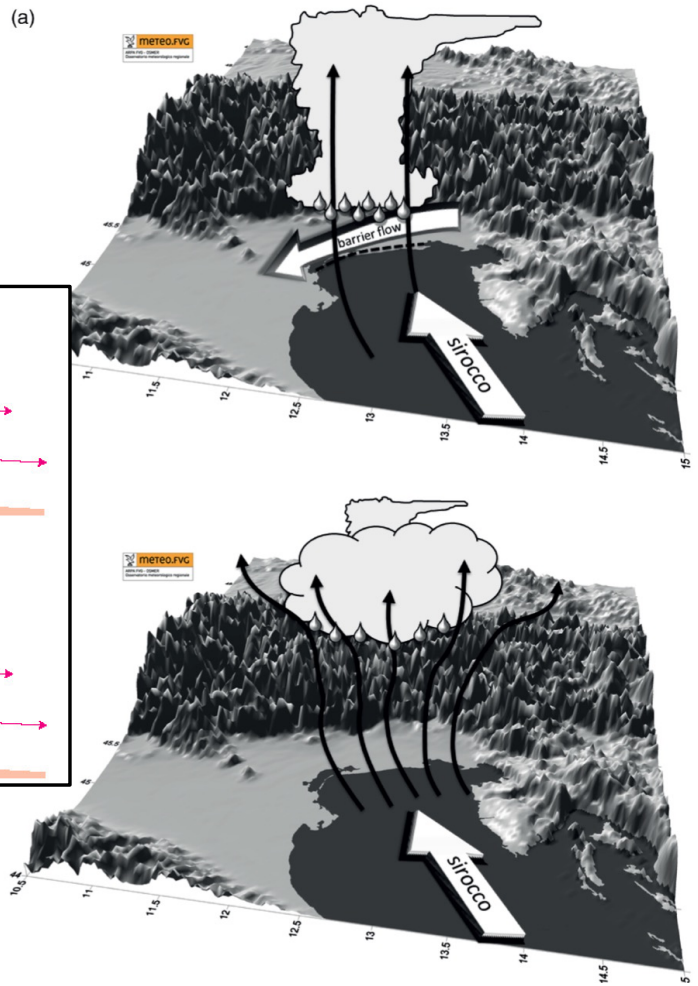
to the microscale

Heavy precipitation and Convective Systems over NE Italy



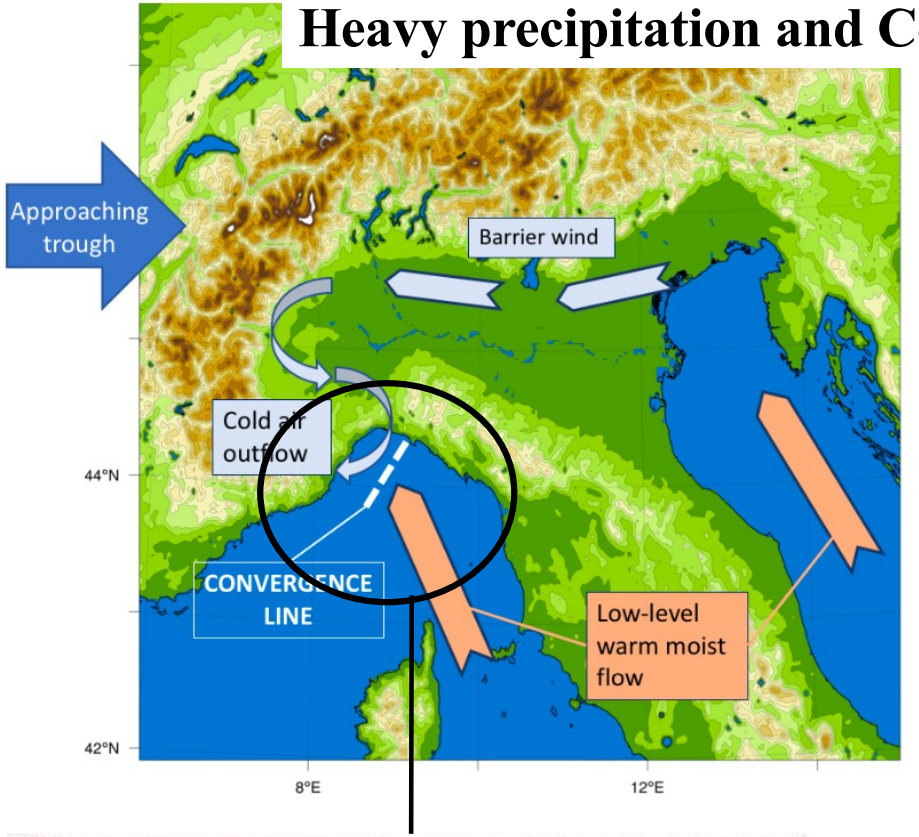


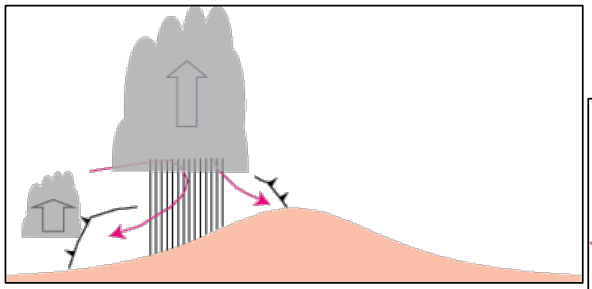
Miglietta & Davolio et al, 2022



Davolio et al, 2016

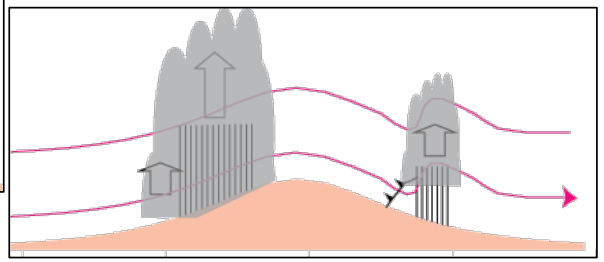
Heavy precipitation and Convective Systems over Liguria



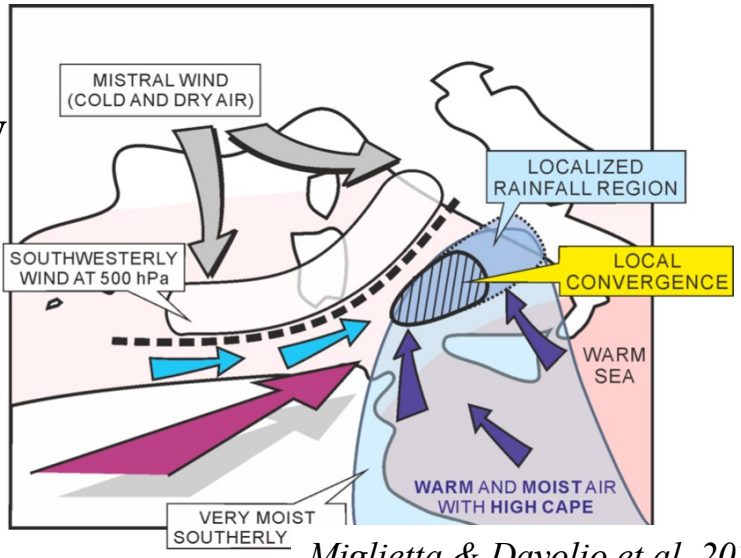


OROGRAPHIC FLOW REGIMES & CONVECTION

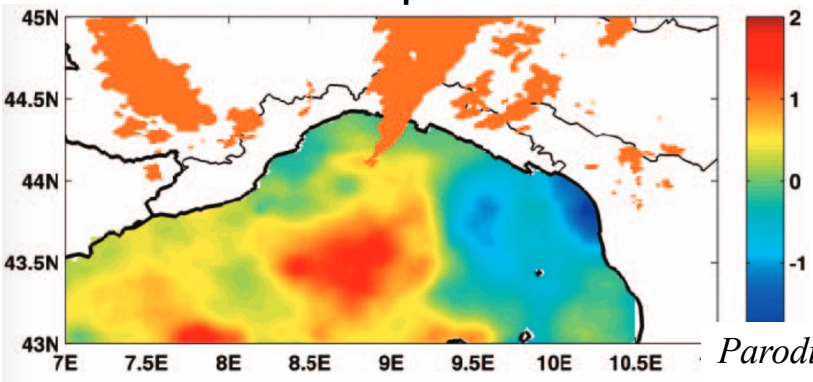
Courtesy Miglietta & Rotunno



over Central Italy



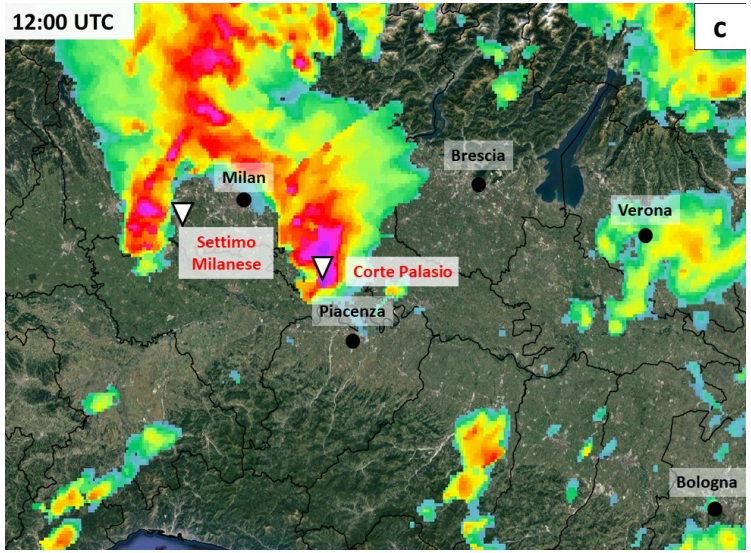
Miglietta & Davolio et al, 2022



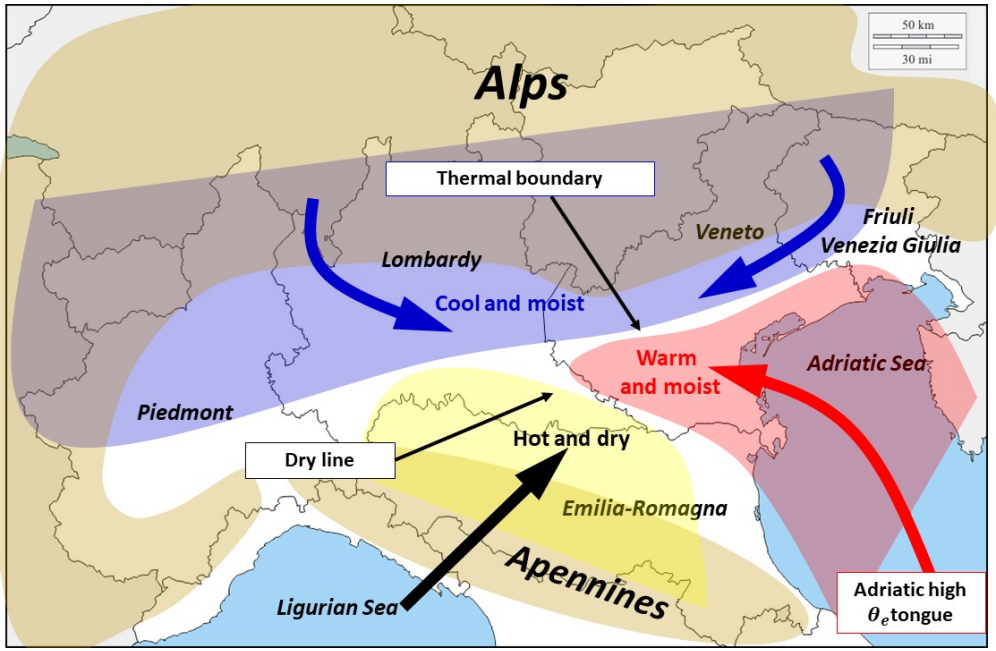
Parodi et al, 2012

Impacts of SST:
atmospheric stability, flow regime, sfc fluxes

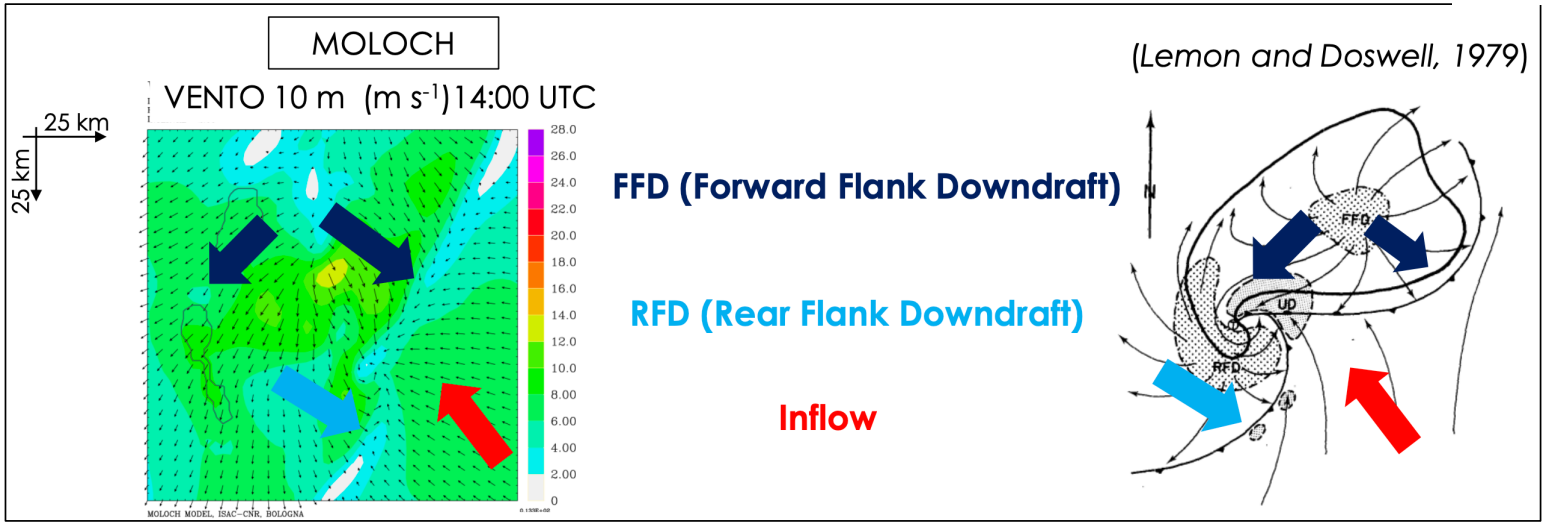
Supercells & Tornadoes



19 settembre 2021



De Martin et al, 2023

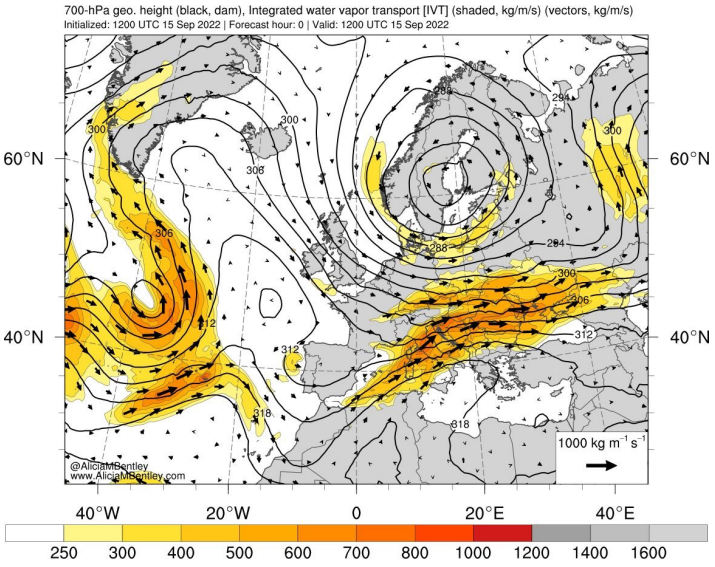


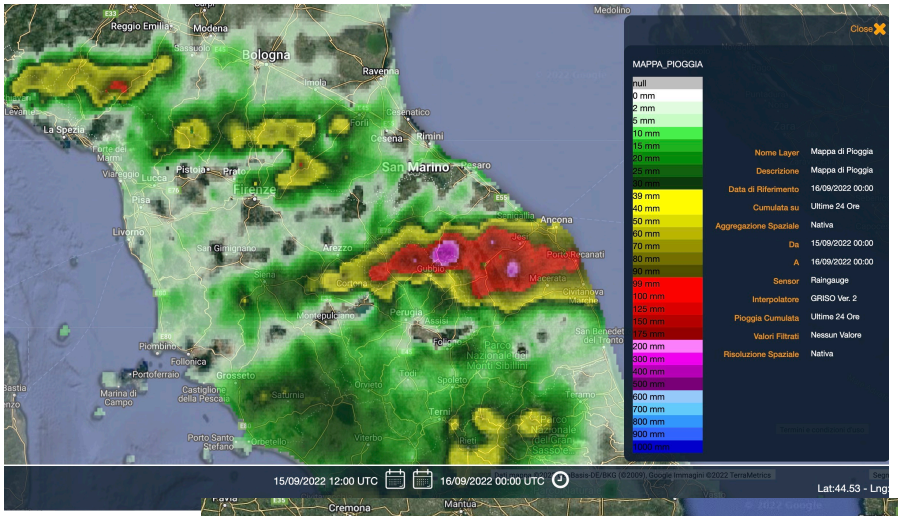
PROSPETTIVE ... WORK IN PROGRESS ... PROPOSTE TESI

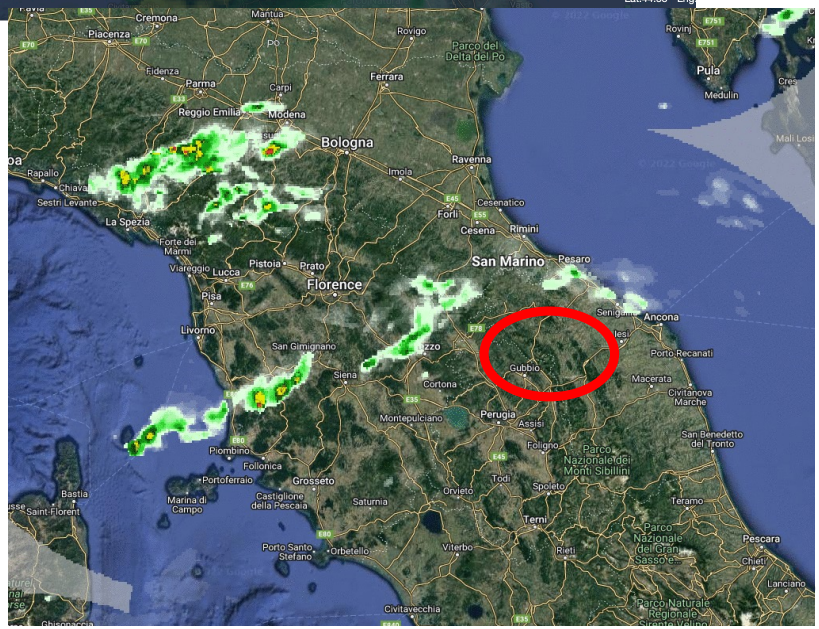
Eventi intensi:

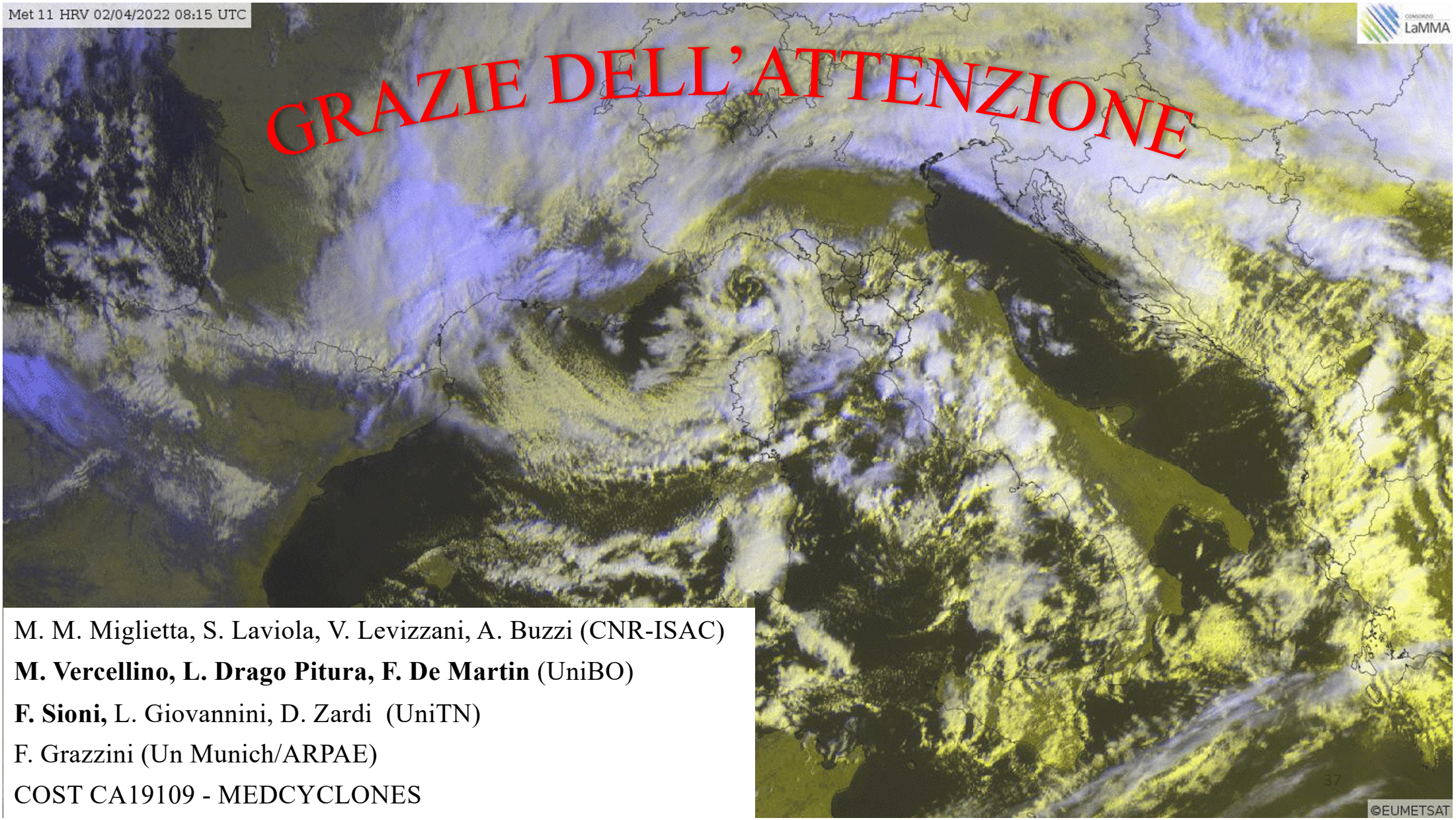
- Caratterizzazione
- Predicibilità
- Previsione operativa
- Assimilazione dati
- Accoppiamento idrologico

Alluvione delle Marche 15 set 2022









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