FROM HIGH WATERS TO HIGH STAKES

Attributing Acqua Alta Events in Venice to Climate Change and the Efficacy of MoSE adaptation strategy

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THE FLOODING EVENTS (ACQUA ALTA) IN VENICE

- **Venice's acqua alta 🌊:**

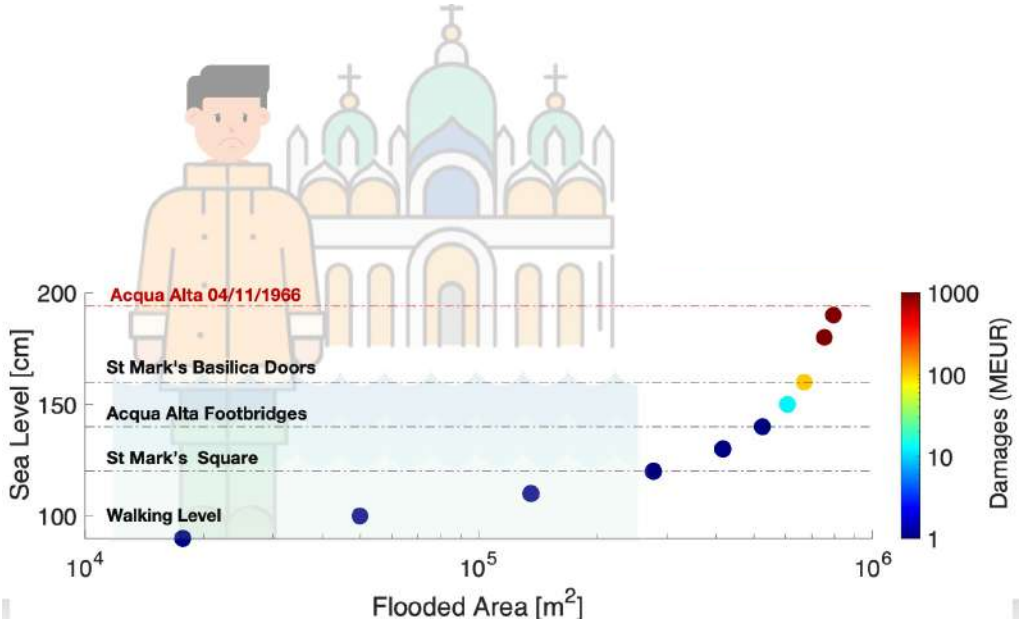
Frequent and severe flooding due to interaction of Mediterranean cyclones with rising sea levels, climate change, and land subsidence.

- **Impacts 💸:**

Societal disruption, infrastructure damage, economic losses, and threats to cultural heritage.

- **This presentation 👉:**

Evaluate the effectiveness of adaptation strategies (MoSE) against MedCyclones producing Acqua Alta events in venice



THE MoSE SYSTEM TO PROTECT VENICE

🚧 **MoSE System**: The MoSE (Experimental Electromechanical Module) is a safeguarding system implemented in Venice to protect against acqua alta. The construction cost is 6000 MEUR

🔧 **MoSE operations:** The MOSE system started its service on 03-10-2020 aiming to mitigate extreme flooding events in the city.

✅ **Activation frequency**: Since its inception, the MOSE system has been activated 43 times to safeguard Venice from high water levels.

HOW EVENTS ARE MODIDIFIED BY CLIMATE CHANGE?
The Attribution science

1. **Detection step** : define the event and be able to detect in climatological data

2. **Factual and Counterfactual worlds**: have sufficient information to compute the probability, intensity and frequency of the event detected in a word with and without anthropogenic emissions.

3. **Natural vs Forced Variability:** have sufficient information to separate the contribution of the anthropogenic climate change from the natural variability

AN ATTRIBUTION SCHEME FOR THE ACQUA ALTA EVENTS IN VENICE
First: evaluate if MedCyclones leading to Acqua Alta have changed charactersitics

Greenhouse Emissions

Climate Variability

Weather Phenomena
Med Cyclones

Climatic Hazards
Wind
Rain
Sea-Level Rise

Impacts
Acqua Alta Event

04/11/1966

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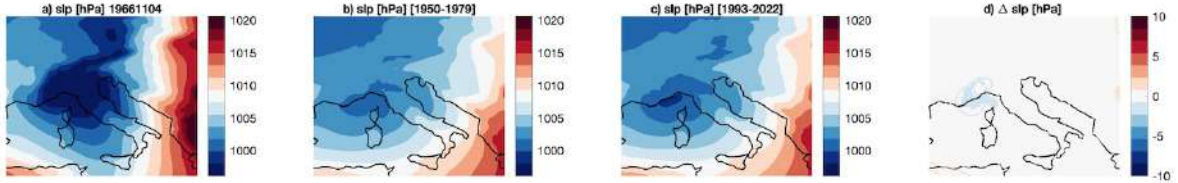
Pression 12/11/2019 | **Analogues '50-'79** | **Analogues '92-22'** | **Change**



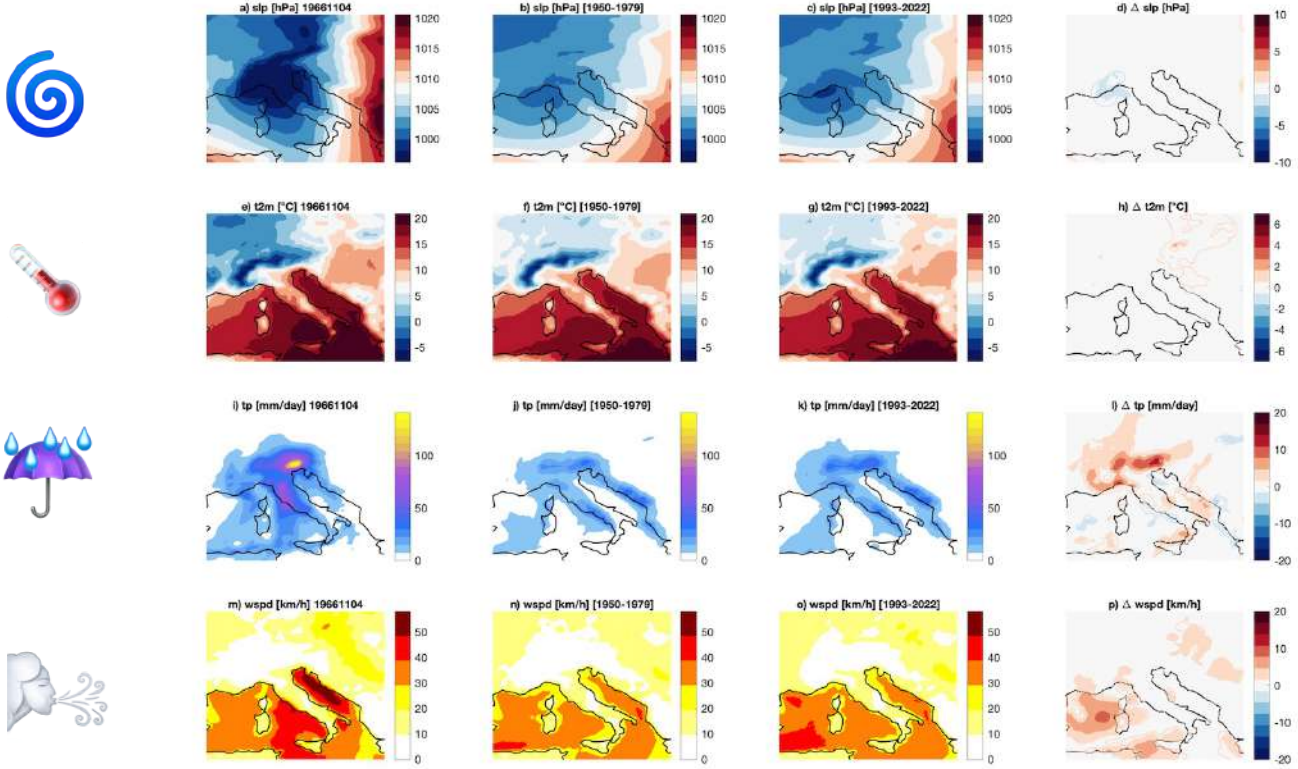
Methods Faranda et al. 2022 Weather & Climate Dynamics, …

A DYNAMICAL SYSTEMS APPROACH FOR ATTRIBUTION

1) Choose an obs. dataset or reanalysis: here ERA5 1950-2022.
2) Identify the region of interest for your event.
3) Divide your dataset in a world with and without climate change: here 1993-2022 and 1950-1979 respectively.
4) Define an observables to look for analogues: here SLP
5) Find analogues in present vs past periods
6) Study the differences between two periods and determine their significance, evaluate the role of El Nino Southern Oscillation and Atlantic Multidecadal Oscillation for the detected analogues

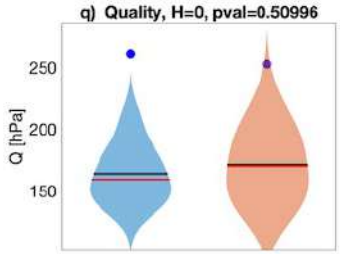
A DYNAMICAL SYSTEMS APPROACH FOR ATTRIBUTION

04-11-1966 PAST PRESENT CHANGES

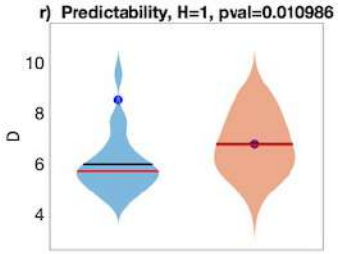


ASSESSING THE EXCEPTIONALITY OF THE EVENT

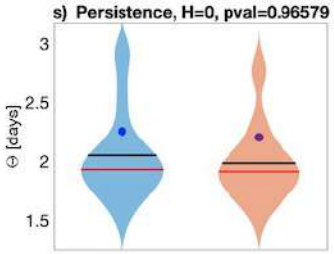
Quality



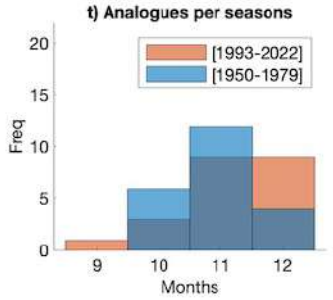
Predictability

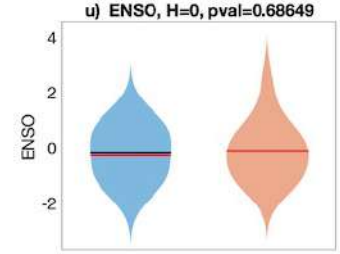


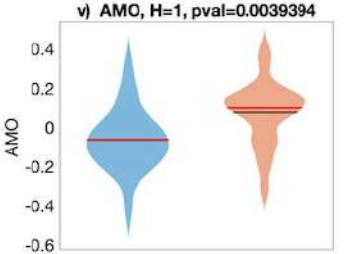
Persistence

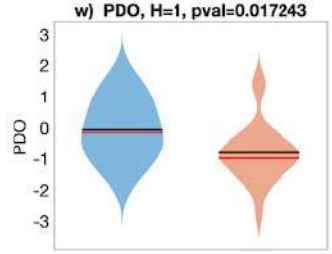


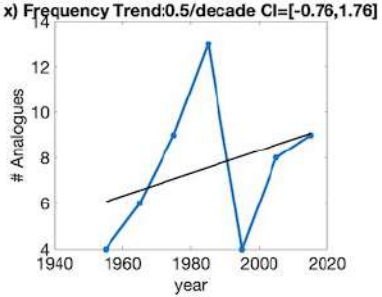
Seasonality











ENSO

AMO

PDO

Frequency

AN ATTRIBUTION SCHEME FOR THE ACQUA ALTA EVENTS IN VENICE
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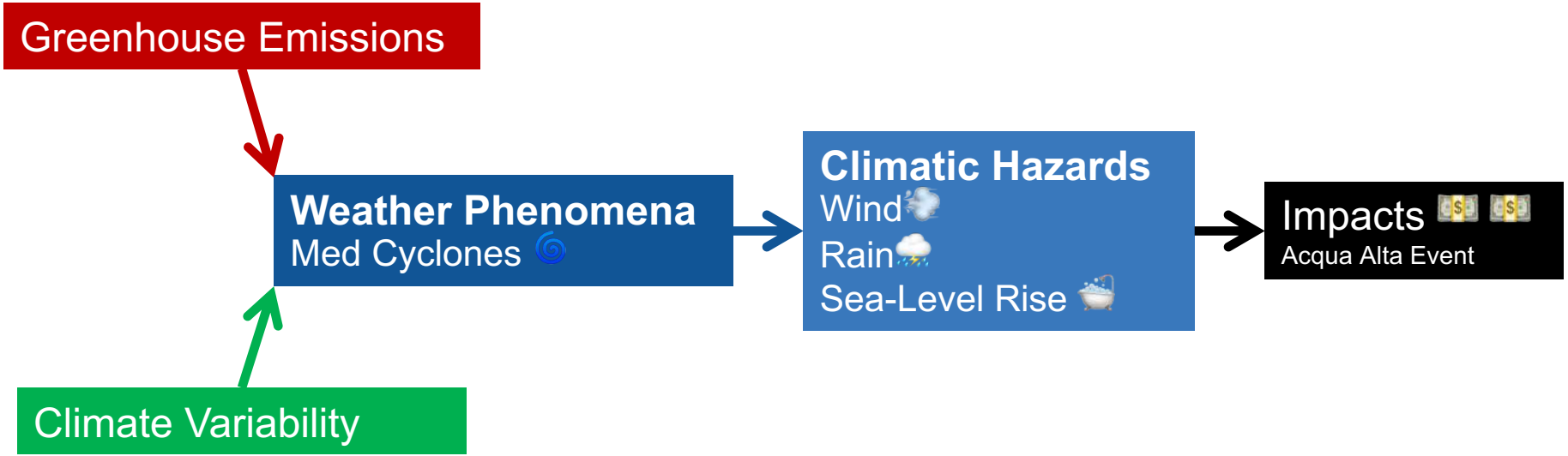
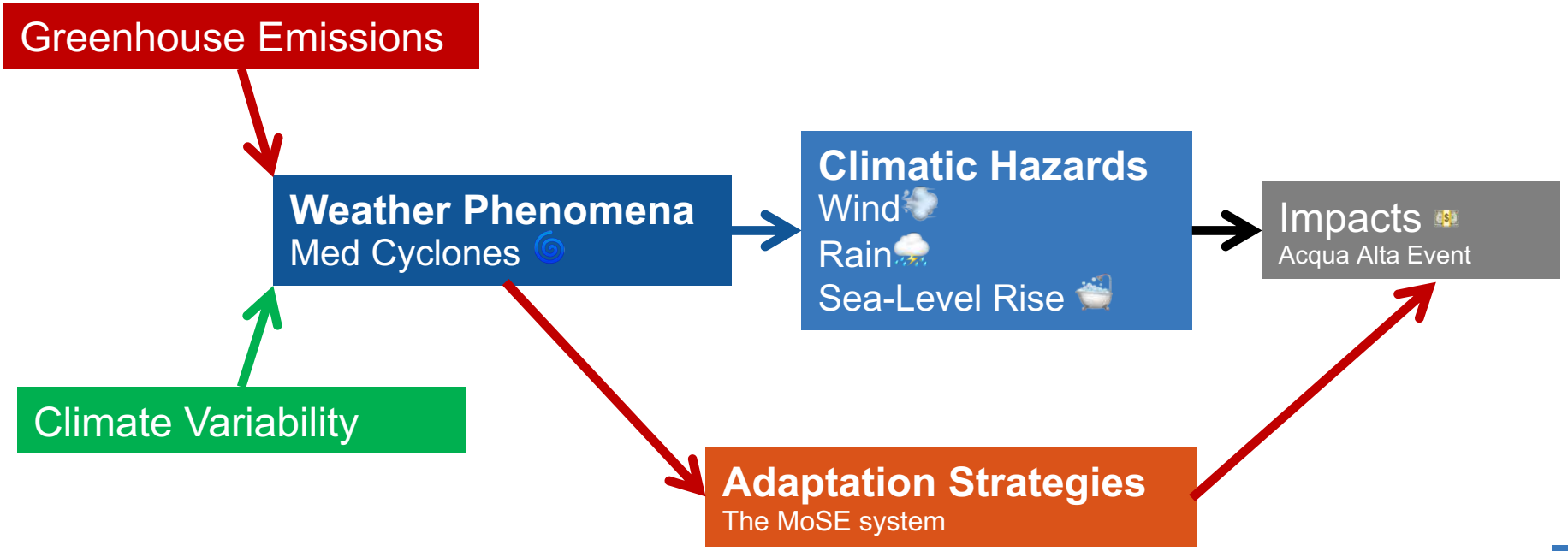


EVALUATING THE EFFECTIVNESS OF MoSE In PROTECTING VENISE
when MoSE is activated we expect to reduce the impacts of Acqua Alta



EVALUATING THE EFFECTIVNES OF MoSE

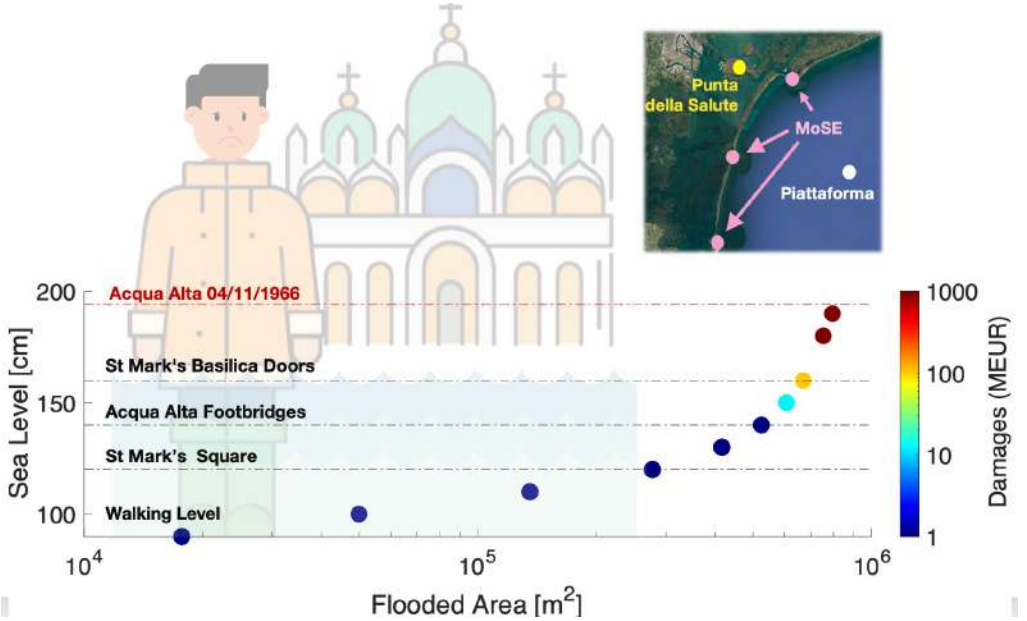
1) We have **a list of analogues dates for the past and present period.**

2) For each date, we use the **sea-level measurement in Punta della Salute.**

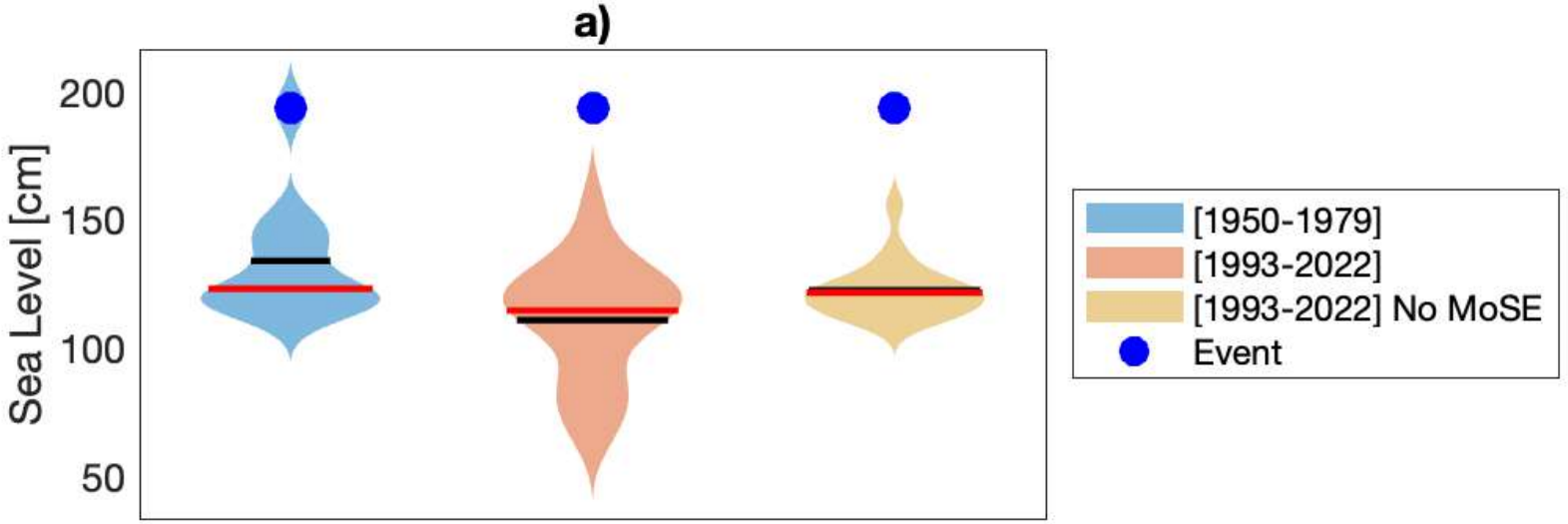
3) To evaluate what would have happened **without MoSE, we use the measurement of Piattaforma**

4) We compute **damages** with an exponential model.

5) If **MoSE is activated** for a given analogues date, we add a 0.025 MEUR cost



EVALUATING THE EFFECTIVNES OF MoSE
Sea Level for analogues dates



EVALUATING THE EFFECTIVNES OF MoSE
Cost Effectiveness of MoSE

	# MoSE	Variables	Event	[1950-1979]	[1993-2022]	[1993-2022] no MoSE
04/11/1966	5 (30%)	SL [cm]	194	123 [116, 194]	115 [69, 150]*	122 [111 150]
		Damages [MEUR]	8000	0.3 [0.1, 4000]	0.25 [0.01, 19]*	0.29 [0.07 19]

The MoSE system is already cost-effective against events similar to 1966 😀

EVALUATING THE EFFECTIVNES OF MoSE
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29/10/2018	1 (6%)	SL [cm]	156	122 [118,144]	125 [96, 155]	125 [111, 155]
		Damages [MEUR]	47	0.3 [0.2, 5.6]	0.5 [0.07, 26]	0.5 [0.07, 26]
12/11/2019	3 (20%)	SL [cm]	187	113 [113 114]	112 [62 183]	118 [110 183]
		Damages [MEUR]	1000	0.09 [0.09 1000]	0.2 [0.06 1600]	0.3 [0.06 1600]

The MoSE system is already cost-effective against events similar to 1966 but two recent events (2018 and 2019) come with new dynamical mechanisms involving mesocyclones on the Adriatic sea: MoSe is (not yet) cost-effective against these events ! 🥲

DISCUSSION

- **MoSE effectiveness** 🚧❓

The analysis shows successful protection against the 1966 extreme event, while 2018 and 2019 outcomes remain inconclusive due to lack of analogues. 😮

- **Future implications** 🌊🌍

These findings have significant implications for Venice and coastal cities facing rising sea levels and extreme events.

- **Adaptation assessment** 🔄📈 **:**

This study offers a framework to evaluate adaptation effectiveness under more frequent and intense events with higher global warming levels.

THANKS FOR YOUR ATTENTION

-Faranda, D., Alberti, T., Coppola, E., Ginesta, M., Anzidei, M. Attributing Venice Acqua Alta events to a changing climate and evaluating the efficacy of MoSE adaptation strategy. NPJ (in review, 2023)

-Faranda, D et aL (2022). A climate-change attribution retrospective of some impactful weather extremes of 2021. Weather and Climate Dynamics, 3(4), 1311-1340.

-Alberti, T., Anzidei, M., Faranda, D. et al. Dynamical diagnostic of extreme events in Venice lagoon and their mitigation with the MoSE. Sci Rep 13, 10475 (2023). https://doi.org/10.1038/s41598-023-36816-8

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