INCREASE OF SOUTHERN EUROPEAN COLD SPELL INTENSITY UNDER CLIMATE CHANGE?

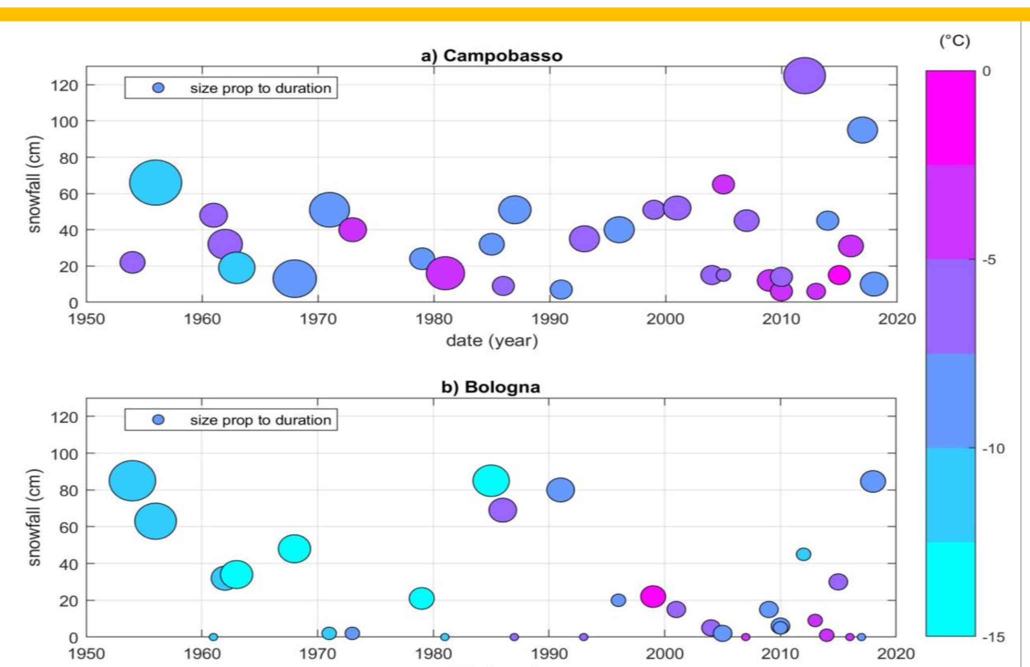
Miriam D'Errico[1], Pascal Yiou[1], Cesare Nardini[2], Davide Faranda[1]

(1) LSCE; (2) SPEC-IRAMIS

miriam.derrico@lsce.ipsl.fr

BACKGROUND

- We investigate winter cold spells in the **Southern Europe region**
- They have a great impact on agriculture, transportation and society.
- A **winter cold spell** is a marked and unusual cold weather characterized by a sharp and significant drop of air temperatures leading to extremely low values, possibly associated to heavy snowfalls (WMO).



February 2012

Figure 1: **Cold spells from documentary sources**. a) Campobasso (686 m of altitude); b) Bologna (54 m of altitude). Each ball represents one cold spell event. The size is proportional to the number of snowfall days. The y-axis shows the snowfall measured during each event. The color shows the minimum near surface temperature recorded during the event.

CHALLENGES

- It is unclear whether anthropogenic forcing would increase or decrease the occurrence of cold spells and change their dynamical evolution.
- Due to the scarcity of these events, climate simulations are required to answer this research question.

SCIENTIFIC QUESTIONS

1) Do different **cold spells** detected in the NCEP reanalysis share **similar dynamical characteristics**?
2) Can their average dynamic be reproduced in **PLASIM** model?
3) Which effect has **climate change** on the characteristics of cold spell ?

32 cold spells found over the period **1948-2018** **(**Fig 1) using documentary research method.

METHOD

- We consider ta **minimal set of variables** that define a cold spell in term of circulation, thermodynamics and precipitation (Fig. 2):

1. **Sea-level pressure (SLP)**
2. **Geopotential height at 500 hPa (HGT500)**
3. **Temperature at 850 hPa (T850)**
4. **Snow depth**

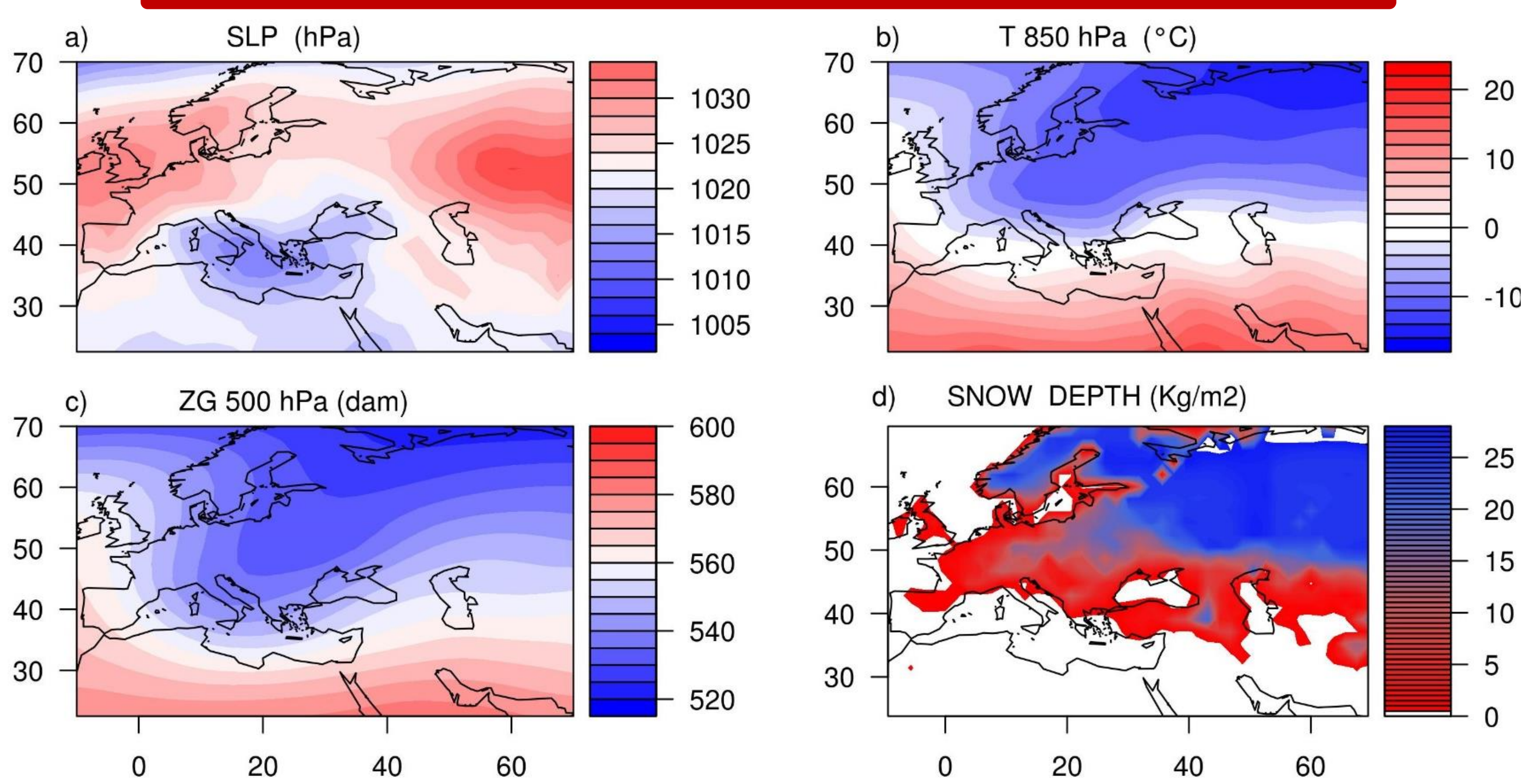


Figure 2: **Averaged cold spells for NCEP reanalysis**. Average of the 32 cold events for a) Sea level pressure (hPa) ; b) Temperature at 850 hPa (°C); c) Geopotential height at 500 hPa (dam); d) Water Equivalent of Accumulation Snow Depth in kg/m^2 for **NCEP** reanalysis.

The dynamical pattern consists of:

- The placement of a **low pressure** over the **Mediterranean sea** and two high pressure patterns over the Iberic Peninsula and Russia (Fig. 2a)
- Incursion of **cold air** coming **from Scandinavia** that extends to South-West Europe (Fig. 2b)
- **Increase** of the **troughs** of **Z500** all over the South Europe (Fig. 2c)
- Where this cold air is advected (Fig. 2d) **snowfall** is observed.

Similar dynamical evolution in cold spells over several days

SIMULATIONS MADE USING PLASIM (The **Plan**et **Sim**ulator)

- The last version (17) of a coupled system of climate components for Earth developed as a model of intermediate complexity [Fraedrich, 2012] .
- It is a reduced complexity AGCM, with the 3-D primitive-equation atmosphere model PUMA at its core [Fraedrich et al., 2005, Lunkeit et al. , 2007]
- Ragone et al. [2017] used PLASIM to force heat waves conditions via large deviations

- We use the **T42** resolution **10** level
- **We** perform **500 years of control simulation with mixed layer ocean** (time running ~15 days on 2CPU)
- 500 year of fixed emissions **RCP8.5** and **4KSST scenarios.**

COLD SPELL IN PLASIM

- To select the cold spells in PLASIM simulation we used 32 best Analogues of averaged cold spells of NCEP.

Fig. 3: **The region selection**. Where the documentary sources about the extreme events are based for our analysis and defined by the black box.

- The **anomalies** of the 32 cold spells are averaged over the region contained in the black box (Fig. 3).

DISCUSSION

Lake-Effect Snow – Gelato Paradox

(Visible Infrared Imaging Radiometer Suite (VIIRS), Aqua and Terra, 09-02-2015).

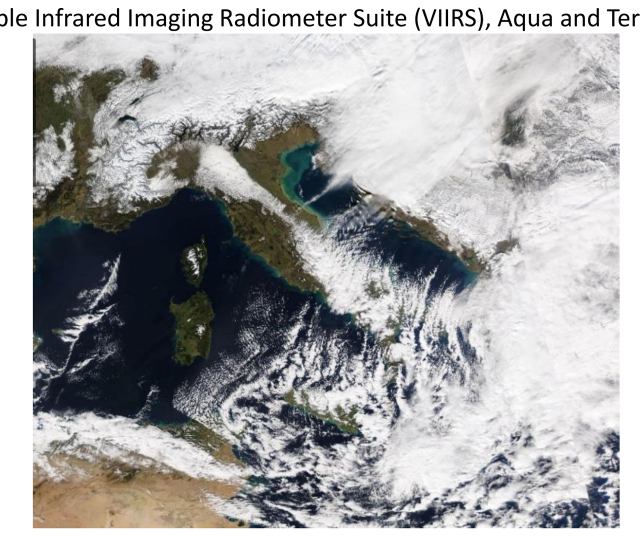


Figure 6: **NASA satellite image** shows the snow convective cloud bands associated to the cold spells.

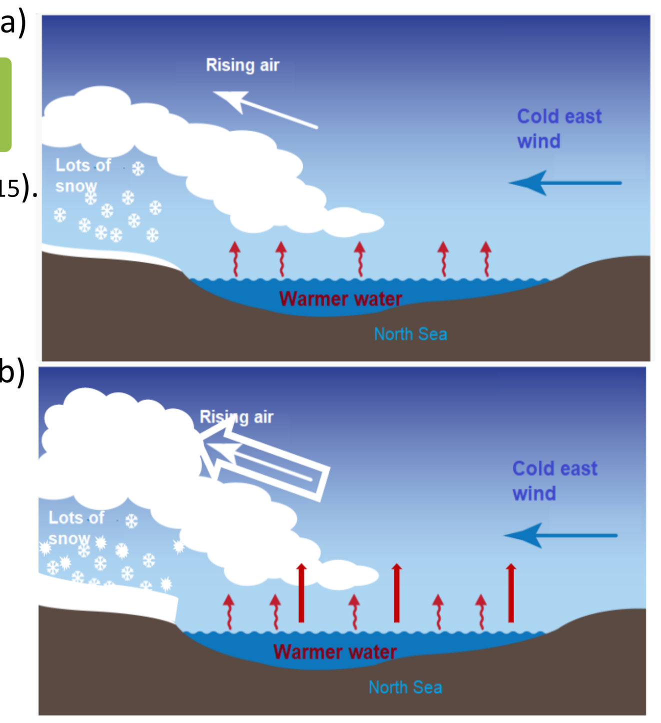


Figure 7: **Lake-Effect Snow.** The sequence of the sketches a)-b) shows the amplification of the lake-effect snow.

- Very **cold** winter **air** mass (from Scandinavian region) flows over relatively **warmer waters** (Mediterranean sea)
- This warmer and **wetter** air rises and cools as it moves away from the water (Italian Apennines mountain range).
- These conditions form **convective** clouds that transform the moisture as **snow**.
- This effect is **amplified** by a warmer ocean in the case of 4K-SST run
  - causing a cooler and **a more snowy cold spell event**.

SIMULATIONS RESULTS

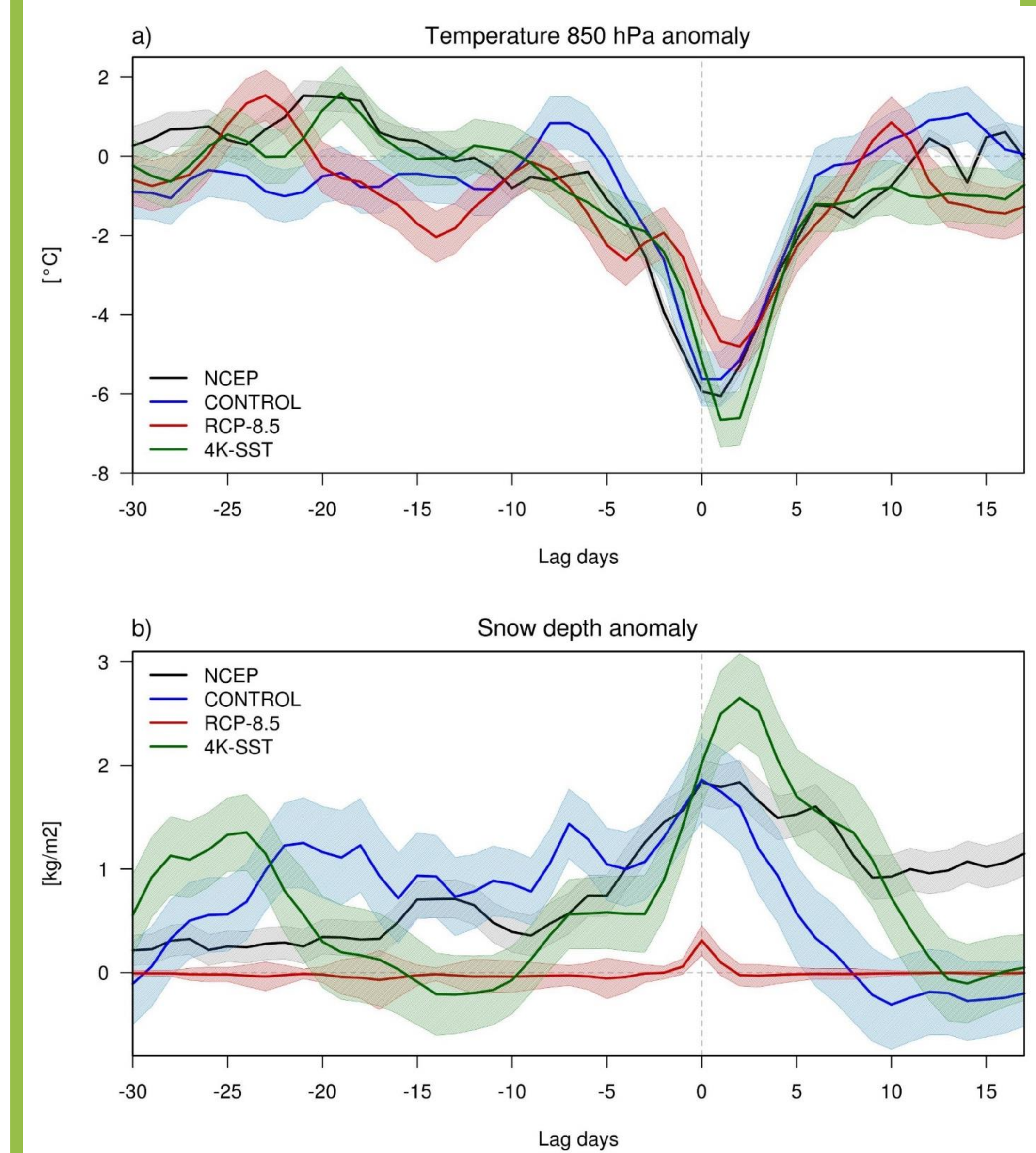


Figure 4: Cold spell anomalies. a) T850 (°C) and b) snow depth (Kg/m2) anomalies of the cold spells in NCEP reanalyses (black line) and of best analogues of PlaSim for control (blue line), RCP8.5 (10−2 Kg/m2) (red line) and 4K-SST (green line) runs at different time lags. Standard deviation represented as shading.

- **Results** are shown for each lag days for PLASIM simulations and NCEP reanalysis (Fig. 4).
- The **4KSST** shows **higher** cold spell **intensity** compared to the control simulation and NCEP dataset.
- The 4K-SST run is more **unstable**, thus explaining the convective feedback triggering heavy snowfalls.

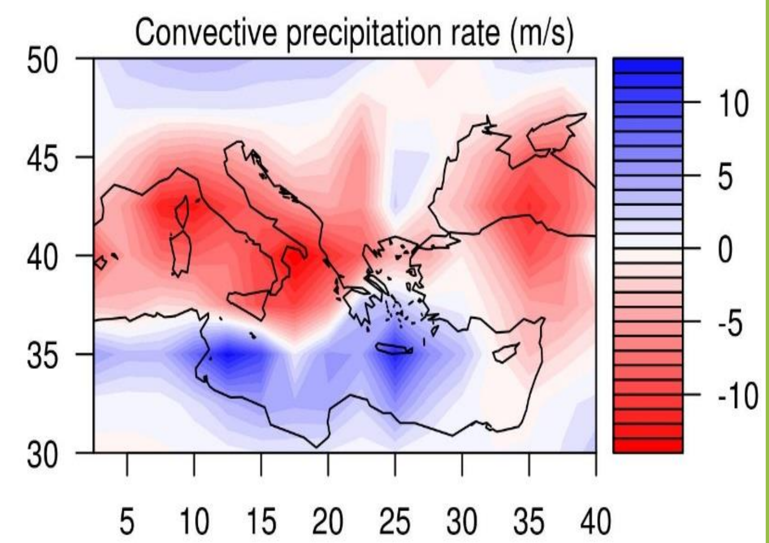


Figure 5: **Convective precipitation rate**. The rate of the convective precipitation (10^{-8} m/s) is shown as difference of 4k-SST run and control run to highlight the atmospheric instability over the Mediterranean sea.

CONCLUSIONS

- The **response** of cold spells to climate change is not purely thermodynamic nor linked to the global average temperature increase, but crucially depends on the **modifications** of atmospheric **circulation** at **mid-latitudes.**

Perspectives:

- Evaluate the effect of climate change on the characteristics of cold spells in the CMIP (Climate Model Inter-comparison Project) models and at different regions (France).

Reference: Fraedrich K., Kirk E., Luksch, U., Lunkeit, F. (2005)b. The portable university model of the atmosphere (PUMA): Storm track dynamics and low-frequency variability. Meteorologische Zeitschrift, 14(6), 735-745. Fraedrich K., Jansen H., Luksch U., Lunkeit F. (2005)a The planet simulator: Towards a user friendly model. Meteorol Z 14:299-304.

Ragone, F., Wouters, J., & Bouchet, F. (2018). Computation of extreme heat waves in climate models using a large deviation algorithm. Proceedings of the National Academy of Sciences, 115(1), 24-29.

Yiou, P., Salameh, T., Drobinski, P., Menut, L., Vautard, R., & Vrac, M. (2013). Ensemble reconstruction of the atmospheric column from surface pressure using analogues. Climate dynamics, 41(5-6), 1333-1344.

Sources: newspapers and periodicals [*La Repubblica; Le Parisien, …,*]; websites [meteo-net.it, www.3bmeteo.com, ...,]; temperatures and hydrological records [www.evalmet.it]; NCEP dataset