Present and future synoptic circulation patterns associated with cold and snowy spells over Italy

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LSCE - IPSL

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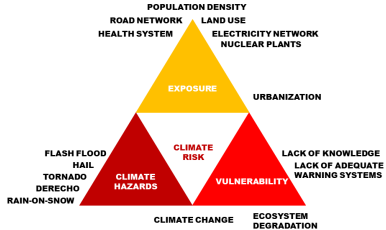
Motivation

1. Impacting extreme events are still possible under climate change, even with decreasing trends on the mean;

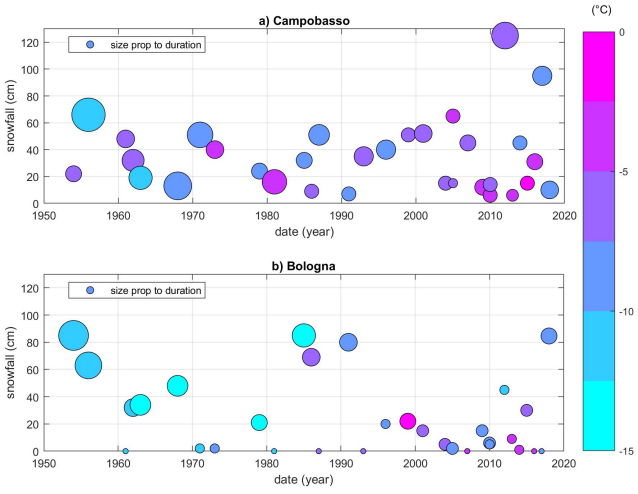
Figure: Snowfall over Fori Imperiali, Rome, 26 Feb. 2018

2. Climate risk does not depend only on hazards, but also on exposure and vulnerability.



Vulnerability to an extreme increases if the phenomenon becomes less frequent and less preventive measures are taken.

Identifying historical impacting cold spells



We identify 32 coldspells in 1954-2018.

- documentary sources
- difficult to find clear trends
  - short time series
  - compound nature of events
  - ...

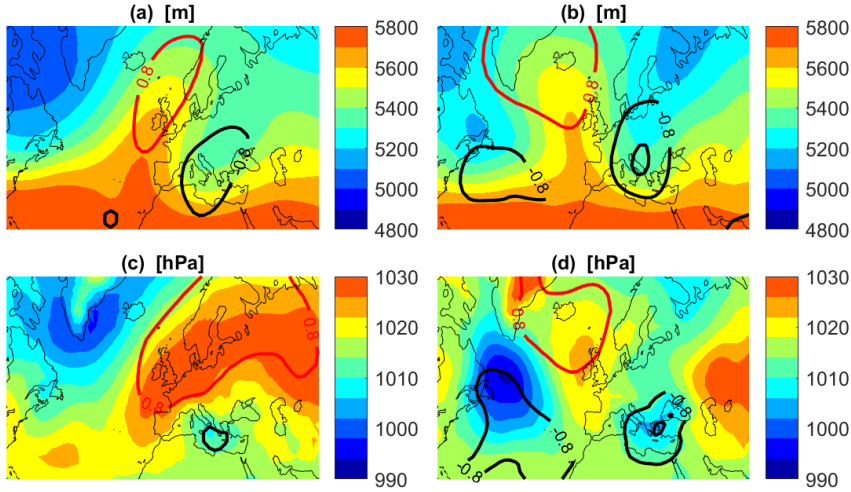
Characterizing cold spells: data & methods

Data. National Centers for Environmental Prediction (NCEPv2) Reanalysis dataset. Domain [22.5–70N, 10W–70E]. We only select DJFM, i.e. the months containing the 32 coldspells.

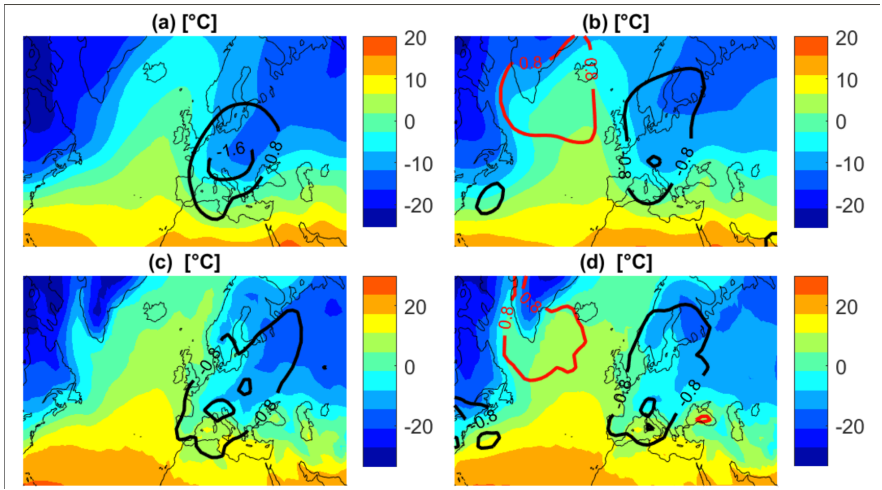
- Z500 and SLP as dynamical fingerprints and to compute the analogues [Jézéquel et al., 2018];
- T850 to track cold air advection without surface disturbances [Grazzini, 2013], T2M to characterize near-surface conditions;
- daily precipitation rate (PRP).

Method. Unsupervised cluster analysis based on the Z500 standardized anomaly fields using a k-means algorithm [Michelangeli et al., 1995].

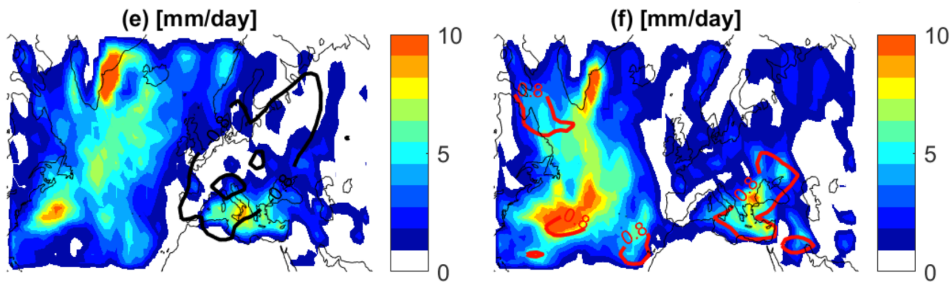
Characterizing cold spells: dynamics



Characterizing cold spells: thermodynamics



Characterizing cold spells: thermodynamics



Assessing future cold spells - PlaSim

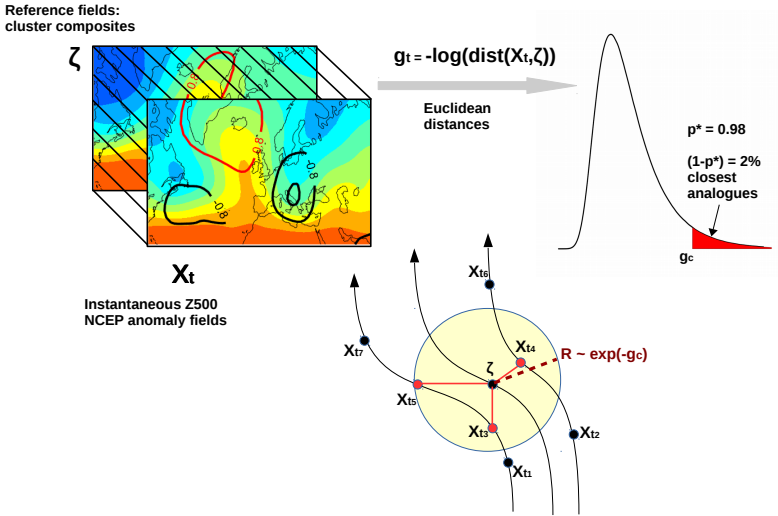
PlaSim [Fraedrich et al., 2005a, Fraedrich et al., 2005b] is an intermediate complexity climate model developed at the University of Hamburg and released open source

Stationary simulations of 3 RCPs, 450 years long, at daily frequency, horizontal resolution $\sim$300 km (T42, $\sim 2.8\,^{\circ} \times 2.8\,^{\circ}$), 10 vertical equidistant levels.

- CTRL: CO_2 at 360 ppmv, corresponding to the CO_2 concentration in the year 2000.
- RCP26: CO_2 at 490 ppmv ($+2.6 W/m^2$)
- RCP45: CO_2 at 660 ppmv ($+4.5 W/m^2$)
- RCP85: CO_2 at 1470 ppmv ($+8.5 W/m^2$)

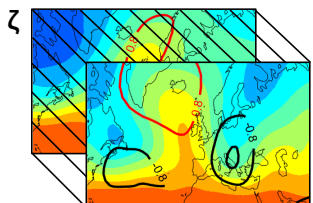
PRO: long stationary simulations to compute **analogues**.
CON: strong simplification of reality; possible dynamic biases.

Analogues detection - step 1



Analogues detection - step 2

Reference fields:
cluster composites

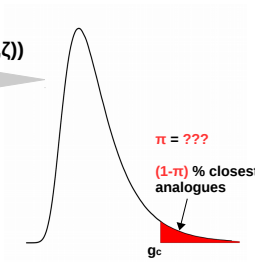


Instantaneous Z500
PlaSim anomaly fields

- **CTRL run**
- **RCP26, RCP45, RCP85 end of 21st century, stationary**

$g_t = -\log(\mathrm{dist}(X_t, \zeta))$

Euclidean distances



$\Delta p = \pi - p^*$

-Δp / (1-p*) = % change in frequency of events that are cold spell dynamic analogues

Analogues Detection: results from PlaSim

For each cluster:

- estimate probabilities $\pi_{i,r} = P(g_{t,r}^{Z500} \leq g_c^{Z500})$ and compare them to the reference value p^*;
- consider cold spell analogues all events satisfying $g_{t,r}^{Z500} \geq g_c^{Z500}$;

	Cluster 1		Cluster 2	
run	$\pi_{1,r}$	$-\Delta p_{1,r}/(1-p^*)$	$\pi_{2,r}$	$-\Delta p_{2,r}/(1-p^*)$
CTRL	0.9683	+58.6%	0.9556	+122.1%
RCP2.6	0.9735 (0.9617)	+32.6% (+91.3%)	0.9711 (0.9467)	+44.3% (+166.4%)
RCP4.5	0.9726 (0.9609)	+37.0% (+95.7%)	0.9642 (0.9397)	+79.2% (+201.3%)
RCP8.5	0.9575 (0.9458)	+112.5% (+171.2%)	0.9334 (0.9090)	+232.9% (+355.0%)

Concluding Remarks

- difficult to quantify trends in impacting cold spells despite clear trends in temperature and average snowfall;
- PlaSim simulations suggest that climate change may increse the frequency of dynamic configurations leading to cold spells in current climate;
- Increased dynamical frequency may partially compensate higher temperatures, leading to occasionally disruptive Mediterranean cold spells even in warmer climates.

Thank you.

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Thank you.

Fraedrich, K., Jansen, H., Kirk, E., Luksch, U., and Lunkeit, F. (2005a).
The planet simulator: Towards a user friendly model.
Meteorologische Zeitschrift, 14(3):299–304.

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The portable university model of the atmosphere (puma): Storm track dynamics and low-frequency variability.
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ECMWF Newsl, 136:31–35.

Jézéquel, A., Yiou, P., and Radanovics, S. (2018).
Role of circulation in {European} heatwaves using flow analogues.
Climate Dynamics.

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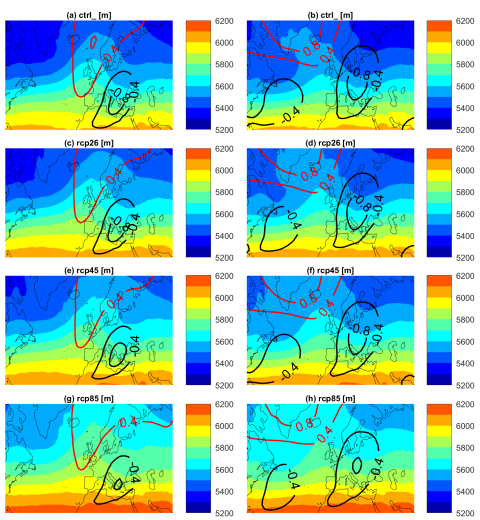
Weather regimes: Recurrence and quasi stationarity.
Journal of the atmospheric sciences, 52(8):1237–1256.

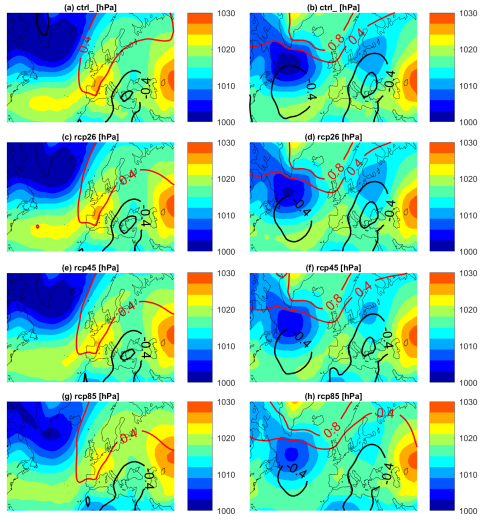
Analogues detection - PlaSim

The dynamical core for the atmosphere is adopted from Portable University Model of the Atmosphere (PUMA). The model includes

- Full set of parameterizations of physical processes for radiative transfer, clouds formation, and turbulent transport across the boundary layer.
- The horizontal heat transport in the ocean can be prescribed or parameterized by horizontal diffusion.
- The atmospheric dynamical processes are modelled using the primitive equations formulated for vorticity, divergence, temperature, and the logarithm of surface pressure.
- governing equations solved using a spectral transform method.
- The model is forced by diurnal and annual cycles.

Analogues Characterization in PlaSim





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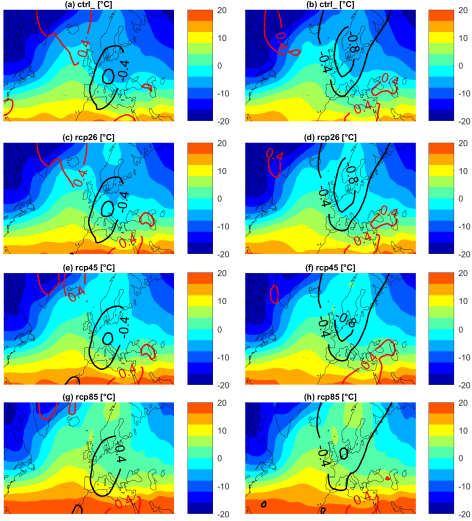

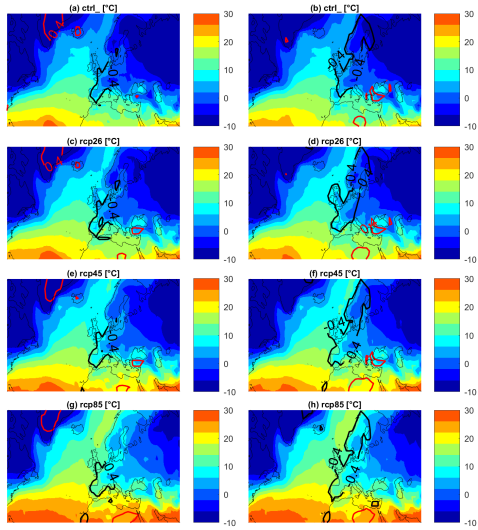

Analogues Characterization in PlaSim