Characterization of atmospheric heat waves in New Caledonia

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Introduction

New Caledonia, located in a subtropical region, has a varied climate, combining temperate and tropical characteristics and is influenced by its steep topographic features. Using the EHF (Excess Heat Factor) index, this study aims to answer the following questions: what are the characteristics of heat waves (duration, intensity, number)? Were the most significant episodes localized or did they affect the whole country and what atmospheric mechanisms are involved?

Excess Heat Factor $EHF_i = max\left(1, EHI_{acc_i}\right) \times EHI_{sig_i}$ with $EHIsig_i = \frac{TM_i + TM_{i-1} + TM_{i-2}}{3} - T90\%$

$$EHIacc_i = \frac{TM_i + TM_{i-1} + TM_{i-2}}{3} - \frac{TM_{i-3} + \ldots + TM_{i-32}}{30}$$

T90% the 90th percentile, $TMi = \frac{(Tmax + Tmin)}{2} i$ and i the timestep under consideration.

EHF characterizes heat stress (EHIacc) and excess heat (EHIsig). A period is classified as a heat wave if the EHF is positive for at least three consecutive days.

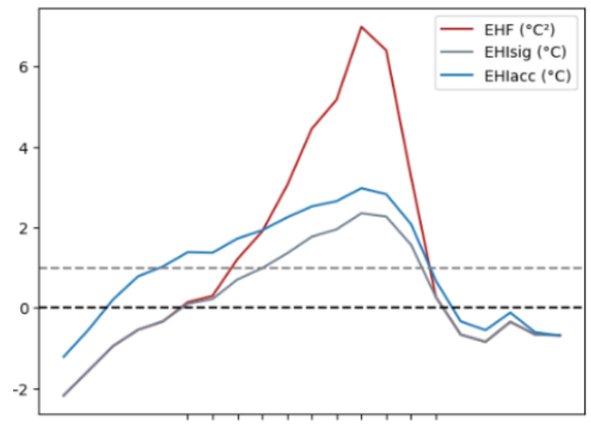

Fig1: EHF, EHIsig and EHIacc indices during a heat wave in Nouméa, , the capital of New Caledonia. The dotted black line characterizes the limit beyond which EHF defines a heat wave. The grey dotted line corresponds to the limit beyond which EHIacc reaches 1 and the factor then influences the calculation of EHF.

Data

EHF is calculated with maximum (Tx) and minimum (Tn) temperatures on each land grid point of ERA5 Land reanalysis (0.1° x 0.1°) and on 8 Météo-France stations with observational data (length > 30 years).

Climatologies

Methods

The climatologies of the numbers, average durations and average intensities (EHF) of heat waves are calculated over the period 01/01/1985-31/12/2021, using reanalysis data presented above and compared with in-situ data.

Results

With ERA5 Land data, annual climatologies reveal an average of 4 to 5 heatwaves per year. These last an average of 4 to 5 days, and are most intense in the mountainous areas of Grand Terre located in its center. These results are consistent with in-situ data for numbers and durations of heat waves.

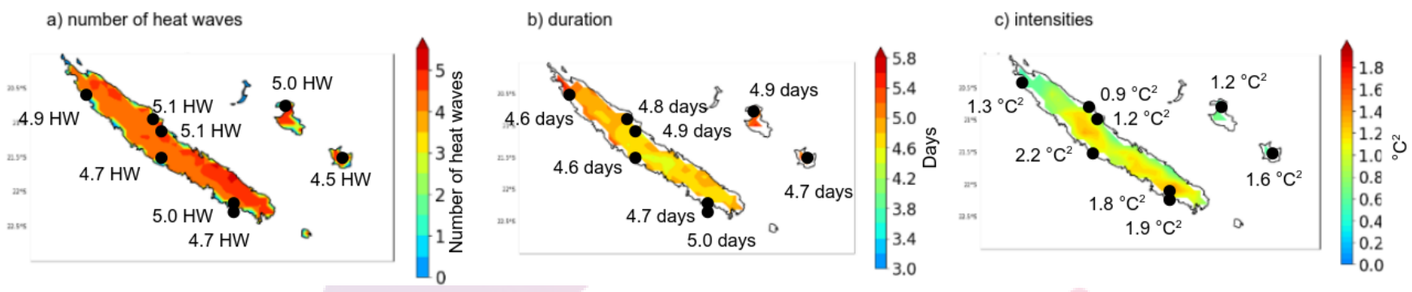

Fig2: Annual climatologies of (a) number of heat waves, (b) durations, (c) intensities (EHF) over the period 1985-2021, with ERA5 Land (colors) and in-situ data (black). HW means Heat Waves.

Most intense heat waves : archetypal analysis

Methods

Archetypal analysis (AA) is used to detect patterns (spatial and temporal) in the extremes of a data set. Let X be the matrix containing the EHF data (0 if there is no heat waves), over the warm season (November to March), from 1981 to 2021. AA finds the eigenvalues (time series) and eigenvectors (spatial maps referred to archetypes) that solve the minimisation problem: $\arg\min_{C,S} \|X - XCS\|^2$

Results

Fig3 represents the 6 archetypes constructed. Archetype 0 corresponds to a situation where there is no heat wave on the territory. Archetypes 4 and 5 represent the highest intensities, and reveal situations occurring particularly on the relief and east coast of New Caledonia main island (grande Terre). The other three archetypes represent more moderate situations, highlighting the West coast (archetype 1), the North (archetype 2) and the South of grande Terre (archetype 3).

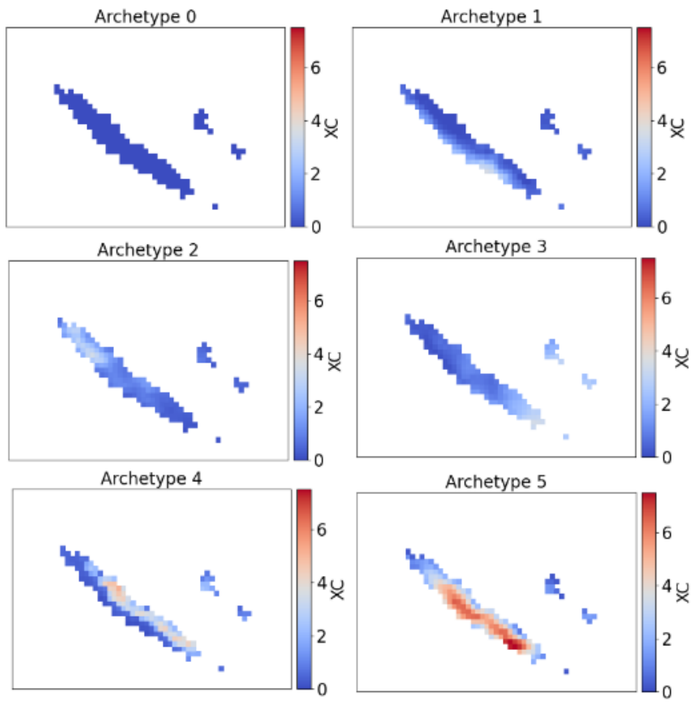

Fig3: 6 archetypes (Z=XC) constructed by the AA.

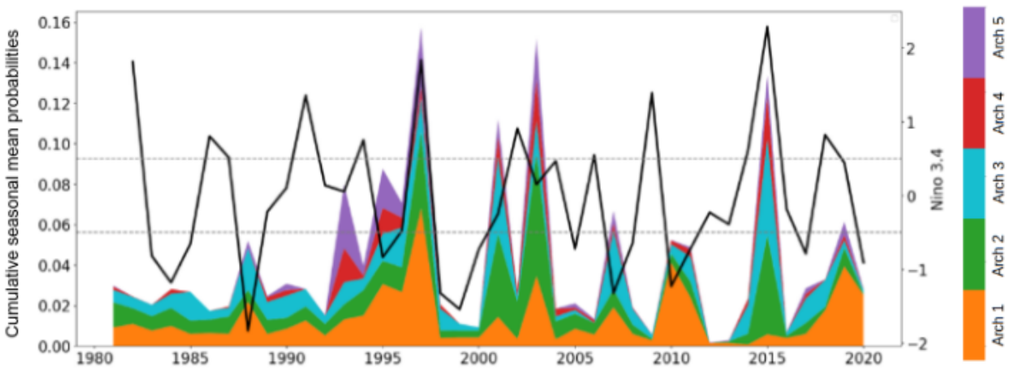

Fig4: Cumulative average probability (over the season) of expression of archetypes and average Niño index 3.4

Fig4 shows the cumulative seasonal mean probabilities of each archetype over the period 1981-2021, superimposed on the summer means of the Niño 3.4 index. we observe a strong coincidence between the archetype occurence probabilities and the two major El Ninos: 1997-1998 and 2015-2016.

Conclusion

- 4 to 5 heat waves per year, lasting an average of 4-5 days, more intense in moutains.
- Climatologies based on ERA5 Land of heatwave numbers and durations are consistent with observations, but underestimate intensities (~0.6°C²).
- ENSO influences the occurrence of heat waves : Major El Ninos are coincident with the major heat waves in New Caledonia.

References:

- *Christopher C. Chapman, J. R. M. F. B. M. S., Didier P. Monselesan, 2022: A large-scale view of marine heatwaves revealed by archetype analysis. Nat Commun 13.*
- *Perkins, S. E. and L. V. Alexander, 2013: On the measurement of heat waves. Journal of Climate, 26 (13).*