Emergence of compound events: quantifying the importance of marginal and dependence properties changes

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EGU 2022 – Compound weather and climate events (NH10.2)

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Credit: Copernicus C3S

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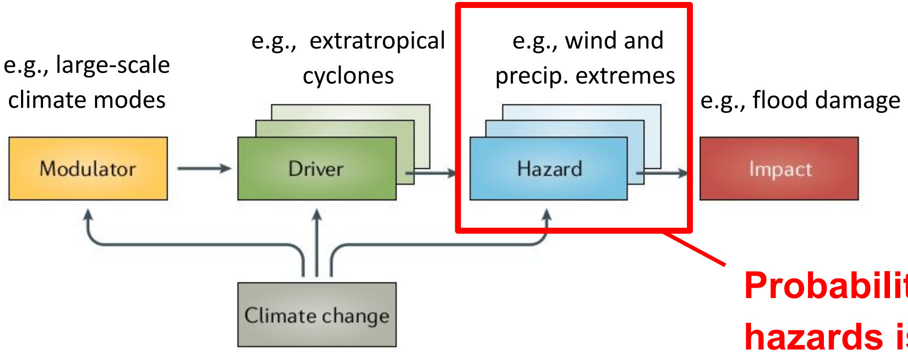
Sharing is encouraged

Introduction & objectives

- Many climate-related disasters are often caused by **"compound events" (CEs)**.



Probability of multivariate hazards is crucial to analyse

- **When** do probabilities *emerge* from the natural variability?

  ⇒ **Time of Emergence** *(e.g., Giorgi and Bi, 2009)*

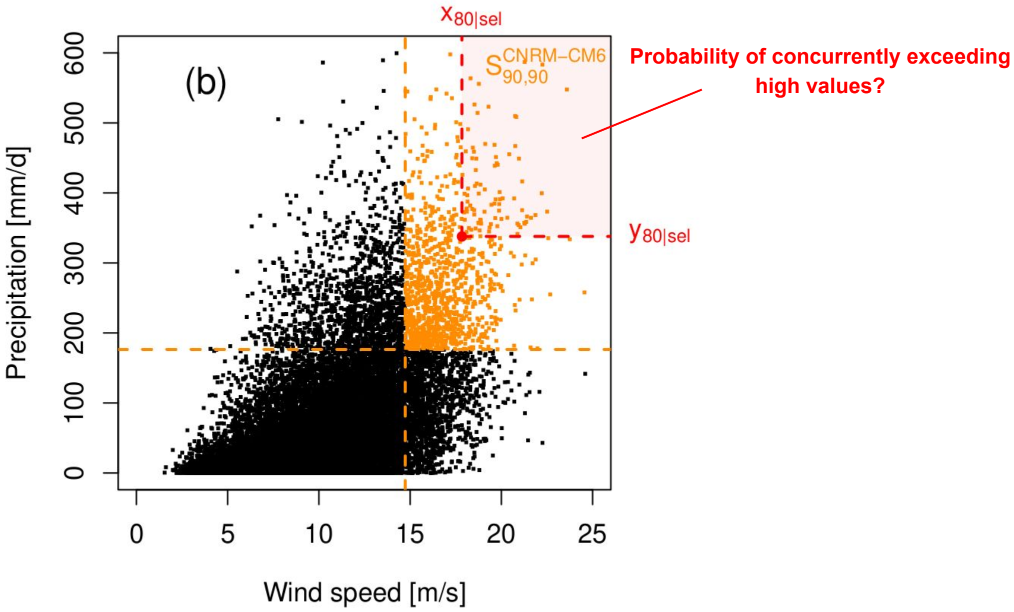
- Statistical properties of hazards *(e.g., mean, variance, correlation…)* characterize CEs probabilities.

  ⇒ **Contribution of marginal and dependence properties to probability changes.**

Zscheischler et al. (2020), Nature Reviews Earth & Rev.

Analysis of a bivariate CE

Compound wind and precipitation extremes over Brittany (France) in winter



- **Models**: 13-member multi-model ensemble (CMIP6).
- **Period**: **1871-2100** (hist. + ssp585)
- Models considered *individually.* (Multi-model synthesis not shown)

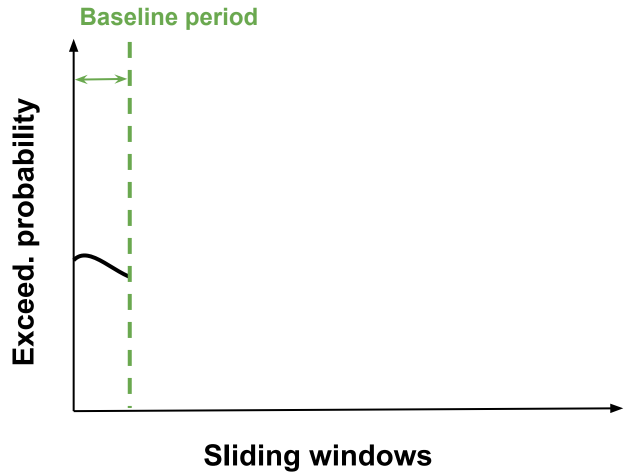
Figure: Compound wind and precipitation extremes for CNRM-CM6.

A new methodology for ToE and contributions

Copula modelling (Sklar, 1959), 2-d form.: $\mathbb{P}(X \leq x \cap Y \leq y) = C(F_X(x), F_Y(y))$ for x, y fixed.

Time of Emergence (ToE) for CE probas

- **Sliding window:** 30 years
- **Baseline period:** 1871-1900



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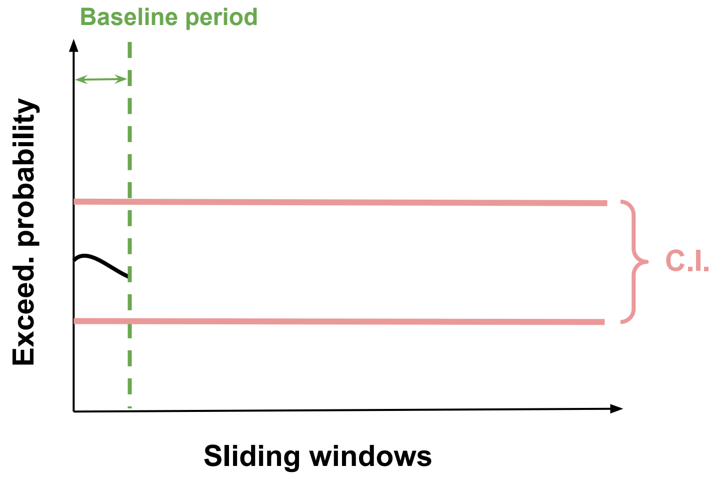

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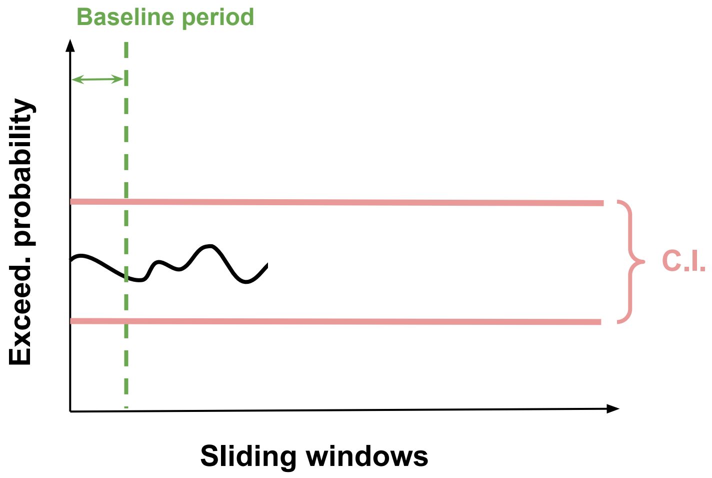

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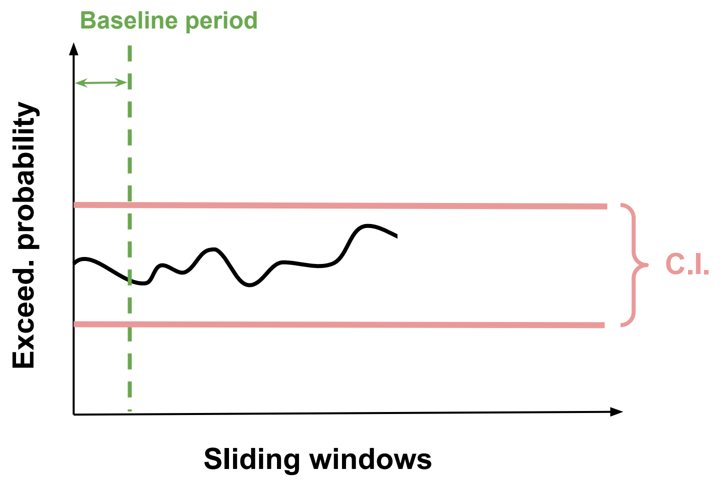

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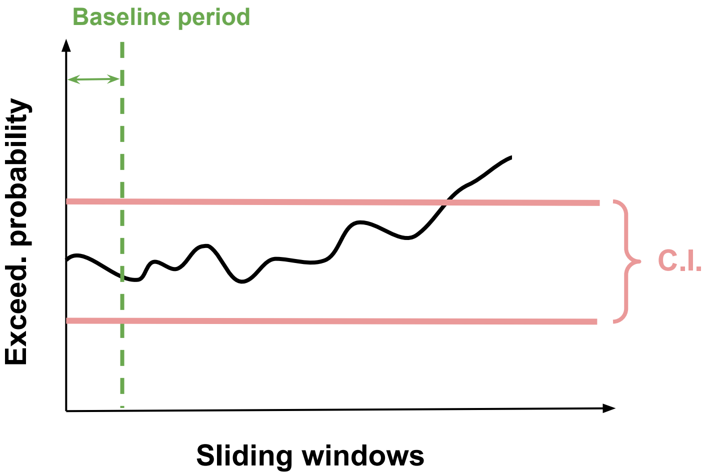

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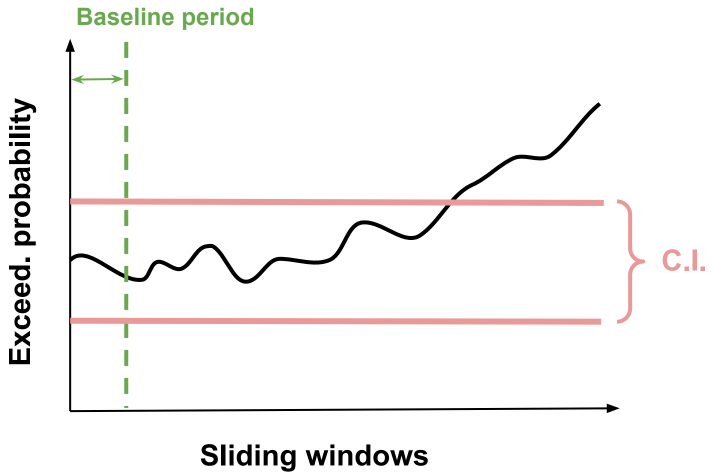

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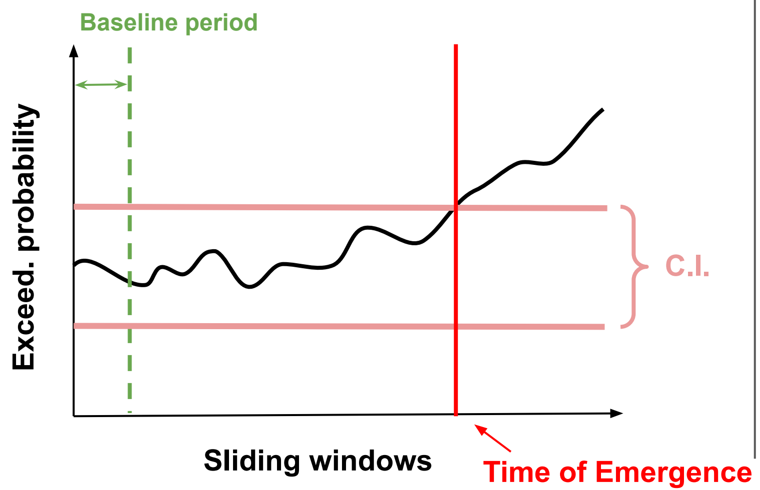

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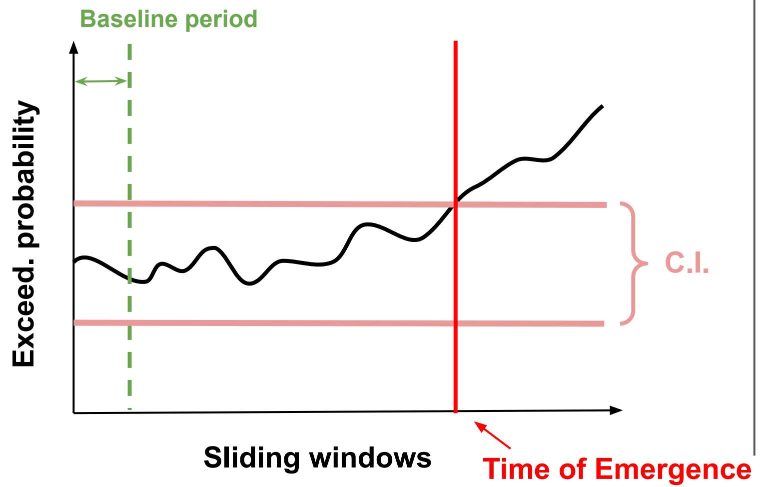
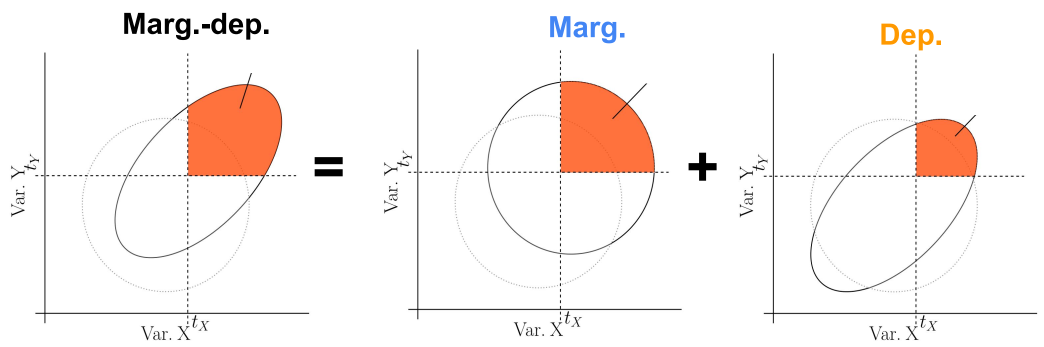


How much do marginal and dependence contribute?



⇒ **Contribution** (in %) of **marginal** and **dependence** to global probability changes:

$$\Delta P = \Delta M + \Delta D + \Delta I.$$

Marg. effect (ΔM), (Residual) (ΔI), Proba change (ΔP), Dep. effect (ΔD)

Results for wind and precipitation extremes

Time of Emergence

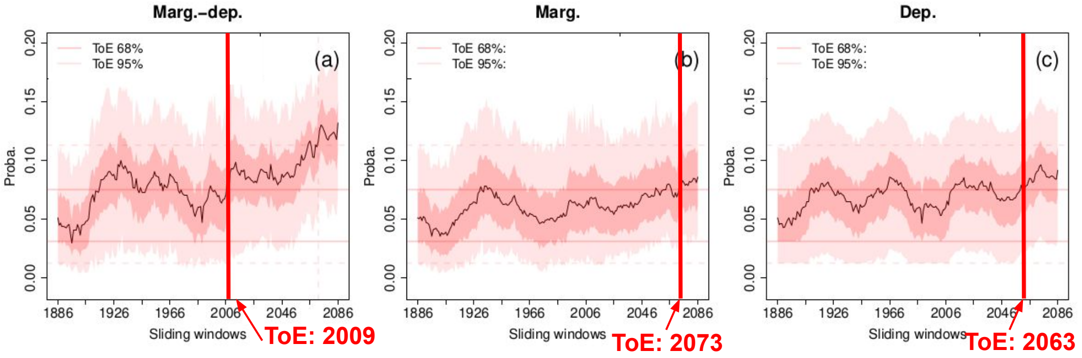


Figure: Proba. of compound wind and precipitation extremes ($\geq q_{80}$, $\geq q_{80}$) for CNRM-CM6.

For the 13 models of the ensemble:

- “Marg-dep”: **6/13 ToE** (min: 2009, max: 2083).
- “Marg”: **7/13 ToE** (min: 2041, max: 2086).
- “Dep”: **2/13 ToE** (min: 2063, max: 2081).

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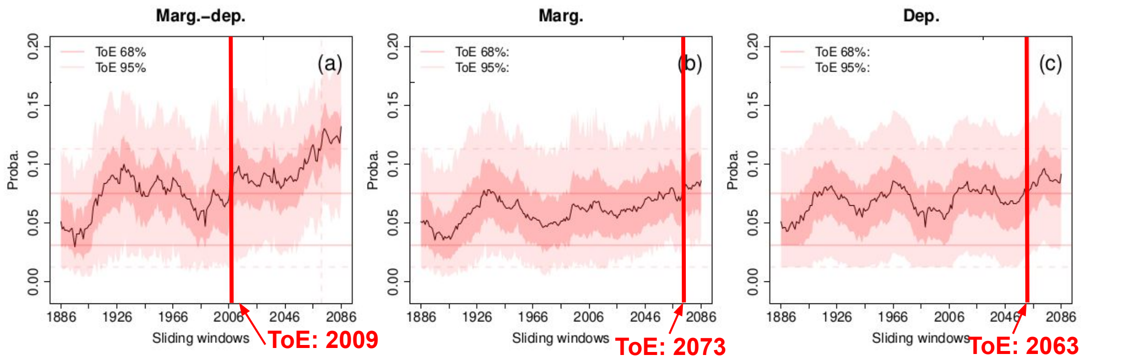

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Contributions

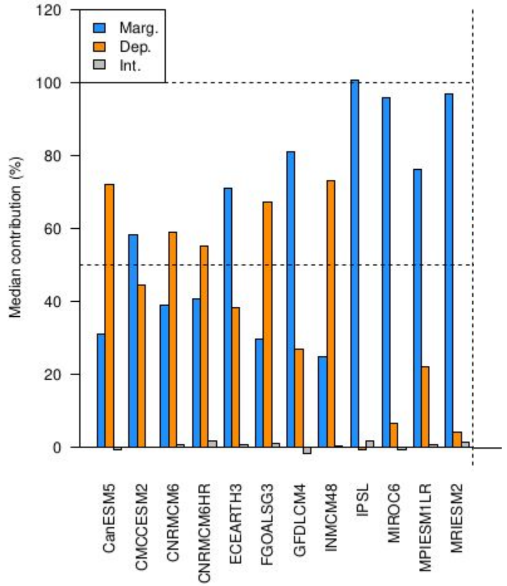


Figure: Median contributions (%) to probas changes.

Mixed importance of **marginal** and **dependence** properties.

⇒ Inter-model differences

Conclusions & Perspectives

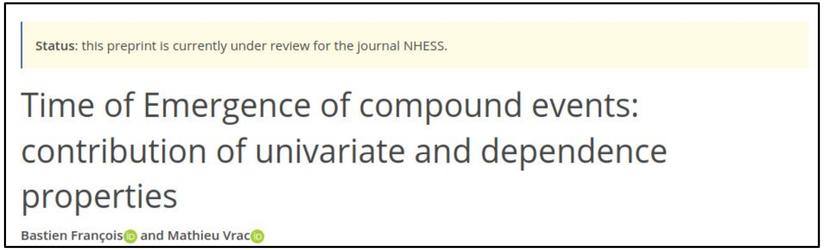
- Design of a new methodology to analyse multivariate hazard probabilities:
  - 1) Time of Emergence
  - 2) Contribution of marginal and dependence properties

- Contribution of marginal and dependence properties can be **different**
  - from **one model to another,**
  - and from a **climate hazard to another**.

Marginal and dependence must be taken into account!

- **Perspectives:**
  - Large ensembles ⇒ more robust results/uncertainties.
  - Multivariate event attribution: characterising the statistical features of climate change.

- Preprint under consideration
  ⇒ comments are welcome!


Status: this preprint is currently under review for the journal NHESS.

Time of Emergence of compound events: contribution of univariate and dependence properties

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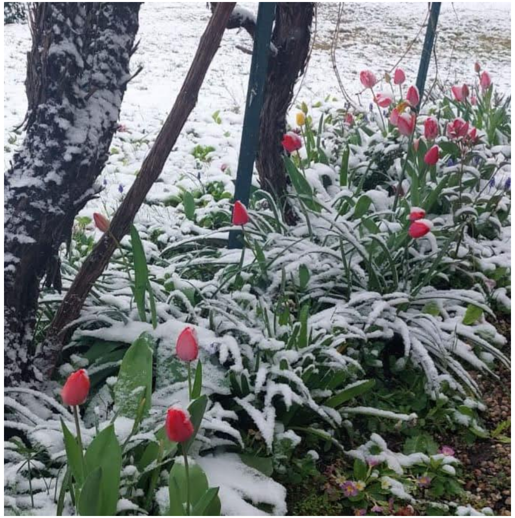
Thanks for your attention!



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Additional slide

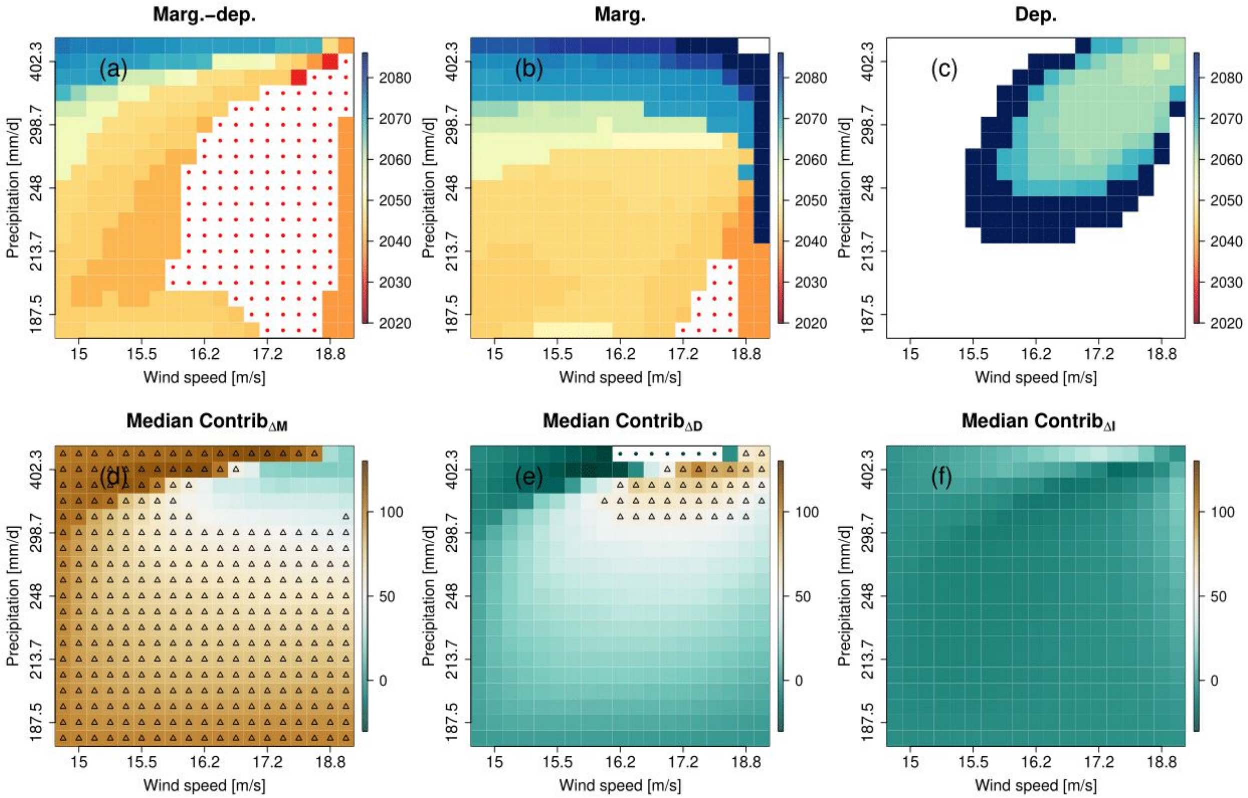

Figure: CNRM-CM6 (a-c) ToE for compound wind and precipitation extremes. (d-f) Matrices of median contributions. Results are presented for varying exceedance thresholds.

Additional slide

Frost events occurring over Central France during the growing season

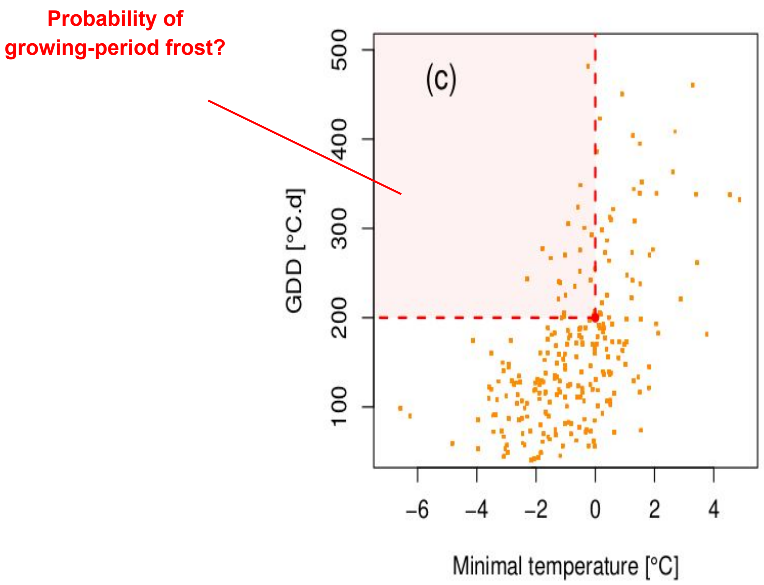

Figure: Growing-period frost data for CNRM-CM6.

Results for growing-period frost events

Time of Emergence

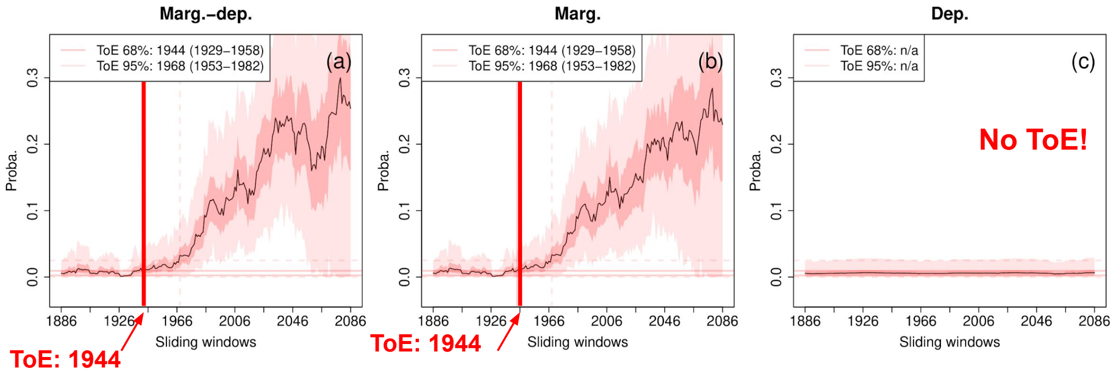

Figure: Proba. of growing-period frost events for CNRM-CM6.

Contributions

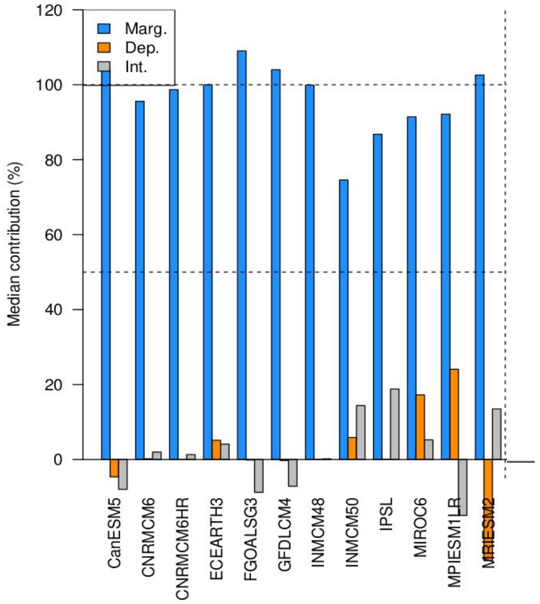

Figure: Median contributions (%) to probas changes.

For the 13 models of the ensemble:

- “Marg-dep”: **11/13 ToE** (min: 1900, max: 2075)
- “Marg”: **11/13 ToE** (min: 1900, max: 2075)
- “Dep”: **0/13 ToE**

⇒ Majority of models agrees on the emergence of probabilities.

⇒ Dominant contribution of marginal changes.