Projected Changes in Internal Variability of the Climate System: Annual Mean 2m Temperature and Precipitation

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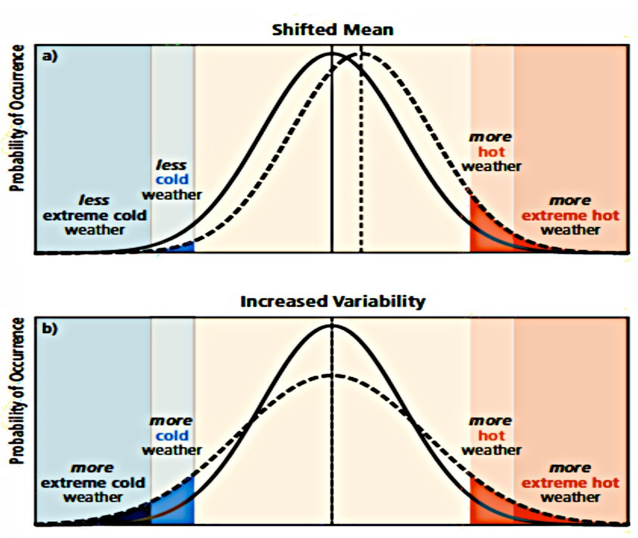


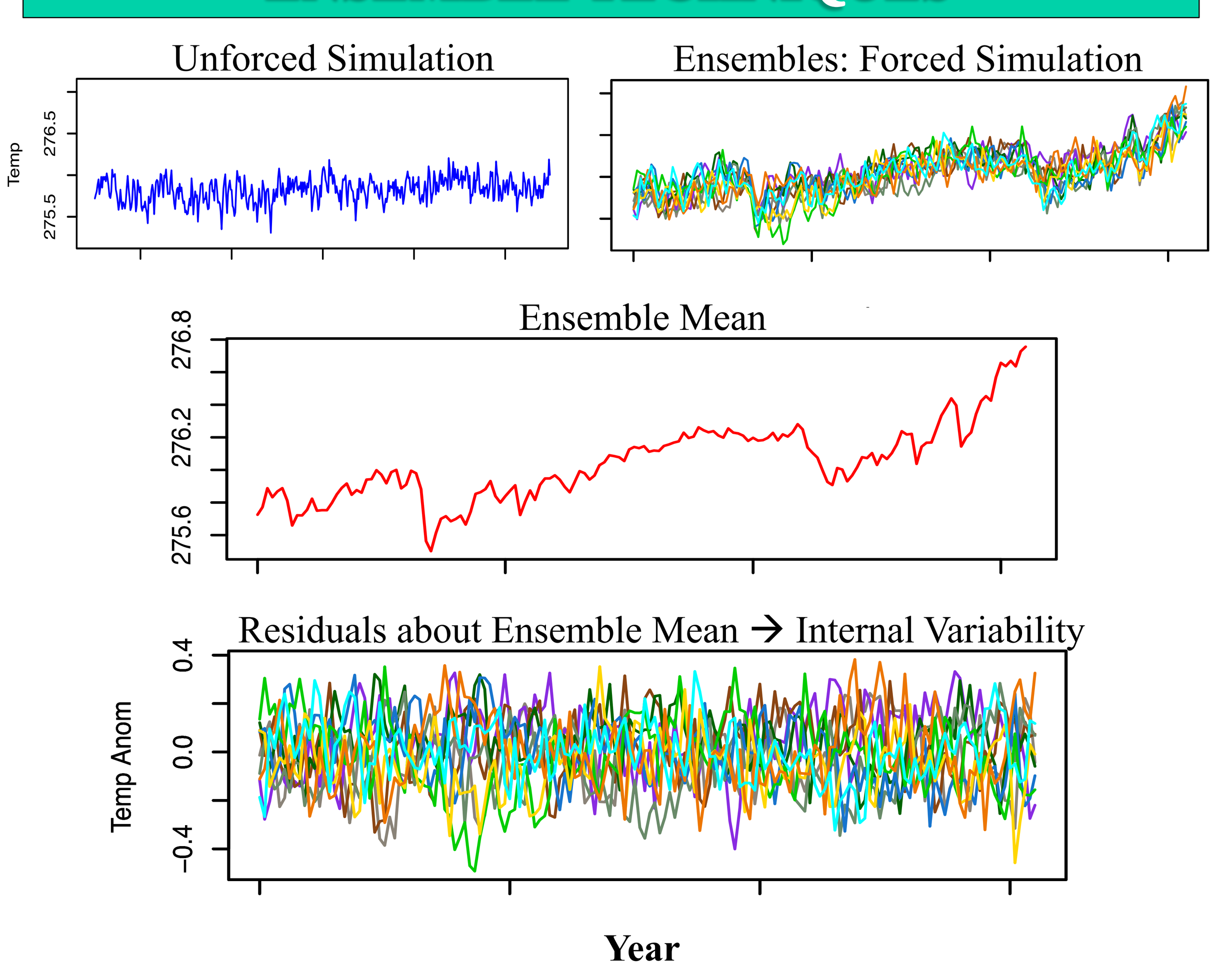
EXTREME WEATHER:

- **Inherent to climate system**
- **Impacts society**
- **IPCC SREX → frequency and intensity changing**

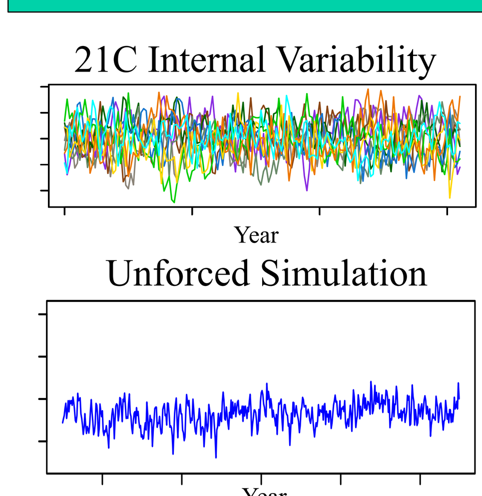
Warmer climate → more hot and extreme hot weather – ***How can we measure this?***

- A *shift* in the mean distribution of temperature – *strongly supported*
- A change in the *shape* of the distribution – *jury is out*
- What do the models say about 21C **changes in variability**?

ENSEMBLE TECHNIQUES



MEASURING CHANGES IN VARIANCE



$$\sigma^2_{s,21C} = \frac{1}{Y_{21C}(E-1)} \sum_{y=1}^{Y_{21C}} \sum_{e=1}^{E} (U^{21C}_{s,y,e})^2$$

$$\sigma^2_{s,ctr} = \frac{1}{Y_{ctr}-1} \sum_{y=1}^{Y_{ctr}} (U^{ctr}_{s,y})^2$$

$$F_s = \frac{\sigma^2_{s,21C}}{\sigma^2_{s,ctr}}$$

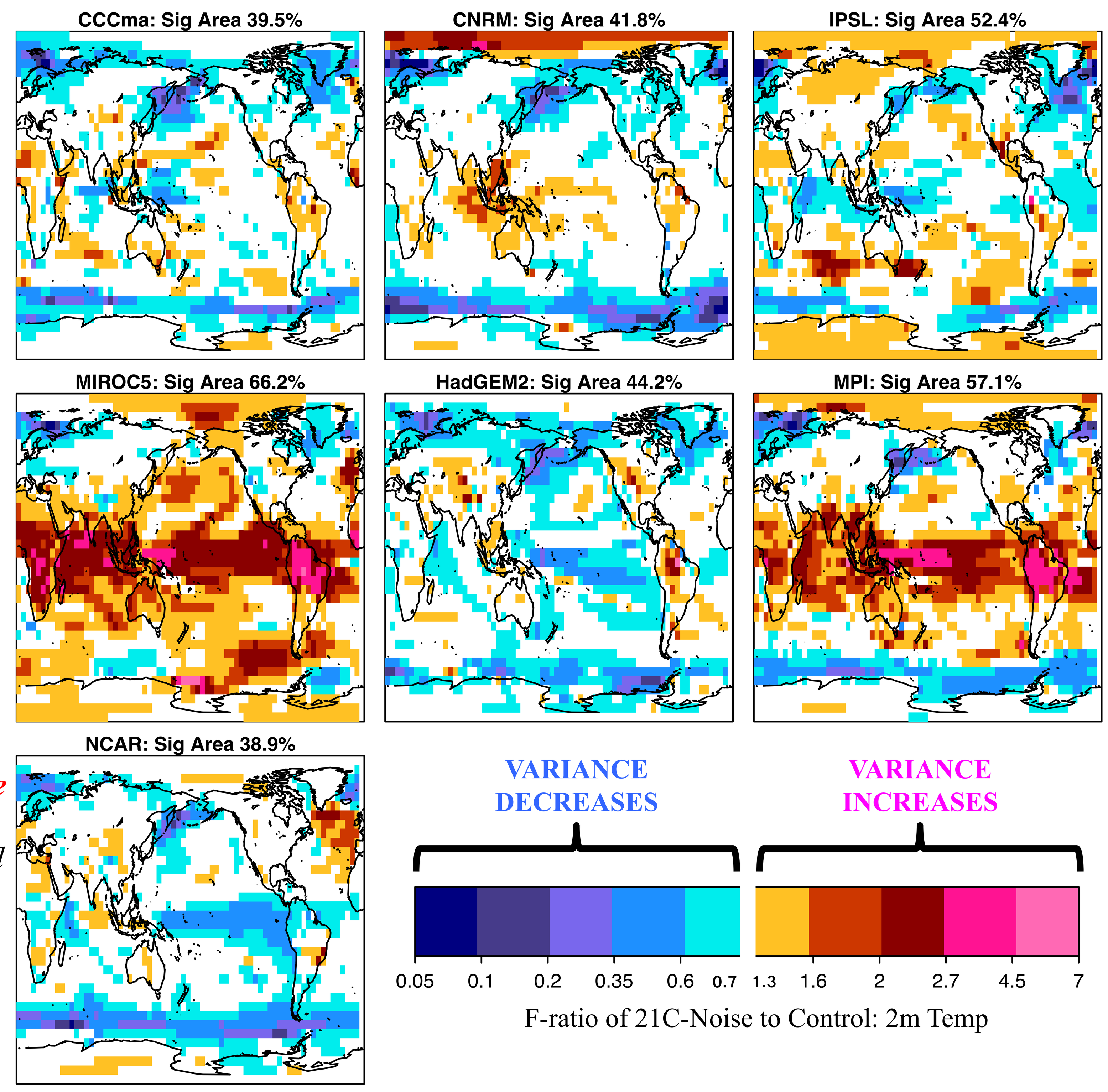
- **21C noise-to-control ratio**
- ***F* significantly different from 1 suggests internal variability changes in response to anthropogenic forcing**

DATA

- **2m temperature and precipitation (CMIP5)**
- Annual and seasonal means (JFM, AMJ, JAS, OND)
  - **Forced simulation → RCP8.5**
    - 3-member ensemble
    - 90-year period from 2006 to 2095
    - radiative forcing peaks at 8.5 Wm^{-2} (Collins et al. 2013b)
  - **Unforced simulation → Preindustrial control simulation**
    - 500 years
    - Forcings do not change from year to year

- **MODELS:**
  - **CCCma, CNRM, HadGEM2, IPSL, MPI, MIROC5, and NCAR**

21st Century VARIABILITY CHANGES: Annual Mean 2m Temperature



Percent area of significant change at the 90% CL is given in each title: across-model ranges → 38% - 66%

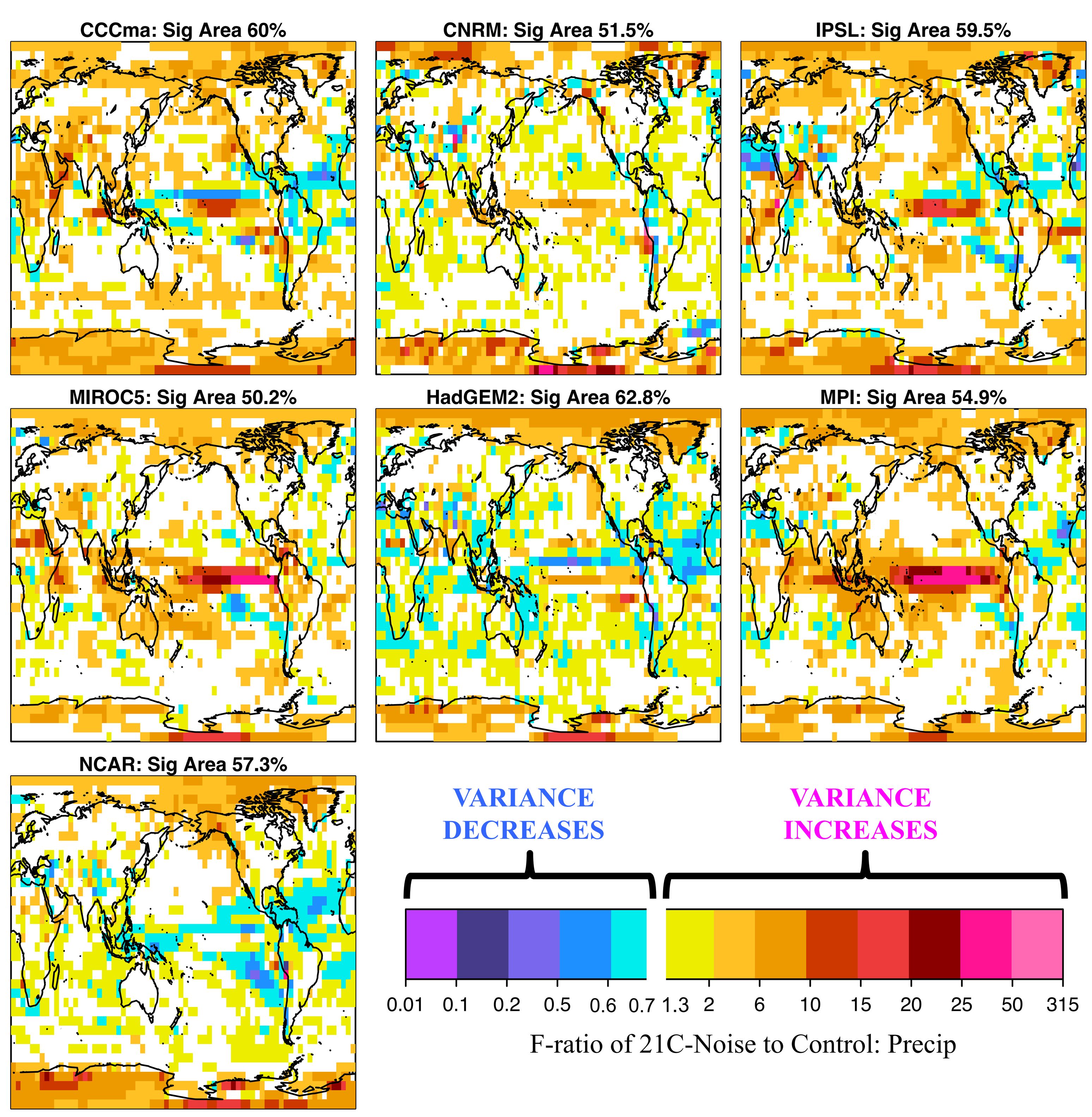
NOTICE: *consistent decreases in regions of sea ice* in the Northern Hemisphere → Greenland Sea, Bering Sea, and Sea of Okhotsk

NOTICE: changes in the ENSO region are *model dependent*

NOTICE: *consistent decreases in the regions of sea ice* in the Southern Hemisphere

NOTICE: some models indicate variance doubles → MIROC5 and MPI

21st Century VARIABILITY CHANGES: Annual Mean Precipitation



Percent area of significant change at the 90% CL is given in each title: across-model ranges → 59% - 63%

NOTICE: Robust increases in variance at polar latitudes

NOTICE: Changes in tropics are model dependent, mostly increases in variance along equator

NOTICE: Half the globe, or more, experiences changes for every model

NOTICE: Robust decreases in variance for the equatorial Atlantic area

ADDITIONAL WORK & REFERENCES

Seasonal results were remarkably similar to these annual mean results. Most differences occurred in the middle latitudes. For some models, it was clear that the annual mean changes were dominated by changes in one particular season. We extended this study using multivariate techniques to determine if individual components of the climate system, such as ENSO, were projected to change variance. In particular, we projected to a subspace represented by 80 EOFs. We estimated the covariance matrices for the 21C and the control runs. The covariance matrix accounts for correlations in space and time between the gridpoints. We then used discriminant analysis to determine if the covariance matrices were the same, or put another way, to determine if a single or few components were changing variance. Discriminant analysis is a useful tool in the sense that if a significant difference is detected, then, the spatial and temporal characteristics of that difference can be visualized. Surprisingly, despite the widespread significant local changes in variance of annual mean 2m temperature (shown above), no single component of variability is significantly changing variance in the 21st century, in a robust sense across models. However, we did find significant components changing variance with respect to the precipitation data. In particular, those changes were primarily across the Pacific Ocean and Maritime Continents. See LaJoie and DelSole, 2016 (**Changes in Internal Variability due to Anthropogenic Forcing: A New Field Significance Test. *J Clim*, 29, 5547-5560**) for details of this work and additional work on changes in internal variability. The techniques presented here can be adapted for any timescale or variable.