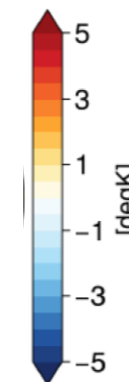
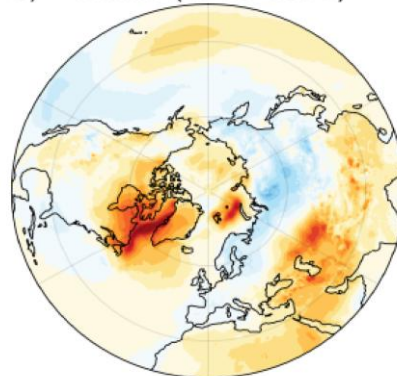


Attributing surface climate impacts to decadal variability of the Northern Hemisphere stratospheric polar vortex

Chaim I. Garfinkel, Amy H. Butler, Alexey Yu. Karpechko, Judah Cohen, Pu Lin, Alexis Mariaccia, Isla R. Simpson, Clara Orbe, Qi Tang, Jacob Shpund

In review in npj climate and atmospheric science

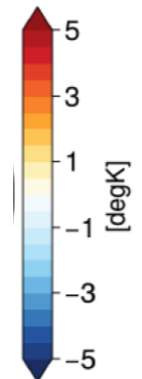
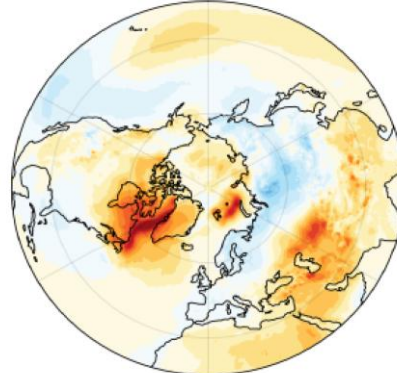
T2m (1999-2010)
b) minus (1990-1998)



Motivation

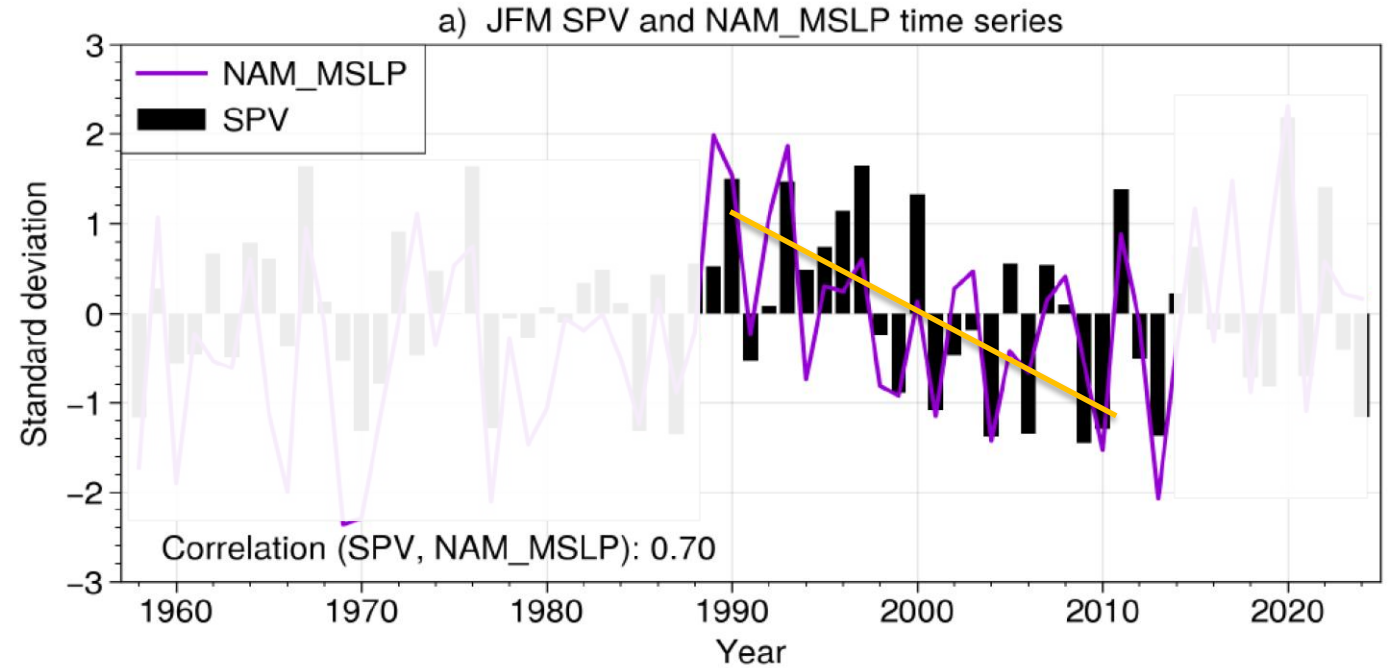
- Arctic amplification \neq uniform warming
- Eurasian winter cooling (1990–2010)
- Attribution challenge

T2m (1999-2010)
b) minus (1990-1998)

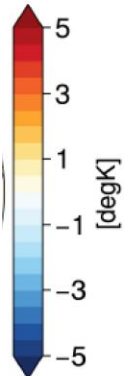
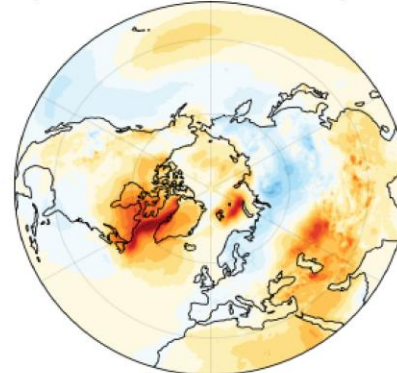


Hypothesis

- Stratospheric vortex → NAO/NAM
- Controls surface variability



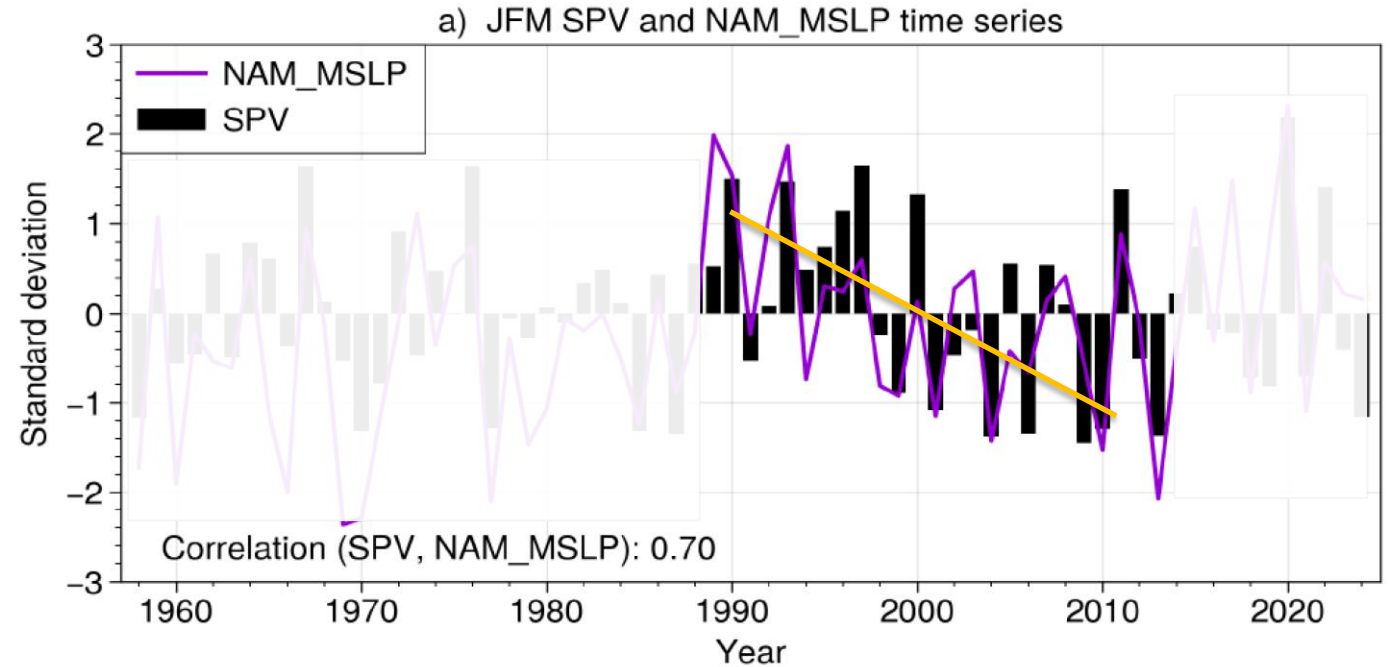
b) T2m (1999-2010) minus (1990-1998)



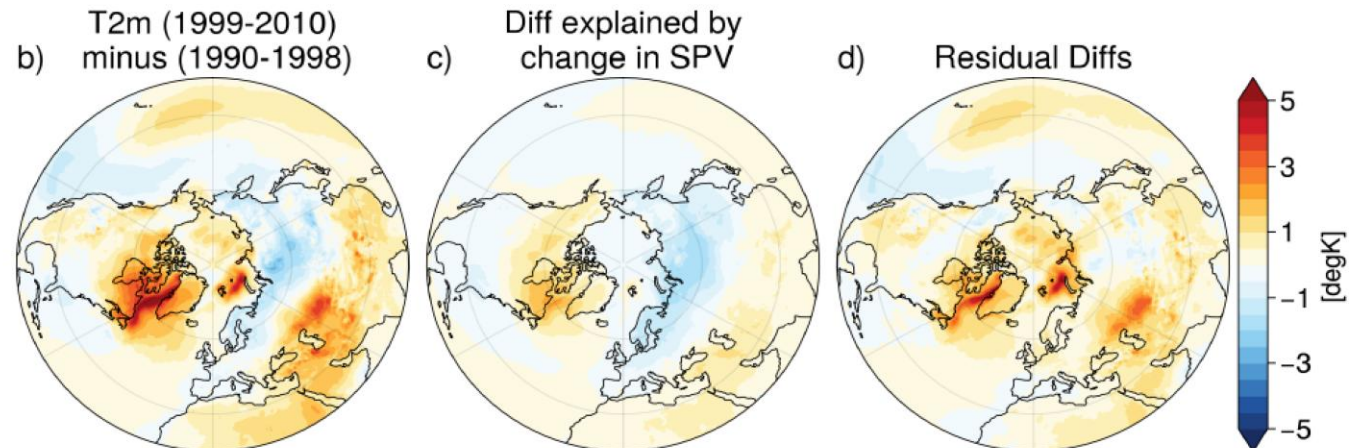
e.g., Garfinkel et al 2017, GRL

Hypothesis

- Stratospheric vortex → NAO/NAM
- Controls surface variability
- Need causal attribution

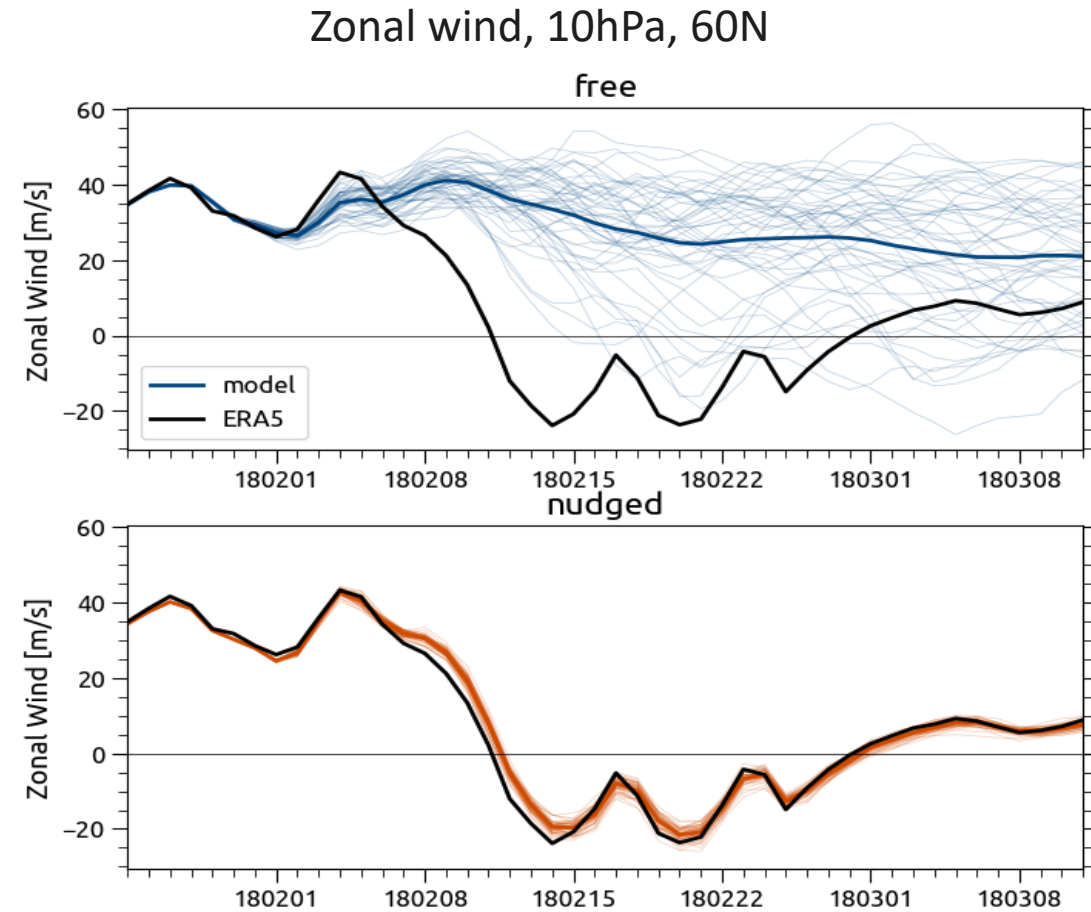


e.g., Garfinkel et al 2017, GRL



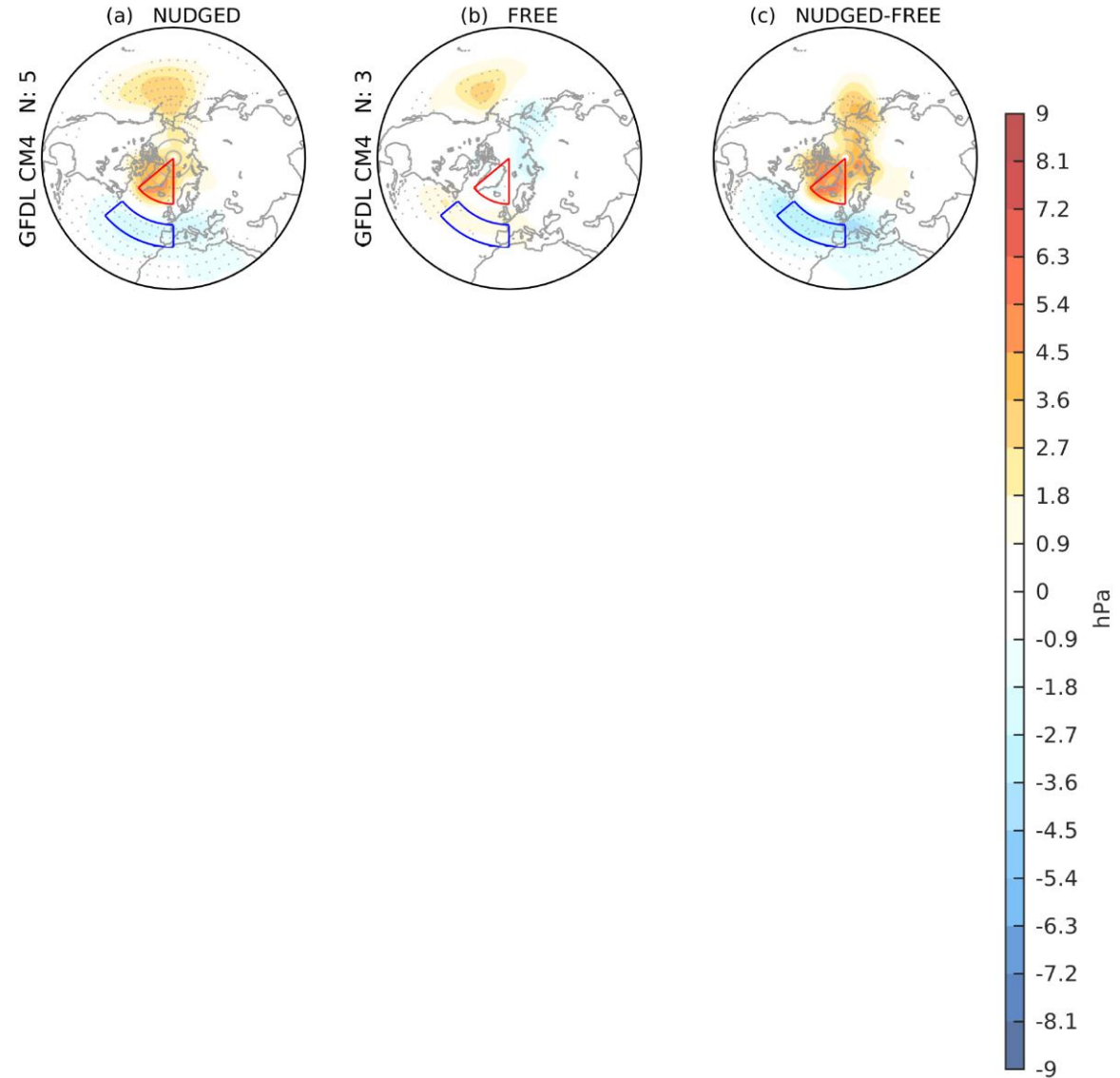
Experimental Design

- **Free:** Free running, no vortex trend
- **Nudged:** stratosphere nudged to **observed evolution**
- **1980-2014**
- Stratospheric impact=NUDGED-FREE
Removes anthropogenic forcing signal
- 4 models for robustness,
>3 members per model per experiment



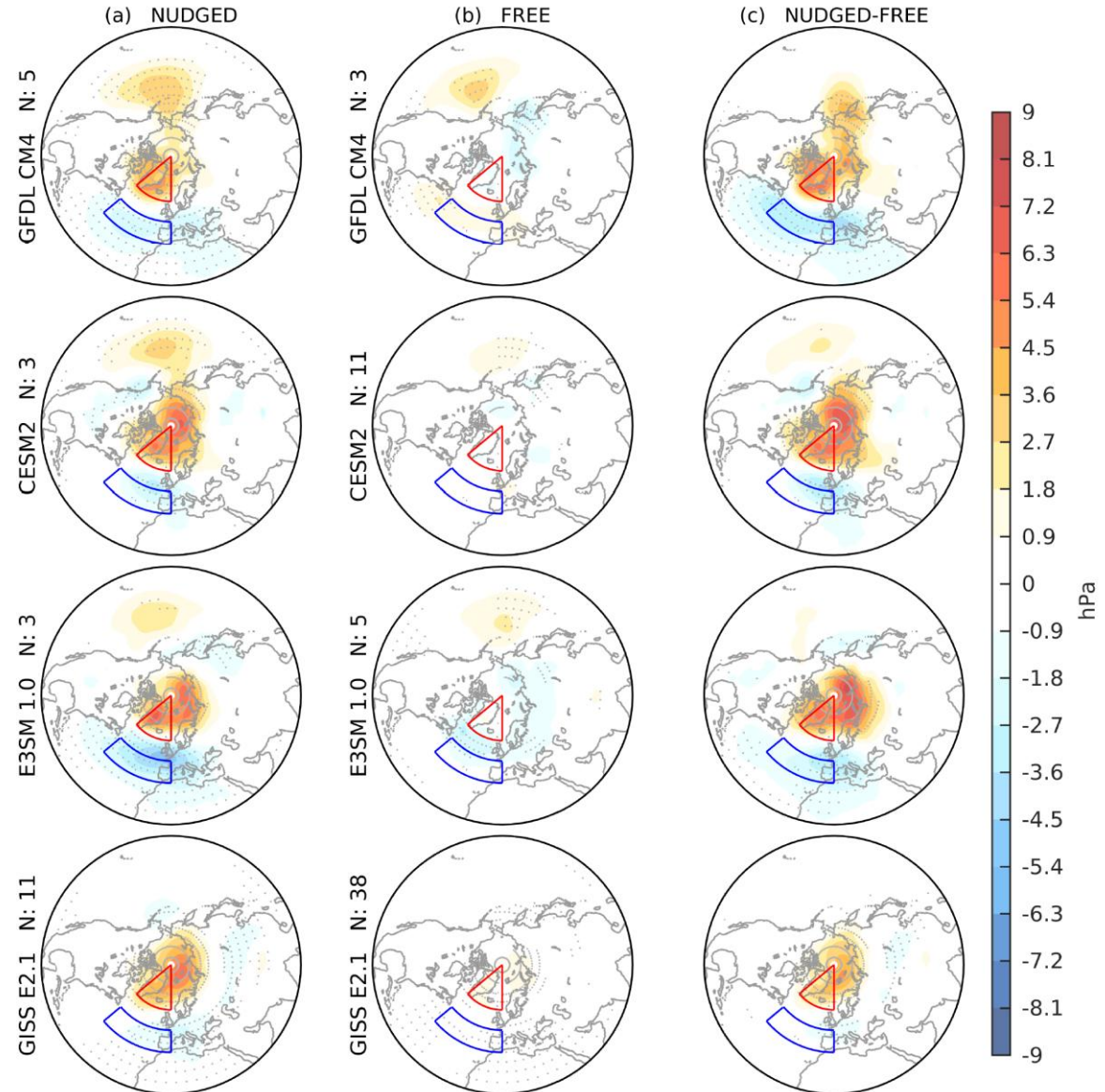
Sea level pressure response, JFM, [1999-2010] – [1990-1998]

- NUDGED → negative NAO
- FREE → weak signal



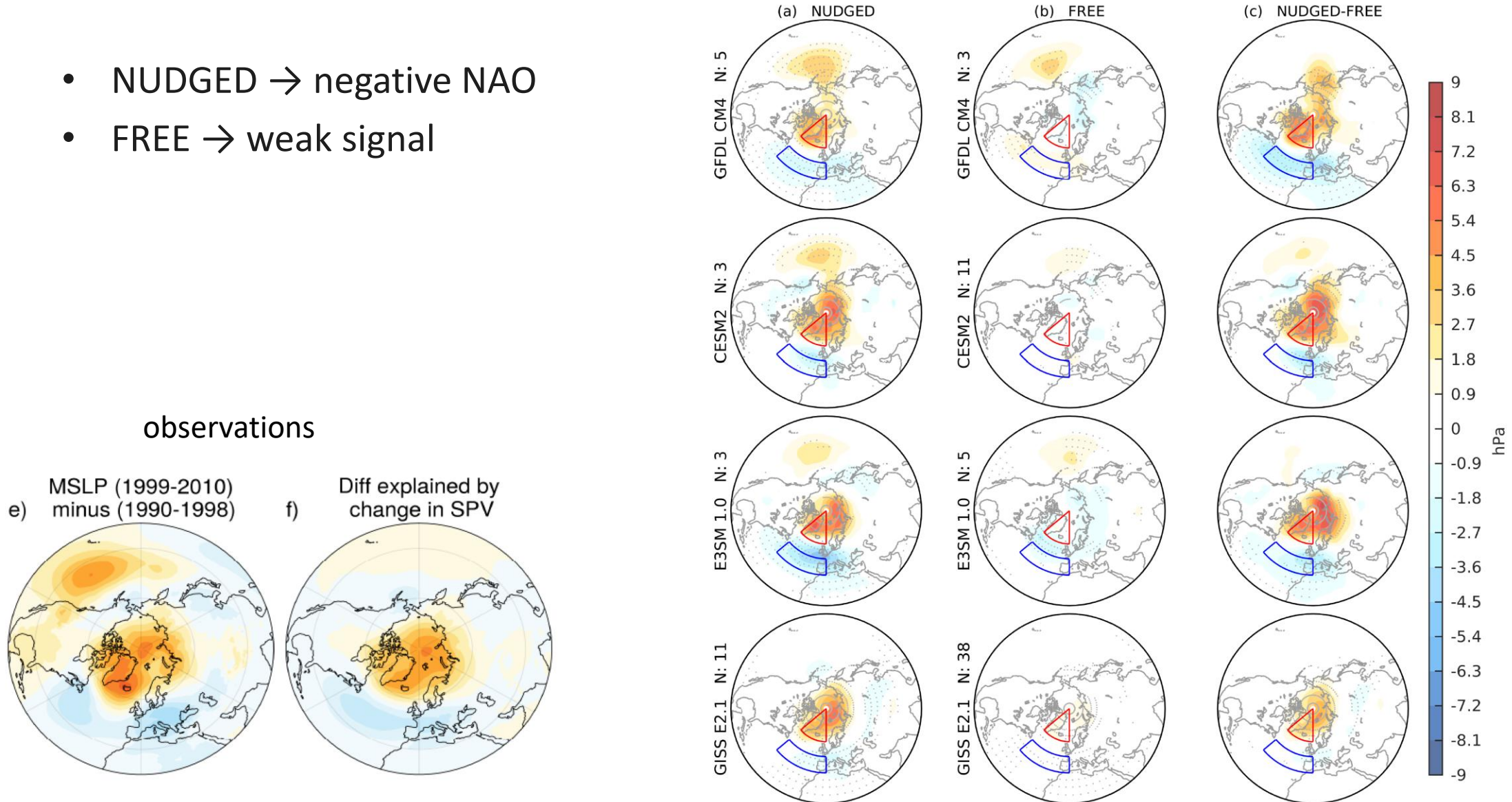
Sea level pressure response, JFM, [1999-2010] – [1990-1998]

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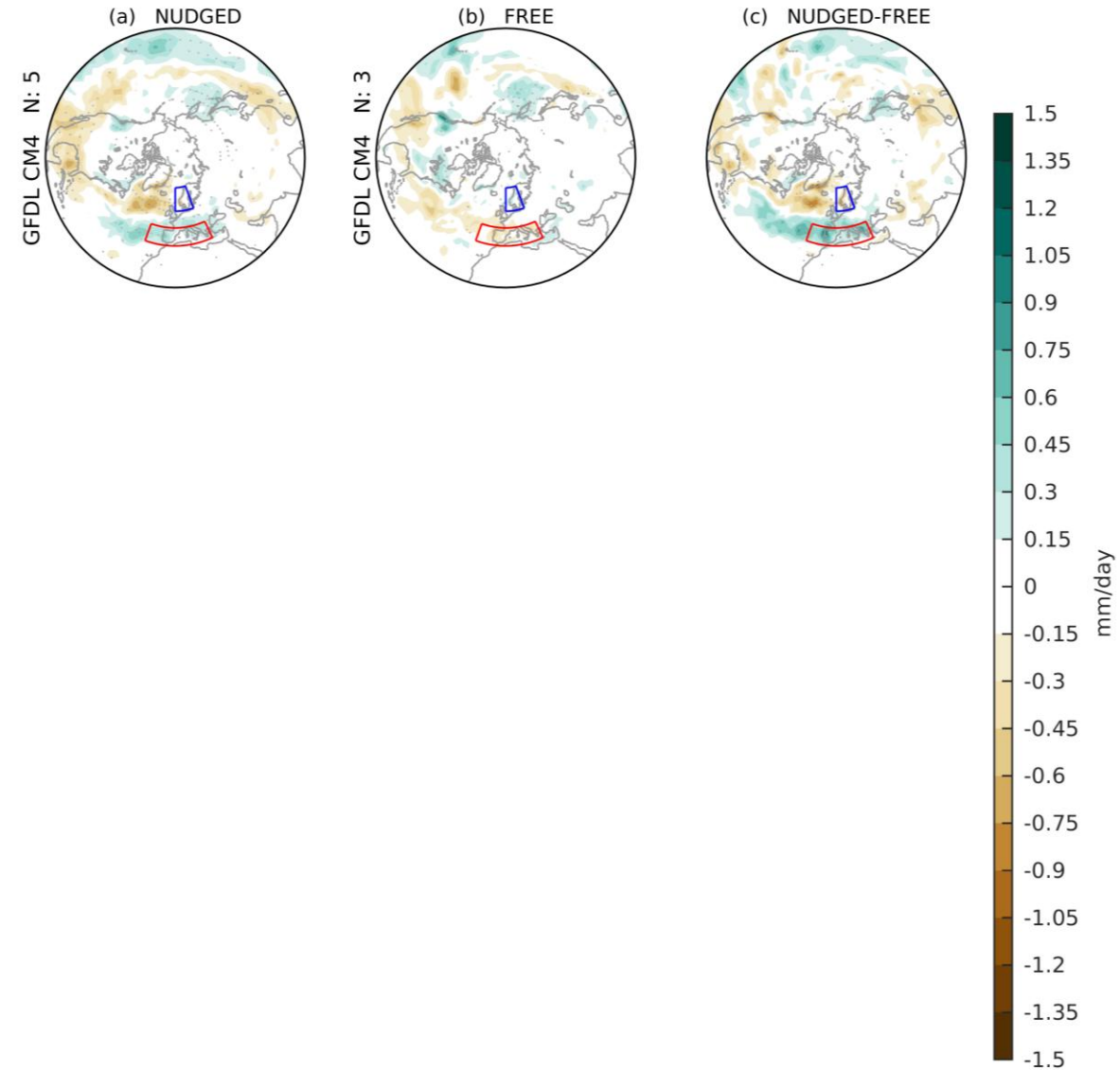
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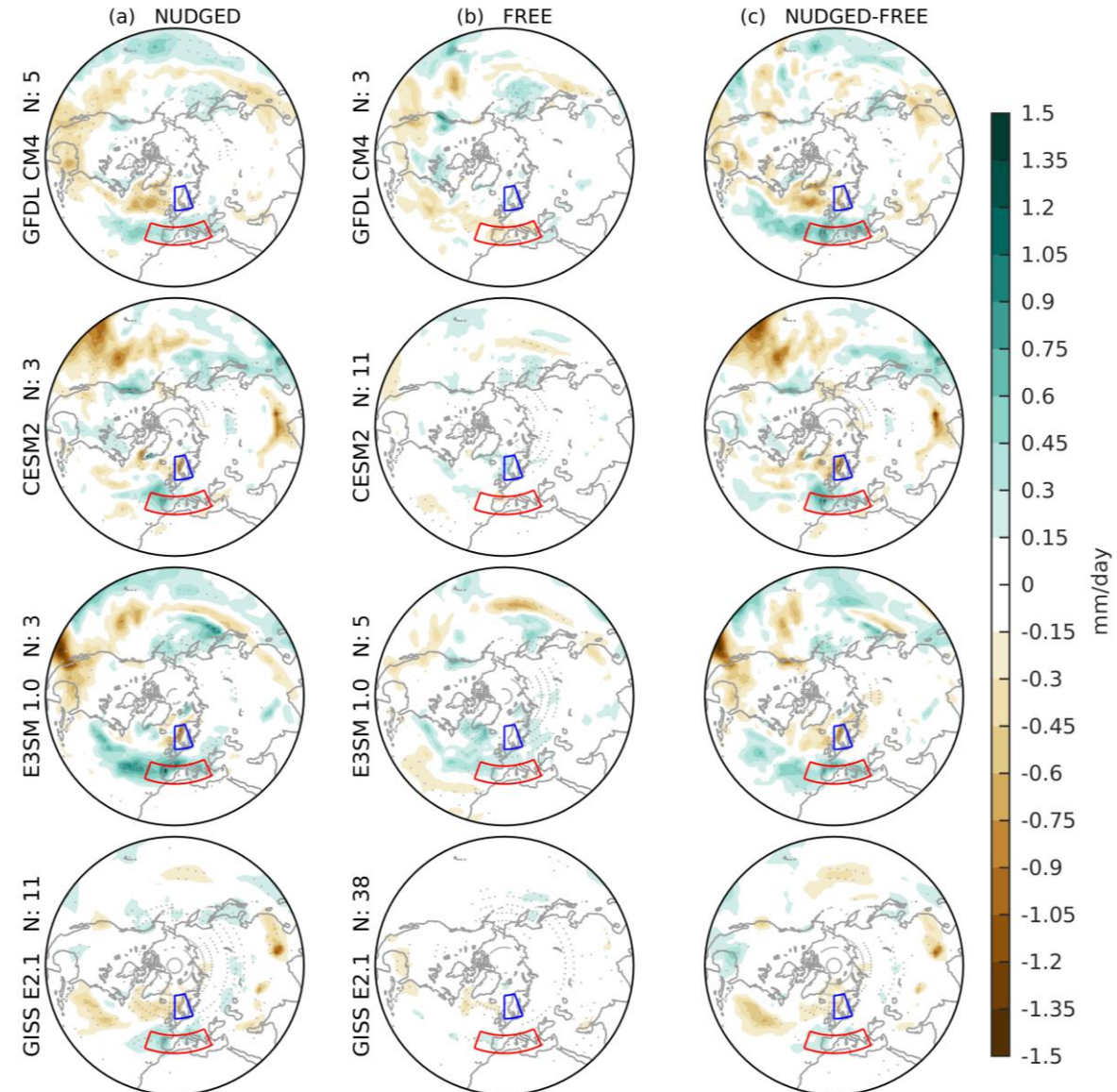
Precipitation, JFM, [1999-2010] – [1990-1998]

- Wetter S. Europe
- Drier Scandinavia
- NAO-like dipole



Precipitation, JFM, [1999-2010] – [1990-1998]

- Wetter S. Europe
- Drier Scandinavia
- NAO-like dipole

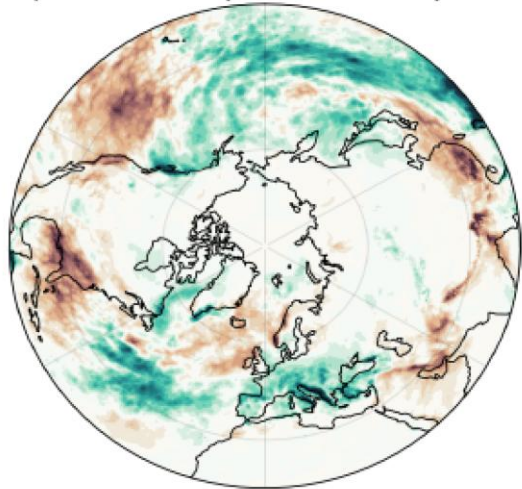


Precipitation, JFM, [1999-2010] – [1990-1998]

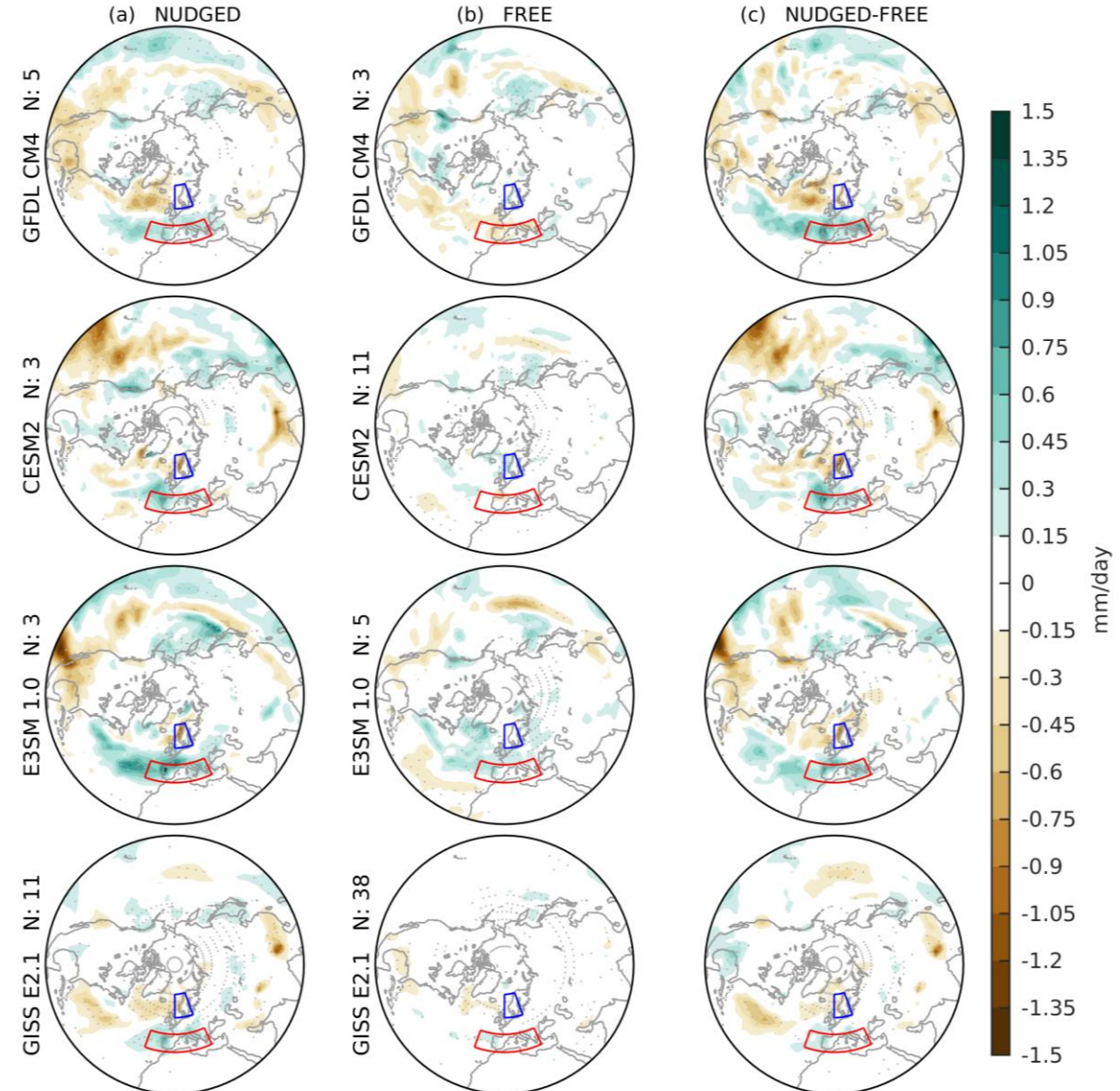
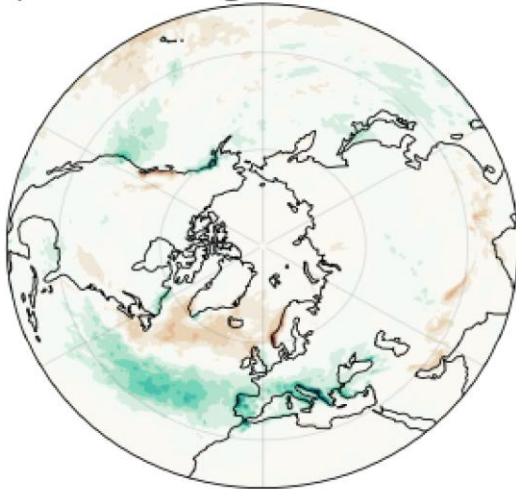
- Wetter S. Europe
- Drier Scandinavia
- NAO-like dipole

observations

h) T_p (1999-2010) minus (1990-1998)

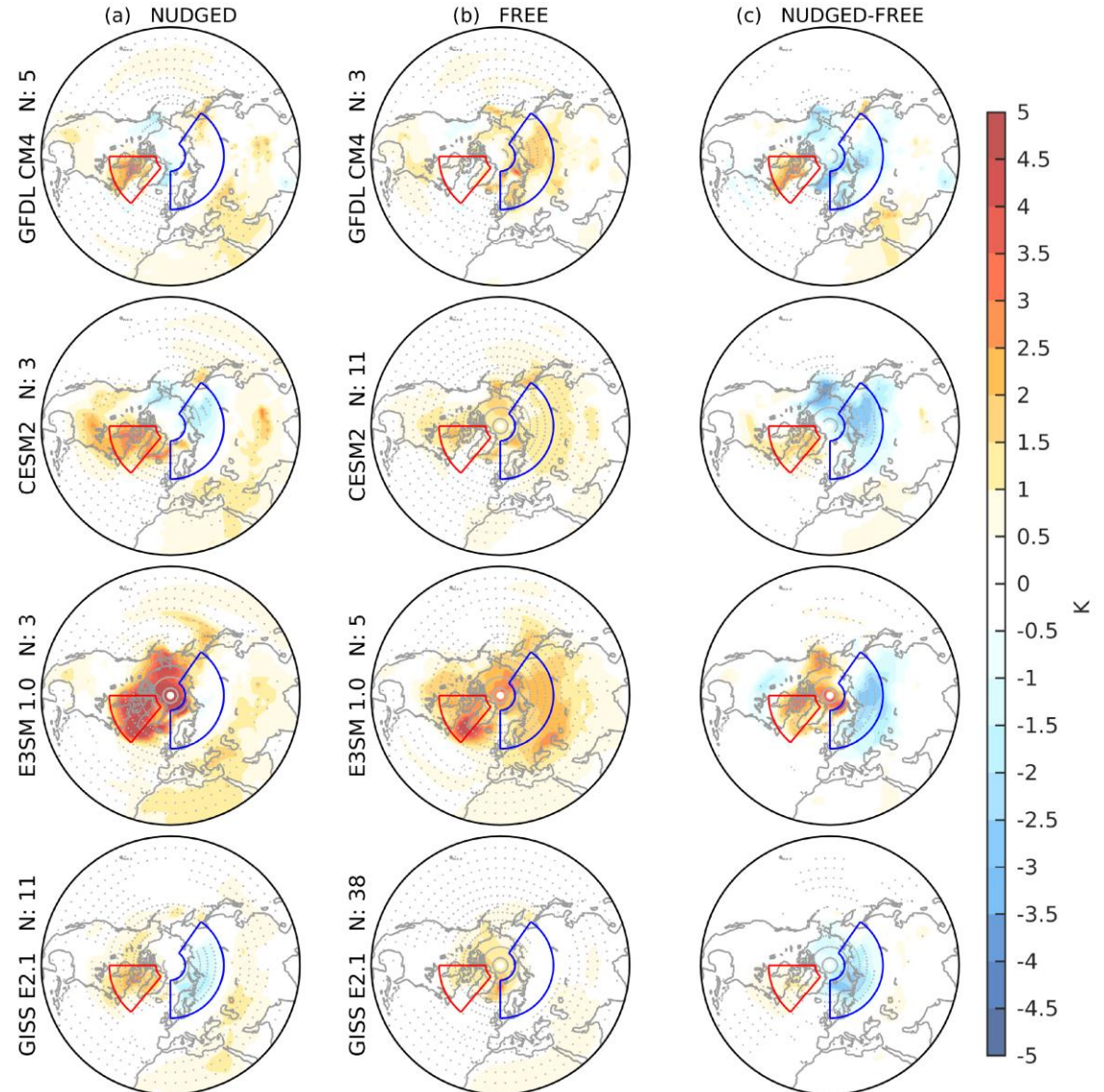


i) Diff explained by change in SPV



Temperature Response, JFM, [1999-2010] – [1990-1998]

- Cooling subpolar Eurasia
- Warming Eastern Canada
- FREE shows greenhouse warming

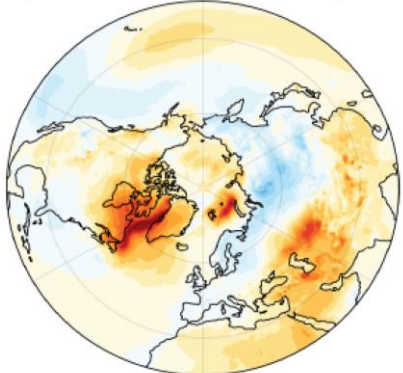


Temperature Response, JFM, [1999-2010] – [1990-1998]

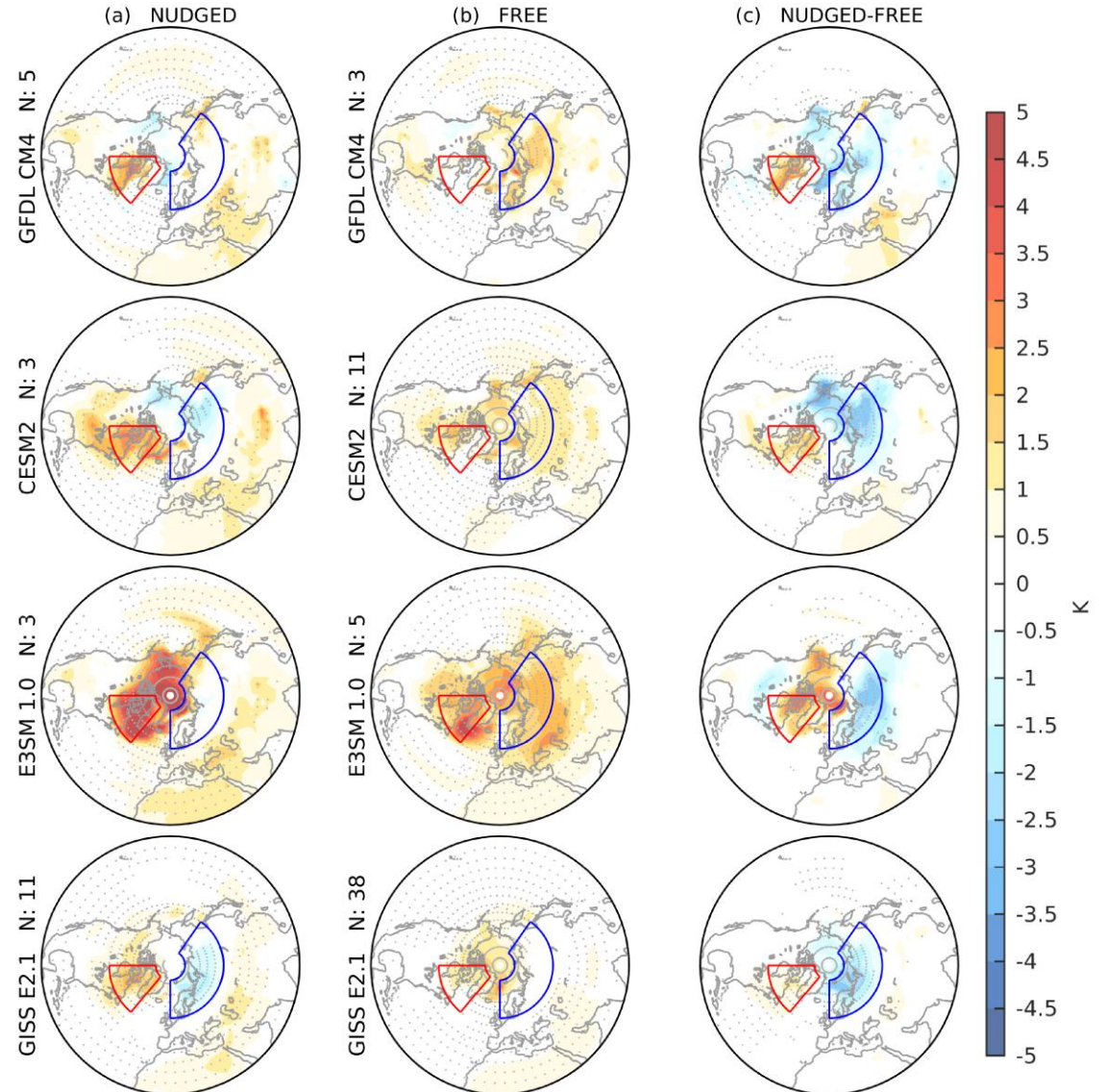
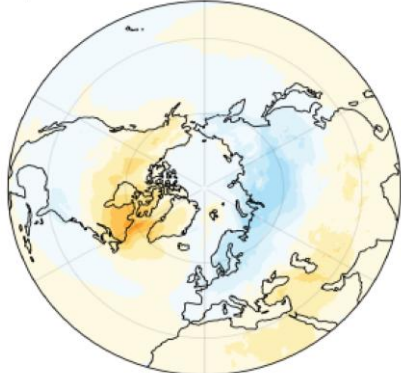
- Cooling subpolar Eurasia
- Warming Eastern Canada
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observations

b) T2m (1999-2010) minus (1990-1998)

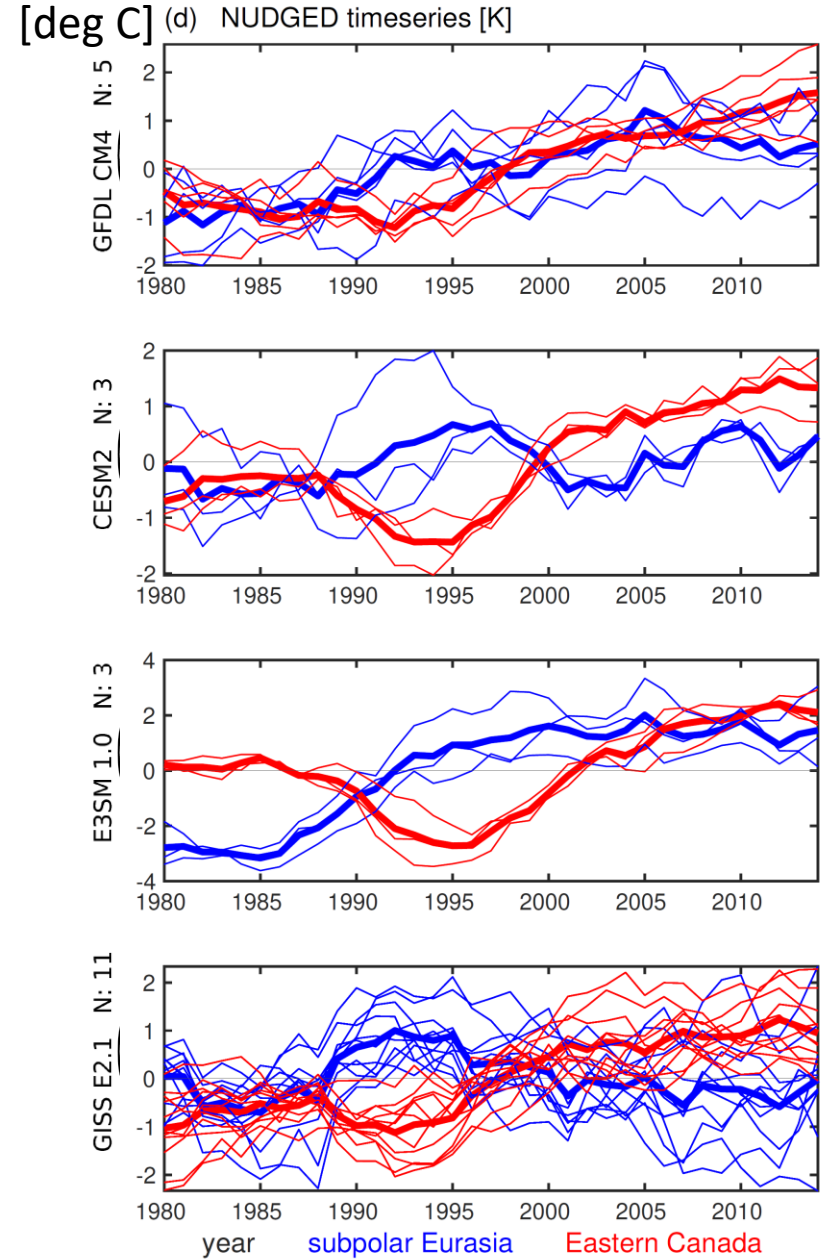


c) Diff explained by change in SPV







Key Result

- Offsets warming
- Decadal cooling emerges
- $\sim 2^{\circ}\text{C}$ impact



Take-Home Messages

-  First **causal attribution** of Eurasian cooling to stratosphere
-  Stratospheric variability can **dominate regional climate on decadal scales**
-  Important source of **internal variability + uncertainty**

-  The stratosphere matters for surface climate — even in a warming world.