



Stratosphere-Troposphere Interactions and  
Prediction of Monsoon weather EXtremes  
2-7 June, 2024, IITM, Pune, India

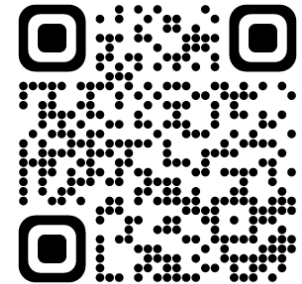
# Assessing stratospheric contributions to subseasonal prediction: The SNAPSI project

P. Hitchcock, A. Butler, C. Garfinkel, H. Kim,  
W. Seviour, B. Ayarzagüena, H. Pahlavan,  
S. Noguchi

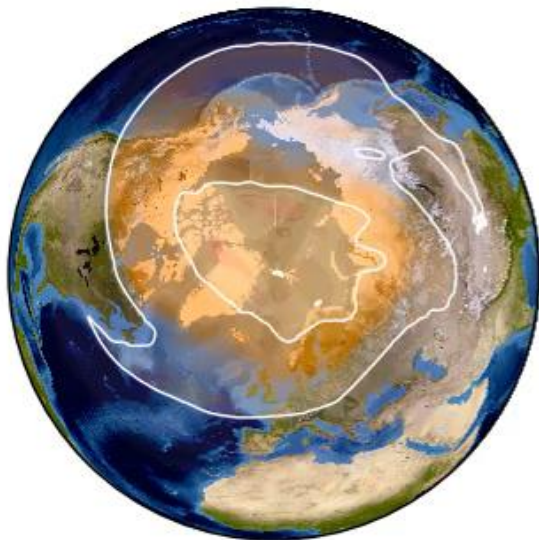


Protocol description paper: <https://doi.org/10.5194/gmd-15-5073-2022>

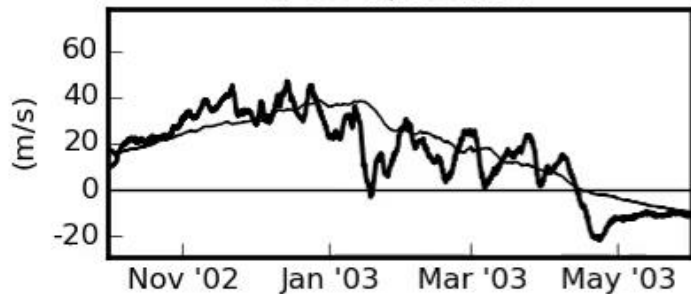
SNAP is a project/activity of  
both S2S and SPARC/APARC



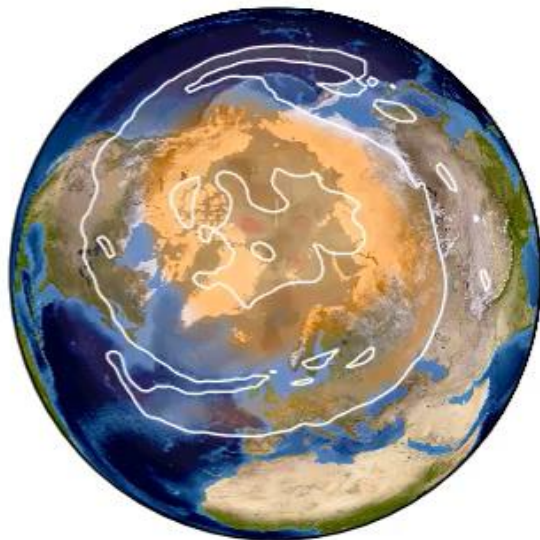
PV 850 K: 00:00 Oct 01, 2002



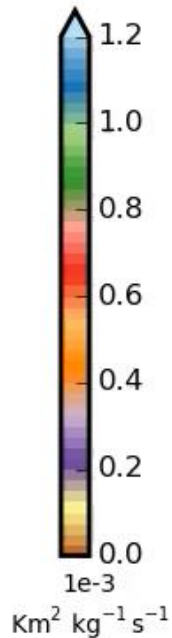
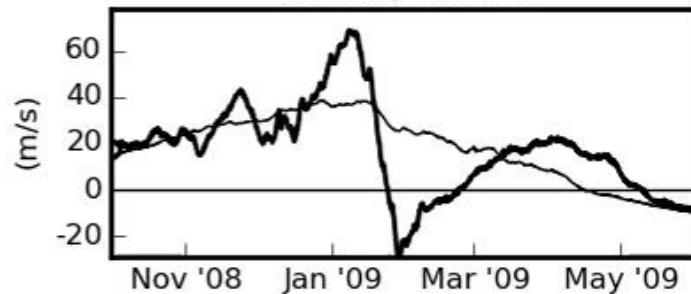
Short Recovery Event  
u 60 N, 10 hPa



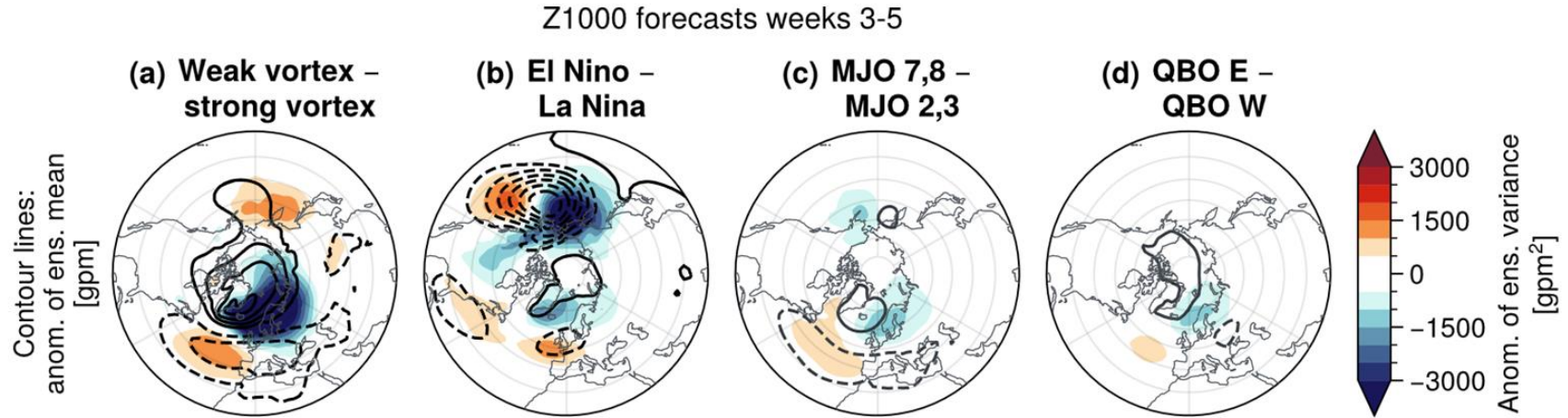
PV 850 K: 00:00 Oct 01, 2008



Extended Recovery Event  
u 60 N, 10 hPa



# Predictability from the Polar Vortex?

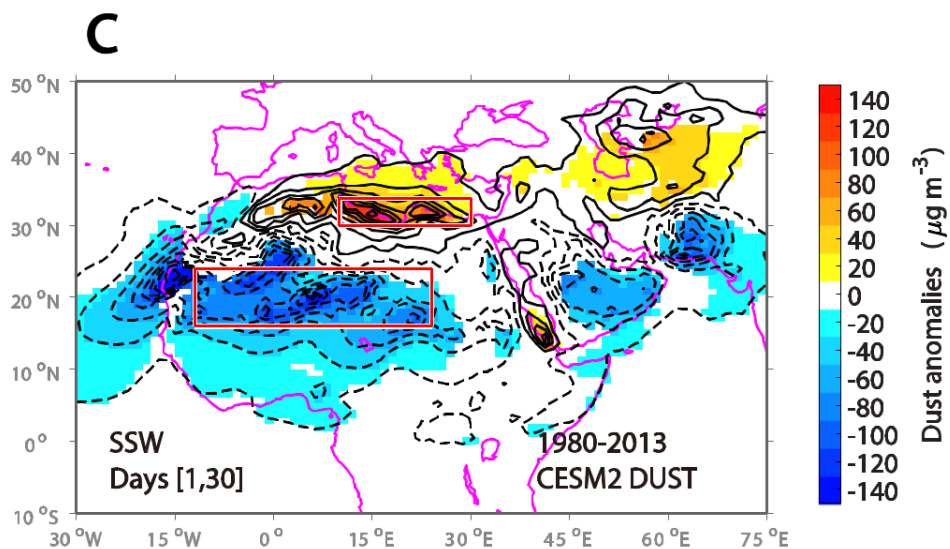
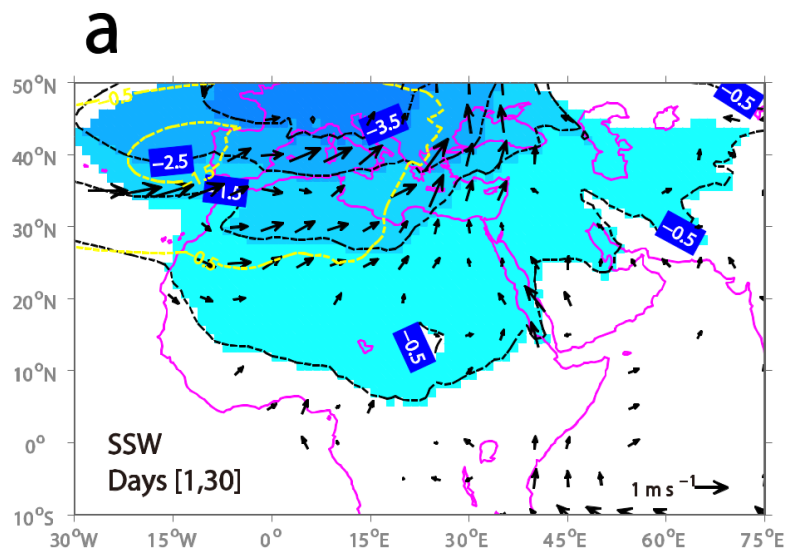
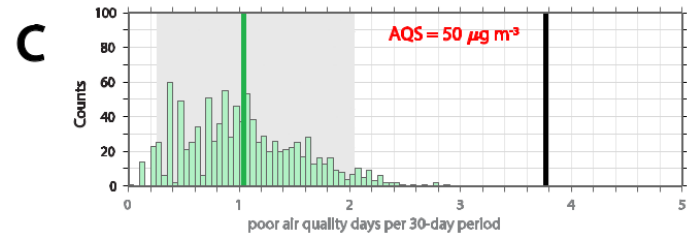


Spaeth et al, Comm. Earth & Env. (2024)

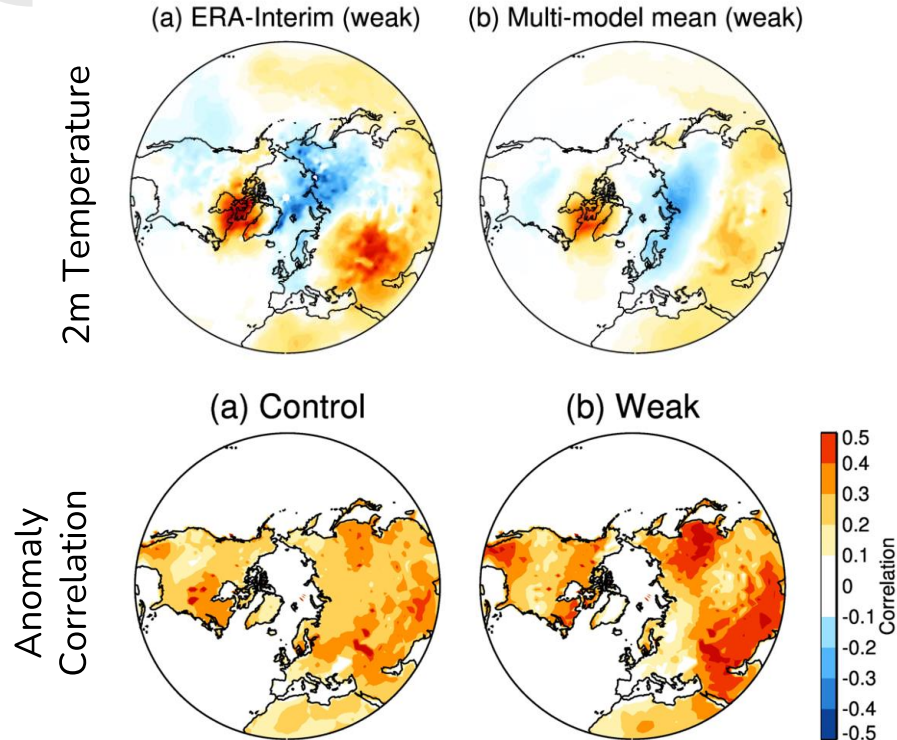
- How can we best use the stratosphere to **improve** subseasonal forecasts?
- Are models capturing this coupling correctly?

# Compositional Impacts?

Finokalia, Greece



# Motivations



- Stratospheric sudden warmings have the **potential** to contribute significant skill to **subseasonal forecasts**
- There is a need for a **multi-model, controlled experiment**, designed to assess and quantify this potential



# Experimental Design

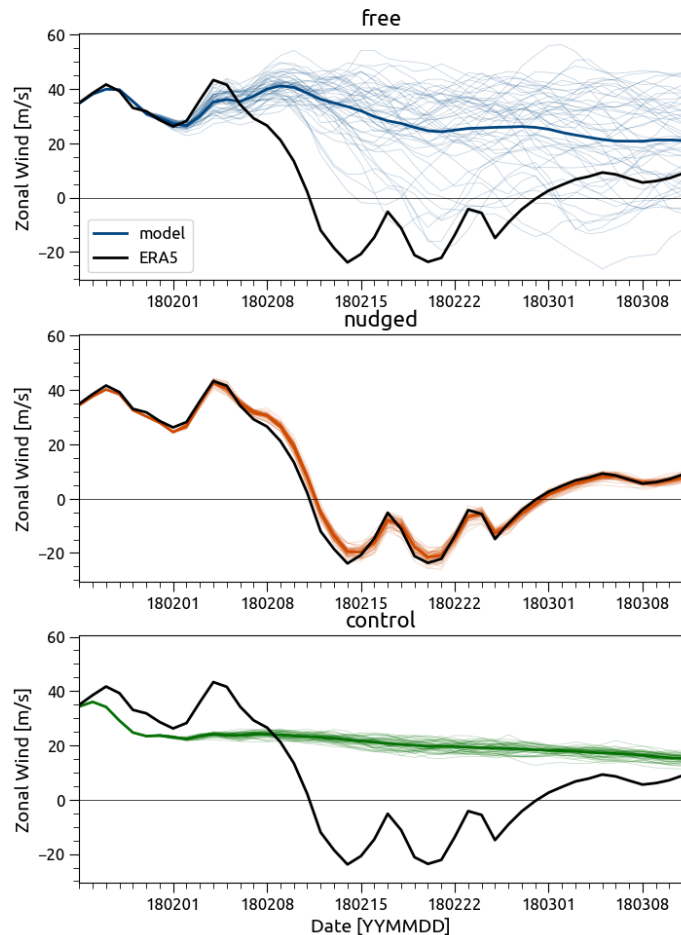
The SNAPSI protocol defines **three core types** of ensemble forecasts (>50 members)

- **Free:** Free running ensemble forecast
- **Nudged:** *Zonally symmetric* component of stratosphere nudged to **observed evolution**
- **Control:** *Zonally symmetric* component of stratosphere nudged to **climatology**

Forecasts have been made of three recent events:

- **Major NH SSWs of 2018 and 2019**
- **Minor SH Warming of 2019**

10 hPa, 60°N Zonal Mean U  
KMA GloSea6-GC32 s20180125





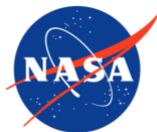
# Participating Modeling Centers/Groups

BCC	BCC-CSM2-HR	Wu et al. (2019, 2021)
CNR-ISAC	GLOBO	Malguzzi et al. (2011) Mastrangelo and Malguzzi (2019)
ECCC	GEM-NEMO	Smith et al. (2018) Lin et al. (2020)
ECCC	CanESM5	Swart et al. (2019) Sospedra-Alfonso et al. (2021)
ECMWF	IFS	ECMWF (2020)
GFDL	SPEAR	Delworth et al. (2020)

SNU	GRIM	Hong et al. (2013) MacLachlan et al. (2014)
KMA	GloSea5-GC2	Williams et al. (2015) Walters et al. (2017)
Météo-France	CNRM-CM 6.1	Voldoire et al. (2019)
NCAR	CESM2(CAM6)	Danabasoglu et al. (2020) Richter et al. (2021)
NRL	NAVGEN	Hogan et al. (2014) McCormack et al. (2017) Eckermann et al. (2018)
UKMO	GloSea5	MacLachlan et al. (2014)

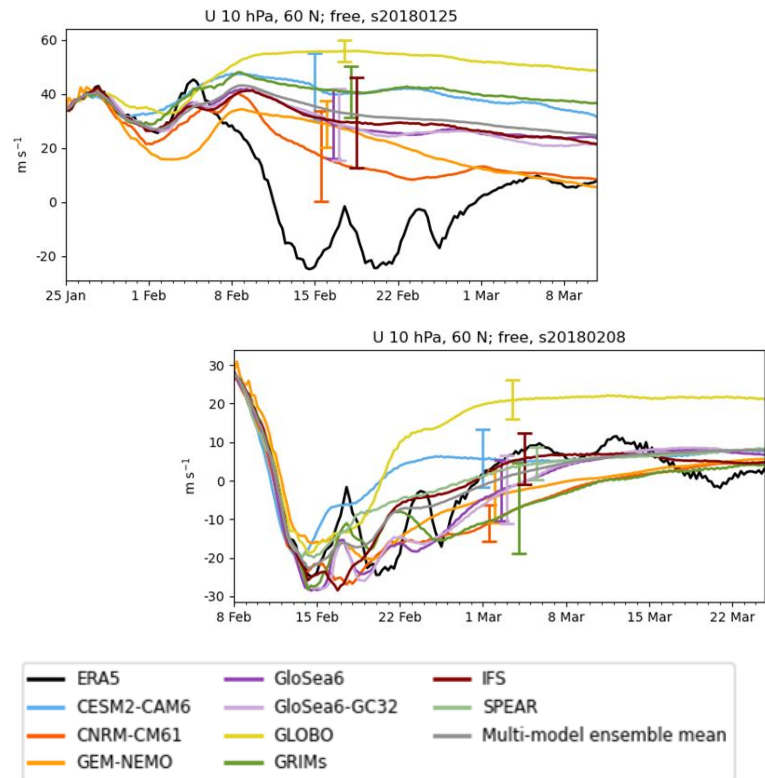
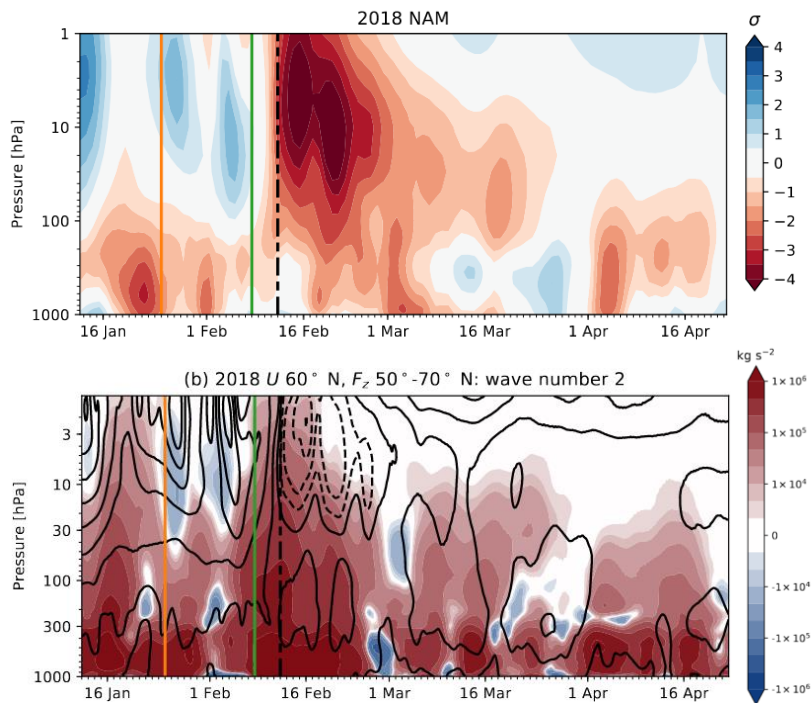
Output fully archived

Some output is still expected



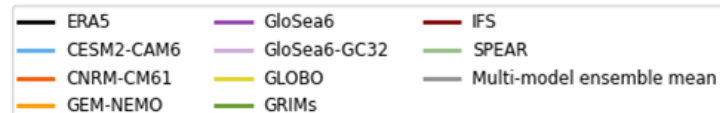
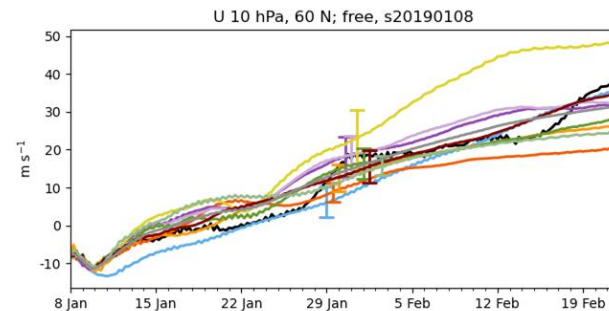
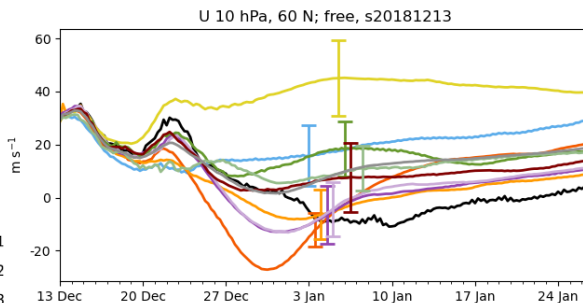
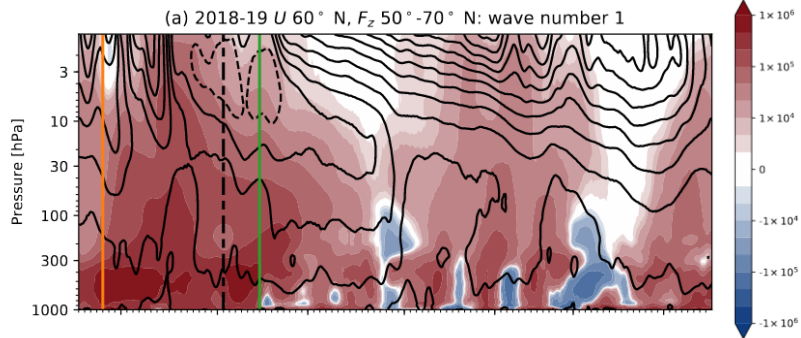
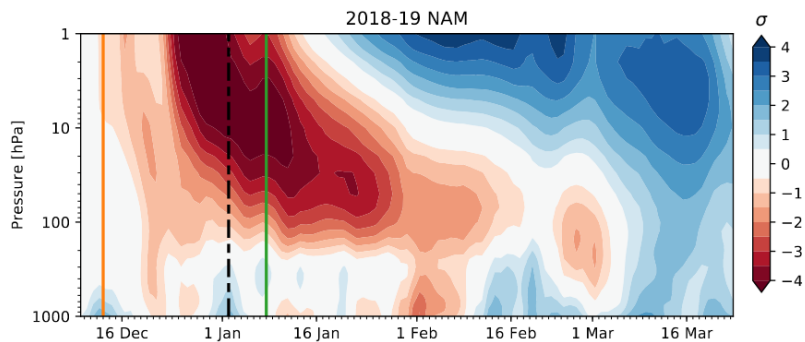
Experiments with NASA's GEOS-S2S model will also be carried out, thanks to support from NASA ESD

# Case Study 1: Boreal SSW, 12 Feb 2018

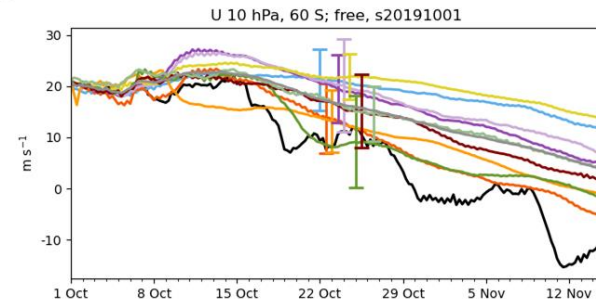
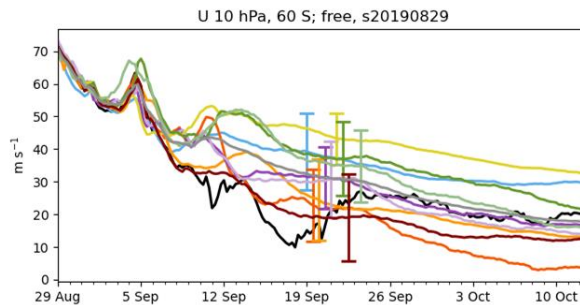
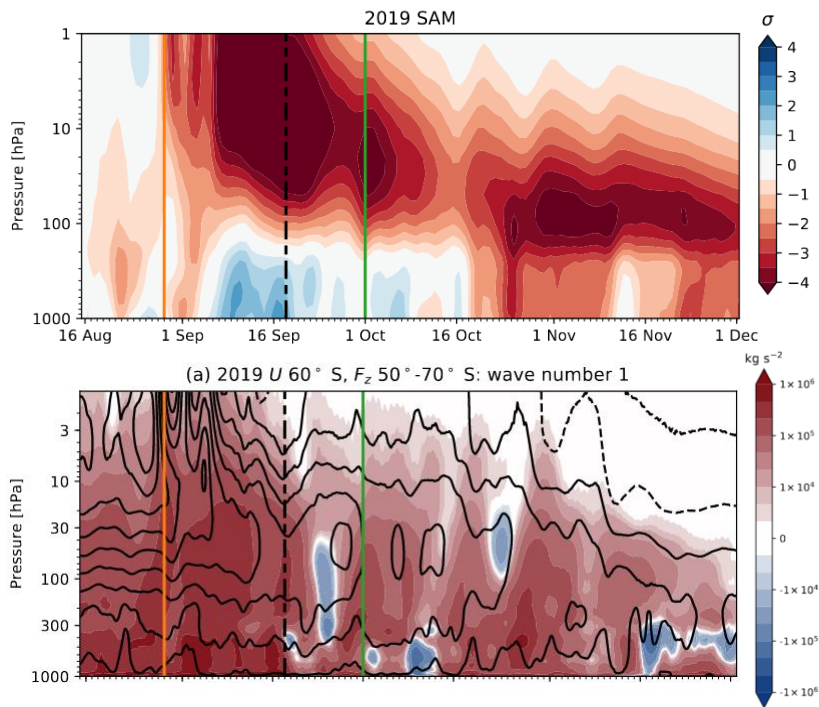




# Case Study 2: Boreal SSW, 2 Jan 2019



# Case Study 3: Austral Minor Warming, Sep 2019





# Data Request

## Priority 1 request

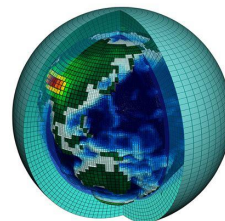
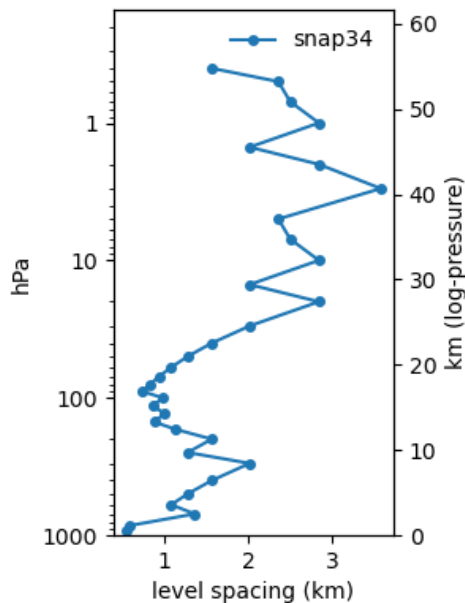
- Full 3d meteorological fields (T, U, V,  $\omega$ ,  $\Phi$ , q) every 6 hours, 1° resolution on 34 pressure levels
- Surface/column fields (ps, mslp, T 2m, U,V 10 m, precip)

## Priority 2 request (coverage varies, but is substantial)

- Zonal mean momentum and thermodynamic budgets
- TEM quantities
- Further land/ocean/cryosphere parameters, etc.

Output is [archived](#) on CEDA and is available to the community.

Many more variables than S2S or SubX datasets!



 **CEDA  
Archive**



# Analysis: Community Working Groups

## Core Science Questions

1. **Predictability:** lead Hera Kim, SNU
2. **Attribution:** lead Will Seviour, U. Exeter
3. **Mechanisms:** lead Peter Hitchcock, Cornell U.
4. **Upward Coupling:** lead Blanca Ayarzagüena, U. Madrid

## Additional Science Questions

5. **QBO:** lead Hamid Pahlavan, NWRA/Rice U.
6. **Tropical Convection:** lead Shunsuke Noguchi, Kyushu U.

Some highlights presented here

# WG1: Predictability; Lead Hera Kim (SNU)

1st Init.

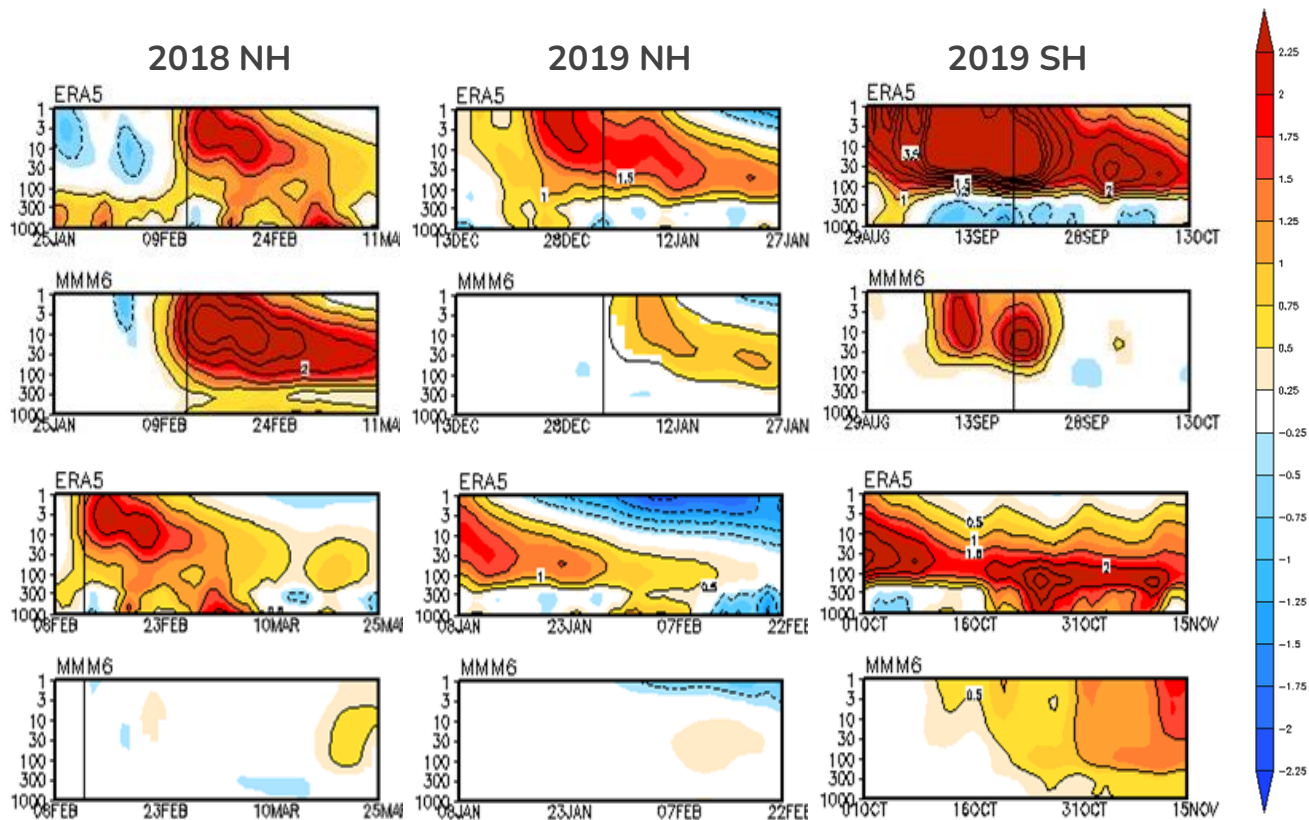
ERA 5

Nudged - Free

2nd Init.

ERA 5

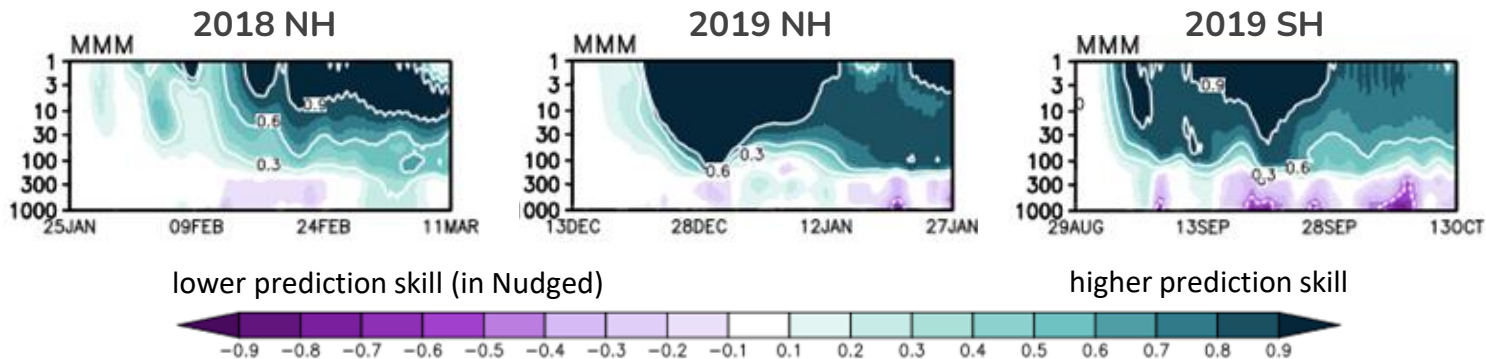
Nudged - Free



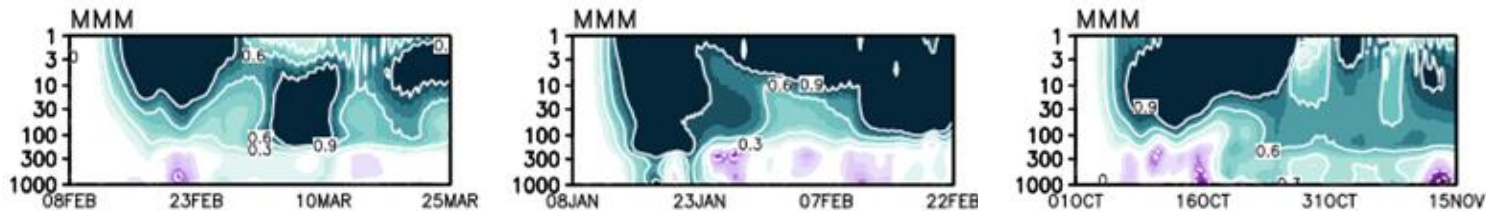
# Improvements in forecast skill

MSSS of Z [45:90°] difference (Nudged-Control), MMM

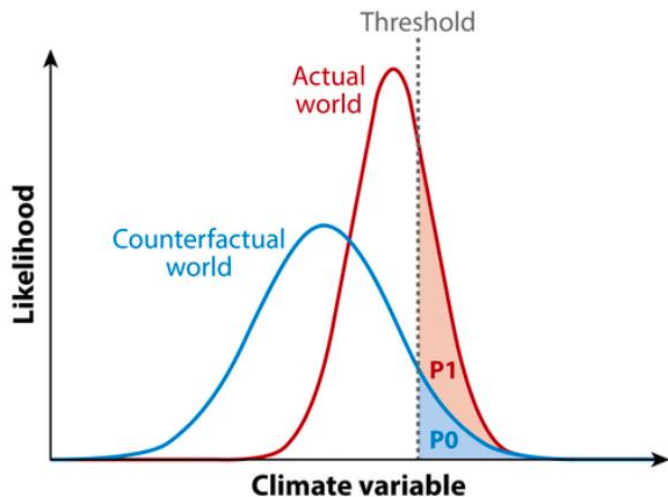
1st Init.



2nd Init.



## WG2: Attributing Extremes Lead Will Seviour (U. Exeter)



Otto (2017)

### SNAPSI probabilities

#### 'Actual (forecast) world'

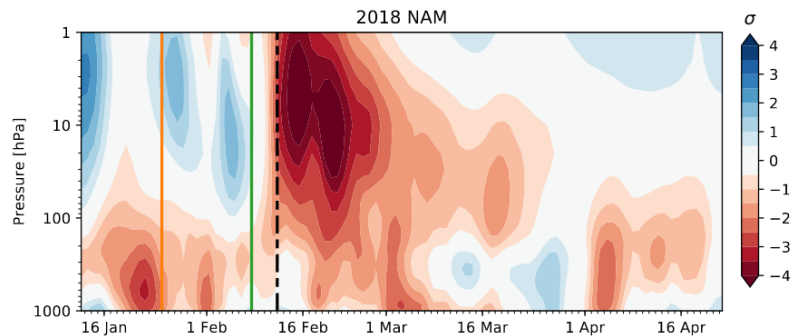
$p(A)$ : probability of extreme event A (from **free**)

#### 'Counterfactual worlds'

$p(A | V^-)$ : probability given weekend polar vortex (from **nudged**)

$p(A | V^0)$ : probability given climatological polar vortex (from **control**)

# 2018 European Cold Air Outbreak



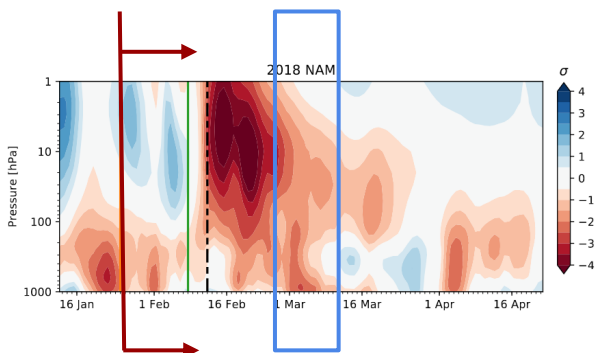
Snow in Rome,  
26 February 2018

	Long lead time (18 days pre SSW)	Short lead time (4 days pre SSW)
Improving the stratospheric forecast	↑ (4x)	— (1x*)
Degrading the stratospheric forecast	↓ (2.4x)	↓ (2.7x)

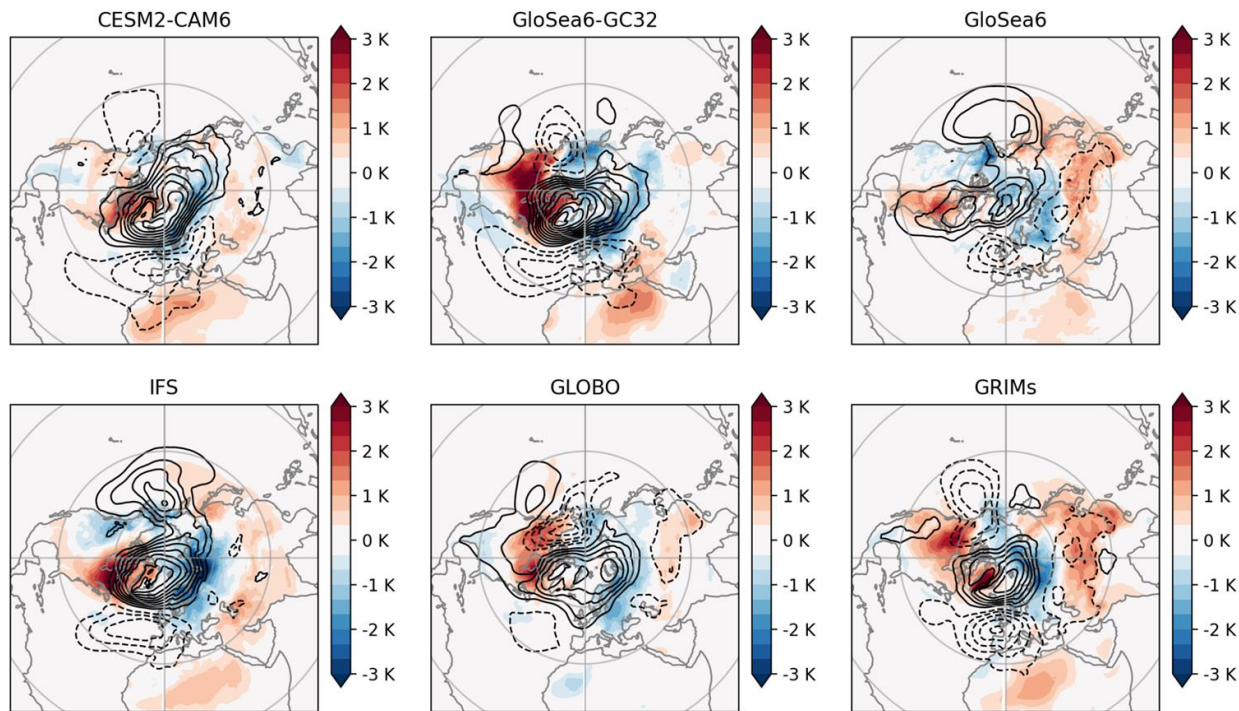


# WG3: Mechanisms

## Lead P. Hitchcock (Cornell U.)

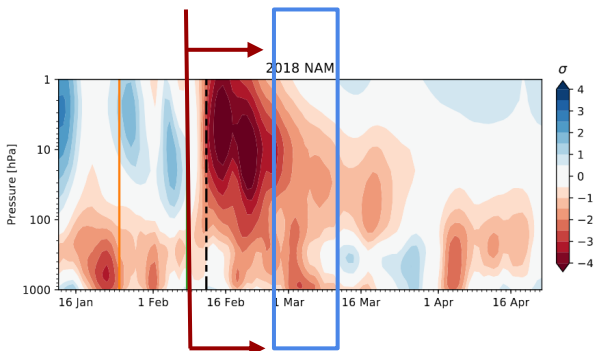


**Nudged - Control:**  
Initialized 25 Jan 2018,  
Averaged 26 Feb to 11 Mar

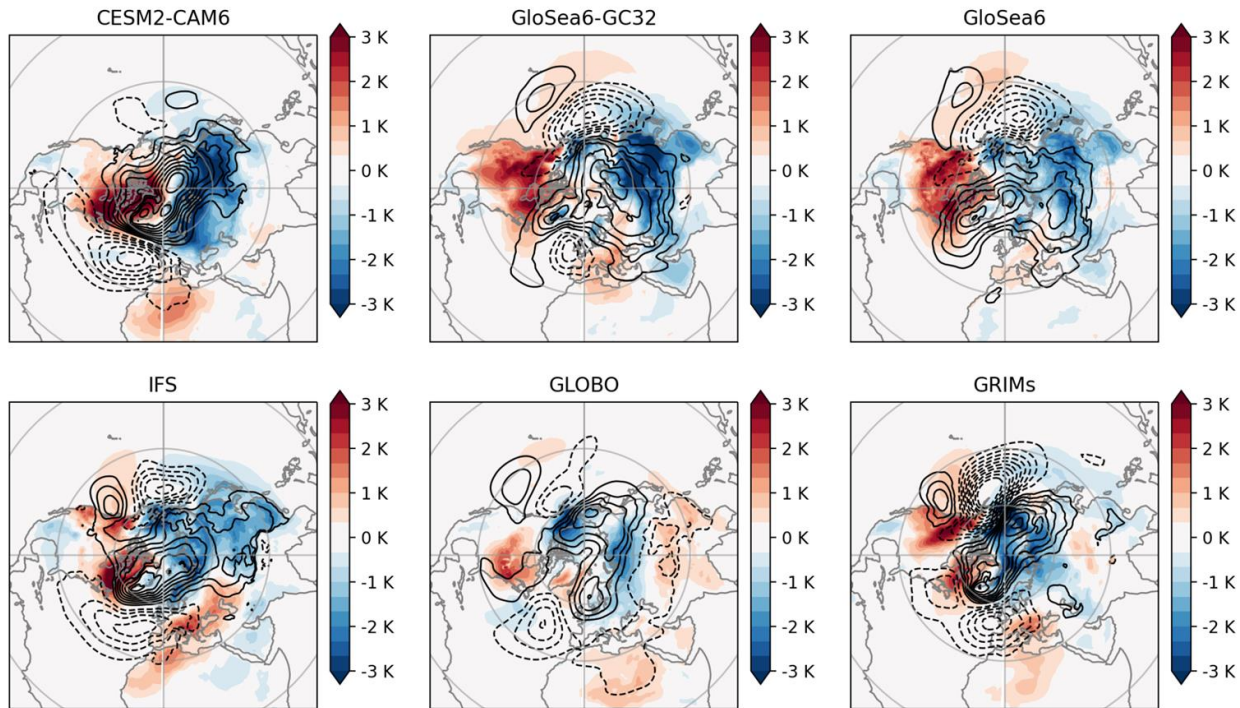


# WG3: Mechanisms

## Lead P. Hitchcock (Cornell U.)



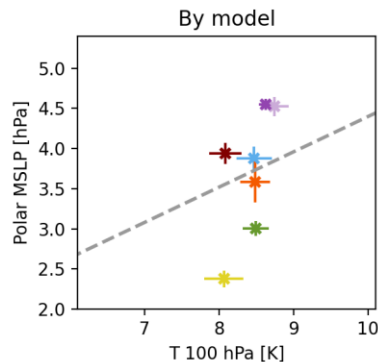
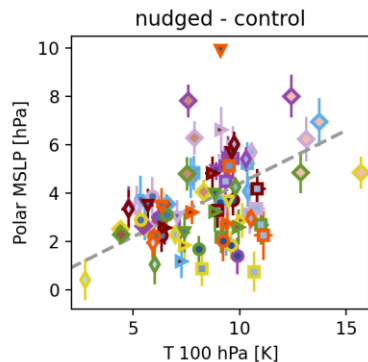
**Nudged - Control:**  
Initialized 8 Feb 2018,  
Averaged 26 Feb to 11 Mar





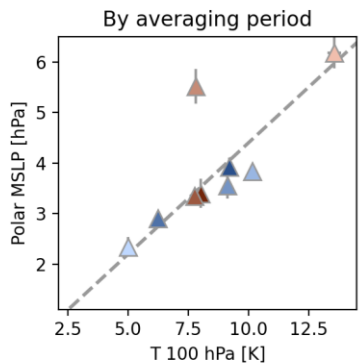
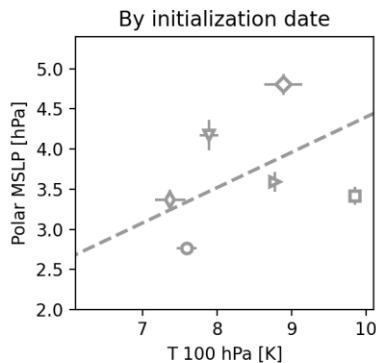
# Quantifying Coupling Strength?

--- (0.44 hPa/K)  $\Delta T_{100}$   
hPa



- CESM2-CAM6
- GloSea6-GC32
- GloSea6
- IFS
- GLOBO
- GRIMs
- CNRM-CM61

- s20180125
- s20180208
- s20181213
- s20190108
- s20190829
- s20191001

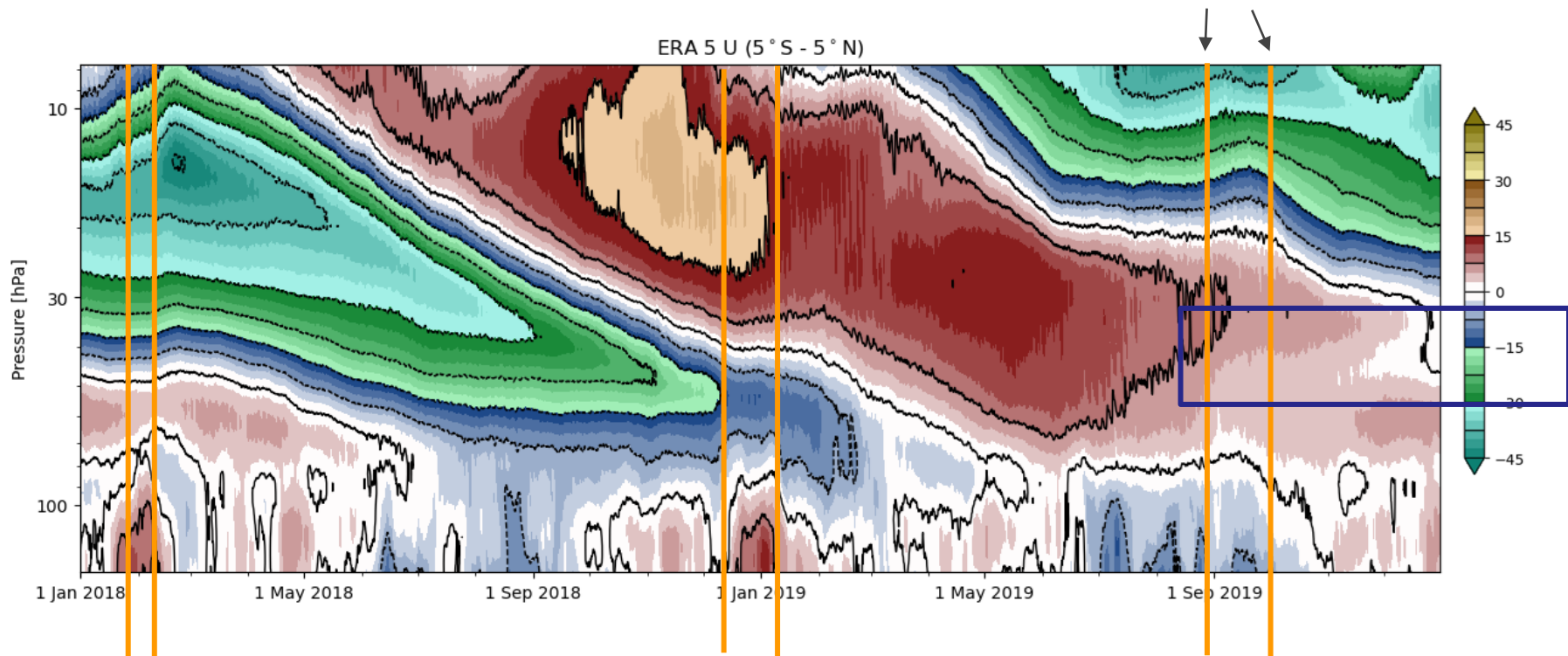


- 20180212-20180225
- 20180226-20180311
- 20190101-20190114
- 20190115-20190128
- 20190129-20190211
- 20190915-20190928
- 20191001-20191012
- 20191015-20191028
- 20191029-20191111

# WG5: QBO

## Lead Hamid Pahlavan (NWRA)

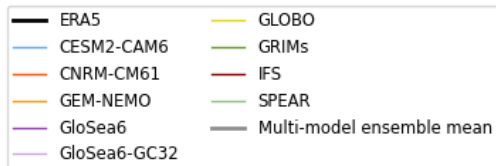
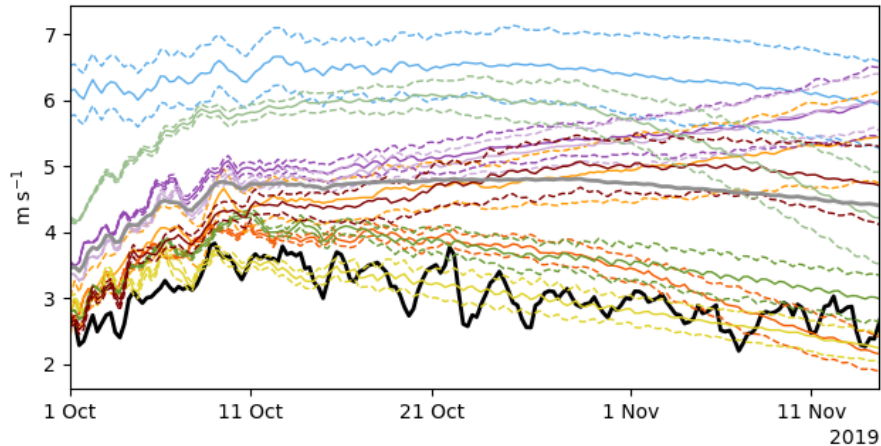
Initialization dates  
(45-day forecasts)



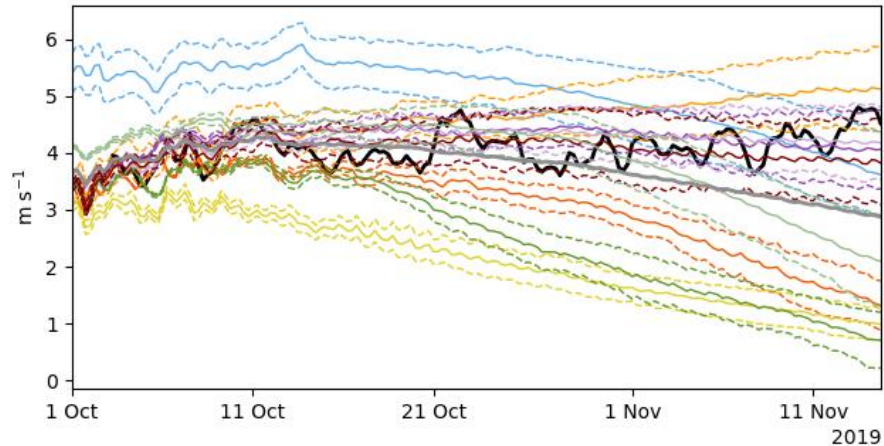


# Maintenance of QBO winds?

U 50 hPa, 5 S-N; free, s20191001

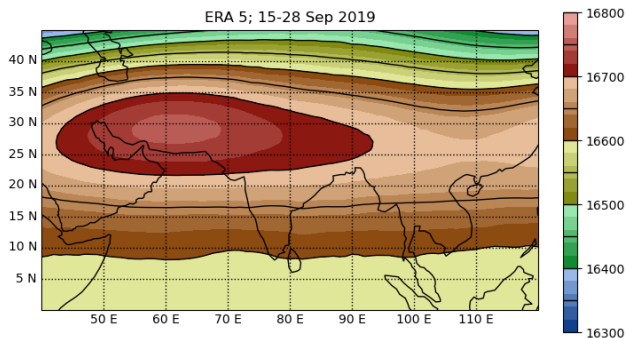


U 60 hPa, 5 S-N; free, s20191001

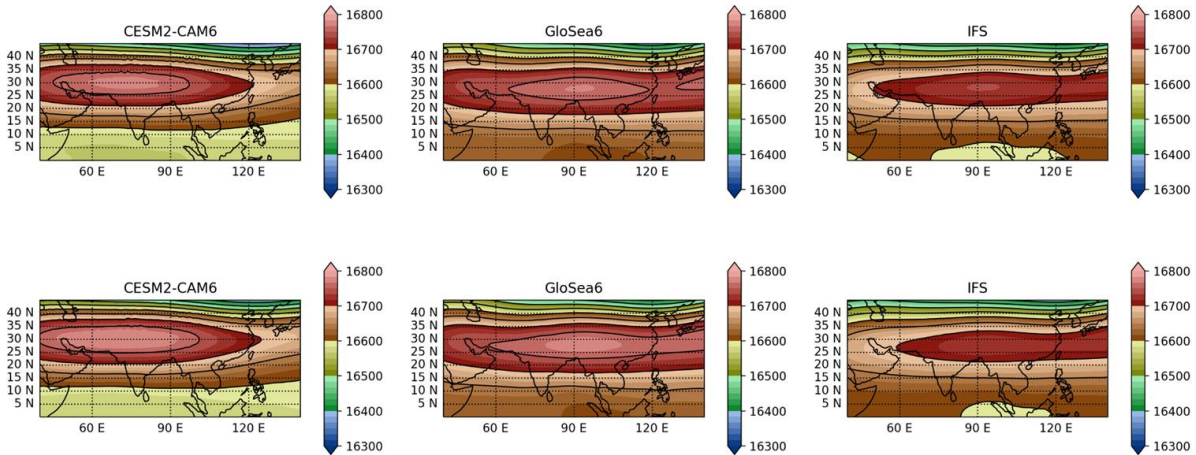


# Potential for Monsoon studies?

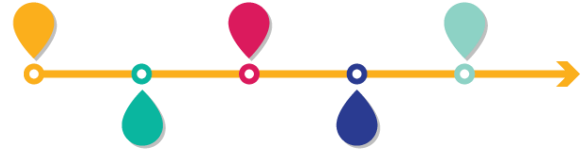
100 hPa Geopotential Height



**Nudged:** Initialized 28 Aug 2019, Averaged 15-28 Sep 2019

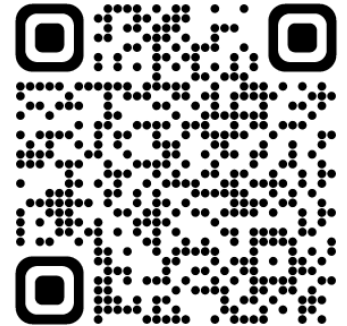


**Free:** Initialized 28 Aug 2019, Averaged 15-28 Sep 2019



# Status and Outlook

- Community science papers are in preparation
- Archive will be a **valuable community dataset** for studying
  - role of stratosphere in subseasonal forecasting
  - attribution of extreme events to dynamical modes of variability
  - mechanisms of stratosphere-troposphere coupling
  - **Monsoon processes?**
- Data is available for download from CEDA



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Chaim Garfinkel  
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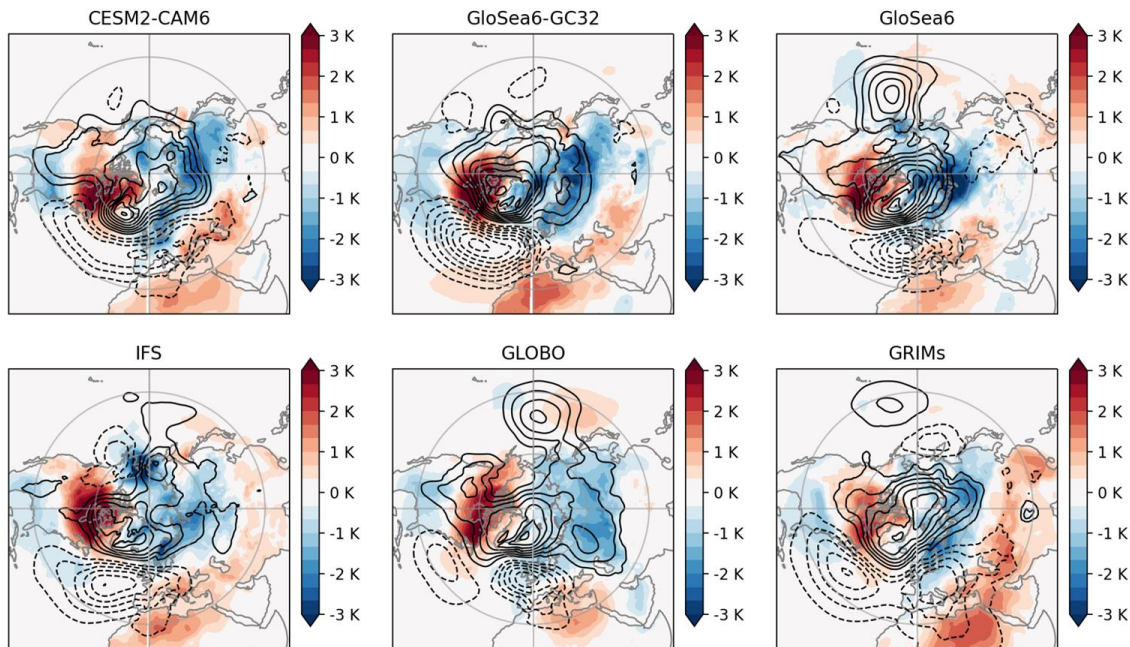
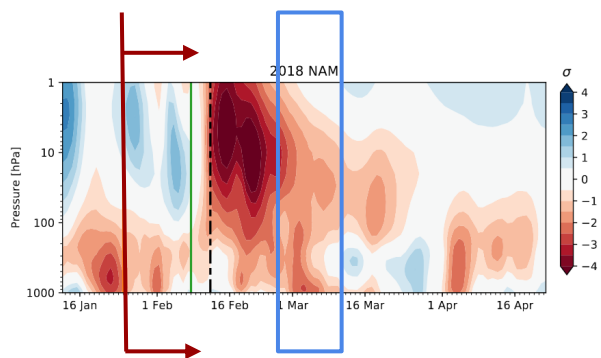
# Extra Slides

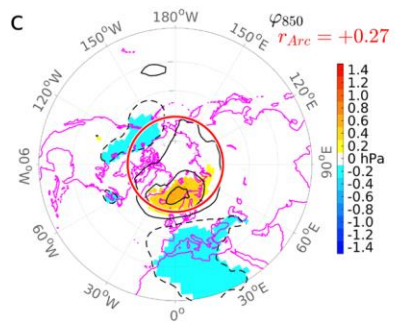
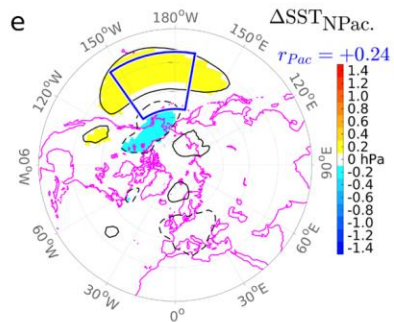
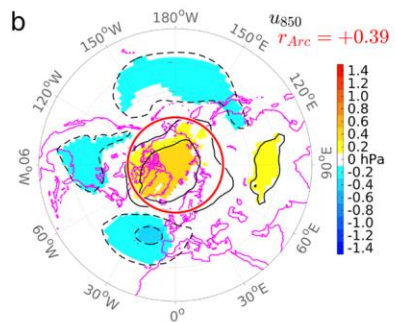
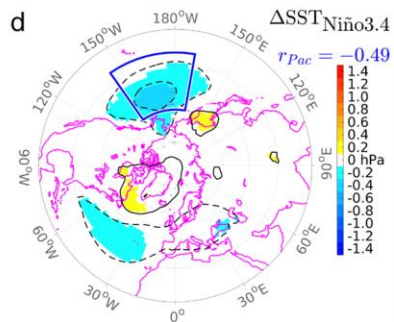
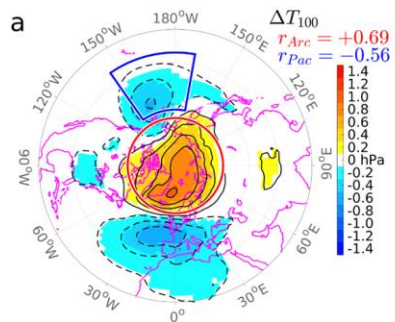




# Dependence on initial conditions

nudged - control: Initialized 25 Jan 2018, averaged 26 Feb to 11 Mar











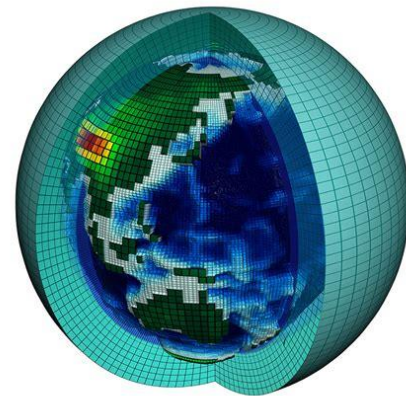
# Data Archiving and Timeline



Data is being archived at the Centre for Environmental Data Analysis

(Thank you to Charlotte Pascoe and Martin Jukes at CEDA)

- Metadata standards based on CMIP6/CMOR have been adopted
- Deadline of Jan 1st 2023 for full consideration by core working groups
- Data is open to the community (under CC Attribution-ShareAlike 4.0 license) for research use



**Oct 24-28 2022:**  
SPARC GA

**May 1 2023:**  
Initial results  
from WGs

**Jan 2024:**  
Co-authorship  
requirement lifted

**Jan 1 2023:**  
Deadline for  
data upload

**Sep 2023:**  
Submission of  
WG papers

Geosci. Model Dev., 15, 5073–5092, 2022

<https://doi.org/10.5194/gmd-15-5073-2022>

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# **Stratospheric Nudging And Predictable Surface Impacts (SNAPSI): a protocol for investigating the role of stratospheric polar vortex disturbances in subseasonal to seasonal forecasts**

Peter Hitchcock<sup>1</sup>, Amy Butler<sup>2</sup>, Andrew Charlton-Perez<sup>3</sup>, Chaim I. Garfinkel<sup>4</sup>, Tim Stockdale<sup>5</sup>, James Anstey<sup>6</sup>, Dann Mitchell<sup>7</sup>, Daniela I. V. Domeisen<sup>8,9</sup>, Tongwen Wu<sup>10</sup>, Yixiong Lu<sup>10</sup>, Daniele Mastrangelo<sup>11</sup>, Piero Malguzzi<sup>11</sup>, Hai Lin<sup>12</sup>, Ryan Muncaster<sup>12</sup>, Bill Merryfield<sup>6</sup>, Michael Sigmond<sup>6</sup>, Baoqiang Xiang<sup>13,14</sup>, Liwei Jia<sup>13</sup>, Yu-Kyung Hyun<sup>15</sup>, Jiyoung Oh<sup>16</sup>, Damien Specq<sup>17</sup>, Isla R. Simpson<sup>18</sup>, Jadwiga H. Richter<sup>18</sup>, Cory Barton<sup>19</sup>, Jeff Knight<sup>20</sup>, Eun-Pa Lim<sup>21</sup>, and Harry Hendon<sup>21</sup>