Stratospheric nudging and predictable surface impacts (SNAPSI): nudging the stratosphere to unravel factors that degrade the representation of stratosphere-troposphere coupling in models in subseasonal forecast systems

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Introduction

- Two-way coupling between the stratosphere and troposphere is recognized as an important source of subseasonal-to-seasonal (S2S) predictability and can provide forecast windows of opportunity.
- Model biases can, however, lead to a poor representation of such coupling processes; at lead times of one to two weeks, drifts in a model's circulation related to model biases, resolution, and parameterizations have the potential to feed back on the circulation and affect stratosphere-troposphere coupling.

Conclusions

- **How far have we come?**
  - Current S2S prediction models have ability to predict the downward impact of the SSW, when the stratospheric anomalies are well predicted (good initial condition, gradual development of SSW).
  - The models have difficulty: (i) capturing an abrupt SSW event, (ii) maintaining SSW anomalies on a S2S timescale.
- **Is the stratosphere important?**
  - YES! Better stratosphere → better surface prediction
  - Although the nudging seems to have no effect on the surface skill in some cases, it is likely because the models are already utilizing the SSW as a predictability source.
- **How far can we go?**
  - By improving the stratosphere (e.g. capture abrupt SSWs), we can expect to reduce surface predictability error (by more than 25% of observed variance in the example of SAT in NH extratropics)
- **Areas for improvement?**
- Both stratospheric state and tropospheric precursors are relevant for the occurrence of SSWs
- Capturing both the tropospheric precursors and the interactions of waves with the stratospheric flow are crucial for the occurrence of SSWs. However, the relative role of each contribution is different depending on the individual event.

Take home message: Nudging the stratosphere can isolate the role of SSWs for surface prediction, and also reveal areas for improvement

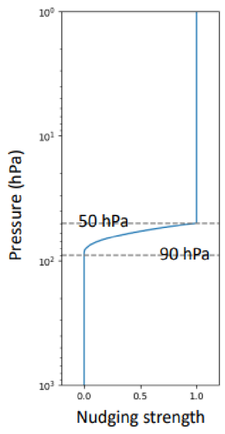
2. Methodology

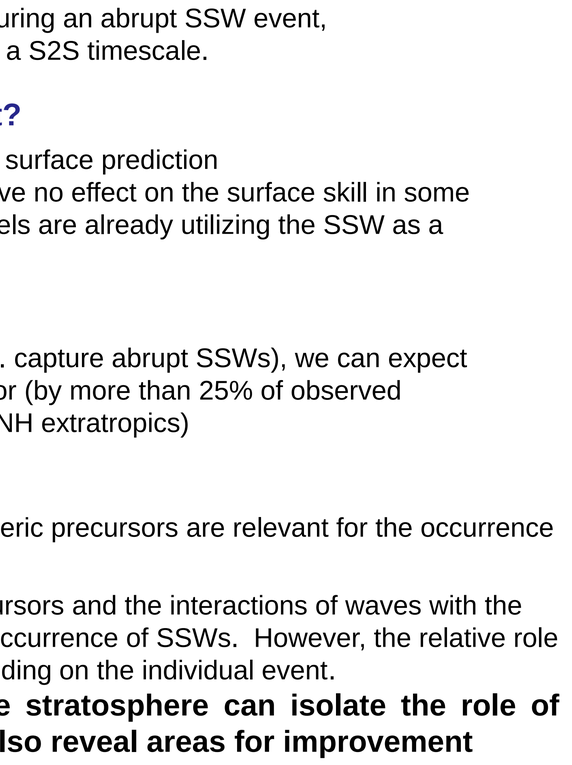
three core types of ensemble forecasts

- **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.

11 models participating, >50 ensemble members





SSW event	Initialization
SSW 2018	01/25/2018
	02/08/2018
SSW 2019	12/13/2018
	01/08/2019
SSW 2019 SH	08/29/2019
	10/01/2019

3. Key research questions

- Why do models differ in the strength of the extratropical response to SSWs? In the predictability of SSW?
- How does nudging affect the upward propagation of planetary waves?
- What is the improvement in surface skill and in the representation of surface extremes from a 'perfect' stratosphere?
- Can improved forecasts of the stratospheric state lead to earlier accurate forecasts of a given extreme event and its impacts?

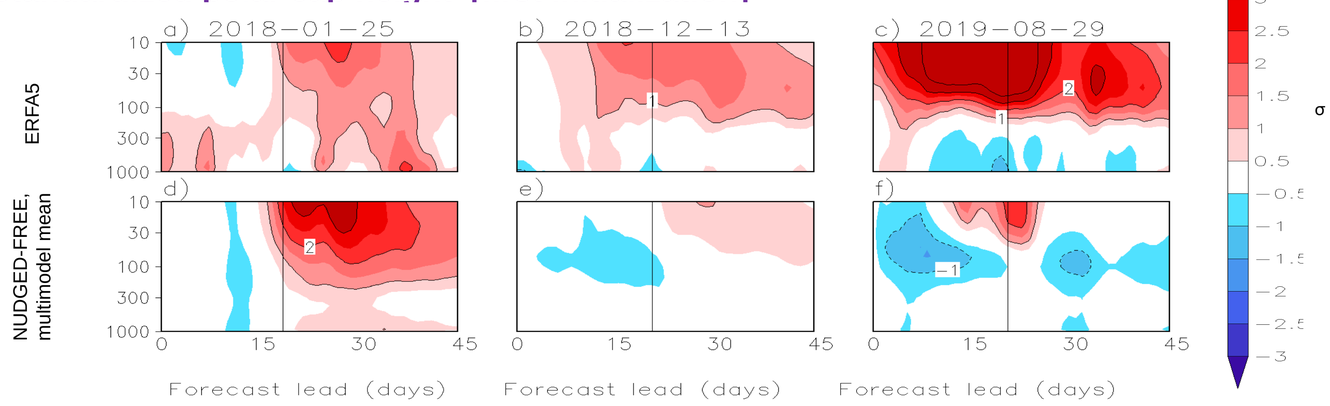
Additional research questions:

- Why does the Quasi-Biennial Oscillation decay in models? Does nudging improve the representation of the propagation of tropical waves?
- What is the impact of SSWs on tropical convection?

6 WGs are analyzing the output and aim to submit papers in 2024

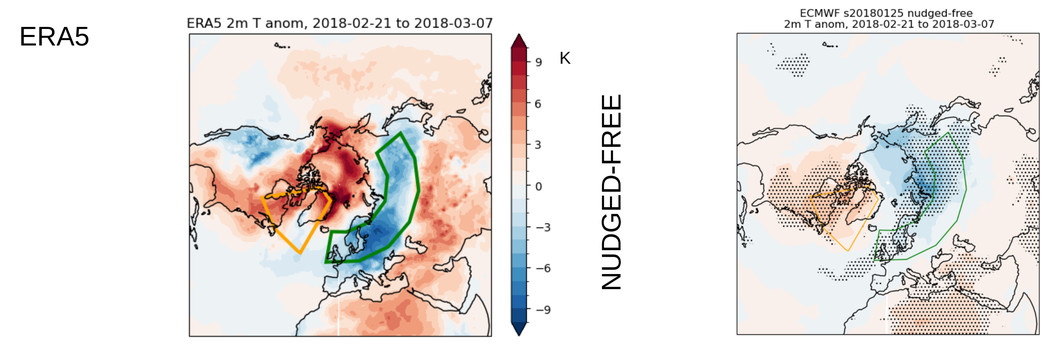
4. Isolating the role of SSWs

Standardized polar cap height [first initialization]



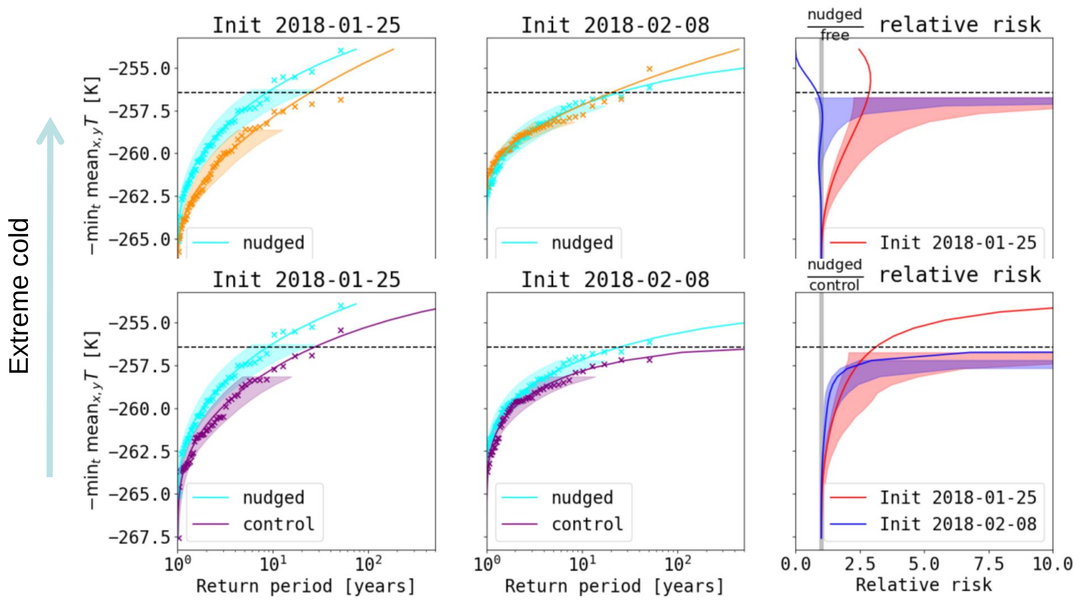
- With stratospheric zonal-mean nudging, tropospheric NAM/SAM is better predicted.

2meter temperature [first initialization, 2018 SSW]



5. Impact on Extremes

Eurasian Temperature



For long-lead forecasts, risk of extreme cold is ~3x higher in nudged than free, but at for short leads risks are roughly equivalent.

However, nudged risk is higher than control for both initialisations, indicating a continuing role for the stratosphere in driving cold spell risk.

Figure:Justin Finkel

Australian Hot-Dry-Windy wildfire index (Srock et al 2019)

$$\text{FAR} = 1 - \frac{\text{control risk}}{\text{nudged risk}}$$

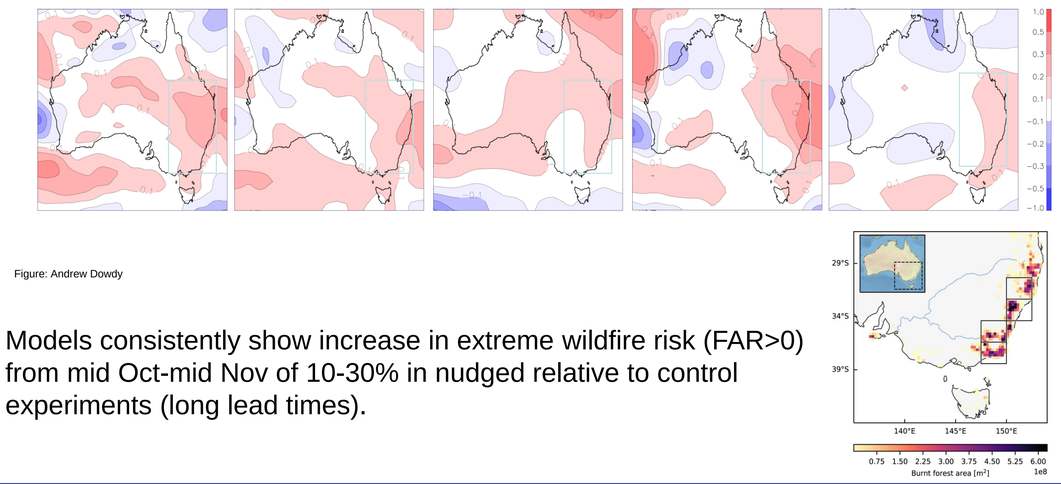
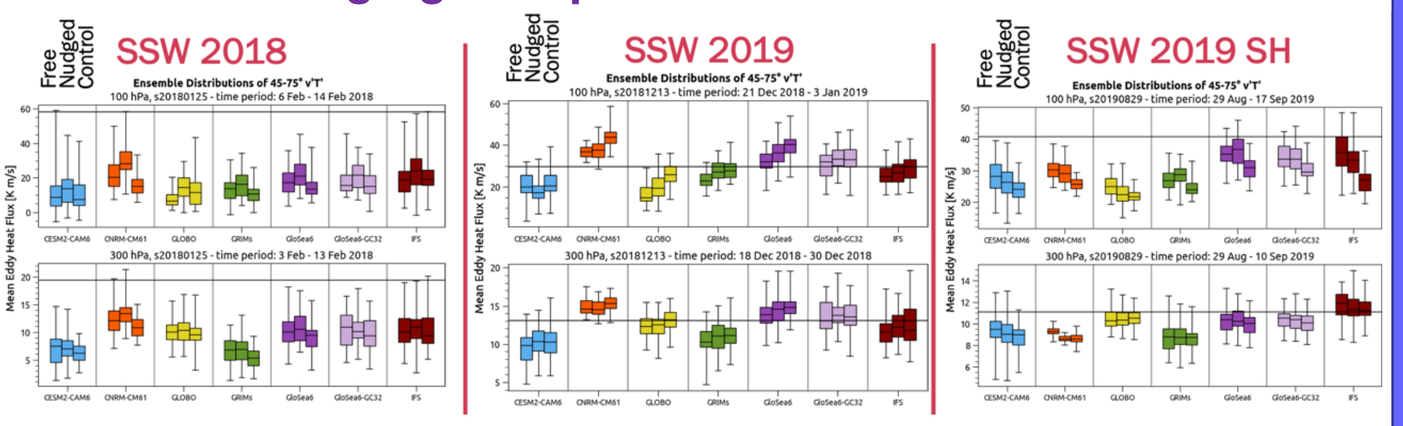


Figure: Andrew Dowdy

Region of increased risk aligns with region of observed wildfires (Squire et al. 2021).

Models consistently show increase in extreme wildfire risk (FAR>0) from mid Oct-mid Nov of 10-30% in nudged relative to control experiments (long lead times).

6. Role of nudging for upward wave flux



- Similar results in FREE, NUDGED and CONTROL experiments in the upper troposphere, but different in the stratosphere → isolates role of the stratospheric state for stratospheric wave activity.
- SSW2018: Differences in the zonal mean stratospheric state cannot explain the large FREE deviations from reanalysis→ tropospheric precursors and zonally asymmetric stratospheric state are also important
- SSW2019: CONTROL has largest 100hPa heat flux values → only CONTROL still has a vortex to allow wave propagation
- SSW2019SH: CONTROL has weakest heat flux values → ducts waves away