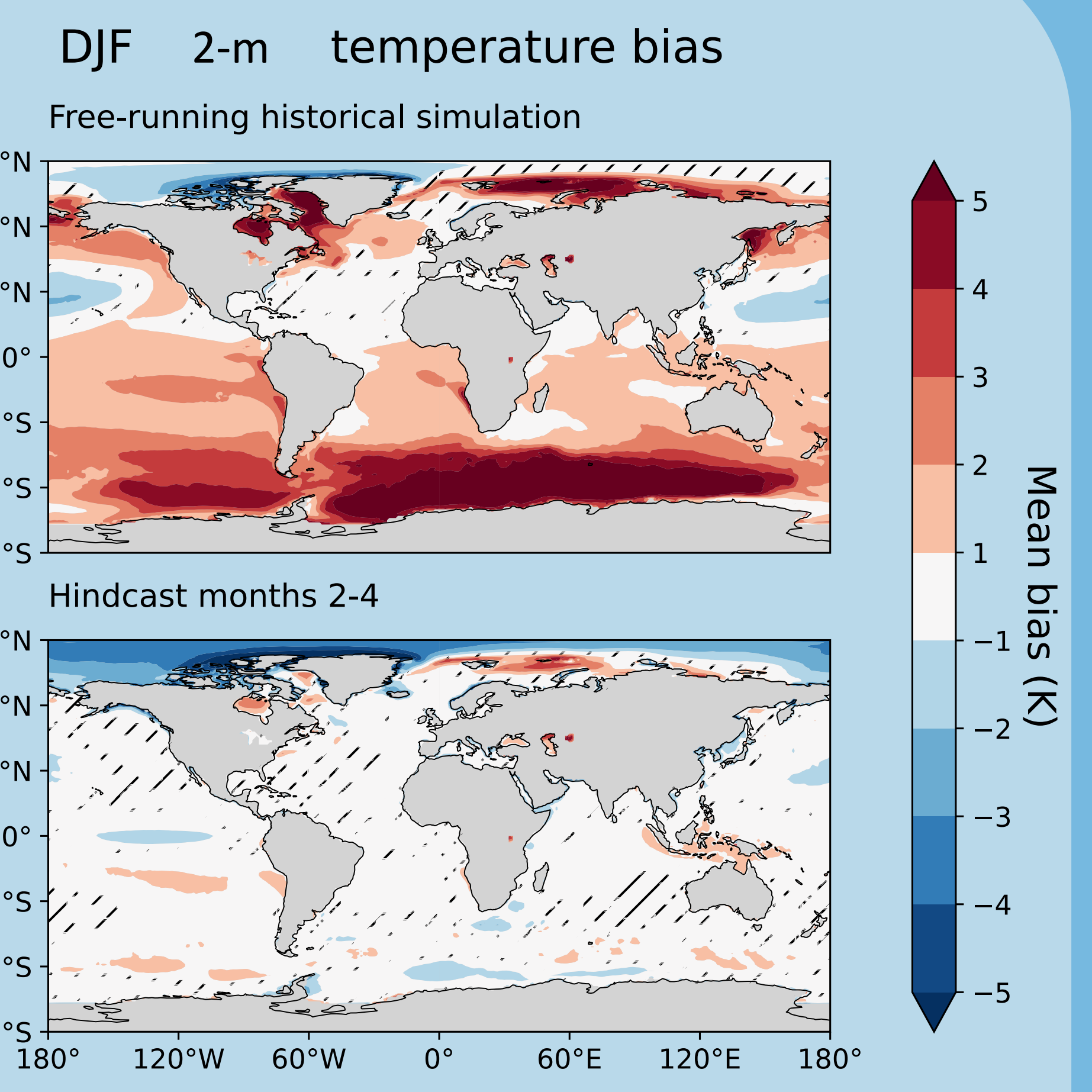
Hindcast-based estimates of recent climate trends

Rhidian Thomas[1], Tim Woollings[1], Nick Dunstone[2]

[1]University of Oxford, Atmospheric, Oceanic, and Planetary Physics
[2]Met Office Hadley Centre, Exeter, UK



Oceanic T_{2m} bias (model minus ERA5) for two instances of HadGEM3-GC2.
Top: free-running simulation with historical forcing
Bottom: the same model, but run in hindcast configuration, with frequent reinitialization from observations.

1. Introduction and aims

Free-running coupled simulations often struggle to reproduce observed trends in the atmosphere on large scales.

One reason for this is mean biases that develop as the model drifts towards a preferred state and away from the initial conditions.

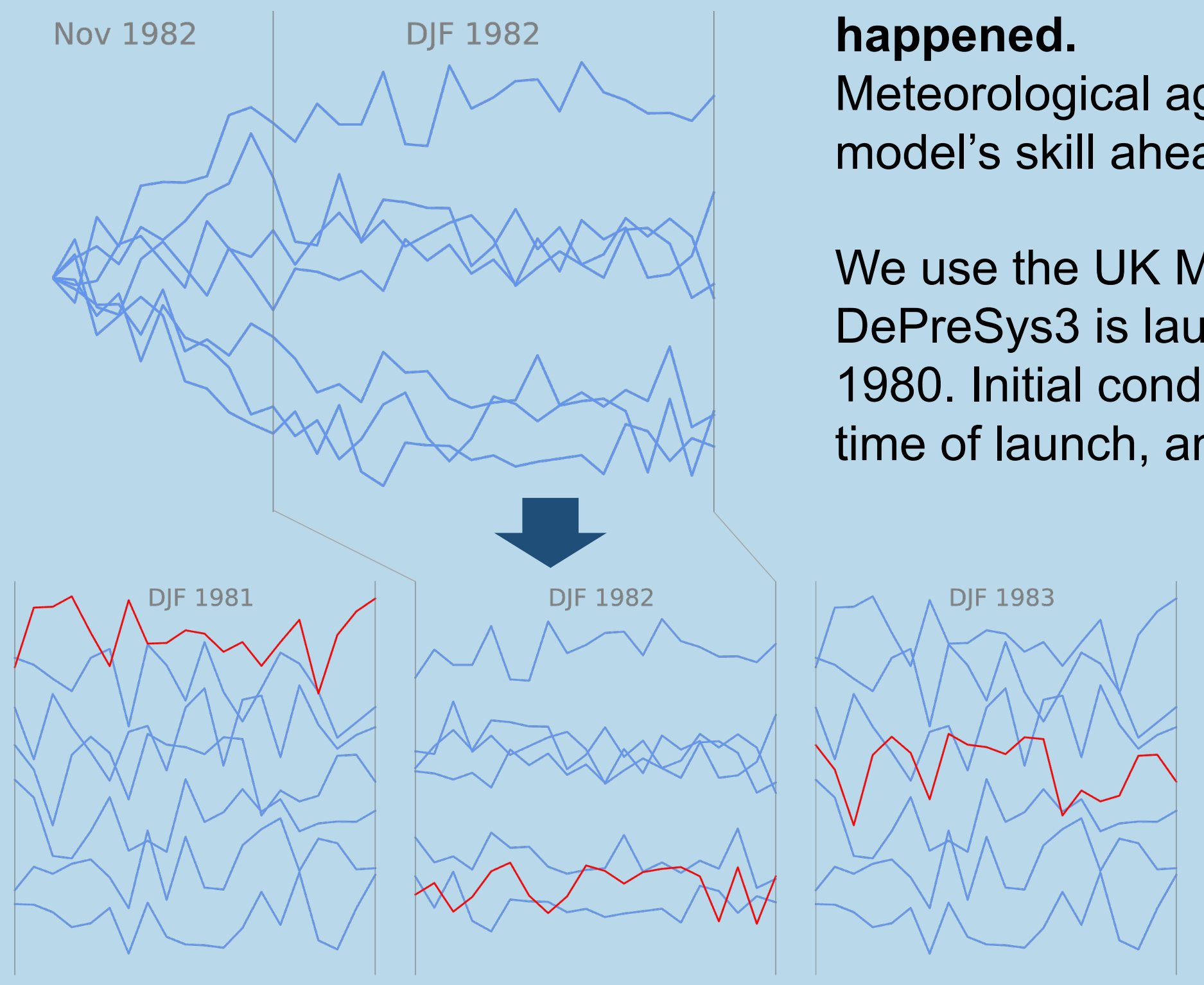
In seasonal and decadal forecasts, biases are minimised by combining (1) high resolution models, (2) large ensembles, and (3) short lead times following initialisation.

Can hindcasts bridge the gap between observations and free-running models?

2. Research questions

- Do coupled hindcasts capture present-day **trends in reanalyses**?
- How do the hindcast trends compare to **free-running models**? Do they share similar biases in their trends relative to observed changes?

3. Long-term trends using near-term hindcasts



A hindcast is a forecast of something that has already happened.
Meteorological agencies routinely use hindcasts to validate their model's skill ahead of forecasting the future.

We use the UK Met Office's DePreSys3 decadal prediction model. DePreSys3 is launched twice annually (1st May, 1st Nov) since 1980. Initial conditions are derived from observed conditions at the time of launch, and each simulation lasts less than 55 months.

How can we study multidecadal trends using these short simulations?
Instead of calculating trends within a single simulation, we instead **treat each run as a snapshot in time**; the long-term trend is then calculated over successive snapshots.

40 members are launched per start date, and members in successive launches are unrelated to each other.

Above: by randomly selecting a single member (red) from each launch, we build a bootstrapped distribution of 10,000 possible trends consistent with the hindcasts.

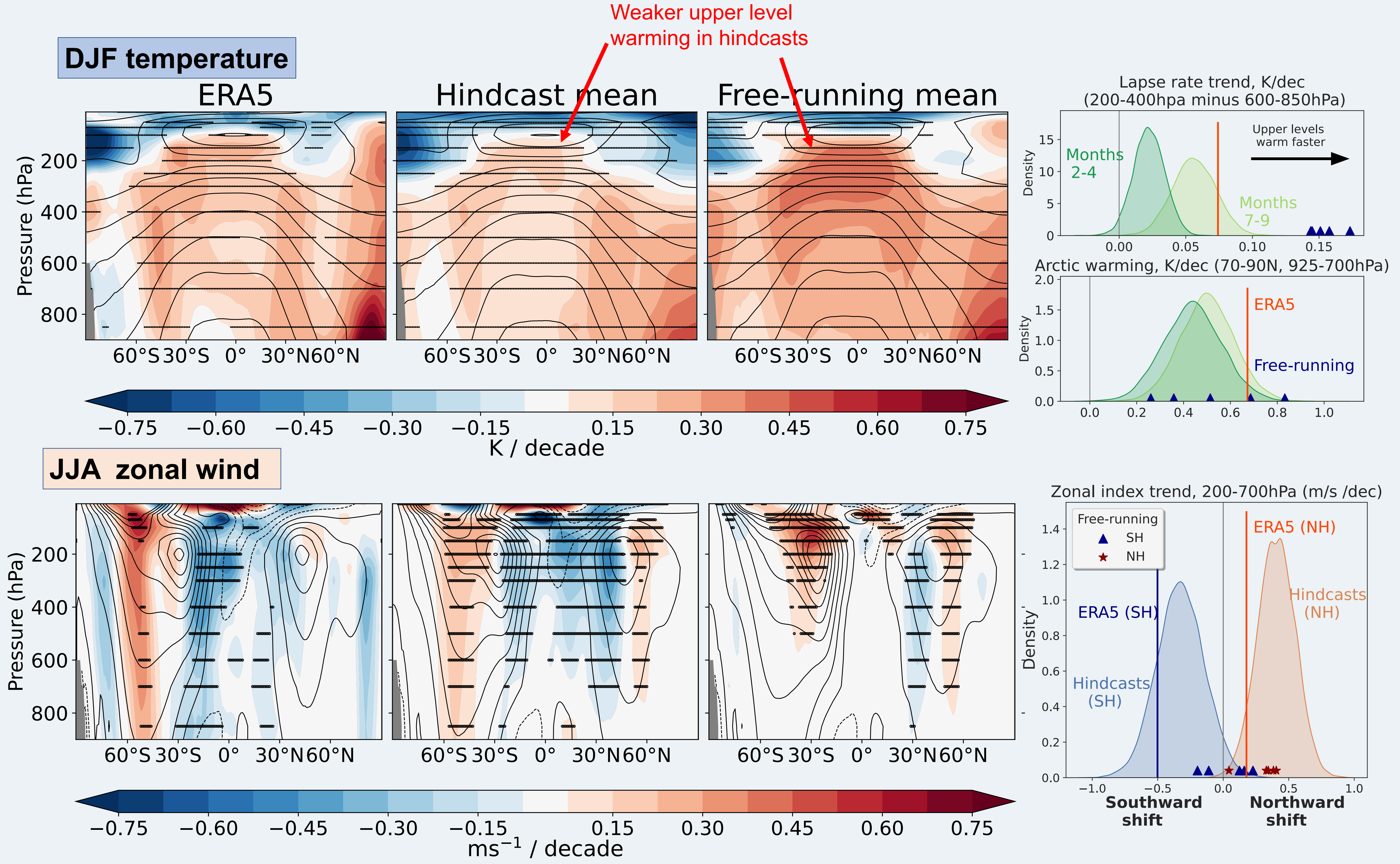
Summary

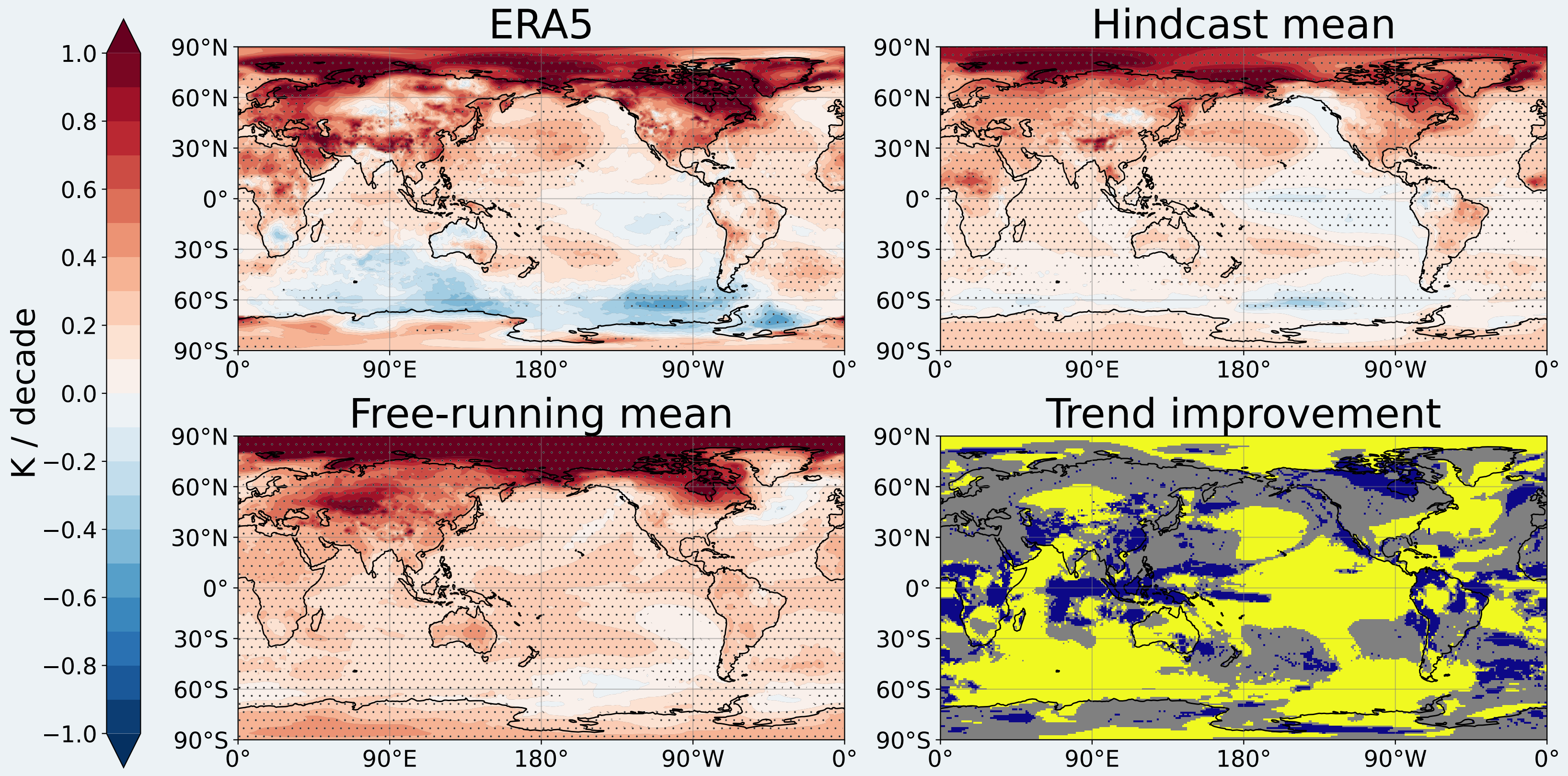
- Trends in the Met Office's decadal hindcasts often, but not always, agree better with ERA5 than the equivalent free-running model does.
- Initialisation is a strong constraint on trends in the tropics; on the other hand, internal variability contributes substantially to trends at high latitudes, even a short time after the initialisation.
- Trend biases in the tropical lapse rate and Pacific SST gradient are reduced in the hindcasts, while Southern Ocean cooling remains a challenge even at short lead times.

4. Results

Right: DJF $\langle T \rangle$ and JJA $\langle U \rangle$ trends, 1981-2022

- In the **tropical upper troposphere**, the hindcasts warm much less than the free-running model for lead times of at least 7 months.
- DJF **Arctic amplification** is similar in the hindcasts and the free-running model, with a wide spread in each.
- Hindcasts capture the structure of the ERA5 **SH winter wind trends** better than the free-running model.





Left: DJF T_{2m} trends, 1981-2022

In the bottom right plot, yellow indicates where 97.5% of the hindcast trends agree better with ERA5 than the free-running model does.

- The trend bias relative to ERA5 is reduced over most ocean basins.
- The hindcasts capture the strengthening **tropical Pacific SST gradient**, but the magnitude of **Southern Ocean** cooling remains a challenge, even at short lead times.
- ERA5's **Eurasian cooling** trend is better represented in the hindcasts than the free-running model.

Comments and feedback welcomed!
rhidian.thomas@physics.ox.ac.uk