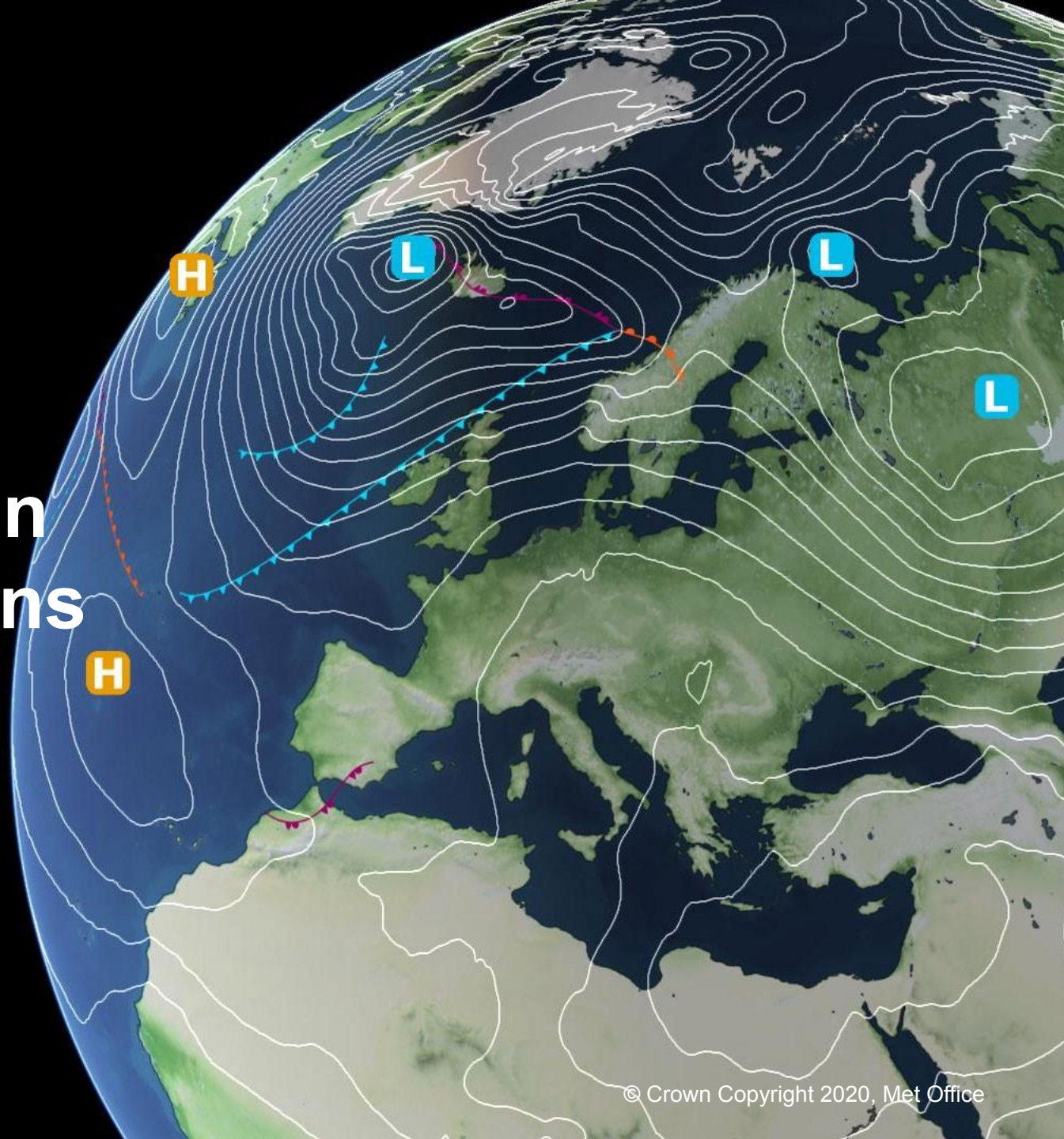
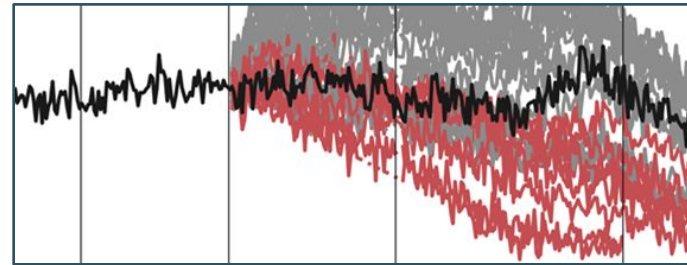


# Utilising ensembles to predict slowdown of the Atlantic Meridional Overturning Circulation in coupled model simulations

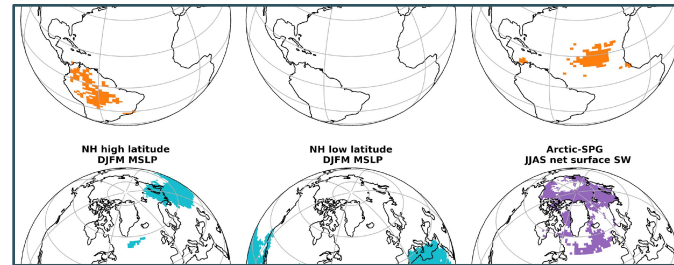
Kuniko Yamazaki, Laura C Jackson and David MH Sexton



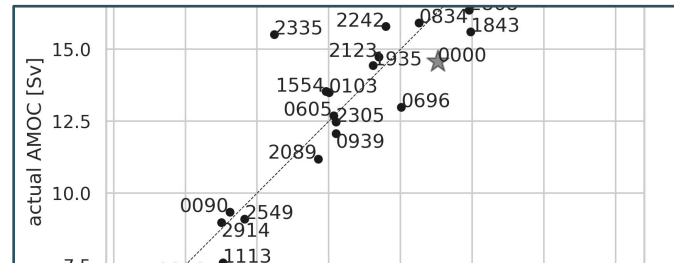
# We used a perturbed parameter ensemble (PPE) to identify the drivers of and predict the strength of the Atlantic Meridional Overturning Circulation (AMOC) in the PPE



Problems with AMOC slowdown in a PPE



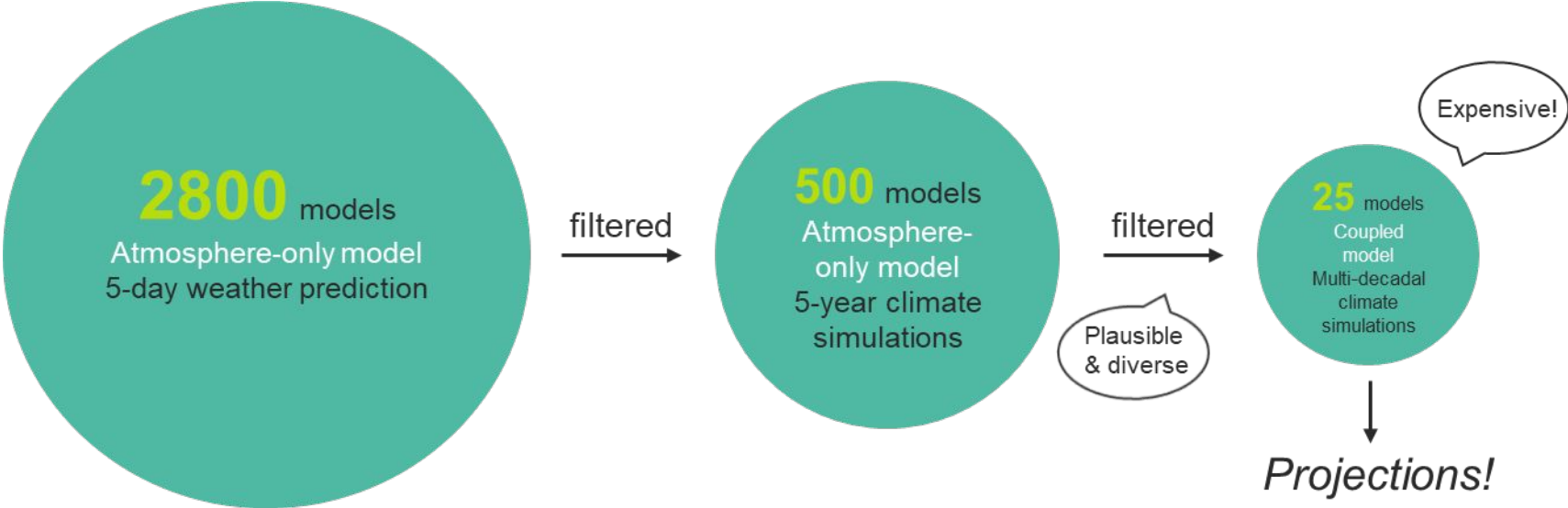
How to identify drivers of the AMOC strength



How to predict the AMOC strength and filter on it

# UKCP18 project used PPE experiments to make projections of UK and global climate

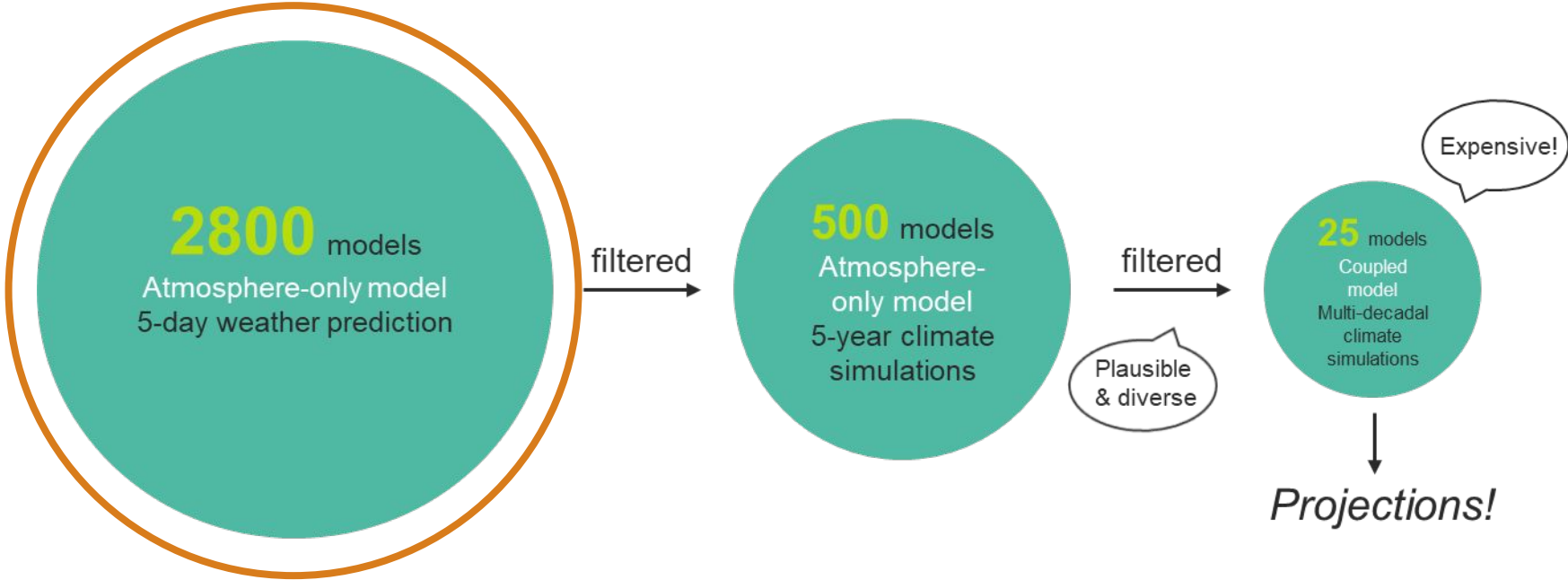
47 atmosphere and land-use model parameters were perturbed



Yamazaki et al. 2021, Sexton et al. 2021

# UKCP18 project used PPE experiments to make projections of UK and global climate

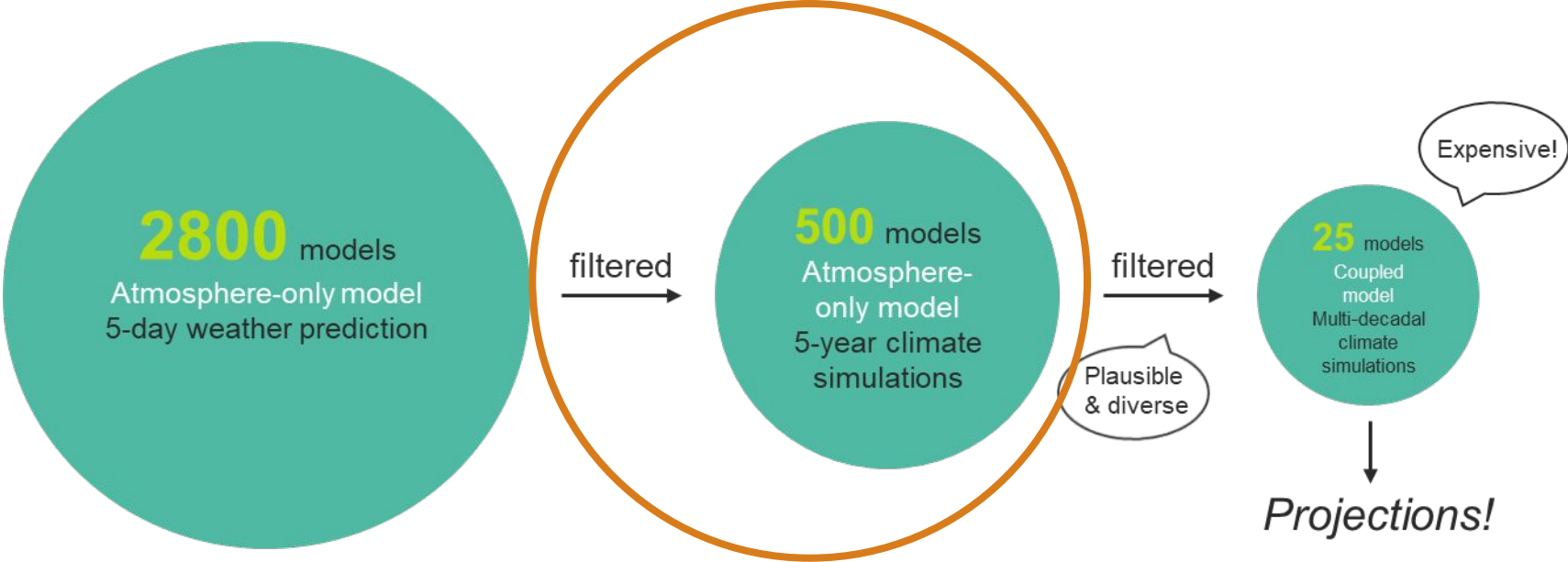
47 **atmosphere** and **land-use** model parameters were perturbed



Yamazaki et al. 2021, Sexton et al. 2021

# UKCP18 project used PPE experiments to make projections of UK and global climate

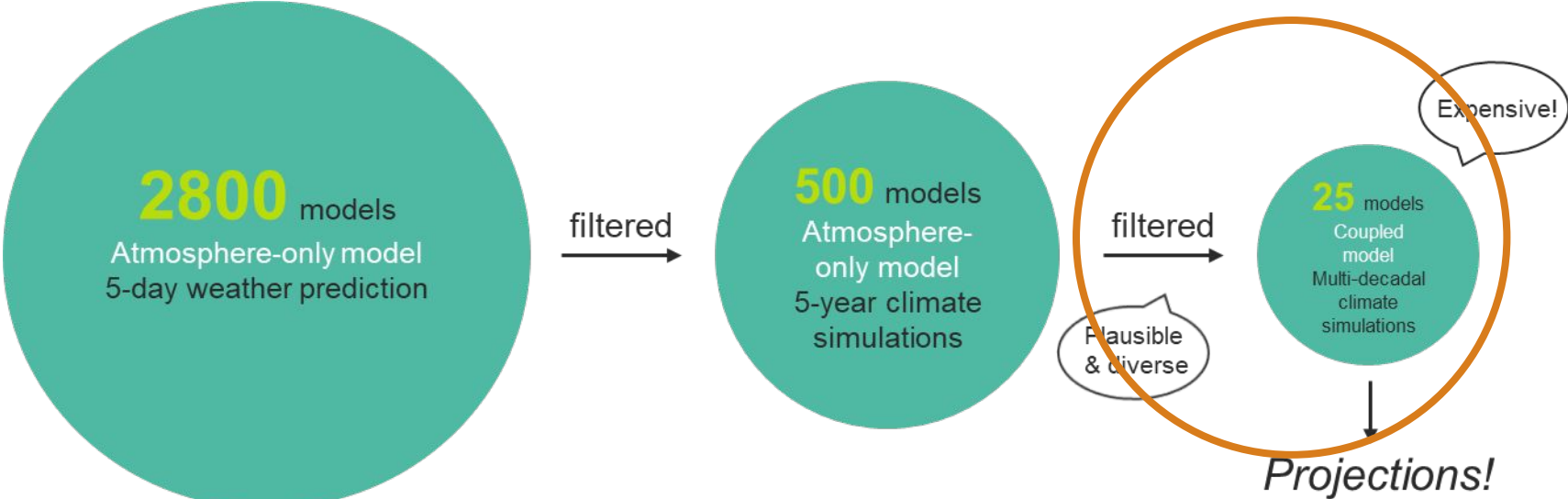
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Yamazaki et al. 2021, Sexton et al. 2021

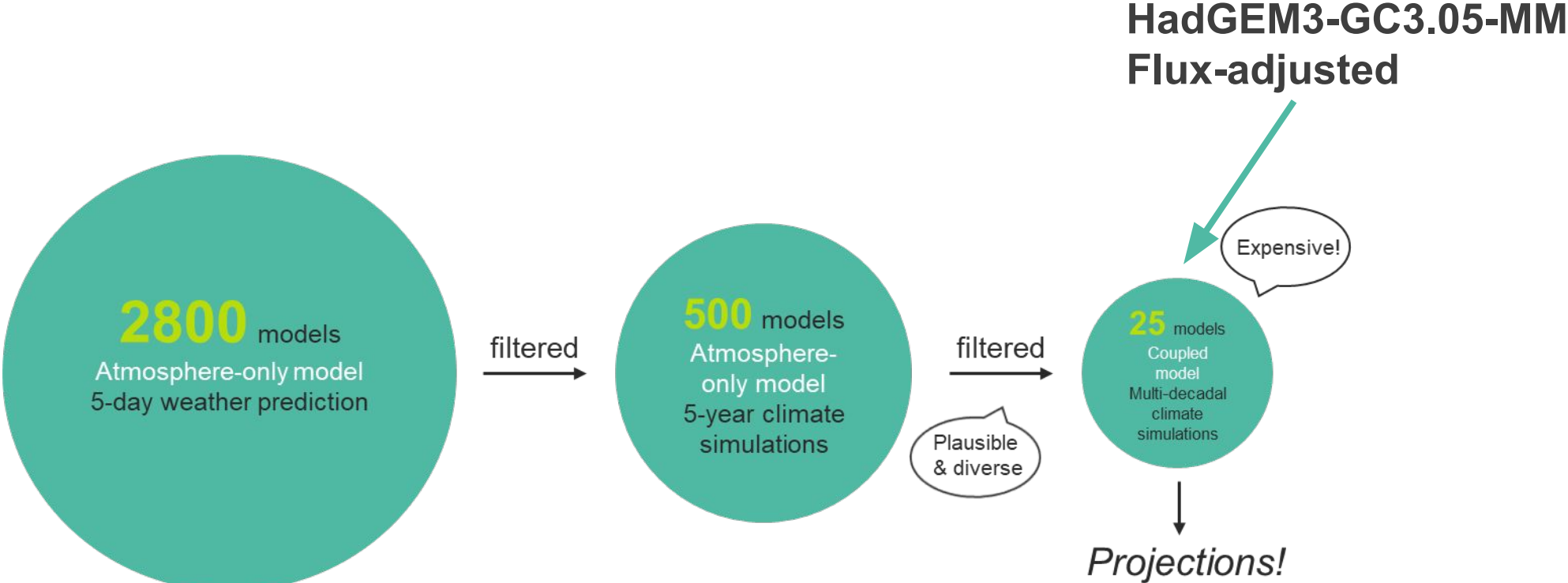
# UKCP18 project used PPE experiments to make projections of UK and global climate

47 atmosphere and land-use model parameters were perturbed



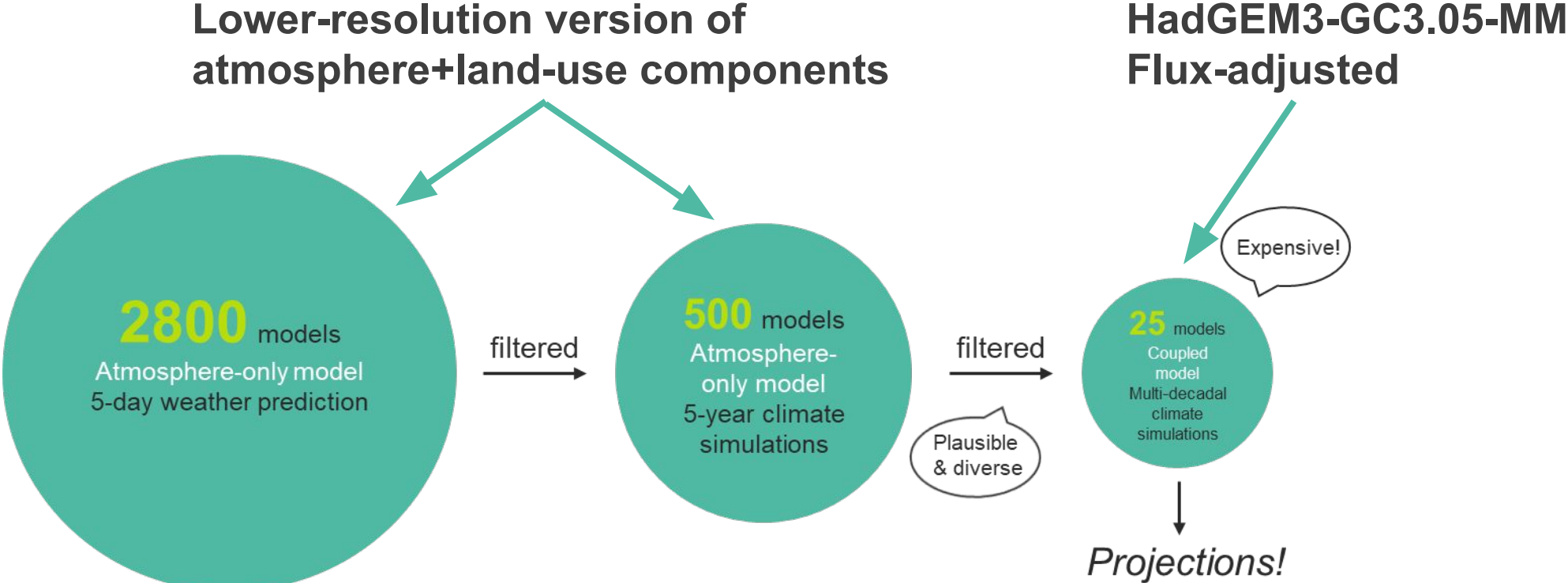
Yamazaki et al. 2021, Sexton et al. 2021

# UKCP18 project used PPE experiments to make projections of UK and global climate



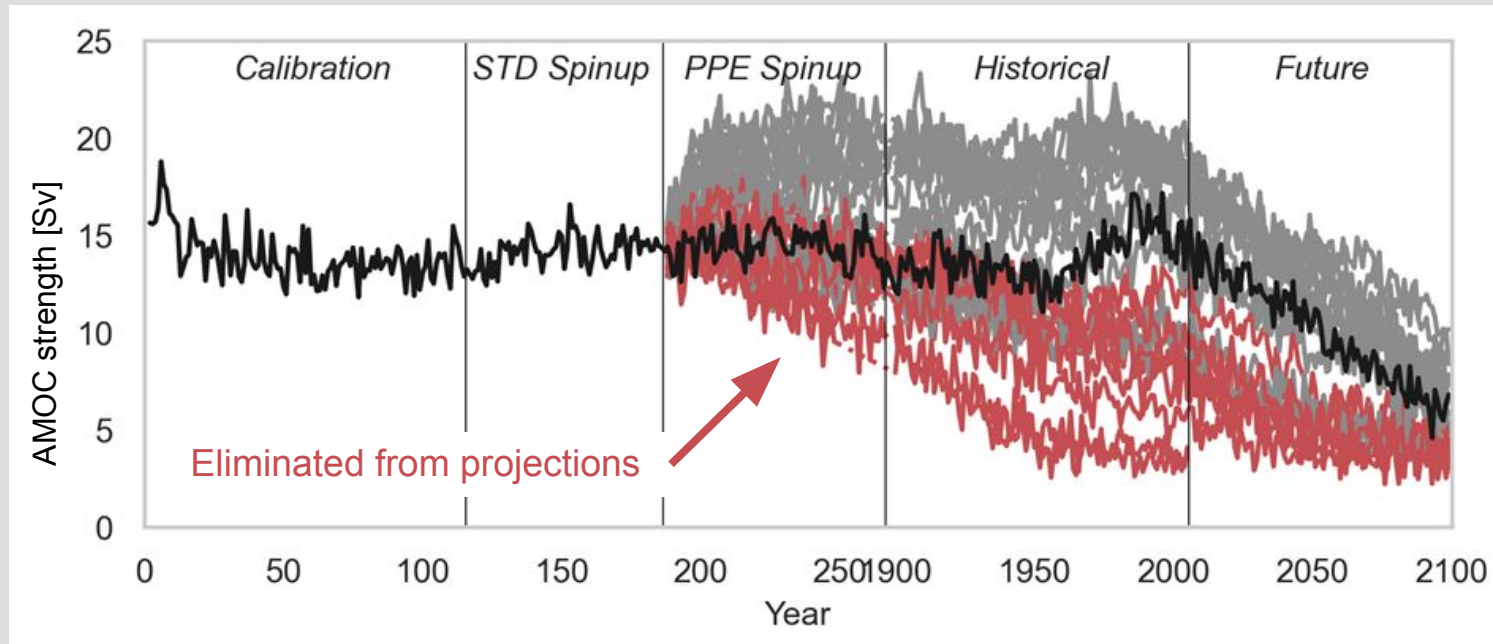
Yamazaki et al. 2021, Sexton et al. 2021

# UKCP18 project used PPE experiments to make projections of UK and global climate

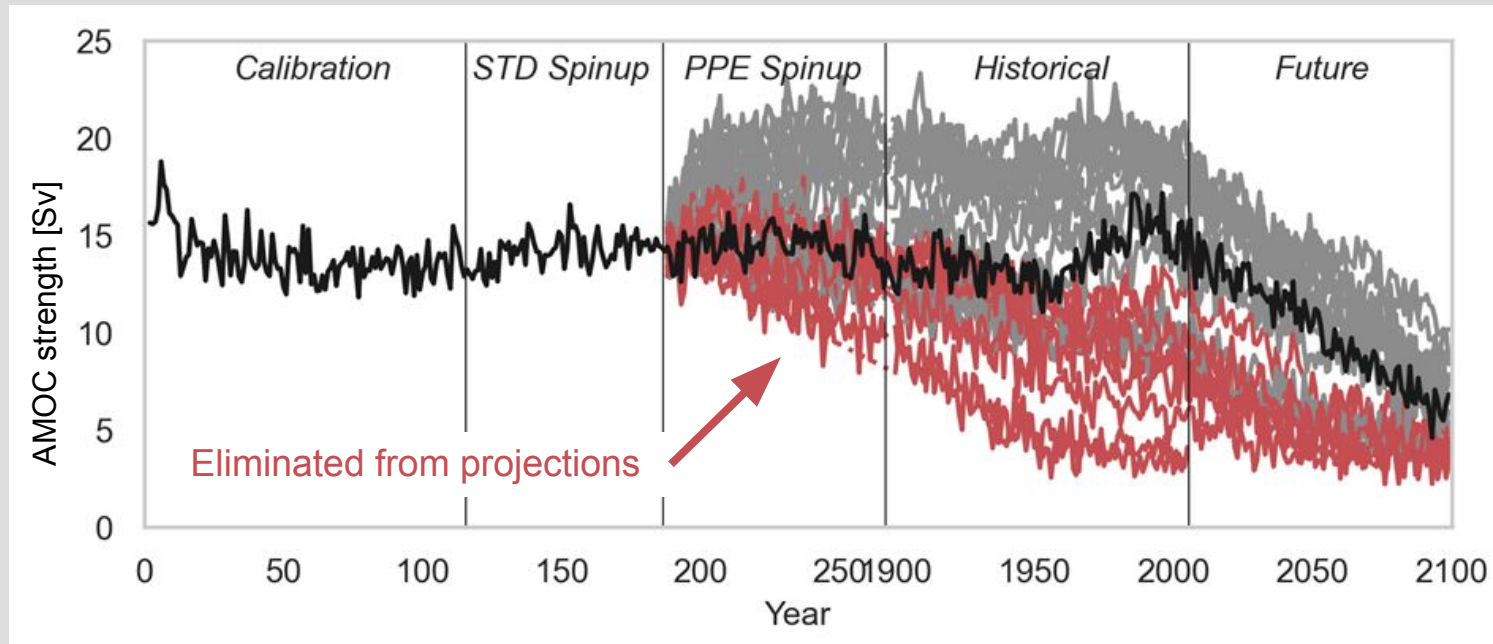


Yamazaki et al. 2021, Sexton et al. 2021

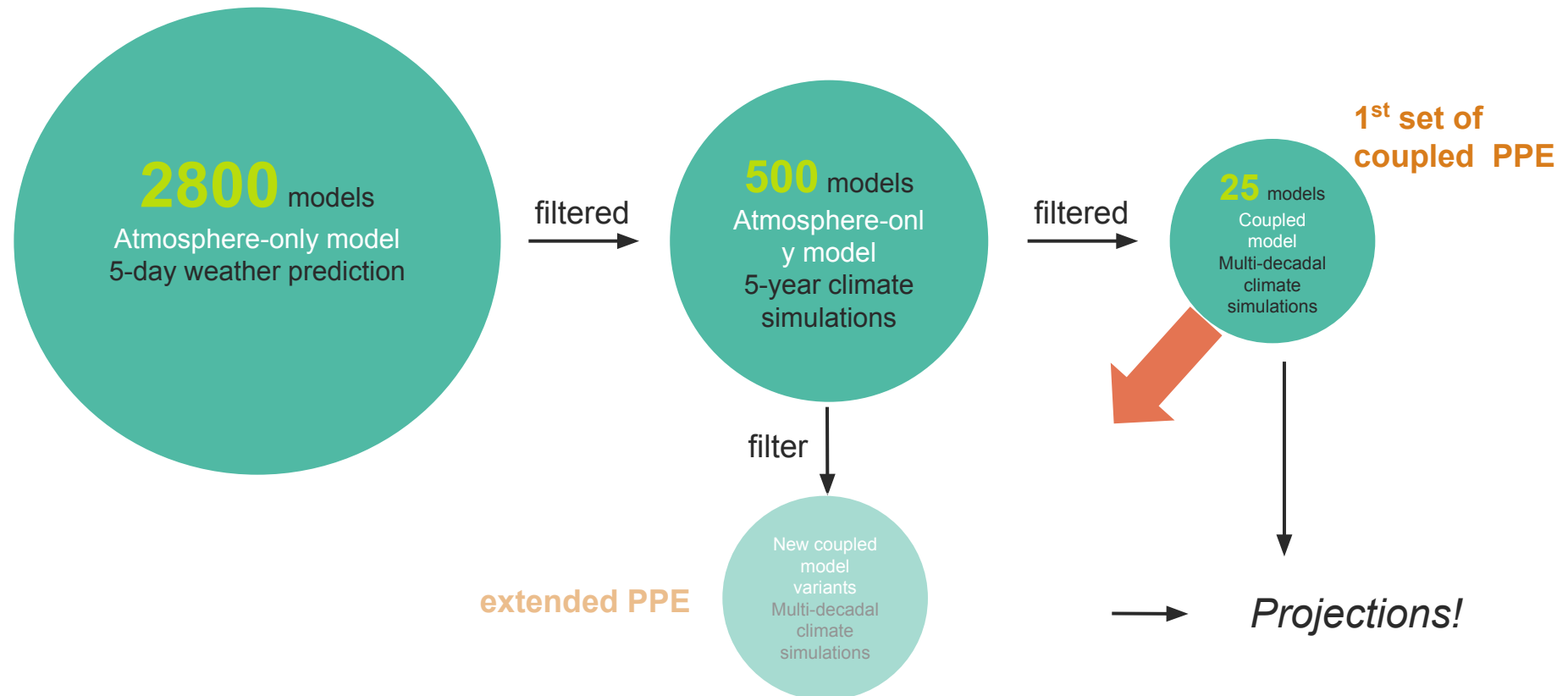
**Problem:** When coupled, AMOC weakened unrealistically in some PPE members, rendering them unusable for projections



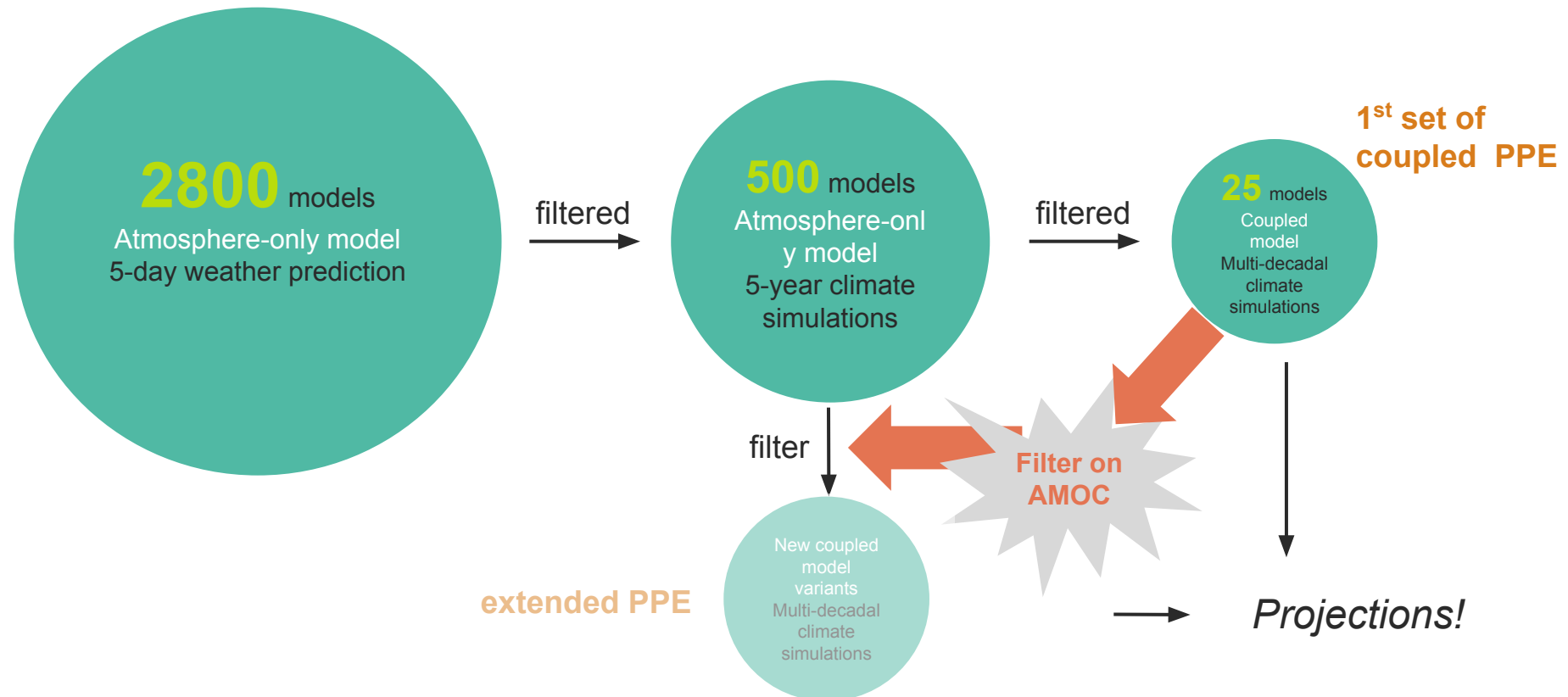
# Possible improvement: Consider coupled response during the parameter selection process



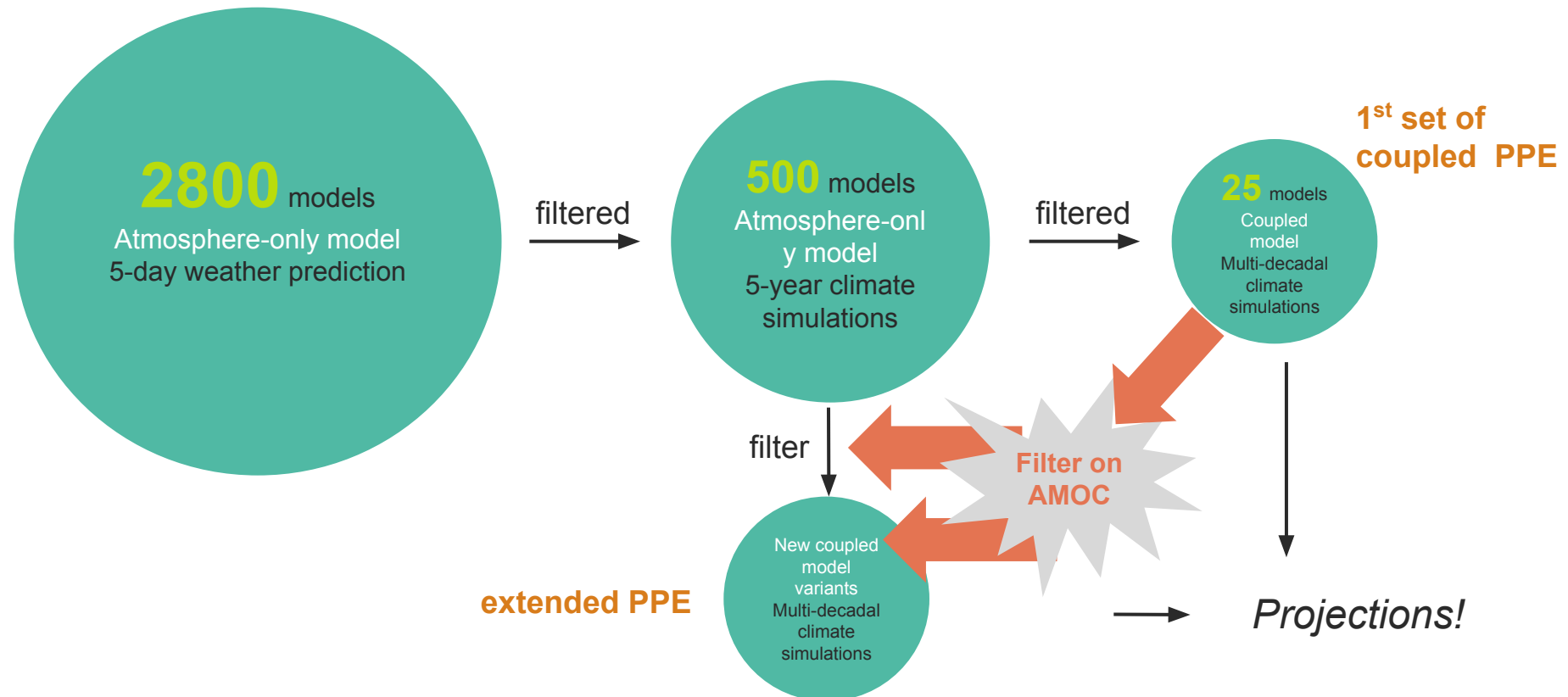
# Q: Can we utilise data from the first set of coupled PPE to predict AMOC and inform filtering when building an extended PPE?



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We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength

**Identify drivers**  
of AMOC  
strength

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**Identify drivers**  
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Build a  
**predictive**  
**model** trained  
on drivers

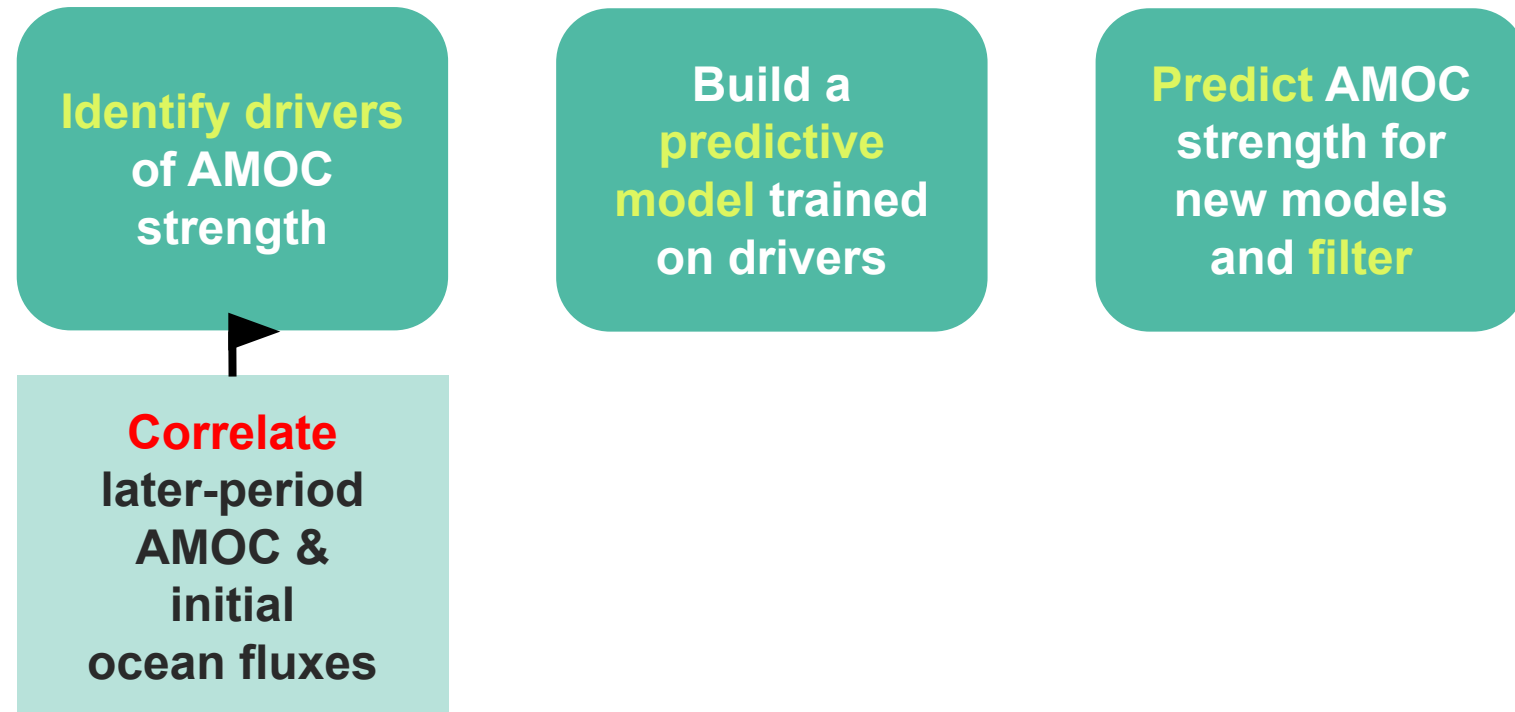
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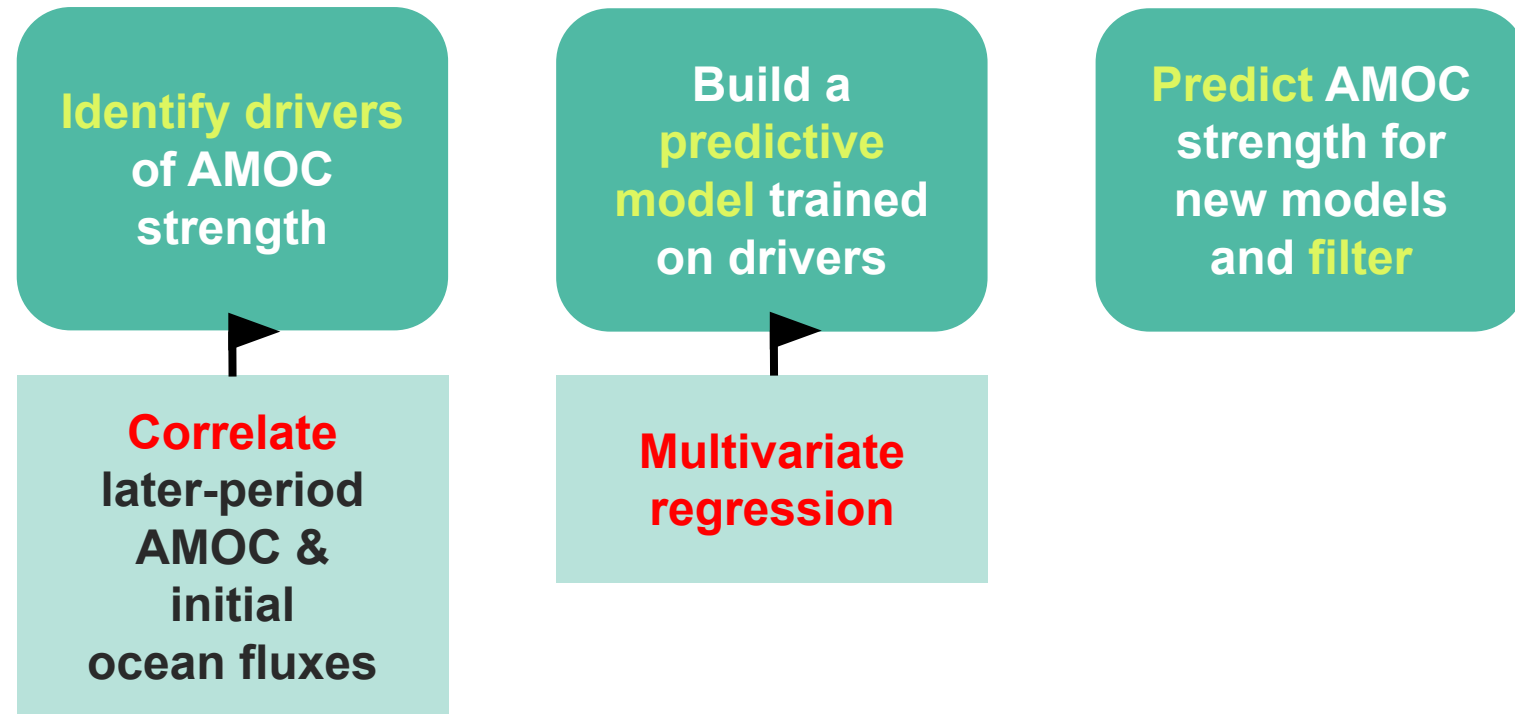
**Predict** AMOC  
strength for  
new models  
and **filter**

# We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength



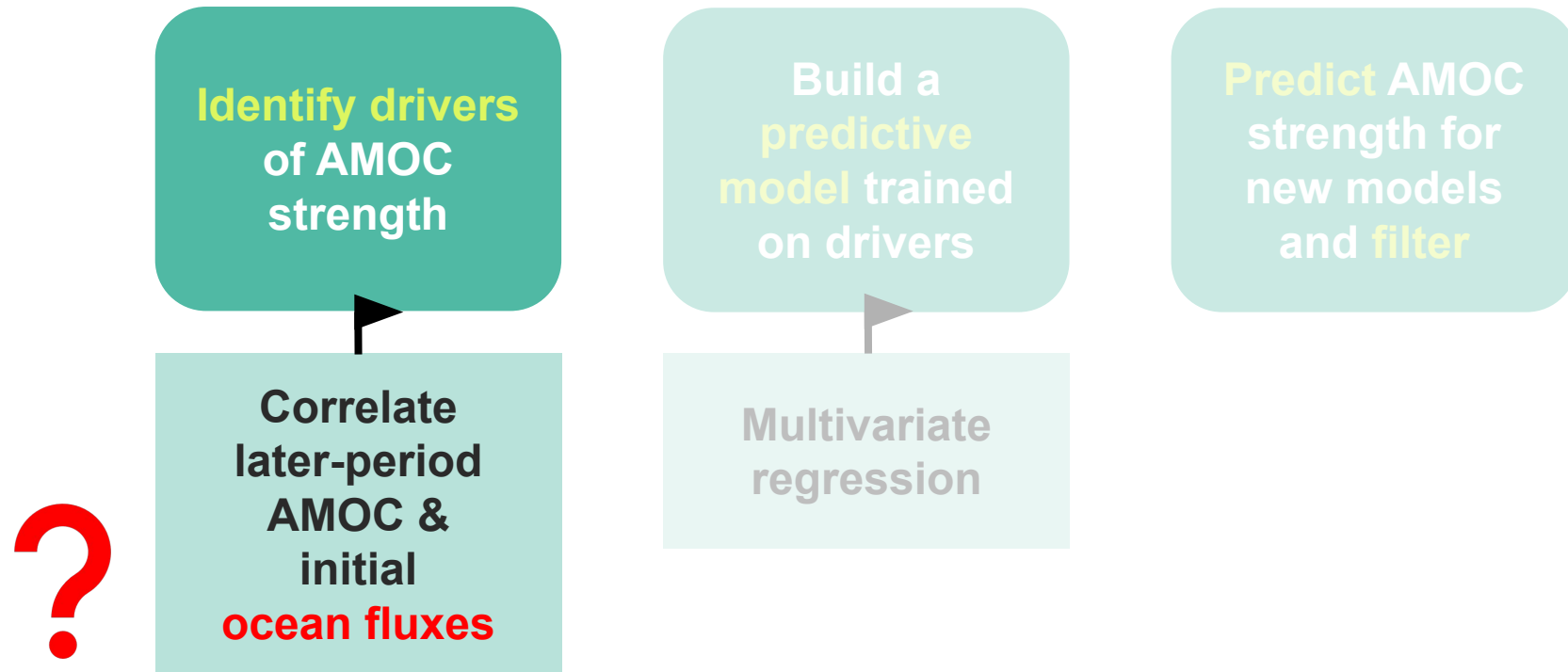
Yamazaki, Jackson and Sexton, 2024

# We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength



Yamazaki, Jackson and Sexton, 2024

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Yamazaki, Jackson and Sexton, 2024

# We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength

In the ocean model, only **boundary conditions** (= ocean fluxes) **differed** among PPE members



**Identify drivers** of AMOC strength

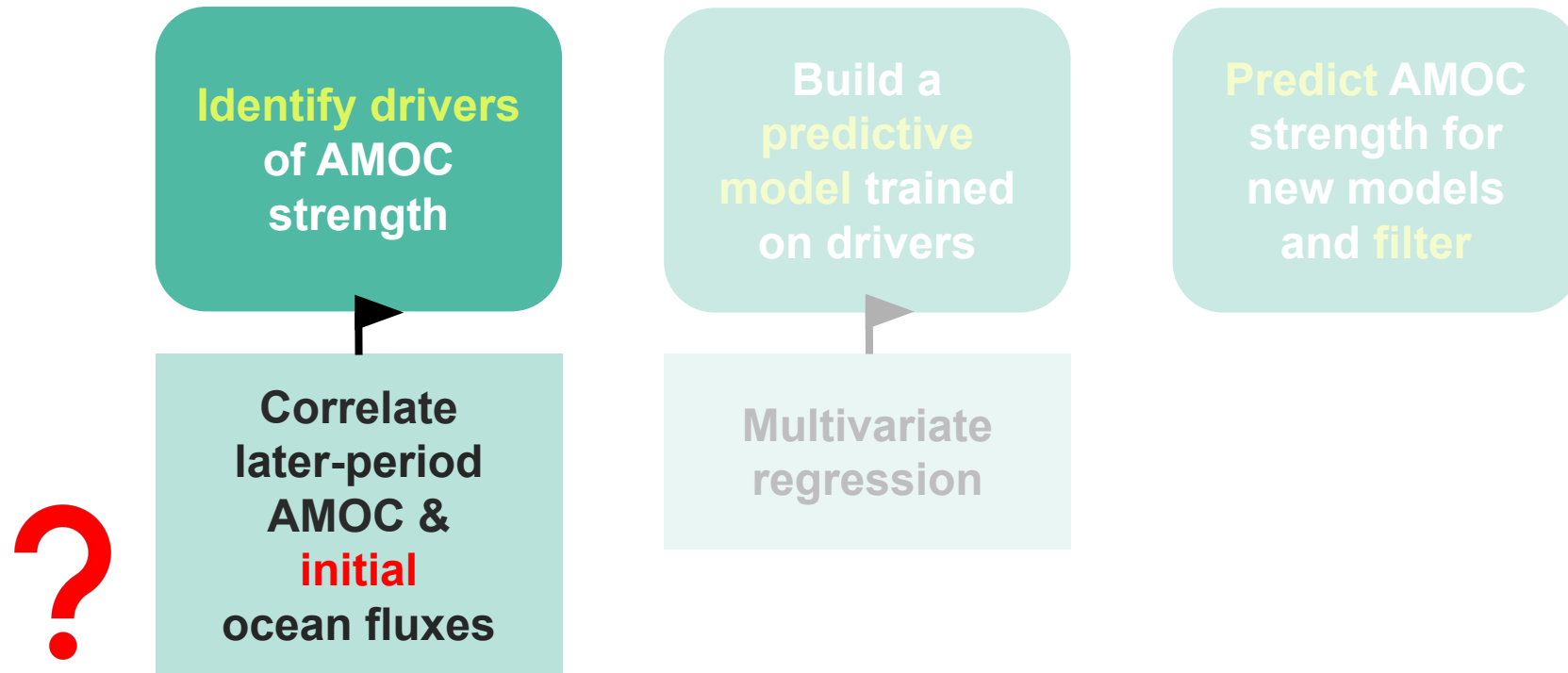
Correlate later-period AMOC & initial **ocean fluxes**

Build a **predictive model** trained on drivers

Multivariate regression

**Predict** AMOC strength for new models and **filter**

# We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength



Yamazaki, Jackson and Sexton, 2024

# We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength

Used **initial** ocean fluxes **before other feedbacks** kicked in and confused the picture



**Identify drivers** of AMOC strength

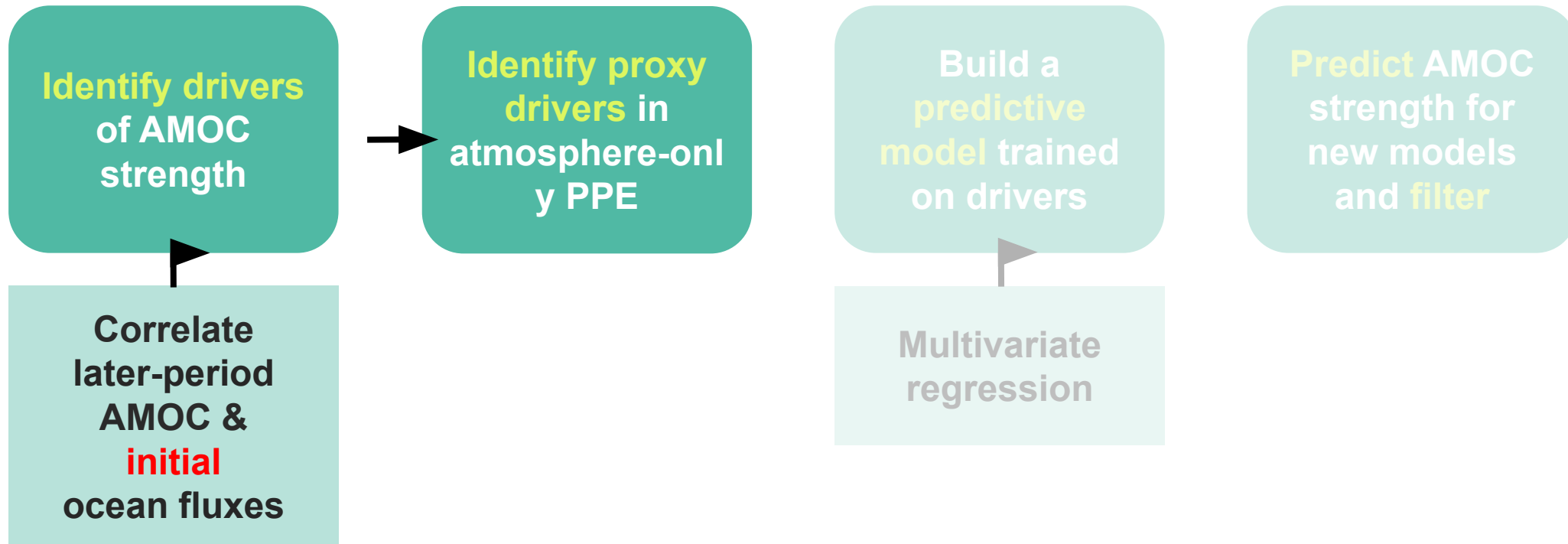
Correlate later-period AMOC & **initial** ocean fluxes

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**Predict** AMOC strength for new models and **filter**

# We propose a 4-step approach using simple statistical methods to **identify drivers** of and to **predict** AMOC strength



We applied this method to a **lower-resolution PPE** (HadGEM3-GC3.1-**LL**) with the **25 members** with the same **parameter perturbations** as the MM PPE

Motivation was to **extend the size** of the coupled **LL PPE**

# Step 1&2 Result: 6 key drivers of AMOC strength were identified

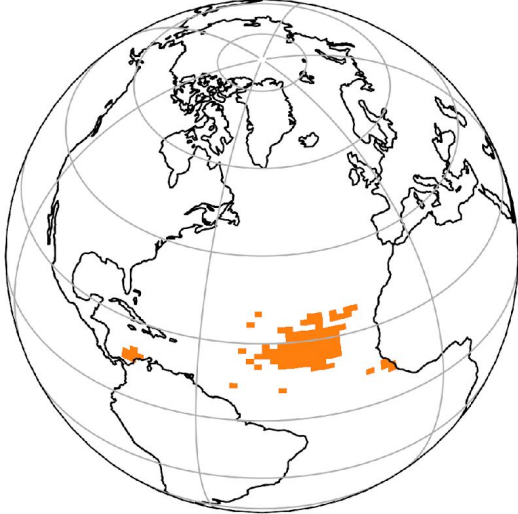
Amazon-Orinoco River Basin  
annual precip - evap



Labrador Sea  
annual precip - evap



Tropical N Atlantic  
annual precip - evap



Precip - evap

NH high latitude  
DJFM MSLP

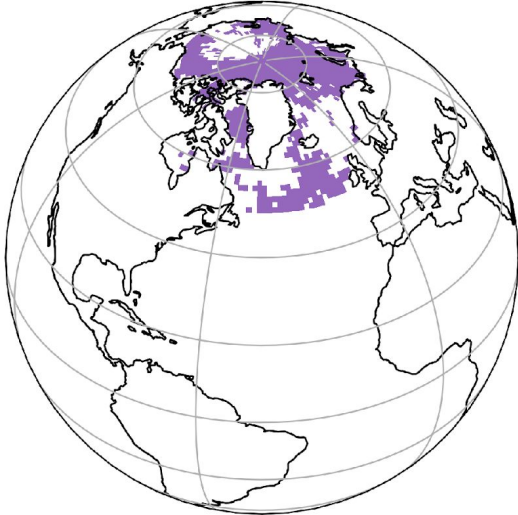


NH low latitude  
DJFM MSLP



Winter  
mean sea level  
pressure

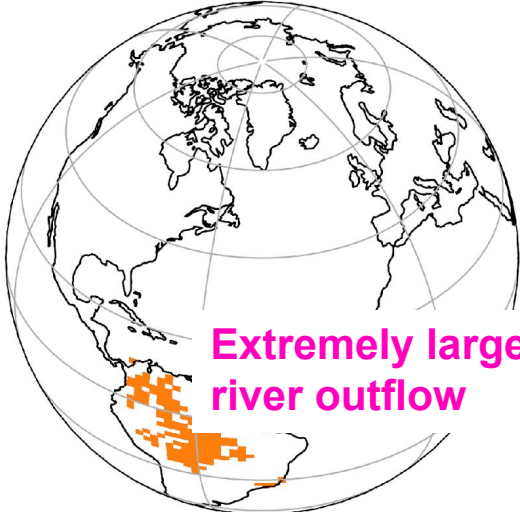
Arctic-SPG  
JJAS net surface SW



Summer  
surface net  
downward SW

# Step 1&2 Result: 6 key drivers of AMOC strength were identified

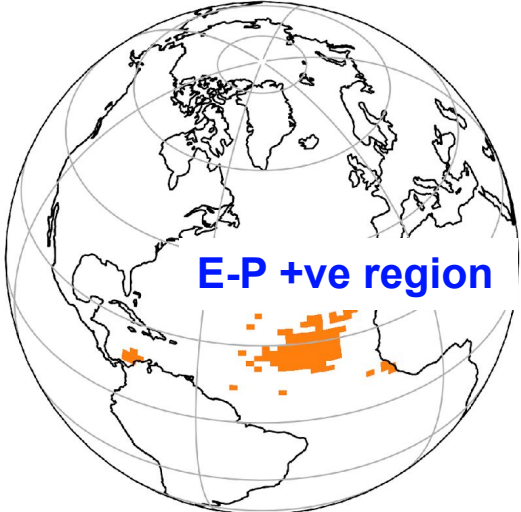
Amazon-Orinoco River Basin  
annual precip - evap



Labrador Sea  
annual precip - evap



Tropical N Atlantic  
annual precip - evap



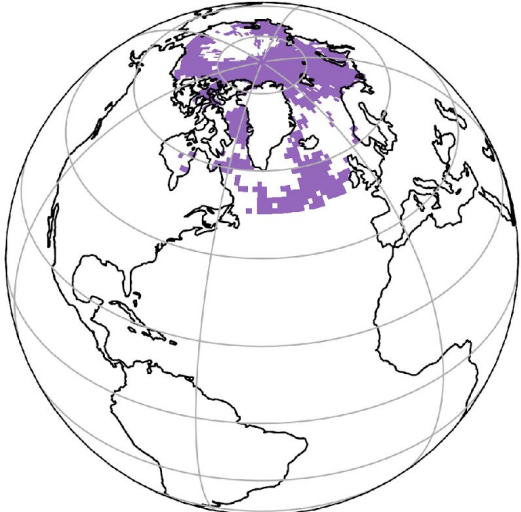
NH high latitude  
DJFM MSLP



NH low latitude  
DJFM MSLP



Arctic-SPG  
JJAS net surface SW



**Step 3.1: Using proxy drivers from atmosphere-only PPE data that represent coupled surface fluxes, built multivariate regression model to predict AMOC strength**

$$Y_{AMOC} = \beta_0 + \sum_i^6 \beta_i X_i$$

where

$i = 1$ : annual precip – evap in Amazon-Orinoco River Basin

$i = 2$ : annual precip – evap in Labrador Sea

$i = 3$ : annual precip – evap in Tropical North Atlantic

$i = 4$ : DJFM mean sea level pressure in NH high-latitudes

$i = 5$ : DJFM mean sea level pressure in NH low-latitudes

$i = 6$ : JJAS surface net SW in Arctic and SPG region

## Step 3.2: Stepwise regression reduced the number of predictors in the multivariate regression model to 3

$$Y_{AMOC} = \beta_0 + \sum_i^3 \beta_i X_i$$

where

$i = 1$ : annual precip – evap in Amazon-Orinoco River Basin

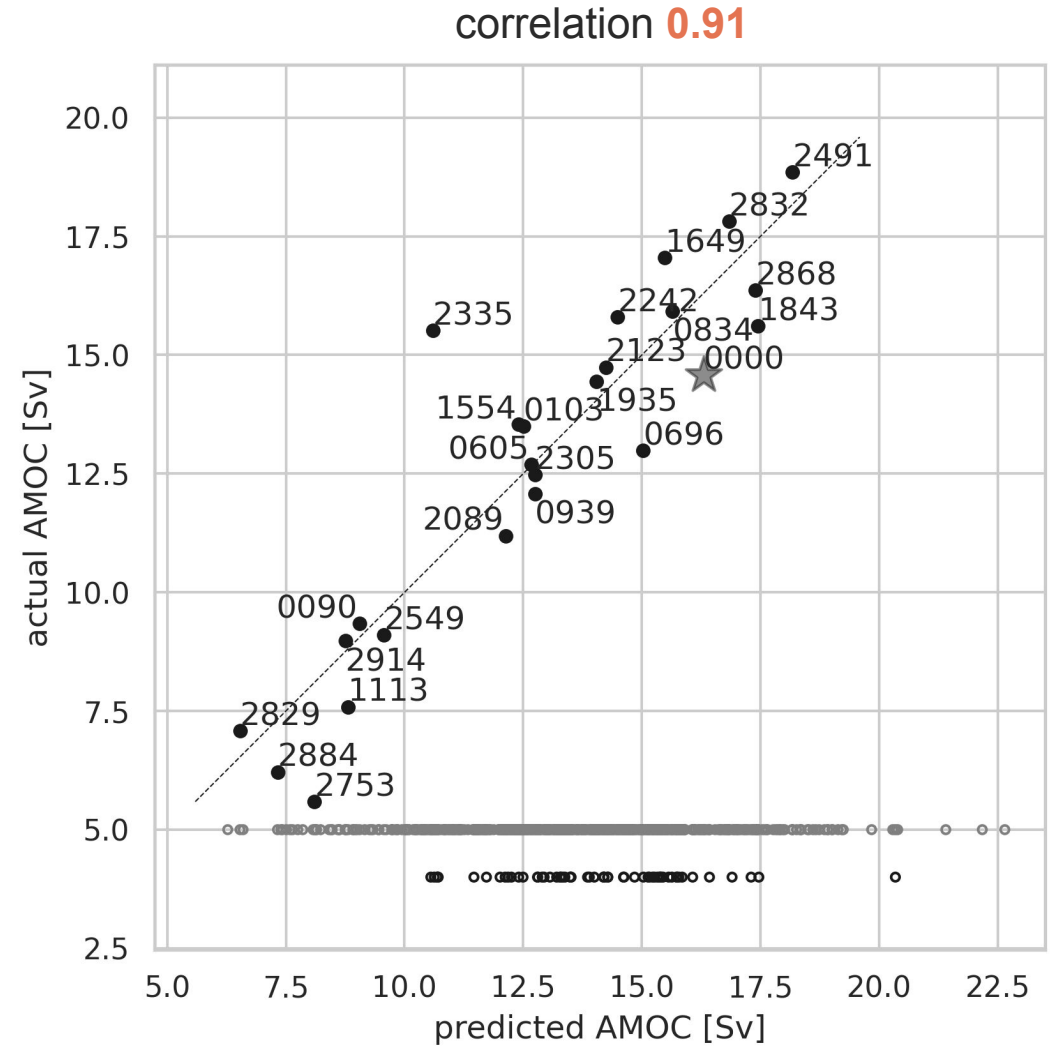
$i = 2$ : annual precip – evap in Labrador Sea

$i = 3$ : annual precip – evap in Tropical North Atlantic

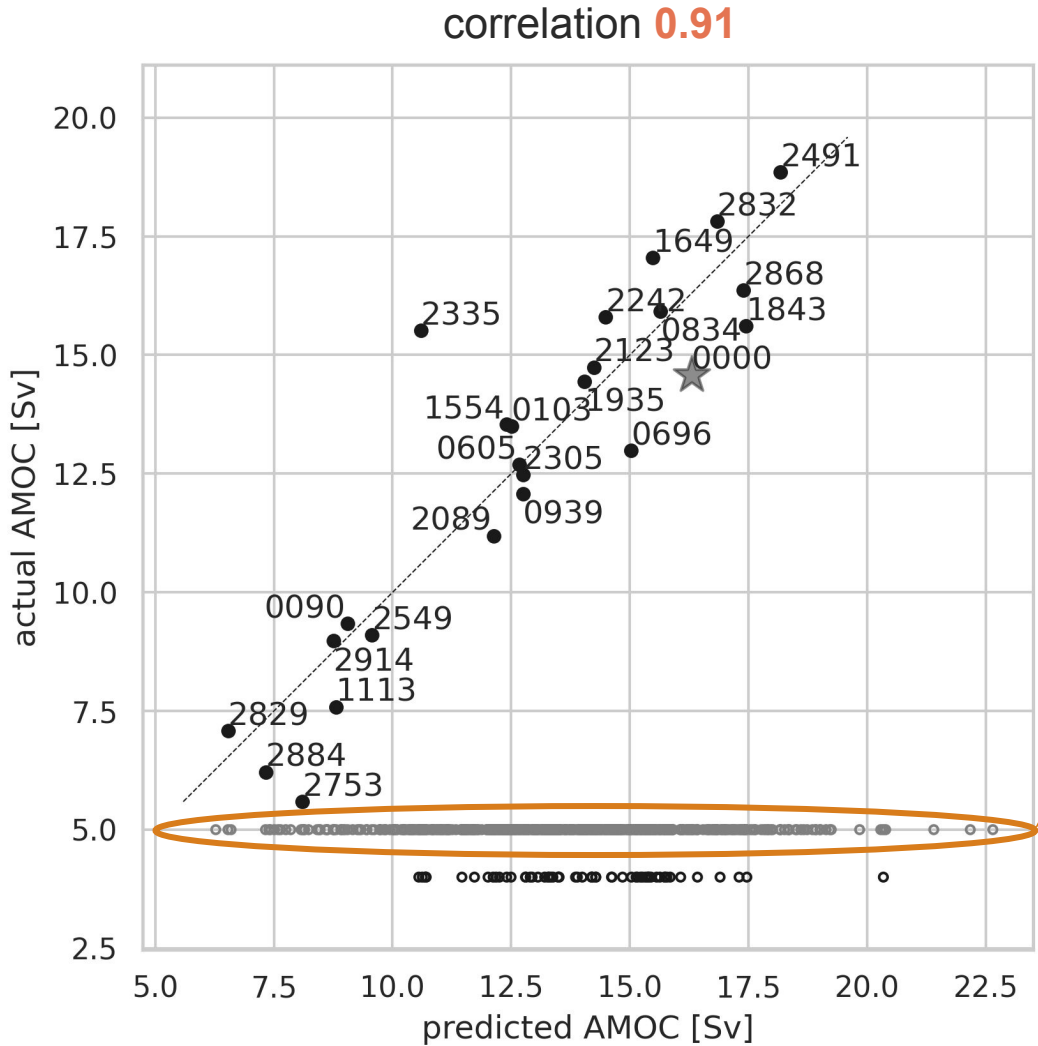
\* The predictors and the model itself are all statistically significant

**The identified drivers were checked to ensure they physically credible and thus were not results of spurious correlations**

# Step 4.1 Result: A multivariate regression model trained on the proxy drivers (and coupled AMOC) yielded good predictions

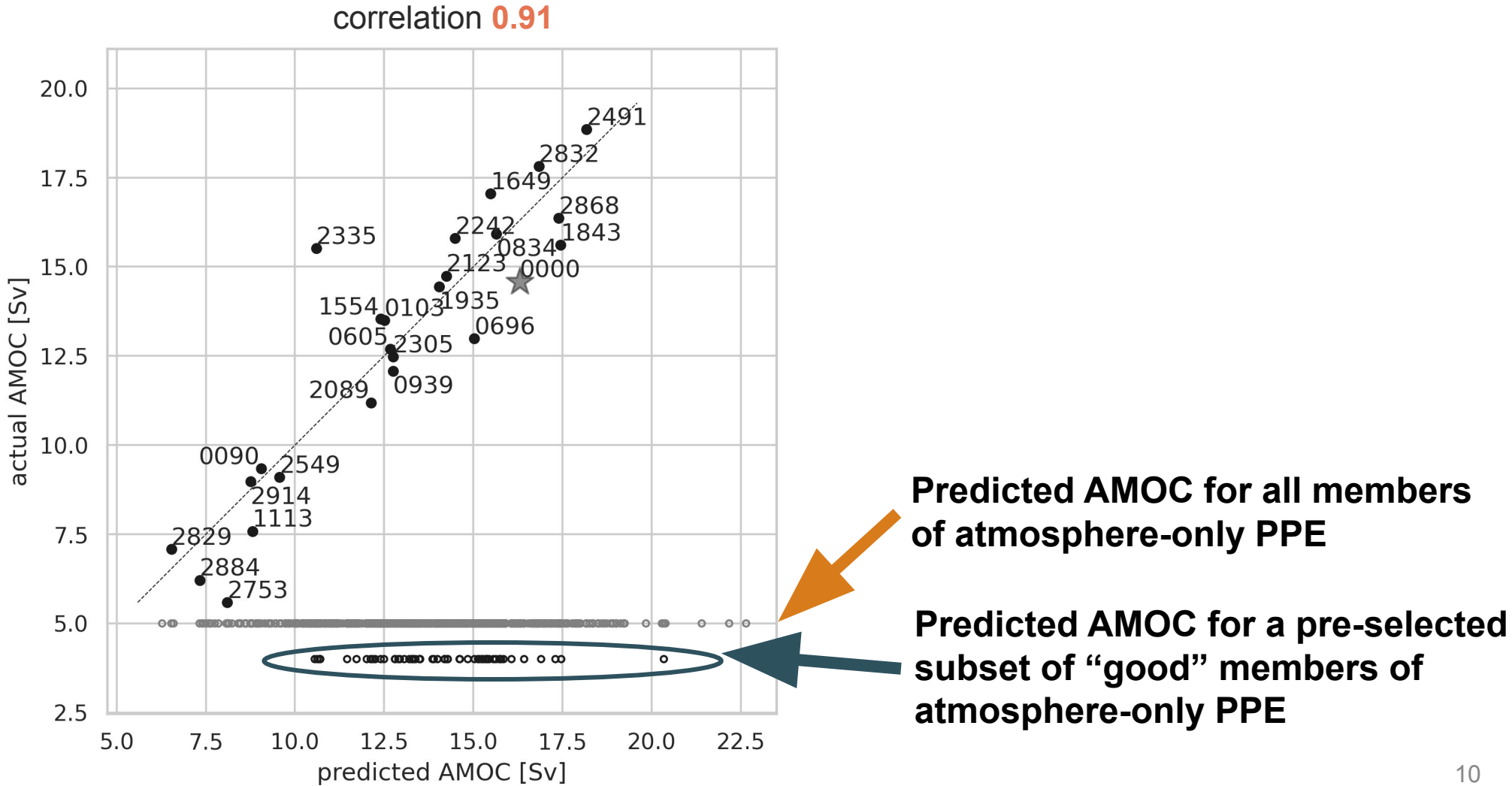


# Step 4.1 Result: A multivariate regression model trained on the proxy drivers (and coupled AMOC) yielded good predictions



**Predicted AMOC for all members of atmosphere-only PPE**

# Step 4.1 Result: A multivariate regression model trained on the proxy drivers (and coupled AMOC) yielded good predictions

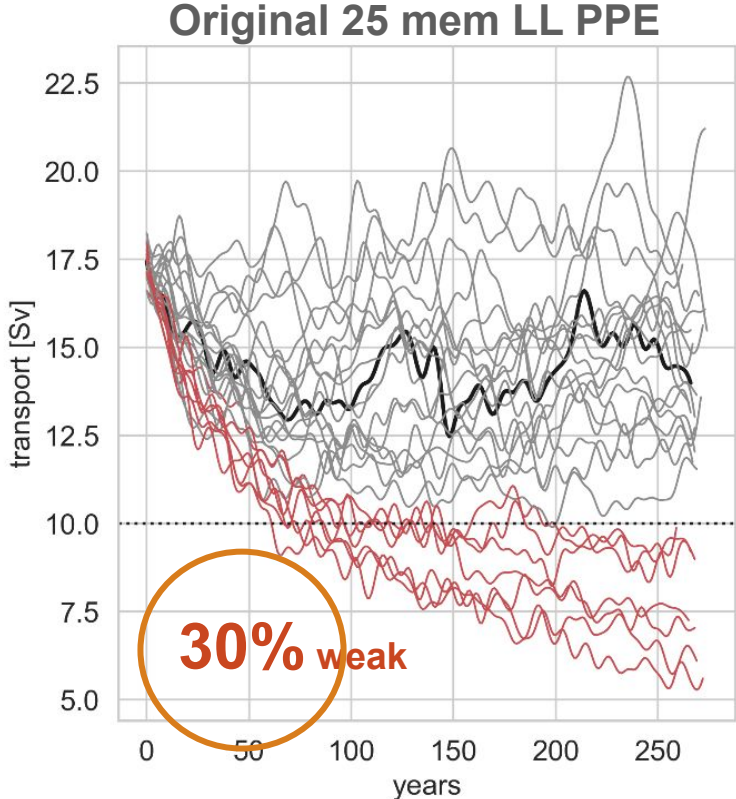


## **Step 4.2: extended the lower-resolution PPE**

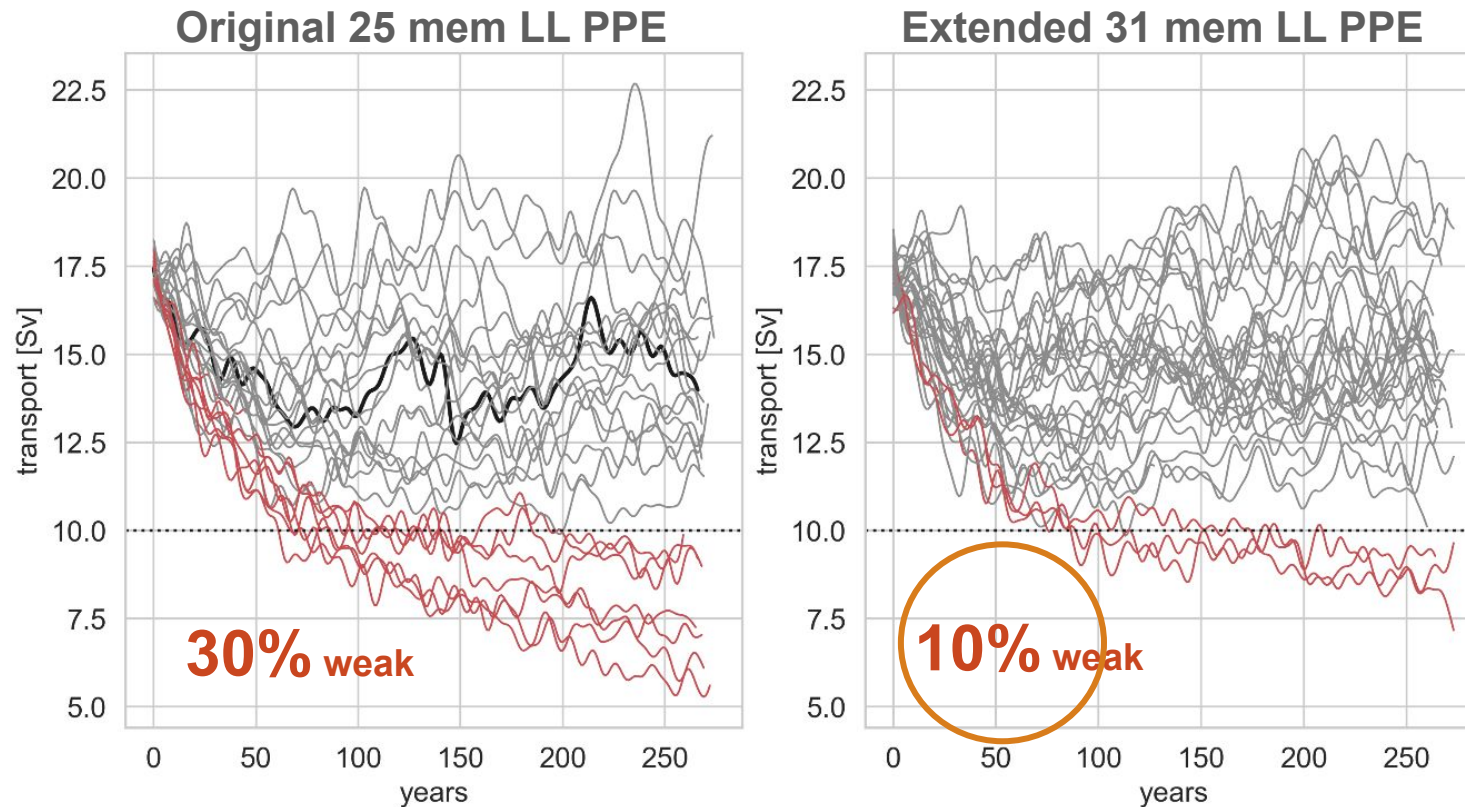
- We selected **31 new members**\* that were predicted to have realistic AMOC strengths.
- We then ran these selected 31 members coupled.

\* From a subset of members with a good overall atmosphere state

# Step 4.2 Result:



## Step 4.2 Result: In the extended coupled PPE, fewer models exhibited weak AMOC, and weaker models were less weak



# Summary and Discussion

**We utilised a PPE to identify multiple drivers of the AMOC strength & made good predictions**

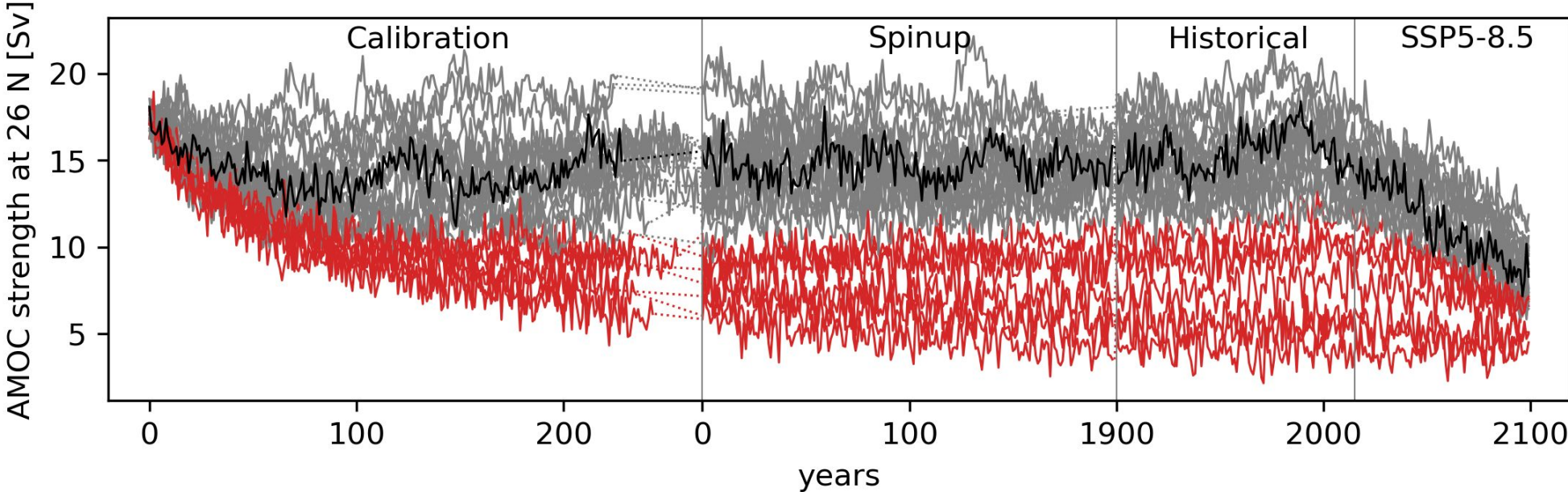
**Found multiple drivers simultaneously and objectively (Other studies have found similar drivers separately)**

**This method may be a useful tool across models for process understanding & for model development**

**Thank you!**

**Backup slides**

# Original 25-member LL PPE



# Identified drivers were checked to ensure they physically credible and thus were not results of spurious correlations

Composite difference of annual SSS (strong – weak AMOC members)

