

Idealized Atlantic Multidecadal Variability Experiments with the Community Earth System Model (CESM)

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AMV climate impacts Motivation and Goals

Our primary goals are to

- document climate impacts of sea surface temperature (SST) anomalies related to the Atlantic Multidecadal Variability (AMV);
- investigate the associated physical mechanisms

We follow a common experimental protocol (with GFDL) to the extend possible and perform suites of idealized AMV SST perturbation experiments using CESM1 and GFDL CM2.1 fully coupled models.

In addition to addressing various science questions, we aim to assess

- robustness of our results across our coupled model simulations, and
- investigate whether tropical or subpolar Atlantic SST anomalies show the largest climate impacts.

AMV climate impacts

AMV SST pattern

Follows an updated version of the Ting et al. (2009) recipe which makes use of models and observations to produce an AMV index:

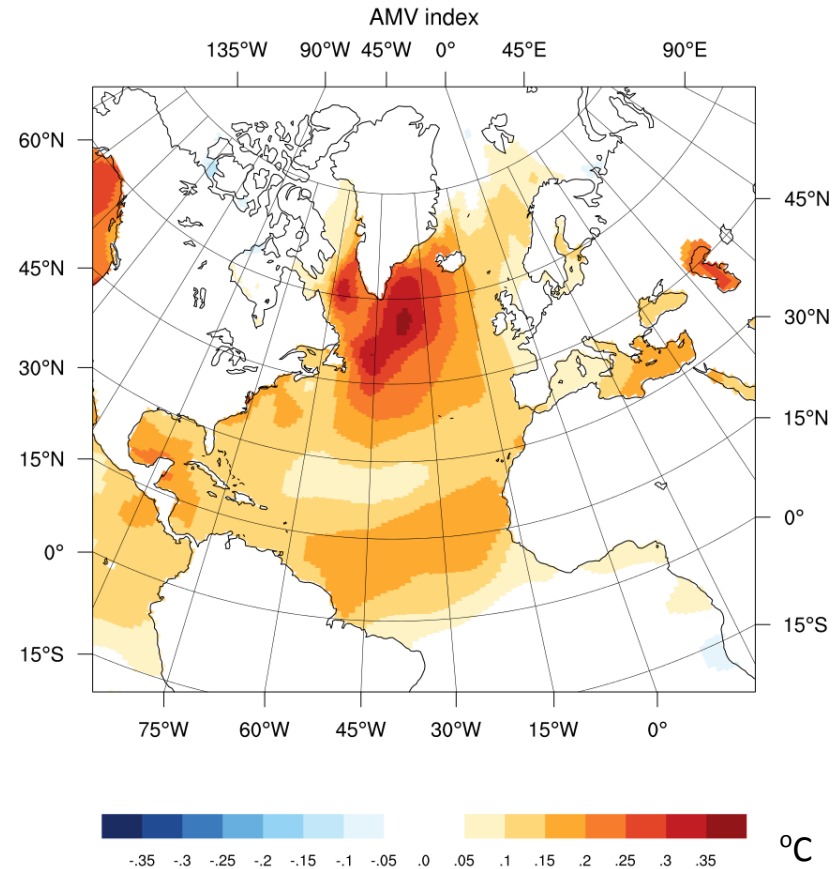
- A set of coupled model simulations for the 20th century are used together with a signal-to-noise-maximizing EOF analysis to determine a model-based estimate of the forced component in the North Atlantic SST variability
- This forced component is subtracted from the observed North Atlantic SSTs to obtain an AMV index
- Observed SSTs are regressed onto the AMV index to get the SST spatial pattern

Models: CMIP5 20th century simulations; multiple ensemble members per model

Observations: NOAA ERSSTv3

Region: 0°-60°N – 7.5°-75°W

Filter: 10-year low-pass



AMV pattern on ocean model grid

A map of North America is shown in the background, overlaid with a color gradient. The colors range from light yellow in the south to dark red in the north, indicating a temperature gradient or climate impact. The title text is centered over this map.

AMV climate impacts

Model & Experimental Procedure

- NCAR experiments use the Community Earth System Model version 1 (CESM1)
- Base code is identical to the version used for the 2200+ -year CESM Large Ensemble pre-industrial control simulation
- 1° horizontal resolution in all components
- Parallel Ocean Program version 2 (POP2); Community Atmospheric Model version 5 (CAM5)



AMV climate impacts

Model & Experimental Procedure

- AMV SST pattern is super-imposed onto the model's own SST climatology
- AMV SST pattern is time independent
- Over the North Atlantic, the coupled model is restored to the resulting SST patterns; elsewhere the model evolves freely
- A control integration is obtained in which the North Atlantic SSTs are restored to the model's own SST climatology
- Daily model SST climatology obtained from a 1000-year segment of the control simulation (for years 500 to 1500)
- 5-day SST restoring time scale over the first layer thickness (10 m)
- No restoring under sea ice



AMV climate impacts Experiments

10-year long **ensemble experiments**:

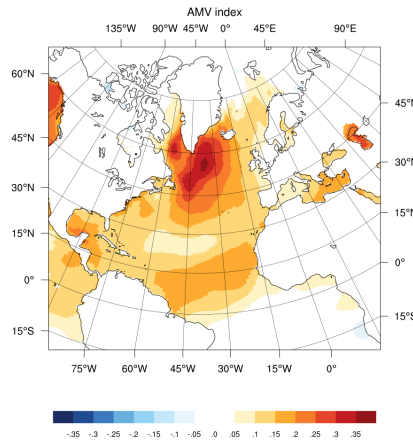
- ◆ **CONT** daily SST climatology (separate for each sensitivity experiment)
- ◆ **AMV+** daily SST climatology + AMV⁺ pattern
- ◆ **AMV-** daily SST climatology + AMV⁻ pattern
- ◆ **AMV+_SPNA** daily SST climatology + AMV⁺ pattern in the subpolar North Atlantic only
- ◆ **3xAMV+_SPNA** daily SST climatology + 3 x AMV⁺ pattern in the subpolar North Atlantic only
- ◆ **AMV+_TA** daily SST climatology + AMV⁺ pattern in the tropical Atlantic only

Results are presented as differences from CONT;

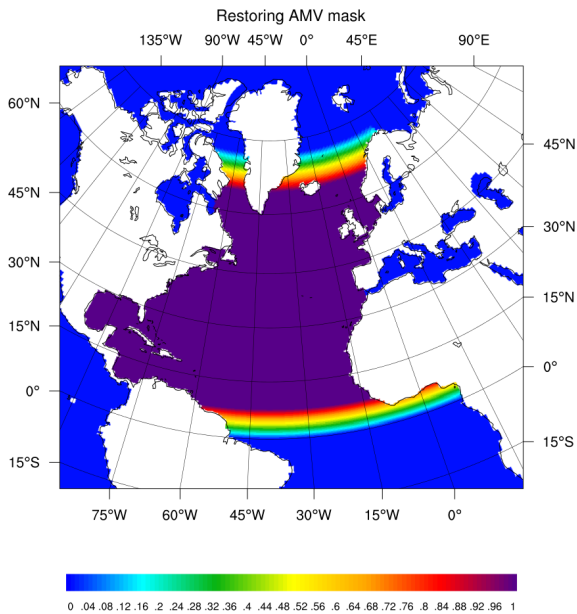
Stippled: 95% confidence level (2-tailed t-test)

AMV climate impacts

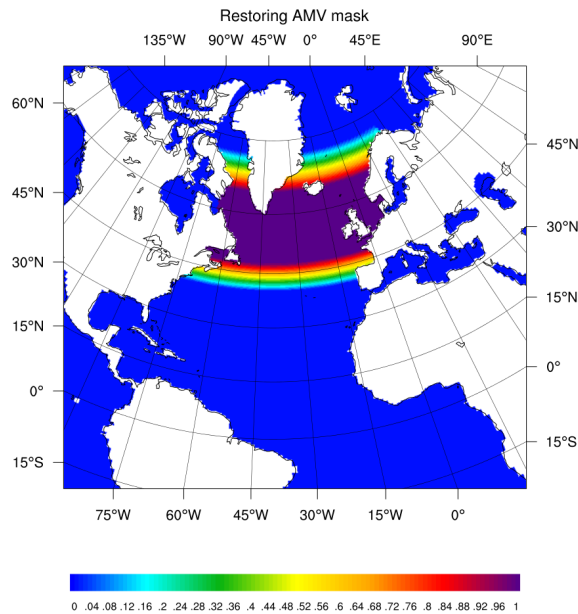
Experimental set up



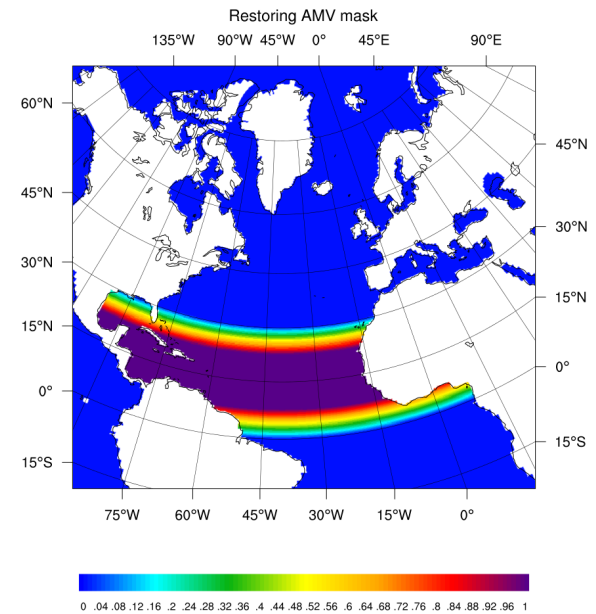
AMV pattern




Full NA restoring



SPNA restoring



TA restoring



AMV climate impacts

Experimental set up

30 members in each ensemble

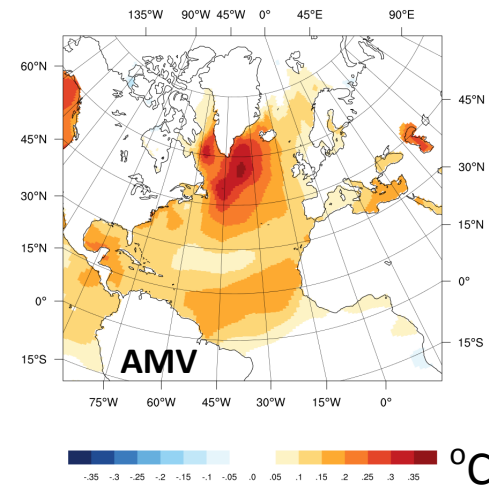
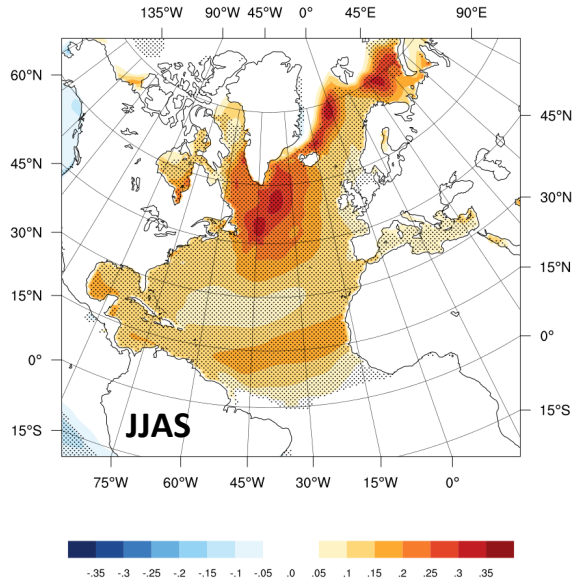
=> combination of MACRO and MICRO perturbations similar to Hawkins et al. (2015)

- ◆ **MACRO:** 3 different oceanic initial conditions
- ◆ **MICRO:** from each MACRO initial condition, 10 members are produced using atmospheric initial condition perturbations at round-off level (temperature)

AMV climate impacts

Preliminary results: verification

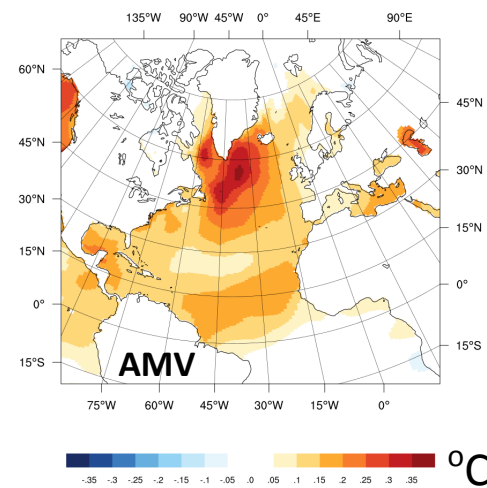
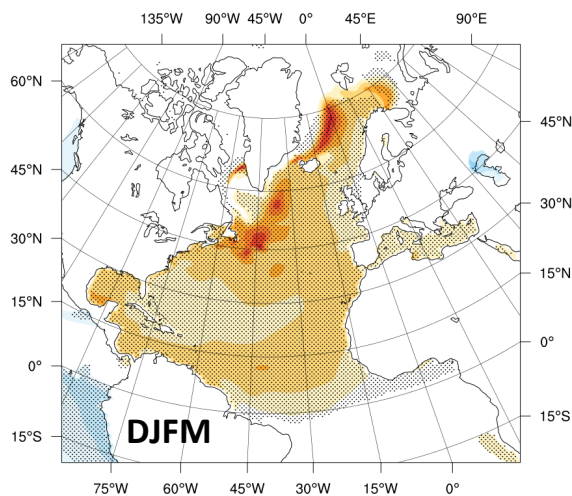
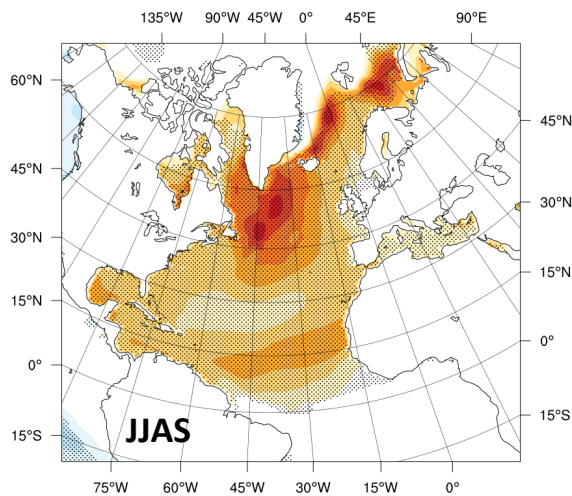
- AMV restoring works very well over summer



AMV climate impacts

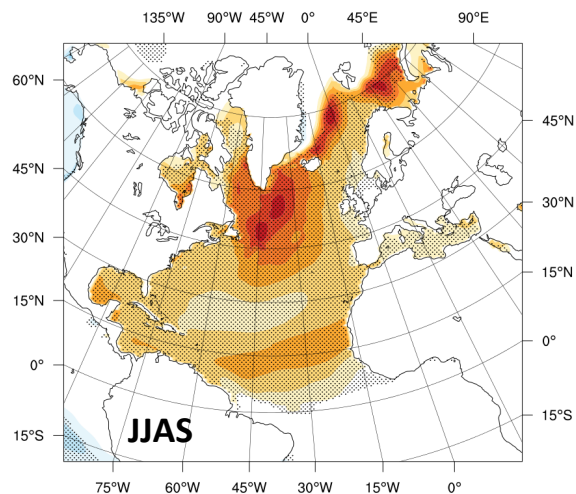
Preliminary results: verification

- AMV restoring works very well over summer
- Not as well in winter
 - ⇒ this is probably to be expected:
 - ◇ No restoring when sea-ice is present
 - ◇ Faster more energetic dynamics in winter



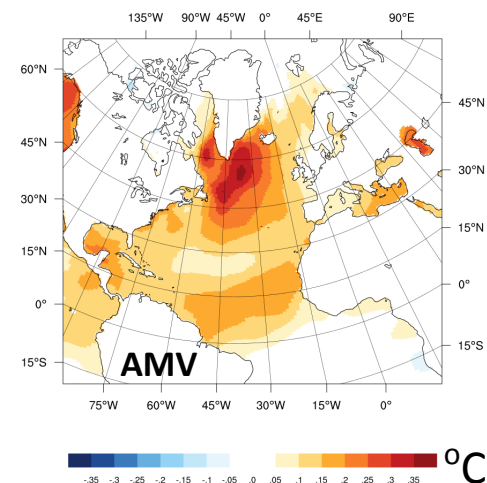
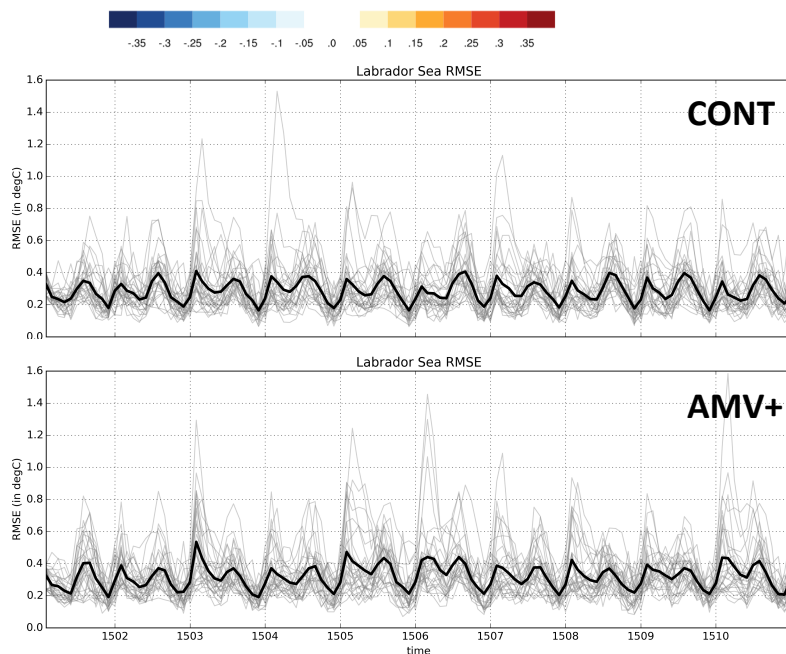
AMV climate impacts

Preliminary results: verification



- AMV restoring works very well over summer
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 - ⇒ this is probably to be expected:
 - ◇ No restoring when sea-ice is present
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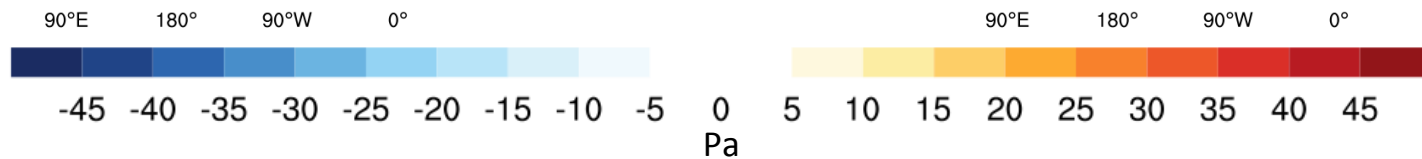
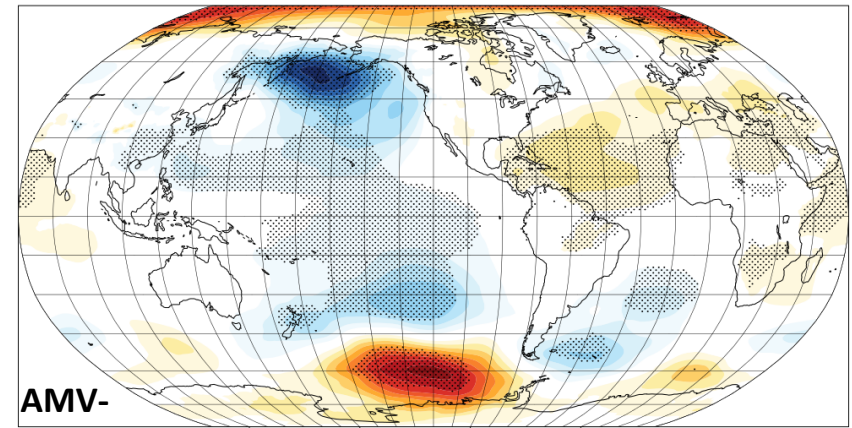
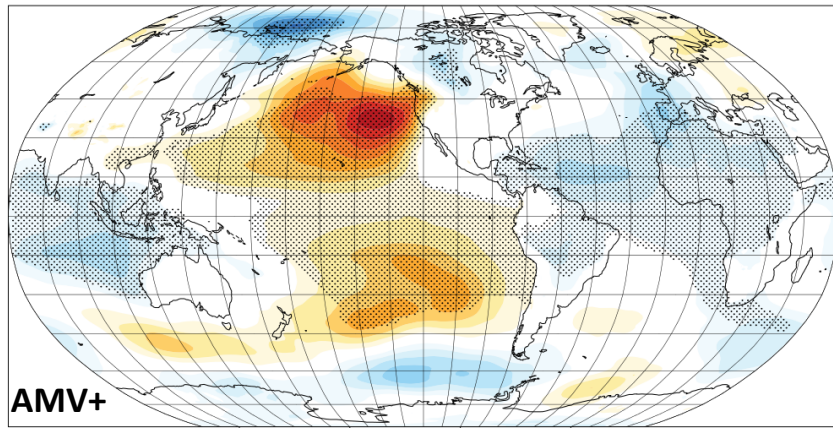
- Seasonality in the RMSE, but **NO** trend over the 10-year simulation



AMV climate impacts

Preliminary results: AMV+/AMV-

Sea Level Pressure (SLP) 10-year climatological composite (30 members)

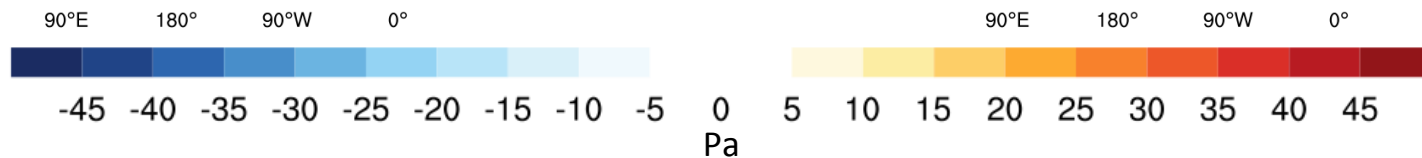
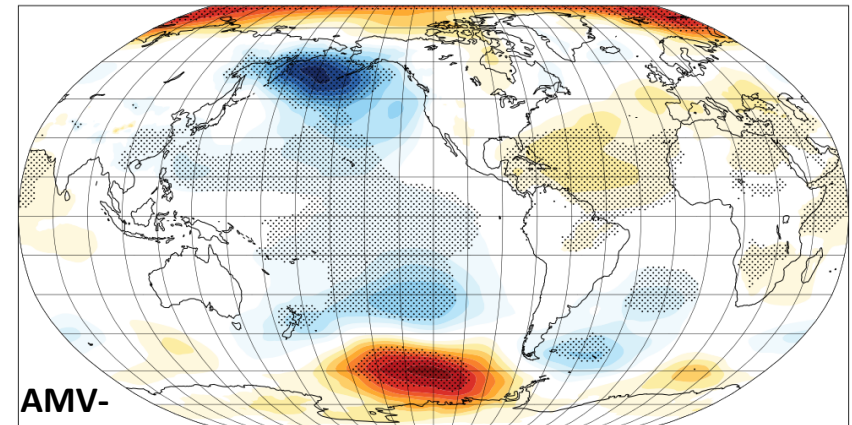
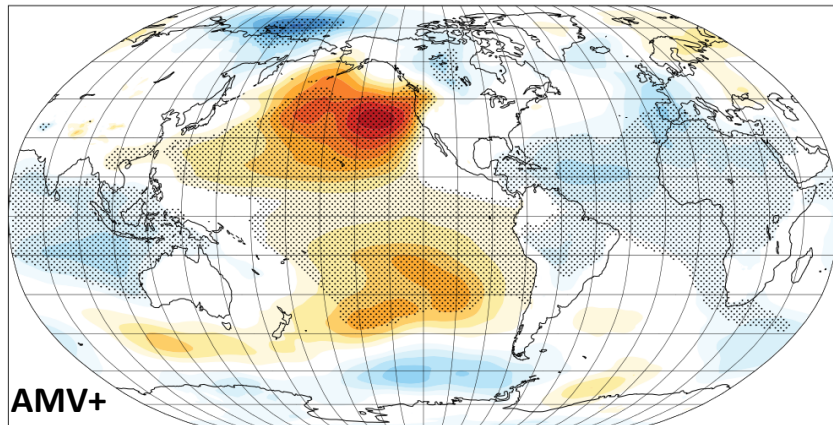


- First order response is primarily linear

AMV climate impacts

Preliminary results: AMV+/AMV-

Sea Level Pressure (SLP) 10-year climatological composite (30 members)



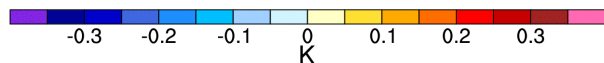
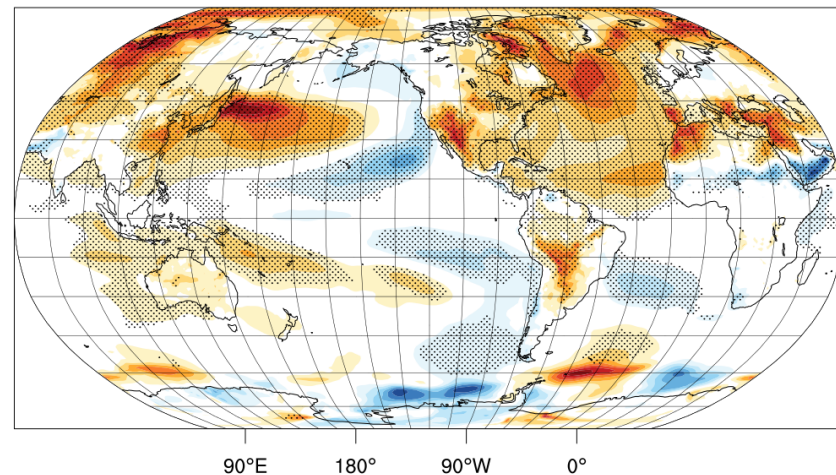
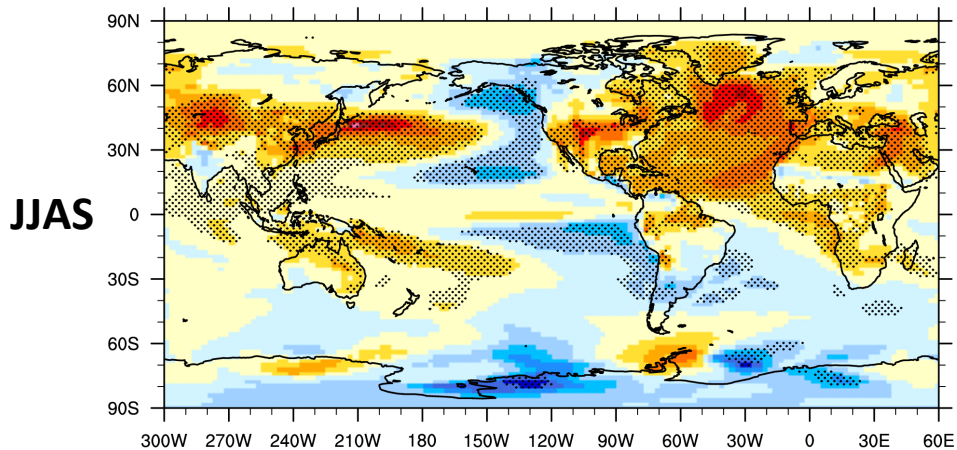
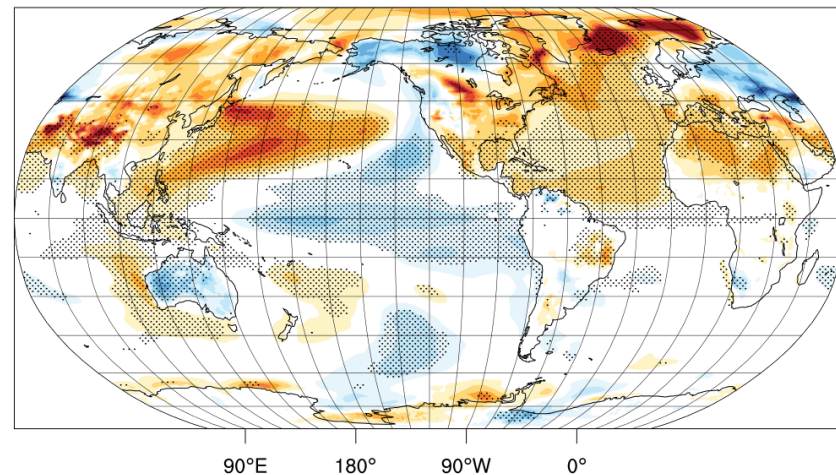
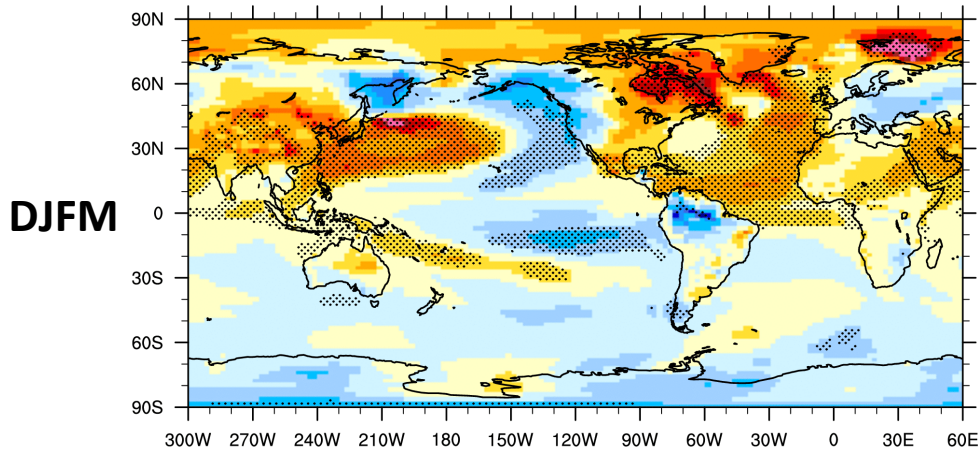
- First order response is primarily linear

=> We are going to focus on the AMV+ response

AMV climate impacts

Preliminary results: GFDL vs NCAR

T2M climatological composite (30 members)

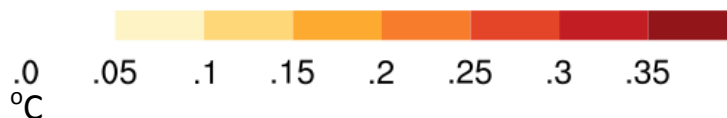
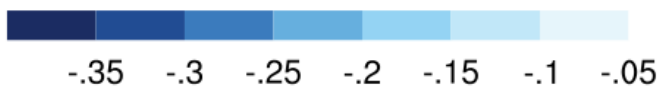
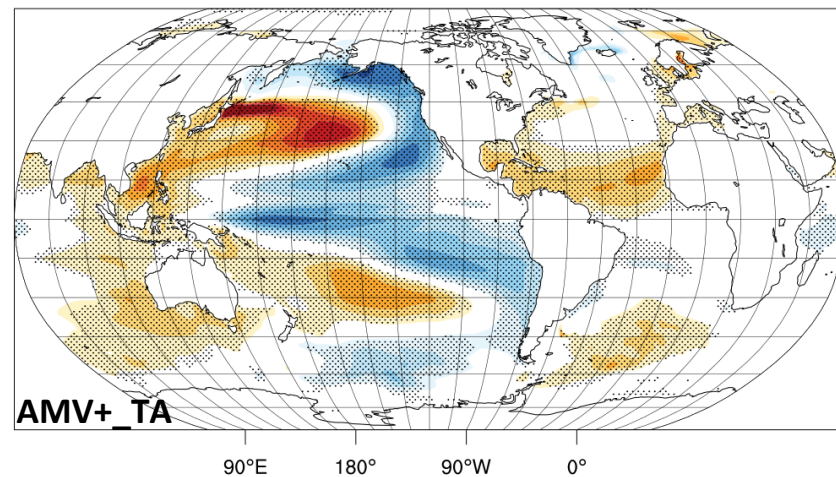
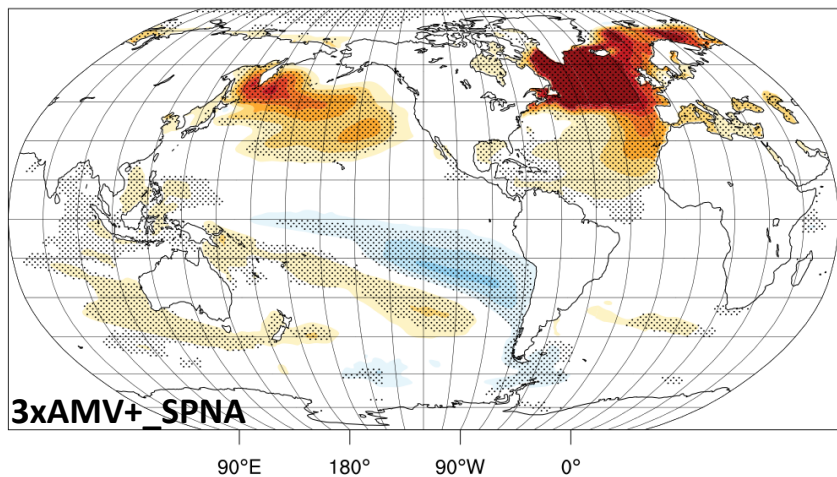
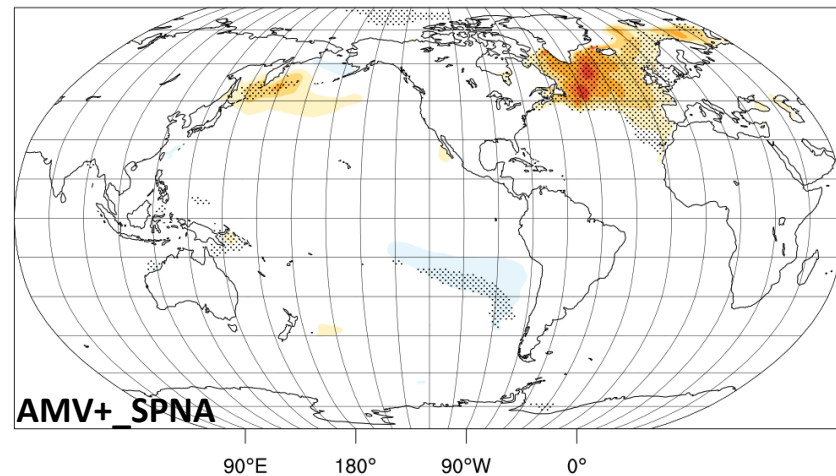
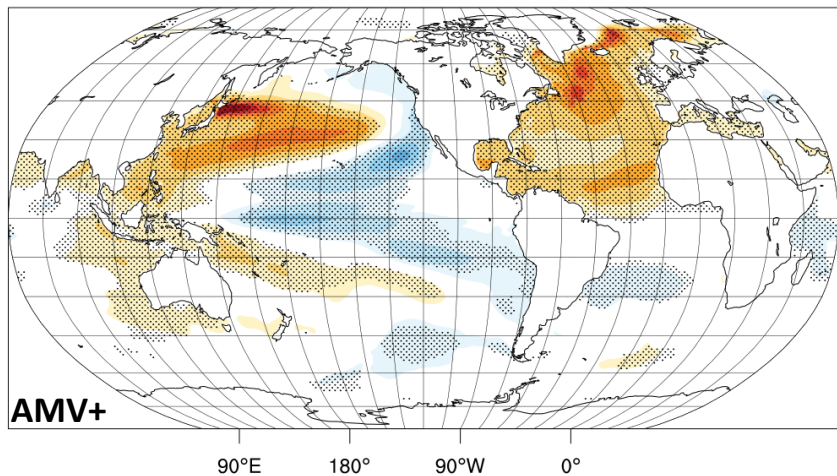


- Very similar results for CM2.1 and CESM1

AMV climate impacts

Preliminary results: SST

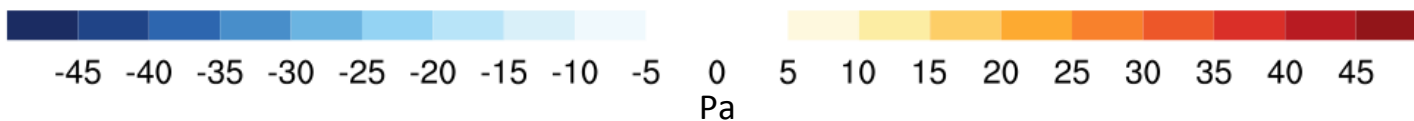
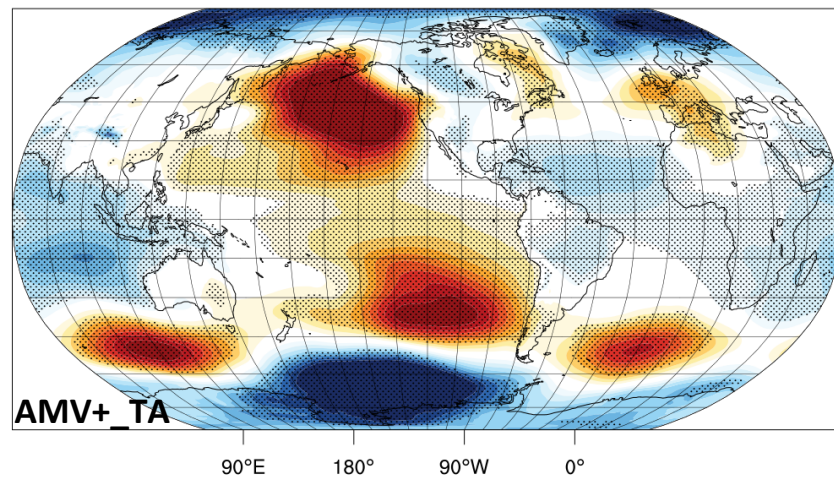
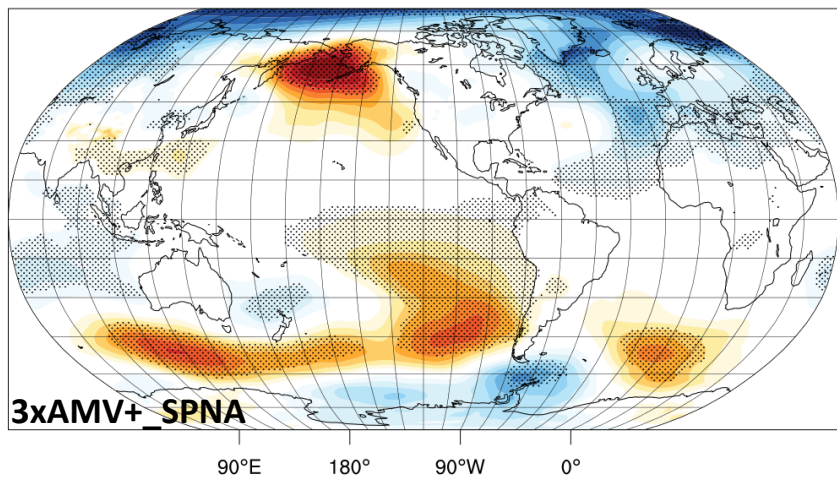
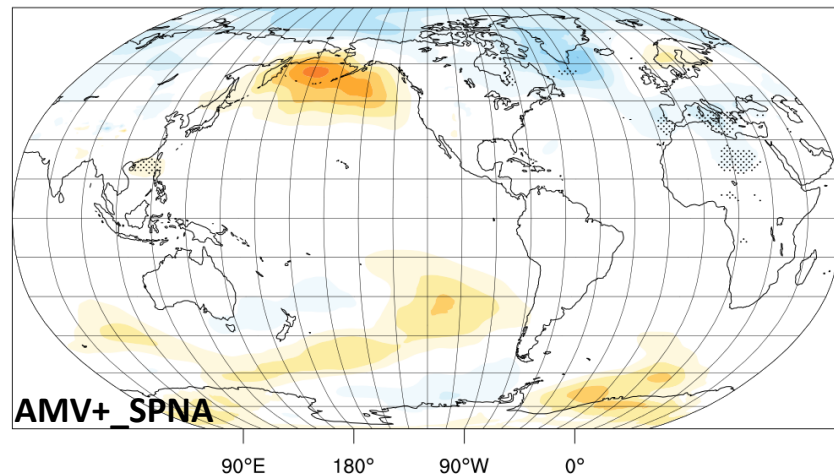
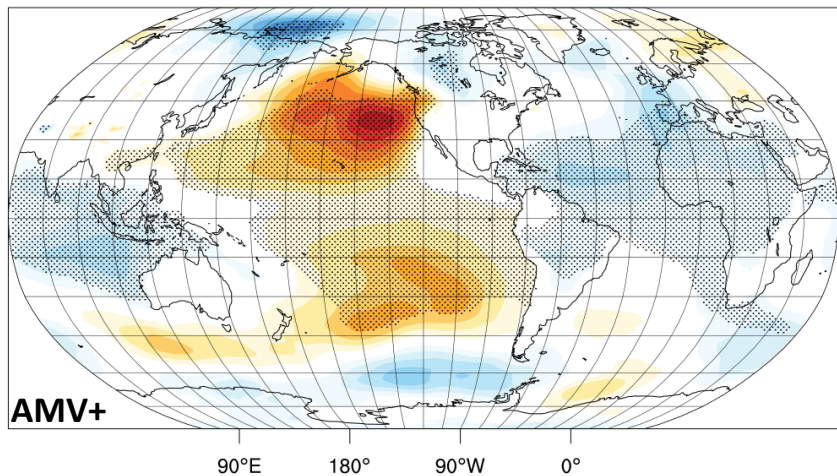
10-year climatological composite (30 members)



AMV climate impacts

Preliminary results: SLP

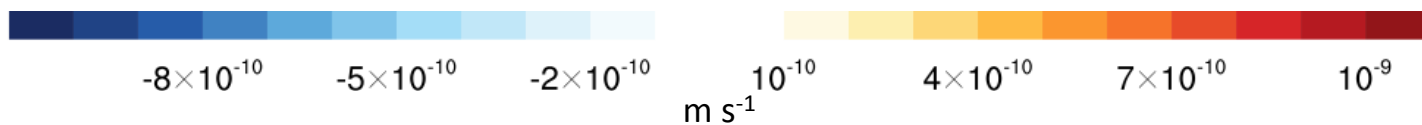
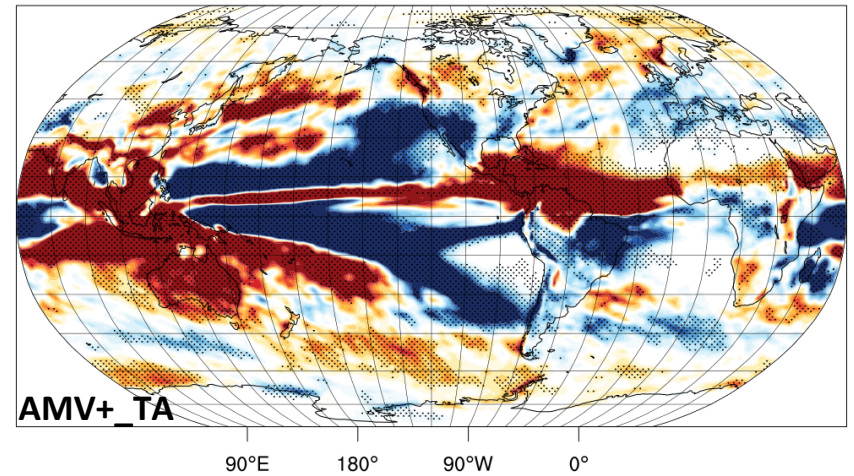
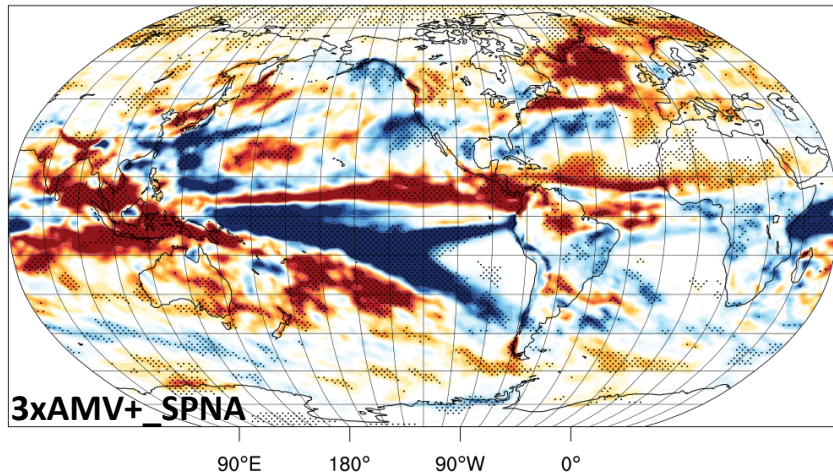
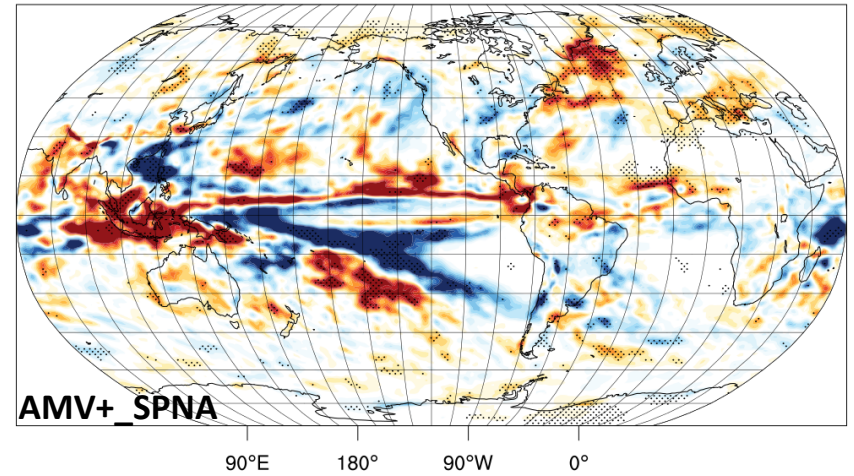
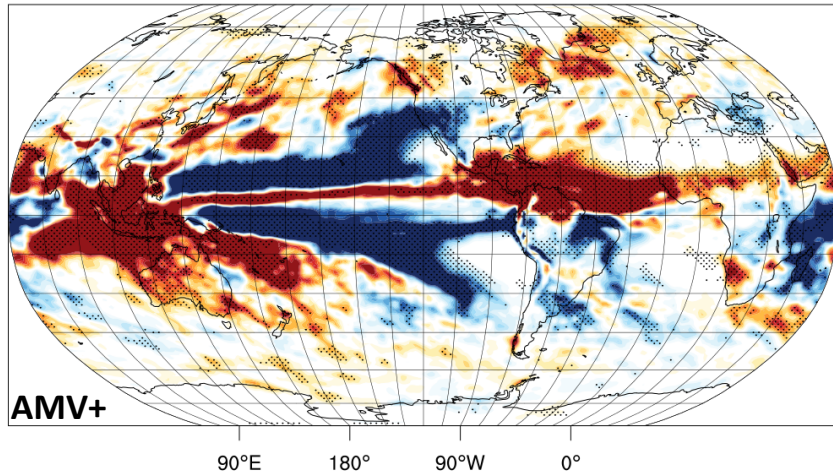
10-year climatological composite (30 members)



AMV climate impacts

Preliminary results: Precipitation

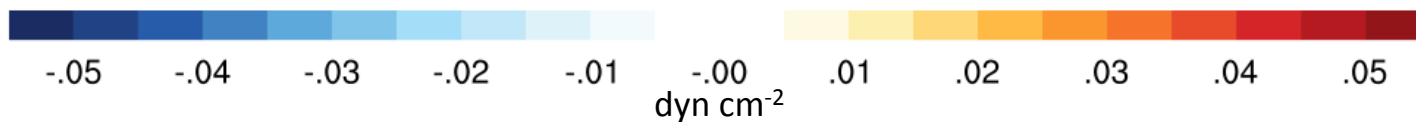
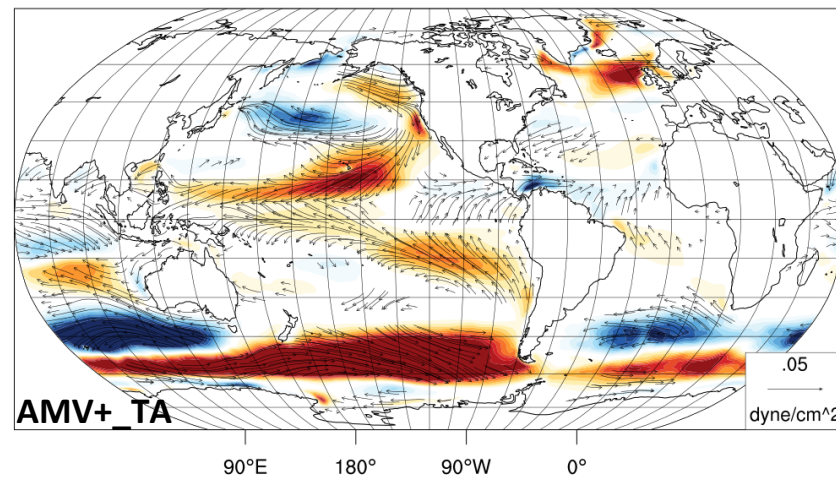
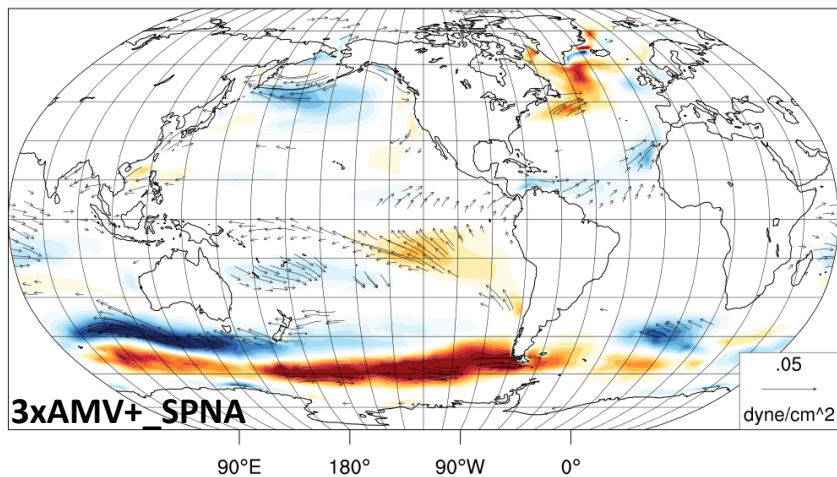
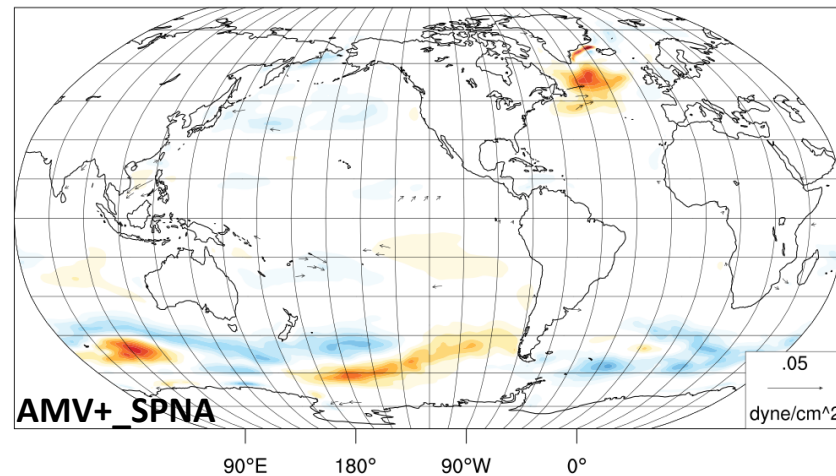
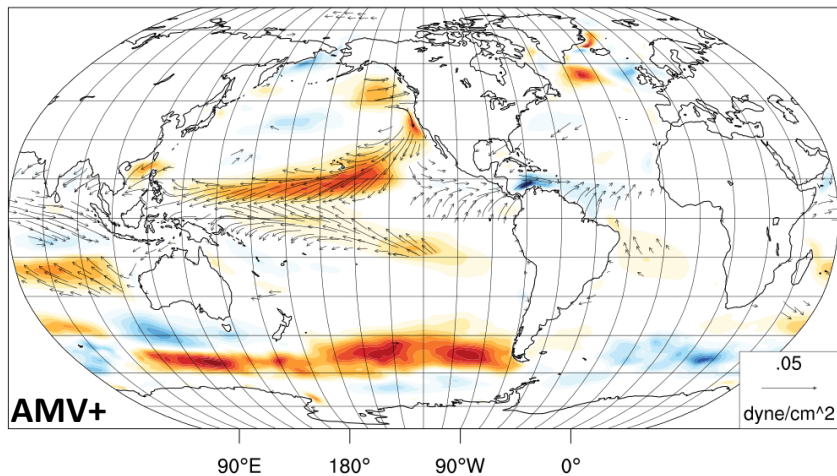
10-year climatological composite (30 members)



AMV climate impacts

Preliminary results: surface wind stress

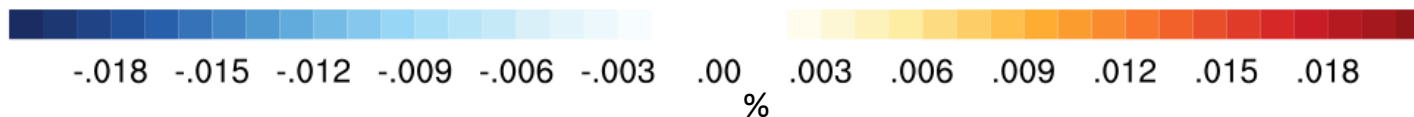
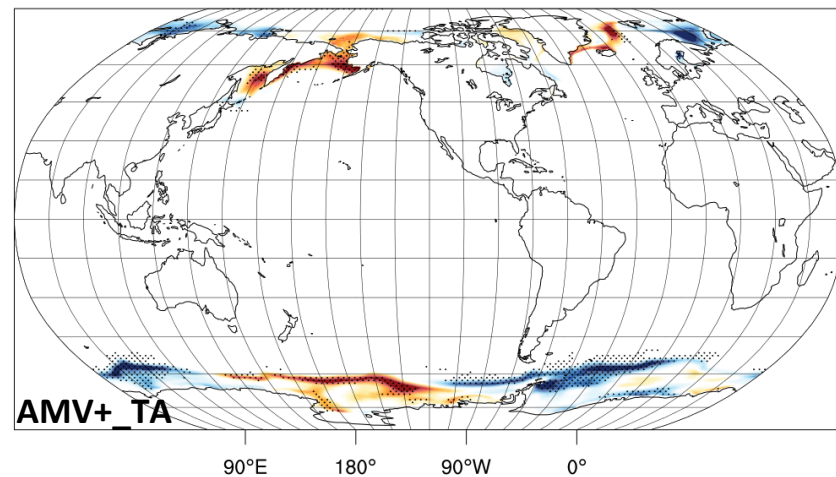
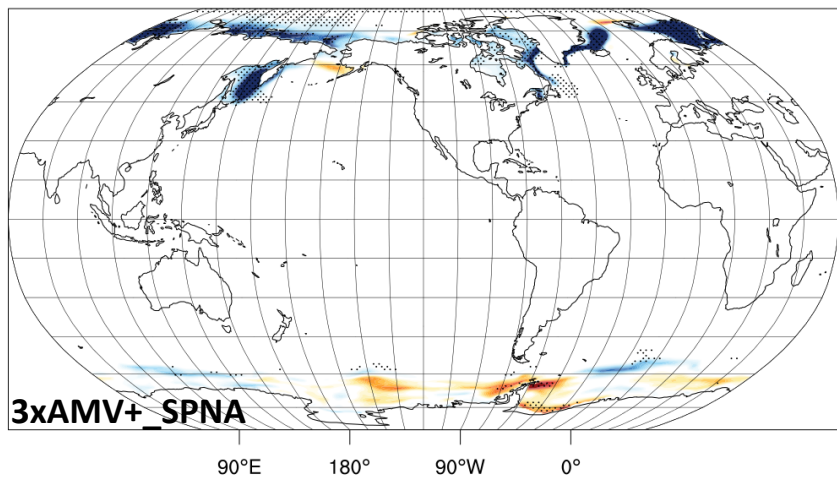
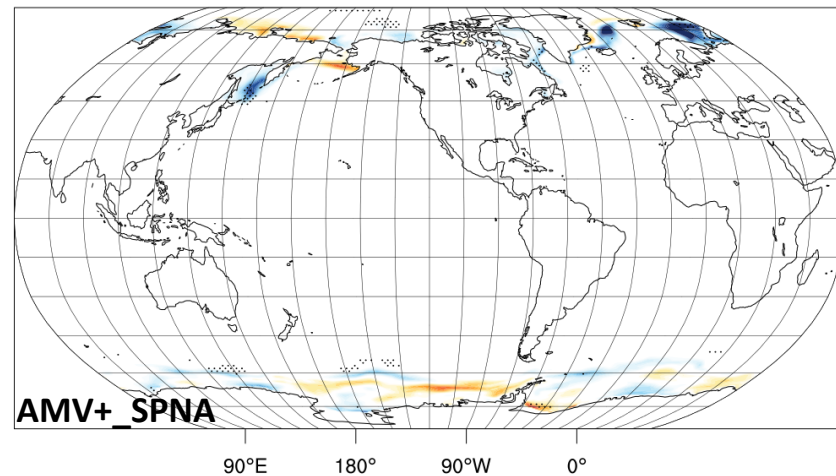
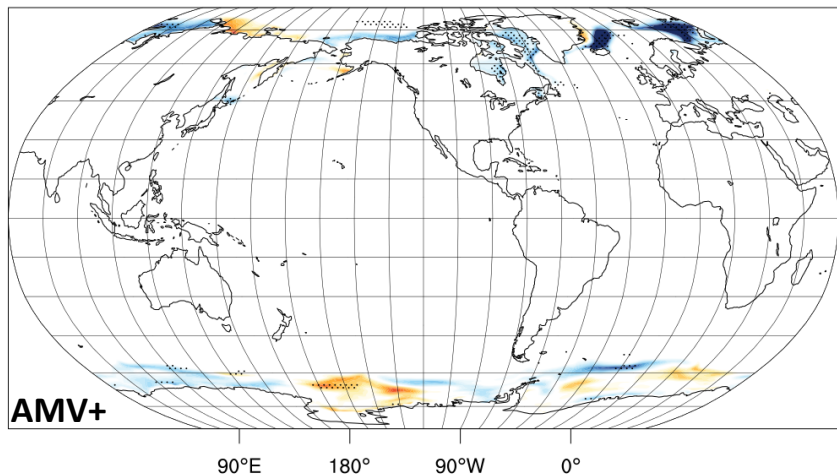
10-year climatological composite (30 members)



AMV climate impacts

Preliminary results: ice cover

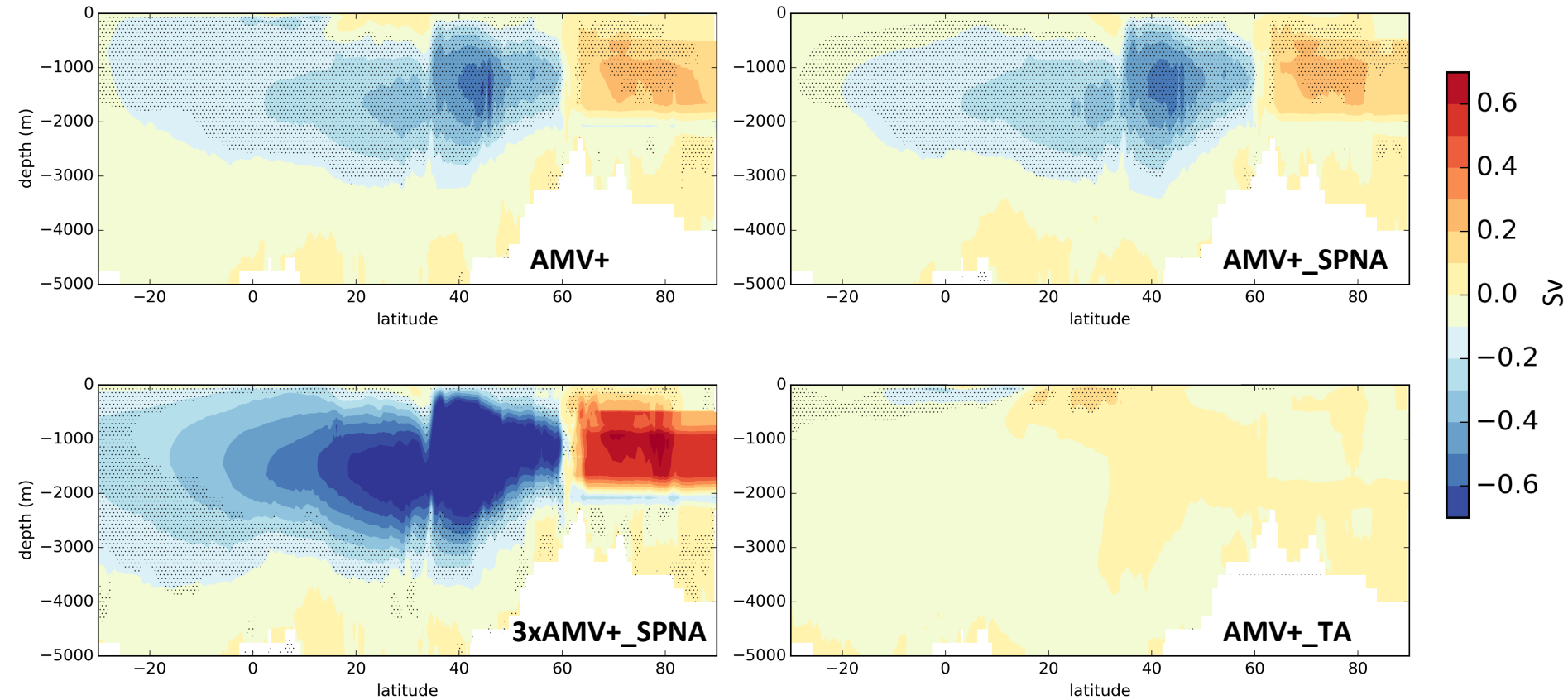
10-year climatological composite (30 members)



AMV climate impacts

Preliminary results: AMOC

10-year climatological composite (30 members)





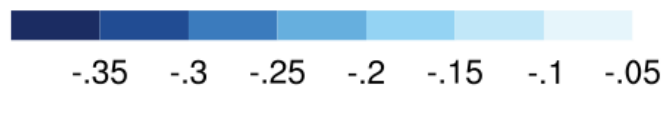
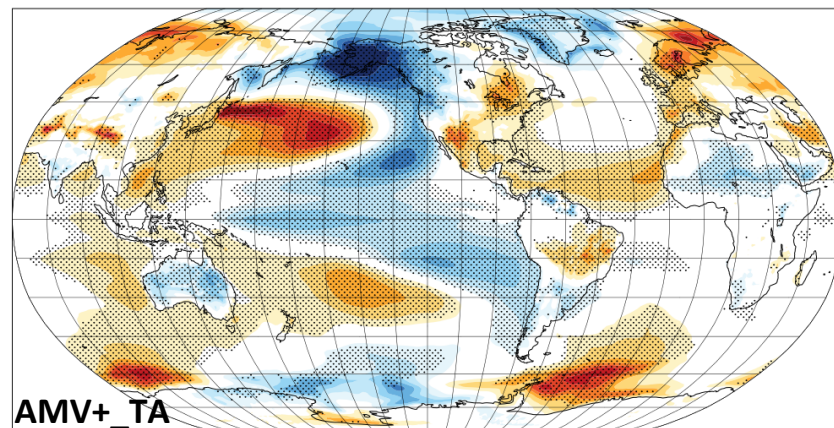
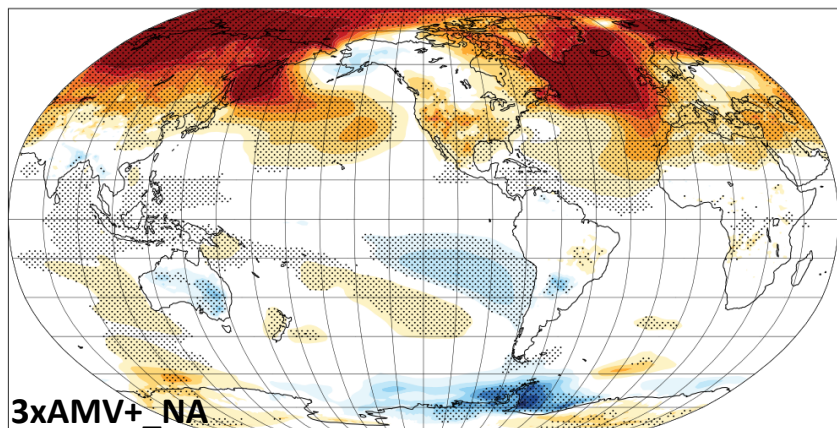
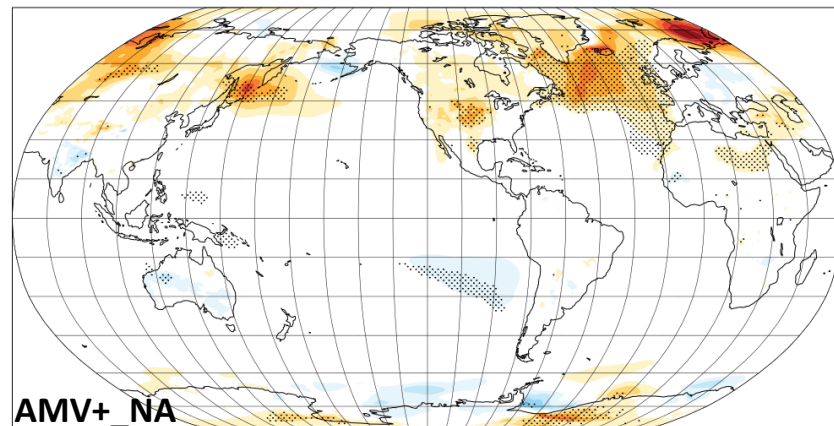
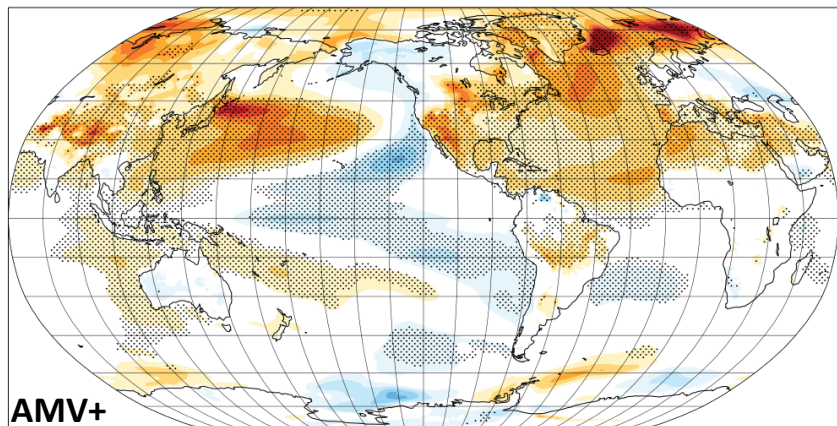
AMV climate impacts Summary

- We have designed along with GFDL an experimental protocol to assess climate impacts of AMV and to understand the associated physical mechanisms
- This protocol is now a candidate for one of experiments for the component C Predictability, mechanisms, and case studies of the Decadal Climate Prediction Project (DCPP) Model Intercomparison Project (MIP)
- Preliminary results:
 - The Tropical Atlantic controls the first order AMV impacts
 - AMV+ (AMV-) lead to a negative (positive) PDV response in the Pacific Ocean
 - Other impacts include poleward shift of tropical precipitation; stronger zonal winds in the Southern Ocean; ...
 - AMV impacts results from mechanisms involving atmospheric teleconnections
 - More analysis is underway to identify and better understand the mechanisms at play, e.g., considering seasonal responses

AMV climate impacts

Preliminary results: T2M

10-year climatological composite (30 members)

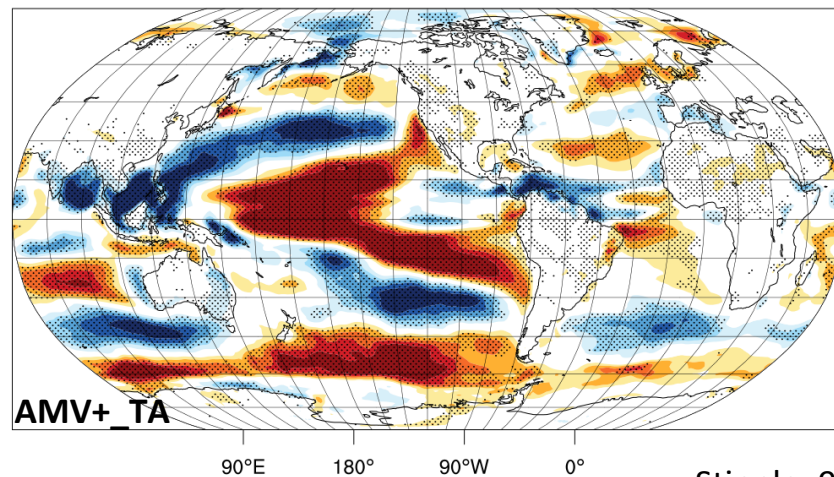
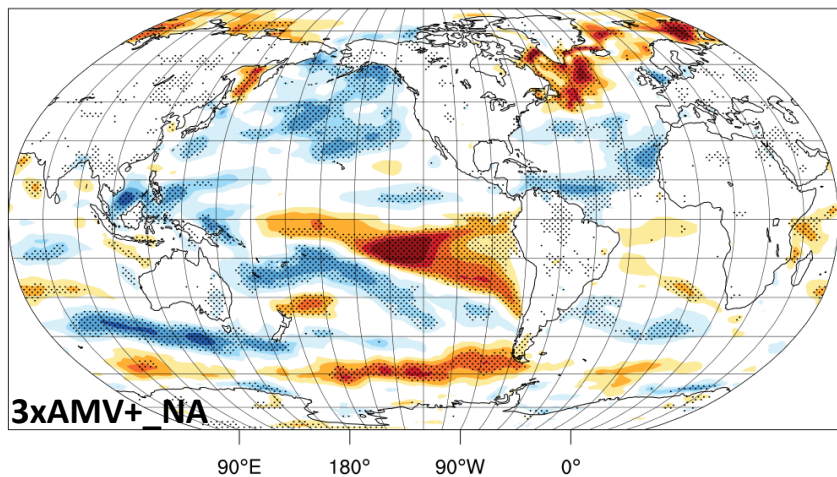
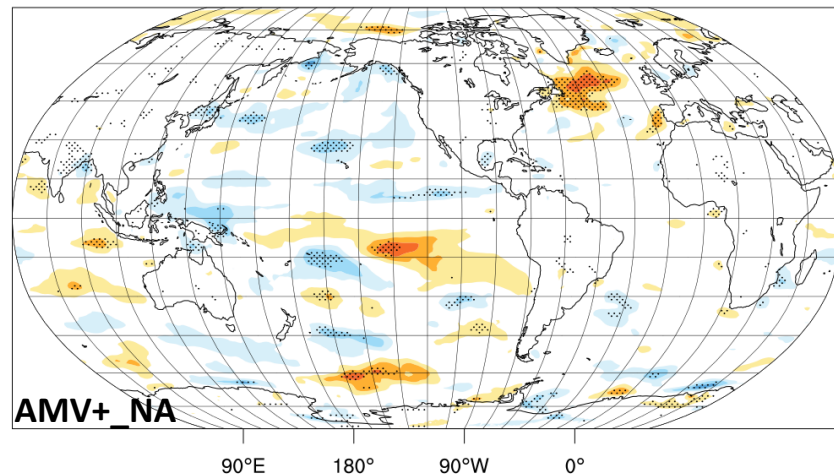
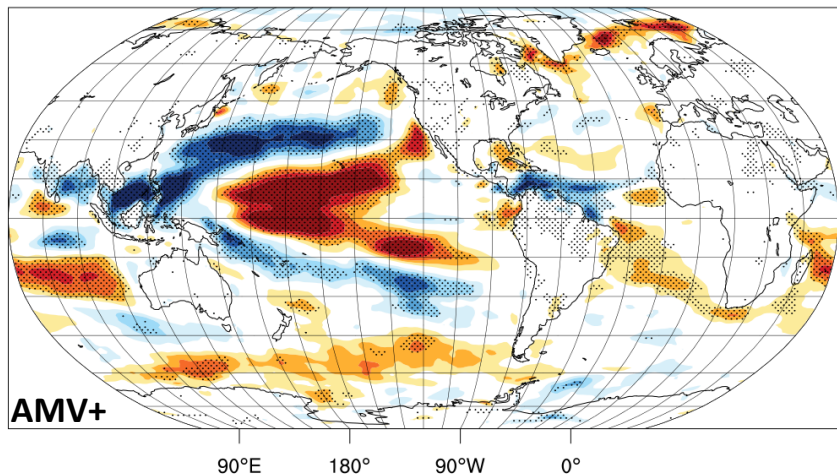


Stipple: 95%
significance
(2-tail t-test)

AMV climate impacts

Preliminary results: 10-meter winds

10-year climatological composite (30 members)



ms⁻¹

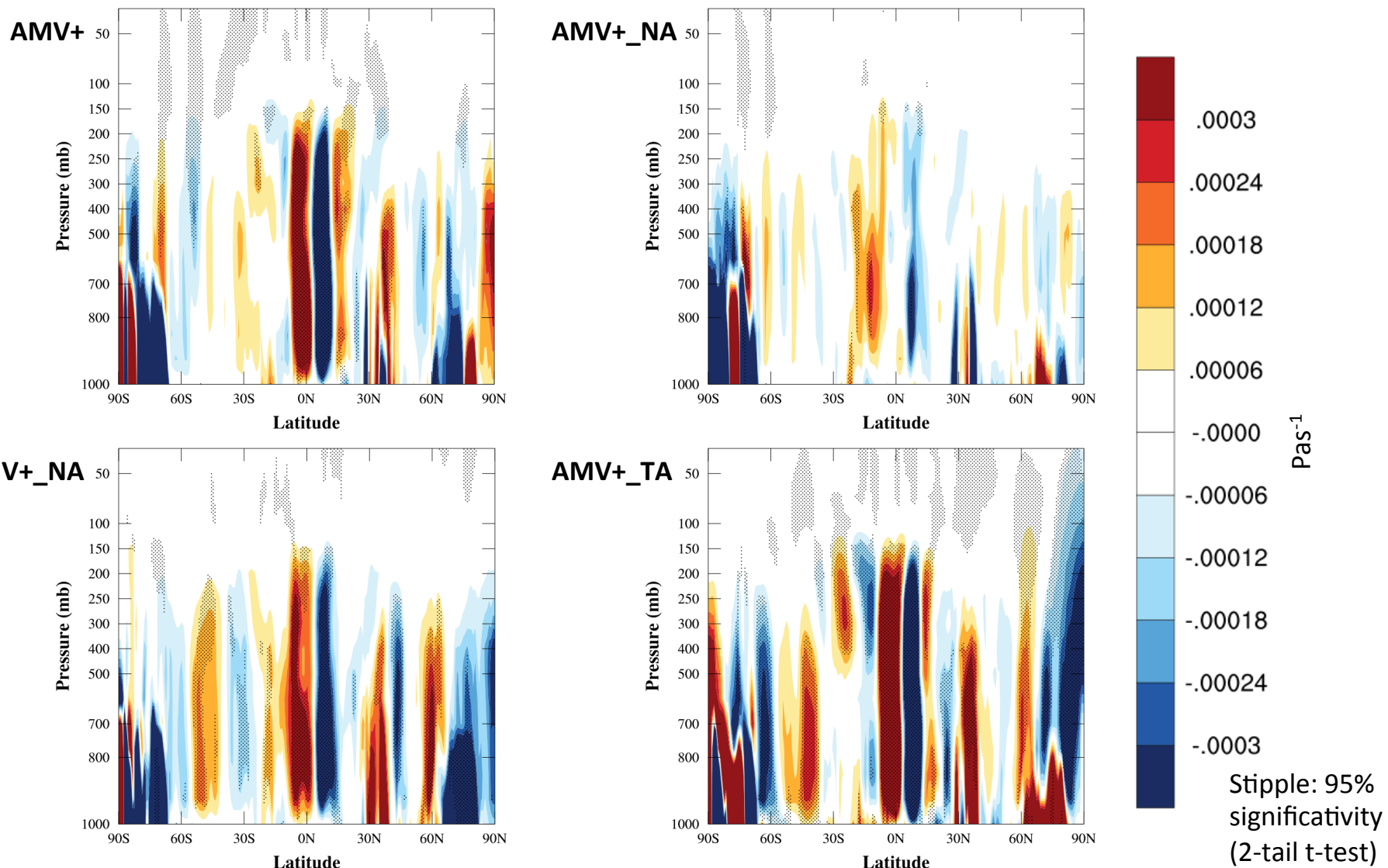


Stipple: 95%
significance
(2-tail t-test)

AMV climate impacts

Preliminary results: OMEGA

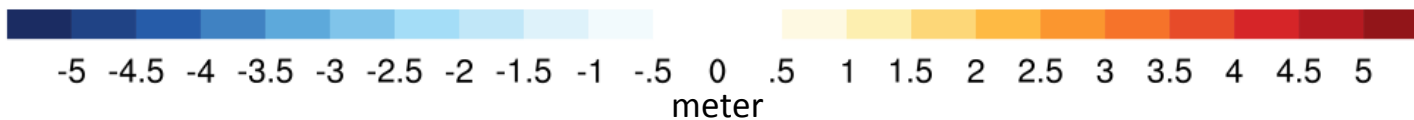
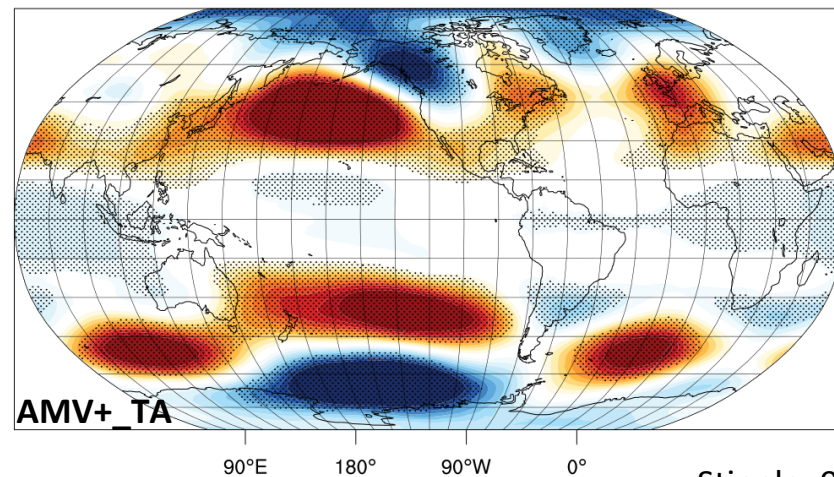
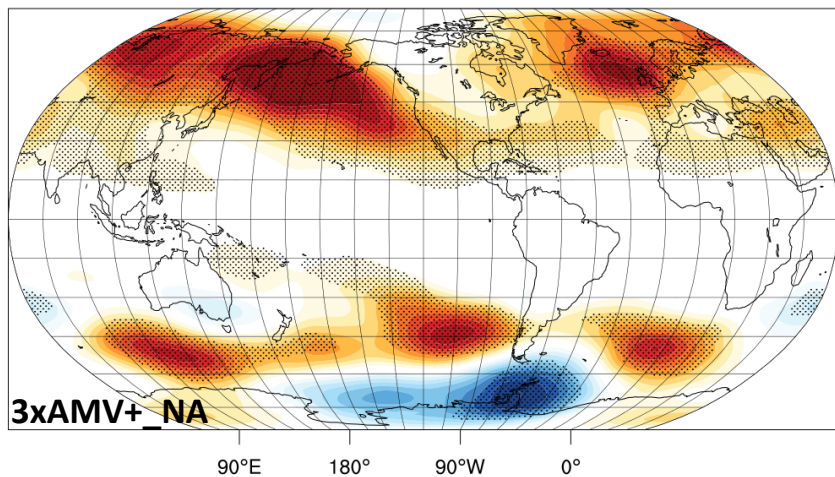
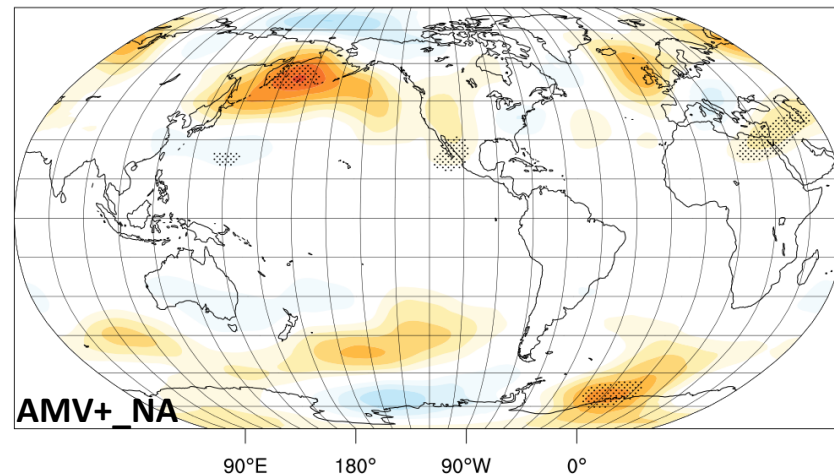
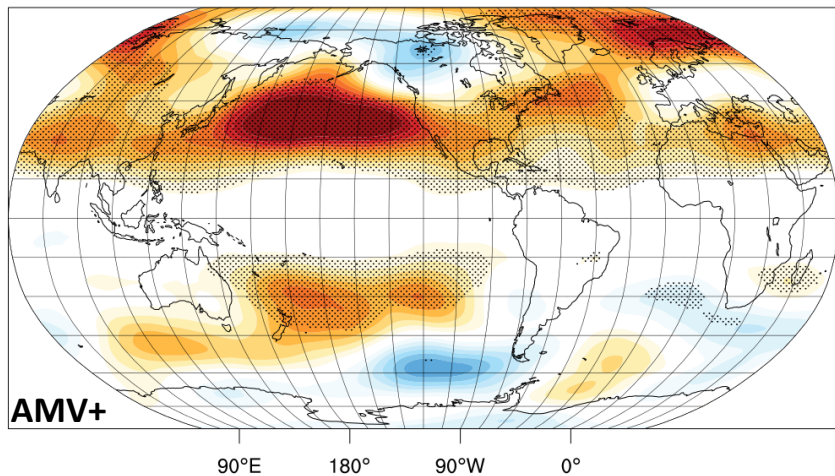
10-year climatological composite (30 members)



AMV climate impacts

Preliminary results: Z500

10-year climatological composite (30 members)

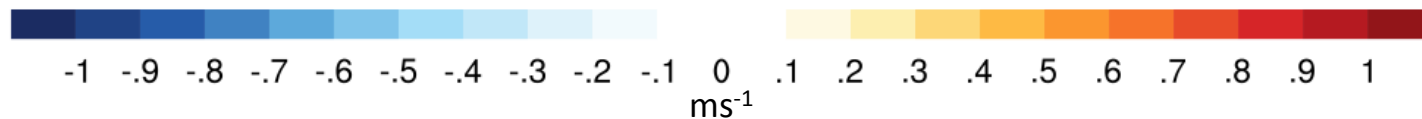
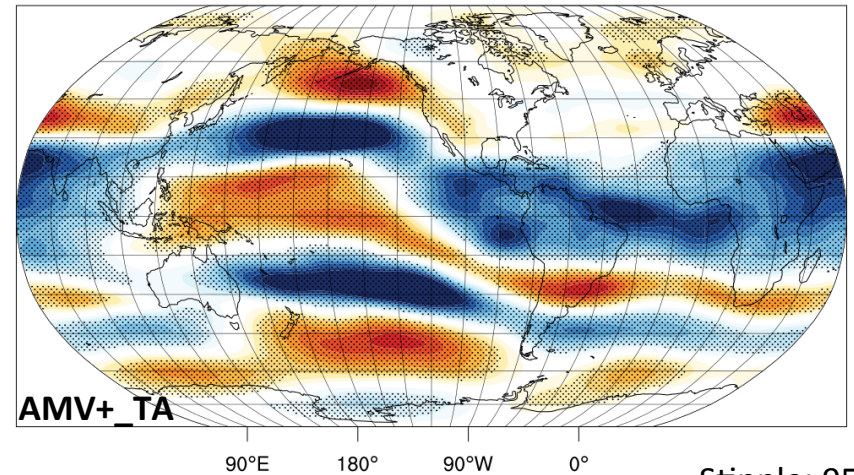
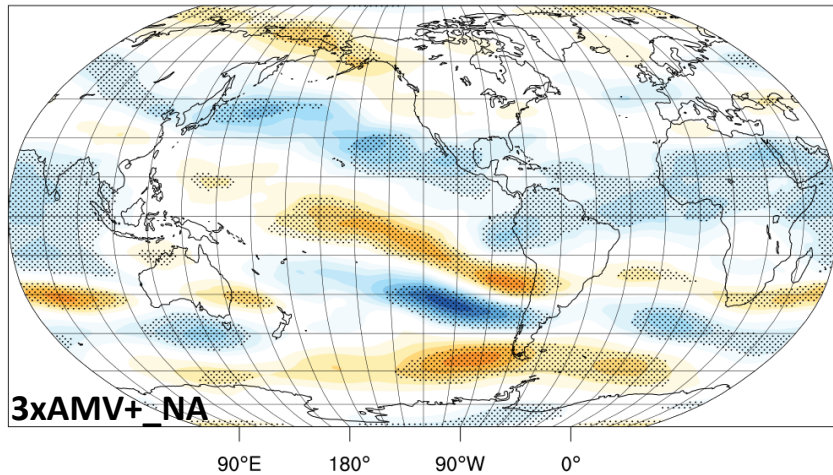
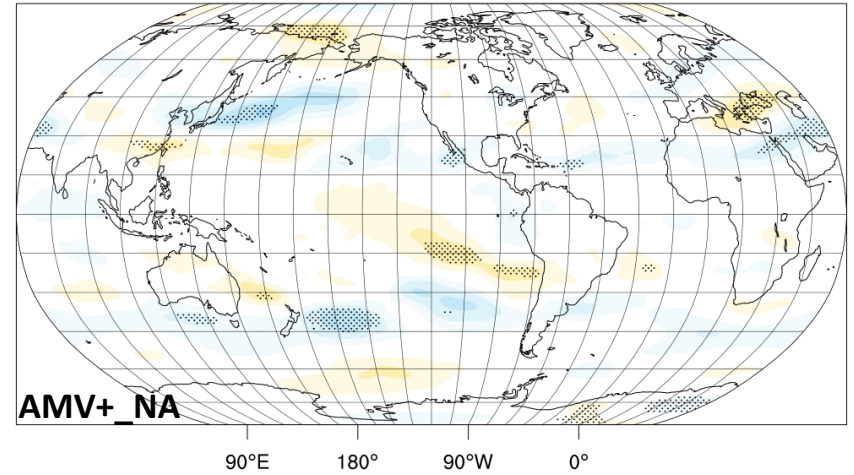
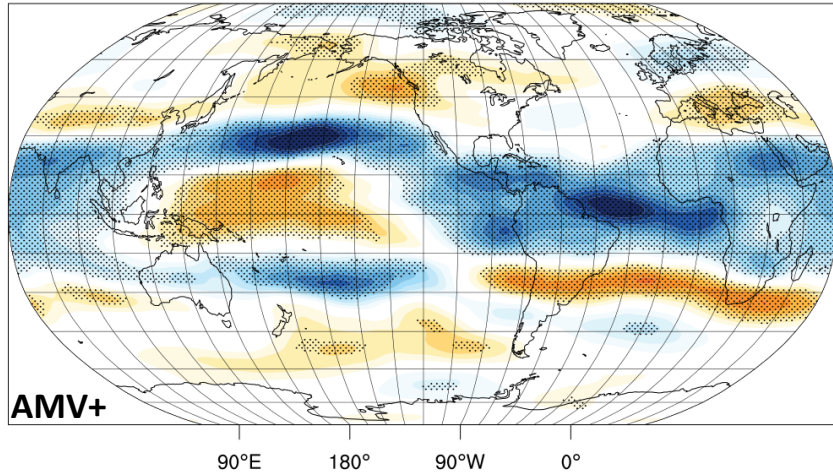


Stipple: 95%
significativity
(2-tail t-test)

AMV climate impacts

Preliminary results: U200

10-year climatological composite (30 members)



Stipple: 95%
significance
(2-tail t-test)

AMV climate impacts

Preliminary results: Storm Track (V'500)

10-year climatological composite (30 members)

