

Impact of stochastic parameterizations in coupled simulations with CESM2

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Stochastic parameterization

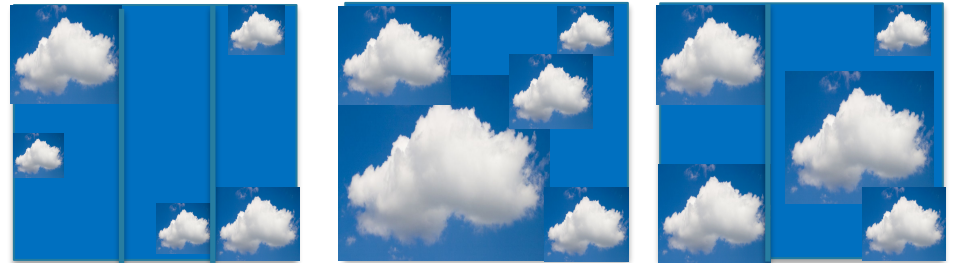
- Provides stochastic **realizations of the subgrid-flow**, not some assumed bulk scale flow
- Stochastic parameterization schemes describe the subgrid-scale motion in terms of a **pdf constrained by the resolved flow**

Equilibrium



100km

Stochastic realizations



Stochastically perturbed tendency scheme (SPPT)

Rationale: Especially as resolution increases, the equilibrium assumption is no longer valid and fluctuations of the subgrid-scale state should be sampled (Buizza et al. 1999)

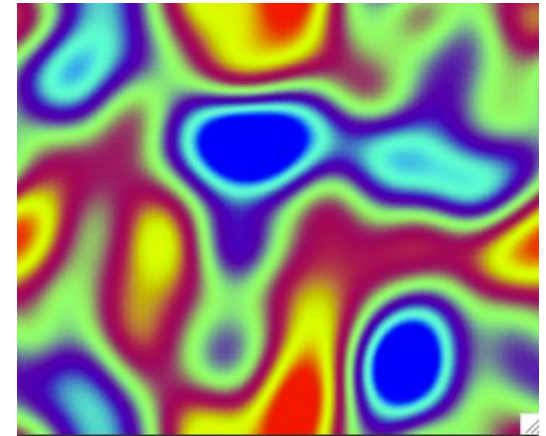
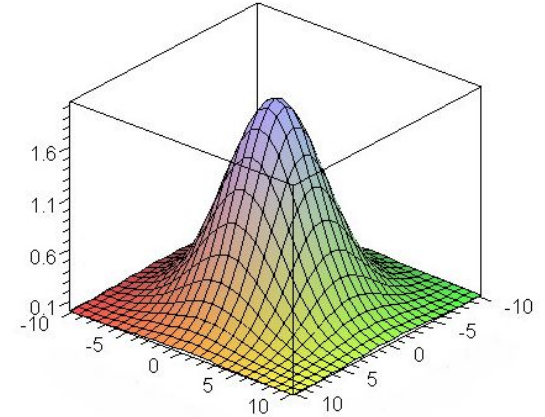
$$\frac{\partial X}{\partial t} = D_X + (r+1)P_X$$

Local tendency
for variable X

Dynamical
tendencies =>
Resolved scales

Physical
tendencies
=> Unresolved
scales

- ✧ Perturbs accumulated U,V,T,Q tendencies from physical parameterizations packages
- ✧ Radiative tendencies not perturbed
- ✧ Moisture fixer (perturb(P-E), so that humidity is conserved)



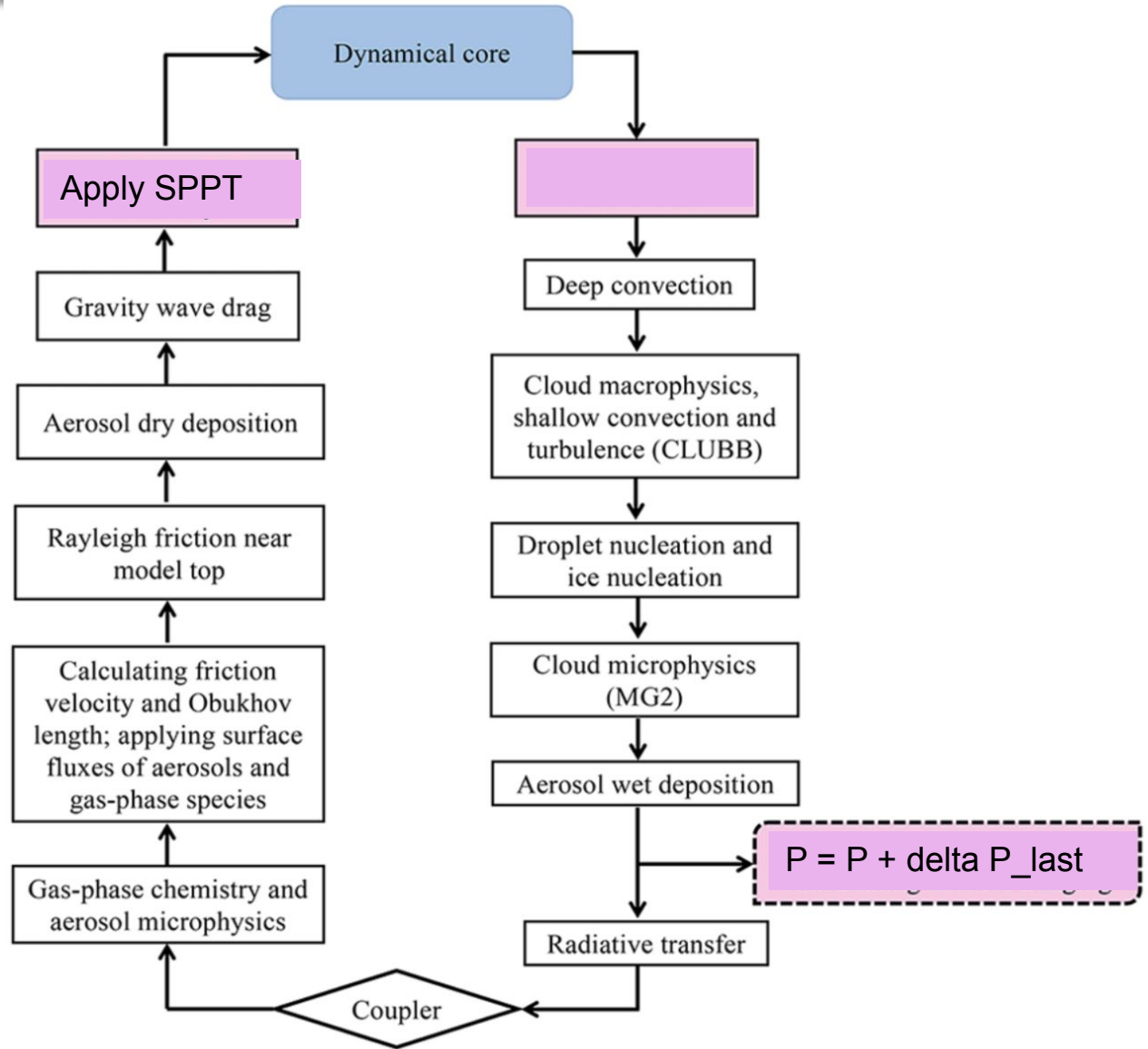
Moisture conservation

- SPPT itself does not conserve humidity and energy
- Climate models have energy fixers, so energy conservation is dealt with

$$\frac{1}{g} \int_{p_{surf}}^0 \left(\frac{dq_v}{dt} + \frac{dq_l}{dt} + \frac{dq_i}{dt} + \frac{dq_r}{dt} + \frac{dq_s}{dt} \right) dp_h = \frac{1}{g} \int_{p_{surf}}^0 \frac{dq_t}{dt} dp_h = F_{pr} - F_e$$

- SPPT perturbations should be added to precipitation and evaporation (P-E), i.e. surface fluxes (pers comm. Christensen, Pegion, Davide, Weisheimer, Subramanian)
- In practice, not straightforward (see next slide)

Calculate
 $\Delta P_{last} = r P$



Experiment setup

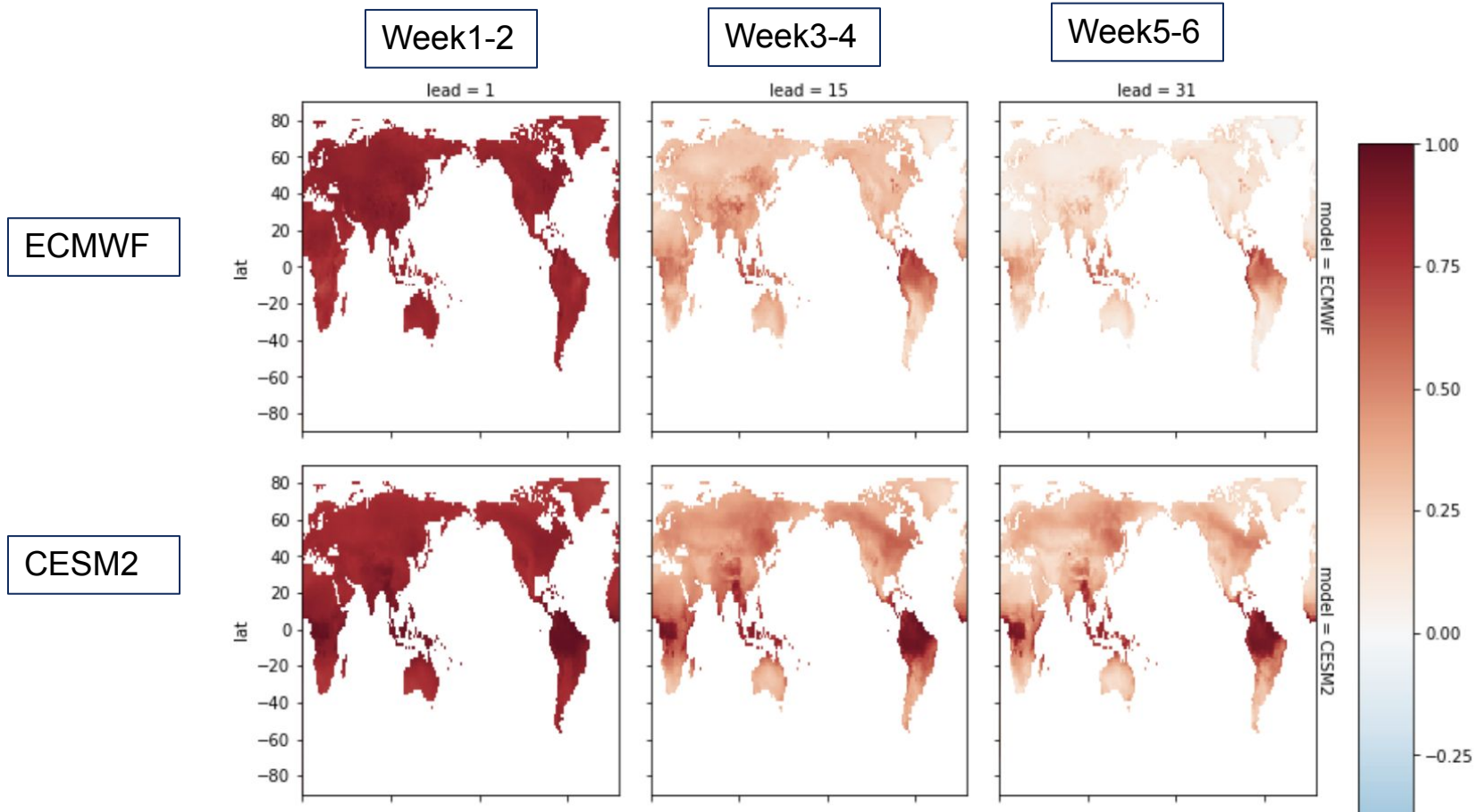
- Coupled Global Climate model
- CESM2 (CMIP6 control tag)
- 1 degree horizontal resolution in atmosphere and ocean
- Subseasonal to seasonal runs: 1999-2018 weekly initializations
- (Coupled climate run: 45 years, constant preindustrial forcing)

Outline

- Impact on subseasonal-to-seasonal skill
- Impact on systematic error in mean and variance
- Impact on modes of variability

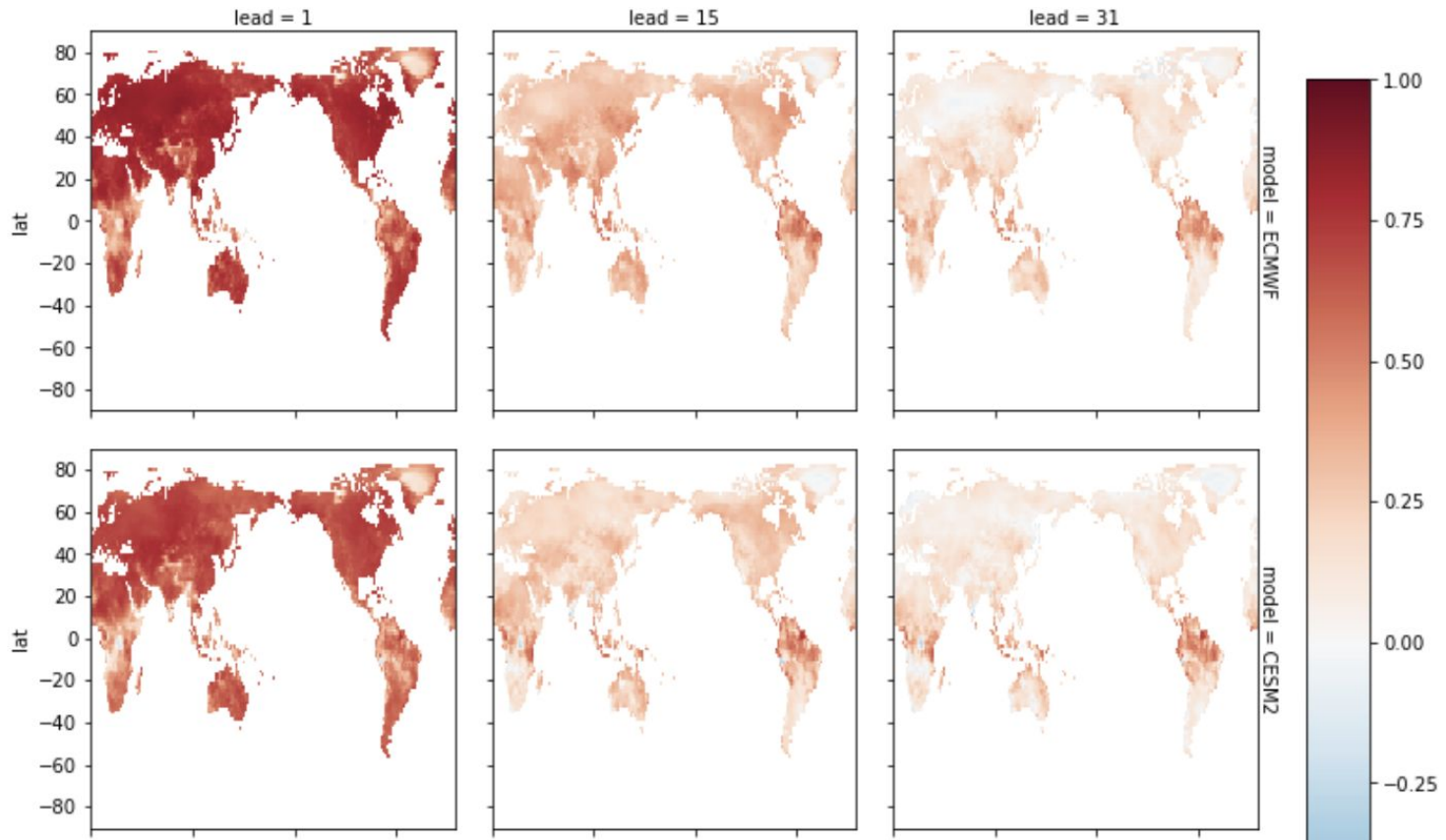


Perfect Model skill, ACC for T2m



- Most skill in the tropical belt
- CESM2 has more skill than ECMWF for weeks 3-4 and longer
- Large RMS error over NH land is an expression of large amplitude anomalies, not necessarily predictive skill

Actual Model skill, T2m

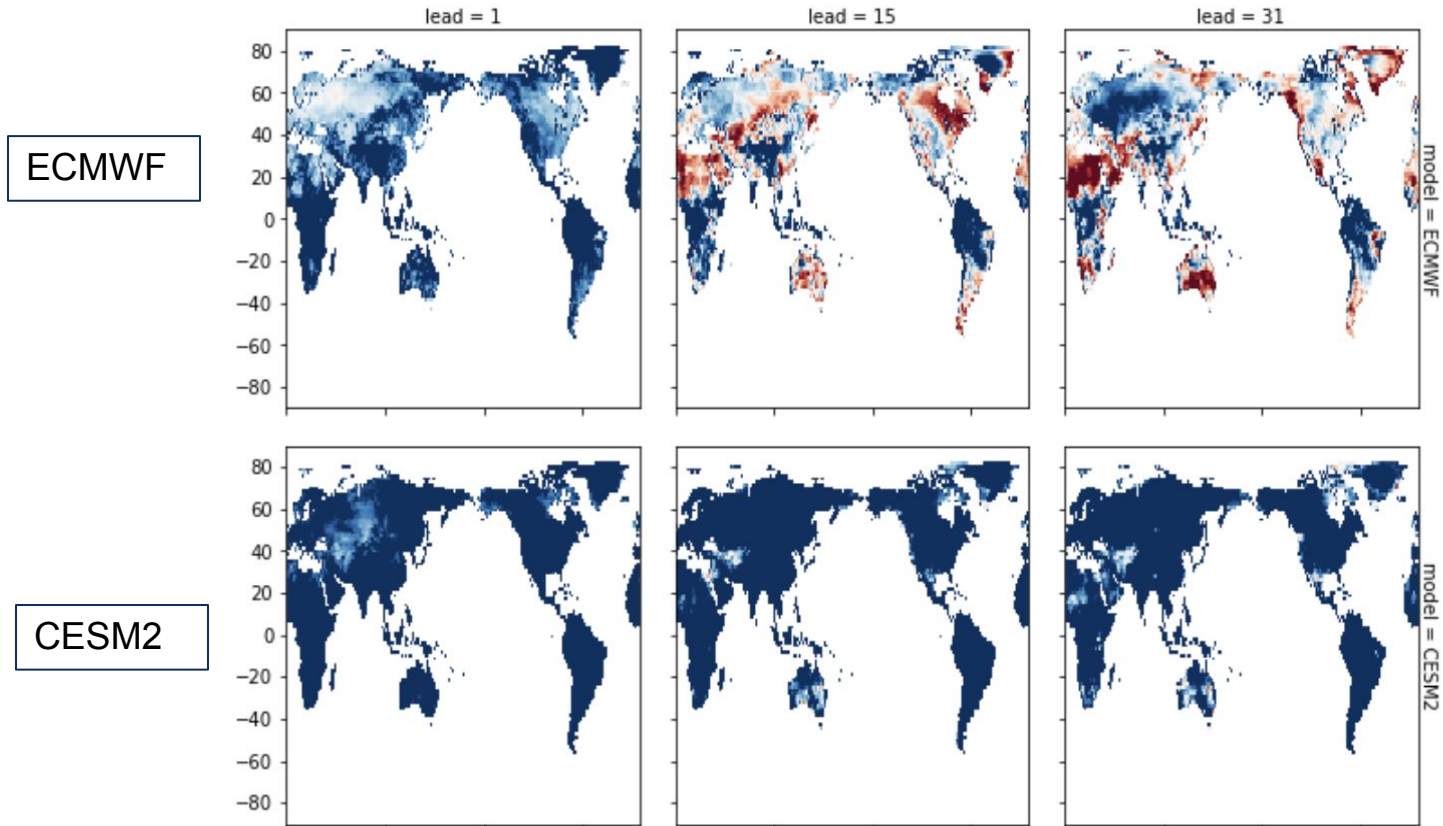


ECMWF

CESM2

- ECMWF better, especially at week 3-4
- Climate model developed to capture teleconnections

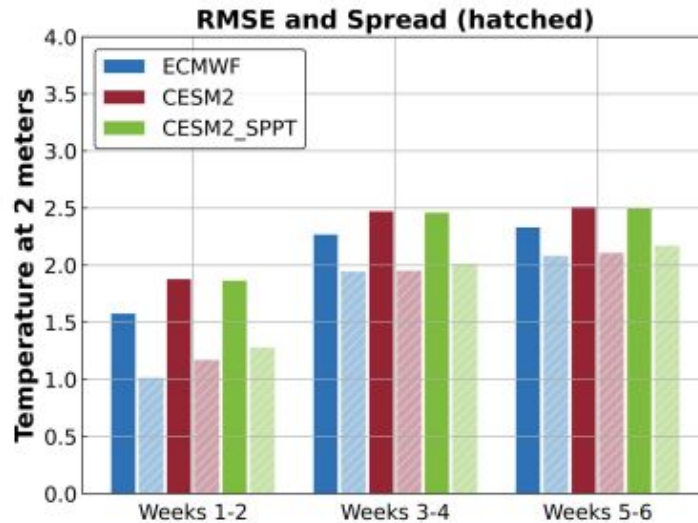
Signal-to-noise “paradox”



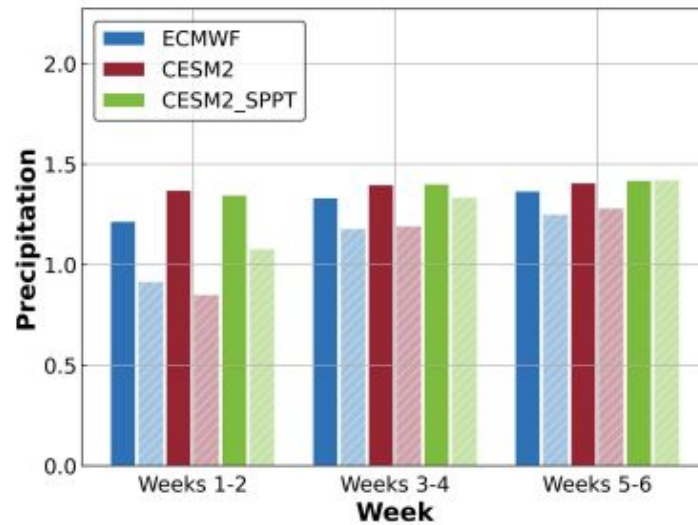
- ❖ $RCP = ACC_{actual} / ACC_{perfect}$, here difference
- ❖ $RCP = 0$; actual predictability reaches predictability limit
- ❖ ECMWF exhibit regions where actual skill is higher than potential skill
 - sign of signal-to-noise paradox
- ❖ Intrinsic predictability of CESM2 is higher than ECMWF

Spread/Error for hindcasts, DJF

T2m

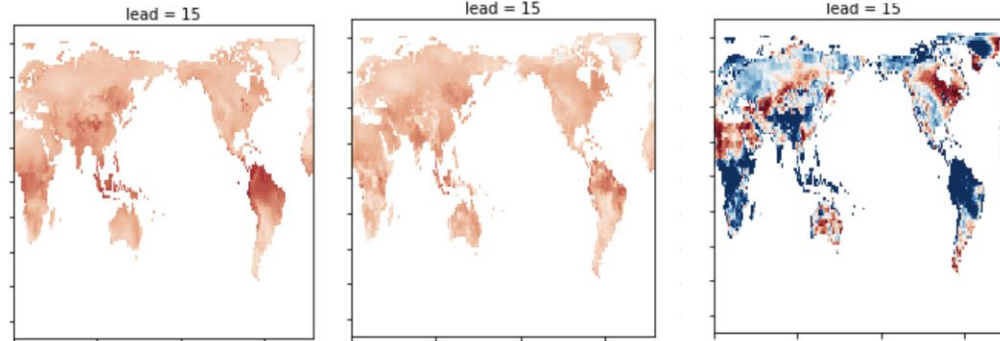


Precip

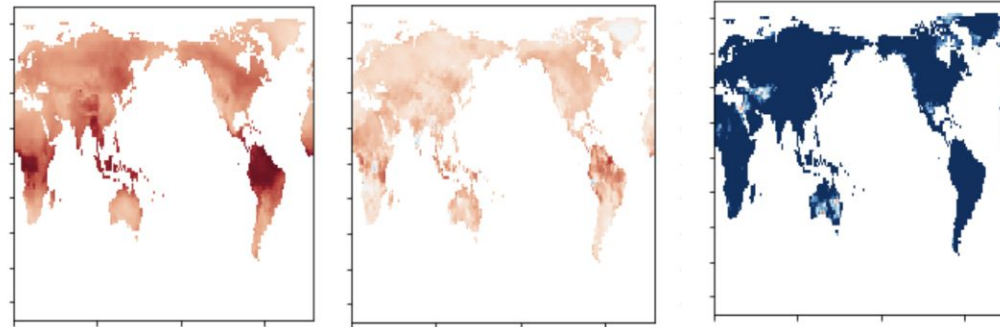


Signal-to-noise “paradox”, weeks 3-4, DJF

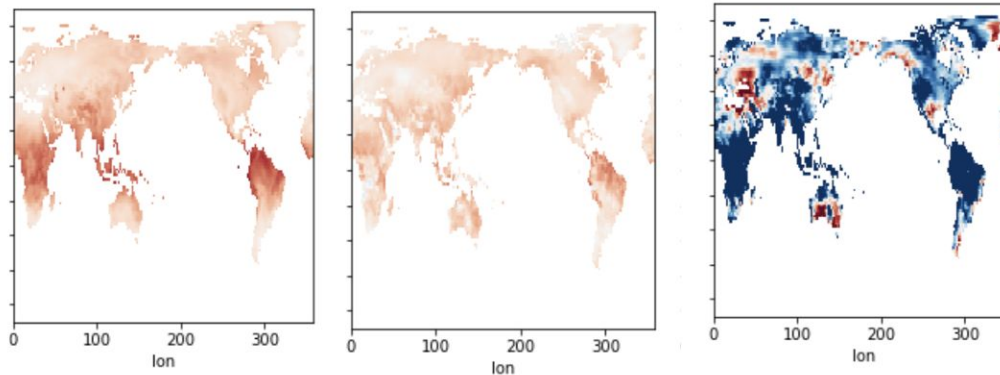
ECMWF



CESM2



SPPT

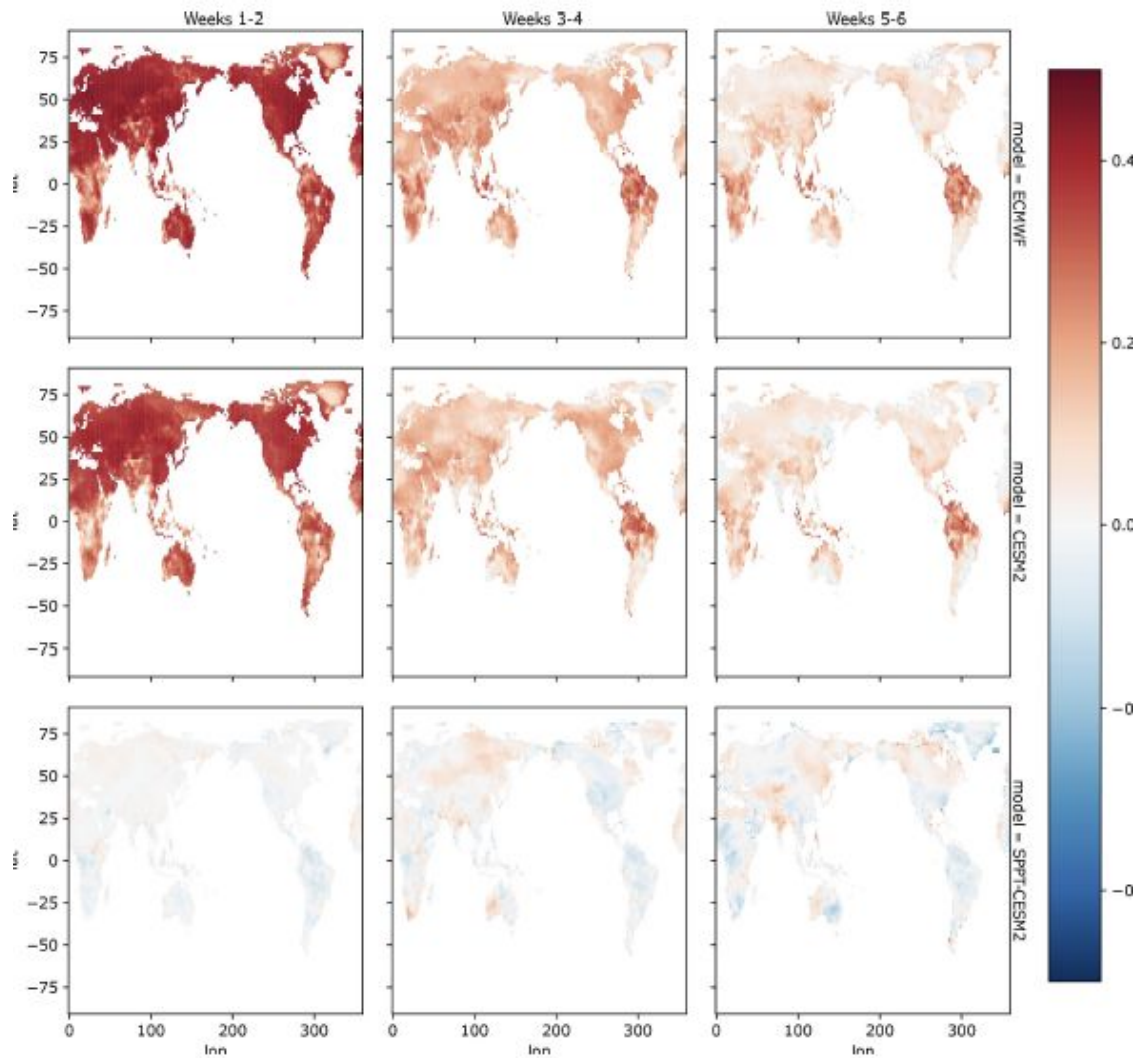


Actual Model skill, T2m, DJF

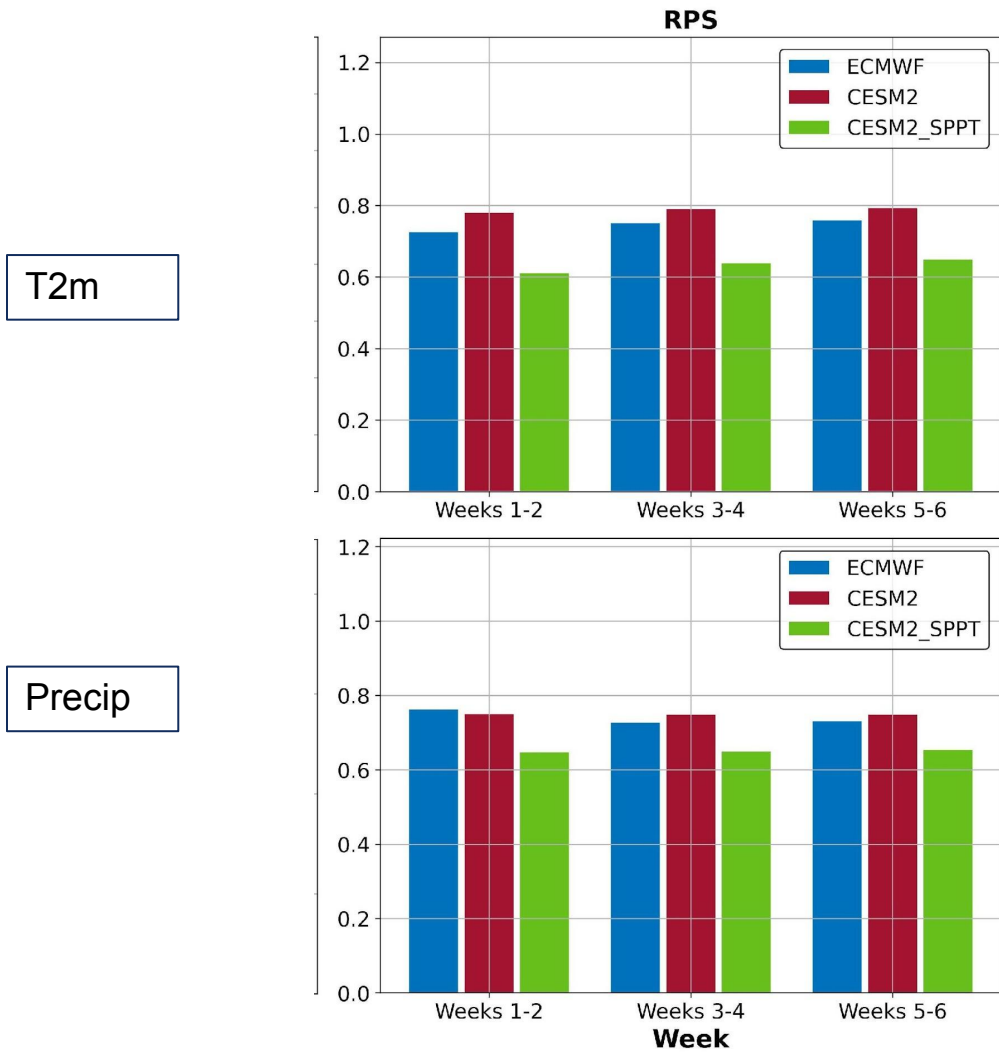
ECMWF

CESM2

SPPT-CES
M2



Ranked probability score of tercile forecasts



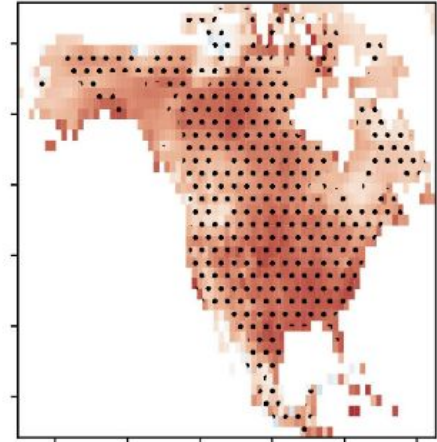
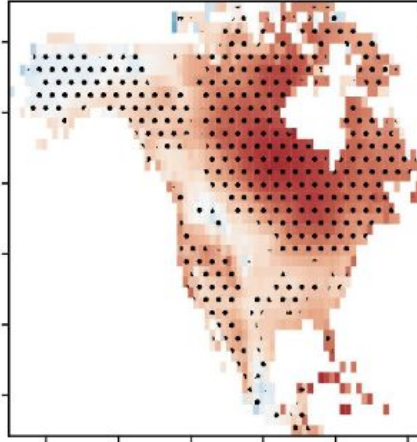
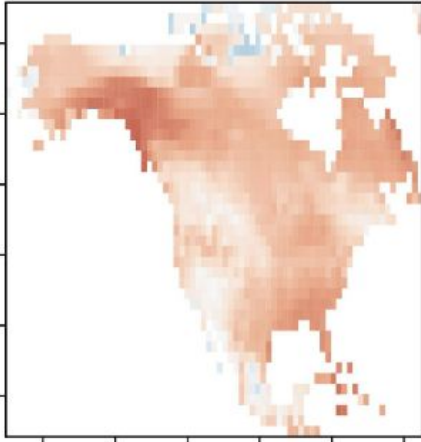
Skill conditioned on PNA, week 3-4

Neutral

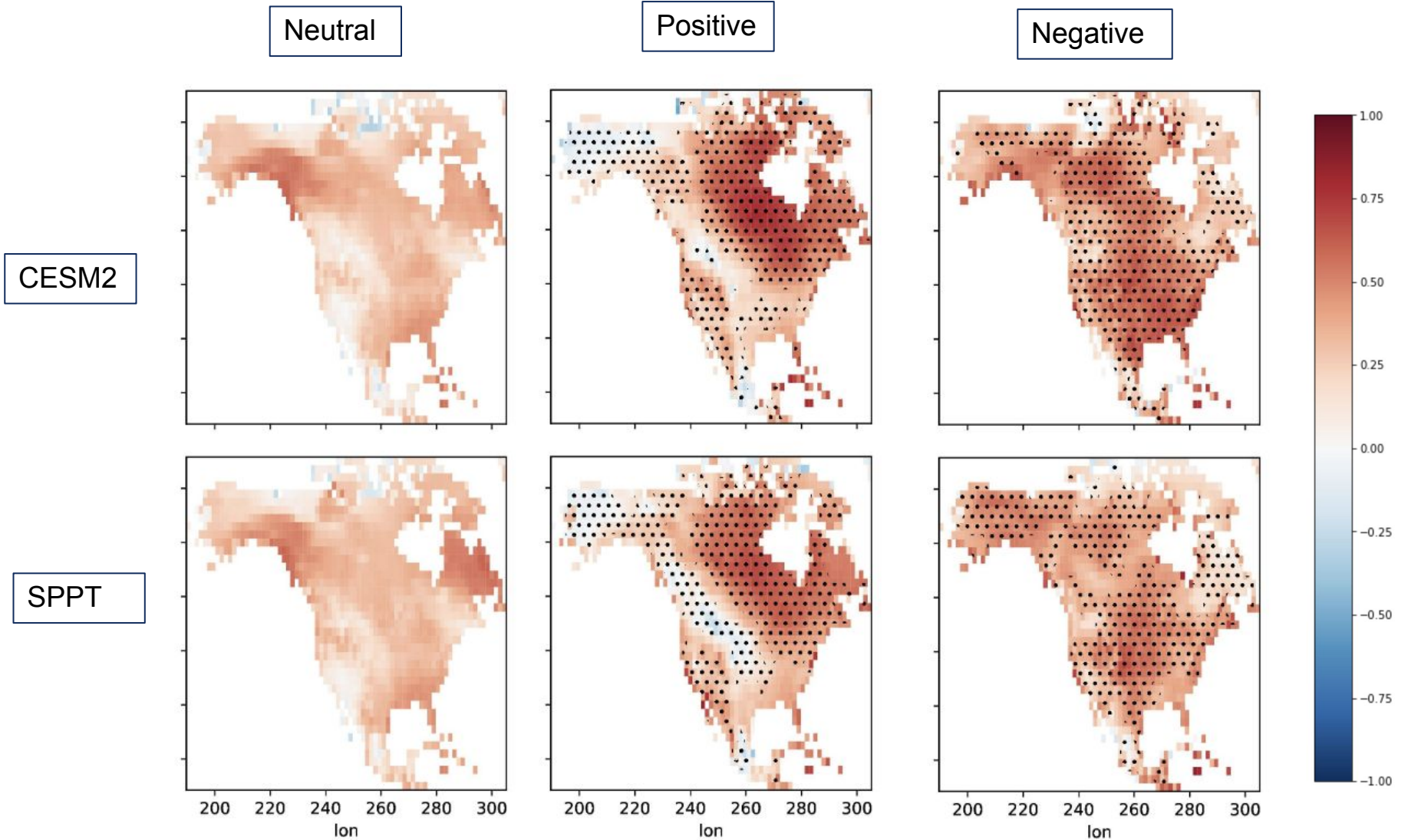
Positive

Negative

CESM2



Skill during positive and negative PNA, week 3-4



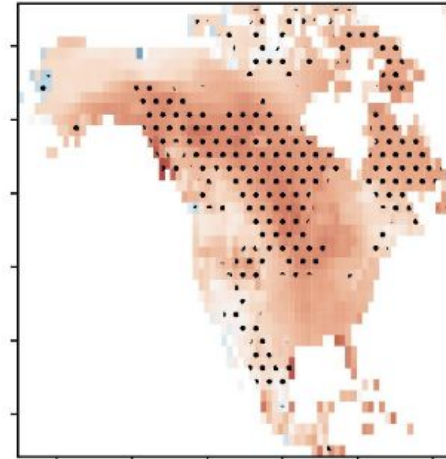
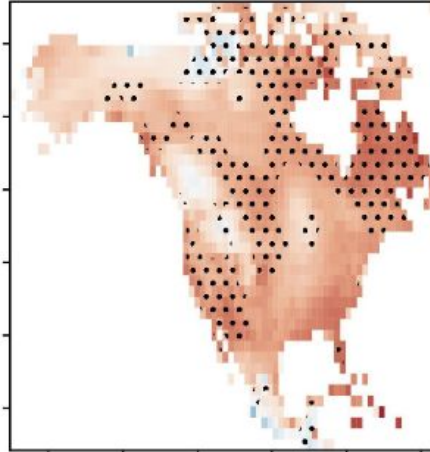
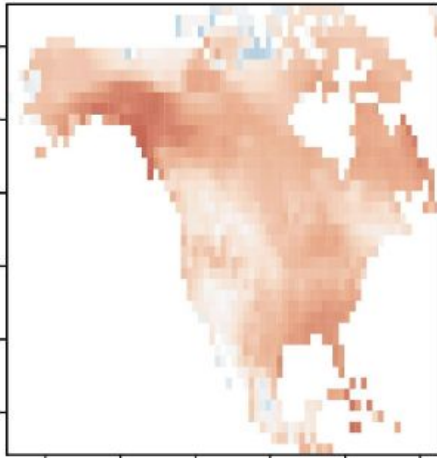
Skill during ENSO, week 3-4

Neutral

Positive

Negative

CESM2



Skill conditioned on ENSO, week 3-4

