II.3.2 The Coupled Model Historical Forecasting Project

II.3.3 Forecast Combination, Calibration and Verification

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CCCma

CHFP Status

- **CHFP1** complete
  - 12 month 10-ensemble forecasts initialized 1 Dec,1 Mar, 1 Jun and 1 Sep 1972-2001
  - Skills exceed GCM3 component of HFP2, approach 4x10-ensemble HFP2 for Canadian air temperature e.g.

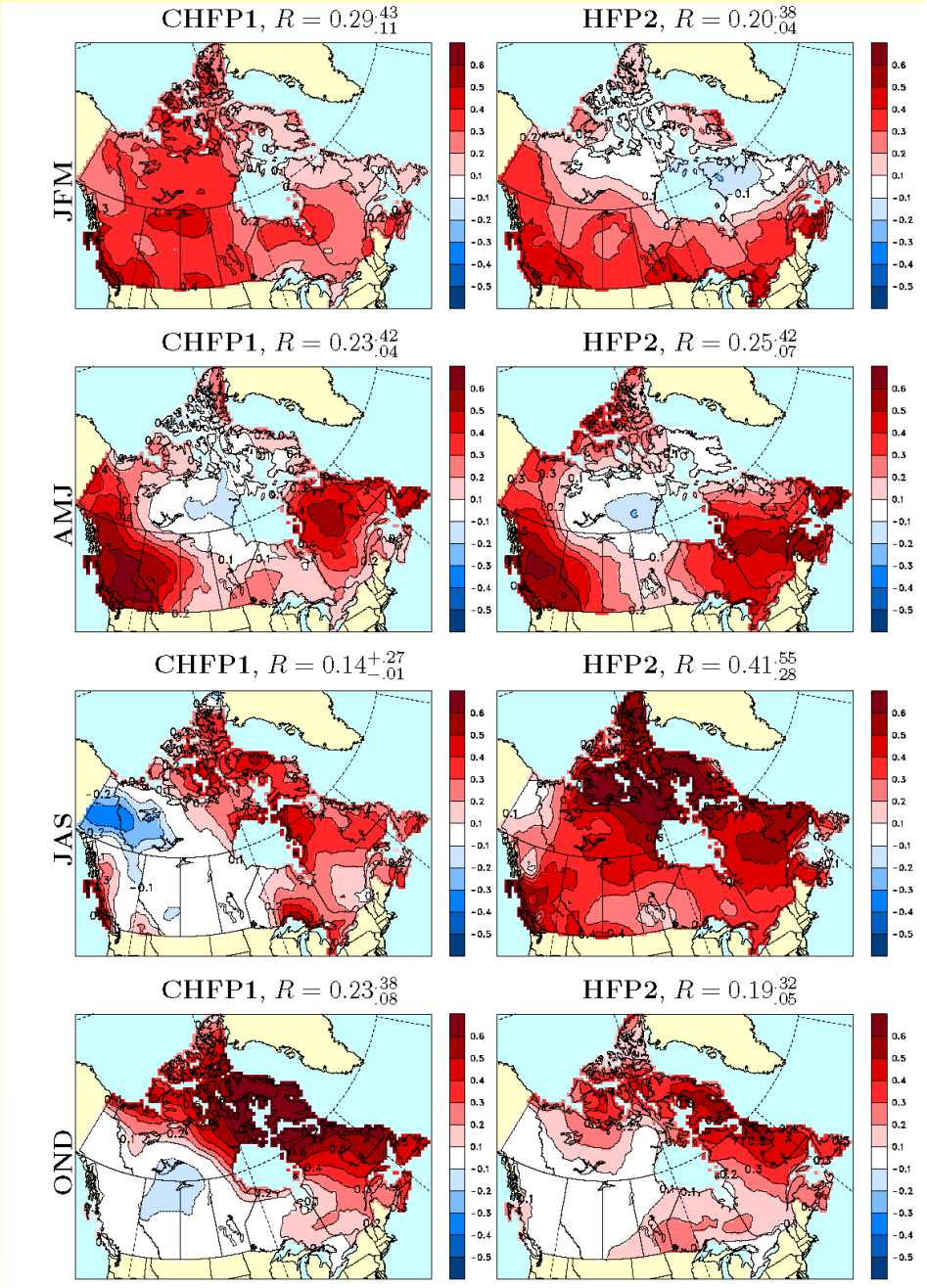
CHFP1 vs HFP2

Correlation skill

Surface air temperature over Canada

1-month lead

Season	JFM	AMJ	JAS	OND	ALL
Correlation					
CHFP1	$\mathbf{.29}^{.43}_{.11}$	$.23^{.42}_{.04}$	$.14^{+.27}_{-.01}$	$\mathbf{.23}^{.38}_{.08}$	$.22^{.30}_{.12}$
HFP2/MM4	$.20^{.38}_{.04}$	$\mathbf{.25}^{.42}_{.07}$	$\mathbf{.41}^{.55}_{.28}$	$.19^{.32}_{.05}$	$\mathbf{.26}^{.37}_{.17}$
HFP2/GCM3	$.22^{.41}_{.05}$	$.15^{+.32}_{-.06}$	$.23^{.35}_{.12}$	$.05^{+.23}_{-.11}$	$.16^{.28}_{.08}$



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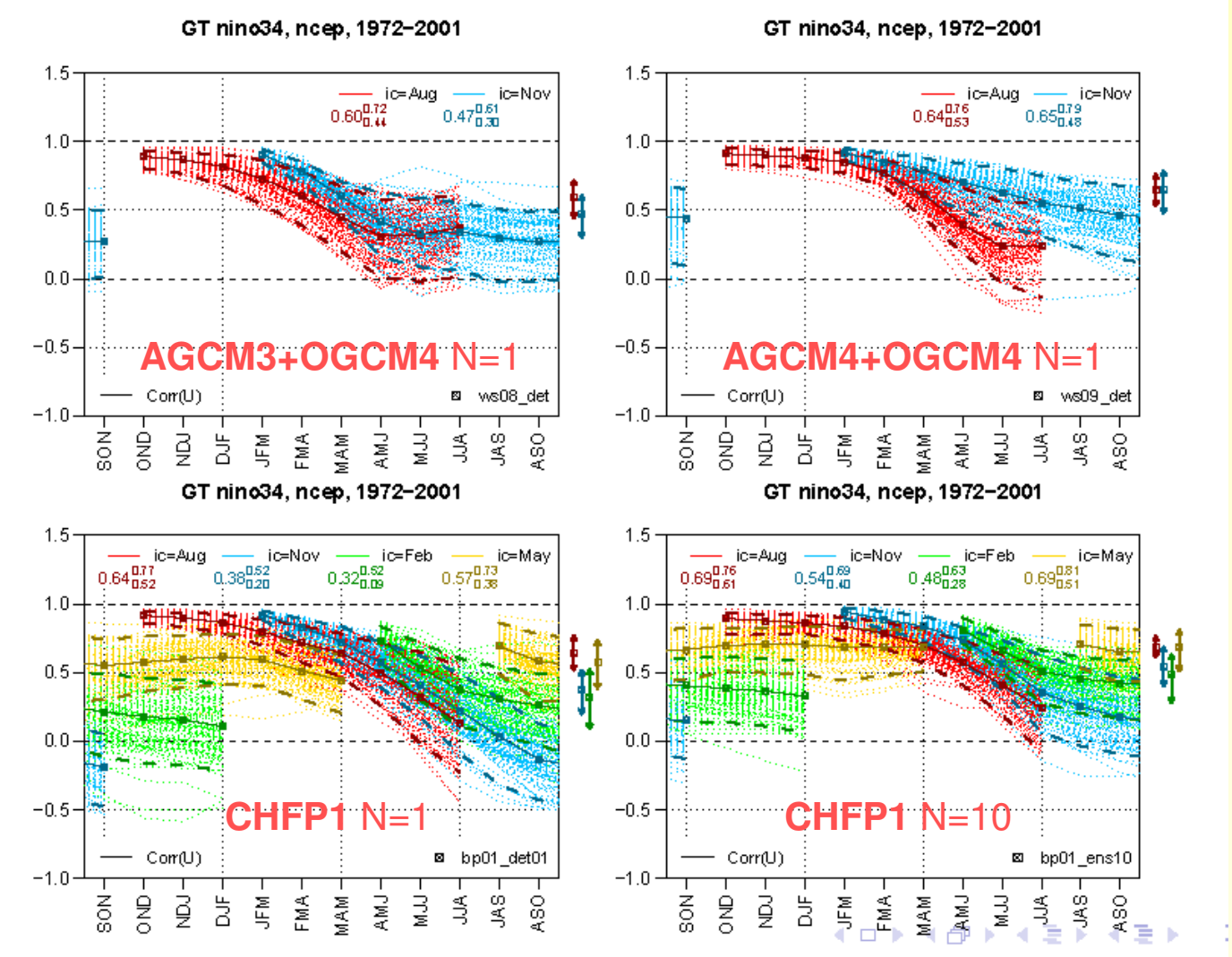
- **CHFP2** model components finalized; initialization procedures undergoing final testing/evaluation

Impact of Model improvements on ENSO Prediction

Nino3.4 correlation skill

SST nudging initialization



Impact of Model improvements on ENSO Prediction

	OGCM AGCM	Ens size	Avg skill
CHFP2	OGCM4 + AGCM3	1	0.55
CHFP2	OGCM4 + AGCM4	1	0.64
CHFP1	OGCM3 + AGCM3	1	0.48
CHFP1	OGCM3 + AGCM3	**10**	**0.60**

Mean NINO3.4 correlation skill of rolling 3-month forecasts

Dec → Nov Mar → Feb Jun → May Sep → Aug

SST nudging only 1972-2001

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N=1 CHFP2 skill exceeds N=10 CHFP1 skill

→ much further room for improvement through ensembles + better initialization

Mean NINO3.4 correlation skill of rolling 3-month forecasts

Dec → Nov Mar → Feb Jun → May Sep → Aug

SST nudging only 1972-2001

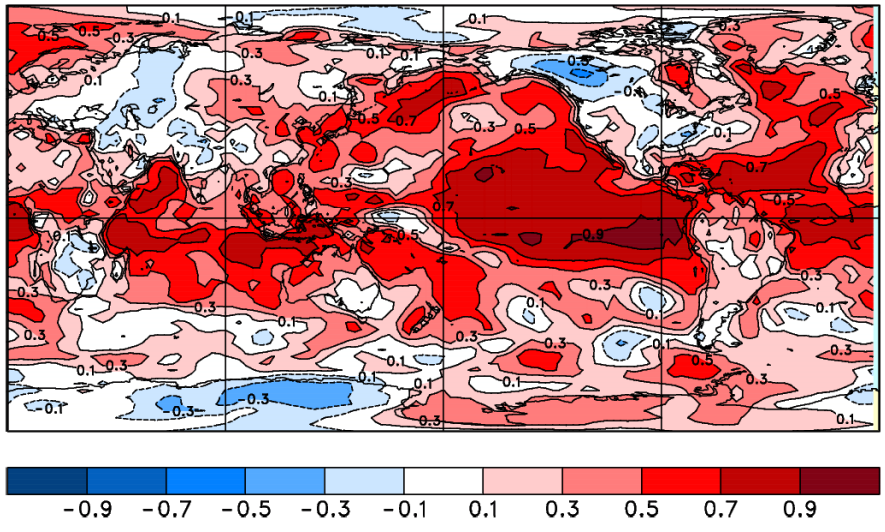
Impact of AGCM NCEP Initialization

Surface temperature correlation skill

First forecast month from 1 Sep

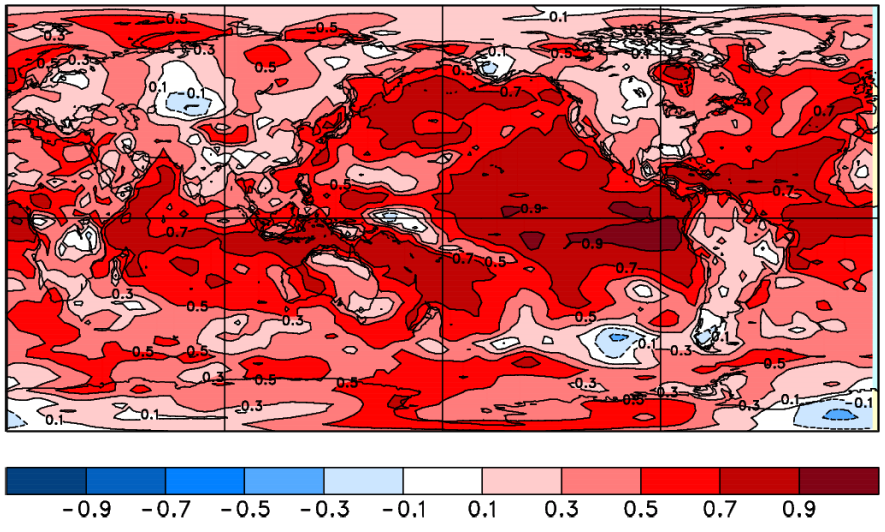
SST nudging only

WS09 ERA40 ST M09 I=08 L=0 1972-2001 CORR(U)=0.3543 L=0.152 O=0.442



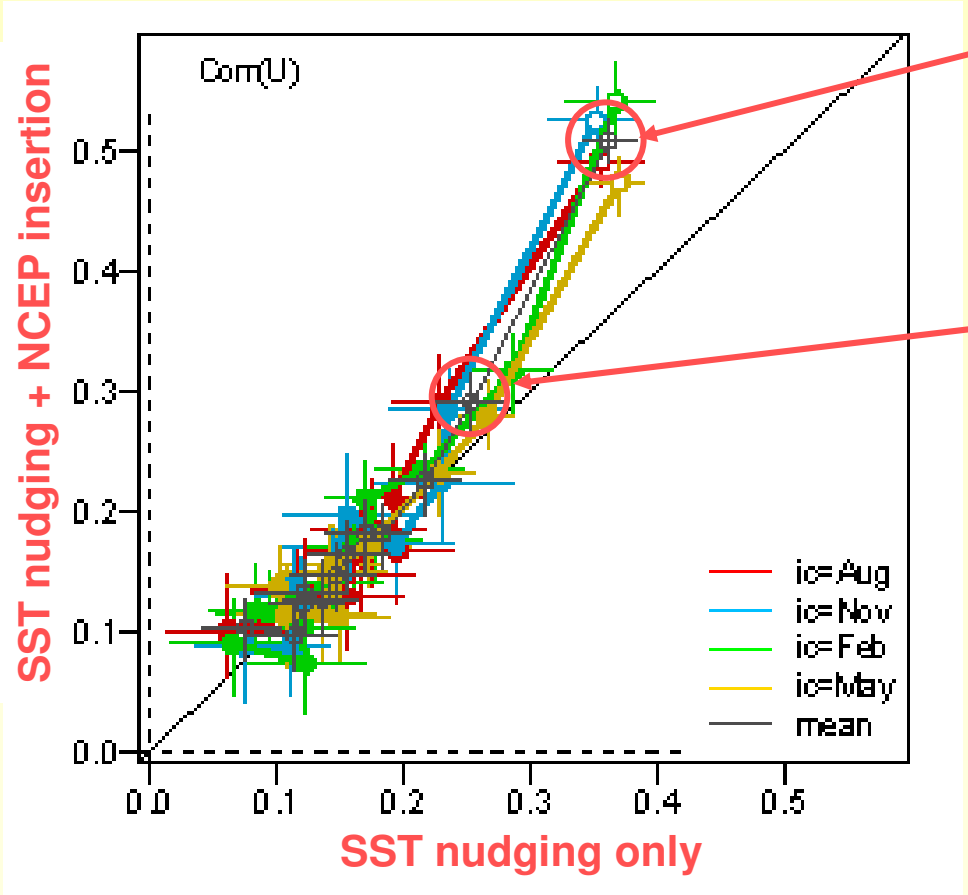
SST nudging + NCEP insertion

WS09N ERA40 ST M09 I=08 L=0 1972-2001 CORR(U)=0.4920 L=0.318 O=0.568



Impact of AGCM NCEP Initialization

Surface temperature correlation skill: Global mean



1st month improvement

possible 2nd month improvement

Skill dependence on initialization: more assessments

- **OGCM *T* and *S* assimilation**
  - extensive tests using earlier model version reported in Woo-Sung Lee's talk
  - testing with final model version underway
- **Land surface initialization**
  - initialization data transferred from Guelph to CCCma
  - incorporate into model initial conditions
- **IAU AGCM assimilation:** testing of IAU underway
- **Sea Ice Initialization:** nudging procedure being tested
- **OGCM spectral nudging:** initial tests of procedure underway

Forecast Combination, Calibration and Verification

Skill assessment of seasonal hindcasts from the Canadian Historical Forecast Project

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George J. Boer[1], Jacques Derome[3], Juan Sebastian Fontecilla[4]

[1] Climate Research Division, Environment Canada, Victoria, BC, Canada

[2] Climate Research Division, Environment Canada, Toronto, ON, Canada

[3] Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, QC, Canada

[4] Canadian Meteorological Centre, Environment Canada, Montreal, QC, Canada

HFP2 skill vs. ensemble size

Consider all possible 1-, 2-, 3-, 4-model combinations

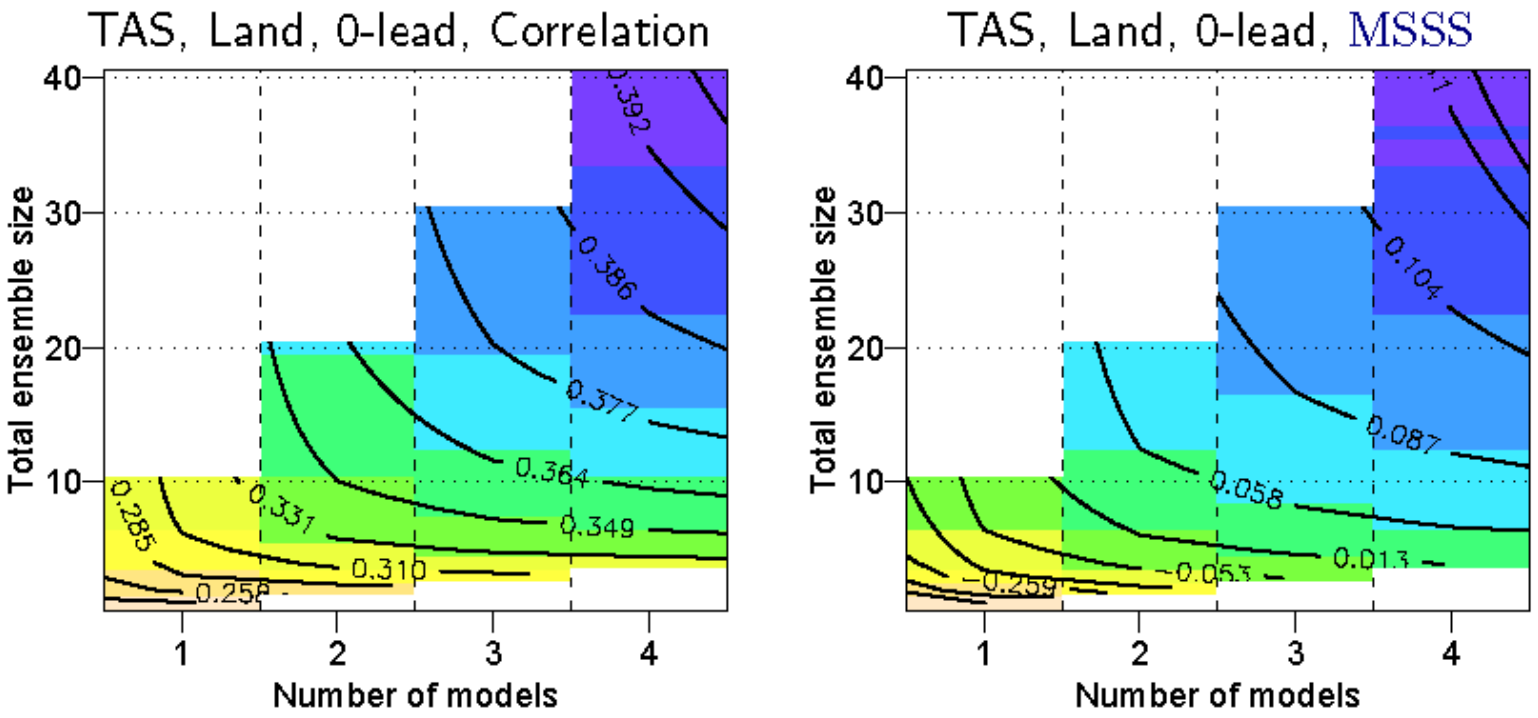


Figure: The correlation skill score (left) and MSSS (right) of 0-lead TAS forecasts over land as the function of the number of models in a multimodel ensemble (x-axis) and the total ensemble size (y-axis). Skill scores are averaged over all 12 rolling seasons.

HFP2 skill vs. ensemble size

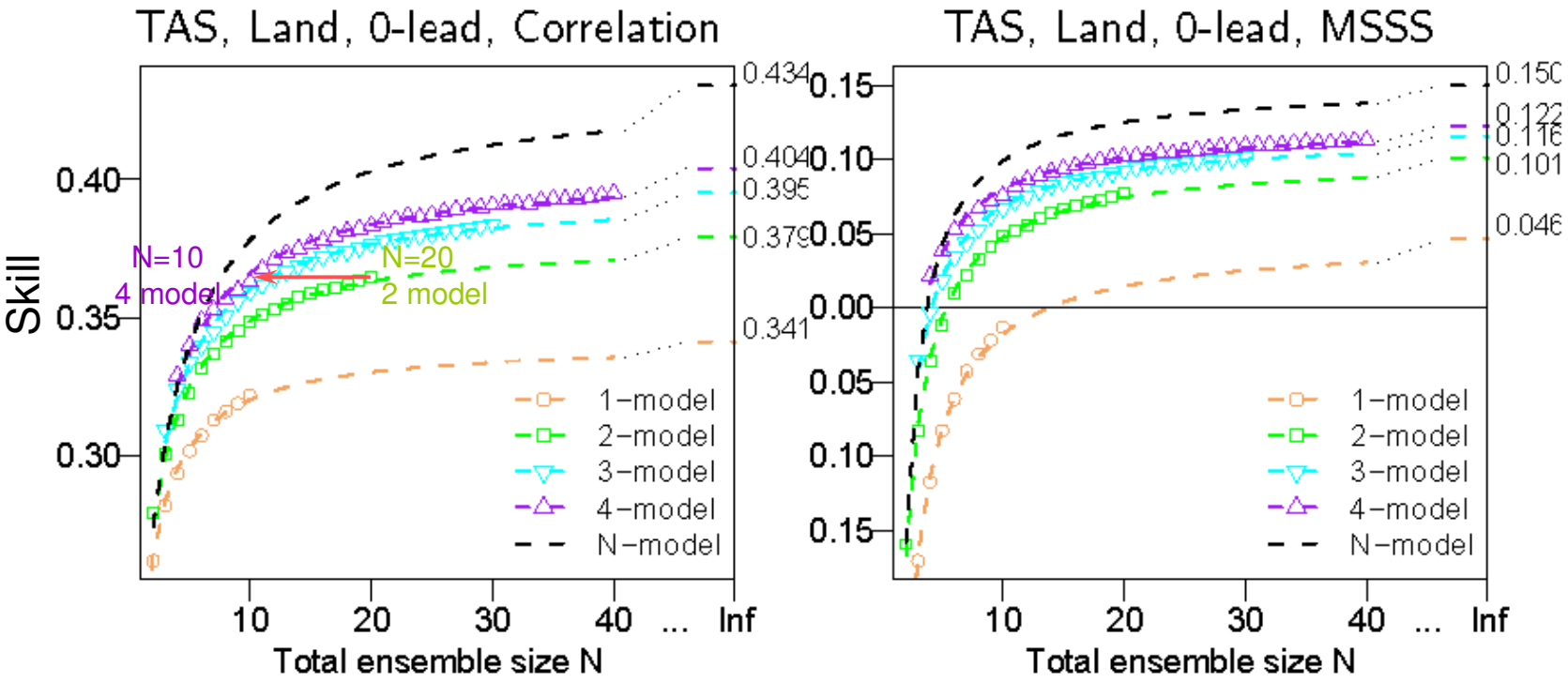
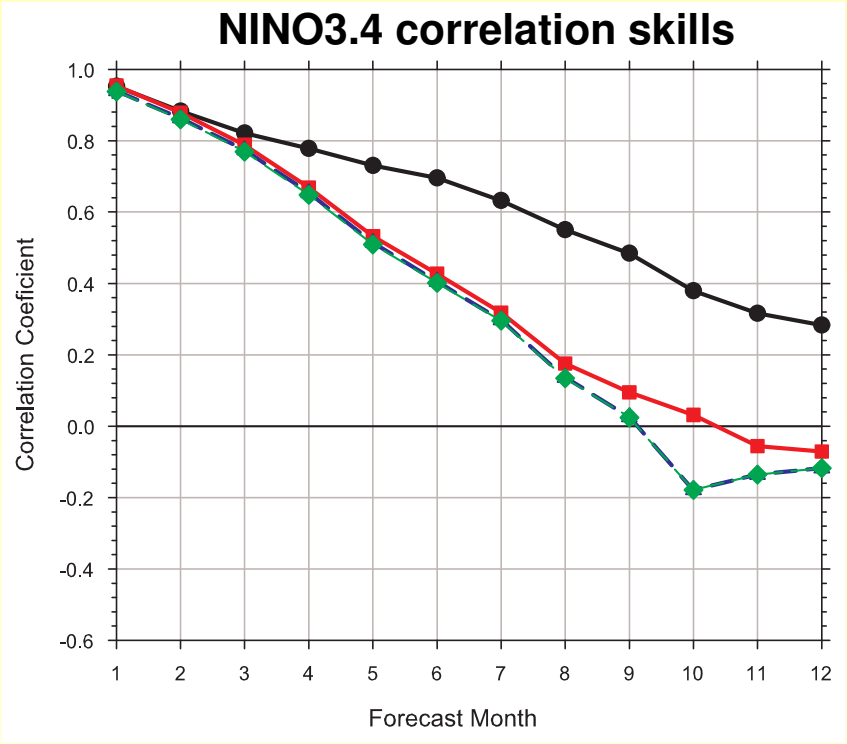


Figure: The 12-season mean correlation skill score (left) and MSSS (right) of 0-lead forecasts of TAS over land as the function of the total ensemble size.

CHFP1 vs HFP2



Mean NINO3.4 correlation skill of rolling 3-month forecasts

OGCM AGCM	Ens size	Dec → Nov	Mar → Feb	Jun → May	Sep → Aug	Avg
OGCM4 + AGCM3	1	0.63	0.52	0.42	0.63	0.55
OGCM4 + AGCM4	1	0.65	0.67	0.56	0.67	0.64
OGCM3 + AGCM3	1	0.64	0.38	0.32	0.57	0.48
OGCM3 + AGCM3	**10**	**0.69**	**0.54**	**0.48**	**0.69**	**0.60**

"Perfect model" framework

- X - observations, F_n - forecasts:

$$\begin{aligned} X &= \beta + \epsilon, \\ F_n &= \beta + \epsilon'_n, \ n = 1, \ldots, N_{\text{ens}}, \end{aligned}$$

where β is a predictable component, ϵ is an unpredictable component, N_{ens} is the ensemble size.
$\rho^2_{\text{pot}} = \sigma^2_\beta / \sigma^2_X$ is the potential predictability.

- Correlation skill score:

$$\rho^2(N_{\text{ens}}) = \text{Cor}(X, \langle F \rangle) = \rho^2_{\text{pot}} \frac{N_{\text{ens}}}{N_{\text{ens}} + \rho^{-2}_{\text{pot}} - 1}$$

- MSE skill score:

$$\text{MSSS}(N_{\text{ens}}) = 1 - \frac{\text{MSE}_{\langle F \rangle}}{\text{MSE}_C} = 1 + (\rho^2_{\text{pot}} - 1) \frac{1 + 1/N_{\text{ens}}}{1 + 1/N_{\text{clim}}},$$

Correlation score vs. ensemble size

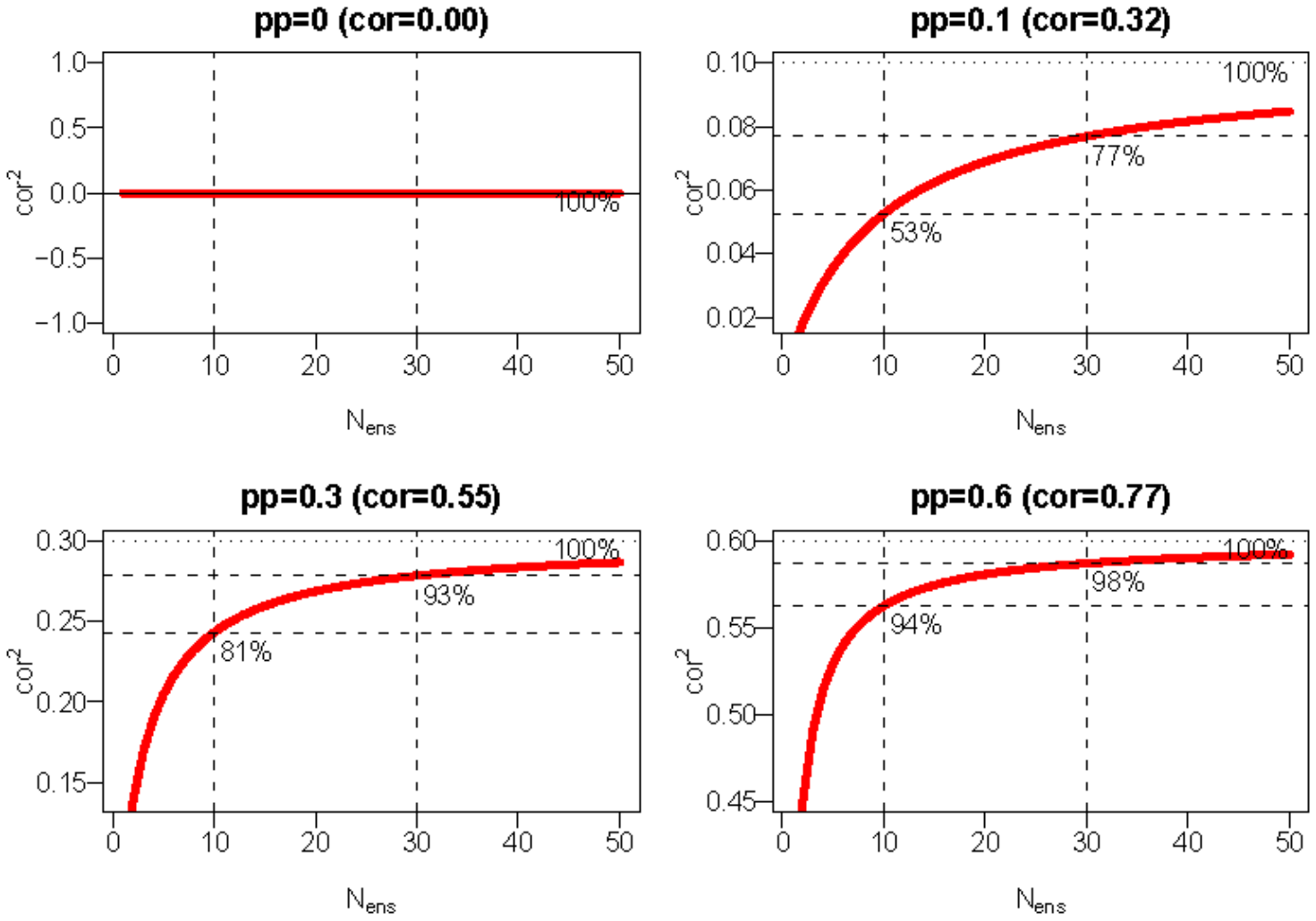


Figure: ρ^2 as a function of the ensemble size for ρ^2_{pot}=0, 0.1, 0.3, 0.6.

Conclusions

- HFP2 skill scores increase both with the overall ensemble size and with the number of models $\Rightarrow$ there are genuine advantages in the multimodel approach.
- 4-model HFP2 ensemble with 10 ensemble members per model is a reasonable multimodel configuration.
  - $N_{\mathrm{tot}} > 30$;
  - ensembles with fewer models would need at least 3 times larger ensemble size to match the performance of 4-model ensemble;
  - any additional model would add little skill.

Other implications:

- there are potentially large gains from using a great number of different models in seasonal forecasting.
- community efforts where the costs of large number of models is spread across different organizations are important.
- a possible venue of increasing the ensemble size with little additional cost is by changing model tunable parameters within a reasonable range.