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A simple ocean performance metrics applied to historical CMIP5 simulations

PRIMAVERA

Motivation and introduction

- For atmospheric models performance metrics very common, for example Reichler and Kim (2008)
- Not for ocean models !!!
- Here we define simple ocean performance metrics in a similar way as Reichler and Kim (2008) did for the atmosphere.

Performance metrics

- For each 3D grid point of the PHC climatology the absolute error for potential temperature T and salinity S is calculated and averaged over ocean basins / the global ocean
- The mean absolute error over all CMIP5 models for an ocean basin / the global ocean serves as a reference and a specific model can be compared to the CMIP5 ensemble
- A performance index (PI) of 1 indicates same performance as CMIP5 ensemble
- A PI of less than 1 indicates better performance than CMIP5 ensemble, of greater than 1 worse performance

Example output: performance of AWI-CM

global	S DJF	0.800658287
global	S JJA	0.792248607
global	T DJF	0.809991717
global	T JJA	0.756092548
average:global		0.789754510
southoce	S DJF	0.713550925
southoce	S JJA	0.642232180
southoce	T DJF	0.582666814
southoce	T JJA	0.625893474
average:southoce		0.641085863
indoce	S DJF	0.637605846
indoce	S JJA	0.651327014
indoce	T DJF	0.717630625
indoce	T JJA	0.591852546
average:indoce		0.649603963
pacoce	S DJF	0.956561685
pacoce	S JJA	0.922508359
pacoce	T DJF	0.936220169
pacoce	T JJA	0.839840889
average:pacoce		0.913782775
npacoce	S DJF	1.02797759
npacoce	S JJA	0.972718418
npacoce	T DJF	1.03628802
npacoce	T JJA	0.929830909
average:npacoce		0.991703749
spacoce	S DJF	0.893189490
spacoce	S JJA	0.878341854
spacoce	T DJF	0.847220480
spacoce	T JJA	0.753928125
average:spacoce		0.843169987
atloce	S DJF	0.746122181
atloce	S JJA	0.750263929
atloce	T DJF	0.711102664
atloce	T JJA	0.752087116
average:atloce		0.739893973
natloce	S DJF	0.633922219
natloce	S JJA	0.636811793
natloce	T DJF	0.729878187
natloce	T JJA	0.813130796
average:natloce		0.703435779
satloce	S DJF	0.896557152
satloce	S JJA	0.903289855
satloce	T DJF	0.691242218
satloce	T JJA	0.685272276
average:satloce		0.794090390
arcoce	S DJF	0.611582994
arcoce	S JJA	0.662069023
arcoce	T DJF	0.658231497
arcoce	T JJA	0.720392108
average:arcoce		0.663068891

One sees straight away in which area / parameter / season the model performs better / worse than CMIP5 average. In this example: AWI-CM very good!

Conclusions

- A simple ocean model performance metrics has been defined and applied to CMIP5 and prototype HighResMIP simulations
- Allows to quickly diagnose in which ocean basin and in which depth the model drift is strongest
- State-of-the-art ocean models show large errors which exceed the interannual variability and from 500 m depth downwards even the climate change signal
- Shows that in ocean models there is still much room for improvements

Vertical profiles

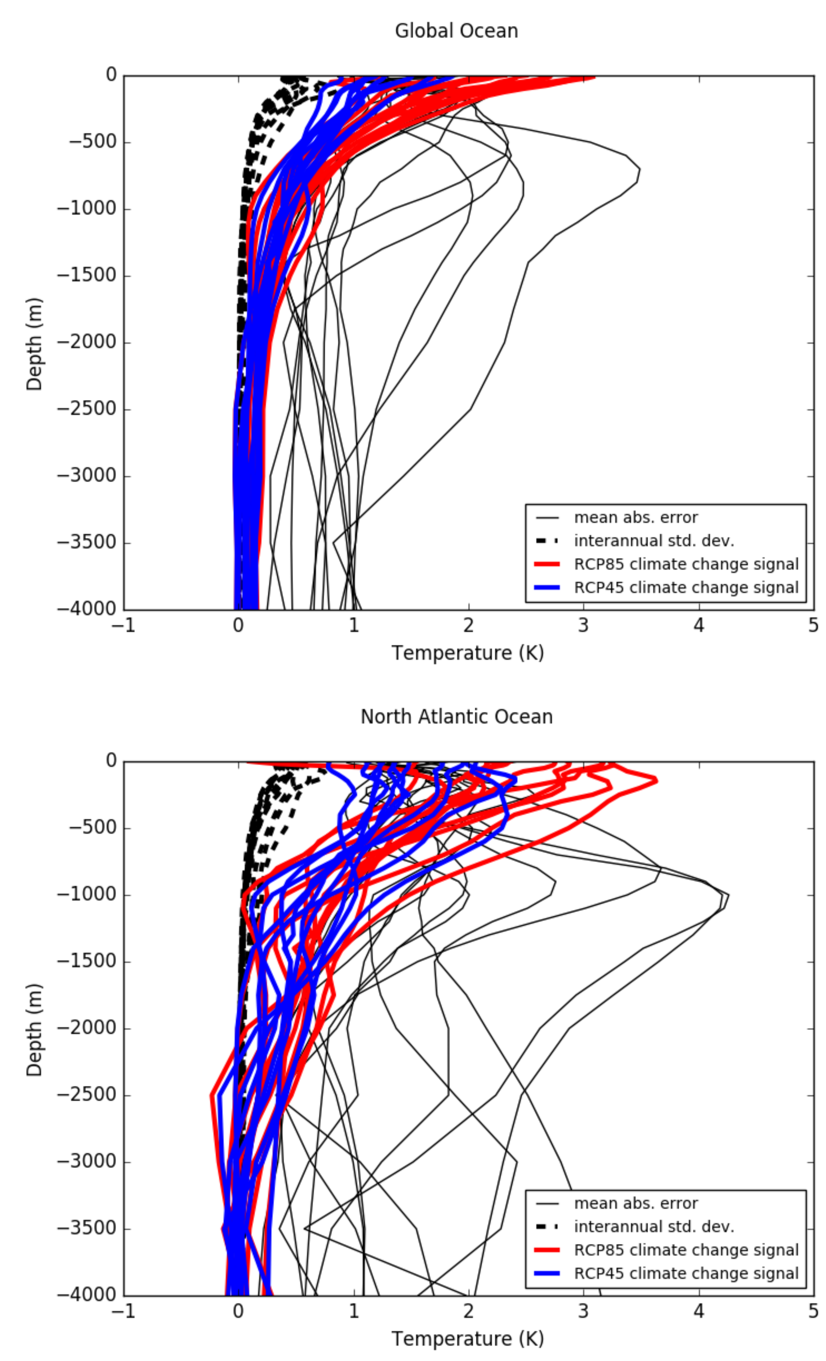

Fig. 1: *Profiles of potential temperature mean absolute error for years 1971—2000 of the historical simulations from 13 CMIP5 models contrasted to model interannual standard deviation and climate change signal 2071-2100 minus 1971-2000.*
Above: global ocean
Below: North Atlantic ocean

- The mean absolute error is everywhere and in all models larger than the interannual standard deviation.
- Except for near-surface layers it is even larger than the climate change signal.

Potential temperature bias 1000 m

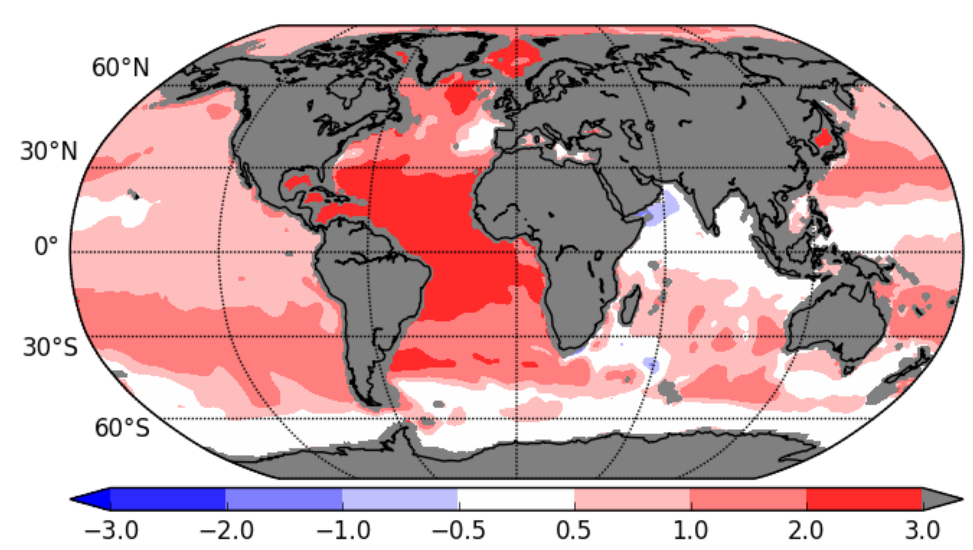

Fig. 2: *Potential temperature bias for years 1971—2000 of the historical simulations from 13 CMIP5 models*

Strong warm bias in 1000 m depth especially in Atlantic

Example application: error growth

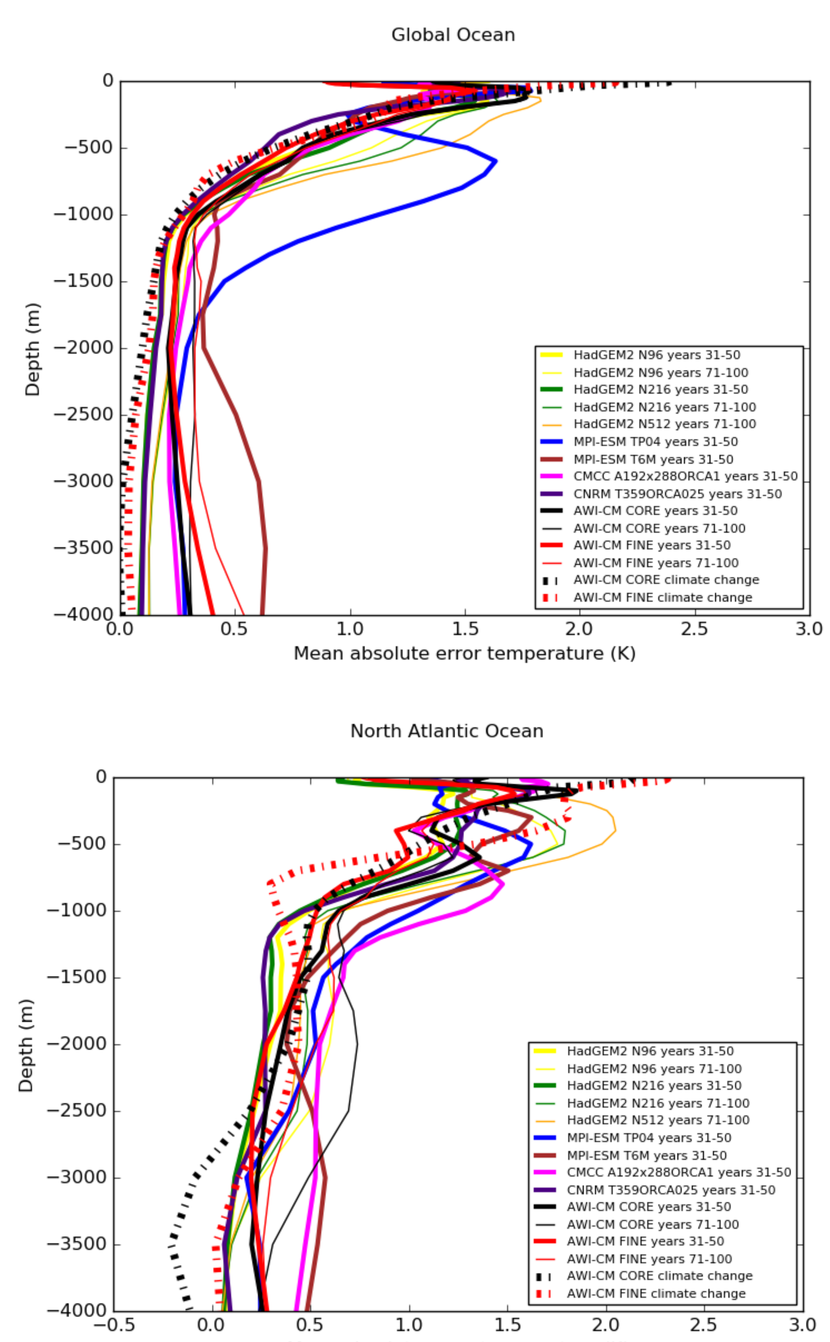

Fig. 3: *Profiles of potential temperature mean absolute error averaged over 31-50 years and over 71-100 years after initialization with PHC climatology from different PRIMAVERA HighResMIP prototype simulations.*
Above: global ocean
Below: North Atlantic ocean.

- Error growth from years 31-50 to years 71-100 visible
- Already after such a short time from initialization the error is often larger than climate change signal

References for AWI-CM:
- **Sidorenko, D. , Rackow, T. et al. (2015)**: Towards multi-resolution global climate modeling with ECHAM6-FESOM. Part I: model formulation and mean climate. *Clim. Dyn. Vol. 44, Issue 3, pp 757—780 , doi:* 10.1007/s00382-014-2290-6
- **Rackow, T. et al. (2016)**: Towards multi-resolution global climate modeling with ECHAM6-FESOM. Part II: climate variability. *Clim. Dyn., doi:* 10.1007/s00382-016-3192-6

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