Propagation of tropospheric signal to the stratosphere in the CMCC seasonal prediction system

Alice Portal[1,2], Paolo Ruggieri[2], Silvio Gualdi[2]
[1] Universitá di Modena e Reggio Emilia, [2] Centro Euro-Mediterraneo sui Cambiamenti Climatici (BO).

Motivations

Rossby planetary waves [PWs] can propagate from the troposphere to the stratosphere transporting *eddy heat fluxes* (*upward troposphere–stratosphere [t–s] coupling*)

↓

variability of the SPV[a] in winter

↓

Source of predictability for the extratropical NH troposphere from subseasonal to seasonal (extreme SPV events propagate to the troposphere)

Looking into seasonal prediction systems...

i. How do they represent the mean winter SPV?

ii. Is the model *upward t–s coupling* similar to the observed *coupling*?

[a]stratospheric polar vortex

Multi-model data

Initialization at the beginning of November (1993–2016) for C3S[a] seasonal prediction systems:

CMCC3: 40 e.m., h.r.∼100 km, 46 v.l.

MF6: 30 e.m., h.r.∼100 km, 95 v.l.

SYS5: 25 e.m., h.r.∼36 km, 91 v.l.

DWD: 25 e.m., h.r.∼60 km, 91 v.l.

UKMO: 21 e.m., h.r.∼60 km, 95 v.l.

e.m. for ensemble members, h.r. for horizonal resolution, v.l. for vertical levels

[a]Copernicus Climate Change Service

Diagnostics

SPV ⟶ U10 = zonal mean zonal wind in stratosphere (10 hPa, 60 N)

PWs ⟶ V'T'100 = zonal mean meridional eddy heat fluxes at the tropopause (100 hPa, 40-80 N)

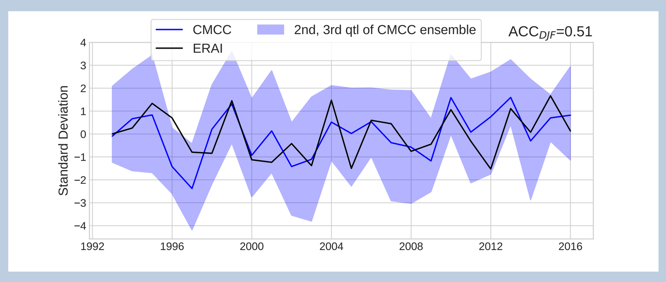
Relation between **SPV** and **PWs**: we approximate the vorticity equation described in Hinssen and Ambaum, 2010[1] by considering ΔU10 proportional to the zonal mean potential vorticity anomaly

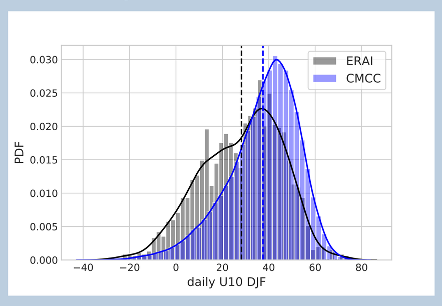
$$\Delta U^*10(t) = \overbrace{\Delta U10(t_0)\, e^{-\delta t_0/\tau}}^{\text{transient initial SPV condition}} - B \overbrace{\int_{t_0}^{t} \Delta V'T'100(t_f)\, e^{-\delta t_f/\tau}\, dt_f}^{\text{integral on the vertical PW flux}}, \qquad (1)$$

where ΔU^*10 is the reconstruction of ΔU10 produced by heat flux anomalies, $\tau = 45$ d the radiative timescale at 10 hPa, $\delta t_f = t - t_f$ and $\delta t_0 = t - t_0$, with t_0 at the beginning of November.

Analysis on CMCC-SPS3

The mean DJF U10 has a non neglectable predictability (ACC=0.51), even though the distribution of U10 values is very different compared to the reanalyses.

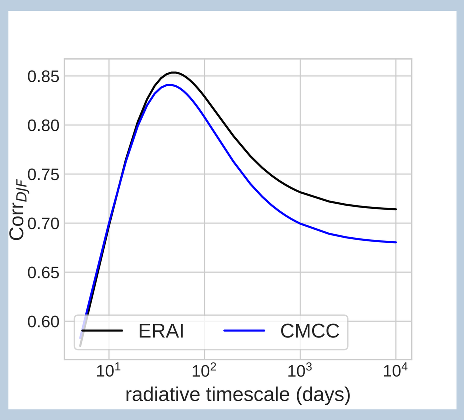


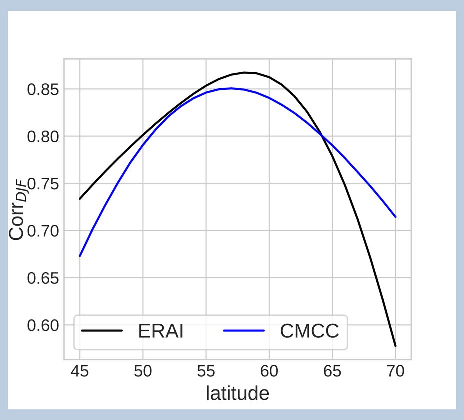


We report sensitivity experiments regarding

$$\mathrm{Corr}_{DJF} = \left\langle \frac{Cov(\Delta U10, \Delta U^*10)}{Std(\Delta U10)\cdot Std(\Delta U^*10)}(t) \right\rangle_{DJF}$$

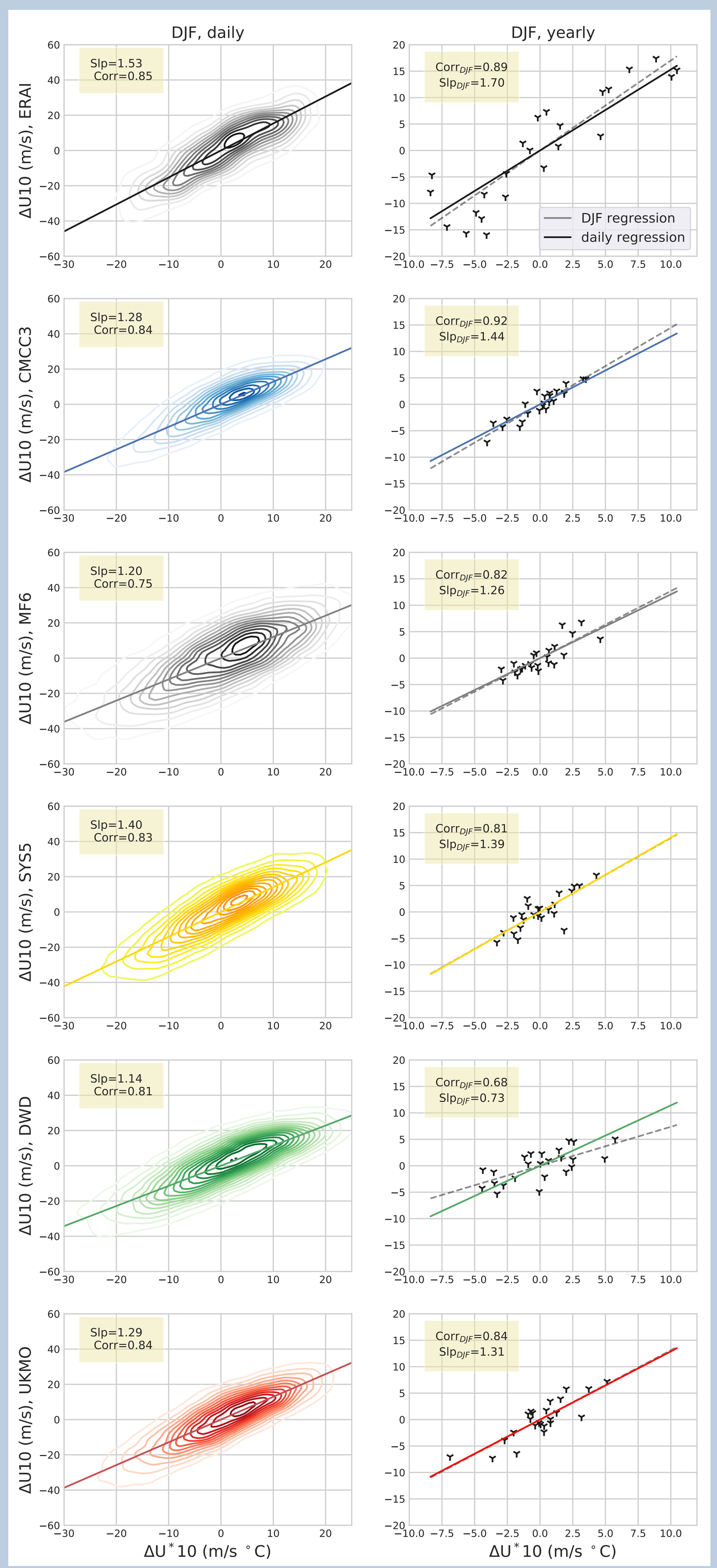
at different latitudes and radiative timescales.



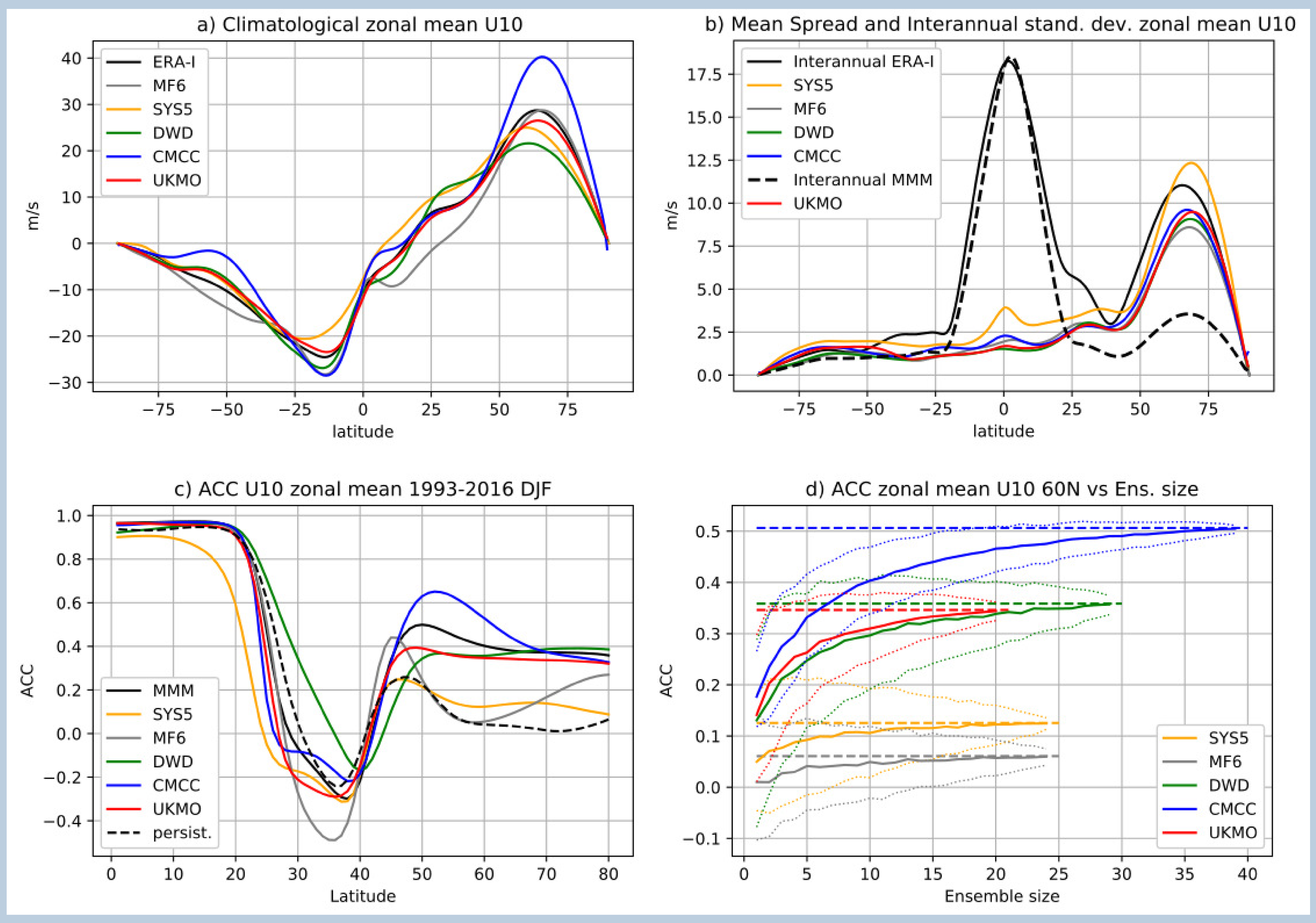


Upward t–s coupling

Scatterplots of ΔU10 versus ΔU^*10, the reconstruction of zonal mean zonal wind anomaly from heat flux anomalies (see Eq. (1)). On the left (DJF, daily) the densities of the scatterplots realised with daily values, on the right (DJF, yearly) the scatterplots of average yearly values.



Predictability of the stratosphere



All calculations shown here are computed on the variable "zonal mean zonal wind at 10 hPa averaged on DJF". In panel a) climatological mean over all latitudes; in b) individual mean model spread, ERA-Interim interannual standard deviation and multi-model mean of model interannual standard deviation (interannual MMM) over all latitudes; in c) individual model ACC and multi-model mean ACC over all positive latitudes; in d) mean ACC at latitude 60N over different ensemble sizes [ACC is calculated 100 times at ensemble size n_e by extracting 100 random n_e ensembles from the total number of members N_e: the thin dotted lines represent the 2nd and 3rd quartile ACC limits].

Seasonal ACC values

ACC values of the yearly DJF U10 and U*10, yearly NDJF V'T'100 with respect to ERA-Interim.

Models	ACC_{U10}	$ACC_{V'T'100}$	ACC_{U^*10}
CMCC3	0.51	0.44	0.44
MF6	0.05	0.17	-0.03
SYS5	0.12	0.35	0.00
DWD	0.36	0.33	0.14
UKMO	0.35	0.43	0.39

Summary and future work

i. CMCC-SPS3 shows higher values of U10 ACC compared to the other models: from panel d) above we discover it depends relatively on ensemble size, from the table on the right we see it may depend partially on the values of V'T'100 ACC (UKMO has similar V'T'100 ACC, but lower U10 ACC). Further research and discussion is needed.

ii. Daily scatterplots in "Upward t–s coupling" show that the responce of the modellised SPVs to PW forcing has a wide inter-model variability, which may be influenced by ensemble size, by the strength of the simulated SPV, by the responce to extreme positive/negative PW forcing and by the different parametrizations.

iii. The QBO has a high winter predictability (see panel c)). Does it influence the seasonal predictability of the SPV?

References & Glossary

[1] Yvonne Hinssen, Marteen Ambaum: *Relation between the 100-hPa Heat Flux and Stratospheric Potential Vorticity*, Journal of Atmospheric Sciences (2010)

Δ anomaly from climatological value

SPV stratospheric polar vortex

PWs Rossby planetary waves

DJF(NDJF) December(November)–February

ACC Anomaly Correlation Coefficient

t–s troposphere–stratosphere