Atmospheric moisture anomalies associated with ENSO and future changes in CMIP6 simulations

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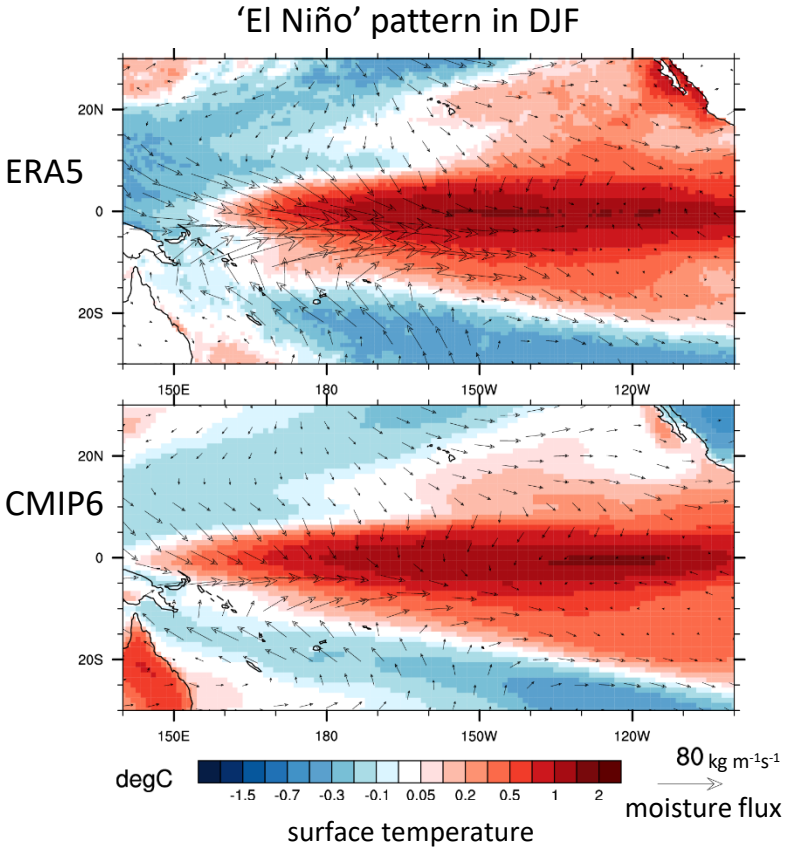


Motivation

- Many previous studies on moisture and ENSO –e.g. Seager et al (2012)
- Atmospheric moisture budget for precip P, evaporation E, water column W

$$P = E + \mathrm{conv}(F) - dW/dt$$

F vertically-integrated moisture flux, (intuaw, intvaw) in CMIP6

- Watterson et al (2021, Int. J. Climatol.) studied *F* from 1pctCO2 runs of 10 models.
- Here, look at present climate, means and ENSO, and future changes

Period 1 1980-2019 in ERA5 reanalyses and historical + SSP5-8.5 runs

Period 2 2040-2079 in SSP5-8.5 runs

Of course, much statistical variation in ENSO from a 40-year period –aim to add information on moisture in a plausible future scenario, using 10-model means

CMIP6 models

Model	Institution	Code	Grid (av, km)	Atm. Lev.	GW (°)	NINO34 SD1 (°)	SD2/ SD1
CNRM-CM6-1	CNRM-CERFACS	cn6	125	91	2.40	1.08	1.05
CNRM-CM6-1-HR	CNRM-CERFACS	cnh	44	91	2.63	0.47	1.48
CNRM-ESM2-1	CNRM-CERFACS	cne	125	91	2.19	1.08	1.05
IPSL-CM6A-LR	IPSL	i6e	157	79	2.63	1.33	0.69
HadGEM3-GC31-MM	MOHC	h3m	60	85	3.20	0.80	0.97
HadGEM3-GC31-LL	MOHC-NERC	h3l	136	85	3.22	0.97	0.99
UKESM1-0-LL	MOHC-*	hue	136	85	3.52	0.91	1.04
ACCESS-CM2	CSIRO-ARCCSS	ac2	136	85	2.74	0.85	1.16
ACCESS-ESM1-5	CSIRO	ace	135	38	2.40	0.80	1.22
MIROC-ES2L	MIROC	mce	250	40	2.04	1.67	0.99

5 run av.: SD1 0.88°, SD2/SD1 1.09

GW global warming (tas), P2 minus P1, average 2.70°C.
For a representative change, average the ten ‘change per degree’ fields, then scale up by 2.7°C.

NINO34 index, by season, Niño34 SST relative to 11-year tropical mean (to avoid trend).
SD1 (combined seasons) interannual standard deviation in P1.
Future SD2, a little larger in six runs. Av10 of SD2/SD1 is 1.10.

Present Climate ENSO

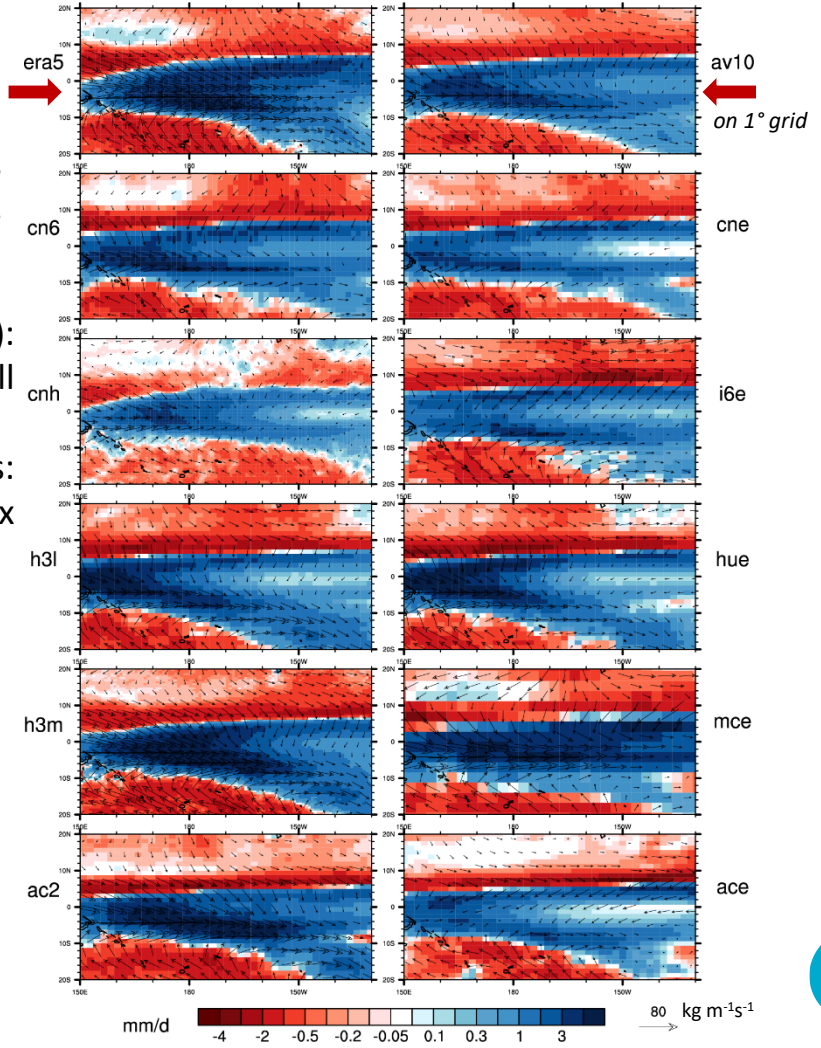
Interannual regression field for 1SD of the NINO34 index, an 'El Niño' pattern.

Grid point values at the same time –anomalies 'linked' to ENSO (and disregarding any asymmetry)

Shown for central Pacific in DJF from 1979-2019

Shading (grid square): Rainfall

Vectors: Moisture flux



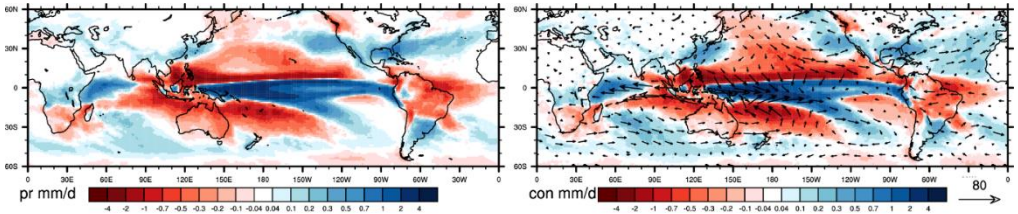
CMIP6 models generally provide a good present climate, compared to ERA5.
Seasonal NINO34 patterns are comparable.

Average of ten, av10, typically better skill than individual models.

The shift and weakness of av10 SST pattern in DJF (intro.) carries over to rain and flux.

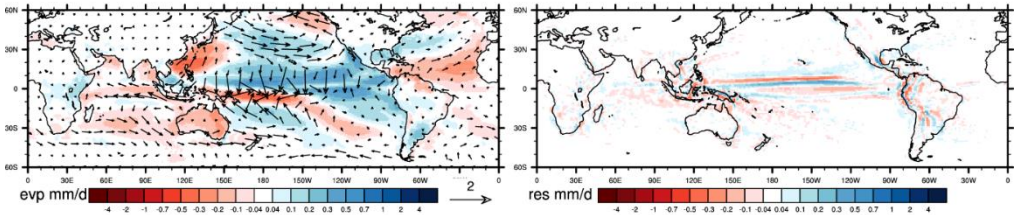
Present Climate, El Niño in DJF, from av10: more quantities over a broader domain

Rain anoms extending to continents



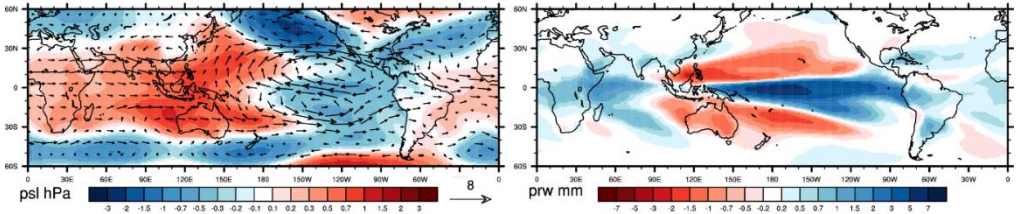
F and Conv(*F*)
-like rain, but for small evap

Surface evaporation with 10m wind (m/s)



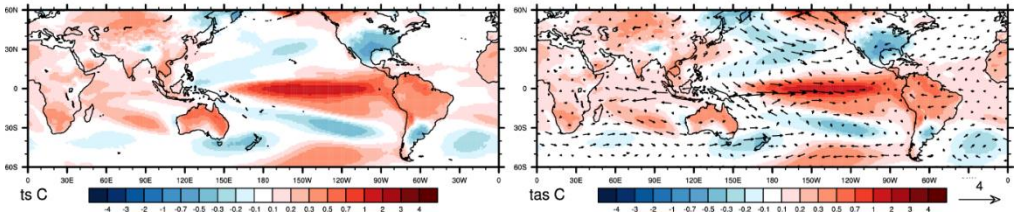
'Residual', P-E-Conv
-Small, change in W plus effect of finite differencing for conv?

Pressure, with 200hPa wind



W, or prw

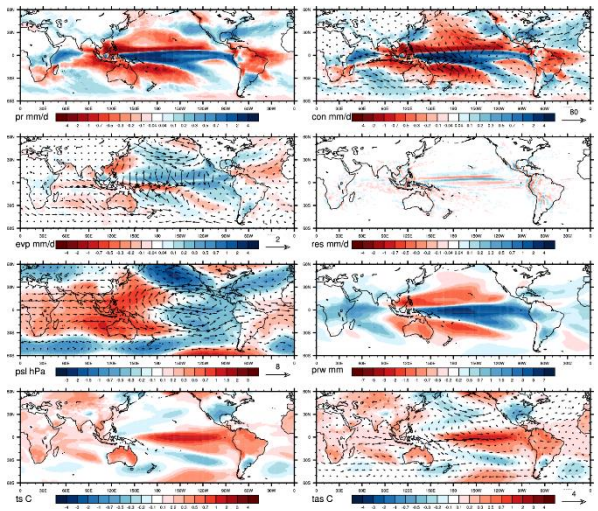
Surface temp, ts



1.8m temp, tas *-like ts*
850hPa wind *-direction of F*

Future Change (GW of 2.7°): El Niño for DJF, from av10

P1



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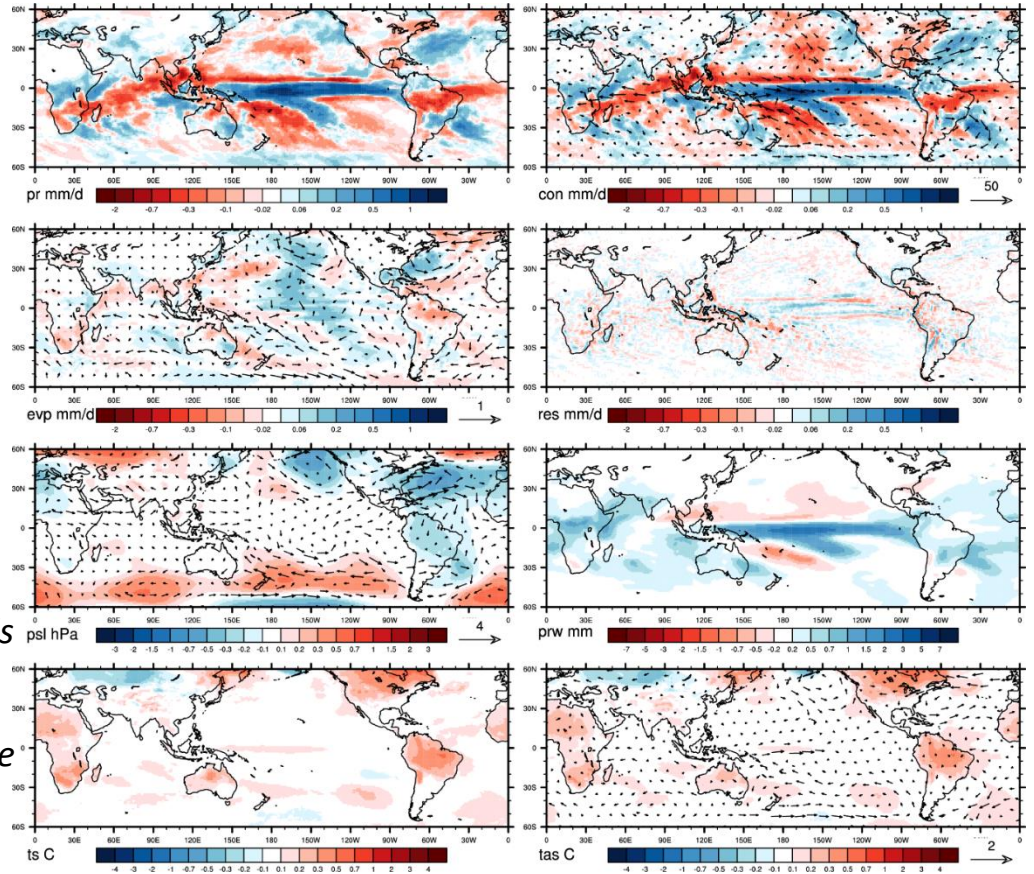


Mostly amplified pr, F, conv, prw in tropics

Mixed change over continents

-e.g. SE Australia

small or mixed changes in psl, winds

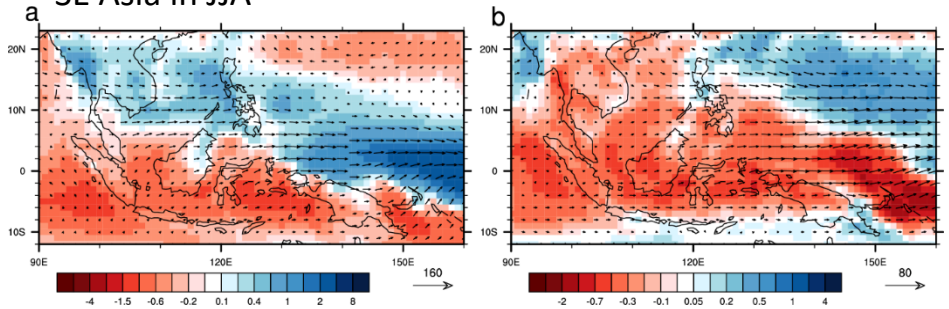
only small increase in NINO34 SST

Note: scales mostly smaller

Regional conv and *F*, for NINO34, from av10: (a) P1 and (b) Change *(smaller scales)*

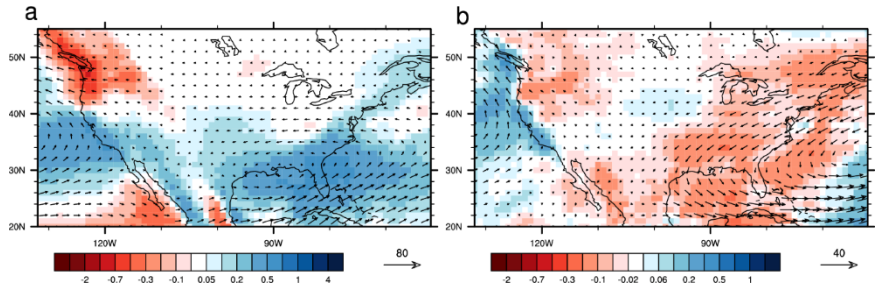
In general change in conv matches that in pr

SE Asia in JJA



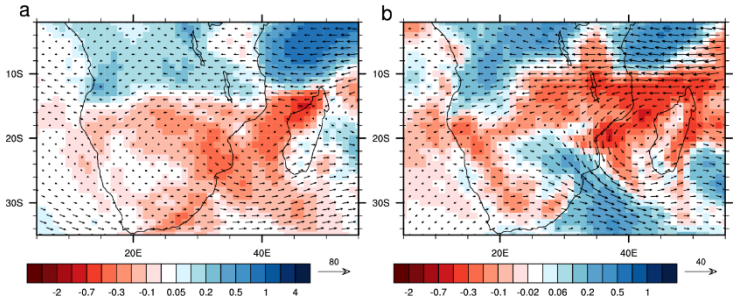
Dryness in Indonesia extends further north

North America in DJF



Mostly decreased amplitudes in conv

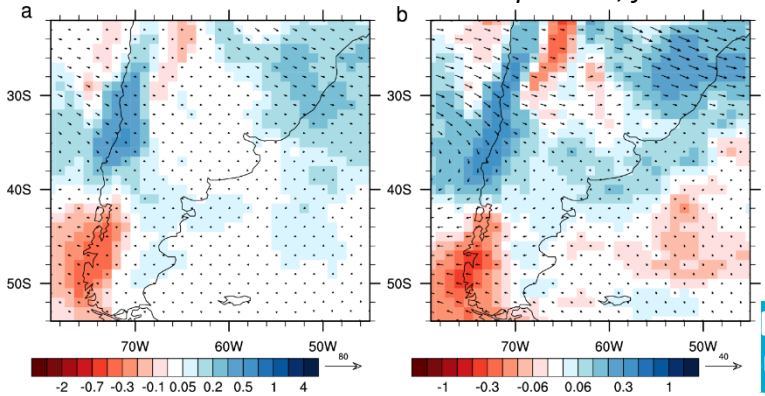
Southern Africa in DJF



Increased amplitude in flux, mixed in conv

Far South America in JJA

Increased amplitudes, flux and conv



Some conclusions

- Vertically integrated moisture flux provides interesting additional information the rainfall anomalies linked to ENSO.
- From the average of ten CMIP6 models there is little future change in the standard deviation in NINO34 SSTs and in related wind anomalies.
- The water column, moisture flux, and rainfall anomalies tend to be amplified in the tropics, in a warmer climate.
- There are mixed changes in the teleconnections to higher latitudes.
- It would be helpful for all CMIP models to output moisture flux, as monthly means, and ideally daily.

Please interact with me on this topic –my approach and results

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Some references

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