Interdecadal variability of the **Tropospheric Biennial Oscillation**





N.C. Jourdain^{1*}, A. Sen Gupta¹, Y. Li¹, A. S. Taschetto¹, C. Ummenhofer²

1- Climate Change Research Centre, University of New South Wales, Sydney, NSW, Australia ; 2- Woods Hole Oceanographic Institution, MA, USA

* n.jourdain@unsw.edu.au

Abstract

The Asian-Australian monsoon system has a significant biennial component of interannual variability: the tropospheric biennial oscillation (TBO). The bienniality varies at interdecadal time-scales.

The CMIP models generally capture in-phase India to Australia monsoon transitions, but not out-of-phase Australia to India transitions (both being part of the TBO). Even taking the interdecadal variability into account, most CMIP models seem unable to produce a TBO similar to the observations.

Acronym	Ι	Institute	Spatial	Start	Resol	References
-	D		coverage	date		
CMAP	α	UCAR/ NCAR/ CISL/ DSS	Global	1979	2.5°	Xie and Arkin, 1997
GPCP	β	NOAA/ OAR/ ESRL PSD,	Global	1979	2.5°	Adler et al., 2003
GPCC	γ	Boulder, CO, USA	Global land	1901	0.5°	Rudolf et al., 2011
AWAP	δ	BOM, Australia	Austr. land	1900	0.25°	Jones et al., 2009
APHRODITE	δ	ERTDF, Japan	S-E Asia land	1951	0.25°	Yatagai et al., 2012
TRMM-3B42 v6	ϵ	NASA/ GIES/ DISC,	$50^{\circ}\mathrm{S}$ - $50^{\circ}\mathrm{N}$	1998	0.25°	Adler et al., 2000
TRMM-3B43 v6	ζ	USA	$50^{\circ}\mathrm{S}$ - $50^{\circ}\mathrm{N}$	1998	0.25°	Adler et al., 2000
HadISST	η	Met Office,	Global	1870	1.0°	Rayner et al., 2003
HadSST2	θ	Hadley Centre, UK	Global	1850	5.0°	Rayner et al., 2006
NCEP-NCAR I	λ	NOAA/ OAR/ ESRL PSD,	Global	1948	2.5°	Kalnay et al., 1996
NCEP-DOE II	μ	Boulder, CO,	Global	1979	2.5°	Kalnay et al., 1996
NCEP-CFSR	π	USA	Global	1979	0.5°	Saha et al., 2010
ERA-40	ρ	ECMWF, UK	Global	1957	2.5°	Dee et al., 2011
ERAinterim	τ	ECMWF, UK	Global	1979	0.7°	Dee et al., 2011
JRA-25	ψ	JMA/ CRIEPI, Japan	Global	1979	2.5°	Onogi et al., 2007
MERRA	σ	NASA	Global	1979	0.5°	Rienecker et al., 2011

Datasets and indices



The interdecadal variability of the strength of TBO transitions is not related to an IOP-like signal in the majority of the CMIP models

CMIP3 simulations from 24 models: 20c3m scenario (1850-2000) **CMIP5** simulations from 35 models: historical scenario (1850-2006) \rightarrow at least 3 ensemble members for more than half of the models

Indian and Asian monsoons —— \rightarrow JJAS Australian and Maritime Continent - \rightarrow DJFM

Interdecadal variability of TBO transitions

We split each time-series into 15-year periods, and for each period, we calculate the correlation coefficient between the Indian summer monsoon rainfall and the following Australian monsoon rainfall (in-phase transition of the TBO), and the correlation coefficient between the Australian monsoon rainfall and the following Indian monsoon (out-of-phase transition of the TBO). We repeat this across ensemble members when available.

	In-phase LIND -> LAUS transit	tion				C	Dut-of-phase LAUS -> LIND transition	า	
			AWAP/APHR	GPCC				AWAP/APHR	GPCC
MERRA								1	1
JRA23 ERAinterim			1	1	significance	ERAinterim		1	1
FRA40			1	1	of correlations	ERA40		I	I
NCEP-CFSR	- •	_	Ì	l	• < 80%	NCEP-CFSR		I	I
NCEP-DOE-II	─ ● ●		I	I	● > 80% > 00%	NCEP-DOE-II	⊢ ● ● ─ ─	I	I
NCEP-NCAR-I	⊢ ● ● ●		I	I.	● > 90% > 95%	NCEP-NCAR-I			
AWAP/APHRODITE			1		> 99%	AWAP/APHRODITE			
GPCC			0.000 (0%)	0.107 (99%)		GPCC		0.000 (0%)	0.273 (99%)
GPCP								1	1
NorESM1_ME			0 000 (0%)	0,000,(0%)		NorESM1–ME		0.077 (95%)	0.001 (38%)
NorESM1-M		• _	0.020 (66%)	0.001 (60%)		NorESM1–M		0.034 (82%)	0.002 (72%)
MRI–CGCM3		_	0.043 (94%)	0.001 (55%)		MRI-CGCM3		0.048 (95%)	0.005 (95%)
MPI-ESM-MR			0.100 (99%)	0.000 (0%)		MPI-ESM-MR		0.018 (58%)	0.000 (0%)
MPI-ESM-LR			0.059 (91%)	0.006 (91%)		MPI-ESM-LR		0.032 (92%)	0.000 (35%)
MIROC-ESM			0.031 (61%)	0.000 (0%)	1	MIROC-ESM		0.038 (94%)	0.000 (21%)
MIROC5			0.058 (97%)	0.000 (23%)				0.028 (79%)	0.000 (11%)
IPSL-CM5A-MR			0.098 (99%)	0.000 (0%)				0.024 (75%)	0.000 (14%)
IPSL-CM5B-LK			0.042 (70%)	0.000(0%)				0.014 (07%)	0.001 (07%)
IFOL-UNDA-LK			U.U// (95%) 0 100 (02%)	0.001 (03%) 0.001 (15%)	1	inmcm4		0.048 (62%)	0.000 (0%)
HadGFM2_ES			0.024 (79%)	0 000 (0%)		HadGEM2-ES		0.050 (95%)	0.002 (81%)
HadGEM2-CC			0.050 (93%)	0.003 (81%)		HadGEM2-CC		0.001 (6%)	0.000 (0%)
HadGEM2-AO			0.086 (82%)	0.000 (0%)		HadGEM2-AO		0.052 (62%)	0.000 (19%)
HadCM3		•	0.088 (96%)	0.000 (0%)		HadCM3		0.021 (70%)	0.000 (0%)
GISS-E2-R		\neg	0.070 (98%)	0.000 (52%)	N	GISS-E2-R		0.043 (86%)	0.001 (49%)
GISS-E2-H			0.044 (96%)	0.000 (0%)	L	GISS-E2-H		0.008 (18%)	0.000 (23%)
GFDL-ESM2M			0.020 (70%)	0.005 (88%)	=	GFDL-ESM2M		0.026 (50%)	0.000(0%)
GFDL-ESM2G			0.031 (83%)	0.001 (51%)	\geq	GEDL-ESM2G		0.066 (92%)	0.001 (48%)
GFDL-GM3			0.144 (99%)	0.000(31%)	$\overline{\mathbf{O}}$	FIO-ESM		0.044 (07 %)	0.000 (32%)
FGOALS-S2			0.045 (84%)	0.000(0%)		FGOALS-s2		0.007 (18%)	0.000 (12%)
FGOALS-a2			0.054 (99%)	0.000 (0%)		FGOALS-g2		0.022 (83%)	0.000 (24%)
EC-EARTH						EC-EARTH			
CSIRO-Mk3-6-0		• -	0.066 (97%)	0.001 (73%)		CSIRO-Mk3-6-0		0.070 (98%)	0.001 (67%)
CNRM-CM5			0.120 (99%)	0.000 (0%)		CNRM-CM5		0.029 (83%)	0.000 (25%)
CMCC-CM	- • • • • • •		0.090 (99%)	0.000 (0%)		CMCC-CM		0.012 (45%)	0.000 (0%)
CCSM4			0.060 (97%)	0.000 (27%)				0.021 (75%)	0.000 (0%)
CESM1-WACCM			0.000 (0%)	0.000 (0%)				0.093 (95%)	0.000 (0%)
			0.058 (99%)	0.000 (28%)		CESM1-CAM5		0.092 (99%)	0.000 (0%)
CanESM2			0.082 (98 %)	0.000 (0%)		CanESM2		0.057 (96%)	0.000 (23%)
bcc-csm1-1			0.073 (91%)	0.000 (0%)		bcc-csm1-1		0.017 (79%)	0.000 (26%)
ACCESS1-3	- •• ••• •		0.011 (47%)	0.000 (0%)		ACCESS1-3		0.013 (22%)	0.000 (0%)
ACCESS1-0	- • • • • •	_	0.046 (84%)	0.001 (38%)		ACCESS1-0		0.035 (61%)	0.000 (13%)
ukmo-hadgem1		_	0.041 (81%)	0.000 (0%)		ukmo-hadgem1		0.037 (72%)	0.001 (32%)
ukmo-hadcm3			0.061 (93%)	0.000 (0%)		ukmo-hadcm3		0.025 (32%)	0.000 (0%)
ncar-pcm1		\neg	0.038 (97%)	0.000 (56%)		ncar-pcm1		0.023 (52%)	U.UU1 (29%)
ncar-ccsm3-0			0.056 (95%)	0.000(0%)		mri_cocm2_3_2a		0.035 (90%)	0.001 (70%)
mni_echam5			U.UOI (99%) 0 051 (94%)	0.000 (30%) 0 006 (770 /)		mpi-echam5		0.009 (62%)	0.000 (0%)
miuh-echo-a			0.096 (98%)	0.001 (62%)		miub-echo-a		0.016 (63%)	0.003 (80%)
miroc3–2–medres			0.107 (82%)	0.000 (0%)	1	miroc3-2-medres		0.014 (55%)	0.000 (0%)
miroc3-2-hires		\neg		I		miroc3-2-hires		I	I
ipsl–cm4		\neg	0.046 (75%)	0.000 (0%)		ipsl-cm4		0.075 (83%)	0.000 (28%)
inmcm3–0			0.009 (30%)	0.000 (0%)	<u> </u>	inmcm3–0		0.036 (37%)	0.000 (0%)
ingv-echam4			0.000 (0%)	0.000 (0%)		ingv-echam4		0.090 (82%)	0.000 (0%)
iap-tgoals1-0-g			0.000 (0%)	0.000 (0%)		aiss model or		0.052 (72%)	0.000 (0%)
yiss-model-e-r aise-model a b			U.U/J (98%) 0 078 (02%)		U	giss-model-e-h		0.060 (87%)	0.000 (26%)
giss-model-e-n giss-aom			0.078 (98%)	0.000 (39%)	_	giss-aom		0.026 (61%)	0.000 (0%)
afdl-cm2-1			0.000 (0%)	0.006 (58%)		gfdl–cm2–1		0.004 (51%)	0.000 (0%)
gfdl–cm2–0			0.029 (83%)	0.006 (94%)		gfdl-cm2-0		0.110 (87%)	0.000 (0%)
csiro-mk3-5			0.009 (31%)	0.000 (37%)	I	csiro-mk3-5		0.008 (27%)	0.000 (0%)
csiro-mk3-0		\neg	0.030 (61%)	0.003 (66%)		csiro-mk3-0		0.029 (88%)	0.000 (0%)
cnrm–cm3		•	0.000 (0%)	0.001 (52%)		cnrm-cm3		0.002 (10%)	0.000(0%)
cccma-cgcm3-1-t63			0.090 (95%)	0.000 (0%)				0.000 (0%) 0 030 (039/)	U.UUO (JZ%) N NN1 (RQ0/)
cccma-cgcm3-1			U.1U3 (99%) 0 09 <i>4 (</i> 77%)	0.000(0%)		bccr_bcm2_0		0.039 (93%)	0.002 (67%)
			U.UO4 (<i>1 1 %</i>)	0.000 (0%)					
	-0.8 -0.4 0 0.4 0	.8					-0.8 -0.4 0 0.4 0.8		
	correlation coefficient						correlation coefficient		
			1	1					

Model assessment

Jourdain et al., Clim. Dyn. 2012



- Large spread in both Indian and Australian average monsoon rainfall and in their interannual variations.

While the multi model mean monsoon rainfall from 60 CMIP models fall within the observational considerable uncertainty, model spread exists.

- Rainfall seasonality consistent across observations and reanalysis, but most CMIP models have biases in monsoon season duration, with CMIP5 models generally performing better than CMIP3.

- Most models reproduce the observed ENSO-Australian monsoon teleconnection, with the strength of the relationship dependent on the strength of the simulated ENSO.

- The Indian monsoon-ENSO relationship is affected by overly persistent ENSO events in many CMIP odels. Models with stronger monsoon-NSO relationships generally have a ronger monsoon-IOD relationship.

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	mo
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lag-correlation between LIND at	El
vear0 and monthly NINO34.	sti

-0.4

relationship to the IPO



Correlation coefficients related to TBO transitions for different IPO phases. Each bar is centered on the mean correlation for every 15-year period of a given phase, and its width shows the standard error (std/ \sqrt{N}). IPO phases are estimated using 15-year averages of OND NINO34.

	positive
	neutral
	negative

Meehl and Arblaster (2011) have suggested that the decadal variability of the TBO could be related to the **IPO:** warmer Pacific SSTs being associated with less biennial Indian monsoons.

This is however not found in most of the CMIP simulations that show no significant change in the strength of TBO transitions as the IPO phases vary.

We now assess as to whether results from the few observed 15-year periods could arise from an interdecadal variability such as captured by the CMIP models. We use a Monte-Carlo method, which consists of randomly resampling (10⁴ times) correlation coefficients from the distribution of a given model. This gives the probability to find the observed series of correlation coefficients assuming that they follow the model distribution (and allowing an uncertainty of +-0.1 on correlations). This is done for AWAP/APHRODITE (left) and for GPCC (right). The significance (into brackets) is estimated by comparing the probability of observed series of correlations to the probability of each of the 10⁴ randomized series. For instance, a significance of 90% means that only 10% of the randomly sampled series of correlations are more probable than the observed one.

•Most CMIP models, reanalysis, and observational products show more **significant in-phase transitions** from the Indian monsoon to the following Australian monsoon than out-of-phase transitions.

• The observed period is marked by out-of-phase transitions from the Australian monsoon to the following Indian monsoon, but the significance of the anti-correlation is weak. By contrast, numerous CMIP models show more significant in-phase than out-of-phase transitions.

(these results are described in Li et al., 2012).

Strong inter-decadal variability of the two **TBO transitions in the CMIP models.**

Only ~10% of the CMIP models are very likely to produce six 15-year periods presenting **TBO** transitions similar to the ones from GPCC.

In other words, a majority of the CMIP models capture an interdecadal variability of the **TBO** that is not consistent with observations.

References

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