Tropical Eastern Pacific Seasonal Climate Biases in CGCMs and Sensitivity in the IPRC Regional Ocean-Atmosphere Model (IROAM)

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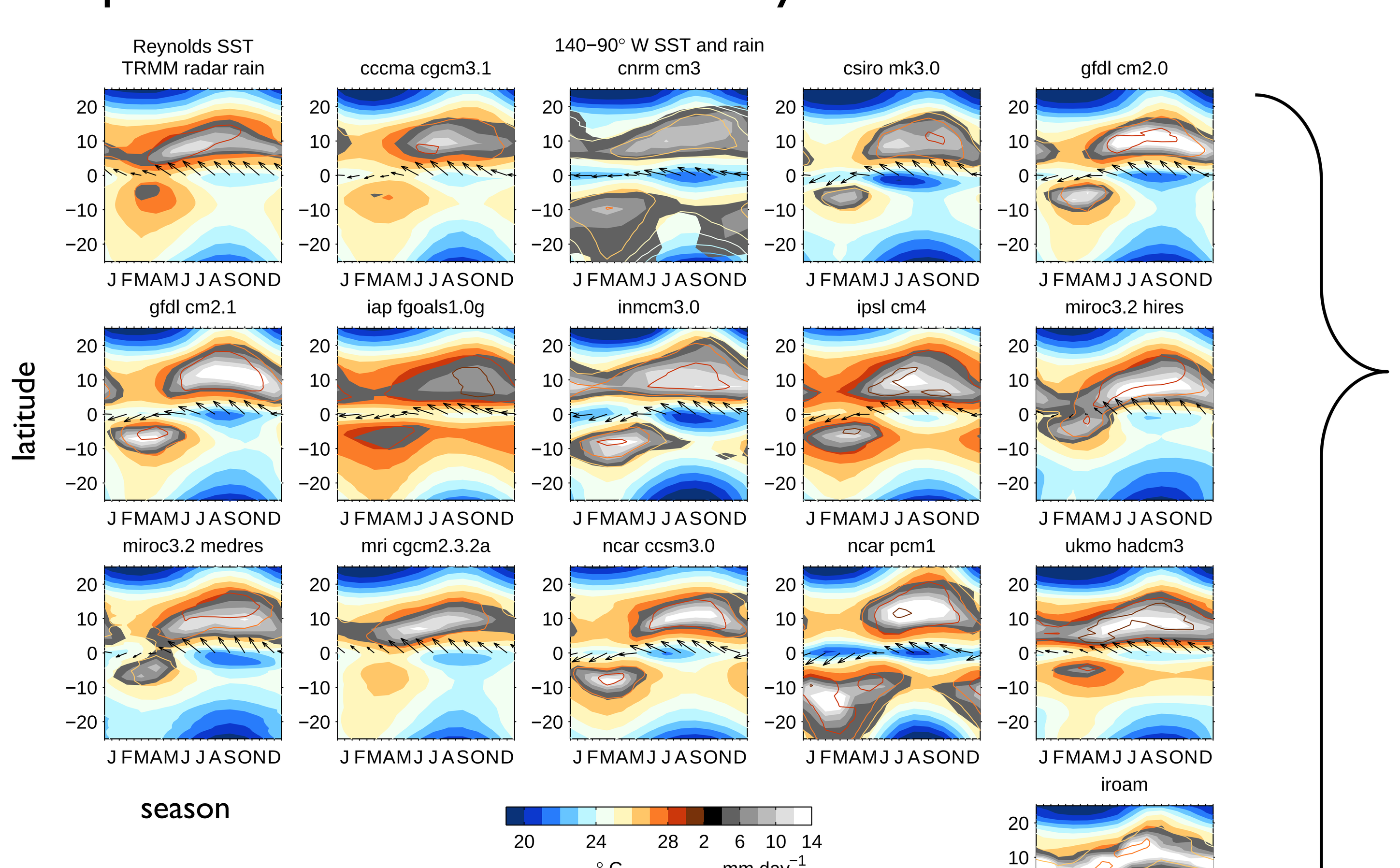
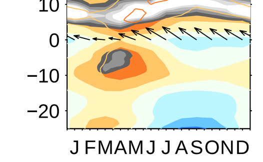
Introduction Mechoso et al. (1995) compared the seasonal cycle in the tropical eastern Pacific in coupled atmosphere-ocean GCMs, finding a common double-ITCZ bias. We examine 20th Century Climate in Coupled Models (20C3M) simulations submitted to PCMDI for the IPCC fourth assessment report. Most models now have a seasonally *alternating* ITCZ. Metrics of the seasonal cycle of the meridional distribution of SST and rain assess the current models. Physical mechanisms for common biases are diagnosed using the ensemble of coupled simulations. (de Szoeke and Xie, in preparation)

Tropical eastern Pacific seasonal cycle of SST and rain

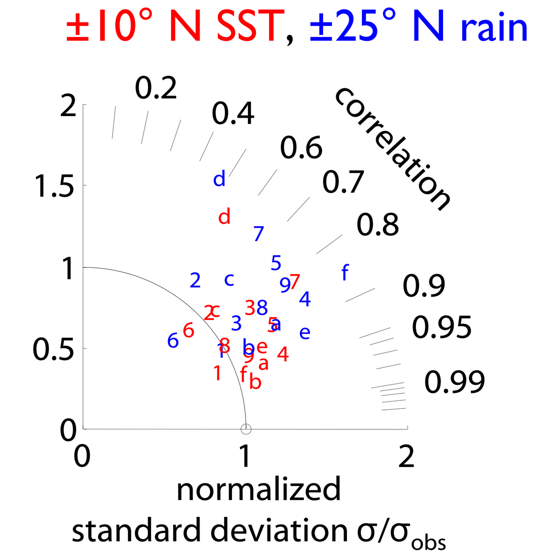




140-90°W zonal average (excludes land) meridional-seasonal SST and rain, and equatorial wind.

Seasonal cycle metrics for models

Taylor (2002) diagram
±10° N SST, ±25° N rain



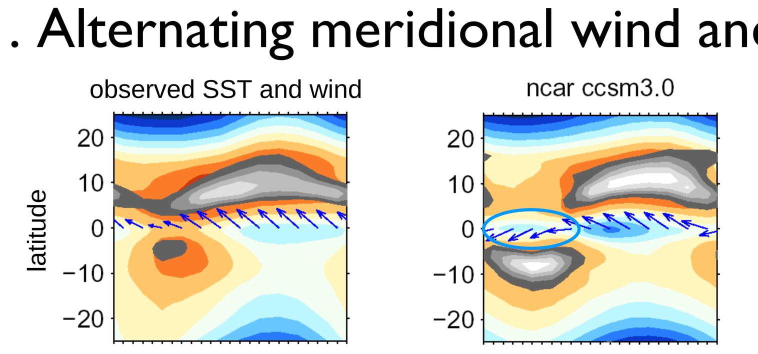
	Model	RMS error SST	RMS error rain
1	cccma cgcm3.1	0.38	0.49
2	cnrm cm3	0.74	0.95
3	csiro mk3.0	0.72	0.62
4	gfdl cm2.0	0.47	0.84
5	gfdl cm2.1	0.62	1.01
6	iap fgoals1.0g	0.70	0.71
7	inmcm3.0	0.92	1.18
8	ipsl cm4	0.51	0.72
9	miroc3.2 hires	0.42	0.88
a	miroc3.2 medres	0.38	0.64
b	mri cgcm2.3.2a	0.26	0.48
c	ncar ccsm3.0	0.74	0.91
d	ncar pcm1	1.29	1.53
e	ukmo hadcm3	0.48	0.66
f	iroam	0.30	1.10

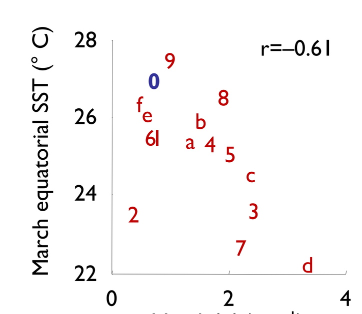
σ_{obs} = 1.42° C, 2.05 mm day^{-1}

- SST and precipitation skill are correlated.
- Large uncertainty in precipitation magnitude exists, even among observations.

Physical mechanisms for biases: how the seasonal cycle affects the ocean

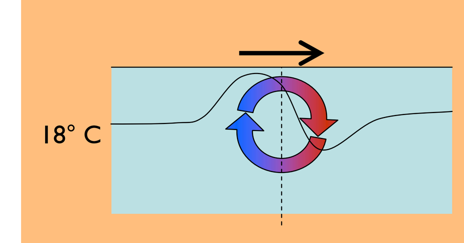
1. Alternating meridional wind and semiannual equatorial cold bias



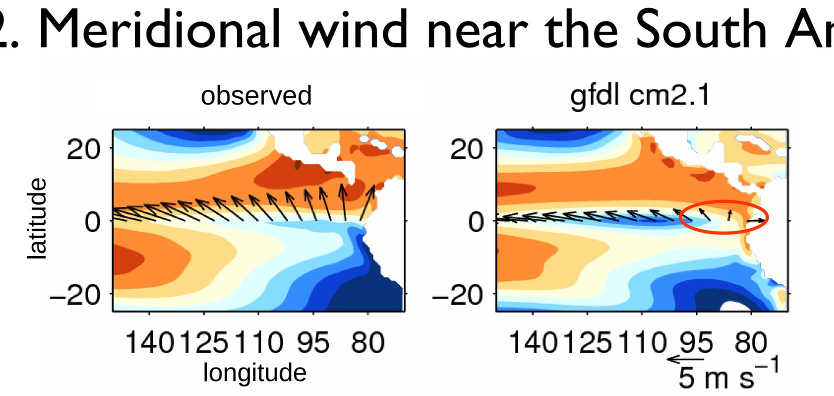


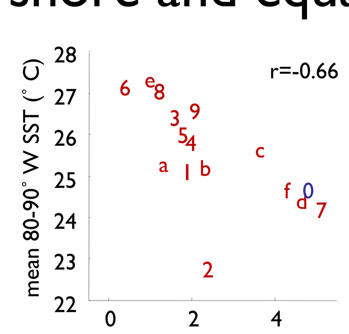
Northerly wind in January-April associated with a southern ITCZ causes a semiannual cycle of equatorial SST and a rectified cold bias on the equator. Therefore models with stronger March wind have cooler equatorial SST.

Meridional wind drives a meridional cell in the equatorial ocean with upwelling on the windward side of the equator. (Philander, 1981; Xie, 1994)
→ cools equator



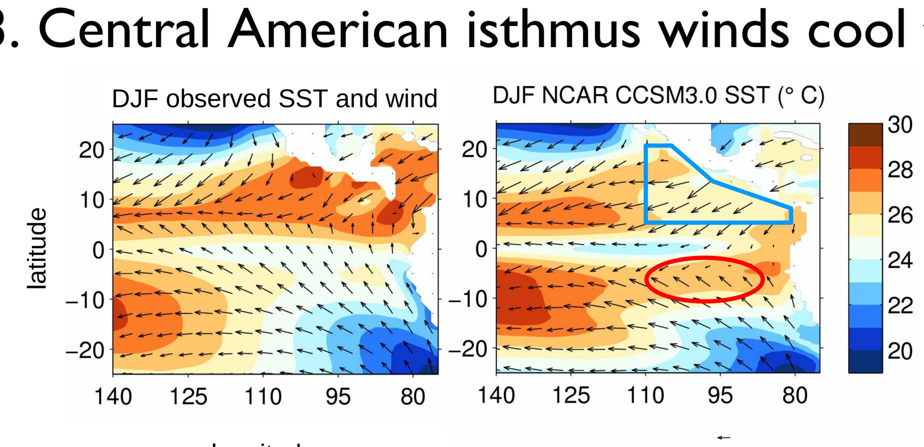
2. Meridional wind near the South American shore and equatorial warm bias

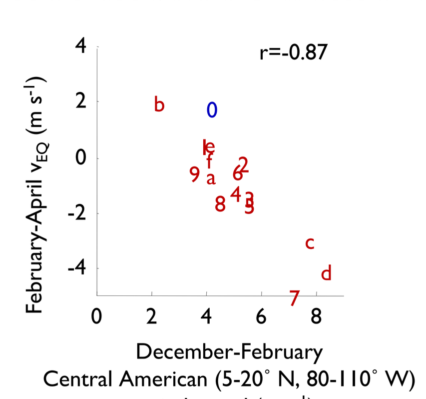




Meridional wind is important for upwelling where zonal wind is weak east of 95° W. Representation of winds and the near-coast cold tongue could depend on how well models resolve the Andes. Models with stronger meridional wind near the coast have cooler SST.

3. Central American isthmus winds cool the northeast Pacific warm pool





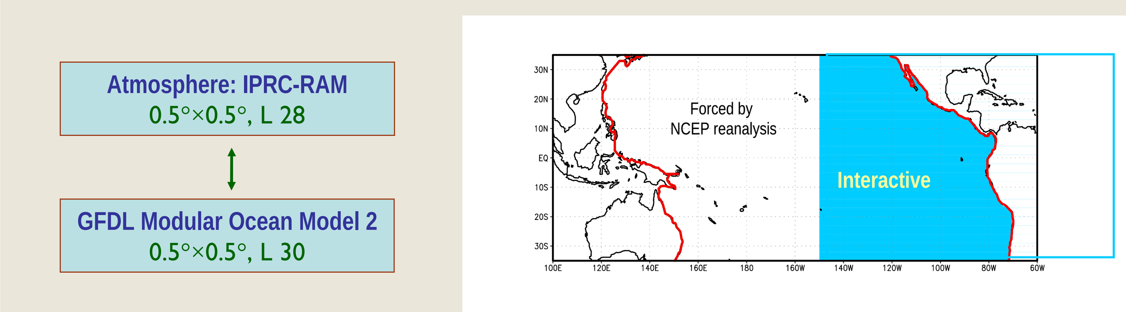
In boreal winter, northeasterlies cross the Central American isthmus and blow across the east-Pacific warm pool. In models with stronger wind, the warm pool cools to such an extent that it contributes to the early shift of the ITCZ into the southern hemisphere.

IROAM simulates a realistic seasonal cycle. Coupled regional modeling has the following advantages:

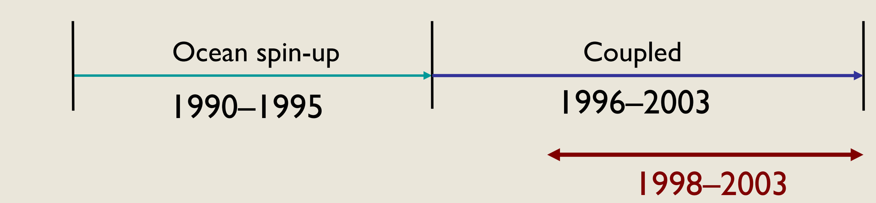
- Isolates regional physics.
- Boundary conditions constrain climate.
- Affords high resolution, useful for
  - -fine-scale ocean circulation and orography
- Suitable for verification with point observations.
  - -IROAM will be verified with EPIC, PACS, and Stratus observations of the eastern Pacific.
- IROAM is a tool to test ideas with numerical experiments.

Here the sensitivity of eastern Pacific climate to low cloud is explored by eliminating shallow cumulus convection (de Szoeke et al., 2006).

IROAM configuration

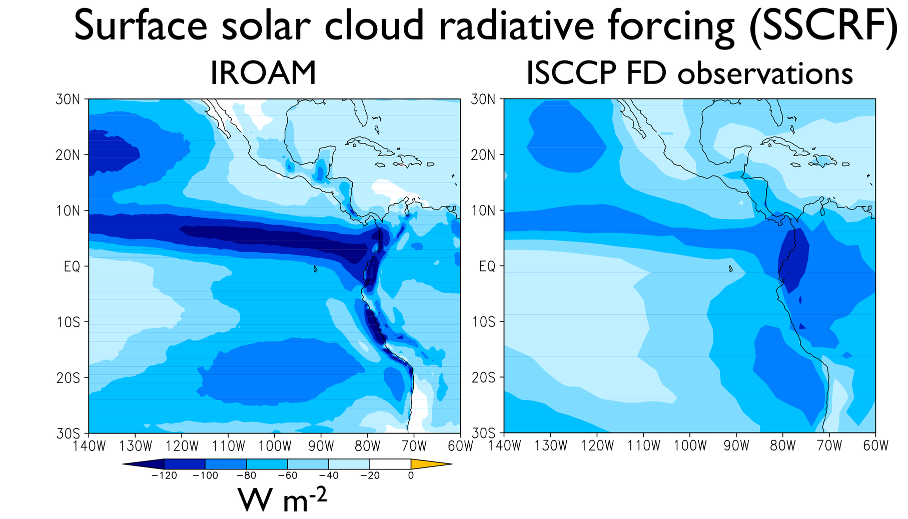


- Reynolds SST is supplied to the RAM over the Atlantic Ocean.
- NCEP reanalysis provides the surface flux boundary condition for the MOM2 over the western Pacific, and the lateral conditions for the RAM.
- The IROAM is run on the Earth Simulator supercomputer in Yokohama, Japan, supported by JAMSTEC.



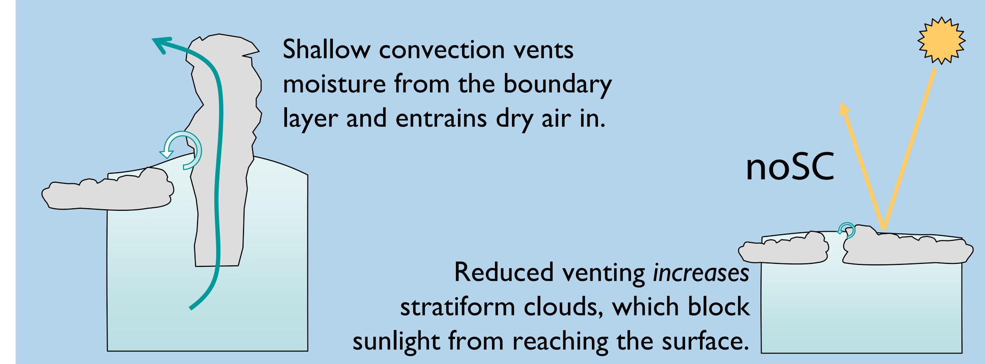
The ocean is spun up for 6 years before coupling to the atmosphere. Averages are over 1998-2003.

Surface solar cloud radiative forcing (SSCRF)



No shallow convection (noSC) experiment

Prohibit shallow convection in the Tiedke (1989) mass-flux convection scheme.



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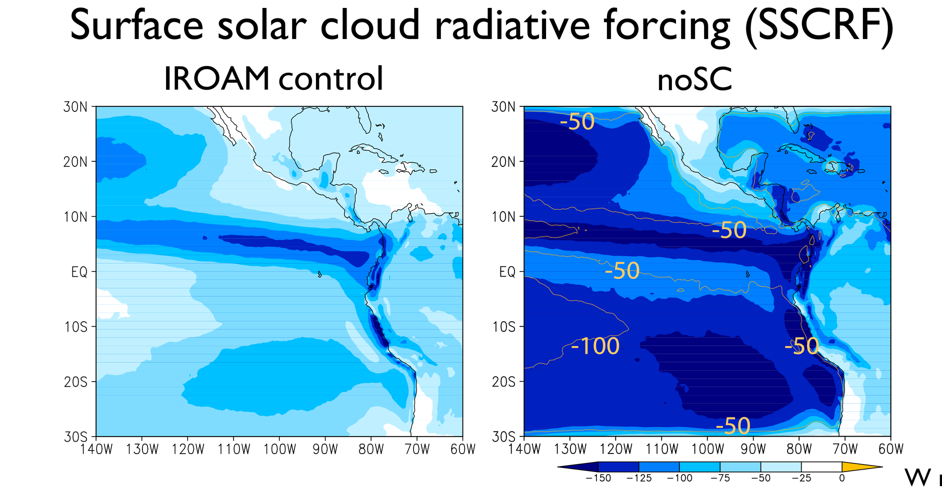
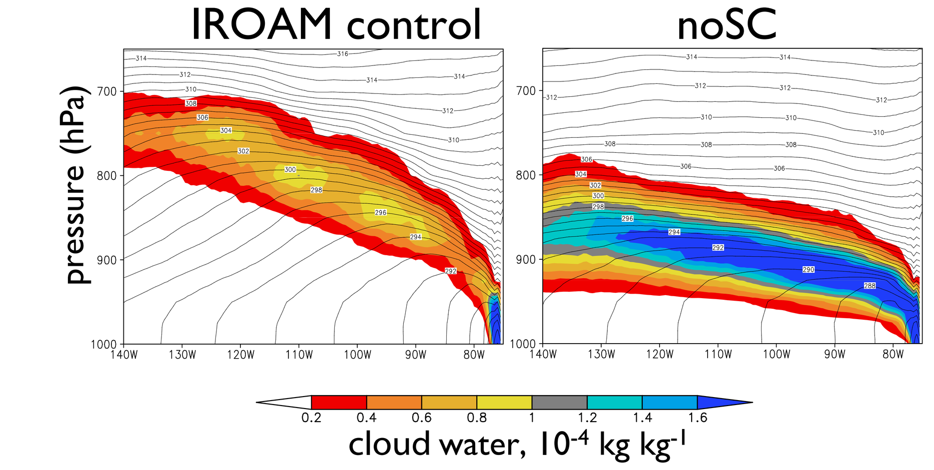


Increased stratiform clouds dim sunlight by 50-100 W m^{-2}.

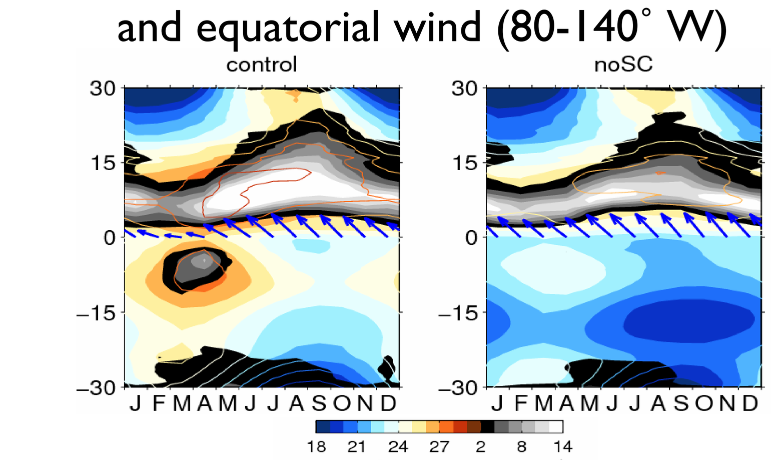
Removal of shallow cumulus convection increases stratocumulus in noSC, especially in the southern hemisphere where stratocumulus are prevalent, and over warm SST in the west where shallow convection dries the boundary layer in the control simulation.

Cloud water and potential temperature (K)



Vertical-longitude structure of clouds along 15° S in September for the control experiment and noSC. In control shallow cumulus form a decoupled layer that deepens over warmer temperature to the west. Clouds are lower, atop a shallow mixed layer in noSC.

Seasonal cycle of SST, rain, and equatorial wind (80-140° W)



Both hemispheres cool in noSC. The southern hemisphere cools more, so that the SST never warms enough for significant rain in the southern hemisphere. The meridional asymmetry is enhanced, and perennial northerlies cool the equator.