Importance of the Agulhas SST front in shaping clouds and circulations over the south Indian Ocean

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Summary

Impacts of the Agulhas SST front on clouds and circulations

✓ **Poleward shift of the polar front jet and the expanded subtropical high associated with more active transient eddies**

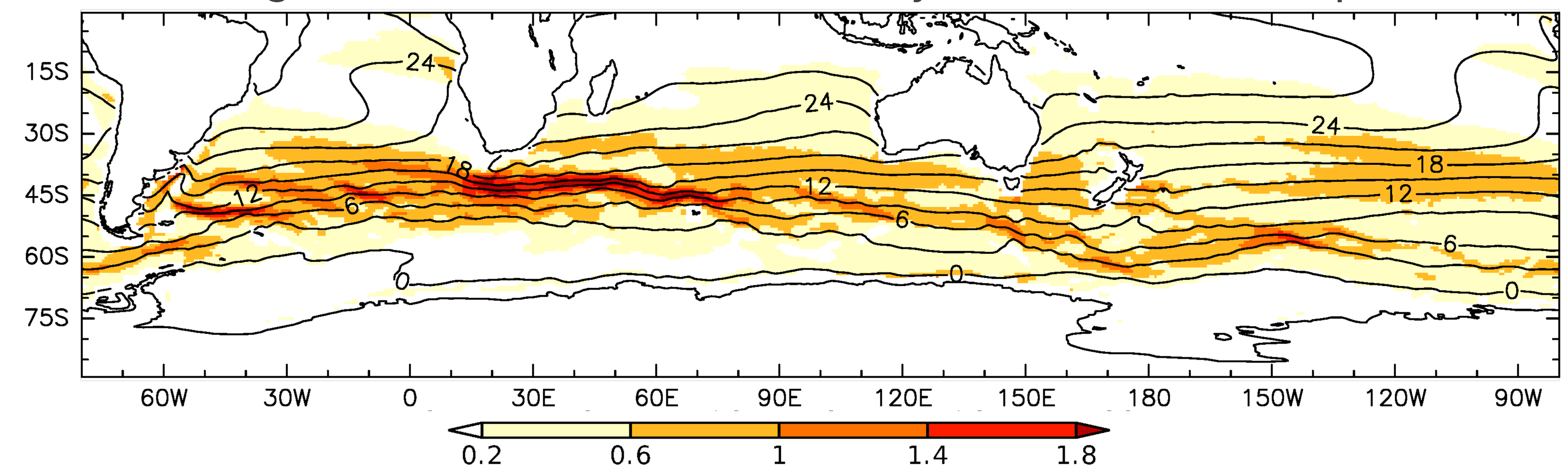
✓ **Enhanced turbulent heat flux associated with energized transient eddies promotes low clouds, leading to shortwave cooling over warmer water**

✓ **Intermodel spread in the cloud radiative effect in HighResMIP AGCMs is comparable to that of turbulent heat flux**

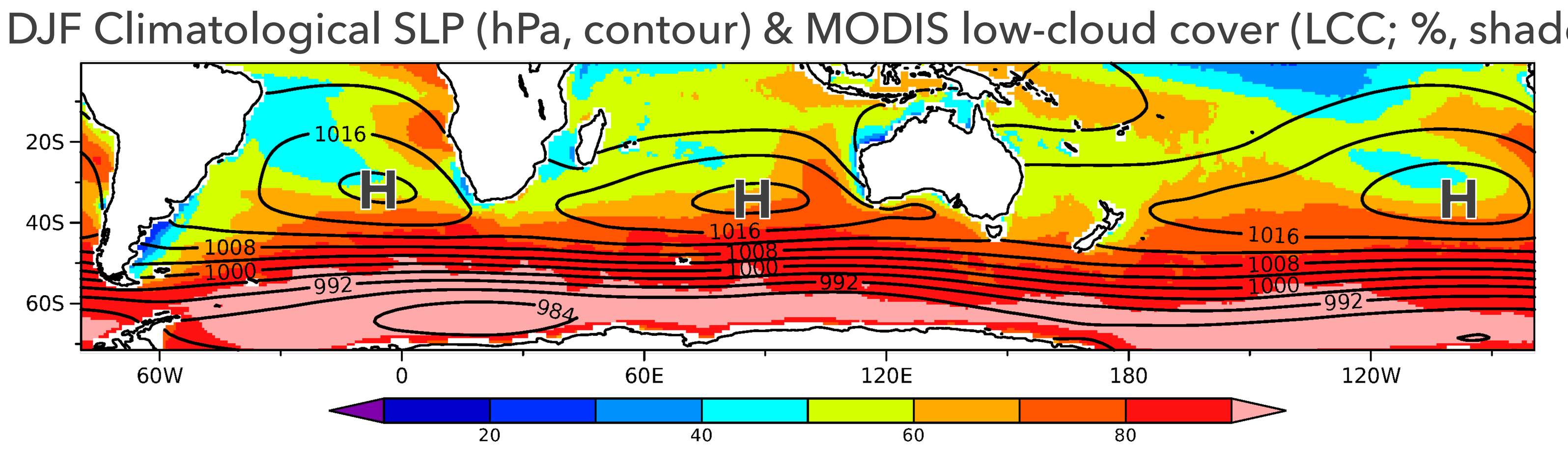
1. Miyamoto, A., H. Nakamura, and T. Miyasaka, 2018, Influence of the subtropical high and storm track on low-cloud fraction and its seasonality over the south Indian Ocean. J. Climate, doi:10.1175/JCLI-D-17-0229.1
2. Miyamoto, A., H. Nakamura, T. Miyasaka, Y. Kosaka, B. Taguchi, and K. Nishii, 2022, Maintenance mechanisms of the wintertime subtropical high over the south Indian Ocean, J. Climate, doi:10.1175/JCLI-D-21-0518.1
3. Miyamoto, A., H. Nakamura, T. Miyasaka, Y. Kosaka, B. Taguchi, and K. Nishii, 2023, in preparation

1. Introduction

DJF climatological SST (°C, contour) & dSST/dy (°C/100km, shade) prescribed in CTL



DJF Climatological SLP (hPa, contour) & MODIS low-cloud cover (LCC; %, shade)



✓ The south Indian Ocean is characterized by

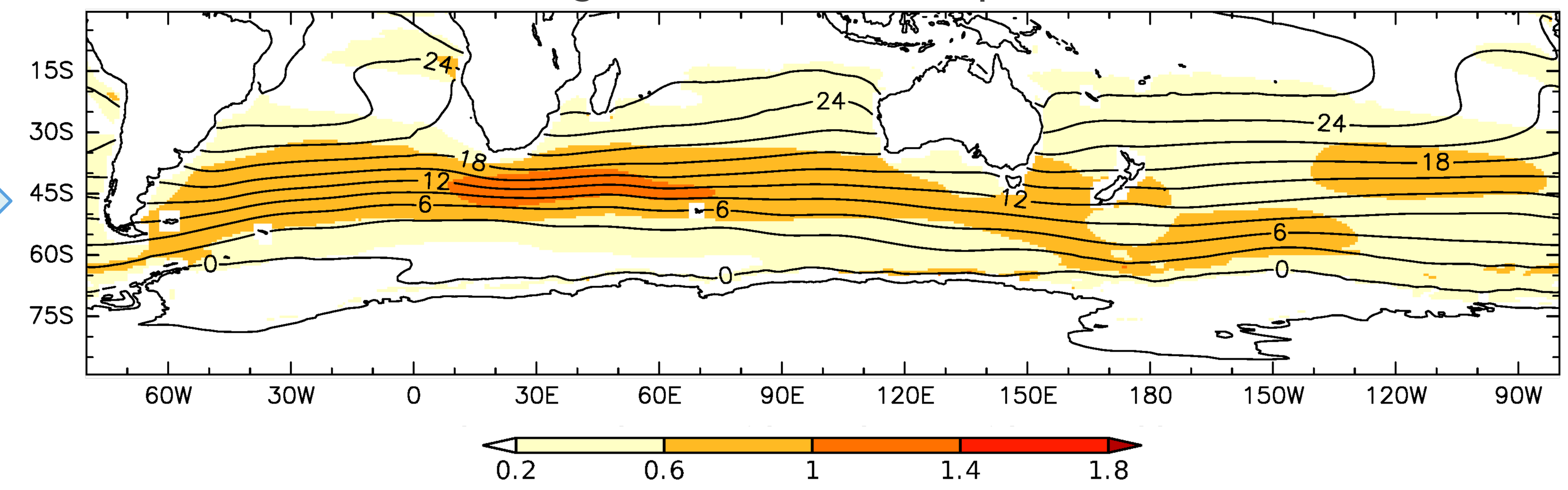
- Meridional SST gradient in the confluent region of the warm Agulhas Return Current and cool Antarctic Circumpolar Current
- Cross-frontal contrasts in surface turbulent heat flux
- Strong eddy-driven jet on the poleward flank of the subtropical high
- Large low-cloud cover (LCC) over the midlatitude ocean

Q. How does the frontal SST gradient influence the clouds and circulations?

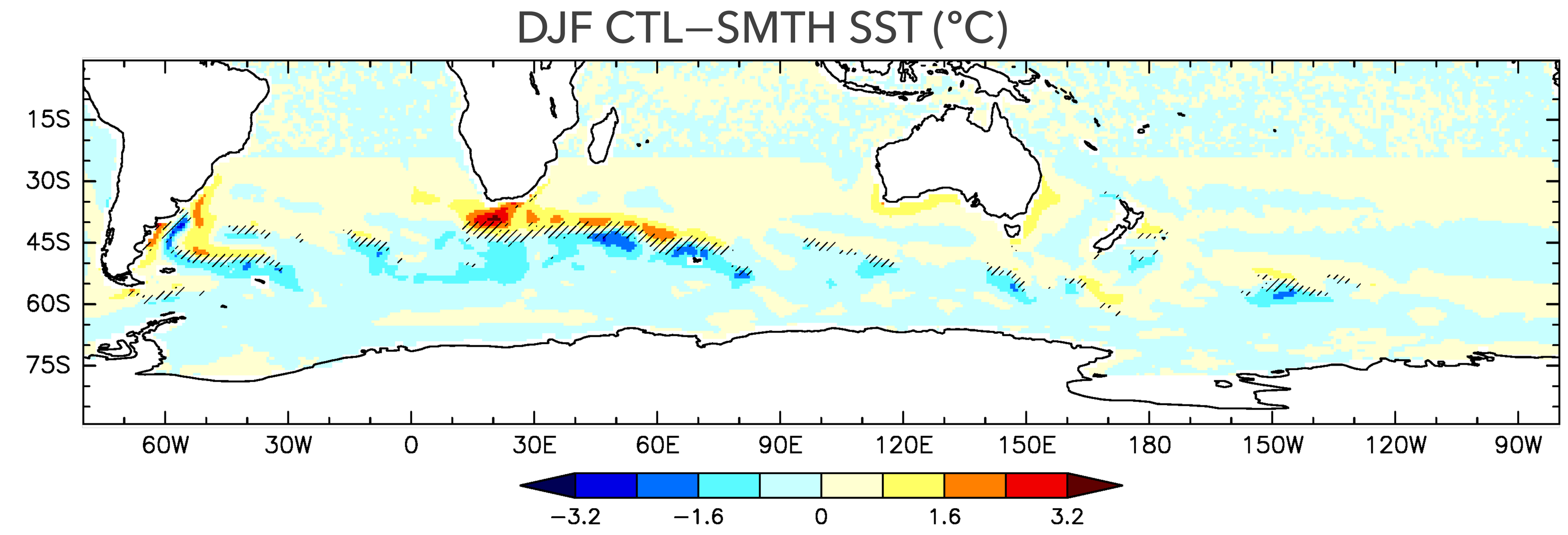
Prescribed SST

2. AGCM experiments

DJF climatological smoothed SST prescribed in SMTH



DJF CTL−SMTH SST (°C)



AGCM for Earth Simulator (AFES) — See Miyamoto et al. (2022) for details

✓ T119L56 → regrid to 1°

✓ 15-member ensemble prescribed with OISST (1982/12-2013/11)

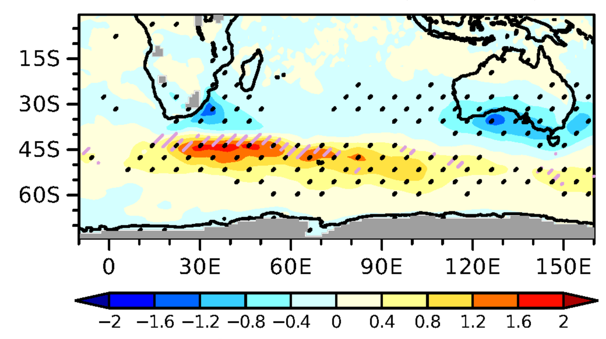
✓ **CTL (original OISST)** & **SMTH (smoothed OISST** by Gaussian filter (600km e-folding scale) in 60°N-30°S & 55°N-30°N

➢ We compare **CTL** and **SMTH** climatology

3. Large-scale circulation response

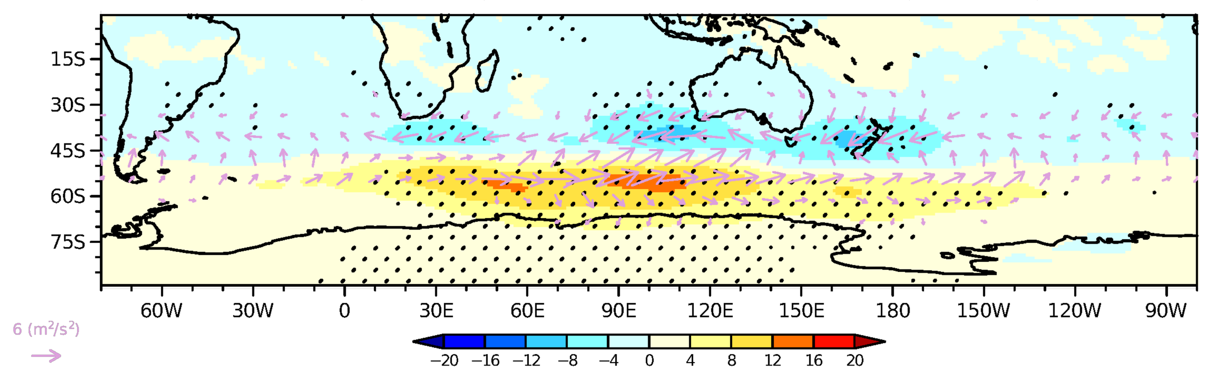
DJF CTL−SMTH → Impact of sharpening of the front

−V'T'850 (K m/s)

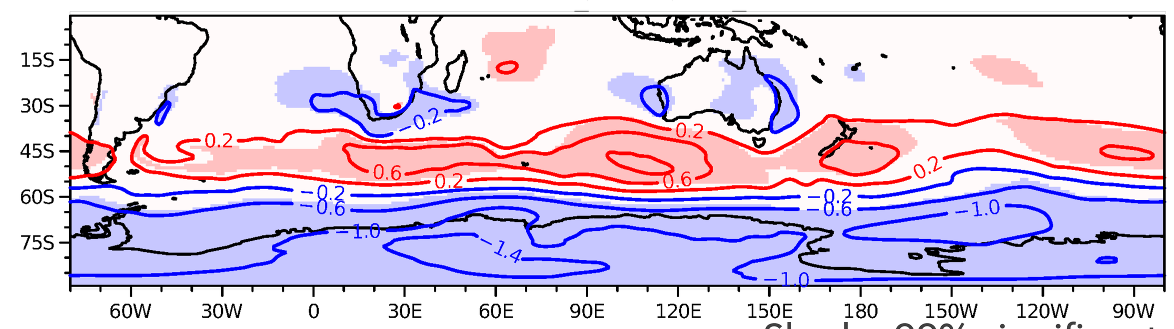


Dot: 99% significant

EKE250 (m²/s²) & extended EP-flux (arrow)



SLP (hPa)



Shade: 99% significant

✓ Enhanced poleward heat transport (−V'T') by transient eddies (8day highpass filtered component) along the Agulhas SST front

✓ Enhanced eddy kinetic energy (EKE) with poleward shift signal expanding downstream

✓ Accelerated westerlies at 60°S with poleward expansion of the subtropical high

Similar response in winter (See Miyamoto et al. 2022 details)

4. Frontal structure of cloud radiative effect (CRE)

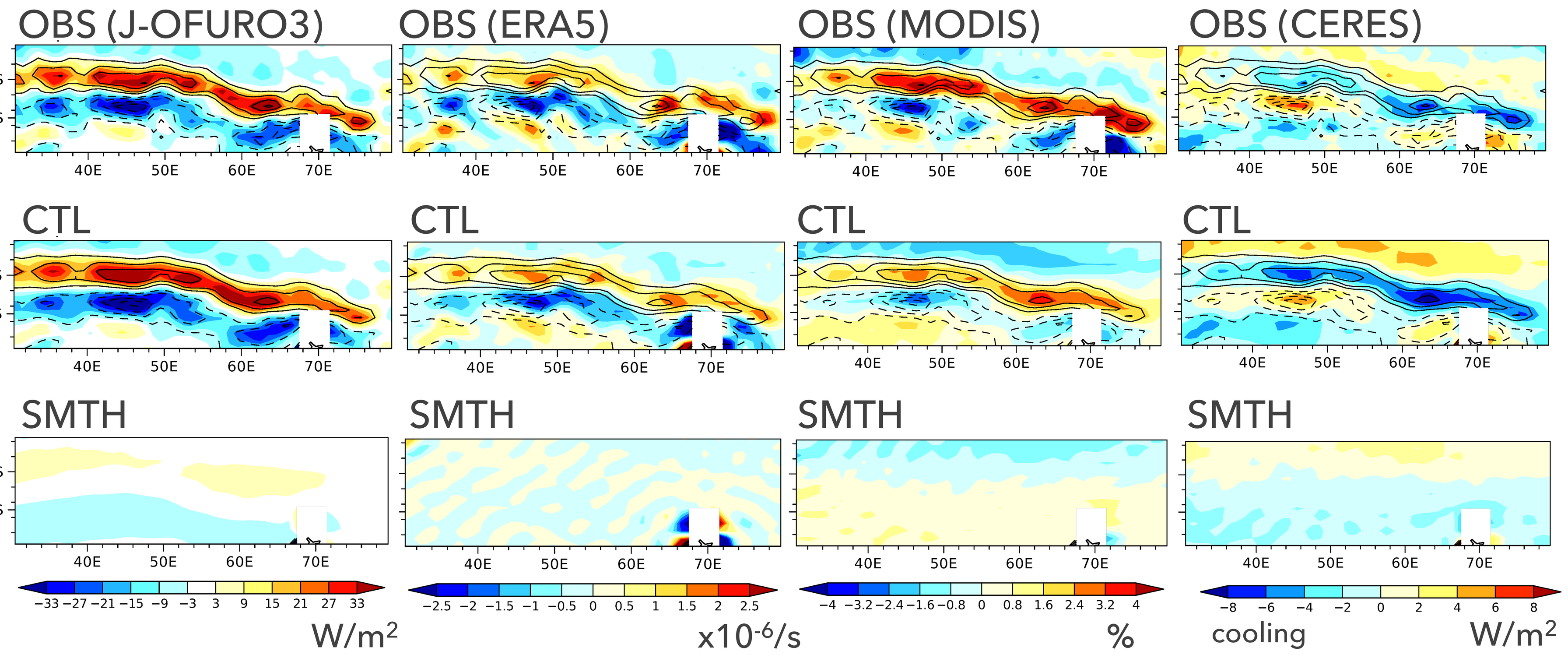
➢ Latitudinal 9° highpass filtering to highlight the impacts of the Agulhas SST front

$CRE = R_{all}^{SW+LW} - R_{clr}^{SW+LW}$

R: surface radiation

Contour: DJF SST (every 0.5°C; solid lines → warmer SST)

Upward SHF+LHF | Surface convergence | Low-cloud cover (LCC) | surface CRE



✓ Enhanced upward turbulent heat flux and surface convergence associated with active transient eddies acts to increase LCC on the warmer side of the SST front → reduce incoming shortwave radiation (~negative CRE)

Miyamoto et al. (2018)

✓ AFES CTL captures the frontal structure while SMTH

5. Cloud radiative effect in HighResMIP AGCMs

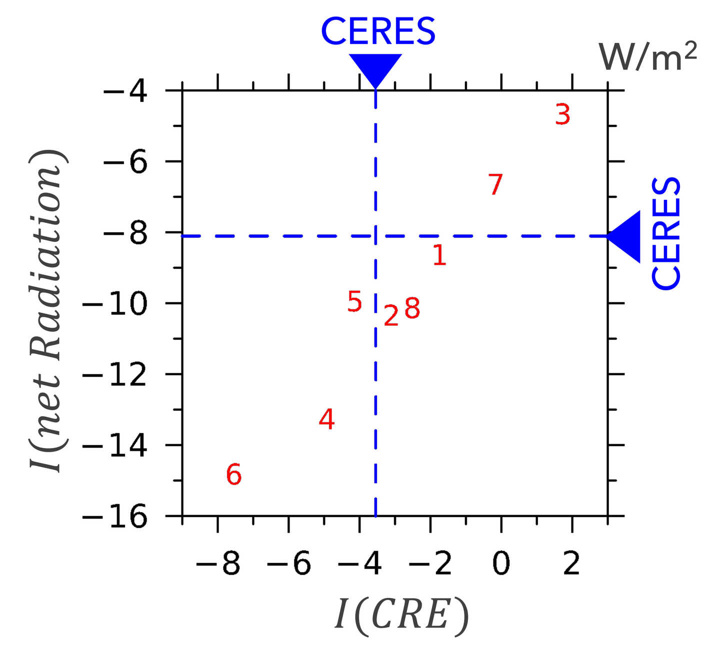
- HighResMIP AGCMs forced with ¼° HadISST2 (highresSST-present; 1982/12-2013/11; regrid to 1°)
- Within the same model group, the highest resolution version is used
- Frontal contrast index (warm water average − cool water average)

$$I = avg(SST_h > 0.7°C) - avg(SST_h < -0.7°C)$$

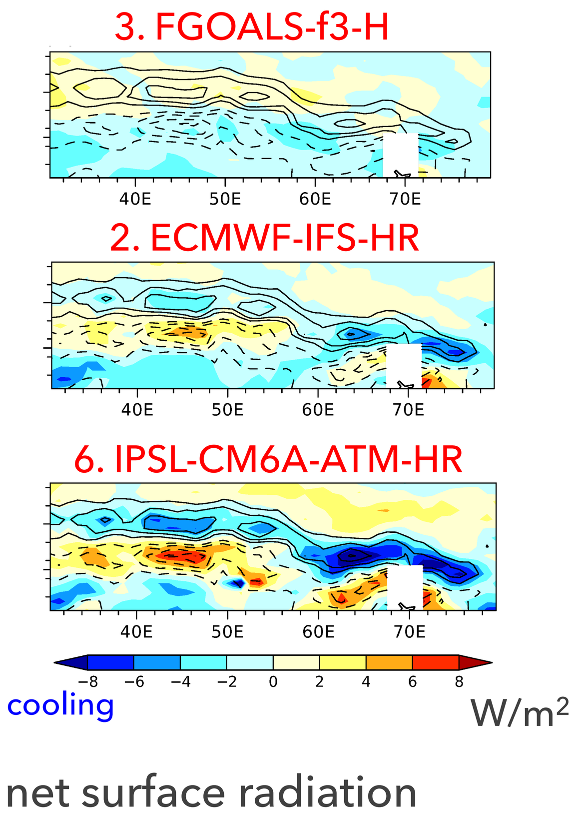
h: latitudinal 9° high-pass filtering; Weak dependence of results on threshold values

DJF surface CRE & radiation

1	CMCC-CM2-VHR4
2	ECMWF-IFS-HR
3	FGOALS-f3-H
4	HadGEM3-GC31-HM
5	INM-CM5-H
6	IPSL-CM6A-ATM-HR
7	MPI-ESM1-2-XR
8	CMCC-CM2-VHR5



DJF surface CRE (shade) & SST (every 0.5°C)



✓ Cloud radiative effect explains intermodel spread of net surface radiation

✓ Intermodel spread of radiation (3.3W/m²) is comparable to that of turbulent heat flux (4W/m²), biasing surface energy budget