Study on Subtropical Marine Stratocumulus toward JMA/MRI-CPS4

CHIBA Jotaro[1*], KUBO Yutaro[1,2], OCHI Kenta[1,2], ADACHI Yukimasa[1,2], HIRAHARA Shoji[1,2], KOMORI Takuya[3]

[1]Numerical Prediction Development Center, Japan Meteorological Agency [2]Meteorological Research Institute, Japan Meteorological Agency [3]Information Policy Division, Japan Meteorological Agency

Summary

- Verification results of the JMA's seasonal prediction system (CPS3) show insufficient cloud cover for subtropical marine stratocumulus (SC), which causes warm SST biases in SC regions due to radiative flux errors.
- The SC parameterization has been adjusted to represent SC up to the top of the planetary boundary layer, resulting in improved biases in radiative flux and SST.

1. Introduction

- A realistic representation of subtropical marine stratocumulus (SC: e.g. off the coast of Peru, California) has been difficult in general circulation models due to its complexities.
- The JMA's next seasonal prediction system (CPS4) is under development based on CPS3 (Hirahara et al. 2023) and shows some issues for SC.
  - There are positive biases in downward shortwave radiative flux and SST in SC regions due to lack of cloud cover.
- We tested a SC parameterization to represent SC better in CPS4.

2. Experimental settings

- Hindcast experiments were conducted using an atmosphere/ocean/land/sea ice-coupled prediction model based on CPS4.

	AGCM	OGCM
Base Model	GSM2003C+	MRI.COM v5
Horizontal Resolution	TL319 (~55km)	0.25° (Lon) × 0.25° (Lat)
Vertical Resolution	128 levels (0.01hPa)	60 levels
Period	1991 - 2020	
Initial Date	10/28	
Ensemble Member	1-member	

- The vertical output were thinned to 1000, 975, 950, 925, 900, 875, 850, 825, 800, 775, 750 and 700hPa as in JRA-3Q and ERA5.

3. Issues of SC off the coast of Peru

- In CNTL, cloud cover is insufficient around an altitude of 1500m against the CloudSat+CALIPSO observation and peaked at 500m around 80W.
- The height of the top of the planetary boundary layer (PBL) is almost consistent with JRA-3Q and ERA5.

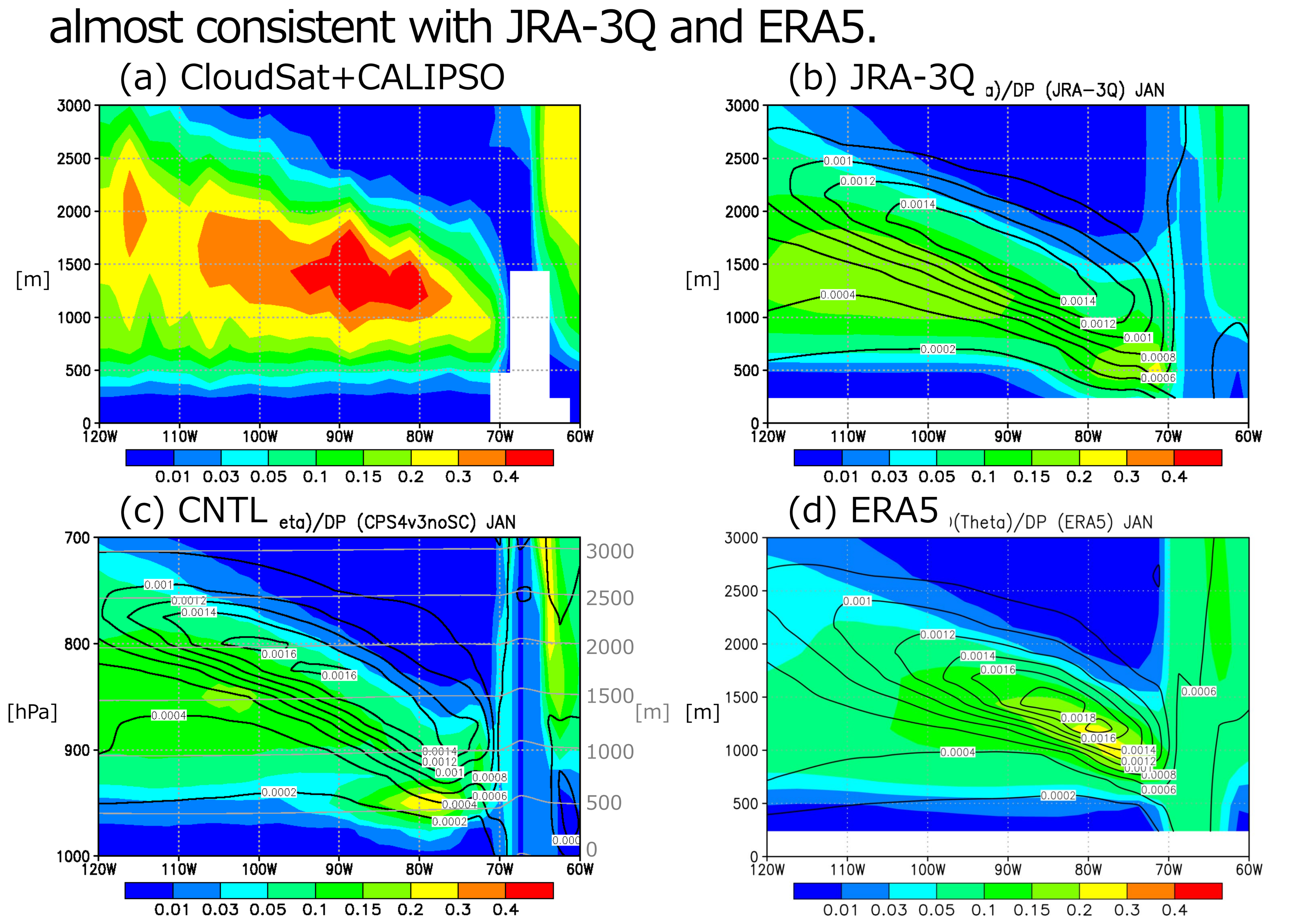

Figure 1 Longitude-height cross section (20S) of climatological cloud fraction [1] (shade) and vertical gradient of potential temperature (dθ/dP) [K/Pa] (contour) in January. (a) combined product of CloudSat and CALIPSO observation (Bertrand et al. 2024) (b) JRA-3Q (Kosaka et al. 2024) (c) CNTL (d) ERA5 (Hersbach et al. 2020).

4. Simple approach to the issues

- In the SC parameterization, the vertical diffusion is set to much weaker and the cloud top entrainment is suppressed if the estimated cloud-top entrainment index (ECTEI: Kawai et al. 2017, 2019) is above the threshold.
- The SC parametrization is activated up to 924hPa altitude in CPS3.
- A simple approach for the issues is to change the upper limit from 924hPa to 700hPa which covers the top of the PBL.

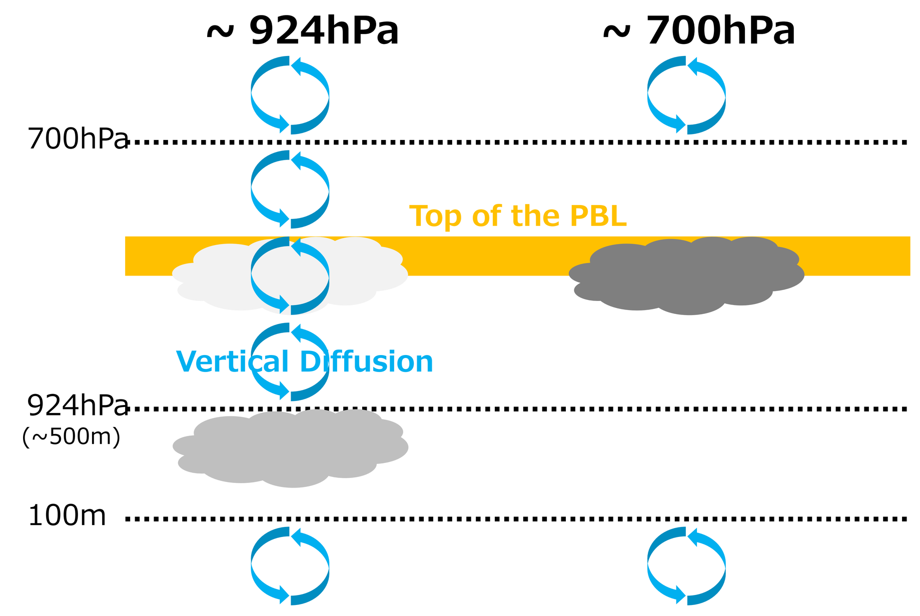

Figure 2 Schematic of the SC parameterization activated up to (left) 924hPa (right) 700hPa. The intensity of cloud color shows the amount of cloud. The blue circular arrows are vertical diffusion, areas where the SC parameterization is not activated. The yellow band is the climatological top of the planetary boundary layer in SC regions.

5. Test of the adjusted SC parameterization

- TEST with the adjusted SC parameterization shows:
  - The maximum in cloud cover around 80W is represented better, but the altitude is lower than the CloudSat+CALIPSO observation and the cloud cover around 1500m altitude is still insufficient.
  - The biases in downward shortwave radiative flux and SST are reduced.

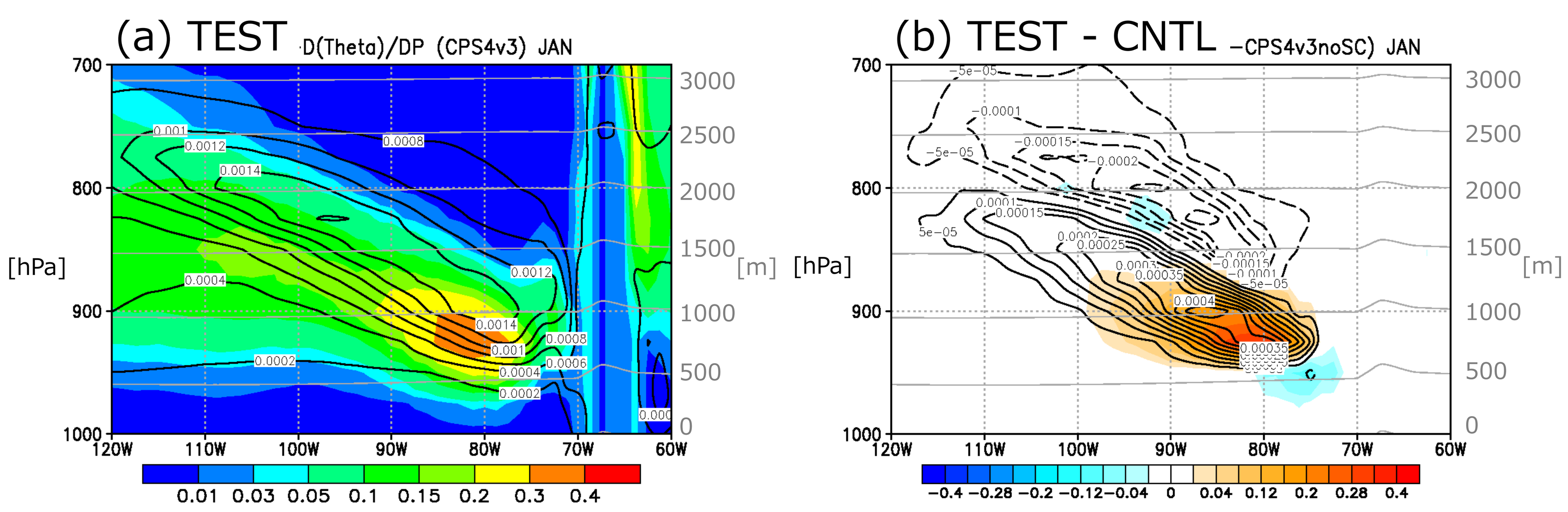

Figure 3 Same as Fig. 1. (a) TEST (b) TEST-CNTL.

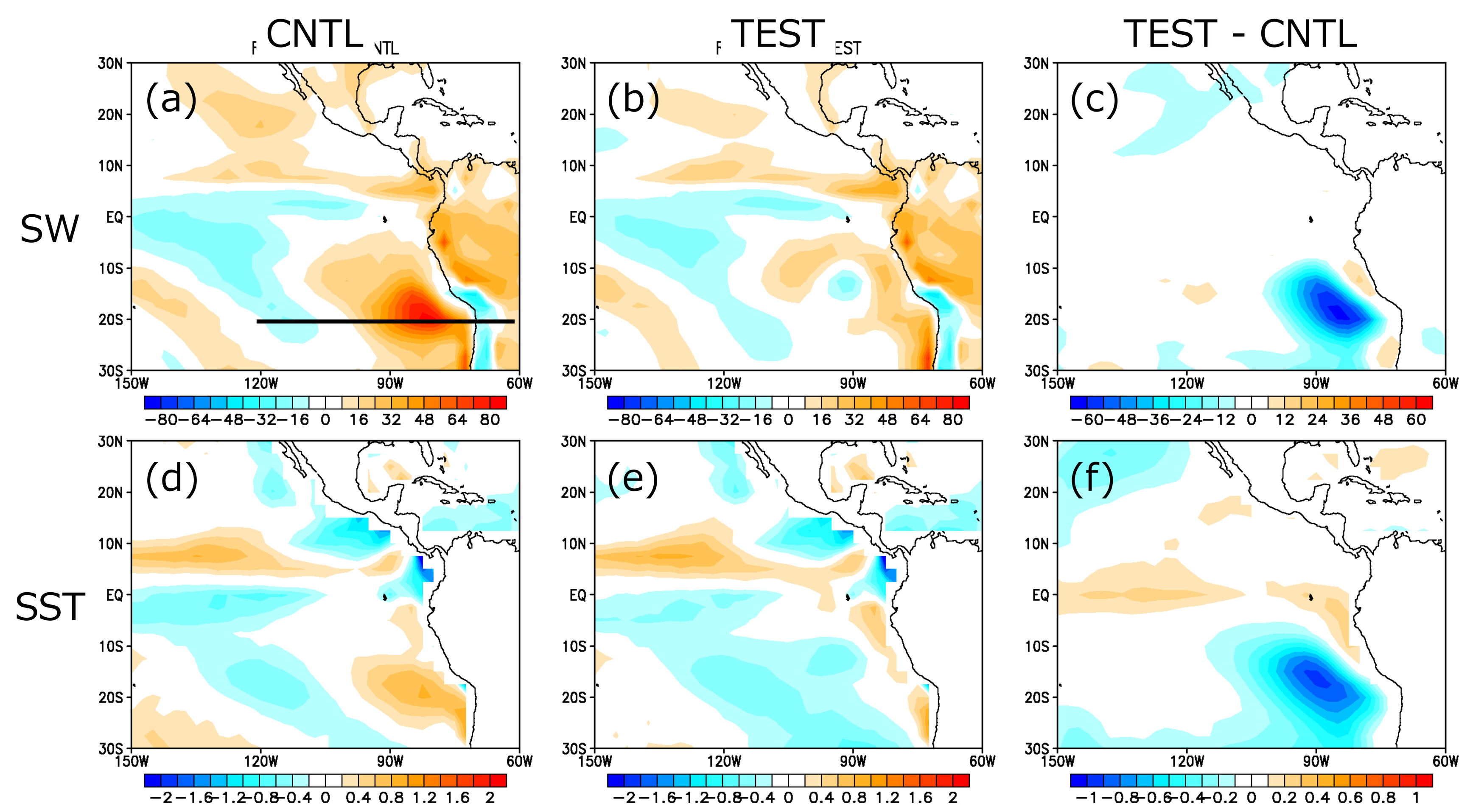

Figure 4 Bias of (a,b,c) surface downward shortwave radiative flux (SW) [W/m²] against CERES-EBAF (Kato et al. 2018) (d,e,f) SST [K] against MGDSST (Kurihara et al. 2006) in January. (a,d) CNTL (b,e) TEST (c,f) TEST-CNTL.

Reference

Bertrand, L., Kay, J. E., Haynes, J., and de Boer, G.: A global gridded dataset for cloud vertical structure from combined CloudSat and CALIPSO observations, Earth Syst. Sci. Data, 16, 1301–1316, https://doi.org/10.5194/essd-16-1301-2024, 2024.

Hirahara, S., Y. Kubo, T. Yoshida, T. Komori, J. Chiba, T. Takakura, T. Kanehama, R. Sekiguchi, K. Ochi, H. Sugimoto, Y. Adachi, I. Ishikawa, and Y. Fujii: Japan Meteorological Agency/Meteorological Research Institute Coupled Prediction System version 3 (JMA/MRI-CPS3). J. Meteor. Soc. Japan, 101, 149-169, https://doi.org/10.2151/jmsj.2023-009, 2023.

Kawai, H., Koshiro, T., and Webb, M. J.: Interpretation of factors controlling low cloud cover and low cloud feedback using a unified predictive index, J. Climate, 30, 9119–9131, https://doi.org/10.1175/JCLI-D-16-0825.1, 2017.

Kawai, H., Yukimoto, S., Koshiro, T., Oshima, N., Tanaka, T., Yoshimura, H., and Nagasawa, R.: Significant improvement of cloud representation in the global climate model MRI-ESM2, Geosci. Model Dev., 12, 2875–2897, https://doi.org/10.5194/gmd-12-2875-2019, 2019.

気象庁 Japan Meteorological Agency