Mechanisms of Changes in Marine Fog in CMIP5 Multi-Model Simulations

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Abstract

In this study, the changes in the occurrence of marine fog over the summer North Pacific in warmer sea surface temperature (SST) or increased CO2 climates were investigated based on atmospheric model simulations by using the fifth phase of the Climate Model Intercomparison Project (CMIP5) multimodel data. Initially, the marine fog representation in CMIP5 multimodels was briefly evaluated globally. We found that the simulated marine fog occurrence was represented relatively well in boreal summer but poorly in other seasons. The results indicated that the changes in the North Pacific high-pressure system accompanied by changes in horizontal wind patterns control the changes in marine fog occurrence in the North Pacific. The magnitude of contrasting pair changes in marine fog occurrence in the western and eastern North Pacific are primarily determined by the magnitude of changes in the North Pacific high-pressure system. Global-scale changes in the vertical profiles of the atmosphere (stability changes) can also affect the marine fog changes. These changes in marine fog over the North Pacific were consistent among most CMIP5 models.

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Purpose

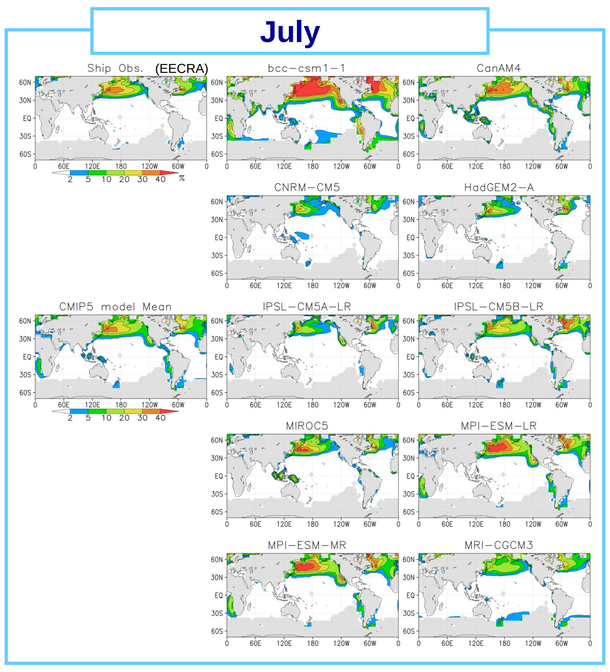
Reveal the followings:

- How well do the CMIP5 multi-models reproduce marine fog?
- How does marine fog change under different climates in CMIP5 simulations?
  - Under warmer SST climates
  - Under an increased CO_2 climate (without changes in SST)
- What is the mechanism of the marine fog changes?

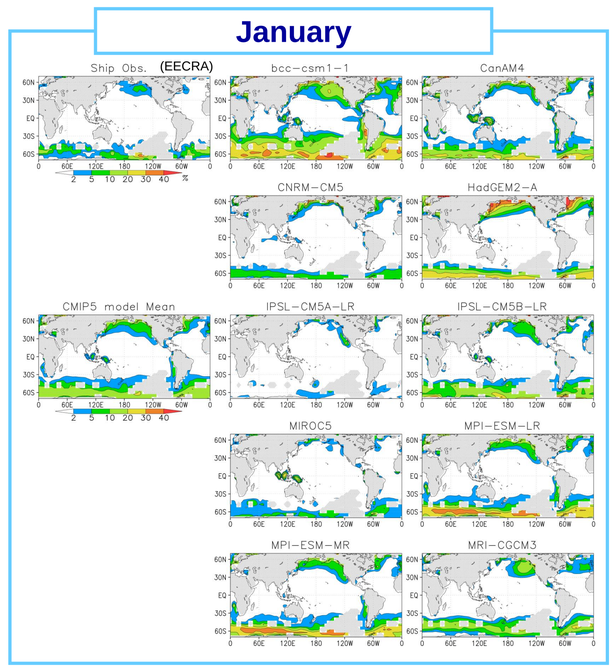
Data

- 10 CMIP5 multi-model data
- Experiments:
  - amip — observed SST is given
  - amip4K — 4K SST increase (uniform)
  - amipFuture — 4K SST increase (patterned)
  - amip4xCO2 — CO_2 is increased under fixed SST
- Period: 31 years (1979−2009)
- Monthly average data
  - Model level data:
    Definition of fog: cloud at the lowest model level
  - 2D (SLP, 1000hPa wind), 3D p-level data (T, q)

Simulated Fog in CMIP5 models

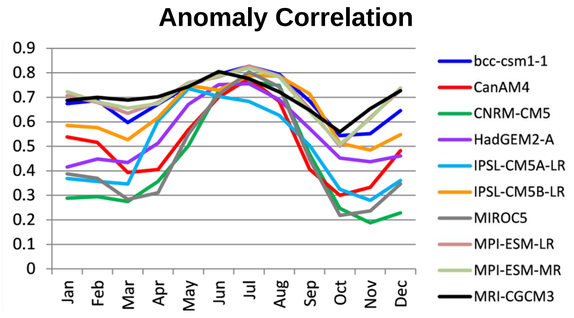


Represented well in July for the North Pacific!



Represented poorly in January...

Score



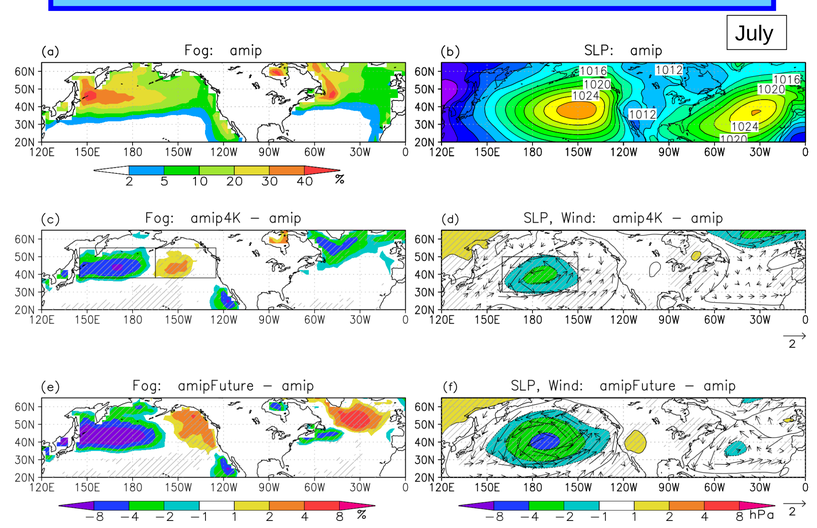
Data over the ocean 70°S–70°N

(boreal) summer: Score is high for all models
(boreal) winter: Score is low and extremely low in some models

⇩

Discuss fog changes for July in the NH.

Increased SST Climate

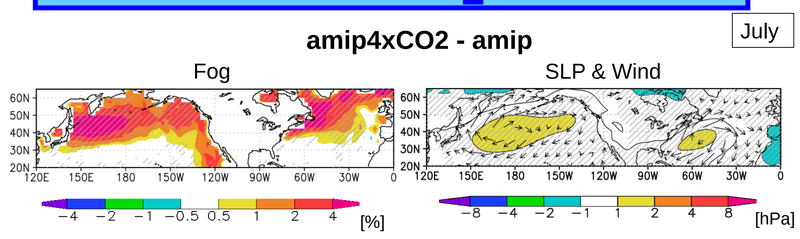


Increased SST
⇨ Weakened North Pacific high pressure system

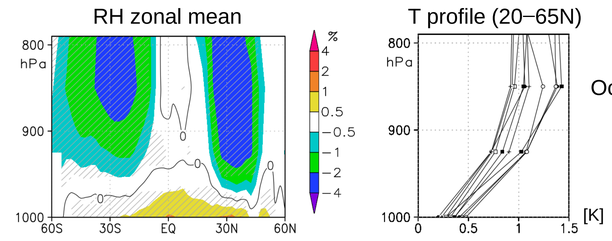
⇩

Western N. Pac. : Weaker southerly wind -> Less advection fog
Eastern N. Pac. : Stronger southerly wind -> More advection fog

Increased CO_2 Climate



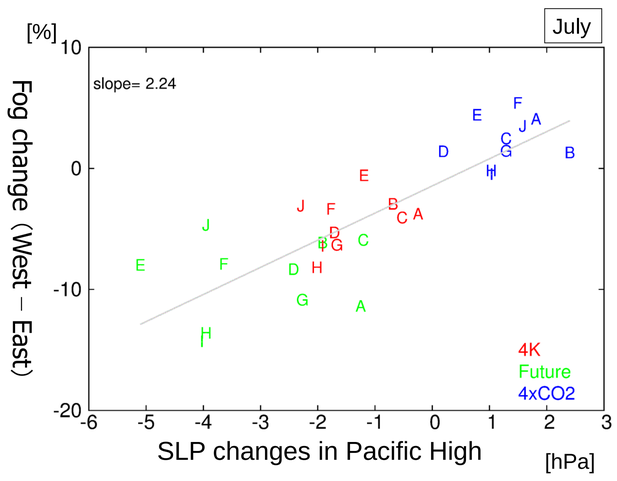
Strengthened North Pacific high pressure system
⇨ Fog is increased a lot over the area with increased southerly wind. However, fog is increased everywhere. Why?

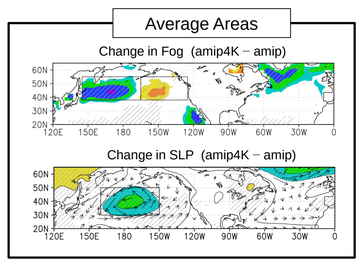


Ocean grids only

When only CO_2 is increased without changes in SST, ABL becomes more stable.
-> RH near the surface is increased. (Kamae et al. 2015)

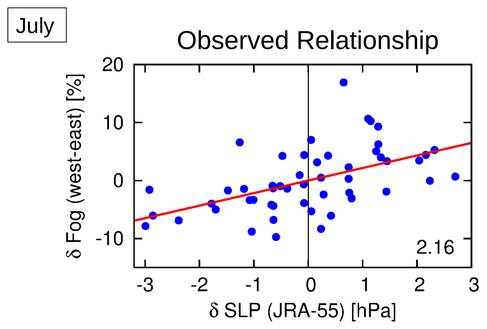
SLP & Fog Change Relationship





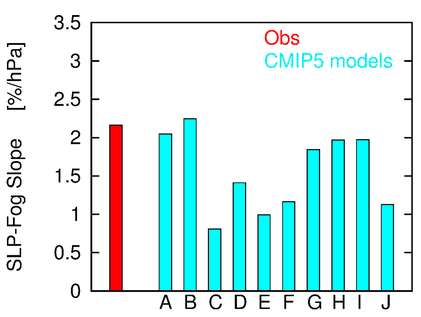
Clear relationship between the west-east contrast of fog change & change in the North Pacific high!

SLP & Fog Interannual Variations



Fog Obs.: Shipboard observation data (EECRA)
Past SLP: JRA55

The observed slope for interannual variation is close to the simulated slope for climate change.



CMIP5 models roughly reproduce the relationship for interannual variations.

Summary

(Kawai et al. 2018)

- There is a large variety in representation of marine fog in CMIP5 models.
- Marine fog is well represented in CMIP5 models over the North Pacific in boreal summer, but not in boreal winter.
- Changes in marine fog in CMIP5 models correspond to changes in sea level pressure patterns.
  - Fog increase (decrease) for the region of strengthened (weakened) southerly wind.
  - Consistent with MRI-CGCM3 results in Kawai et al. (2016).
- Only CO_2 increased experiment shows the increase in marine fog especially for strengthened southerly wind areas. But also in weakened areas. (Main cause: Stabilization of ABL. (Kamae et al. 2015))
- There is a clear relationship between the changes in the North Pacific high pressure system & west-east contrast of fog change.

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