Characteristics of vertical structures of marine boundary layer clouds over mid-latitudes

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Motivation

- Mid-latitude marine boundary layer clouds have not been studied so intensively compared with subtropical BL clouds.
- We want to know the vertical structures of the clouds and fog distribution globally. However, conventional satellite infrared imagers can give information of cloud top only and they cannot give the vertical profile information. Moreover, even the estimation of cloud top height from the infrared data includes huge uncertainty.

→ Is it possible to reveal the vertical structures of low clouds and fog frequency globally using the data from satellite cloud radar and lidar, and to know the relationships with meteorological parameters using reanalysis data?

e.g. What are seasonal variations of vertical structures of mid-latitude low clouds? Are there differences between in NH and SH? If there are differences, what brings them?

Data

Cloud observation data

Hagihara cloud mask data retrieved from CloudSat and CALIPSO (Hagihara et al. 2010, JGR). “CloudSat or CALIPSO mask (C4) data” are used.

Why Hagihara Cloud Mask?

CALIPSO can capture clouds even for the altitude lower than 1km. But there are a lot of aerosols in lower troposphere. Therefore, it’s important to eliminate a contamination of aerosol signals from low clouds signals. Such aerosol signals are eliminated in Hagihara cloud mask data by a sophisticated algorism and it can be appropriate data for studies of low clouds.

Limitations:

CALIPSO cannot detect lower clouds under non-transparent upper clouds. CloudSat cannot detect clouds lower than 720m due to surface clutter and CloudSat cloud masks can contain drizzle or rain.

Meteorological data

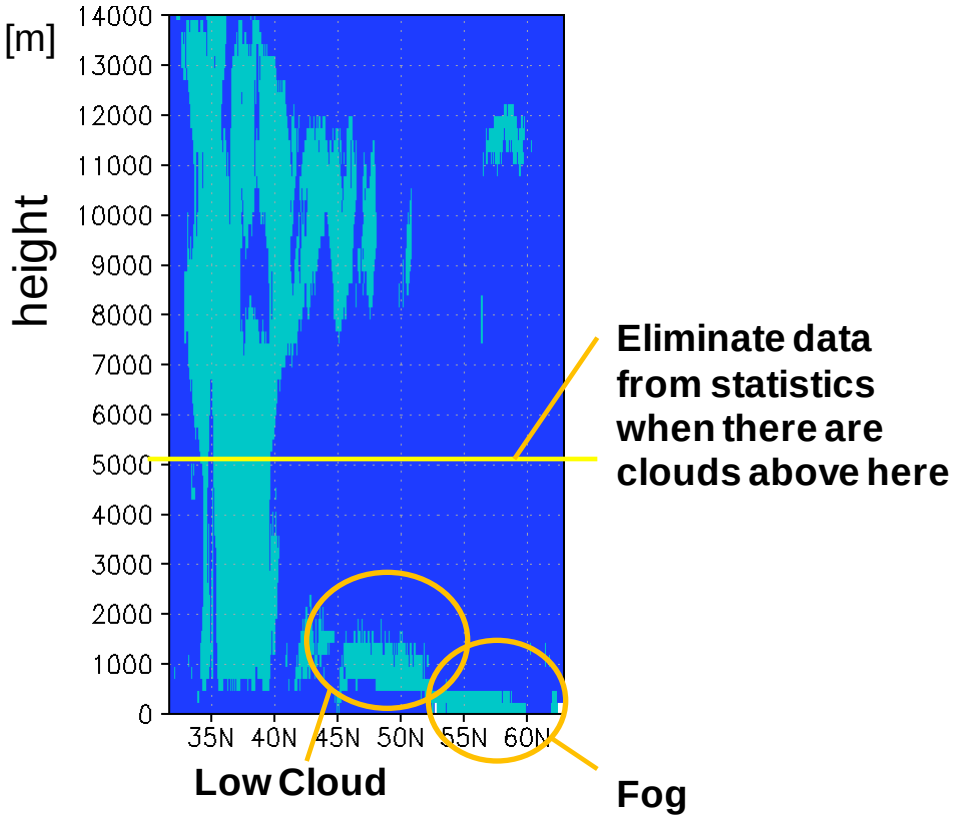
ERA-Interim

Processing

The data are eliminated from statistics when there are clouds above 5km.
→ The statistics include only the data without any clouds above 5km.

Reasons:
* The reliability of cloud mask is low when the cloud is deep or covered by upper clouds.
* Low clouds uncovered by upper clouds are much more important for global radiation budget.

Example of Hagihara Cloud mask



An Orbit along around 175E

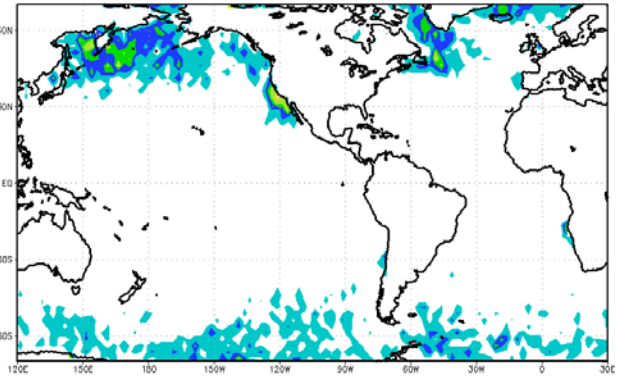
Data Period : Monthly climatology is created using data of 2007 - 2009

Can this data capture low clouds and fogs?

July

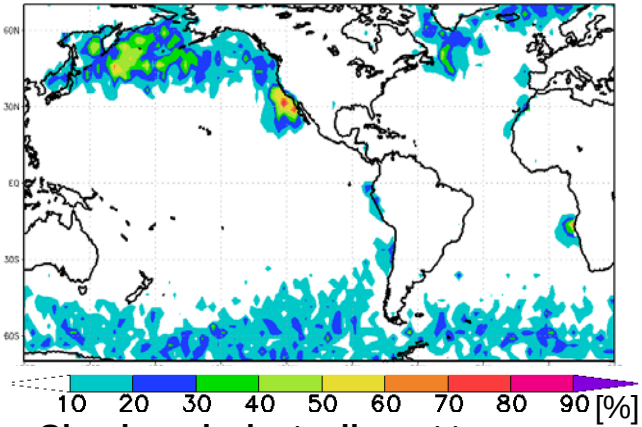
– Frequency of cloud at each height –

0 - 240 m



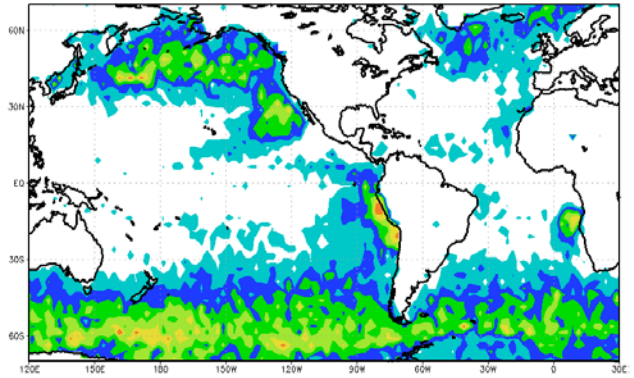
Cloud masks in North Pacific and near Newfoundland
No cloud masks in unlikely areas

240 - 480 m



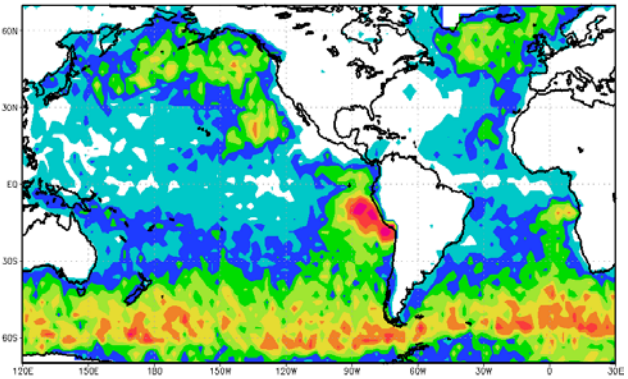
Cloud masks just adjacent to California

480 - 720 m



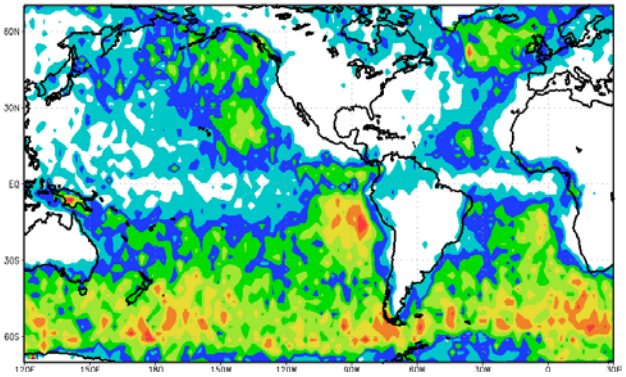
Cloud masks just adjacent to Peru

720 - 960 m



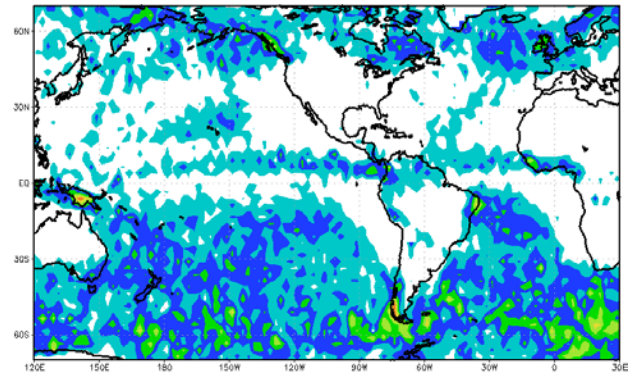
No cloud masks just adjacent to California

1200 - 1440 m



In subtropics, cloud masks in areas away from the continents. No cloud masks near California

1920 - 2160 m



In subtropics, no cloud masks near California or Peru

This data seems to capture low clouds even below 1000m well!

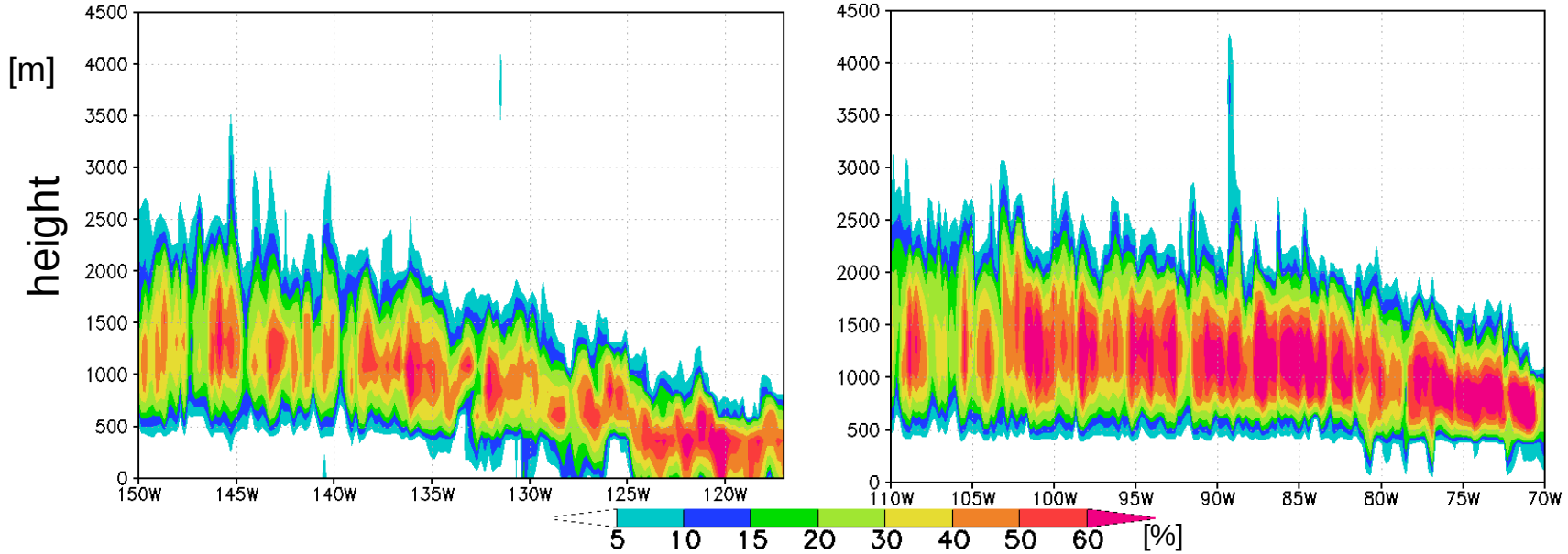
Can this data capture low clouds and fogs?

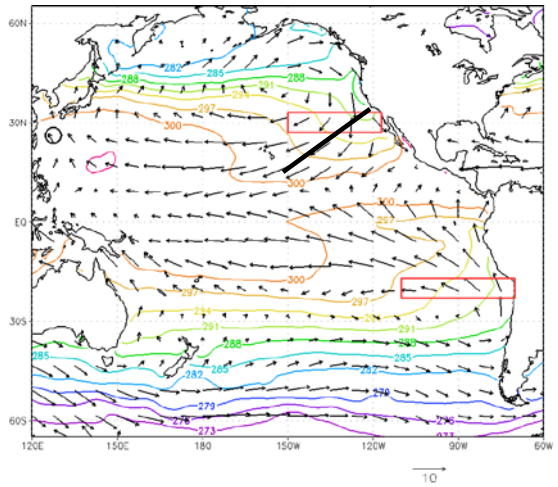
– Subtropical low clouds –

July

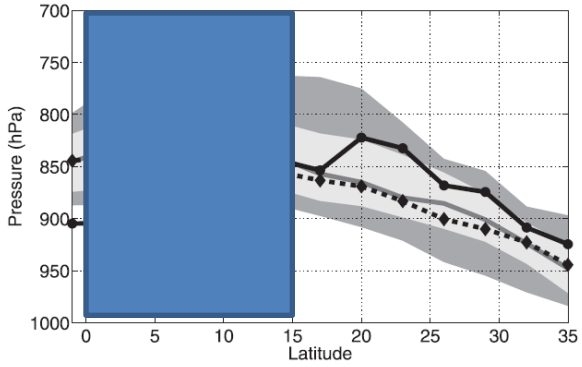
Off California along 30N

Off Peru along 20S





The data capture features that the cloud layers gradually increase going away from the continents, and that cloud layer is lower near California than near Peru!



Cloud Top height along GPCI

Model range
Inter–quartile model range
Model median
ECMWF–analysis
MISR

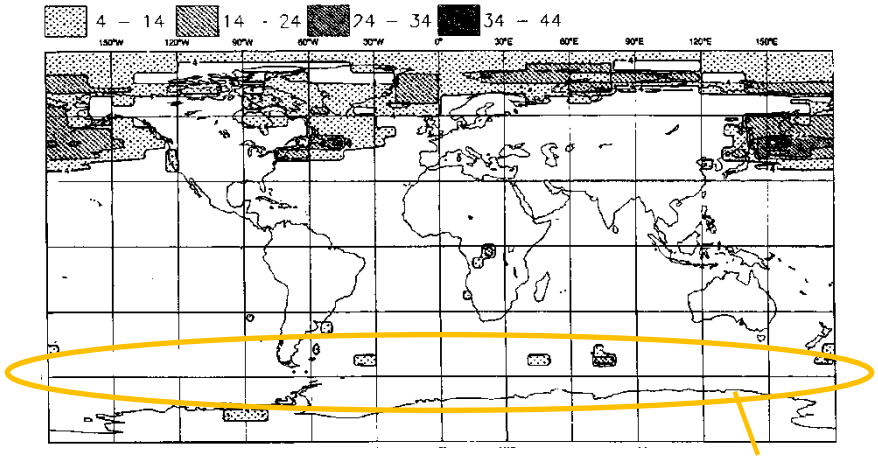
June – August 2003

Copied from Karlsson et al. (2010)

Frequency of occurrence of fogs

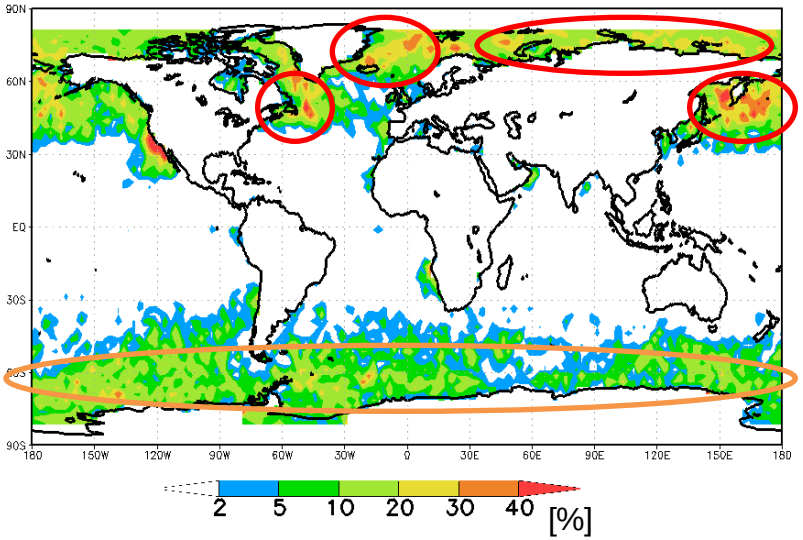
Observational Climatology (Jun. - Aug.)

(Teixeira 1999, Warren et al. 1986,1988)

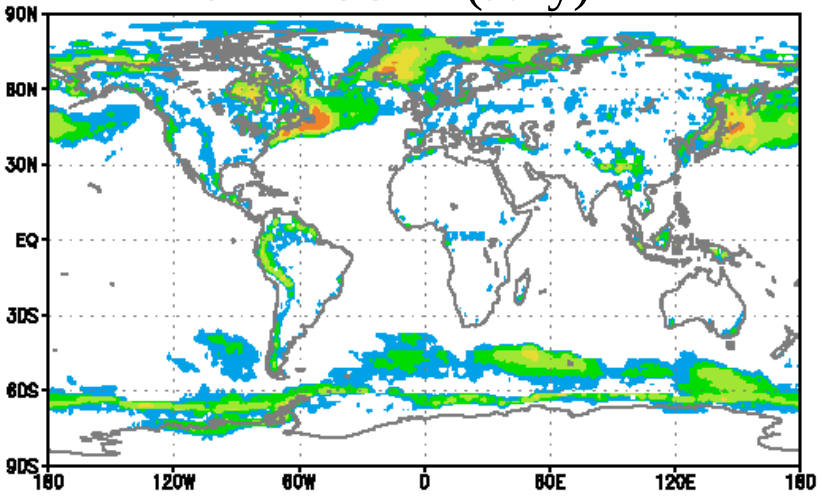


Southern Ocean in Winter, Ship obs. were few

Hagihara Cloud Mask 0-240m (July)



JMA GSM (July)



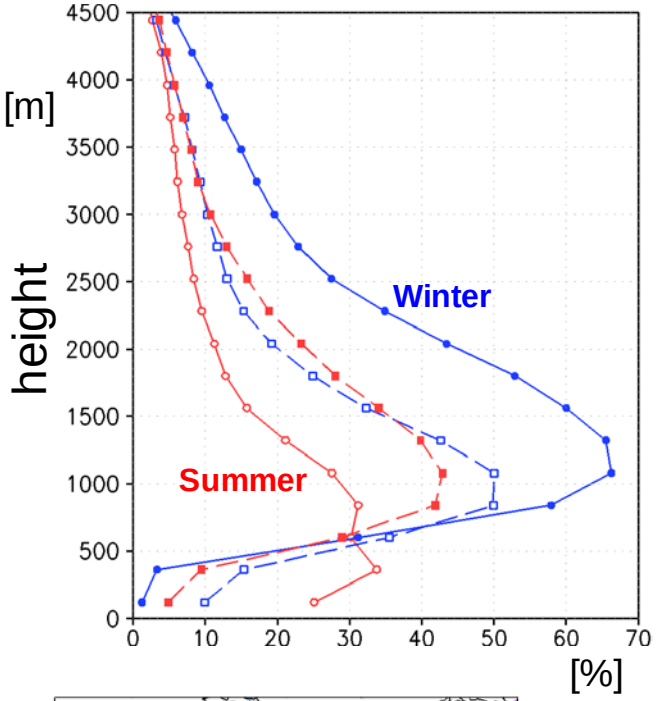
* Around Kamchatka Peninsula
* Near Newfoundland
* North of Iceland
* Arctic Ocean along Eurasia
* Southern Ocean

Hagihara cloud mask seems to capture fogs relatively well!

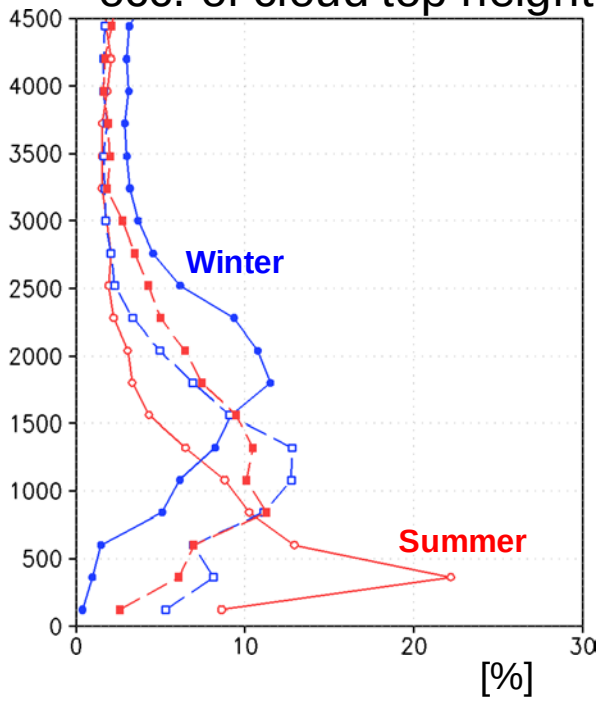
(frequency in model is halved according to Teixeira (1999).)

Comparison of Vertical Structures of mid-latitude low clouds between NH and SH

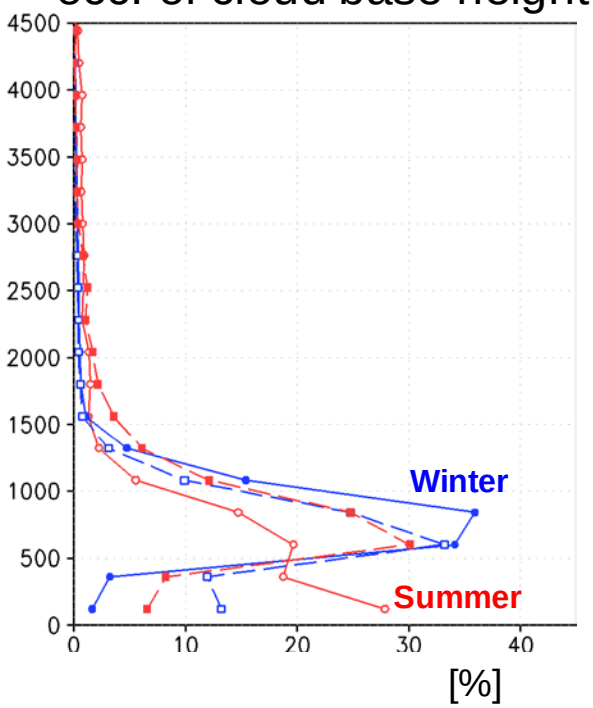
Cloud Cover
(frequency of occ. of cloud)

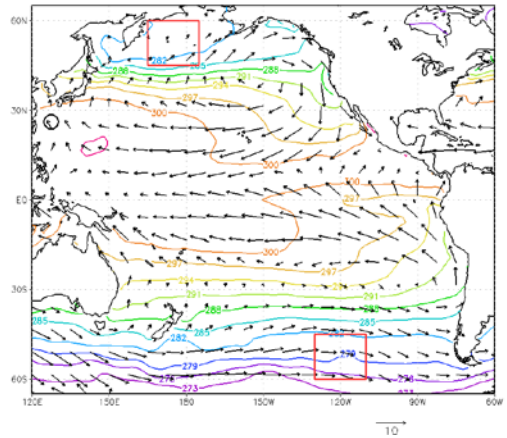


Relative frequency of
occ. of cloud top height



Relative frequency of
occ. of cloud base height





NH Summer
NH Winter
SH Summer
SH Winter

Jan. or Jun. data

NH: mid-latitude low clouds have low cloud top height and low cloud base height in summer. They are high in winter.

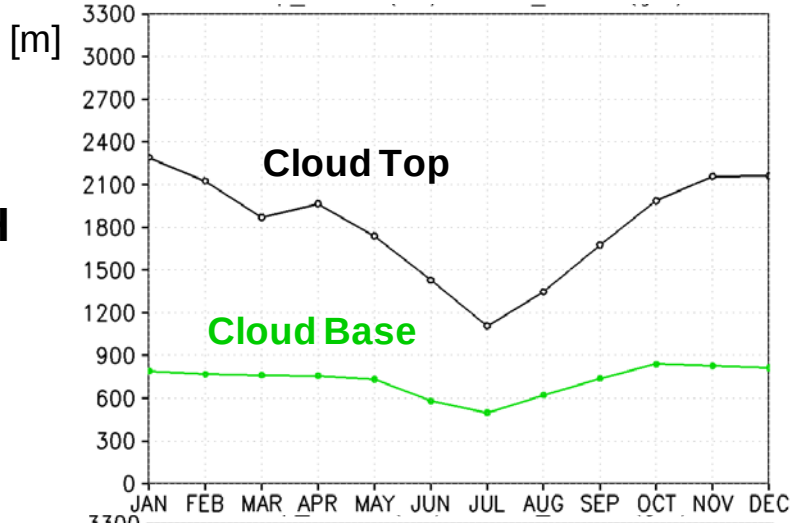
SH: Their seasonal differences are very small.

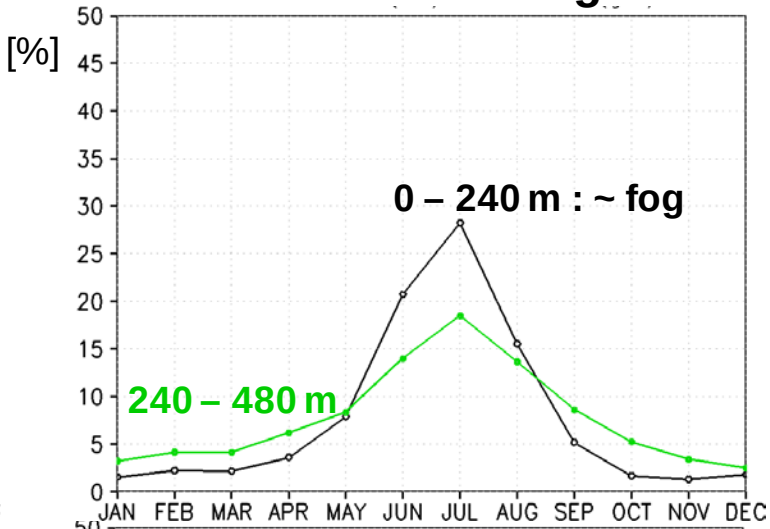
Seasonal Variations of Vertical Structures of Mid-latitude Low Clouds

Cloud Top/Base Height

Relative frequency of occurrence of cloud base height

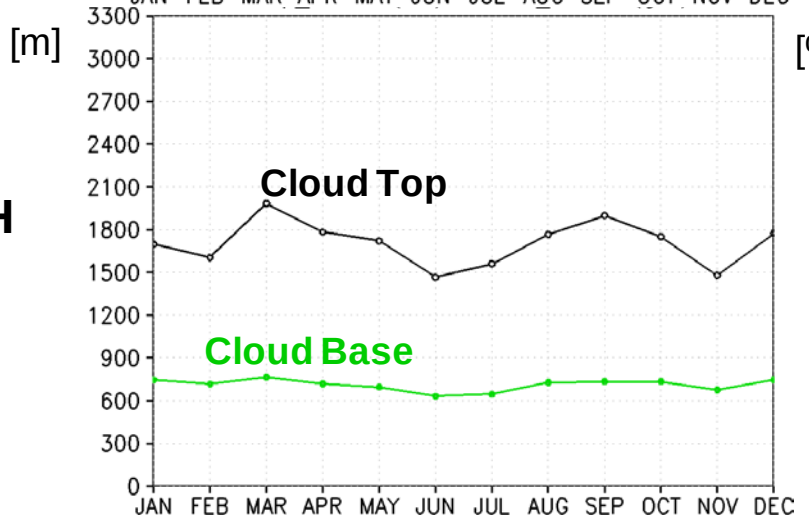
NH

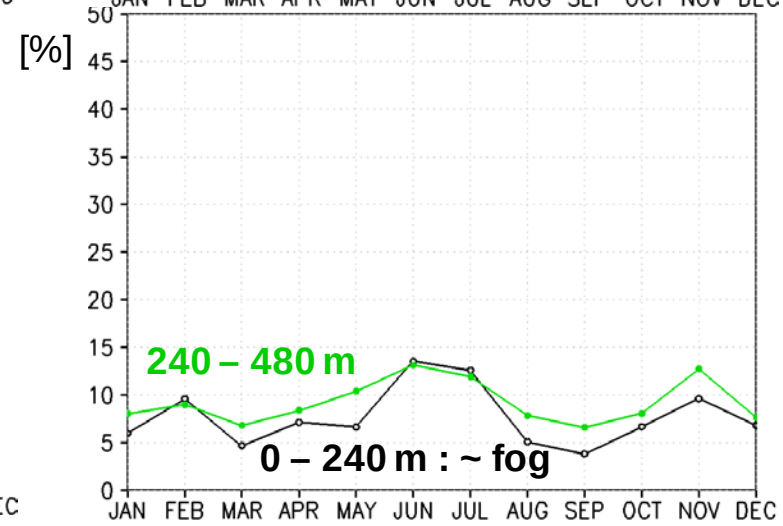




Clear Seasonal Variation

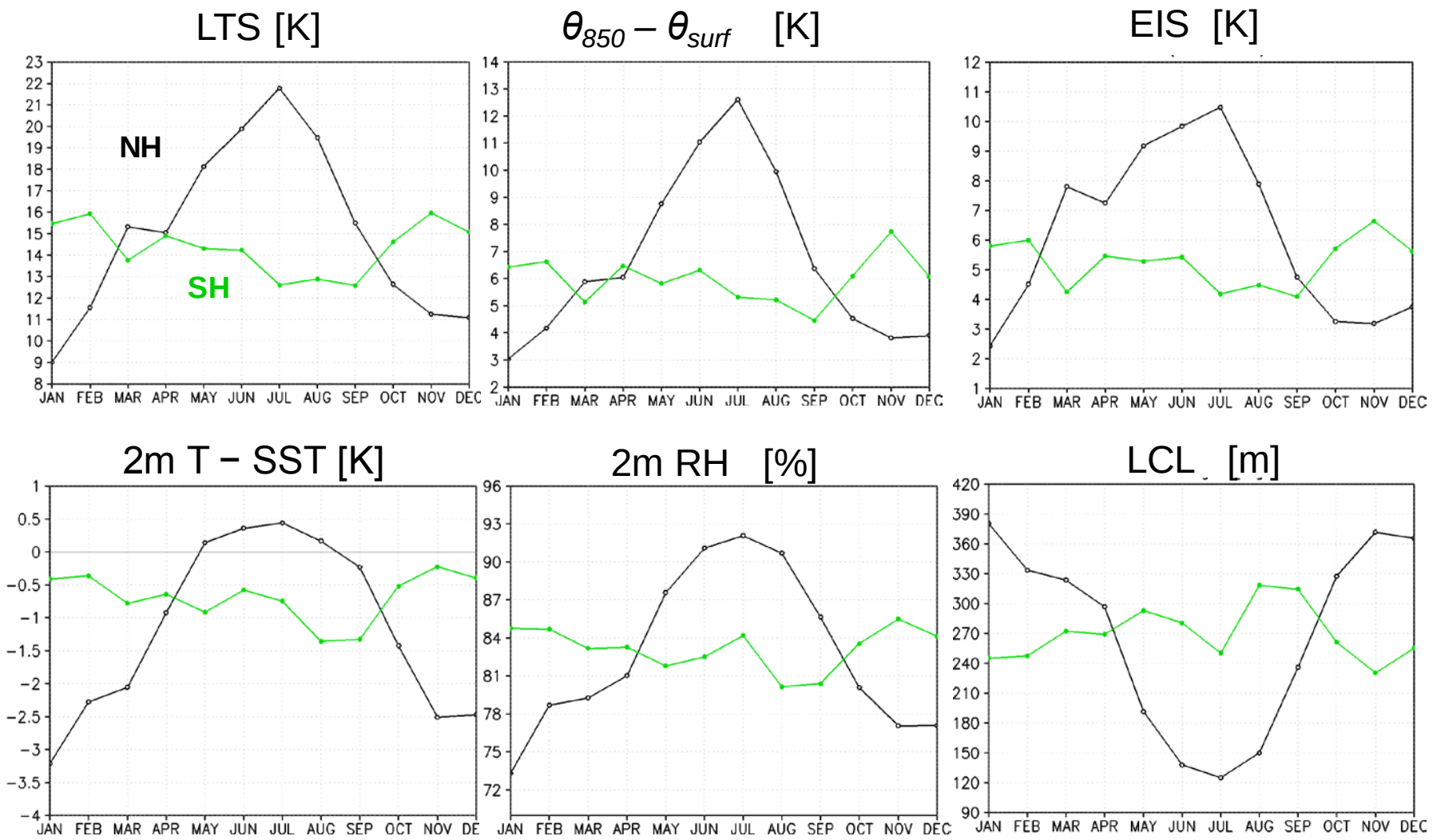
SH





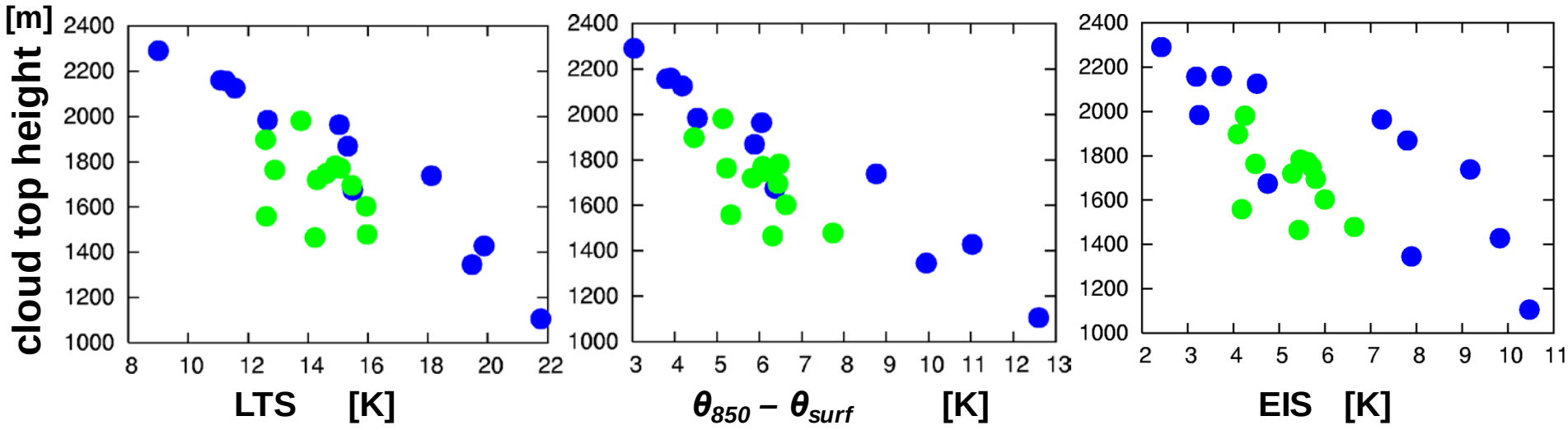
Unclear Seasonal Variation

Seasonal Variations of Meteorological Factors



The seasonal variations of meteorological factors are clear in northern hemisphere.
They are not clear in southern hemisphere.

Cloud Top Height and Meteorological Factors



● NH mid-latitude

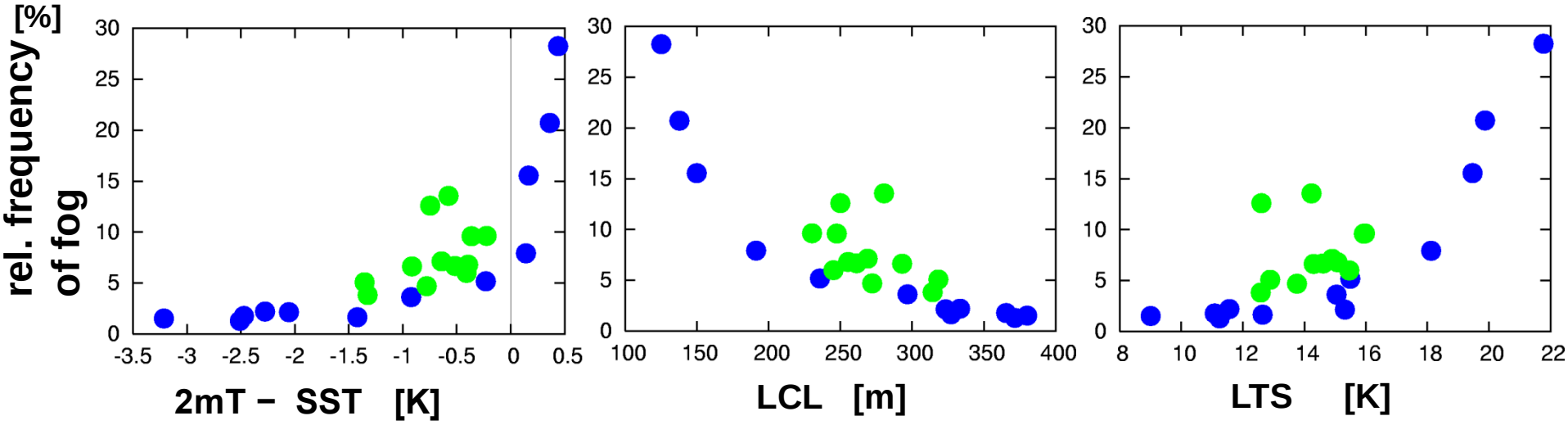
● SH mid-latitude

Monthly data (12 for each hemisphere) are plotted.

Larger stability → Lower Cloud Top Height
Smaller Cloud Depth (not shown)
Lower Cloud Base Height (not shown)

SH: Both seasonal variations of cloud top height and meteorological factors are small.

Occurrence of fogs and meteorological factors



y axis:
relative frequency of occurrence of the cloud base height at 0 - 240m

● **NH mid-latitude**
● **SH mid-latitude**

Monthly data (12 for each hemisphere) are plotted.

Warm temperature advection

2mT – SST is positive
LCL is low (2m RH is high (not shown))
Sensible heat flux is small (not shown)
[Latent heat flux is small (not shown)]
[Stability is large]

→ High frequency of occurrence of fog

Summary

1. It was roughly checked if Hagihara cloud mask data can capture the detailed vertical structures of low clouds.

   → The data seems to capture the structures relatively well and, probably, it can be used for low cloud studies.

2. Difference of vertical structures of low clouds and the frequency of occurrence of fogs between NH and SH, and their seasonal variations were investigated.

3. Relationships between vertical structures of low clouds and meteorological factors were investigated and clear relationships between the structures and atmospheric stability were confirmed. The relationships between fogs and meteorological factors were also investigated and correlation between frequency of fog occurrence and difference between 2m temperature and SST, 2m RH, and LCL were shown.

Future Plan

1. The following results related to vertical structures of mid-latitude low clouds will be shown at the coming GASS meeting.

   A) Analysis of detailed geographical distribution

   B) Difference between subtropical and mid-latitude low clouds.

   C) Comparison of these obs. data and low clouds in models

2. Characteristics of mid-latitude low clouds will be investigated using other data set.

Thank you!

Figure 3 of
Hagihara et al. 2010, JGR