Responses of marine stratocumulus cloud to perturbed lower atmospheres

A.T. Noda, K. Nakamura, T. Iwasaki, and M. Satoh

- A.T. Noda and M. Satoh, 2014
  Intermodel variances of subtropical stratocumulus environments simulated in CMIP5 models, *Geophys. Res. Lett.* (under revision)
- A.T. Noda, K. Nakamura, T. Iwasaki, and M. Satoh, 2014
  Responses of marine stratocumulus cloud to perturbed lower atmospheres, *SOLA*, **10**, 34-38

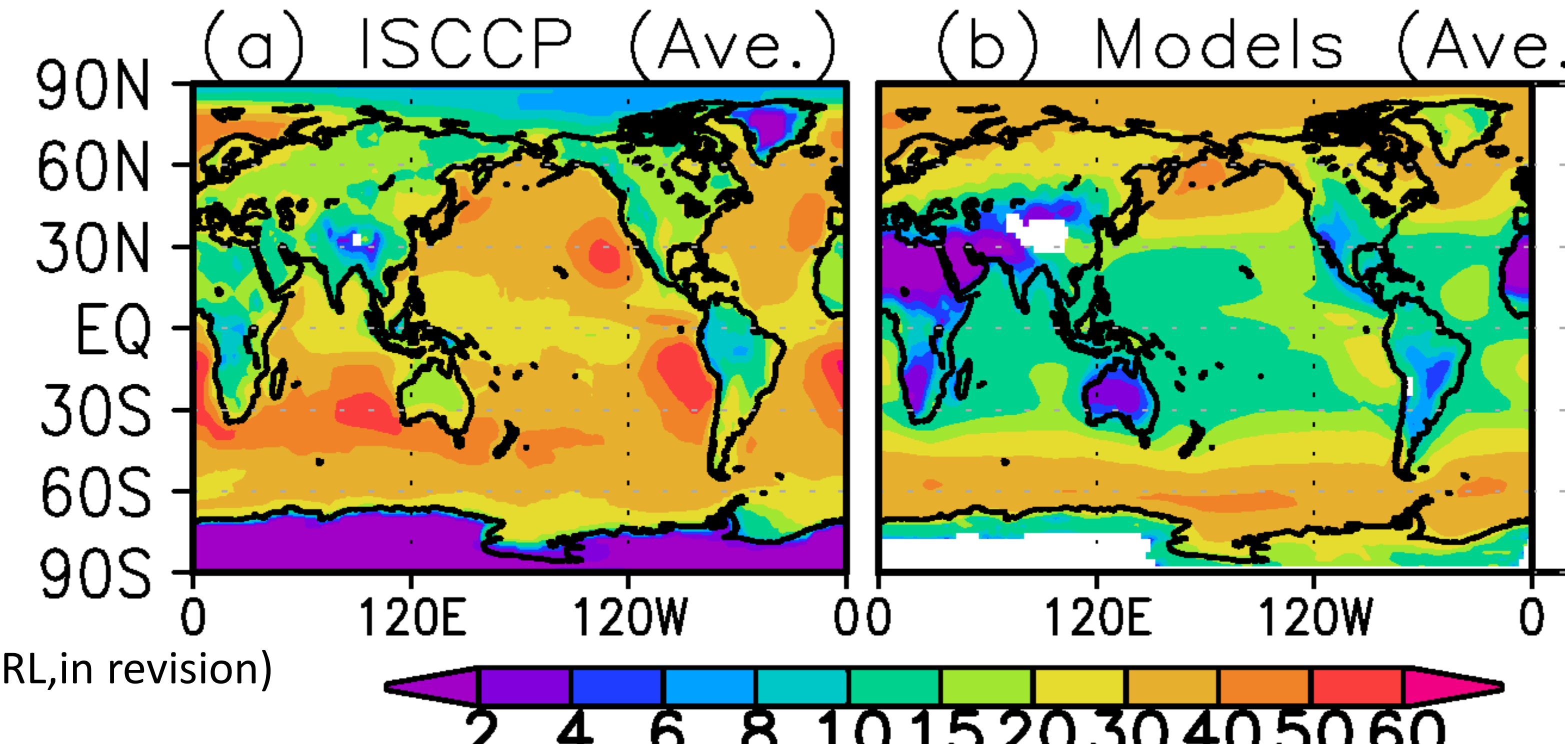
Low clouds in CMIP5 models

Noda et al. (GRL,in revision)

ISCCP obs. vs. CMIP5 models

Even the state-of-art GCMs still suffer from simulating subtropical clouds
In general, GCMs simulate less low clouds and less spatial contrasts over the subtrops

25-yr mean Low cloud cover

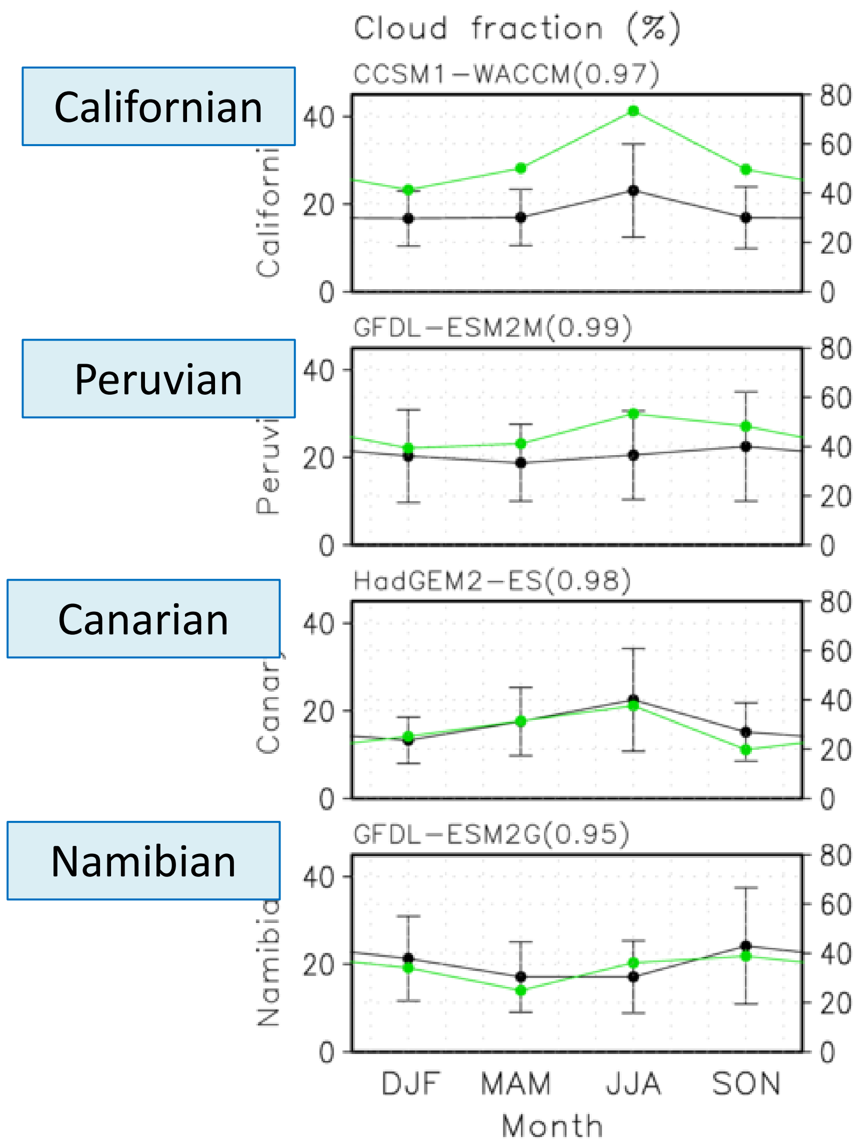


Noda et al. (GRL,in revision)

Seasonal cycle

40 GCMs (left axis)
ISCCP obs (right axis)

- GCMs can simulate seasonal cycles to some extent, but their amplitudes are much weaker than real atmosphere.
- Modeled seasonal cycles in northern hemisphere is somewhat better than those in the southern hemisphere



Noda et al. (GRL,in revision)

LTS vs. Seasonal cycle

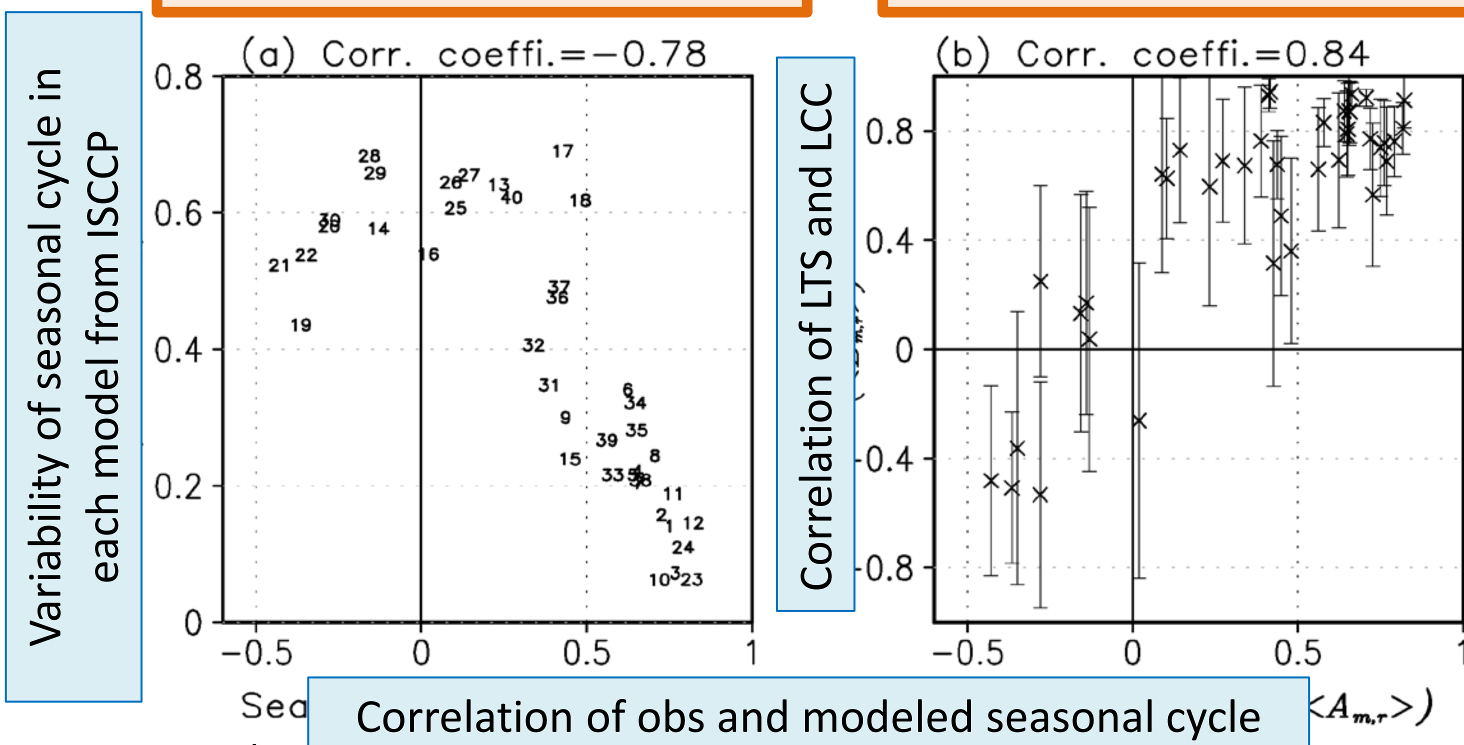
#s are model ID (40 GCMs)

LTS idea is still important if to simulate or improve seasonal cycle of BL clouds such as using in parameterization of BL clouds in GCMs

between LTS and LCC.

Relation of skill of modeled seasonal cycle and its spread in 4 Sc regions

Relation between LTS and low cloud cover



Noda et al. (GRL,in revision)

Responses of marine stratocumulus cloud to perturbed lower atmospheres

(Short-term scale～6hrs)

(Noda et al. 2014,SOLA)

- Background
  - Intermodel uncertainty in present GCMs are still large (Wang and Su 2013)
  - due to …
    - Lack of insufficiency of PBL parameterization (active perspective)
    - Lack of simulation error of background Sc environments (passive perspective)
- Objective
  - Which factors are more important in simulating Sc clouds?
    - e.g., For better prediction of Sc (in a shorter time scale), which GCM biases are prioritized to reduce?
    - or. What is the cloud variability in an SCM of GCMs under a perturbed lower atmosphere?
- Problem setting
  - How changes of Sc environment affect cloud behavior?

LES studies of cloud response to perturbed BL environment

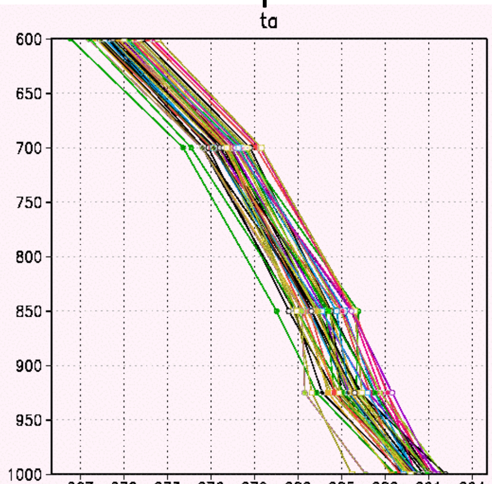
- Study of Each component
  - Stratification of inversion gap (Ackerman et al. 2004; Yamaguchi and Randall 2008; Lock 2009; Dussen et al. 2013; Noda et al. 2014)
  - Wind shear near the inversion (Wang and et al. 2008)
  - Large-scale subsidence (Blossey et al. 2013)
- Previous studies of influences of perturbed environmental conditions on cloud behavior
  - Sandu and Stevens (2011), Chung et al. (2012)
    - Transition of Sc to Cu
    - Importance of *temperature* gap of inversion
  - Chlond and Walkou (2000)
    - Realizavility of Sc
    - Perturbation based on their LES ensembles
    - Environmental wind, and velocity and Boundary-layer conditions not investigated
  - Bretherton et al. (2013)
    - Responses of Sc, Sc-topped Cu, Cu to warmed atmospheres
    - Influence of perturbations due to *global warming*
- etc …

More efforts is needed to clarify which factors are important in simulating low clouds, focusing especially on <u>individual types of clouds</u> such as sc, cu, sc-topped cu, …

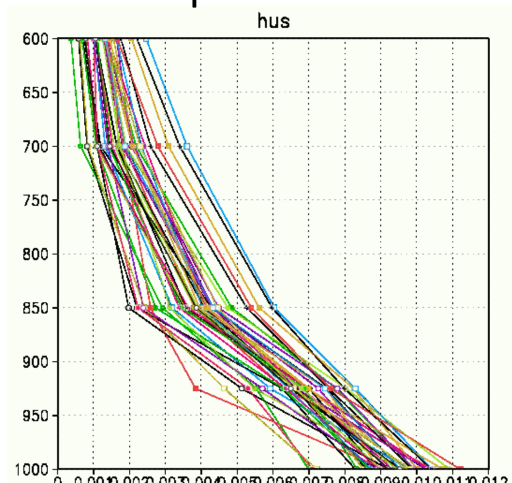
Variance of thermodynamic and dynamic environment in CMIP5 present climate simulations

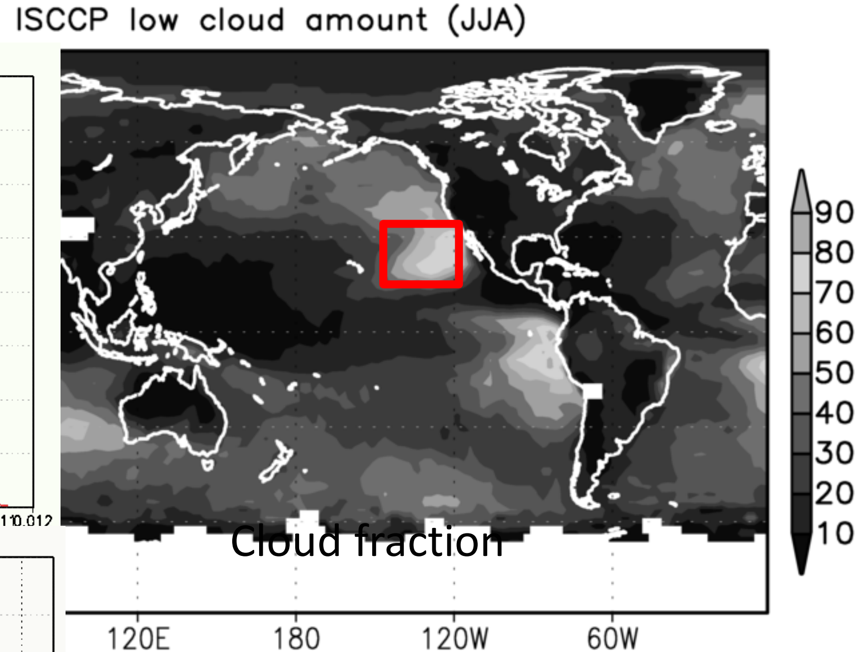
Californian stratocumulus region
averaged over 1980-2005

Temperature

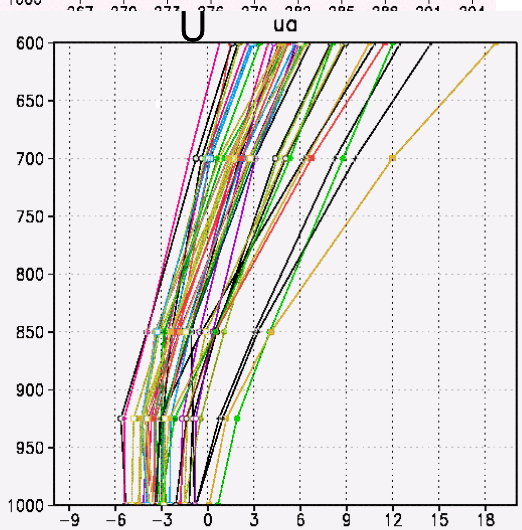


Vapor

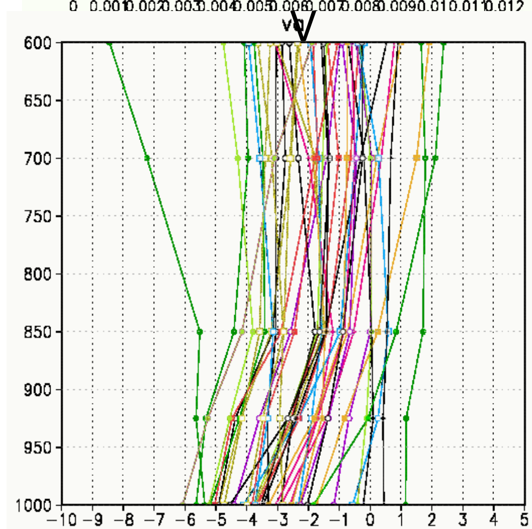




U



V



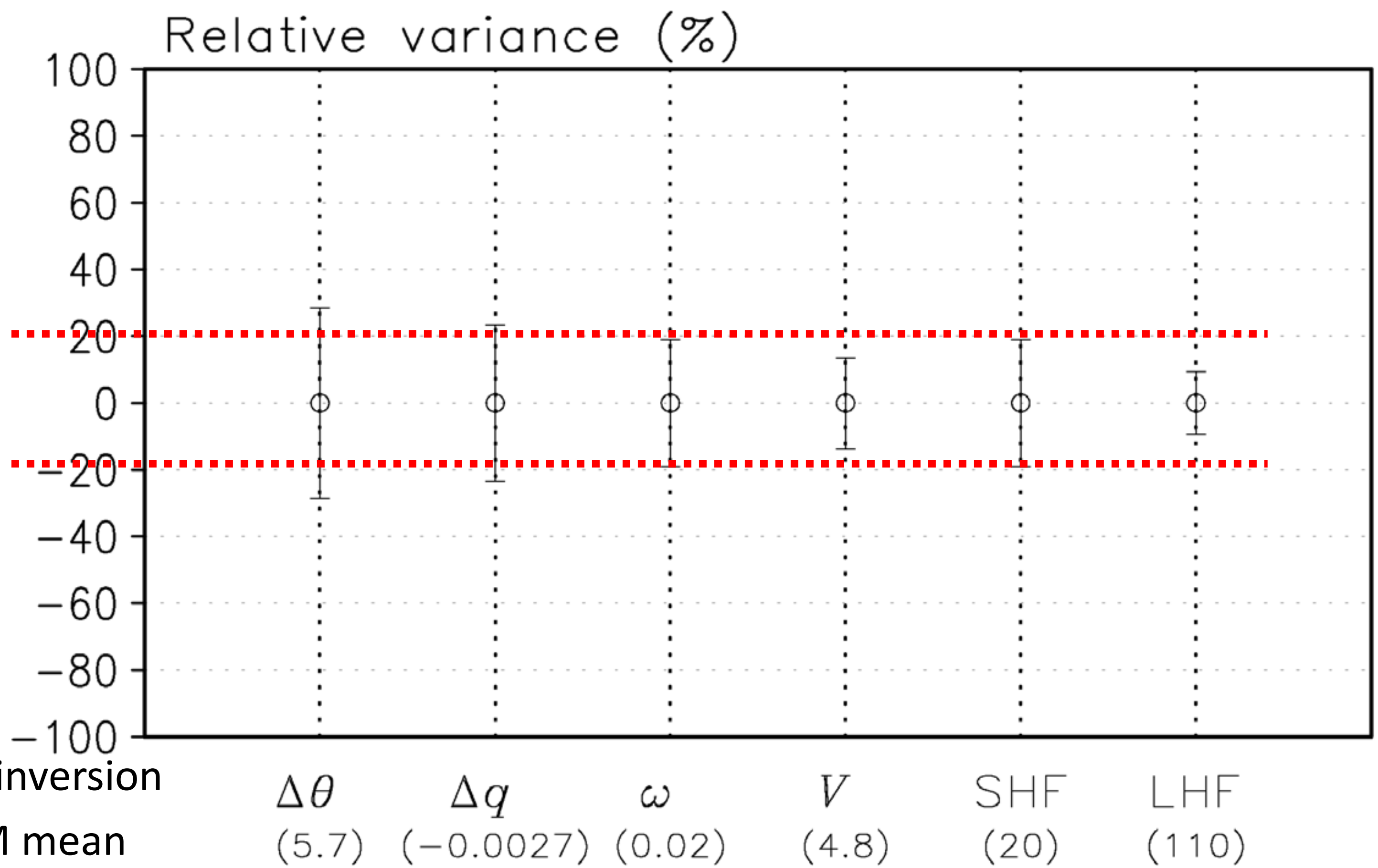
Noda and Satoh (2014, GRL, in review)

Spread of Californian Sc environment in CMIP5 present climate simulations

(Noda et al. 2014,SOLA)

Californian stratocumulus region
averaged over 1980-2005

～20%



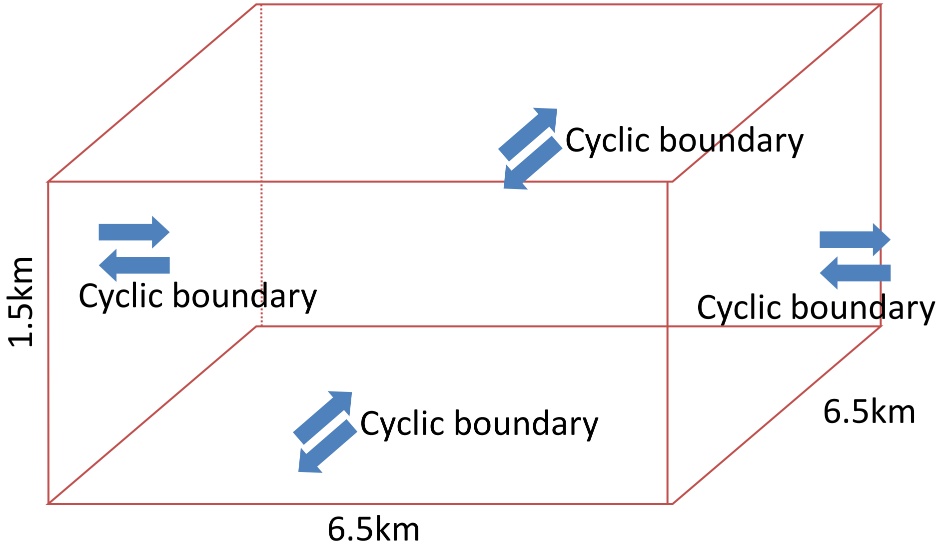
Δ: gap across inversion

( ): GCM mean

LES setting (1)
~Domain and physics~

LES model: NonHydrostatic Model
(NHM, LES mode of old JMA operational model, Saito et al. 2001)

Horizontal and vertical resolutions: 50m and 5m
Integration period: 6hrs
Subgrid turbulence: Deardorff (1980)
Cloud: Only water cloud with saturation adjustment



(Noda et al. 2014,SOLA)

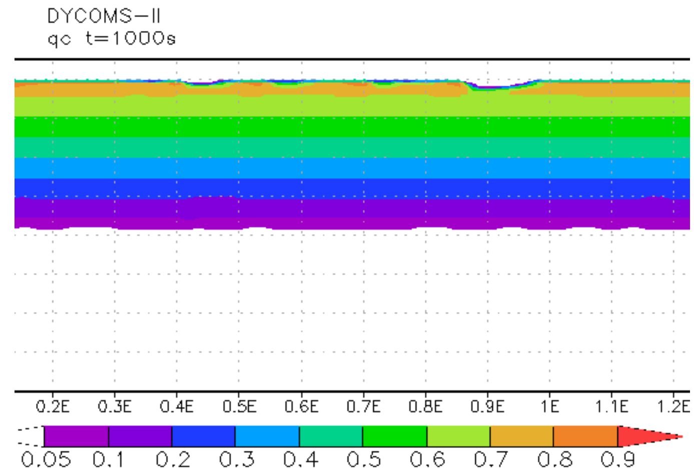
Elements to study

- Δq: gap of vapor across inversion
- EIS: gap of potential temperature across inversion
- V: Mean wind velocity of PBL
- ω: subsidence
- C_{SHF} : Sensible heat flux
- C_{LHF} : Latent heat flux

Perturb magnitudes of each element by ±20%

LES setting (2)
~Initial conditions~

↓Control run
Cloud water (color)
Vertical velocity (contour)



Modification from original DYCOS-II (Ackerman et al. 2009)

- constant wind velocity (U=8m/s) over entire domain
- sfc fluxes based on similarity theory

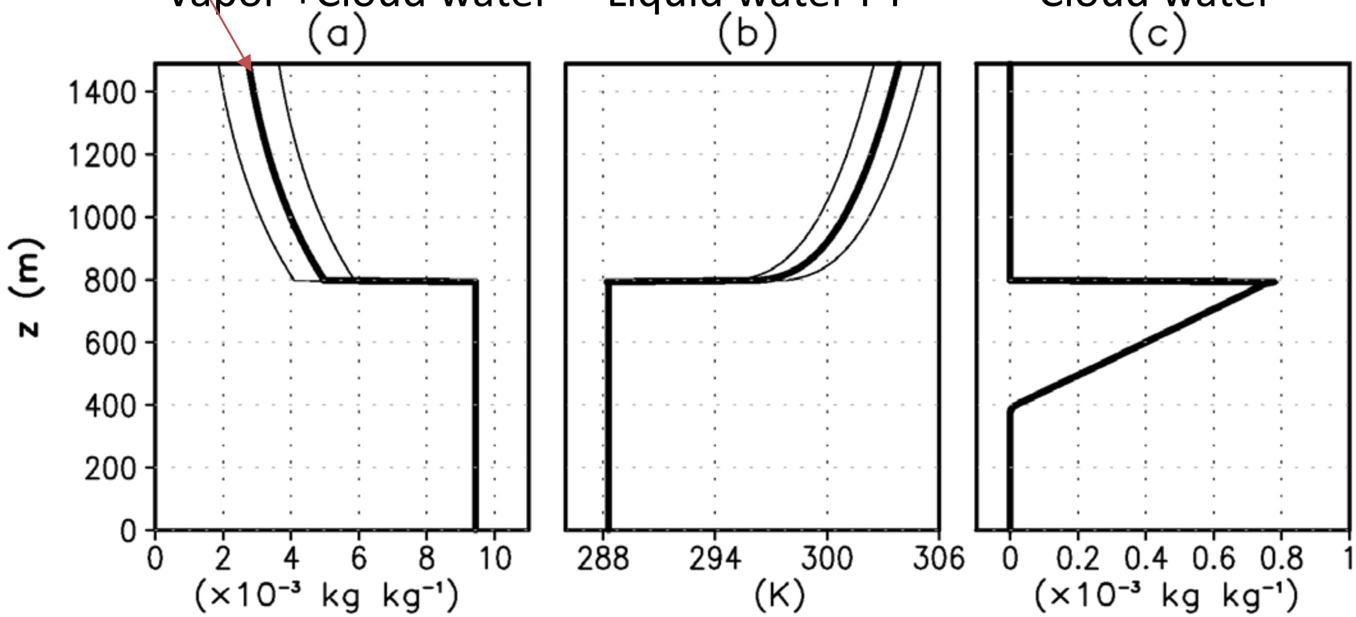
DYCOMS-II LES study)

Vapor +Cloud water | Liquid water PT | Cloud water

Bottom of free atmos.

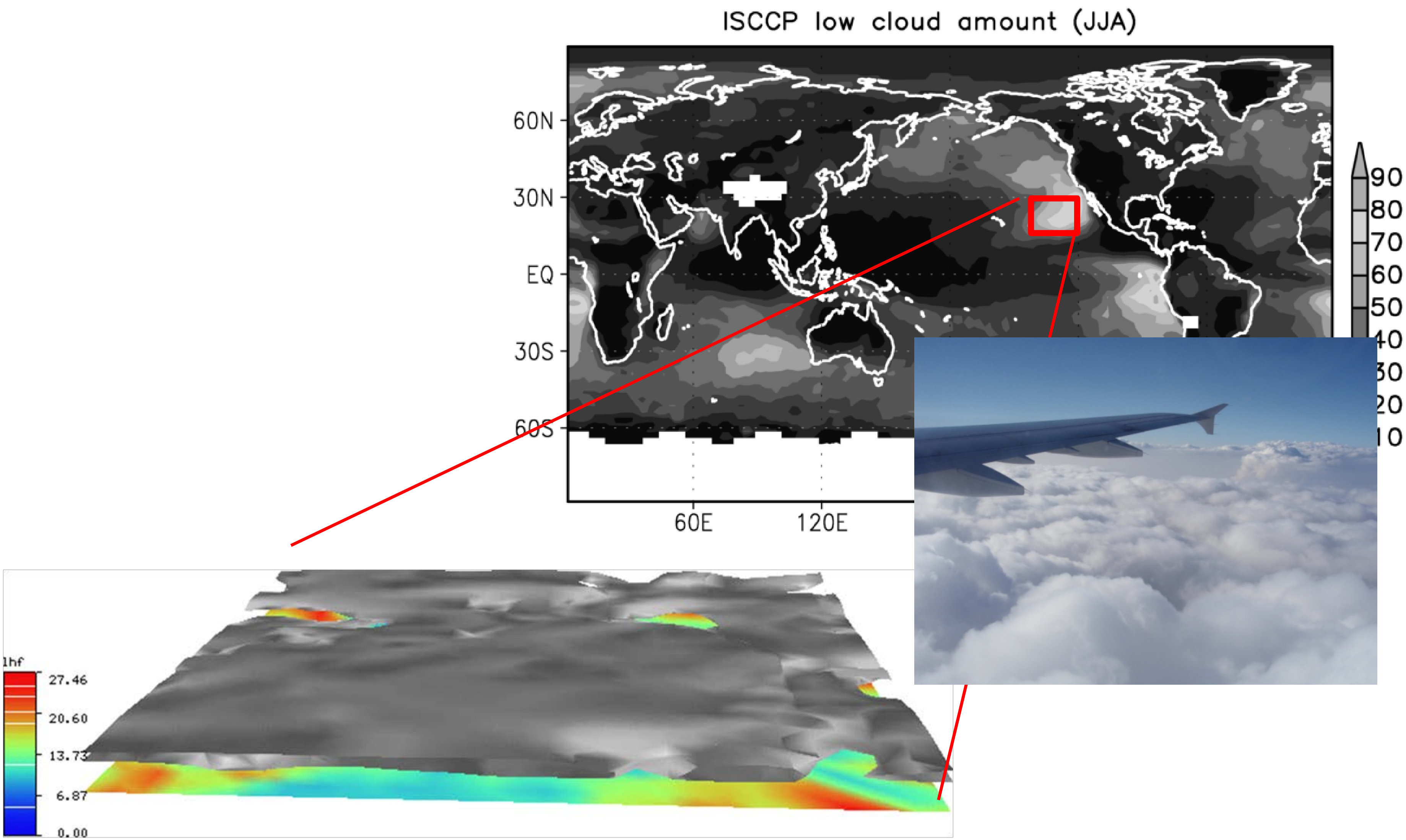
BL top →

BL



Effect of perturbation of BL elements.

～Image of LES result～

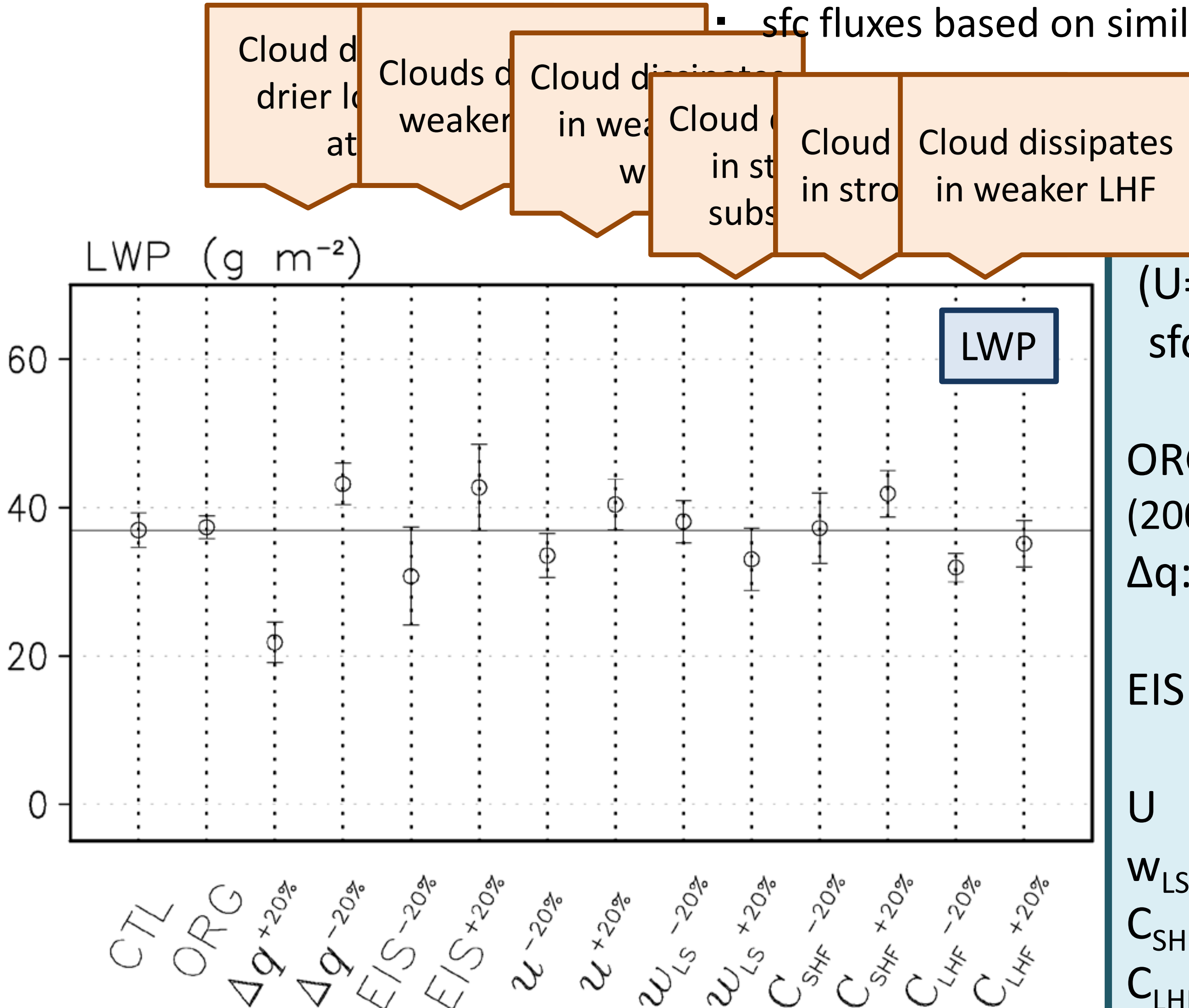


Responses to perturbed atmospheres

Mean during last 2 hours
Error bars are STD in every 1 min data

Modification from original DYCOS-II (Ackerman et al. 2009)

- constant wind velocity (U=8m/s) over entire domain
- sfc fluxes based on similarity theory



...: control exp.
(U=8m/s, constant
sfc fluxes by similarity law)

ORG: Same as Ackerman et al. (2009)

Δq: gap of vapor across inversion

EIS: gap of potential temp. across inversion

U : BL wind

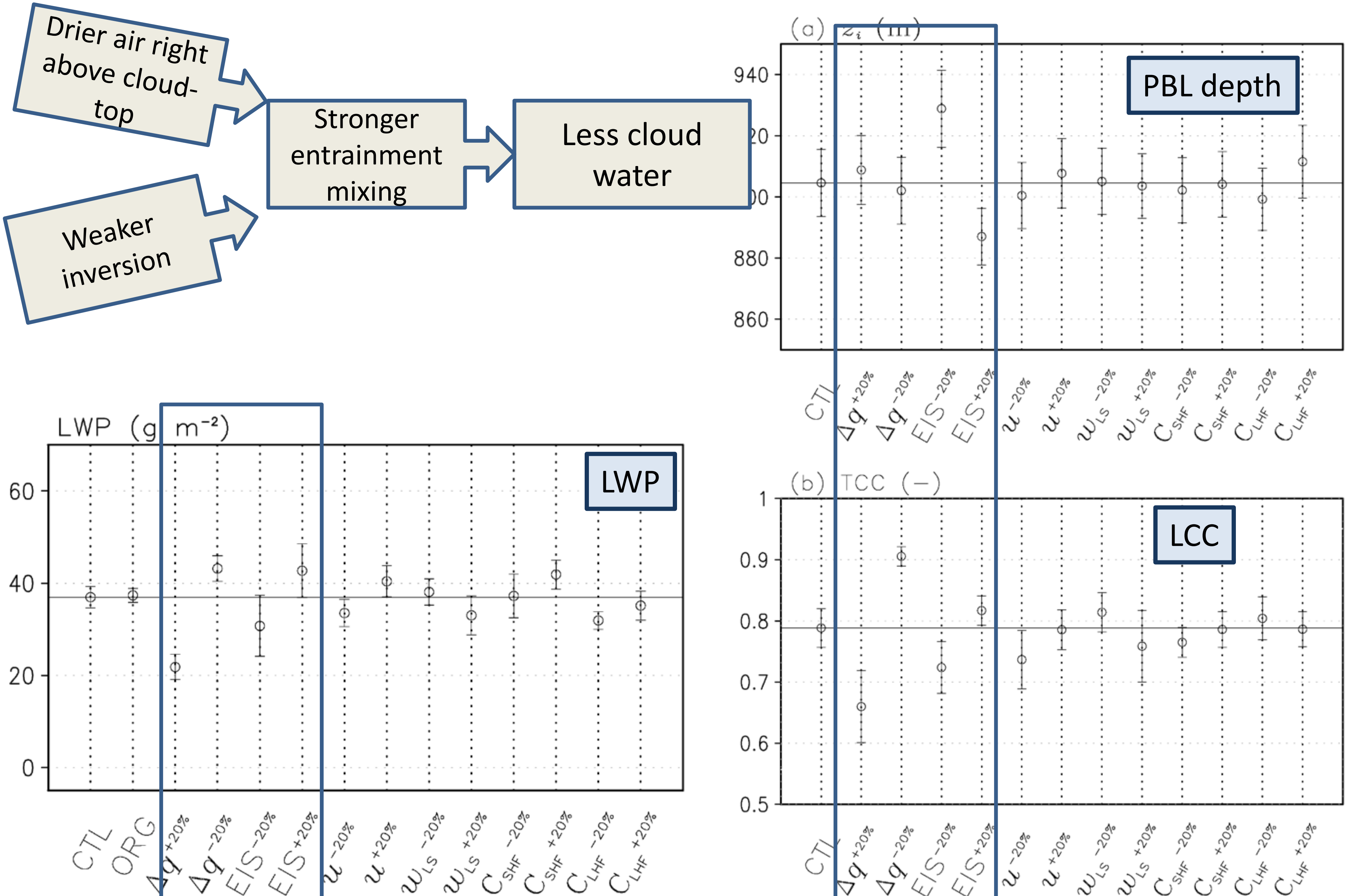
w_{LS}: Subsidence

C_{SHF}: SHF

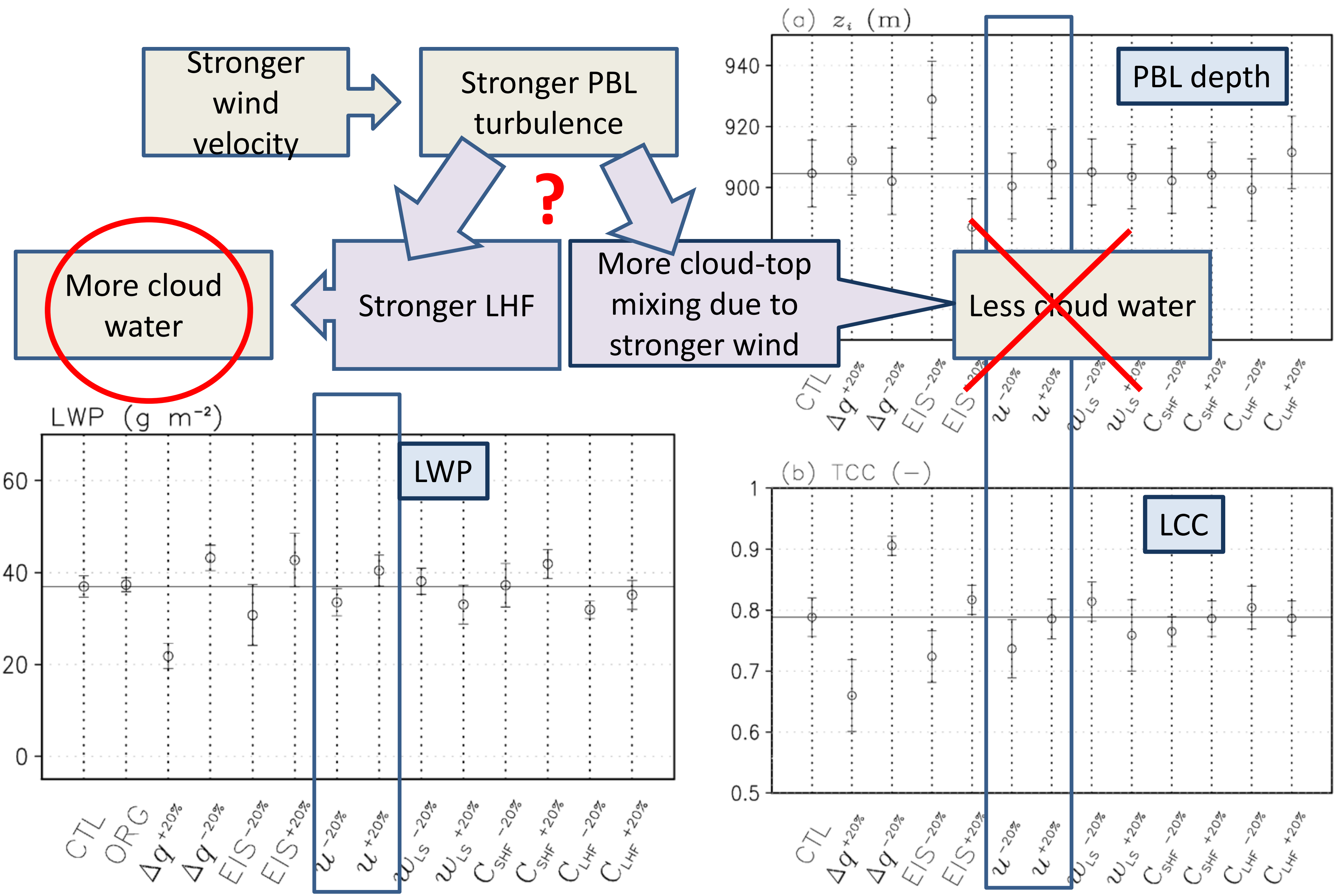
C_{LHF}: LHF

(Noda et al. 2014,SOLA)

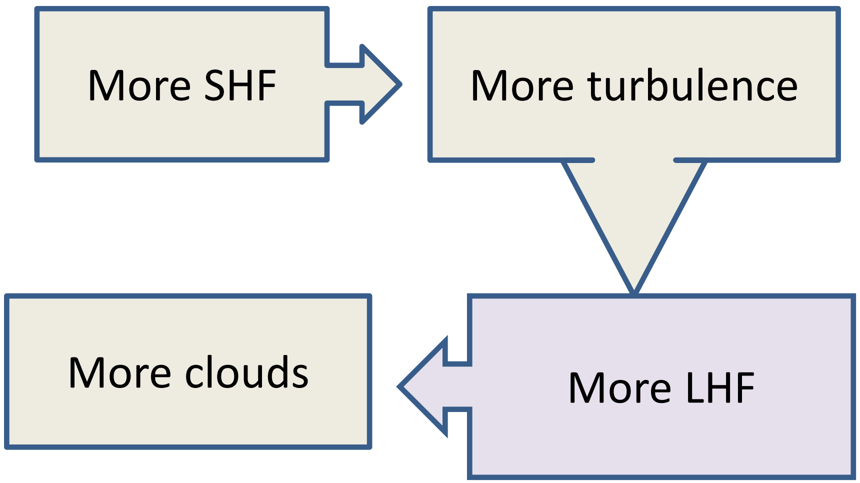
Effect of stratification near a cloud top

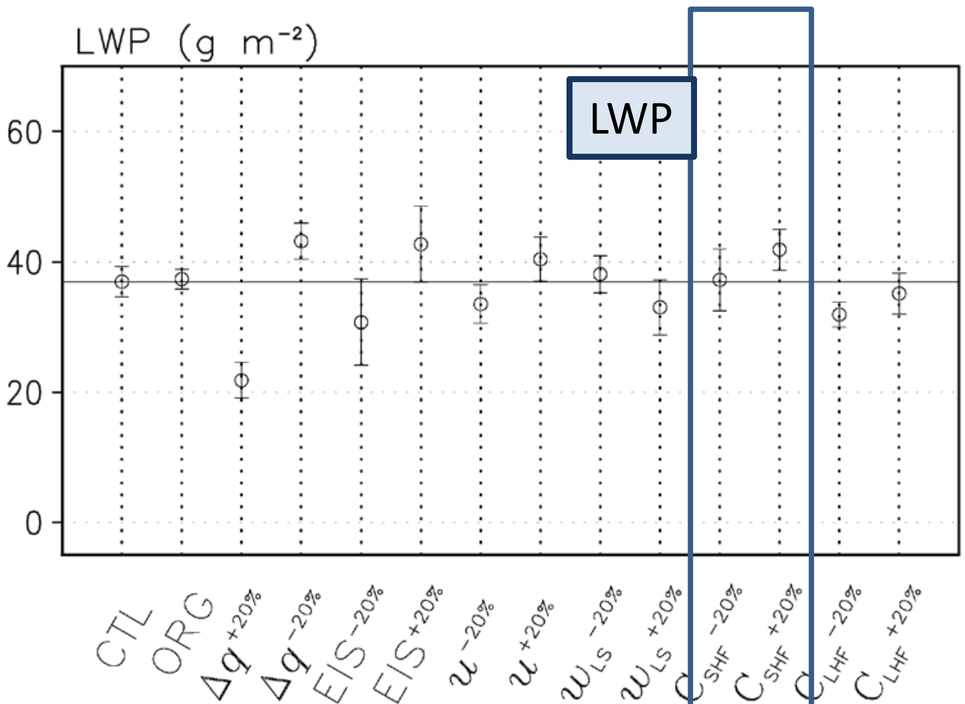


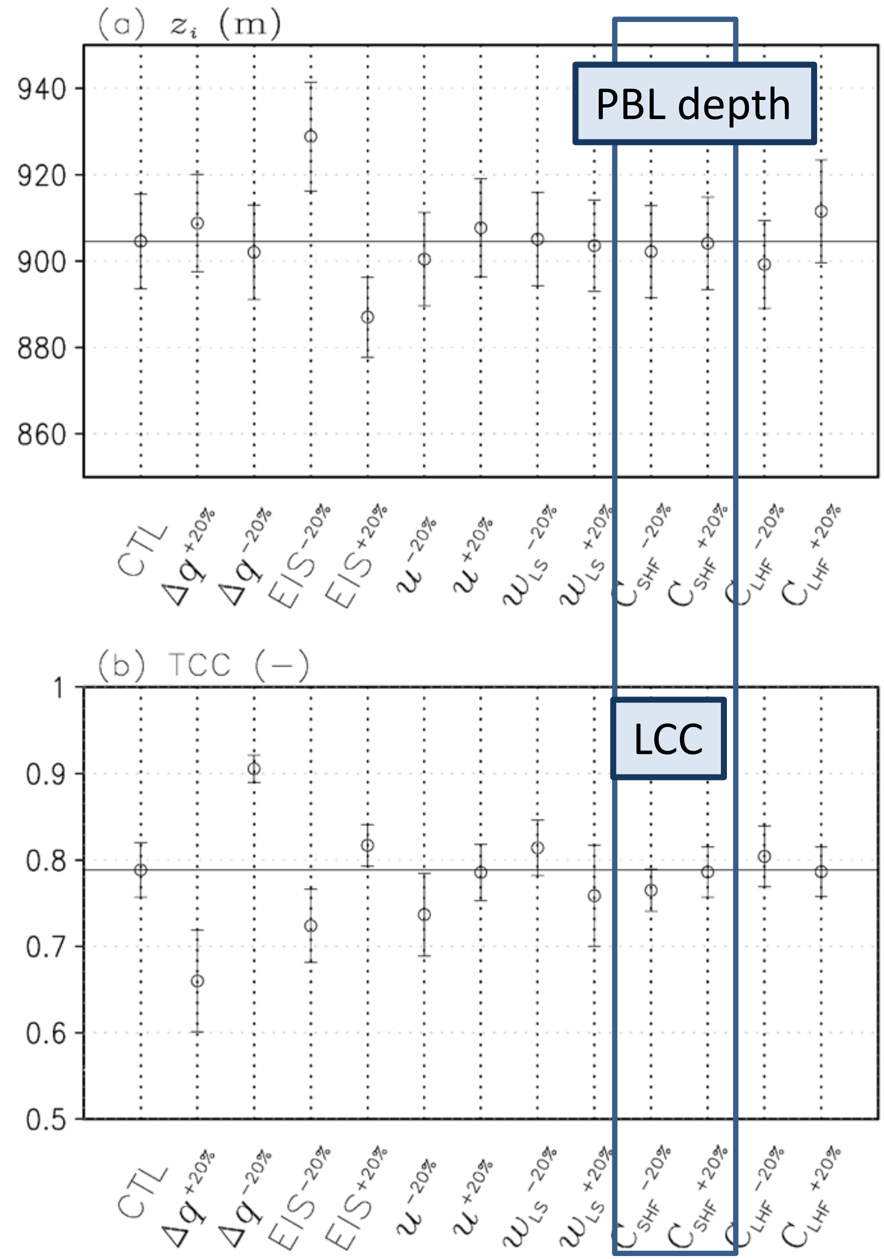
Interaction in PBL wind－Turbulence－Cloud



Interaction in SHF－Turbulence－Cloud



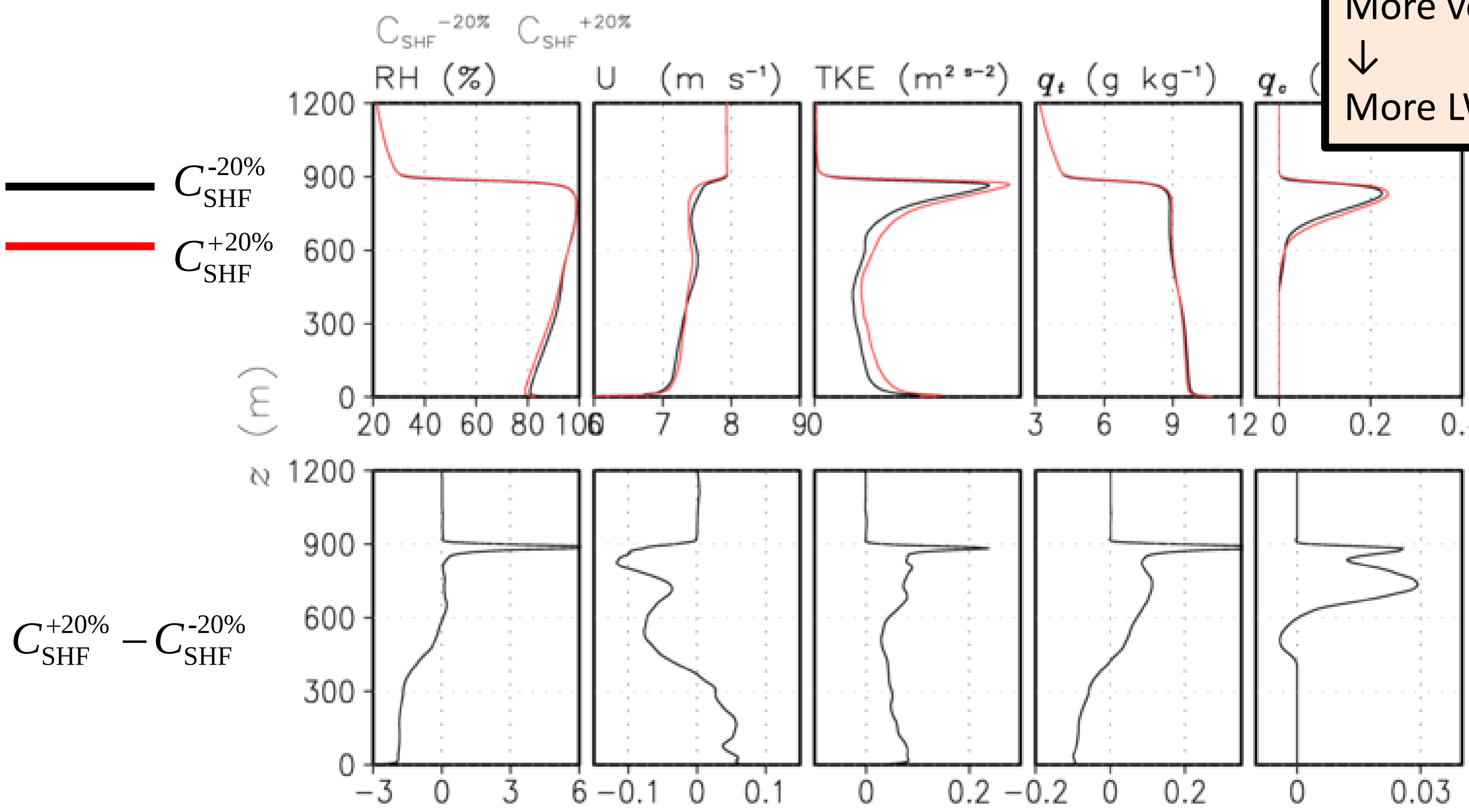




Interaction of SHF－Turbulence－Clouds

Cloud building process by interaction between turbulence－cloud prevails against cloud dissipation by more SHF

More SHF
↓
More TKE、Stronger near-surface wind
↓
More vertical vapor transport
↓
More LWP



Conclusions

- Noda, A. T., and M. Satoh, 2014: Intermodel variances of subtropical stratocumulus environments simulated in CMIP5 models (in review)
- Noda, A.T. , K. Nakamura, T. Iwasaki, and M. Satoh, 2014: Responses of marine stratocumulus cloud to perturbed lower atmospheres. SOLA, 10, 34-38

- <u>Longer time scale (from GCMs)</u>
  - LTS is important to simulate seasonal cycle of low-level clouds
- <u>Shorter time scale (from LESs)</u>
  - Sequence of important element for simulating DYCOMS-II Sc cloud、
    - Gaps of vapor and temperature across inversion
    - BL wind velocity
    - Subsidence
    - Surface heat fluxes
  - For improving (spontaneous) prediction of Sc clouds of SCM in GCM, reducing BL elements in higher ranks should be prioritized
    - Improving BL parameterization is also needed, since the result assumes "perfect BL parameterization"
    - Plus, vertically finer resolution in GCM is also preferable to resolve an inversion structure as much as possible