Dependency of the Tropical Convective Clouds on the Sea Surface Temperature Simulated by a High-Resolution Coupled Model

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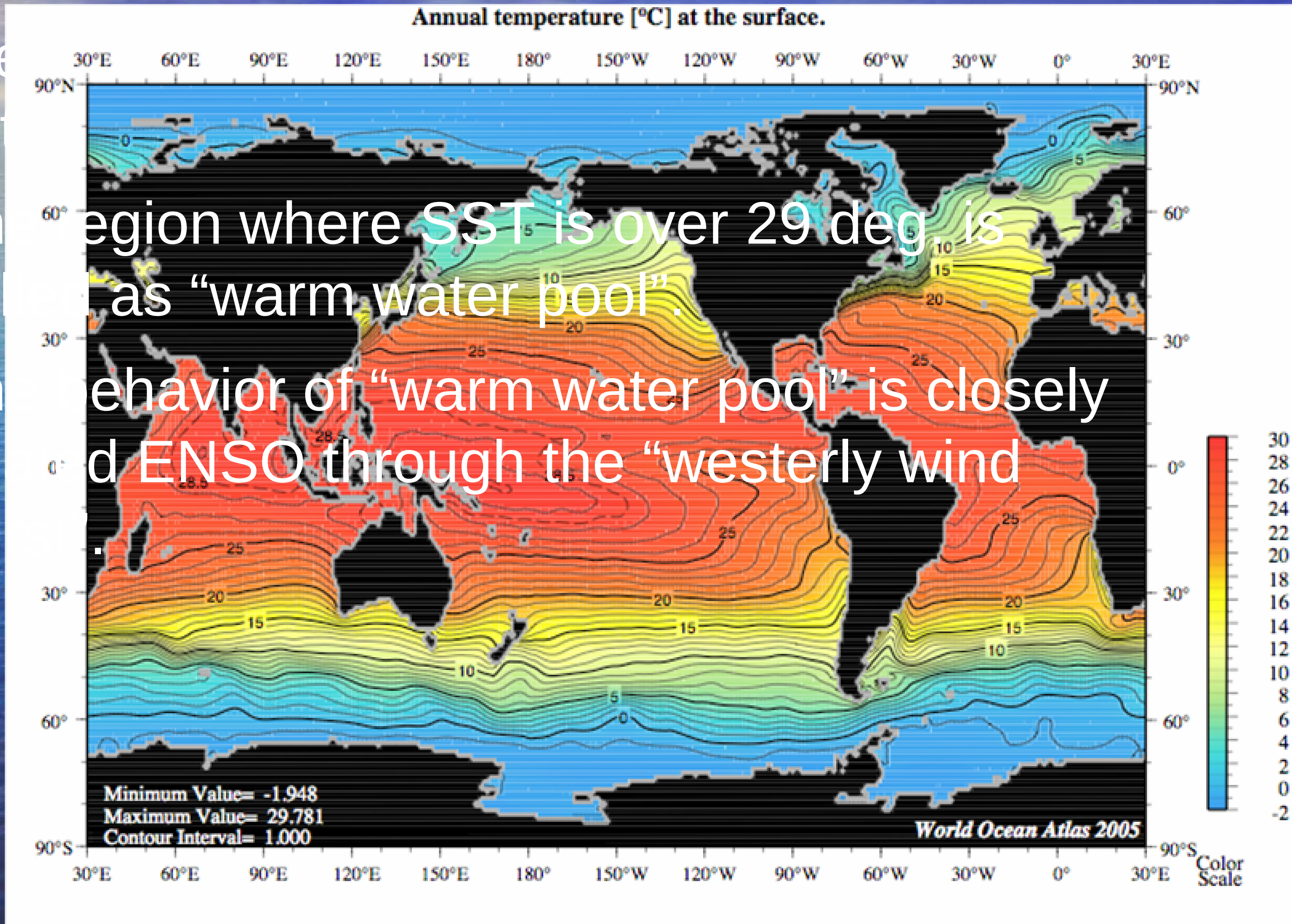
Introduction

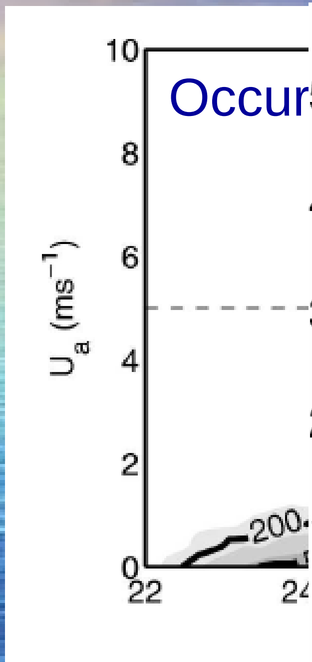
- We
  in t
- Th egion where SST is over 29 deg. is cal d as “warm water pool”.
- The behavior of “warm water pool” is closely rel d ENSO through the “westerly wind bu ”.



Warm water pool and Westerly wind burst

Importance of 29deg.

OLR vs. SST



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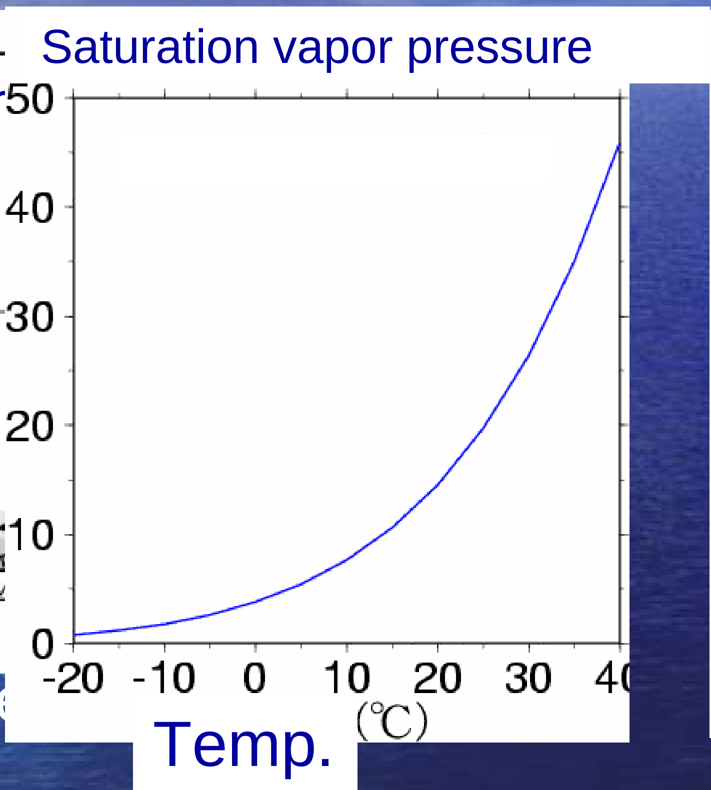


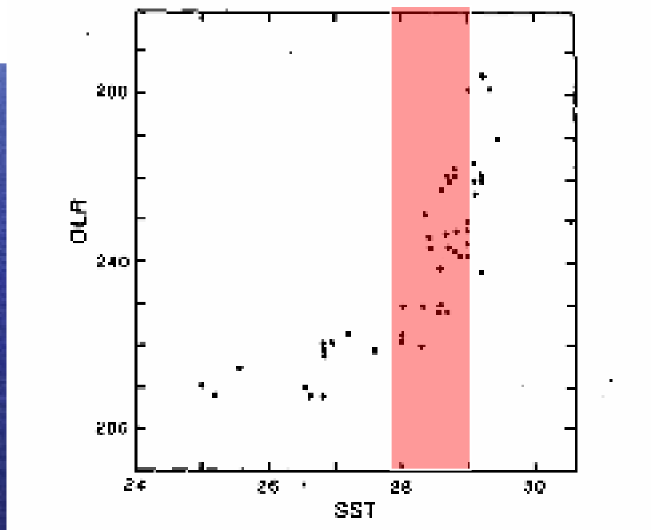


FIG. 19. Plot of outward longwave radiation (OLR; W m^{-2}) versus underlying SST (°C) in the equatorial Pacific. OLR and SST values represent averages between 5°N and 5°S and over monthly periods given by Arkin et al. (1983). Values here are from 150°E, 180°, 150°W and 120°W at two month intervals over the period September 1981–July 1983.

After Hirst (1986)

It is considered the jump in 29 deg. is caused by nonlinearity of saturation vapor pressure. However, there is no jump in saturation vapor pressure.

Atmosphere model

- Non-hydrostatic compressive atmosphere model (Satomura, 1989)
  - Vertical z* coordinate
  - k-ε turbulent scheme (Detering and Etling, 1985)
  - Bulk cloud micro physics (Ikawa et al., 1987)
  - Simple radiation process (Katayama, 1972)
  - Constant flux layer (Barker and Baxter, 1975)

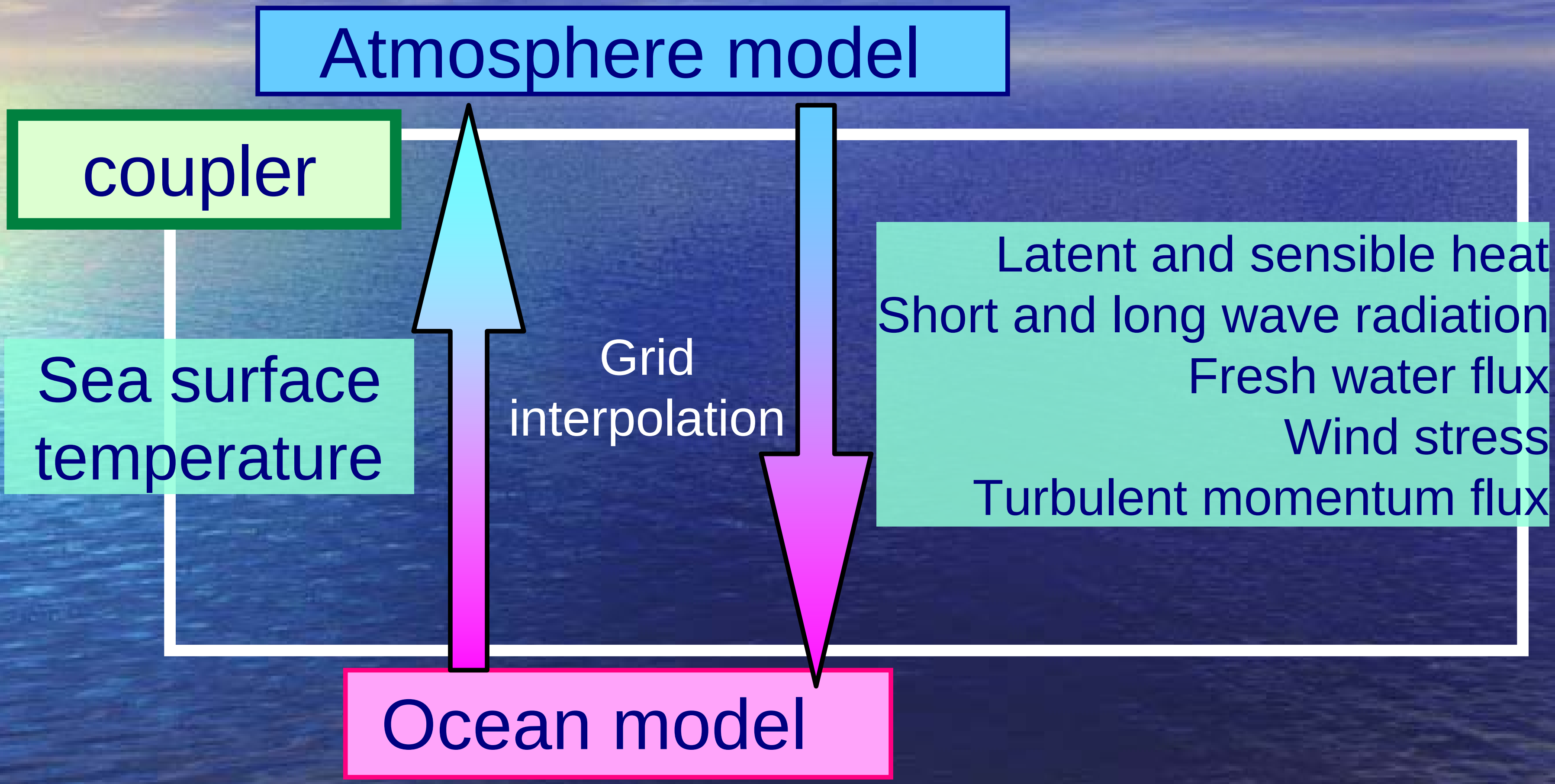
Horizontal resolution 1km
Vertical resolution 50m-500m (58 levels)
Periodic horizontal boundary condition

Ocean model

- Hydrostatic ocean general circulation model (Ishikawa et al., 2007)
  - Vertical σ-z hybrid coordinate
  - Turbulent closure mixed layer scheme (Noh, 1996)
  - 3rd-order advection scheme (Hasumi, 2000)

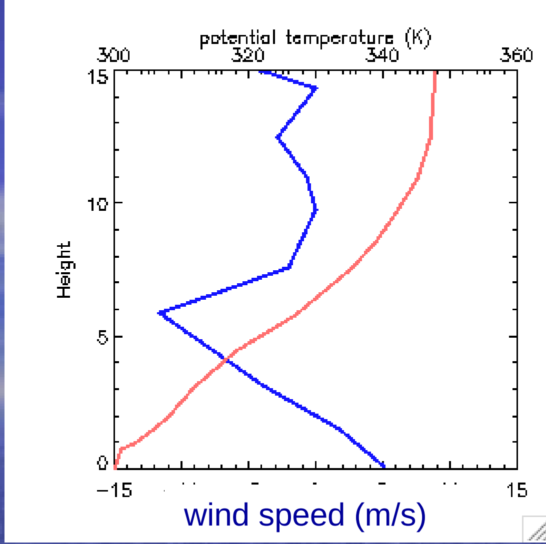
Horizontal resolution 1km
Vertical resolution 0.5m (200 levels)

Flux coupler



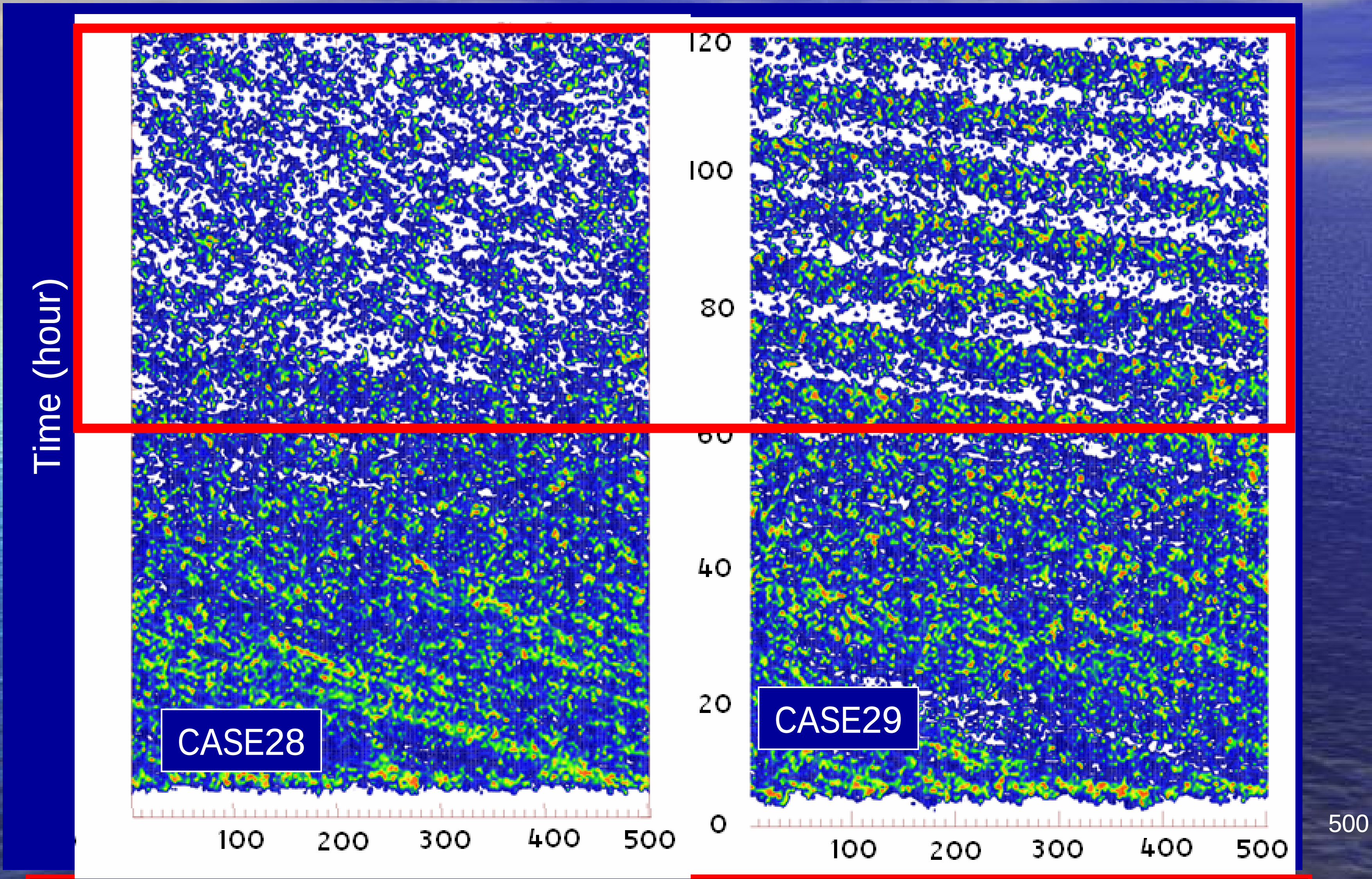
Exchange variables every 10min.

Experimental design



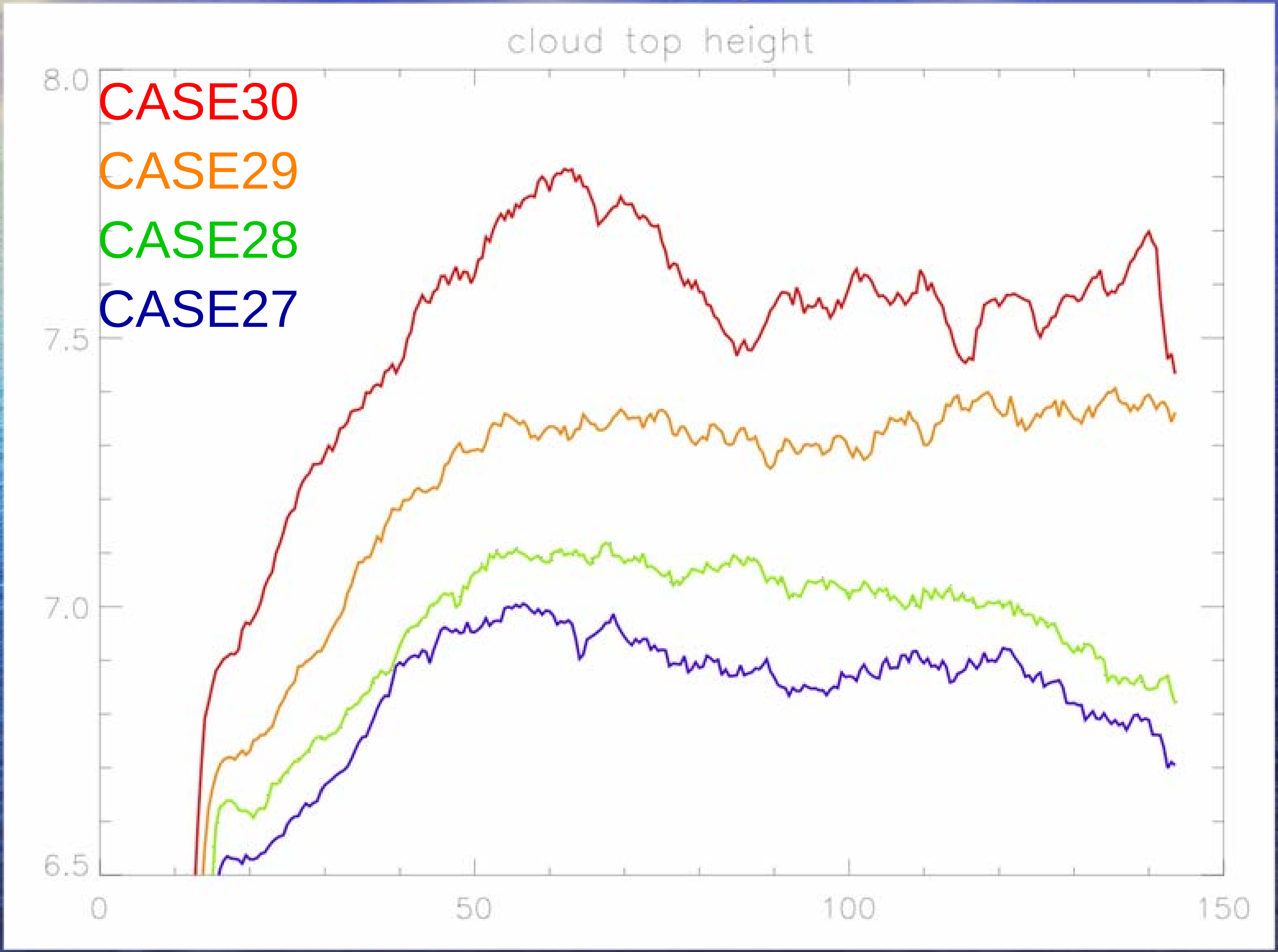
- Initial condition
  - Atmosphere model
    - Observation data derived from TOGA-COARE (Keifu-maru)
    - random perturbation is added for temperature in lowest level
    - Dumping of horizontal mean field to initial condition
      (1 hour for wind, 10 day for temperature and humidity)
  - Ocean model
    - Uniform (temperature 4 CASES, salinity 34psu) and rest
    - Initial temperature: 27, 28, 29, 30 degree.
- Domain size: 500km (east-west) x 100km (north-south)
- Located at Equator
- Start from 0 a.m. and 5 day integration

Cloud mixing ratio at 5km height

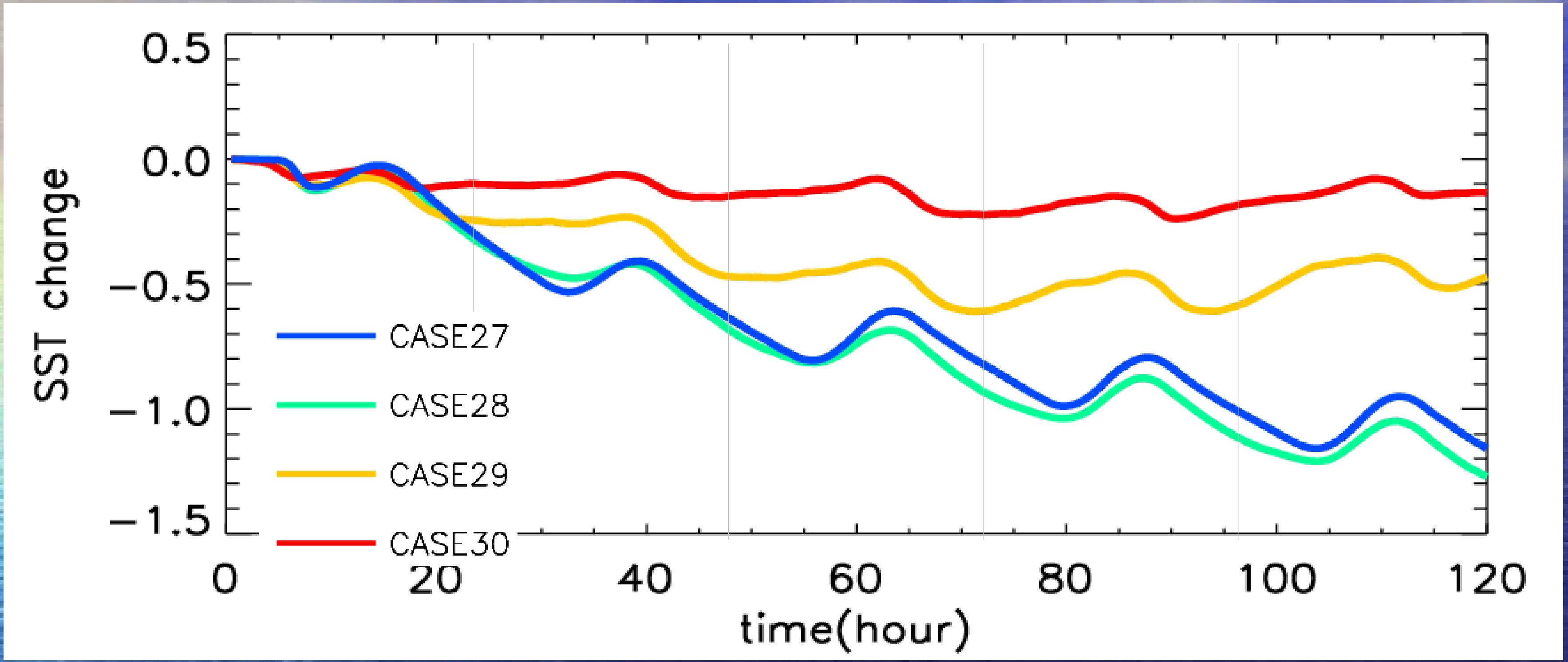


After day 3, strong cloud can be seen in CASE29

Time series of cloud top height

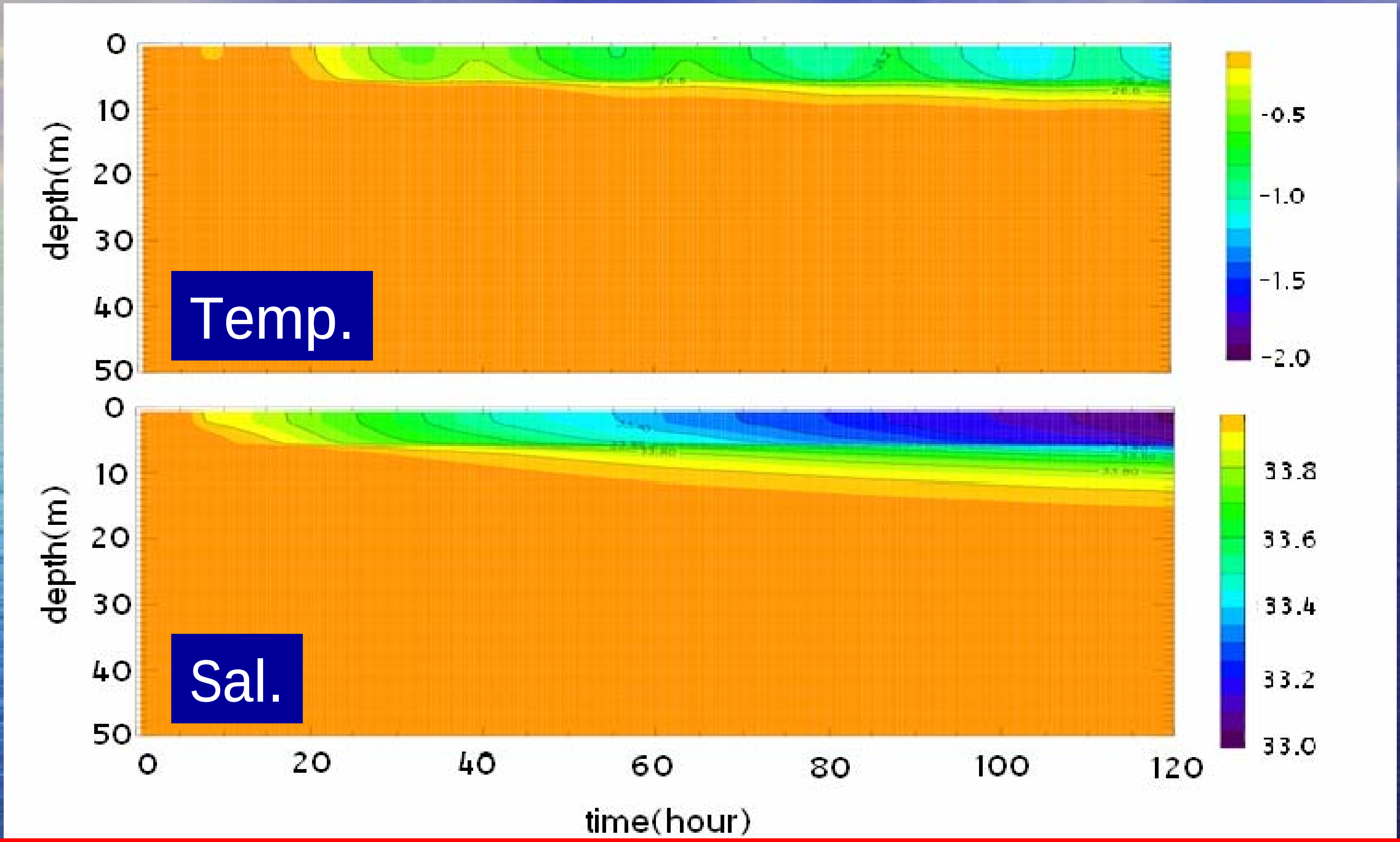


Horizontal mean SST difference from initial condition



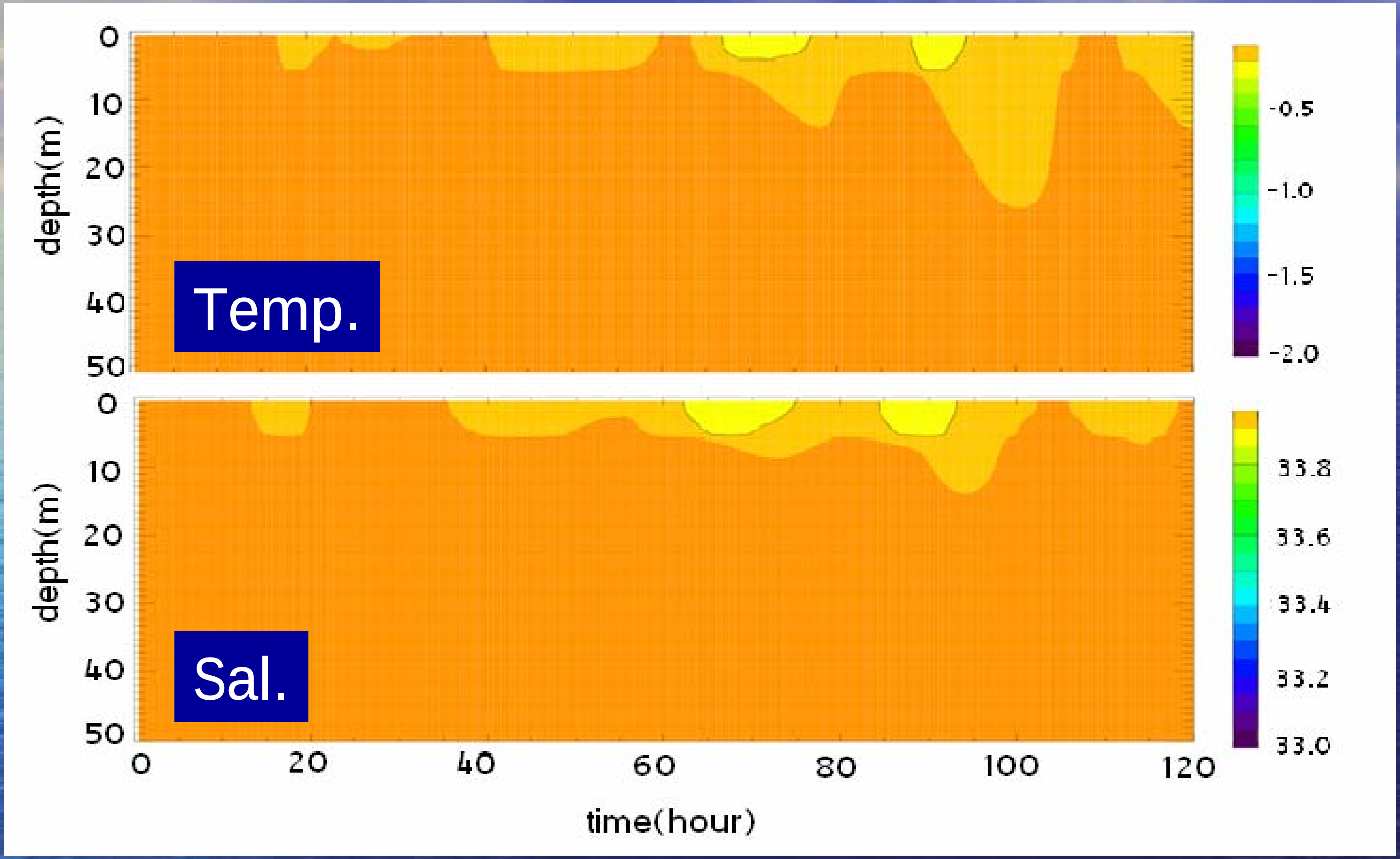
CASE27, CASE28 : Decrease (over -1.0deg/5day)
CASE29 : Almost constant after day 3 (-0.5deg/5day)
CASE30 : Almost constant (-0.1deg/5day)
->SST decrease in low SST cases.

Horizontal mean temperature and salinity　(CASE27)



Temp. and Sal. above 10m decreases.
->Low salinity caused by the precipitation make strong stratification and suppress the mixing.

Horizontal mean temperature and salinity (CASE30)

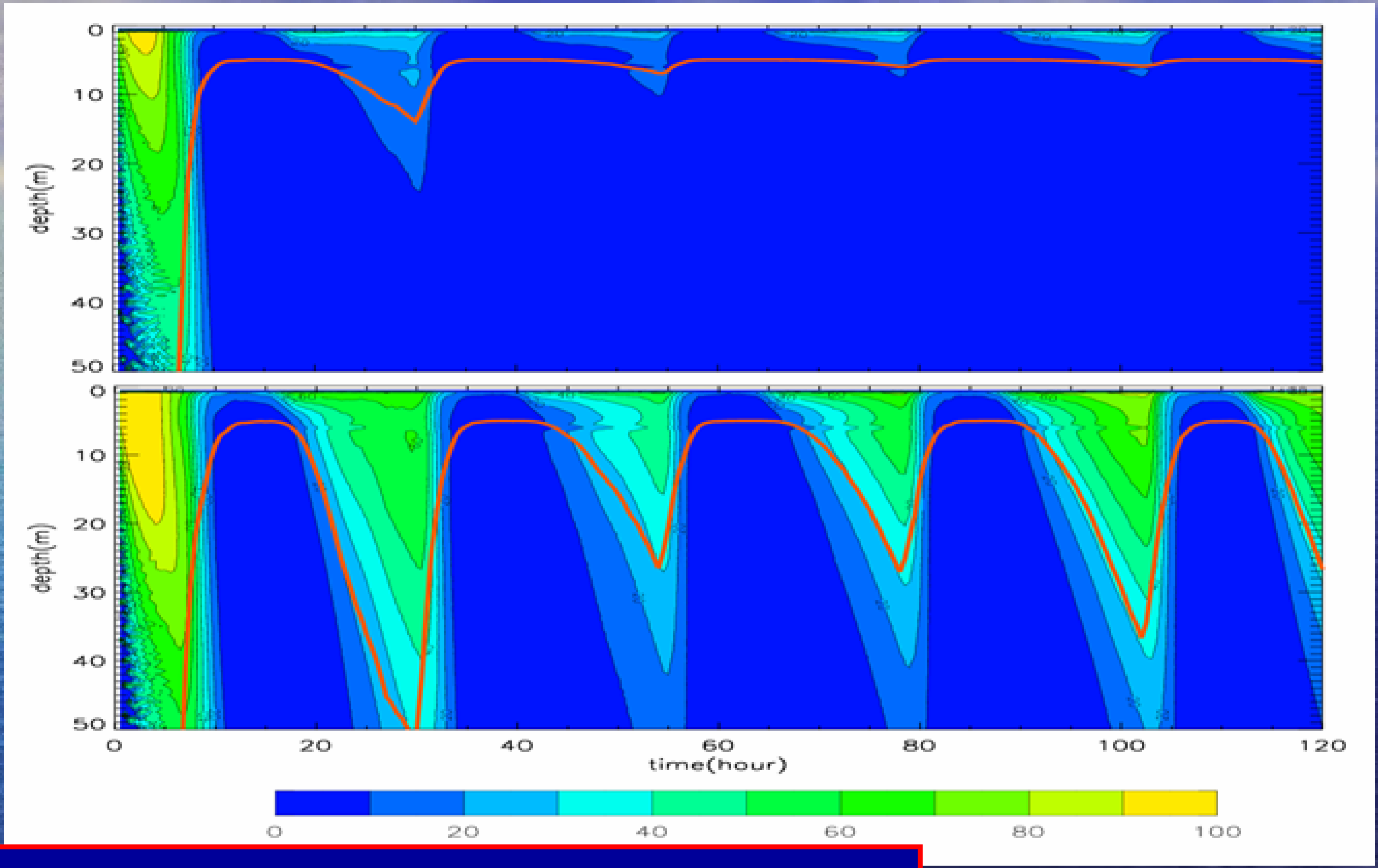


Mixing with lower layer keeps high SST and SSS.

Percentage of static instability and mixed layer depth

CASE28

CASE29

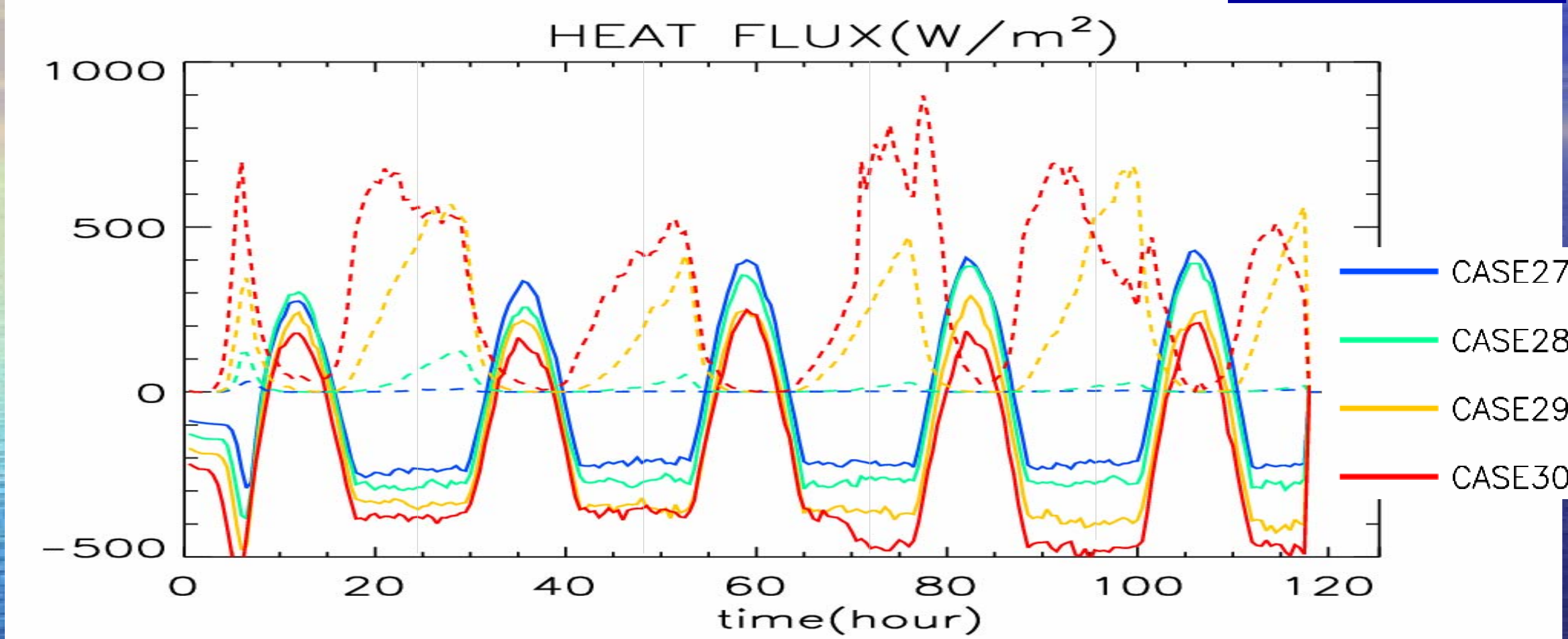


CASE28：Only is 1st day

CASE29：Occurs in every night time.

Heat budget in ocean mixed layer

Solid: surface
Dash: bottom



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In CASE29、CASE30, entrainment of warm water through the bottom of the ocean mixed layer compensate the surface cooling in night time.

ocean mixed layer process

Convective clouds bring the precipitation,

- In Case27,28:
  - Unstable heat flux < stable fresh water flux
  - Shallow ocean mixed layer by precipitation is robust
  - Heat flux over shallow mixed layer -> SST is easy to decrease
  - Convective clouds decay soon.
- In Case29,30:
  - Unstable heat flux > stable fresh water flux
  - Shallow ocean mixed layer is destroyed in night time
  - High SST keeps due to the entrainment.
  - Convective clouds keep their activity.

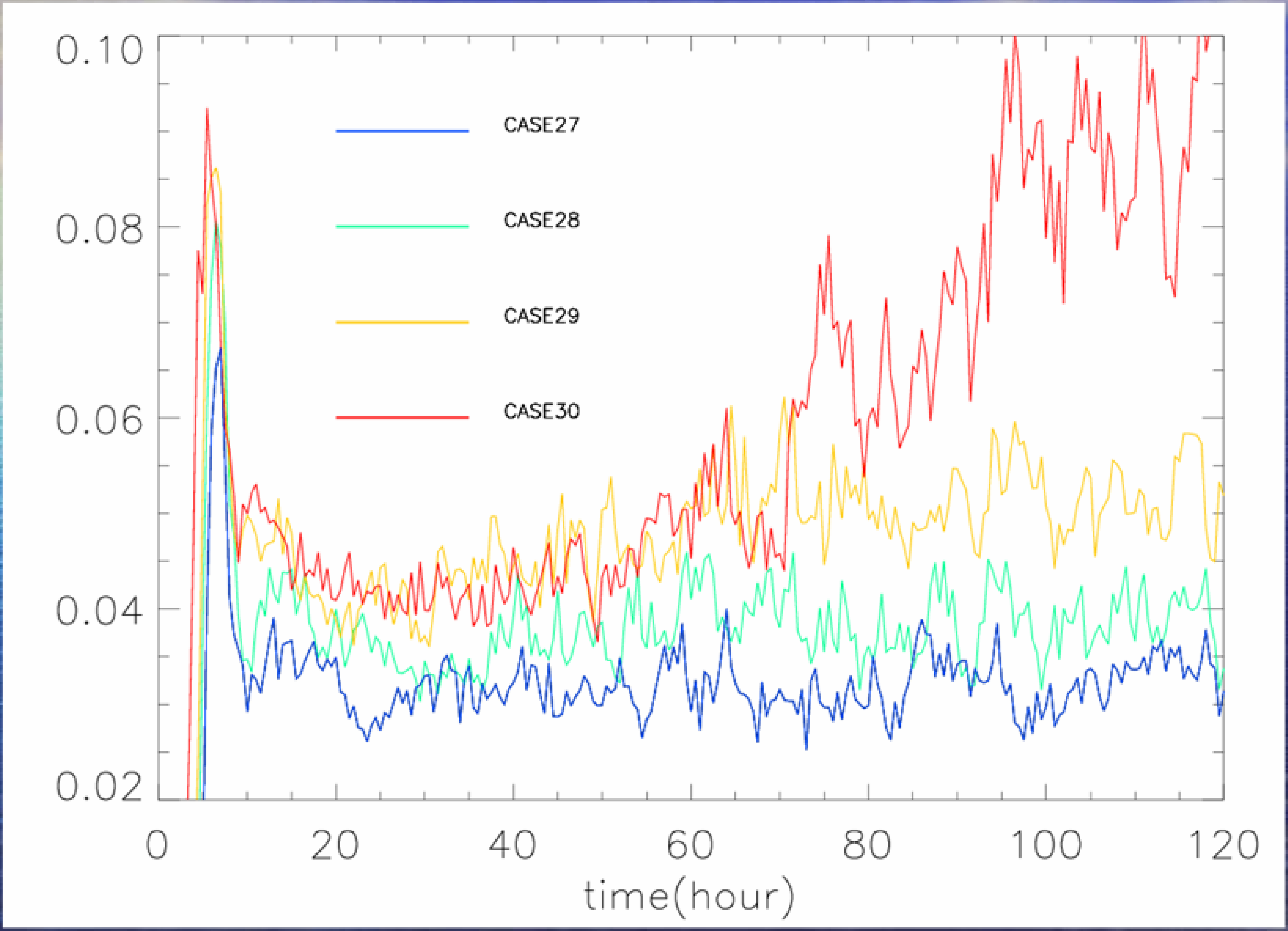
Summary

- Dependency of cloud activity on SST is examined using high resolution atmosphere-ocean coupled model.
- The cloud activity becomes stronger abruptly over 29 deg. of SST, similar to observed features.
- The causes of jump in cloud activity is the difference in the ocean mixed layer process, that is, SST tends to decrease in low SST cases, while the SST keeps high in high SST cases.
- Keeping shallow SST in the low SST cases, salinity stratification due to the precipitation is essential.

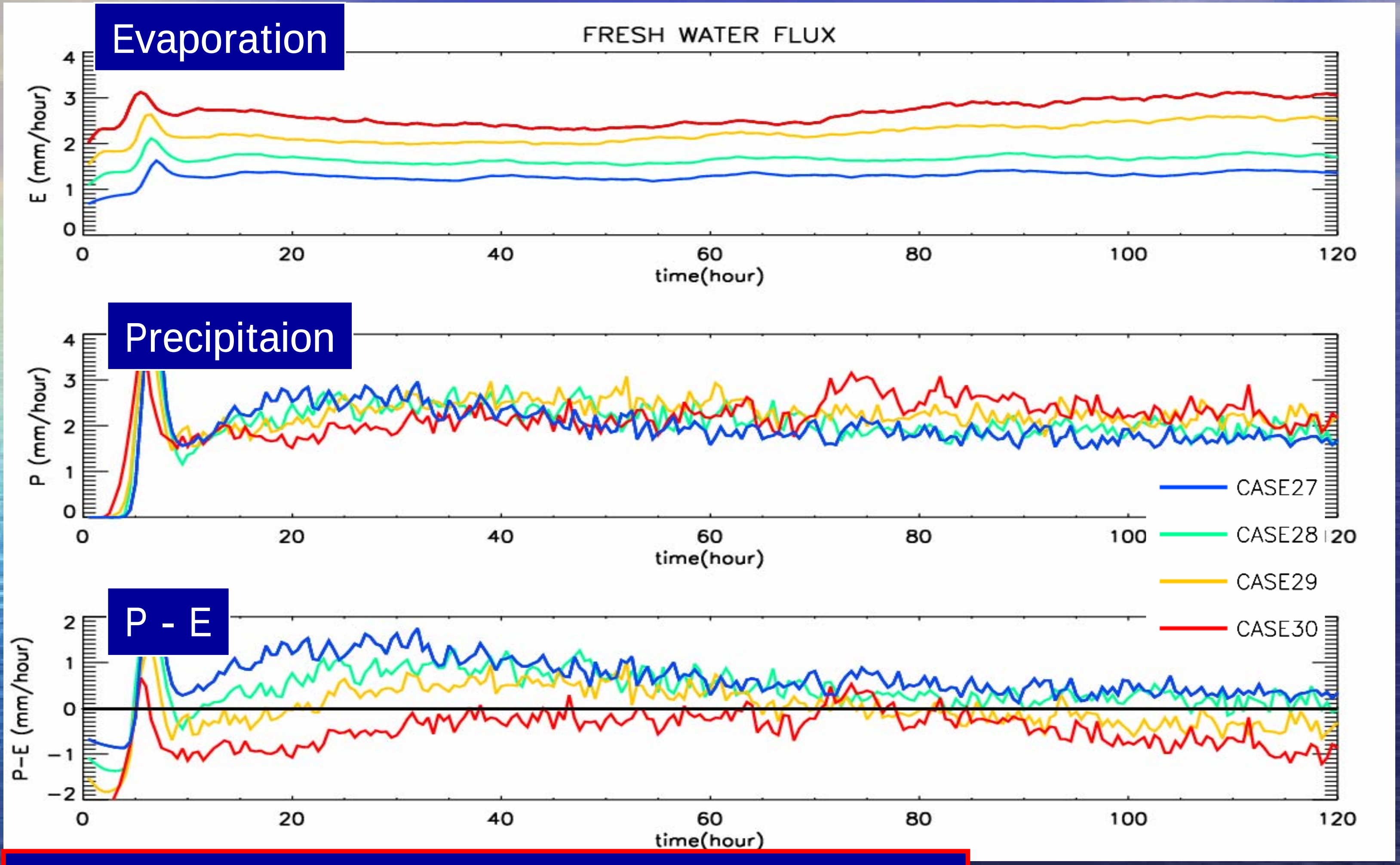
Future works

- Longer experiment:
  - In Case 27,28, Does cloud activity become strong again?
  - In Case 29, 30, How long does strong cloud activity continue?
- More realistic experiment:
  - Initial stratification of ocean
  - Horizontal variation of background field
  - Time change of boundary condition

Standard deviation of surface wind stress

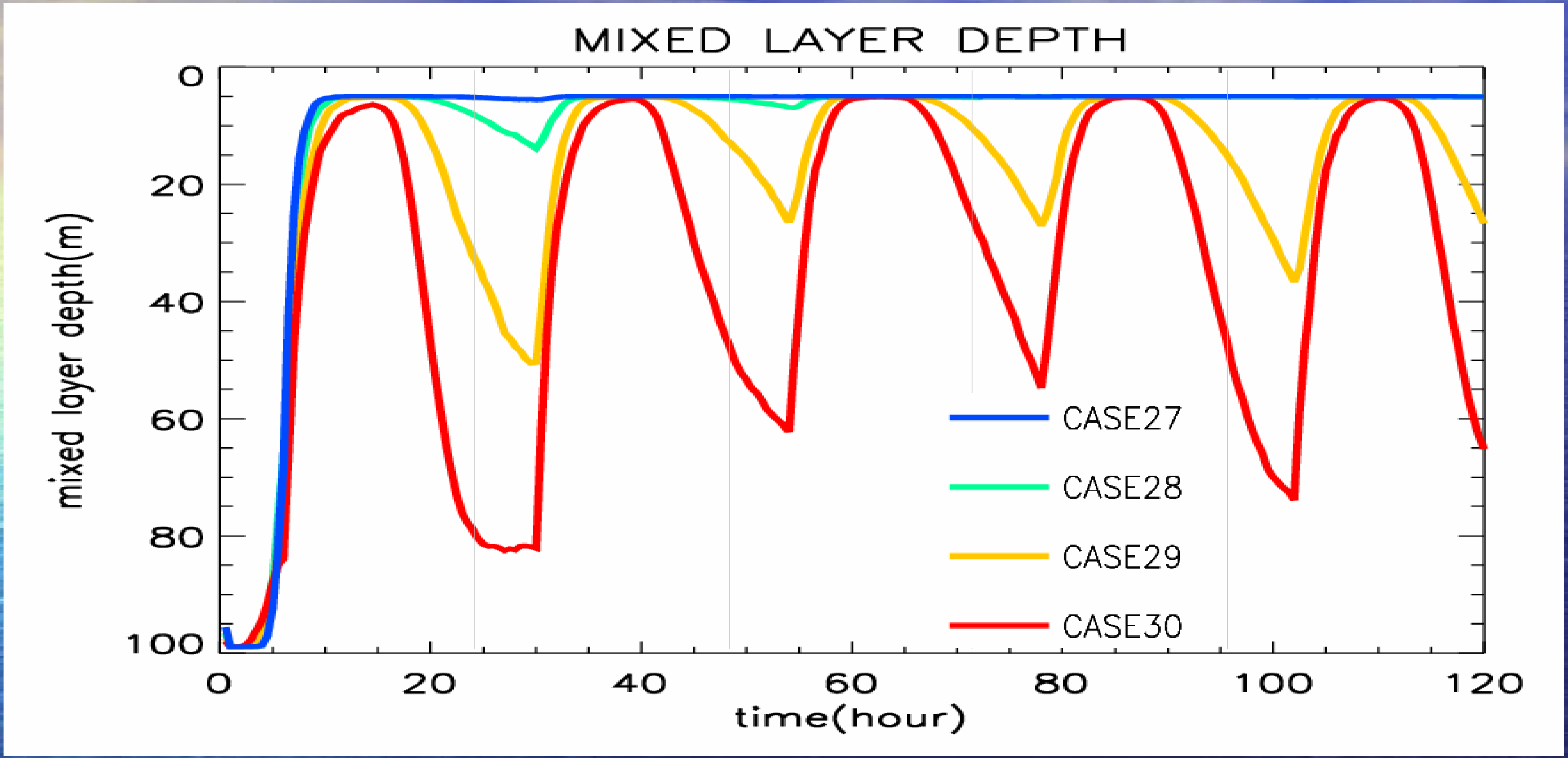


Fresh water flux



Higher SST leads higher evaporation.
→Unstable in High SST case

Variability of mixed layer depth



CASE27,CASE28 : Constant about 5m depth.
CASE29,CASE30 : Strong diurnal variability.