Diurnal Variations of liquid cloud Properties over Eastern North Atlantic Ocean using MeteoSat and ground-based during 2017-2018 ARM IOPs

Baike Xi, Xiquan Dong, and Peng Wu

University of Arizona

Sunny Sun-Mack, Bill Smith, NASA Langley Research Center

Outline

Part I: Use MeteoSat measurements to demonstrate the diurnal and spatial variations of liquid clouds in 10°x10° study area→ compare to previous study (Dong et al. 2014)

Part II: Compare MeteoSat measurements and retrievals over a grid box of 0.25° x0.25° centered on ENA site with ARM ground-based measurements →compare to previous study (Dong et al. 2014; McHardy et al. 2018)

ARM ACE-ENA 2017/2018 two IOPs

Data sets

- MeteoSat 400x600 pixels within a grid box of 10°x10°
- Ground-based observations over ARM ENA site

Method

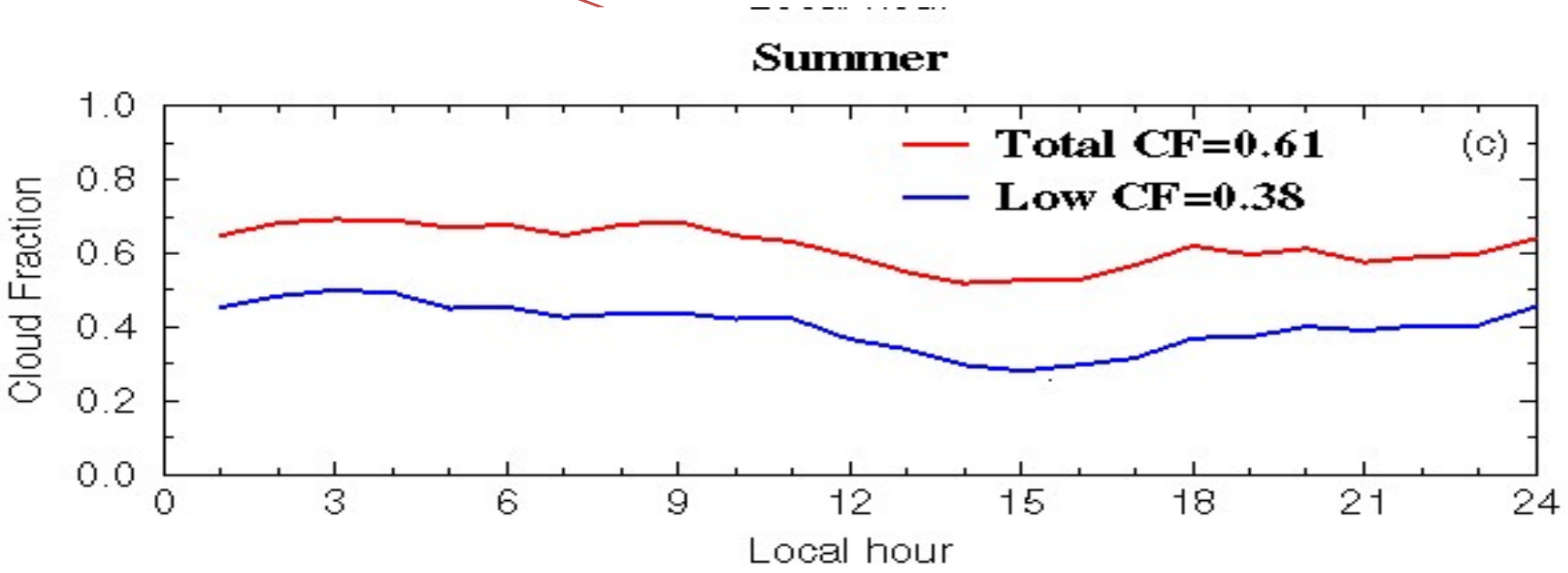
- MeteoSat: for each grid box of 0.25°x0.25°

➔Step1: Select all pixels with T_{top} >0 ºC and liquid CF>0% and 90%;

➔Step2: Compare the diurnal variations of liquid CF, T_{top} and H_{top} between MeteoSat and ground-based observations (one grid centered at the site);

➔Step3: Compare the diurnal variation of cloud macro- and micro-physical properties.

Diurnal variation of summer CF from ARM (Dong et al. 2014)

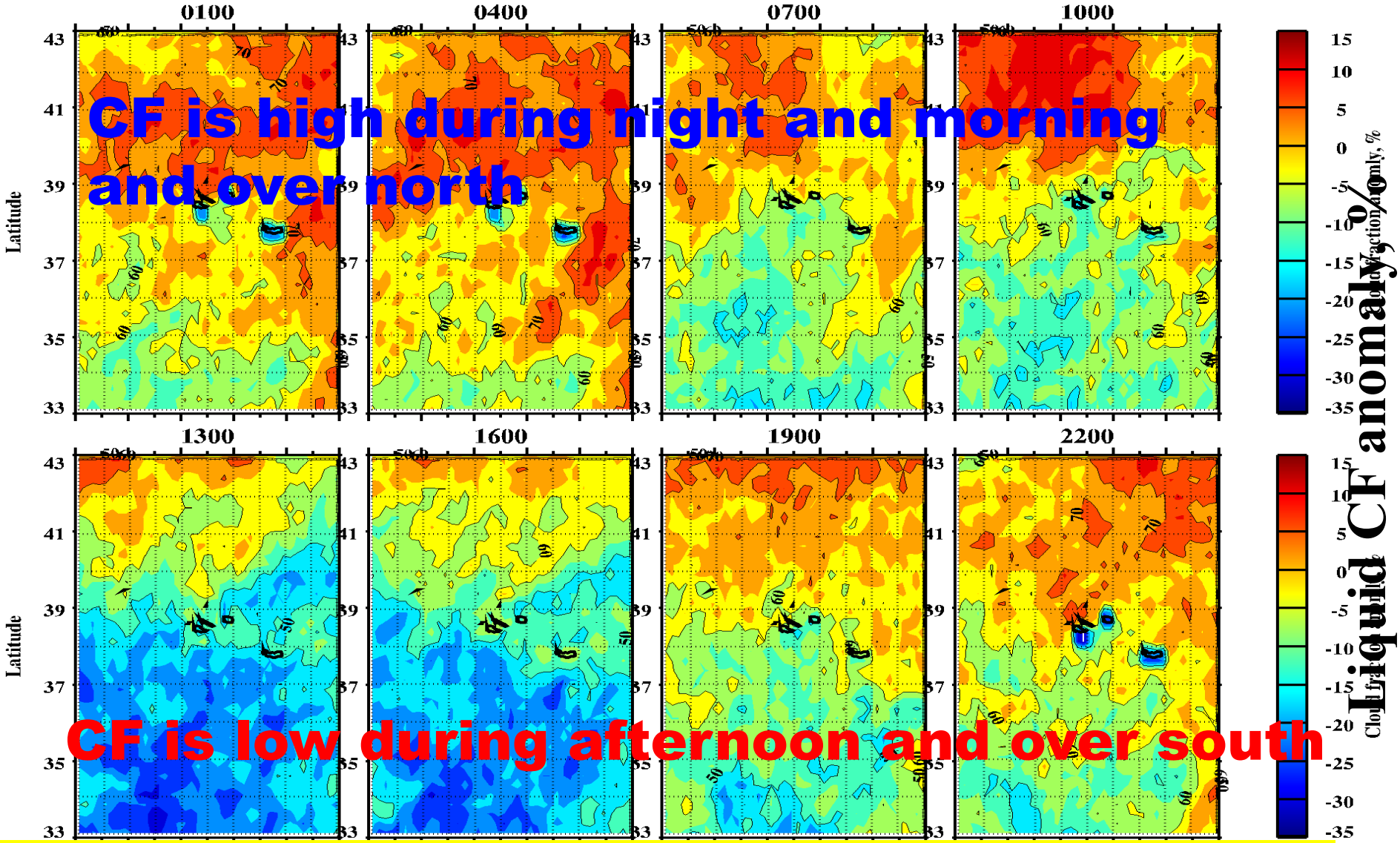


Using the ARM AMF measurements during 06/2009-12/2010:

- The Low-level clouds (defined as $Z_{top} \leq 3$km) have very similar diurnal variation as total cloud fraction;
- The peak happens at around 3Z and the minimum is at 15Z during Summer over the ENA site.

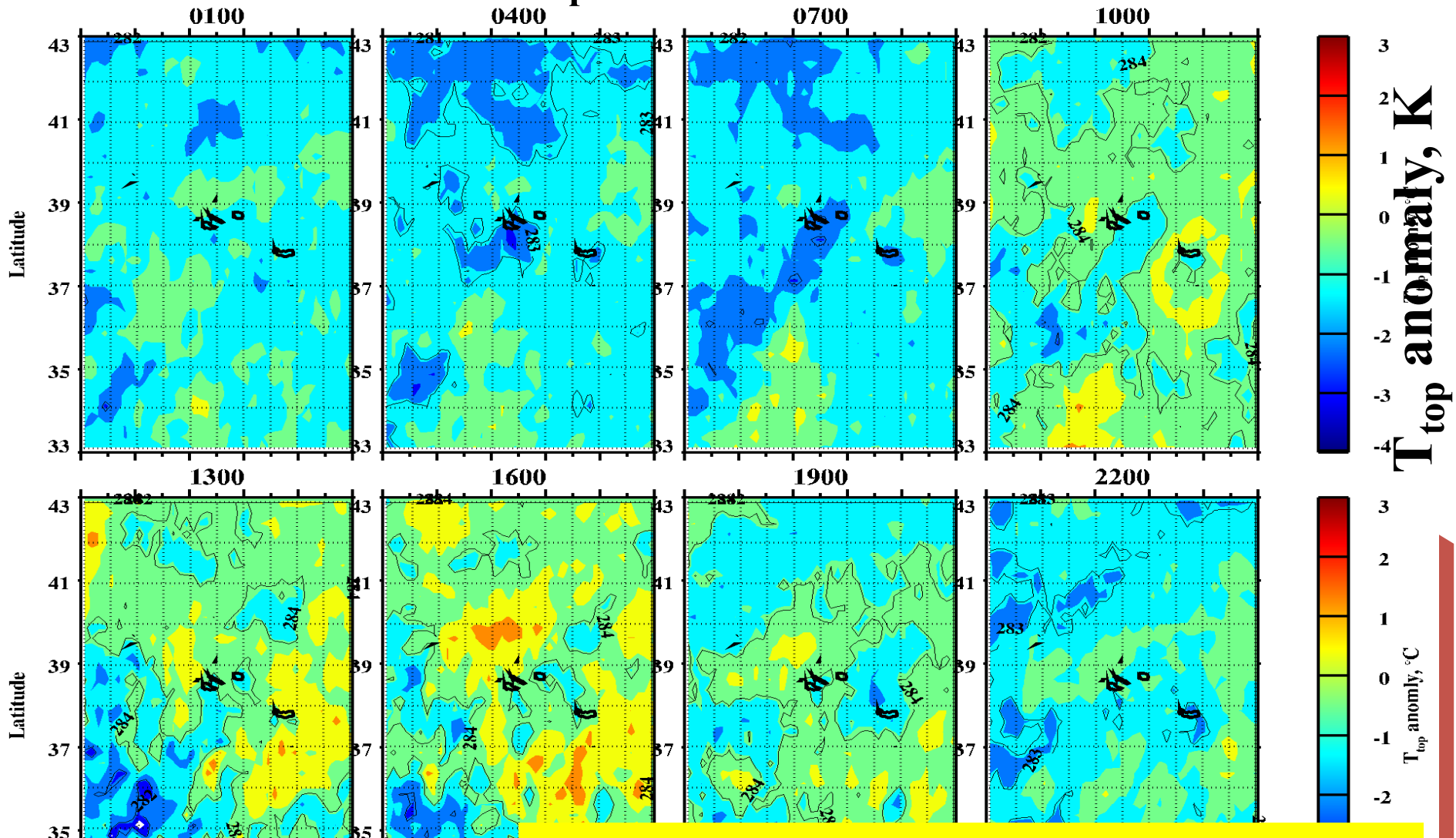
➔The next few slides will analyze the diurnal variation of warm clouds, which will be a slightly different from our previous study.

Part I: Diurnal variation of liquid CF during 2017 summer IOP



The highest liquid CF occurs at 4Z, and the lowest CF happens at 16Z, which is consistent to the previous study (Dong et al. 2014)

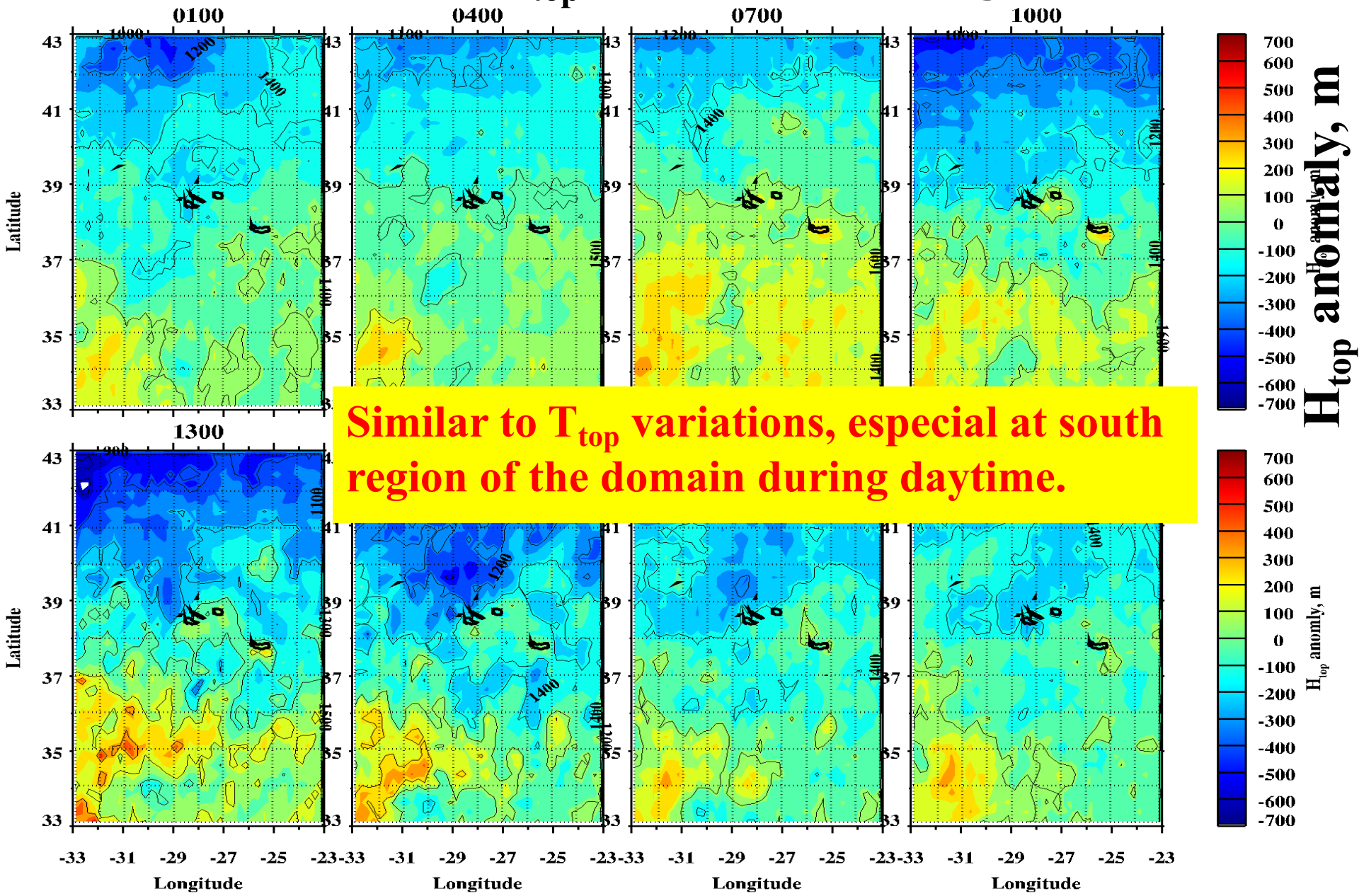
Diurnal variation of T_{top} (CF>90%) during Summer 2017



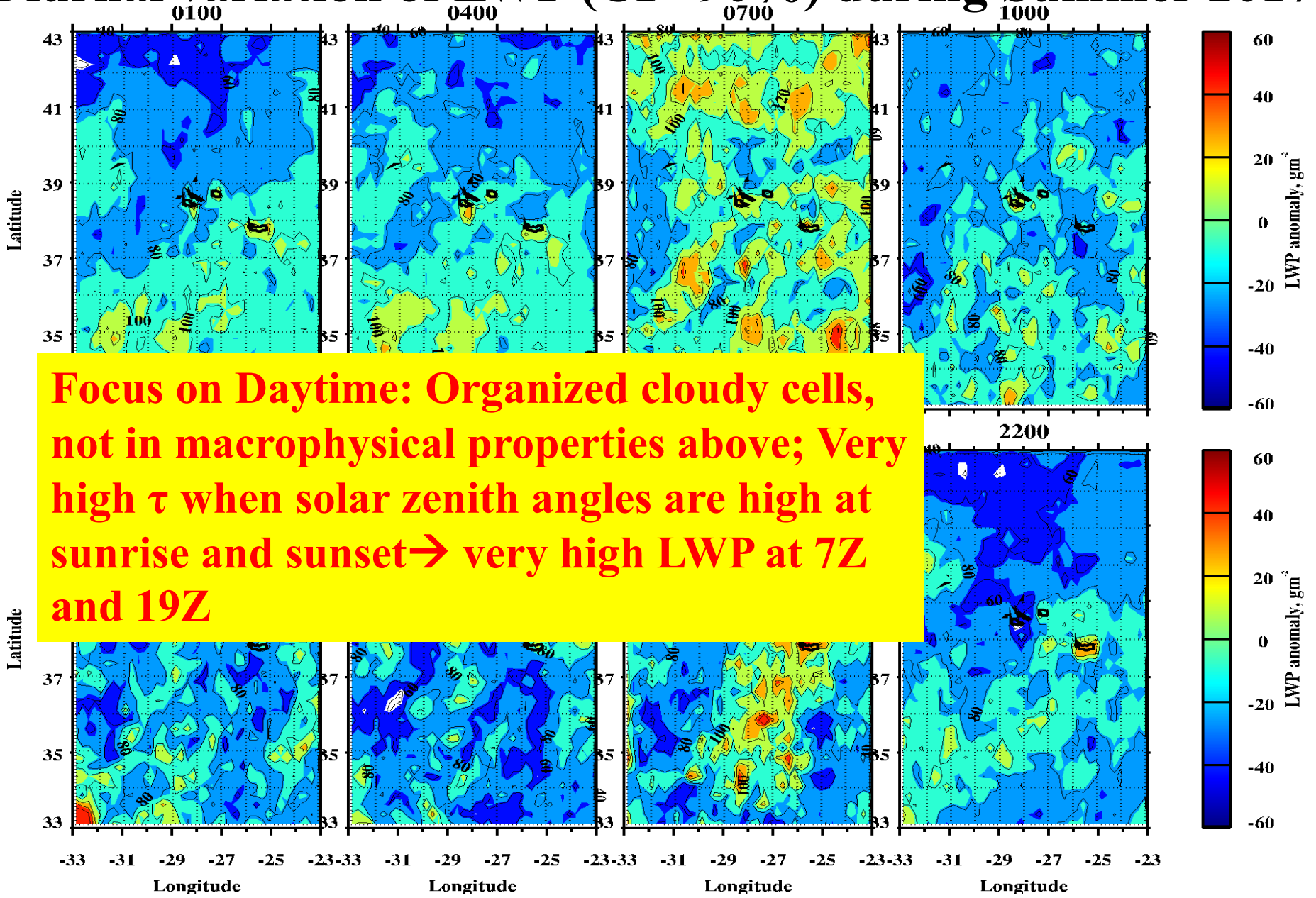
➔Strong diurnal variation

➔Cold during night and over North, warm during daytime and over south

Diurnal variation of H_{top} (CF>90%) during Summer 2017

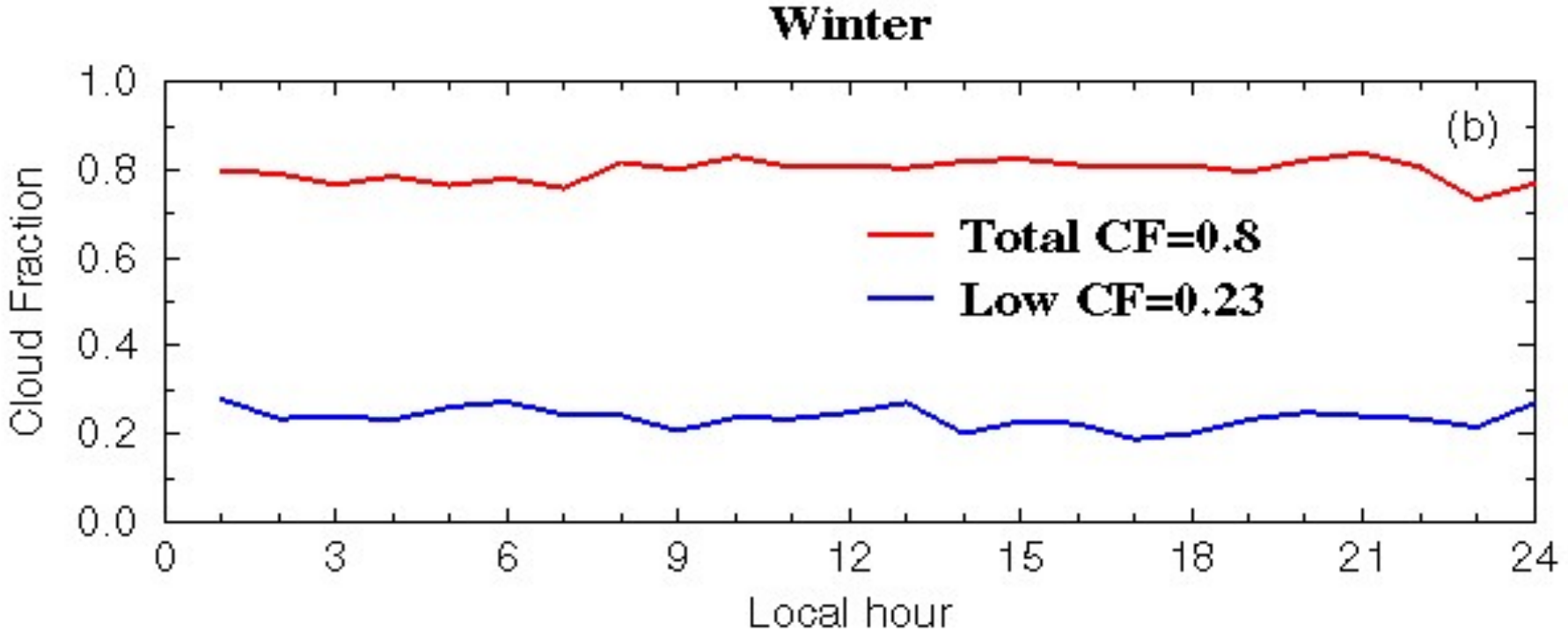


Diurnal variation of LWP (CF>90%) during Summer 2017



Focus on Daytime: Organized cloudy cells, not in macrophysical properties above; Very high τ when solar zenith angles are high at sunrise and sunset→ very high LWP at 7Z and 19Z

Diurnal variation of Winter CF from ARM (Dong et al. 2014)

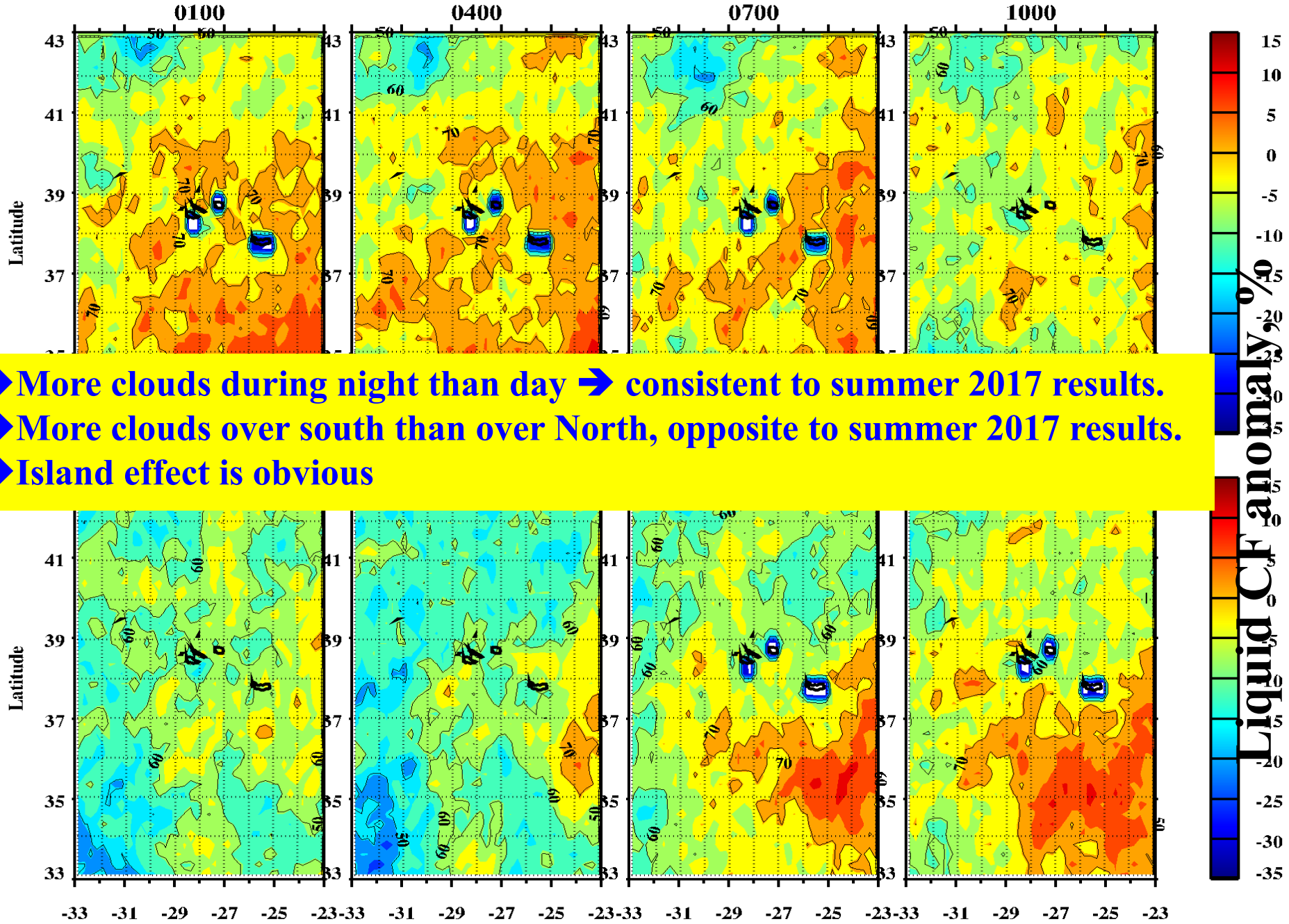


Using the ARM AMF measurements during 06/2009-12/2010

- The Low-level clouds have slightly different diurnal variation as total cloud fraction;

➔The next few slides will analyze the diurnal variation of warm clouds during winter 2018 IOP.

Diurnal variation of Liquid CF during 2018 winter IOP

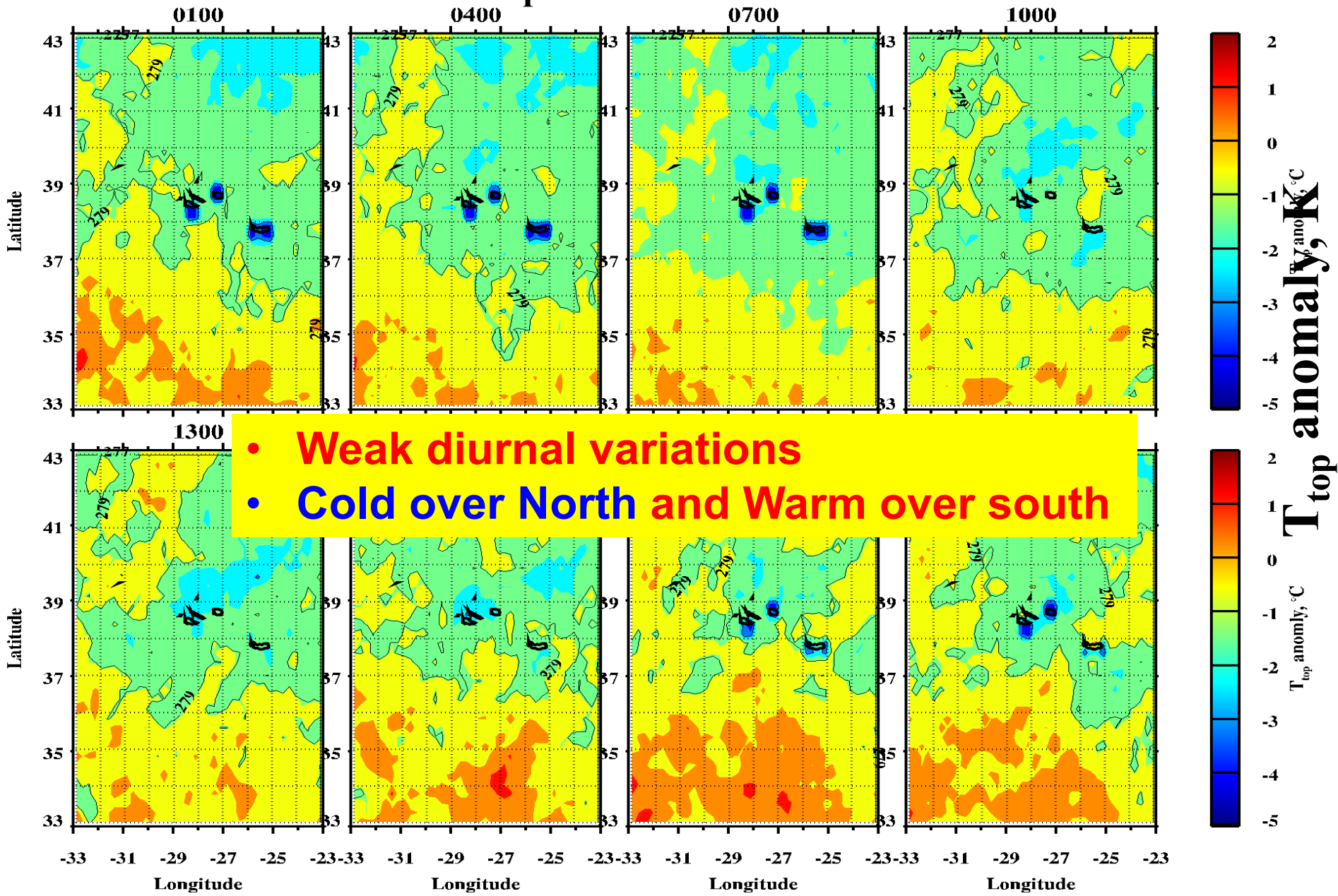


➔More clouds during night than day ➔ consistent to summer 2017 results.

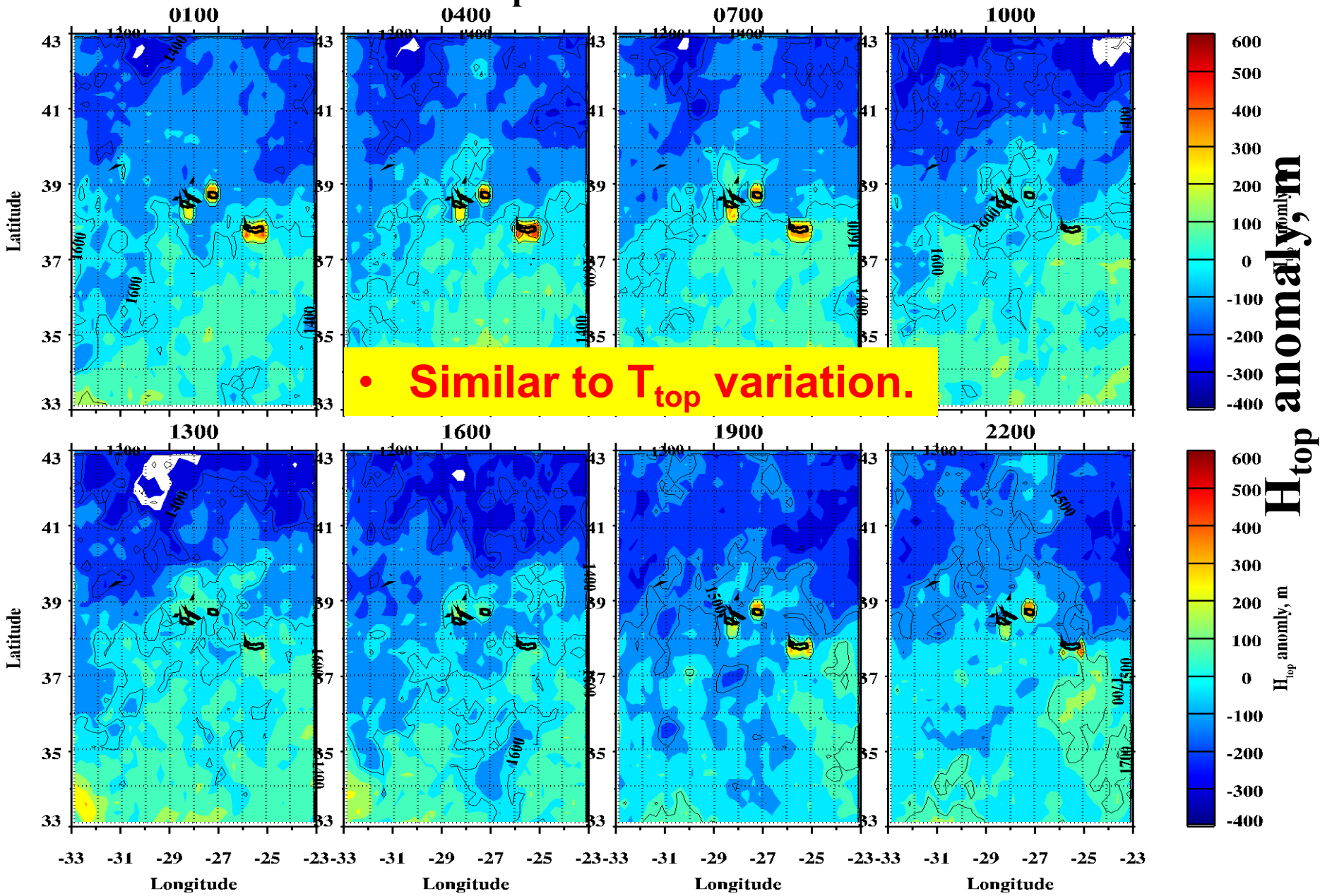
➔More clouds over south than over North, opposite to summer 2017 results.

➔Island effect is obvious

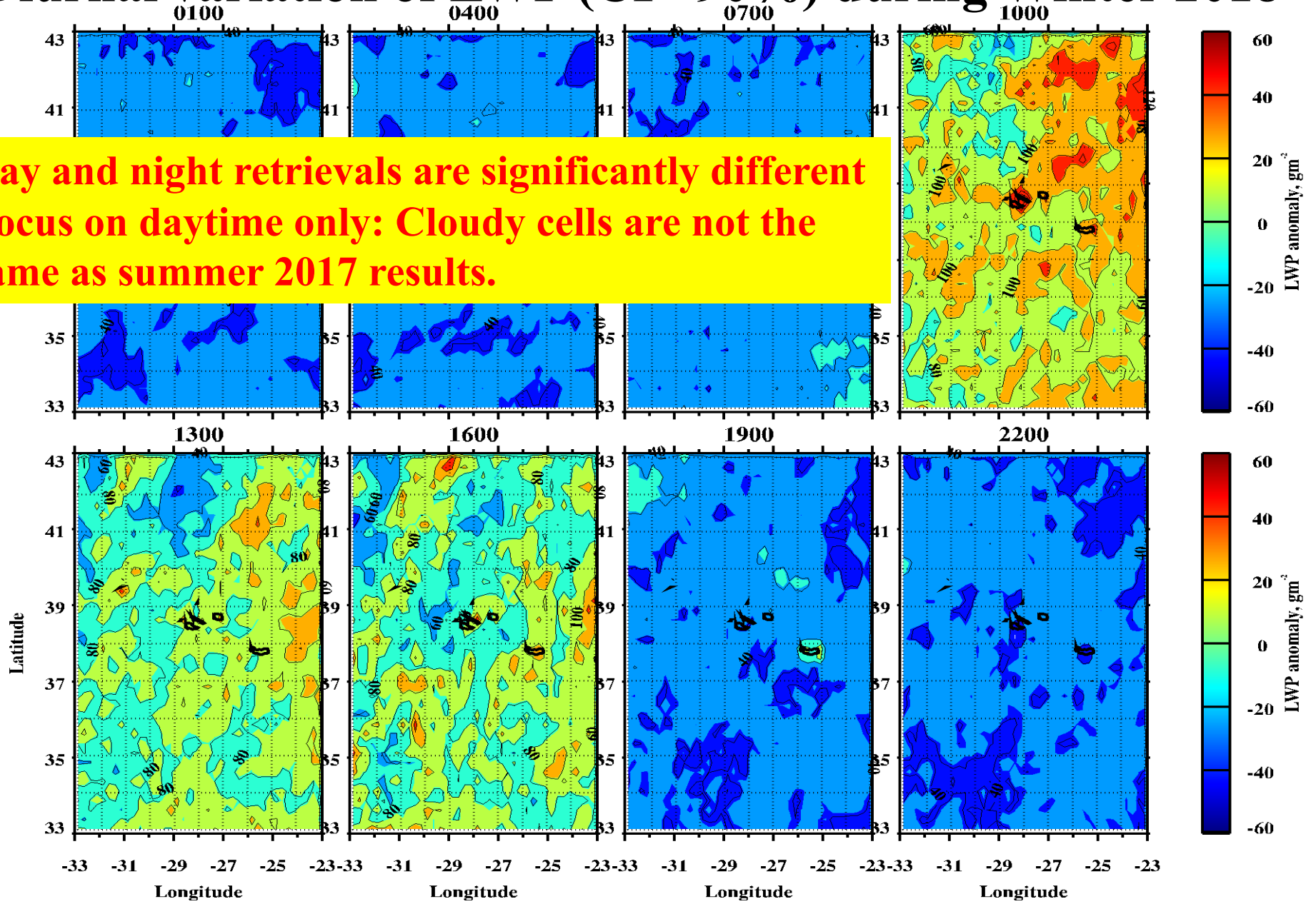
Diurnal variation of T_{top} (CF>90%) during winter 2018



Diurnal variation of H_{top} (CF>90%) during winter 2018



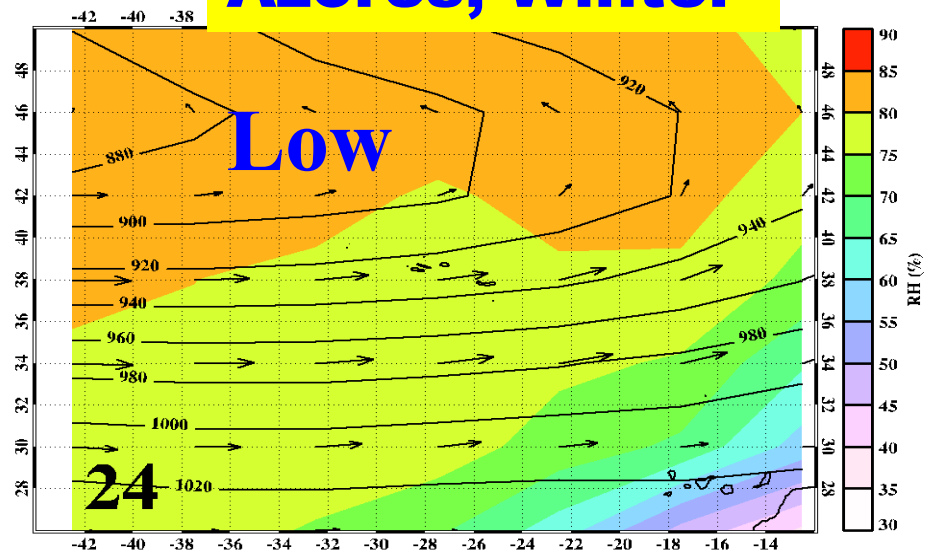
Diurnal variation of LWP (CF>90%) during Winter 2018



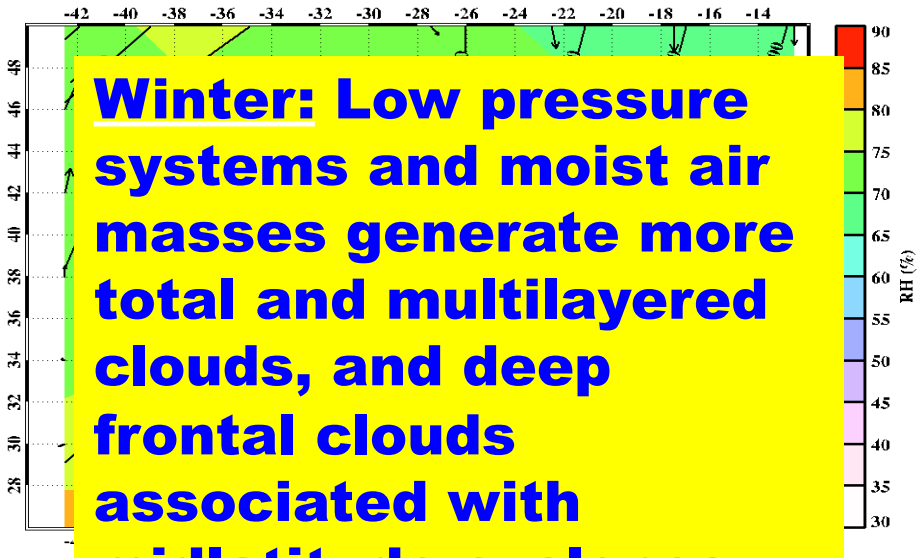
Day and night retrievals are significantly different
Focus on daytime only: Cloudy cells are not the same as summer 2017 results.

Synoptic patterns during 6/2009-12/2010

Azores, Winter

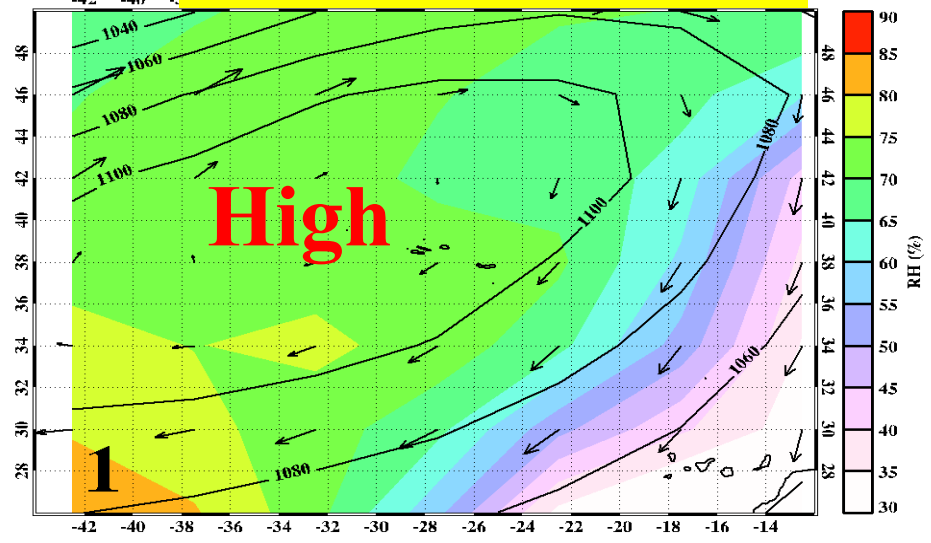


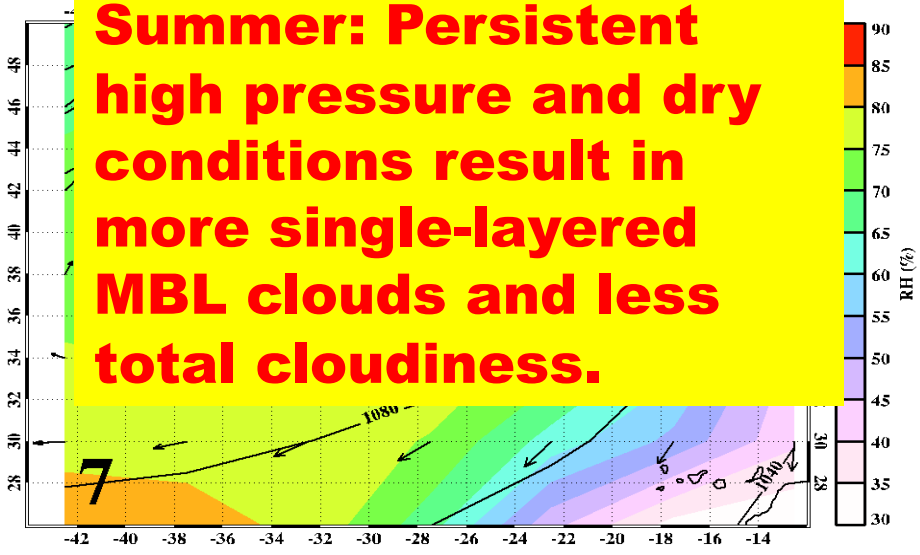
MAM



Winter: Low pressure systems and moist air masses generate more total and multilayered clouds, and deep frontal clouds associated with midlatitude cyclones.

Azores, Summer

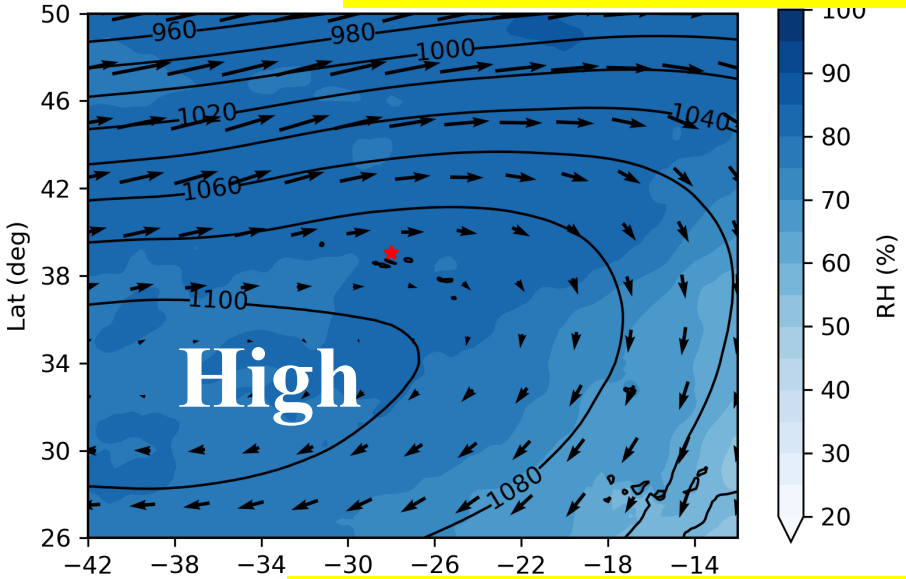


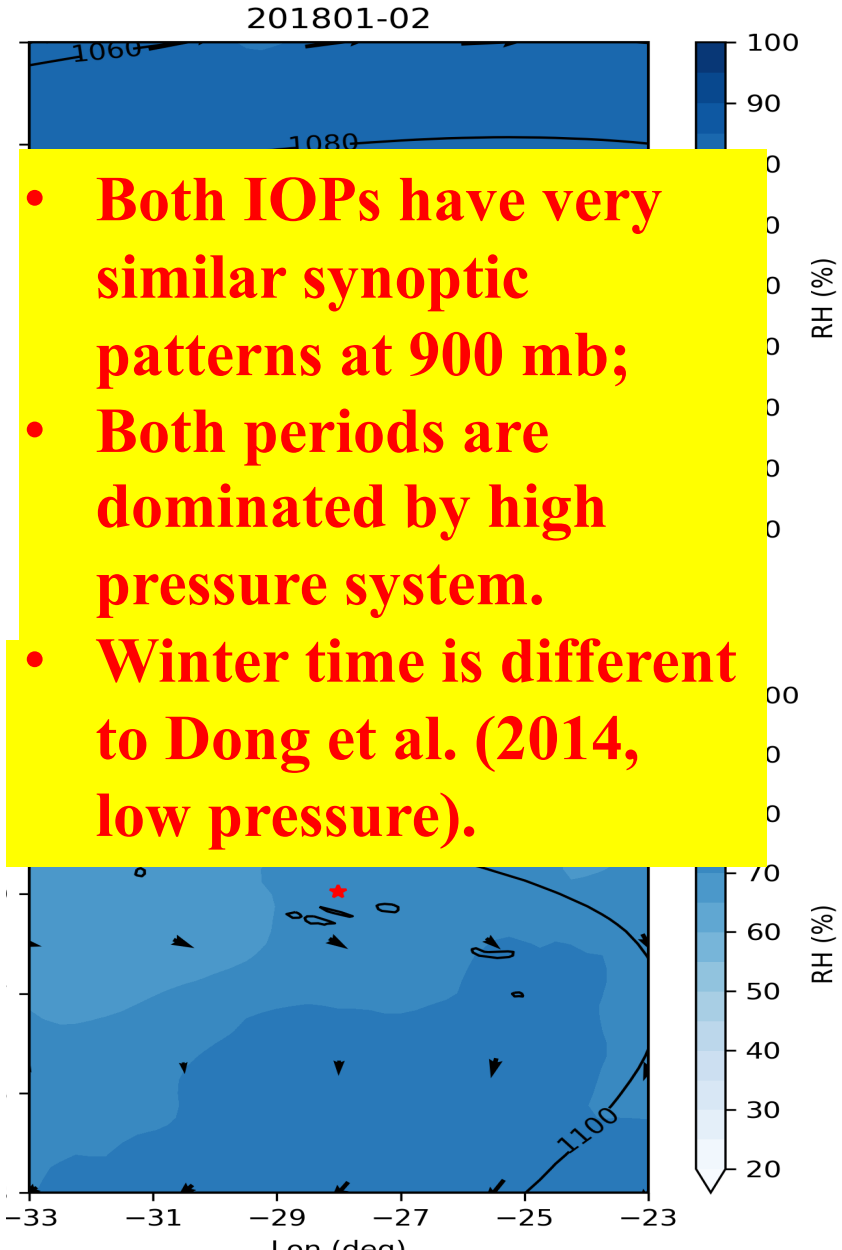


Summer: Persistent high pressure and dry conditions result in more single-layered MBL clouds and less total cloudiness.

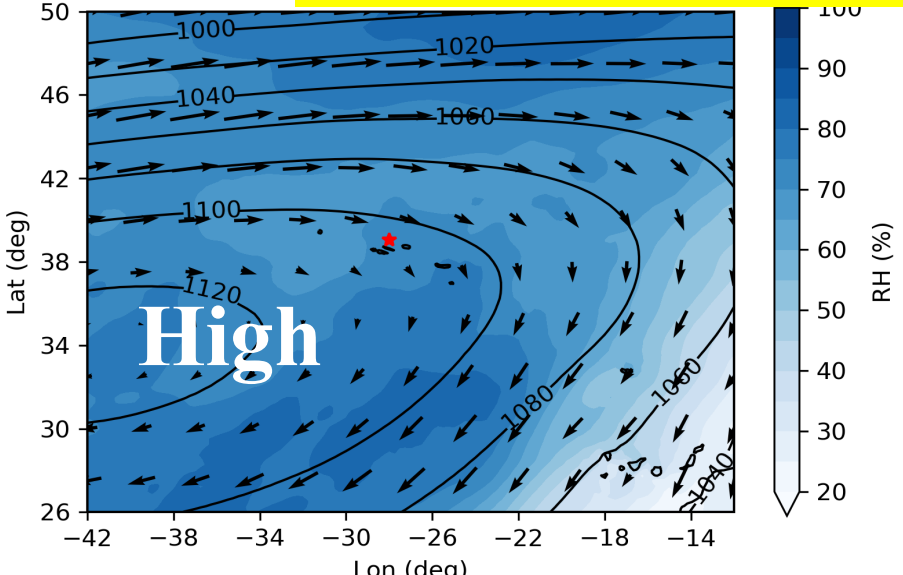
Synoptic patterns during winter 2018 and summer 2017

ENA, Winter 2018



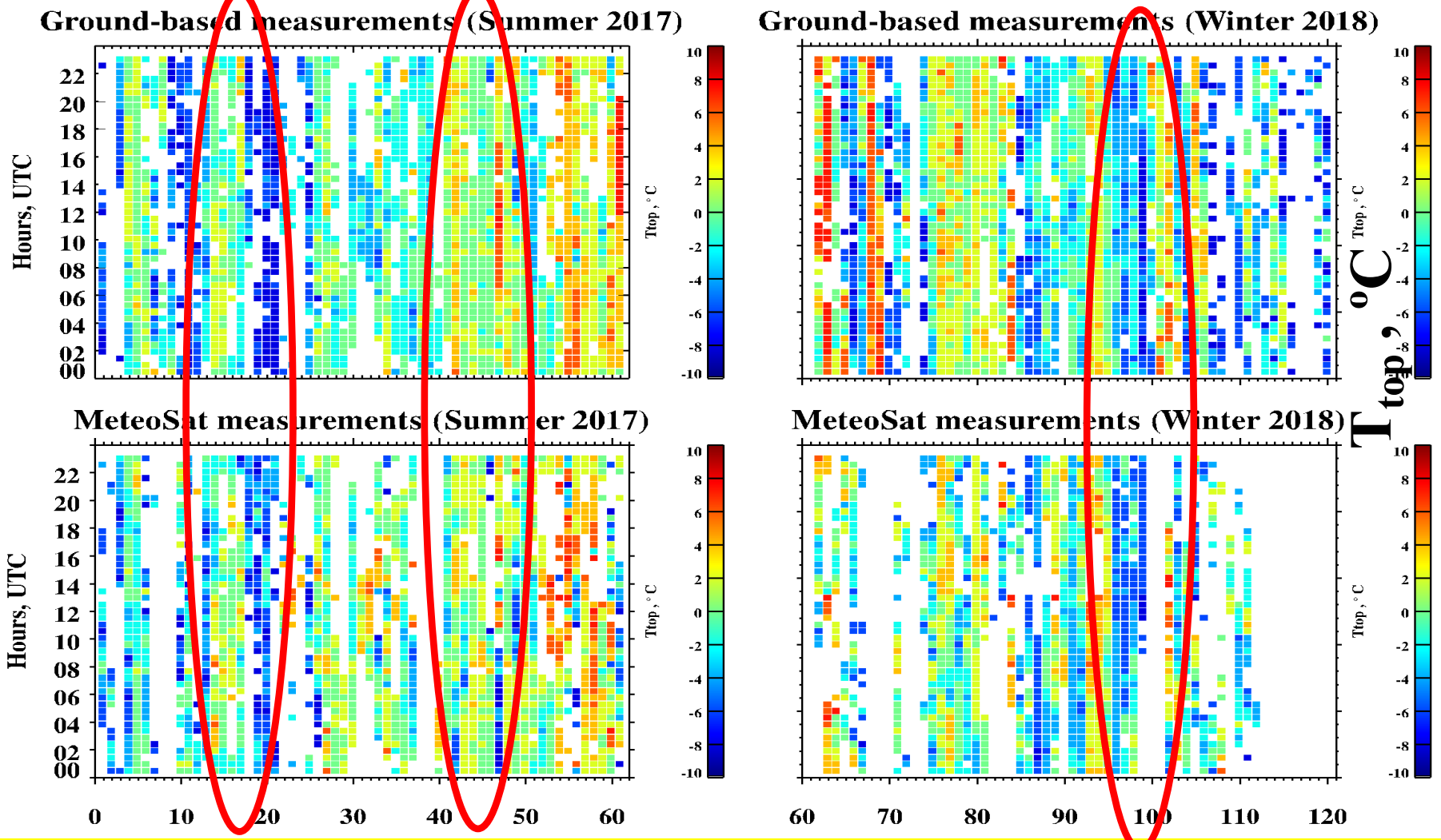


ENA, Summer 2017



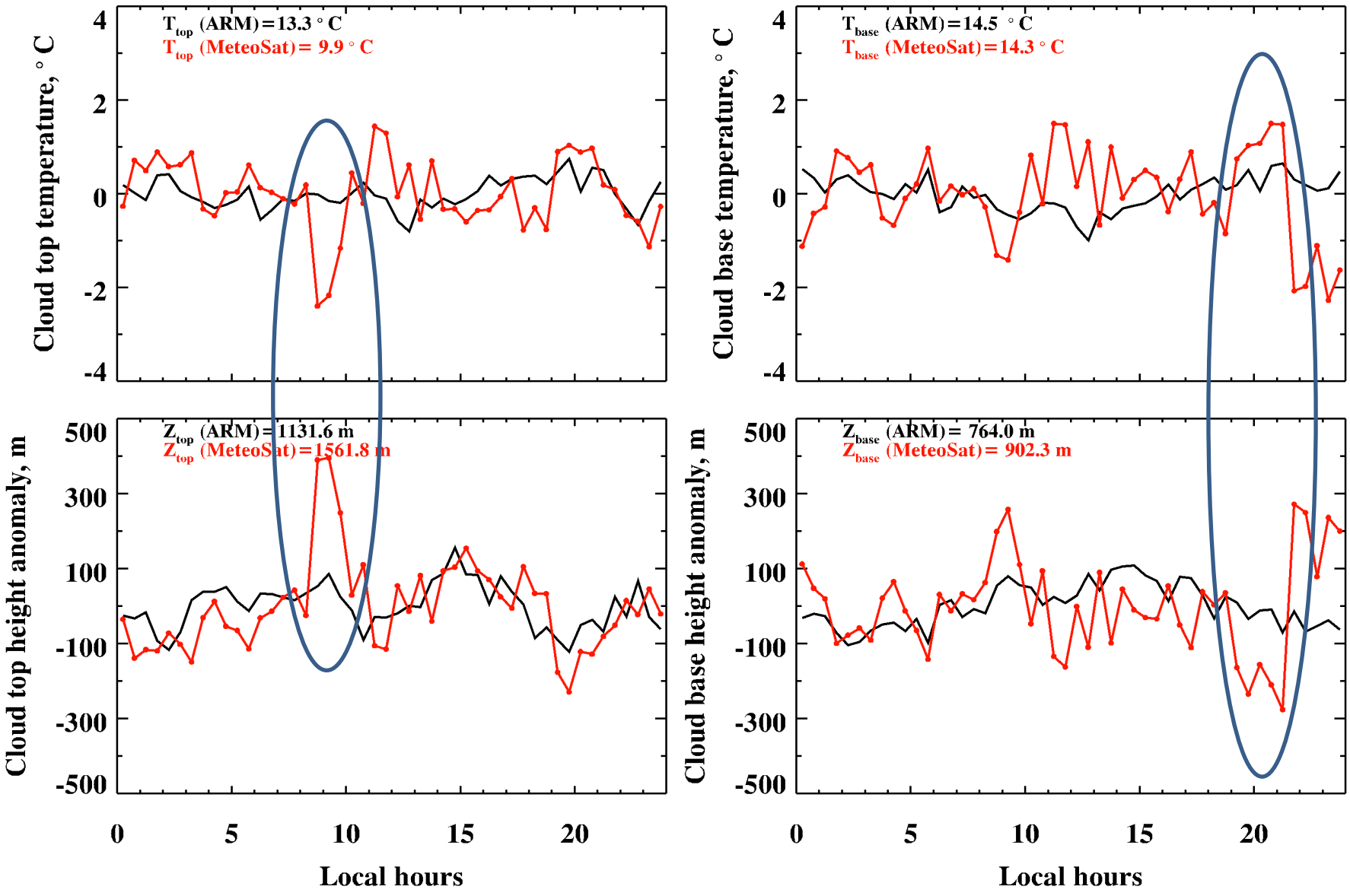
- Both IOPs have very similar synoptic patterns at 900 mb;
- Both periods are dominated by high pressure system.
- Winter time is different to Dong et al. (2014, low pressure).

Part II: Compare MeteoSat results over a grid box of 0.25° x0.25° centered on ENA site with ARM ground-based measurements

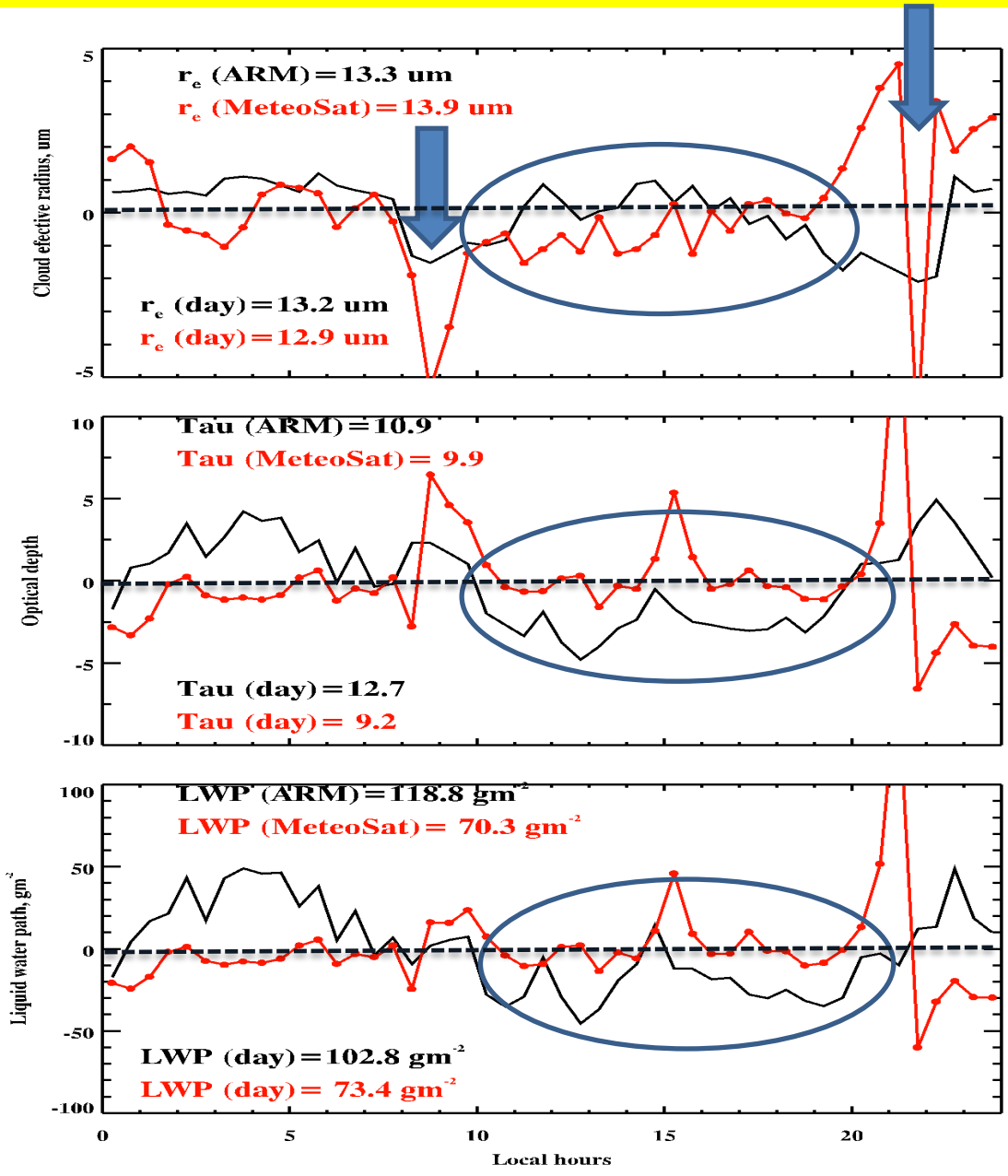


A total of 3125 paired samples are selected for analyzing effect of the spatial and temporal variability on the mean difference between two measurements. Some agreements can be found, e.g. within ovals

Cloud height and Temp anomalies at ENA, Summer 2017



Microphyscial property anomalies at ENA, Summer 2017



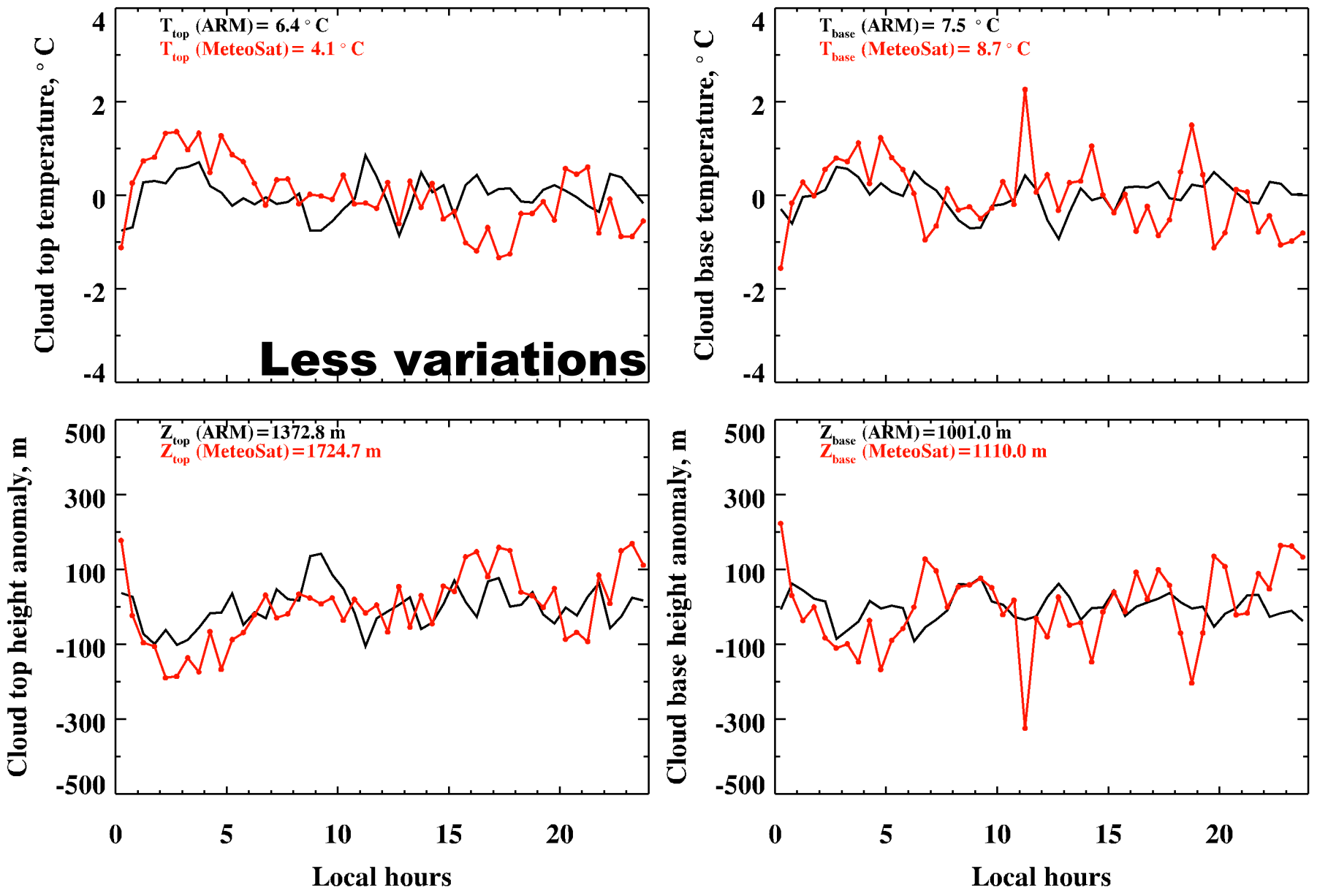
➔When the solar zenith angle is low: Small variations in both retrievals, but MeteoSat mean r_e, τ and LWP are lower than ARM results.

➔ During daytime, the τ and LWP anomalies have similar variations as ARM but in opposite sign.

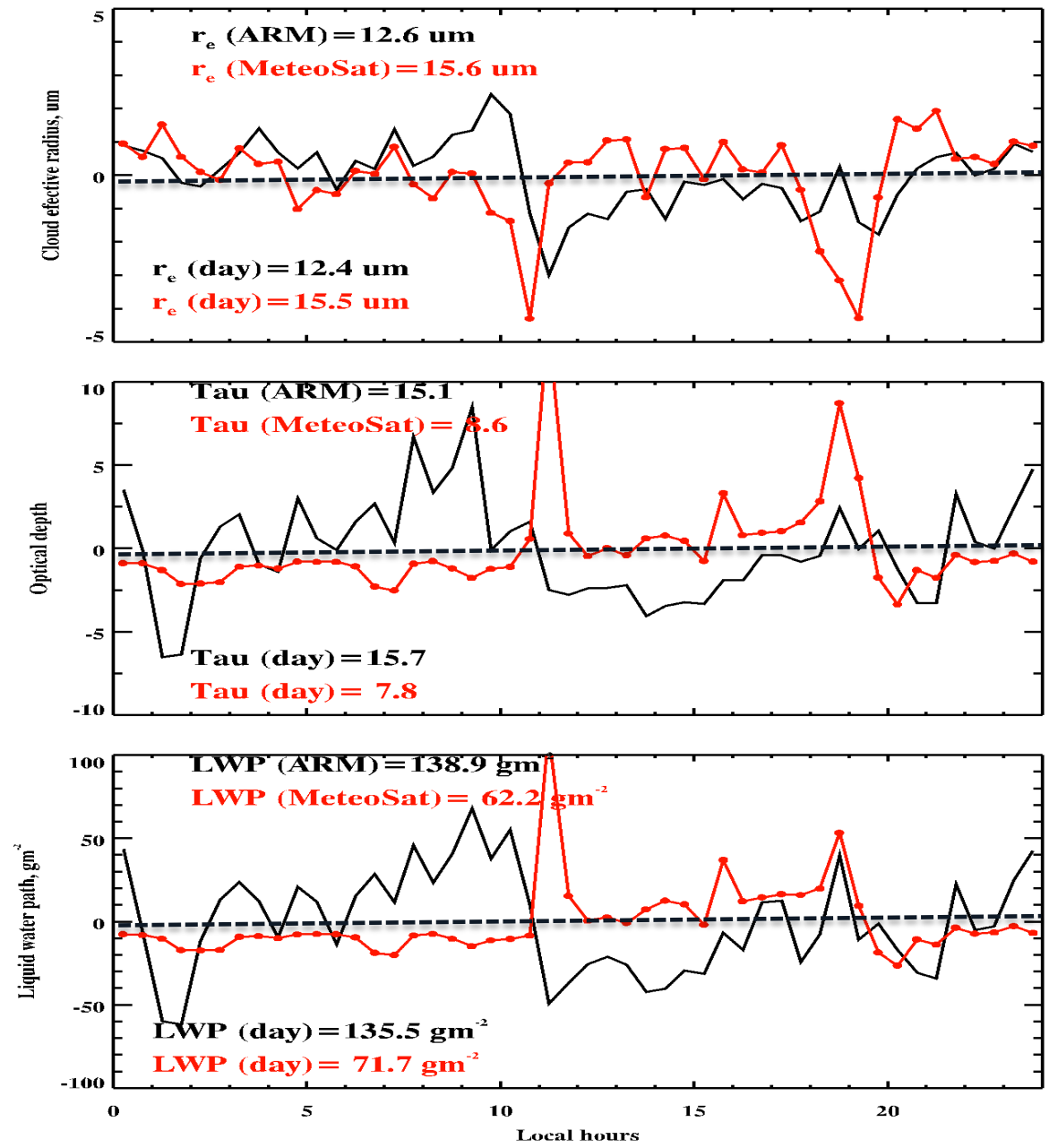
➔ During early morning and before Sunset, large variations in MeteoSat retrievals (τ increases with SZA in McHardy et al. 2018)

Summer	r_e	τ	LWP
day	12.7	14	114.4

Cloud height and Temp anomalies at ENA, Winter 2018



Microphyscial property anomalies at ENA, Winter 2018



During daytime:

- **MeteoSat mean r_e is much larger than ARM r_e**
- **MeteoSat τ and LWP are almost half of ATM counterparts.**
- **The winter r_e anomaly has opposite sign as that during summer;**
- **The τ and LWP anomalies are similar as those during summer.**

Winter	r_e	τ	LWP
day	12.4	12.1	99

Summary part I: Macrophysical comparisons

CF: Summer CFs are higher during night and morning and over north, but are lower during afternoon and over south.

More winter clouds during night than during day➔ consistent to the summer 2017 results. More clouds over south than over North, opposite to the summer 2017 results.

T_{top}: Strong diurnal variation during summer 2017, cold during night and over North, warm during daytime and over south.

Weak diurnal variation during winter 2018, cold over North and warm over south.

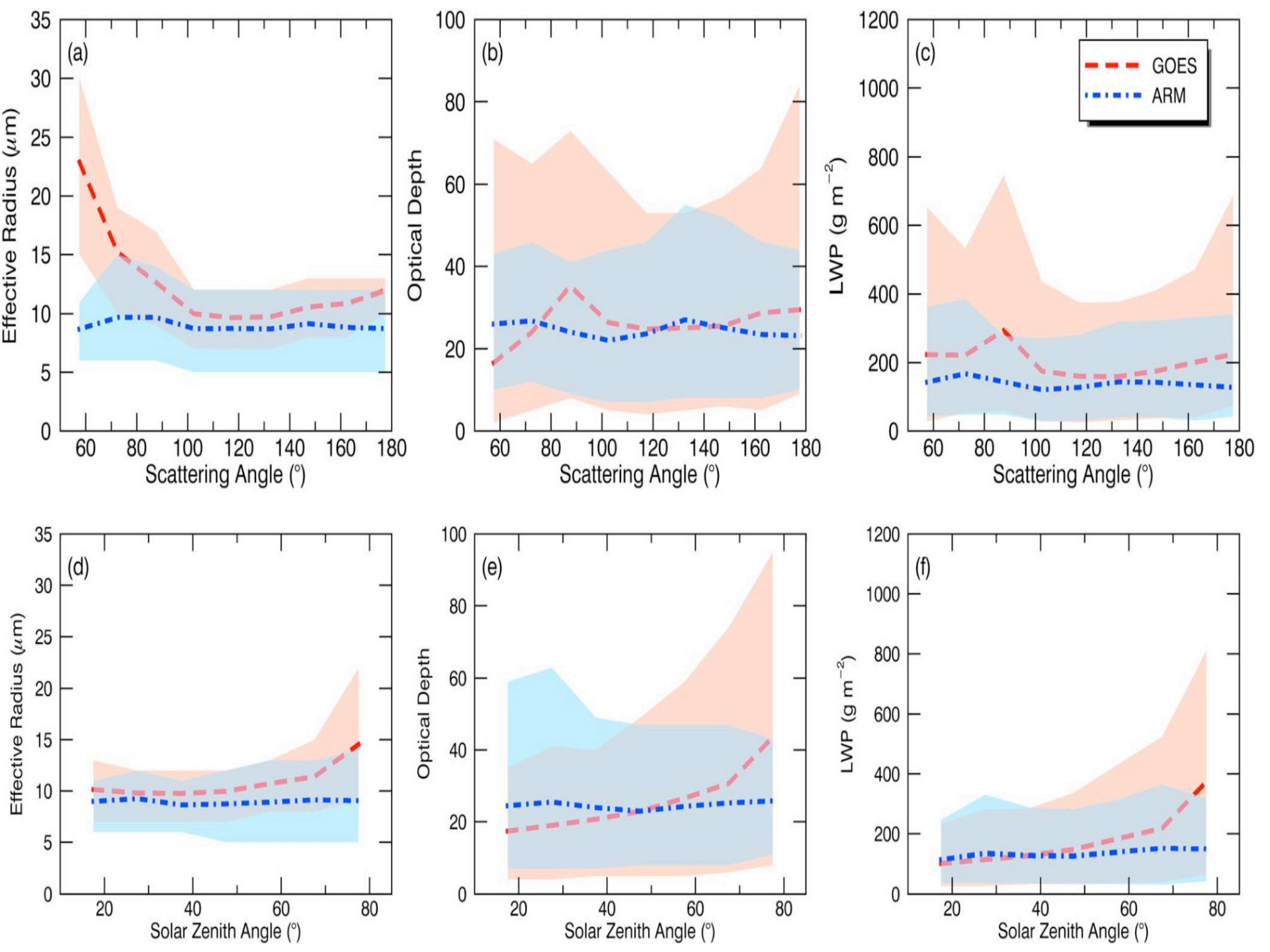
H_{top}: H_{top} during summer are oppsite to their T_{top} variation; H_{top} during winter are similar to their T_{top} variations.

Summary part II: Microphysical Comparisons

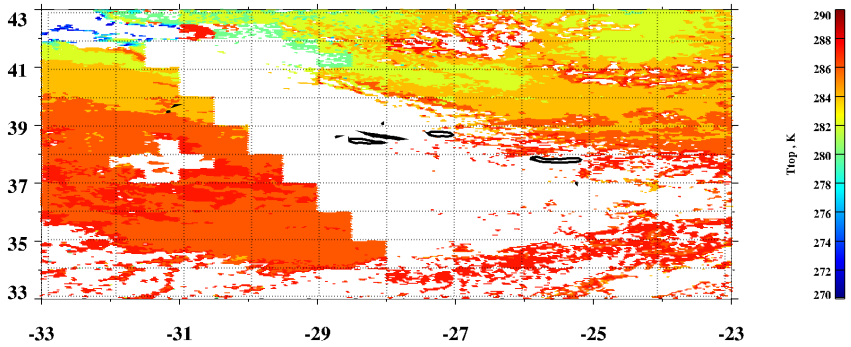
➔When the solar zenith angle is low: Small variations in both retrievals. During summer, mean MeteoSat r_e is 0.3 um less than ARM r_e but τ is 3.5 less ➔LWP much lower than ARM LWP; During winter, mean MeteoSat r_e is 3.1 um greater than ARM r_e, but τ is ~half of ARM τ ➔LWP ≈0.5 ARM LWP;

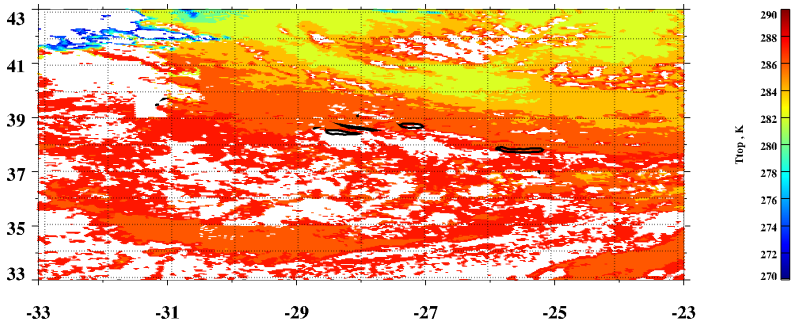
➔ During early morning and late afternoon, large variations in MeteoSat retrievals.

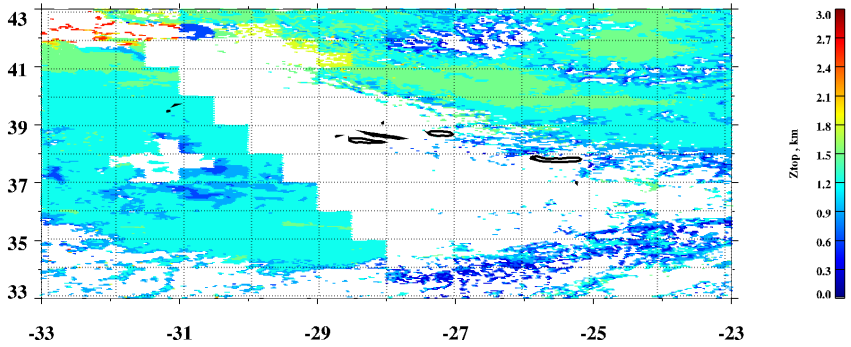
Backups

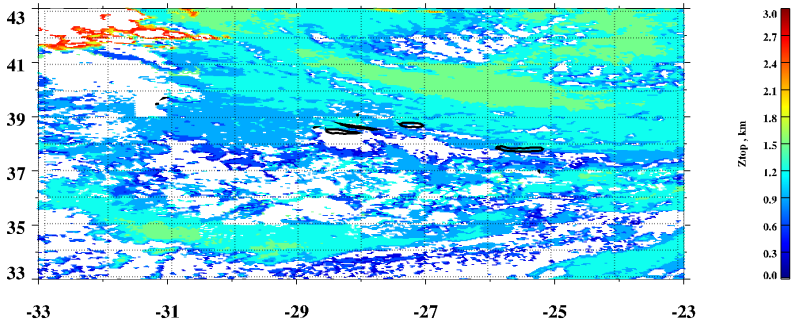

(a)
Effective Radius (μm)
Scattering Angle (°)
(b)
Optical Depth
Scattering Angle (°)
(c)
GOES
ARM
LWP (g m^{-2})
Scattering Angle (°)
(d)
Effective Radius (μm)
Solar Zenith Angle (°)
(e)
Optical Depth
Solar Zenith Angle (°)
(f)
LWP (g m^{-2})
Solar Zenith Angle (°)

MeteoSat 20170718 7:30/8:30









2017 IOP

2018 IOP