Marine and Continental Low-level Cloud Processes and Properties

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Goal of this study is to investigate the similarity and difference of

1) Cloud formation-dissipation processes

2) Seasonal and Diurnal Variation of Low-level Cloud Fraction and Properties

Dong, X., P. Minnis, and B. Xi, 2005: A climatology of midlatitude continental clouds from ARM SGP site. Part I: Low-level Cloud Macrophysical, microphysical and radiative properties. *J. Climate*. 18, 1391-1410.

Dong, X., B. Xi, A. Kennedy, P. Minnis and R. Wood, 2013: A 19-month Marine Aerosol-Cloud-Radiation Properties derived from DOE ARM AMF deployment at the Azores: Part I: Cloud Fraction and Single-layered MBL cloud Properties. Accepted by J. Clim.

Location of DOE ARM SGP site

ARM SGP site represents continental clouds with periodic episodes of Marine airmass advected from The Gulf of Mexico.

Dong et al. 2005

Location of DOE ARM Azores site

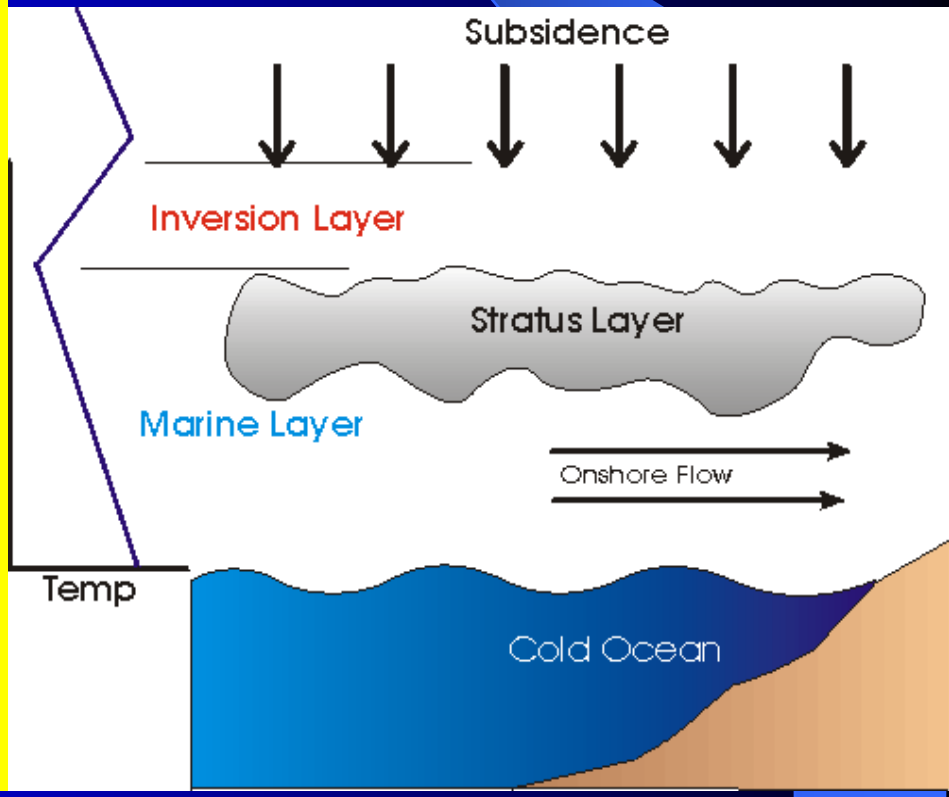
Dominated by clean airmasses but with periodic episodes of polluted air masses advected from the continents

Dong et al. 2013

1) MBL formation-dissipation processes

➔More MBL clouds occur over the east side of subtropical/mid-lat. oceans under conditions of modest cold advection during periods of equatorward flow.

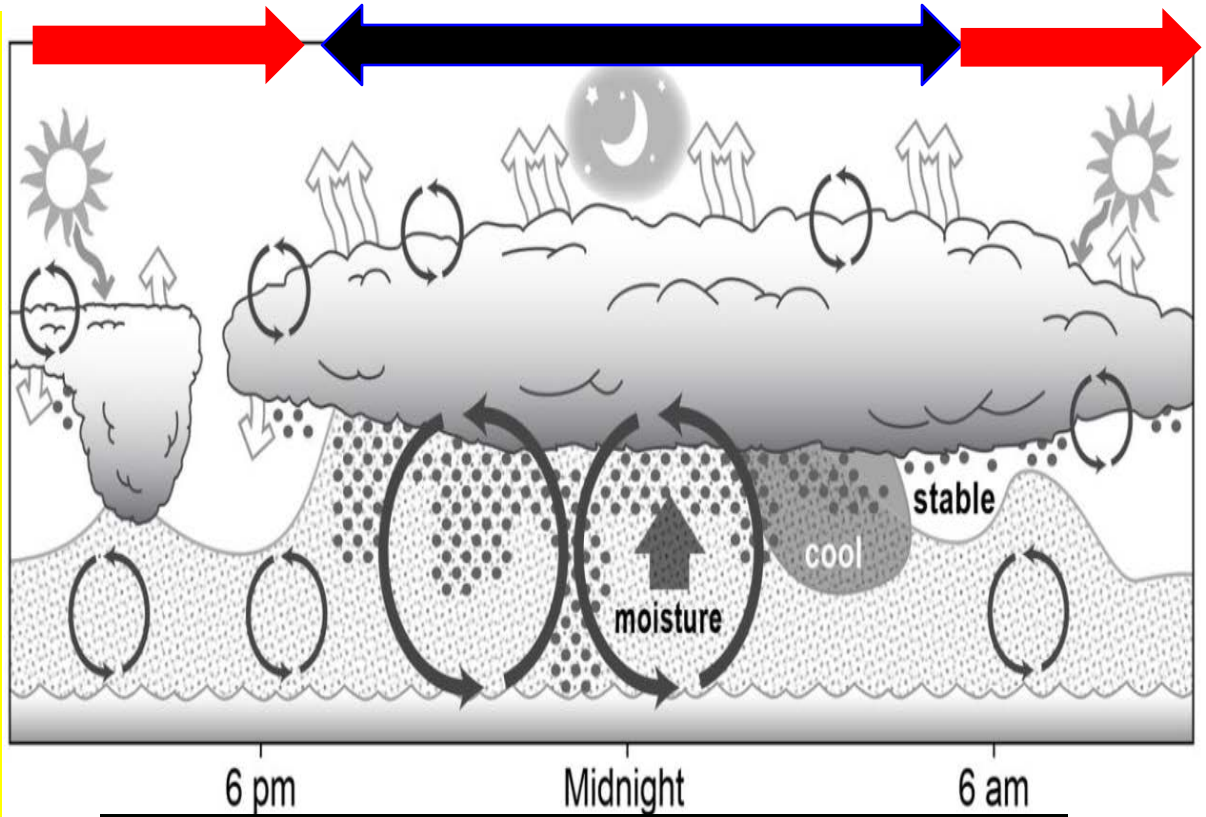
➔A strong temp. inversion at the top of the MBL, maintained by large-scale subsidence, combined with cold sea-surface temp., are ideal conditions favoring MBL clouds.



These MBL clouds are turbulently mixed from top to down due to LW radiative cooling at cloud top.

Night:
Turbulence➔cloud layer is high and deep with more LWP and LWC (well mixed)

Daytime:
Solar absorption at cloud top supresses Turbulence➔ cloud layer is low and thin with less LWP and LWC.



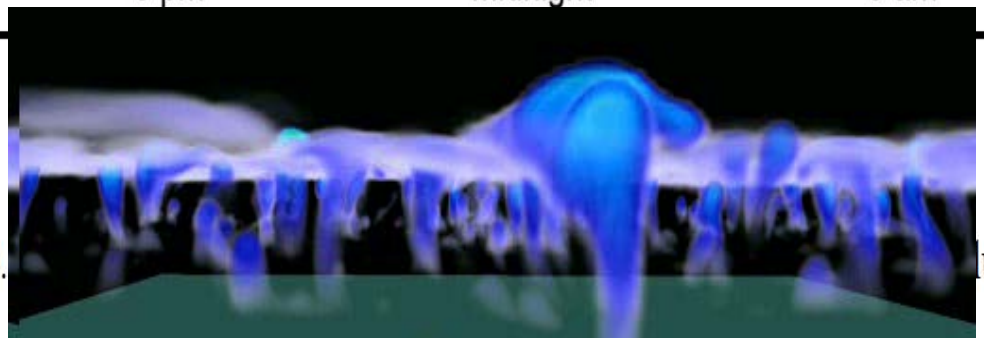


FIG. 12. ...lus cloud

Low cloud formation process over land

When the land surface is moist, solar absorption at the land surface can be converted into sensible and latent heat providing moisture directly to the cloud layer.
In contrast to MBL clouds, continental low clouds are usually mixed from the bottom up

Similarities and differences between Marine and Continental low clouds

Over Azores, the moisture comes directly from the surface, which also maintains a relatively stable temp. throughout the day.

➔20% well-mixed MBL (LCL within 150 m of cloud base height)

➔80 Decoupled MBL

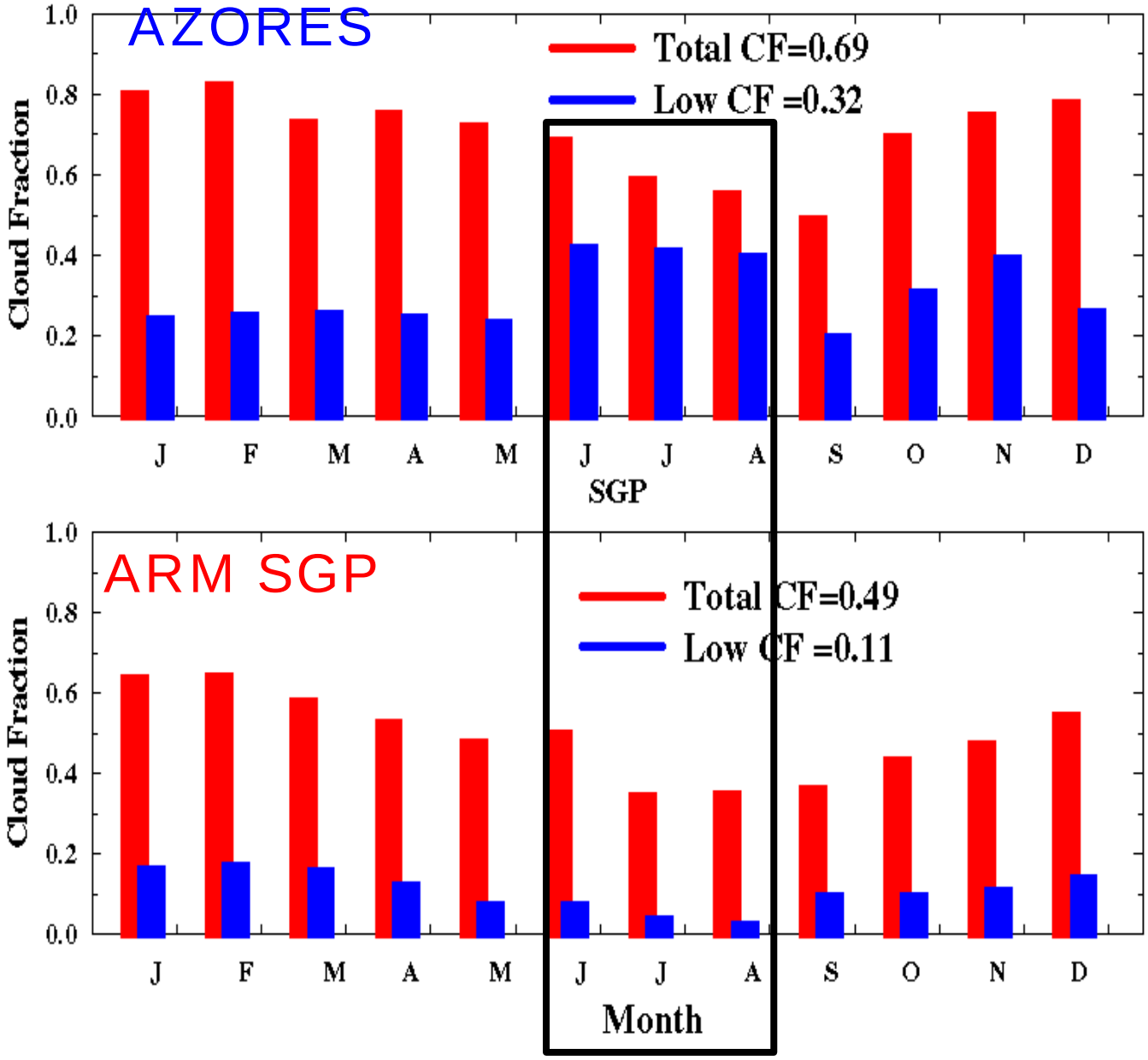
Over SGP, the water vapor is typically advected into the region with an air mass, as well as local evaporation.

➔23% clouds are well mixed boundary layer

➔77% Decoupled Boundary Layer

2a) Cloud Fractions at ARM Azores and SGP sites

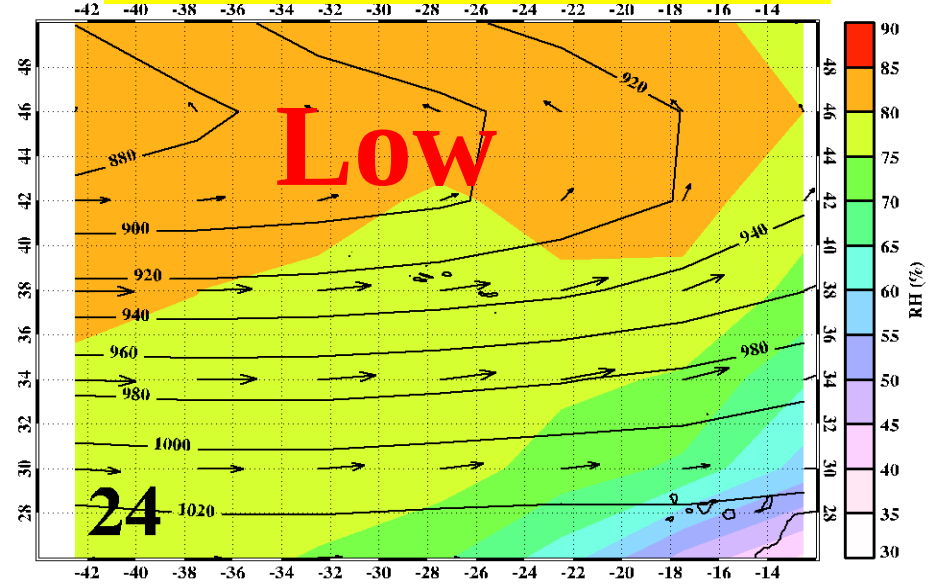
Seasonal Variations of CFs



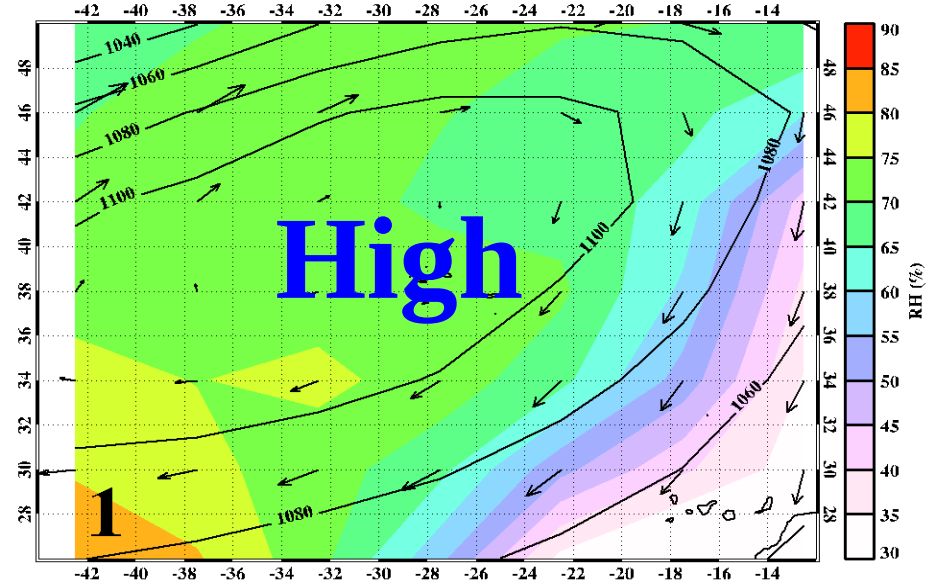
Similarity:
Total CFs decrease from winter to Summer at two sites

Difference:
Both total and Low clouds at Azores are much higher than those at SGP.
More single-layered low clouds at Azores during summer.

Azores, Winter



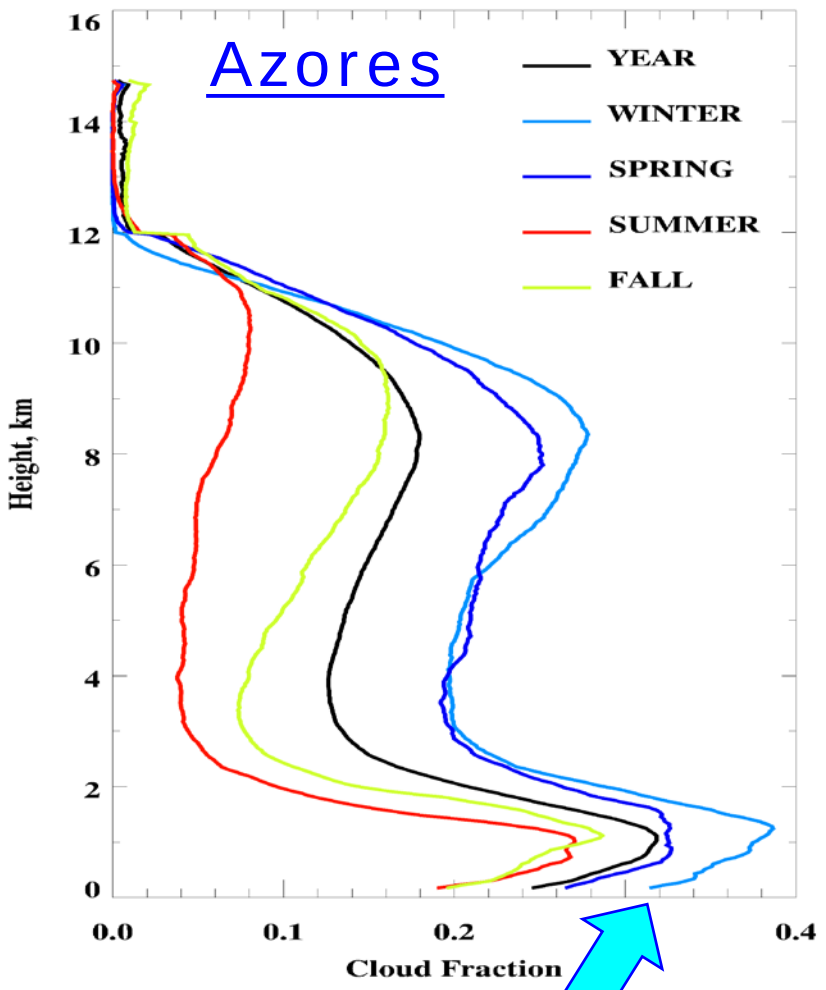
Azores, Summer

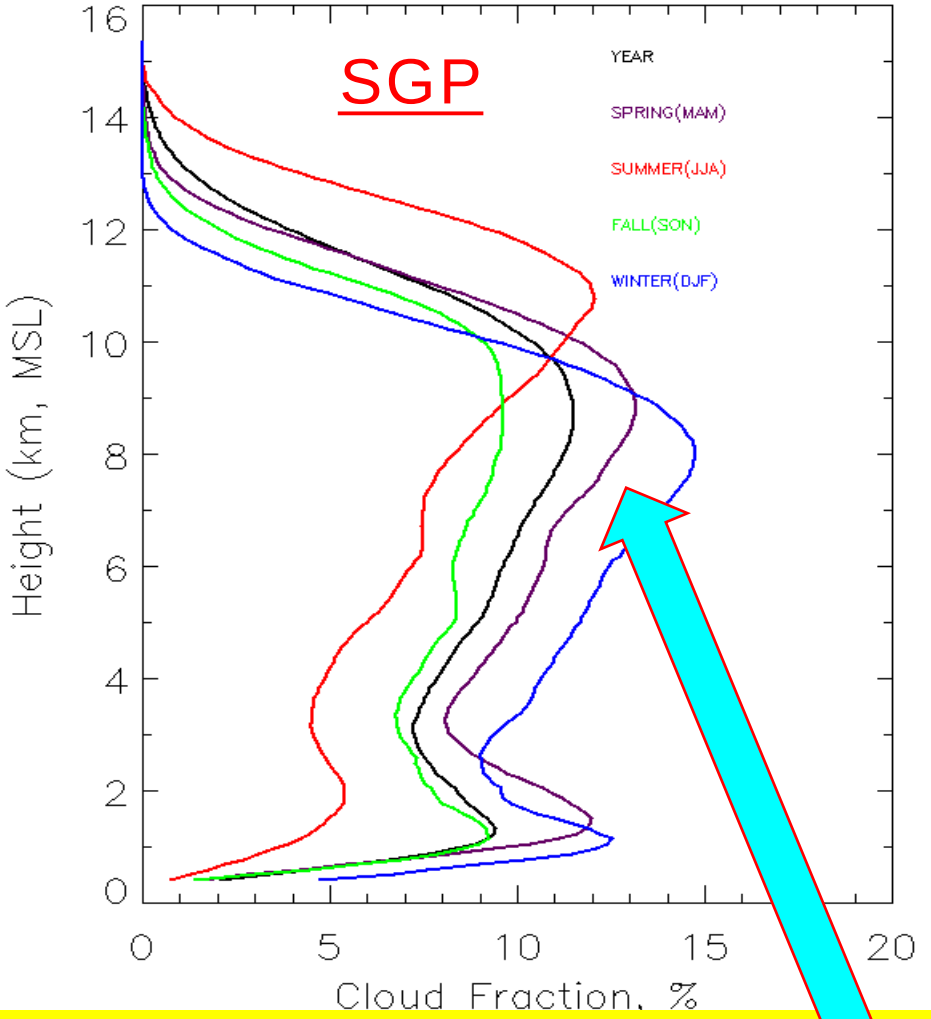


Winter: Low pressure systems and moist air masses generate more total and multilayered clouds, and deep frontal clouds associated with midlatitude cyclones.

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

Vertical distributions of CFs

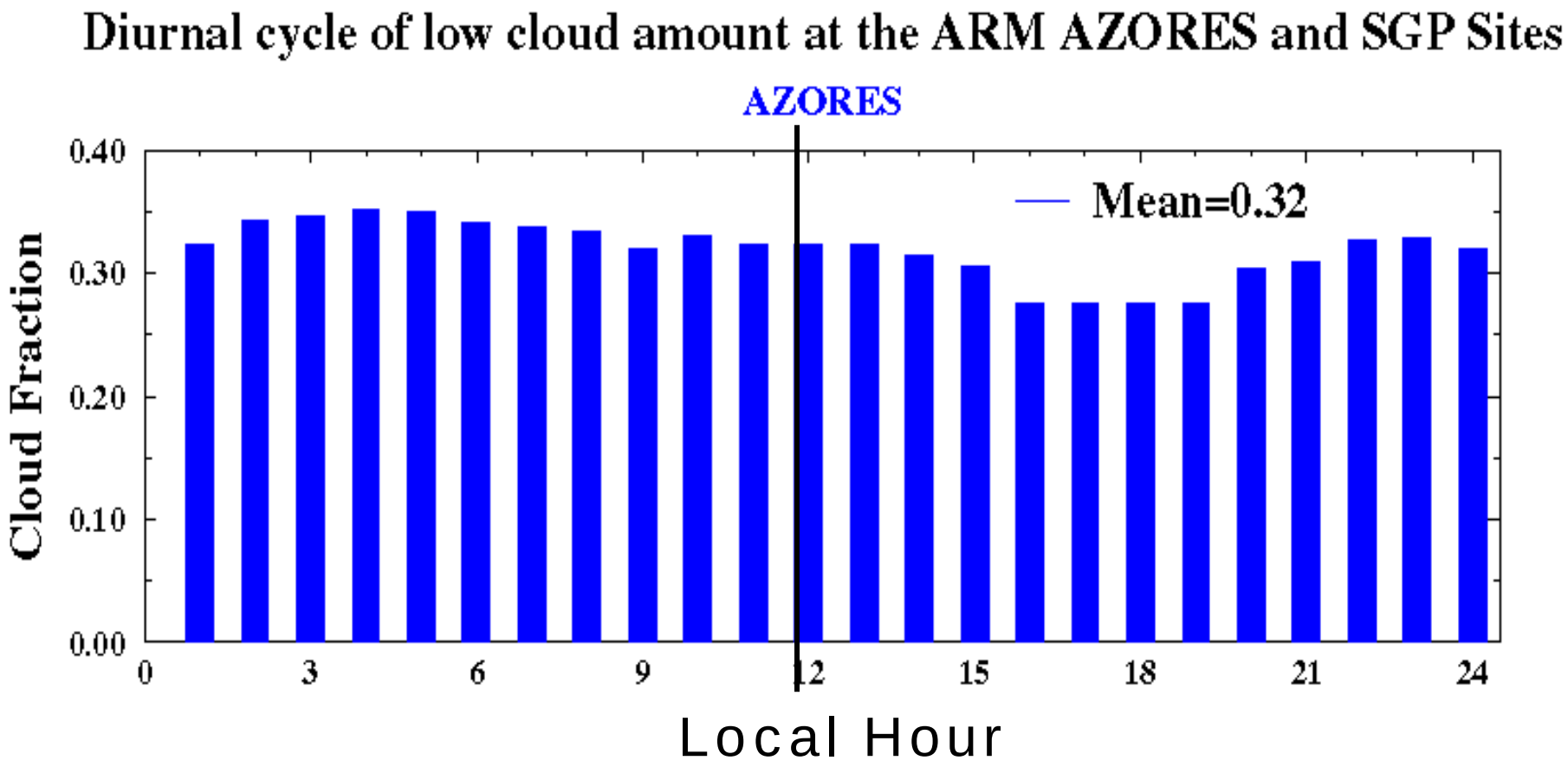




Similarity: Bimodally distributed at two sites, more clouds during winter and spring, less clouds during summe

Difference: More low clouds at Azores, but more high clouds at SGP

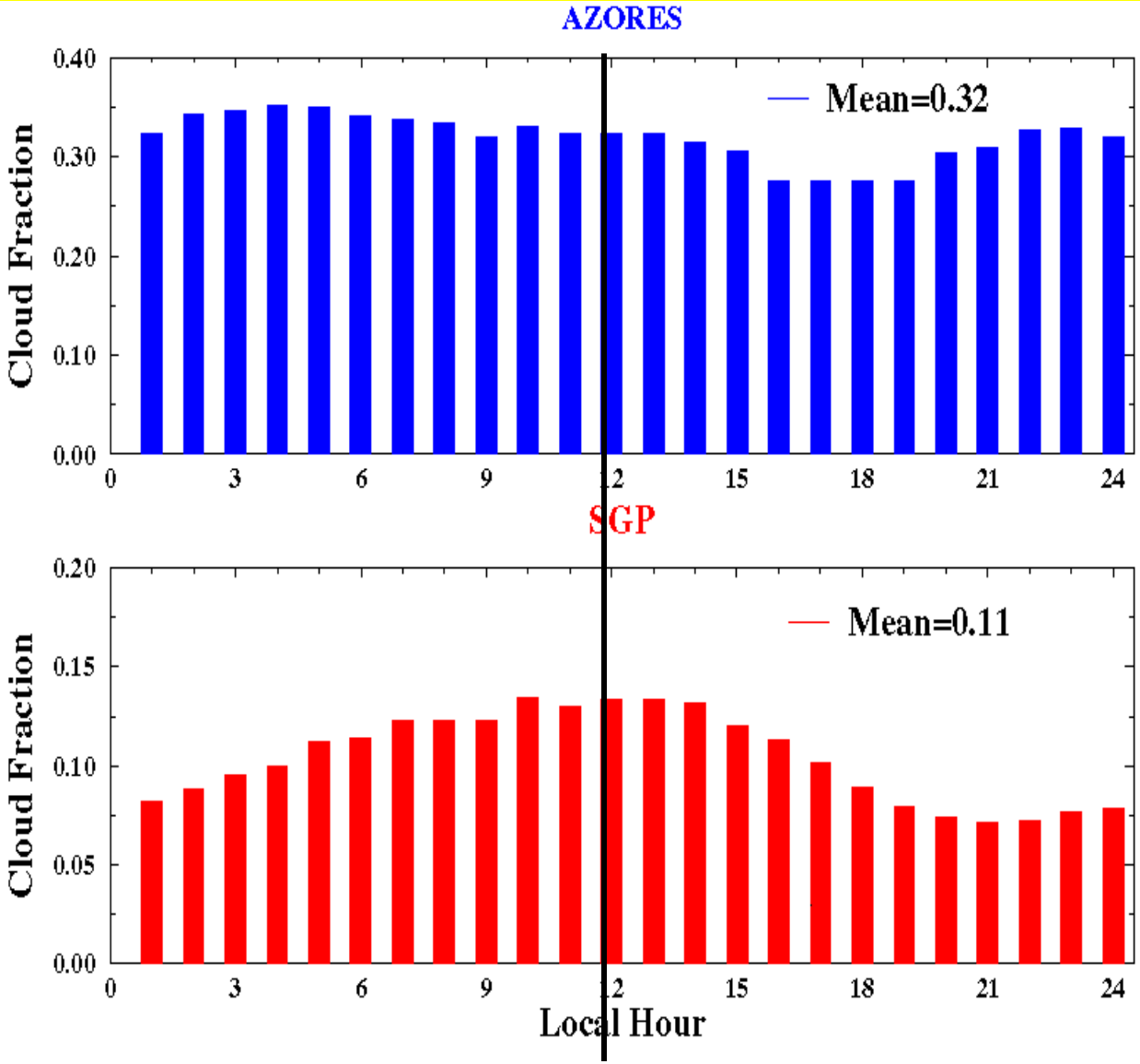
19 months of ARM radar-lidar data at Azores



➔More MBL clouds during night/morning than during afternoon due to strong turbulence (radiative cooling at cloud top at night)

➔During day, absorption of solar radiation near cloud top warms cloud layer and partially offsets the LW radiative cooling, which suppresses the turbulence and MBL cloud formation.

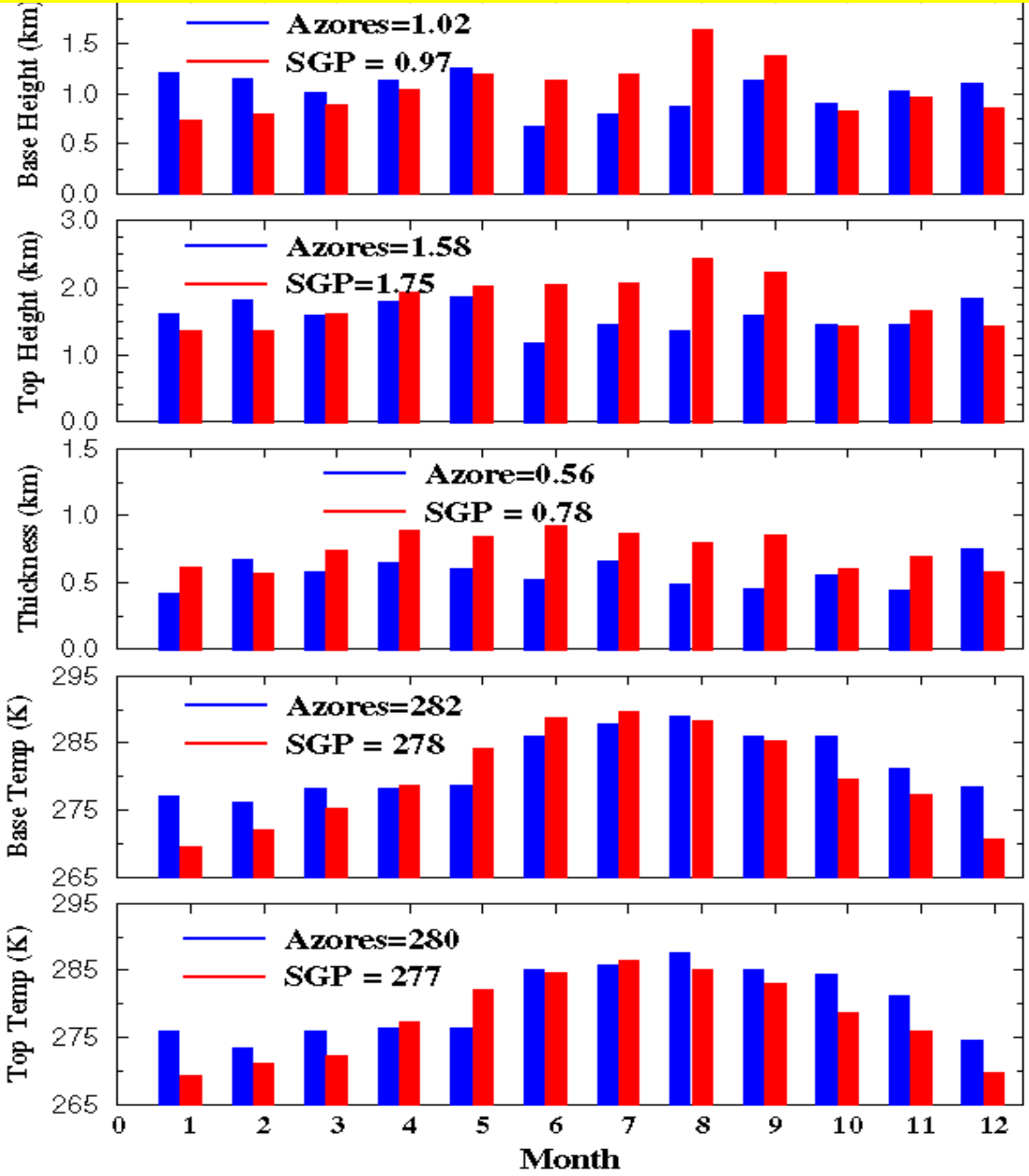
A NEW conceptual model of Continental Low-Level clouds (ARM SGP, Dong et al. J Clim 2005)



➔A strong diurnal cycle in continental low clouds than MBL clouds due to fast response of land from solar radiation.

2b. Low-level cloud macrophysical and microphysical properties

Seasonal Variations of height/temp

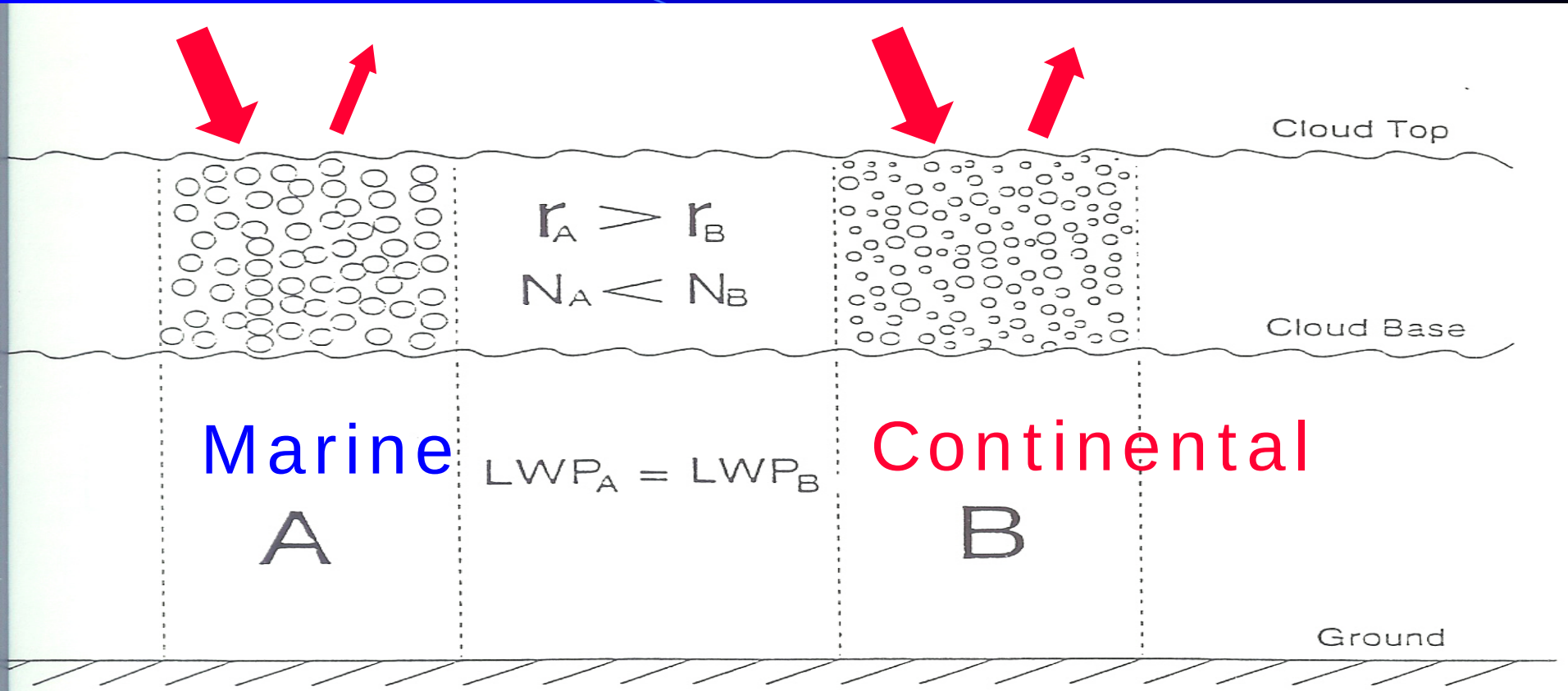


a-b) Cloud layer:
Azores: Winter/spring is deeper than summer/fall due to low-pressure systems
SGP is opposite due to strong solar radiation in summer

c) Cloud thickness:
SGP is thicker than Azores

d-e) Cloud Temps.
Strong seasonal variation at SGP than at Azores.

What are the aerosol-cloud interaction?

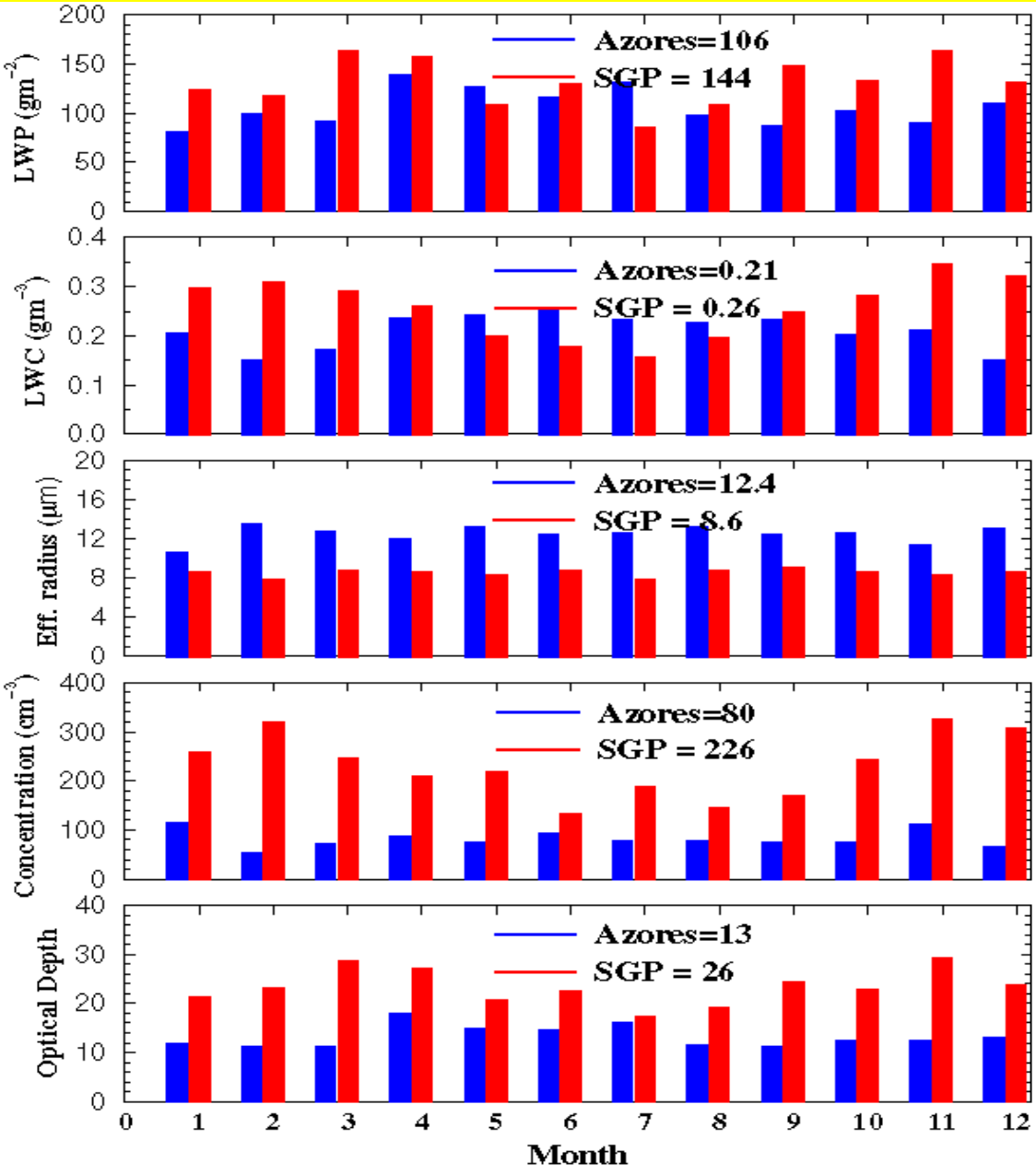


Continental: More aerosols➔More CCNs➔More small cloud droplets (B), they will

1) Reflect more sunlight
2) Last longer (less precipitation)

So, clouds will cool the Earth surface

Seasonal Variations of LWP/re/Nd/tau



a-b) LWP and LWC:

Azores: Summer higher than winter.

SGP: Opposite

c) Effective radius re:

SGP < Azores

No seasonal variation

d) Number concen. Nd

SGP > Azores

Azores: near constant

SGP: Higher in winter than in summer

Re and Nd represent typical continental and marine low cloud microphysics

e) Optical depth

SGP > Azores

Following their LWP patterns(tau=1.5LWP/re)

Similarity and difference between Marine and Continental low cloud Properties

At Azores:

a) Summer: MBL cloud layer is shallow, thin and warm with large *LWP* and *LWC*,

b) Winter: it is deep, thick and cold with less *LWP* and *LWC*.

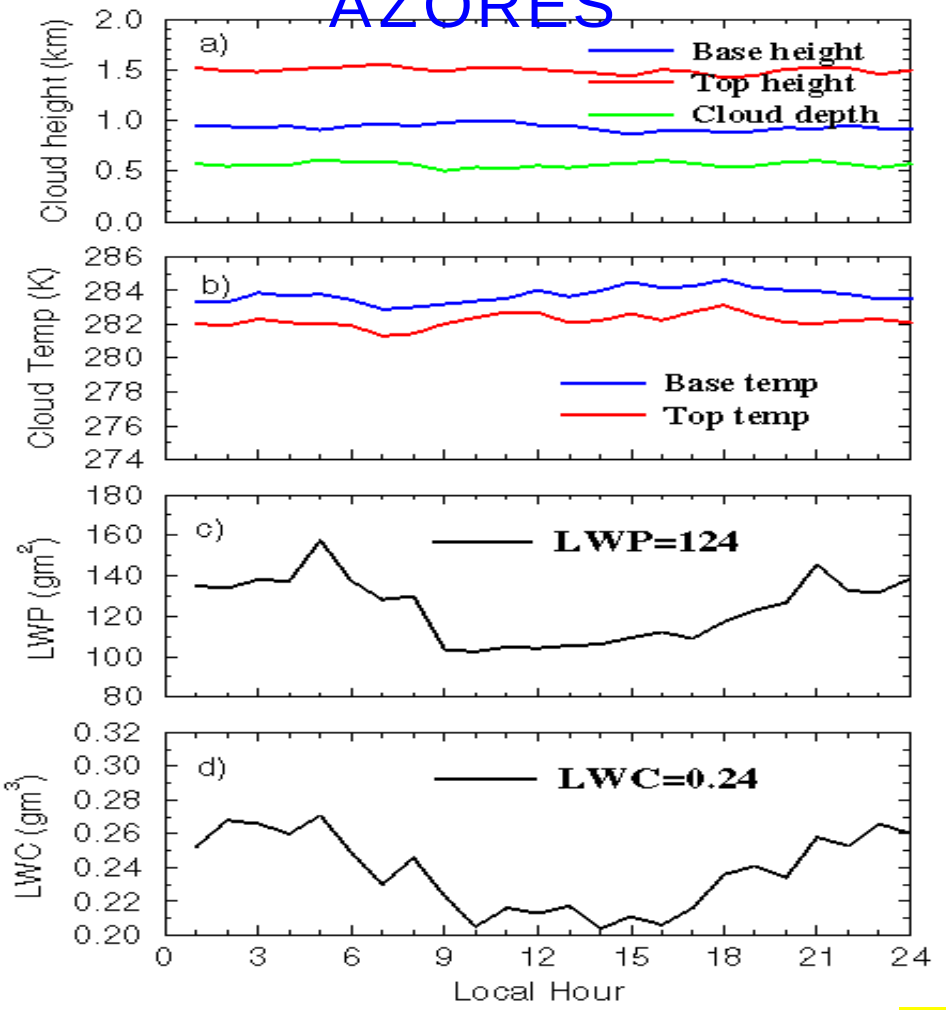
At SGP: Opposite to those at Azores

Low-level cloud layer is deeper, thicker, and warmer with less *LWP* and *LWC* during summer than those during winter.

Challenge: What processes control these similarities/differences? Can we model them?

Diurnal Cycle of cloud properties

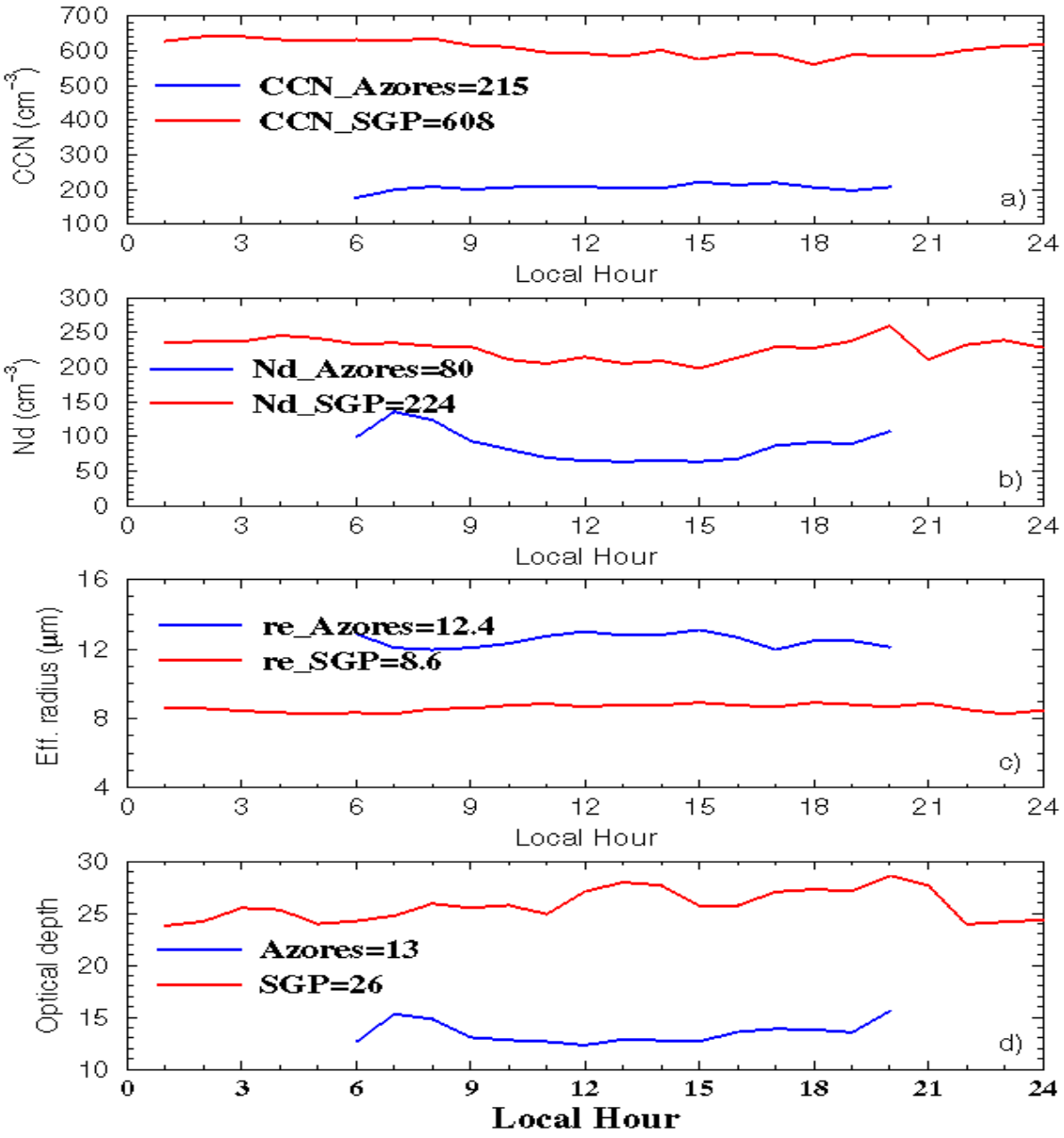
AZORES



Cloud heights, depth, and temps are nearly constant with higher LWP/LWC during night than during daytime.

In the morning, stratus cloud layer is low, thick and warm with less LWP/LWC, while in the afternoon it is deep, thin and cold with more LWP/LWC.

Diurnal cycle of microphysical properties



Overall: There are NO strong diurnal variations at two sites.

a-b) CCN and Nd
SGP >> Azores

c) Effective radius:
SGP < Azores

d) Optical depth
SGP > > Azores
Following their LWP patterns(tau=1.5LWP/re)

Summary of Azores and SGP clouds

Parameter	Azores	SGP
Total CF	0.70	0.49
Low CF	0.30	0.11

Both total and Low-level clouds at Azores are much higher than those at SGP.

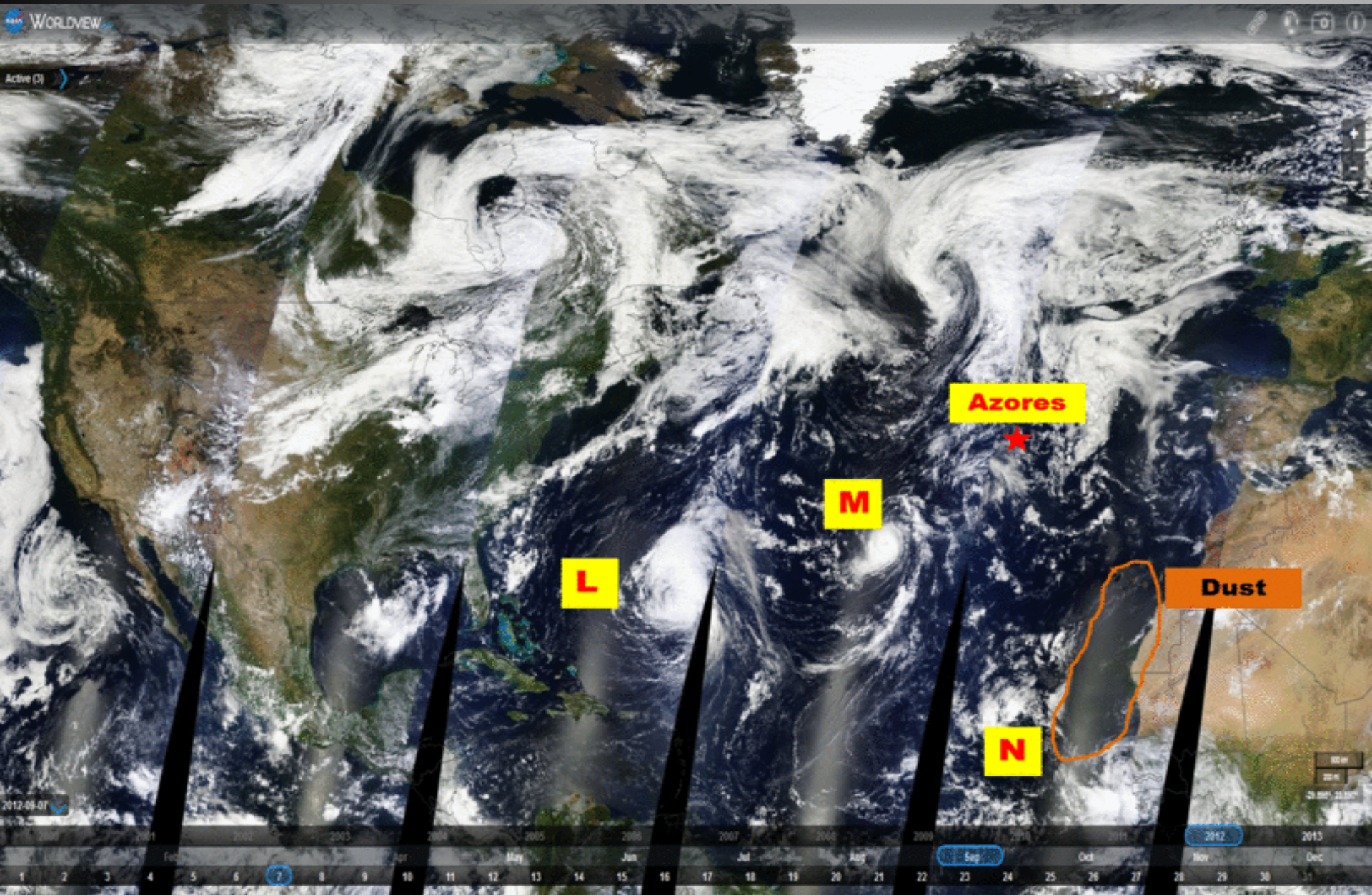
Azores: More clouds during winter/spring than during summer/fall.

Cloud bases at two sites are same, but Azores cloud top, depth, temp are shallow, thin and warm than at SGP.

At Azores, cloud layer, depth, and tem
higher LWP/LWC during night than dur
At SGP, stratus cloud layer in the mo
thick and warm with less LWP/LWC, v
afternoon it is deep, thin and cold wit

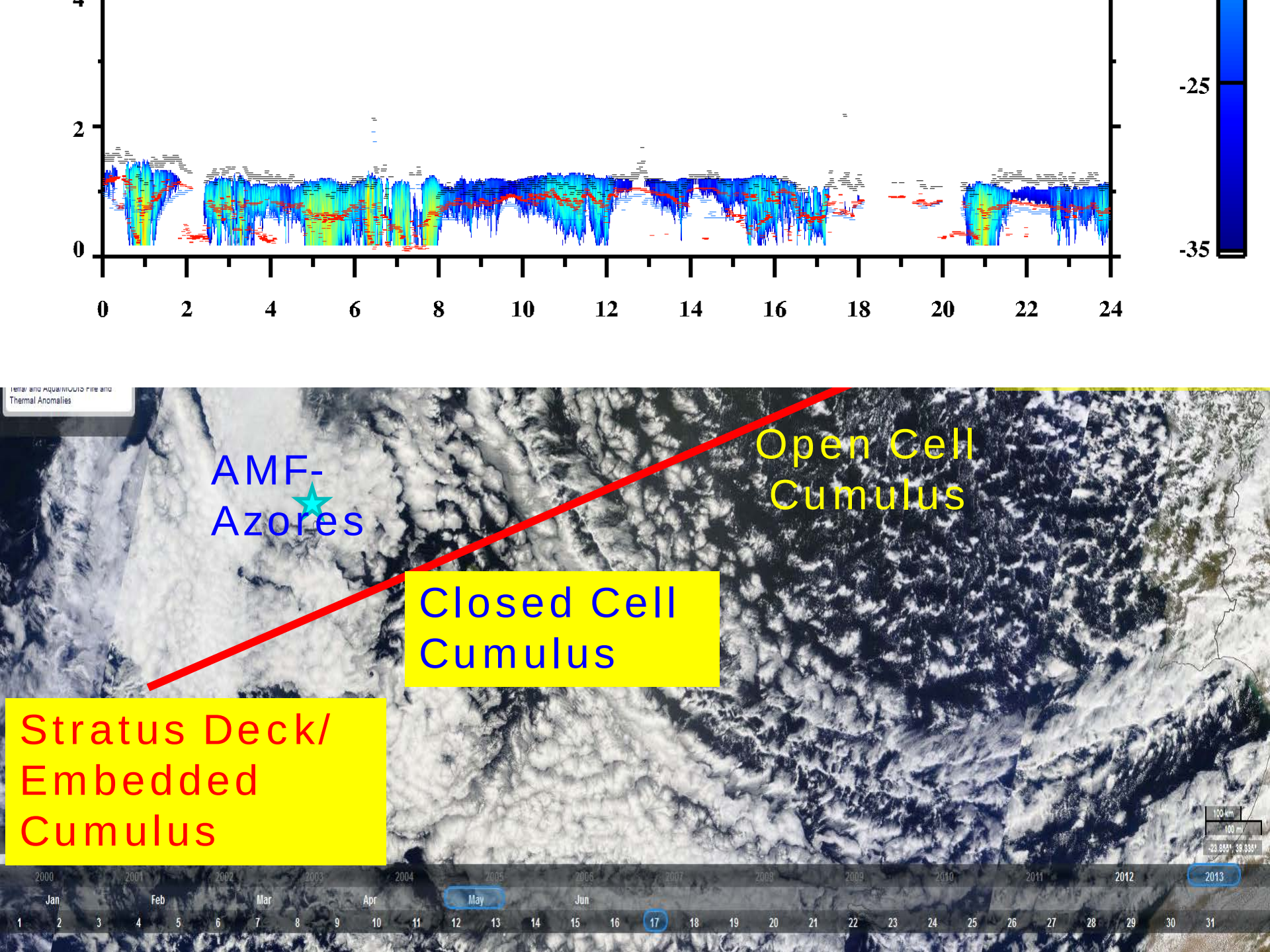
The differences between Marine and continental cloud u-properties are significant.

Animation of Hurricane Nadine



A new Tool for remote Sensing

NASA Global Hawk onboard Lidar measured Sahara Dust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AMF-
Azores
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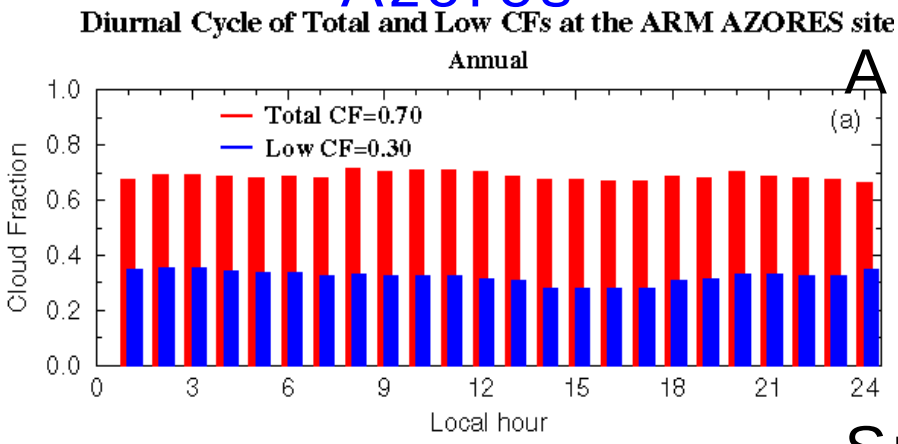
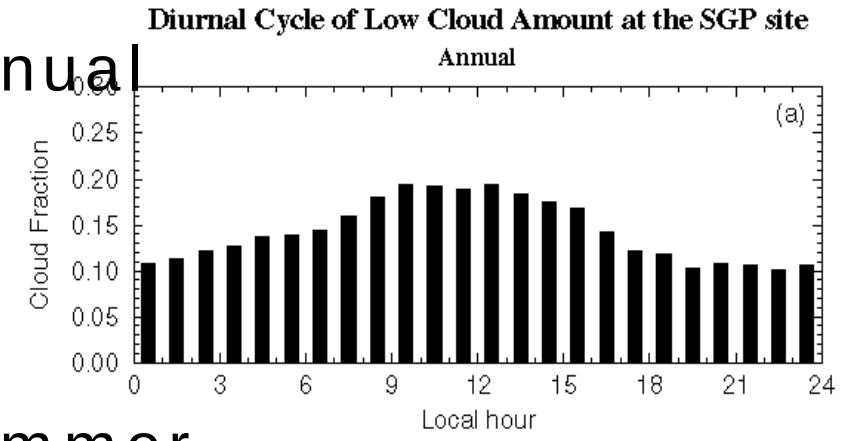
Cumulus
Closed Cell
Cumulus
Stratus Deck/
Embedded
Cumulus

Azores

SGP

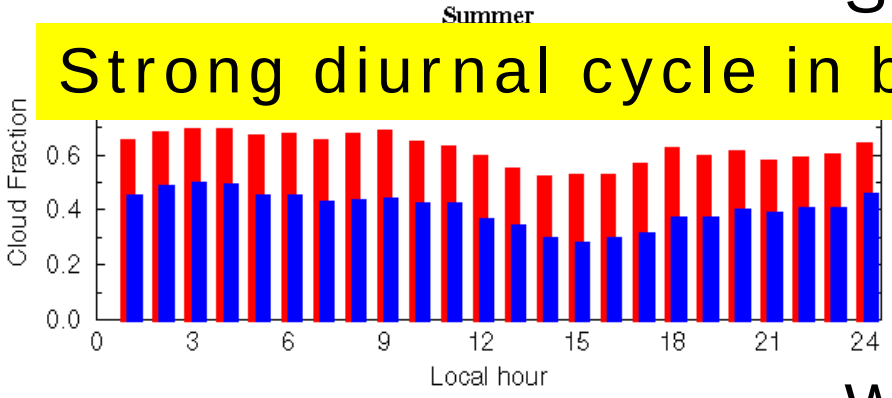


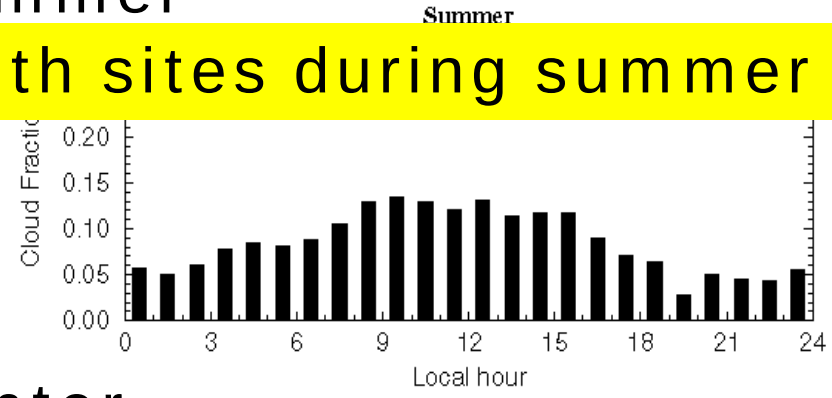


Annual

Summer

Strong diurnal cycle in both sites during summer





Winter