The Transition from Sc to Sc-Cu cloud condition during MAGIC

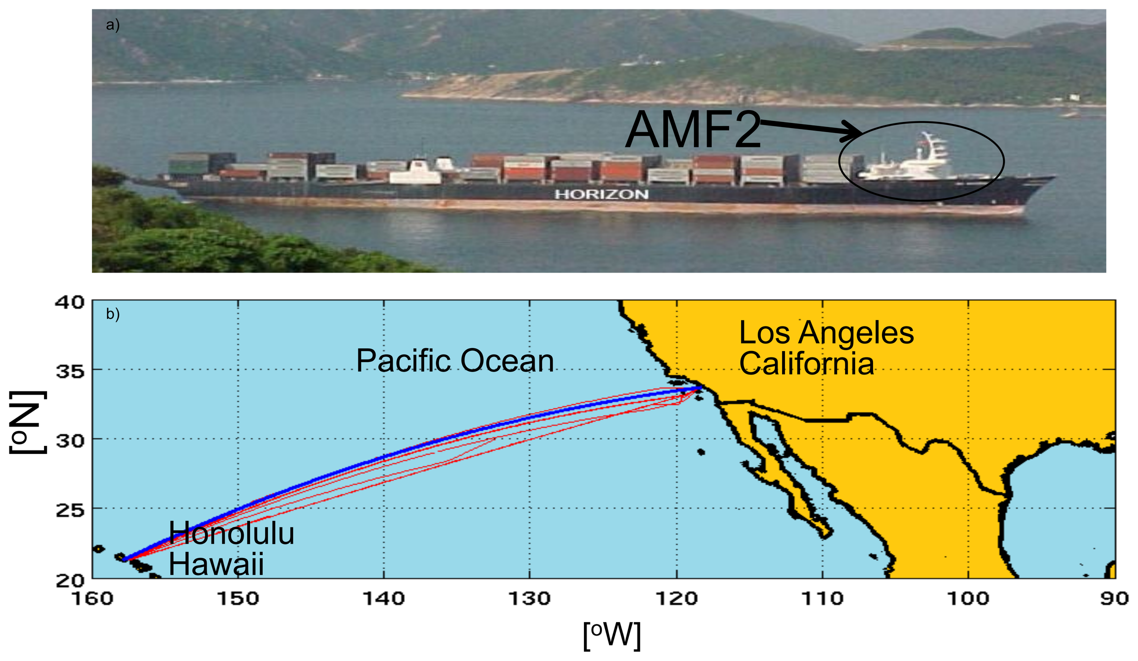
Xiaoli Zhou[1], Pavlos Kollias[1] and Ernie R. Lewis[2]
[1]Department of Atmospheric and Oceanic Science, McGill University, Montreal, QC, Canada
[2]Environmental Science Department, Brookhaven National Laboratory, Upton, NY

Introduction

- Marine Boundary Layer (MBL) clouds exert an outsized influence on the global radiation budget, hydrological cycle, and thus in climate and climate change.
- Observation show that important climatic cloud transitions occur from stratocumulus (Sc) regimes with high coverage off the coast of California, to cumulus (Cu) regimes with much lower coverage close to Hawaii, and then eventually to deep convective Cu over the Intertropical Convergence Zone (ITCZ).
- Global weather and climate prediction models are notoriously inadequate in reproducing the transitions of MBL cloud regimes.
- A recent field Campaign MAGIC was launched to improve the understanding of Sc-to-Cu transition.

MAGIC

MAGIC: the Marine Atmospheric Radiation Measurement Program (ARM) Global Energy and Water Cycle Experiment (GEXWEX) Cloud System Studies (GCSS) Pacific Cross-section Intercomparison (GPCI) Investigation of Clouds.



From October 2012 through October 2013, 20 round trips was made between Los Angeles, California, and Honolulu, Hawaii with the second ARM Mobile Facility (AMF2) deployed on the container ship Spirit. Each round trip is called a "leg" and legs are numbered sequentially as "LegxxA" and "LegxxB" for the trip from Los Angeles to Honolulu and for the return trip respectively.

Methodology

Cloud type classification:
-Use the KAZR-derived hydrometeor mask and ceilometer cloud base height to define Cloud tops and bases and get cloud mask;
-Define clouds using cloud mask as clusters of more than 25 connected pixels;

		Cloud Type					
				BL cld			
		Cirrus	Alto	Cu	Sc	Ind	Deep Conv.
Minimum cloud base		≥ 6 km	[2 km, 6 km]	< 3km	< 3 km	< 2 km	< 2 km
Maximum cloud top		—	—	< 3 km	< 3 km	< 3 km	≥ 3 km
Duration		—	—	< 20 min	≥ 20 min	≥ 20 min	—
CT variability based on cloud duration	[20 min, 2 hr]	—	—	—	< 100 m	≥ 100 m	—
	(2 hr, 10hr]	—	—	—	< 160 m	≥ 160 m	—
	> 10 hr	—	—	—	< 200 m	≥ 200 m	—

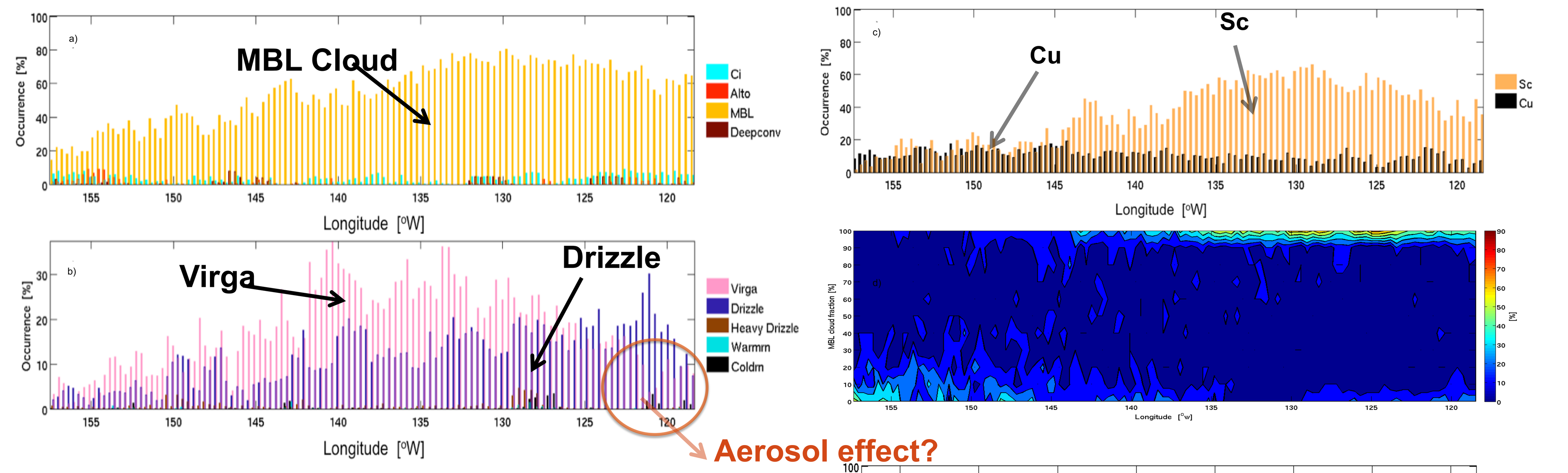
Precipitation type classification:
-A KAZR echo is classified as precipitation if it is detected below the ceilometer cloud-base height.

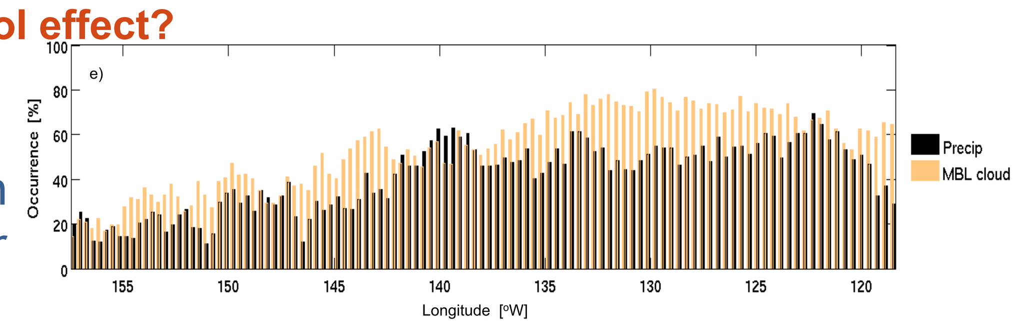
	Precipitation Type				
	Virga	Drizzle	Warm Rain (Heavy Drizzle)	Cold Rain	Conv. Rain
Echo base	> First gate	≤ First gate	≤ First gate	≤ First gate	≤ First gate
Base reflectivity	—	<0dBZ	>0dBZ	>0dBZ	>0dBZ > First Top reflectivity
Surface Rain	No	No	Yes	Yes	Yes
First cloud top	< Freezing level	< Freezing level	< Freezing level	> Freezing level	—
Echo below cloud base	Yes (50 m lower)	Yes (50 m lower)	Possible	Possible	Possible

Quantify inversion and transition layer using radiosonde:
-A inversion is detected somewhere between 500 m and 3 km by the level of maximum increase of temperature with height. The inversion layer location is then defined as all levels around it still characterized by an increase of temperature constrained by the decreasing water vapor mixing ratio with height.
-The transition is detected as long as the maximum value of μ is positive and greater than 1.3 times the vertical mean value of μ based on Yin and Albrecht 2000:

$$\mu = -\left(\frac{\partial\theta}{\partial p} - \frac{0.608\theta}{1+0.608r}\frac{\partial r}{\partial p}\right)$$

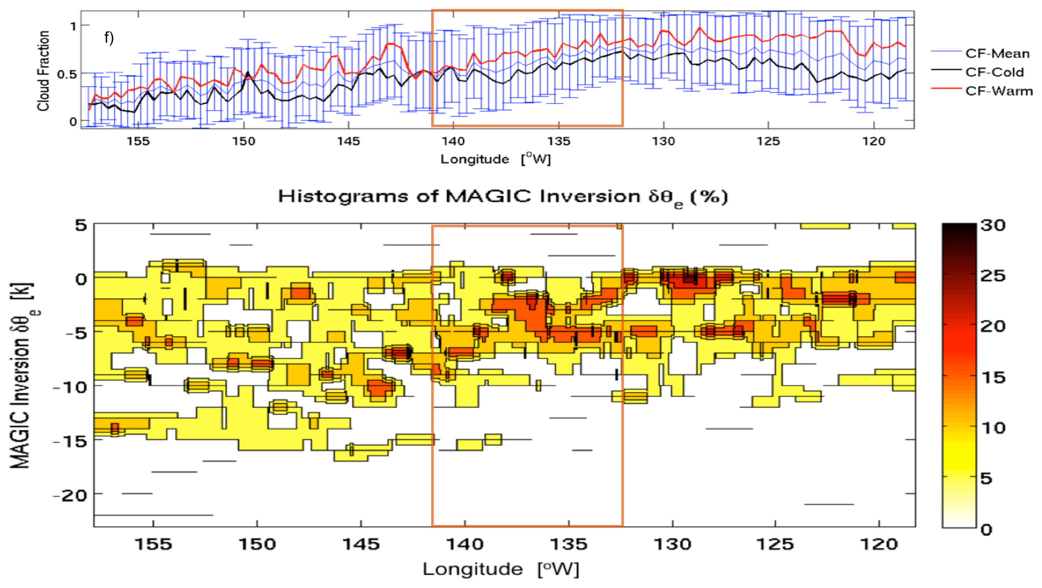
Statistical Results

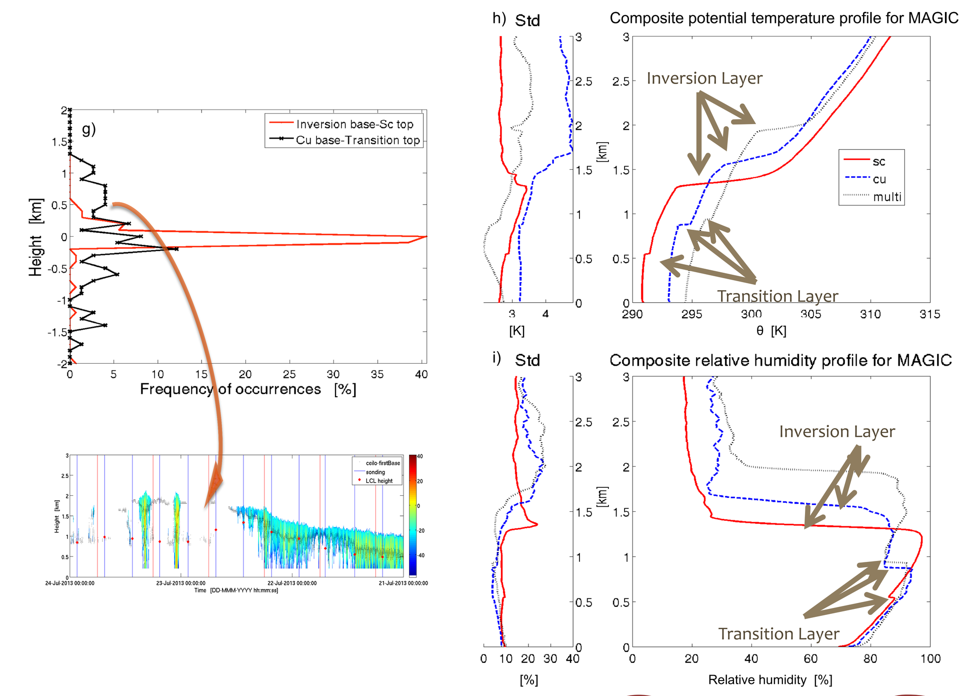




a. MBL clouds dominate the whole MAGIC transect
b. Virga and drizzle are the primary precipitation type. Virga dominates the transect except near the cost of California.

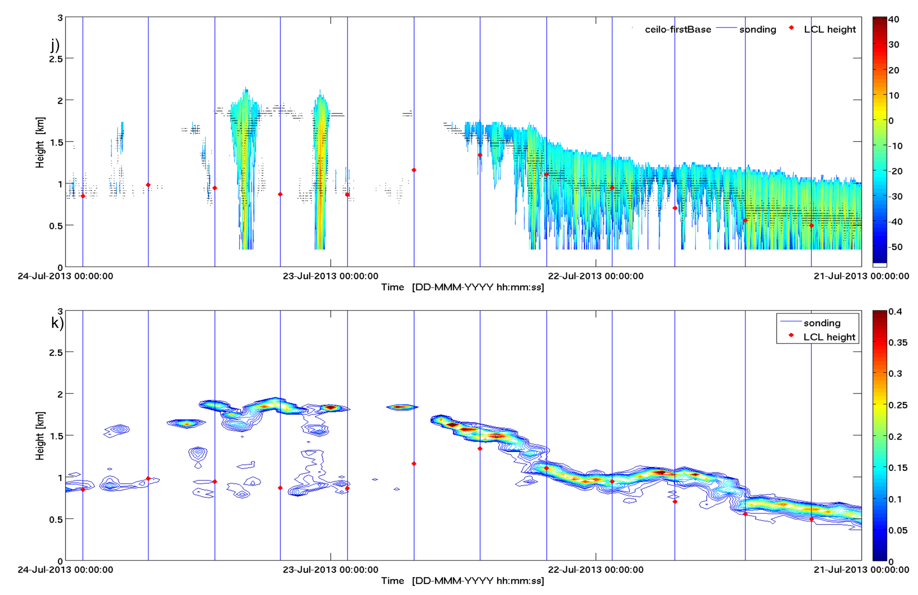
c. Sc sees higher frequency of occurrence east of 145 °W and decrease to 10% near Hawaii, while Cu increase gradually from 3% near California to over 10% near Hawaii.
d. Clear bimodal structure of CF distribution with 100% east of 145 °W and 0% to the west
e. On average over 73% of the MBL is consistent with precipitation. The evident decrease of the frequency of MBL occurrence coincide with the sudden increase of the precipitation, suggesting that precipitation might inhibit the MBL clouds.

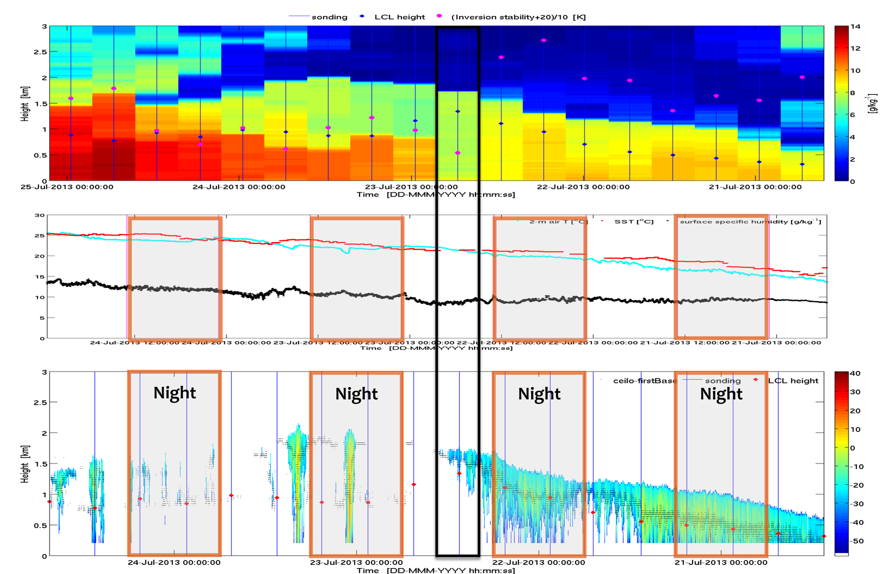




f. The mean MBL cloud fraction generally decreases from 0.7 to 0.2 from California to Hawaii and has the fastest decrease between 133 °W and 143 °W, coinciding with the sharp decrease of the inversion stability.
g. The Sc tend to form right below the inversion layer. Although the Cu show broader distribution, most of the Cu occur above or inside the transition layer.
h. The Sc exhibit the lowest but strongest inversion layer, together with the weakest transition layer, suggesting sufficient moisture supply from the sea surface; Cu see the highest and weakest inversion layer, with the strongest transition layer, implying a greater chance to entrain dry air and be separated from the surface moisture supply.
i. The dryer air between the transition and the inversion layer in the case of Cu(blue dashed line) is very difficult for the Sc to maintain.

Case Study





j. A case from leg15A showing the transition between single-layer Sc to double-layer Sc-Cu.
k. The corresponding frequency of cloud base occurrence.
l. A minimum specific humidity in the vertical air column coincides with the starting of the decoupling

xiaoli.zhou@mail.mcgill.ca