Cloud, Precipitation and Marine Boundary Layer Structure during MAGIC

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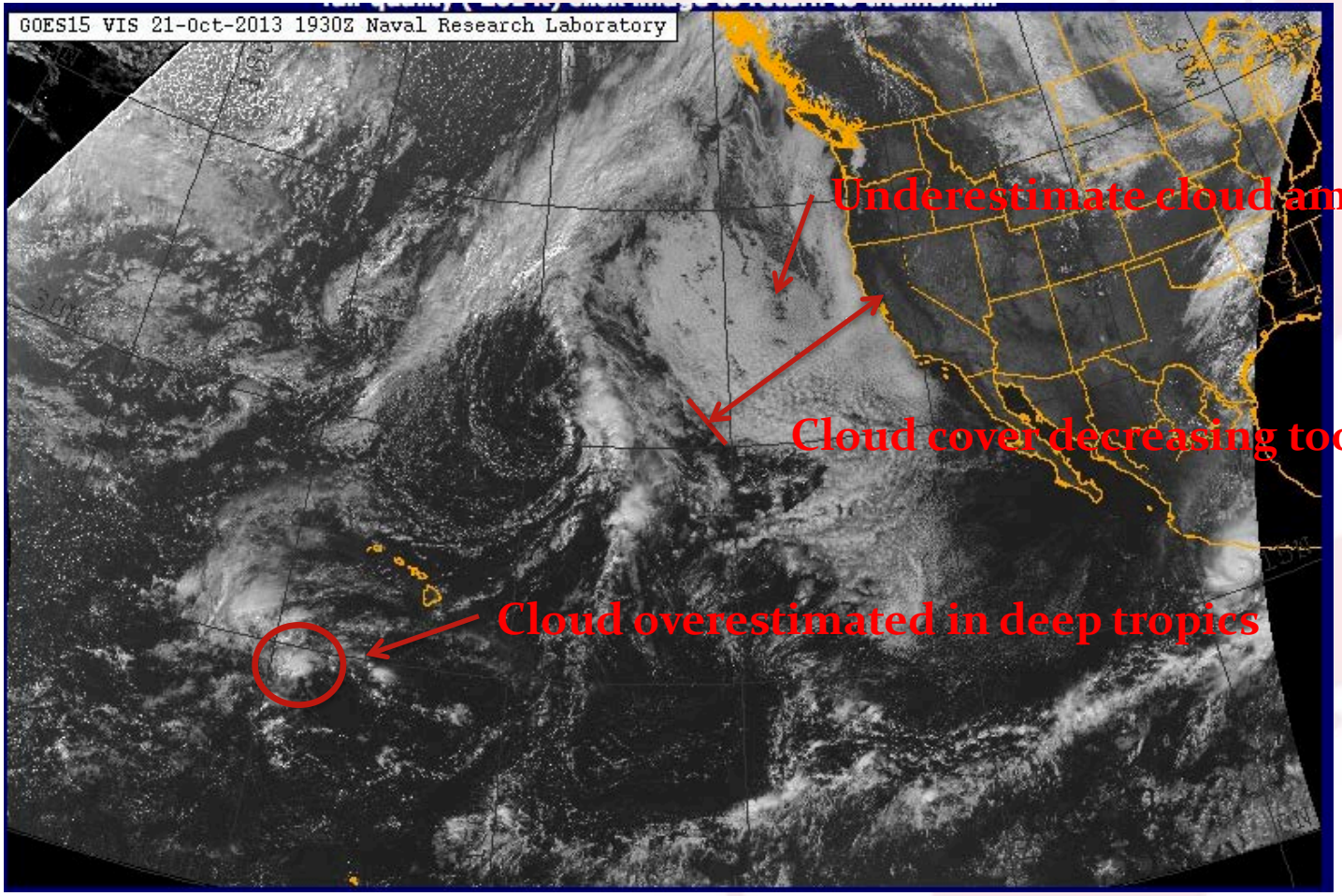
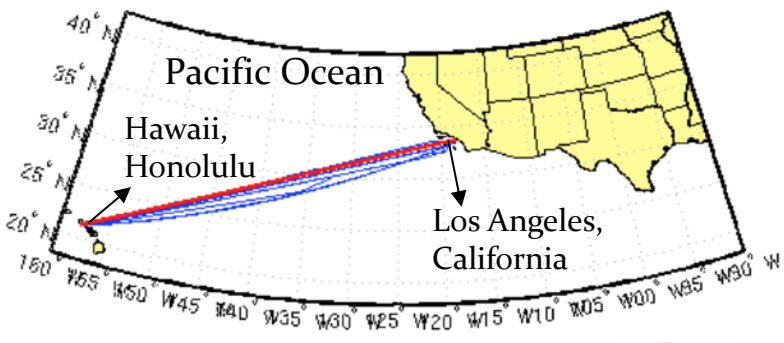
Motivation

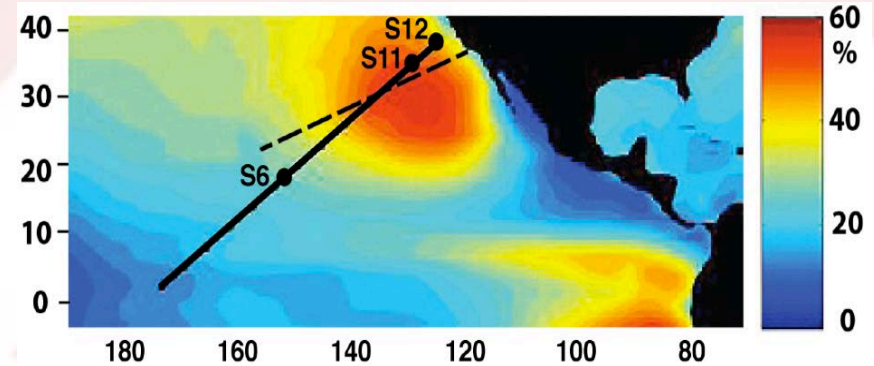


J. Teixeira et al. 2011

MAGIC

- 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 (http://www.arm.gov/sites/amf/mag/)





Annual average low-level cloud cover from ISCCP (International Satellite Cloud Climatology Project), with Horizon Spirit route (dashed) from Los Angeles to Honolulu and GPCI transect (solid)

- From October 2012 through October 2013
- The Horizon Lines cargo container Spirit
- between Los Angeles (LA), California, and Honolulu (HH), Hawaii
- Great circle route
- 21 round trips
- 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.

Data during MAGIC

Leg0a		Leg0b	
Leg1a		Leg1b	
Leg2a		Leg2b	
Leg3a		Leg3b	
Leg4a		Leg4b	
Leg5a		Leg5b	
Leg6a		Leg6b	
Leg7a		Leg7b	
Leg8a		Leg8b	
Leg9a		Leg9b	
Leg10a		Leg10b	
Leg11a		Leg11b	
Leg12a	Ceilo missing (Jun. 8-10)	Leg12b	
Leg13a		Leg13b	
Leg14a	IOP	Leg14b	IOP
Leg15a		Leg15b	
Leg16a		Leg16b	
Leg17a		Leg17b	
Leg18a		Leg18b	Sounding data missing
Leg19a	Sounding data missing	Leg19b	Sounding data missing
leg20a		leg20b	

AMF2 instruments: KAZR, Ceilometer, MWR, AOSMET, Radiosonde

Only data in leg3-8,11-17 are analyzed in this study

KAZR data not available or are not continuous during the whole section

Radiosonde data missing during the whole section

Ceilometer data availability

IOP: Intensive Observation Periods (Radiosondes launched 8 times per day)

METHODOLODGY

- **Mask** (KAZR)
  - Identifying the radar range gates that contain significant returns from atmospheric targets

- **Precipitation classification** (KAZR mask, ceilometer, MWR, AOSMET, radiosonde)
  - Define Virga, drizzle, warm rain, cold rain and deep convective rain type

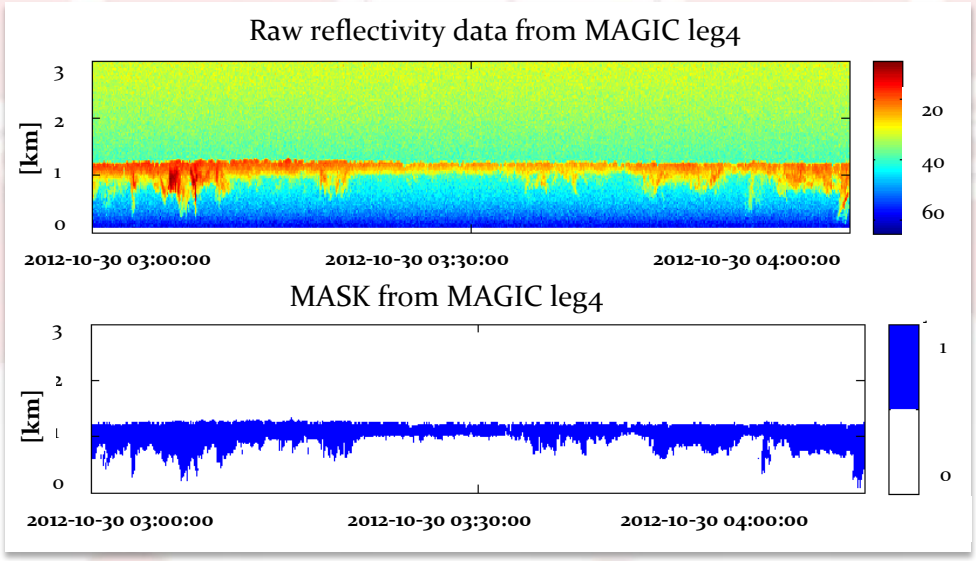
- **Cloud classification** (KAZR mask, ceilometer)
  - Define Cirrus, Alto clouds, Boundary Layer (BL) Clouds and Deep Convective Clouds
  - Define subtypes of BL clouds: Stratocumulus (Sc), Cumulus (Cu), Indeterminate (Ind)
  - Identify cloud tops and bases

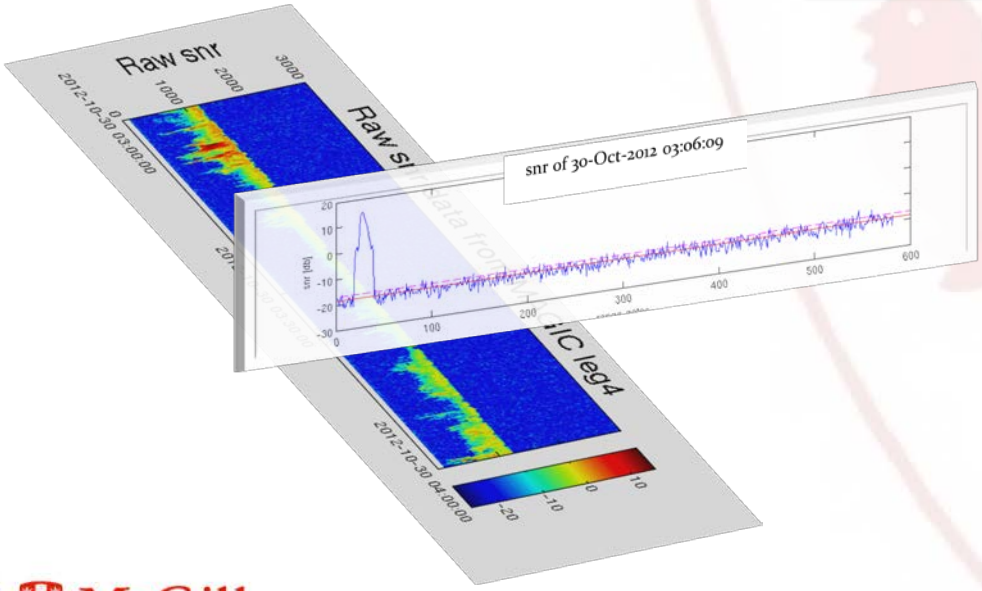
- **Radiosonde analysis**
  - Quantitatively define Inversion and Transition layers (tops and bases)
  - Averaging various profiles together by a layer-by-layer procedure

Mask

Two steps:
Remove receiver noises:
Use a two-dimensional (time-height) filter.

Importance of KAZR mask:
Estimate the number of hydrometeor layers in the atmospheric column and their corresponding boundaries.

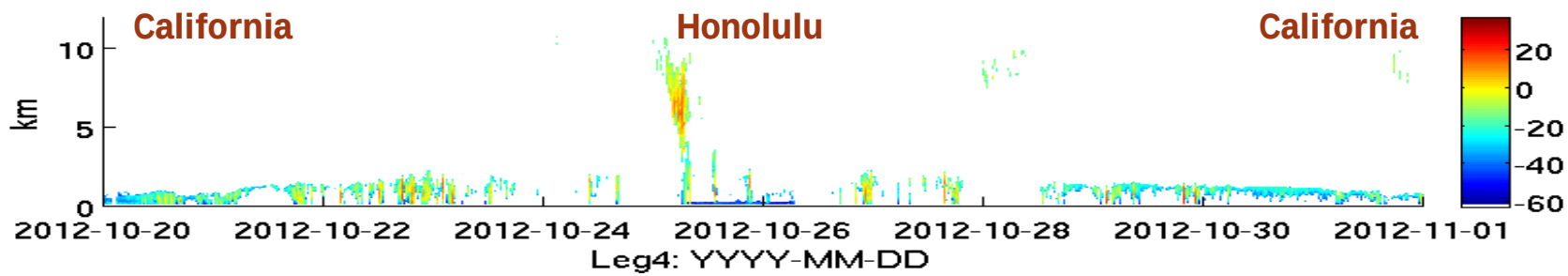


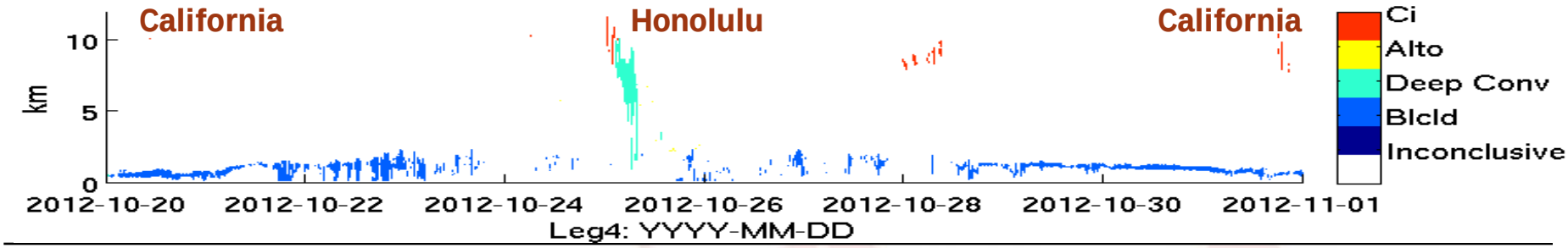


Based on Hildebrand and Sekhon (1974) :

2-D signal-to-ratio (snr) data
→ 1-D snr

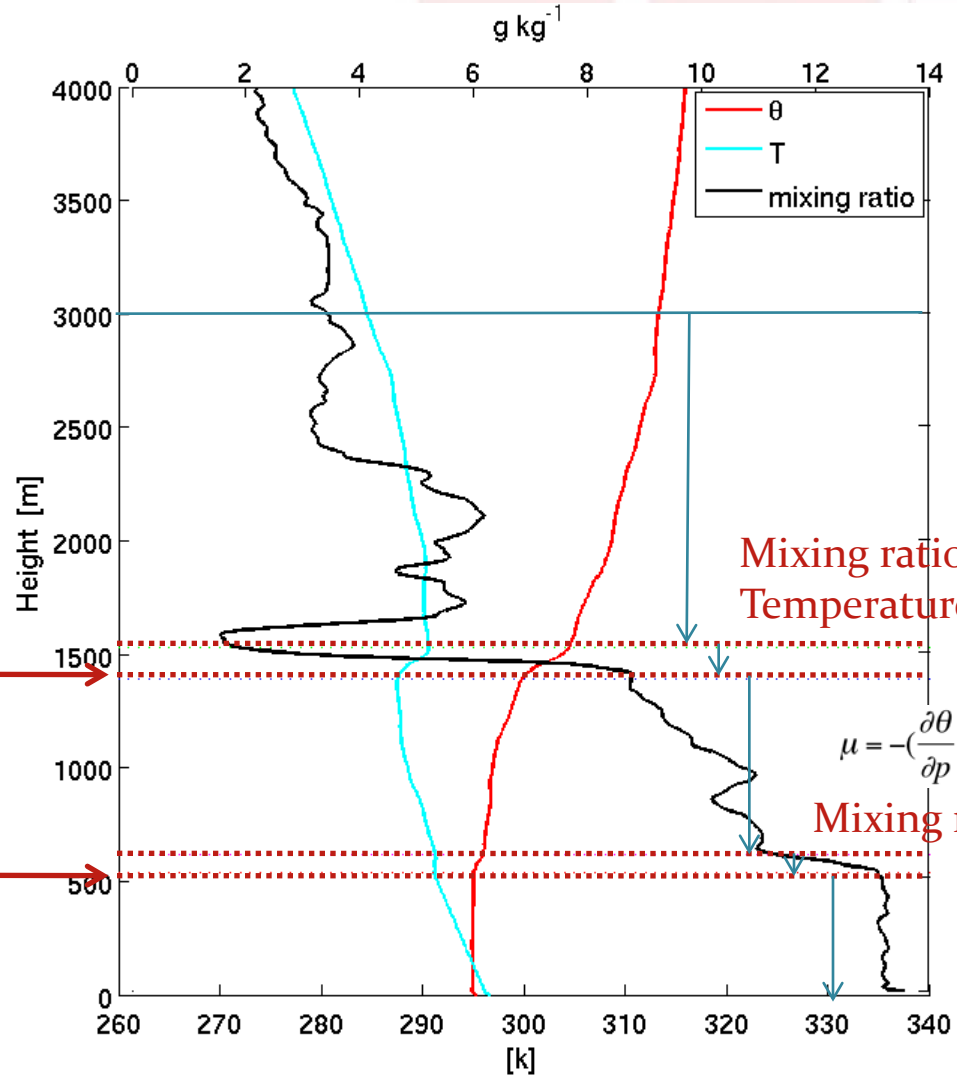
Precipitation and Cloud Classification





		Cloud Type					
				BL cld			
		Cirrus	Alto	Cu	Sc	Ind	Deep Conv.
Minimum cloud base		≥ 6 km	[2 km, 6 km]	< 2 km	< 2 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	—

Radiosonde Analysis



Inversion Layer

Transition Layer

Mixing ratio decrease with height

Temperature strongly increase with height

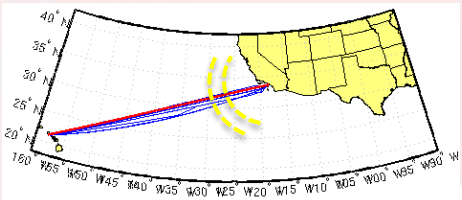
$$\mu = -\left(\frac{\partial \theta}{\partial p} - \frac{0.608\theta}{1+0.608r}\frac{\partial r}{\partial p}\right)$$

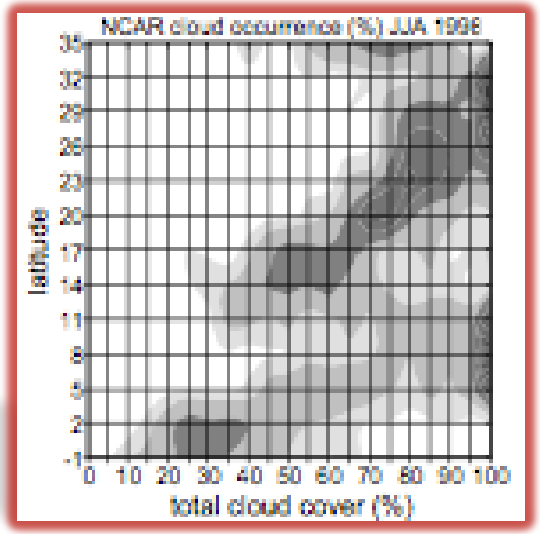
Mixing ratio decrease with height

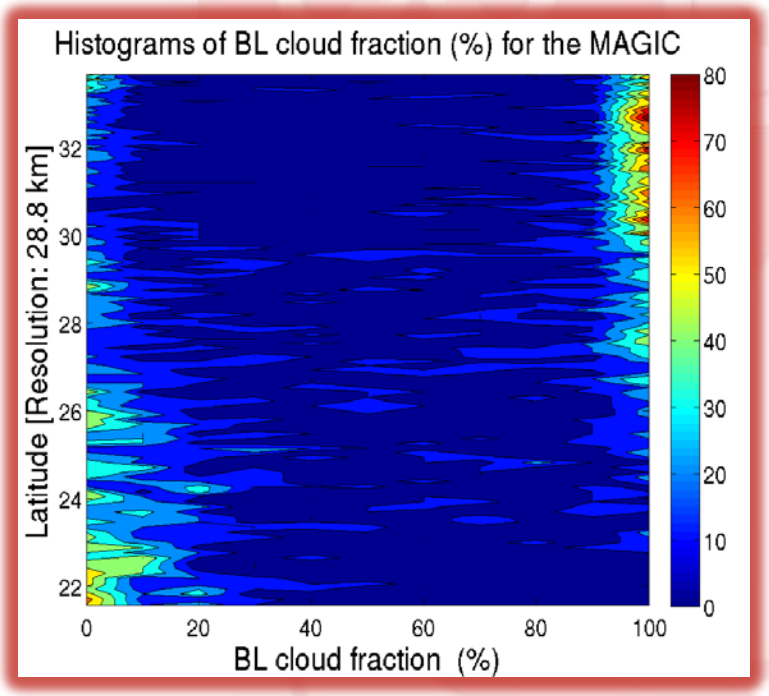
Preliminary Results

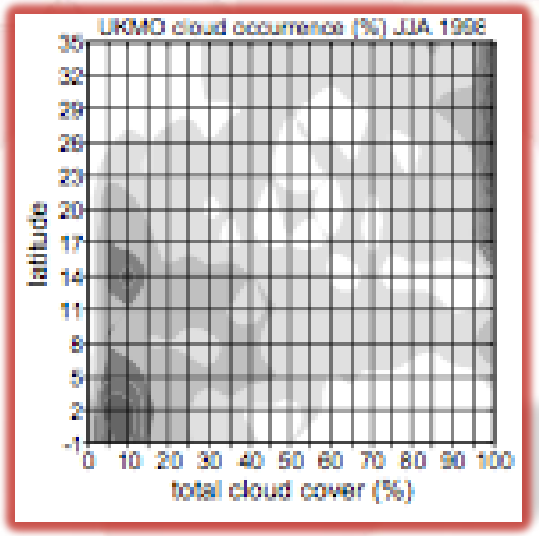
Histograms of MBL cloud fraction

✓ cloud fractions are computed every 28.8 km









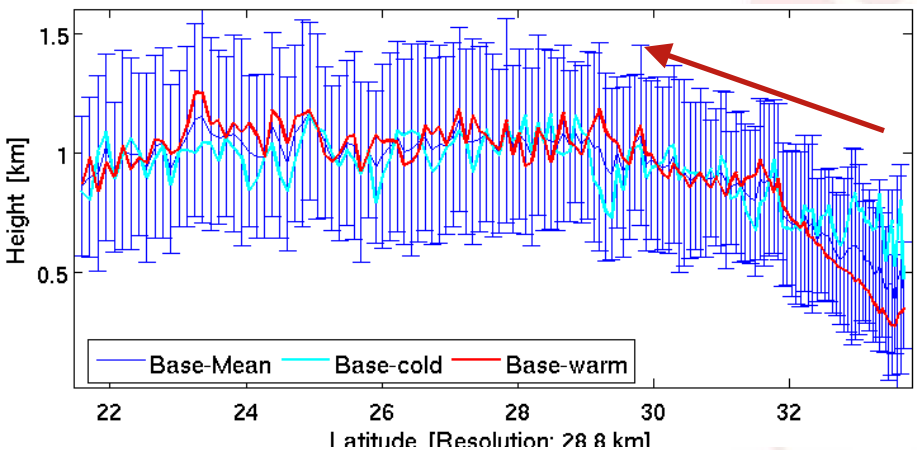
NCAR (TCC)
Bin size : 10%

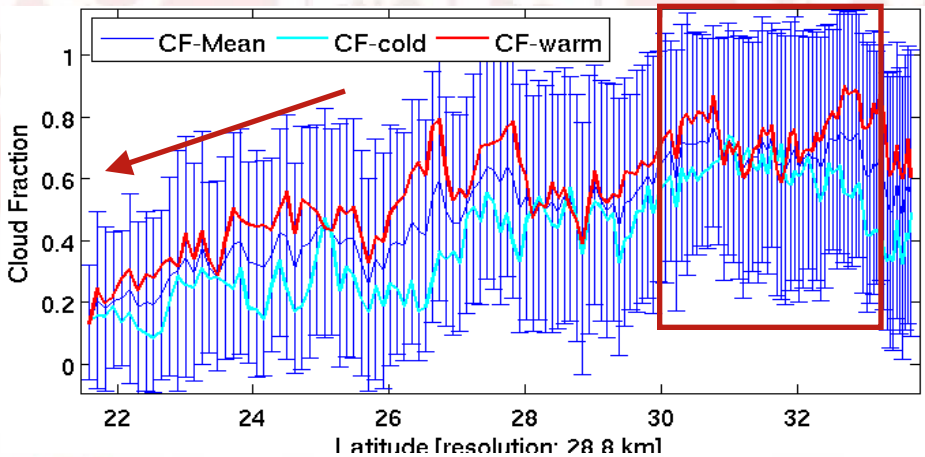
MAGIC
Bin size: 10%

UKMO (TCC)
Bin size: 10%

➢**Clear bimodel structure: 0% close to Honolulu**
100% close to California

Mean and Seasonal variation of cloud macroscopic properties

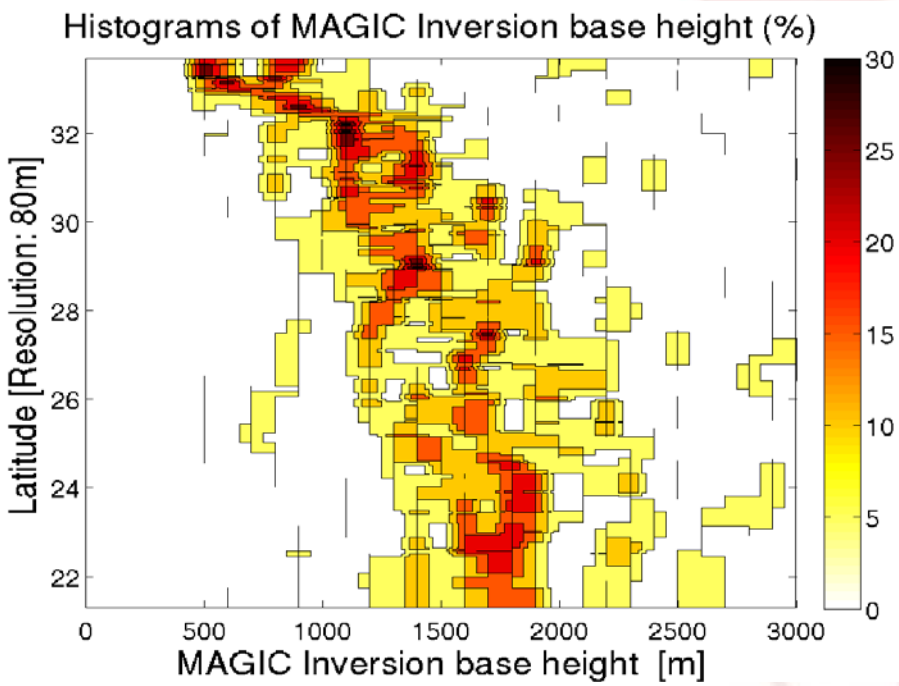


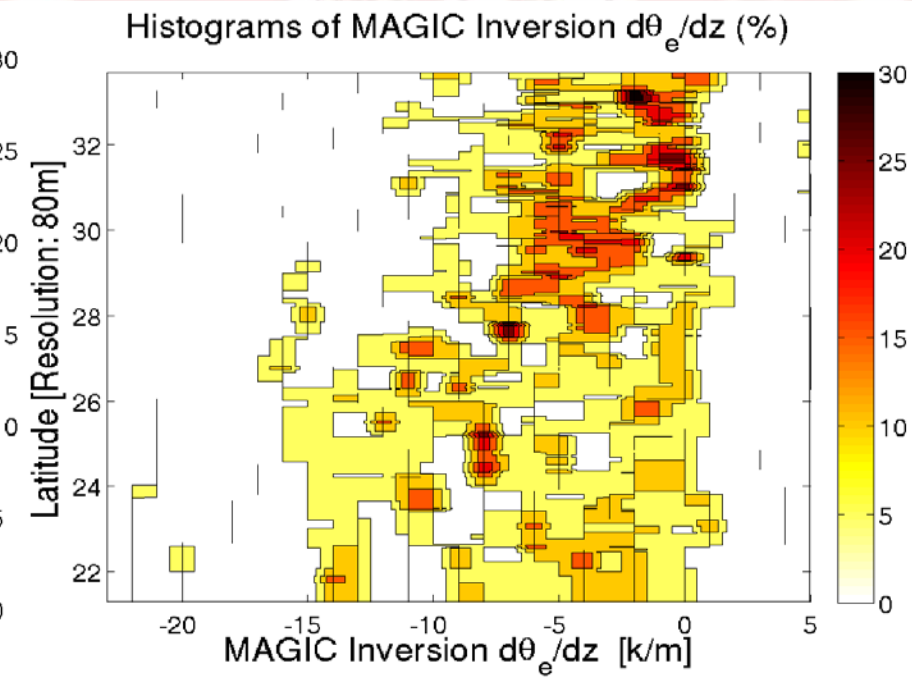


- All data are averaged every 28.8 km
- Warm season refers to leg3-leg8 (Oct.6.2012-Dec.27.2012)
- Cold season refers to leg11-leg17(May.25.2013-Aug.29.2013)
- Error bars show the standard deviation of the mean

- The coverage gets the greatest near California, but not immediately adjacent to the coastline;
- Cloud base increase with deeper MBL;
- Sc starts to break and cloud fraction decrease when it goes further west;
- Warmer season has higher cloud fraction due to strong Hadley Cell.

Thermodynamics Statistics during MAGIC:

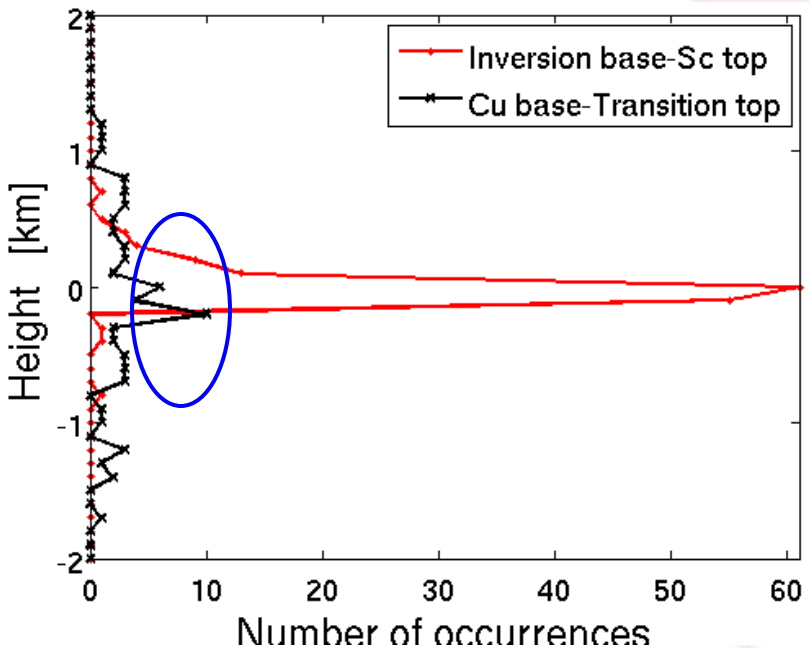




- Assume each sounding profile standing for the atmospheric vertical conditions during 6 hours (3 hours for IOP)
- Bin size: 100 m

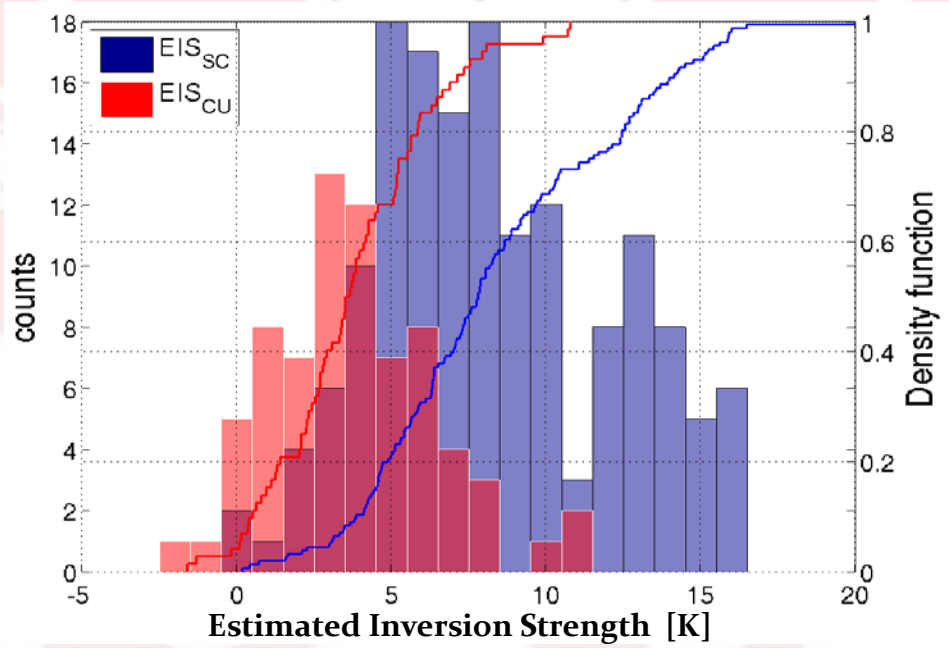
- Inversion base gets higher when close to Honolulu;
- Inversion strength gets weaker;
- data too coarse

Statistics of pure Sc and Cu Location



Height bin size: 100m

Histogram of EIS for pure Sc and Cu



$$EIS = LTS - \Gamma_m^{850}(Z_{700} - LCL)$$

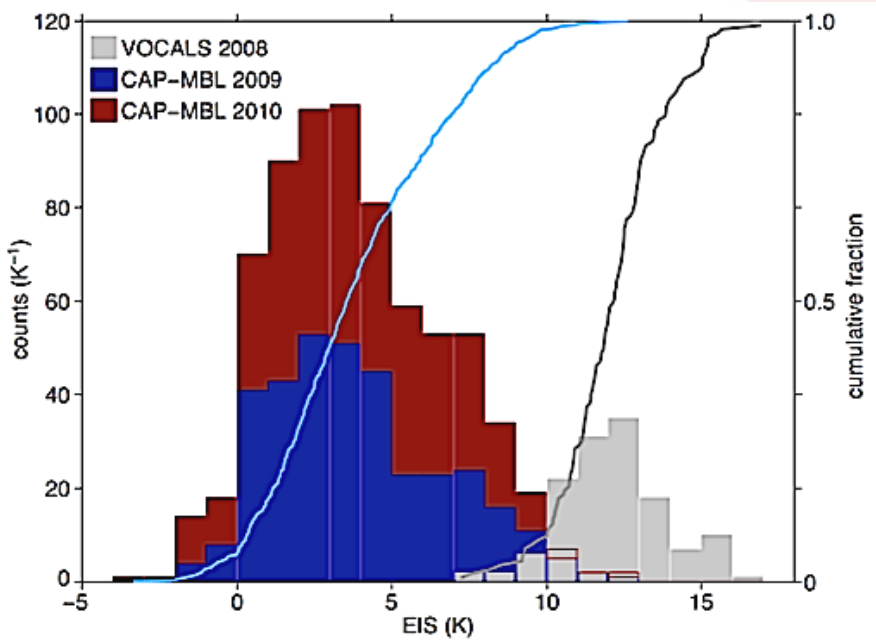
$$LTS : \theta_{700hPa} - \theta_{surface}$$

$$\Gamma_m^{850} = \Gamma_m([T_0 + T_{700}]/2, 850hPa)$$

- Using 1-hour cloud-boundary data centered on the sounding launch time
- Pure Sc and Cu cases (not contaminated by other MBL clouds)

- **Sc form right below the inversion layer;**
- **Cu have broader distribution;**
- **high LTS -> Sc; low LTS-> Cu**

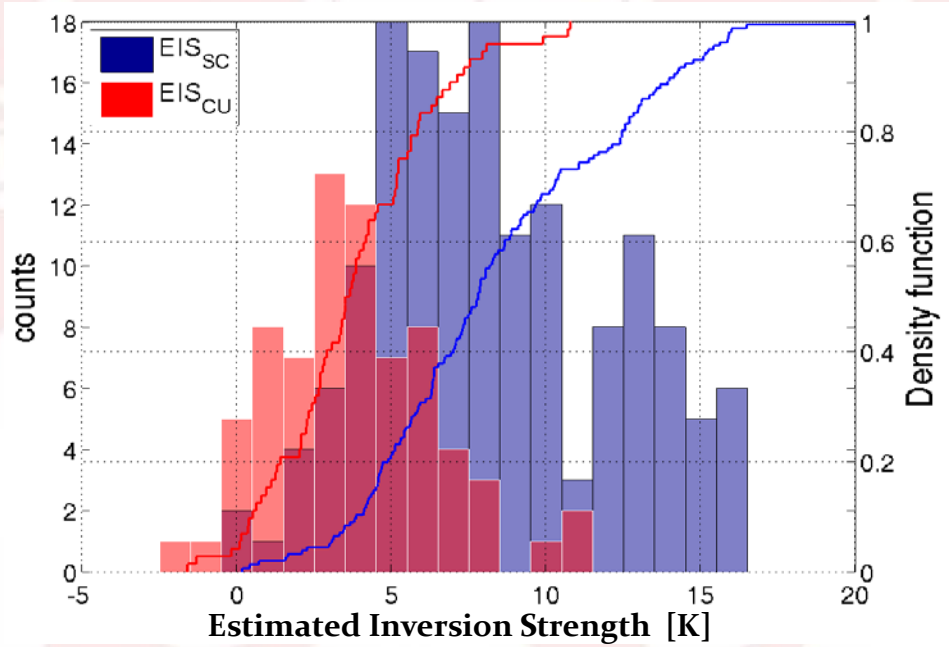
Histogram of EIS for other regions



Height bin size: 100m

Cited from Robert Wood et al.: Clouds, Aerosol, and Precipitation in the Marine Boundary Layer: An ARM Mobile Facility Deployment.
EIS bin size: 1K.
Right axis shows cumulative distributions of EIS (Estimated Inversion Strength) for all of CAP-MBL (blue line) and VOCALS (gray line).

Histogram of EIS for pure Sc and Cu



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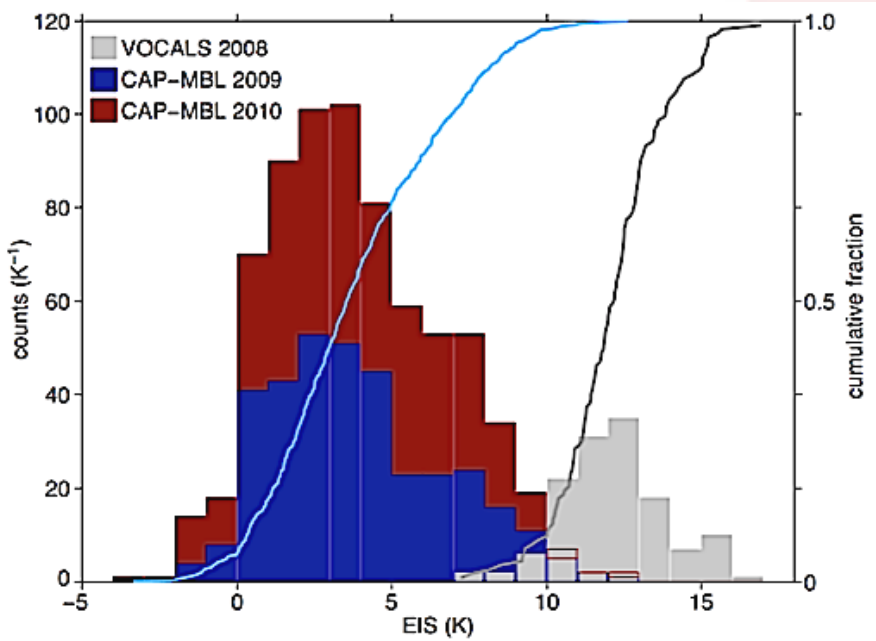

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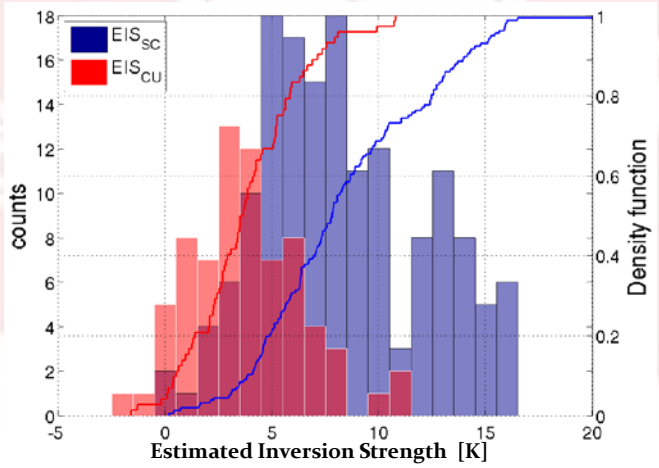
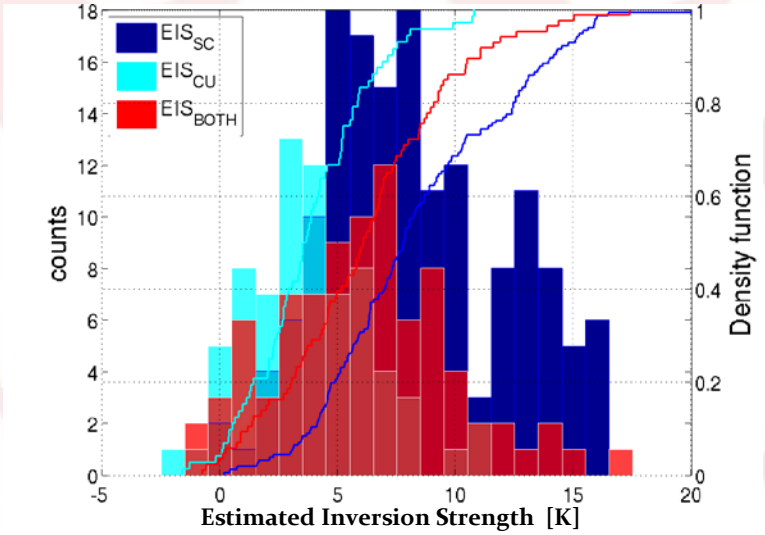
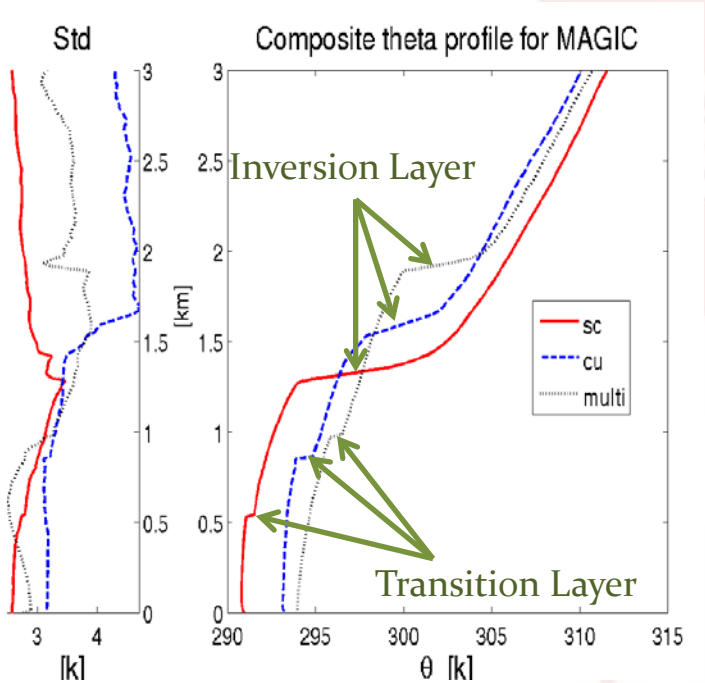
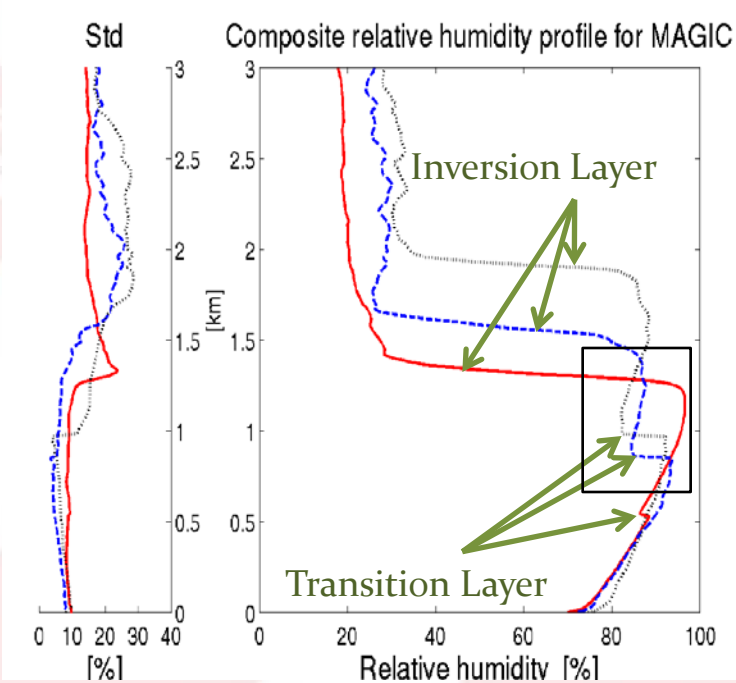


Histogram of EIS for all Sc and Cu



Composite Sounding Profiles during MAGIC

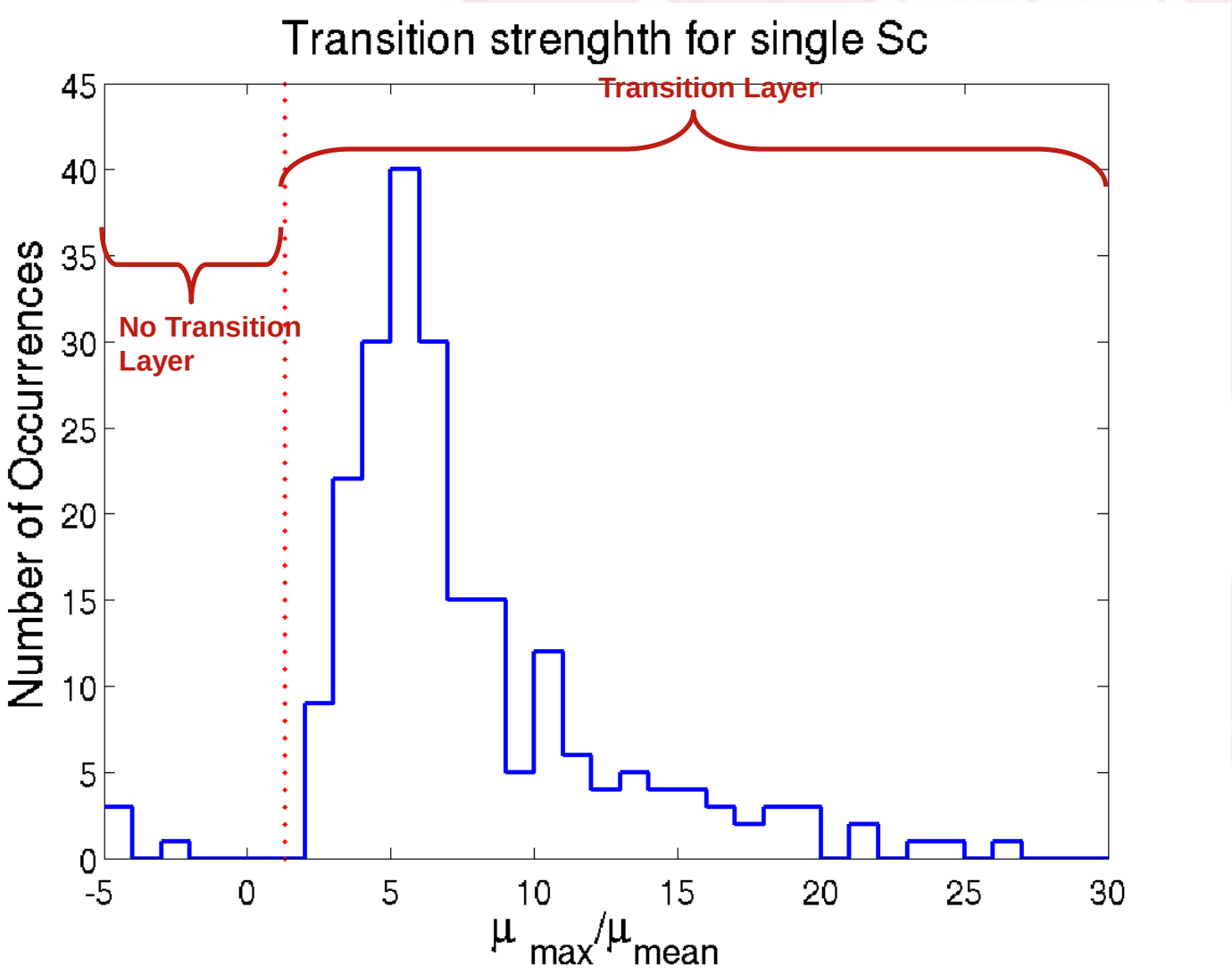




- Single layer Sc or Cu
- Sc close to inversion, Cu close to transition
- layer-by-layer profile

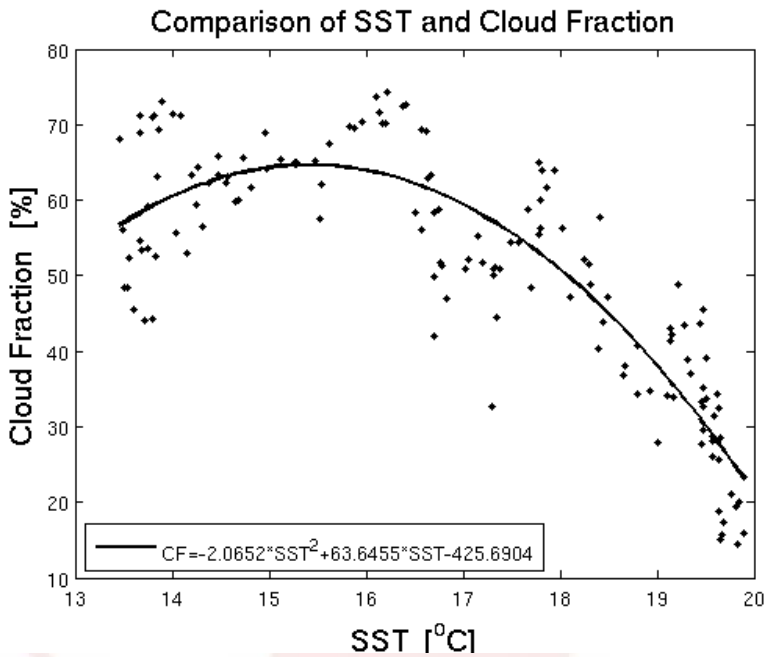
- **Sc:** Stronger and shallower inversion layer;
  Weaker transition layer;
  High relative humidity in the subcloud layer.
- **Cu:** Stronger transition layer;
  Upper subcloud layer is lack of surface moisture supply;
  Difficult for Sc to survive.

A quick look at Single layer Sc



Future work

- **Future Work:**
- Sounding data → wind profiler (much higher temporal resolution)

- SST> 18 °C, nearly linear; relation nonlinear with lower SST.
  More parameters constrain the result, e.g. the vertical velocity at 700 hPa or LTS

- Radiative flux data is also a potential trigger
Aerosol data from AOTMET might be used