Aerosol-cloud interactions and regional patterns over the northeast Pacific during MAGIC

David Painemal[1,2], Patrick Minnis[2], and Michele Nordeen[1,2]

[1]Science Systems and Applications Inc.

[2]NASA Langley Research Center

ASR Fall Working Group, Nov. 2014

MAGIC

- ARM Mobile Facility (AMF2)
- Nine months of measurements
  - Operational: Oct-Jan 2012-2013, May-Sept 2013.
  - L.A.-Honolulu: More than 30 transects (legs).
  - Each leg: 6-7 days

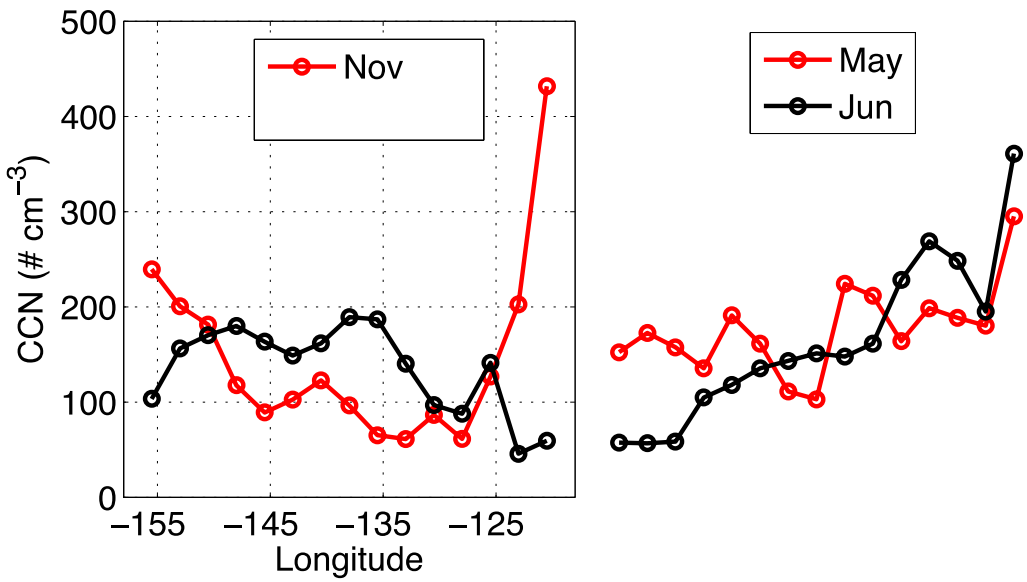
Objectives

- Describe monthly/seasonal variability of cloud condensation nuclei (CCN) along the ship transect.
- Determine regional patterns that accounts for CCN variability at synoptic scales using satellite proxies and ERA-Interim reanalysis.
- Analyze the interdependence between cloud number of droplets (N_d) and CCN

Dataset

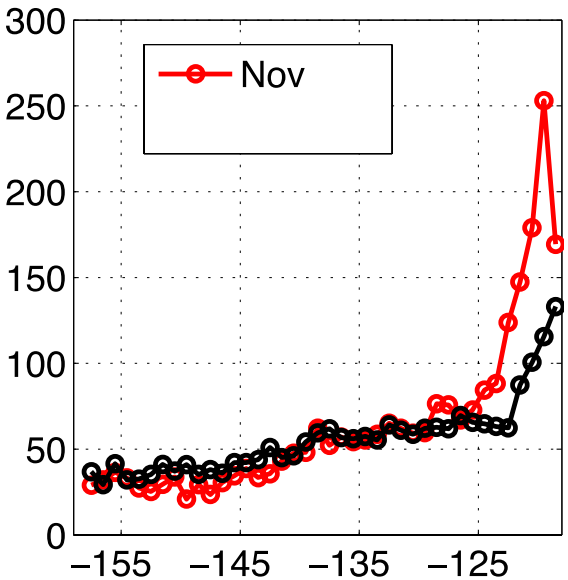
- ***MAGIC data***: Radiosondes, ceilometer, CCN particle counter, meteorological data.
- **Satellites** (cloud microphysics):
  - MODIS Terra: level 3 (1˚x1˚) ~ 13:30 LT overpass (NASA-Langley).
  - GOES-15: 4km pixel resolution (nadir-view) every 30 min. Analysis constrained to samples with SZA <60˚
  - $N_d = K \cdot \tau^{1/2} \cdot r_e^{5/2}$
- Meteorological **reanalysis**
  - ECMWF ERA interim : 1˚x1˚

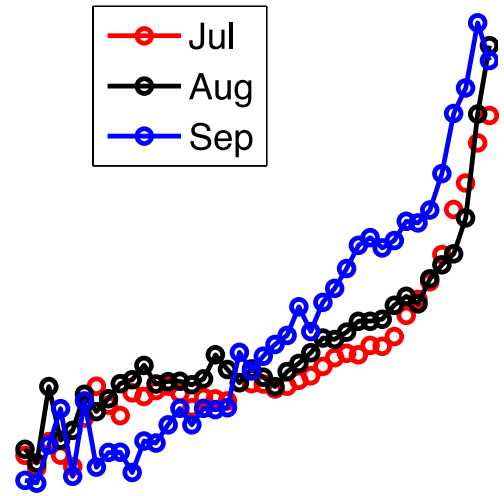
Monthly means and seasonal evolution



- On average, CCN decreases westward
- Zonal gradients occur from May until Sept.
- Minima coastal CCN during Dec-Jan

Climatological MODIS N_d along MAGIC transect

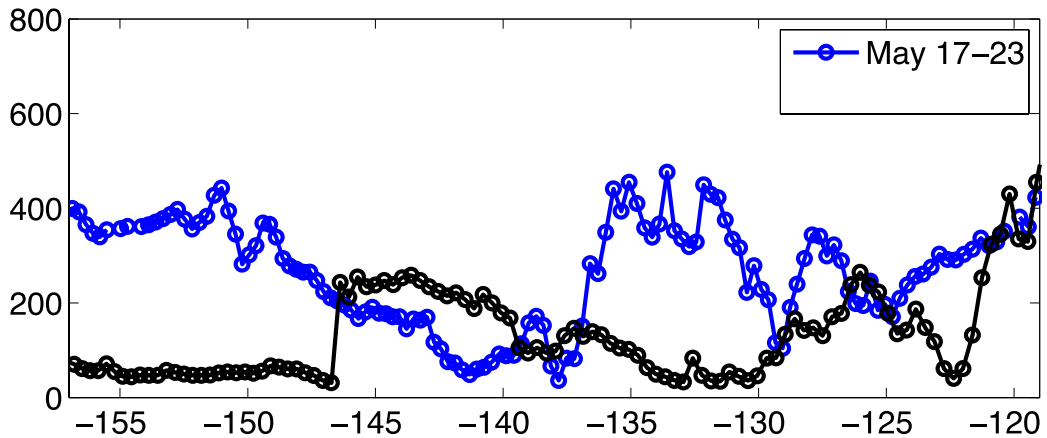




- Zonal gradient very consistent with observations
- Evidence of annual cycle
- Lowest N_d during Dec-Jan
- Abrupt westward decrease in Nov.

Synoptic patterns: a few examples

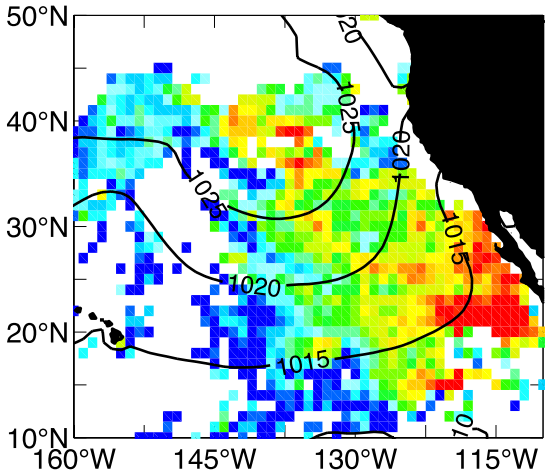
- Two examples with contrasting variations in CCN
- <u>May 2013</u>
- May 17-23 (—): High CCN concentration
- May 25-30 (—): Low concentration



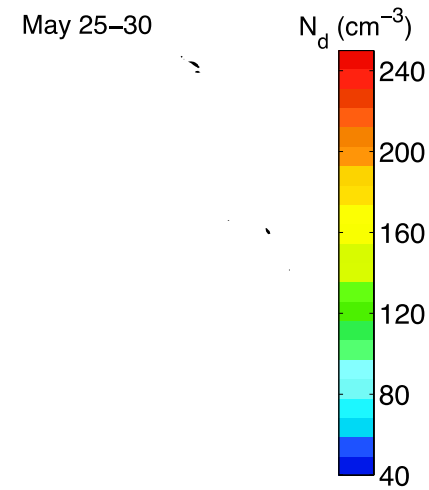
May 2013, regional fields

- MODIS N_d
- SLP(contours)

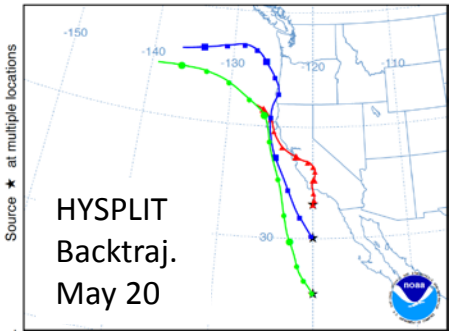
High CCN

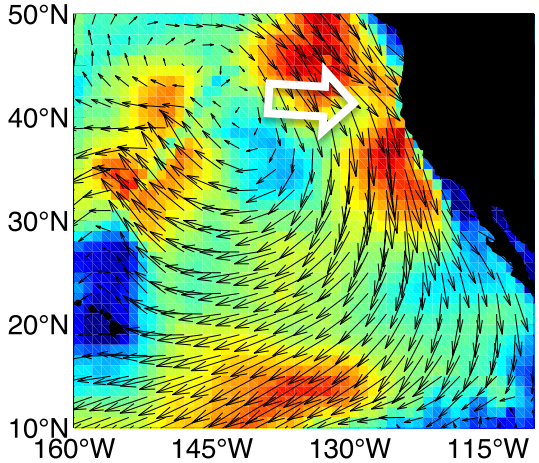


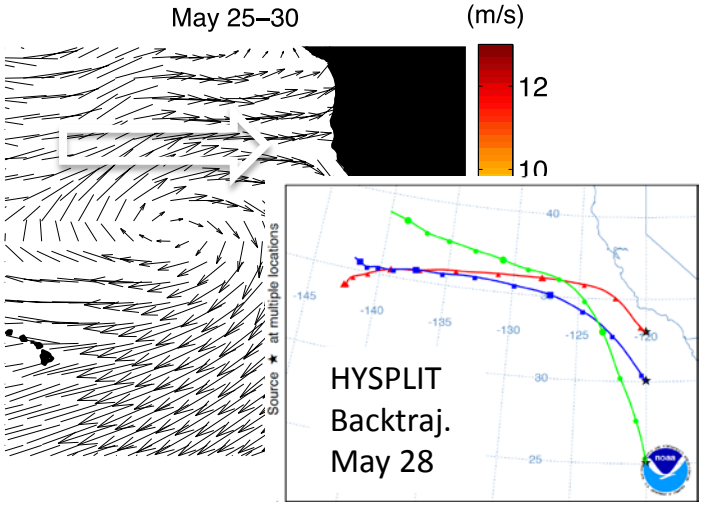
Low CCN



- Surface winds

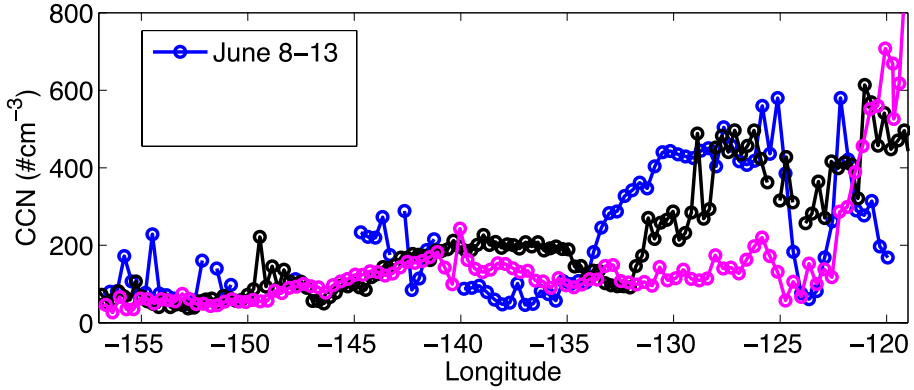






CCN events for June 2013

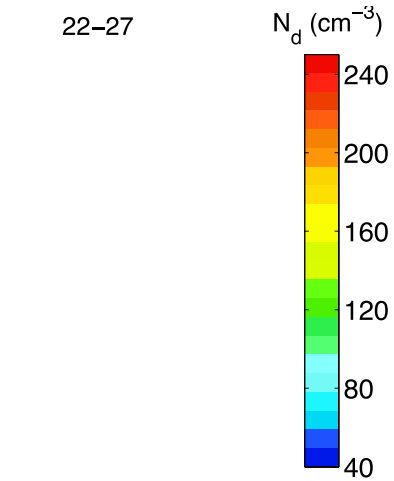
- June 8-13, June 14-20: High CCN
- June 22-27: Low CCN



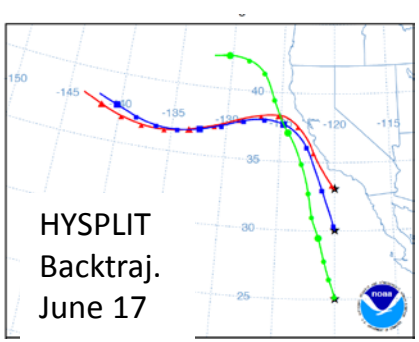
June 2013, regional fields

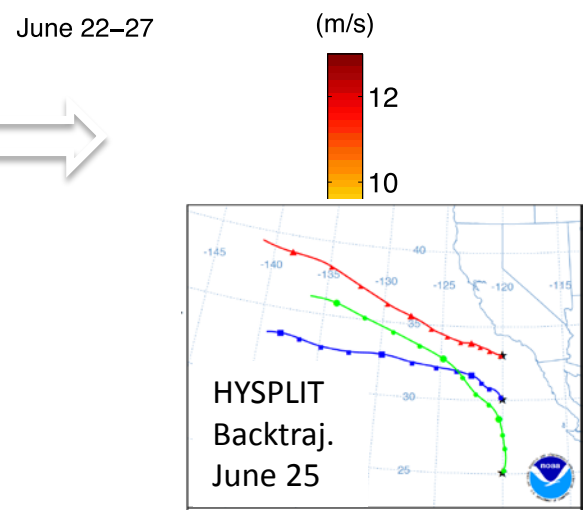
High CCN ***Low CCN***

- MODIS N_d
- SLP(contours)



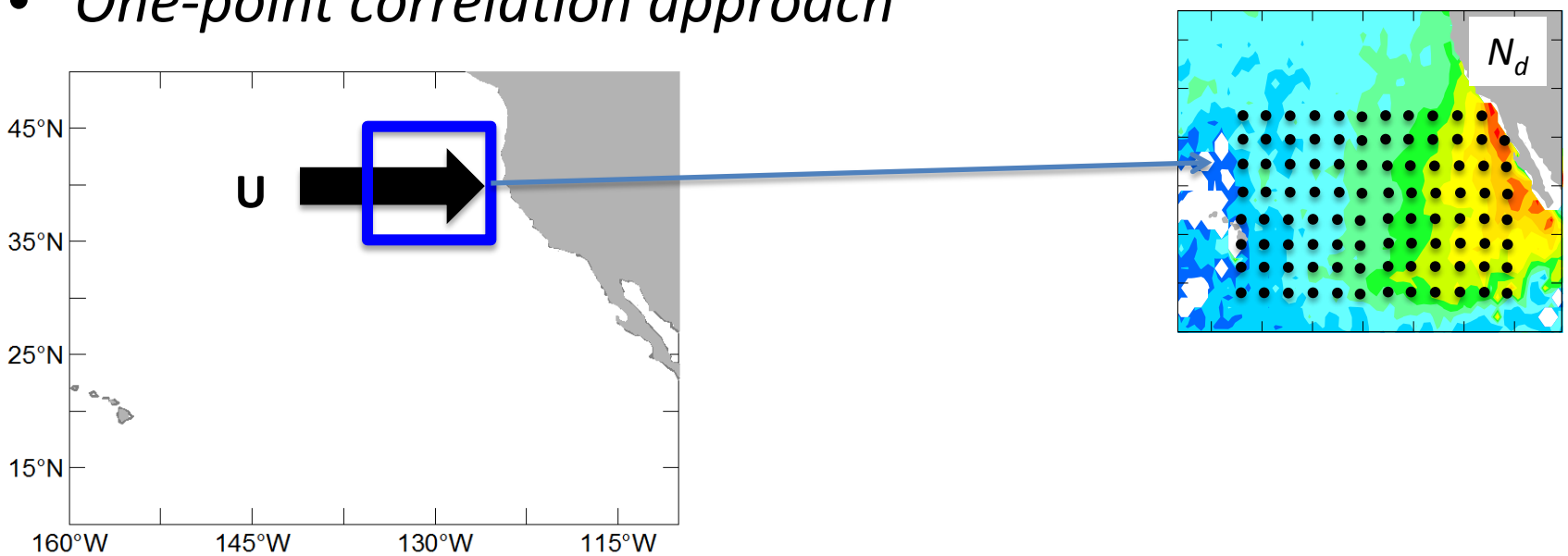
- Surface winds





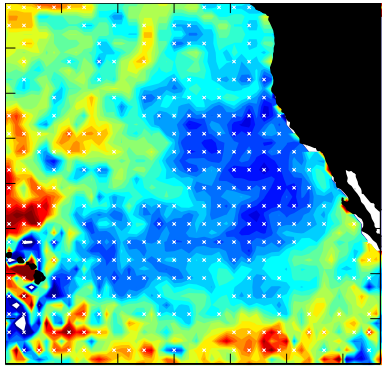
Synoptic patterns

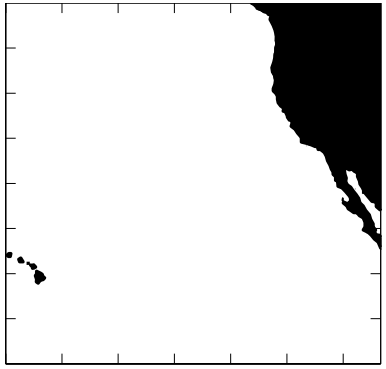
- Previous examples suggest a link between zonal winds, low-level jet (LLJ) strength and N_d variability.
- Westerlies hamper offshore transport of aerosols?
- LLJ favors the transport of continental aerosols?
- *One-point correlation approach*



Spring-Summer daily variations

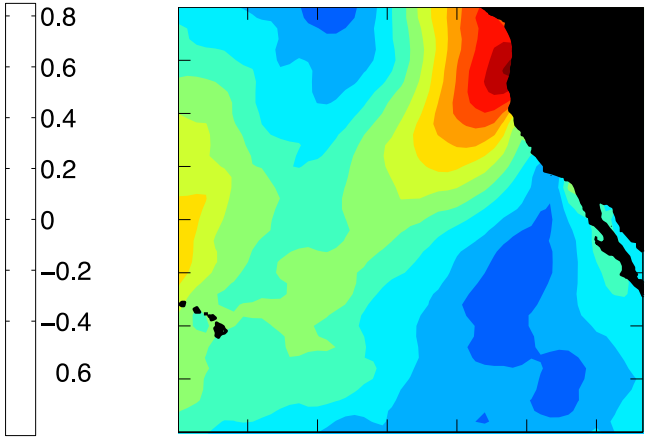
- One-point correlation (ρ): mean-box zonal wind time series (U) and MODIS N_d fields: ρ(U(t-3$_{days}$),N_d), ρ(U(t-2$_{days}$),N_d)….





ρ(U,SLP)

ρ(U,V)



- Stronger easterlies northward:
  - N_d decreases
  - Dipole-like SLP
  - Low-level jet weakening

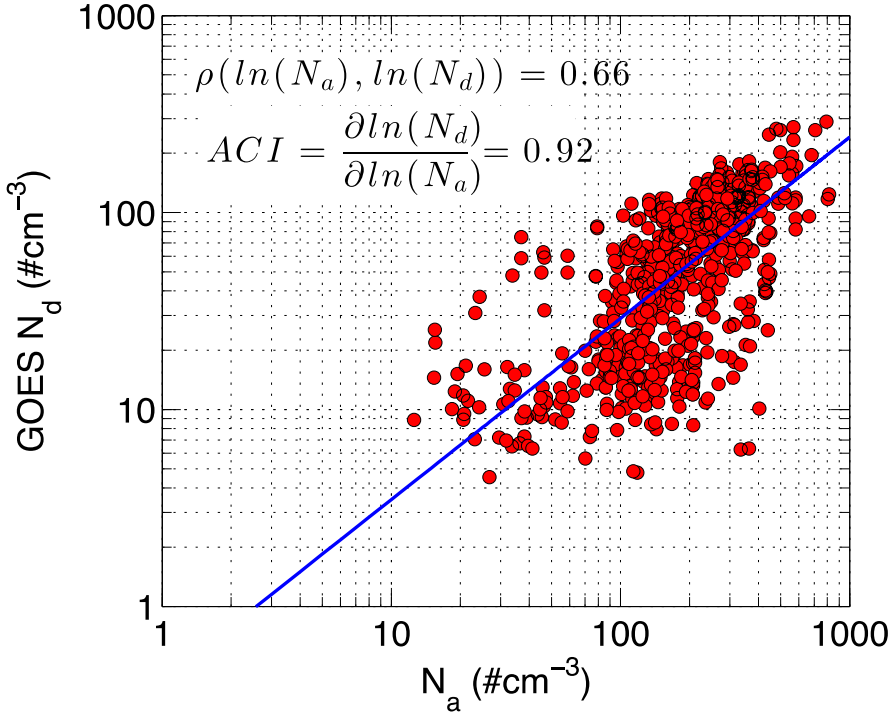
Aerosol-cloud interactions

- What is the link between aerosols and clouds?
- Aerosol-cloud interaction metric (ACI):

$$\boxed{\mathrm{ACI}_N = \frac{d \ln N_\mathrm{d}}{d \ln N_\mathrm{a}}} \leq 1$$

- Different studies yield dissimilar ACI magnitudes:
  - NE Pacific, Point Reyes, ARM-AMF: ACI~0.48 (McComiskey et al. 2009, JGR)
  - Aircraft observations reveal stronger ACI (ACI >0.8):
    - NE Pacific DYCOMS-II: ACI~0.8-0.9 (Twohy et al., 2005 JGR)
    - SE Pacific VOCALS-REx: ACI~0.8-0.9 (Painemal and Zuidema 2013 ACP)
    - Shallow cumulus in Barbados: ACI~0.81-1.05 (Werner et al. 2014 JGR)

ACI: satellite N_d collocated with MAGIC CCN (N_a)

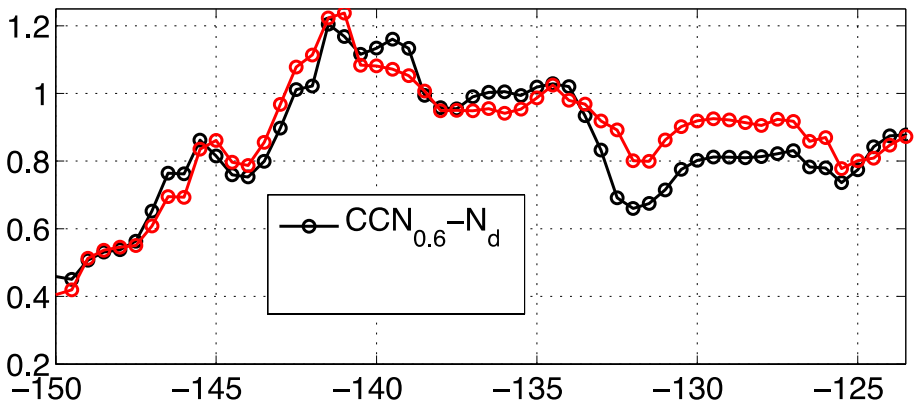


- CCN (0.6% sat) combined with GOES retrievals
- GOES 20 km average, 1 hour CCN mean, overcast satellite scene.
- **ACI=0.92**, near the upper physical limit

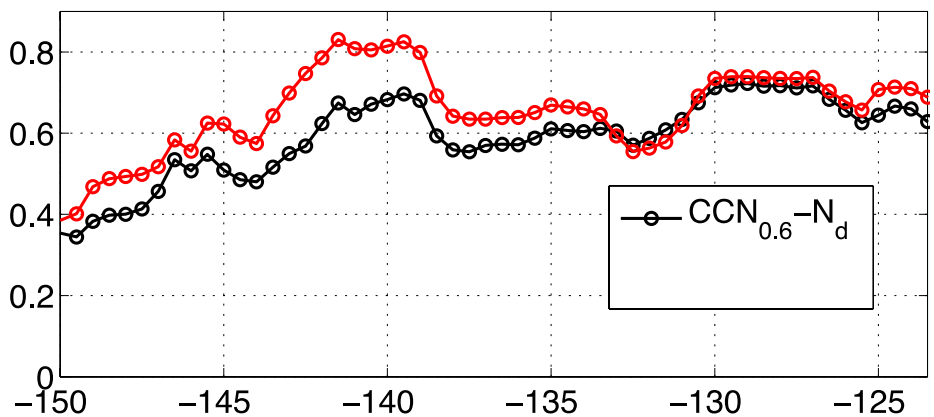
ACI: Longitudinal variations

- Statistics calculated as a function of longitude (and lat.)

Hawaii

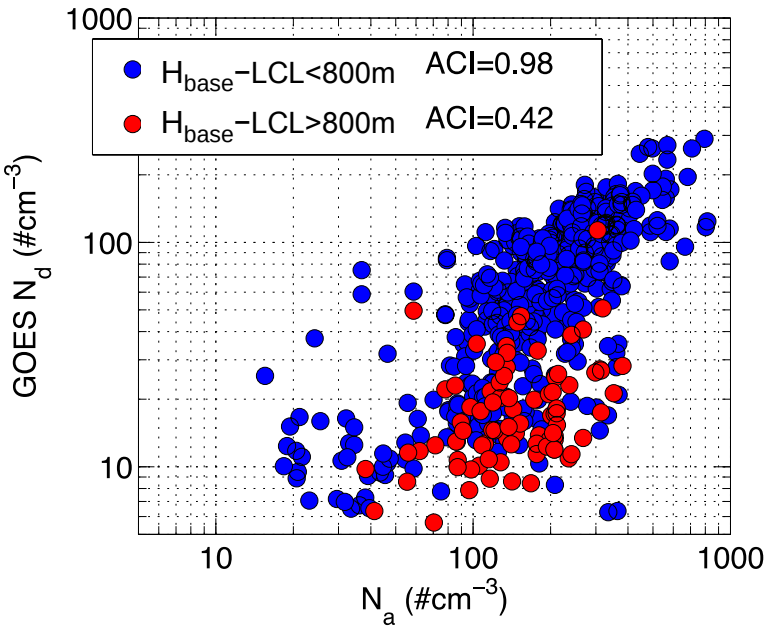


L.A.

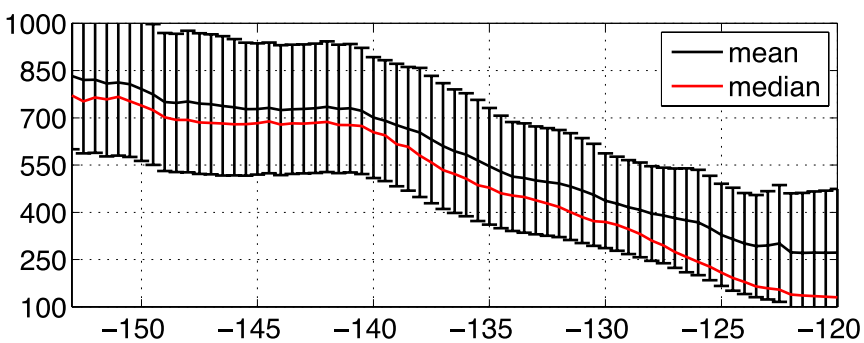


- ACI relatively constant east of 145˚W.

ACI: zonal differences and boundary layer coupling



- Boundary layer coupling: cloud base-lifting condensation level



- Less coupled conditions exhibit low CCN-N_d correlations and ACI.

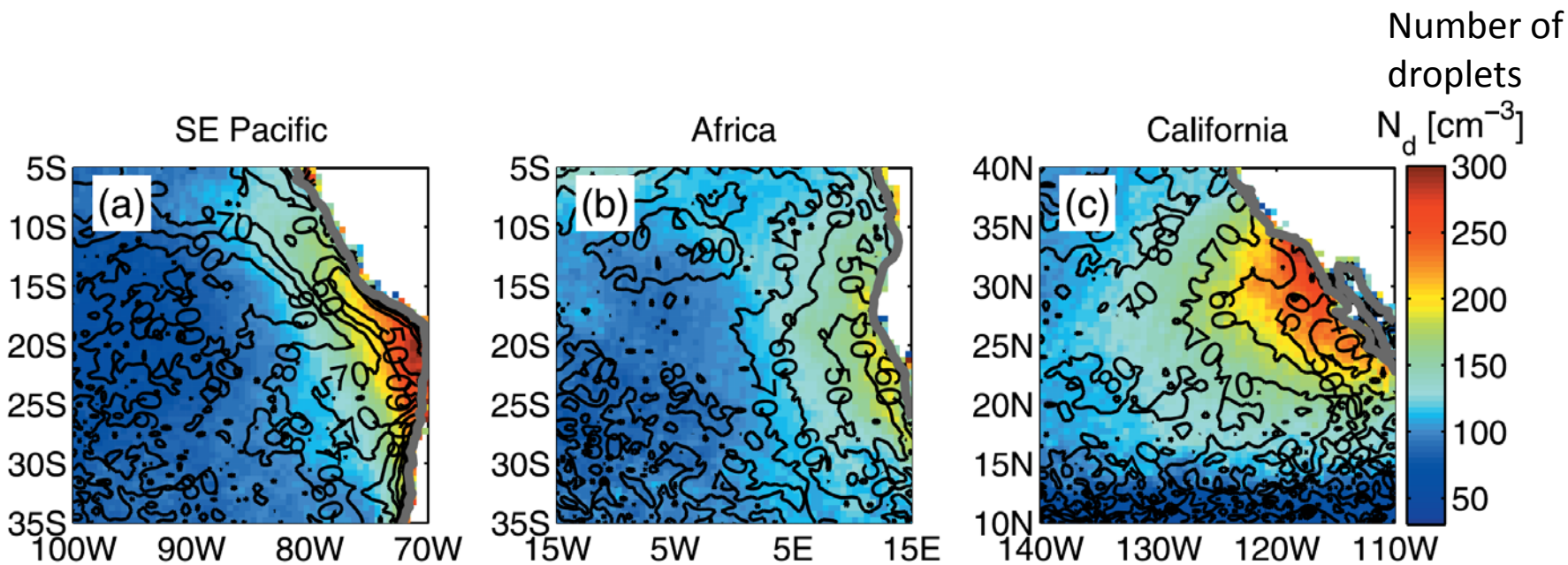
Conclusions

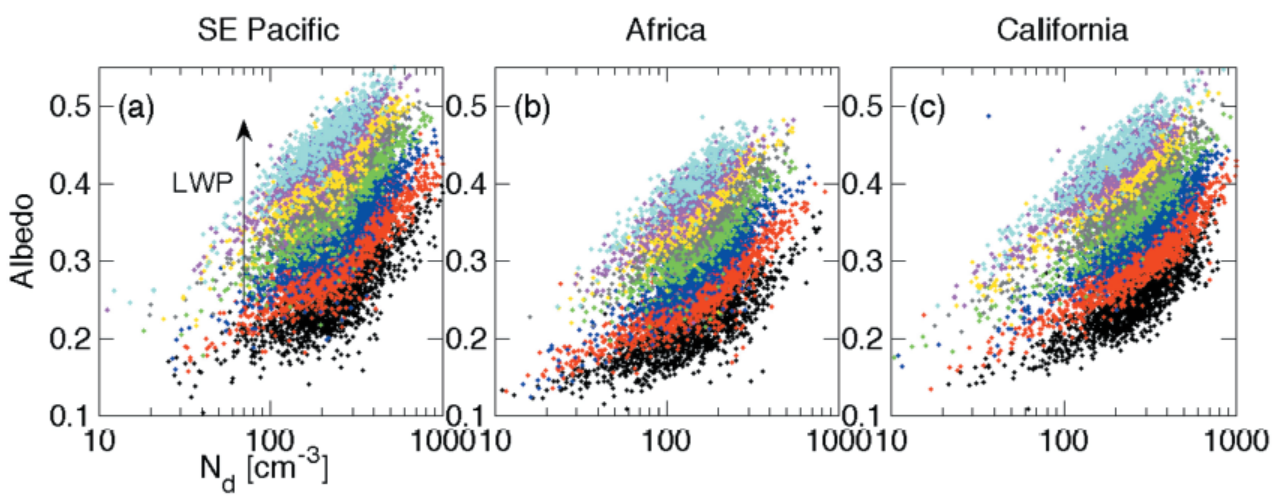
- Aerosol variability consistent with MODIS N_d.
- Zonal winds north of 35˚ appear to explain aerosol transport and cloud microphysics variability.
- The role of the coastal low level jet requires further analysis
- Robust aerosol-cloud statistics, stronger than those derived at Point Reyes (CA)
- A westward decrease in ACI likely explained by boundary layer decoupling.
- **Future work:** Use of cloud υ-physics derived from shipborne instruments, cloud radars (precip).

- *Acknowledgements*: DOE grant DE-FOA-0000885, Kuan-Man Xu (NASA-LaRC), Ernie Lewis (BNL) and the team involved in MAGIC campaign.

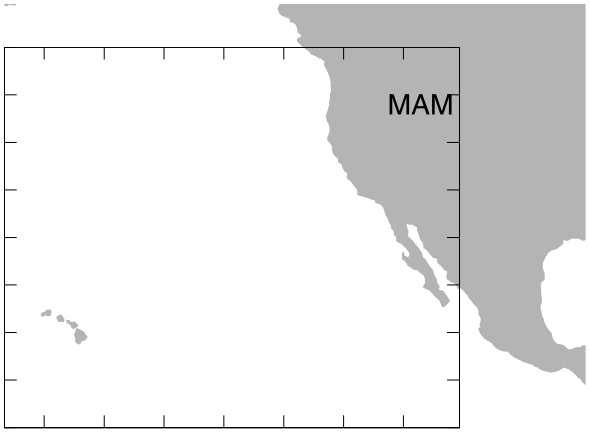
Backup slides

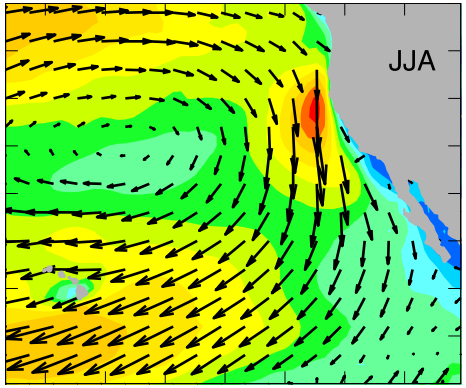
Marine boundary layer cloud regimes





Painemal and Minnis (2012 JGR)



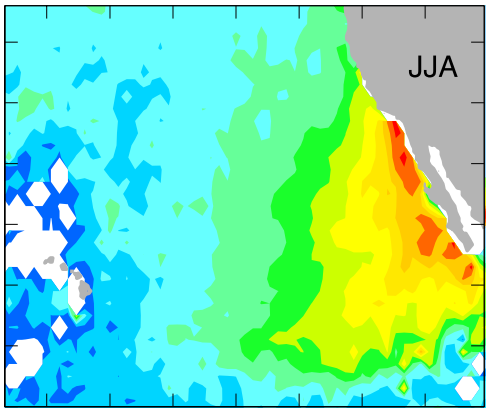


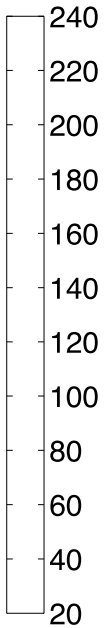
- Strong cycle north of 40˚N
- Occurrence of a low level jet during spring/spring(ref)

- N_d anomalies for weak zonal winds

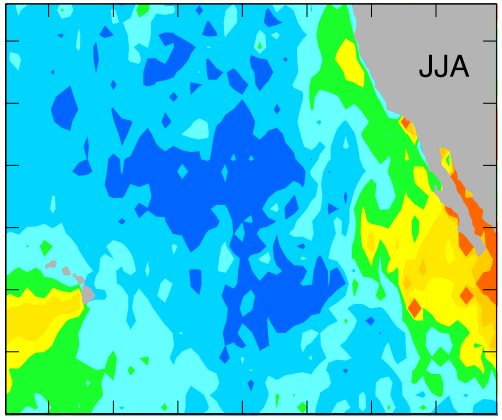
Annual cycle: Number of droplets N_d

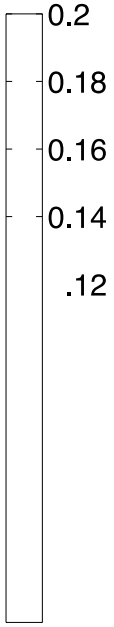
- Annual cycle near the coast.



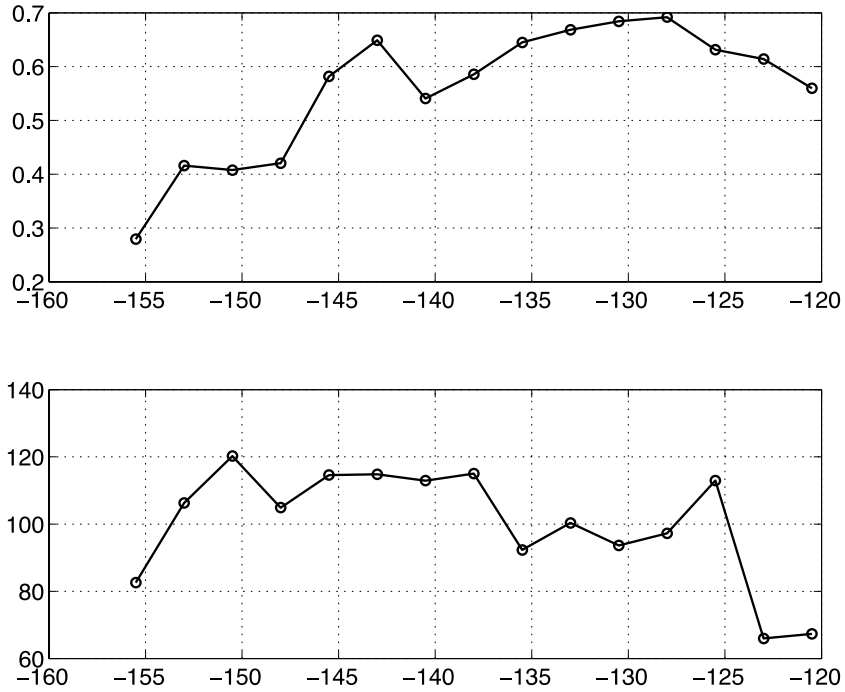


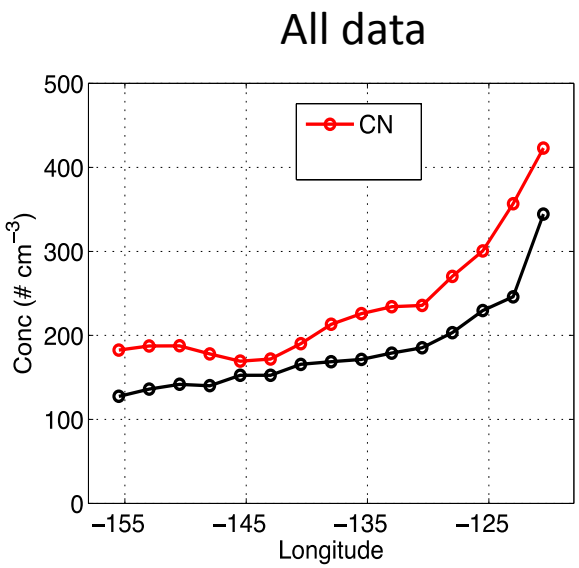
Aerosol optical depth

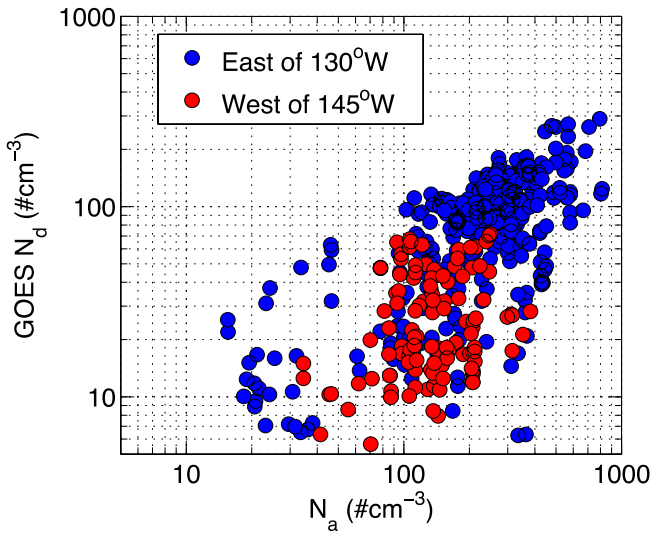




MAM: Aerosol transport from Asia


0.7
0.6
0.5
0.4
0.3
0.2
−160
−155
−150
−145
−140
−135
−130
−125
−120
140
120
100
80
60
−160
−155
−150
−145
−140
−135
−130
−125
−120


All data
CN
Conc (# cm^{-3})
Longitude
500
400
300
200
100
0
−155
−145
−135
−125


East of 130°W
West of 145°W
GOES N_d (#cm^{-3})
N_a (#cm^{-3})
1000
100
10
10
100
1000