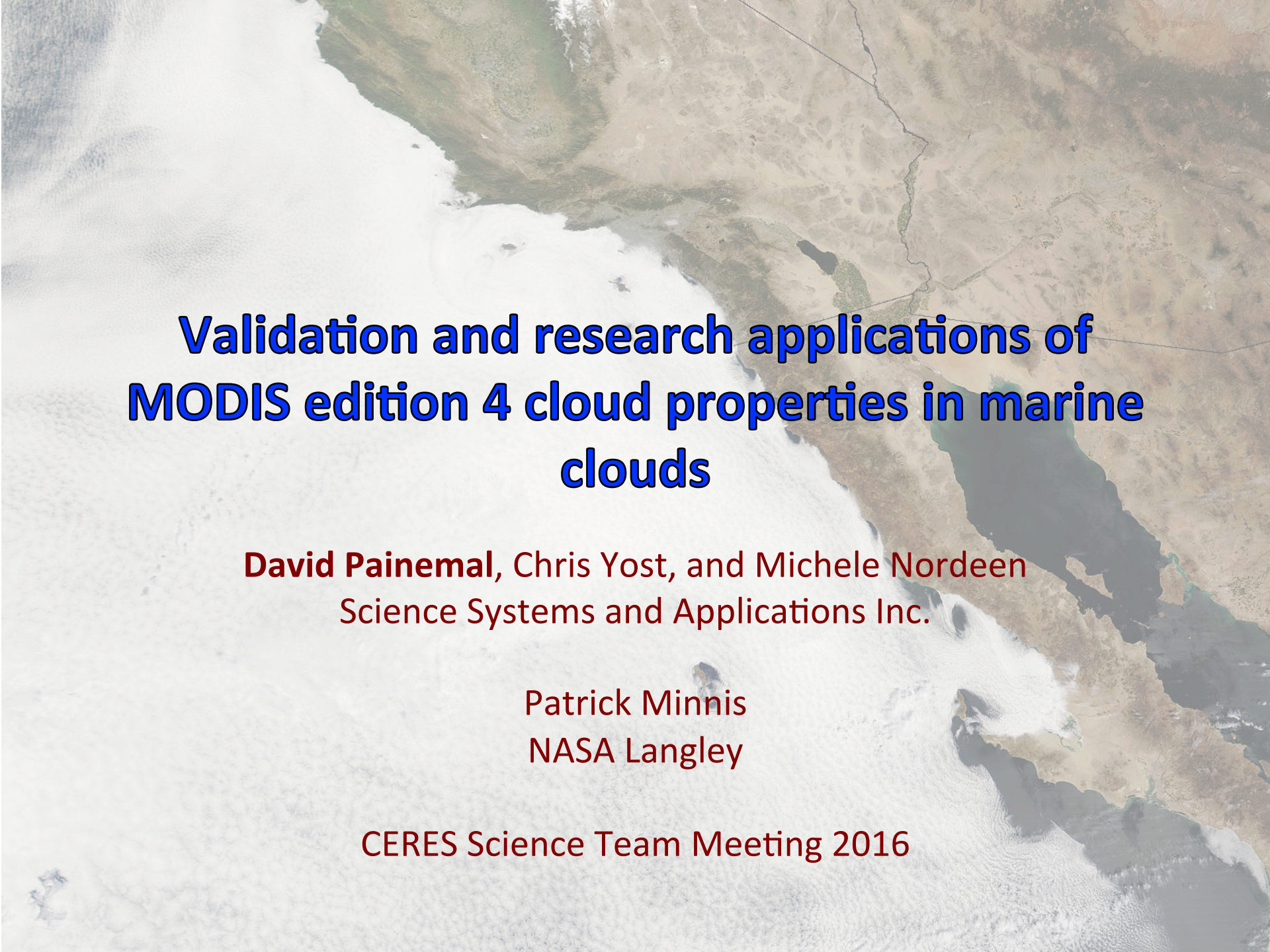

Validation and research applications of MODIS edition 4 cloud properties in marine clouds

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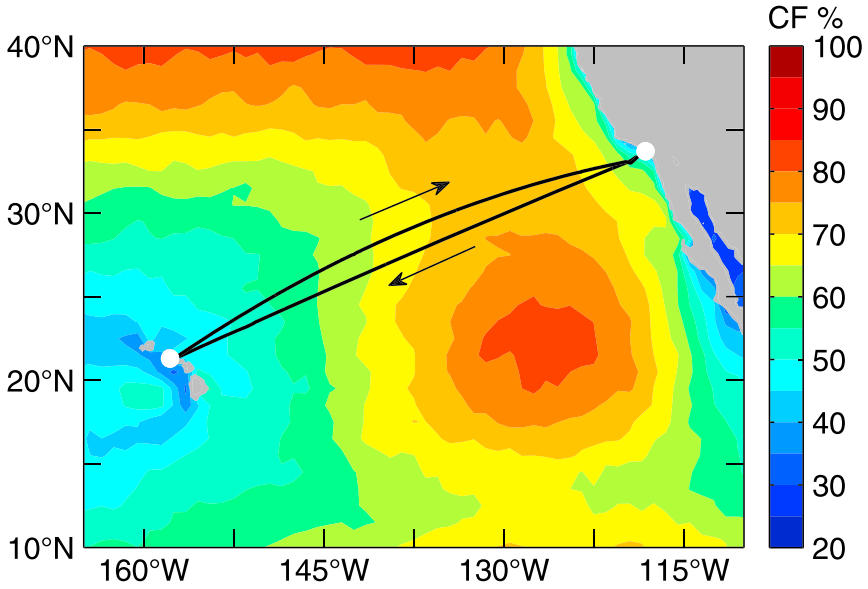
Satellite retrievals validation

- Validation of satellite retrievals hampered by the lack of reliable in-situ data.
- Aircraft data: detailed microphysical observations, but limited sampling.
- Ground-based: Adequate temporal sampling but very limited spatial sampling. Retrieving cloud properties can be challenging.
- Ship-based data: Adequate temporal sampling and better spatial coverage.

MAGIC

- ARM Mobile Facility (AMF2): radars, lidars, microwave and visible radiometers, sondes, and aerosol probes.
- Nine months of measurements
  - Operational: Oct-Jan 2012-2013, May-Sept 2013.
  - L.A.-Honolulu: More than 30 transects.
  - ~6 days/leg

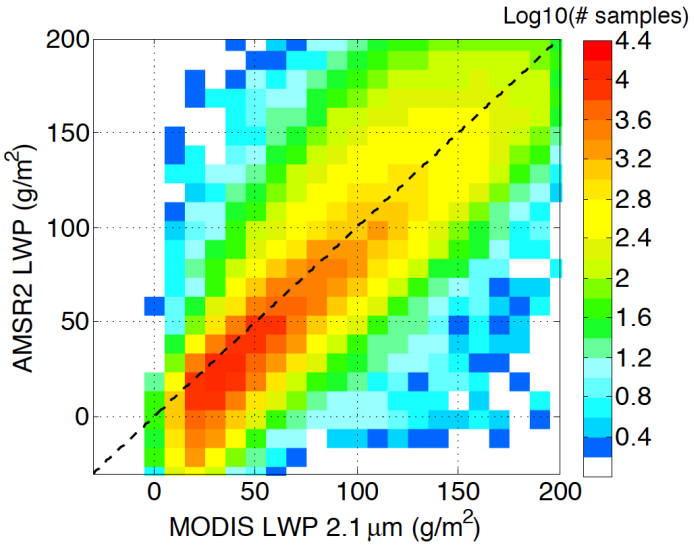


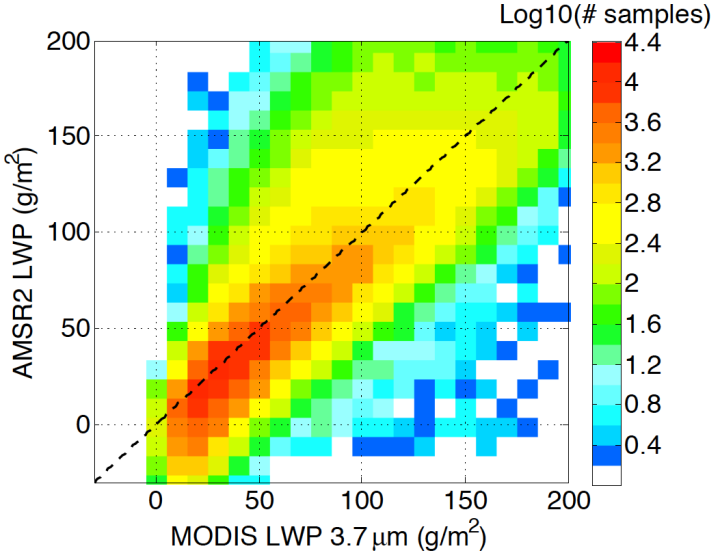
Dataset

- ***MAGIC data***:
  - Clouds microphysics from a Cimel sun-photometer (Chiu et al. 2012 ACP): cloud optical depth (τ) and effective radius (r_e)
  - Three-channel microwave liquid water path (Cadeddu et al., 2013, AMT)
  - Cloud radar and radiosondes: cloud height and temperature
- **Satellites**:
  - **Edition 4** MODIS retrievals (Terra and Aqua), 1km pixel resolution.
  - Daytime GOES-15: 4km pixel resolution (nadir-view) every 30 min with SZA<60˚.
  - MODIS/GOES liquid water path (LWP): adiabatic-like assumption: **LWP=5/9**$\cdot\rho_w\cdot r_e\cdot\tau$
  - Satellite microwave liquid water path from AMSR2 (0.25˚x 0.25˚)

Satellite vs Satellite: AMSR2-MODIS

- Afternoon pass ~ 1:30 pm, overcast scenes
- AMSR2, Wentz algorithm at 0.25˚x 0.25˚
- LWP estimates based on 3.7 μm and 2.1 μm effective radius



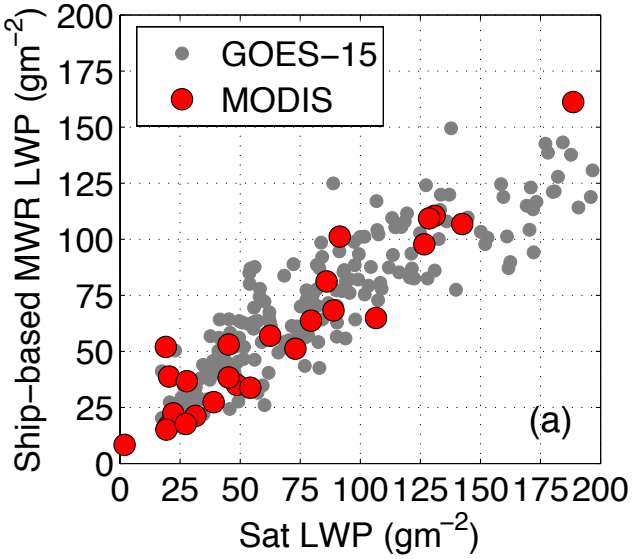


- MODIS2.1μm-AMSR2: r=0.89, bias=5.5 g/m^2 (9.3%)
- MODIS3.7μm-AMSR2: r=0.85, bias=0.81 g/m^2 (**1.3 %**), nearly unbiased!!

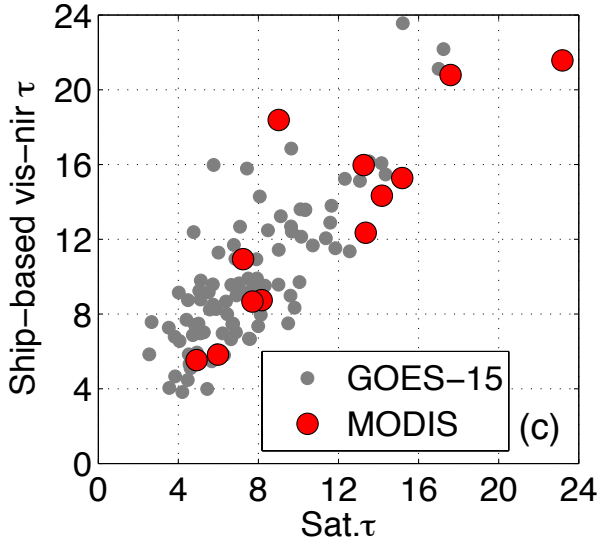
Ship-based data: Cloud microphysics and liquid water path

- LWP:Ship-based 3-channel μwave radiometer
- Cloud optical depth (τ): sun-photometer (Chiu et al., 2012)

r=0.94, bias=9.1 g/m^2,rsme=18.9 g/m^2



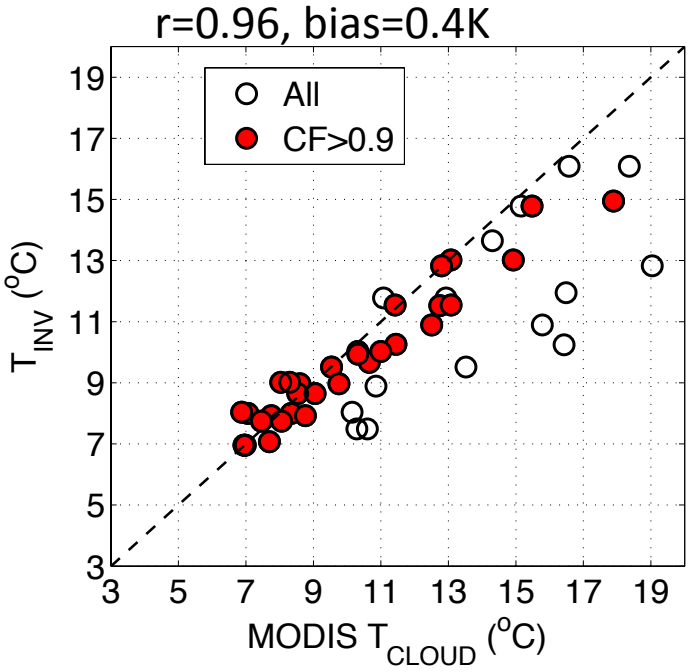
r=0.85, bias=1.5, rsme= 3.21

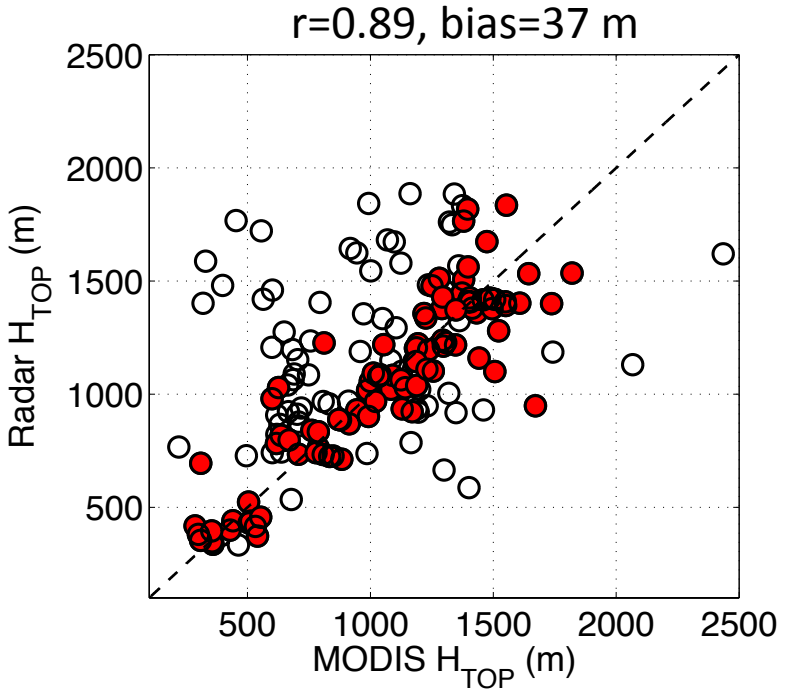


- Cloud effective radius? Comparison is uncertain, ground-based r_e is less robust than τ.

Cloud temperature and height

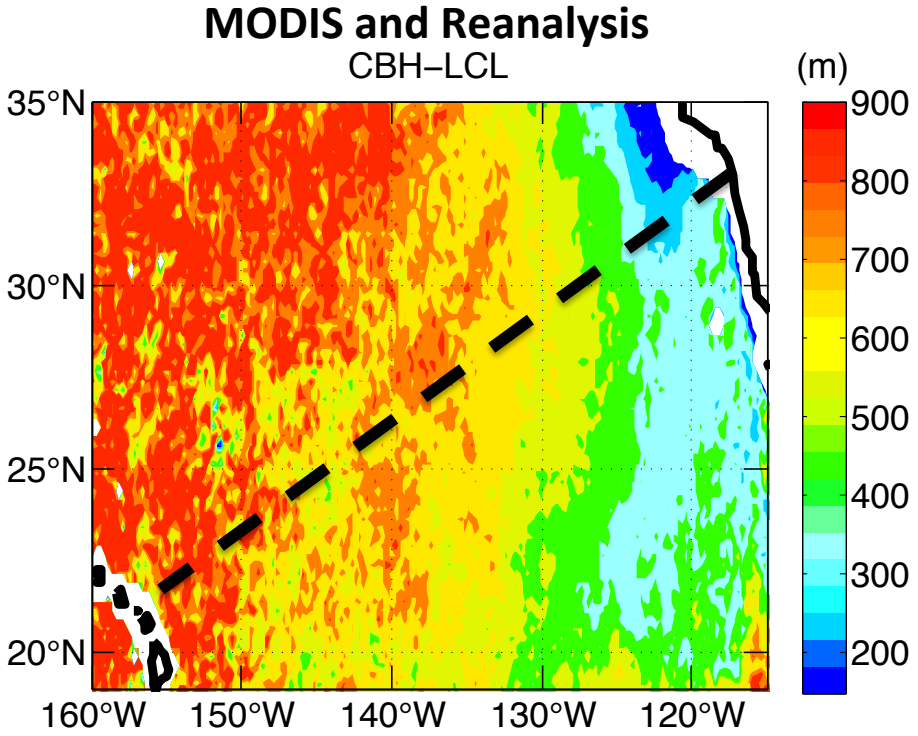
- MODIS cloud temperature vs inversion temperature (radiosonde)
- MODIS cloud height: linear fit from Painemal et al. 2013, that relates T_{top} – SST to cloud height.
- Ship-based cloud top height from a k-band radar (three months)

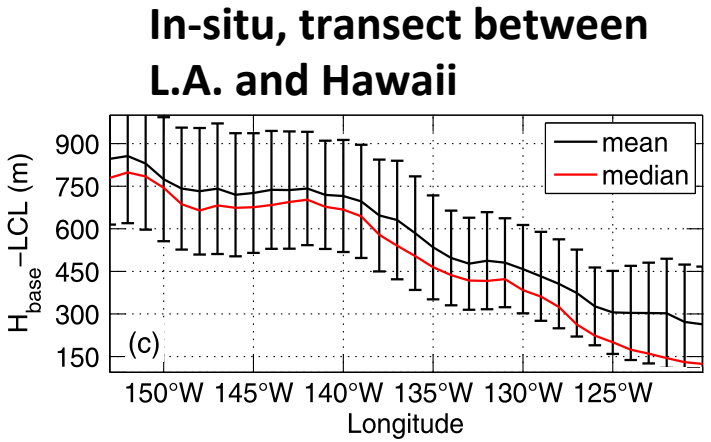




Applications: Boundary layer evolution

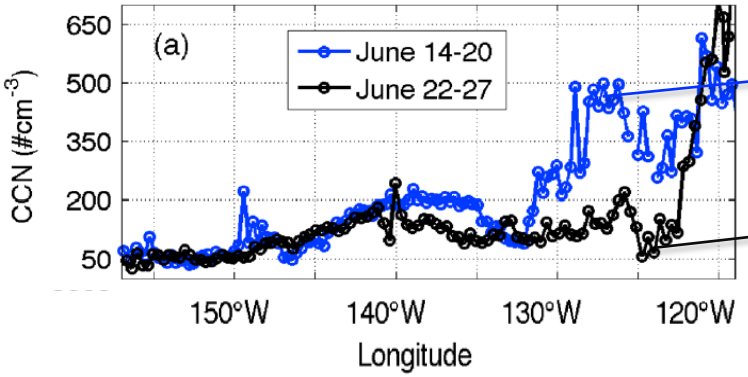
- Adiabatic approximation for computing cloud base height
- Boundary layer degree of turbulent mixing: Difference between cloud base height (CBH) and lifting condensation level (LCL).

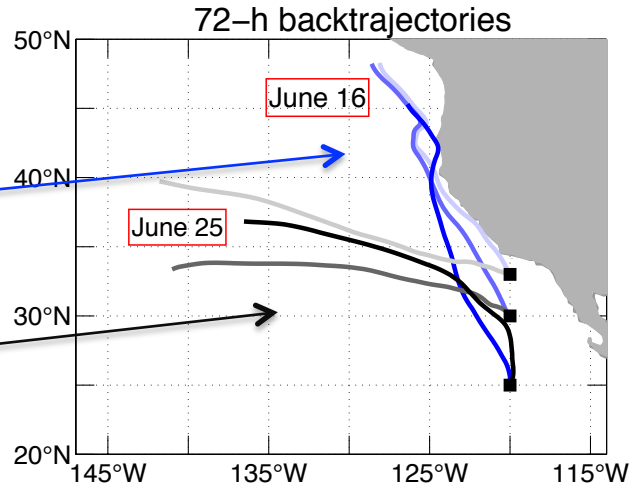




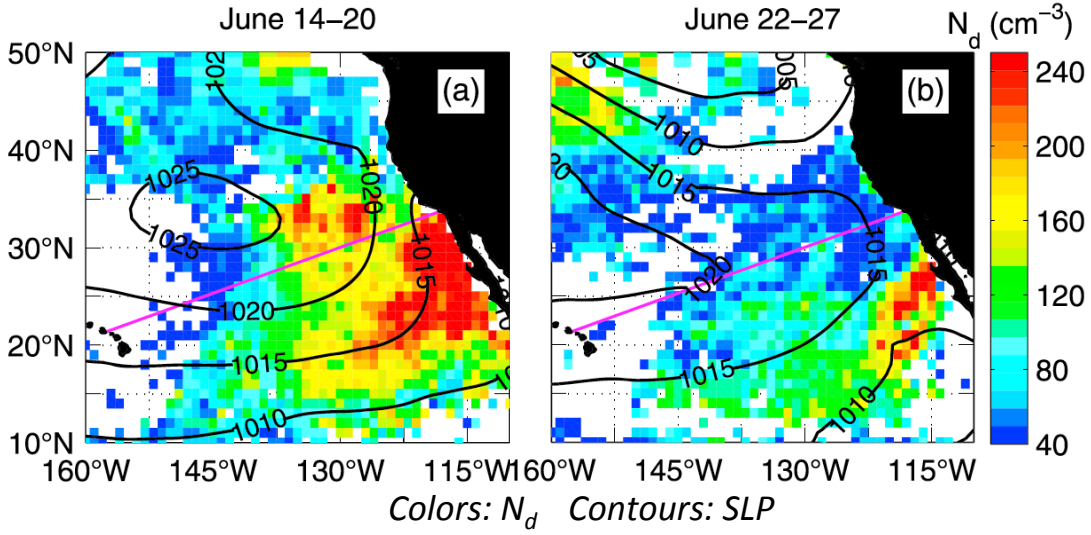
Regional patterns of aerosol transport

MAGIC cloud condensation nuclei CCN observations





Satellite-based cloud number of droplets (N_d), $N_d = K \bullet r_e^{-5/2} \bullet \tau^{-1/2}$



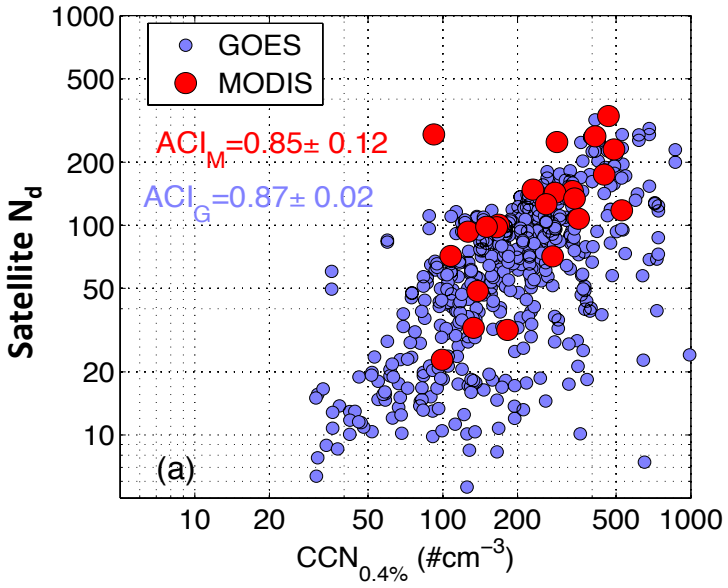
Colors: N_d Contours: SLP

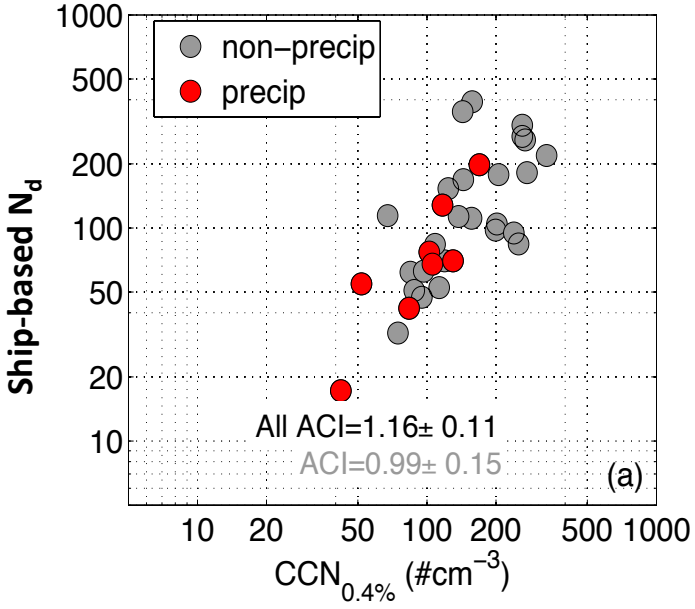
- Periods with high CCN consistent with back-trajectories originated near the coast
- Aerosol changes during MAGIC associated with synoptic changes in circulation

Painemal et al. (JGR, 2015)

Aerosol indirect effect

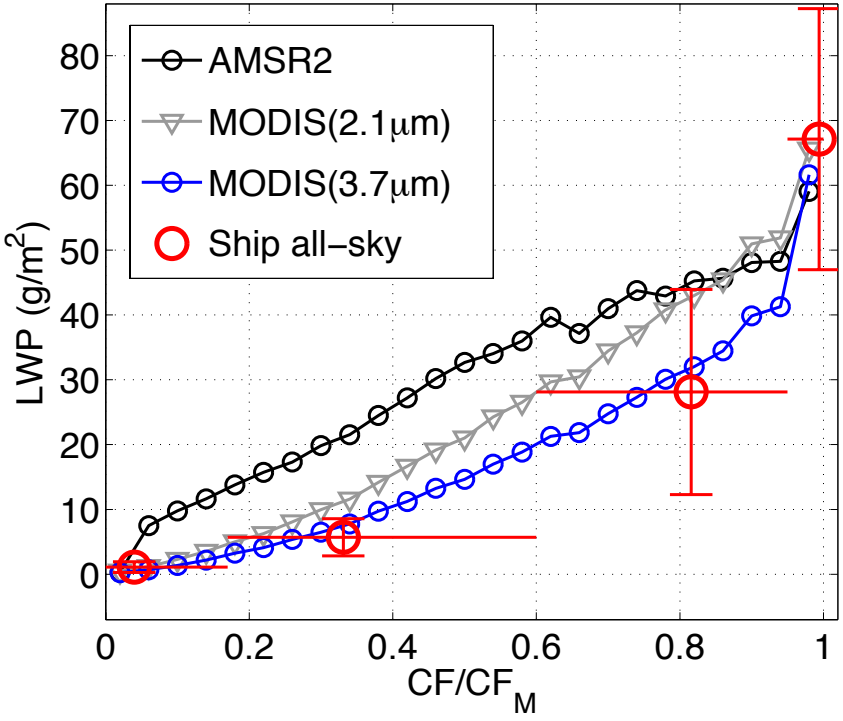
- Quantification of the relationship between aerosol and cloud microphysics
- Cloud droplet number concentration $N_d = K \cdot r_e^{-5/2} \cdot \tau^{-1/2}$
    - Co-variability between aerosol (cloud condensation nuclei) and N_d (Painemal et al. 2016, in prep.)





Partially cloudy scenes: LWP

- Are satellite cloud data reliable in partially cloudy scenes for climate applications?



- MODIS LWP=LWP$_{cloudy}$•CF$_M$
- Data binned as a function of satellite cloud frequency (CF) and MODIS cloud fraction (CF$_M$)
- AMSR-2 and MODIS(2.1μm) overestimate the ship-based data
- MODIS(3.7μm) is nearly unbiased !!!

Painemal et al 2016 (GRL, under review)

Future satellite-aircraft intercomparisons

- CSET: Northeast Pacific

- ORACLES and LASIC: Northeast Atlantic

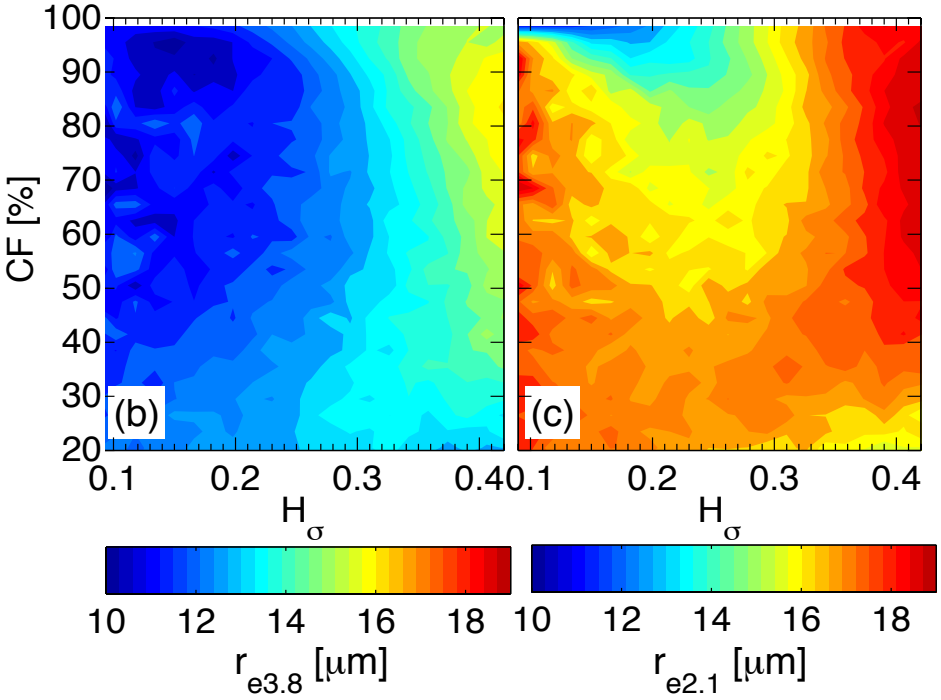
Concluding remarks

- MODIS LWP and ship-based retrievals are highly correlated.
  - For broken scenes, MODIS LWPxCF reproduces the LWP dependence on cloud cover
- MODIS τ correlates well with sun-photometer τ.
- Lapse rate technique is adequate for deriving cloud height using cloud temperature and SST

- Current research activities:
  - Marine boundary layer evolution: boundary layer coupling, cloud top longwave cooling, and entrainment.
  - Evaluation of satellite microwave retrievals in broken scenes.
  - Quantification of the aerosol indirect effect:
    - Co-variability between cloud and aerosol properties.
    - Albedo perturbations associated with changes in cloud microphysics.

- *Acknowledgements: ARM-DOE grant DE-FOA-0000885, CERES program*

Partially cloudy scenes II: Cloud effective radius



- CF: Cloud fraction
- H_σ: heterogeneity factor, $\sigma_{0.64\mu m}/\mu_{0.64\mu m}$ (Liang et al., 2009, JGR)
- $r_{e3.78}$ less sensitive to CF and H_σ
- *Painemal et al. (2013 ACP)*