# MAGICal Results on Marine Clouds

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BROOKHAVEN
NATIONAL LABORATORY

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# Marine ARM GPCI Investigation of Clouds

ARM: Atmospheric Radiation Measurement Climate Research Facility
of the US Department of Energy

GPCI: GCSS Pacific Cross-section Intercomparison
GCSS: GEWEX Cloud System Studies
GEWEX: Global Energy and Water Cycle Experiment

GPCI no longer operational
GCSS now GASS: Global Atmospheric System Studies
GEWEX now Global Energy and Water Exchanges Project

"MAGIC" is easiest

# Origin of MAGIC

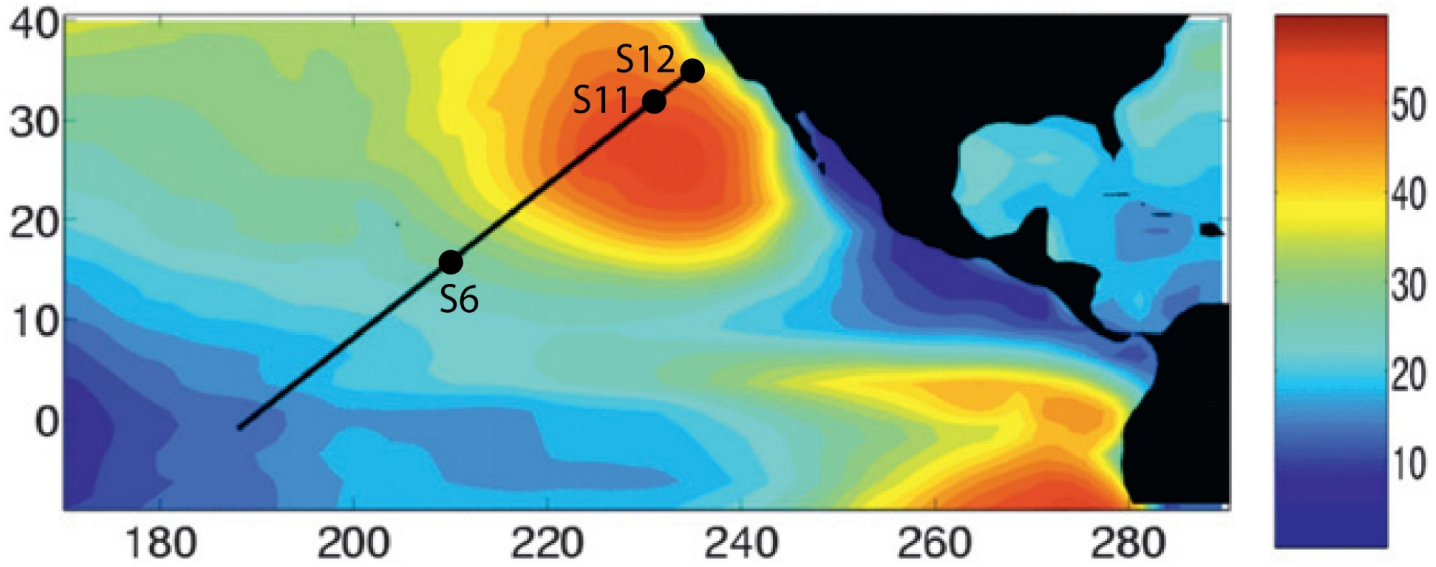
Joao Teixeira (JPL)

Warren Wiscombe (ex-NASA)

Nicki Hickmon (ANL)


Ernie Lewis (BNL) & Mike Reynolds (RMR Co.)

# GPCI Transect

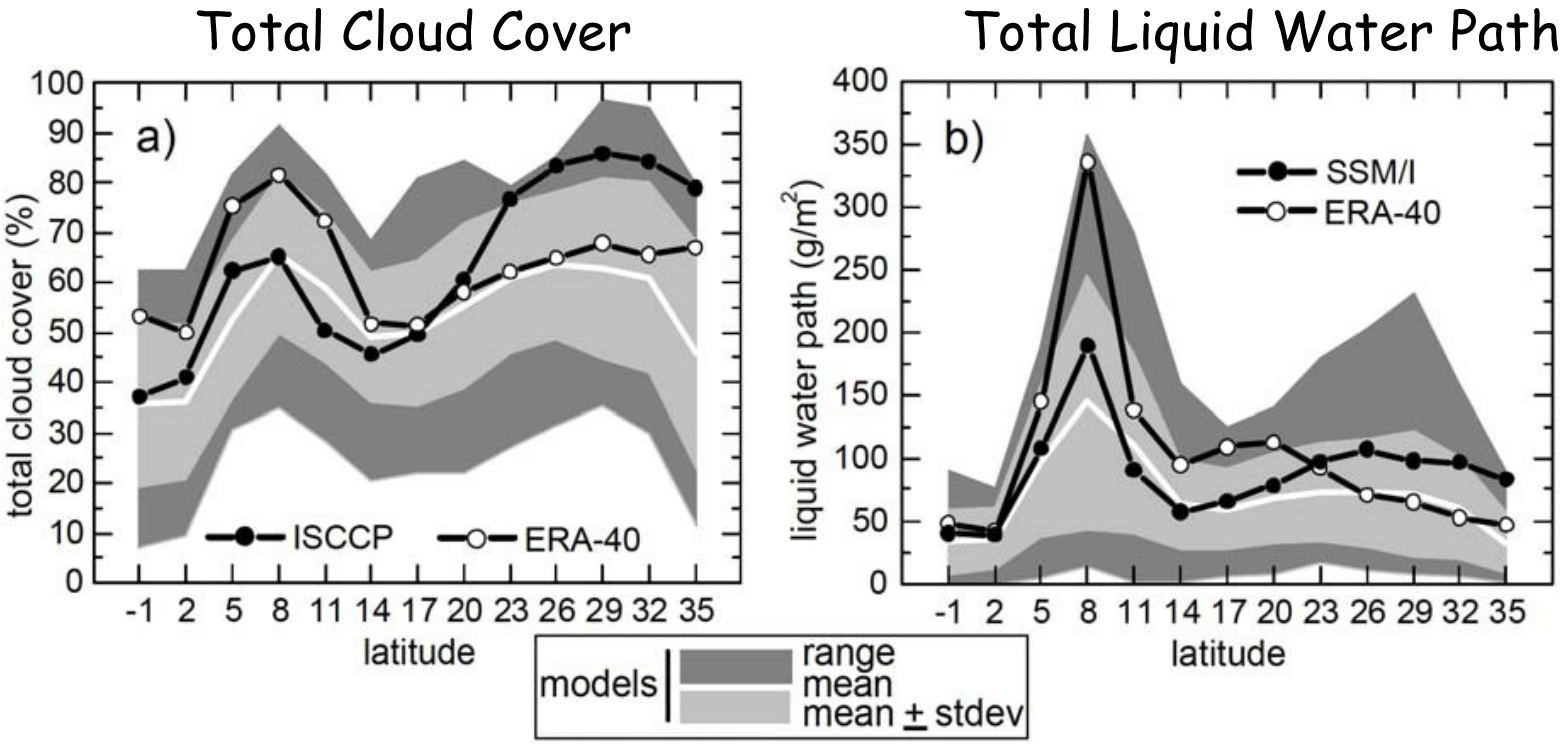



Per cent JJA average low-level cloud cover with GPCI transect & CGILS points

Adapted from Teixeira et al., J. Climate, 2011

Model intercomparison done along transect.

# Models Exhibit Some Disagreement



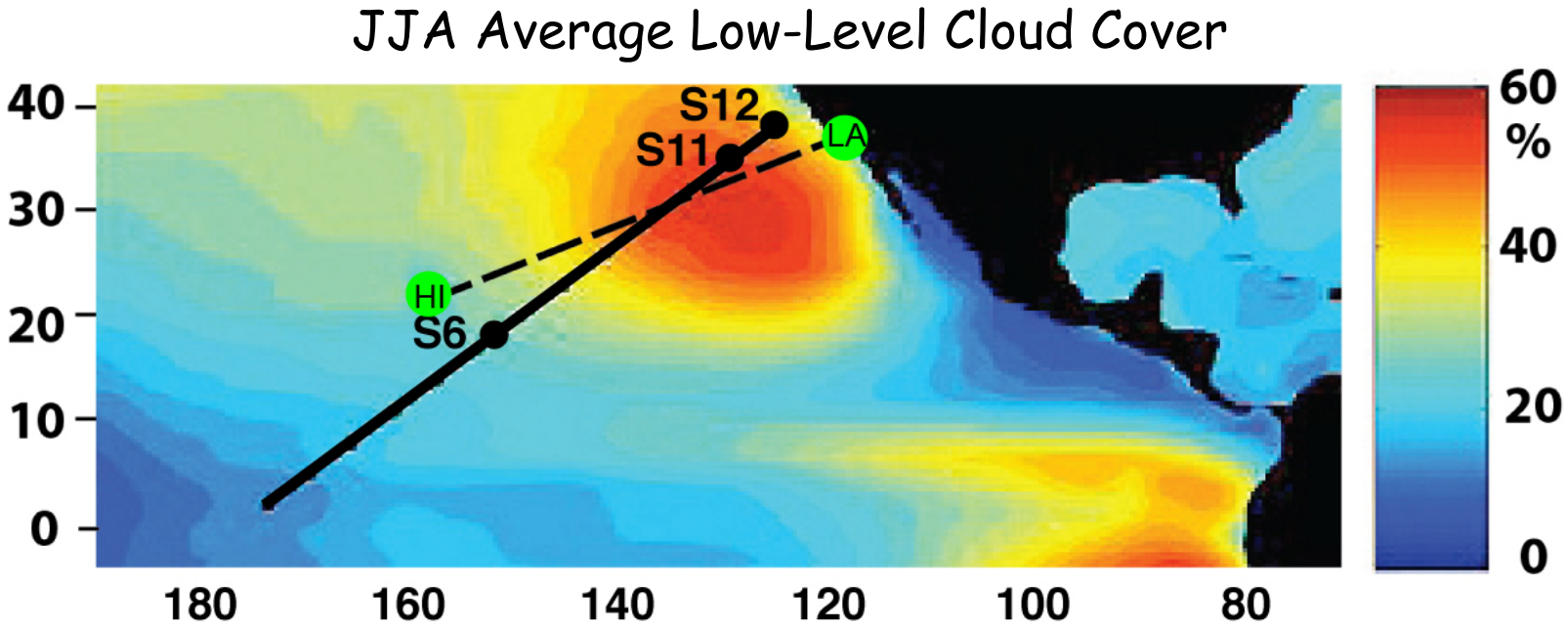

**from Teixeira et al., 2011**

For JJA 1998 along GPCI

Ensemble results from 23 models; mean plus or minus standard deviation

Range extends from minimum to maximum values.

# MAGIC Transect




JJA average low-level cloud cover with MAGIC route, GPCI transect, & CGILS points

Adapted from Teixeira et al., J. Climate, 2011

- 4100 km from Los Angeles to Honolulu
- Important climatic region
- near GPCI transect

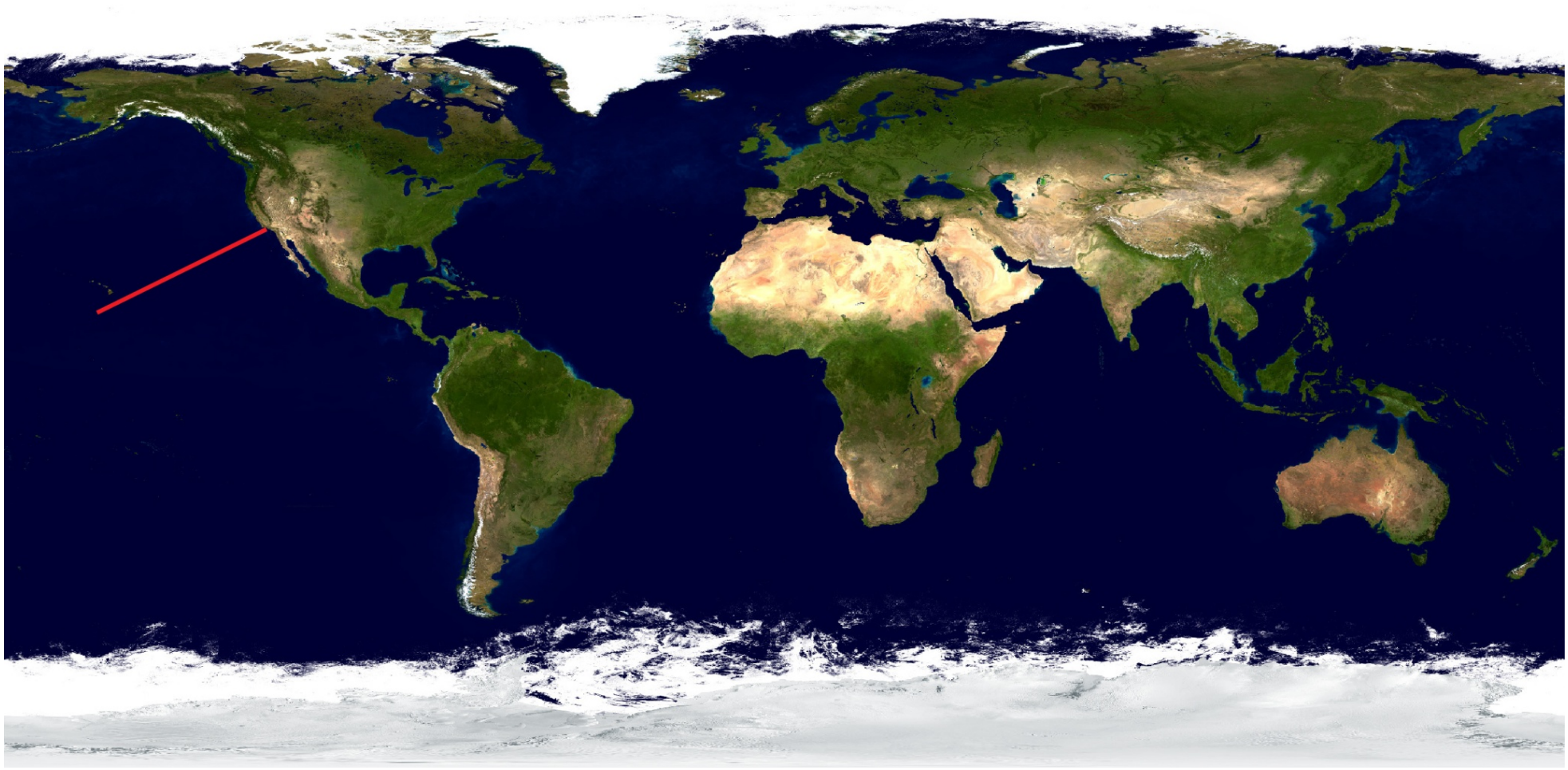
# MAGIC Objectives

The scientific objectives are:

1) improve the representation of the Sc-to-Cu transition in climate models by characterizing the essential properties of this transition

2) to produce the observed statistics of these Sc-to-Cu characteristics along these transects during the deployment period.

# MAGIC is a True Marine Deployment



2015/01 – 2015/02

ACAPEX

2017/09 – 2018/04

MARCUS

2019- 2020 ??

MOSAiC

2015/01 – 2015/02  ACAPEX MAGIC North

2017/09 – 2018/04  MARCUS MAGIC South

2019- 2020 ??  MOSAiC MAGIC Arctic

# Horizon *Spirit*


We thank the Horizon Lines and the Captain and crew of the Horizon *Spirit* for their hospitality and their support and enthusiasm of MAGIC!

HORIZON LINES

# *Spirit*

The *Spirit* is 272 m long and 30 m wide, with a maximum speed of ~11 m $s^{-1}$

It is a Class C9 ship built in 1980 and has Jones Act designation.

It has a FEU (forty-foot equivalent unit) capacity of 1218.

It makes the round trip from Los Angeles to Hawaii (4100 km) every two weeks.

Los Angeles to Hawaii takes $4\frac{1}{2}$ days.

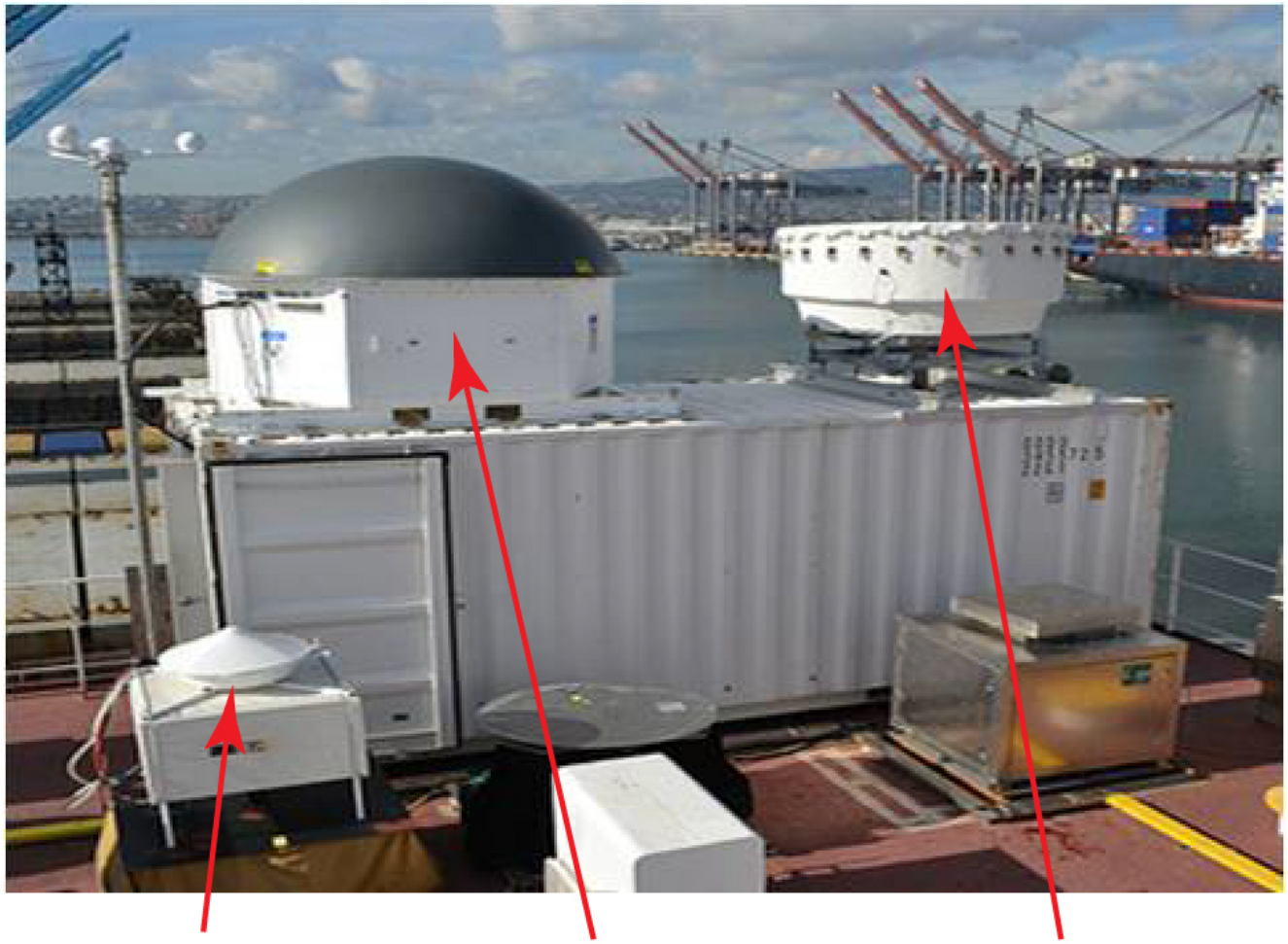
Hawaii to Los Angeles takes $6\frac{1}{2}$ days.

MAGIC made 20 round trips (~200 days at sea) between Sept, 2012 and Oct, 2013.

# Two ARM Technicians Lived on the *Spirit*


Mark, Tom, Brett, Pat

# MAGIC Had Three Radars



zenith-pointing W-band (95 GHz) on stable table

beam-steerable wind profiler (1290 MHz)

vertically-pointing Ka-band (35 GHz)

Corrections for ship motion have been made.

# Cloud & Precipitation Instruments

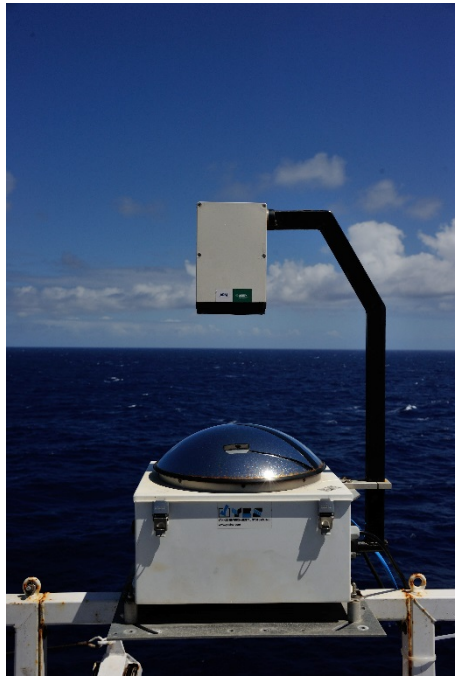
Disdrometers

Ceilometer

2 Channel MWR

3 Channel MWR

LIDAR



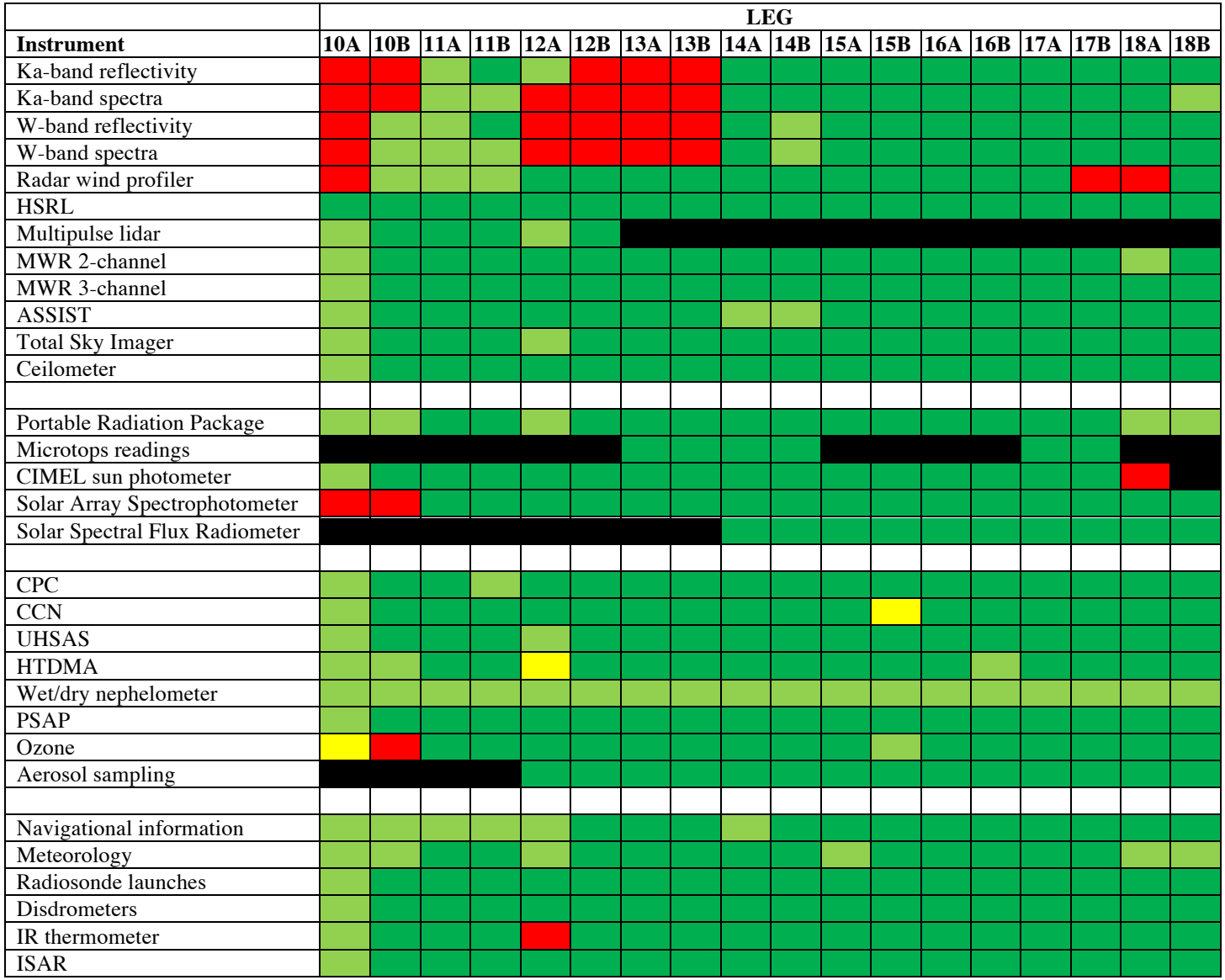
Total Sky Imager

CIMEL (cloud mode)

# Instrument Status Tables Leg03A-Leg09A

| | Leg | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Instrument** | **03A** | **03B** | **04A** | **04B** | **05A** | **05B** | **06A** | **06B** | **07A** | **07B** | **08A** | **08B** | **09A** |
| Ka-band reflectivity | | | | | | | | | | | | | |
| Ka-band spectra | | | | | | | | | | | | | |
| W-band reflectivity | | | | | | | | | | | | | |
| W-band spectra | | | | | | | | | | | | | |
| Radar wind profiler | | | | | | | | | | | | | |
| HSRL | | | | | | | | | | | | | |
| Multipulse lidar | | | | | | | | | | | | | |
| MWR 2-channel | | | | | | | | | | | | | |
| MWR 3-channel | | | | | | | | | | | | | |
| ASSIST | | | | | | | | | | | | | |
| Total Sky Imager | | | | | | | | | | | | | |
| Ceilometer | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Portable Radiation Package | | | | | | | | | | | | | |
| Microtops readings | | | | | | | | | | | | | |
| CIMEL sun photometer | | | | | | | | | | | | | |
| Solar Array Spectrophotometer | | | | | | | | | | | | | |
| Solar Spectral Flux Radiometer | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| CPC | | | | | | | | | | | | | |
| CCN | | | | | | | | | | | | | |
| UHSAS | | | | | | | | | | | | | |
| HTDMA | | | | | | | | | | | | | |
| Wet/dry nephelometer | | | | | | | | | | | | | |
| PSAP | | | | | | | | | | | | | |
| Ozone | | | | | | | | | | | | | |
| Aerosol sampling | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Navigational information | | | | | | | | | | | | | |
| Meteorology | | | | | | | | | | | | | |
| Radiosonde launches | | | | | | | | | | | | | |
| Disdrometers | | | | | | | | | | | | | |
| IR thermometer | | | | | | | | | | | | | |
| ISAR | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

# Instrument Status Tables Leg10A-Leg18B



| | LEG | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Instrument** | **10A** | **10B** | **11A** | **11B** | **12A** | **12B** | **13A** | **13B** | **14A** | **14B** | **15A** | **15B** | **16A** | **16B** | **17A** | **17B** | **18A** | **18B** |
| Ka-band reflectivity | | | | | | | | | | | | | | | | | | |
| Ka-band spectra | | | | | | | | | | | | | | | | | | |
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| Portable Radiation Package | | | | | | | | | | | | | | | | | | |
| Microtops readings | | | | | | | | | | | | | | | | | | |
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| Solar Spectral Flux Radiometer | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| CPC | | | | | | | | | | | | | | | | | | |
| CCN | | | | | | | | | | | | | | | | | | |
| UHSAS | | | | | | | | | | | | | | | | | | |
| HTDMA | | | | | | | | | | | | | | | | | | |
| Wet/dry nephelometer | | | | | | | | | | | | | | | | | | |
| PSAP | | | | | | | | | | | | | | | | | | |
| Ozone | | | | | | | | | | | | | | | | | | |
| Aerosol sampling | | | | | | | | | | | | | | | | | | |
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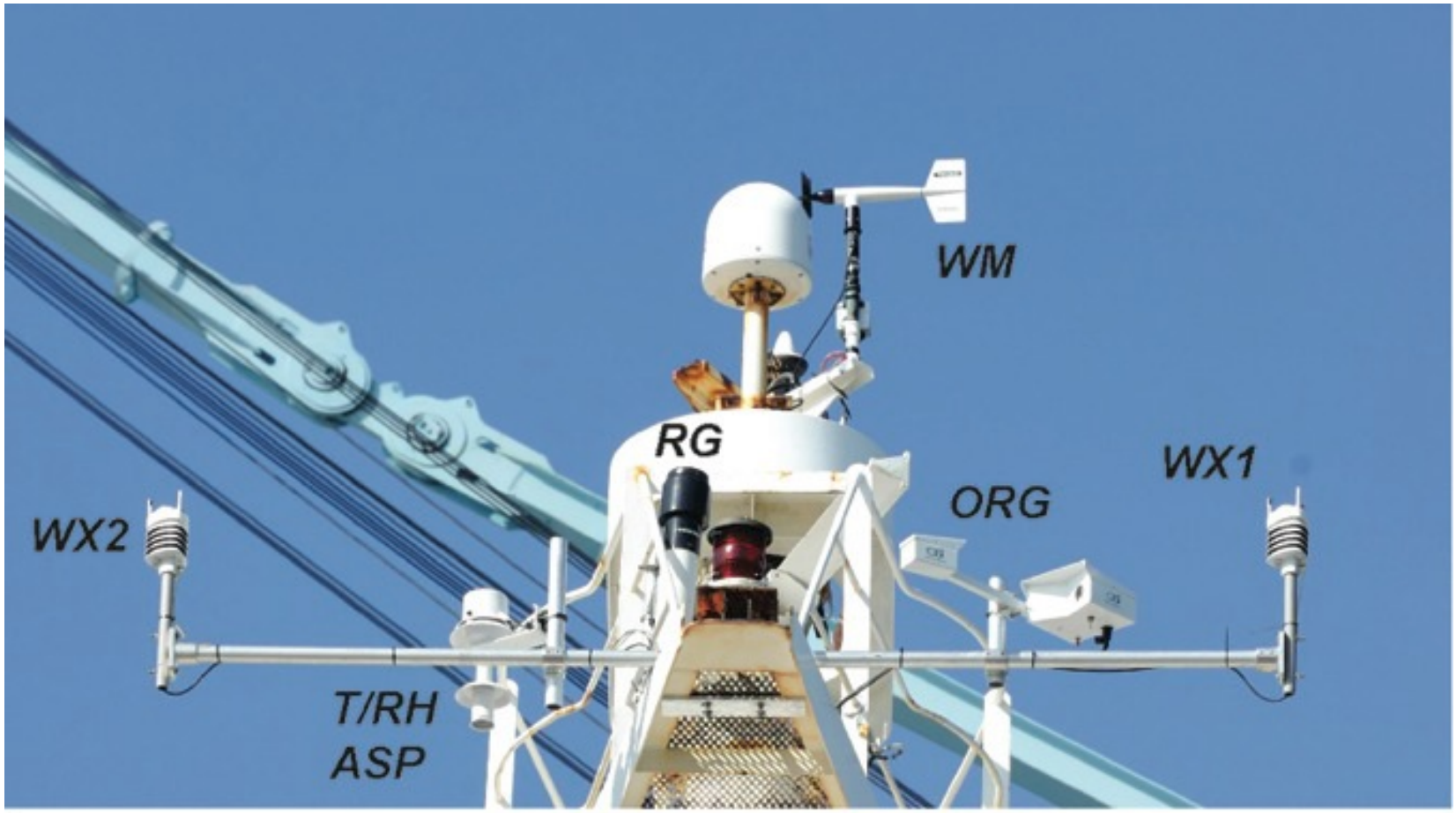
| Navigational information | | | | | | | | | | | | | | | | | | |
| Meteorology | | | | | | | | | | | | | | | | | | |
| Radiosonde launches | | | | | | | | | | | | | | | | | | |
| Disdrometers | | | | | | | | | | | | | | | | | | |
| IR thermometer | | | | | | | | | | | | | | | | | | |
| ISAR | | | | | | | | | | | | | | | | | | |

# Meteorological Measurements


The meteorological mast is ~27 m above sea level.

# Mast Meteorological System



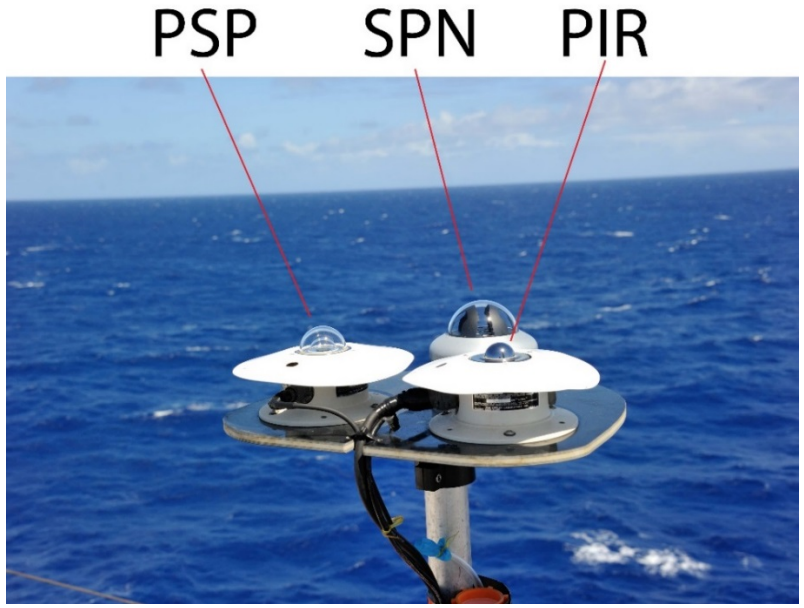

WX1, WX2 = Vaisala WXT520 (ws,wd,ta,rh,bp,ri)
RG = Young 50203 Siphon Rain Gauge
WM = Young 05106 Wind Monitor

T/RH = Vaisala HMP155, ASP = Aspirator
ORG = OSI Optical Rain Gauge

met-boom

Multiple measurements of T, P, RH, wind speed and direction, precipitation.

# Radiation Measurements




Portable Radiation Package (PRP)

PRP with FRSR

Two Portable Radiation Packages (PRP) – one on each side of ship

Fast Rotating Shadowband Radiometer (FRSR)

# Additional Radiometric Instruments

Solar Array Spectrometer

Solar Spectrum Flux Radiometer (SSFR)

CIMEL Sunphotometer in cloud mode for cloud optical depth
Microtops sunphotometer measurements on some legs

Sea surface temperature was also measured using an ISAR

# Surface Fluxes during MAGIC

1-minute time series of surface energy fluxes (latent and sensible heat, precipitation, SW and LW) during MAGIC are available in the ARM archive

Two data files are available: "flux.mat" and "magic_flux.txt"

To access these data,

1) go to www.arm.gov/campaigns/amf2012magic
2) go to "Bulk Aerodynamic Fluxes" under "Campaign Data Sets"
3) click "Order Data"

Be sure to read the file "magic_flux_readme_arm.txt" which is also in the archive, and the document "OnDataProcessing" at www.rmrco.com/cruise/magic/data/OnDataProcessing/

# Radiosonde Launches

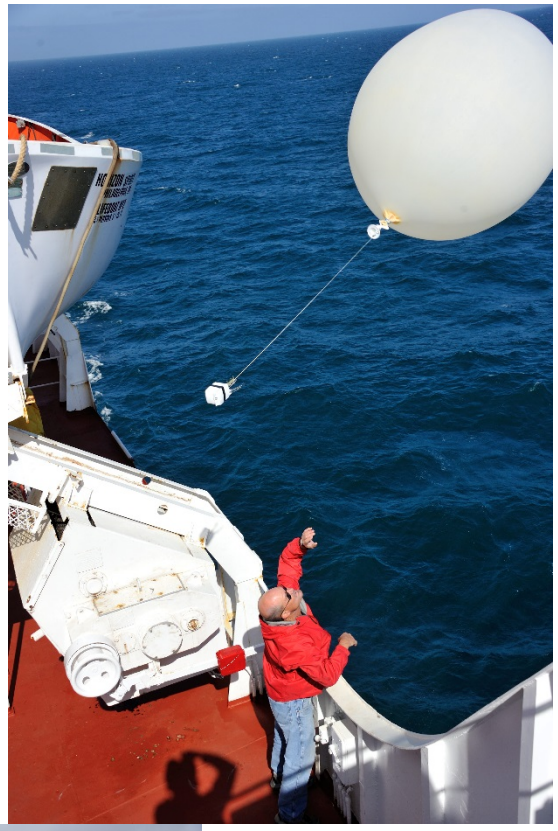
4/day throughout the deployment

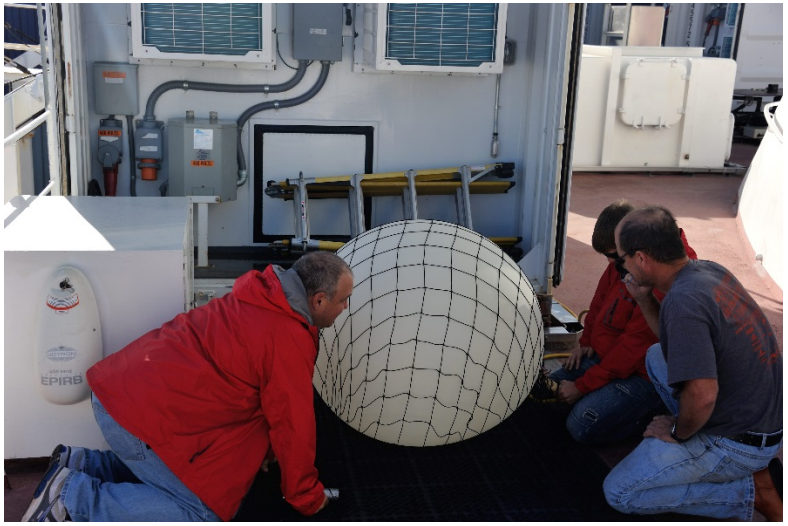
8/day for one round trip in July, 2013

565 successful launches out of 695 attempts (> 80% success rate!)

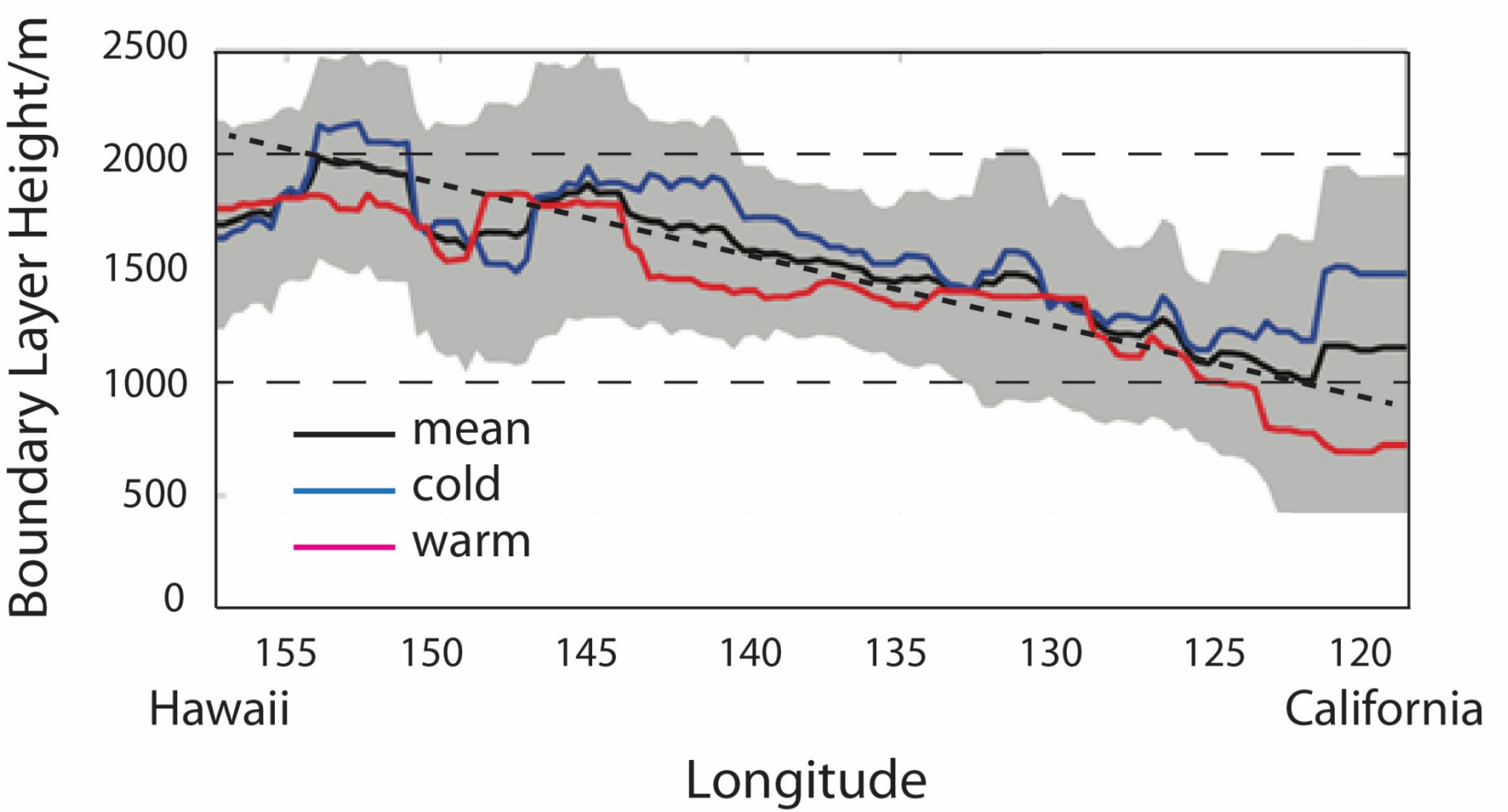
# Successful Launches at $U_{relative}$ > 24 m $s^{-1}$ !!


45
45
45
45



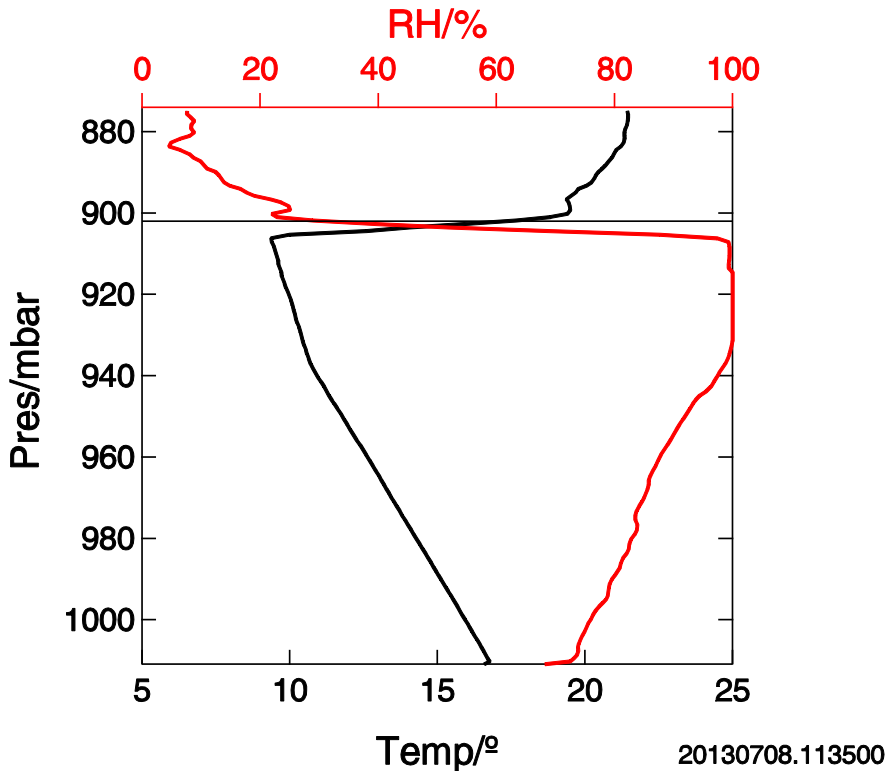


# MAGIC Marine Boundary Layer Heights

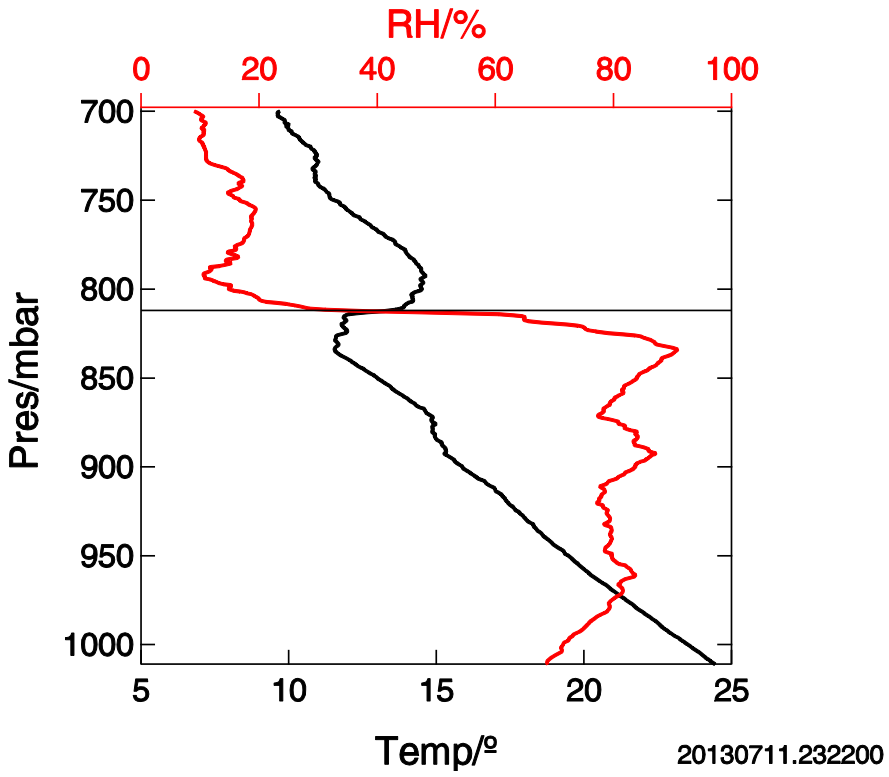



$H_{MBL}$ increases from ~1 km near California to ~2 km near Hawaii

# Stratocumulus Deck: 125° W




# Decoupled MBL: 156° W



# ECMWF along-track forecast data now available

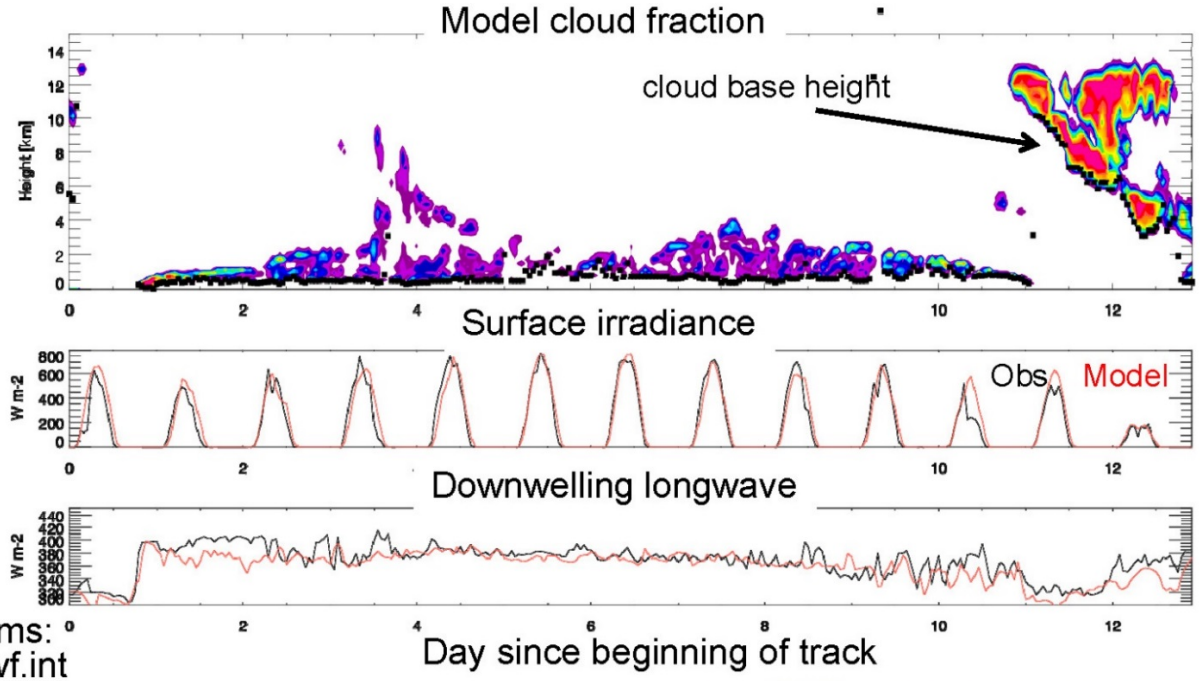
**Upper air fields**: T, q, u, v, w, CC, CLWC, CIWC, rain, snow

**Surface fields**: T 2m, D 2m, u10, v10, surface radiation and fluxes, BLH, cloud base height, surface precip etc.

**Operational forecast**, initialized at 12 UTC, forecast steps 12-33 (verification time 00-23UTC). Nearest model grid point at full resolution (~16km) picked hourly

Sondes were **not** assimilated

Quick look: Track 5
Nov 3-16 2012




For questions or problems:
Maike.ahlgrimm@ecmwf.int

# Publications Relating to MAGIC


**2014**

Kalmus, P., M. Lebsock, and J. Teixeira (2014), Observational boundary layer energy and water budgets of the stratocumulus-to-cumulus transition, *J. Climate*, 27(24), 9155-9170. DOI:10.1175/JCLI-D-14-00242.1

Lewis, E. (2014), MAGIC studies clouds, aerosols, radiation, and fluxes in the Eastern North Pacific, *SOLAS Newsletter*, Summer, 2014, pp. 24-25.

**2015**

Kalmus, P., S. Wong, and J. Teixeira (2015), The Pacific subtropical cloud transition: A MAGIC assessment of AIRS and ECMWF thermodynamic structure, *IEEE Geosci. Remote Sens. Lett.*, 12(7), 1586-1590. DOI:10.1109/LGRS.2015.2413771

DeMott, P. J. et al. (2015), Sea spray aerosol as a unique source of ice nucleating particles, *Proc. Nat. Acad. Sci.*, Early Edition. DOI:10.1073/pnas.1514034112.

Zhou, X., P. Kollias, and E. R. Lewis (2015), Clouds, precipitation, and marine boundary layer Structure during the MAGIC field campaign, *J. Climate*, 28, 2420-2441. DOI:10.1175/JCLI-D-14-00320.1

Painemal, D., P. Minnis, and M. Nordeen (2015), Aerosol variability, synoptic-scale processes, and their link to the cloud microphysics over the Northeast Pacific during MAGIC, *J. Geophys. Res. – Atmos.*, 120, 5122-5139. DOI:10.1002/2015JD023175

Lewis, E., and J. Teixeira (2015), Dispelling clouds of uncertainty, *EOS*, 96(12), 16-19.; Online at https://eos.org/project-updates/dispelling-clouds-of-uncertainty.

Y. Zheng, and D. Rosenfeld (2015), Linear relation between convective cloud base height and updrafts and application to satellite retrievals, *Geophys. Res. Lett.*, 42, 6485-6491. DOI:10.1002/2015GL064809

Fielding, M. D., J. C. Chui, R. J. Hogan, G. Feingold, E. Eloranta, E. J. O'Connor, and M. P. Cadeddu (2015), Joint retrievals of cloud and drizzle in marine boundary layer clouds using ground-based radar, lidar and zenith radiances, *Atmos. Meas. Tech.*, 8, 2663-2683. DOI:10.5194/amt-8-2663-2015; Online at http://www.atmos-meas-tech.net/8/2663/2015/amt-8-2663-2015.pdf.

**2016**

Millán, L., M. Lebsock, E. Fishbein, P. Kalmus, & J. Teixeira (2016), Quantifying marine boundary layer water vapor beneath low clouds with near-infrared and microwave imagery, *J. Appl. Meteor. Climatol.*, 55, 213-224. DOI: 10.1175/JAMC-D-15-0143.1

Rosenfeld, D., et al. (2016), Satellite retrieval of cloud condensation nuclei concentrations by using clouds as CCN chambers, *Proc. Natl. Acad. Sci.*, Early Edition. DOI:10.1073/PNAS.15140441113.

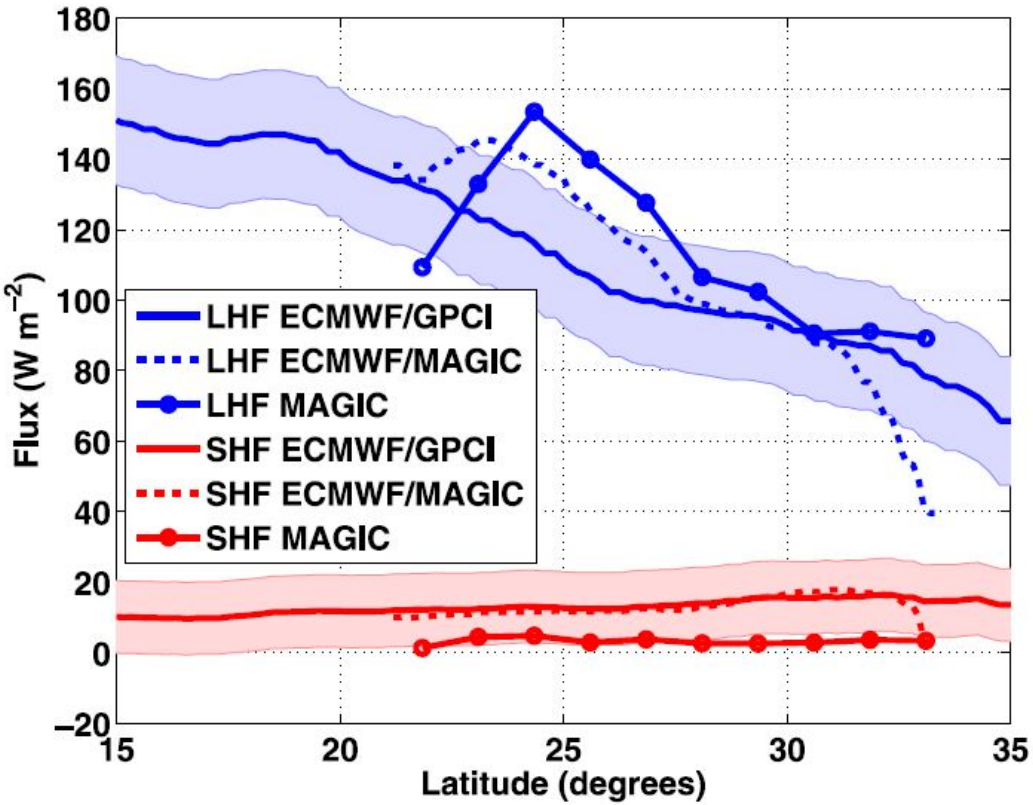
JOURNAL OF CLIMATE VOLUME 27

15 DECEMBER 2014 KALMUS ET AL. 9155

# Observational Boundary Layer Energy and Water Budgets of the Stratocumulus-to-Cumulus Transition

PETER KALMUS, MATTHEW LEBSOCK, AND JOÃO TEIXEIRA

*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California*

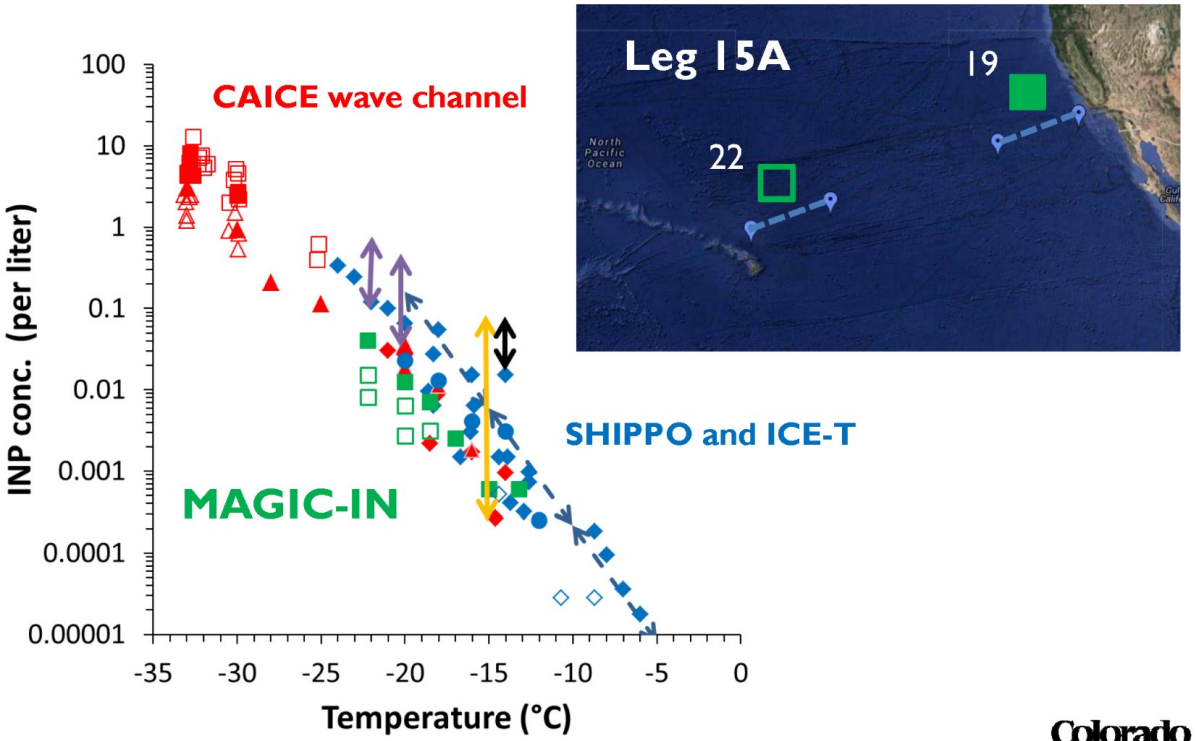


PNAS Early Edition, 2015

# Sea spray aerosol as a unique source ofice nucleating particles

Paul J. DeMott [a,1], Thomas C. J. Hill [a], Christina S. McCluskey [a], Kimberly A. Prather [b,c], Douglas B. Collins [b], Ryan C. Sullivan [d], Matthew J. Ruppel [b,2], Ryan H. Mason [e], Victoria E. Irish [e], Taehyoung Lee [f], Chung Yeon Hwang [g], Tae Siek Rhee [g], Jefferson R. Snider [h], Gavin R. McMeeking [i], Suresh Dhaniyala [j], Ernie R. Lewis [k], Jeremy J. B. Wentzell [l], Jonathan Abbatt [m], Christopher Lee [b], Camille M. Sultana [b], Andrew P. Ault [n,o], Jessica L. Axson [o], Myrelis Diaz Martinez [p], Ingrid Venero [p], Gilmarie Santos-Figueroa [p], M. Dale Stokes [c], Grant B. Deane [c], Olga L. Mayol-Bracero [p], Vicki H. Grassian [q], Timothy H. Bertram [r], Allan K. Bertram [e], Bruce F. Moffett [s], and Gary D. Franc [t,3]

## Comparison for a few recent MAGIC samples




Colorado State University

Slide courtesy Paul DeMott

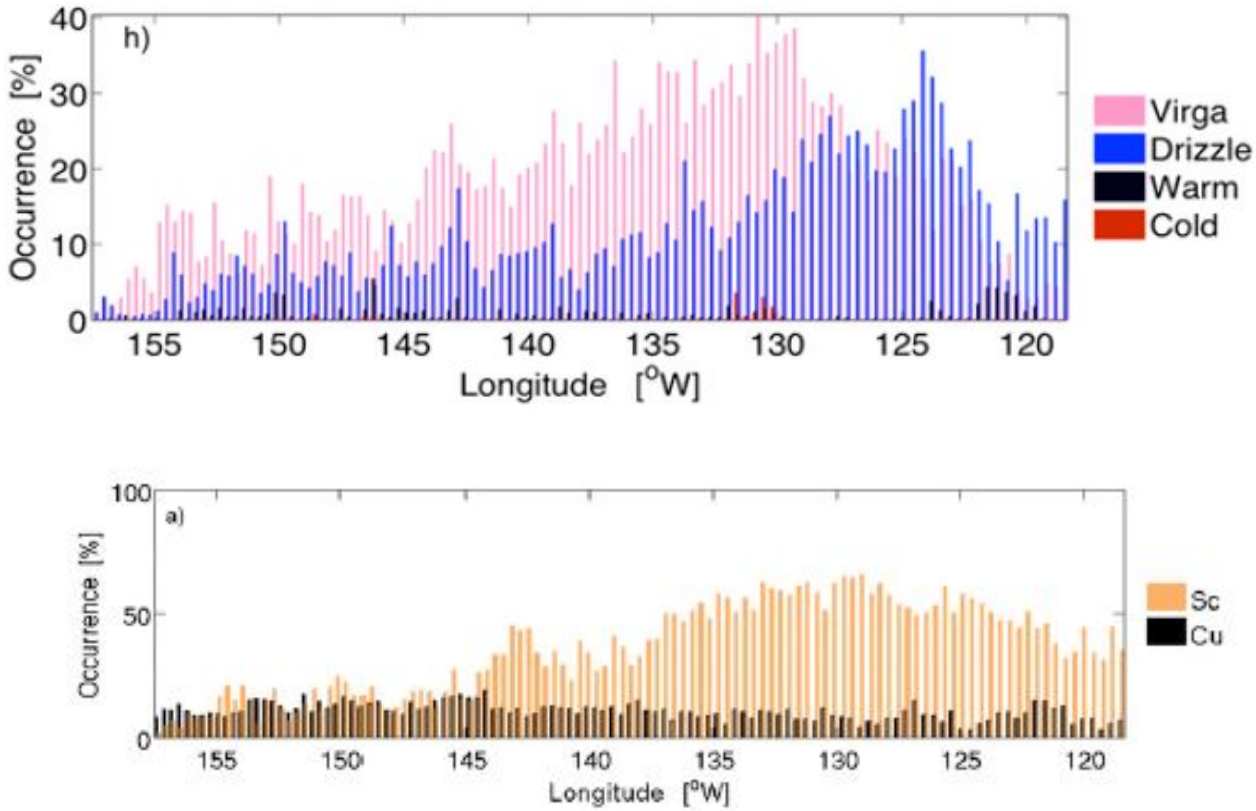
# Clouds, Precipitation, and Marine Boundary Layer Structure during the MAGIC Field Campaign

XIAOLI ZHOU AND PAVLOS KOLLIAS

*Department of Atmospheric and Oceanic Sciences, McGill University, Montreal, Quebec, Canada*

ERNIE R. LEWIS

*Biological, Environmental and Climate Sciences Department, Brookhaven National Laboratory, Upton, New York*



EOS July 1, 2015

# DISPELLING CLOUDS of UNCERTAINTY

By Ernie R. Lewis and João Teixeira

AGU PUBLICATIONS

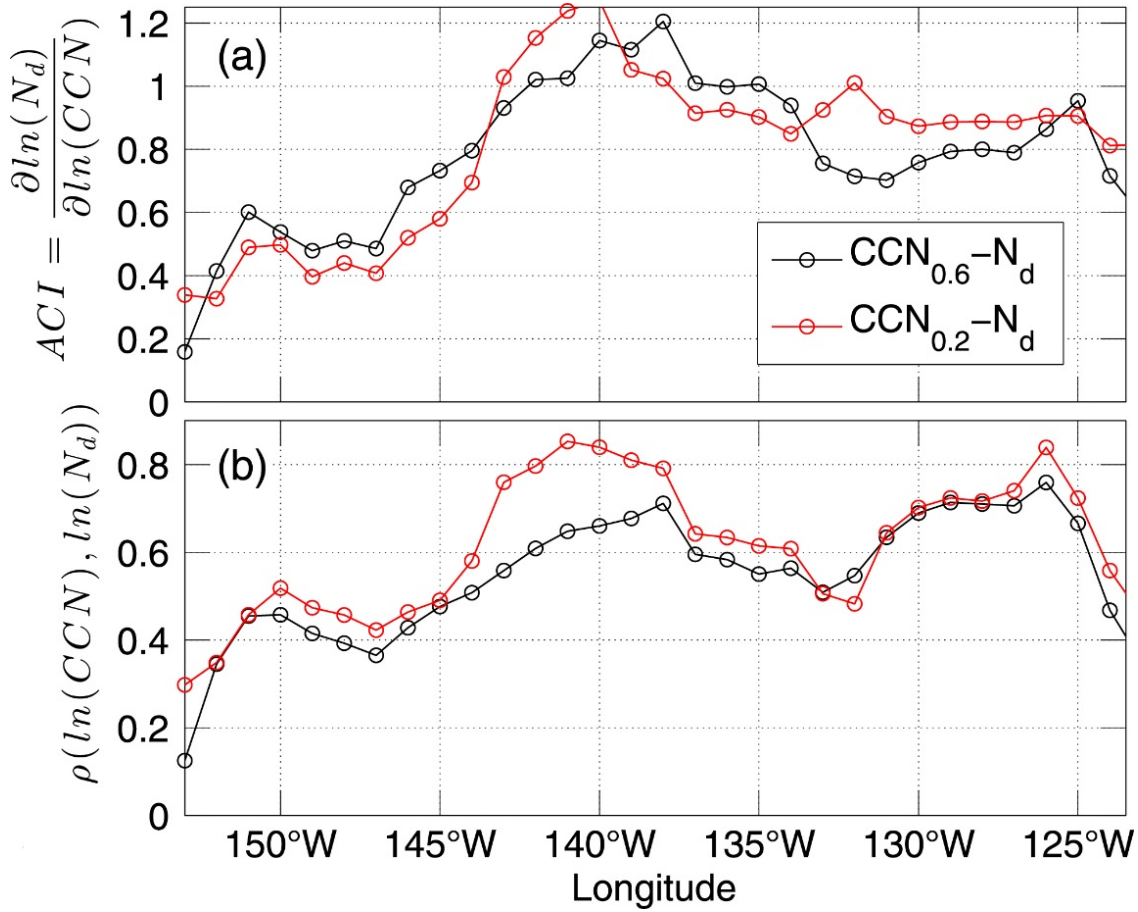
JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE
10.1002/2015JD023175

# Aerosol variability, synoptic-scale processes, and their link to the cloud microphysics over the northeast Pacific during MAGIC

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

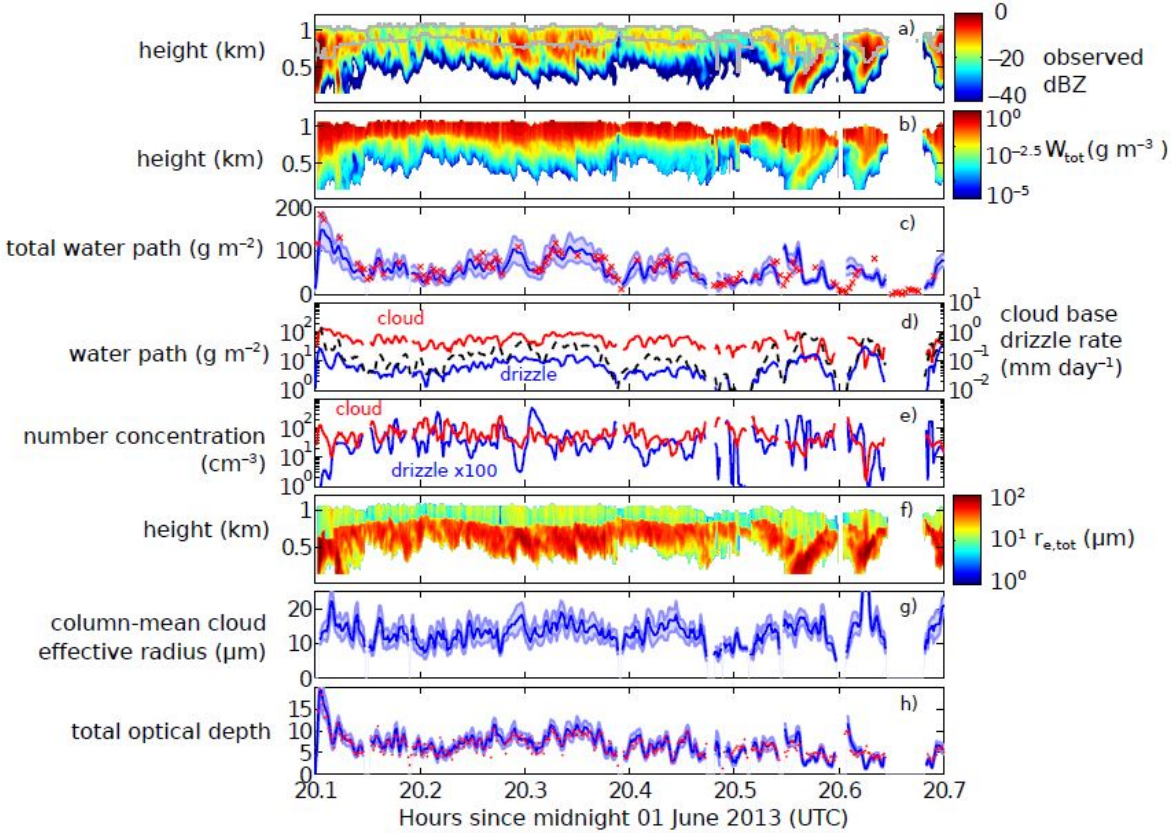


Atmos. Meas. Tech., 8, 2663–2683, 2015
www.atmos-meas-tech.net/8/2663/2015/
doi:10.5194/amt-8-2663-2015


Atmospheric Measurement Techniques
Open Access

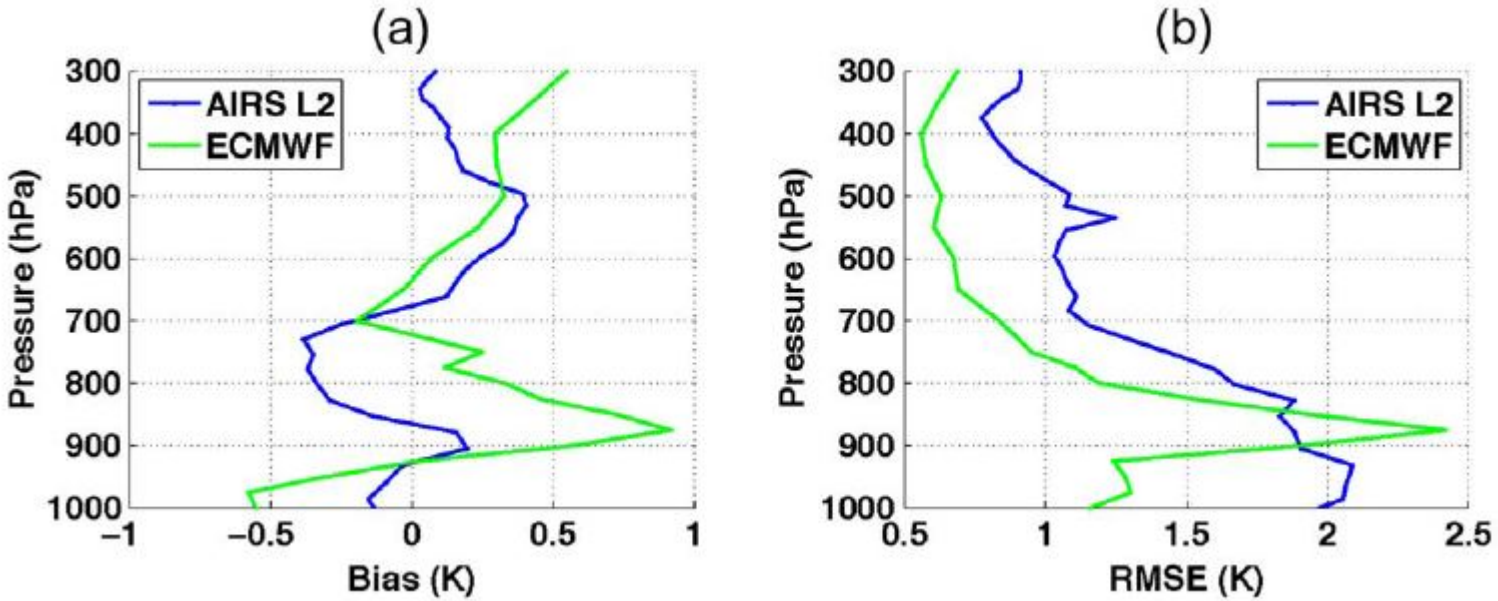
# Joint retrievals of cloud and drizzle in marine boundary layer clouds using ground-based radar, lidar and zenith radiances

**M. D. Fielding[1], J. C. Chiu[1], R. J. Hogan[1], G. Feingold[2], E. Eloranta[3], E. J. O'Connor[1,4], and M. P. Cadeddu[5]**



# The Pacific Subtropical Cloud Transition: A MAGIC Assessment of AIRS and ECMWF Thermodynamic Structure

Peter Kalmus, Sun Wong, and João Teixeira



AGU PUBLICATIONS

Geophysical Research Letters

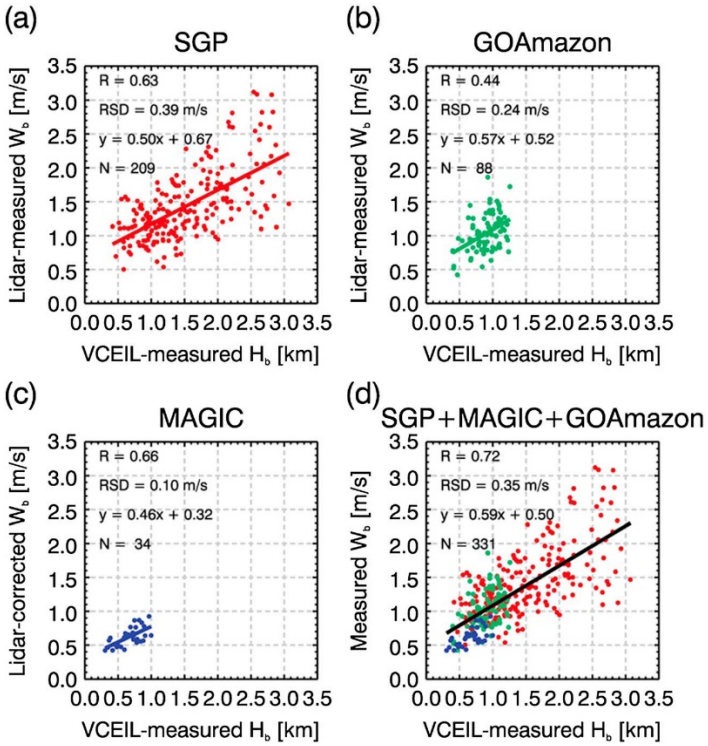
RESEARCH LETTER
10.1002/2015GL064809

Key Points:
- A tightly linear relationship was found between cloud base height and updraft
- This relationship works over both ocean and land
- A method of retrieving cloud base updrafts from satellite was proposed

# Linear relation between convective cloud base height and updrafts and application to satellite retrievals

Youtong Zheng [1,2] and Daniel Rosenfeld [2]

[1]Department of Atmospheric and Oceanic Science and Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, USA, [2]Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem, Israel



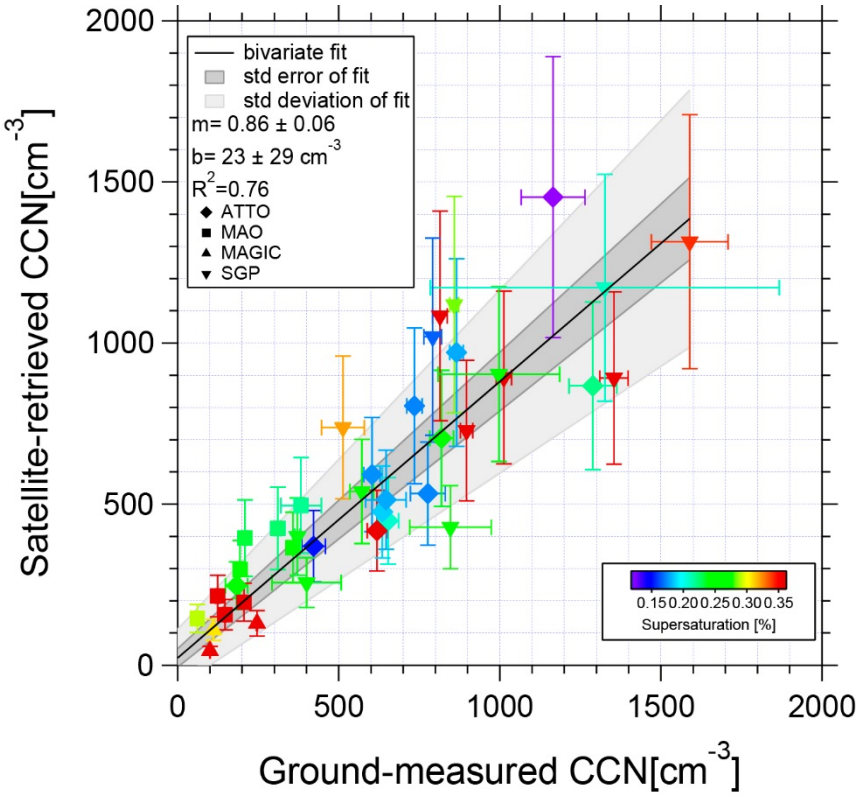
PNAS



COLLOQUIUM PAPER

# Satellite retrieval of cloud condensation nuclei concentrations by using clouds as CCN chambers

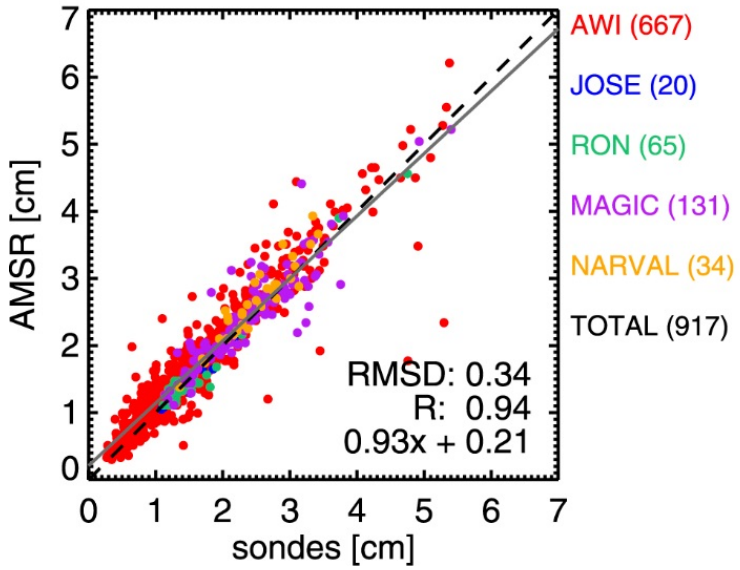
Daniel Rosenfeld [a,1], Youtong Zheng [b,c,d], Eyal Hashimshoni [a], Mira L. Pöhlker [e,f], Anne Jefferson [g], Christopher Pöhlker [e], Xing Yu [h], Yannian Zhu [d,h], Guihua Liu [h], Zhiguo Yue [h], Baruch Fischman [a], Zhanqing Li [b,c,d], David Giguzin [a], Tom Goren [a], Paulo Artaxo [i], Henrique M. J. Barbosa [i], Ulrich Pöschl [e,f], and Meinrat O. Andreae [e]

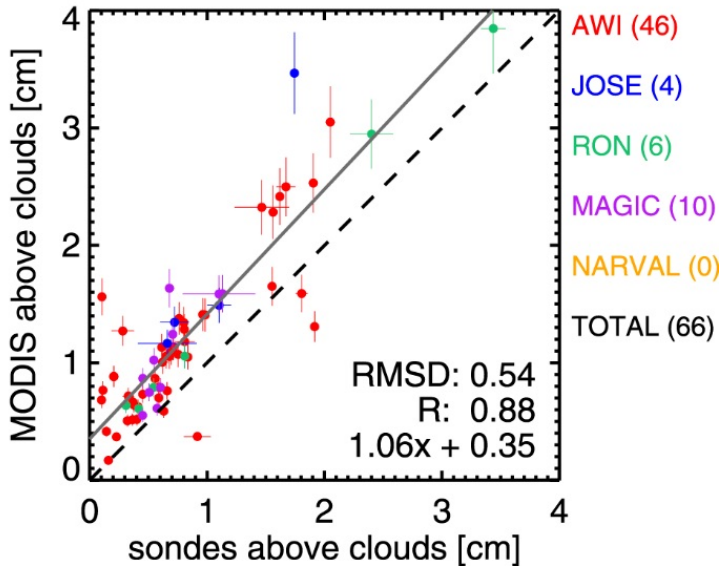


**Quantifying Marine Boundary Layer Water Vapor beneath Low Clouds with Near-Infrared and Microwave Imagery**

LUIS MILLÁN, M. LEBSOCK, E. FISHBEIN, P. KALMUS, AND J. TEIXEIRA

# Column Water Vapor



# Additional Information

MAGIC Navigation Best Estimate magnavbe VAP (at 10 Hz and 1 min time resolutions)
includes leg numbers, “on route” flag, lat/lon, etc.

Mike Reynolds has some wonderful data sets:
"Best Estimate 1-min Time Series Data" (MARMET)
"Bulk Aerodynamics Fluxes"
"Ship Leg Reports"

ECMWF along-track data (Maike Ahlgrimm).

# Websites:

https://www.bnl.gov/envsci/cloud/campaigns/MAGIC

http://www.arm.gov/campaigns/amf2012magic

http://www.rmrco.com/cruise/magic/

I have files of:

- Start/stop times for legs
- Instrument status tables
- Radiosonde launches

Also, readme documents to explain topics.

Contact me (elewis@bnl.gov) to be put on a MAGIC distribution list.

# MAGIC Breakout Session, Wednesday 1:30-3:30, Potomac Room

Ed Luke - "MBL cloud rain rate retrievals during MAGIC"

Greg McFarquhar - "An overview of MARCUS"

David Painemal - "Aerosol proxies and their co-variability with cloud microphysics during MAGIC"

Rob Wood (and Johannes Mohrmann) - "Using MAGIC data to constrain the marine boundary layer CCN budget in the Sc-Cu transition region"

Weidong Yang (NASA) - "Spectrally-invariant properties of clouds in transition zones during MAGIC"

Chris Bretherton (and Jeremy McGibbon) - "Comparison of ship-following large-eddy simulations with cloud and boundary layer structure observed in MAGIC"

Maike Ahlgrimm - "Ship-following single-column model preliminary results – a proof of concept"