MAGIC

The Marine ARM GPCI Investigation of Clouds

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ARM

ARM CLIMATE RESEARCH FACILITY

Summary

MAGIC was a field campaign sponsored and operated by the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility.

Its goal was to study the stratocumulus-to-cumulus transition (Sc-to-Cu) in the Eastern North Pacific.

Objectives were to: 1) measure properties of clouds and precipitation, aerosols, radiation, and atmospheric structure, and 2) improve the representation of the transition in climate models.

MAGIC deployed the AMF2 (the Second ARM Mobile Facility) on the Horizon Lines cargo container *Spirit*.

Repeated transects between Los Angeles, CA and Honolulu, HI were made over a period of one year (October, 2012 – January, 2013 and May, 2013 - September, 2013).

MAGIC had 20 round trips and nearly 200 days at sea.

A comprehensive data set was collected and is freely available to all in the ARM Data Archive.

MAGIC: Marine ARM GPCI Investigations of Clouds

Principal Investigator

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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

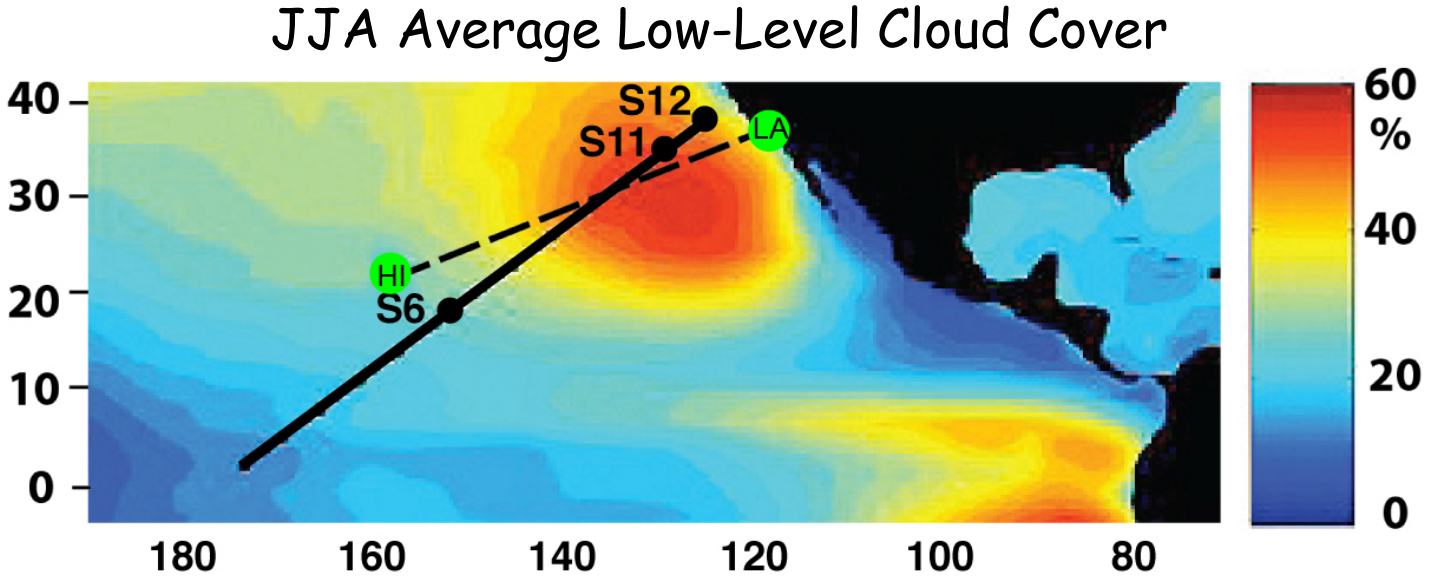
"MAGIC" is easiest

MAGIC: Motivation

Marine clouds play a critical role in the global radiation budget and hydrological cycle, and clouds in the marine boundary layer exert an extremely large and poorly quantified influence on Earth's climate through reflection of sunlight and mediation of air-sea interactions.

Models have difficulty in accurately representing low marine boundary layer clouds. Specifically, the transition in cloud type from stratocumulus (Sc) to cumulus (Cu), such as occurs in the Eastern North Pacific from Los Angeles to Hawaii presents a large challenge.

MAGIC Transect

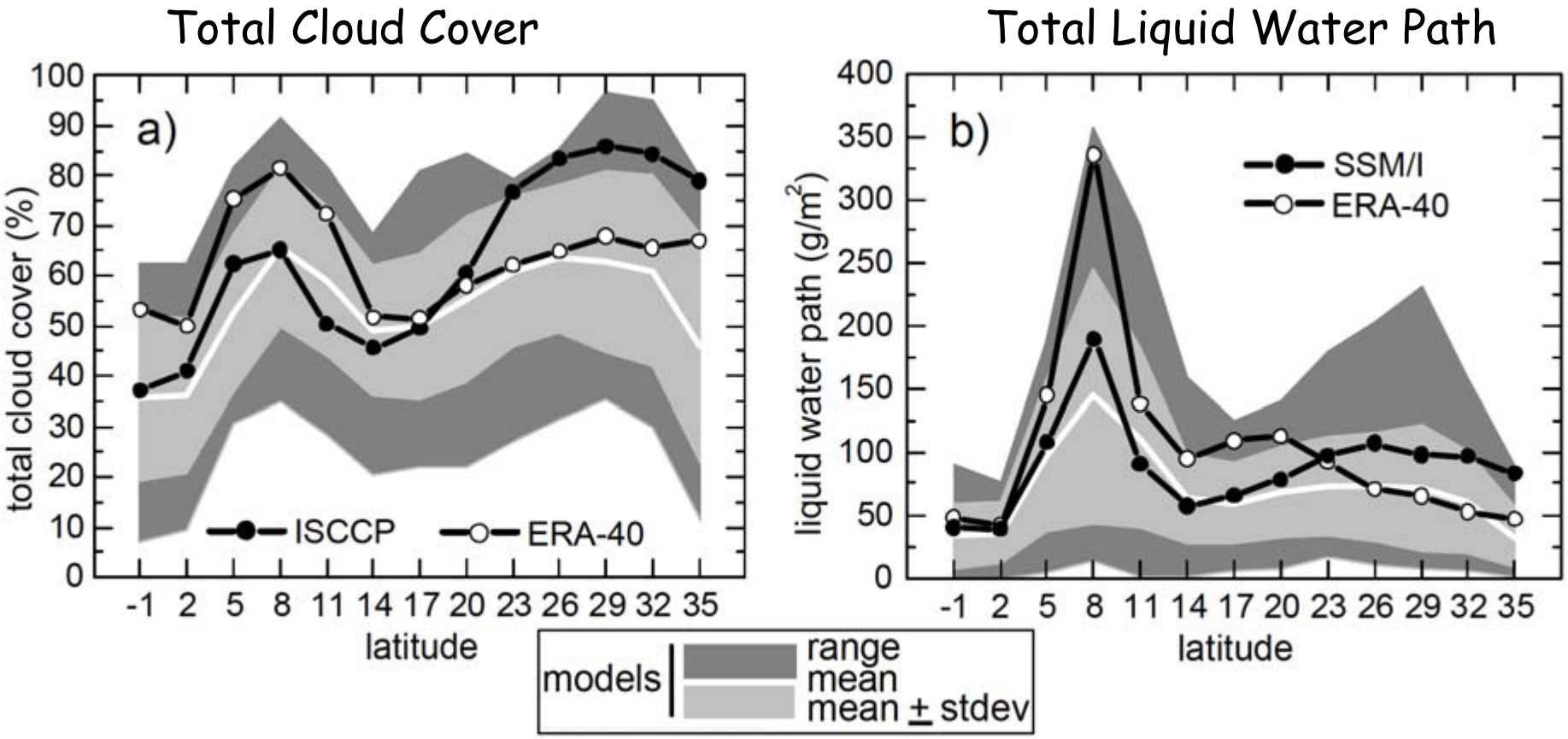


JJA average low-level cloud cover with MAGIC route, GPCI transect, & CGILS points

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

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

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.

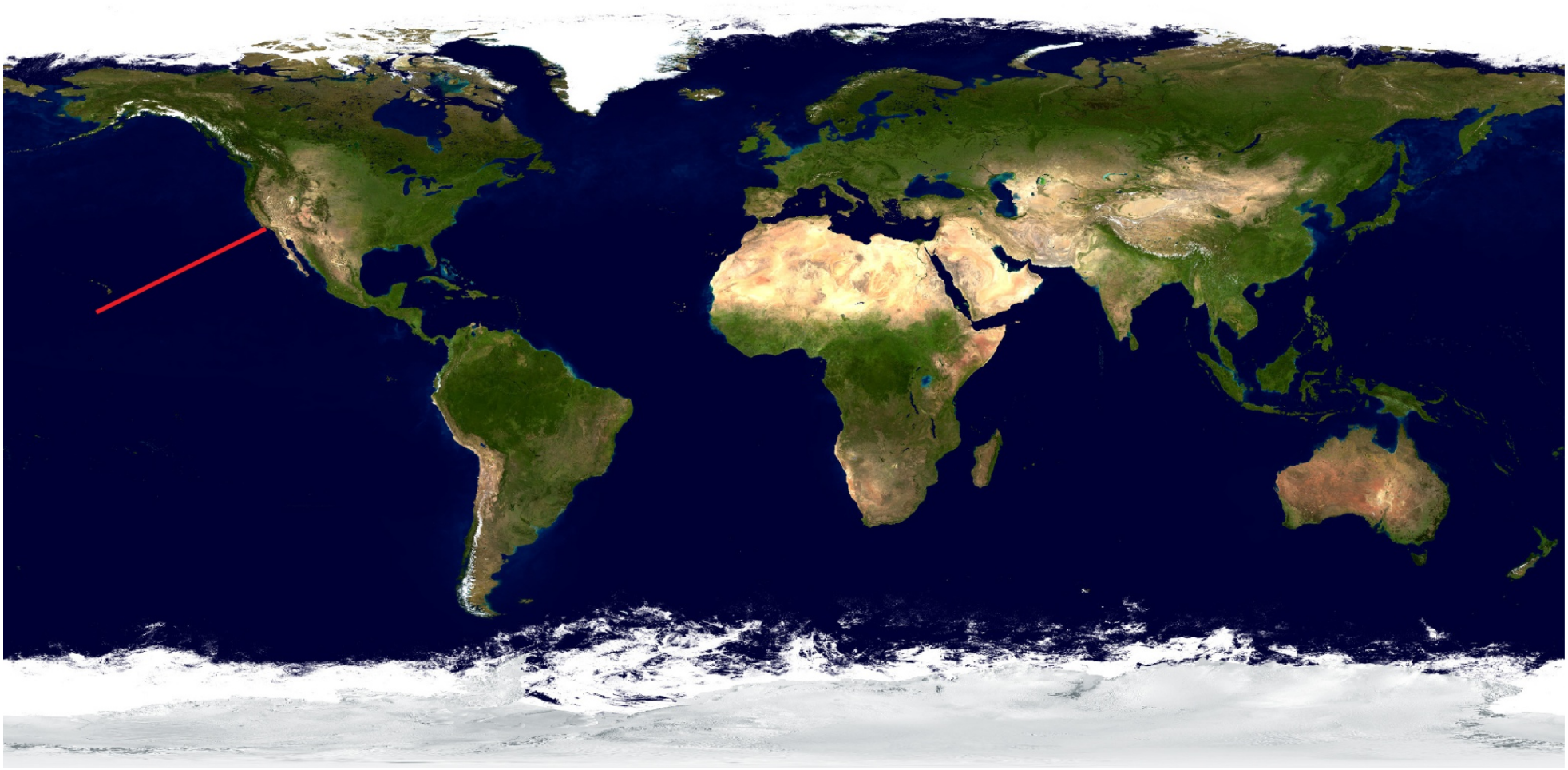
MAGIC Objectives

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



Approach

- Measure the properties of clouds and precipitation:
  cloud type, fractional coverage, base height, physical thickness, LWP, and optical depth;
  drizzle and precipitation frequency, amount, and extent.

- Measure atmospheric and oceanographic conditions:
  temperature, RH, wind speed and direction, and their vertical profiles;
  sea state, sea surface temperature and salinity

- Measure the properties of aerosols:
  size distribution, light-scattering behavior, hygroscopic behavior, CCN behavior (composition?)

- Measure the spectral and broadband SW and LW radiation and their interaction with clouds and aerosols:
  broadband and narrow-channel direct and diffuse fluxes;
  downwelling and upwelling spectral radiances;
  cloud and aerosol spectral optical thicknesses

Model Intercomparisons Are Interested in MAGIC

GPCI, the GCSS Pacific Cross-section Intercomparison (GCSS: GEWEX Cloud Systems Study; GEWEX: Global Energy and Water Cycle Experiment, a core project of the World Climate Research Programme) used a transect near the route taken by the *Spirit*.

Along this GPCI transect, cloud type and cover vary from low stratocumulus with high coverage near Los Angeles to puffy cumulus with low coverage near Hawaii.

EUCLIPSE, the European Union Cloud Intercomparison, Process Study & Evaluation Project (a collaborative effort of 12 institutes in Europe) also uses the GPCI transect.

CGILS: the CFMIP- GCSS Intercomparison of Large Eddy Models and Single Column Models compares results at locations S6, S11, and S12 along the GPCI transect.

ARM: Atmospheric Radiation Measurement Climate Research Facility

The Atmospheric Radiation Measurement (ARM) Program (http://www.arm.gov/) of the U. S. Department of Energy was created in 1989 "to study cloud formation processes and their influence on radiative transfer."

ARM manages three fixed study sites, three mobile facilities, an aircraft facility, and a data archive, and it sponsors and operates field programs around the world.

MAGIC Was Funded and Operated by ARM

ARM Fixed Sites

SGP: Southern Great Plains (OK)
NSA: North Slope of Alaska
TWP: Tropical Western Pacific

ARM Mobile Facility (AMF) Deployments

2005 Point Reyes, CA
2006 Niamey, Niger
2007 Black Forest, Germany
2008 Shouxian, China
2009 Graciosa Island, Azores
2010 Steamboat Springs, CO
2011 Long Island, NY
2011 Ganges Valley, India
2012 Gan Island, Maldives

2012 Cape Cod, MA
2013 Eastern North Pacific

Upcoming

2013 Oliktok Point, Alaska
2014 Amazon, Brazil
2014 Hyytil, Finland
2015 California Coast

!! map is outdated !!

MAGIC Deployed the Second ARM Mobile Facility (AMF2)

The second ARM Mobile Facility (AMF2) consists of three 20-foot modified "SeaTainers" & other smaller modules containing radars & other instruments.

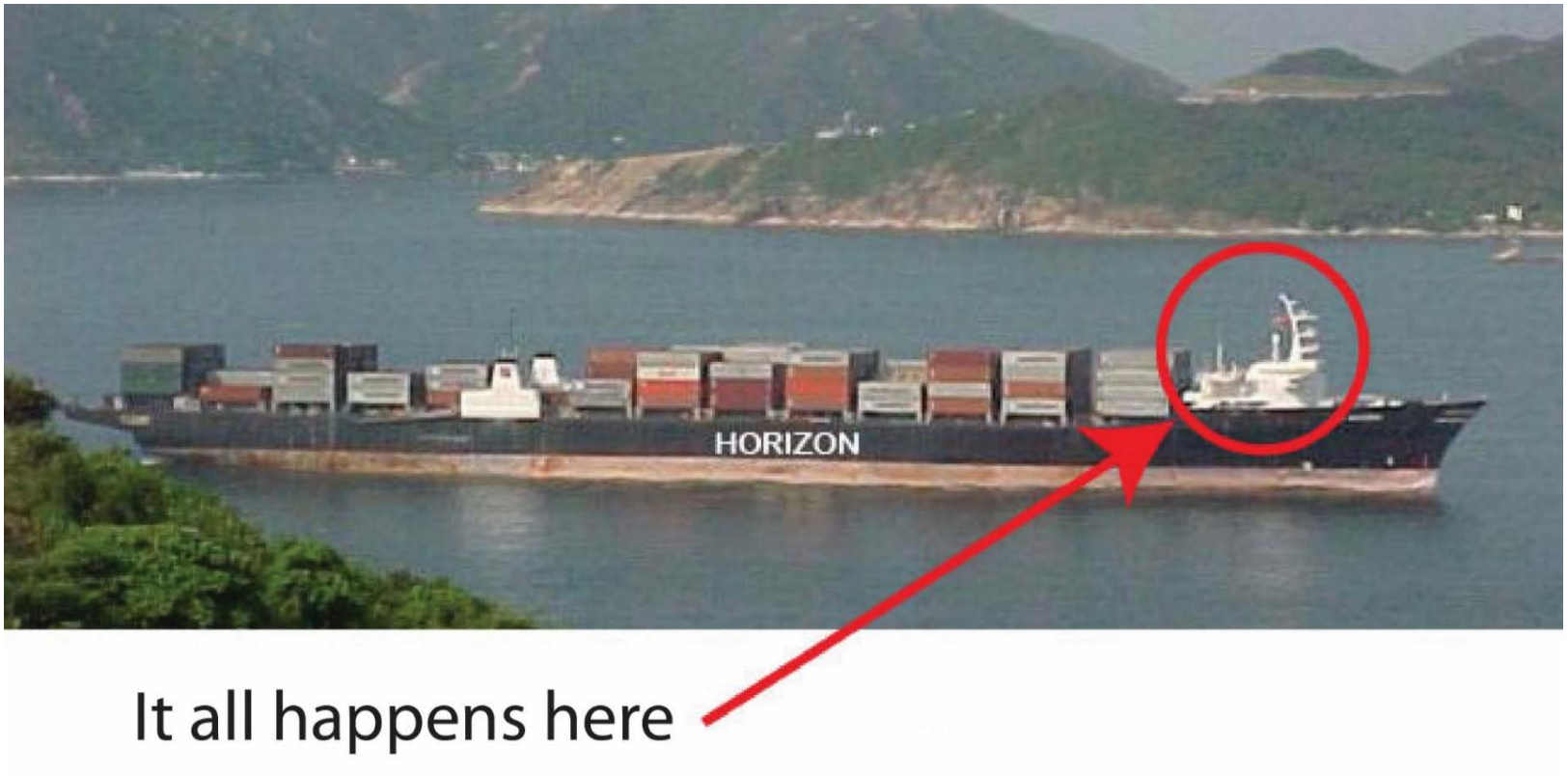
AMF2 radar SeaTainer

AMF2 aerosol SeaTainer

Module

It was designed for marine deployments.

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

Horizon *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.

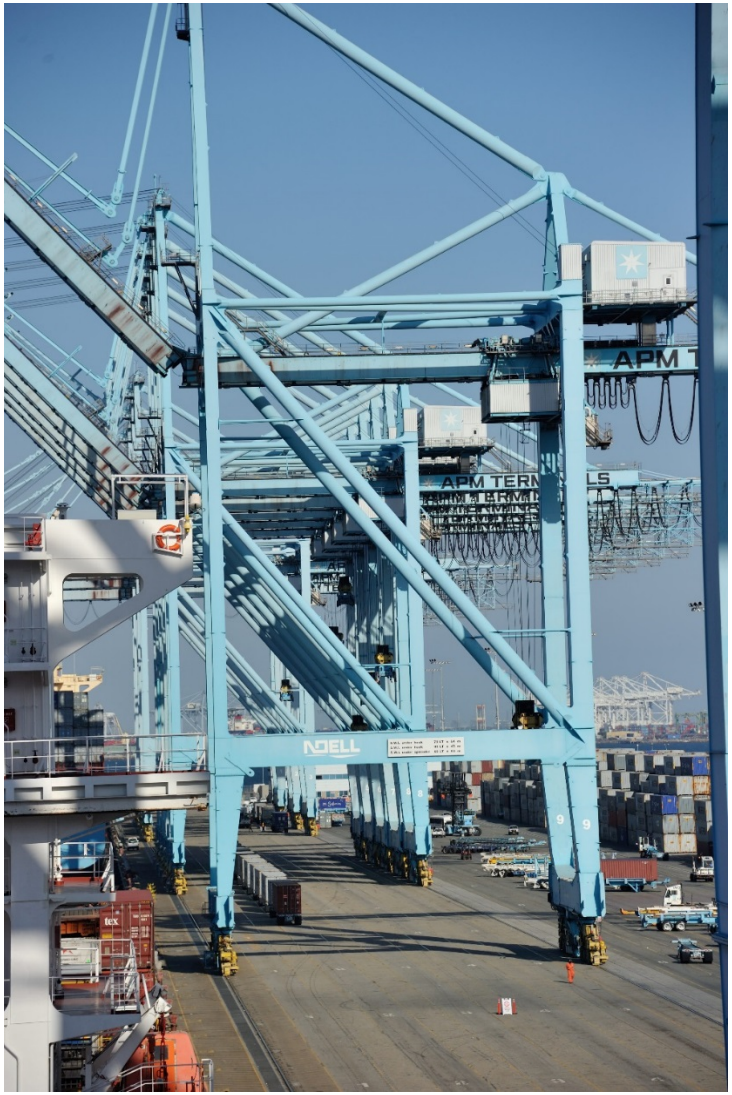
It has a FEU (forty-foot equivalent unit) capacity of 1218.

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.


APM
NOELL


NOELL
S.W.L under hook 70 LT x 64 m
S.W.L under hook 90 LT x 45 m
S.W.L under spreader 60 LT x 64 m
HORIZON


HORIZON SPIRIT

Two ARM Technicians Lived on the *Spirit*

Mark, Tom, Brett, Pat

Challenges of Marine Deployment

Cost

Finding a platform (ship) that will agree to a deployment
(and all that this entails)
- personnel on board
- equipment on board
- loading equipment & supplies (helium) regularly
- balloon launches
- modifications to ship
- etc.

Finding suitable locations for AMF2 & equipment on the ship

General concerns with marine deployment

Miscellaneous

Requirements for Platform

Must traverse route of interest

- difficult to find ship covering remote oceans for long times
- only two companies run shipping routes US-Hawaii (must be Jones Act)

Must allow us to put instruments on board (and modify ship)

- difficulty of scientists to negotiate with nothing to offer

Must allow technicians to work on board

- labor issues, sufficient room, bunk space

Must allow scientists to go on ship

- sufficiently room, bunk space

Preferably a Jones Act ship (non-US routes have many issues)

Requirements for Location on Ship

Clear view of sky for radars, radiometric instruments

Clear air for aerosol instruments (upwind of stack)

Clear view of ocean for sea surface temperature

Unperturbed wind flow for flux measurements

Easy access to containers

No disturbance to/from crew/passengers

Not having to relocate or move instruments regularly

Location for balloon/sonde launches

Location for helium storage & ability to regularly load/unload

General Concerns with Shipboard Deployment

Inability to choose route (shipping lines unalterable)

Inability to stop or find port to fix equipment

Modifications to ship for containers (welding, brackets, etc.)

Labor union issues with technicians on board

Release of balloons not "green" and may require waiver

Power: continuous OR clean – not both (UPS for radars?)

Inability to move radars and other equipment during storm

Bumping when loading other containers

Restocking supplies (especially helium) in port

Interference (either way) with radars, internet, etc.

Concern with lasers, radioactive sources, hazmat

Other Challenges with Shipboard Deployments

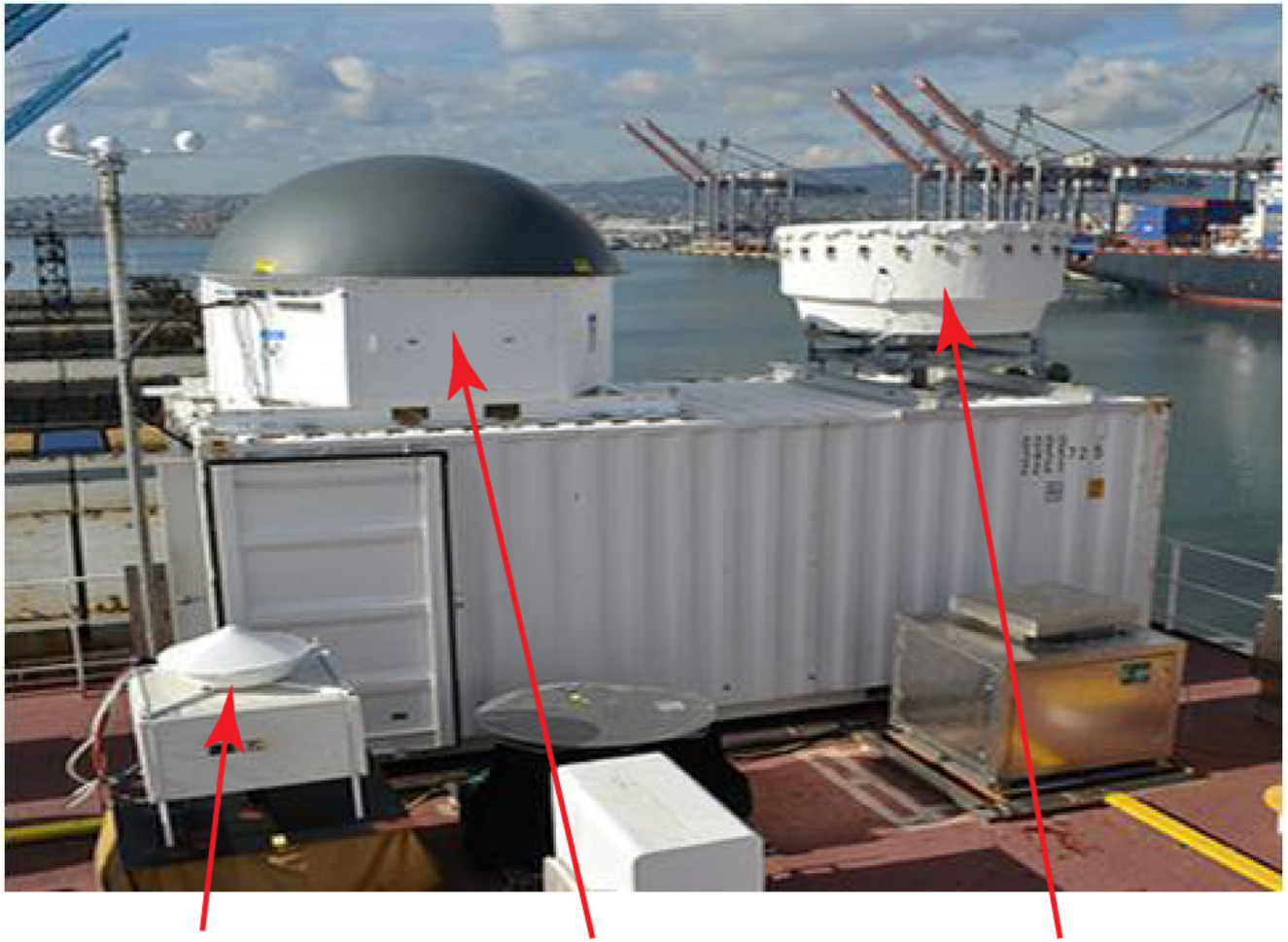
Ship motion (affects vertically pointing instruments and those such as radiometers that require accurate knowledge of sun position)

Screening by ship structures, which limits views of the sky

Ship-induced flow perturbations, which affect determination of wind speed and direction and thus flux determinations

Ship effects on radiation and meteorological measurements through screening, reflection, and heating

MAGIC Had Three Radars



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

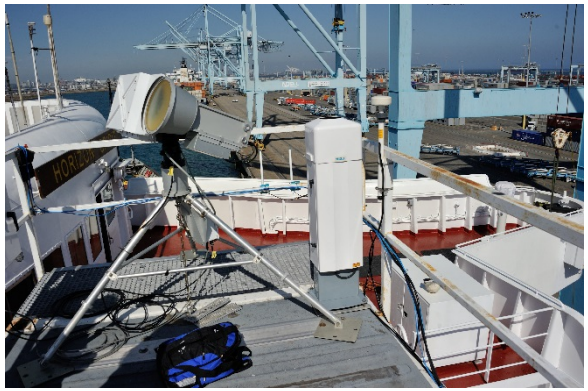
beam-steerable wind profiler (1290 MHz)

vertically-pointing Ka-band (35 GHz)

Corrections for ship motion have been made.

Cloud & Precipitation Instruments

Disdrometers

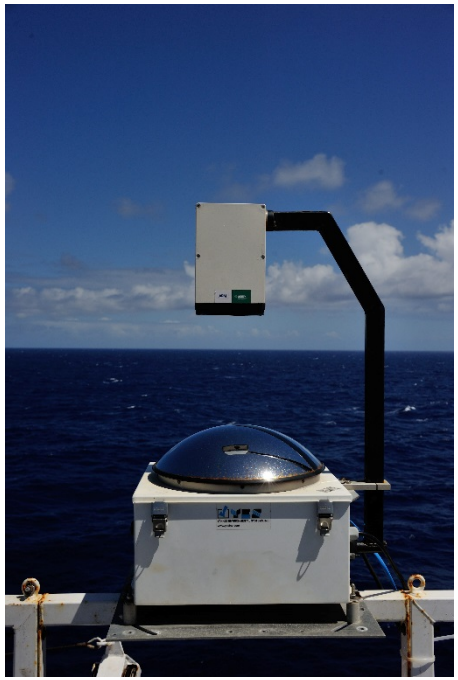


Ceilometer

2 Channel MWR

3 Channel MWR

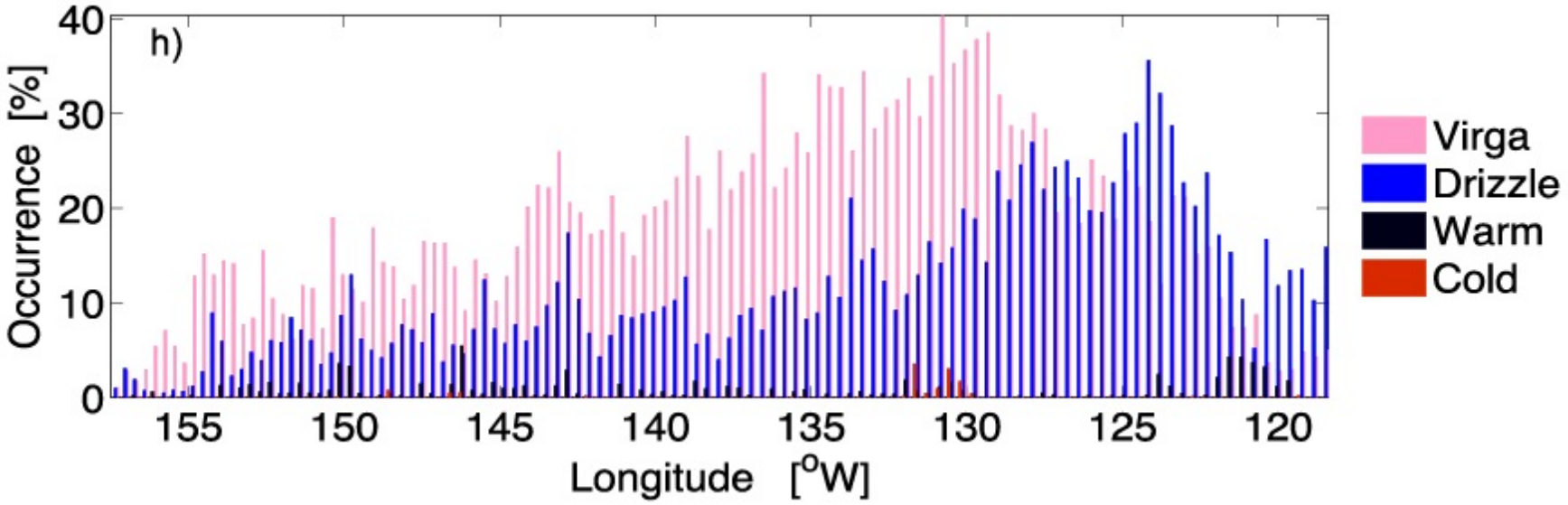
LIDAR



Total Sky Imager

CIMEL (cloud mode)

Precipitation During MAGIC



Hawaii

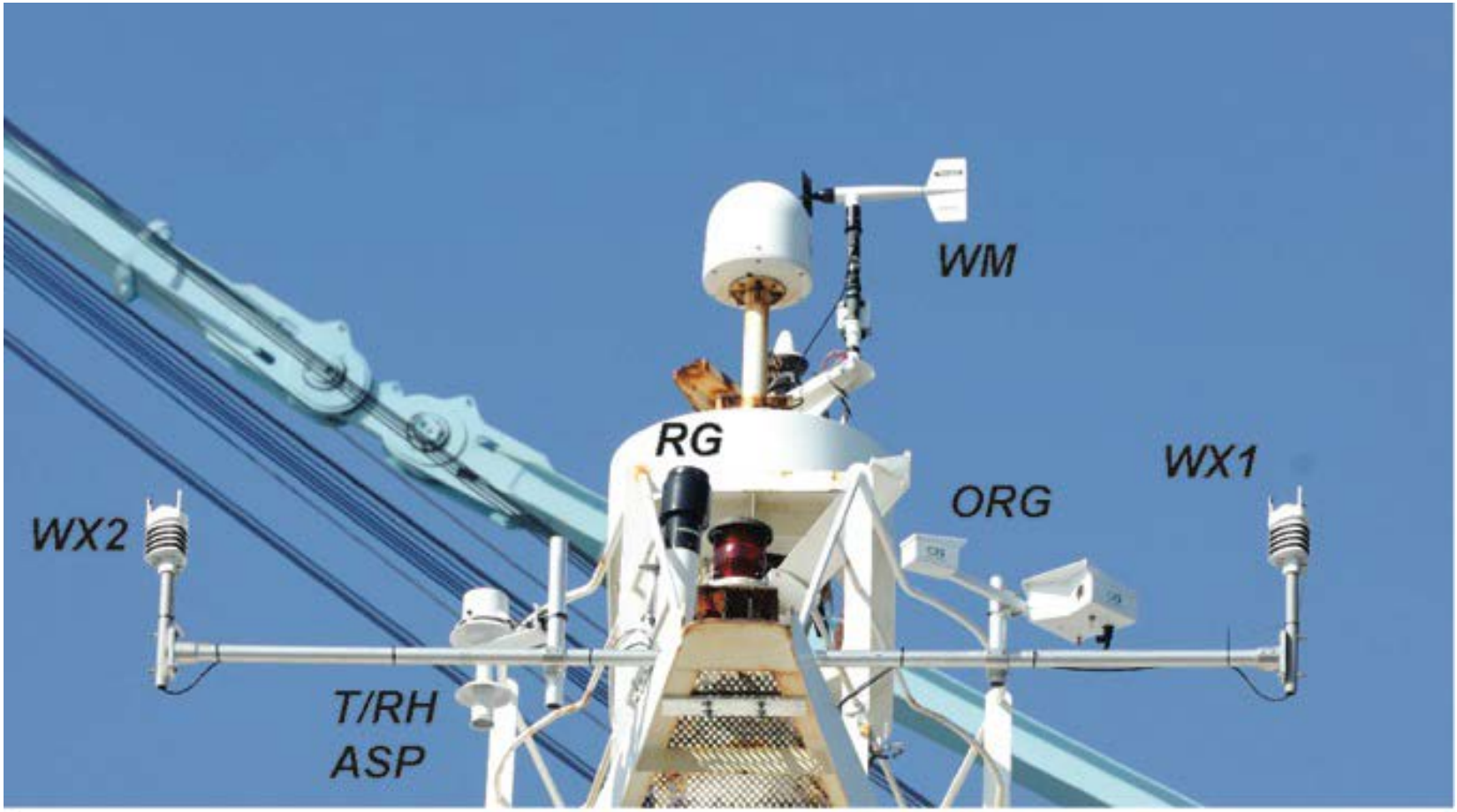
Los Angeles

Xiaoli Zhou, McGill University

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

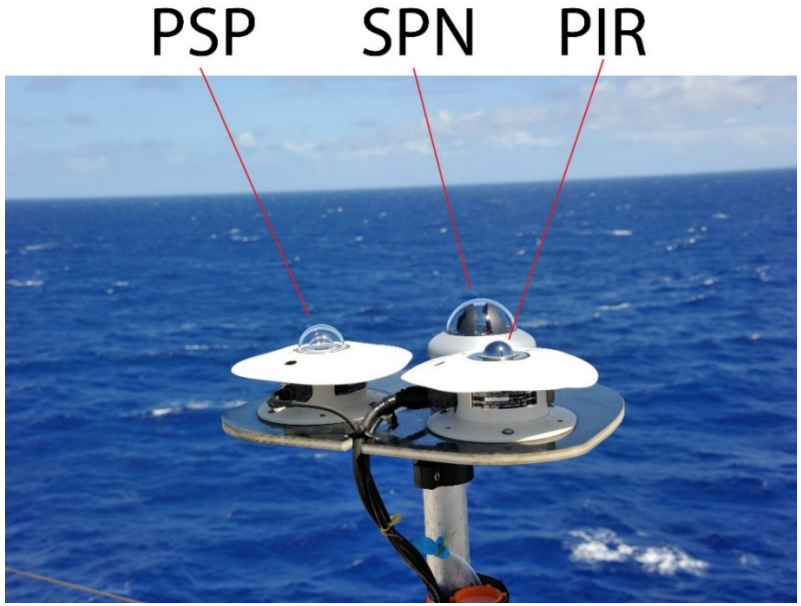
T/RH = Vaisala HMP155, ASP = Aspirator
ORG = OSI Optical Rain Gauge

met-boom

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

Meteorological Measurements

Radiation Measurements



Portable Radiation Package (PRP)

PRP with FRSR

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

Precision Spectral Pyranometer (PSP) – downwelling broadband, 0.285-2.8 μm

Precision Infrared Radiometer (PIR) – downwelling broadband, 4-50 μm

Sunshine Pyranometer (SPN1) – total and diffuse irradiance

Fast Rotating Shadowband Radiometer (FRSR)

– 10 nm wide channels at 415, 500, 680, 870, and 940 nm

- direct normal irradiance, diffuse irradiance, total irradiance; also AOT

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 during MAGIC
are available on the ARM archive

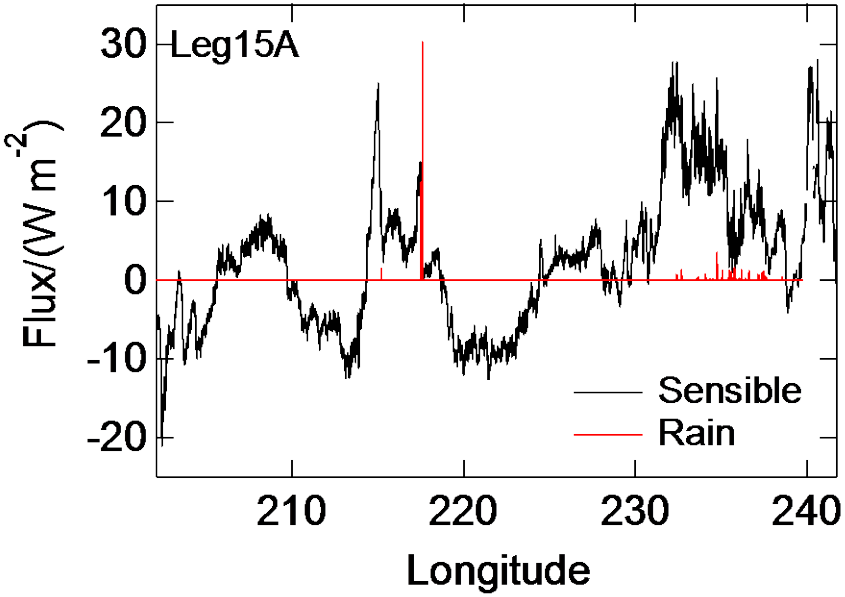
These include SW, LW, sensible and latent heat, and precipitation

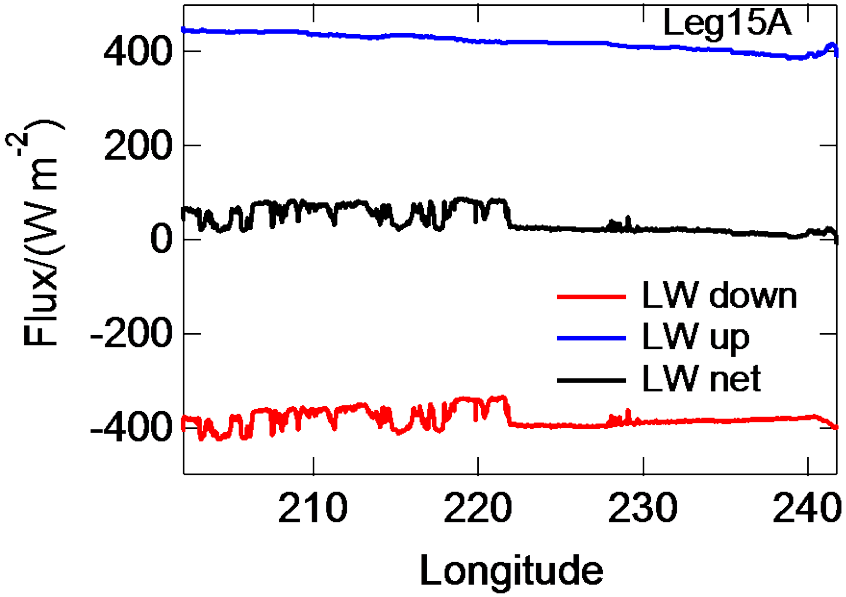
Two data files are available: "flux.mat" and "magic_flux.txt"
To access these data,

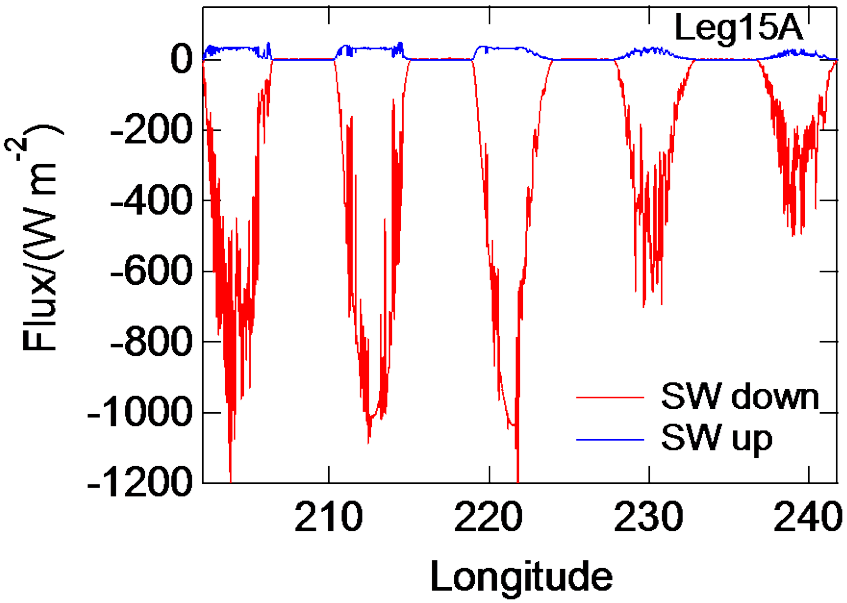
1) go to www.arm.gov/campaigns/amf2012magic
2) go to "Bulk Aerodynamic Fluxes" under "Campaign Data Sets"
3) click "Order Data"

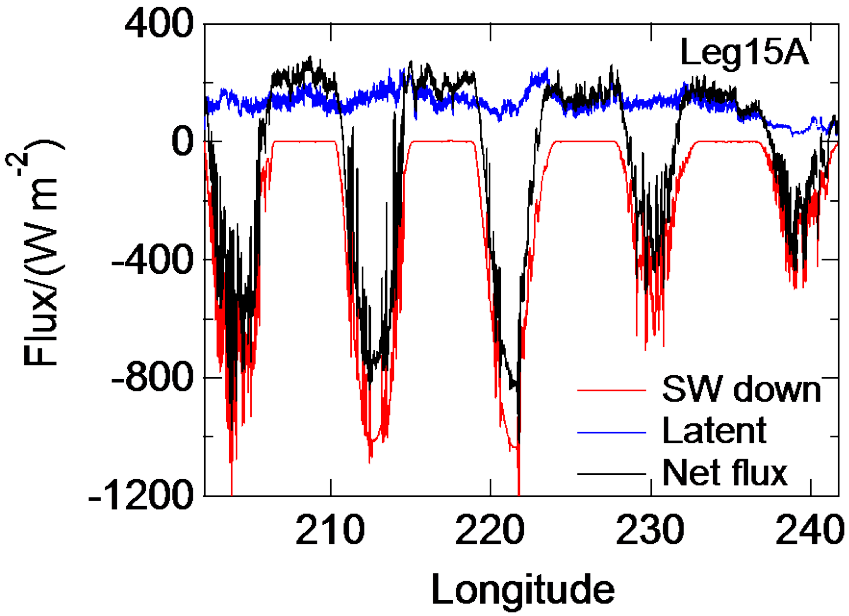
Be sure to read the file "magic_flux_readme_arm.txt" which is also in the archive, and the document "OnDataProcessing" at
www.rmrco.com/cruise/magic/data/OnDataProcessing/

Leg15A (2013-07-20 to 2013-07-25) Fluxes

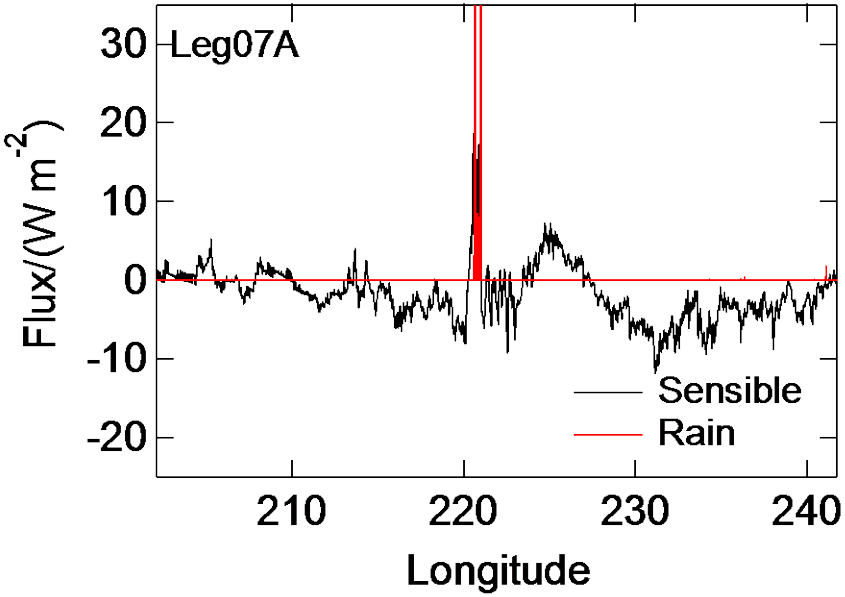


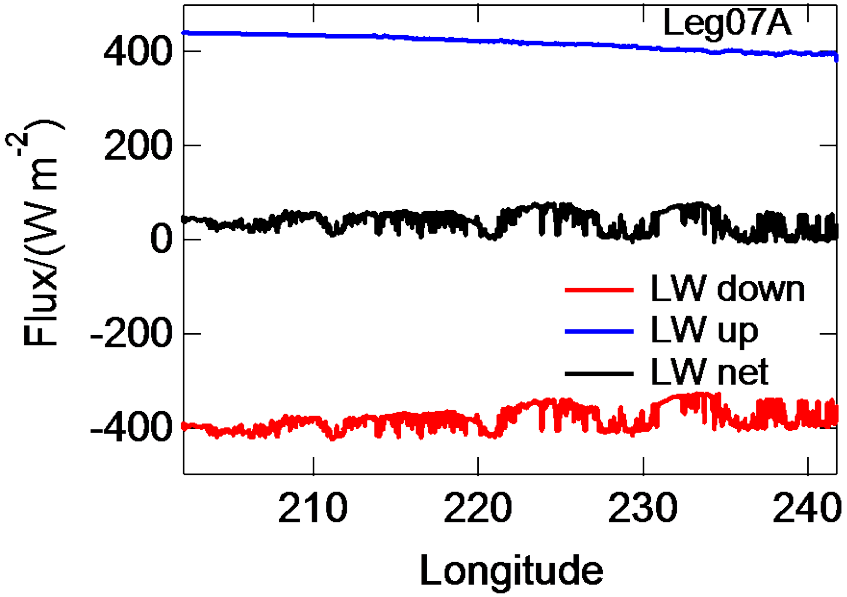


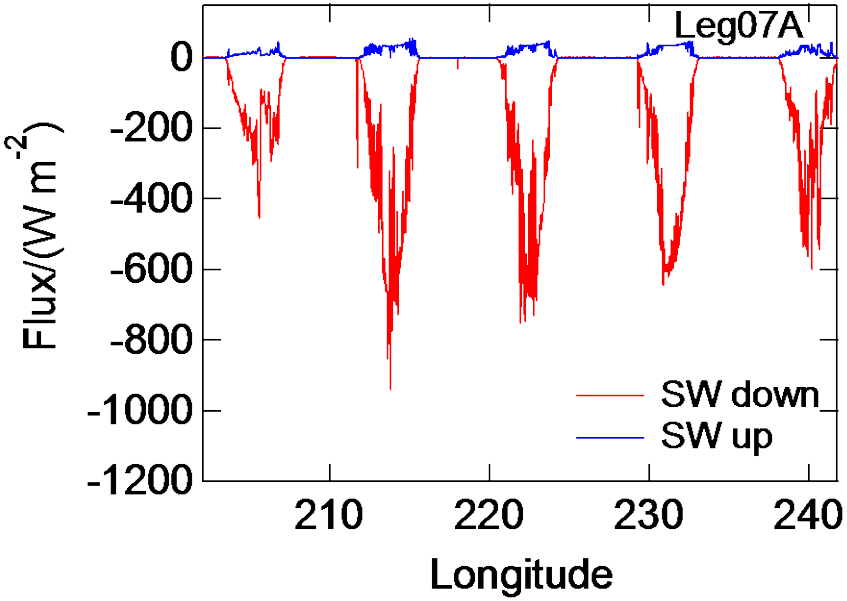


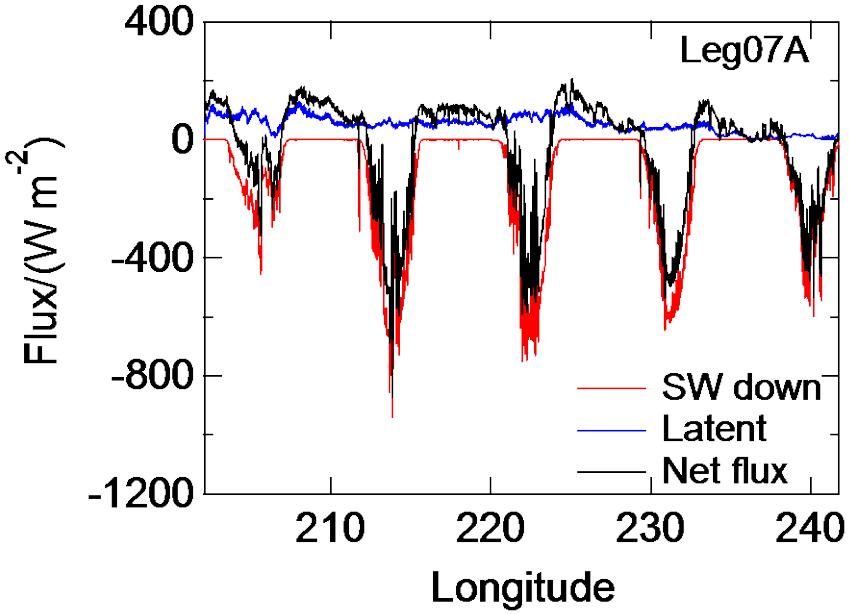


Leg07A (2012-12-01 to 2012-12-06) Fluxes









Radiosonde Launches

Four radiosonde launches/day throughout the deployment.

Eight radiosonde launches/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} !!

launch date	launch time UTC	surf TempC	surf RH%	wind dir	rel ws m/s	units	max ht km	min Pmbar	comments
at end of cruise please email to elewis@onl.gov									
thank you									
20121020	1800	15.5	89.9	052	**23.9**	TF			Terminated after launch
20121020	1820	15.6	85.1	060	**24.1**	TF	17.800	79.6	
20121020	2335	16.5	94.7	070	**22.7**	TF			Terminated sounding due to high
20121021	0530	17.2	82.4	031	**12.7**	TF	28.700	13.9	
20121021	1130	7.8	77.2	021	**7.8**	TF	26.900	18.3	
20121021	1730	18.9	70.9	004	**9.7**	TF	28.529	14.3	
20121021	2330	20.1	74.0	353	**11.4**	TF	27.686	16.2	
20121022	0530	19.9	80.2	350	**10.9**	MS			
20121022	1130	20.7	77.6	013	**15.1**	TF			Terminated sounding. Sonde hit
20121022	1730	21.5	68.2	020	**11.7**	TF	27.450	16.8	
20121022	2330	20.7	81.2	033	**2.5**	MS	25.698	22.1	
20121023	0530	20.7	87.9	066	**0.9**	MS	25.697	22.1	
20121023	1130	22.1	77.3	350	**4.7**	MS	27.028	17.9	
20121023	1730	22.5	76.2	294	**5.5**	TF	26.754	18.7	
20121023	2330	23.8	74.0	342	**11.7**	TF	27.814	15.9	
20121024	0530	23.9	70.2	323	**7.3**	TF	27.639	16.4	
20121024	1130	23.7	73.4	343	**5.0**	TF	26.399	19.7	
20121024	1730	24.3	68.6	318	**12.3**	MS	28.175	15.0	
20121024	2330	25.0	71.6	301	**10.9**	MS	28.581	14.0	
Arrivied in Hawaii 25Oct2012 061									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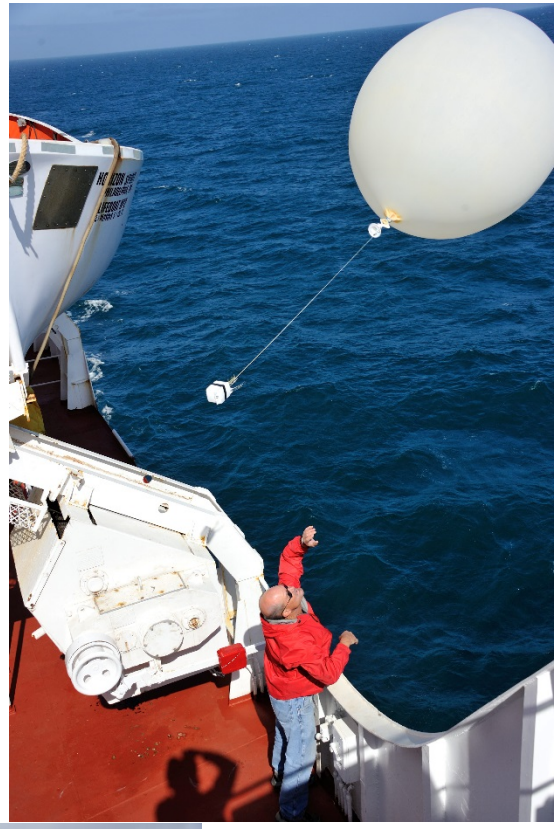

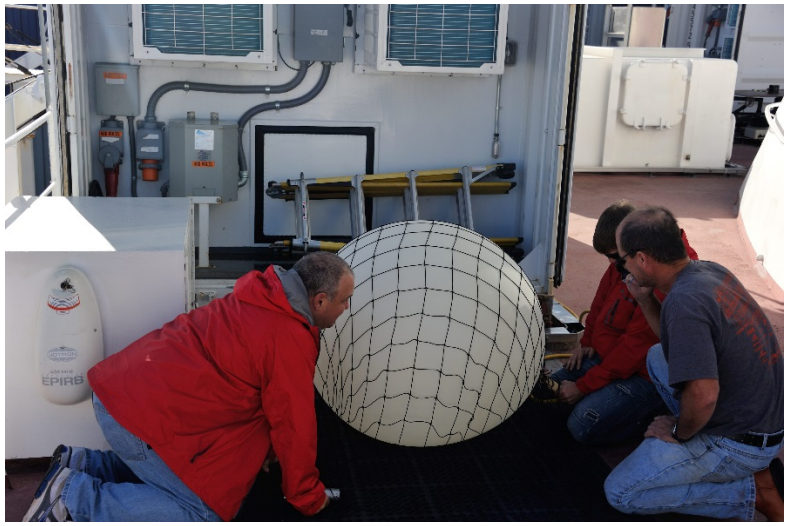


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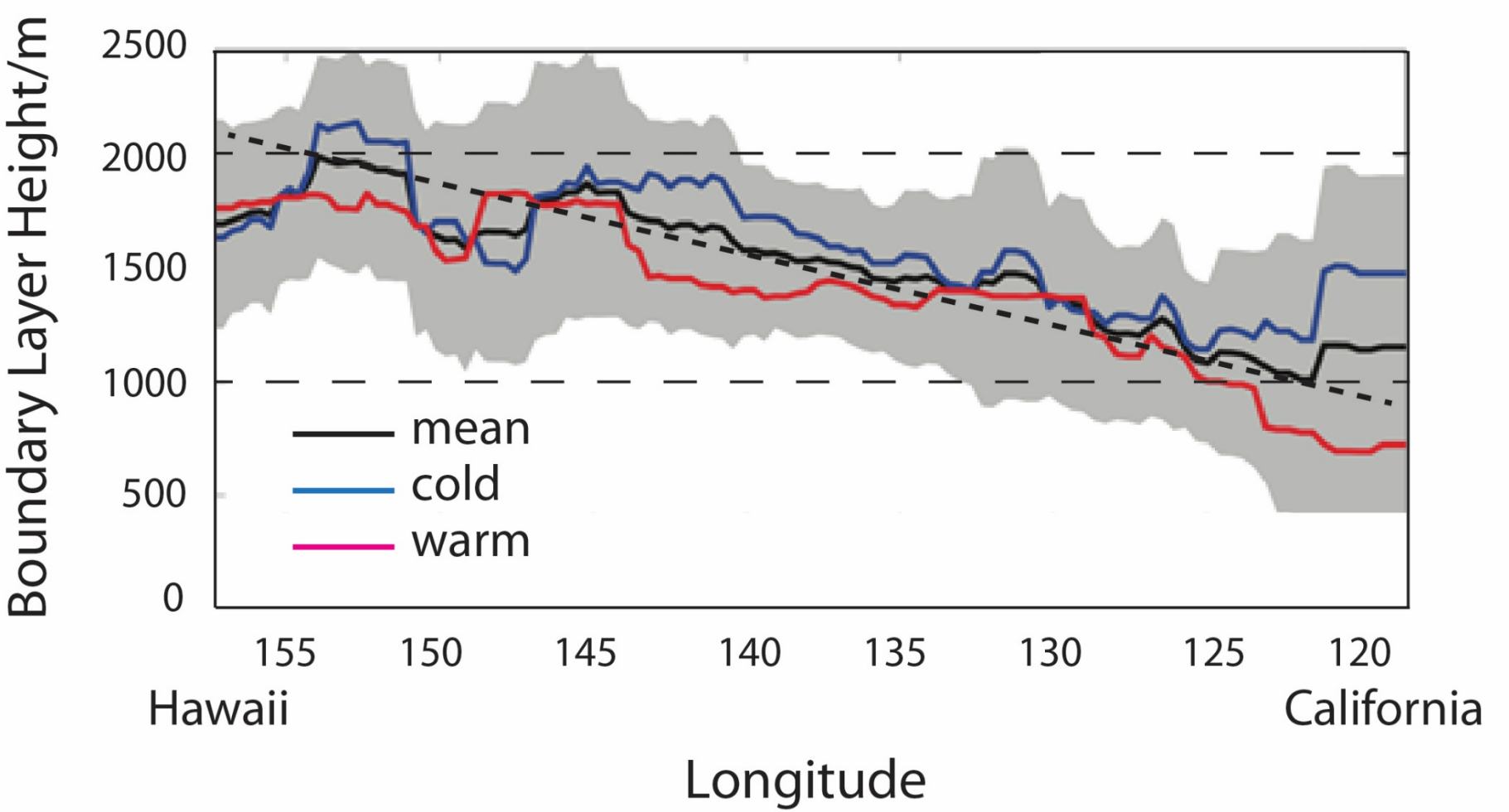
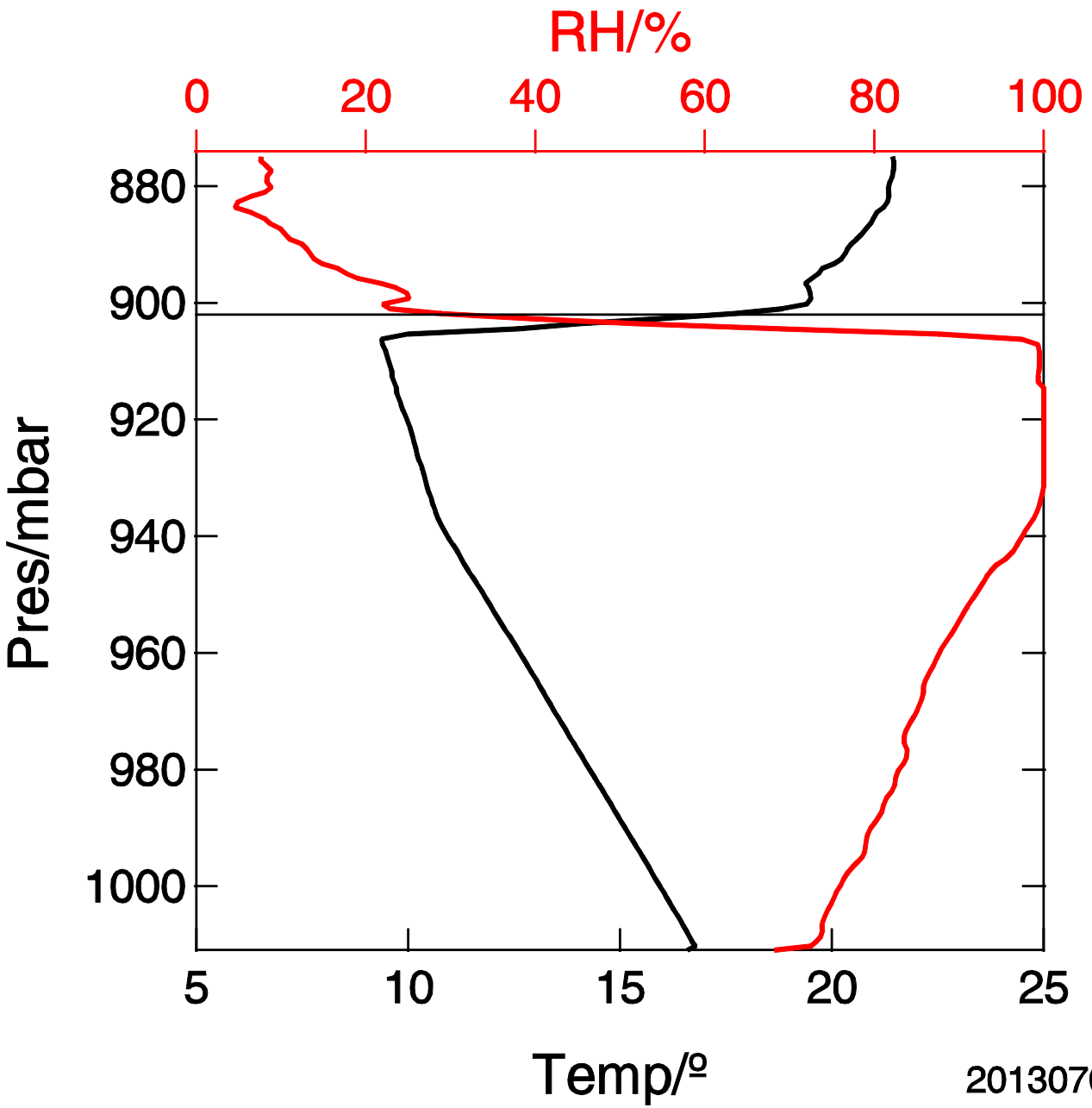
MAGIC Marine Boundary Layer Heights

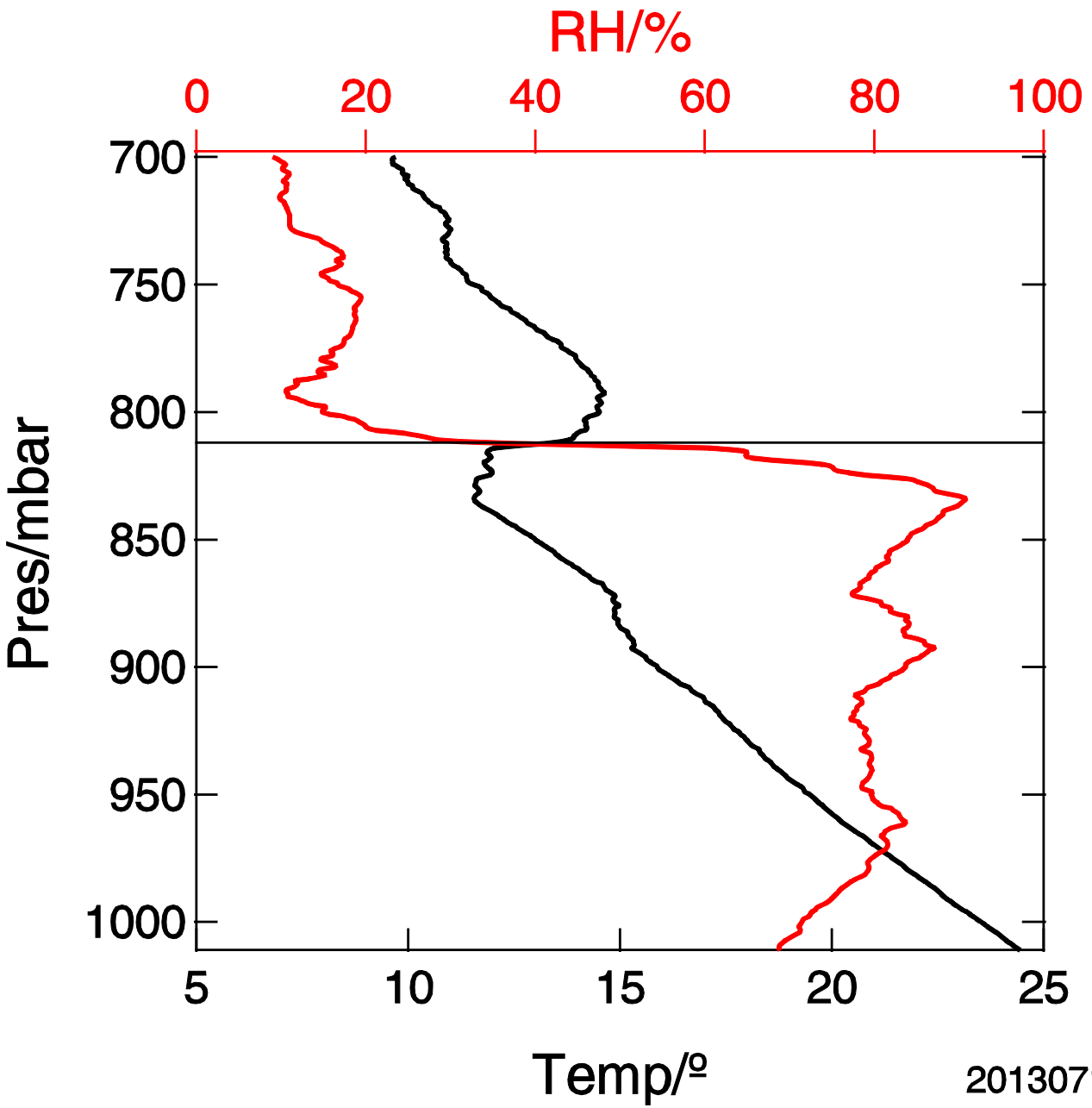


H_{MBL} increases from ~1 km near California to ~2 km near Hawaii

Stratocumulus Deck: 125° W



Decoupled MBL: 156° W



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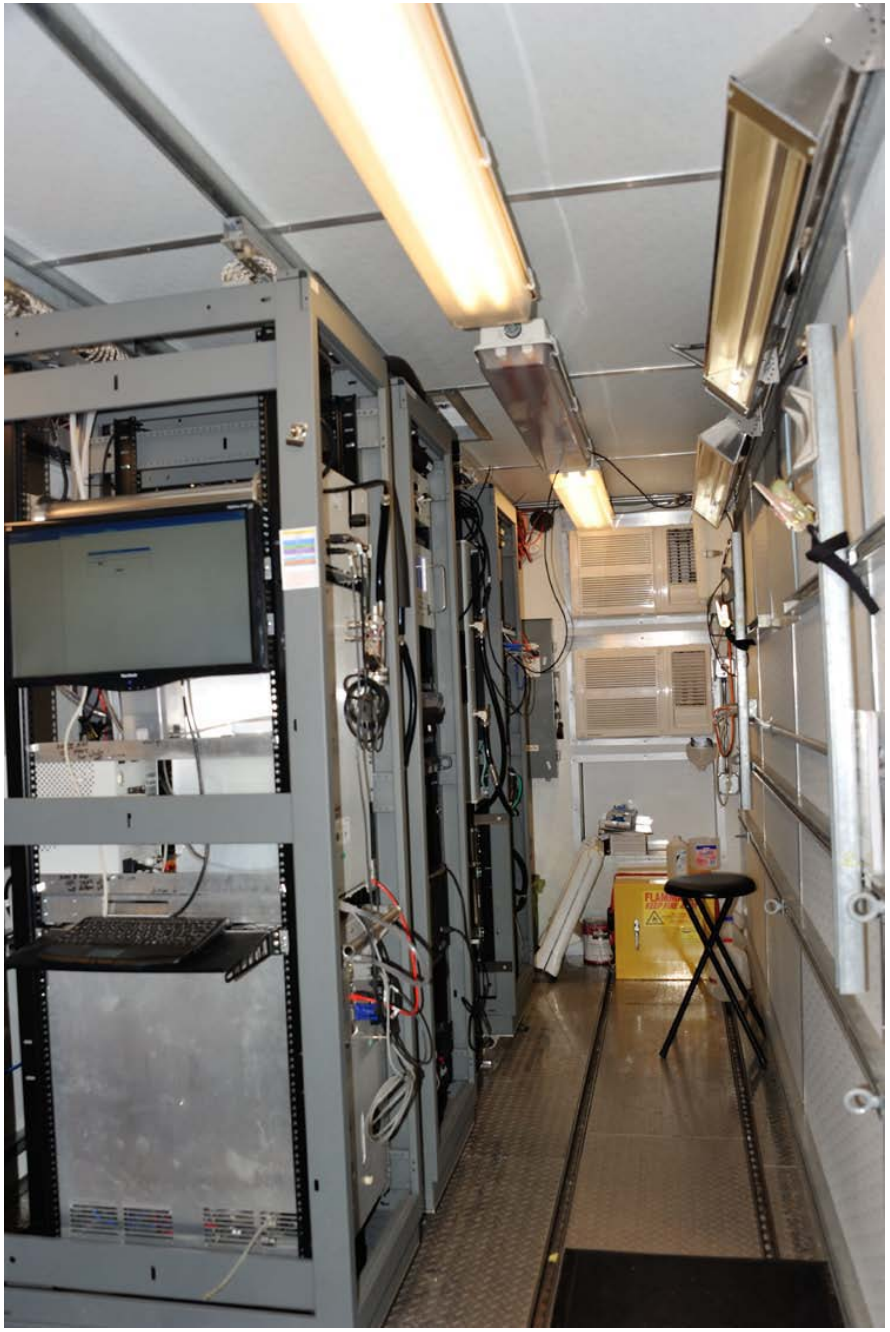
Aerosol Observing System (AOS)



Aerosol Measurements

Condensation Particle Counter (CPC): D > 10 nm

Cloud Condensation Nuclei Counter (CCN): supersats 0.2, 0.4, 0.6, 0.8, 1%

Ultra-high Sensitivity Aerosol Spectrometer (UHSAS):

size distribution & number concentration D > 55 nm

Dry and humidified nephelometer:

3λ (red, green, blue); ambient & scan 30-80% RH; 1 & 10 μm cuts

Particle Soot Absorption Spectrometer (PSAP):

3λ (red, green, blue); 1 & 10 μm cuts

Hygroscopic Tandem Differential Mobility Analyzer (HTDMA):

D = 100, 150, 200, 250, 300 nm, dry and 90% RH

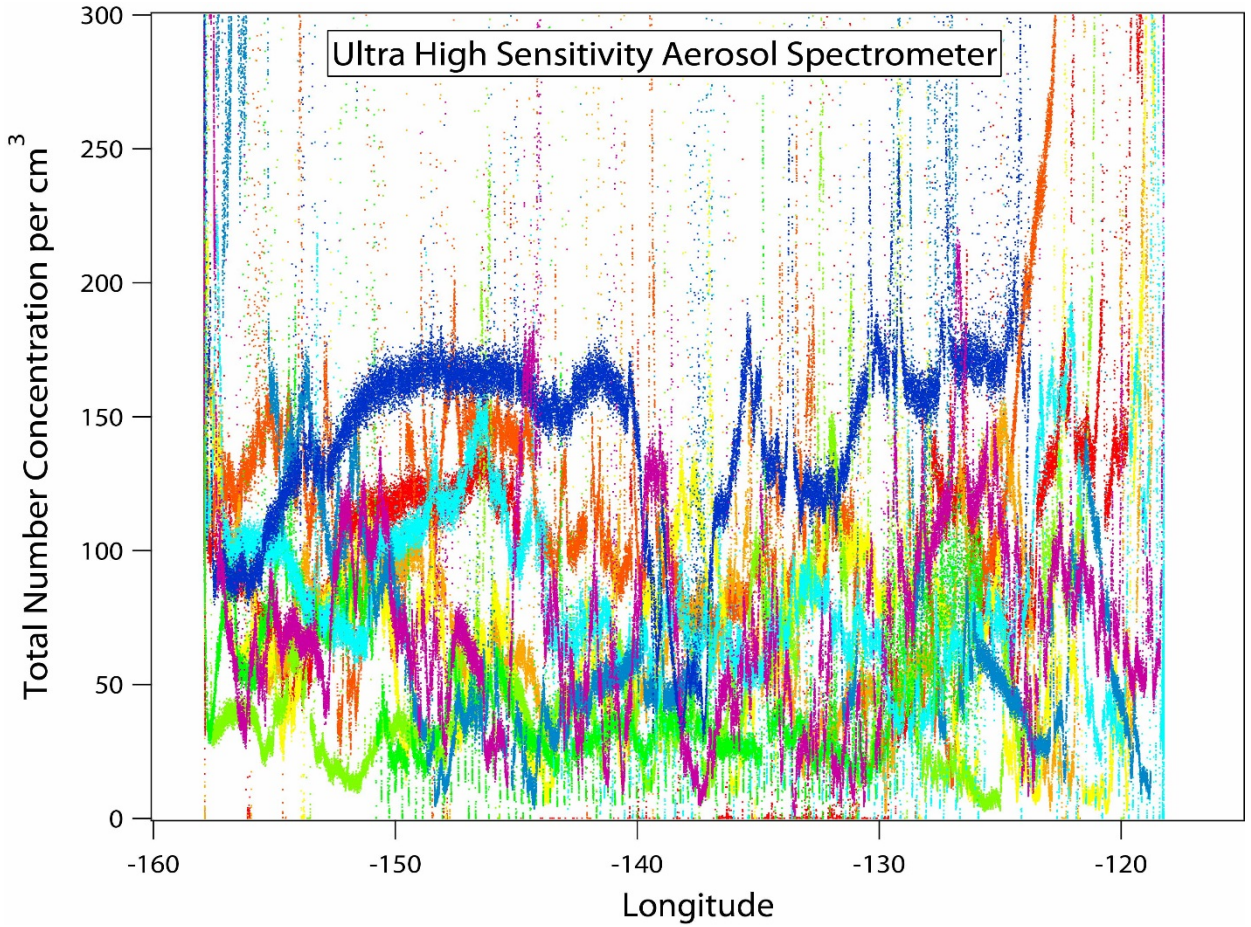
Ozone

Aerosol sampling

bulk & individual particle composition, individual particle morphology

Ice Nuclei, RNA

Aerosol Number Concentration for D_{opt} > 55 nm



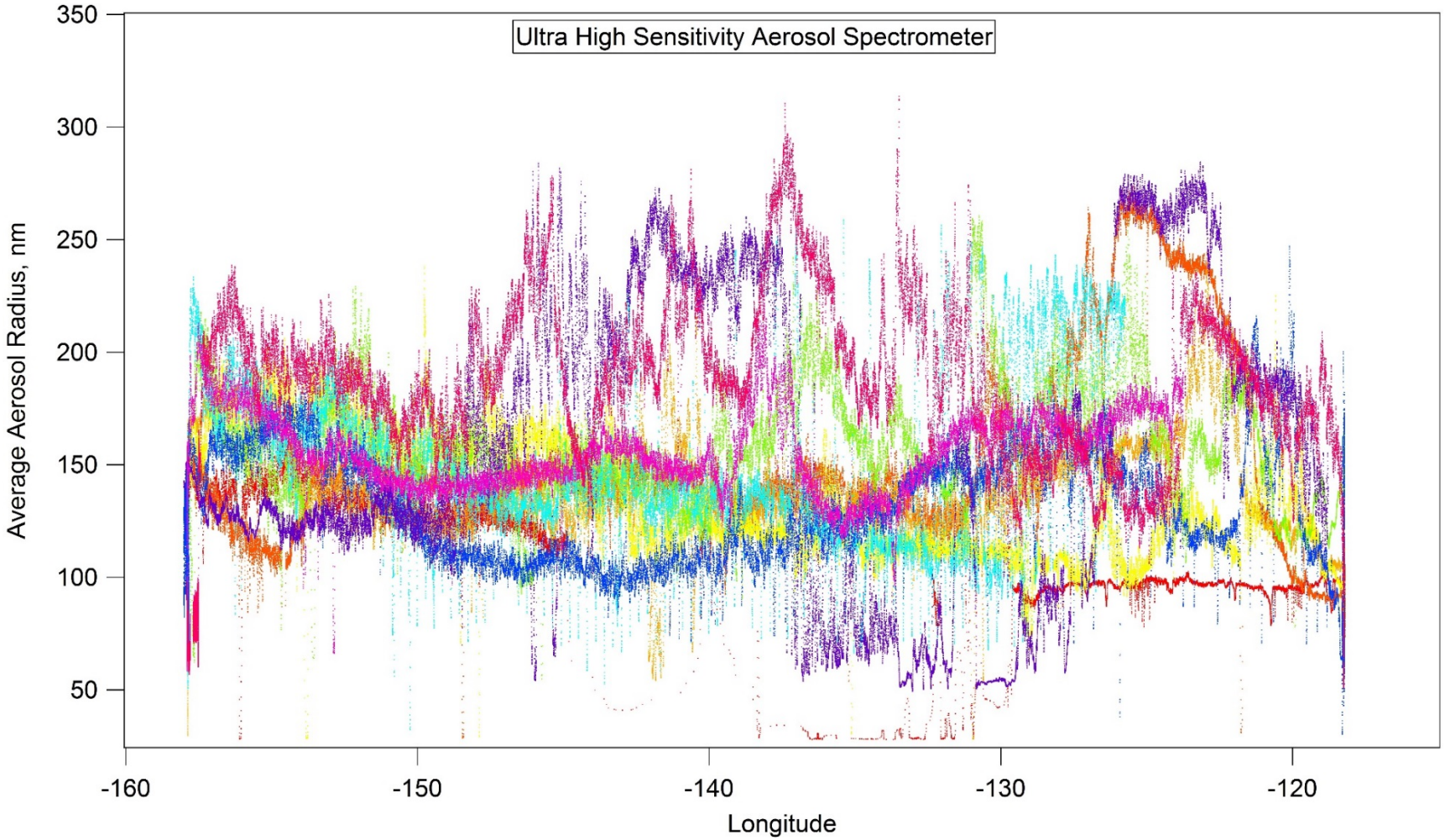
Hawaii

Los Angeles

Graph courtesy of Gunnar Senum

Each color represents measurements from a given transect.

Average Particle Radius (UHSAS)

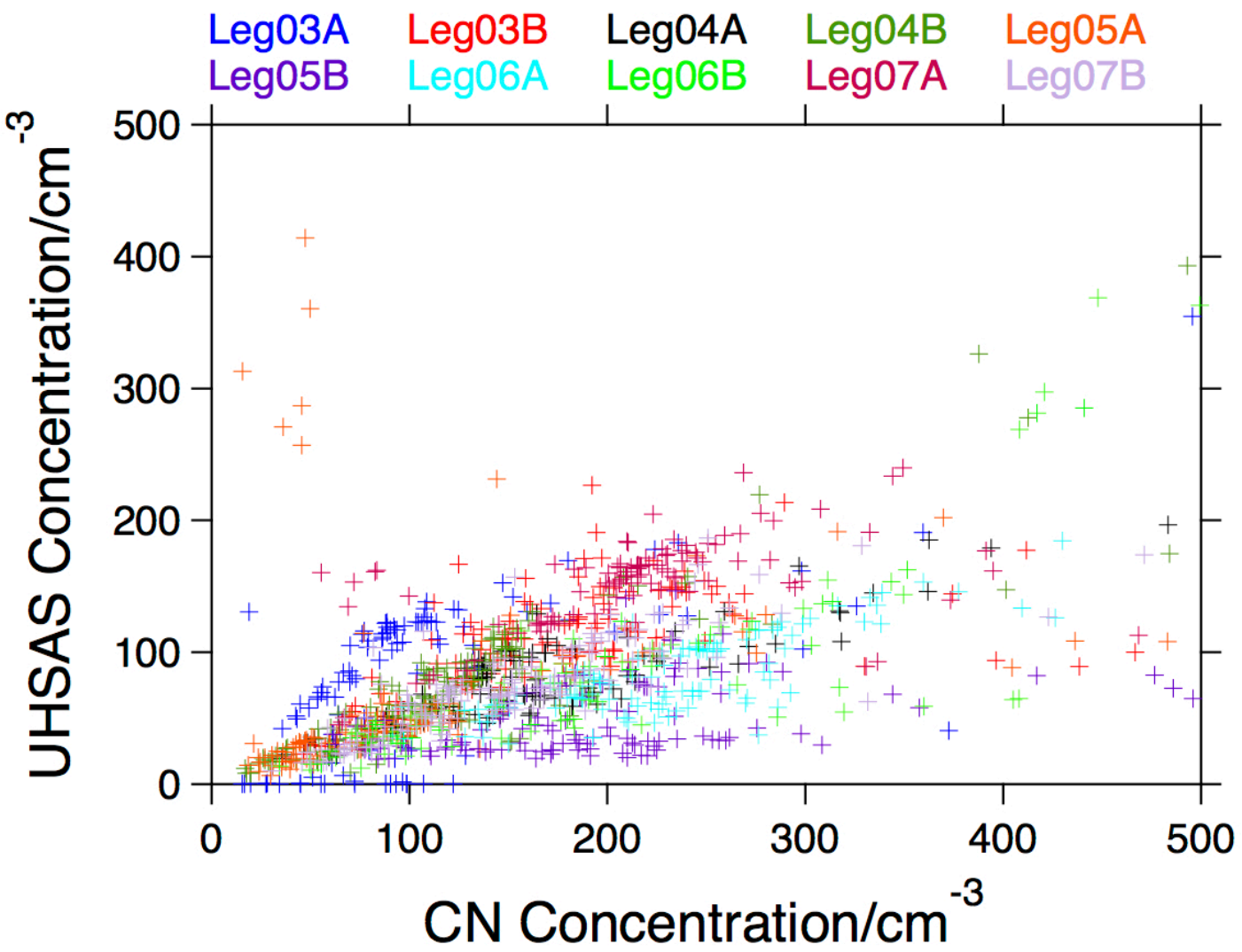


Hawaii

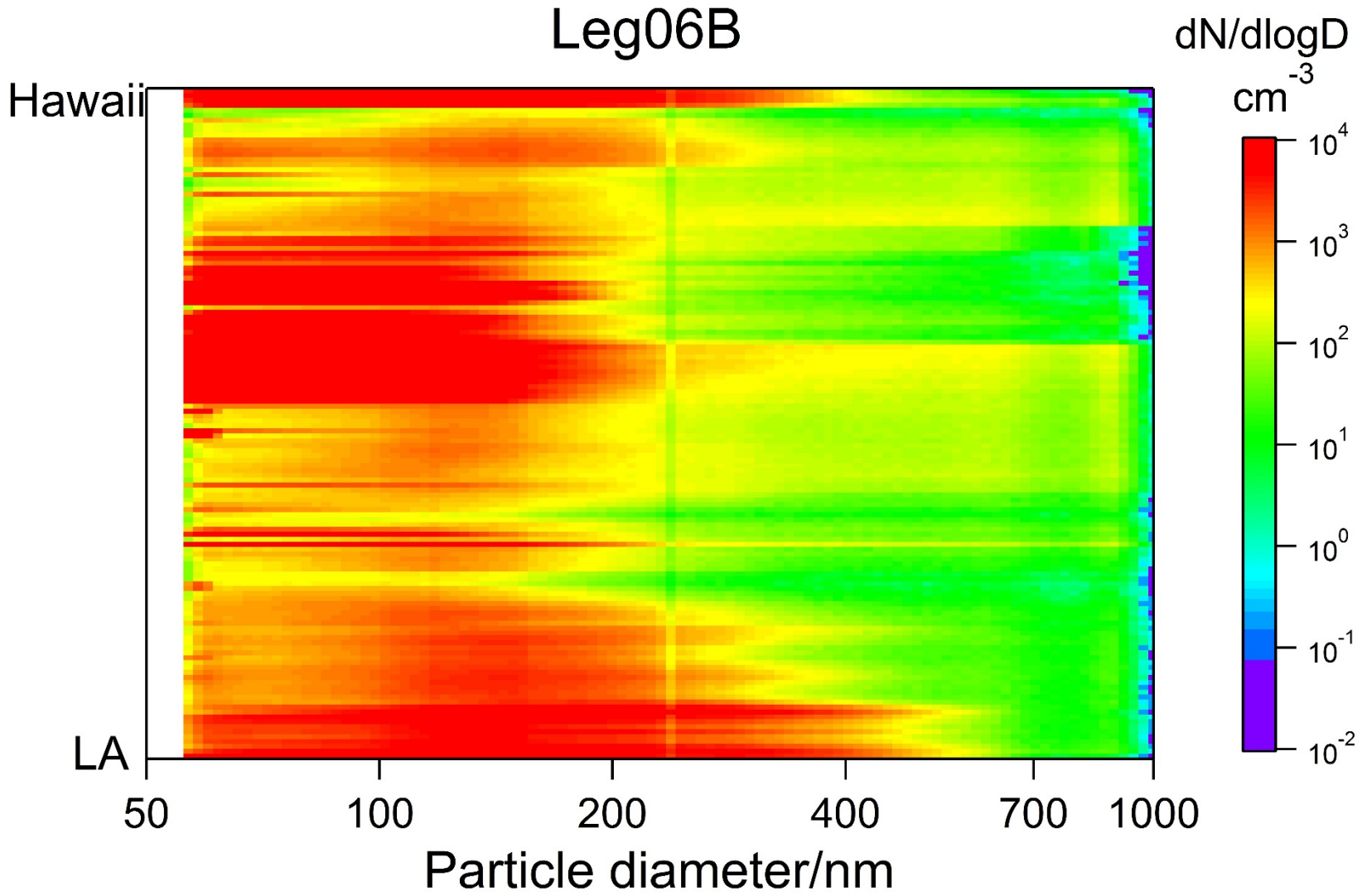
Los Angeles

Graph courtesy of Gunnar Senum

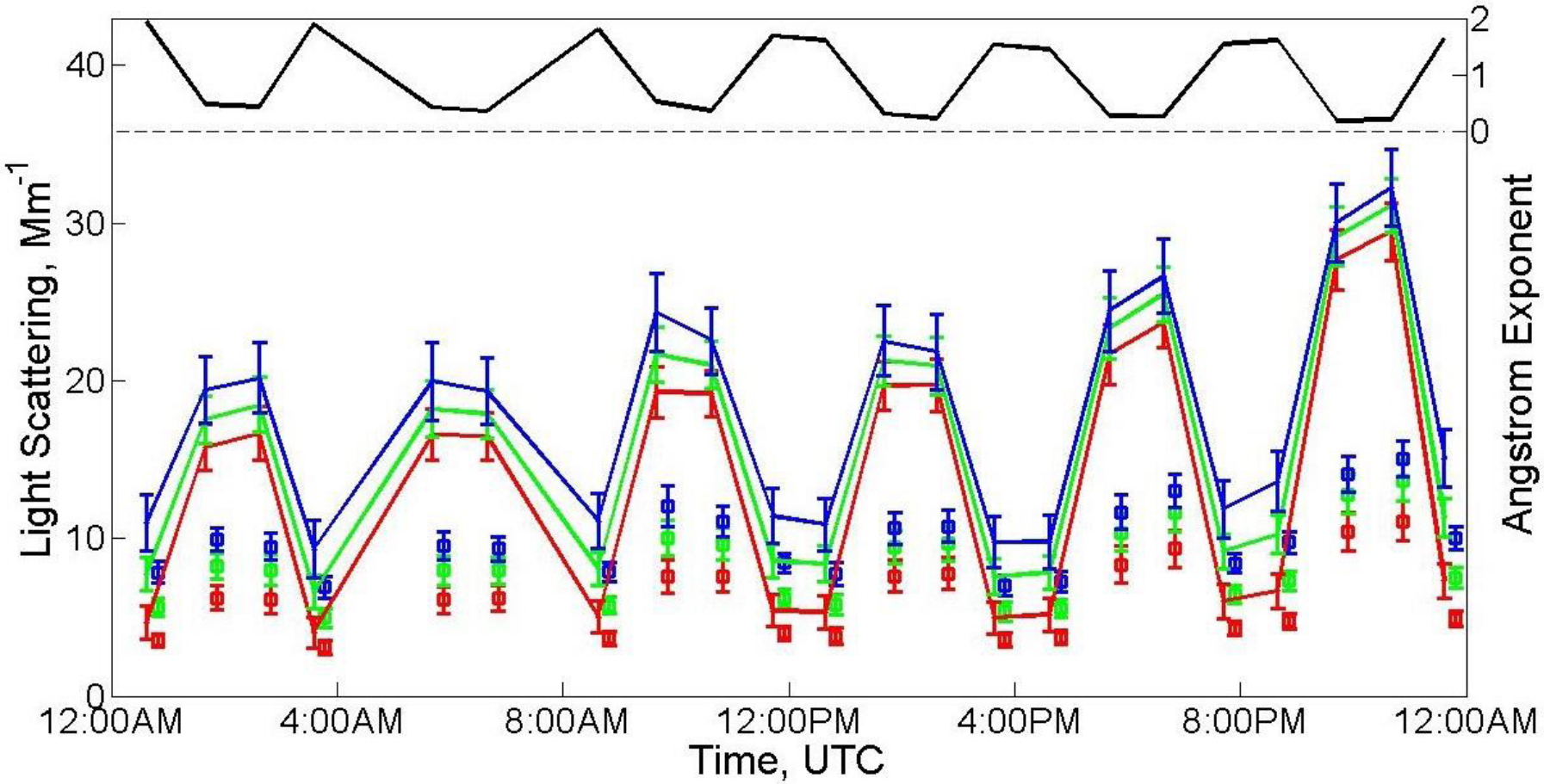
Conc (d_{opt} > 60 nm) vs. Conc (d_p > 10 nm)



UHSAS Size Distributions

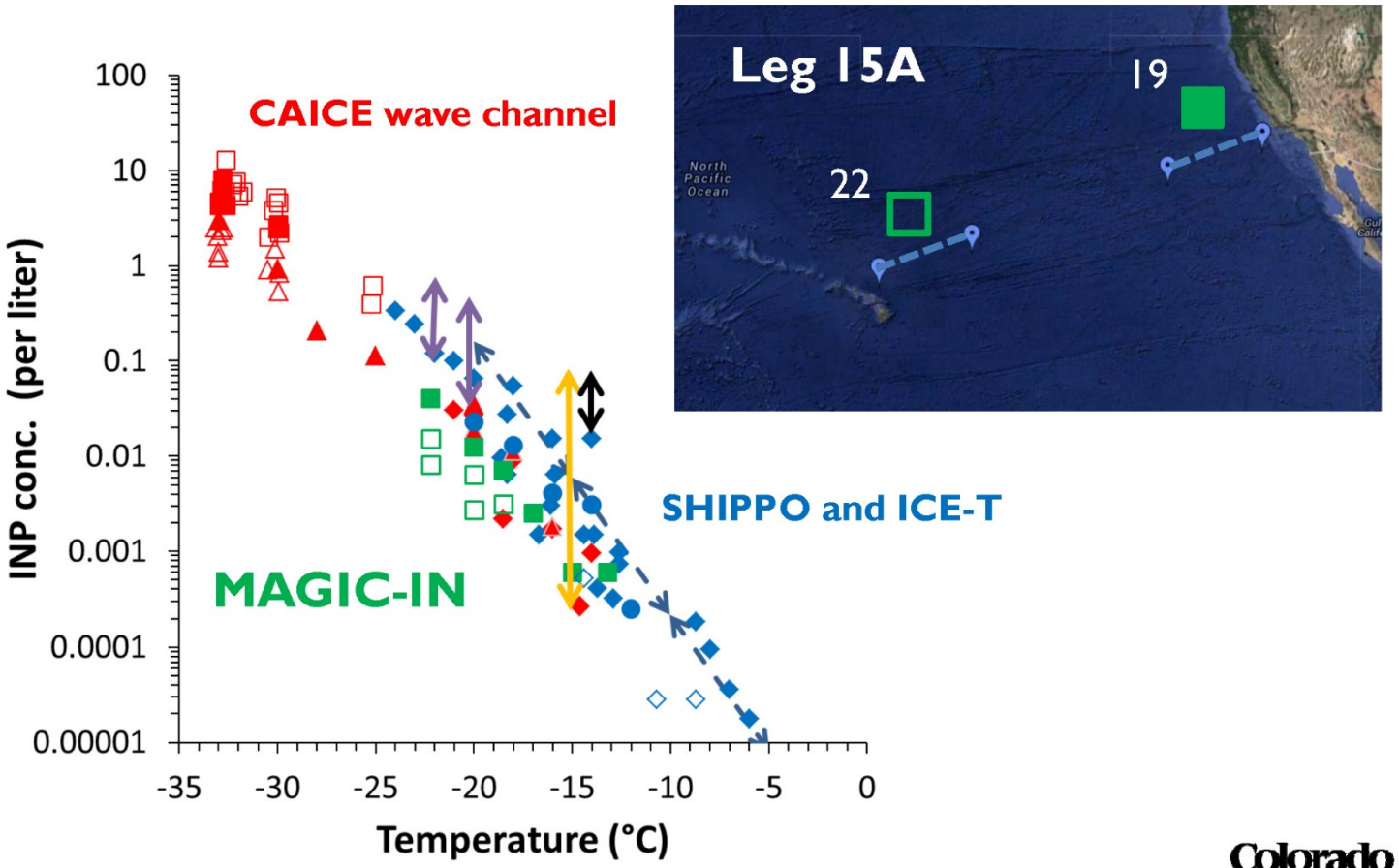


Nephelometer Closure



More than half of the light scattering is from D > 1 μm

Comparison for a few recent MAGIC samples



Colorado State University

Slide courtesy Paul DeMott

ECMWF along-track forecast data now available

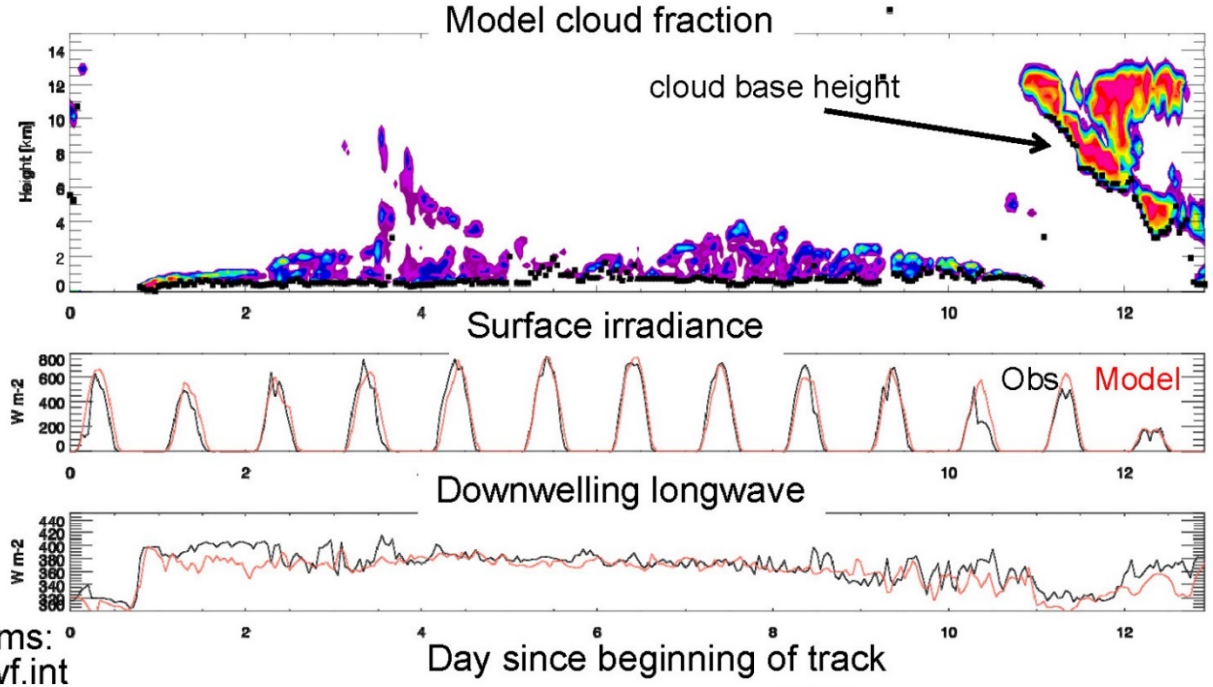
Upper air fields: T, q, u, v, w, CC, CLWC, CIWC, rain, snow

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

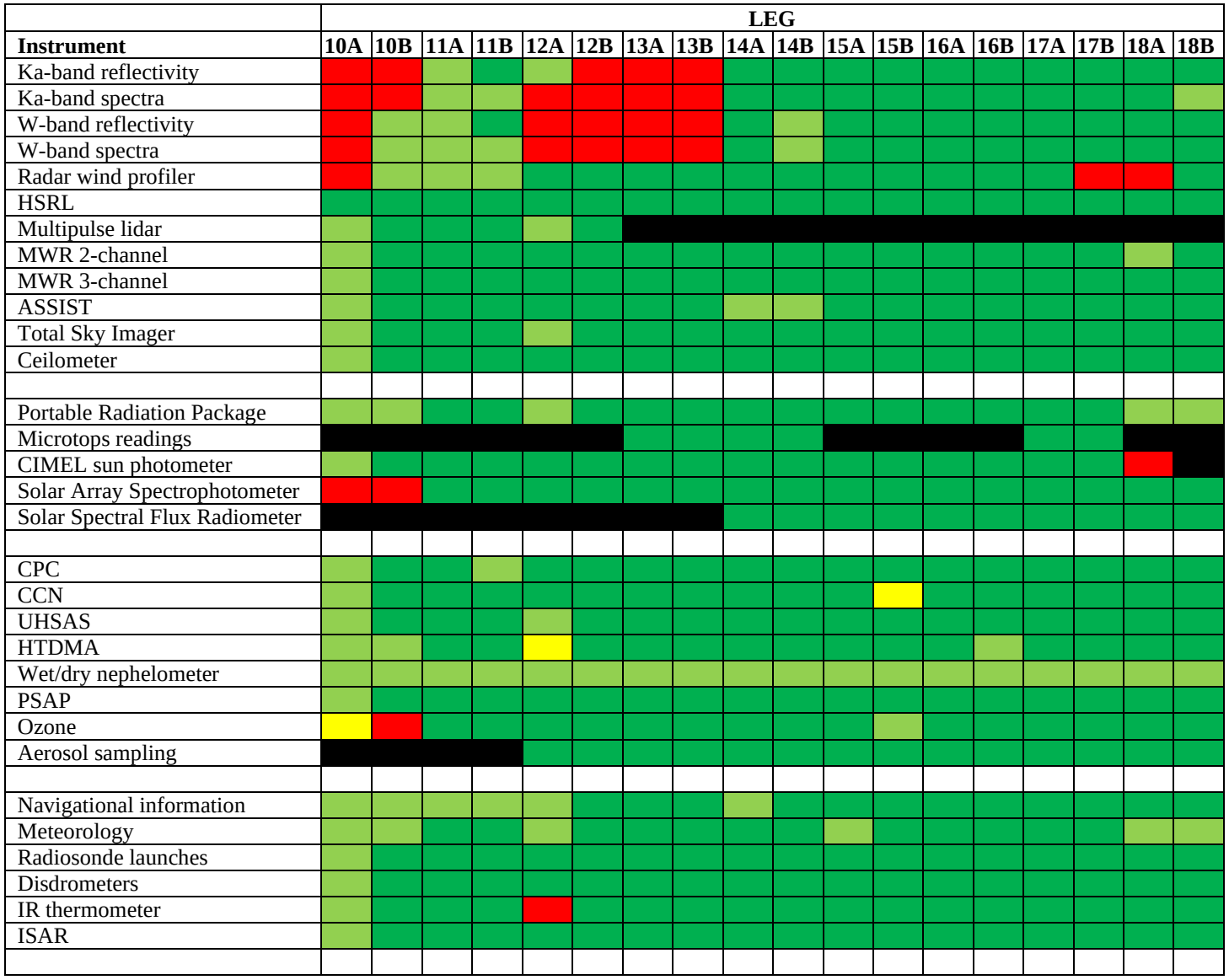


For questions or problems:
Maike.ahlgrimm@ecmwf.int

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																		
W-band reflectivity																		
W-band spectra																		
Radar wind profiler																		
HSRL																		
Multipulse lidar																		
MWR 2-channel																		
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Navigational information																		
Meteorology																		
Radiosonde launches																		
Disdrometers																		
IR thermometer																		
ISAR																		

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*, Issue 16, 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

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

Future Plans

MAGIC-2 was proposed several times

- A full-year deployment with the same platform and transect as MAGIC

MAGIC-Lite was proposed

- A subset of MAGIC measurements using robust autonomous instruments:
  - Mast Meteorological System (T, P, RH, wind speed & dir, precip.)
  - Portable Radiation Package, consists of PSP, PIR, SPN, FRSR
  - Ceilometer (cloud base)
  - Microwave radiometer (liquid and vapor water column amounts)
  - Total sky imager (cloud fraction)
  - Infrared Scanning Autonomous Radiometer, ISAR (SSST)
  - CIMEL sunphotometer in cloud mode (cloud optical depth)

Other plans

MAGIC Data

MAGIC data are freely available to all and can be found at the bottom of the AMR MAGIC webpage at http://www.arm.gov/campaigns/amf2012magic/

A tutorial on accessing ARM data can be found at http://www.youtube.com/watch?v=xHIRXwGyrOs&list=UUYwRLlD9RZGZcKO9882B3ig&feature=em-share_video_in_list_user (starting at ~7:00)

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.

Thank you!