(MARCUS): Measurements of Aerosols, Radiation and CloUds Over the Southern OCeans

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What is MARCUS?

- **What?** MARCUS targets observations of clouds, aerosols, precipitation and radiation over the Southern Ocean (SO)
- **Where?** The Australian Antarctic supply vessel Aurora Australis (AA) will make routine transits between Hobart, Australia and the Antarctic stations Mawson, Davis and Casey, and Macquarie Island.
- **How?** AMF-2 installed on AA will measure CCN and INPs at surface, retrieve profiles of macrophysical and microphysical properties of liquid and mixed-phase clouds, downwelling radiation, etc. , and launch soundings
- **When?** 7-month period between September 2017 to April 2018 centered on summer
- **Why?** Measurements in cold waters at latitudes poleward of 55˚S are sparse and climatologically important since there are large GCM biases in modeled SW absorption, and supercooled and mixed-phase clouds are frequent & not well retrieved

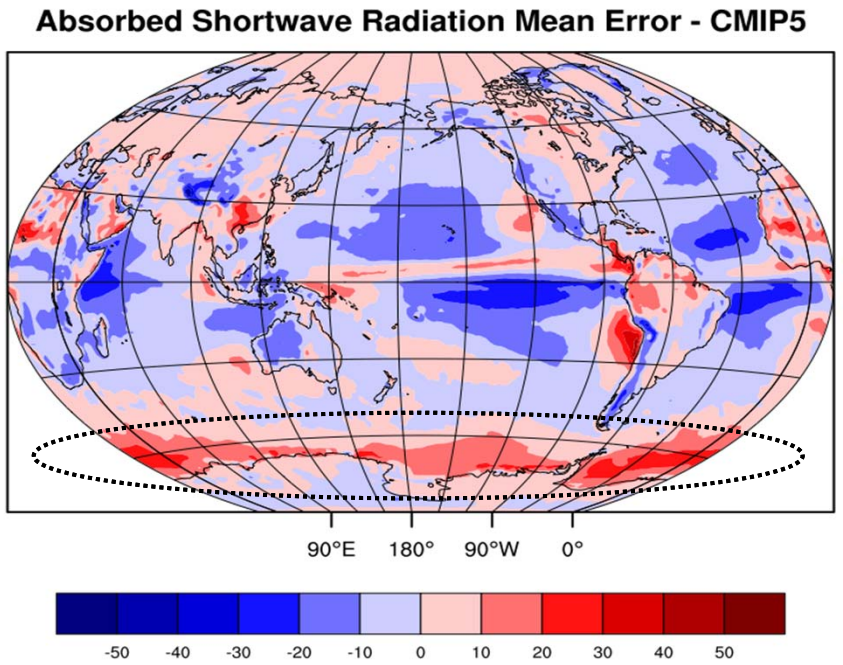
More information at https://www.arm.gov/campaigns/amf2017marcus/

Outline

1. Motivation for MARCUS
2. MARCUS Science Themes & Testable Hypothesis
3. Planned Measurements for MARCUS
4. Planned Analysis Strategy
5. Information about planned coincident SOCRATES campaign

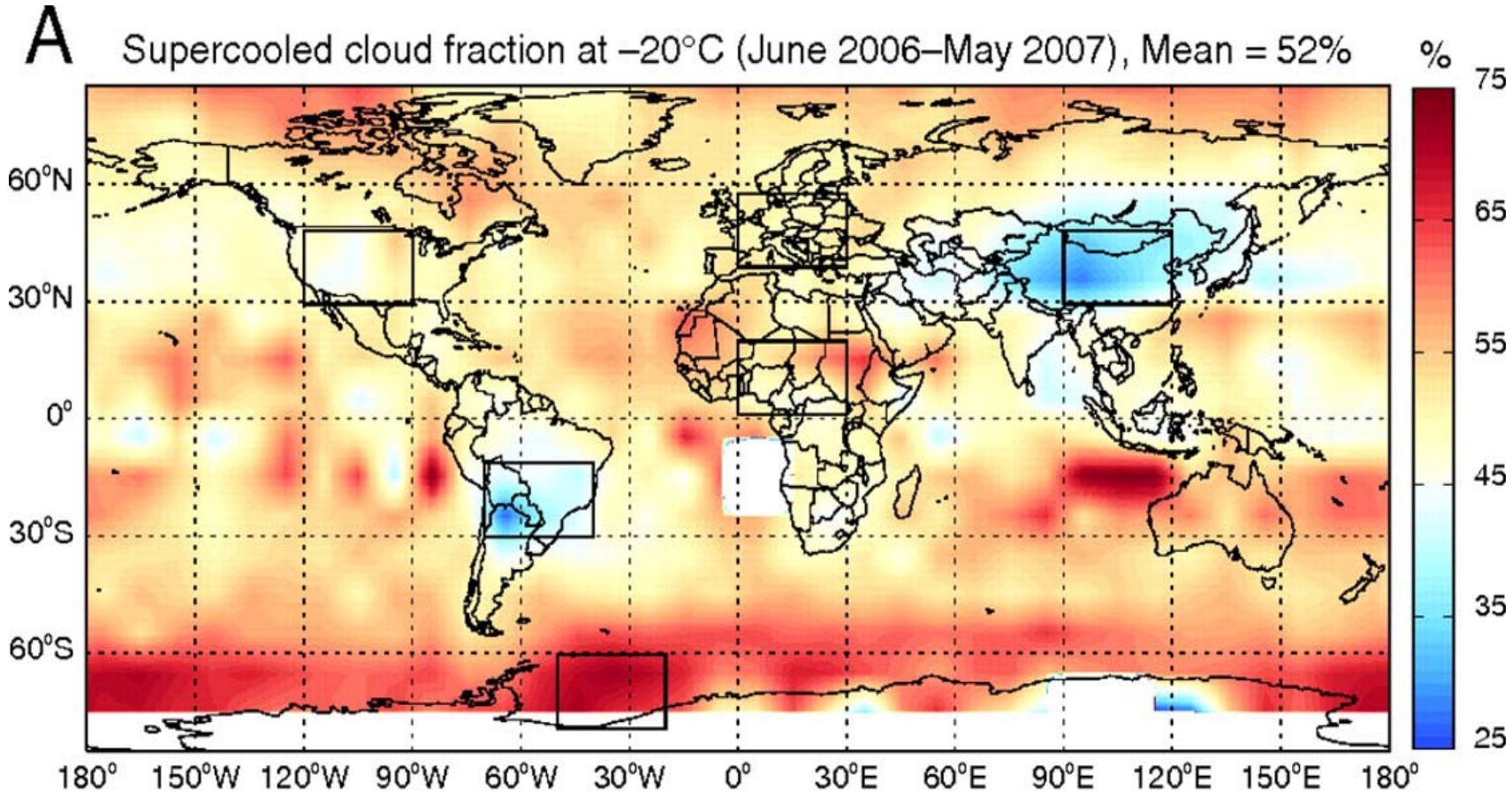
Climate model biases & observational knowledge gaps

- Climate models have uncertainties & biases in simulating SO clouds, aerosols & air-sea exchanges due to poor understanding of physical processes
- Clouds (particularly low-mid level clouds in cold sector) are poorly represented in GCM & NWP analyses
- Uncertainty in natural aerosol processes (CCN & INPs) are major source of uncertainty in radiative forcing from aerosols
- Large radiation biases interact with location of SH jet in GCMs, influence circulation and may correlate with climate sensitivity



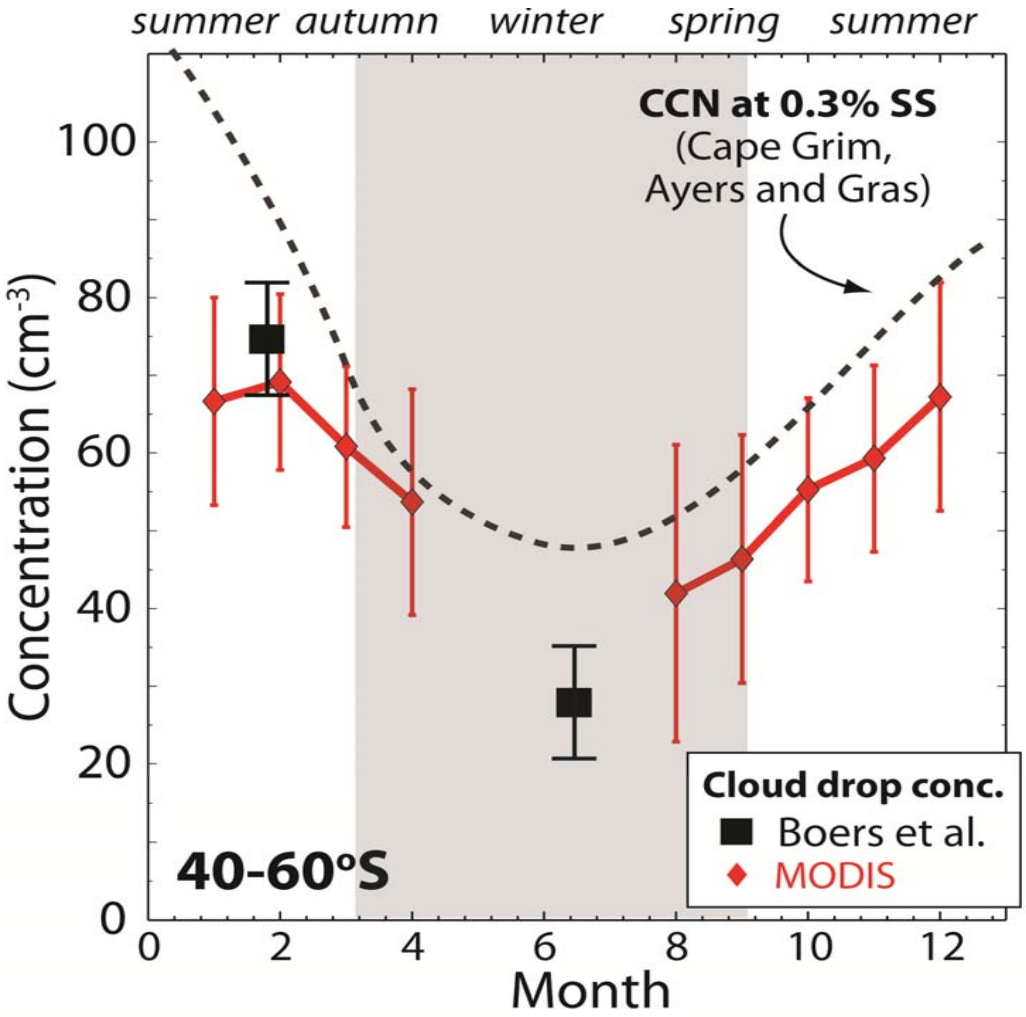
CMIP5 model clouds do not reflect enough sunlight over SO. Ensemble mean error for CMIP5 models in shortwave radiation absorbed by the Earth System. Positive values indicate too much shortwave radiation absorbed.

SO Cloud and Aerosol Properties



Large fraction of cloud-tops at temperatures near -20˚C contain supercooled liquid water, *as retrieved using CALIPSO depolarization measurements (Choi et al. 2010); GCMs have broad range of sensitivities to liquid vs. ice partitioning to temperature in SO clouds showing need for in-situ observational constraints*

SO Cloud and Aerosol Properties



Large seasonal cycles of cloud droplet & CCN concentrations exist over the SO. Biogenic sources are believed responsible, but much unknown about aerosol composition and underlying physical processes, especially at more southerly latitudes.

MARCUS observational and modeling requirements

MARCUS observational requirement	To enhance knowledge of SO aerosols, clouds & their interactions in variety of synoptic settings and to narrow uncertainties in representing key processes in GCMs, a comprehensive dataset is needed that documents BL structure, and associated vertical distributions of liquid and mixed-phase cloud and aerosol (including CCN and INP) properties over the SO under a range of synoptic settings.
MARCUS modeling requirement	For such a dataset to have broad impact on GCMs, the modelling community must be an integral part of the MARCUS design and be involved in a systematic confrontation of leading GCMs with MARCUS data, e. g. using short-term hindcasts as in VOCALS (Wyant et al. 2014).

MARCUS Science Themes

Theme 1: Synoptically-varying vertical structure of SO BL clouds and aerosols

Theme 2: Variability of sources and sinks of SO CCN and INPs and role of local biogenic sources over spring, summer & fall.

Theme 3: Supercooled liquid clouds over SO

Theme 4: Advancing retrievals related to clouds, precipitation, and aerosols, over SO

Specific testable hypotheses proposed for each theme

MARCUS Platform: Aurora Australis

- During each operational season (Oct. – Mar.), AA traverses SO ~ 4 times to resupply coastal East Antarctic bases(Mawson, Casey & Davis) and Macquarie Island.
  - Not dedicated research vessel (minimal influence on tracks)
  - Typical voyage ~ 10 to 14 days traversing SO (depending on ice conditions) and ~ 1 week moored at coast for resupply
- Space on AA for 2 AMF2 shipping containers to be installed for the entire operational season.
  - One will be located forward of bridge on port side, second aft of bridge on bridge deck
  - additional space on monkey deck above bridge to locate instruments requiring clear view of sky


P&O
AURORA AUSTRALIS

- **AA ran aground during blizzard at Mawson on Feb. 24, 2016 in 70 knot winds; refloated 2 days later but did have breach in hull**
- **Due back in Hobart on 10 May 2016 having been undergoing sea trials in Singapore where was in dry dock**

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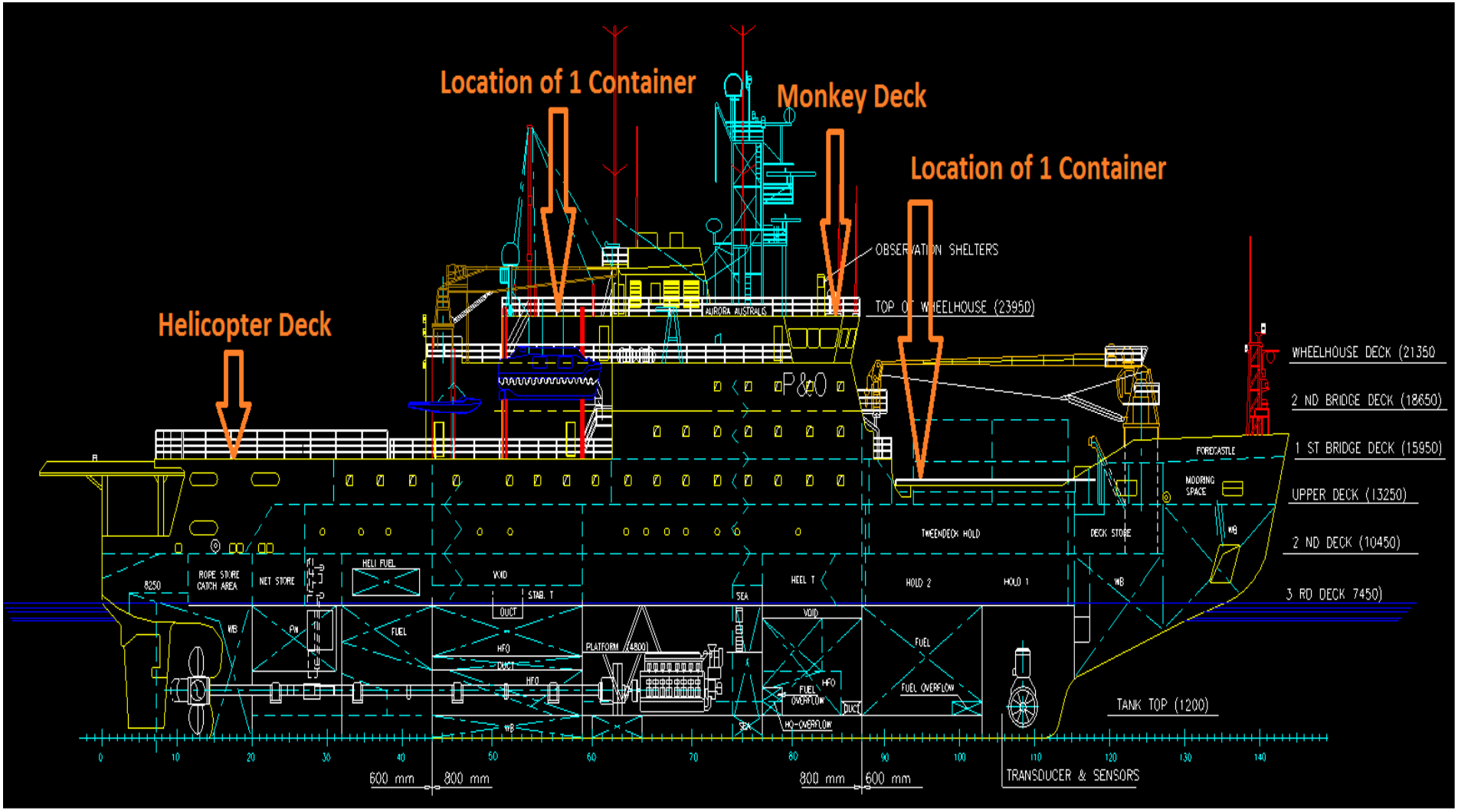
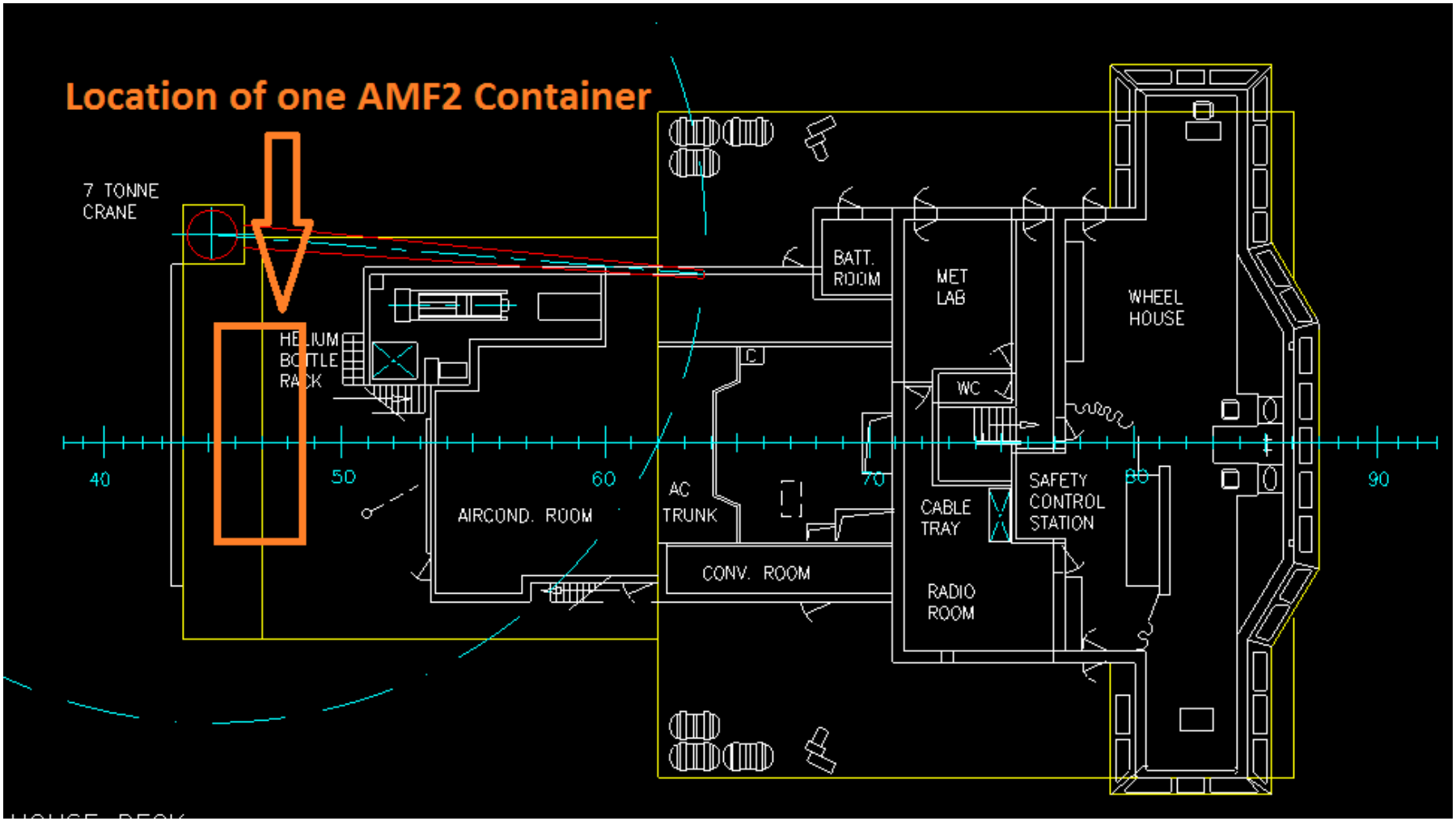
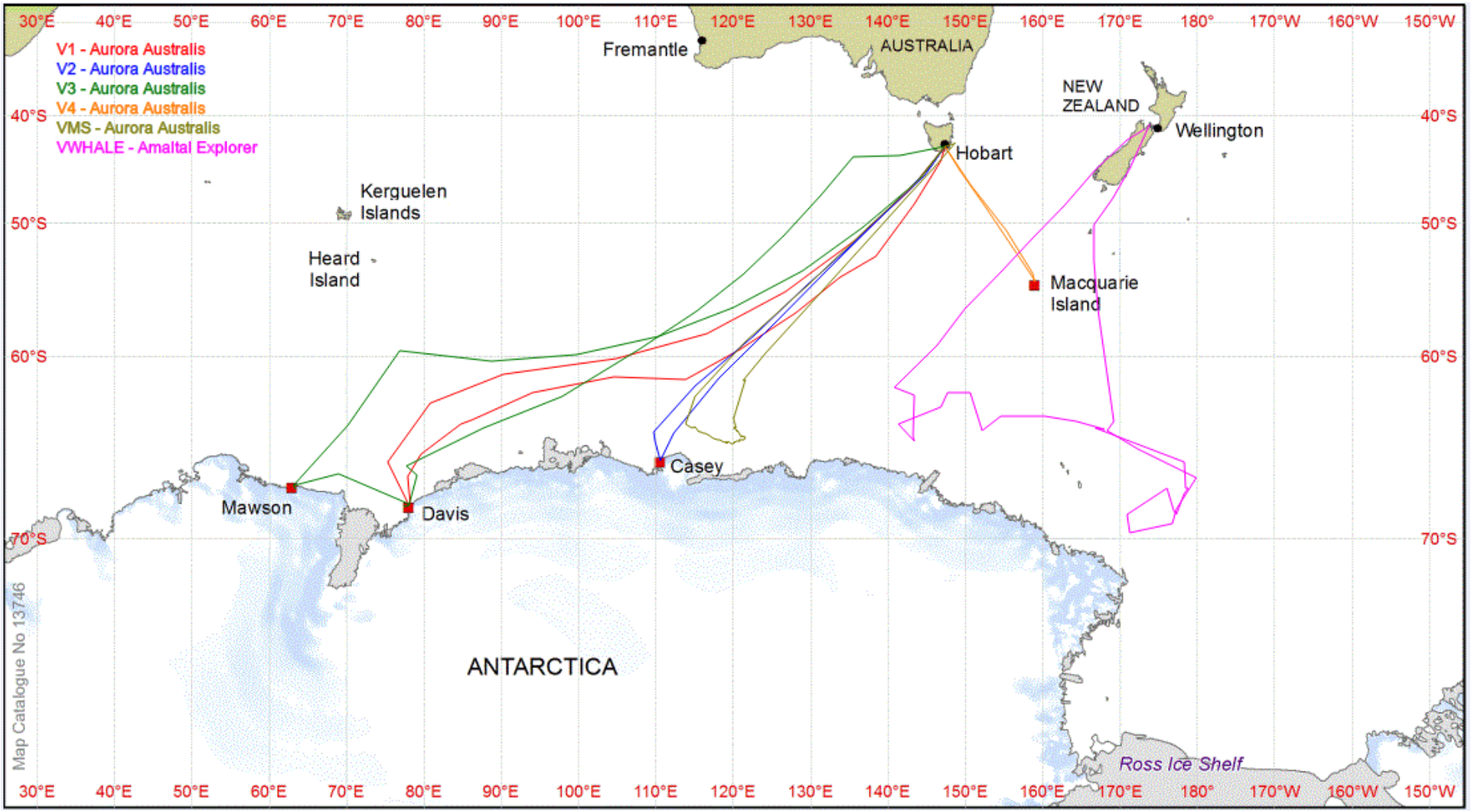

Location of 1 Container
Monkey Deck
Location of 1 Container
Helicopter Deck
OBSERVATION SHELTERS
TOP OF WHEELHOUSE (23950)
AURORA AUSTRALIS
P&O
WHEELHOUSE DECK (21350
2 ND BRIDGE DECK (18650)
1 ST BRIDGE DECK (15950)
UPPER DECK (13250)
2 ND DECK (10450)
3 RD DECK 7450)
FORECASTLE
MOORING SPACE
TWEENDECK HOLD
DECK STORE
HOLD 2
HOLD 1
HEEL T
VOID
STAB. T
DUCT
HELI FUEL
ROPE STORE CATCH AREA
NET STORE
8250
WB
FUEL
HFO
PLATFORM (4800)
SEA
FUEL OVERFLOW
HFO OVERFLOW
TANK TOP (1200)
600 mm
800 mm
800 mm
600 mm
TRANSDUCER & SENSORS


Location of one AMF2 Container
7 TONNE CRANE
HELIUM BOTTLE RACK
AIRCOND. ROOM
AC TRUNK
CONV. ROOM
BATT. ROOM
MET LAB
WC
CABLE TRAY
RADIO ROOM
SAFETY CONTROL STATION
WHEEL HOUSE
40
50
60
70
80
90



- Voyages from 2012-13 season
  - Similar tracks expected for 2017-18
- Will be best set of data on clouds & aerosols south of 55˚S where cold SSTs and supercooled water expected to be ubiquitous.

AMF2 Aerosol Instruments

Instrument	Measurement	Priority
CCN Counter	CCN as function of supersaturation	1
Ambient nephelometer	Light scattering aerosol coefficient as function of RH	2
Wet nephelometer	As above, over range of RH	1
Condensation Particle Counter	Concentration of aerosols > 10 nm	2
Ultra-High Sensitivity Aerosol Spectrometer (USHAS)	Aerosols SDs (0.06 to 1 μm) at higher time resolution than from HTDMA	1
3-λ Particle Soot Absorption Photometer (PSAP)	Optical transmittance of particles at 3 λ	2
CO Detector	Good influence of anthropogenic influences	1
Local Meteorology	Wind Speed, Direction, T, RH, P and precipitation	1
Ozone	Part of AOS	3

AMF2 Priority 1 Instruments

Instrument	Measurement	Priority
Cimel Sunphotometer	Multi-channel radiometer (direct solar irradiance and sky radiance)	1
Balloon-borne Soundings	Vertical profiles of T, RH & winds (4/day)	1
Micropulse lidar	Vertical profiles of clouds/aerosols	1
Microwave Radiometer	Tb in channels sensitive to H20v and liquid (prefer 3 channel version)	1
Marine 95 GHz cloud radar on stabilized platform (SWACR)	Z, Vdop and spectral data	1
Vaisala Ceilometer	Detection of vertical cloud layers	1
Stability Platform	Corrects role, pitch & heave	1
Portable Radiation Measurement Package & Sun Pyranometer	PSP, PIR and Fast Rotating Shadow-band Radiometer (FRSR) and Sun Pyranometer	1 (for downwelling)
Ocean Temperature	Ocean Surface Temperature	1
Video or Parsivel Disdrometer	Raindrop size distributions	1
Inertial Navigation System	High accuracy motion data (SeaNav)	1

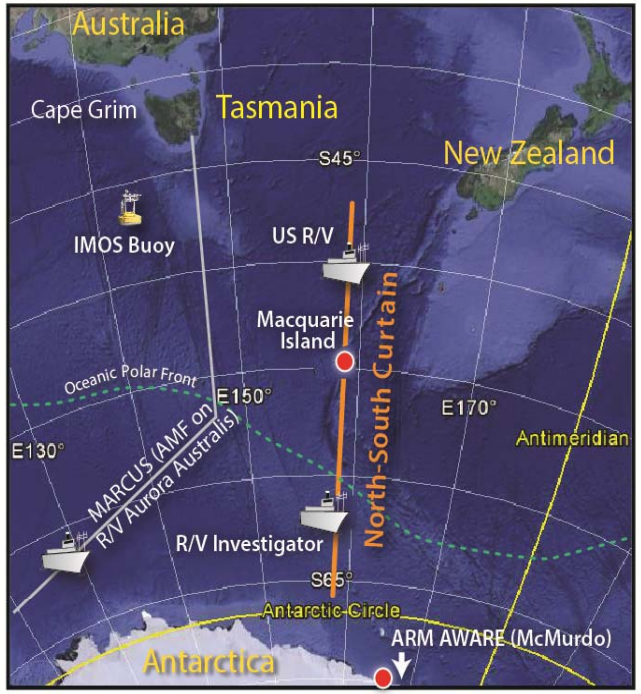
AMF2 Lower Priority Instruments

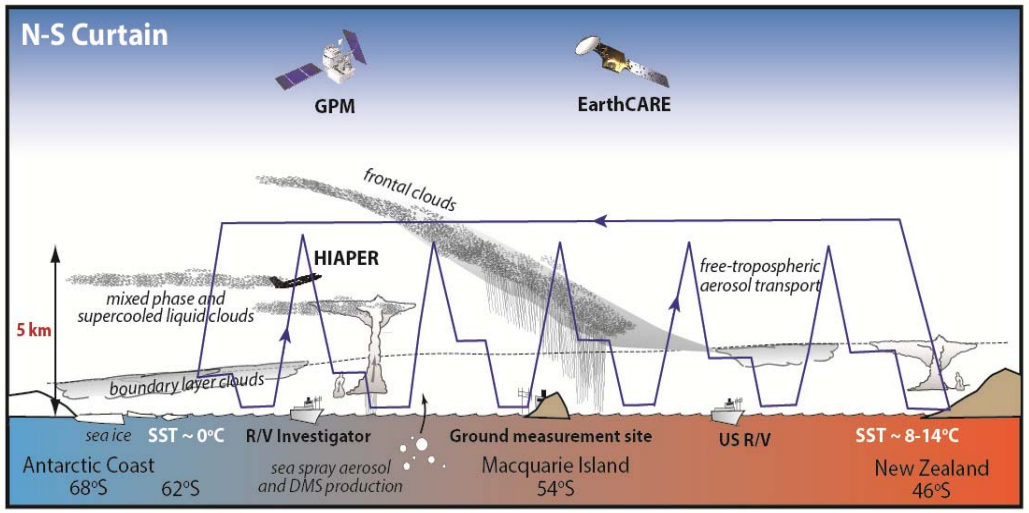
Instrument	Measurement	Priority
Total Sky Imager (TSI)	Time series of hemispheric images	2
High Spectral Resolution Lidar	Calibrated measurements of aerosol τ, volume backscatter coefficient, cross section & depolarization	2 (no space)
Dual-frequency (X-Ka) scanning cloud radar (KA-SACR; X-SACR)	Dual frequency scanning cloud radar measuring Z, Vdop	3 (no space)
Ka-band zenith radar (KAZR)	Millimeter wavelength cloud radar	2 (1 if stabilized platform)
Radar wind profiler (RWP)	Wind profiles & backscatter signal	2 (space uncertain)
Marine Emitted Radiance Interferometer (MAERI)	Thermal spectral radiance & measures of surface T & emissivity)	2-3
Bulk aerodynamic fluxes	Measurement of aerodynamic fluxes	2

Additional observations for MARCUS

- CSU filter samples (funded)
- Aerosol chemical composition measurements (proposed): filter samples and heated/unheated SDs
- MICROTOPS sun photometer measurements of aerosol optical depth

SOCRATES N-S Curtain:





Other Funded activities:

- *Australian R/V Investigator for 2016 and 2018*
- *DOE & Australian funded instruments on Macquarie Island*
- *IMOS Buoy in SOCRATES domain*
- *R/V Tangaro in Ross Sea*

Proposed Activities:

- *NSF G-V deployment*
- *U.S. Ship for Austral summer*

G-V Goal:

- *Characterize clouds, radiation, aerosols, and precipitation along SOCRATES curtain*
- SOCRATES data will be used to test and advance GCMs.