Cross-disciplinary coordination in observing cloud, radiation and aerosol properties over the Southern Ocean

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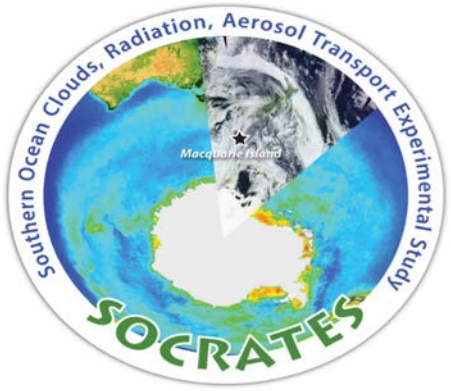

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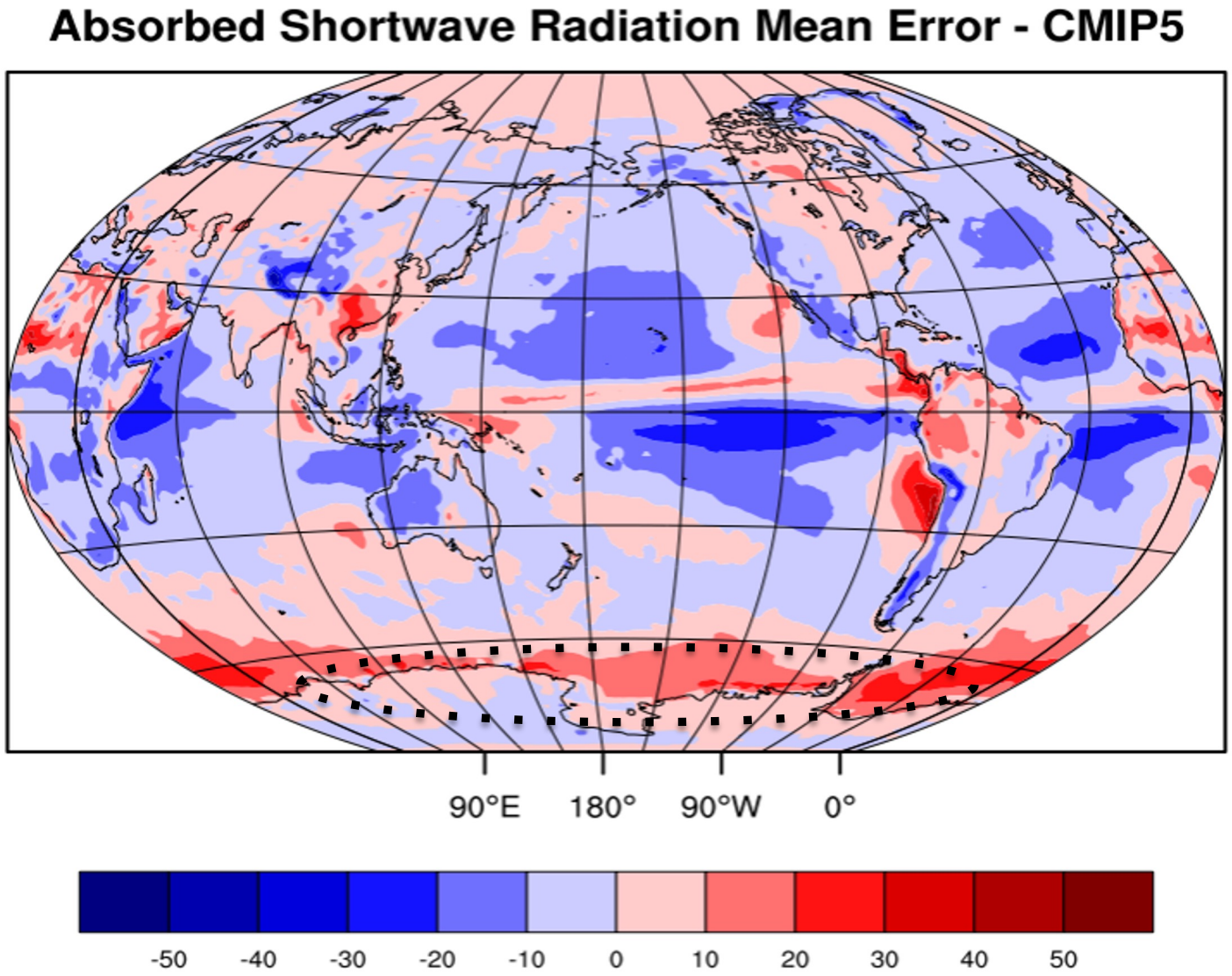
Outline

1. Motivation for Campaigns over SO
2. Overview and Synergy of Field Campaigns over SO
3. Differences in Interdisciplinary Coordination/Projects
4. Conclusions and Future Efforts over SO (PICASSO)

Motivation

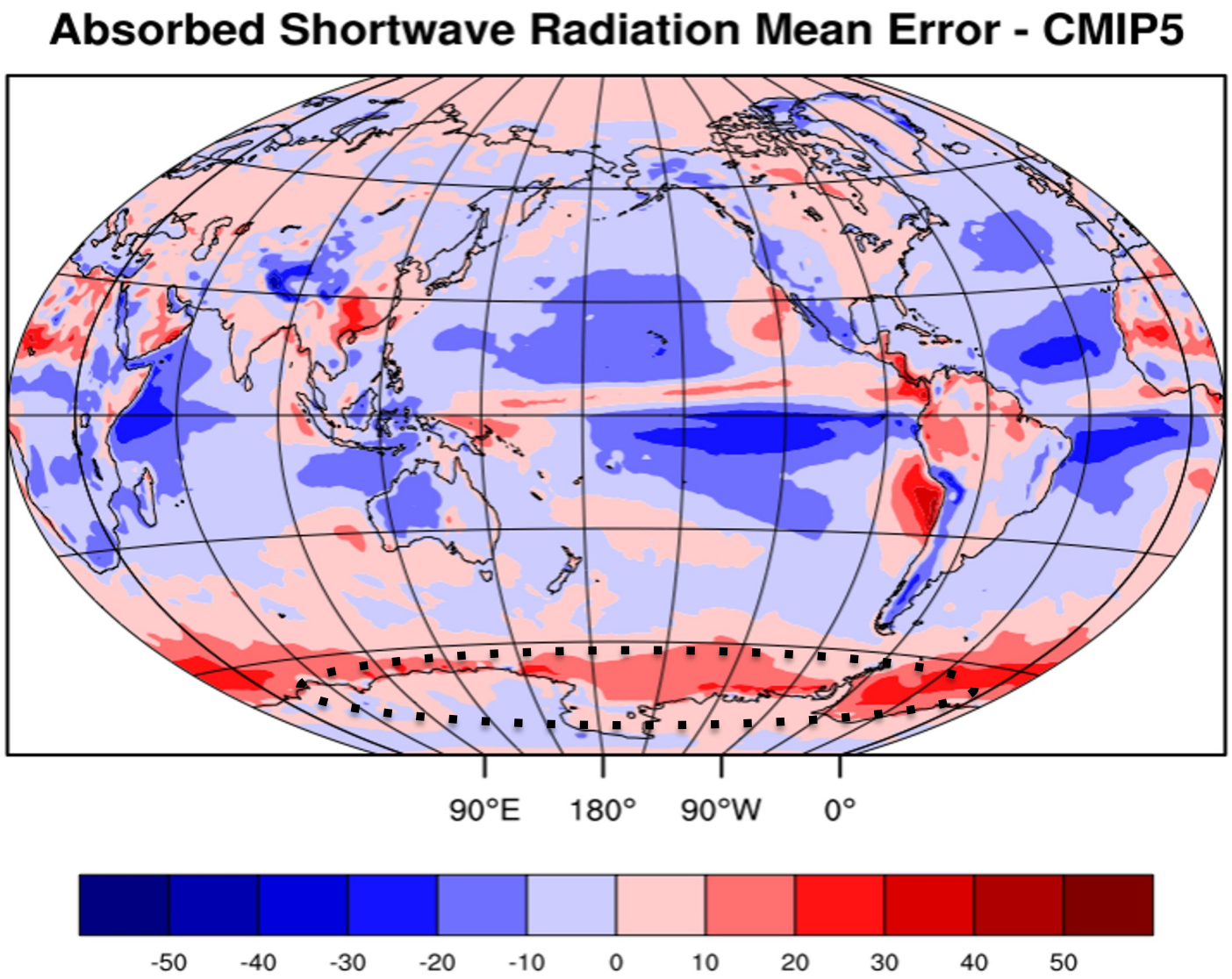
- Southern Oceans (SO) one of cloudiest regions on Earth
- Earth's climate sensitive to representation of SO clouds
  - Impact on global energy budget , simulated global cloud feedbacks & carbon-cycle feedbacks on climate change
  - Location of tropical rainfall belts
  - SO surrounds Antarctic & interacts with ice shelves whose stability to climate change is unknown
- Remoteness from anthropogenic & natural continental aerosol sources makes SO unique testbed for understanding cloud-aerosol interactions in liquid & ice clouds
  - One of largest uncertainties in determining aerosol indirect effects for climate models is poor understanding of what is pre-industrial state

Climate model biases & observational knowledge gaps



CMIP5 model clouds do not reflect enough sunlight over SO. *Ensemble mean error indicates too much SW radiation absorbed by Earth system; biases influence circulation and may correlate with climate sensitivity*

Climate model biases & observational knowledge gaps

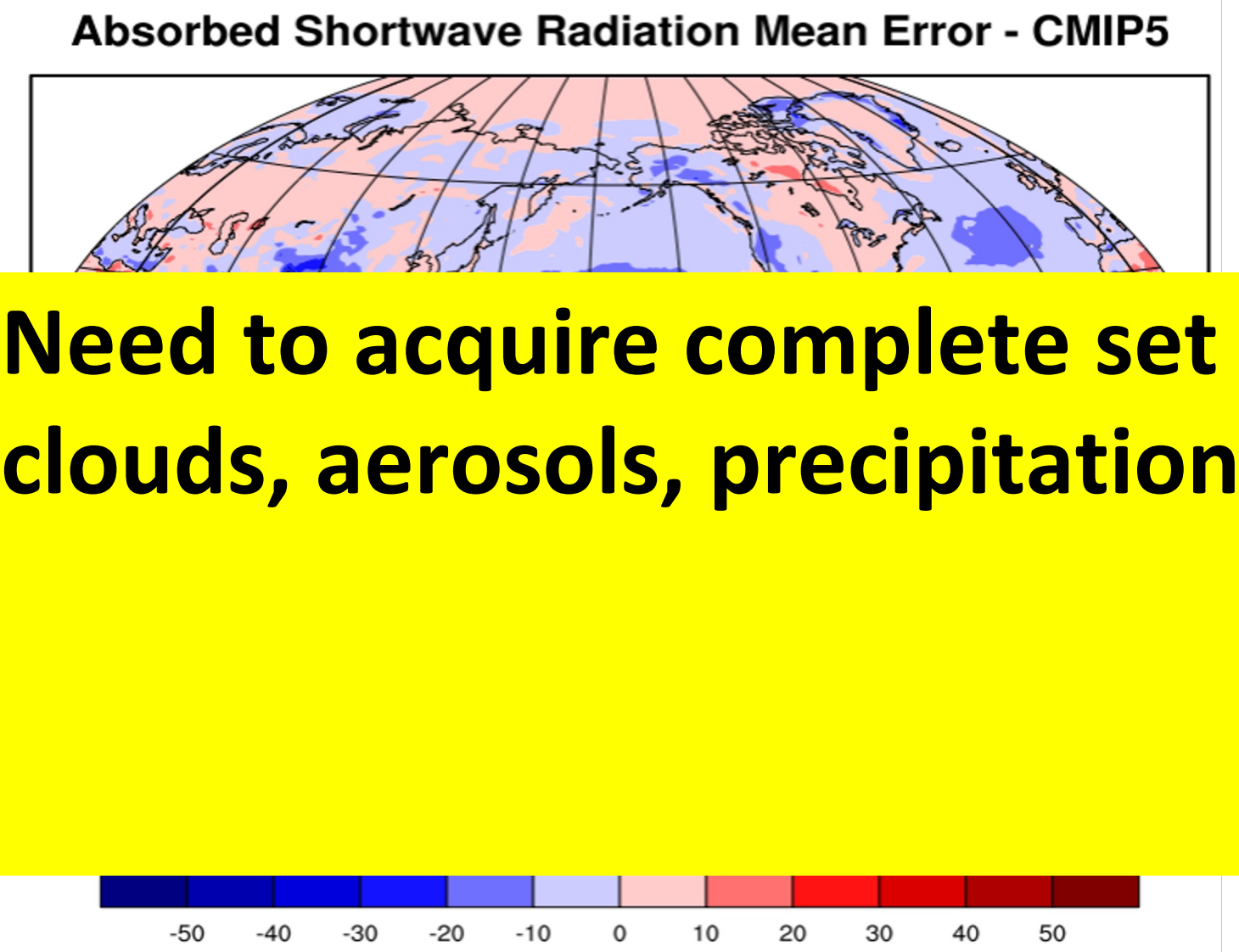


***CMIP5 model clouds do not reflect enough sunlight over SO**. Ensemble mean error indicates too much SW radiation absorbed by Earth system; biases influence circulation and may correlate with climate sensitivity*

Clouds (particularly low-mid level clouds) poorly represented in GCM/NWPs

Believe underestimate supercooled water perhaps due to pristine nature;

Climate model biases & observational knowledge gaps



CMIP5 model clouds do not reflect enough sunlight over SO. *Ensemble mean error indicates too much SW radiation absorbed by Earth system;*

Need to acquire complete set of observations on clouds, aerosols, precipitation and radiation

Southern Ocean Research Themes

Theme 1: Documenting the synoptically-varying vertical structure of SO boundary layers and clouds

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

Theme 3: Supercooled liquid clouds over SO

Theme 4: Retrieving the properties of mixed-phase clouds

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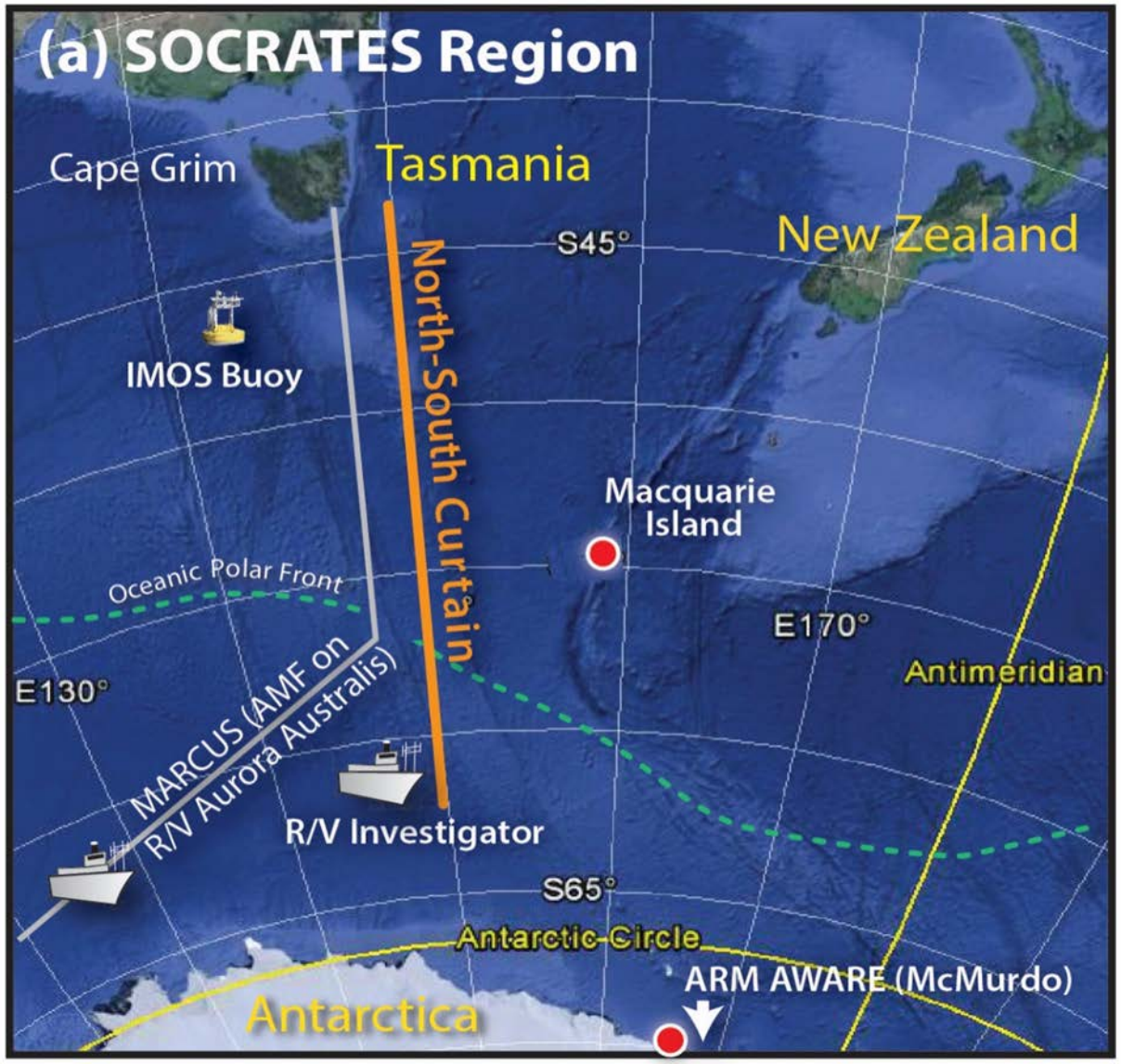
For data to have broad impact on climate modeling, modeling community was integral part of project design so as to use data for systematic confrontation of leading climate models

SOCRATES/CAPRICORN/MICRE/MARCUS Coordinated Observations



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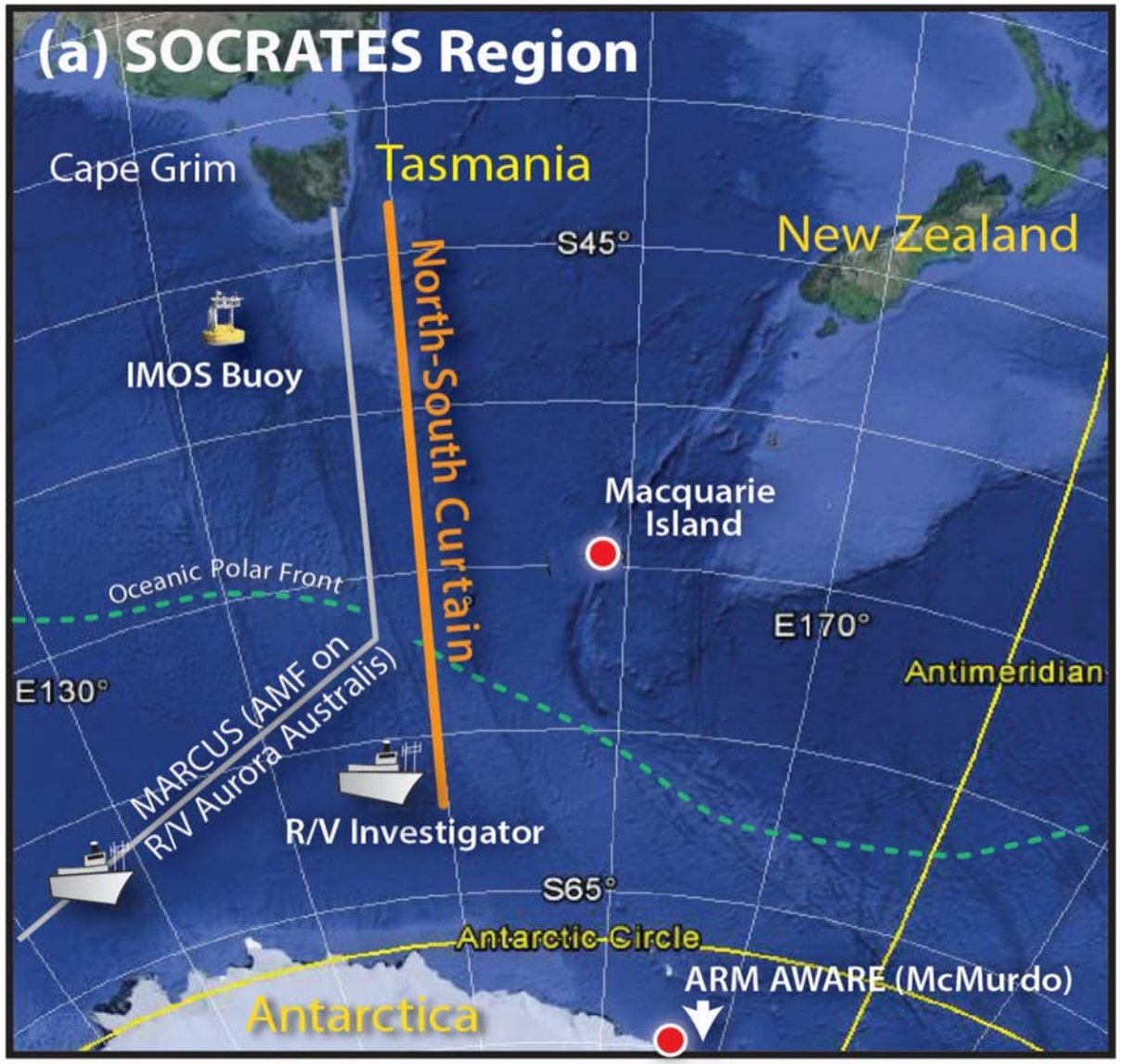
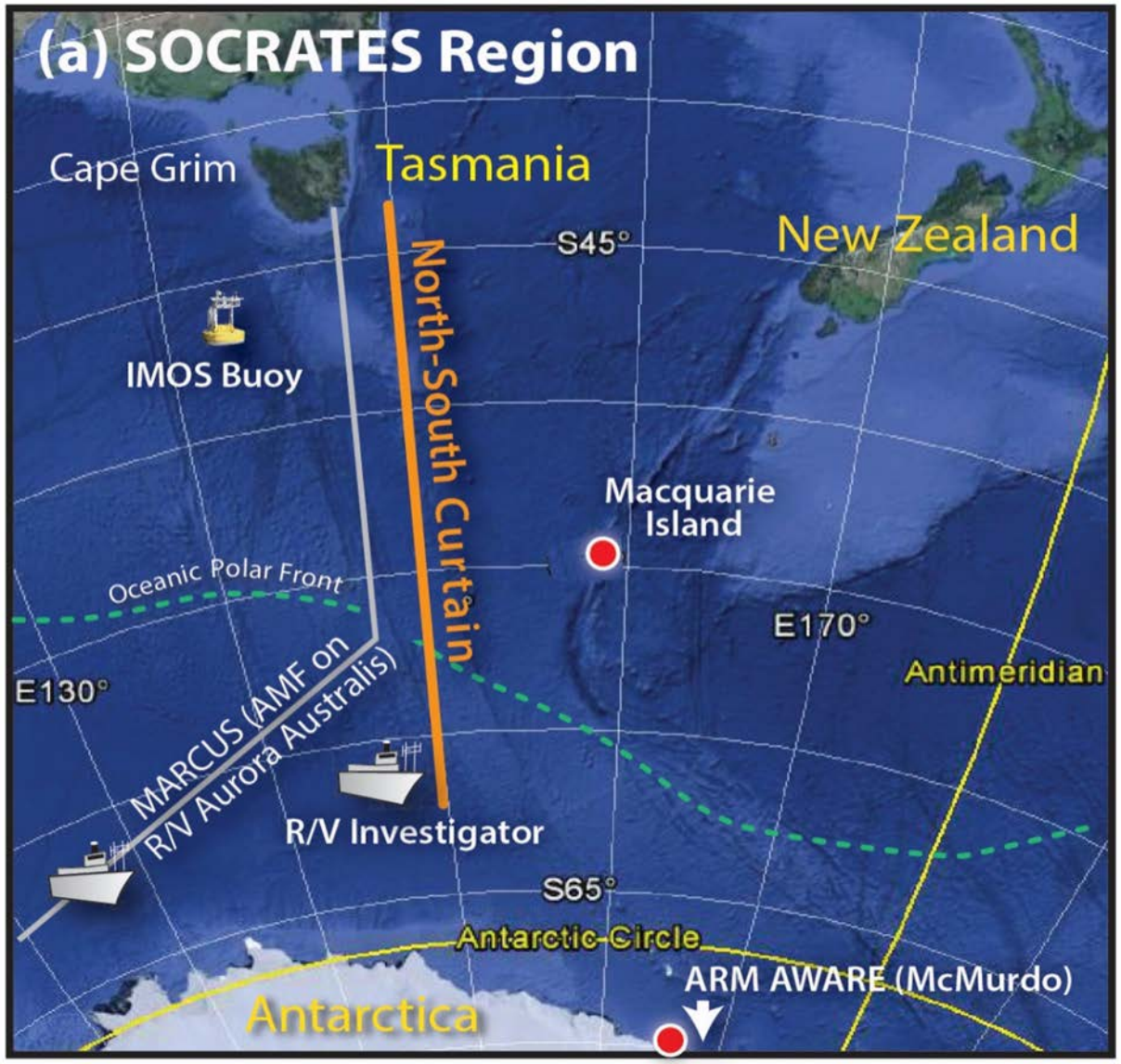


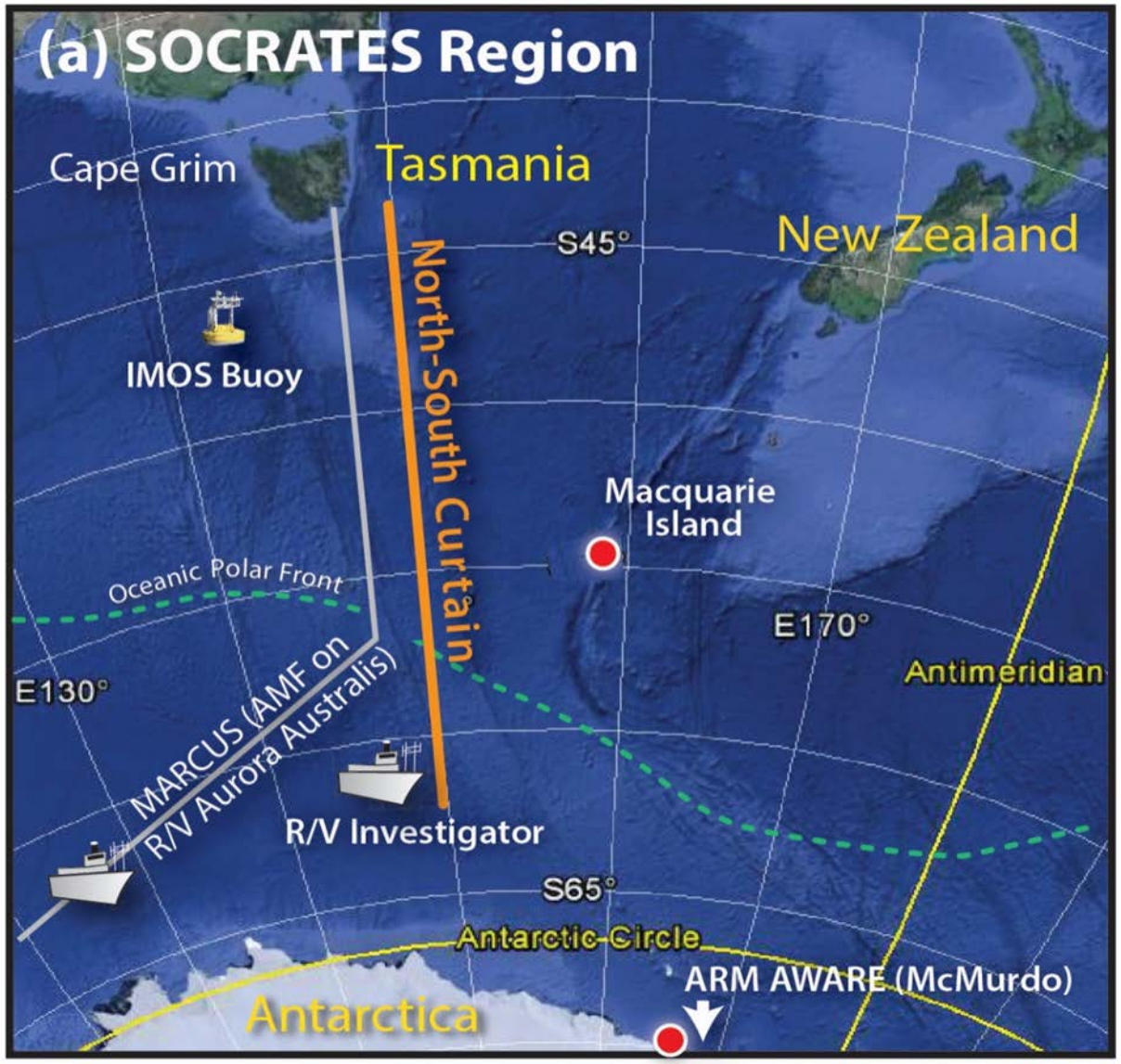
SOCRATES (Jan 15-Feb 26 2018): NSF G-V deployment

SOCRATES/CAPRICORN/MICRE/MARCUS Coordinated Observations



CAPRICORN (2016-2018):
Australian R/V Investigator

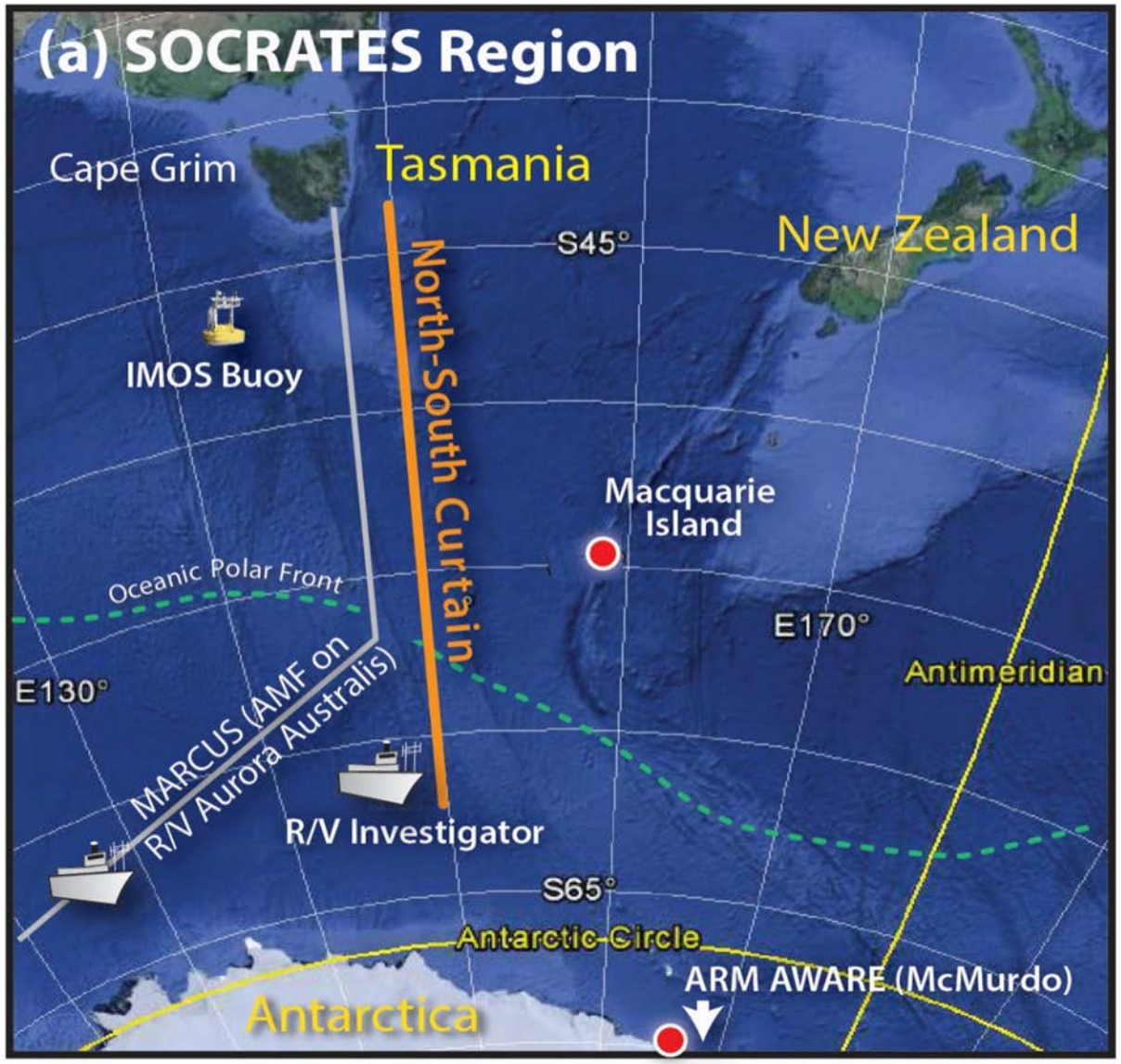
SOCRATES/CAPRICORN/MICRE/MARCUS Coordinated Observations



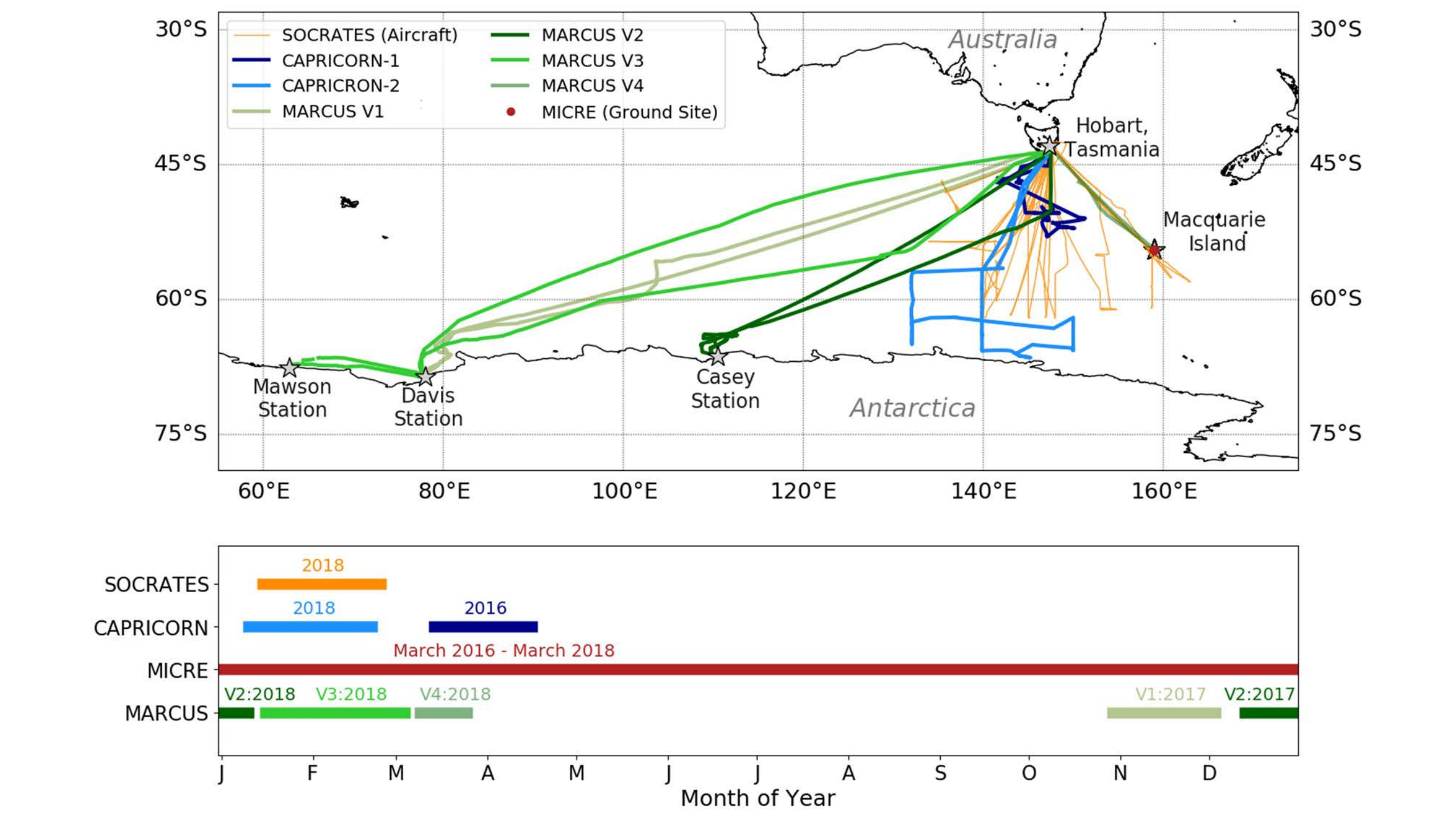
MICRE (2017-2018):

DOE, AUS instruments on Macquarie Island

SOCRATES/CAPRICORN/MICRE/MARCUS Coordinated Observations



MARCUS (2017-2018):
AMF-2 on Aurora Australis


SOCRATES (Aircraft)
CAPRICORN-1
CAPRICRON-2
MARCUS V1
MARCUS V2
MARCUS V3
MARCUS V4
MICRE (Ground Site)
Australia
Antarctica
Hobart, Tasmania
Macquarie Island
Mawson Station
Davis Station
Casey Station
30°S
45°S
60°S
75°S
60°E
80°E
100°E
120°E
140°E
160°E
SOCRATES
CAPRICORN
MICRE
MARCUS
2018
2018
2016
March 2016 - March 2018
V2:2018
V3:2018
V4:2018
V1:2017
V2:2017
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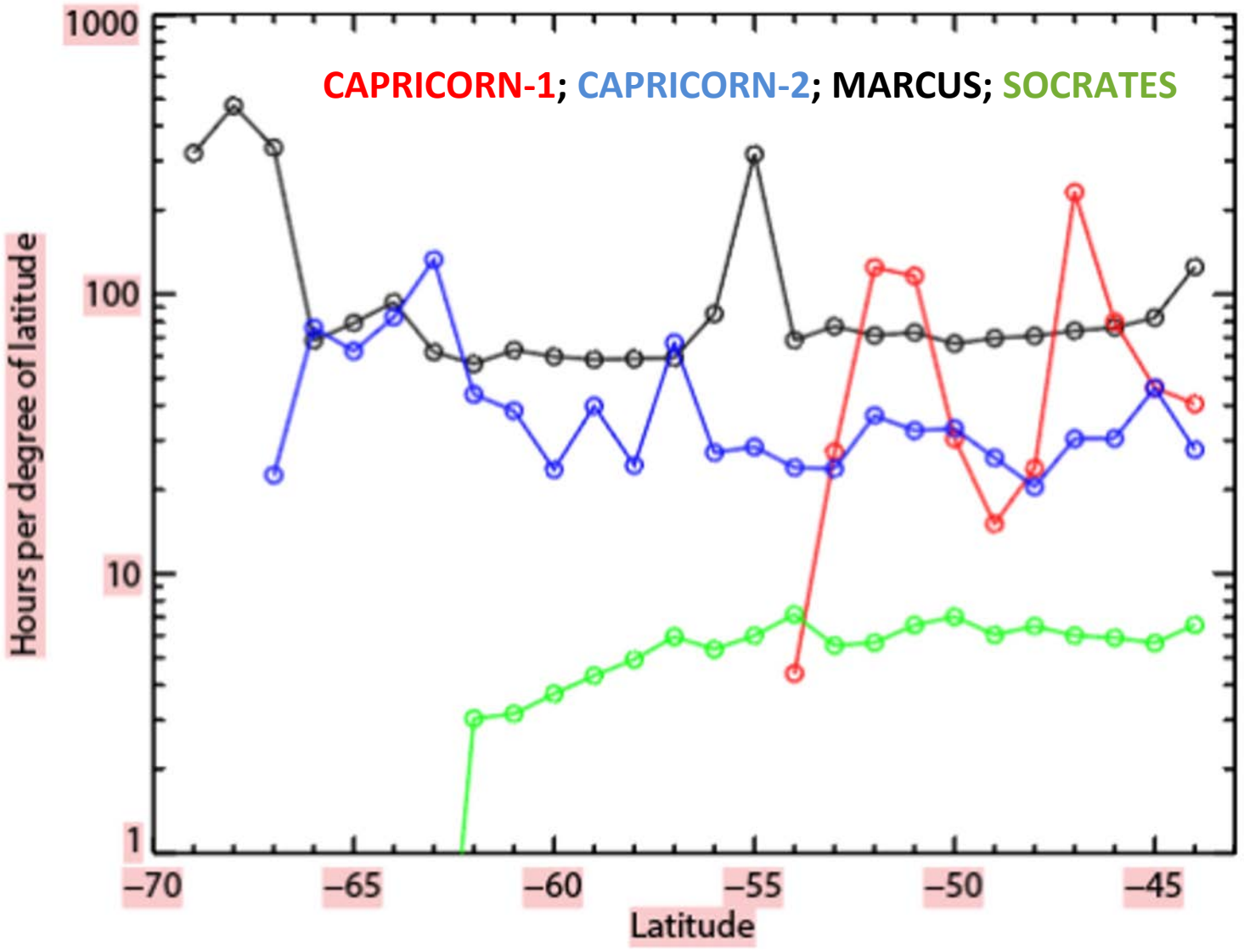
Month of Year

Synergy between projects



McFarquhar et al. 2021, BAMS

Campaign Advantages

MICRE: Long seasonal sample

CAPRICORN: More detailed oceanographic, aerosols & surface flux measurements

MARCUS: Seasonal cycles poleward of 60˚S

SOCRATES: Process studies and remote sensing evaluation

What was done to prepare for collaborations?

- March 2014 (Seattle, WA): Workshop on Clouds, Aerosols, Radiation and Air-Sea Interface of Southern Ocean: Establishing Directions for Future Research
  - 60 scientists (grad students, postdocs, senior researchers) from US and foreign universities and government labs attended
  - Identify state of knowledge over SO
  - Identify strategies for reducing uncertainties in global/regional models
  - Overview presentations and breakout sessions
  - Deliverable: White paper
  - Microsoft Word - SOCRATES_white_paper_Final_Sep29_2014.docx (uw.edu)

What was done to prepare for collaborations?

- July 2014: Summary of SOCRATES plans presented to US CLIVAR
- October 2014: Visits to funding agencies including NSF, DOE and NASA to inform of project (McFarquhar & Bretherton)
- Similar visits took place in Australia
- Proposals written to agencies
  - Key was that proposal to each agency had to be “stand-alone” and not rely on contributions from other agencies
  - Synergy came from fact that all projects ended up being together, but that could not be used to sell the projects

How were differences in sampling methods and model currencies coordinated?

- Each project was a separate effort, and no formal steering committee coordinated the projects
- Many investigators served on advisory board of several of the projects and there was much collaboration between campaigns.
- There was one integrated planning workshop (2017 Boulder) for all projects where participants discussed optimal ways to work together

How was analysis synthesized among campaigns?

- Two integrated data workshops were held after completion of projects (2018 Boulder, 2019 Hobart)
- Data have been freely exchanged among participants, and a special collection of papers in the *Journal of Geophysical Research/ Geophysical Research Letters* covering all four projects has been established and currently contains 39 papers
- Many investigators are using observations from several of the campaigns in their study
  - E.g., NSF-funded investigators must use SOCRATES data in their funded projects but can also use results from other campaigns
  - Many authors combined data and model simulations

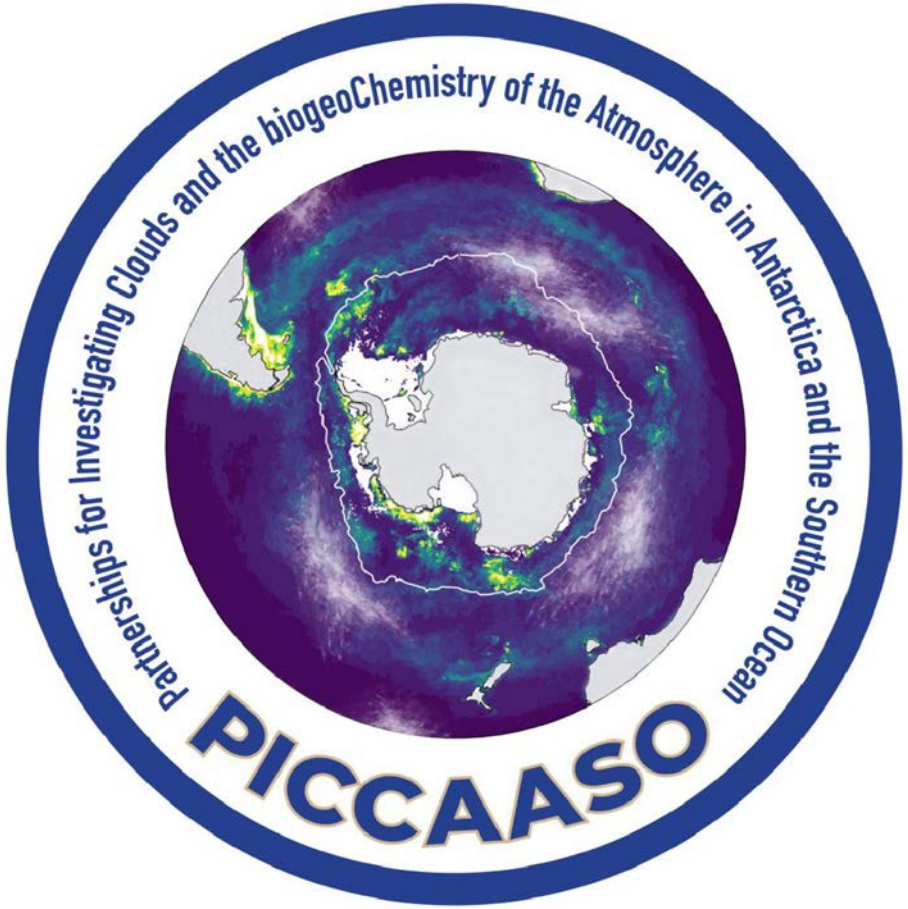
Lessons Learned

- Coordination is difficult from funding perspective, but with dedicated science team this can be overcome
- Collaboration was essential to maximize projects impacts
  - Overflights of NSF G-V over both R/V Investigator and ARM Ground site
- Synergistically data provide best available measurements of BL and Free troposphere structure, together with vertical distribution of liquid and mixed-phase clouds over cold waters of SO where SLW and mixed-phase clouds frequent

Lessons Learned

- Future measurements needed over SO and with data we collected we learned what should be done in future cmpaigns
  - Lagrangian rather than Eulerian Experiment (track air masses coming off Antarctic ice sheet to see evolution of aerosols, CCN, cloud & precipitation properties)
  - Observations closer to Antarctic (southern of 62^{o}S to examine where errors in model are largest)
  - More comprehensive data on aerosol composition
  - Shipborne measurements less contaminated by ship stack

Future Efforts

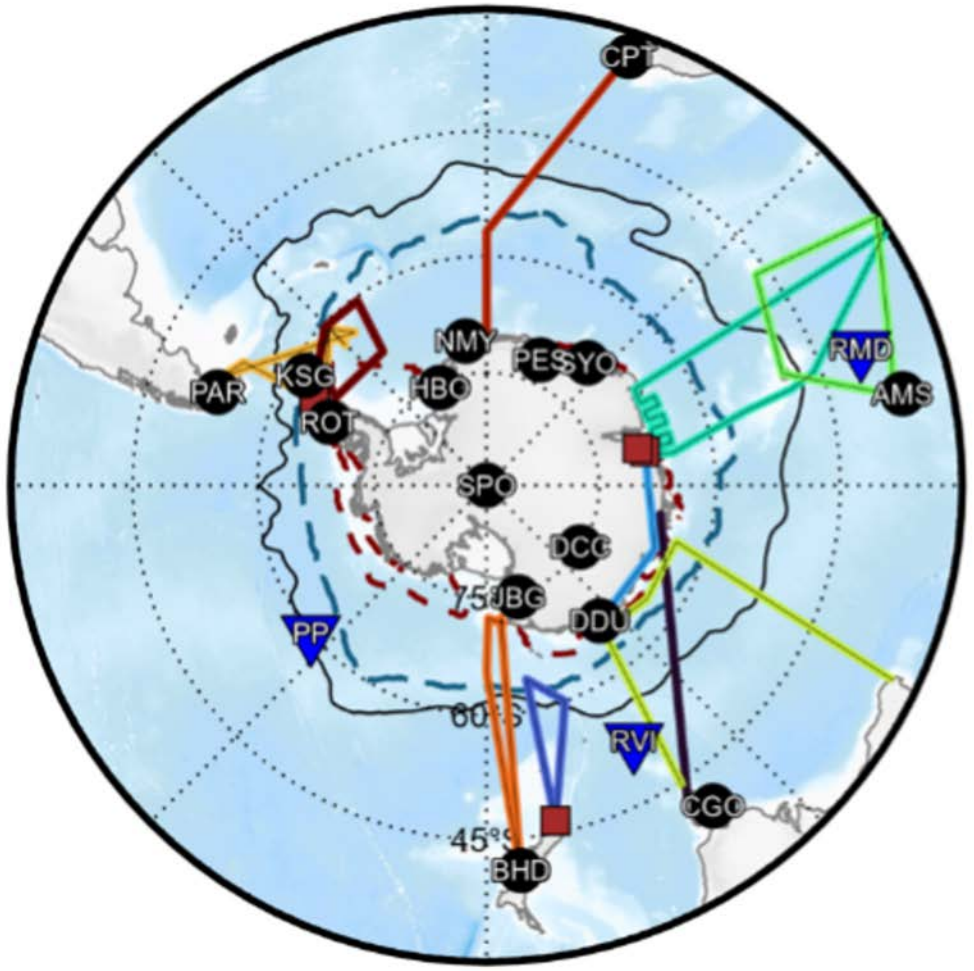


- PICCAASO's mission is to amplify scientific discovery of the many upcoming projects occurring in the Antarctic and Southern Ocean by facilitating global collaboration & coordination.

- PICCASSO's specific focus is on scientific questions surrounding link between biogeochemistry & atmospheric processes

- Paper describing PICASSO published in Elementa, Mallett et al. Untangling the influence of Antarctic and Southern Ocean life on clouds

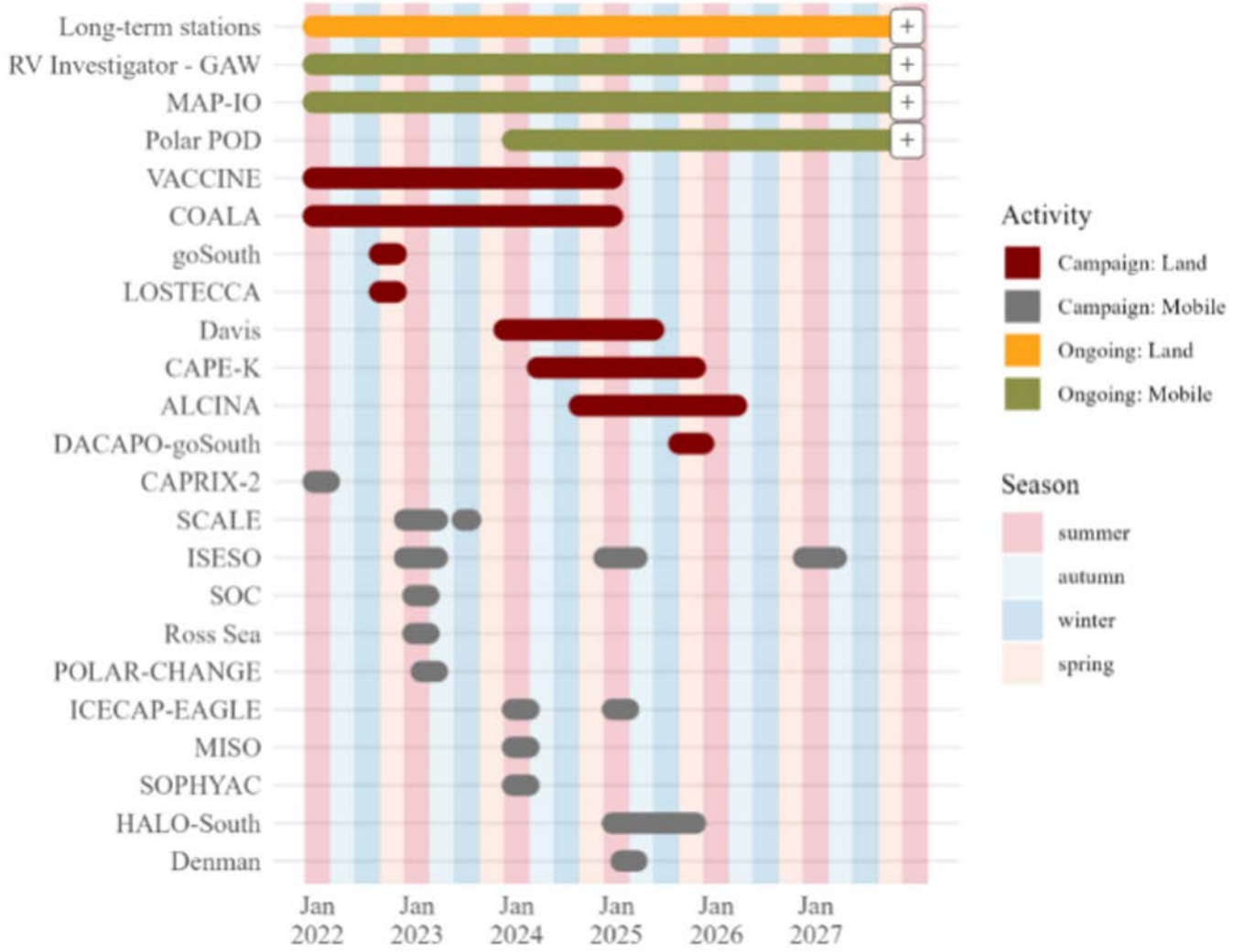
Future Efforts



- PICASSO sponsors regular online meetings and meetings of opportunities at international conferences (e.g., at recent IUGG/IAMAS Conference in Berlin)

- Denman Voyage
- HALO-South
- ICECAP-EAGLE
- ISESO
- MAP-IO/SOPHYAC
- MISO
- POLAR-CHANGE
- Ross Sea Voyage
- SCALE
- SOC

Future Efforts



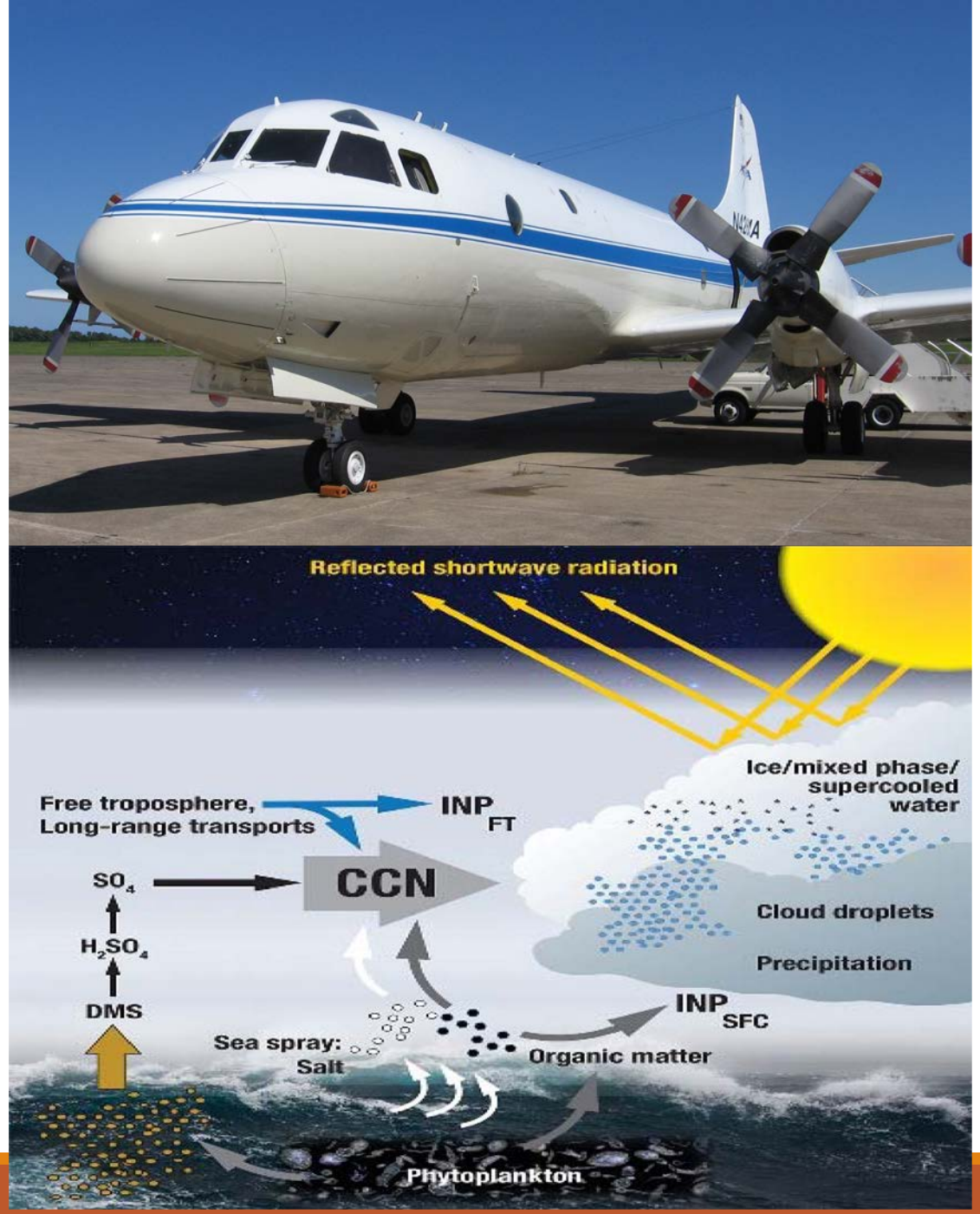
Helpful that all are aware of opportunities from timing/location of other projects when planning other projects

ARISTOTLE: Aerosols, Radiation, cloud, SouThern Ocean sysTems Lagrangian Experiment

Greg McFarquhar[1,2], Jay Mace[3] and Christina McCluskey[4]

[1]Cooperative Institute for Severe and High Impact Weather Research & Operations, University of Oklahoma
[2]School of Meteorology, University of Oklahoma
[3]University of Utah
[4]National Center for Atmospheric Research

Upcoming Southern Ocean Initiatives Business Meeting
13 July, IUGG 2023 Berlin

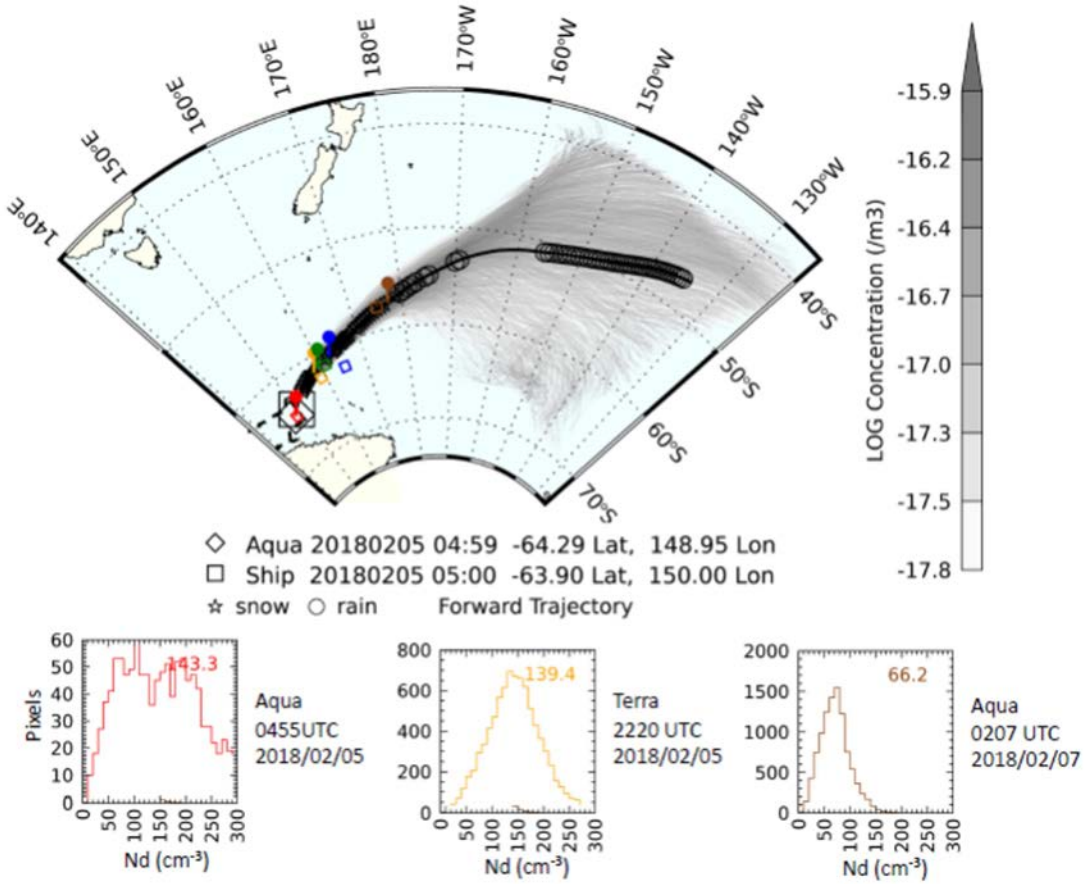


ARISTOTLE studies aerosol-cloud-precipitation interactions in pristine low clouds over the Antarctic, Marginal Ice Zone (MIZ) and Southern Ocean (SO) from process-oriented perspective in order to resolve prominent Earth System Model (ESM) biases south of 62°S

Funding requested from NASA EVS4 program

If selected for funding, there will be a future ROSES call for participation in campaign

ARISTOTLE Overview



Tracers released at 1 km for 120 h, with colored boxes showing where MODIS Level-II Nd data are extracted

Two 6-week deployment of NASA P-3, from McMurdo Station (Christchurch 2nd option)

- **Nov-Dec 2025/2026 to sample summer onset of ocean biology & aerosol**
- **Lagrangian framework to sample air masses coming off Antarctic ice sheet to observe coevolution of aerosols, CCN, clouds, precipitation & dynamics**
- **Investigate how aerosols & dynamics modulate cloud properties & precipitation, and hence radiation**

ARISTOTLE Science Themes

1. Aerosol formation/growth processes

1. How aerosol/dynamics modulate gradients in cloud/precipitation properties

1. Evaluation of satellite remote sensing of ocean biogeochemical, aerosol & clouds

1. Address unconstrained model representations of ocean-ice-atmosphere interactions