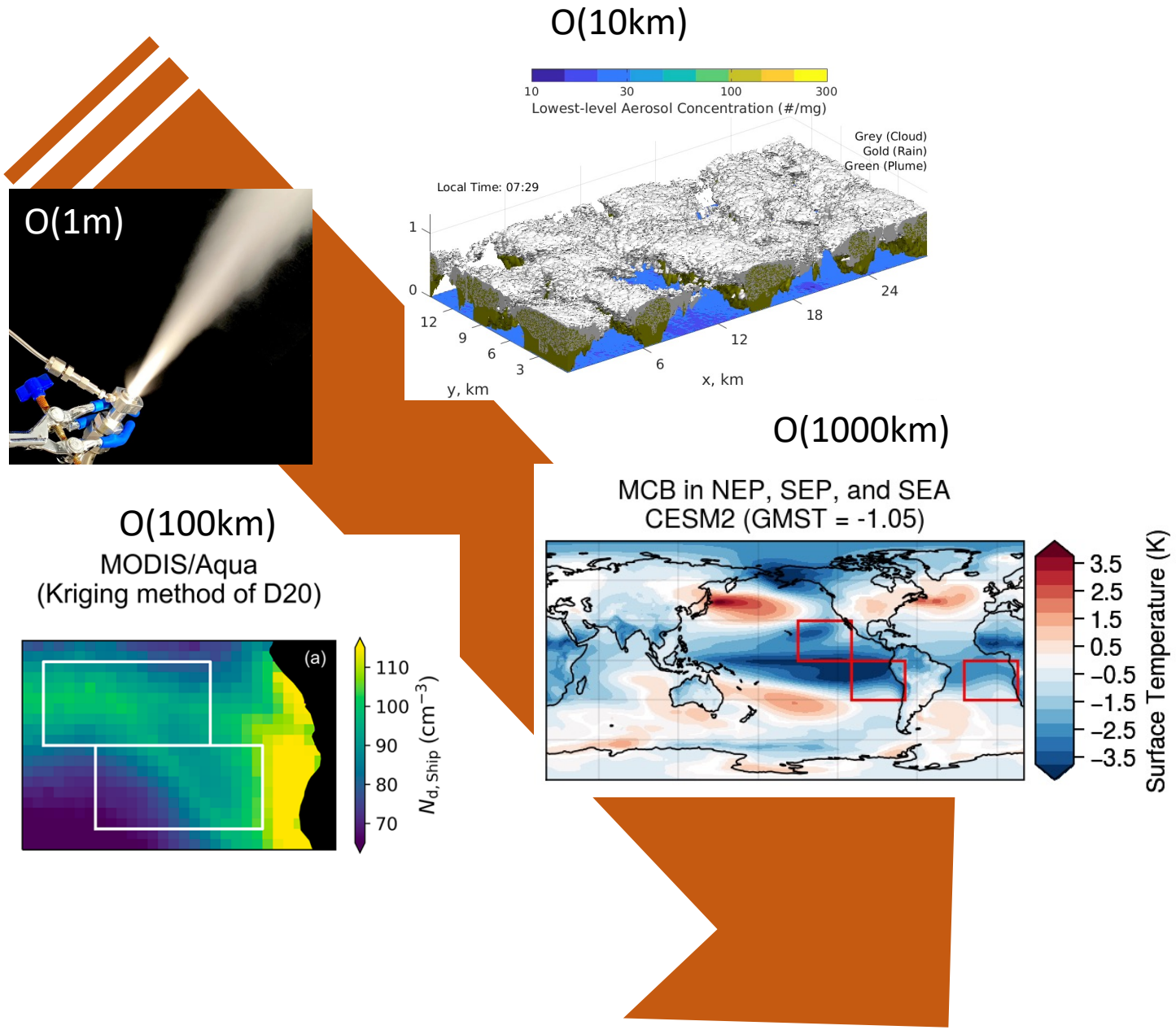
Physical science questions in MCB

Processes:

How do we deliver the right size of aerosols?
How much can we brighten clouds?
Which clouds can we brighten?

Impacts:

How much cooling would would brightening clouds cause?
What are the large-scale climate responses to MCB?
What are the regional impacts of MCB?



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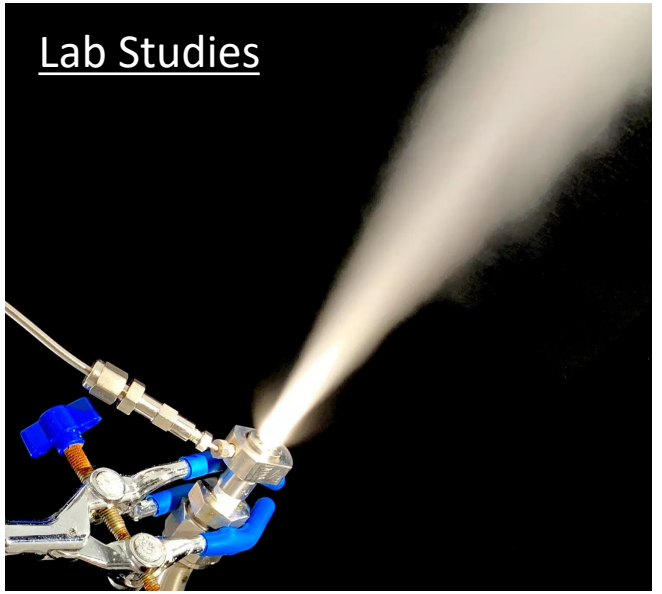
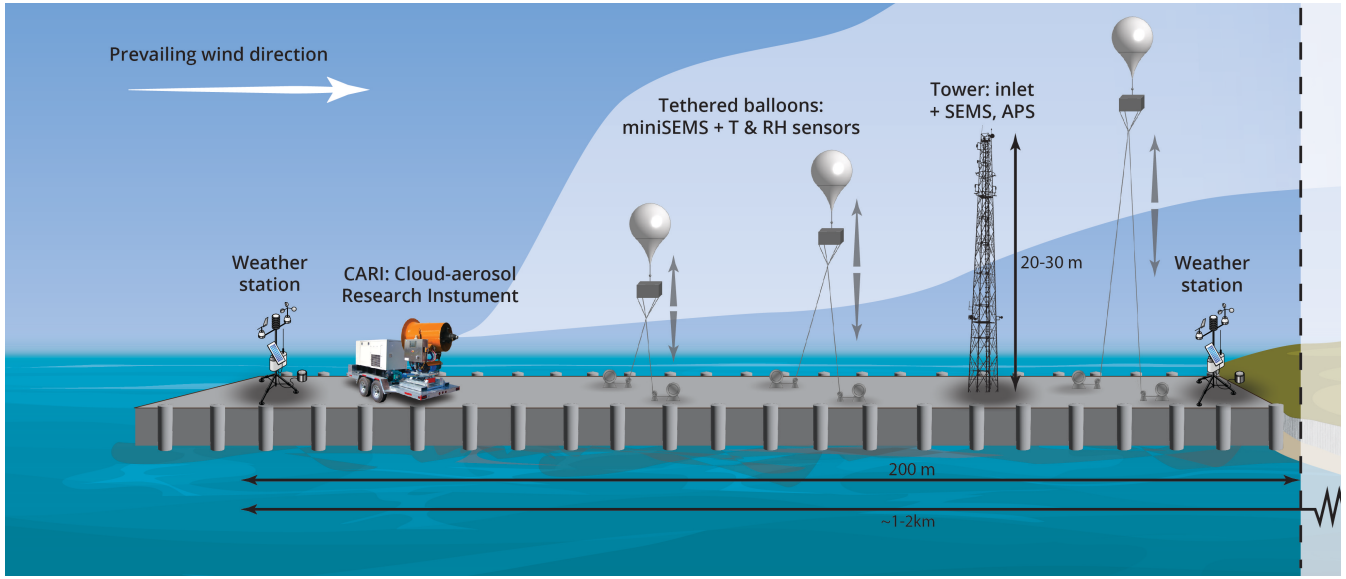


Outdoor studies



Physical science questions in MCB

Significant uncertainties in aerosol/cloud processes and their representation in climate models

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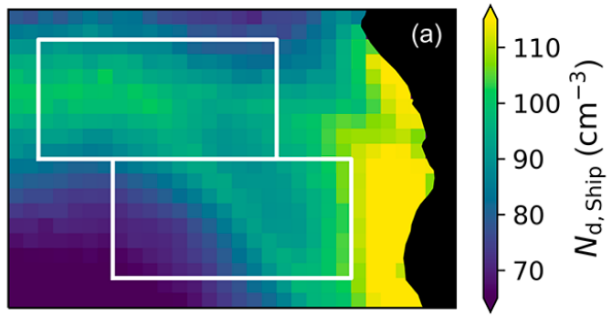
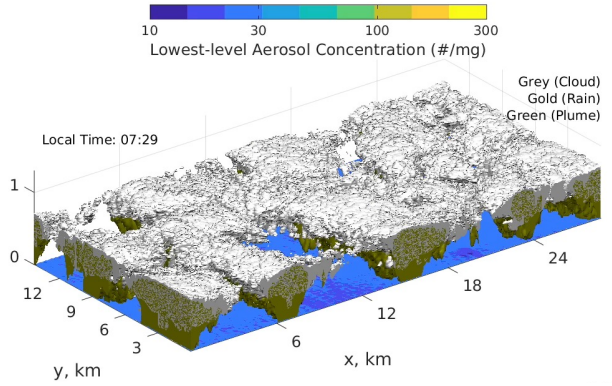
Satellite analysis

MODIS/Aqua
(Kriging method of D20)

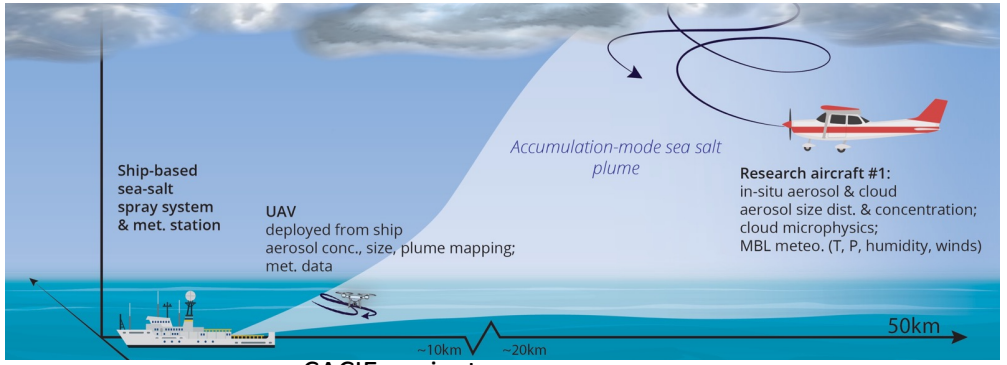


Diamond et al., 2020

Cloud resolving modeling e.g., Large Eddy Simulations



Observational studies



CACIE project

Physical science questions in MCB

Climate models are used to assess:

- **Global-scale MCB forcing**
- **Climate feedbacks**
- **Large scale circulation response**

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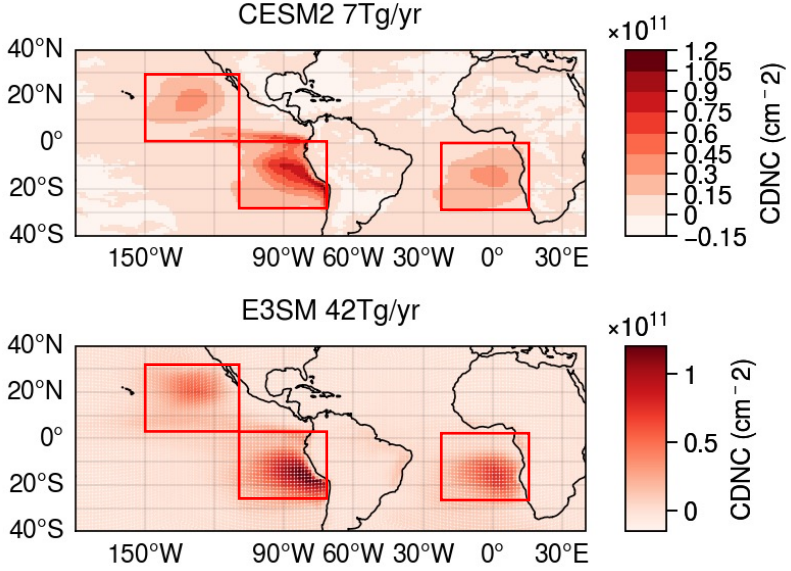
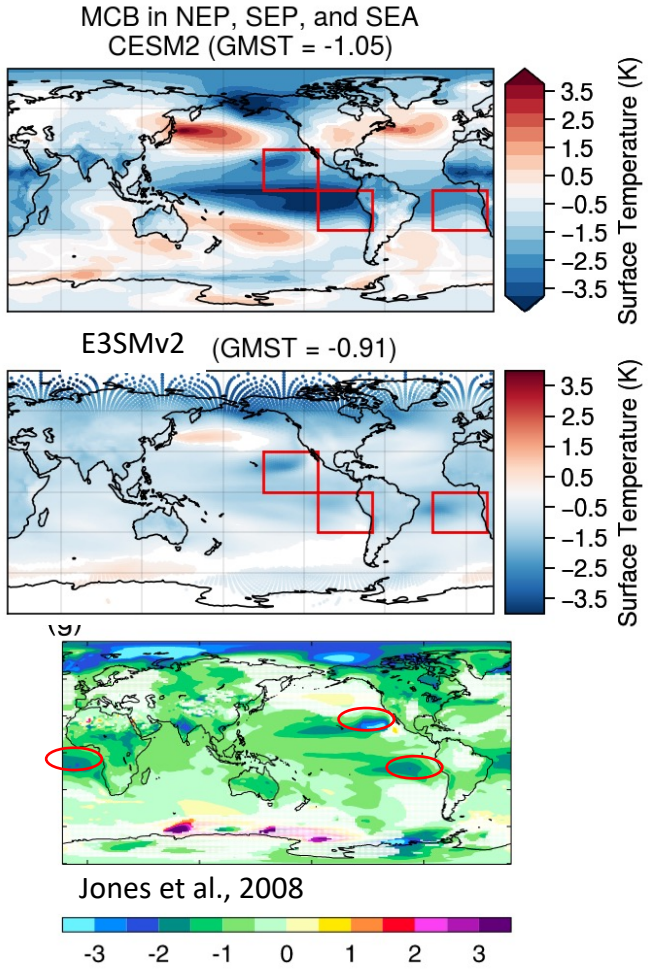
Cloud droplet number enhancement due to sea salt emissions



- MCB forcing regions (SEA, SEP, NEP)

Temperature impact of MCB forcing in three Global Climate Models



Jones et al., 2008

Physical science questions in MCB

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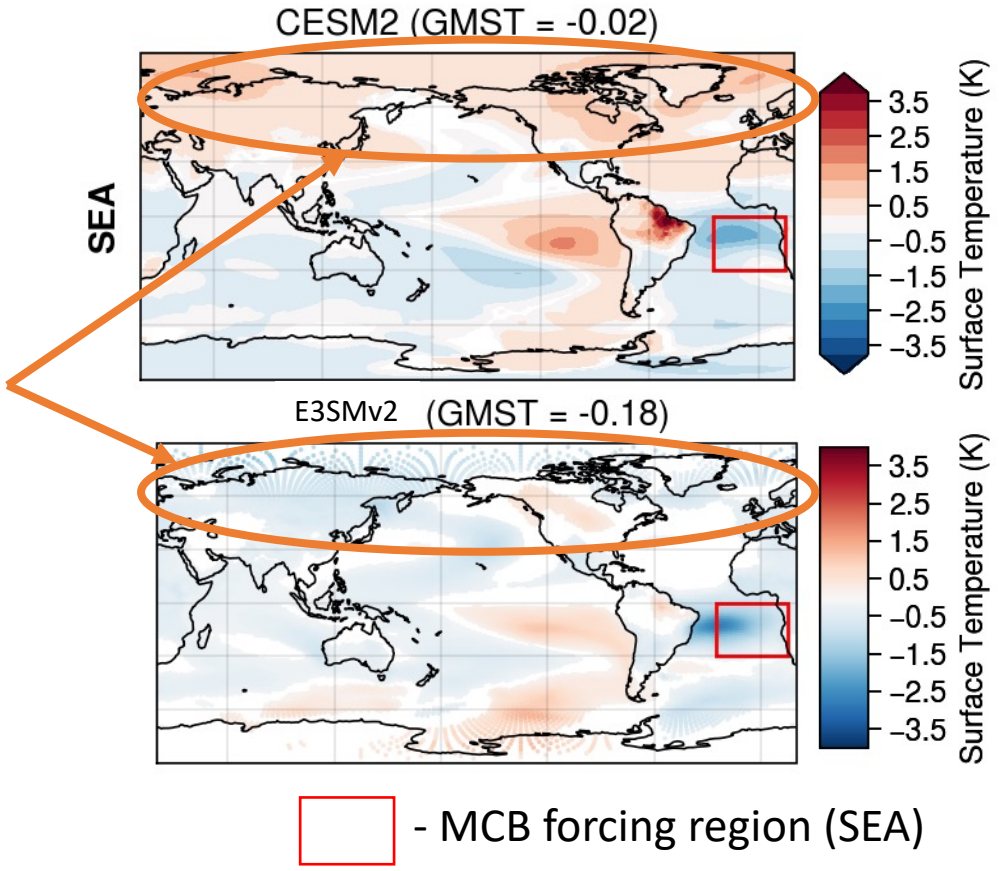
Even with two related climate models, we see notable regional uncertainties

Different signed northern hemisphere responses



Physical science questions in MCB

MCB effects on e.g., hydroclimate, marine ecosystems, and atmospheric chemistry

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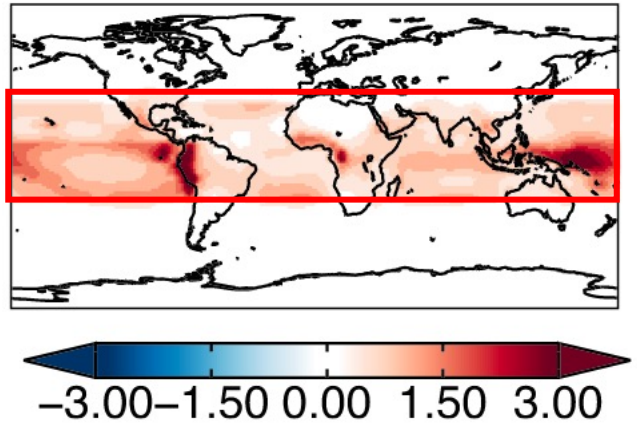
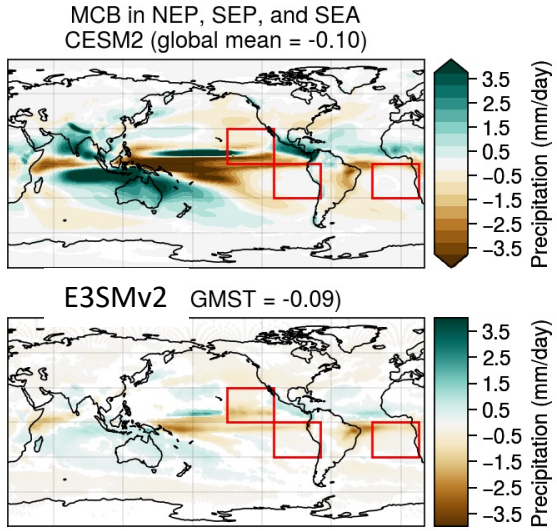
Tropospheric Chlorine increase due to MCB
Horowitz et al., 2019



Precipitation impact of MCB forcing in two Global Climate Models



- MCB forcing regions

Supplementary slides

Contact

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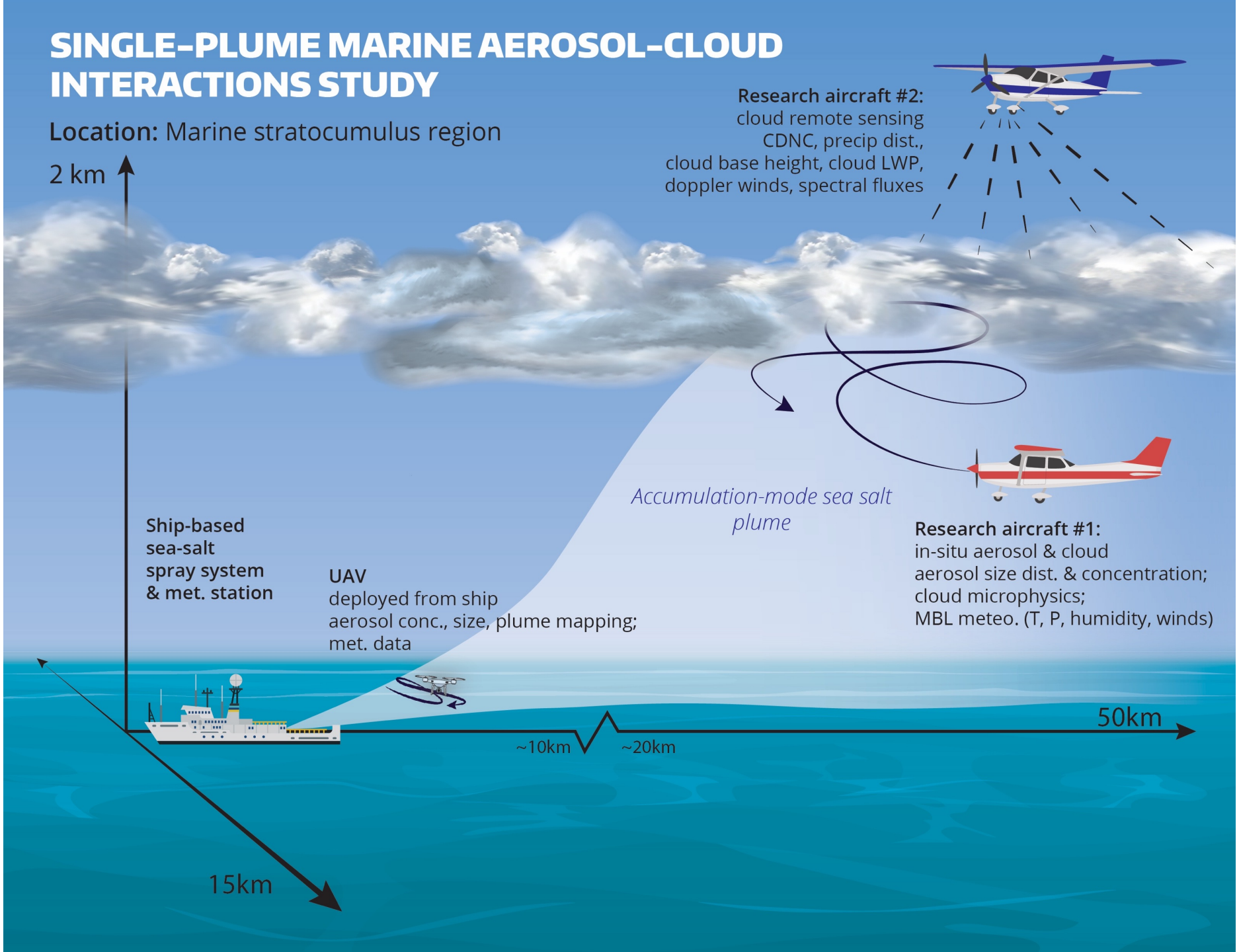
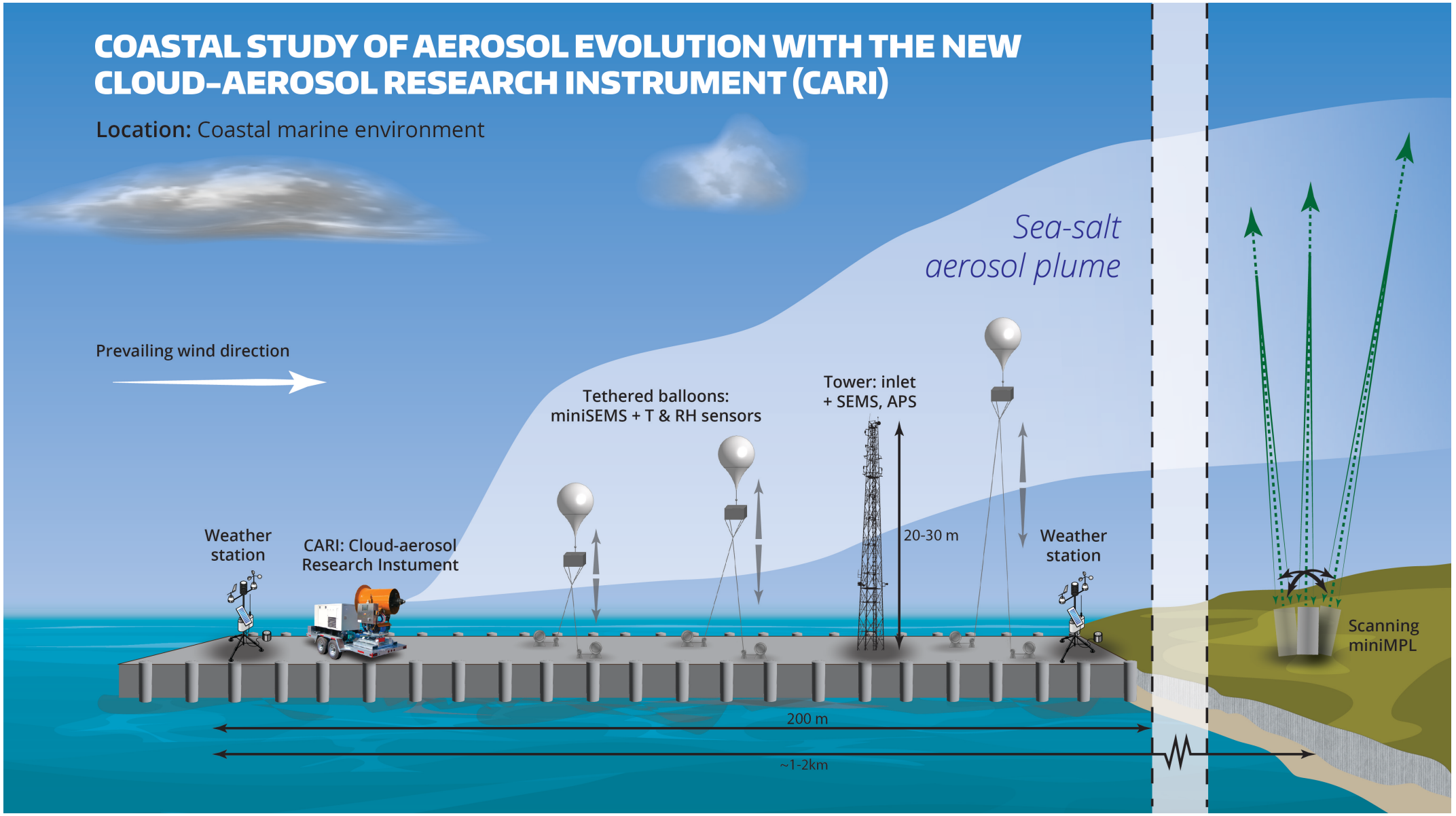
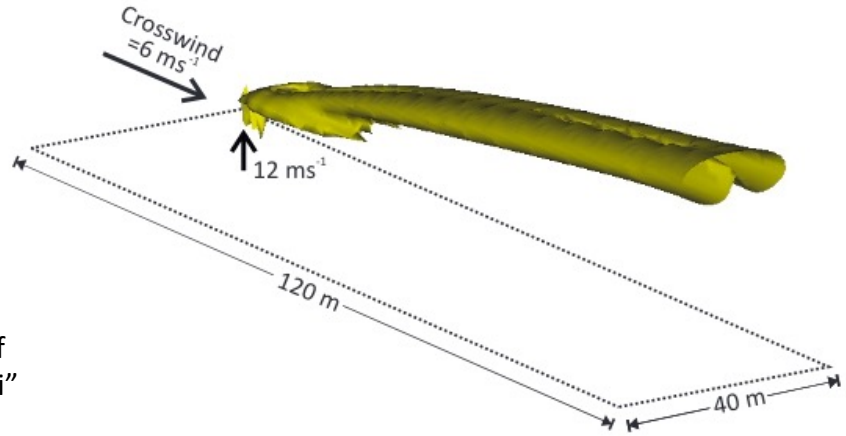
  - hhirasawa@uvic.ca
- Colleagues on CESM2 and E3SMv2 MCB modeling project:
  - Hansi Singh and Dipti Hingmire, University of Victoria
  - Mingxuan Wu and Hailong Wang, PNNL
  - Philip Rasch, Robert Wood, Sarah Doherty, and Kyoungock Choi, University of Washington
  - Linda Hedges, SilverLining


SINGLE-PLUME MARINE AEROSOL-CLOUD INTERACTIONS STUDY
Location: Marine stratocumulus region
2 km
Research aircraft #2:
cloud remote sensing
CDNC, precip dist.,
cloud base height, cloud LWP,
doppler winds, spectral fluxes
Accumulation-mode sea salt plume
Ship-based
sea-salt
spray system
& met. station
UAV
deployed from ship
aerosol conc., size, plume mapping;
met. data
Research aircraft #1:
in-situ aerosol & cloud
aerosol size dist. & concentration;
cloud microphysics;
MBL meteo. (T, P, humidity, winds)
50km
~10km
~20km
15km

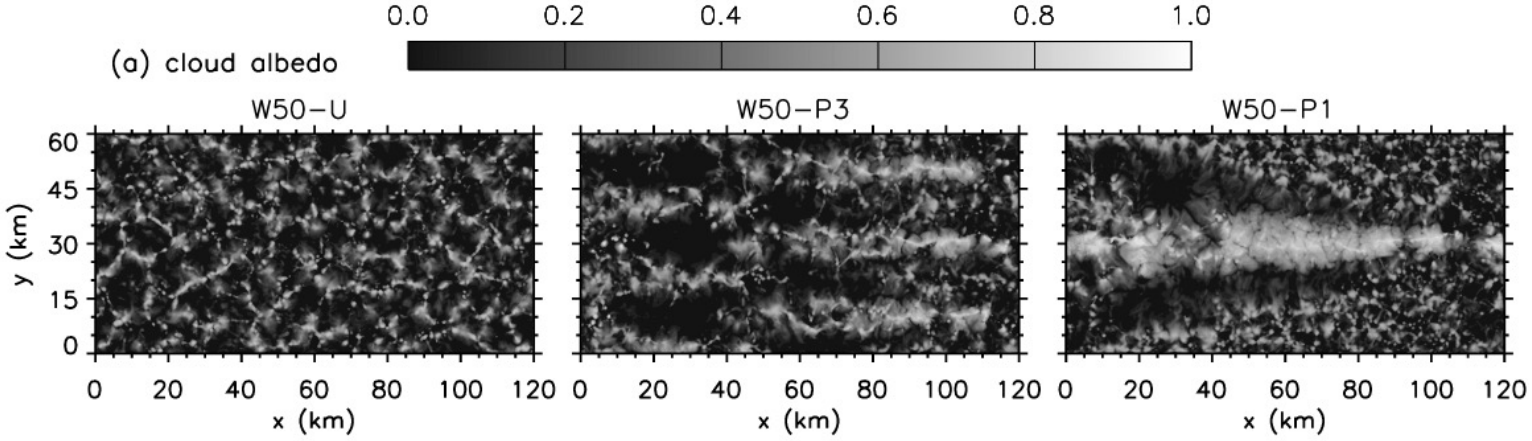

COASTAL STUDY OF AEROSOL EVOLUTION WITH THE NEW CLOUD–AEROSOL RESEARCH INSTRUMENT (CARI)
Location: Coastal marine environment
Sea-salt aerosol plume
Prevailing wind direction
Tethered balloons: miniSEMS + T & RH sensors
Tower: inlet + SEMS, APS
20-30 m
Weather station
CARI: Cloud-aerosol Research Instument
Weather station
Scanning miniMPL
200 m
~1-2km

Cloud resolving modeling

Typical aerosol plume in LES from Stuart et al., Atmos. Chem. Phys., 13, 10385–10396, 2013

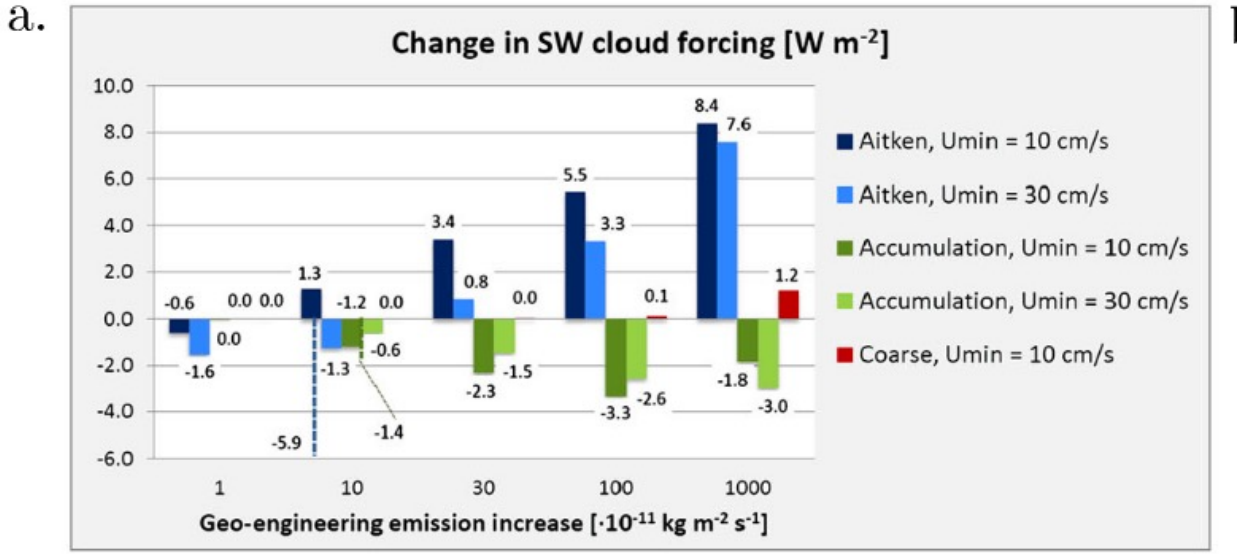


Cloud resolving WRF cloud albedo response to different MCB injection methods from: "Manipulating marine stratocumulus cloud amount and albedo: a process-modelling study of aerosol-cloud-precipitation interactions in response to injection of cloud condensation nuclei" Wang et al., 2011. Atmos. Chem. Phys.,

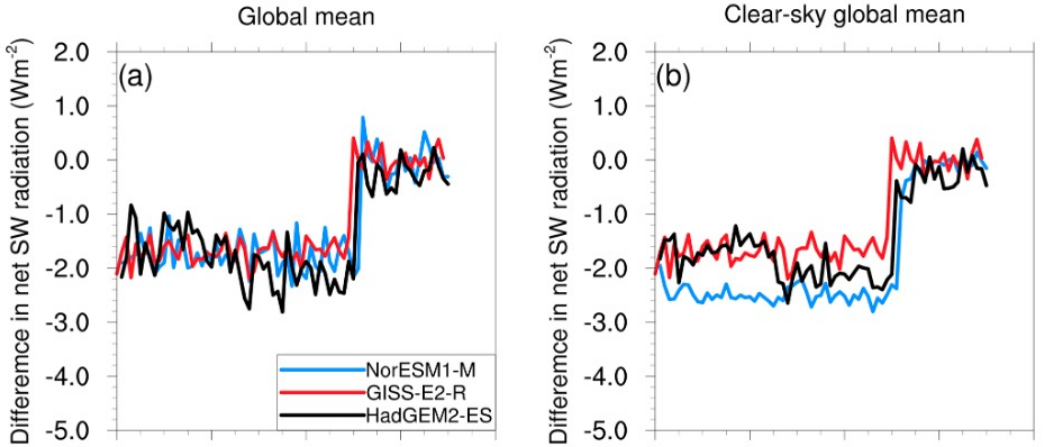


Global model forcing

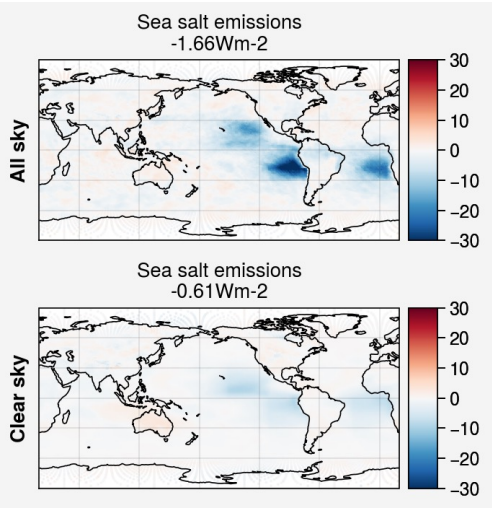
Shortwave cloud forcing due to tropical sea salt aerosol emissions from "The sign of the radiative forcing from marine cloud brightening depends on both particle size and injection amount" Alterskjær and Kristjánsson, 2012



All and clearsky radiative forcing due to tropical sea salt aerosol emissions in three models from "Marine cloud brightening – as effective without clouds" Ahlm et al., 2017

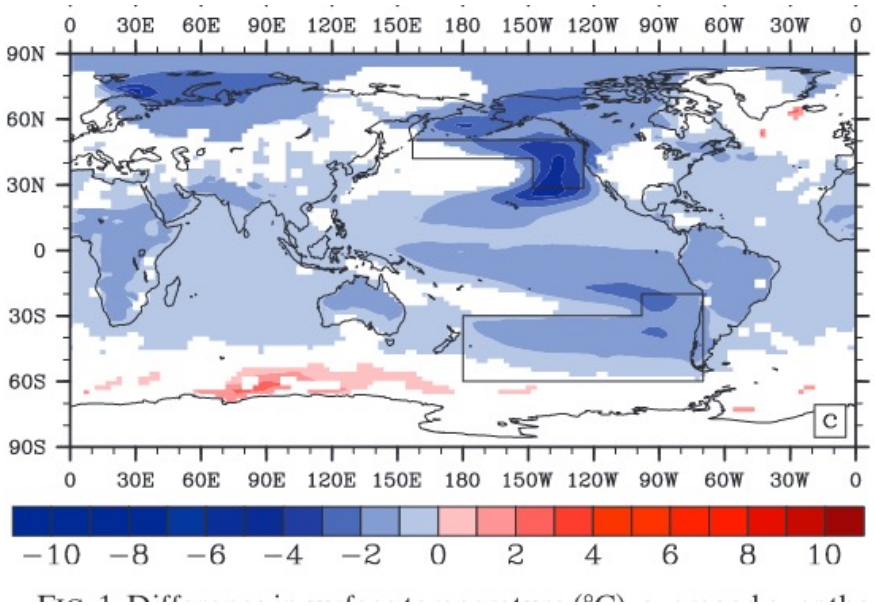


All and clear sky E3SMv2 forcing at 42Tg/yr emissions

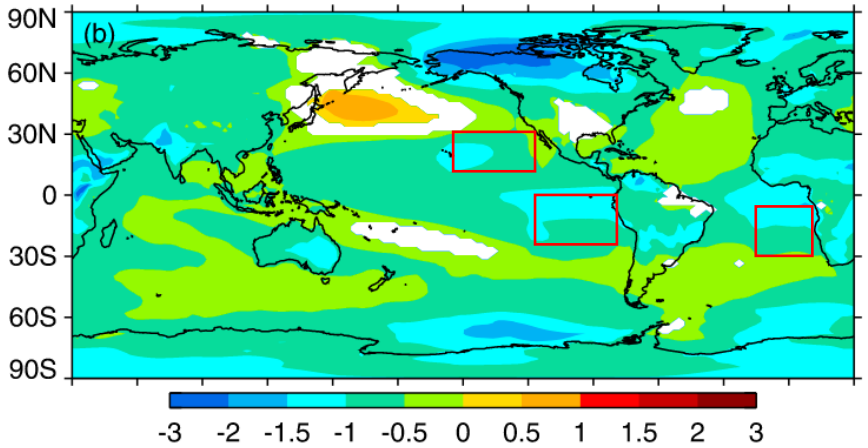


Global Model Responses

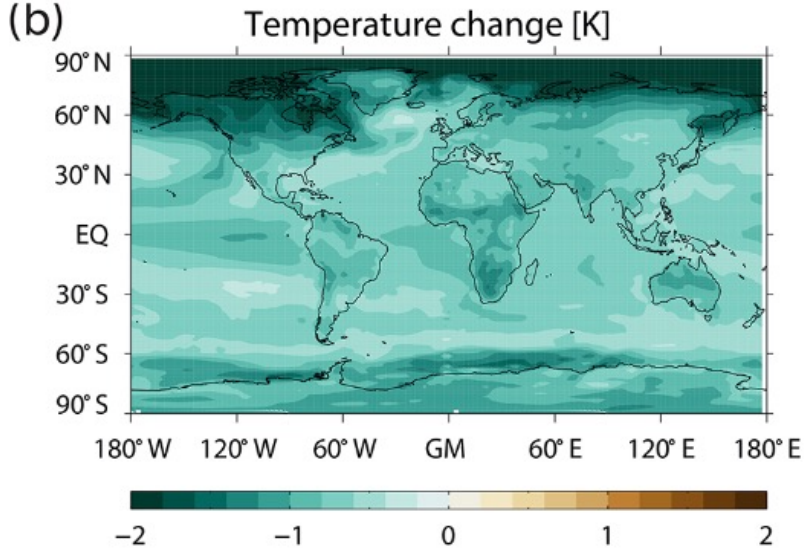
Temperature response to MCB in GFDL-CM2 from "Investigation of the Surface and Circulation Impacts of Cloud-Brightening Geoengineering" Baughmann et al., 2012. J. Clim.



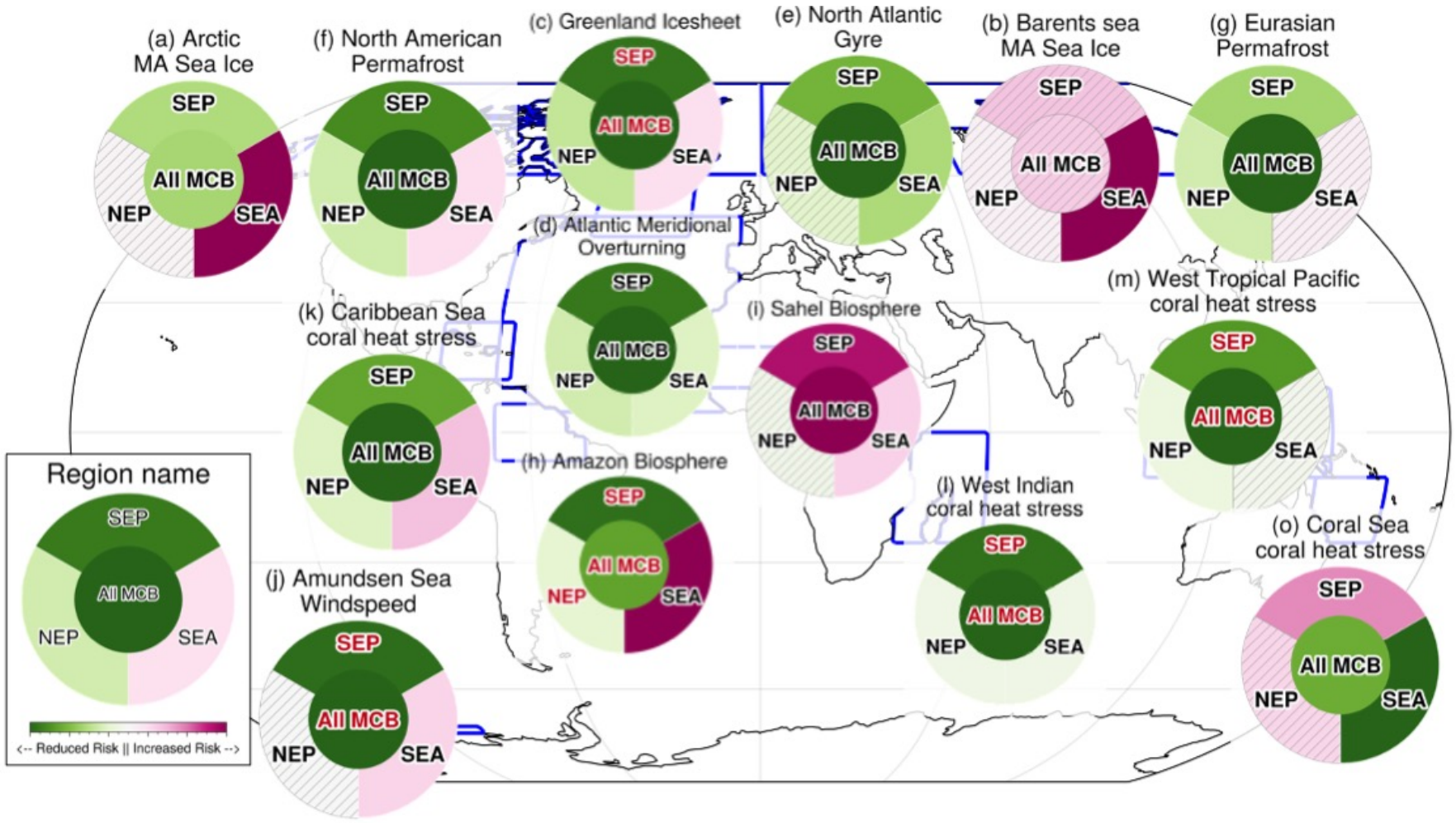
Temperature response to MCB in GFDL-CM2 from "Nonlinear climate response to regional brightening of tropical marine stratocumulus" Hill and Ming, 2012. GRL



Multimodel ensemble mean temperature response from G4cdnc simulations (global forcing) from "Response to marine cloud brightening in a multi-model ensemble" Stjern et al., 2018



MCB effect on tipping elements



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