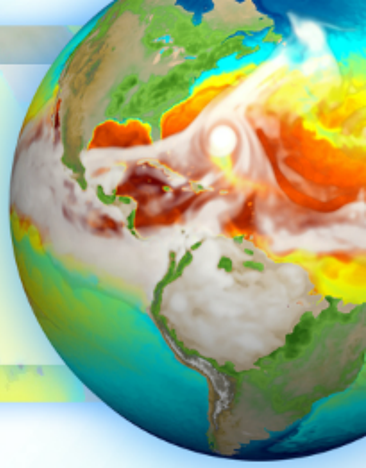

ESMD/E3SM PI MEETING 2020 FALL

E3SM's Skill at Simulating the Drivers of Surface Melt on GrIS

Wenshan Wang[1], Charles S. Zender[1], & Qi Tang[2]

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E3SM Energy Exascale Earth System Model

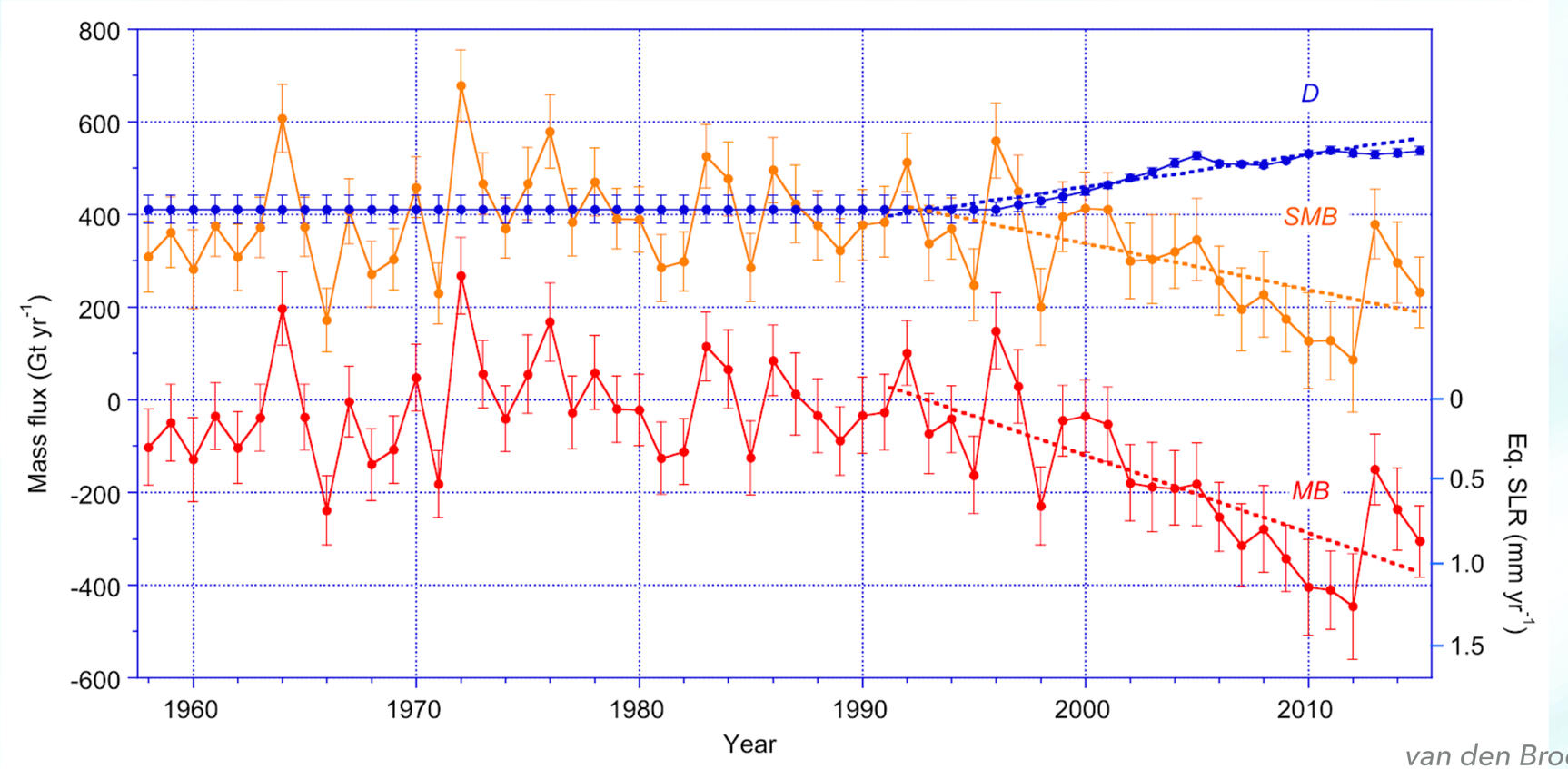
UCI Department of Earth System Science

Lawrence Livermore National Laboratory

U.S. Department of Energy

Profound Climate Effects of GrL Surface Melt

- Primary cryospheric source of sea-level rise *van den Broeke et. al., 2016*
- Possible cause of AMOC slowdown *Rahmstorf et. al., 2015*
  AMOC = the Atlantic meridional overturning circulation
- Leading contribution to TOTAL mass loss *Enderlin et. Al., 2014; van den Broeke et. al., 2016*



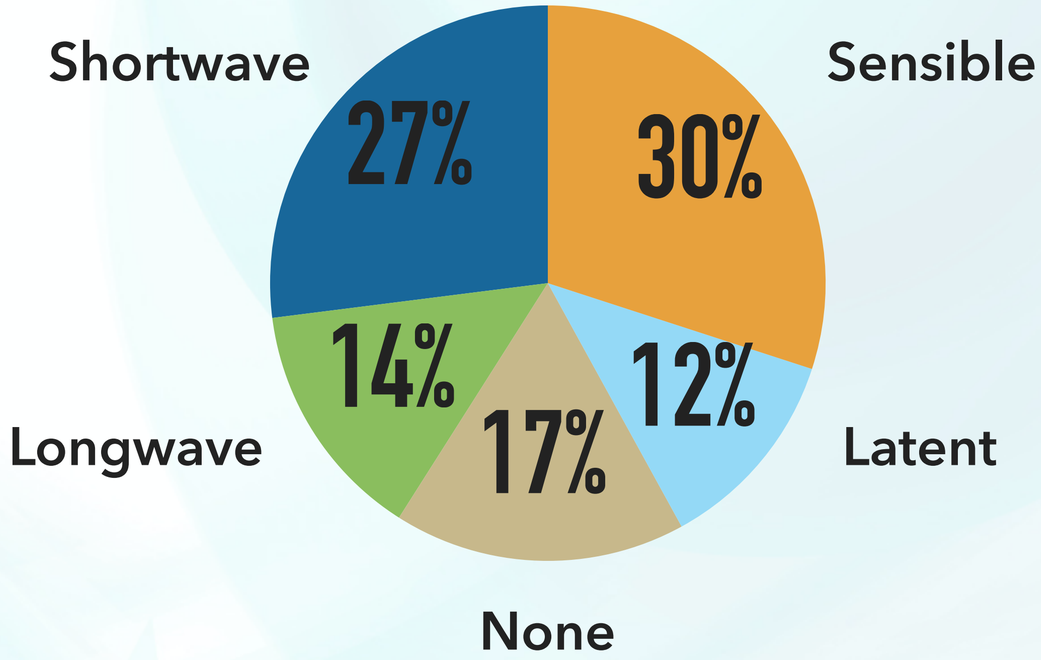
van den Broeke et. al., 2016

Two Questions:

- What are **the primary drivers** of surface melt on GrIS?
- How is **E3SM** doing at simulating these SEB components and meteorological conditions?

Q1: What are **the primary drivers** of surface melt on GrIS?

Sensible & Shortwave Heating Dominate Sub-Seasonal Melt



- Seasonal and diurnal timescales –> shortwave
- Sub-seasonal (i.e., daily, intradiurnal, or day-to-day) timescales

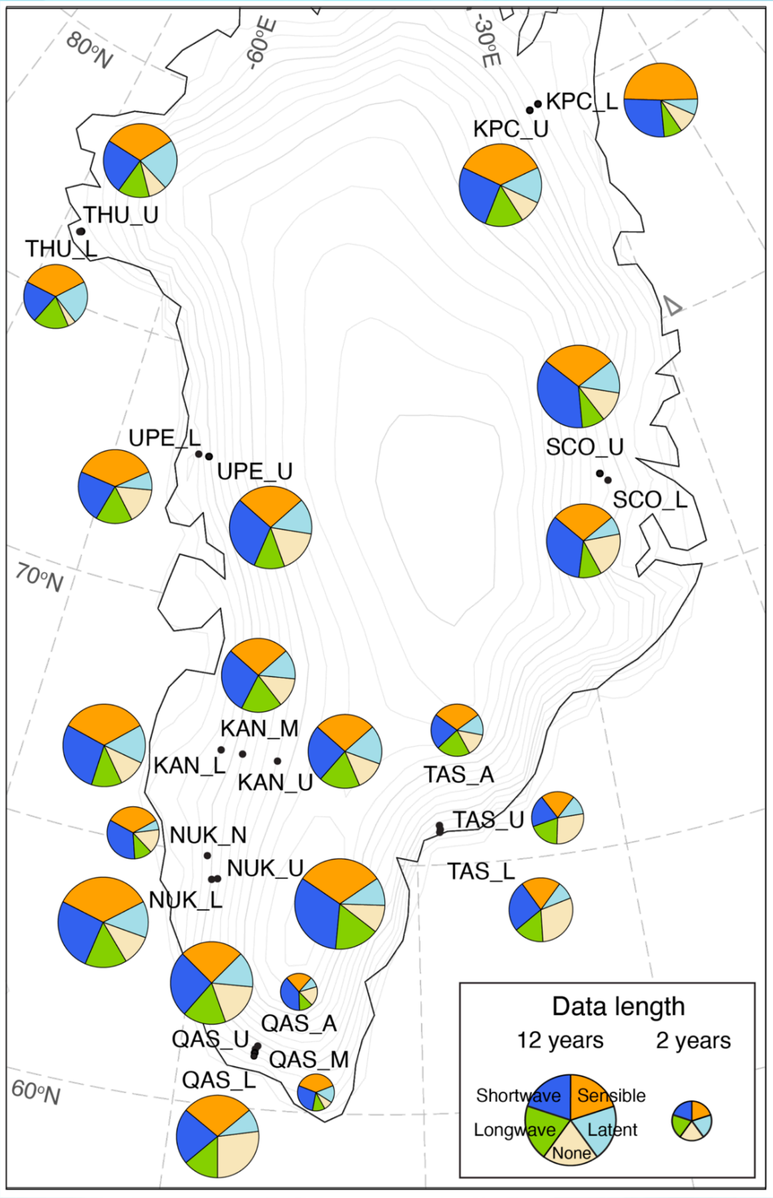


Fig. Fractions of surface melt daily variability driven by sensible heat, latent heat, net shortwave radiation, and net longwave radiation.
Pie areas = length of data available.

Q1: What are **the primary drivers** of surface melt on GrIS?

Sensible & Shortwave Heating Enhanced During Katabatic Winds

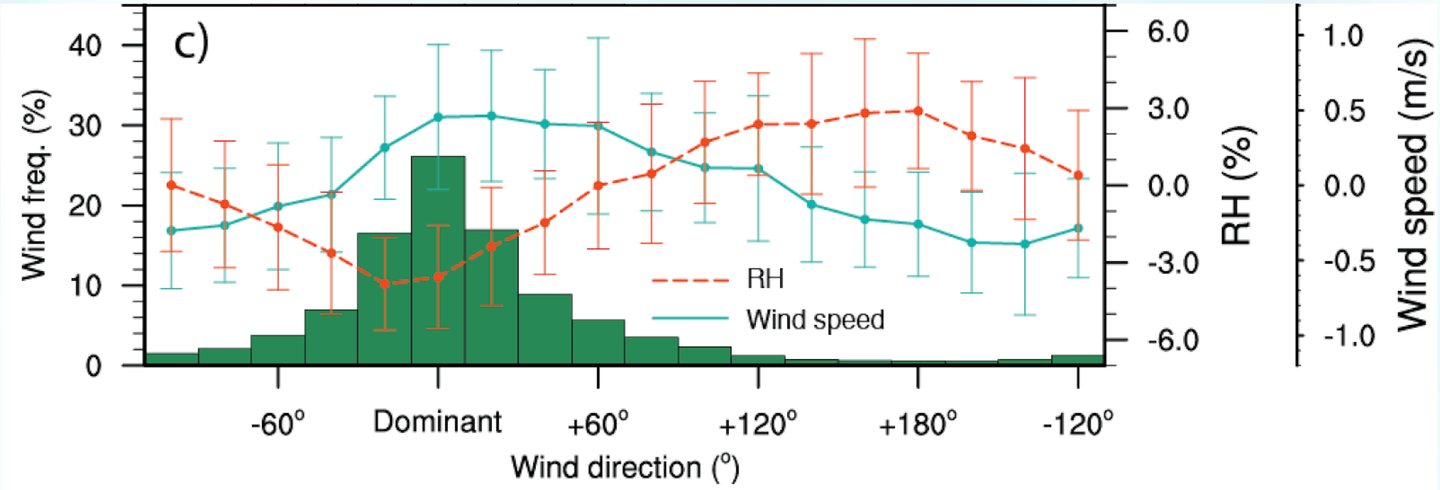
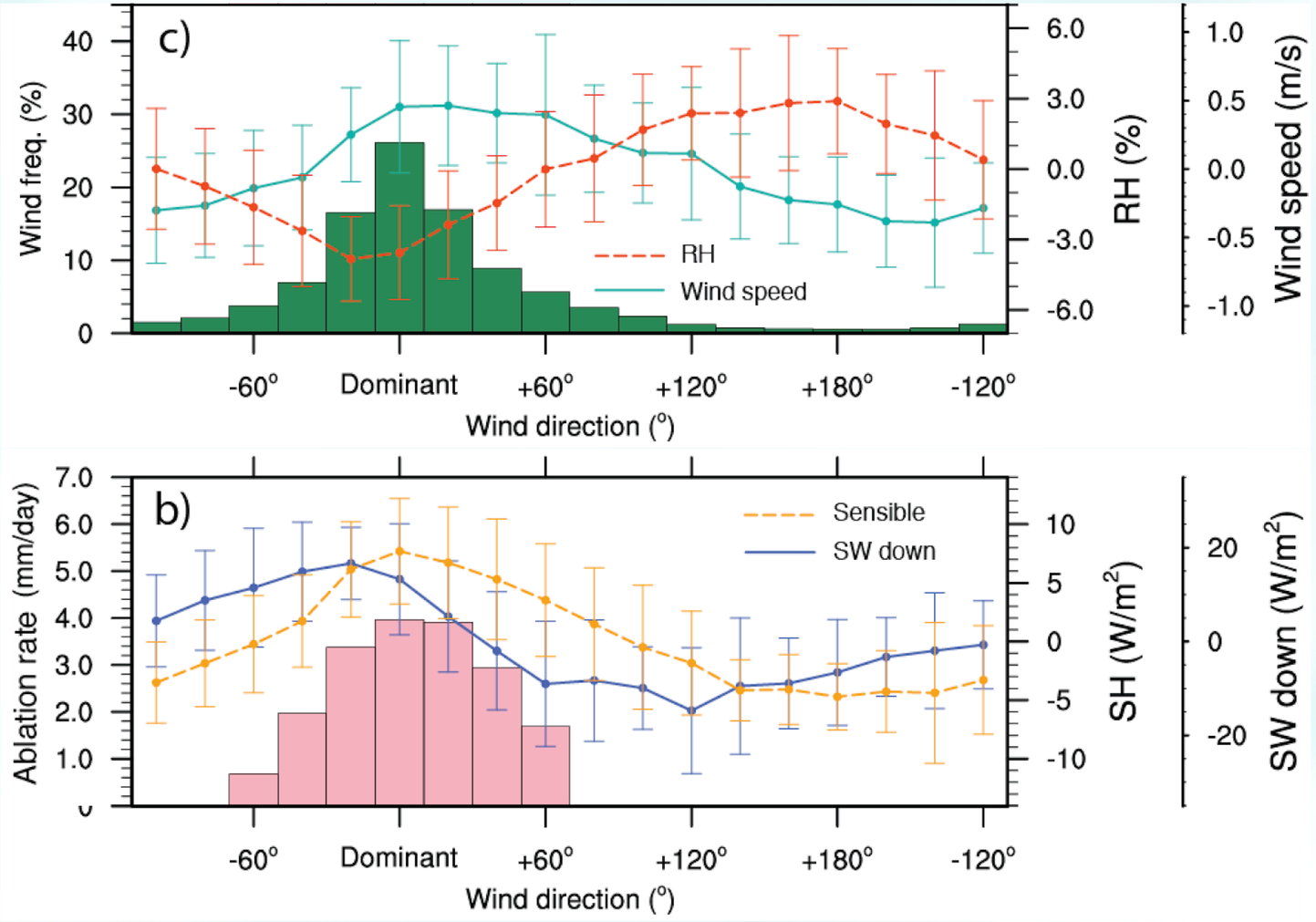


Fig. Averages of (top panel) wind frequency (green histogram), relative humidity (orange line), and wind speed (green line); (bottom panel) melt rate (pink histogram), sensible heat (yellow line), and shortwave downwelling radiation (blue line) binned by wind-from directions. Error bars represent plus/minus one standard deviation.

Q1: What are **the primary drivers** of surface melt on GrIS?

Sensible & Shortwave Heating Enhanced During Katabatic Winds



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Two Questions:

- What are **the primary drivers** of surface melt on GrIS?
  - Seasonal and diurnal: shortwave through solar zenith angle and albedo
  - Sub-seasonal: sensible & shortwave, enhanced during katabatic winds
- How is **E3SM** doing at simulating these SEB components and meteorological conditions?

Q2: How is **E3SM** doing at simulating these primary drivers?

E3SM Configuration

- EAM v1
- Temporal resolution of outputs: 3 hourly
- Time range: 2004-2013
- Compset: FC5AV1C-04P2
- Grid: conusx4v1 (~1°) with fine resolution patch over the CONUS
  - Regrid to match the ERA5 grid over Greenland (~0.25°)
- U&V nudging
  - ERA-Interim at 6 hours
  - Outside of the CONUS domain

See simulation details in Tang *et. al.*, 2019: gmd.copernicus.org/articles/12/2679/2019/

Q2: How is **E3SM** doing at simulating these primary drivers?

Skill: Spatial Pattern of Sensible Heat Driven Melt Is Good

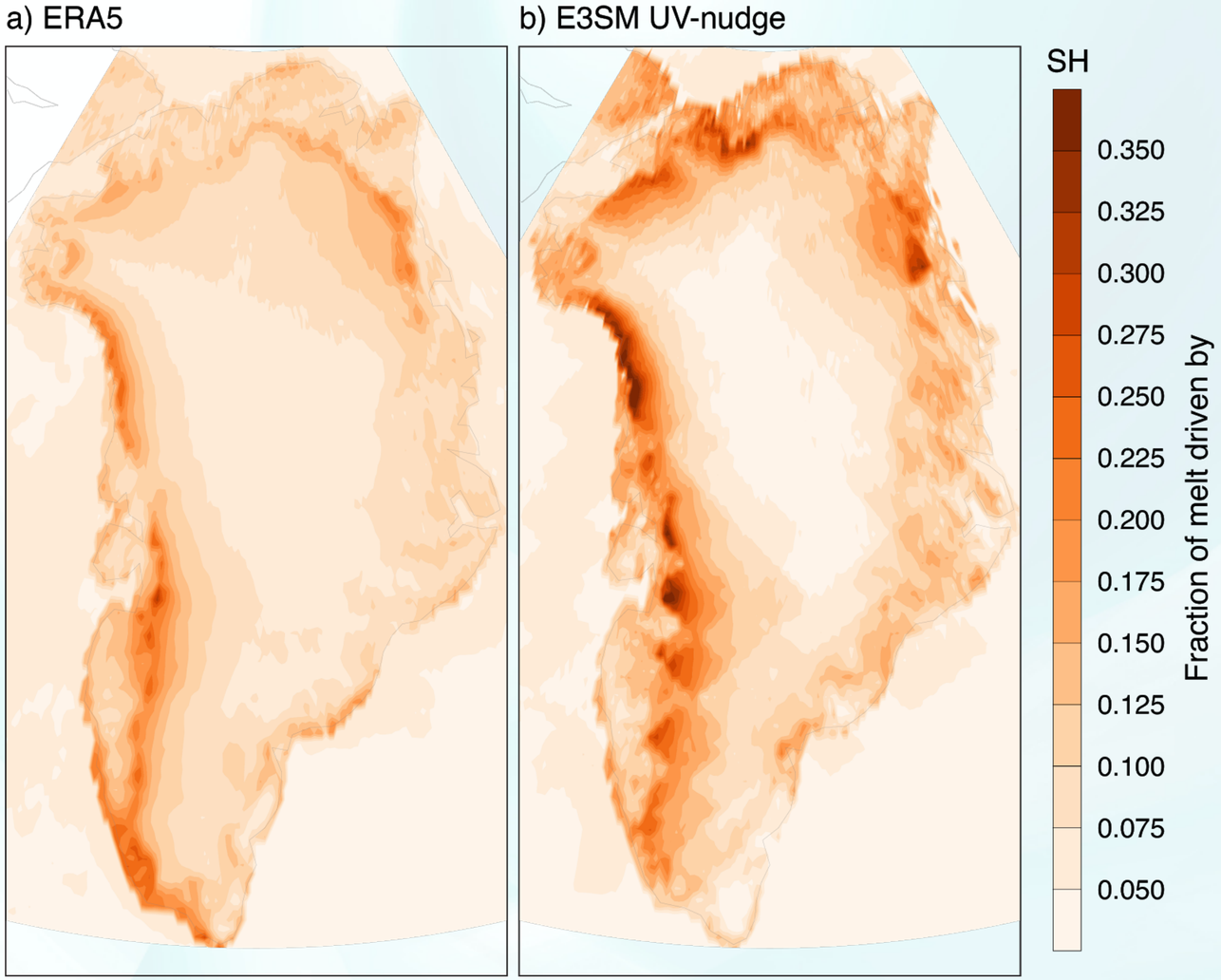
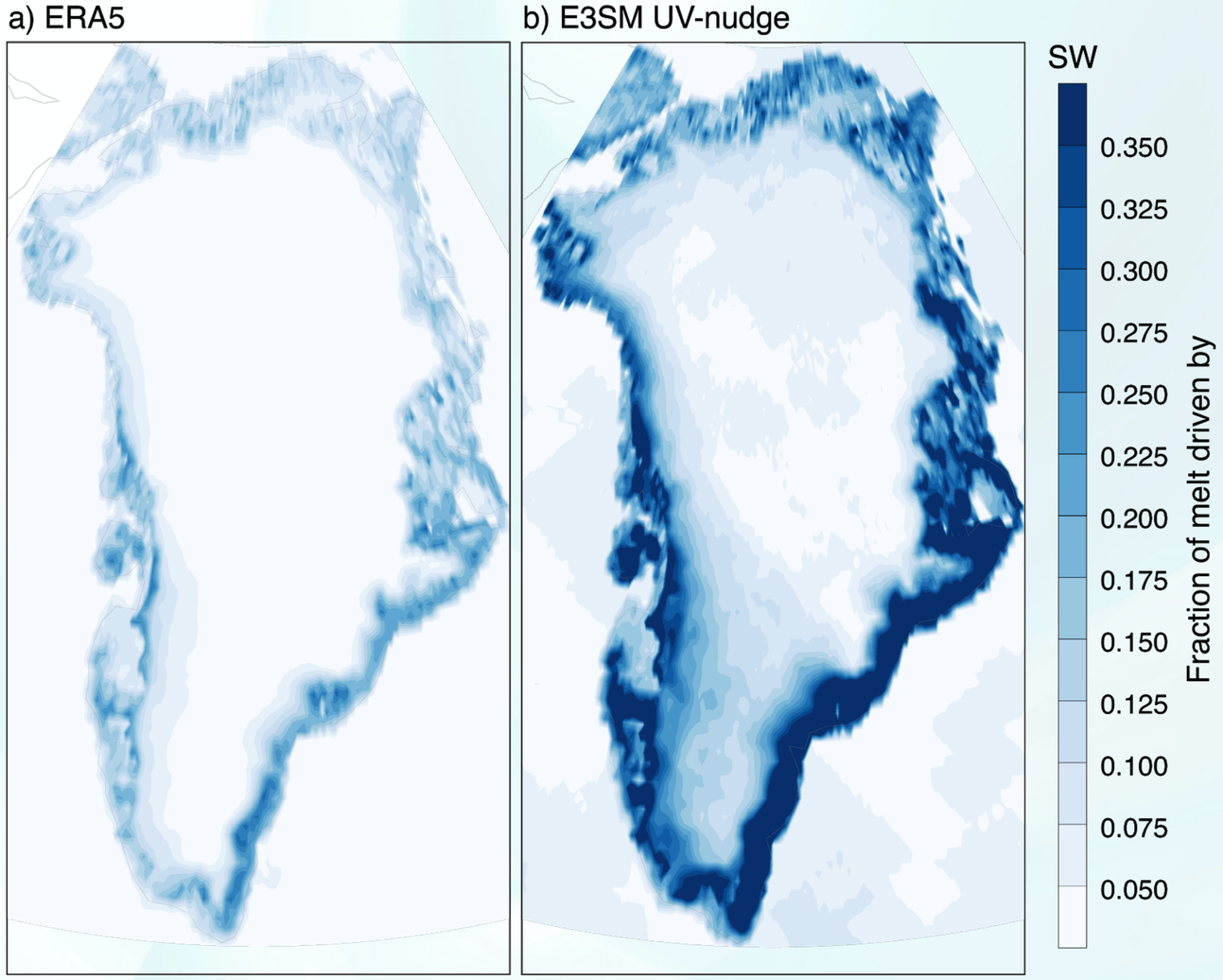


Fig. Fractions of surface melt daily variability driven by sensible heating (seasonal and diurnal cycles are removed)

- Sensible heating enhances melt on the northern and western periphery of the ice sheet
- E3SM grid imprinting might be caused by nudging
- RACMO underestimates turbulent fluxes on sub-seasonal timescales by at least one order of magnitude

Q2: How is **E3SM** doing at simulating these primary drivers?

Challenge: E3SM Overestimates Shortwave Driven Melt

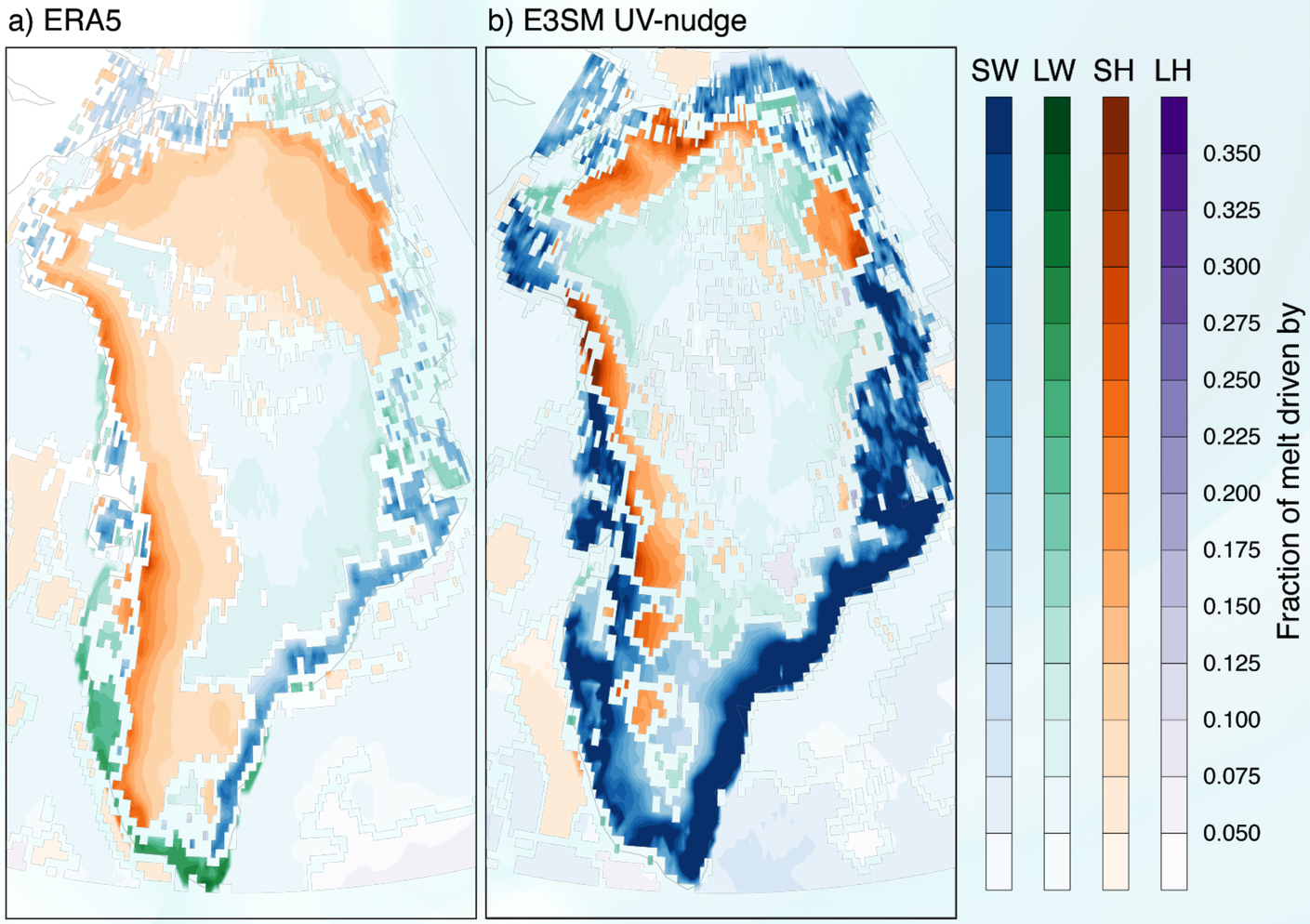


- Shortwave heating enhances melt on the periphery of the island
- E3SM overestimates shortwave driven melt

Fig. Fractions of surface melt daily variability driven by sensible heating (seasonal and diurnal cycles are removed)

Q2: How is **E3SM** doing at simulating these primary drivers?

Challenge: E3SM Overestimates Shortwave Dominated Area

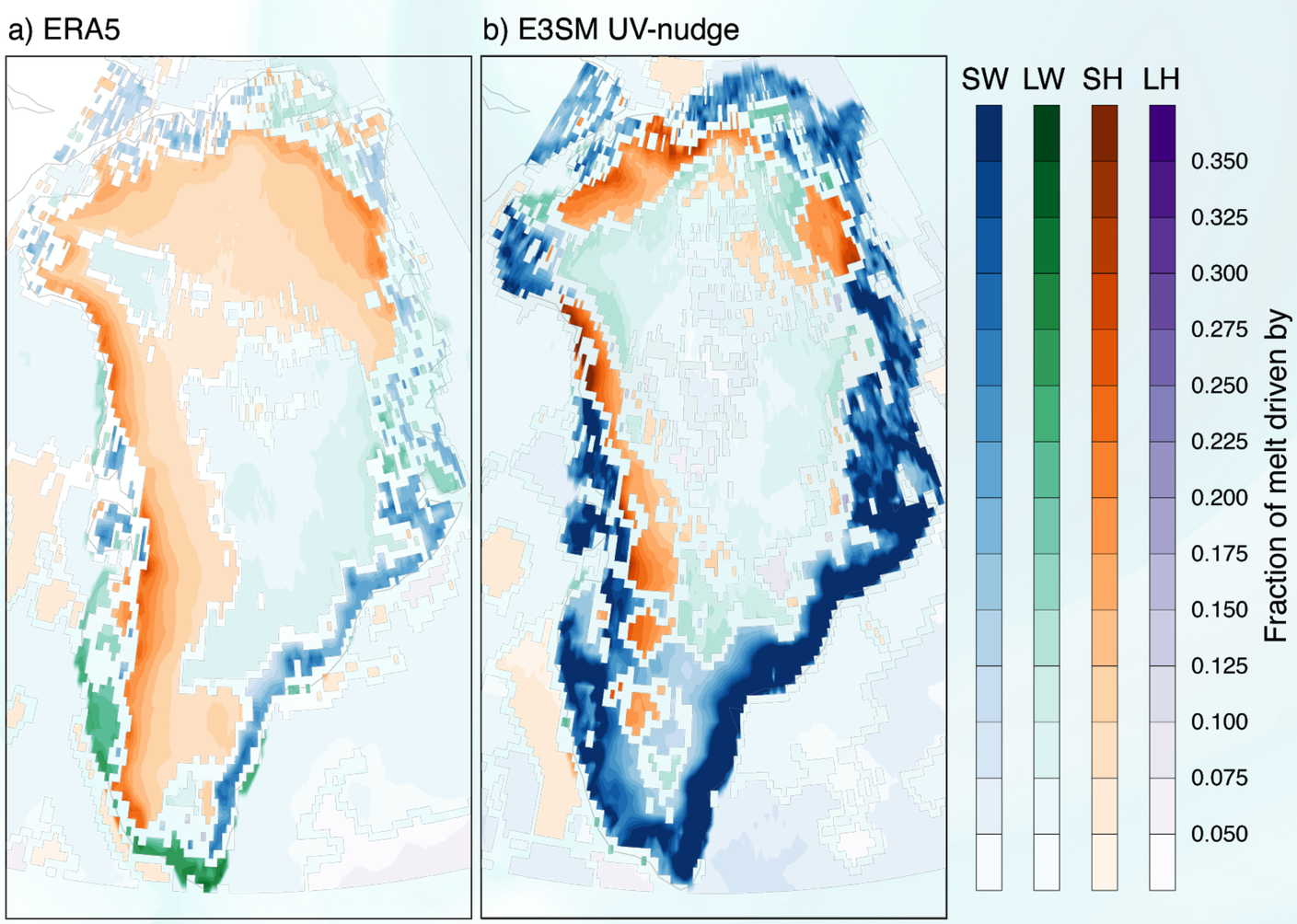


- ERA5:
  - Sensible: northern and western ice margins
  - Shortwave: eastern ice margins
  - Longwave: southern ice margins and tundra
  - Latent: minimal
- E3SM: overestimated shortwave occupies areas of sensible and longwave

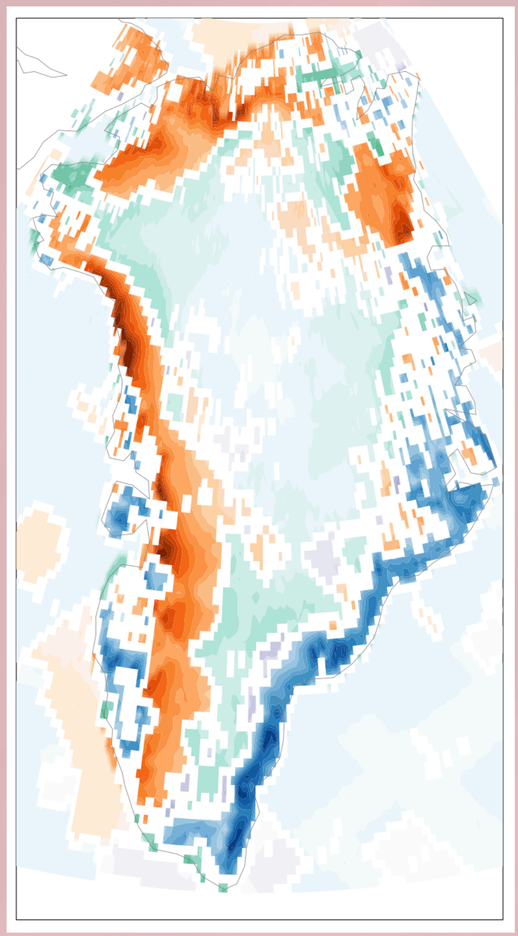
Fig. Fractions of surface melt daily variability driven by surface energy components in their dominant areas.

Q2: How is **E3SM** doing at simulating these primary drivers?

Future Work: Mitigate Excessive Sub-Seasonal Variability of Shortwave Heating



Half shortwave!

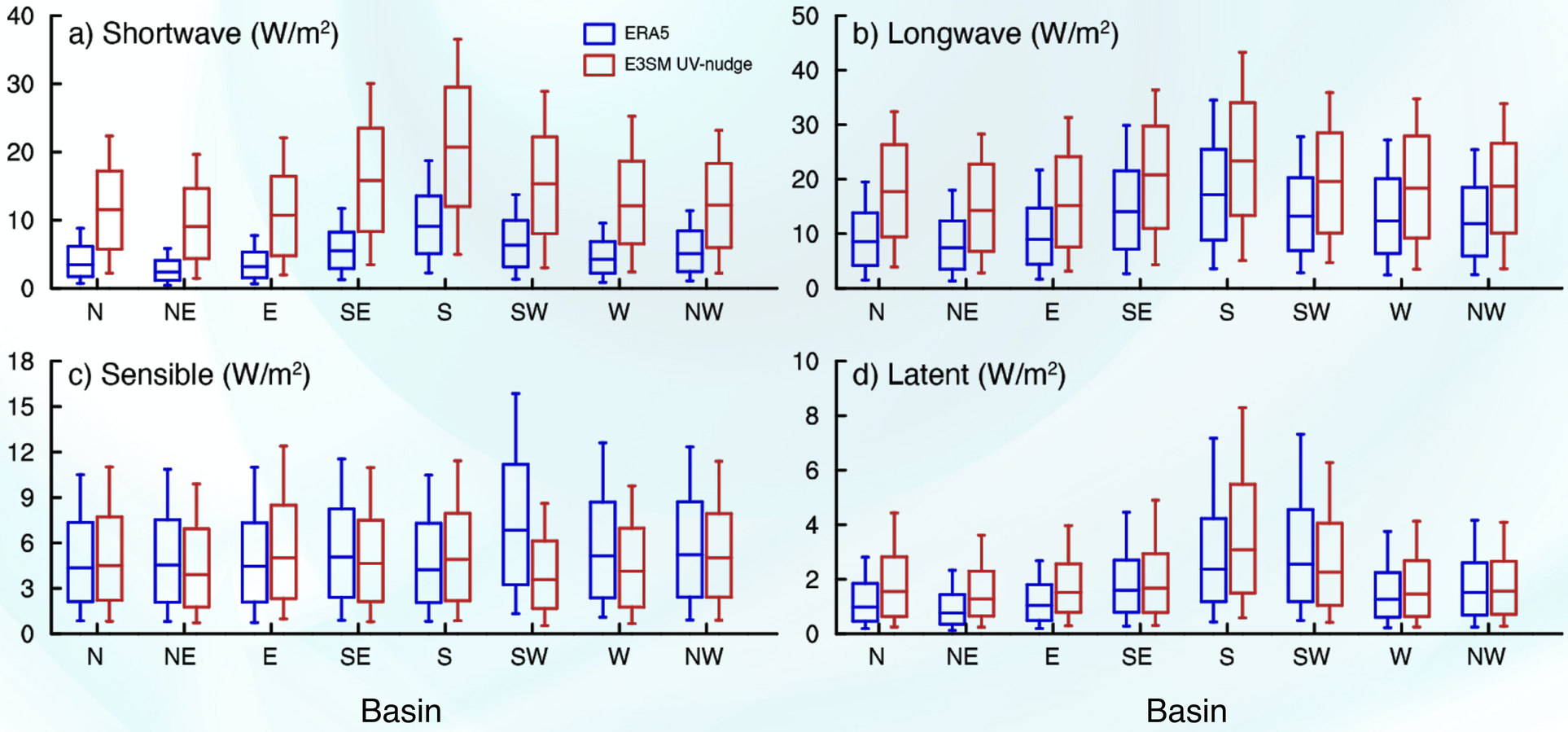


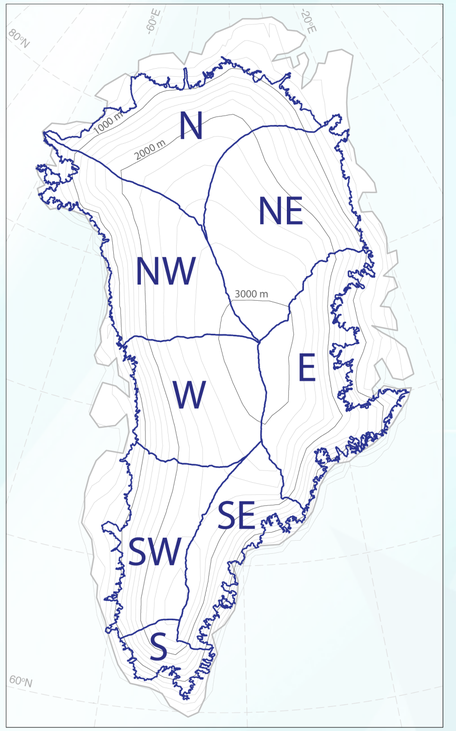
E3SM UV-nudge

Fig. Fractions of surface melt daily variability driven by surface energy components in their dominant areas.

Q2: How is **E3SM** doing at simulating these primary drivers?

Radiative Energy in E3SM Varies More Than That in ERA5



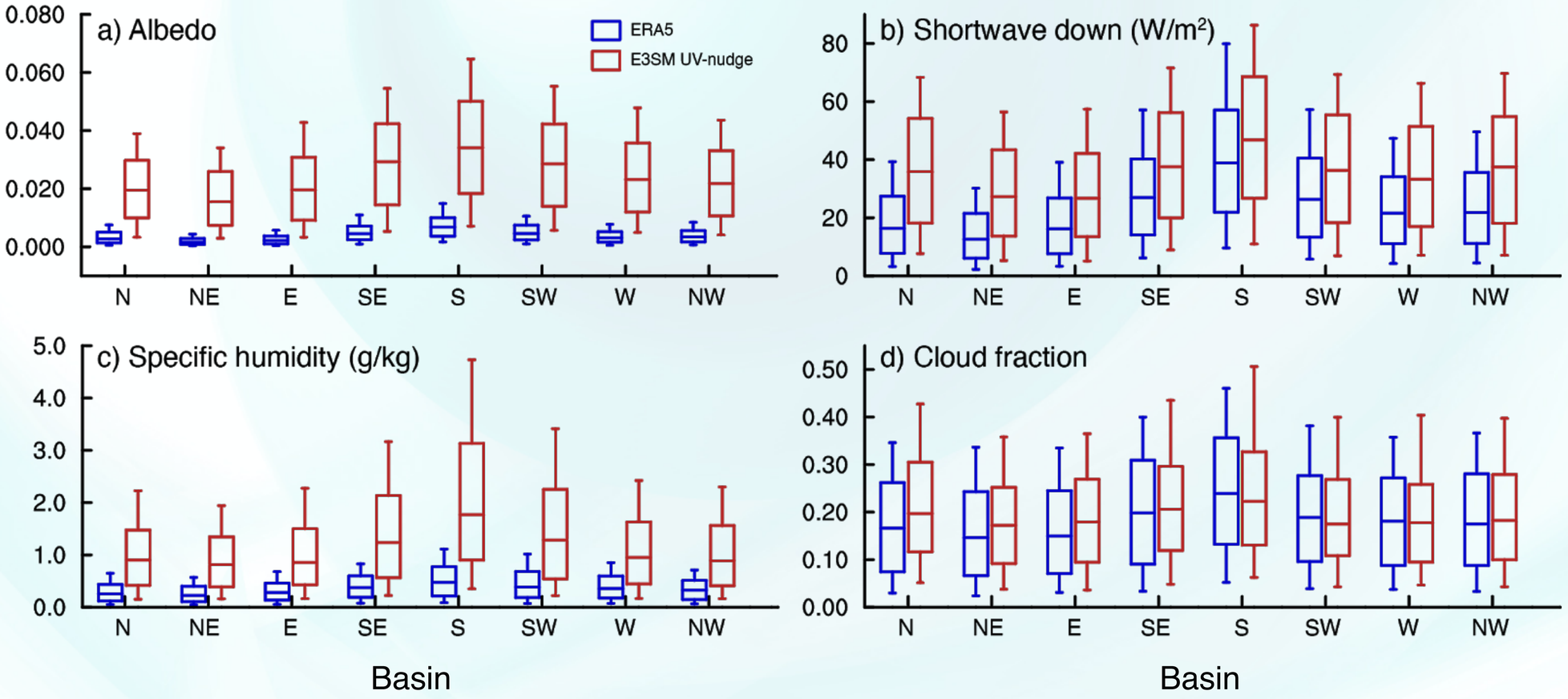


Data from Zwally et. al., 2012

Fig. Sub-seasonal variability (deviation not averages) of surface energy budget components in each drainage basin.

Q2: How is **E3SM** doing at simulating these primary drivers?

Large Variabilities in Albedo and Humidity in E3SM



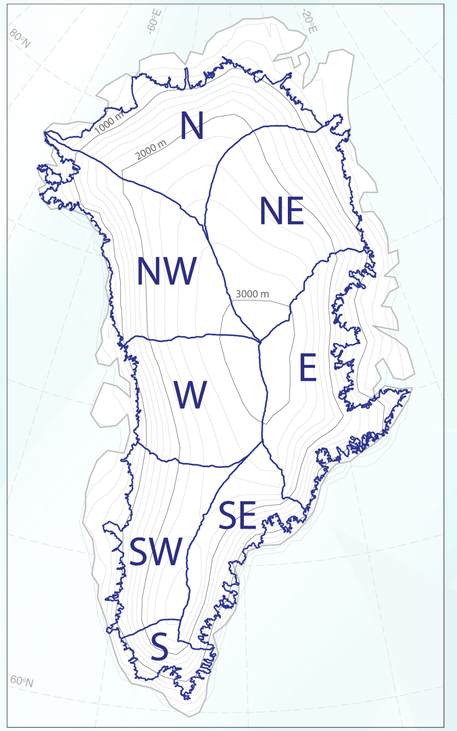


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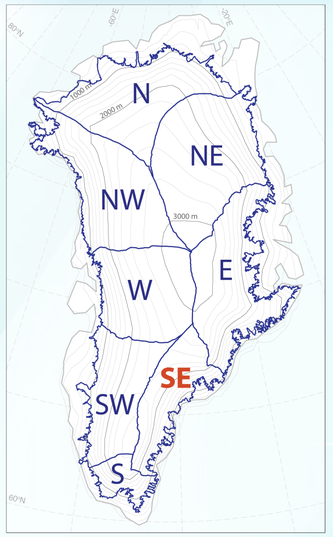
Fig. Sub-seasonal variability (deviation not averages) of meteorological conditions in each drainage basin.

Q2: How is **E3SM** doing at simulating these primary drivers?

Skill: Consistent Meteorological Drivers of Melt



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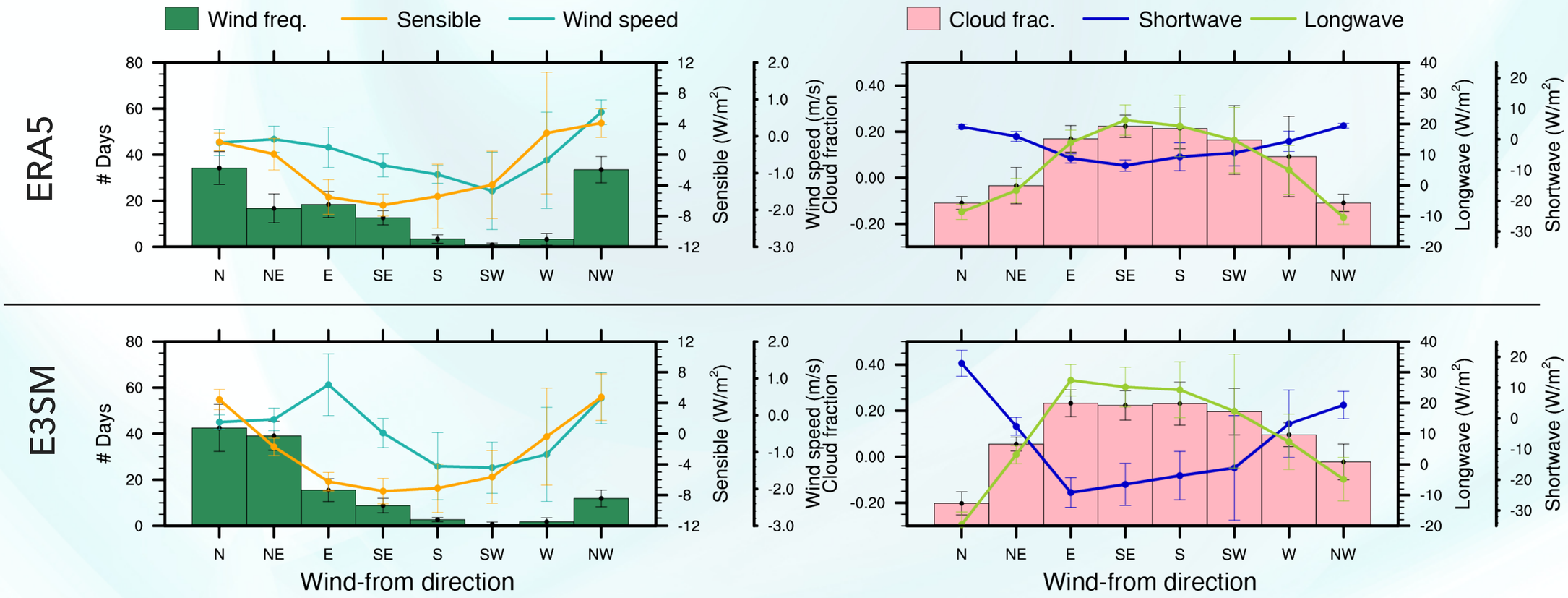

Fig. Averages of (left panels) wind frequency (green histogram), sensible heat (orange line), and wind speed (teal line); (right panels) cloud fraction (pink histogram), shortwave radiation (blue line), and longwave radiation (green line) binned by wind-from directions in Basin SE.
Error bars = one standard deviation; Top panels = ERA5; bottom panels = E3SM.

Summary

- What are **the primary drivers** of surface melt on GrIS?
  - Seasonal and diurnal: shortwave through solar zenith angle and albedo
  - Sub-seasonal: sensible & shortwave, enhanced during katabatic winds
- How is **E3SM** doing at simulating these SEB components and meteorological conditions?
  - Skills
    - Similar spatial patterns of melt driven by sensible & shortwave heating to ERA5
    - Surface energy and meteorological fields vary with wind direction in the same way as ERA5
  - Identified biases in drivers of GrIS surface melt in v1
    - E3SM overestimates sub-seasonal variabilities of shortwave heating, caused by overestimates in albedo (land) and humidity (atmosphere)
  - Improvements in progress (ELM snowpack and firn)
    - Improved snow density (Adam Schneider's poster: PS1-Cryosphere/Schneider_Adam_PS1-Cryosphere_2020-10-26.pdf)

Contact: Wenshan Wang (wenshanw@uci.edu)

Summary

Thank You!

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Backup Slides

Backup slides

Fraction of Time When Melt Is Driven by SEB Components

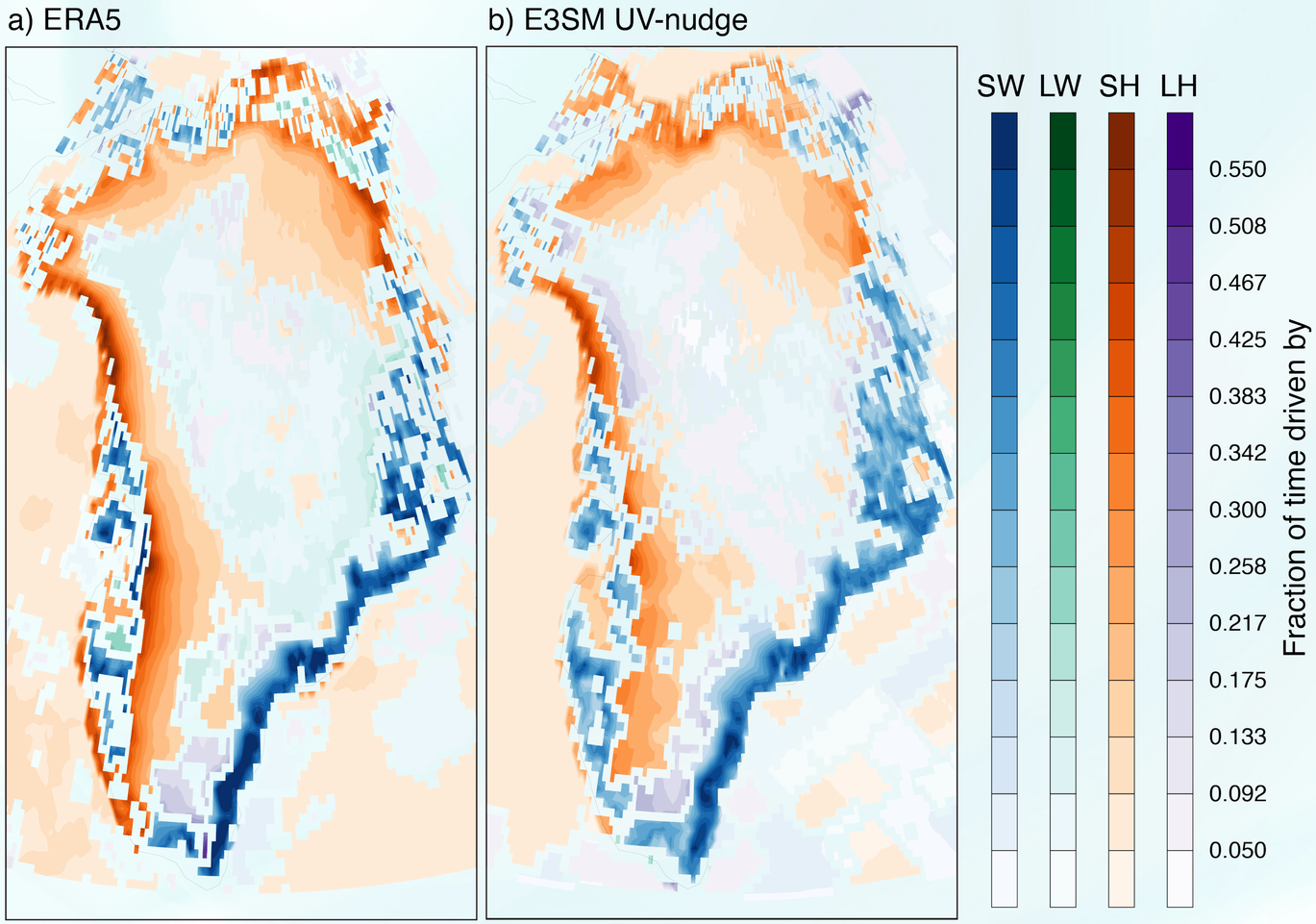
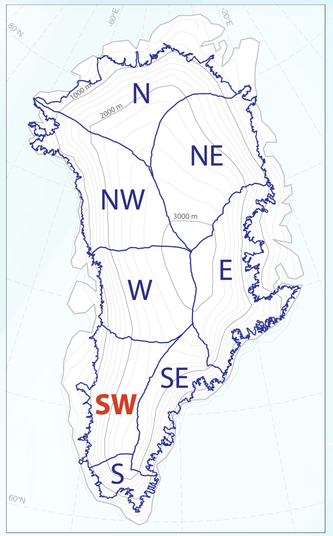


Fig. Fractions of time when surface melt daily variability driven by surface energy components in their dominant areas.

Q2: How is **E3SM** doing at simulating these primary drivers?

Skill: Consistent Meteorological Drivers of Melt

BASIN SW



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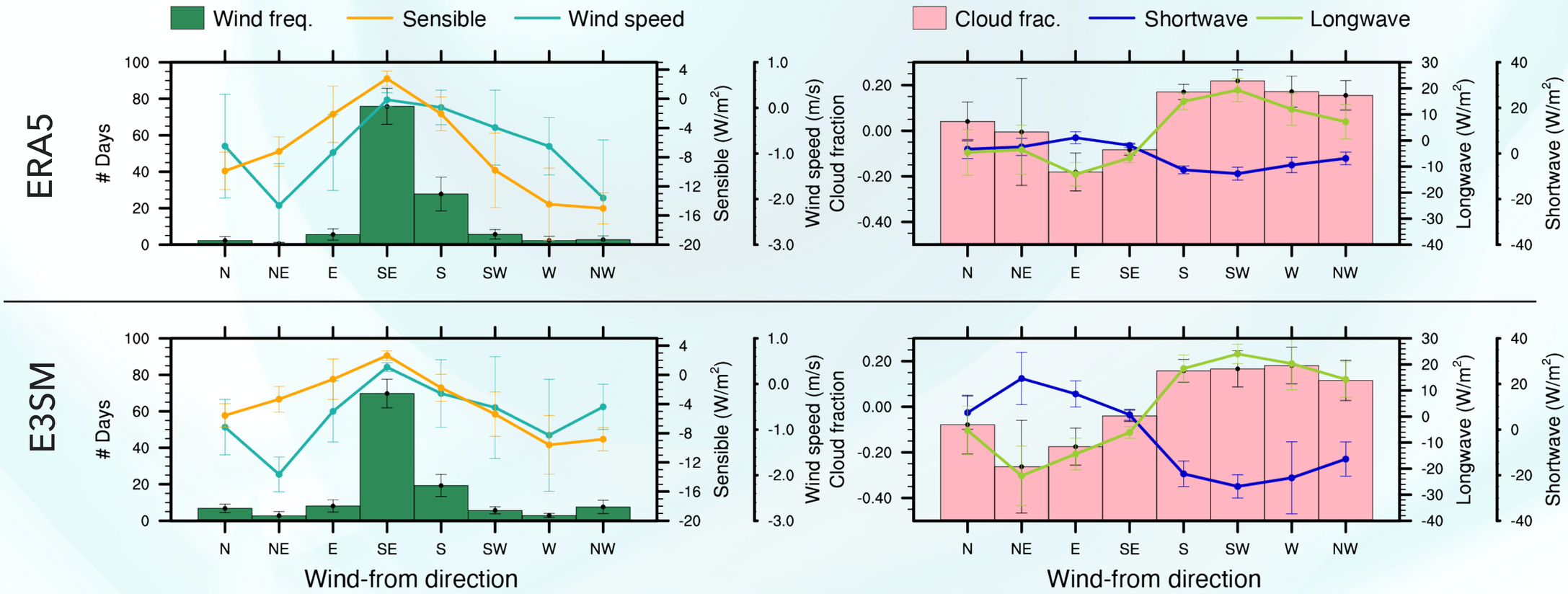

Fig. Averages of (left panels) wind frequency (green histogram), sensible heat (orange line), and wind speed (teal line); (right panels) cloud fraction (pink histogram), shortwave radiation (blue line), and longwave radiation (green line) binned by wind-from directions in Basin SW.
Error bars = one standard deviation; Top panels = ERA5; bottom panels = E3SM.

Q2: How is **E3SM** doing at simulating these primary drivers?

Challenge: Daily Wind Direction

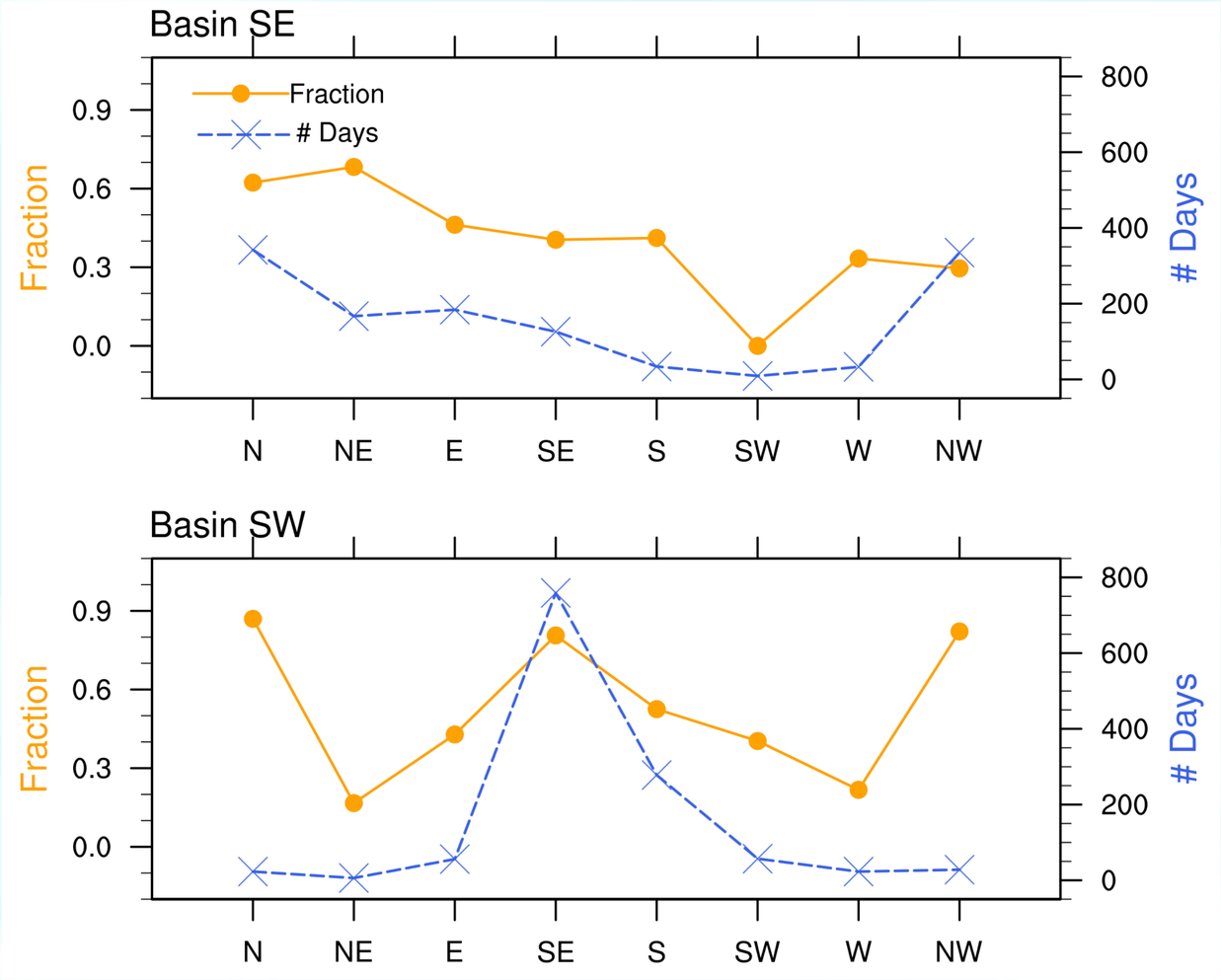

Fig. Fractions of days when wind-from directions in E3SM and ERA5 are the same (left axis) and number of days of ERA5 wind-from directions (right axis).