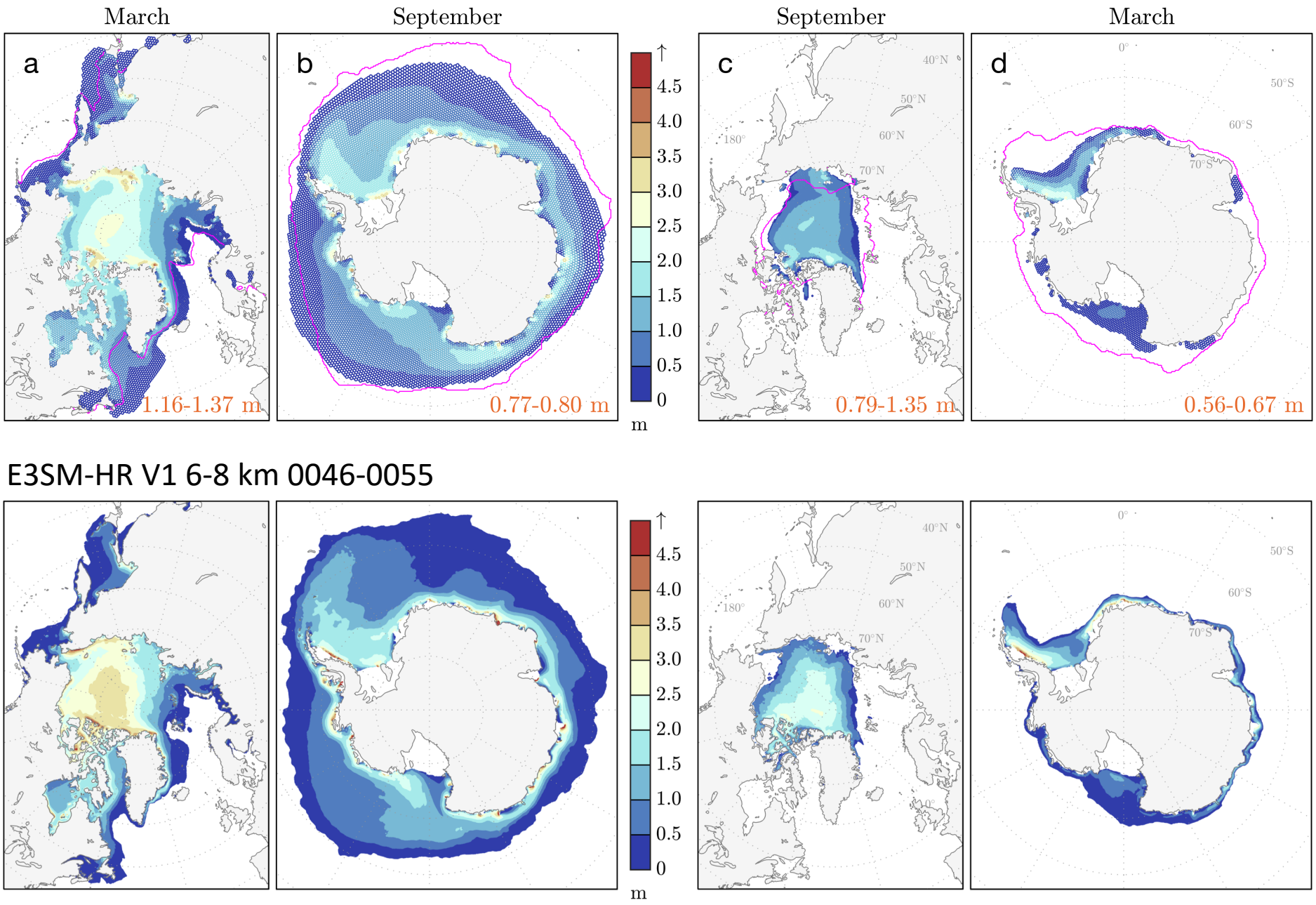
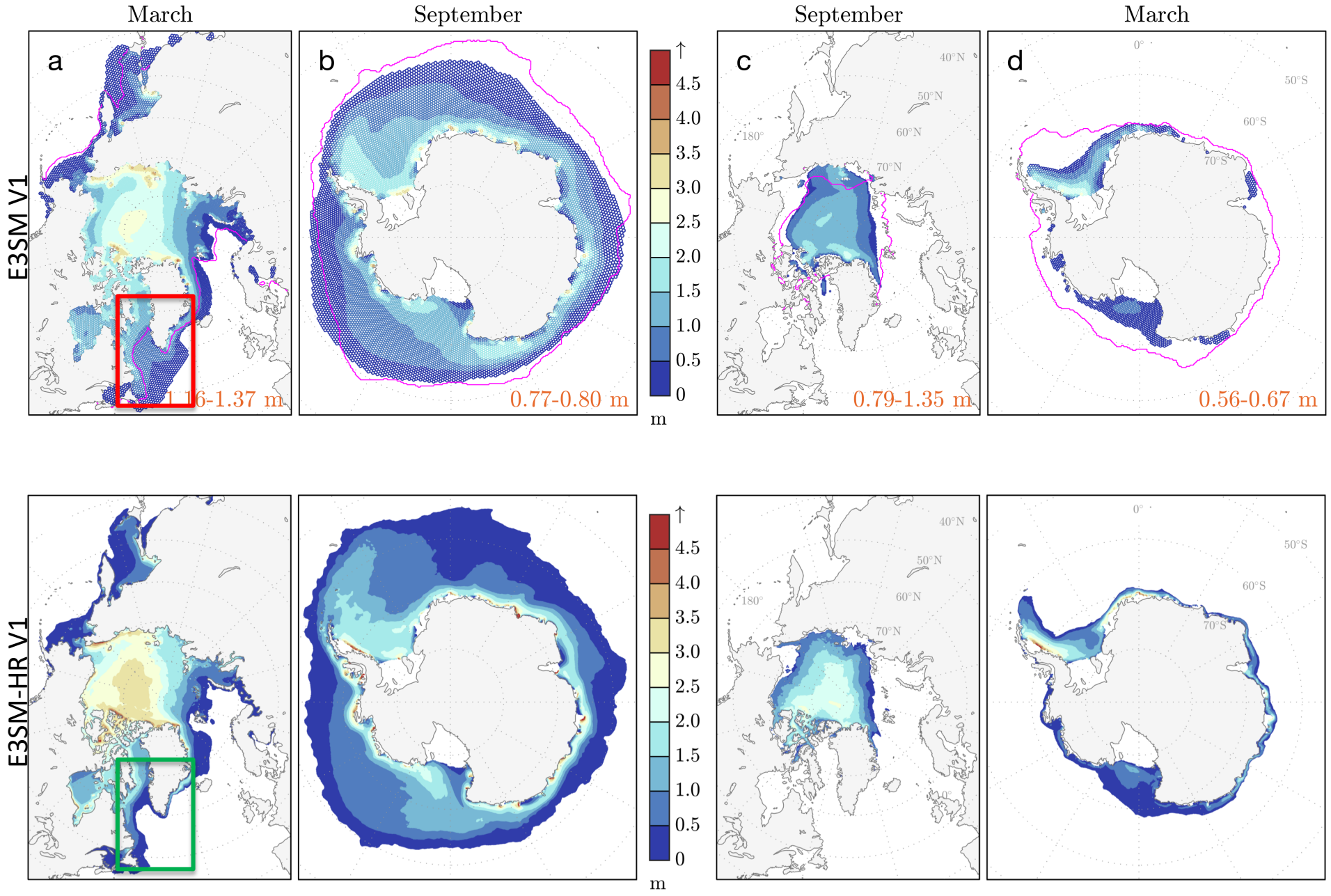
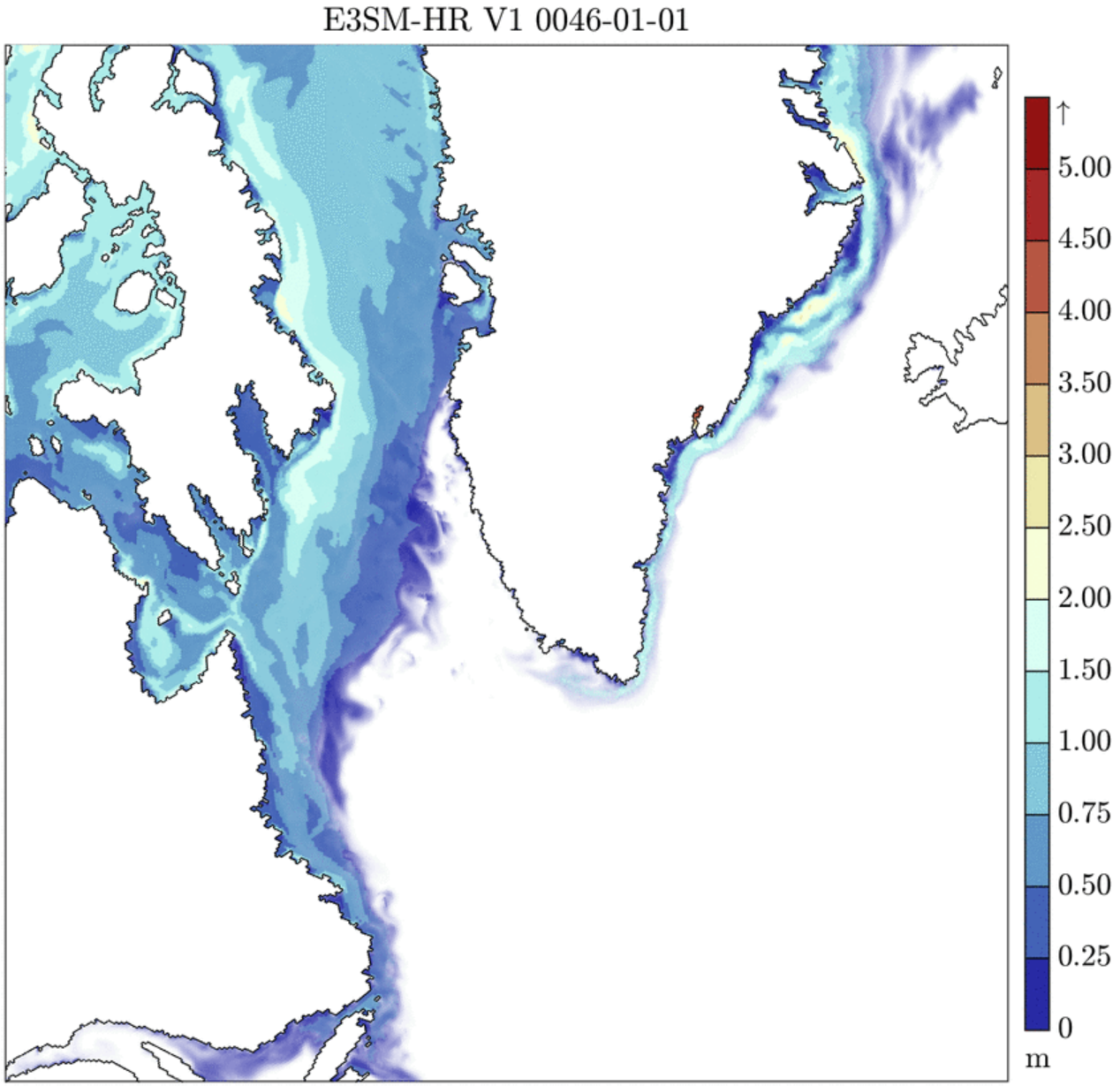
Sea Ice

- A long term goal of E3SM is to be able to simulate decadal trends in sea ice cover, matching observations and hence providing confidence in model projections.
- Sea ice extent is often considered the key metric of ice cover, but we should be focusing instead on the thickness distribution *g(h)*, because ice thickness, *h*, is a state variable of the ocean. Ice extent is not.
- What does *h* tell us about the polar climate in E3SM V1?


E3SM V1 H1-H5 Ensemble Mean 2000-2014
March
September
September
March
a
b
c
d
1.16-1.37 m
0.77-0.80 m
0.79-1.35 m
0.56-0.67 m
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
m
40°N
50°N
60°N
70°N
180°
0°
50°S
60°S
70°S
E3SM-HR V1 6-8 km 0046-0055

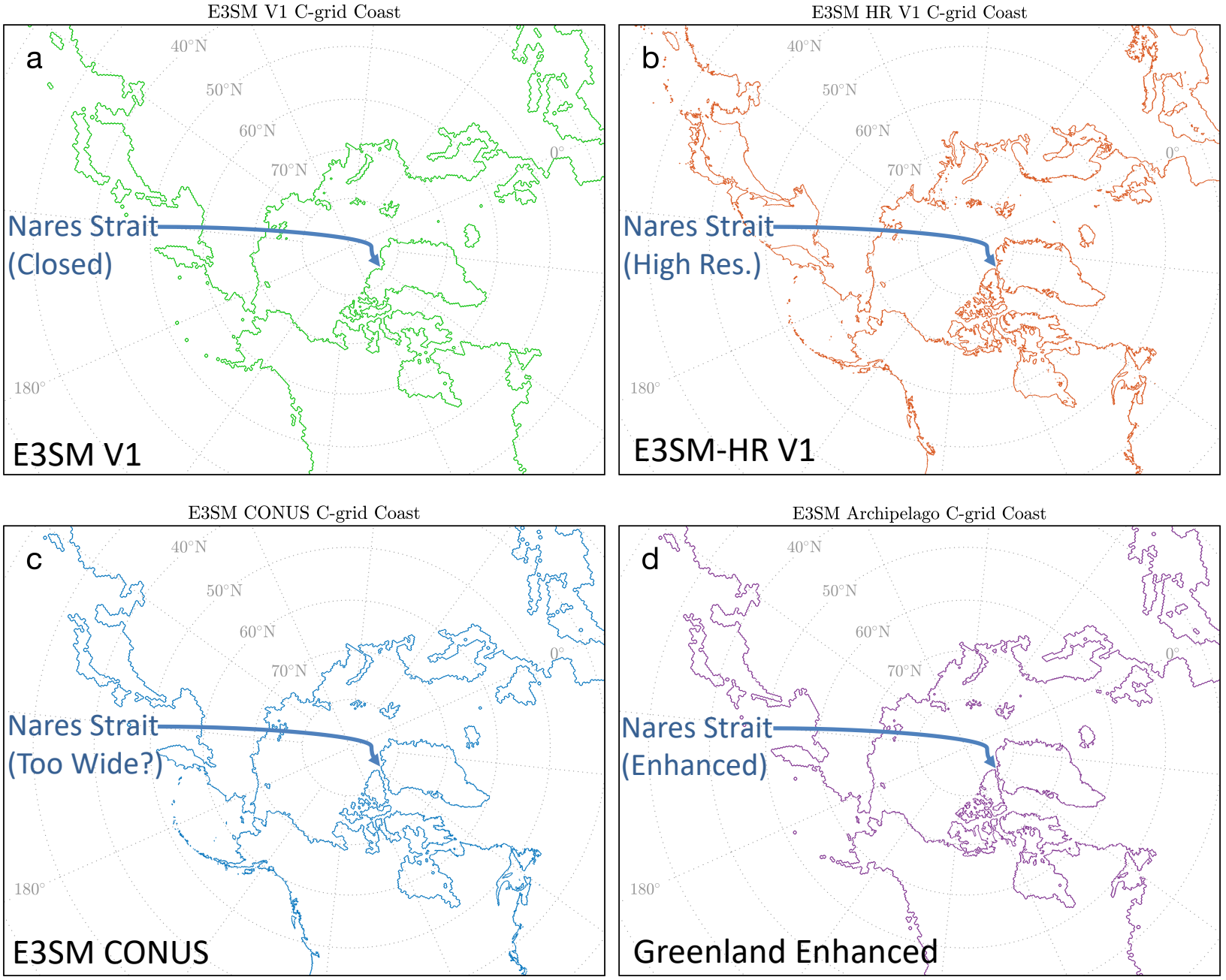
The Labrador Sea bias



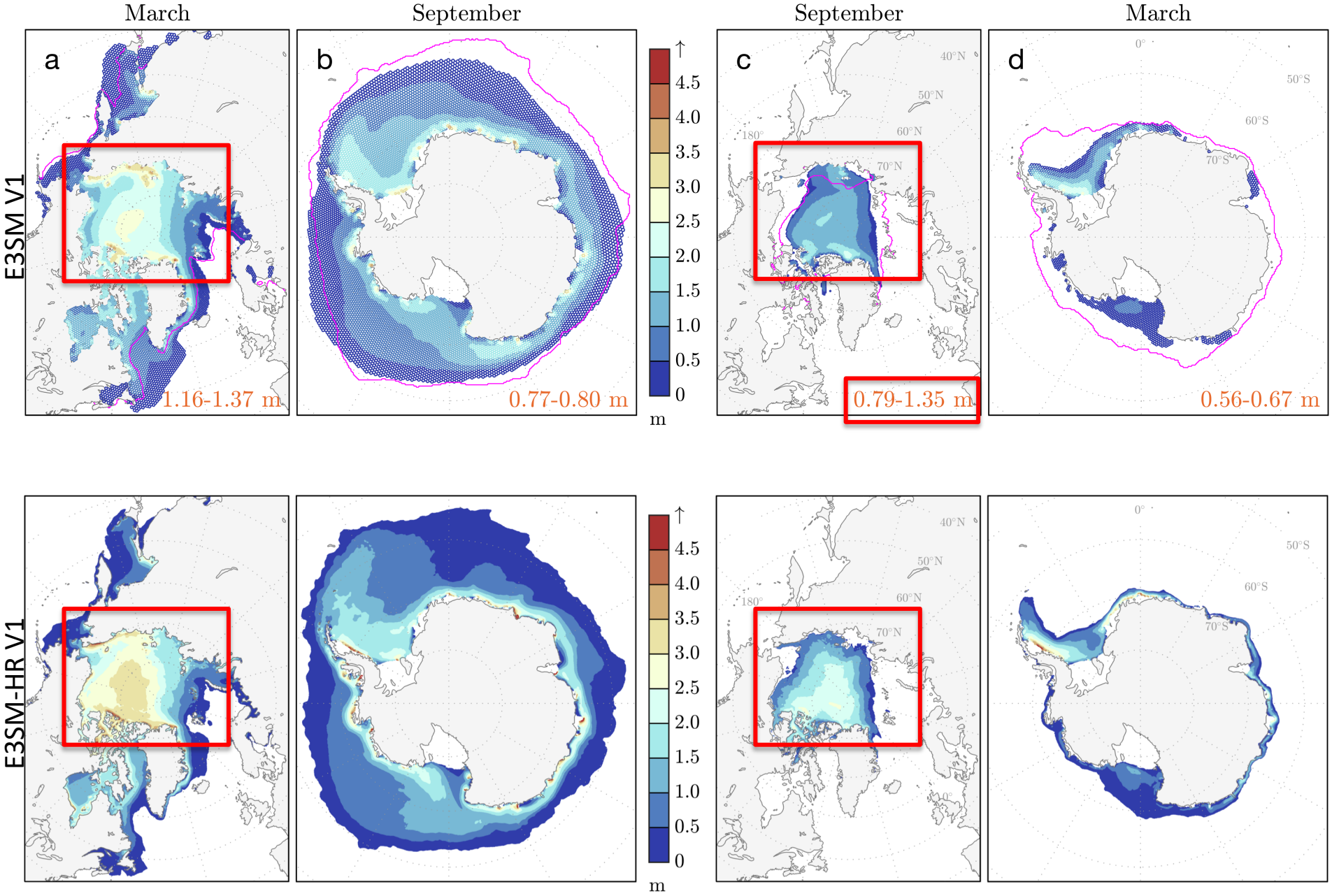


The Labrador Sea bias disappears at high resolution 6-18 km

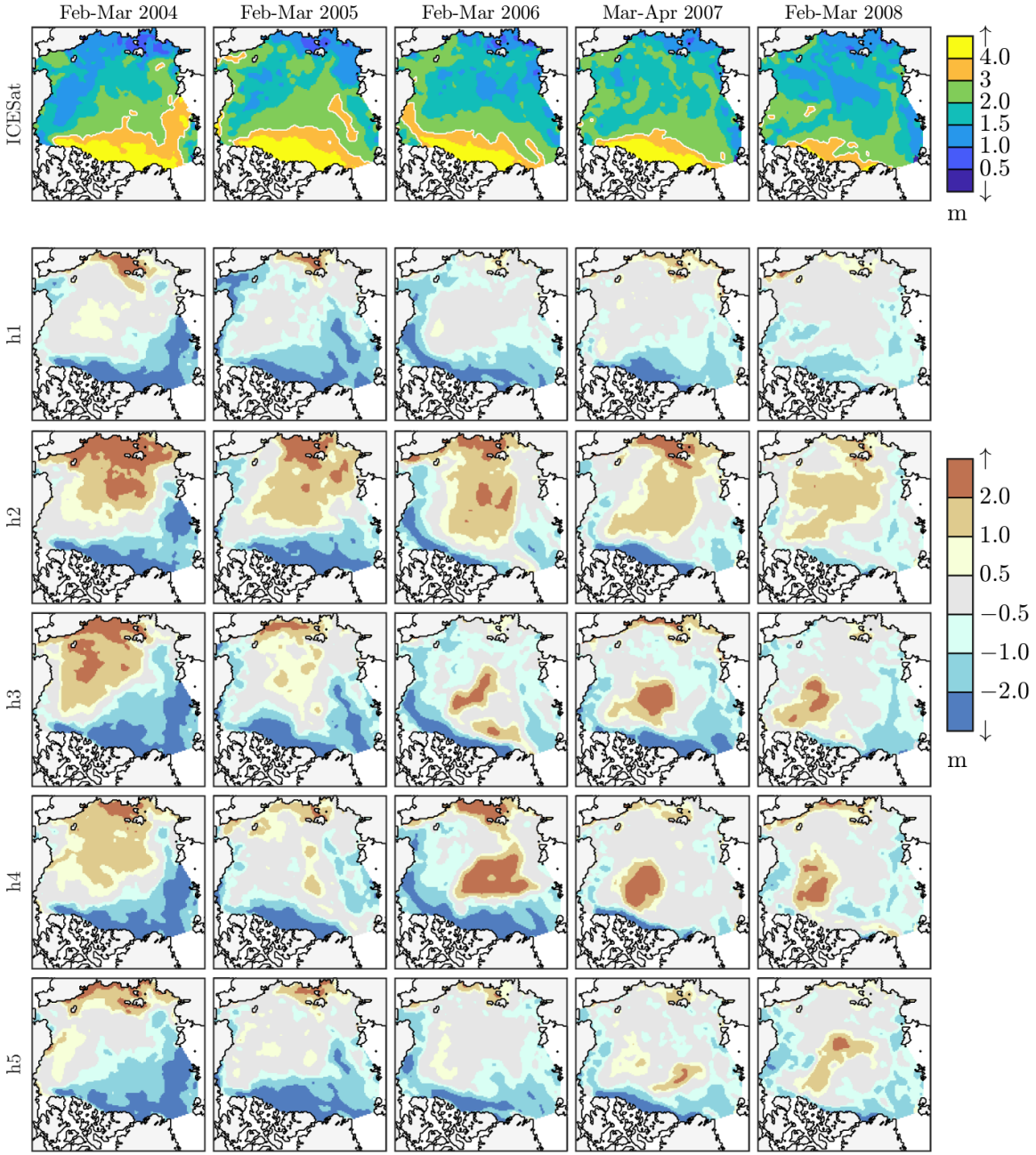
V2 Low Hanging Fruit: Labrador Sea bias disappears with enhanced resolution



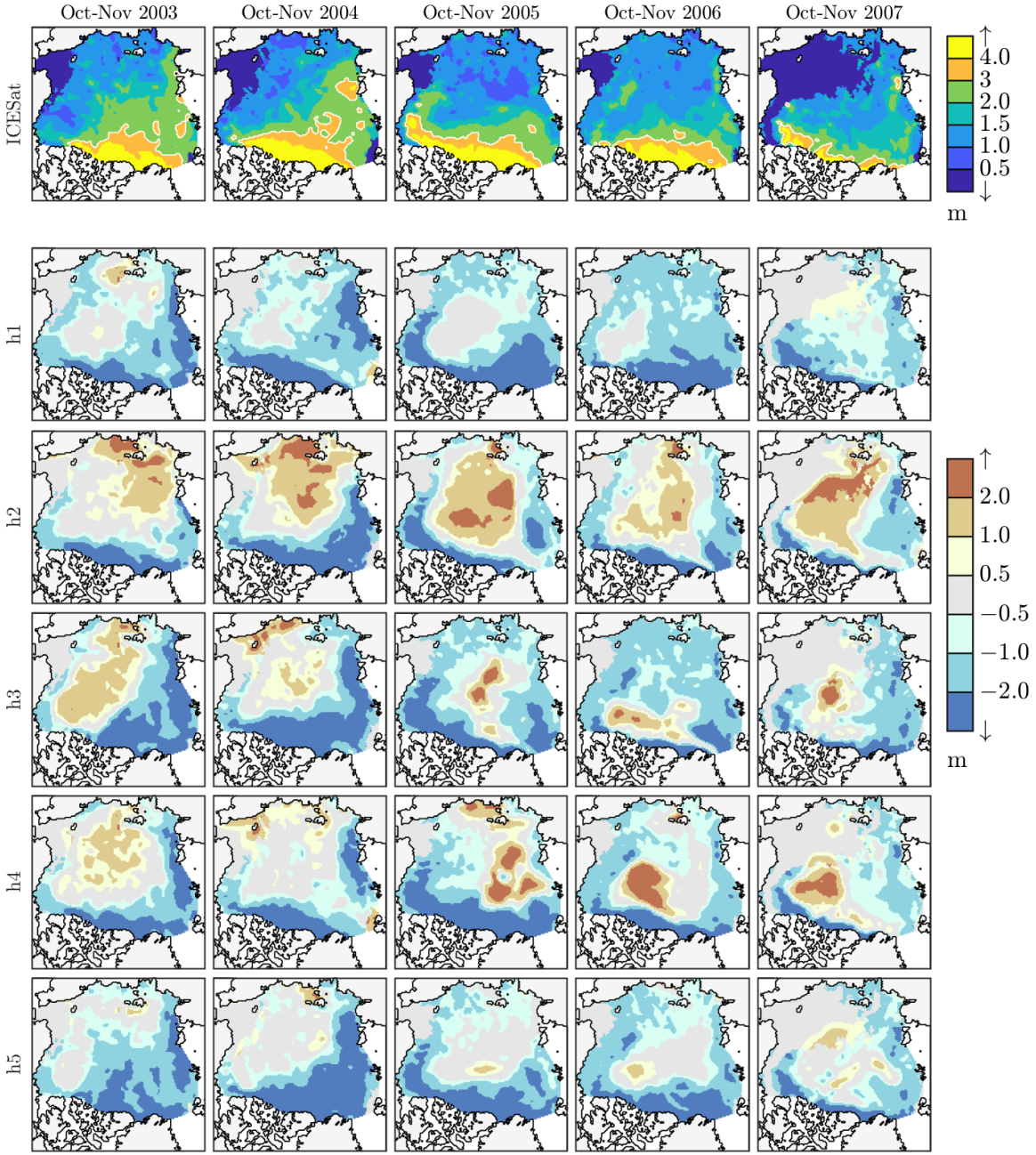
The Arctic Ocean problem



Spring thickness difference from Kwok and Cunningham (2008) on SSM/I mesh



Fall thickness difference from Kwok and Cunningham (2008) on SSM/I mesh



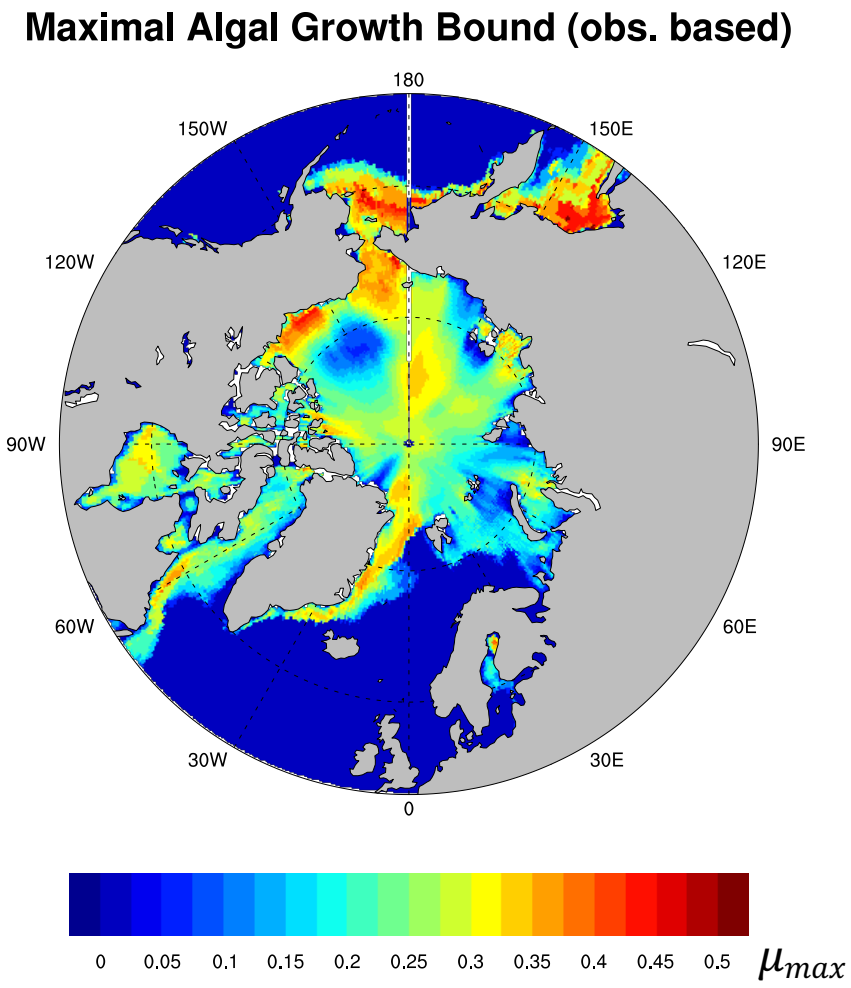
Maximal Ice Algal Growth Bound:

Nicole Jeffery

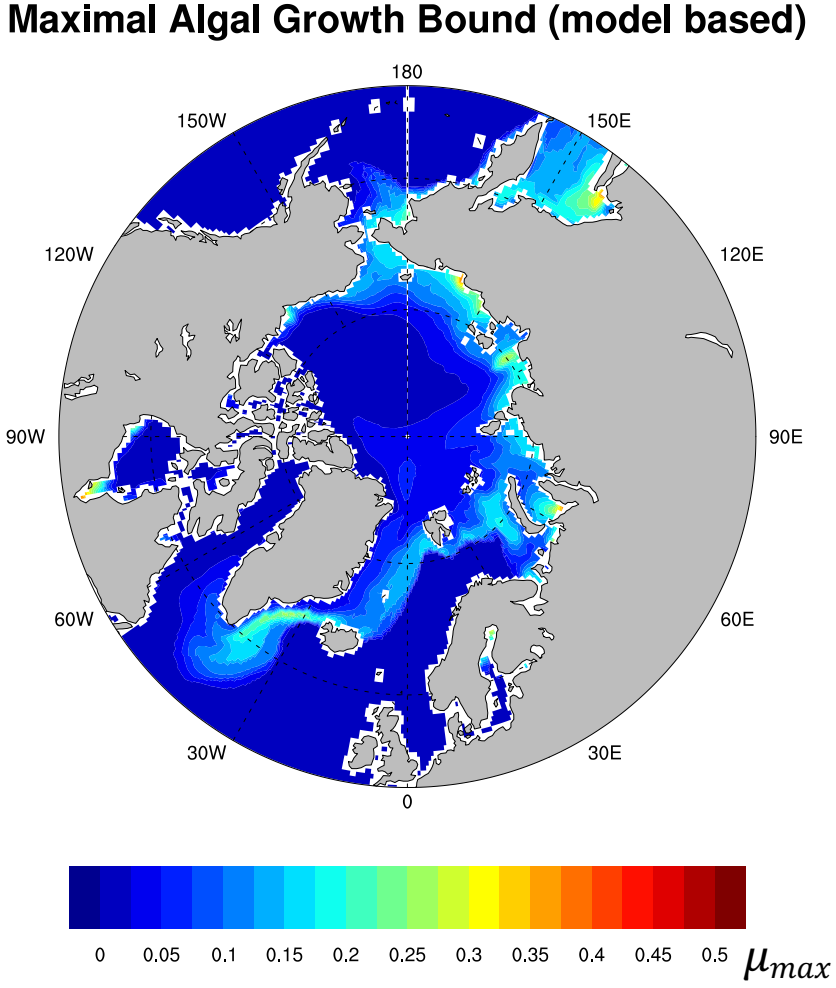
Combines mean annual incident shortwave with upper ocean nitrate and silicate concentrations to estimate the maximum mean ice algal growth rate in ice covered regions.

Biases in upper ocean nitrate/silicate significantly reduces predictions of Arctic Ice Algal Production.

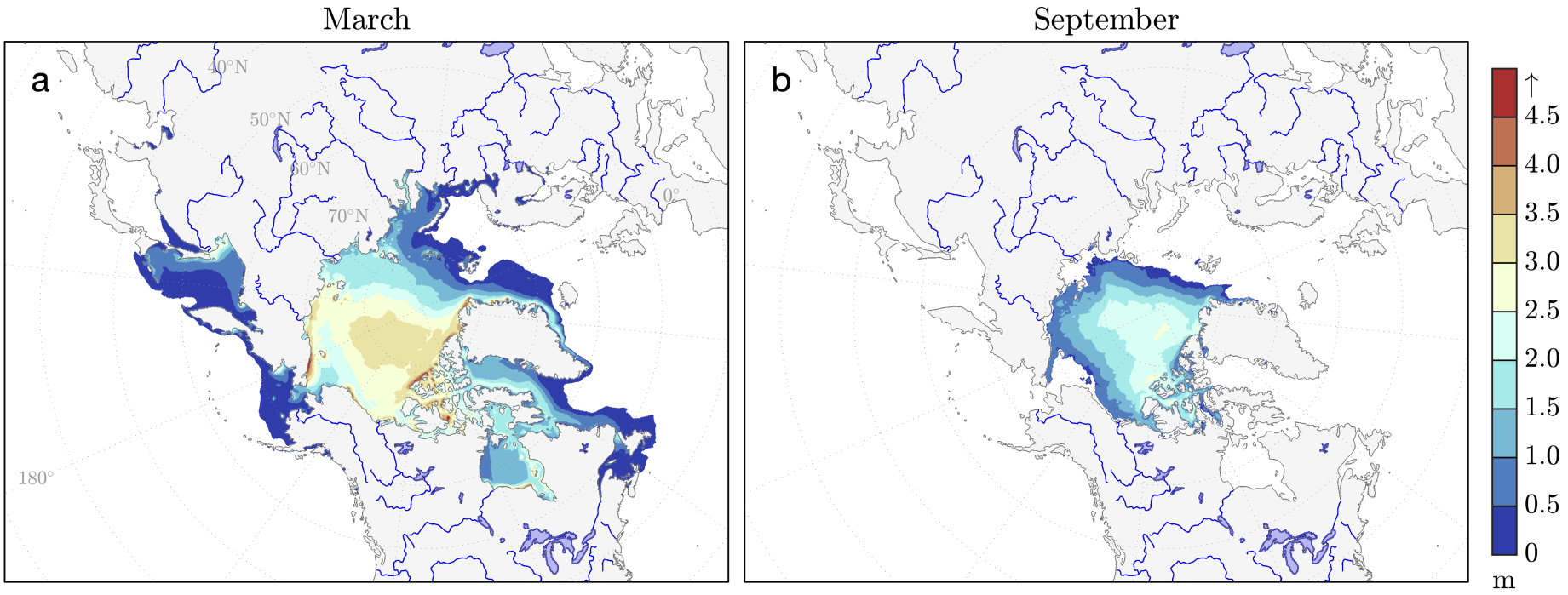
Observation Based (Present Day)

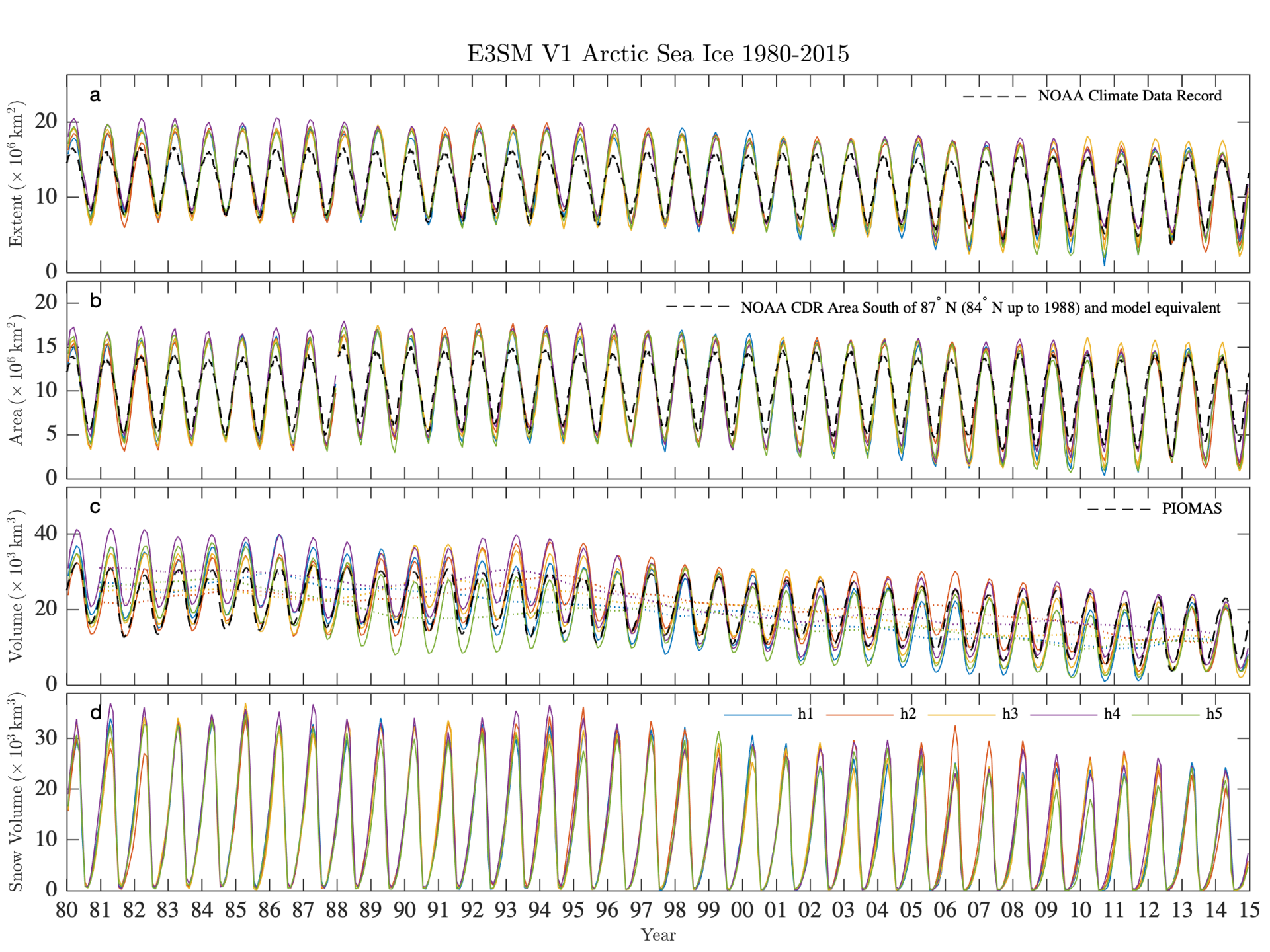


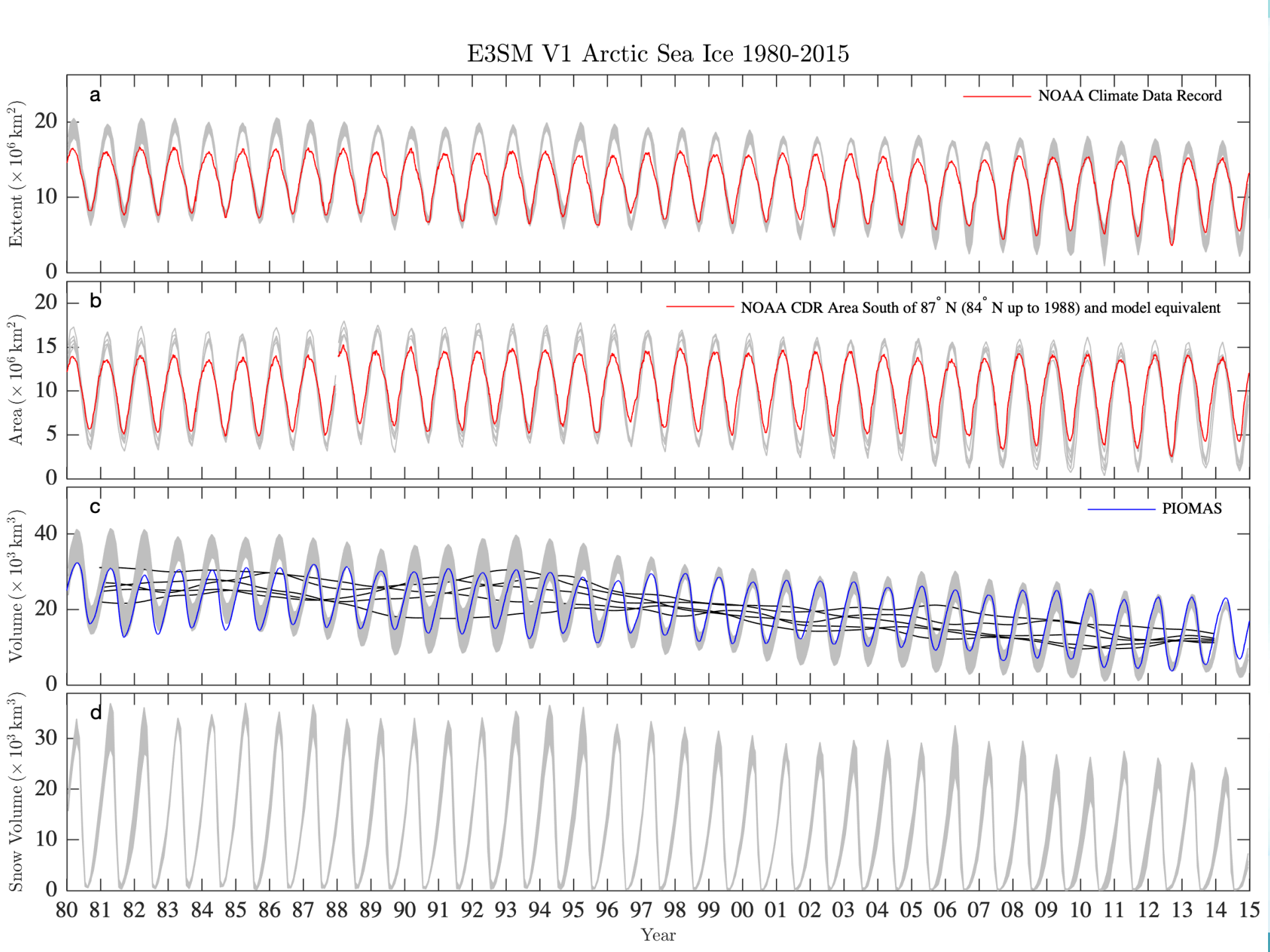
Model Based (1850 CBGC Control)

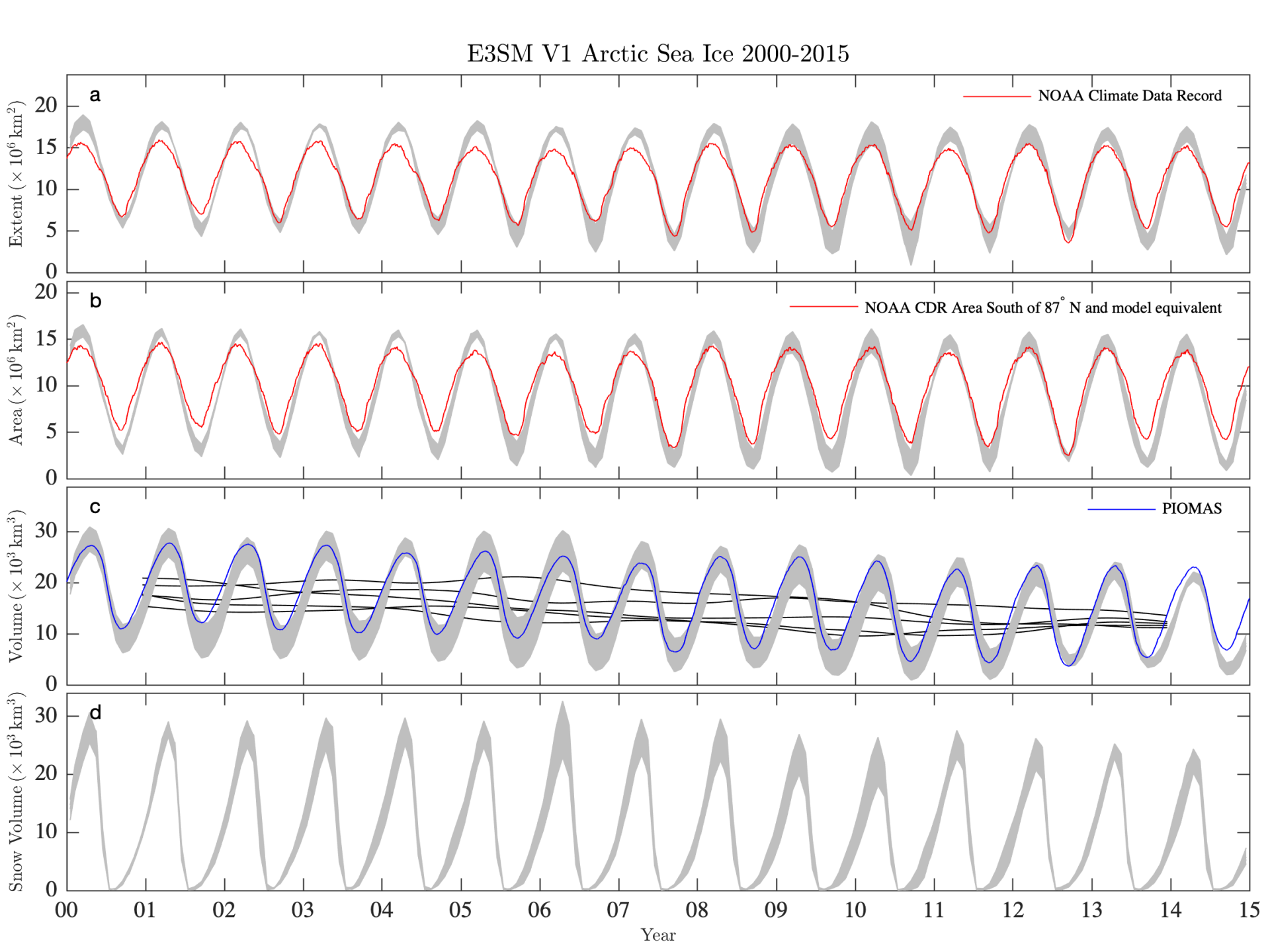


A current blind spot: Hydrology affecting the Arctic Ocean




E3SM V1 Arctic Sea Ice 1980-2015
a
NOAA Climate Data Record
Extent ($\times 10^6$ km^2)
b
NOAA CDR Area South of 87° N (84° N up to 1988) and model equivalent
Area ($\times 10^6$ km^2)
c
PIOMAS
Volume ($\times 10^3$ km^3)
d
h1
h2
h3
h4
h5
Snow Volume ($\times 10^3$ km^3)
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Year


E3SM V1 Arctic Sea Ice 1980-2015
a
NOAA Climate Data Record
Extent ($\times 10^6$ km^2)
0
10
20
b
NOAA CDR Area South of 87° N (84° N up to 1988) and model equivalent
Area ($\times 10^6$ km^2)
0
5
10
15
20
c
PIOMAS
Volume ($\times 10^3$ km^3)
0
20
40
d
Snow Volume ($\times 10^3$ km^3)
0
10
20
30
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Year


E3SM V1 Arctic Sea Ice 2000-2015
a
NOAA Climate Data Record
Extent ($\times 10^6$ km^2)
b
NOAA CDR Area South of 87° N and model equivalent
Area ($\times 10^6$ km^2)
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PIOMAS
Volume ($\times 10^3$ km^3)
d
Snow Volume ($\times 10^3$ km^3)
0
5
10
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20
30
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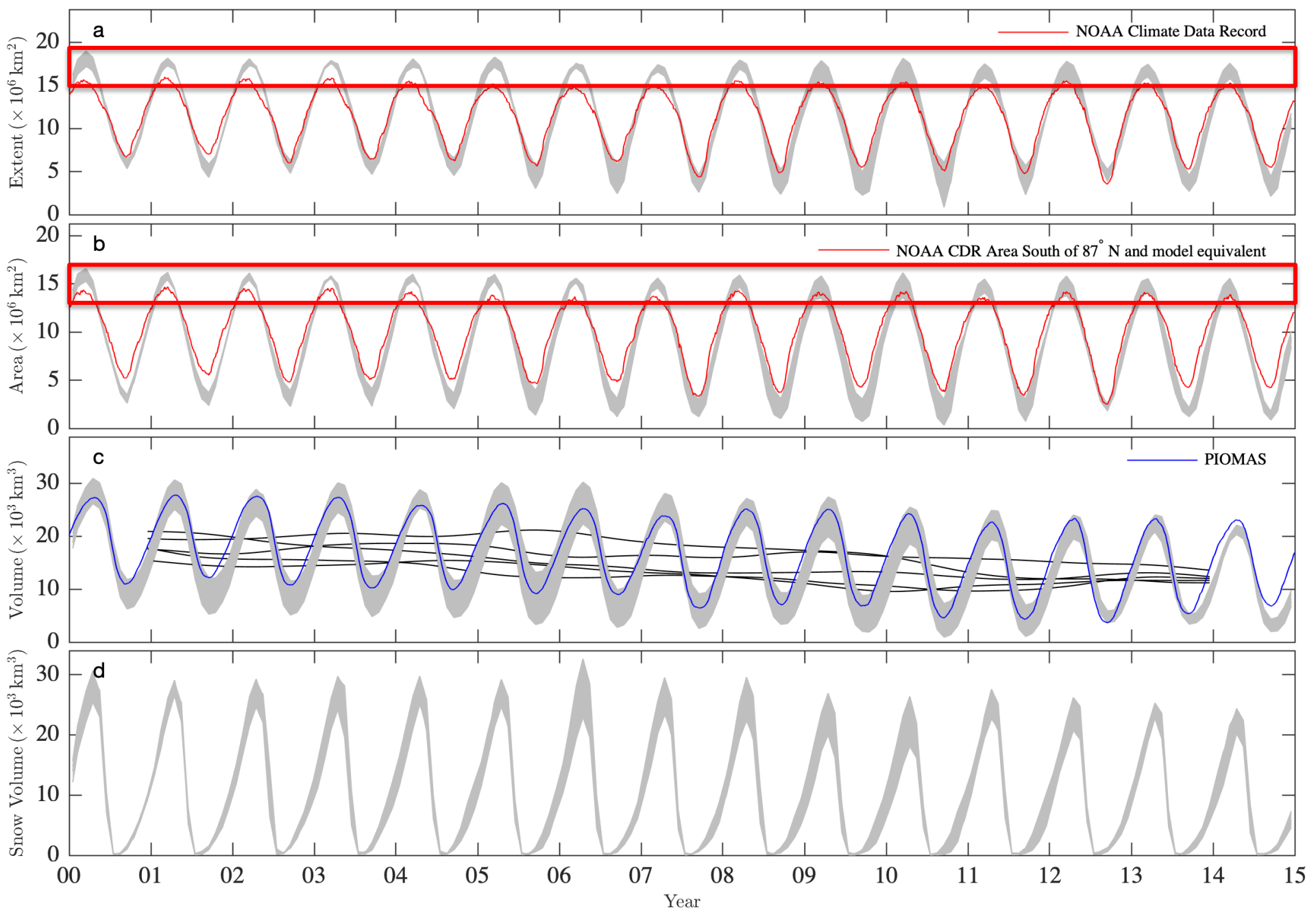
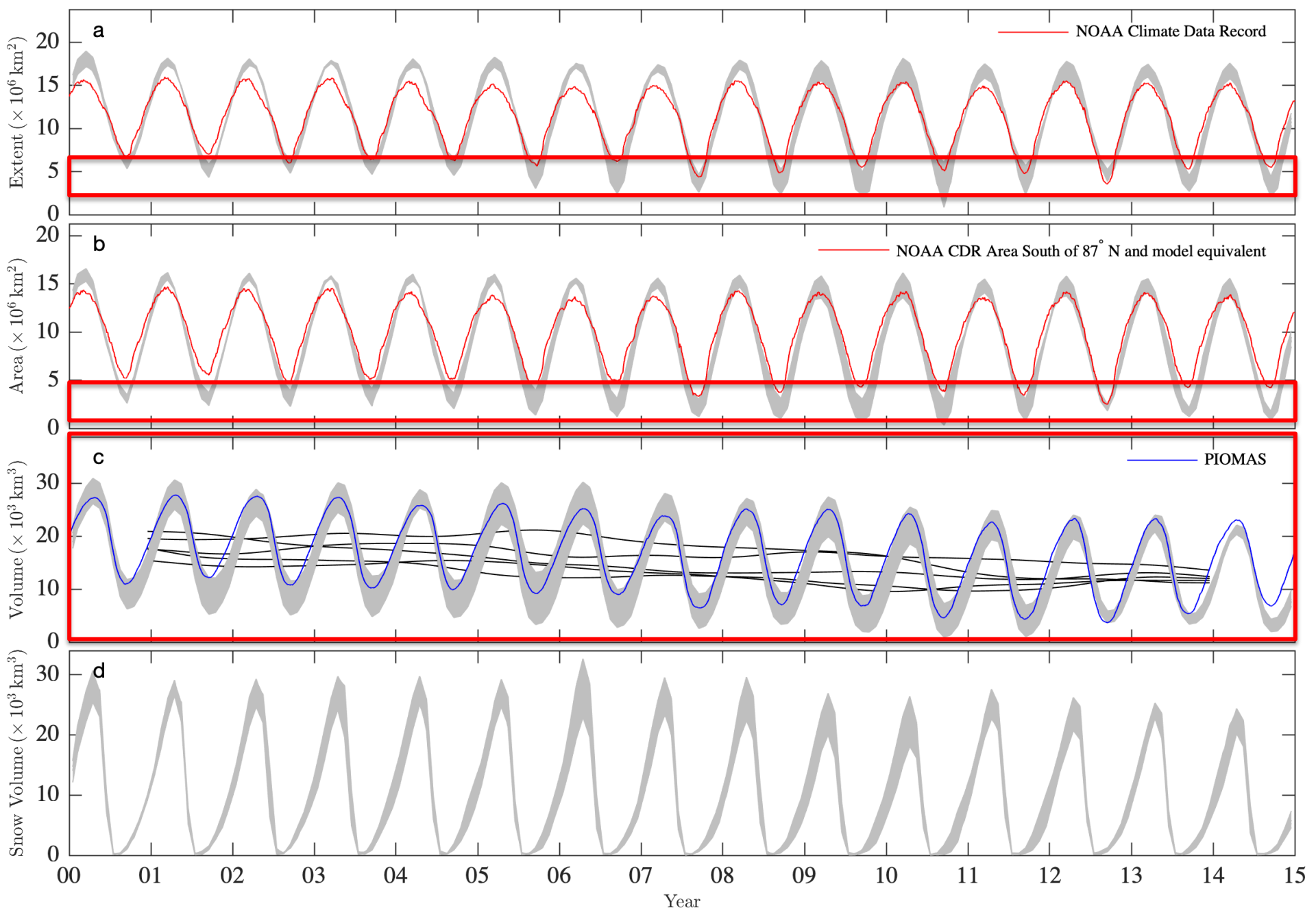
14
15
Year

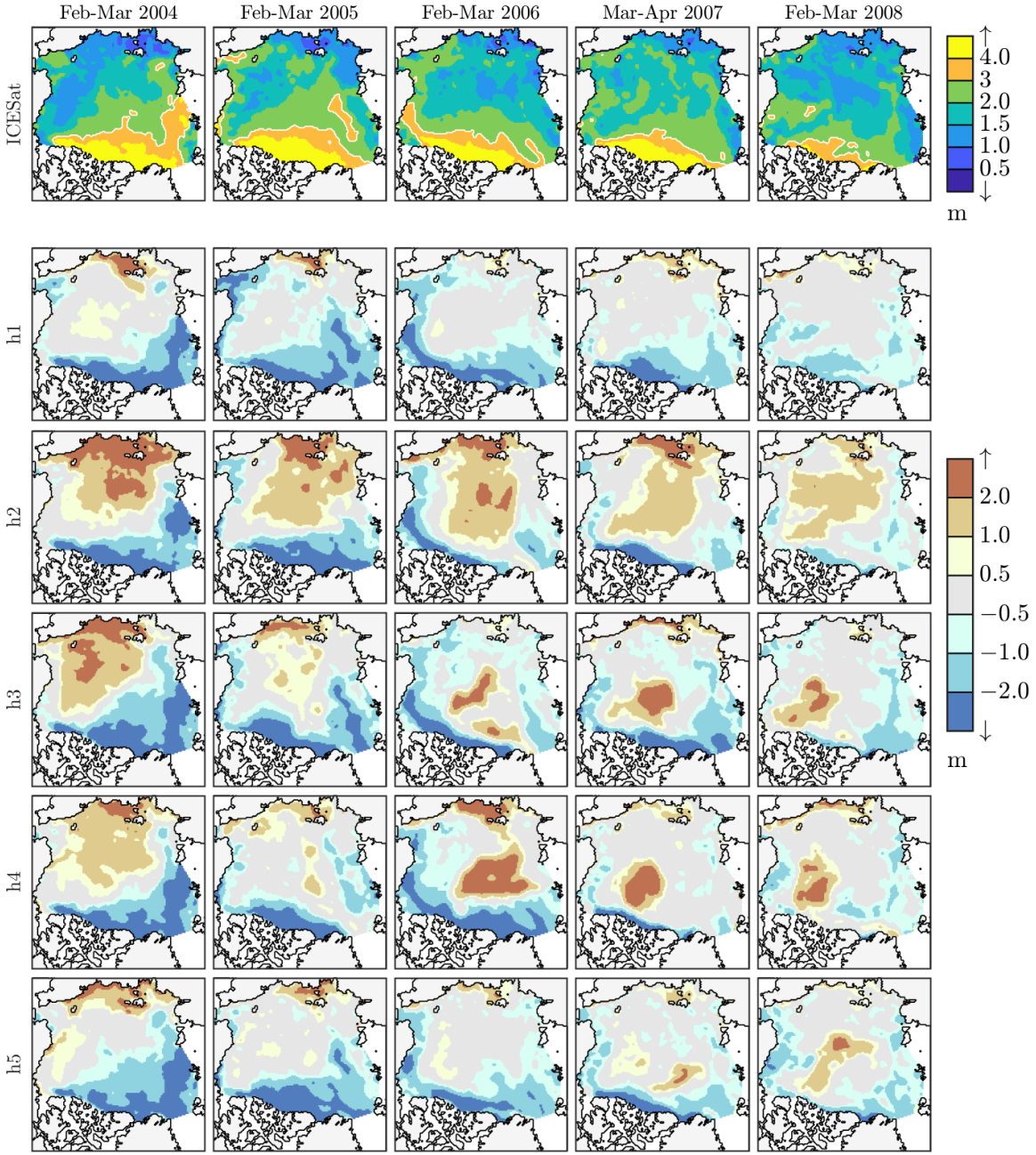
Bias: Labrador Sea



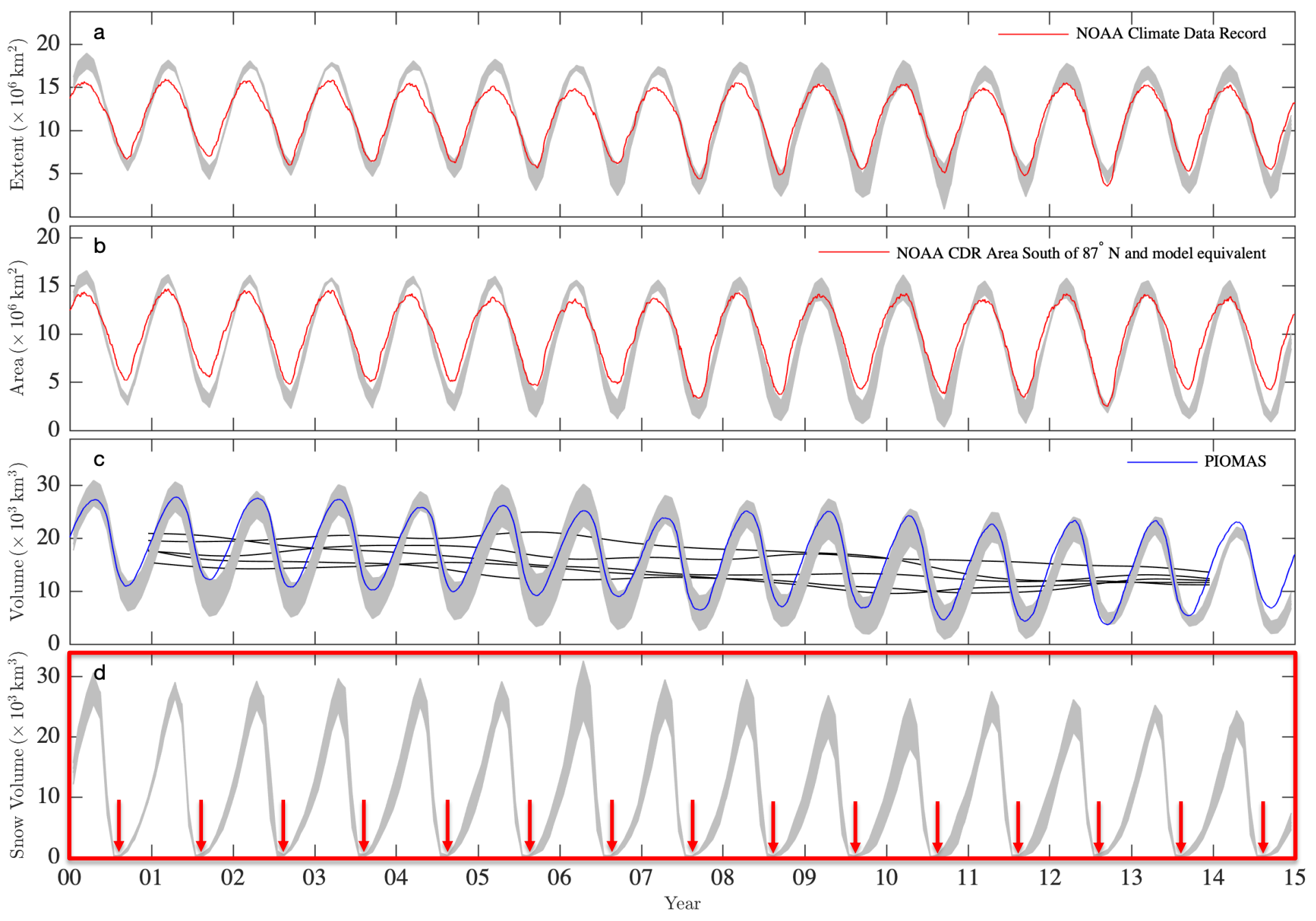
Bias: “Siberian Gyre”



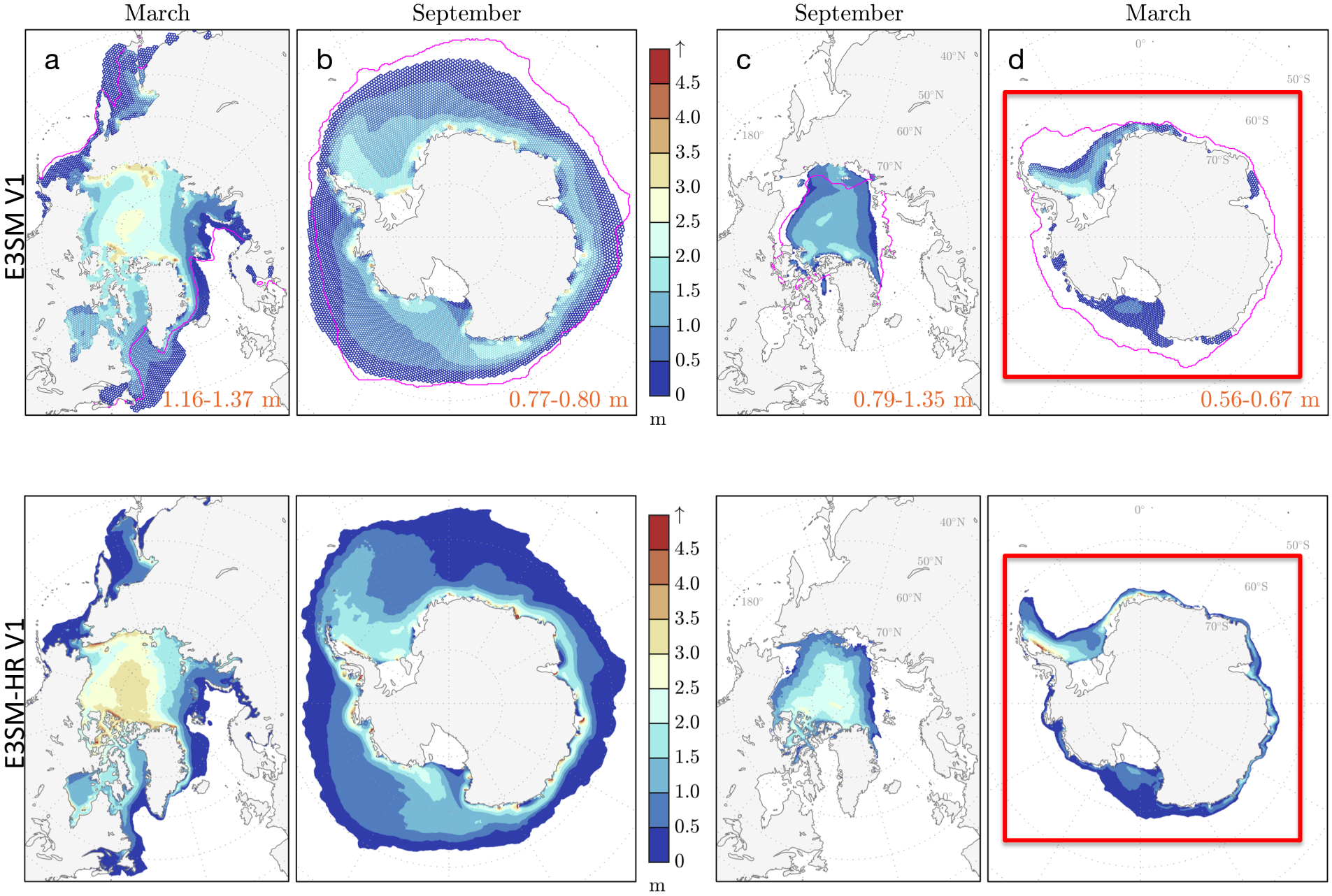
Spring thickness difference from Kwok and Cunningham (2008) on SSM/I mesh



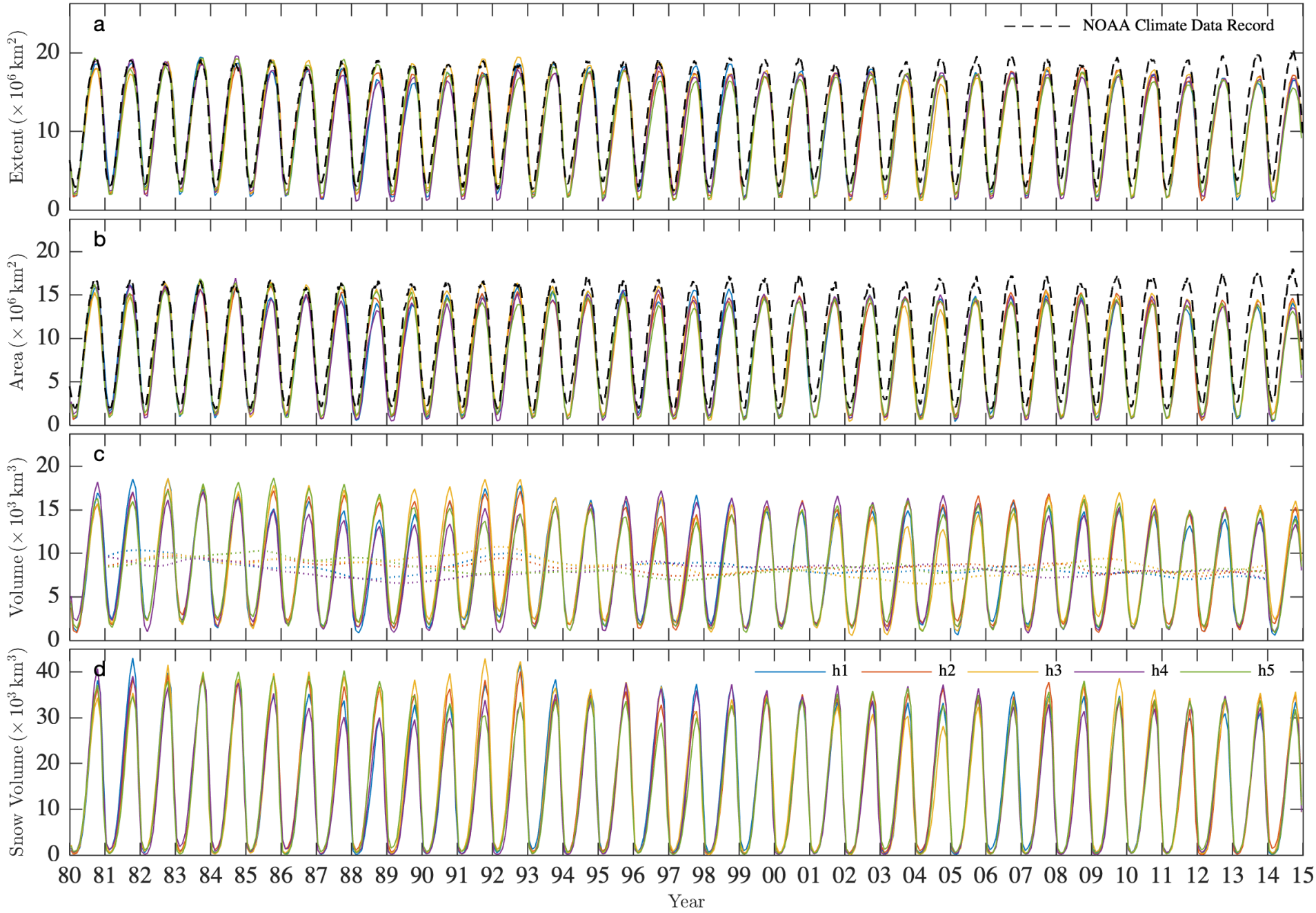
Bias in snow? We don't know

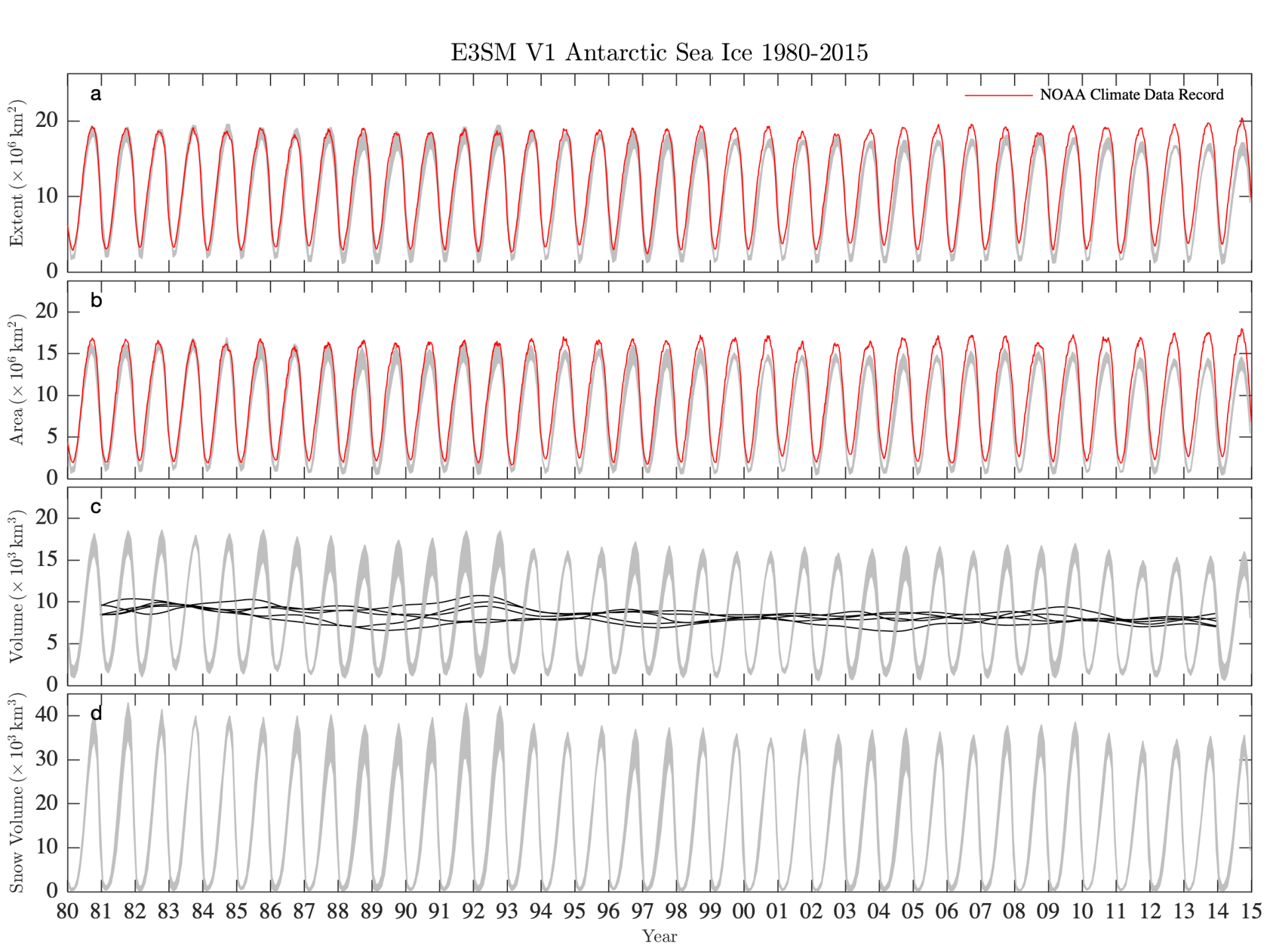


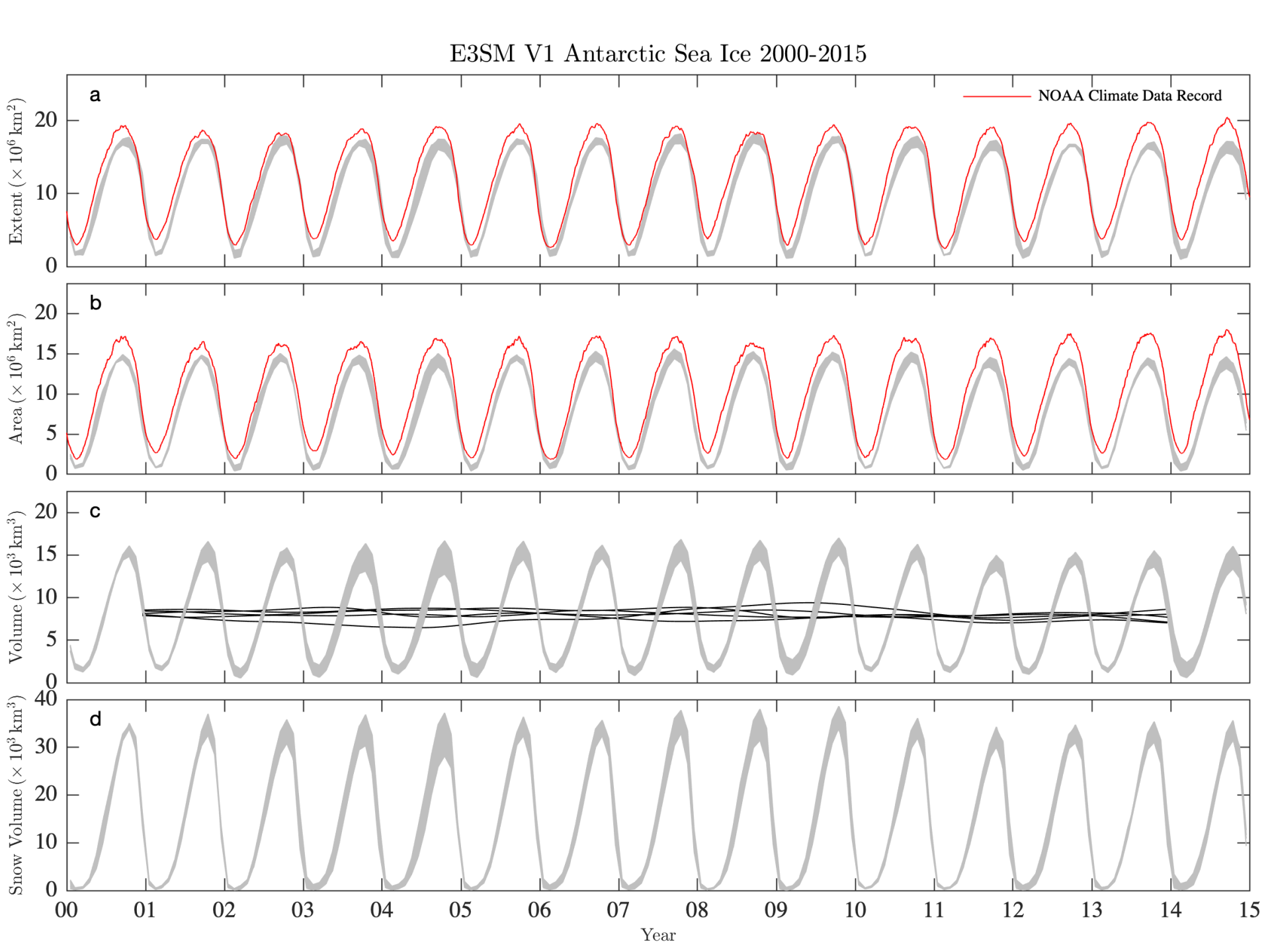
The Southern Ocean



The Southern Ocean




E3SM V1 Antarctic Sea Ice 1980-2015
a
NOAA Climate Data Record
Extent ($\times 10^6$ km^2)
0
10
20
b
Area ($\times 10^6$ km^2)
0
5
10
15
20
c
Volume ($\times 10^3$ km^3)
0
5
10
15
20
d
Snow Volume ($\times 10^3$ km^3)
0
10
20
30
40
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15
Year


E3SM V1 Antarctic Sea Ice 2000-2015
a
NOAA Climate Data Record
Extent ($\times 10^6$ km^2)
0
10
20
b
Area ($\times 10^6$ km^2)
0
5
10
15
20
c
Volume ($\times 10^3$ km^3)
0
5
10
15
20
d
Snow Volume ($\times 10^3$ km^3)
0
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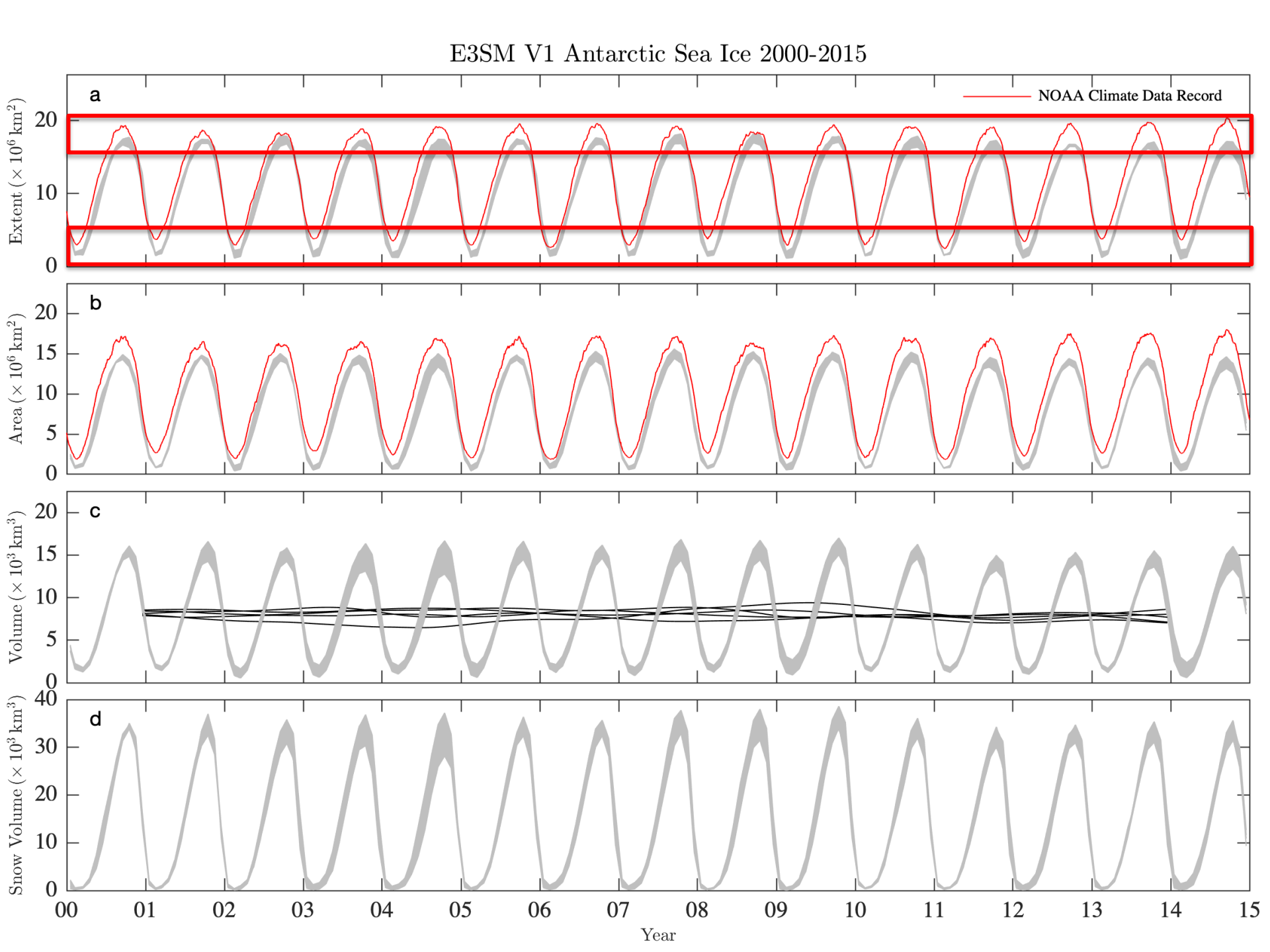
Year


E3SM V1 Antarctic Sea Ice 2000-2015
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0
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Area ($\times 10^6$ km^2)
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Volume ($\times 10^3$ km^3)
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Snow Volume ($\times 10^3$ km^3)
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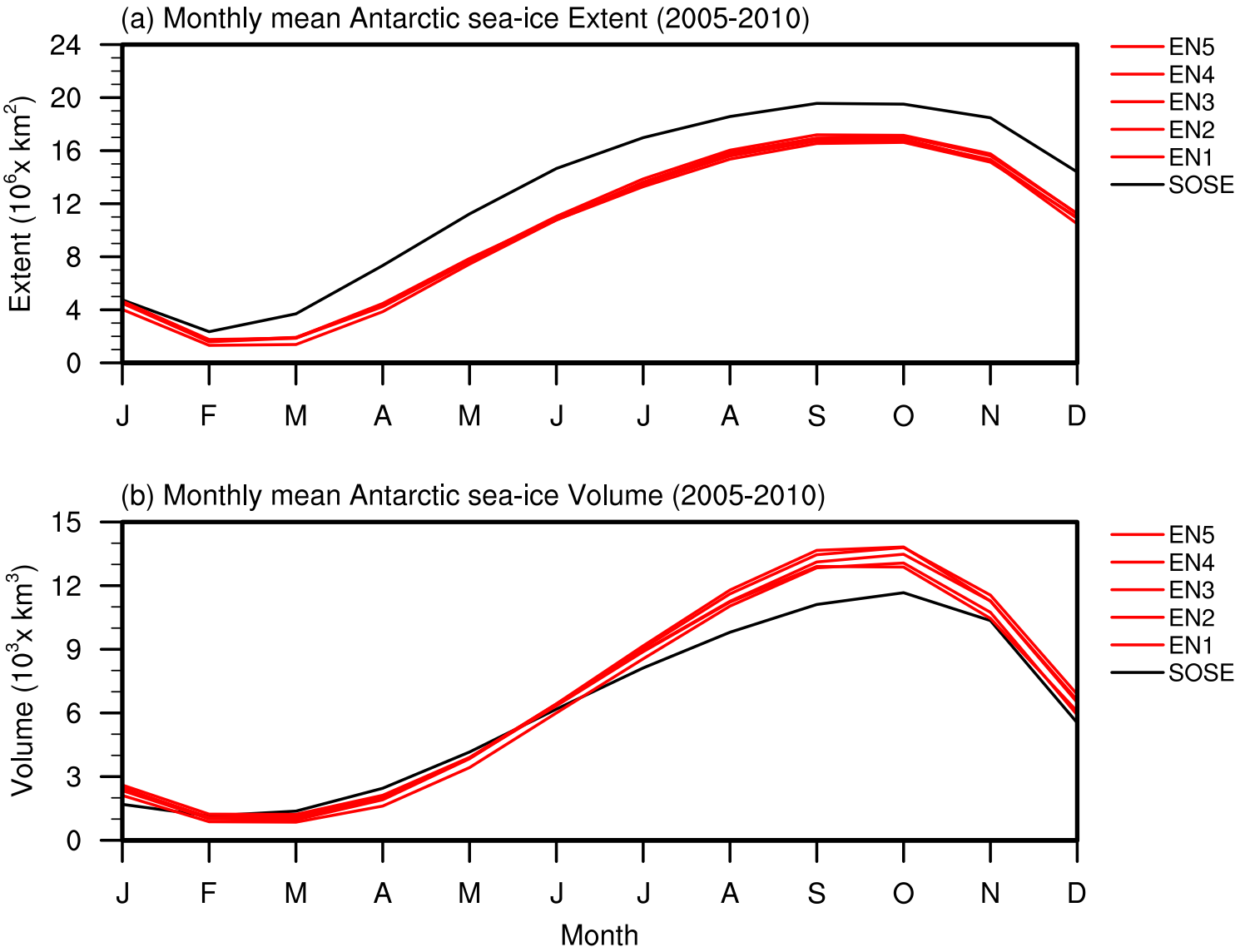
Year

Hyein Jeong

Comparison with the Southern Ocean State Estimate (SOSE)

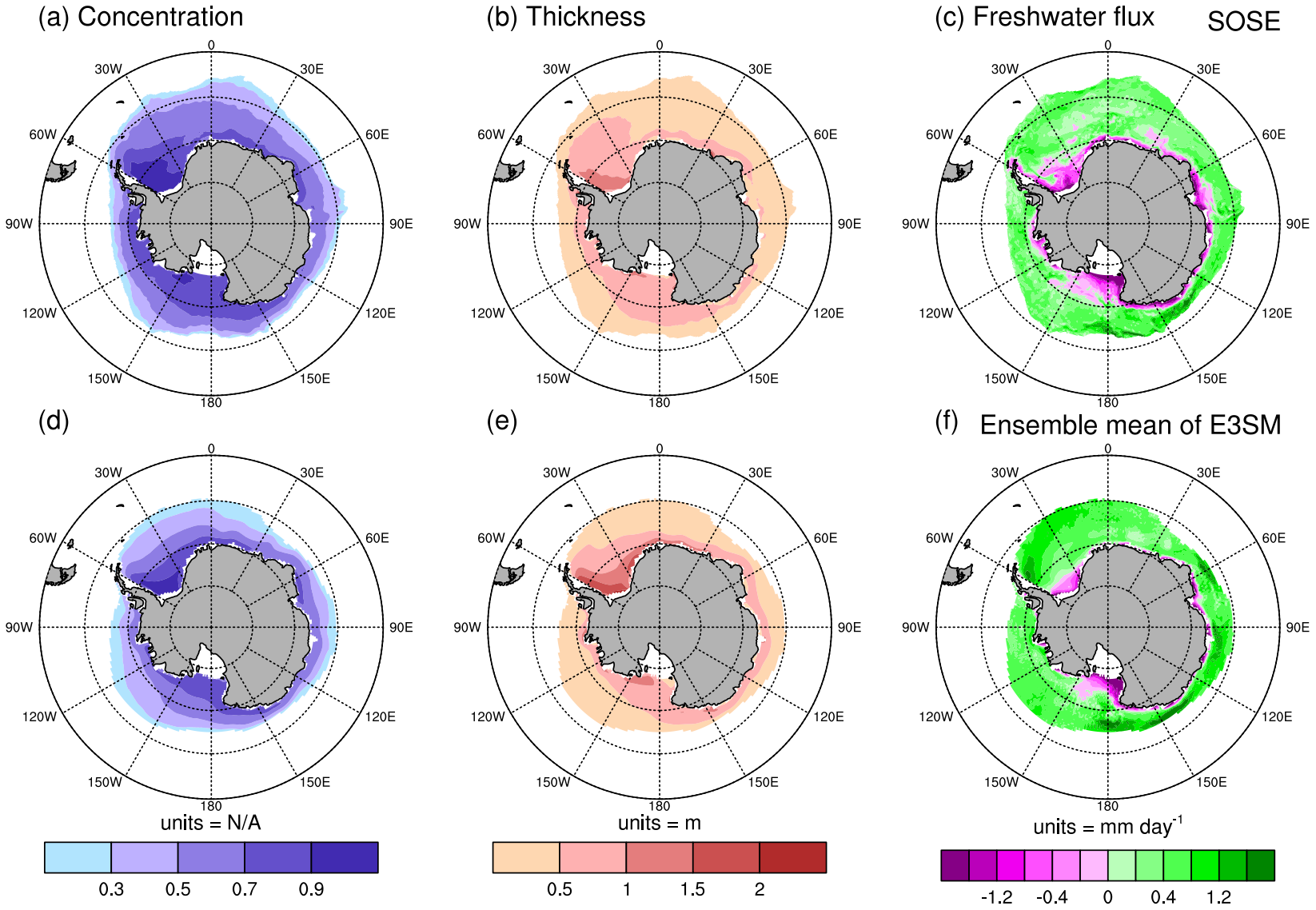


Comparison with the Southern Ocean State Estimate (SOSE)

Hyein Jeong

Comparison with the Southern Ocean State Estimate (SOSE)

Annual Mean



V2 steps to help fix the sea ice bias

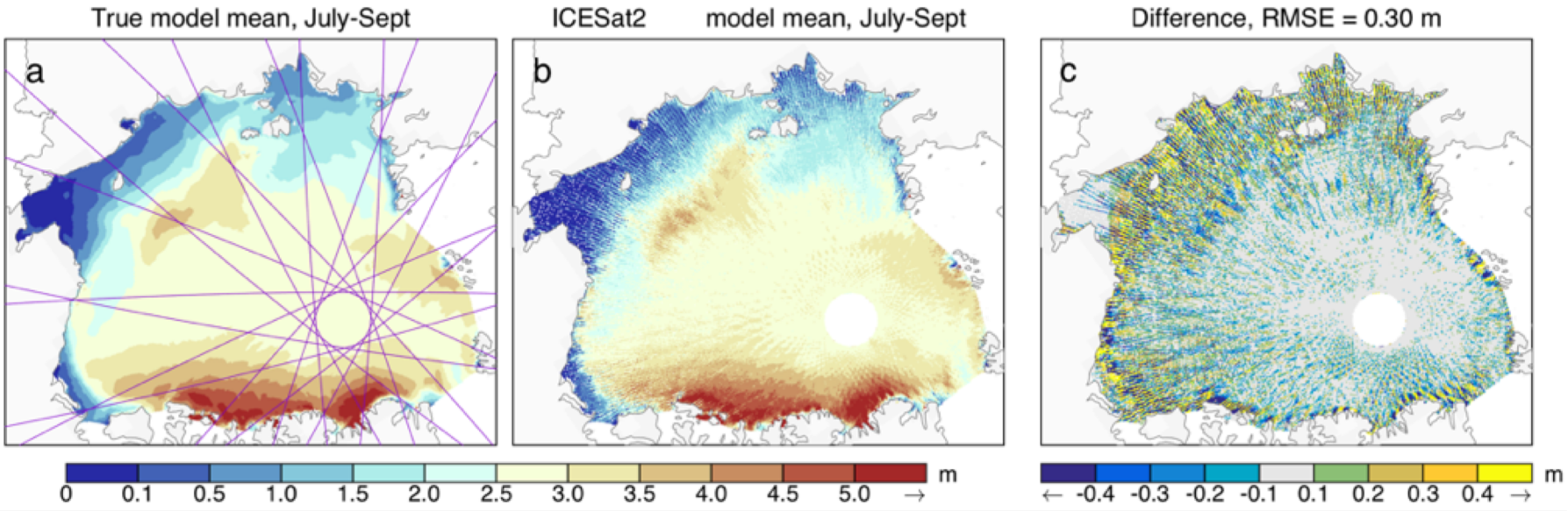
- Nicole Jeffery, Elizabeth Hunke: Snow on sea ice
- Cheng Dang, Charlie Zender: New radiative coupling
- Fix the ice-ocean freezing temperature coupling (major issue)
- Refine the coastline

Steps to understand and improve bias

- Luke Van Roekel: Mixing
- Andrew Roberts, Elizabeth Hunke, Adrian Turner: Morphology
- Phillip Wolfram: Waves
- Analysis using emulators rather than gridded measurements

One final note…

View of a model from a 91-day repeat ICESat-2 orbit



Observational gridded data is just as fallible as our model.