SEASONAL TRANSITIONS OF ARCTIC SEA ICE OVER THE SATELLITE ERA IN CMIP6 MODELS

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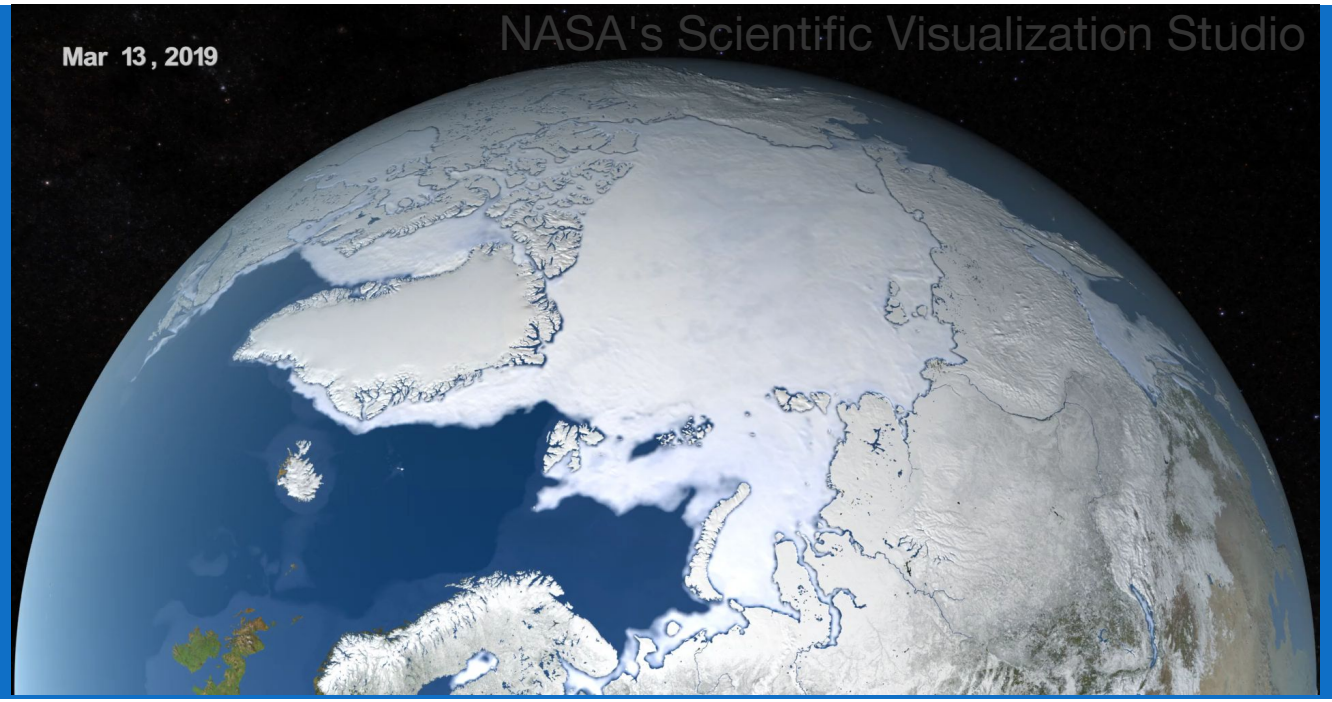
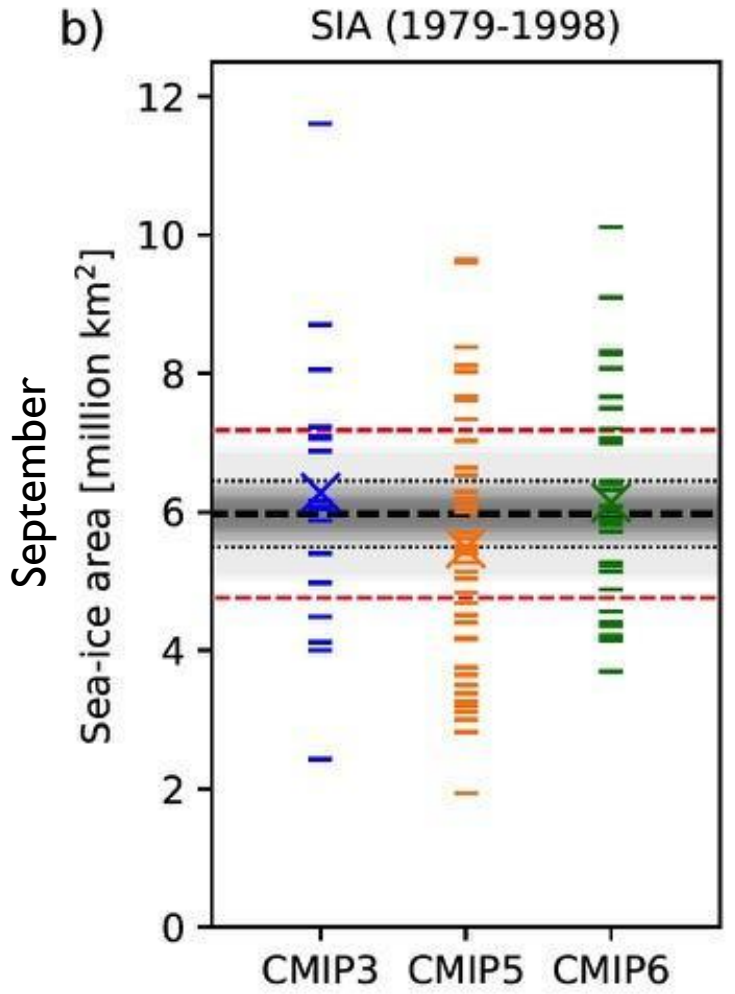


Seasonal sea ice transitions may help us understand the model spread

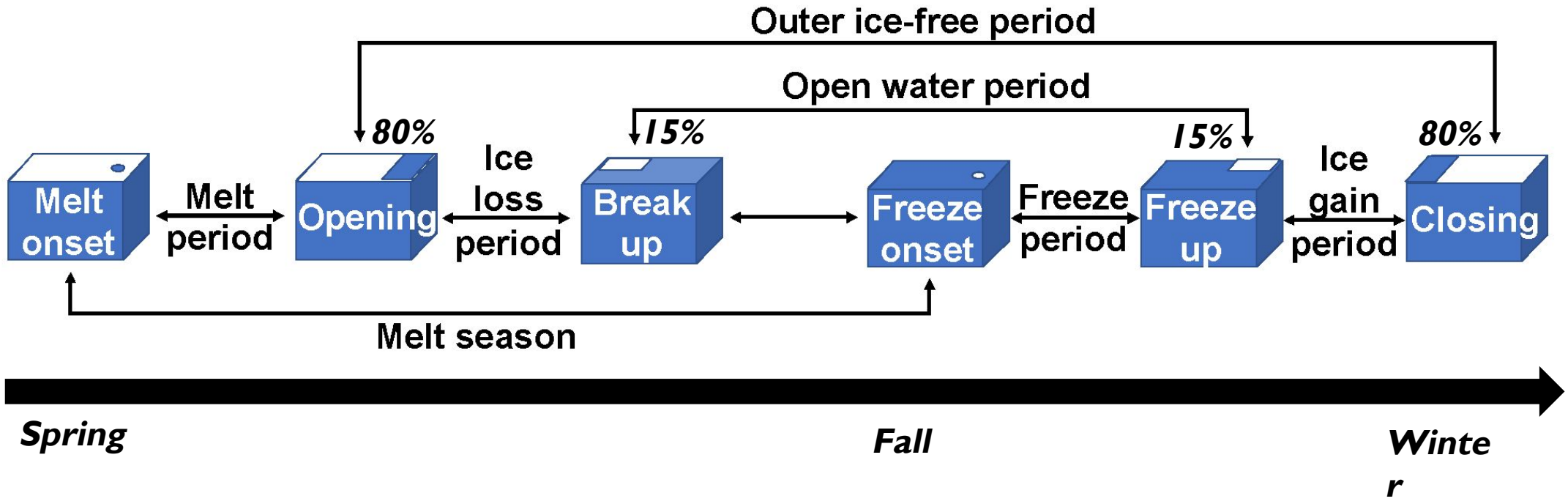
- Large model spread in CMIP3, CMIP5 and CMIP6 (on the order of millions of square kilometers)
- Trends in sea ice melt season are related to trends in September sea ice extent (Smith and Jahn, 2019)



SIMIP Community, submitted to *GRL*

Many definitions for describing seasonal sea ice changes in the Arctic

Smith et al., in prep



Objective: Use a range of data products to investigate when and where thermodynamic processes may relate to sea ice biases in climate models

Data and methods

Models

- **CMIP6 models**
  - 8 models: BCC-CSM2-MR, BCC-ESM, CESM2, CESM2-WACCM, CNRM-ESM2-1, CNRM-CM6-1, CanESM5, IPSL-CM6A-LR
  - Historical radiative forcing 1979-2014
- **CESM Large Ensemble**
  - 40 member ensemble
  - Historical radiative forcing scenario from 1979-2005 and RCP8.5 from 2006-2014 (Kay et al, 2015)

Satellite observations

- Arctic Sea Ice Seasonal Change and Melt/Freeze Climate Indicators from Satellite Data, Version 1 from 1979-2014 (Steele et al., 2019)

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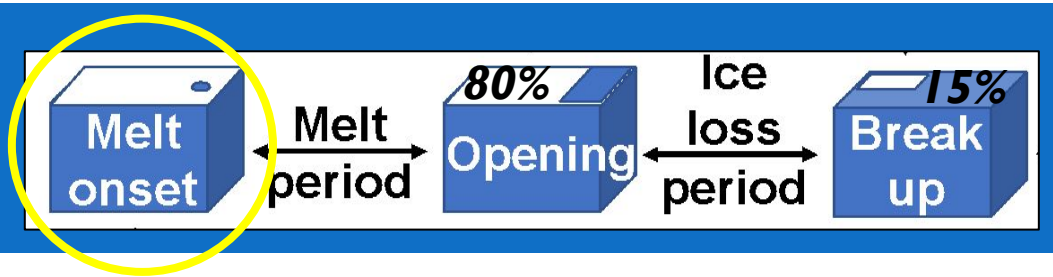
Melt and freeze onset dates derived using surface temperature of ice (Smith and Jahn, 2019)

Satellite observations

- Arctic Sea Ice Seasonal Change and Melt/Freeze Climate Indicators from Satellite Data, Version 1 from 1979-2014 (Steele et al., 2019)

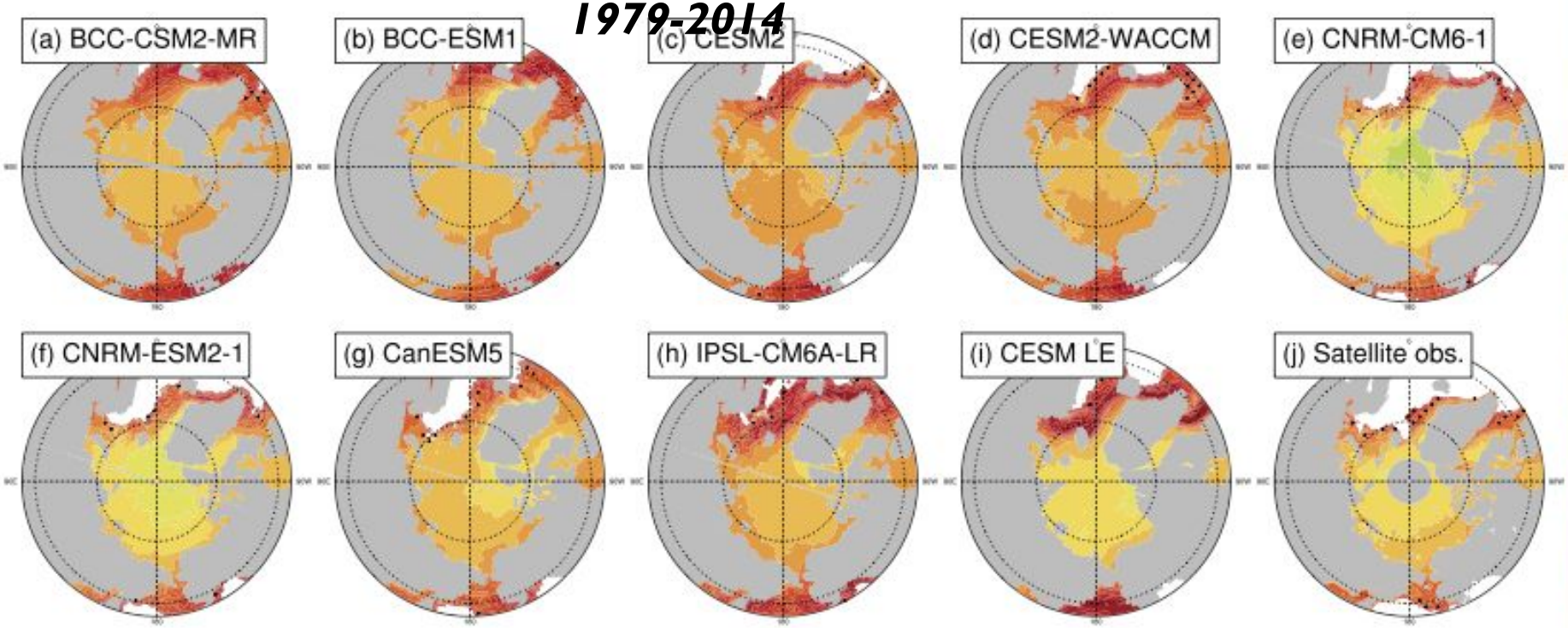
Melt and freeze onset dates derived using passive microwave brightness temperatures (Markus et al., 2009, Stroeve et al., 2014)

Melt onset



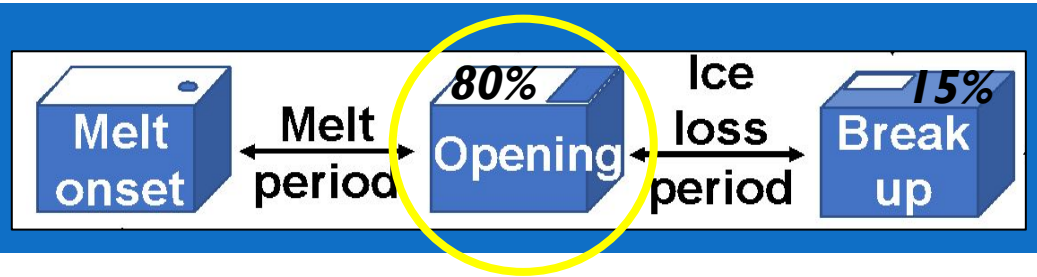
- Median melt onset dates range from April 30-June 1
- Model spread in medians: **35 days**

Mean melt onset dates 1979-2014



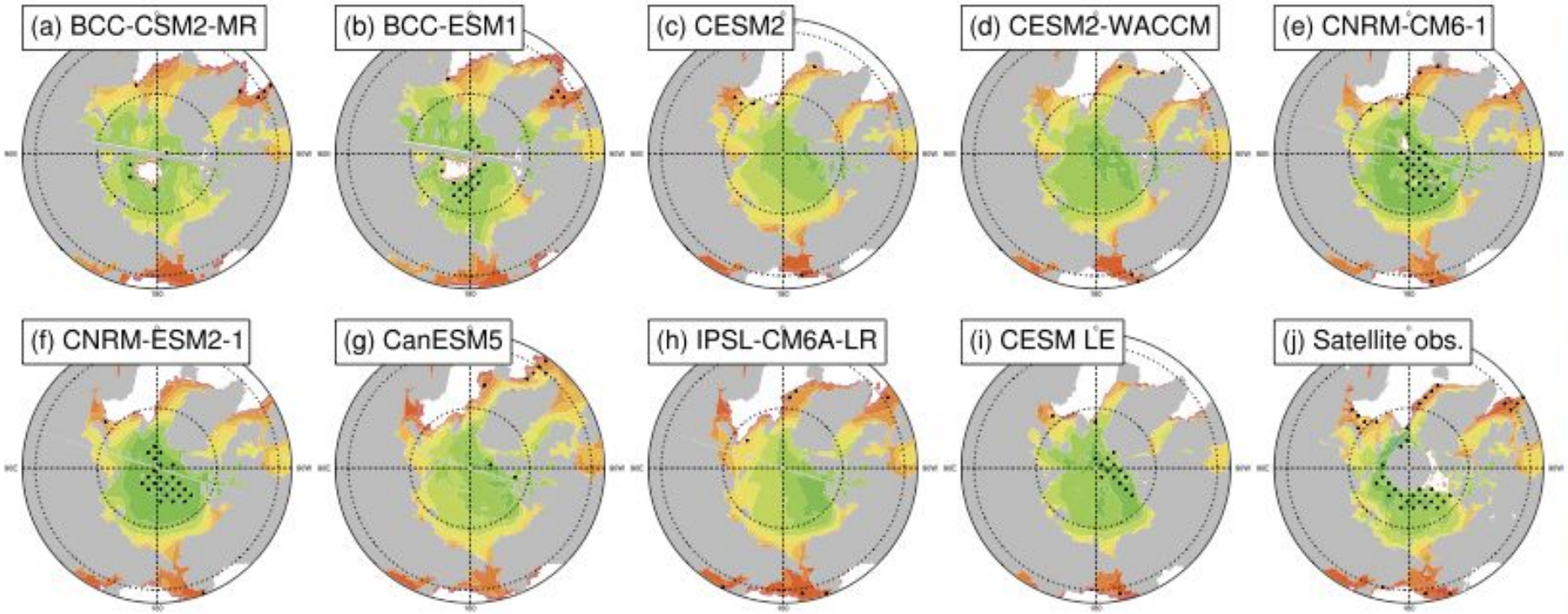
Smith et al., in prep

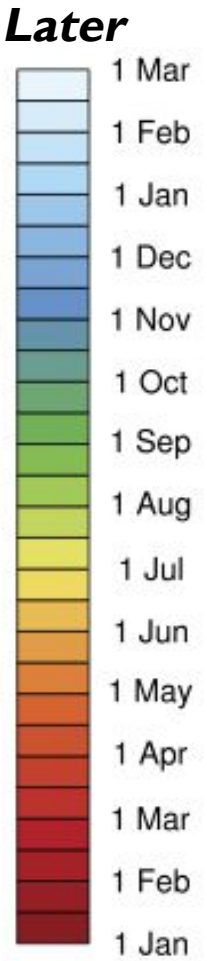
Opening



- Median opening dates range from June 24-July 7
- Model spread in medians: **15 days**

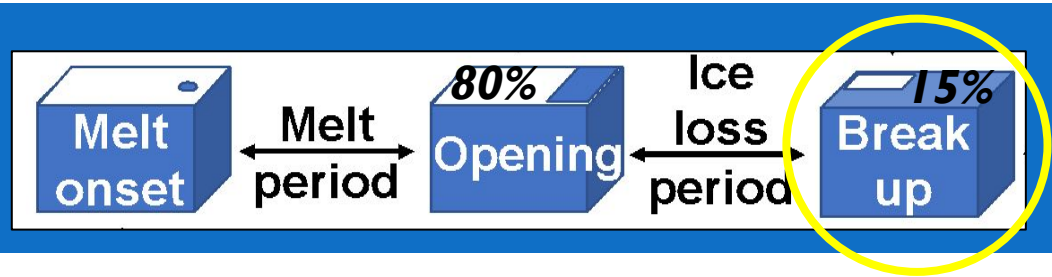
Mean opening dates 1979-2014





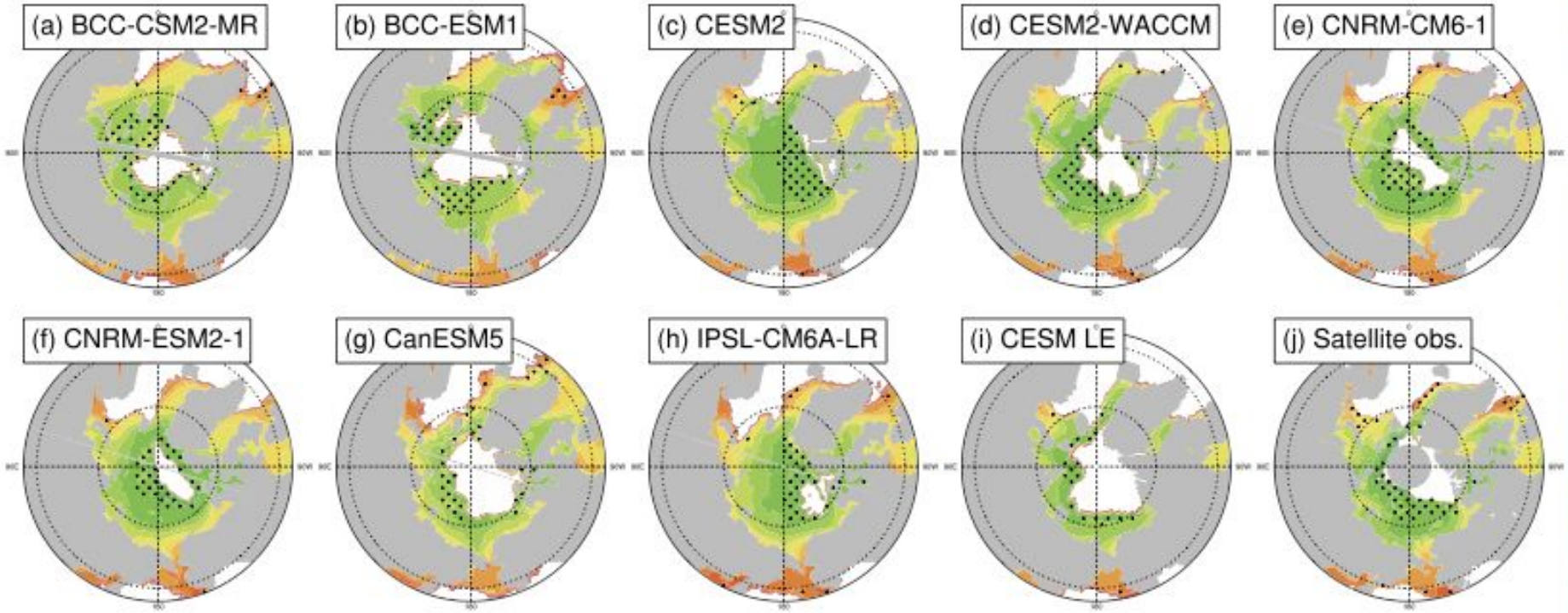
Smith et al., in prep

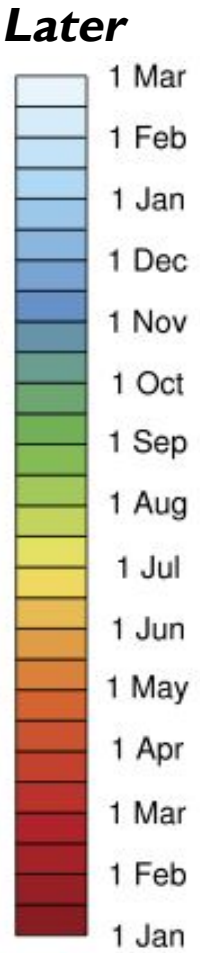
Break-up



- Median break-up dates range from July 7-July 23
- Model spread in medians: **16 days**

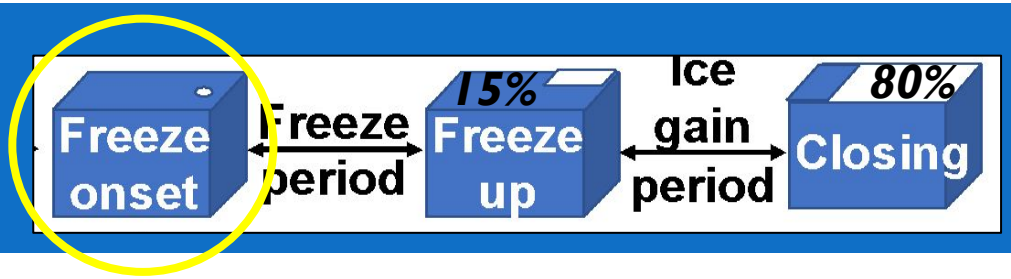
Mean break-up dates 1979-2014





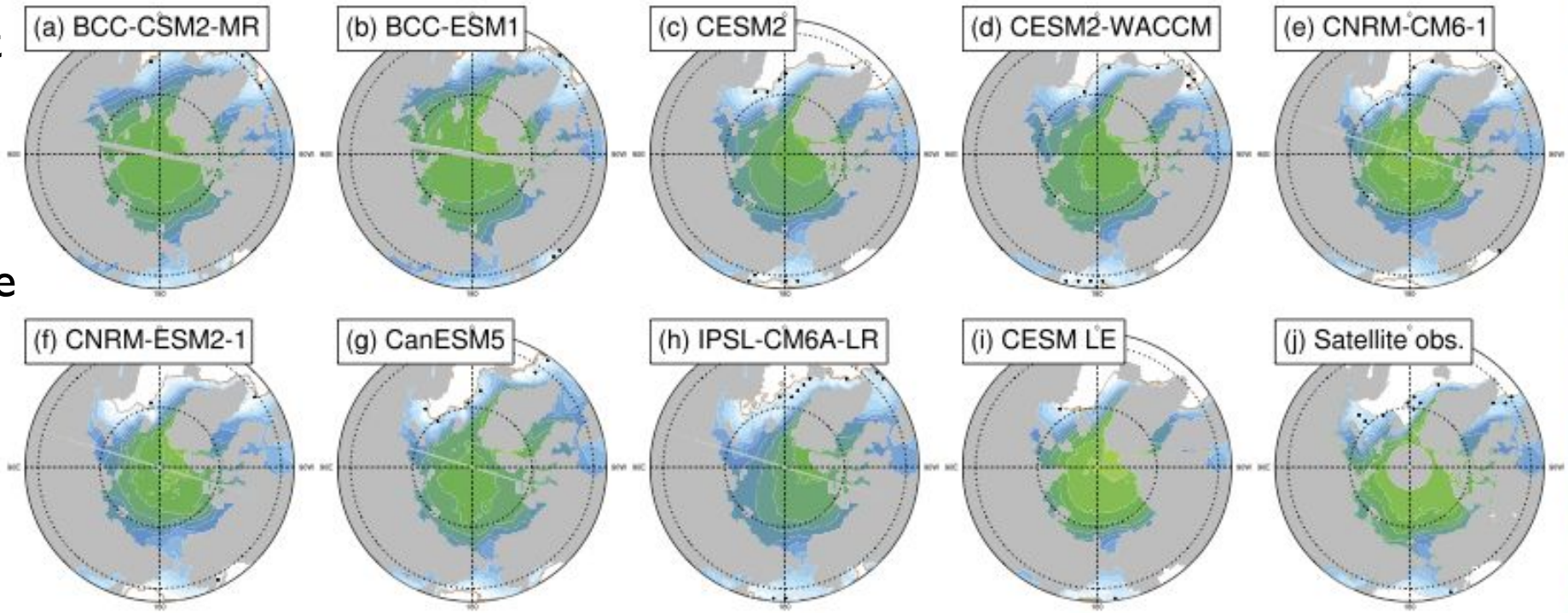
Smith et al., in prep

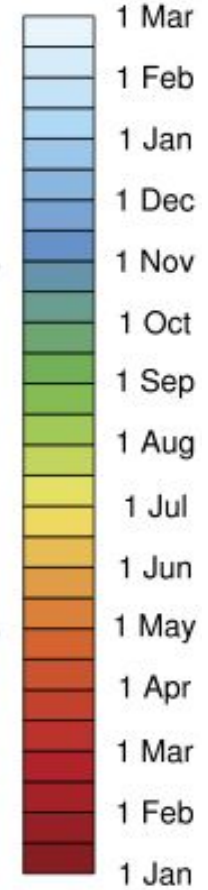
Freeze onset



- Median freeze onset dates range from October 16-November 19
- Model spread in medians: **34 days**

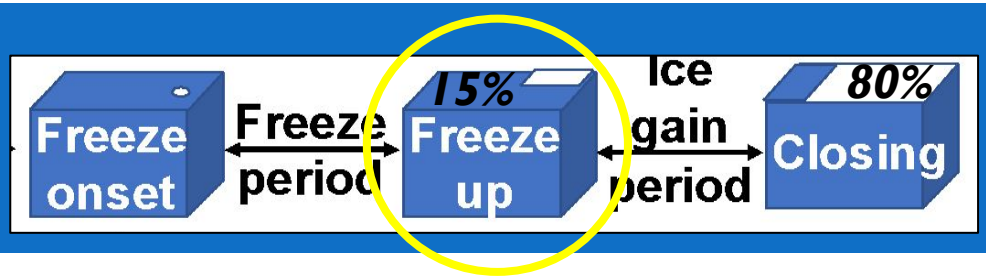
Mean freeze onset dates 1979-2014





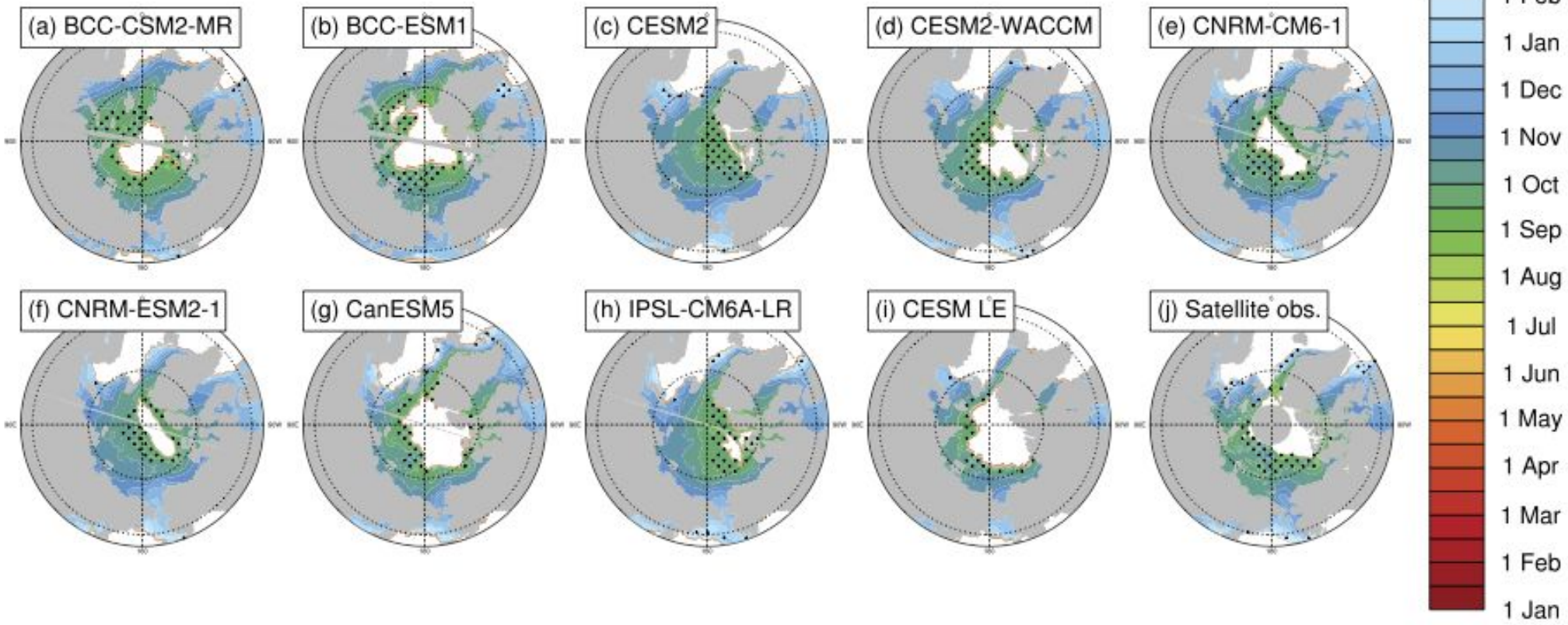
Smith et al., in prep

Freeze-up



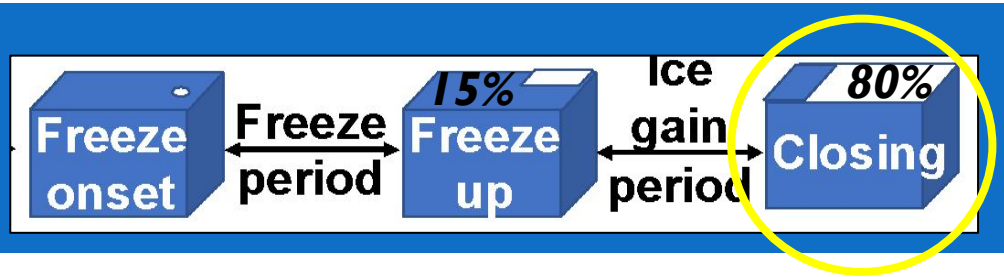
- Median freeze-up dates range from October 24-November 9
- Model spread in medians: **16 days**

Mean freeze-up dates 1979-2014



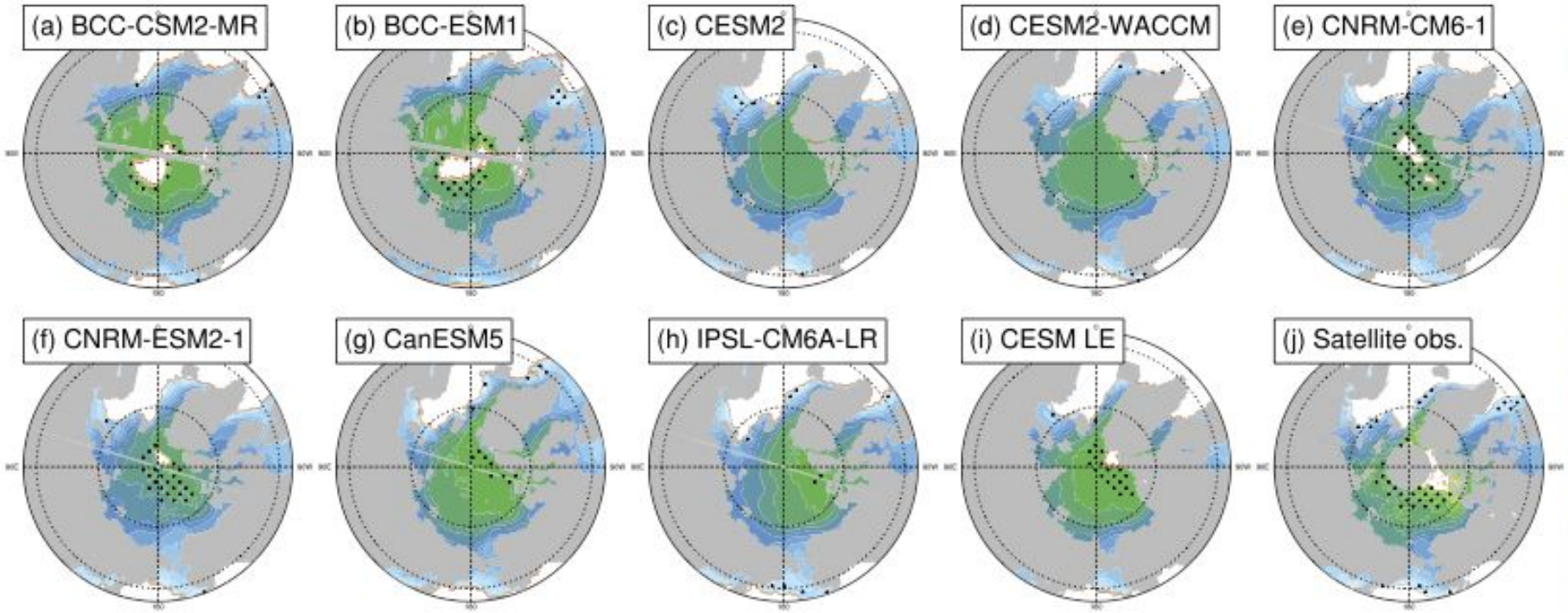
Smith et al., in prep

Closing



- Median closing dates range from October 17-November 16
- Model spread in medians: **31 days**

Mean closing dates 1979-2014



Smith et al., in prep

Model spread exceeds internal variability for all transition dates

- Differences between climate model representations of seasonal sea ice transitions are likely not due to internal variability alone

	Melt onset	Opening (80%)	Break-up (15%)	Freeze onset	Freeze-up (15%)	Closing (80%)
BCC-CSM2-MR	May 10	Jul 2	Jul 15	Oct 31	Oct 24	Oct 26
BCC-ESM1	May 14	Jul 6	Jul 17	Oct 25	Oct 27	Oct 26
CESM2	May 12	Jun 29	Jul 22	Nov 7	Nov 6	Nov 7
CESM2-WACCM	May 11	Jul 5	Jul 23	Nov 5	Nov 5	Nov 2
CNRM-ESM2-1	Jun 1	Jul 7	Jul 16	Nov 11	Nov 9	Nov 16
CNRM-CM6-1	Jun 4	Jul 7	Jul 17	Nov 5	Nov 5	Nov 11
CanESM5	May 24	Jun 29	Jul 9	Nov 3	Nov 2	Nov 2
IPSL-CM6A-LR	Apr 30	Jun 21	Jul 7	Nov 19	Nov 7	Nov 9
CESM LE	May 2	Jul 4	Jul 17	Oct 16	Oct 25	Oct 17
Satellite data	May 23	Jun 24	Jul 14	Oct 10	Oct 21	Oct 22
Model spread (days)	35	15	16	34	16	31

Model spread

Estimations of internal variability (models with at least 30 members)

	Melt onset	Opening (80%)	Break-up (15%)	Freeze onset	Freeze-up (15%)	Closing (80%)
CanESM5	3	4	5	4	5	8
IPSL-CM6A-LR	7	5	4	9	6	10
CESM LE	4	5	7	5	6	5

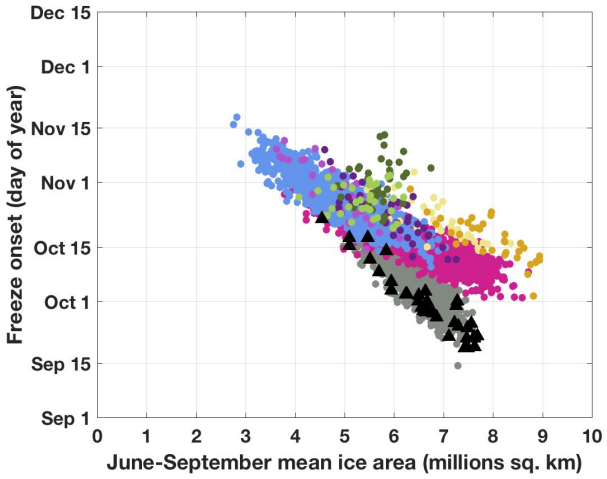
Smith et al., in prep

Relationships exist between seasonal transitions and other ice characteristics (area, thickness)

Smith et al., in prep

- Out of the six transition dates, melt and freeze onset show the strongest relationships with ice area and mean thickness
- Melt and freeze onset affect sea ice year-round through the ice-albedo feedback

Satellite obs.
CESM LE
BCC-C2M2-MR
BCC-ESM1
CESM2
CESM2-WACCM
CNRM-CM6-1
CNRM-ESM2-1
CanESM5
IPSL-CM6A-LR



Low summer ice area

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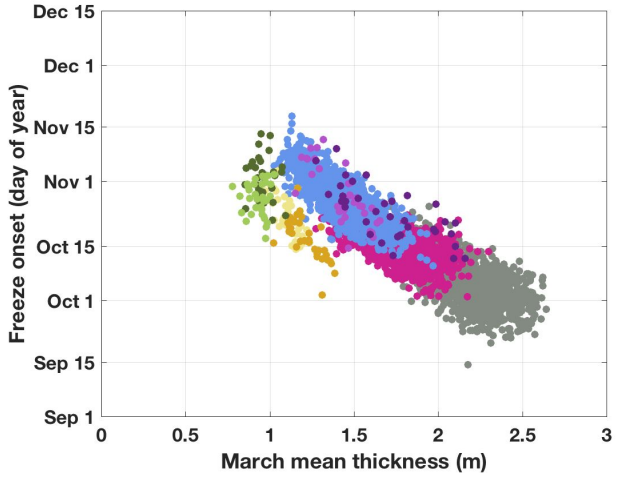
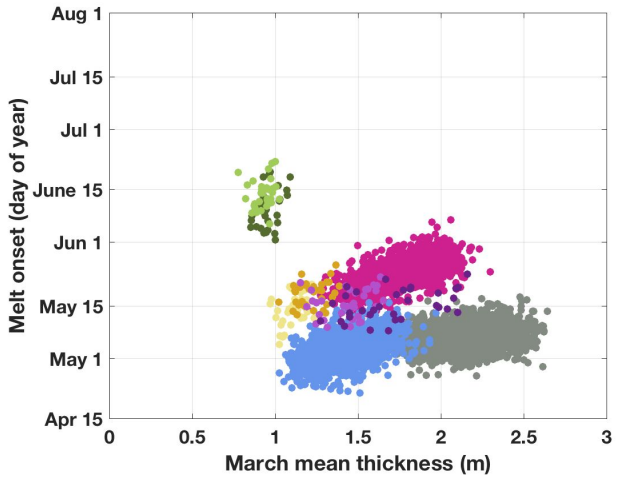
Later freeze onset



Later freeze onset

↓

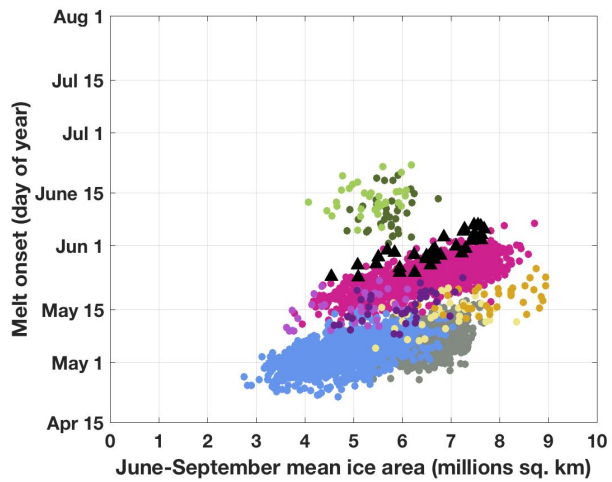
Lower March thickness



Lower March thickness

↓

Earlier melt onset



Earlier melt onset

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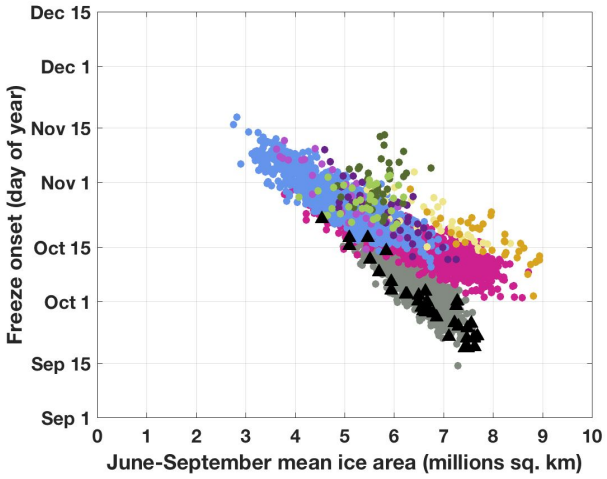

Low summer ice area

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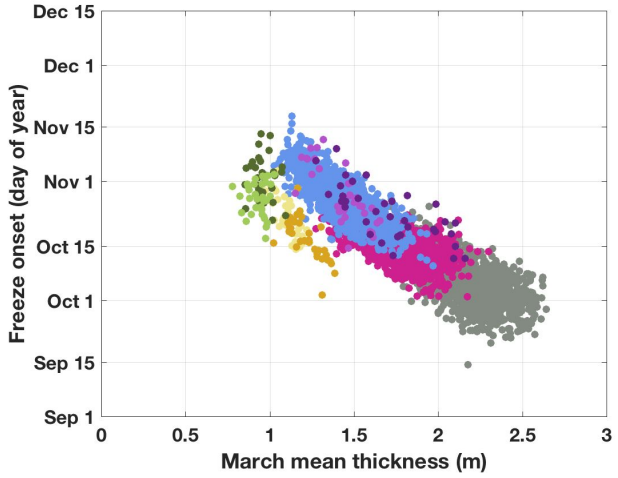
Later freeze onset



Later freeze onset

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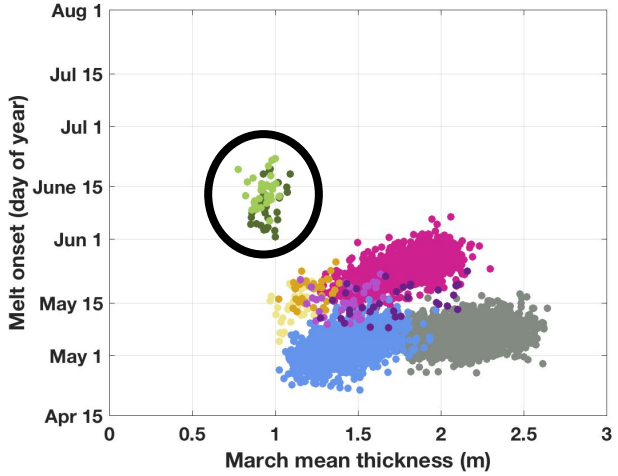
Lower March thickness



Lower March thickness

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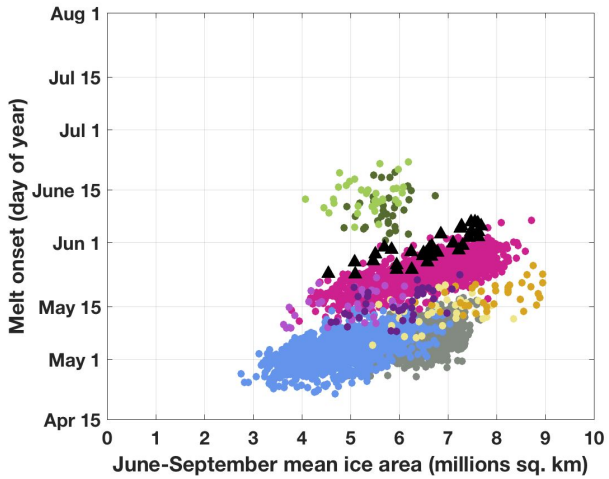
Earlier melt onset



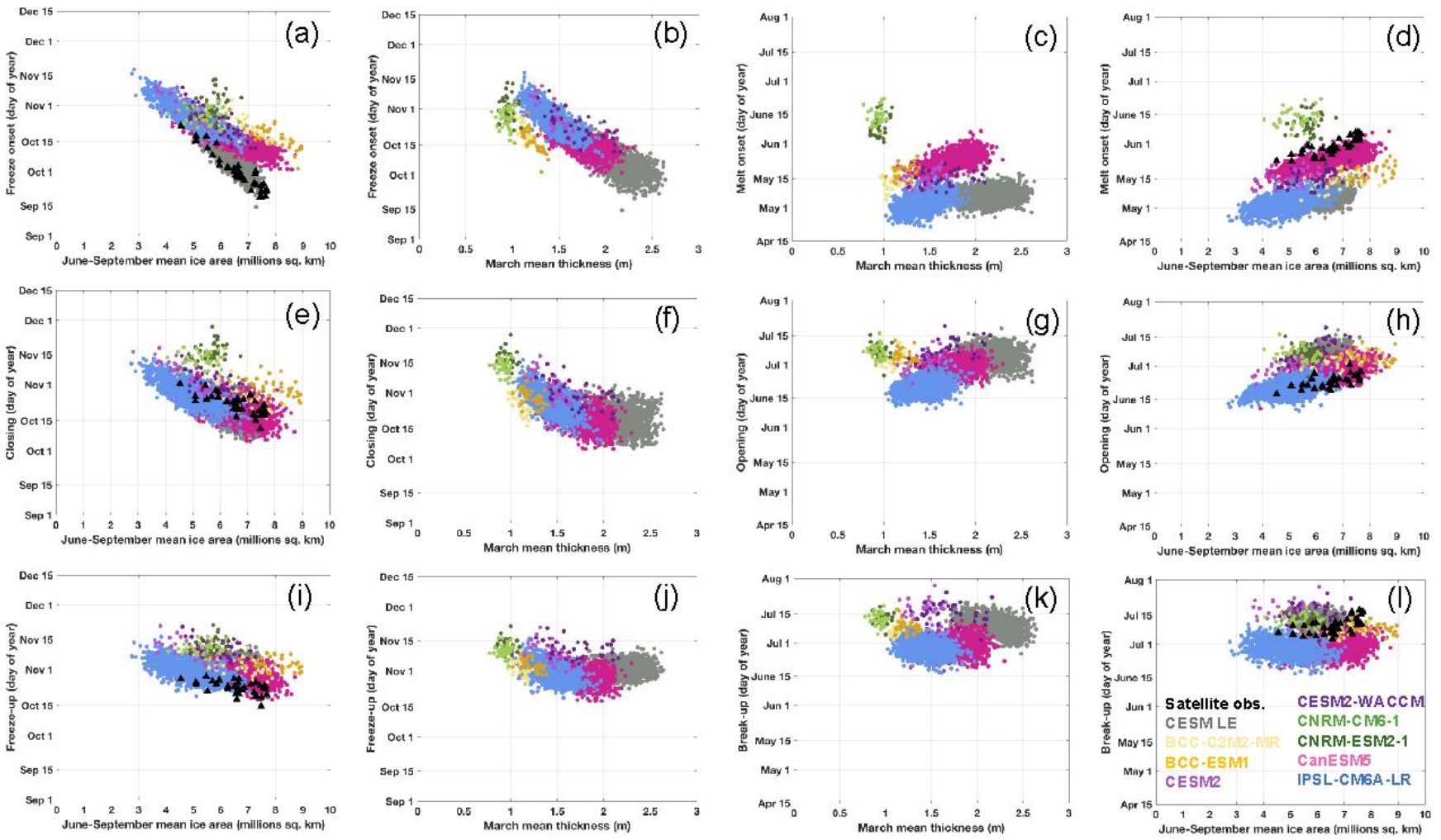
Earlier melt onset

↓

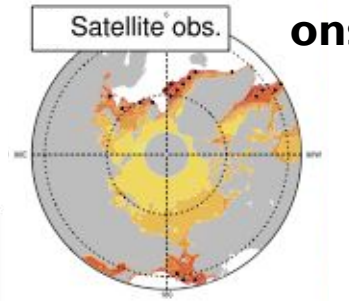
Lower summer ice area

Spatial coverage matters for describing pan-Arctic relationships

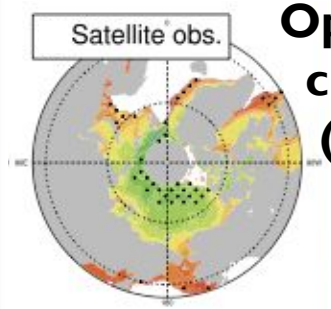
Smith et al., in prep



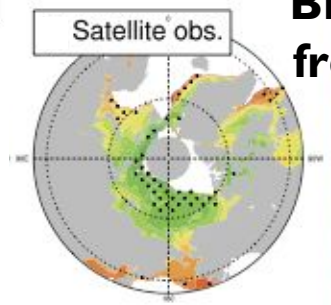
Decreasing spatial coverage



Melt/freeze onset



Opening/ closing (80%)



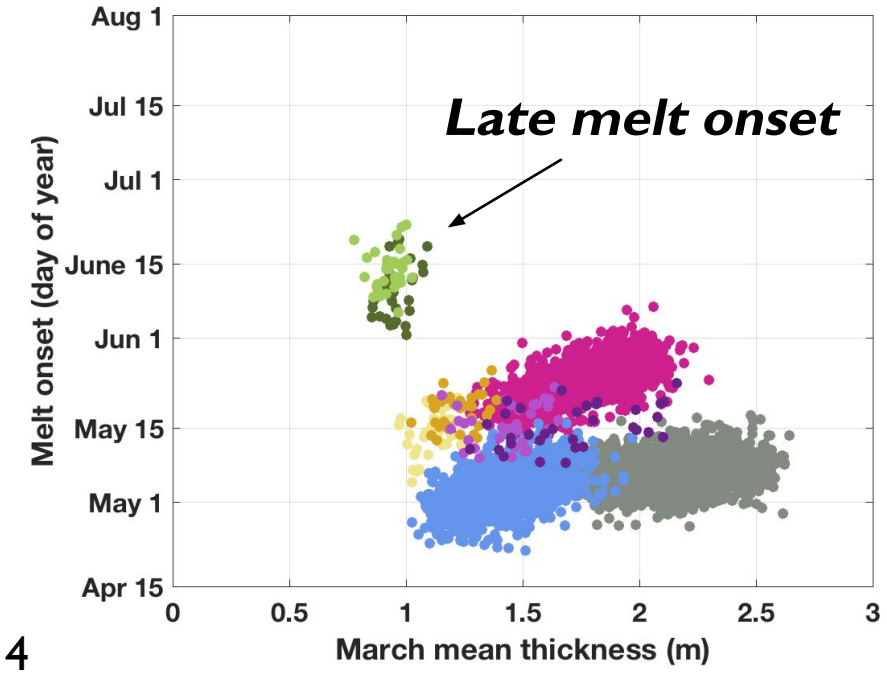
Break-up/ freeze-up (15%)

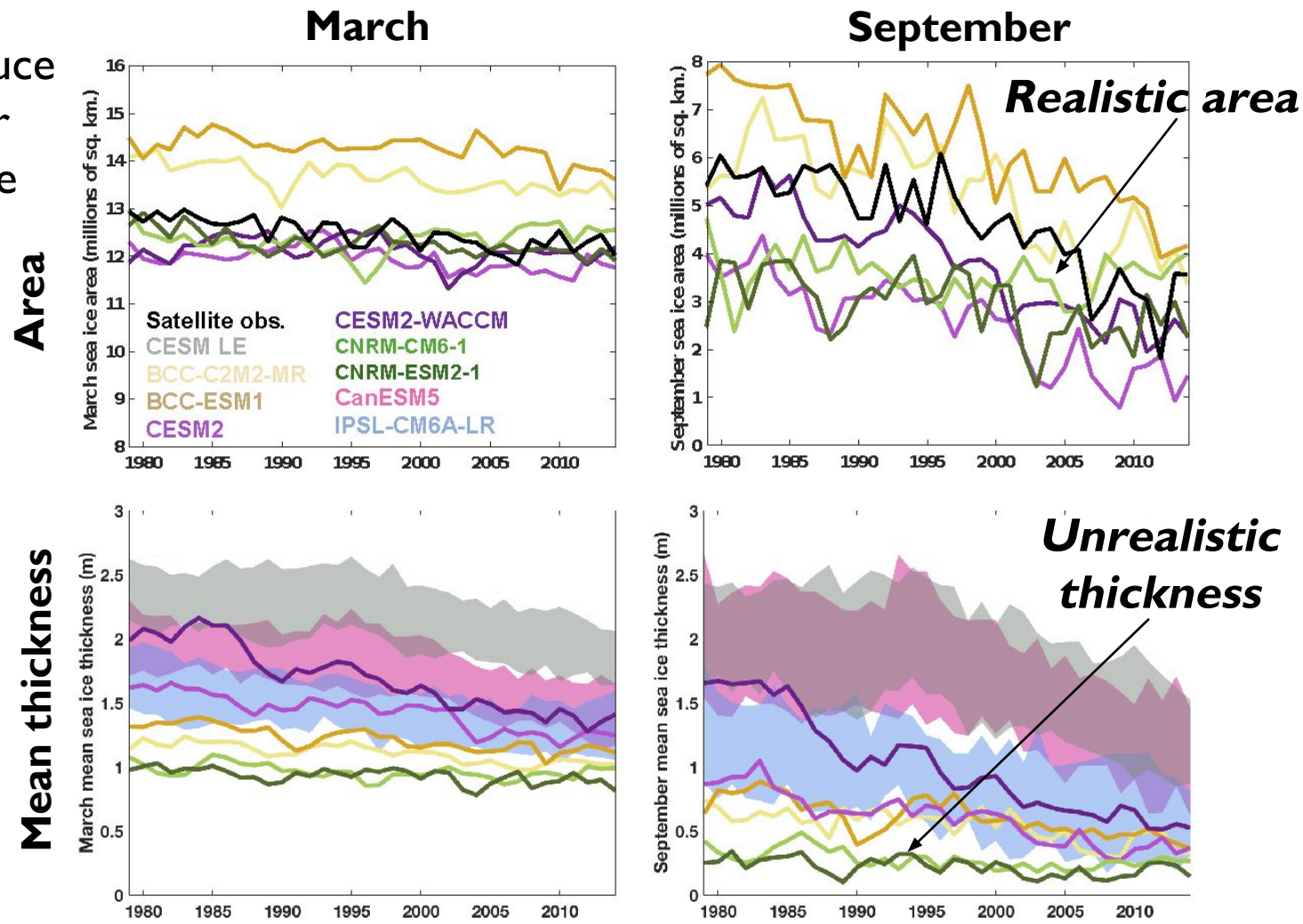
Seasonal transitions can compensate for other unrealistic aspects of simulated sea ice

Smith et al., in prep

Late melt onset retains thin ice that would otherwise disappear.

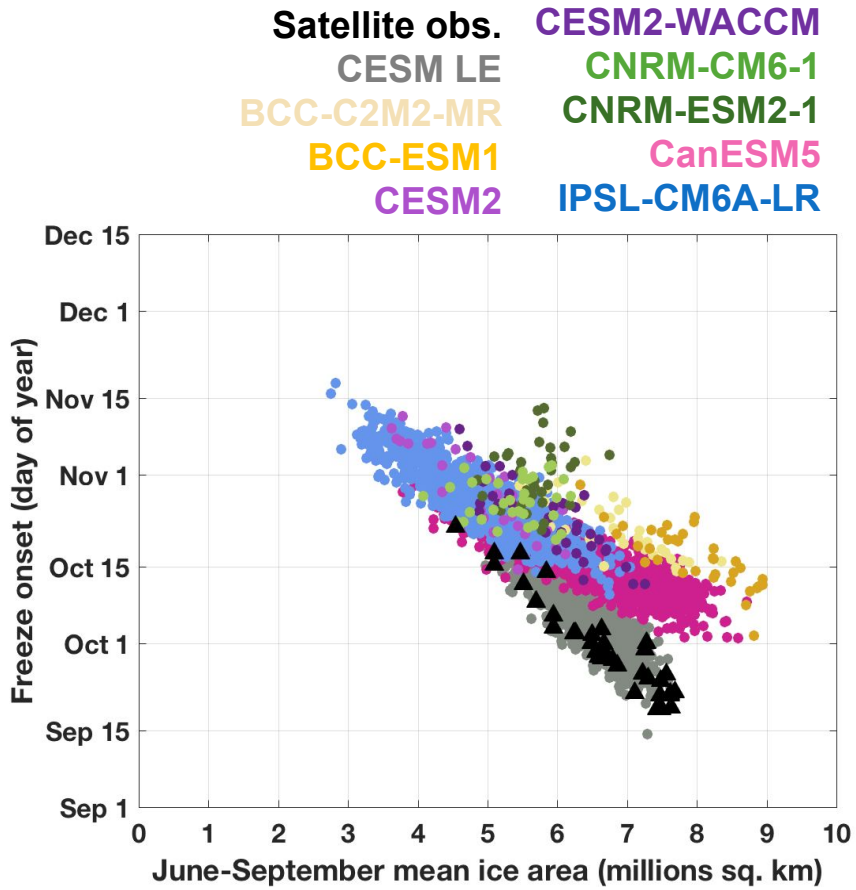
CNRM models produce realistic September ice coverage for the wrong reasons.





Summary

- **Metrics of seasonal sea ice change are not all the same or related to other ice characteristics in the same ways.**
- Melt and freeze onset affect sea ice year-round through the ice-albedo feedback.
  - Other transition dates show weaker relationships to ice area and mean thickness, but are limited by spatial coverage.
- Biases in seasonal transitions can compensate for unrealistic aspects of the sea ice (such as later melt onset and lower ice thickness), producing realistic September ice area for the wrong reasons.



Smith et al., in prep

THANK YOU!

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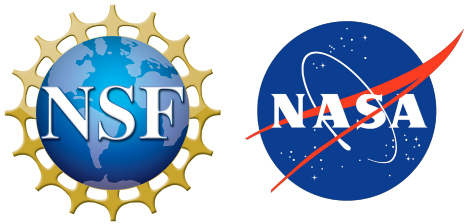

Special thank you to NCAR's Computational and Information Systems Laboratory (CISL)