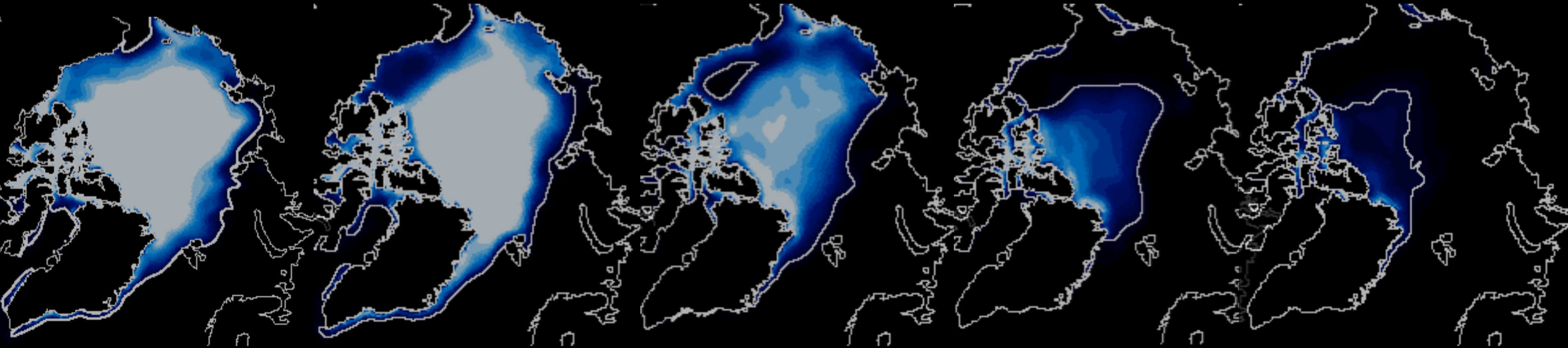

Sea ice influences on projected changes in Arctic surface heat budgets

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NCAR is sponsored by the National Science Foundation

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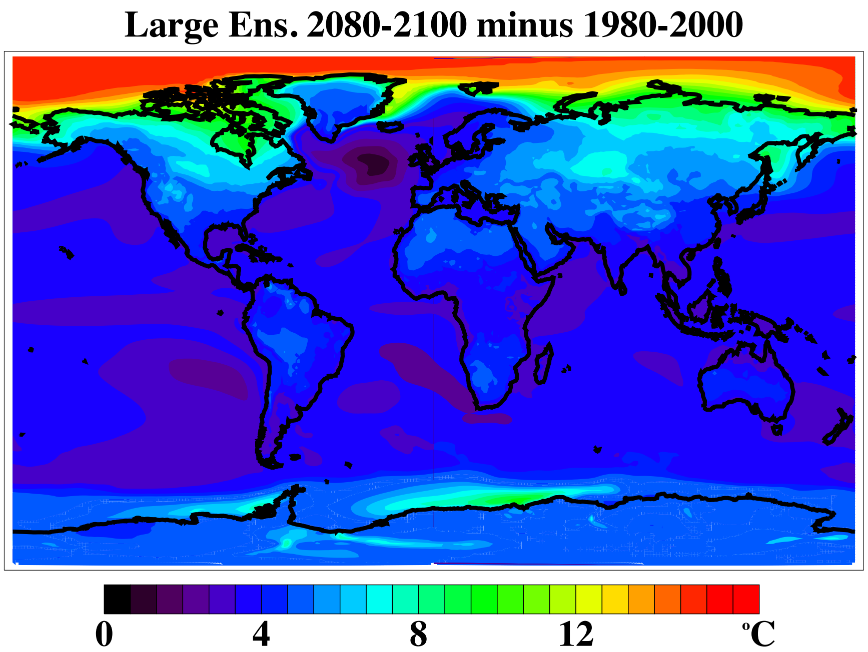
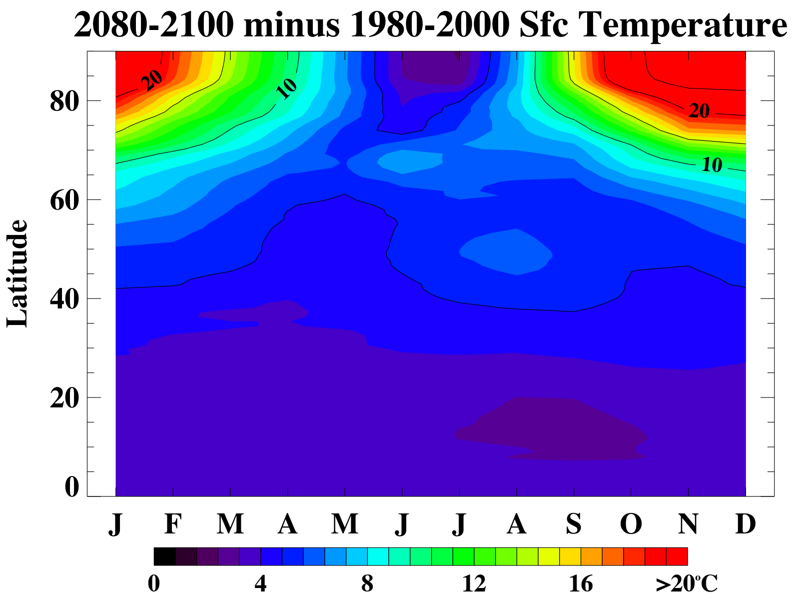
Projected Change in Surface Air Temperature





Results from CESM-CAM5 Large Ensemble (Kay et al., 2015)

- Amplified Arctic warming
- Warming rates elevated 3-4 times above the global average
- Largest surface air temperature change in fall/winter (>20C)

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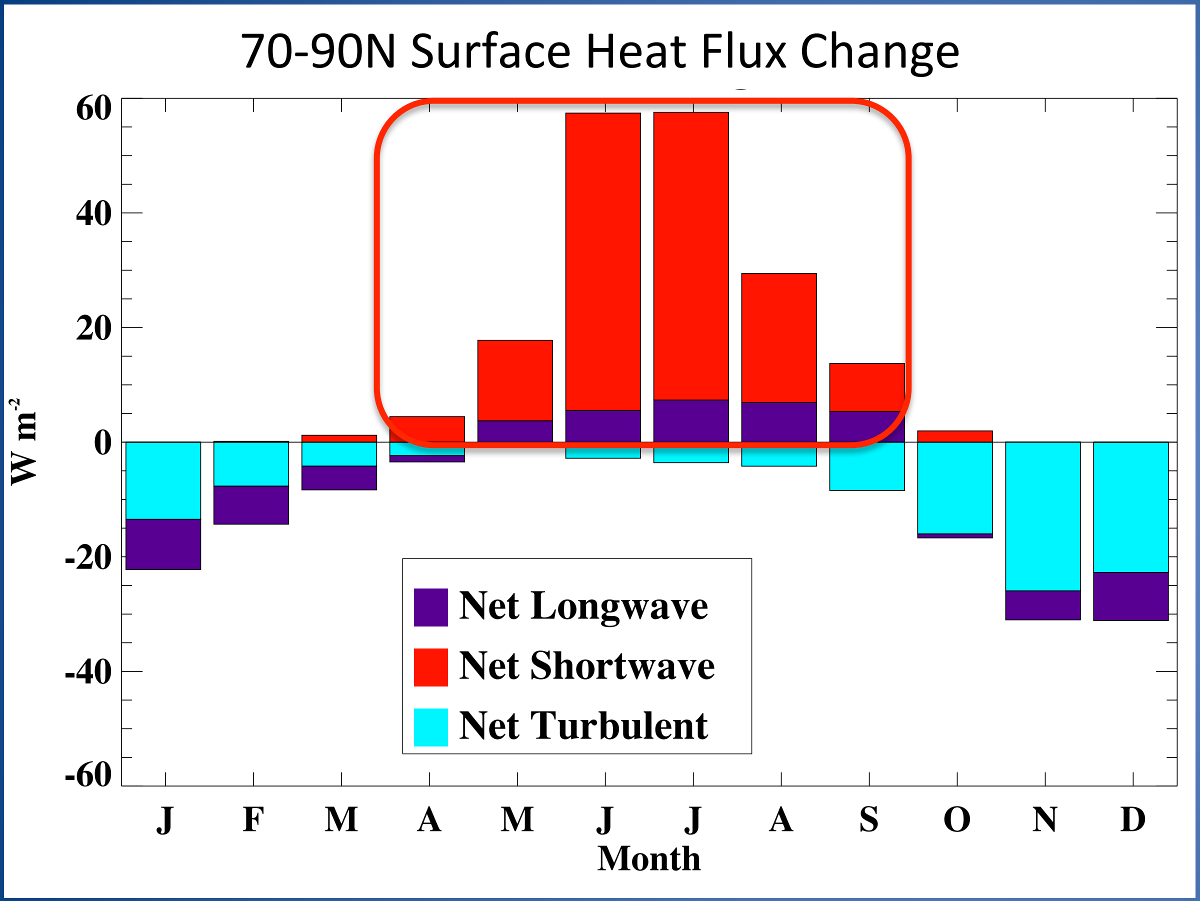
Simulated Surface Heat Flux Change



As in other models, the CESM-LE exhibits:

- Surface heating in summer - increased net shortwave
- Increased flux of heat to the atmosphere in fall/winter

2060-2080 relative to 1920-1950
(positive down)

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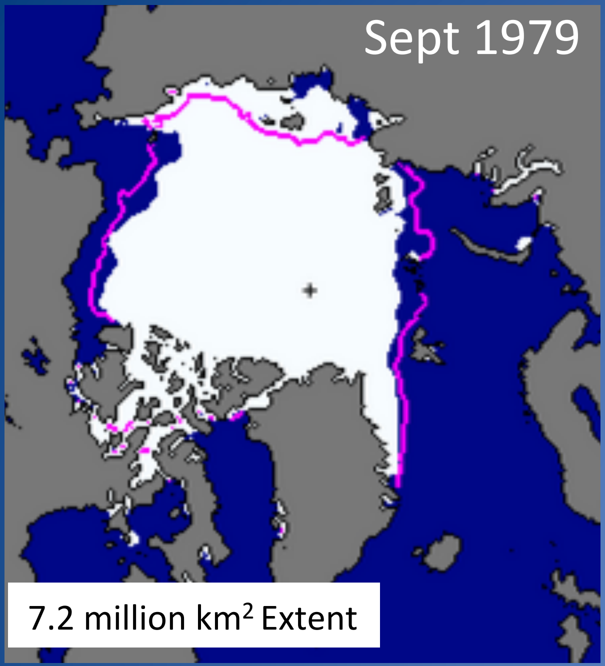
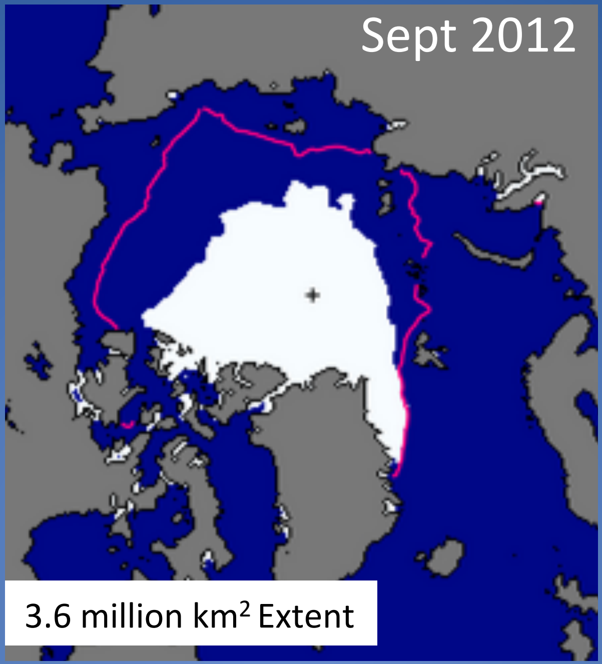
What controls the surface albedo response?

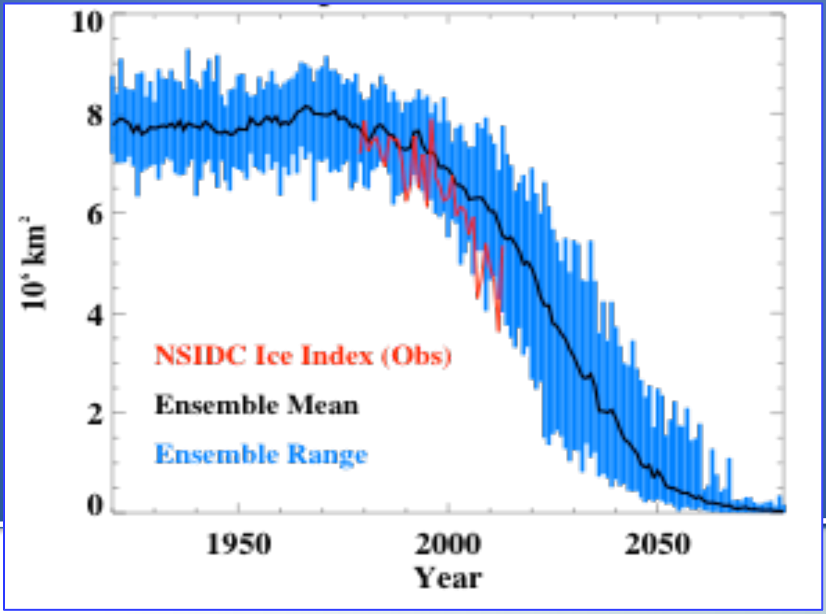




changes in ice area

Largest at end of melt season (Sept)

Incoming SW <50 W/m2



CESM-LE September Ice Extent

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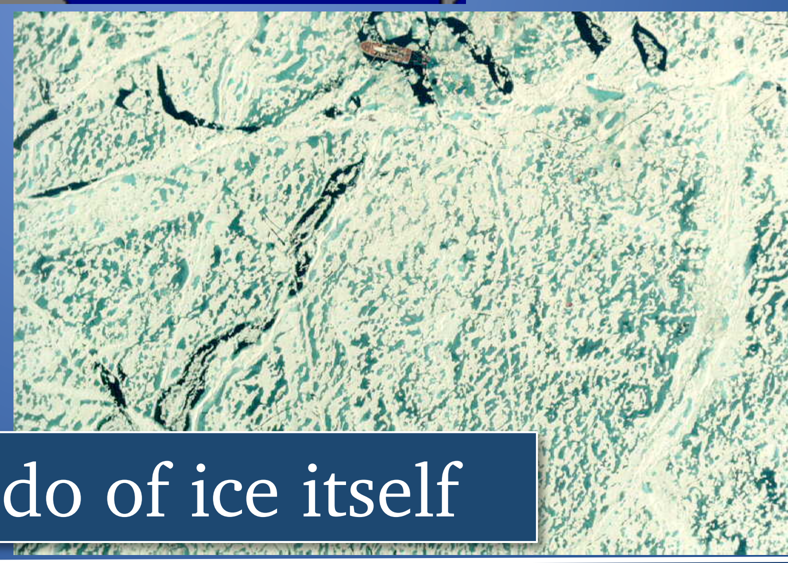
What controls the surface albedo response?

changes in ice area

Largest at end of melt season (Sept)

Incoming SW <50 W/m2



changes in albedo of ice itself

Mostly at melt onset ~June

Incoming SW >250 W/m2

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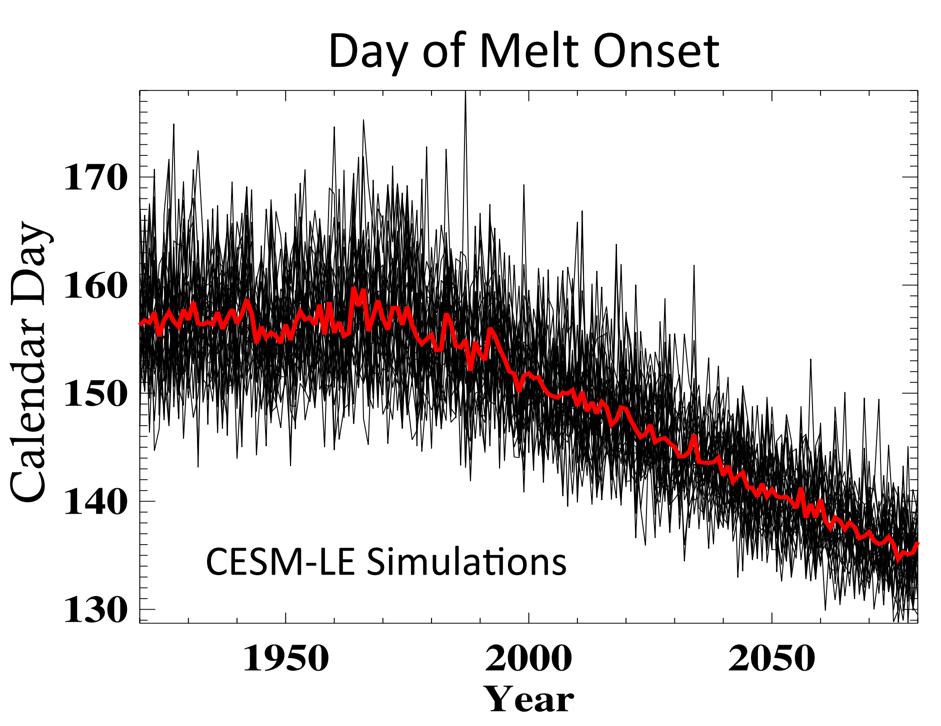
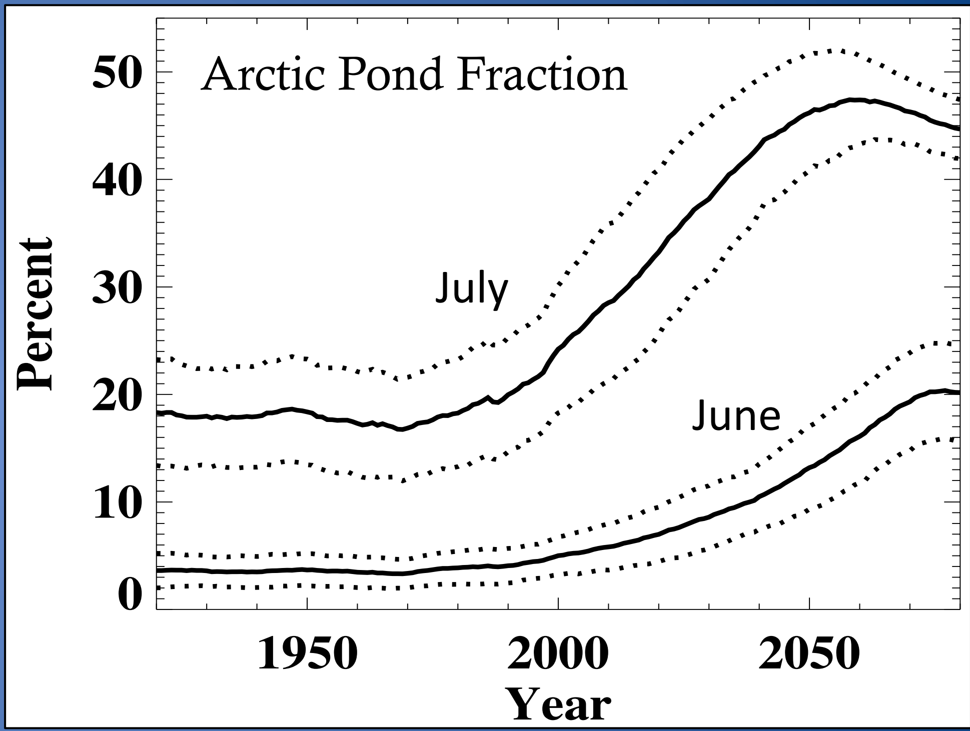
Factors affecting the albedo of sea ice are projected to change in the 20th-21st century





CESM-LE simulations

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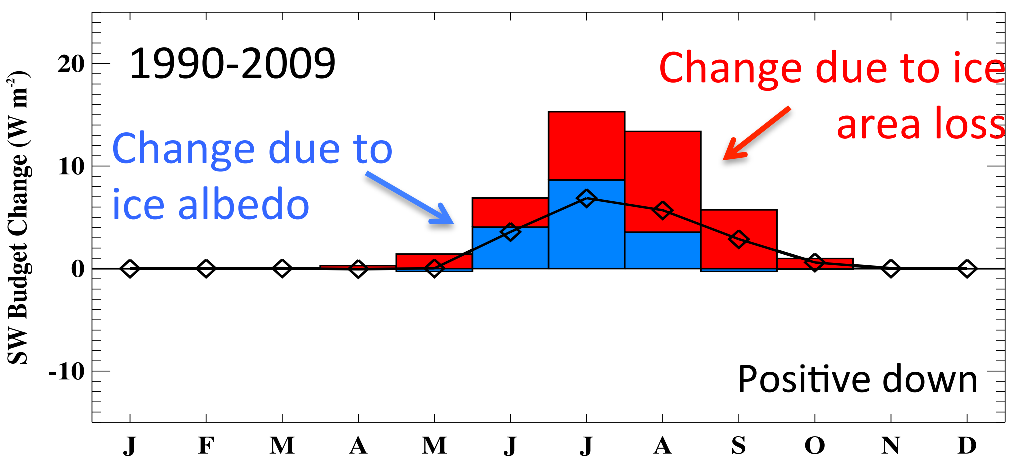

Arctic Surface Shortwave Budgets

- With declining ice albedo, more absorbed SW in ice, especially in June & July
- More SW absorbed in ocean with reduced ice cover

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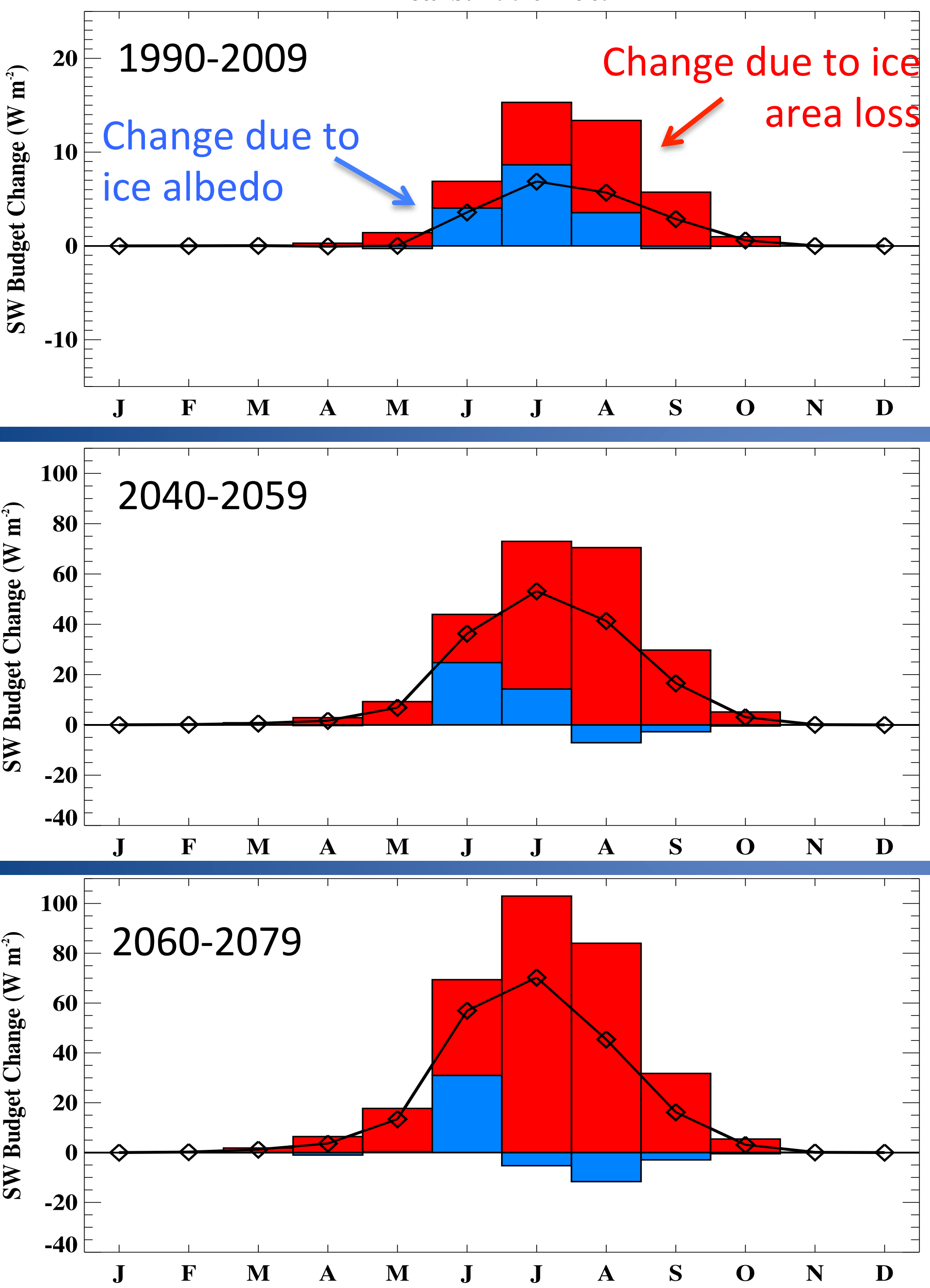

Arctic Surface Shortwave Budgets

- With declining ice albedo, more absorbed SW in ice, especially in June & July
- More SW absorbed in ocean with reduced ice cover
- Later in 21st century, ice area change dominates, but ice albedo change remains important in June at melt season start

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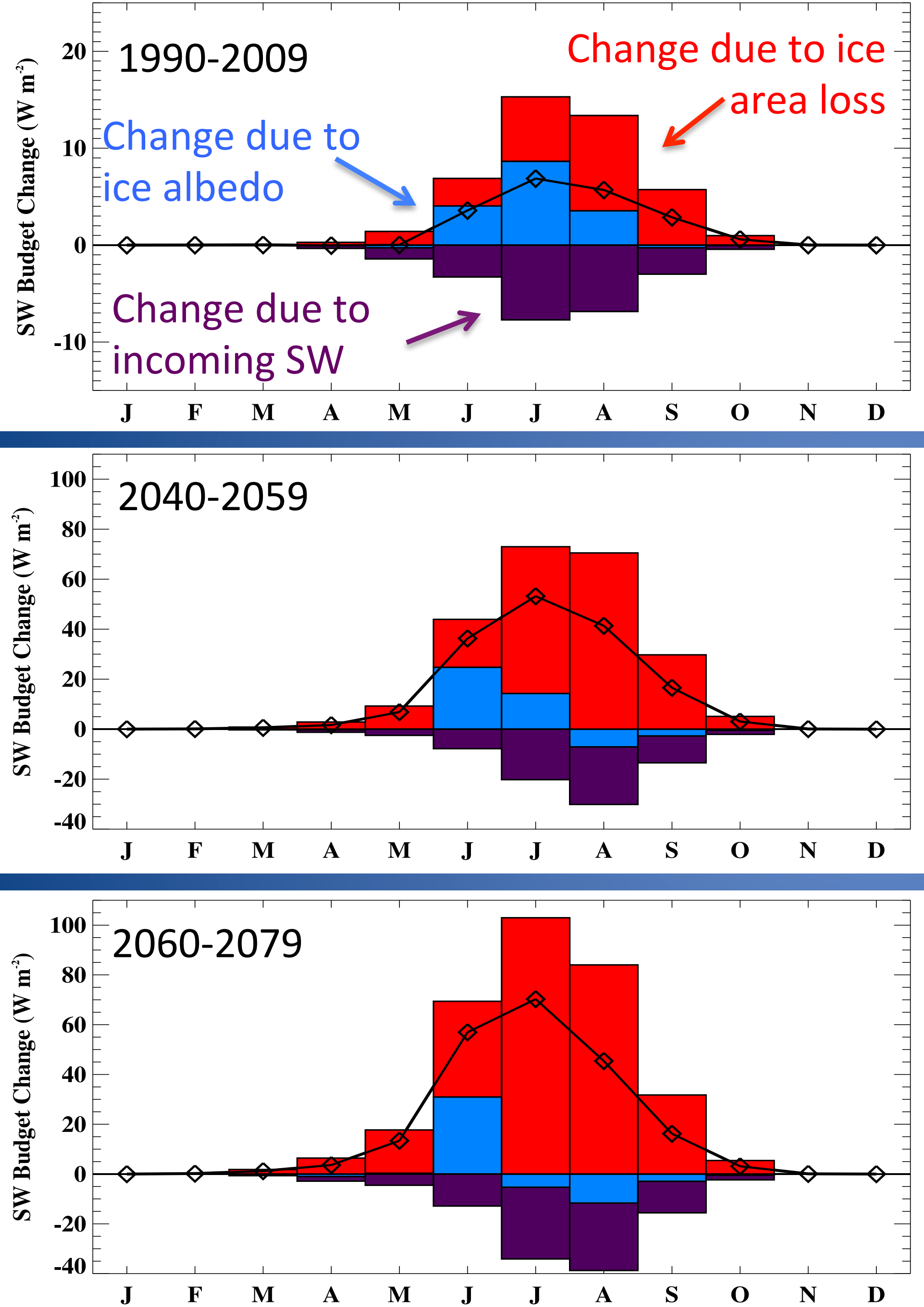
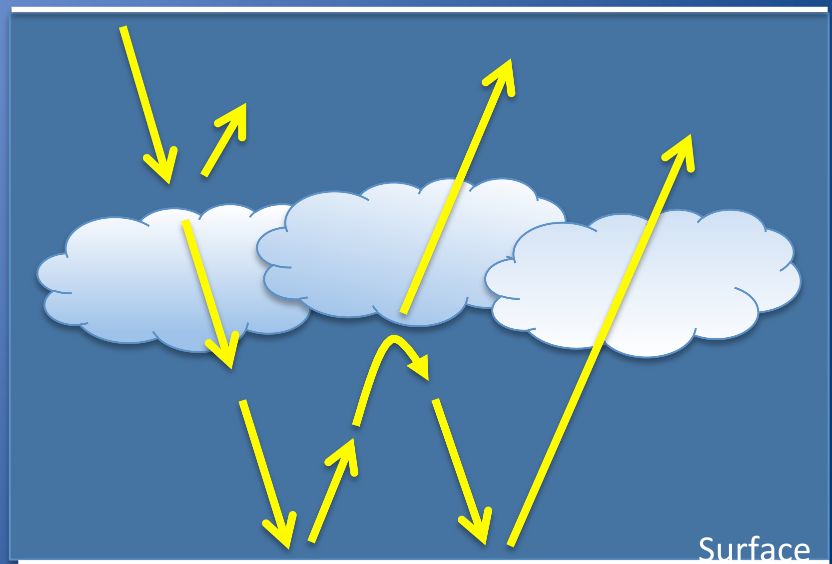


Simulated Arctic Surface SW Budgets

- Surface SW absorption increases
- Incoming shortwave radiation decreases



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Investigating Uncertainty in Climate Model Projections

How do these factors affect across-model scatter in climate projections?

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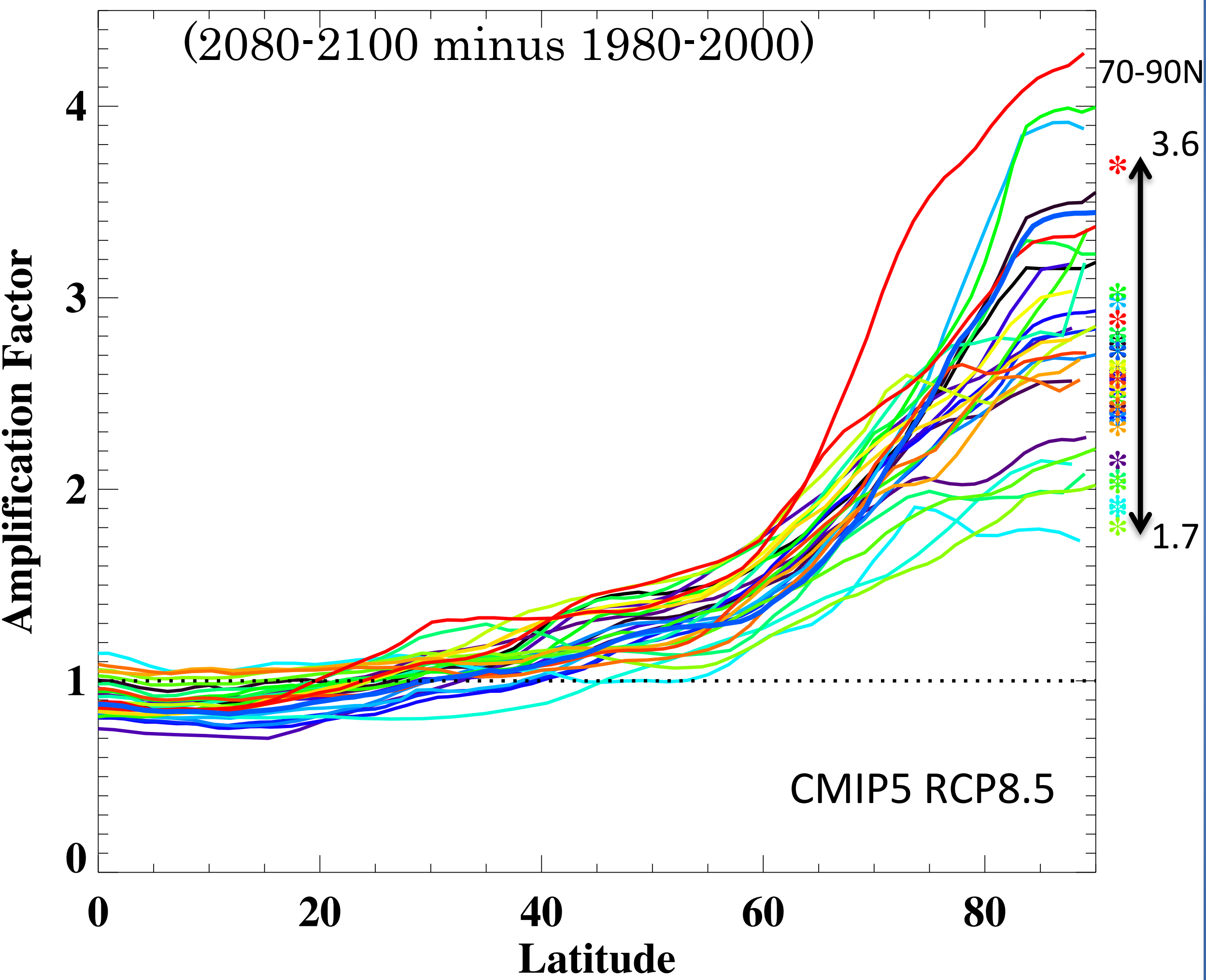
Projected Change in Surface Air Temperature



Amplification Factor:

- Change in zonal average relative to global mean change
- All models show amplified warming
- Model scatter in magnitude of amplification is large

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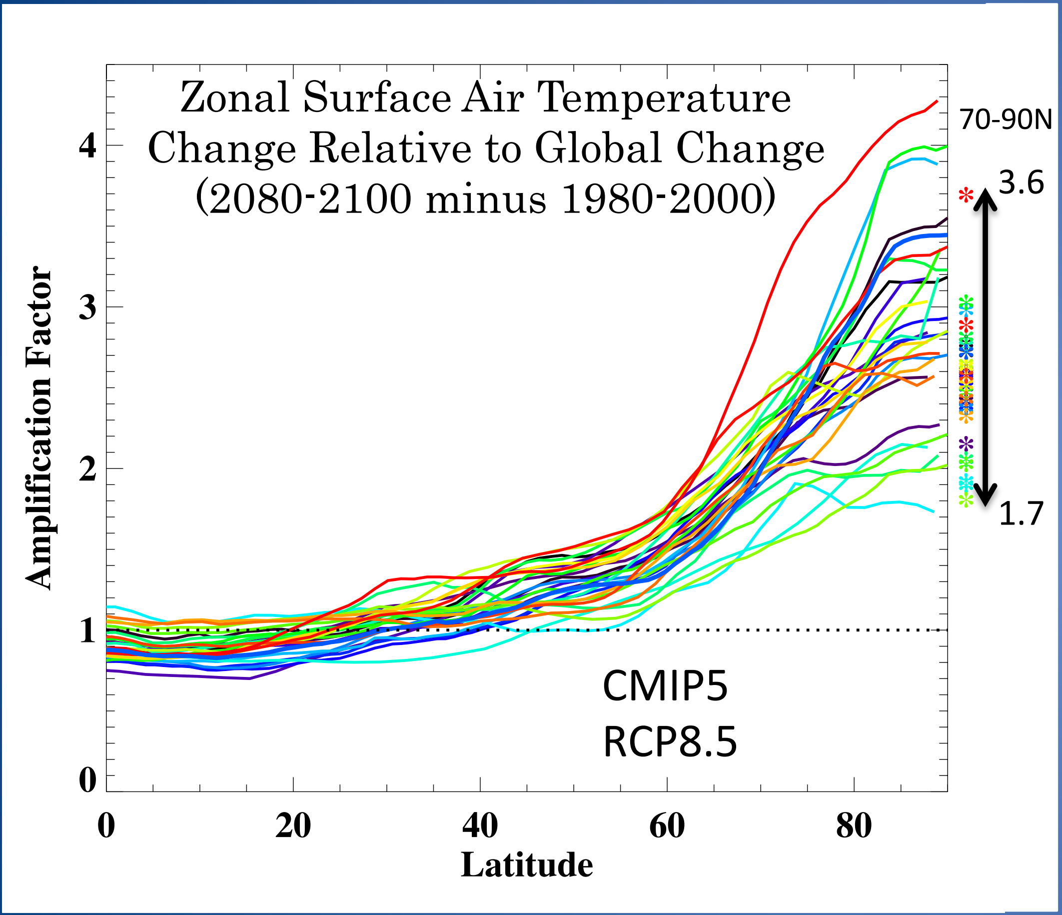
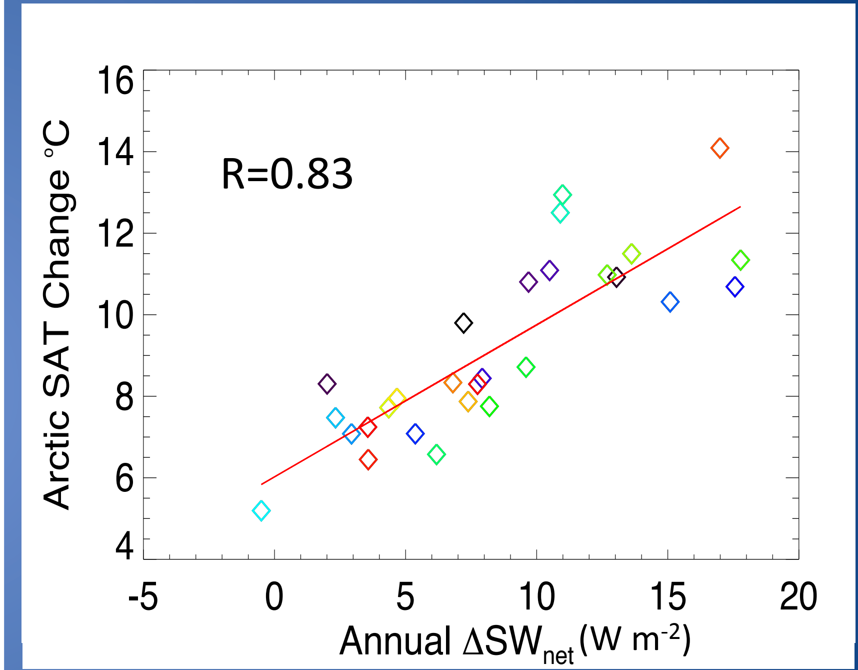
Model Scatter in Arctic Amplification





Across model scatter in Arctic warming is related to changes in the net solar heating

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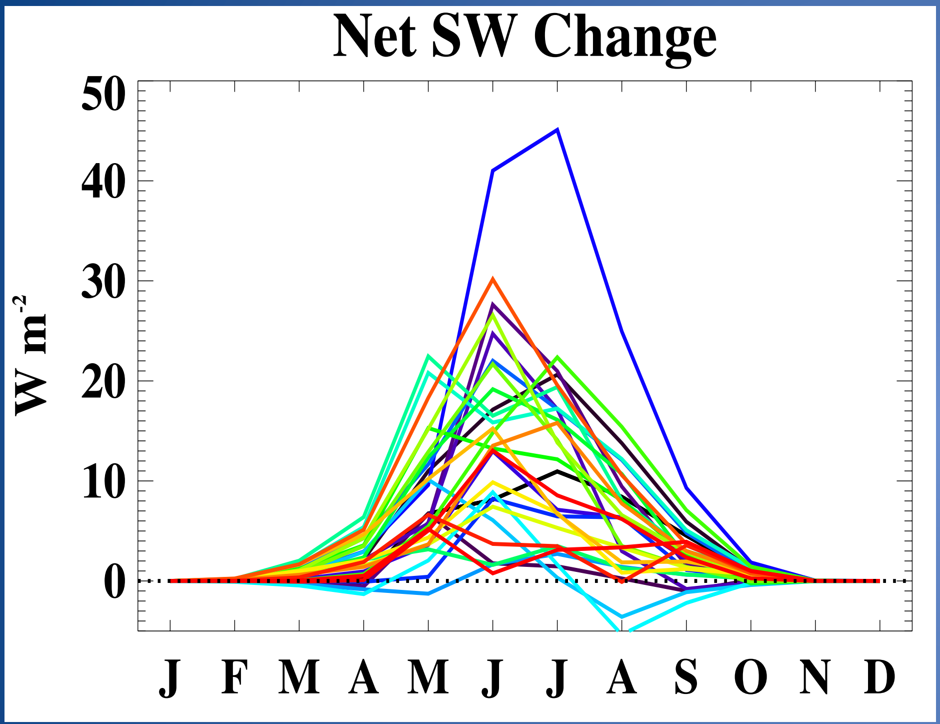
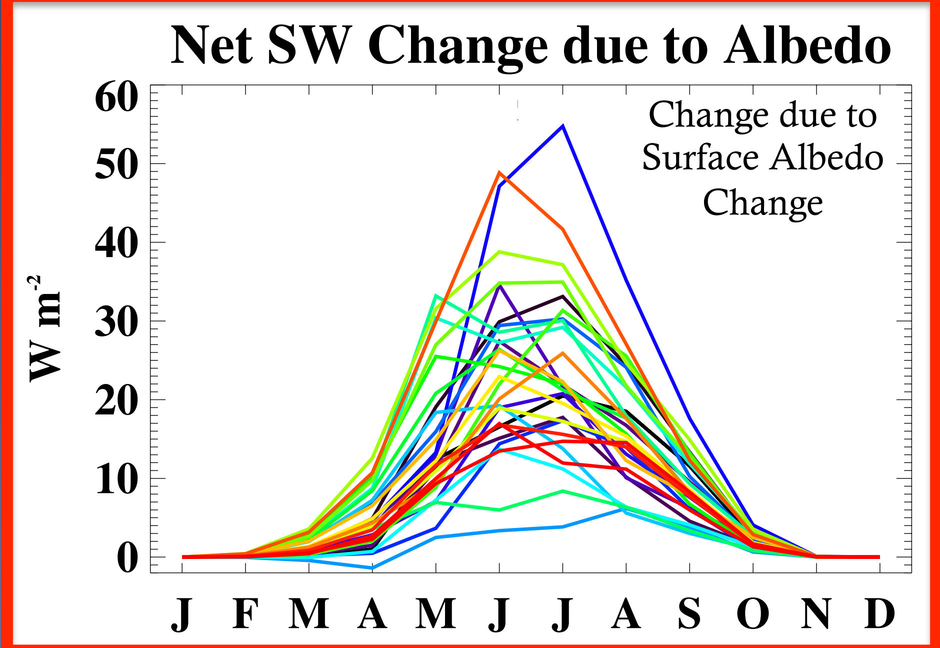
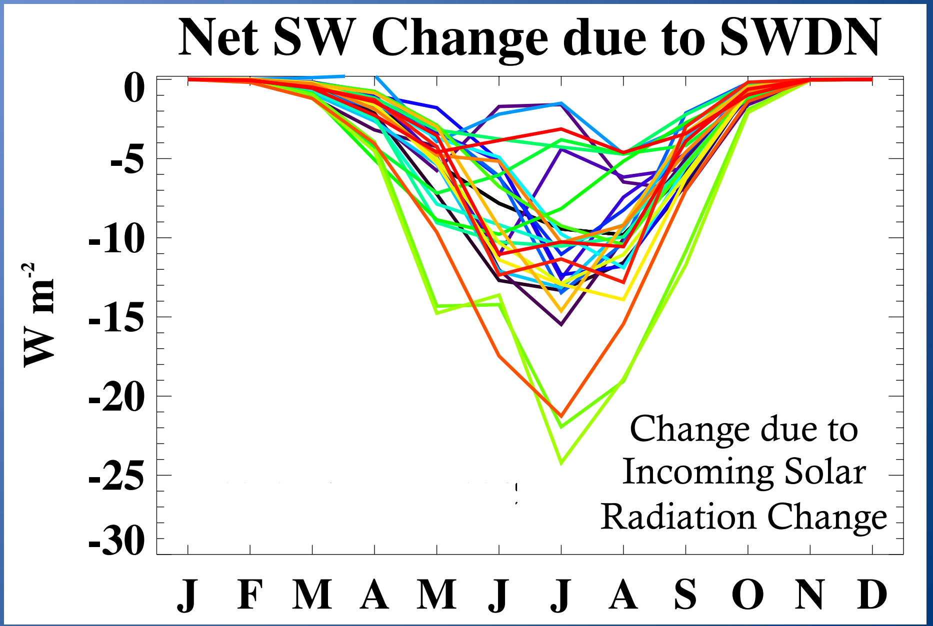
Projected Changes in Solar Heating at 2050



Change in Surface Net Shortwave Flux in CMIP5 models at Year 2050

70-90N





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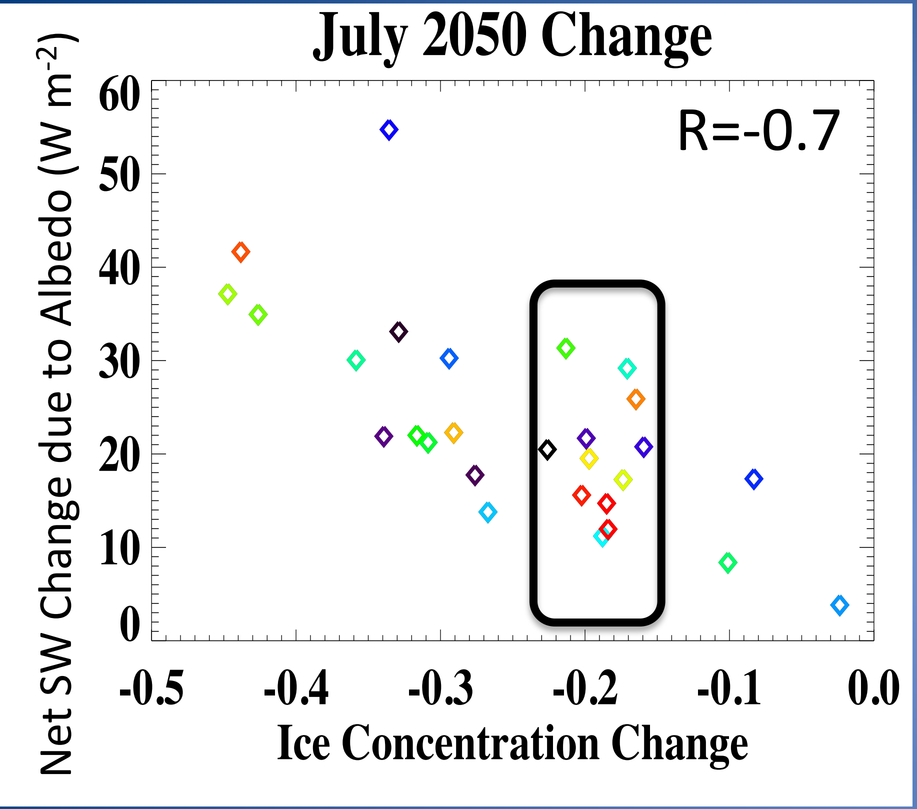
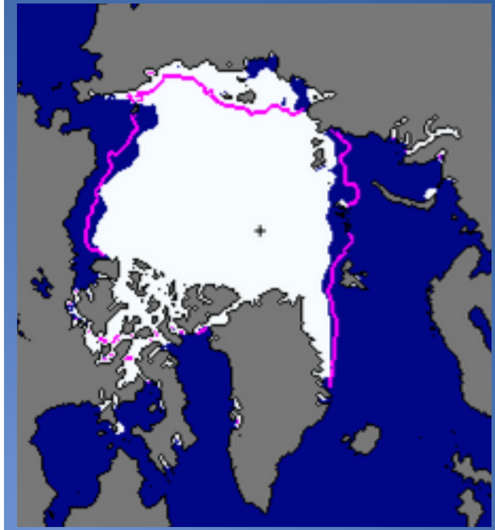
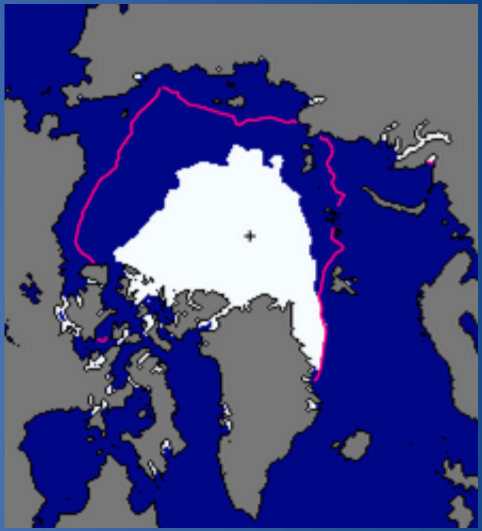
Important role of ice area change







- Albedo-related Solar Heating change is strongly correlated with change in ice concentration
- However, even for similar ice loss amount, the heating change can vary by a factor of ~3

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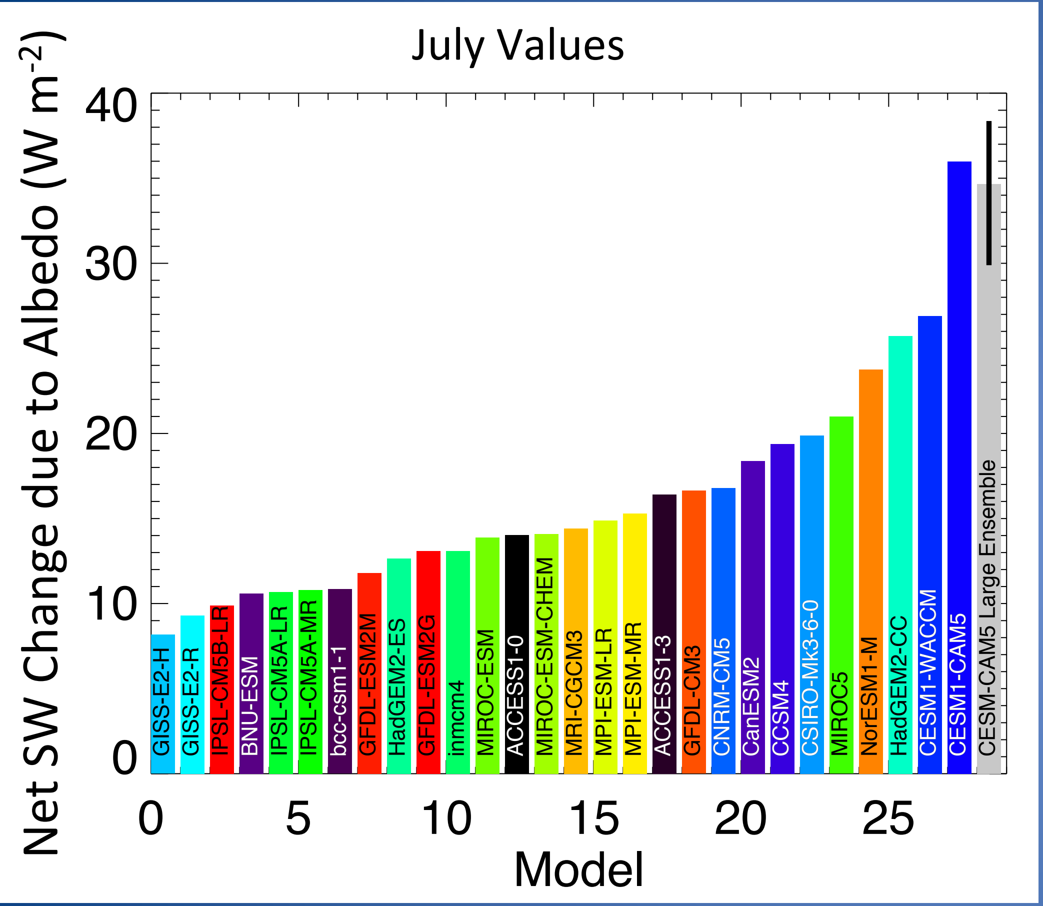
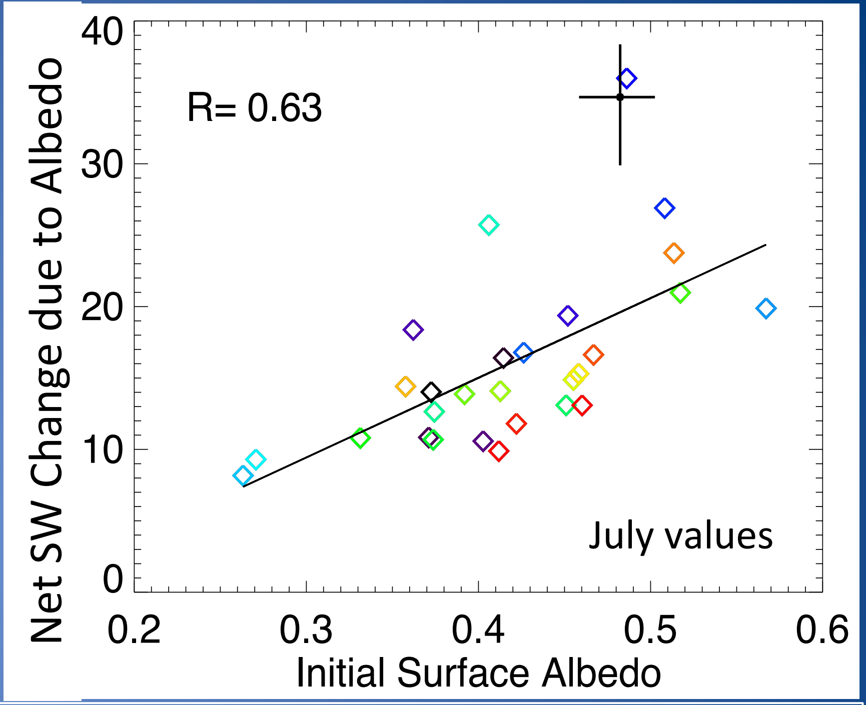
For same ice area loss, change influenced by initial albedo





For the same ice loss, the increase in albedo-related net solar heating can vary by a factor of >3

For the same ice area loss –

Larger increases in net solar heating occur in models with higher initial (late 20th century) surface albedo

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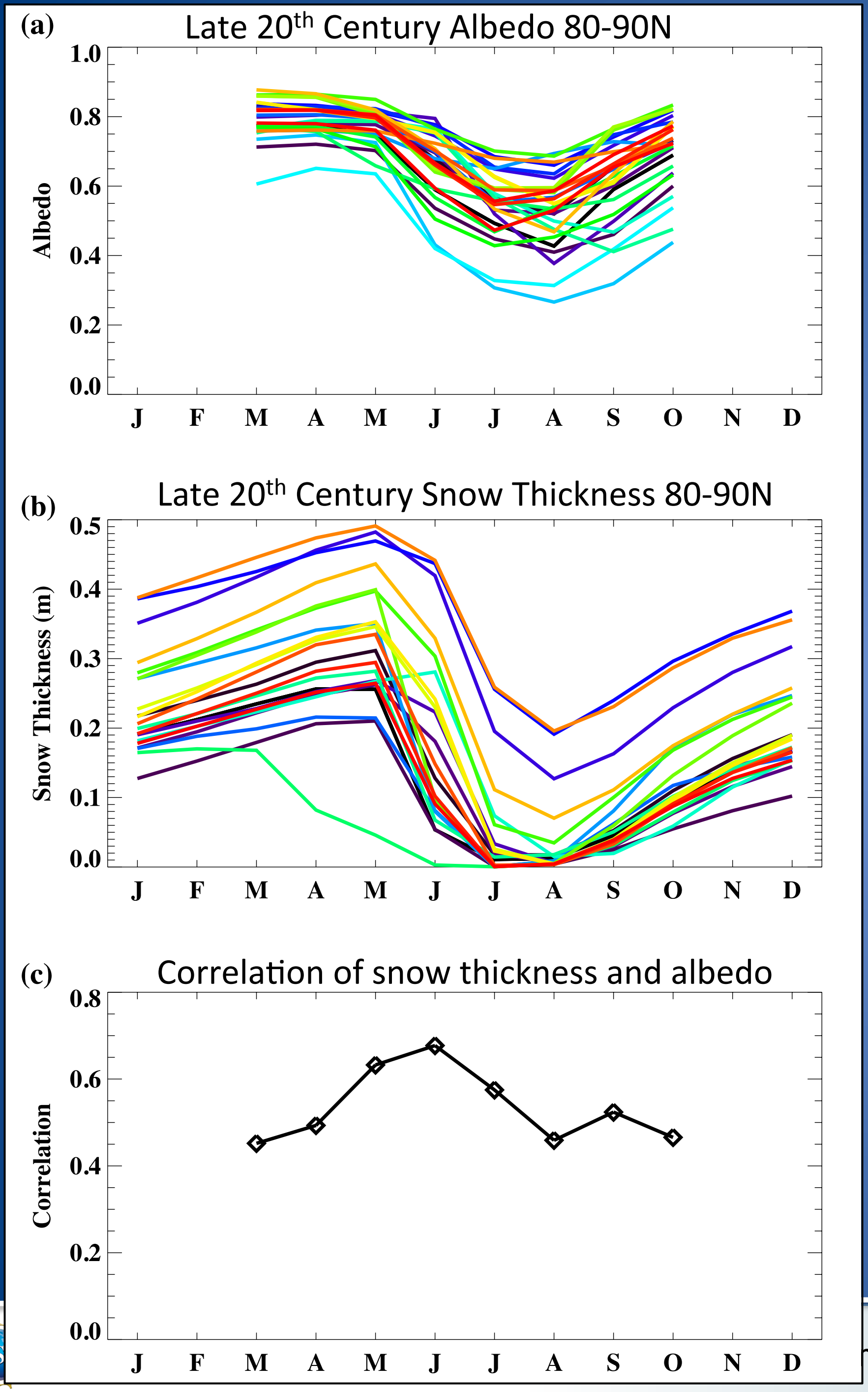

Late 20th century surface albedo influenced by:

- Simulated surface state
  - snow conditions
  - ponding on sea ice
- Albedo tuning may also play a role

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Conclusions

- Net Arctic surface heating is driven by increased shortwave absorption that is partly compensated by declining incoming solar radiation
- Projections of Arctic surface albedo decline include contributions from:
  - Reduced ice albedo
  - Increased open water area
- Models have large uncertainty in their future Arctic change due in part to albedo projections
  - Different ice loss rates
  - Different initial surface albedo

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Questions?

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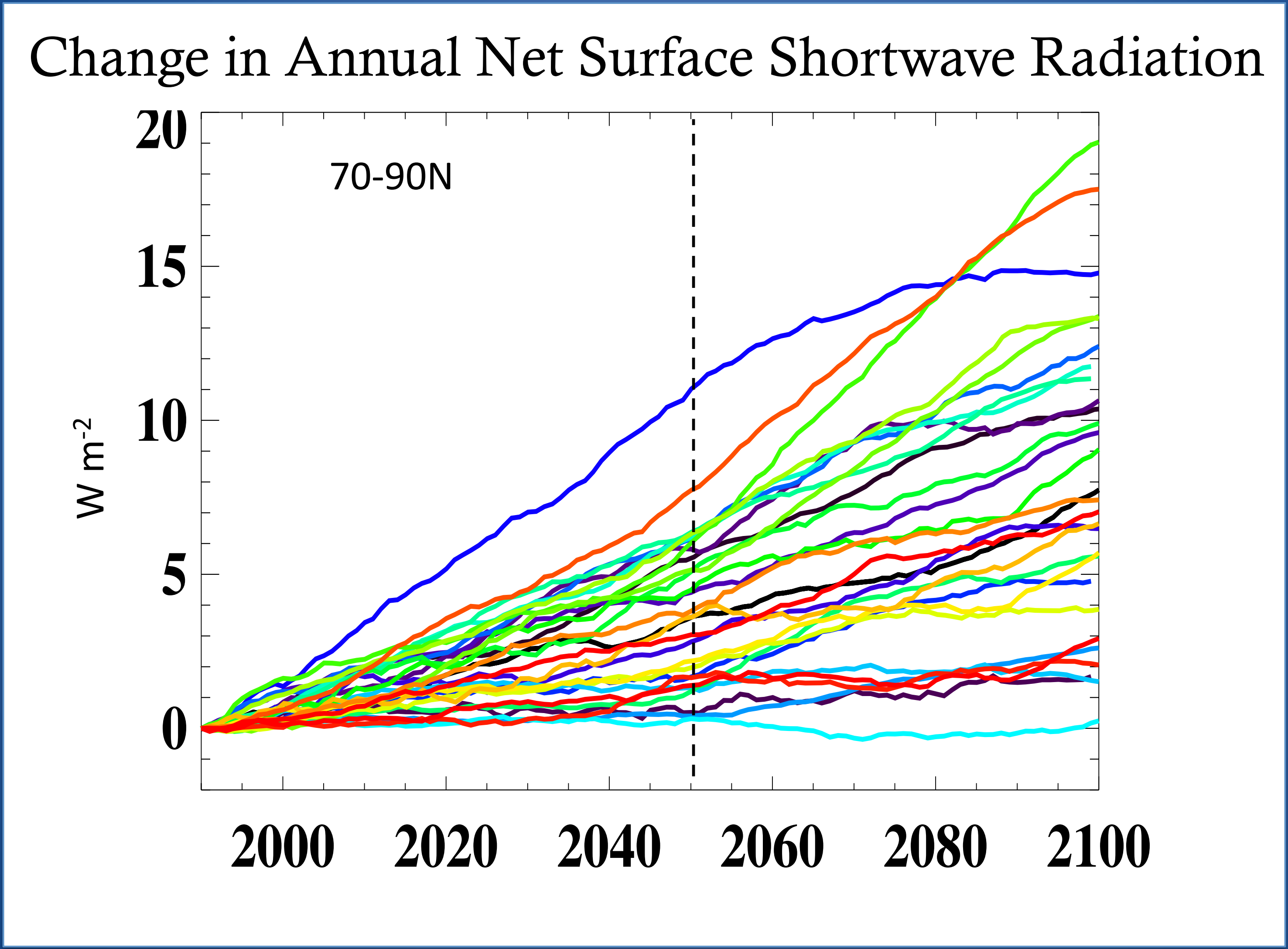
Across-Model Scatter in Arctic Shortwave Heating



28 CMIP5 Models

RCP8.5 Forcing

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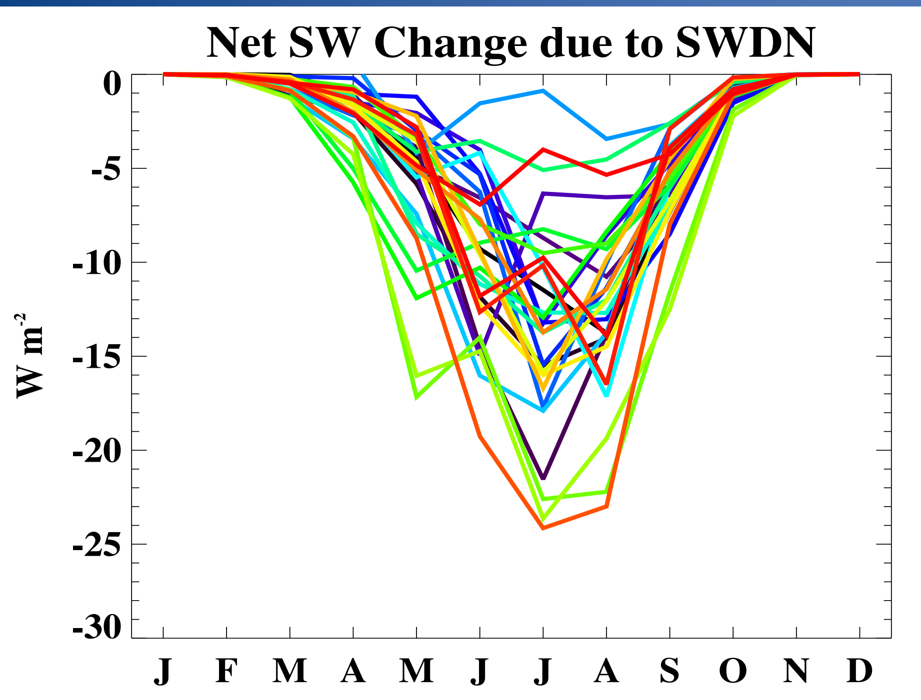
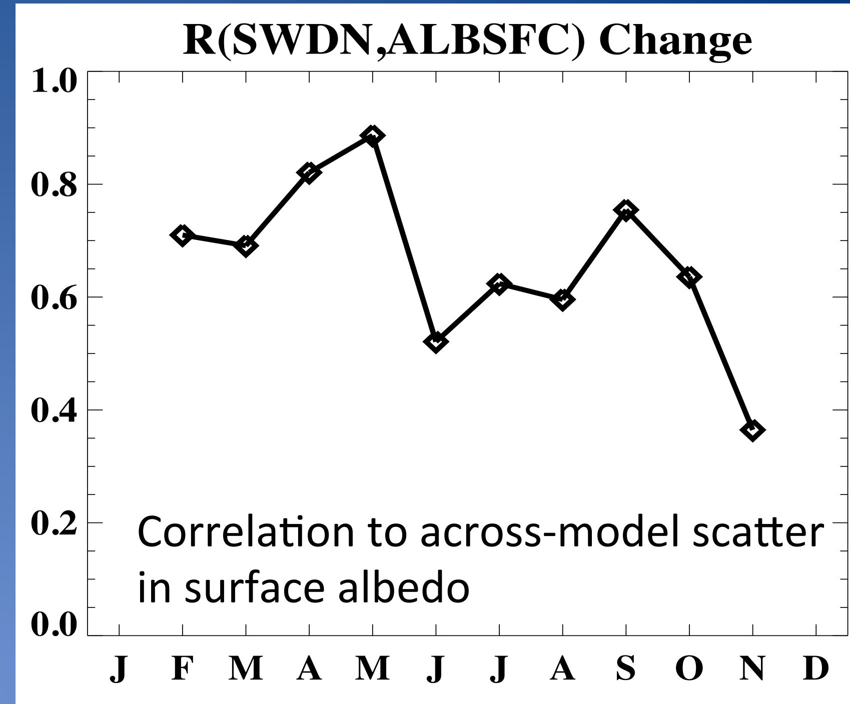
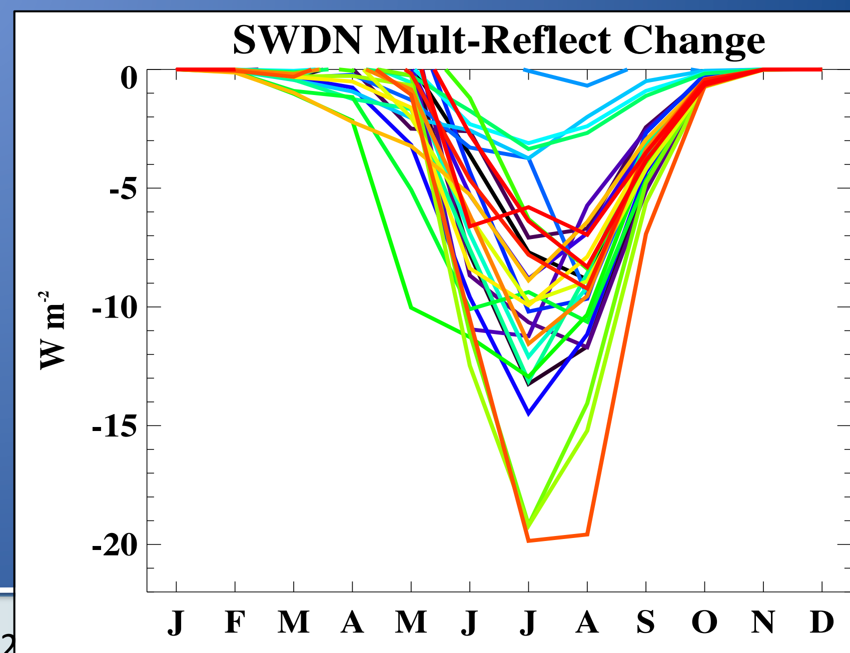
Changes in Net Shortwave Radiation due to Incoming Shortwave Change

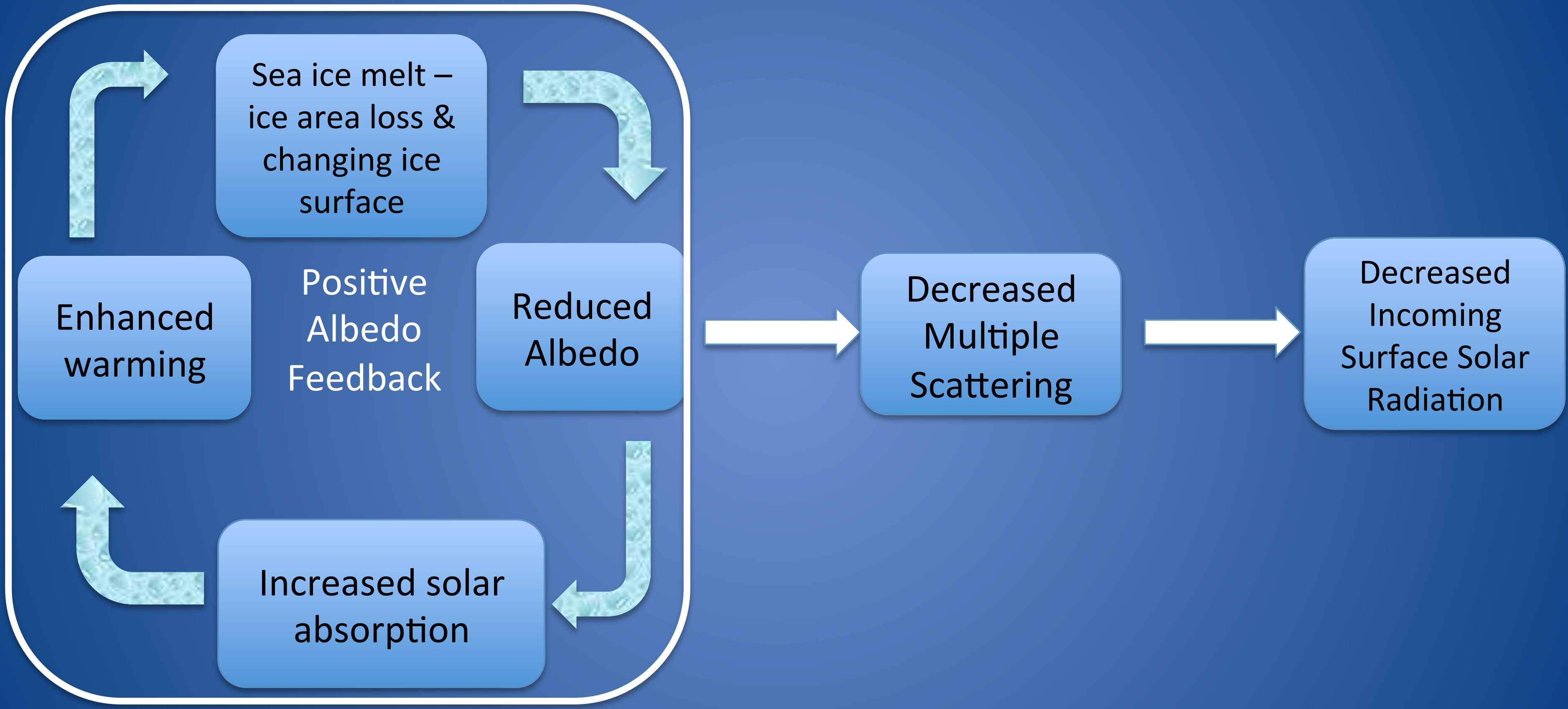






Relationship to Surface Albedo Changes

Surface Albedo and Net Shortwave Budgets



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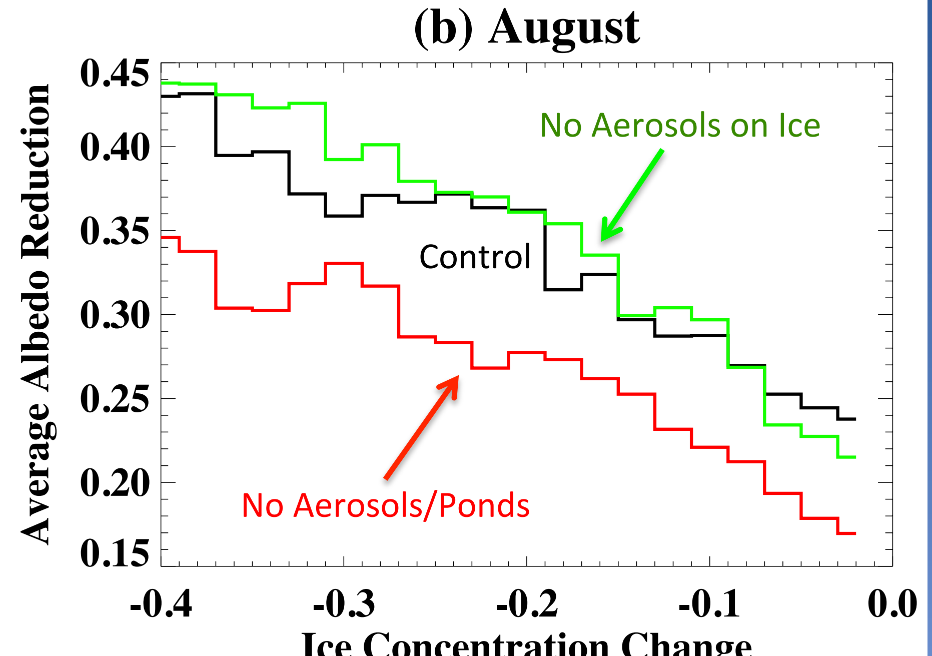

Holland et al., 2012

(NASA GSFC, ICESCAPE project)

Improving our ability to predict

Sea ice physics

- Improved representation of ice surface properties

Improved coupling

- Better representation of surface fluxes, for example precipitation and radiation
- Cloud interactions

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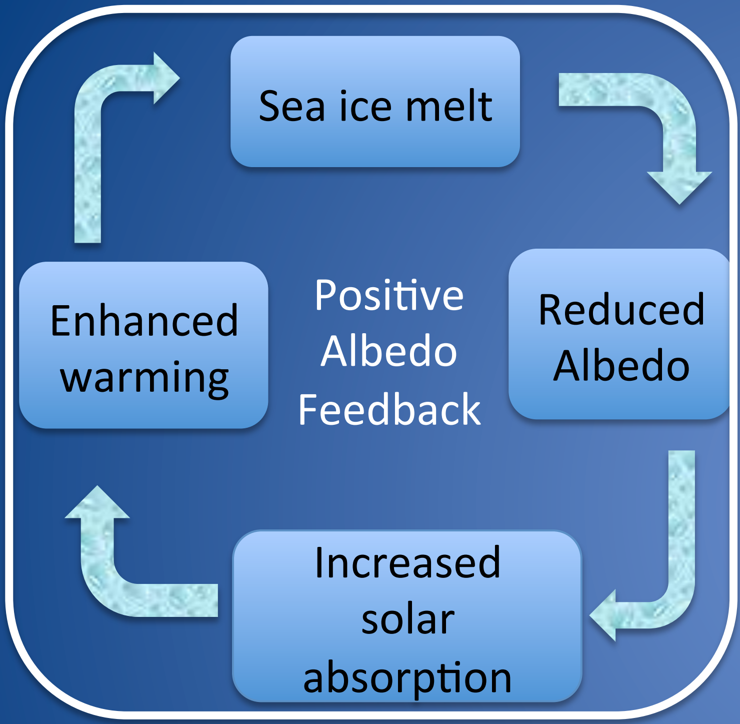
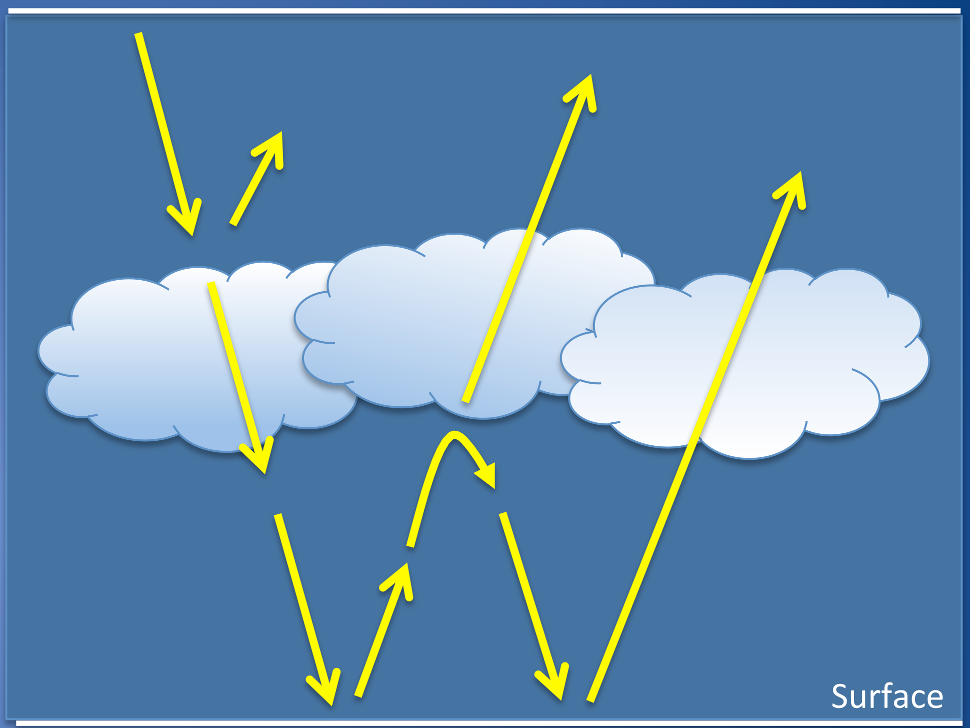
Changing Surface Albedo and Surface Heating





Surface albedo reductions:

- Enhance solar absorption (enhance warming)
- Affect multiple surface reflections with overlying clouds and reduce incoming solar radiation (reduce warming)

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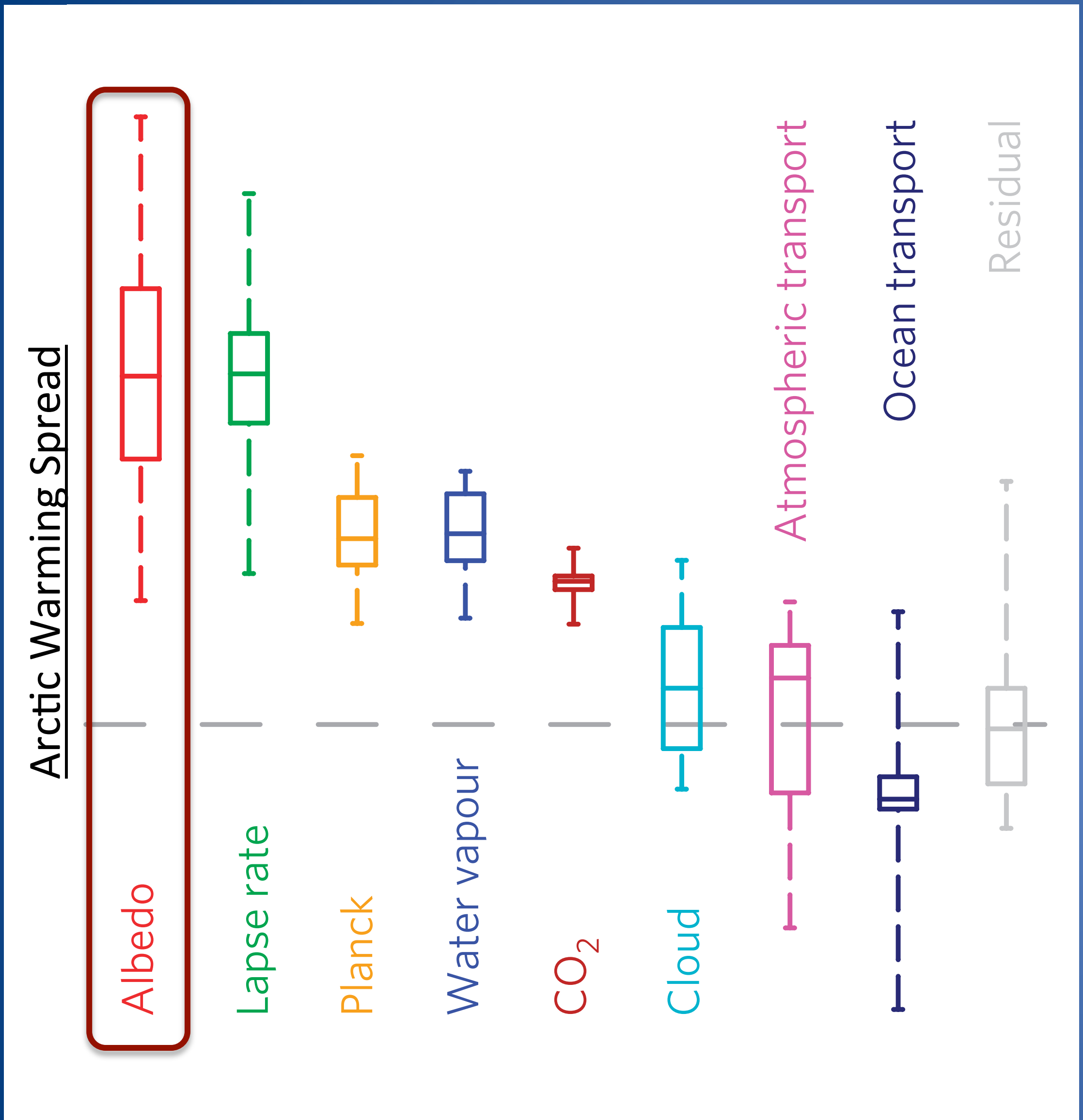
Inter-model Scatter in Arctic Warming due to various feedbacks



Differences in albedo feedback strength are associated with a large fraction of the scatter in Arctic warming

Pithan and Mauritzen Nature Geosci, 2014

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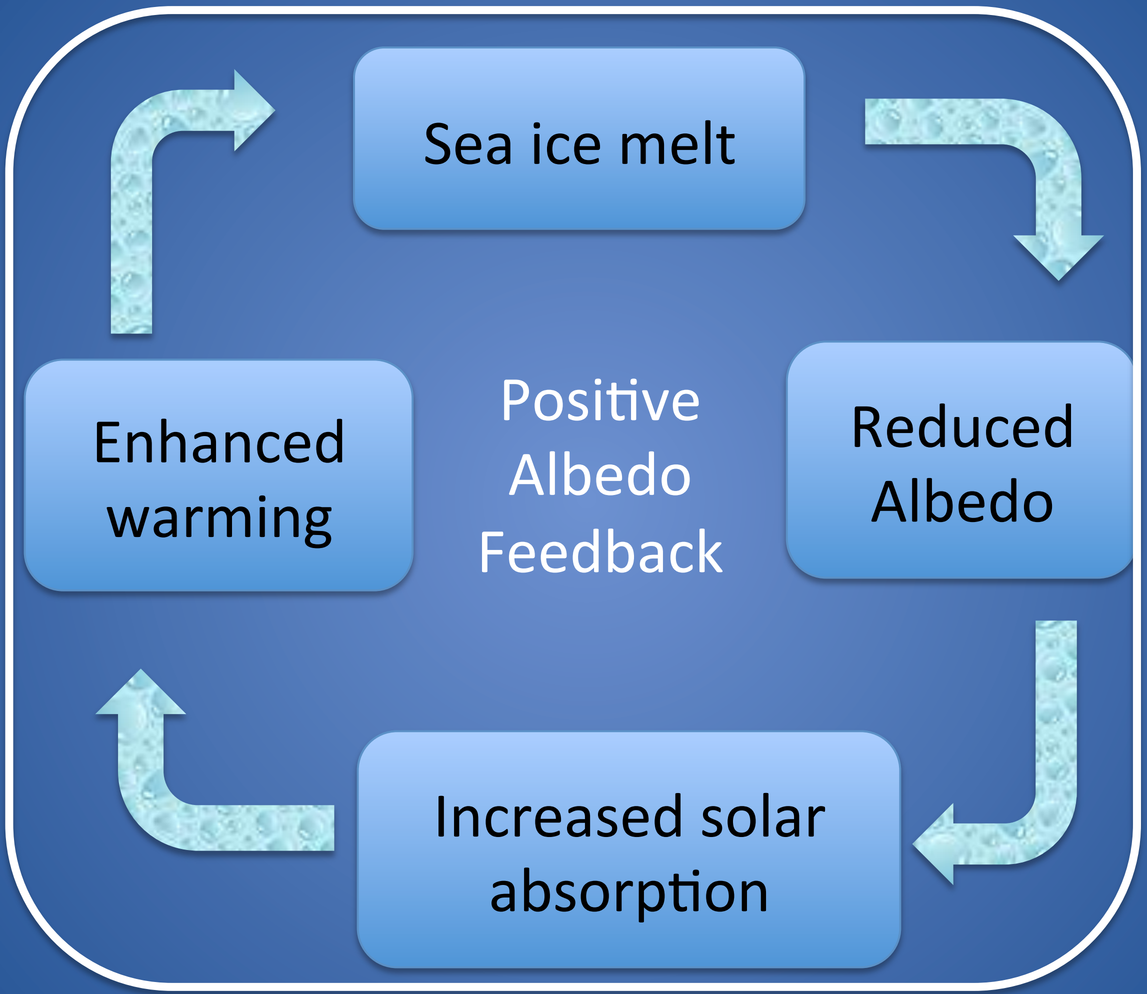
Surface Albedo Feedback



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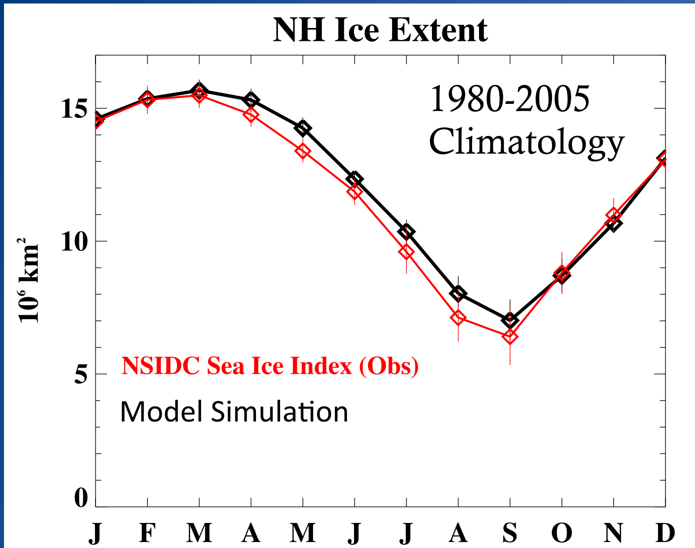
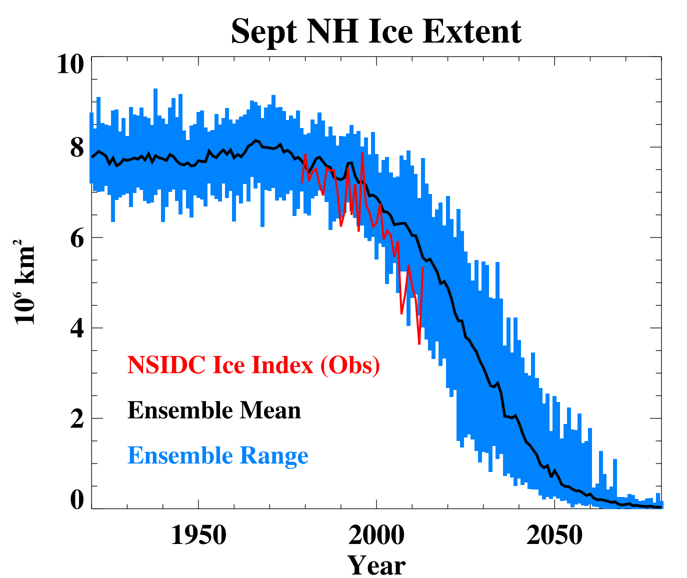
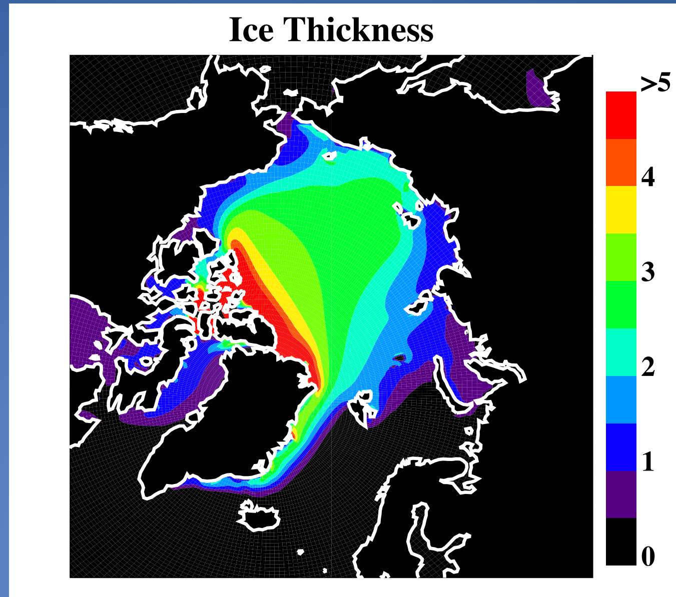
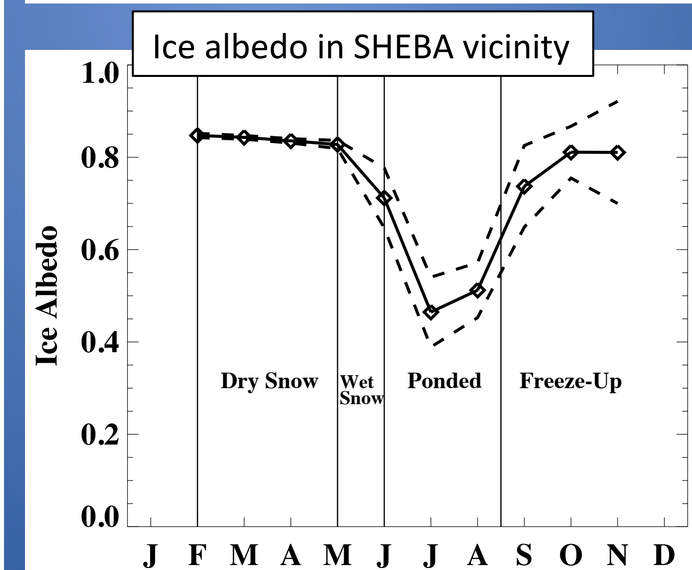
Model Simulations









- CESM-CAM5 Large Ensemble
- 30 Members
- 1920-2100
- RCP8.5 forcing
- Reach near ice-free Sept (<1 million km^2) from 2032-2053

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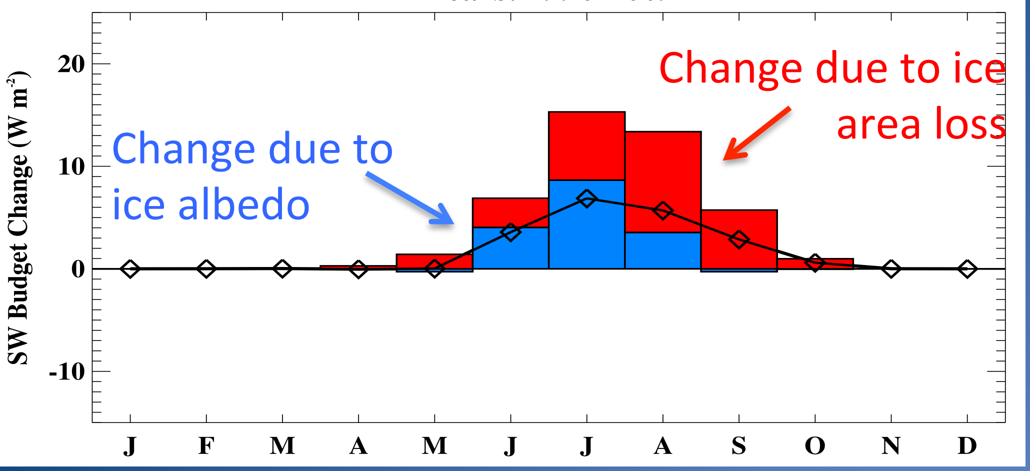

Change for 1990-2009 average relative to 1920-1950

Arctic Surface Shortwave Budgets

- With declining ice albedo, more absorbed SW in ice, especially in June & July
- More SW absorbed in ocean with reduced ice cover

Diagnose changes in surface net shortwave associated with a changing surface albedo

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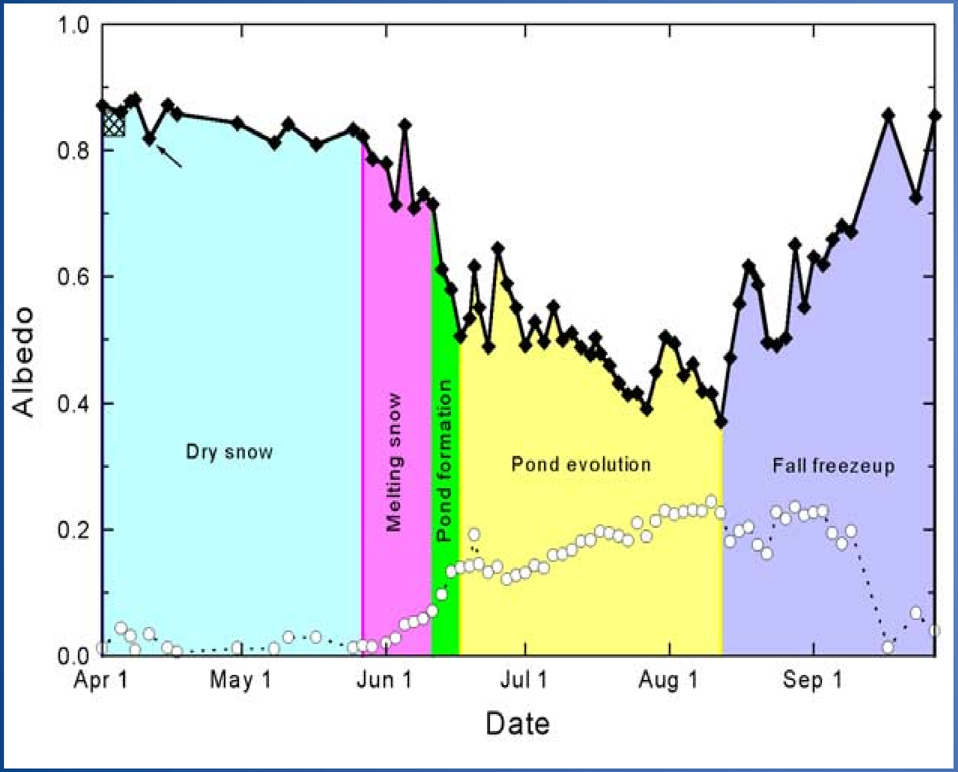
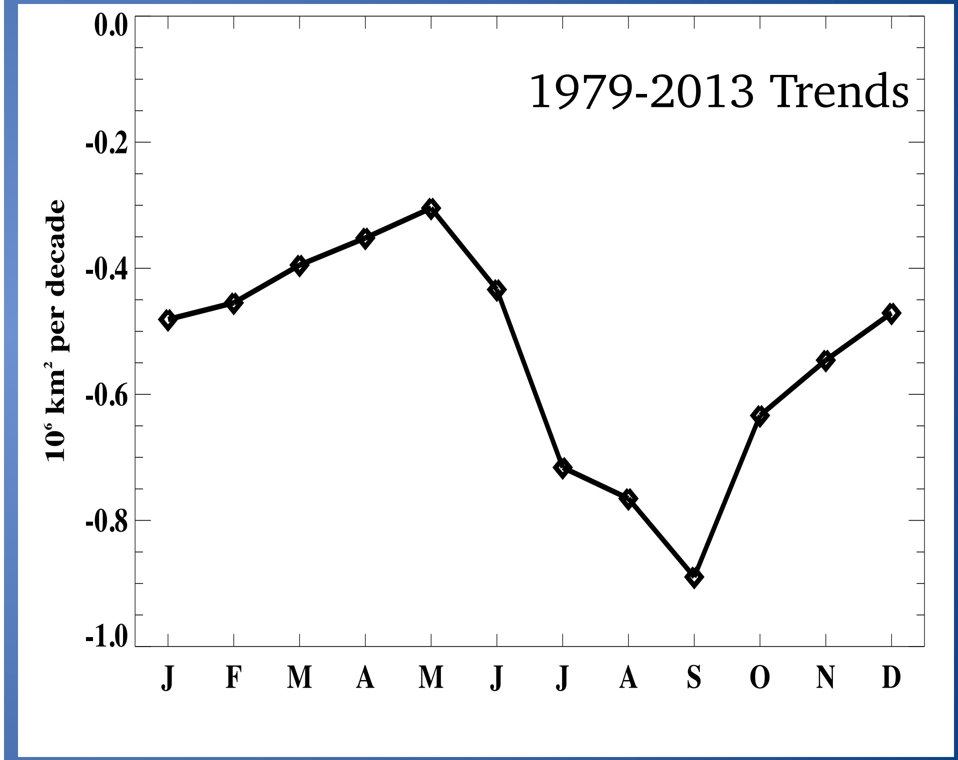
Arctic Observations
From the SHEBA Drifting Station

Albedo of Sea Ice



Arctic Ice Extent Trends



(Perovich et al., JGR, 2002)

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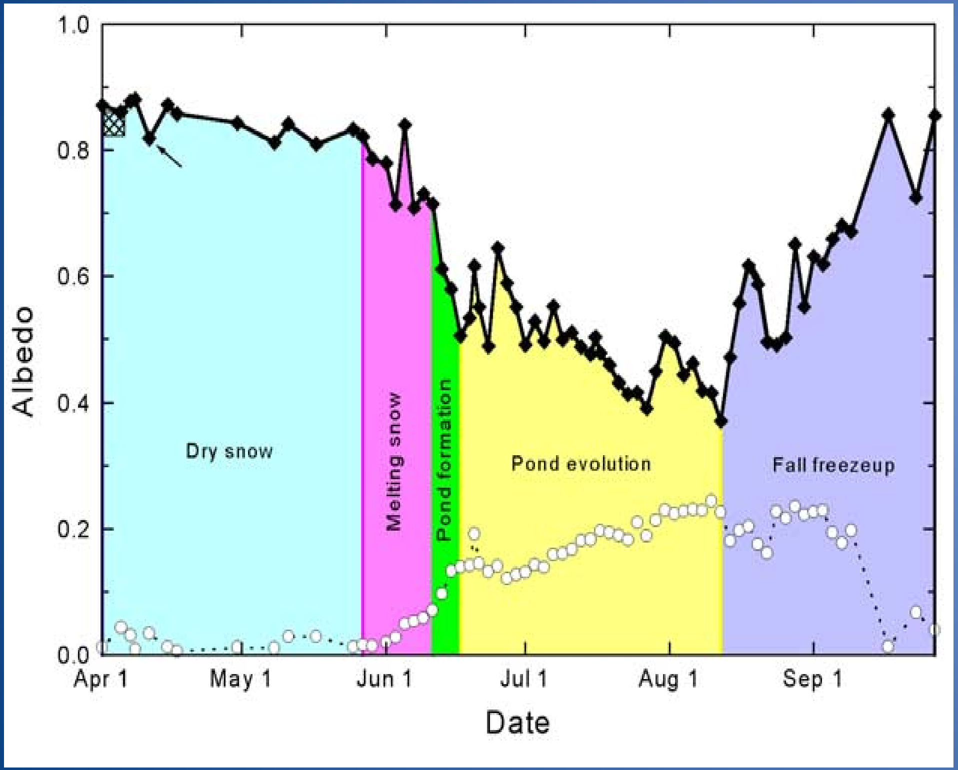
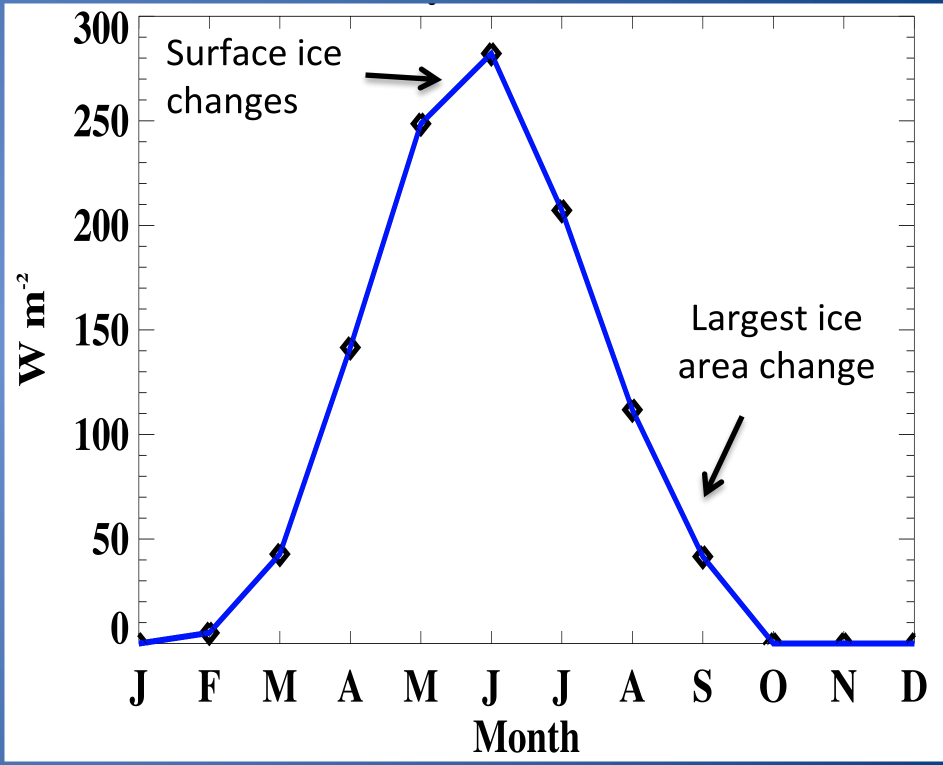
Arctic Observations
From the SHEBA Drifting Station

Albedo of Sea Ice



Incoming Surface Solar Radiation



(Perovich et al., JGR, 2002)

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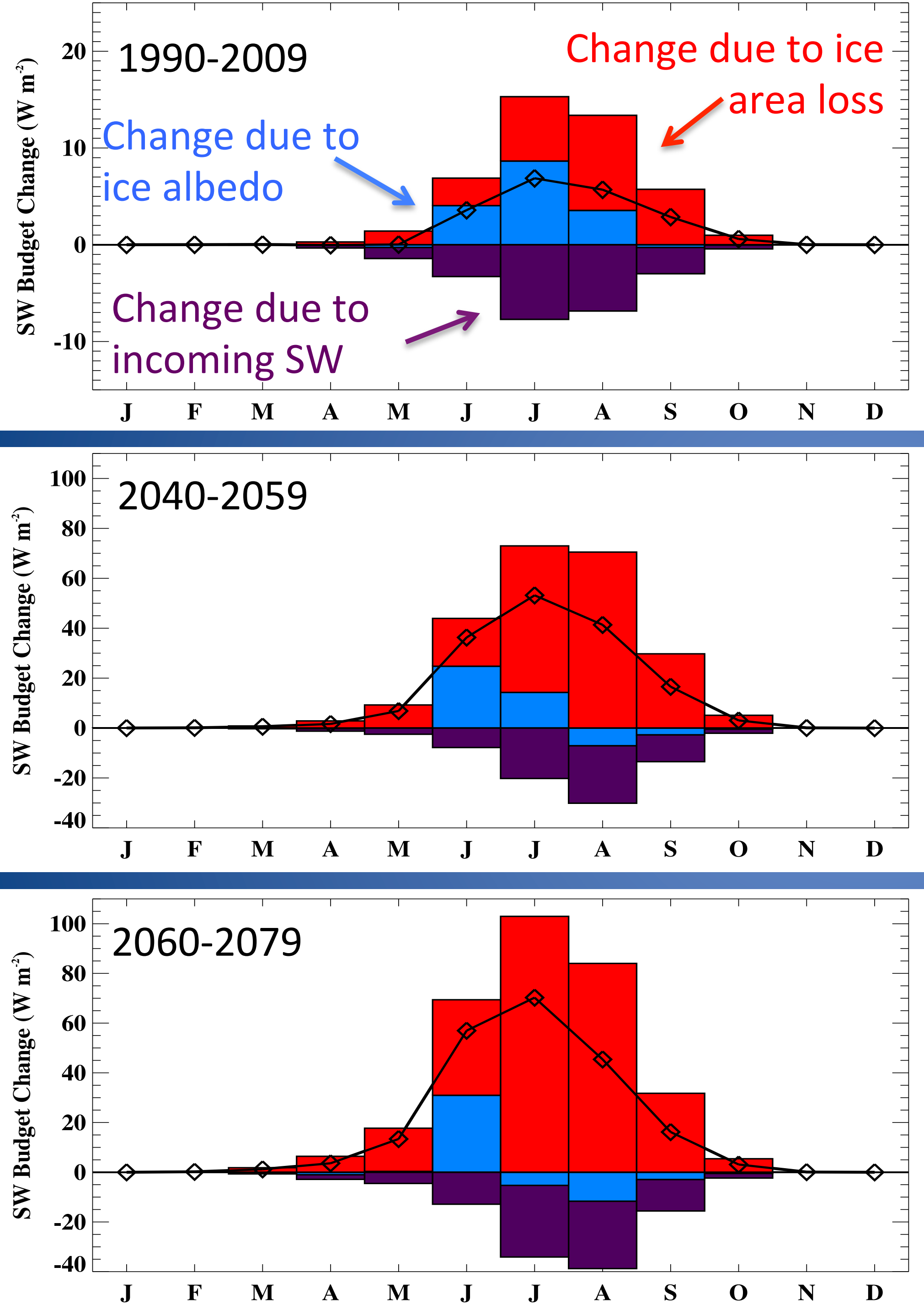
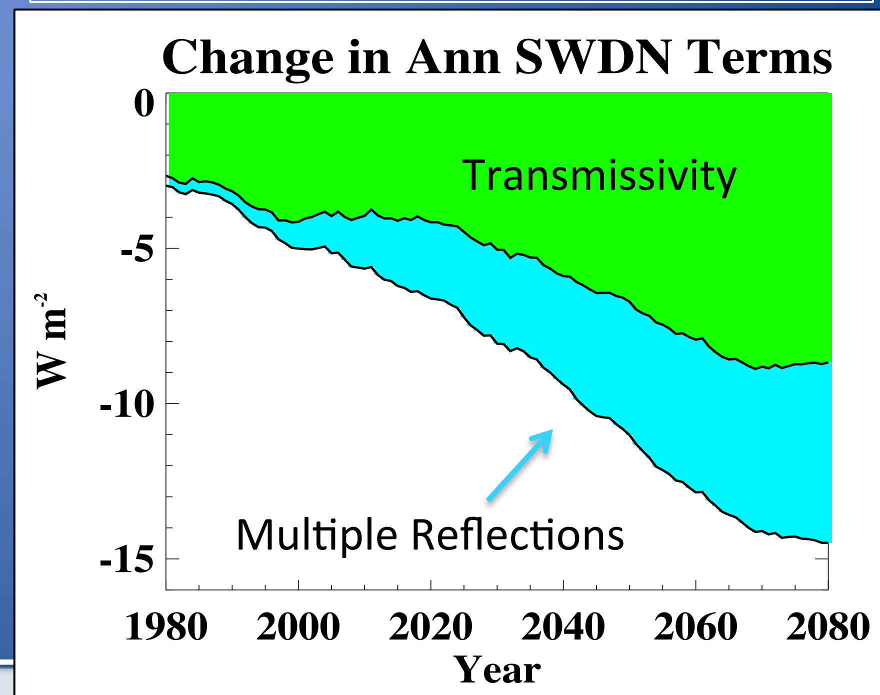
Simulated Arctic Surface SW Budgets

- Surface SW absorption increases
- Incoming shortwave radiation decreases





2018

(Diagnosed using method from Winton 2005)