Linking Stratospheric Circulation Extremes and Minimum Arctic Sea Ice Extent

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AGCI Workshop on Polar Amplification
June 15, 2017

Image courtesy of NASA
Interannual SIC variability

Strong et al. 2009
Interannual SIC variability

NAO Leads

SIC Leads

Strong et al. 2009
Interannual SIC variability

Correlation between AO and September SIE

Rigor et al. 2002; Holland & Stoeve, 2011
Interannual SIC variability

Daily Average Sea Ice Thickness

Data: PIOMASS
Interannual SIC variability

Dynamic Pre-conditioning

Data are for 1993-2014

Rigor & Wallace 2004; Williams et al. 2016
Interannual SIC variability

$r = -0.56$

Williams et al. 2016
Stratospheric circulation and the AO/NAO

SSW Composite: AO Index

SAT & SLP days 10-60 after SSW

data: ERA-I 1979-2012
SSWs & SPVs - Definitions

- **SSW identification**: Zonal wind reversal at 60°N and 10 hPa

- **SPV identification**: Zonal wind exceeds 48 m/s at 60°N and 10 hPa
Model & Integration

• **Model:** CESM1(WACCM), fully coupled, stratosphere-resolving model.

• **Integration:** 400-year long *Year-2000* Control integration, no QBO, solar average.

• Daily atmospheric data (+ SSTs & SIC) and monthly data for all other sea ice fields
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<tr>
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<th>Number of SSWs &amp; SPVs</th>
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<tr>
<td></td>
<td>ERA-I</td>
<td>WACCM</td>
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<tr>
<td>SSWs</td>
<td>21</td>
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<td>SSW Years</td>
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<td>SPVs</td>
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<td>156</td>
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<td>SPV Years</td>
<td>14</td>
<td>99</td>
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</table>
SSWs & SPVs - Definitions

(a) SSW Composite: $\bar{u}_{60^\circ}$N
(b) SPV Composite: $\bar{u}_{60^\circ}$N

ERA-I

WACCM
SSWs & SPVs - Surface Signatures

(a) SSW Composite: days 0-40

(b) SPV Composite: days 0-40

(c) SSW Years: JFM

(d) SPV Years: JFM
Sea Ice Extent

Total

Barents

Laptev/E. Sib/ Chukchi

Berring/ Okhotsk

Significant SIE anomalies extending well into late summer
Sea Ice Extent

Total

Barents

Laptev/E.Sib/Chukchi

Bering/Okhotsk
Sea Ice Extent

Total

Barents

Laptev/E.Sib/Chukchi

Berring/Okhotsk

tropospheric precursor?
Sea Ice Concentration

(a) SSW Years: JFM
(b) SSW Years: AMJ
(c) SSW Years: JAS
(d) SPV Years: JFM
(e) SPV Years: AMJ
(f) SPV Years: JAS
Sea Ice Concentration

- **Barents Sea**: SSW & SPV anomalies are ~25% of a STDEV.

- **Laptev/E. Sib/Chukchi Seas**: SSW anomalies are ~25% of a STDEV and SPV anomalies are ~50% of a STDEV.
Story so far:

1. SSWs and SPVs are followed by SIC anomalies in the Barents Sea in spring and the Laptev/E. Siberian/Chukchi Seas in summer

2. Anomalies appear to be consistent with the interannual relationships between AO/NAO and SIC in literature

Are the mechanisms also consistent?
Laptev/E. Sib/Chukchi Seas: SSW anomalies are \(~16\%\) of a STDEV and SPV anomalies are \(~32\%\) of a STDEV.
Processes: Barents Sea

(a) BA Region: SIC and SIC Tendency

(b) BA Region: Ice Thickness and Volume Tendency

SIC Tendencies

SIT Tendencies
Processes: Laptev, E. Siberian & Chukchi Seas

(b) L/ES/C Region: SIC and SIC Tendency

(d) L/ES/C Region: Ice Thickness and Volume Tendency
SSWs & SPVs: Reanalysis

(a) SSW Composite: $\bar{u}_{60^\circ N}$

(b) SPV Composite: $\bar{u}_{60^\circ N}$

ERA-I
Sea Ice Concentration: NSIDC

(a) SSW Years: JFM
(b) SSW Years: AMJ
(c) SSW Years: JAS
(d) SPV Years: JFM
(e) SPV Years: AMJ
(f) SPV Years: JAS
Sea Ice Extent: NSIDC

Barents

Laptev/E.Sib/Chukchi
Conclusions

- **SSWs:** *Positive* SIC anomalies in Barents Sea in spring and Laptev/E. Siberian/Chukchi Seas in summer

- **SPVs:** *Negative* SIC anomalies in Barents Sea in spring and Laptev/E. Siberian/Chukchi Seas in summer

- In the BA region, SIE anomalies are driven by winter ice advection, while SIE anomalies in the L/ES/C region arise due to ice thickness anomalies, generated by coastal sea ice divergence in late winter and enhanced by thermodynamical feedbacks in spring and summer.

- Because stratospheric anomalies precede AO anomalies in the troposphere, there is the potential to extend the period over which skillful prediction of Arctic SIE may be achieved if knowledge of stratospheric conditions is known.
Multi-decadal stratospheric influence on Arctic
Multi-decadal stratospheric influence on Arctic

Polvani, Previdi, Smith (in prep)
Multi-decadal stratospheric influence on Arctic

(c) April–May ΔTS (LO–HI; 25OZ)

(f) surface T

CAM4

WACCM4

Smith & Polvani 2014
Calvo et al. 2015
Multi-decadal stratospheric influence on Arctic

Historical - FixODS