Albedo decrease caused by vanishing Arctic sea ice

Observational determination using CERES

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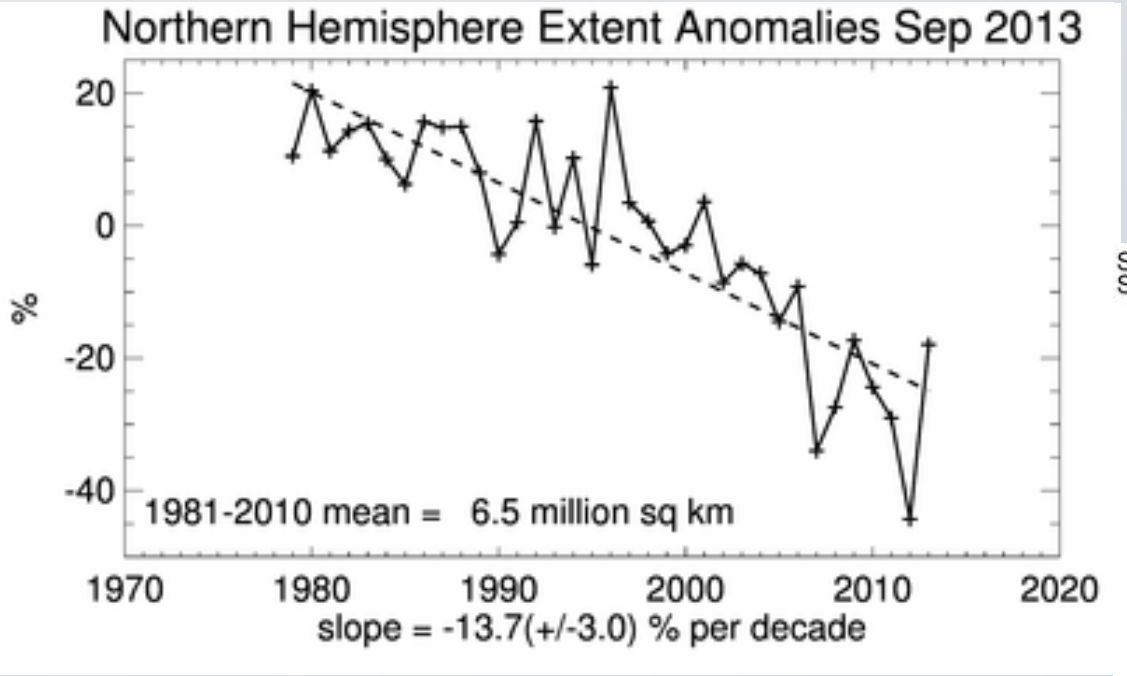
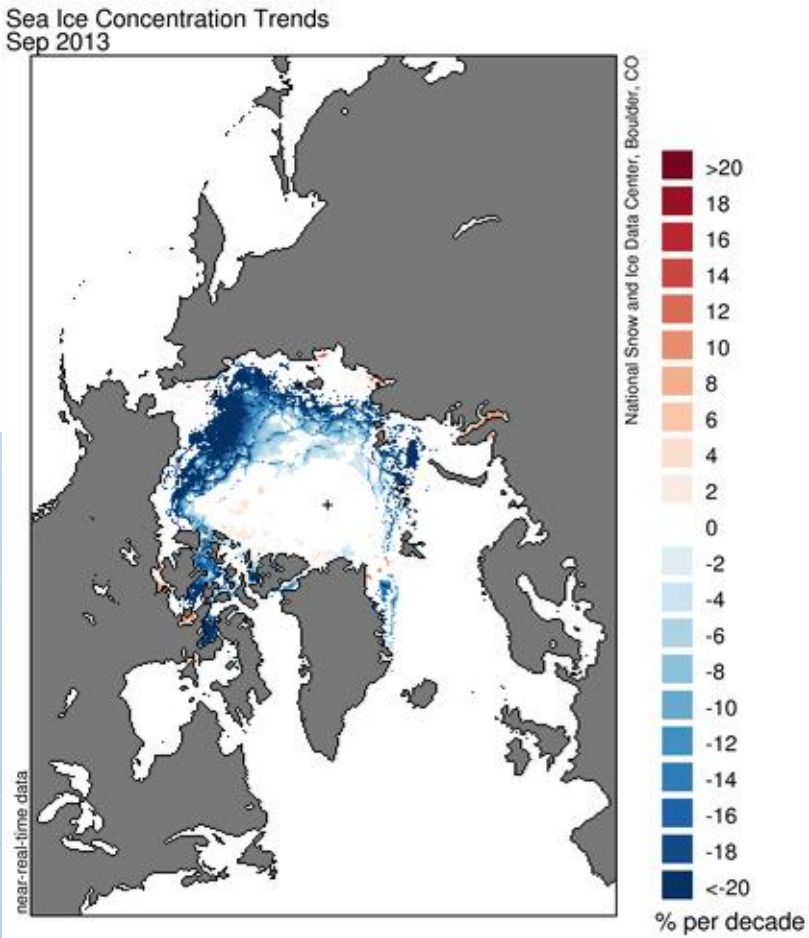
The Arctic sea ice is shrinking



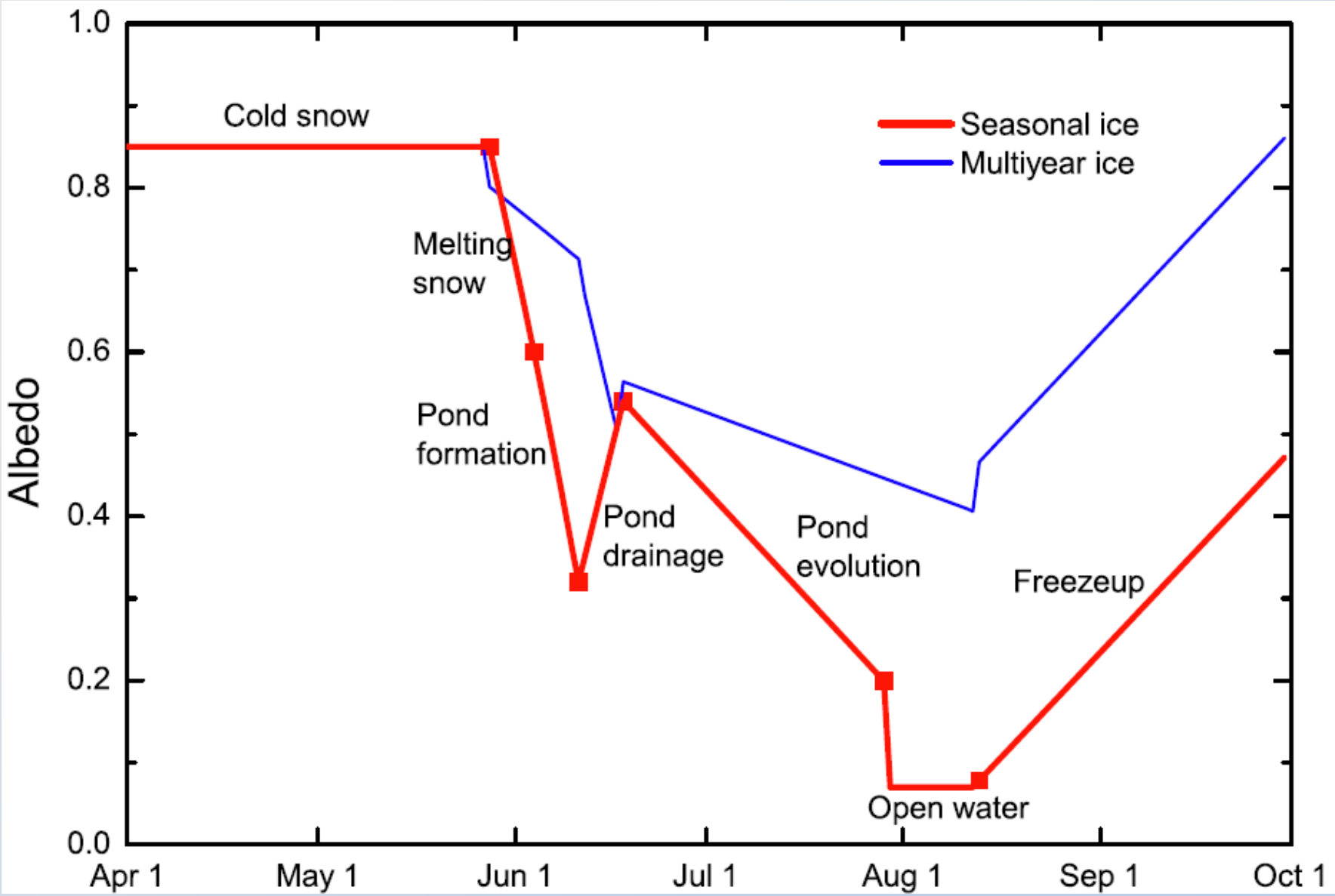


http://nsidc.org/data/seaice_index/archives/

Decreasing ice area reduces albedo

- Amount of incoming solar radiation reflected back to space
- White surfaces reflect more; dark surfaces absorb more sunlight
- Ice albedo feedback
- Albedo of ice itself will change seasonally or with other factors
- Clouds are white

Seasonal cycle of ice albedo



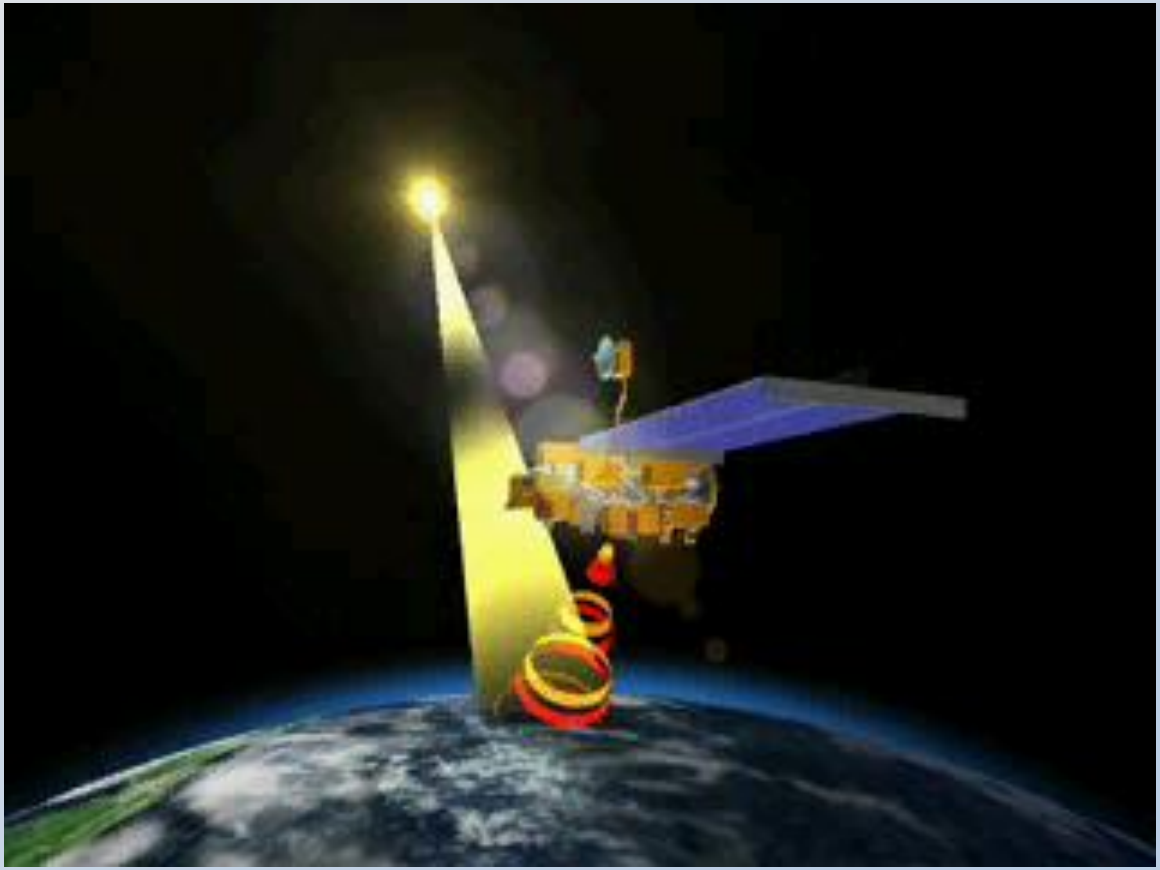
Perovich and Polashenski , GRL (2012)

Our Question:

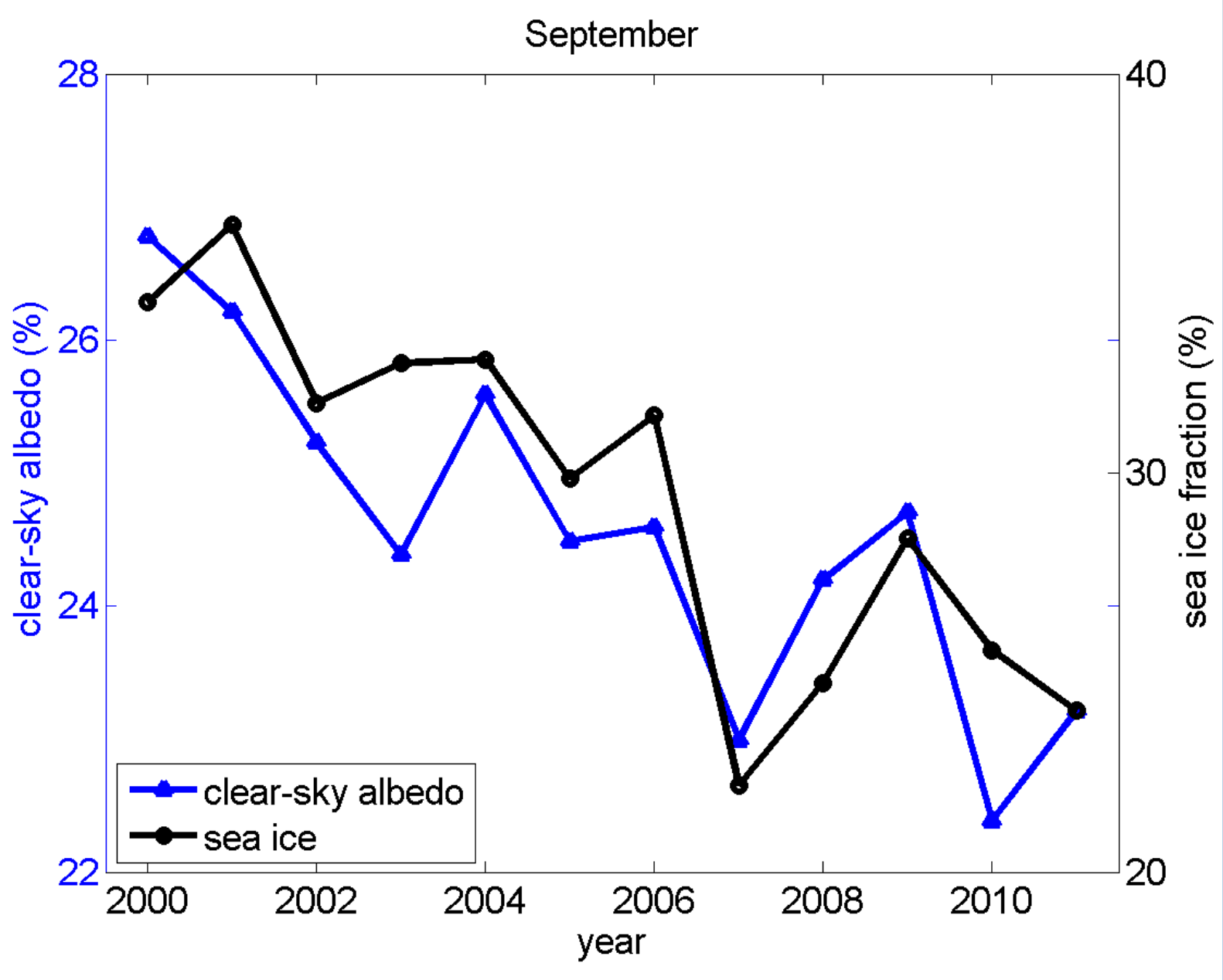
- How much does the albedo of the Arctic change as the ice retreats?
- How much extra energy does this mean for the Arctic?
- Are there any compensating effects to mitigate the albedo decrease?

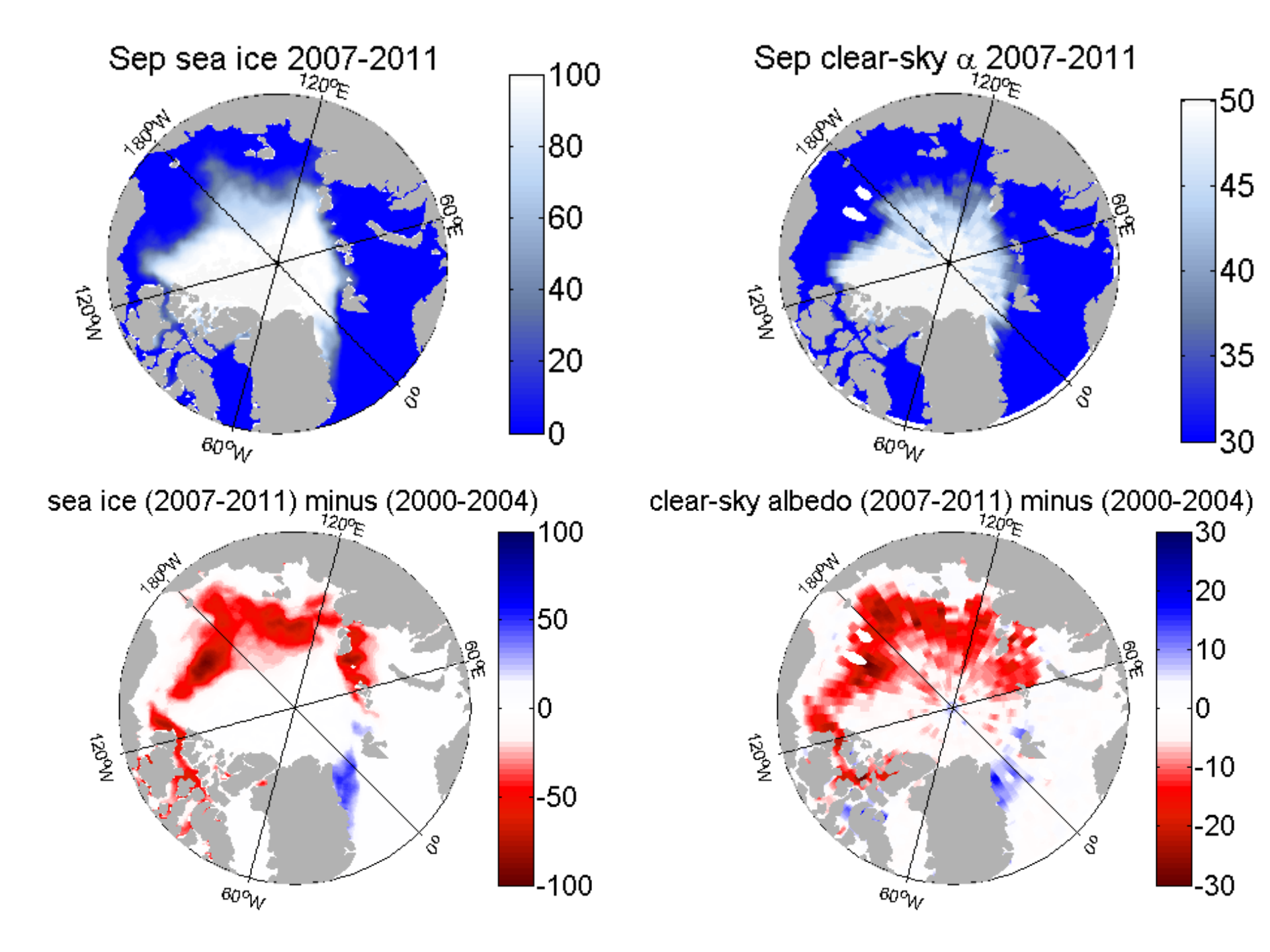
Observational Data

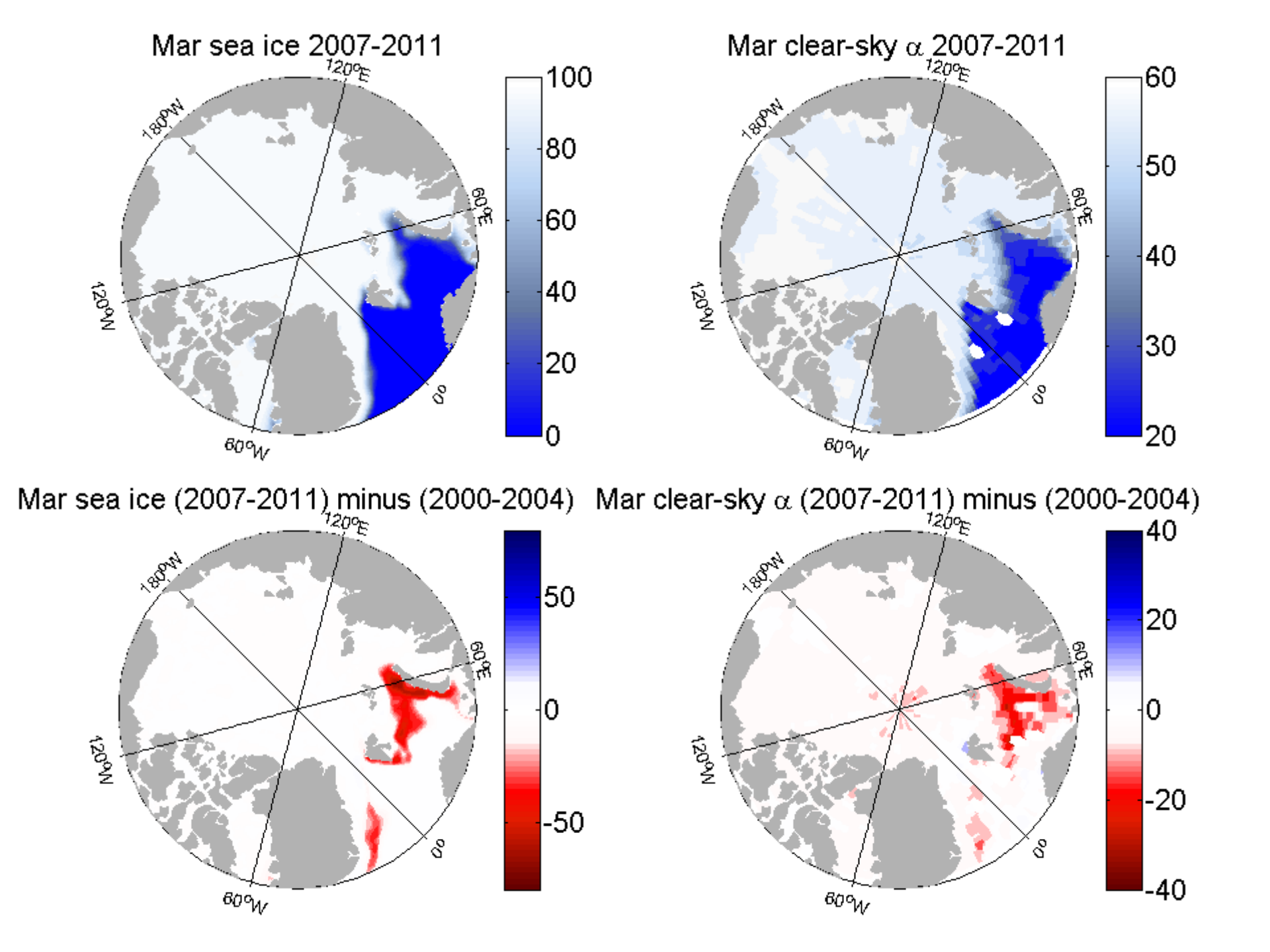
- Shortwave radiation (0.3-5μm), 1°x1° resolution data from CERES Terra SSF Ed 2.6
- NSIDC: sea ice concentration measured from microwave satellites (SSM/I) since 1979
  - Monthly-averaged data, coincident with CERES from March 2000 through December 2011

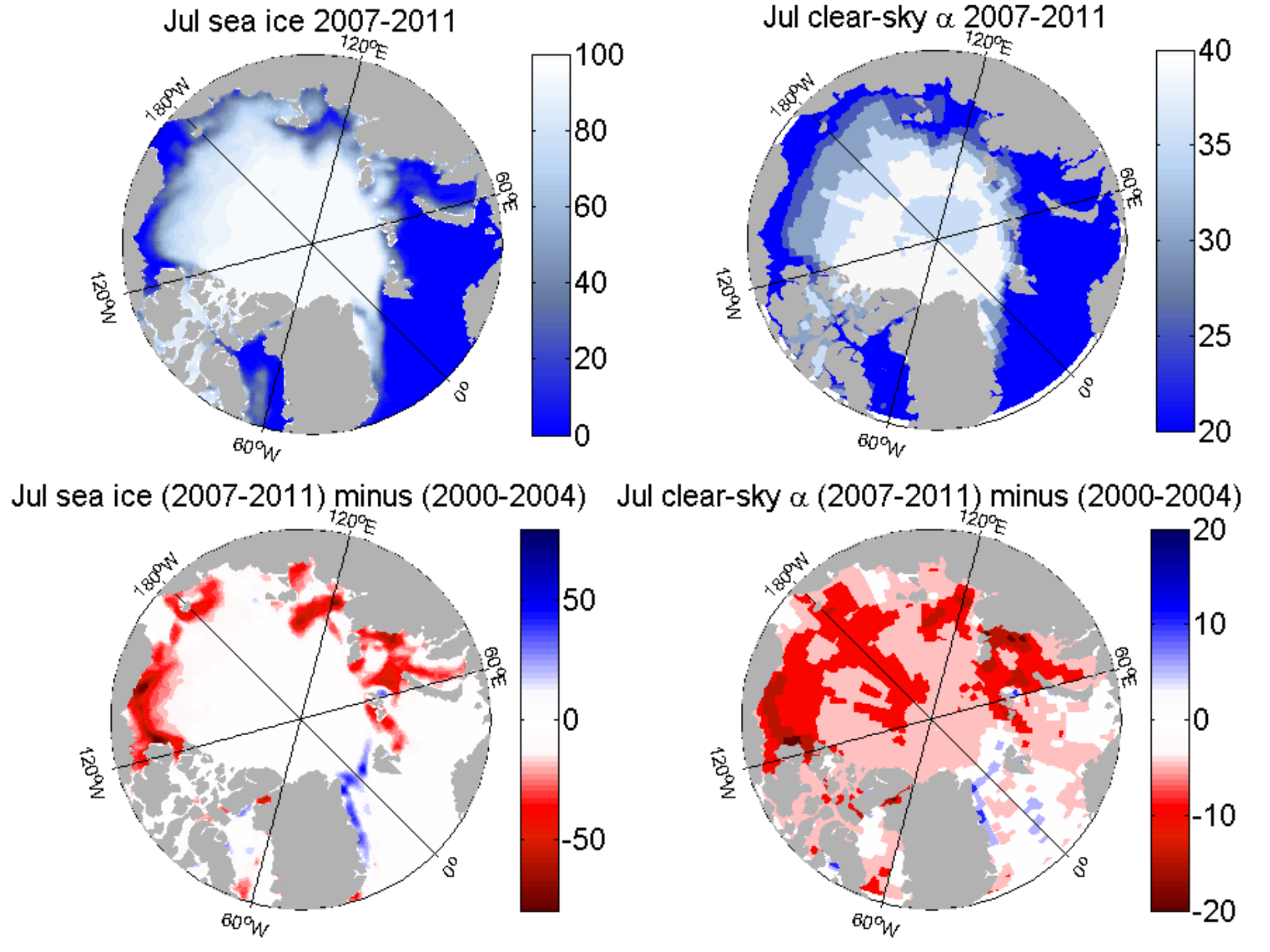


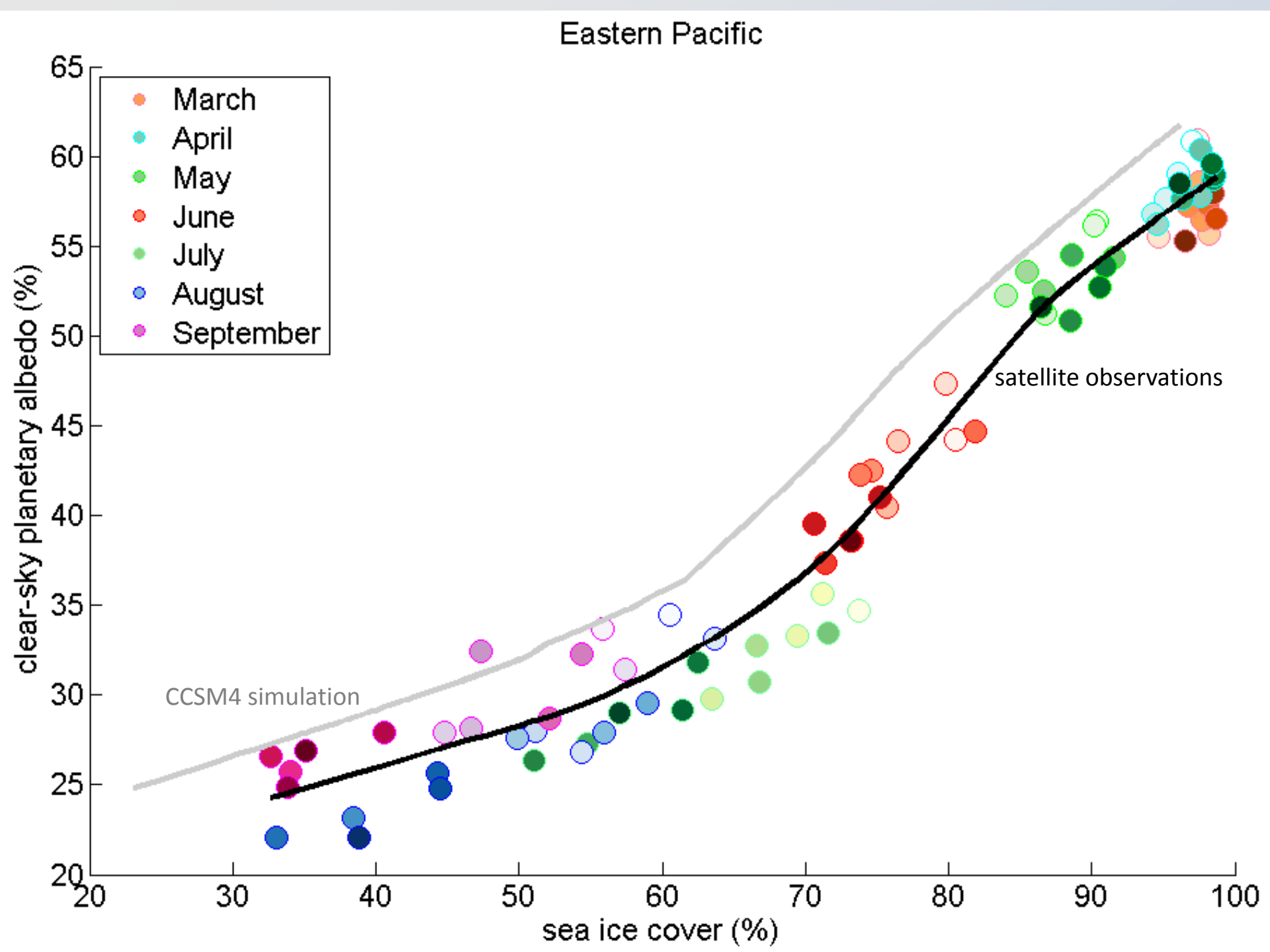
Albedo tracks with sea ice decrease

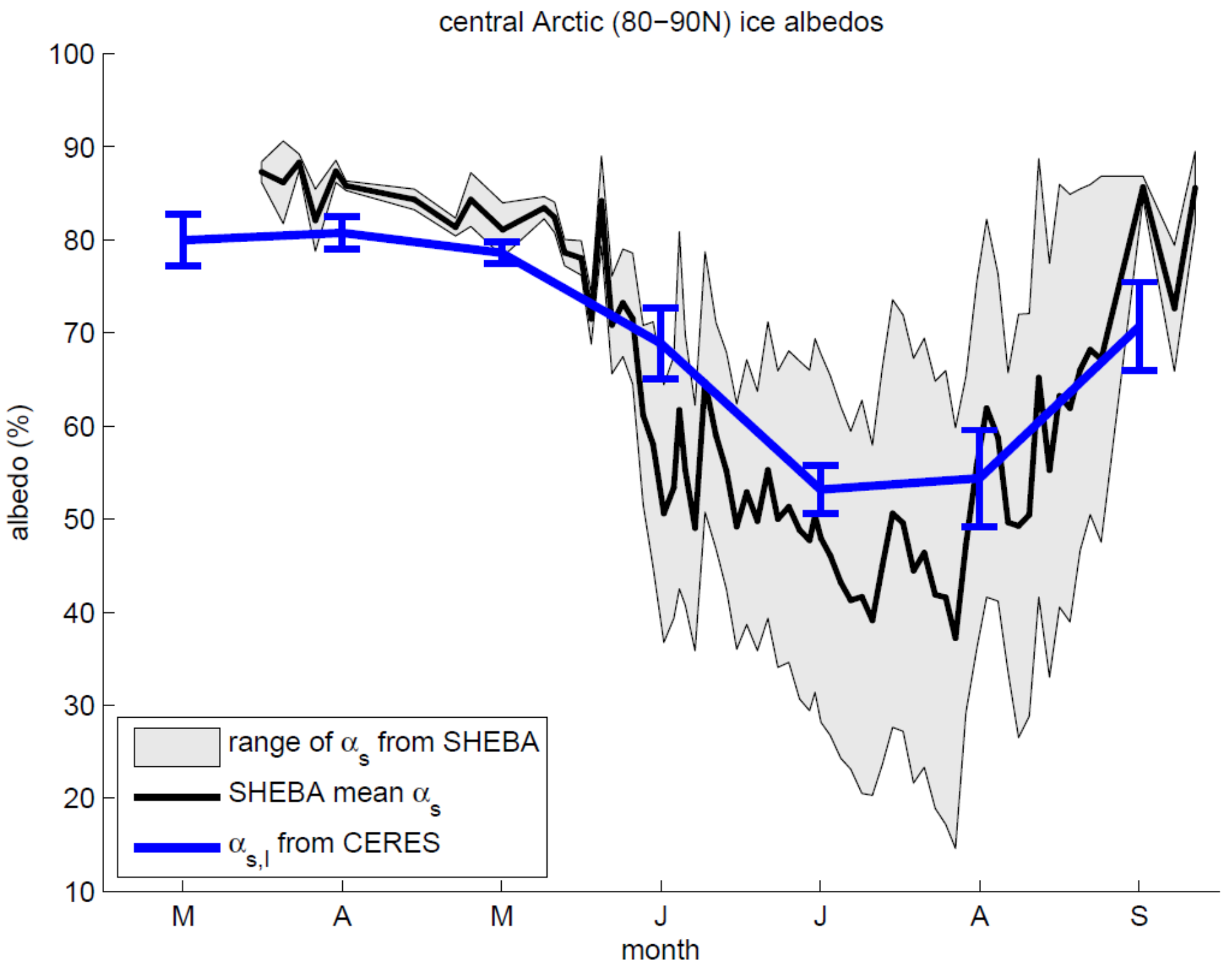


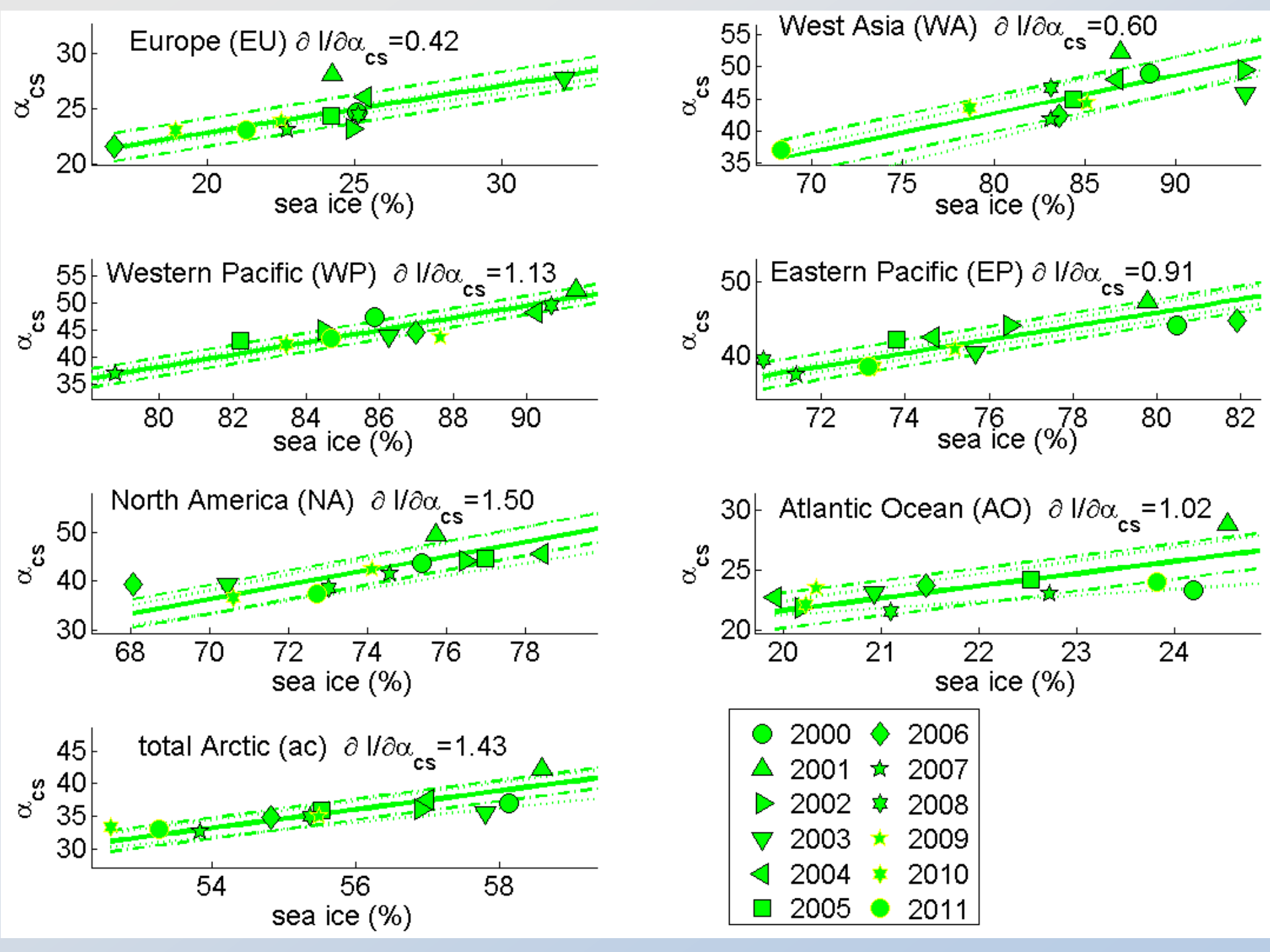

Sep sea ice 2007-2011
120°E
180°W
60°E
120°W
0°
60°W
100
80
60
40
20
0
Sep clear-sky α 2007-2011
120°E
180°W
60°E
120°W
0°
60°W
50
45
40
35
30
sea ice (2007-2011) minus (2000-2004)
120°E
180°W
60°E
120°W
0°
60°W
100
50
0
-50
-100
clear-sky albedo (2007-2011) minus (2000-2004)
120°E
180°W
60°E
120°W
0°
60°W
30
20
10
0
-10
-20
-30

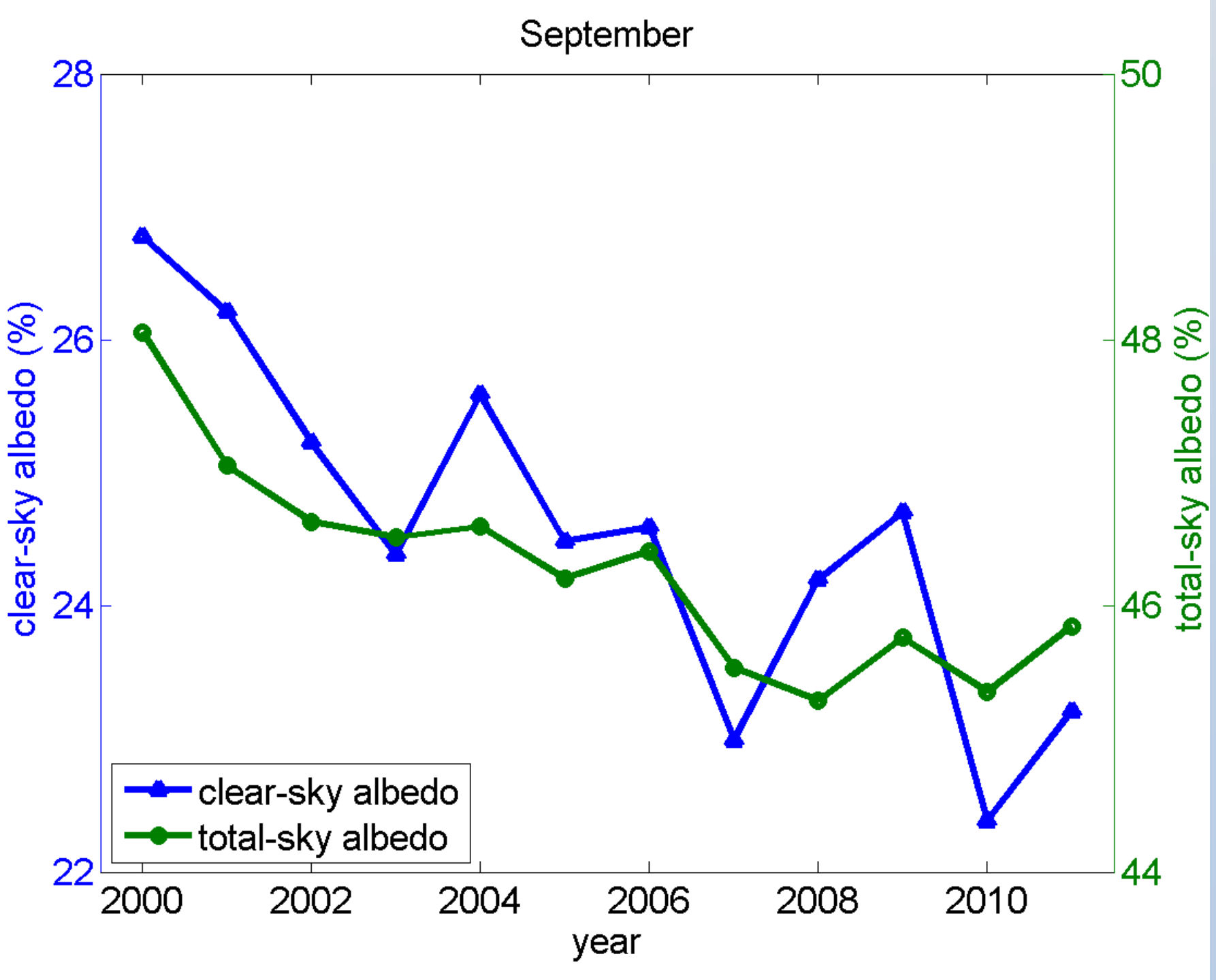

Mar sea ice 2007-2011
120°E
180°W
60°E
120°W
0°
60°W
100
80
60
40
20
0
Mar clear-sky α 2007-2011
120°E
180°W
60°E
120°W
0°
60°W
60
50
40
30
20
Mar sea ice (2007-2011) minus (2000-2004)
120°E
180°W
60°E
120°W
0°
60°W
50
0
-50
Mar clear-sky α (2007-2011) minus (2000-2004)
120°E
180°W
60°E
120°W
0°
60°W
40
20
0
-20
-40

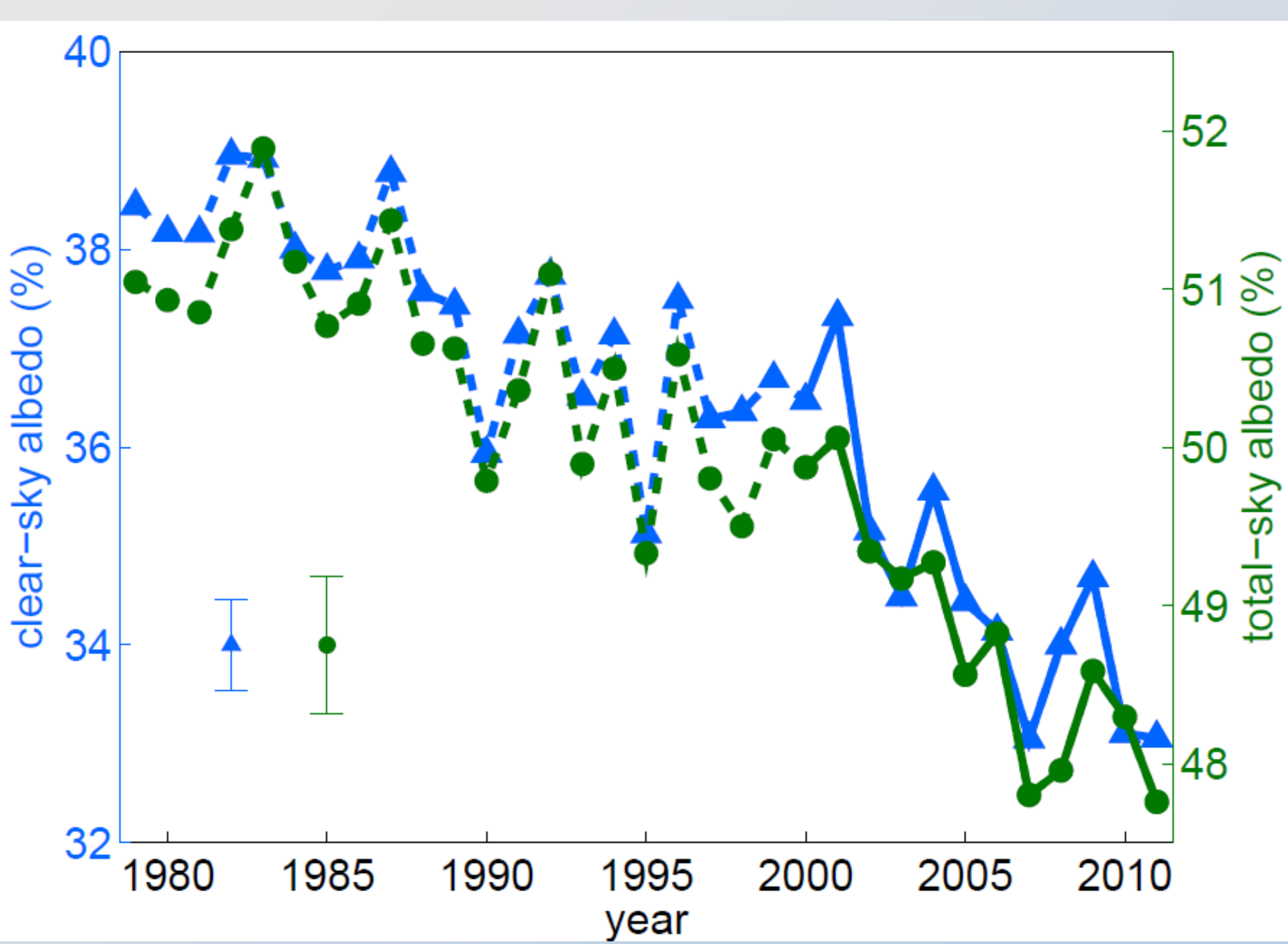

Jul sea ice 2007-2011
120°E
180°W
60°E
120°W
0°
60°W
100
80
60
40
20
0
Jul clear-sky α 2007-2011
120°E
180°W
60°E
120°W
0°
60°W
40
35
30
25
20
Jul sea ice (2007-2011) minus (2000-2004)
120°E
180°W
60°E
120°W
0°
60°W
50
0
-50
Jul clear-sky α (2007-2011) minus (2000-2004)
120°E
180°W
60°E
120°W
0°
60°W
20
10
0
-10
-20

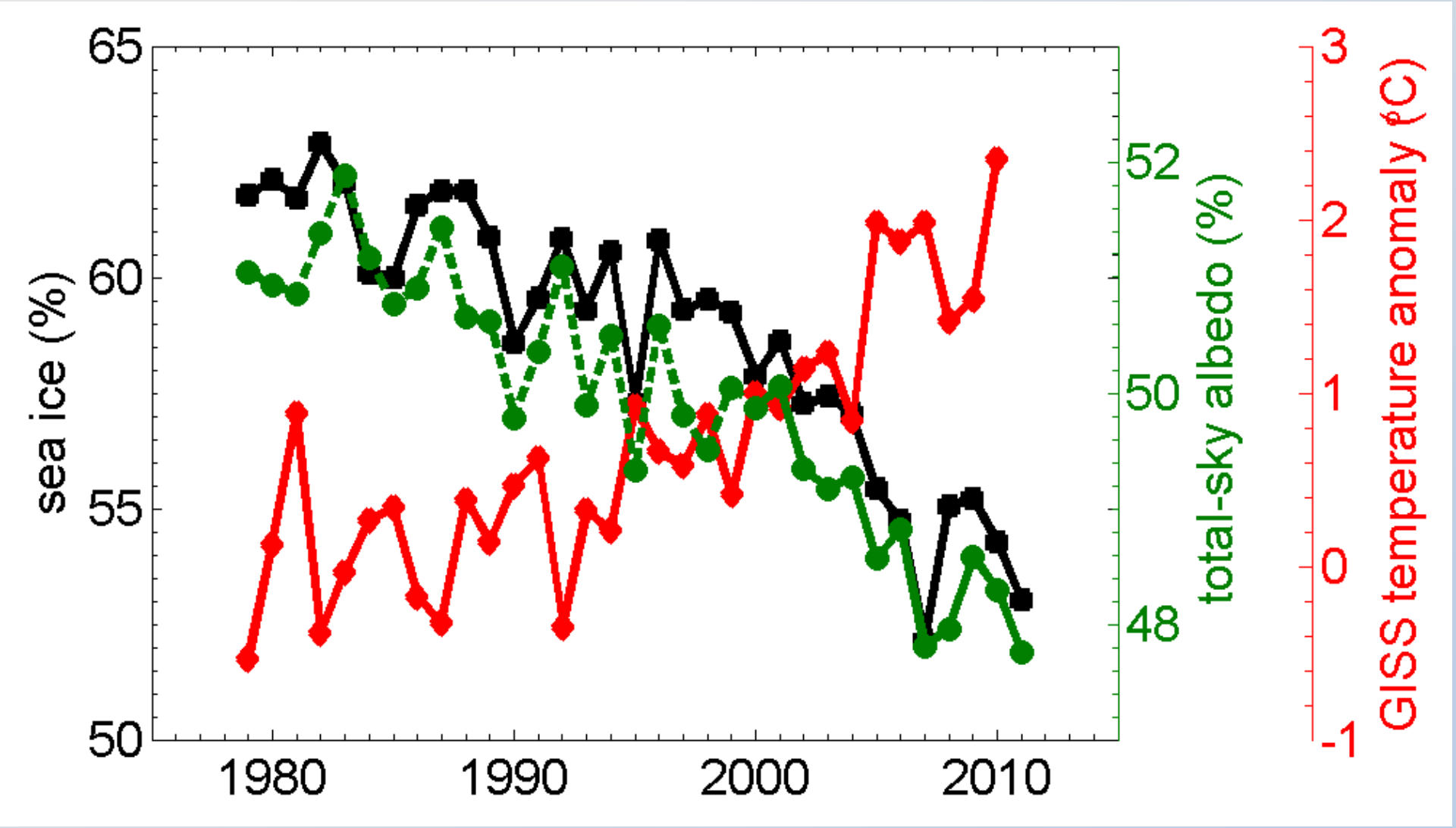

Eastern Pacific
March
April
May
June
July
August
September
satellite observations
CCSM4 simulation
clear-sky planetary albedo (%)
sea ice cover (%)
65
60
55
50
45
40
35
30
25
20
20
30
40
50
60
70
80
90
100


central Arctic (80–90N) ice albedos
albedo (%)
100
90
80
70
60
50
40
30
20
10
M
A
M
J
J
A
S
month
range of α_s from SHEBA
SHEBA mean α_s
$\alpha_{s,I}$ from CERES


Europe (EU) ∂ I/∂α_cs =0.42
West Asia (WA) ∂ I/∂α_cs =0.60
Western Pacific (WP) ∂ I/∂α_cs =1.13
Eastern Pacific (EP) ∂ I/∂α_cs =0.91
North America (NA) ∂ I/∂α_cs =1.50
Atlantic Ocean (AO) ∂ I/∂α_cs =1.02
total Arctic (ac) ∂ I/∂α_cs =1.43
α_cs
sea ice (%)
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


September
clear-sky albedo (%)
total-sky albedo (%)
year
clear-sky albedo
total-sky albedo
28
26
24
22
50
48
46
44
2000
2002
2004
2006
2008
2010


40
38
36
34
32
clear−sky albedo (%)
52
51
50
49
48
total−sky albedo (%)
1980
1985
1990
1995
2000
2005
2010
year


65
60
55
50
sea ice (%)
1980
1990
2000
2010
52
50
48
total-sky albedo (%)
3
2
1
0
-1
GISS temperature anomaly (°C)

Increase in Arctic SW heat flux 1979-2011

- The decrease in albedo of 4% corresponds to an increase of 6.4±0.9 W/m^2 in absorbed solar radiation over the Arctic Ocean (1979-2011).
  - 0.43±0.07 W/m^2 over NH
  - 0.21±0.03 W/m^2 averaged over the globe, approx 25% the magnitude of CO_2 forcing during this period
- Compared with previous studies and models:
  - Perovich et al 2007: 5.6 W/m^2 into Arctic Ocean
  - Flanner et al 2011: 0.22 W/m^2 (0.15-0.32 W/m^2) for NH
  - CCSM4: lower measured trend, but $\delta\alpha/\delta I$ is consistent

Conclusions

- Independent datasets strongly corroborate one another
- Arctic albedo under cloudless conditions has decreased from 37% to 31% between 1979 and 2011; total-sky albedo decreased from 52% to 48% during the same period. This is larger than previous estimates.
- While GCMs underestimate ice retreat, the ice-albedo feedback appears well-captured.

Questions?