CLOUD CHANGES IN RECENT DECADES ENHANCE ARCTIC WARMING

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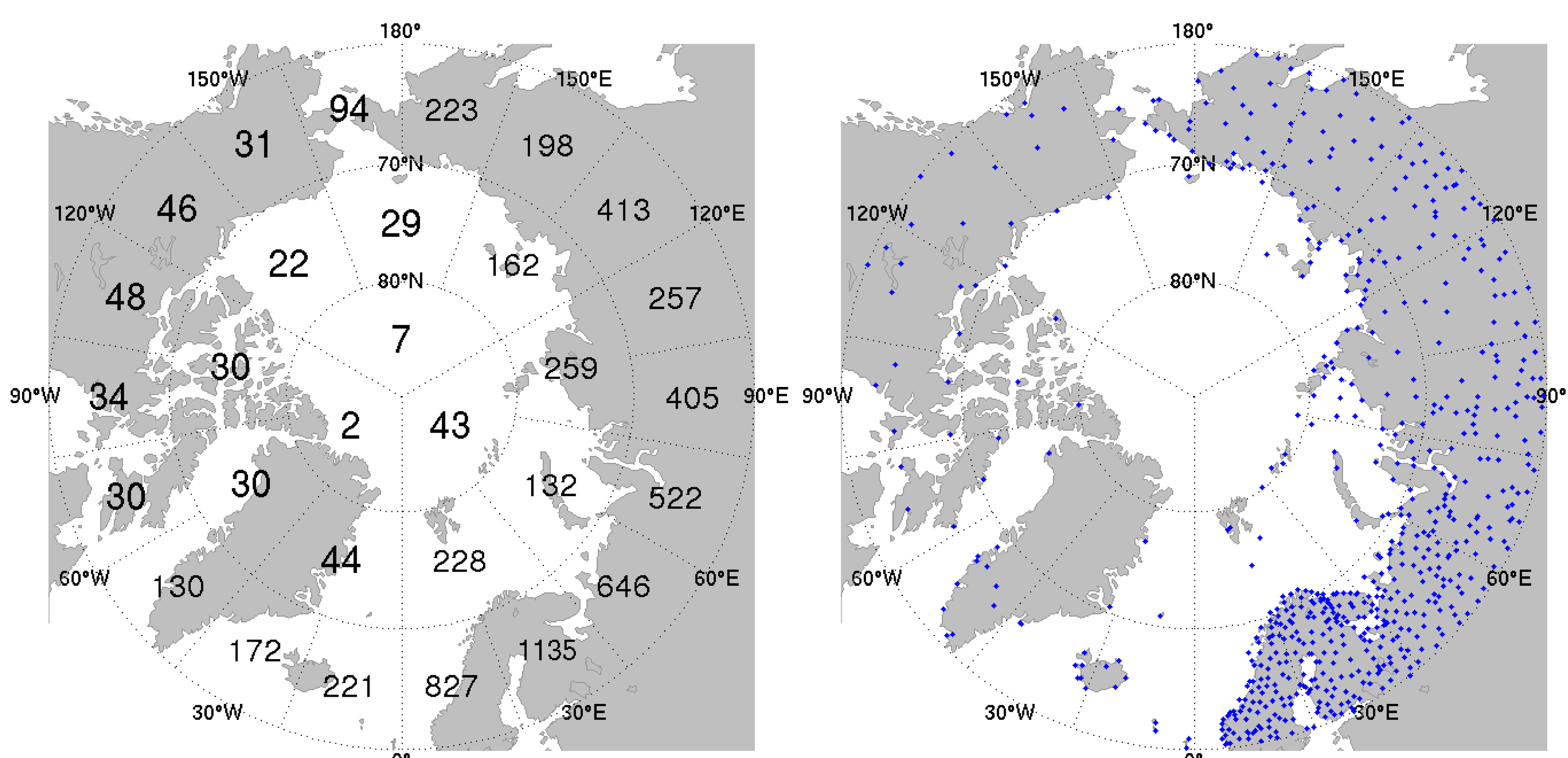
Abstract

Interannual variations in sea ice extent and thickness may be affected by cloud radiative forcing, and sea-ice changes may in turn impart changes to cloud cover. Visual cloud reports are analyzed for land and ocean regions including total cloud cover and five low cloud types (fog, St, Sc, Cu, Cb), three middle cloud types (Ns, As, Ac) and high cloud amount.

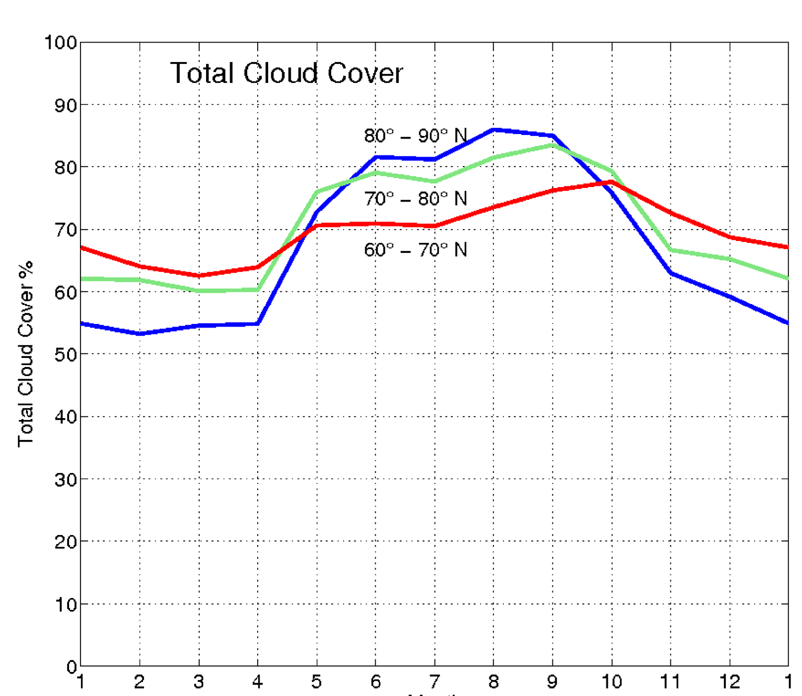
Year to year variations of cloud amounts over the Arctic Ocean show significant correlations with surface air temperature, total sea ice extent, and the Arctic Oscillation. A composite climatology for years with high and low September ice extent indicates significant relationships between cloud cover and sea ice extent. Trends in surface cloud data disagree with those from AVHRR satellite data in autumn and winter. The multidecadal trends from surface observations show increasing cloud cover in autumn, winter, and spring which would promote arctic warming, and a decrease in summertime precipitating clouds, which appears to promote ice loss.

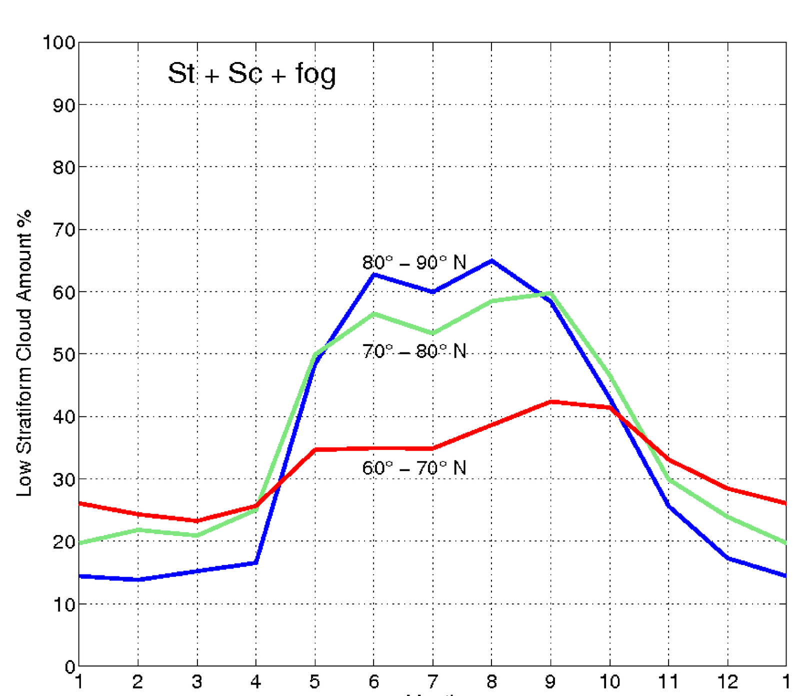
Cloud Data. Arctic cloud data from synoptic weather reports have been compiled into a climatology for land stations from 1971 through 2007, and for ships and drifting stations from 1954 through 1997. An update in ocean data through 2008 is forthcoming.



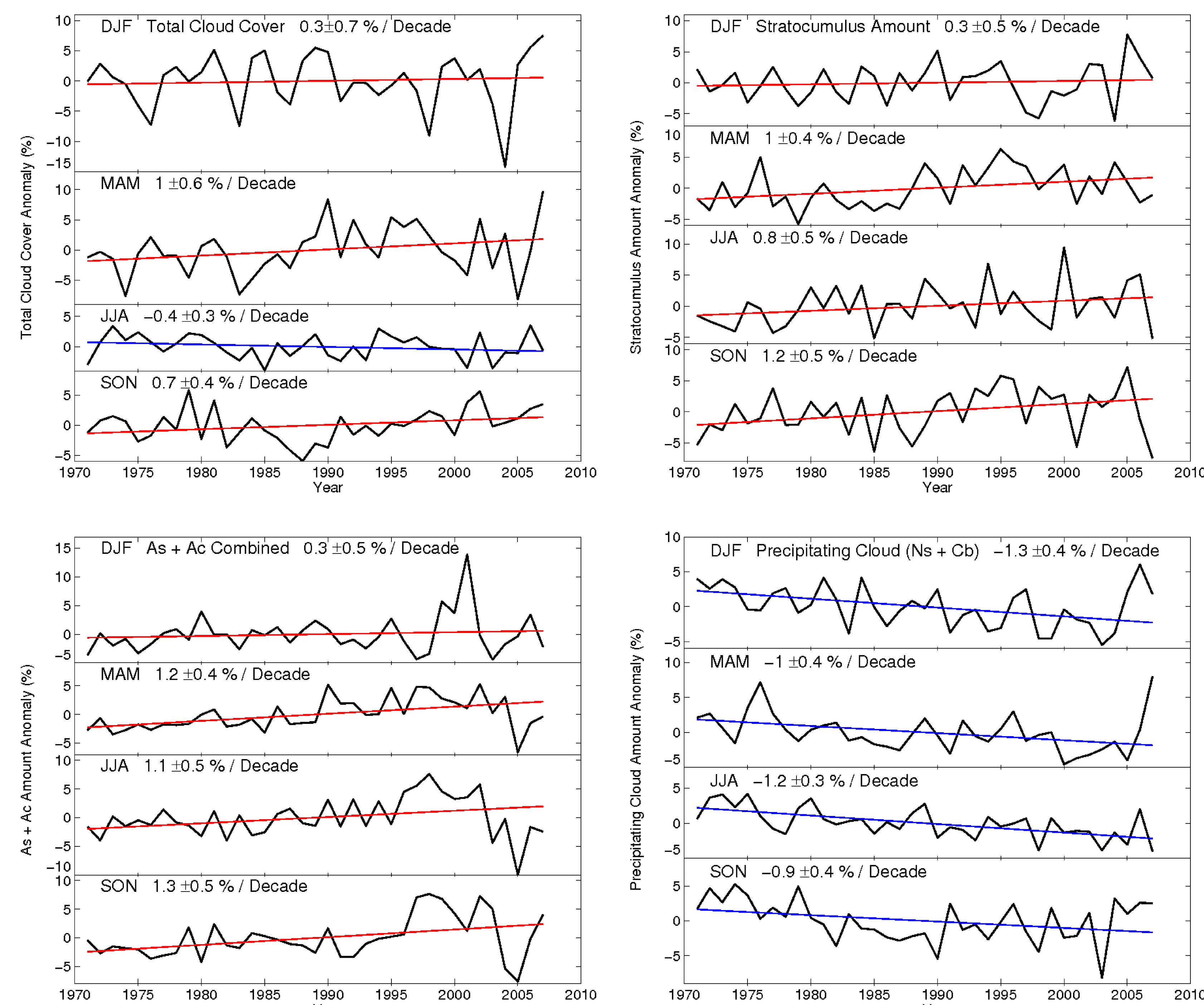
Left frame: Number of cloud observations (in hundreds) per year for both land and ocean. Right frame: Distribution of weather stations over the Arctic

Annual Cycle. The annual cycle of Arctic cloud cover is more pronounced at higher latitudes and is attributed to low stratiform cloud cover:





Trend Analysis. Significant trends are found for several cloud types in an anomaly time series over the Arctic Ocean only, using drifting stations, ship reports and coastal/island land stations:



Correlation Analysis. Time series for all cloud types over the Arctic Ocean have been correlated with September sea ice extent from NSIDC, seasonal surface air temperature from the International Arctic Buoy Programme, and the seasonal Arctic Oscillation index. The correlation coefficient is printed in bold if it exceeds the 95% significance level.

Correlations with September Sea Ice Extent

	Total	St	Sc	Fog	Cu	Cb	Ns	As + Ac	High	Middle	Low	Precipitating
DJF	-0.2	-0.2	-0.3	0.3	0.1	-0.3	0.0	0.0	-0.1	0.0	-0.3	0.0
MAM	-0.3	-0.2	-0.2	**-0.4**	0.0	**-0.4**	0.0	-0.2	-0.2	-0.1	-0.3	-0.1
JJA	0.1	-0.2	0.2	-0.2	0.3	0.0	**0.6**	0.2	0.0	**0.4**	-0.1	**0.6**
SON	**-0.5**	-0.2	0.0	-0.3	0.0	**-0.5**	0.2	-0.3	0.0	-0.1	-0.4	-0.2

Correlations with Seasonal Temperature Anomalies

	Total	St	Sc	Fog	Cu	Cb	Ns	As + Ac	High	Middle	Low	Precipitating
DJF	0.3	0.2	0.3	-0.1	-0.1	-0.2	0.0	0.3	-0.1	0.3	0.3	0.0
MAM	**0.8**	**0.5**	**0.7**	0.1	0.2	-0.3	0.3	**0.8**	0.2	**0.9**	**0.8**	0.2
JJA	0.1	0.4	-0.1	0.1	0.1	-0.3	-0.2	0.0	-0.1	-0.1	0.3	-0.3
SON	**0.6**	0.3	**0.5**	**0.5**	-0.1	0.1	0.3	**0.5**	-0.4	**0.5**	**0.6**	0.3

Correlations with Seasonal Arctic Oscillation Indices

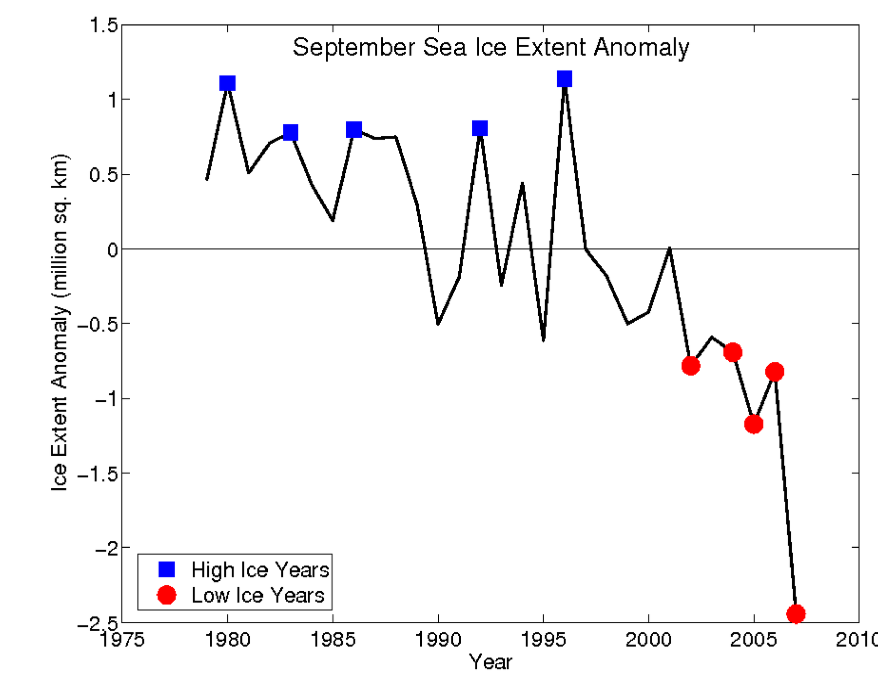
	Total	St	Sc	Fog	Cu	Cb	Ns	As + Ac	High	Middle	Low	Precipitating
DJF	0.2	-0.1	0.2	-0.3	0.3	0.1	0.1	-0.1	**0.4**	0.0	0.1	0.1
MAM	**0.5**	0.1	0.1	0.1	0.0	0.2	0.1	**0.3**	**0.6**	**0.3**	0.2	0.2
JJA	**0.4**	-0.2	**0.5**	-0.1	-0.1	0.2	0.3	0.2	0.1	0.3	0.3	**0.4**
SON	**-0.5**	-0.3	-0.2	-0.3	0.1	0.0	-0.1	**-0.4**	0.1	**-0.4**	-0.3	-0.1

Sea ice table: Stratus, stratocumulus and fog all correlate negatively with sea ice extent. Enhanced summertime Ns (and therefore a likely increase in snowfall) is associated with greater September sea ice extent.

Temperature table: Most cloud types correlate positively with surface temperature, most significantly in spring and autumn. Only precipitating clouds in summer seem to be associated with a cooler surface temperature in the Arctic

Arctic Oscillation (AO) table: A positive AO index indicates lower atmospheric pressure in the arctic and during winter, spring and summer is associated with increased cloud cover. During autumn, a positive AO is associated with reduced cloud cover.

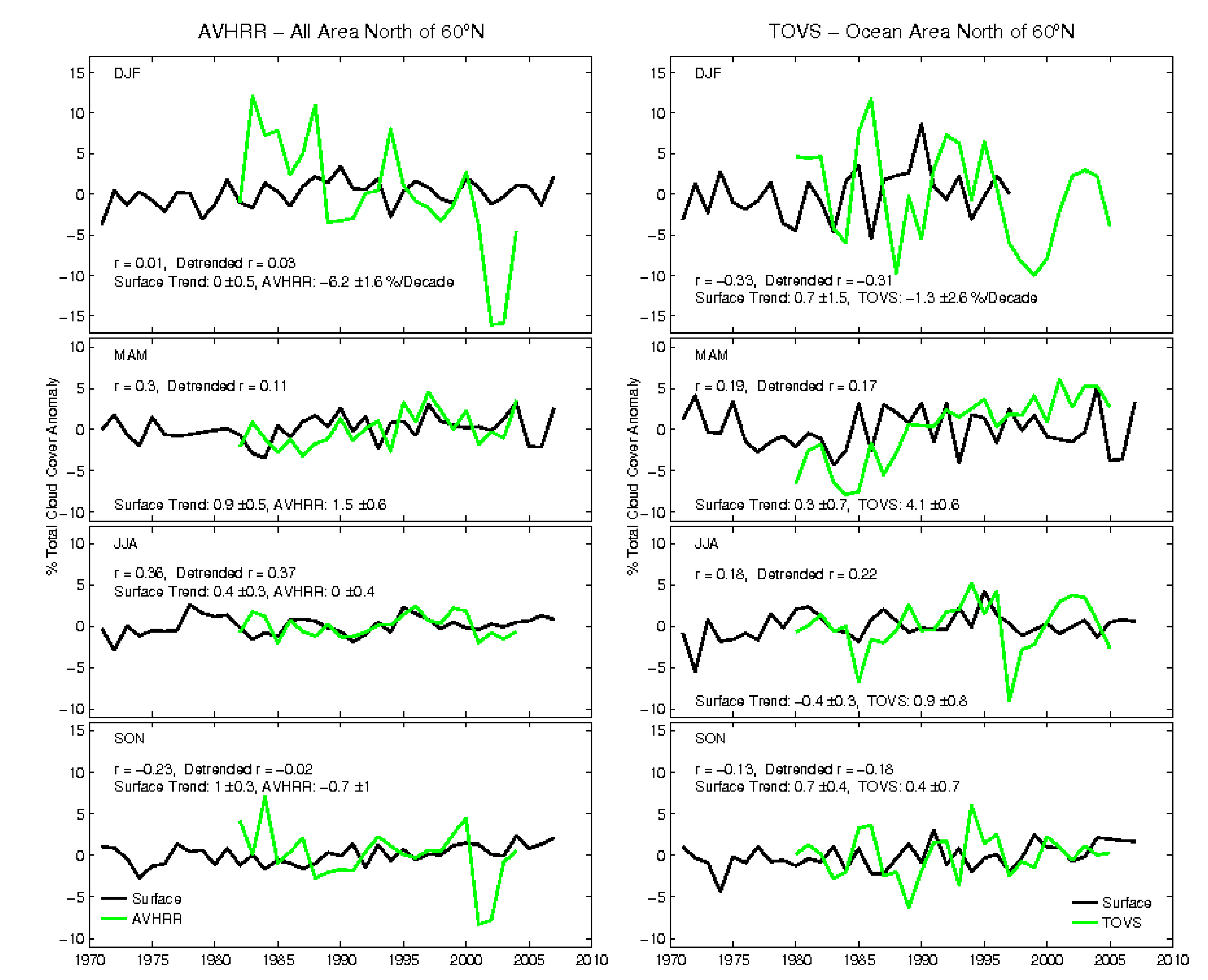
Superposed Epoch Analysis. Cloud anomalies during the five years with the greatest September sea ice extent were averaged, and likewise for the five with the least ice extent. The table below shows that low September ice extent is generally preceded by a summer with decreased high, middle and precipitating clouds. Following a low-ice September there is enhanced Cumulonimbus and Stratus in autumn. Total cloud cover appears to be greater throughout the year during low-ice years.:



Superposed Epoch Study (% Cloud Cover in Low – High Ice Years) Bold is 90% significant

	Total	St	Sc	Fog	Cu	Cb	Ns	As + Ac	High	Middle	Low	Precipitating
DJF (previous)	2.1	1.4	3.6	0.0	-0.2	0.1	2.0	-0.3	-3.0	1.7	4.8	2.0
MAM	1.6	0.3	0.6	0.2	-0.3	0.6	-1.0	-0.3	3.2	-1.6	1.4	-0.4
JJA	0.4	1.1	-0.4	0.7	**-0.6**	0.5	-2.7	-2.8	-2.2	**-6.0**	1.3	-2.1
SON (following)	**4.1**	**3.2**	-0.2	0.7	-0.3	**3.8**	-1.8	1.4	1.4	-0.5	**7.3**	**2.1**
DJF (following)	2.4	2.8	3.3	0.0	-0.1	0.1	-1.0	0.6	-1.4	-0.3	6.1	-0.8

Satellite Comparisons. Surface observations of total cloud cover are compared to satellite cloud data (TOVS Path-P and AVHRR) over similar time spans and regions. Some agreement is shown during sunlit months, but large disagreements arise during autumn and winter.



Time series of AVHRR on the left (Wang & Key 2005, J. Climate) and TOVS Path-P on the right (Francis & Schweiger 1999, 2008, NSIDC) compared to surface observations. Trends are computed for the overlapping time period only

Summary. Clouds tend to be increasing outside of summertime, and increasing most substantially during spring and autumn, when they show the strongest relationship with warming. Low-ice years appear to be associated with increased cloud cover.