Comparison of Two Extreme Minimum Arctic Sea-Ice Extents:

The Record High During 1996 and Record Low During 2007

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Introduction

A warming Arctic climate is experiencing significant environmental changes. These changes are most evident by the reduction of Arctic sea-ice extent and thickness during the summer. Several factors are believed to have significant impacts on the coverage and thickness of the Arctic sea-ice. These include dynamic and thermodynamic forcing parameters such as large-scale atmospheric circulation patterns, downwelling radiative fluxes, advective heating, and wind stress. This study will investigate the possible causes affecting the sea-ice extent and how they relate to the minimum extent that occurs each year in September. An investigation based on reanalysis data will be made on the cloud and radiation impacts as well as the influence of large-scale dynamics on the Arctic sea-ice melt.

Objectives

- To identify the contributing factors influencing the minimum Arctic sea-ice extent during September

1) What factors led to the record minimum in 2007 and the record maximum in 1996?

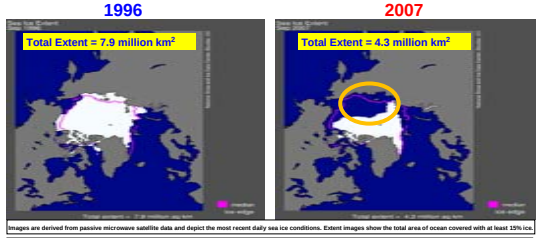
2) How did atmospheric conditions differ between 1996 and 2007?

Data and Methodology

- This study is based on the NCEP-DOE Reanalysis II project (1979-current). Anomalies calculated for the extreme years are daily averages from June 15 to September 15 (JJAS) and are based on the 30 year mean from 1979 to 2008. September sea-ice extent images and values were obtained from the National Snow and Ice Data Center.

Motivation

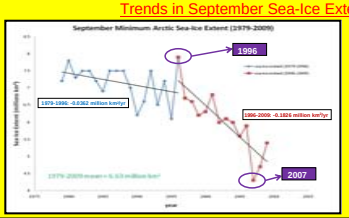
1996 | 2007



Images are derived from passive microwave satellite data and depict the most recent daily sea ice conditions. Extent images show the total area of ocean covered with at least 15% ice.

➢ Major difference in the location of the sea-ice coverage between the two extreme years:
- Western Arctic
- Beaufort Sea
- East Siberian Sea
- Laptev Sea

Trends in September Sea-Ice Extent

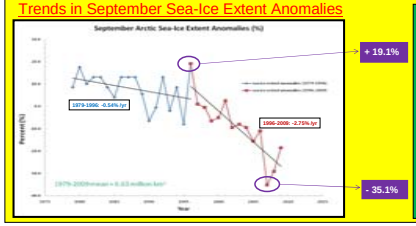


➢ The decline in ice extent has considerably accelerated over recent trends (4-5 times)

➢ The maximum September sea-ice extent occurred in 1996 during the middle of the declining trend

➢ The record minimum Arctic sea-ice extent occurred in 2007 covering roughly 4.28 million km²

Trends in September Sea-Ice Extent Anomalies



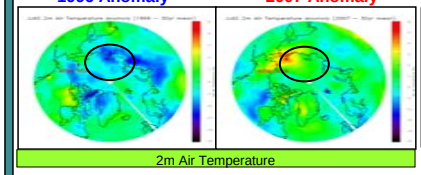
➢ The record 2007 September sea-ice extent was 35% below the 1979-2009 average.

➢ The September sea-ice extent in 1996 was 19% above the 1979-2009 average

➢ The average September ice-extent over the 31-year period (1979-2009) was around 6.63 million km²

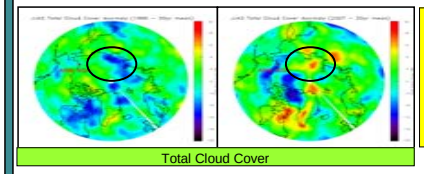
Cloud and Radiation impacts on Arctic sea-ice extent

1996 Anomaly | 2007 Anomaly



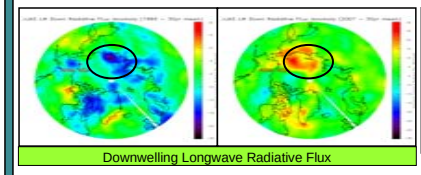
2m Air Temperature

- Positive temperature anomalies were present over much of the western Arctic during the summer of 2007
- The majority of the Arctic region experienced below normal temperatures during the summer of 1996



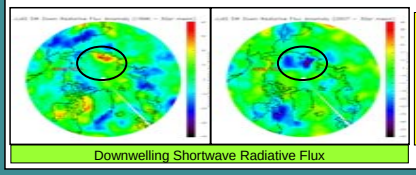
Total Cloud Cover

- In 2007 summertime cloud fractions were above normal over the East Siberian Sea while below normal over the Beaufort Sea
- Negative cloud fraction anomalies spread across the East Siberian Sea and Laptev Sea in 1996



Downwelling Longwave Radiative Flux

- The record minimum sea-ice extent year was associated with large positive downwelling LW radiation anomalies
- The summer of 1996 experienced less downwelling LW radiation
- Downwelling LW radiation seems to be positively correlated with sea-ice melt

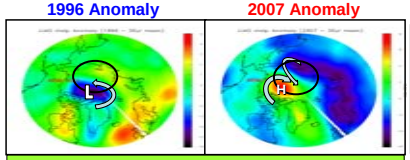


Downwelling Shortwave Radiative Flux

- Negative downwelling SW radiation flux anomalies were present during 2007
- Downwelling shortwave radiative flux anomalies appear to be negatively correlated with sea-ice melt

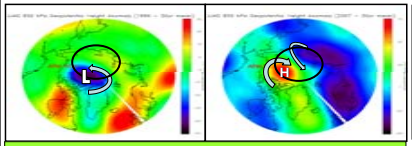
Large-scale dynamics impact on Arctic sea-ice extent

1996 Anomaly | 2007 Anomaly



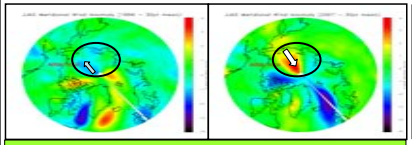
MSLP

- Area of high SLP stationed over Beaufort Sea while low pressure extends along Siberian coastline in 2007
- 2007 pattern favors warm low level southerly flow into the Western Arctic



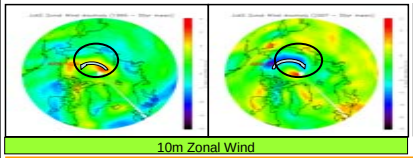
850 hPa Geopotential Heights

- Persistent area of high pressure at 850 hPa present over the Beaufort Sea during summer of 2007
- Lower geopotential height anomalies at 850 hPa were present over the central Arctic in 1996



10m Meridional Wind

- In 2007 strong southerly wind anomalies led to poleward heat transport and favored poleward transport of sea-ice
- In 1996 northerly wind anomalies were present perhaps causing the sea-ice to spread southward and out towards the Siberian coast



10m Zonal Wind

- Easterly zonal wind anomalies in 2007 support the transport of sea-ice eastward into the Arctic Transpolar Drift
- The zonal wind anomalies associated with the summer of 1996 support the transport of sea-ice westward towards the Alaska and Eastern Siberian coastlines

Summary

➢ NCEP-DOE global reanalysis II indicates that the increased summer sea-ice melt is associated with increased surface temp, cloud cover, and downwelling LW flux, and decreased downwelling SW flux, as evident in the record melt year during Summer 2007

➢ A persistent anti-cyclonic summertime circulation pattern was present across the Western Arctic and Beaufort Sea during 2007

➢ Positive MSLP anomalies over Beaufort Sea and associated strong anomalous pressure gradient during 2007, while negative MSLP anomalies over Western Arctic during 1996

➢ Positive temperature anomalies (3-5 K) over the Western Arctic associated with record melt year (2007) and negative temperature anomalies across the Western Arctic and Siberian coast associated with September maximum sea-ice extent year (1996)

➢ Record melt year was accompanied by strong anomalous southerly flow across the Western Arctic and East Siberian Sea enhancing poleward heat transport while northerly wind anomalies were present across the Western Arctic during 1996 aiding in the transport of sea-ice outwards towards the Siberian coastline

Future Work

- Compare results using NASA's MERRA reanalysis data set
- Perform a similar comparison between multiple high September sea-ice extent years and multiple low September sea-ice extent years
- Combine surface observations with derived satellite observations for better validation of results