Investigation of two extreme summer Arctic Sea-ice extent anomalies in 2007 and 1996

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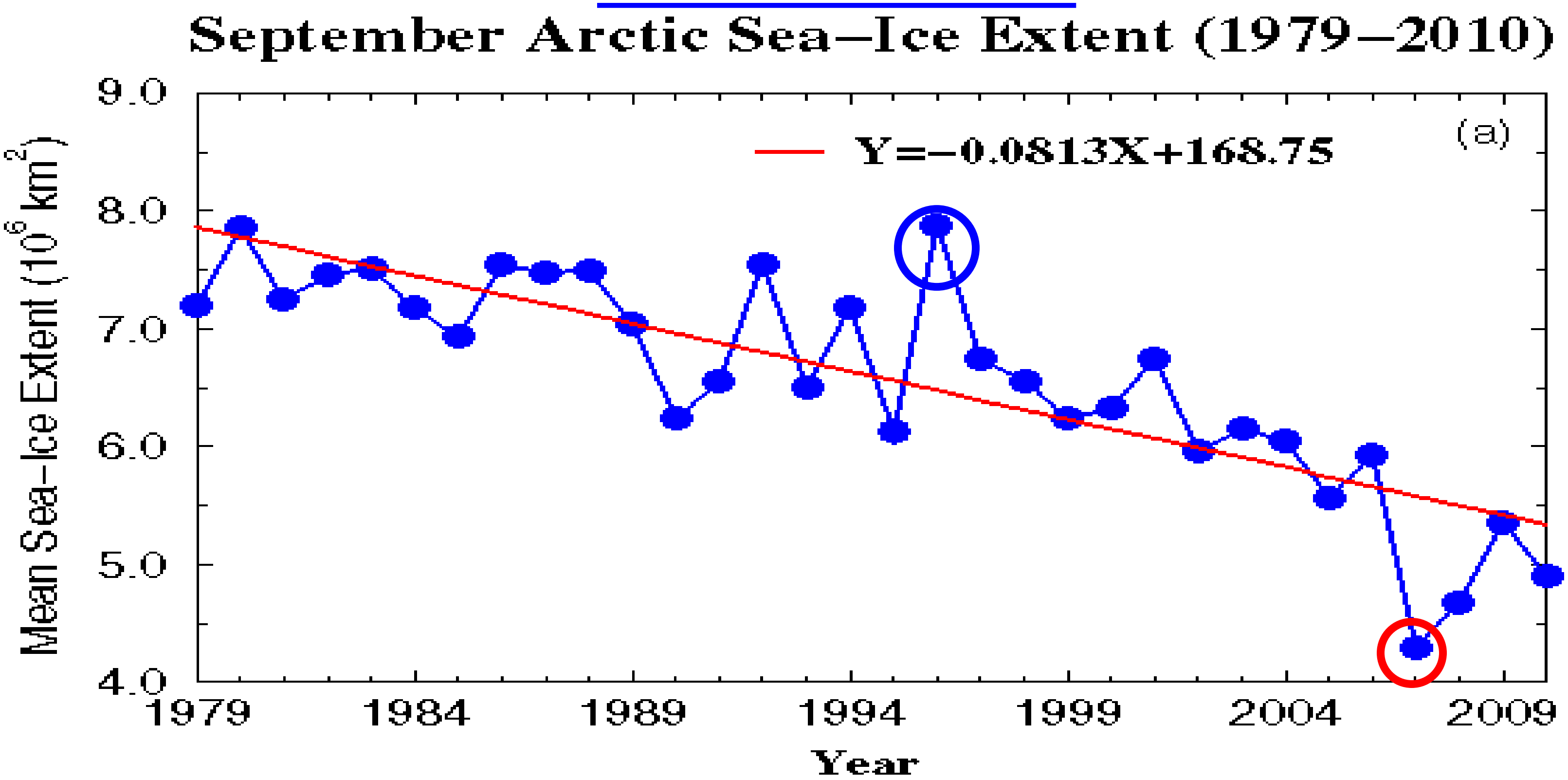
<u>Outline:</u>

1) Extremes were triggered by anomalous synoptic patterns
2) Cloud-Radiation-PWV positive feedback on 2007 low SIE
3) Progress made by UND group for MAPP project

Dong et al., 2014, Climate Dynamics

Motivation



The summer of 2007 caught the attention of the Arctic research community because September sea-ice extent plummeted to a record minimum, it was 35% below the 1979-2010 average.

Although most efforts have been devoted to understanding the 2007 low, a contrasting high September SIE in 1996 might share some related but opposing forcing mechanisms.

Objectives

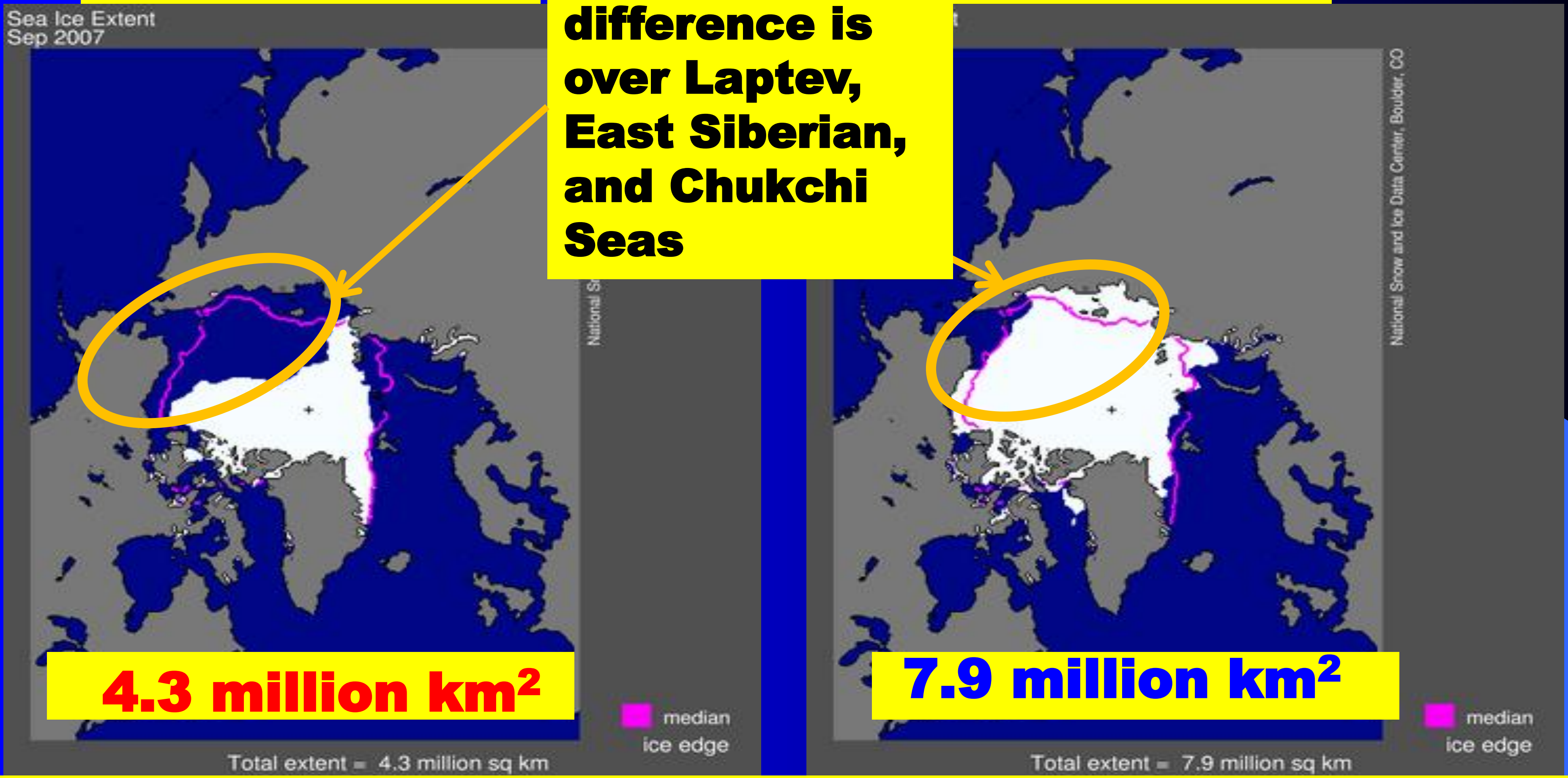
1. Explore the detailed insights about the underlying mechanisms driving these two contrasting extreme events (2007 and 1996), and compare their similarities and differences with respect to the major contributing factors and different atmospheric conditions.

2. Investigate the positive Cloud-Radiation-Water vapor Feedback on the 2007 summer low using US National Snow and Ice Data Center (NSIDC) and NASA MERRA

September Sea-Ice Extent Comparison

2007 | **1996**

Major difference is over Laptev, East Siberian, and Chukchi Seas

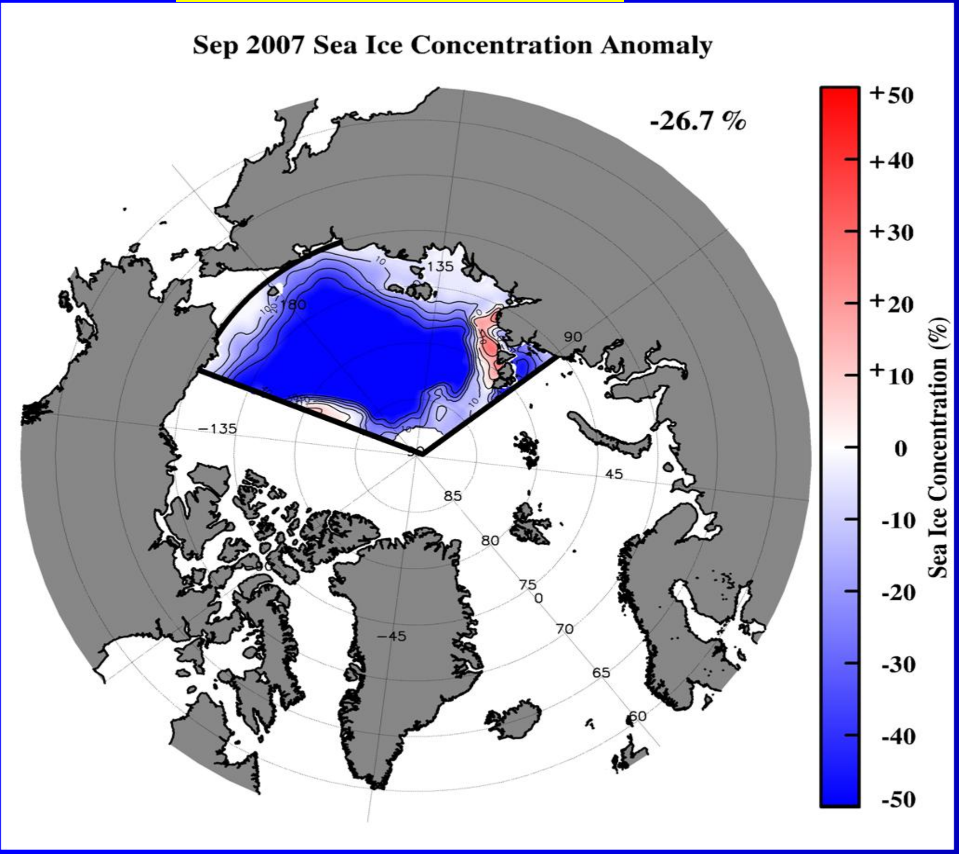


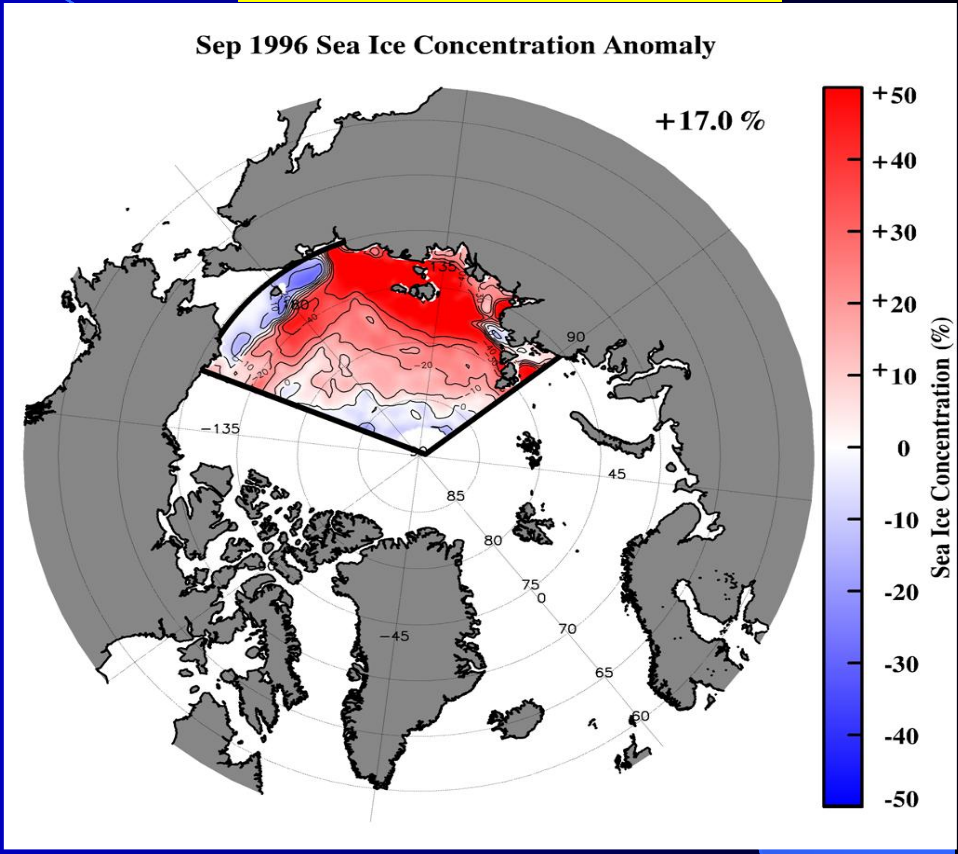
4.3 million km² | **7.9 million km²**

Therefore, we focus on the area of Laptev, East Siberian and Chukchi seas (70-90 °N, 90-210 °E) and define it as the Area Of Focus (AOF) in this study.

September Sea-Ice Concentration Comparison

2007	1996





-26.7% below climate mean

+17.0% above climate mean

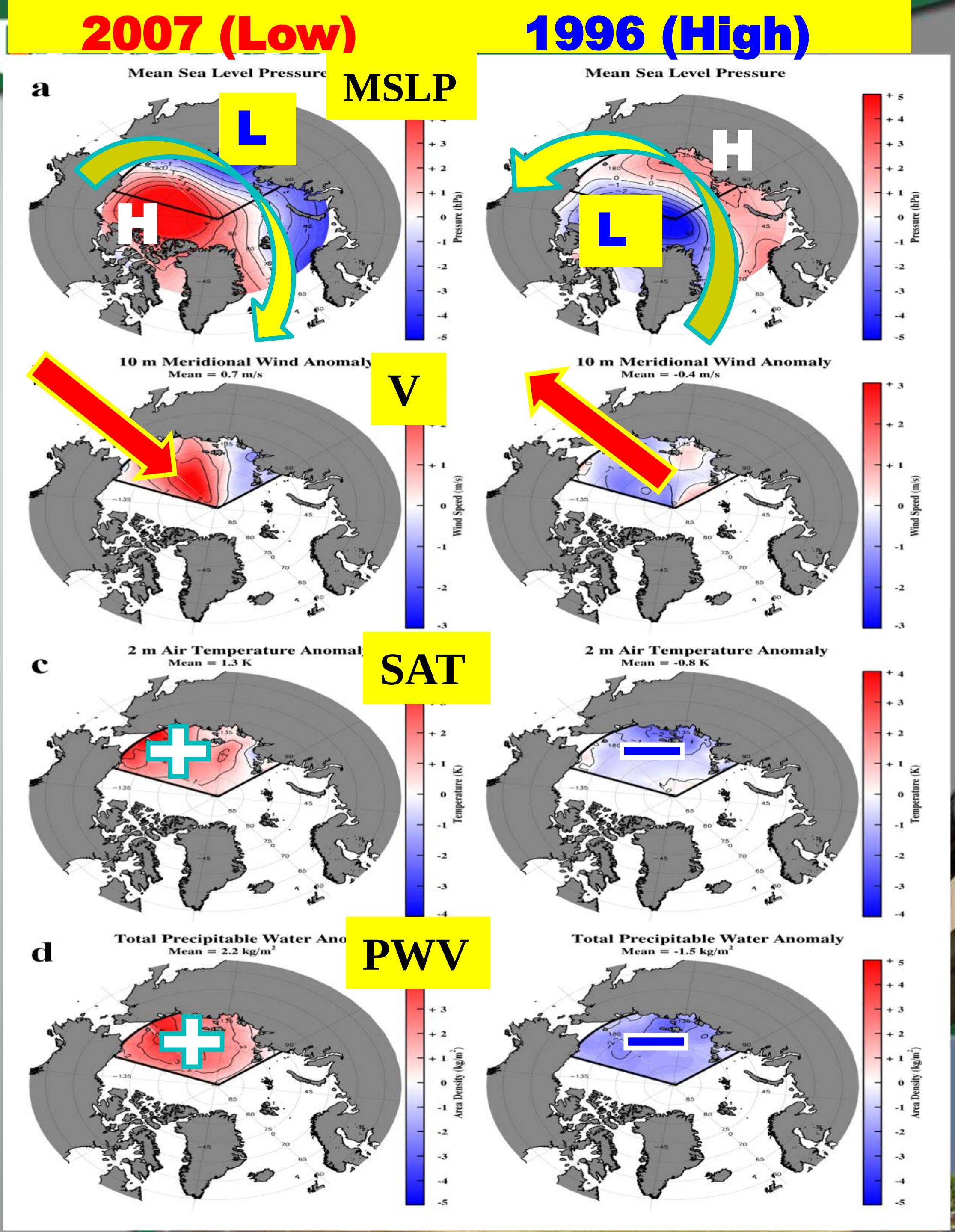
The area of Laptev, East Siberian and Chukchi seas (70-90 °N, 90-210 °E) is defined as the Area Of Focus (AOF) in this study.

Atmospheric anomalies over AOF

During Summer 2007

- ➔ **A persistent anticyclone was positioned over the Beaufort Sea, coupled with an area of low pressure over the Eurasia region .**
- ➔ **Under this synoptic pattern, strong positive anomalies in meridional winds (southerly) are evident over the AOF, which transports warm (positive anomaly of SAT) and moist air (positive anomaly of PWV) from the North Pacific.**

The variables during the summer 1996 are opposite to those in 2007.

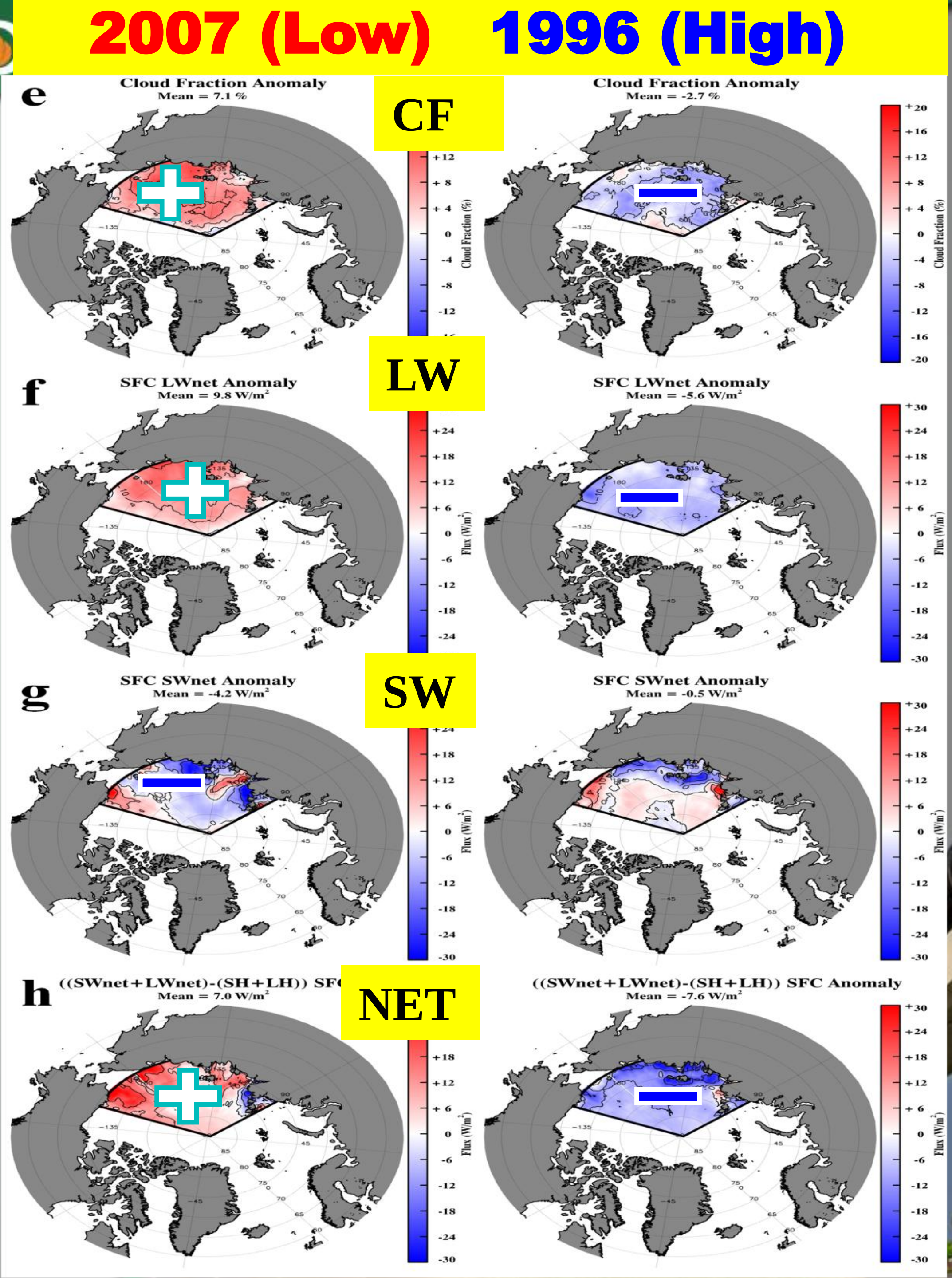


During Summer 2007

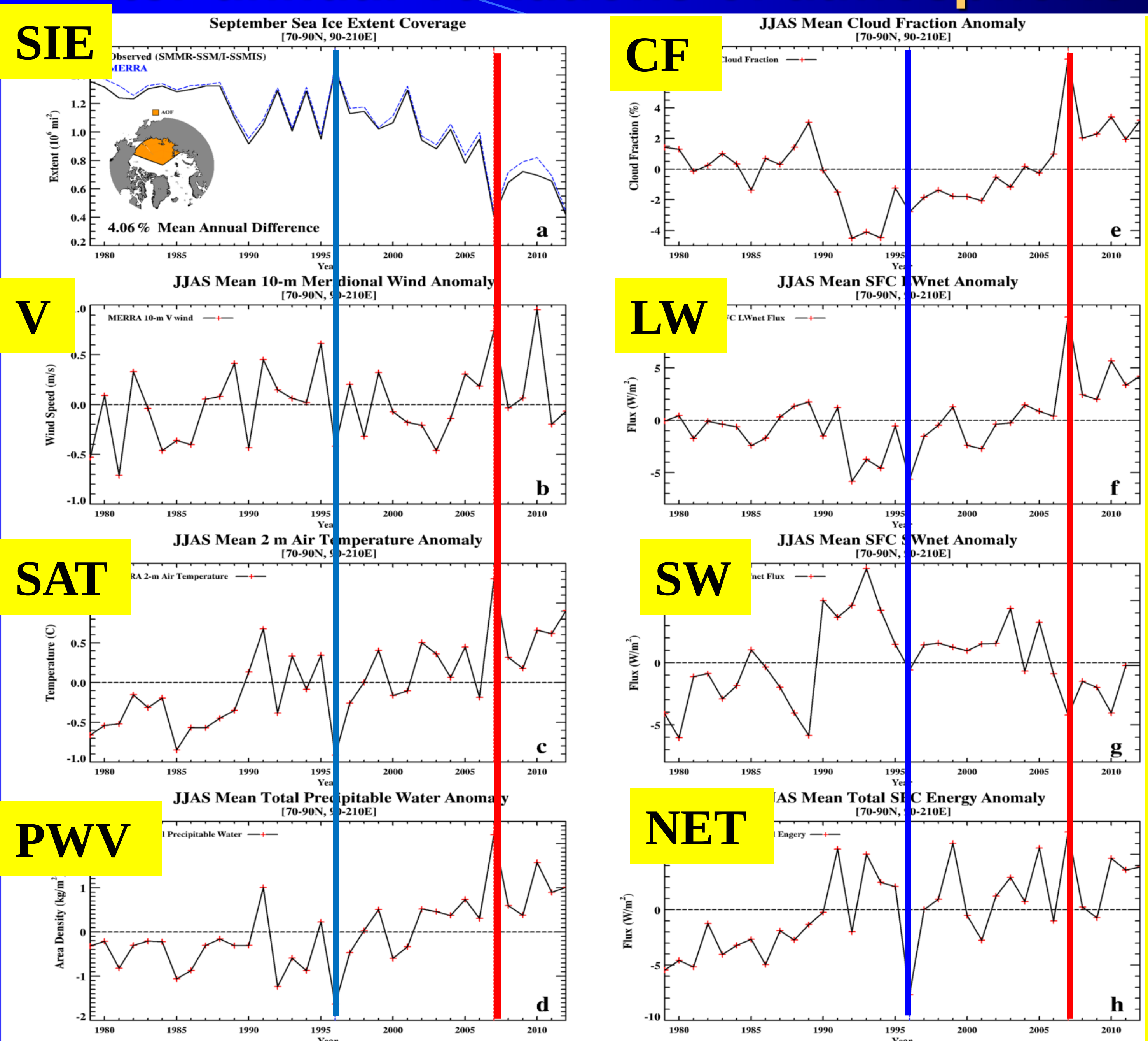
- ➔CF over AOF is 7.1% higher than climate mean
- ➔ NET LW flux is +10 Wm^{-2}
- ➔NET SW flux is -4.2 Wm^{-2}
- ➔Total NET surface energy budget = (NET LW+SW)-(SH+LH) = +7 Wm^{-2}.

Indicating that 7 Wm^{-2} more heat than its climate mean value was absorbed by Arctic oceans over the AOF during the summer 2007. This extra 7 Wm^{-2} has partially contributed to the 1.3 K increase in SAT and the low September sea-ice extent in 2007.

Summer 1996 is reversed



Inter-annual Variations of atmospheric anomalies

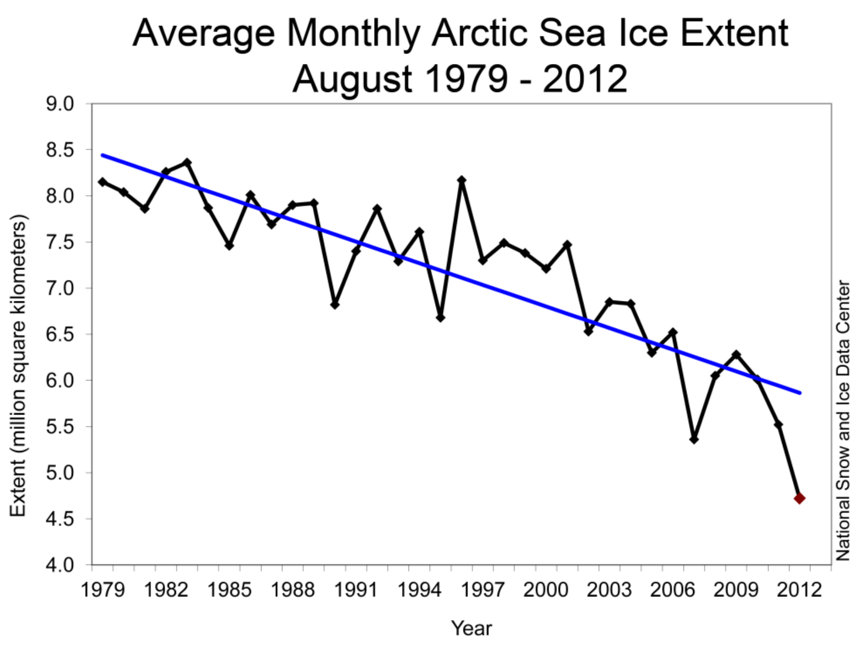


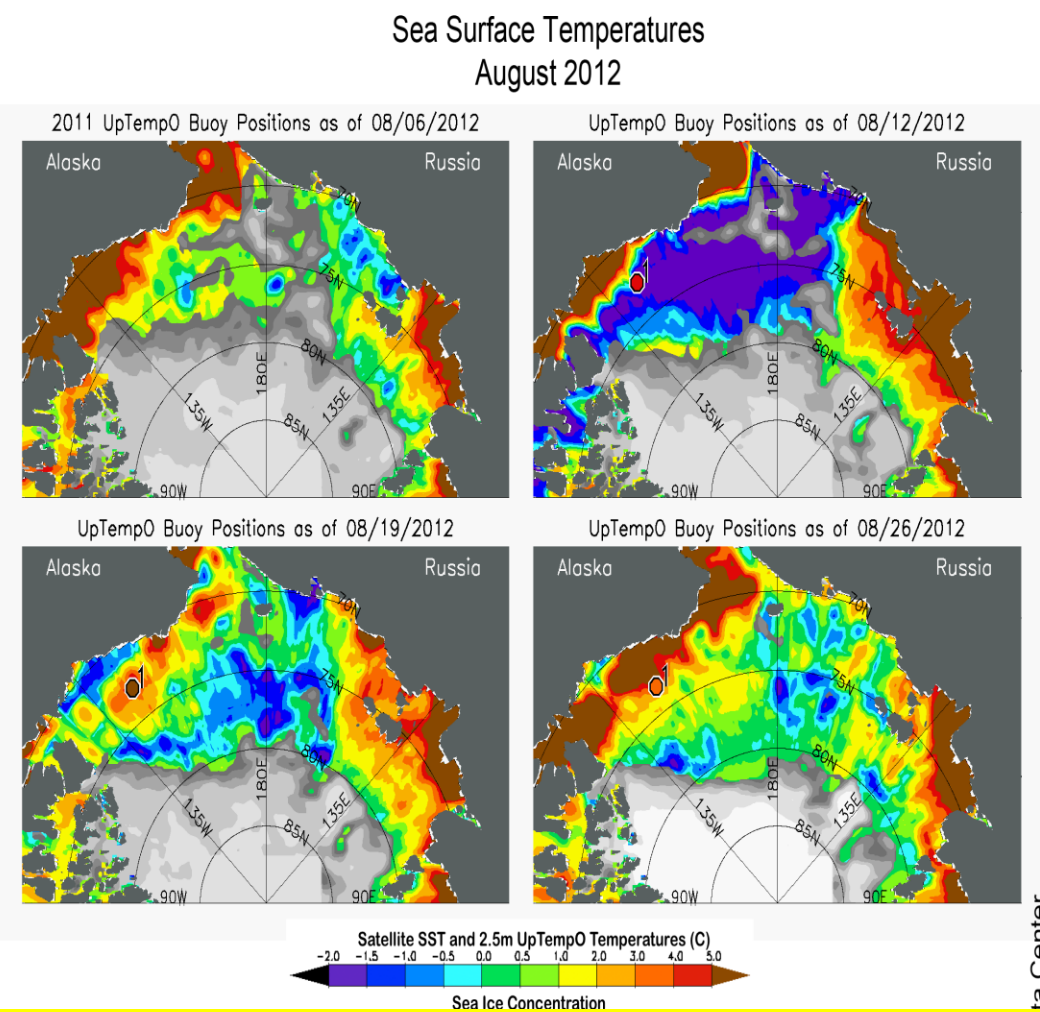
During summer 2007, all variables have max positive anomalies Except for SW.

During summer 1996, most are Max negative anomalies.

These results indicate the selected two opposing extreme years 2007 and 1996 are robust.

2012 new record low in SIE





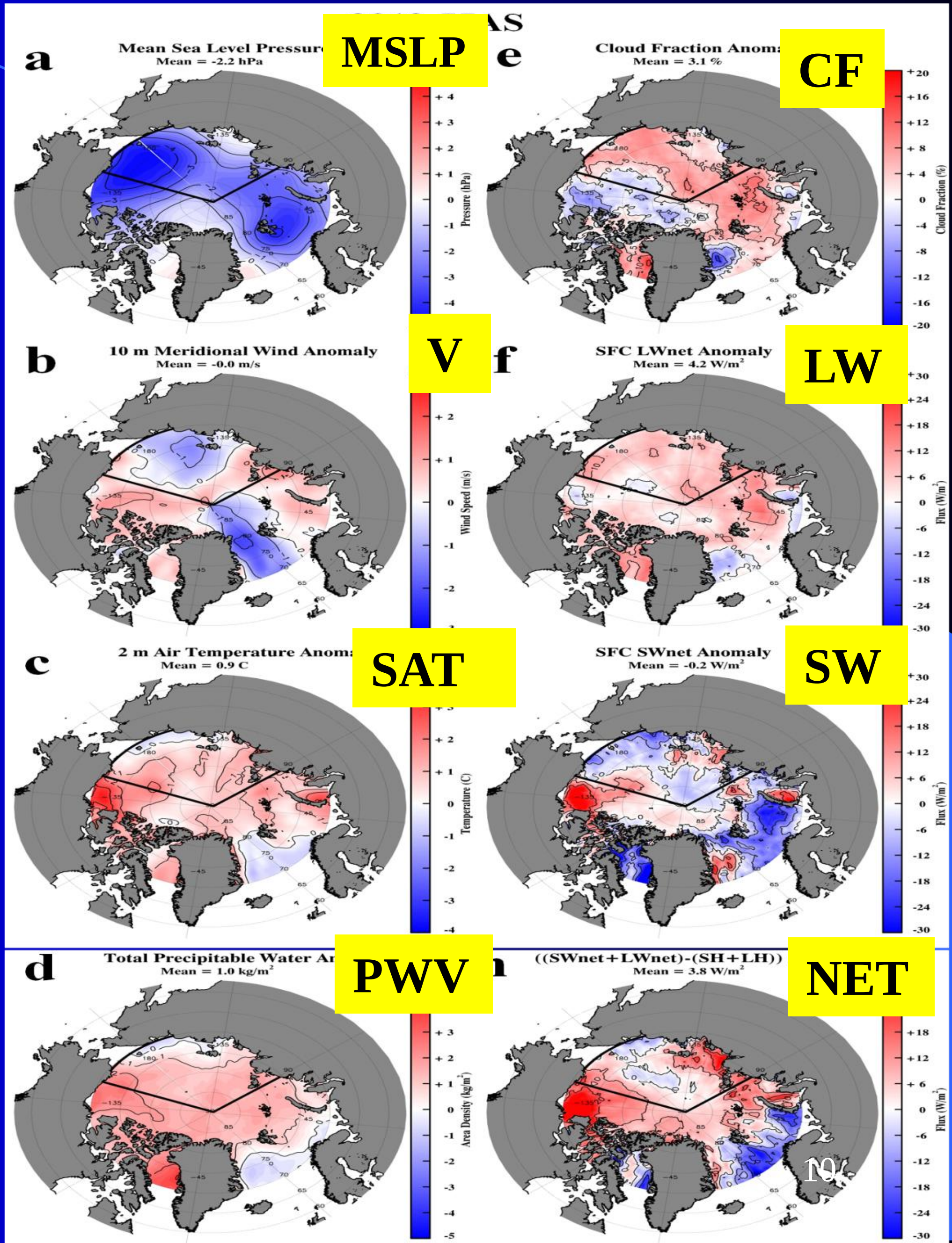
It was mainly triggered by a super storm over the central Arctic Ocean in early August that caused substantial mechanical ice deformation on top of the long-term thinning of an Arctic ice pack

2012 Summer

→The synoptic and wind patterns in 2012 were significantly different from those in 2007.

→Low pressure systems covered the entire Arctic with two centers, resulting in weak anomalous northerly winds over most of the AOF and the Fram Strait.

→Although the patterns and signs of the anomalies of the atmospheric parameters in 2012 are the same as those in 2007, their magnitudes are much smaller.



Summary I: two extreme years

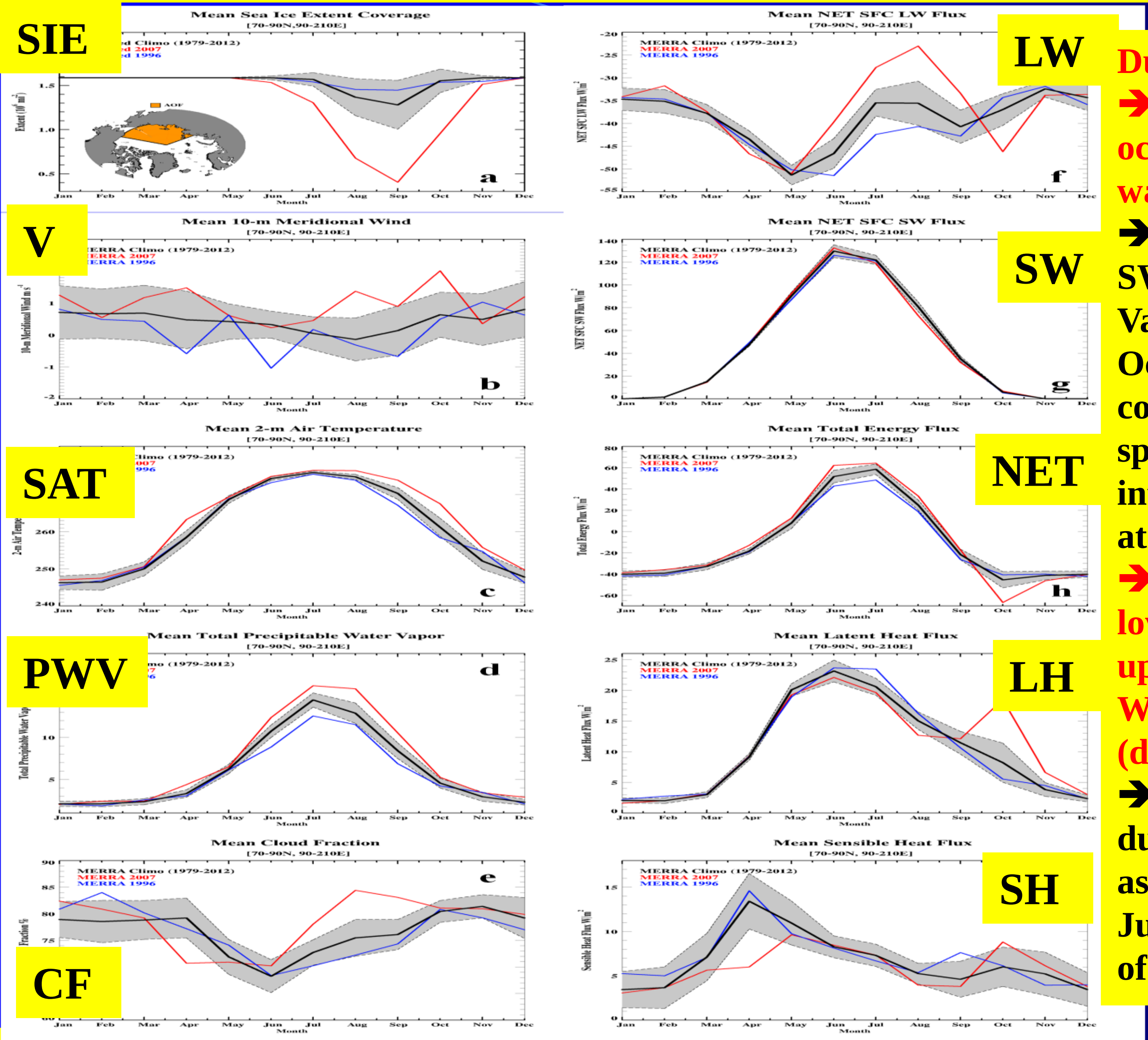
1) The low Sea Ice Extent (SIE) in 2007 was associated with a persistent anticyclone over the Beaufort Sea coupled with low pressure over Eurasia, which induced anomalous southerly winds. Ample warm and moist air from the North Pacific was transported to the AOF and resulted in positive anomalies of cloud fraction (CF), precipitable water vapor (PWV), surface LWnet (down-up), total surface energy and temperature.

2) In contrast, the high SIE event in 1996 was associated with a persistent low pressure over the central Arctic coupled with high pressure along the Eastern Arctic coasts, which generated anomalous northerly winds and resulted in negative anomalies of above mentioned atmospheric parameters.

Part II: Cloud-Radiation-PWV feedback on 2007 low SIE

- **We hypothesize that the onset of the 2007 low sea-ice extent was triggered by the large-scale atmospheric circulation anomaly during spring, and later on enhanced by a positive cloud-radiation-PWV feedback process over the AOF during the summer and early autumn of 2007.**
- **Now we want to improve this hypothesis using seasonal variation and daily anomalies from June 15 to Sept. 15 of 2007.**

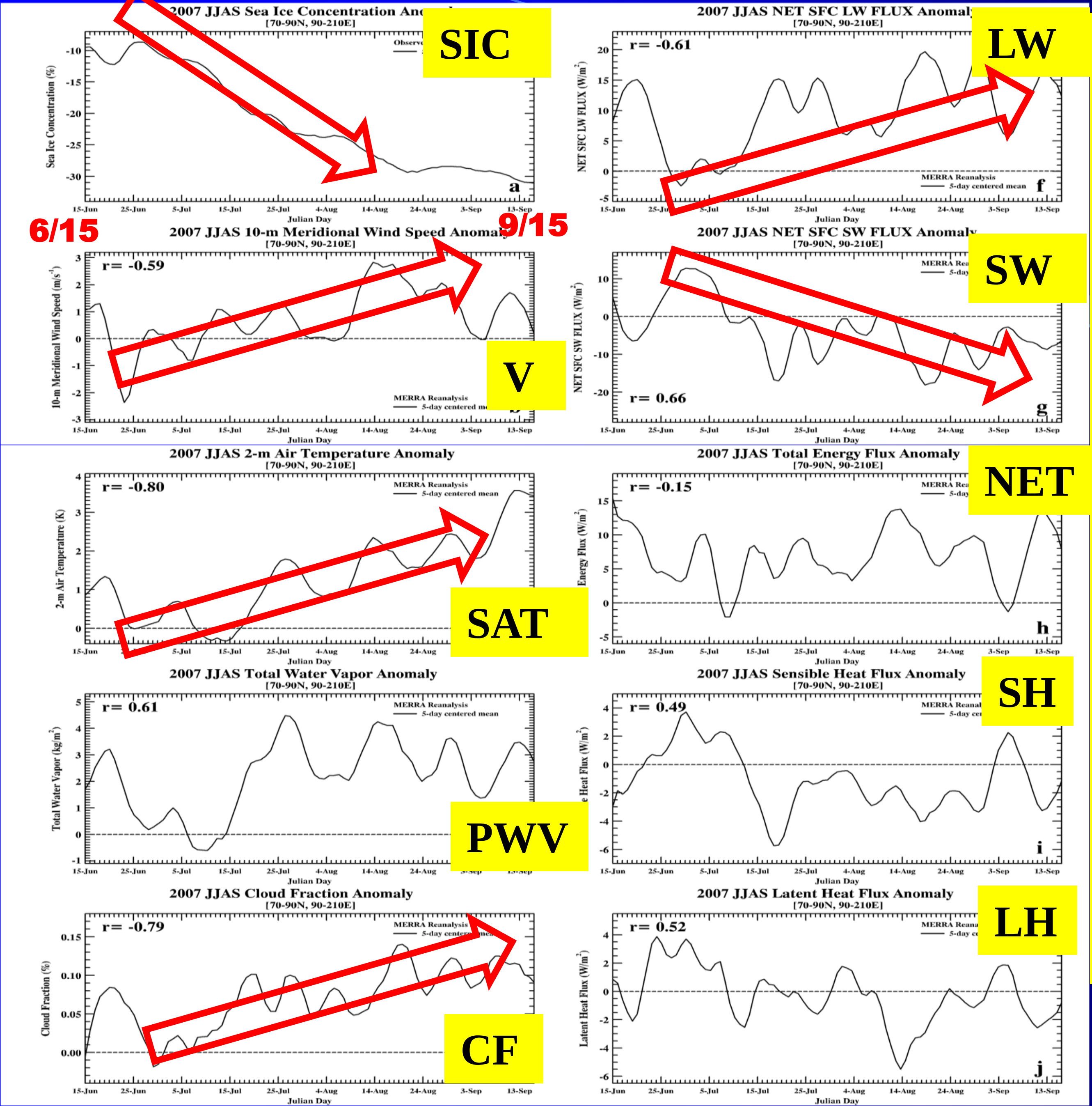
Seasonal Variations of SIE and atmospheric variables over the AOF



During Spring months of 2007,
➔strong southerly winds occurred, which brought more warm and moist air to the AOF.
➔However, the CF, LW and SW were below their climat. Values because most of Arctic Ocean surfaces were still covered by sea ice during spring, thus there are minimal interactions between ocean and atmosphere
➔SH flux in April was 8 Wm^{-2} lower than the climatology (less upward flux, resulting in 3–5 Wm^{-2} more total surface energy (down in) than the climatology .
➔This 3–5 Wm^{-2} extra energy during spring months, as well as 10 Wm^{-2} extra energy in June, used to trigger the onset of 2007 low.

Monthly means (solid black line) and standard deviations (shaded area) for 1979-2012, 2007 (red) and 1996 (blue) (averaged over the AOF).

Correlations of daily anomalies between SIC and atmospheric parameters



➔The high correlations (0.58-0.79) of anomalies between SIC and V, SAT, PWV, CF, LWnet and SWnet further proved that meridional winds, water vapor, clouds, and radiation are indeed having significant impacts on the SIC variations.

➔The increased SAT along with a positive cloud-radiation-PWV feedback amplified the signal initiated by the atmospheric circulation anomaly, accelerated the sea-ice retreat during the summer of 2007.

Summary II (feedbacks)

The proposed hypothesis regarding the triggering and enhancing mechanisms of the Arctic sea-ice retreat during the summer of 2007 has been improved as

➔The onset of the 2007 low sea-ice extent was triggered by the large-scale atmospheric circulation anomaly during the spring months of 2007.

➔Strong southerly winds brought warm and moist air from the North Pacific, which not only initiated sea-ice melting, but also increased PWV and formed more clouds over the AOF, particularly over open seas.

➔When CF was high and Arctic surfaces were covered by snow and ice, particularly during the onset of sea-ice melting (May-June), the cloud-greenhouse (LW) effect overwhelmed the cloud-albedo (SW) effect, producing a positive cloud radiative effect on the surface radiation budget.

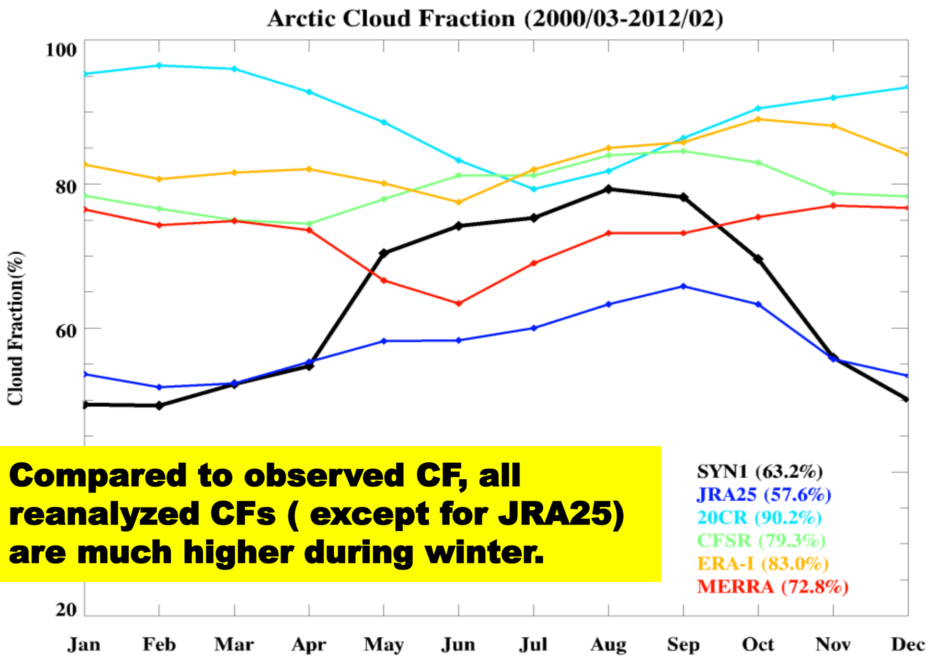
➔Downwelling LW flux increased significantly with increased PWV, generating another positive feedback to increase surface temperature and enhance sea-ice retreat.

➔Later on, more sea-ice was melted, additional SW (and LW) radiation was absorbed by open seas to increase surface temperature, and more water vapor evaporated to form more clouds, which further enhanced the positive cloud-radiation-PWV feedback.

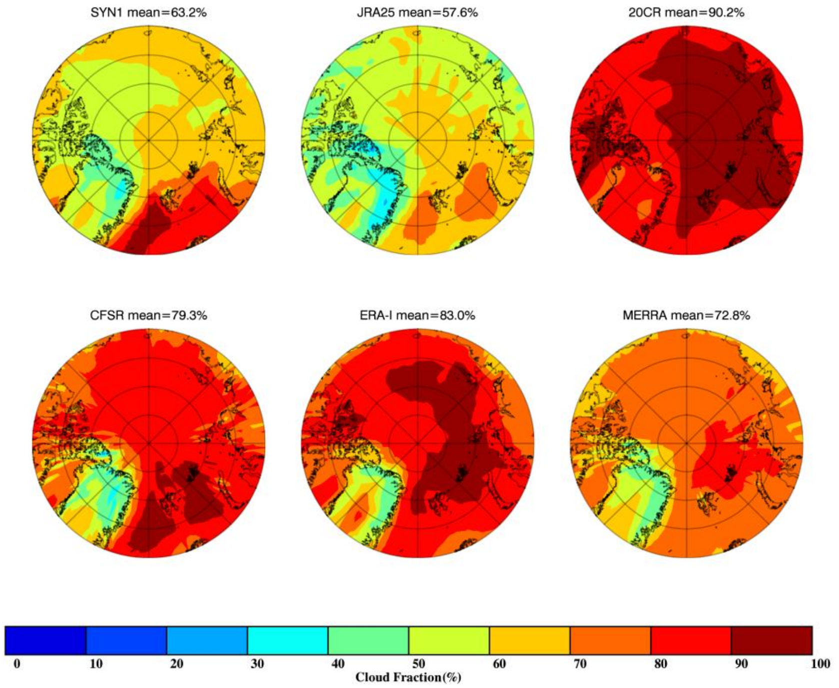
Progress made by UND group

- Arctic clouds and Radiative Forcing by Yiyi Huang
- Comparison of GPCP precipitation with Q2 precipitation over the CONUS by Wenjun Cui

Assessment of reanalyzed Arctic Clouds and Radiative Forcing using Satellite Observations by Yiyi Huang



Compared to observed CF, all reanalyzed CFs (except for JRA25) are much higher during winter.



Time Period : 03/2000 – 02/2012
Area of Interest: Arctic (70-90°N)
Satellite Results: CERES-MODIS for cloud fraction, CERES-EBAF for radiative fluxes at TOA and surface
Reanalyses: Monthly means from JRA25, 20CR, CFSR, ERA-Interim and MERRA

Comparison of GPCP precipitation with Q2 precipitation over the CONUS by Wenjun Cui

Dataset: GPCP-1DD, NEXRAD Q2 Precipitation Product

Time Period: 2010-2012

Methodology: monthly mean

Selected Region: 6 tiles in Central and Eastern US

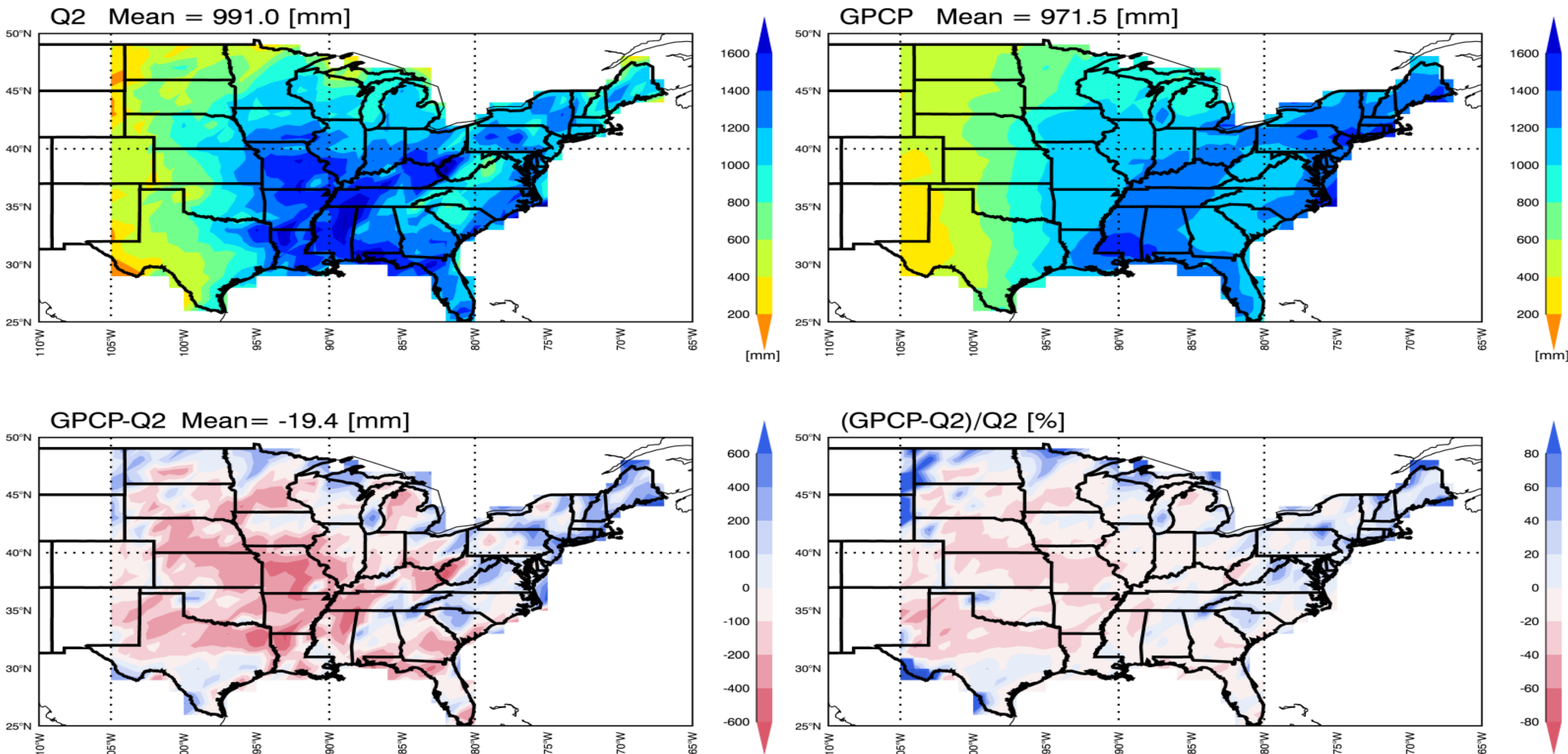
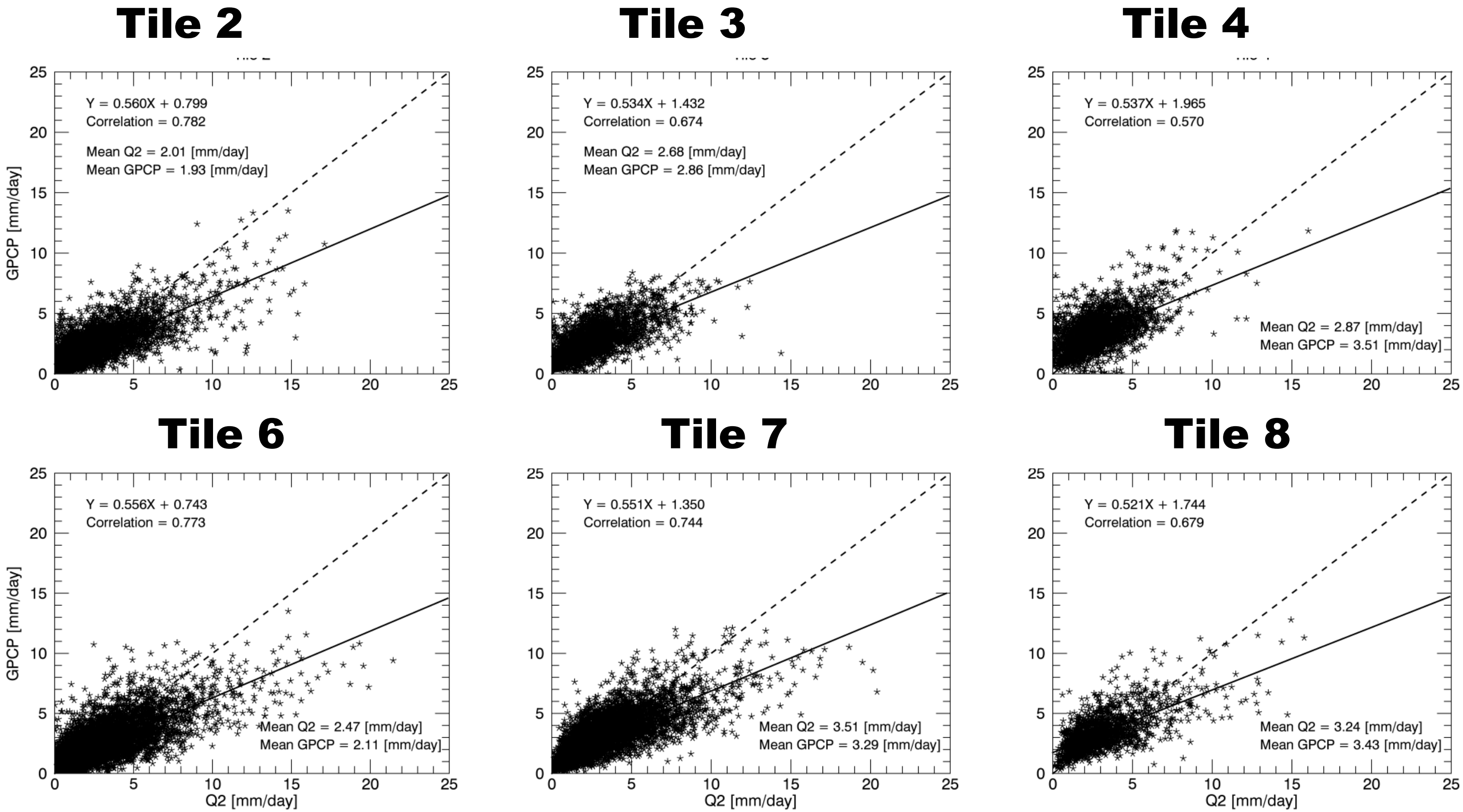


Fig. 1. Spatial Distribution for Annual Mean Precipitation

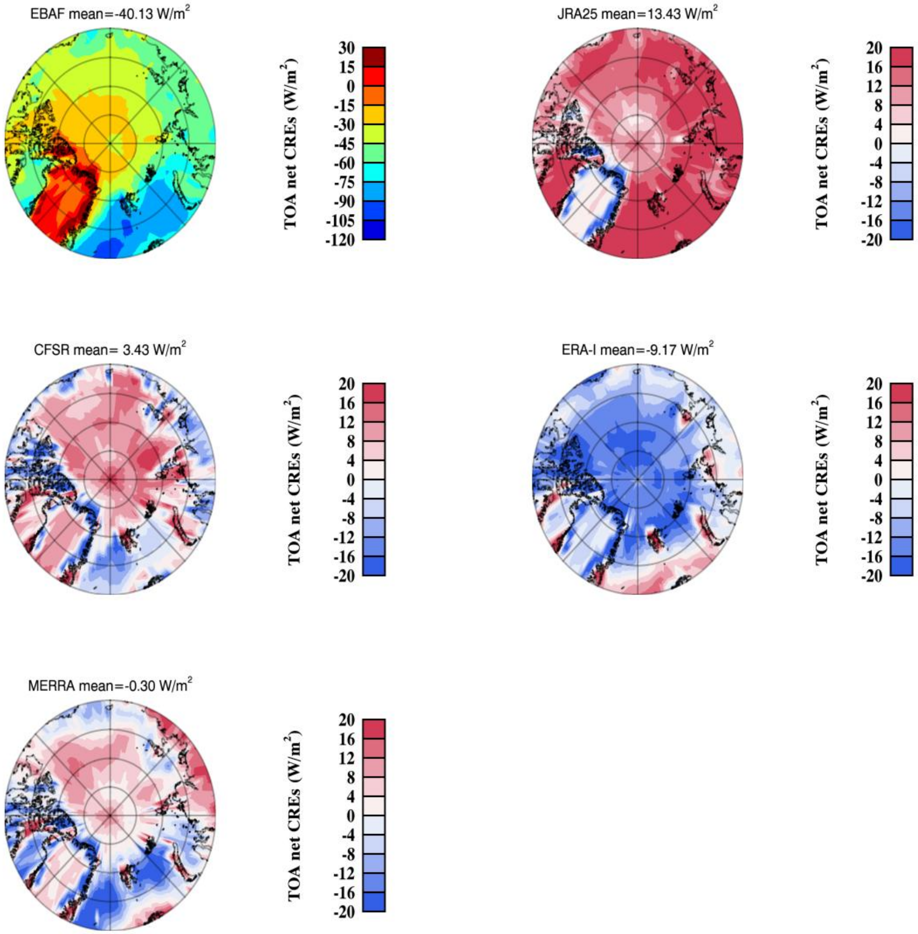
Scatterplot of monthly mean precipitation



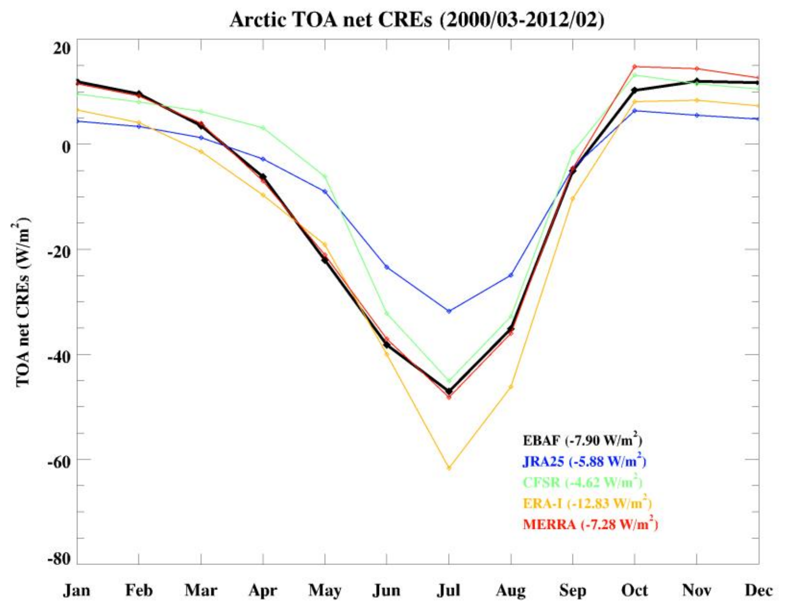
[mm/day]	Tile 2	Tile 3	Tile 4	Tile 6	Tile7	Tile8
Q2	2.01	2.68	2.87	2.47	3.51	3.24
GPCP	1.93	2.86	3.51	2.11	3.29	3.43
Diff (GPCP-Q2)	-0.08	0.18	0.73	-0.36	-0.23	0.21
CC	0.782	0.674	0.570	0.773	0.744	0.679

Thanks for your attention!
Xiquan Dong's research group (2014-15)

The Evaluation and Intercomparison of Radiative Forcing and Cloud Fraction in Recent Reanalyses over the Entire Arctic using Satellite Observations

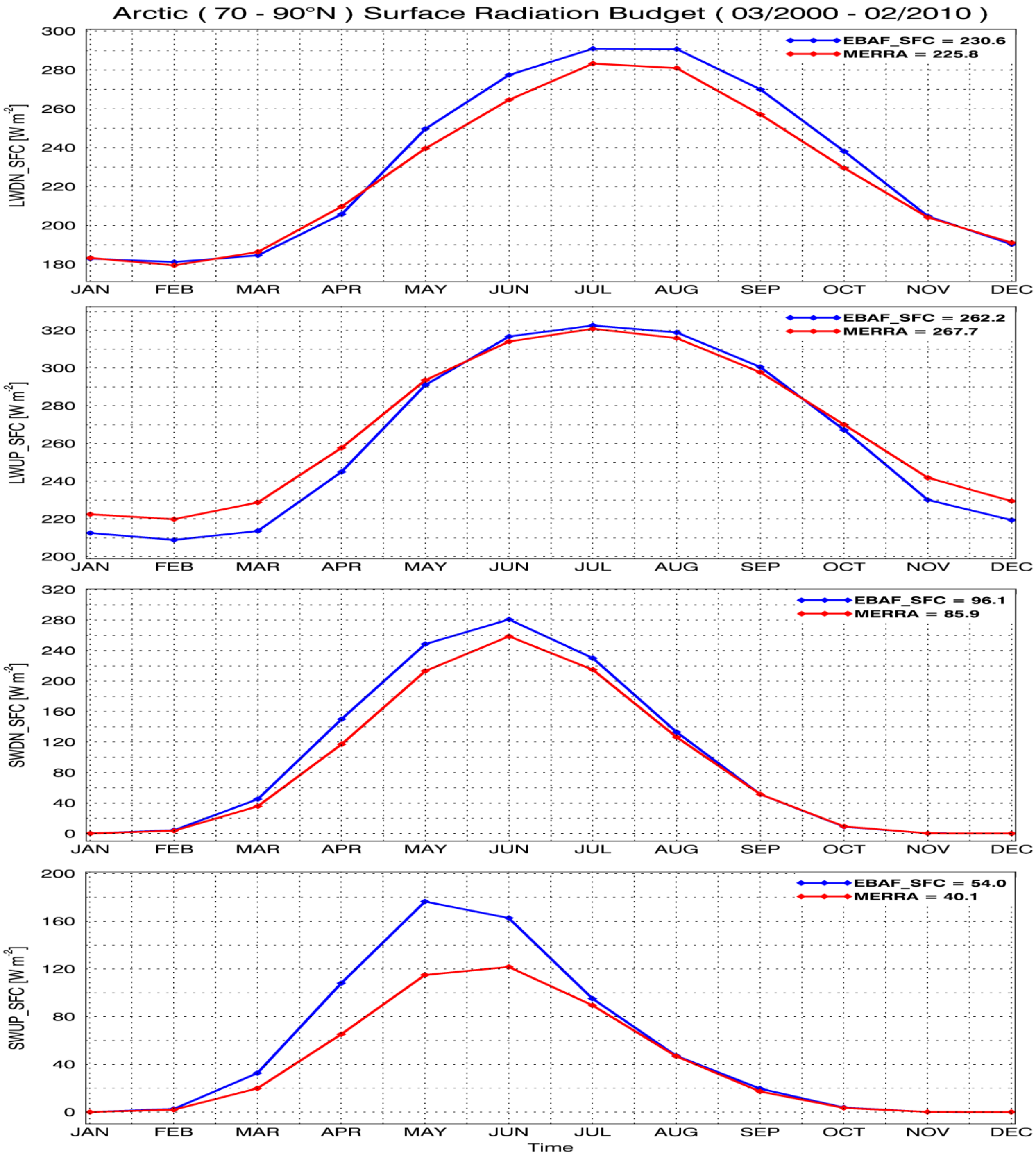


Arctic-wide warm season (Jun.-Aug.) average net CREs at TOA from EBAF along with biases from four reanalyses



- Methodology:

For all available CFs and radiation fluxes datasets from five reanalyses, the monthly means, annual means, cold season means, warm season means and biases were computed against satellite observations.


Arctic (70 - 90°N) Surface Radiation Budget (03/2000 - 02/2010)
EBAF_SFC = 230.6
MERRA = 225.8
LWDN_SFC [W m-2]
EBAF_SFC = 262.2
MERRA = 267.7
LWUP_SFC [W m-2]
EBAF_SFC = 96.1
MERRA = 85.9
SWDN_SFC [W m-2]
EBAF_SFC = 54.0
MERRA = 40.1
SWUP_SFC [W m-2]
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Time

Datasets

The monthly mean sea-ice extent and SIC were provided by the US National Snow and Ice Data Center (NSIDC) using Nimbus-7 SSMR and DMSP SSM/I Passive Microwave Data and Near-Real-Time SSM/I Polar Gridded SIC dataset.

Clouds, Water vapor, Radiation and Atmospheric variables were provided by NASA MERRA reanalysis