2021 CESM Polar Climate Working Group Meeting
February 10, 2021

SUMMERTIME LOW CLOUDS MEDIATE THE IMPACT OF THE LARGE-SCALE CIRCULATION ON ARCTIC SEA ICE

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Huang Y., et al. (2021): Summertime low clouds mediate the impact of the large-scale circulation on Arctic sea ice. Communications Earth & Environment. https://www.nature.com/articles/s43247-021-00114-w

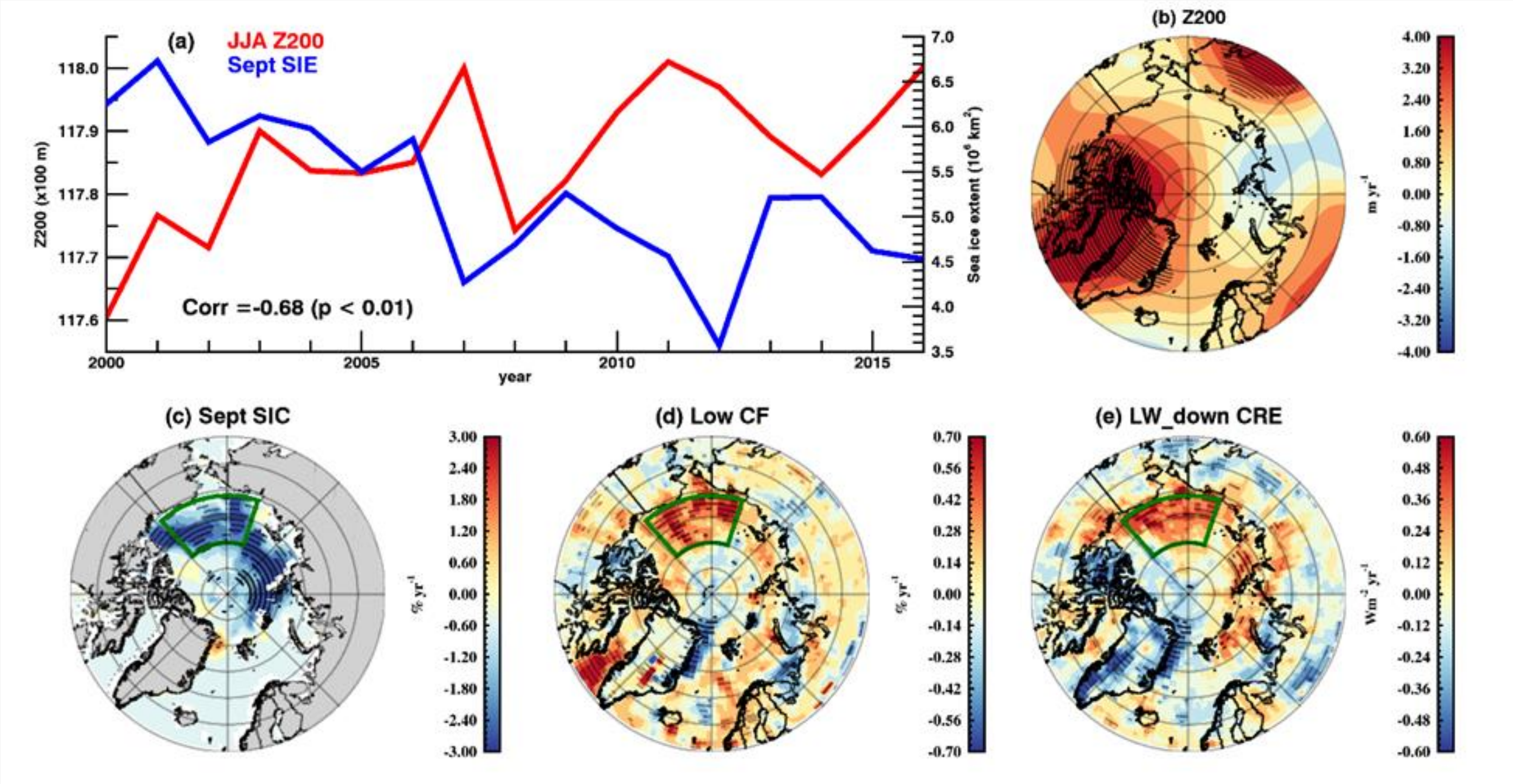
THE LINEAR TREND OF SUMMERTIME (JJA) ATMOSPHERIC CIRCULATION, LOW CLOUD AND SEA ICE DURING 2000-2016

Why low clouds?

Arctic low clouds (cloud top height < 3 km) are an important climate feature of the atmospheric boundary layer over the Arctic Ocean during summer

- Arctic low clouds are close to the sea ice and strongly influence the amount of solar and infrared radiation that is incident on the ice surface, thus affecting the melting rate of the pack ice

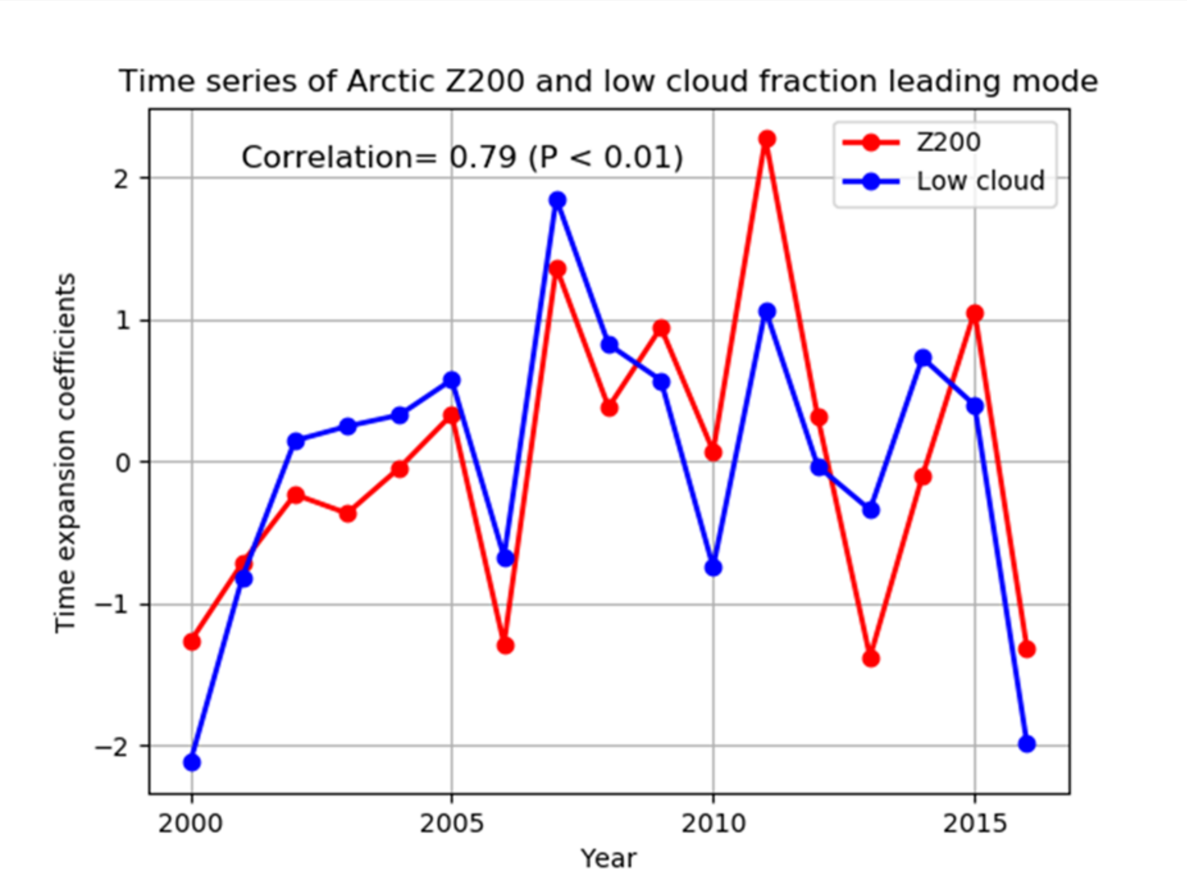
- Low cloud variability can strongly modify the vertical structure of temperature and humidity in the boundary layer, affecting the low-level heat, moisture and momentum fluxes

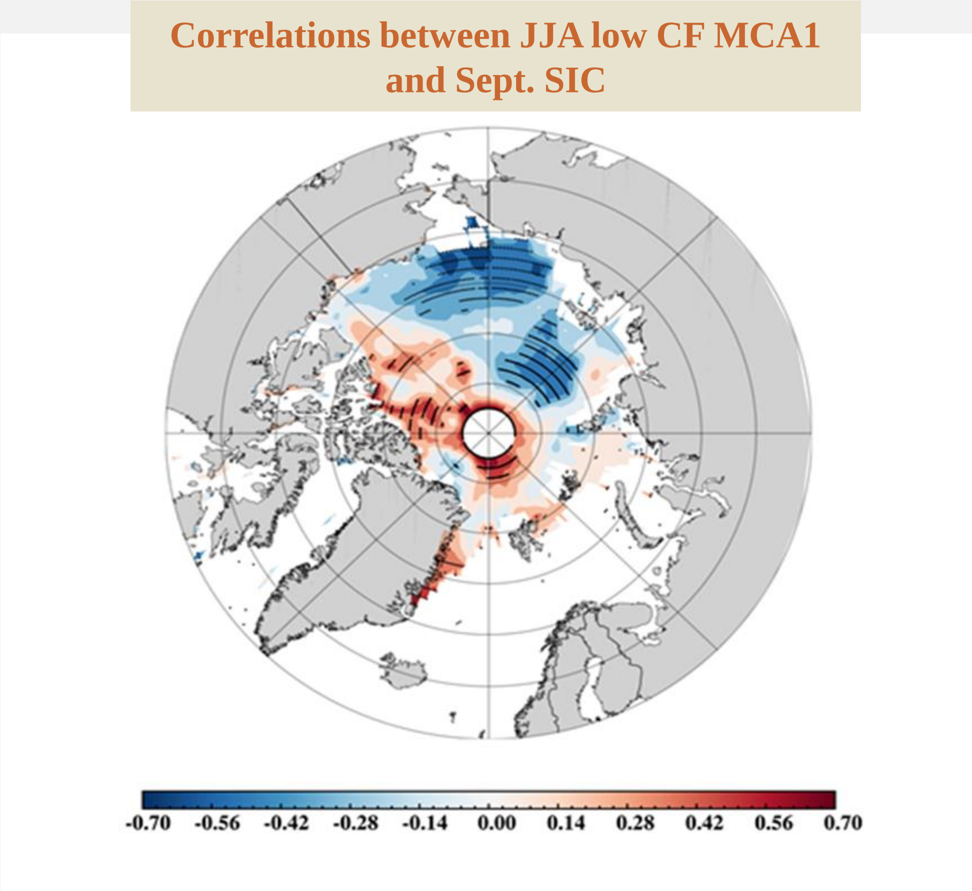


The 200hPa geopotential height (Z200) has been rising over the northeastern Canada and Greenland, accompanied by rapid Arctic sea ice decline in the early 21st century

*Black dots mark 10% significance level

THE RELATIONSHIPS BETWEEN SUMMERTIME LOW-LEVEL CLOUDS AND SEPTEMBER SEA ICE CONCENTRATION VARIATIONS

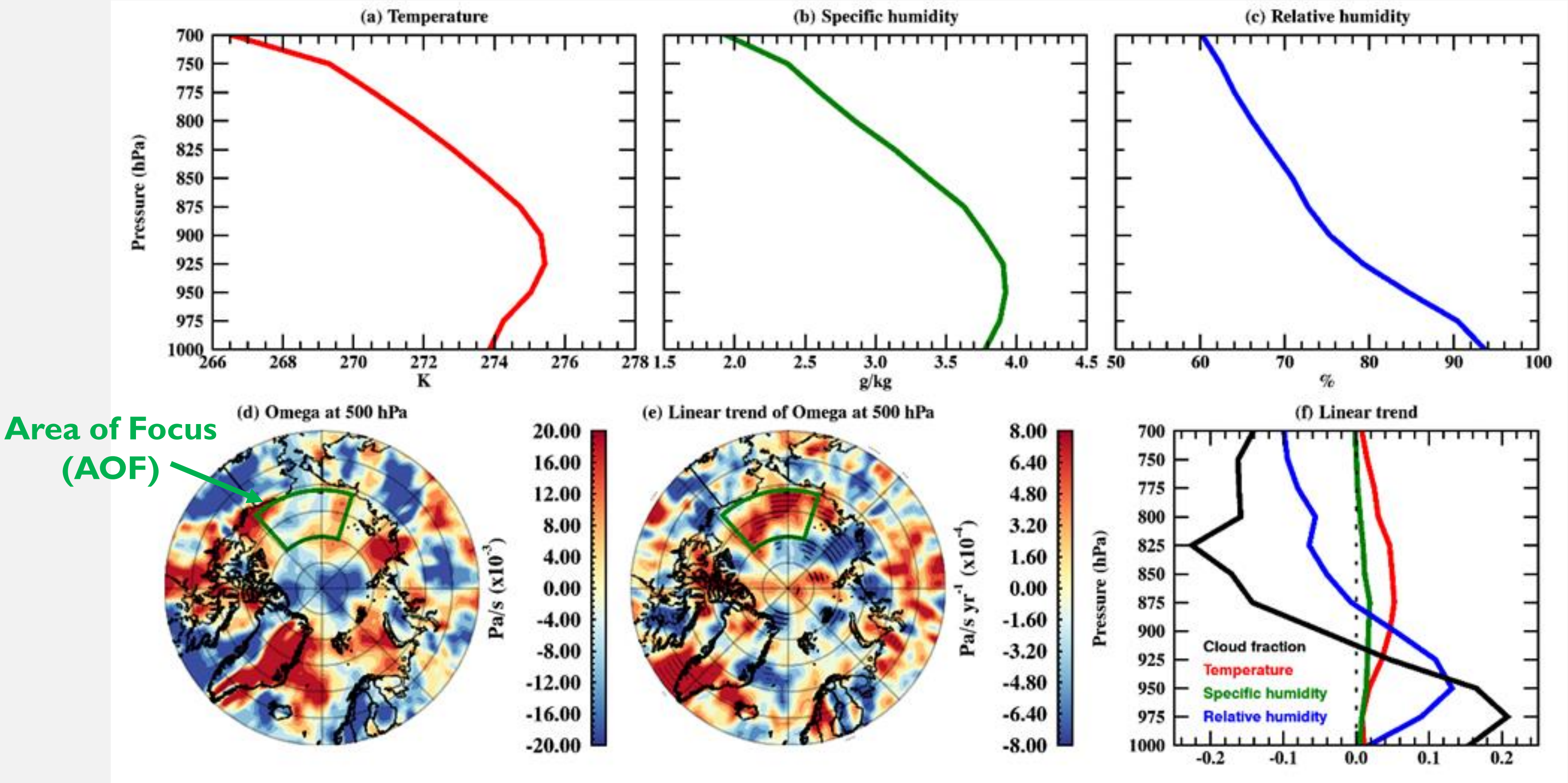




- Based on maximum covariance analysis (MCA), the leading mode (MCA1) accounts for 49.6% of the covariance between JJA Z200 and Arctic low-level clouds
- The increasing JJA low-level clouds can affect subsequent sea ice decline because of enhanced longwave cloud radiative effect and reduced shortwave cloud radiative effect

Black dots mark 10% significance level

THE MECHANISM CONNECTING LARGE-SCALE CIRCULATION VARIABILITY AND INCREASING LOW-LEVEL CLOUDS

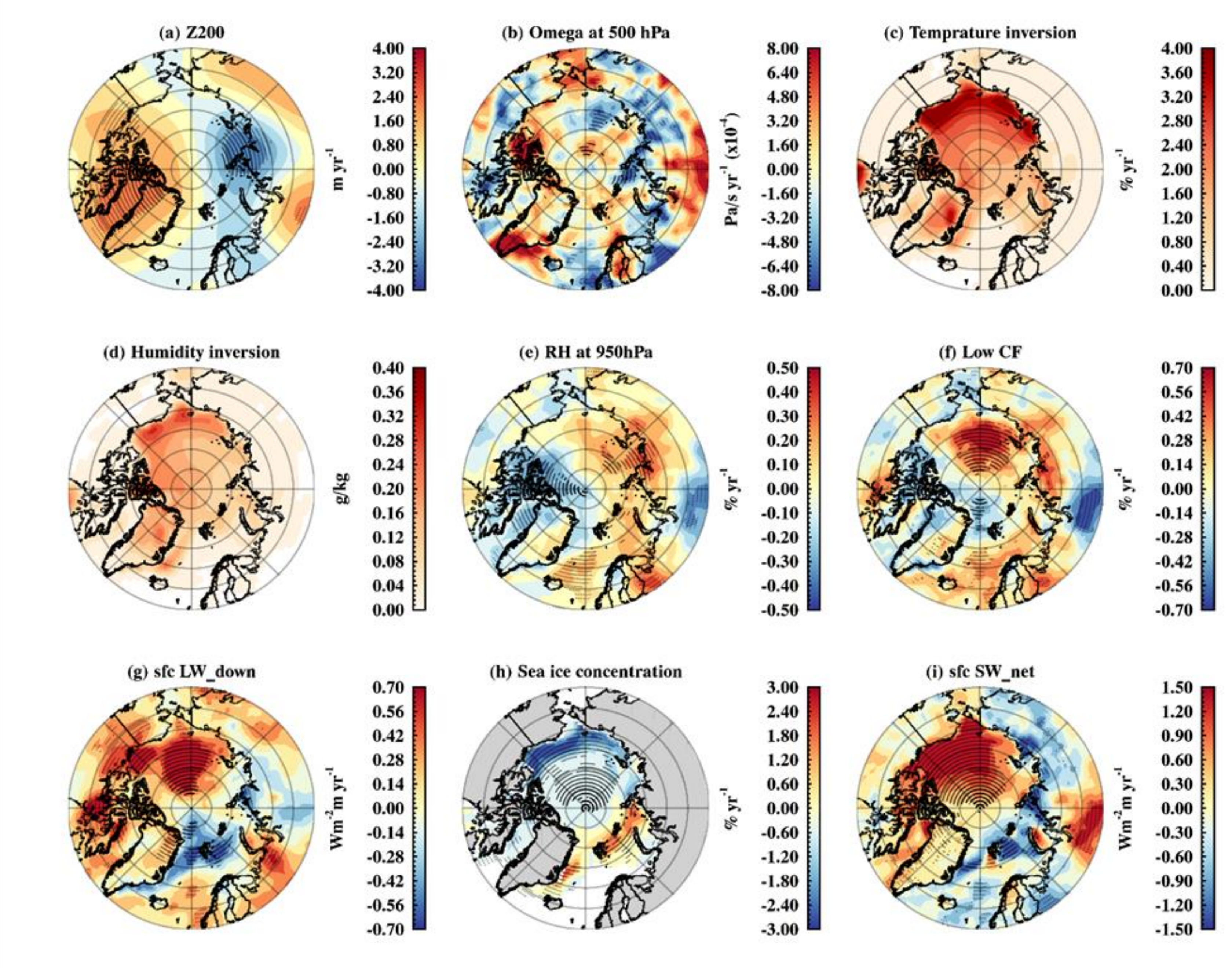


- Both temperature and humidity inversion existed below 900 hPa
- The stronger downward motion occurred over the Beaufort/Chukchi Sea
- The low-level clouds mainly increased at ~975 hPa, which is closely match with the largest increasing trend of relative humidity

**Black dots mark 10% significance level*

THE LINEAR TREND OF SUMMERTIME LOW CLOUDS, LARGE-SCALE CIRCULATION AND SEPTEMBER ARCTIC SEA ICE FROM SELECTED 20-YEAR EPISODE IN CESM PRE-INDUSTRIAL FULLY COUPLED SIMULATION

- The increased low CF and LW_down flux occur mainly over the Chukchi and East Siberian Seas, with comparable magnitudes in observations
- The sea ice decline and increase of SW_net flux has a comparable magnitude as observations
- The stronger downward motion is not perfectly simulated by CESM



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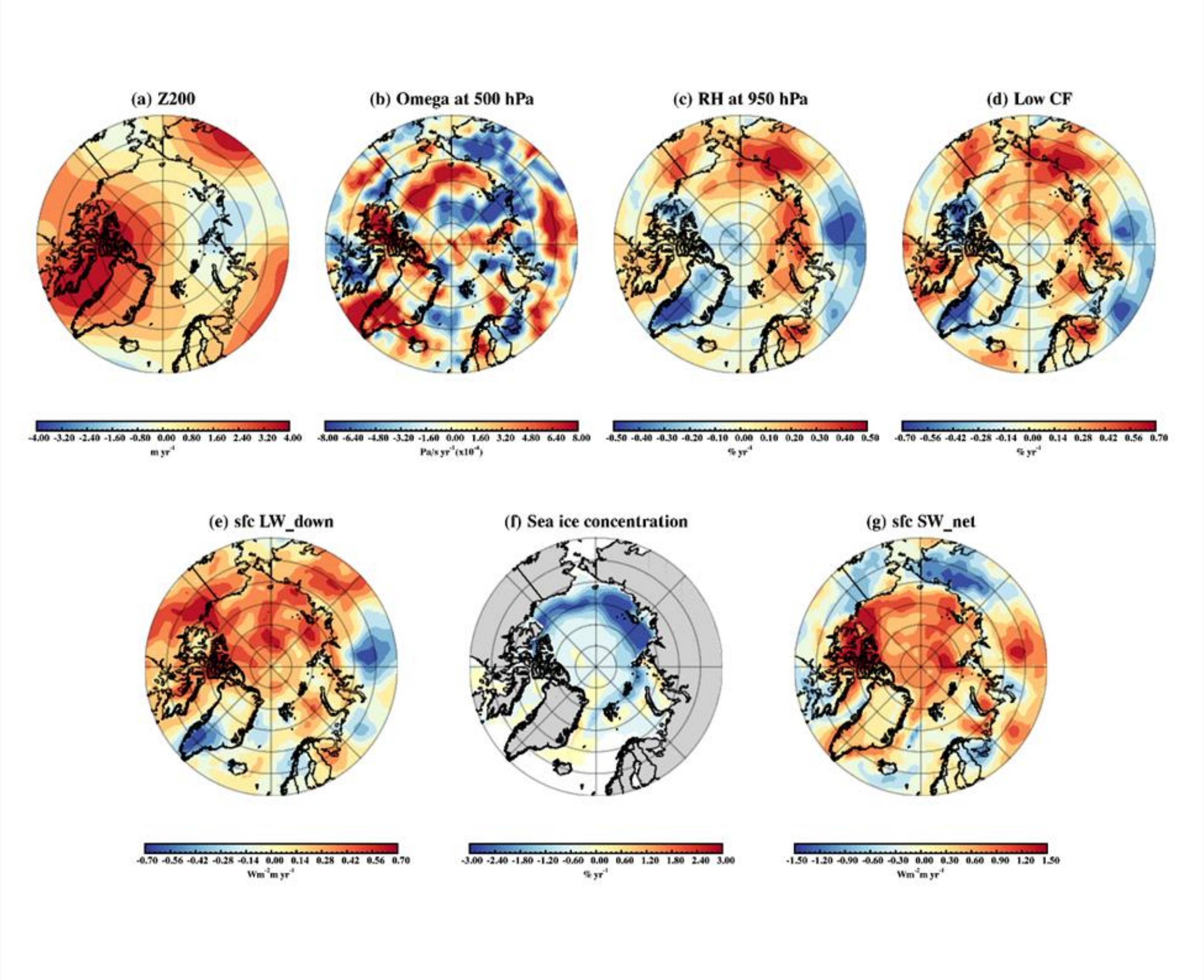
CESM NUDGING EXPERIMENTS

- Model version: CESM 1_2_2_1
- Fully coupled simulation (atmosphere, land, ocean and sea ice)
- Atmosphere/Land resolution: 0.9° x 1.25°, 30 vertical levels
- Ocean/sea ice resolution: gx1v6 (~1 degree)
- External forcing: Year 2000 emission scenario (present-day), GHG remains constant
- The domain of nudging: Arctic (60°-90°N)
- The strength of nudging: 0.5

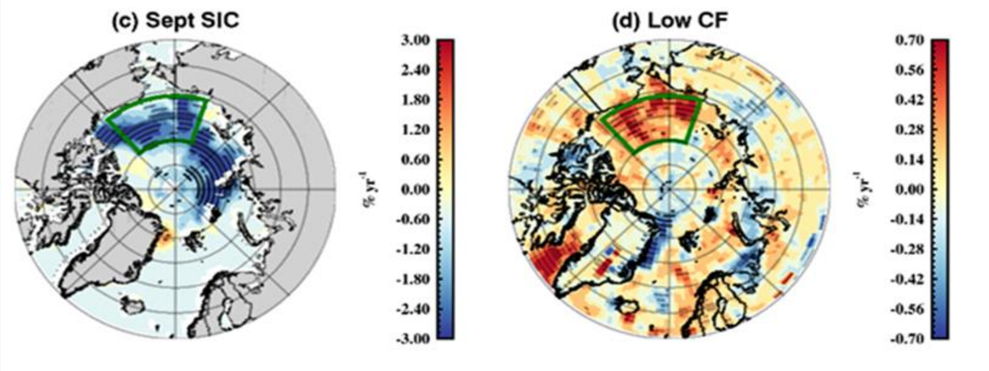
Experiment	Initial conditions	Wind fields from ERA-Interim	Vertical levels	The length of simulation
Exp-1	Default initial condition from Compset B2000	U,V during 1979-2016	860 hPa above	38 years
Exp-2	Default initial condition from Compset B2000	U,V during 1979-2016	All vertical levels	38 years
Exp-3	Year 2000 from CESM-LE BTR20 member 23 (high sea ice volume)	U,V during 1979-2016	860 hPa above	38 years
Exp-4	Year 2000 from CESM-LE BTR20 member 22 (low sea ice volume)	U,V during 1979-2016	860 hPa above	38 years
Exp-5	Year 2000 from CESM-LE BTR20 member 23 (high sea ice volume)	U,V during 2000-2016	860 hPa above	17 years
Exp-6	Year 2000 from CESM-LE BTR20 member 22 (low sea ice volume)	U,V during 2000-2016	860 hPa above	17 years
Exp-7	Year 2000 from CESM-LE BTR20 member 14 (thick sea ice)	U,V during 2000-2016	860 hPa above	17 years
Exp-8	Year 2000 from CESM-LE BTR20 member 20 (thin sea ice)	U,V during 2000-2016	860 hPa above	17 years

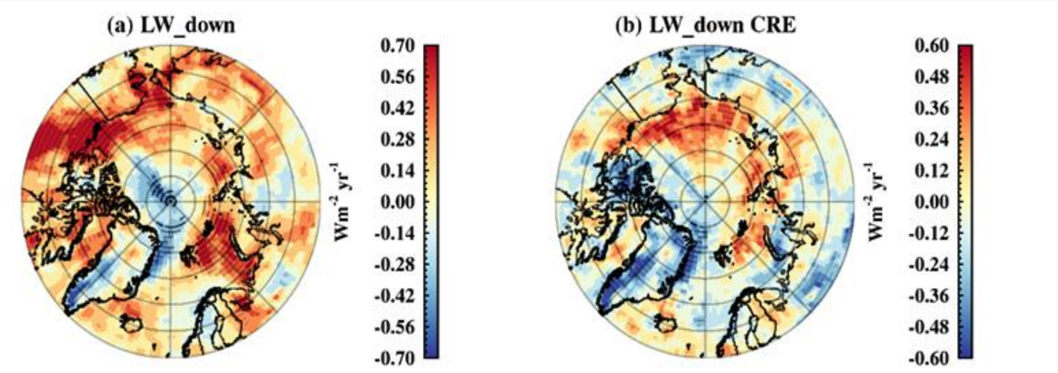
THE LINEAR TREND OF SUMMERTIME CLOUD AND RADIATIVE PROPERTIES AND SEPTEMBER ARCTIC SEA ICE FROM CESM NUDGING EXPERIMENTS

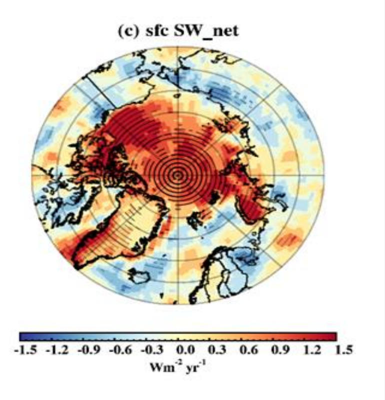
CESM Nudging Experiments



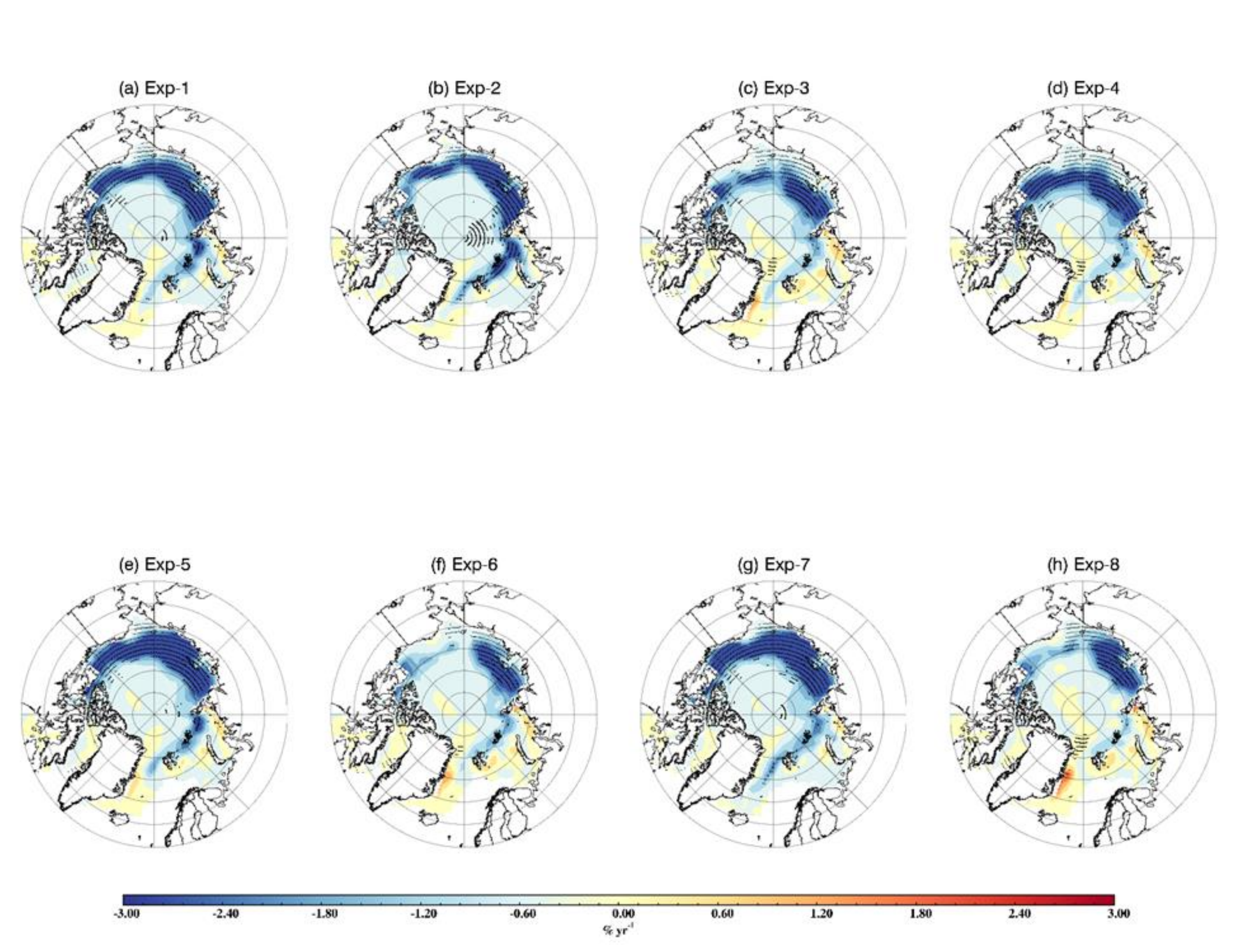
Observations







LINEAR TREND OF SEPT. SEA ICE CONCENTRATION IN CESM NUDGING EXPERIMENTS



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SUMMARY

- The rapid Arctic sea ice retreat in the early 21st century is believed to be driven by several dynamic and thermodynamic feedbacks
- The role of clouds in these feedbacks remains unclear since the causality between clouds and these processes is complex
- Observational and modeling analyses suggest that summertime low clouds have played an important role in driving sea ice melt by amplifying the adiabatic warming induced by a stronger anticyclonic circulation aloft
- The upper-level high pressure regulates low clouds through stronger downward motion and increasing lower troposphere relative humidity
- The increased low clouds favor more sea ice melt via emitting stronger longwave radiation, then decreased surface albedo triggers a positive ice-albedo feedback, which further enhances sea ice melt
- Accurate simulation of summertime large-scale circulation and low clouds is a prerequisite for climate models to produce reliable future projections of Arctic sea ice

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