The Bering Strait's Overlooked Role in Amplified Arctic Warming: Insights from High-Resolution Climate Simulations

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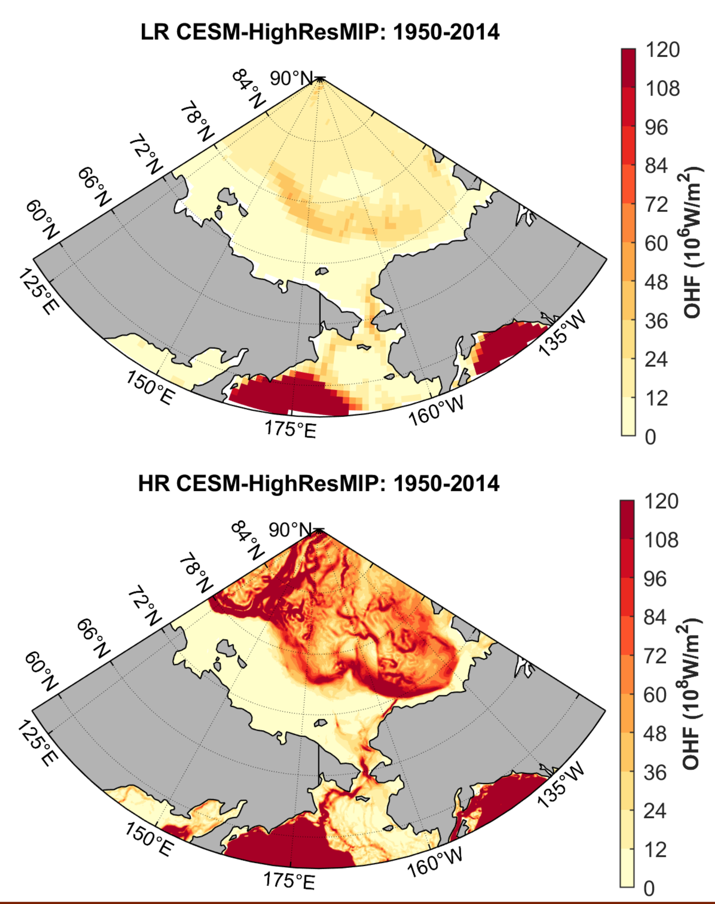
I. Introduction



- Ocean heat transport (OHT) is a cause for model uncertainty in projected Arctic warming (Mahlstein and Knutti, 2010).
- Barents Sea Opening: 50-70 TW, Fram Strait: 36±6 TW, Bering Strait: 10-20 TW.
- Increasing the ocean resolution to 0.25° or higher leads to an increased poleward OHT into the Arctic (Kinney et al., 2014; Left figure)
- **Can model resolutions impact Arctic warming through Bering Strait OHT?**

II. Datasets

- **Observations:** MODIS SST, NOAA/NSIDC Passive Microwave Sea Ice Concentration, Bering Strait OHT estimated by mooring data
- **Models:** 33 CMIP5 models; High-resolution (HR) CESM: 0.1° ocean and sea ice, 0.25° atmosphere and land**;** Low-resolution (LR) CESM: 1° ocean, sea ice, atmosphere and land. Three ensemble members of HR and LR CESM are used.

III. Historical Period Validation

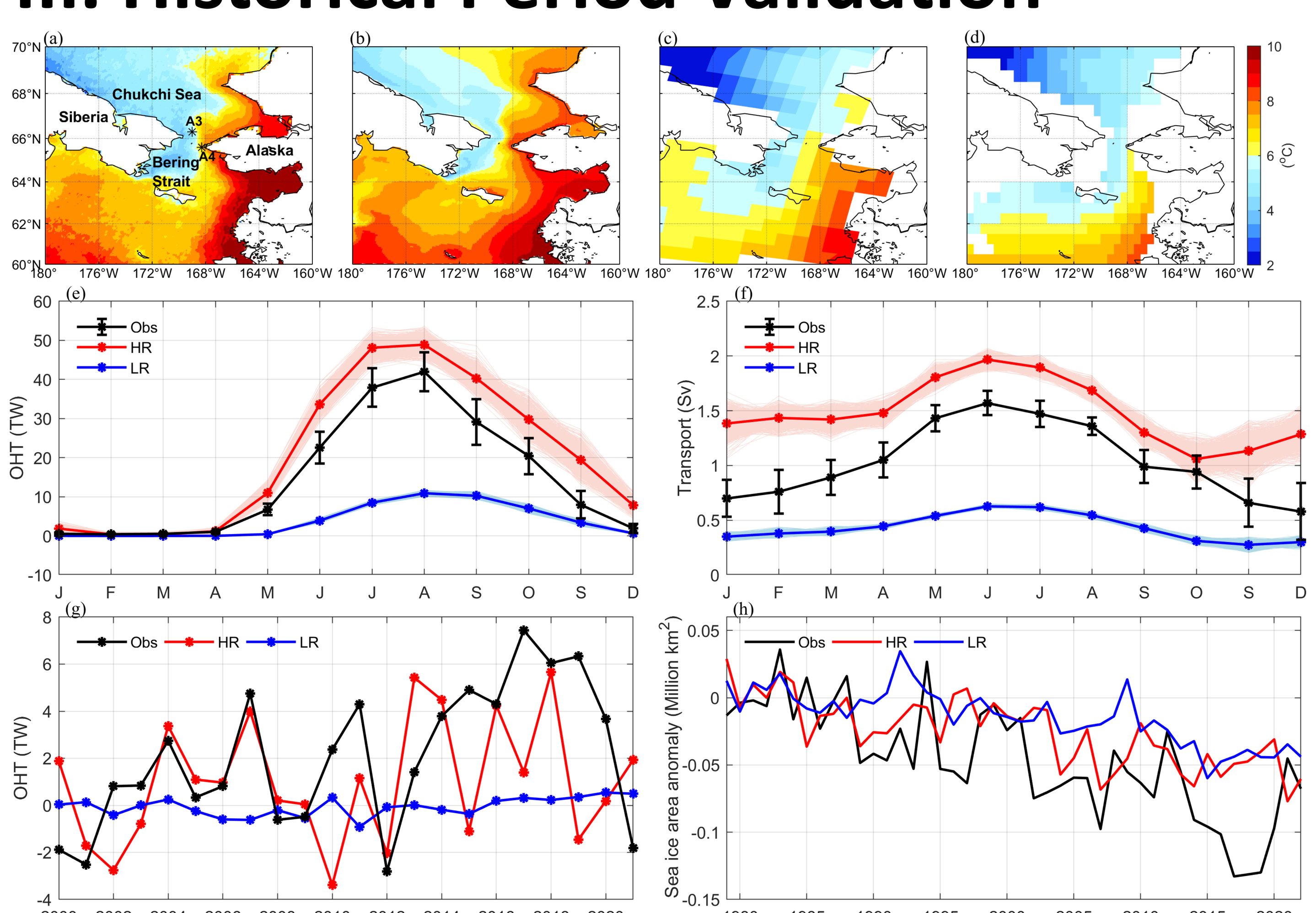


Fig. 1 SST in August-October from **(a)** the observations, **(b)** HR, **(c)** LR, and **(d)** multi-model-mean CMIP5 simulations. **(e)** Seasonal cycle of OHT through the Bering Strait from the mooring-based estimates (black), HR (red), and LR (blue) **(f)** Similar to (e) but for northward volume transport. **(g)** Annual-mean OHT changes relative to the 2000-2004 mean. **(h)** Annual mean sea ice area anomalies relative to the 1979-1988 mean.

- **Cold SST biases are reduced from LR to HR (Fig. 1a-d).**
- **Seasonal cycles of OHT and volume transport are improved from LR to HR (Fig.1e-f).**
- **Increases in OHT is more realistic in HR than in LR (Fig. 1g).**
- **The sea ice decline in 1979-2005 is better captured by HR than LR (Fig. 1h).**

References:

Mahlstein, I. & Knutti, R. Ocean heat transport as a cause for model uncertainty in projected Arctic warming. *J. Clim.* **24**, 1451–1460 (2011).

Clement Kinney, J. *et al.* On the flow through Bering Strait: A synthesis of model results and observations. *Pac. Arct. Reg. Ecosyst. Status Trends Rapidly Chang. Environ.* 167–198 (2014).

IV. Future Projections with RCP8.5 forcing

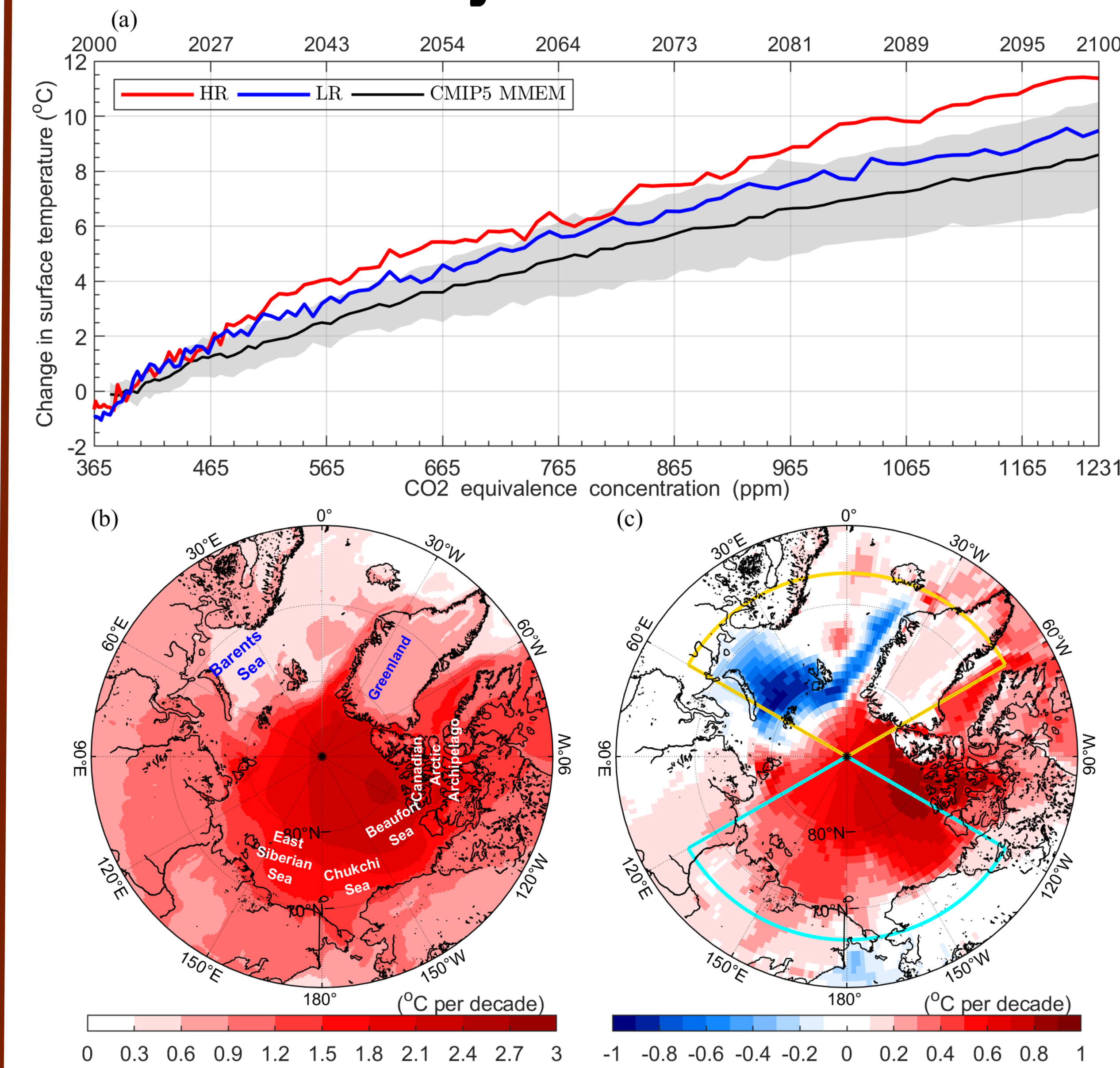


Fig. 2 (a) The Arctic-averaged (north of 66°N) surface air temperature changes relative to 2006-2015 in HR (red), LR (blue), and CMIP5 MMEM (black). **(b)** The trend of surface air temperature in HR over the period of 2006-2100. **(c)** The difference in the trend of surface air temperature between HR and LR (HR minus LR). Cyan (yellow) outline is the Pacific (Atlantic) sector of the Arctic.

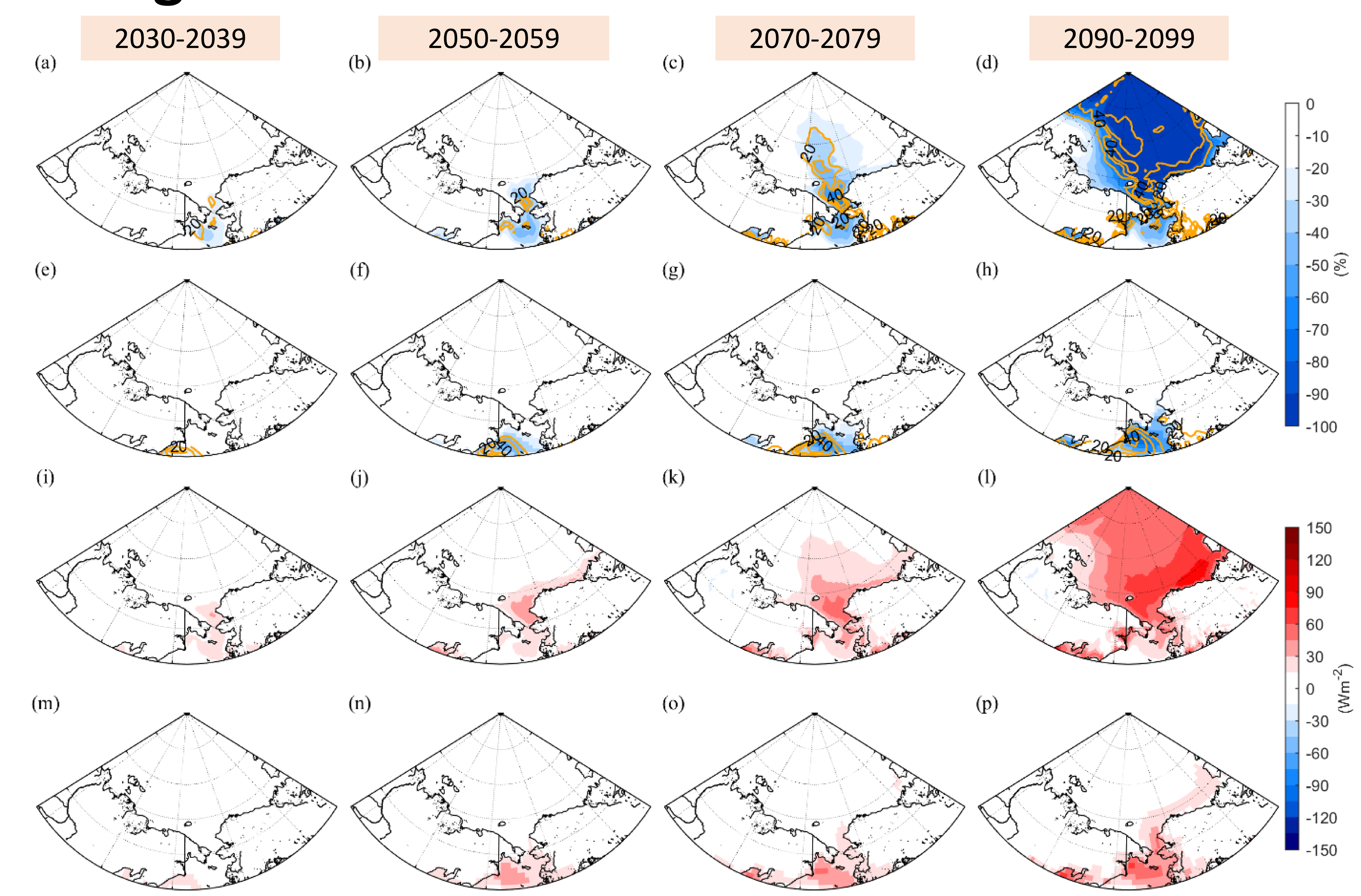
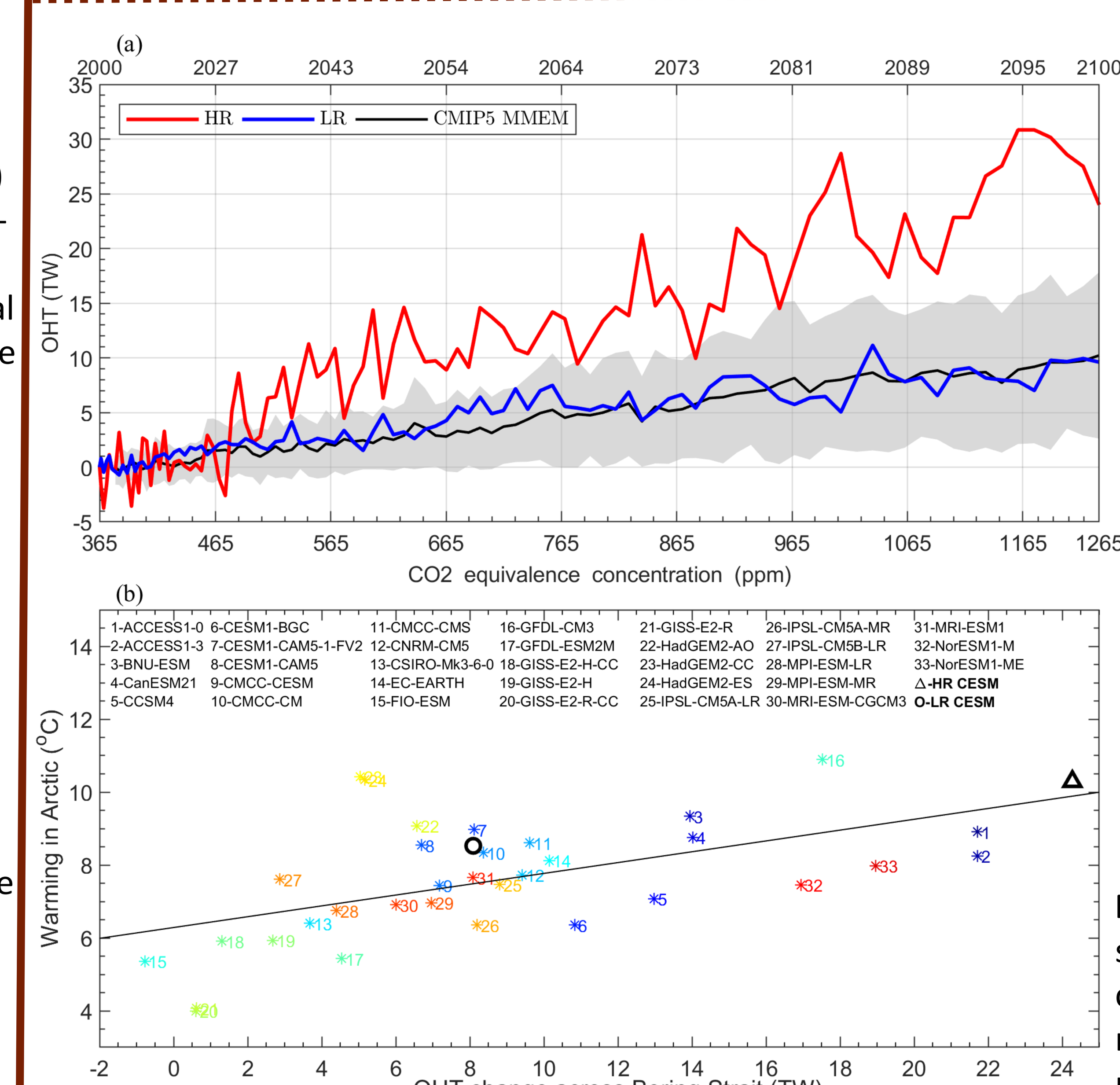


Fig. 4 (a-d) Changes in sea ice concentration (turbulent heat flux) during boreal spring (MAM) in HR depicted by color shades (contours). **(e-h)** Same as a-d but for LR. **(i-l)** Changes in the net shortwave surface heat flux during MAM in HR. **(m-p)** Same as i-l but for LR. Contour interval in a-h is 10 Wm^{-2}, and 20, 40, 60 Wm^{-2} levels are labelled. Positive turbulent heat flux is upward (from the ocean to the atmosphere). Positive shortwave surface heat flux is downward (from the atmosphere to the ocean).



- **The Arctic surface air temperature is projected to increase at a rate of 1.28°C per decade in HR over the period of 2006-2100 (Fig. 2a), approximately 20% higher than the rate projected by LR.**
- **The enhanced Arctic warming rate in HR is primarily driven by the warming difference between HR and LR over the Pacific sector(Fig. 2c).**
- **The increase in Bering Strait OHT is considerably more rapid in HR compared to LR (Fig.3a). Moreover, future Arctic warming is significantly correlated to changes in Bering Strait OHT in HR, LR, and CMIP5 models (Fig. 3b).**
- **The Bering Strait OHT can modulate the differences in Arctic warming rates between HR and LR through sea ice loss, which directly influences the air-sea heat exchange (Fig. 4).**

Fig. 3 (a) OHT changes relative to the 2006-2015 mean in HR (red), LR (blue), and CMIP5 MMEM (black). The gray shading represents the range of one ensemble standard deviation above and below the MMEM. **(b)** Scatterplot of changes in Bering Strait OHT and Arctic-averaged surface air temperature in HR (triangle), LR (circle), and CMIP5 models (stars). The changes in (b) are defined as the difference between the 2081-2100 mean and the 2006-2015 mean.. Linear regression based on CMIP5 models passes the 95% significance test with a slope of 0.15°C per TW.

V. Conclusions

Under the RCP8.5 emission scenario, HR projects a more rapid increase in Bering Strait OHT compared to LR and other CMIP5 model simulations. The intensified Bering Strait OHT in HR results in accelerated sea ice loss in the Pacific sector of the Arctic, strengthening the increase in shortwave heat flux absorption in the region. Consequently, more heat is released from the ocean to the atmosphere in HR compared to LR.