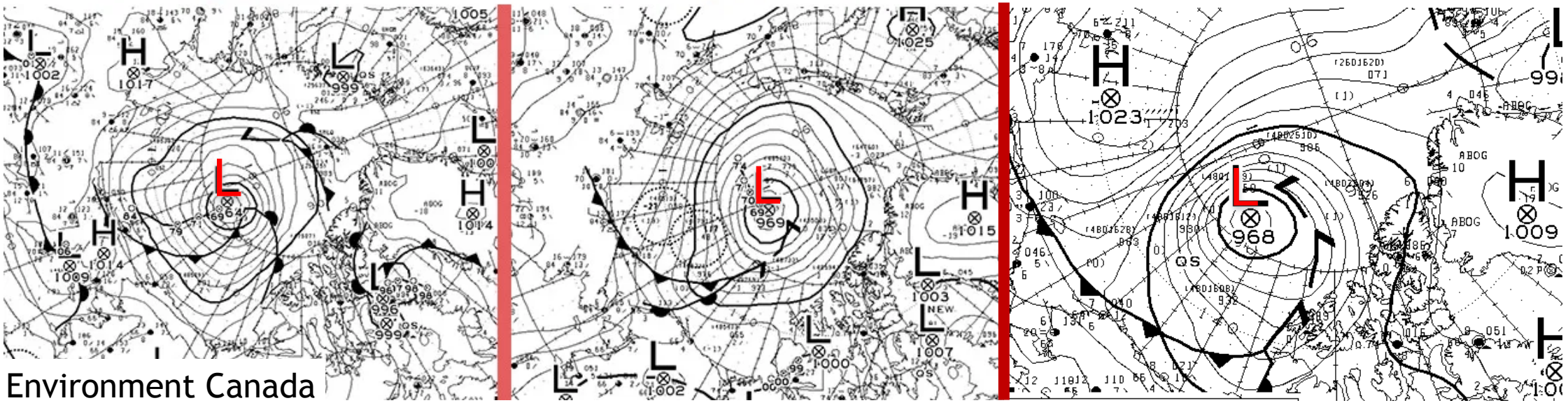
06Z August 6, 2012 00Z August 16, 2016 12Z July 7, 2018



Environment Canada

Impacts of Arctic climate change on synoptic cyclones and Beaufort High

Minghong Zhang, William Perrie,

and Zhenxia Long

Bedford Institute of Oceanography (BIO)

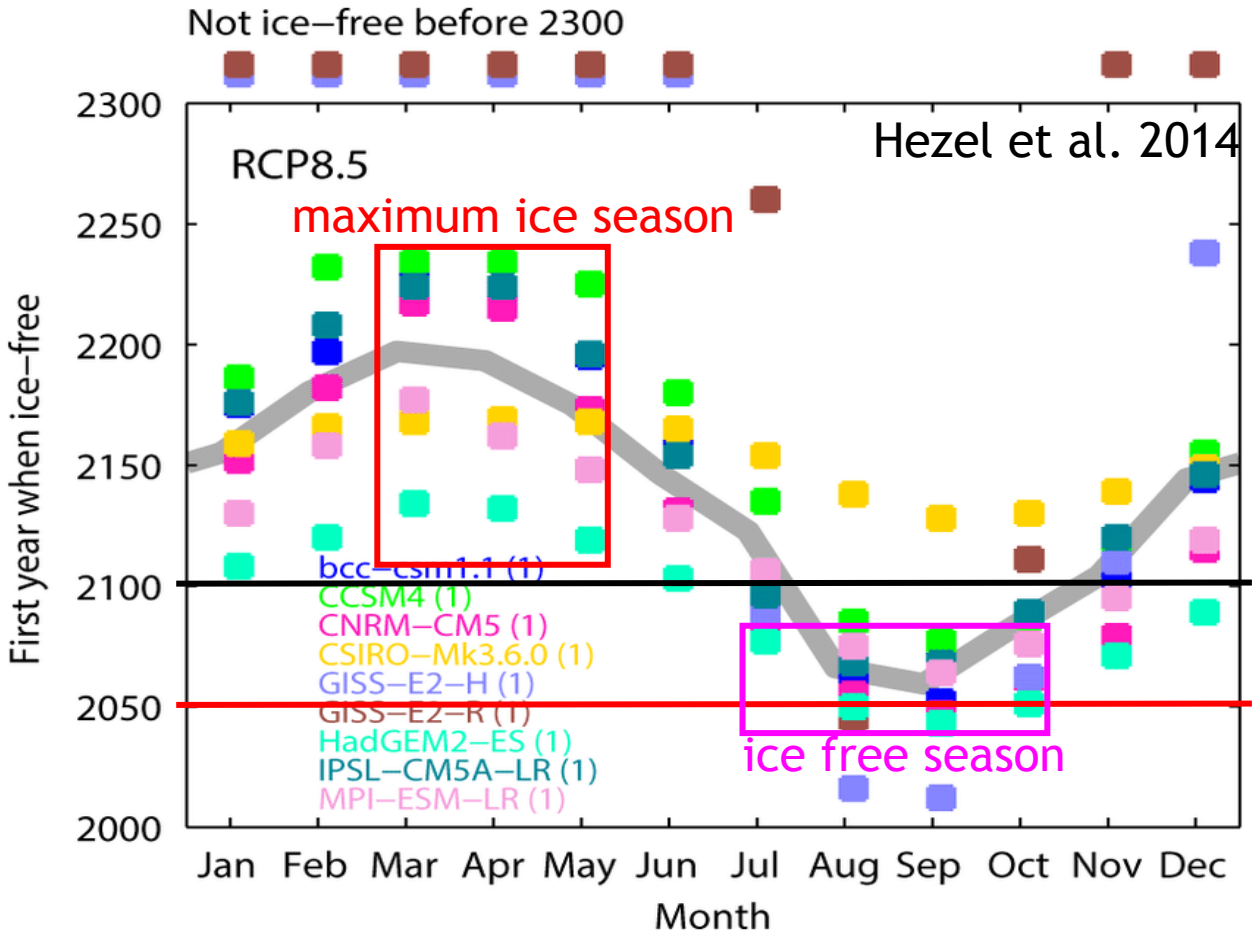
CESM Workshop/CVCWG, 2020/06/17

Outline

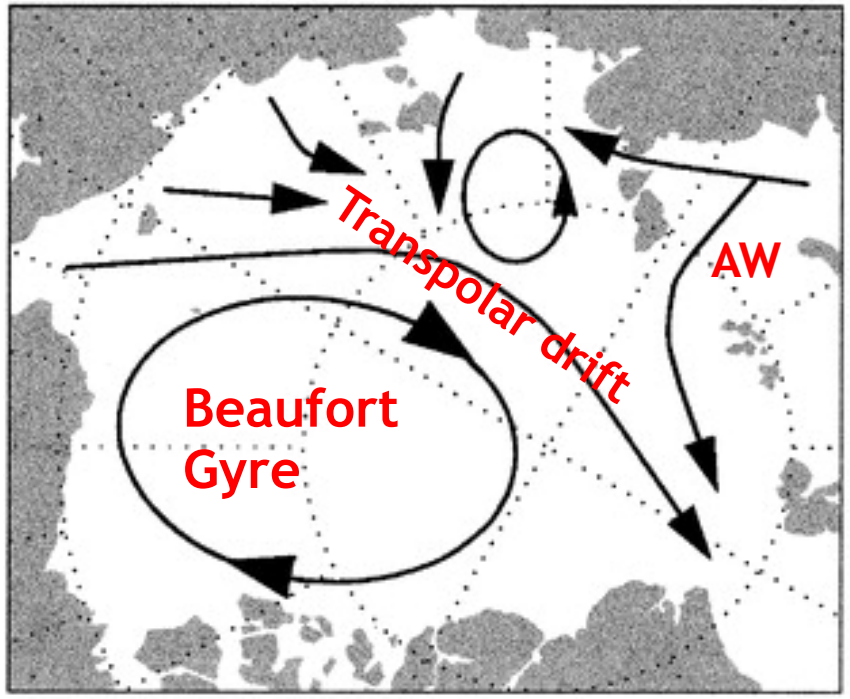
1. Background: Changing Arctic climate
2. Polar WRF Setup and Validation
3. Cyclone responses in Winter (NDJF) and Summer (JASO)
4. Conclusions

Rapid climate change is happening in the Arctic

- **Rapid reduction in Arctic sea ice, more open water -> strong air-sea-ice interaction**
- **Multiple-year ice -> seasonal ice-> vulnerable to atmospheric forcing, synoptic weather systems**
- **Ice motion/freshwater re-distribution <- Important role of synoptic weather systems**



Wind-driven ocean current



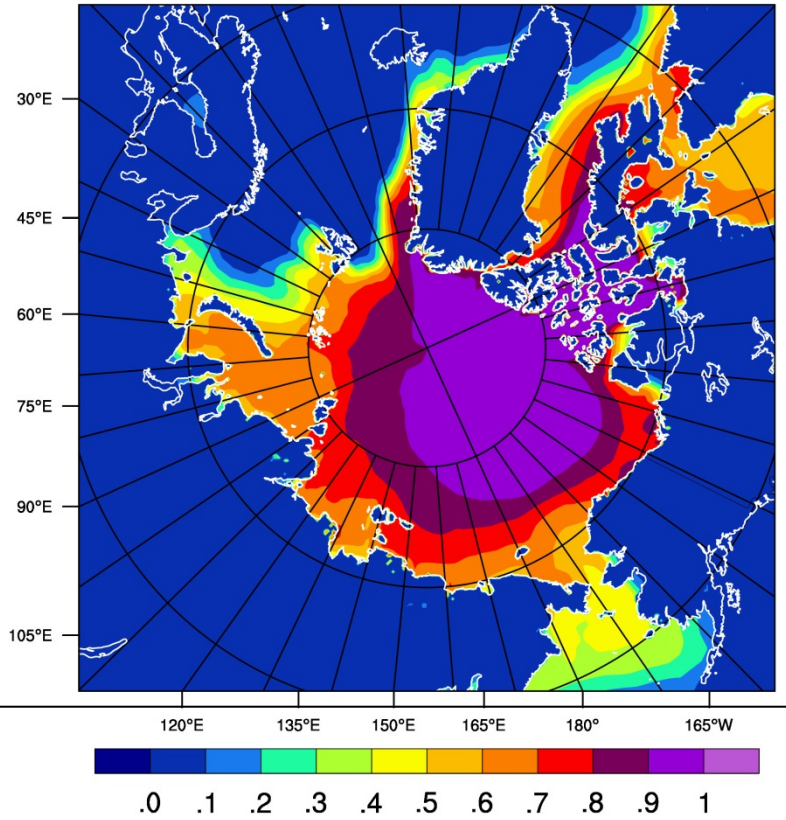
Model Setup and Validation

Model: Polar WRF 3.6

- 25 km x 25 km, 38 levels (up to 20hPa)

IPCC5 GCM: HadGEM-ES2

- Historical run over the period 1970-2004 for validation
- Future scenarios RCP 8.5/4.5: 2005-2099

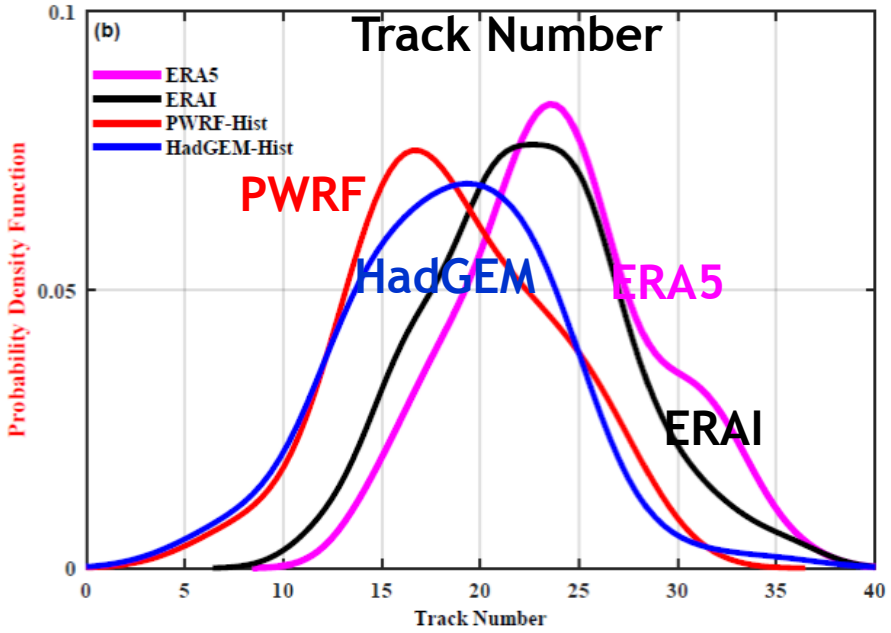


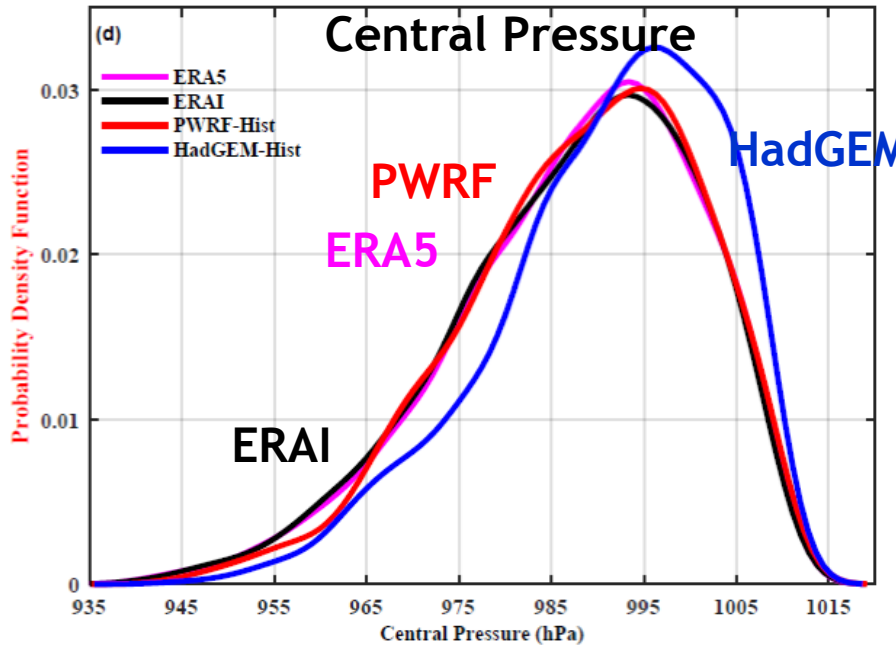
Validation and methodology:

- ERA-Interim (0.75^0x0.75^0) & HadGEM, 1.5^0x1.2^0
- University of Melbourne automatic cyclone tracking scheme (North of 65^0 , >= 24-hours)
- Polar WRF improves the simulation of Arctic cyclone, including frequency and intensity (Zhang et al. 2019)

Zhang, M., William Perrie and Zhenxia. Long, 2019: Dynamical Downscaling of the Arctic Climate with a Focus on Polar Cyclone Climatology. Atmosphere-Ocean. 57(1), 41-60.

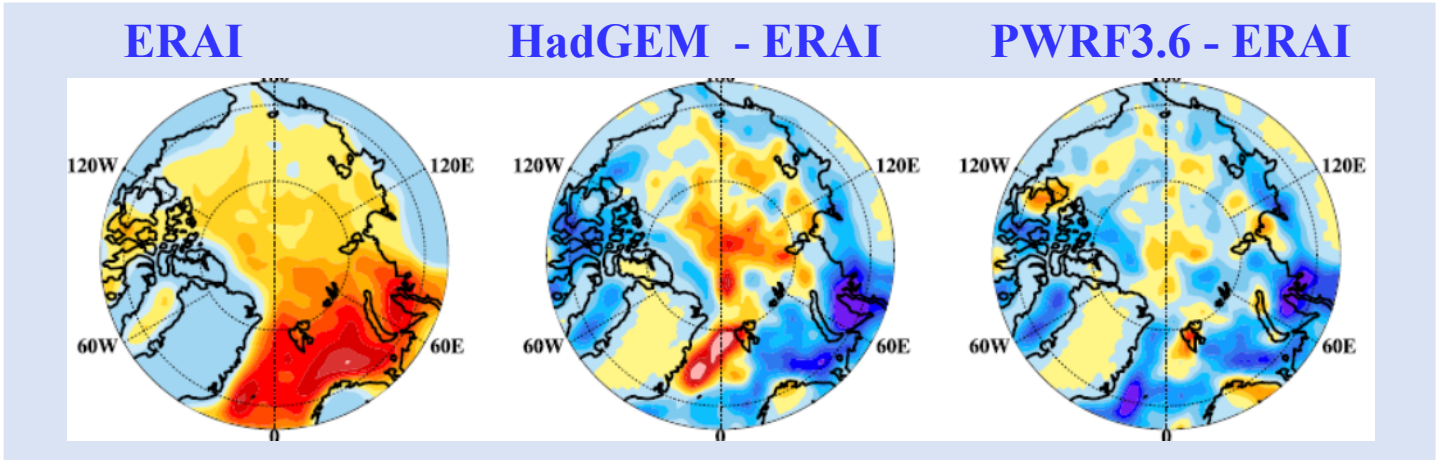
Frequency and intensity of cyclones in NDJF, Historical climate





Frequency:

1) Both models underestimate the frequency of Arctic cyclones.
2) Polar WRF has comparable cyclones density as in GCM.

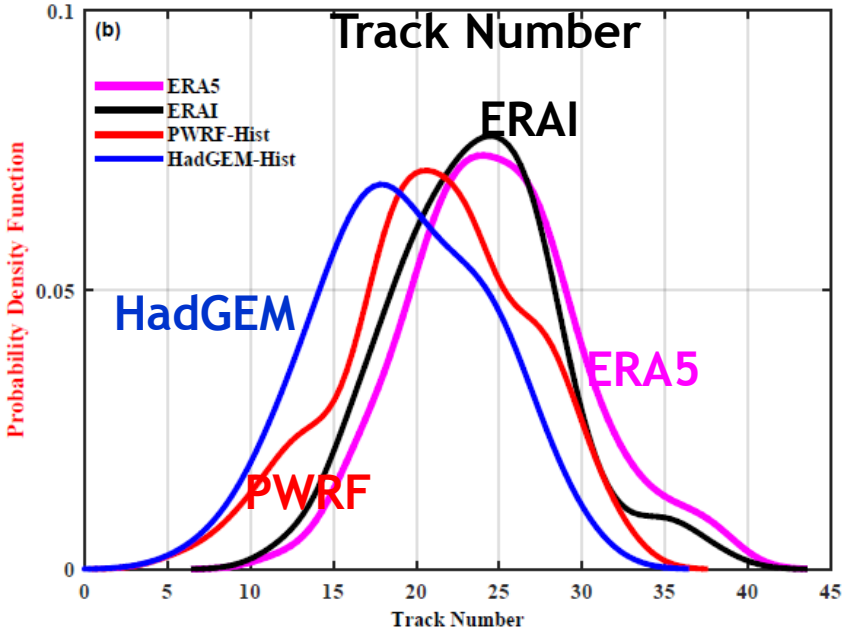


Intensity:

1) Cyclones in Polar WRF show comparable intensity as in ERA5 and ERAI.
2) HadGEM underestimate the intensity of Arctic cyclones

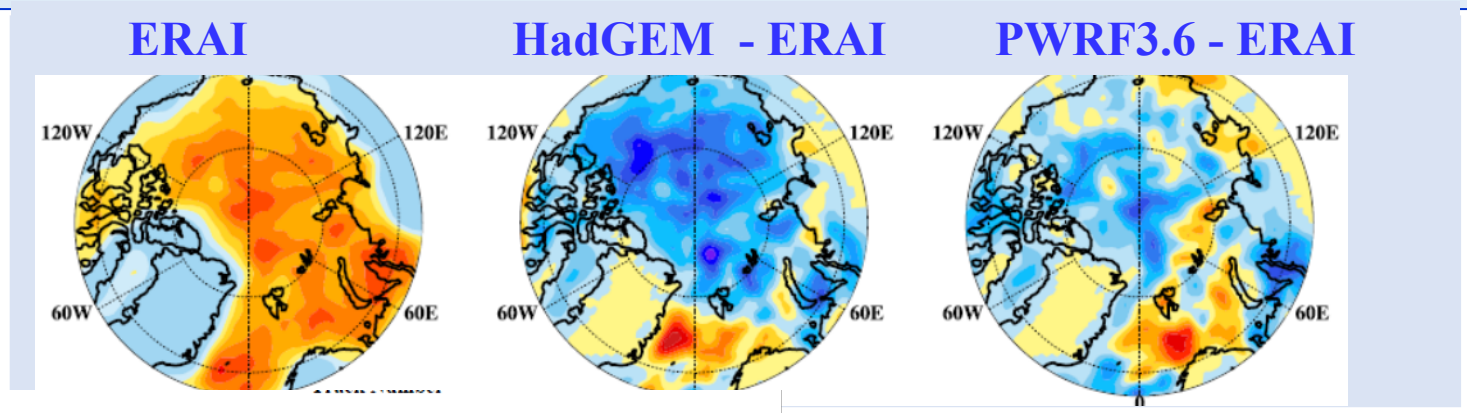
Zhang, M., William Perrie and Zhenxia. Long, 2019: Dynamical Downscaling of the Arctic Climate with a Focus on Polar Cyclone Climatology. Atmosphere-Ocean. 57(1), 41-60.

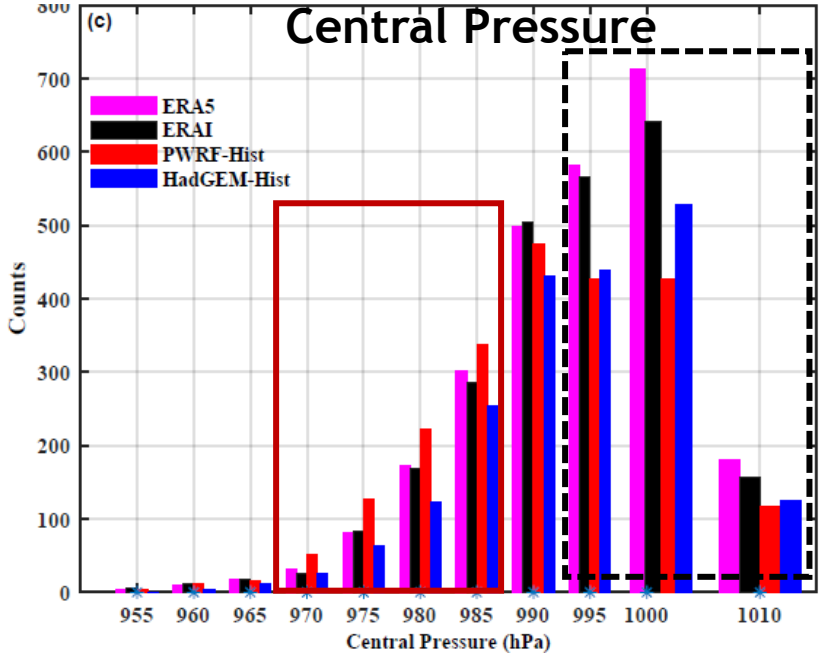
Frequency and intensity of cyclones in JASO, Historical climate

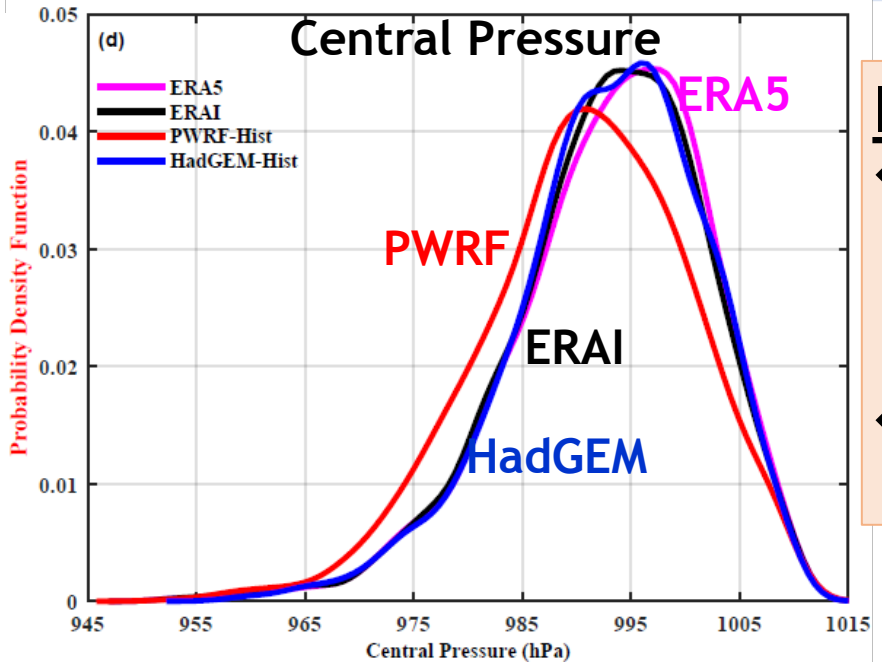


Frequency:

- Both models underestimate the frequency of Arctic cyclones.
- Polar WRF simulates more cyclones than shown by GCM.







Intensity:

- Polar WRF has more intense cyclones, and fewer moderate cyclones than ERA5, ERAI, and HadGEM.
- HadGEM has the least intense cyclones.

Changes in Winter Cyclones Track density (NDJF)

Differences plots:(2070-2099) - (1979-2004)

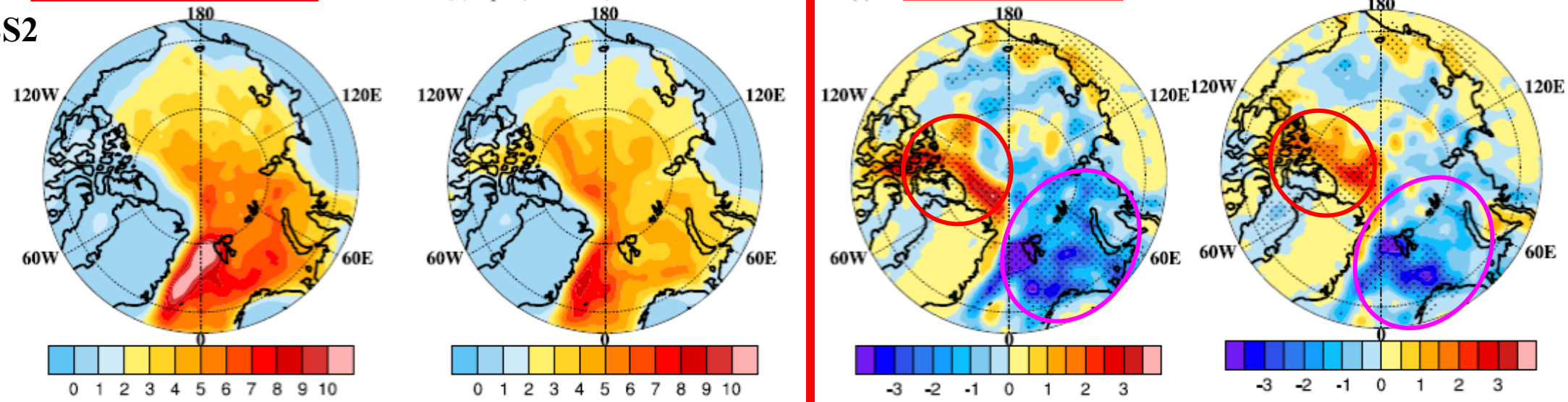
Hist 1979-2004

RCP8.5 2070-2099

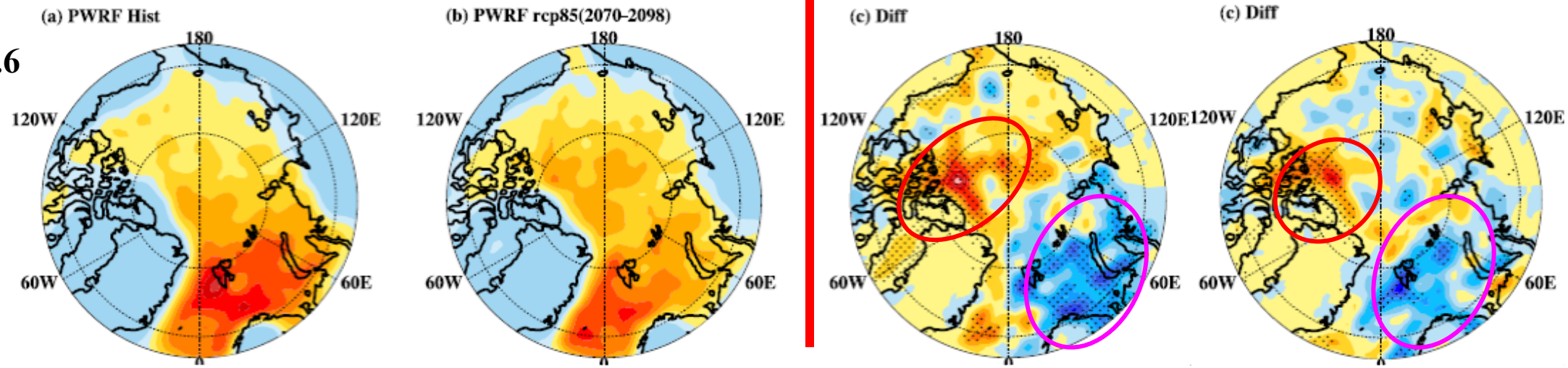
RCP8.5-Hist

RCP4.5-Hist

HadGEM-ES2

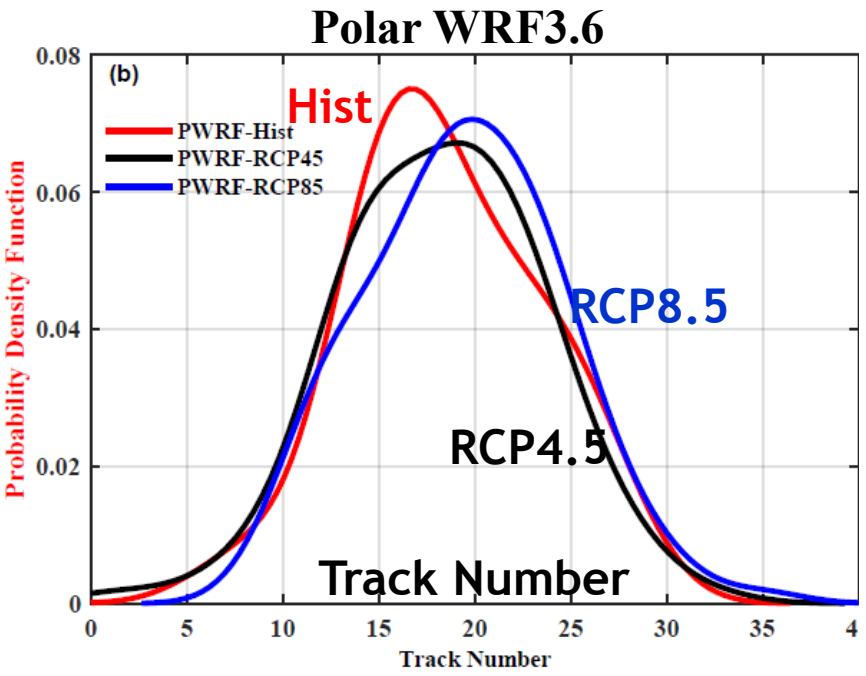


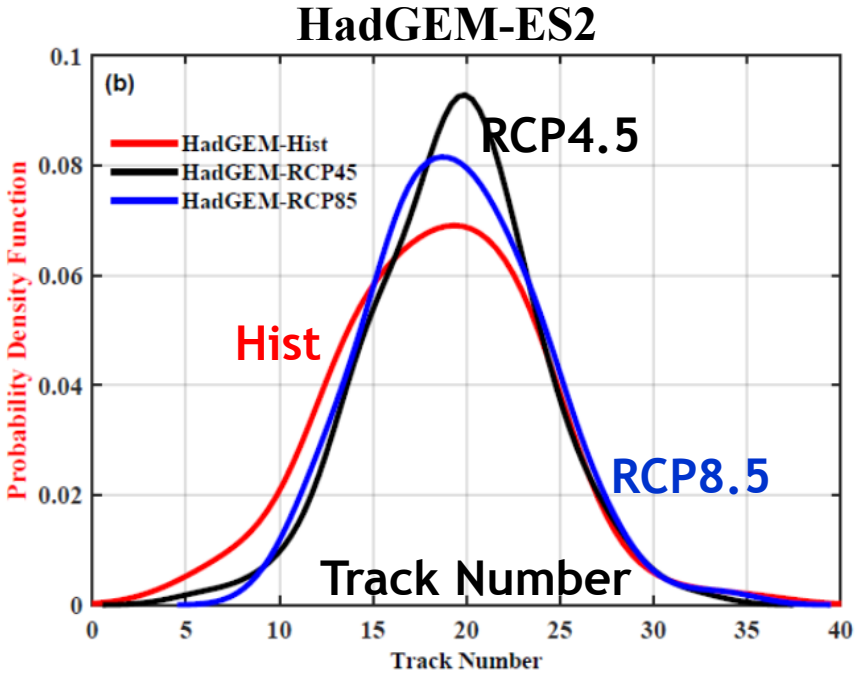
Polar WRF3.6



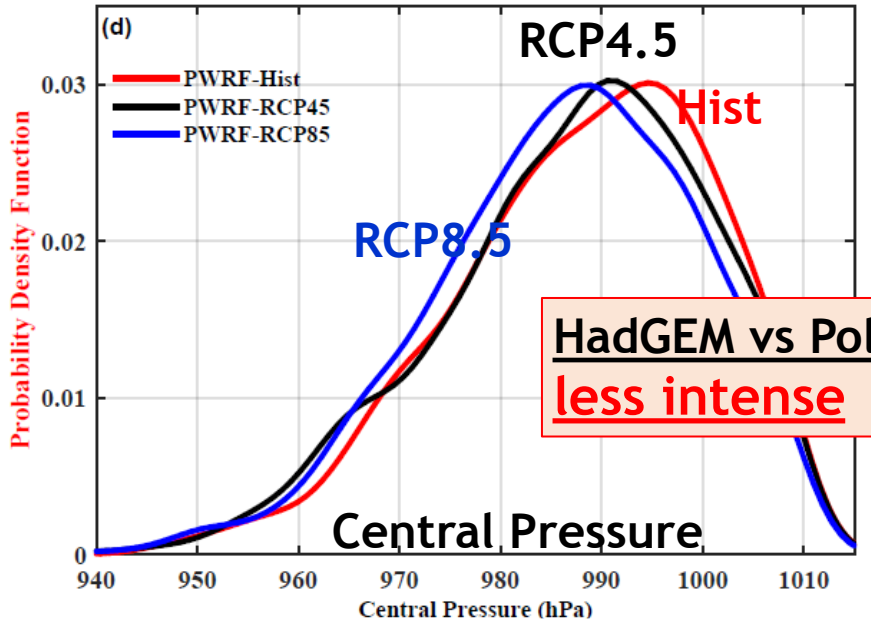
Changes in Frequency and intensity of cyclone

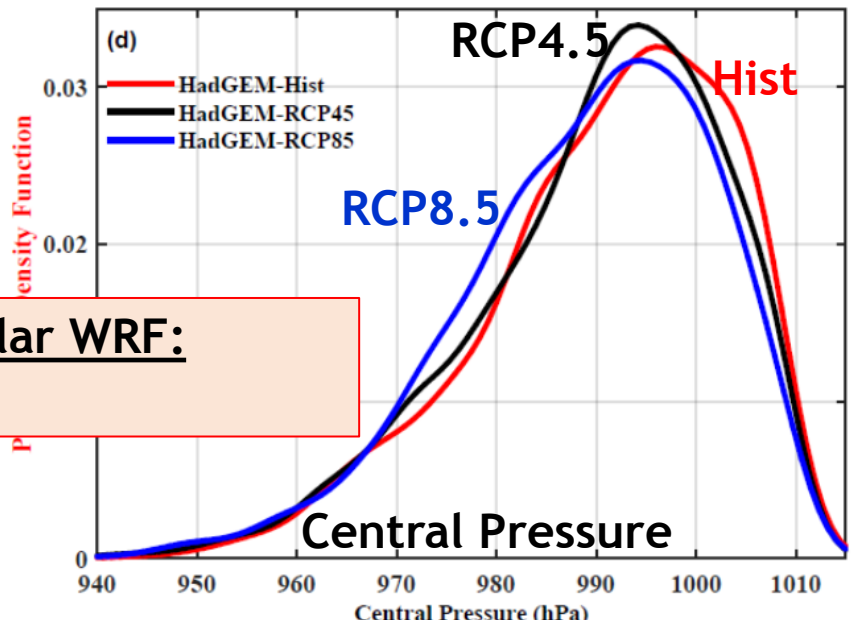
(2070-2099) vs (1979-2004)





Frequency: comparable
Increased cyclones in Central/ West Arctic compensated by decreased Atlantic Arctic cyclones

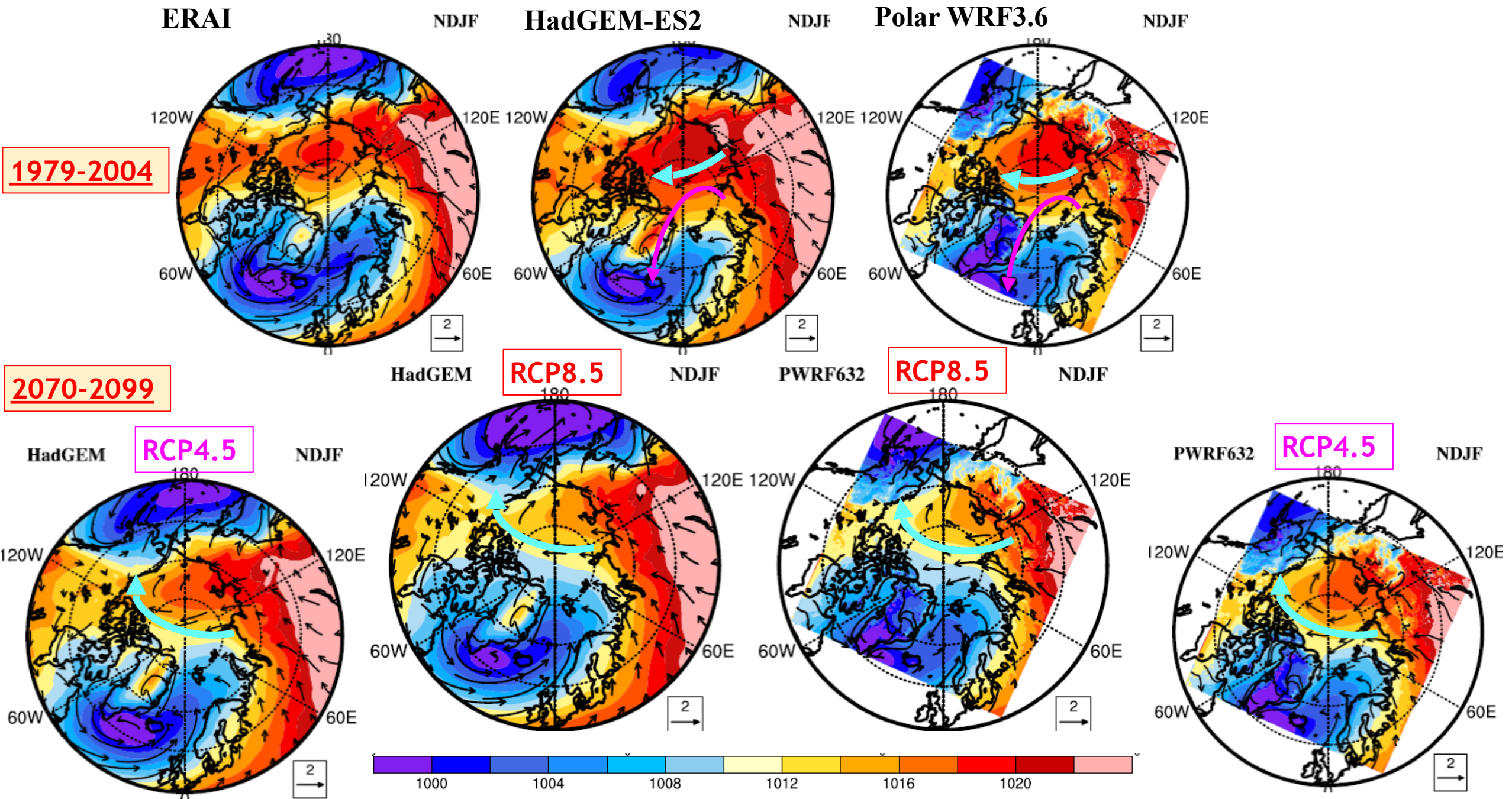




HadGEM vs Polar WRF:
less intense

Intensity: increase
More intense cyclones in RCP8.5 and RCP4.5 compared with the historical climate

SLP NDJF: Beaufort High becomes weakening ⬅ increased frequency and intensity of Arctic cyclones



Winter Cyclones genesis

Hist 1979-2004

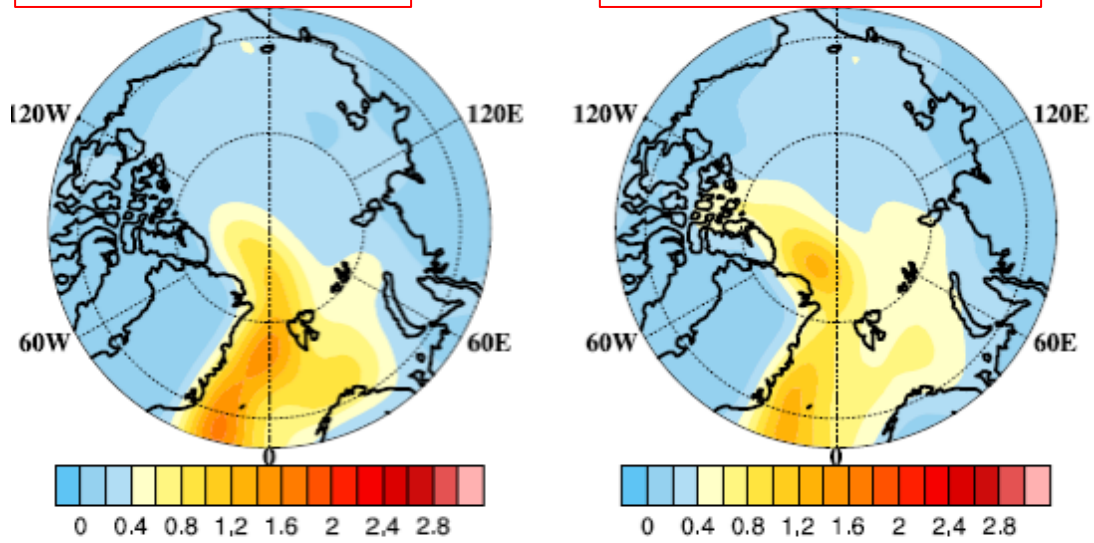
RCP8.5 2070-2099

Differences plots:(2070-2099) - (1979-2004)

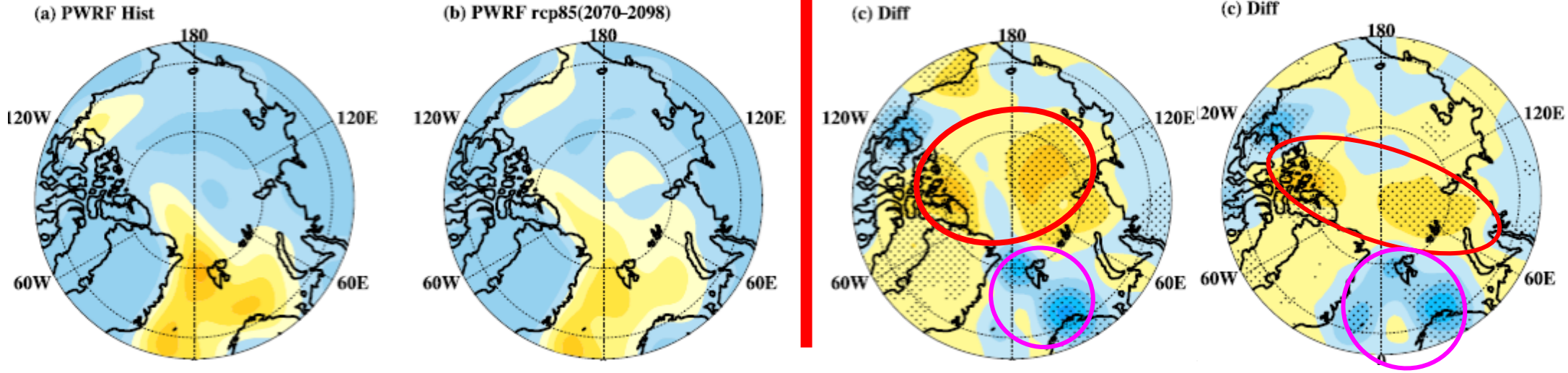
RCP8.5-Hist

RCP4.5-Hist

HadGEM-ES2



Polar WRF3.6



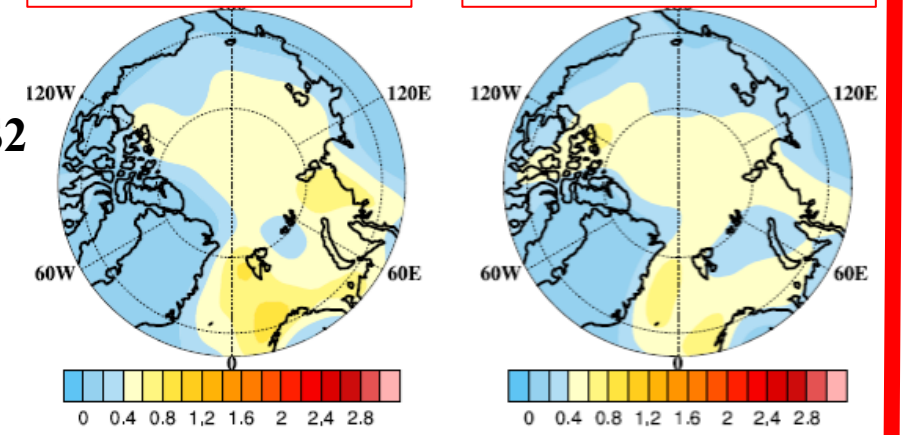
Poleward displaced frontal zone in the Pacific and Atlantic Arctic → genesis zone is polarward extended

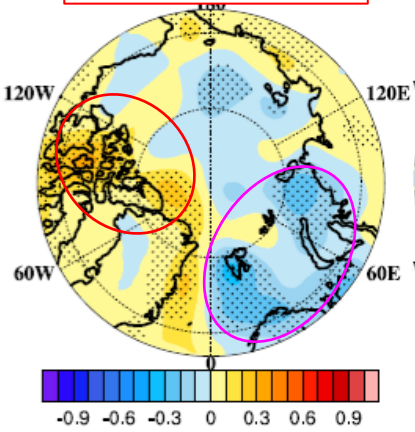
Winter Cyclones Lysis (NDJF)

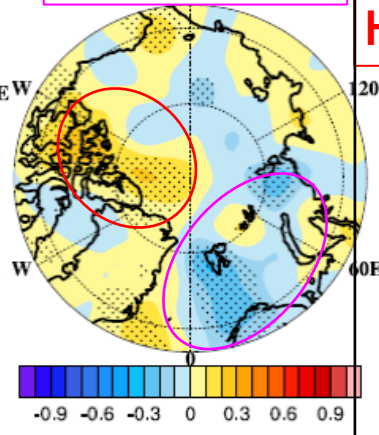
Difference plots:(2070-2099) - (1979-2004)

Hist 1979-2004 | RCP8.5 2070-2099 | RCP8.5-Hist | RCP4.5-Hist

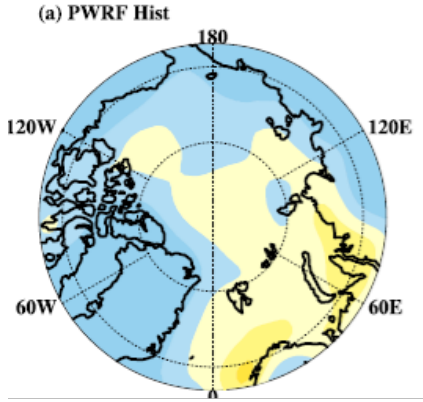
HadGEM-ES2

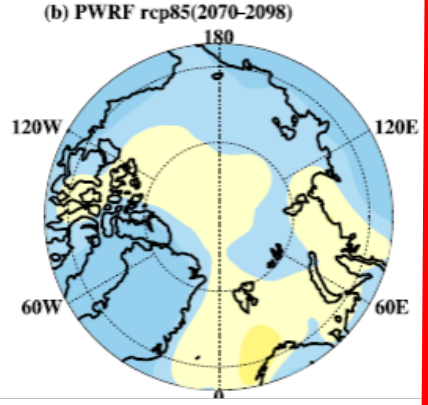


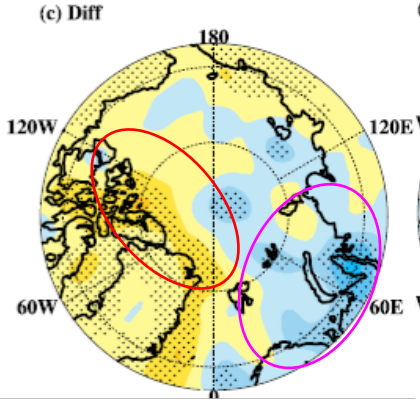


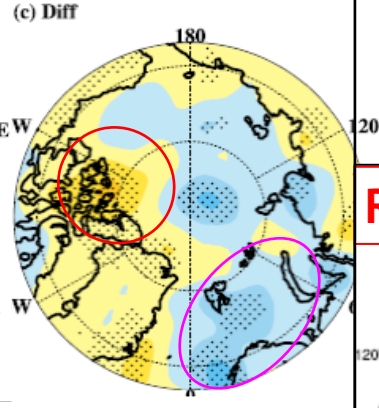


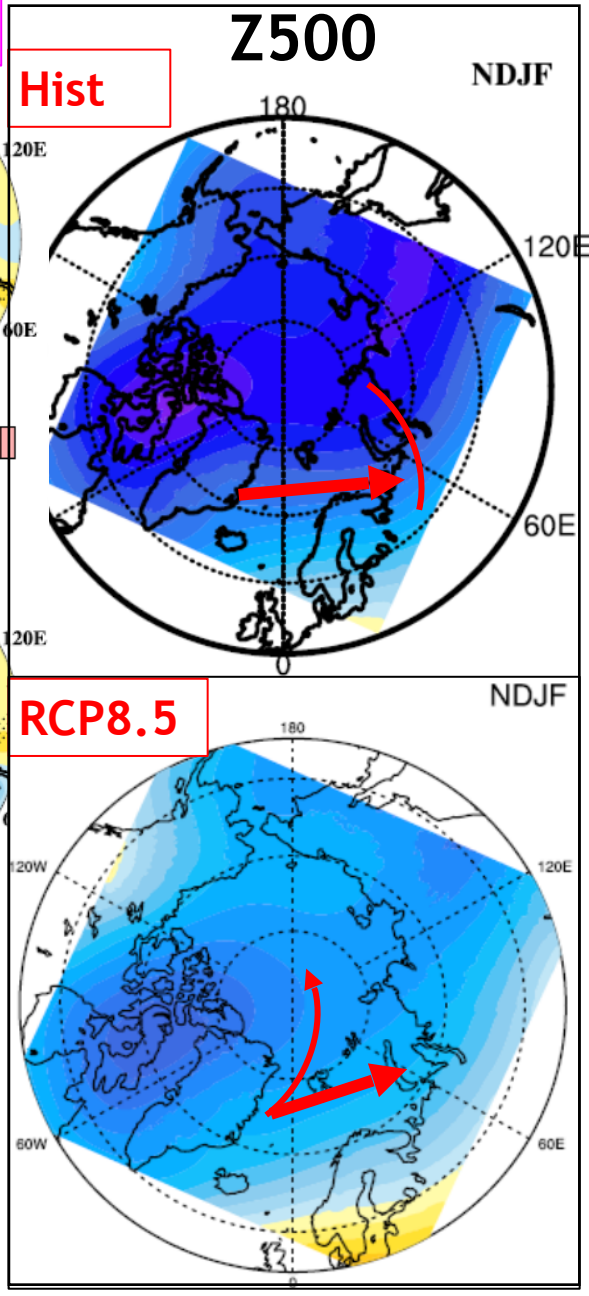
PWRF3.6











Polar vortex becomes warmer and weakening, and Ural trough becomes shallow

⬇

more cyclones moving into central and west Arctic and less into East Arctic

Summer (Ice-free): Cyclones Track density (JASO)

Difference plots: (2070-2099) - (1979-2004)

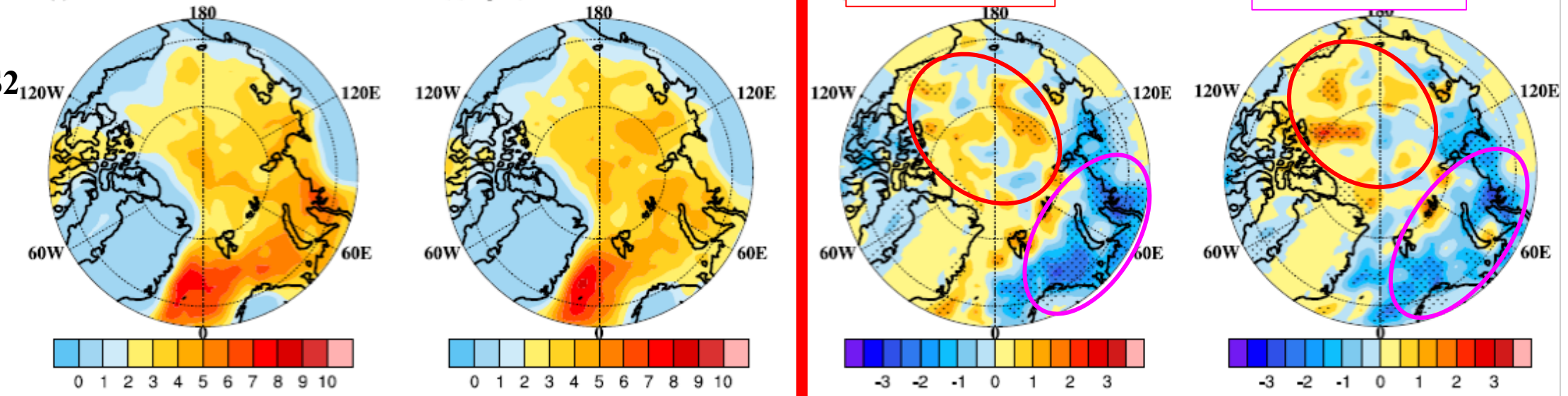
Hist 1979-2004

RCP8.5 2070-2099

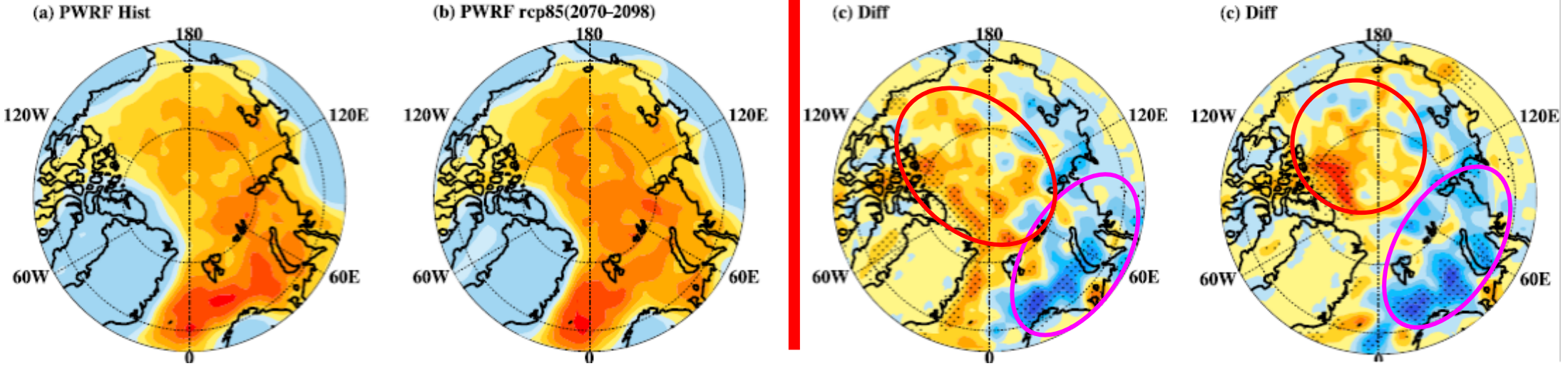
RCP8.5-Hist

RCP4.5-Hist

HadGEM-ES2

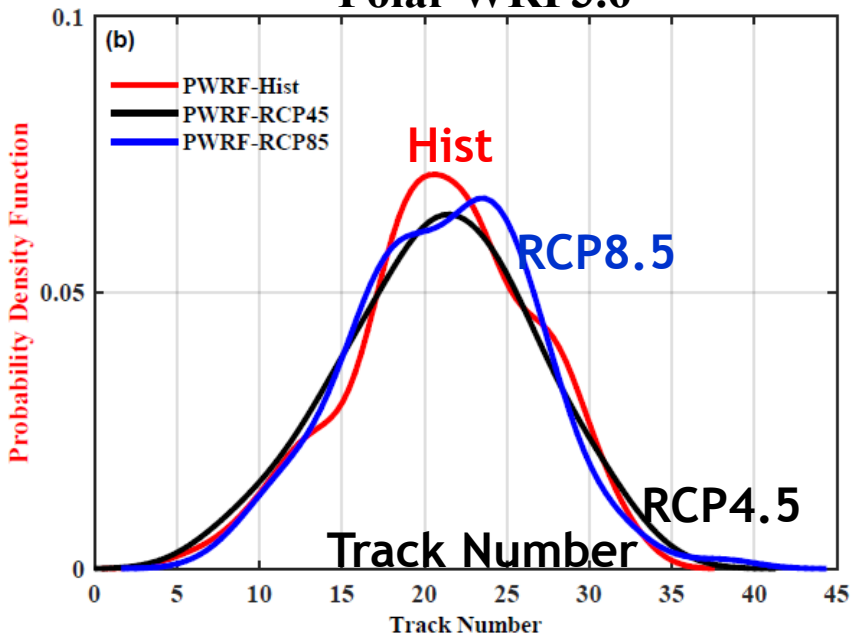


Polar WRF3.6

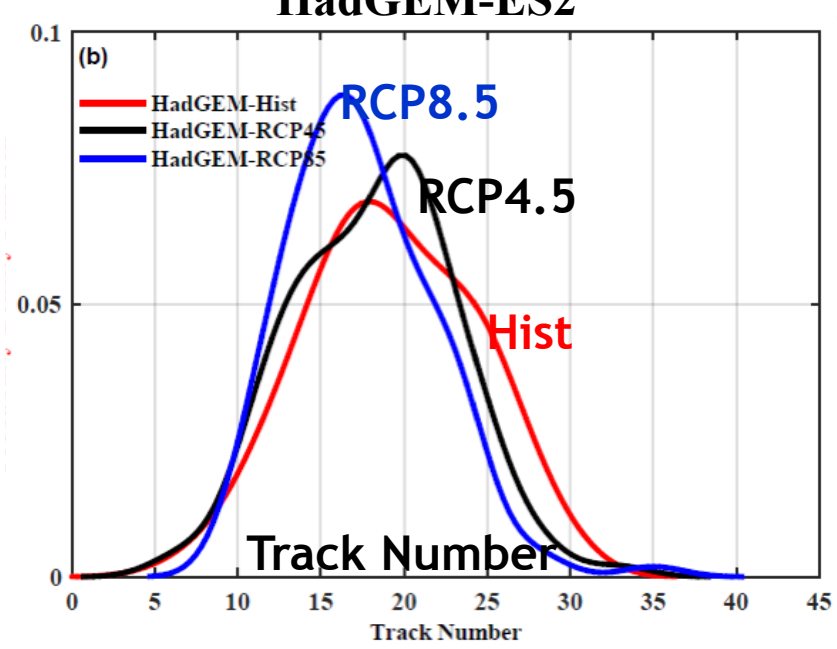


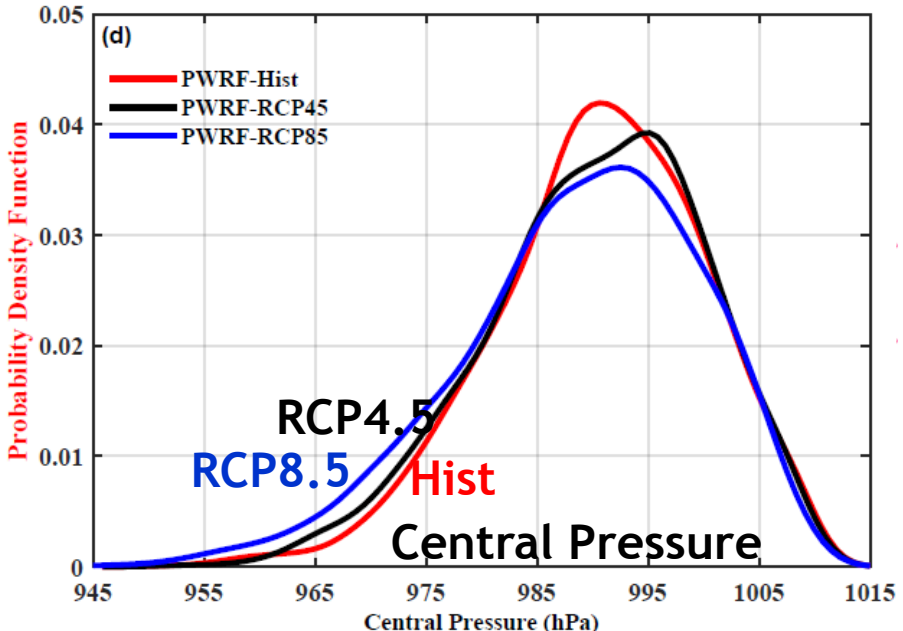
Changes in Frequency and intensity of cyclone

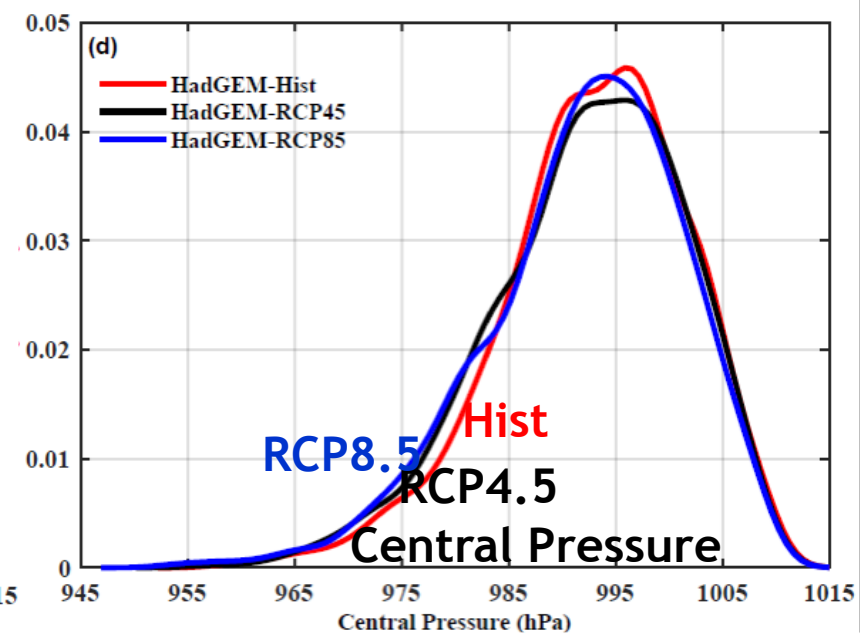
Polar WRF3.6



HadGEM-ES2







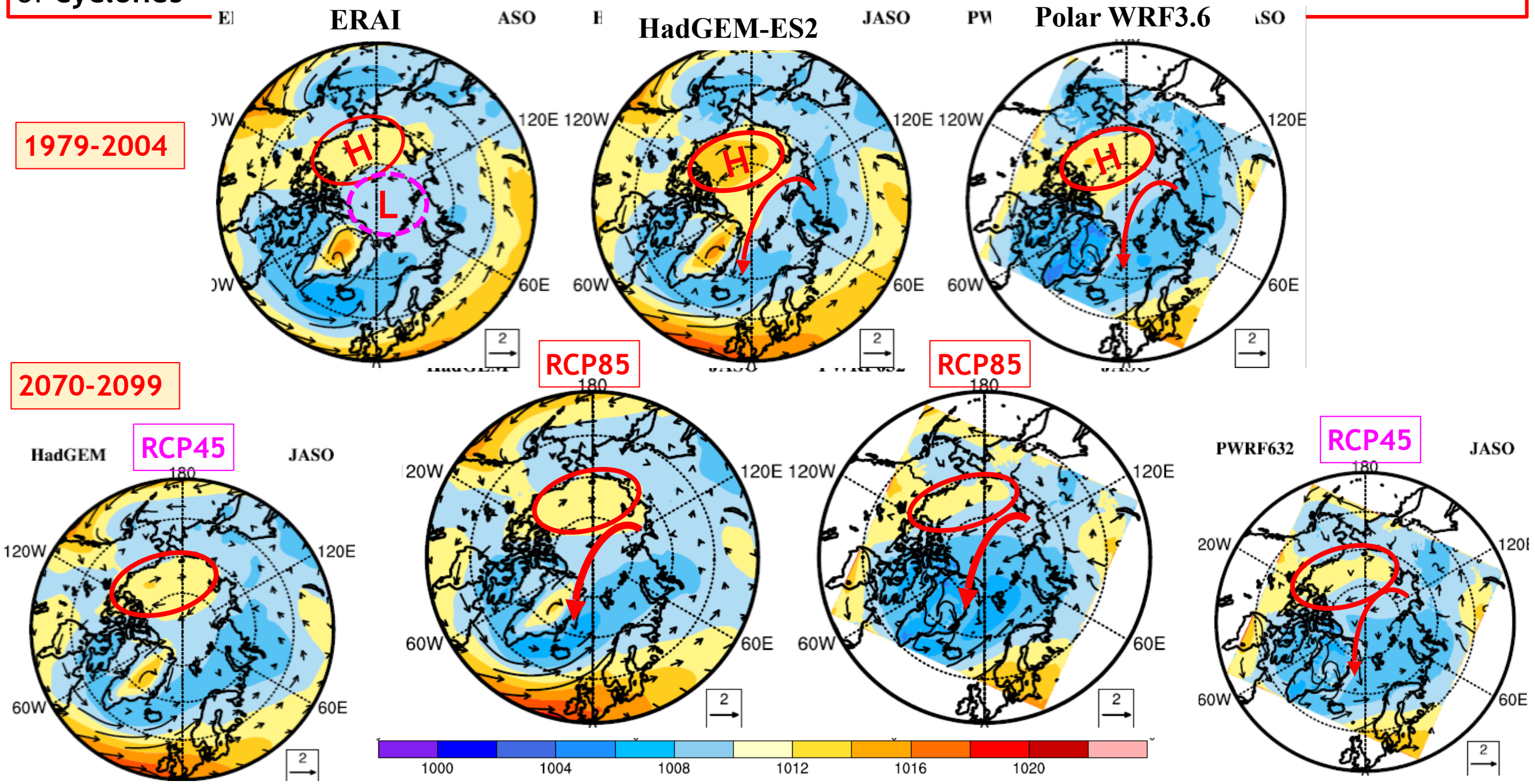
Comparing (2070-2099) vs (1979-2004)

Frequency: comparable
Increased cyclones in Central/ West Arctic compensated by decreased Atlantic Arctic cyclones

Intensity: increase
More intense cyclones in RCP8.5 and RCP4.5 compared with the historical climate

HadGEM vs Polar WRF:
less intense

SLP JASO: weakened Beaufort High + enhanced surface Low ← increased frequency and intensity of cyclones

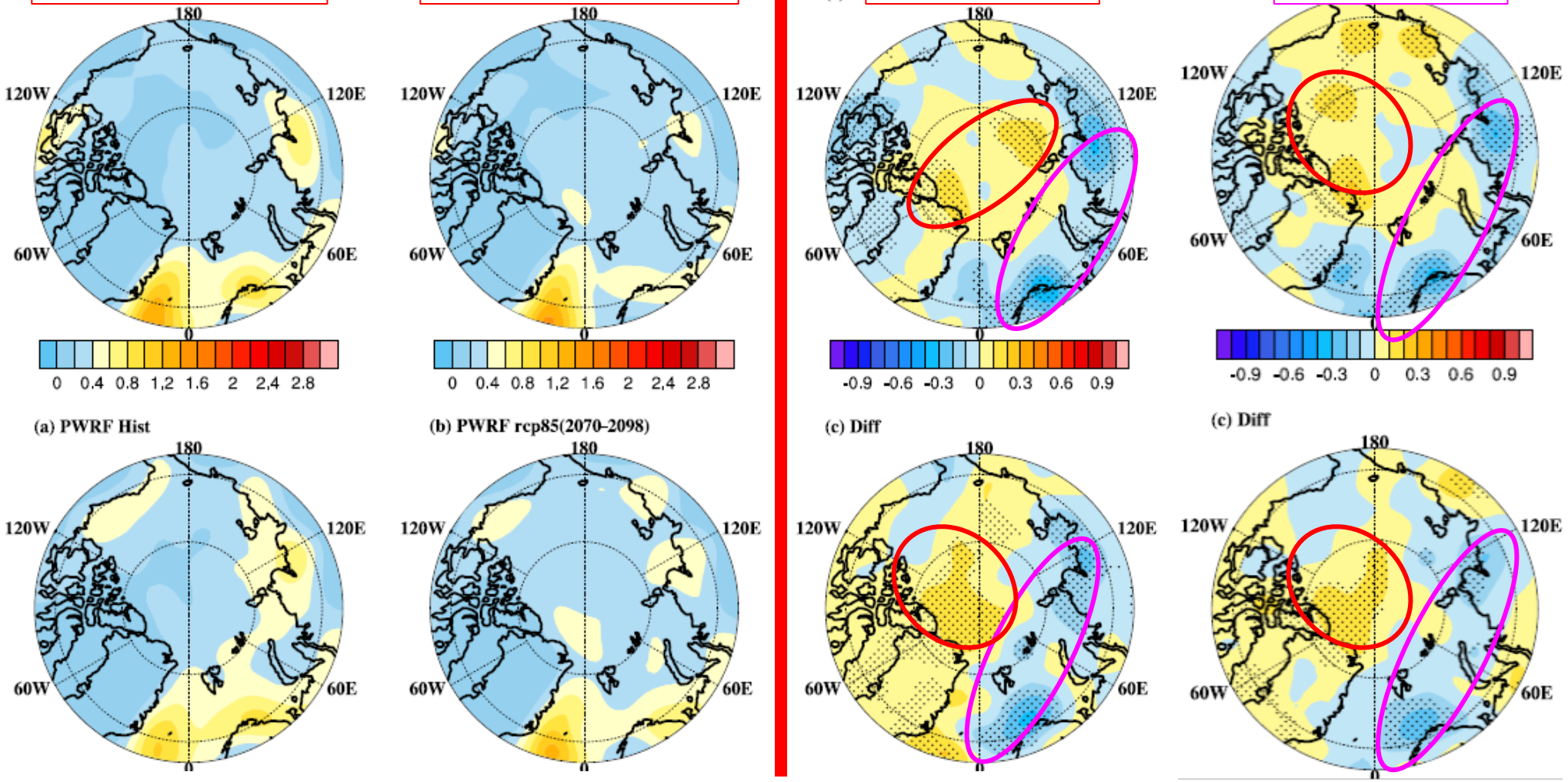


Summer (ice-free): Cyclones genesis (JASO)

Difference plots:(2070-2099) - (1979-2004)

HadGEM-ES2

Polar WRF3.6



Due to the retreat of sea ice, Polar front zone is poleward displaced

Summary

To end-of-century 2100 (2070-2099):

- **Winter (NDJF) :** Beaufort High becomes **weakening**
- **Ice free Summer (JASO)** : **Weakened** Beaufort High and **enhanced** surface Low

Due to:

increased frequency and intensity of **Arctic cyclones**

Due to:

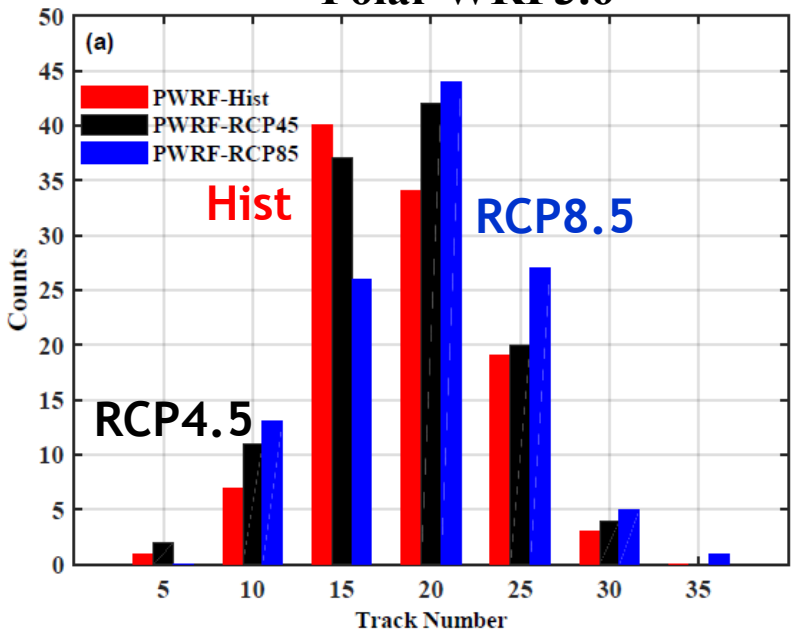
a) Polar fronts in the Pacific and Atlantic Arctic are **poleward displaced**;

b) Weakening Polar Vortex shrinks toward CAA and the changes in the steering flow results in more cyclones moving into central and west Arctic and less into East Arctic.

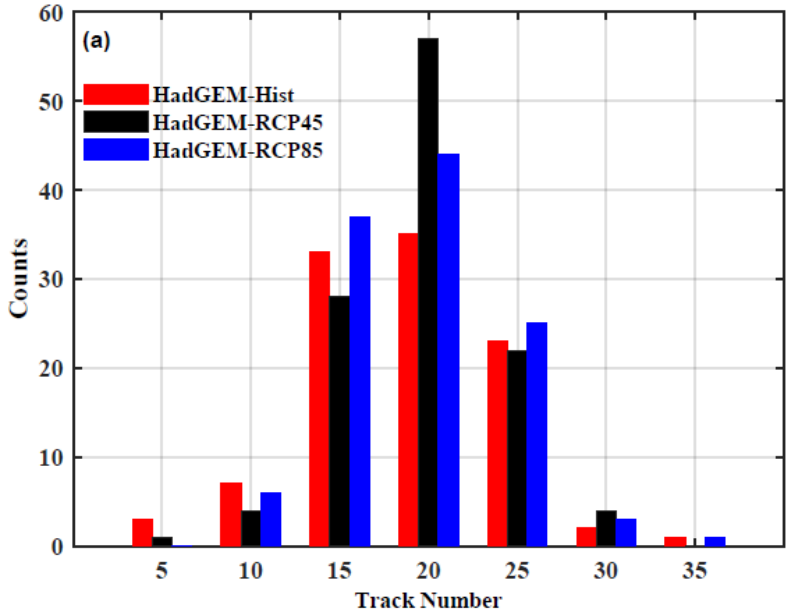
Changes in Frequency and intensity of cyclone

(2070-2099) vs (1979-2004)

Polar WRF3.6



HadGEM-ES2



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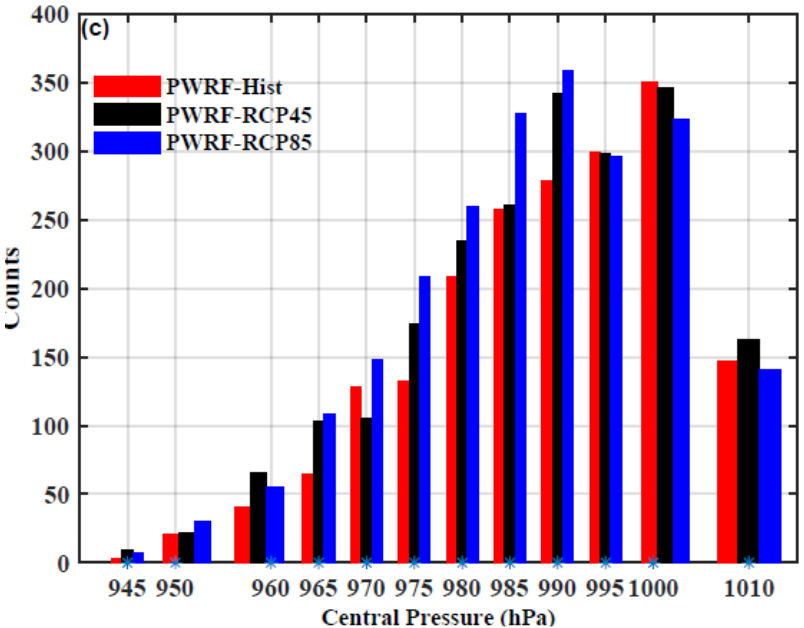

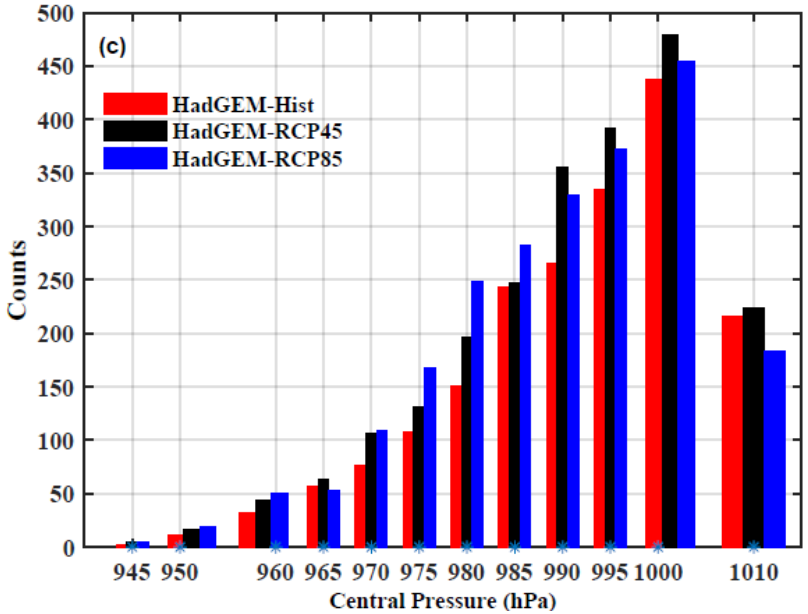

Frequency: comparable

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Intensity: increase

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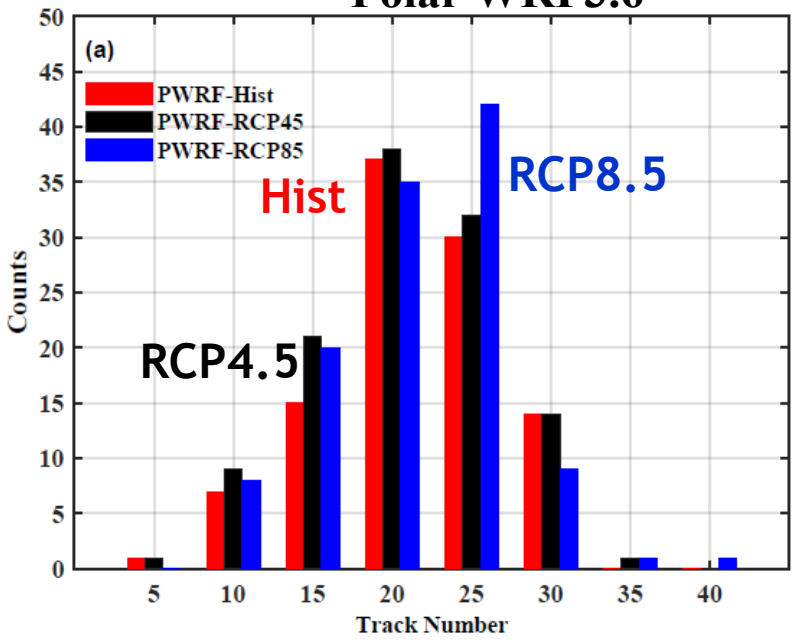
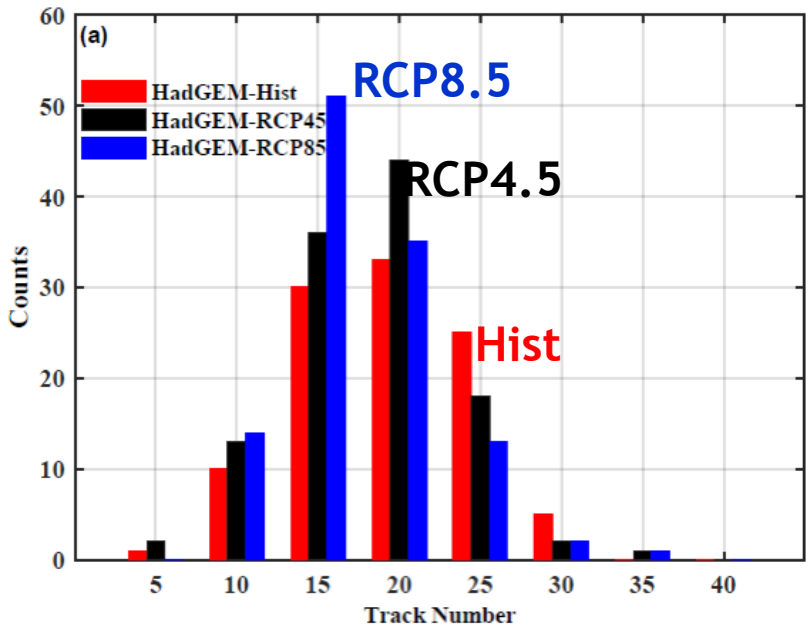
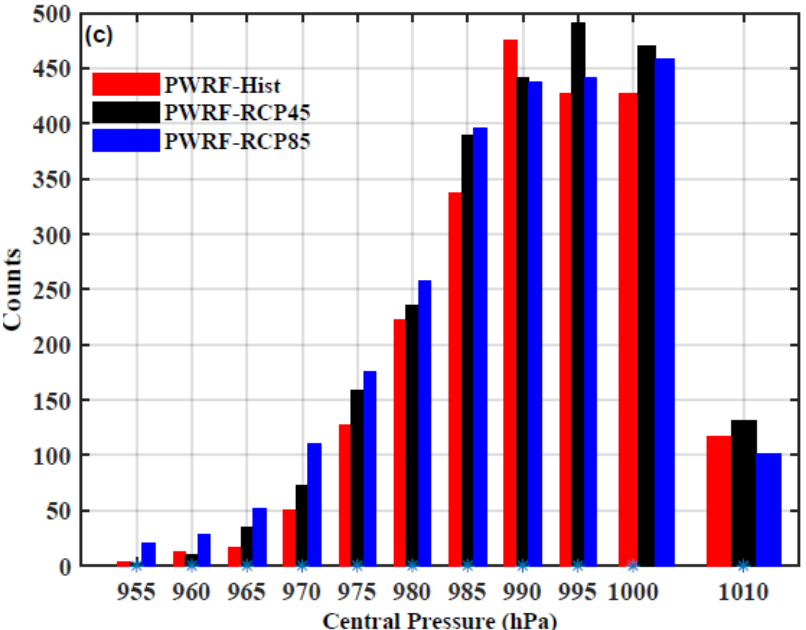
Changes in Frequency and intensity of cyclone

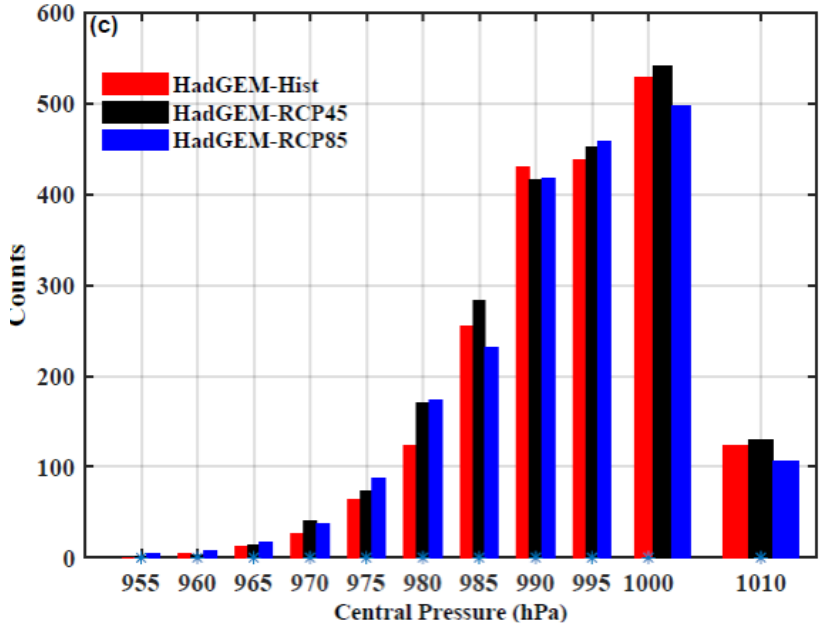
Polar WRF3.6



HadGEM-ES2







Comparing (2070-2099) vs (1979-2004)

Frequency: comparable
Increased cyclones in Central/ West Arctic compensated by decreased Atlantic Arctic cyclones

Intensity: increase
More intense cyclones in RCP8.5 and RCP4.5 compared with the historical climate

HadGEM vs Polar WRF:
less intense

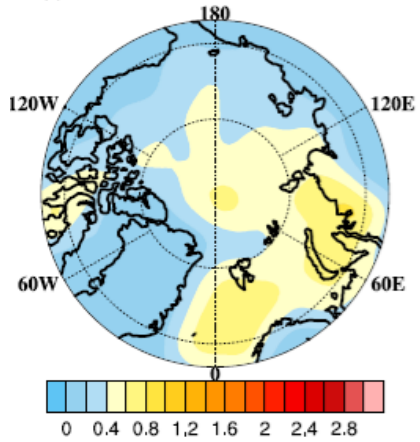
Summer (ice-free): Cyclones Lyisis (JASO)

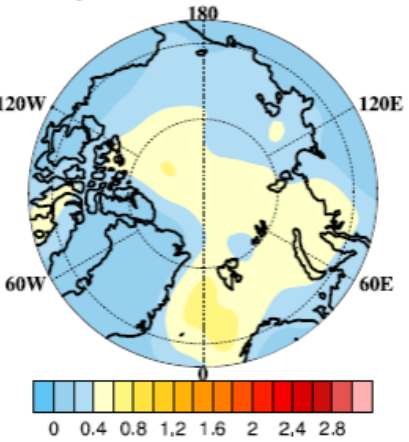
Difference plots

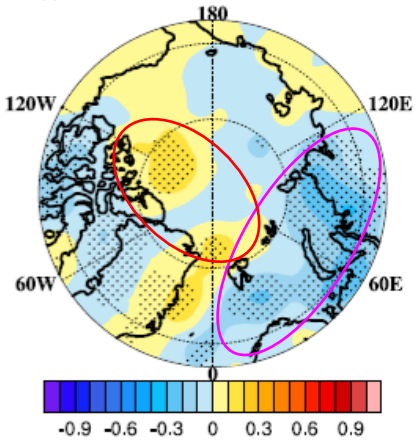
Z500

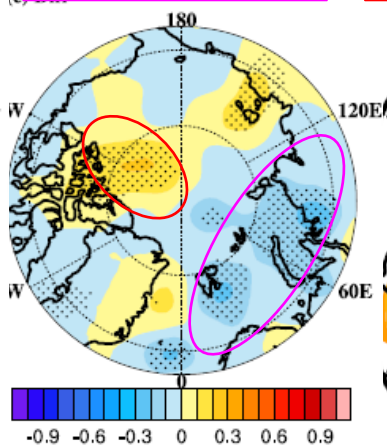
Hist 1979-2004 | RCP8.5 2070-2099 | RCP8.5-Hist | RCP4.5-Hist | Hist

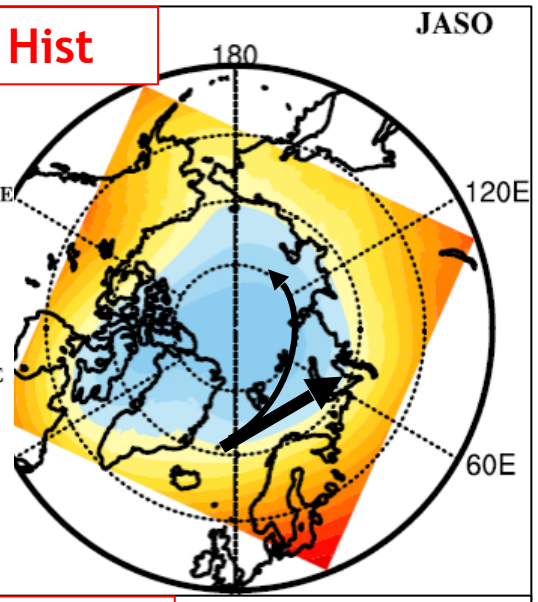
HadGEM-ES2



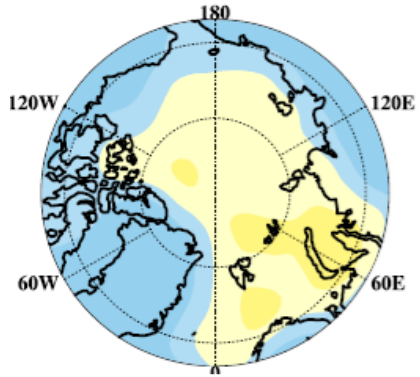


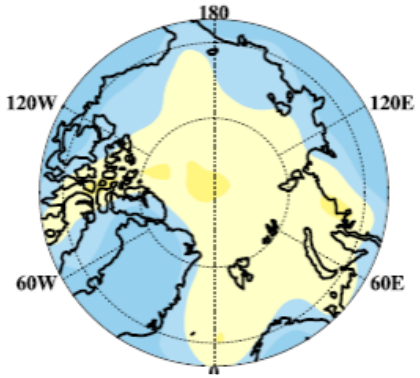


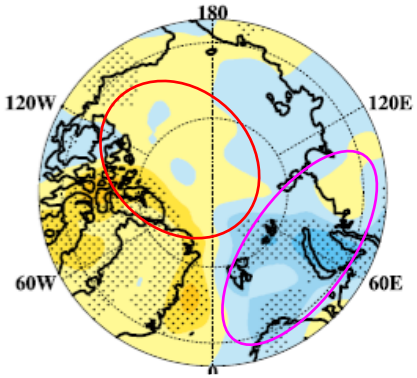


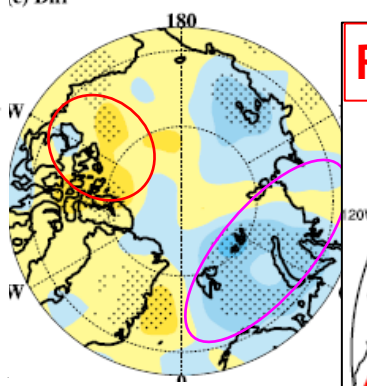


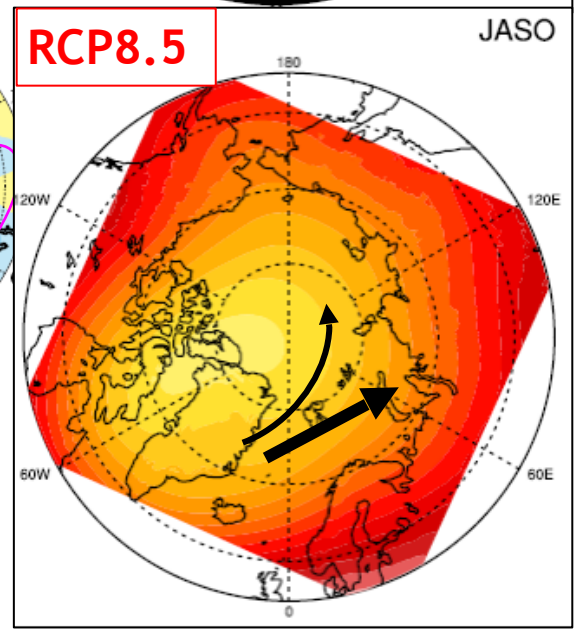
Polar WRF3.6











Polar vortex becomes weakening and shrinking

⬇

more cyclones moving into central and west Arctic and less into East Arctic