Atmospheric winter response to Arctic sea ice changes in reanalysis data and model simulations
The role of troposphere-stratosphere coupling

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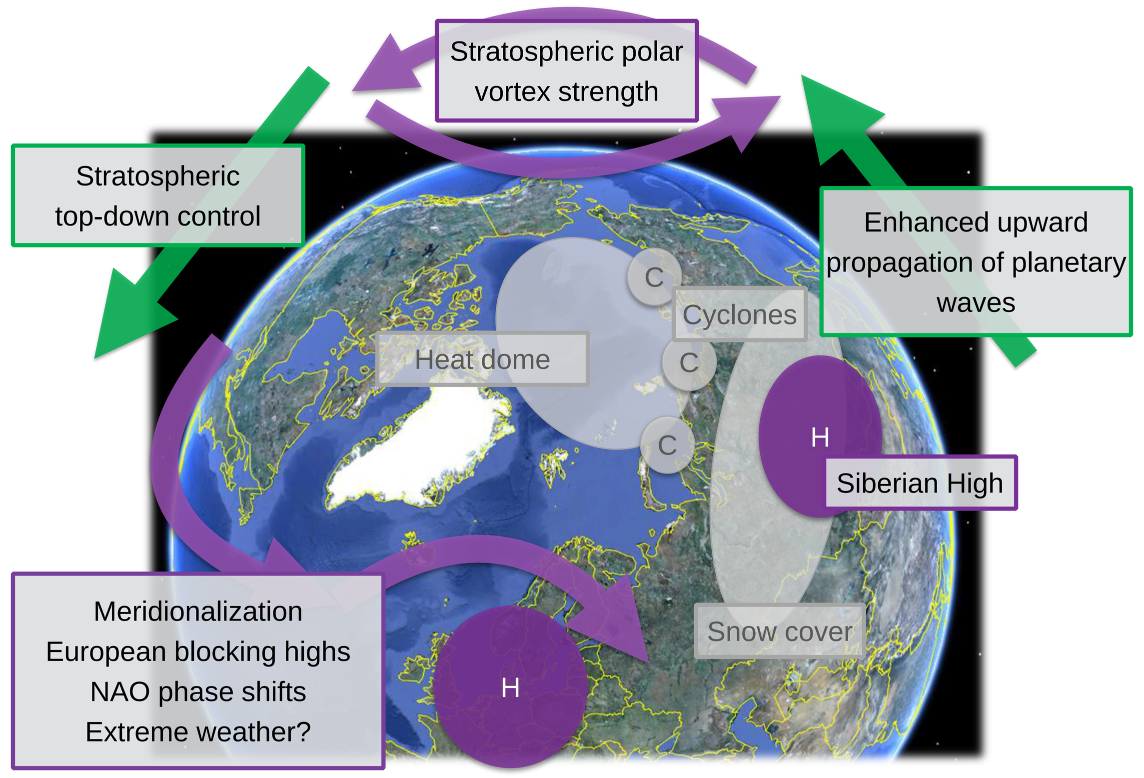
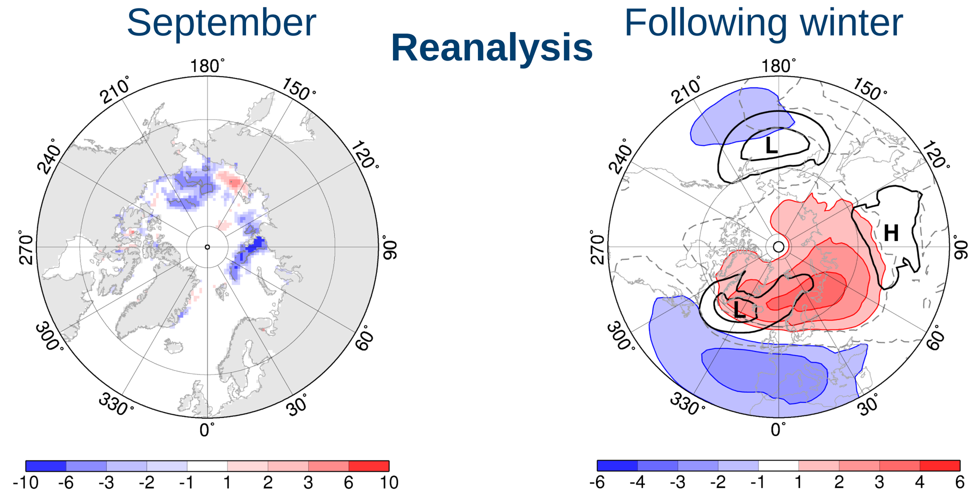
Tropo-stratospheric interactions



Arctic-midlatitude linkages
Coupled Patterns 1979-2015

Sea ice concentration September — **Reanalysis** — **Sea level pressure** Following winter



- Sea ice decline statistically correlates with changed circulation patterns
- Shifts of centers of action
  → westward extension of Siberian High
  → similarity to negative (N)AO pattern
- Observed changes involve tropo- and stratosphere

Challenge
- Mechanisms?
- Representation in models?

Arctic-midlatitude linkages
AGCM model experiments

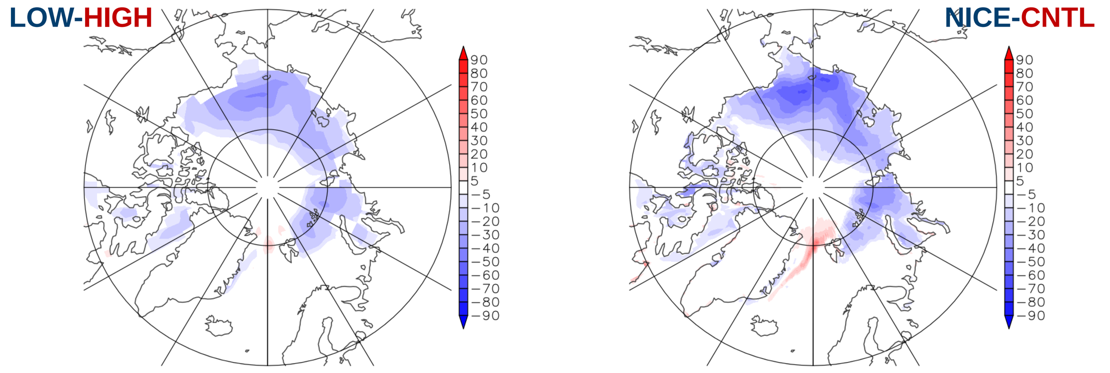
AGCM For Earth Simulator (AFES, T79/L56)
2 model runs with 60 perpetual years each
CNTL: High ice conditions as observed from 1979-1983
NICE: Low ice conditions as observed from 2005-2009
→ Only sea ice is different between both runs

ECHAM6 (T63/L95) with similar boundary conditions
2 model runs with 120 perpetual years each (**HICE** and **LICE**)

Comparison with **ERA-Interim**
HIGH ice (1979/80-1999/00)
LOW ice (2000/01-2013/14)

Arctic sea ice concentration maps SON

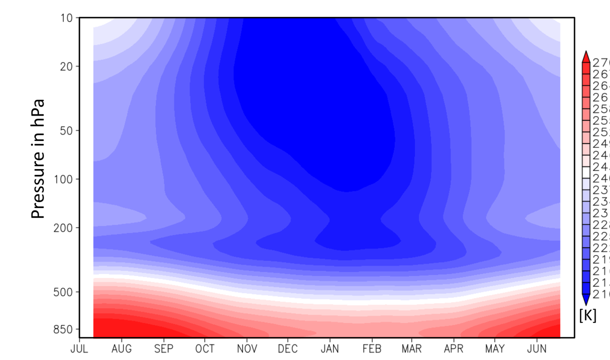
ERA-Interim LOW-HIGH — AFES NICE-CNTL



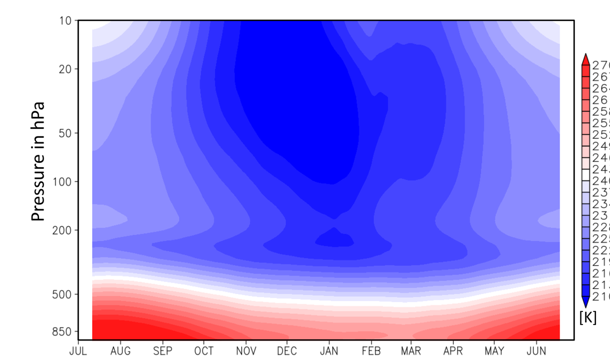
Polar cap temperature change - Temperature [K] average 65°N-85°N

Climatology of polar cap temperature ERA-Interim

High ice 1979/80-1999/00

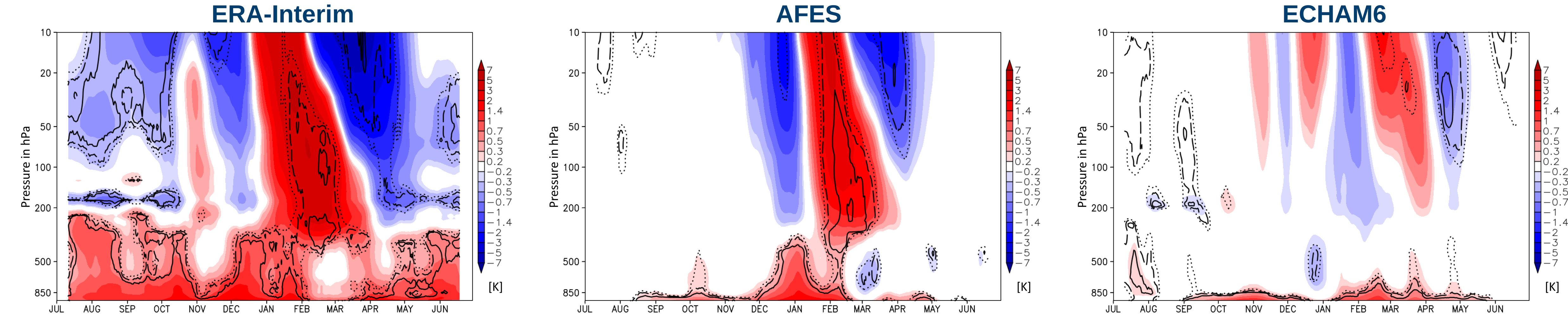


Low ice 2000/01-2013/14



Temperature [K] average 65°N-85°N low minus high ice conditions

ERA-Interim — **AFES** — **ECHAM6**

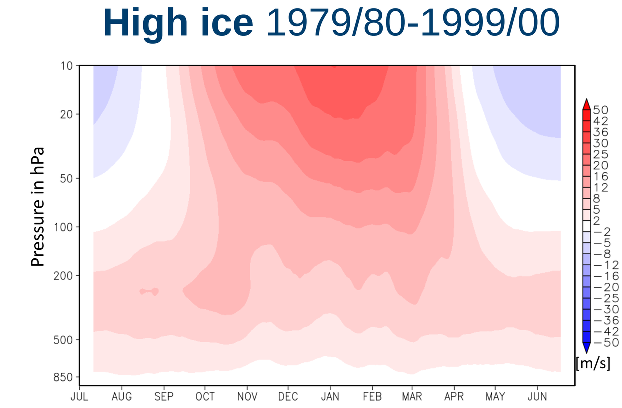


- ERA-Interim: higher tropospheric temperatures all over the year (general global warming signal)
- AFES/ECHAM6: surface warming related to sea ice alone
- Strong significant warming of polar stratosphere in late winter, but weaker signal in ECHAM6
- Polar vortex weakening?
- Very good agreement between AFES and reanalysis in winter (and autumn)

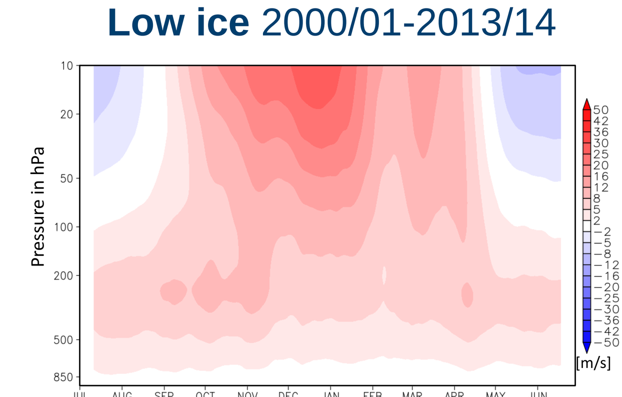
Polar cap zonal wind change - Zonal wind [m/s] average 65°N-85°N

Climatology of polar cap zonal wind ERA-Interim

High ice 1979/80-1999/00

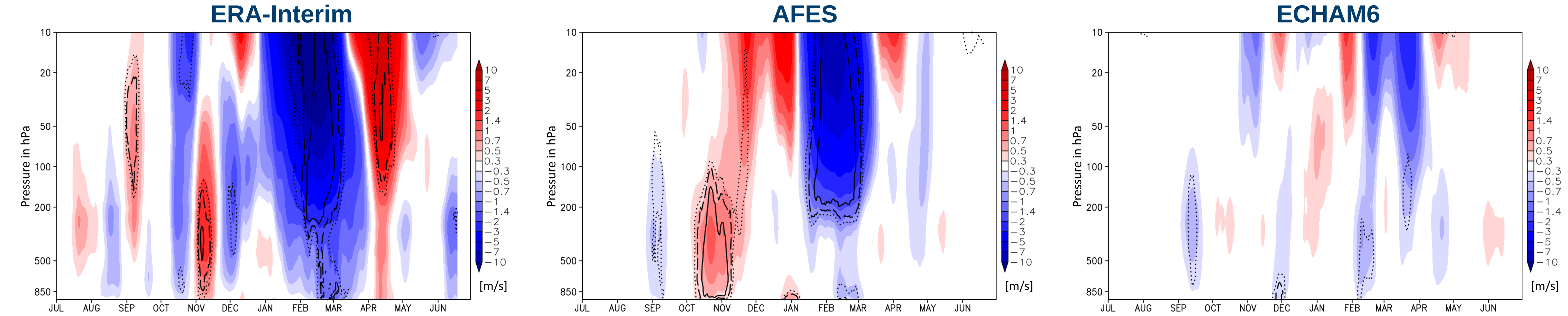


Low ice 2000/01-2013/14



Zonal wind [m/s] average 65°N-85°N low minus high ice conditions

ERA-Interim — **AFES** — **ECHAM6**

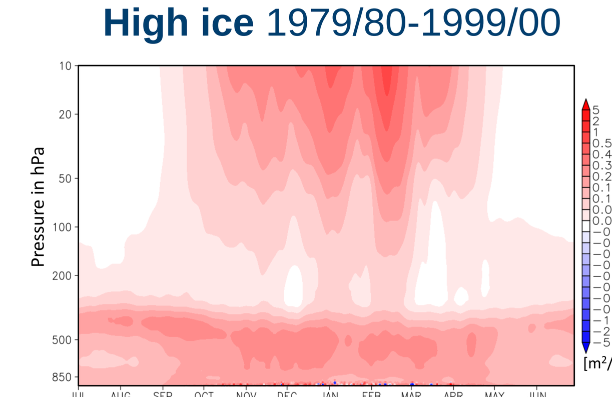


- Clear indication of stratospheric vortex weakening in February
- Stratospheric westerly winds massively reduced (in ERA-Interim and AFES)
- Signal reaching the troposphere
- Weaker signal in ECHAM
- Time delay between models and reanalysis: within weeks depending on model and point in time

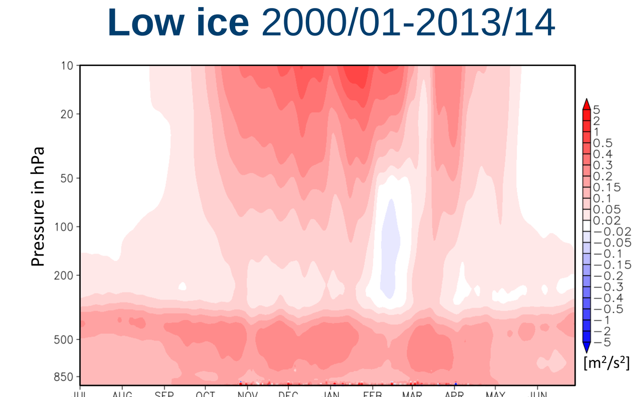
Polar cap vertical wave propagation change
10-90 days filtered vertical component of EP flux vector [m²/s²] average 65°N-85°N

Climatology of polar cap vertical component of EP flux vector ERA-Interim

High ice 1979/80-1999/00

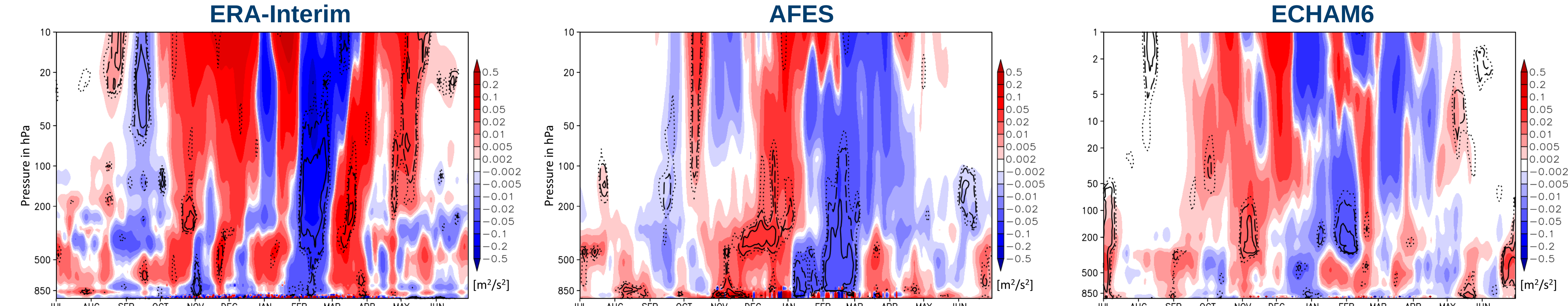


Low ice 2000/01-2013/14



Vertical component of EP flux vector [m²/s²] low minus high ice conditions

ERA-Interim — **AFES** — **ECHAM6**



- Enhanced upward propagation of planetary waves in autumn and early winter
- Disturbing the polar vortex, leading to a vortex weakening
- Vertical wave propagation is reduced in February due to the vortex weakening in ERA-Interim and AFES model simulation
- Consistency of datasets indicates clear impact of sea ice changes
- ERA-Interim is more disturbed in early winter → Impact of additional processes
- ECHAM6 shows similar signals but weaker, more disturbed and less significant

Conclusions & Outlook

- **Troposphere-stratosphere interaction** play a **crucial role** for the **atmospheric response** to present-day sea-ice reduction
- **AGCMs** with realistically prescribed sea-ice reduction are able to **simulate the observed signal** of mid-latitude linkages
- Strength of the signal is **model-dependent** (e.g. in AFES stronger than ECHAM6)
- **Potential** for future studies
  Sensitivity of the model response with respect to
  → boundary forcing (e.g. turbulent surface fluxes)
  → representation of stratospheric processes (e.g. stratospheric chemistry)
- Potential **transition of underlying mechanisms** under stronger than present-day sea-ice reduction (Nakamura et al., 2016)
- Discussion of **autumn to winter** development
  → **Interaction between synoptic and planetary scales**
- Discussion of **late winter** development
  → how is the **stratospheric signal** translated into the **tropospheric negative (N)AO anomaly**

References

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The ERA interim data were obtained from the ECMWF web site (http://data-portal.ecmwf.int/).
The AFES simulations (Nakamura et al. 2015) were performed on the Earth Simulator at the Japan Agency for Marine-Earth Science and Technology.
Merged Hadley-NOAA/OI SST and SIC data were obtained from the Climate Data Guide (https://climatedataguide.ucar.edu/).

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