

Relative contributions from CO₂ and ozone on Southern Hemisphere westerly winds and their consequences for ocean circulation

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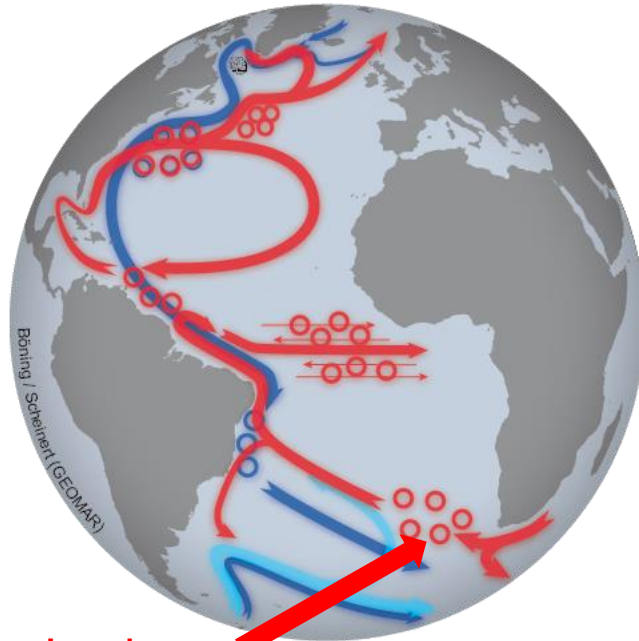
[2] Christian-Albrechts University Kiel, Germany

DynVarMIP Workshop
22-25.10.2019, Madrid, Spain

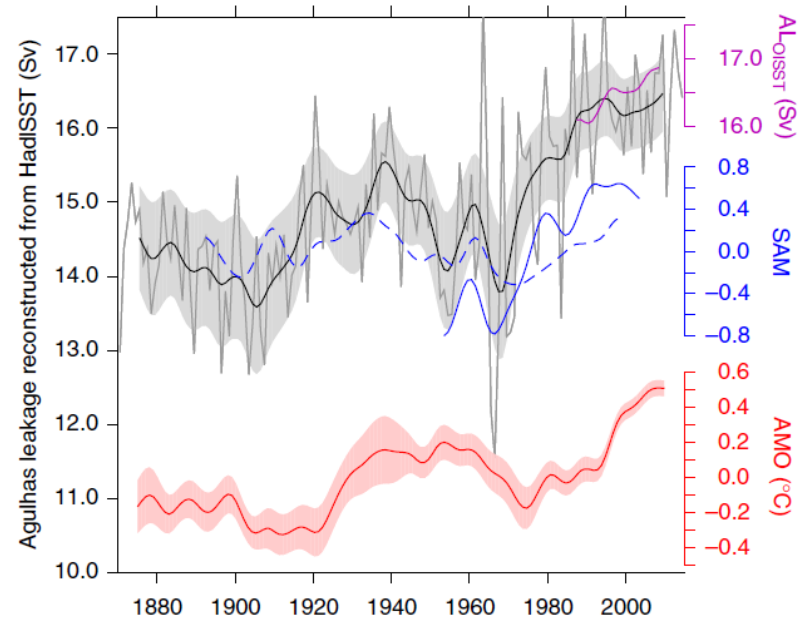
HELMHOLTZ

SPITZENFORSCHUNG FÜR
GROSSE HERAUSFORDERUNGEN





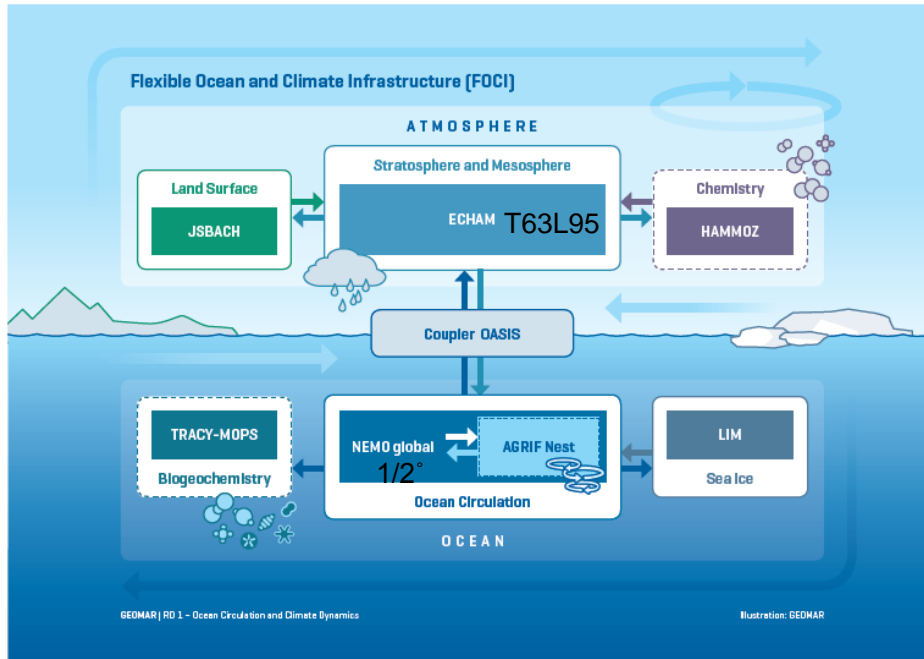
Agulhas Leakage



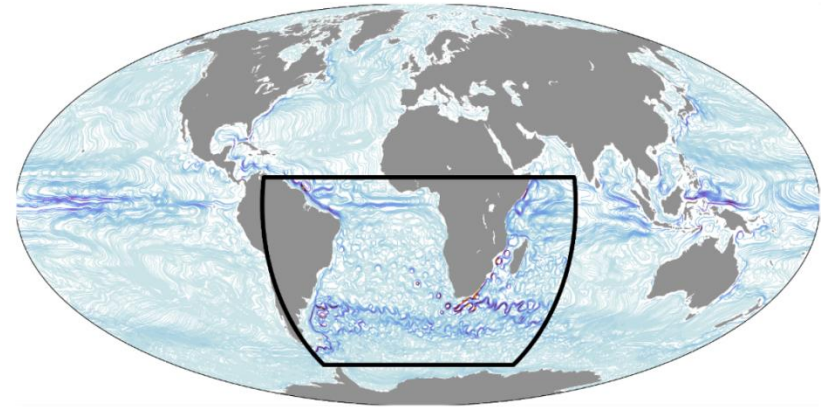
(Biaostoch et al., 2015)

- Increased Agulhas Leakage affects the AMOC
- Agulhas Leakage trend linked to strengthened westerlies

The Coupled Climate Model FOCI



INALT10X 1/10° ocean nest



(Matthes et al., 2019, to be submitted)

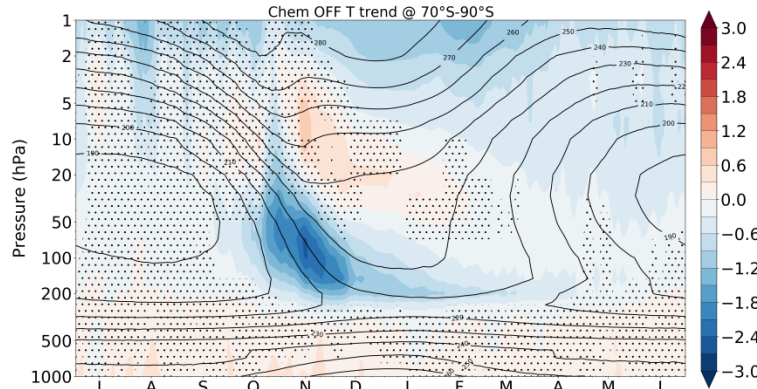
Experiments:

- 3 x Chem OFF 1850  2013
- 3 x Chem ON 1958  2013
- Chem & Nest ON Sensitivity exp. 1958  2013

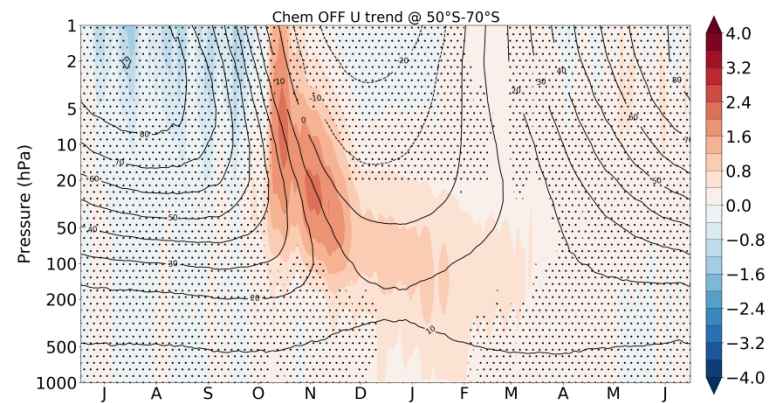
Importance of Interactive Chemistry 1958-2013

Chem OFF

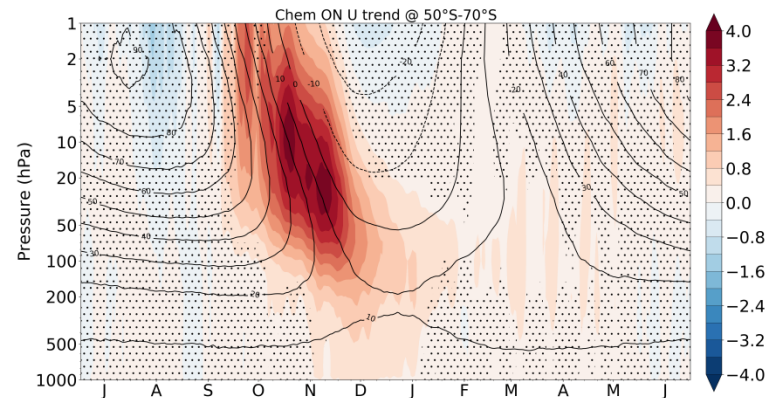
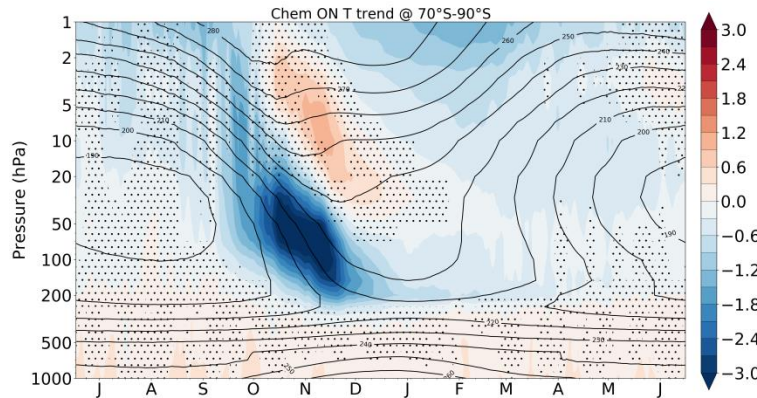
Polar cap T trend (K/dec)



SH westerlies trend (ms⁻¹/dec)



Chem ON



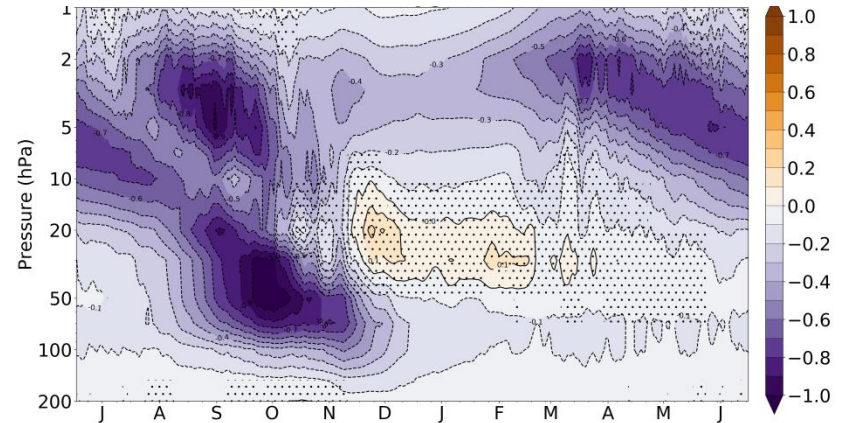
Chem ON = interactive

Chem OFF = prescribed monthly 3D CMIP6

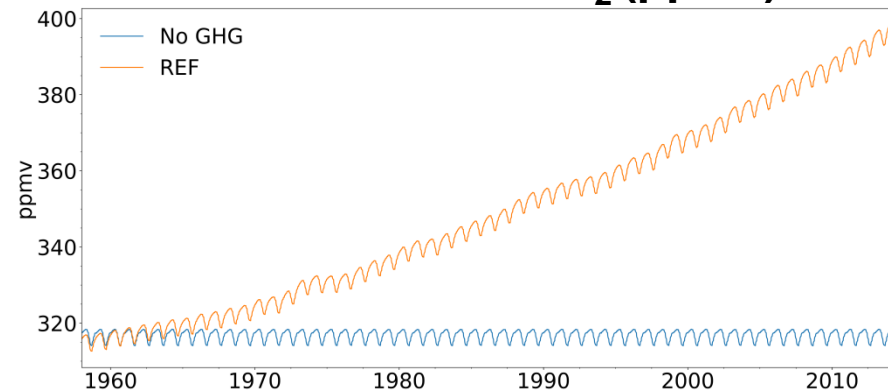
Historical (1958-2013) sensitivity experiments:

- **REF:** both O₃ and GHG vary
- **No ODS:** repeated 1960 ODS annual cycle → **no O₃ hole**
- **No GHG:** repeated 1960 CO₂ and CH₄ annual cycle → **no climate change**

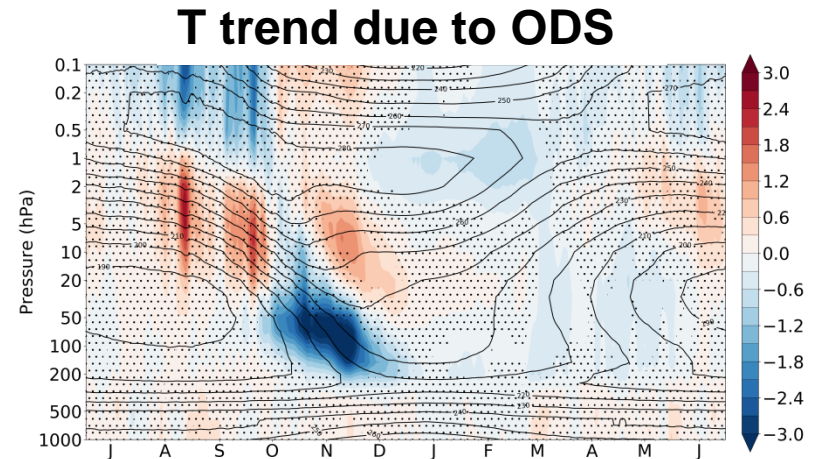
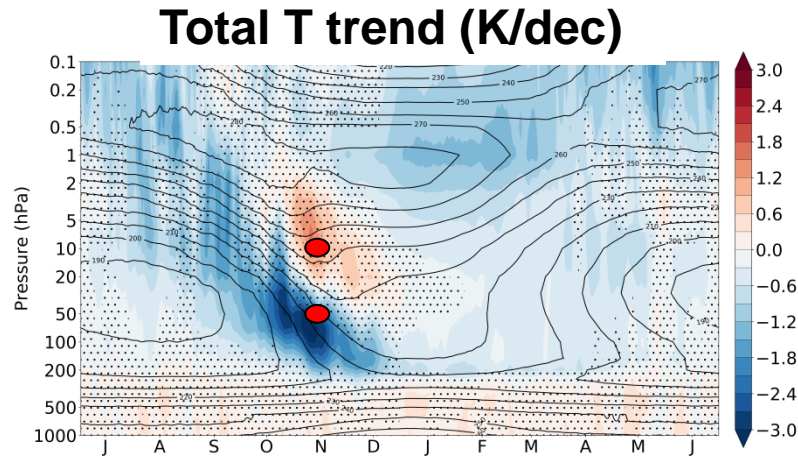
REF – NoODS polar cap O₃ (ppmv)



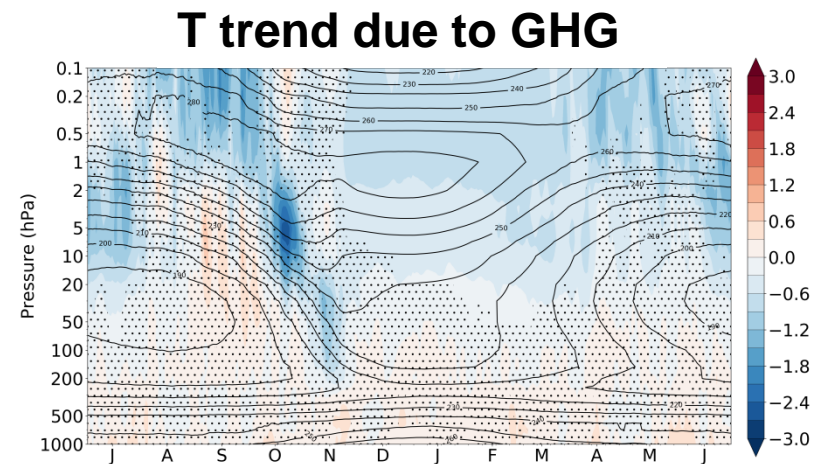
Global 850 hPa CO₂ (ppmv)



O₃ vs GHG Effect on Polar Cap Temperature 1958-2013



- Spring cooling due to O₃ hole
- Spring warming due to dynamical response to O₃ hole
- Summer stratopause cooling due to both O₃ ↓ and GHG ↑



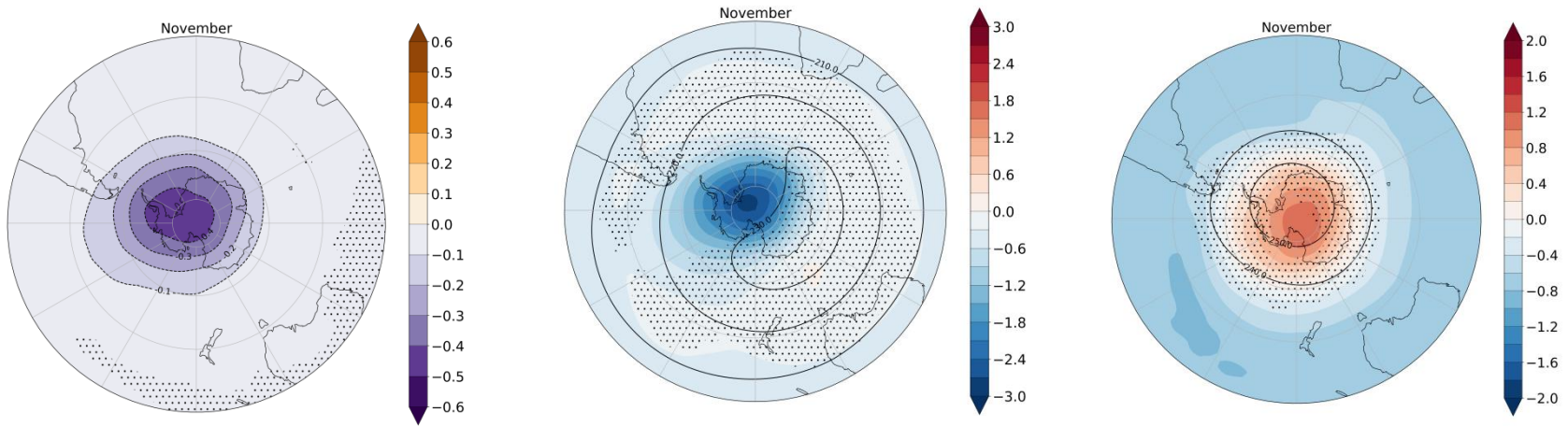
November O₃ Effect on Temperature 1958-2013

50 hPa O₃ trend (ppmv/dec)

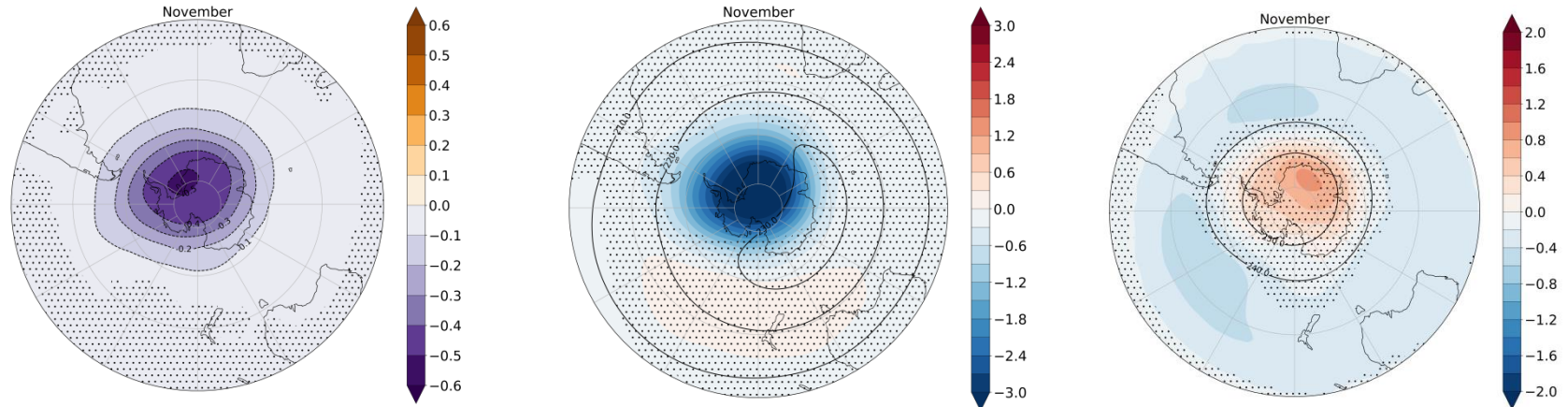
50 hPa T trend (K/dec)

10 hPa T trend (K/dec)

Total

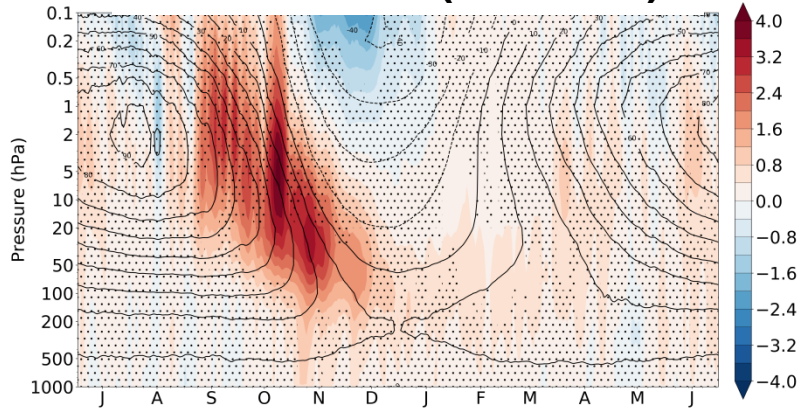


ODS only

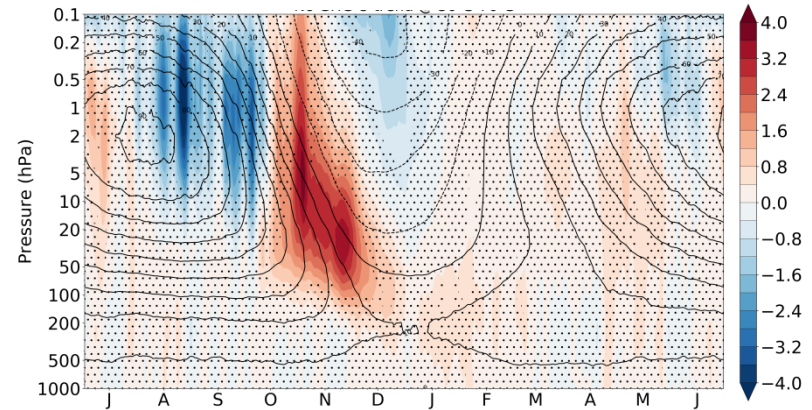


O₃ vs GHG Effect on the Westerlies 1958-2013

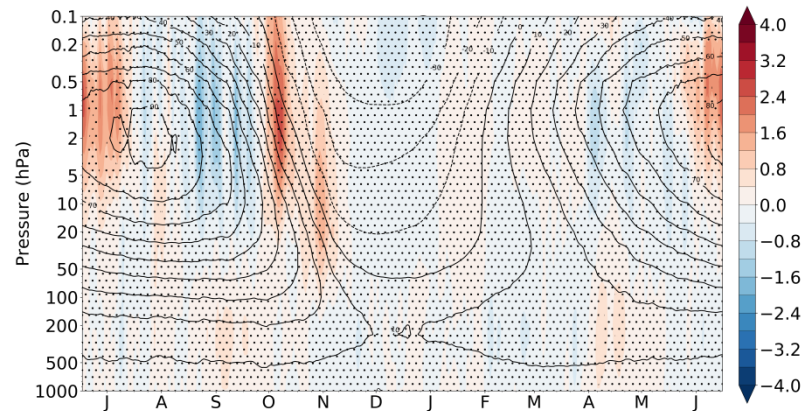
Total U trend (ms⁻¹/dec)



U trend due to ODS



U trend due to GHG



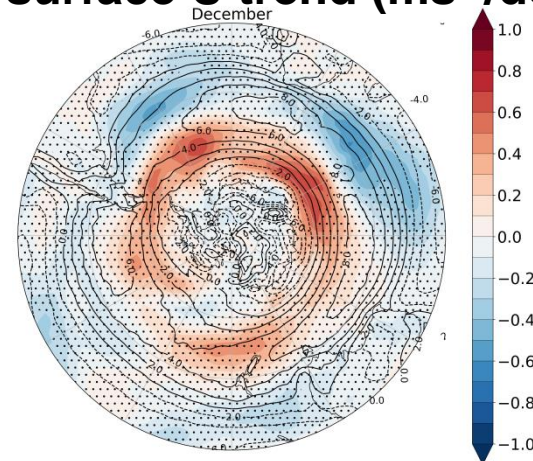
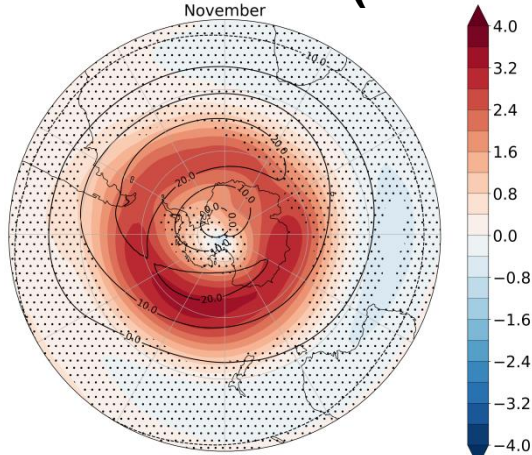
- Southern Hemisphere westerlies spring strengthening in FOCI attributed to O₃ depletion.

O₃ Hole Effect on the Westerlies

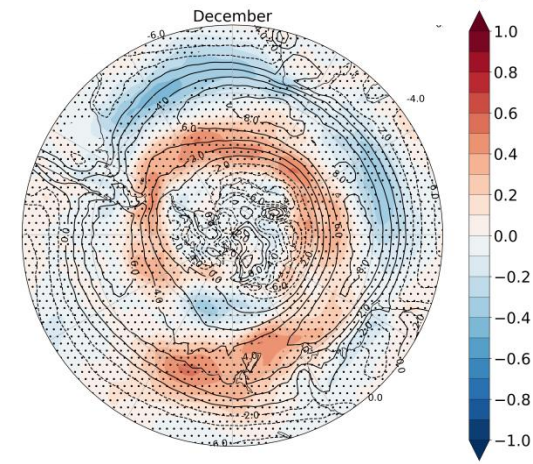
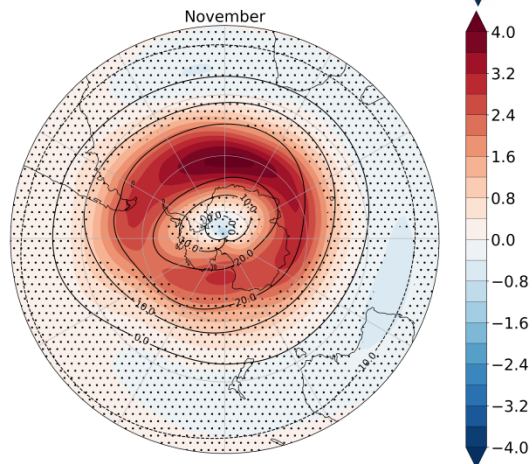
Nov. 50 hPa U trend (ms⁻¹/dec)

Dec. surface U trend (ms⁻¹/dec)

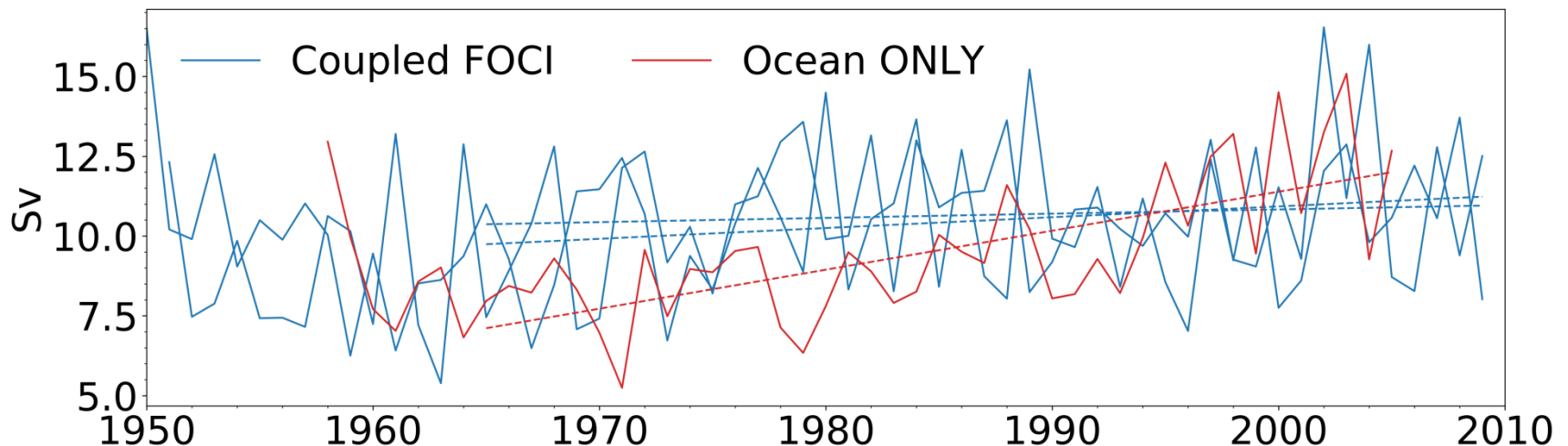
Total



ODS only



Agulhas Leakage transport (Sv)



Trends (1965-2009): — 0.34 / 0.13 Sv/dec — 1.22 Sv/dec

- Weak historical trend in Agulhas Leakage in FOCI as the westerlies maximum is biased towards the equator.

Summary:

- SH temperature and westerly jet **trends stronger when interactive chemistry** is used vs. 3D prescribed chemistry.
- Historical SH polar cap **cooling** and westerly jet **strengthening attributed to O₃ depletion** and not GHG increase.
- Surface westerlies strengthen, but impact on the Agulhas leakage is small due to westerlies position bias in FOCL.

Outlook:

- **Heating rates** calculation to distinguish radiative and dynamical effects.
- **Reduce bias** in the position of maximum SH westerlies.
- Perform **future sensitivity experiments** to assess the impact of O₃ recovery vs. continued GHG increase.