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Exploring uncertainty in stratosphere-resolving climate simulations of the Maunder minimum

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Oxford Physics

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Rationale

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The “little ice age” or Maunder minimum

- *approximately 1650-1750*
- *very little to no sunspot activity*
- *lower solar irradiance (though change uncertain)*
- *slightly colder temperatures globally (uncertain)*

Some doubt as to the global nature of the signal

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The “little ice age” or Maunder minimum

- *colder winter temperatures over western Europe*
- *colder winters in North America*
- *growth of Alpine glaciers*

Rather than having a similar spatial pattern to CO_2, one interpretation of the Maunder minimum is a small global signal with a large (dynamical) amplification in Northern winter

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GCM simulations *(e.g. Shindell et al 1999, 2001)*

- *Relatively coarse horizontal resolution (8°x10°)*
- *Effect of ozone change parameterised*
- *slab ocean with heat flux climatology*

Simulations suggest more negative NAM in Maunder minimum

Recent work connects "open solar flux" with European winters *(blocking/NAM) (Lockwood et al 2010)*

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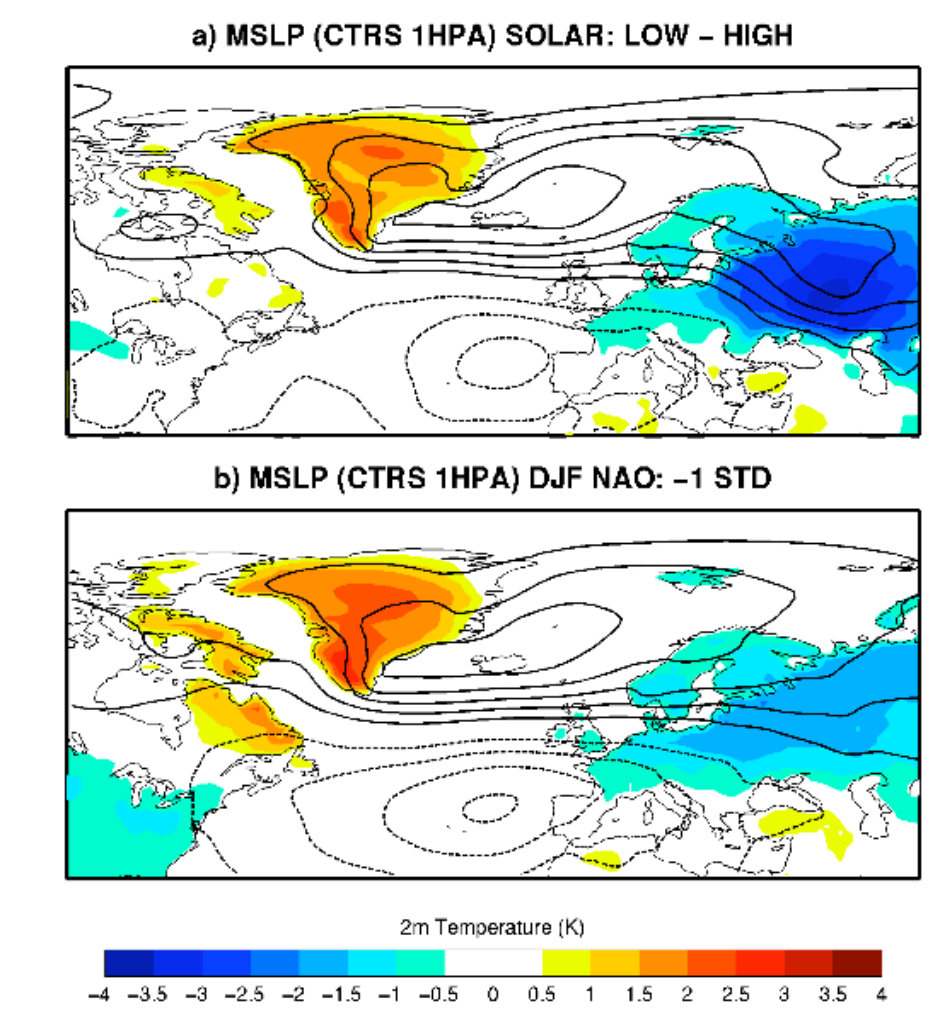

From Woollings et al 2010

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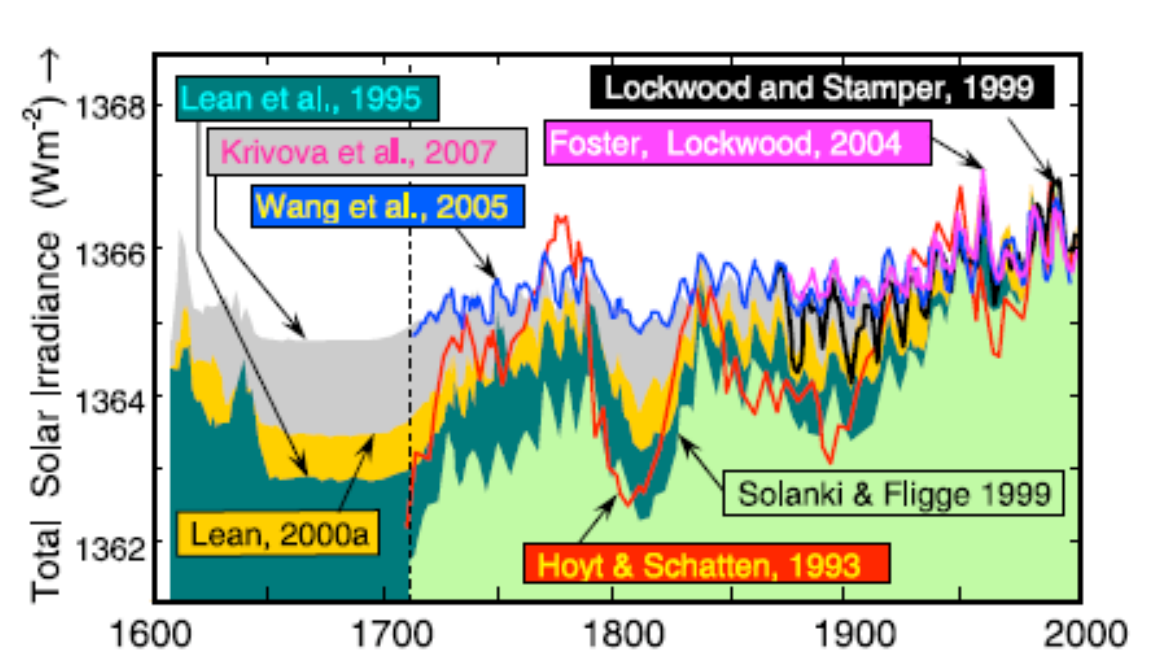
Different reconstructions of solar flux have been made over time

Change of solar radiation with respect to present-day ***uncertain***



Gray et al 2010

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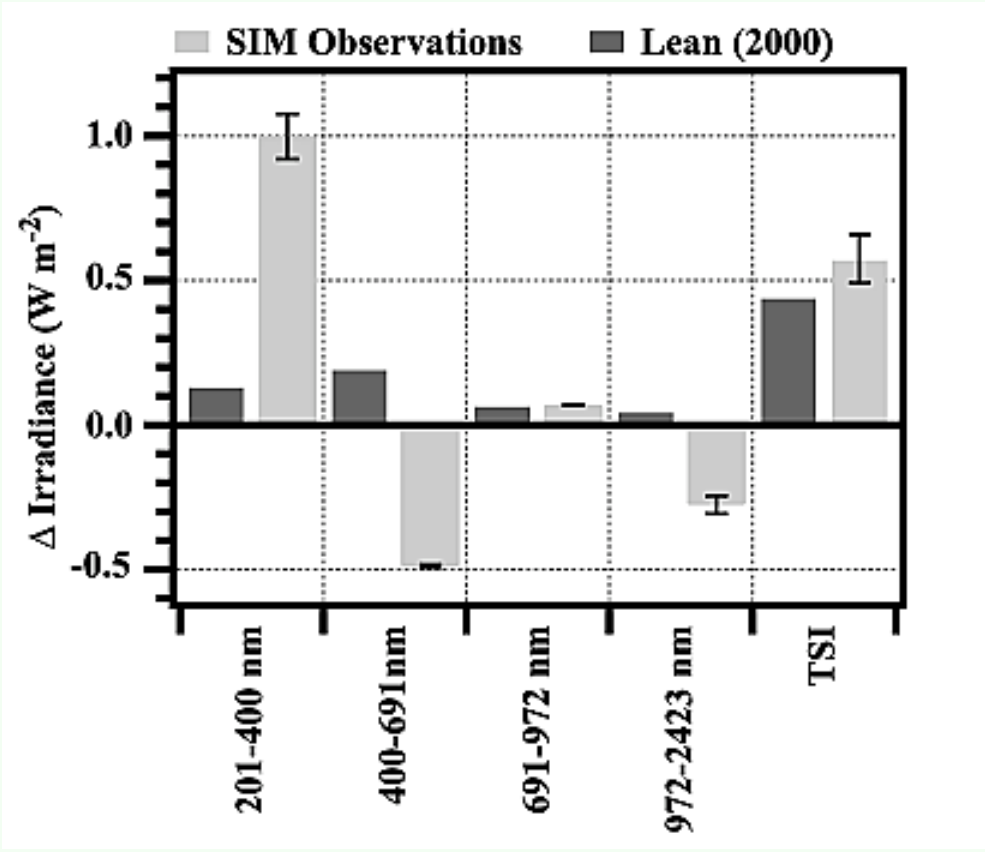
Different estimates of amplification in UV change
Lean et al (2000)
Harder et al (2010)

GCM with *Harder et al* forcing gives colder Europe during solar minimum *(Ineson et al 2011)*

UV amplification uncertain



Harder et al

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Present work: stratosphere-resolving T42L35 IGCM

- climate studies, especially stratosphere-related

  (Forster et al 2000, Rosier et al 2000, Bell et al 2009)

- slab ocean with heat flux climatology

- enables longer integrations and *investigations of effect of uncertainty in model forcing*

Irradiance, UV amplification and ozone changes

examine response on regional and seasonal climate

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The model

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For this talk I'll talk about two 60-year long integrations:

- ΔO_3 = *(-)4 x (solar min minus max)*
- ΔS_o = *- 0.6 Wm^{-2}, ΔUV ("Lean" like change)*

Most related research regresses ozone onto F10.7 flux

We regress ozone onto **open solar flux**

- *highly anticorrelated with cosmic ray fluxes*
- *correlates very well with irradiance (with 1 year lag)*

(Lockwood et al 2010)

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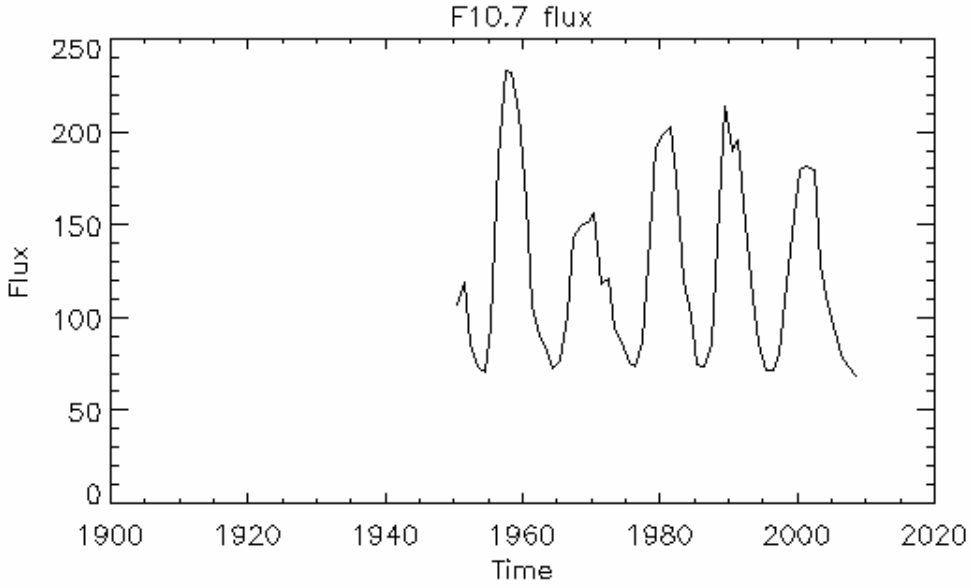
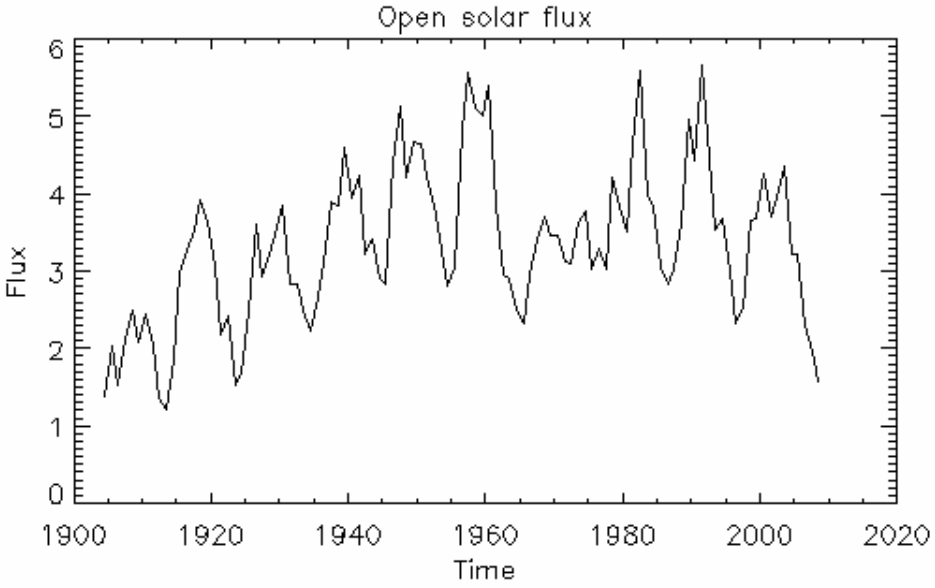
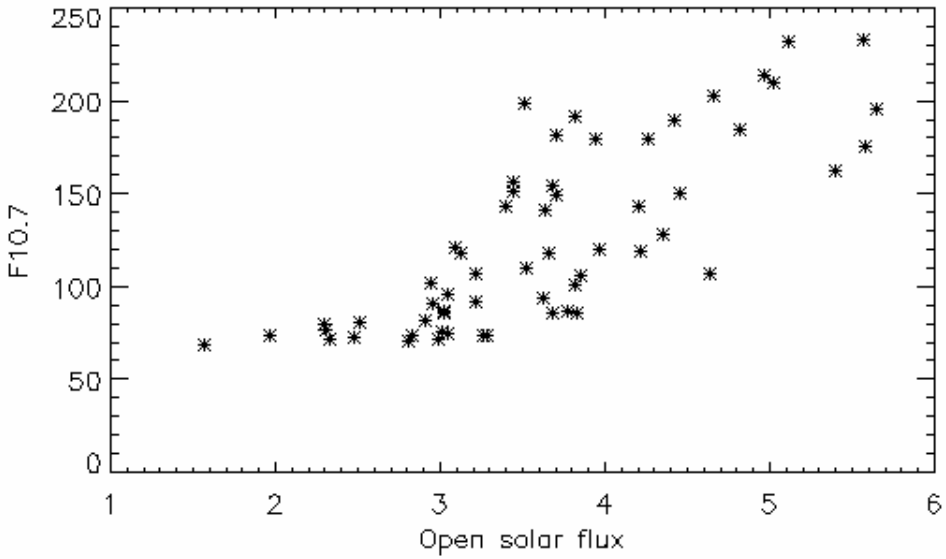
The model







Open solar flux has more decadal variability

Results

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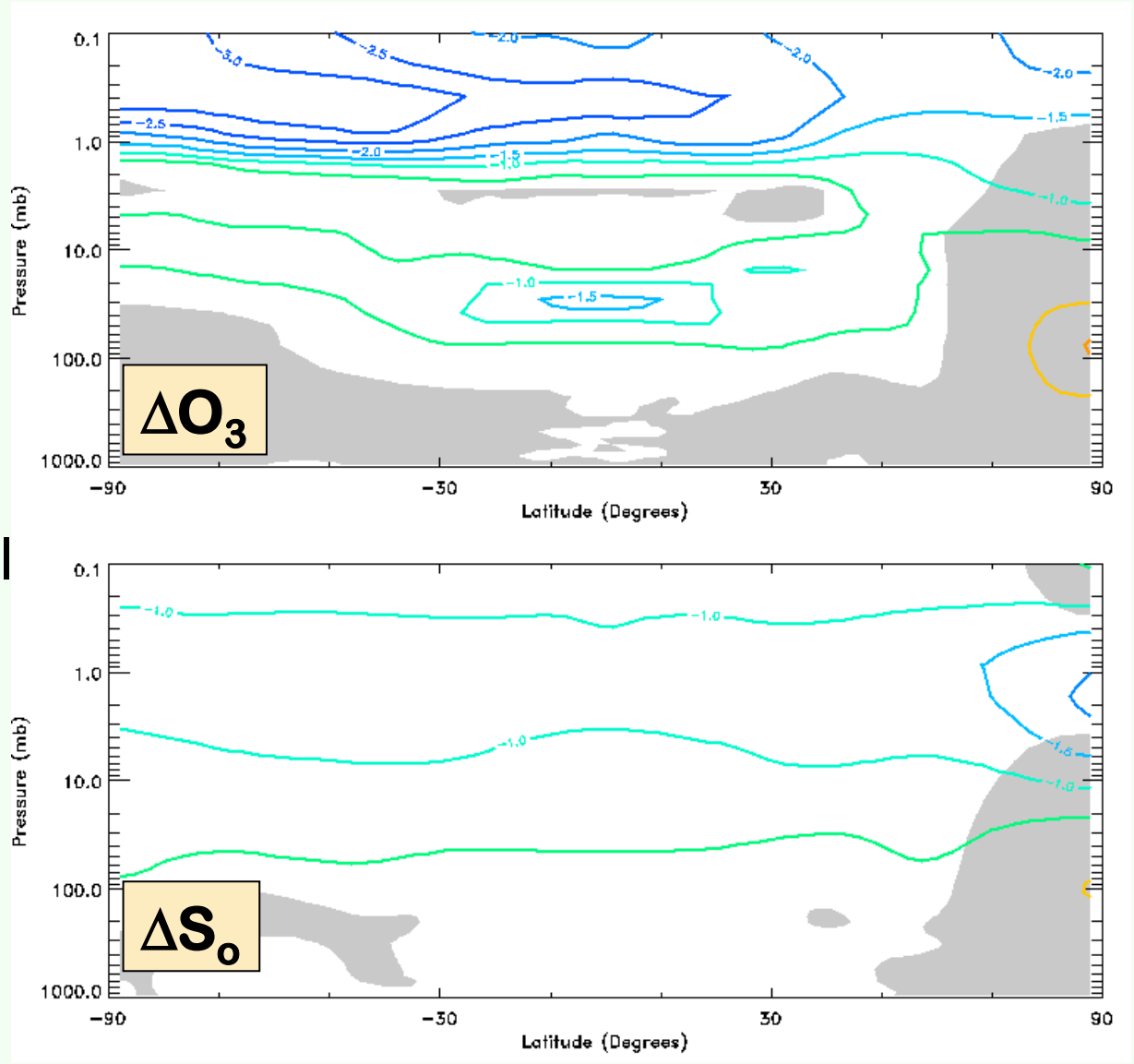
Jan-Feb-Mar zonal mean temperature difference shown on RHS

2K cooling in upper stratosphere and small signal of UTLS winter warming in ΔO_3

Smaller cooling in ΔS_o



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Results

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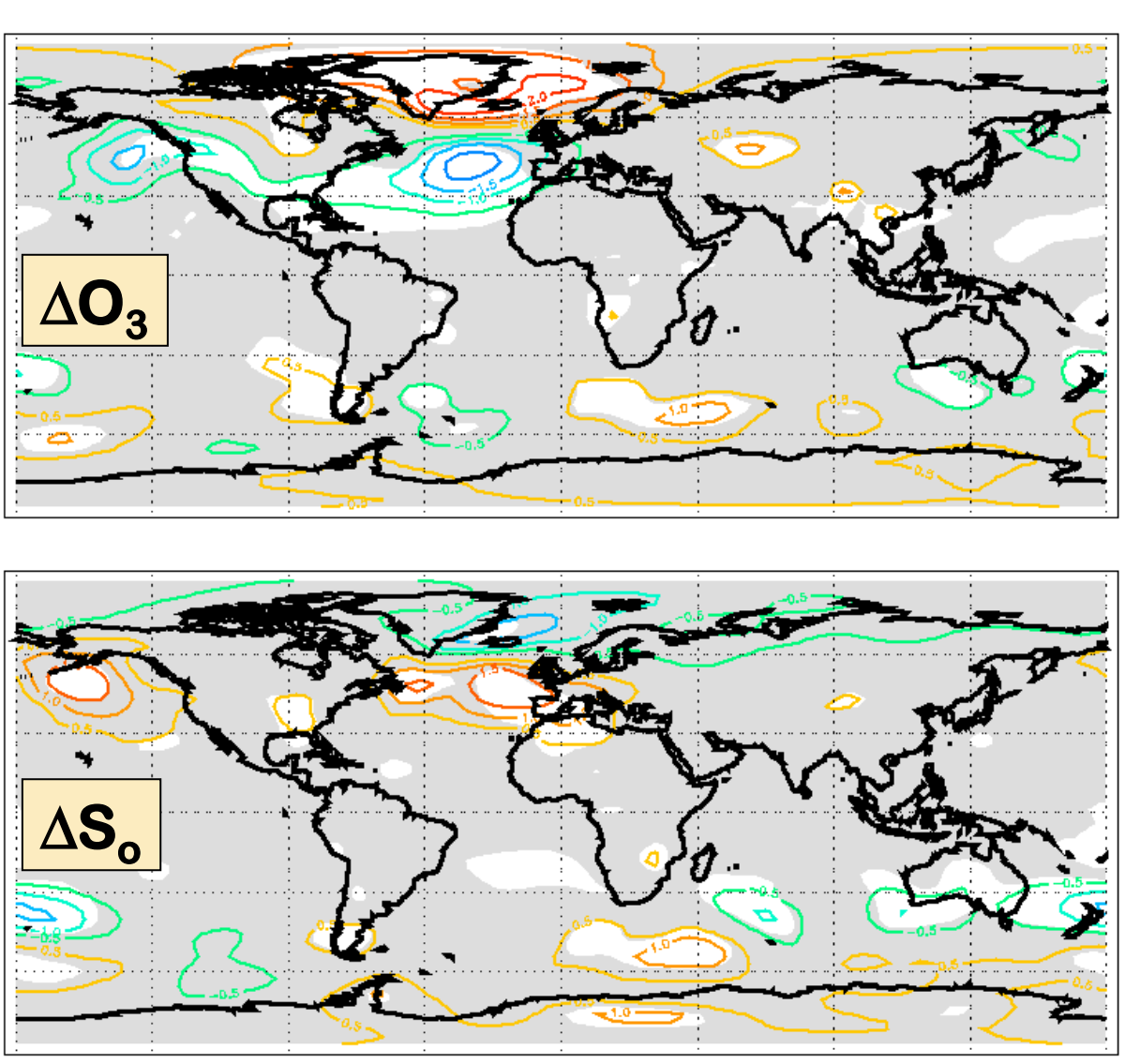
Jan-Feb-Mar MSLP difference shown on RHS

Negative NAO-like pattern evident in ΔO_3

More SSWs in ΔO_3

Smaller signature in ΔS_o: more "blocking" like



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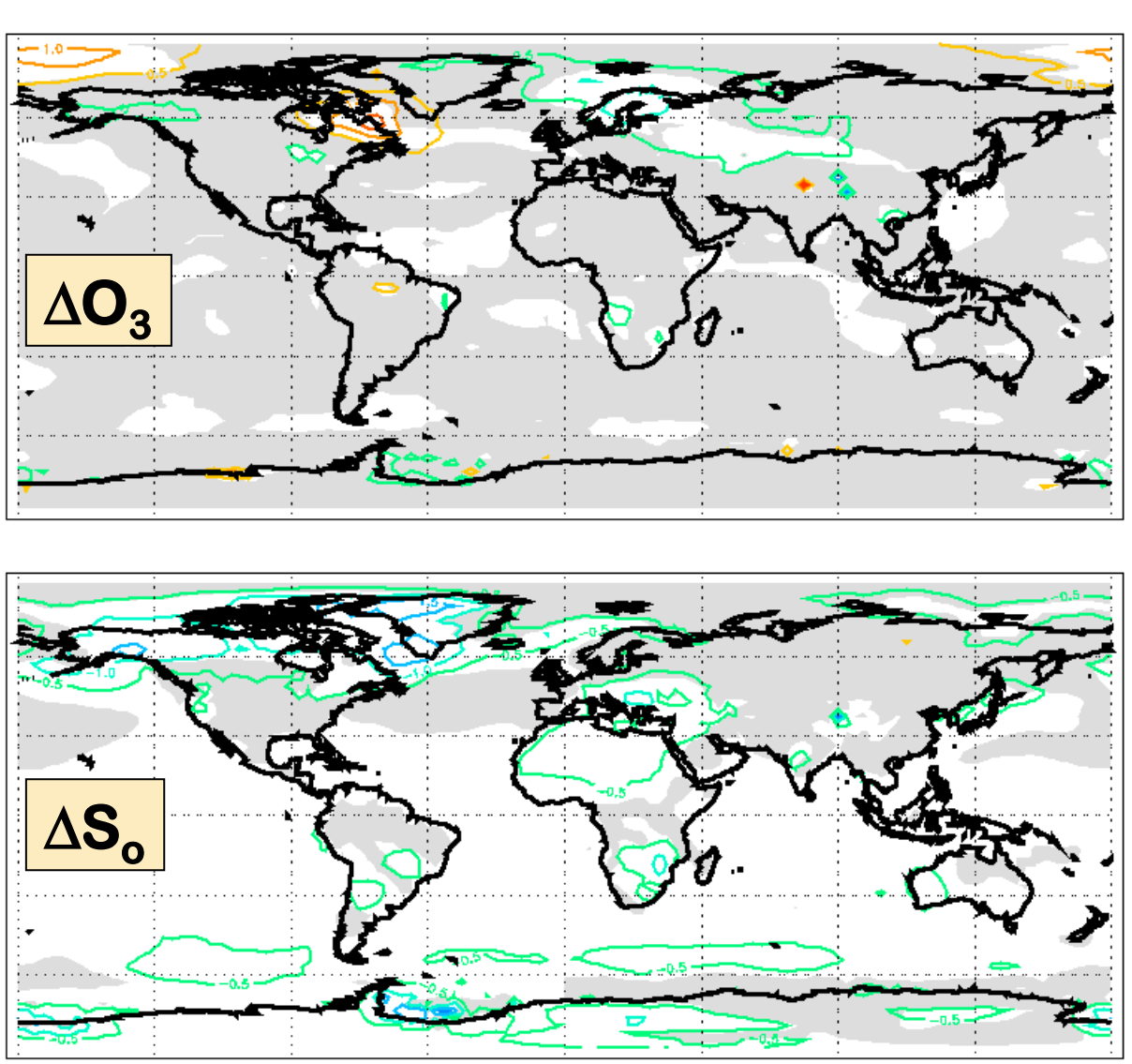
Jan-Feb-Mar Tsurf difference shown on RHS

Cooling largest in N Atlantic/European region in ΔO_3

Smaller signature in ΔS_o in above region; more cooling elsewhere



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Conclusions *(so far!)*

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ΔO_3 cools Northern Europe especially in winter-

negative NAO-like pattern

This is associated with a higher frequency of SSWs

ΔS_o cooling has a more global pattern in winter-

North Atlantic "blocking-like" pattern

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Future Work

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Analyse these results more

Analyse response to different representations of ΔUV

(Higher amplification "Harder-like" vs Lean-like)

Analyse response to combined changes (ΔO3+ ΔUV)

Sensitivity to representations of ΔO3, ΔUV, ΔS_o

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Thank you for your attention

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Results

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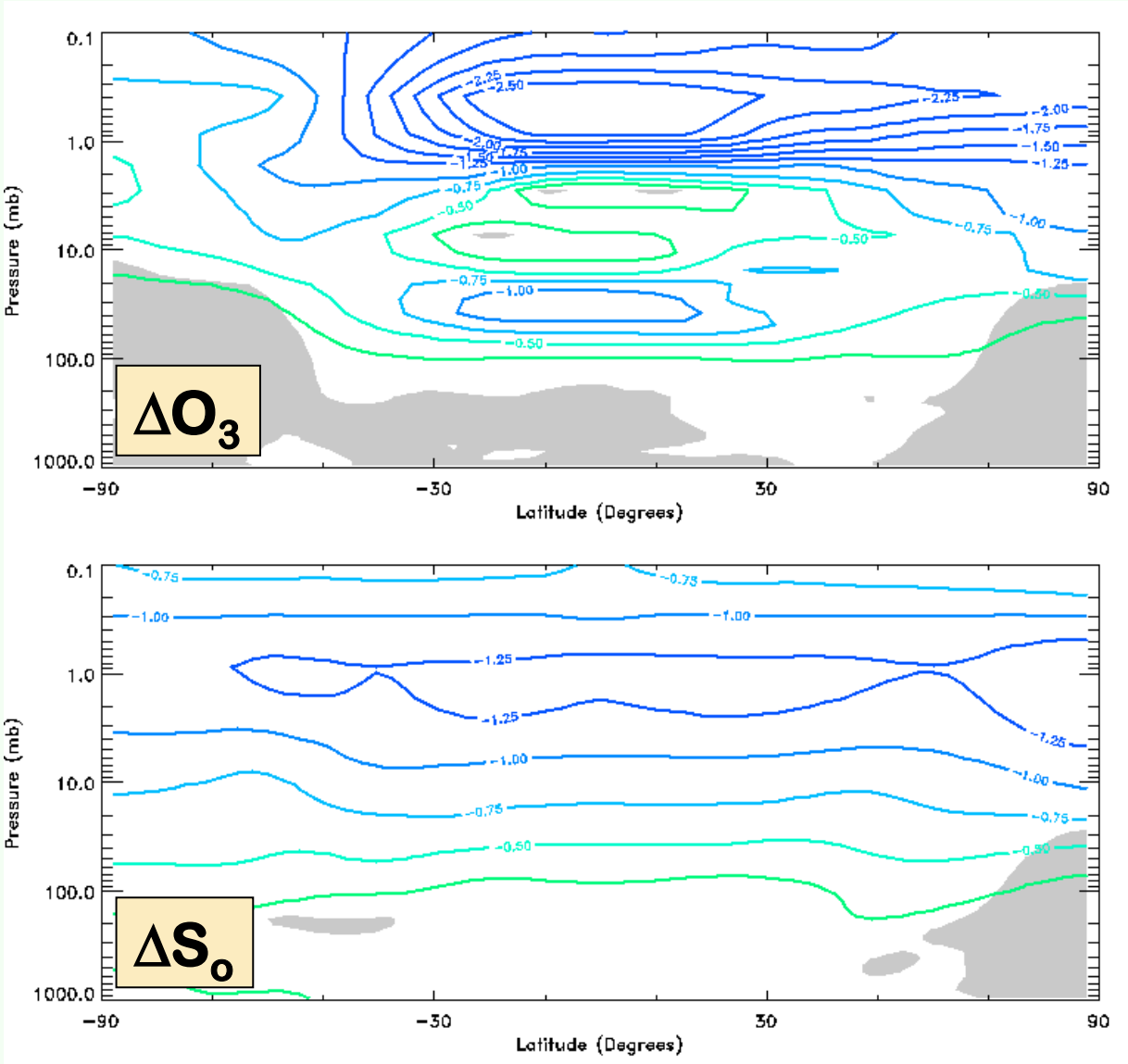
Annually averaged zonal mean temperature pattern is shown on RHS

2K cooling in upper stratosphere from ΔO_3

Smaller cooling from ΔS_o



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