

Update on Eocene climate modeling

- Implications of new data
- Preliminary CESM1 --CCSM3 Comparison
- Solution to the Equable Climate Problem?
- EOMIP
- Feedback Analysis Climate Sensitivity

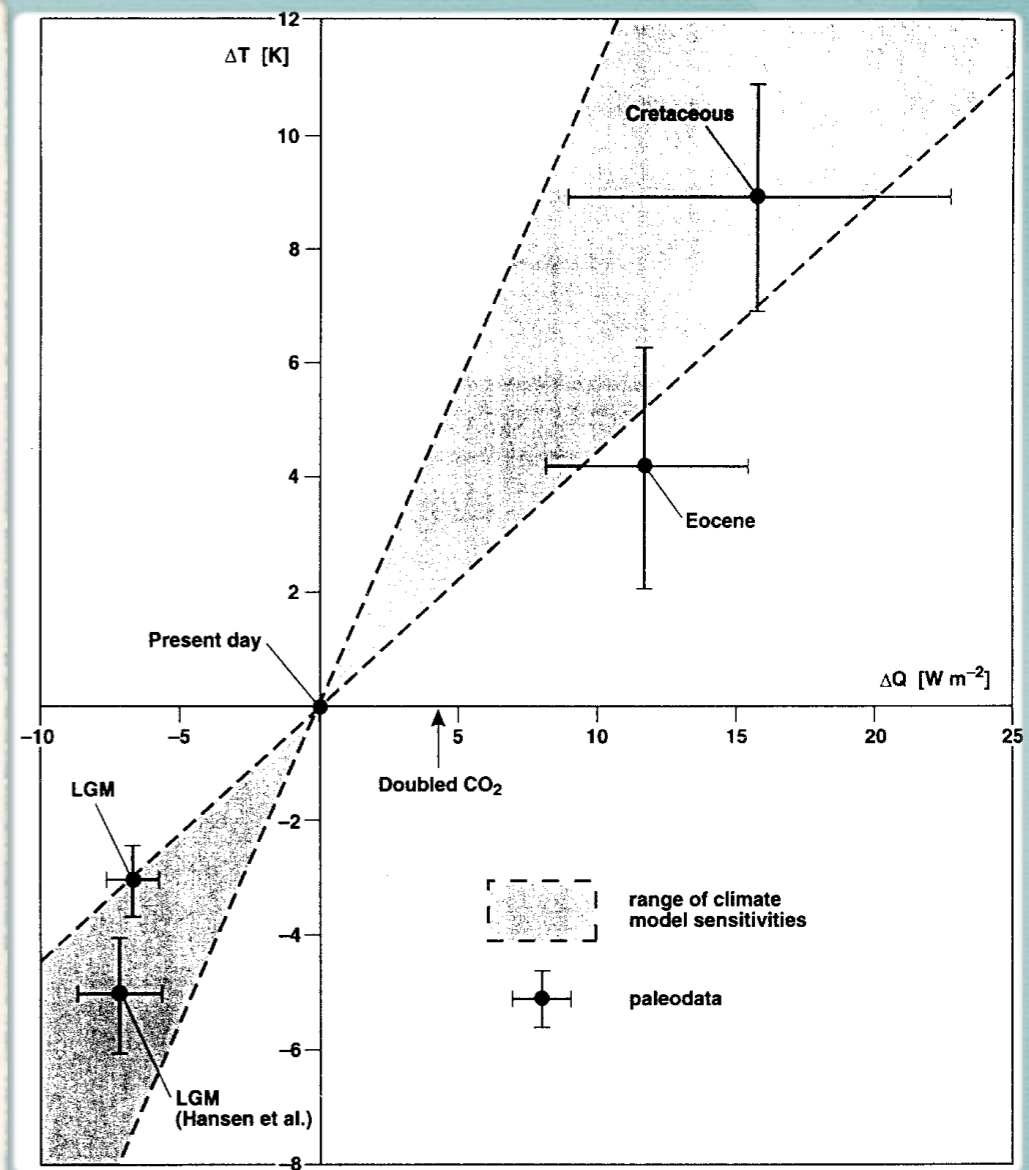
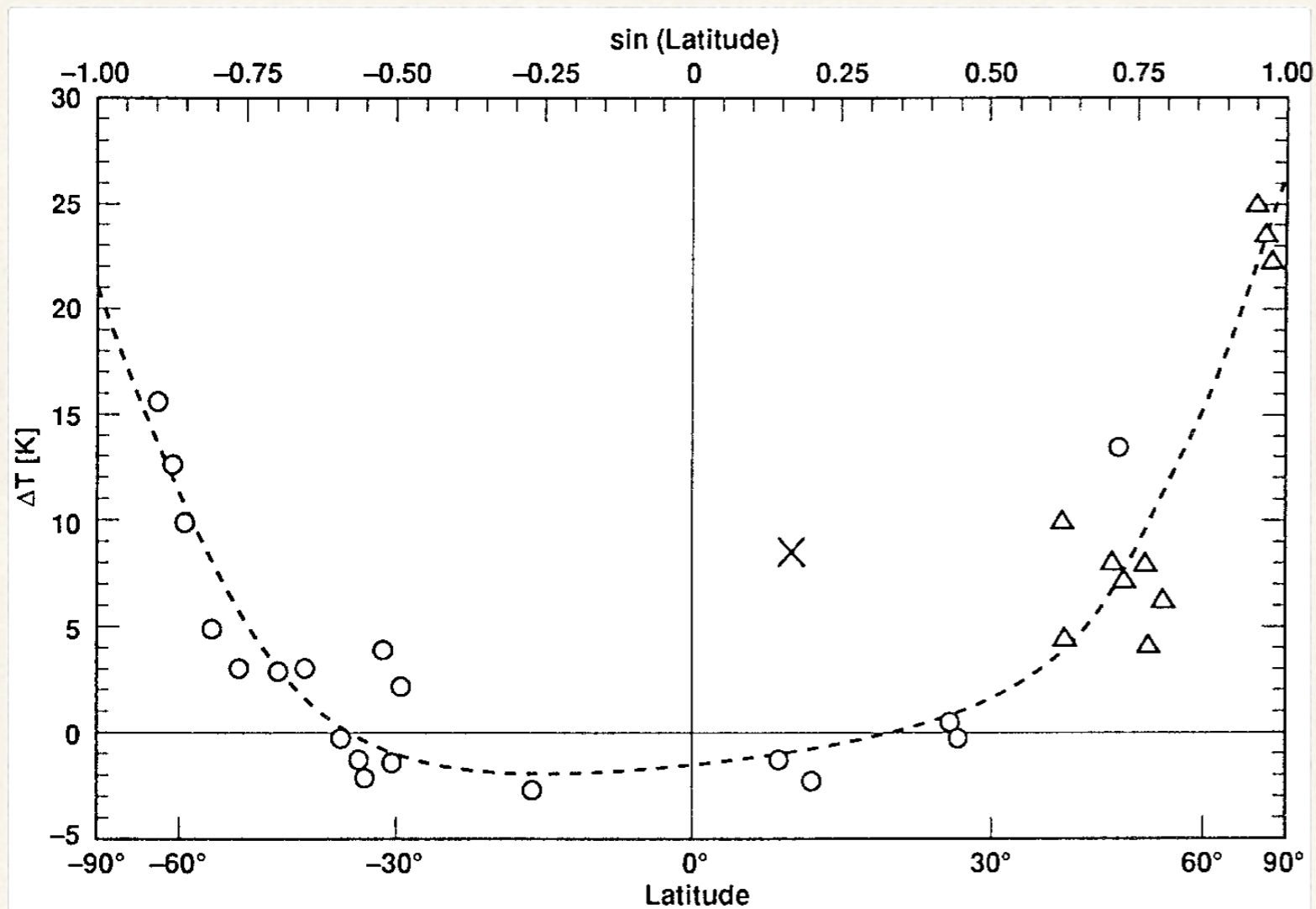
Funded by NSF 0902780-ATM, 0902882-OCE

Fundamental Climate Change Questions

- Is global mean temperature sensitivity to greenhouse gas forcing on the low end ($<2^{\circ}\text{C}$) or the high end ($>4^{\circ}\text{C}$)?
- How strong is polar amplification of climate change?
- Is there a thermostat that buffers tropical climates from warming?

New proxy records are hotter

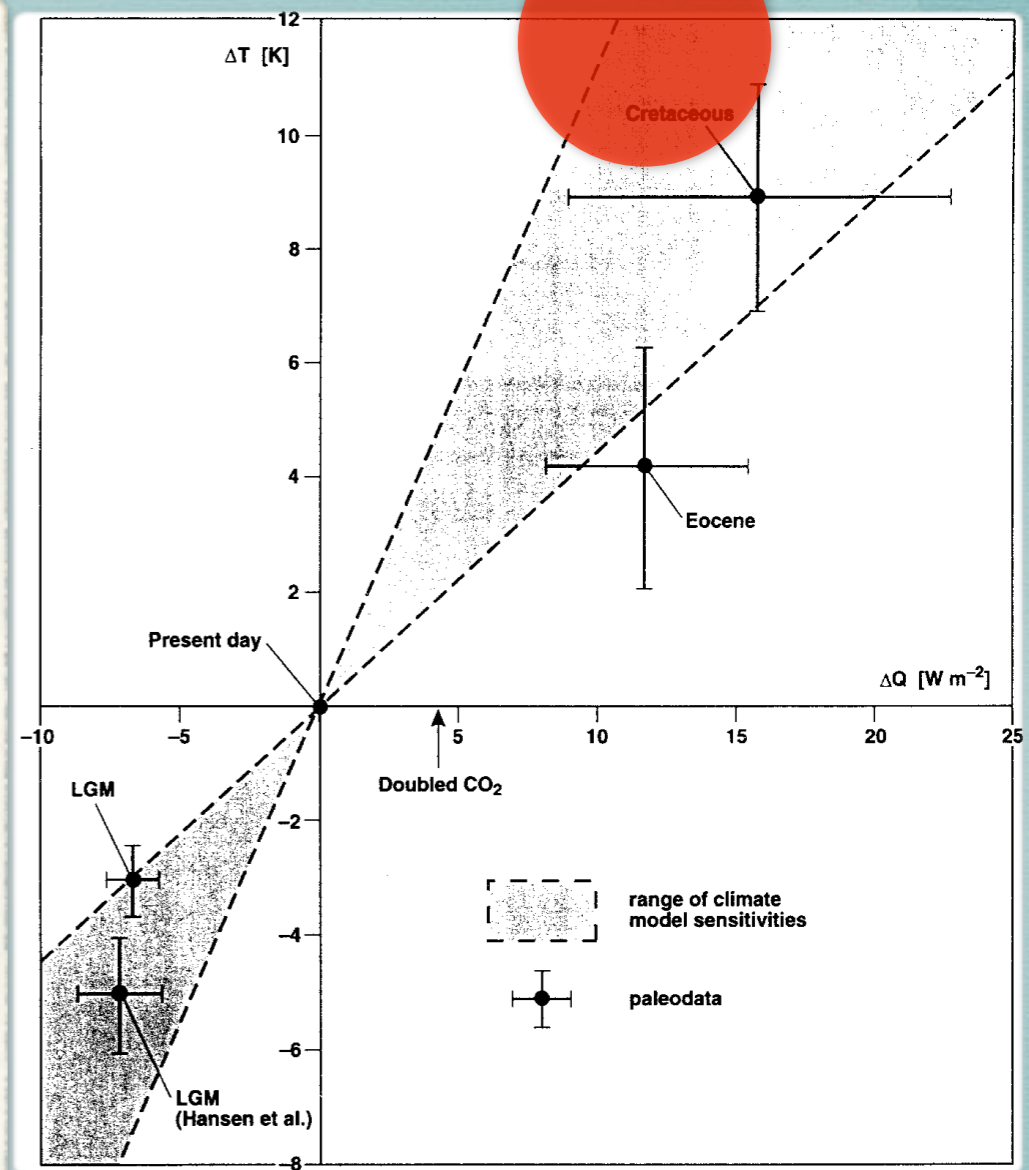
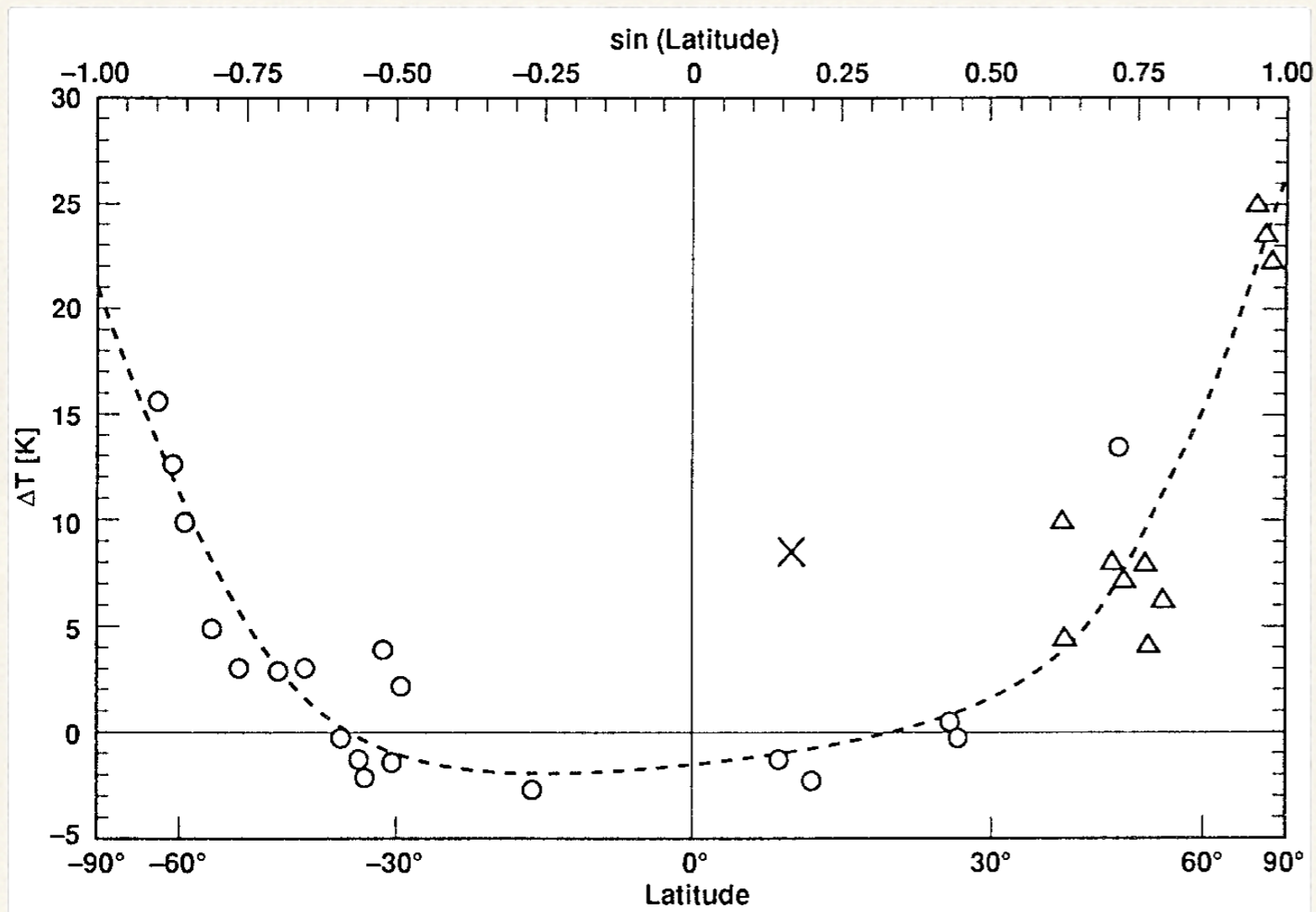
- Temperatures in the Eocene were 5-10 °C warmer than we thought 10 years ago, on land and in the ocean
- New proxies, new records, recognition of cold bias of older records (Pearson et al., 2001, 2007; Sluijs et al., 2006; Pagani et al., 2006; Brinkhuis et al., 2006; Weijers et al., 2007; Hollis et al., 2009; Liu et al., 2009; Eldrett et al., 2009; Kowalski and Dilcher, 2003; Fricke and Wing, 2004; Head et al., 2009; Jaramillo et al., 2010)
- What does this imply for our understanding of climate change?
- Eocene tropical temperatures were *warmer* than 30°C
- Eocene high latitude surface temperatures warm or were they hot?



Covey et al., 1996

The world was hotter than we thought

New proxy records, especially from organic geochemical proxies are game changers



Covey et al., 1996

The world was hotter than we thought

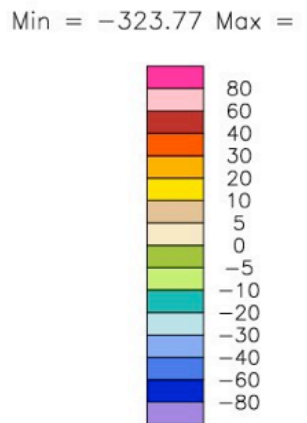
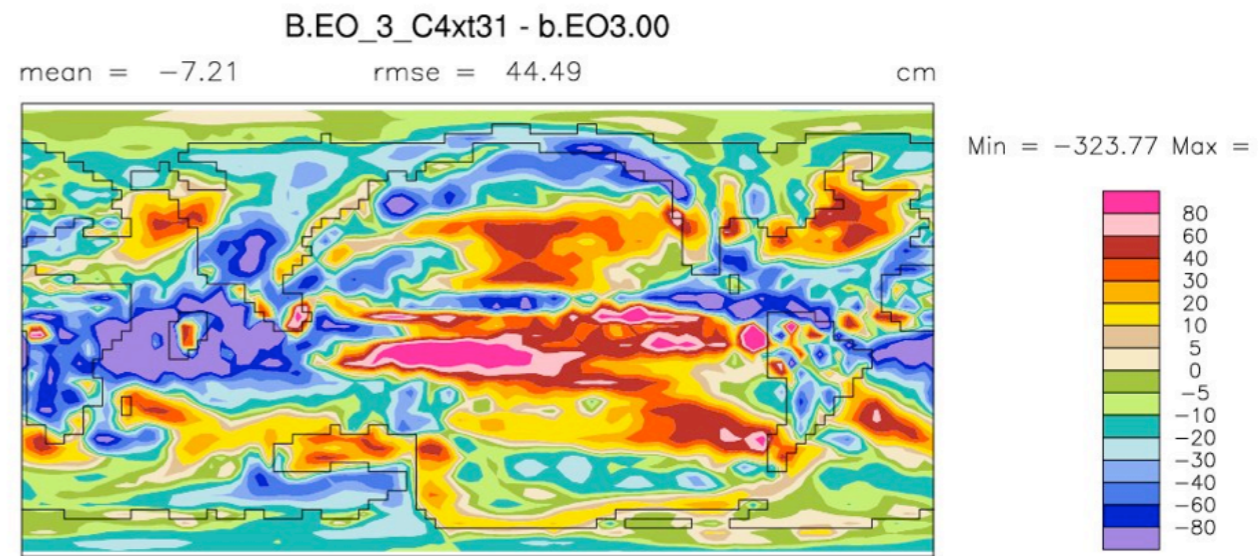
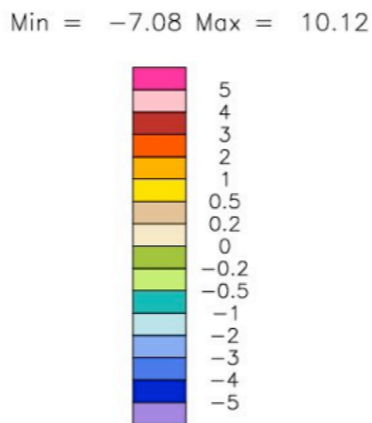
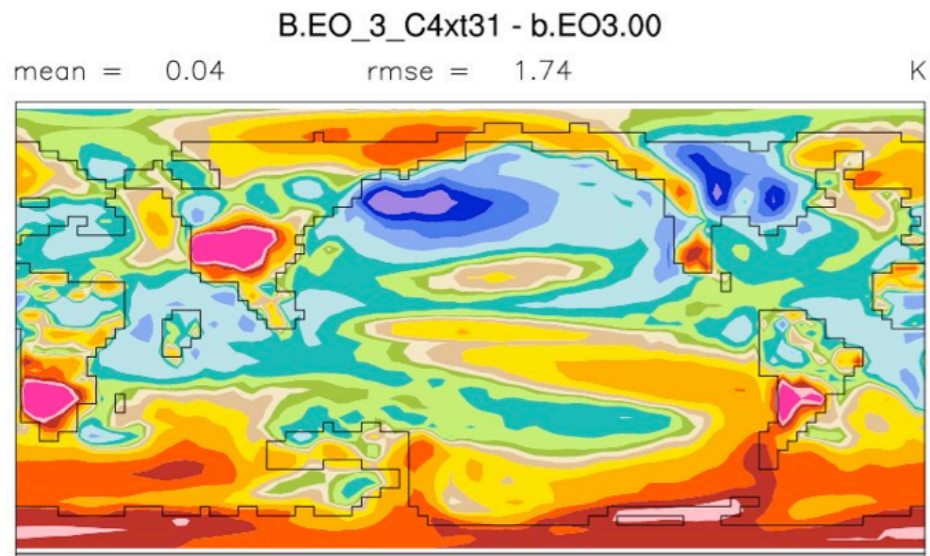
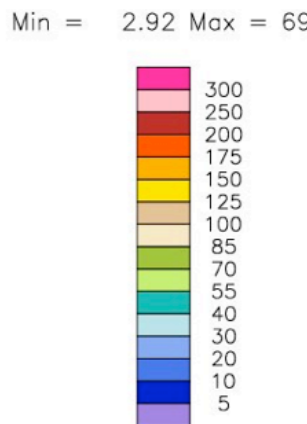
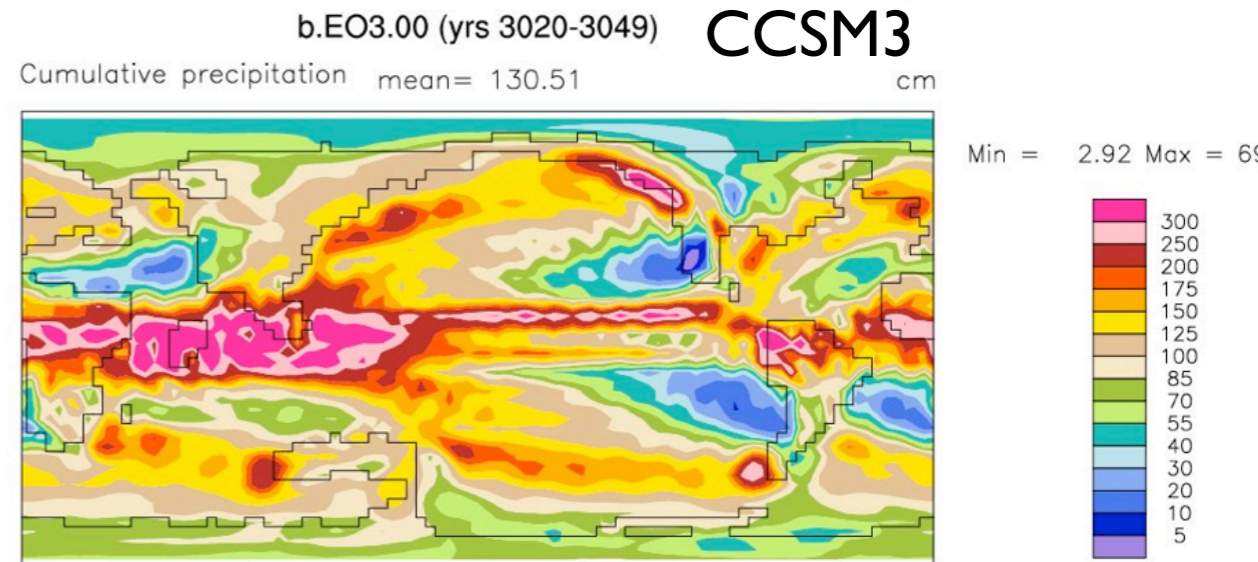
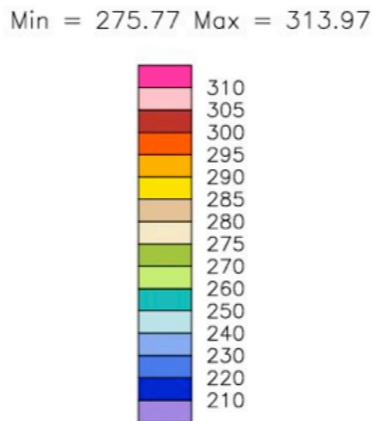
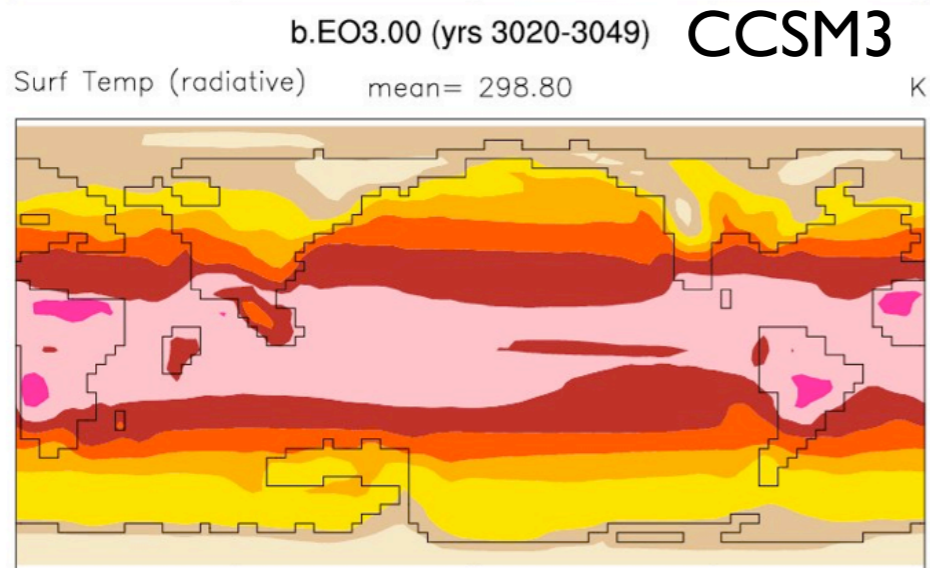
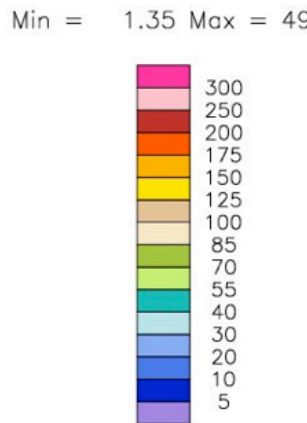
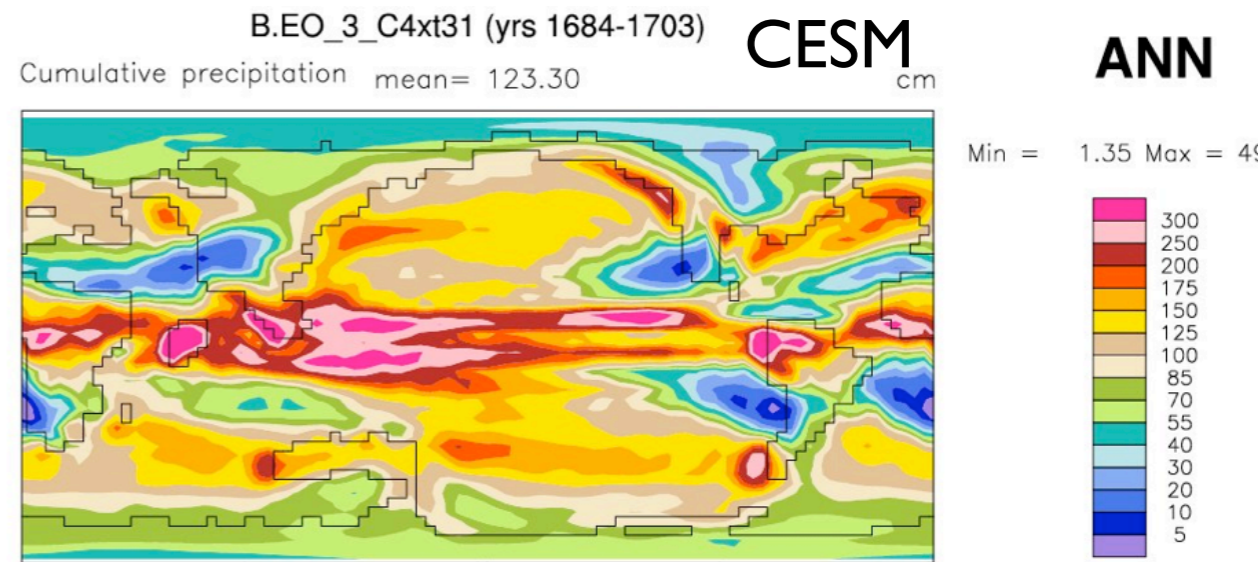
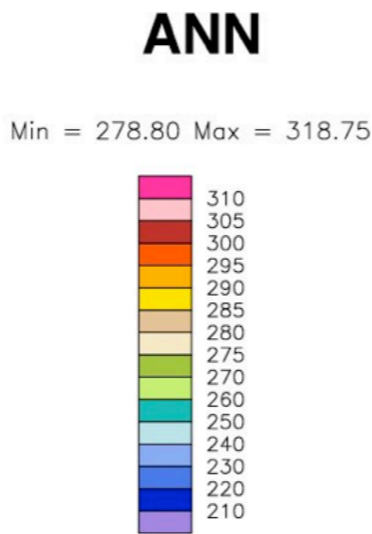
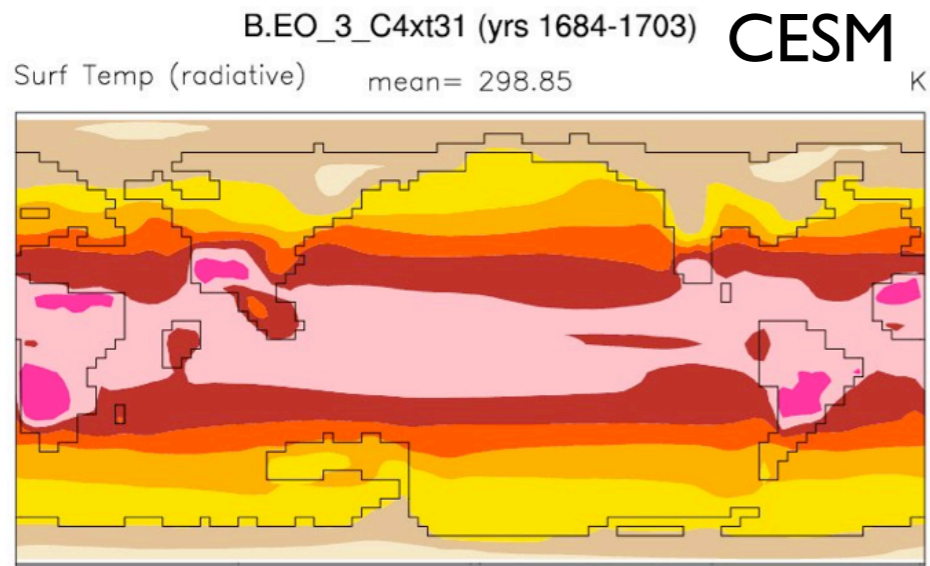
New proxy records, especially from organic geochemical proxies are game changers

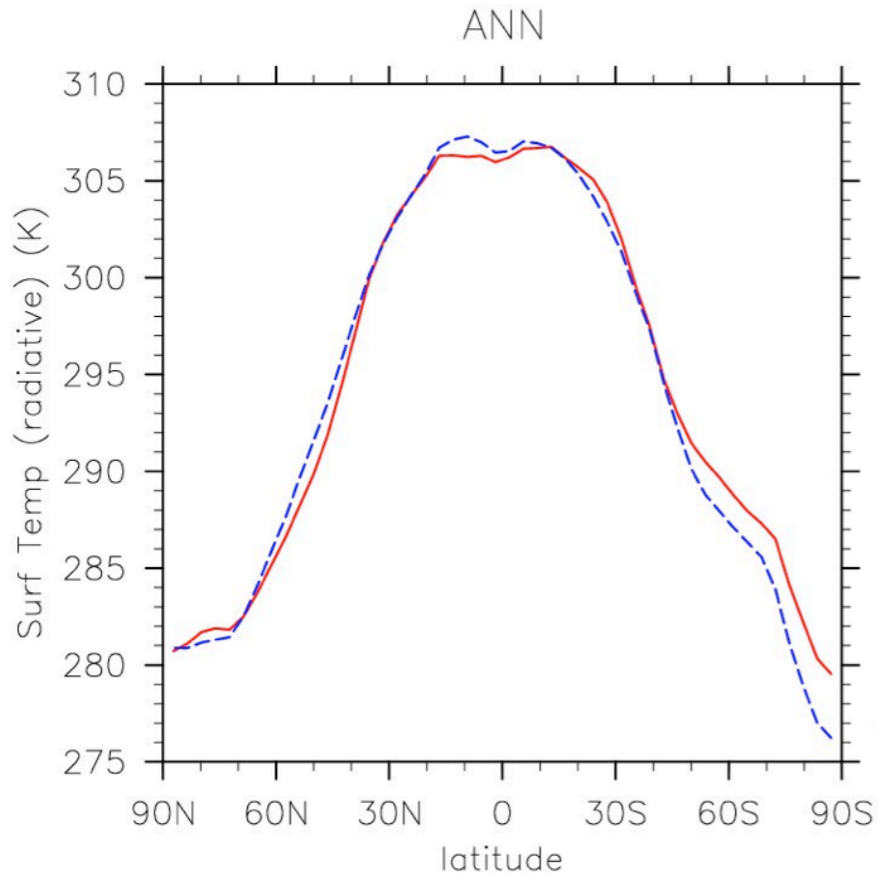
Eocene CESM

Coupled T31 runs at 2240 ppm CO₂

Thanks to Christine Shields for assistance.

For more Eocene CESM see Aaron Goldner's talk this afternoon!

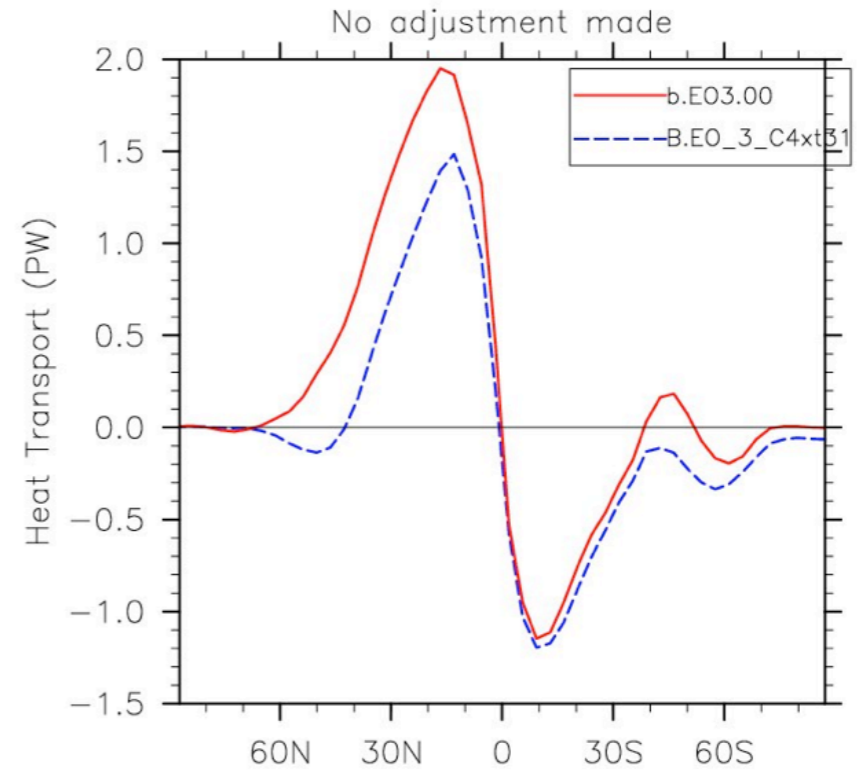




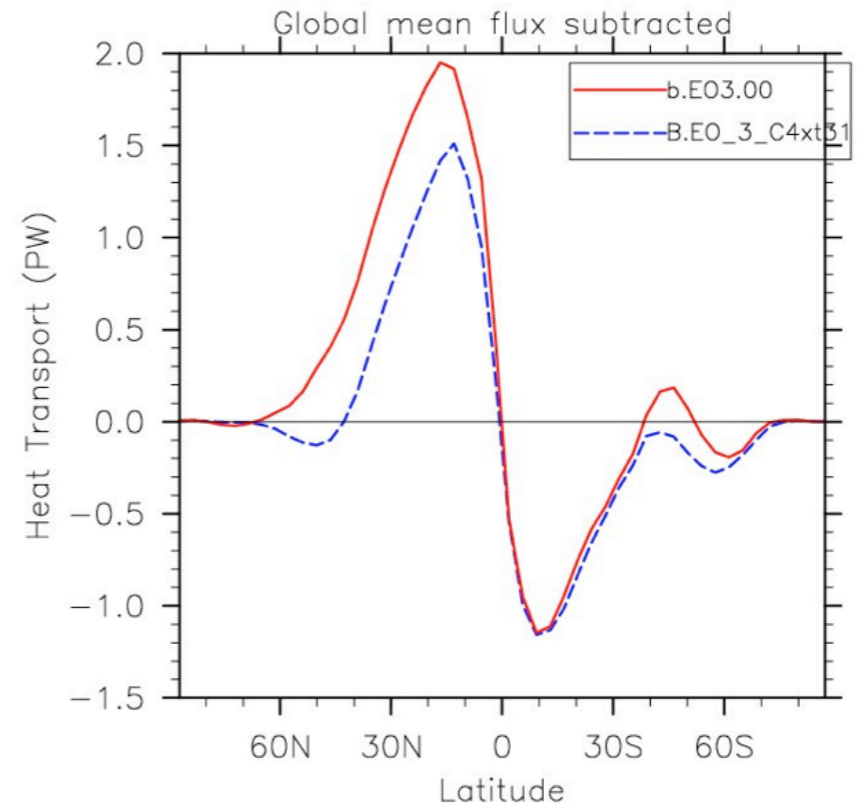
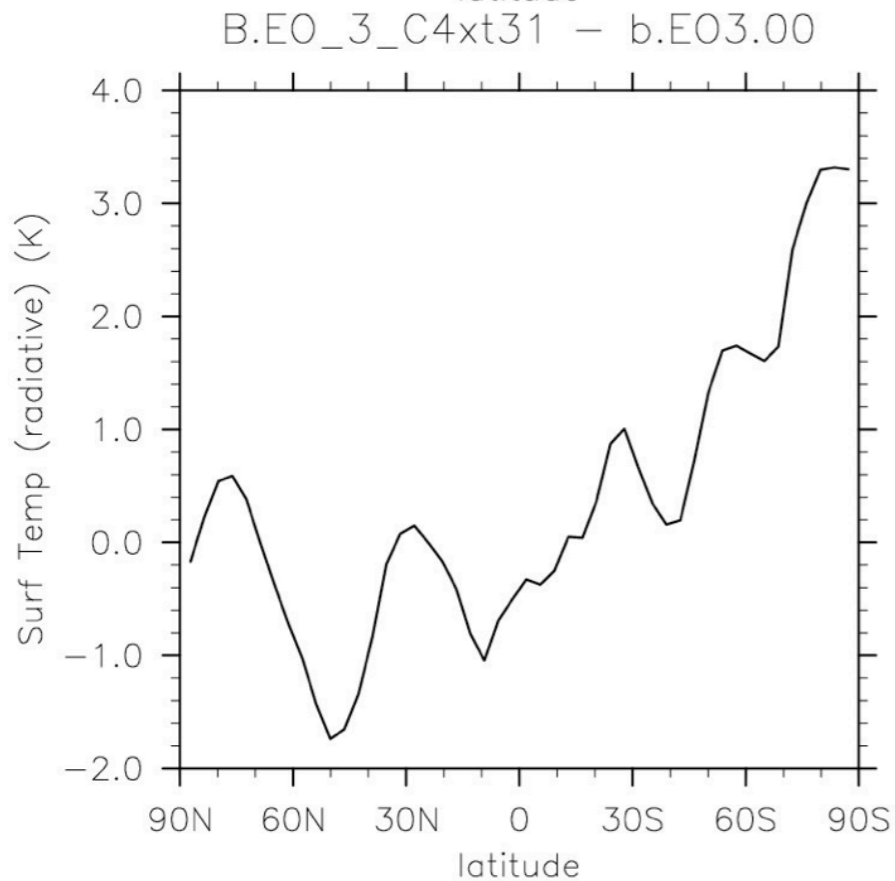
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**CCSM3
CESM**

Annual Implied Northward Heat Transport



**CCSM3
CESM**



CESM

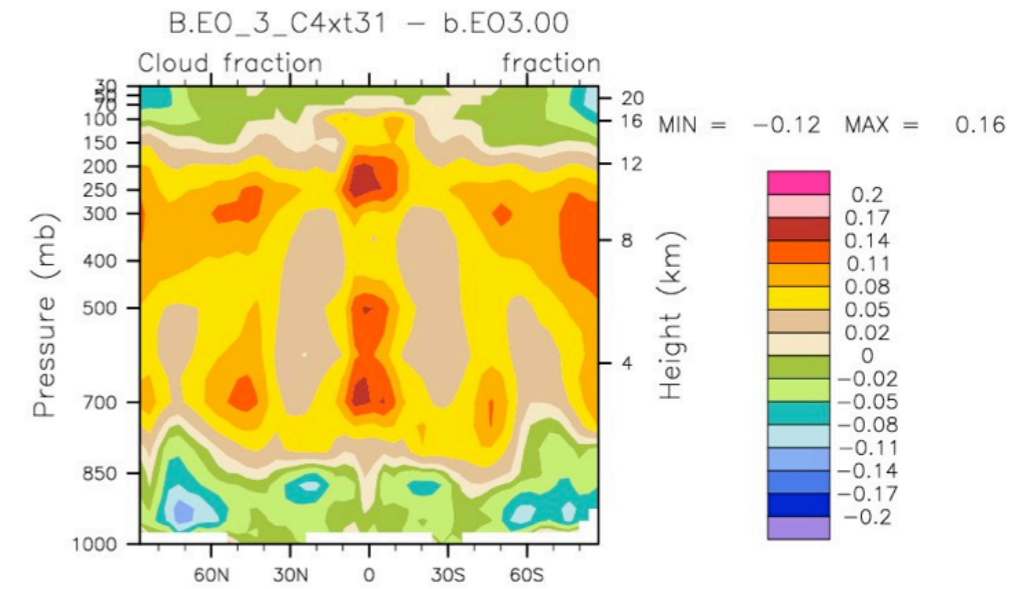
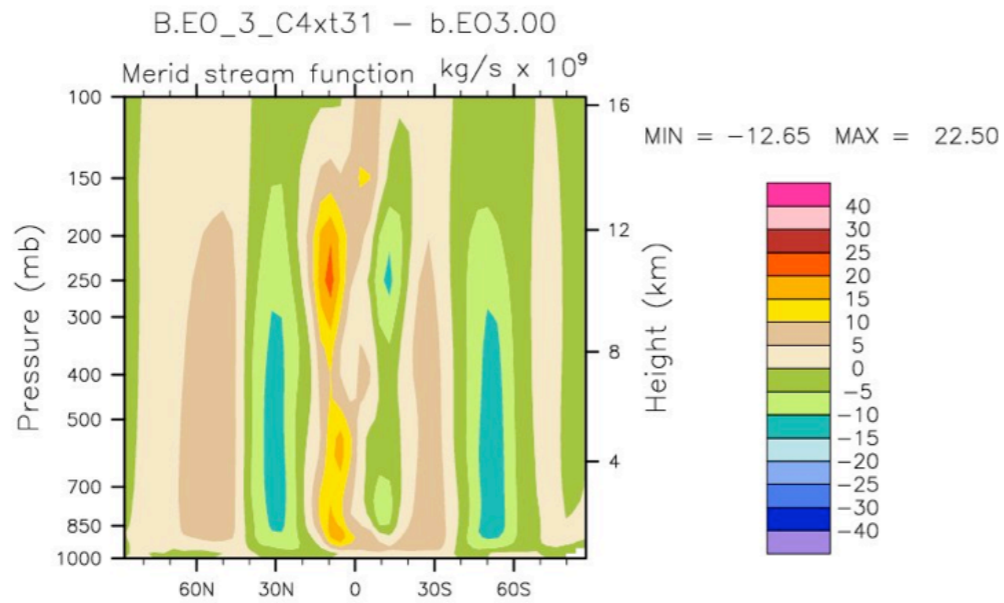
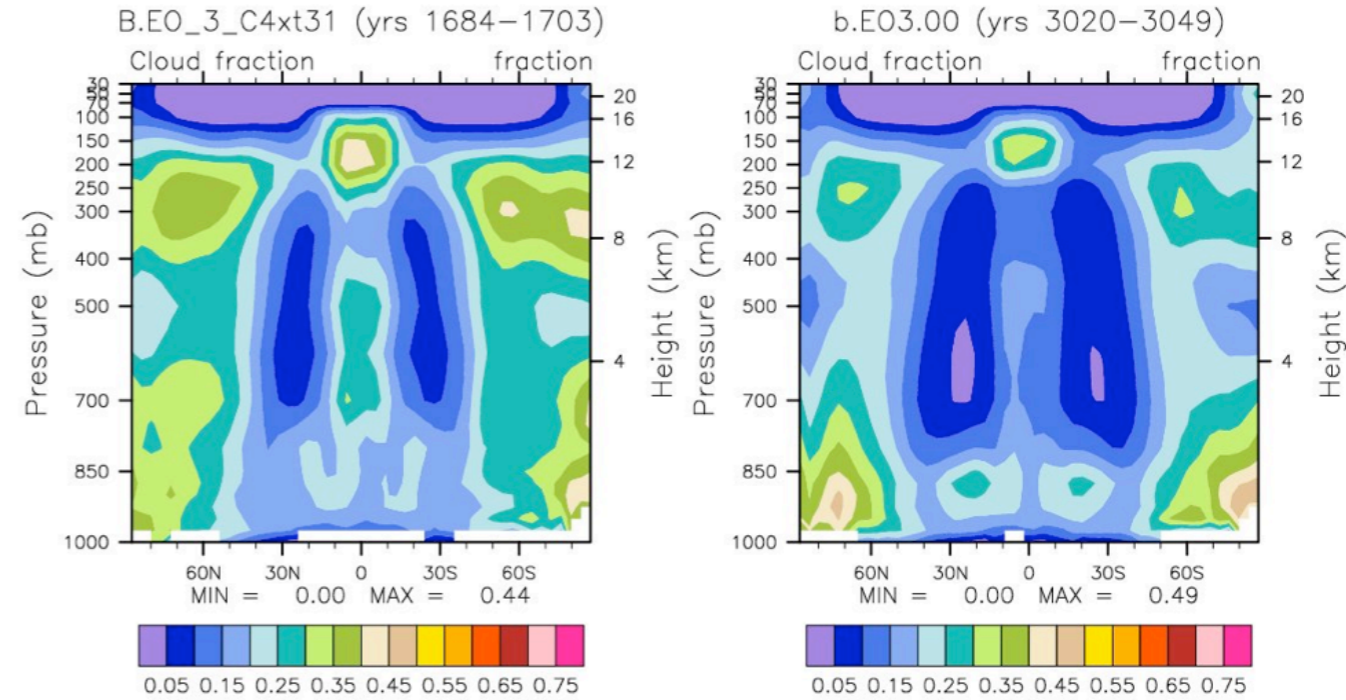
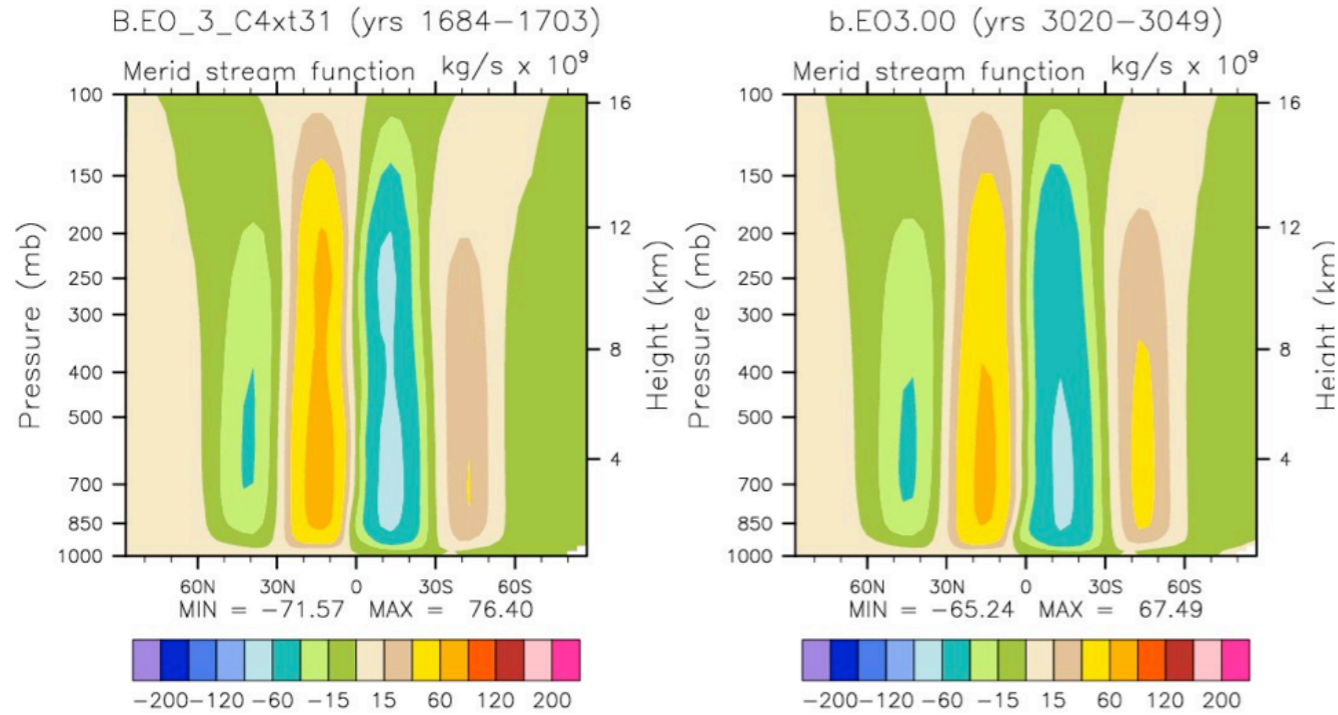
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CCSM3

CESM

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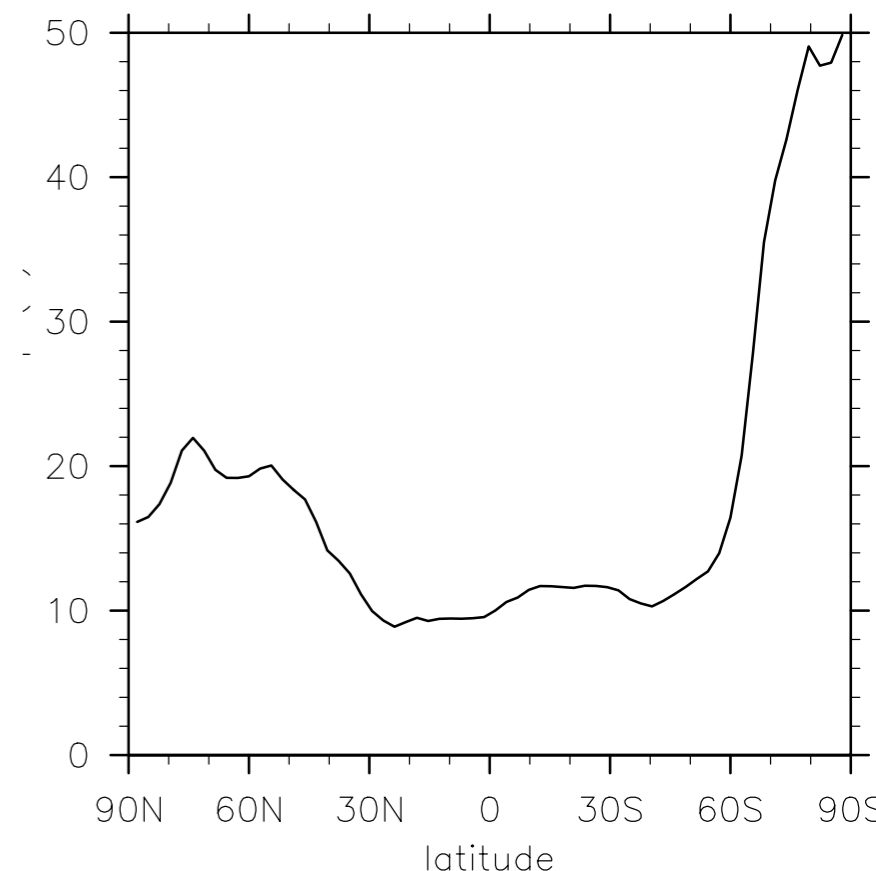
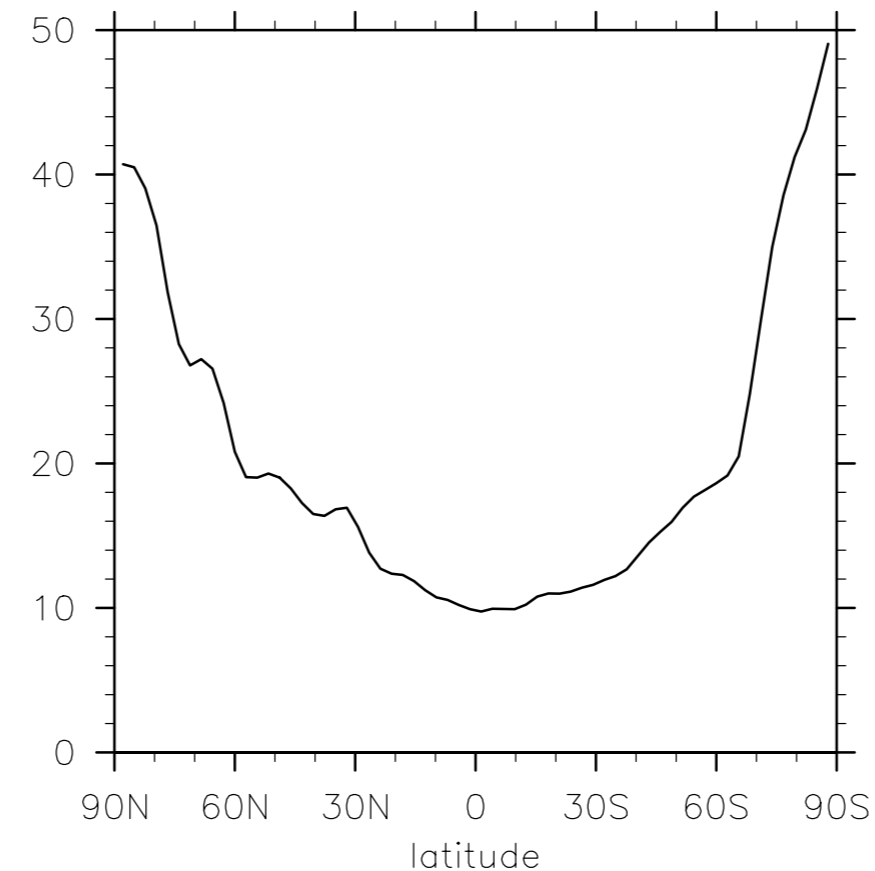
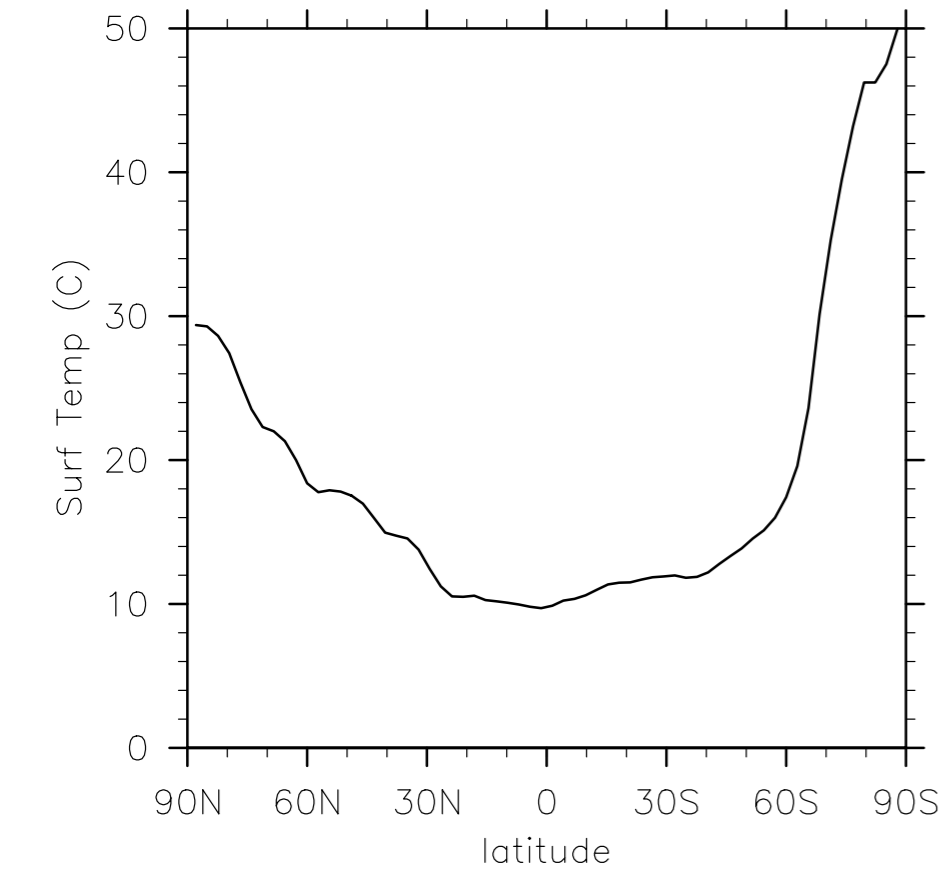
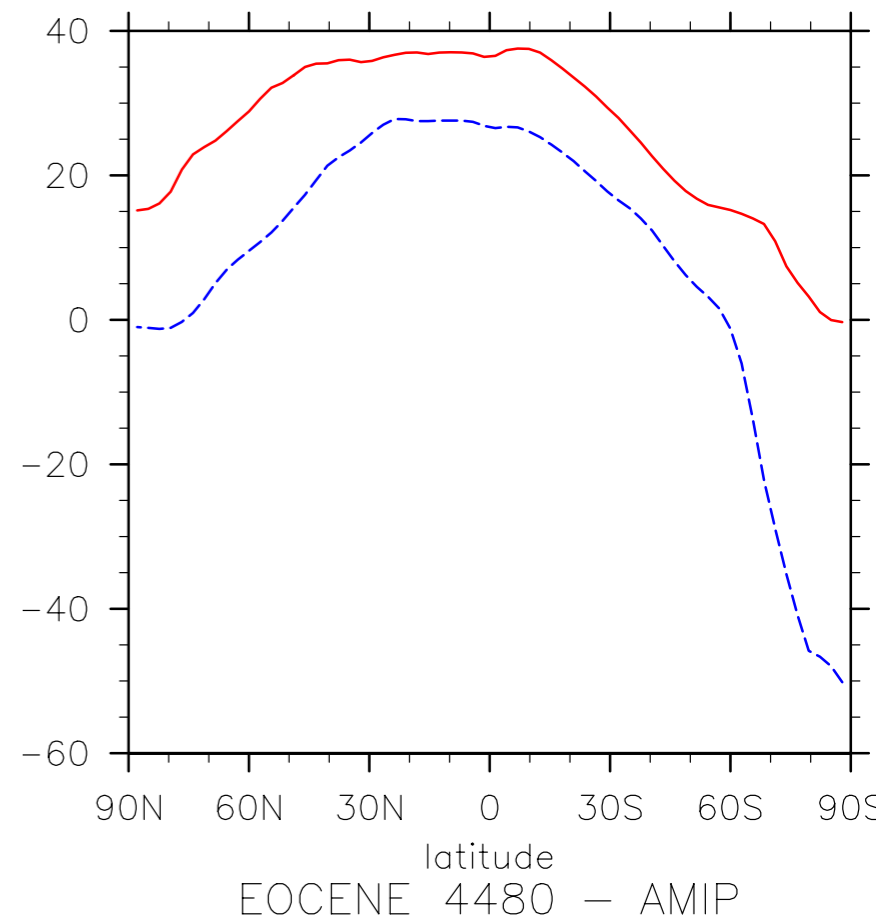
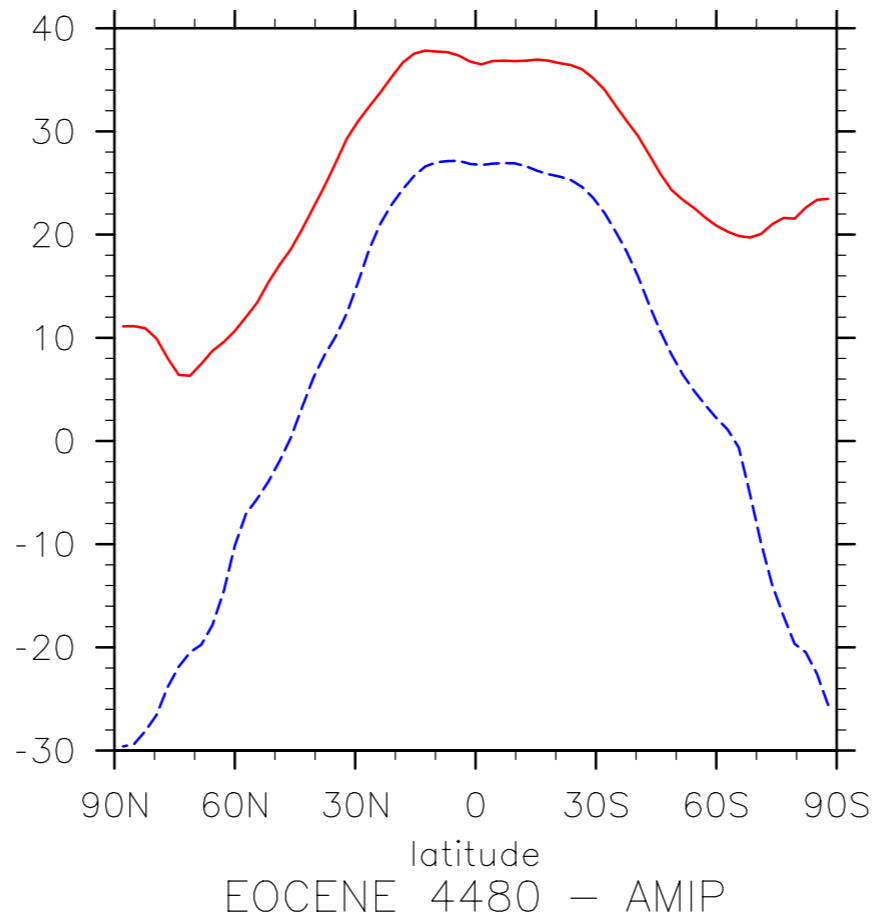
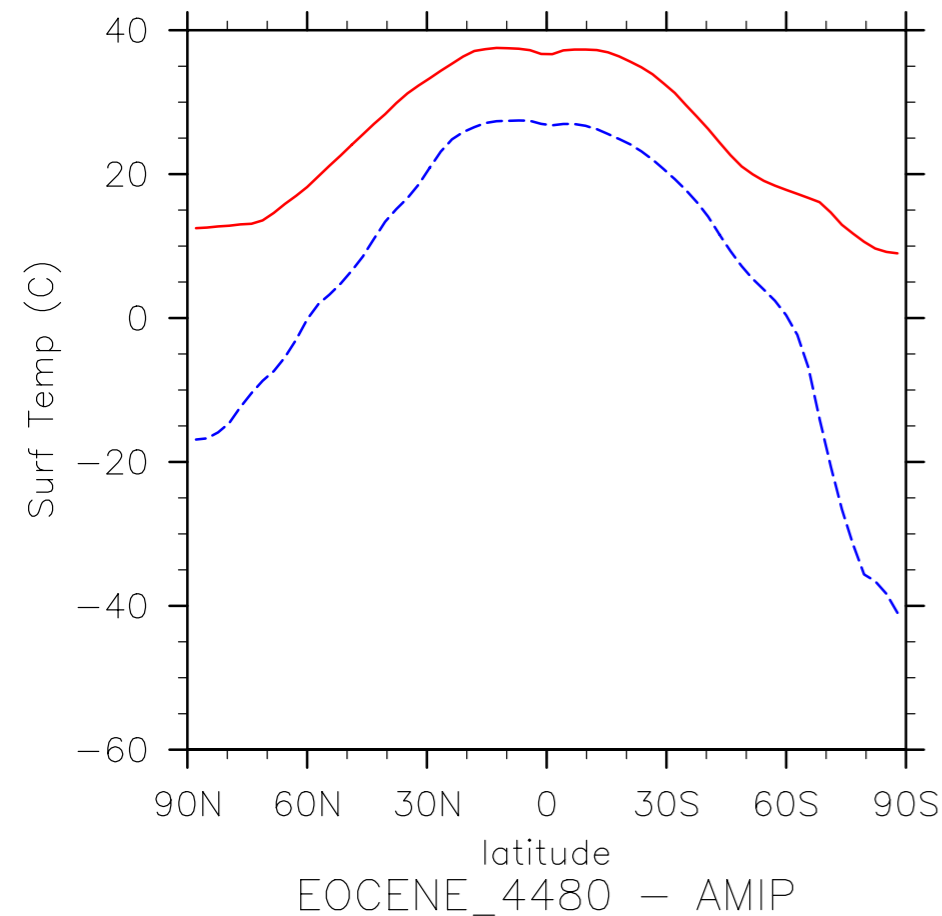
CCSM3



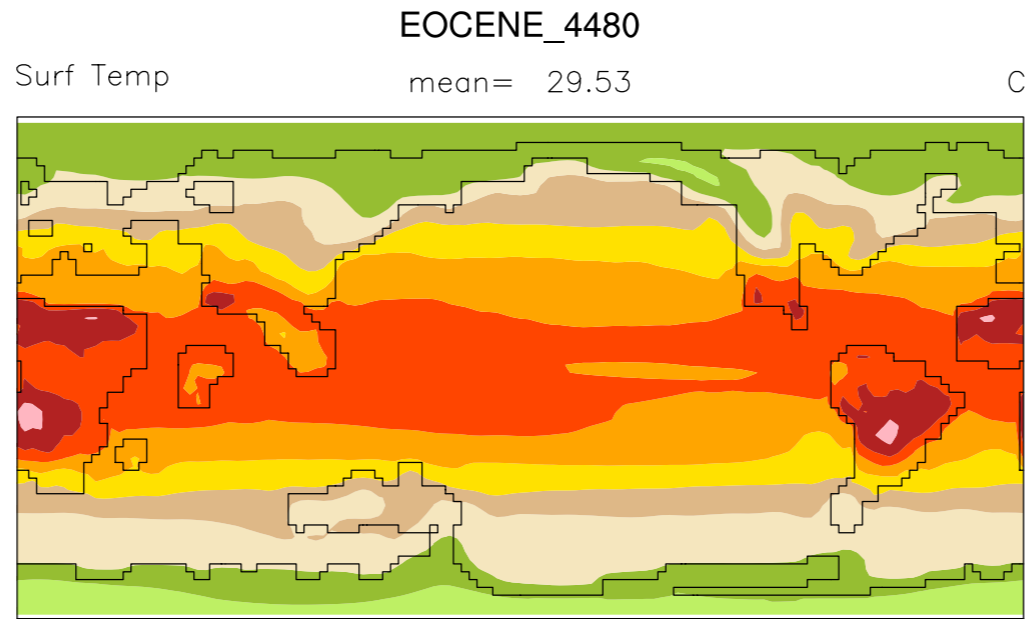
End of the Eocene Equable Climate Problem?

CCSM3/CAM3 results

EOCENE Model at 4480 ppm CO₂ Compared with modern Model

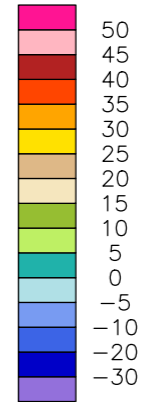


Eocene Model at 4480

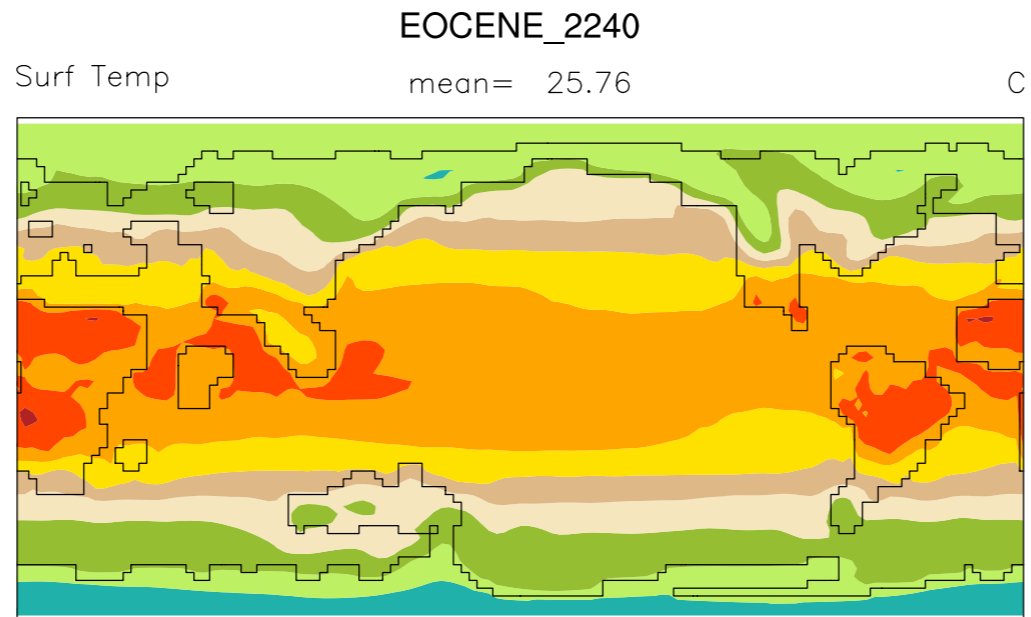


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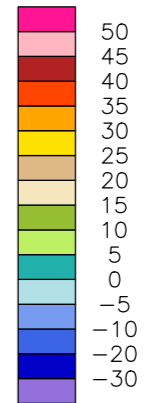
Min = 8.74 Max = 46.66



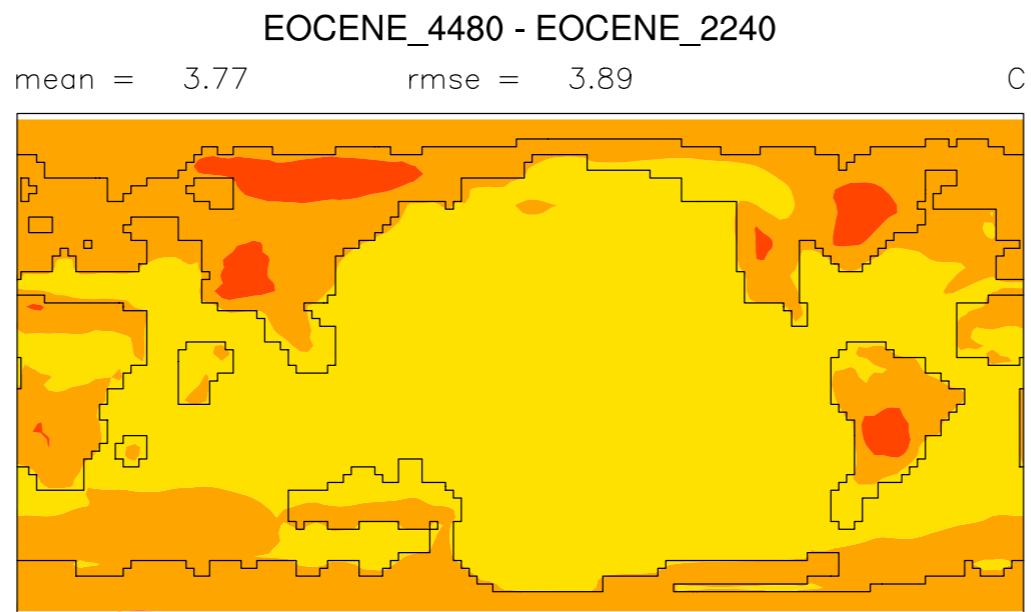
Eocene Model at 2240



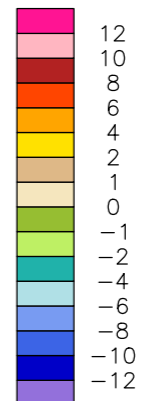
Min = 2.81 Max = 40.79



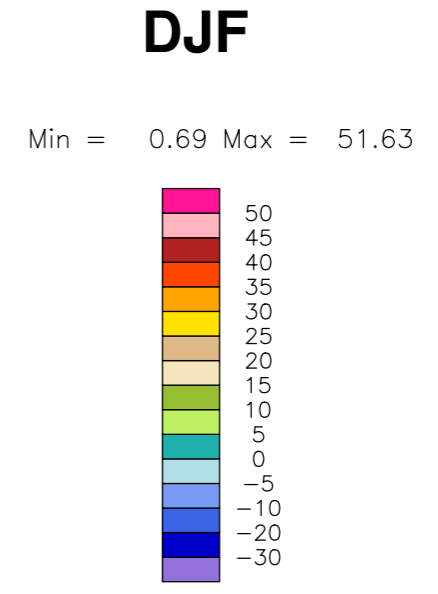
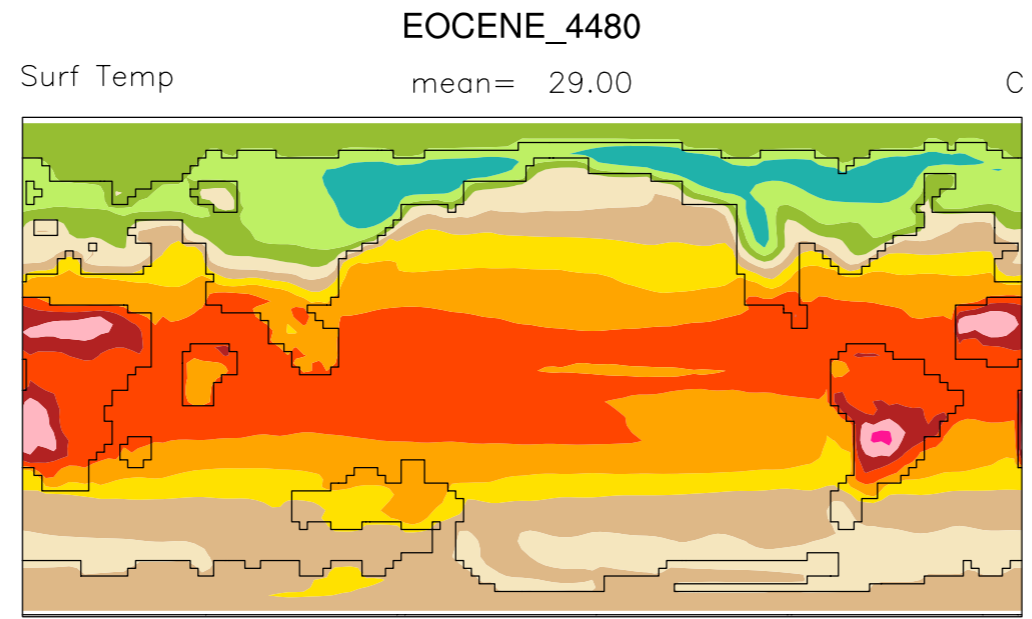
Anomaly



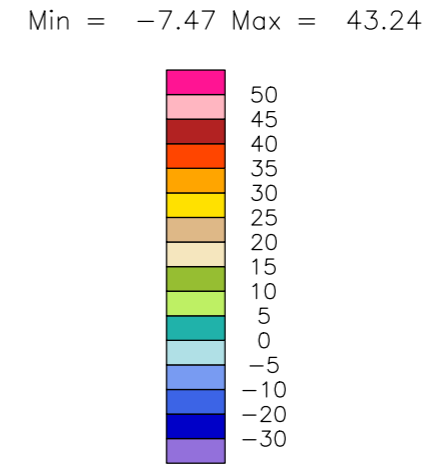
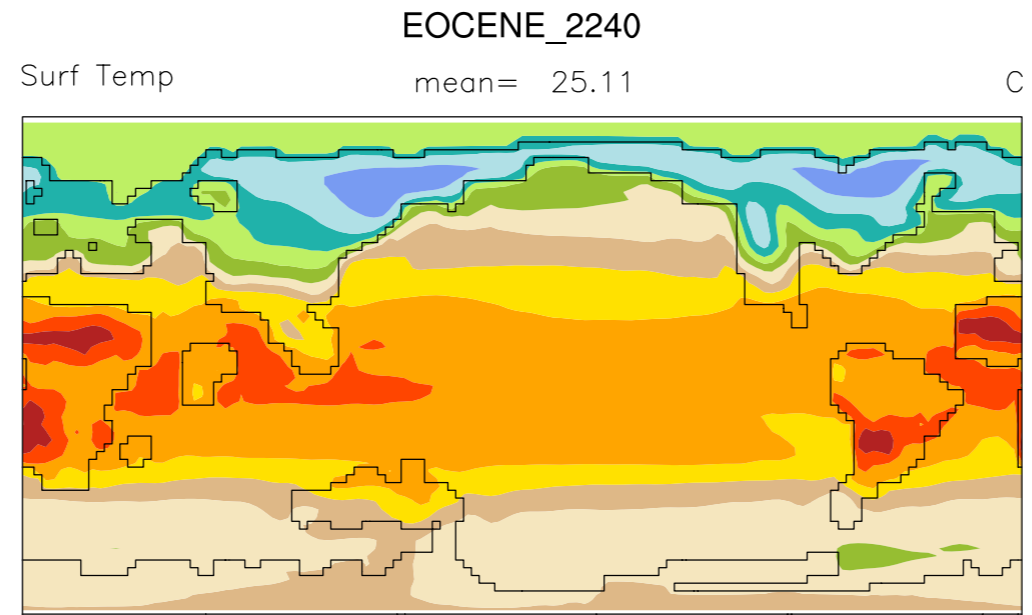
Min = 2.26 Max = 7.55



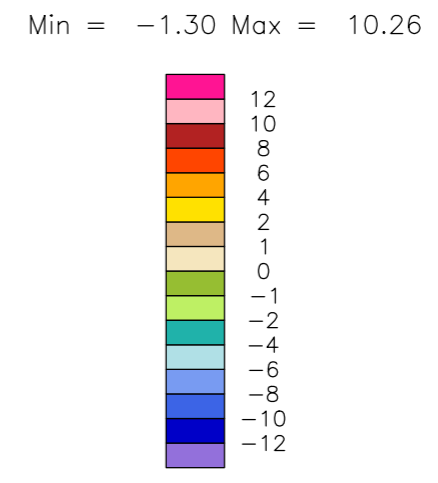
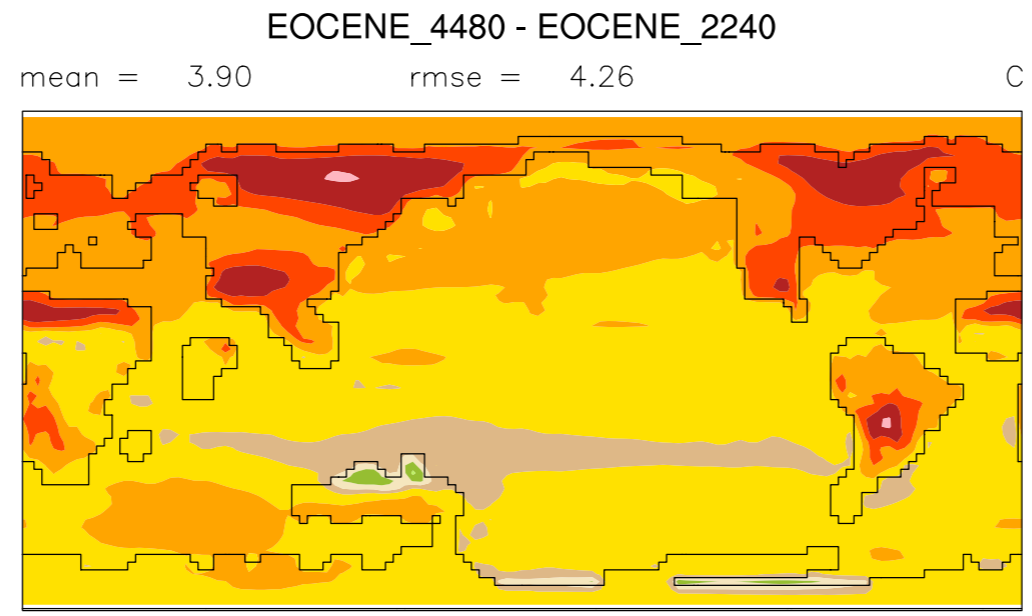
Eocene Model at 4480



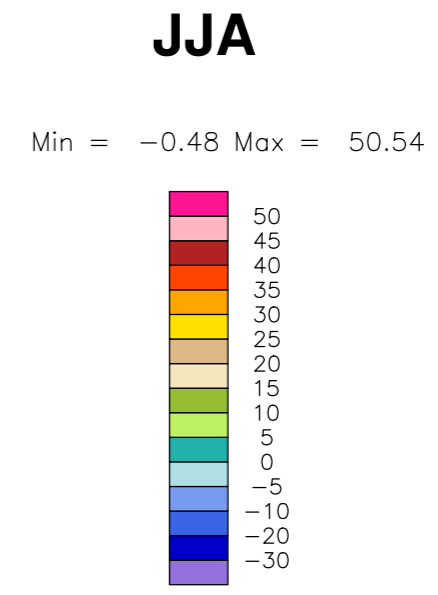
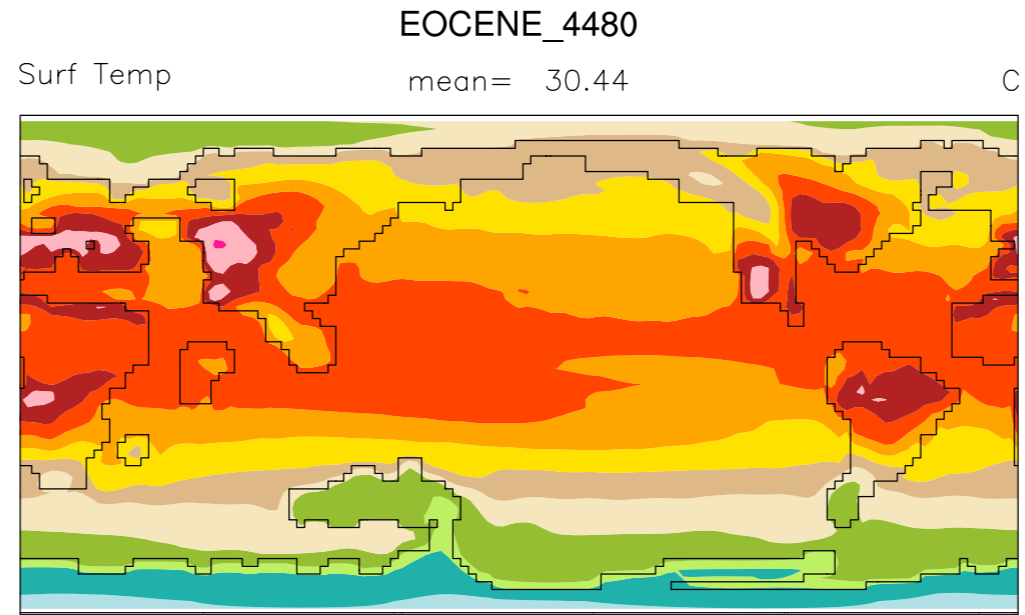
Eocene Model at 2240



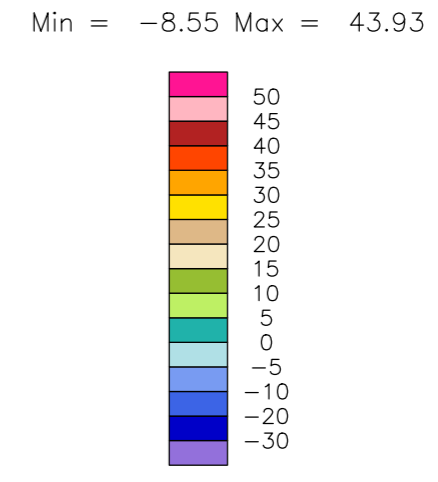
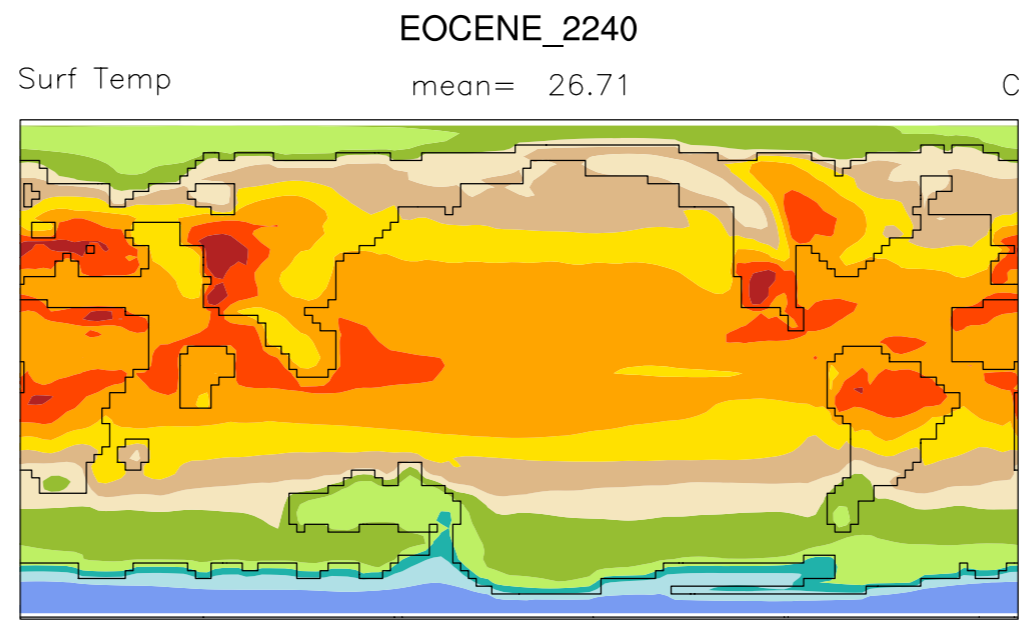
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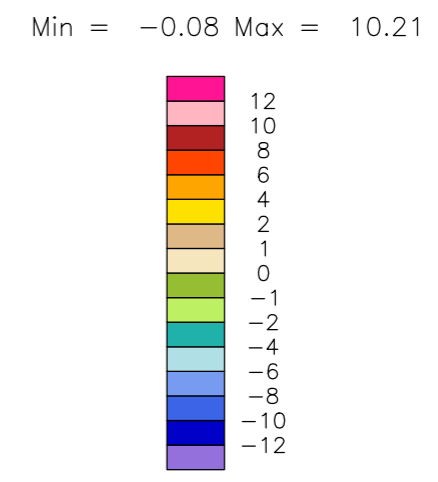
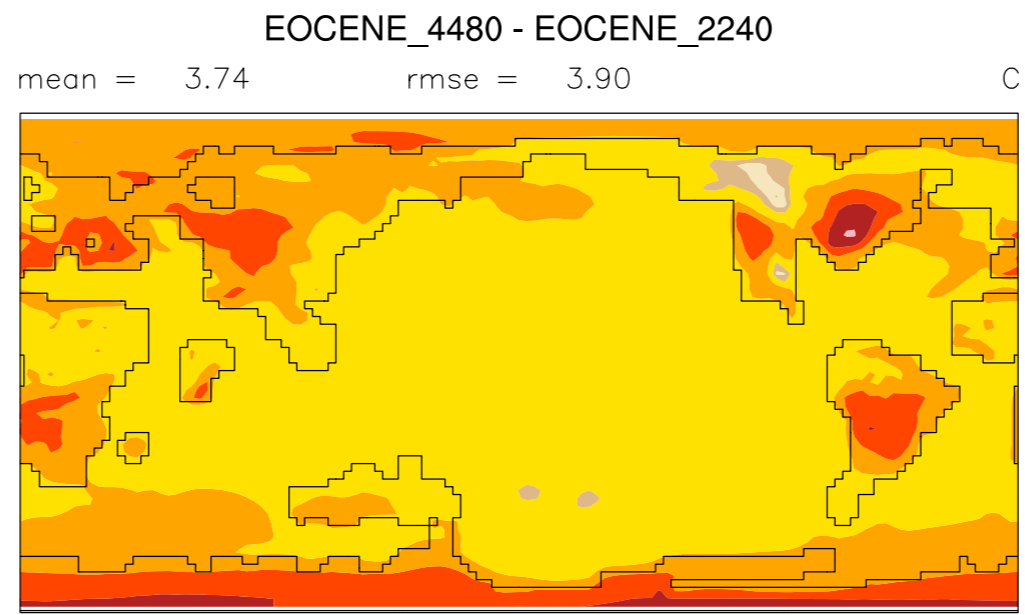
Eocene Model at 4480



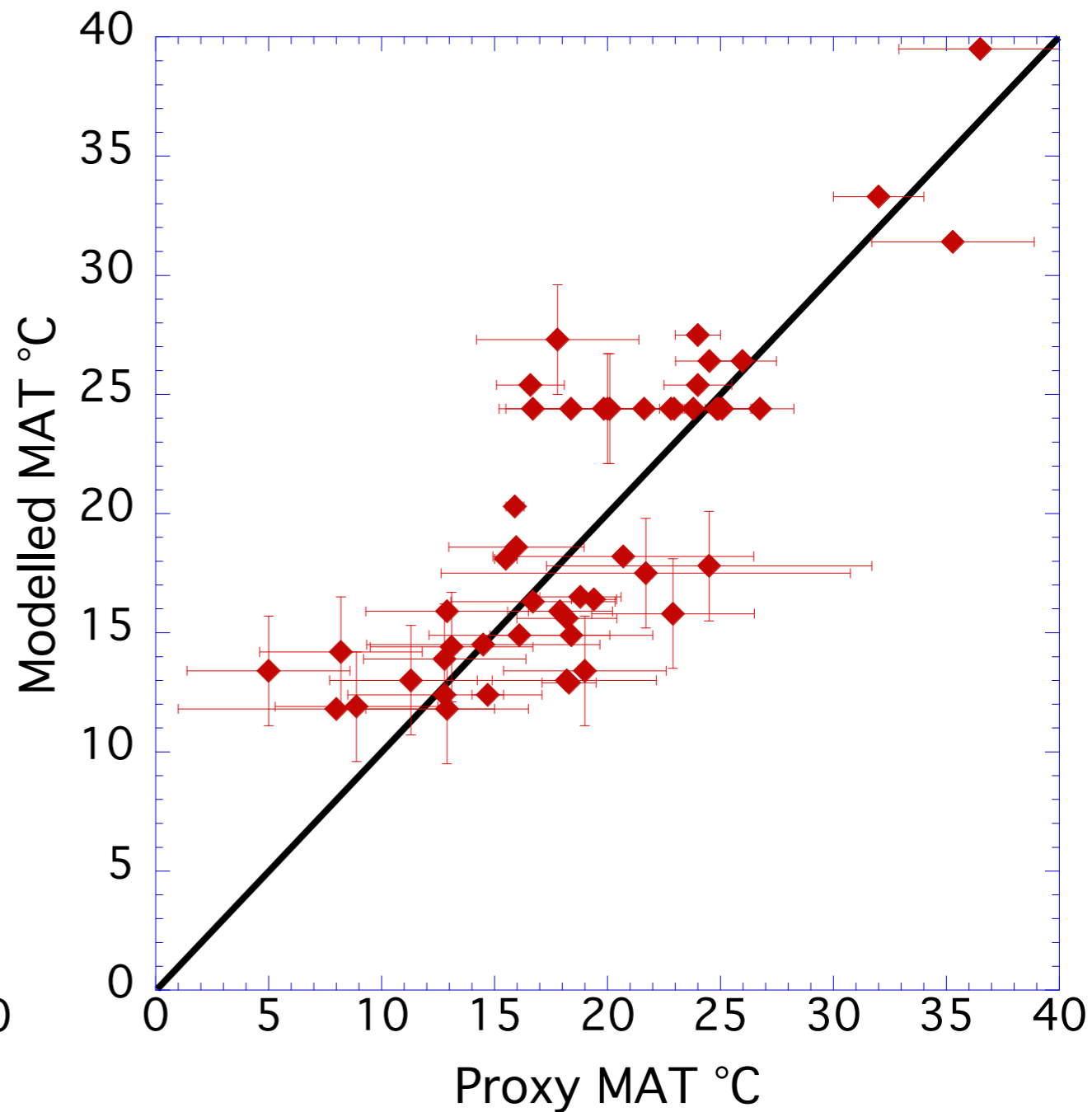
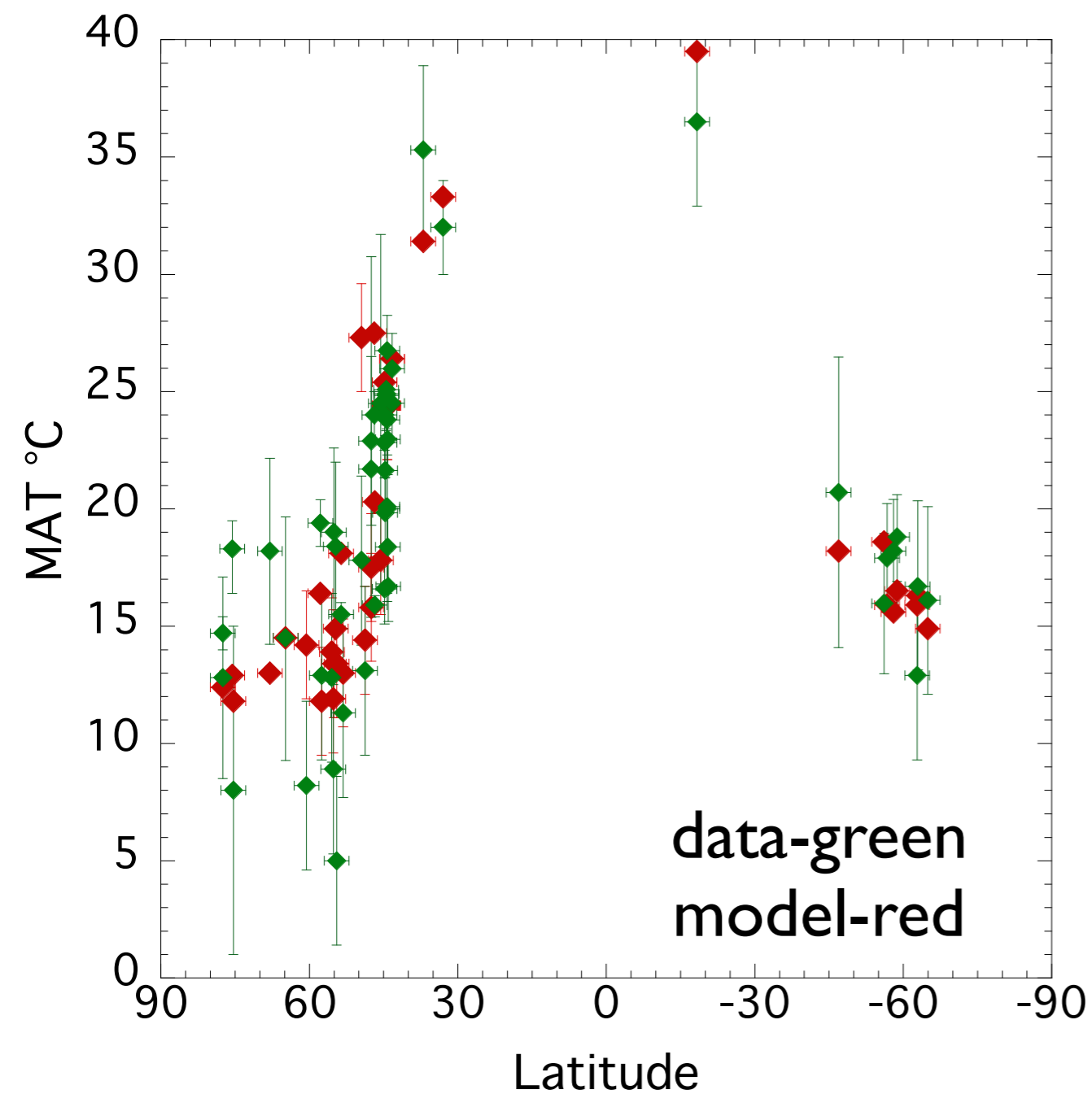
Eocene Model at 2240



Anomaly

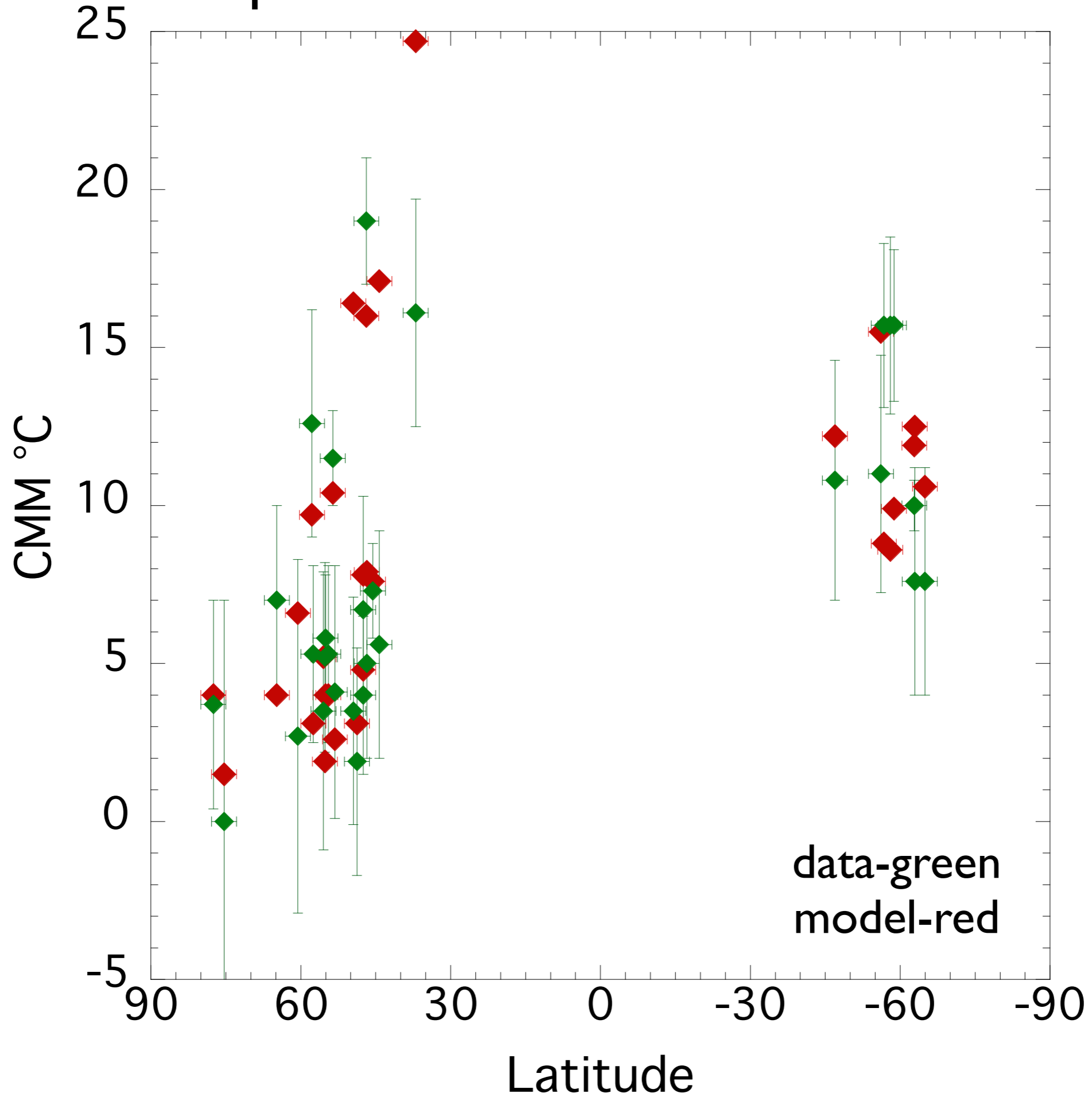


Model-data comparison

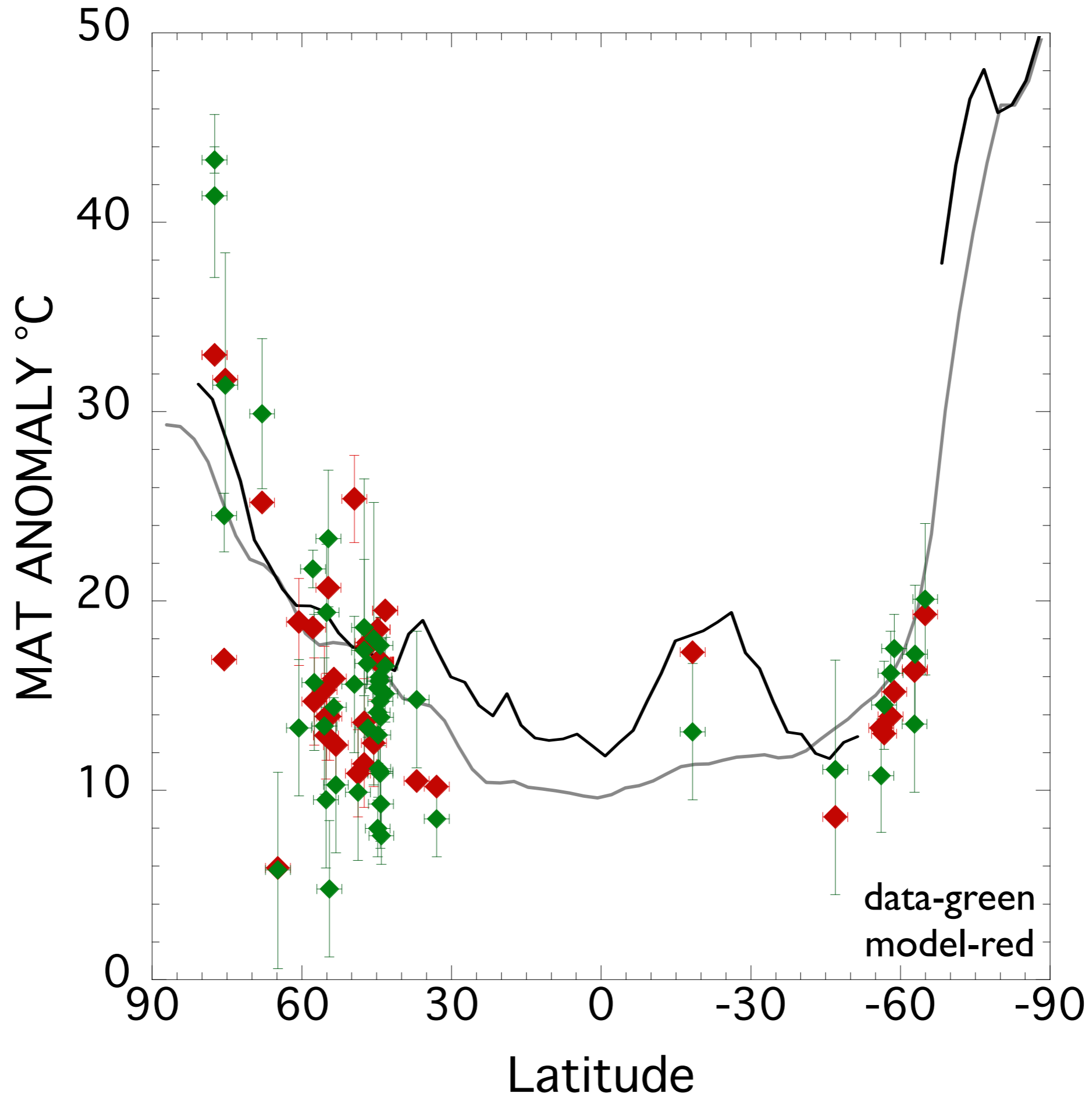


EOCENE Model at 4480 ppm, early Eocene proxy data

Model-data comparison for Cold Month Mean Temperature



Model-data comparison for warming with respect to Modern



A model-data comparison for an multi-model ensemble of Early Eocene Atmosphere-Ocean simulations: EoMIP.

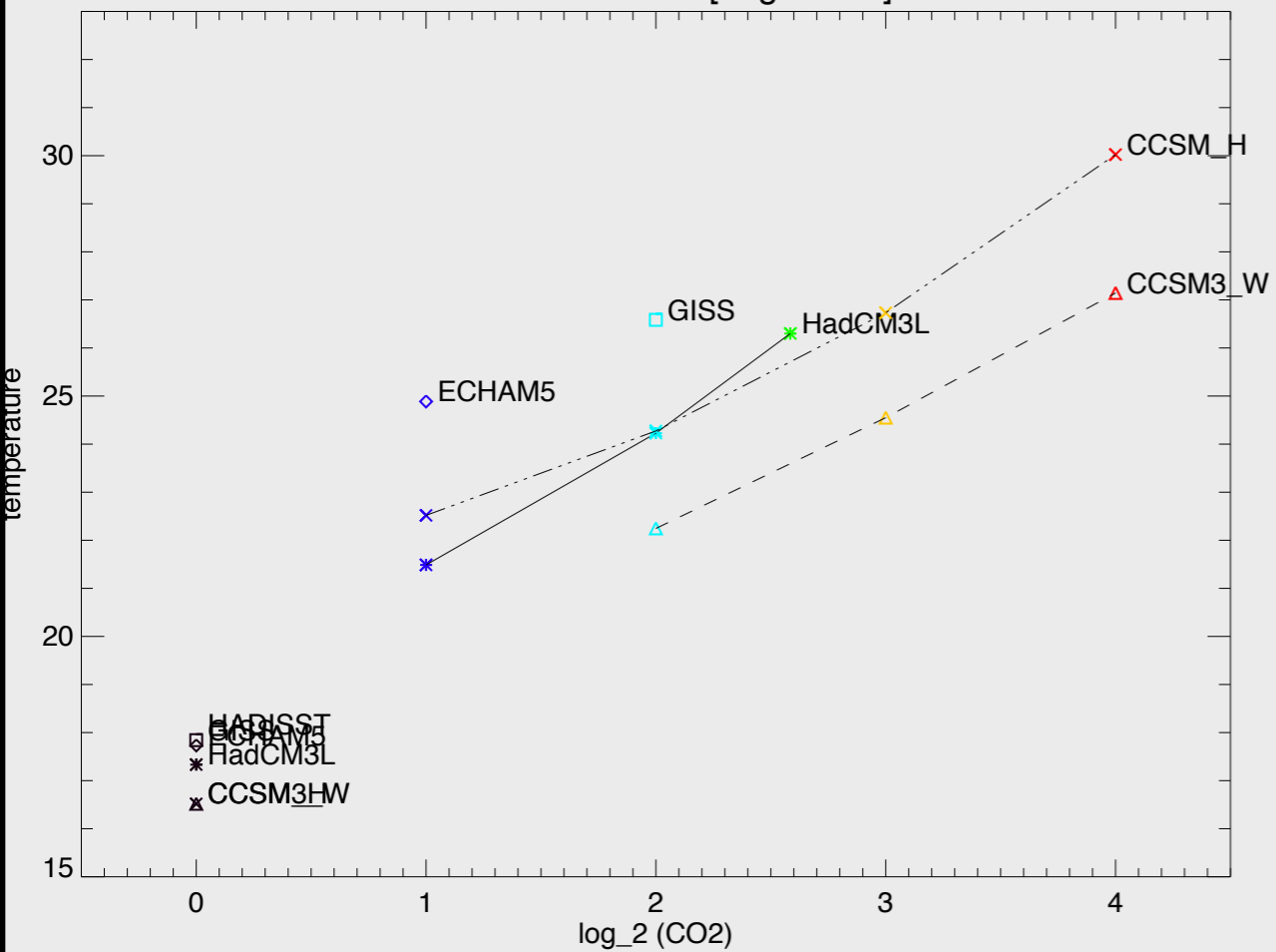
Daniel J. Lunt ^{*,1}, Tom Dunkley Jones ², Matt Huber ³, Malte Heinemann ⁴, Allegra LeGrande ⁵, Arne Winguth ⁶, Claire Loptson ¹

| Name | Eocene simulation reference | model name and reference | atmosphere resolution | ocean resolution | paleogeography | sim. length [years] | CO ₂ levels | vegetation | aerosols |
|--------|--------------------------------|--|-----------------------|------------------|-----------------------------|---------------------|------------------------|-----------------------------|------------|
| HadCM3 | Lunt <i>et al.</i> (2010) | HadCM3L, Cox <i>et al.</i> (2001) | 96×73×19 | 96×73×20 | propriety | >3400 | ×2,4,6 | homogenous shrubland | as control |
| ECHAM5 | Heinemann <i>et al.</i> (2009) | ECHAM5/MPI-OM, Roeckner <i>et al.</i> (2003) | 96×48×?? | ??×??×40 | Bice and Marotzke (2001) | 2500 | ×2 | homogenous low albedo | ?? |
| CCSM_W | Winguth <i>et al.</i> (2010) | CCSM3, Collins <i>et al.</i> (2006), Yeager <i>et al.</i> (2006) | 96×48×26 | 100×116×2 | Sewall <i>et al.</i> (2000) | 1500 | ×4,8,16 | Shellito and Sloan (2006) | ?? |
| CCSM_W | Huber and Caballero (2011) | CCSM3, Collins <i>et al.</i> (2006), Yeager <i>et al.</i> (2006) | 96×48×26 | 100×116× | Sewall <i>et al.</i> (2000) | 1500 | ×2,4,8,16 | Shellito and Sloan (2006) | ?? |
| GISS | Roberts <i>et al.</i> (2009) | GISS ModelE-R, Schmidt <i>et al.</i> | 72×45×20 | 72×45×13 | Bice and Marotzke (2001) | 2000 | ×2 | Sewall <i>et al.</i> (2000) | ?? |

Table 1: Summary of model simulations in EoMIP. Some models have irregular grids in the atmosphere and/or ocean, or have spectral atmospheres. The atmospheric and ocean resolutions are given in number of gridboxes, X×Y×Z where X is the effective number of gridboxes in the zonal, Y in the meridional, and Z in the vertical. See the original references for more details.

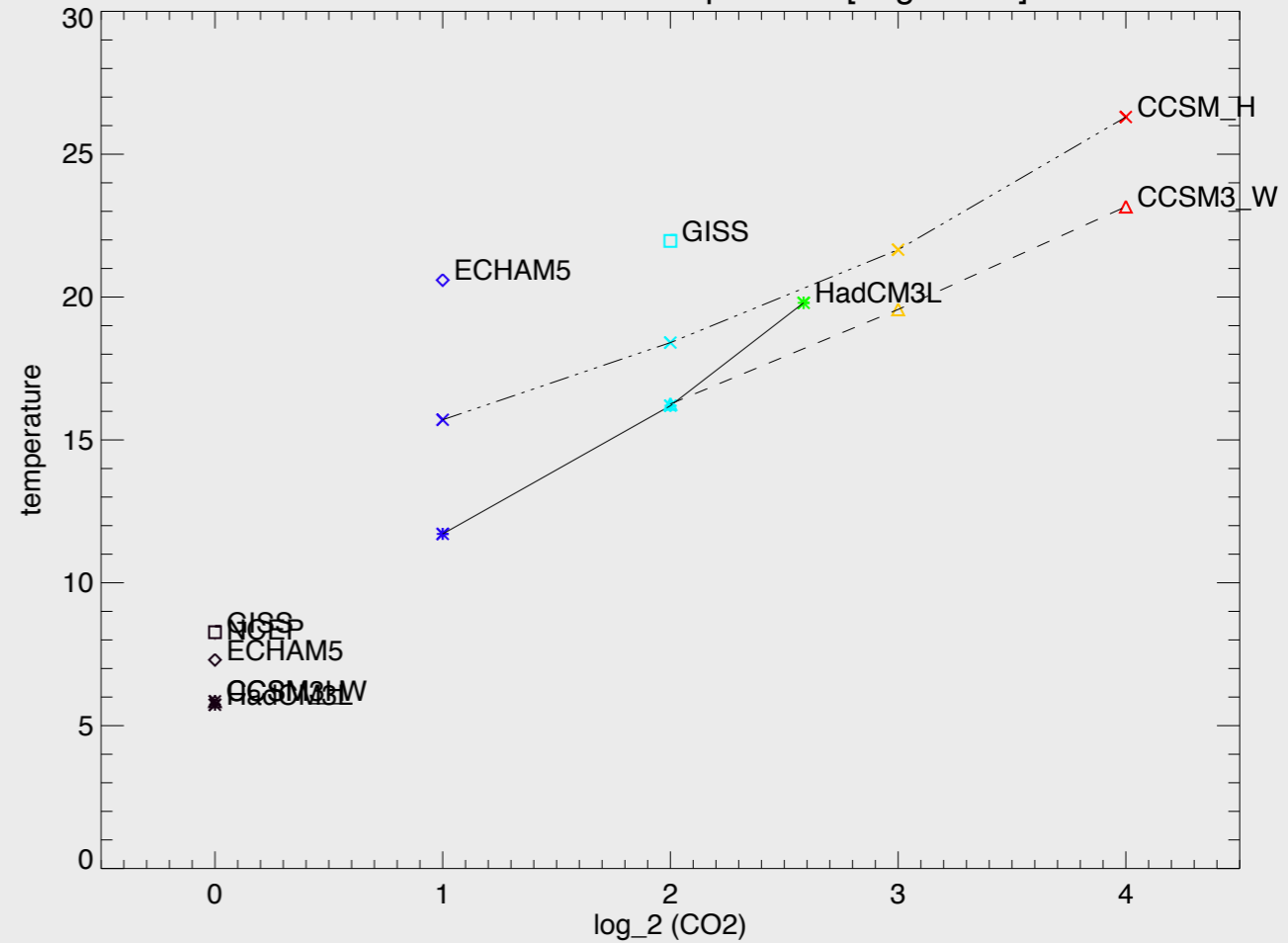
Lunt et al, in prep

Global mean SST [degrees C]



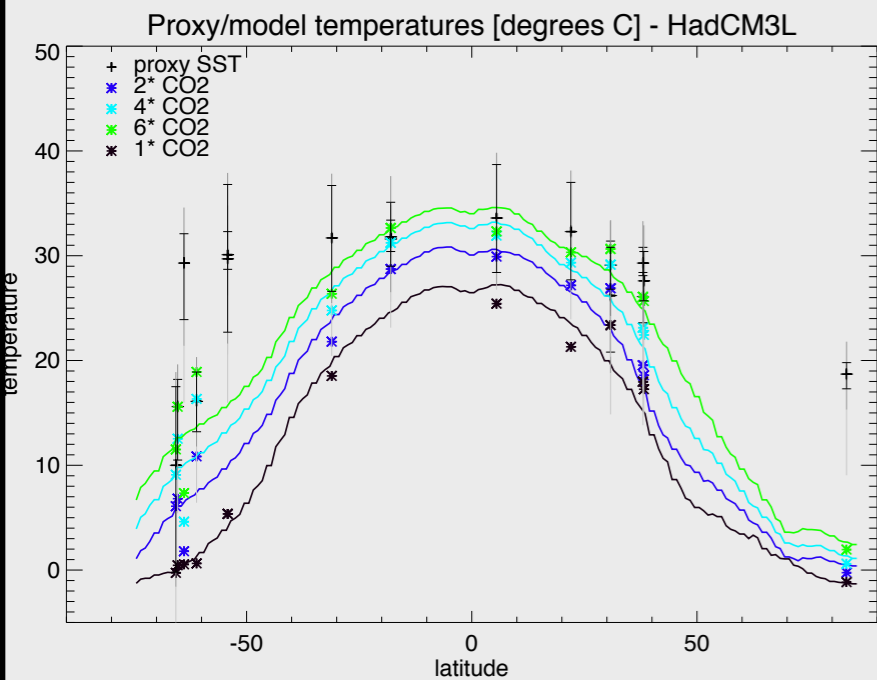
(a)

Global mean surface temperature [degrees C]

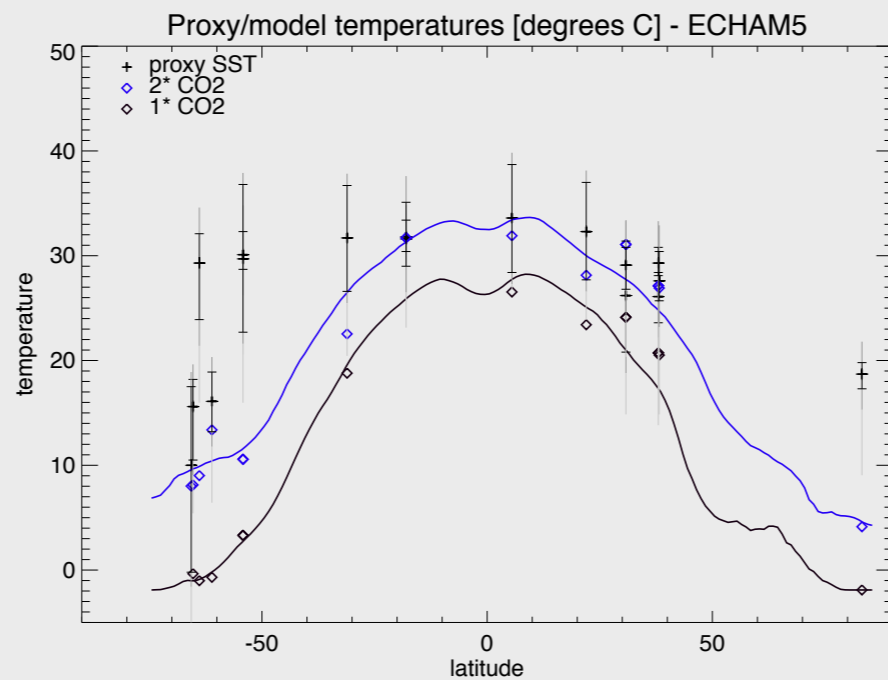


(b)

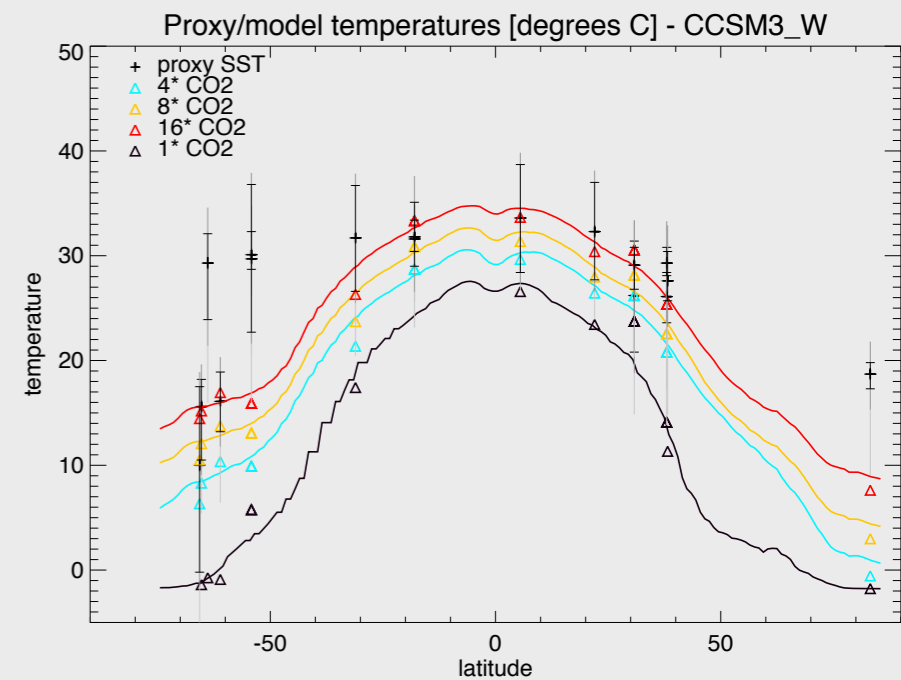
Lunt et al, in prep



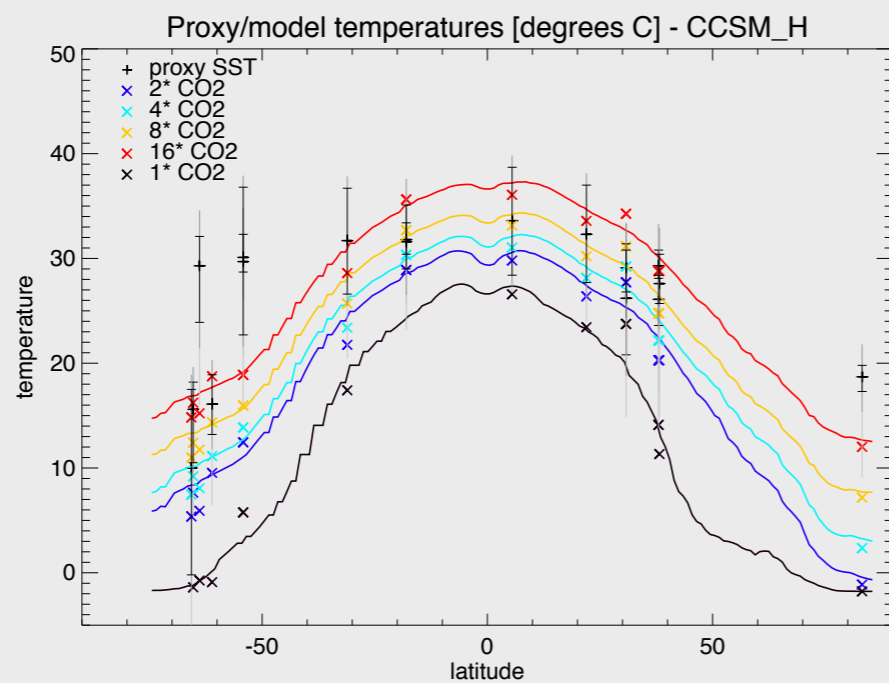
(a)



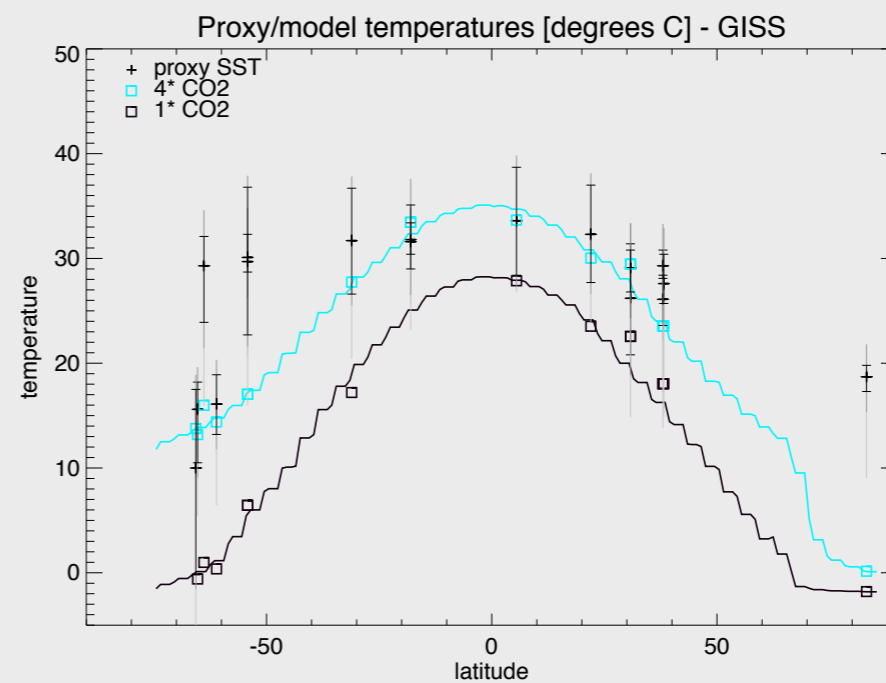
(b)



(c)

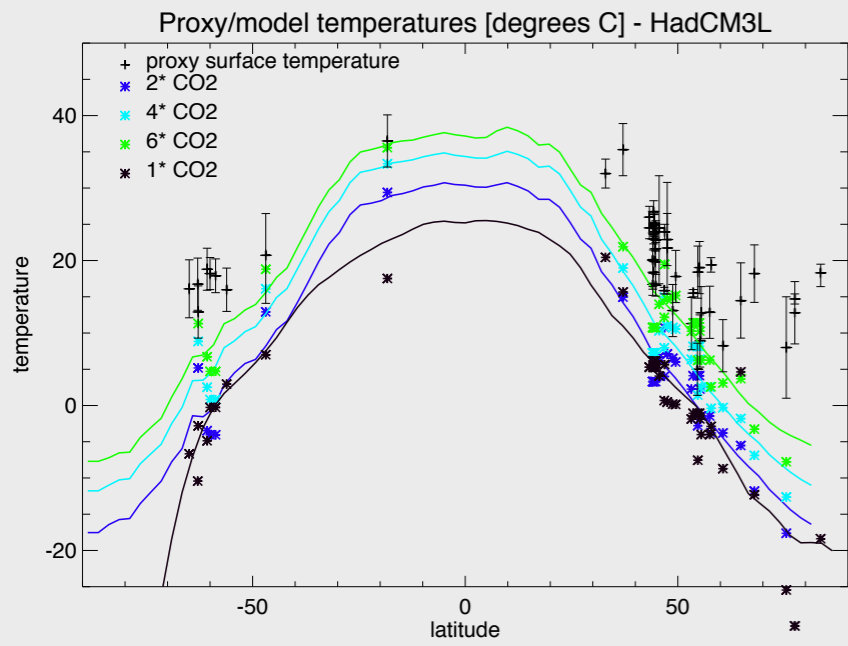


(d)

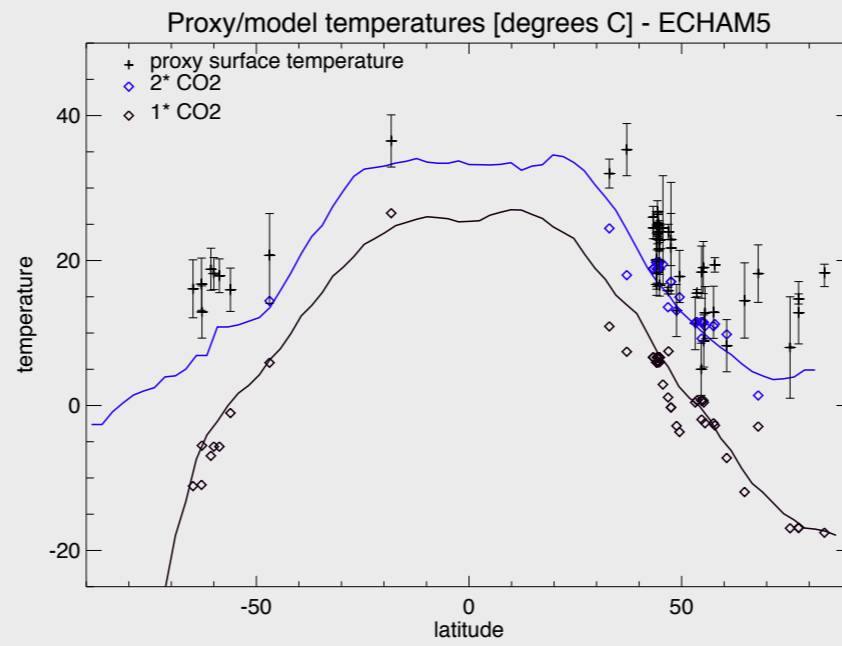


(e)

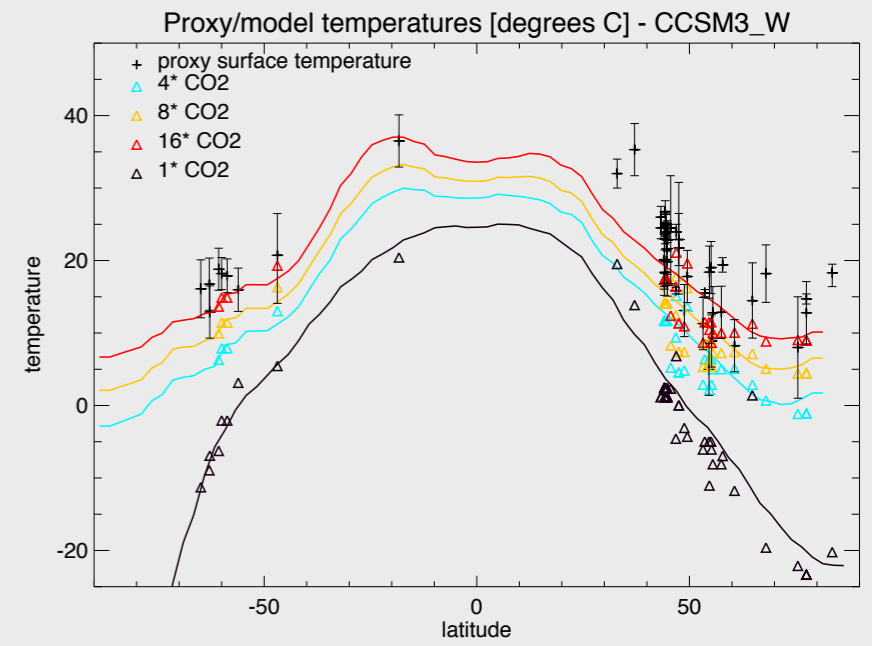
Lunt et al, in prep



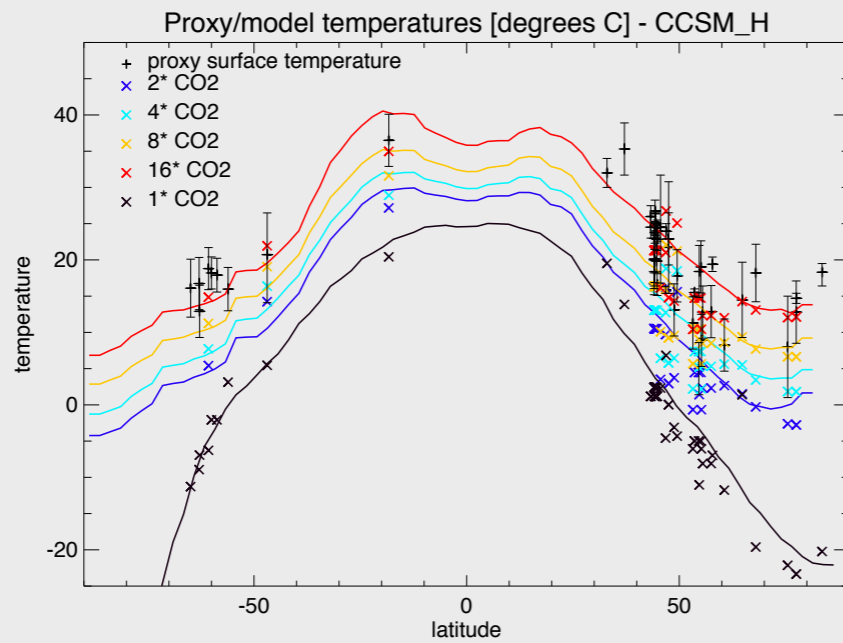
(a)



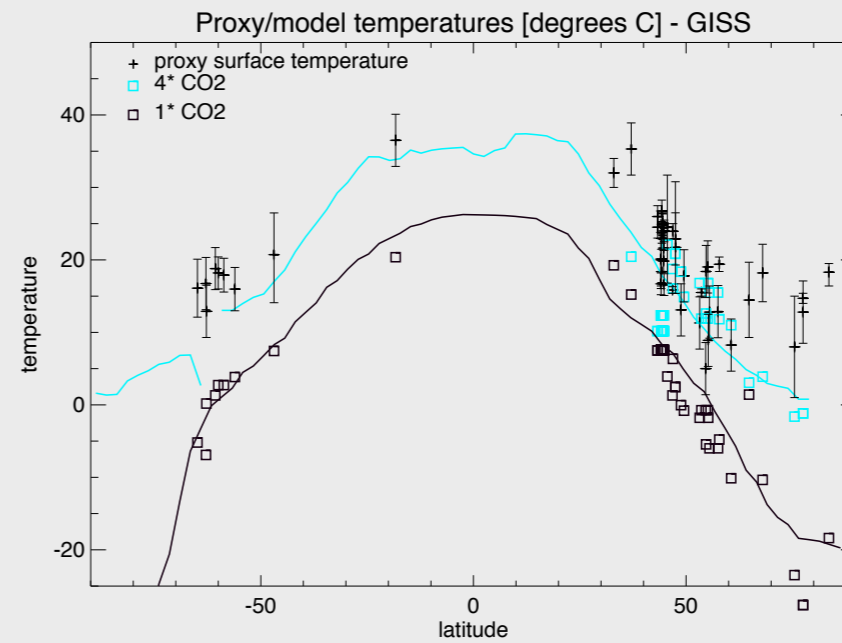
(b)



(c)

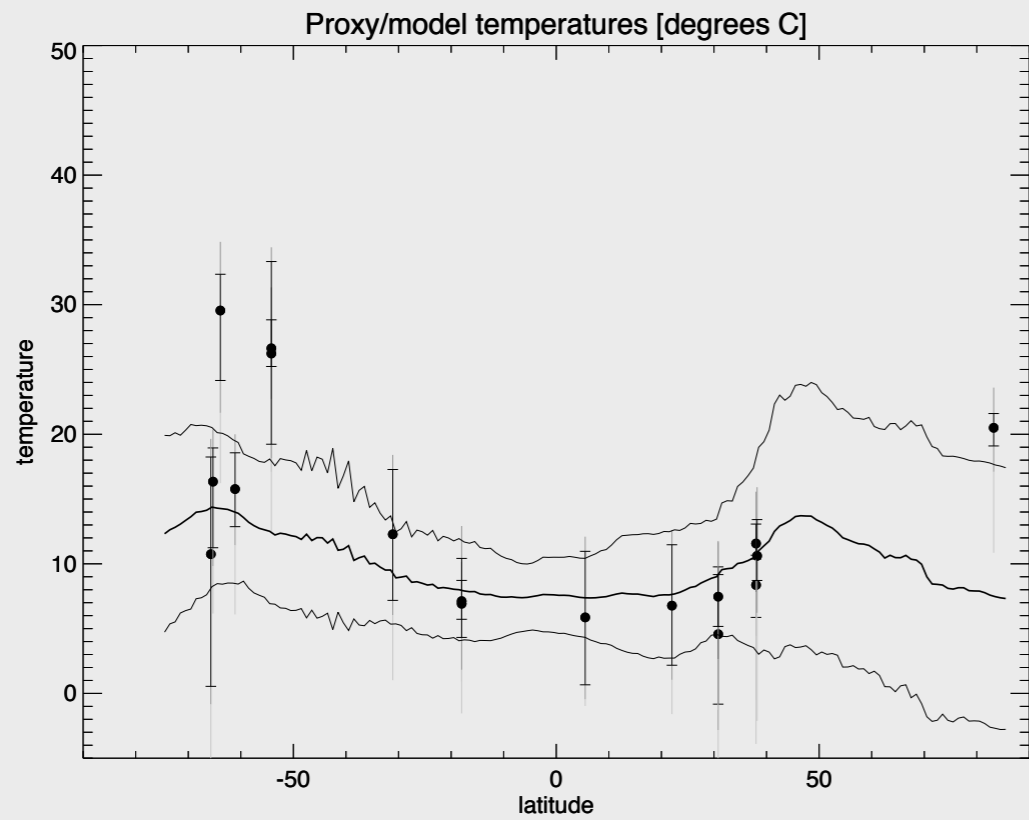


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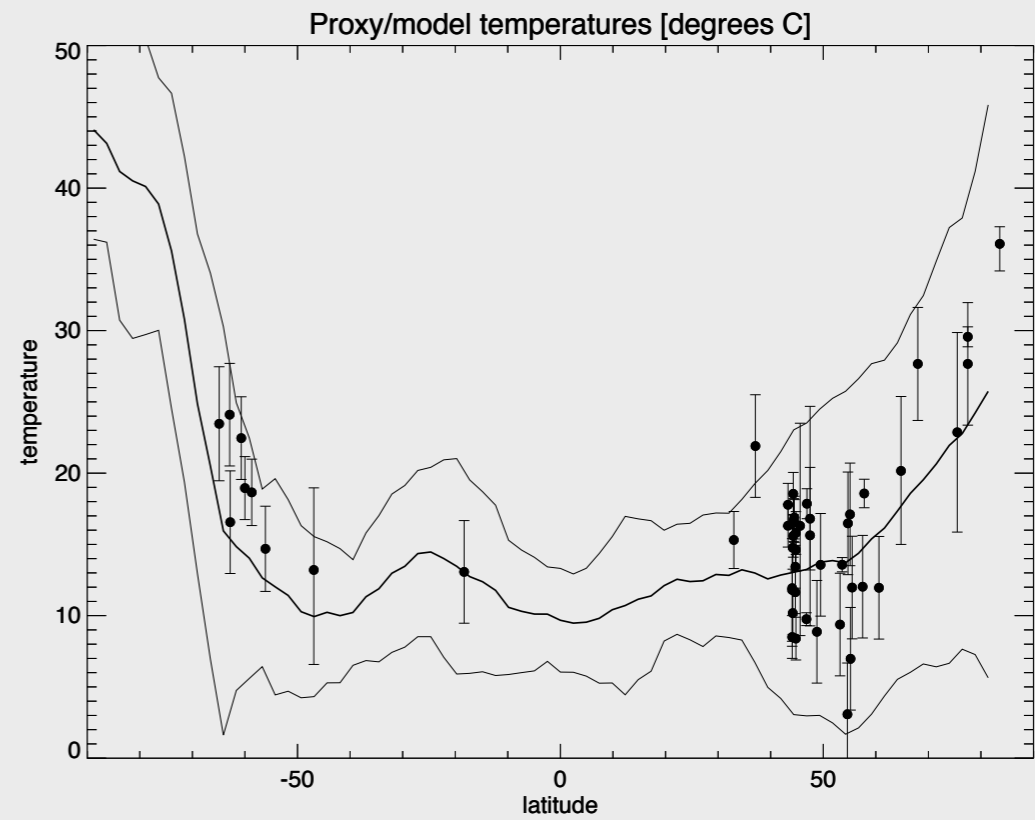


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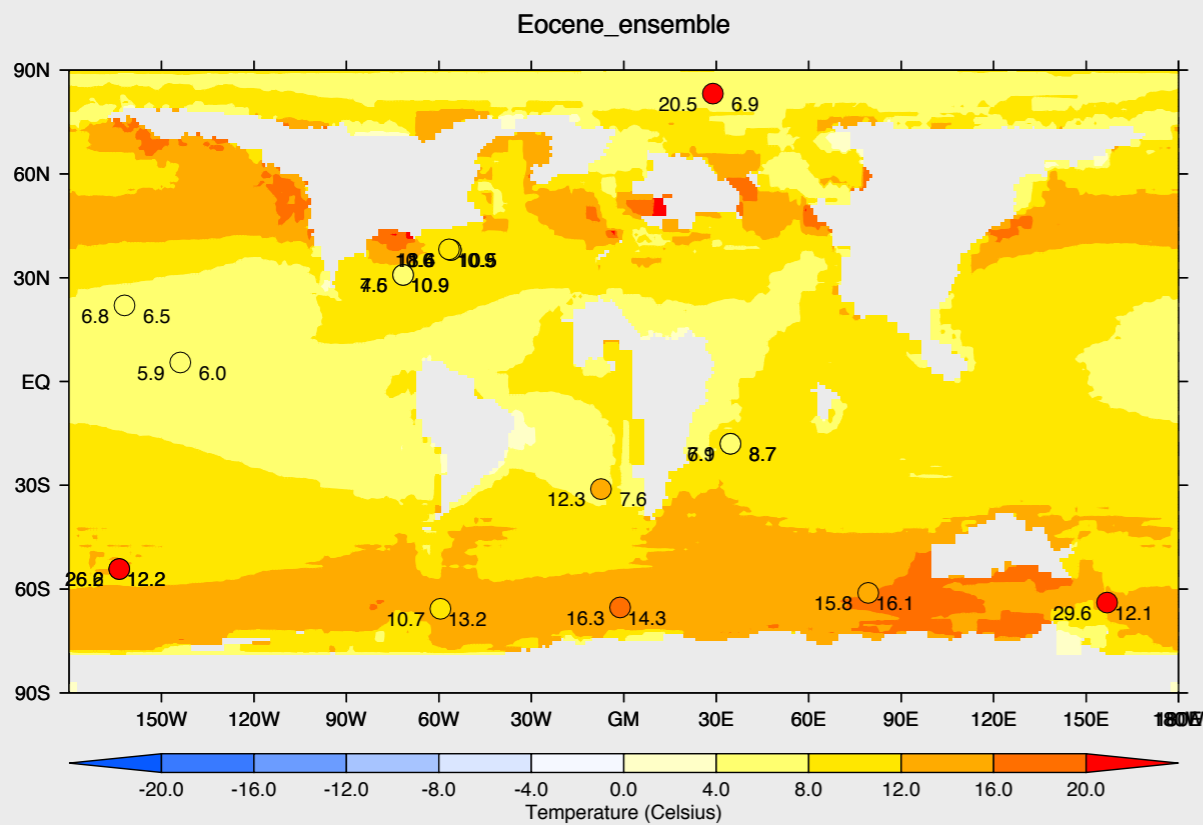
Lunt et al, in prep



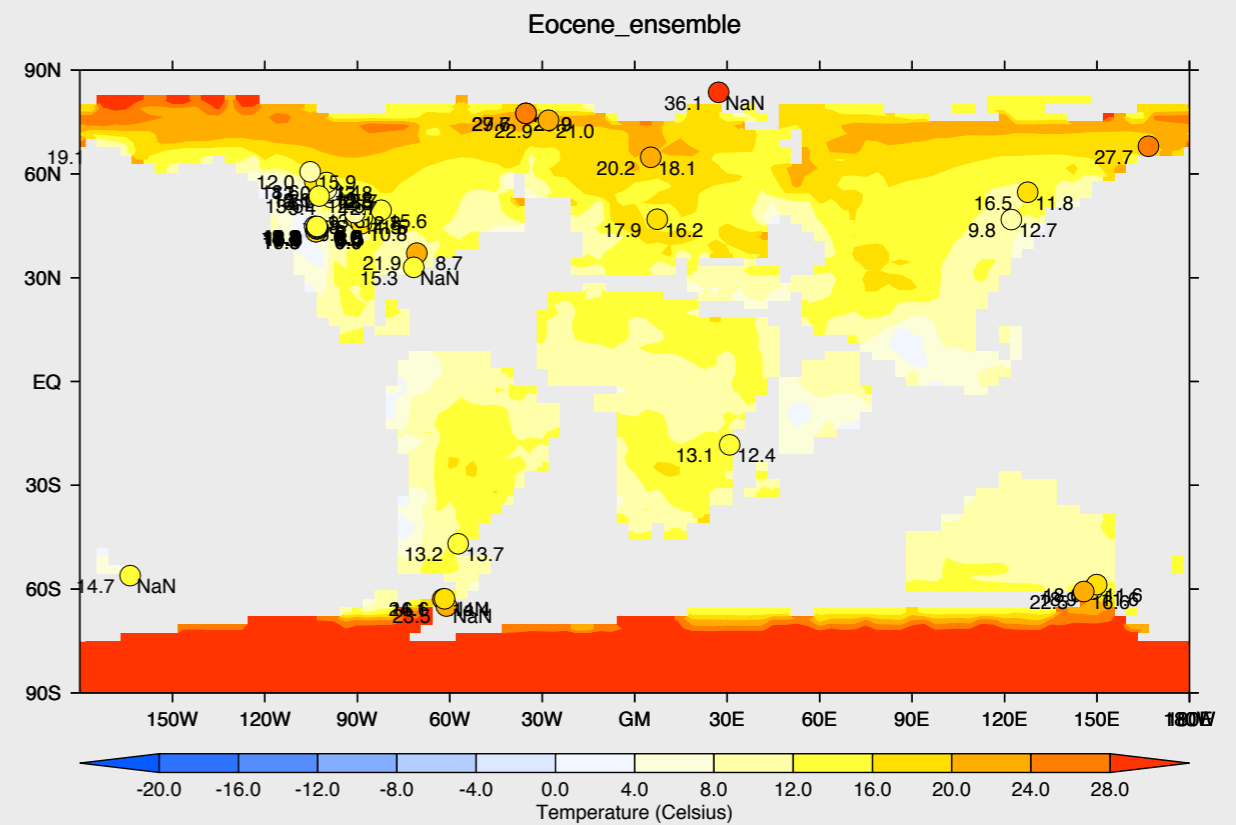
(a)



(b)



(a)

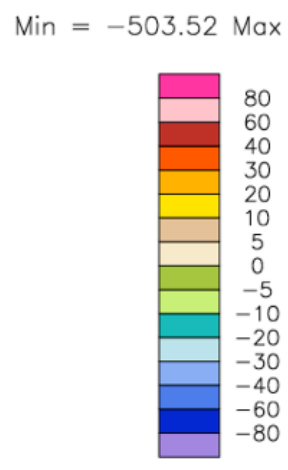
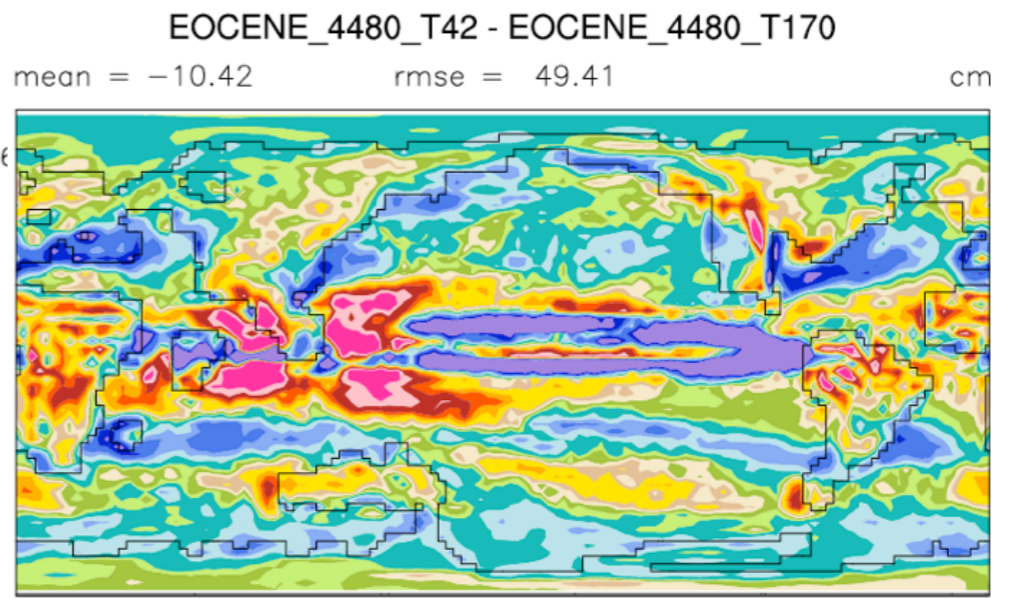
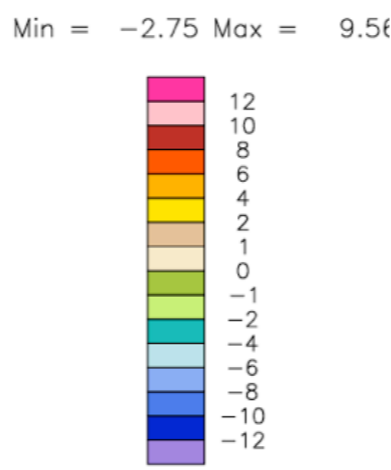
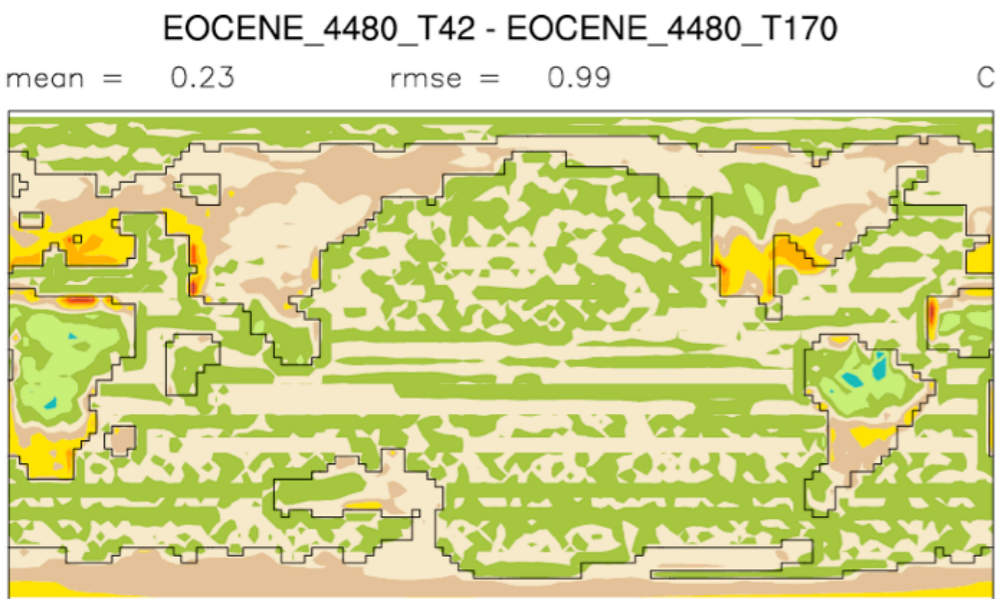
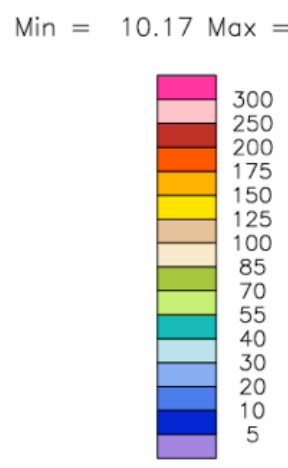
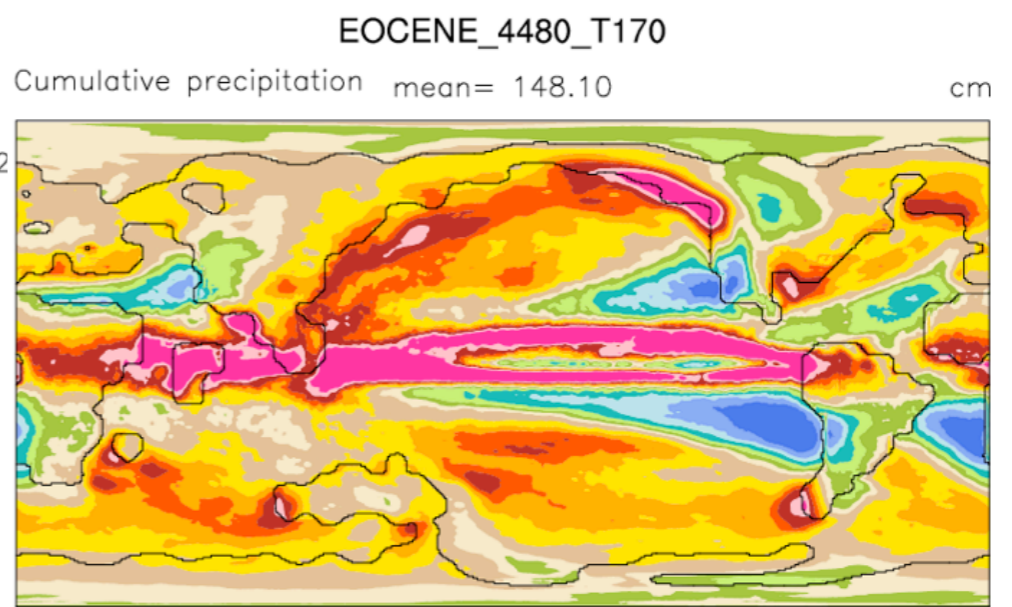
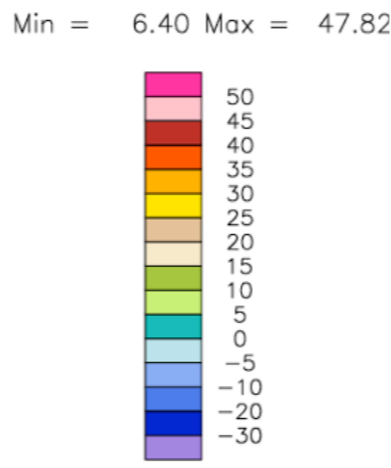
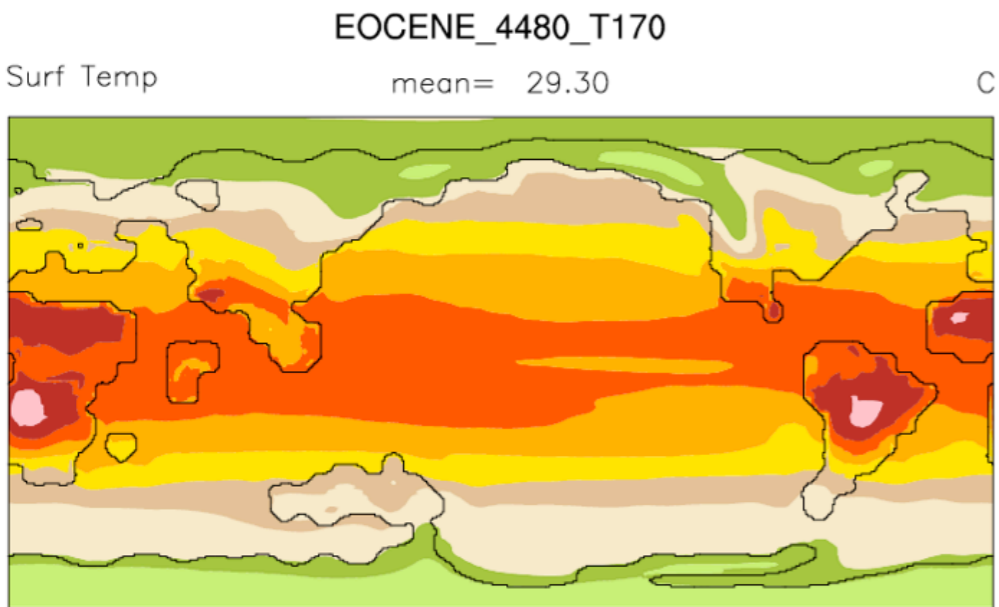
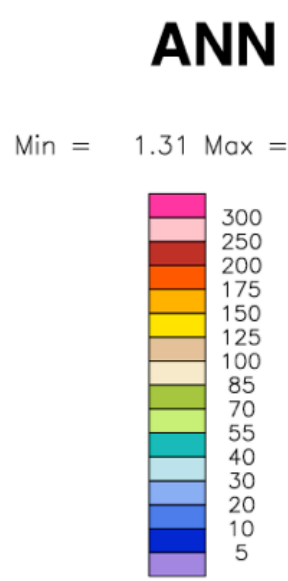
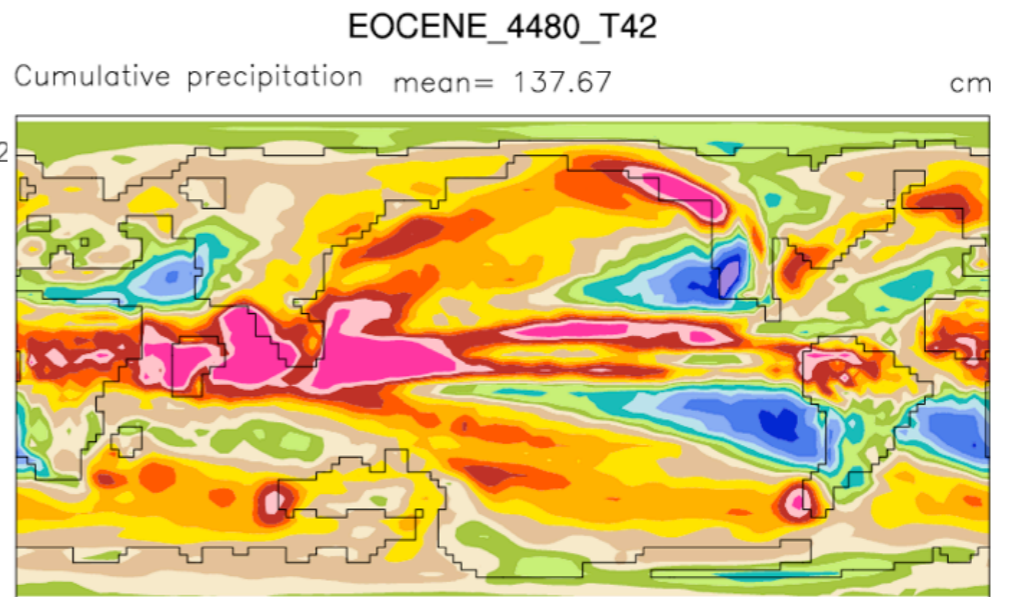
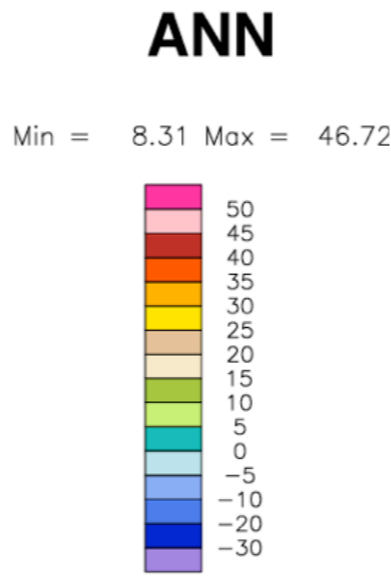
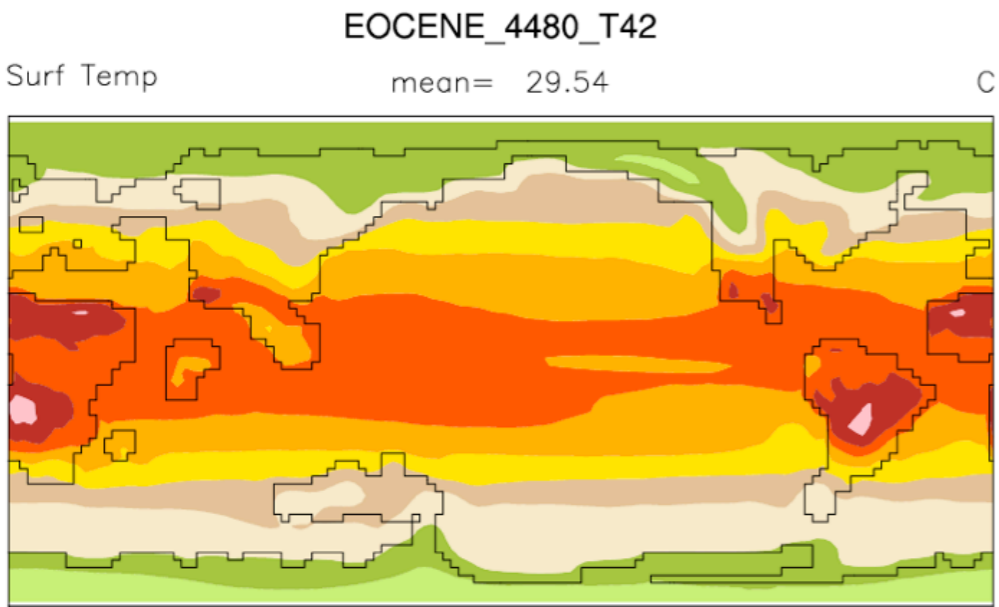


(b)

Lunt et al, in prep

High Resolution CAM3

- T170 versus T42 Eocene Fixed SST at 4480 ppm CO₂



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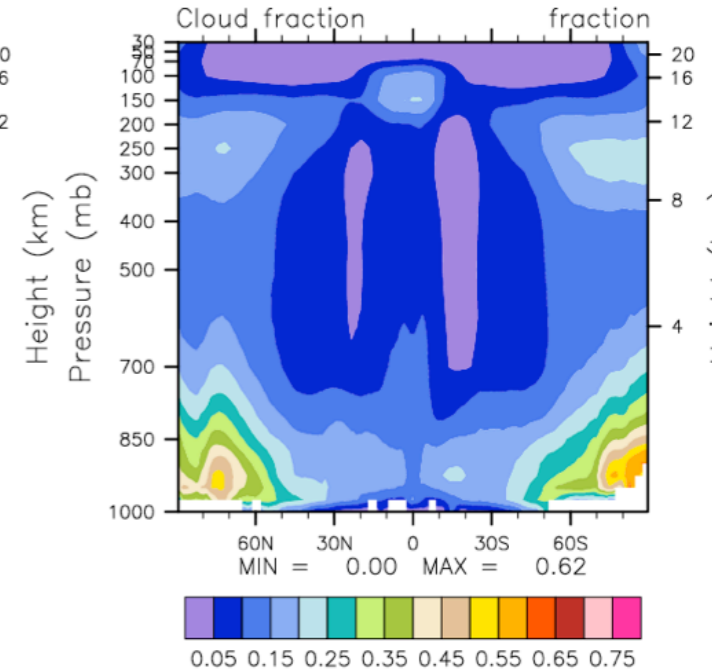
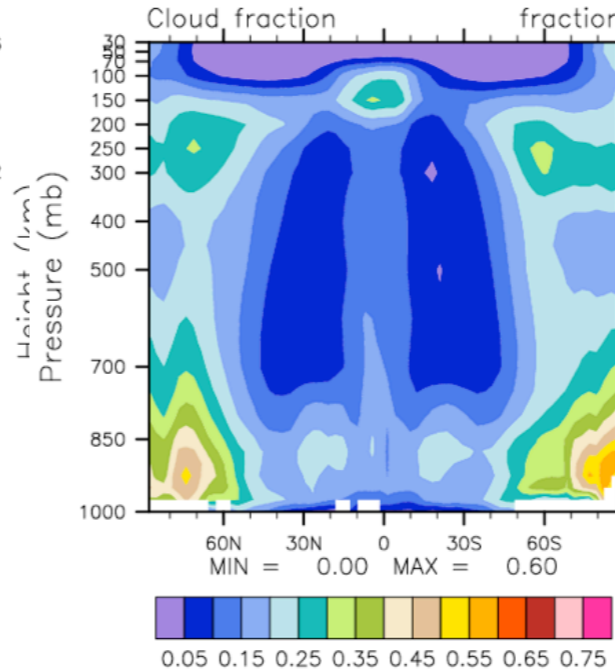
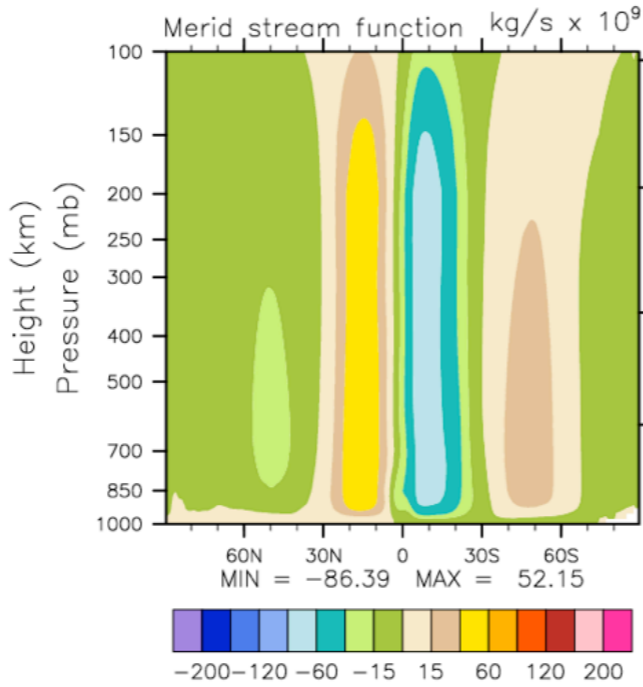
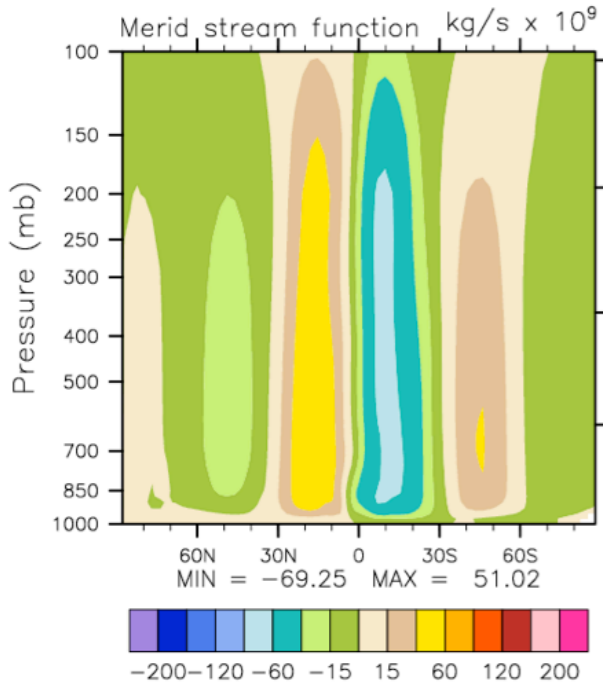
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EOCENE_4480_T42

EOCENE_4480_T170

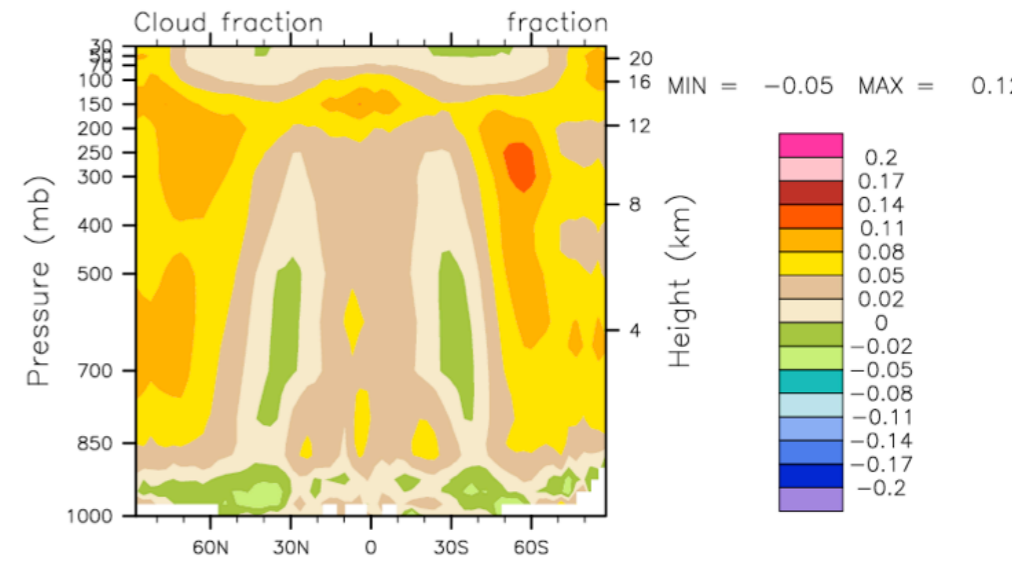
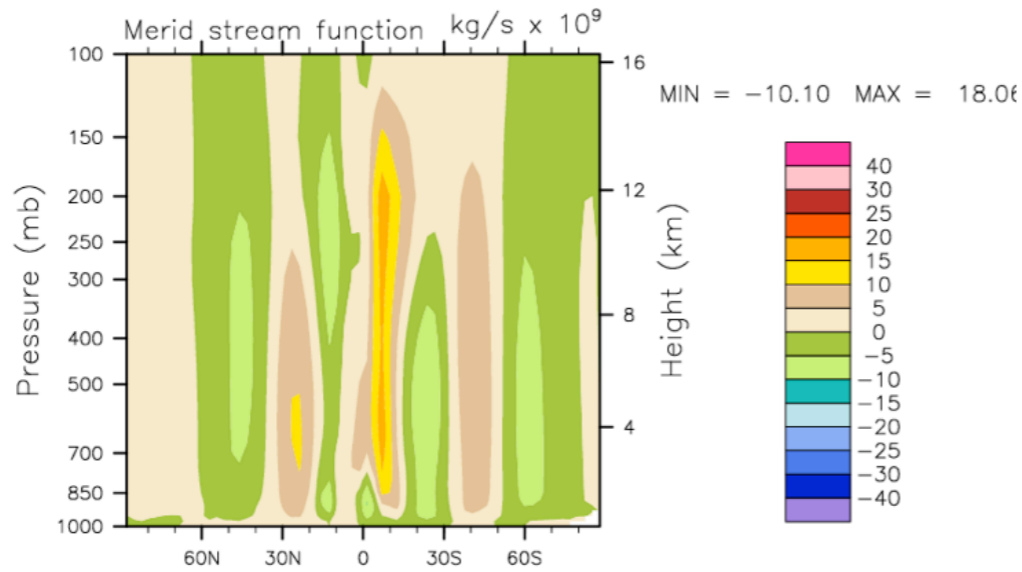
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EOCENE_4480_T170



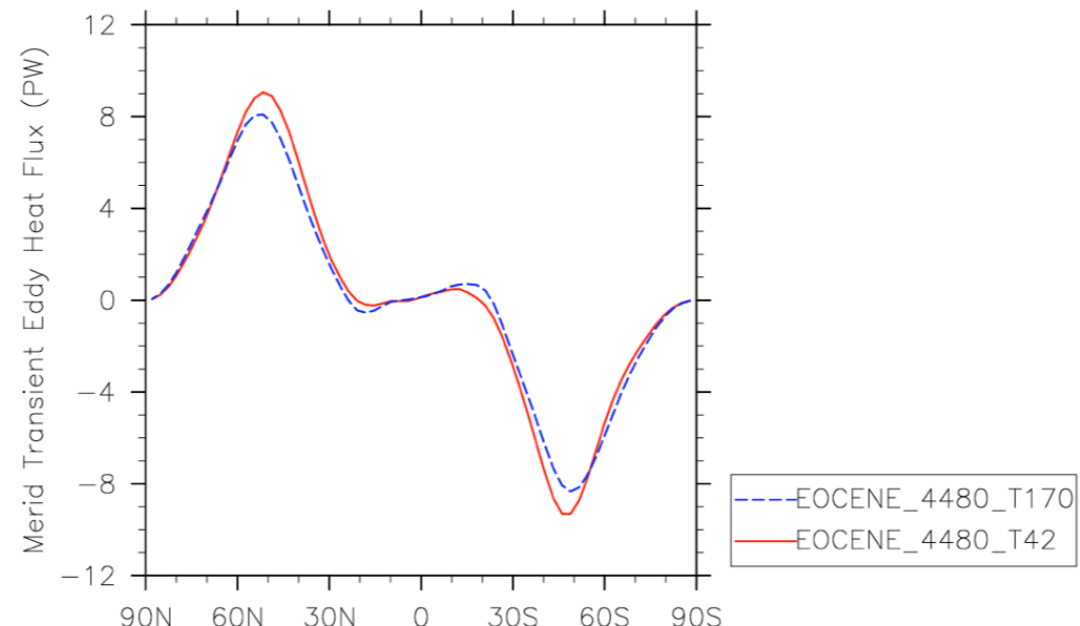
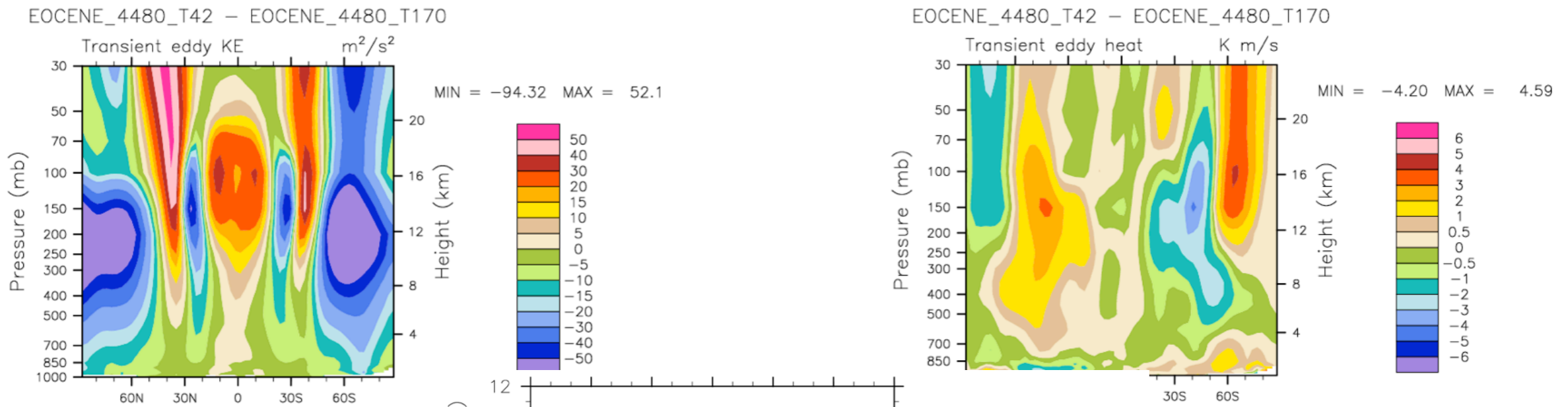
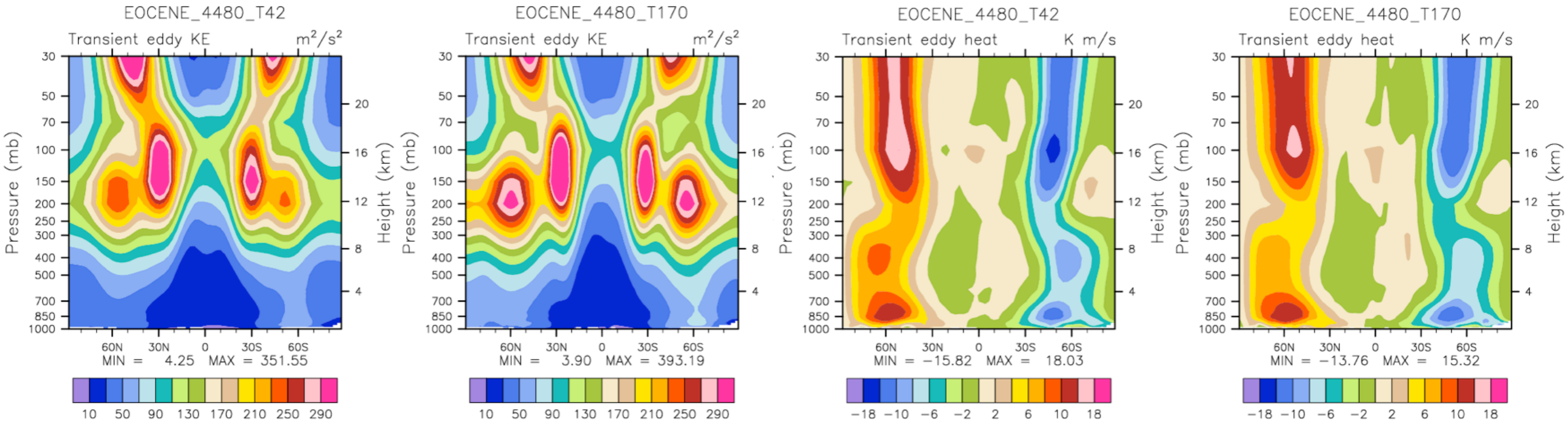
EOCENE_4480_T42 - EOCENE_4480_T170

EOCENE_4480_T42 - EOCENE_4480_T170



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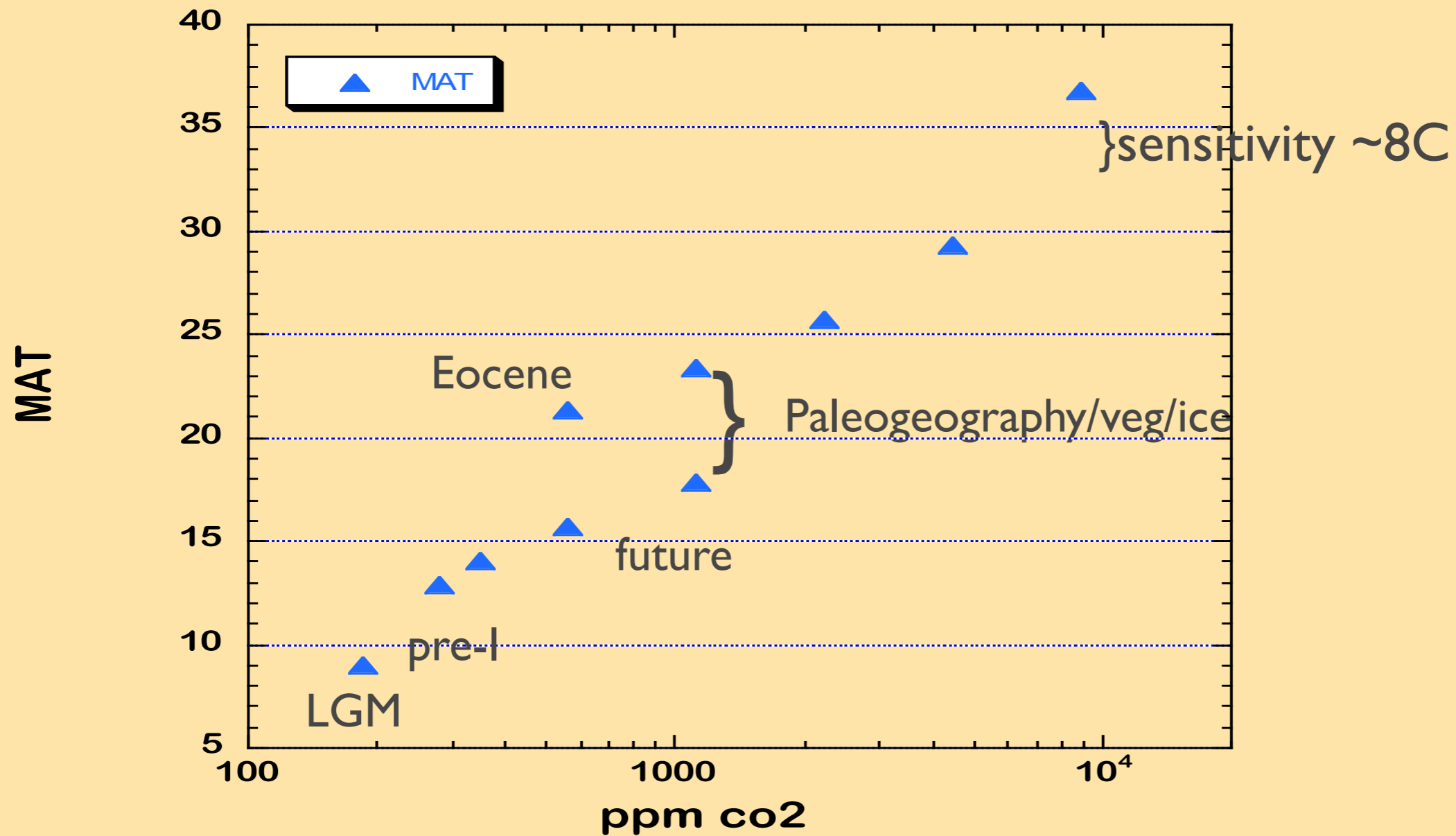
DIAG Version: 10040

Implications for sensitivity

putting it all together

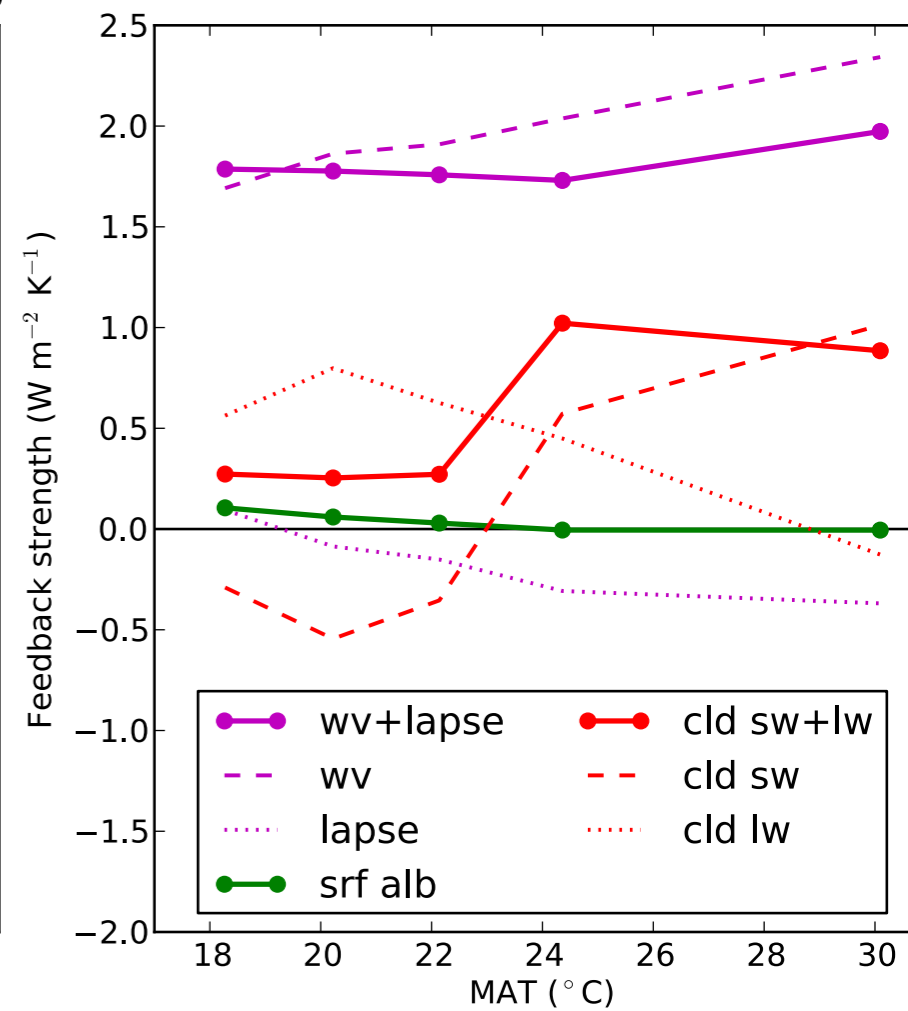
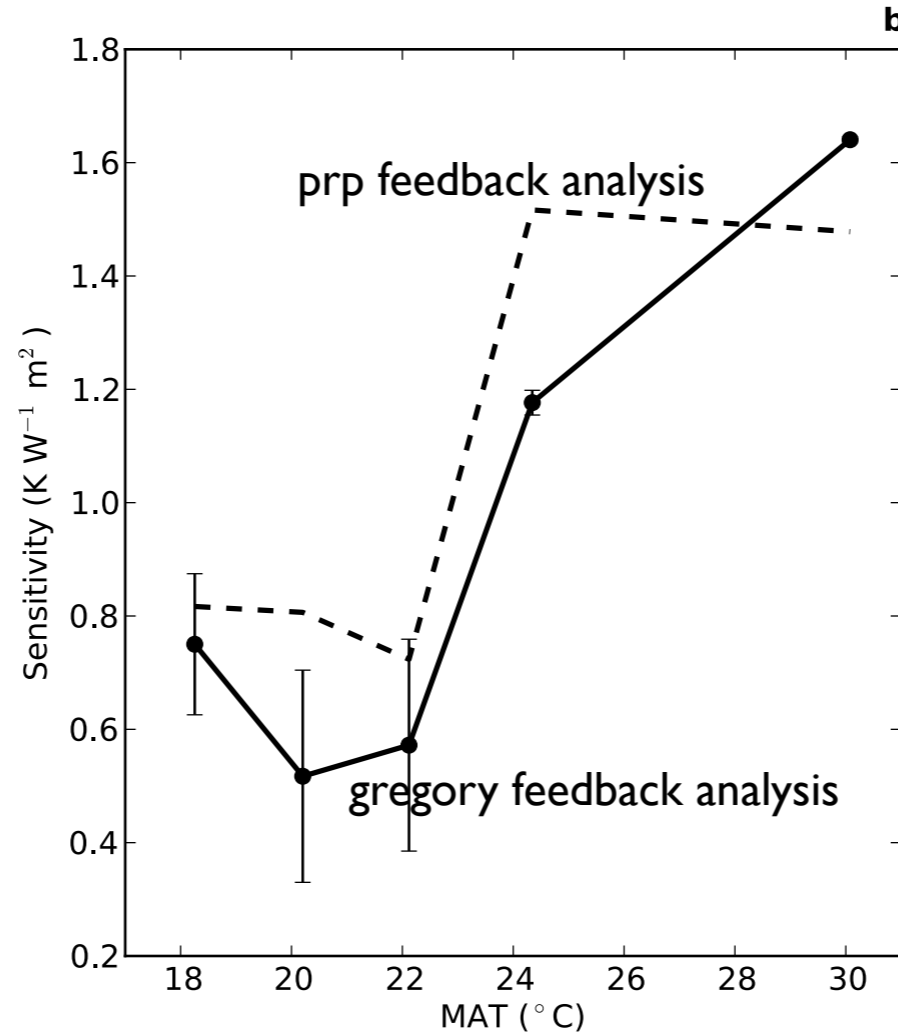
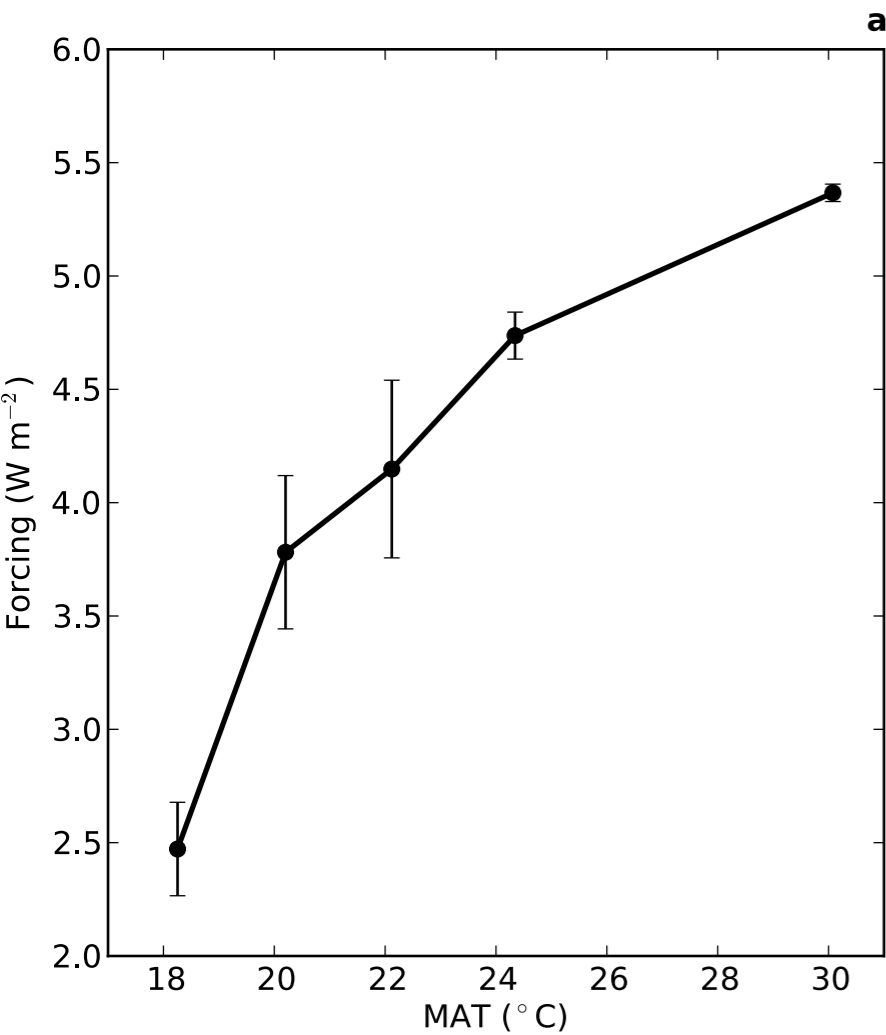
in collaboration with Rodrigo Caballero

Sensitivity increases with Temperature



CCSM3 results

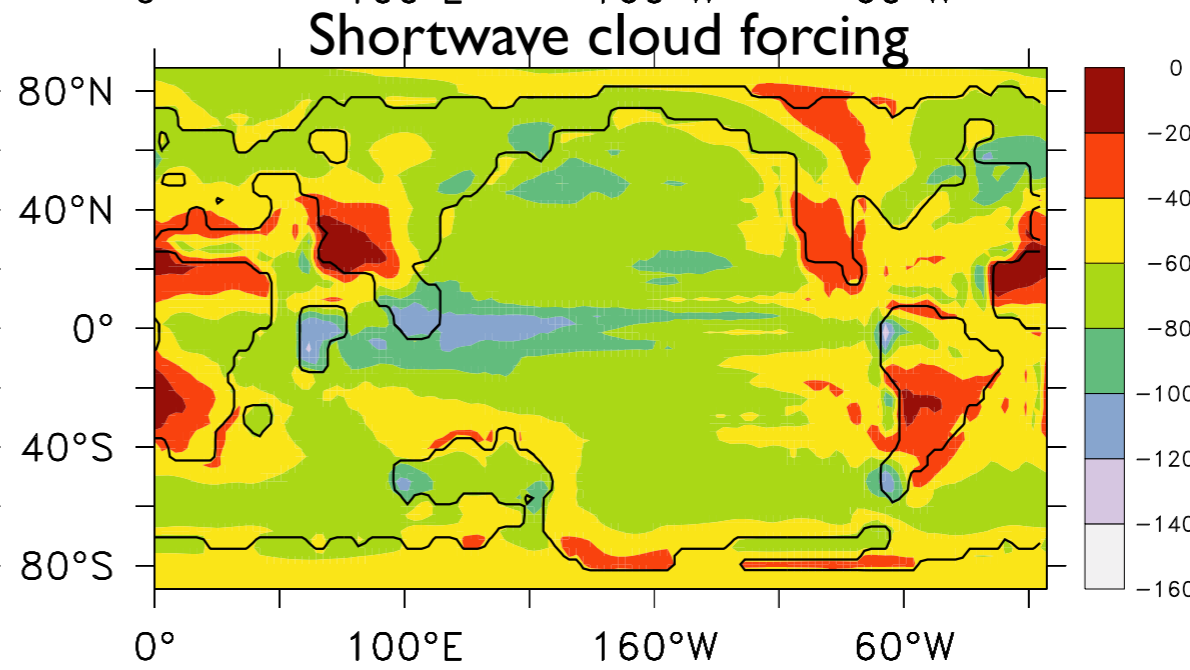
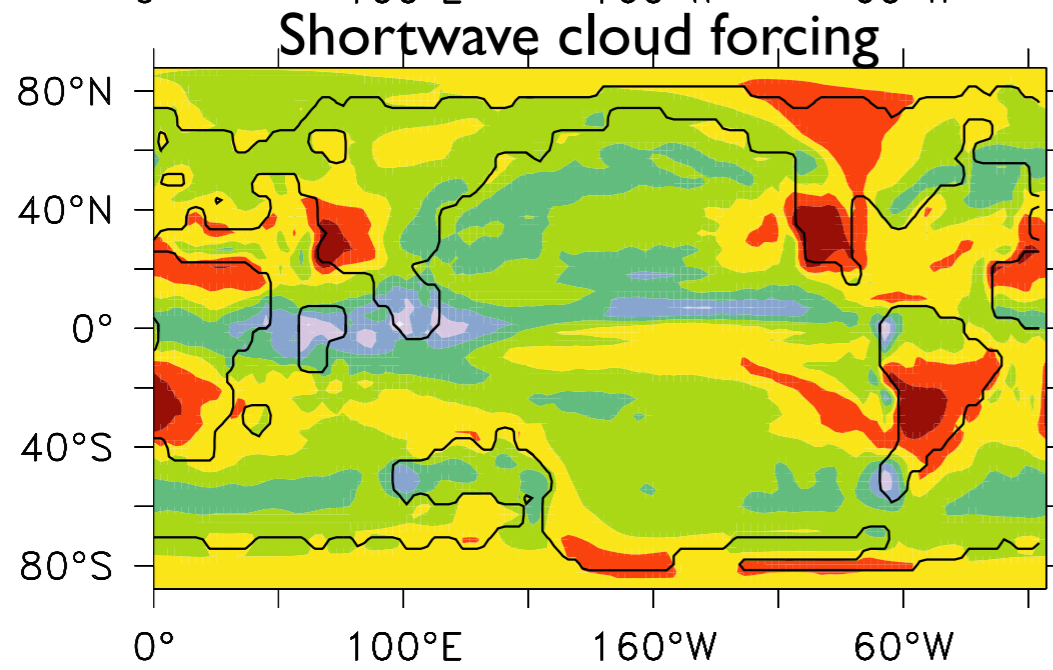
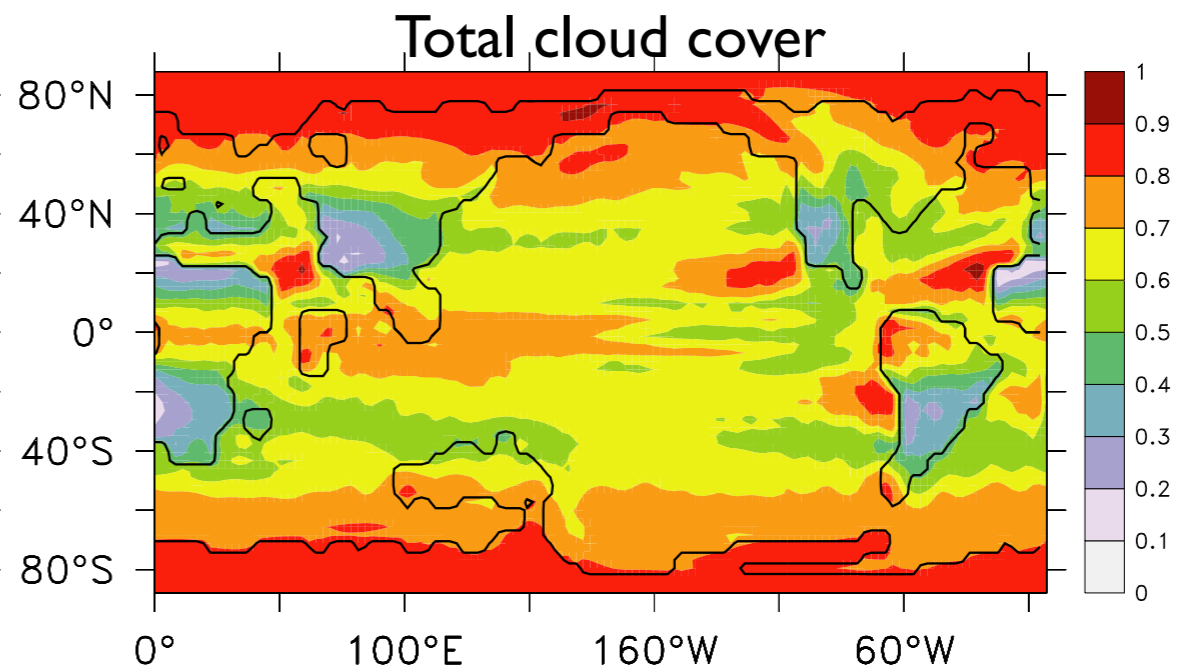
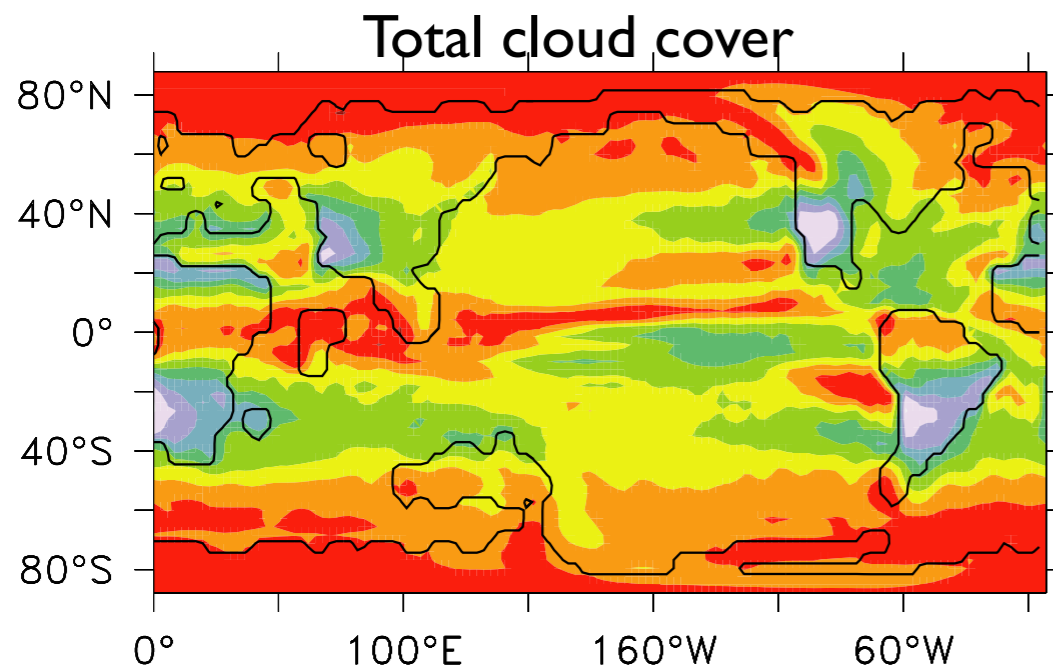
Sensitivity Feedback Analysis



in collaboration with Rodrigo Caballero

Eocene 2240 ppm CO₂

Eocene 4480 ppm CO₂



in collaboration with Rodrigo Caballero

Conclusions

- One can approximately reproduce Eocene climate with sufficiently large radiative forcing--apparently in all models
- CESM was easy to setup and run for deep paleo on a university cluster--thanks to the Software Engineers!
- CCSM3 is not importantly different than CESM (CAM4) for the Eocene, nor is high resolution an important factor--We're eager to use CAM5 but that's not currently possible
- Climate sensitivity ("fast" or "slow"--we can't say which) is higher than that indicated by CCSM3/CESM (given the overly large radiative forcing required)