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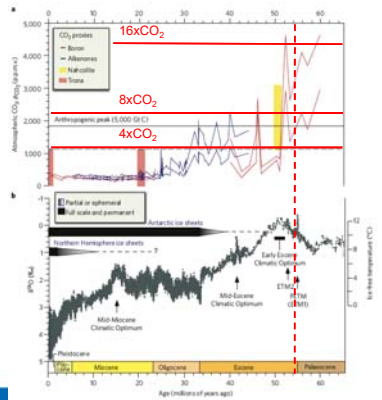
Eocene Hyperthermal Events – A Model Study with

Arne M.E. Winguth[1]
Liz Griffith[1]
Taylor Hughlett[1]
Celli Hull[2]
Jeff Kiehl[4,5]
Robert Letscher[3]
Mathew Rothstein[4]
Christine Shields[5]
Ellen Thomas[2,6]
Cornelia Winguth[1]

[1]University of Texas at Arlington
[2]Yale University
[3]University of California, Irving
[4]University of California, Santa Cruz
[5]National Center for Atmospheric Research
[6]Wesleyan University



Zachos et al., Nature, 2008

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Evidence for Hothouse at the Early Eocene

- Crocodiles and Turtles in the Arctic (Marvick et al., 1998)
- Palm trees in Antarctica with temperatures exceeding 10 °C in the winter time and 25 °C in the summer time (Pross et al., 2012)
- Titanoboa in Columbia (Head et al., 2009)

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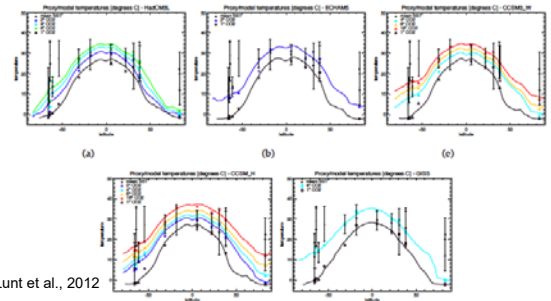
Model-Data Comparison Sea Surface Temperature [°C]



Lunt et al., 2012

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Proposals why climate models simulated too cold polar regions

- ❑ Increased ocean heat transport (Barron and Washington, 1982)
- ❑ Polar stratospheric clouds related to enhanced atmospheric methane (CH4) (Sloan and Pollard, 1998)
- ❑ Increased deep cloud convection at high latitudes with associated longwave cloud radiative forcing
- ❑ Opening of passageways in the Arctic (Shellito et al., 2009; Cope and Winguth, 2011)

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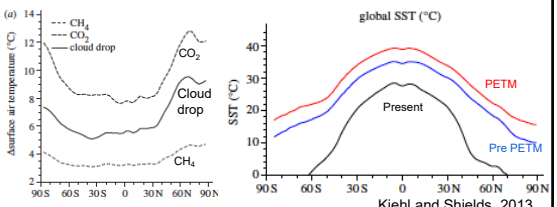
Alternative hypothesis for polar warming: reduction in cloud condensation nuclei (Kump and Pollard, 1998)



Kiehl and Shields, 2013

Paleo latitude	surface temperature (°C)
75° N (Arctic)	25 (17) [28]
47° N (Big Horn, WY)[a]	20–26 (25) [40]
~ 36° N (NJ coast)	33 (32) [37]
~ 6° N (Columbia)[a]	38–40 (38) [37]
55° S (New Zealand)	33 (23) [28]
65° S	25 (23) [28]

Moderate Resolution CESM 1.2.2
Atmosphere: FV1.9° x 2.5°
Ocean: ~1° x 1°

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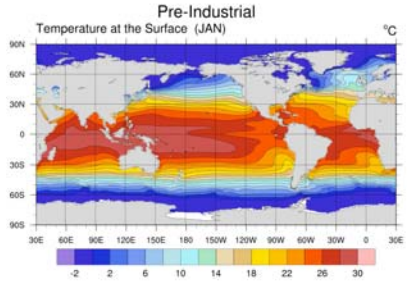

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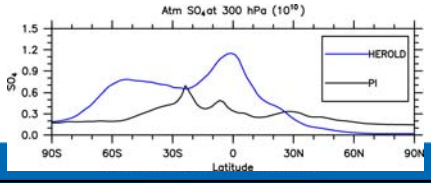
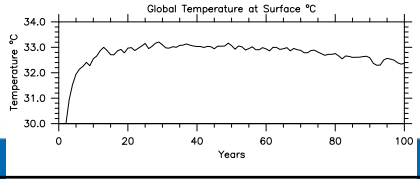
PETM Boundary Conditions (DeepMIP; Lunt et al., 2017)

- PI solar constant 1361 W m^{-2}
- PI orbital cycles
- Increase of CO_2 concentration to 6xCO_2 PAL
- Other boundary conditions from Herold et al., 2014

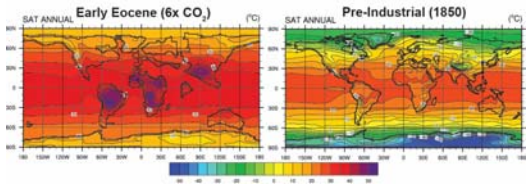


PETM Initial Conditions

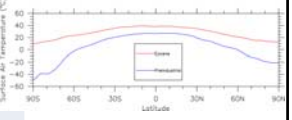
- Atmosphere: PI 1850 scenario
- Ocean Physics: Lunt et al., in press (temperature: 25°C (surface) and 10°C (deep sea); salinity: 34.7 psu
- Otl 4



Surface Air Temperature



Paleolatitude	Paleoproxy T [°C]	CESM1.2 T [°C]
75 °N (Arctic)	25	15-20
47 °N (B. Horn, WY)	20-26	25
36 °N (NJ Coast)	33	30
6 °N (Columbia)	38-40	35
55 °S (N. Zealand)	33	25
65 °S	25	20



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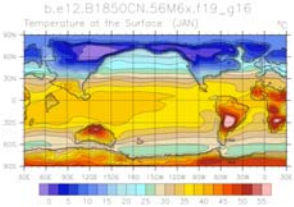

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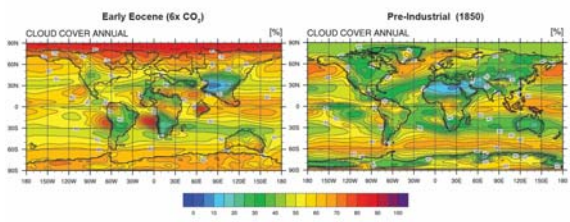
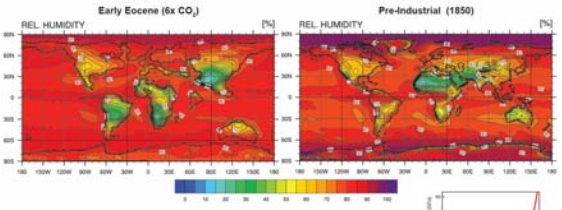
Change in Cloud Cover



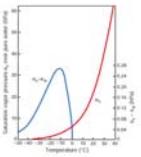
Following differences relative to the PI simulations occur:

1. Higher cloud cover in high latitudes
2. Higher cloud cover upwelling zones
3. Higher Eocene cloud cover by enhanced convection in the tropics

Change in Rel. Humidity

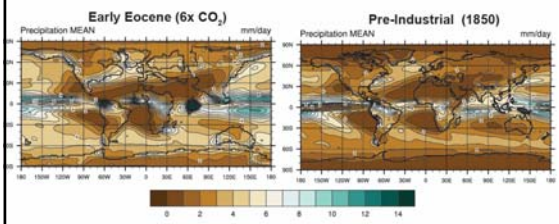


Relative humidity decreases with global warming due to a higher water vapor saturation pressure.

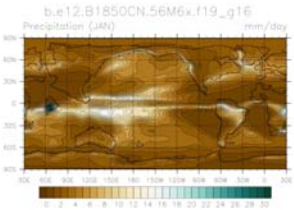


Wallace and Hobbs, 2006

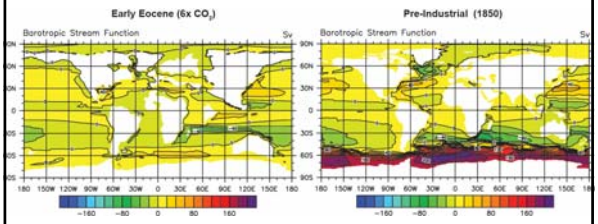
Precipitation



- Hydrological cycle is intensified
- Increased rainfall in polar and tropical regions.
- Dryer subtropics



Ocean Circulation



Low Eocene Antarctic Circumpolar Current is linked to:

- Closure of the Drake Passage
- Southward position of Australia
- Ice-free Antarctica in a high CO_2 world

Conclusions

- Hothouse climates in the past are likely caused by a combination of multiple effects such as substantially higher greenhouse gas forcing and lower cloud albedo
- Future investigations are required to quantify biophysical cloud feedbacks (see poster of Kelin Zhuang)