STRIPPING BACK THE MODERN TO REVEAL CRETACEOUS CLIMATE UNDERNEATH

M. Laugié[1], Y. Donnadieu[1], J.-B. Ladant[2]

M. Green[3], L. Bopp[4], F. Raisson[5]

1 cerege CENTRE EUROPÉEN DE RECHERCHE ET D'ENSEIGNEMENT DES GÉOSCIENCES DE L'ENVIRONNEMENT

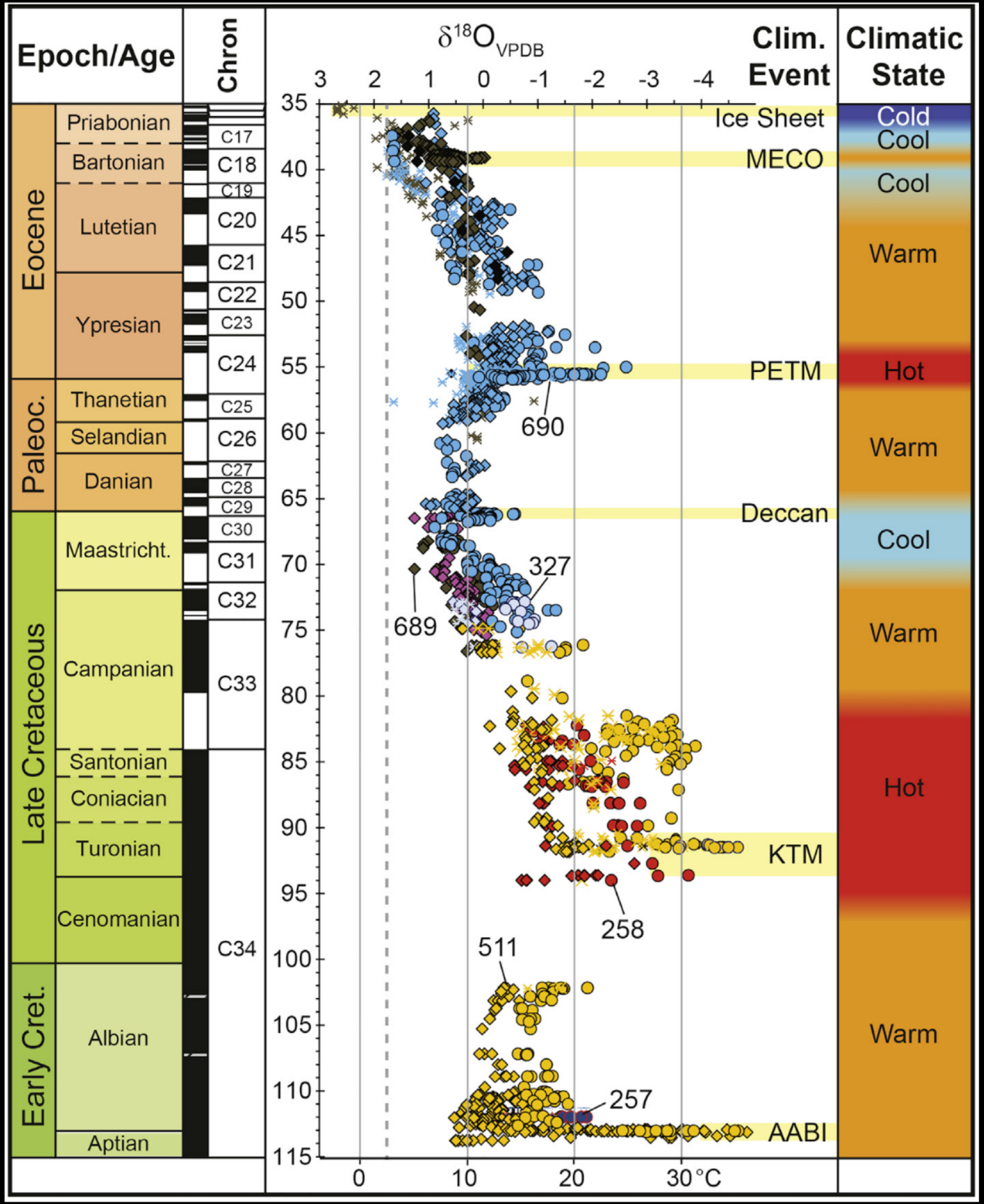
2 UNIVERSITY OF MICHIGAN

3 PRIFYSGOL BANGOR UNIVERSITY

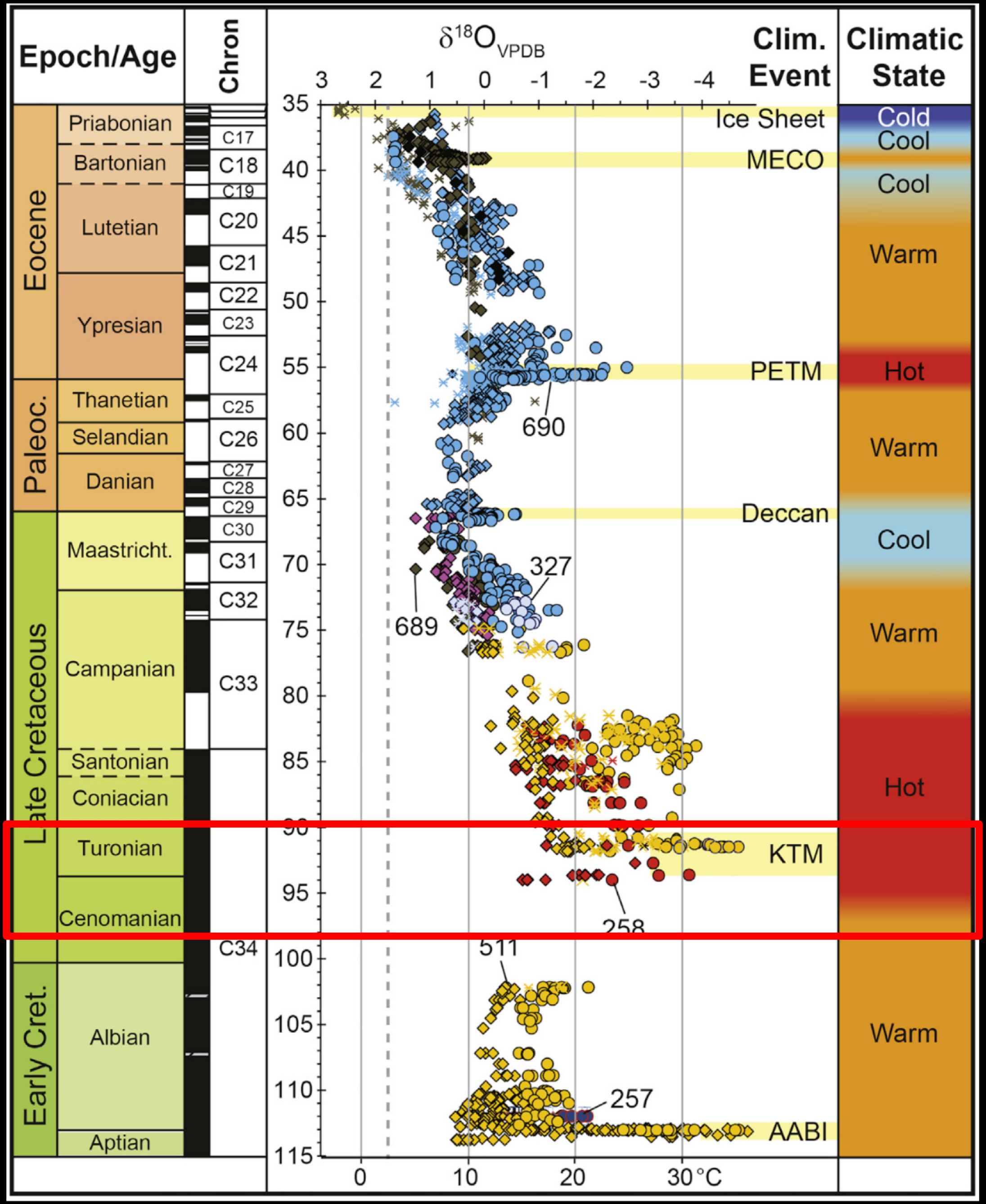
4 ENS

5 TOTAL

AGU 100 FALL MEETING

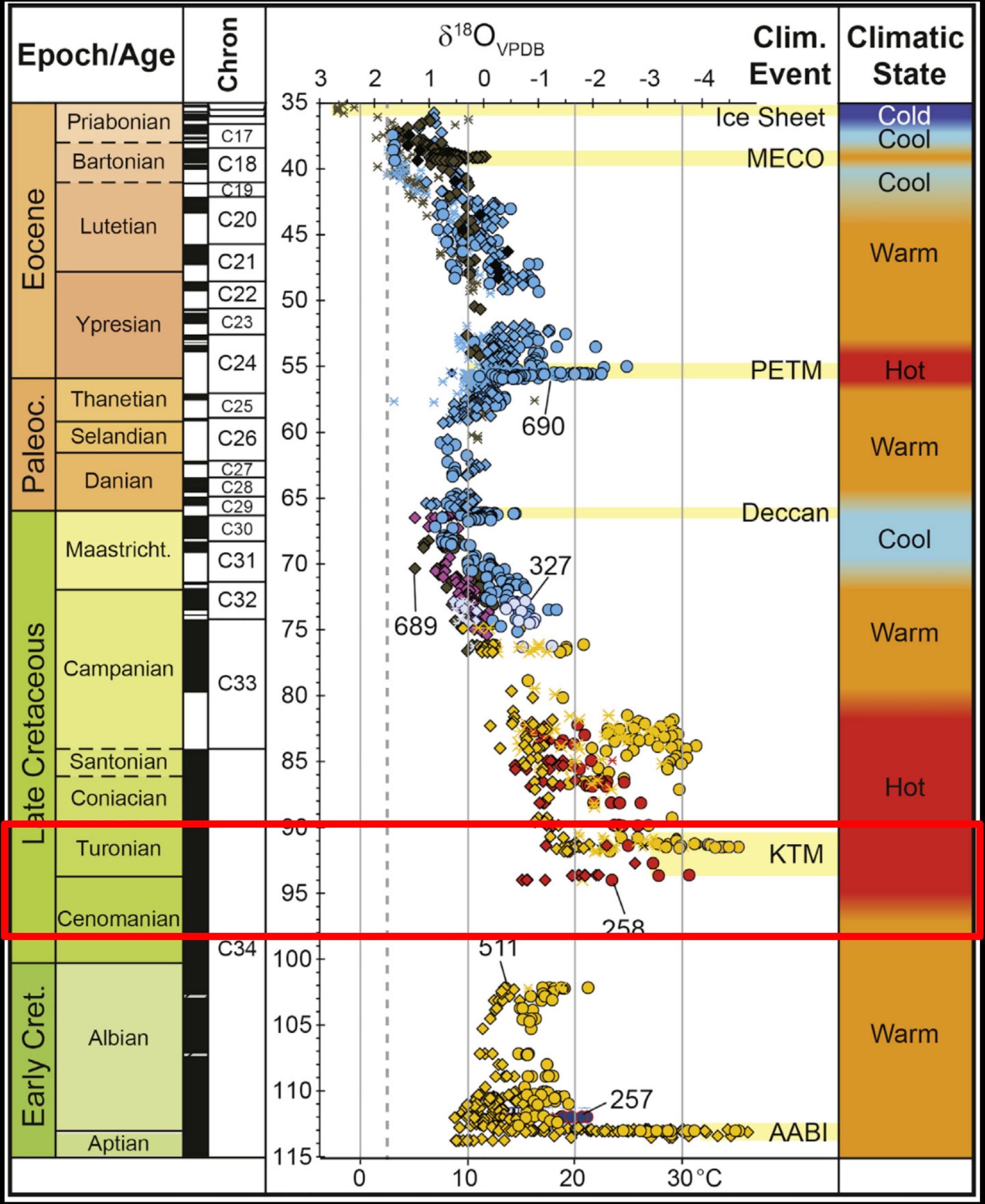


Huber et al., 2018 – Global and Planetary Change

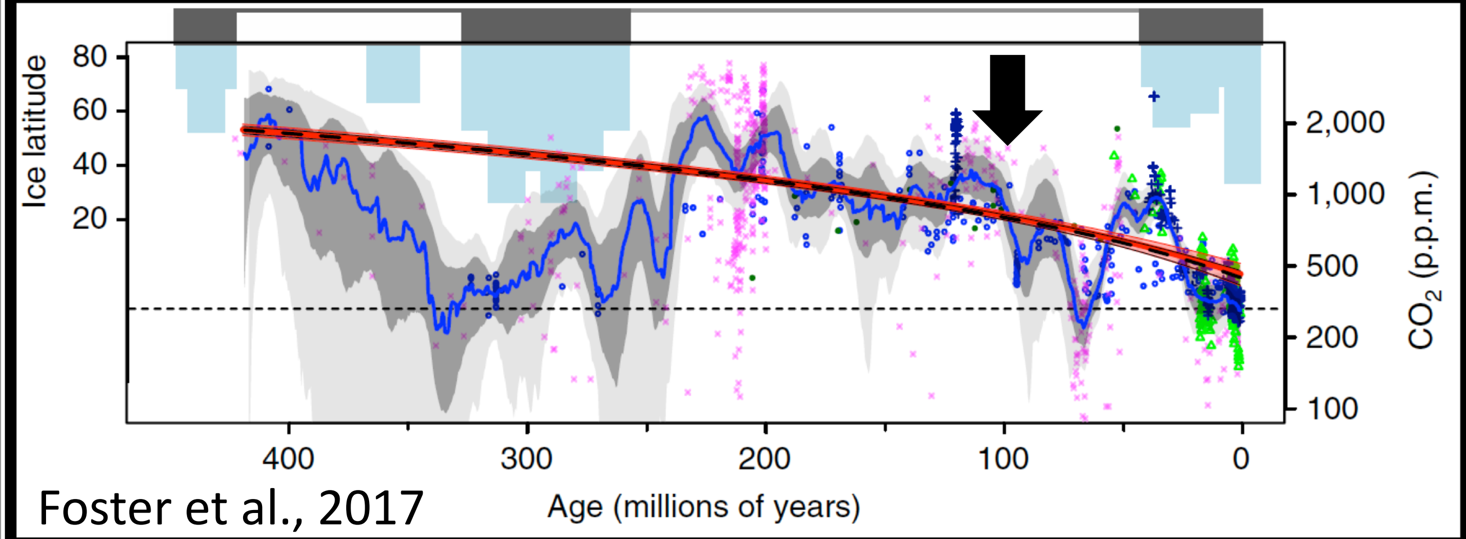


Huber et al., 2018 – Global and Planetary Change

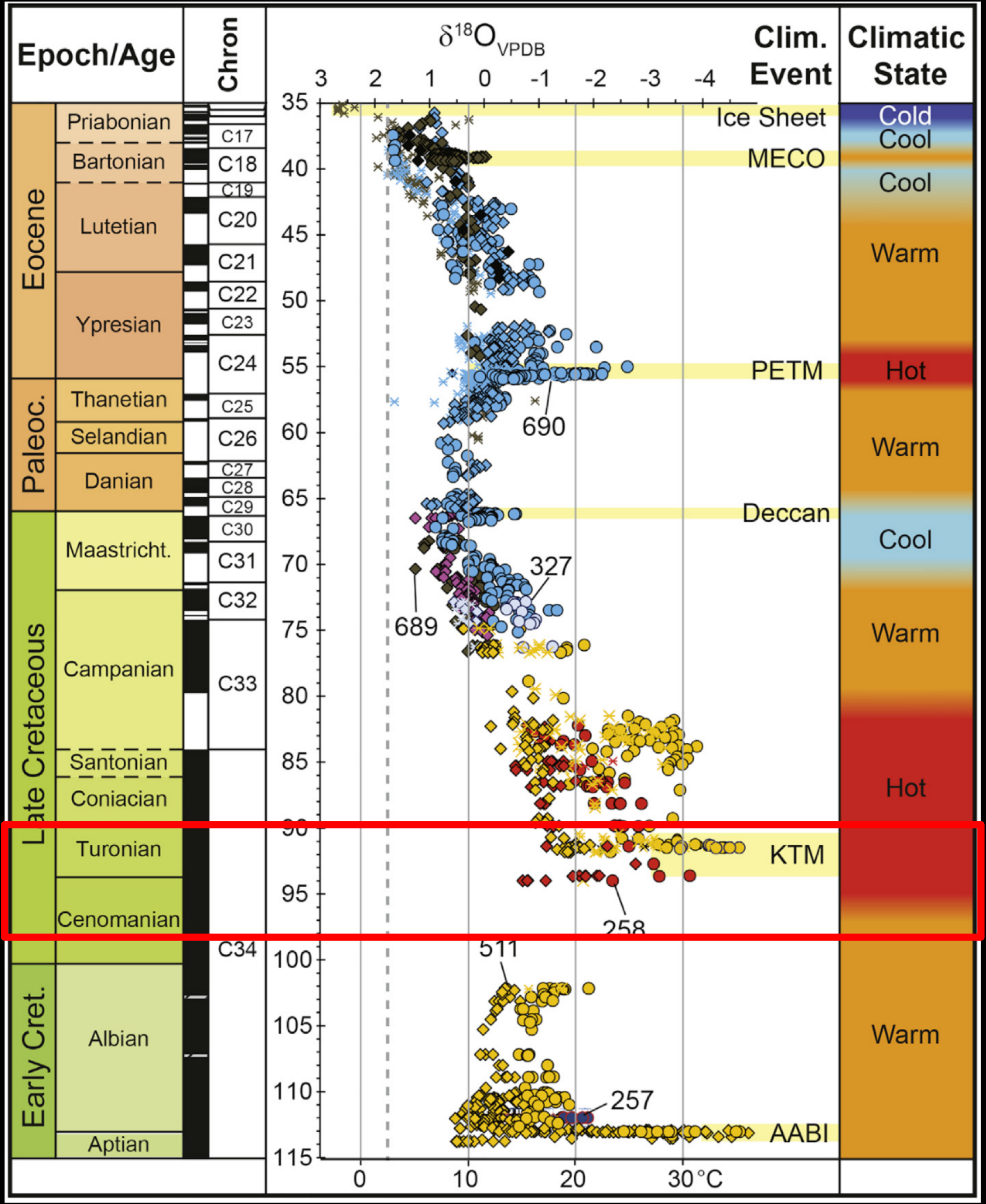
Primary climate forcing → CO_2



Huber et al., 2018 – Global and Planetary Change

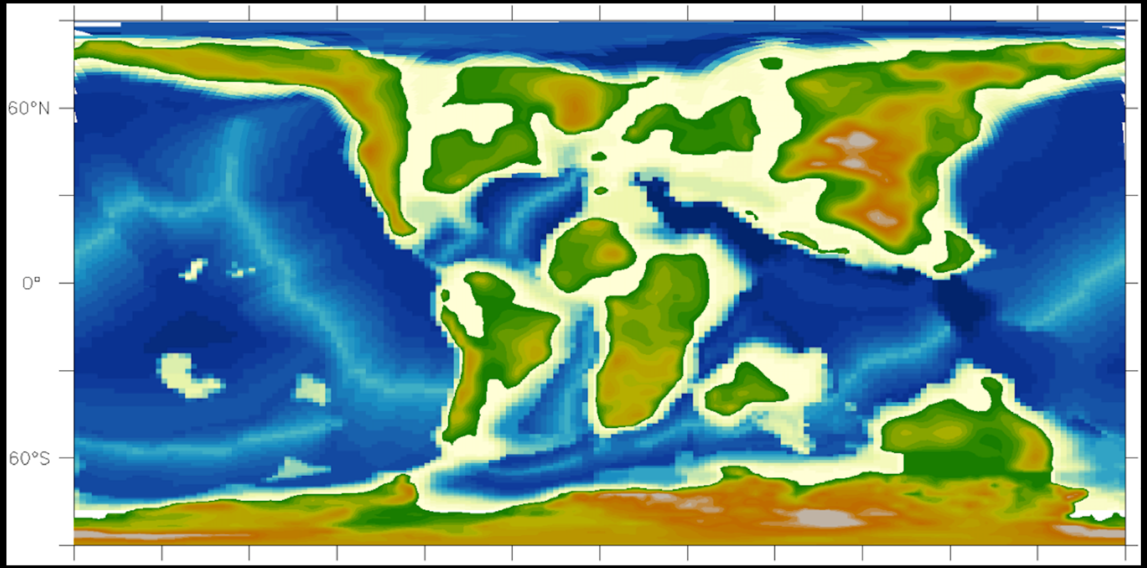


Foster et al., 2017



Primary climate forcing → CO_2

Role of paleogeography?

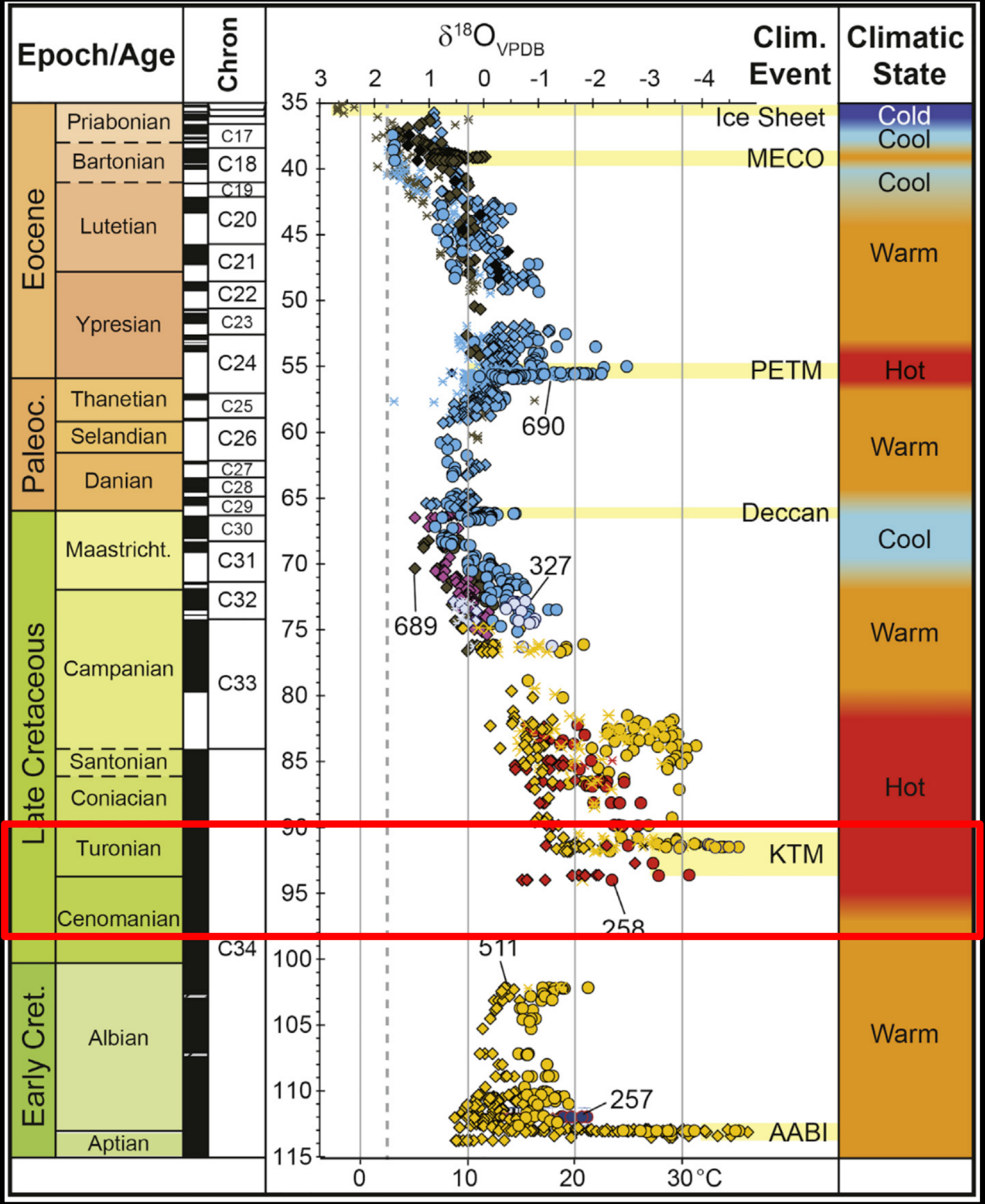


CT Paleogeography (90 Ma) – After Scotese and Müller

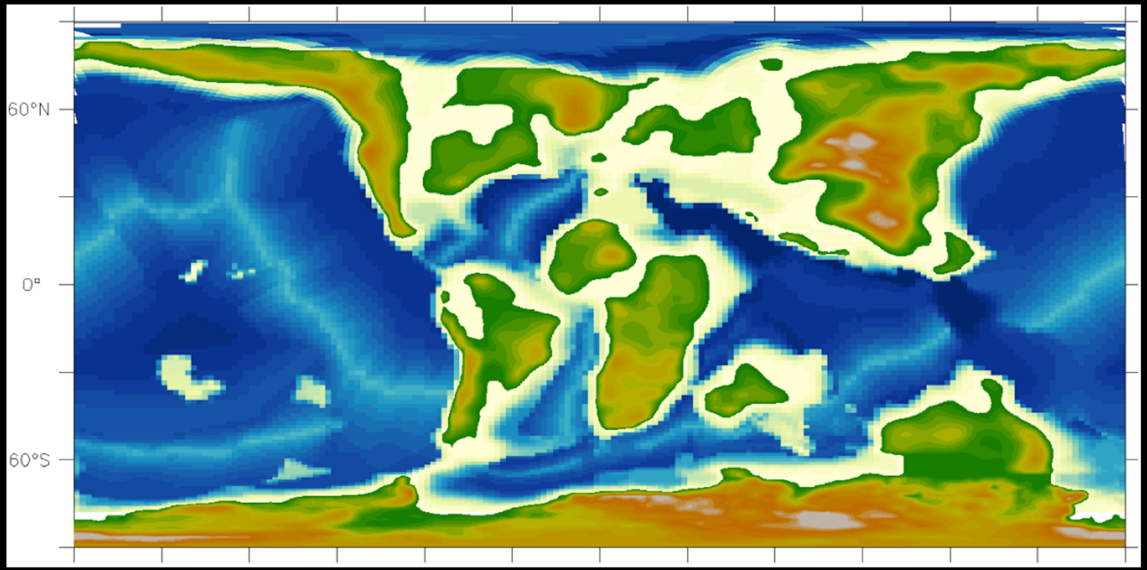
Huber et al., 2018 – Global and Planetary Change

Primary climate forcing → CO_2

Role of paleogeography?



Huber et al., 2018 – Global and Planetary Change

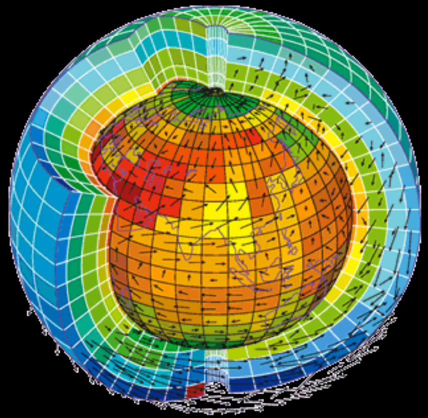


CT Paleogeography (90 Ma) – After Scotese and Müller

- Negligible? (Barron et al., 1995)
  - Only regional? (Lunt et al., 2016; Tabor et al., 2016)
    - As strong as a doubling of pCO_2? (Crowley et al., 1986, Ladant & Donnadieu, 2016)

MODELING SET-UP

IPSLCM5A2 Earth System Model



LMDZ atmosphere:
3,75° x 1,875° x 39
ORCHIDEE
land surface model:
3,75° x 1,875°
NEMO ocean:
2° x 0,5-2° x 31

Pre-Industrial
piControl

1X-NOICE

4X-NOICE

4X-NI-PFT-SOIL

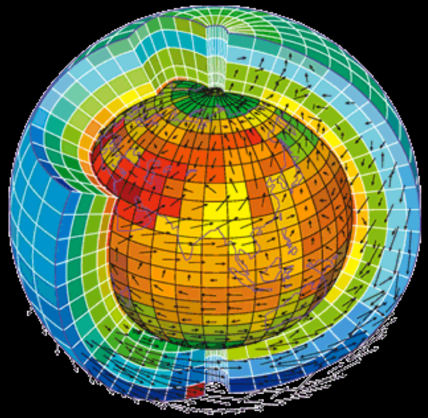
4X-NI-PFT-SOIL-SOLAR

Cenomanian-Turonian
4X-CRETACEOUS

- 2000 year simulations
- Present-day orbital configuration

MODELING SET-UP

IPSLCM5A2 Earth System Model



LMDZ atmosphere:
3,75° x 1,875° x 39
ORCHIDEE
land surface model:
3,75° x 1,875°
NEMO ocean:
2° x 0,5-2° x 31

Pre-Industrial
piControl

Polar ice sheet removal

1X-NOICE

4X-NOICE

4X-NI-PFT-SOIL

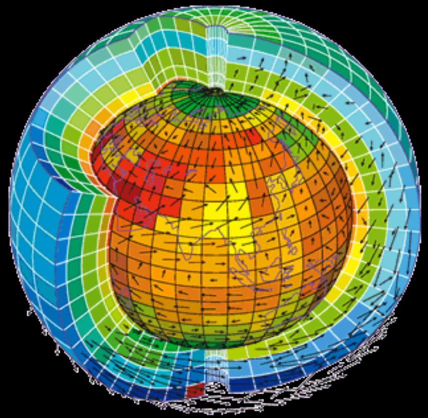
4X-NI-PFT-SOIL-SOLAR

Cenomanian-Turonian
4X-CRETACEOUS

- 2000 year simulations
- Present-day orbital configuration

MODELING SET-UP

IPSLCM5A2 Earth System Model



LMDZ atmosphere:
3,75° x 1,875° x 39
ORCHIDEE
land surface model:
3,75° x 1,875°
NEMO ocean:
2° x 0,5-2° x 31

Pre-Industrial
piControl

Polar ice sheet removal

1X-NOICE

pCO_2 x4 = 1120 ppm

4X-NOICE

4X-NI-PFT-SOIL

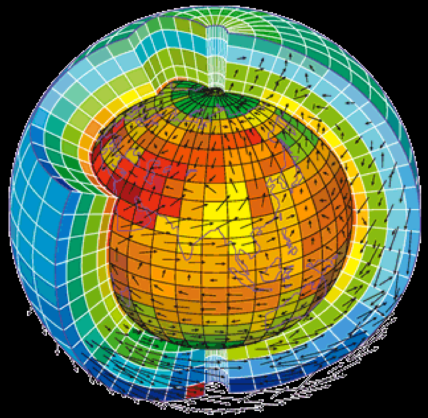
4X-NI-PFT-SOIL-SOLAR

Cenomanian-Turonian
4X-CRETACEOUS

- 2000 year simulations
- Present-day orbital configuration

MODELING SET-UP

IPSLCM5A2 Earth System Model



LMDZ atmosphere:
3,75° x 1,875° x 39
ORCHIDEE
land surface model:
3,75° x 1,875°
NEMO ocean:
2° x 0,5-2° x 31

Pre-Industrial
piControl

Polar ice sheet removal

1X-NOICE

pCO_2 x4 = 1120 ppm

4X-NOICE

Zonal vegetation,
Homogeneous soil color

4X-NI-PFT-SOIL

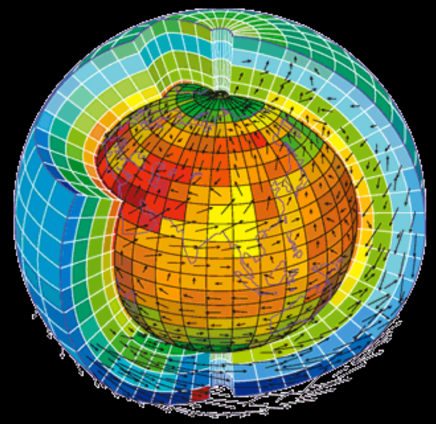
4X-NI-PFT-SOIL-SOLAR

Cenomanian-Turonian
4X-CRETACEOUS

- 2000 year simulations
- Present-day orbital configuration

MODELING SET-UP

IPSLCM5A2 Earth System Model



LMDZ atmosphere:
3,75° x 1,875° x 39
ORCHIDEE
land surface model:
3,75° x 1,875°
NEMO ocean:
2° x 0,5-2° x 31

Pre-Industrial
piControl

Polar ice sheet removal

1X-NOICE

pCO_2 x4 = 1120 ppm

4X-NOICE

Zonal vegetation,
Homogeneous soil color

4X-NI-PFT-SOIL

Solar constant
diminution (-1%)

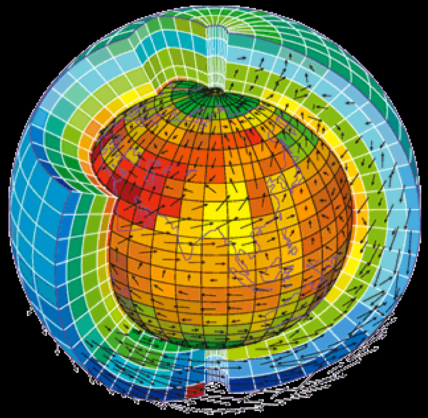
4X-NI-PFT-SOIL-SOLAR

Cenomanian-Turonian
4X-CRETACEOUS

- 2000 year simulations
- Present-day orbital configuration

MODELING SET-UP

IPSLCM5A2 Earth System Model



LMDZ atmosphere:
3,75° x 1,875° x 39
ORCHIDEE
land surface model:
3,75° x 1,875°
NEMO ocean:
2° x 0,5-2° x 31

Pre-Industrial
piControl

Polar ice sheet removal

1X-NOICE

pCO_2 x4 = 1120 ppm

4X-NOICE

Zonal vegetation,
Homogeneous soil color

4X-NI-PFT-SOIL

Solar constant
diminution (-1%)

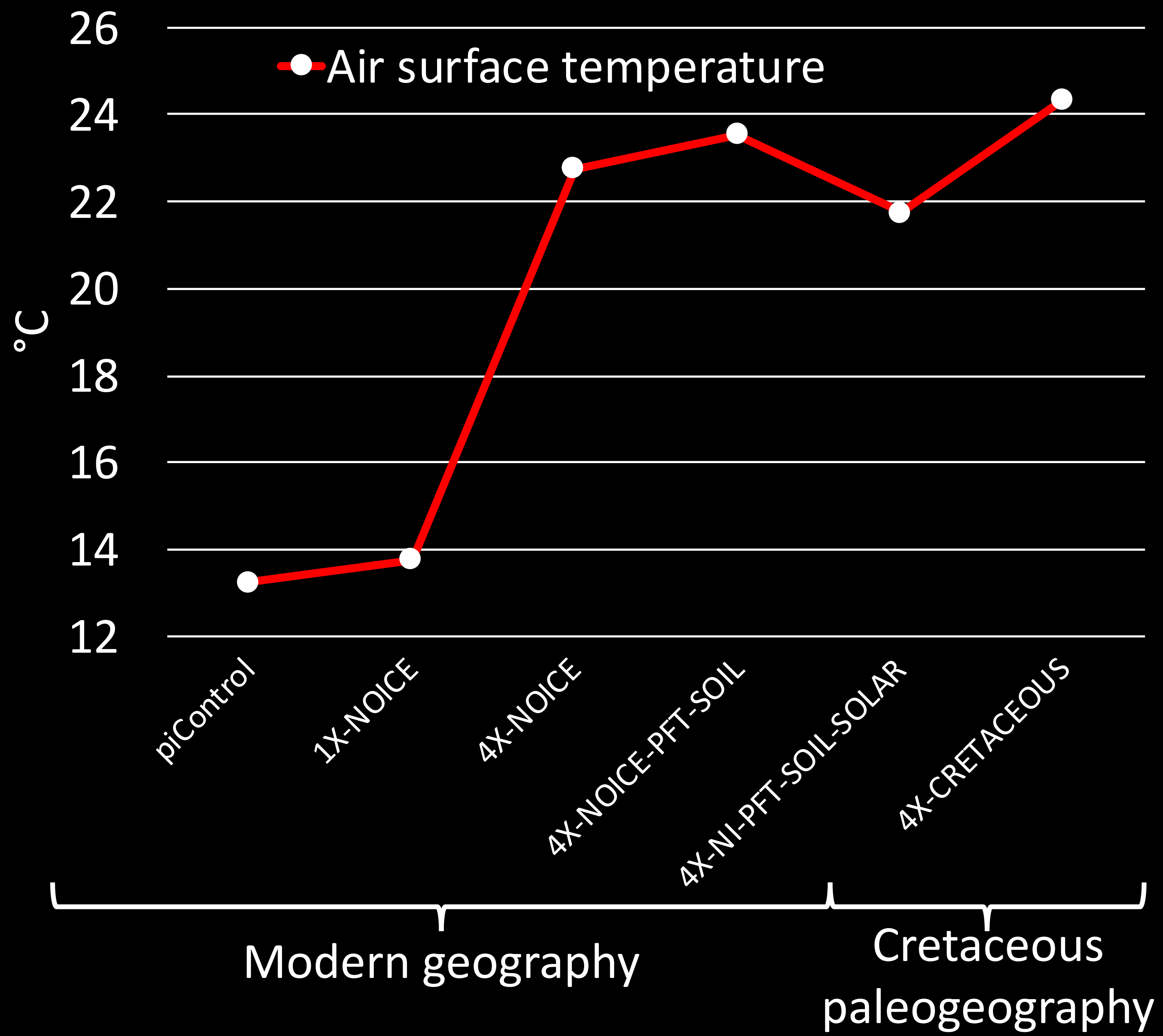
4X-NI-PFT-SOIL-SOLAR

Paleogeography
change

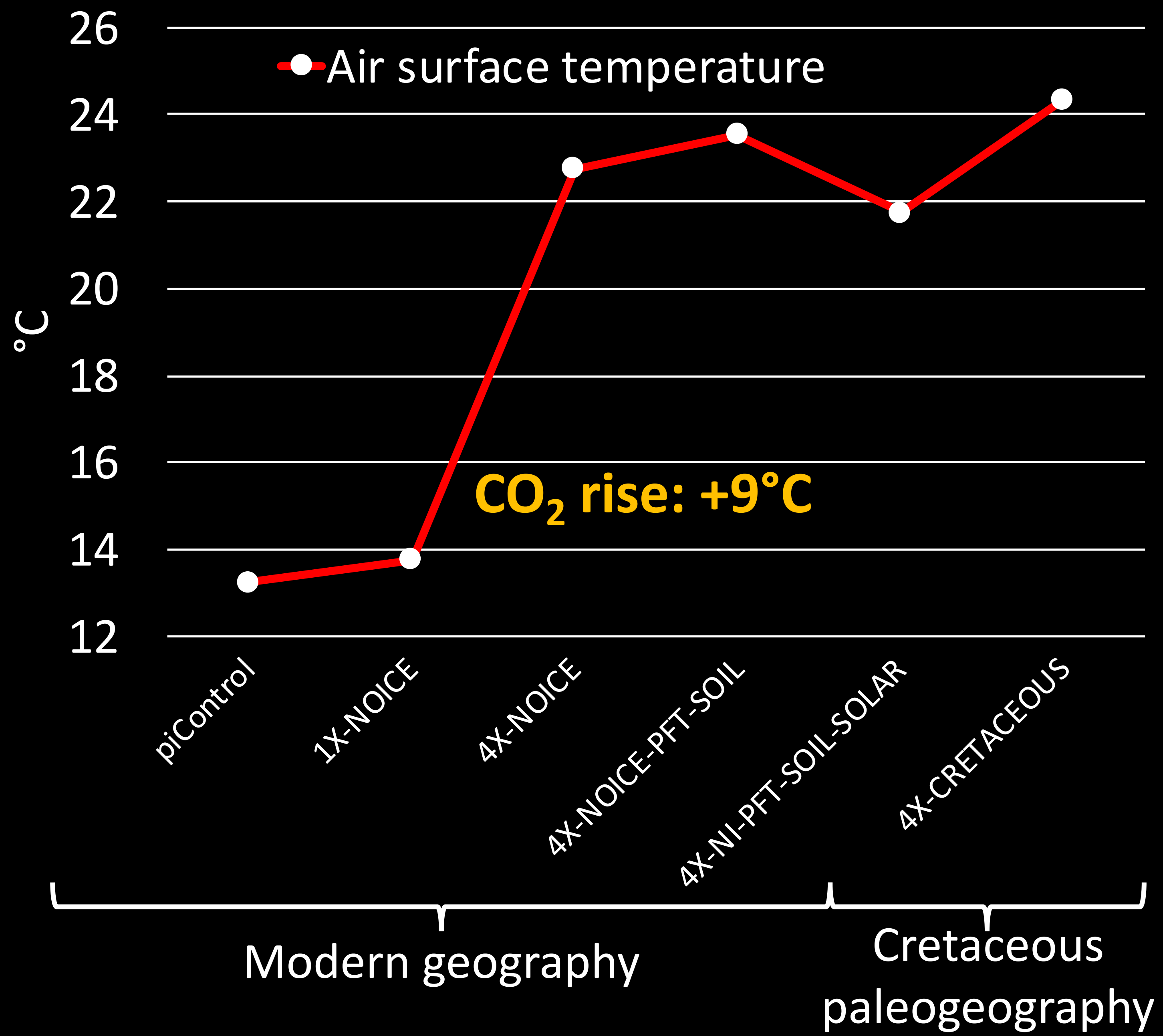
Cenomanian-Turonian
4X-CRETACEOUS

- 2000 year simulations
- Present-day orbital configuration

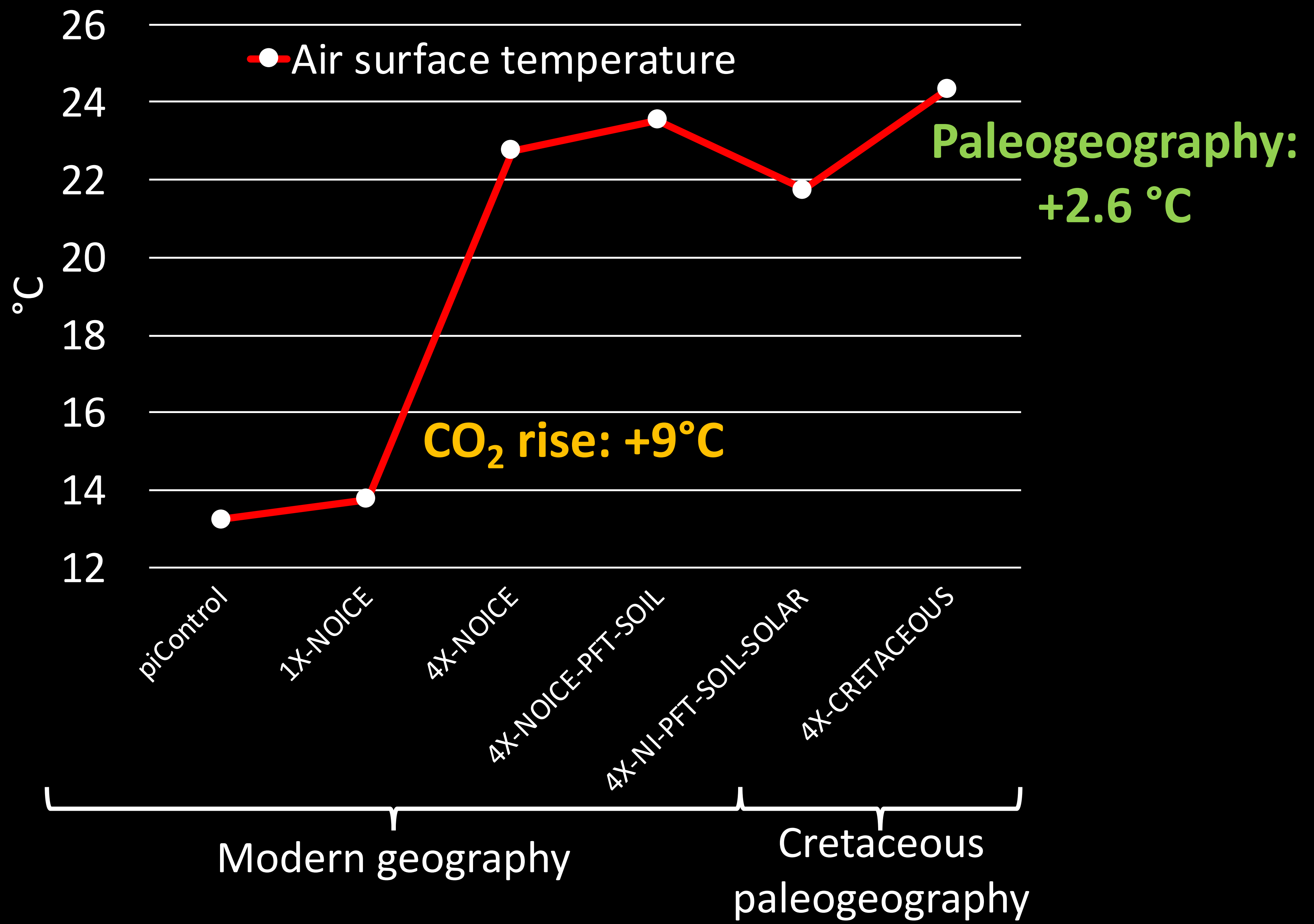
GLOBAL ANNUAL TEMPERATURE EVOLUTION



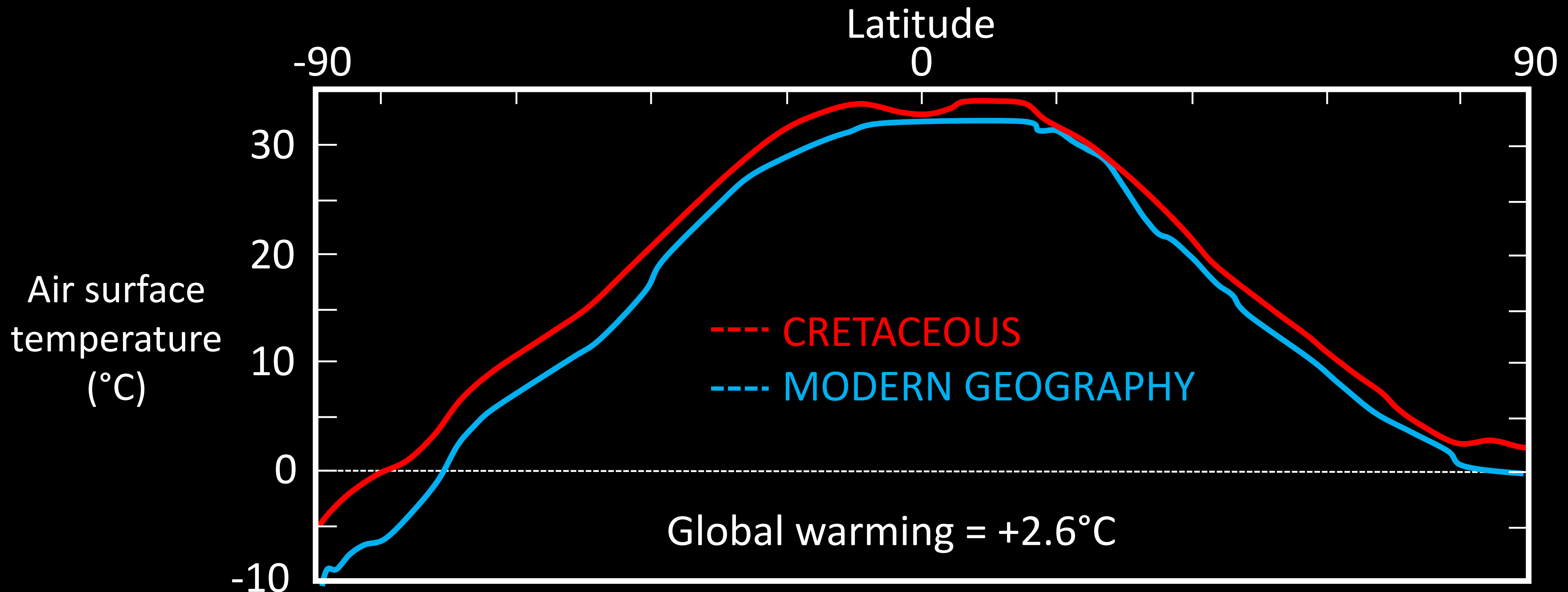
GLOBAL ANNUAL TEMPERATURE EVOLUTION



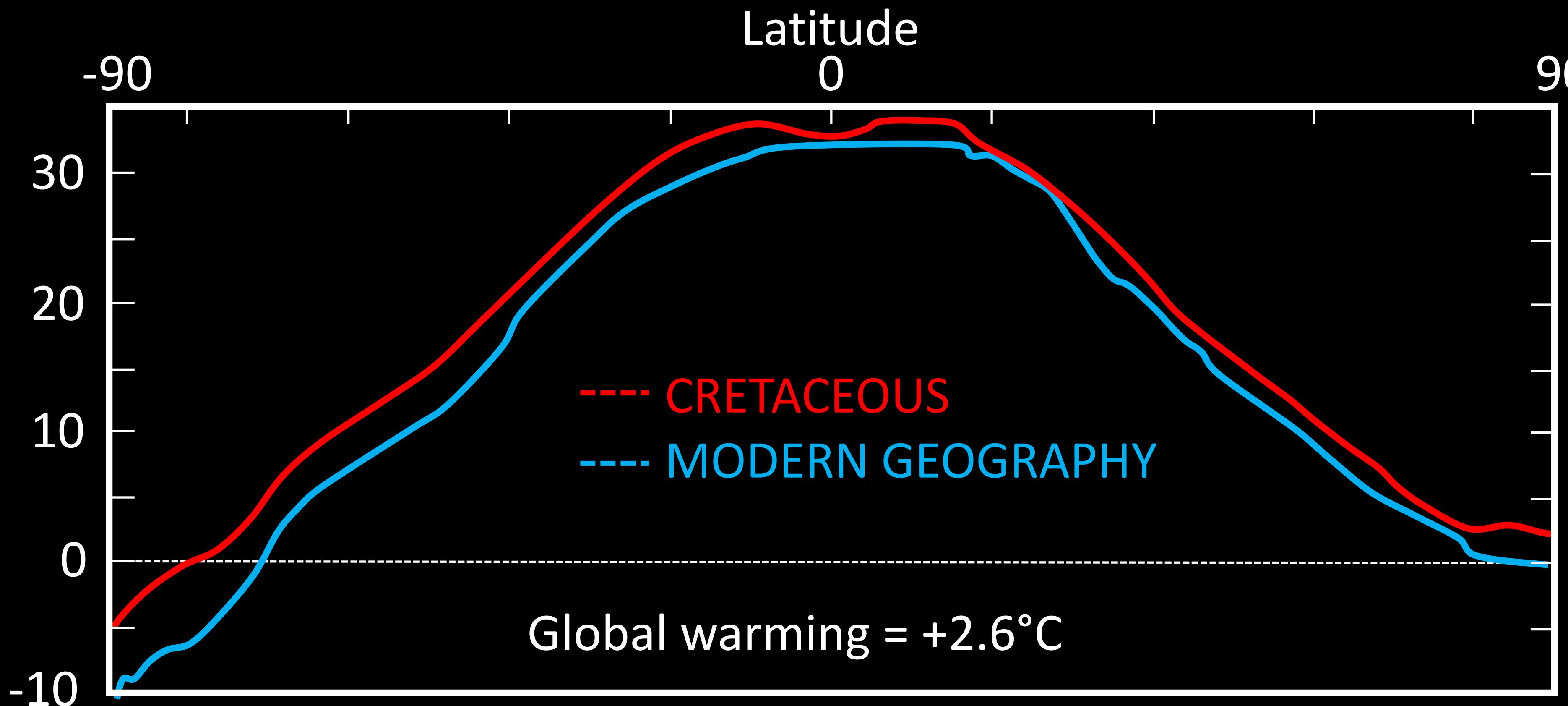
GLOBAL ANNUAL TEMPERATURE EVOLUTION



ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



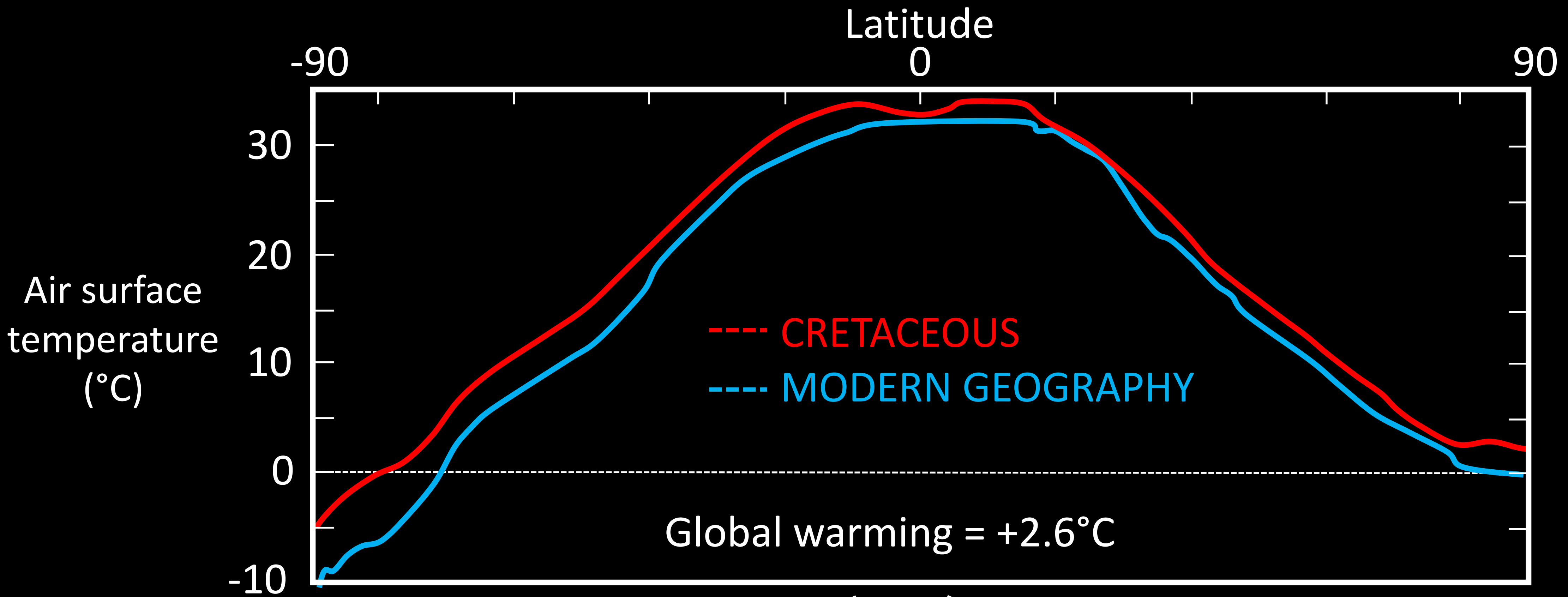
ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



Planetary Albedo
-1.53 % → + 1,6°C

Atmospheric Emissivity (Greenhouse effect)
- 0.73 % → + 1°C

ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE

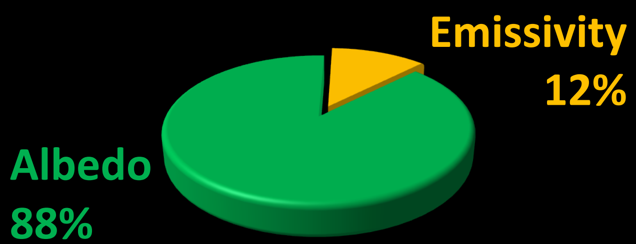


Planetary Albedo
-1.53 % → + 1,6°C

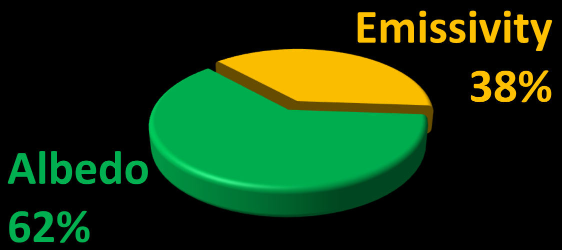
Atmospheric Emissivity (Greenhouse effect)
- 0.73 % → + 1°C

Contribution to warming:

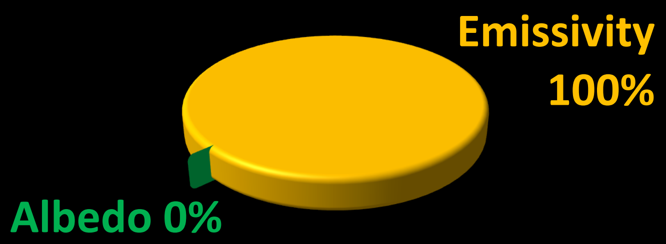
South Hemisphere (30°-90° S)



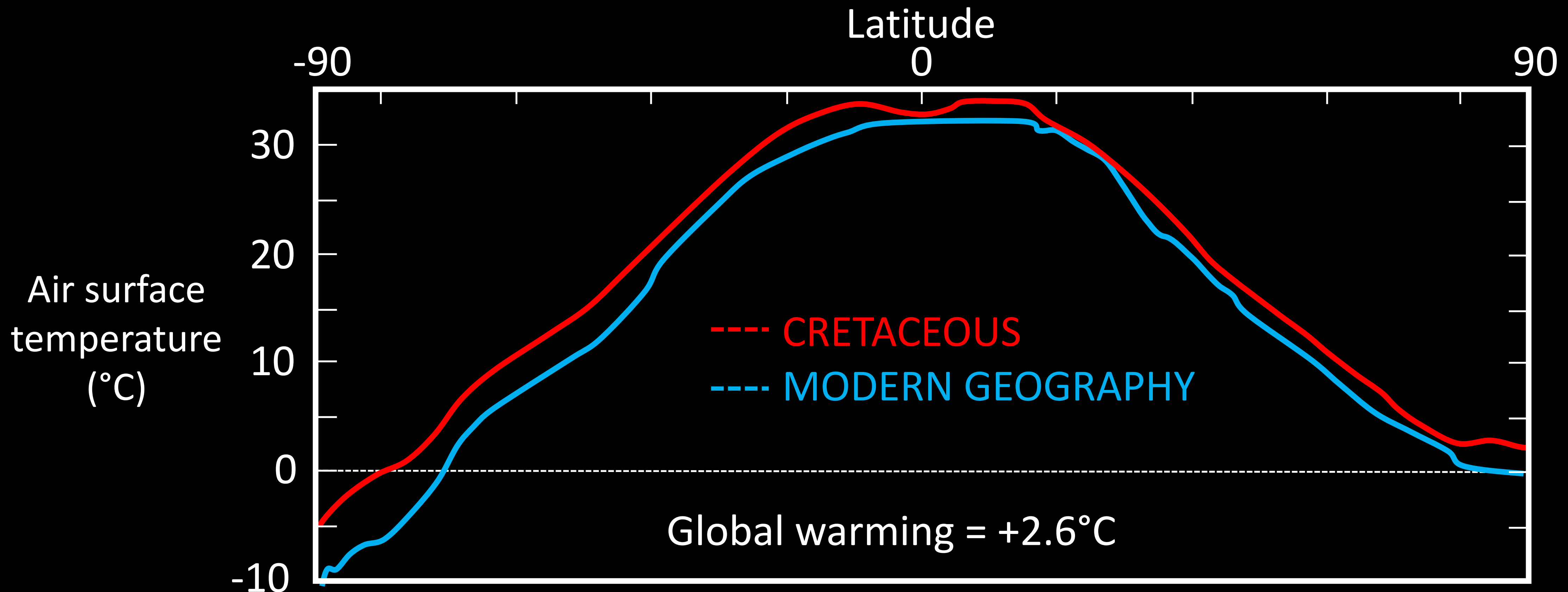
Tropics (30°S-30°N)



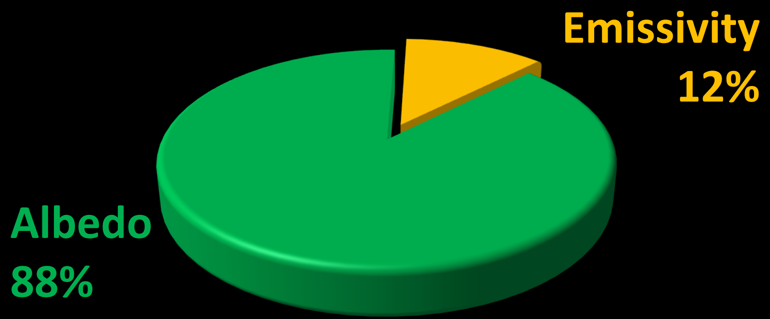
North Hemisphere (30°-90° N)



ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



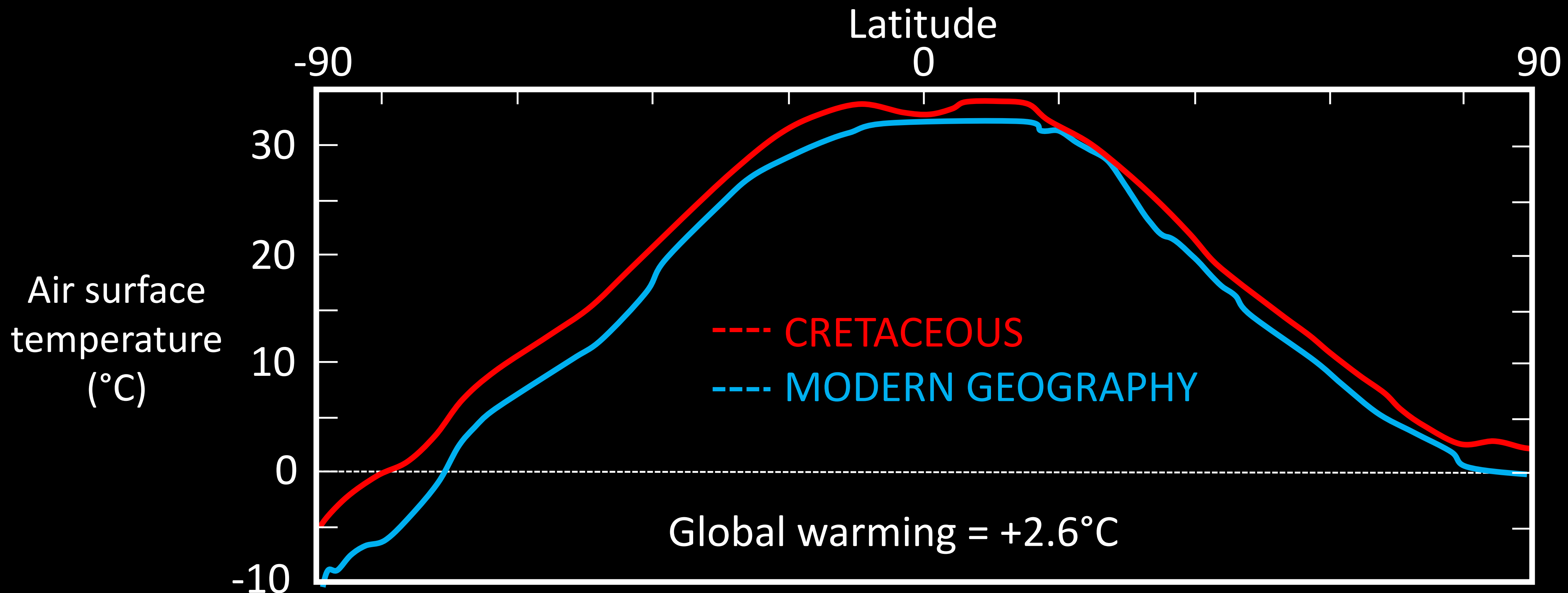
South Hemisphere



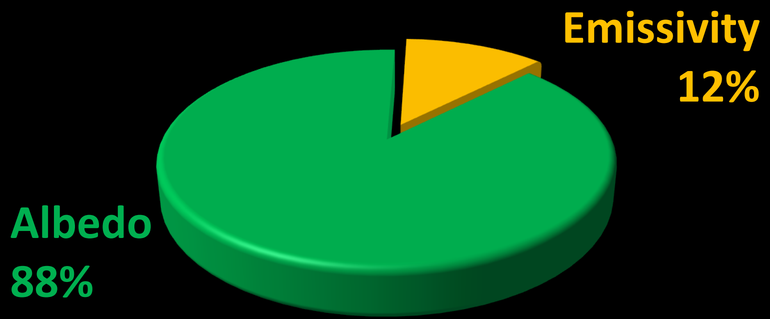
→ Surface albedo ?

→ Low-altitude cloudiness decrease ?

ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



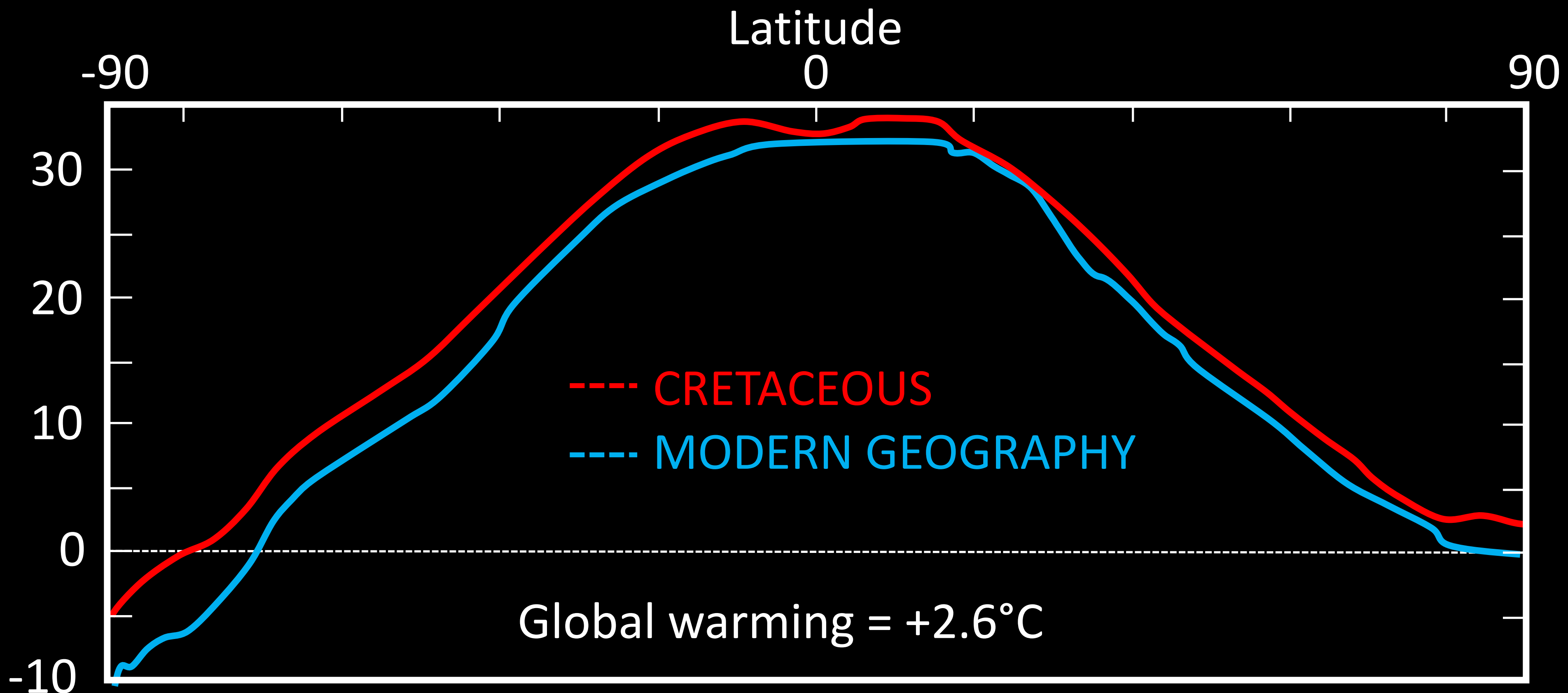
South Hemisphere



→ Surface albedo ? +0.4% = cooling …

→ Low-altitude cloudiness decrease ? -12% = warming !

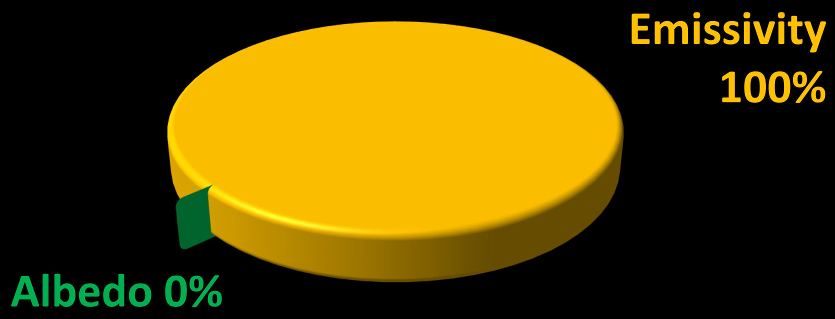
ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



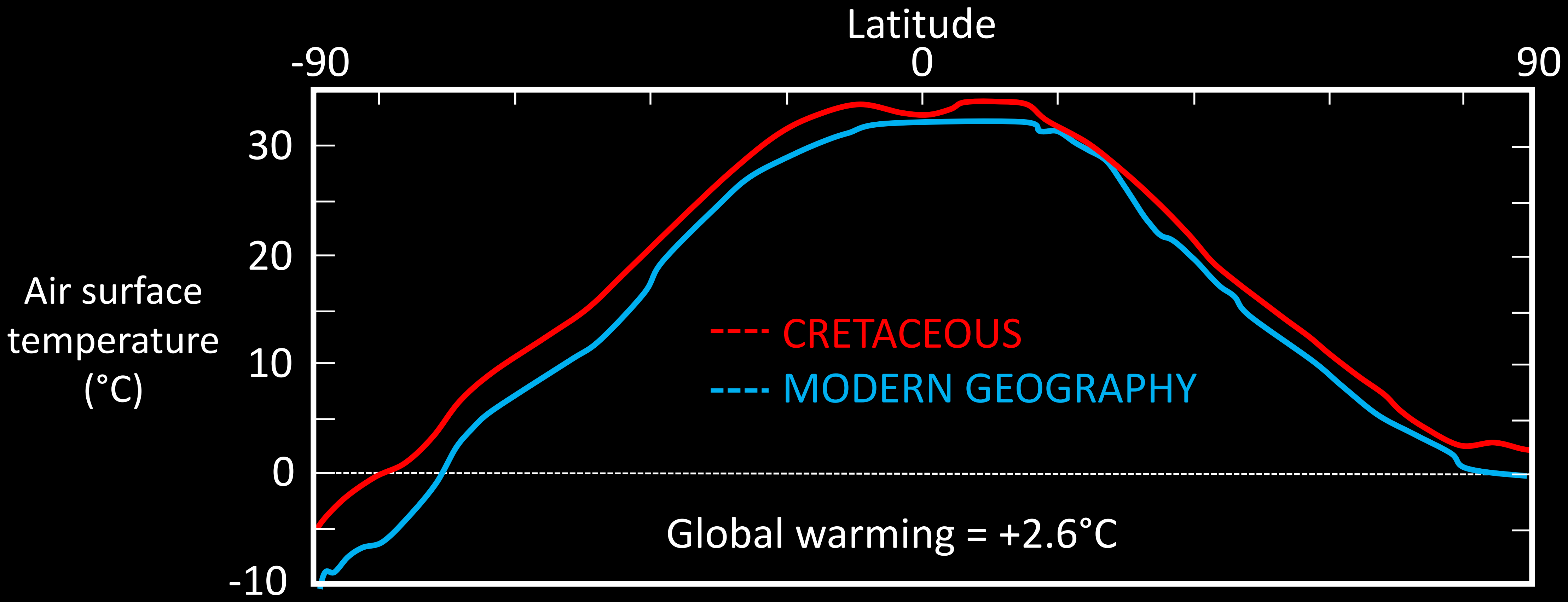
→ Greenhouse gases?

→ High-altitude cloudiness increase?

North Hemisphere



ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE

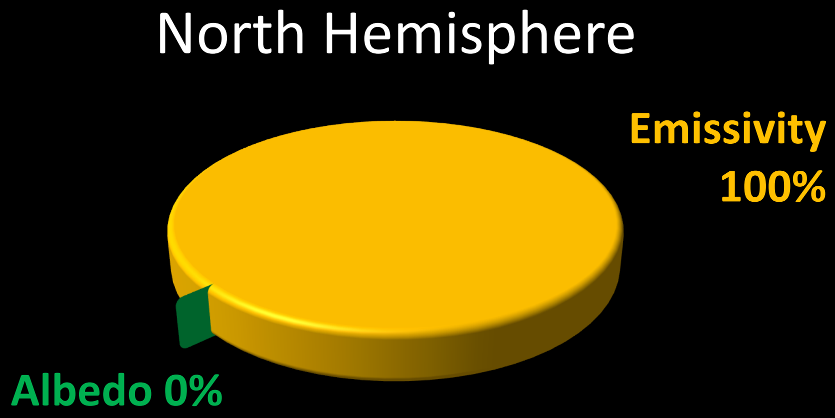


→ Greenhouse gases?

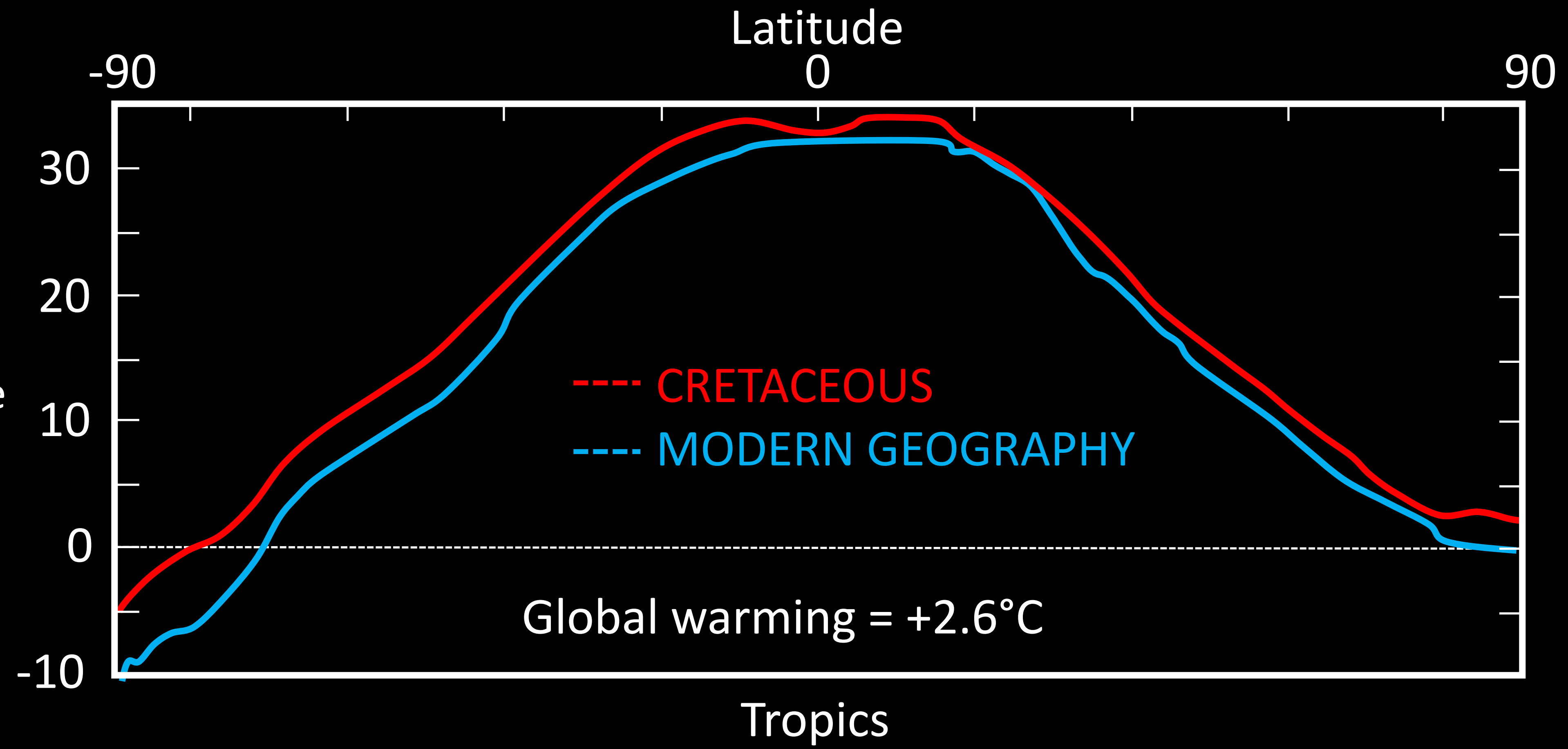
H_20 (+0.3‰)

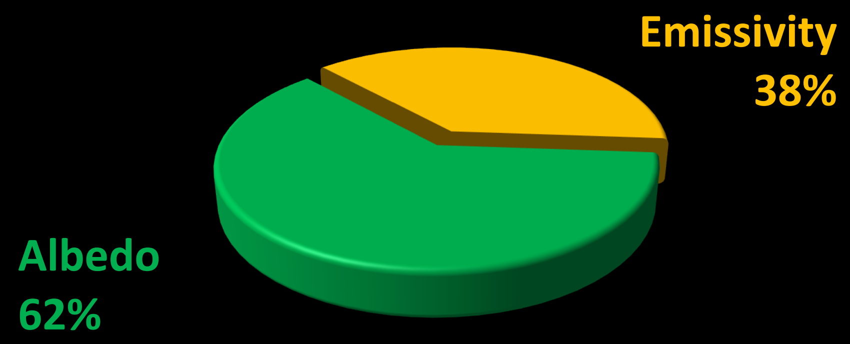
→ High-altitude cloudiness increase?

+1% = Warming

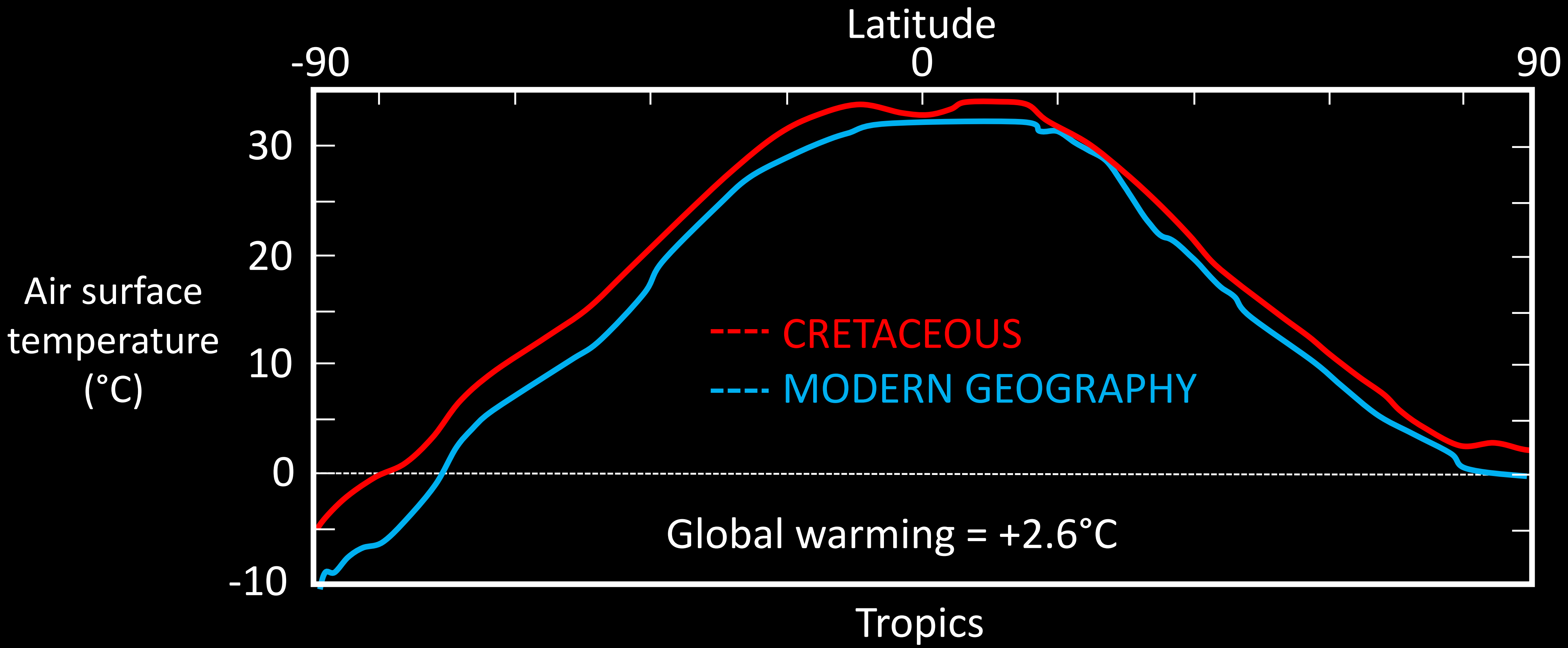


ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



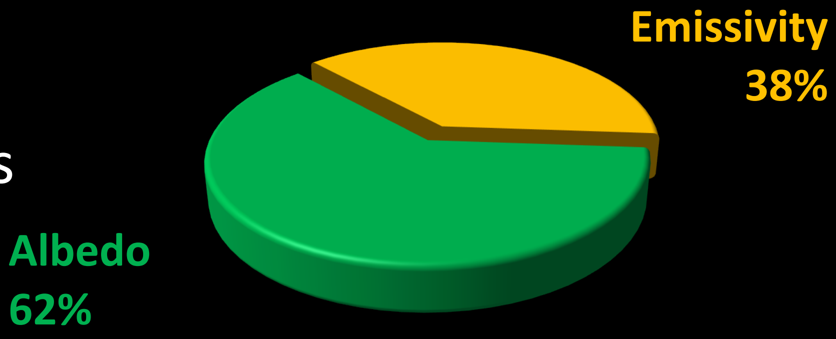


ATMOSPHERIC TEMPERATURES – MERIDIONAL AVERAGE



H_2O = +1‰

Surface albedo
= -0.1%
Low-altitude cloudiness
= -2%

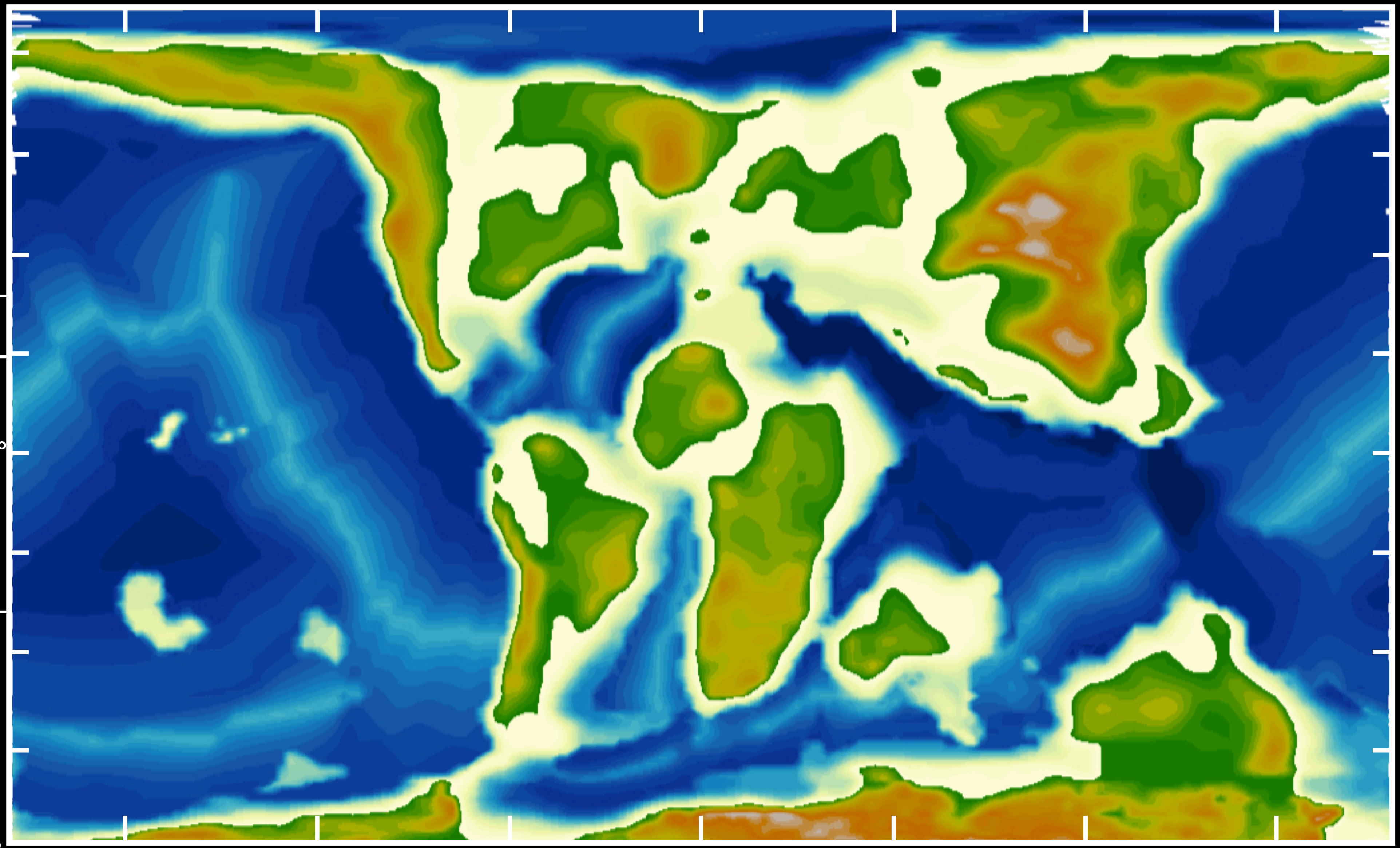


CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)

High-altitude cloudiness increase + H_2O increase

Surface albedo + Low-altitude cloudiness decrease + H_2O increase

Low-altitude cloudiness decrease



Climate warming controller

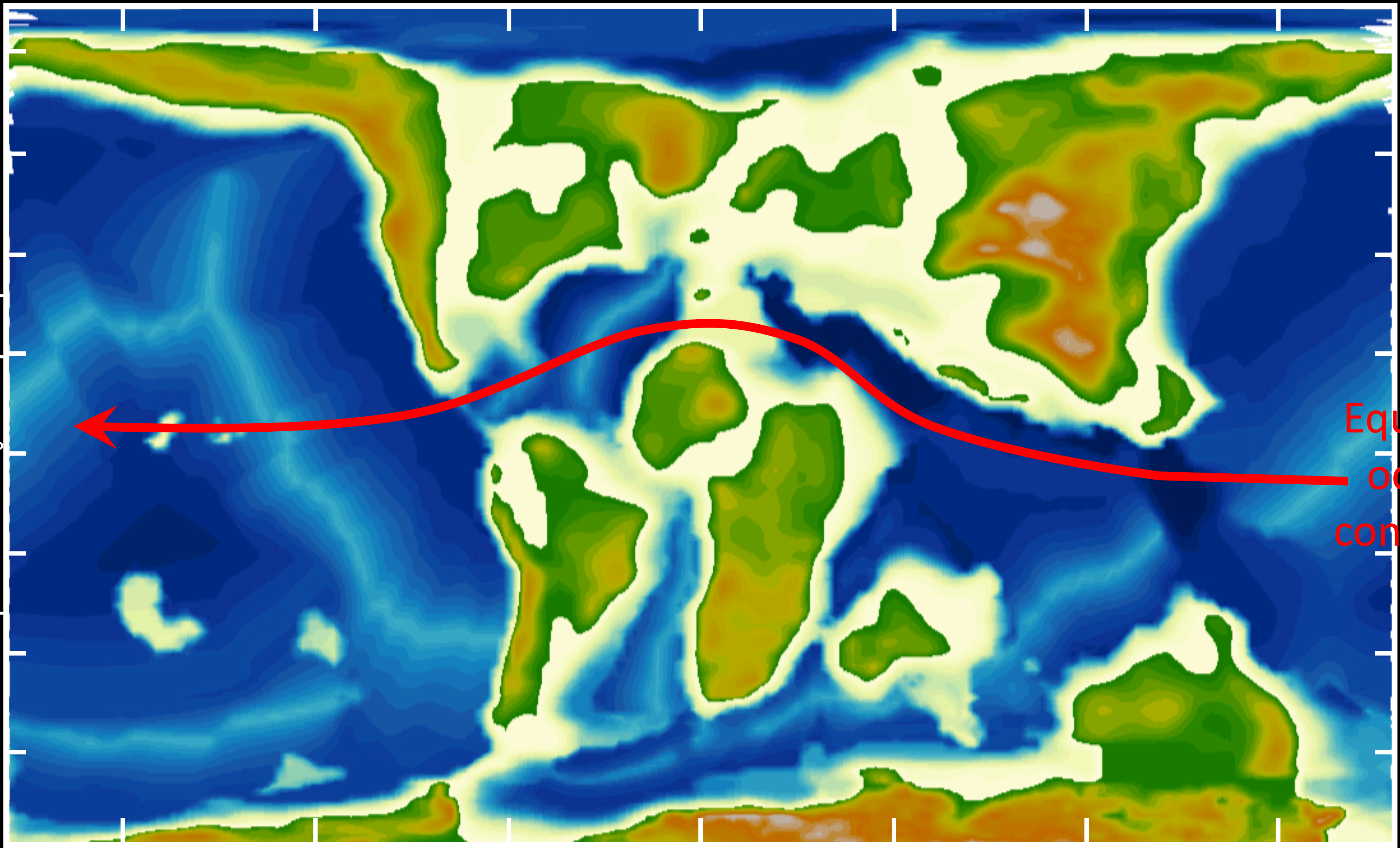
From C. R. Scotese paleogeography (2014), with ocean ridges of Müller et al. (2008)

CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)

High-altitude cloudiness increase + H_2O increase

Surface albedo + Low-altitude cloudiness decrease + H_2O increase

Low-altitude cloudiness decrease



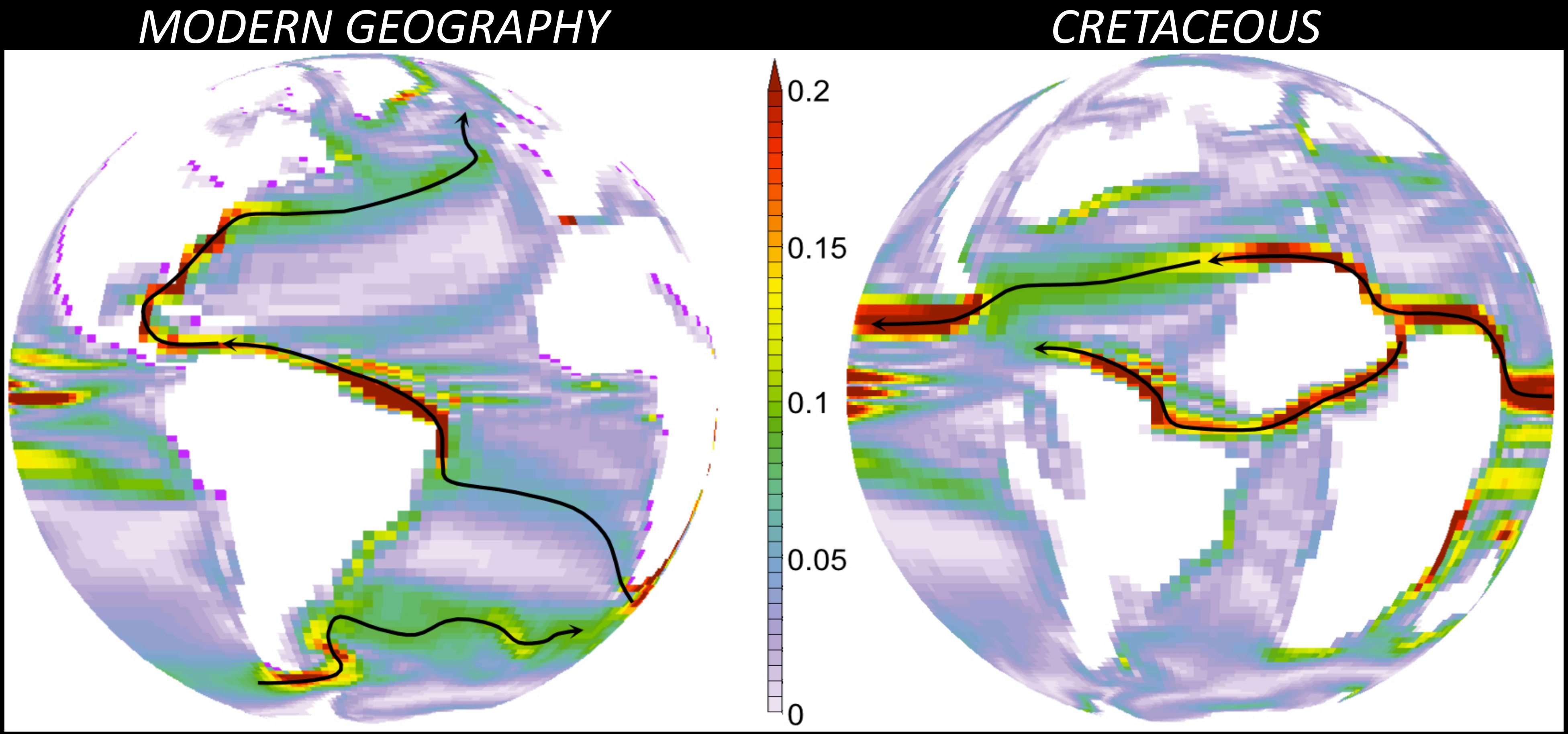
Climate warming controller

From C. R. Scotese paleogeography (2014), with ocean ridges of Müller et al. (2008)

CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)
→ EQUATORIAL OCEANIC CONNECTION

→ CircumEquatorial surface current

→ Enhanced intensity of surface circulation (cf also Hotinski & Toggweiler, 2003)



Intensity of surface currents (Sv)

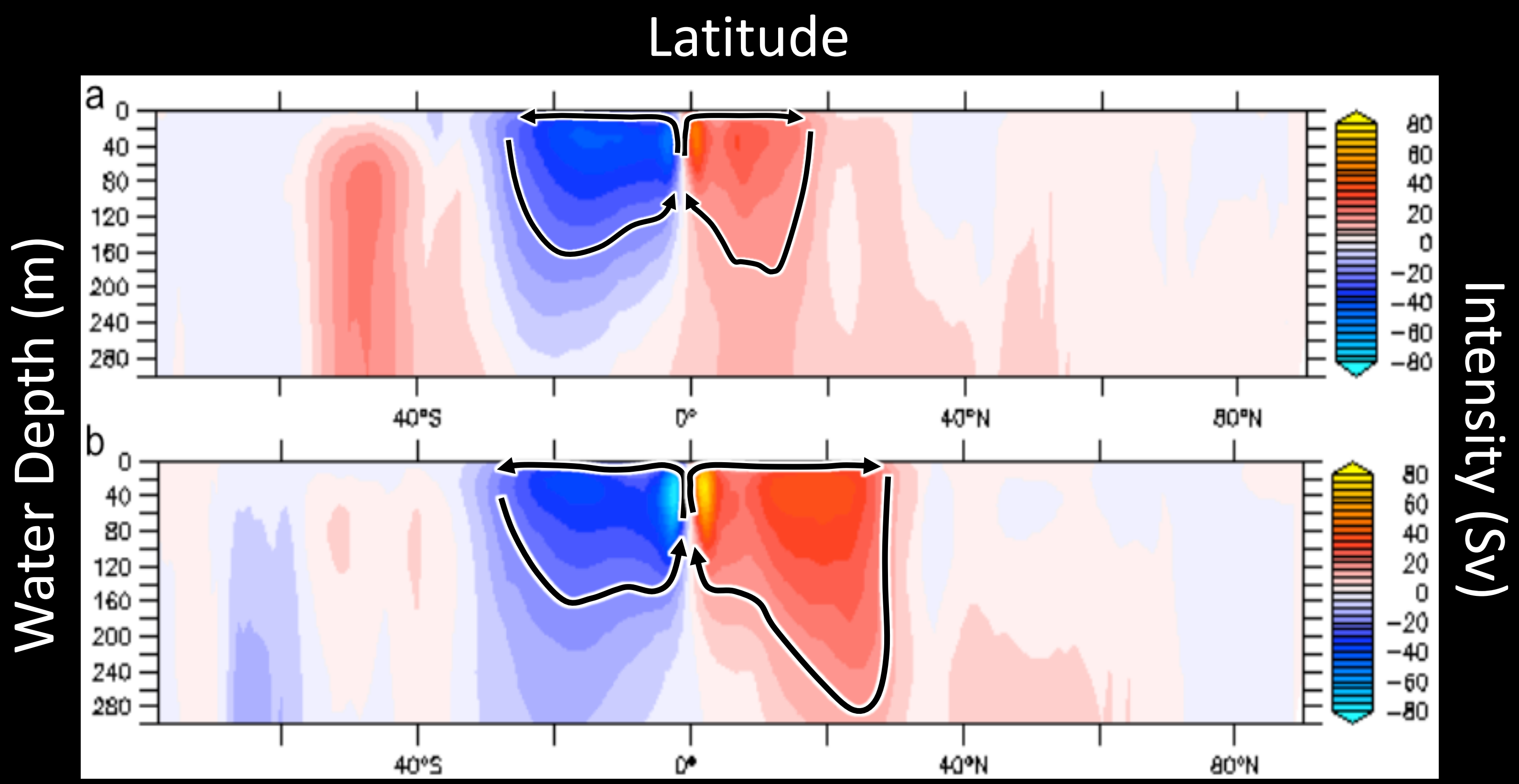
(Annual Mean, 0 to 80 meters of water depth)

CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)
→ EQUATORIAL OCEANIC CONNECTION

MODERN GEOGRAPHY

Surface meridionnal streamfunction

CRETACEOUS

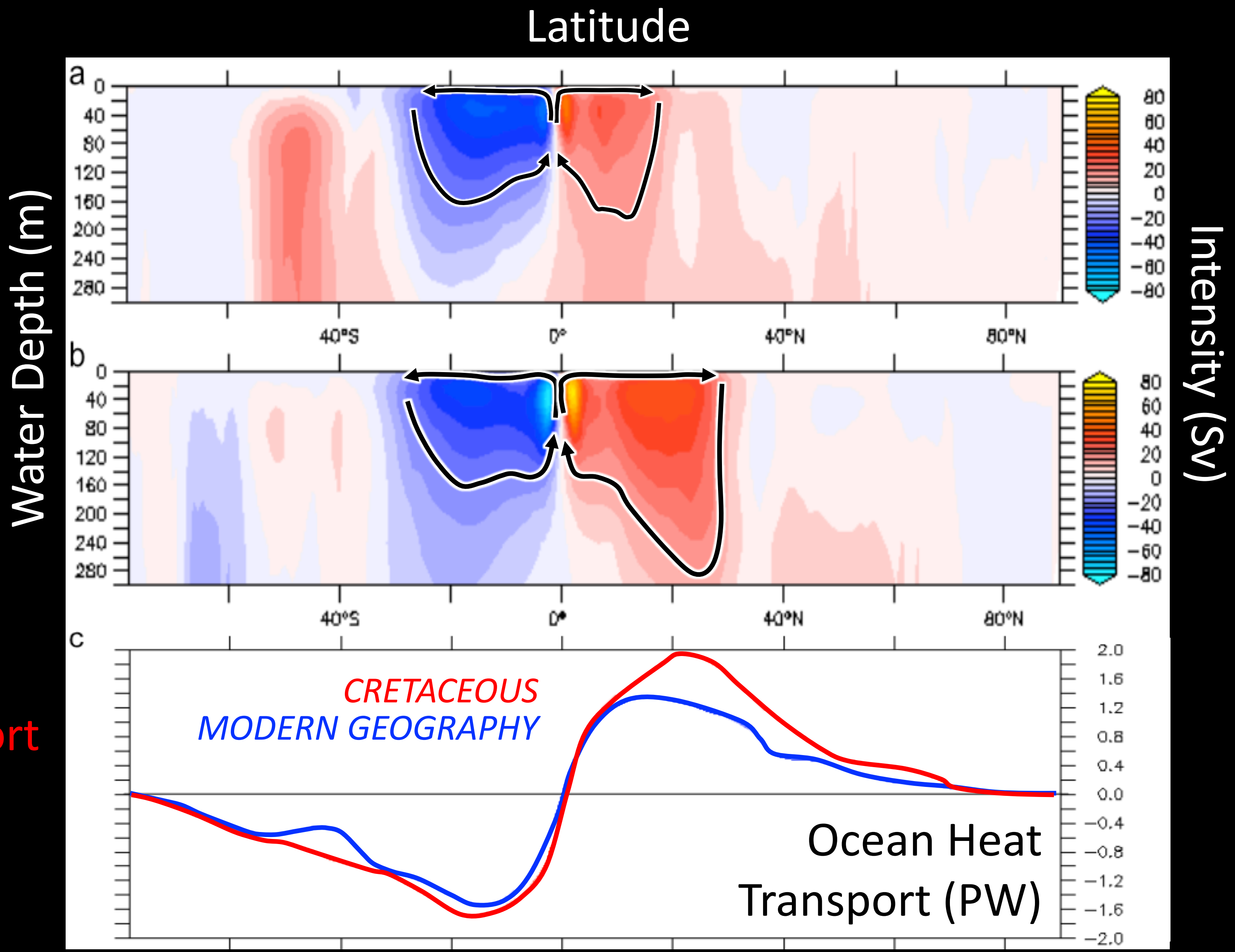


CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)
→ EQUATORIAL OCEANIC CONNECTION

MODERN GEOGRAPHY

Surface meridionnal streamfunction

CRETACEOUS



→ Enhanced ocean heat transport (cf also Hotinski & Toggweiler, 2003)

CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)

→ INCREASED OCEANIC HEAT TRANSPORT

→ Enhanced moisture injection into the upper troposphere

→ Increased high-latitude cloudiness

→ Enhanced greenhouse effect

(cf also Rose & Ferreira, 2013 – Herweijer et al., 2005)

CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)

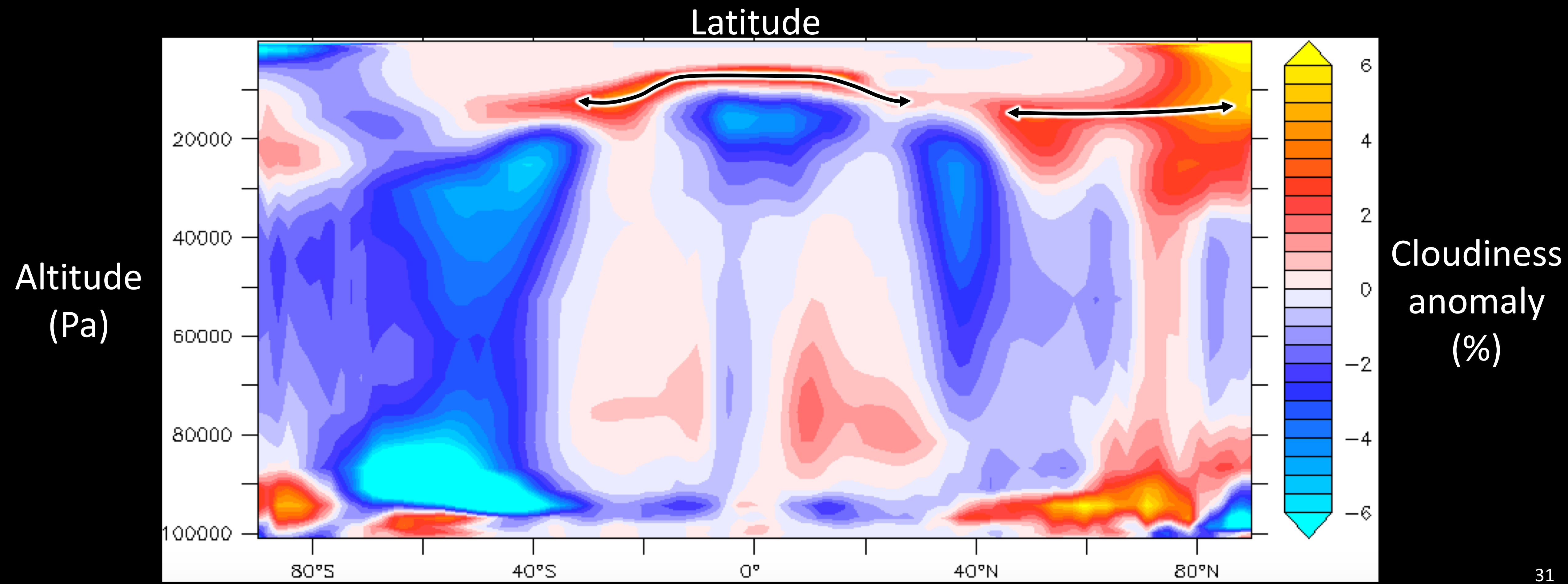
→ INCREASED OCEANIC HEAT TRANSPORT

→ Enhanced moisture injection into the upper troposphere

→ Increased high-altitude cloudiness

→ Enhanced greenhouse effect

(cf also Rose & Ferreira, 2013 – Herweijer et al., 2005)

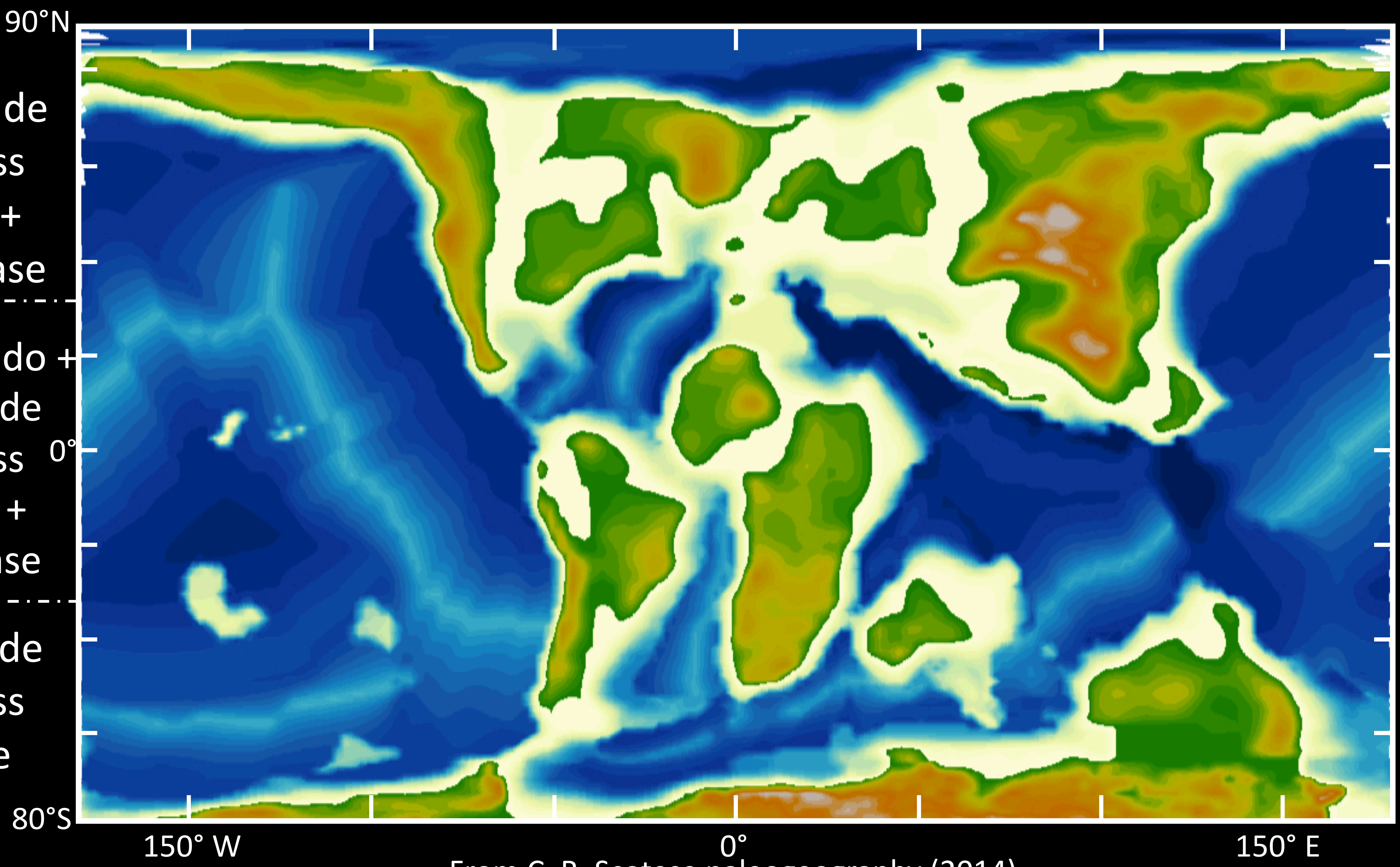


CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)

High-altitude cloudiness increase + H_2O increase

Surface albedo + Low-altitude cloudiness decrease + H_2O increase

Low-altitude cloudiness decrease



Climate warming controller

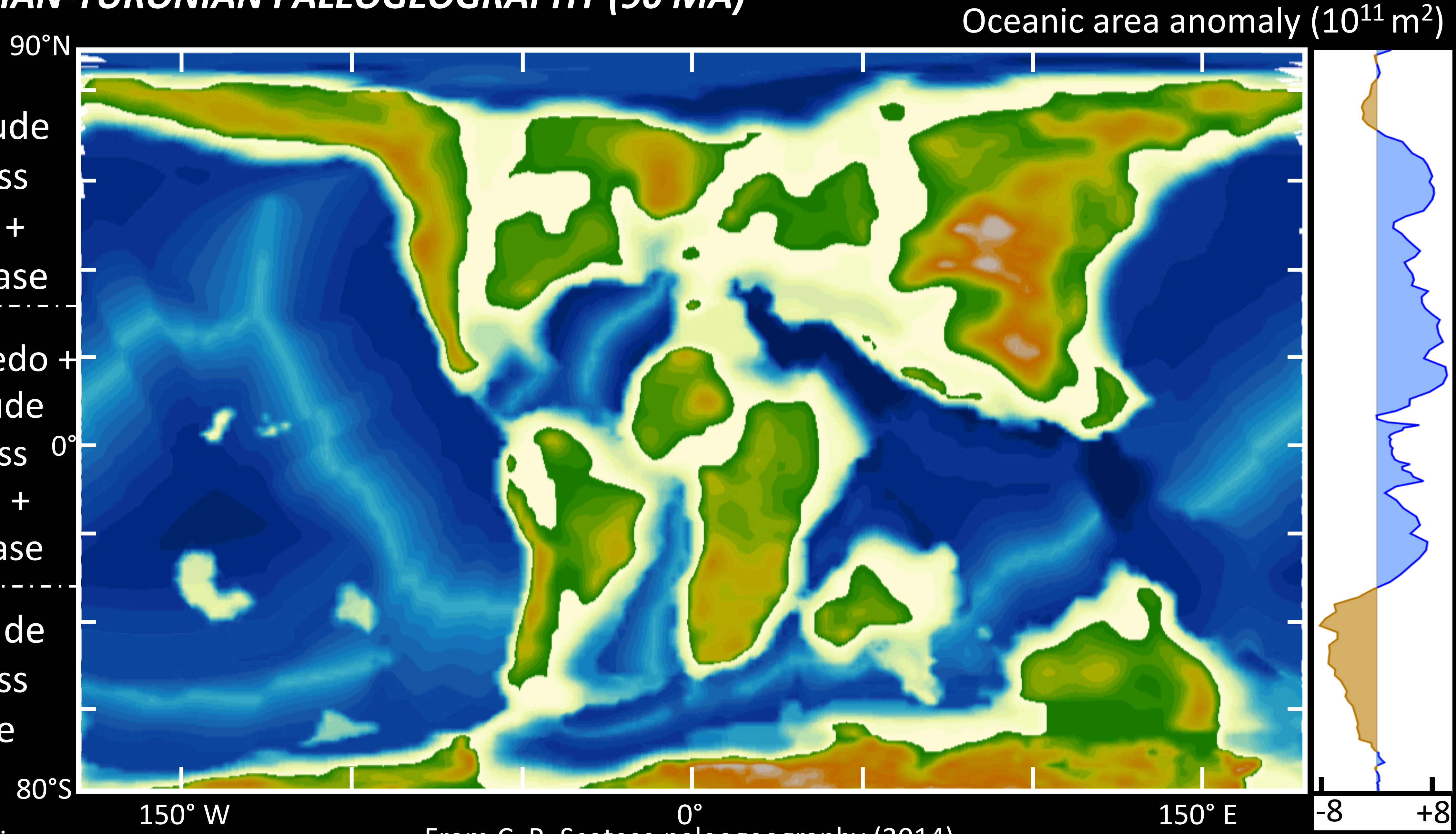
From C. R. Scotese paleogeography (2014), with ocean ridges of Müller et al. (2008)

CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)

High-altitude cloudiness increase + H_2O increase

Surface albedo + Low-altitude cloudiness decrease + H_2O increase

Low-altitude cloudiness decrease



From C. R. Scotese paleogeography (2014), with ocean ridges of Müller et al. (2008)

Climate warming controller

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

- Negligible role?

- Only regional role?

- As strong as a doubling of pCO_2 (~4.5°C here) ?

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

- Negligible role?

  Not here (but dependant on specific geographic features)

- Only regional role?

- As strong as a doubling of $p\mathrm{CO}_2$ (~4.5°C here) ?

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

- Negligible role?

  Not here (but dependant on specific geographic features)

- Only regional role?

  Regional controls, but global impact

- As strong as a doubling of $p\mathrm{CO}_2$ (~4.5°C here) ?

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

- Negligible role?

  Not here (but dependant on specific geographic features)

- Only regional role?

  Regional controls, but global impact

- As strong as a doubling of pCO_2 (~4.5°C here) ?

  Not that much (2.6°C)

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

- Negligible role?

  Not here (but dependant on specific geographic features)

- Only regional role?

  Regional controls, but global impact

- As strong as a doubling of pCO_2 (~4.5°C here) ?

  Not that much (2.6°C)

CONCLUSIONS

- Paleogeography has an impact on climate, driven by specific features :
  - The configuration of equatorial gateways
  - The ocean/continent proportion

- Negligible role?

  Not here (but dependant on specific geographic features)

- Only regional role?

  Regional controls, but global impact

- As strong as a doubling of pCO_2 (~4.5°C here) ?

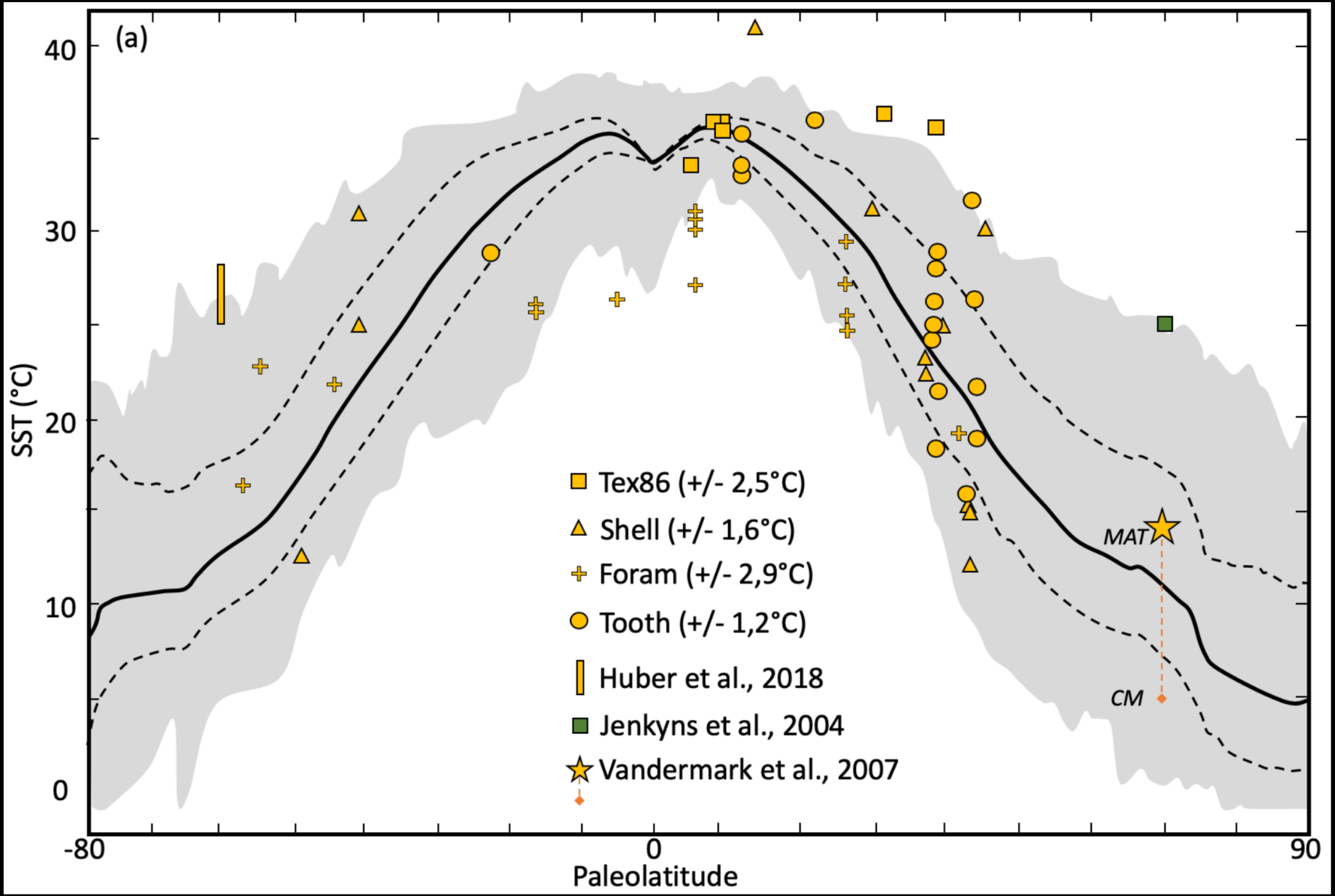
  Not that much (2.6°C)

Thank you for your attention !

laugie@cerege.fr

MORE

4X-CRETACEOUS SIMULATION - RESULTS



CENOMANIAN-TURONIAN PALEOGEOGRAPHY (90 MA)