Earth's next supercontinent climate:
how tectonics, rotation rate, & insolation affect climate

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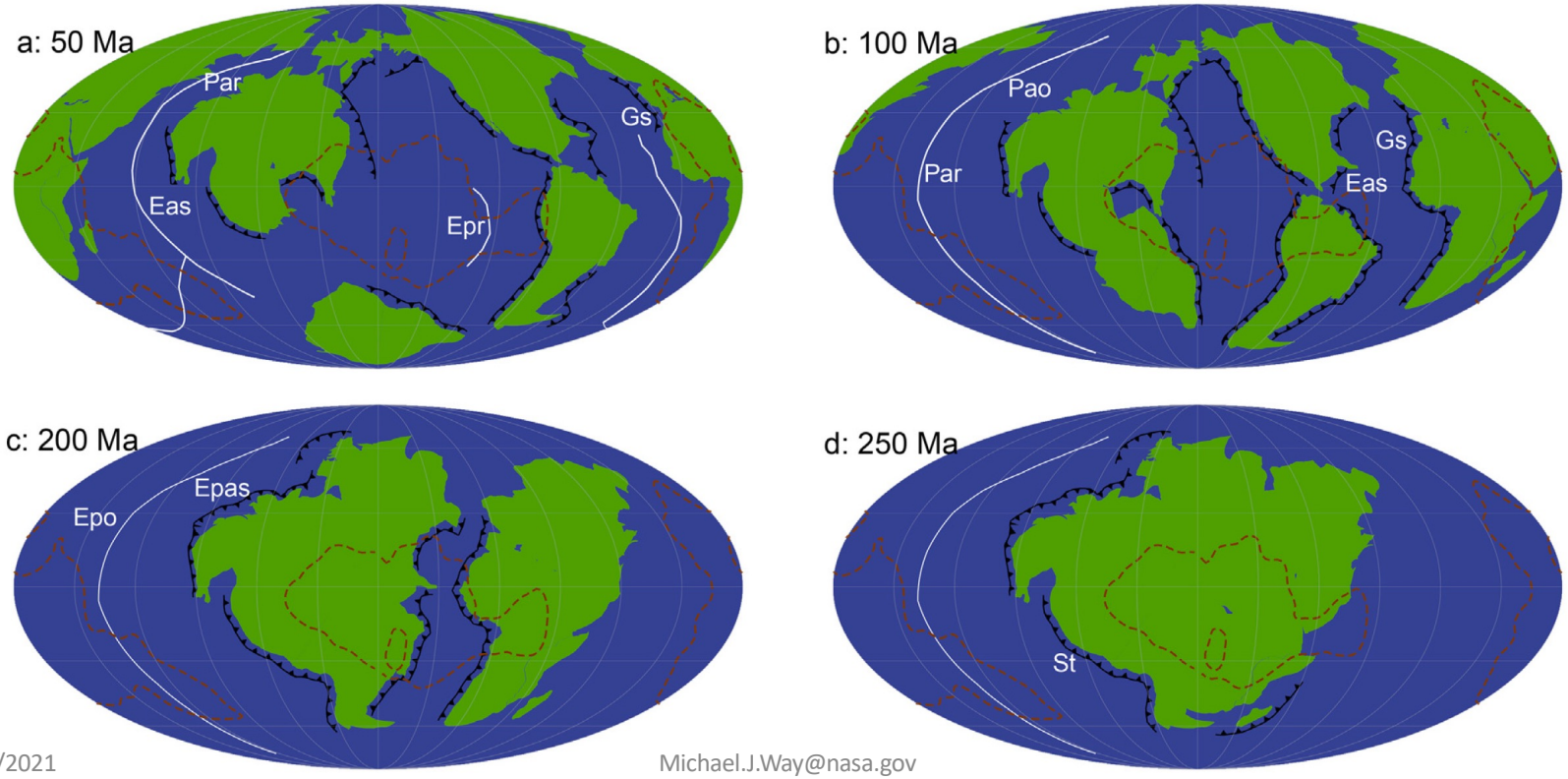
Two future supercontinents

Davies, Green & Duarte (2018) Global and Planetary Change 169, 133
"Back to the future: Testing different scenarios for the next supercontinent Gathering"

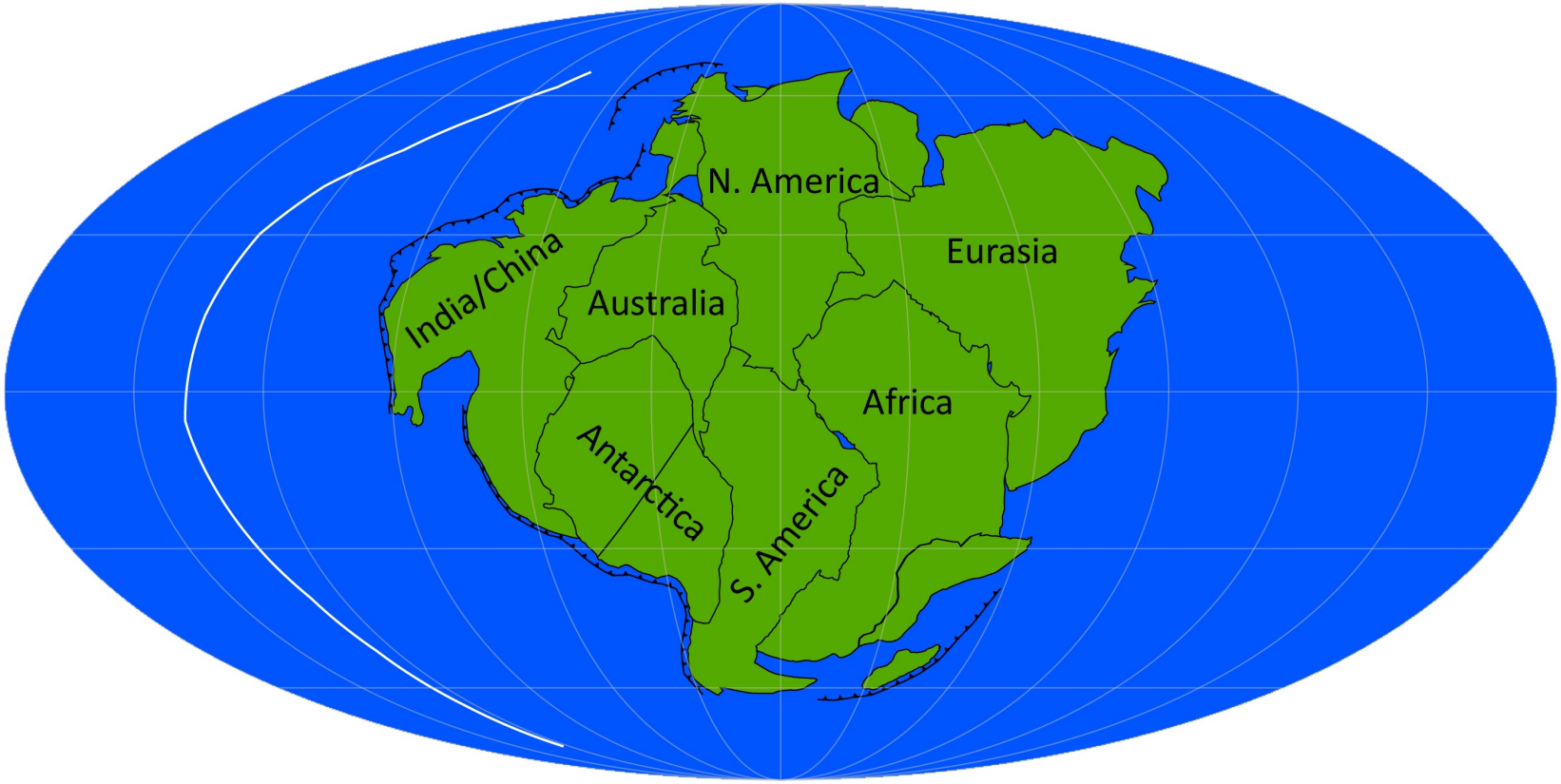
Aurica – The **equatorial** supercontinent
250 Myr into the future

Amasia – The **polar** supercontinent
200 Myr into the future

Aurica – The **equatorial** supercontinent

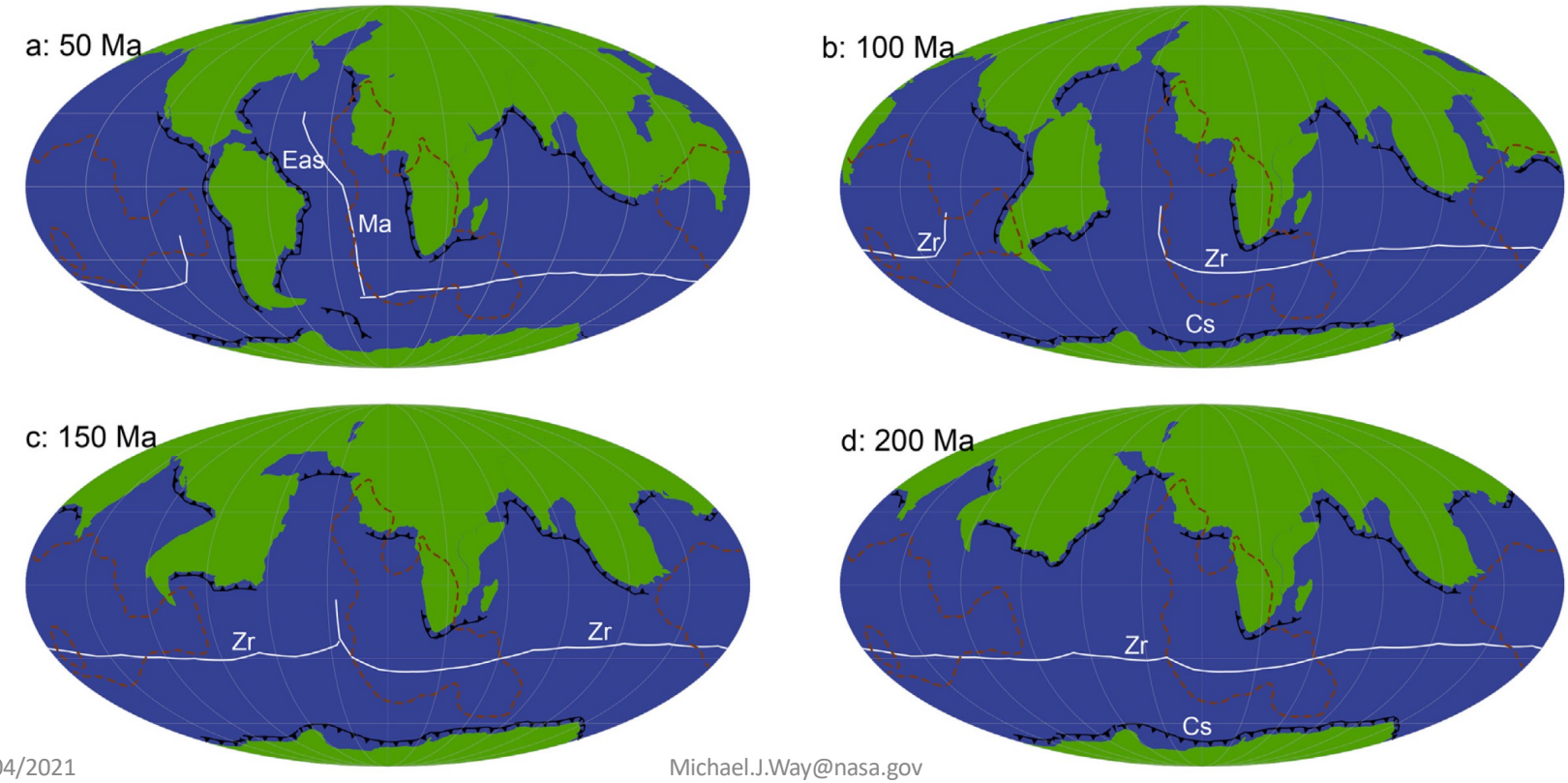


Aurica – The **equatorial** supercontinent

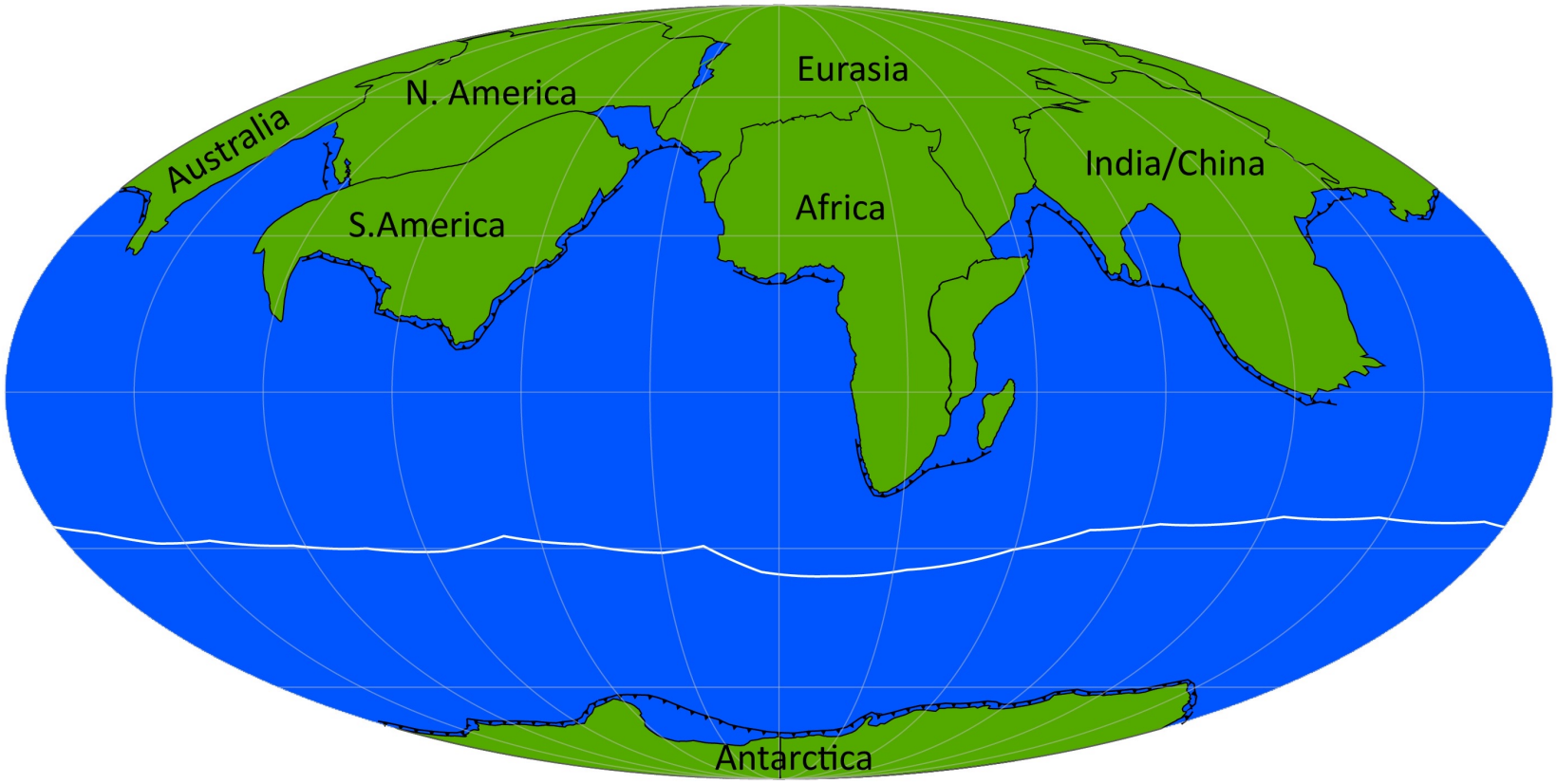


Courtesy H. Davies

Amasia – The polar supercontinent



Amasia – The polar supercontinent

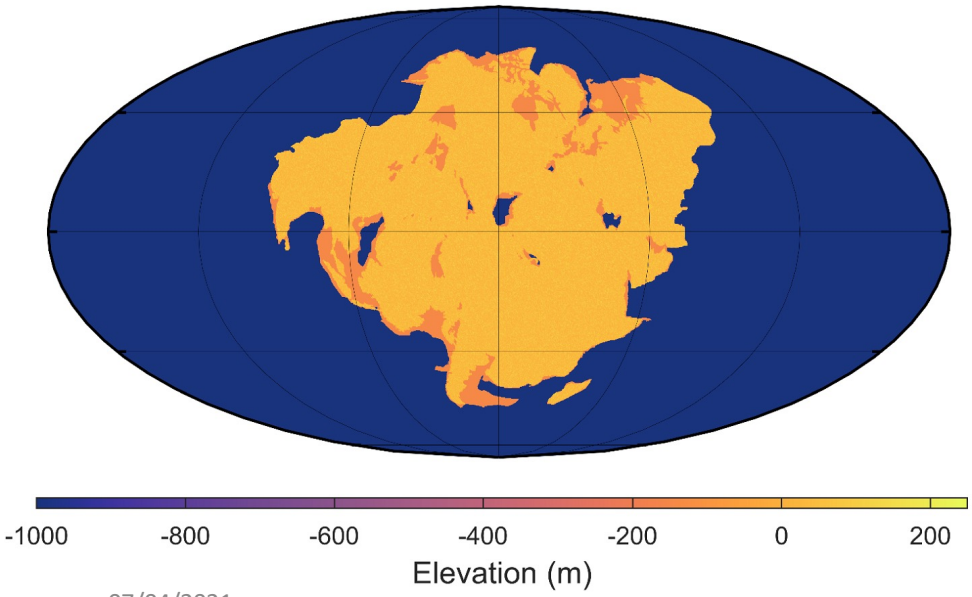


Courtesy H. Davies

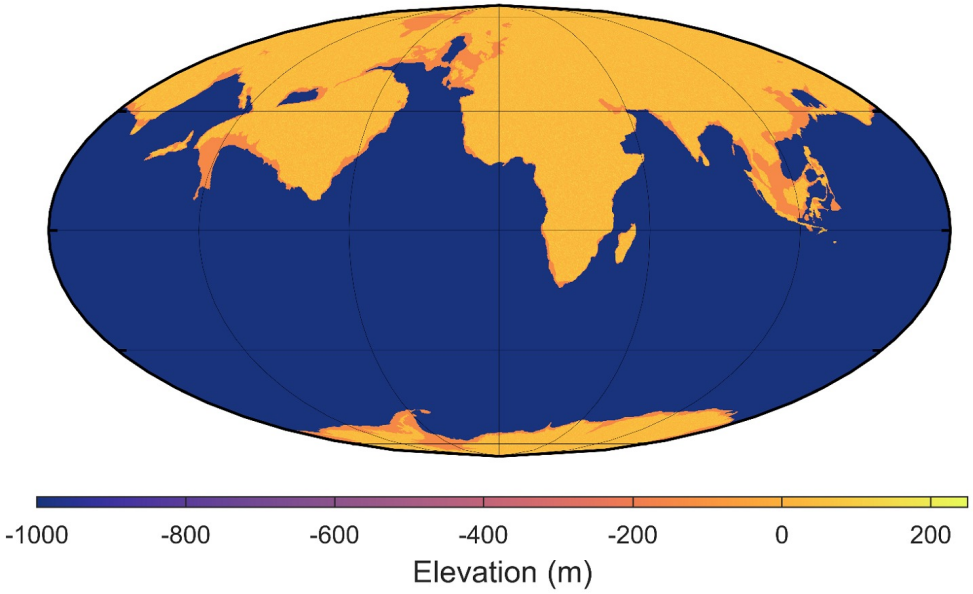
Three topographies of both supercontinents

1.) Low mean topography (land close to sea level), no mountains (CTRL)
Topographic heights of 1 – 200 m

Aurica CTRL



Amasia CTRL

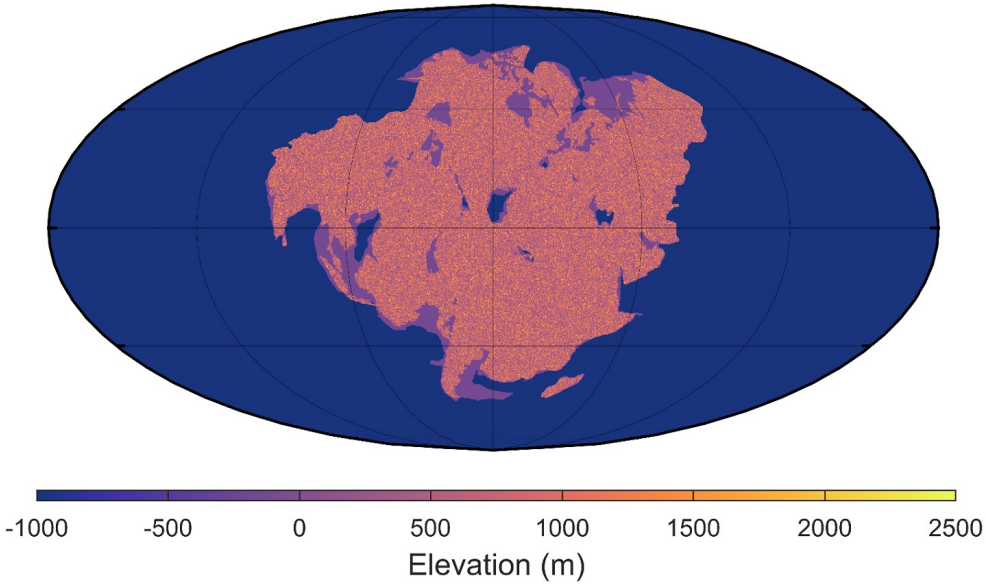


Courtesy H. Davies

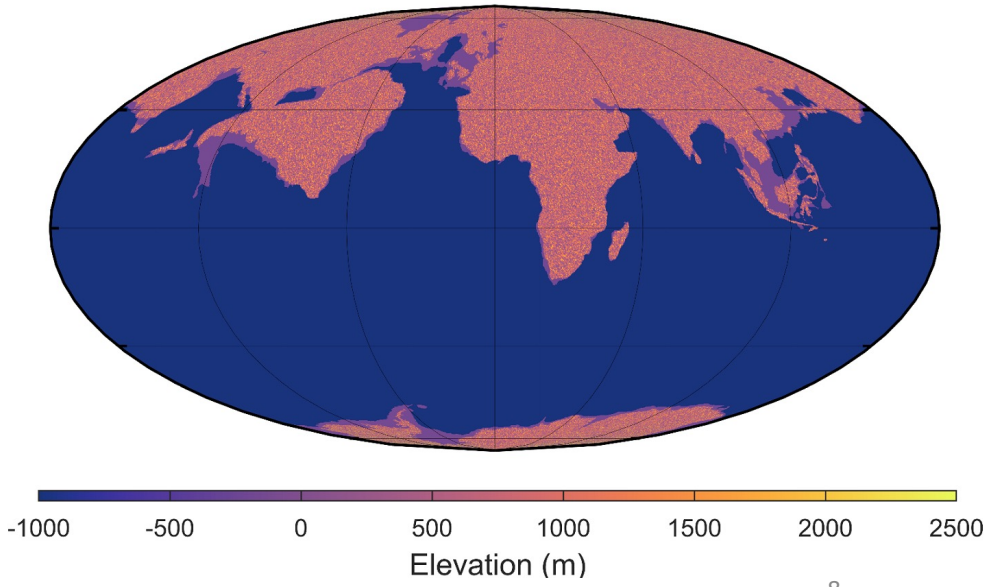
Three topographies of both supercontinents

2.) Higher mean topography: **Present-day** equivalent topography: 1 – 4000 m no mountains (PD)

Aurica PD



Amasia PD

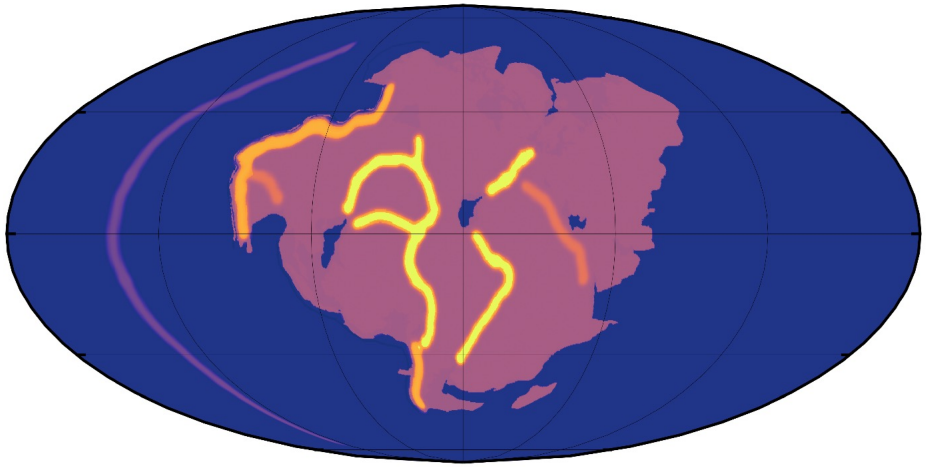


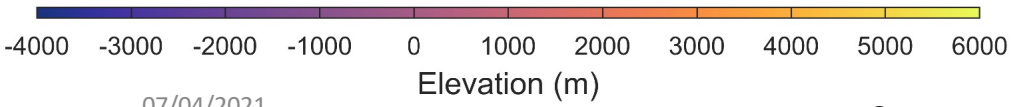
Courtesy H. Davies

Three topographies of both supercontinents

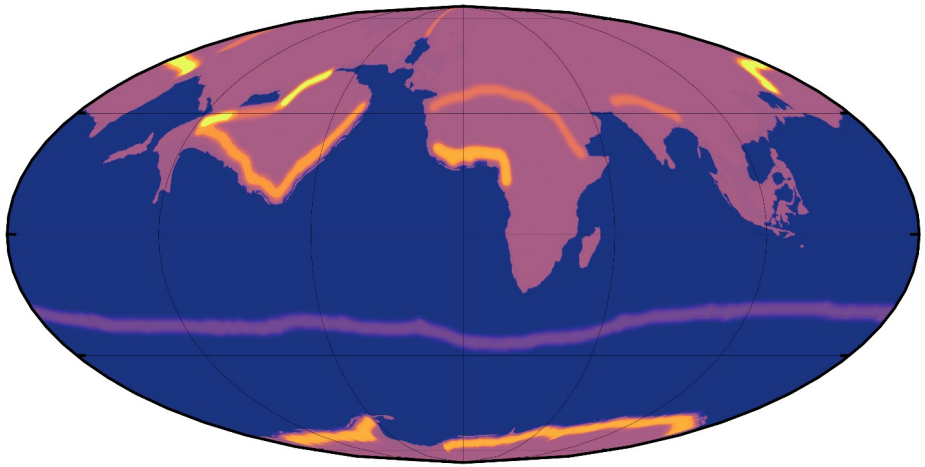
3.) Low topography (1 – 200 m) with mountains (**MTNS**)
<7500 m (Himalaya-type), <4000 m (Andes-type), <2000 m (Appalachian-type)

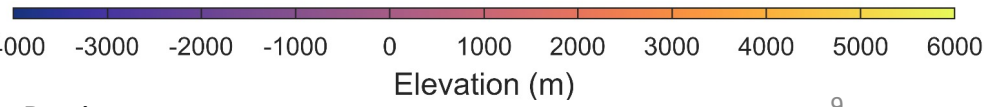
Aurica MTNS





Amasia MTNS





Courtesy H. Davies

ROCKE-3D: 3-D General Circulation Model
(Way et al. 2017 ApJS 231,12)

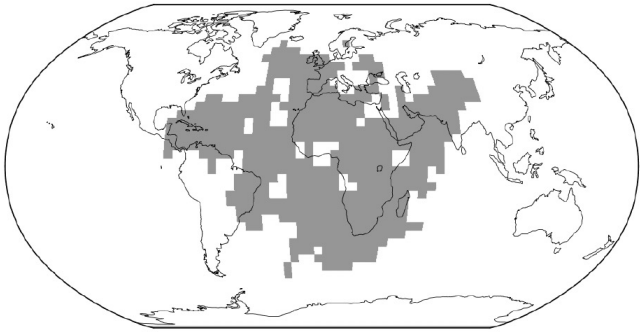
- Resolution 4x5° lat x lon, 40L atmosphere, 13L ocean
- **Obliquity/Eccentricity: Modern**
- Rotation Rate: 24.0 & 24.5 hours/day
- **Land: Albedo=0.2 at model start, 50/50 clay/sand soil**
- Atmosphere **1bar** (modern pre-industrial): CO_2 (285ppm)
- **Aurica (250Myr) Insolation: 1.0260 x Modern = 1396.4 W/m^2**
- **Amasia (200Myr) Insolation: 1.0223 x Modern = 1391.3 W/m^2**
- **Earth (today) + 30min rotation + 1.0260 x Modern**

Simulations

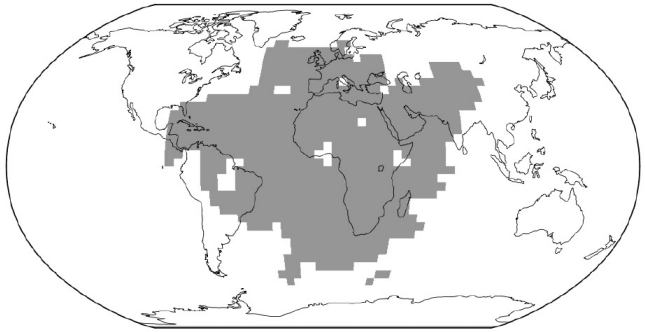
Sim	Name	Topography	Ins[a]	LoD[b] (hrs)	Runtime (years)
		Aurica 250 Myr into future			
01	Aurica	CTRL	1.0260	24.5	2000
02	”	PD	”	24.5	2500
03	”	MTNS	”	24.5	2000
		Amasia 200 Myr into future			
04	Amasia	CTRL	1.0223	24.5	3000
05	”	PD	”	24.5	3000
06	”	MTNS	”	24.5	3000
		Earth today + 30m + insolation			
07	Earth_noAer_noO3		1.0	24.0	2000
08	Earth_noAer_noO3_Rot		1.0	24.5	2000
09	Earth_noAer_noO3_Rot_Ins		1.0260	24.5	2000

Down sampled (via elevation) to 4 x 5 degrees

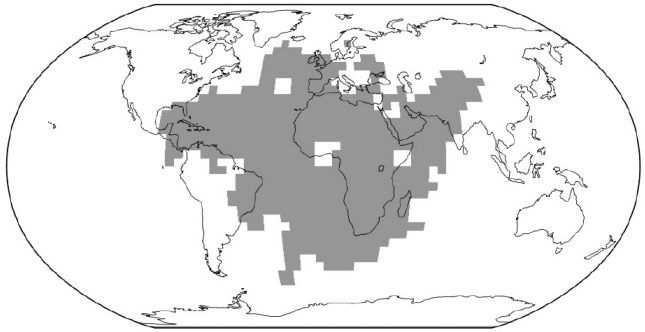
Simulation 01: AURICA CTRL



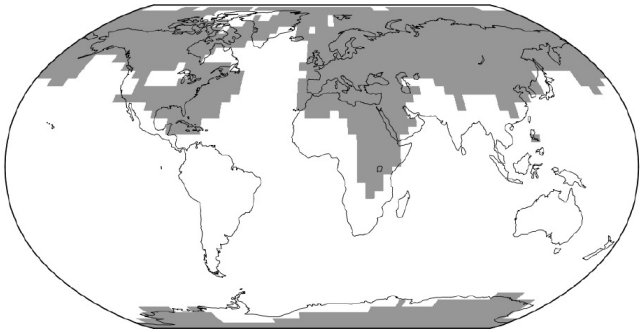
Simulation 02: AURICA PD



Simulation 03: AURICA MTNS

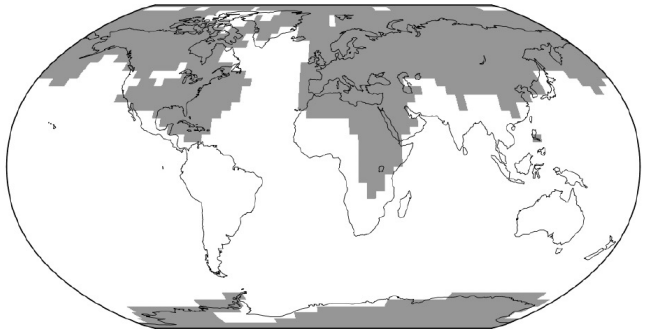


Simulation 04: AMASIA CTRL

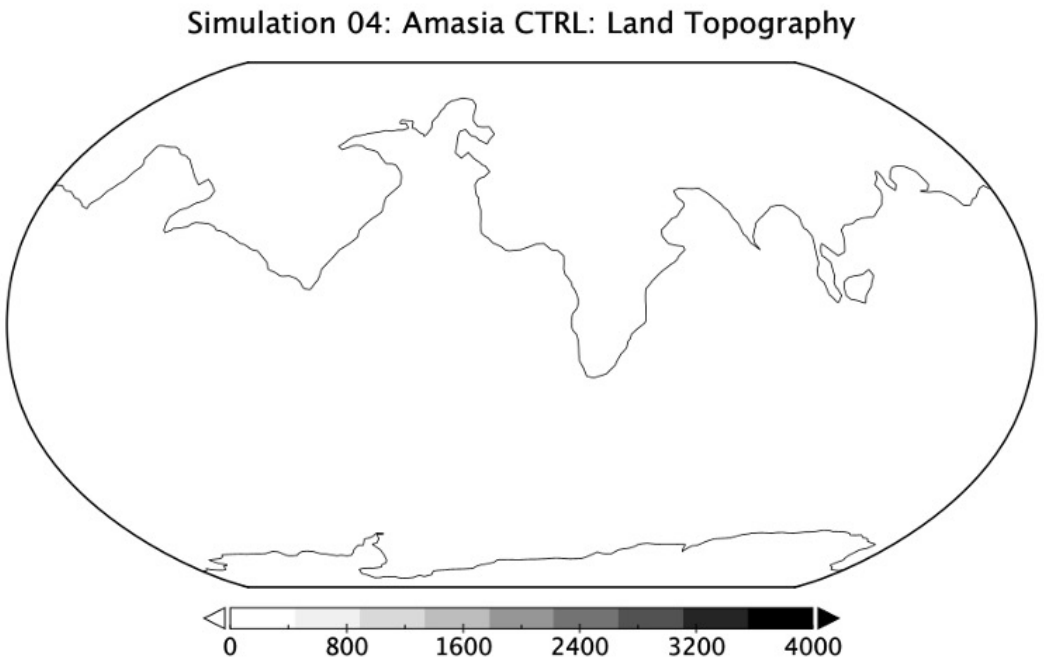


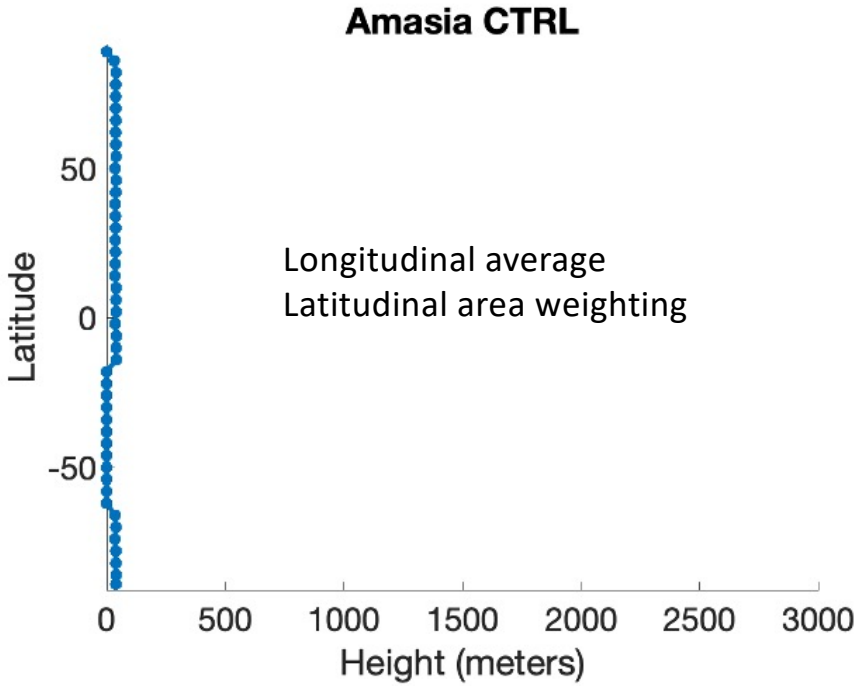
Simulation 05: AMASIA PD

Simulation 06: AMASIA MTNS



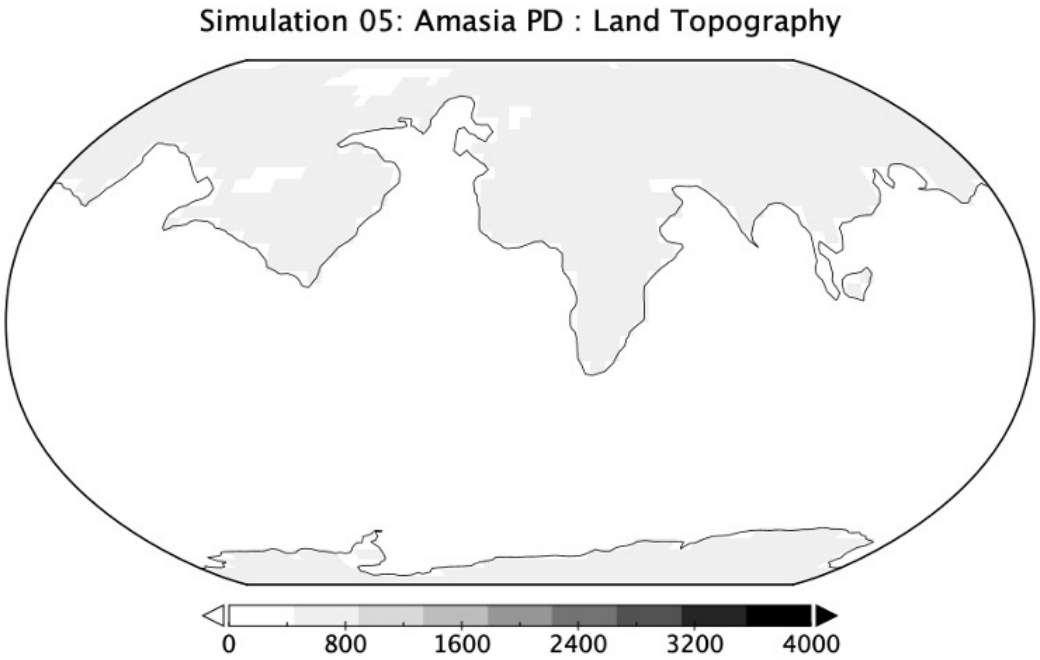
Amasia CTRL Topography

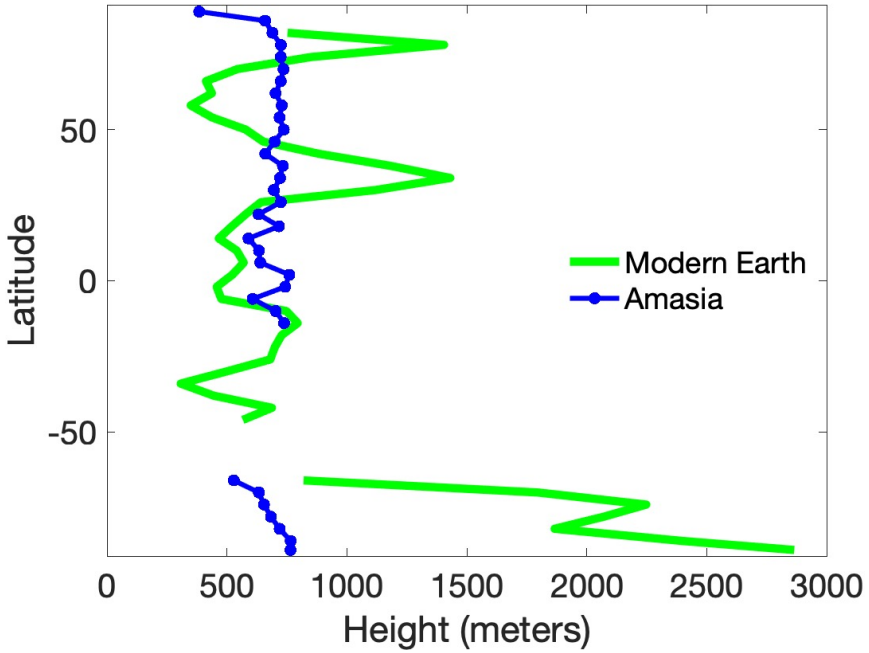




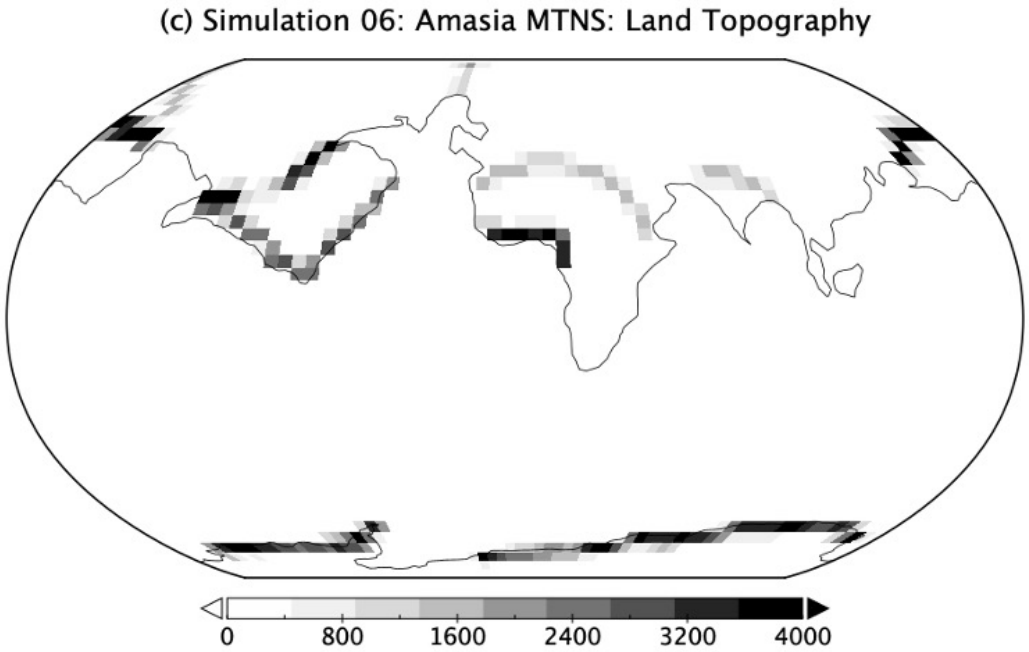
Longitudinal average
Latitudinal area weighting

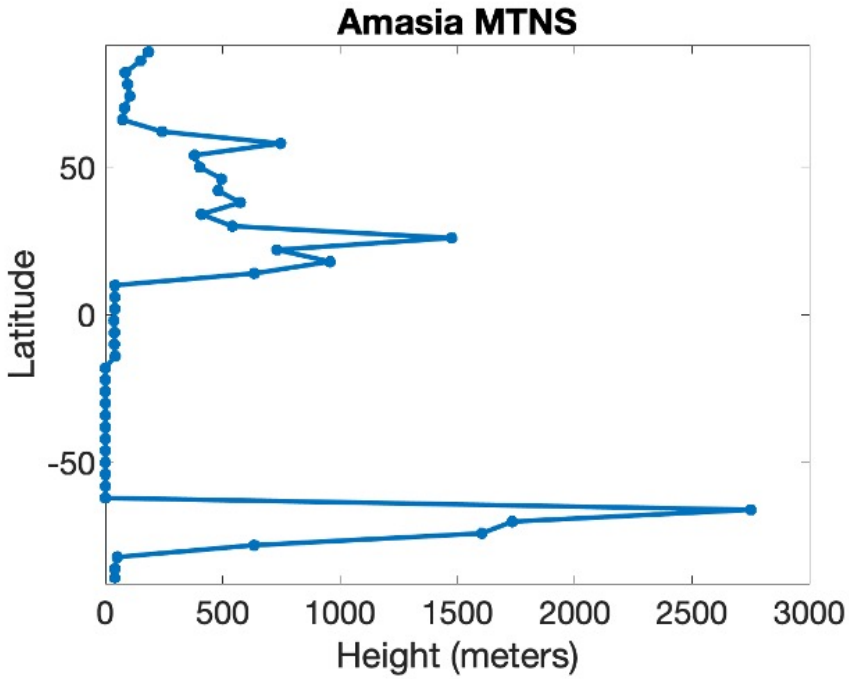
Amasia PD Topography

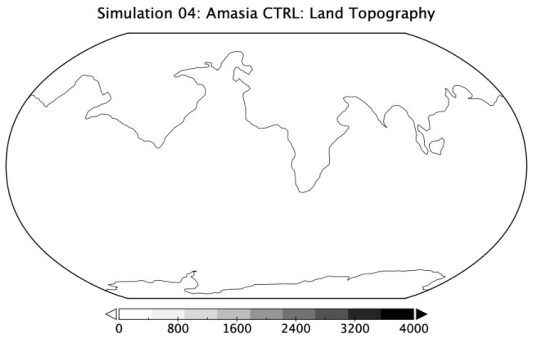


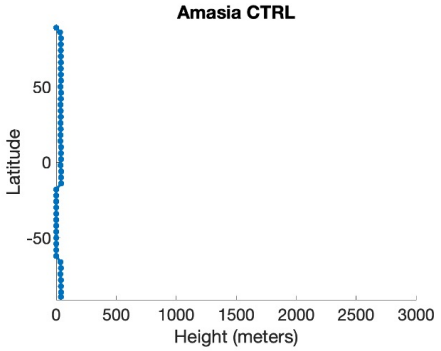


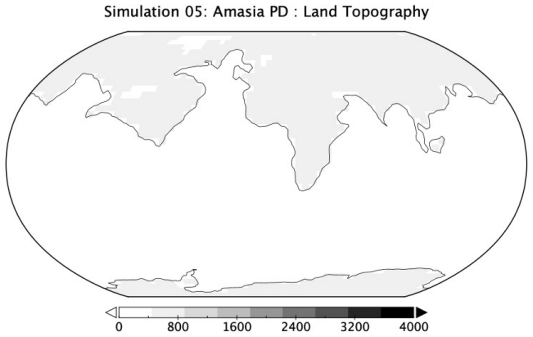
Amasia MTNS Topography

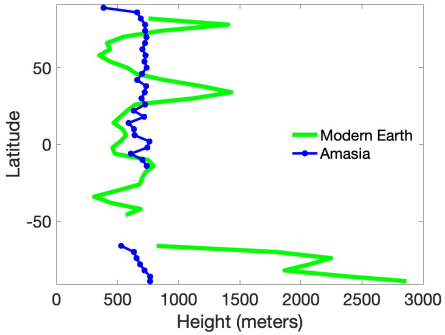


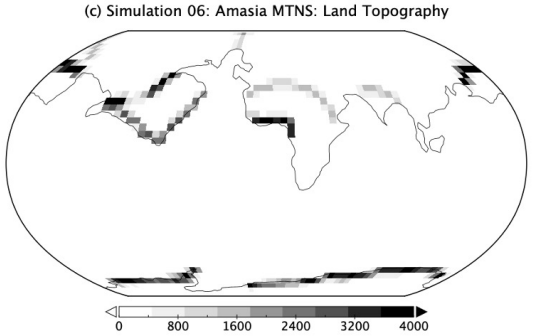


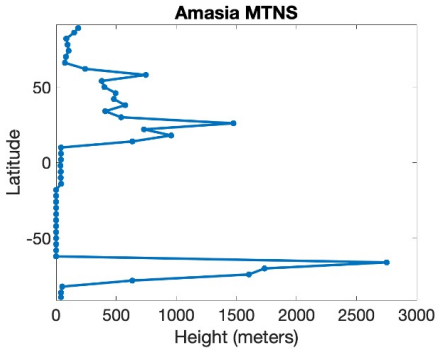

Simulation 04: Amasia CTRL: Land Topography
0
800
1600
2400
3200
4000


Amasia CTRL
Latitude
50
0
-50
0
500
1000
1500
2000
2500
3000
Height (meters)


Simulation 05: Amasia PD : Land Topography
0
800
1600
2400
3200
4000


Latitude
50
0
-50
Modern Earth
Amasia
0
500
1000
1500
2000
2500
3000
Height (meters)


(c) Simulation 06: Amasia MTNS: Land Topography
0
800
1600
2400
3200
4000


Amasia MTNS
Latitude
50
0
-50
0
500
1000
1500
2000
2500
3000
Height (meters)

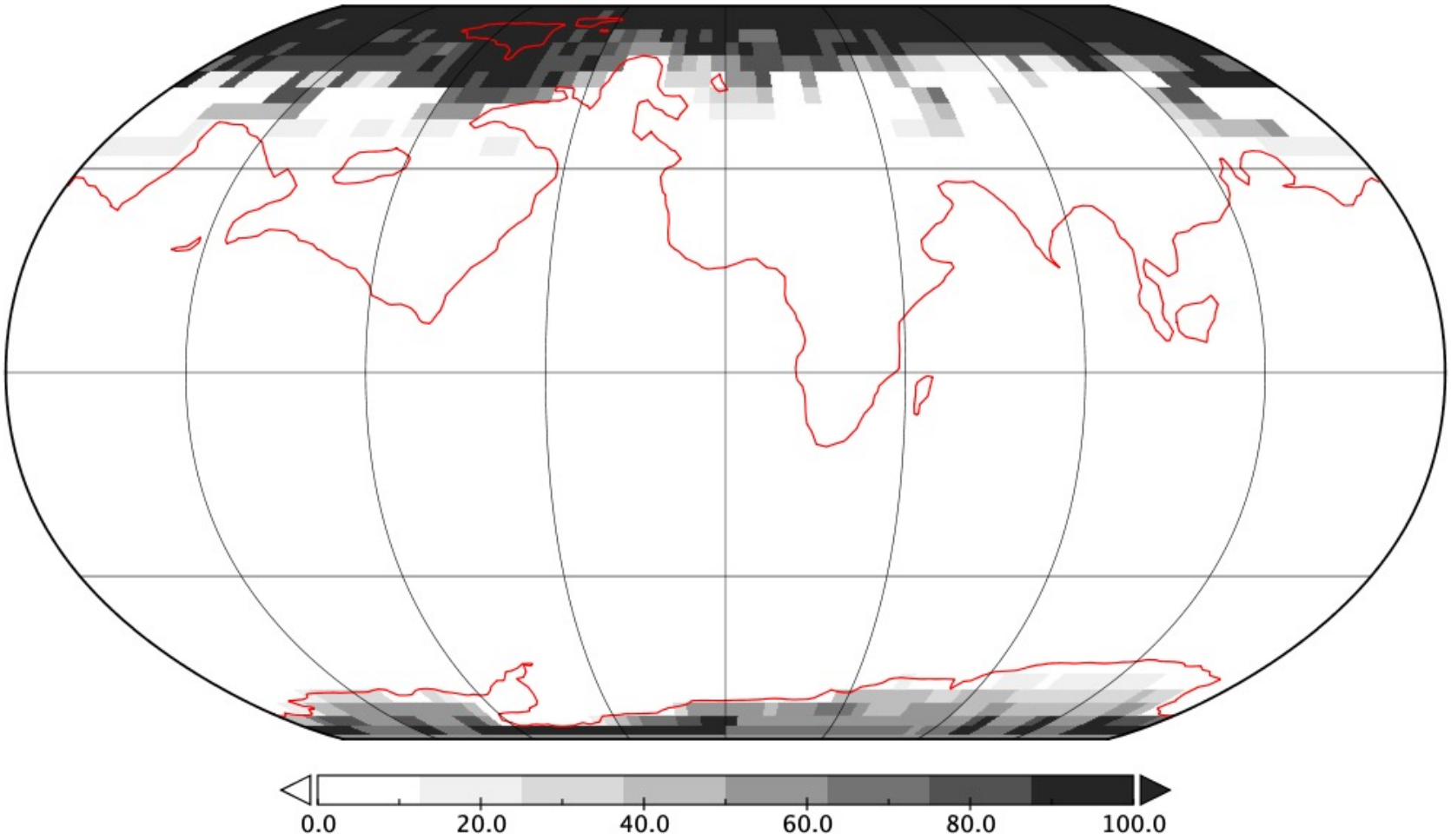
Not so fast!

There are possibilities for ice sheet growth

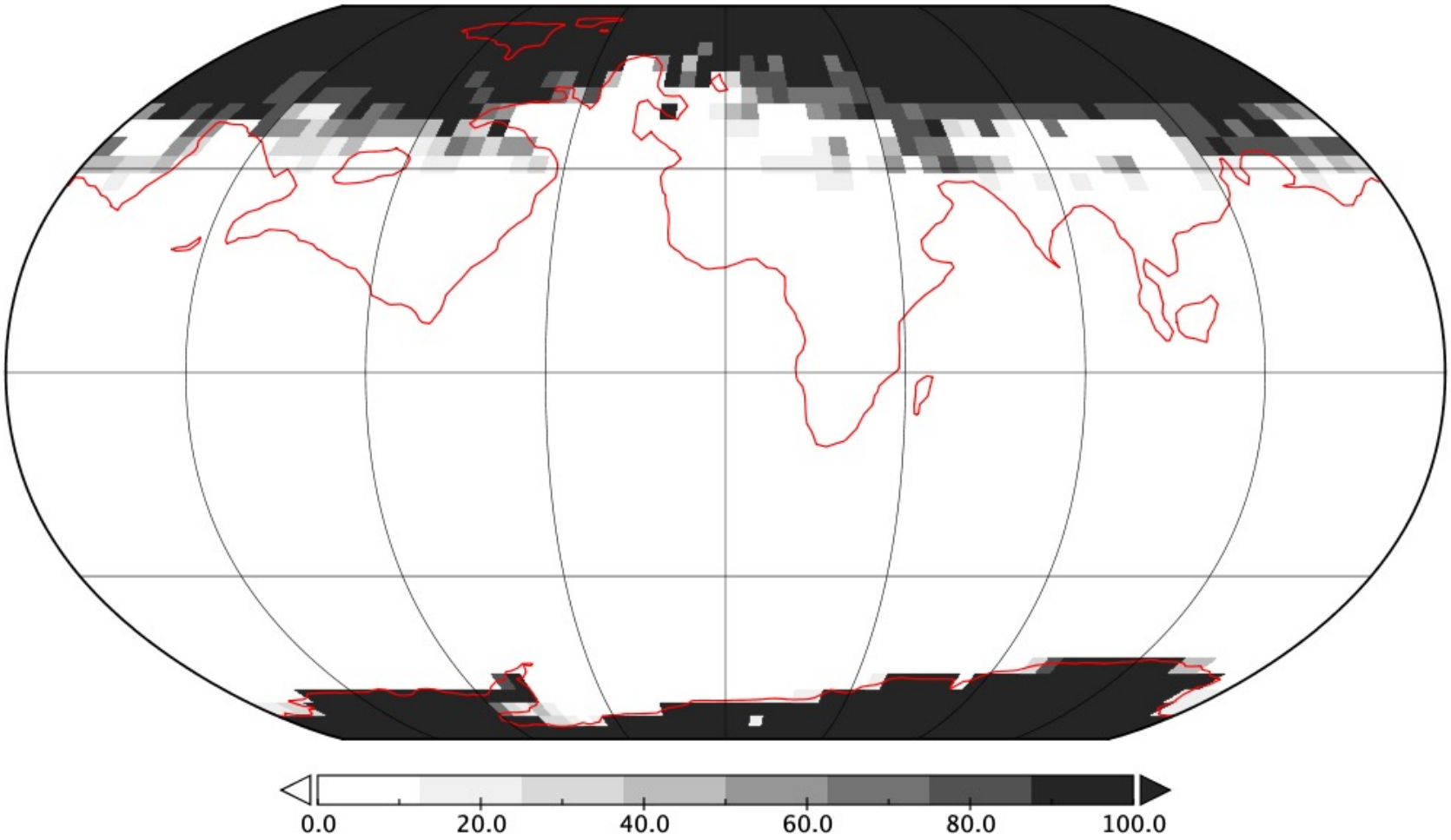
These may seriously affect the climate

Let's examine how we might take that into account

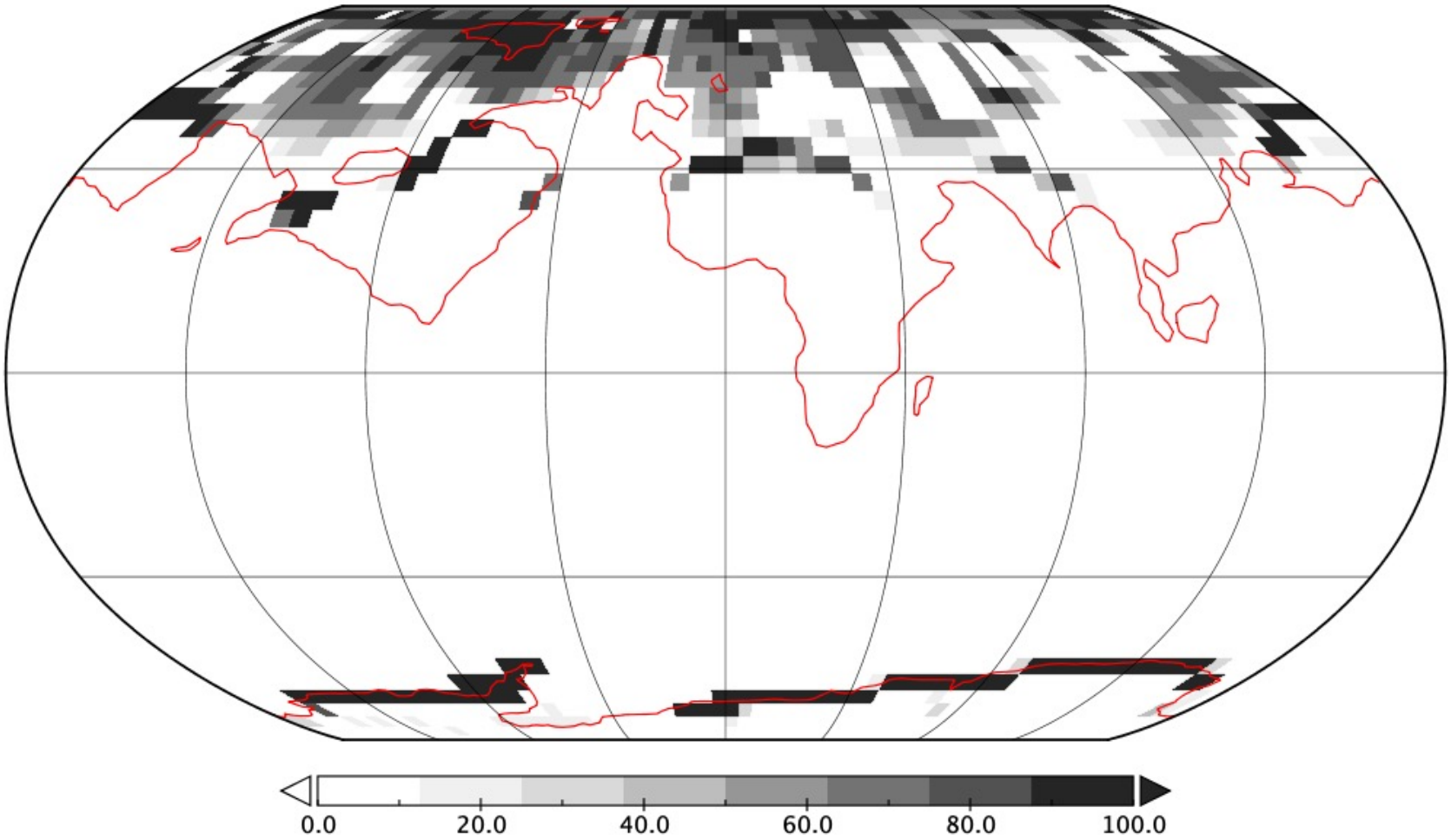
Simulation 04: AMASIA CTRL: Snow and Ice Coverage Dec/Jan/Feb

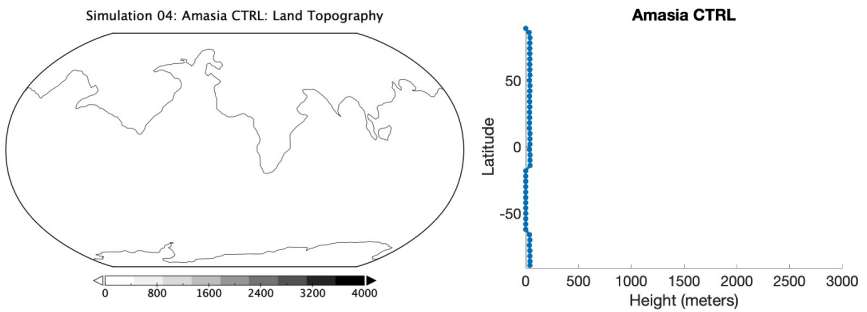


Simulation 05: AMASIA PD: Snow and Ice Coverage Dec/Jan/Feb

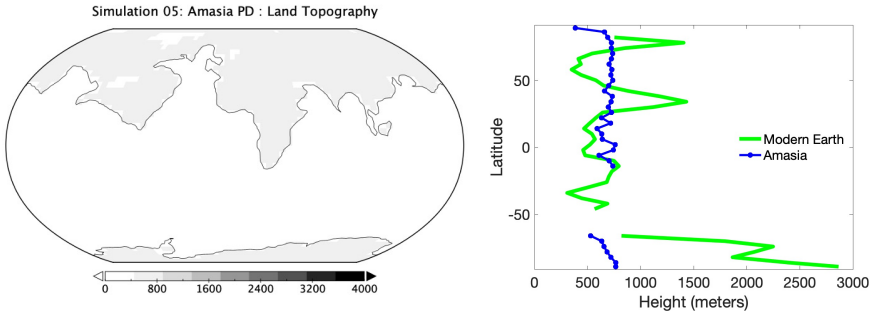


Simulation 06: AMASIA MTNS: Snow and Ice Coverage Dec/Jan/Feb

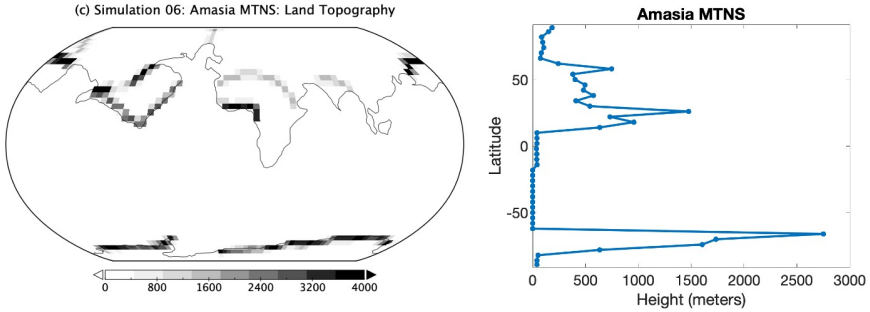



Simulation 04: Amasia CTRL: Land Topography
0 800 1600 2400 3200 4000

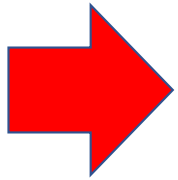
Amasia CTRL
Latitude
50
0
-50
0 500 1000 1500 2000 2500 3000
Height (meters)

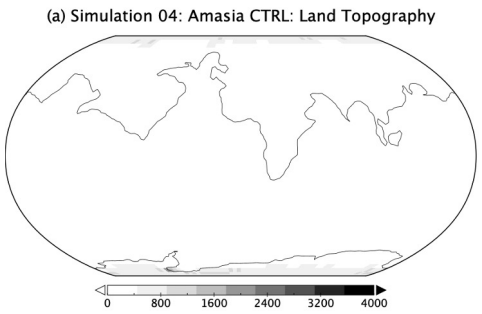

Simulation 05: Amasia PD : Land Topography
0 800 1600 2400 3200 4000

Latitude
50
0
-50
Modern Earth
Amasia
0 500 1000 1500 2000 2500 3000
Height (meters)


(c) Simulation 06: Amasia MTNS: Land Topography
0 800 1600 2400 3200 4000

Amasia MTNS
Latitude
50
0
-50
0 500 1000 1500 2000 2500 3000
Height (meters)




(a) Simulation 04: Amasia CTRL: Land Topography
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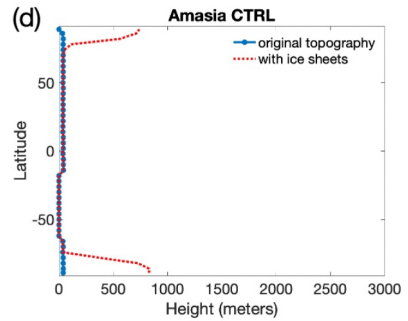
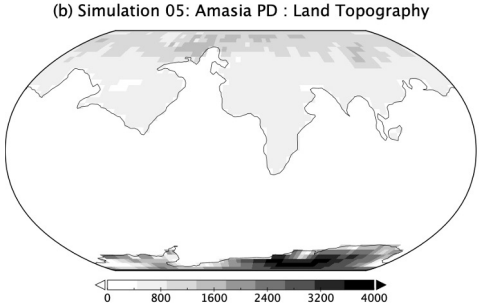
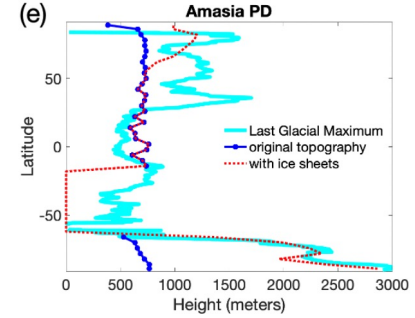
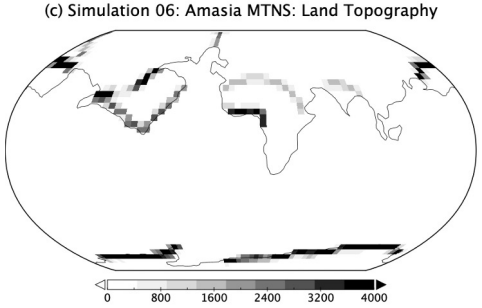

(d)
Amasia CTRL
original topography
with ice sheets
Latitude
50
0
-50
0 500 1000 1500 2000 2500 3000
Height (meters)


(b) Simulation 05: Amasia PD : Land Topography
0 800 1600 2400 3200 4000


(e)
Amasia PD
Last Glacial Maximum
original topography
with ice sheets
Latitude
50
0
-50
0 500 1000 1500 2000 2500 3000
Height (meters)


(c) Simulation 06: Amasia MTNS: Land Topography
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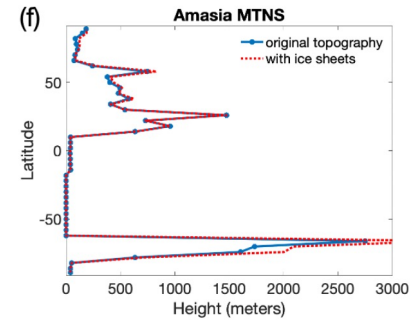
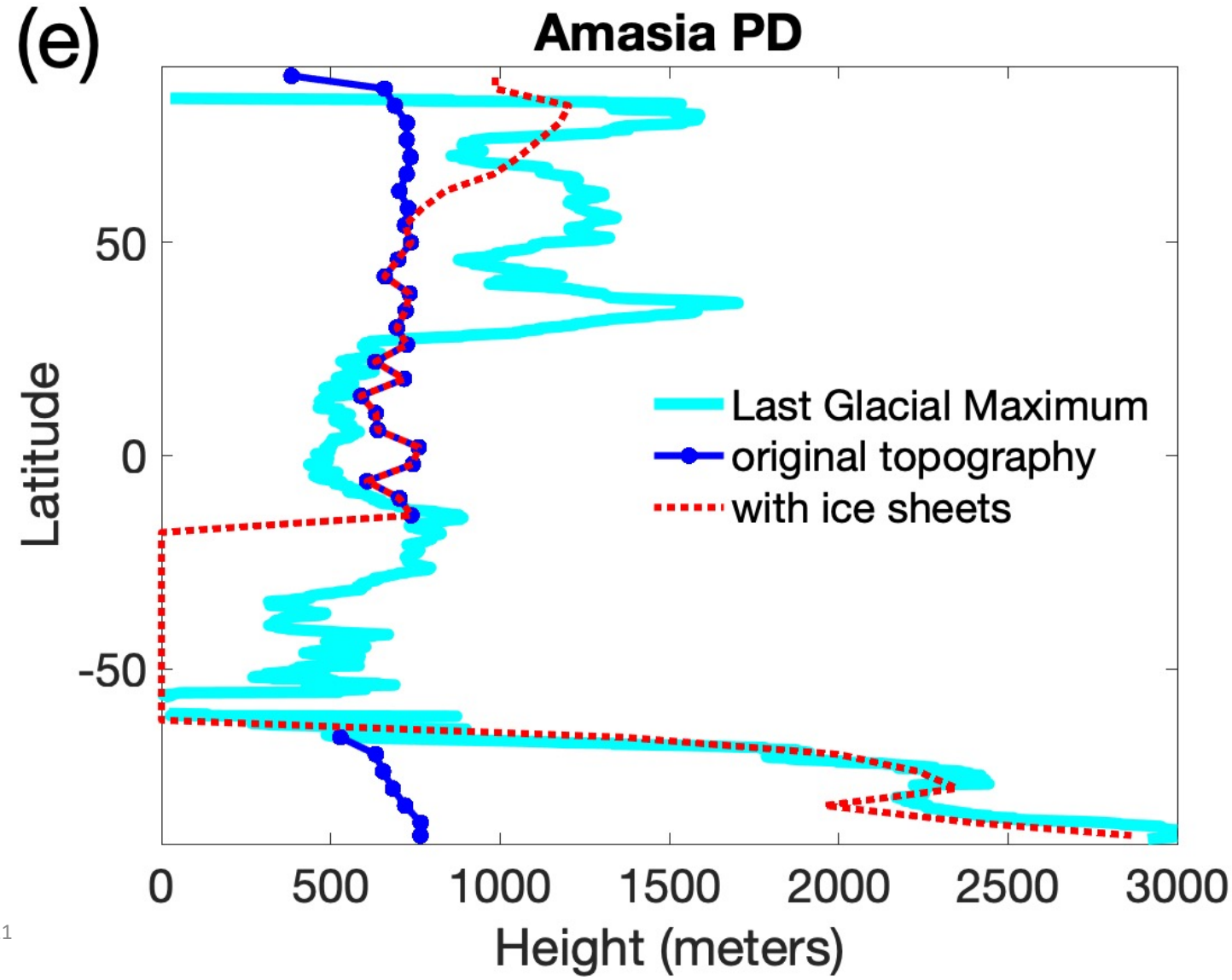
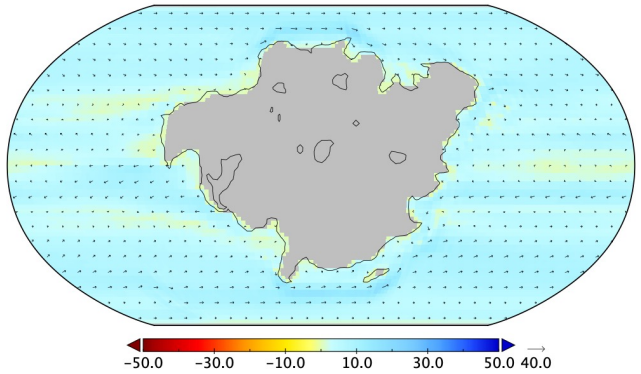

(f)
Amasia MTNS
original topography
with ice sheets
Latitude
50
0
-50
0 500 1000 1500 2000 2500 3000
Height (meters)

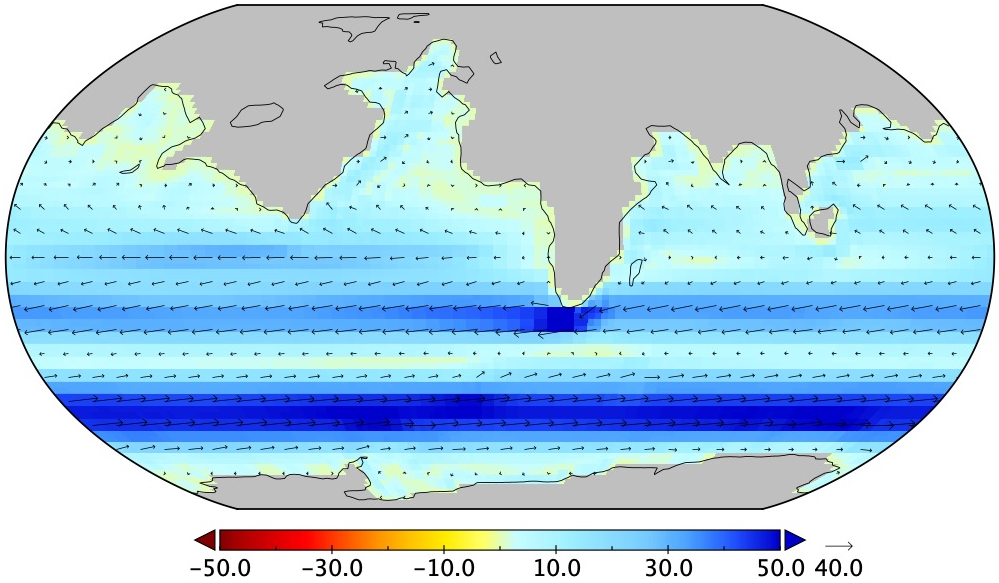

(e)
Amasia PD
50
0
-50
Latitude
Last Glacial Maximum
original topography
with ice sheets
0
500
1000
1500
2000
2500
3000
Height (meters)

Why so much snow & ice deposition at high latitudes compared to Earth or Aurica? ➔ Northern Oceans!

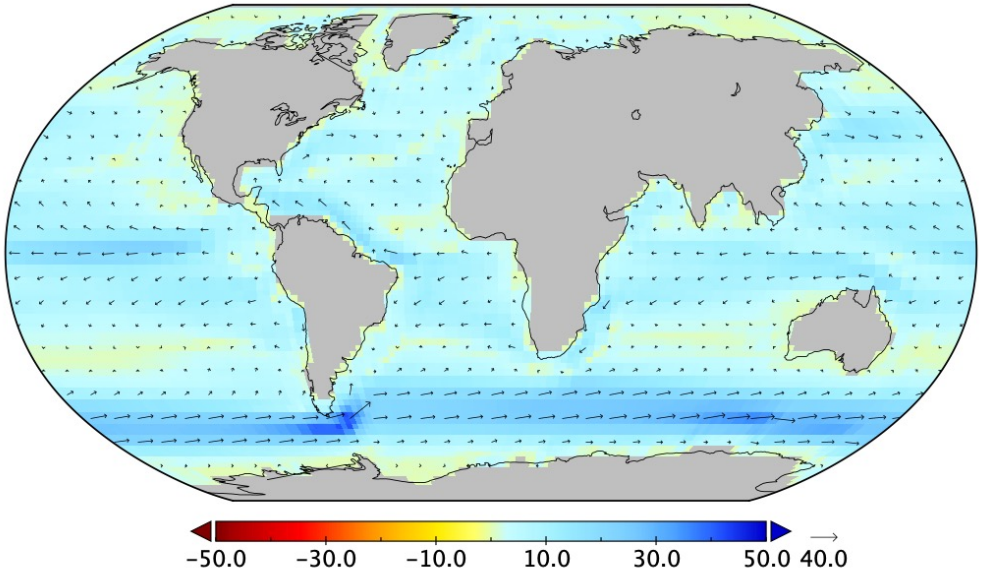
(a) Simulation 02: Aurica PD: Ocean Surface Currents



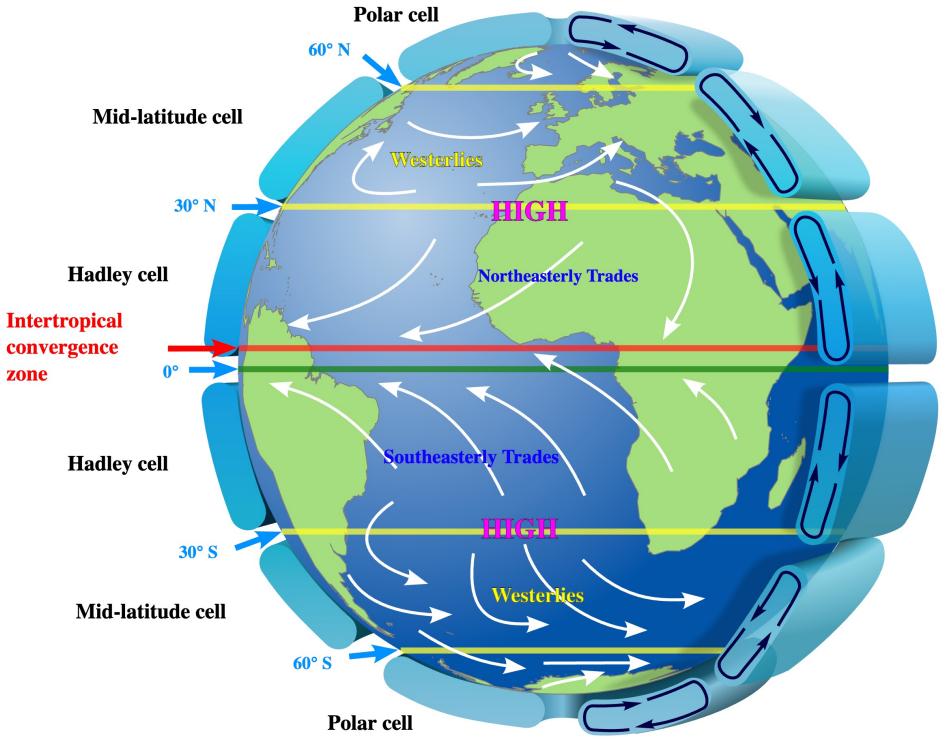
(b) Simulation 05: Amasia PD: Ocean Surface Currents

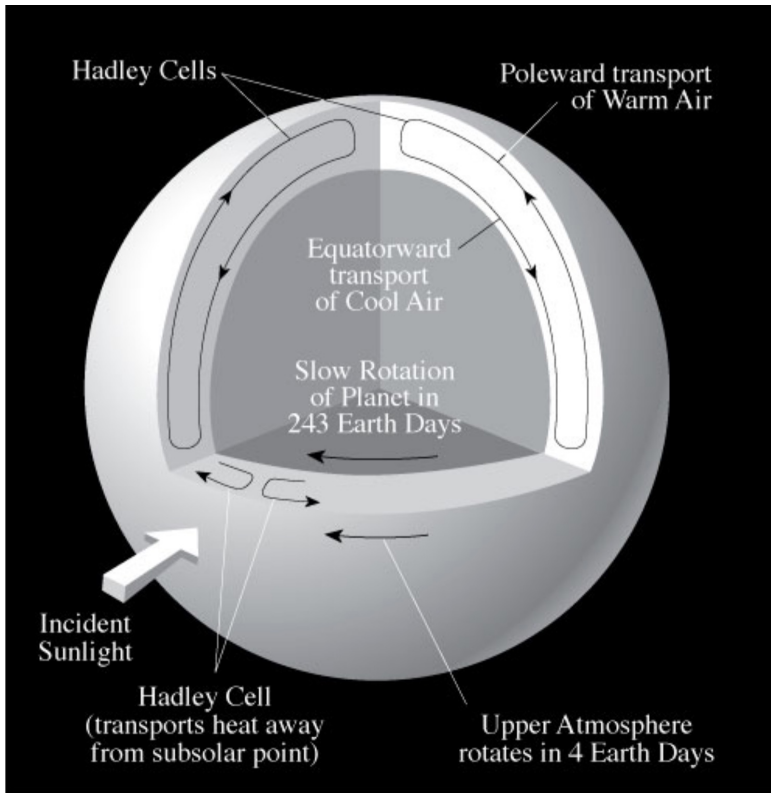


(c) Simulation 09: Earth: Ocean Surface Currents

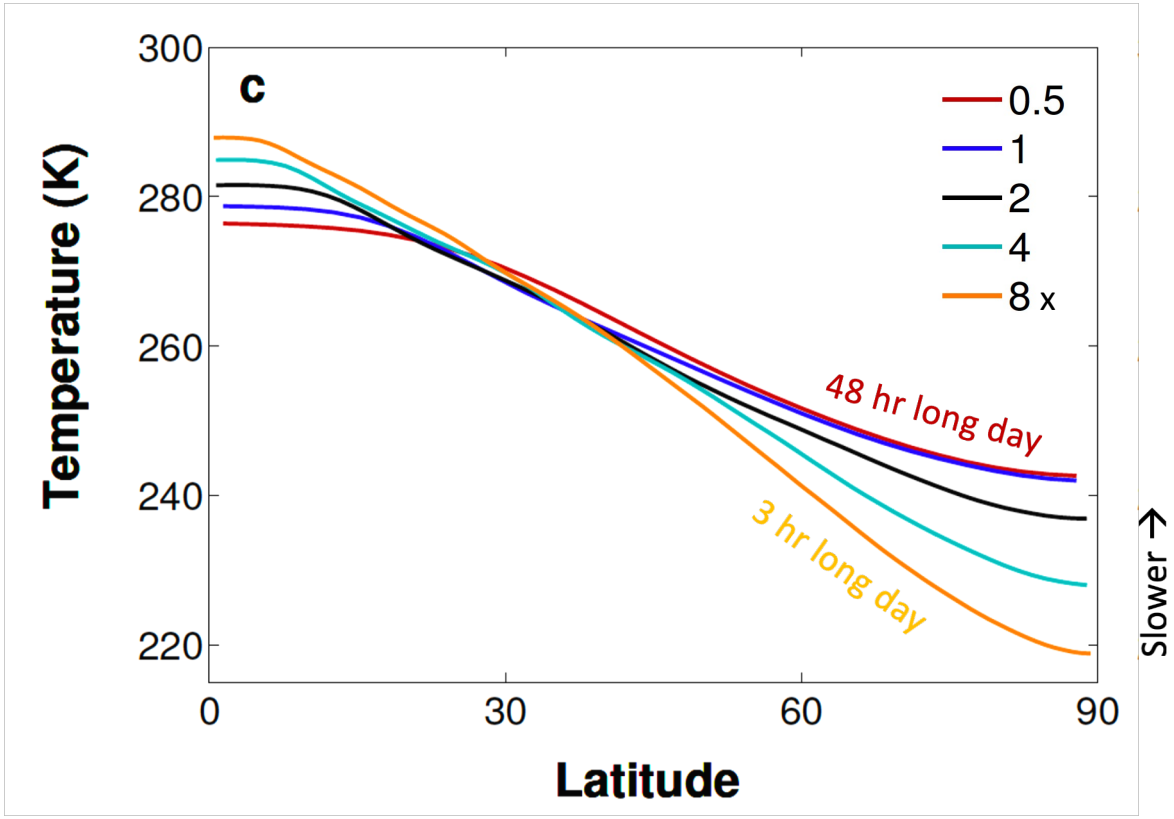


How might a +30m Rotation Rate affect the climate?
Extreme comparison: Earth vs Venus





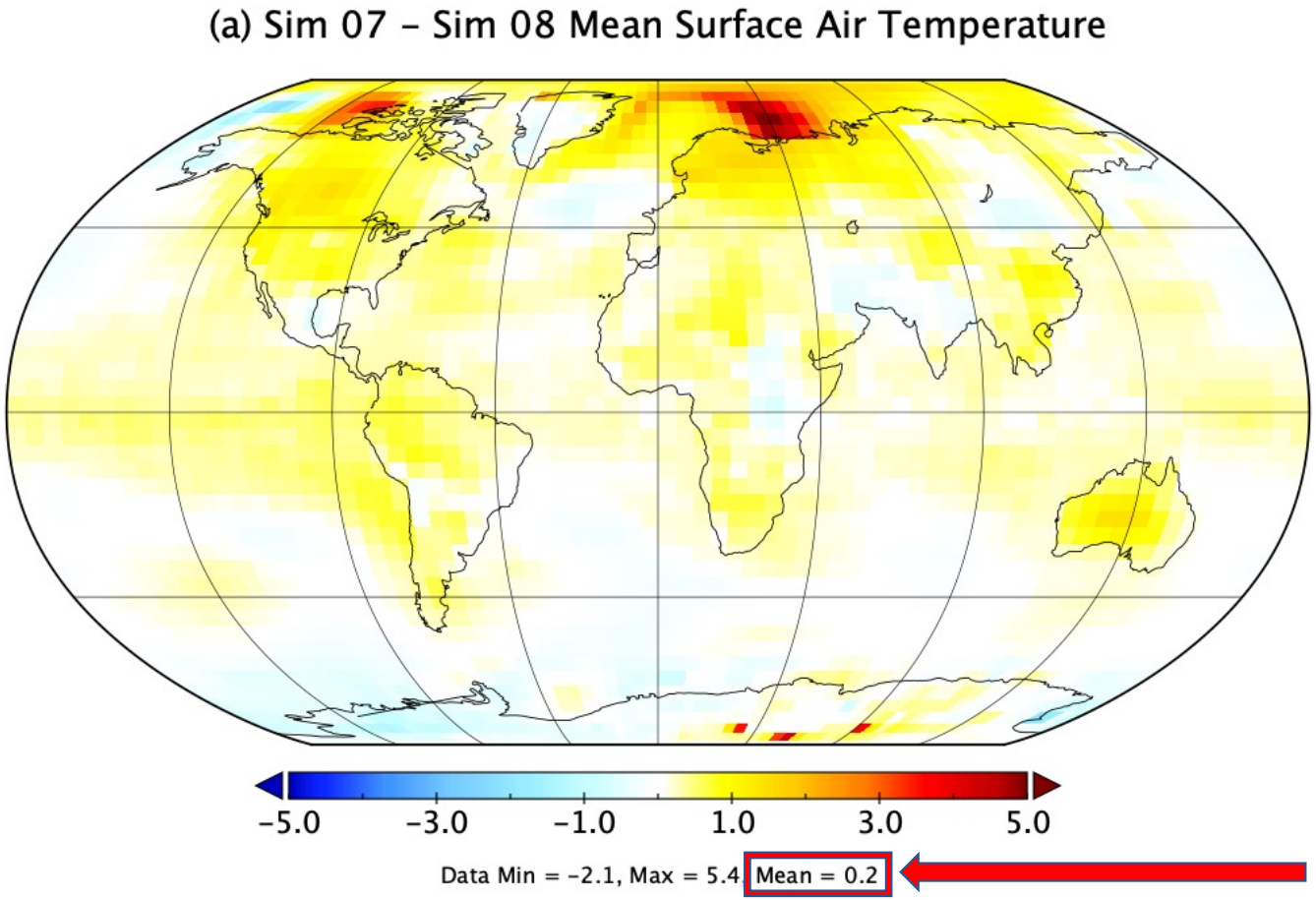
How might a +30m Rotation Rate affect the climate?



Adam Showman et al. 2016 CCTP2

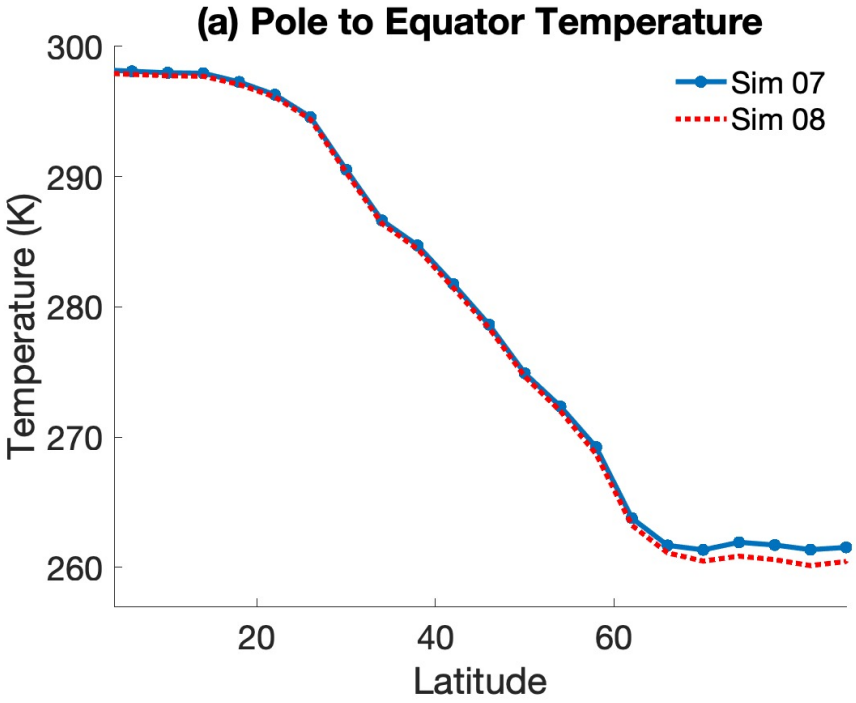
Slower rotation:
lower equator → pole
temperature differences

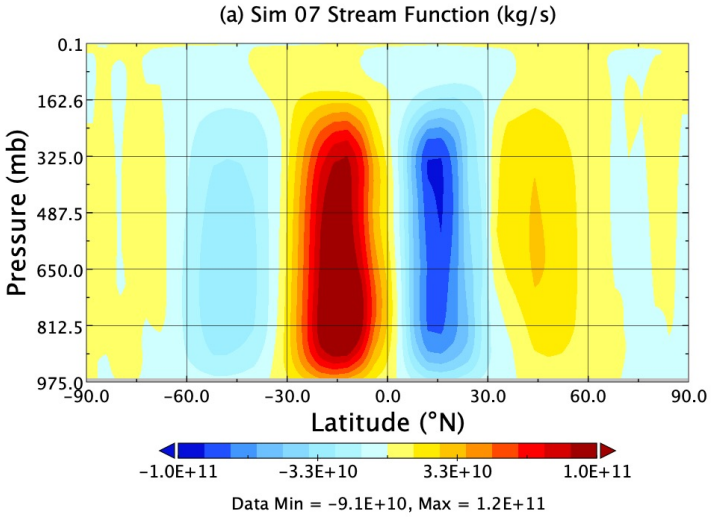
Does +30m Rotation Rate affect the climate?

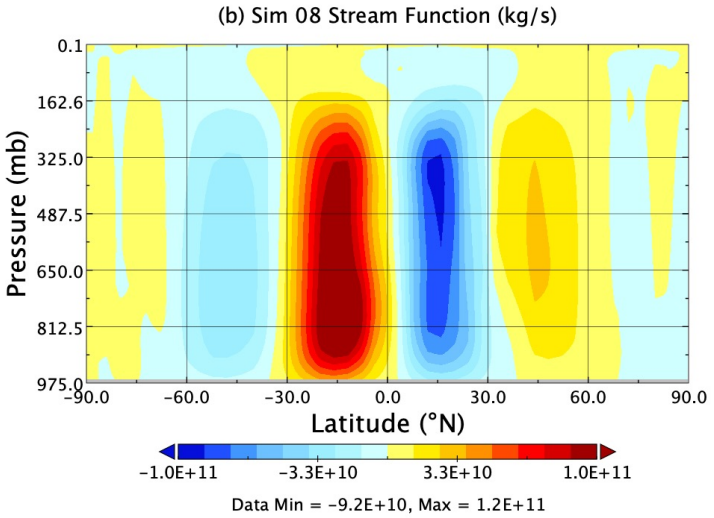


?

Does +30m Rotation Rate affect the climate?

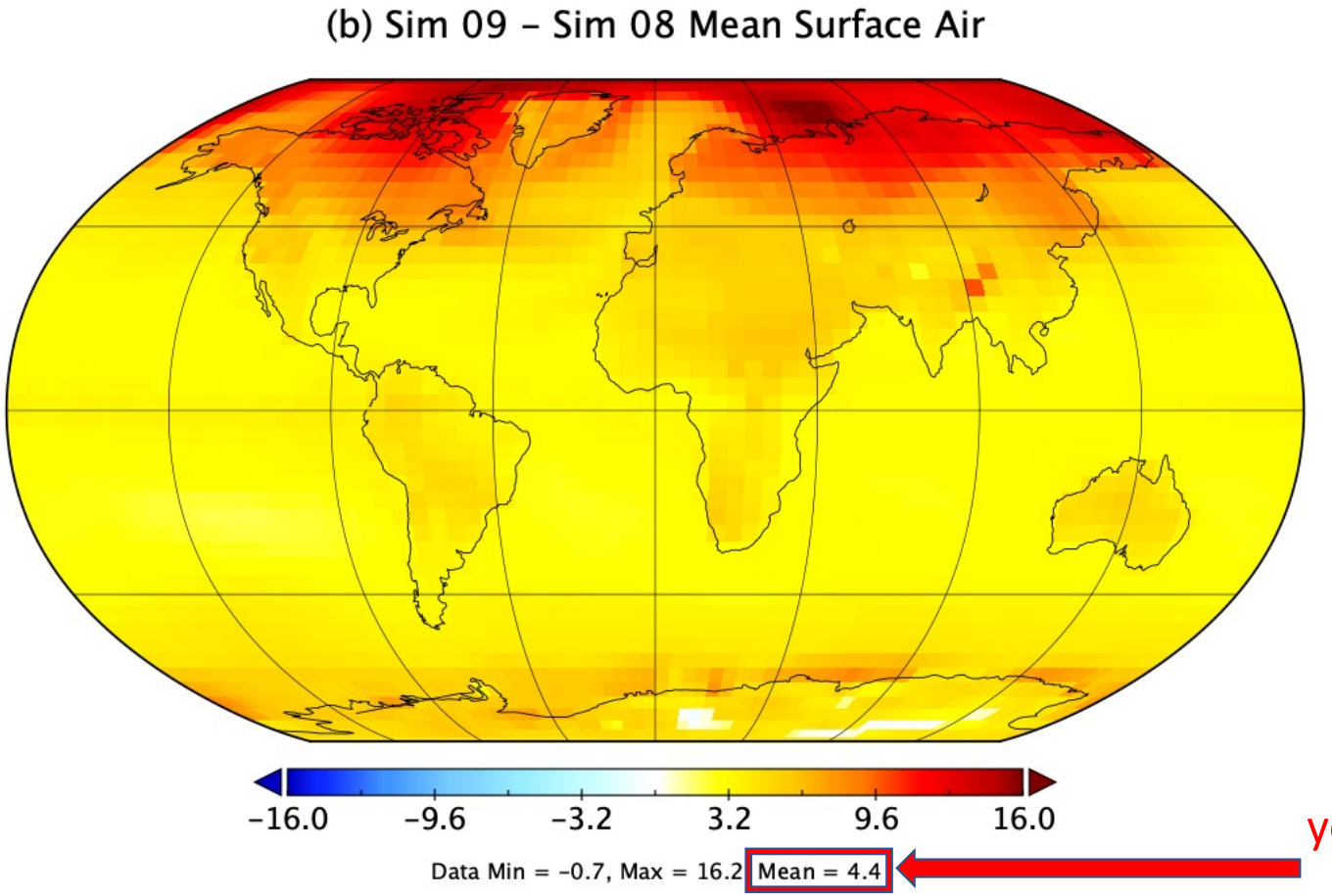






Slower rotation -> lower pole-equator temperature contrast?

Does ~2.5% increase in Insolation affect the climate?



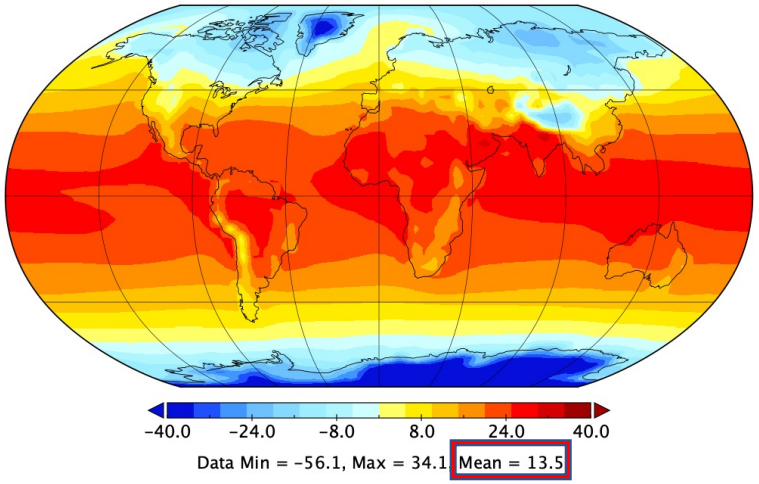
yes

Results

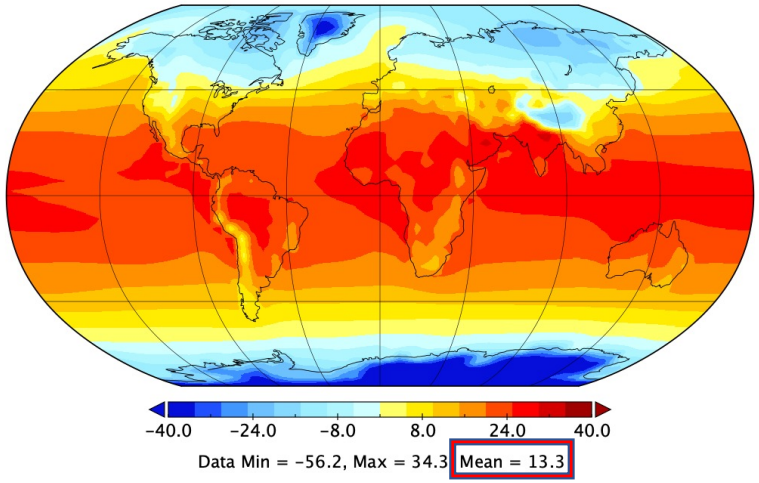
Sim	Name	Topography	Ins[a]	LoD[b] (hrs)	Runtime (years)	T[c] (C)	Balance (Wm^{-2})	A[d] (%)	SnowFr[e] (%).	Hab[f] (%).
				Aurica 250Myr into the Future						
01	Aurica	CTRL	1.0260	24.5	2000	20.5	0.2	30.5	0.5	1.000/1.000
02	”	PD	”	24.5	2500	20.6	0.1	30.1	0.6	0.955/0.956
03	”	MTNS	”	24.5	2000	20.6	0.2	30.3	1.5	0.974/0.983
				Amasia 200Myr into the Future						
04	Amasia	CTRL	1.0223	24.5	3000	19.5	0.3	30.2	5.0	0.932/0.983
05	”	PD	”	24.5	3000	16.9	0.2	31.3	10.2	0.862/0.901
06	”	MTNS	”	24.5	3000	20.2	0.2	30.0	4.7	0.926/0.976
				Modern Earth						
07	Earth_noAer_noO3		1.0	24.0	2000	13.5	-0.1	31.1	9.3	0.869/0.953
08	Earth_noAer_noO3_Rot		1.0	24.5	2000	13.3	0.2	31.0	9.5	0.865/0.951
09	Earth_noAer_noO3_Rot_Ins		1.0260	24.5	2000	17.7	-0.0	30.6	6.4	0.930/0.974

Earth+Rot+Insolation

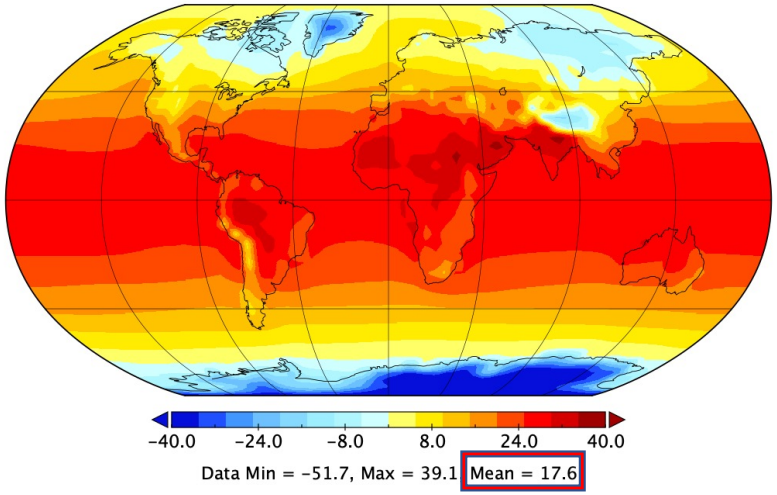
Sim 07 Earth Mean Surface Air Temperature



Sim 08 Earth + Rotation Mean Surface Air Temperature



Sim 09 Earth + Rotation + Insolation Mean Surface Air Temperature

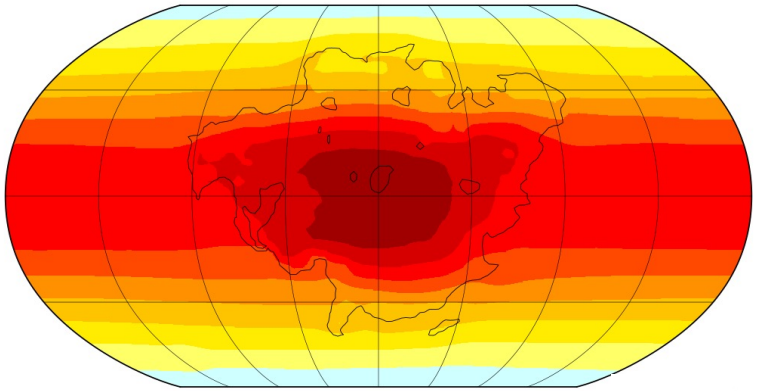


Results

Sim	Name	Topography	Ins[a]	LoD[b] (hrs)	Runtime (years)	T[c] (C)	Balance (Wm^{-2})	A[d] (%)	SnowFr[e] (%).	Hab[f] (%).
				Aurica 250Myr into the Future						
01	Aurica	CTRL	1.0260	24.5	2000	20.5	0.2	30.5	0.5	1.000/1.000
02	”	PD	”	24.5	2500	20.6	0.1	30.1	0.6	0.955/0.956
03	”	MTNS	”	24.5	2000	20.6	0.2	30.3	1.5	0.974/0.983
				Amasia 200Myr into the Future						
04	Amasia	CTRL	1.0223	24.5	3000	19.5	0.3	30.2	5.0	0.932/0.983
05	”	PD	”	24.5	3000	16.9	0.2	31.3	10.2	0.862/0.901
06	”	MTNS	”	24.5	3000	20.2	0.2	30.0	4.7	0.926/0.976
				Modern Earth						
07	Earth_noAer_noO3		1.0	24.0	2000	13.5	-0.1	31.1	9.3	0.869/0.953
08	Earth_noAer_noO3_Rot		1.0	24.5	2000	13.3	0.2	31.0	9.5	0.865/0.951
09	Earth_noAer_noO3_Rot_Ins		1.0260	24.5	2000	17.7	-0.0	30.6	6.4	0.930/0.974

AURICA CTRL → AURICA PD → AURICA MTNS

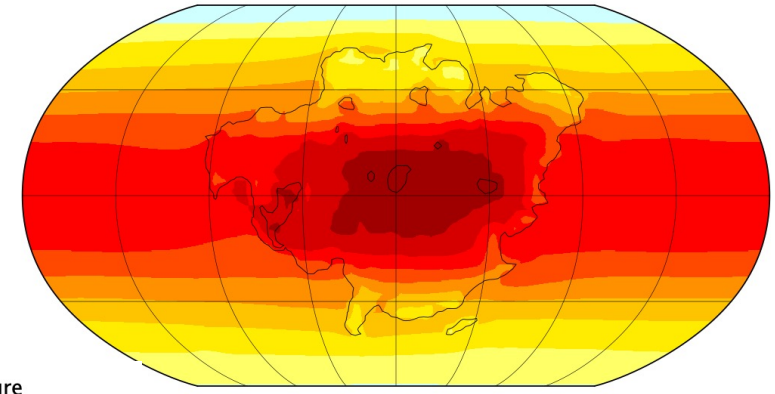
Sim 01 AURICA CTRL Mean Surface Air Temperature



-40.0 -24.0 -8.0 8.0 24.0 40.0

Data Min = -4.6, Max = 38.1, Mean = 20.5

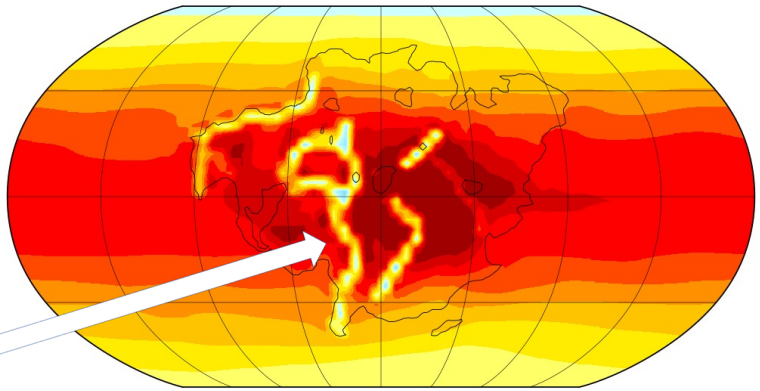
Sim 02 AURICA PD Mean Surface Air Temperature



-40.0 -24.0 -8.0 8.0 24.0 40.0

Data Min = -2.9, Max = 43.8, Mean = 20.6

Sim 03 AURICA MTNS Mean Surface Air Temperature



-40.0 -24.0 -8.0 8.0 24.0 40.0

Data Min = -18.6, Max = 45.0, Mean = 20.6

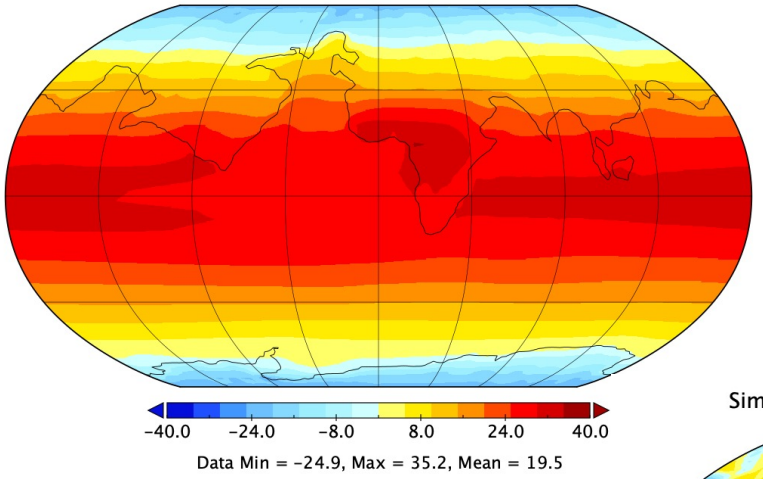
Mountain Chains

Results

Sim	Name	Topography	Ins[a]	LoD[b] (hrs)	Runtime (years)	T[c] (C)	Balance (Wm^{-2})	A[d] (%)	SnowFr[e] (%).	Hab[f] (%).
				Aurica 250Myr into the Future						
01	Aurica	CTRL	1.0260	24.5	2000	20.5	0.2	30.5	0.5	1.000/1.000
02	”	PD	”	24.5	2500	20.6	0.1	30.1	0.6	0.955/0.956
03	”	MTNS	”	24.5	2000	20.6	0.2	30.3	1.5	0.974/0.983
				Amasia 200Myr into the Future						
04	Amasia	CTRL	1.0223	24.5	3000	19.5	0.3	30.2	5.0	0.932/0.983
05	”	PD	”	24.5	3000	16.9	0.2	31.3	10.2	0.862/0.901
06	”	MTNS	”	24.5	3000	20.2	0.2	30.0	4.7	0.926/0.976
				Modern Earth						
07	Earth_noAer_noO3		1.0	24.0	2000	13.5	-0.1	31.1	9.3	0.869/0.953
08	Earth_noAer_noO3_Rot		1.0	24.5	2000	13.3	0.2	31.0	9.5	0.865/0.951
09	Earth_noAer_noO3_Rot_Ins		1.0260	24.5	2000	17.7	-0.0	30.6	6.4	0.930/0.974

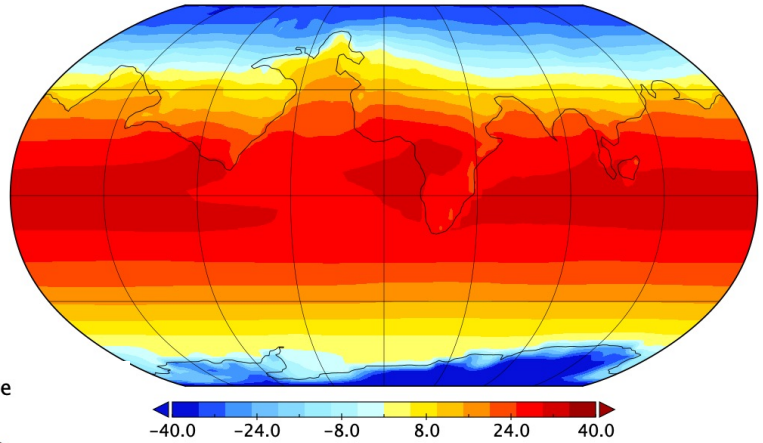
AMASIA CTRL → AMASIA PD → AMASIA MTNS

Sim 04 AMASIA CTRL Mean Surface Air Temperature



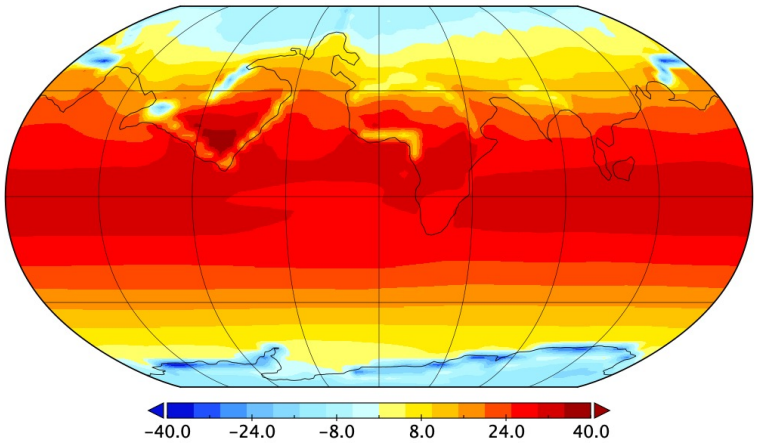
Data Min = -24.9, Max = 35.2, Mean = 19.5

Sim 05 AMASIA PD Mean Surface Air Temperature



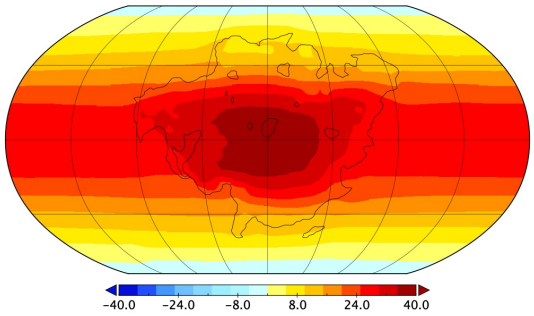
Data Min = -52.6, Max = 33.4, Mean = 16.9

Sim 06 AMASIA MTNS Mean Surface Air Temperature



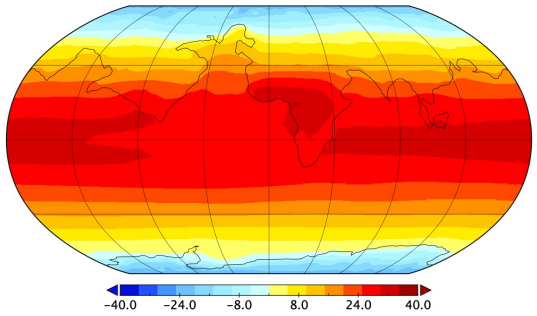
Data Min = -40.8, Max = 40.5, Mean = 20.2

Sim 01 AURICA CTRL Mean Surface Air Temperature



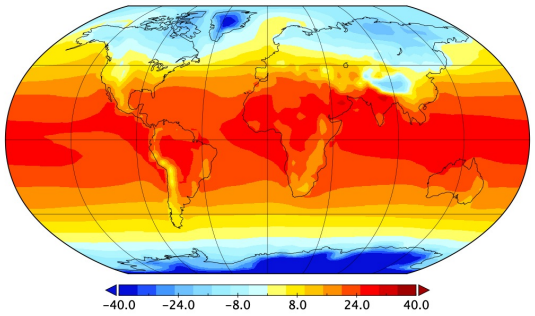
Data Min = -4.6, Max = 38.1, Mean = 20.5

Sim 04 AMASIA CTRL Mean Surface Air Temperature



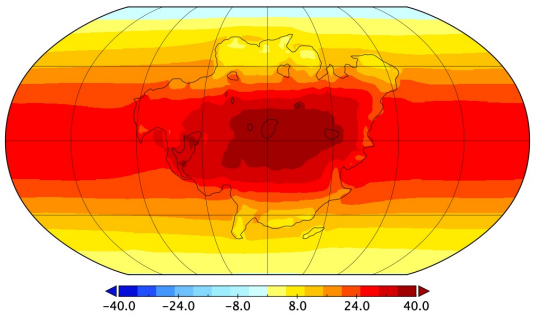
Data Min = -24.9, Max = 35.2, Mean = 19.5

Sim 07 Earth Mean Surface Air Temperature



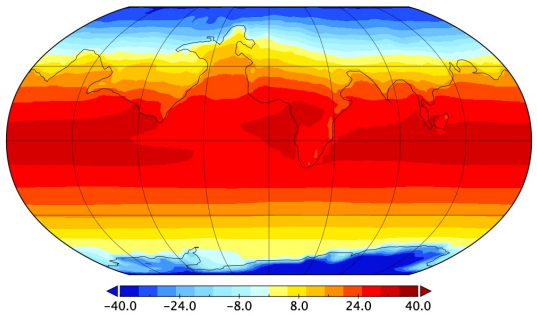
Data Min = -56.1, Max = 34.1, Mean = 13.5

Sim 02 AURICA PD Mean Surface Air Temperature



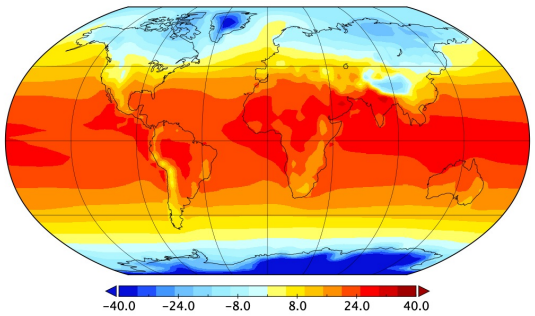
Data Min = -2.9, Max = 43.8, Mean = 20.6

Sim 05 AMASIA PD Mean Surface Air Temperature



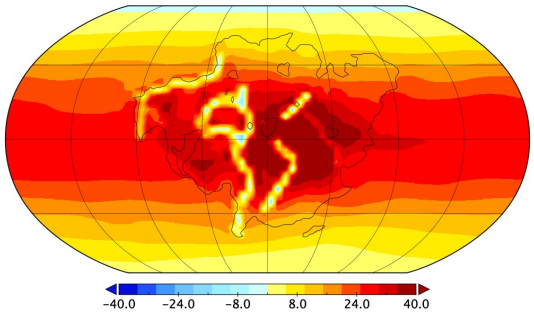
Data Min = -52.6, Max = 33.4, Mean = 16.9

Sim 08 Earth + Rotation Mean Surface Air Temperature



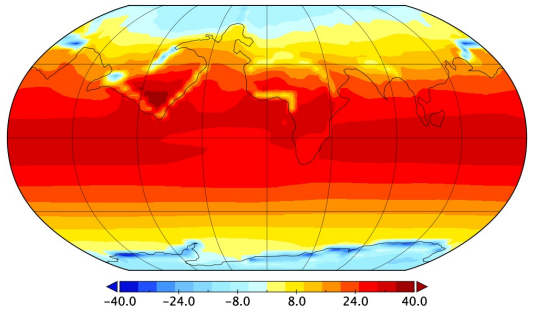
Data Min = -56.2, Max = 34.3, Mean = 13.3

Sim 03 AURICA MTNS Mean Surface Air Temperature



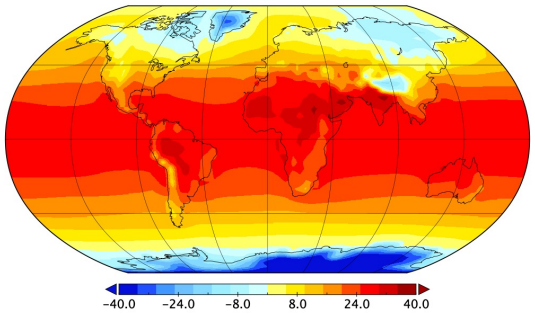
Data Min = -18.6, Max = 45.0, Mean = 20.6

Sim 06 AMASIA MTNS Mean Surface Air Temperature



Data Min = -40.8, Max = 40.5, Mean = 20.2

Sim 09 Earth + Rotation + Insolation Mean Surface Air Temperature



Data Min = -51.7, Max = 39.1, Mean = 17.6

Conclusions

- **Aurica:** Mean surface temperatures for all simulations with large low latitude supercontinent are within 0.1℃. Warmest simulations.
- **Amasia:** Mean surface temperatures span 3.3℃
  - Low surface temperature due to large ice sheets at high latitudes.
  - Oceans cannot transport heat to high northern latitudes.
  - Higher elevations (PD) play a key role
  - Large amounts of water trapped in polar caps (>50m GEL)!
- **Earth**: +Rotation rate (24 vs 24.5) Δtemp ~ 0.2℃
  +Insolation (1.026 x modern) ΔT ~ 4.4 ℃
- Future work: Other reconstructions, more realistic ice sheets, closer examination of sea level fall and its implications.