ATS 421/521

Climate Modeling

Spring 2013

Lecture 5

- Stochastic Climate Models
- Meridional Energy Transport

April 15

Previous Lecture

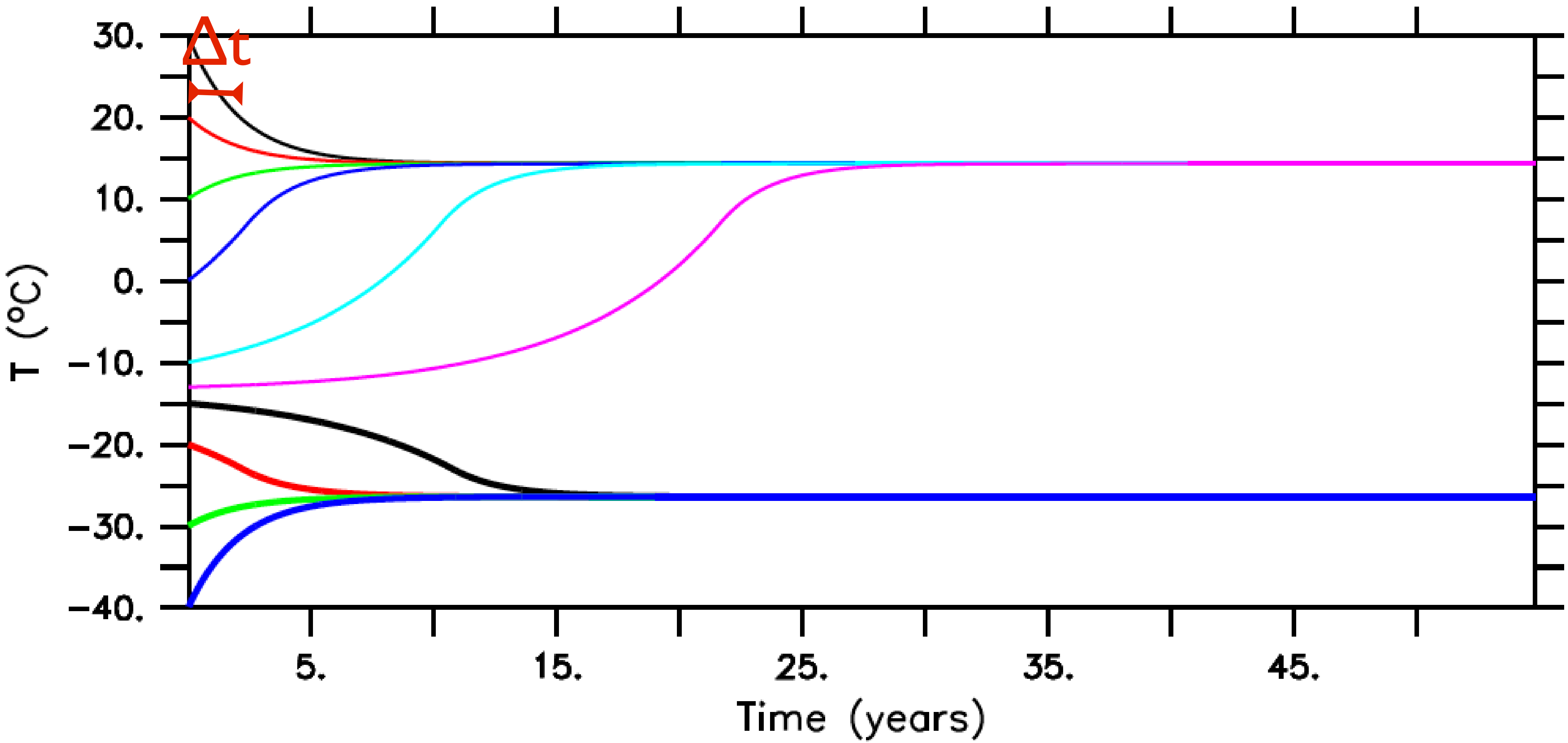
Reading

- For Friday: Hargreaves et al. (2012)
- For Monday: Script chapter 2.5

Stochastic Climate Models

0D-EBM Solutions

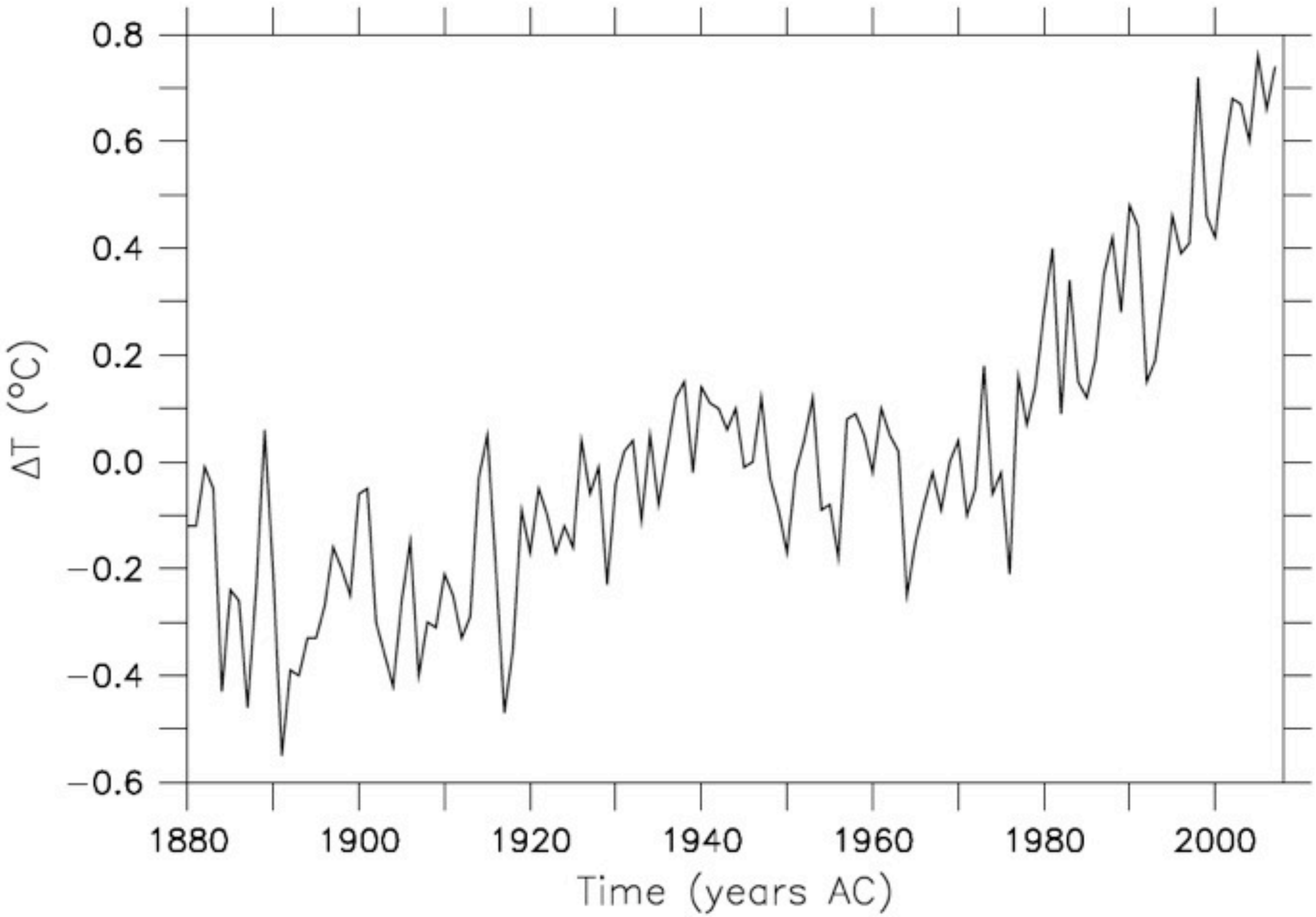
are smooth



Response timescale Δt = C/B = 2 years

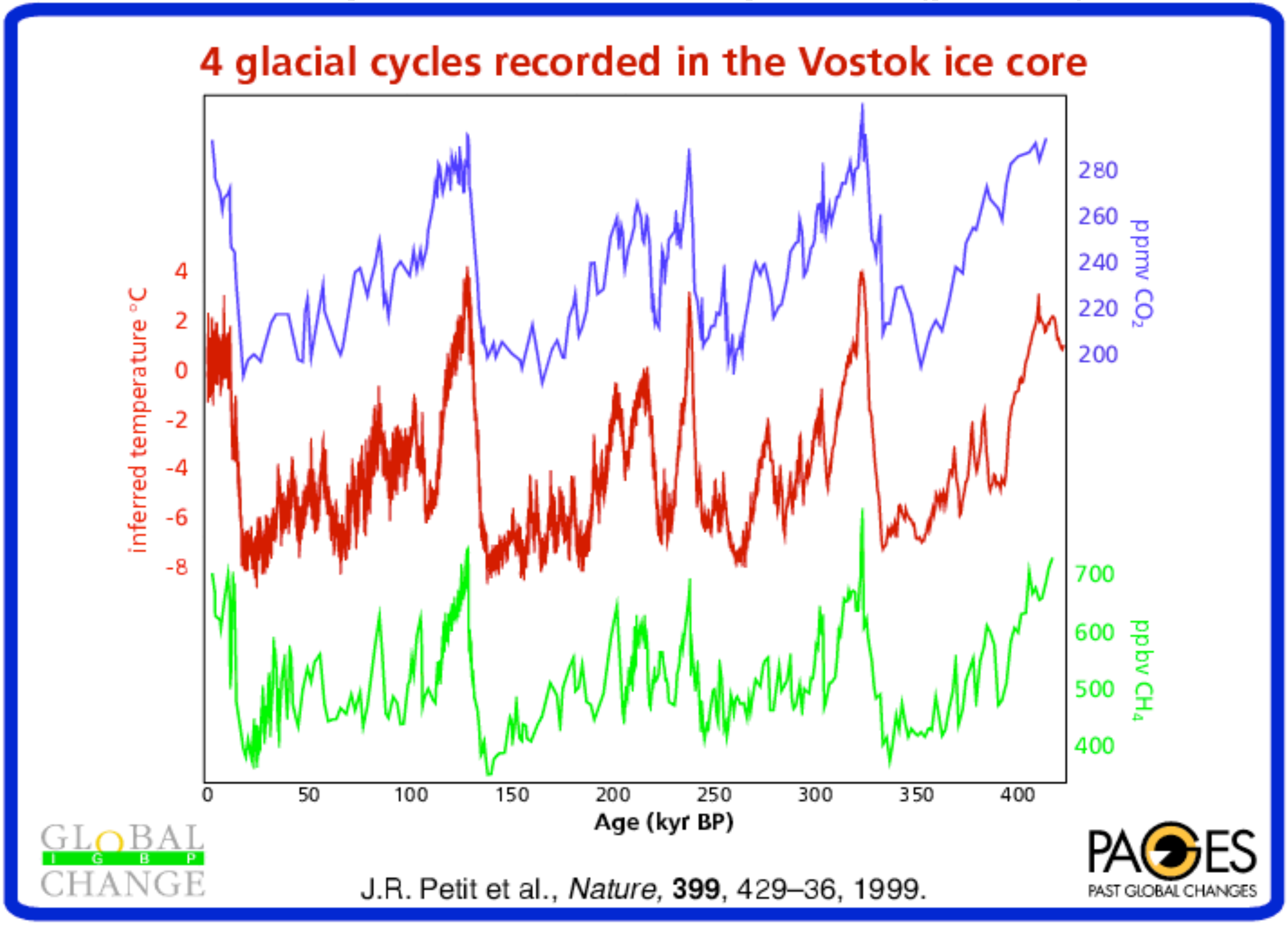
real world has variability

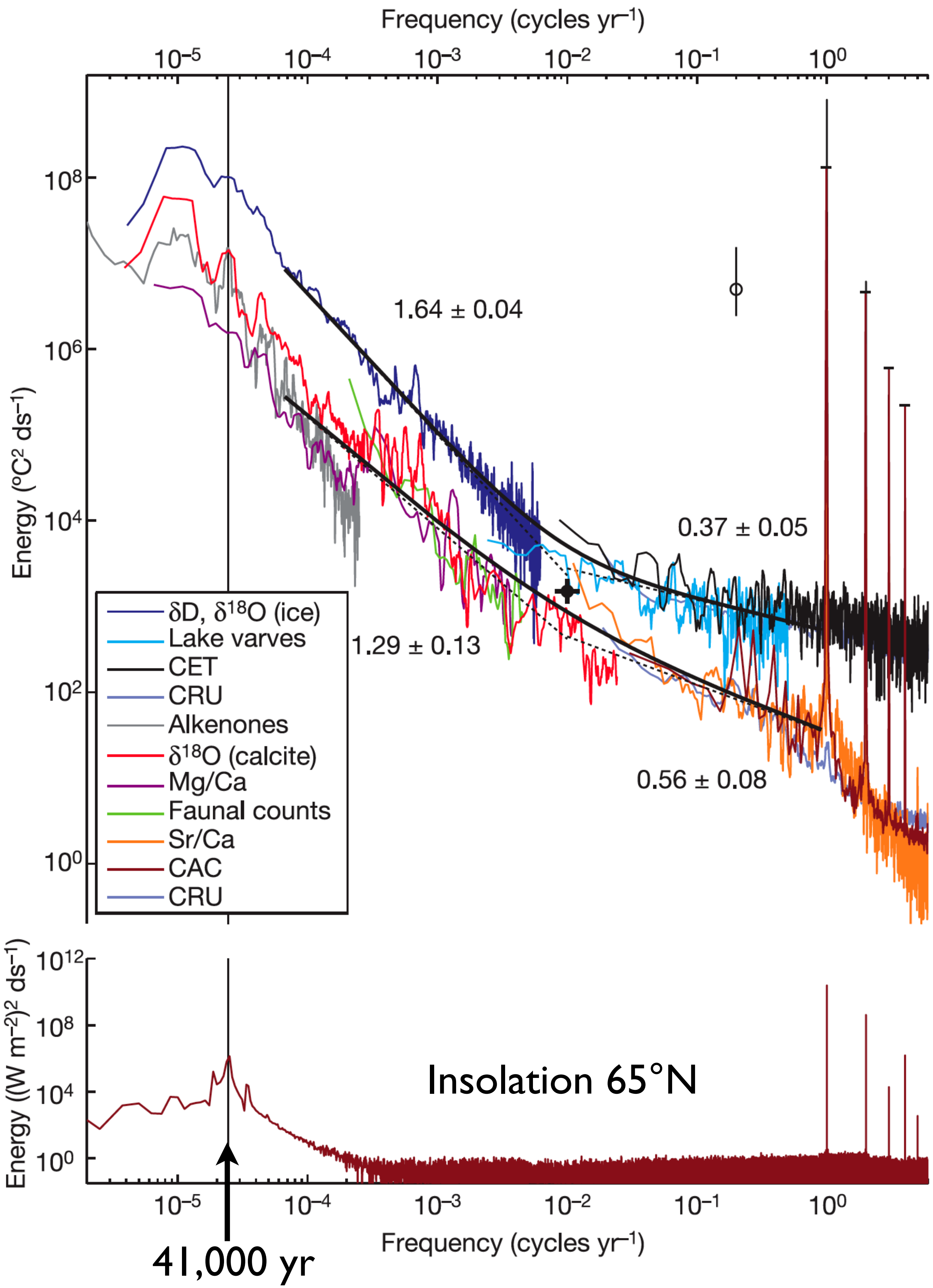
Variability last 150 years (instrumental period)



Global surface air temperature anomaly from NASA/GISS

Variability last 400,000 years (paleo)





Estimated spectrum of surface temperatures including paleoclimate proxies. From Huybers & Curry (2006, Nature 441, 329).

Auto-Regressive Process of Order One (AR1)

$$x_{n+1} = b x_n + w$$

auto-correlation coefficient

white noise

Hasselmann (1976) Tellus

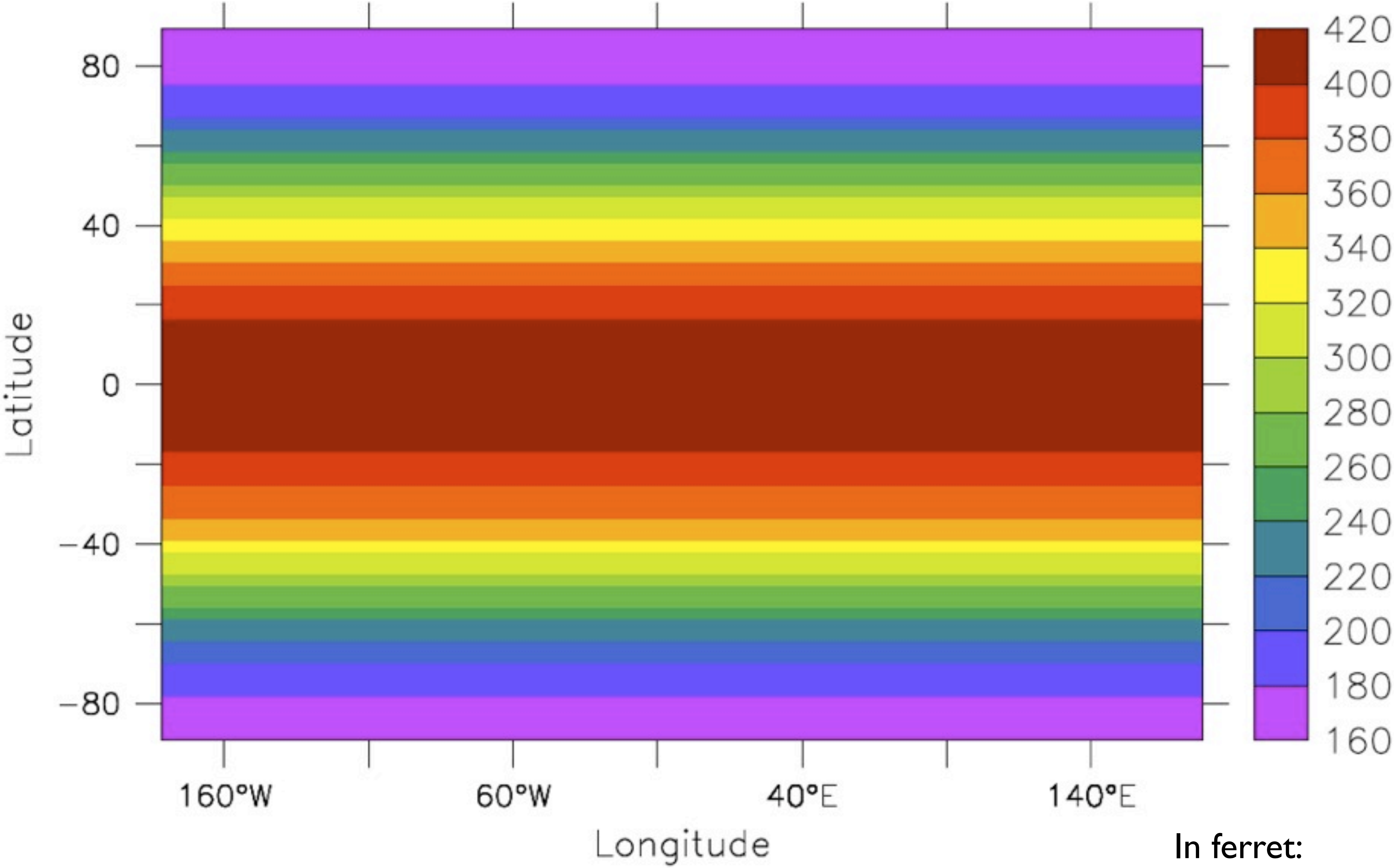
Periodogram

see chapter 12 of the book “Statistical Analysis in Climate Research” by von Storch and Zwiers (2001, Cambridge University Press)

HW2: include variability in your 0D EBM !

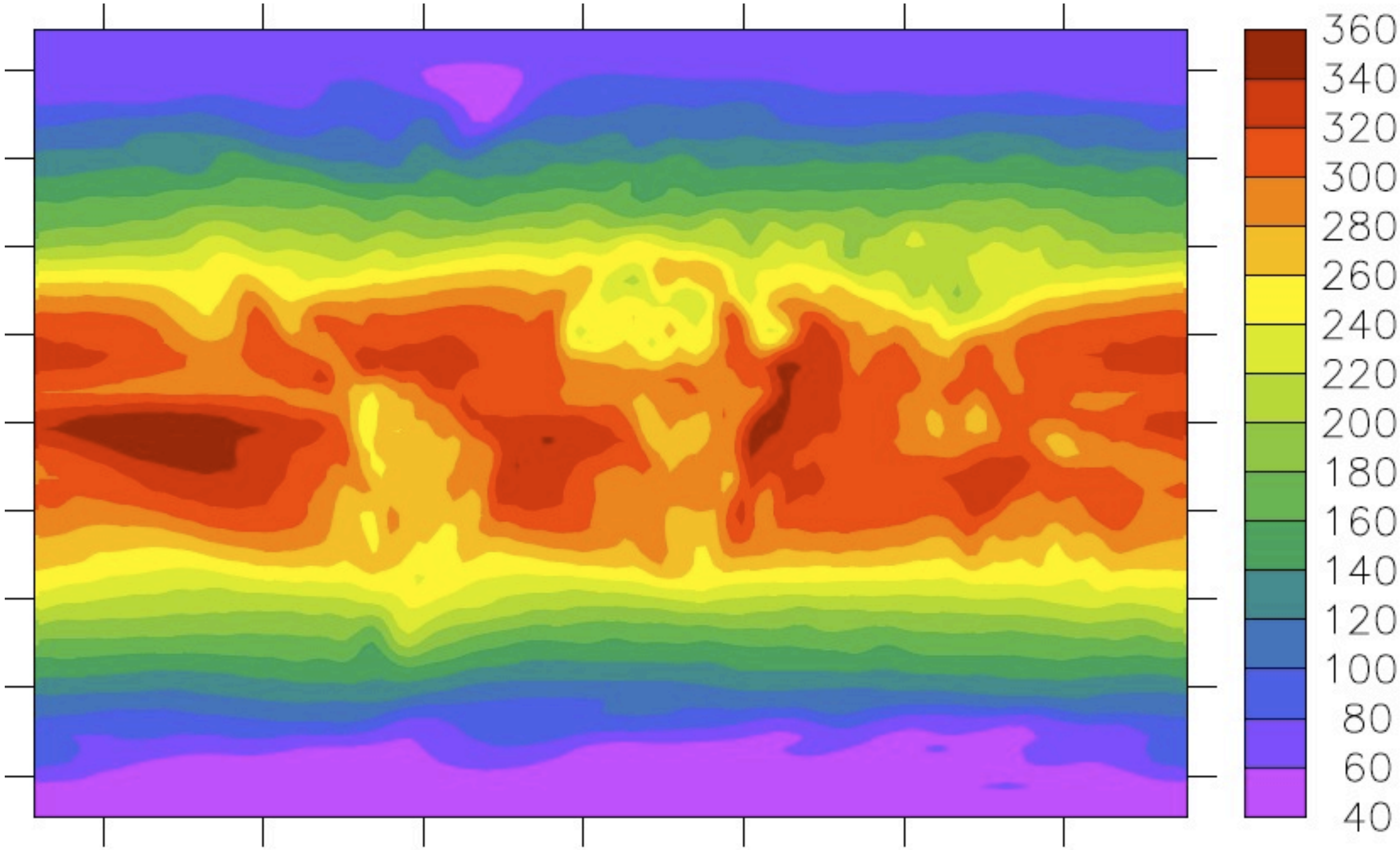
Meridional Energy Transport

TOA Fluxes from Satellites
Earth Radiation Budget Experiment (ERBE)



Total Incident Solar Radiation S (W/m^2)

In ferret:
use ERBE_mean.cdf
shade solar


360
340
320
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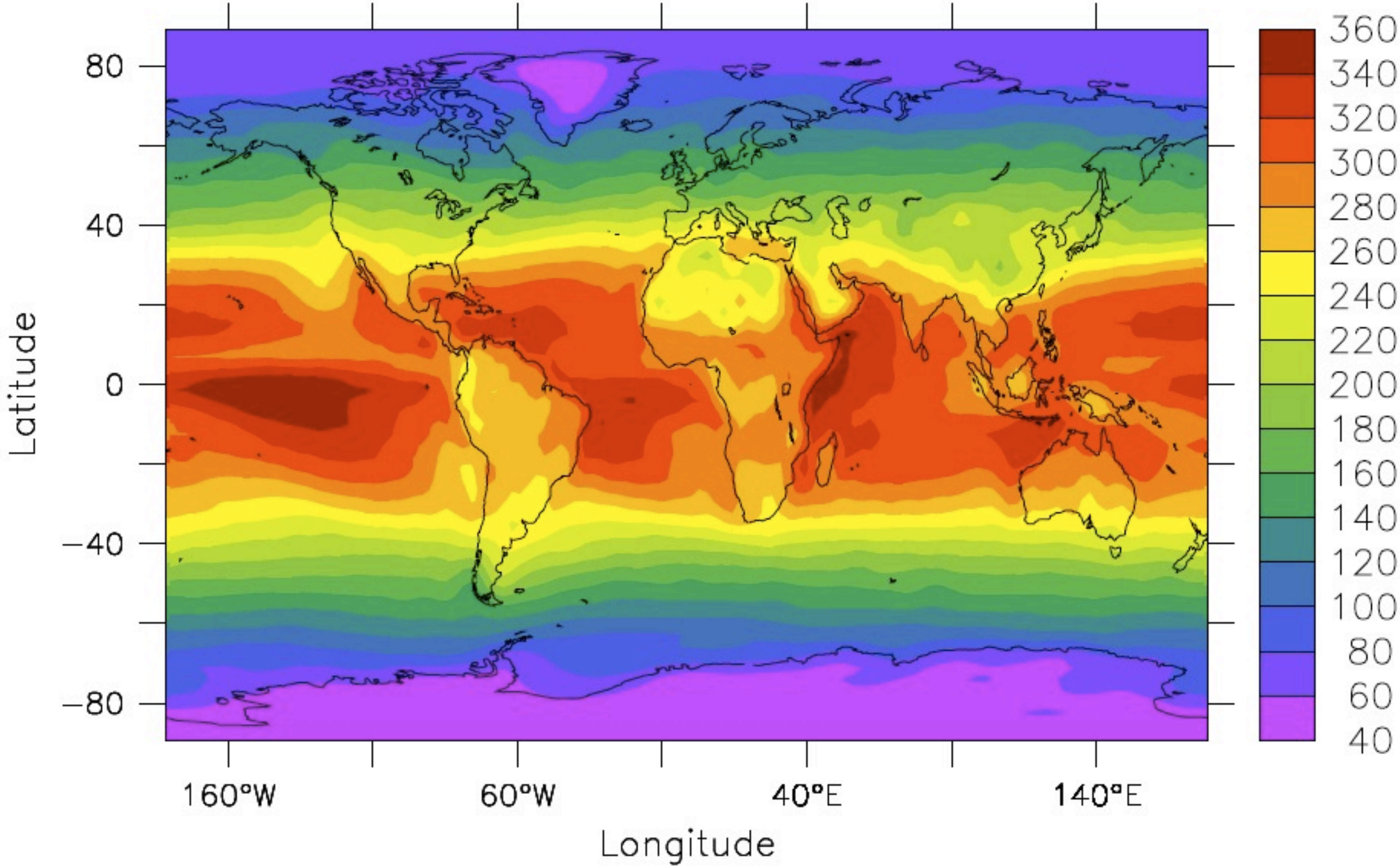
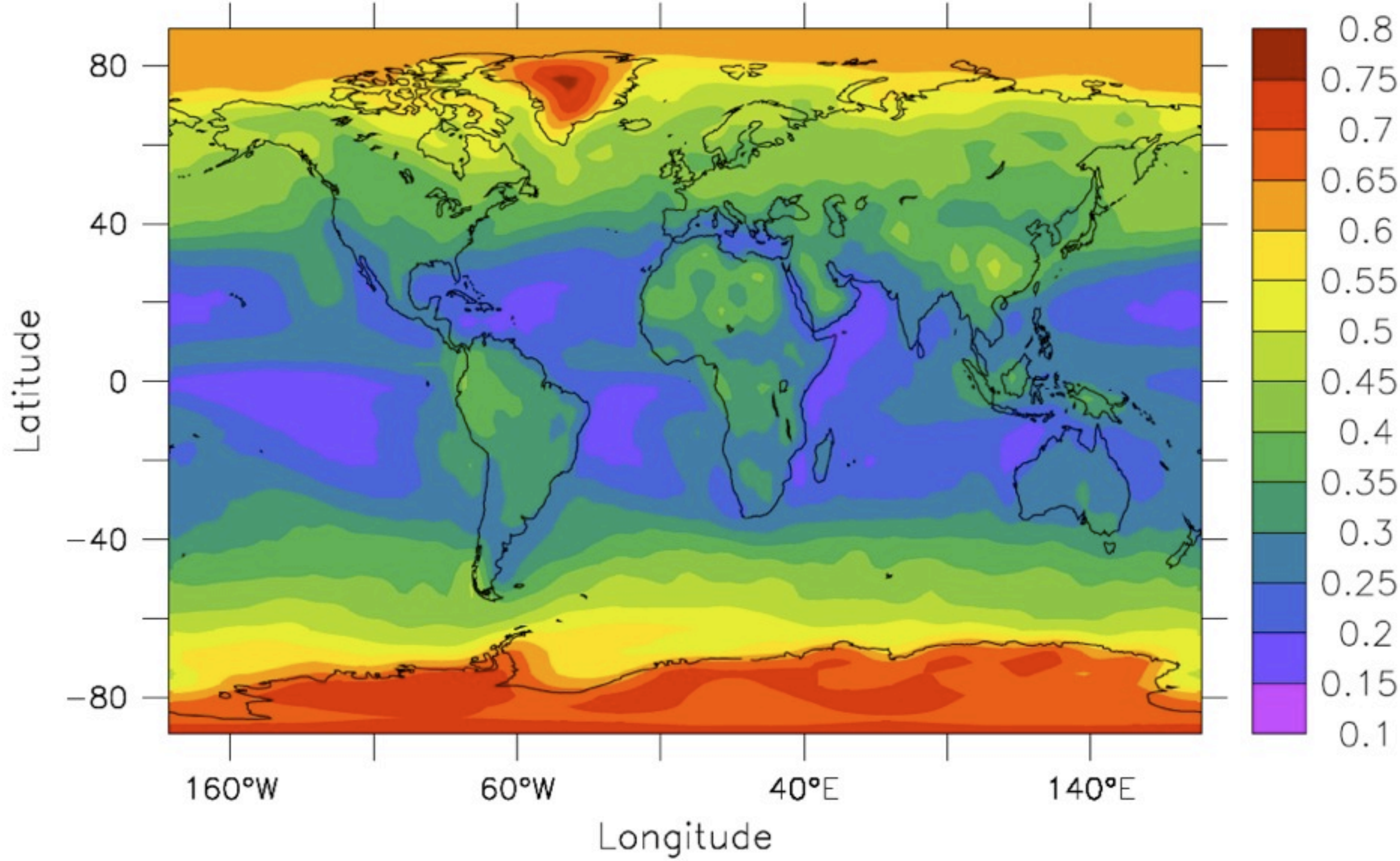
280
260
240
220
200
180
160
140
120
100
80
60
40



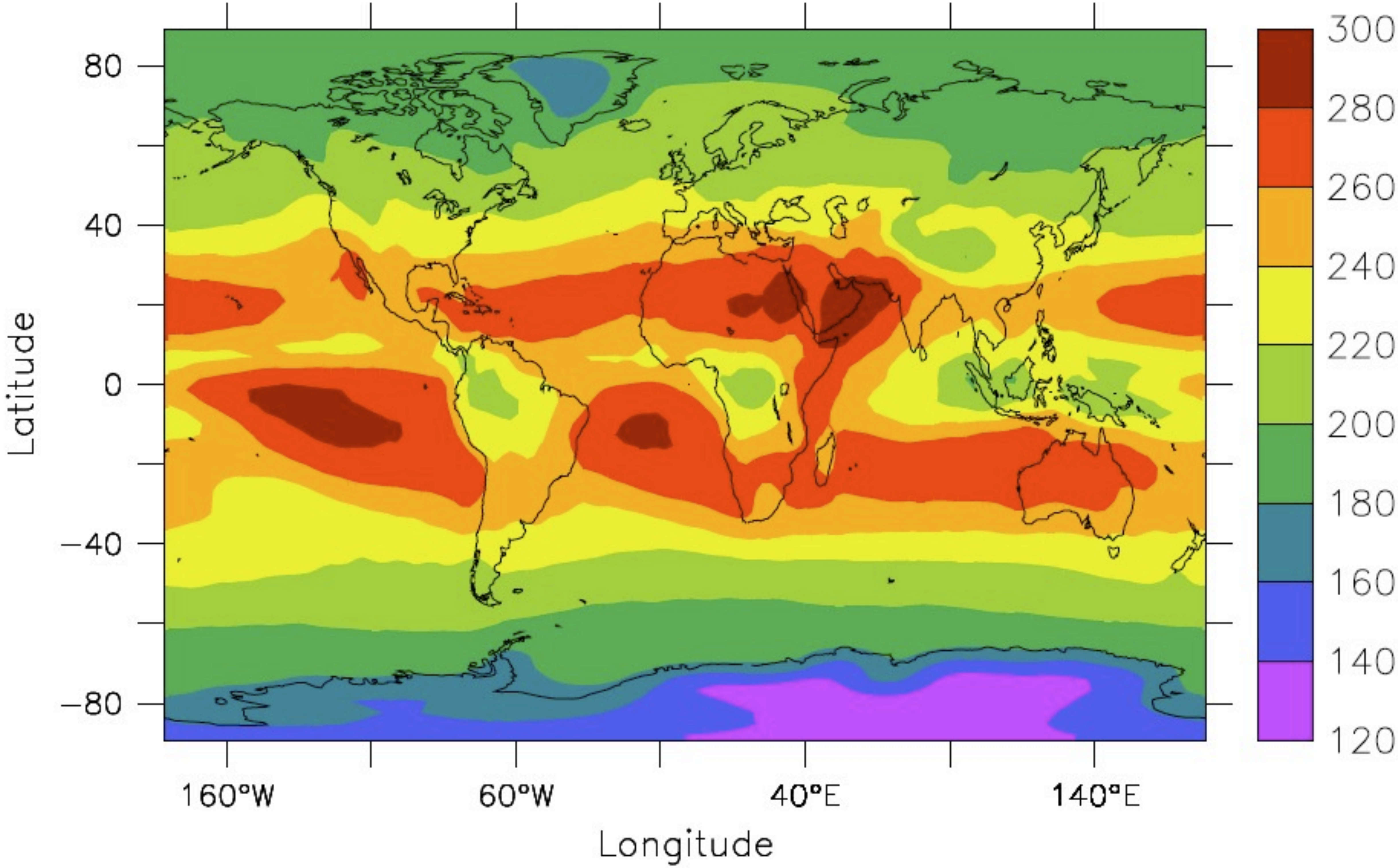
Absorbed Solar Radiation (W/m^2)

In ferret:
shade asr
go land



Planetary Albedo

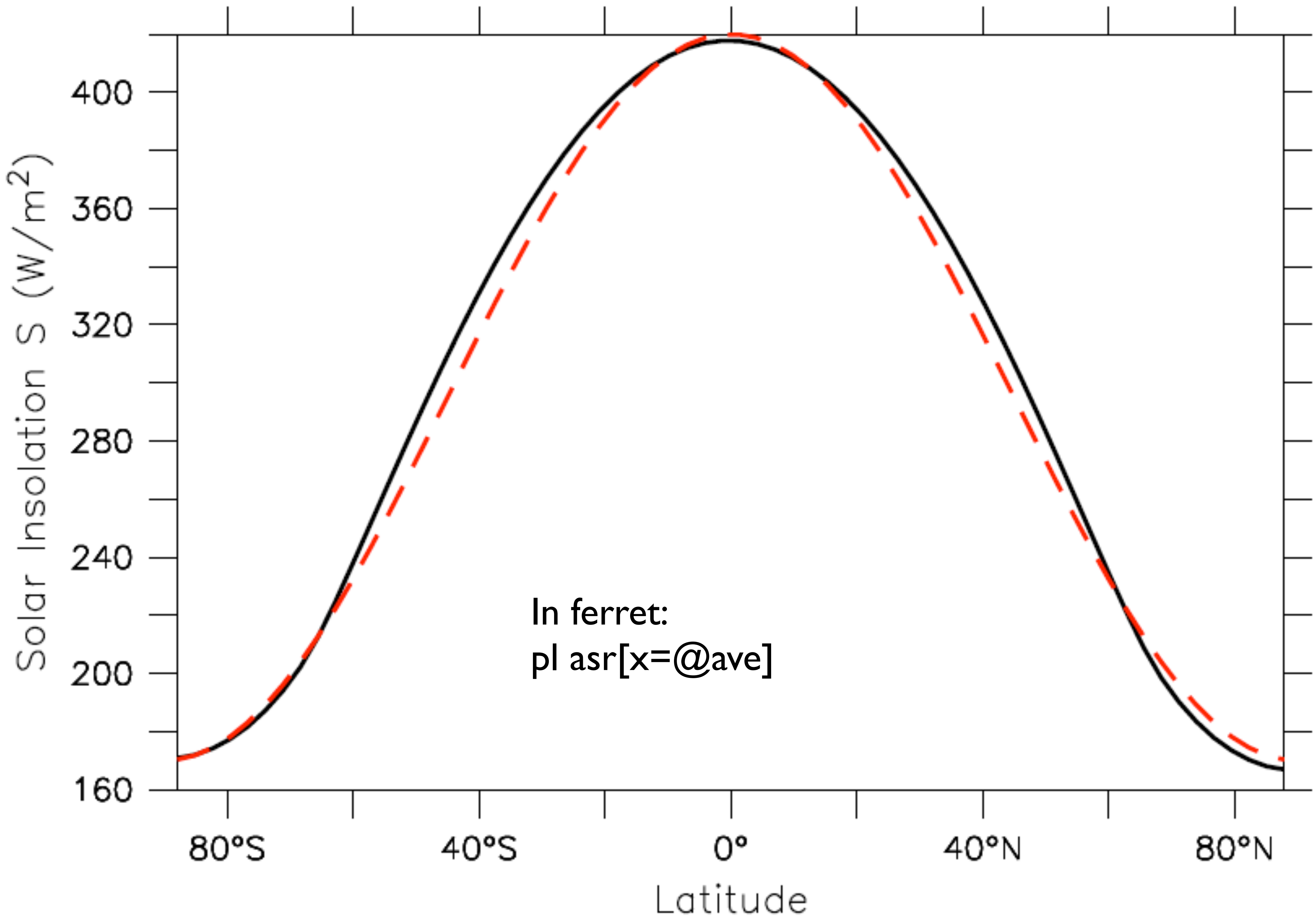
In ferret:
let albedo = refl/solar
shade albedo
go land



Outgoing Longwave Radiation (W/m^2)

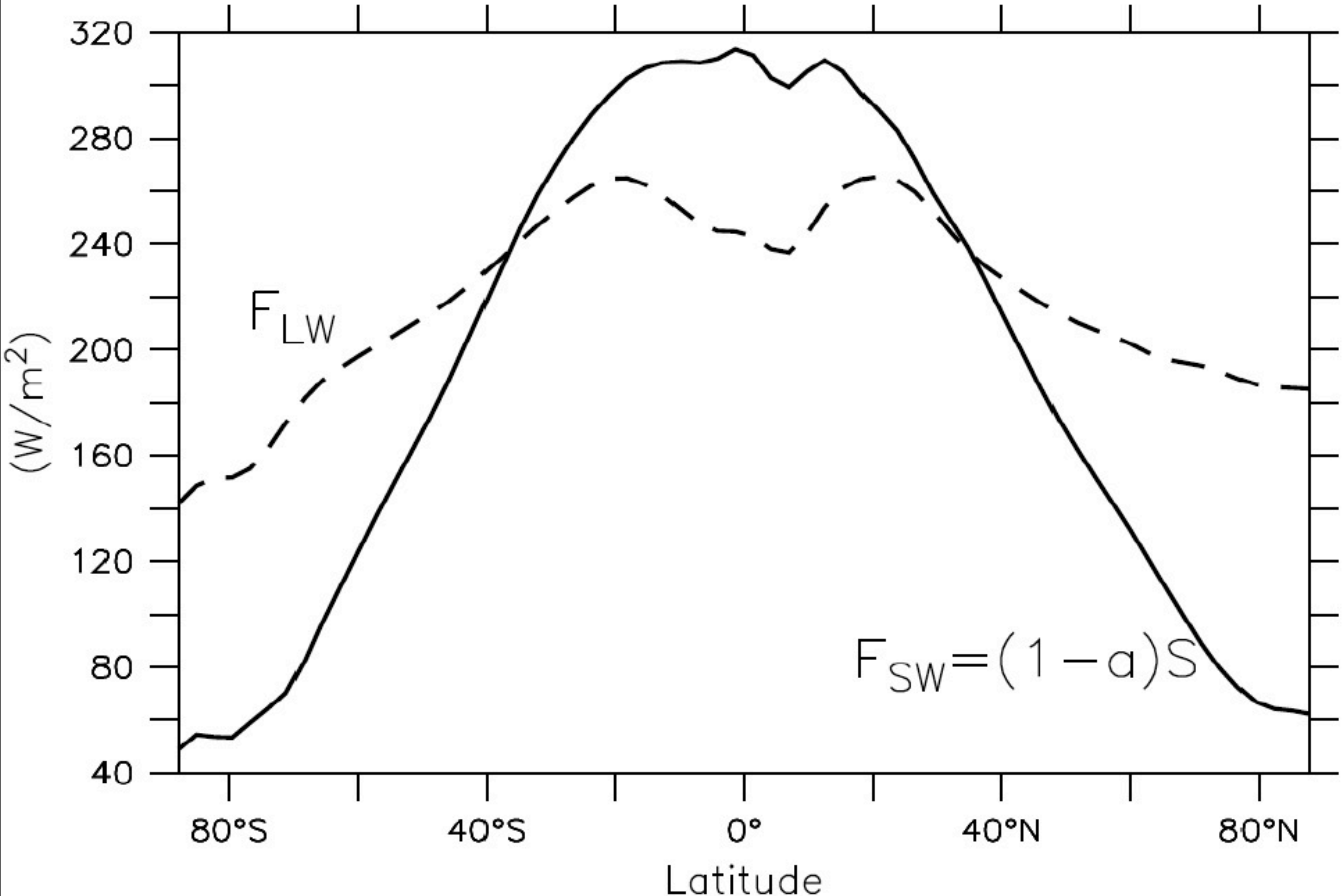
In ferret:
shade olr
go land

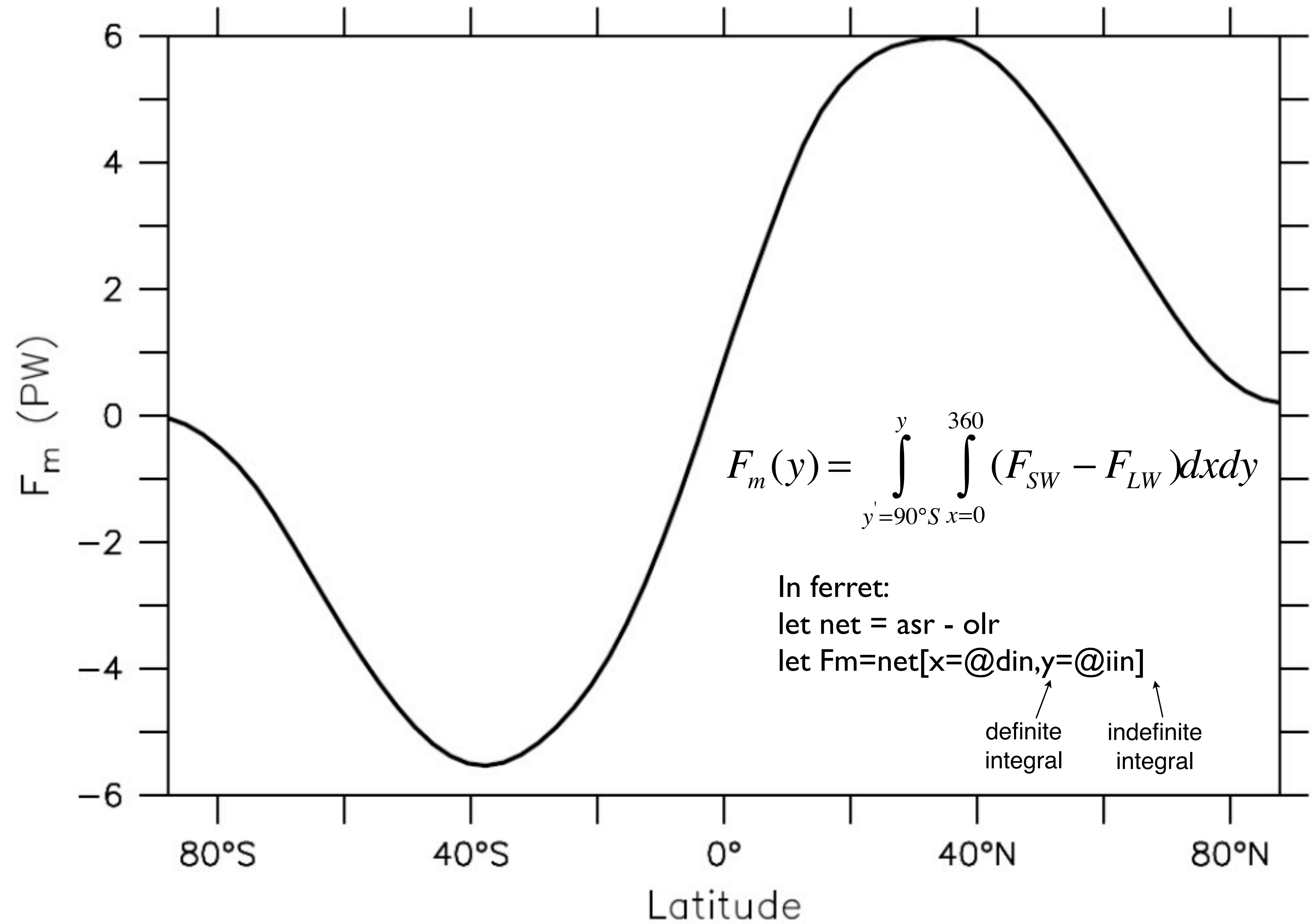
Zonally Averaged Incident Solar Radiation



red: $S(\phi) = 195 + 125\cos(2\phi)$
use in 1D EBM

Zonally averaged absorbed solar and outgoing longwave radiation





$$F_m(y) = \int_{y'=90^\circ S}^{y} \int_{x=0}^{360} (F_{SW} - F_{LW})\,dx\,dy$$

In ferret:

```
let net = asr - olr
let Fm=net[x=@din,y=@iin]
```

Diffusive parameterization of meridional heat transport:

$$\vec{F}_m = -CK\vec{\nabla}T = -CK\frac{\partial T}{\partial y} \qquad (2.18)$$

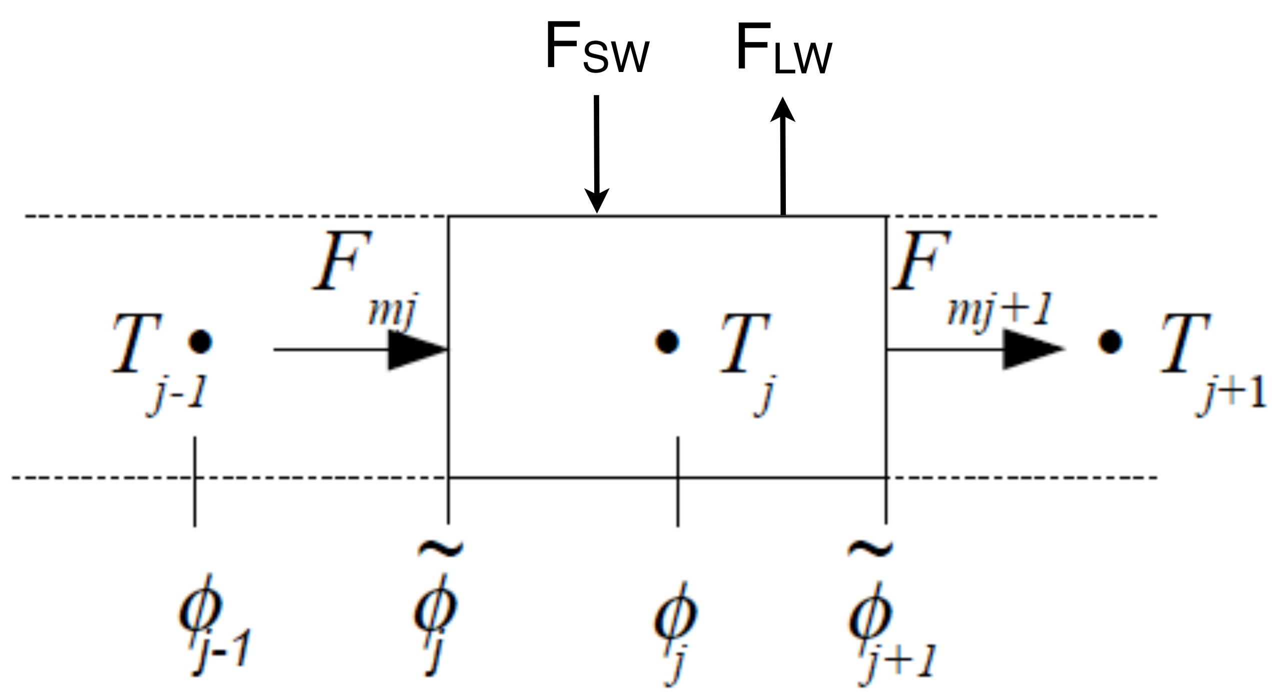
Heat Capacity

Diffusivity

Temperature Gradient

$$C\frac{\partial T}{\partial t} = -\vec{\nabla}\vec{F}_m + F_{SW} - F_{LW}$$

Meridional Heat Flux Convergence



in spherical coordinates

Meridional Heat Flux Divergence:

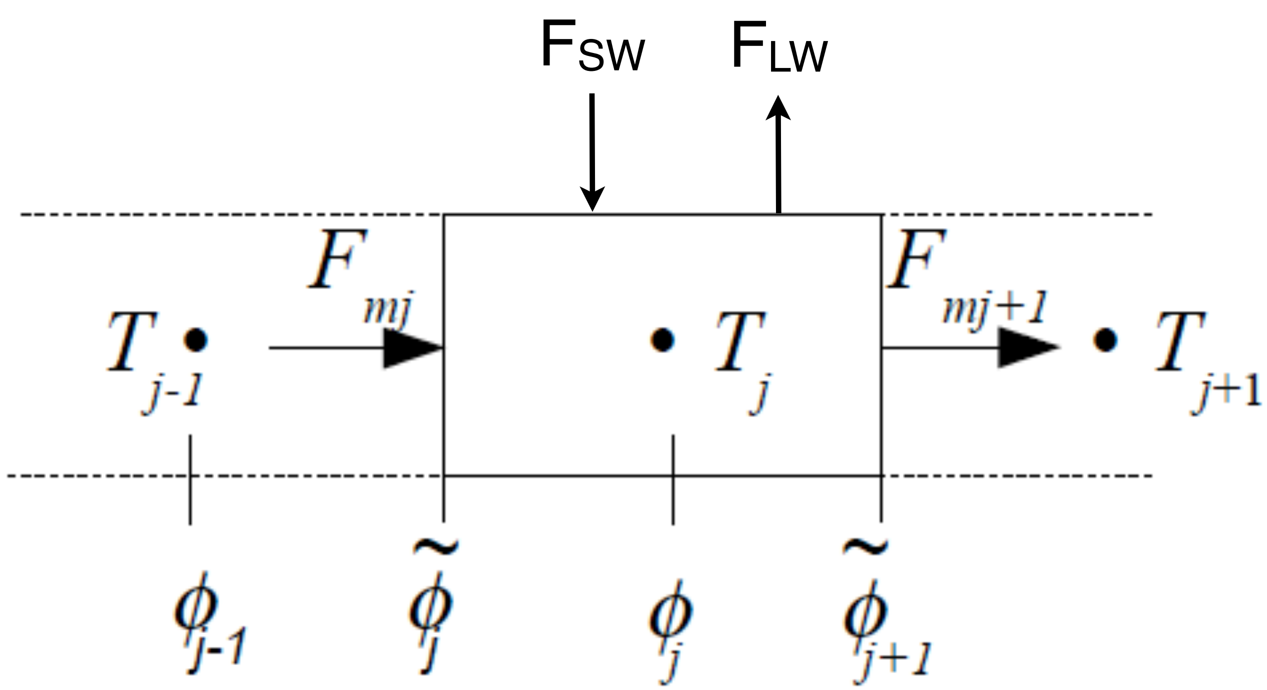
$$\vec{\nabla}\vec{F}_m = -\vec{\nabla}\left(CK\,\vec{\nabla}T\right) = \frac{-1}{R^2\cos\phi}\frac{\partial}{\partial\phi}\left(CK\cos\phi\frac{\partial T}{\partial\phi}\right) \qquad (2.20)$$

latitude

Discretized:

$$-\vec{\nabla}\vec{F}_m = \frac{-1}{R\cos\phi}\frac{\Delta F_m}{\Delta\phi} = \frac{-1}{R\cos\phi}\frac{F_{mj+1}-F_{mj}}{\tilde{\phi}_{j+1}-\tilde{\phi}_j}$$

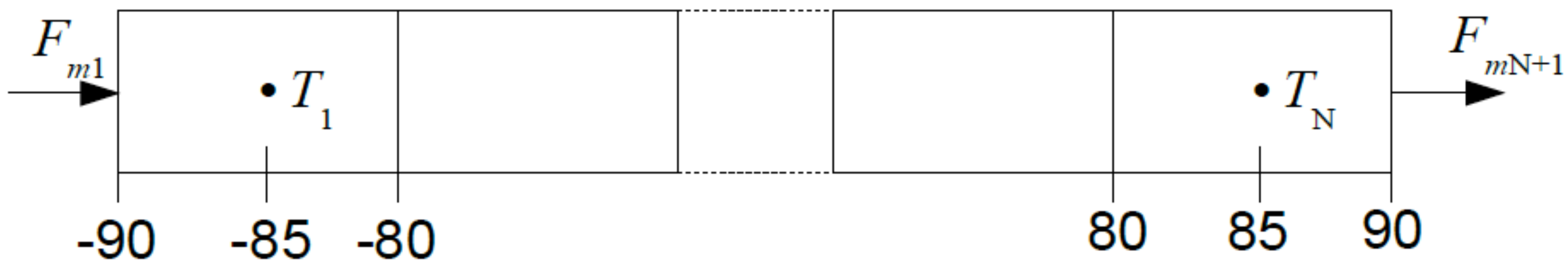
$$F_{mj} = -CK_j\frac{\cos\tilde{\phi}_j}{R}\frac{T_j-T_{j-1}}{\phi_j-\phi_{j-1}}$$

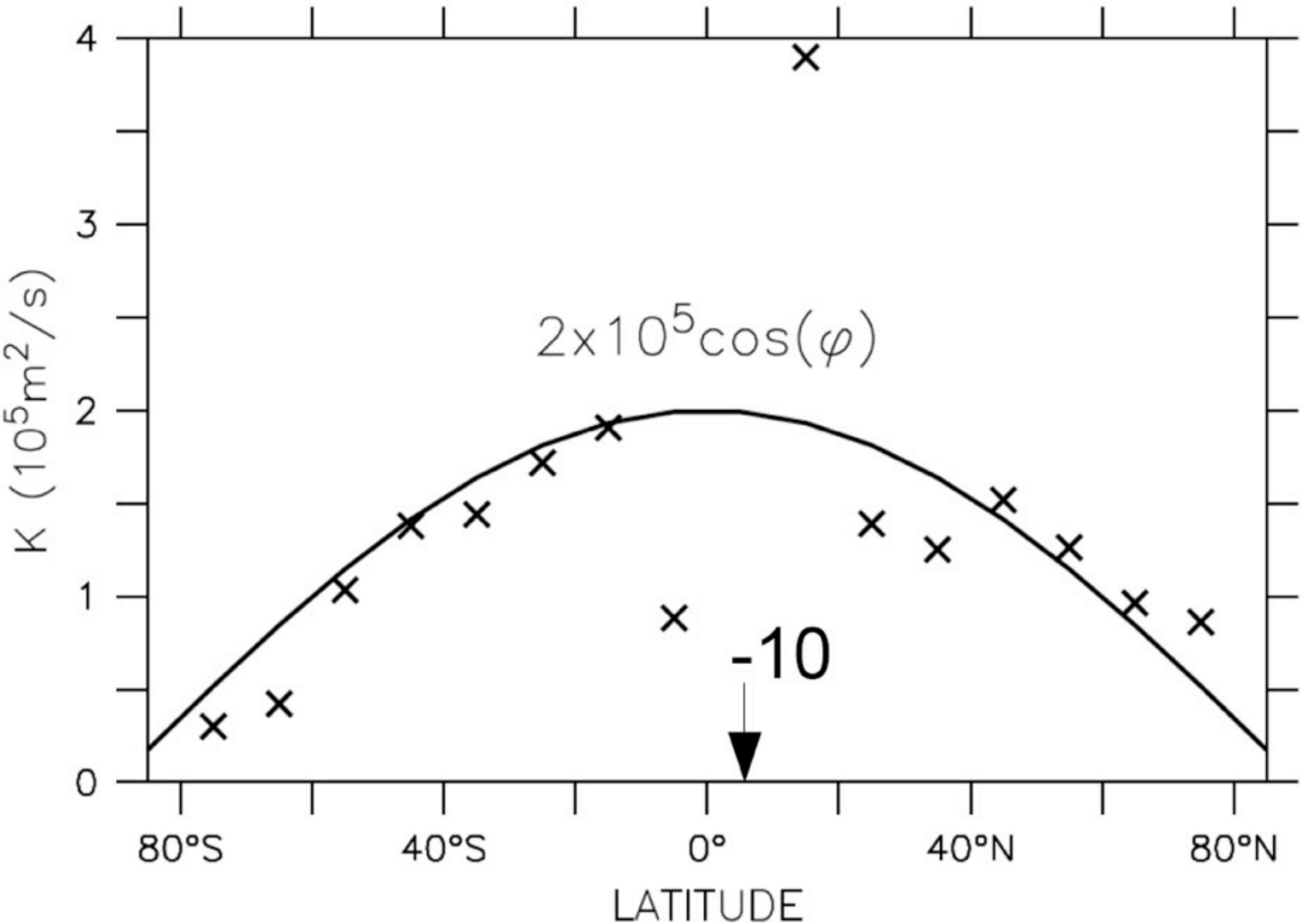


Set up 10 grid from pole to pole.

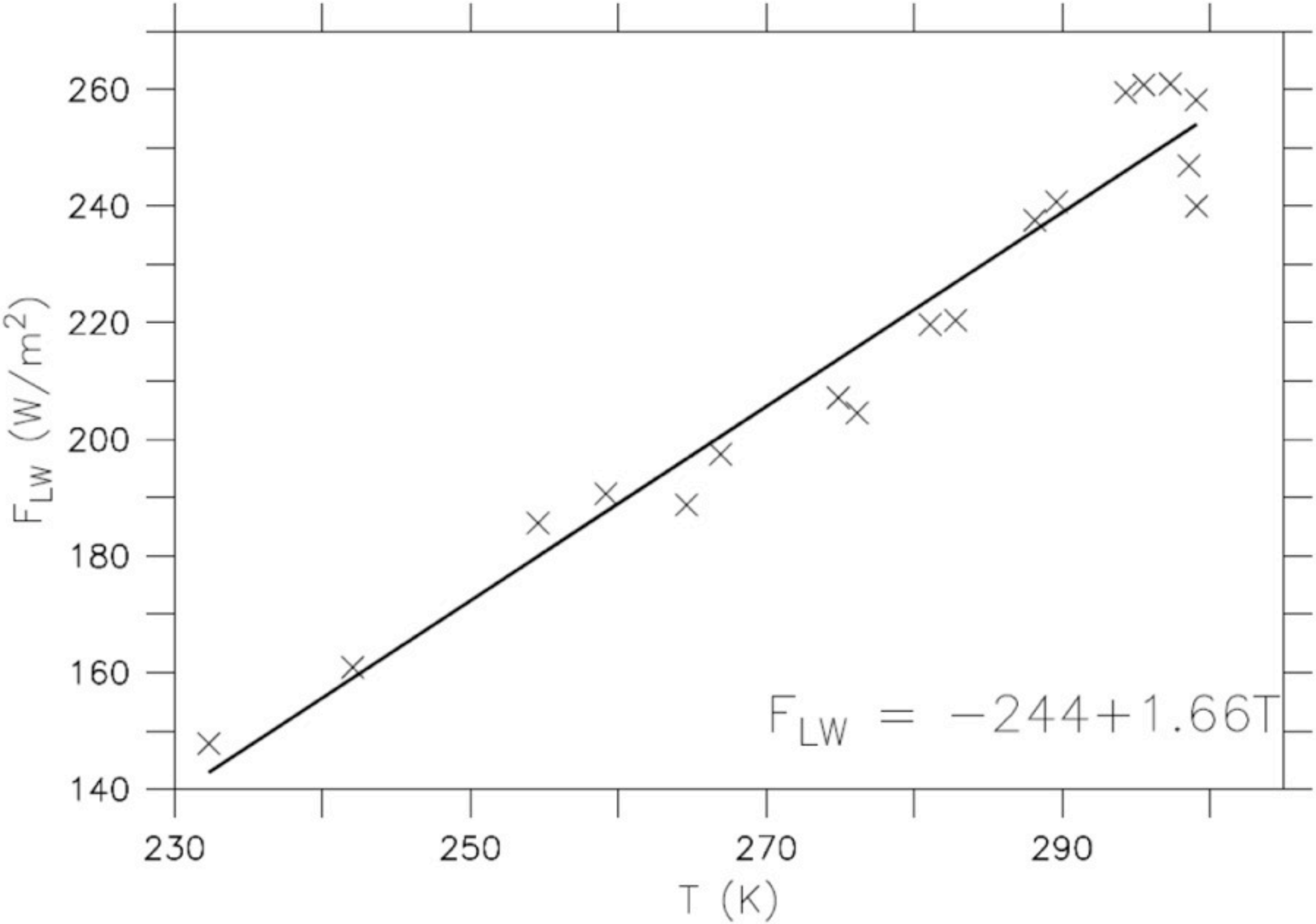
Boundary Conditions:

$$F_{m1} = F_{mN+1} = 0$$





4
3
2
1
0
K (10^{5}m^2/s)
2x10^{5}cos(φ)
-10
80°S
40°S
0°
40°N
80°N
LATITUDE



260
240
220
200
180
160
140
230
250
270
290
T (K)
F_LW (W/m²)
F_LW = −244+1.66T