ATS 421/521

Climate Modeling

Spring 2015

Lecture 5

- Meridional Energy Transport

April 15

Reading

- Today: Course Notes chapter 2.5
- For Monday: Course Notes chapter 2.6.1
- For Friday: Huybers and Curry (2006)

Previous Lecture

Spectral Analysis

Time series $\{x_1, \ldots, x_T\}$ is expanded in Fourier series (assume T is even):

$$x_t = a_0 + \sum_{j=1}^{q} (a_j \cos(2\pi w_j t) + b_j \sin(2\pi w_j t))$$

$$w_j = \frac{j}{T}$$

$$q = \frac{T}{2}$$

The Fourier coefficients are:

$$a_0 = \frac{1}{T} \sum_{t=1}^{T} x_t \qquad a_j = \frac{2}{T} \sum_{t=1}^{T} x_t \cos(2\pi w_j t) \qquad b_j = \frac{2}{T} \sum_{t=1}^{T} x_t \sin(2\pi w_j t)$$

The Peridodogram: $$I_{Tj} = \frac{T}{4}(a_j^2 + b_j^2)$$

Intensities I_{Tj} correspond to frequencies w_j

The Auto-Covariance Function: $\gamma(\tau) = Cov(x_t, x_{t+\tau})$

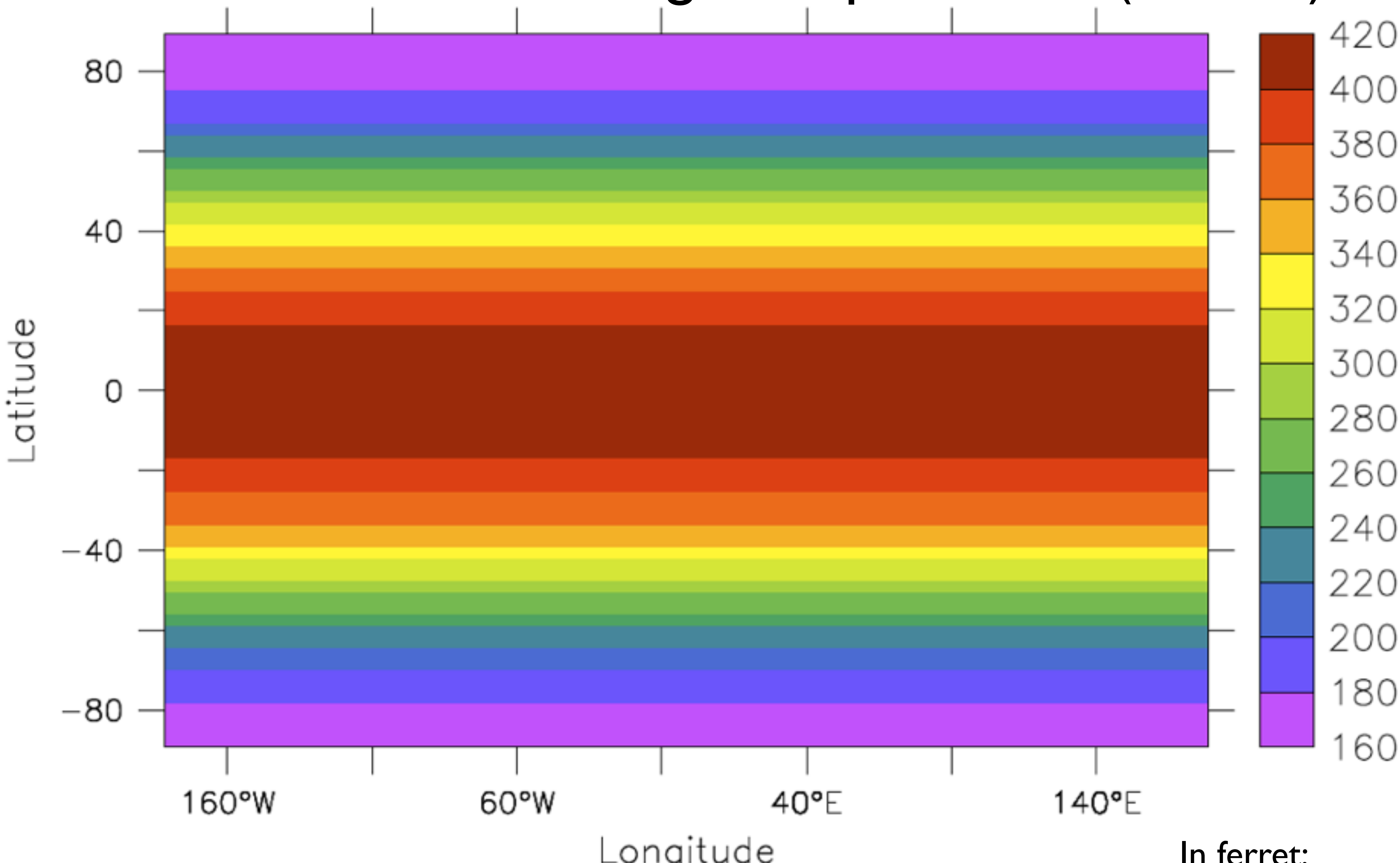
The Auto-Correlation Function: $\rho(\tau) = \dfrac{\gamma(\tau)}{\gamma(0)}$

The Spectrum: $\Gamma(w) = \sum_{\tau=-\infty}^{\infty} \gamma(\tau) e^{-2\pi i \tau w}$ $\quad w \in [-\frac{1}{2}, \frac{1}{2}]$

Here we will use the periodogram is an estimate of the spectrum.

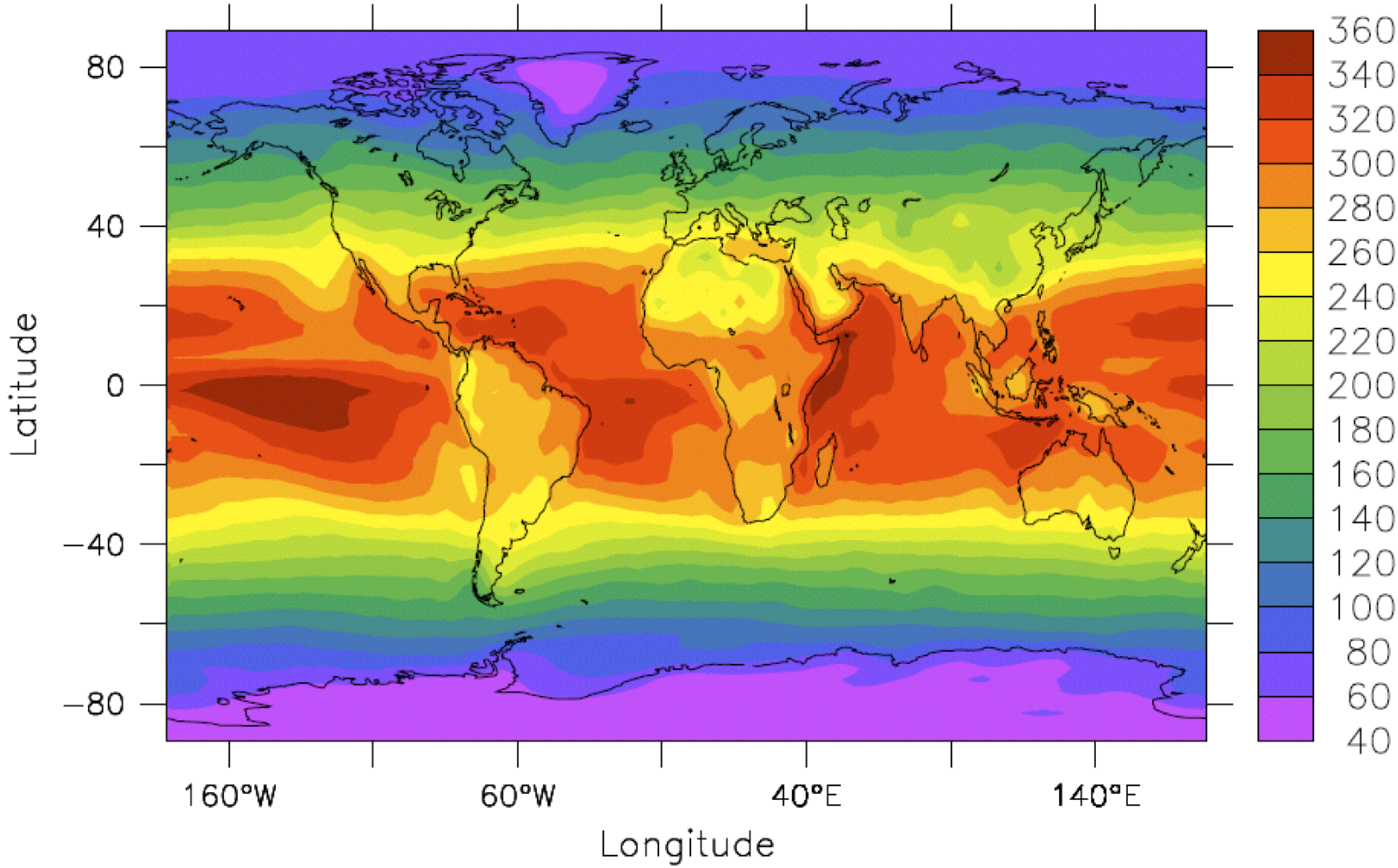
Meridional Energy Transport

TOA Fluxes from Satellites
Earth Radiation Budget Experiment (ERBE)



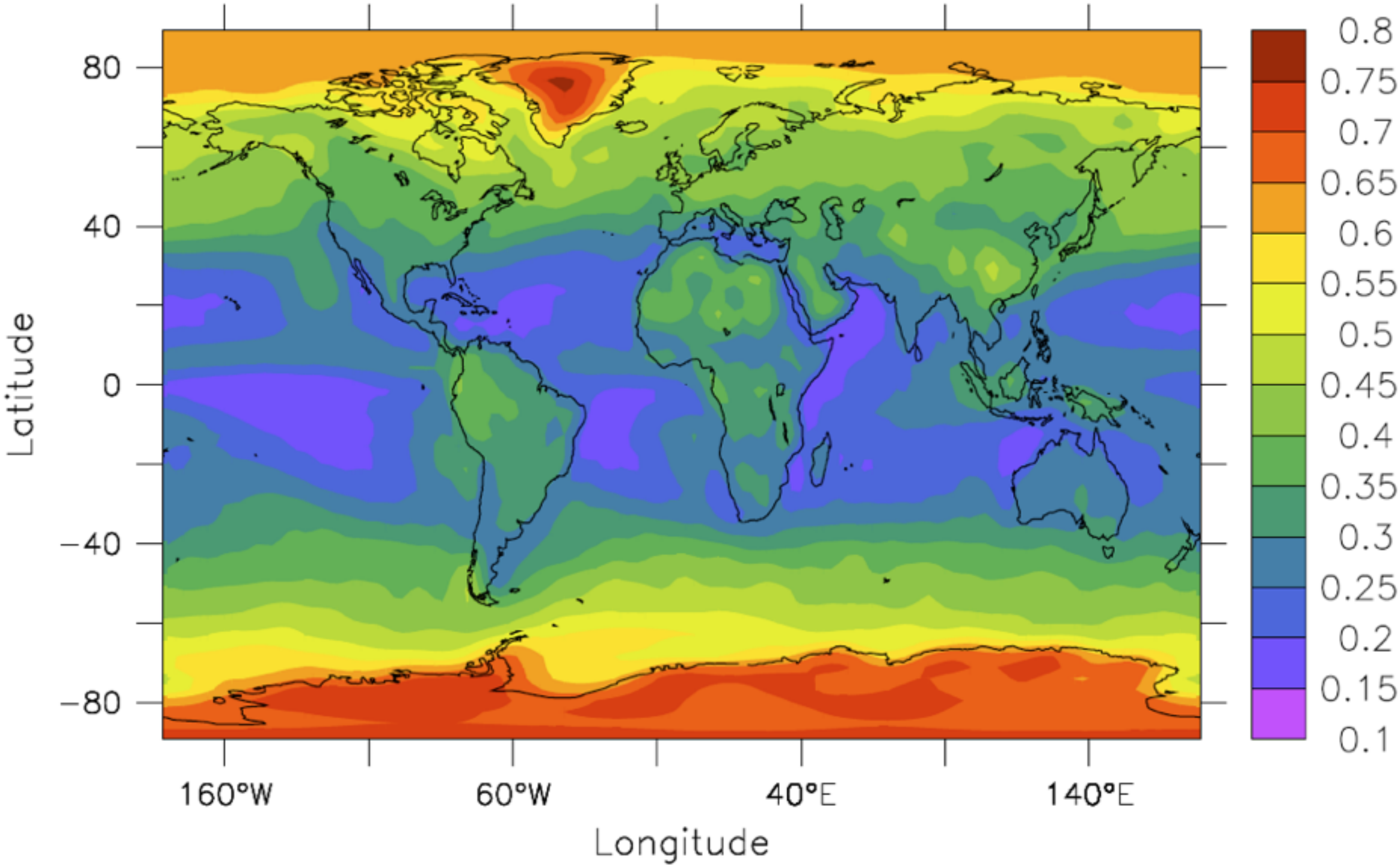
Total Incident Solar Radiation S (W/m^2)

In ferret:
use ERBE_mean.cdf
shade solar



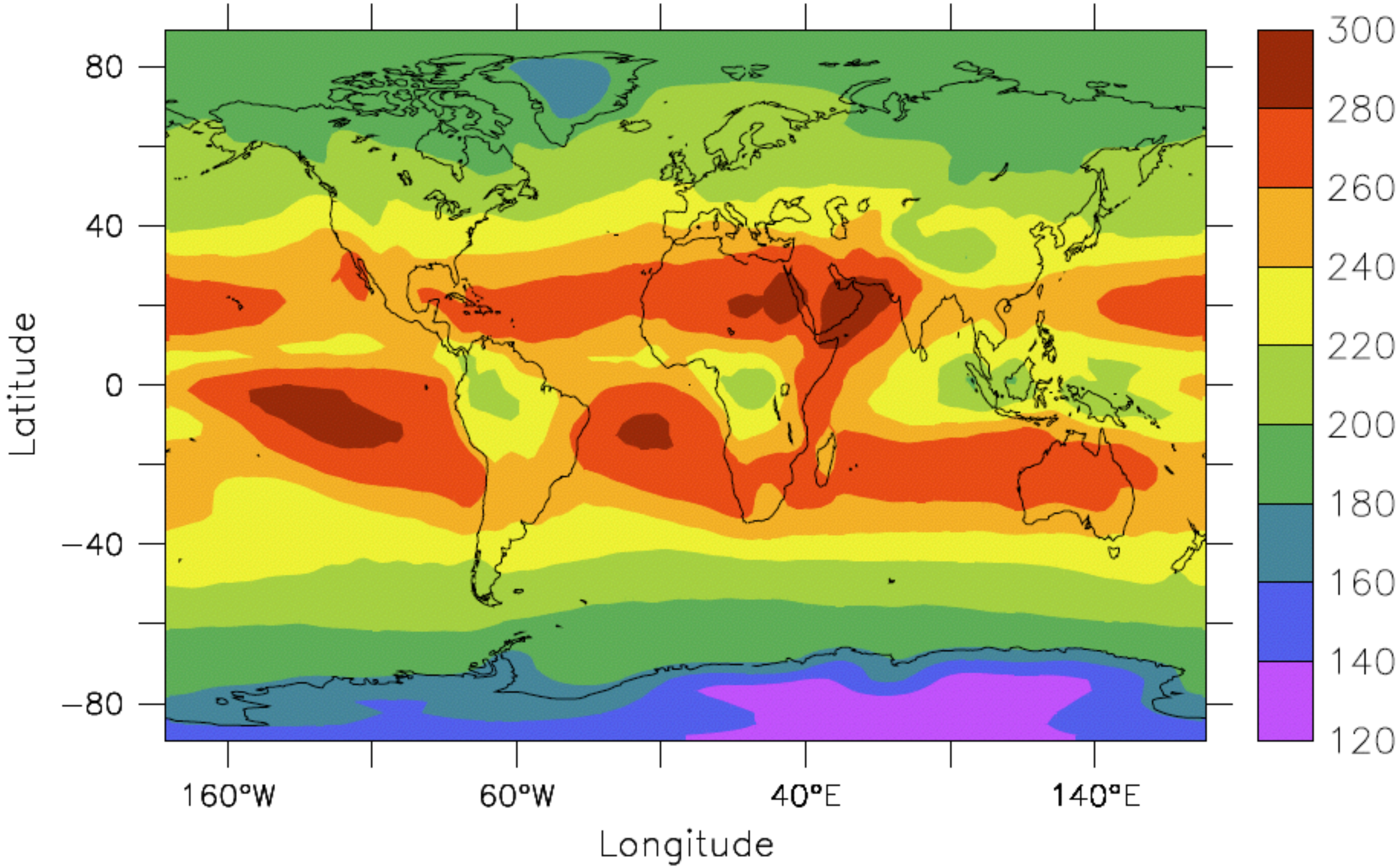
Absorbed Solar Radiation (W/m^2)

In ferret:
shade asr
go land



Planetary Albedo

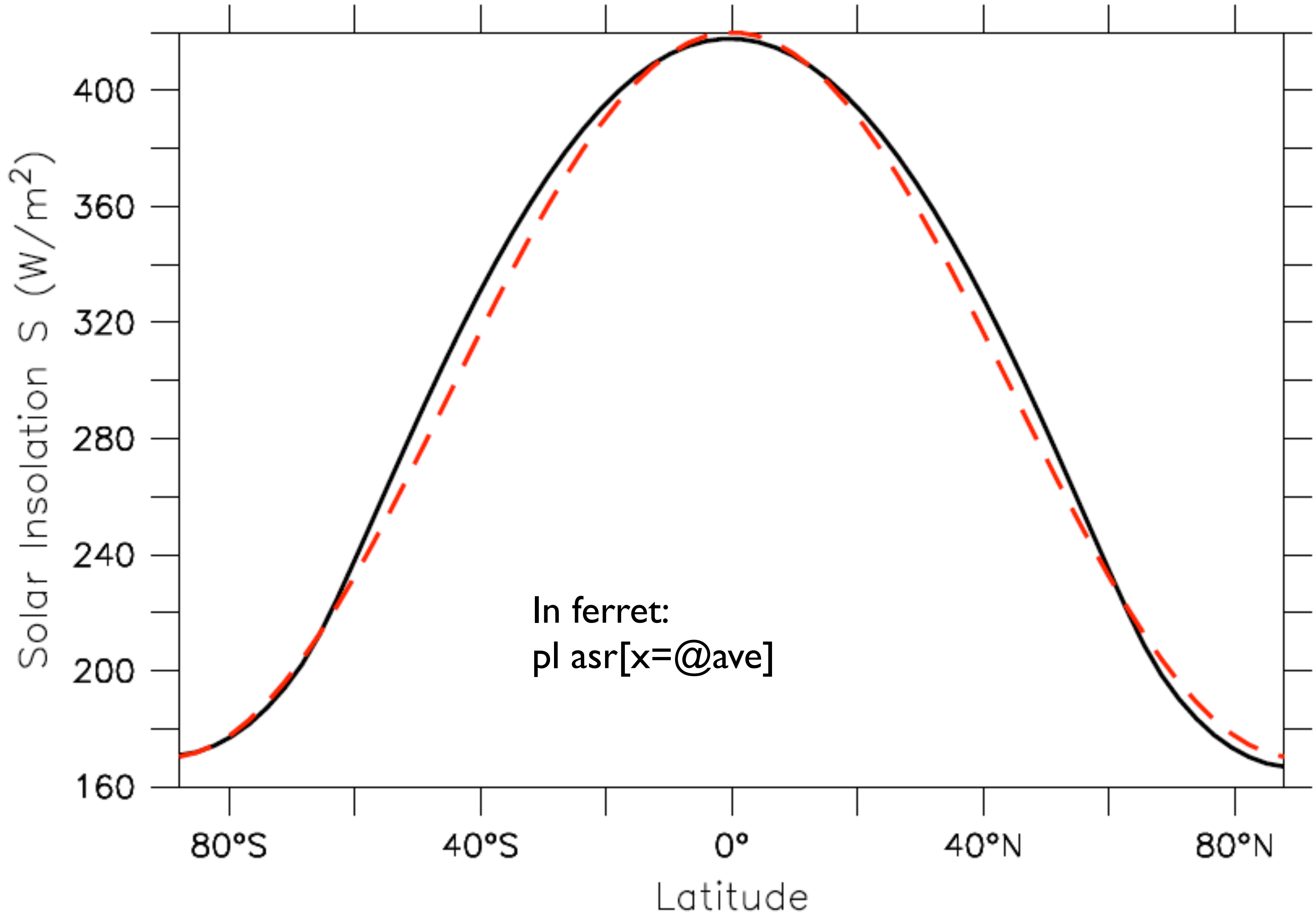
In ferret:
let albedo = refl/solar
shade albedo
go land



Outgoing Longwave Radiation (W/m^2)

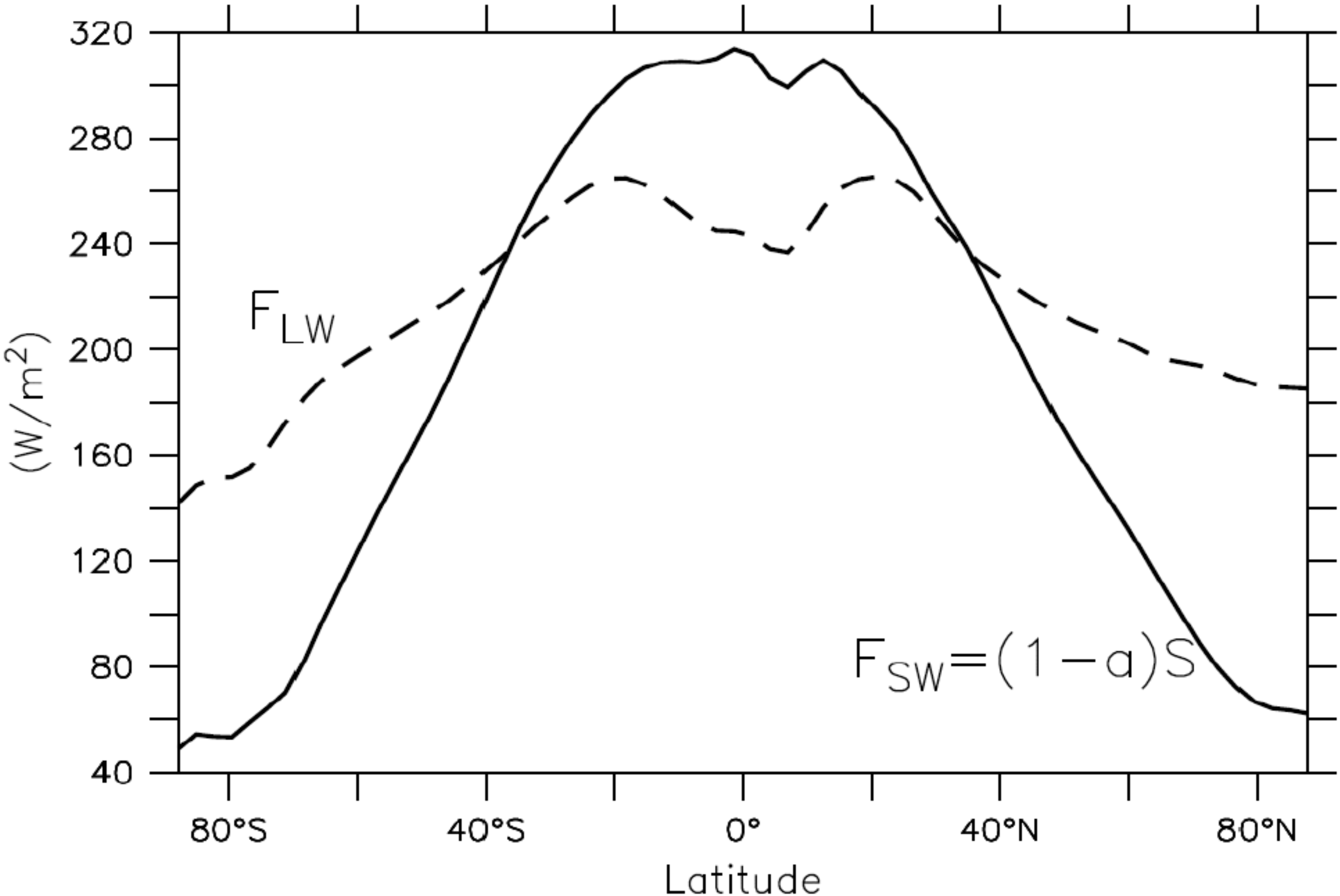
In ferret:
shade olr
go land

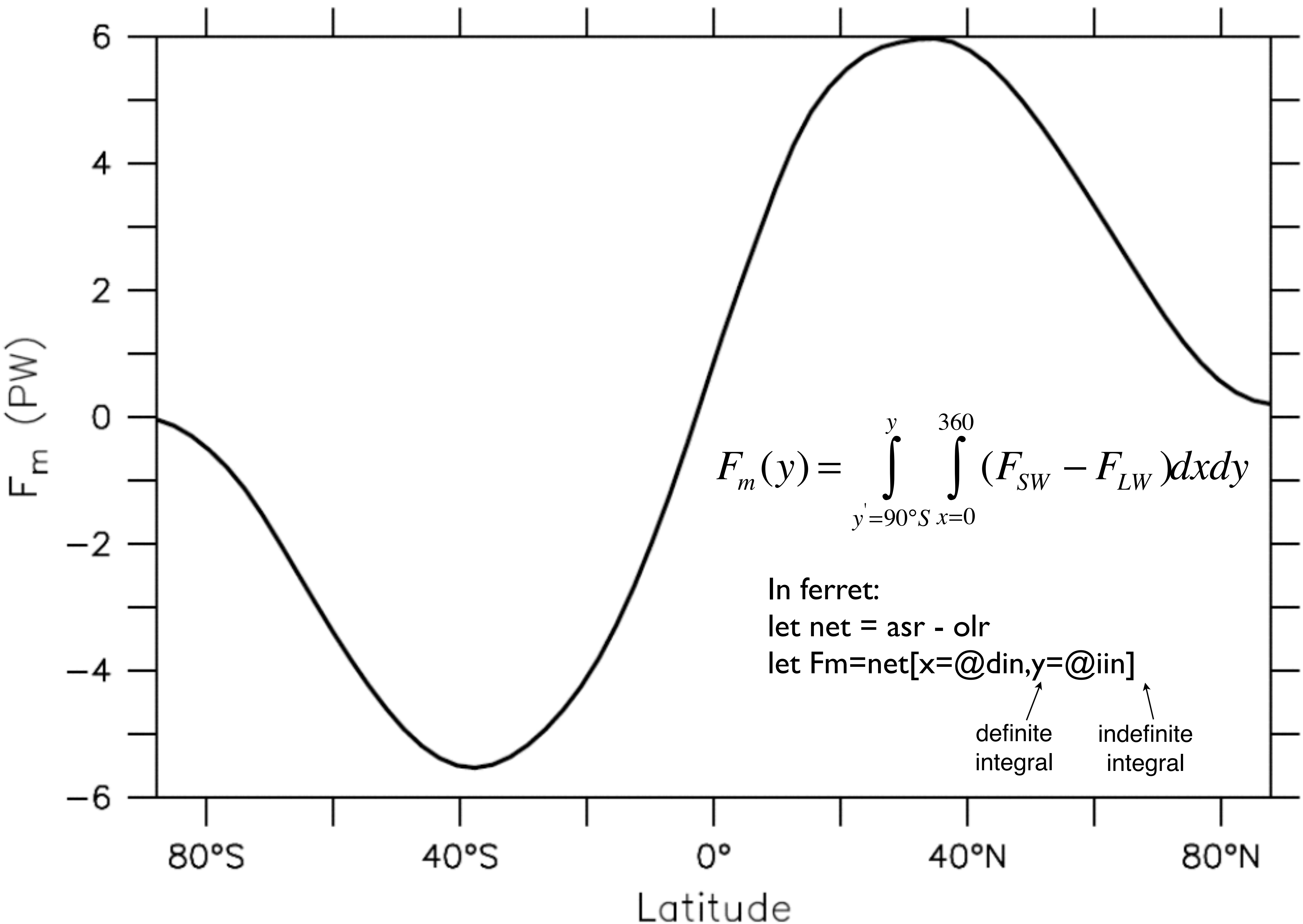
Zonally Averaged Incident Solar Radiation



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

Zonally averaged absorbed solar and outgoing longwave radiation




6
4
2
0
−2
−4
−6
F_m (PW)
80°S
40°S
0°
40°N
80°N
Latitude
$F_m(y) = \int_{y'=90°S}^{y} \int_{x=0}^{360} (F_{SW} - F_{LW}) dx dy$
In ferret:
let net = asr - olr
let Fm=net[x=@din,y=@iin]
definite integral
indefinite integral

Diffusive parameterization of meridional heat transport:

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

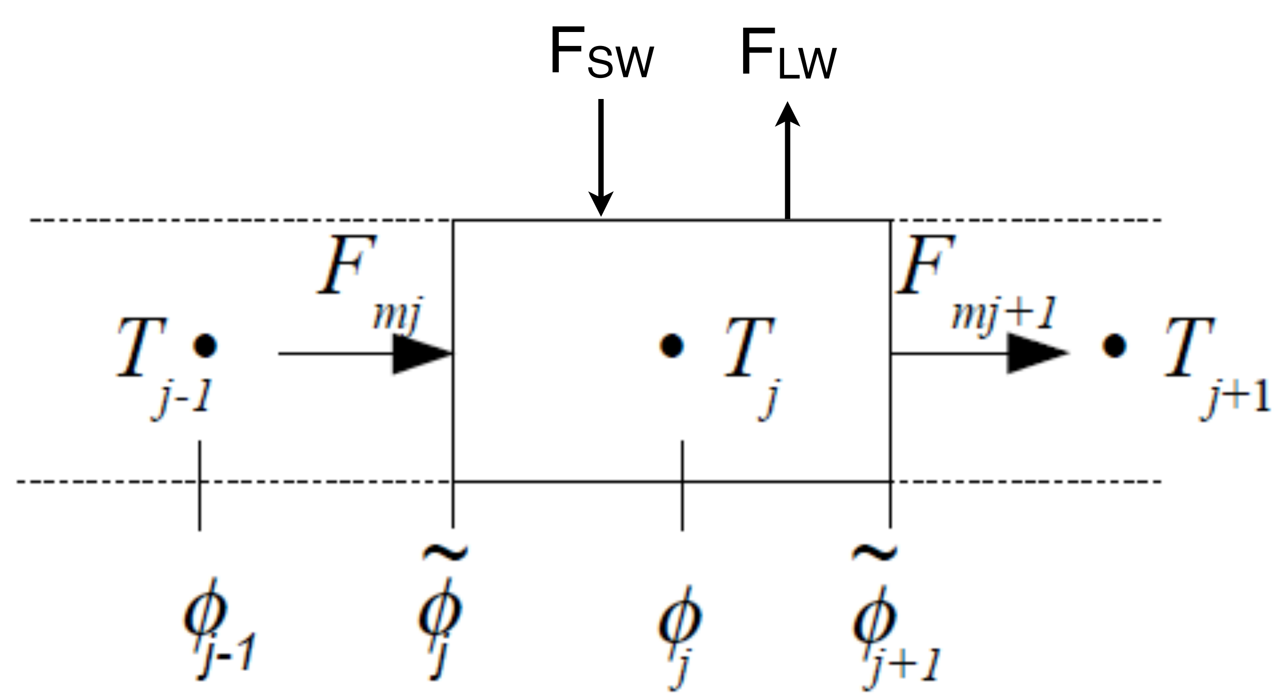
Heat Capacity

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:

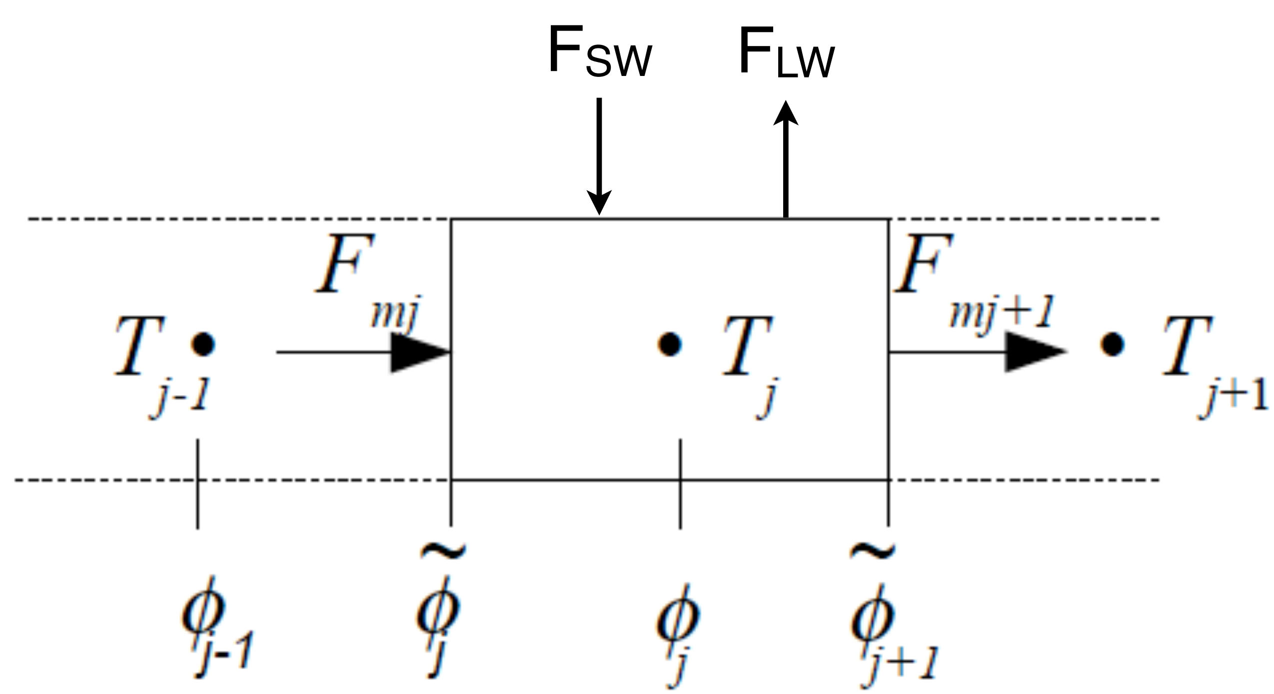
$$\vec{\nabla}\vec{F}_m = -\vec{\nabla}\left(CK\vec{\nabla}T\right) = \frac{-1}{R^2\cos\phi}\frac{\partial}{\partial\phi}\left(CK\cos\phi\frac{\partial T}{\partial\phi}\right) \tag{2.20}$$

latitude

Discretized:

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

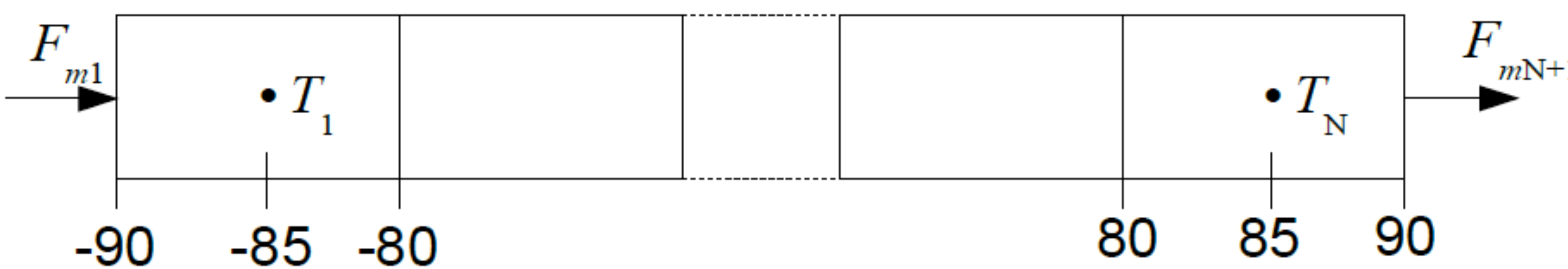
$$F_{mj} = -CK_j\frac{\cos\tilde{\phi}_j}{R}\frac{T_j-T_{j-1}}{\phi_j-\phi_{j-1}}$$

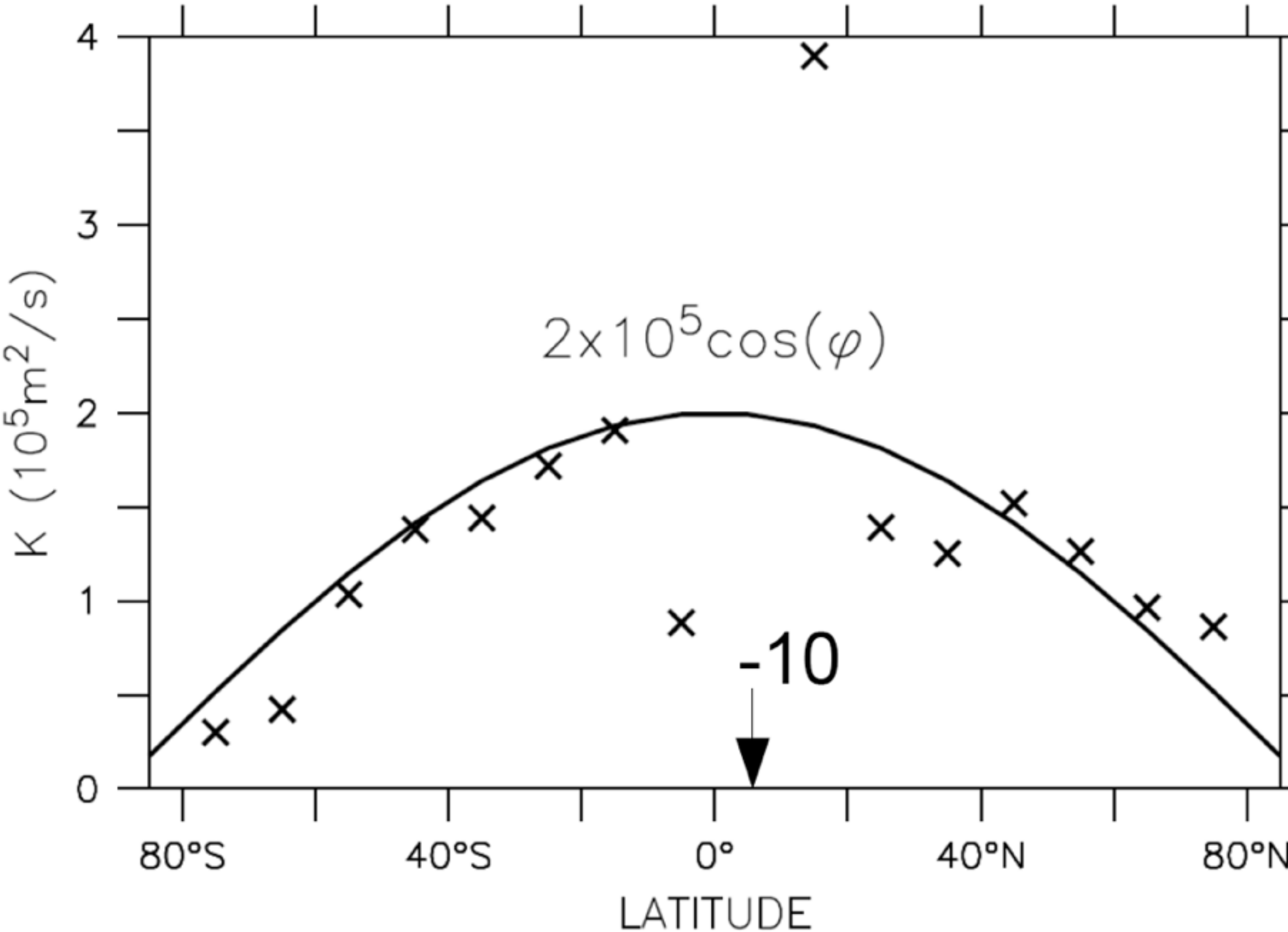


Set up 10 grid from pole to pole.

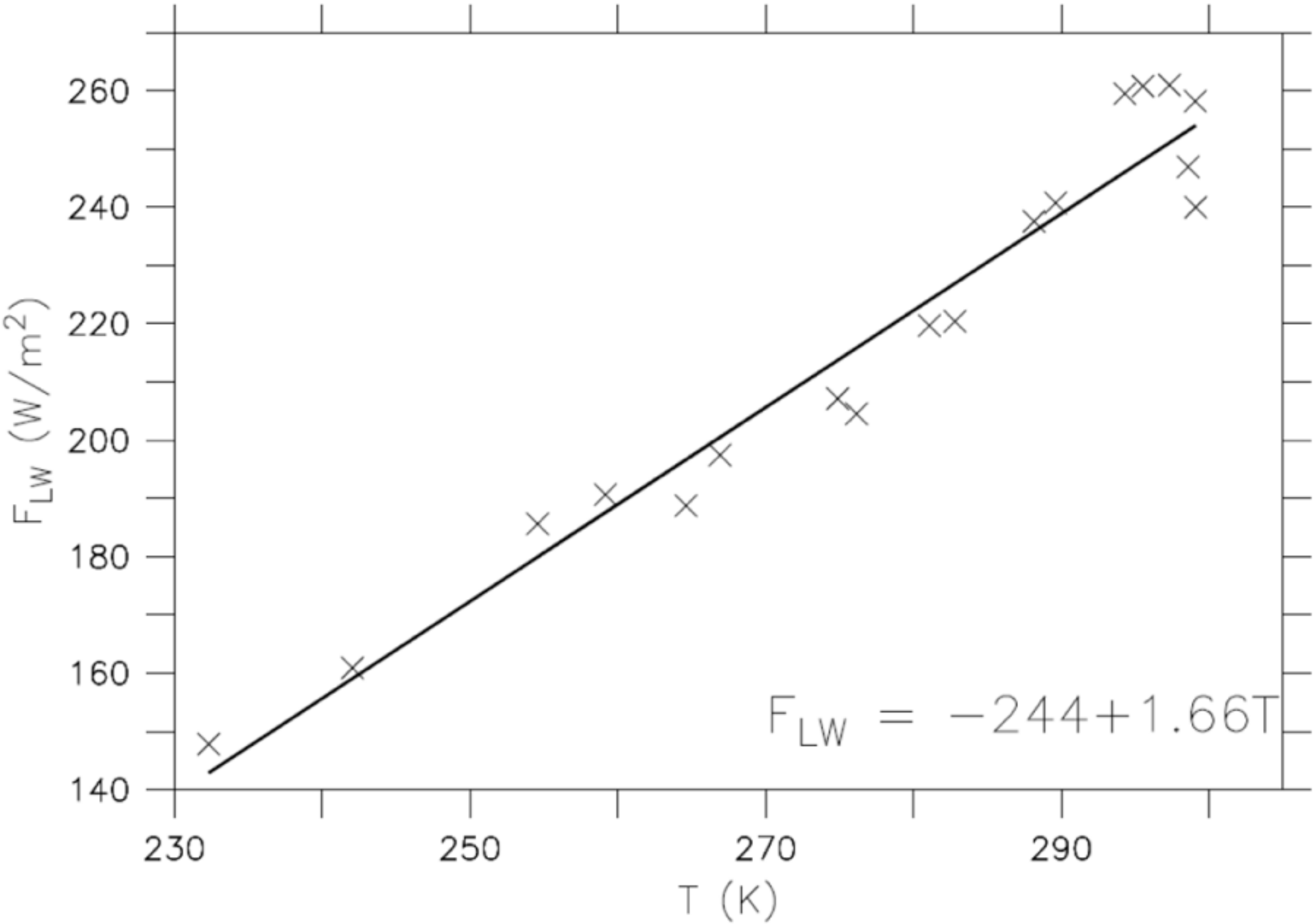
Boundary Conditions:

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





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



260
240
220
200
180
160
140
F_{LW} (W/m^2)
230
250
270
290
T (K)
$F_{LW} = -244+1.66T$