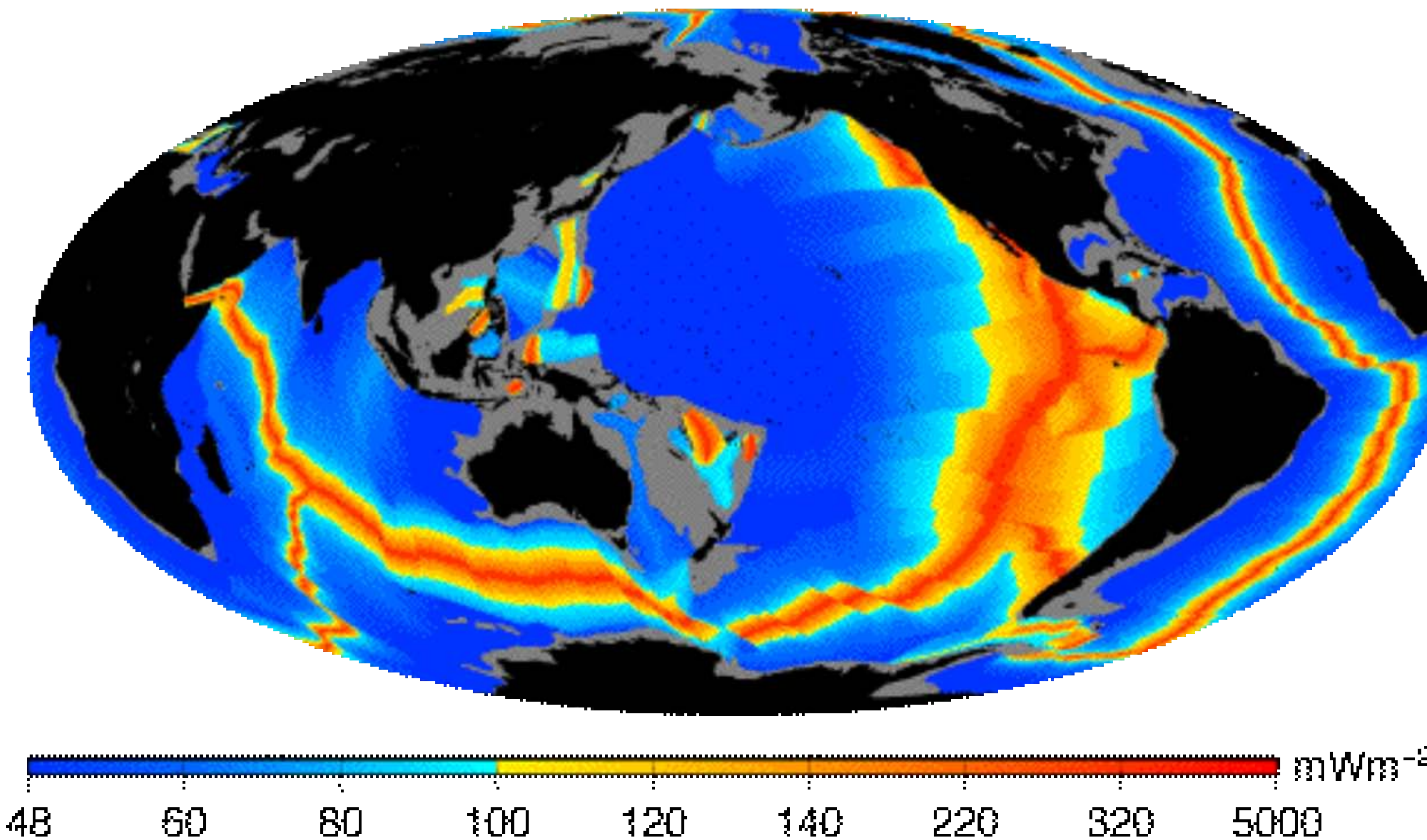
Global Oceanic Heat Flow

Jorge Perez
Caitlin Traver



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Um, don't we go over this in every geophysics class ever?

- Classic problem considers change in depth/age and heat flow across a line perpendicular to the ridge axis
- With this problem, we are looking at an equation for heat flow of the ocean floor in two dimensions

Goal

Derive an expression relating the depth and age of the seafloor to the local heat flow

WHY?

Heat flow measurements are difficult and there is no practical way to have a high density of measurements over the entire ocean basins

By finding an expression relating the depth and age to q_s, heat flow can be estimated without actually taking a heat flow measurement

This approach uses bathymetry data combined with an age grid of the sea floor to find q_s

Assumptions

- Steady state spreading
- Oceanic crust with NO internal heat production
- Lateral heat transport is negligible

Governing equations:

Conservation of energy

$$\rho_m C_p \mathbf{v} \cdot \boldsymbol{\nabla} T = \boldsymbol{\nabla} \cdot \mathbf{q}$$

Density as a function of temperature

$$\rho(T) = \rho_m \left[1 - \alpha(T - T_m)\right]$$

Depth as a function of integrated temperature

$$d(t) = \frac{-\alpha \rho_m}{\rho_m - \rho_w} \int_d^L (T - T_m) dz$$

First, take gradient of each side of depth function then dot product with **v**

$$\mathbf{v} \cdot \nabla d(t) = \frac{-\alpha \rho_m}{\rho_m - \rho_w} \int_d^L \mathbf{v} \cdot \nabla T dz$$

Then plug in for $\nabla \cdot \mathbf{q}$ from conservation of energy

$$\mathbf{v} \cdot \nabla T = \frac{1}{\rho_m C_p} \nabla \cdot \mathbf{q}$$

$$\mathbf{v} \cdot \nabla d(t) = \frac{-\alpha}{(\rho_m - \rho_w) C_p} \int_d^L \nabla \cdot \mathbf{q} \boldsymbol{dz}$$

Then, implement assumption of no lateral heat transport

$$\int_d^L \boldsymbol{\nabla} \cdot \mathbf{q} \boldsymbol{dz}$$

Becomes…..

$$\int_d^L \frac{\partial}{\partial z} q(z) dz = q(L) - q(d) = q_\infty - q_s$$

$$\mathbf{v} \cdot \boldsymbol{\nabla} d(t) = \frac{-\alpha}{(\rho_m - \rho_w) C_p} (q_\infty - q_s)$$

Then, working with a grid of sea floor ages, need to find velocity (measured perpendicular to spreading ridge) Velocity vector is:

$$\mathbf{v} = \frac{\nabla A}{\nabla A \cdot \nabla A}$$

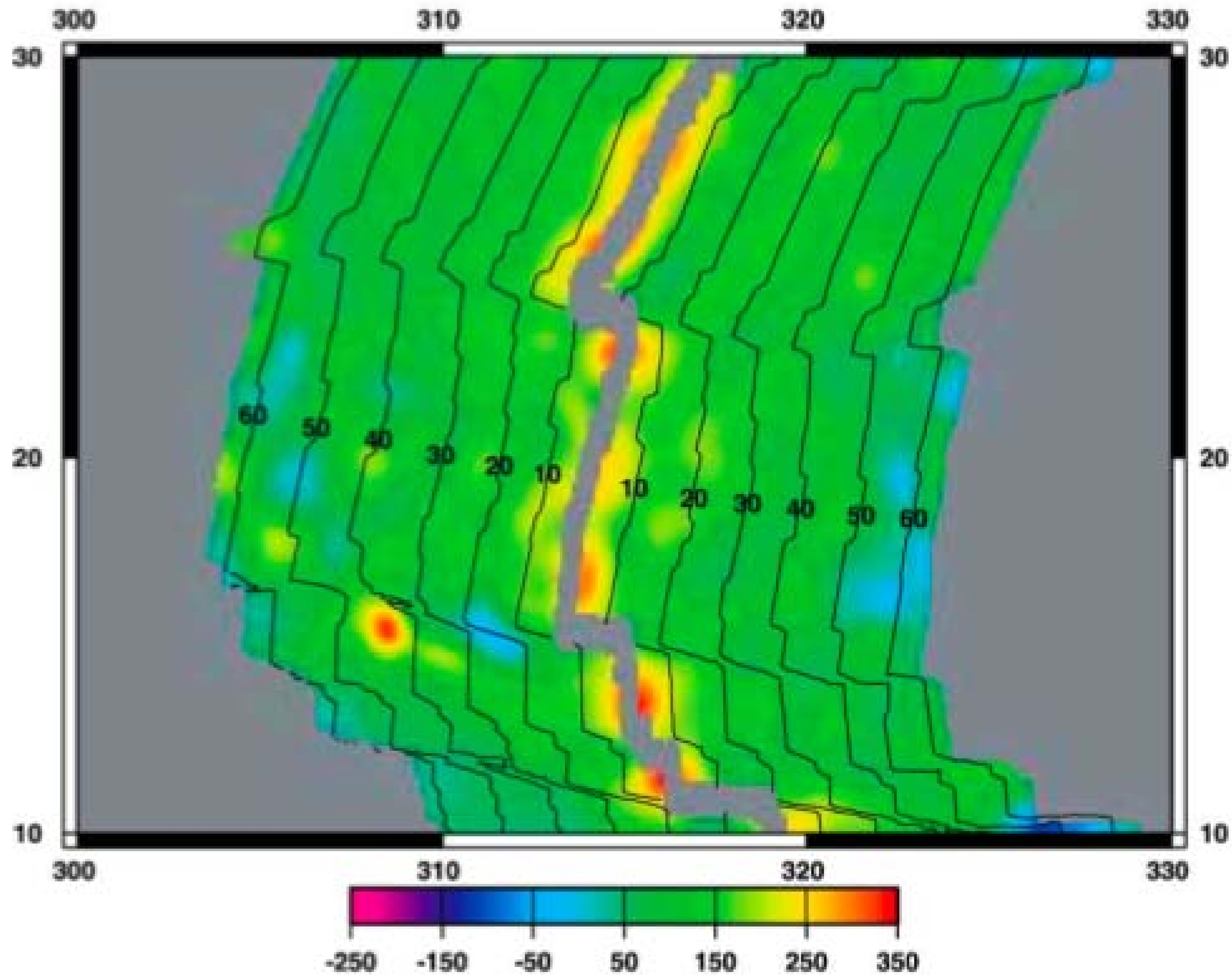
Finally, substituting **v** into equation, we get

$$\frac{\nabla d \cdot \nabla A}{\nabla \mathbf{A} \cdot \nabla A} = \frac{-\alpha}{(\rho_m - \rho_w) C_p} (q_\infty - q_s)$$

End result:

$$q_s = \frac{(\rho_m - \rho_w) C_p}{\alpha} \frac{\nabla d \cdot \nabla A}{\nabla \mathbf{A} \cdot \nabla A} + q_\infty$$

q_s is determined from topography and age data and is dependent upon heat capacity and the coefficient of thermal expansion



Wei, Sandwell 2006

Limitations

- Not taking into account sediment load or subsequent compensation
- Not taking into account seamounts
- Need t have good values for coefficient of thermal expansion as well as heat capacity

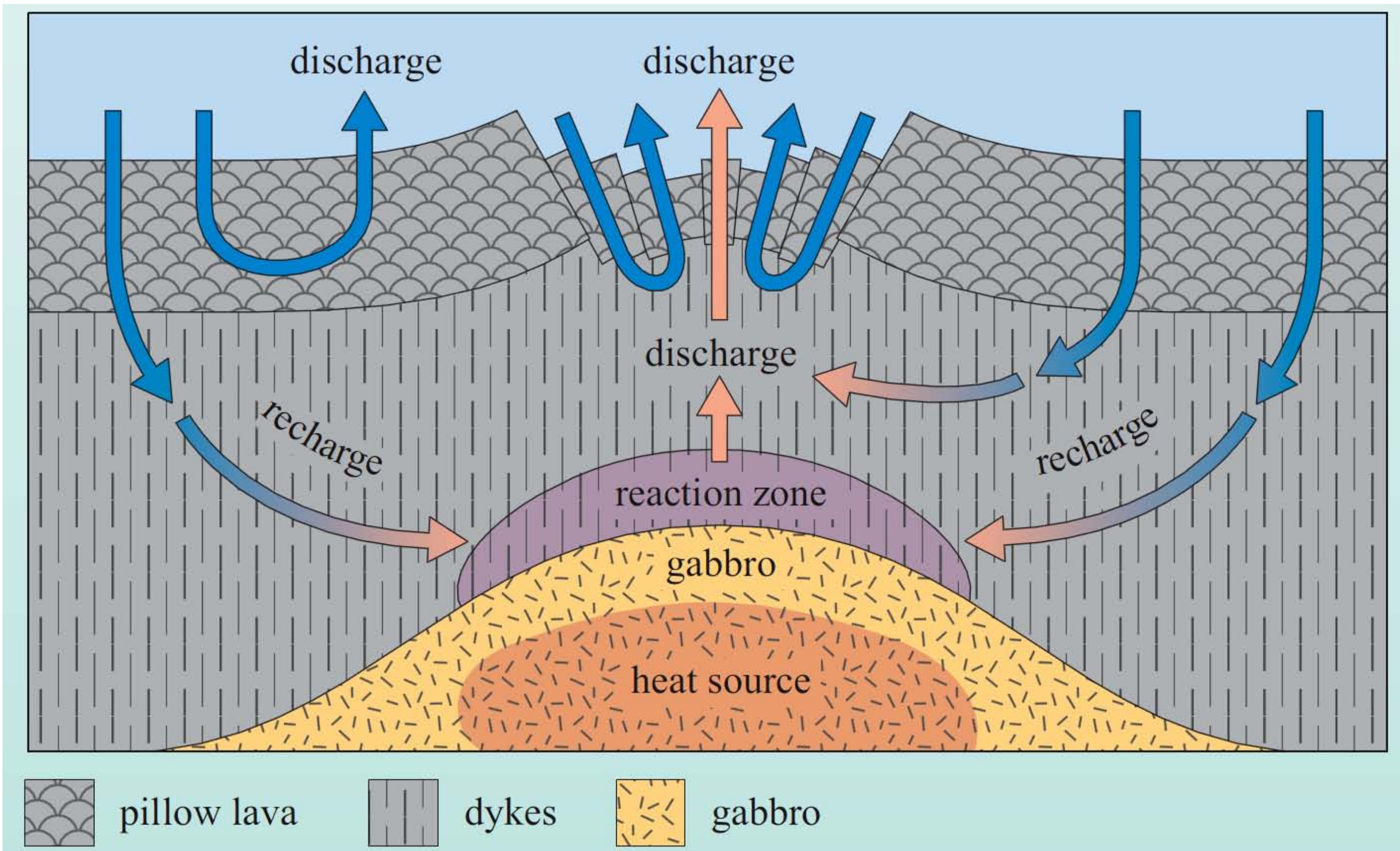
Near the Ridge

- Methods only applicable to crust >3Ma

-Near-axis local isostasy invalid, topography supported dynamics and flexure*, depth won’t correlate to age and heat flow)

- Seafloor subsidence rate is anomolous due to rapid quenching

Hydrothermal Circulation



Estimating global oceanic heat flow: Approach

- Need age grid for entire sea floor
- Need bathymetry data for entire sea floor
- Determine values for α and C_p
- Calculate heat flow at every point(to desired resolution)
- Take average of all calculated heat flow values
- Multiply average heat flow(m^-2)

by total surface area of ocean floor

The end

References:

Wei, Sandwell. Estimations of Heat flow for the Cenezoic Sea Floor Using Global Depth and Age Data. 2006

Cochran, Buck. Near-axis subsidence rates, hydrothermal circulation, and thermal structure of mid-ocean ridge crests. 2001