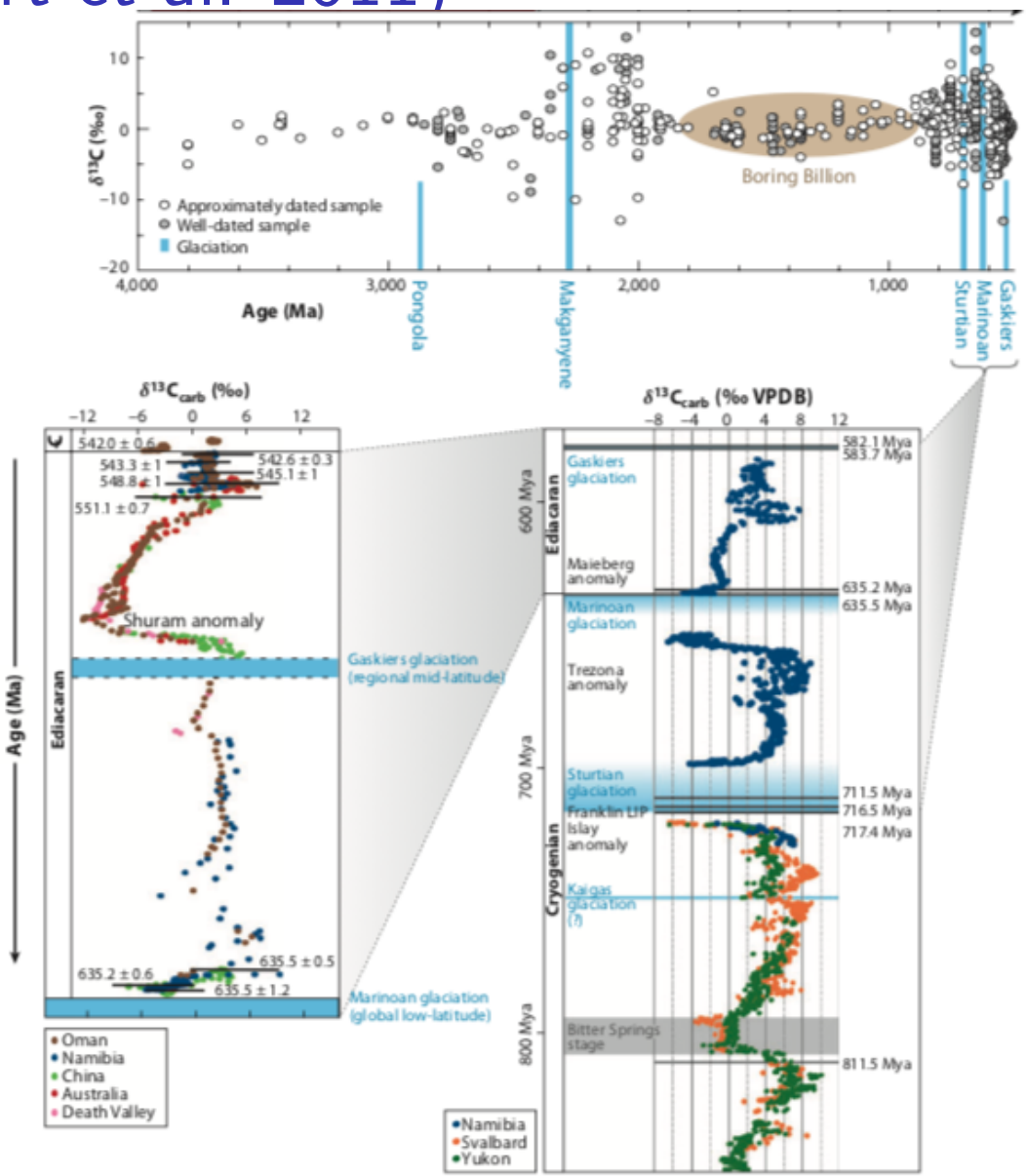
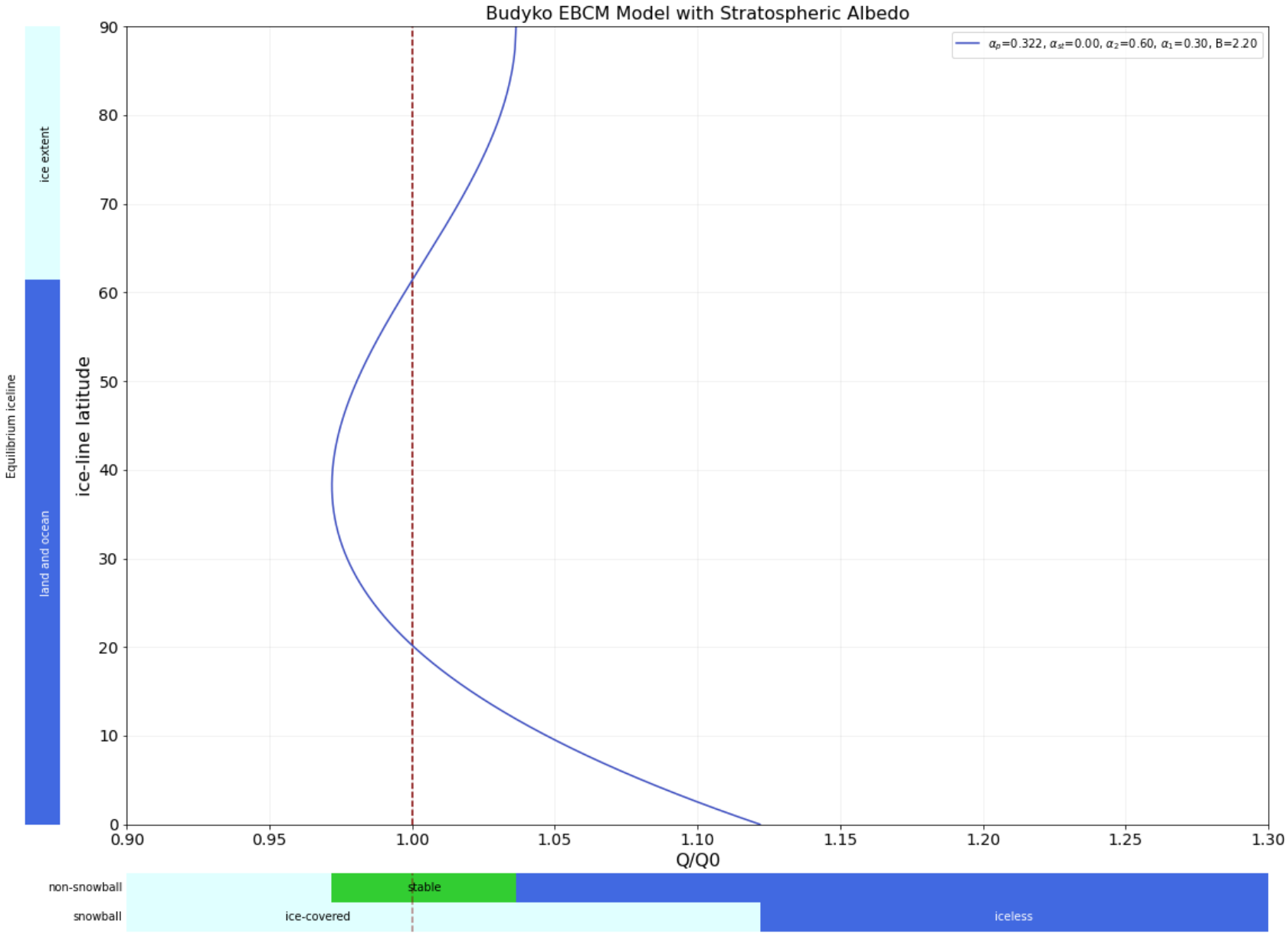
Could albedo changes explain Neoproterozoic glaciations? (Pierrehumbert et al. 2011)

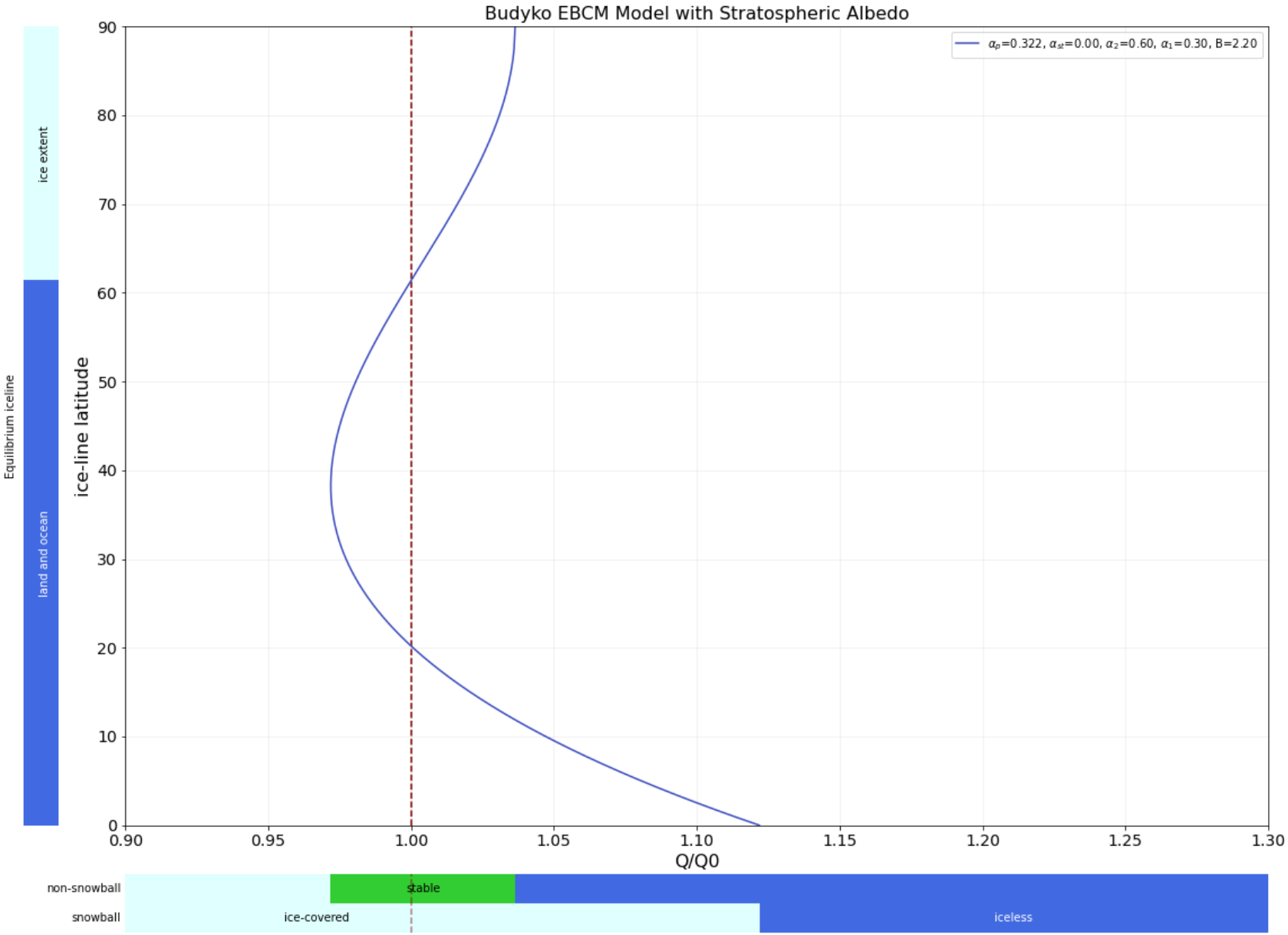


Increasing land and ocean albedo can cause a snowball



Budyko EBCM Model with Stratospheric Albedo

So can increasing ice albedo.



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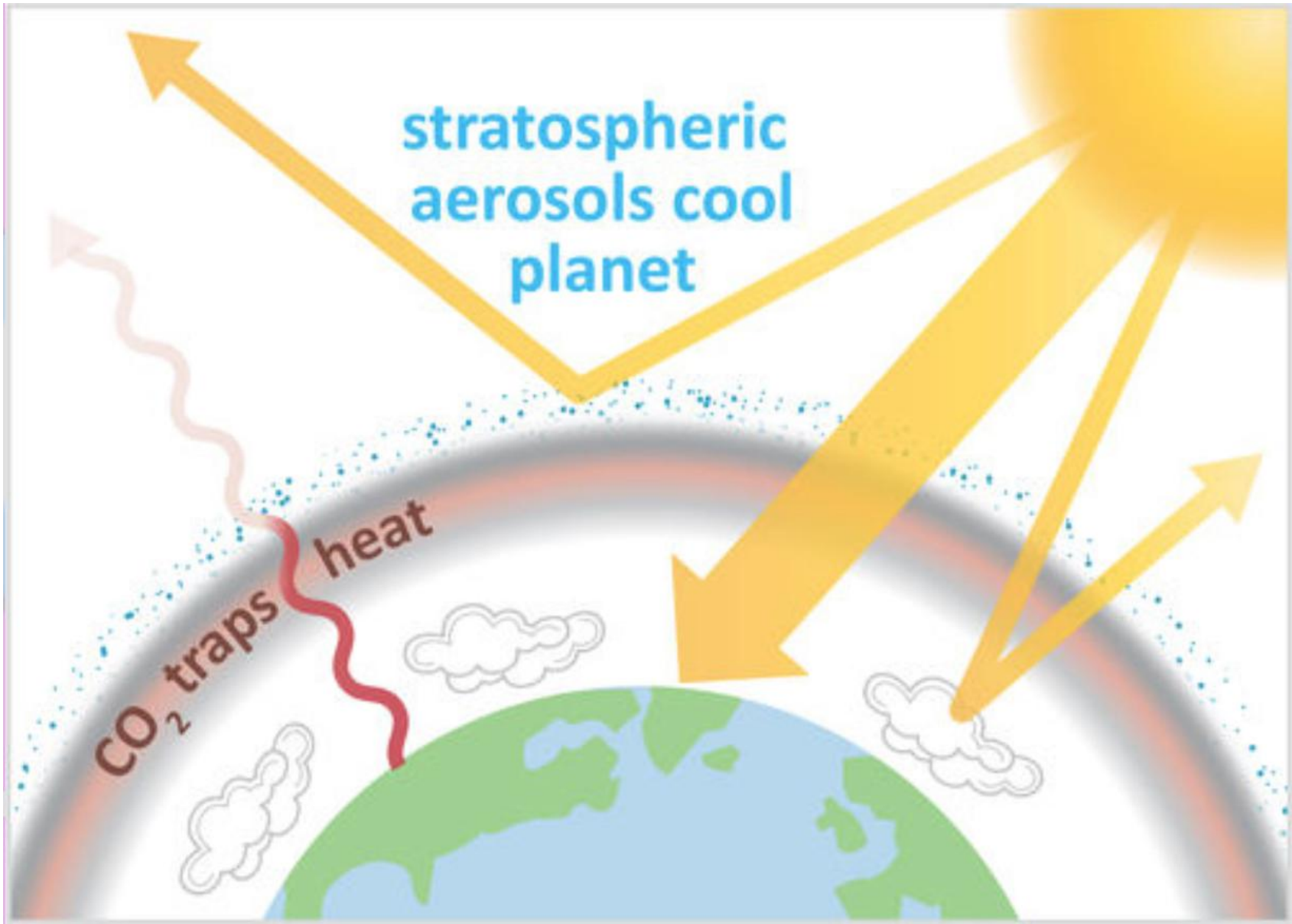
A volcanic mechanism to increase albedo

Volcanoes put particulates into *stratosphere* that increase albedo



τ is Optical Depth, $\alpha_{st}(\tau, x_s)$ is Stratospheric Albedo

Adapted equation from Budyko (1969)

$$\frac{Q_0}{4} S(x_s)(1 - \alpha_{st}(x_s, \tau))(1 - \alpha_{su}(x_s)) = A + BT(x_s) + C(T(x_s) - \bar{T})$$

Assumption: Uniform effect over surface.

$$1 - e^{-\tau m(x)} = \alpha_{st}(x, \tau) = \alpha_{st}(\tau) = 1 - e^{-\tau}$$

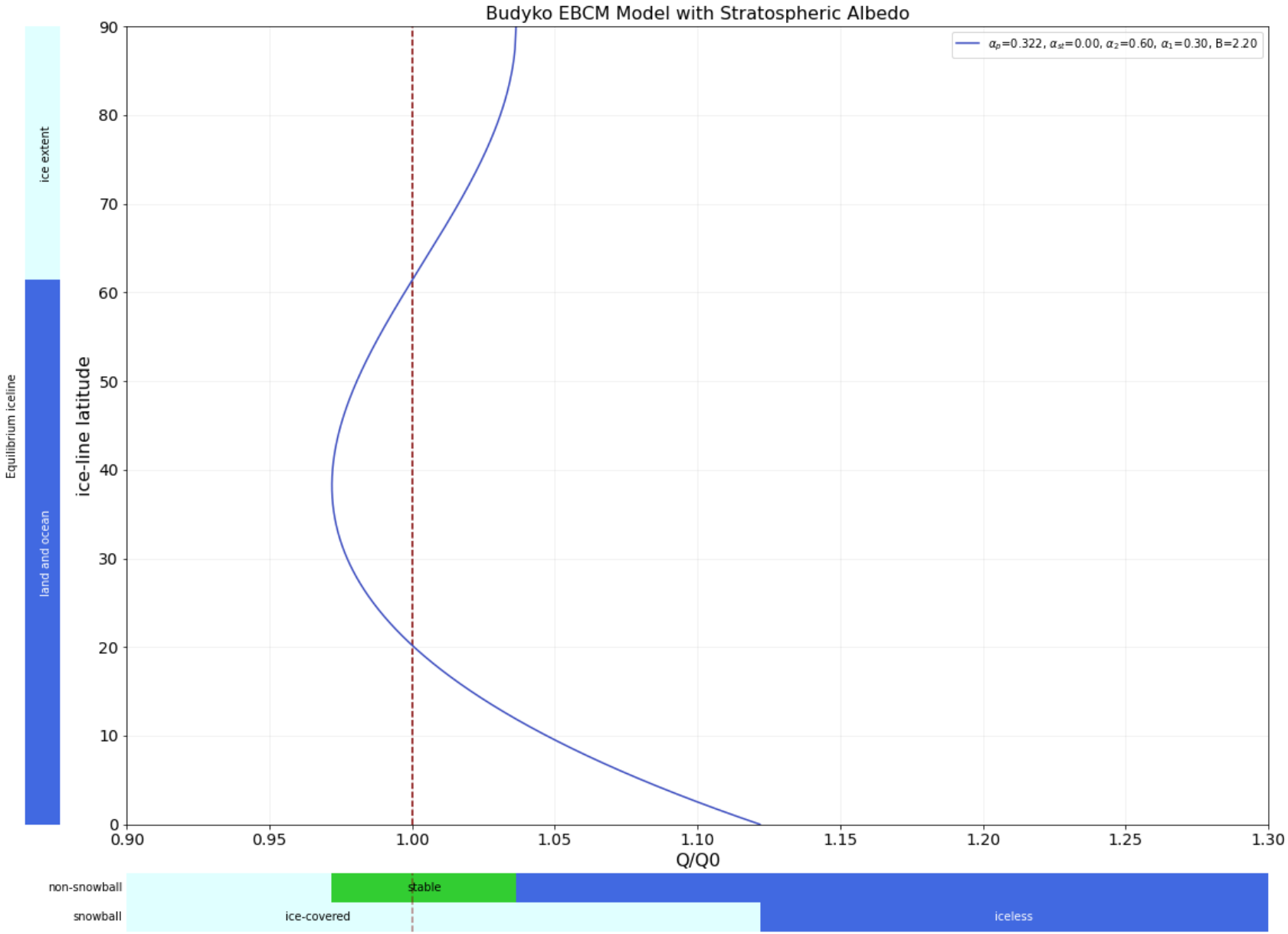
Allowing us to calculate a new planetary albedo (surface + stratosphere)

$$\alpha'_p = \int_0^1 S(x)[\alpha_{st}(\tau) + \alpha_{su}(x_s) - \alpha_{st}(\tau)\alpha_{su}(x_s)]dx,$$

Resulting in a new equation to solve (Roe and Baker 2010)

$$\frac{Q}{4} S(x_s)(1 - \alpha_{su})(1 - \alpha_{st}) + \frac{QC}{4B}(1 - \alpha'_p) = k$$

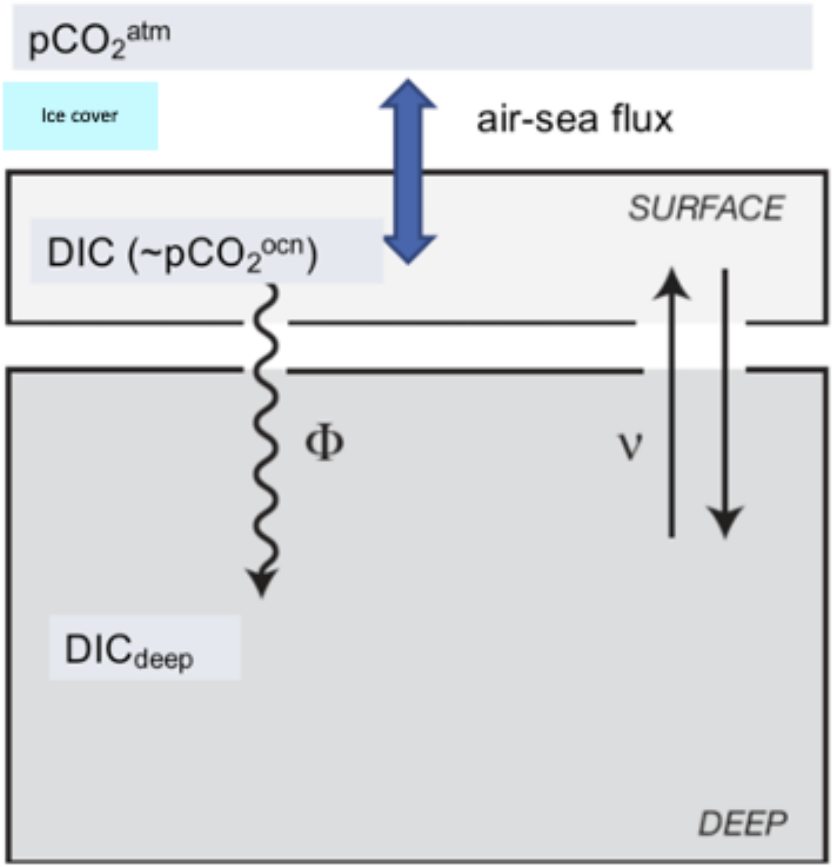
Increasing τ or α_{st}



Budyko EBCM Model with Stratospheric Albedo

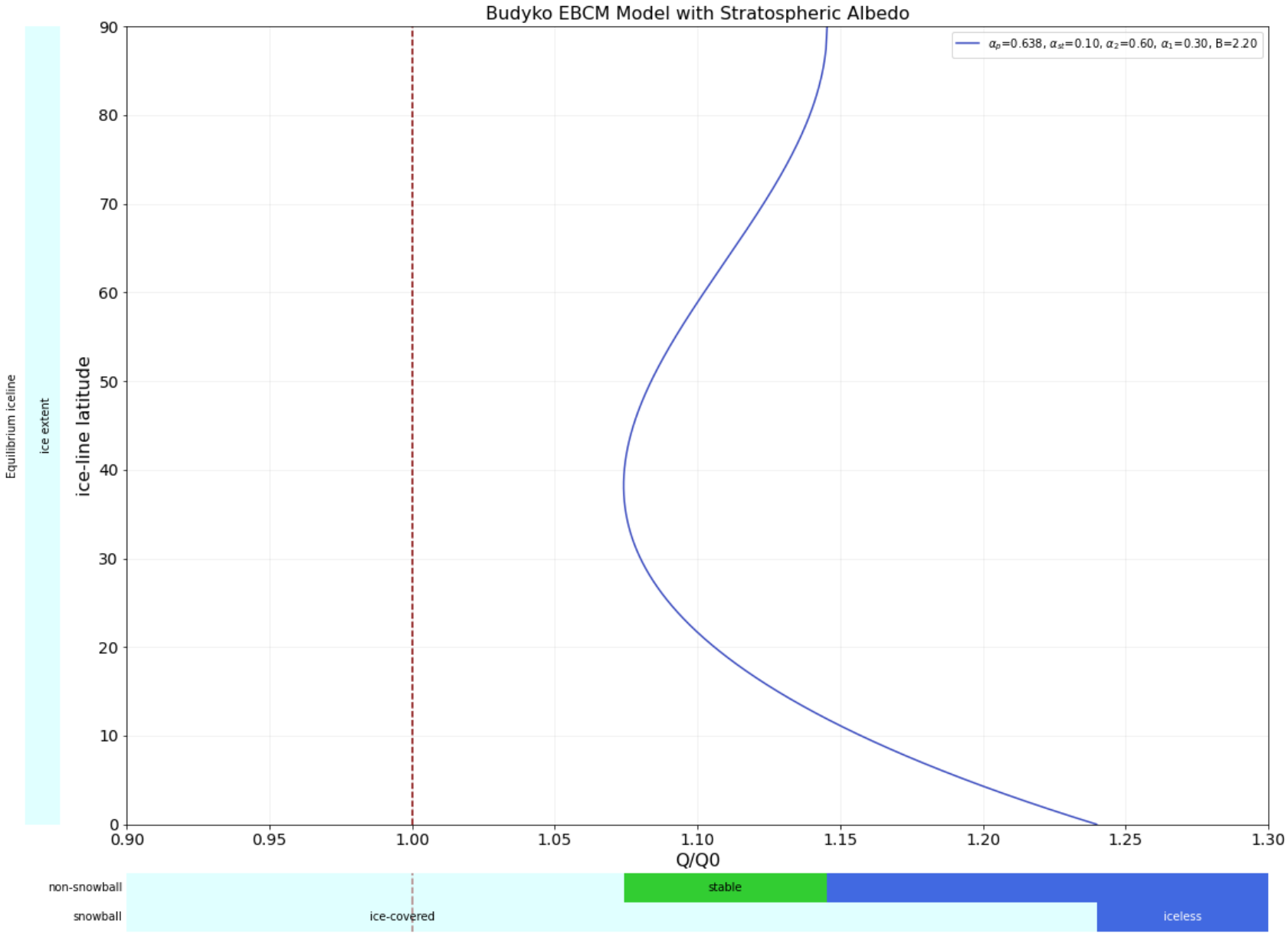
Increasing $CO_2 \approx$ increasing B

Ice sheets block the ocean sink for CO_2

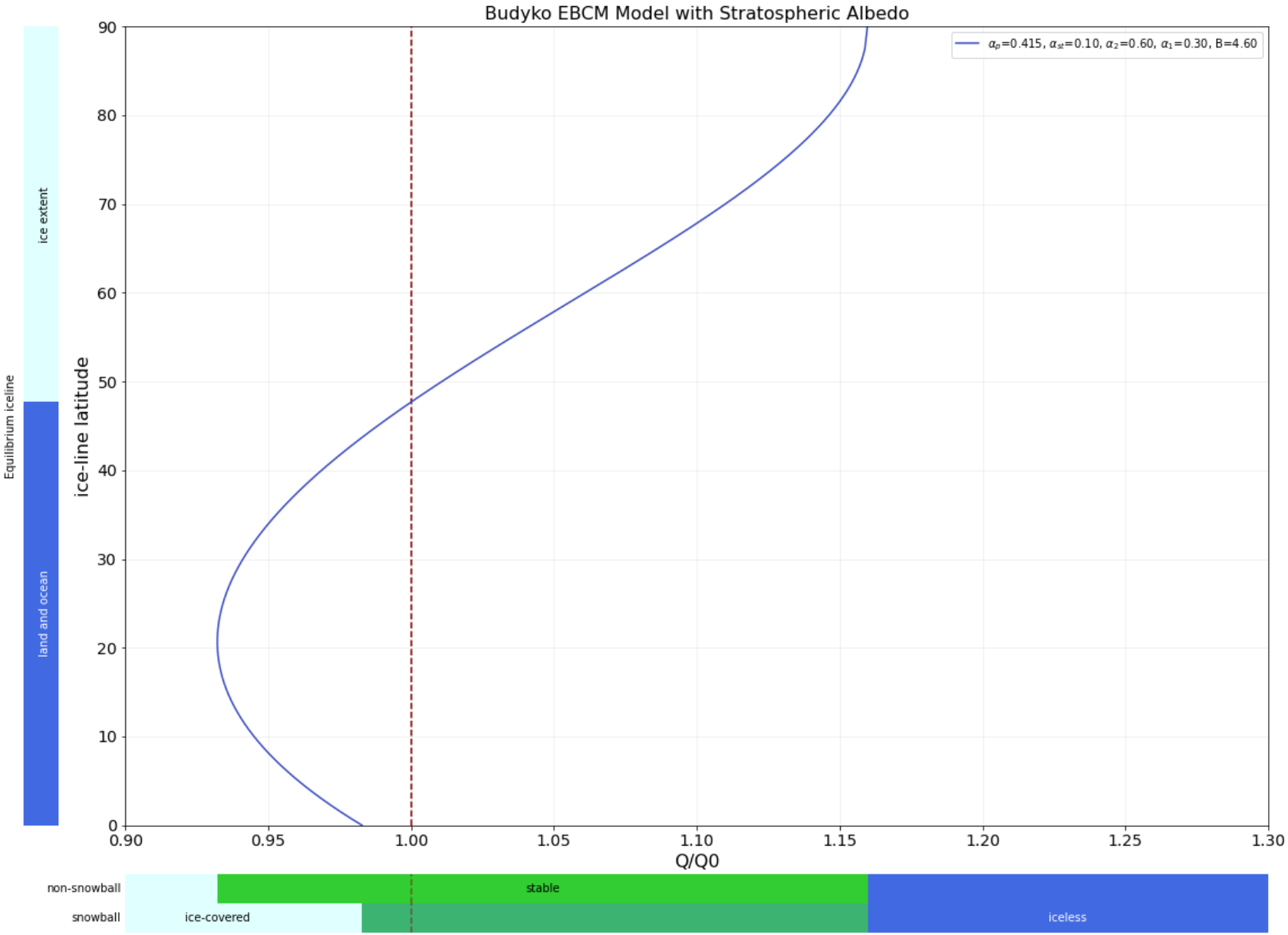


Increasing CO2 increases $\bar{T}$, increasing OLR or B in the Budyko model.

Increasing $CO_2 \rightarrow$ can get us back to a partial-ice world.

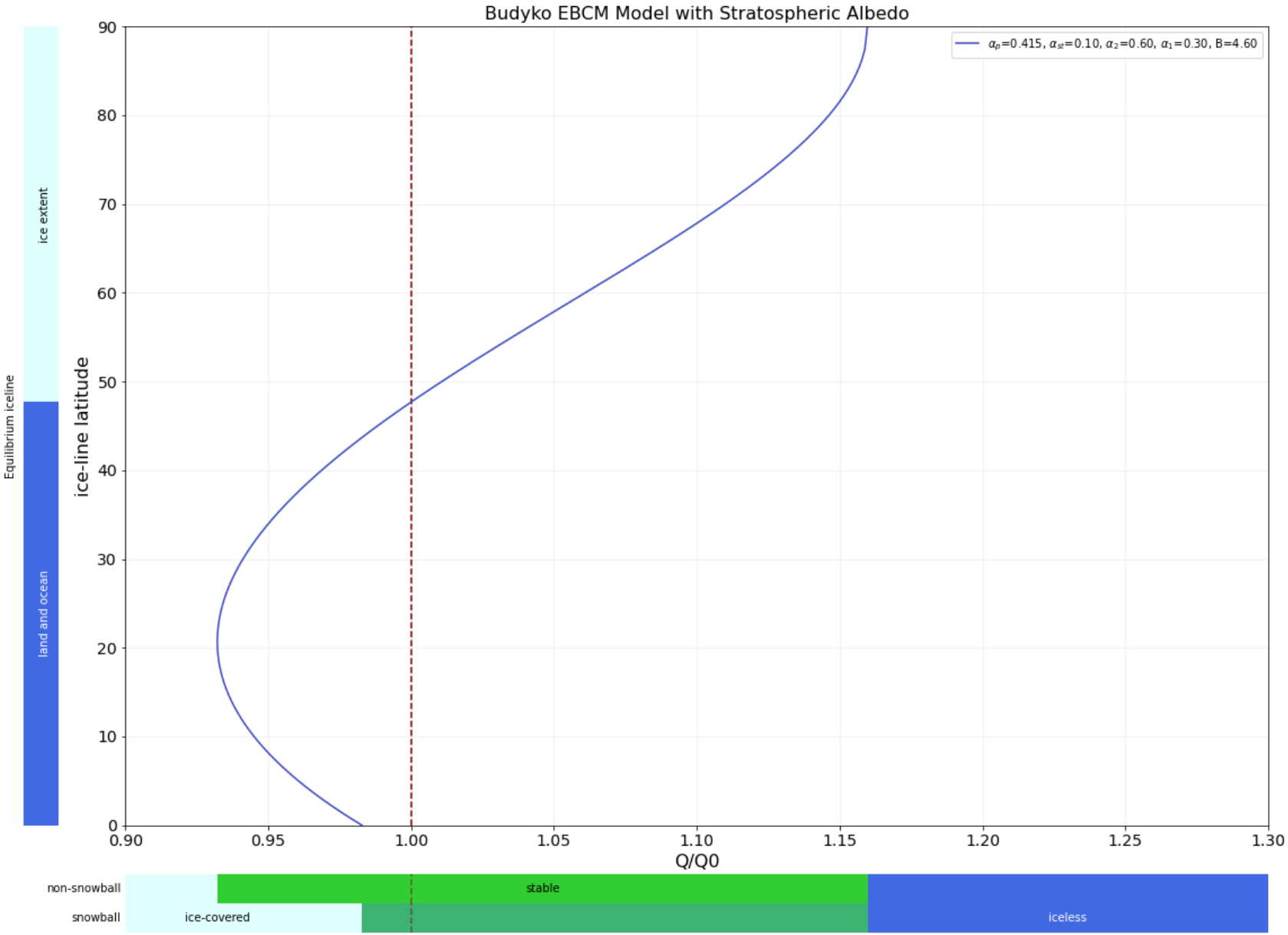


CO2 sink reactivates, causing hysteresis



Budyko EBCM Model with Stratospheric Albedo

CO2 sink reactivates, causing hysteresis



Budyko EBCM Model with Stratospheric Albedo

Could albedo changes explain Neoproterozoic glaciations?