2-2012

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Effects of stochastic freshwater flux on the Atlantic thermohaline circulation

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1 Introduction

The feedback between climate change and changes in ocean circulation patterns has become a topic of growing interest in climate research. Of particular interest is the Atlantic thermohaline circulation (THC). Numerical simulations and simple box models have shown that the Atlantic THC is highly sensitive to freshwater perturbation fluxes and exhibits multiple stable equilibria. It has also been shown that increases from the equatorial region northward toward the polar regions and is responsible for

1.2 Stochastic and multiscale expansion

Stochasticity is added in the salinity forcing term by:

\[ T(y, t) = \bar{T}(y) + T(y, \epsilon) \]

\[ \bar{T}(y) = \text{averaged salinity flux} \]

\[ \epsilon = \text{random number from a Gaussian distribution with } \mu = 0 \text{ and } \sigma = 3.3 \]

3.4 Stochastic forcing

Stochasticity of the freshwater flux is determined by decomposing the non-dimensional freshwater flux into a time-averaged part and a stochastic part:

\[ p = \bar{p} + \epsilon(t) \]

Here, \( \epsilon(t) \) is modeled as stochastic white noise. Discretizing the DE for \( p \) in time, the equation is solved using the Euler scheme, with \( \Delta t = 1, \Delta x = 6.2 \). At each time step, \( p(t) \) is chosen as a random number from a Gaussian distribution with zero mean and standard deviation \( \sigma = 3.3 \).

3.3 Deterministic Perturbations

Let \( p(t) \) be defined as

\[ p(t) = \left\{ \begin{array}{ll}
\mu + \Delta p & 0 \leq t \leq \tau \\
\Delta p & \Delta t \leq t \leq \tau \\
0 & 0 > \tau \end{array} \right. \]

To find the minimum duration \( \tau \) of a perturbation necessary to move the solution past the unstable point, integrate:

\[ \int_{0}^{\mu + \Delta p - \mu} \left( y - \bar{y} \right) \, dy \]

which gives \( \tau \) as a function of the perturbation amplitude \( \Delta p \).

References