Low-frequency oscillations in the atmosphere induced by SST front

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Motivation

Do mid-latitude SSTs affect the atmosphere?

Does extratropical oceanic variability affect climate variability?

Mid-oceanic thermal fronts, such as the Gulf Stream and Kuroshio Extension, are permanent features of the mid-latitude ocean circulation.

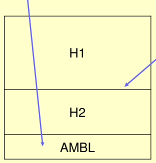
The circulation in the atmospheric marine boundary layer (AMBL) adjusts to changes in the oceanic surface conditions within several hours. The AMBL reaches heights of 600–1200m.

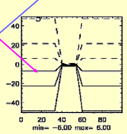
We use a hierarchy of models: quasi-geostrophic (QG) — BT and BC — and GCM.

We study the flow induced by an East-West oriented SST front of finite zonal extent (600 km). The SST front has the pattern: T(y) = – T*tanh(y/50 km)

The atmospheric model is composed of a steady, analytical AMBL and a time-dependent, QG, baroclinic (BC) model with two modes in the vertical (corresponding to two layers).

The computational domain size is 5000 km x 5000 km, with a grid spacing of 50 km.



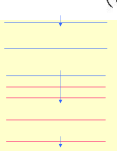


SST front: length 600 km, width ~ 100 km, strength $T^* = 6.1$℃

The vertical velocity, w, at the top of the AMBL, H_E

Mechanical component — Thermal component

$$w(H_E) = -\int_0^{H_E}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)dz = \gamma\nabla^2\psi - \alpha\nabla^2 T$$

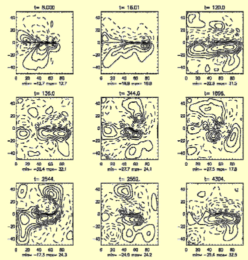


Cold SSTs, air descends => cyclonic flow in the free atmosphere

Warm SSTs, air ascends => anticyclonic flow

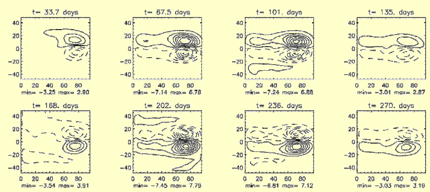
This mechanism spins up an eastward jet in the free atmosphere; see Feliks, Ghil and Simonnet, 2007, *J. Atmos. Sci.*, **64**, 97-116.

The evolution of the barotropic mode. Domain (5000 km x 5000 km)

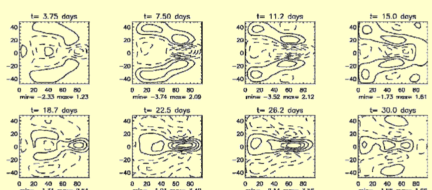


Three kinds of unstable oscillatory modes:

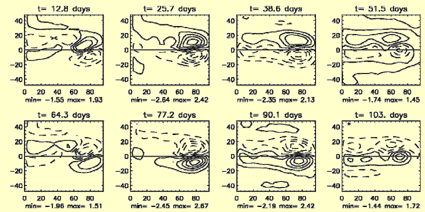
First, **antisymmetric** instabilities are **baroclinic**; they have a standing dipole structure. The dominant mode has a **period of 270 days**.



Second, **symmetric** instabilities are **barotropic** and develop at the eastern edge of the eastward jet; this mode was also obtained in an equivalent barotropic model. The dominant mode has a **period of 30 days**; see also Feliks *et al.*, *JAS*, 2004.



Third, **northward-propagating instabilities** can be decomposed into **two standing parts**, an antisymmetric and a symmetric part. The dominant mode has a **period of 103 days**. The spatio-temporal evolution of this mode resembles the observed 70-day mode of Plaut & Vautard (1994).



Conclusions from the two idealized models

The SST front spins up an eastward jet in the free atmosphere.

Three kinds of unstable oscillatory modes are obtained:

(1) **antisymmetric** due to **baroclinic** instability, with a period of **6–8 months**;

(2) **symmetric** due to **barotropic** instability, with a period of **30 days**;

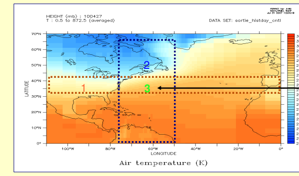
(3) **northward-propagating mode** can be decomposed into an antisymmetric and a symmetric, with a period of **2–3 months**.

These effects depend of the atmospheric model's high resolution of 50 km x 50 km!

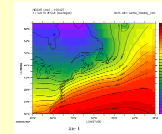
The impact of a realistic oceanic thermal front on the mid-latitude atmosphere over the Gulf Stream

The idealized-model study strongly suggests that the mid-latitude oceans can influence low-frequency atmospheric variability above them, provided oceanic fronts like the Gulf Stream and Kuroshio are sufficiently well resolved spatially.

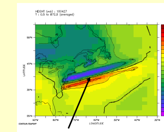
We use an IPCC-class general circulation model (GCM), LMD-Z, and a more realistic mean Gulf Stream SST front. The model is integrated with a high-resolution zoom (hence the 'Z') in the Gulf Stream area to resolve correctly the effects of the front.



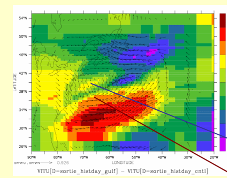
The high resolution Gulf Stream box, with $\Delta x = \Delta y = 0.5$ deg and 19 levels



SST of the standard, low-resolution simulation.

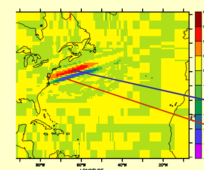


A higher resolution, more realistic thermal-front anomaly has been added.



The mean horizontal wind between days 100–800 for the lower levels of the troposphere.

The flow diverges over the cold side of the SST front, and converges over its warm side.



Air descending over the cold side results in an cyclonic anomaly; ascent over the warm side results in an anticyclonic anomaly.

Preliminary conclusions

The divergence vs. convergence of the atmospheric flow over the two sides of the SST front obtained in the IPCC- class LMD-Z model and the idealized QG model are very similar.

Low-frequency oscillations with a prominent peak at 50 days were found in the LMD-Z model. This peak was enhanced significantly when the realistic oceanic front was added to the model.

North of latitude 400N Cyclonic flow anomaly (realistic-minus-standard run) found over the cold (western) side of the front and the anticyclonic flow anomaly over the warm (eastern) side.