Meridional Shift of the Gulf Stream Front in the Past 34 Years

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The subtropical sea surface temperature fronts (SSTF) in the Ocean, anchored by the strong western boundary currents, are the key regions in the climate system with huge heat and mass transport, high eddy activities, strong atmospheric storms, as well as major CO2 sink. They are also the most challenge areas in the climate model simulations and projections. Ongoing efforts are seeking to understand their variability, especially associated with climate change.
Here, by focusing on the SSTF in the North Atlantic Ocean along the Gulf Stream and its extension, we analyze its meridional shift in the past 34 years (1979~2012) with the Ishii reanalysis data. It is shown that the SSTF moves northward of 0.72 degree from 1979 to 2012. This pole-ward shift may reflect the extension of Hadley Cell under global warming. Interestingly, the SSTF meridional shift is uneven in the past 34 years among different seasons. In winter SSTF moves further northward with more than 1 degree while in other seasons SSTF only shift to north for about 0.5 degree. Meanwhile, the sea surface temperature gradient in the SSTF increases 50% in winter but decreases 10% in summer during that period. Besides the long-term trend of SSTF shift, there are strong decadal and interannual variability. Before 1999, the SSTF shift northward for more than 1 degree, from 39.6N to 40.8N. After 1999, the SSTF stops to move northward and turns to move southward for about 0.5 degree. This decadal change is consistent with the global warming Hiatus, when the global mean SST does not increase remarkably during 1999~2012, and may be partly related with the Atlantic Multi-decadal Variability. There is an extreme southward shift event of SSTF in 2010. It moves from about 38N in 2009 winter to about 36.5N in 2010 winter. It is reported that the observed transport of Atlantic Meridional Overturning Circulation (AMOC) has a dramatic drop in 2010 and the North Atlantic Oscillation also reaches a peak value of its negative phase. Weakening of the westerly wind and shrinking of subtropical ocean circulation will make the SSTF move southward and decrease the transport of AMOC.
Our study highlights the multi-scale variability and their interactions of SSTF. The short-term variability may affect the long-term trend of SSTF shift. For example, the strong southward shift occurred in the 2010 winter reduces the annual mean northward trend from 0.79 degree (1979-2009) to 0.72 degree (1979-2012). Since the Hadley cell will continue to expend pole-ward under the increasing of green-house gas, as predicted by climate models, we could expect the similar meridional shift of the SSTF. But the increasing of extreme events in the warming scenario may cause the SSTF to be more unstable and this needs further study with intense observations and high resolution climate models.

Keywords: Subtropical Sea Surface Temperature Front, Meridional Shift, Multi-scale variability, Gulf Stream