The seasonal evolution of the pattern is revealed by correlating the PC for understanding the climatic impacts of SST throughout the year and for gaining insight into the variability on multi-year time scales.

**Goal of study:**
- Determine the seasonal dependence of the dominant pattern of North Atlantic SST variability.
- Find how it relates to the variability of the atmosphere both simultaneously and with lag.

**Methodology:**
- Use monthly anomalies for all calendar months.
- Normalize each calendar month time series by its month rms value.
- Calculate the covariance matrix of all-months data (this is equivalent to calculating the “common” covariance matrix).
- Calculate the EOFs of the all-months covariance matrix (“common” EOFs).
- Project data month-by-month on the EOFs to determine the EOF temporal amplitudes (principal components, PCs).
- Each PC can be arranged by calendar month and year. By regressing (or correlating) the data by calendar month on that month’s PC values we can determine the typical evolution of the anomaly pattern from one month to the other, throughout the year.

**Data:**
- We use Hadley Center SST data and CDAS-1 SLP between January 1958 and December 1997.
- Analysis is done over the North Atlantic Domain and on a 2.5°x2.5° grid.

**The leading pattern of SST variability:**
- The first EOF of SST explain 24% of the year-round SST variance and is well separated from the rest (next EOF explains 12% of variance). In the present analysis we apply a varimax rotation to the first three EOFs but the results are not sensitive to this procedure.
- The figure below shows the pattern of the first EOF and the distribution of variance explained by calendar month, throughout the year.

**ii. A sharp transition in SST-SLP relationship in spring:**

- The constructive A-O relationship continues to increase into January and is strongest in March (in February there is a perplexing weakening in the atmospheric conditions but not in the SST pattern). In April the SST pattern is as strong as in March but the relationship in the atmosphere is quite different: the large scale NAO-like dipole that begins to emerge in fall breaks down and a local, strong, negative correlation between SST and SLP appears over the subtropical North Atlantic ocean.

- In summer, the SST pattern stays anomalous for a long period over the subtropical ocean. Here the relationship to local SLP that emerged in April lasts into July. The inverse relationship (between SST and SLP) is maintained though a positive feedback with the local atmosphere. The inverse correlation is strongest in a region in central and western North Atlantic. Along the western boundary layer of the sub-tropical gyre there is a positive correlation that strengthens between May and July. The local conditions need to increase over the region when the SST is colder than normal and the pressure is higher than normal. Such a response would shelter the cold ocean surface from the full impact of solar heating during summer.

**Forcing of SST anomalies during winter:**
- We subjected monthly mean SLP anomalies to a similar common EOF analysis. The first EOF explains 29% of the year-round and is also well separated from the other EOFs.
- The figures below are the patterns of the first EOF and the distribution of variance explained by calendar month throughout the year.

**Seasonal dependence of SST variability:**
- The seasonal evolution of the pattern is revealed by correlating the PC values with the gridded data set by calendar month. We also correlate the SST PC with the SLP field to examine the relationship between O & A.
- The key seasonal patterns and transitions are shown below:

1. Forcing of SST anomaly in late fall:

- In fall the amplitude of the SST pattern begins to grow. From October through November and December the atmosphere appears to increase its correlation with the SST anomaly in a “constructive” manner. Note that there is a non-synoptic signal in the subtropical to subpolar ocean area before the A-O alignment occurs.

2. Forcing of SST anomalies during winter:

- The following figures show the relationship between the dominant pattern of wintertime (Jan-Mar) SST variability and the different terms in the mixed layer energy balance (MSE) balance of the marine, subchannel mixed layer. Contours are in 0.5°C and colors in °C (left scale).

- In the subchannel mixed layer (ML) surface heat fluxes (related to changes in wind speed and the air-sea difference in MSE) are balanced by eddy (subchannel and mean horizontal) advection, by solar radiation and vertical eddy fluxes, by radiative cooling, and by convective heat flux through the top. All but the last two terms in this balance can be calculated from data. We use AEMIP (reanalysis) data to calculate the anomalies budget terms and regress them on the leading PC of wintertime SST variability.

- The analysis shows that advection changes in the ML are forcing SST variability north of ~30°N while wind speed variations are playing a similar role in the subtropics. Subsidence is a minor process. Horizontal eddy fluxes are damping SST variability while their vertical counterparts are aligning themselves with the maximum anomalous SST gradient along the axis of North Atlantic Current.

**Conclusions:**
- The persistence of North Atlantic SST anomalies throughout the year explains why the impact of the NAO is felt beyond its active season. The predicitive potential in this phenomenon should be explored and utilized.
- The mechanisms responsible for SST anomaly persistence are most likely geographically dependent (e.g., winter in the mid- and high latitudes, and a boundary layer interaction in the subtropics).
- The persistence of the SST anomalies has a weak but noticeable effect on the atmosphere. Could this be the mechanism that reduces the atmospheric spectrum to produce “decadal” variability?