REGIONAL AND GLOBAL SCALE REDUNDANCY ANALYSES OF THE COUPLED ATMOSPHERE-OCEAN SYSTEM

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Research Motivation

- **Long-Term Research Objectives:**
  - Exploratory studies on joint assimilation into coupled models
  - Model background errors and observation errors for coupled system: ε_b and ε_o
- **Identify global covariance structures of coupled system**
  - investigate lead-lag relations
  - error propagation across mediums
- **Explore new statistical techniques**
- **Locate regions of possible interest**

The Data Variable Fields

- **Global Atmosphere - Ocean Variables:**
  - Sea Surface Temperature (SST)
  - Sea Level Pressures (SLP)
- **CCCma (CGCM3.5) model**
  - 150 year simulation
  - coupled atmosphere-ocean model
  - resolution: (~3.75º atmosphere / ~1.8º for ocean)
- **NCEP reanalysis data**
  - Data range: January 1st 1948 to 2007
  - SST grid: (2º by 2º), SLP grid: (2.5º by 2.5º)

Motivation for Redundancy Analysis

- **Redundancy analysis => directionality**
  - Set up a regression equation
  - Find pattern in one variable that best explains variance in other variable
  - carry out time-lagged analyses
- **Limitation of PCA analyses**
  - Identify patterns that maximize variance in coupled SST and SLP fields … no directionality implied
- **Data assimilation: observation -- model**

Redundancy Analysis

- Assume random vectors **X** and **Y** related by a **regression equation**:

  $$\mathbf{Y = a\, b^T X + \varepsilon}$$

- **Maximize explained variance in Y**: reduces to two Eigenvector equations:

  $$\Sigma_{\mathbf{yx}} \Sigma_{\mathbf{xx}}^{-1} \Sigma_{\mathbf{xy}} \mathbf{a} = \mathbf{a}\, \lambda$$

  $$\Sigma_{\mathbf{xx}}^{-1} \Sigma_{\mathbf{xy}} \Sigma_{\mathbf{yx}} \mathbf{b} = \mathbf{b}\, \lambda$$

- Underlying covariance structure of X and Y, a- and b-patterns

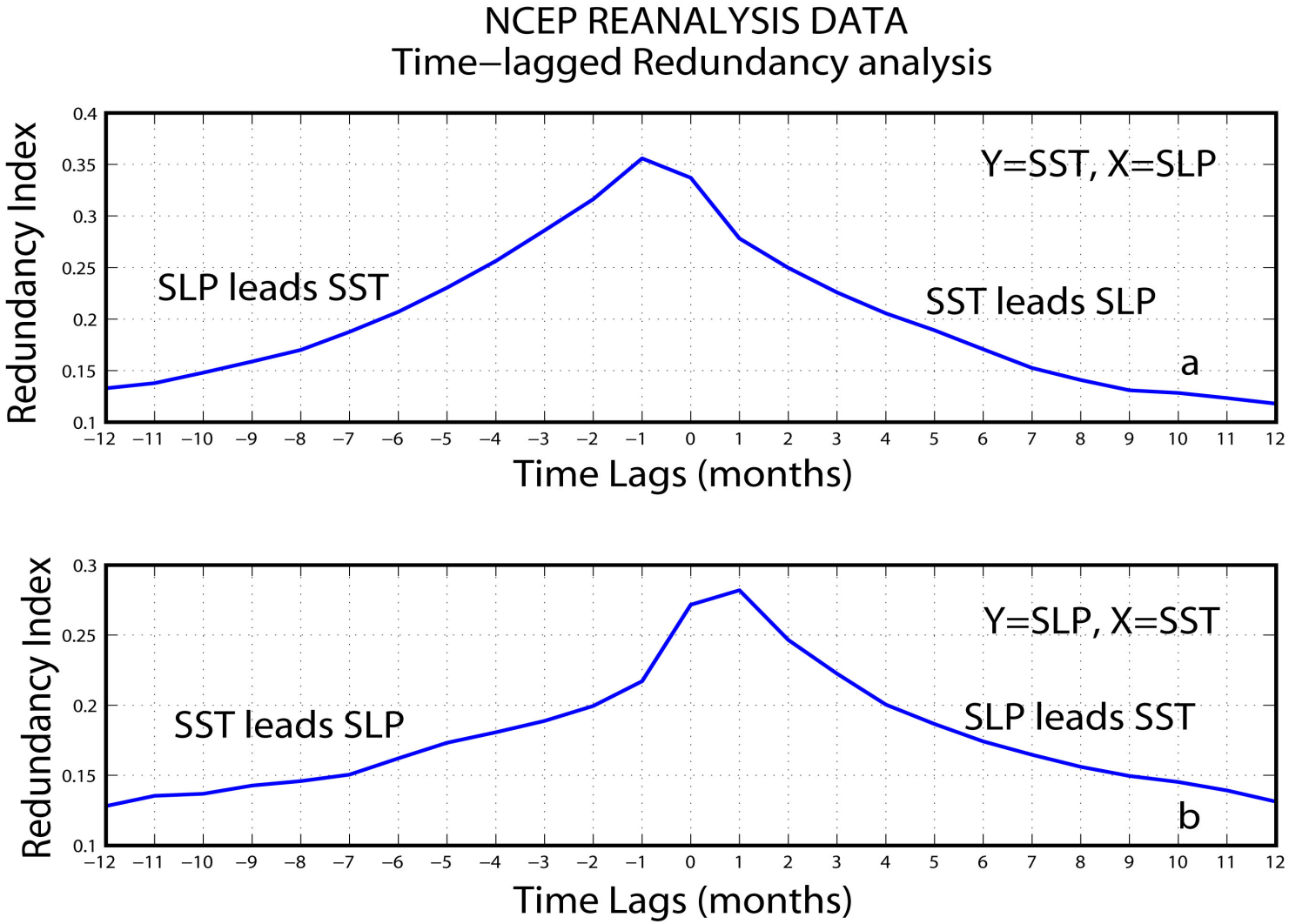
Redundancy Index

- A measure of how much variance in Y data field is expressed by the modeled $\hat{Y} = a\, b^T X$ field:

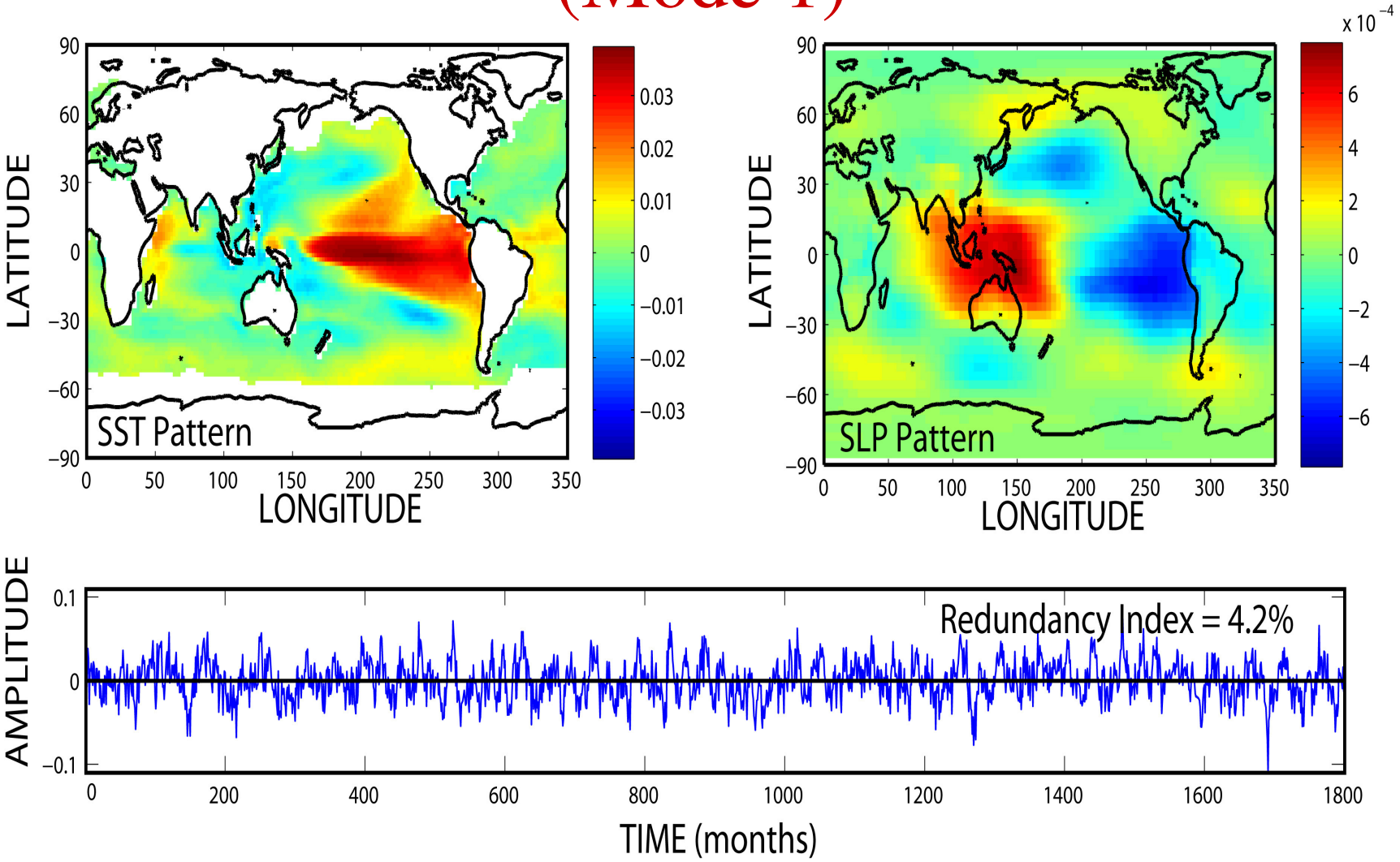
$$R^2(Y:\hat{Y}) = \frac{\sum_{j=1}^{k} \lambda_j}{tr(\Sigma_{YY})}$$

- **Time-Lagged Redundancy Index** as an **indicator of directionality**
- Ocean-atmosphere lead/lag relations

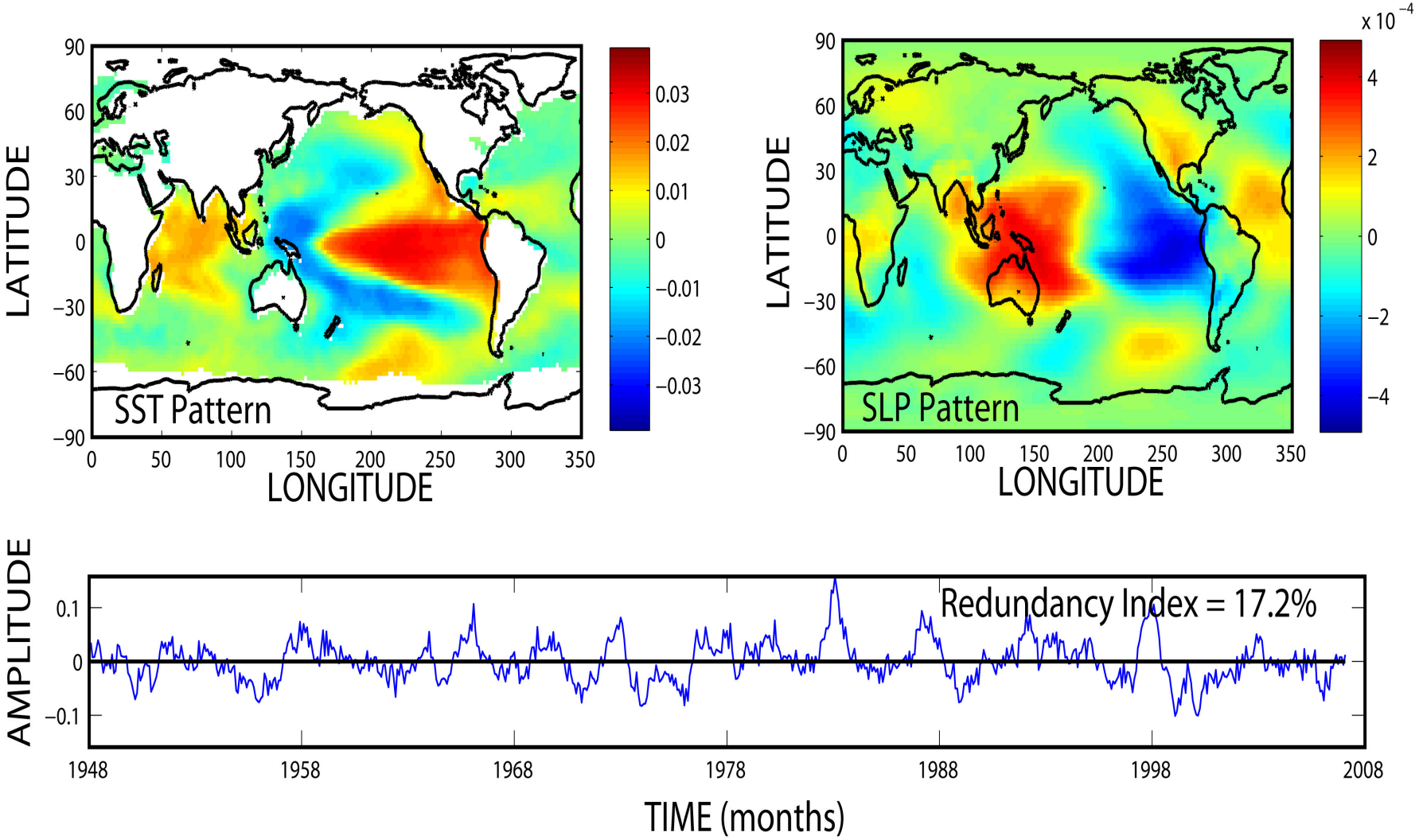
NCEP Redundancy Index: SLP leads SST



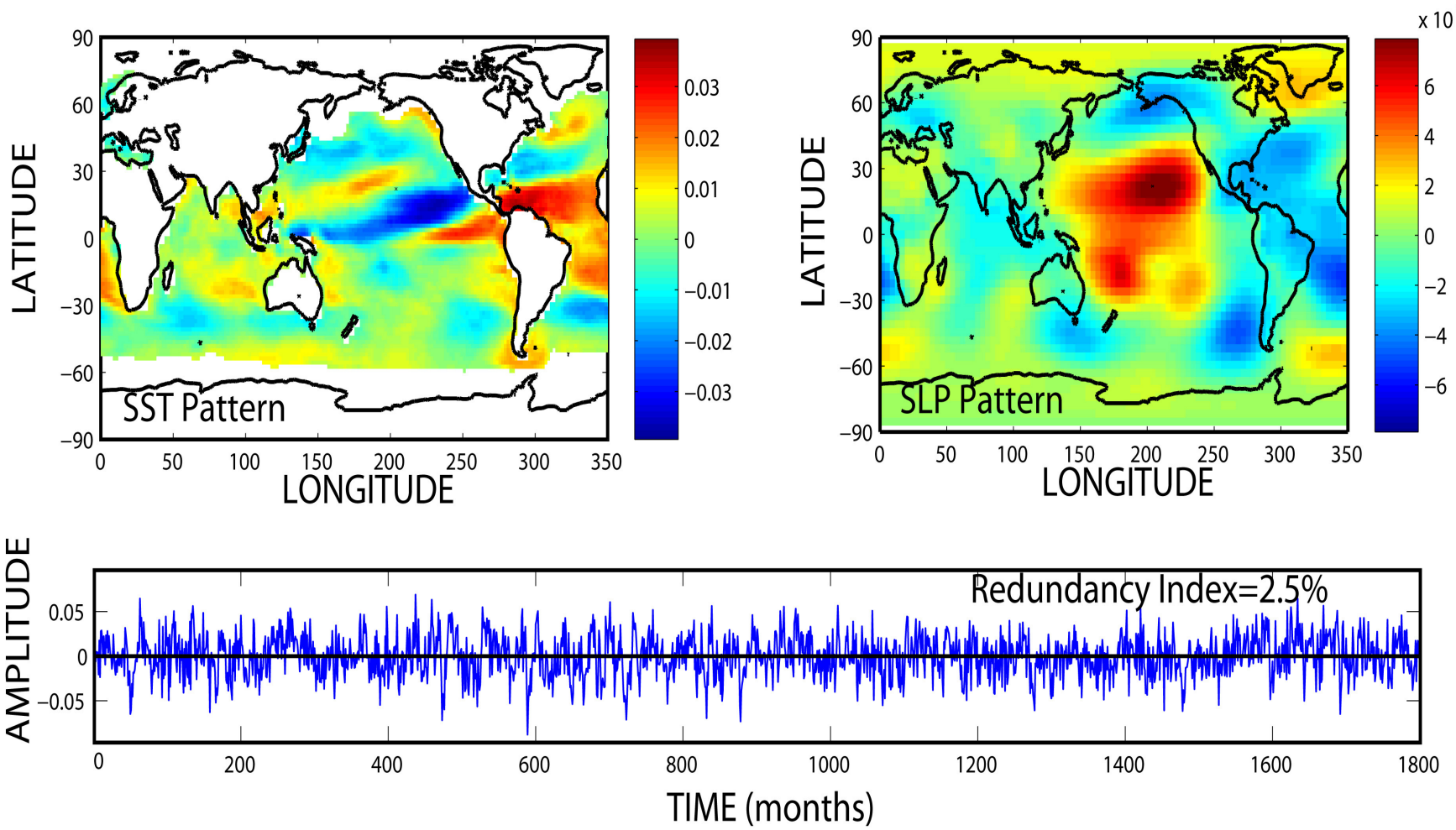
CCCma Redundancy Analysis (Mode 1)



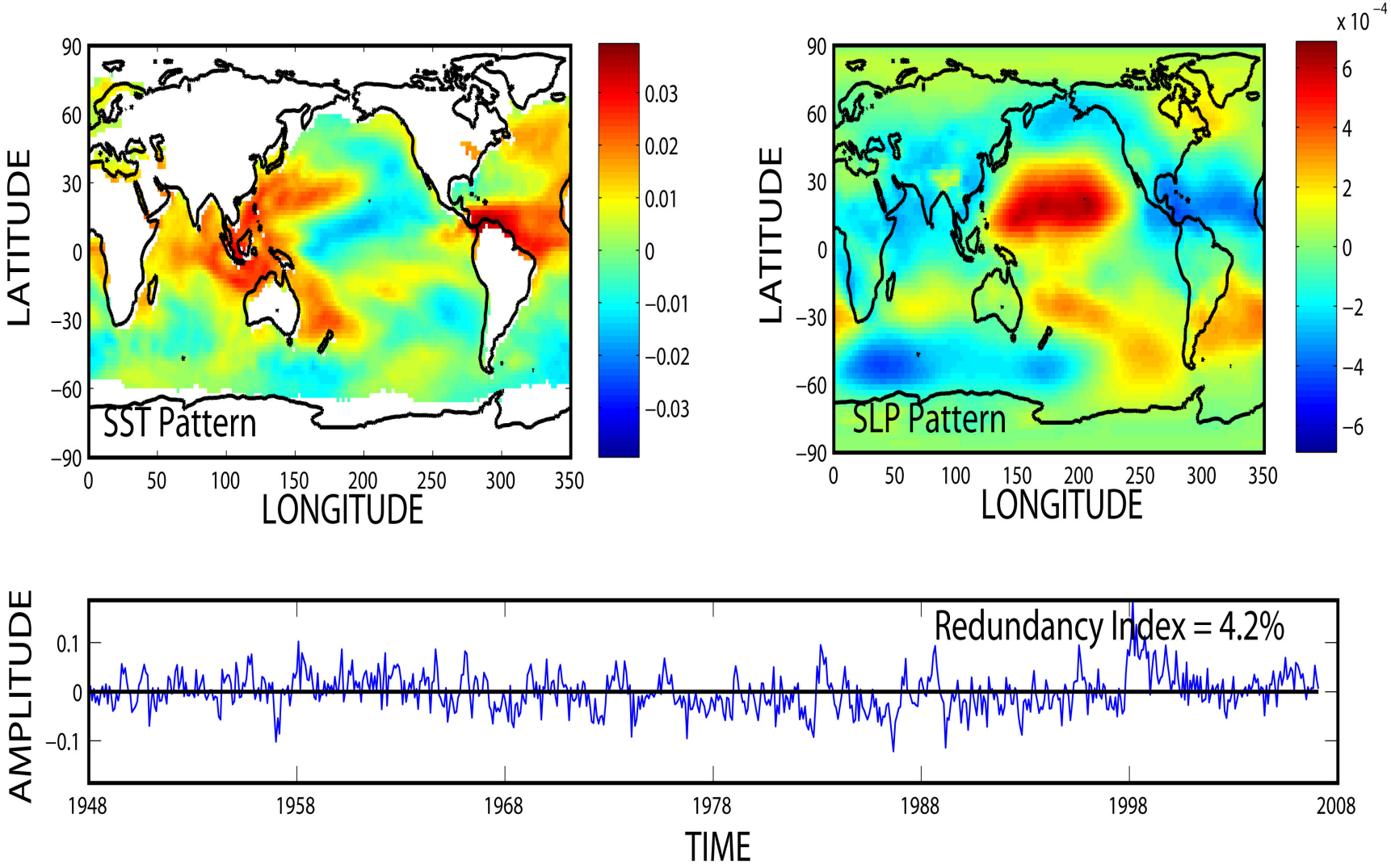
NCEP Redundancy Analysis (Mode 1)



CCCma Redundancy Analysis (Mode 2)



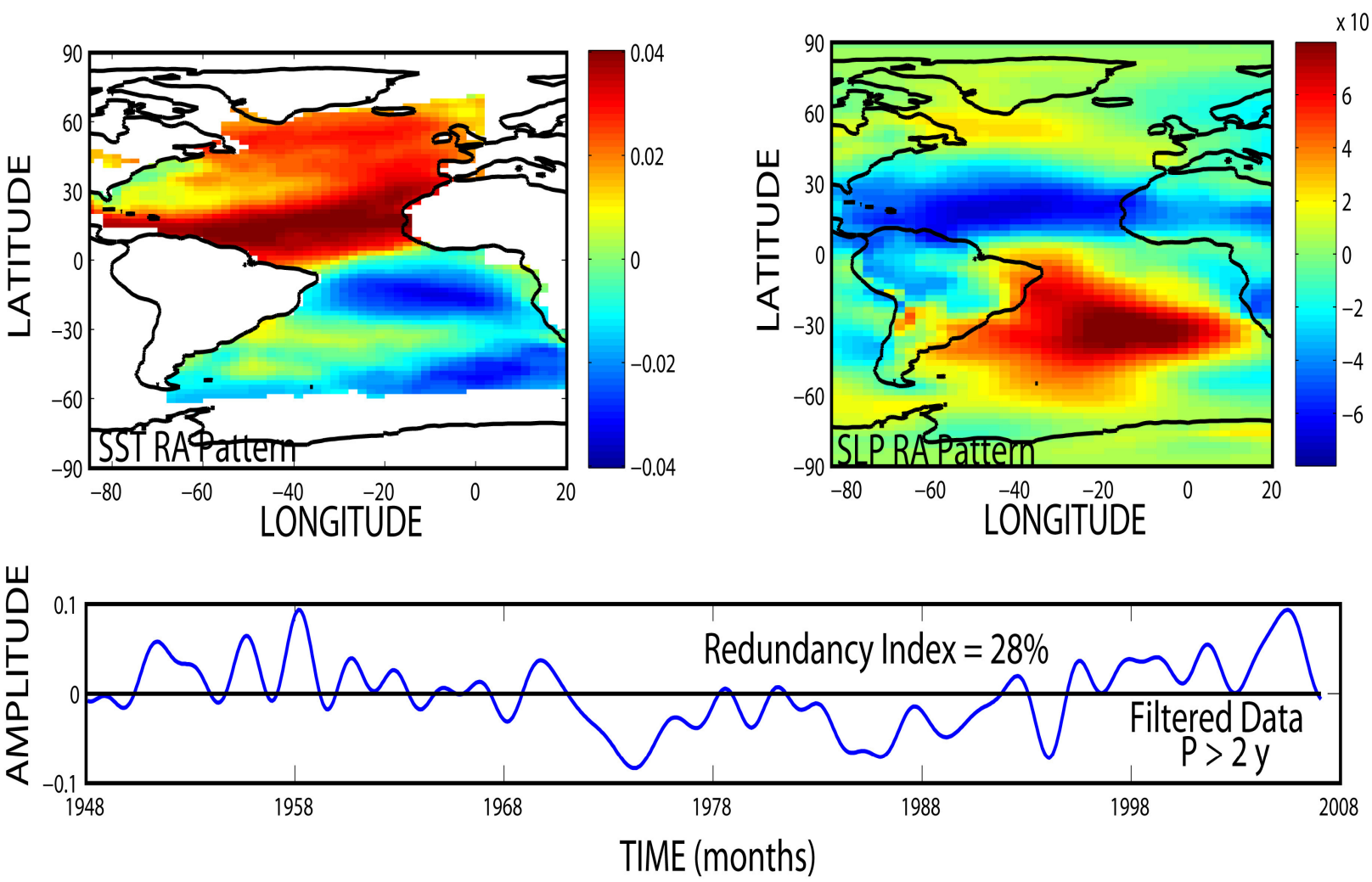
NCEP Redundancy Analysis (Mode 2)



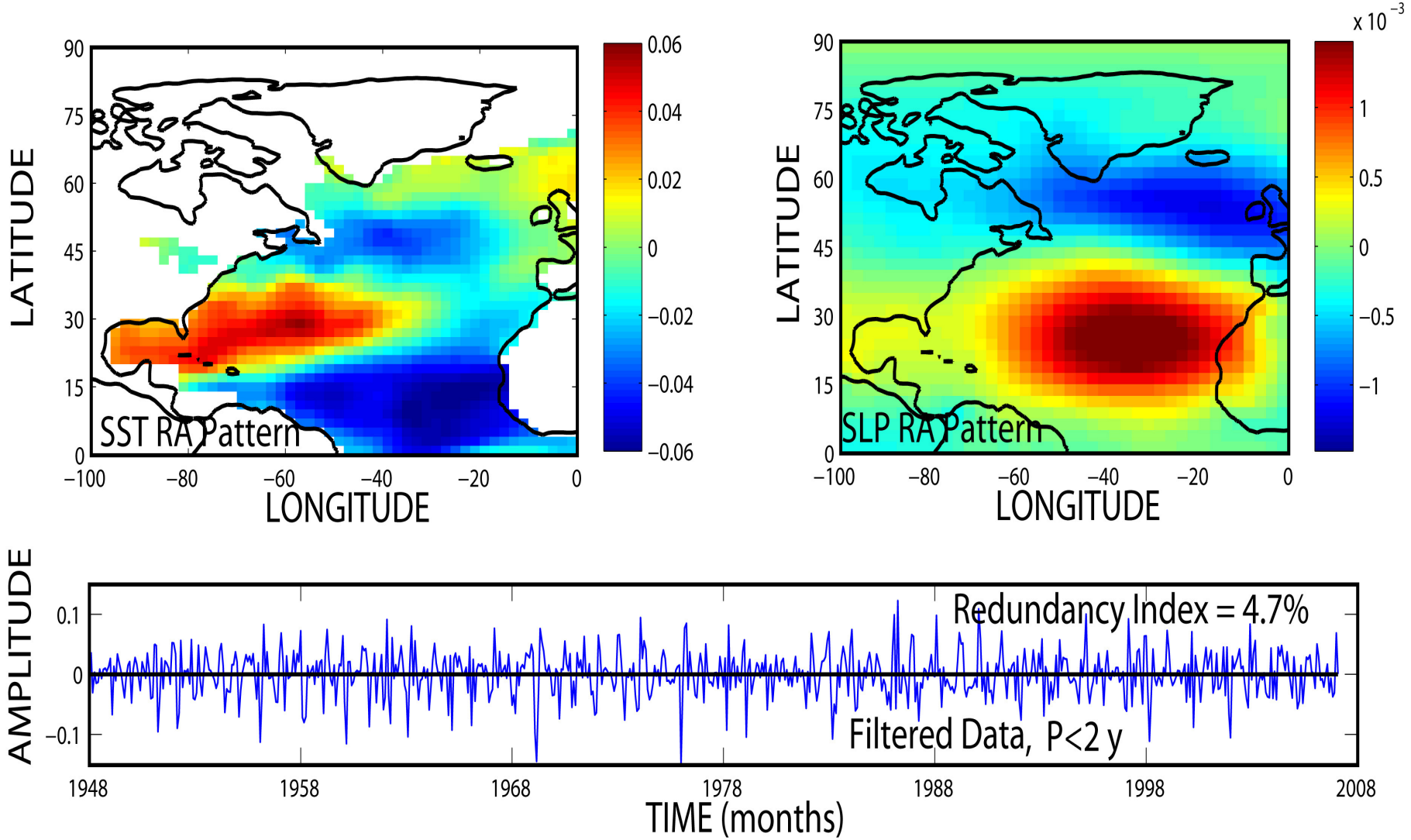
A Geographic Focus: North Atlantic Region

- **Research questions and directions: paving the way for future work**
  - What is the directionality of the lead-lag relations? What variable should we choose as the predictand?
  - What patterns emerge in the fields and how do they differ from the global redundancy analyses?
  - At what spatial dimensions do the patterns start to diverge? What does this tell us about the underlying physical processes? Is there an optimal spatial range?

The Atlantic Multidecadal Oscillation: (Low Frequency filter, Period > 2 years)



North Atlantic SST Tripole Anomaly: (High frequency filter, P < 2 years)



Summary and Final Comments

- **Realistic physical processes identified**
  - El Niño pattern detected in 1st mode
  - Agreement between NCEP and CCCma data
  - not just random patterns
- Lead/lag relations and **directionality** => **predictive tool**
- **identifying covariance structures** and possible sources of **error propagation** between mediums

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