Ensemble Empirical Mode Decomposition (EEMD) for MSU/AMSU Trend Analysis

Xiaolei Zou[1], Z. Qin[1], and Fuzhong Weng[2]

1. Florida State University
2. Center for Satellite Applications and Research

Traditional Method for the Trend Detection of Climate Change

Assume $\{T_i^{obs}, i=1, 2, \ldots, N\}$ is a time series of global average temperature.

Using a linear-regression model

$$T_i^{regression} = a_0 + a_1 t_i + \varepsilon_i, \quad i = 1,2,\ldots,N$$

one may derive an expression for estimating climate change trend of temperature based on temperature observations:

$$a_1 = \frac{12\sum_{i=1}^{N} T_i^{obs}\left(t_i - \bar{t}\right)}{\left(N^3 - N\right)}$$

Trend Detection Error

Climate change trend obtained by linear-regression method contains error. The error variance is

$$\sigma_{a_1}^2 = \frac{12\left(\sigma_{obs}^2 + \sigma_{natural\ variability}^2\right)}{N^3 - N}$$

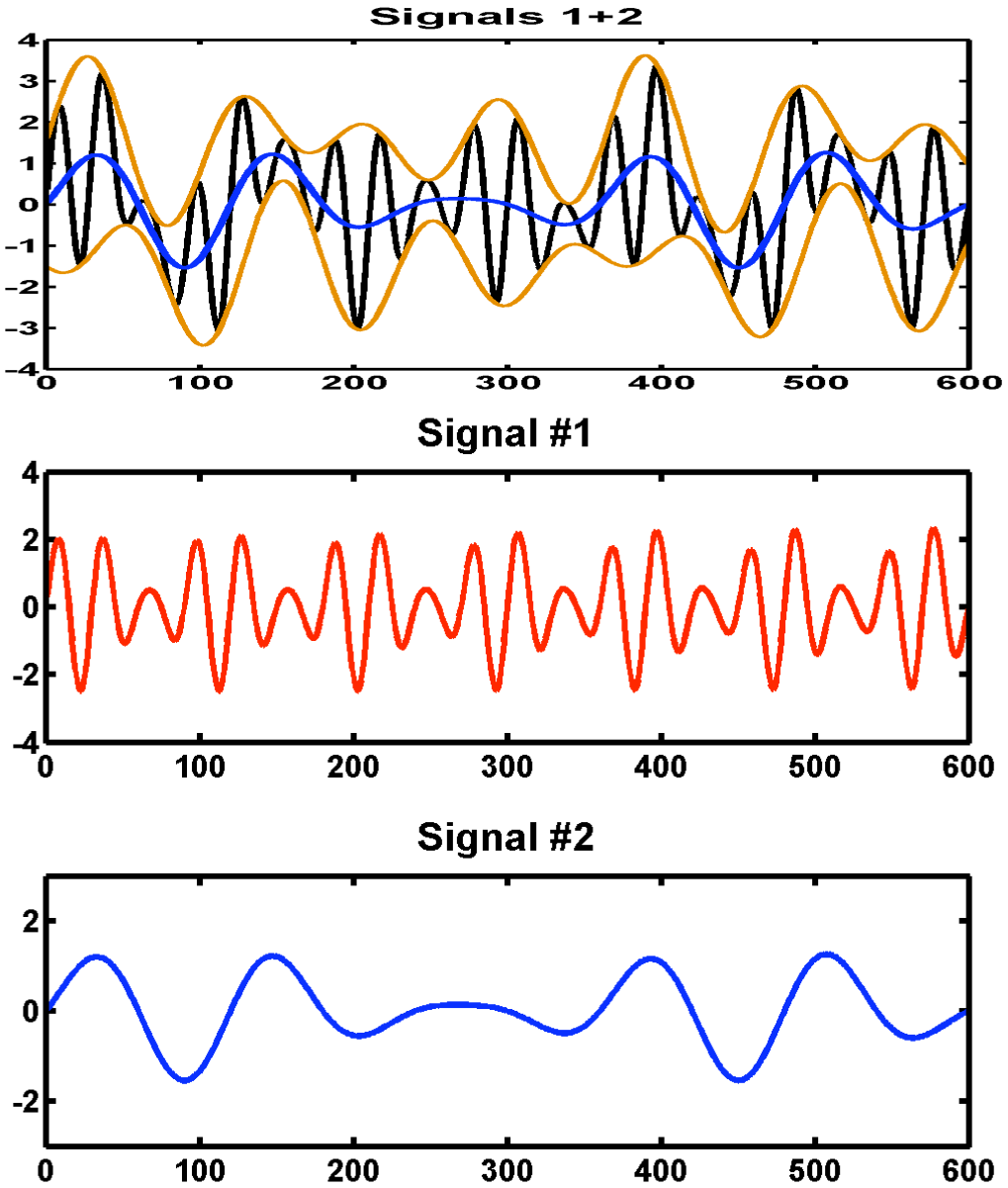
其中

N ——— Data length

σ_{obs}^2 ——— **Observation error**

$\sigma_{natural\ variability}^2$ ——— **Natural variability**

Ensemble Empirical Model Decomposition



(Huang and Wu, 2008
Wu and Huang, 2009)

Linear vs. Non-Linear Trending

- The traditional linear regression method works well for detecting the trend when data information is linear and stationary.

  The EEMD method works without requiring data information being linearity and stationary.

- The trend deduced from the traditional linear regression method does not change during the studying period.

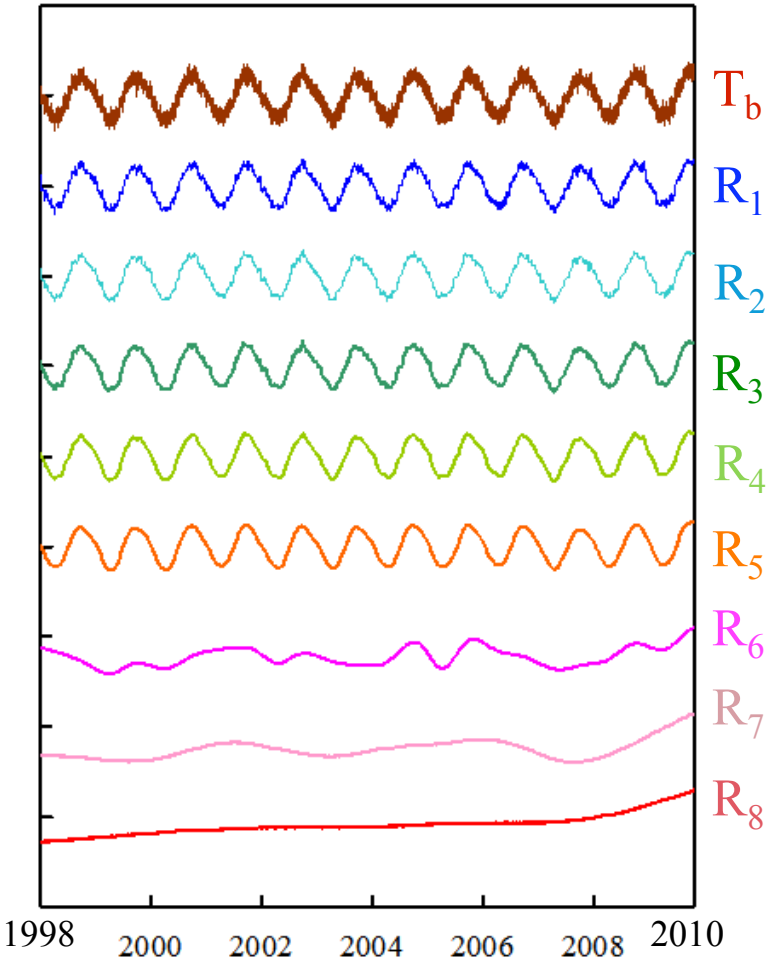
  The trend deduced from the EEMD method changes with time.

- The trend deduced from the traditional linear regression changes when data record is extended in time.

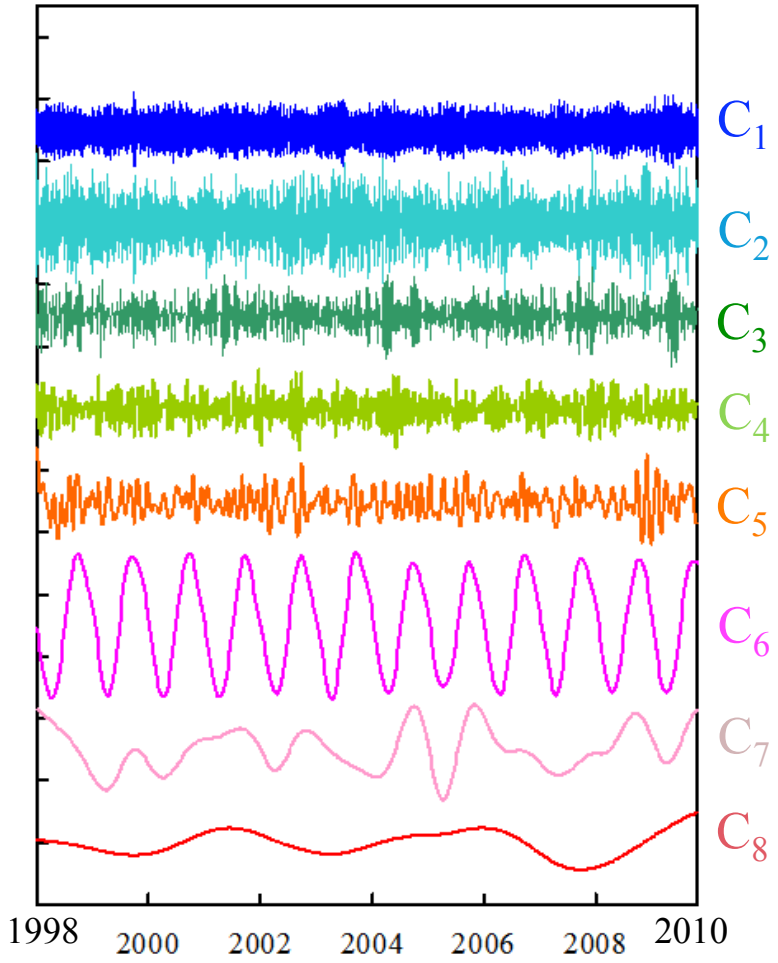
  The trend deduced from the EEMD method in the past does not Change when data record is extended.

NOAA-15 AMSU-A Channel 3 (50.3 GHz, surface)

Global average T_b

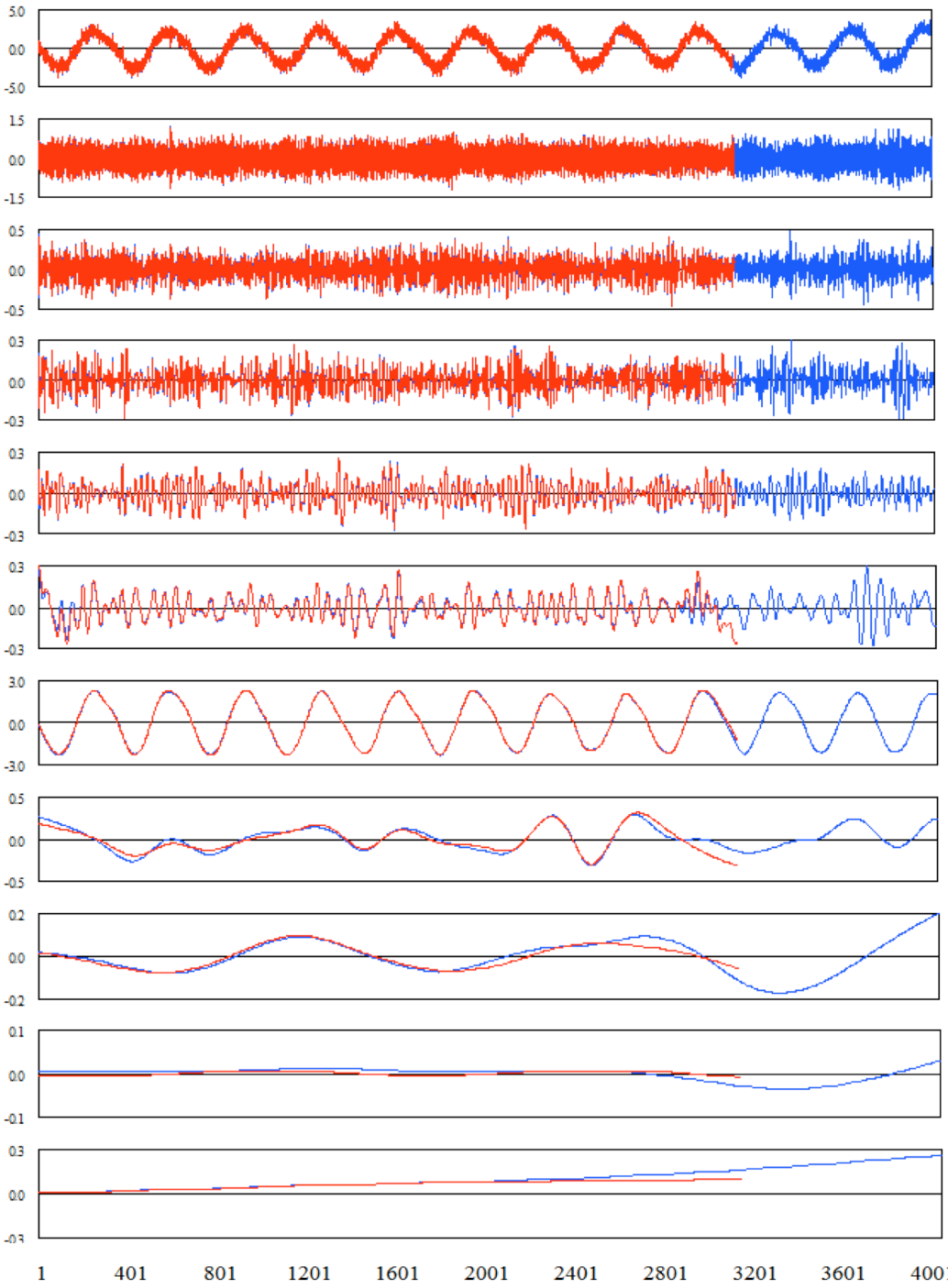


EEMD components



EEMD: $\bar{T}_b(t) = \sum_{j=1}^{n} C_j(t) + R_n(t)$

$R_n(t) = R_{n-1}(t) - C_{n-1}$

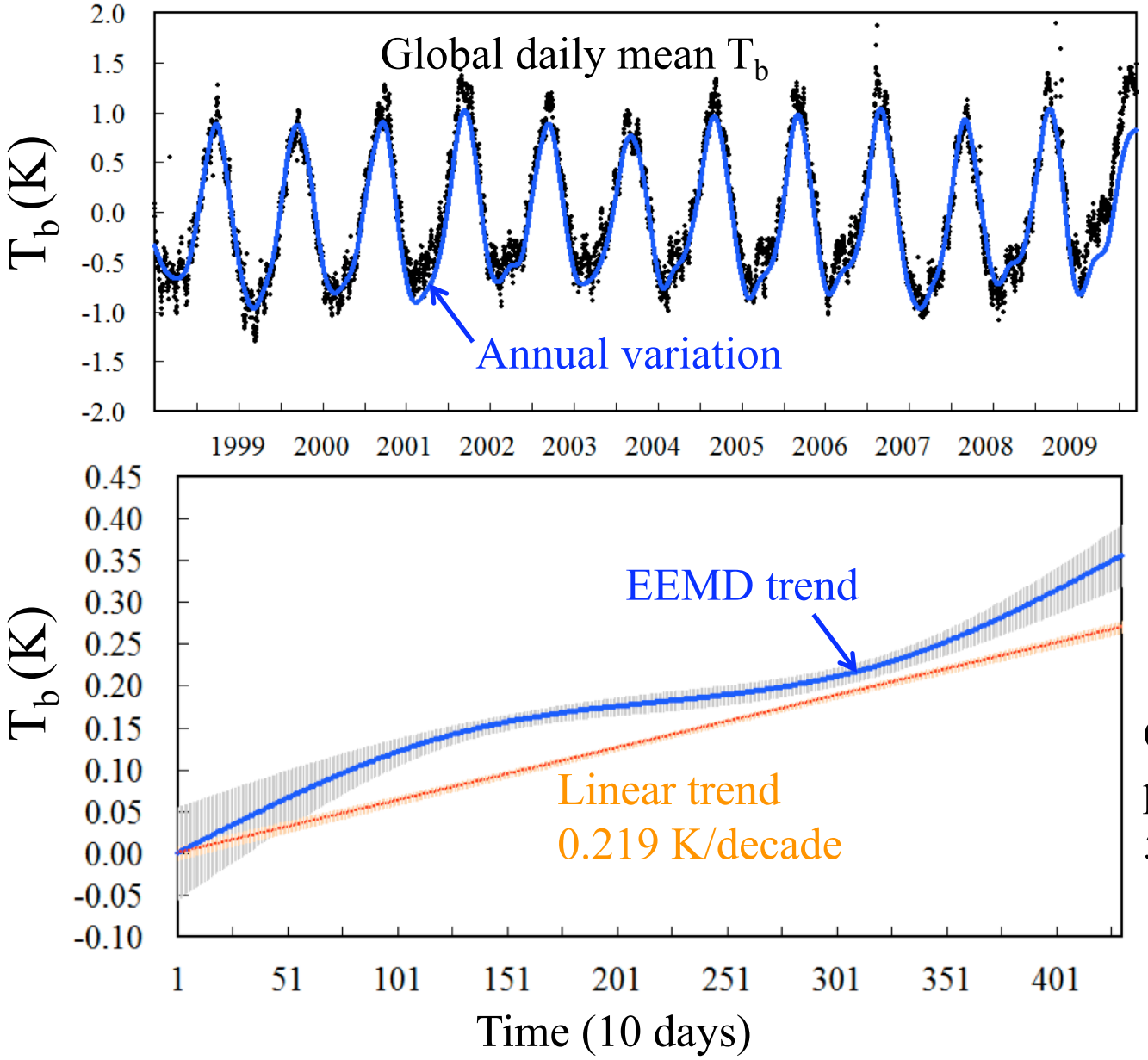


EEMD

13 years:
October 26, 1998
↓
August 7, 2010

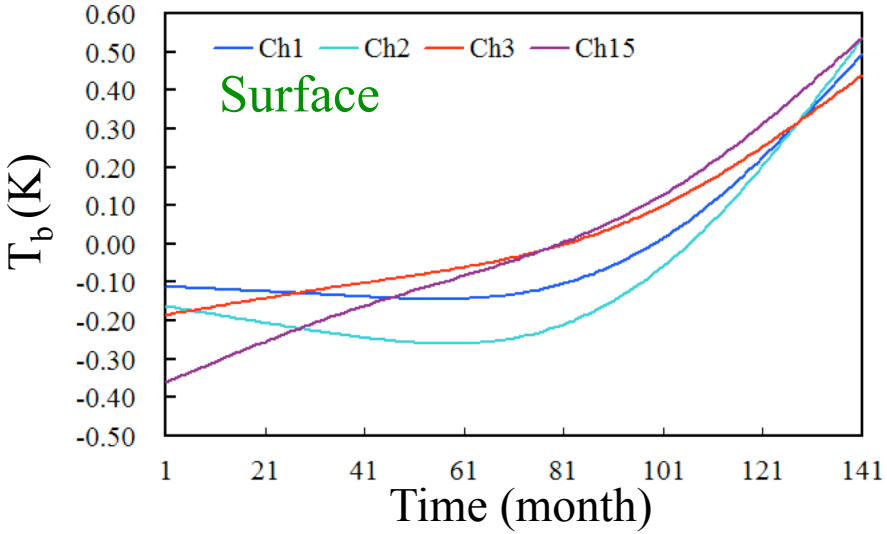
11 years:
October 26, 1998
↓
December 31, 2008

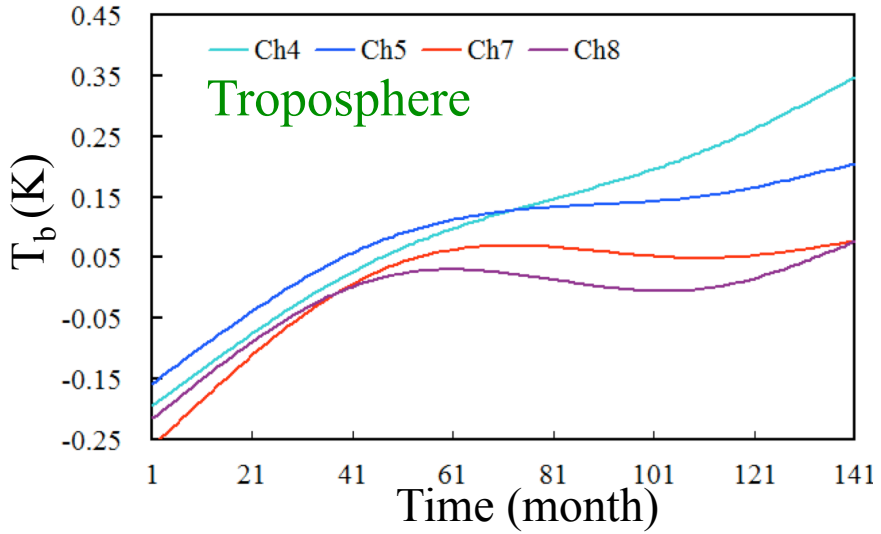
NOAA-15 AMSU-A Channel 5 (53.596 GHz, 700 hPa)

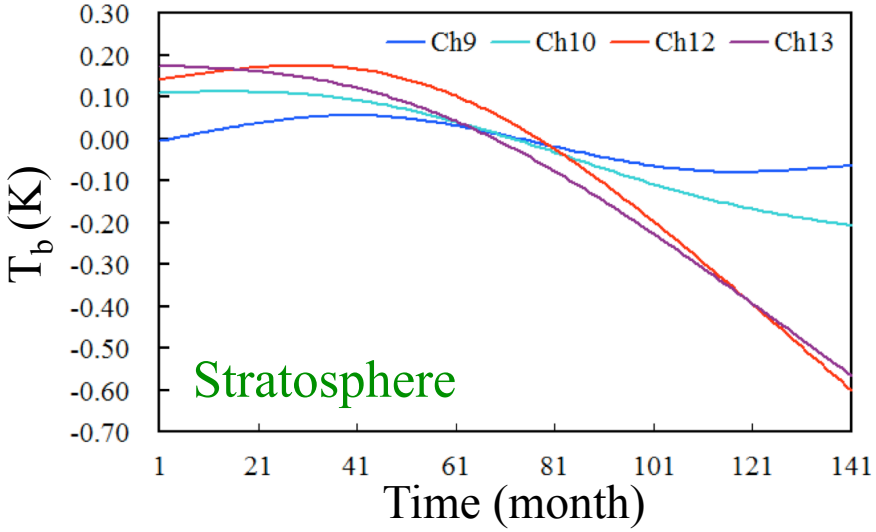


One data point
per 10 days
50 members

Climate Trend Derived by EEMD Method for All AMSU-A Channels on NOAA-15

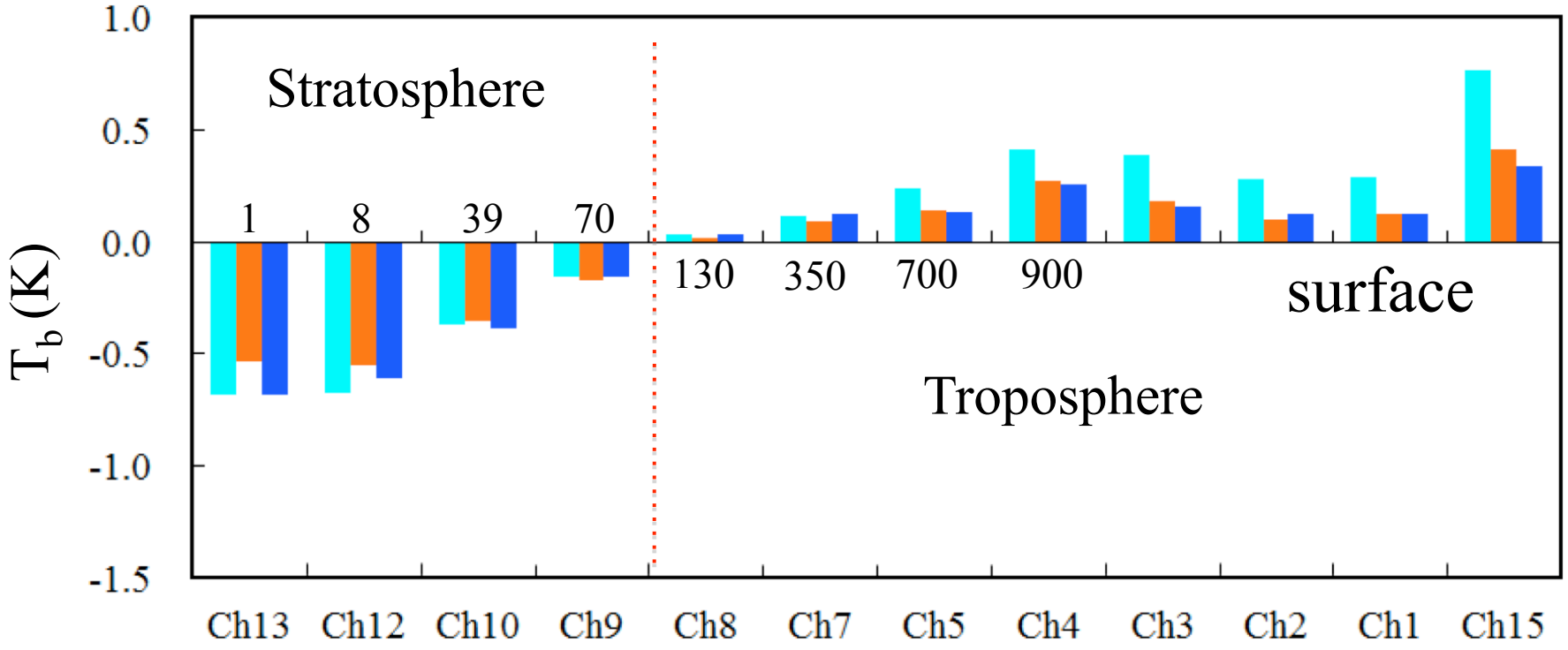






Climate Trend Derived by Linear Regression for All AMSU-A Channels on NOAA-15

October 26 1998 --- August 7, 2010

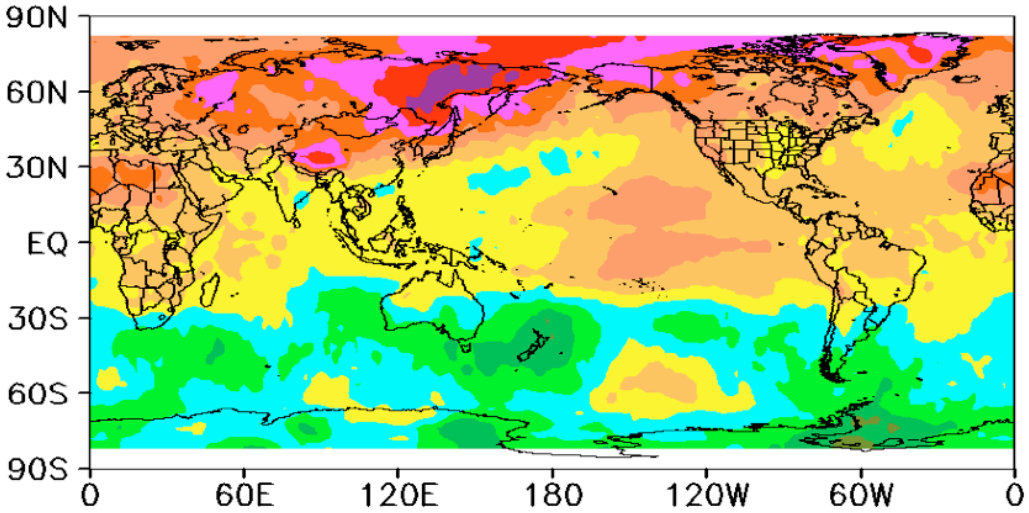


Raw T_b data

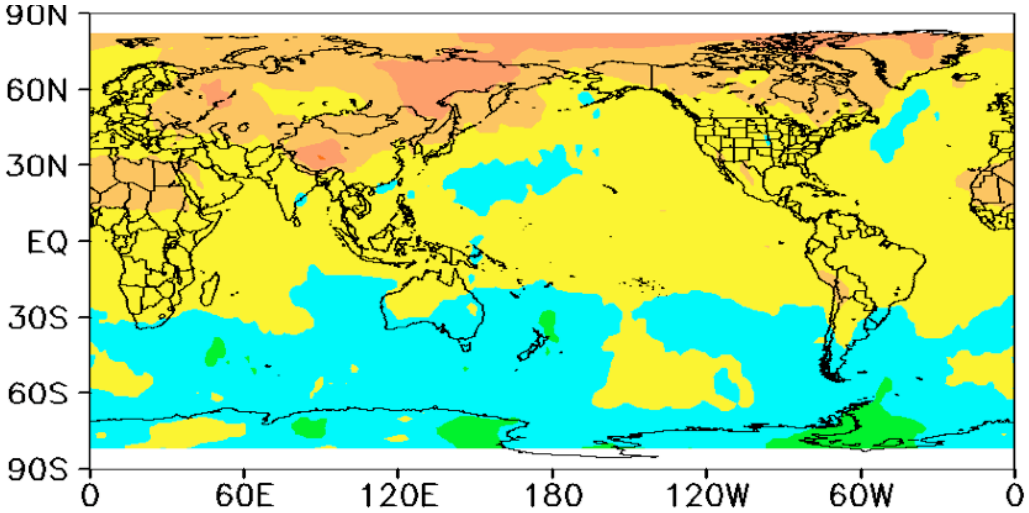
Traditional annual mean subtracted

EEMD annual mean subtracted

EEMD trend



Linear trend (0.12 K/decade)

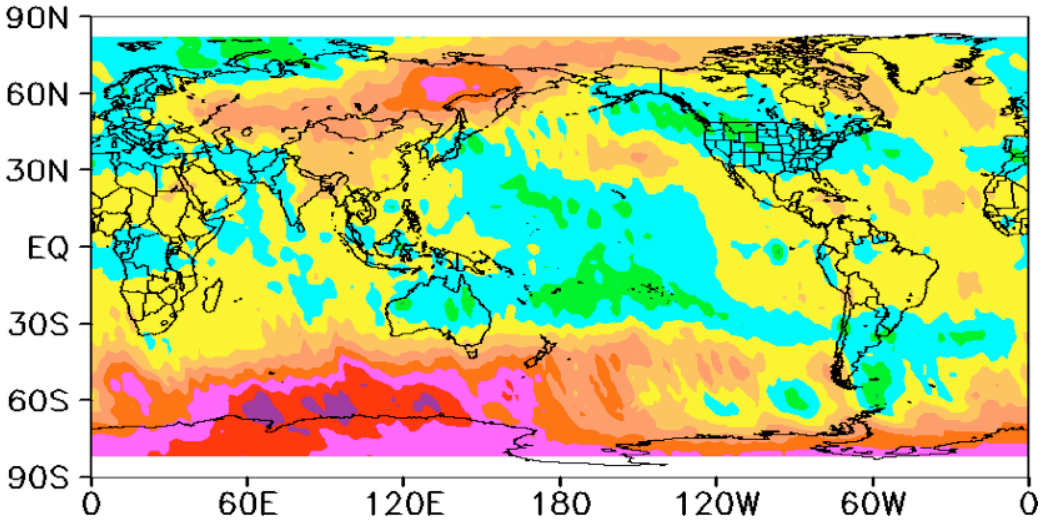


(0.1K)

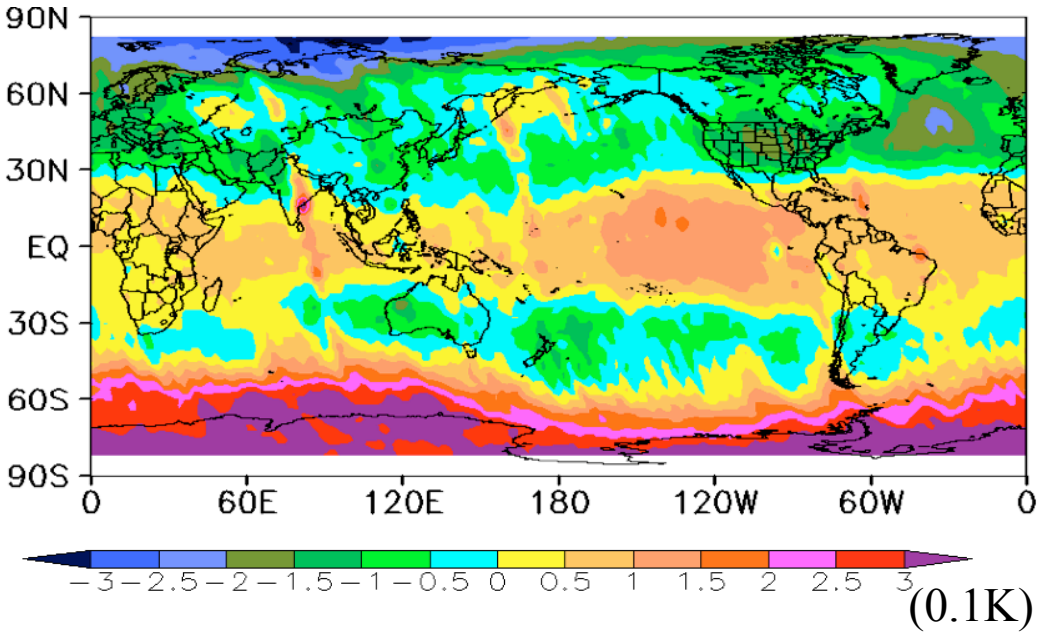
Regressed Mode

Channel 5
(53.596 GHz, 700 hPa)

EEMD trend



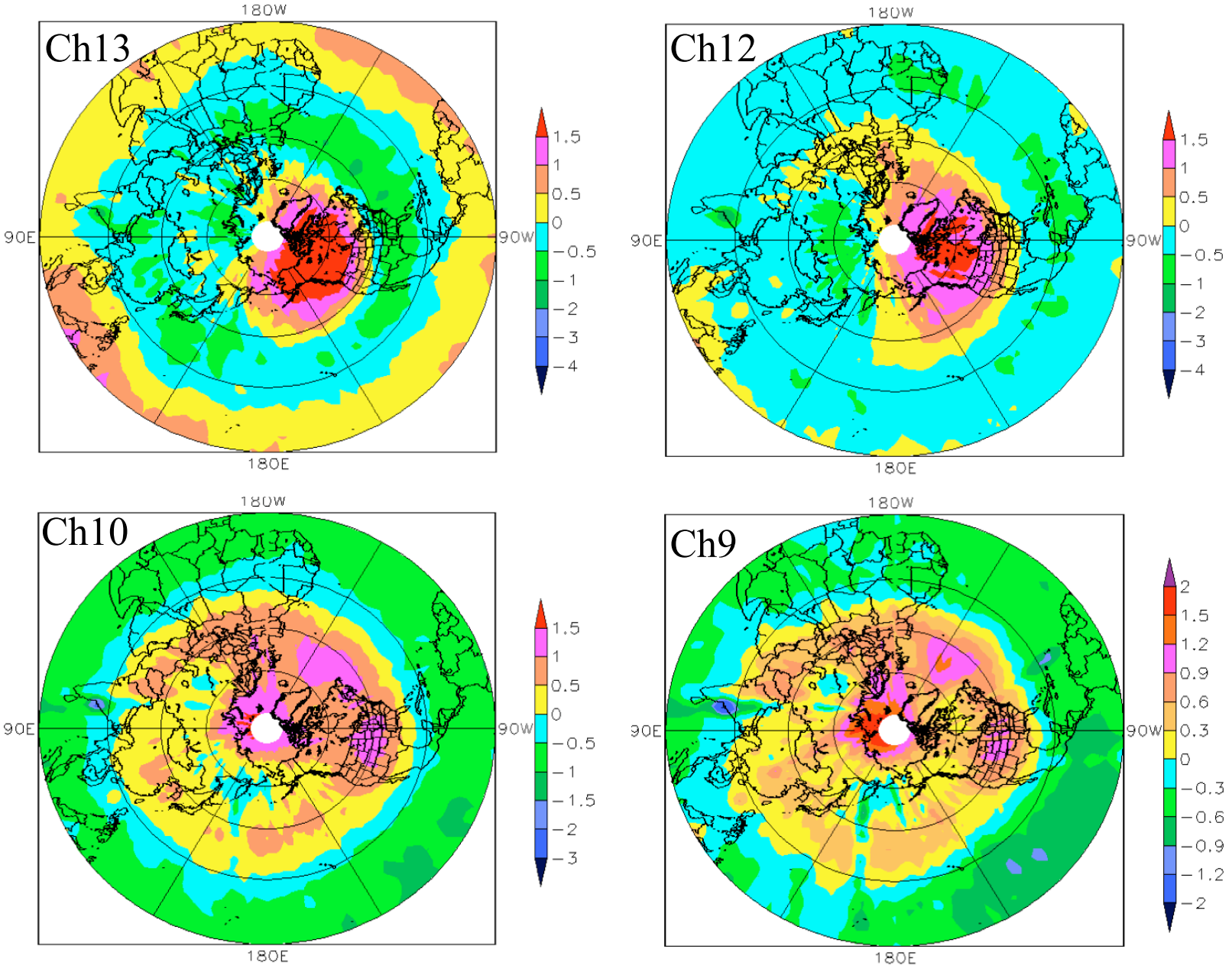
Linear trend (-0.15K/decade)



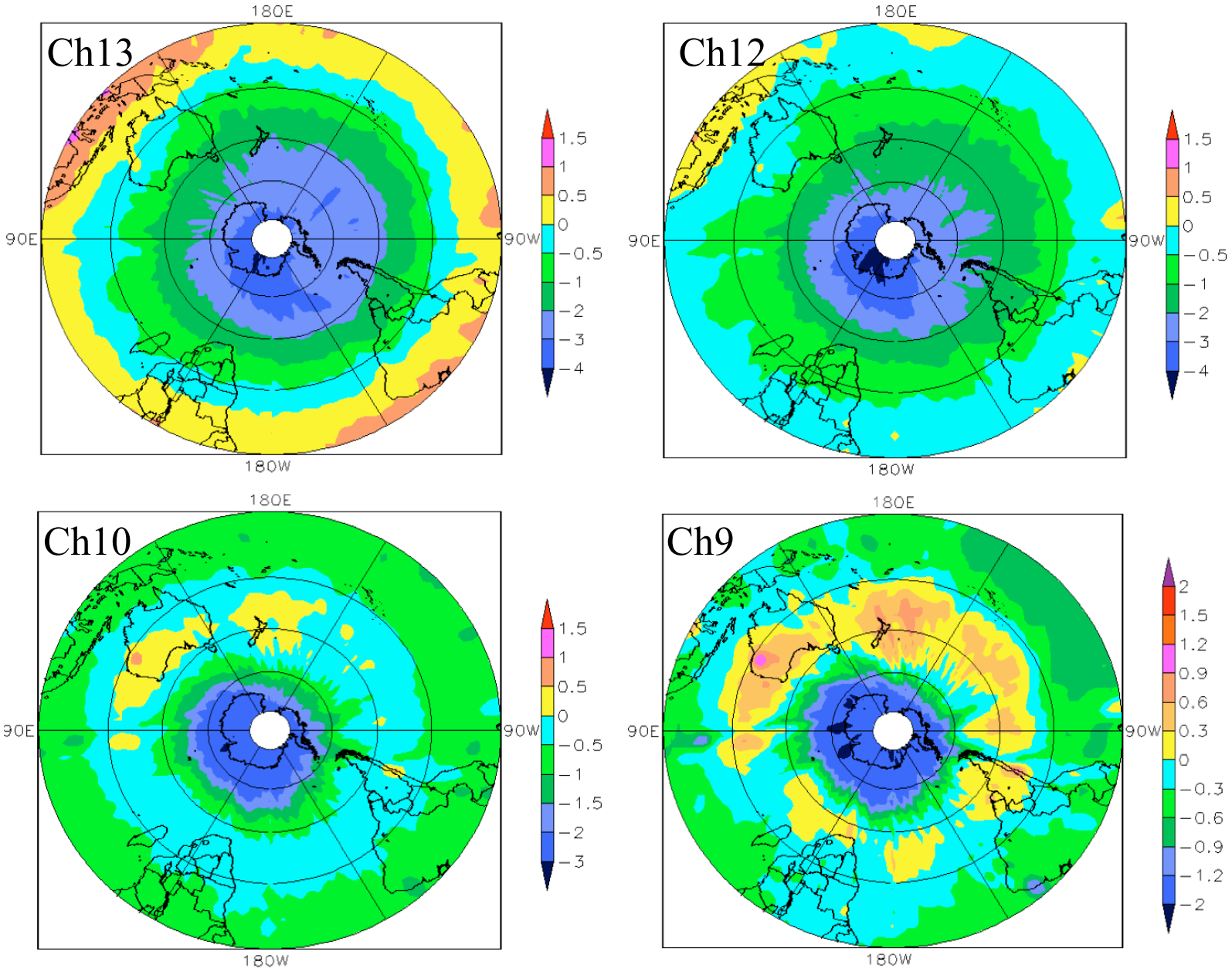
Regressed Mode

Channel 9
(57.29 GHz, 70 hPa)

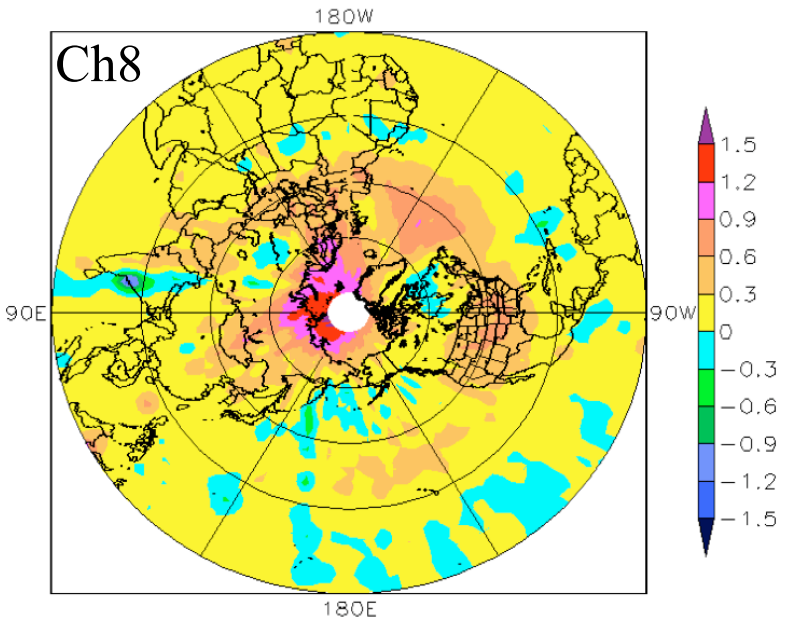
Stratospheric Channels in Northern Hemisphere

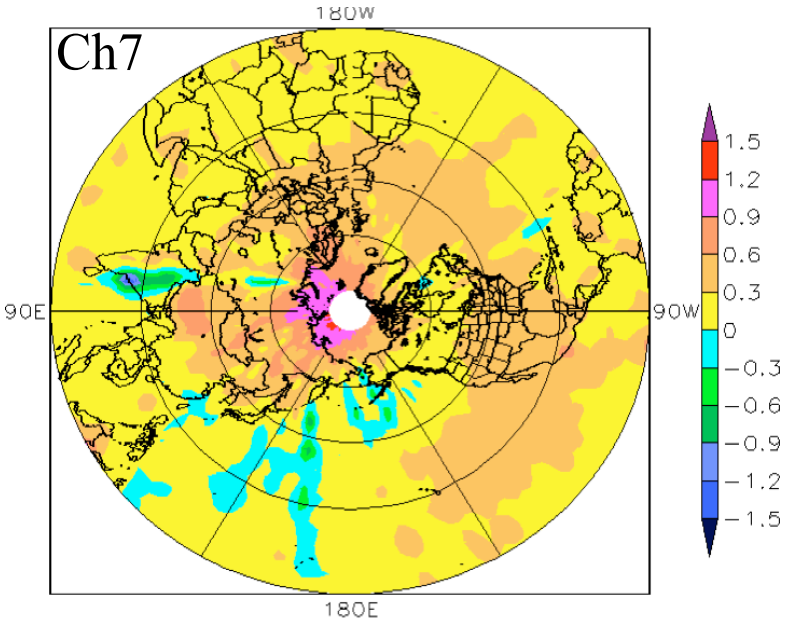


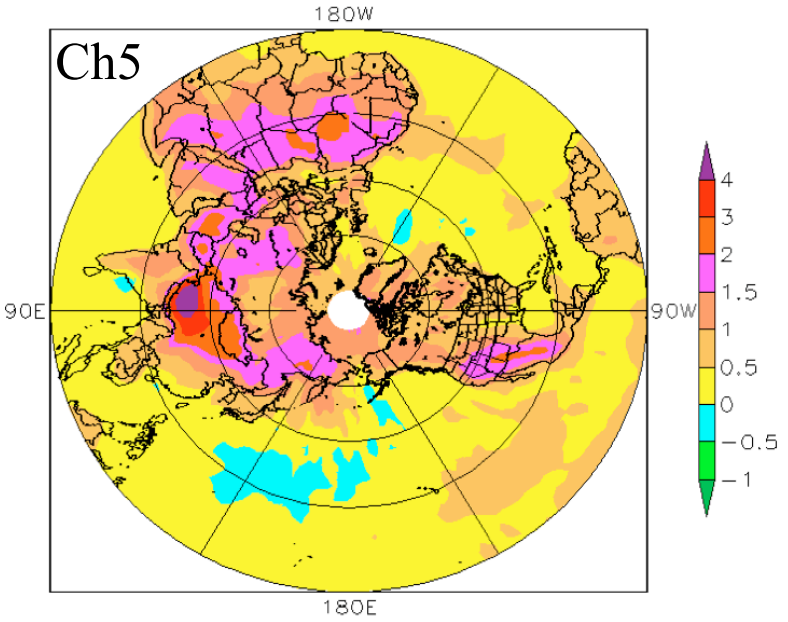
Stratospheric Channels in Southern Hemisphere

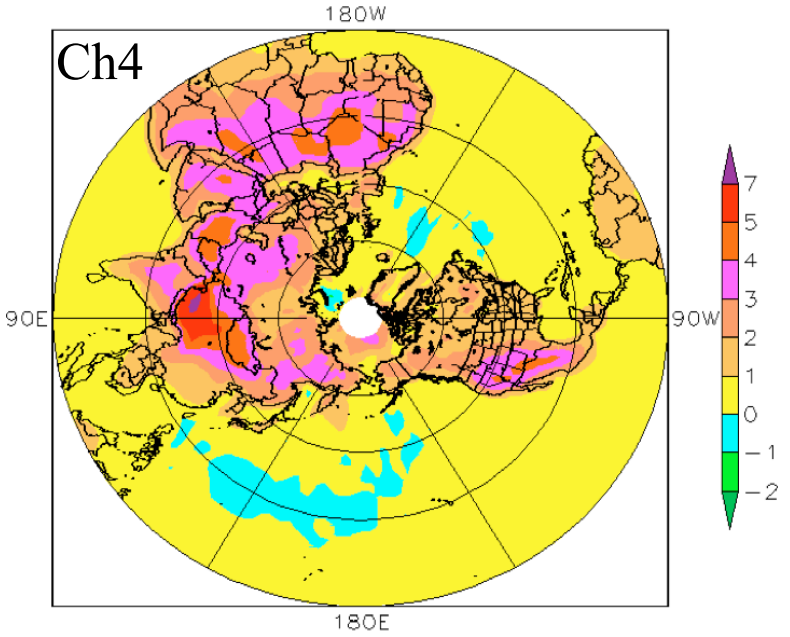


Tropospheric Channels in Northern Hemisphere

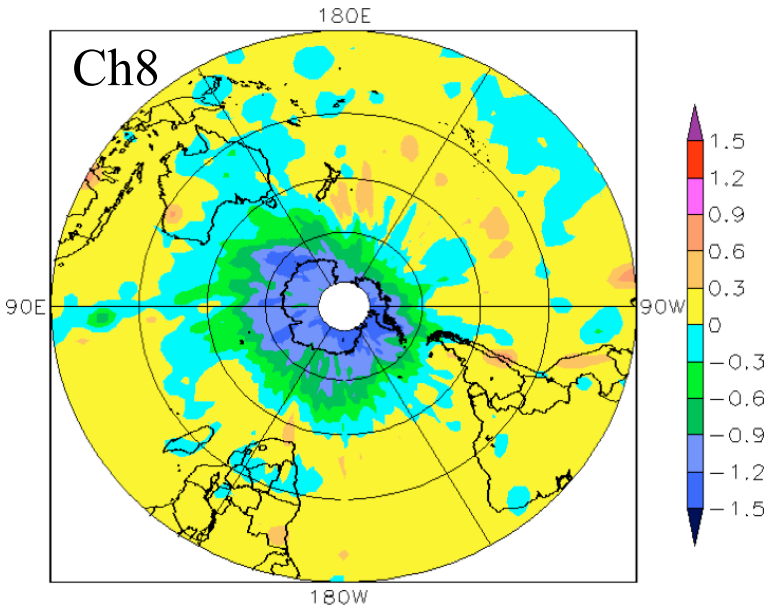


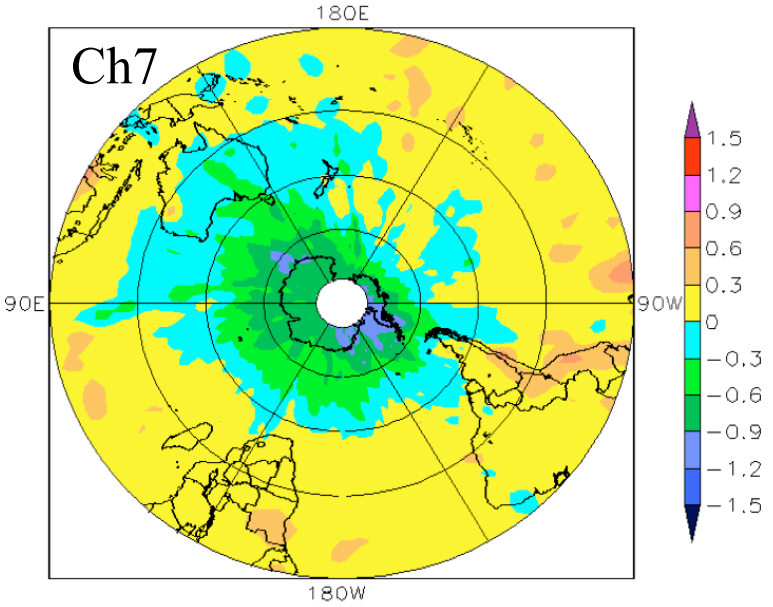


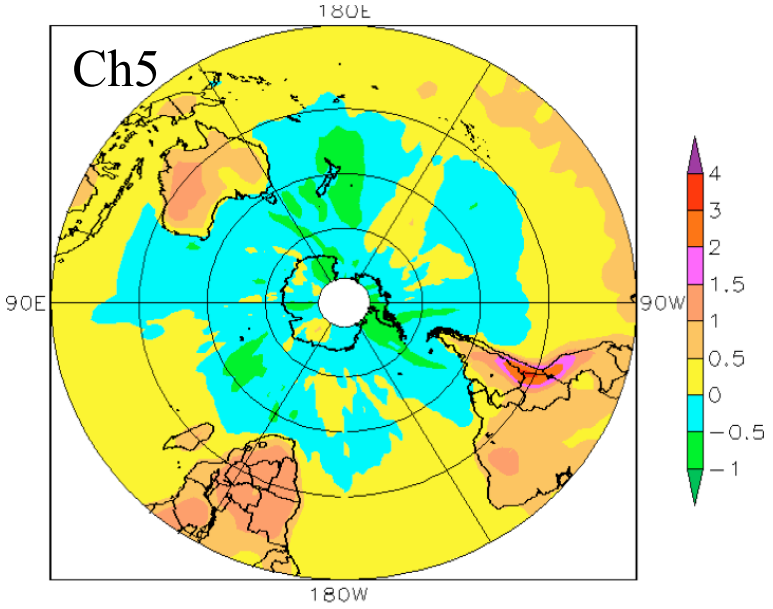


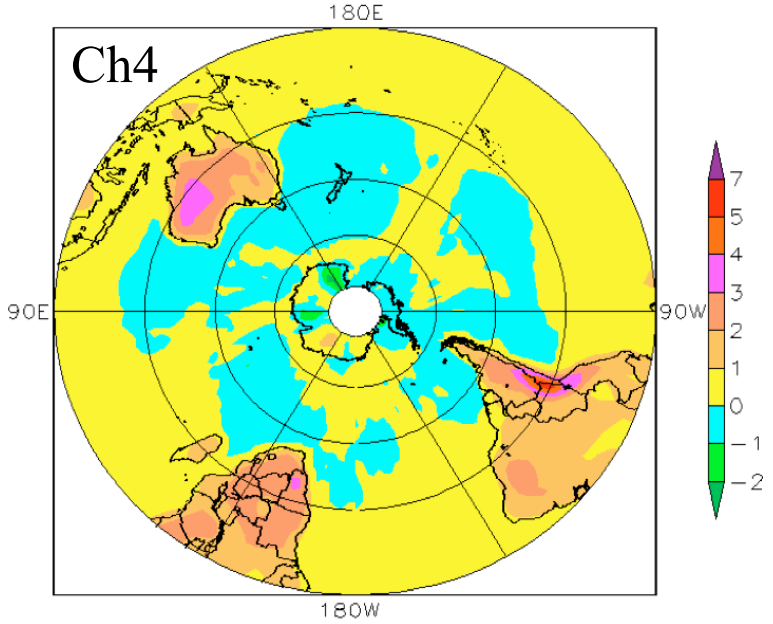


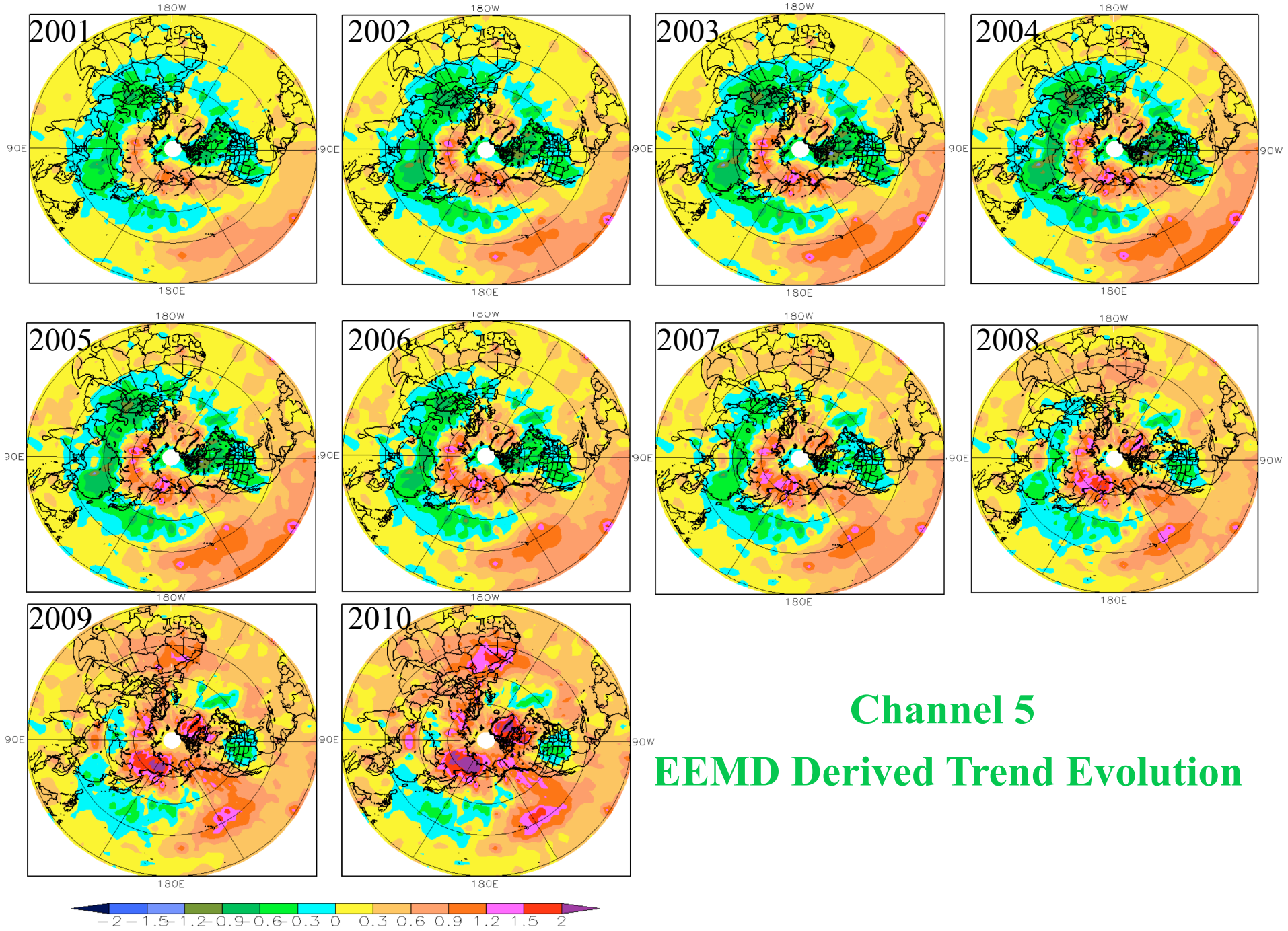
Tropospheric Channels in Southern Hemisphere





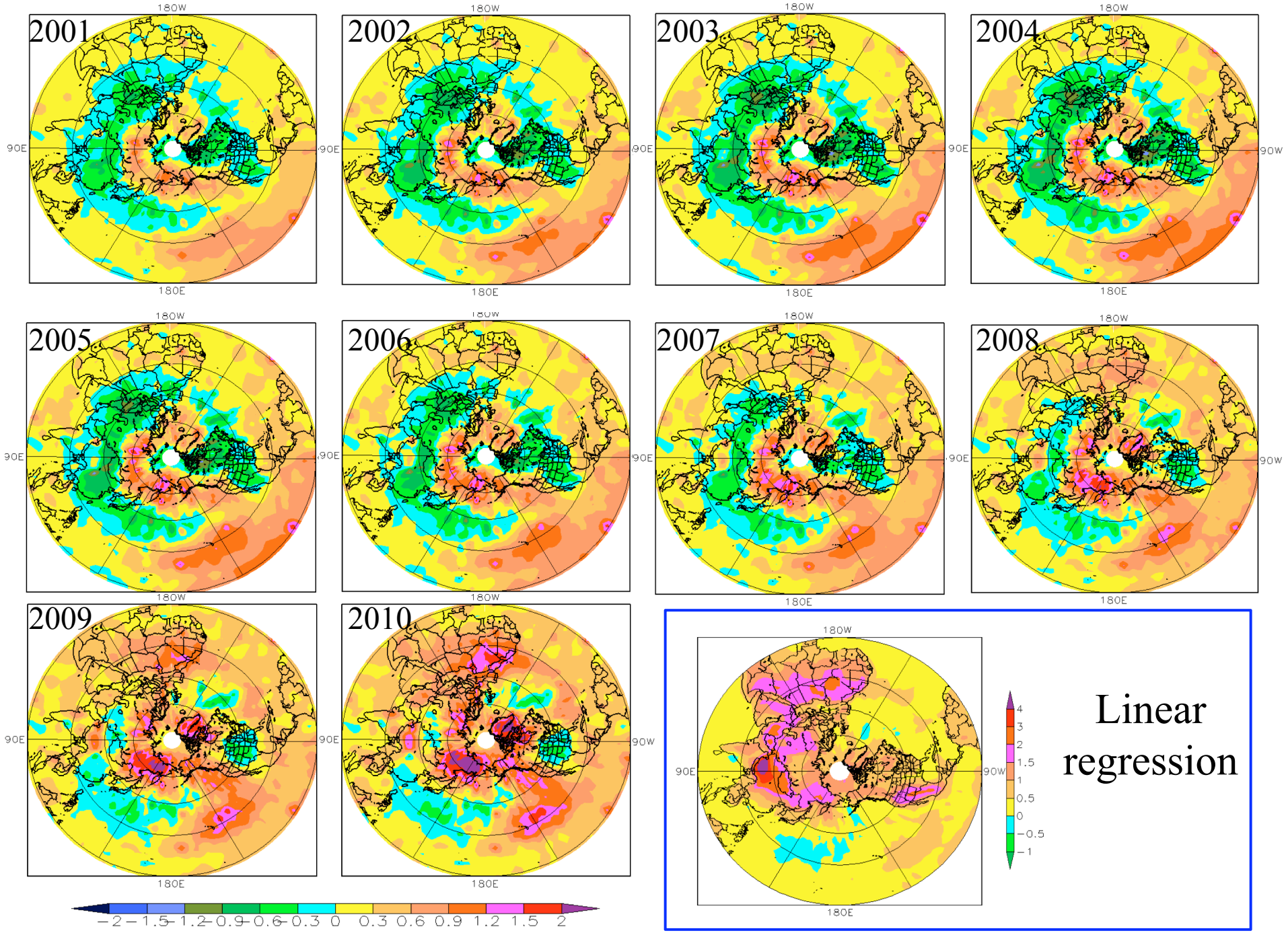






Channel 5

EEMD Derived Trend Evolution


2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
180W
90E
90W
180E
−2 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 2
4 3 2 1.5 1 0.5 0 −0.5 −1
Linear regression

Summary and Future Work

•EEMD is a very powerful tool and can be used for trending the climate from a data set that has a shorter period of time

•EEMD can derive the trend evolution while the linear trend can bias toward the data set at a particular data point

•The EEMD trends may be best connected from the different platforms by requiring the continuity. The cross-calibration of the instruments may not be required