Impact of large-scale circulation patterns on surface ozone concentrations in Houston-Galveston-Brazoria (HGB)

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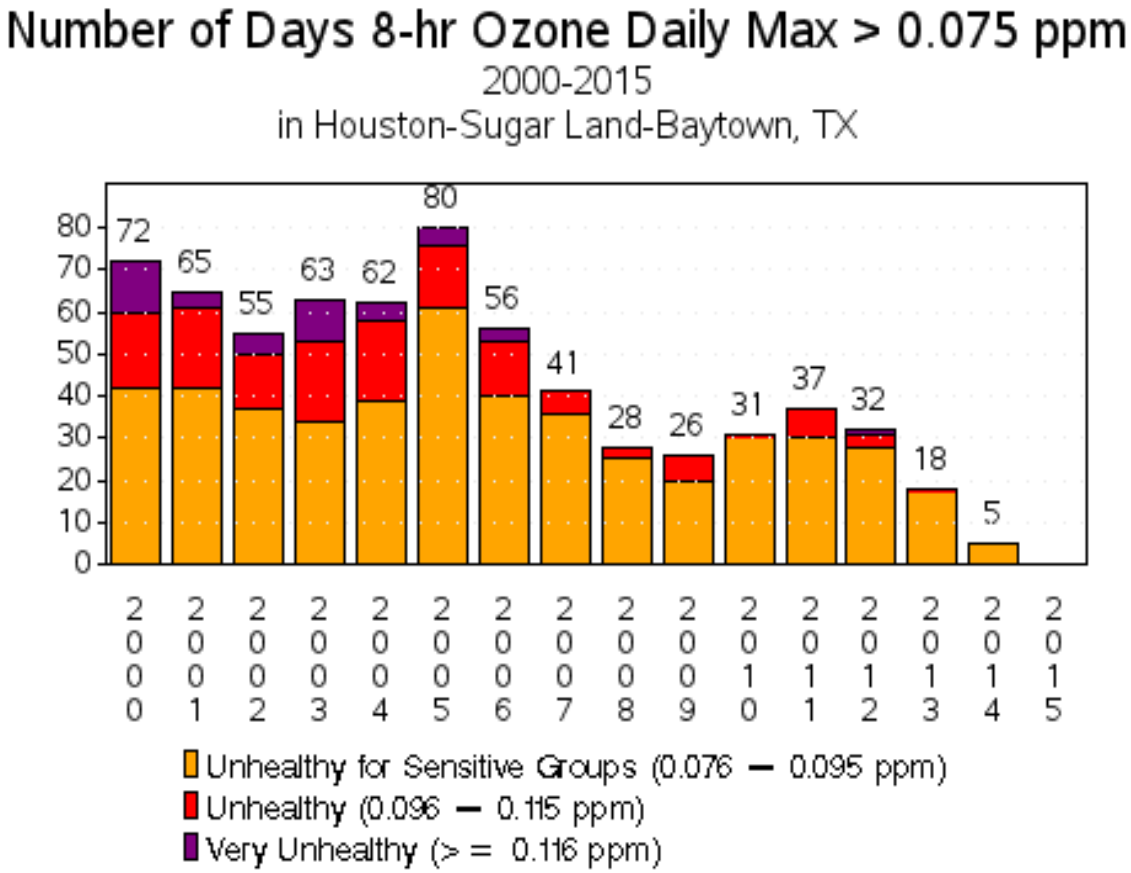
Large interannual variability in HGB O_3

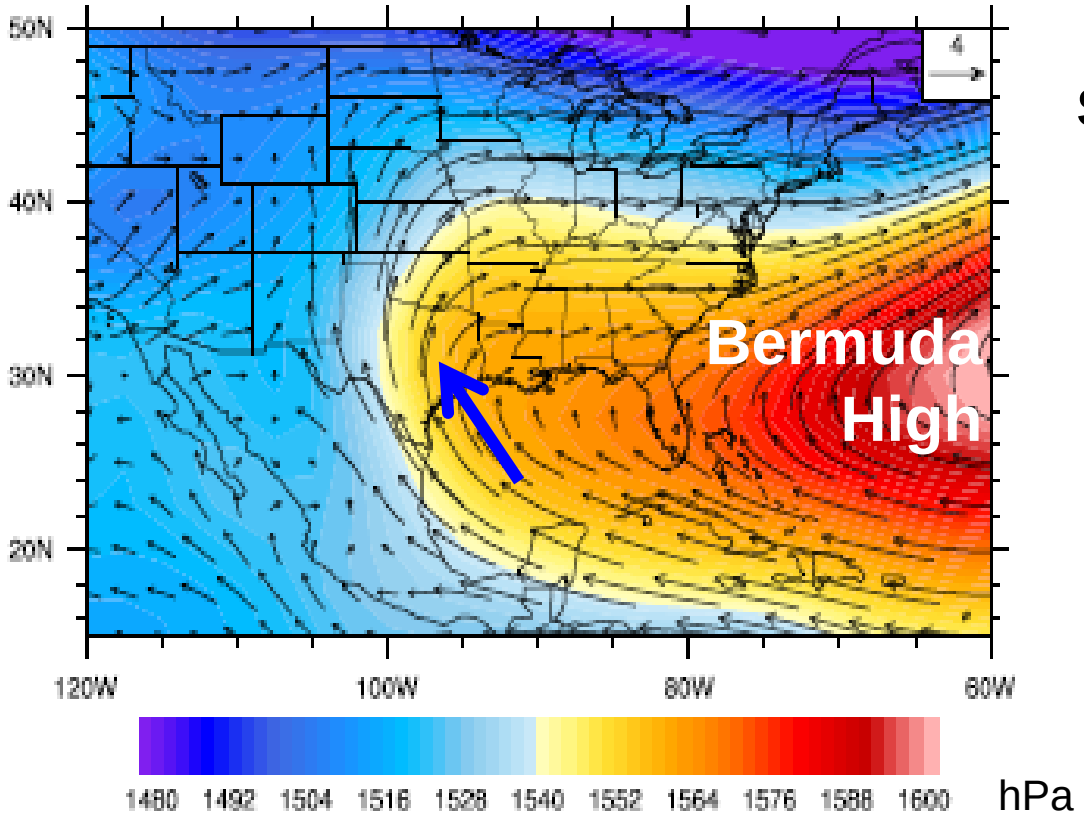


Note: Based on ALL sites
Source: U.S. EPA AirData <http://www.epa.gov/airdata>
Generated: January 18, 2015

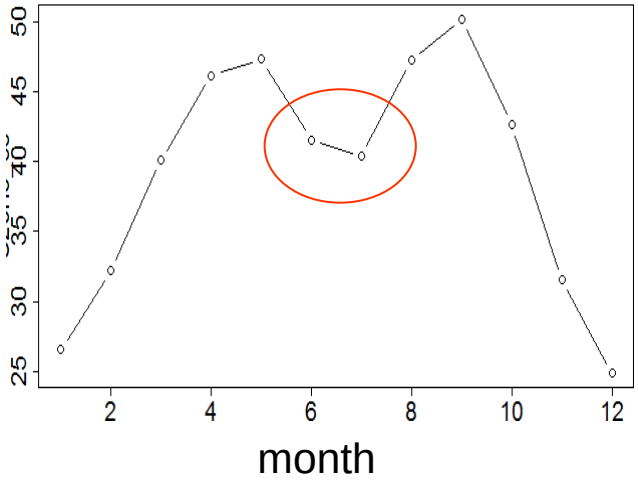
www.epa.gov/airdata/ad_viz_ozcompare.html

Large-scale circulation patterns

July 850hPa geopotential height and winds (1998-2013 mean)



Surface O_3 seasonality in HGB



Project Objectives

Motivating Hypothesis:

Large-scale circulation pattern, particularly the Bermuda High (BH), is the key driver for MDA8 O_3 variability in HGB during the ozone season

Objectives/Tasks:

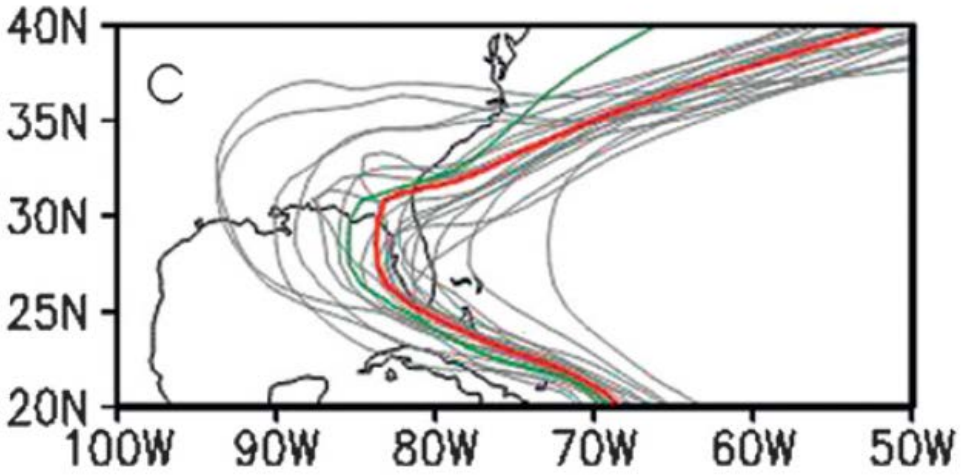
1. Characterize the influence of BH on HGB O_3
2. Develop the statistical relationship between O_3 and BH
3. Apply the statistical relationship to correct background ozone bias in GEOS-Chem global model

Project Period: 01/26/2015 ~ 09/31/2015

Primary Indicators of the Bermuda High

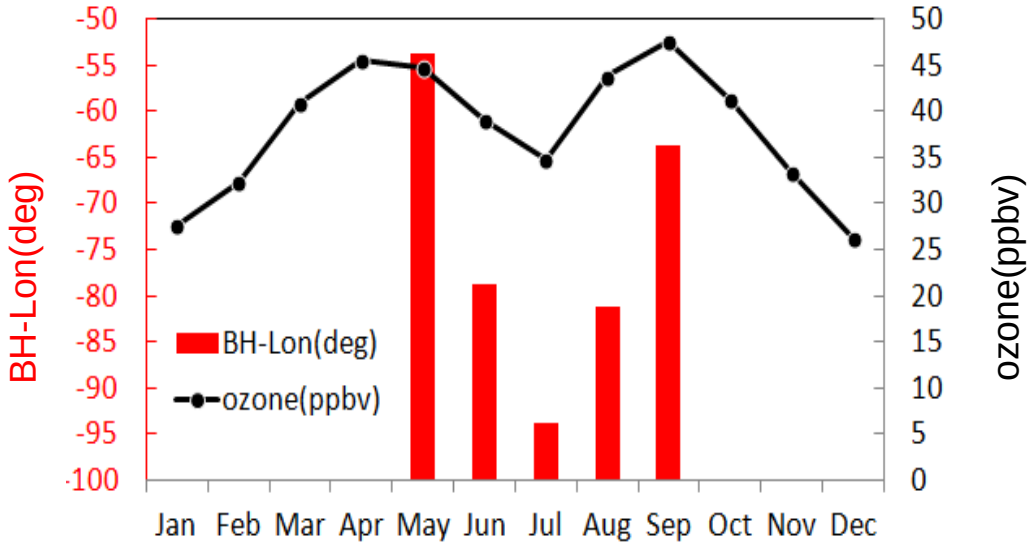
- **Bermuda High Index (BHI): based on intensity.** Mean pressure difference between the Gulf of Mexico and a representative continental location (unit: hPa)
- **BH west edge longitude (BH-Lon): based on position.** The cross point of the 1560-gpm isoline and the 850 hPa wind ridge line (unit: degree longitude)

1560 hPa contour line (NCEP; 1978-2007)

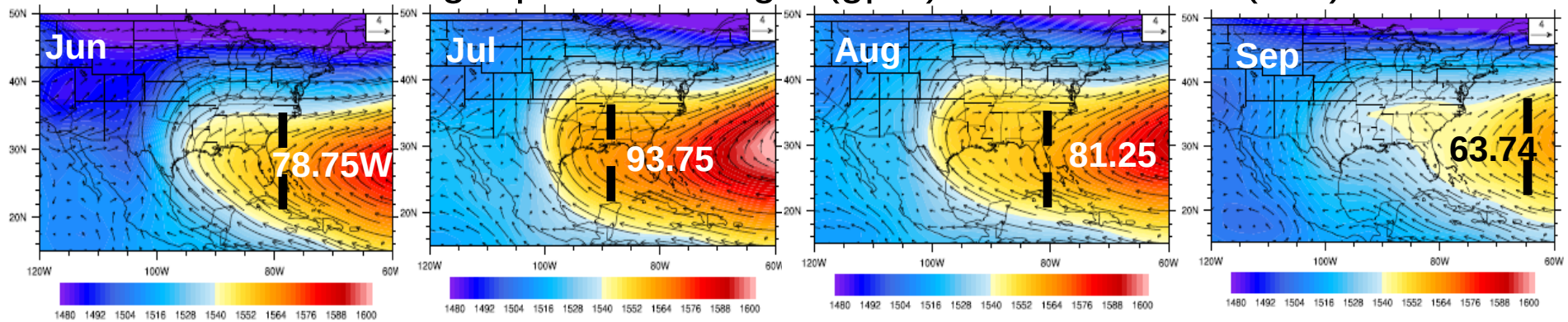


Li et al., 2011

BH-Lon explains the seasonality of HGB O_3



850hPa geopotential height (gpm) and wind fields(m/s)



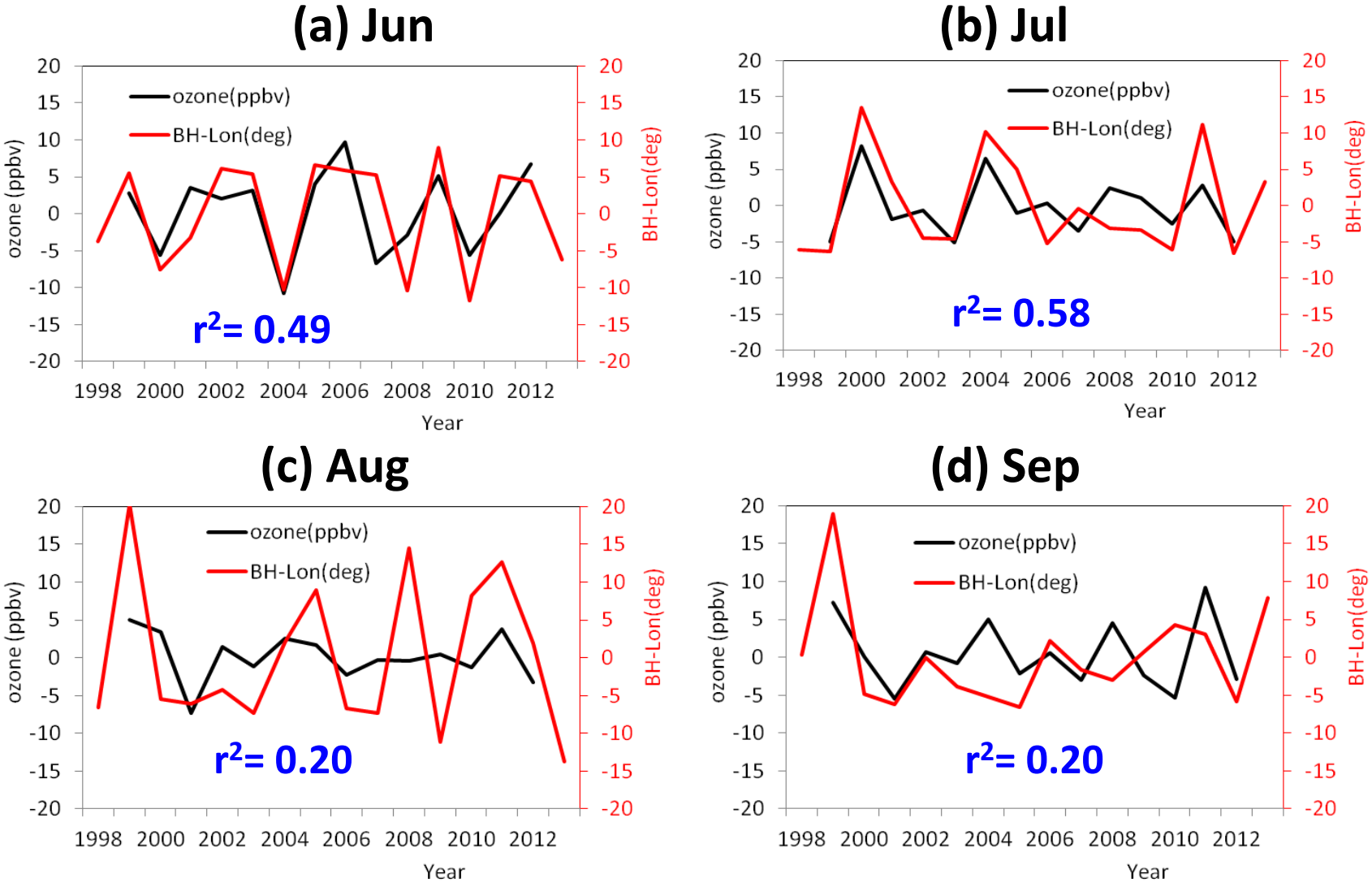
onset of the BH → **decrease of ozone**

retreat of the BH → **increase of ozone**

Refine BH-Lon to better predict HGB O_3

- Li et al. (2011) used a constant isoline (1560-gpm) to define BH-Lon for all the months
- To account for the seasonality of BH, we tested a number of isoline choices to define BH-Lon
- Our best-choice of BH-Lon definition (in terms of correlations with HGB O_3)
  - Jun and July: 1560-gpm isoline
  - Aug: 1556-gpm isoline
  - Sep : 1536-gpm isoline
- Tested and compared BH-Lon from a number of reanalysis products (NCEP, MERRA, NA Regional Reanalysis)

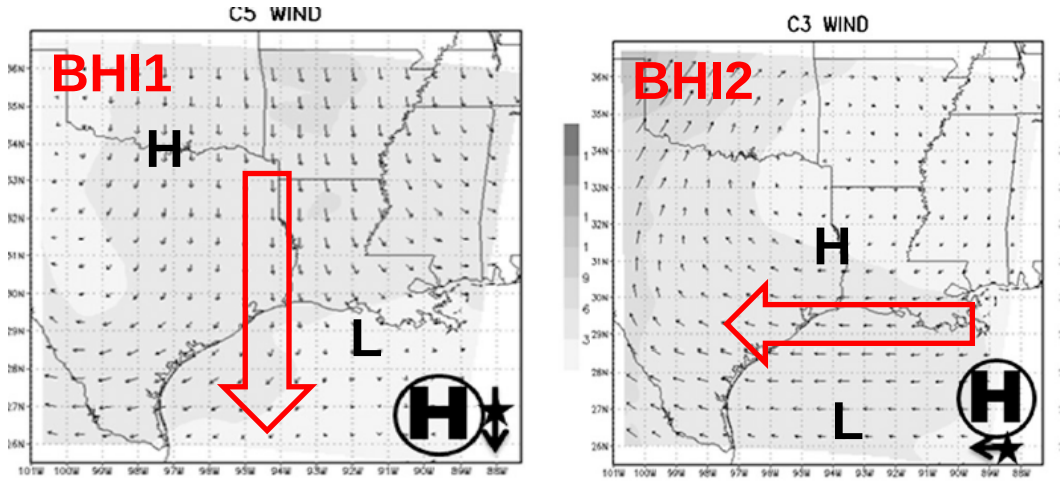
BH-Lon and monthly O_3 (detrended data)



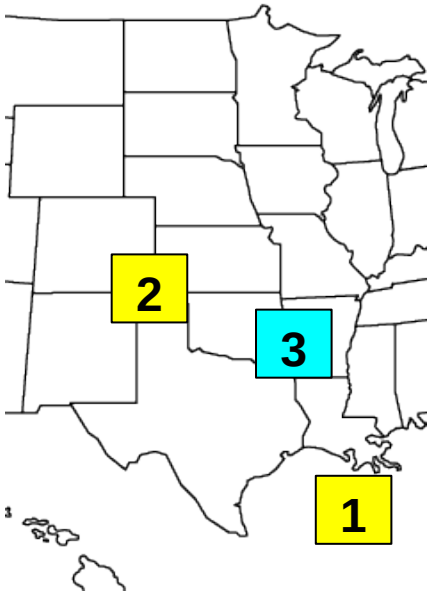
- O_3 data was detrended by subtracting 3-year moving averages
- BH-Lon was detrended by subtracting a linear trend

Refine the BH Intensity index (BHI)

- BHI is conventionally defined as the SLP differences between two representative locations
- *Zhu and Liang* (2013) defined BHI as the SLP difference between Gulf of Mexico and southern Great Plains (box 1 and 2) → **BHI1**
- We proposed a new BHI as the SLP difference between Gulf of Mexico and Northeast TX (box 1 and 3) → **BHI2**

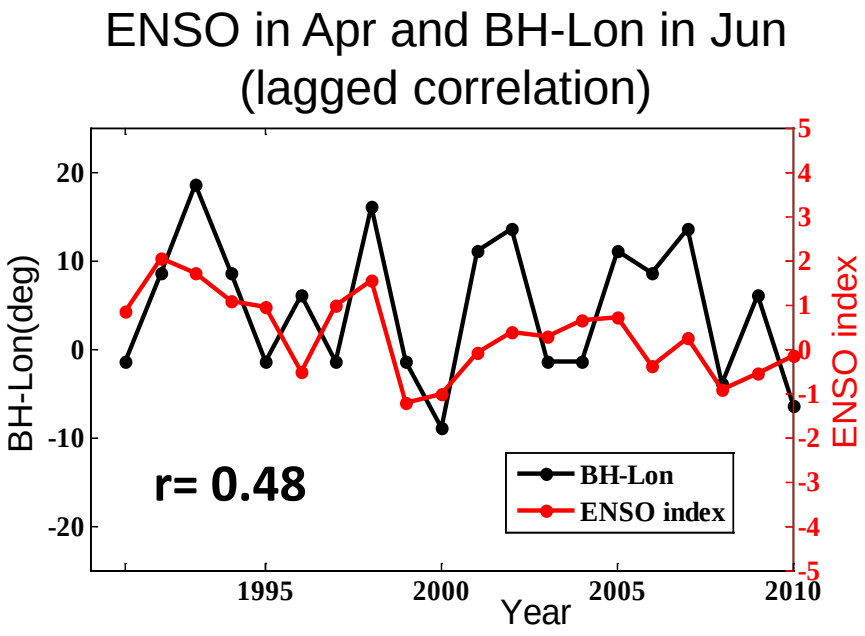


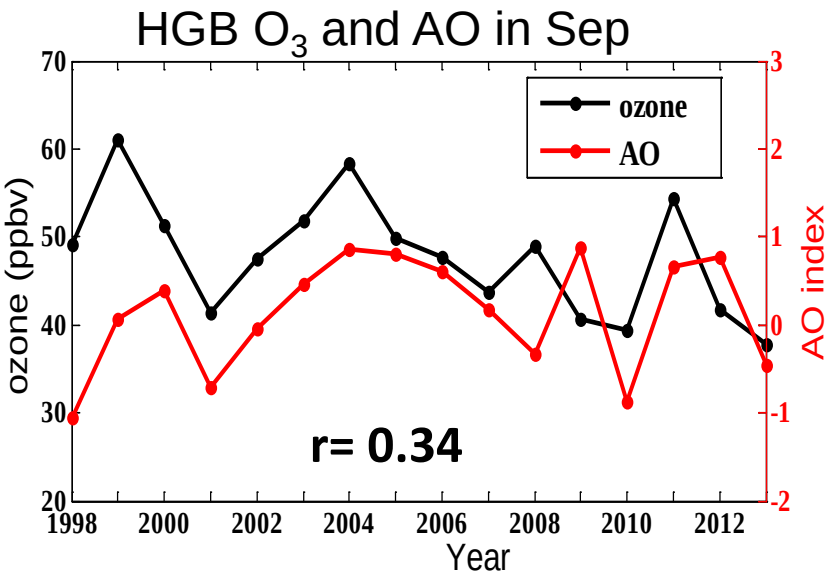
Ngan and Byun, 2011



Other Meteorological Indices

- Palmer Drought Severity Index (PDSI)
- HGB-mean temperature
- ENSO
- Artic Oscillation (AO)





Tested different metrics of HGB O_3: mean, median, background ozone, ozone enhancement

Develop the statistical relationship through multiple linear regression (MLR)

$$y = \sum_{i=1}^{6} \boldsymbol{\beta_i x_i} \, (+ \, interaction \; terms)$$

y (dependent variable): monthly-mean MDA8 O_3 (detrended and normalized)

x_i (independent variables): BH-Lon, BHI1, BHI2, AO, PDSI, Temperature (all detrended and normalized)

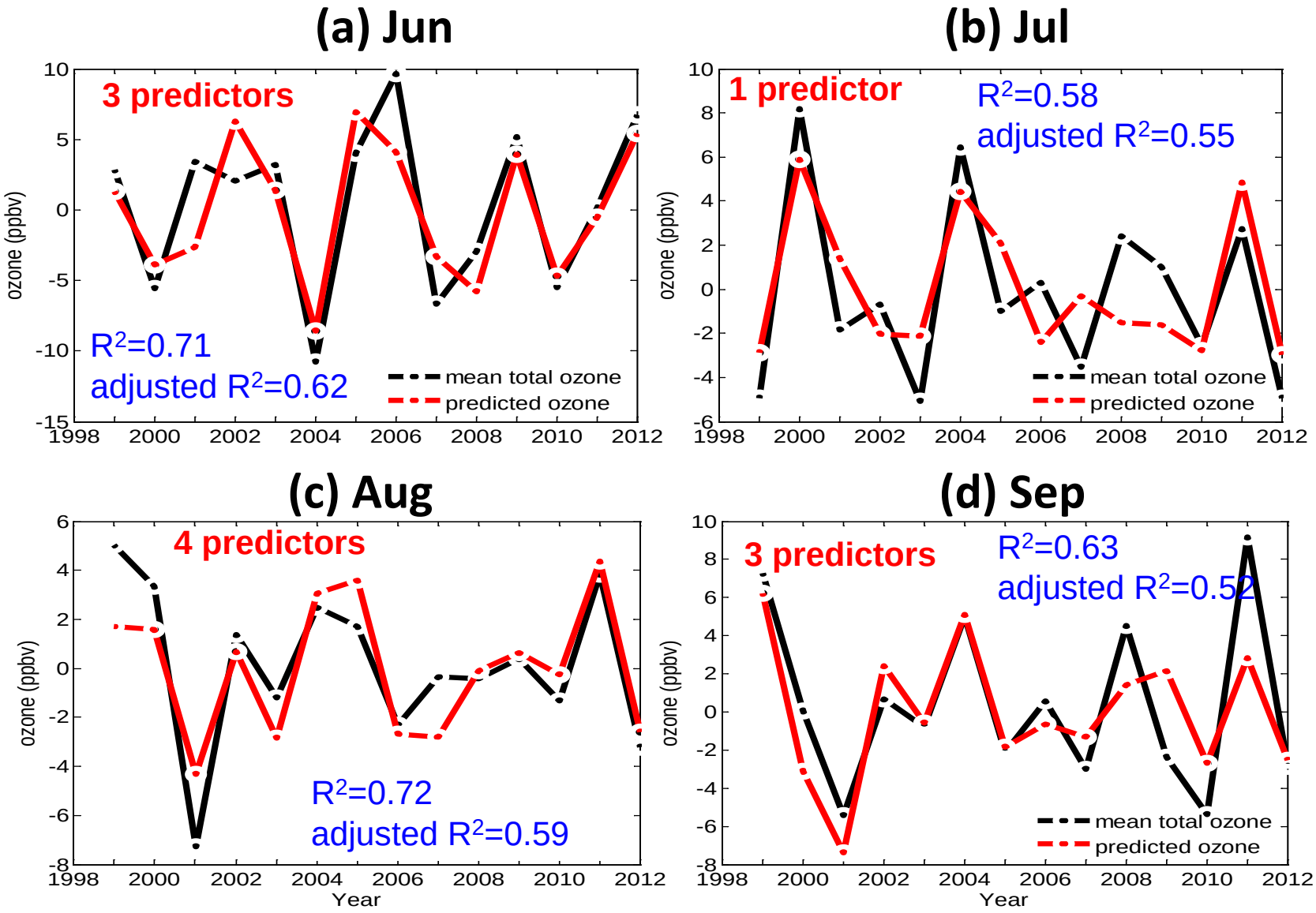
Approaches

(1) Stepwise regression to select variables: terms are added and deleted based on Akaike Information Criterion (AIC)

(2) Collinearity between predictors: variance inflation factor (VIF)

(3) Validation

Best-fit MLR model from stepwise regression

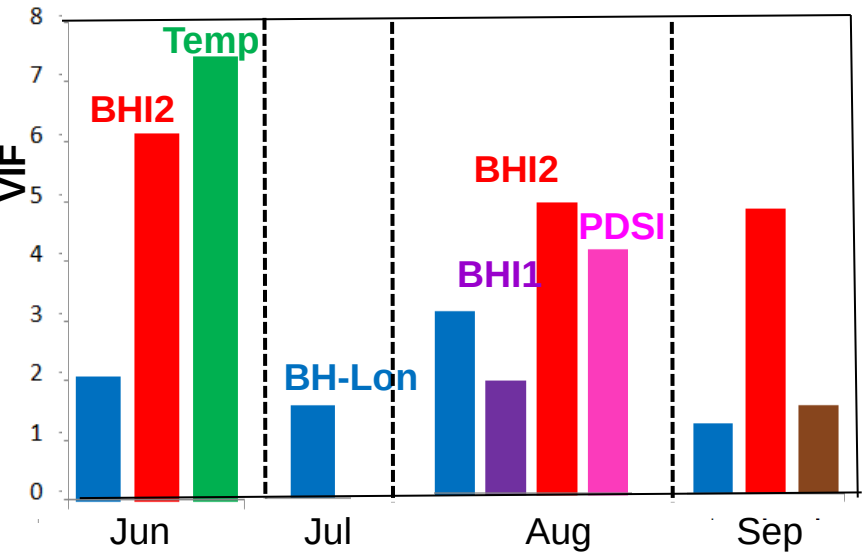


Predictors Selection

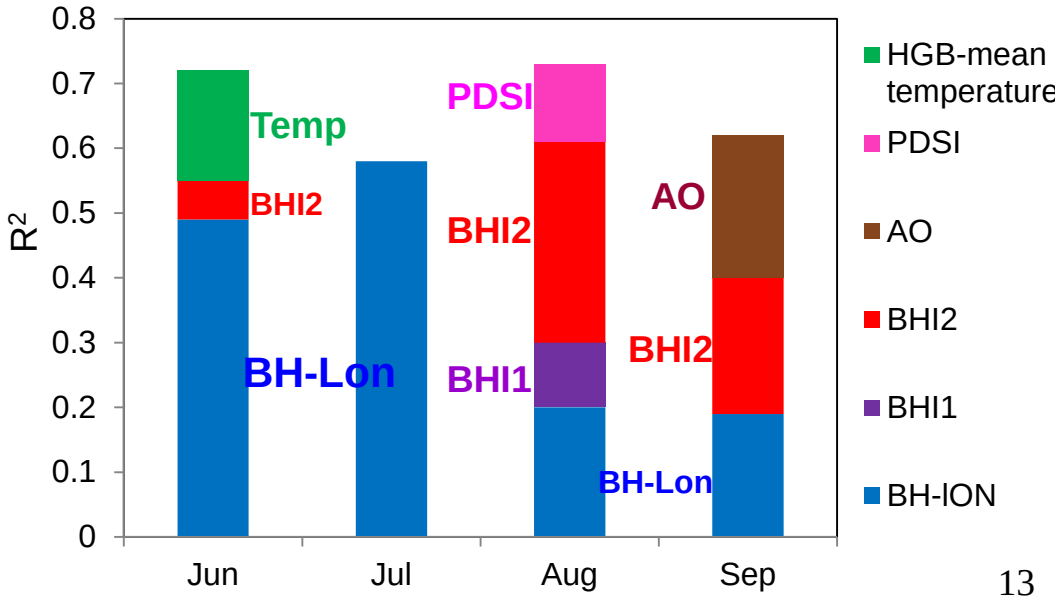
Selected Predictors

June: BH-Lon, BHI2, HGB-mean temperature
July: BH-Lon
August: BH-Lon, BHI1, BHI2, PDSI
September: BH-Lon, BHI2, AO

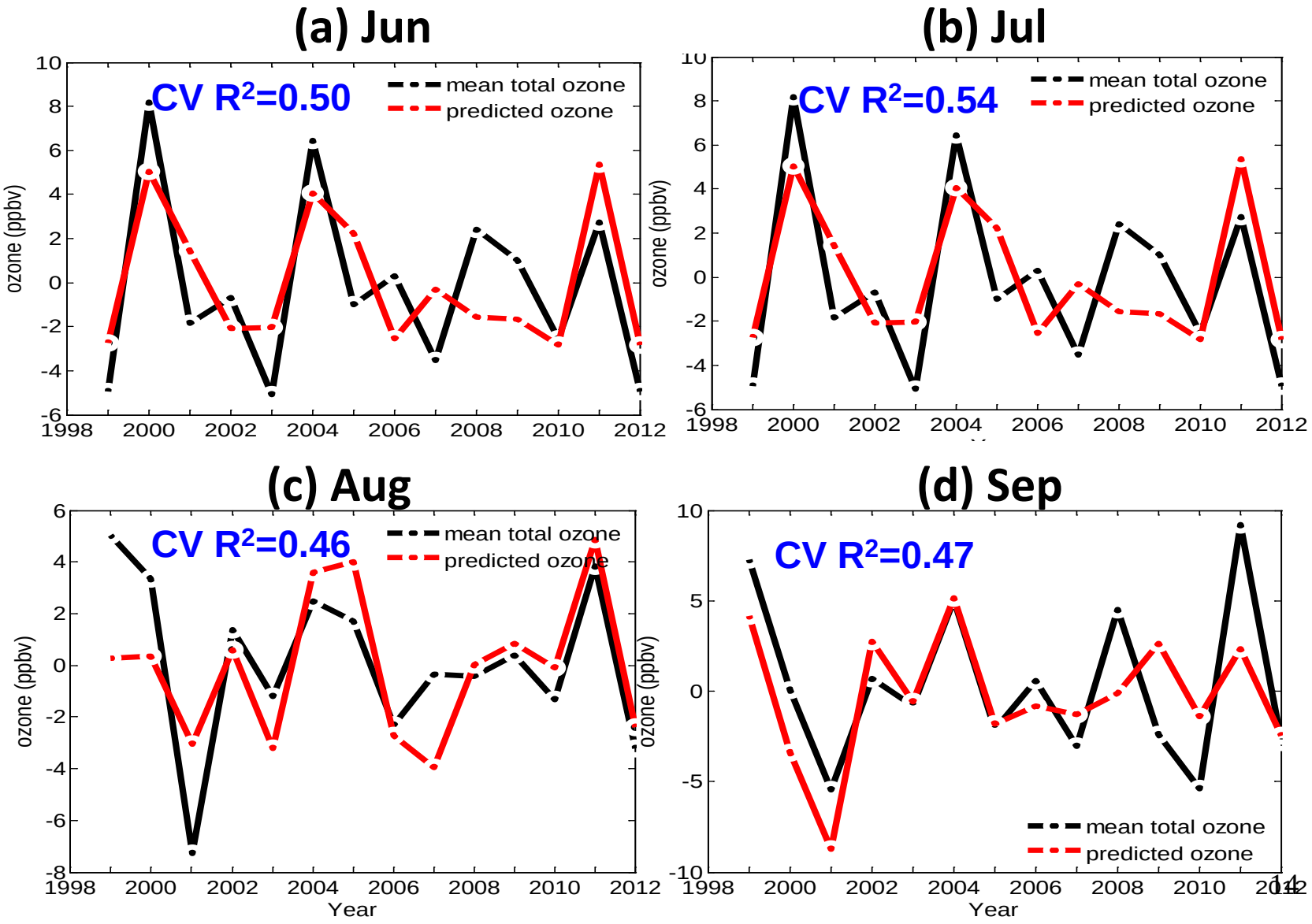
Collinearity between predictors



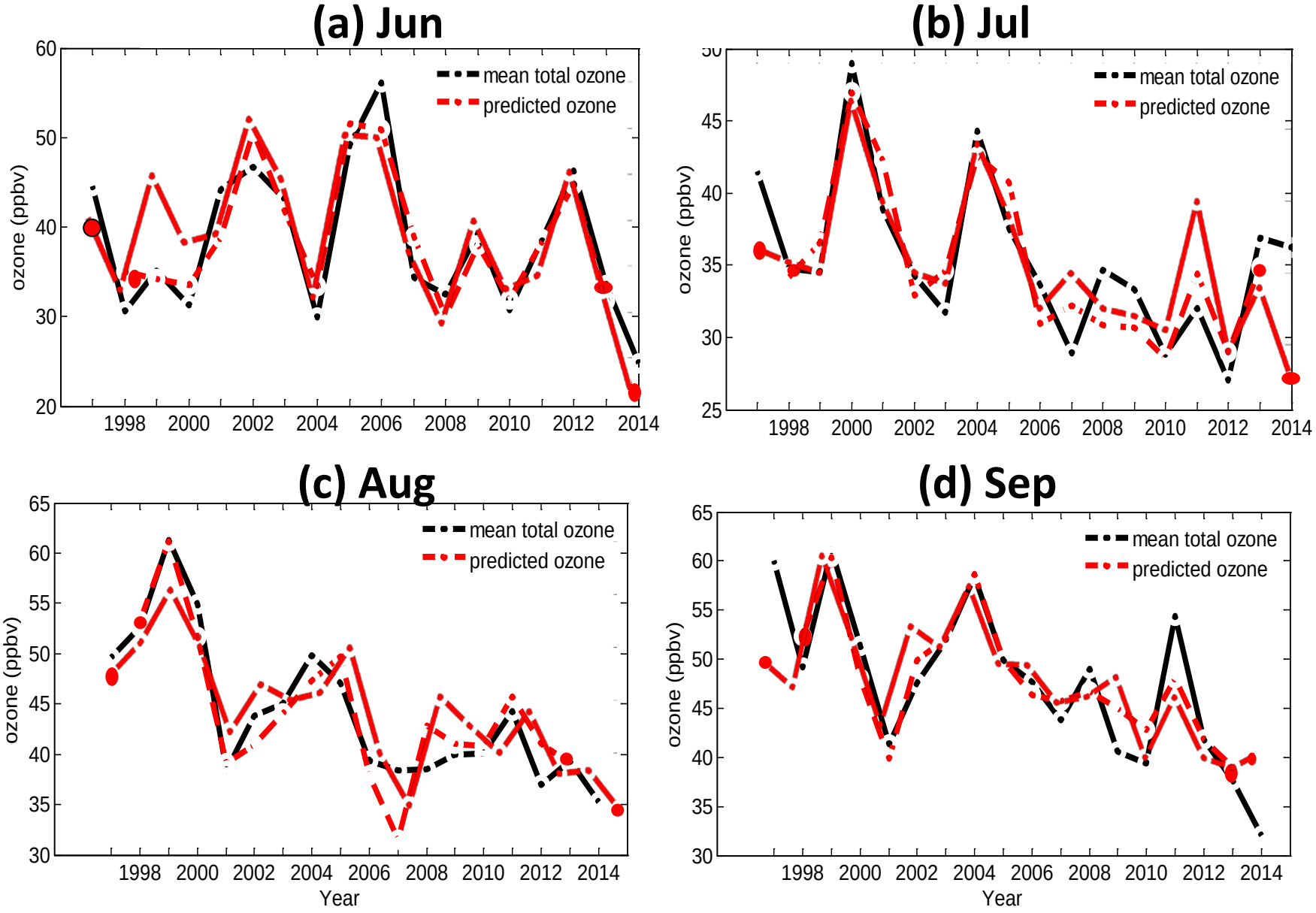
Predictors contribution to R^2



Cross-validation of MLR model



MLR model prediction of O_3



MLR model validation results

Mean bias (ppbv and %)

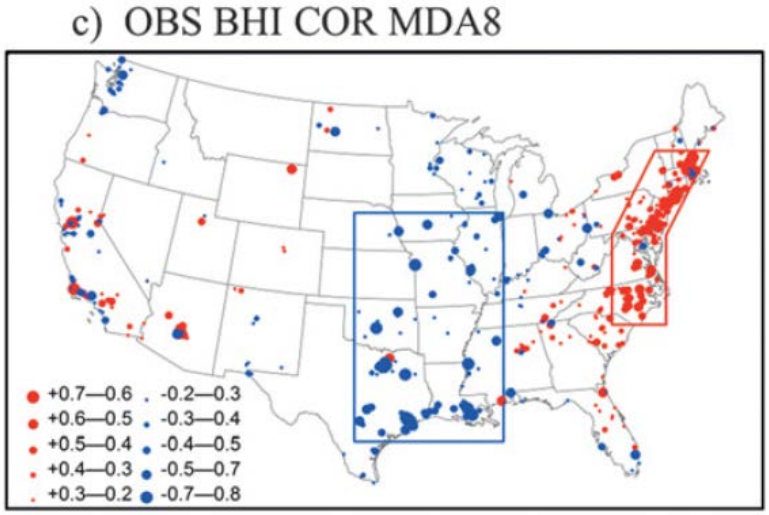
	Jun	Jul	Aug	Sep
3-year moving average	3.2 (5.0)	1.5 (2.0)	0.3 (0.3)	0.2 (0.3)
Linear trend	4.8 (12.3)	6.9 (8.9)	1.2 (1.4)	9.7 (10.5)

Direction of changes

	Jun		Jul		Aug		Sep	
	first	last	first	last	first	last	first	last
3-year moving average	x	√	x	√	√	x	√	√
Linear trend	√	√	√	√	√	√	√	x

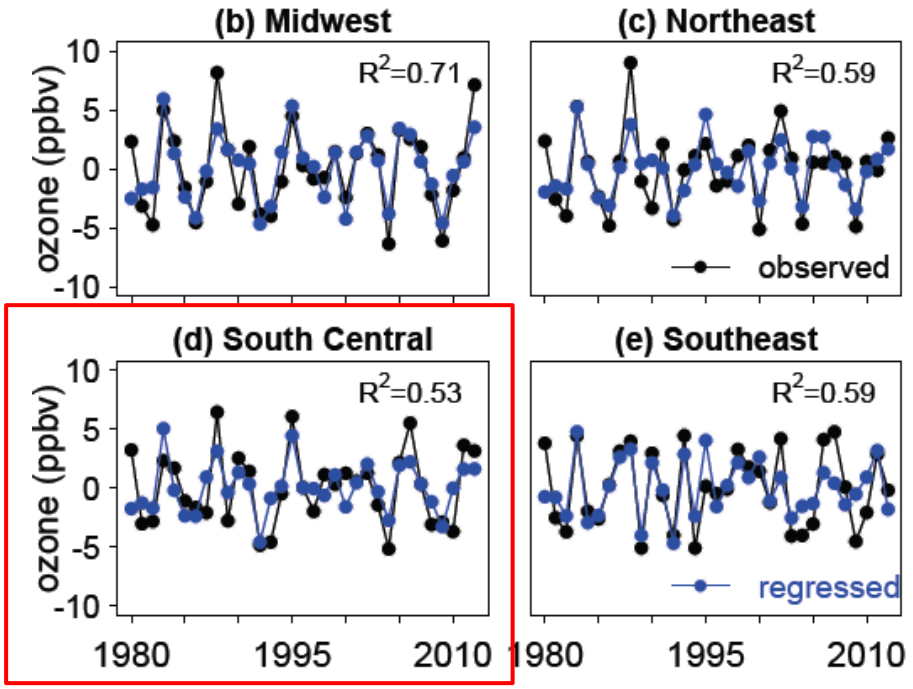
Comparison with other studies

Summer MDA8 and BHI (1993-2010)



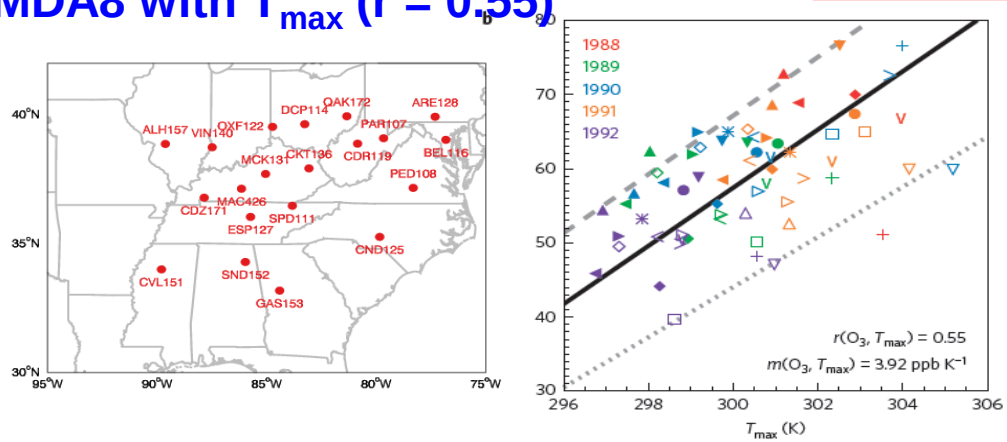
Zhu and Liang, 2013

Summer MDA8 with BH-Lon and polar jet



Shen et al, 2015

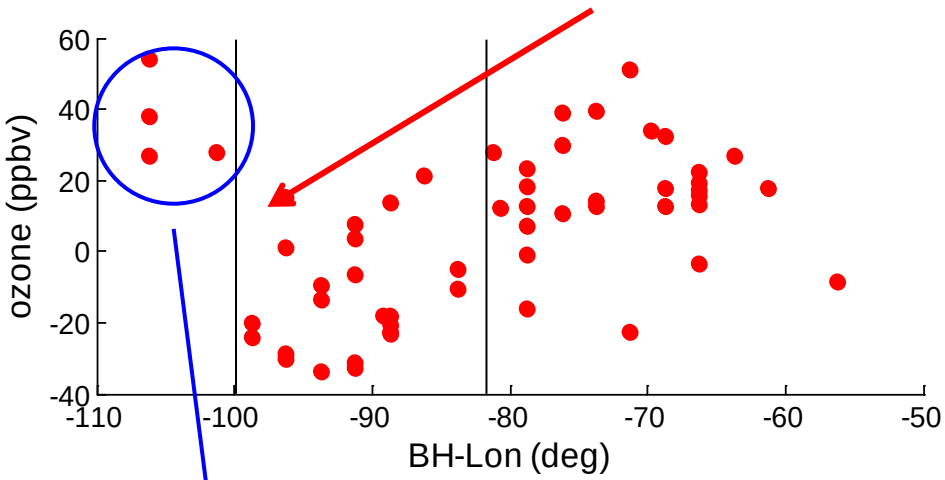
Aug MDA8 with T_{max} (r = 0.55)



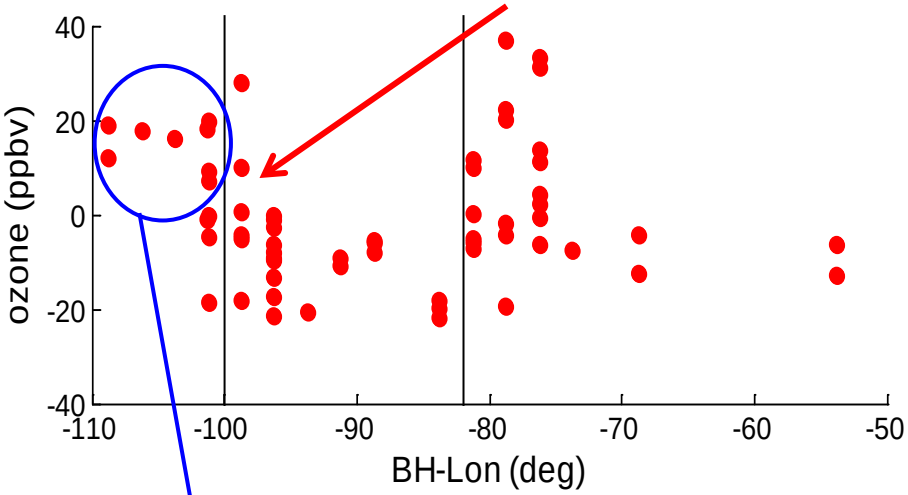
Fu et al, 2015

Future Direction: explore daily scale variability

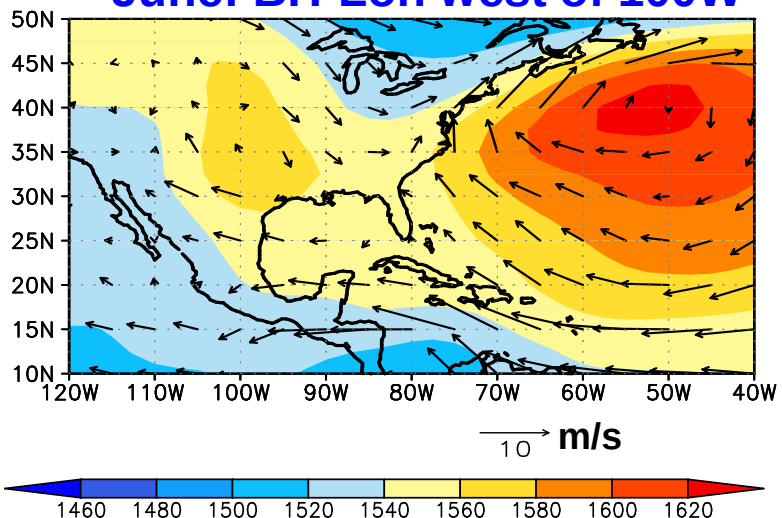
June O_3 daily anomaly vs. BH-Lon



July O_3 daily anomaly vs. BH-Lon

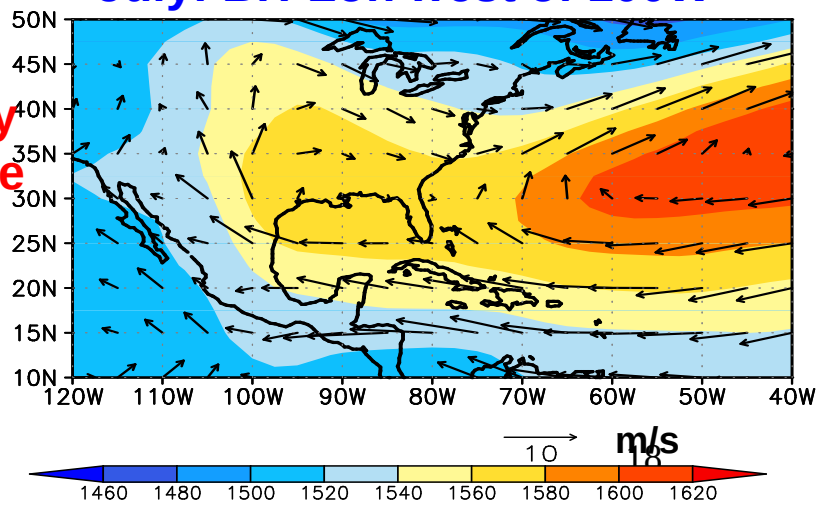


June: BH-Lon west of 100W

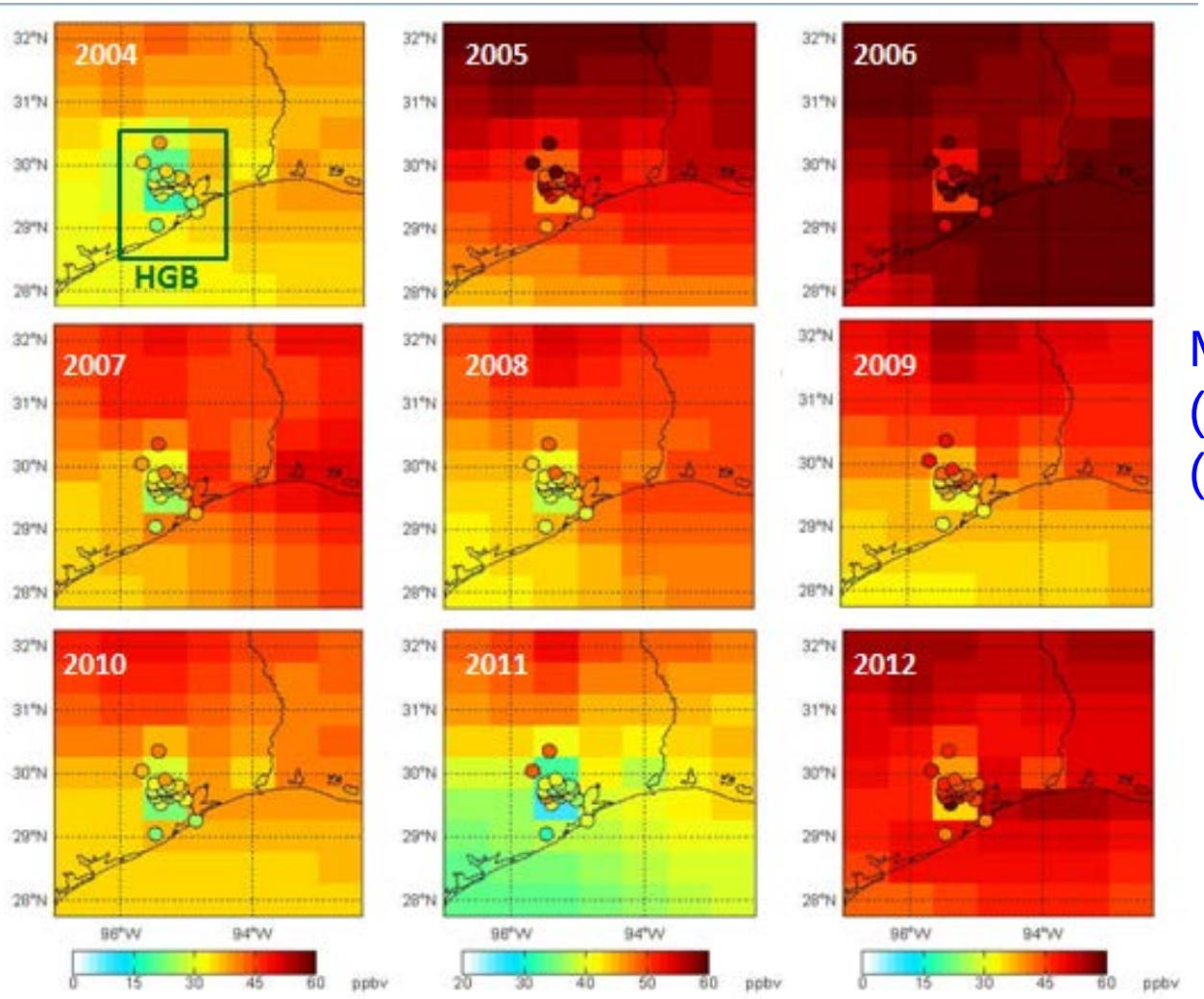


HGB influenced by high pressure system: stable atm, subsidence

July: BH-Lon west of 100W



GEOS-Chem model simulation (Jun 2004-2012)

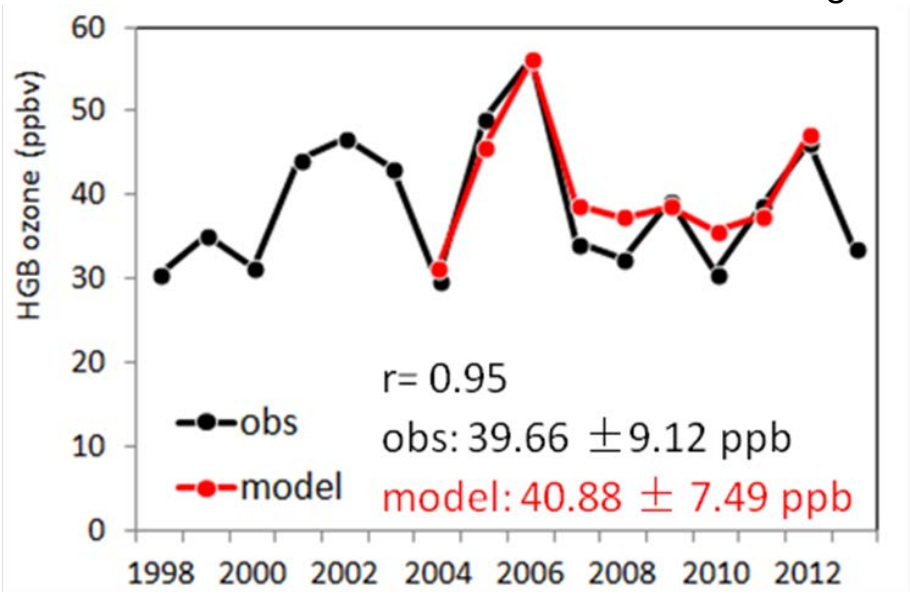


Model has high biases
(1) Coastal regions
(2) Urban sites

Year-to-year change in meteorology (GEOS-5) and emissions (NEI); Model resolution 0.5^{o} x0.667^{o}

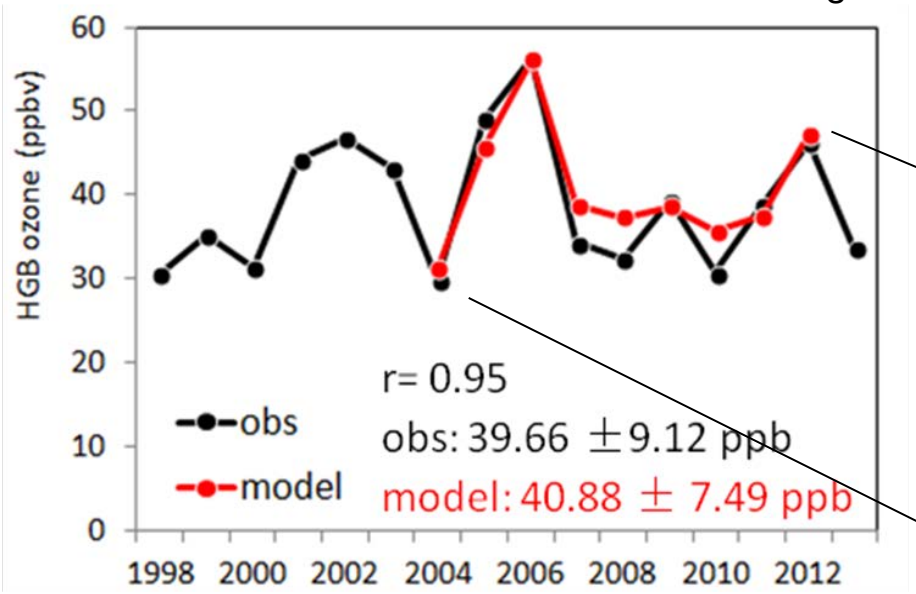
GEOS-Chem model evaluation

Interannual variations of Jun O_3

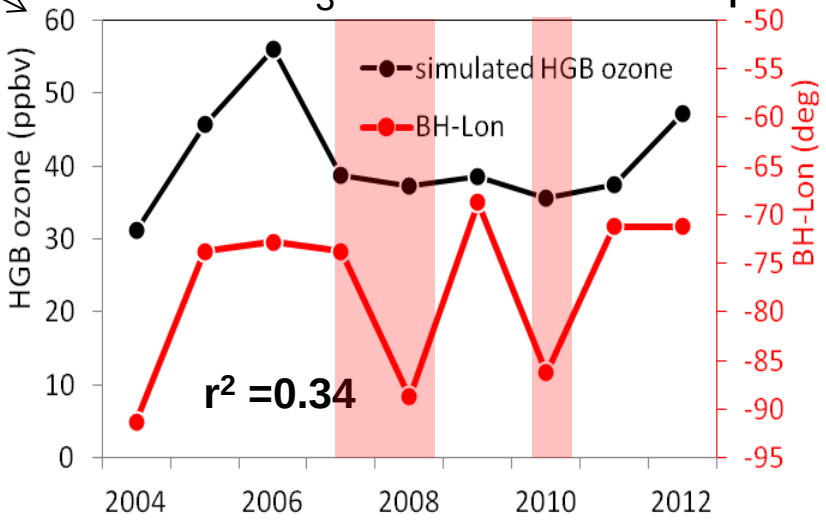


GEOS-Chem model evaluation

Interannual variations of Jun O_3



Simulated O_3 – BH relationship



Proposed Correction Scheme

$$C_{m,c} - C_{m,o} = \beta_0 + \beta'_{BH}\, x_{BH}$$

Progress Summary

Motivating Hypothesis (confirmed)

Large-scale circulation pattern, particularly the Bermuda High (BH), is the key driver for MDA8 O_3 variability in HGB during the ozone season

Deliverables:

1. A number of indicators to characterize the influence of large-scale circulation and BH on HGB O_3 on monthly scale
2. Calibrated and validated MLR model

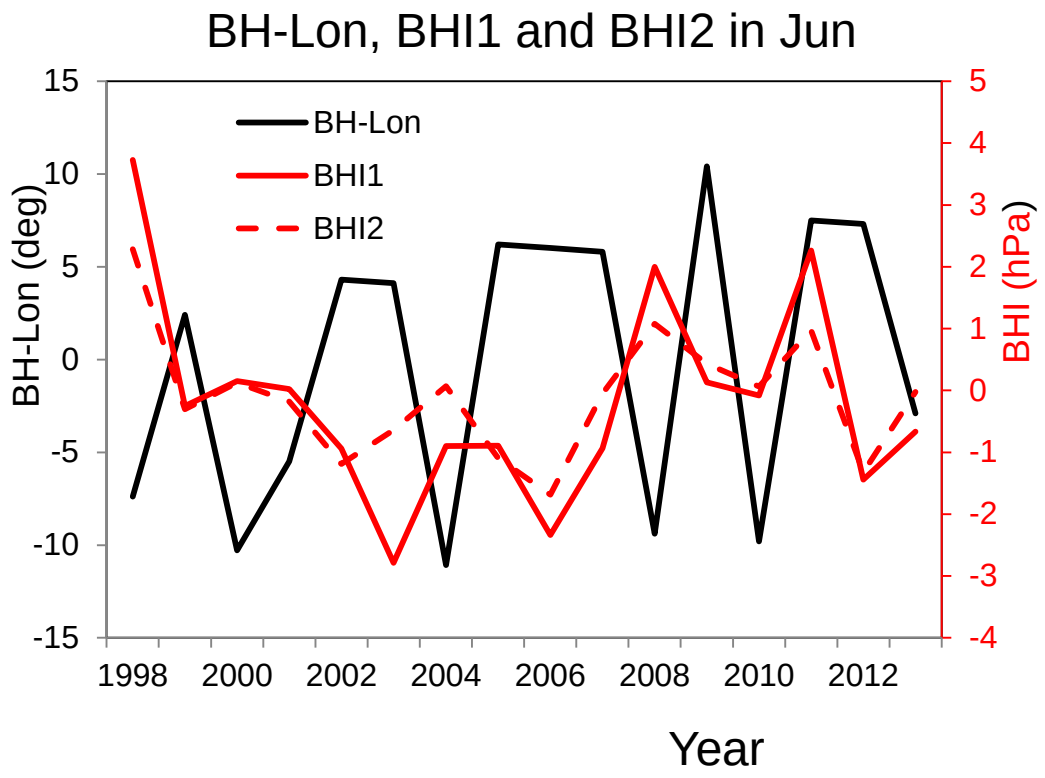
In progress:

Bias correct scheme for background ozone in GEOS-Chem global model

Acknowledgement

- Funding: Texas AQRP
- Graduate Students: Yuanyu Xie, Jiaxi Hu
- Mark Estes (TCEQ)

- BHI1 = SLP1-SLP2
- BHI2 = SLP1-SLP3
- BHI1 and BHI2 are positively correlated.



Correlations:
BH-Lon and BHI1: -0.36
BH-Lon and BHI2: -0.46
BHI1 and BHI2: 0.89

In June, BHI2 is mostly positive (SLP1>SLP3). In September, BHI2 is mostly negative (SLP1<SLP3).