Variability in inter-hemispheric exchange inferred from tropospheric measurements of SF_6

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Thank You to those involved in cooperative sampling network,
and to Fred Moore, Steve Montzka, and Eric Ray

Introduction

Mechanisms of Inter-hemispheric Exchange

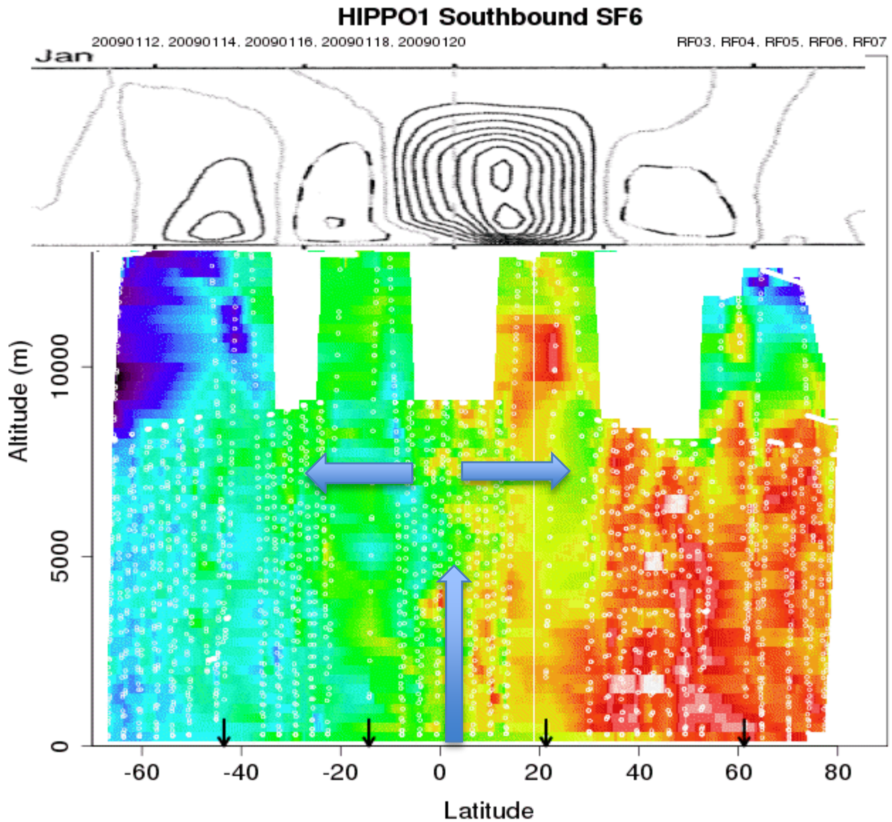
- Convective divergence in the upper troposphere
- Seasonality in Hadley circulation (movement of the ITCZ)
- Propagation of Rossby waves through tropical western ducts

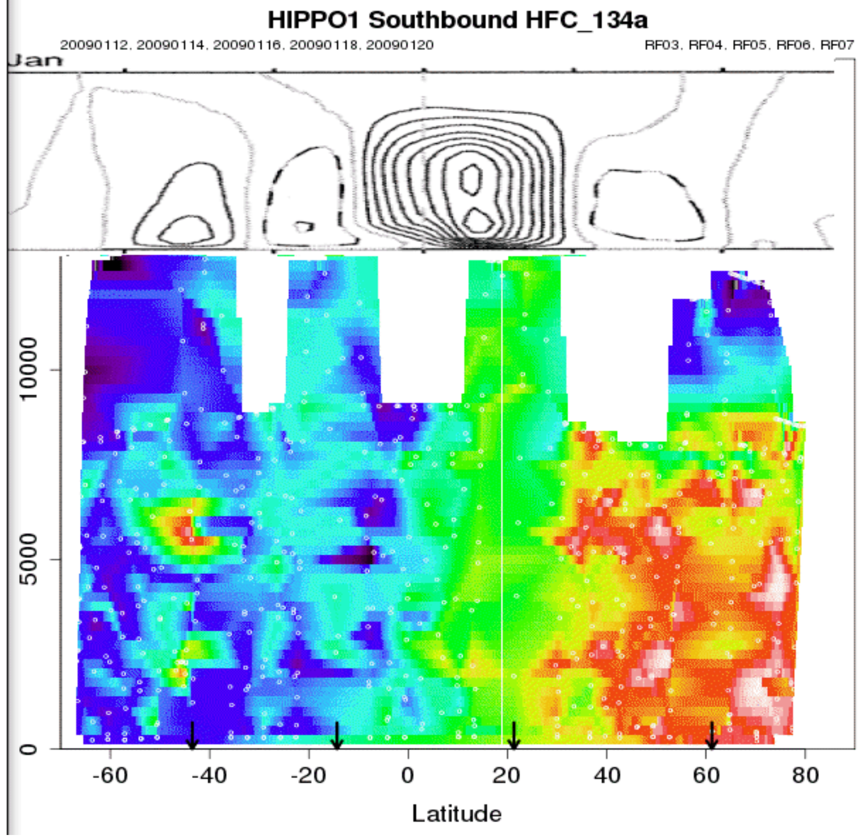
Use global SF_6 observation to examine:

- Annual Cycle
- Inter-Annual Variability
- *Trends*

January: Strong convection, mixing between hemispheres

Mean Stream function - NCEP-NCAR reanalysis (I M Dima and JM Wallace 2002)

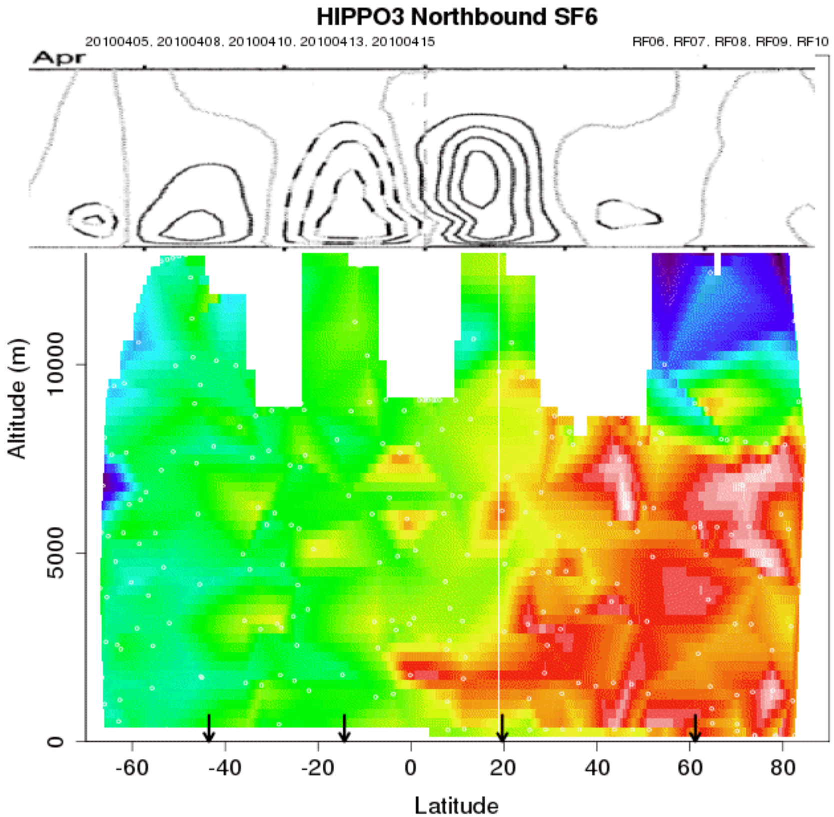


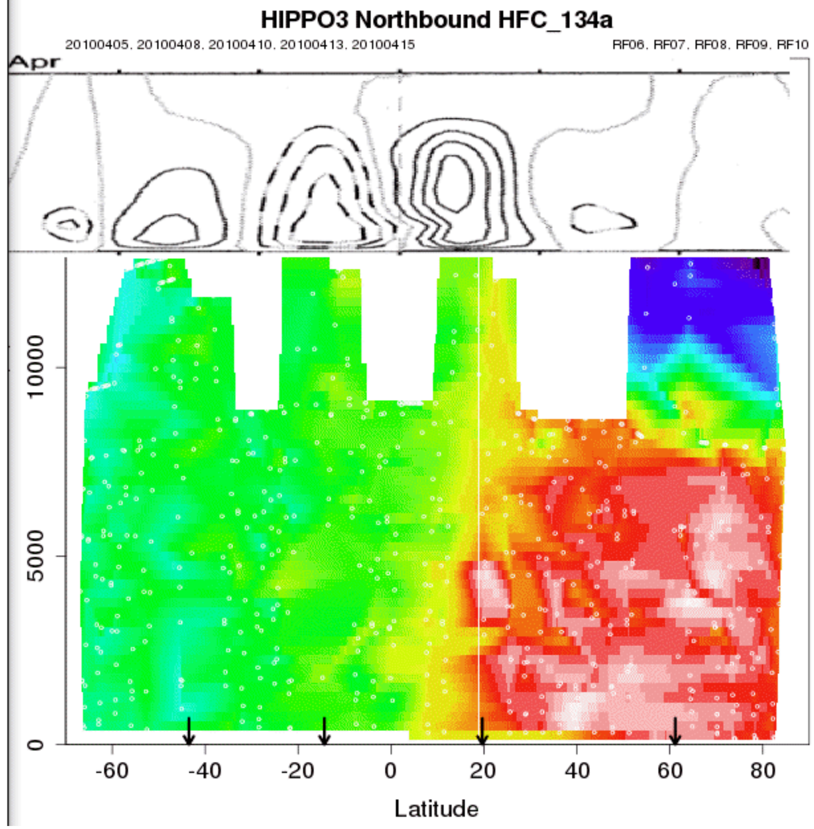


Courtesy of Fred Moore

April: Well-mixed hemispheres, limited mixing between hemispheres

Mean Stream function - NCEP-NCAR reanalysis (I M Dima and JM Wallace 2002)





Courtesy of Fred Moore

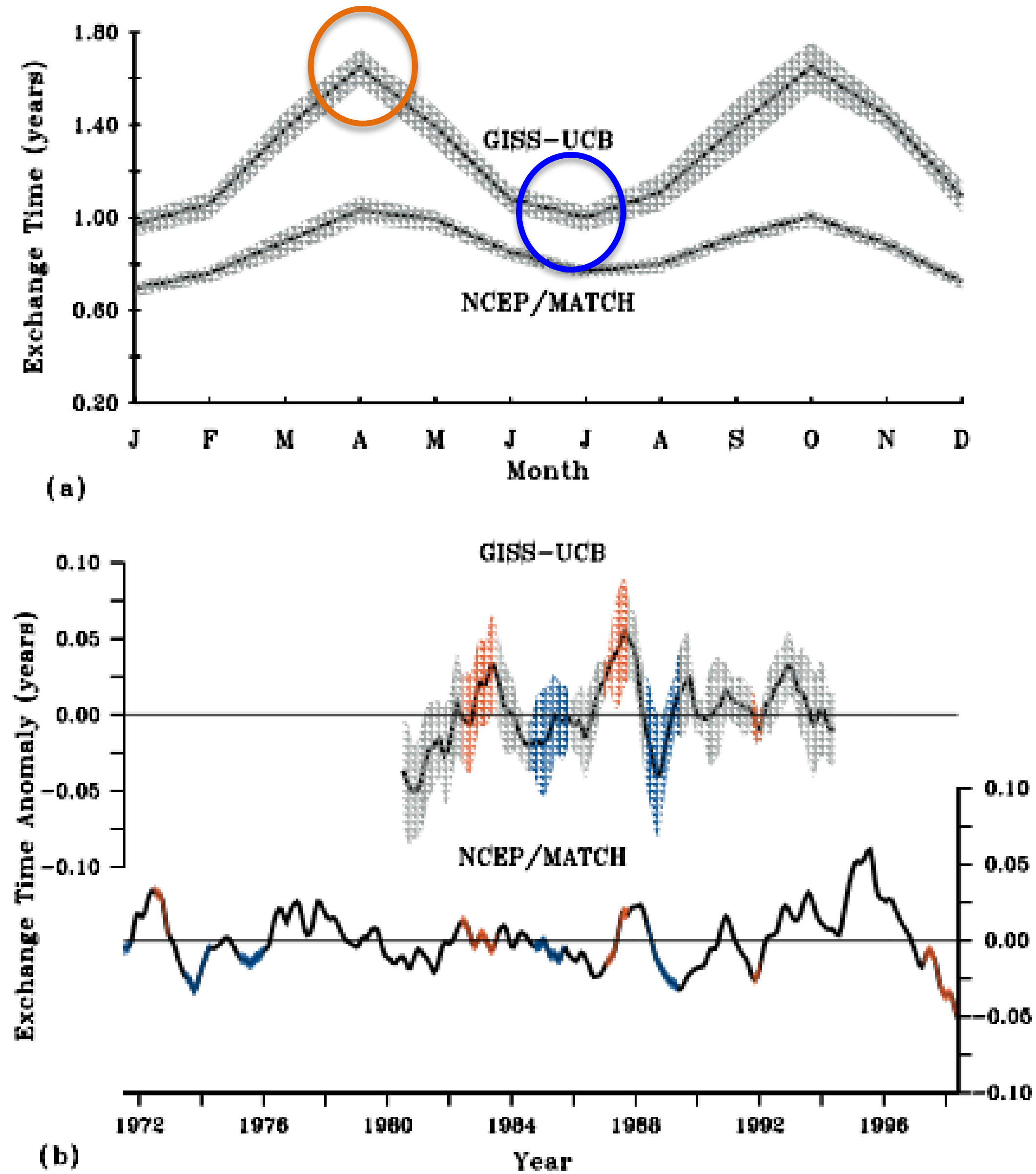
Mean Inter-Hemispheric Exchange time

Range: 1.0-1.5 yr (avg)
Lintner et al., 2004
Waugh et al., 2014
Patra et al., 2009

Models predict bi-modal annual cycle.
Slowest in spring/fall
Fastest in summer/winter

IAV: Mostly studied using models.

- Link to ENSO
- **Slower during El Niño**
- **Faster during La Niña**



Lintner et al (2004)

2-Box Model:

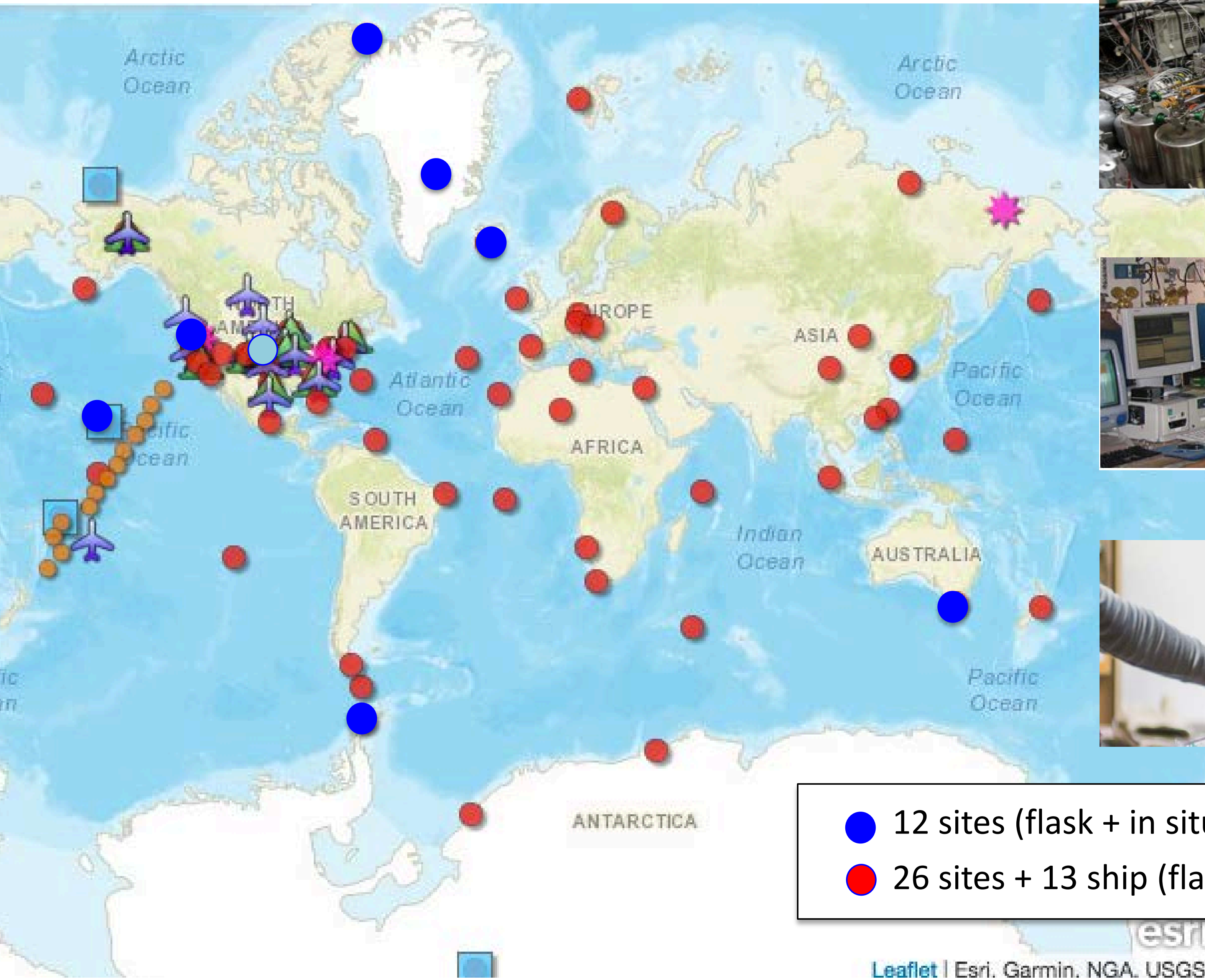
$$\frac{dC_N}{dt} = \frac{E_N}{f} - \frac{(C_N - C_S)}{\tau_{ex}} - \frac{C_N}{\tau_a}$$

$$\frac{dC_S}{dt} = \frac{E_S}{f} + \frac{(C_N - C_S)}{\tau_{ex}} - \frac{C_S}{\tau_a}$$

Let A = E_N/E_S (assume 95% in N.H., A=19)
We do not consider the loss term, or strat/trop exchange

$$\tau_{ex} = \frac{(A+1)(C_N - C_S)}{A\frac{dC_s}{dt} - \frac{dC_N}{dt}} = \frac{20\,(C_N - C_S)}{19\frac{dC_S}{dt} - \frac{dC_N}{dt}}$$

Sampling Networks

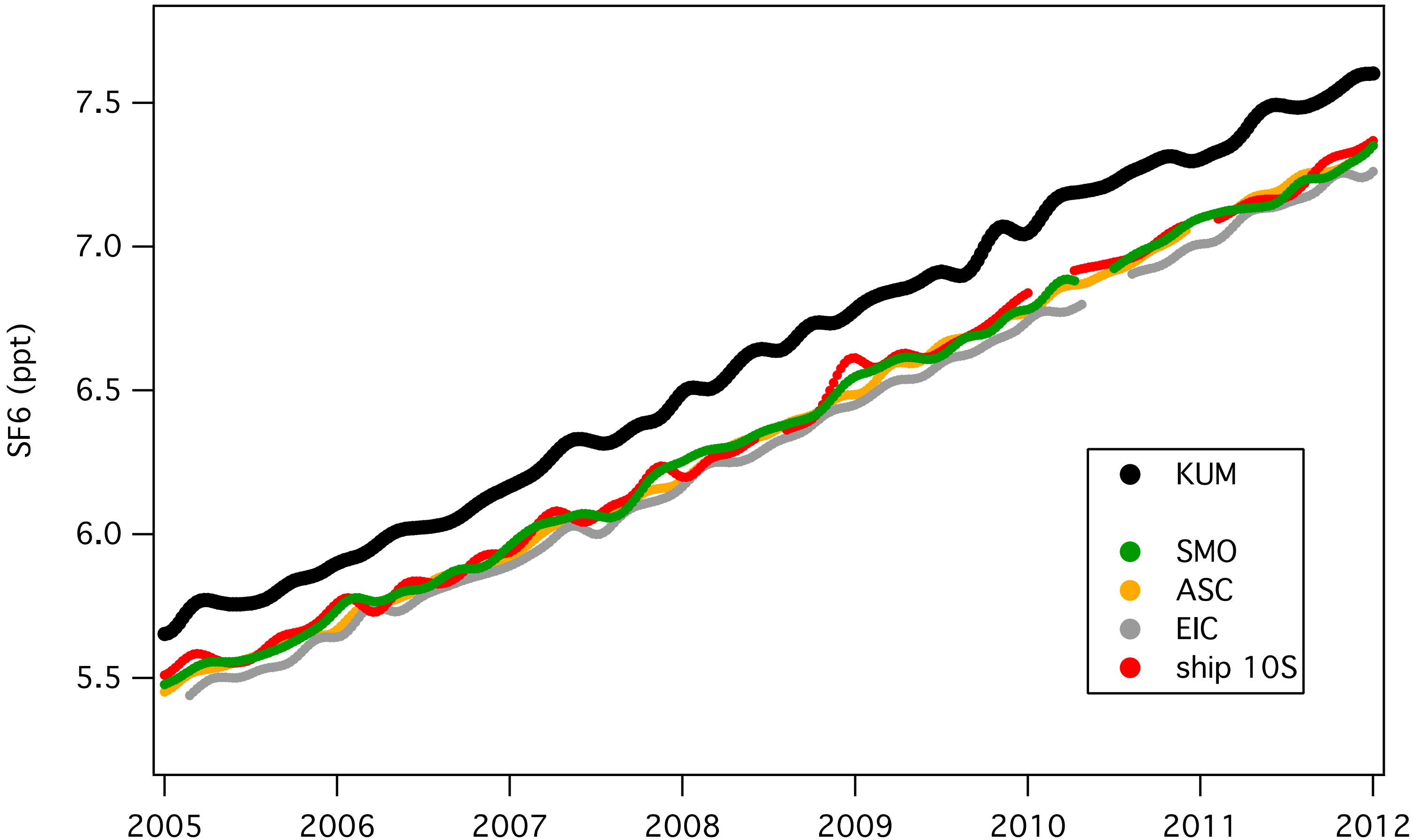


- 12 sites (flask + in situ) (3 high alt.)
- 26 sites + 13 ship (flask) (all MBL)

S.H. Tropics

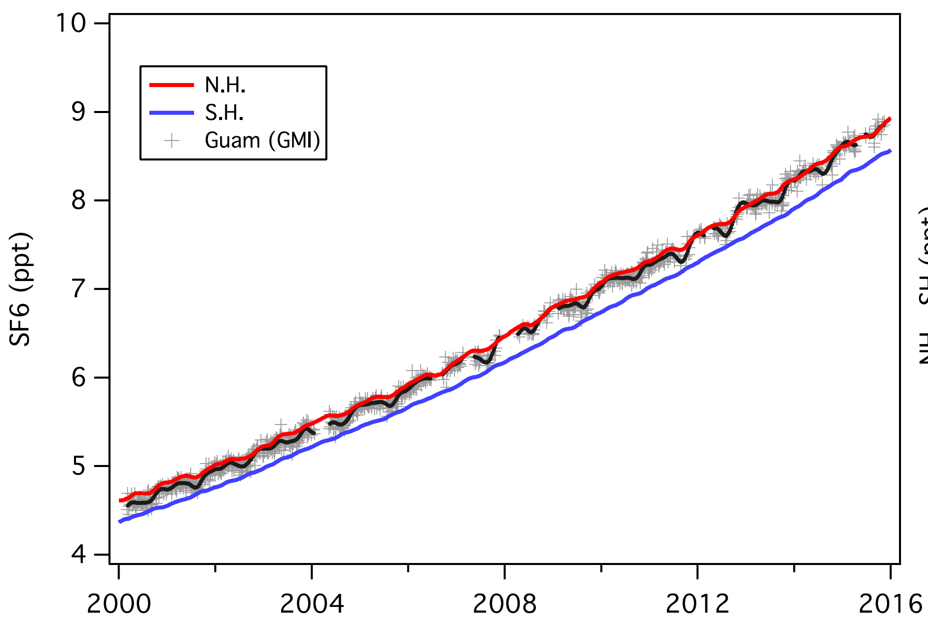
Halocarbon Network: 1 site (SMO), flask + in situ

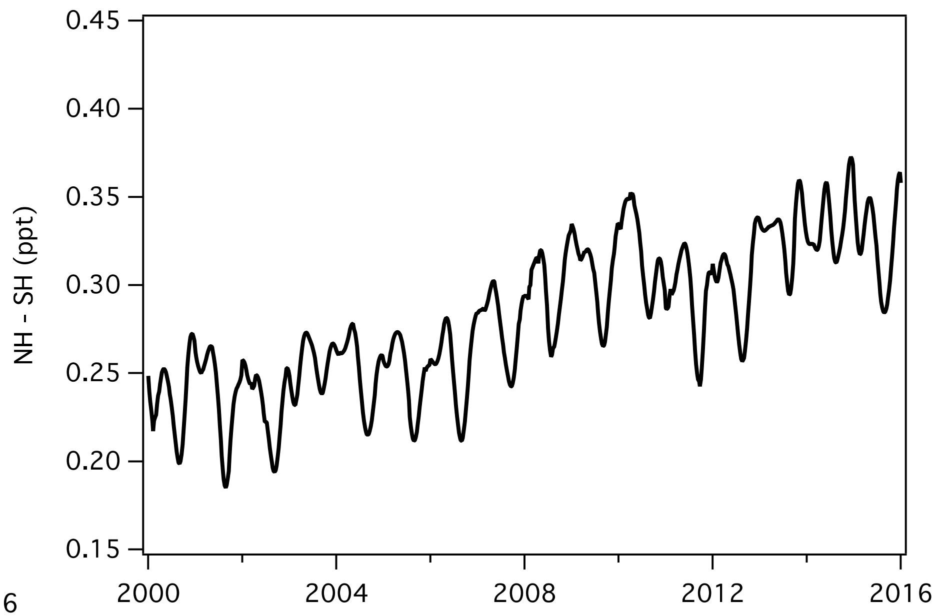
CCGG Network: 2 sites (SMO, ASC, EIC) + 4 ships (-5°, -10°, -15°, -20°)



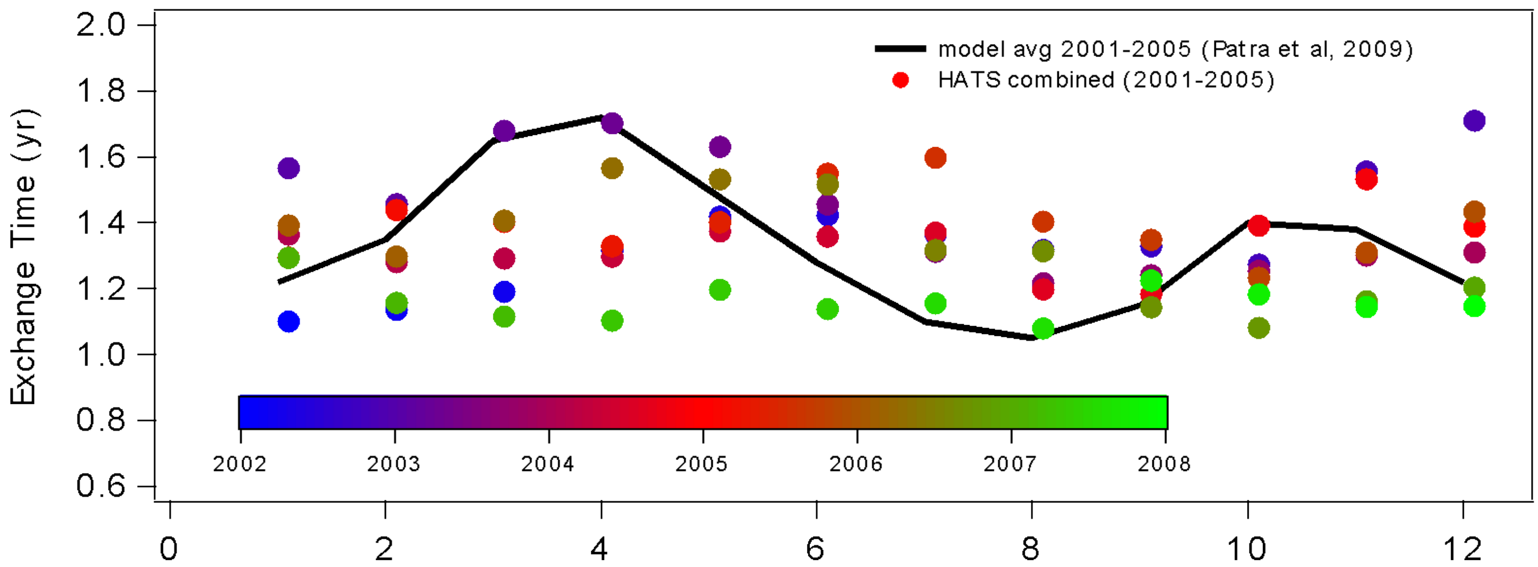
Methods:

- Surface data (marine boundary layer)
- Smoothed, mass-weighed hemispheric averages (CCGG) (Thoning, Massarie)

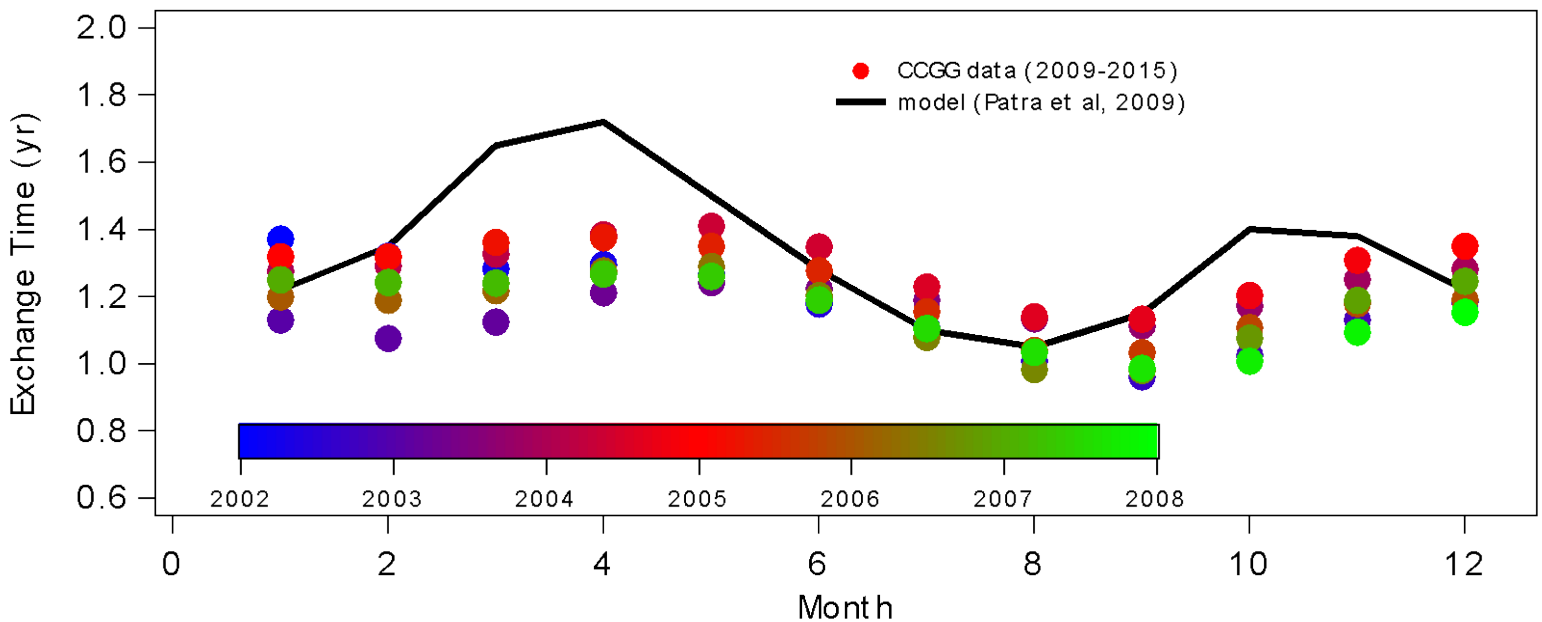




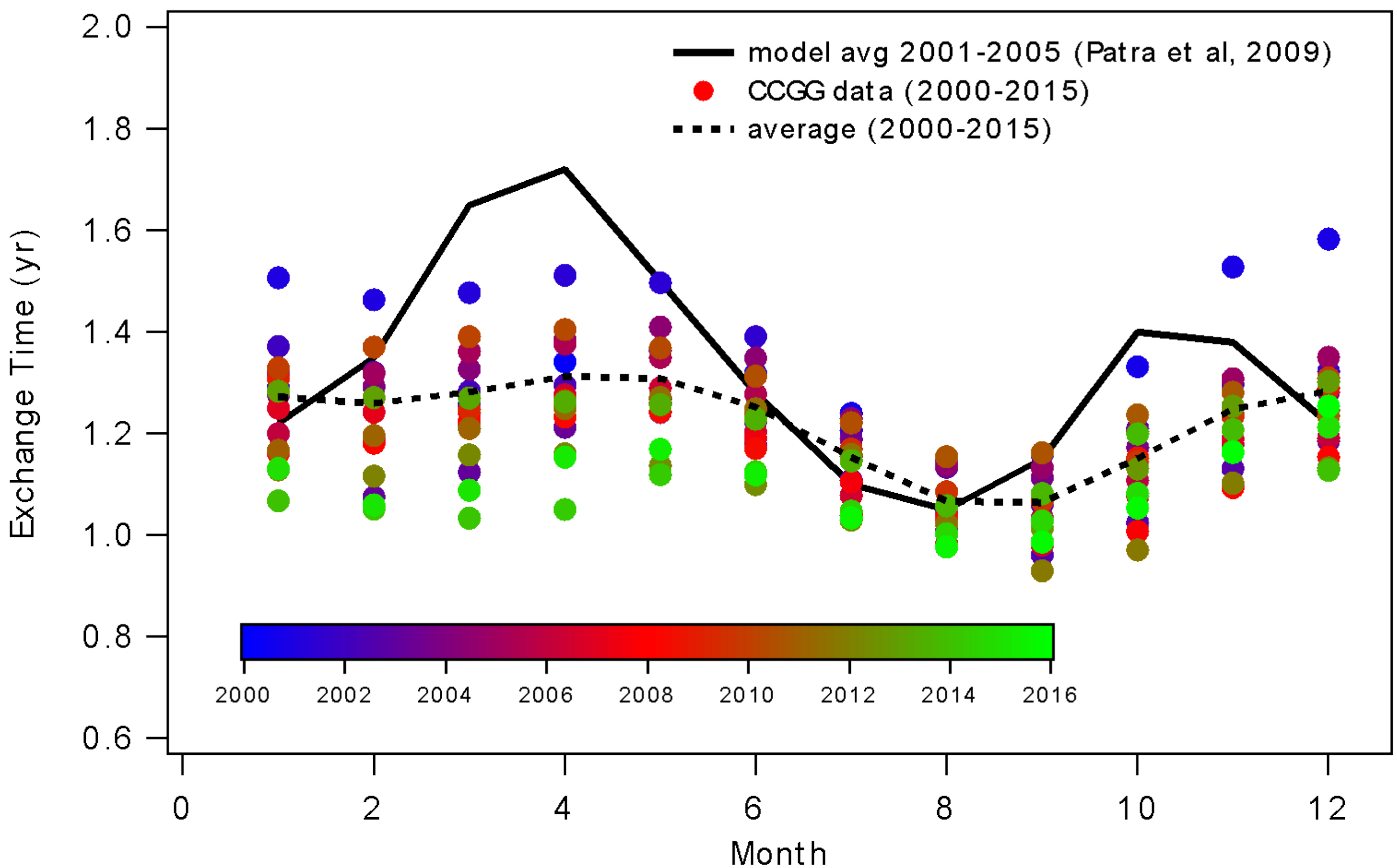
Annual Cycle



Fewer sites



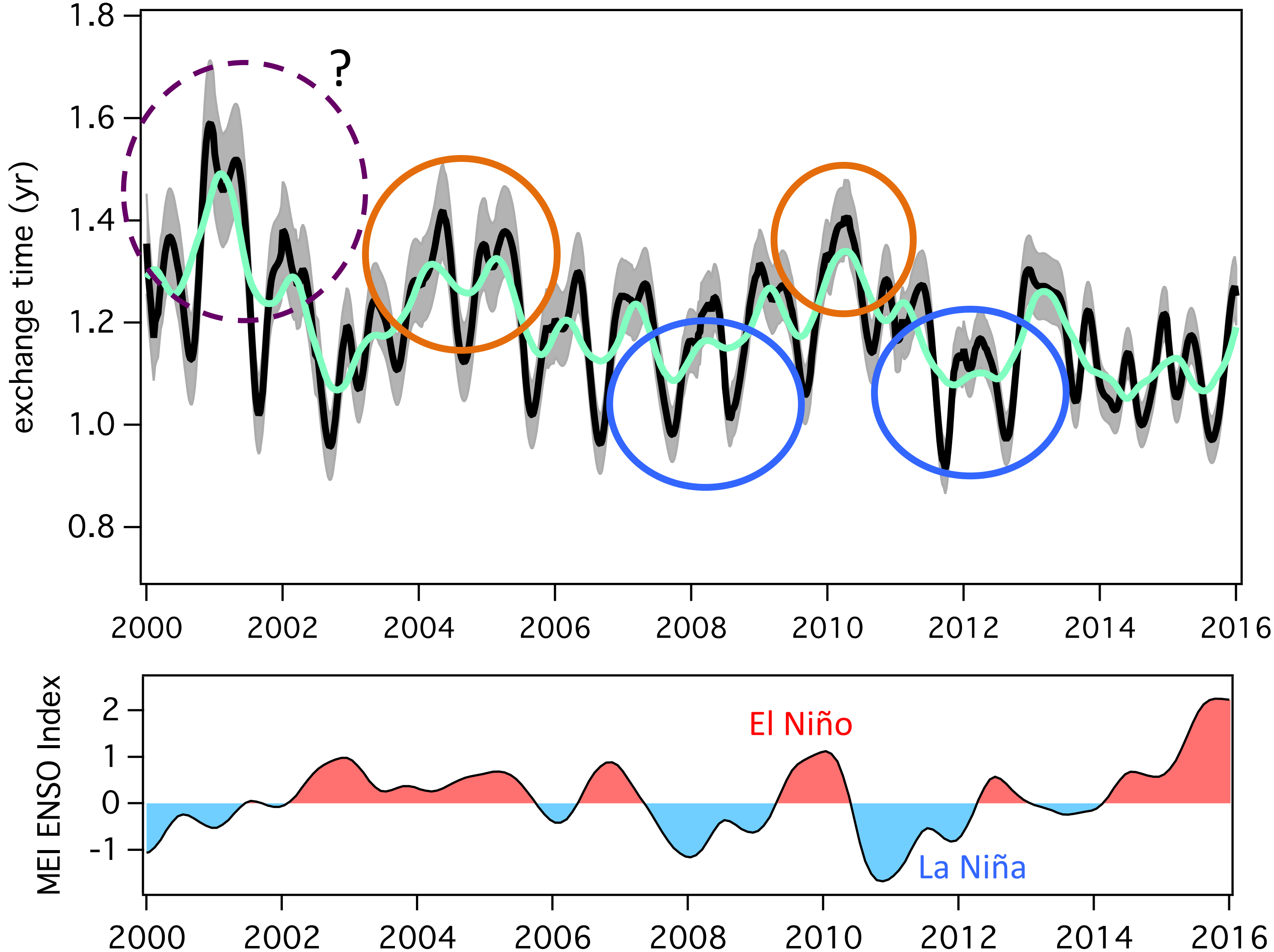
More sites



Mean exchange time (2002-2015) = 1.18 yr

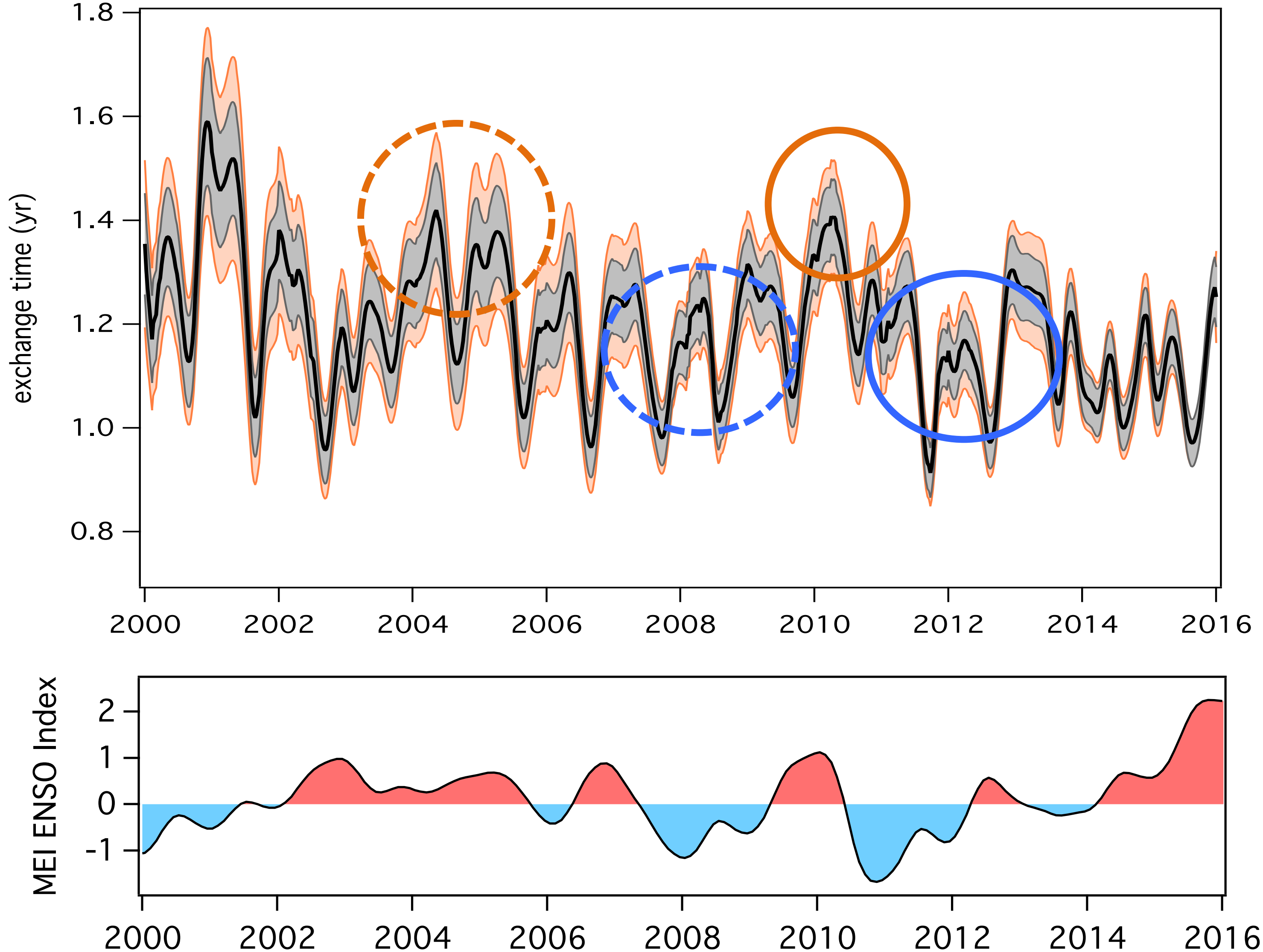
Faster exchange in N.H. late summer.
Faster exchange in N.H. winter solstice not always apparent

Inter-Annual Variability

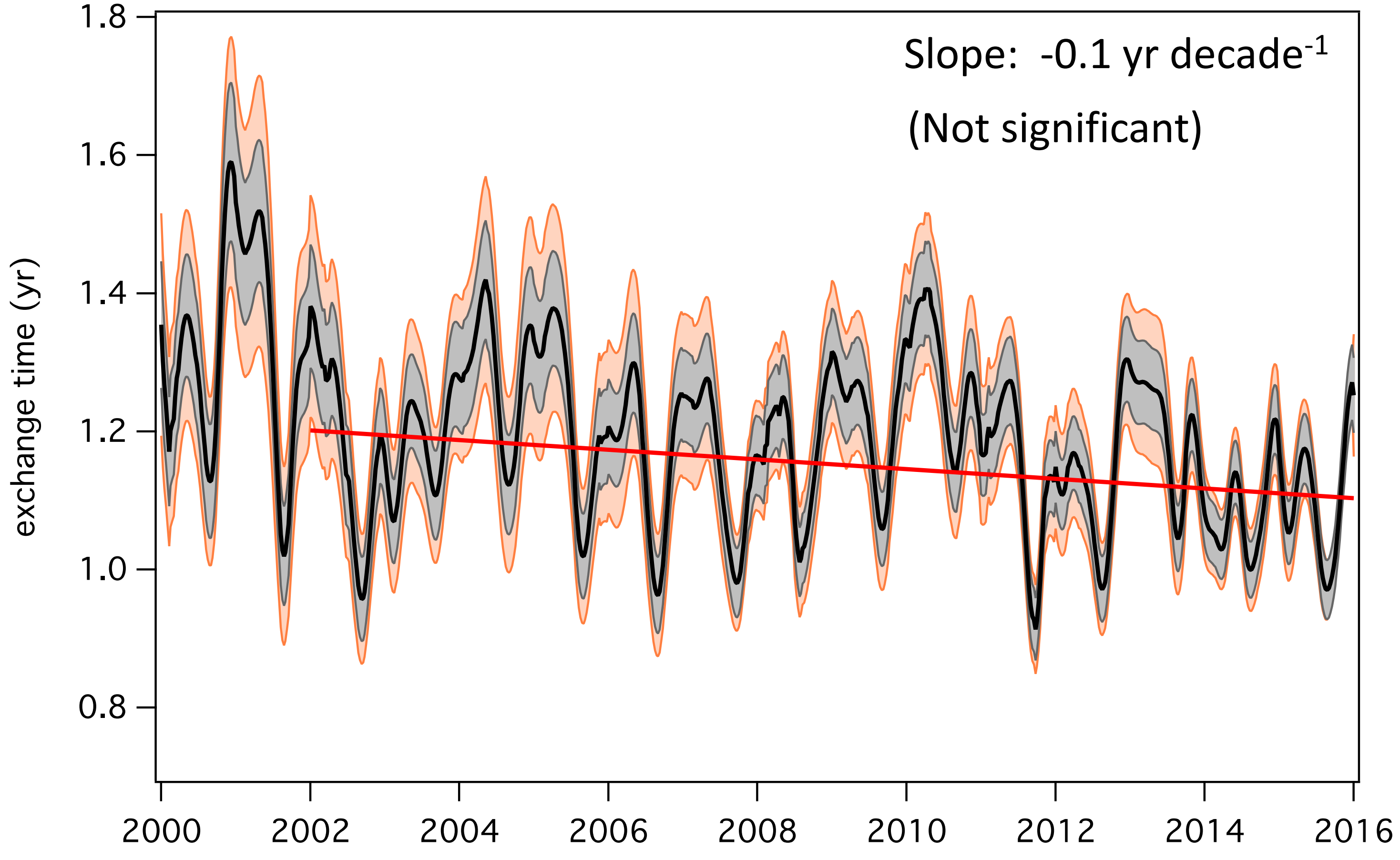


noaaß∑/esrl/psd/mei

Additional Uncertainties

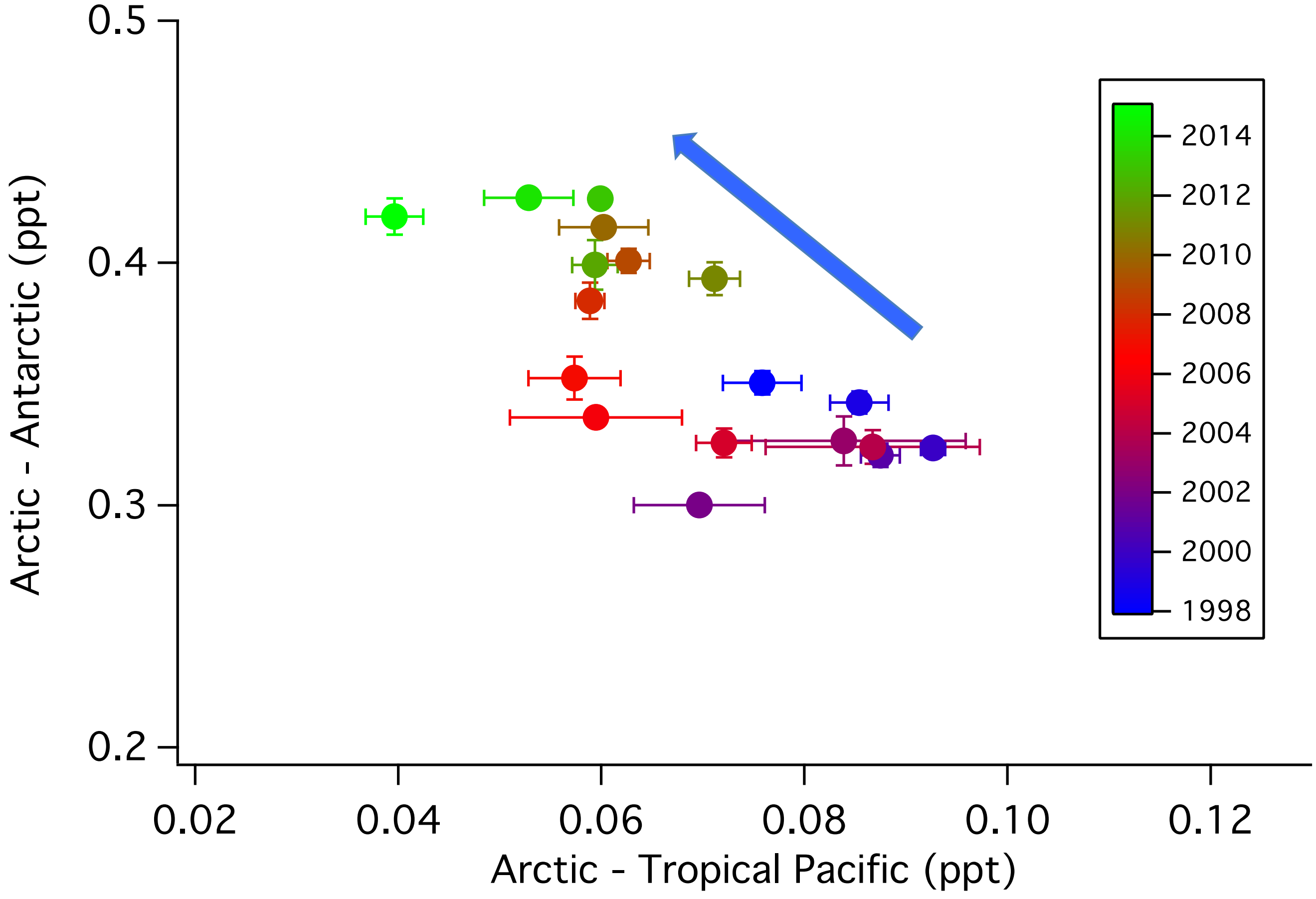


Possible trend towards faster exchange



Assume E_N/E_S constant: 95% from N.H.

Changes in N.H. source distribution: Shift towards lower latitudes



Summary

The mean exchange time from 2002-2015 years is 1.18 yr

We observe an annual cycle, with fastest exchange in Boreal late summer.

Minimum expected in N.H. winter is not always pronounced.

Some IAV correlated with ENSO: Slower during El Niño, faster during La Niña.