Contributions of atmospheric dynamics and chemistry to total ozone variability and trends across the United States: A case study based on long-term ground based data sets

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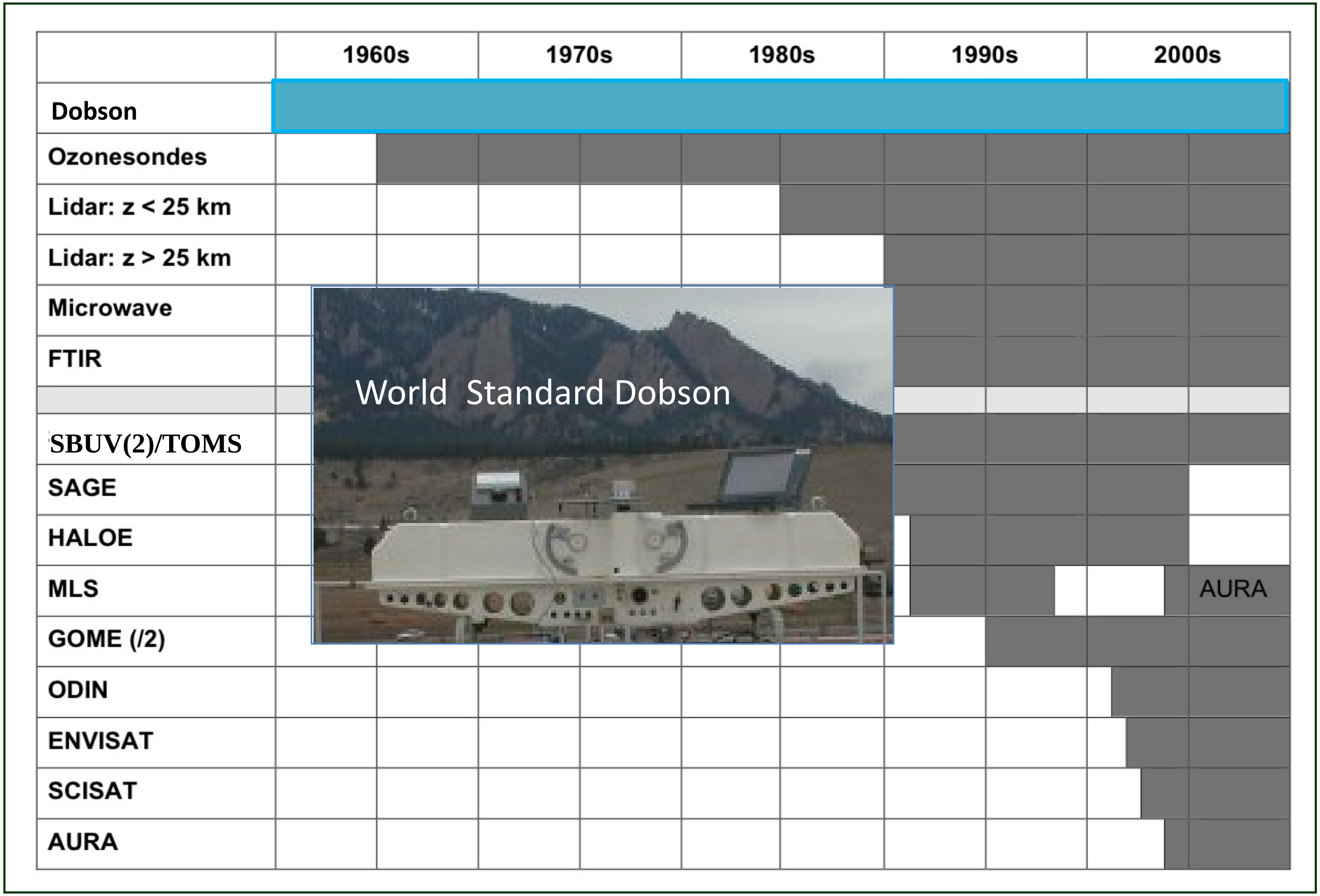
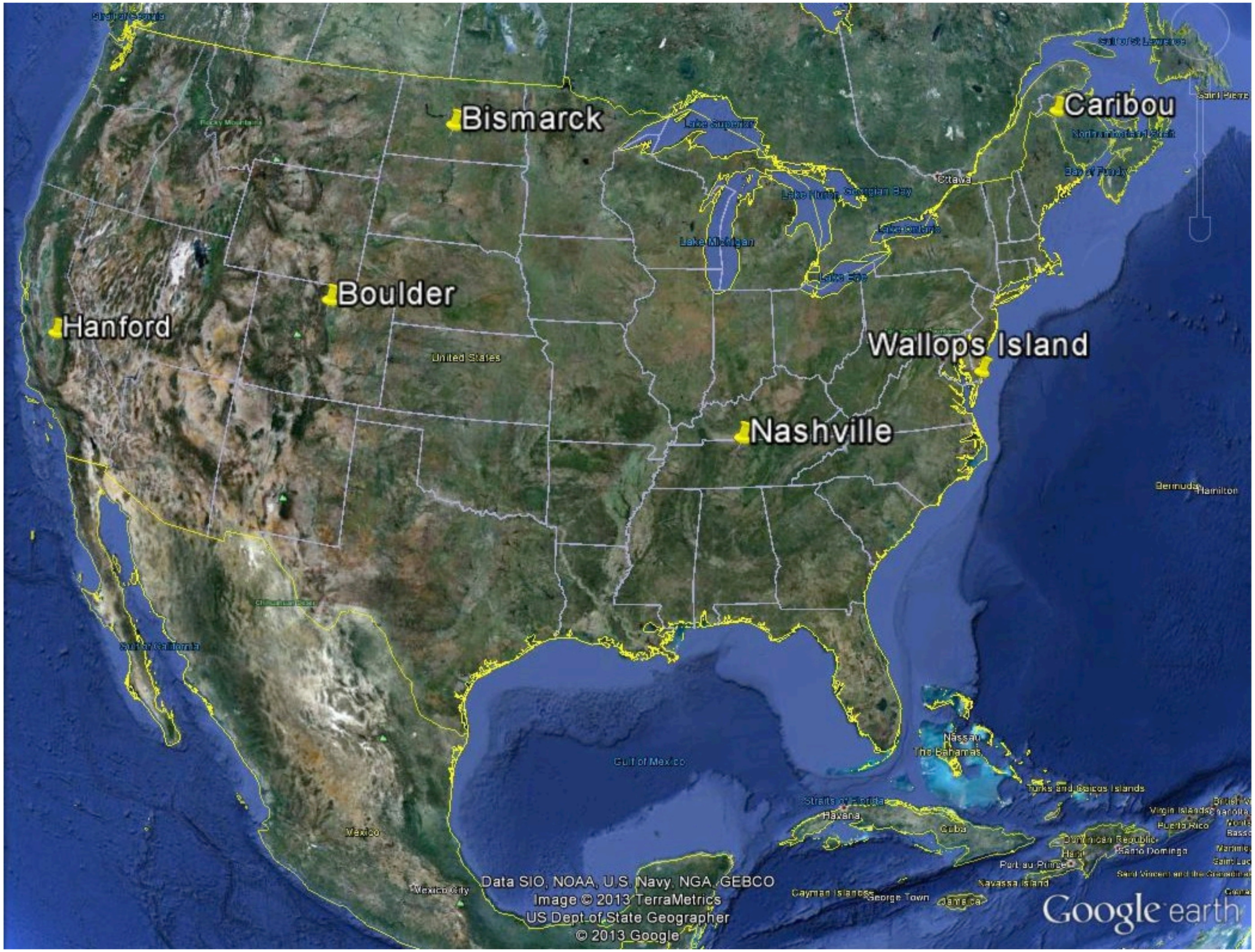
Long-term ozone records



Courtesy of M. Kurylo, SI2N, 2012

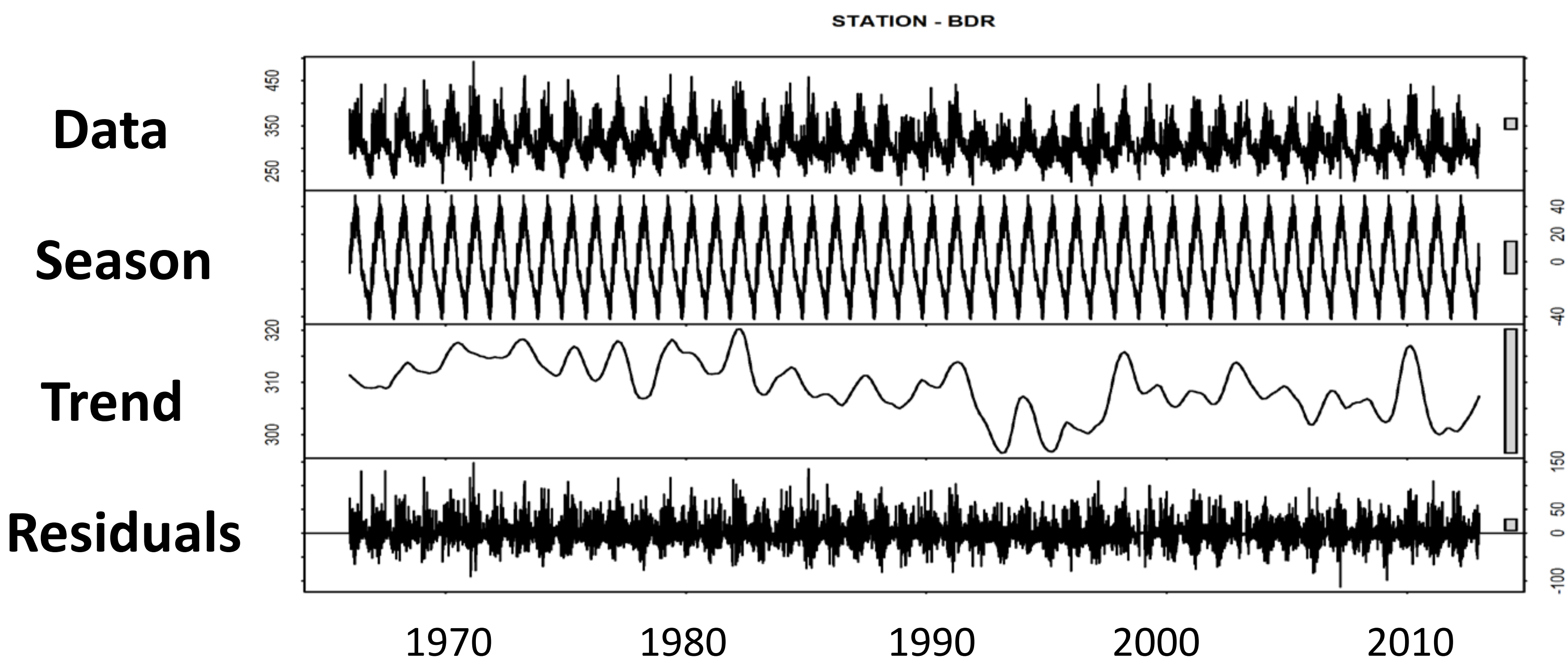
NOAA and NASA USA Dobson stations



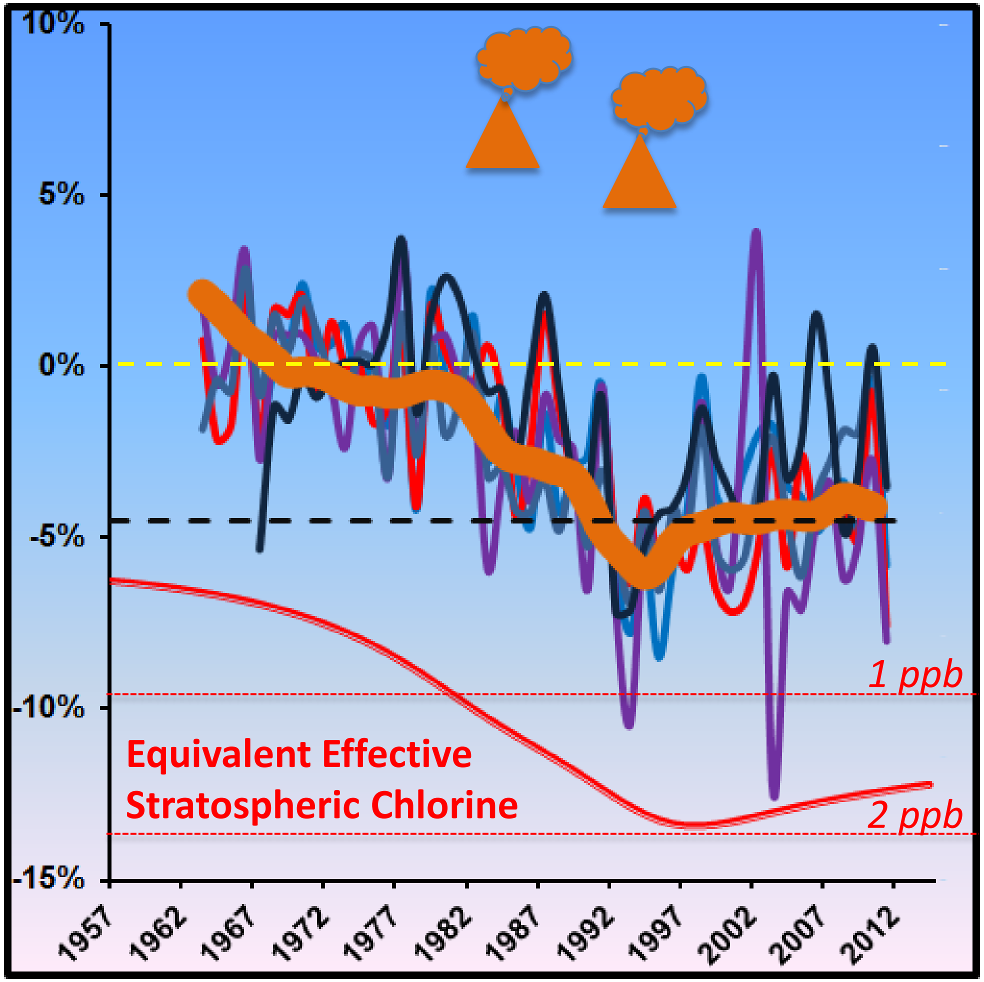
Time series statistical trend analysis:

Seasonal Trend Decomposition based on LOcally wEighted Scatterplot Smoothing (LOESS)

Seasonal Component (S) and
Trend Component (T)
are extracted from data series (D)
Residuals (R) are calculated as R = D-S-T



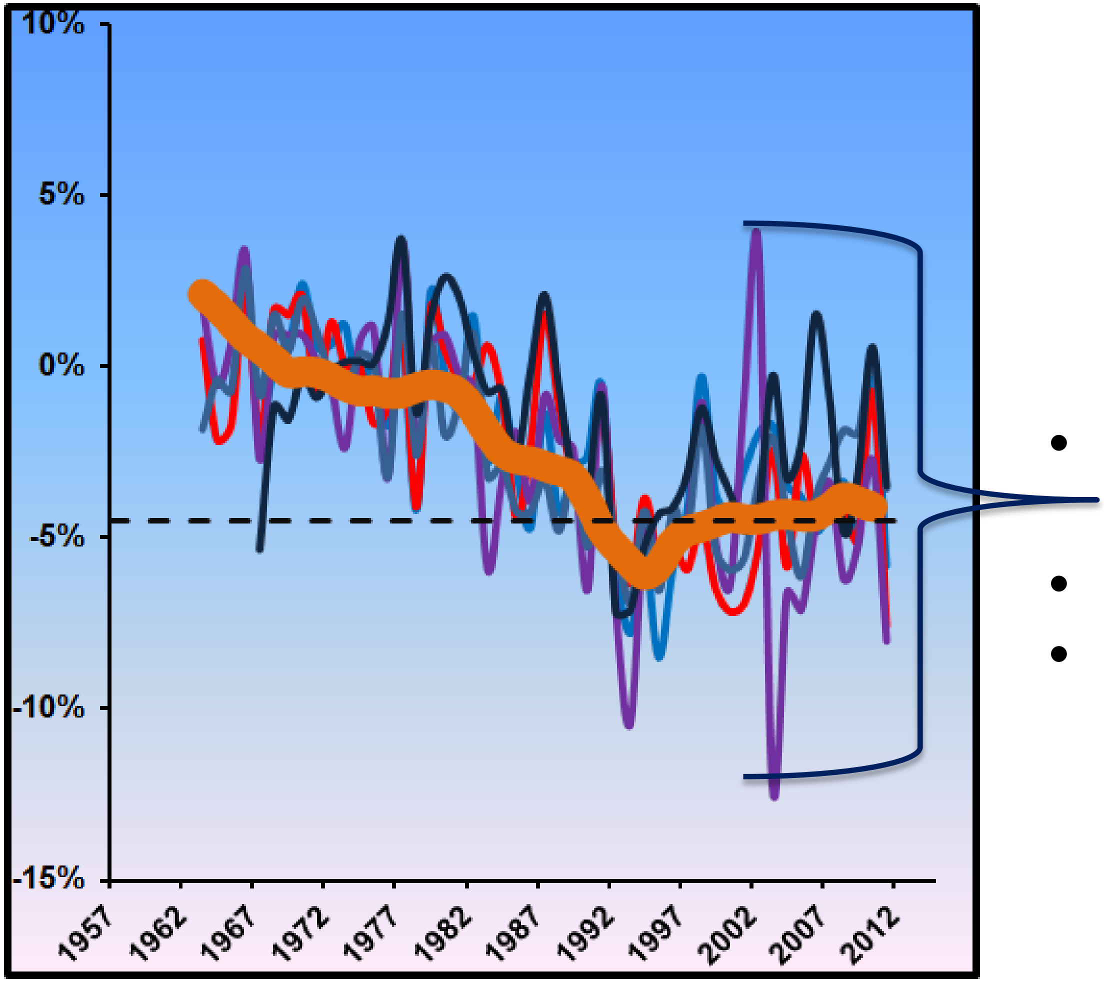
Long term change in stratospheric ozone



El Chichón, Pinatubo

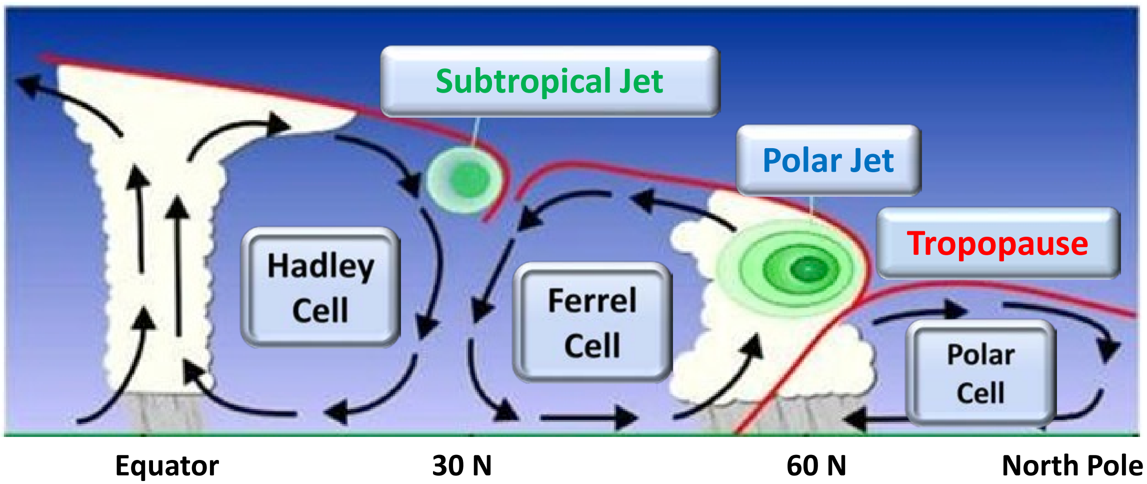
- **62,489**! ozone column
- NOAA middle latitude records shows that mean TO levels are still **4% below** 1970s levels
- **Mechanisms** (Chlorine, volcanic aerosols, solar cycle, transport)

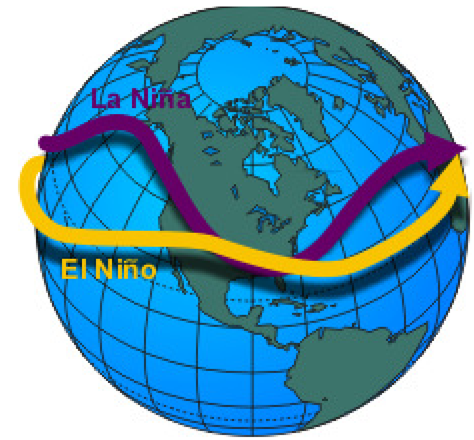
Variability in long term ozone records



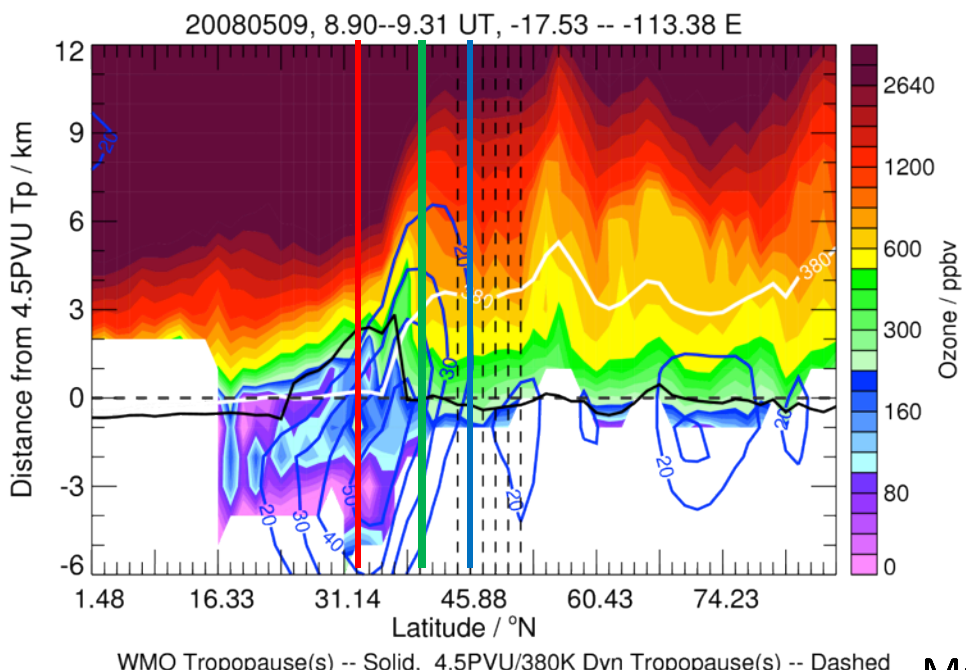
- Increase in inter-annual ozone **variability**
- **What is the cause?**
- Long-term effects of **climate change** on future ozone recovery

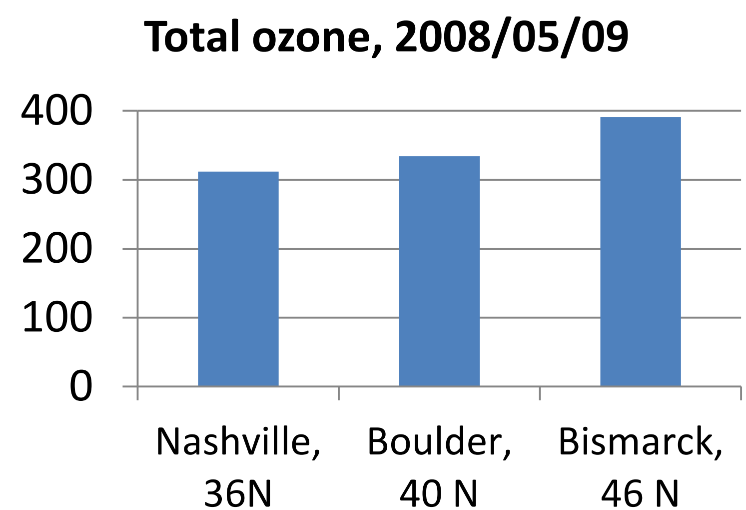
Intra-annual variability and Jet streams





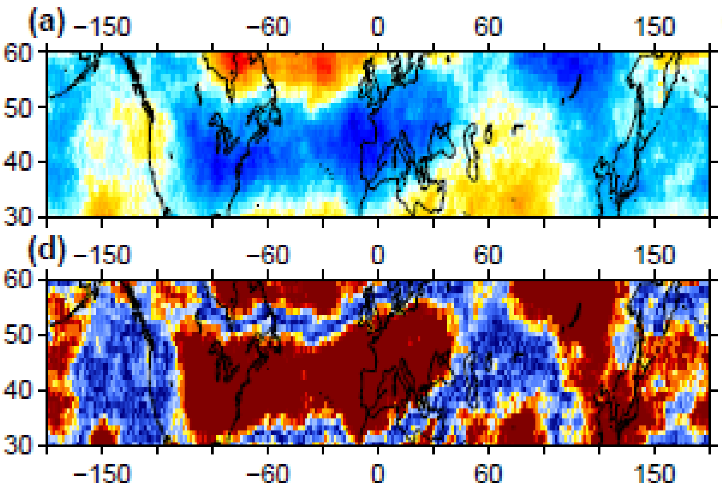
http://www.srh.noaa.gov/jetstream/global/jet.htm





Manney et al, ACP, 2011

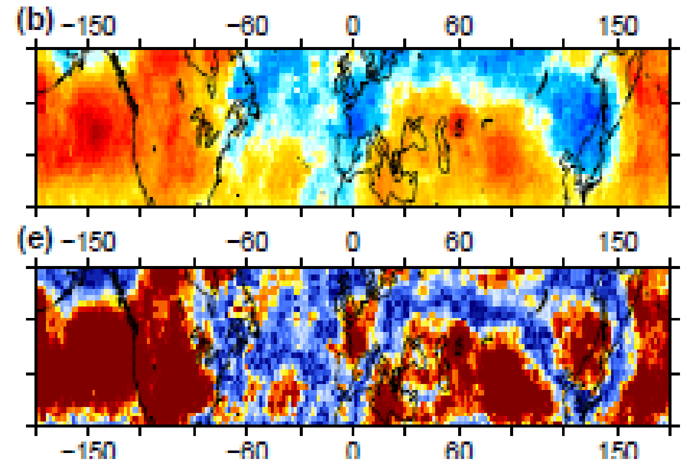
North Atlantic Oscillation → Column Ozone ← El Nino Southern Oscillation



Frossard, et al 2013

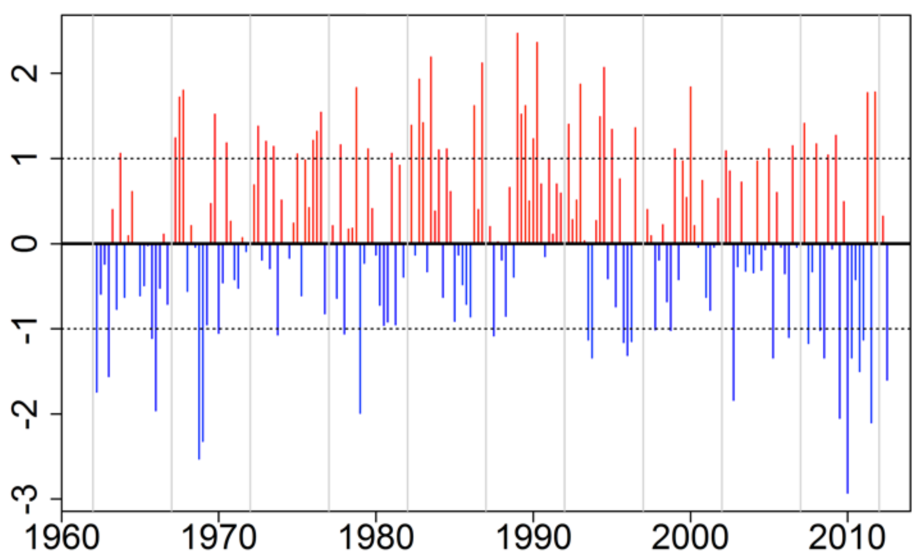
Coefficients

Significance (red >=99%)

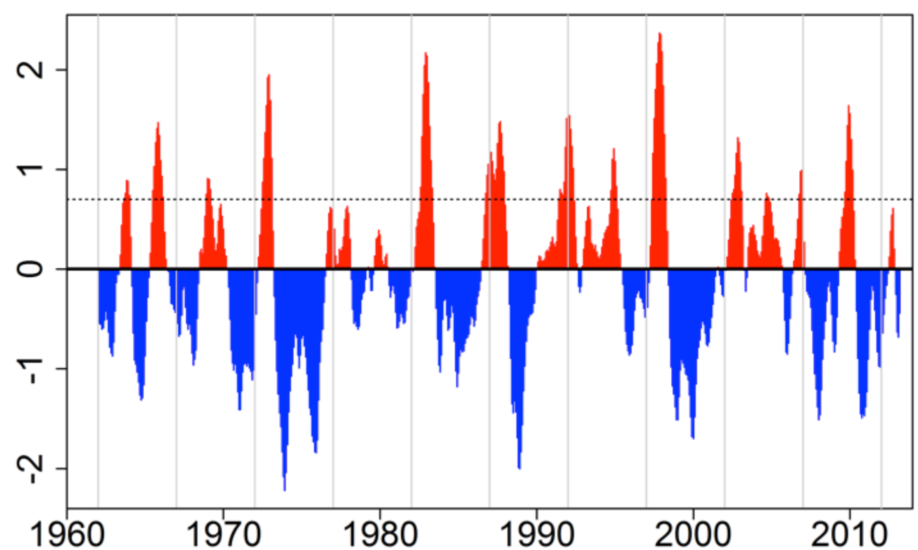


Rieder, et al 2013

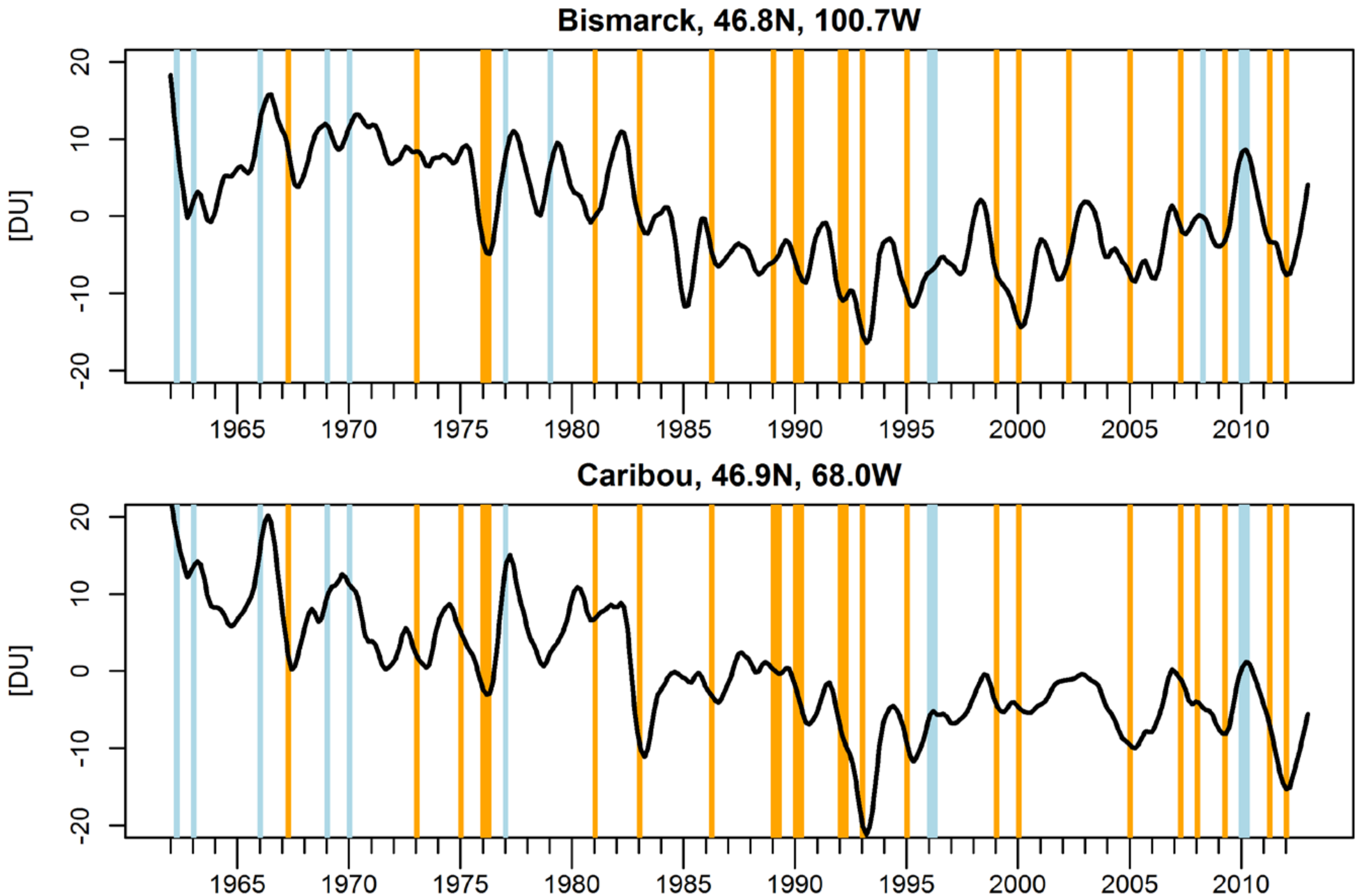
NAO Index



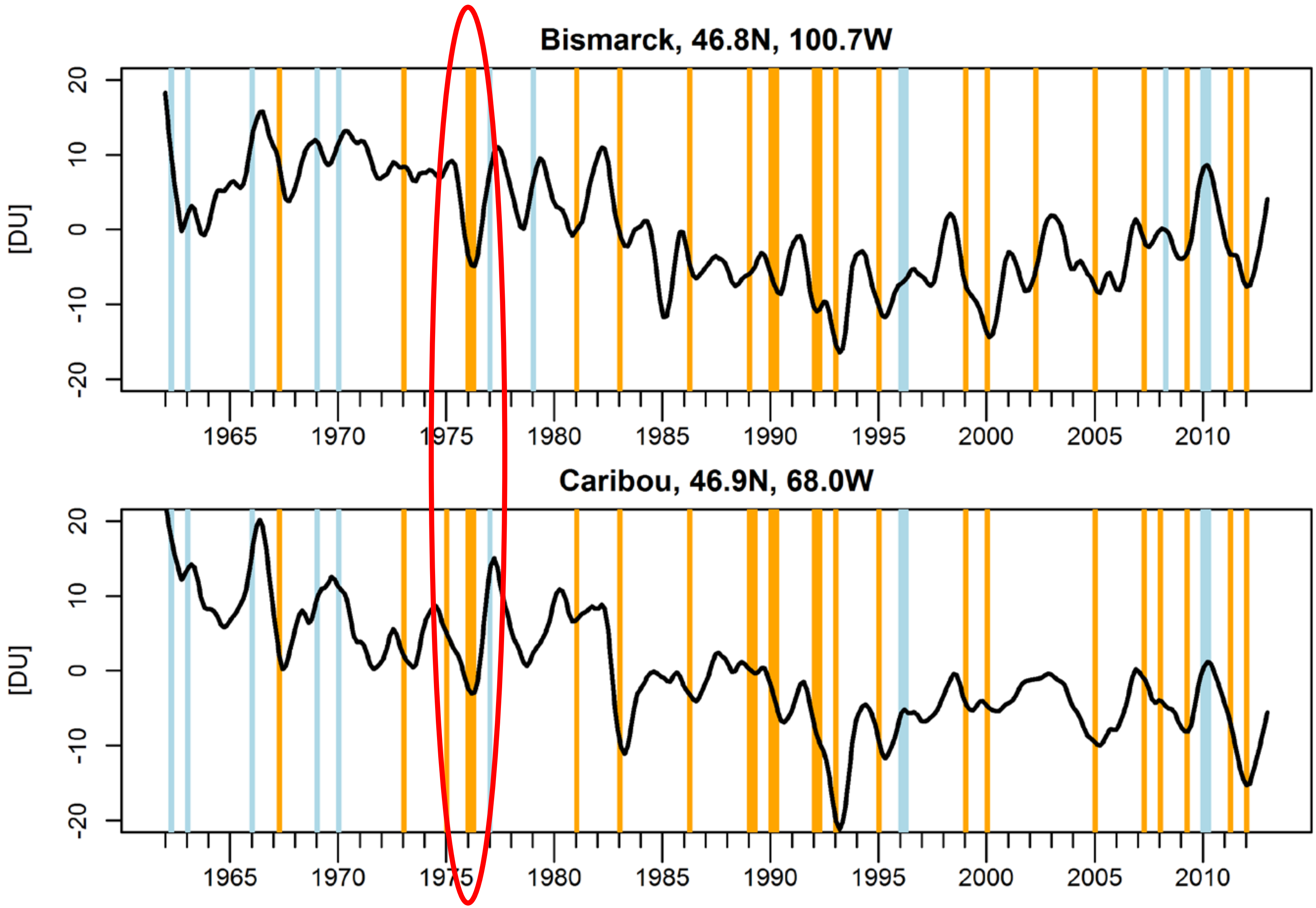
Monthly NINO3.4 Index



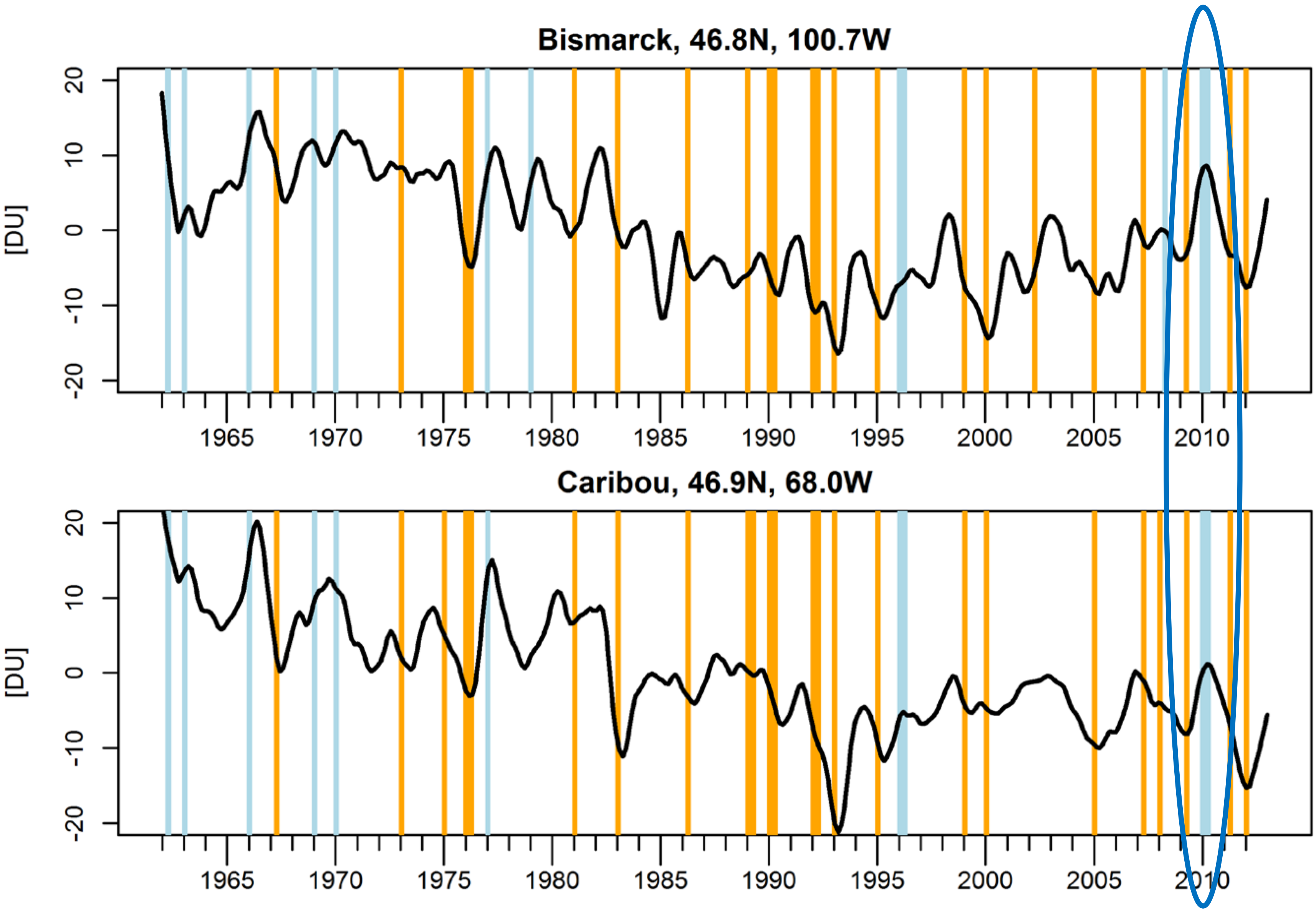
NAO Fingerprints in Trend component

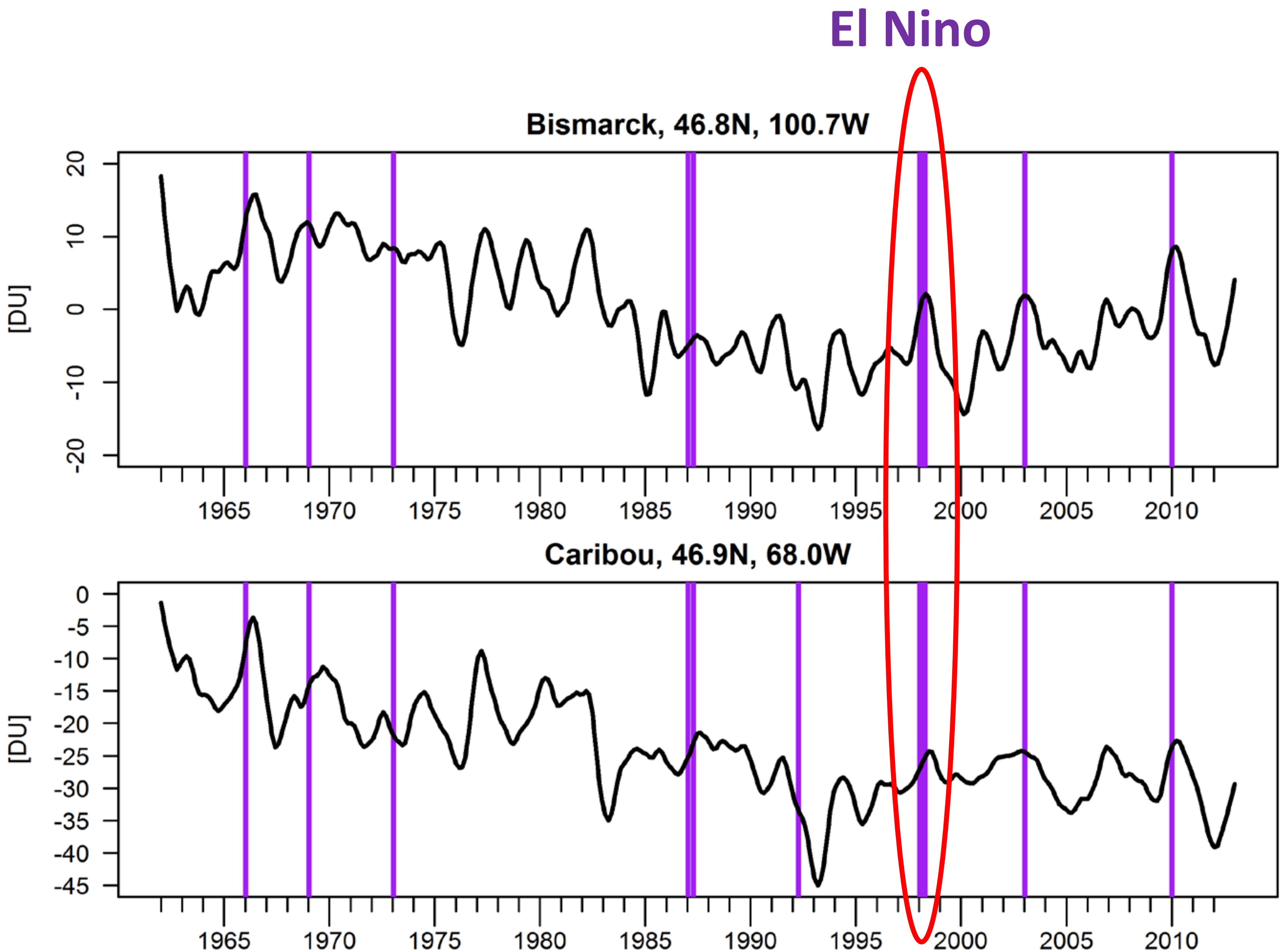


NAO positive (low)



NAO negative (high)





El Nino
Bismarck, 46.8N, 100.7W
[DU]
20
10
0
-10
-20
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Caribou, 46.9N, 68.0W
[DU]
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

APPLICATION OF EXTREME VALUE THEORY

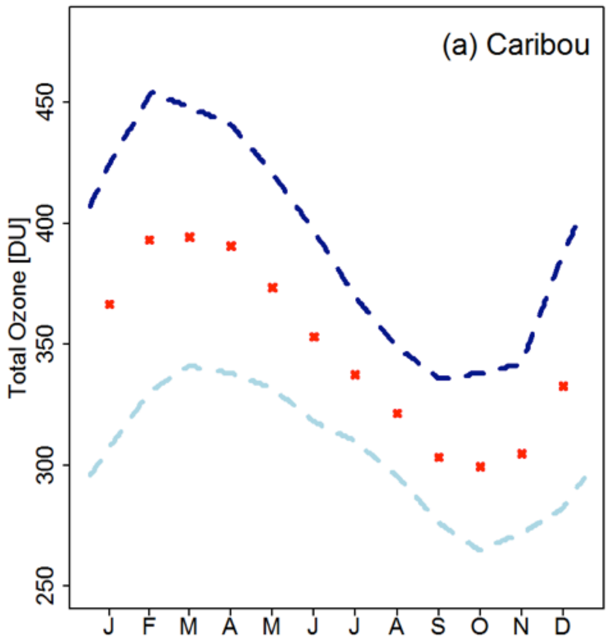
- Peak over Threshold (POT) analysis based on the Generalized Pareto Distribution (GPD)
- POT-package for R *(Ribatet, 2007)*

$$F(x) = 1 - \left(1 + \xi \frac{(x-u)}{\sigma}\right)^{-1/\xi}$$

u is the threshold value

$\sigma > 0$ is the scale parameter

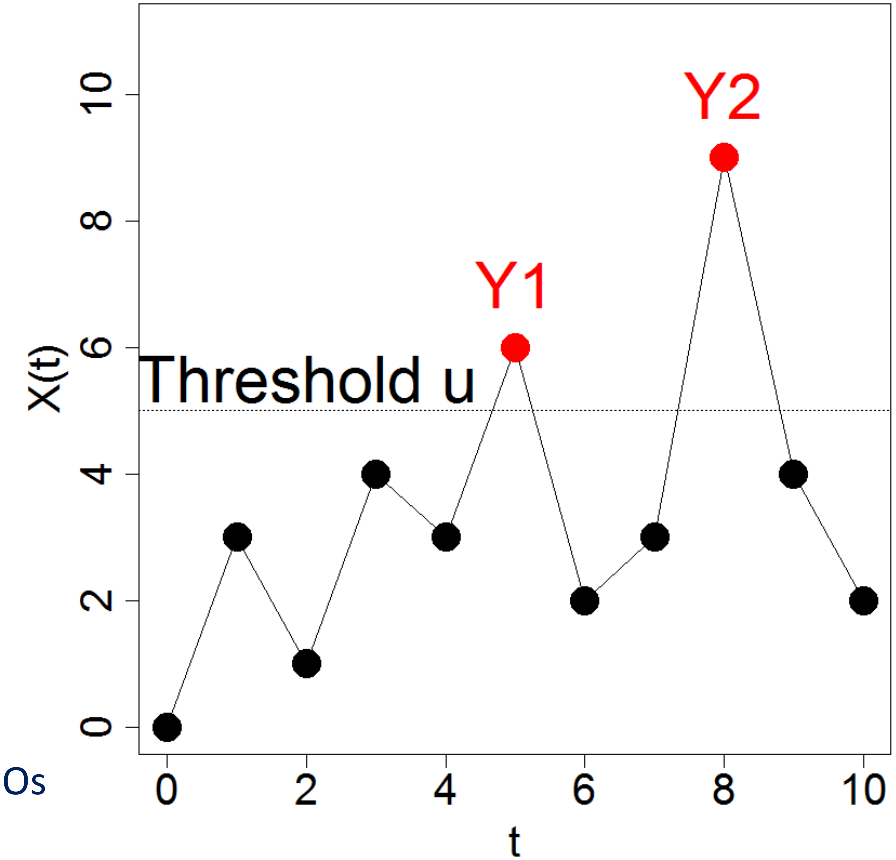
$\xi \in R$ is the shape parameter



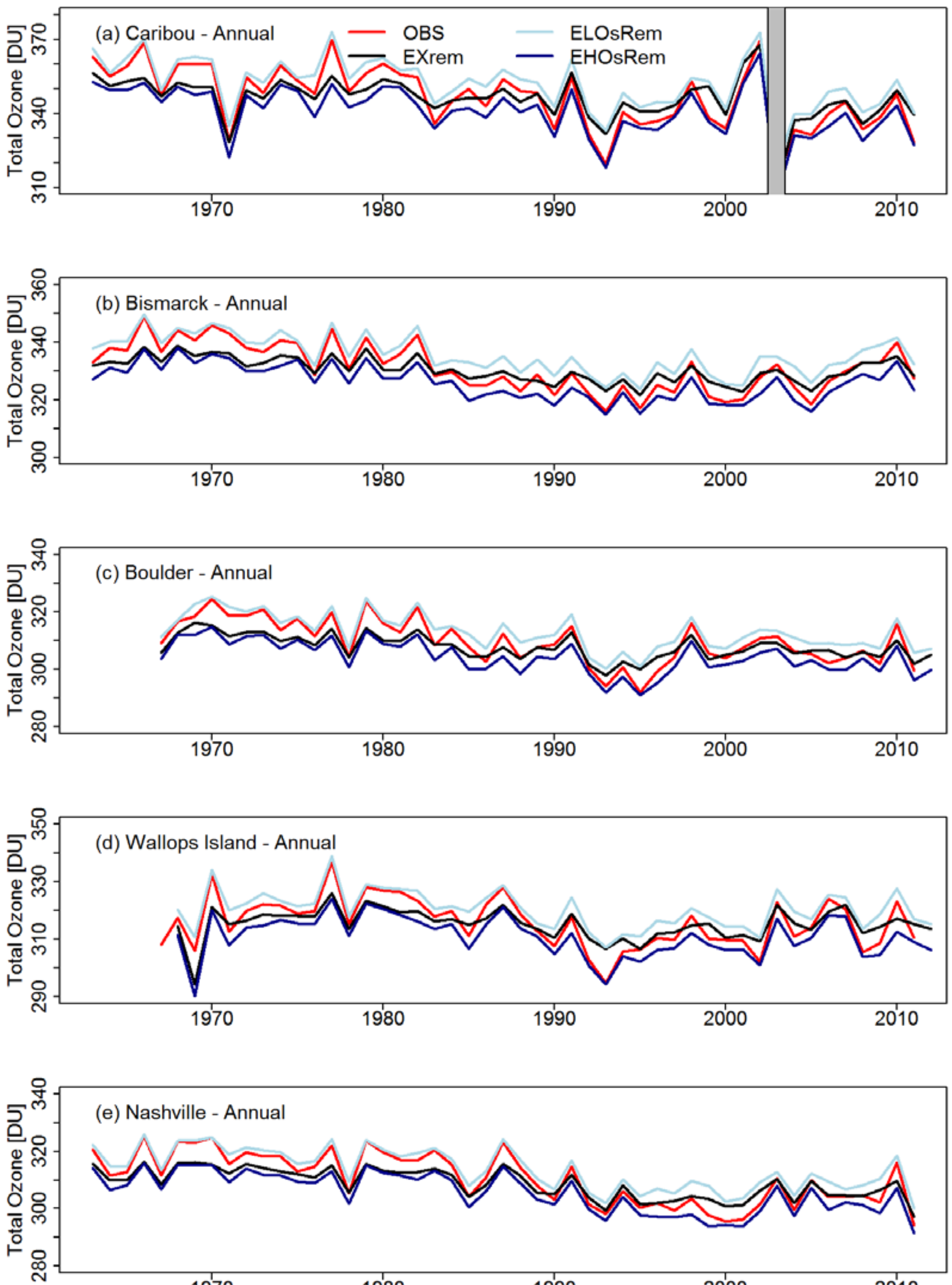
Threshold EHOs

Monthly Mean

Threshold ELOs



Multiple extremes above/below a threshold level *u*



Annual Trends (%/dec)		
STATION	ALL-DATA	EX-REM
Caribou*	-2.1 (±0.9)	-1.0 (±0.4)
Bismarck	-2.9 (±0.5)	-1.4 (±0.3)
Boulder	-2.3 (±0.6)	-1.2 (±0.3)
Wallops I.	-1.2 (±0.7)	-0.6 (±0.4)
Nashville	-1.6 (±0.6)	-1.0 (±0.3)

VARIABILITY & TREND ARE REDUCED WHEN EXTREMES (ELOs/EHOs) ARE REMOVED FROM THE RECORD

Annual trends are reduced by about a factor of 2

Observed and Extreme Trends for US stations are in agreement with results for European sites

Rieder, et al 2010a,b

Conclusions

- Ozone depleting substances (EESC) and the 11-year solar cycle are the main modulating forces for both extremes and mean values.
- Dynamical features such as QBO, ENSO and NAO contribute significantly to ozone variability and trends at 5 US Dobson stations
- 'Fingerprints' are better captured in the tails (extremes) than in the bulk of the record.

(Frossard et al, 2012; Rieder et al, 2013)