Sharing is encouraged

Total ozone trends and variability at three northern high-latitude stations

Leonie Bernet[1], Tove Svendby[1], Georg Hansen[1], Yvan Orsolini[1,2], Arne Dahlback[3], Florence Goutail[4], Andrea Pazmiño[4], Boyan Petkov[5]

[1] Norwegian Institute for Air Research (NILU), Norway
[2] NTNU, Trondheim, Norway
[3] University of Oslo, Norway
[4] LATMOS/IPSL/UVSQ-CNRS, France
[5] University G. d'Annunzio and CNR-ISP, Italy

EGU General Assembly, 23.05.2022

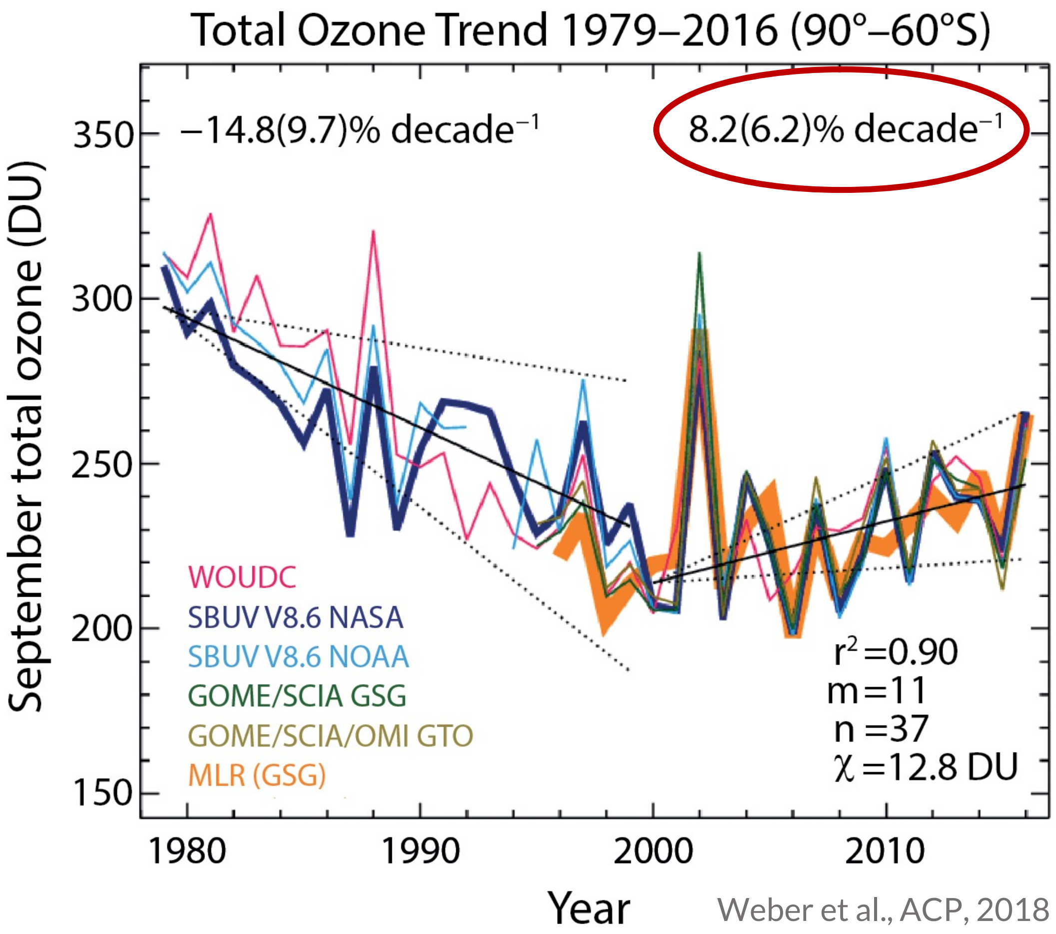
NILU
Norsk institutt for luftforskning
Norwegian Institute for Air Research

Funded by the SNSF
Grant no. 195484

Swiss National
Science Foundation

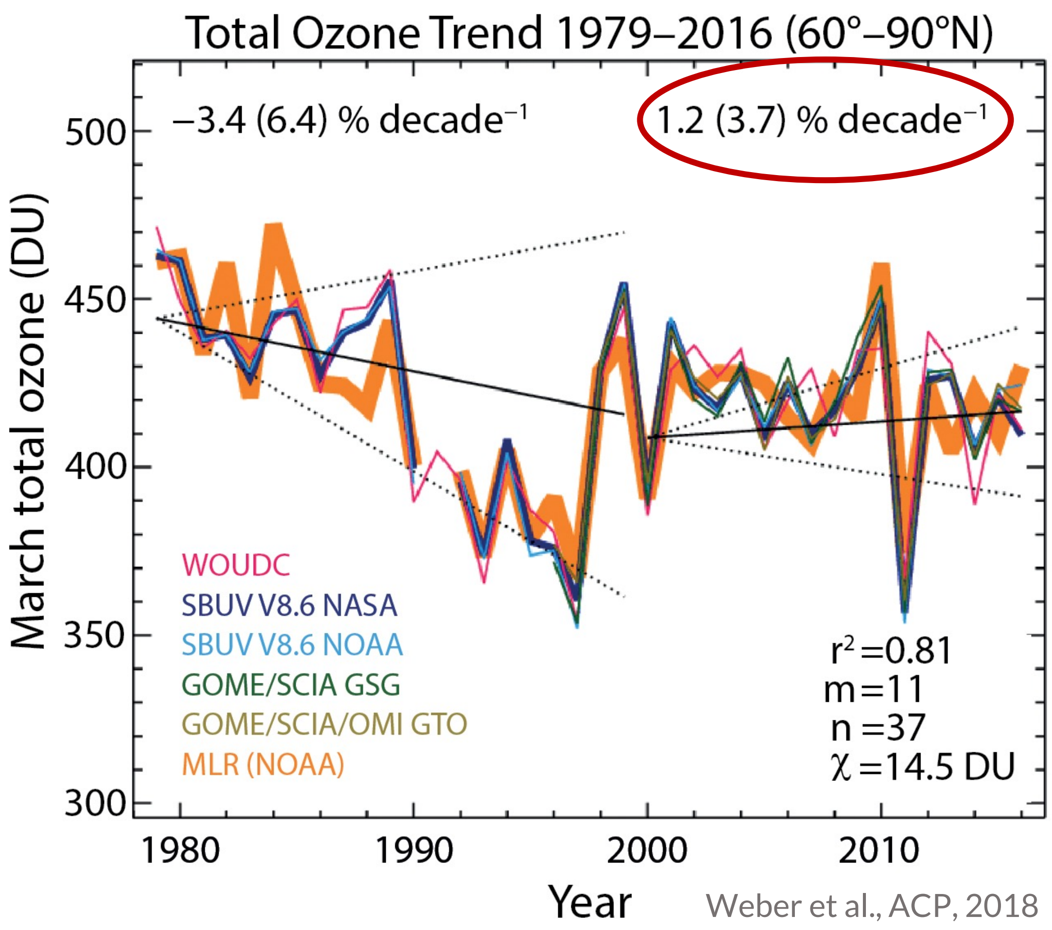
Total ozone recovery is reported in the Antarctic, but trends in the Arctic are difficult to detect due to stronger variability

Antarctic



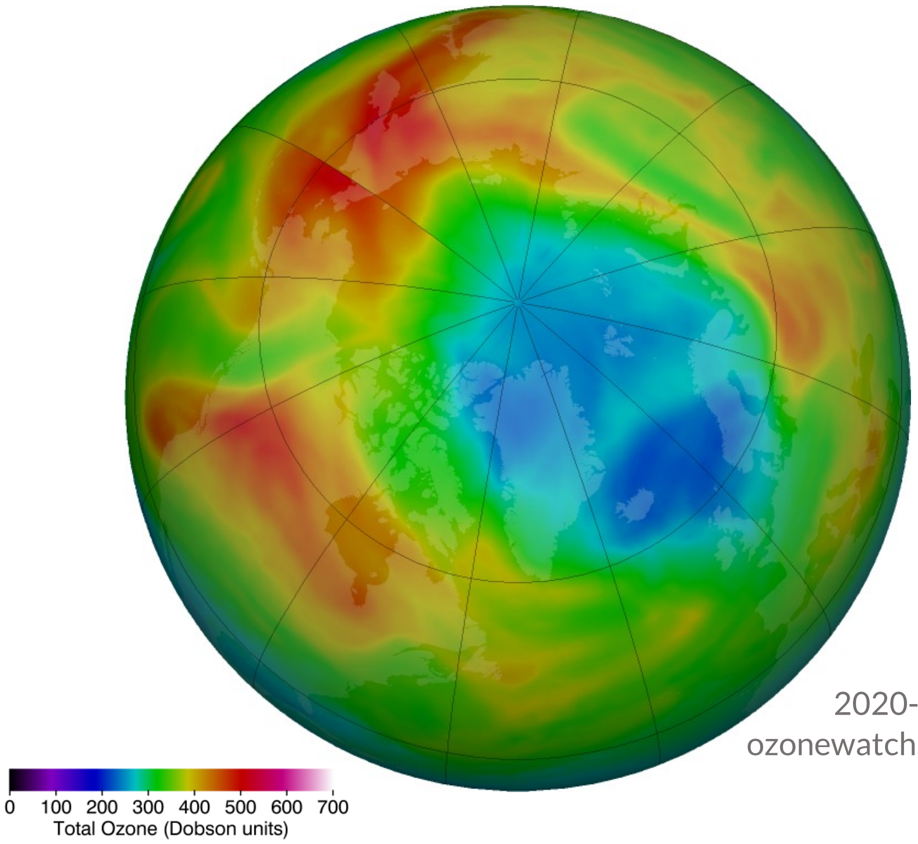
Weber et al., ACP, 2018

Arctic



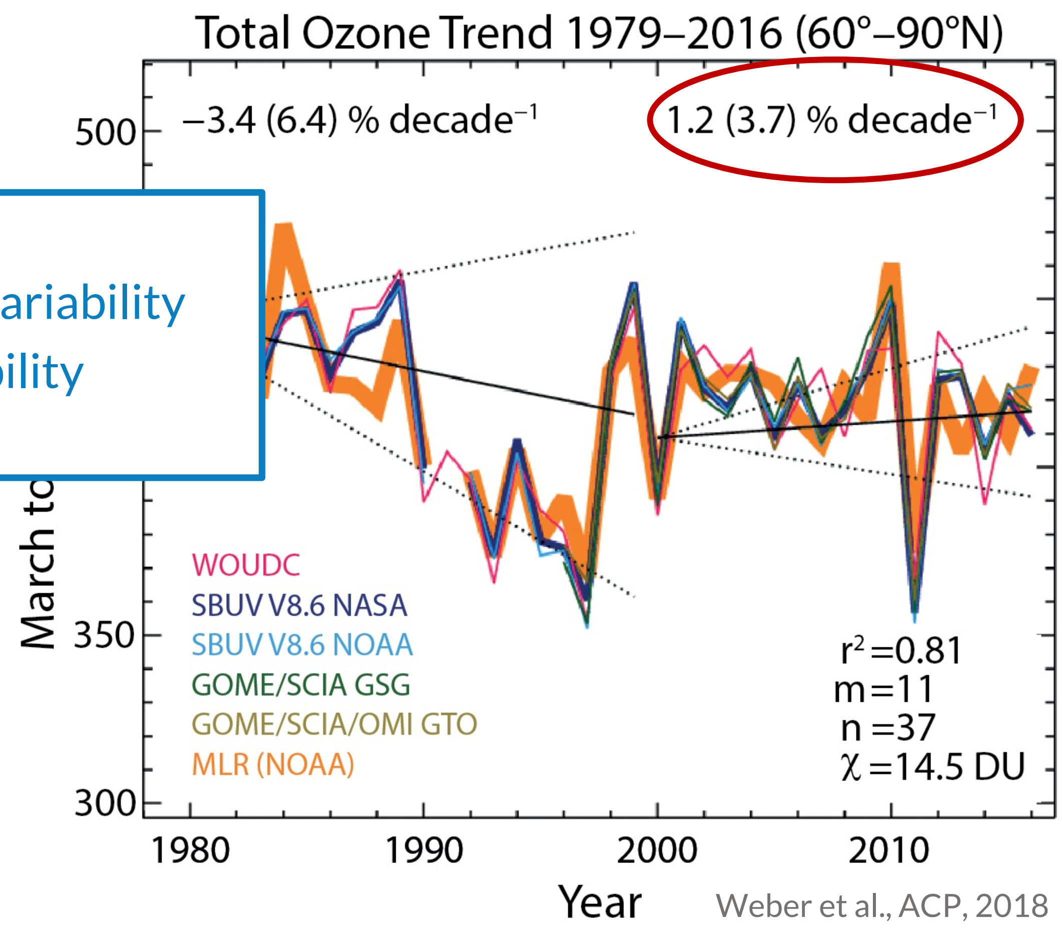
Weber et al., ACP, 2018

Total ozone recovery is reported in the Antarctic, but trends in the Arctic are difficult to detect due to stronger variability



2020-04-05, NASA
ozonewatch.gsfc.nasa.gov

Arctic

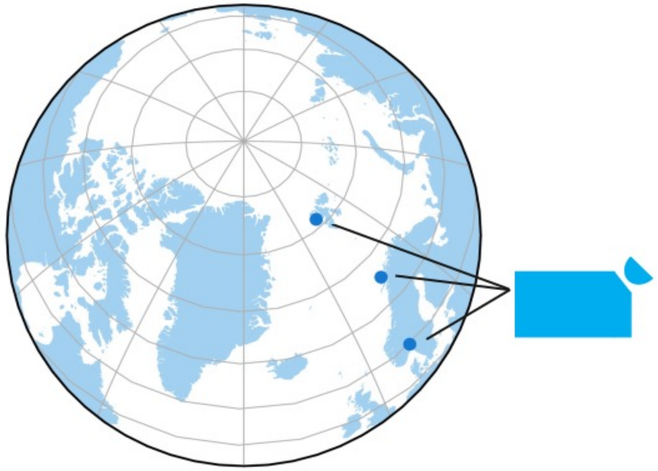


Weber et al., ACP, 2018

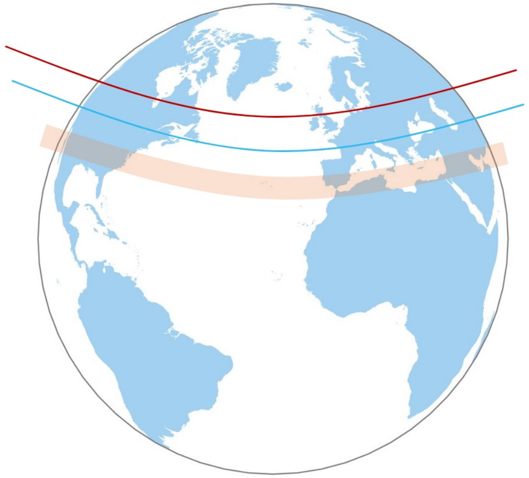
Interannual variability
Spatial variability

→ Because of Arctic spatial variability it is important to derive trends not only for zonal means, but also for individual stations

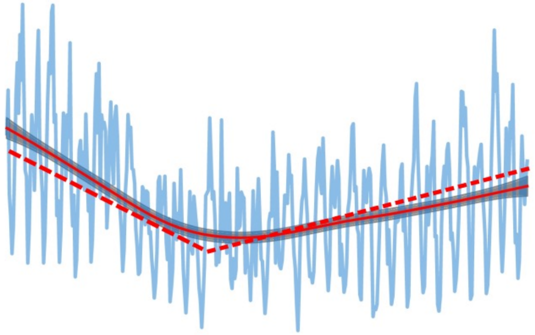
This presentation focuses on total ozone measurements in Norway and presents trends derived with a multiple linear regression model



1) Ozone measurements



2) Regression and predictors

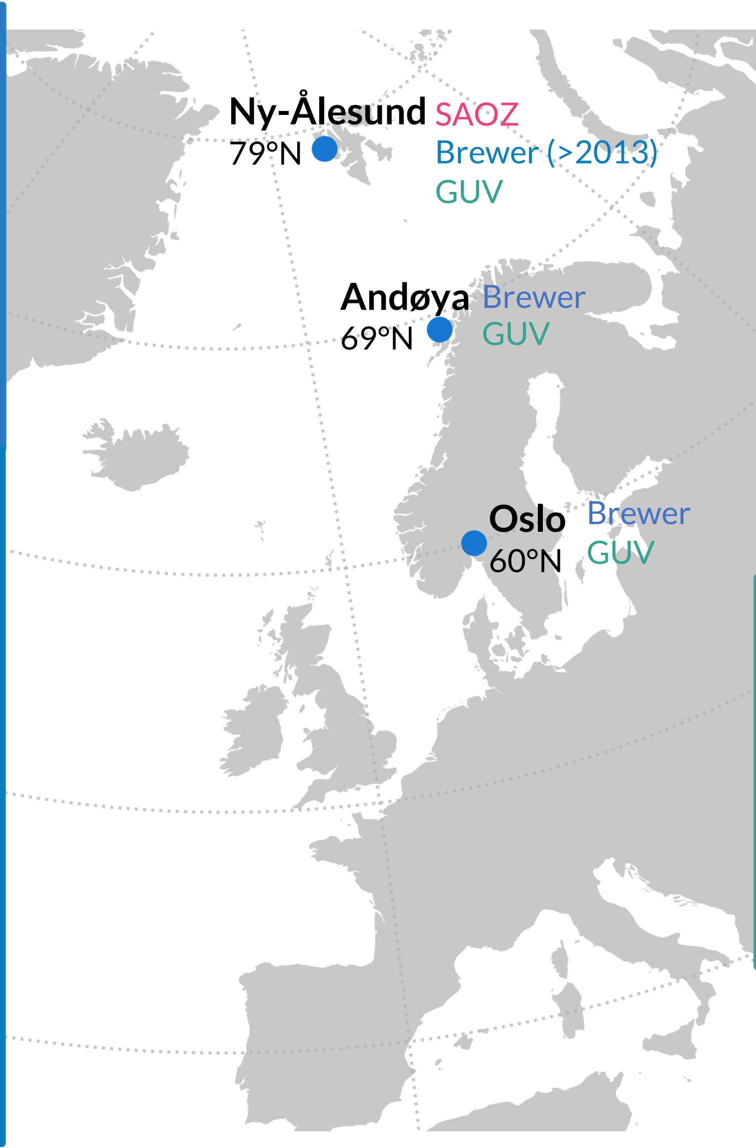


3) Ozone trends

Different ozone measurement techniques are used that complement each other

Brewer spectrophotometer

- 305-320nm
- Standard method (Direct sun):
  - Clear sky days
  - Limited to small solar zenith angles (SZA<72°)
- Global irradiance method (GI):
  - Includes diffuse radiation
  - Works also at larger SZA
  - Used to fill gaps in Brewer DS



SAOZ

Système d'Analyse par Observations Zénithales

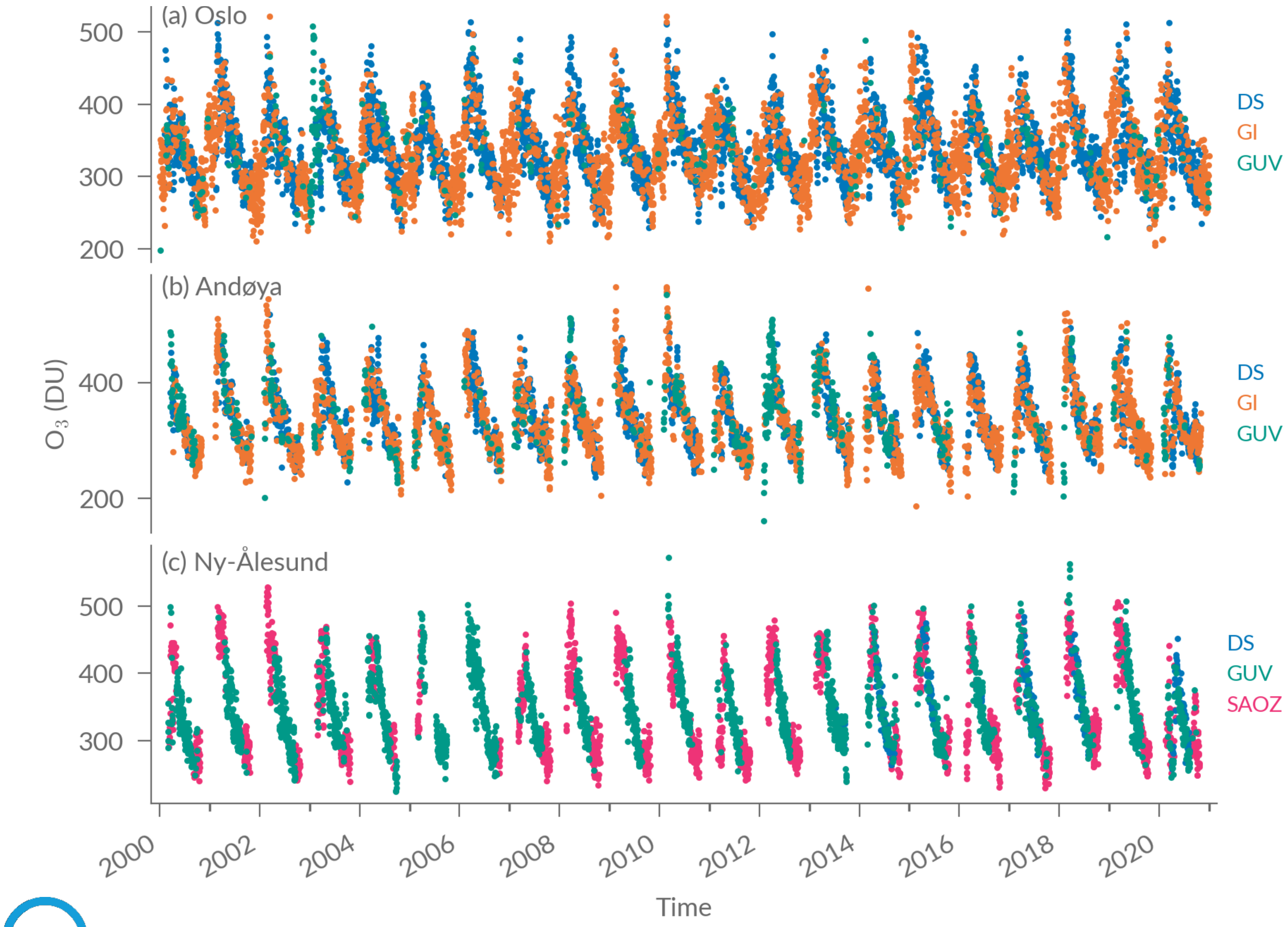
- 450-550nm
- Retrieves ozone during sunrise and sunset
- No measurements from May to August and in winter

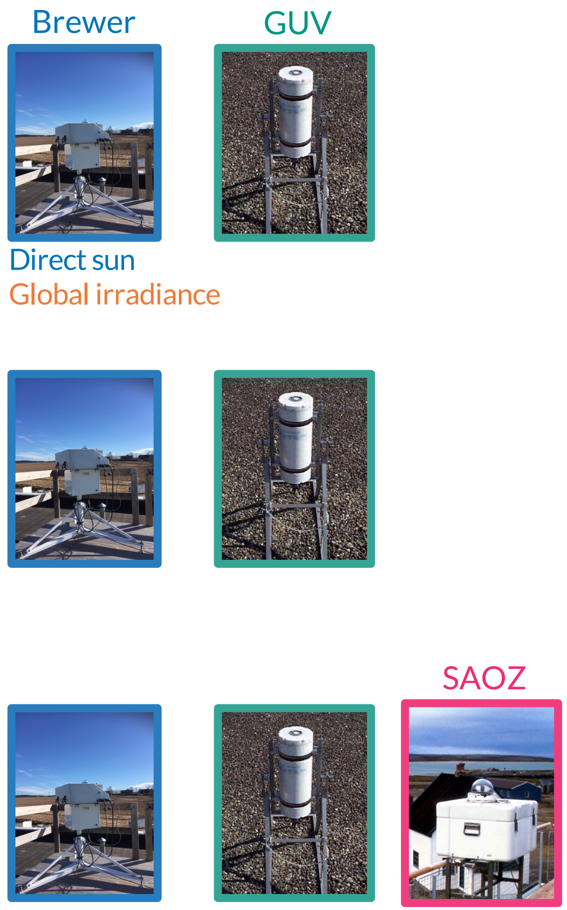
GUV

Ground-based Ultraviolet radiometer

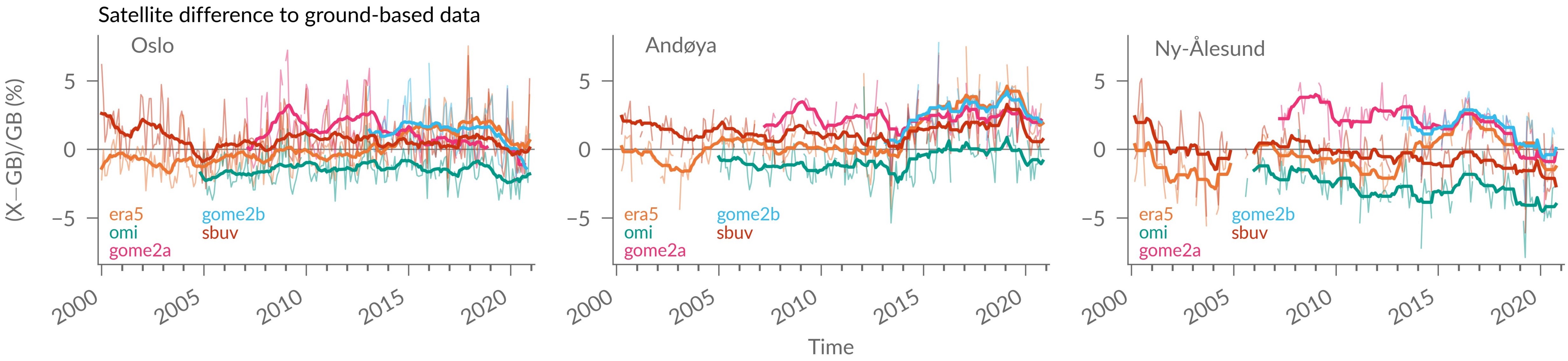
- 305-380nm
- UV instruments that can also be used for ozone retrieval
- Used to fill gaps in Brewer or SAOZ measurements

By combining measurement techniques we obtain an almost continous ground-based time series since 2000





The combined ground-based data agree well with satellite data and reanalyses (ERA5)



→ Averaged differences between ground-based (GB) and satellites/ERA5: 1 to 3%

Multiple linear regression attributes known natural variability to multiple predictors

LOTUS regression

https://arg.usask.ca/docs/LOTUS_regression

Regression input: monthly mean ozone and its uncertainties, starting in 2000

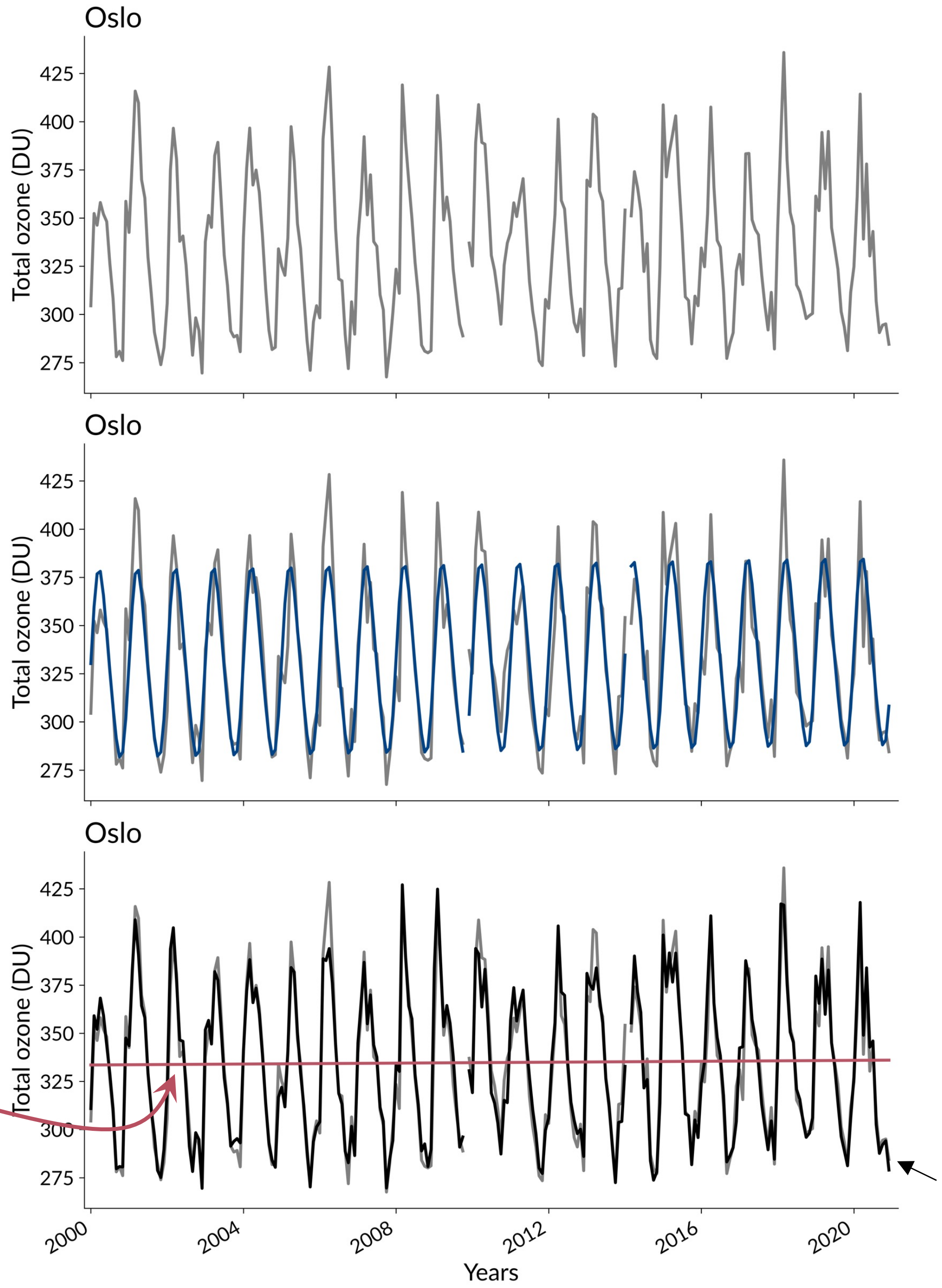
$$\hat{y}(t) = a + b \cdot t + c \cdot \text{seasonal} + d \cdot \text{predictor}_1(t) + \ldots$$

$$\hat{y}(t) = \sum_{n=1}^{p} r_n X_n$$

r_n = regression coefficients

X_n = independent variables (predictors)

Remaining linear trend represents the trend related to changes in ozone-depleting substances (ODS)



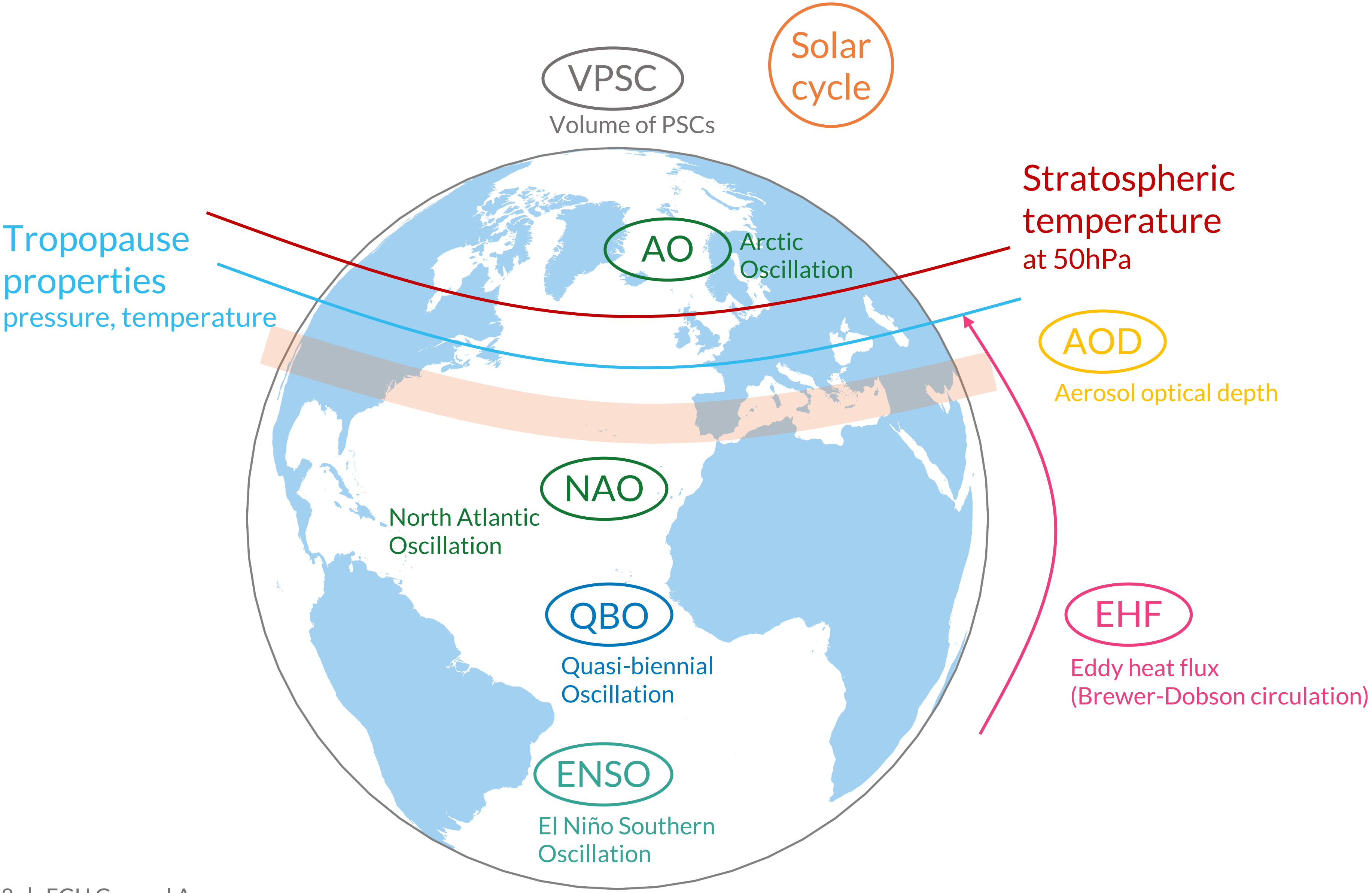
Monthly mean data

seasonal fit

+ various predictors

$\hat{y}(t)$

Various factors affect natural ozone variability and should be considered in the regression model



VPSC
Volume of PSCs

Solar cycle

Stratospheric temperature
at 50hPa

Tropopause properties
pressure, temperature

AO
Arctic Oscillation

AOD
Aerosol optical depth

NAO
North Atlantic Oscillation

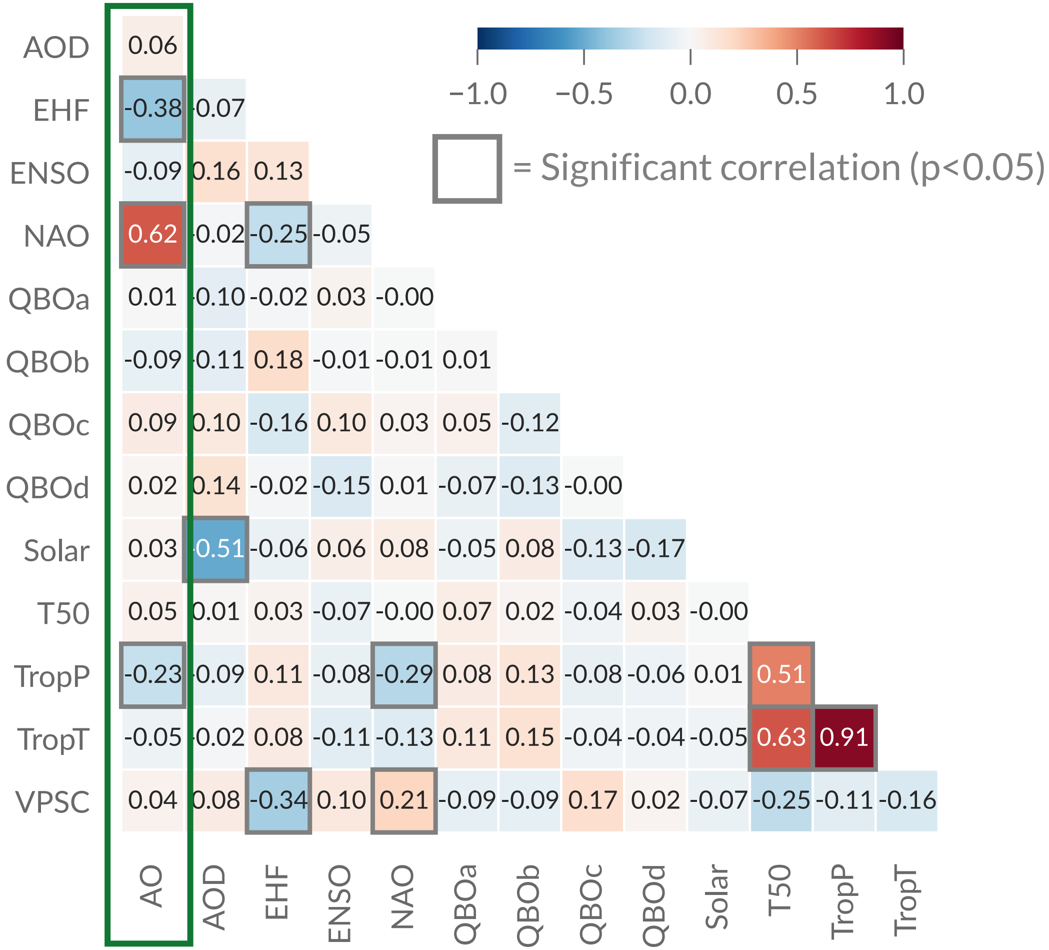
QBO
Quasi-biennial Oscillation

EHF
Eddy heat flux
(Brewer-Dobson circulation)

ENSO
El Niño Southern Oscillation

Some regression predictors are correlated, we therefore chose a specific set of predictors

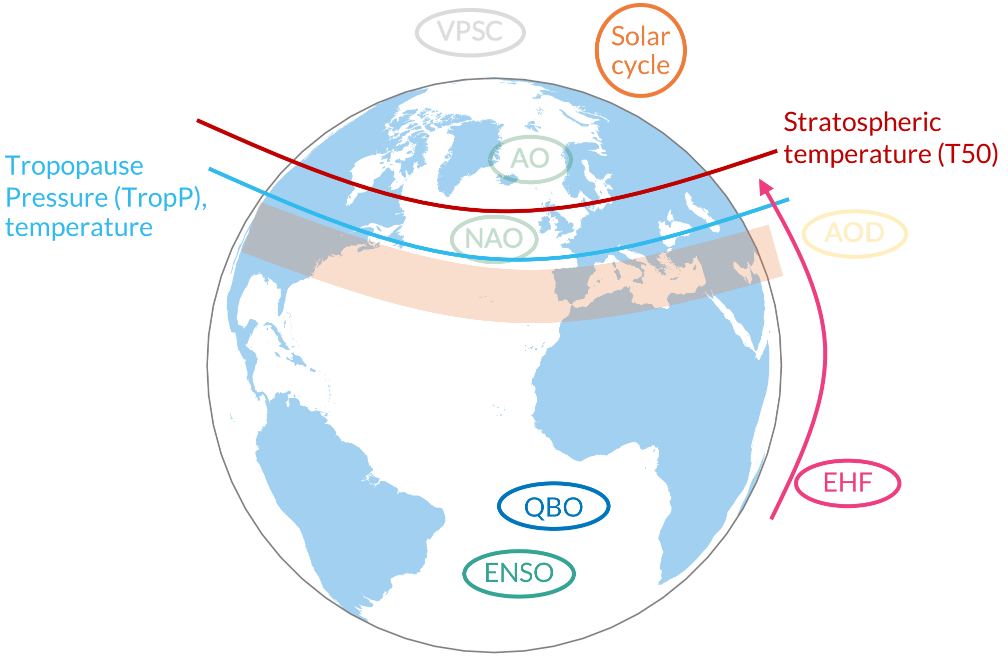
Predictor correlations, Oslo (2000 to 2020)



	AO	AOD	EHF	ENSO	NAO	QBOa	QBOb	QBOc	QBOd	Solar	T50	TropP	TropT
AOD	0.06												
EHF	-0.38	-0.07											
ENSO	-0.09	0.16	0.13										
NAO	0.62	-0.02	-0.25	-0.05									
QBOa	0.01	-0.10	-0.02	0.03	-0.00								
QBOb	-0.09	-0.11	0.18	-0.01	-0.01	0.01							
QBOc	0.09	0.10	-0.16	0.10	0.03	0.05	-0.12						
QBOd	0.02	0.14	-0.02	-0.15	0.01	-0.07	-0.13	-0.00					
Solar	0.03	-0.51	-0.06	0.06	0.08	-0.05	0.08	-0.13	-0.17				
T50	0.05	0.01	0.03	-0.07	-0.00	0.07	0.02	-0.04	0.03	-0.00			
TropP	-0.23	-0.09	0.11	-0.08	-0.29	0.08	0.13	-0.08	-0.06	0.01	0.51		
TropT	-0.05	-0.02	0.08	-0.11	-0.13	0.11	0.15	-0.04	-0.04	-0.05	0.63	0.91	
VPSC	0.04	0.08	-0.34	0.10	0.21	-0.09	-0.09	0.17	0.02	-0.07	-0.25	-0.11	-0.16

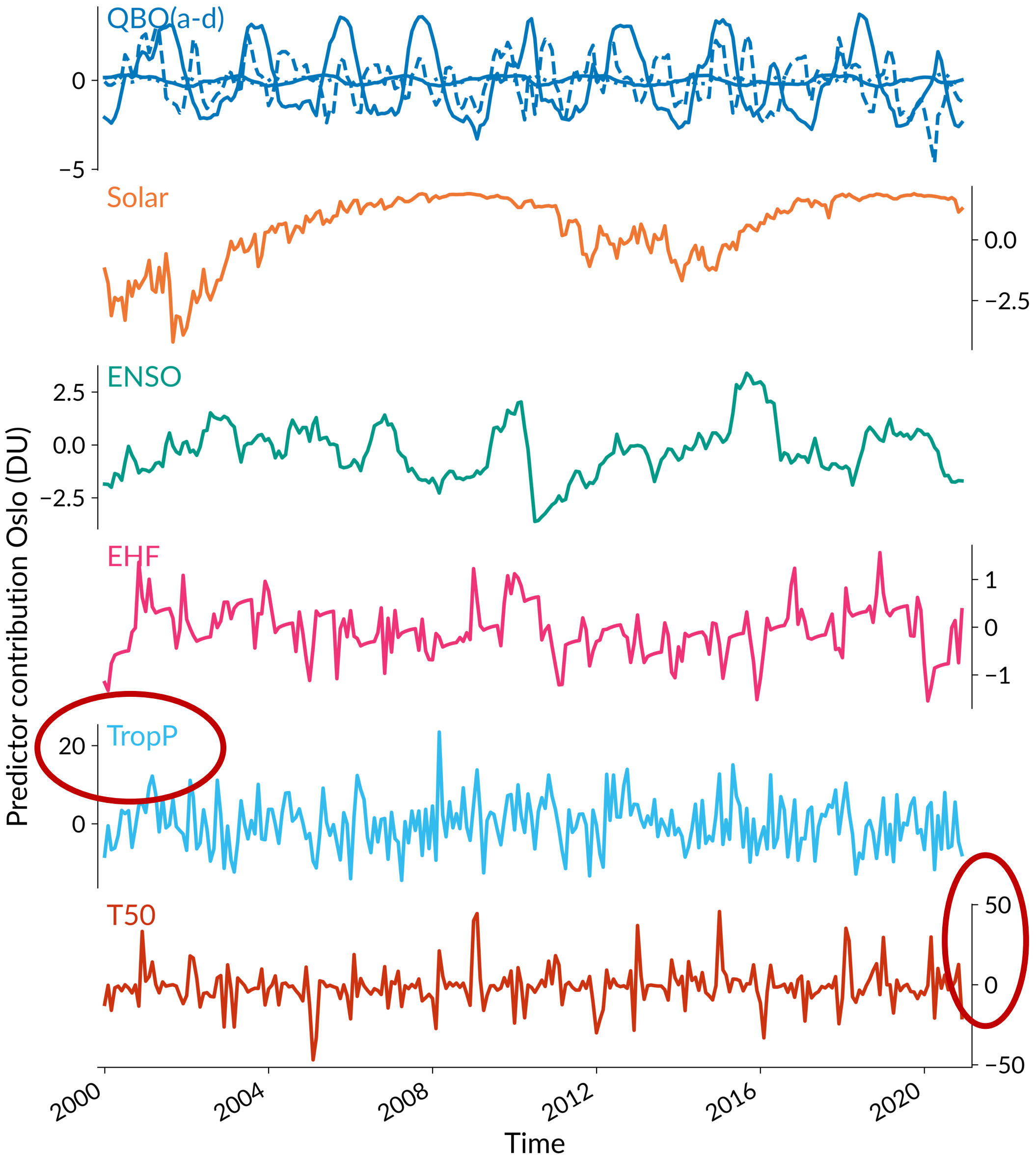
Arctic Oscillation

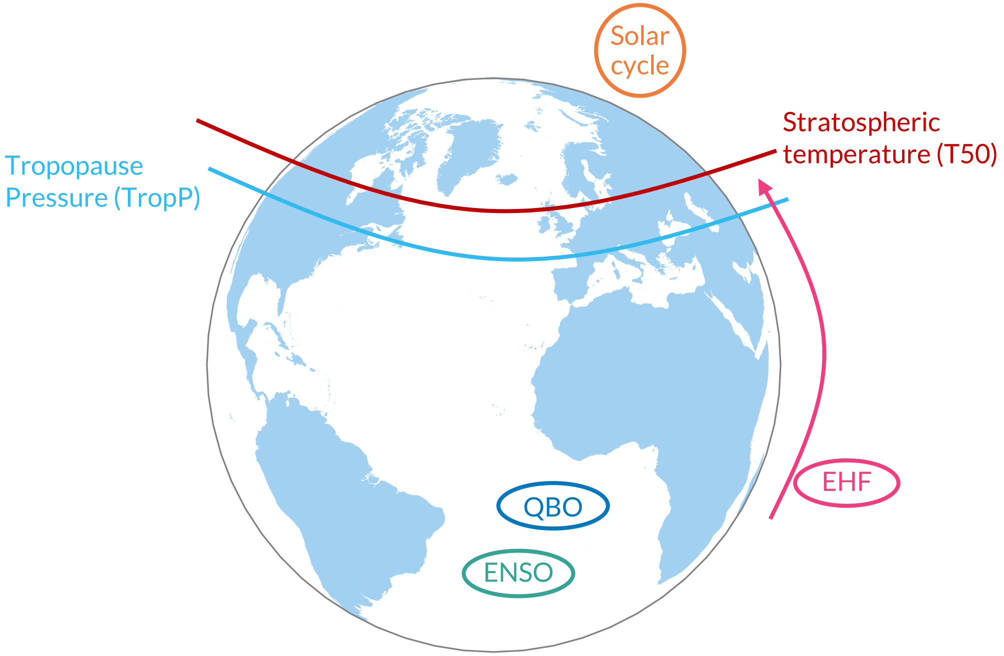
Correlation example: AO and NAO correlate with EHF and TropP



→ don't use AO, NAO, AOD, and VPSC

The predictors that contribute most to natural ozone variability are tropopause pressure and stratospheric temperature

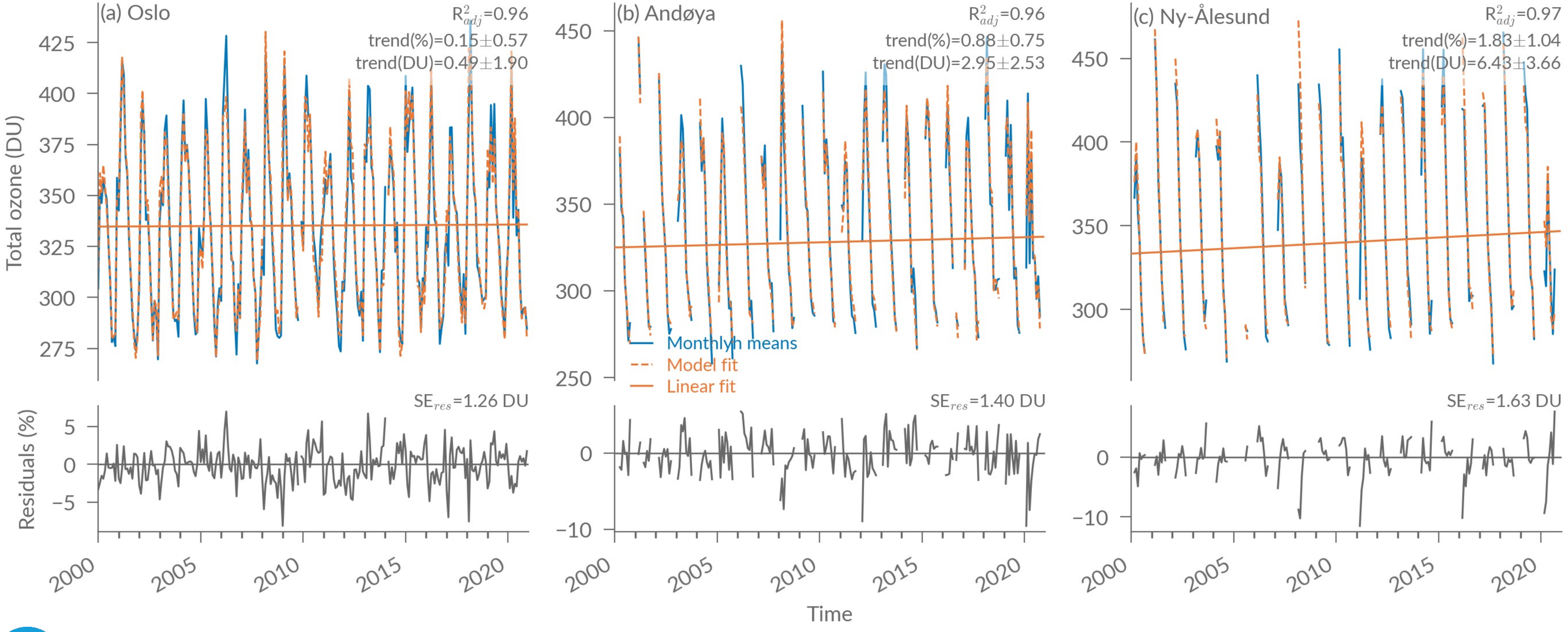




Total ozone increases significantly at the northernmost stations and remains constant in Oslo

Oslo: +0.2 % per decade **Andøya:** +0.9 % per decade **Ny-Ålesund:** +1.8 % per decade

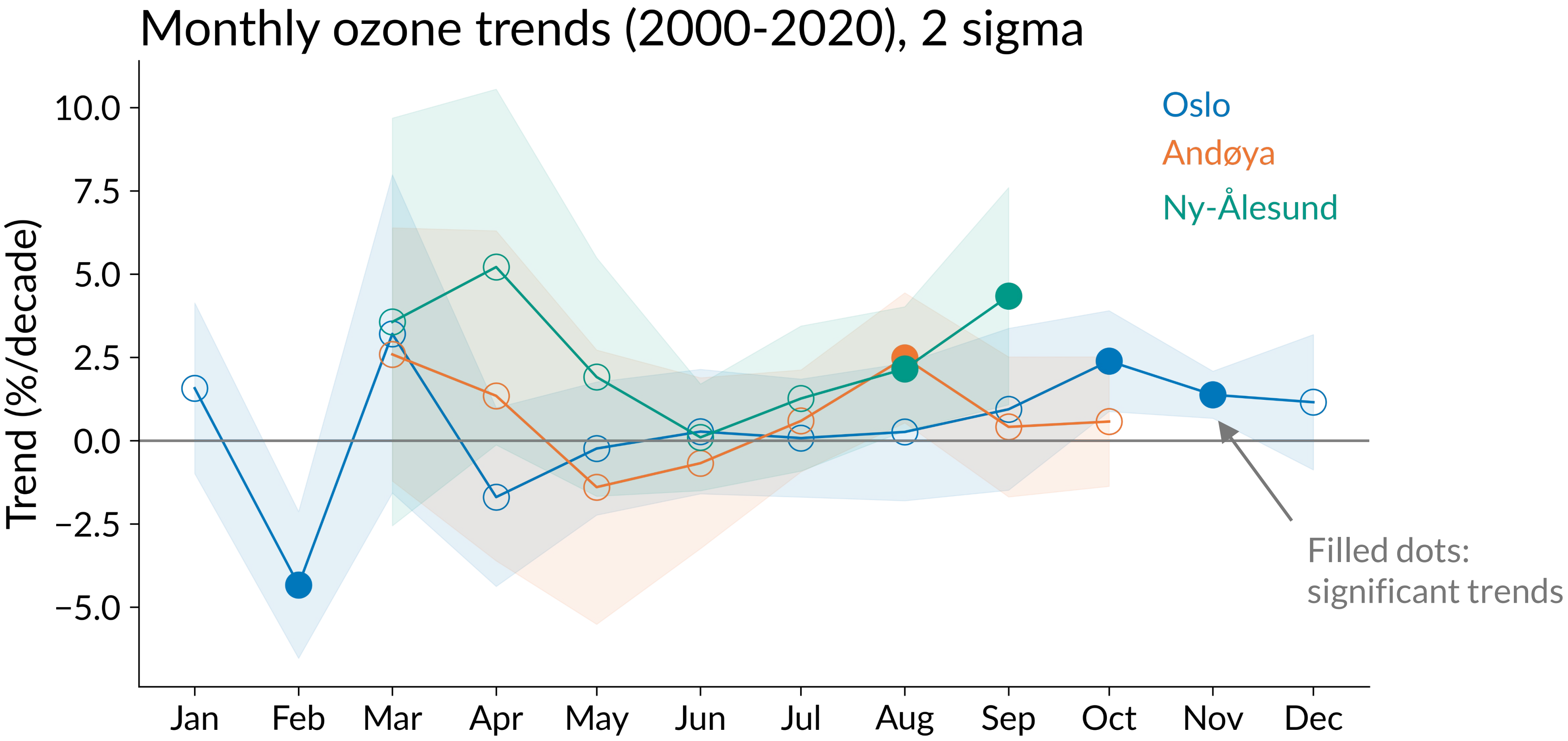
Regression fit (2000-2020)



← Trends with 2 sigma uncertainties

← Standard error of residuals

Monthly trends are mostly positive and significant in some months at 95%-confidence level



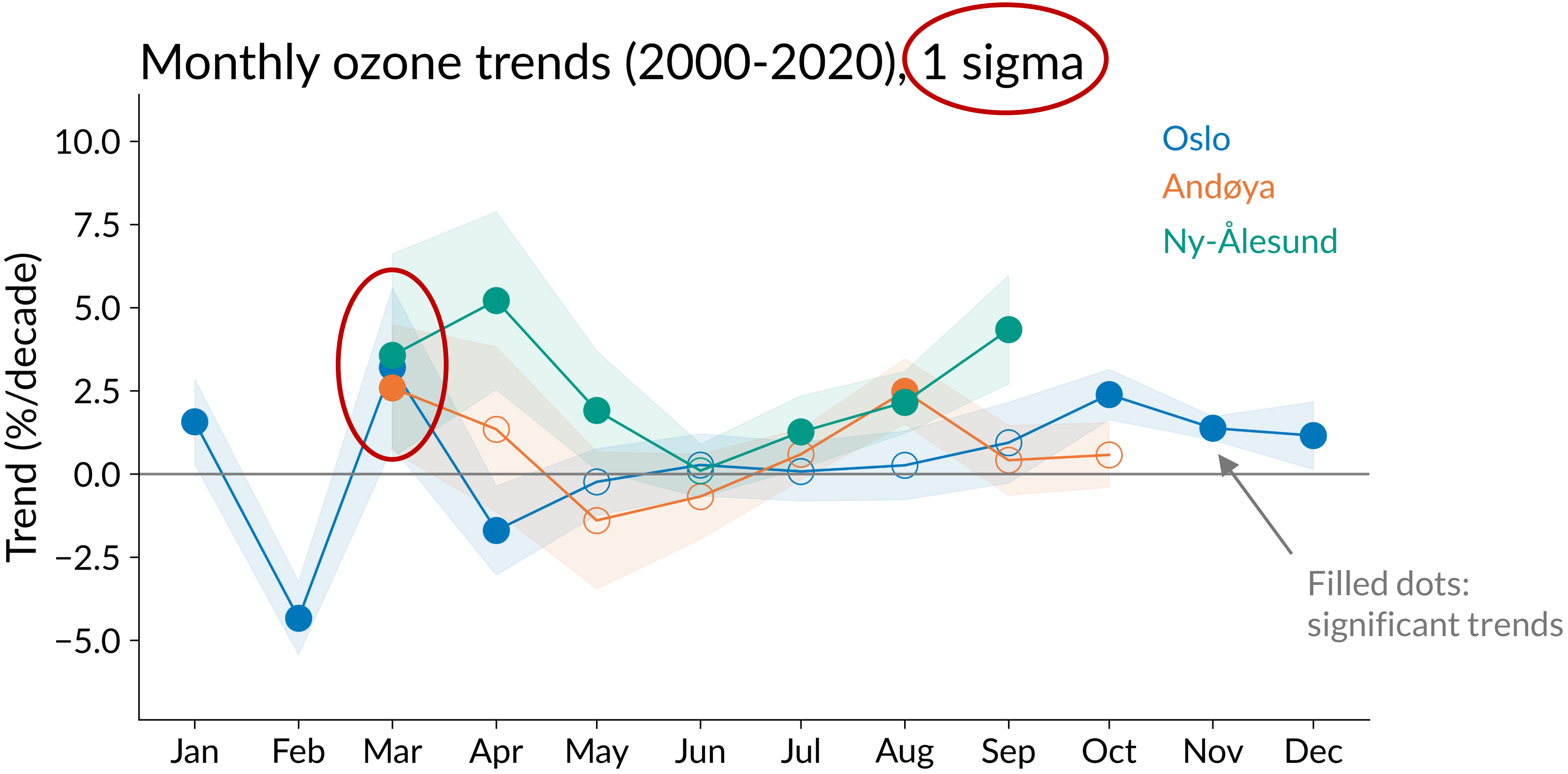
Winter:
variable

Spring:
Positive but insignificant

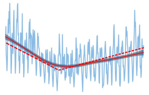
Summer:
no trends

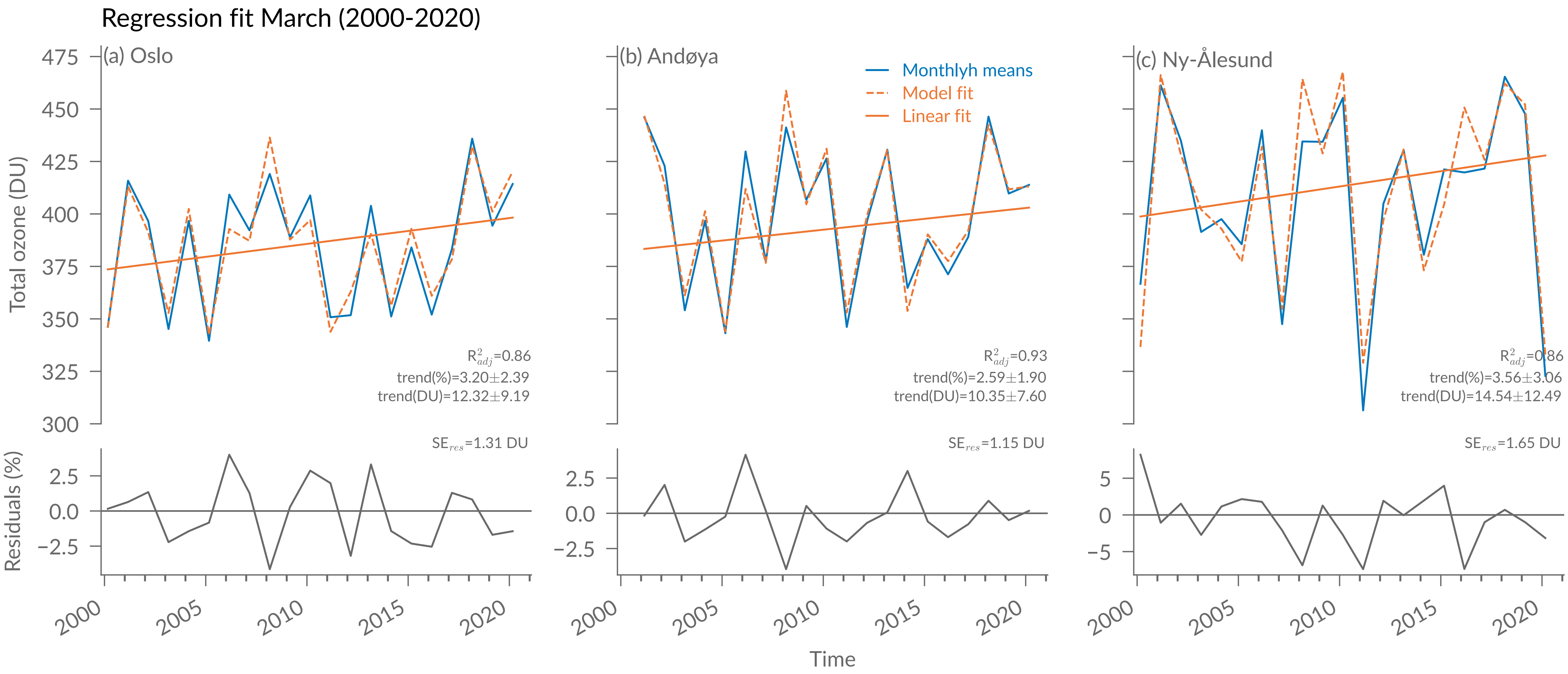
Autumn:
significant positive

… and significant in several months with a 68% confidence



Monthly total ozone trends in March are significant at 68% confidence level



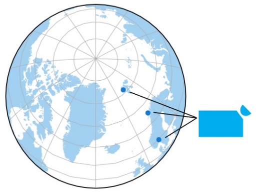


← 1 sigma uncertainties

← Standard error of residuals

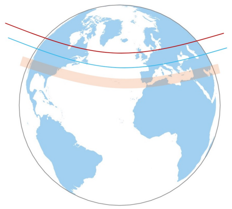
Ozone increases by ~3% per decade in March → Hint for spring ozone recovery

Summary



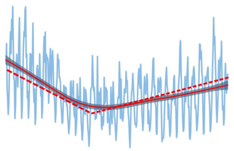
1) We used combined ground-based measurements at three stations in Norway

- Instrument-specific measurement gaps are filled by combining three instrument types
- Good agreement with ERA5 and satellites



2) We test the use of various predictors in the LOTUS multiple linear regression

- Tropopause pressure and stratospheric temperature are the most important predictors



3) Total ozone trends

- Trends are significantly positive at two stations in the Arctic (Ny-Ålesund, Andøya)
- March ozone recovery with 68% confidence

→ Hint for spring-time Arctic ozone recovery
→ Ozone trends at individual stations may differ from zonal mean trends

L. Bernet et al. lber @nilu.no