Interannual variability of the stratospheric hydrogen chloride simulated with SD-WACCM in recent years

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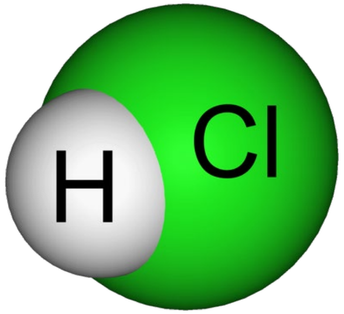
Introduction

1. Monitoring trends in stratospheric HCl is essential for predicting our climate as well as for ozone recovery.

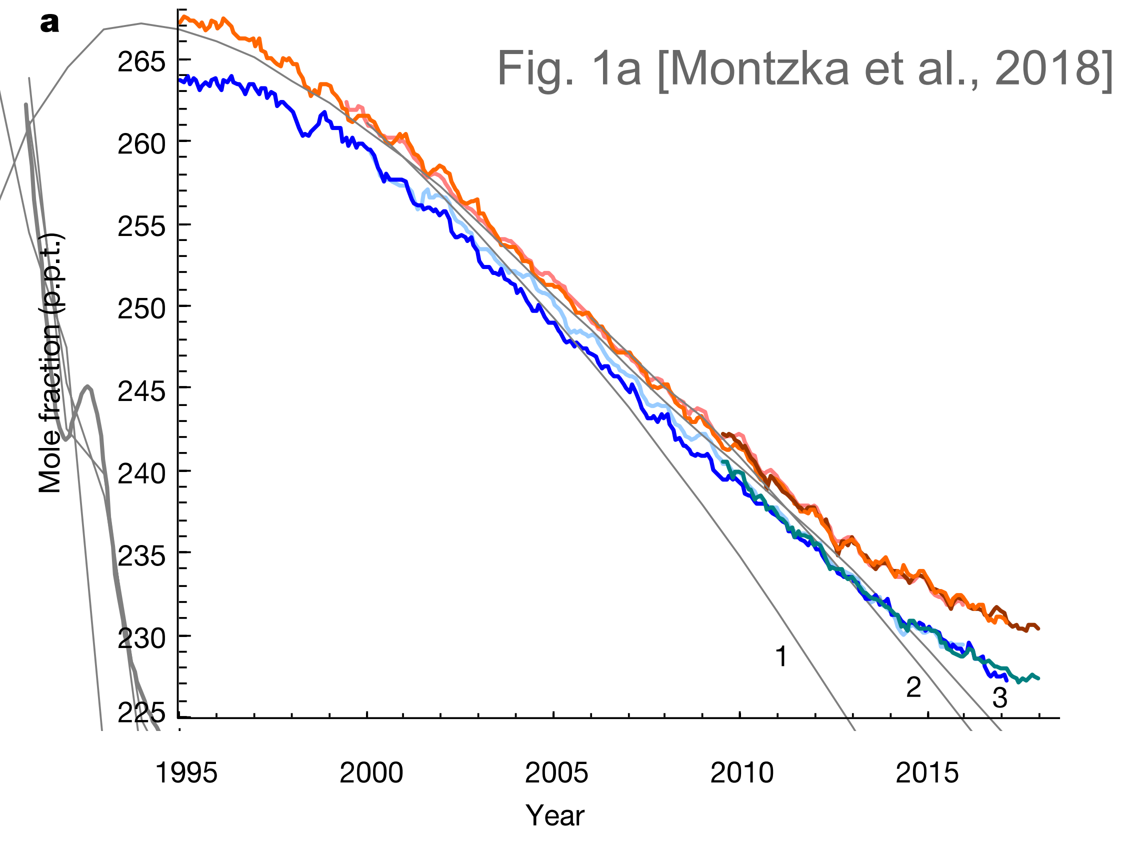


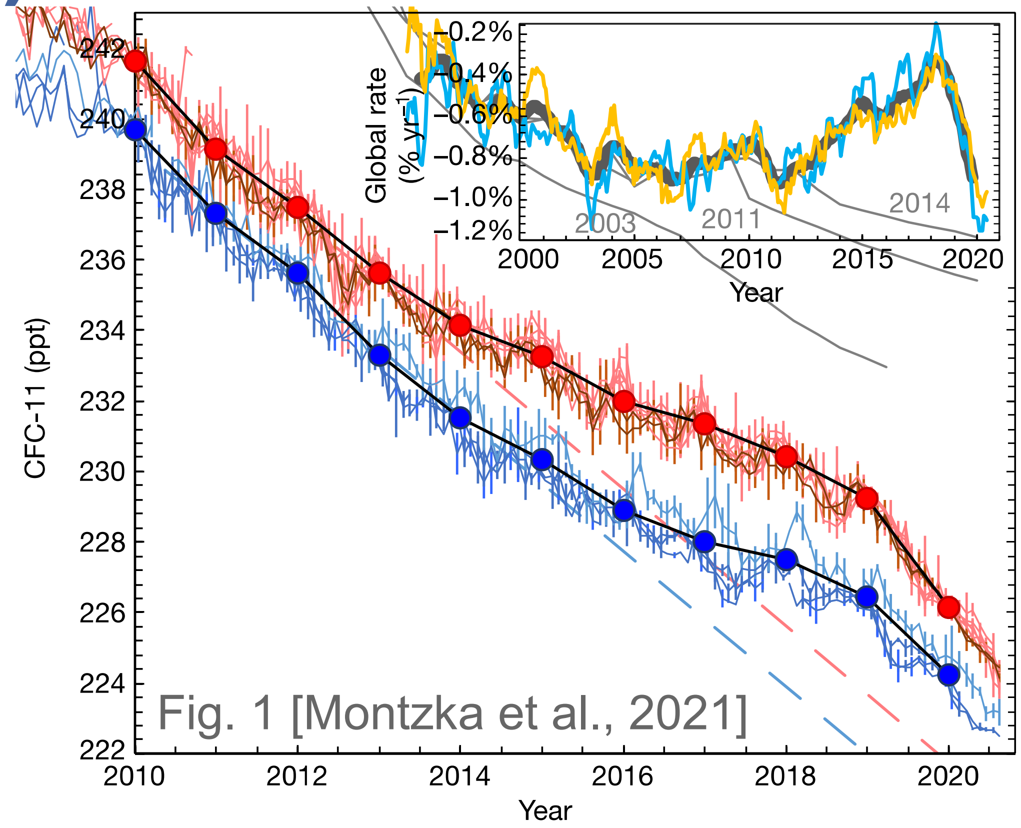
2. **In the NH midlatitudes, the interannual variability of HCl is influenced strongly by the stratospheric large-scale circulation and climate variability.**

3. We use the specified-dynamics version of the Whole Atmosphere Community Climate Model (SD-WACCM) and the measurements of HCl from NASA's Aura Microwave Limb Sounder (MLS).

4. To understand the trends of stratospheric HCl in relation to the QBO and other climate variabilities in recent years (2005-2020).

Sources of HCl (CFC-11)

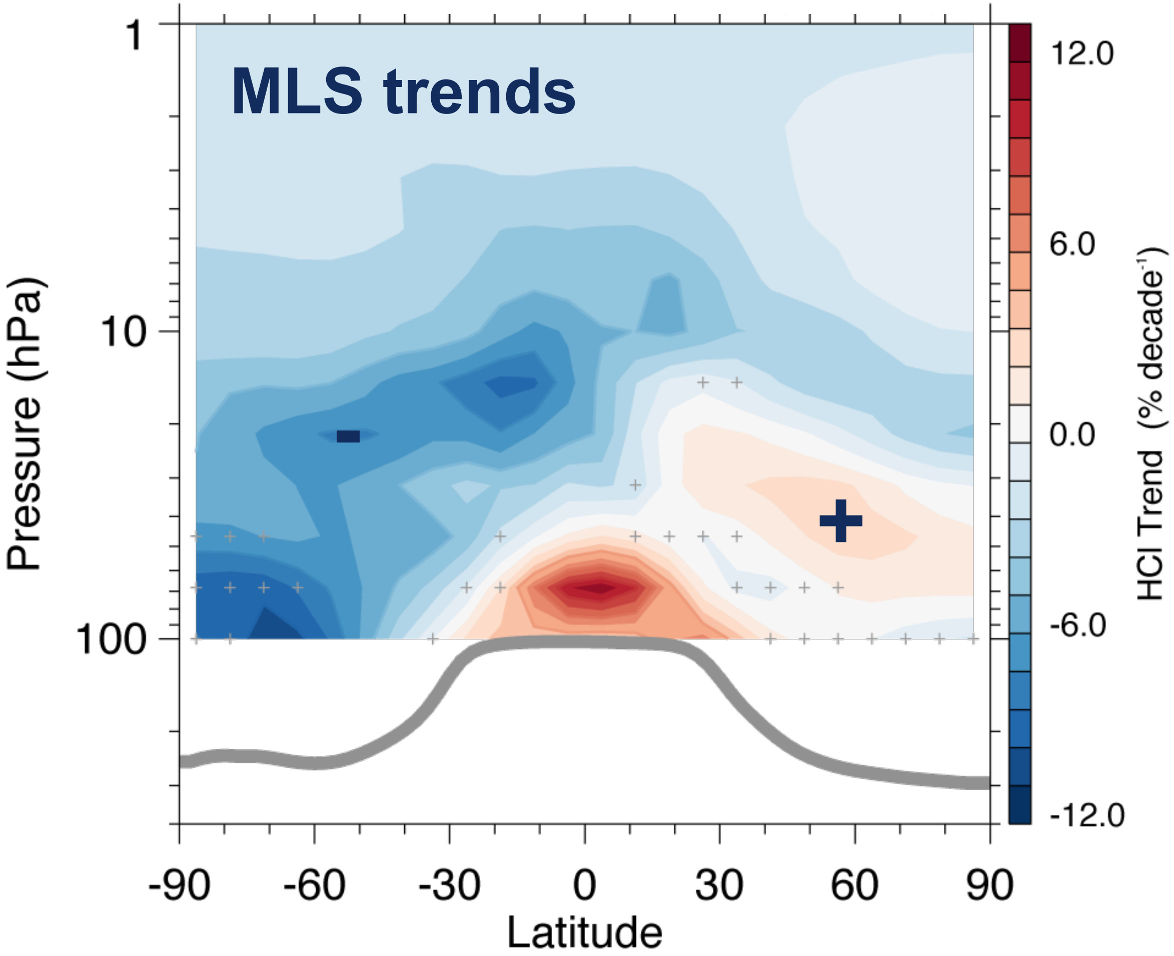




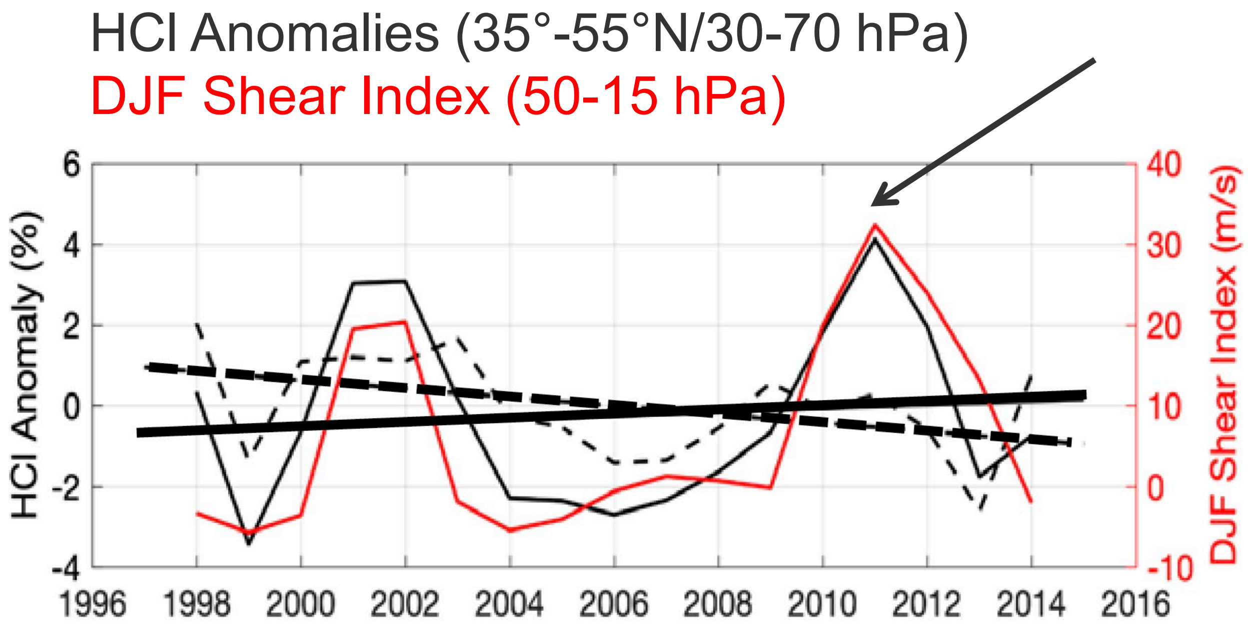
Rate of decline of CFC-11observed was constant (2002-2012) then slowed by ~50% after 2012 (unreported production)

An accelerated decline in the global mean CFC-11 (2019-2020).

HCl in the Stratosphere

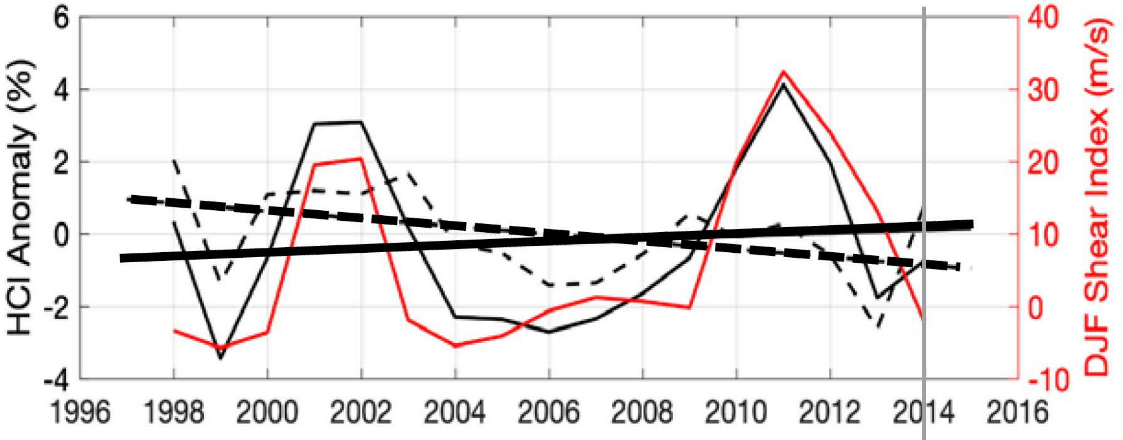


Observations - Negative trends in the SH/ Positive trends in the NH & tropics

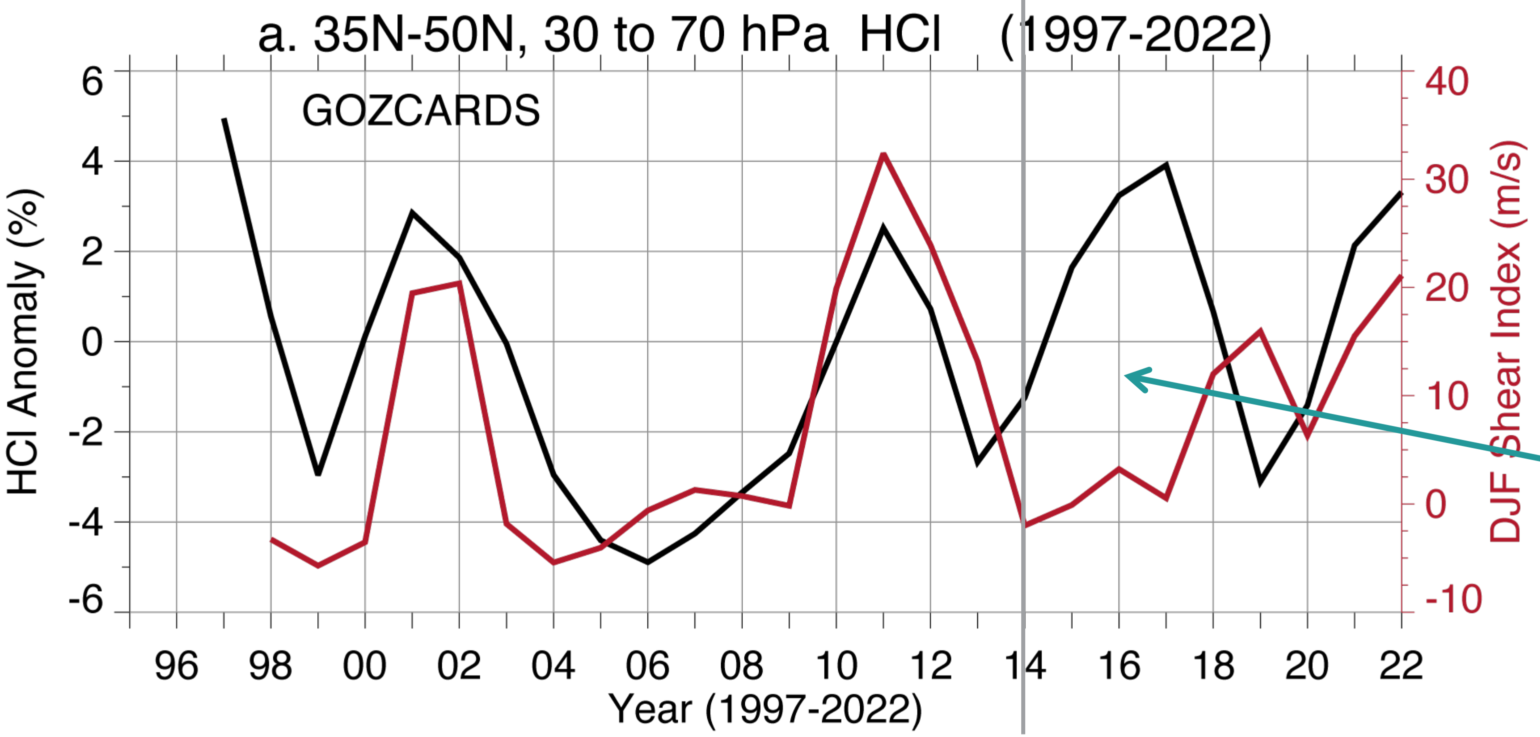


Key point: The DJF Shear Index explains much of the dynamical variability in HCl anomalies in the NH midlatitude (1998-2014).

HCl Anomaly & DJF Wind Shear



1998-2014

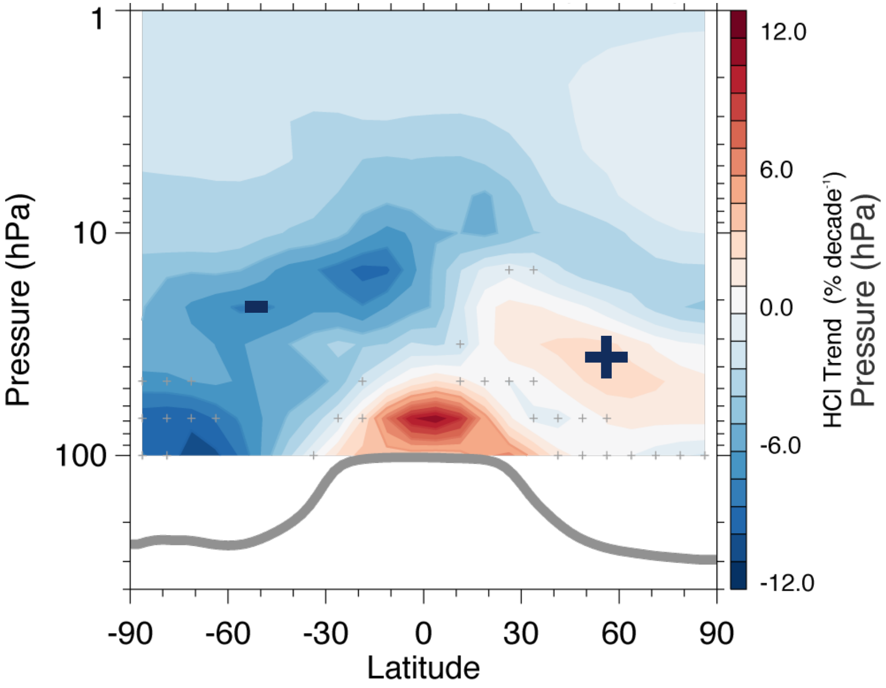


1998-2022

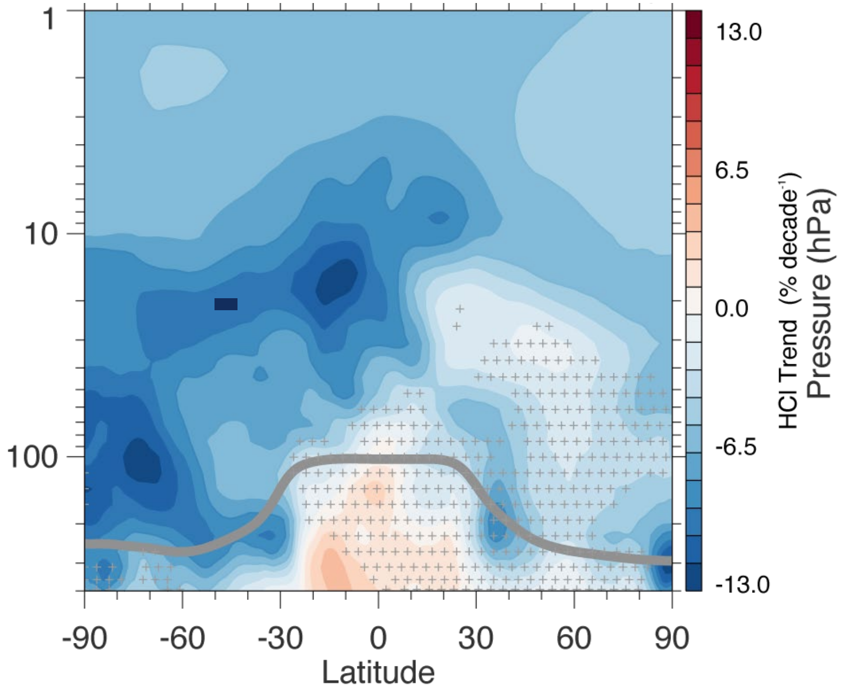
2015-2019: HCl & DJF shear index do not match (2017-High/2019-Low HCl)

HCl Trends in the Stratosphere

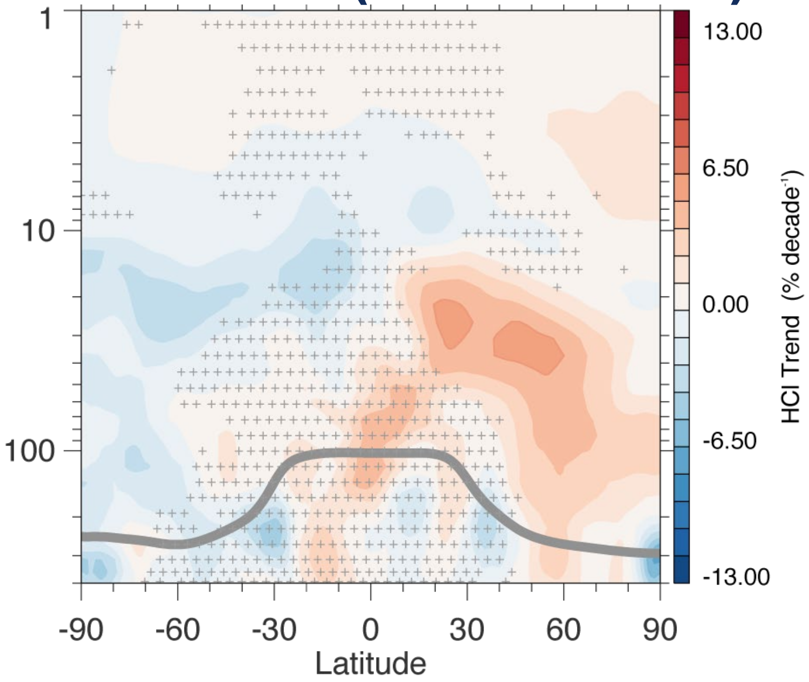
MLS



WACCM6



WACCM6 (HIGHEESC*)



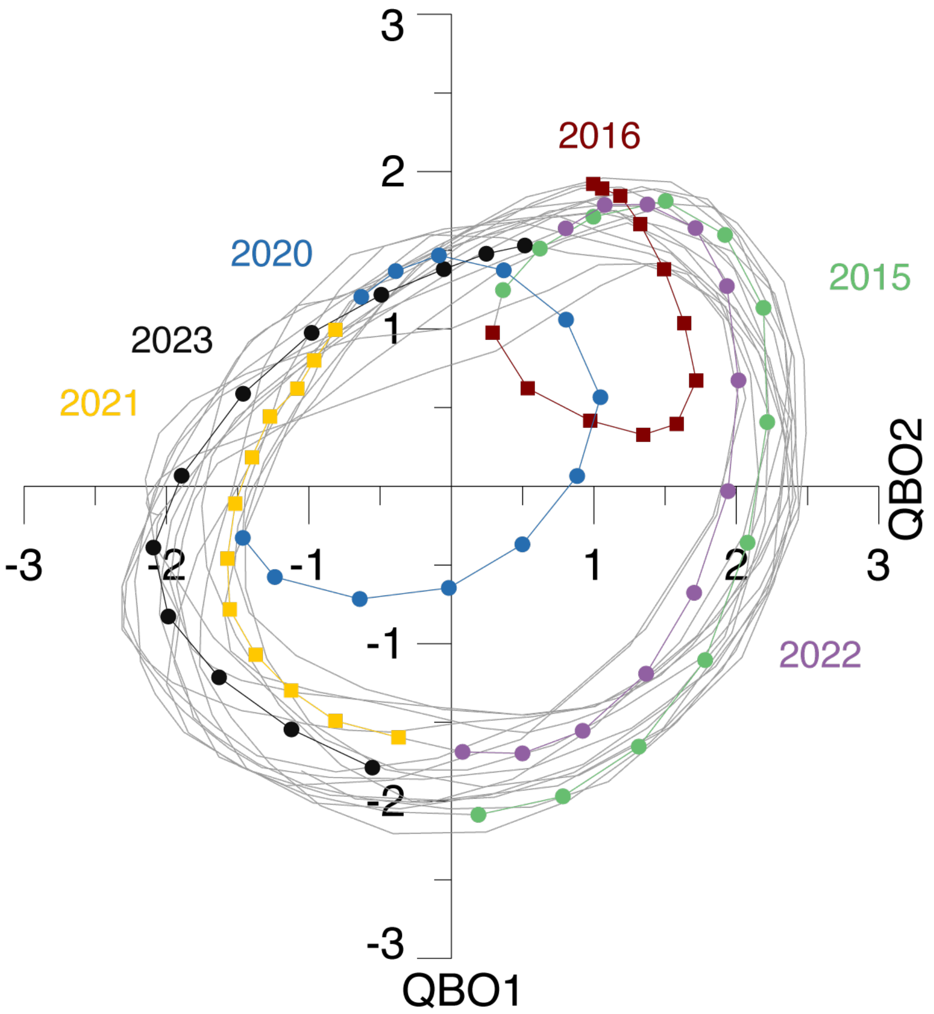
MLS - Negative trends in the SH/ Positive trends in the NH & tropics

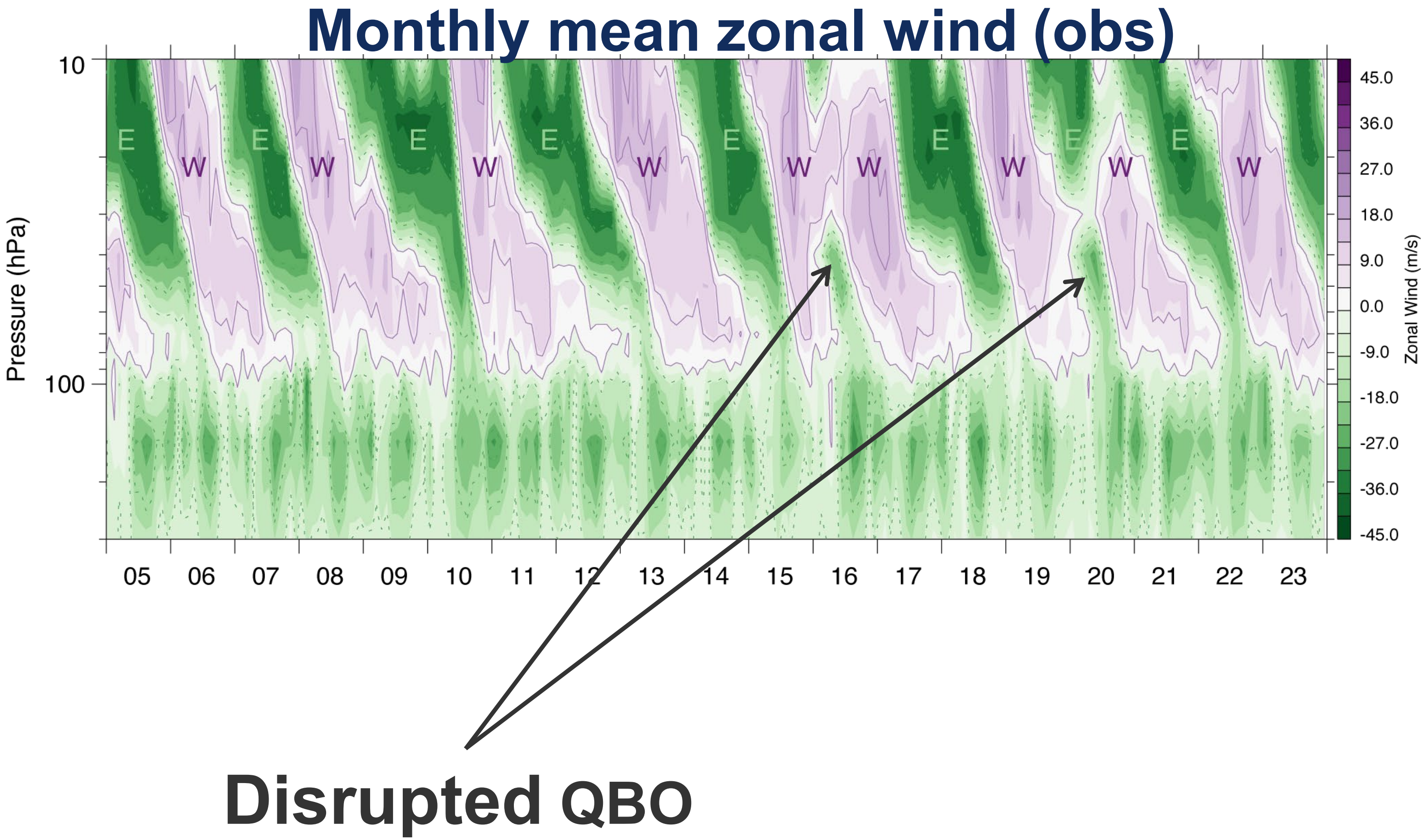
WACCM6 – Trends are lower in the SH & NH

WACCM6 (HIGHEESC) – Positive trends in the NH

*The EESC for the Fixed 1998 ODS scenario is constant through 2020 and ~15% higher than the reference simulation.

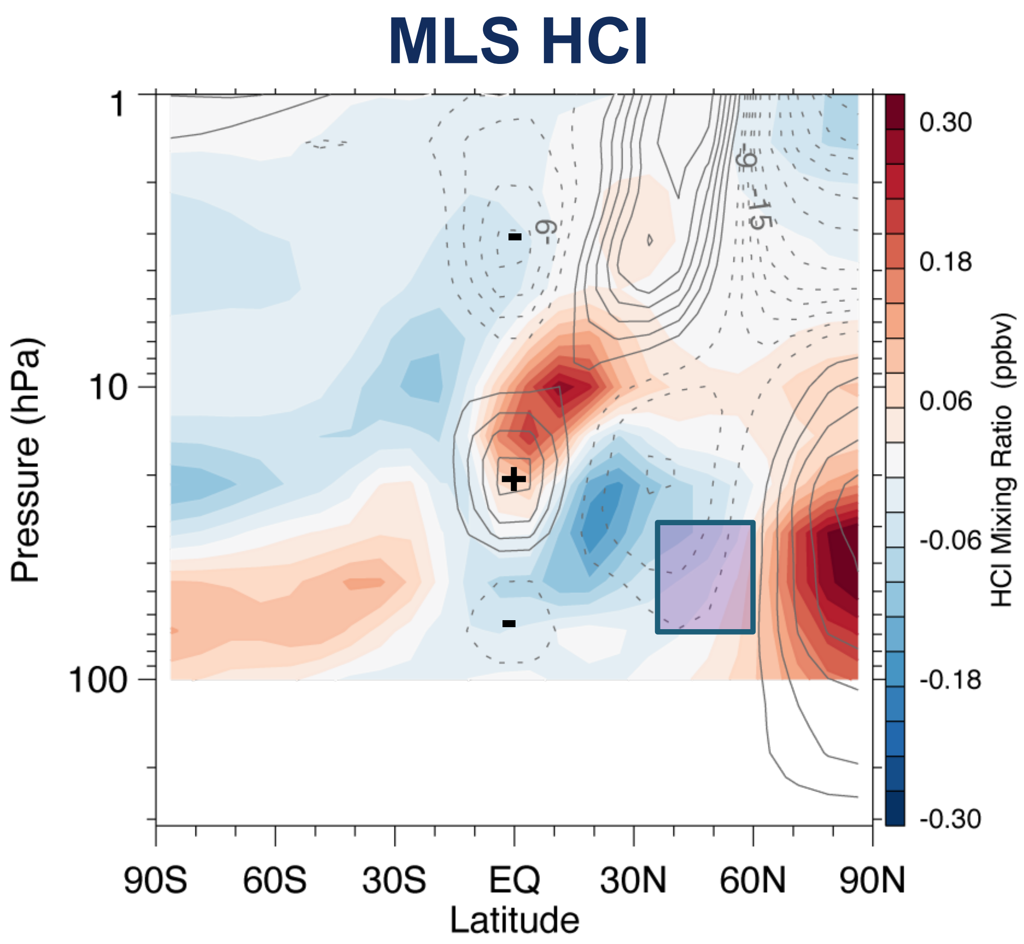
Disrupted QBO (2016 & 2020)

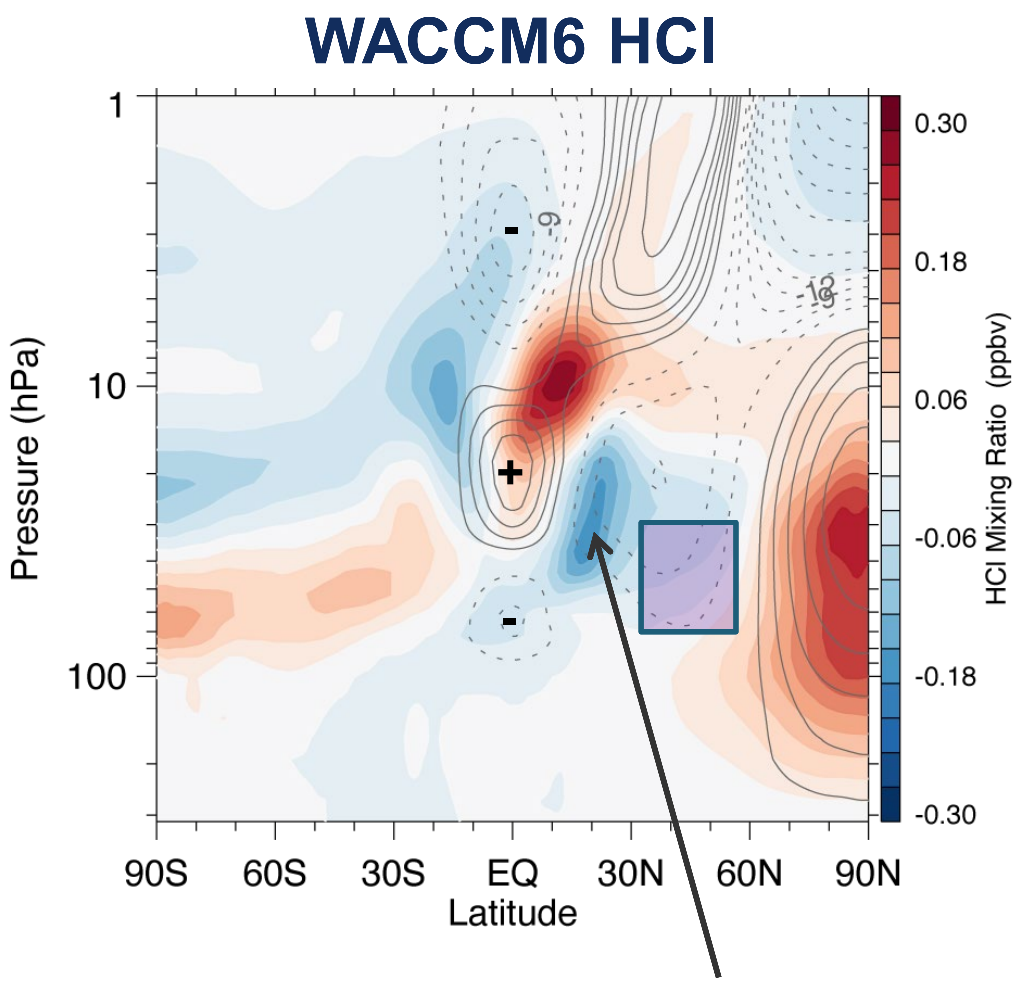




Based on Wallace et al. [1993]

QBO impacts on HCl (QBO-E *vs.* QBO-W)





Contours: temperature anomaly

Low HCl in NH midlatitudes

1276 Y. Li et al.: Monitoring sudden stratospheric warmings under climate change since 1980 based on reanalysis data

SSW

2019– Extreme

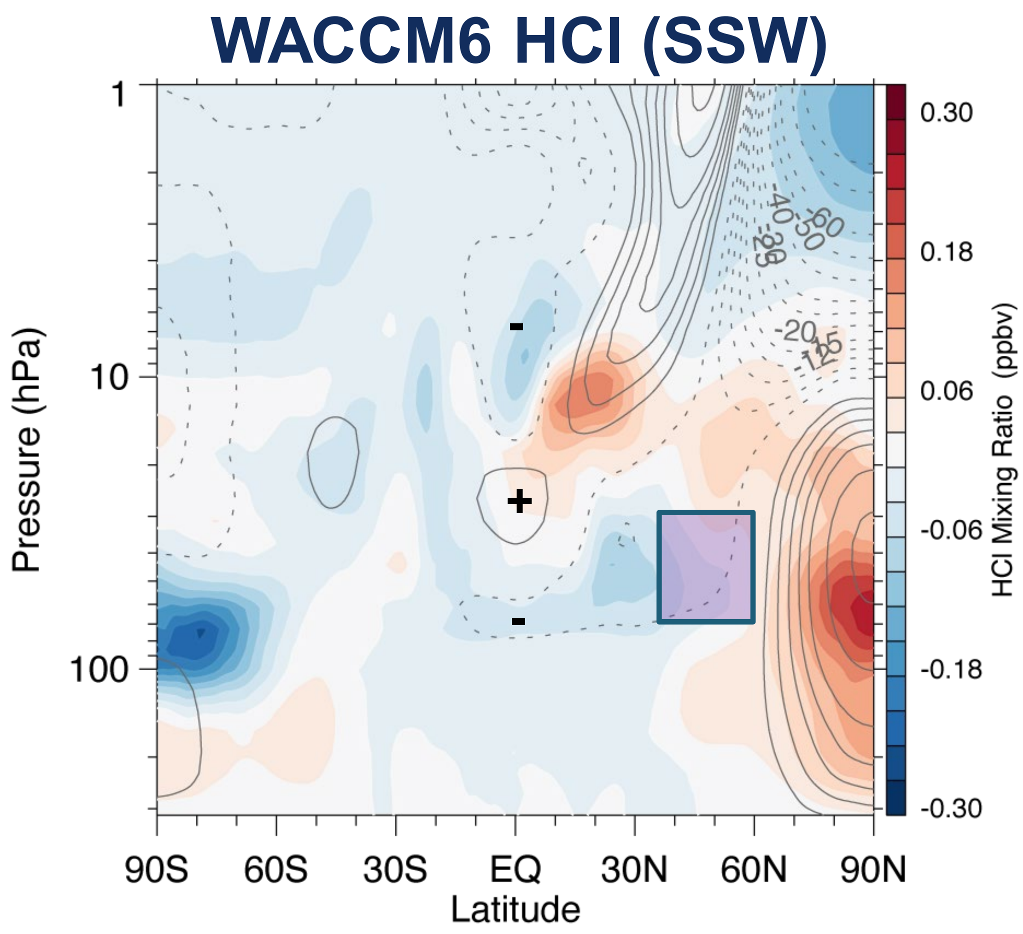
Table 3. Continued.

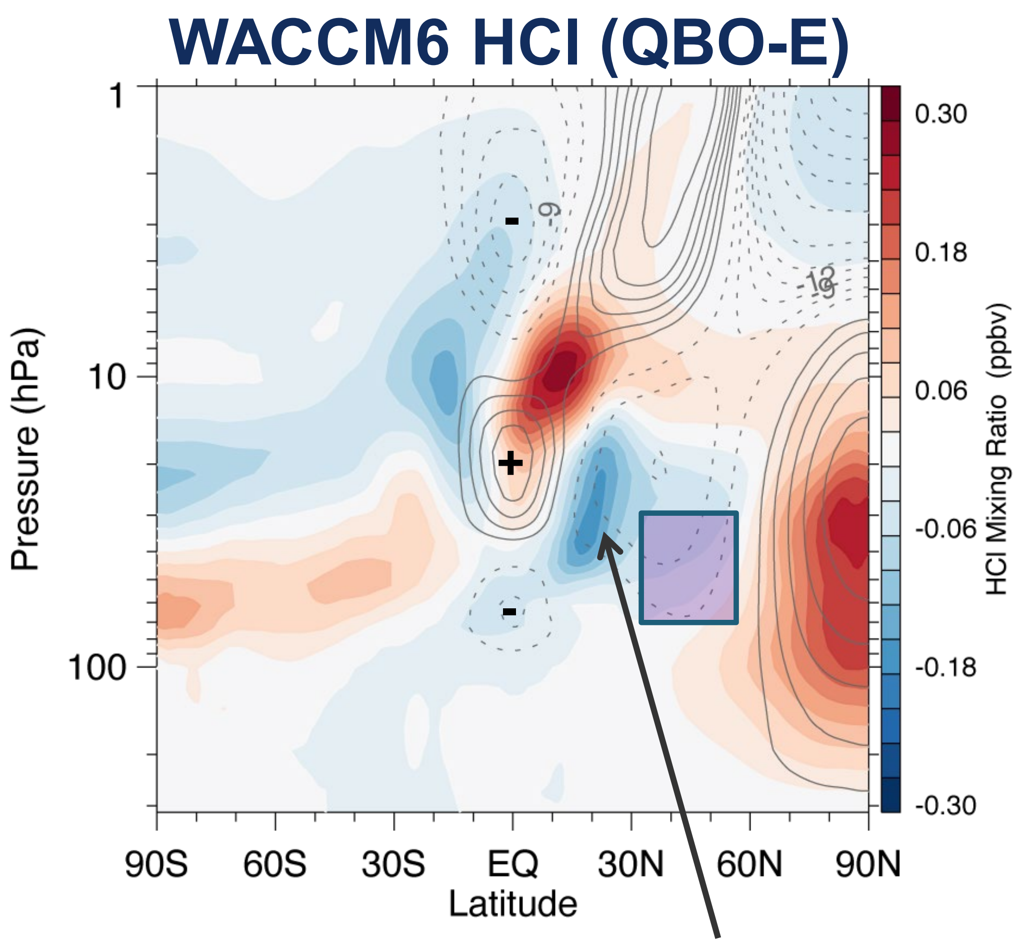
Winters	Onset date	MPS	MPD	MPA	Type	Max ΔT	Onset location	Onset date BG18
W16–17	28 Jan 2017	59.4	10	5.9	Minor	56.8	75.8° N/88.9° E	
	24 Feb 2017	27.8	6	4.6	Minor	46.3	73.1° N/71.7° E	
W17–18	16 Feb 2018	207.5	18	11.5	Extreme	60.9	61.8° N/102.0° W	
W18–19	25 Dec 2018	290.8	31	9.4	Extreme (TC)	60.2	77.9° N/72.5° E	
W19–20	21 Mar 2020	57.1	7	8.2	Minor	41.7	86.5° N/22.8° E	
W20–21	3 Jan 2021	110.2	11	10.0	Major	55.8	75.7° N/11.2° E	

Li et al. [2023]

QBO-E – SSW – HCI (NH midlatitudes)?

SSW impacts on HCl (SSW *vs.* noSSW)

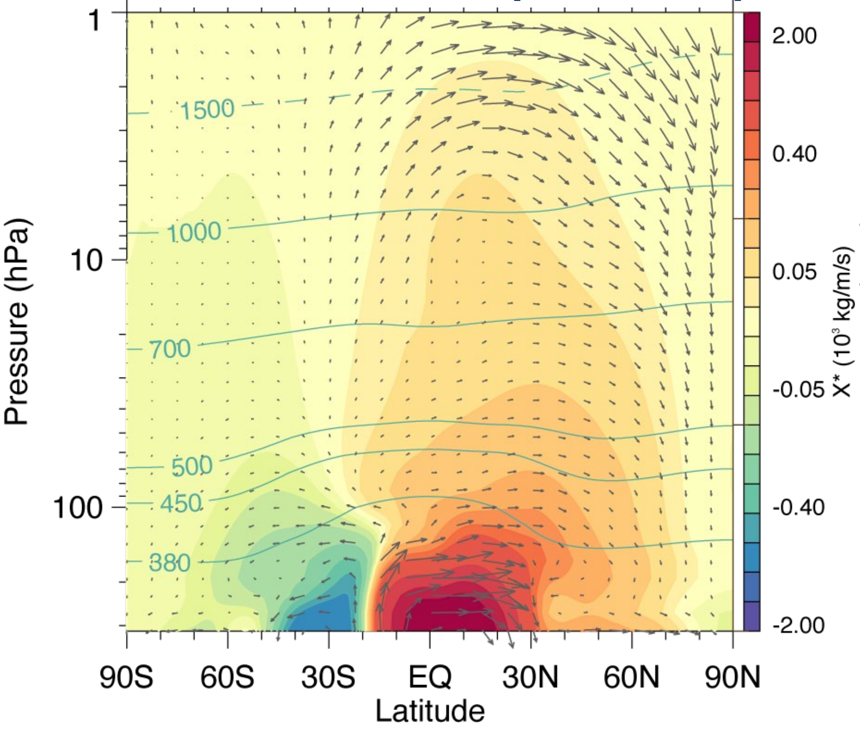




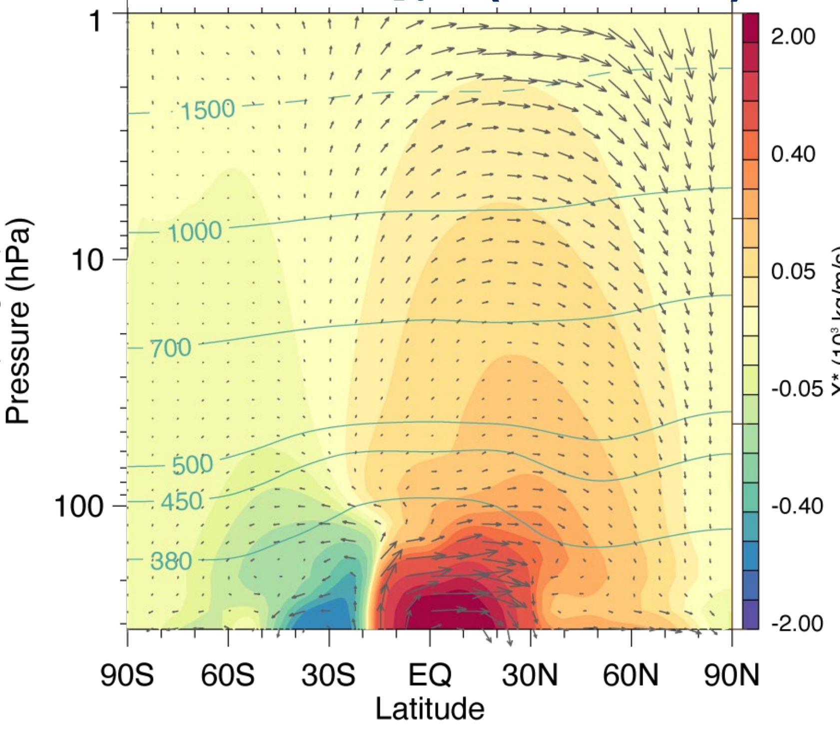
In the NH, the signs of HCl (-) and temperature (-) anomalies are consistent (QBO-E & SSW).

QBO impacts on circulation ($\overline{\chi}^*$)

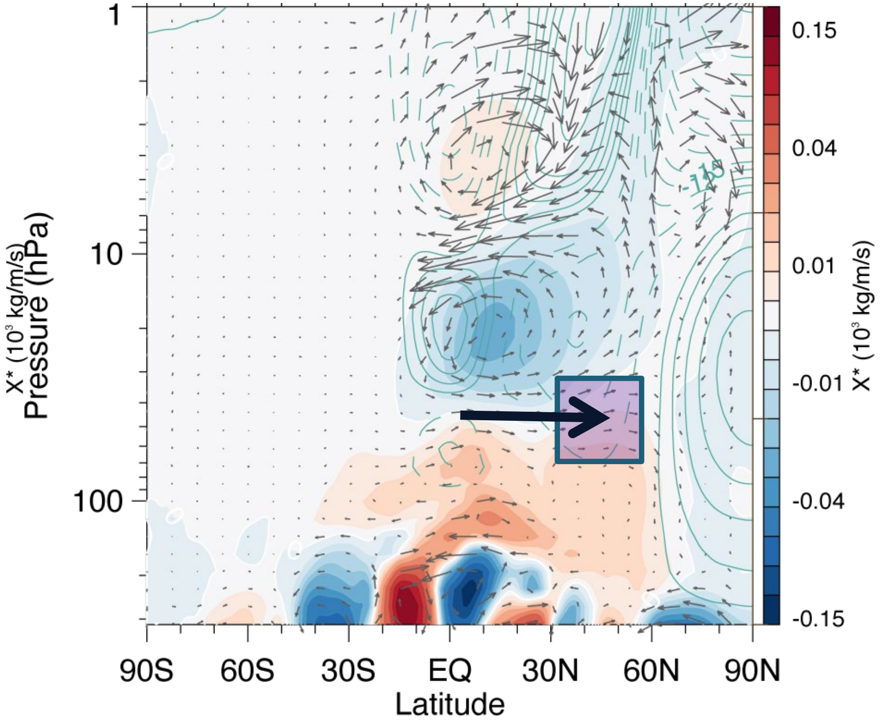
WACCM6 $\overline{\chi}^*$ (QBO-E)



WACCM6 $\overline{\chi}^*$ (QBO-W)



$\overline{\chi}^*$ (QBO-E *vs.* QBO-W)

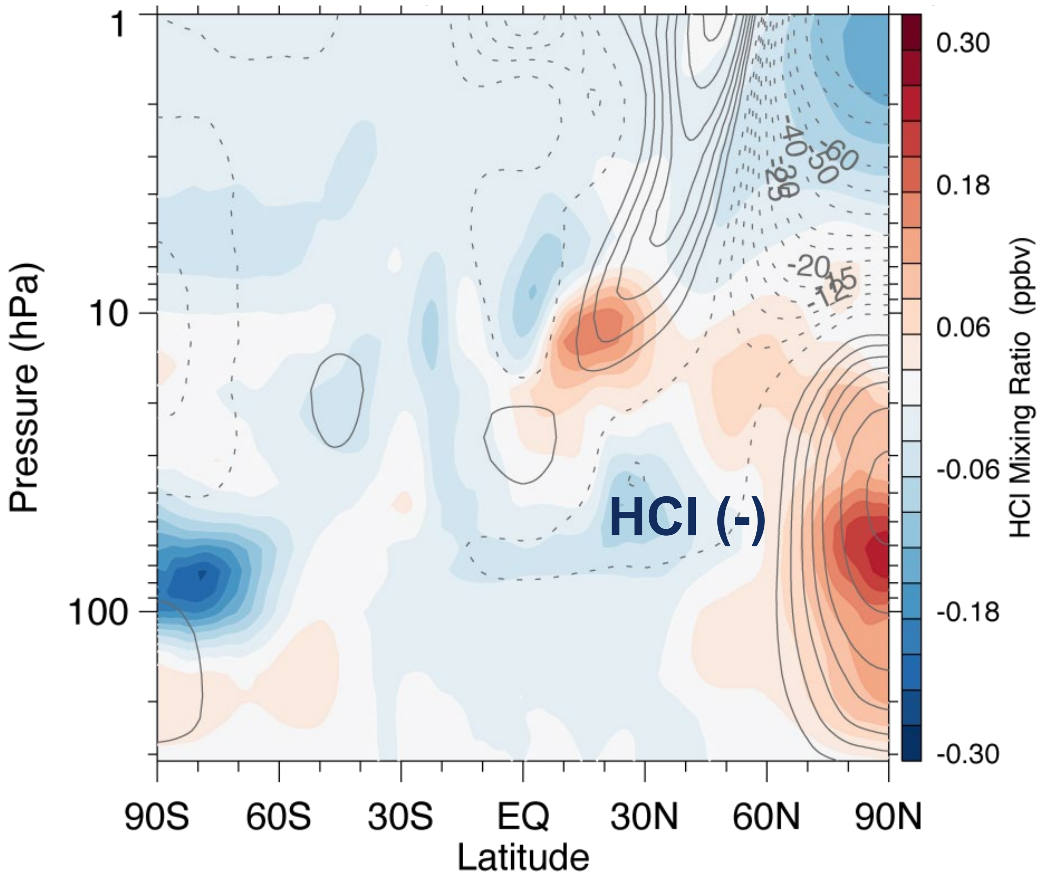


Mass stream function ($\overline{\chi}^*$)
Positive: clockwise
Negative: counter-clockwise

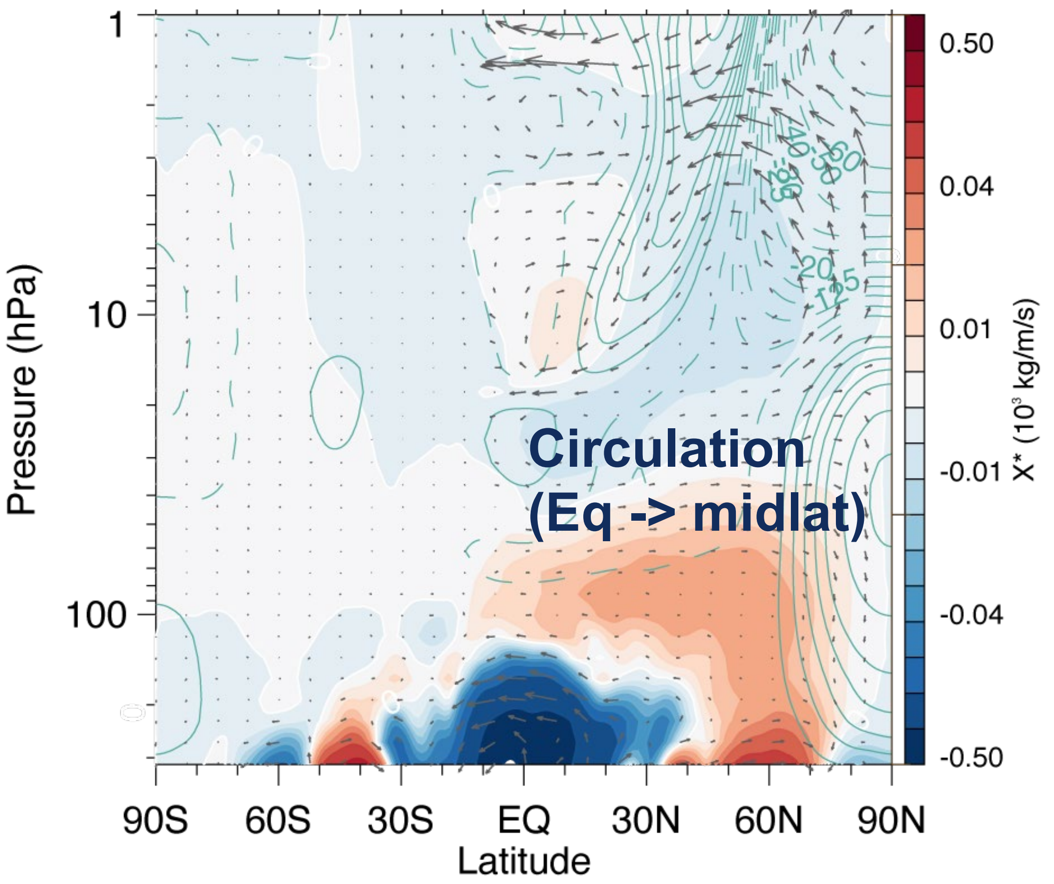
Stronger transport from the tropics to midlatitude during QBO-E.

SSW impacts on HCl & $\overline{\chi}^*$ (SSW)

WACCM6 HCl

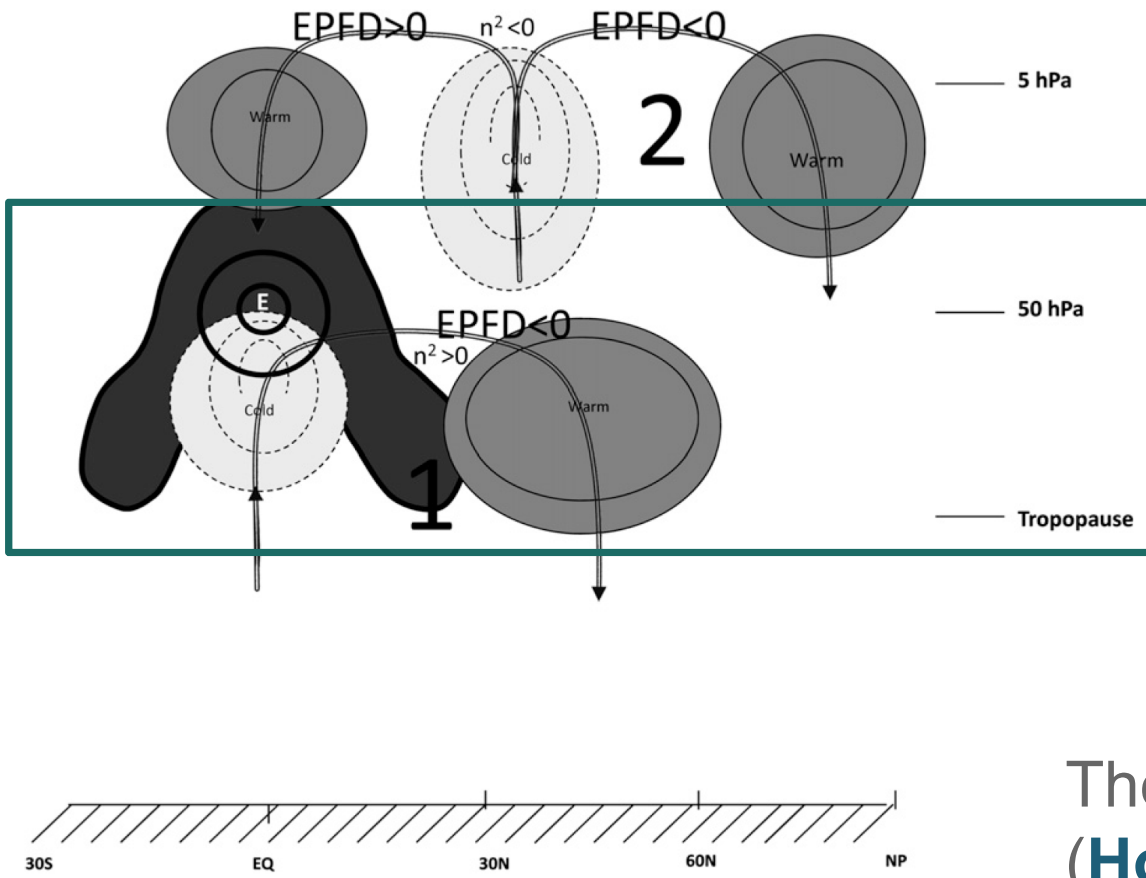


WACCM6 $\overline{\chi}^*$

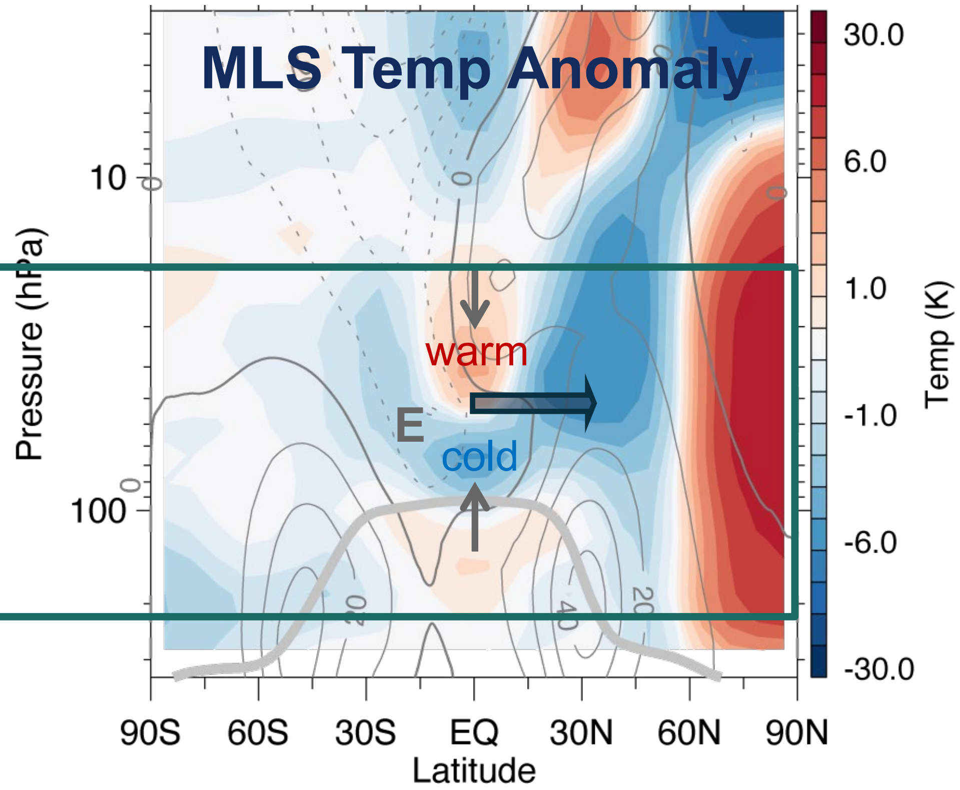


QBO teleconnection

Jan 2019 (QBO-E/SSW)



Garfinkel et al. [2012]



The teleconnection between the QBO and SSW (**Holton-Tan effect**) might have contributed to transport of low HCl from the tropics to the NH midlatitudes.

Summary

1. Observed trends in the stratospheric HCl estimated from the MLS show positive values in the NH midlatitudes for 2005-2020. Trends estimated from the SD-WACCM6 simulations are lower than the MLS estimates globally.
2. It is likely that the underestimation of surface emissions of CFC-11 and the lack of very short lived species (VSLS) played a role in the WACCM6 HCl trend estimate in the NH lower stratosphere.
3. The stratospheric QBO is able to explain much of the variability in the HCl in NH winter for 2005-2014. During the recent disrupted QBO events, this relationship became unclear.
4. For the recent period after 2015, changes in large-scale circulation associated with the QBO *vs.* SSW teleconnection (Holton-Tan effect) seemed to have played a role in HCl variability in the NH midlatitudes.

O_3 Trends in the Stratosphere