Why can we trust climate model simulations of ozone depletion chemistry?

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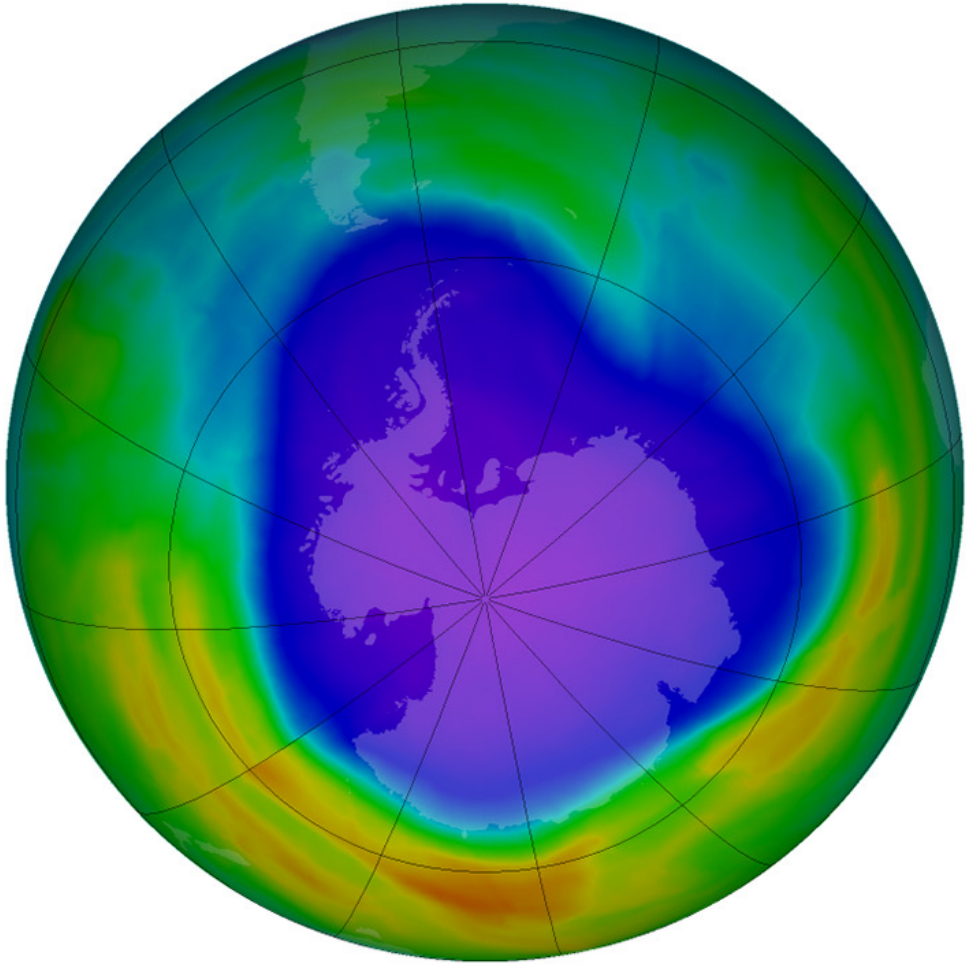
Deutche Physikerinnentagung

What is ozone?



Ozone absorbs UV radiation before it can reach the surface and harm us.

In the 1970s, it was discovered that reactive inorganic chlorine gases in the stratosphere catalyze ozone depletion in the springtime.

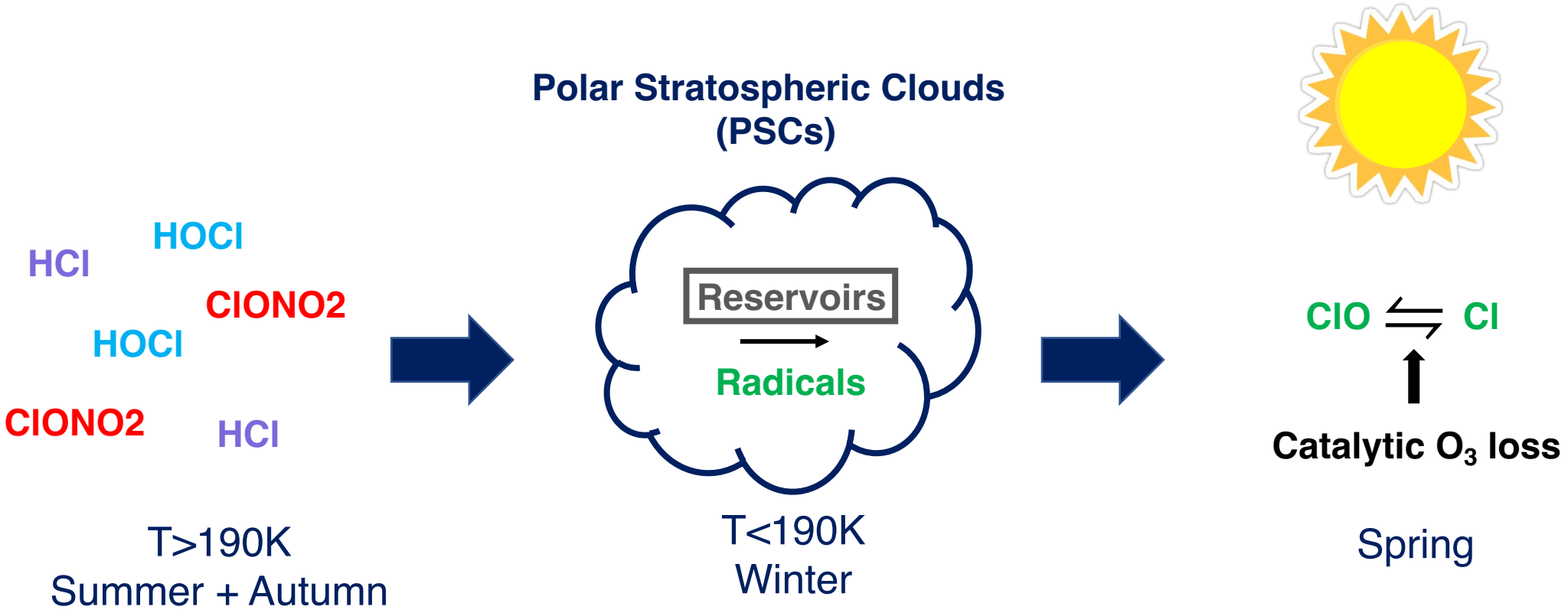
In response, the use of industrial chlorine sources has been phased out by the 1987 Montreal Protocol and its subsequent amendments.

Ozone is on the way to recovery, and **climate models can help predict when it will return to pre-1980 levels**.

Figure: https://www.science.org/content/article/new-threat-ozone-layer-found

What is inorganic chlorine (Cl_y)?

Inorganic chlorine radicals catalytically destroy ozone during polar spring.



$$Cl_y = HCl + ClONO_2 + HOCl + ClO + \text{others}$$

How do we quantify Cl_y?

Reservoirs

Radicals

Cl_y^*

$$Cl_y = HCl + ClONO_2 + HOCl + ClO + \text{others}$$

Satellite measurements

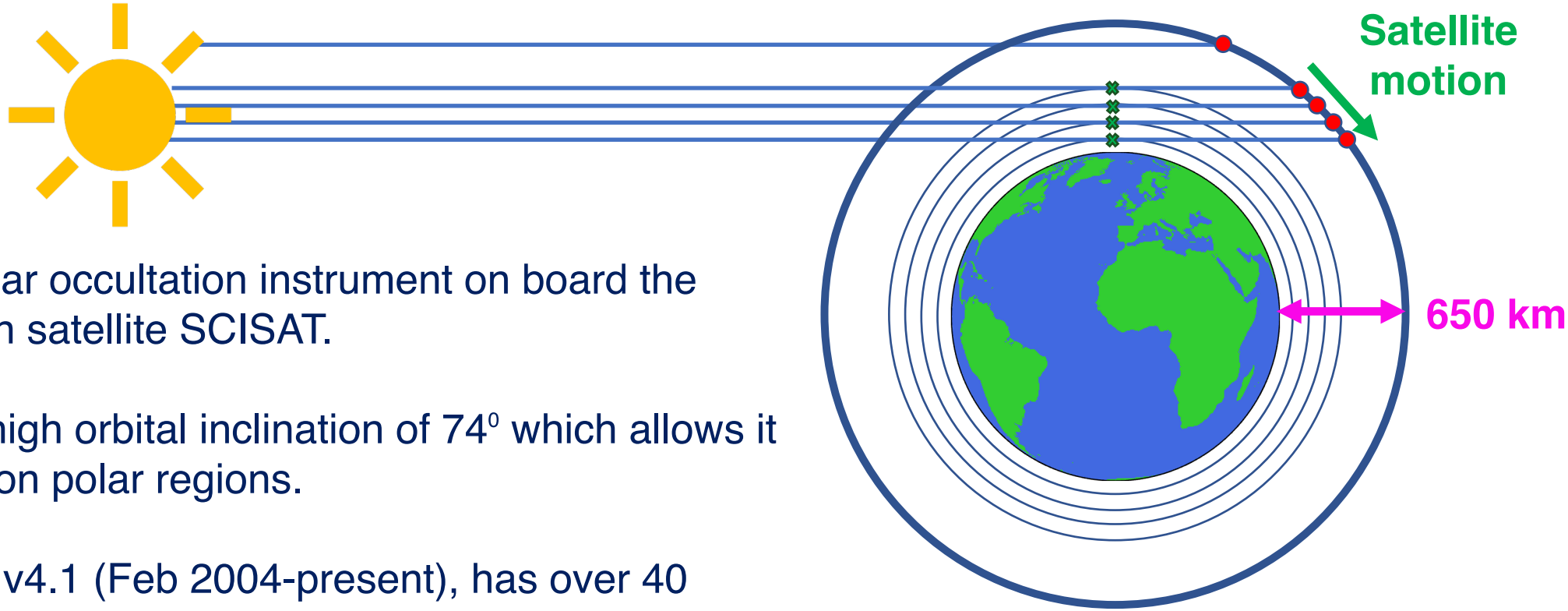
ACE-FTS, supplemented with MLS, MIPAS, SMILES

Model output

Canadian Middle Atmosphere Model, specified dynamics version (CMAM39)

What is ACE-FTS?

The **A**tmospheric **C**hemistry **E**xperiment **F**ourier **T**ransform **S**pectrometer

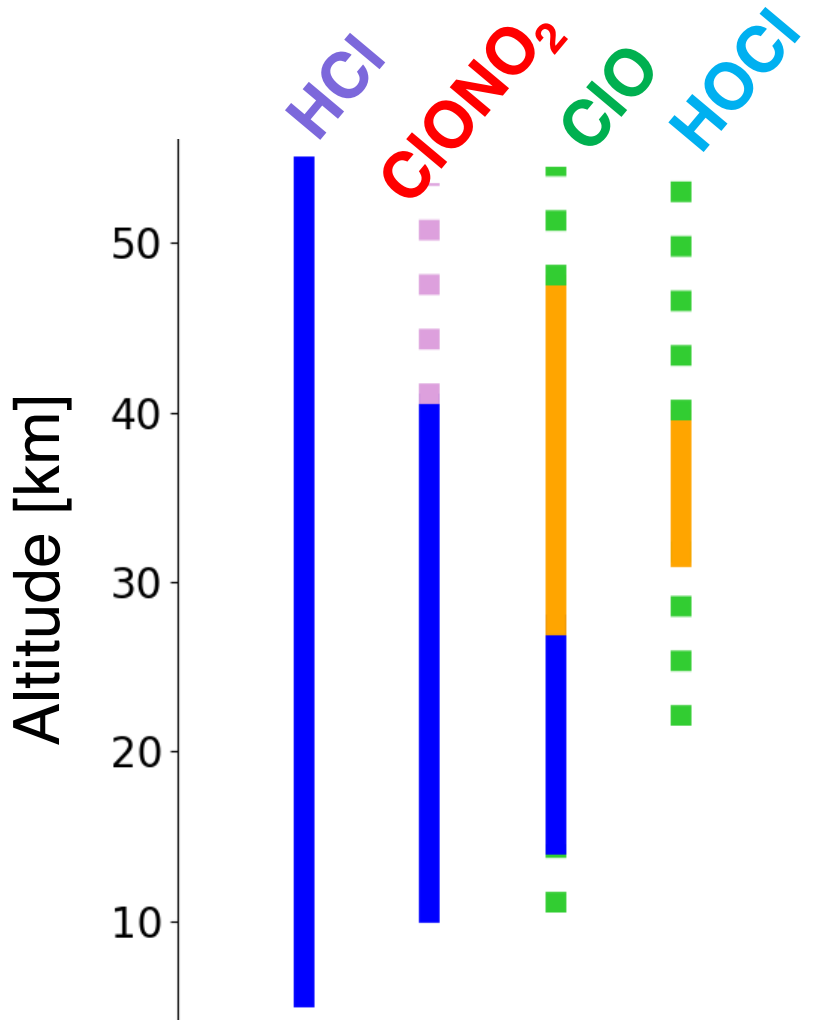


It is a solar occultation instrument on board the Canadian satellite SCISAT.

It has a high orbital inclination of 74^0 which allows it to focus on polar regions.

Dataset: v4.1 (Feb 2004-present), has over 40 molecules and isotopologues (including **HCl**, **$ClONO_2$**, **ClO**, and organic chlorine species).

How are we merging the datasets?



ACE-FTS: 2004-present

MLS: 2004-present
Microwave Limb Sounder on Aura

MIPAS: 2005-2012
Michelson Interferometer for Passive Atmospheric Sounding on ENVISAT

SMILES: Oct 2009-Apr 2010
Superconducting Submillimeter-Wave Limb-Emission Sounder on the ISS

What is CMAM39?

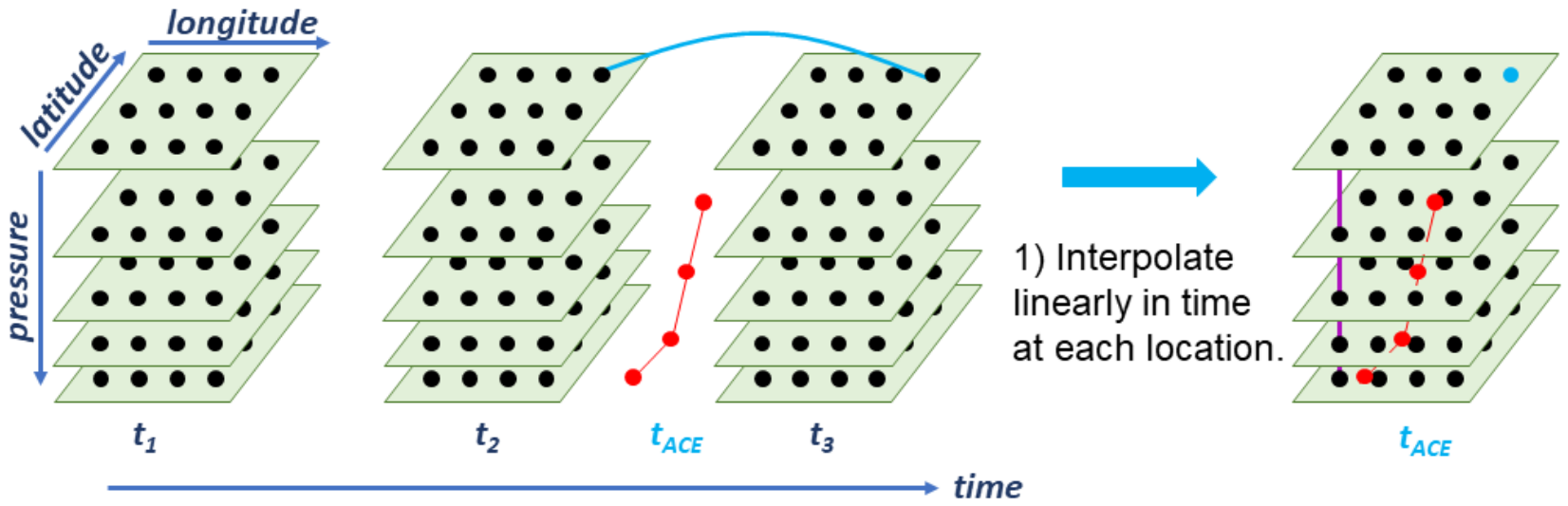
The Canadian Middle Atmosphere Model is a chemistry climate model.

It has an extensive description of stratospheric chemistry.

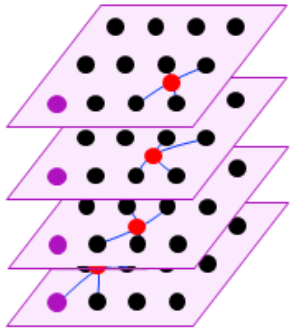
Here, we use 6-hourly fields from 2004 through 2018.

The goal of this work is to use satellite measurements to evaluate total inorganic chlorine partitioning in CMAM39.

How do we make sure the model is representative of the data?



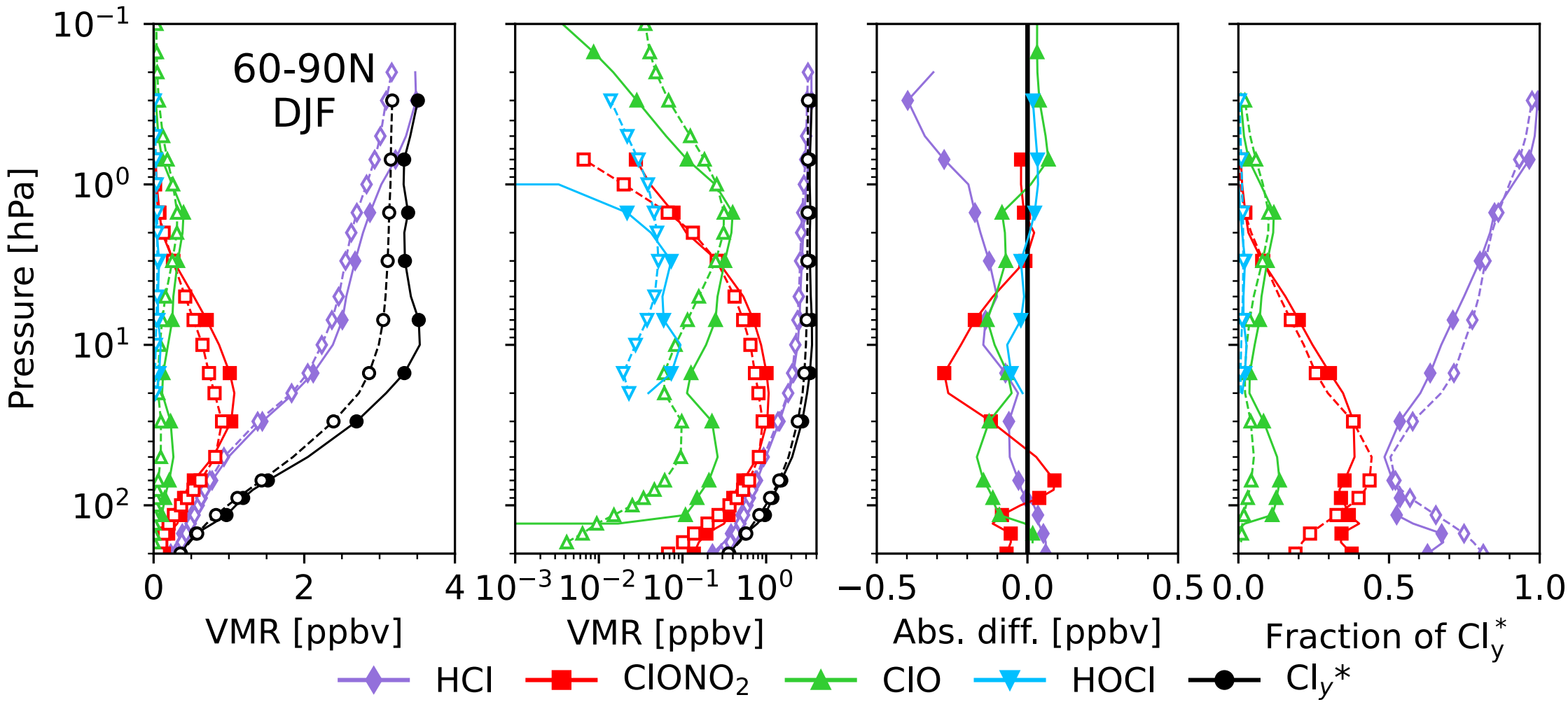
2) At each (lat,lon) coordinate, interpolate linearly in log pressure.



3) At each level, interpolate bilinearly in horizontal space.

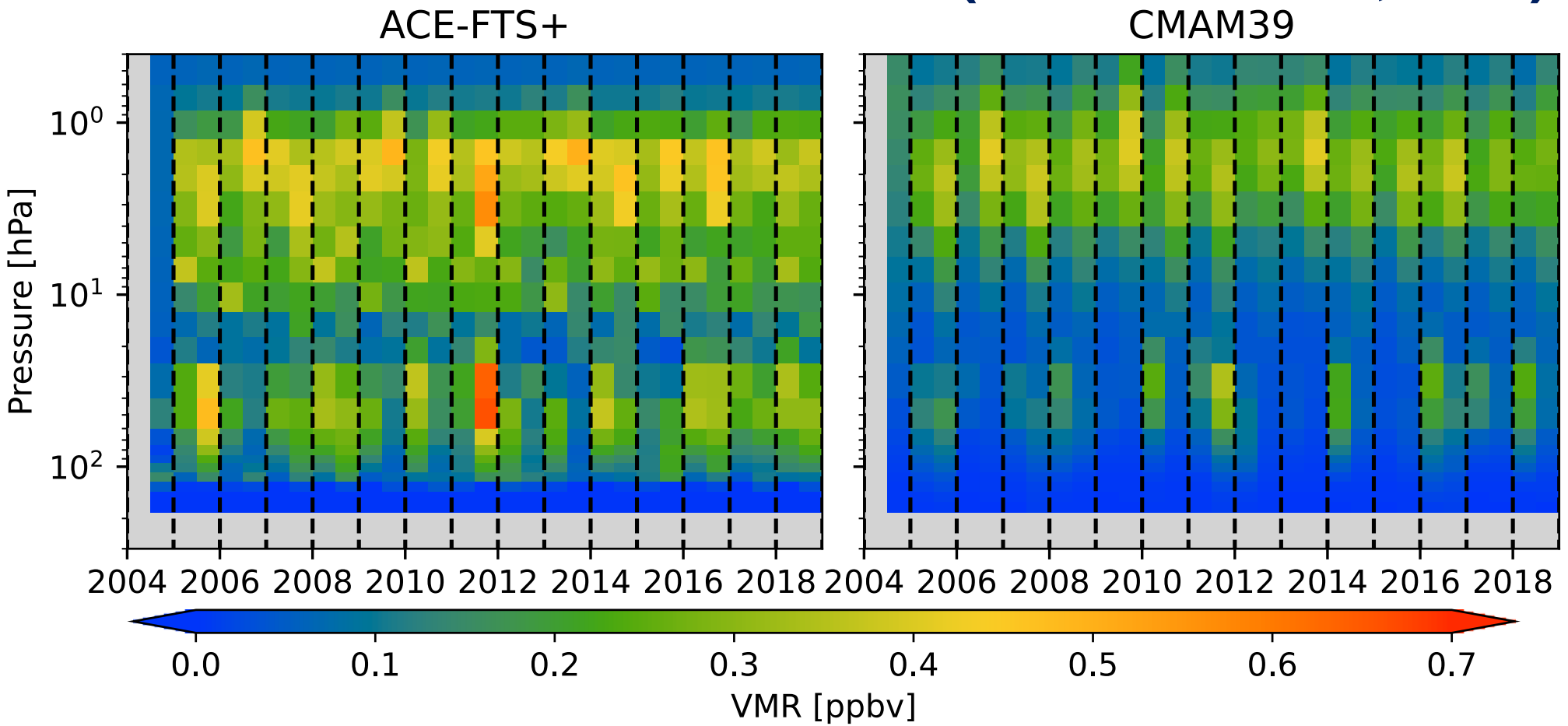
Select results

Profile comparisons – Arctic winter (polar processing is happening)



Solid lines are measurements, dashed lines are CMAM39.

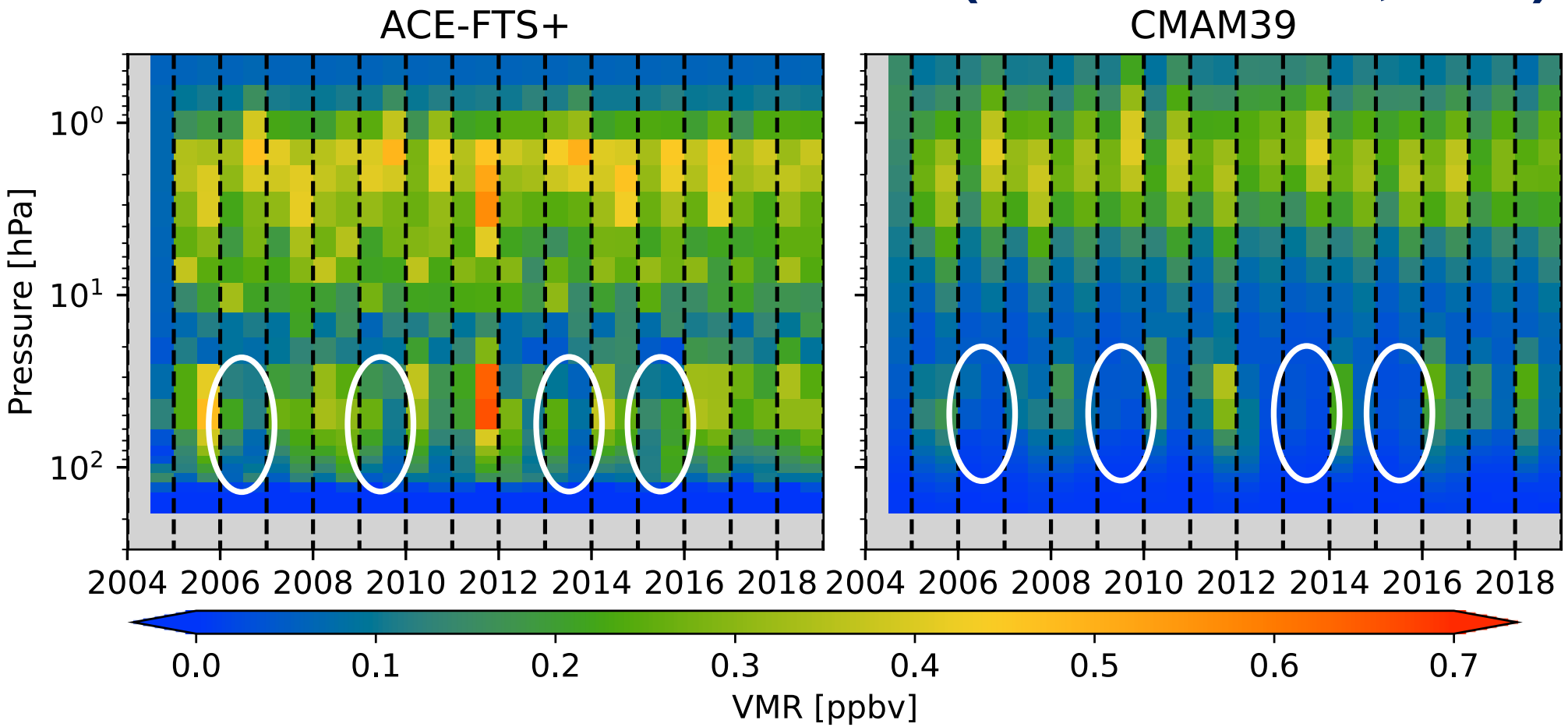
Time series ClO – Arctic winter (60-90°N: Jan, Feb)



Dashed black lines separate the years.

CMAM39 does not have all types of PSCs, which could explain the low ClO activation.

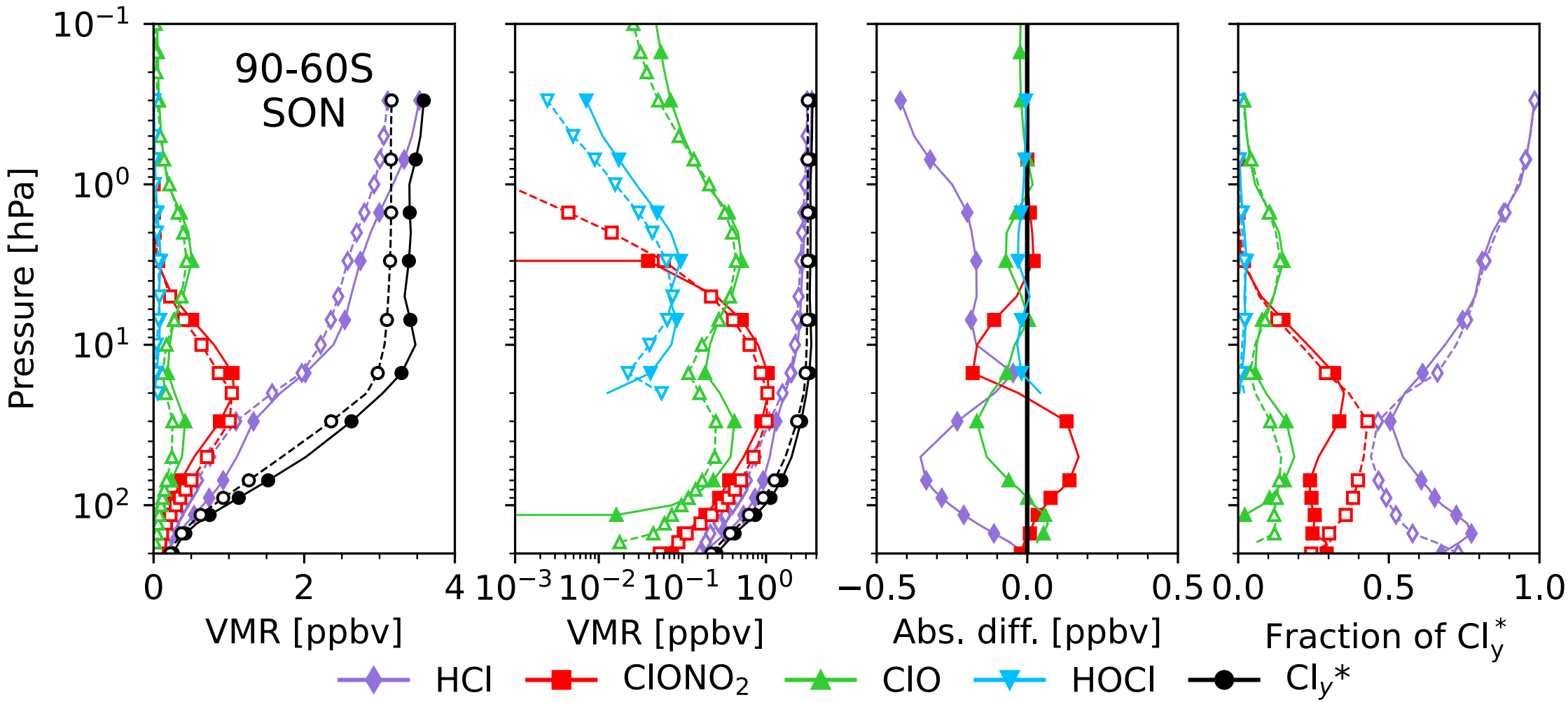
Time series ClO – Arctic winter (60-90°N: Jan, Feb)



Dashed black lines separate the years.

Years with low ozone loss: 2006, 2009, 2013, and 2015.
Pearson correlation coefficient at **30hPa: 0.867, 50hPa: 0.852**

Profile comparisons – Antarctic spring (polar processing is ending)



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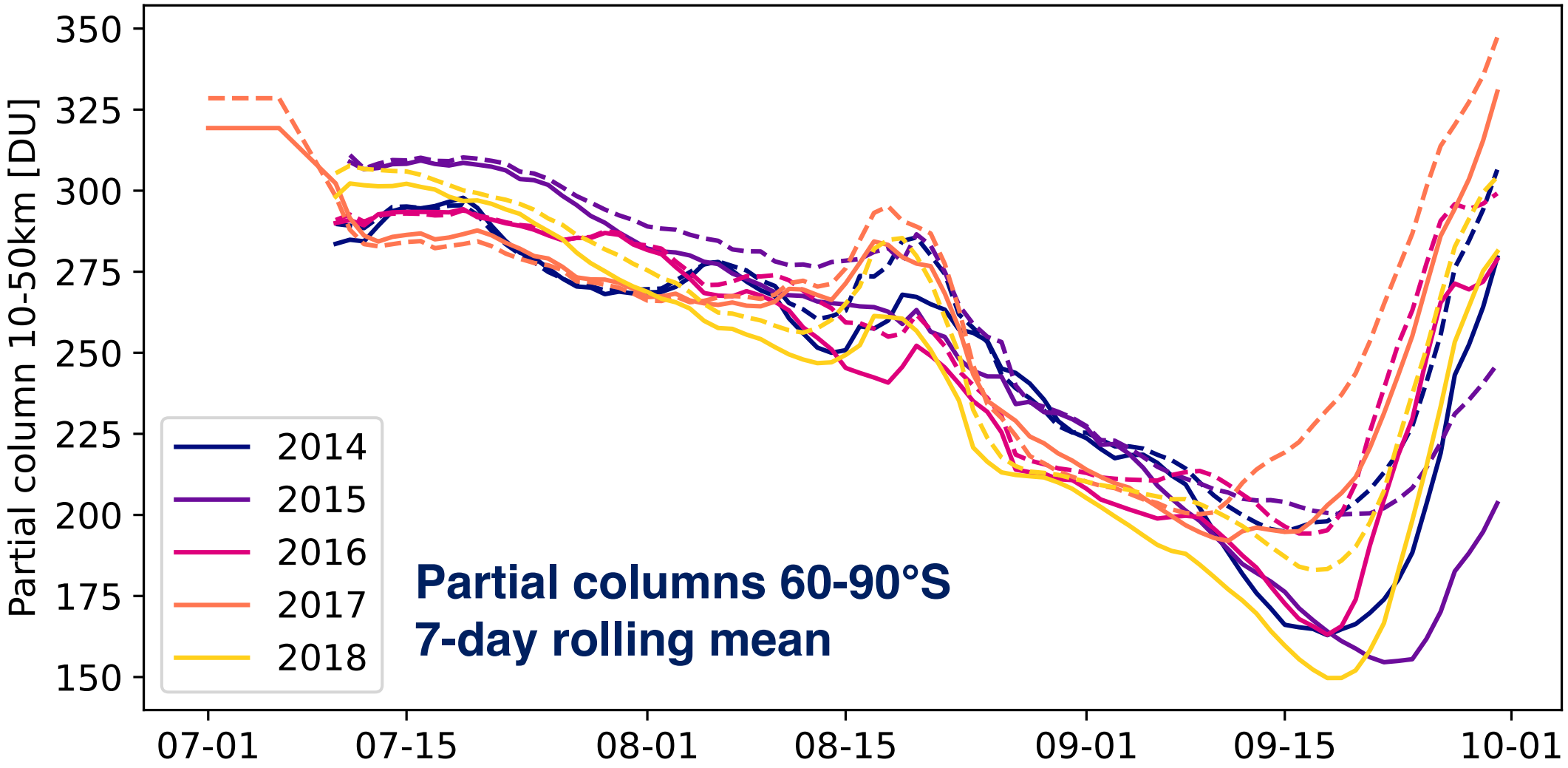
How does this affect ozone depletion in CMAM39?



Solid lines are measurements, dashed lines are CMAM39

Summary

1) CMAM39 appears to underestimate total inorganic chlorine concentrations.

2) When polar processing is not occurring, CMAM39 captures chlorine partitioning very well.

3) During polar processing, CMAM39 underestimates the production of **ClO**, but the interannual variability is represented very well.

4) During Antarctic spring, CMAM39 recovers **$ClONO_2$** too quickly.

5) CMAM39 has somewhat weak ozone depletion.

Now that we know all this, we can take it into account when using CMAM39 for climate studies!

Acknowledgements

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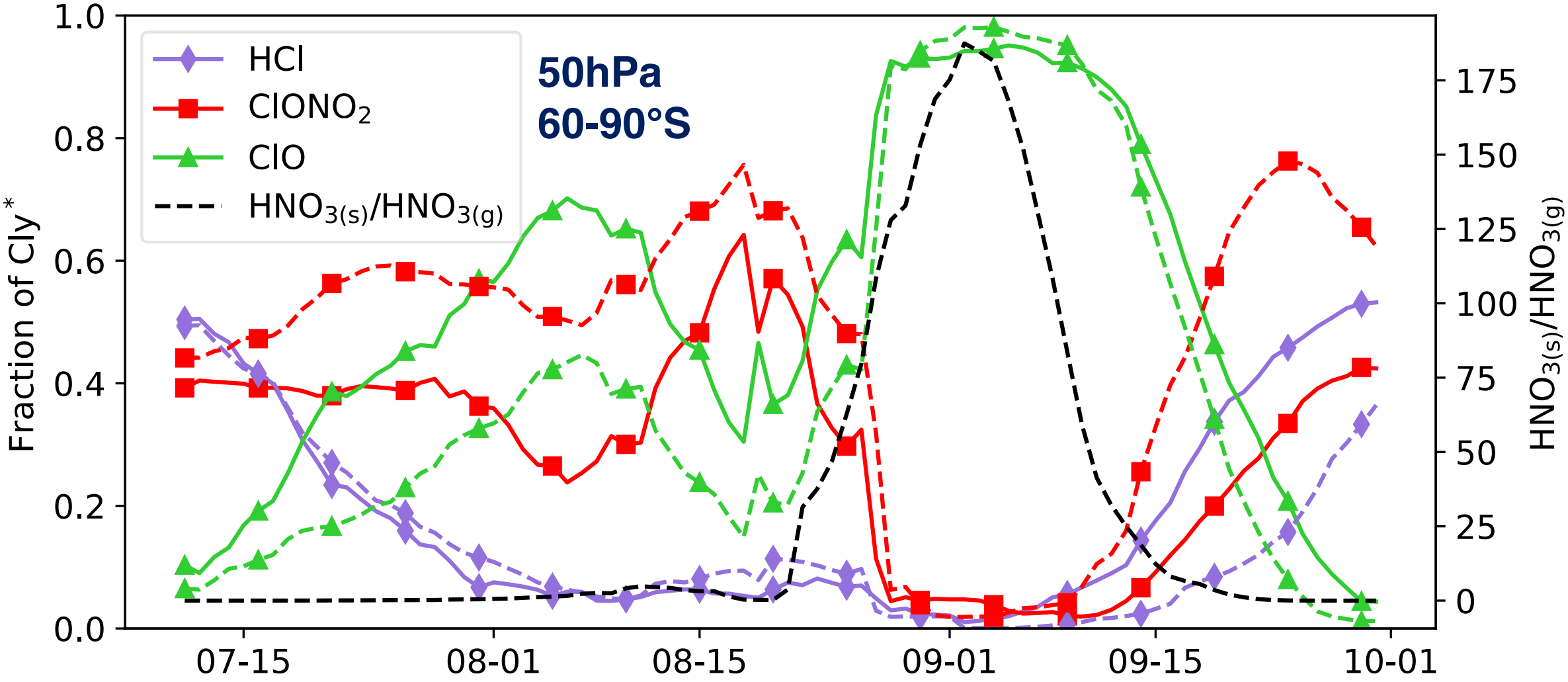
The development of the CMAM39 data set was funded by the CSA. We also thank Ted Shepherd, Dylan Jones, and John Scinocca for their leadership and support of the CMAM39 Project.

Why is CMAM39 recovering $ClONO_2$ too early?



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