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Fachbereich 01

Longitudinally-resolved Long-term Ozone Changes in the Stratosphere from Satellite Limb Observations and CTM Simulations

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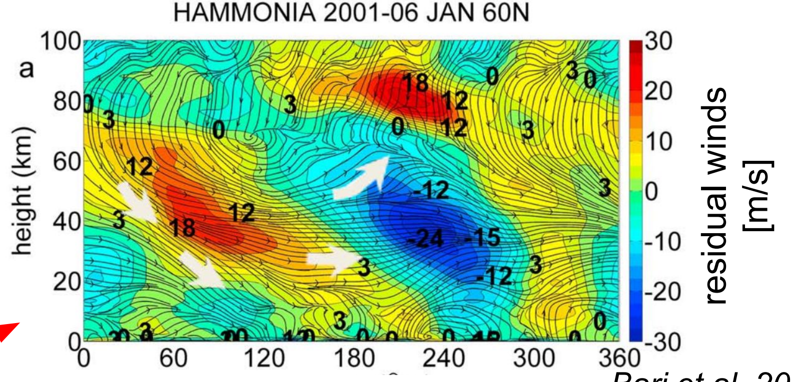
esa European Space Agency

DAAD Deutscher Akademischer Austausch Dienst German Academic Exchange Service

Outline

1. Motivation and data used
2. Comparison between the times series
3. Ozone trend comparison, zonally averaged and resolved
4. Seasonal trends: ozone and temperature
5. Meridional winds and winter wave-1 changes

Motivation and data sets

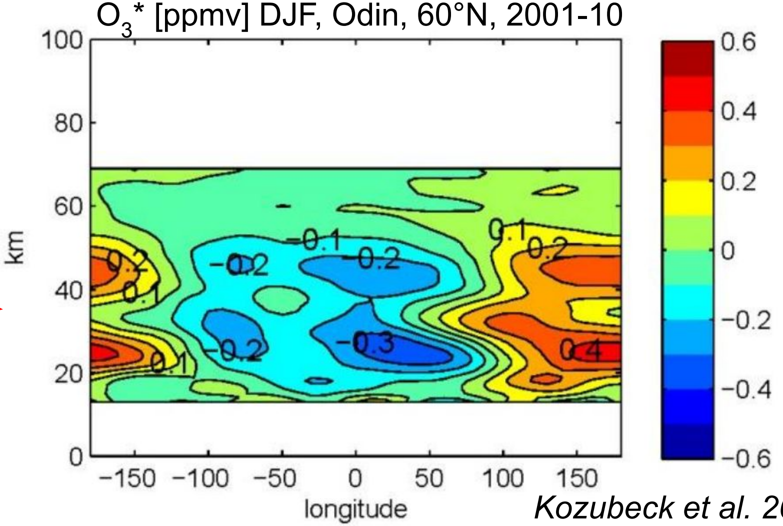


Bari et al. 2013

Aim: study longitudinally resolved ozone trends exploiting the high resolution of satellite limb observations and investigate the driving mechanisms with a chemistry transport model.

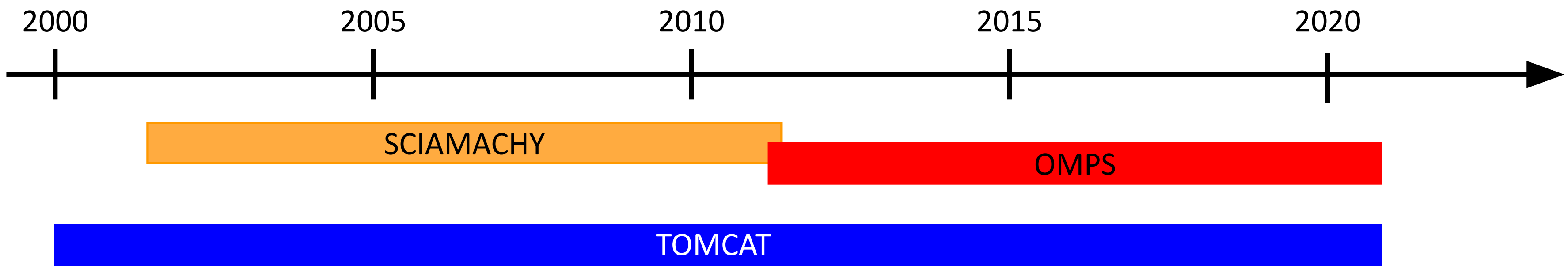
Motivation:

- a 3D structure of the Brewer-Dobson Circulation has been investigated by several studies (e.g. Bari et al., 2013, Kozubeck et al., 2015).
- The presence of zonal asymmetries in several trace gas fields was reported to be relevant in winter.



Kozubeck et al. 2015

Is the ozone recovery zonally uniform or long-term ozone trend also have asymmetries?



<u>Used **limb sounders** time series</u>:

SCIAMACHY:	08.2002 – 04.2012,	100 obs per orbit	Existing data set retrieved at IUP
OMPS-LP:	02.2012 – present,	140 obs per orbit (per slit)	Retrieved and updated at IUP

Merged to get longitudinally resolved time series, on a 5° latitude x 20° longitude grid.

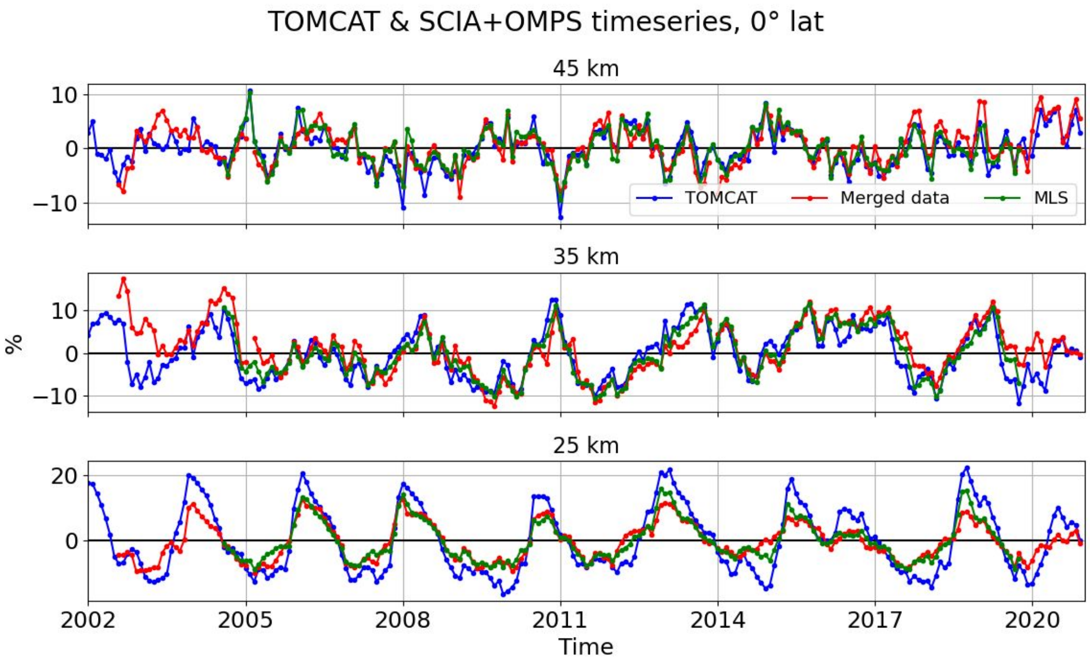
<u>Used **Chemistry Transport Model**</u>:

TOMCAT: 01.1979 – 12.2020

Reference full-chemistry TOMCAT simulation.

Comparing the time series

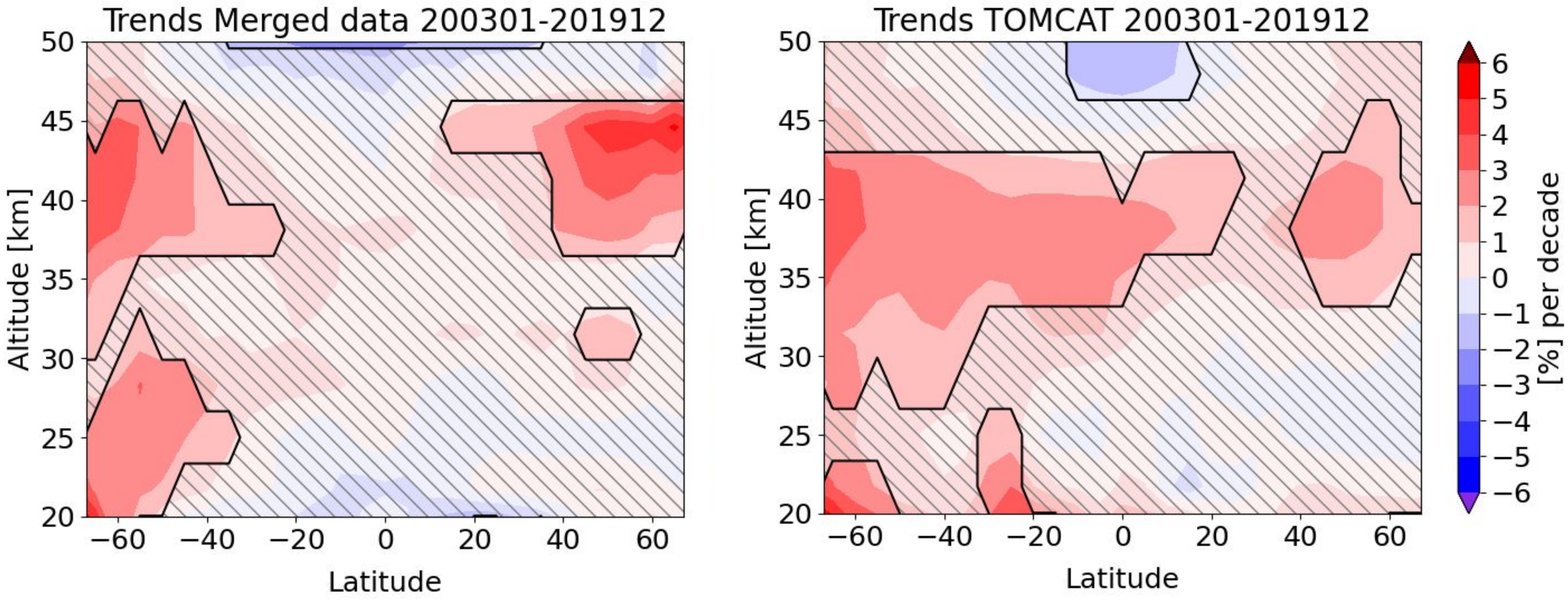
Preliminary comparison of the model with the merged data set and MLS to evaluate the bias and discrepancies in seasonal cycle as a function of altitude, latitude and time. Example of anomalies time series in the tropics:



Anomalies were used to compute long-term trends

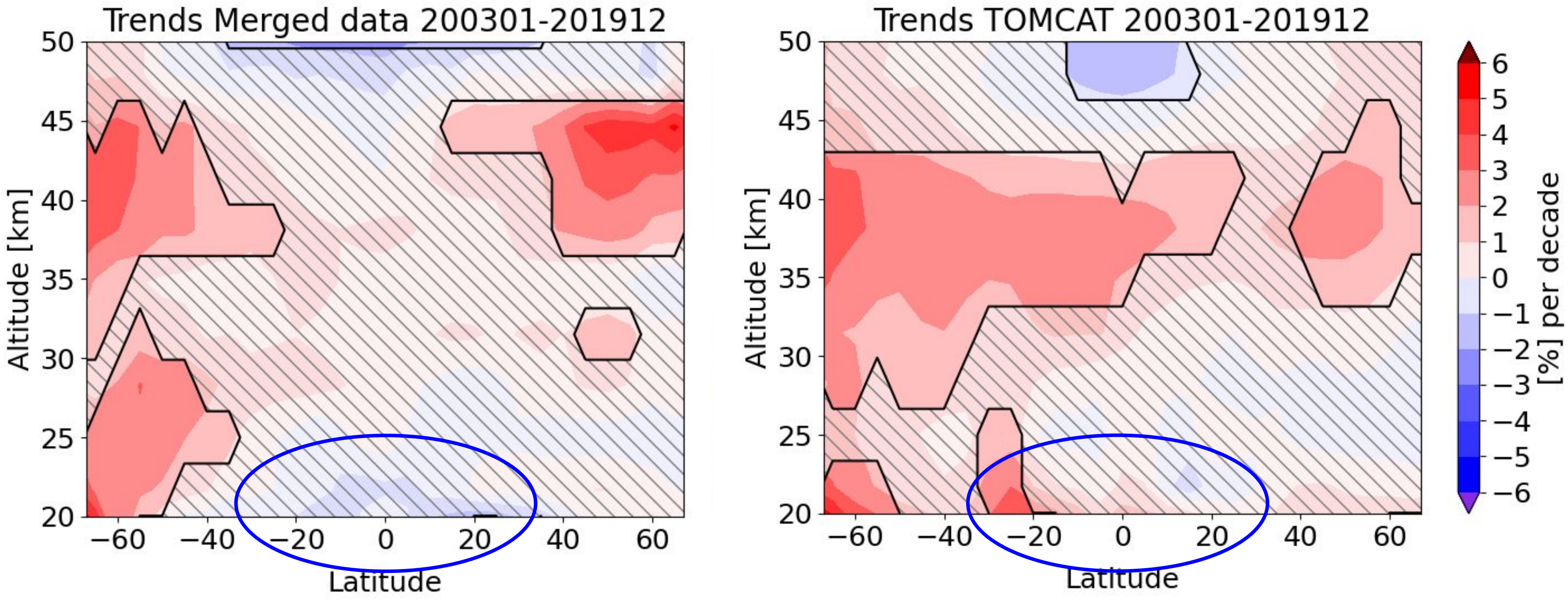
Ozone trends - zonal

- Multi-linear regression model applied to deseasonalized anomalies from both time series.
- Zonal trends show similarities in the middle and upper stratosphere: ozone recovery stronger at mid- and high-latitudes.



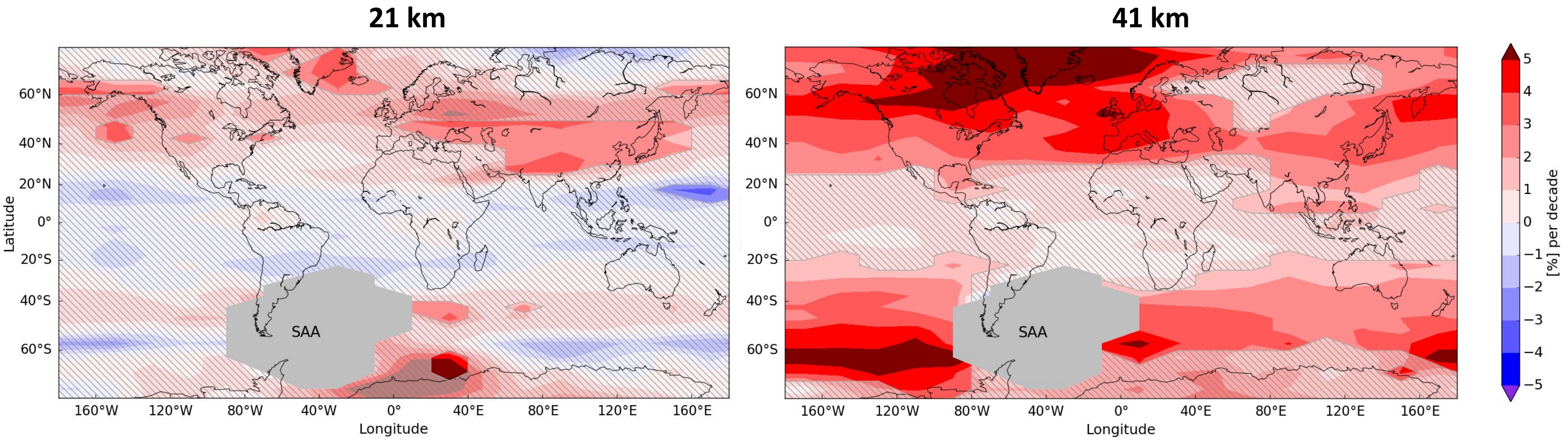
Ozone trends - zonal

- Multi-linear regression model applied to deseasonalized anomalies from both time series.
- Zonal trends show similarities in the middle and upper stratosphere: ozone recovery stronger at mid- and high-latitudes. TOMCAT does not reproduce the negative values in the lower stratosphere.



Ozone trends - resolved

Longitudinally resolved trends from **merged satellite data**, % per decade, 2003-2019



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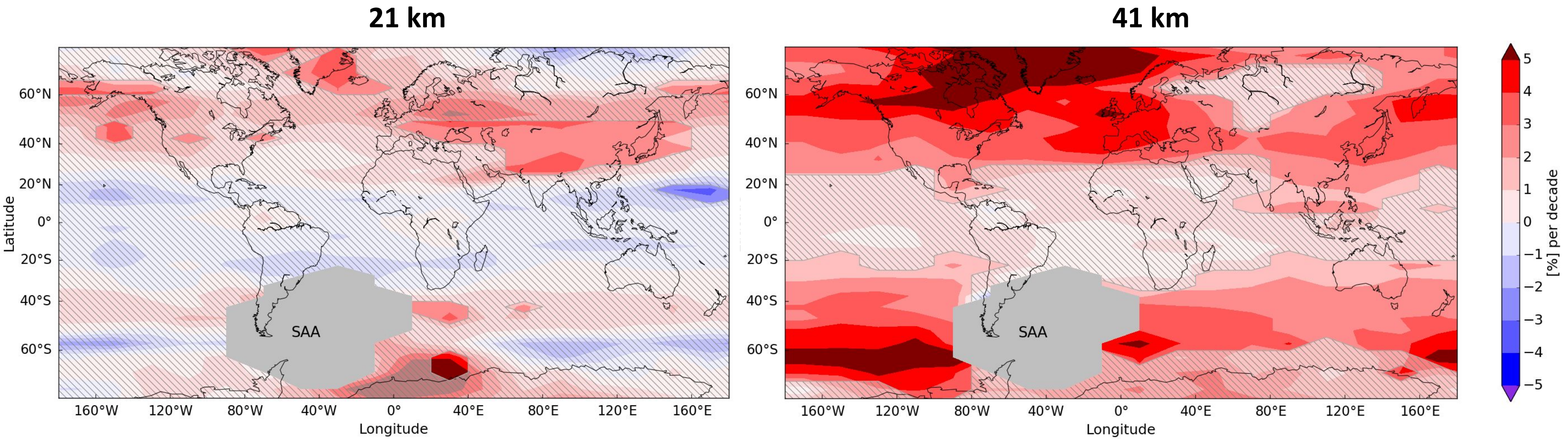

The longitudinal structure of the trends reveals a relevant variability not only in the lower stratosphere but also in the middle upper-stratosphere, where the maximum recovery has been found. This structures have been seen also in MLS series and in the recently developed MEGRIDOP data set (Sofieva).

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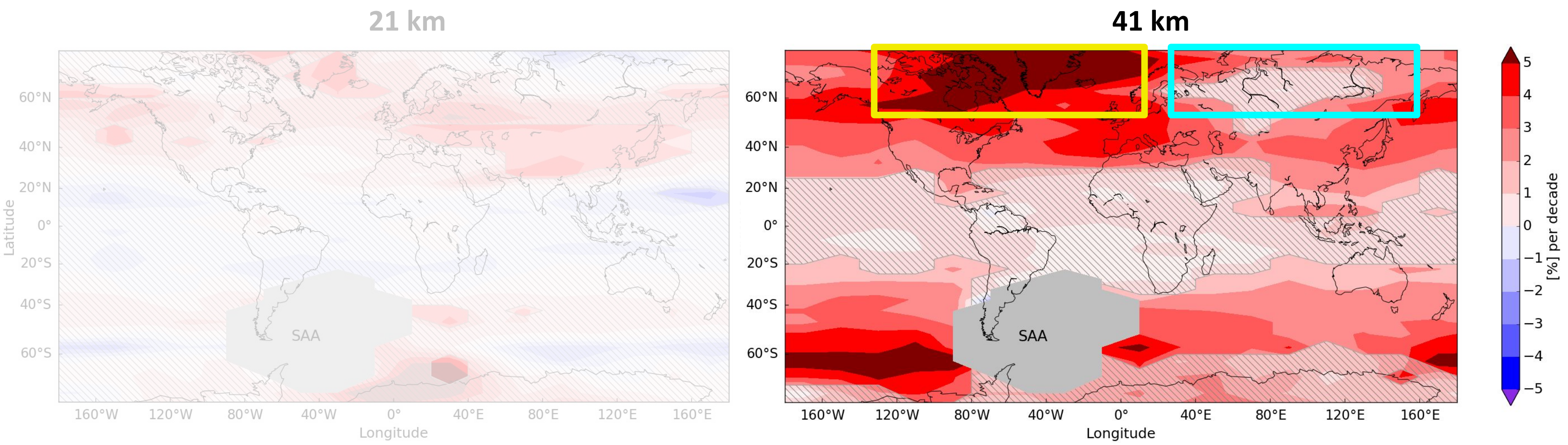

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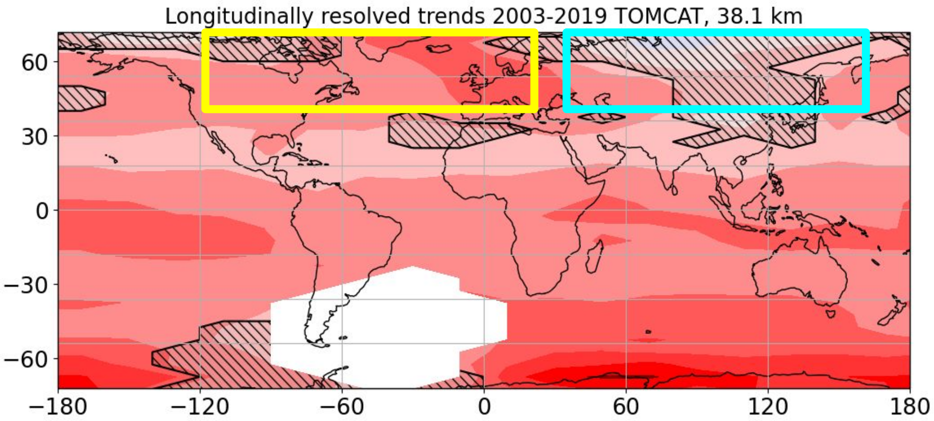

TOMCAT, Focus on the upper atmosphere:
The longitudinal asymmetry is visible not only at ~40 km but also in the stratospheric column trends from the CTM, as it is vertically consistent.

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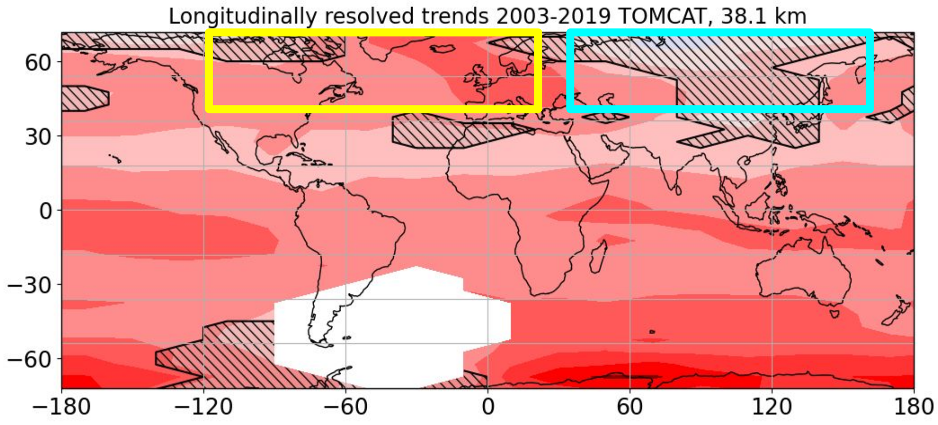

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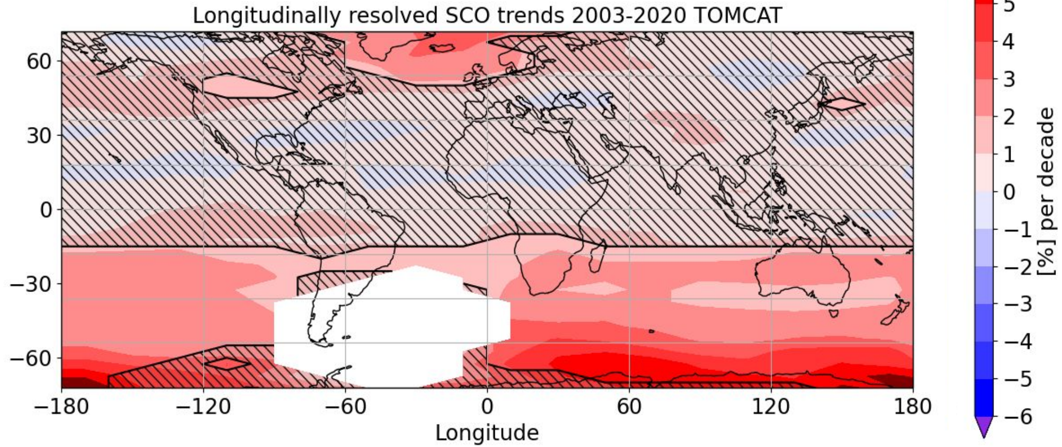
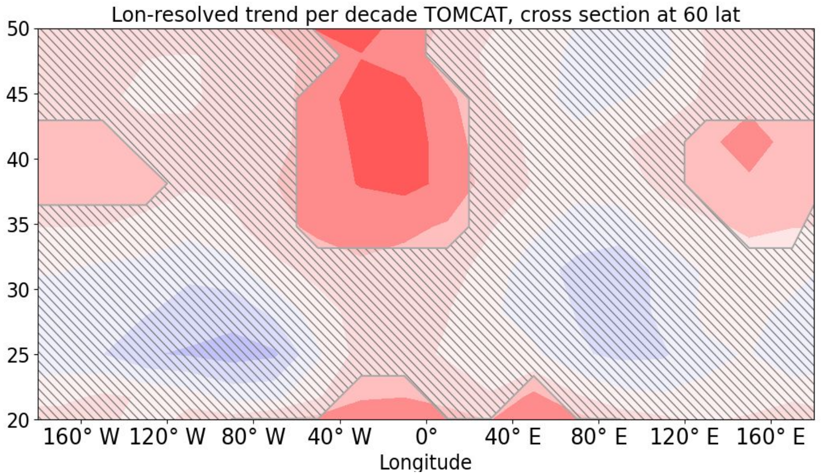


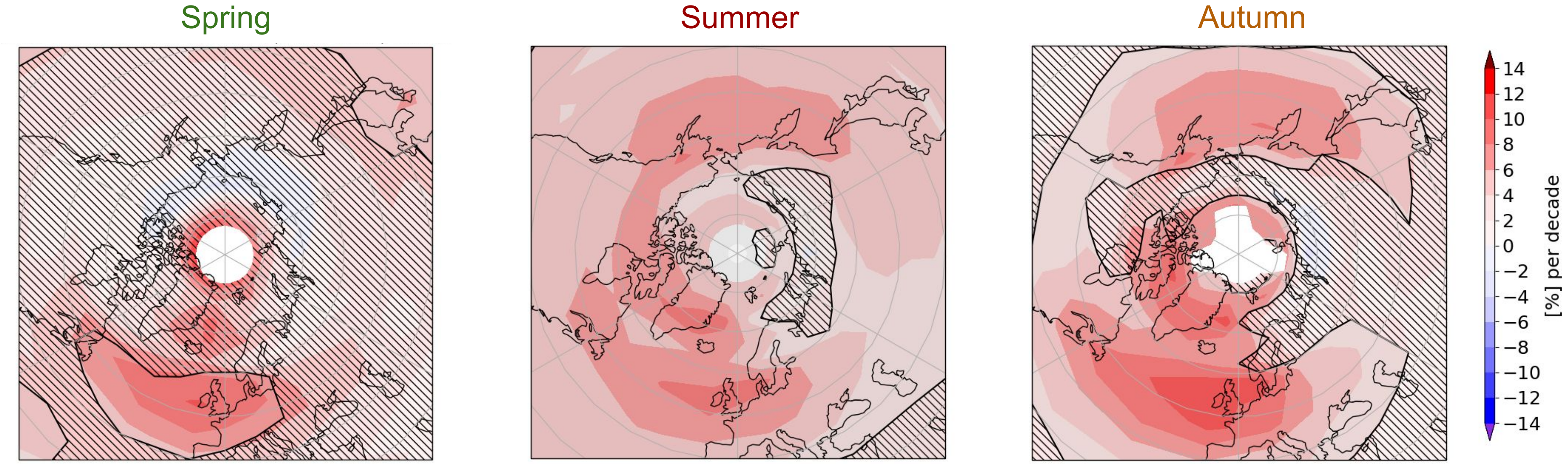


Seasonal trends

Looking at seasonal trends in the merged dataset to see when the asymmetry at northern latitudes is strongest:

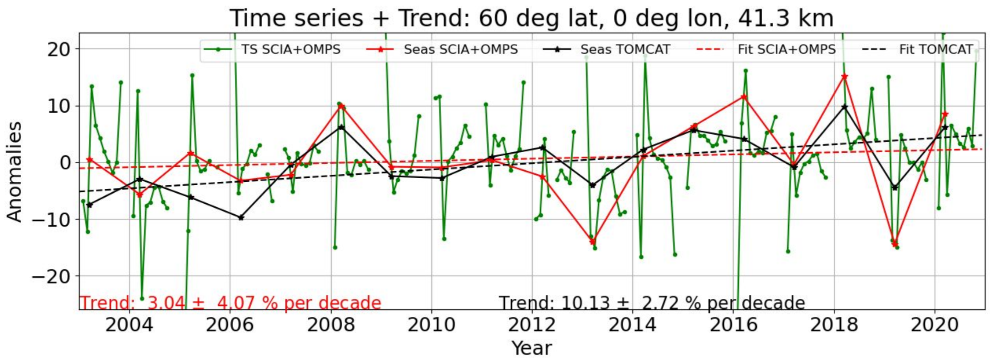
- In summer the field is fairly symmetric;
- In spring and autumn the asymmetry is relevant;
- Hard to draw conclusion for winter as the coverage is poor (polar night above 60° N).

Ozone trends, SCIA+OMPS, 2003-2020, 41 km



dashed areas indicate trends smaller than 2-sigma uncertainty

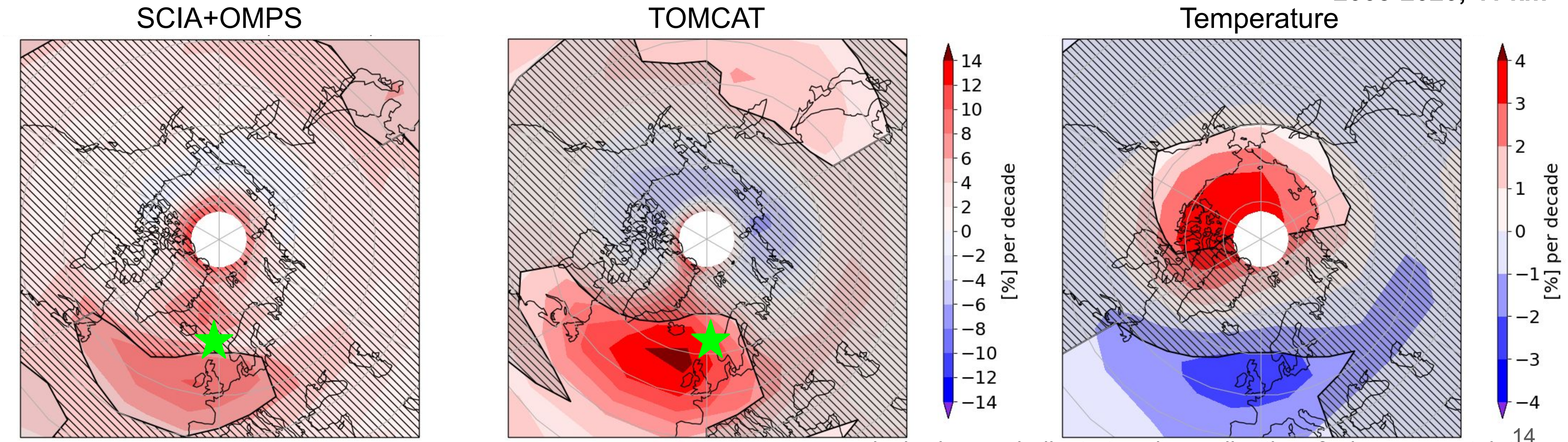
Seasonal trends



Spring:

- good agreement between TOMCAT and SCIA+OMPS data
- strong positive and significant values over Greenland, negative values over Siberia
- Trends in the temperature fairly correspond to the ozone variations, with an inverse sign.

2003-2020, 41 km



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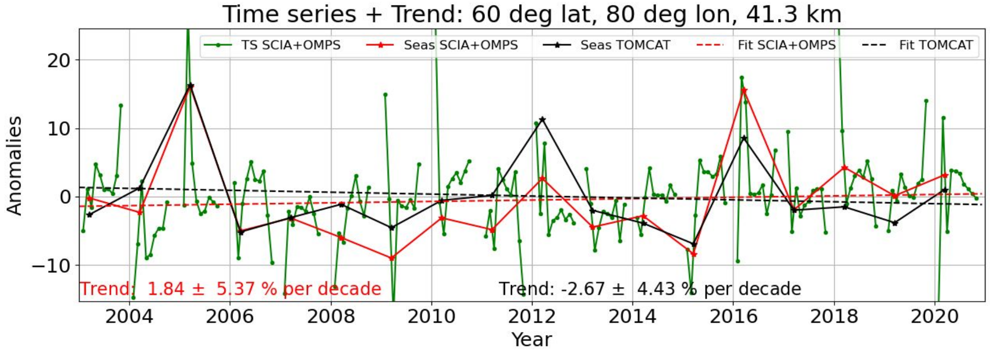

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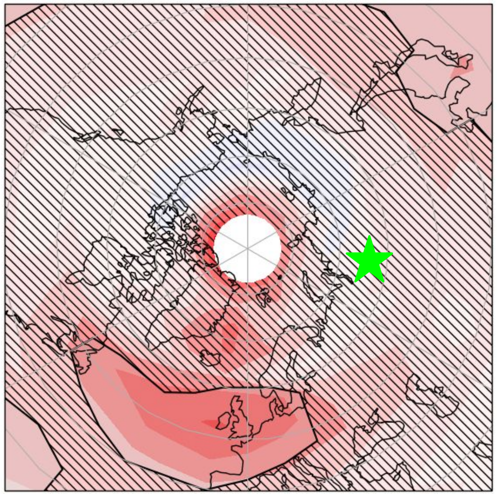
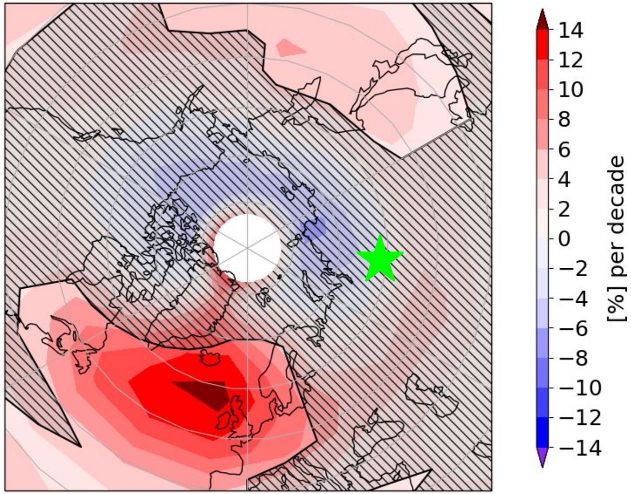
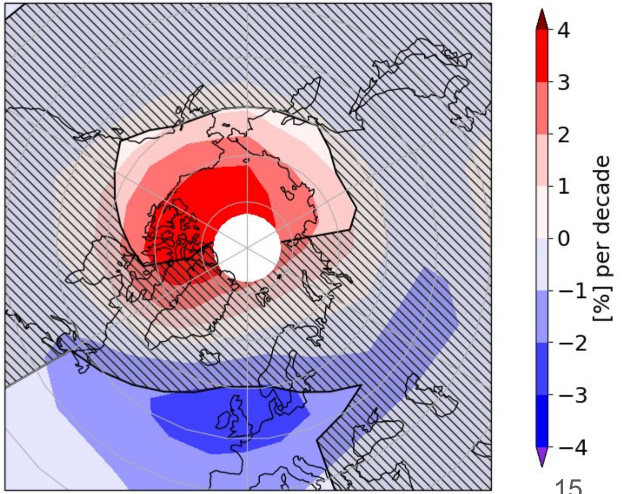


TOMCAT



Temperature



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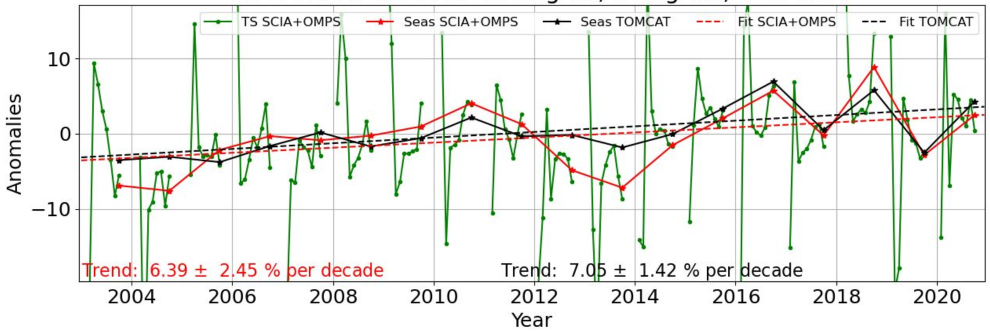
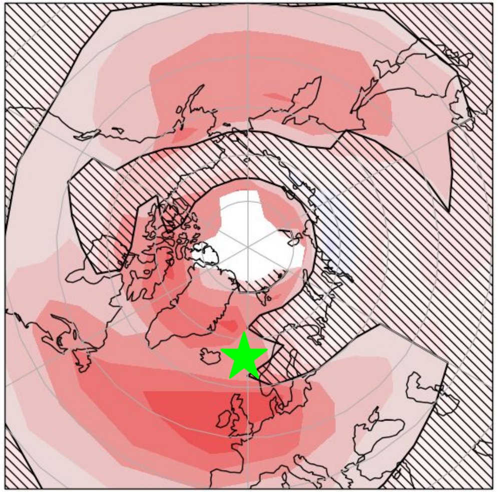


Autumn:

- SCIA+OMPS data show larger positive values
- strong positive and significant values over Greenland, smaller values over Siberia and Alaska (not in OMPS/SCIA however)
- Less correspondence between trends in temperature and in ozone.

2003-2020, 41 km

SCIA+OMPS



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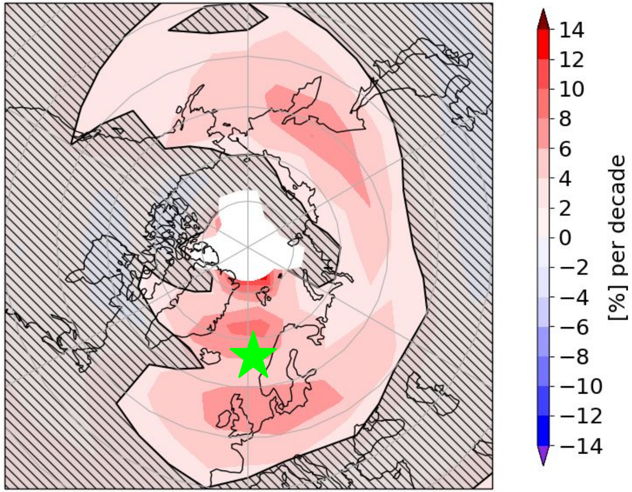

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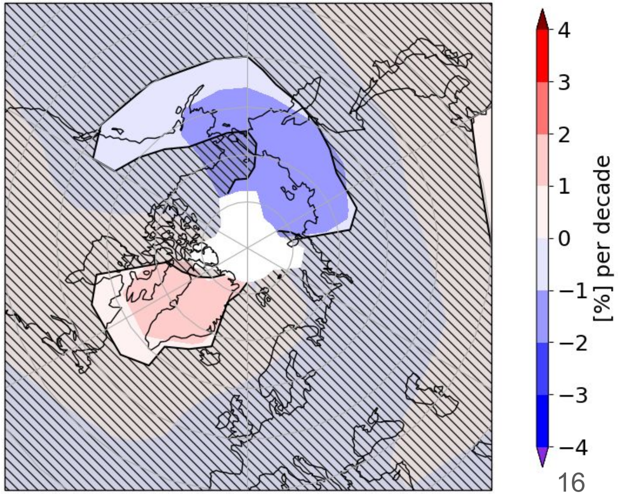

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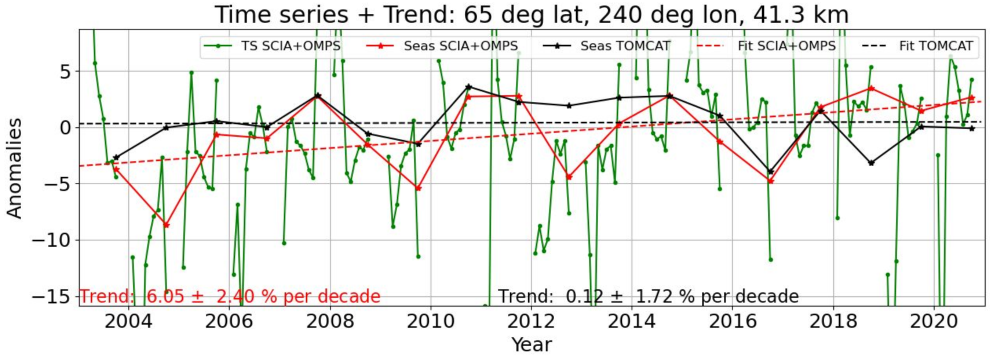

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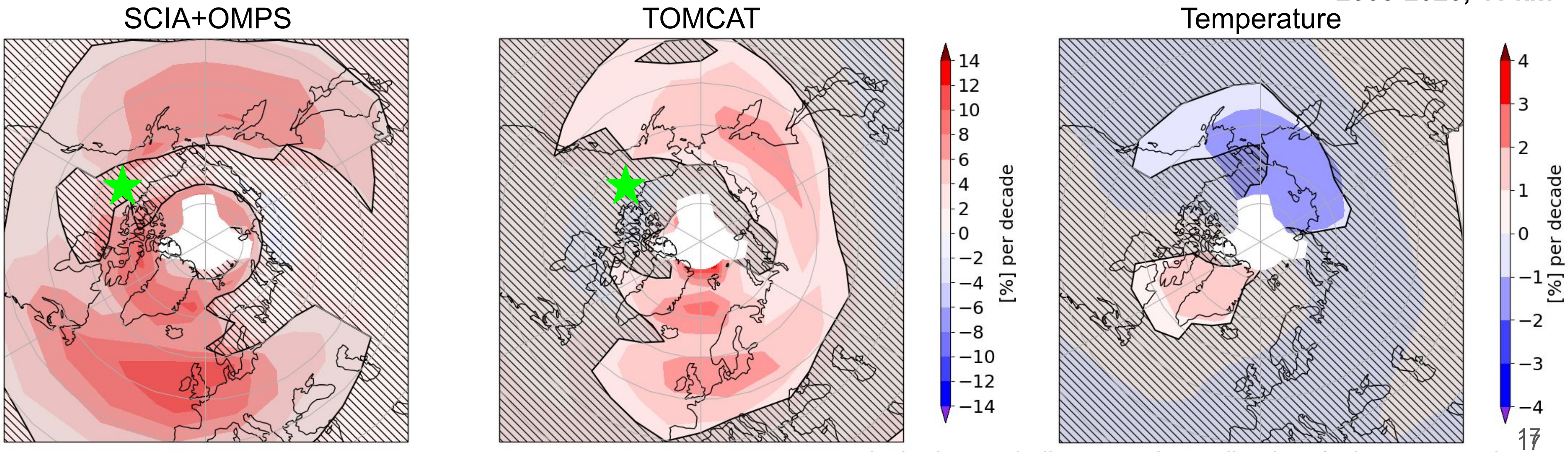

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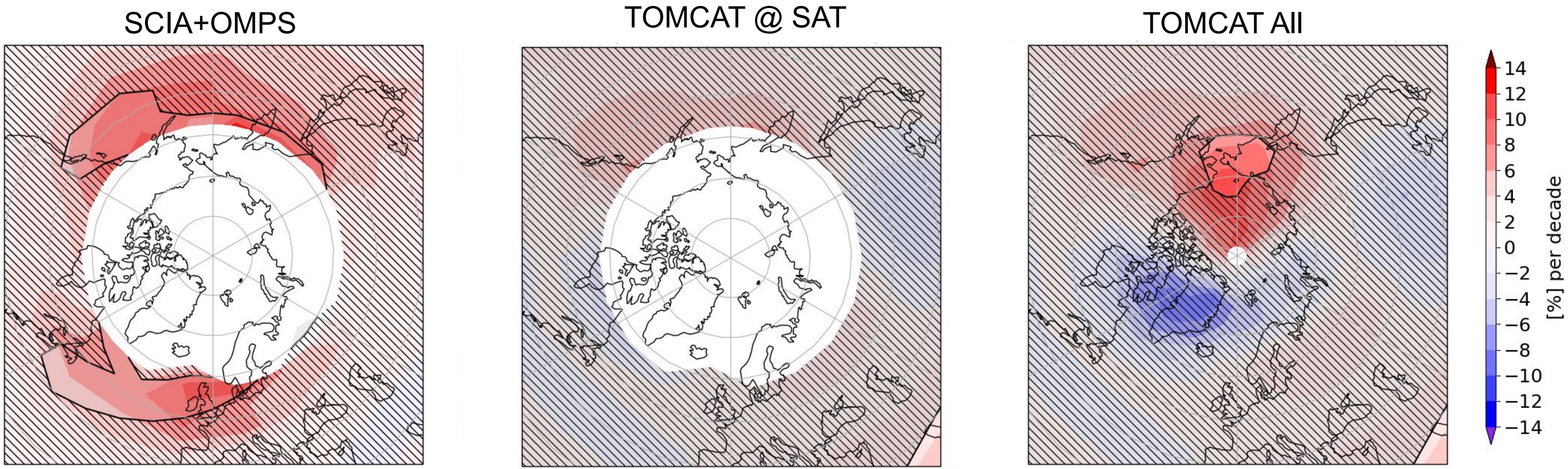
Seasonal trends

Using TOMCAT it is possible to have a look at **winter**, where a complex structure is visible, and negative unexpected trends over Greenland appear, not visible from satellite because of the missing coverage. Satellite data shows overall larger positive values, possibly due to OMPS drift in the upper stratosphere.

Ozone trends winter (JF), 2003-2020, 41 km



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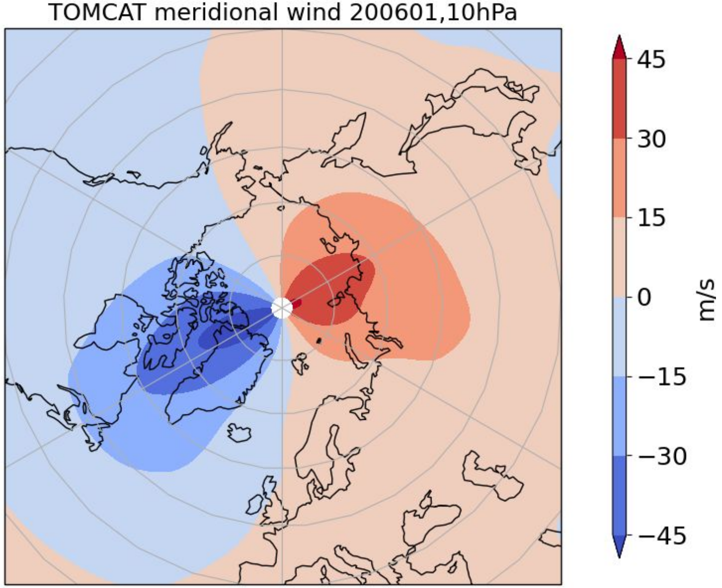
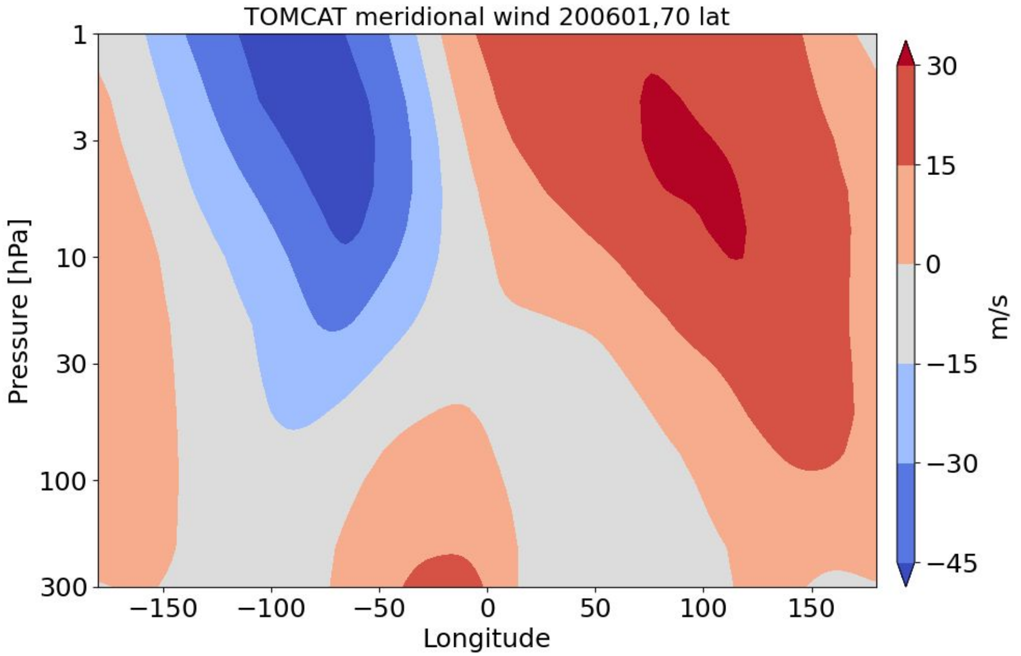
Meridional winds

Looking at meridional wind, the typical wave-one pattern at northern high latitude in winter is clear from the longitudinal cross section, with a two-core structure, over Greenland/North Canada and Siberia, above 10 hPa and a four-core structure in the lower stratosphere.

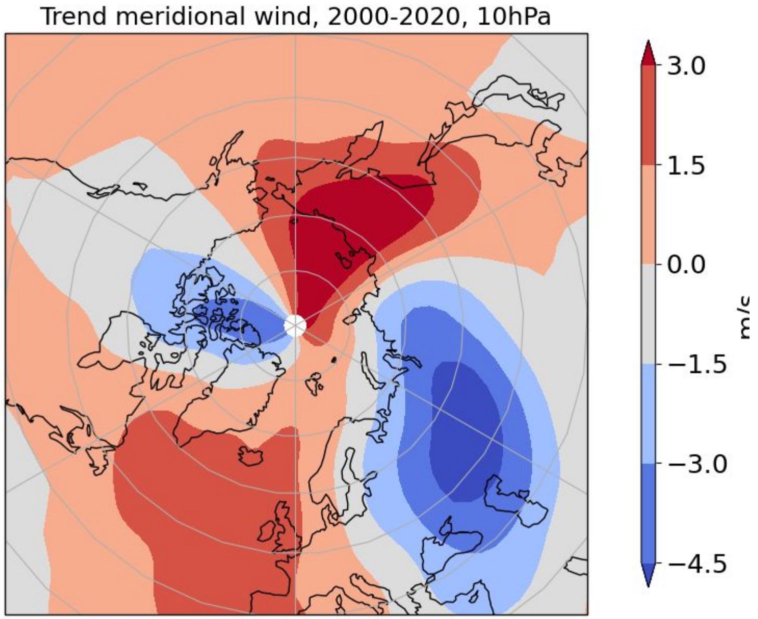


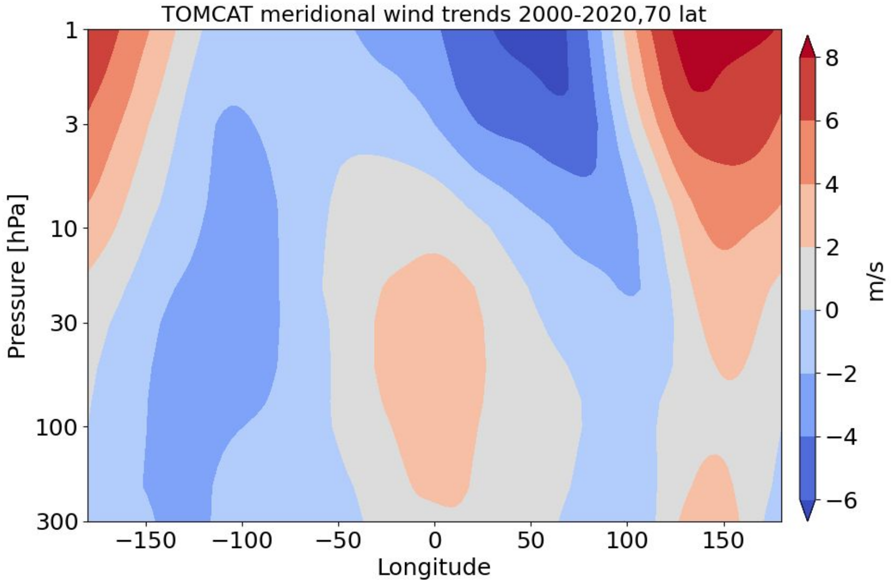


blue=negative wind, towards south; red=positive wind, nortward

Meridional winds

Study long-term trends in the winter-time meridional wind time series from TOMCAT to investigate changes in the wintertime wave-one pattern: a translation and rotation of the structure seems to appear.





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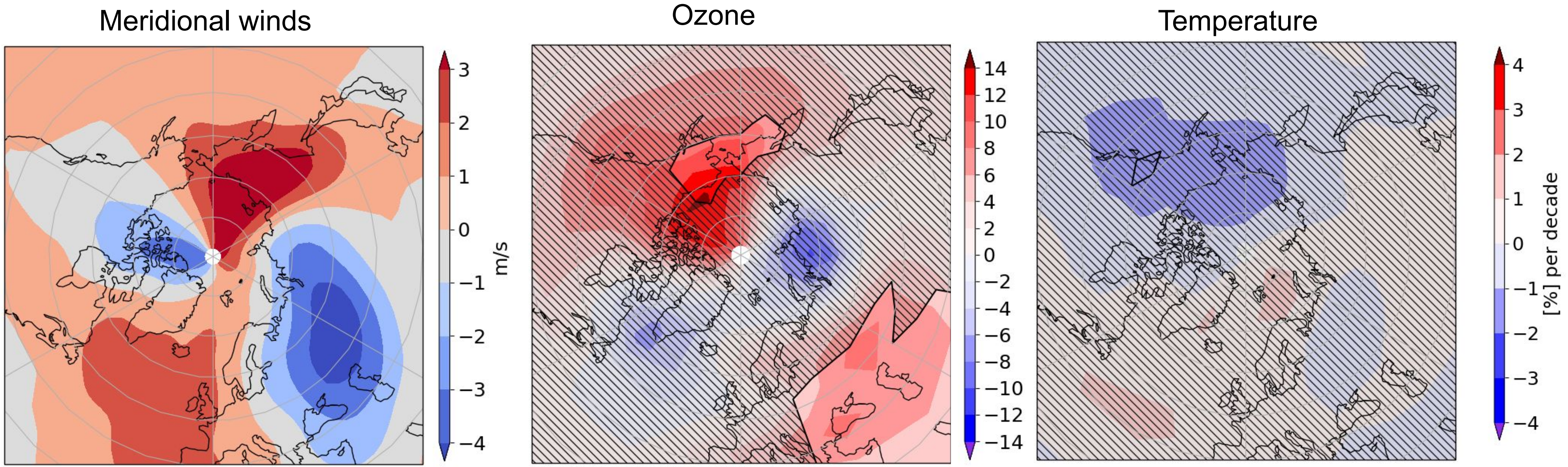
Trends from TOMCAT, 2003-2020, winter-time, % per decade at ~40 km



Conclusion and outlook

Conclusion

- Longitudinal asymmetries at northern high latitudes in ozone trends have been highlighted in both satellite records (SCIA+OMPS, but also in MLS, MEGRIDOP);
- These asymmetries are stronger during the winter semester;
- Associated temperature trend asymmetries have been detected;
- Associated change in meridional winds also detected with an indication of a change in the strength of the wave-one pattern (Kozubeck et al. 2015) and rotation of the stratospheric vortex or change of position (as noted by Zhang et al. 2016).

Outlook:

- Set up TOMCAT simulations to better investigate the driving mechanisms of these asymmetries,
  - sample a high-resolution TOMCAT run at the location of the satellite observations before constructing L3 time series;
  - investigate the role of dynamics and chemistry in these asymmetries ;
- Investigate PV fields.

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