ANALYSIS OF ENVIRONMENTAL INFLUENCES ON TROPOSPHERIC BROMINE OXIDE IN THE ARCTIC USING S5-P/TROPOMI MEASUREMENTS

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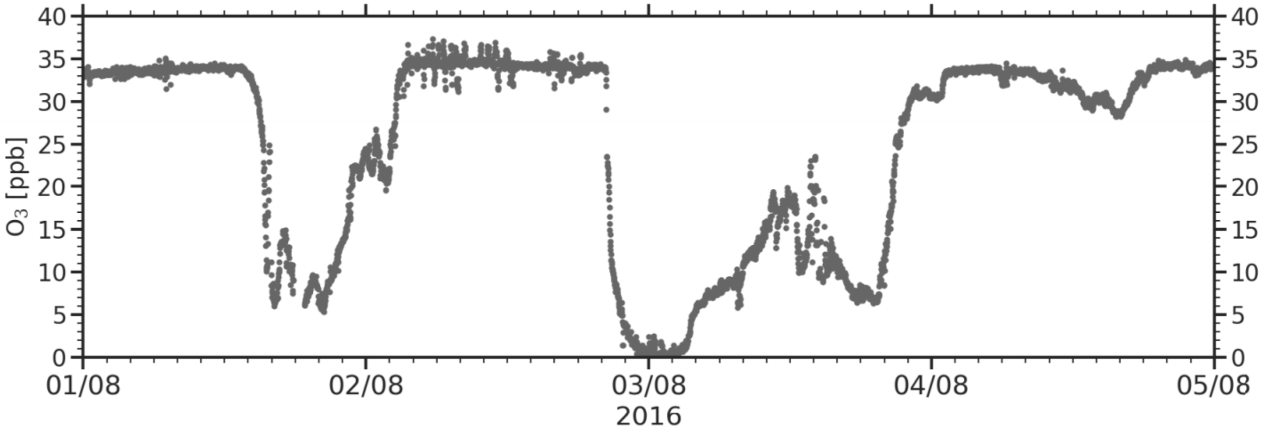
MOTIVATION

OZONE DEPLETION EVENTS & BROMINE EXPLOSIONS

- During polar spring, recurrent episodes of boundary layer ozone destruction are observed, dubbed „Ozone depletion events“ (ODEs)
- Driven by the exponential increase in bromine oxide in the so-called bromine explosion
- Different meteorological conditions seem to favor ODEs:
    - ➢ Low wind speeds, stable boundary layer
    - ➢ High wind speeds and higher, unstable boundary layer



Ozone depletion episode at NM II.
Adapted from *Weller et al. (2017).*

DATA SOURCES

TROPOMI

DOAS

- Our retrieval algorithm is based on the method of **DOAS** (Platt and Stutz; 2008)
- Linearized DOAS fit (Beirle et al., 2017; Borger et al., 2020)

Reference Spectrum

- Daily Earthshine spectrum

Tropospheric Retrieval

- Based on Sihler et al., 2012
- Adapted to TROPOMI

WRF-CHEM

3D chemistry and meteorology model

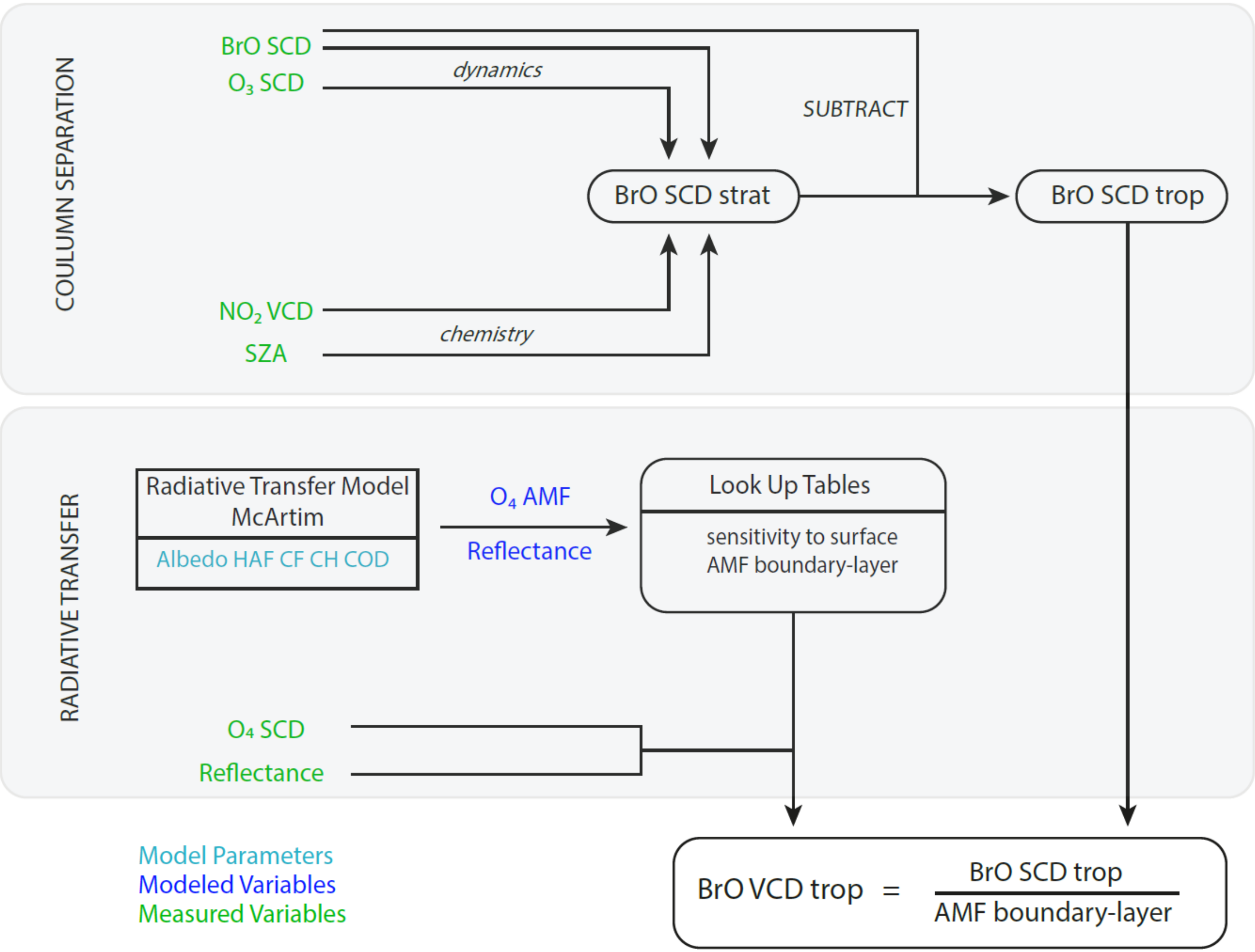
- Based on Herrmann et al., 2021
- In general very good agreement with measurements
- Does not yet include emissions from blowing snow (important later)

DOAS fit settings

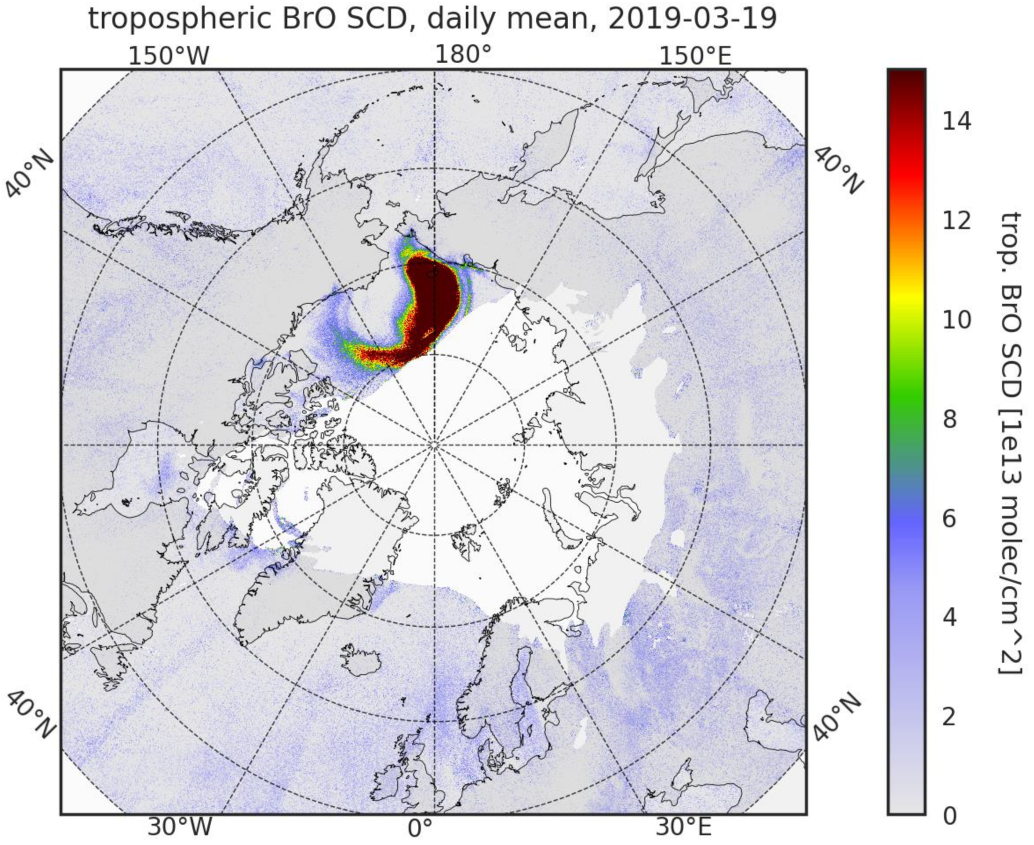
Parameter	BrO Fit
Fit window	336-360 nm
Absorption cross sections	BrO, 223K (Fleischmann et al., 2004) O_4, 203K (Thalman and Volkamer, 2013) O_3, 223K, 243K (Serdyuchenko et al., 2014) NO_2, 220K (Vandaele et al., 1998) SO_2, 203K (Bogumil et al., 2003) OClO, 293K (Bogumil et al., 2003)
Ring effect	Two Ring spectra calculated from daily irradiance
Polynomial	5th order
Pseudo-absorbers	inverse spectrum shift and stretch 2 x Pukite terms at 223K

RETRIEVAL ALGORITHM

- To retrieve tropospheric BrO VCD, we use a two-step approach
  1. The tropospheric BrO SCD is determined, using **solely measurements**
  2. A look up table is created from the McArtim RTM (Deutschmann et al.; 2011) and the relevant boundary layer AMF is calculated from measured O_4 columns and reflectances

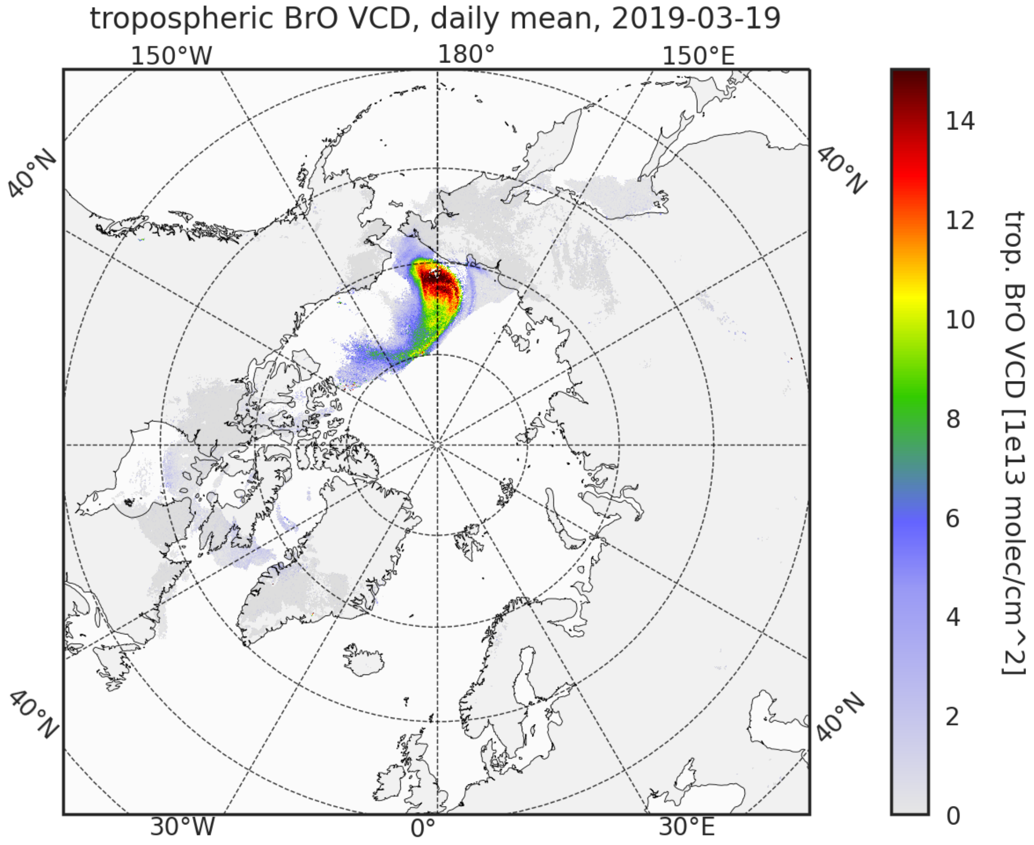


RESULTING TROPOSPHERIC BRO VCD



Masking possibly obstructed measurements

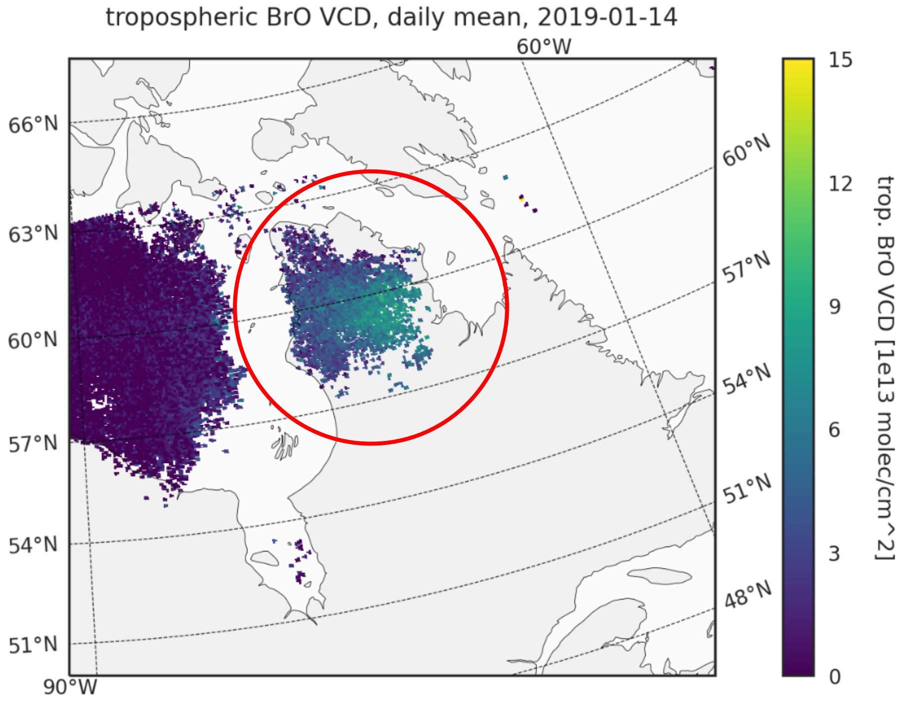
Division through calculated AMF

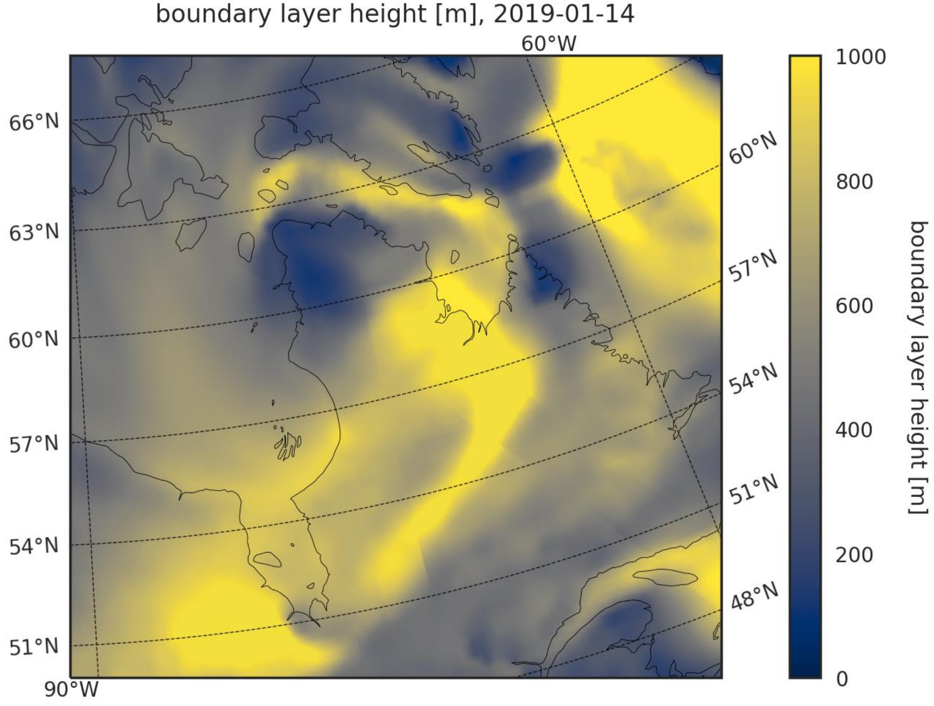


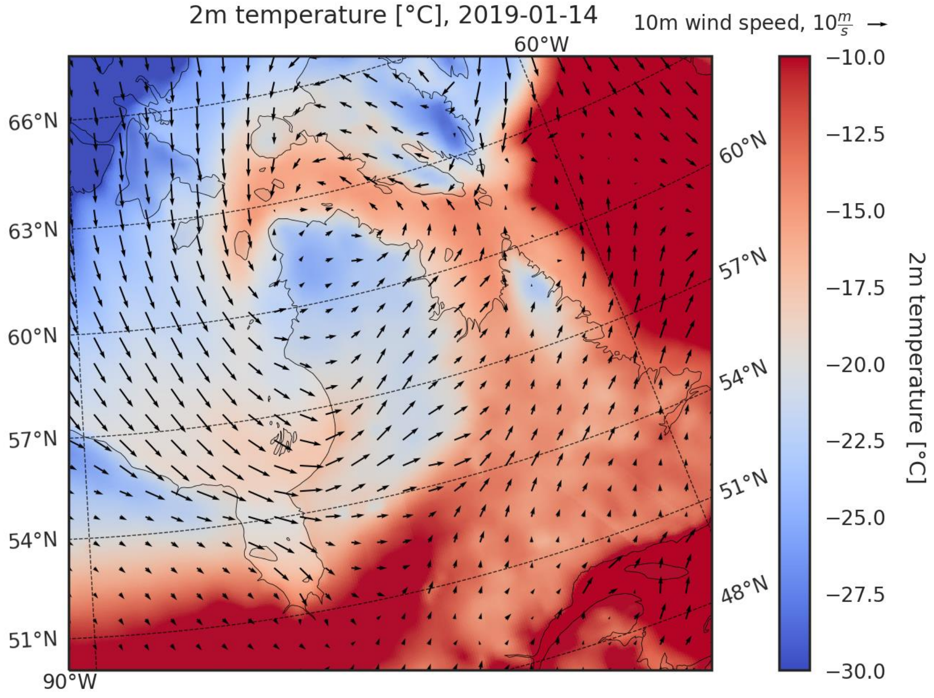
CASE I – EARLY EVENTS

14.01.2019

- Smaller BrO event can be observed already in January near Hudson Bay
- Coincides with **low temperature**, **low wind speeds** and a **low boundary layer**







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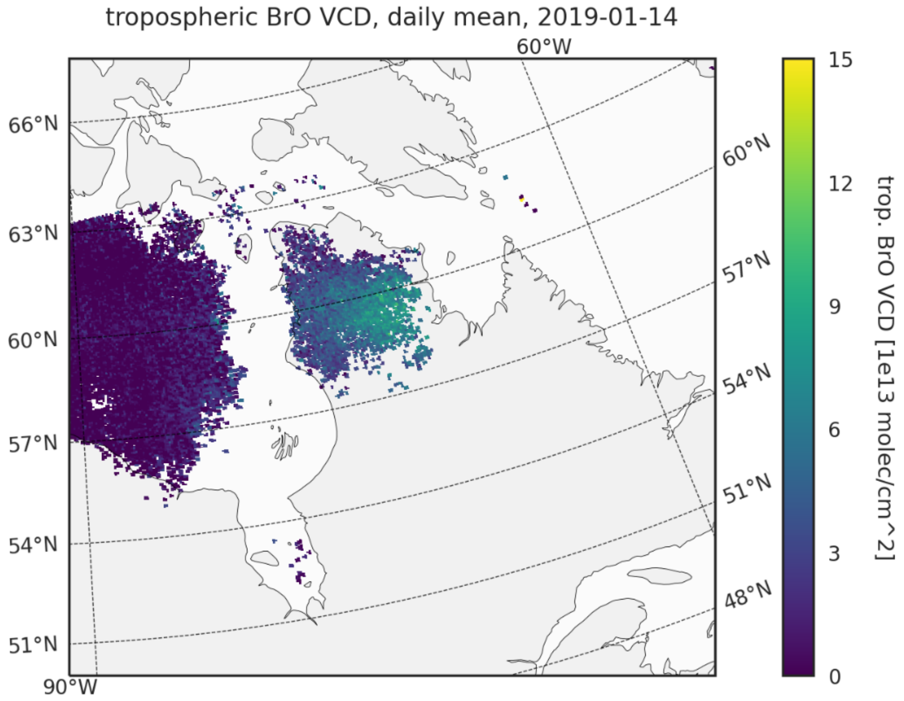
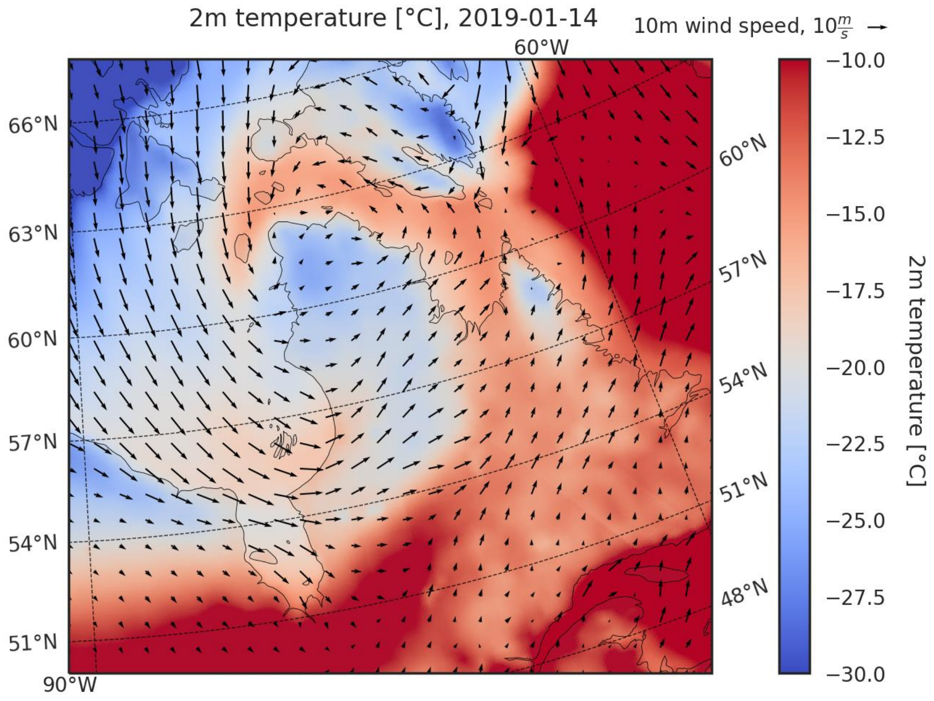
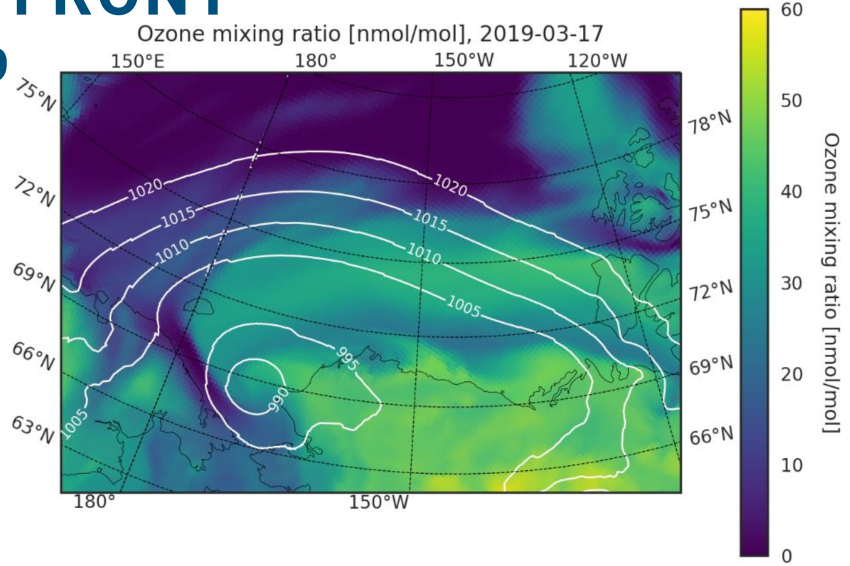
- Coincides with **low temperature**, **low wind speeds** and a **low boundary layer**
- Very little sunlight, therefore not much BrO is released from surface
- Bromine concentrations gets less diluted under stable conditions, accelerates further bromine emissions
- Most observed initial events early in the season exhibit the same dependence on stable conditions
- Agrees with Pratt et al. 2017 and Mareille et al. 2021 findings of oxidation of surface bromide as most important source of BrO

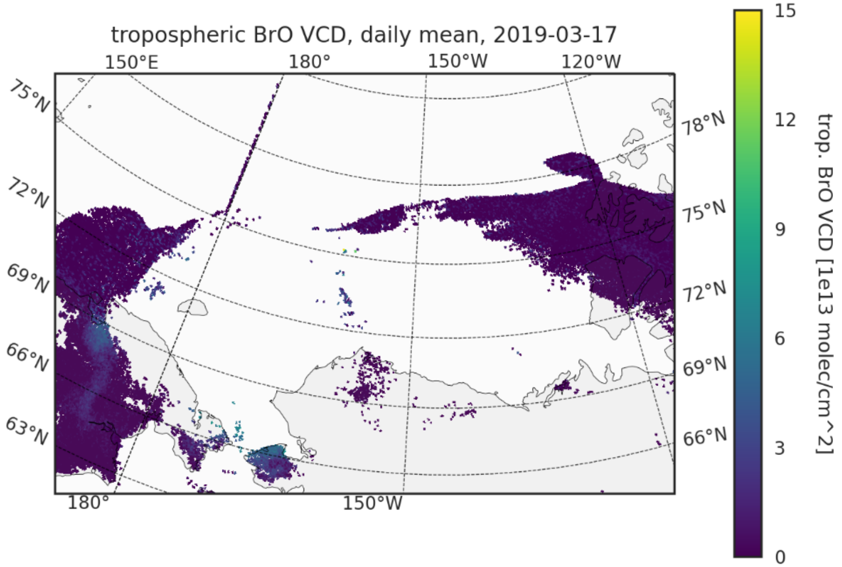


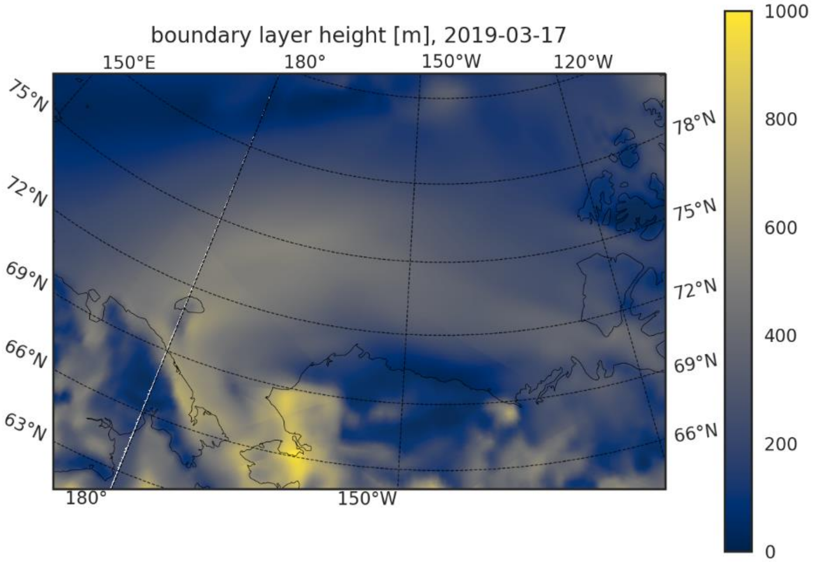


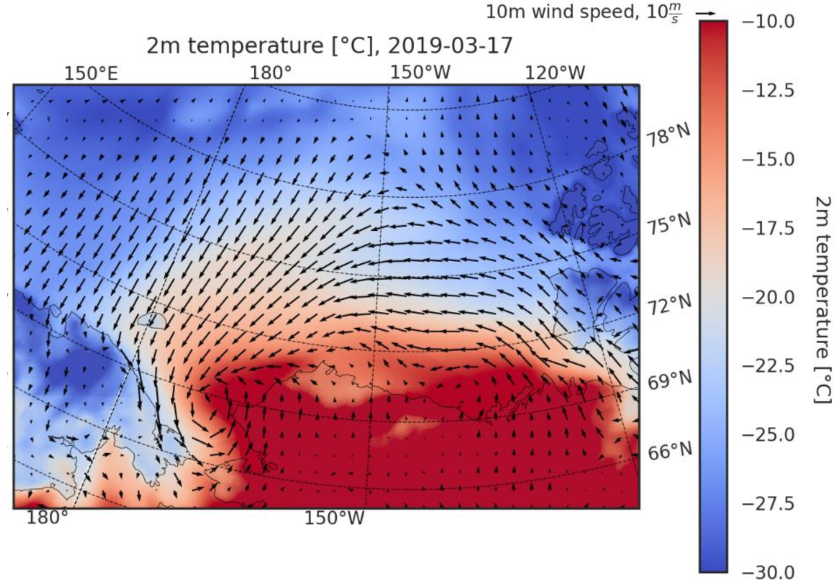
CASE II – BRO IN A FRONT
17.03.2019 – 21.03.2019

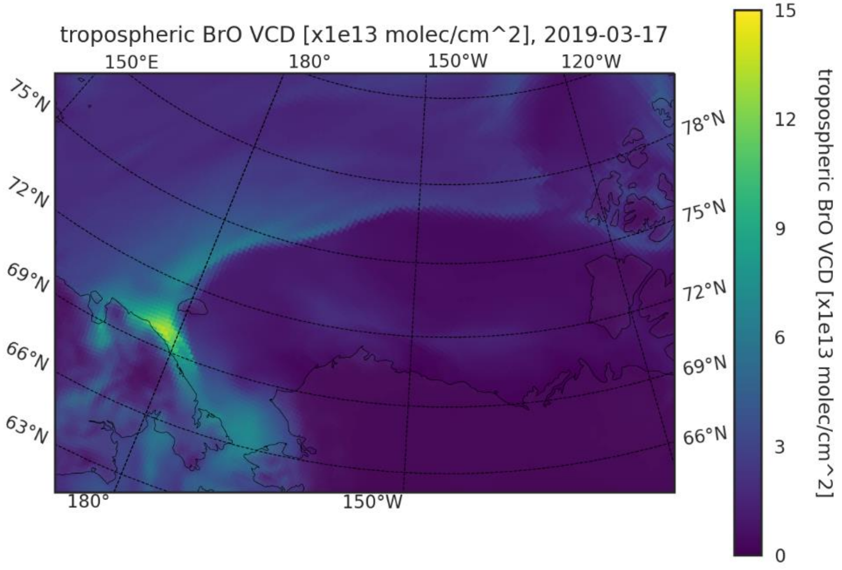
- Large scale event near Barrow, stable over a long time period
- High wind speeds at the edges of the event mix ozone with BrO











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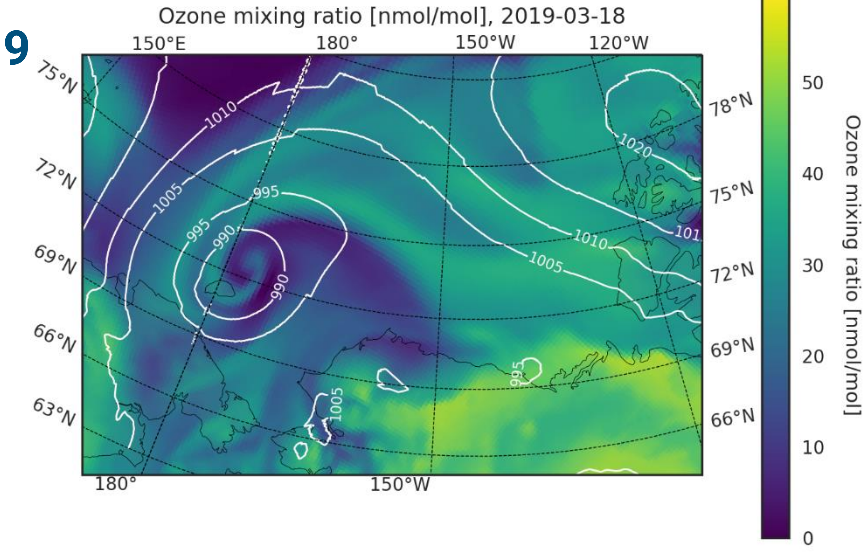

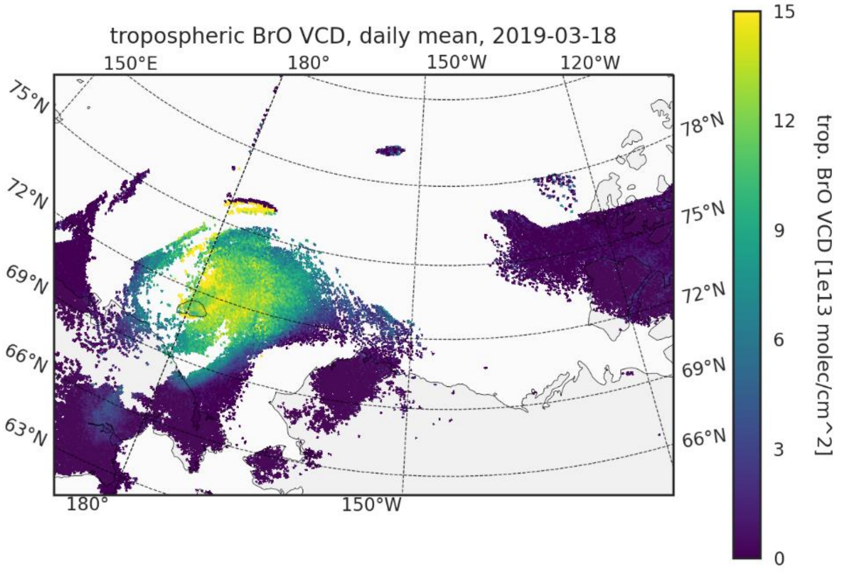

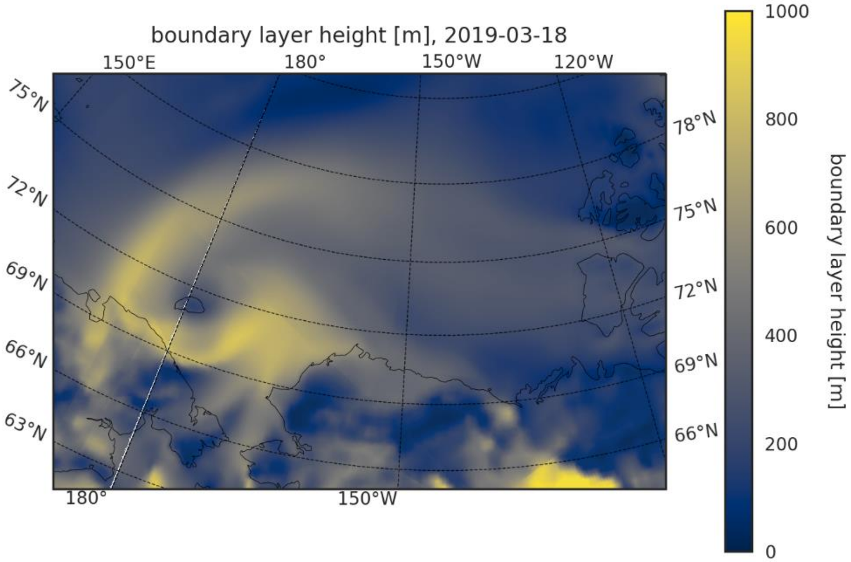

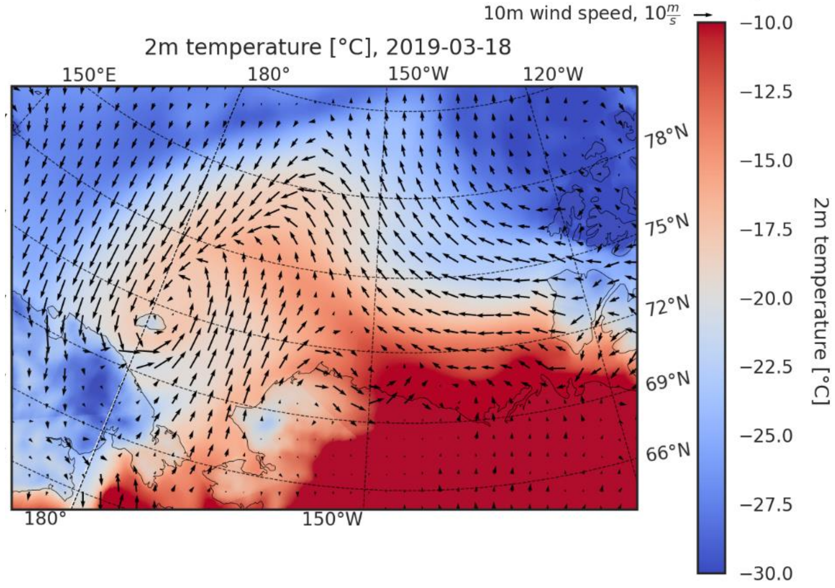

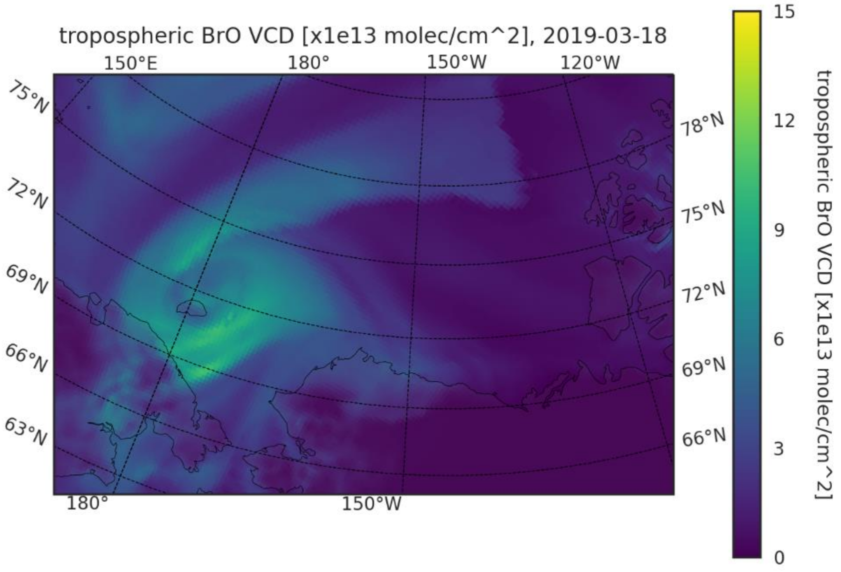

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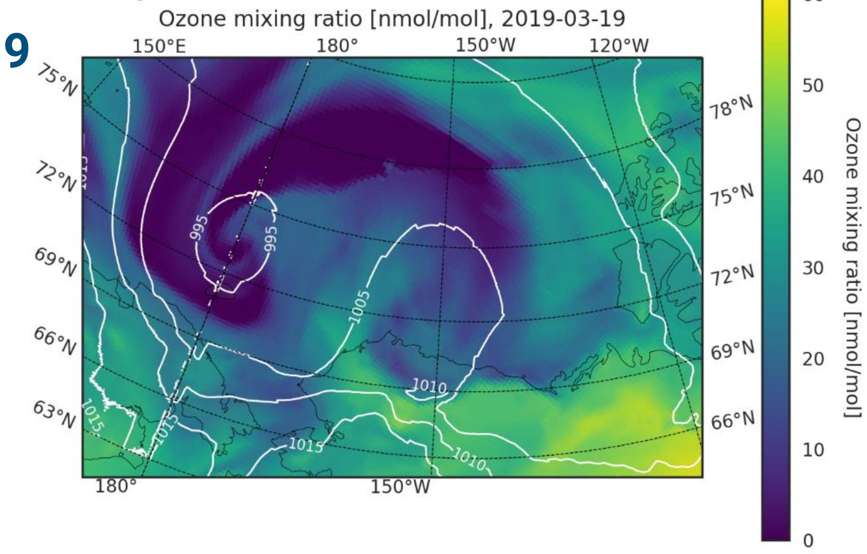

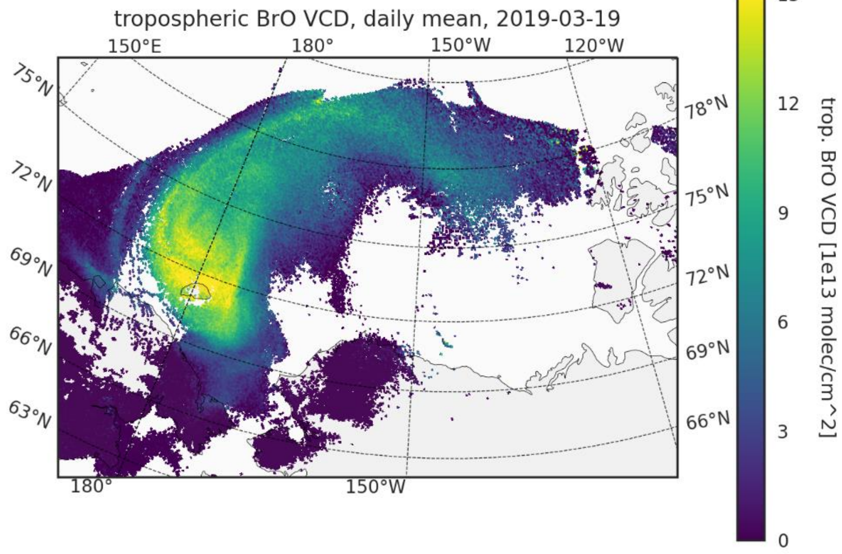

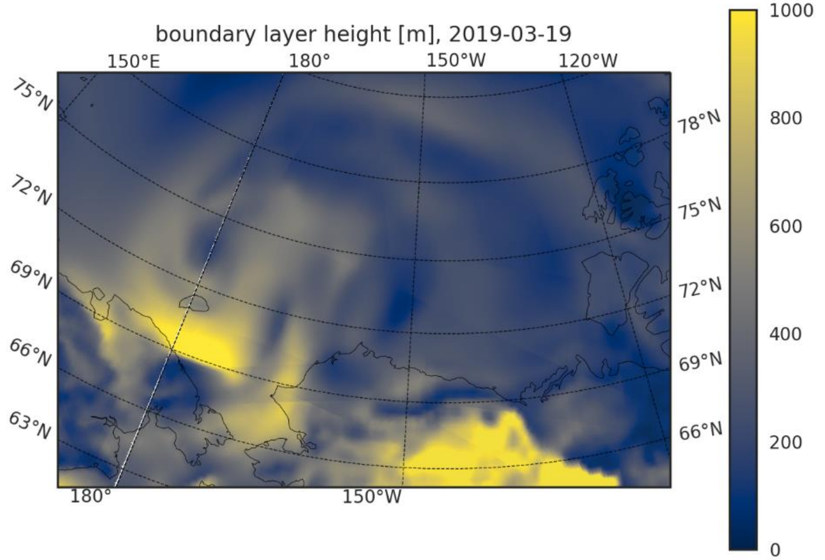

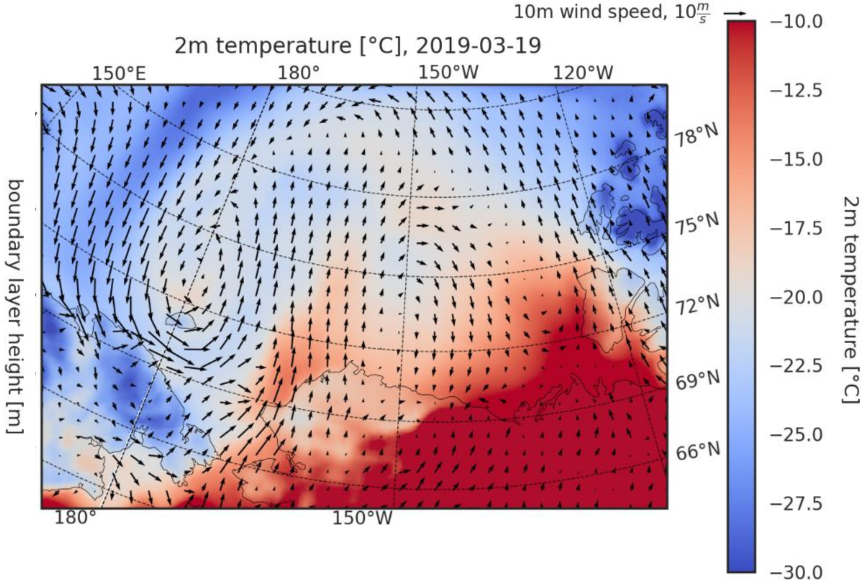

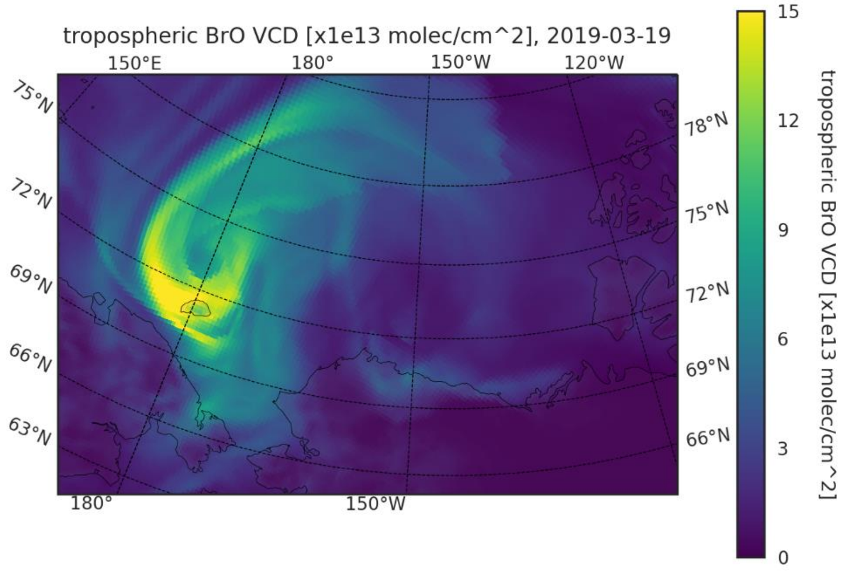

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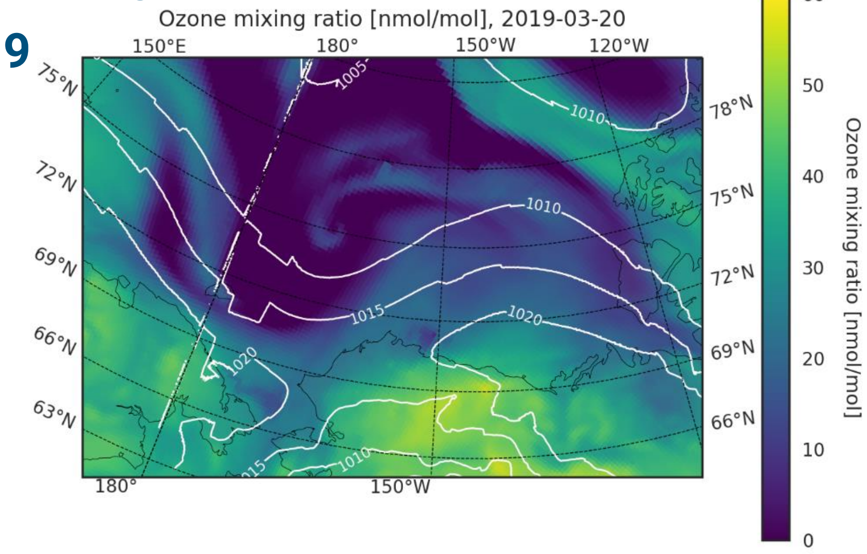

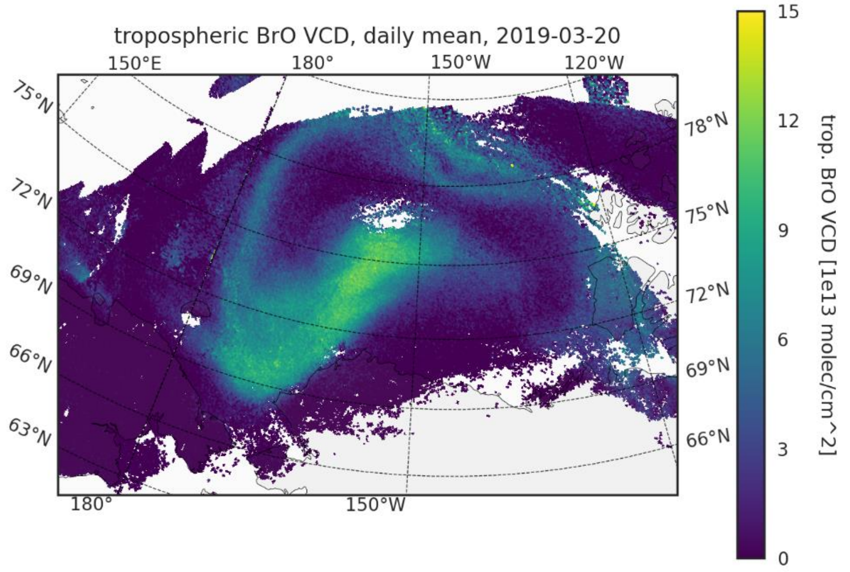

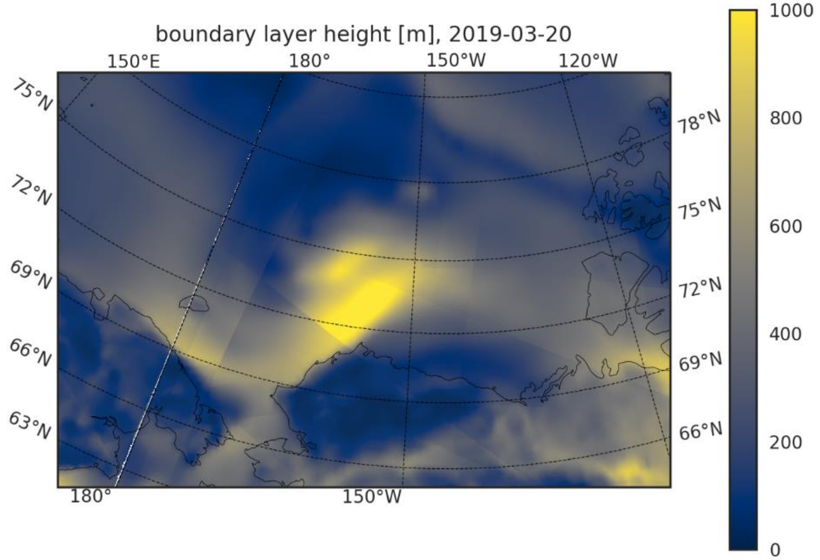

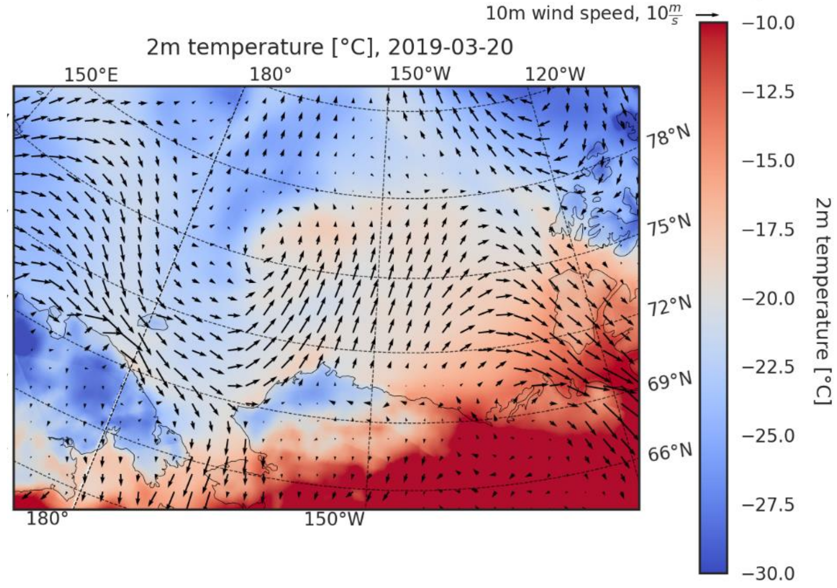

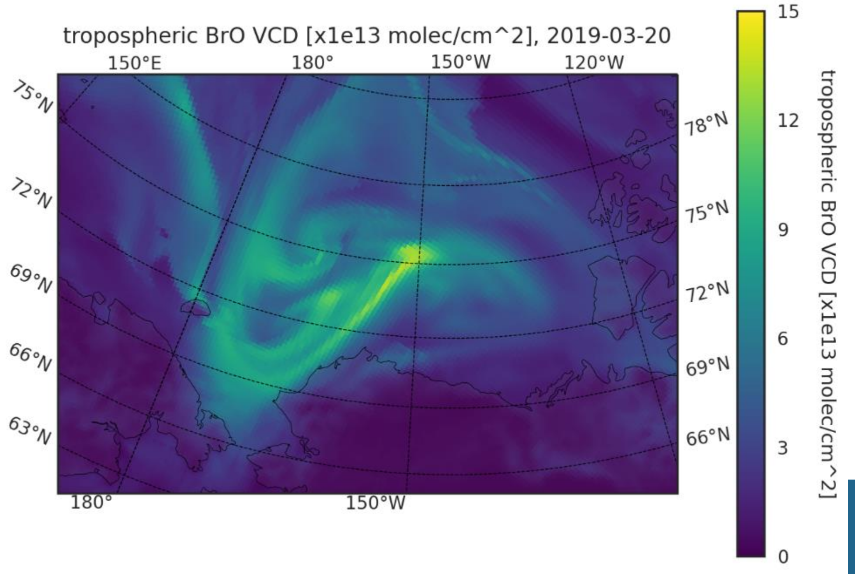

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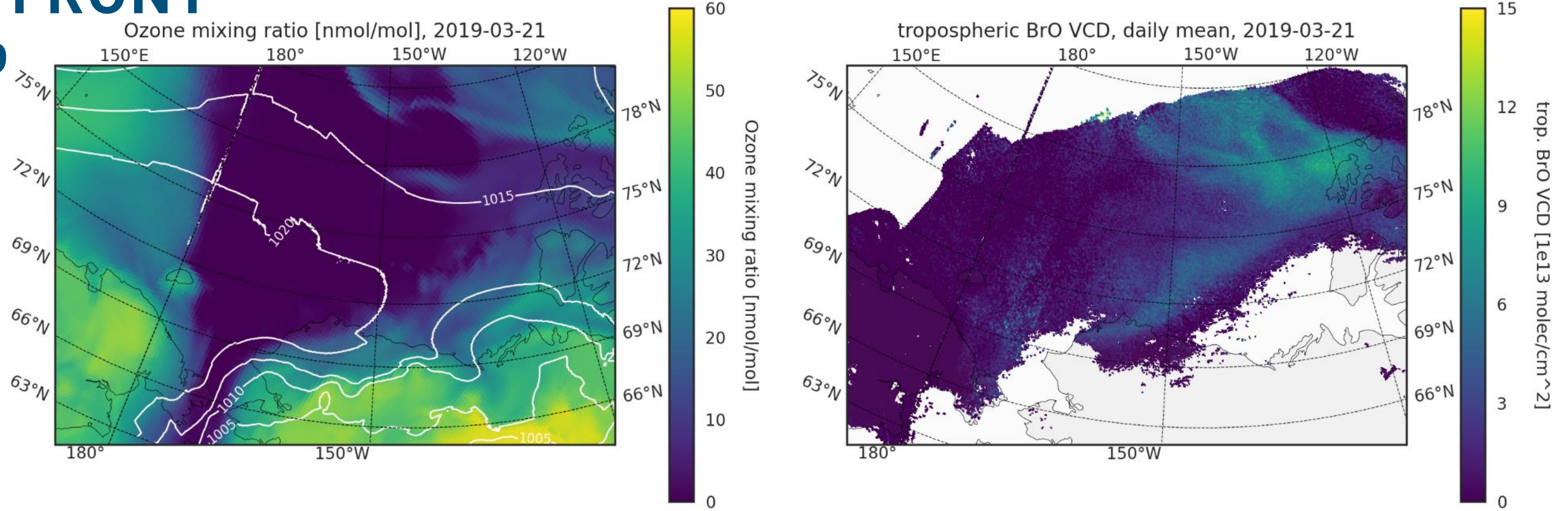

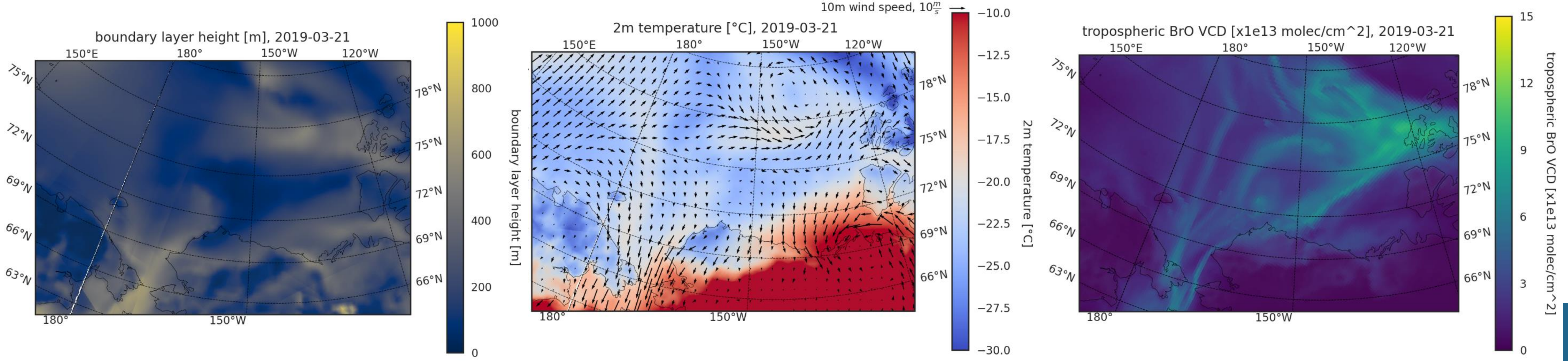

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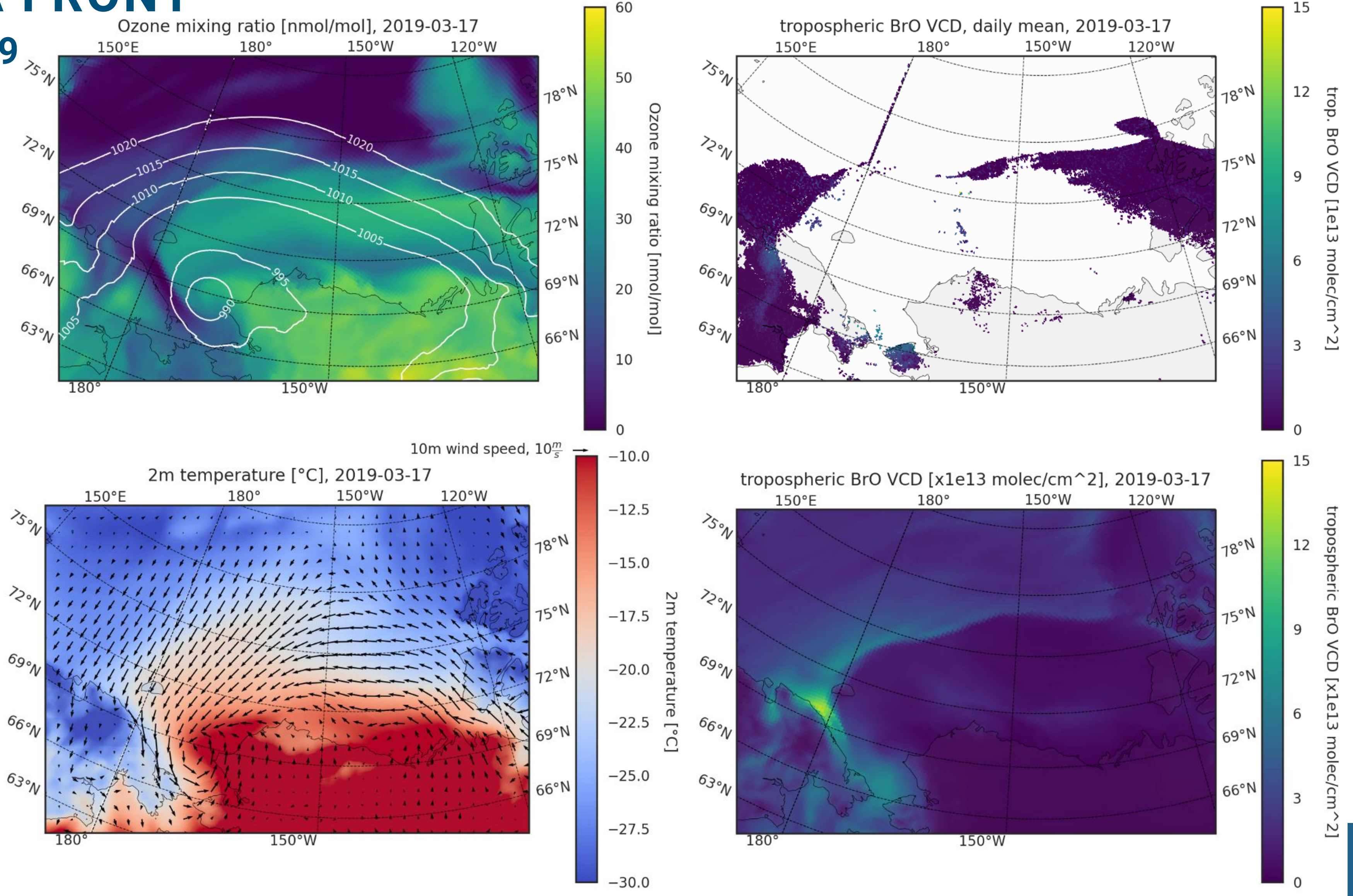
- BrO gets uplifted at the edges of the cold front and mixes with warm air → no dry deposition
- Could explain these events later in the year better than blowing snow hypothesis (WRF Model has no blowing snow)



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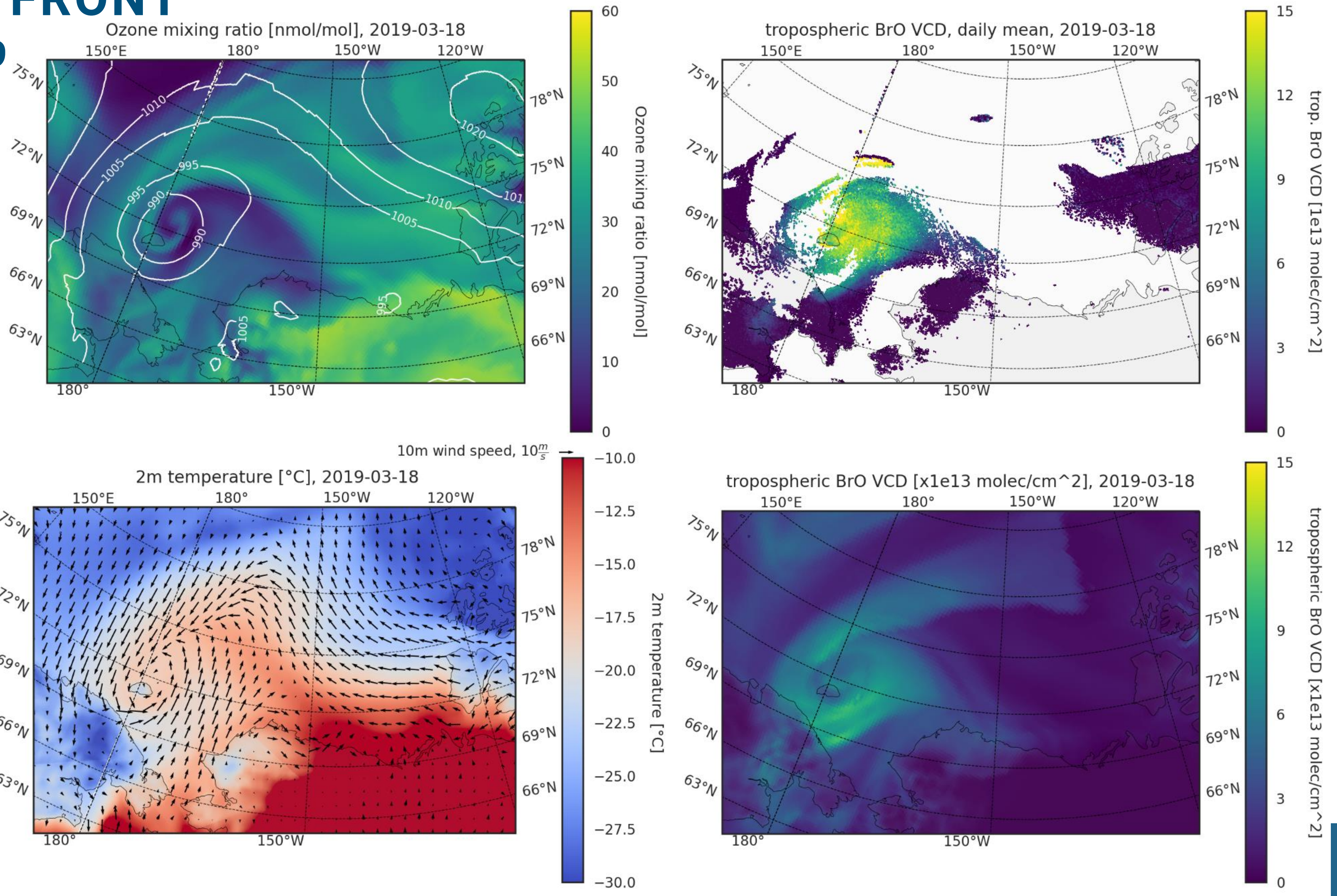

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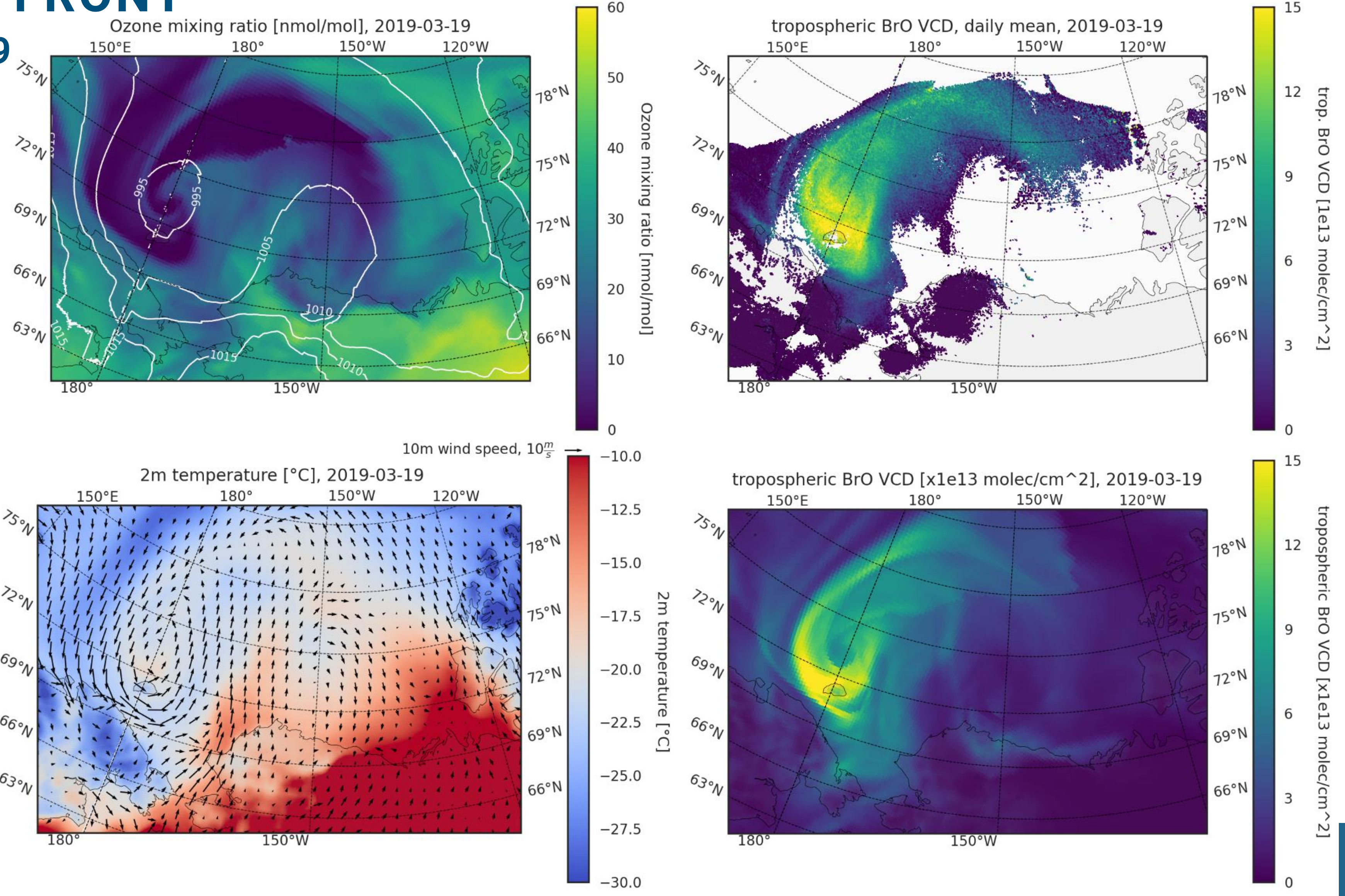

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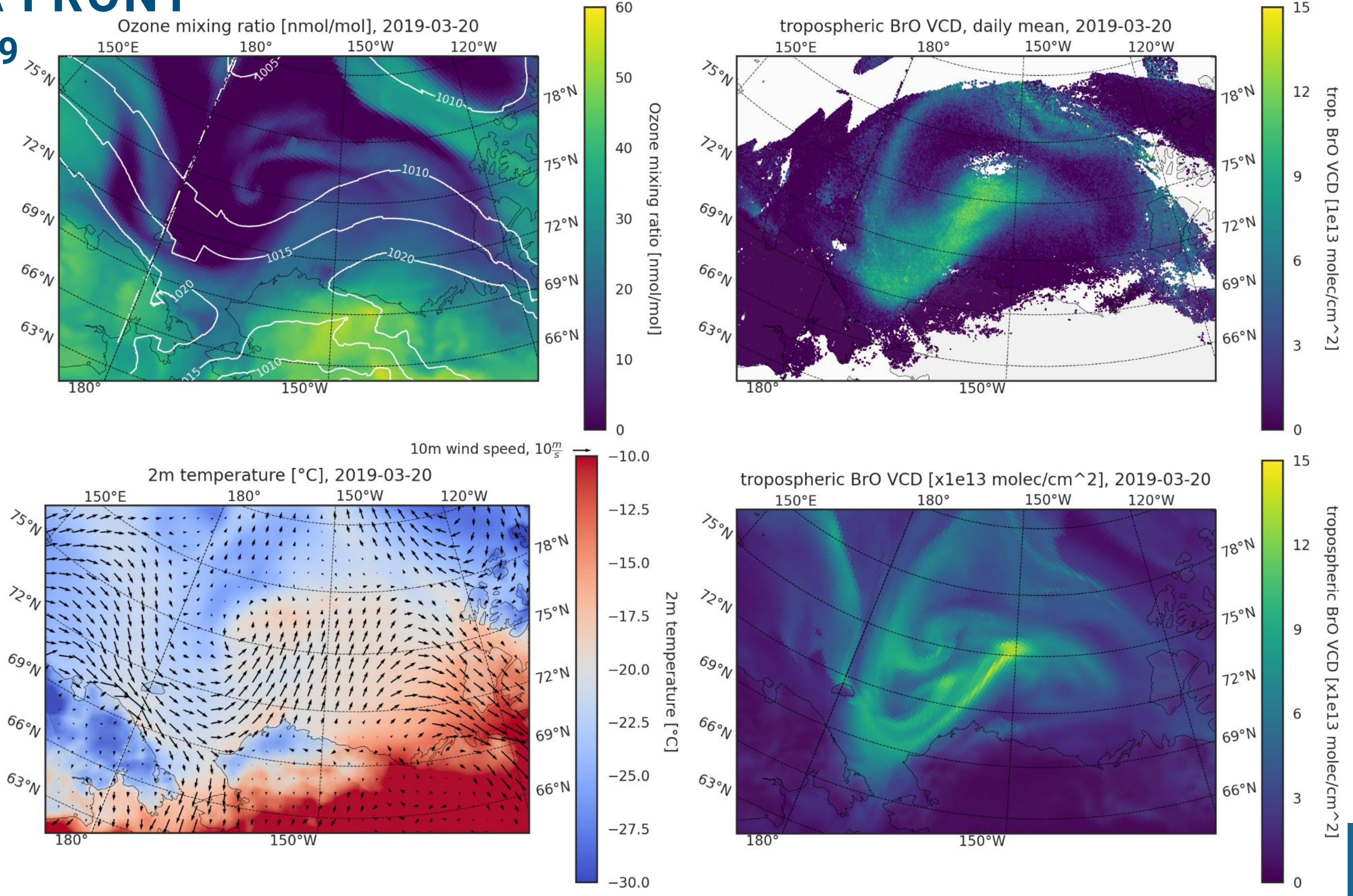

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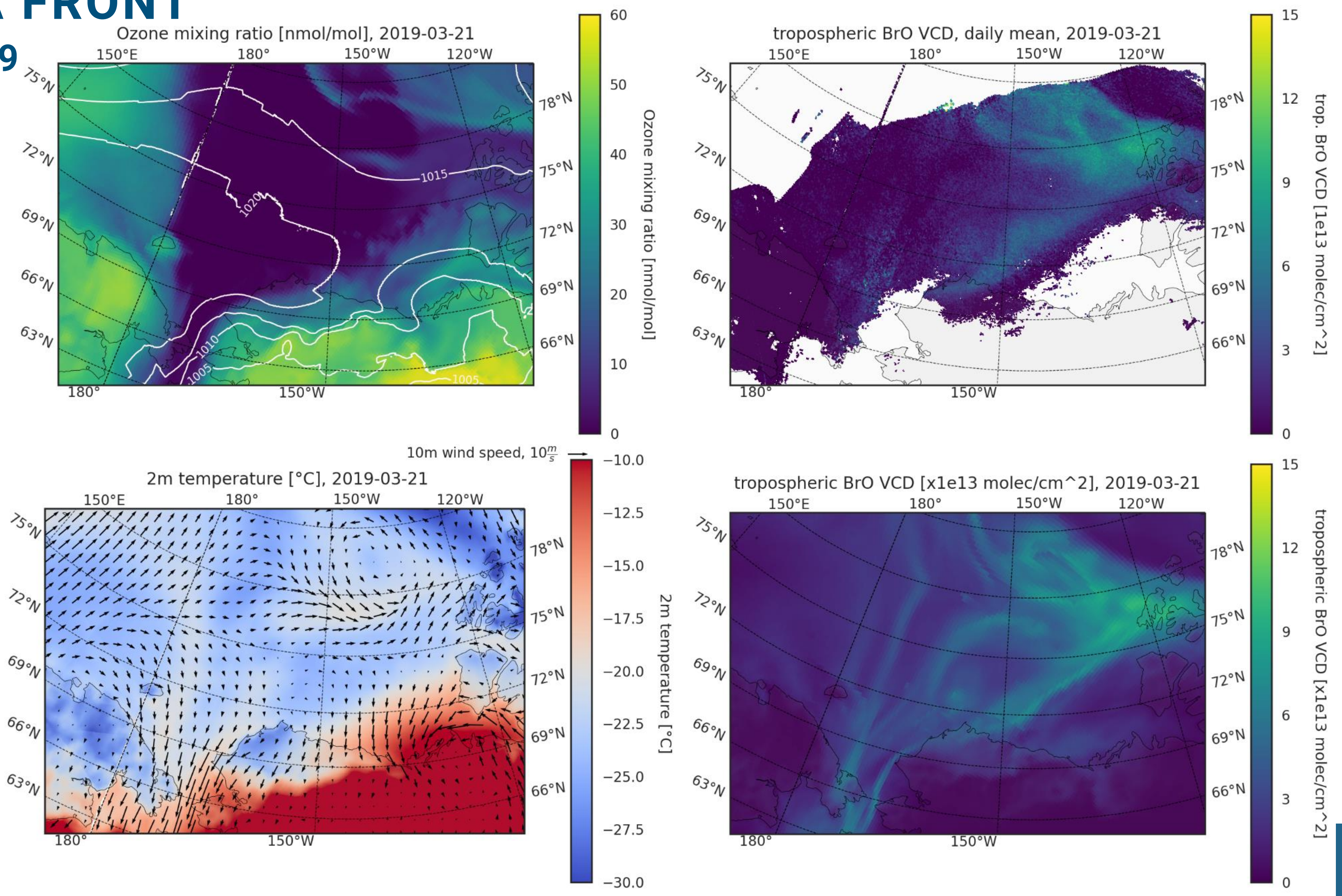
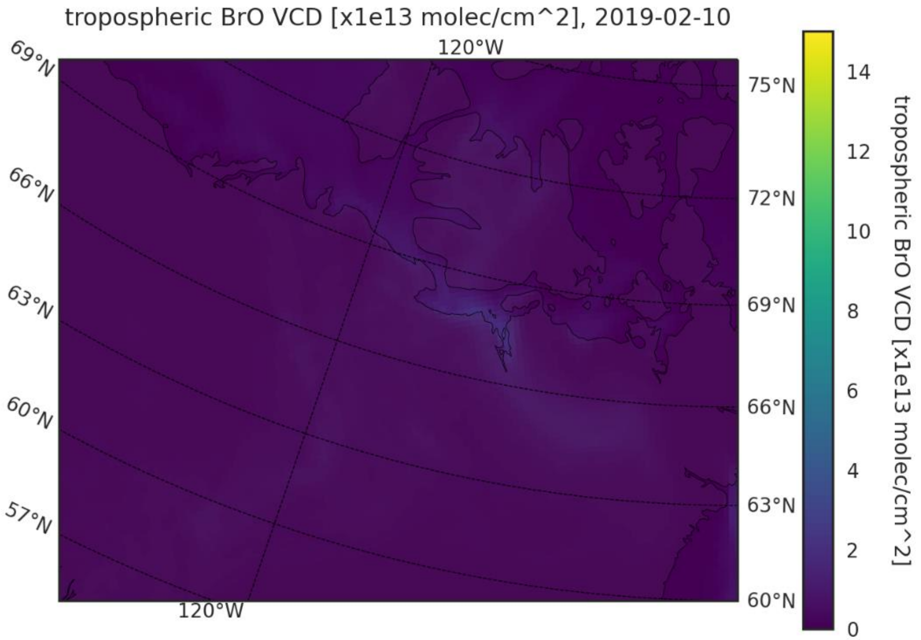
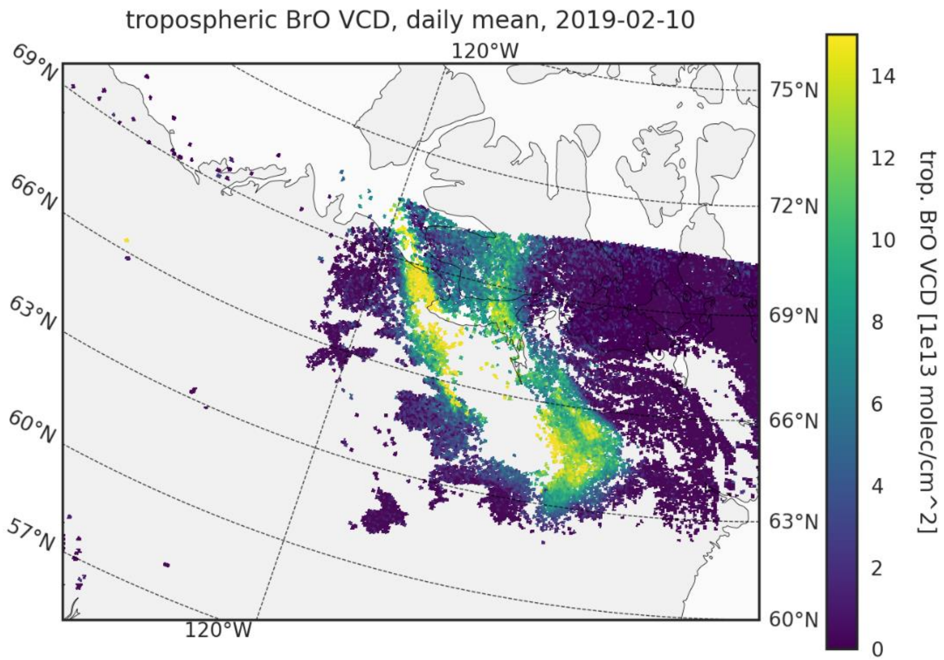


CASE III – NOT SEEN BY MODEL
10.02.2019

- Large event coming from Victoria Island not seen in the model
- For SZA > 85° the bromine from surface emissions in the simulation is close to zero
- Mismatch might confirm conjecture that surface BrO oxidation occurs with almost no light (Pratt et al., 2017)





SUMMARY AND CONCLUSION

- We looked at three case studies of enhanced tropospheric BrO in relation to meteorological surface parameters at different times of the season
- Case I exemplified ODEs at the beginning of polar spring:
  - Occur more commonly in stable boundary layers with low wind speed
  - Indicates these are strongly driven by surface emissions
- Case II investigated an event later in the season:
  - Higher wind speeds and an unstable boundary layer favour BrO events
  - Ambient BrO levels much higher in regions of FY sea ice, BrO explosion seems to be limited mainly by the abundance of ozone
  - High wind speeds could indicate higher supply of ozone to BrO enriched air masses
- Case III showed an event not predicted by the model
  - Inidicates bromine oxidation even under very low light conditions

THANKS FOR YOUR ATTENTION!