On the use of Be-7 observations to study atmospheric processes

Pieter De Meutter[1,2]

1: Belgian nuclear research centre
2: Royal Meteorological Institute of Belgium

INTRODUCTION AND MAIN RESULTS

- Radionuclide stations from the International Monitoring System measure beryllium-7 (Be-7)
- Be-7 is a cosmogenic radionuclide produced in the upper troposphere and lower stratosphere
- Near-ground Be-7 concentrations are governed by atmospheric processes, including deposition and downward advection
- Here we link peak Be-7 observations to an upper level cut-off low and associated tropopause folding

On the use of Be-7 observations to study atmospheric processes

P De Meutter

P5.1-627

Atmospheric transport modelling

1. The Lagrangian particle dispersion model Flexpart v10.4 (Stohl et al. 2005, Pisso et al., 2019) is used to simulate source-receptor sensitivities in backward mode (Seibert and Frank, 2004). Flexpart tracks the position and mass of many computational particles.

2. The position of the particles is governed by (1) advection using wind fields obtained by numerical weather prediction data and (2) dispersion governed by the turbulence parameterisation in Flexpart. In the planetary boundary layer, the turbulence is governed by atmospheric stability. Flexpart was coupled with three-hourly numerical weather prediction data from the Integrated Forecasting System of ECMWF extracted at 0.5° horizontal grid spacings. Additionally, (3) gravitational settling can move aerosols downward, while (4) the convective parameterisation scheme redistributes particles vertically.

3. The mass of particles is initially equal for all computational particles, but decreases with simulation time due to the effect of radioactive decay, and dry and wet deposition.

4. Flexpart converts particle position and mass to concentrations following a user-defined output grid. A schematic picture is given in **Figure 1**.

5. The Flexpart output is coupled to a fictitious Be-7 source function that is representative of slow atmospheric processes not resolved by the Flexpart simulations, to obtain simulated activity concentrations at the IMS stations.

Case study at CAP16

A strong Be-7 peak event was selected for further study. The peak concentration was measured at the IMS station CAP16 in Yellowknife in Canada (62.5N, 114.5W) at 21 June 2020. The peak event is shown in **Figure 2**, together with the corresponding simulated activity concentration. In order to discriminate between the contribution from the troposphere and the stratosphere, the Flexpart model was adapted to separate output for troposphere and stratosphere based on the thermal tropopause definition.

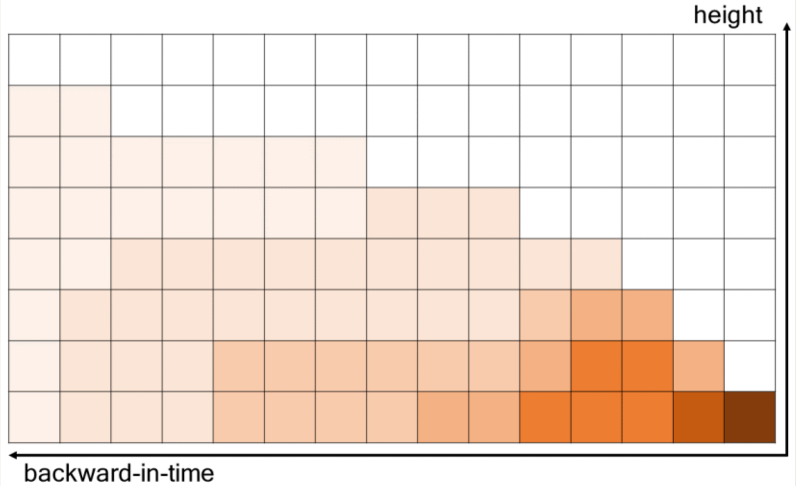

Figure 1: Schematic picture of Flexpart output. Particles are released at the radionuclide station (bottom right corner) and are advected and dispersed backward-in-time. Some of the computational particles will travel aloft.

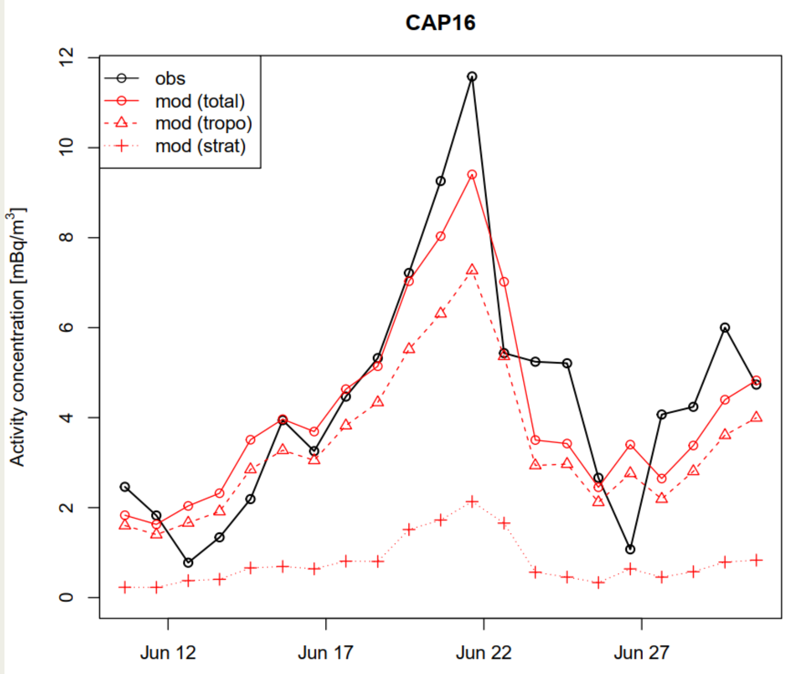

Figure 2: Observed Be-7 activity concentration at the IMS station CAP16 mid-June 2020. The simulated Be-7 are also shown: total Be-7 (solid line); tropospheric Be-7 (dashed line); stratospheric Be-7 (dotted line).

sck cen RMI

On the use of Be-7 observations to study atmospheric processes

P De Meutter

Link with upper-air cut-off low

The position of the retroplume as it travels backward-in-time can be inferred from **Figure 3 (next slide)**, which shows the average height of the source-receptor sensitivities weighted by its contribution to the sample activity concentration. Thick black contours show which regions contribute most to the simulated Be-7 activity concentration. Initially, the retroplume moves south and then east in the first two days before collection stop. It quickly gains height as it travels further north-eastwards along the northern edge of a through (visible on the 500 hPa geopotential height, not shown here). Then, the bulk contributing most to the Be-7 activity concentration travels westwards while gaining further height, until it reaches a cut-off low on 14 June 2020. The latter is clearly visible on the 300~hPa geopotential height maps which are shown in **Figure 4 (next slide)**, together with the relative humidity for the same area and dates as the Flexpart output in **Figure 3 (next slide)**. Interestingly, the bulk remains around this cut-off low for several days. Its position coincides with a region of high stratosphere-to-troposphere transport (Boothe and Homeyer, 2017).

Cut-off lows are known to feature troposphere-stratosphere folding (e.g., Langford et al., 1996; Price and Vaughan,1993). This, in combination with descent along the northern edge of a through (Itoh and Narazaki, 2016), explains the peak Be-7 activity concentration measured at CAP16.

Acknowledgements

The author acknowledges the station operators of CAP16 and the CTBTO for sharing the data.

References

Boothe, A. C., & Homeyer, C. R. (2017). Global large-scale stratosphere–troposphere exchange in modern reanalyses. *Atmospheric Chemistry and Physics*, *17*(9), 5537-5559.

Langford, A. O., Masters, C. D., Proffitt, M. H., Hsie, E. Y., & Tuck, A. F. (1996). Ozone measurements in a tropopause fold associated with a cut-off low system. *Geophysical research letters*, *23*(18), 2501-2504.

Pisso, I., Sollum, E., Grythe, H., Kristiansen, N. I., Cassiani, M., Eckhardt, S., ... & Stohl, A. (2019). The Lagrangian particle dispersion model FLEXPART version 10.4. *Geoscientific Model Development*, *12*(12), 4955-4997.

Price, J. D., & Vaughan, G. (1993). The potential for stratosphere-troposphere exchange in cut-off-low systems. *Quarterly Journal of the Royal Meteorological Society*, *119*(510), 343-365.

Seibert, P., & Frank, A. (2004). Source-receptor matrix calculation with a Lagrangian particle dispersion model in backward mode. *Atmospheric Chemistry and Physics*, *4*(1), 51-63.

Stohl, A., Forster, C., Frank, A., Seibert, P., & Wotawa, G. (2005). The Lagrangian particle dispersion model FLEXPART version 6.2. *Atmospheric Chemistry and Physics*, *5*(9), 2461-2474.

sck cen RMI

On the use of Be-7 observations to study atmospheric processes

P De Meutter

P5.1-627

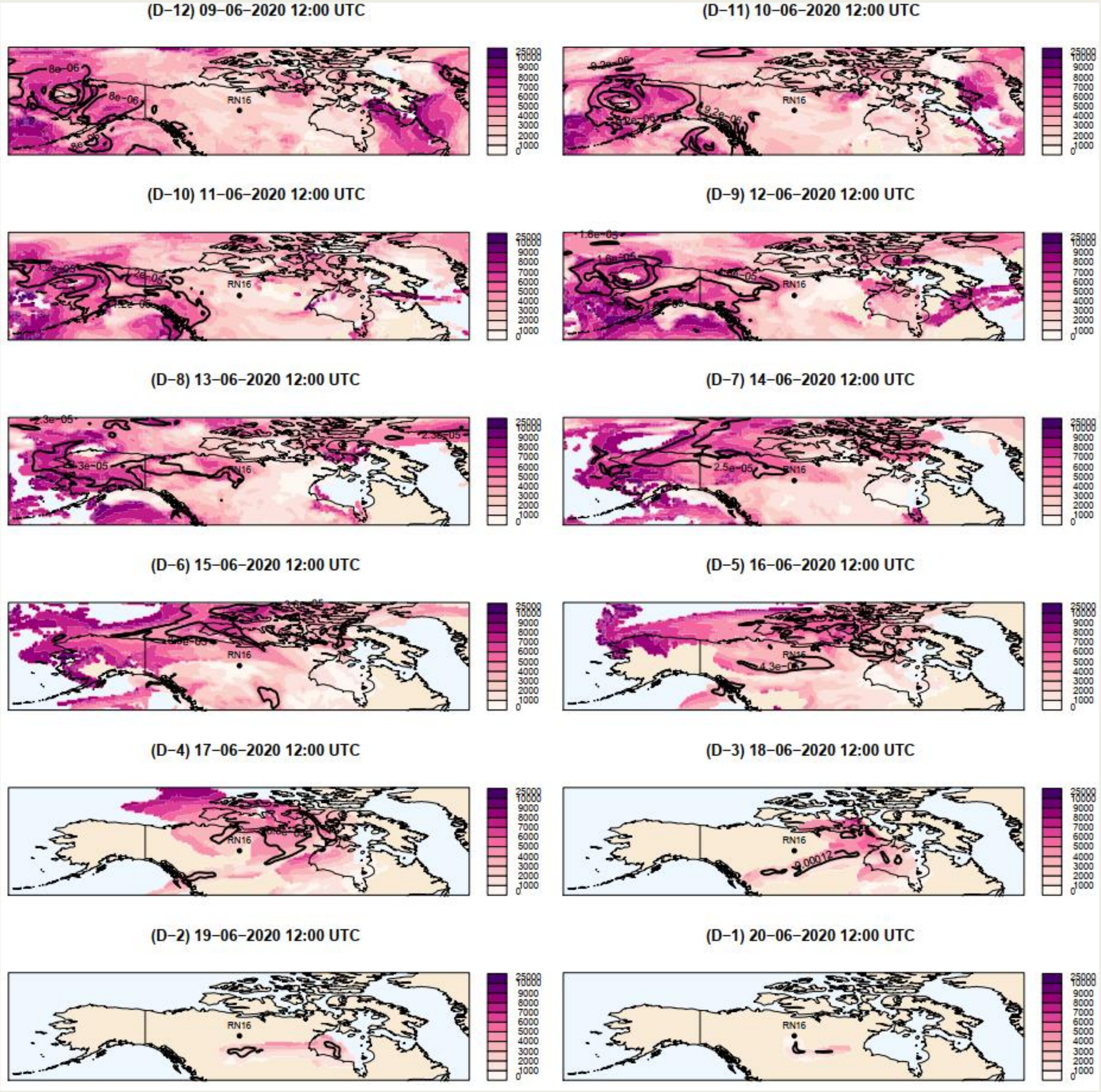

Figure 3: Assessing the origin of the Be-7 peak concentration in the sample measured at CAP16 with collection stop 21 June 2020 using Flexpart. The colors represent the average height [m] of the source-receptor sensitivities, weighted by its contribution to the sample activity concentration. Furthermore, a contour plot is drawn on each map, showing the 90% percentile of the total column Be-7 contribution to the sample. The plot titles show the date and the corresponding number of days back-in-time with respect to the sampling stop date.

sck cen RMI

SnT 2025
8 SEPTEMBER ONLINE DAY
9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

On the use of Be-7 observations to study atmospheric processes

P De Meutter

P5.1-627

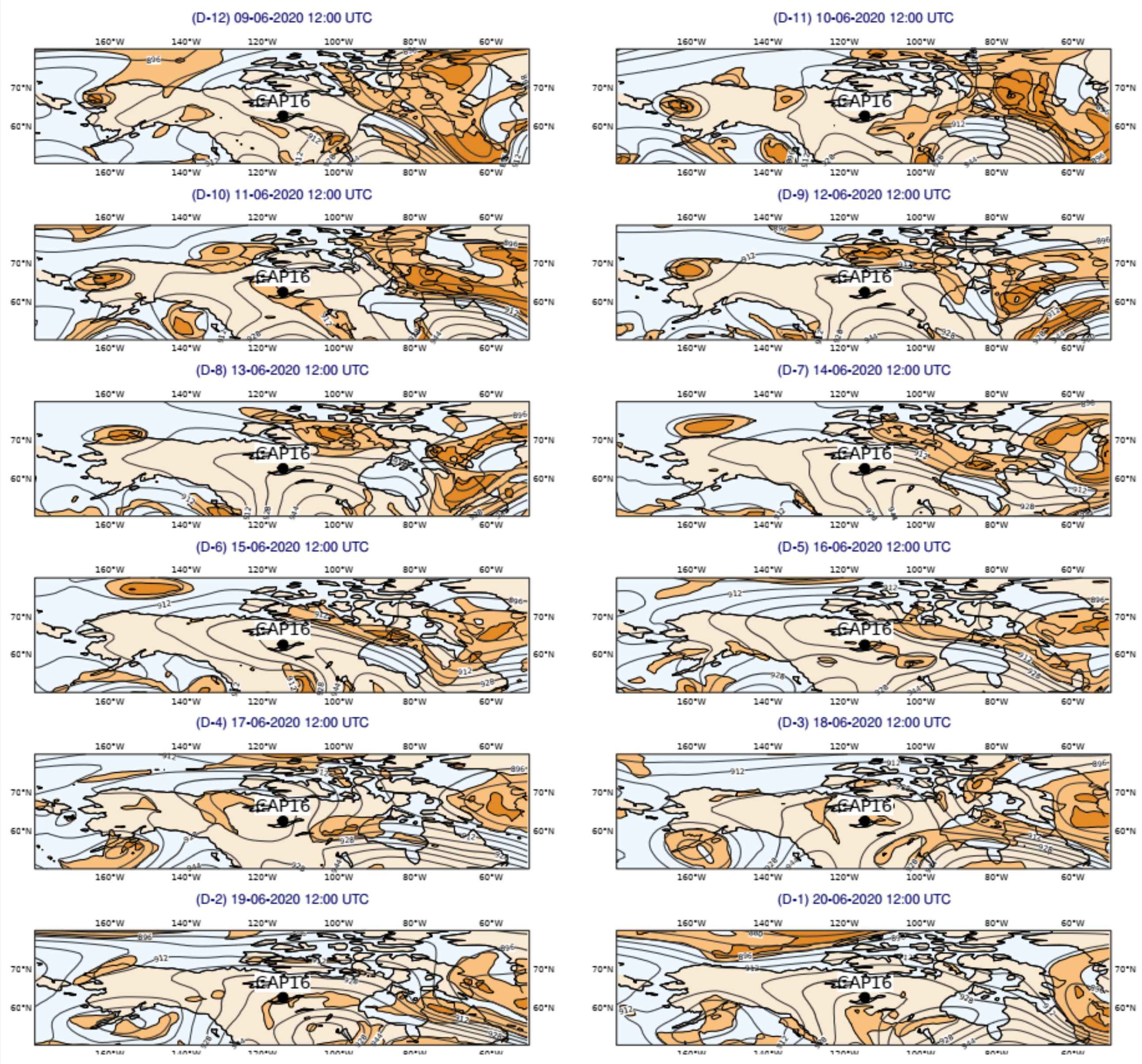

Figure 4: 300 hPa geopotental height [dam] (black contours) and relative humidity [%] (color shadings; light orange for RH < 40% and dark orange for RH < 10%). The plot titles show the date and the corresponding number of days back in time with respect to the sampling date.