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email:jolanta.kusmierczyk-michulec@ctbto.org

The interhemispheric transport of anthropogenic emissions: additional challenge for source localization

Jolanta Kuśmierczyk-Michulec and Jonathan Baré

CTBTO, International Data Centre

CTBTO PREPARATORY COMMISSION

Introduction

Upon completion, the radionuclide technology of the IMS will comprise 80 stations, of which 73 are currently certified and regularly send data to the International Data Center (IDC). At the time of entry into force, 40 out of 80 stations are expected to be equipped with additional noble gas capability (with the option of being deployed throughout the entire network after entry into force). This unique monitoring network enables a continuous worldwide observation of aerosol samples of radionuclides and noble gases. Currently, in the Southern Hemisphere, 27 out of the 31 stations foreseen by the Treaty are operating (see Figure 1).

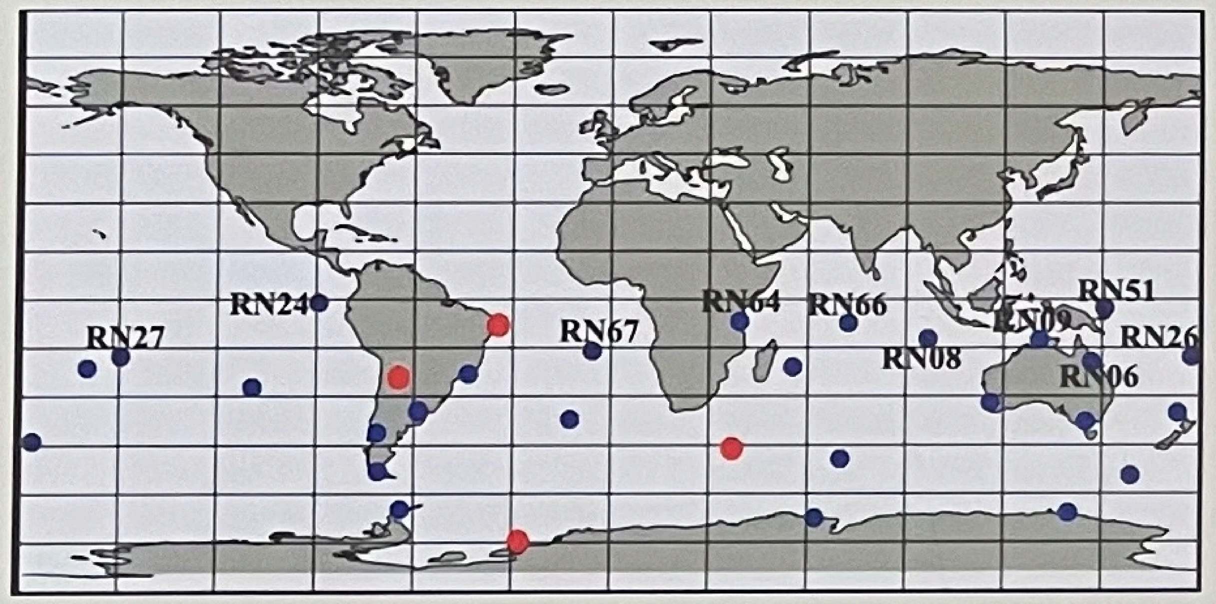

Figure 1. Map showing the location of IMS RN stations in the Southern Hemisphere. Stations considered in this study are labeled; stations not constructed yet are indicated in red.

Seasonal trends in the wind field spatial distribution-modelling results

To investigate seasonal changes in the paths of air masses during their transport between the Southern and the Northern Hemispheres, the maps showing the Network Coverage (NET-MDC) for four seasons straddling over 2021 and 2022: DJF (December 2021, January 2022, February 2022), MAM (March, April. May), JJA (June, July, August) and SON (September, October, November), were generated for IMS stations indicated in Figure 1 .

Quarterly NET-MDC products for IMS stations depend on the monthly mean wind patterns (direction, speed, variability). Figure 2 reveals that south of the Tropic of Capricorn, the patterns are quite stable throughout the year. Between the Equator and the Tropic of Capricorn, the impact of the ICTZ (the Intertropical Convergence Zone) can be observed. Figure 2a &2b illustrate that during DJF and MAM seasons, the winds cross the Equator, indicating a possible North to South air mass transport.

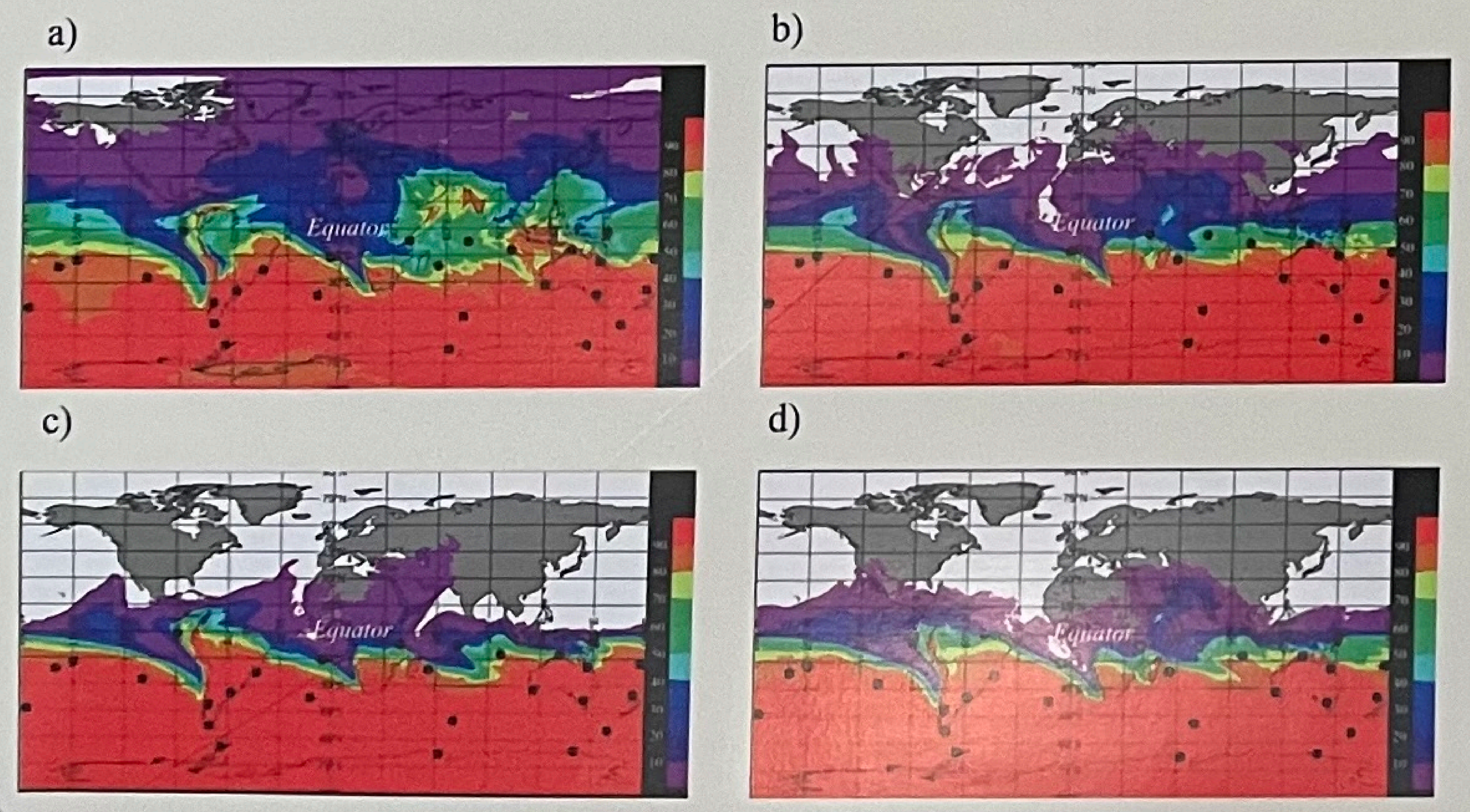

Figure 2. Quarterly Network Coverage for RN IMS stations located in the Southern Hemisphere for 2022. a) DJF, b) MAM , c) JJA and d) SON. Black dots represents the location of RN IMS stations.

North-to-South Air Mass Transport - observational evidence

The radioactivity measurements registered in the aftermath of the Fukushima accident by the IMS network provide evidence of North to South air mass transport. On a smaller scale, similar evidence is also provided by the episodic releases of both radioactive particles and noble gas from civil nuclear facilities.

The Fukushima accident

On 12 March 2011, in the aftermath of the Fukushima Daiichi NPP accident, a massive discharge of radionuclides into the air and the ocean took place. In April 2011, the IMS stations RN26 and RN51, located in the Southern Hemisphere, detected radioactivity from the Fukushima accident. ^{131}I was first detected at the station RN51, Papua New Guinea, on the 1st of April (i.e. 20 days later). Next detections took place between the 5th and the 15th of April. ^{137}Cs and ^{134}Cs were also detected on the 9th and the 10th of April. ^{131}I was detected at the station RN26, Fiji, form the 5th to the 14th of April, i.e. for 10 consecutive days.

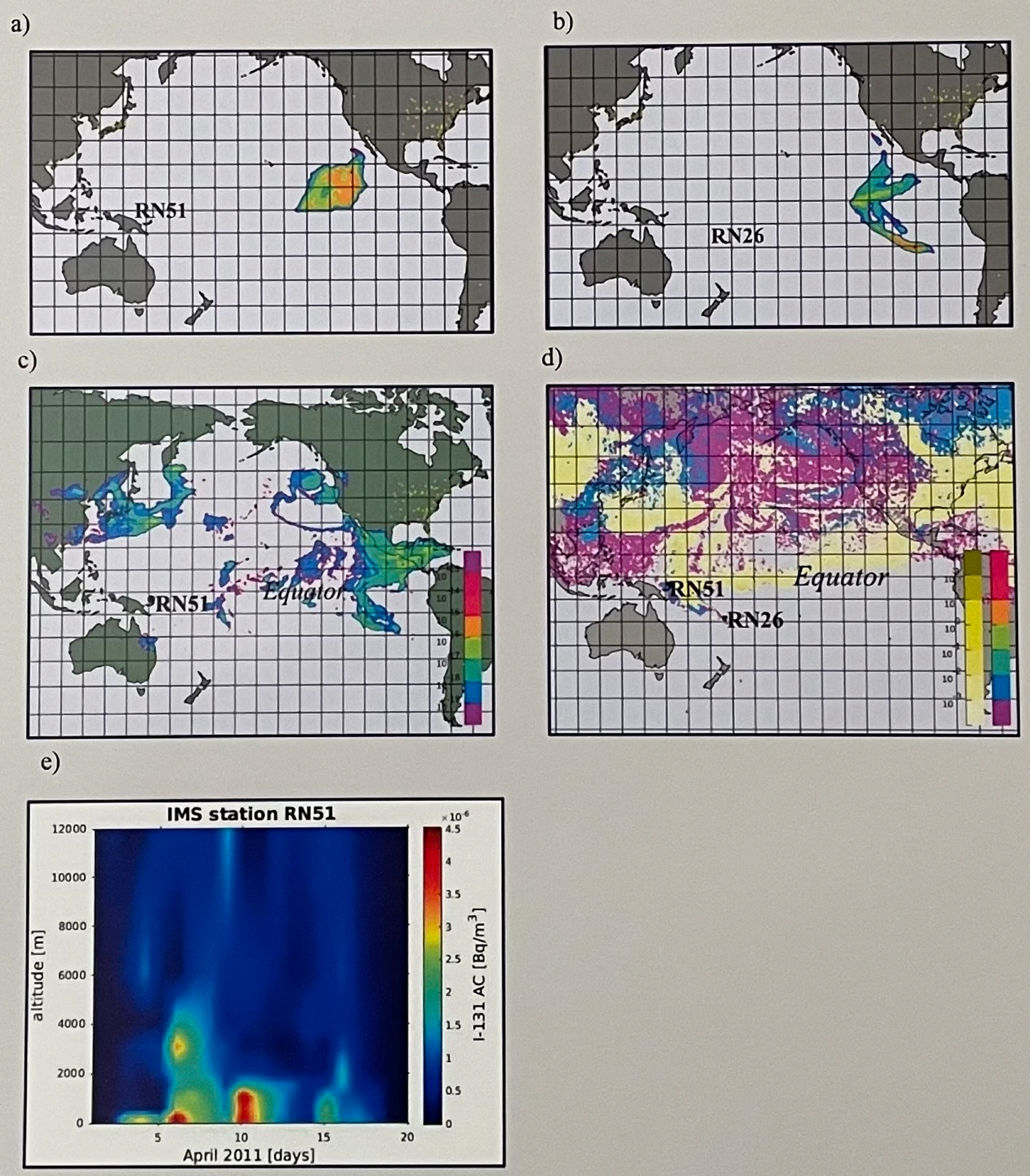

Figure 3. ATM simulations related to Fukushima accident. **a)** Snapshot showing that after 14 days backward simulations, counting from the 1st of April 2011 (the first day of detection), air masses did not reach a coastline. b) Snapshot illustrating that after 14 days, counting from a detection on the 5th April 2011, air masses were far from the coastline. **c)** Snapshot taken on 19th March 2011, 20 days prior to the detection on the 9th of April at RN51 (ATM backward simulation). **d)** Snapshot taken on 6th April 2011 at 12:00 illustrating that both IMS stations RN26 and RN51 are influenced by emissions from Fukushima (ATM forward simulations). The yellow colors indicate the plume released on the 19th of March 2011, the multi-colors indicate the plume released on the 13th of March 2011; both plumes contribute to the detections at IMS stations RN51 and RN26. **e)** The passage of the ^{131}I plume over RN51 associated with daily ^{131}I releases from Fukushima between the 12th and the 19th of March 2011.

Challenge for source localization

Identifying the possible source of radioactivity detected at the International Monitorin System (IMS) stations is both challenging and central to the CTBTO mandat Atmospheric transport modelling (ATM) calculations enable identification of possib source areas of these radionuclide detections. Due to the atmospheric circulation and th air mass transport from the Northern to the Southern Hemisphere, stations located in th Southern Hemisphere may face additional challenges in source localization, especial over the period December to April. The ATM simulations and their correct and accura interpretation is then critical in analysing these cases.

Figure 4a illustrates the North-to-South air mass transport in case of locations dominat by the prevailing wind from the east or southeast. A detection of ^{137}Cs on the 19th January 2018 at RN08, Cocos Islands, Australia, could be caused by a release from a N in India, but an additional contribution of emissions from a NPP in South Africa cannot ruled out.

Figure 4b reveals that a detection of ^{137}Cs noted at the IMS station RN64, Dar es Salaa Tanzania, on the 6th of February 2008, could be caused by one of the many NPPs facili in the Northern Hemisphere. The closest NPP facility is in Armenia, at a distance of onl days, and the closest known IPF in Dimitrovgrad, at a distance of 10 days. This exam illustrate the complexity related to source localization.

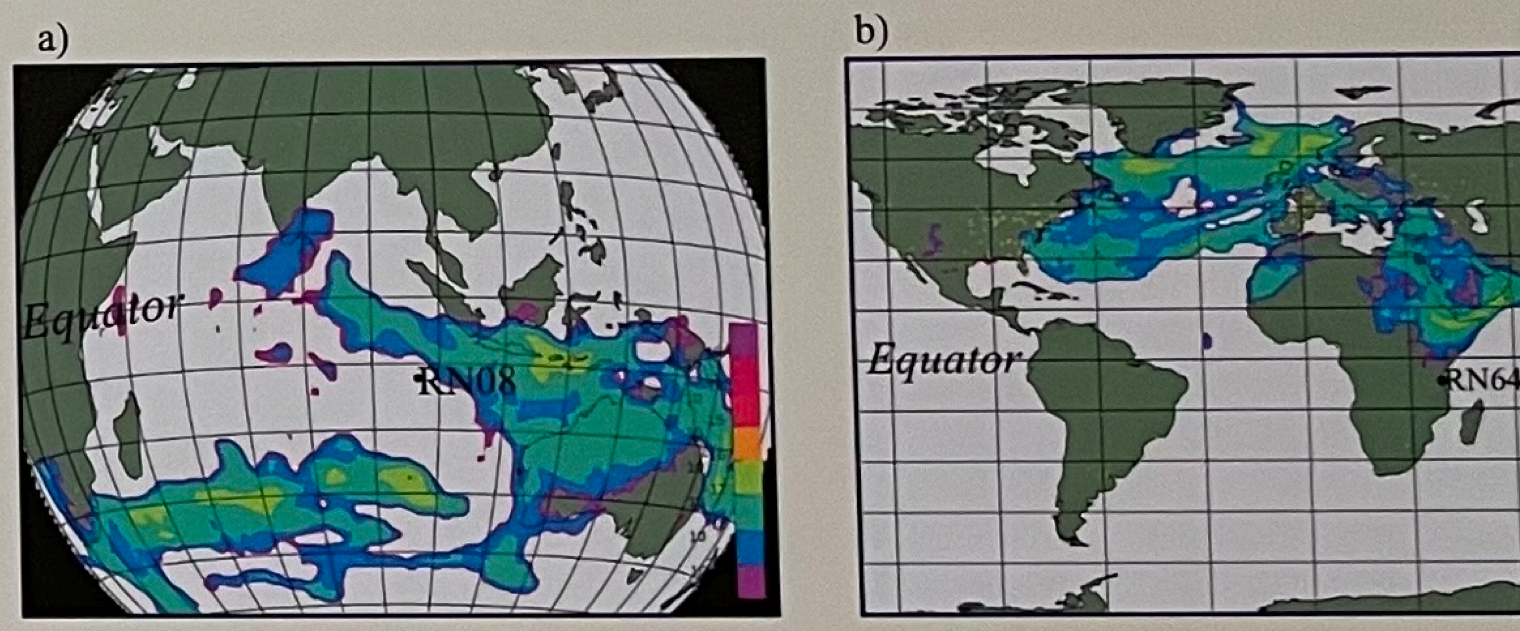

Figure 4. Example of occasional releases from civil nuclear facilities located in the Northern Hemisphere and detected by the IMS located in the Southern Hemisphere. a) RN08, b) RN64

For some stations like RN26 and RN51, the standard time of 14 days in bacl simulations is not sufficient to reach a coastline and indicate a potential sour radioactivity. This is illustrated in Figure 5.

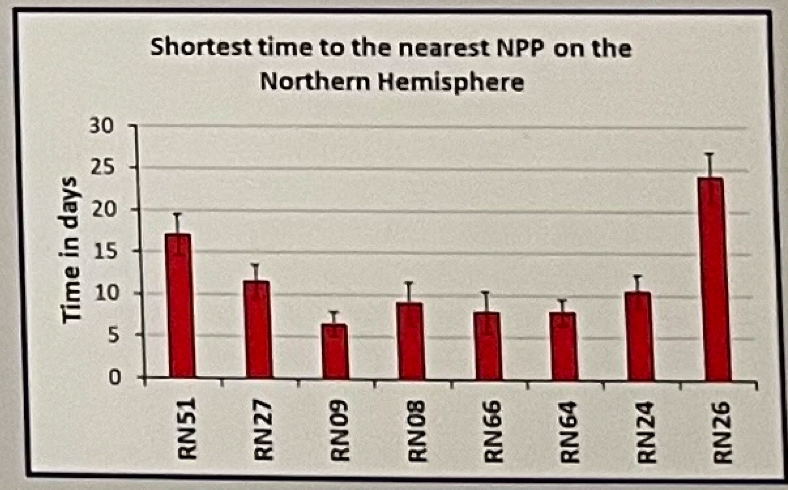

Figure 5. Minimum time needed to reach the nearest NPP located on the Northern Hemisphere, as indicated by ATM backward sin for the period December-April.

Concluding remarks

North-to-South air mass transport is a rather rare – but observed – phenomenon. It i frequently observed between January and April. The fact that such a transport takes longer than the 14 days considered by operational ATM simulations presents additic challenges. It is therefore recommended that the ATM backward simulations perfor the CTBTO are extended to at least 21 days in routine operations.

References

Kuśmierczyk-Michulec and J. Baré, Global atmospheric monitoring of radionuclides and noble gases: insights into the interhemispheric anthropogenic emissions, submitted to Atmospheric Environment , 2023.