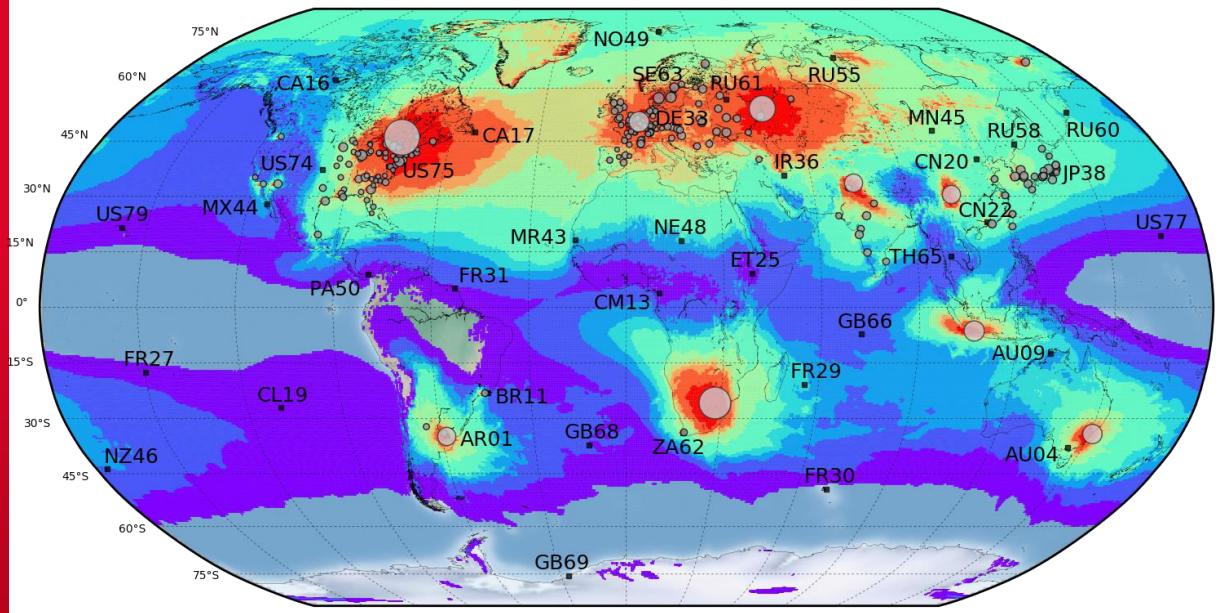
DE LA RECHERCHE À L'INDUSTRIE



SEASONAL VARIABILITY OF XE-133 ATMOSPHERIC BACKGROUND:

Characterization and implications for the International Monitoring System of the Comprehensive nuclear-Test-Ban Treaty

Sylvia Generoso, Pascal Achim, Mireille Morin, Philippe Gross, Gilbert Le Petit

Science and Technology 2017
June 26-30, 2017, Vienna, Austria

Introduction

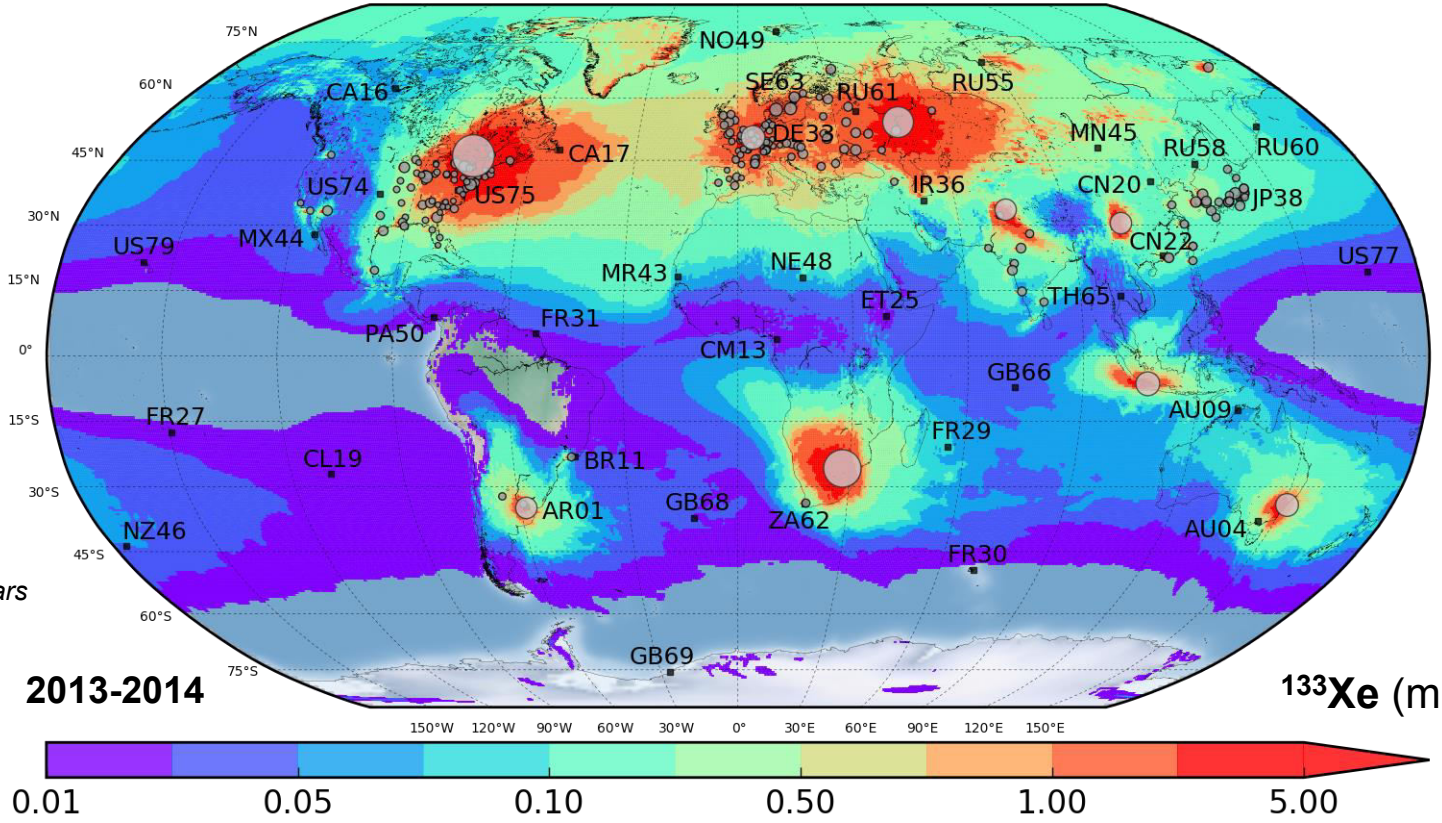
- **The goal** of the present study is **to describe the variability** of Xe-133 atmospheric background **related to meteorological seasonal patterns**:
  - Across the globe (ground level)
  - At IMS stations

- **Simulation of two years (2013-2014)** of Xe-133 background:
  - Summary of methodology and main findings
  - Validation of the simulated "global picture" with measurements at the 29 operational IMS stations (2 years of data, 6000 detections)

P. Achim, S. Generoso, et al., *Characterization of Xe-133 global atmospheric background: implications for the International Monitoring System of the Comprehensive nuclear-Test-Ban Treaty*, **JGR Atmospheres, Vol 121, Issue 9, 2016**

- **Seasonal cycles**:
  - Simulated from two years of data (2013-2014)
  - Observed from 4 years of measurements (2013-2016)

Map of annual average Xe-133 activity concentrations from industrial sources



Average from 2 years of simulated data, ground level (in the layer 0-100m AGL)

2013-2014

^{133}Xe (mBq/m^3)

Sources

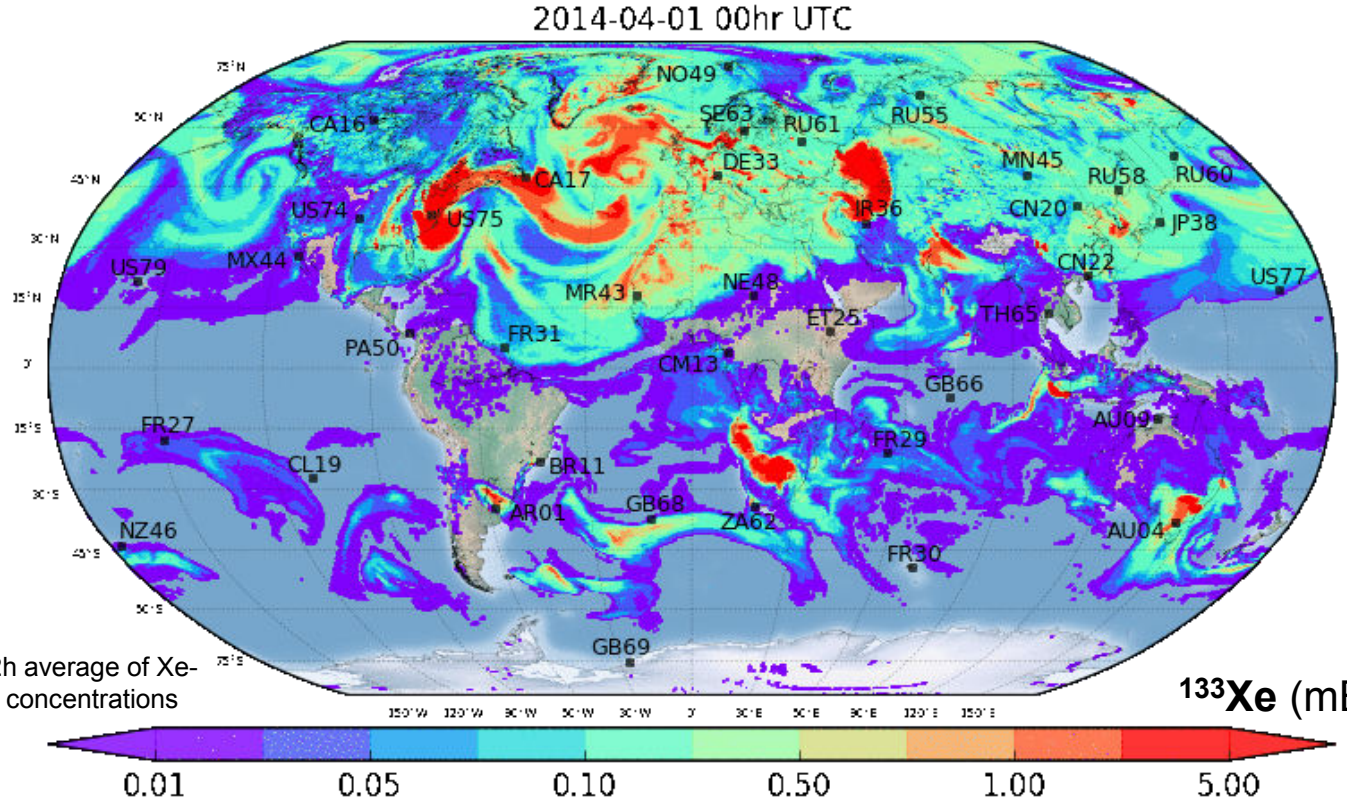
Medical Isotope Production (MIPs) ● Nuclear Power Plants (NPPs) ●

- **~51 TBq** Xe-133/day
- 9 MIPs representing 95% of the total emission
- 178 NPPs (383 reactors)
- 65% released in the Northern Hemisphere / 35% in the Southern Hemisphere

Achim, Generoso et al, JGR, 2016 for detailed inventory and references

A large spatial variability explained by the coupling between location of sources and atmospheric circulation

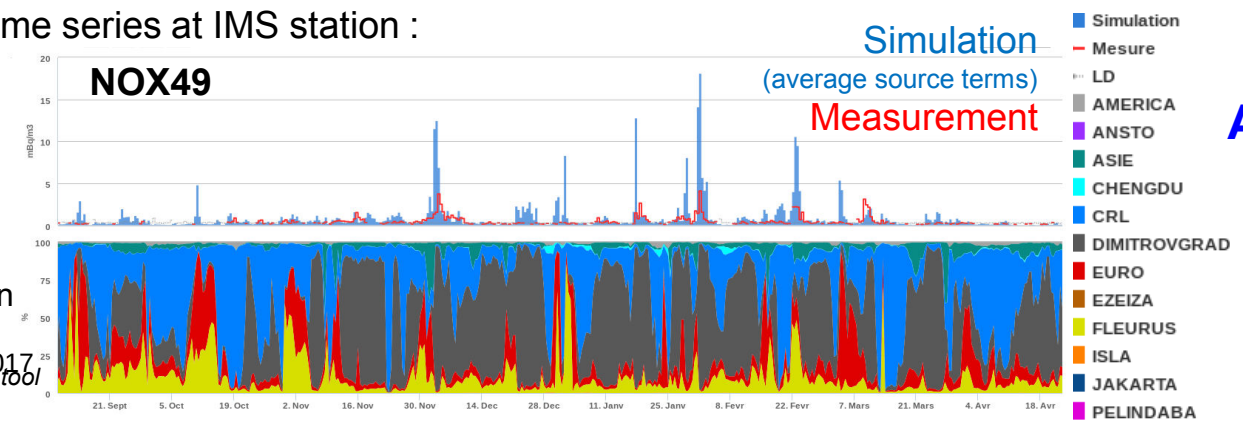
Daily variations of Xe-133 levels and contributors



Simulated 12h average of Xe-133 activity concentrations

^{133}**Xe** (mBq/m^3)

Example of time series at IMS station :



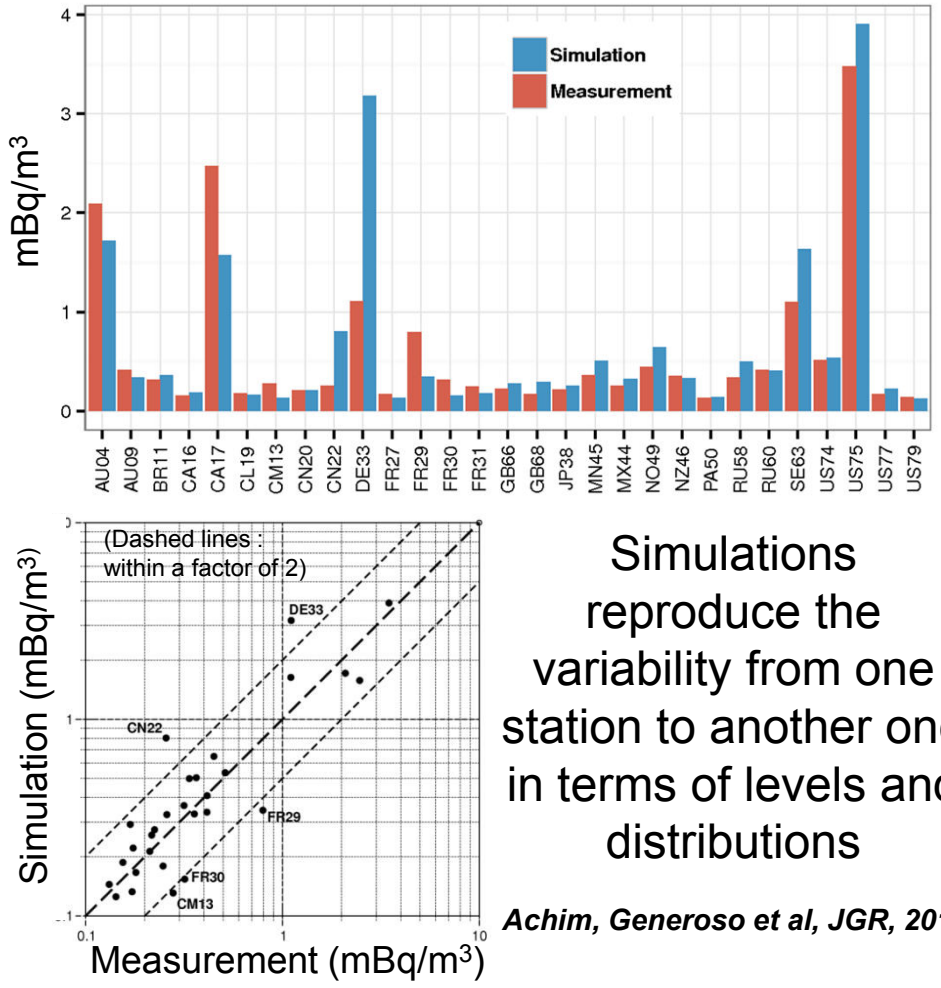
A daily variability of Xe-133 levels and origins

CTBTO SnT2017

From CEA automatic tool

Simulations versus measurements
Xe-133 activity concentrations at IMS stations (2013-2014)

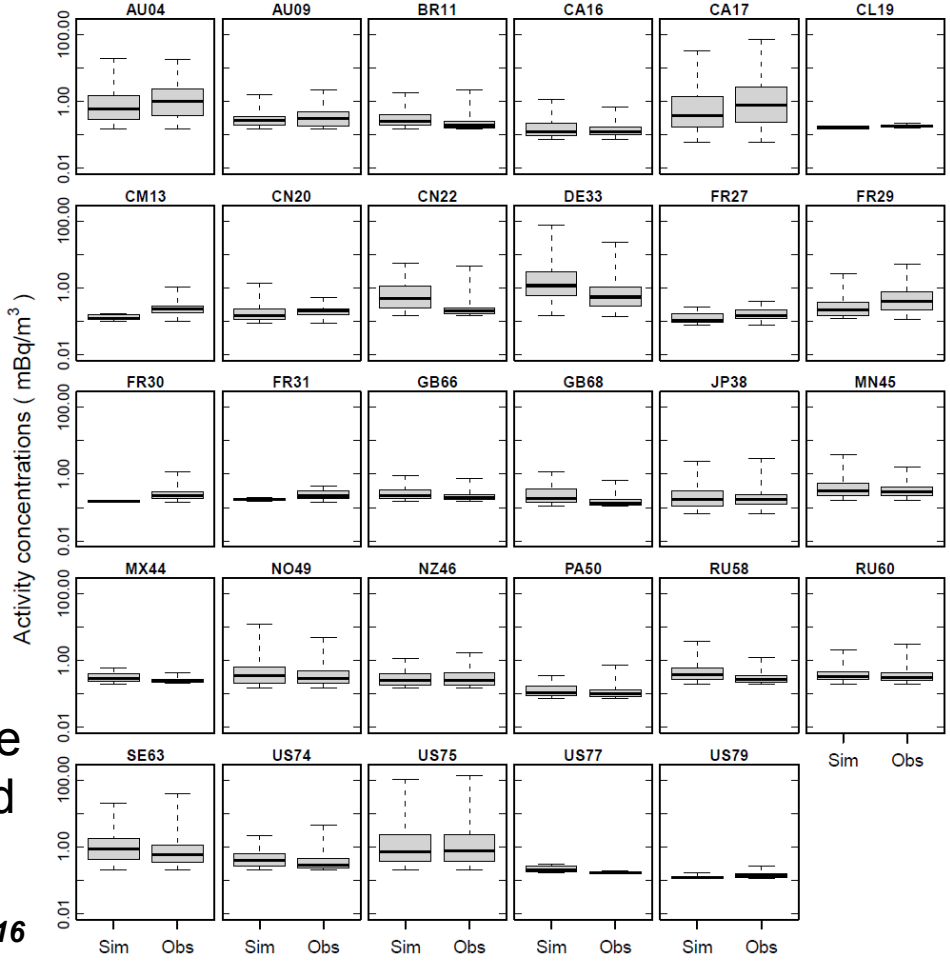
Annual averages



Simulations reproduce the variability from one station to another one in terms of levels and distributions

Achim, Generoso et al, JGR, 2016

Distributions (of 12 hour average points)



Comparison to 6000 detections at 29 IMS stations across the globe validates the description of the global mechanisms at the origin of the industrial background

Addressing seasonal variations of Xe-133 background

- **Is part of the variability of Xe-133 atmospheric background explained by seasonal patterns of the atmospheric circulation?**
- **Can we see seasonal patterns on the IMS network?**

→ Seasonal variations is addressed by describing **time series of monthly averages**
Ideally, it requires many years of data (e.g. > 10 years)

Simulation

- **Meteorological variability** can be addressed with multiple-year simulation including previous (validated) constant emission inventory

2 years: 2013-2014

IMS Measurement

- **Real emission variability**, varying year-by-year (increasing)

→ exhaustive sources (including hospitals, research reactors, etc.)
→ real amplitudes
→ real timing of releases (production stops, exceptional peaks, etc.)

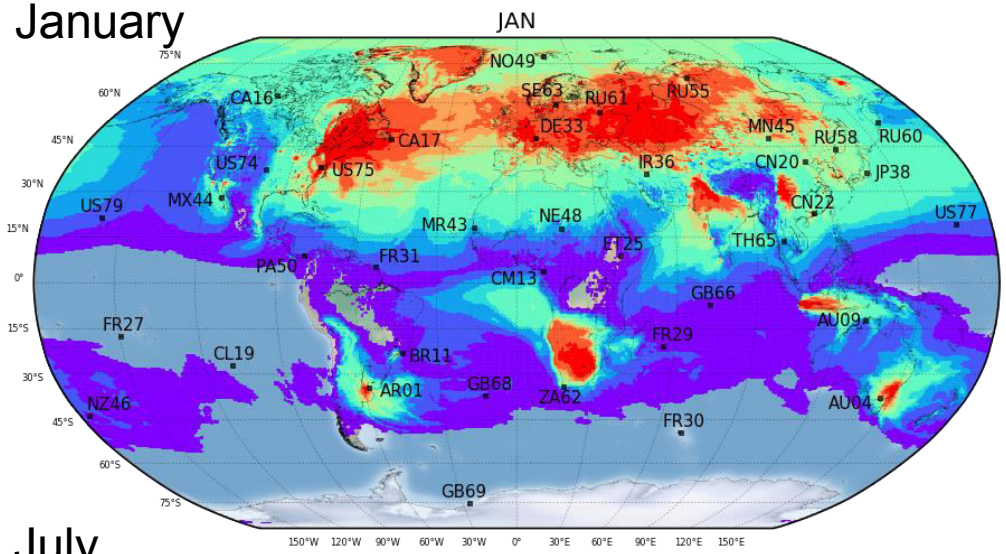
➔ Considering long multi-annual time series adds source variability in addition to seasonal variability

4 years: 2013-2016

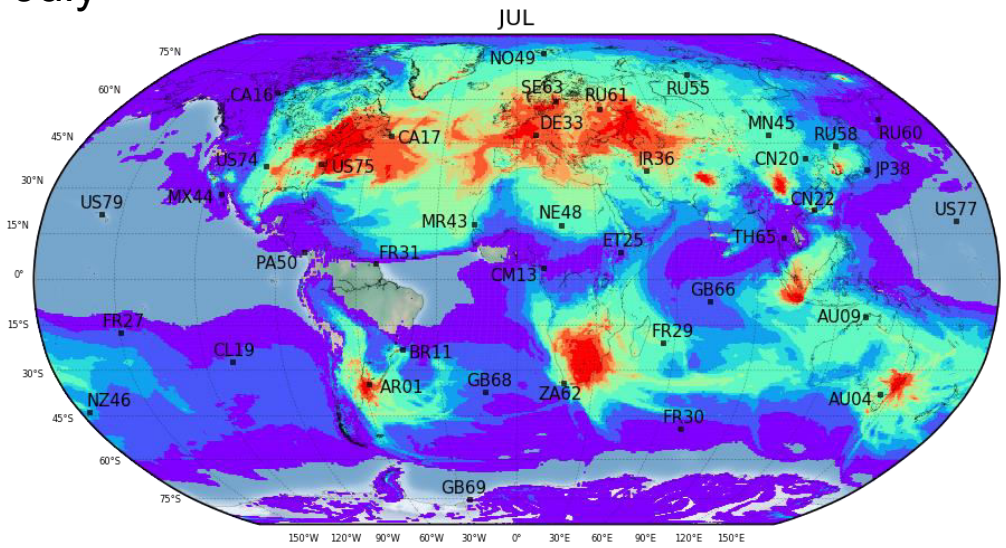
Are there <u>trends</u> in terms of seasonal variations on the basis of these first 2 complete years of simulations and of 4 years of measurements?

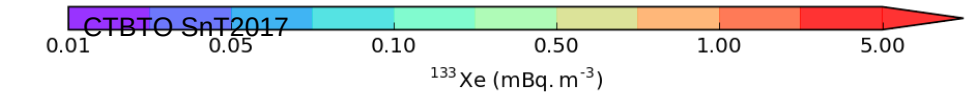
Seasonal variations of the Xe-133 atmospheric background: at global scale

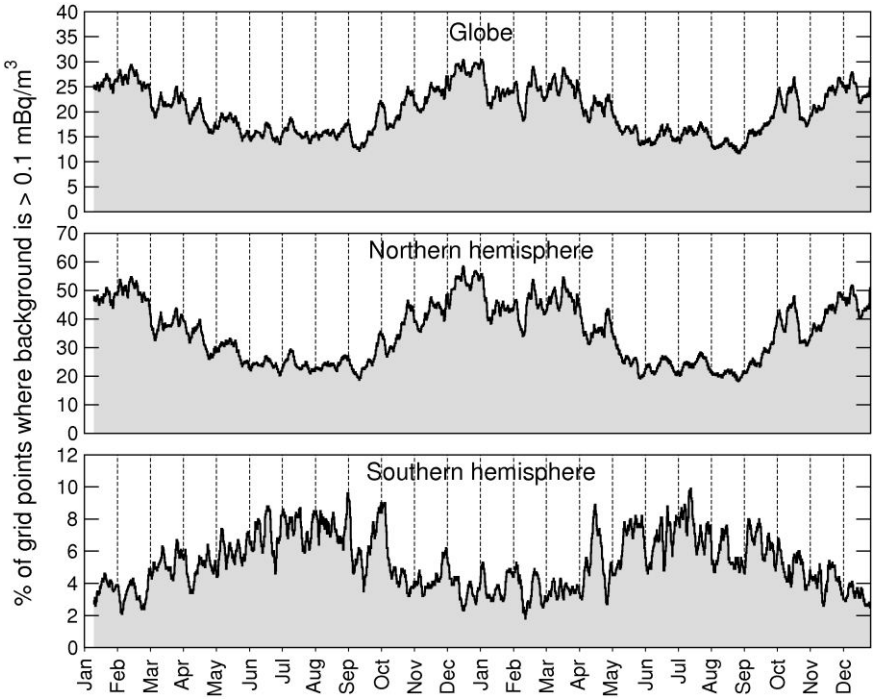
January



July





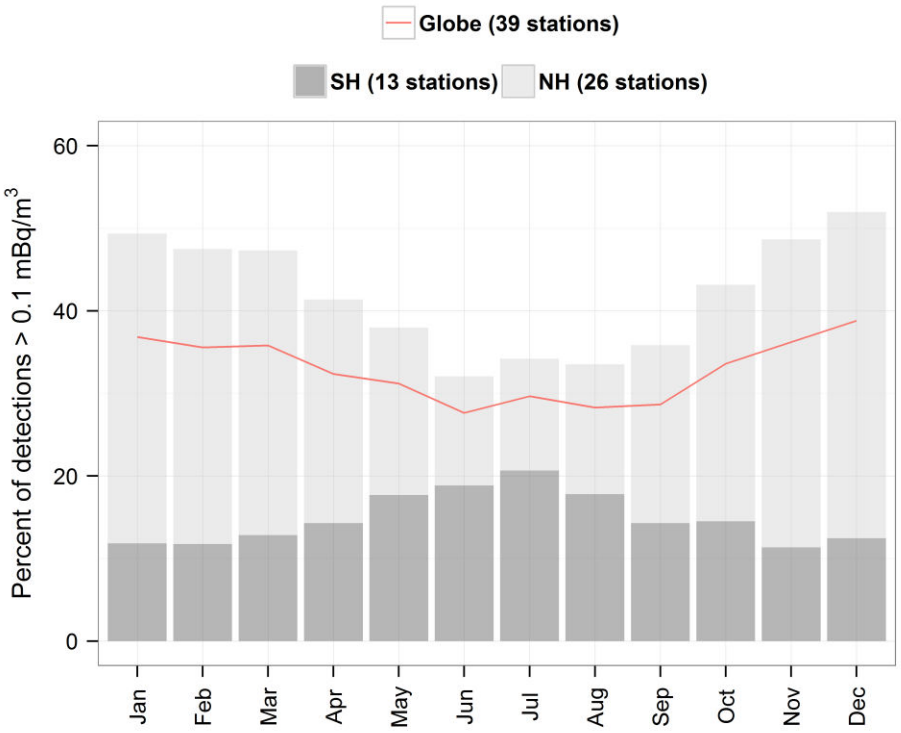


Spatial extension of the atmospheric background during Winter months

➔ What is the consequence on the IMS network?

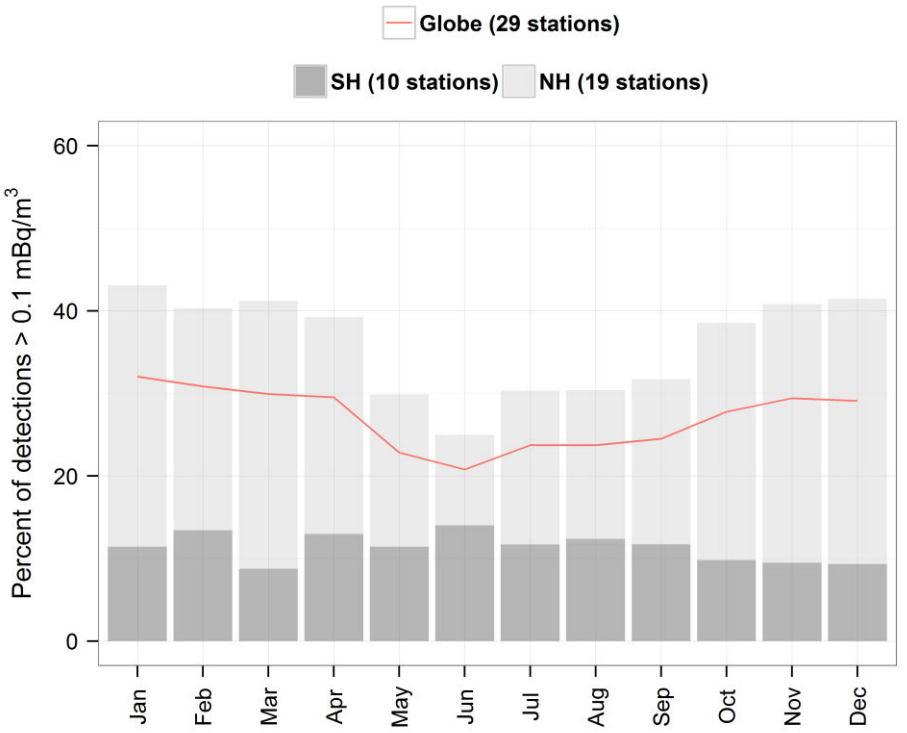
Predicted and observed occurrences of detections of Xe-133 atmospheric background for the IMS network

SIMULATION (2013-2014)



Predicted percent of detections > 0,1 mBq/m³ per month on the IMS network (Global / Northern Hemisphere / Southern Hemisphere) from two years of simulation

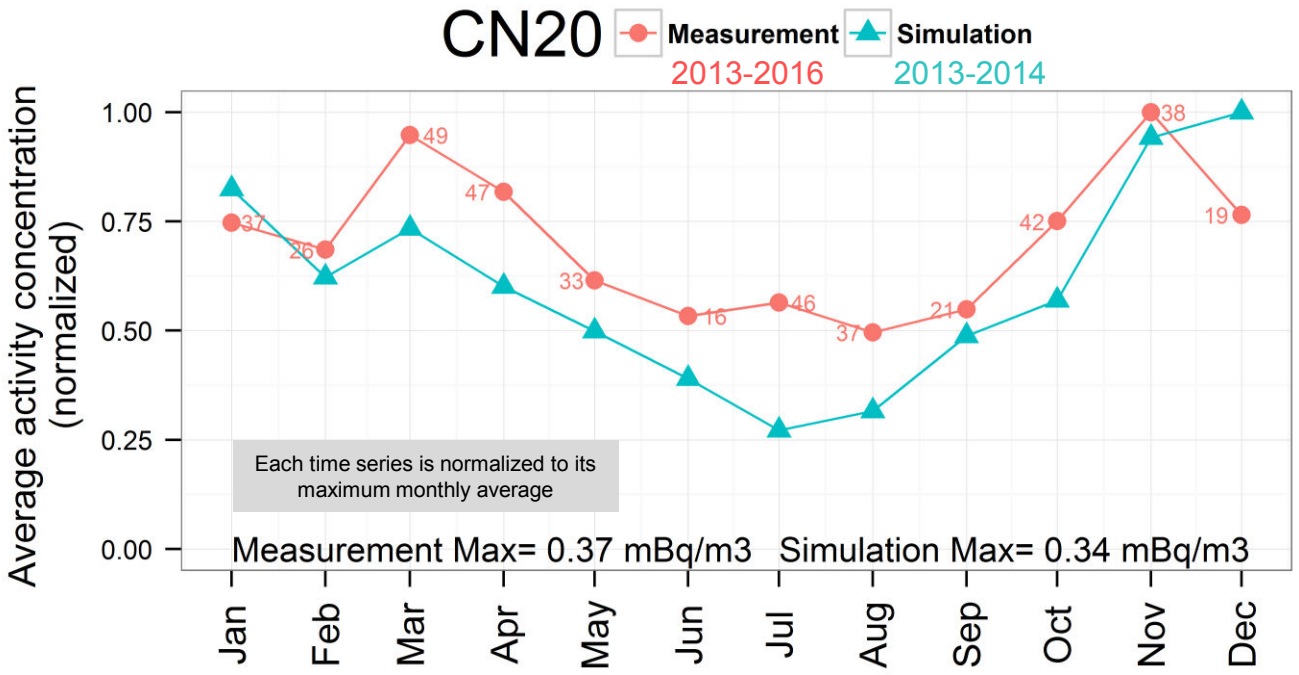
MEASUREMENTS (2013-2016)



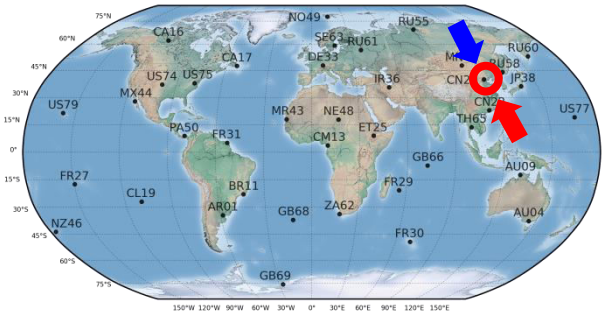
Percent of detections > 0,1 mBq/m³ per month on the IMS network from four years of measurements (corrected by station availability)

Increase of occurrences of detections at IMS stations during Winter periods for both hemispheres, although more pronounce in the NH

Average Xe-133 levels at IMS stations
Example: CNX20-Beijing, China

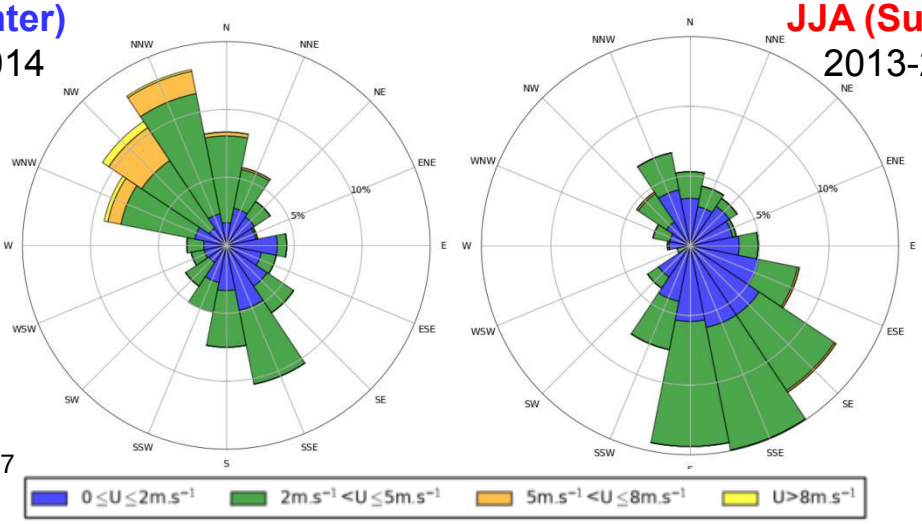


In Winter, continental sources. In Summer, oceanic air masses

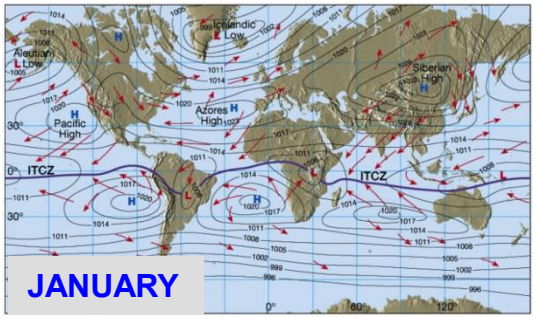


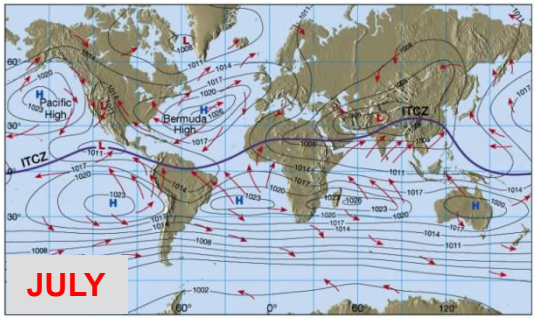
DJF (Winter)
2013-2014

JJA (Summer)
2013-2014



NCEP/GFS meteorological data (large scale circulation)

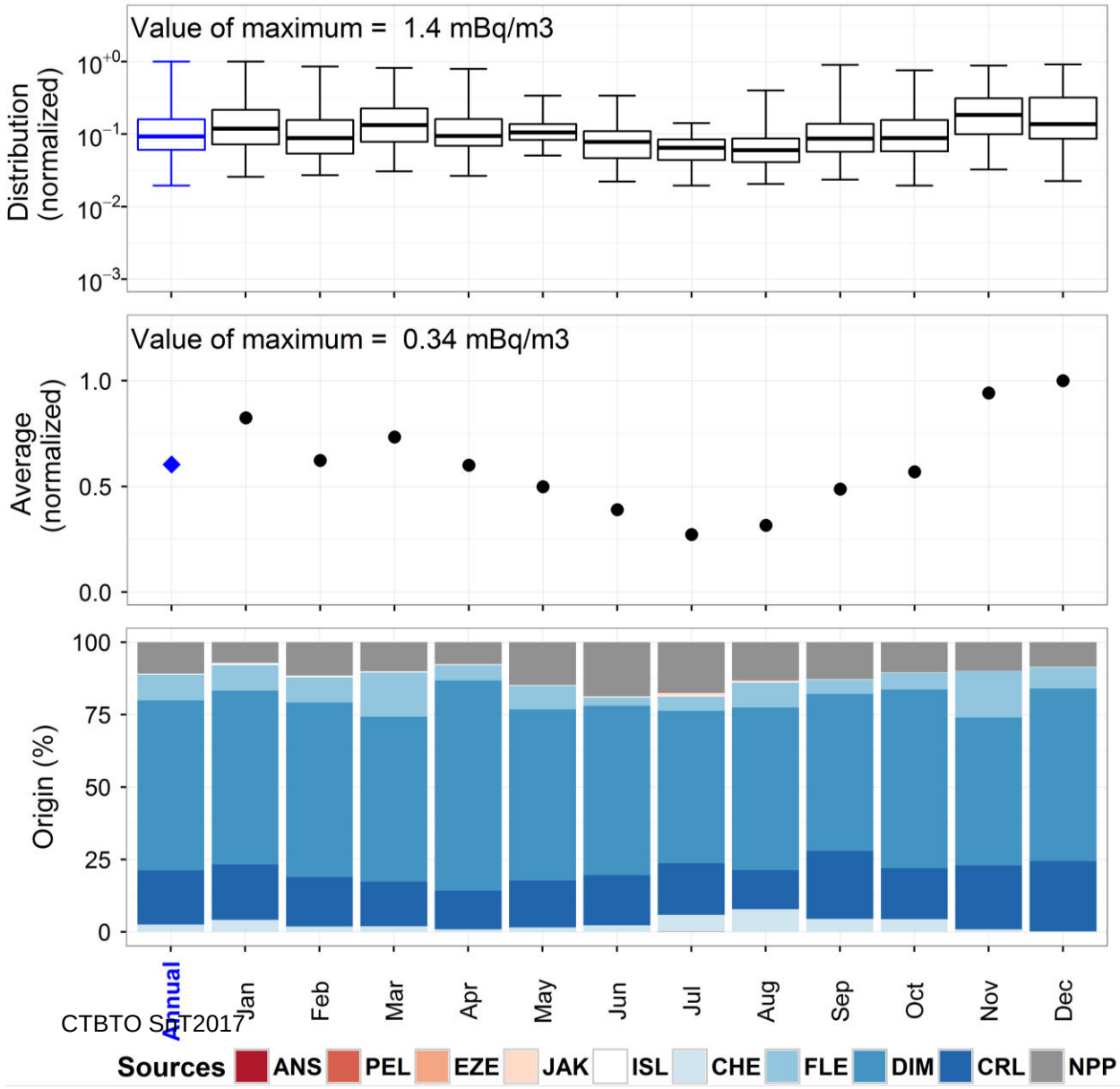


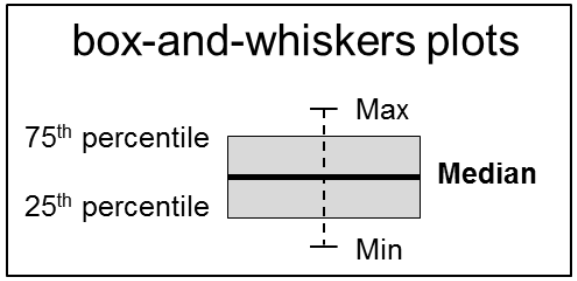


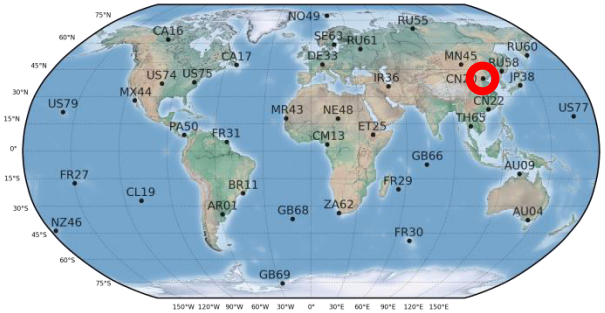
Average surface pressures and surface wind patterns in January and July

Monthly simulated characteristics at IMS stations

Example at CNX20-Beijing, China



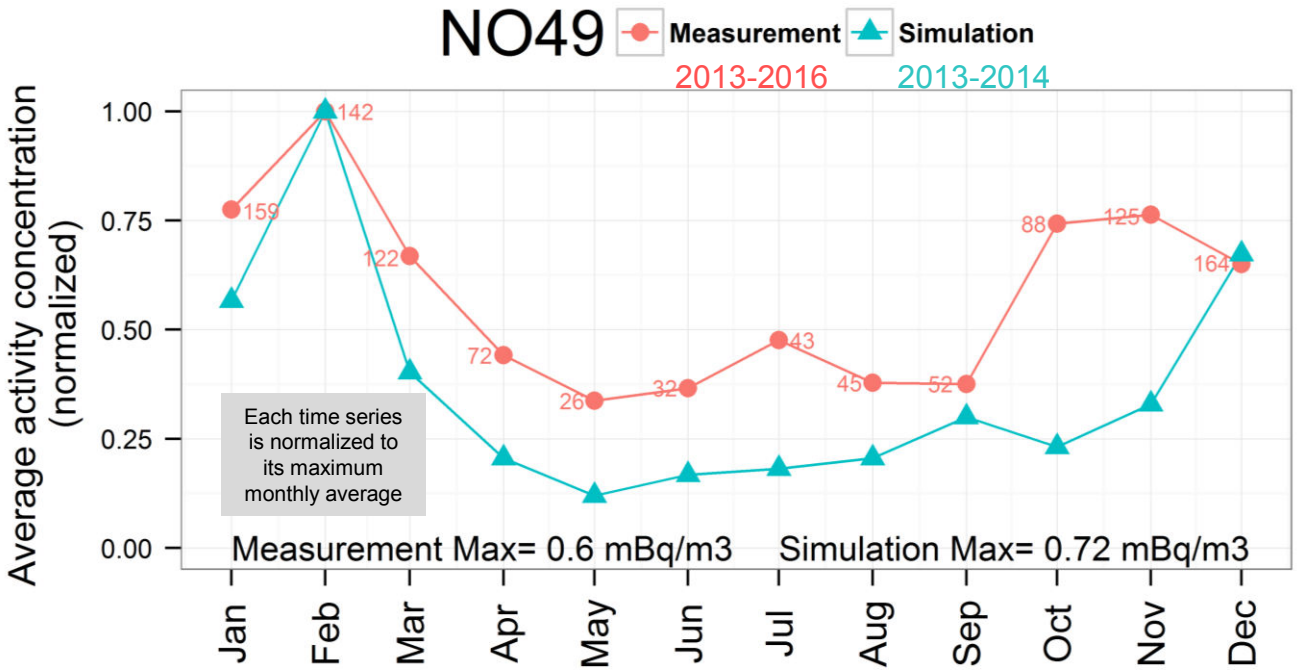


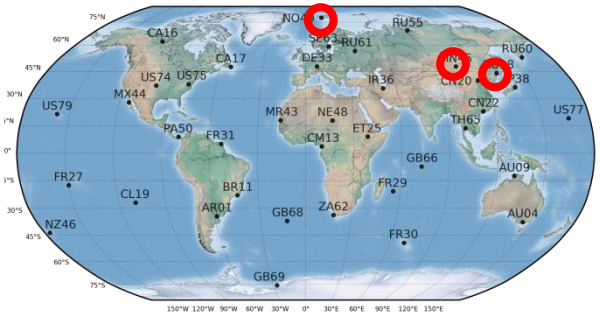


Same contributors all year long

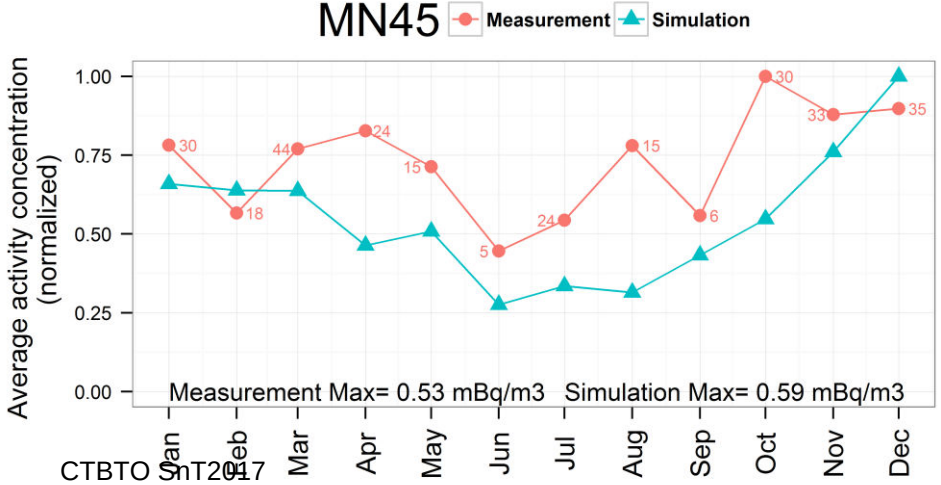
Seasonal variations in Xe-133 levels at CNX20

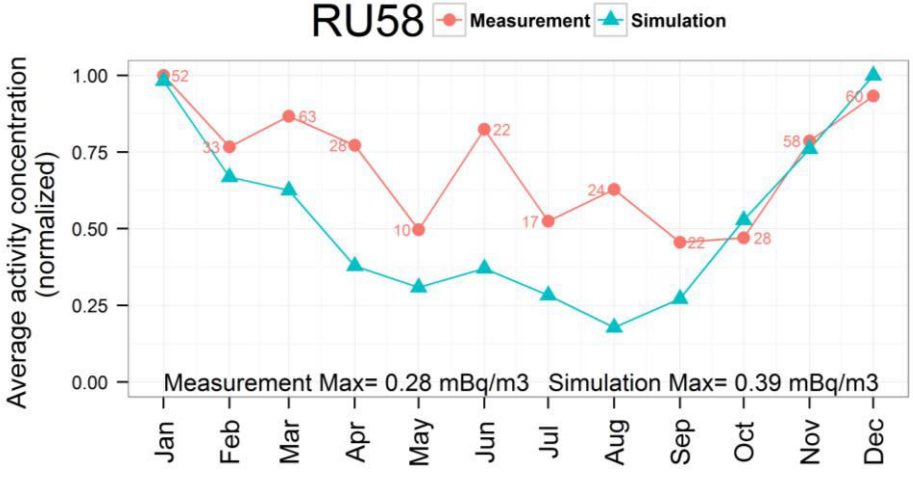
Average Xe-133 levels at IMS stations
Example: Northern Hemisphere



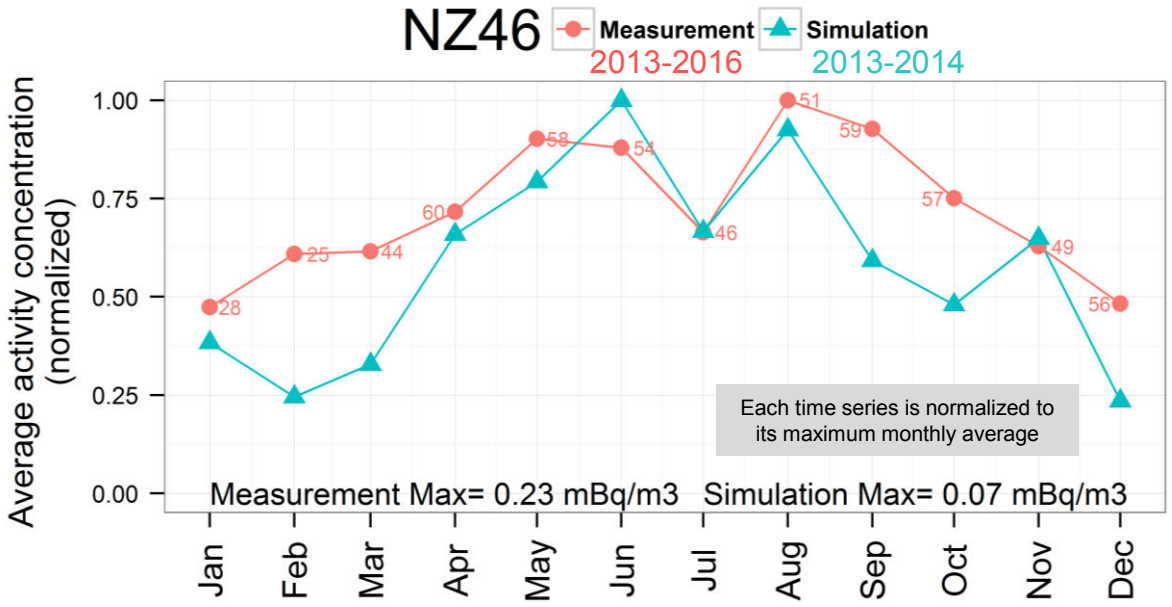


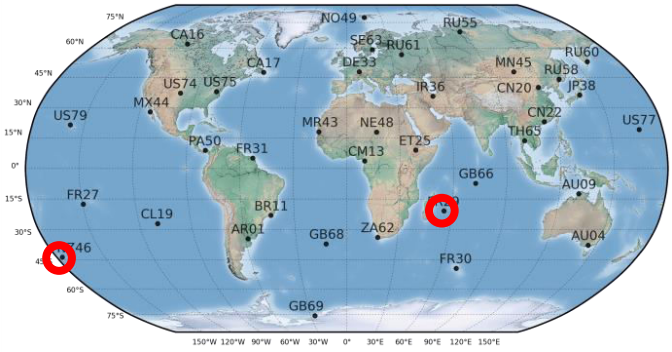
In Winter, higher Xe-133 levels simulated and measured

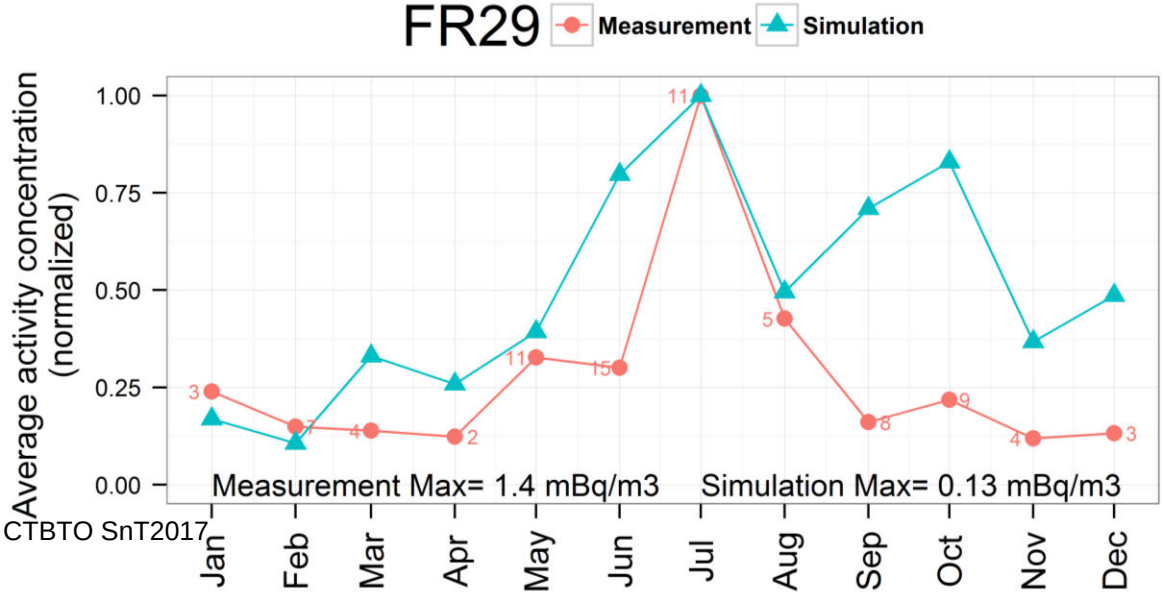




Average Xe-133 levels at IMS stations
Example: Southern Hemisphere



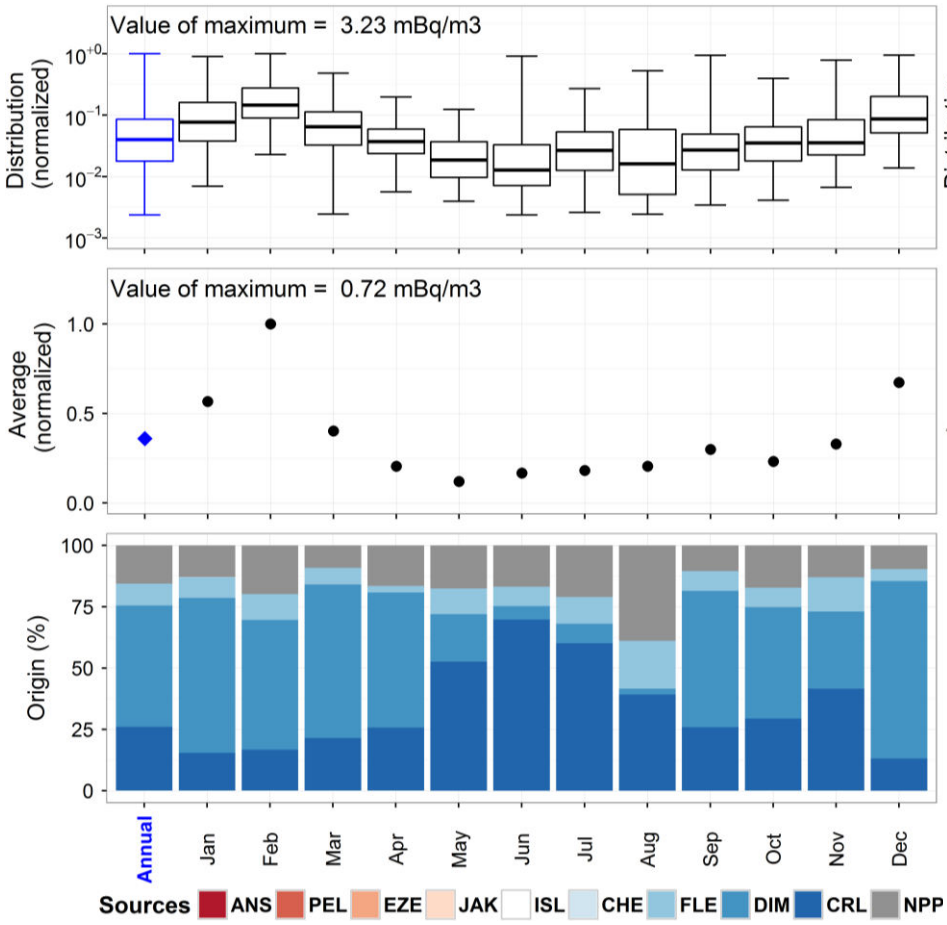




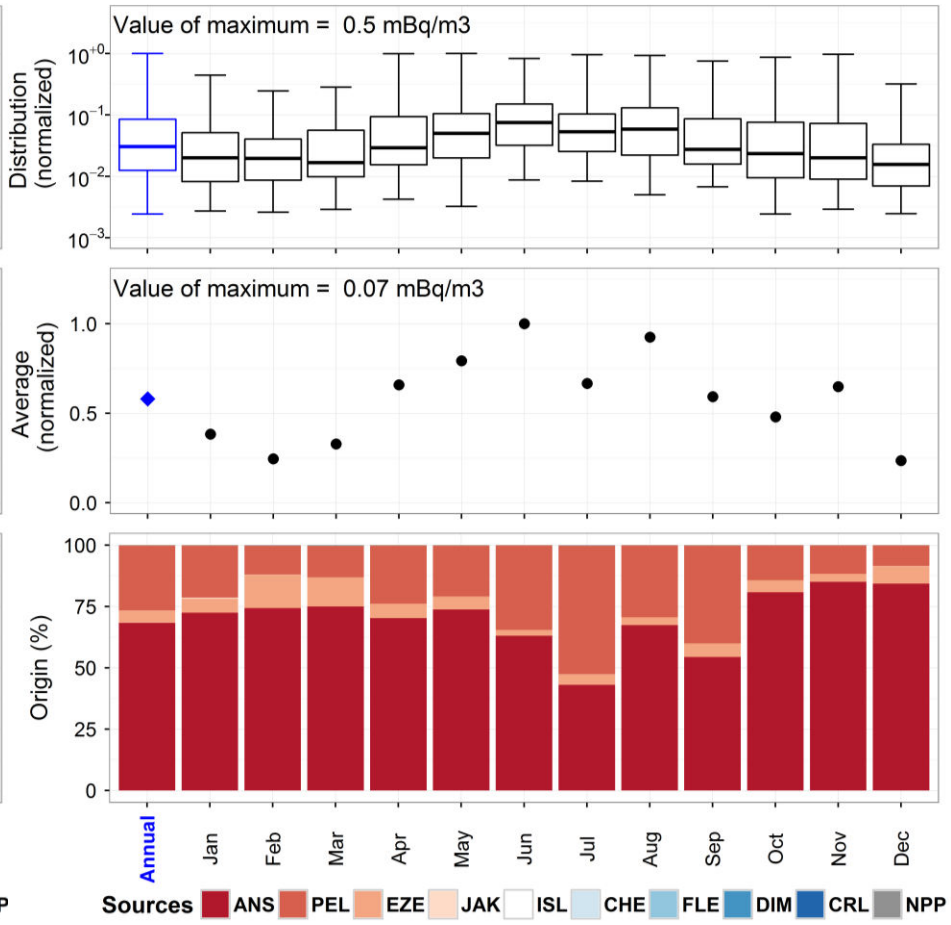
In Winter, higher Xe-133 levels simulated and measured

Monthly simulated characteristics at IMS stations
Example at a Northern and a Southern station

NOX49 – Northern Hemisphere



NZX46 – Southern Hemisphere



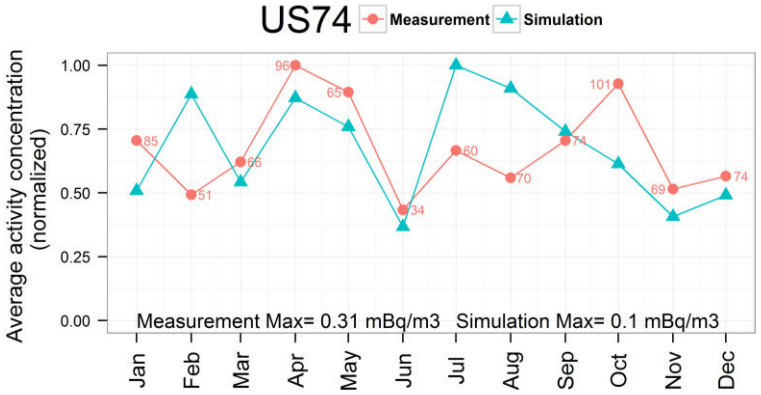
Same contributors all year long, but variable proportions

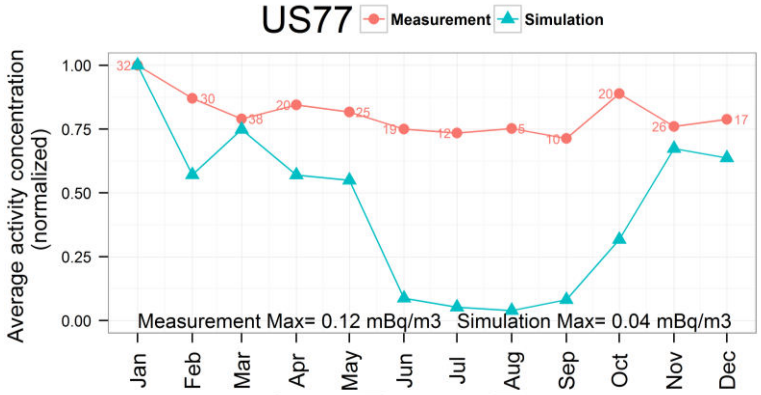
Seasonal variations in Xe-133 levels

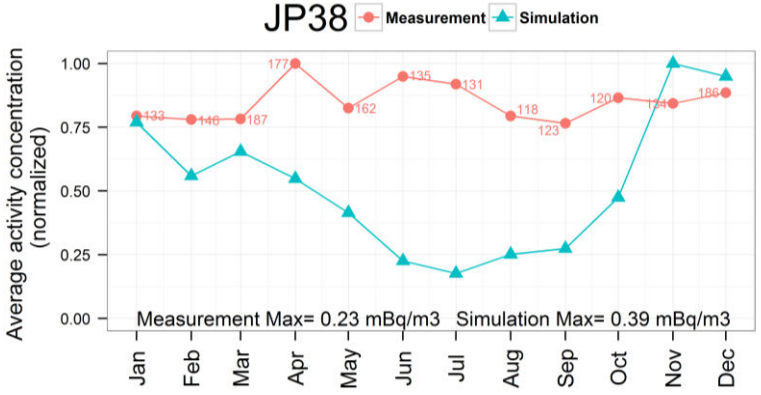
"Opposite" behavior in the Northern vs Southern Hemisphere

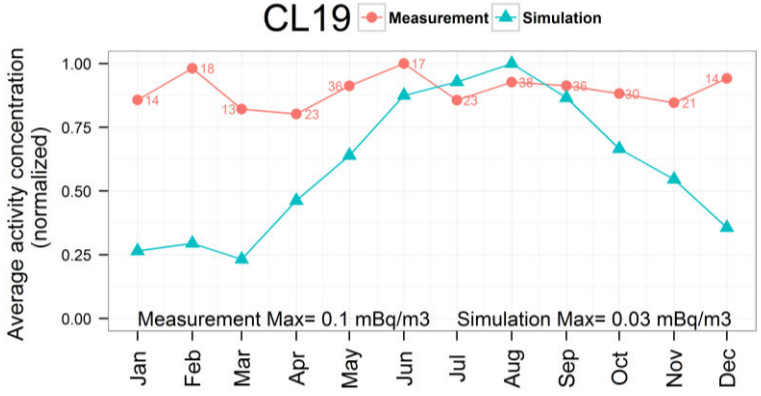
Average Xe-133 levels at IMS stations

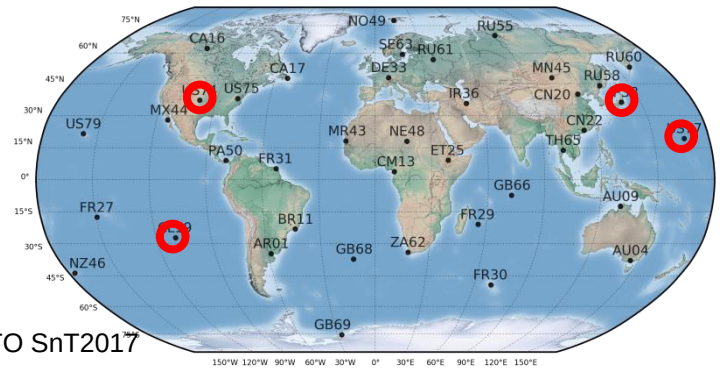
Example with no obvious seasonal variations







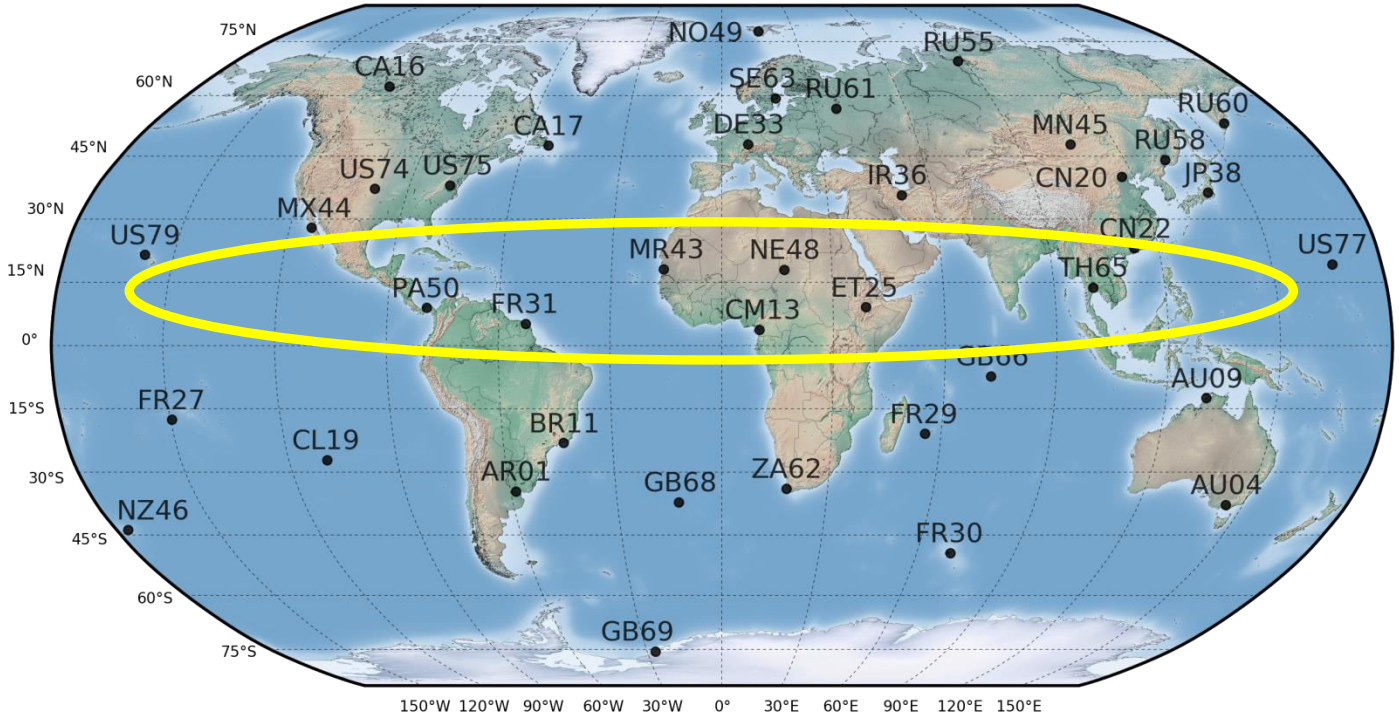




- **No seasonal patterns** apply given the location of sources, of the station and prevailing winds
- Possible **local source missing** nearby JPX38 (seasonal wind patterns clearly established)
  Achim et al, SnT 2013
- **Detection limits** might cut the lower part of observed distributions

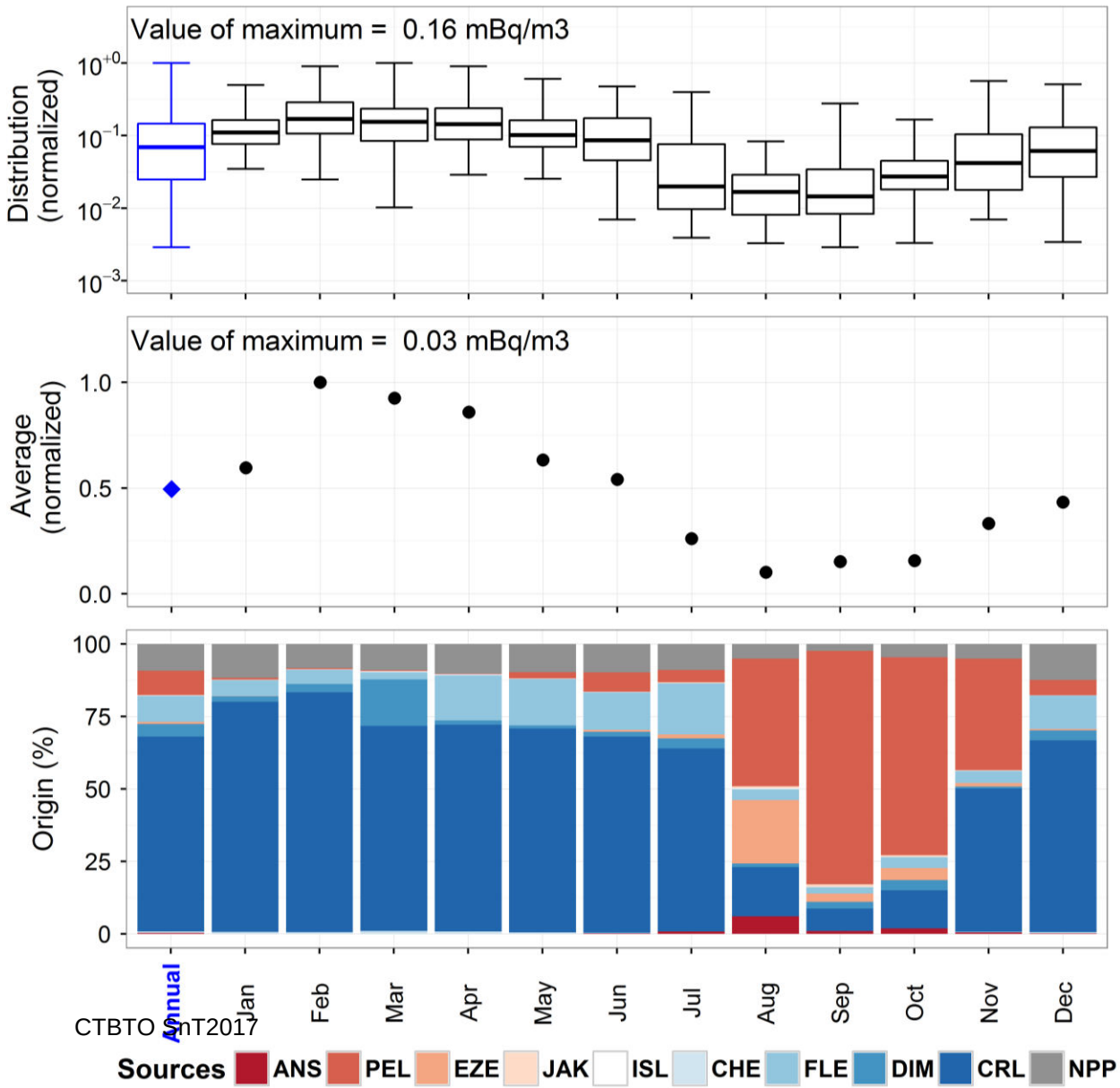
IMS stations near the Equator

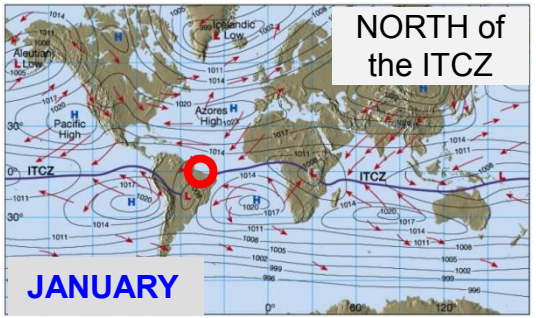
Is there a seasonal pattern for IMS stations located nearby the InterTropical Convergence Zone (ITCZ) ?

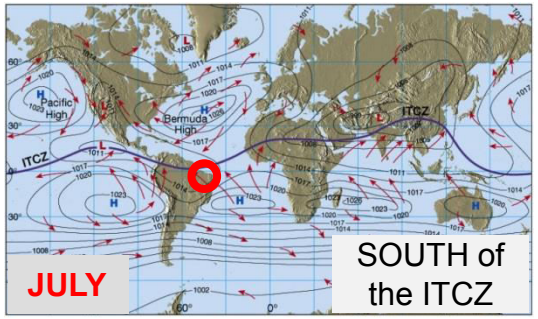


Monthly simulated characteristics at IMS stations

Example at FRX31-Kourou, French Guyana





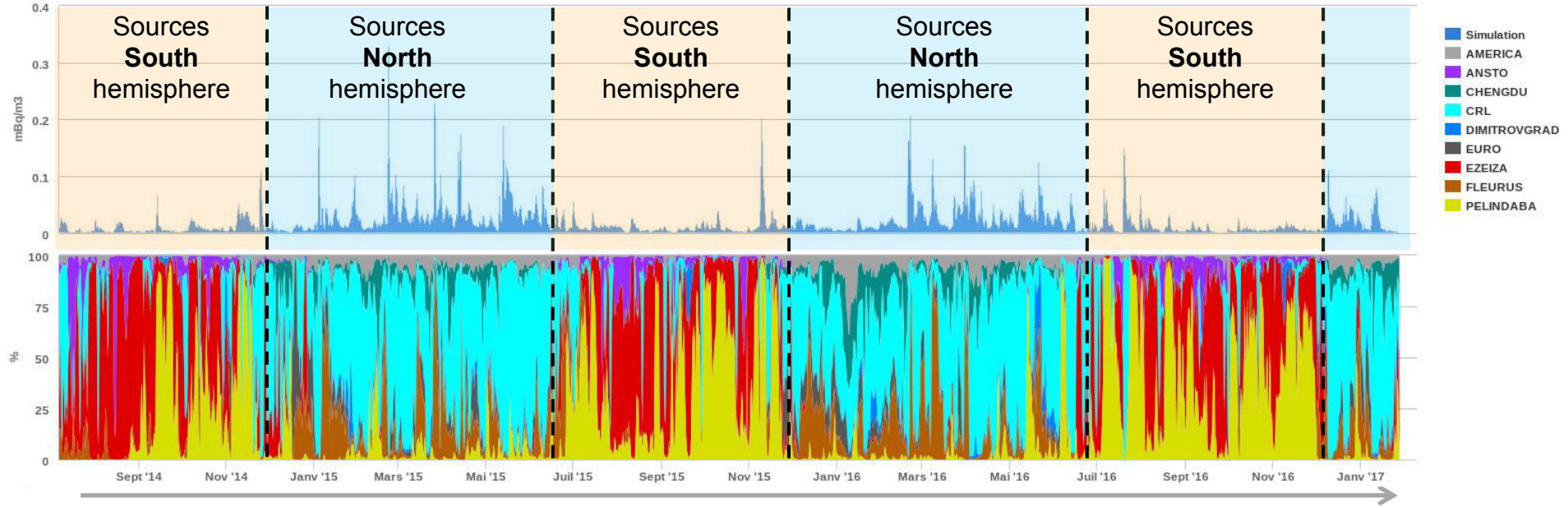


Subject to seasonal variations of the InterTropical Convergence Zone (ITCZ)

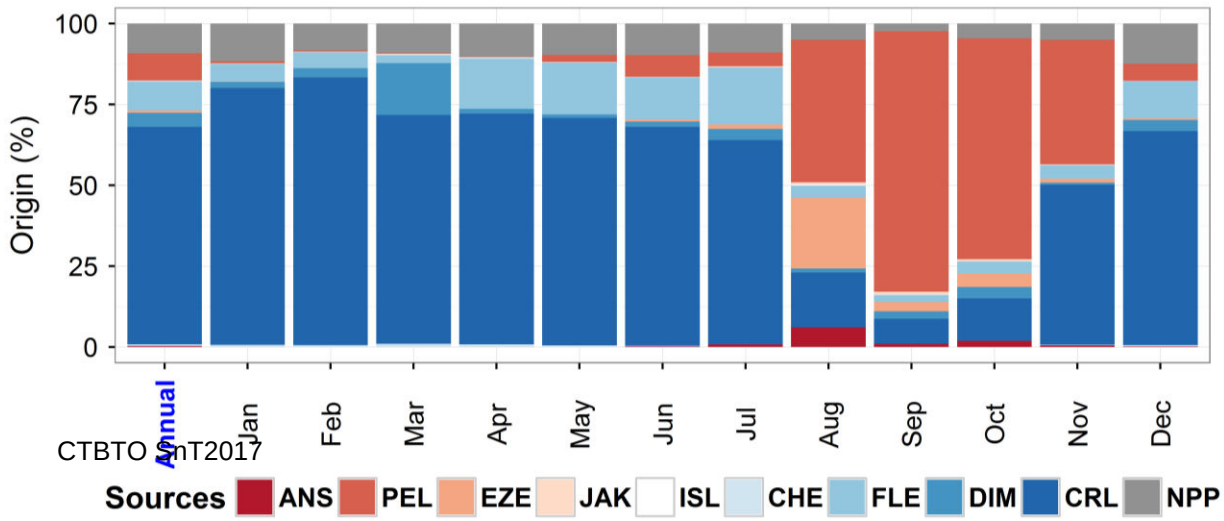
Alternatively influenced by Northern / Southern sources depending on the location of the ITCZ

Monthly simulated characteristics at IMS stations

Example at FRX31-Kourou, French Guyana



2,5 years time series (Sept 14-Jan 17) of simulated atmospheric background at FRX31 shows a clear trend of seasonal variations of contributors to level of Xe-133 (from French NDC Operational tool)

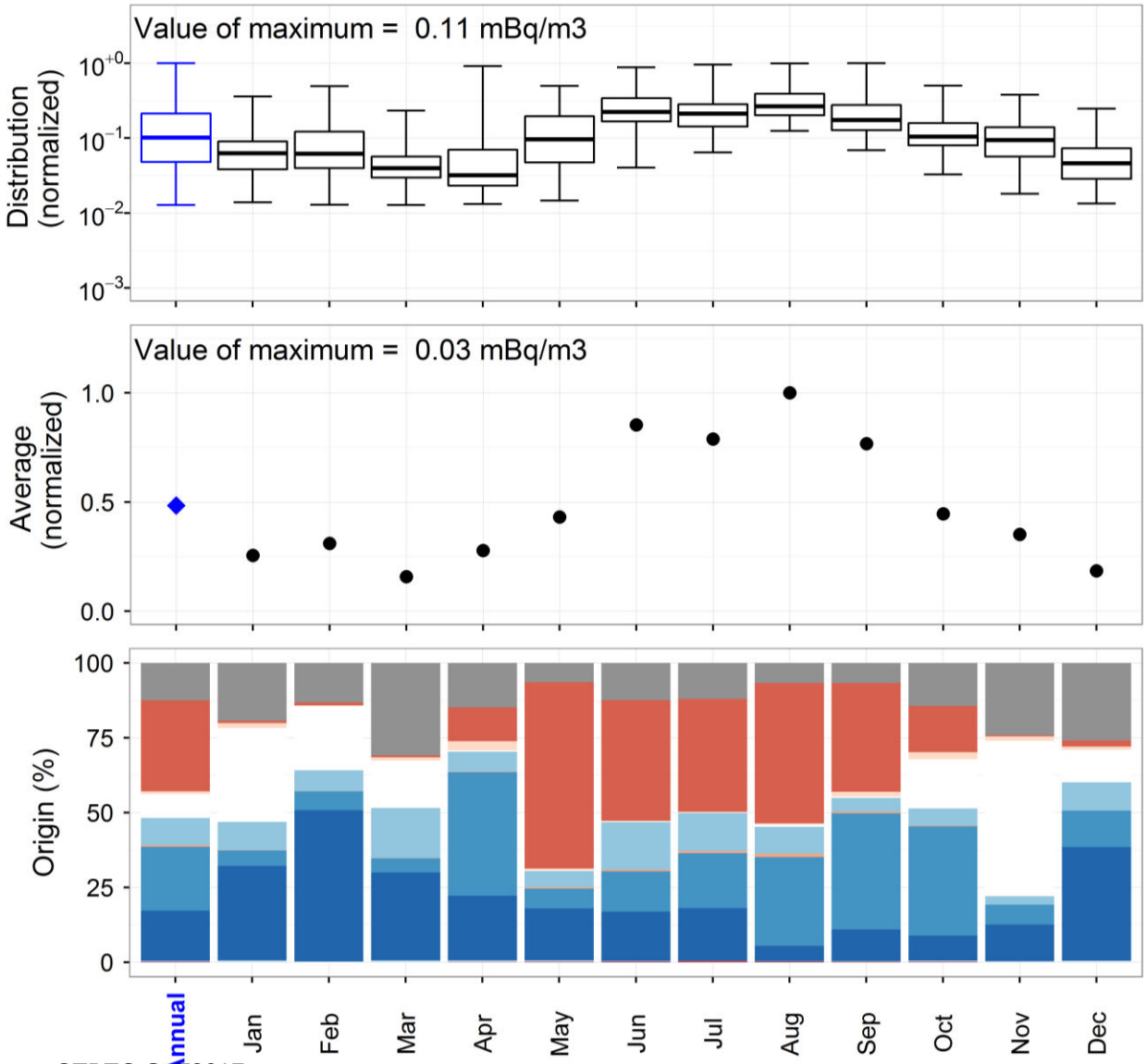


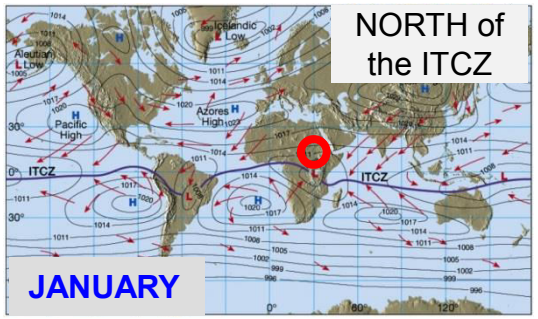
Subject to seasonal variations of the InterTropical Convergence Zone (ITCZ)

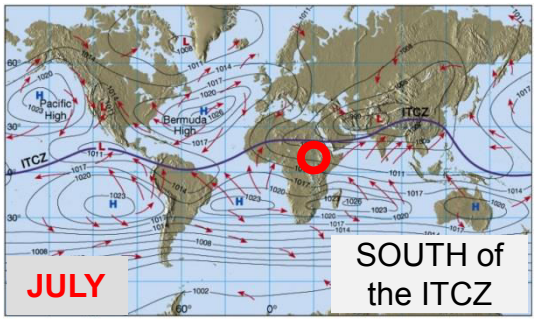
Alternatively influenced by Northern / Southern sources depending on the location of the ITCZ

Monthly simulated characteristics at IMS stations

Example at ET25-Addis Ababa, Ethiopia (PLANNED)



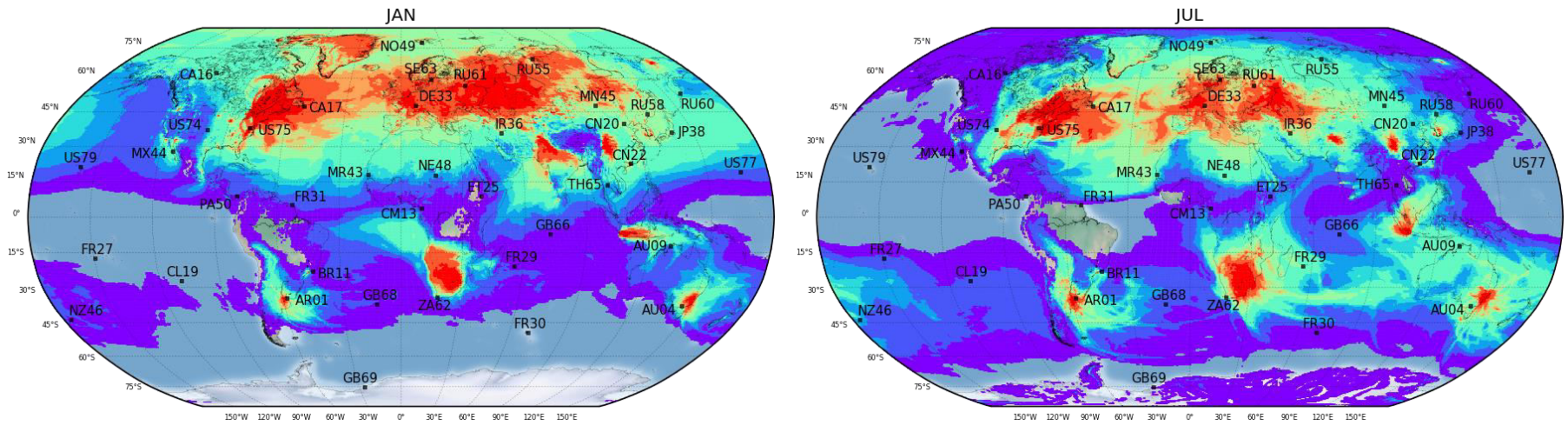




Subject to seasonal variations of the InterTropical Convergence Zone (ITCZ)

Alternatively influenced by Northern / Southern sources depending on the location of the ITCZ

Conclusion



- **A good comprehension of the "global picture"**
  - **Large spatial and daily variability** explained by the coupling between location of sources and atmospheric circulation
  - **Origins** of Xe-133 at IMS stations from **multiple, local and distant sources**
  - **Validated description of the global mechanisms** at the origin of the industrial background through comparison to 6000 detections at 29 IMS stations across the globe

P. Achim, S. Generoso, et al., *Characterization of Xe-133 global atmospheric background: implications for the International Monitoring System of the Comprehensive nuclear-Test-Ban Treaty*, **JGR Atmospheres, Vol 121, Issue 9, 2016**

- **Seasonal meteorological variability with effect on the IMS network**
  - **Number of IMS detections** increase in Winter for both hemisphere (simulated and observed)
  - **Some IMS stations in the NH and in the SH** present a significant seasonal variability (simulated and observed) **in terms of levels and origins**
  - Not all IMS stations are subject to seasonal variations

S. Generoso, P. Achim, et al., *Seasonal variability of Xe-133 atmospheric background: Characterization and implications for the International Monitoring System of the Comprehensive nuclear-Test-Ban Treaty,* **In preparation**

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