Abstract SNT2017-T1.5-06
Theme 1. The Earth as a complex system
Topic: 1.5 Civil, Scientific and Industrial Applications
of IMS data and IDC Products
Vienna, Hofburg, Rittersaal
27 June 2017 3.00 pm

World-wide seasonal variation of 7Be related to large-scale atmospheric circulation dynamics

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Objective:

Reconstruction of 7Be concentration maps using IMS data & correlate trends with meteorological processes

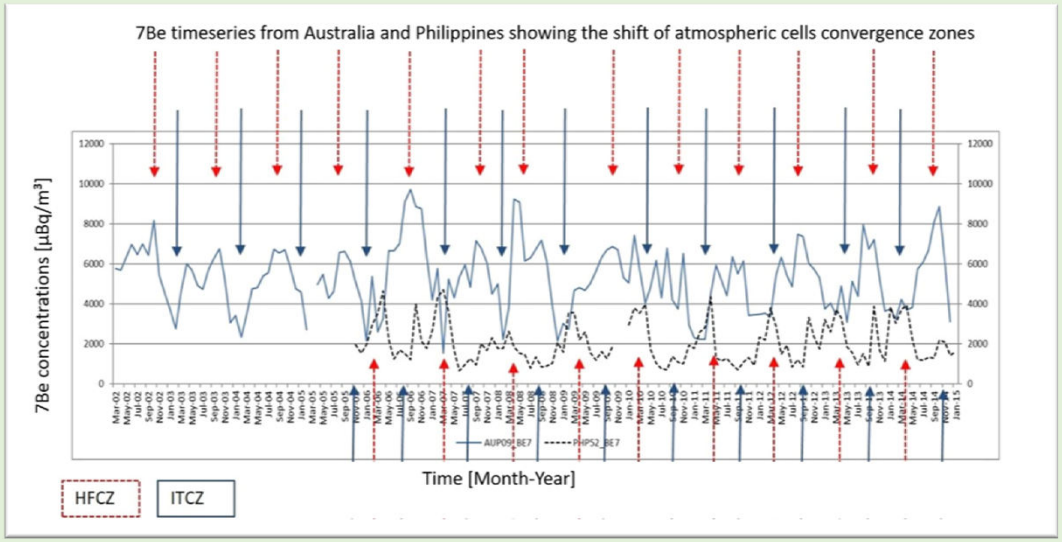
- CTBTO has established an International Monitoring System (IMS) for treaty verification based on waveform and radionuclide (RN) technologies.
- The RN network, comprises 80 stations of which 63 are certified and operational as of mid-2016.
- Each RN station collects daily radionuclide aerosols into a sample of which a gamma spectrum is sent to the international data centre (IDC) in Vienna for analysis.
- Stations are run at high data availability.

Beryllium-7

- ^{7}Be decays with a 53.3-day half-life and is one of the sampled particle-bound natural radionuclides. It is largely produced in the lower stratosphere and upper troposphere as a result of spallation of nuclei of atmospheric gases, mainly oxygen and nitrogen.
- ^{7}Be attaches to aerosol particles and is removed mainly by wet deposition.
- This effect of wash out by precipitation in the intertropical convergence Zone (ITCZ) is marked by low concentrations.
- Hadley-Ferrel convergence zone (HFCZ) marks the increase in beryllium concentrations because of the vertical downward air flux producing a double high activity band, one in each hemisphere moving in north-south direction with the seasons.

^{7}Be time series in Australia and Philippines

^{7}Be(µBq/m³)/time(mm/yy)

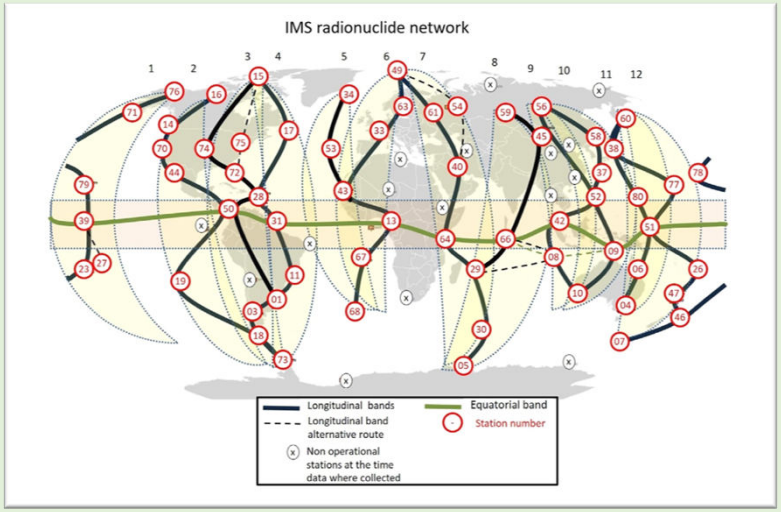


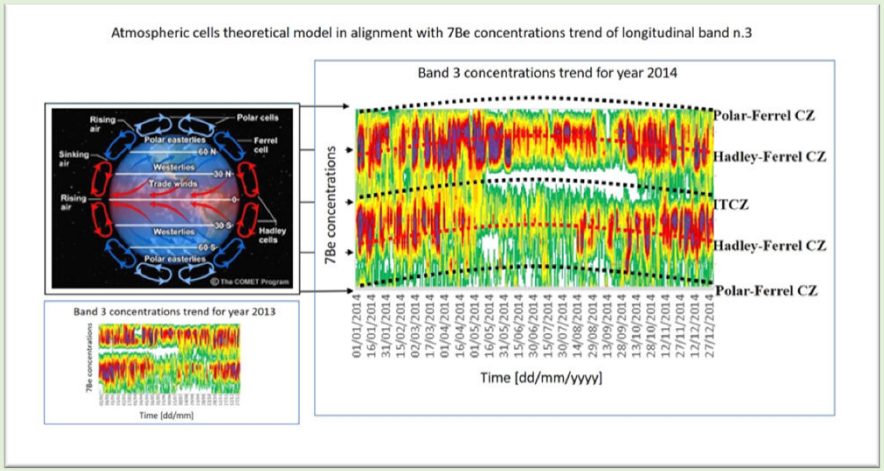
- This study uses monthly averages of ^{7}Be (µBq/m3) time series as long as 15 Years (2001 to 2015) for a total of over 200,000 samples of analysed data.
- Seasonal variation pattern were found especially for latitudes between 10 and 50 (+/-).
- To highlight seasonal variations, time series from two stations with different latitude and similar longitude are compared to see the pattern shift.
- The shift represents the progression of atmospheric cells convergence zones.

Methods

- Stations are divided into 12 longitudinal bands to compare the seasonal variation for stations with a common longitude.

- ^{7}Be time series are then interpolated into surface graphs to plot 7Be activity concentration versus latitude confirming the theoretical model with two maximum concentration lines related to the HFCZ alternated by three minimum concentration lines related to one ITCZ and two Polar-Ferrel Convergence Zones (northern and southern hemisphere).



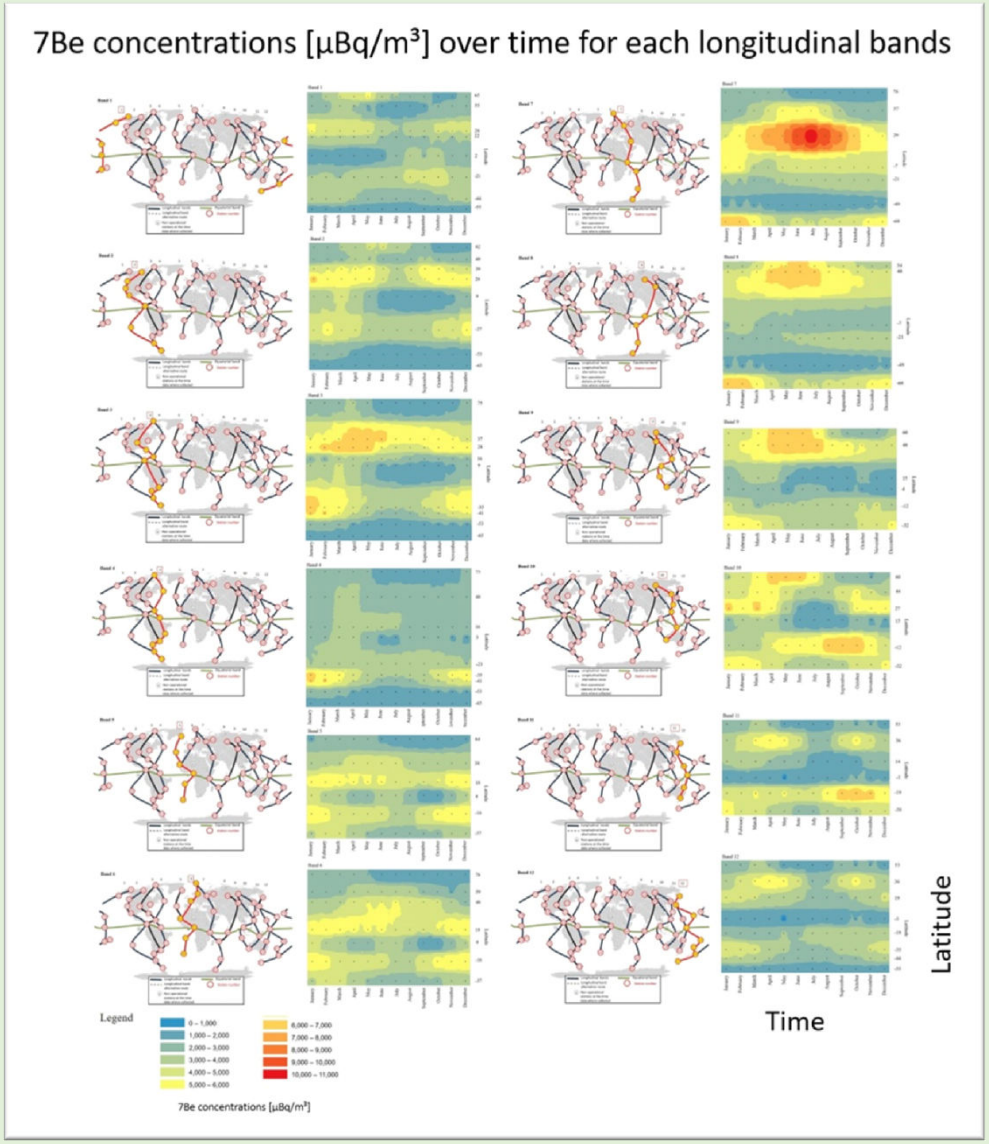


Observed ^{7}Be global seasonal variation as an expression of atmospheric cell migration, ITCZ, Hadley-Ferrel Convergence Zone, Polar-Ferrel Convergence Zone.

Longitudinal bands

- Figure shows resulting concentrations as they change over time for each longitudinal band.

- The convergence zone structures can be well seen by the concentration minima (blue-green) and maxima (orange-red).



Monthly averages of ^{7}Be time series from 63 IMS radionuclide stations displayed as 12 longitudinal bands.
^{7}Be**(µBq/m³)**/time**(mm/yy)**

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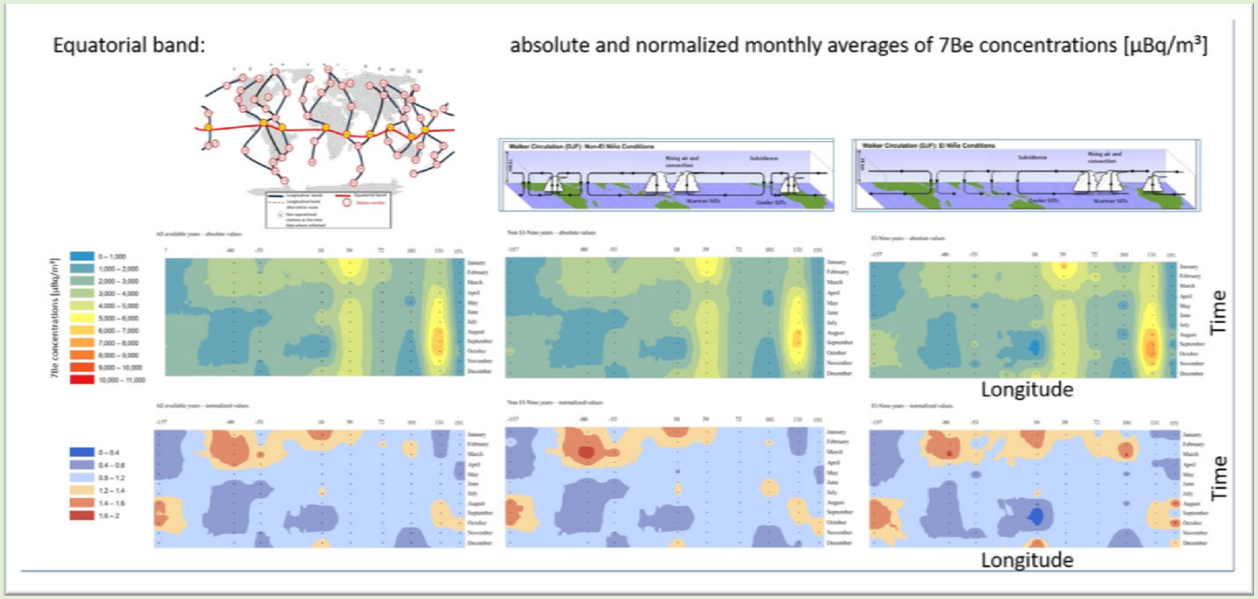
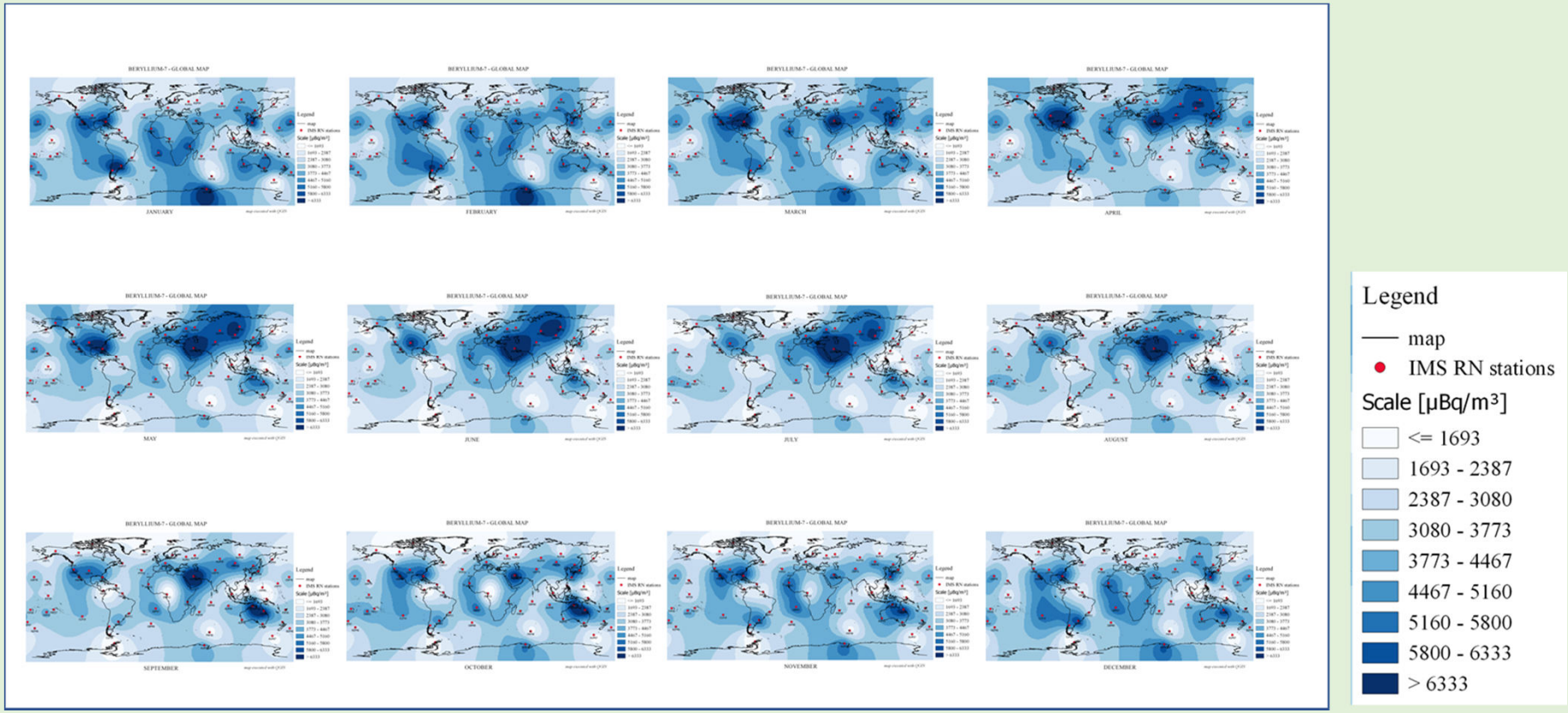
Equatorial band

- Stations along the equator have been grouped in an equatorial band to correlate ^{7}Be activity variations with circulation patterns during El Niño condition.
- Increment of ^{7}Be concentrations are highlighted during ENSO periods.
- There is correspondence between higher beryllium concentrations and downward atmospheric influx.

Monthly averages of ^{7}Be time series from IMS radionuclide stations displayed as 1 equatorial band.
^{7}Be(μBq/m³)/time(mm/yy)



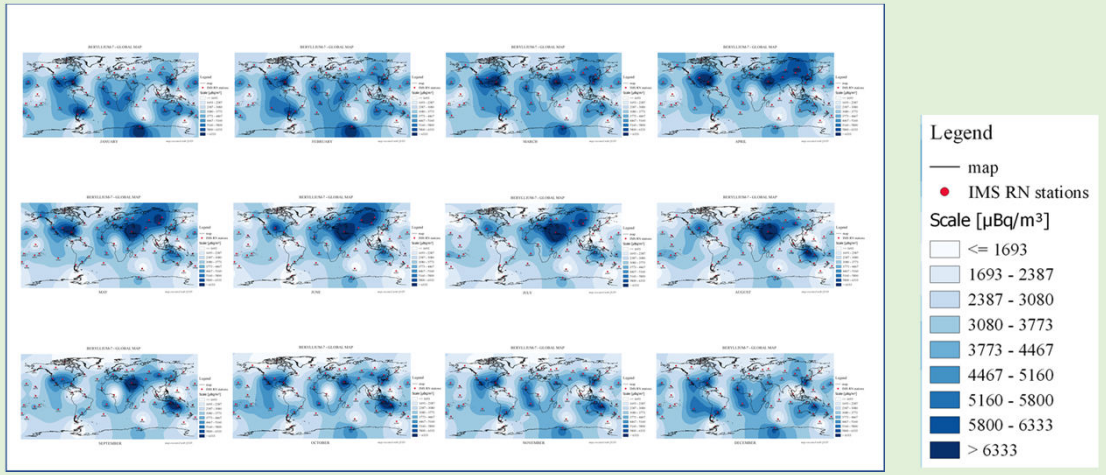
Monthly ^{7}Be map grid: absolute values



Concentration [µBq/m³] for each station are interpolated into a global ^{7}Be map grid for each month

Monthly ^{7}Be map grid: absolute values

- Finally monthly averaged concentration for each station are interpolated into a global ^{7}Be map grid for each month.
- Green-blue areas are indicating ITCZ and PFCZ, while yellow-orange-red are related to HFCZ in both Northern and Southern Hemispheres.
- ^{7}Be levels increase between June and August in the region extending from the Middle East to East Asia and decrease until minimum is reached in December. That area is correlating with the Hadley-Ferrel Convergence Zone in the Northern Hemisphere.
- Summertime hot spot over Middle East is related to the tropopause fold due to dynamical interactions between the subtropical jet and the Asian monsoon anticyclone.
- In the Southern Hemisphere, HFCZ is strong in December and January and decreases till a minimum is reached in June.

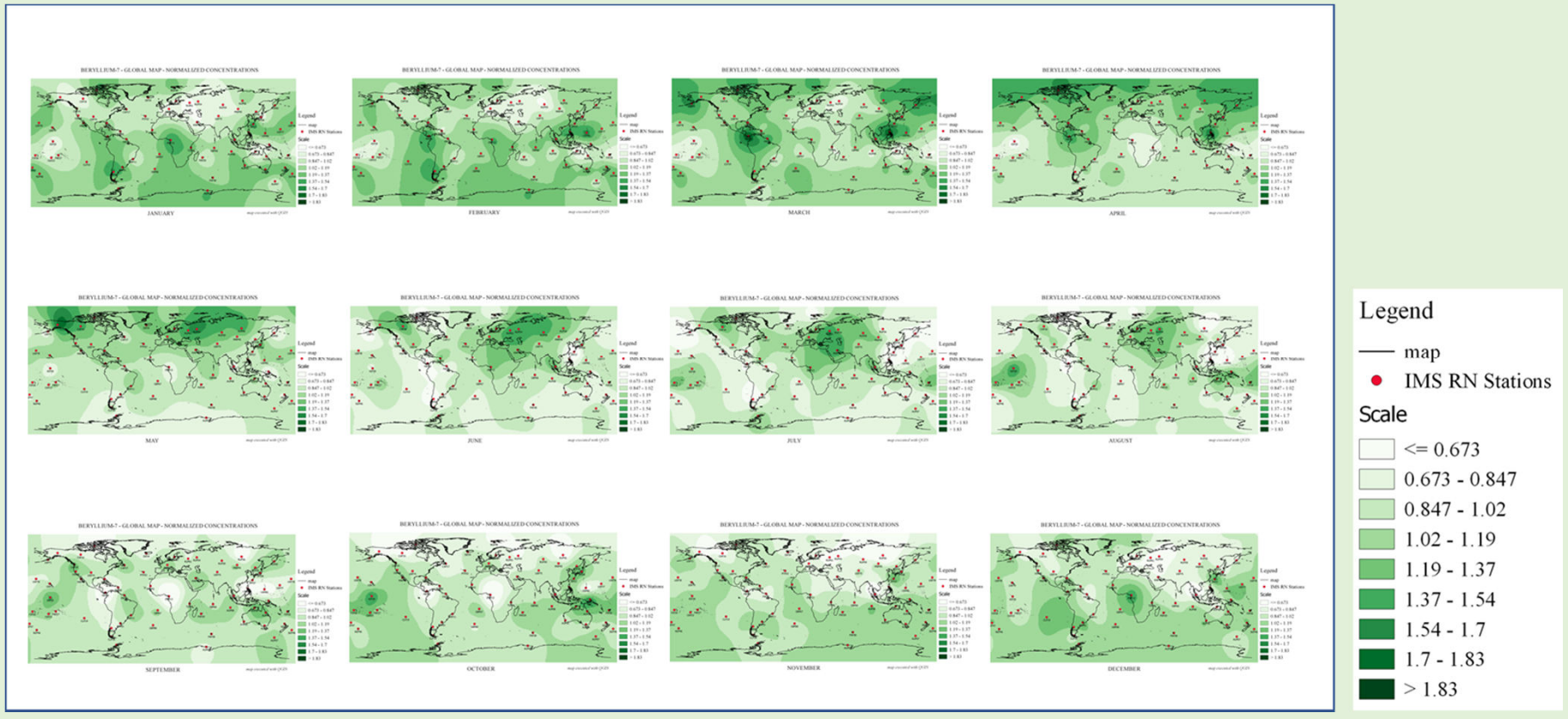


Beryllium-7 Global Map

Absolute concentrations

[µBq/m³]

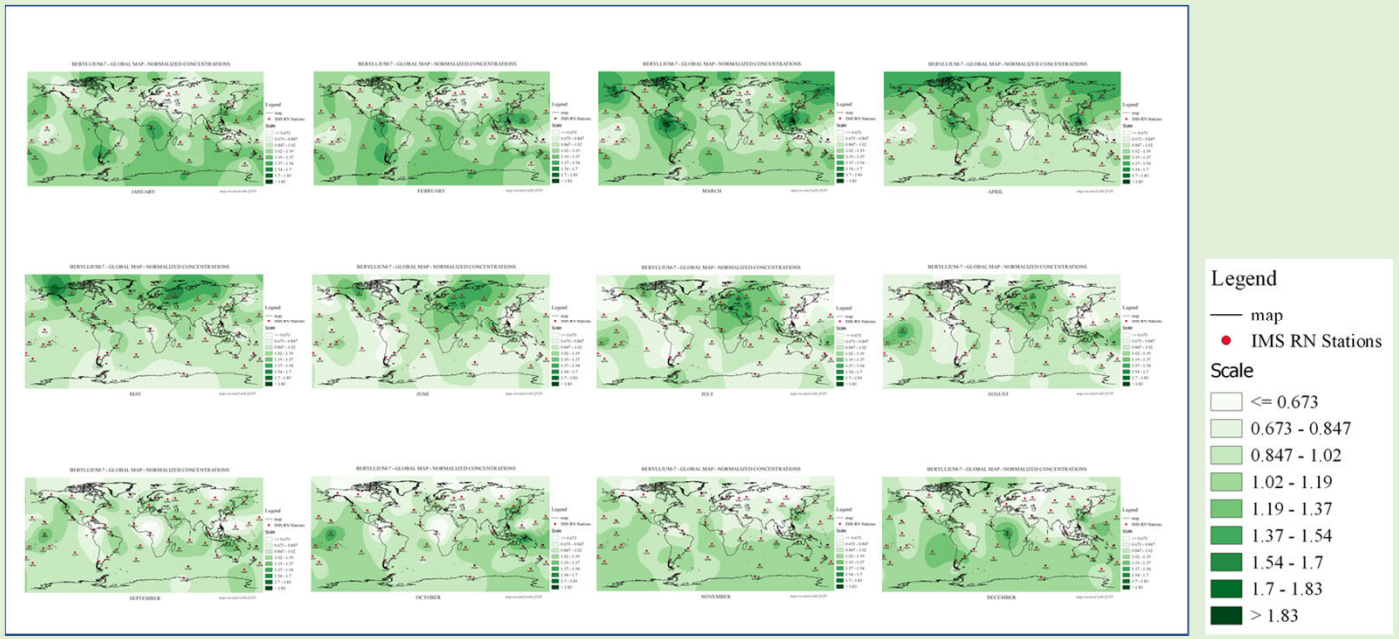
Monthly ^{7}Be map grid: normalized values



Normalized concentration for each station are interpolated into a global ^{7}Be map grid for each month.

Monthly ^{7}Be map grid: normalized values

- To highlight monthly modulations normalized values were calculated dividing the monthly average by the average over all months for each grid point.
- Northward trend is visible from January to July and southward from July to December with peaks in March/April and October.

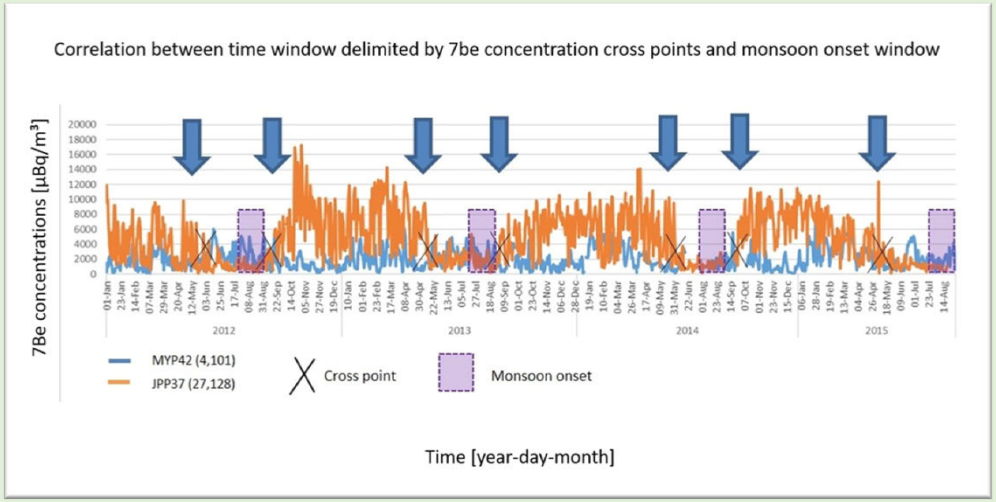


Beryllium-7 Global Map

Normalized concentrations

Indian Monsoon

- Onset and withdrawal of Indian monsoons is one many meteorological phenomena that has been tested in our study for a correlation with 7Be activity concentrations.
- Monsoon withdrawal is caused by southward movement of the ITCZ via displacement of moist with dry air, anticyclonic flow, and rainfall reduction. The relative humidity and temperature thresholds as cross points can be used to predict monsoon onset and withdrawal.
- Following this approach we looked for cross points in ^{7}Be time series for RN42 and RN37 as both stations are located in regions affected by Indian monsoons.



- The drop of ^{7}Be levels appears about 30 days prior to the monsoon onset, this may indicate the possibility to use cross points (i.e. where levels of ^{7}Be are equal for both locations) as new monsoon-indicating threshold. Rather than considering the increase of ^{7}Be concentration at RN37 alone, cross points indicate the position of an atmospheric cell relative to two locations giving more guarantee that the time window delimited by the cross point is indeed monsoon related.
- Similar pattern were found for the station pair RN09-RN52.

Summary

- For deciphering various meteorological processes, the global network of IMS RN stations offers an unprecedented opportunity using ^{7}Be as aerosol tracer. In this study it is shown how one can reconstruct the location of the Hadley-Ferrel cell convergence zone (HFCZ) worldwide and its progression at any point in time using ^{7}Be activity concentrations measured at 63 different IMS stations around the globe.

- Minima in time series of ^{7}Be fluxes can be interpreted as precipitation associated to monsoons and accordingly associated with Walker circulation patterns and El Niño southern oscillation (ENSO).

- In a publication recently submitted, further possibilities are presented relating ^{7}Be concentrations to global atmospheric circulation patterns such as tropopause height, sudden stratospheric warmings (SSW), solar energy particle (SEP) events and quasi-biennial oscillation (QBO) and it is demonstrated that these would benefit from further studies.

- Practical applications may arise from utilizing ^{7}Be concentration patterns to validate and complement other methodologies for determining atmospheric phenomena and ^{7}Be might possibly serve as an early warning indicator for emerging El Niños and Indian monsoons. For this purpose, most promising are the onsets of ^{7}Be concentrations at RN37 in Okinawa, Japan, in comparison with the levels at RN42, Tanah Rata, Malaysia. A 30-day warning prior to monsoon onset appears achievable.

- The final purpose of this project is not only to attempt studying circulation pattern to suggest new scientific work, but to demonstrate the power of global RN tracer datasets that can be interpolated into a global concentration map.