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The Surveillance of the
Air Quality in the Vicinity of an Active
Volcano: Case of the Piton de la Fournaise

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1. Introduction

Atmospheric pollution may be of both anthropogenic and natural origin (Levine, 1996; Finlayson and Pitts, 1999; IPCC, 2000; Delmas et al., 2005). Concerning natural pollution, most active volcanoes emit, among others, gases (eg. sulphur dioxide) and particles into the atmosphere during eruption events (Hobbs et al., 1991; Bhugwant et al., 2009). It is thus important to conduct the monitoring of these pollutants for active volcanoes all over the world, in order to take the adequate measures of air pollution (eg. to establish evacuation plans for the surrounding population) and also to study the long-term trends and effects caused by volcanic activity. In this sense, since a decade the World Health Organization (WHO), the European Community and the French Ministry of Environment (MEDDTL: Ministère de l'Ecologie, du Développement Durable, du Transport et du Logement) have established SO_2 guideline levels, following the severity of the impact of this pollutant on human health and on the environment (WHO, 2005).

Previous experimental (ground-based and air-borne) studies indicate that major volcanic eruptions such as Mount St Helens (May 1980), El Chicon (March-April 1982) and Pinatubo (June 1991) injected large amounts of solid particles and volatile gases in the troposphere and the stratosphere, up to an altitude of 25 km high (Turco et al., 1993; Trepte et al., 1993; Krueger et al., 1995; Schneider et al., 1999). Another study showed, in a statistical approach, the global distribution of volcanic SO_2 degassing during the last century (1900-2000) and further indicated that each eruption (even for non monitored ones) could affect the stratosphere, based on empirical observations (Hamler et al., 2002). More recently, the eruption of the Eyjafjallajökull volcano in Iceland, which began on April 14th 2010 and ended in October 2010, caused enormous disruption to air travel across western and northern Europe, due to huge amounts of ash and particles emitted in the atmosphere.

Volcanic eruptions may cause irreversible environmental and ecological impacts (burial by ash, mud, etc.), via lava or pyroclastic flows, dusts and ash falls and/or gaseous emissions, while they may also increase the economic burden in socio-economic sectors, by causing infrastructure and habitation damages (e.g. houses, buildings, roads, fields and forests covered with ash and/or lava) (Munich Re, 1998; Brosnan, 2000). It is now clearly

established that the volcanic pollutants have damaging effects on both human health and ecology. The human health effects from air pollution vary in the degree of severity, covering a range of minor effects to serious illness such as impaired pulmonary function as well as premature death in certain cases (Brantley and Myers, 2000).

Volcanic eruptions mostly emit water vapour, sulfur dioxide (SO_2), hydrochloric acid (HCl), hydrofluoric acid (HF) and carbon dioxide (CO_2) (Tabazdeh et al., 1993; Evans and Staudacher, 2001; Kinoshita, 2003; Dubosclard et al., 2004). Once emitted in the atmosphere, they contribute to acid rain and may also affect the stratosphere (Galindo et al., 1998).

The atmospheric SO_2 emitted during volcanic eruptions is chemically transformed into sulphate aerosols (H_2SO_3 and H_2SO_4) during transport (McKeen et al., 1984). These sulphate aerosols may remain in suspension in the atmosphere for several years mainly in the stratosphere, while in the troposphere they are washed out in between weeks (Graf et al., 1993). A recent epidemiological study showed that the SO_2 emitted during the eruption of the Piton de la Fournaise volcano might have a potential sanitary impact on the surrounding population (Viane et al., 2009).

The mean residence time of ambient SO_2 concentration is about 1 day, in absence of sink processes such as rainfall (Delmas et al., 2005). However, the public may be exposed to sulfur dioxide concentrations that are higher than typical outdoor air levels. The effects of exposure to any hazardous substance depend on the dose, the duration, the way one may be exposed, the personal traits and habits. Short-term exposures to high levels of sulfur dioxide can be life-threatening (ATSDR, 1999; WHO, 2005).

The study of gaseous and particulate emissions in the atmosphere induced by natural events such as volcanic eruptions may therefore help for a better comprehension of their impact, especially on the atmospheric chemistry and on human health.

However, up to now, very few studies based on atmospheric measurements have been undertaken with links to sources such as volcanic eruptions in the southern hemisphere, especially at Reunion island, where atmospheric measurements such as SO_2 and particles are still scarce (Bhugwant and Brémaud, 2001; Bhugwant et al., 2002; Halmer, 2005; Bhugwant et al., 2009).

This chapter presents the SO_2 concentration measurements, undertaken over Réunion island and in the vicinity of the Piton de La Fournaise volcano during and off eruption events from 2005 to 2010. This volcano is located in the south-eastern part of the Réunion island, a tiny island found in the south-western Indian Ocean (21° S; 55,5° E). It is surrounded by quite densely inhabited regions from the north-eastern to the southern part of it. This active volcano erupts regularly, at least once a year, with notable amount of degassing. However, due to the geographic configuration, coupled with the meteorological conditions which prevail regionally (easterlies) and locally (land/sea breezes) over the island, the volcanic plumes are regularly transported towards the inhabited regions located downwind and may cause sanitary and environmental impacts.

The SO_2 concentration was measured continuously with an analyser in different parts of the island and with passive diffusion samplers in the vicinity of the Piton de La Fournaise volcano since 2005. The tremor activity of the Piton de La Fournaise volcano and the meteorological data (winds and rainfall) were measured at several locations over the island for each eruption. The analysis of these datasets have contributed towards explaining the spatial distribution and the temporal evolution of the volcanic SO_2 emissions, mainly due to dynamical (transport) and deposition (wet/dry) processes.

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2. Guideline values for the SO$_2$ concentration levels

It has been shown that high SO$_2$ concentration levels present in ambient air may cause considerable environmental and sanitary impacts (EPA, 1997). It is thus important to conduct the monitoring of this pollutant, in order to take the adequate measures of air pollution and also to study its long-term trends and effects. In this sense, since a decade the World Health Organization (WHO), the European Community and the French Ministry of Environment (MEDDTL : Ministère de l'Ecologie, du Développement Durable, du Transport et du Logement) have established guidelines for the SO$_2$ concentration levels, following the severity of the impact of this pollutant on human health and the environment.

The French National air quality criteria is mainly based on the Decree n°2002-213 of 15th February 2002 and recently on the Decree n°2010-1250 of the 21st October 2010, concerning the air quality survey, in particular for SO$_2$, and its effects on the human health and the environment, in the air quality objectives, in the alert thresholds and in the limit values (ADMINET, 2002, 2010).

The European Council Directive (1999) also defines the limit values for sulfur dioxide in the ambient air (see Table I). The objectives of this directive are, to establish limit values and alert thresholds for sulfur dioxide concentrations in ambient air intended to avoid, prevent and/or reduce harmful effects on human health as well as on the environment.

The Table I summarizes briefly the main SO$_2$ guideline values (critical levels) for the human health and for the vegetation, in order to establish the regulation context of this study (Council Directive, 1999 ; ADMINET, 2002; WHO, 2005).

LIMIT VALUES AND THE ALERT THRESHOLD FOR SULFUR DIOXIDE - EC 1999

Limit values must be expressed in µg/m^3. The volume must be standardised at a temperature of 293 °K and a pressure of 101,3 kPa.

	Averaging period	Limit Value	Margin of Tolerance	Date by which limit value is to be met
1- Hourly limit value for the protection of human health	1 hour	350 µg/m^3, not to be exceeded more than 24 times a calendar year	500 µg/m^3 (43%) on the entry into force of this Directive, reducing on 1 January 2001 and every equal months thereafter by equal annual percentages to reach 0 % by January 2005	1 January 2005
2- Daily limit value for the protection of human health	24 hours	125 µg/m^3, not to be exceeded more than 3 times a calendar year	None	1 January 2005
3- Limit value for the protection of ecosystems	Calendar year and winter (1 October to 31 March)	20 µg/m^3	None	1 July 2001

Table I. (a) Council directive 1999/30/EC of 22 April 1999 relating to limit values for sulfur dioxide, in ambient air.

II. Alert threshold for sulfur dioxide

500 µg/m³ measured over three consecutive hours at locations representative of air quality over at least 100 km² or an entire zone or agglomeration, whichever is the smaller.

LIMIT VALUES AND THE ALERT THRESHOLD FOR SULFUR DIOXIDE - ADMINET 2002

The volume must be standardised at a temperature of 293 °K and a pressure of 101,3 kPa. The annual reference period is the calendar year.

Quality Objective : 50 µg/m³, on annual average.

Recommendation and information threshold (**SRI**) : 300 µg/m³ on hourly average.

Alert threshold (**SA**) : 500 µg/m³ on hourly average, exceeded during consecutive three hours.

Limit values for the protection of the human health :

- Centile 99,7 (that is authorized 24 hours of overtaking a calendar year of 365 days) hourly concentrations: 350 µg/m³. This value is applicable as from the 1st January 2005. Before this date, the applicable limit value is the value of 2005 increased by the following margins not to be exceeded :

Calendar year considered :	**2001**	**2002**	**2003**	**2004**
Sets the margins not to be exceeded (µg/m³) :	120	90	60	30

- Centile 99,2 (i.e. 3 authorized days for values exceeding a calendar year of 365 days) daily average concentrations : 125 µg/m³.
- Limit values for the protection of the ecosystems : 20 µg/m³ on average annual average and 20 µg/m³ on average over the period going from the 1st October till the 31st March.

Table I. (b) Decree n° 2002-213 of the 15th February 2002 of the French Ministry of Environment relating to limit values for sulfur dioxide, in ambient air.

TARGET VALUES FOR SULFUR DIOXIDE - WHO 2005

*WHO air quality guidelines and interim targets for SO₂ : 24-hour and 10-minute concentrations*

	24-hour average (µg/m³)	**10-minutes average (µg/m³)**	**Basis for selected level**
Interim target-1 (IT-1)[a]	125	-	
Interim target-2 (IT-2)	50	-	Intermediate goal based on controlling either motor vehicle emissions, industrial emissions and/or emissions from power production. This would be a reasonable and feasible goal for some developing countries (it could be achieved within a few years) which would lead to significant health improvements that, in turn, would justify further improvements (such as aiming for the AQG value).
Air quality guideline (AQG)	20	500	

[a]Formerly the WHO Air Quality Guideline (WHO, 2005).

Table I. (c) WHO Air quality guidelines, Global update 2005.

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3. Experimental set-ups and measurements

The ORA measured SO_2 concentrations using passive diffusion samplers on 10 inhabited sites (1 to 10) located in the vicinity of the Piton de La Fournsaise volcano from mid 2005 to late 2007. During the April-2007 eruption however, SO_2 concentrations were measured using passive diffusion samplers on 12 (11 to 22) additional inhabited sites located close to the Piton de La Fournaise volcano. Since 2009, 4 more sites (23 to 26) have been added to reinforce the SO_2 survey in the vicinity of the volcano (Figure 1). All the selected sampling sites are located in inhabited areas, with almost no traffic circulation and at more than 1 to 2 km away from busy highways, in order to avoid local anthropogenic contamination.
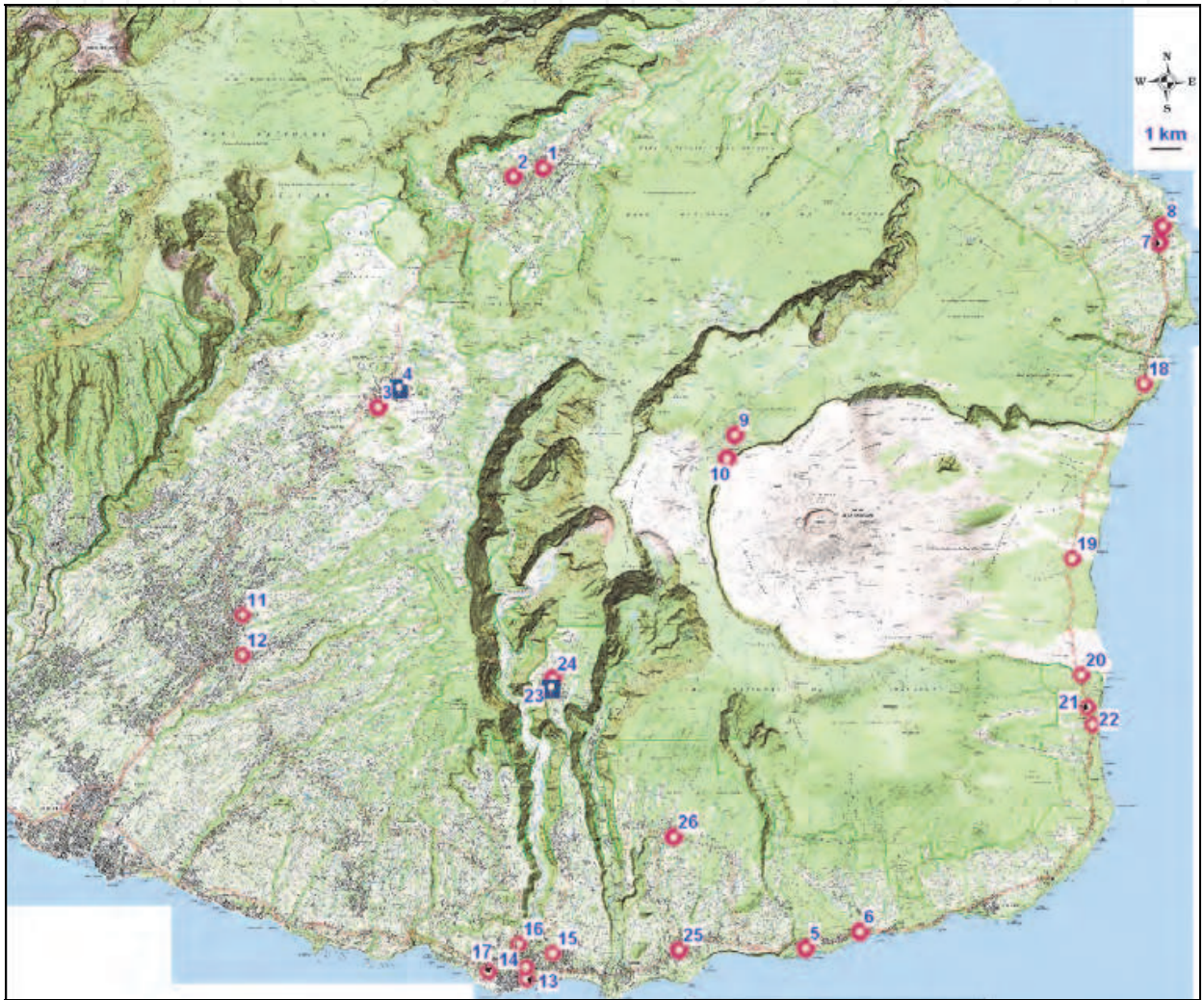
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Fig. 1. Map with indication of the sampling sites (red circles) dedicated for the SO_2 measurements with passive diffusion tubes from 2005 to 2010

3.1 Atmospheric measurements

3.1.1 SO₂ measurement using passive diffusion samplers

Passive diffusion samplers (Ferm, 1991) were used at 10 sites located around the Piton de La Fournaise volcano for the measurement of the ambient SO_2 concentration since September

2005. The measurements by passive diffusion samplers are based on the property of molecular diffusion of gases and species-specific collection on an impregnated filter specific to the SO_2 pollutant measured. The passive diffusion samplers, which were exposed over a period of one week to 10 days, provided quantitative SO_2 concentration measurements and the spatial distribution of this pollutant during and off volcanic eruptions of the Piton de La Fournaise volcano.

The uncertainty on the SO_2 concentrations measured by passive samplers was evaluated during two inter-comparison phases in late 2005, with two series of SO_2 tubes sampled on the sites. One of the series was analysed by the Joint Research Center (JRC) and the other one by the Gradko International Limited (Bhugwant et Siéja, 2005, 2006). This sampling technique has also been tested in different tropical and subtropical regions (Carmichaël et al., 2003; Ferm and Rodhe, 1997).

On the monitoring sites, the samplers are installed mesh side down in the underside of a plastic disc screwed at the top of a wooden pole and left in position for one week to 10 days (see Figure 2).
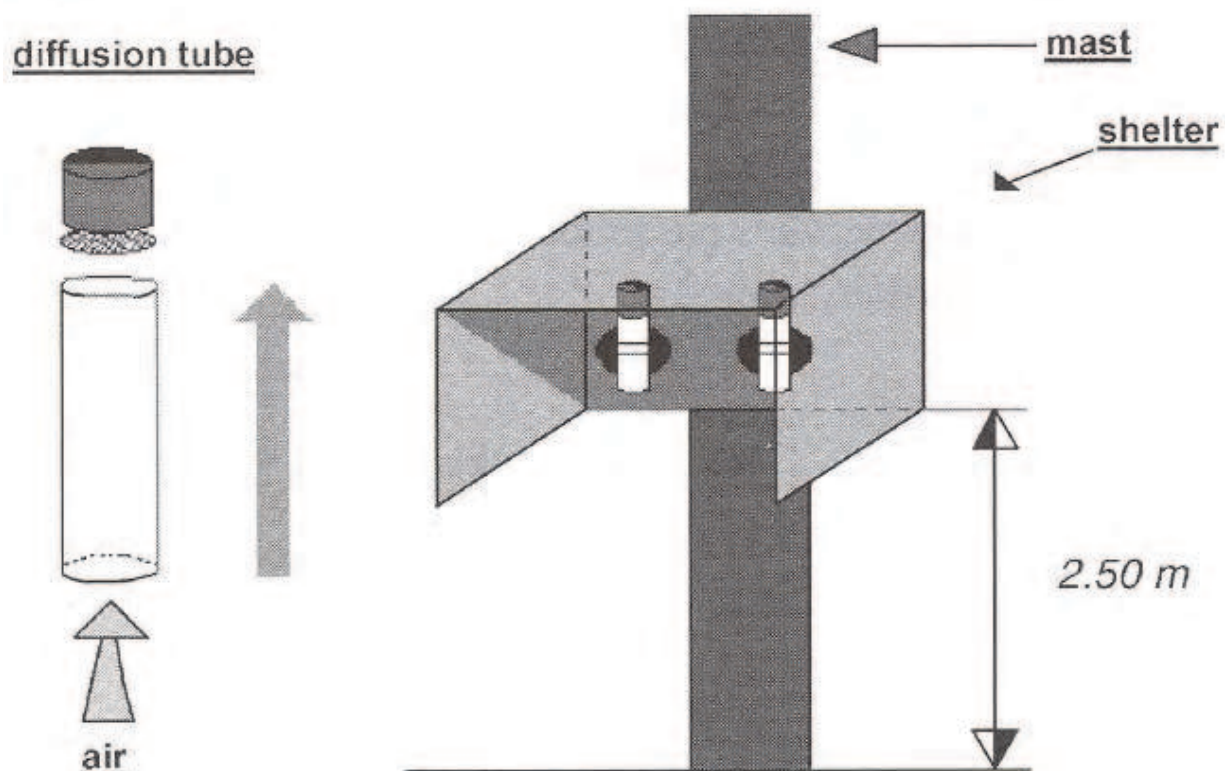

Fig. 2. Schematic representation of a SO_2 passive diffusion tube (left) and the sampling system (right : shelter and mast) for protecting against meteorological conditions (UV radiation, rains …).

After they are taken off, the exposed samples are stored in a refrigerator, in order to stabilize the trapped air samples. Then, they are sent to Gradko International Limited for subsequent laboratory analysis, via Ion Chromatography, in order to calculate the SO_2 concentration. The precision of the samplers, expressed as mean percentage difference between duplicates was found to be in the 10-25% range for SO_2 (Ayers et al., 1998).

3.1.2 SO$_2$ monitoring using SF-2000 analyser

The ORA also measured SO$_2$ concentration continuously with automatic analysers in an atmospheric network composed of fixed stations at different parts over Réunion island (Figure 3). During the April-May 2007 eruption, an SO$_2$ analyser SF-2000 (SERES) model was installed temporarily at two additional sites located in the south-western and southern parts of the island (see points 20: TR_1 and 22: TR_2 respectively, in Figure 3).
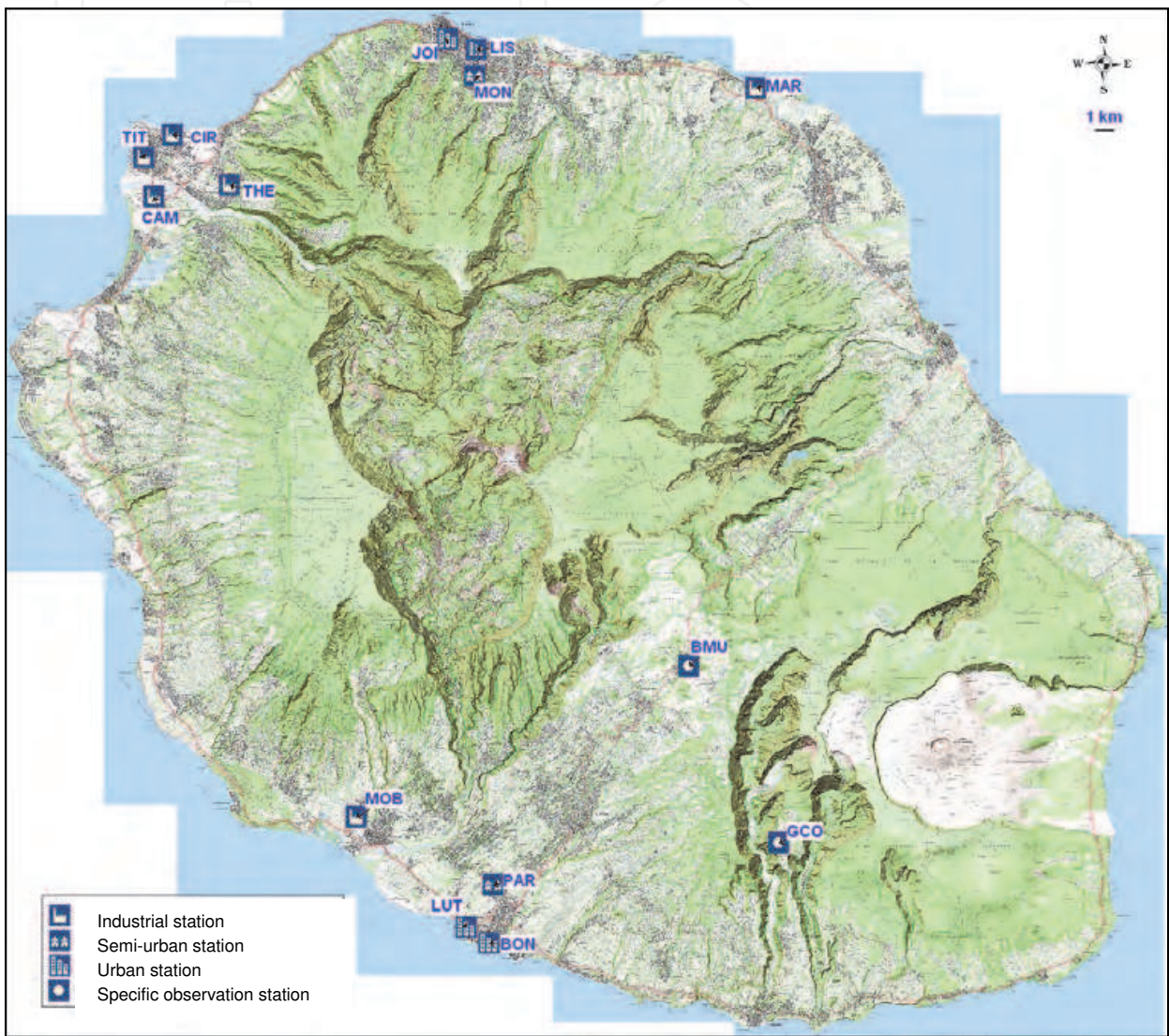
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Fig. 3. Map of Réunion island, with indication of the atmospheric network composed of fixed atmospheric stations over different parts of the island

The instrument analyses ambient air by the ultraviolet (UV) fluorescence technique, at a time-base of 15 minutes, subsequently averaged to 1 hour, for analysis with other datasets such as tremor intensity, winds and rainfall.

Sulfur dioxide molecules are brought to fluorescence once irradiated by ultraviolet radiation in the 190-390 nm wavelength range.

This UV fluorescence is the maximum for a wavelength found in the 210-230 nm range produced by a UV radiation generator which uses a zinc vapour lamp. In the case of the SF-

2000 analyser, the UV radiation of 215 nm wavelength produced by the zinc vapour lamp excites SO_2 molecules contained in the sampling vat, as shown by the equation (1) :

$$SO_2 + h\nu \rightarrow SO_2^* \qquad \text{adsorption - excited state} \qquad (1)$$
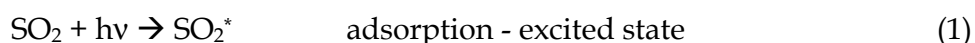
The excited SO_2^* molecule regains its initial energetic state E by emitting a radiation of wavelength λ', as indicated in the equation (2):

$$SO_2^* \rightarrow SO_2 + h\nu' \qquad \text{unexcited state} \qquad (2)$$

The re-emitted energy is lower than $h\nu$, the excitation energy, and hence the wavelength of the UV fluorescence radiation λ' (240-240 nm) is greater than that of the stimulation source wavelength λ (=215 nm). The fluorescence phenomenon stops when the excitation source is suppressed. The intensity of radiation of the sample is proportional to the SO_2 concentration: $[SO_2] = k \times I_F$, where k is the proportionality factor and I_F is the measured intensity (Ruidavets et al., 2005).

The SO_2 concentration measured by the SF-2000 analysers at the four locations situated in the north-western part of the island is carried out continuously since January 2001. However, only atmospheric data collected during summer 2005 and spring 2007 will be discussed in this work, as notable volcanic pollutants emitted during these eruption episodes were dispersed over different inhabited parts of the island.

3.2 Seismic network

The Observatoire Volcanologique du Piton de la Fournaise (OVPF) is in charge of the seismic and deformation network which has been implemented over the Piton de la Fournaise volcano since 1980. This network is composed, among others, of 25 seismic stations, with 1Hz and large band instruments (Aki and Ferrazzini, 2000; Staudacher at al., 2009). It records the seismic activity and deformation of Piton de la Fournaise 24 hours throughout a day and transfers data by radio in real time to the observatory. The seismic stations closer to the volcano enclosure (Staudacher at al., 2009) and to the eruption site are best representative of the eruptive tremor, and have been studied in particular for the April-May 2007 eruption (Bhugwant et al., 2005, 2009).

3.3 Meteorological data

The local meteorological parameters such as wind speed, wind direction, and rainfall are measured from the instruments onboard a tower at 10 m above the ground level, close to most of the sampling locations. These meteorological stations are managed by the French Meteorological Service (Météo-France, 2000). The wind fields calculated from the ECMWF (European Center for the Medium-Range Weather Forecast) data archives are also analysed (not shown) in order to study the dynamical processes prevailing on regional scale over Réunion Island (Bhugwant et al., 2009).

3.4 Tropospheric SO_2 concentration variability measured from satellite data

The Ozone Monitoring Instrument (OMI) is dedicated to detect and measure volcanic eruptions degassing and anthropogenic pollution from space. The OMI is a hyperspectral UV-Visible spectrometer with a resolution of 13x24 km at nadir. In order to gain more information about the spatial distribution of the SO_2 and the characteristics (composition, etc.) of the volcanic plumes, satellite data retrieved each day from the Aura OMI satellite

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following the eruptions were analysed (Carn et al., 2003, 2007; Yang et al., 2007; Bhugwant et al., 2009).

3.5 Field observations of the Piton de la Fournaise activity

It is now well established that the Piton de la Fournaise volcano is one of the most active volcanoes in the world, with one eruption every 8 months, over the last century. Since 1998, a particular intense volcanic activity is observed, with 2 to 4 eruptions per year. These eruptions are mainly basaltic, producing generally lava fountains of 50 to 100 m high and fluid lava flows of aa or pahoehoe type and of aphyric to olivine-rich composition. Most eruptions of Piton de la Fournaise last between 2 weeks and 1 month. However, the March 1998 eruption lasted 196 days. As the driving force of every eruption is the trapped gas, they always accompany each eruption. However, significant gas emissions are observed at Piton de la Fournaise during intense eruptions only (Bhugwant et al., 2001, 2009).

3.6 Sanitary and environmental survey

Following the recent population control, Réunion island holds a population of 730 000 inhabitants (INSEE, 2010). About 24% of the population of the island lives in the vicinity of the Piton de La Fournaise volcano and may thus be exposed to sanitary hazards during eruption episodes. Moreover, a large part region localised close to the Piton de La Fournaise is composed of agricultural lands and also forests with endemic species, which may be subject to environmental impacts (eg. acid rains) during eruptions.

4. Results & discussions

4.1 Spatial SO_2 concentration distribution during late December 2005 eruption

The methodology applied to calculate the spatial distribution of the SO_2 concentrations measured at different locations over Réunion island is the kriging interpolation method (Carletti et al., 2000).

The Figure 4 presents the GIS (geographic information system) plot of the spatial distribution of the mean SO_2 concentration measured during an eruption event which occurred on late December 2005-early January 2006, i.e., from 27th December 2005 to 3rd January 2006. The mean SO_2 concentration shown in this figure consists of the data obtained from both passive diffusion samplers and the automatic analysers on the atmospheric stations. It may first be observed that the highest SO_2 concentration ($\sim 70\ \mu g/m^3$) is mostly confined on the southern and the south-eastern parts of the island. Then, it decreases rapidly after a few kilometres from the eruption vent. Importantly, it may be seen that the eastern to north-eastern part of the island is weakly concerned by the SO_2 concentration emitted during this eruption event. The main causes are, among others, the ranges of mountains Cilaos, Mafate and Salazie (see Figure 2), which constitute a natural barrier for the transfer of atmospheric pollutants downwind, over the eastern to northern parts of the island. Moreover, due to the conjunction of the important relief of the island and the easterlies prevailing over the south-western Indian Ocean, the air masses originating from the south-eastern part of the island tend to by-pass it (Météo-France, 2000). Also, the geographic configuration of the island tends to generate microclimates over the island. Consequently, the windward side of the island is more windy with high rainfall levels throughout the year while the leeward side of it is drier with less winds. This parameter may also in part explain the low SO_2 concentration observed on the eastern to northern sectors.
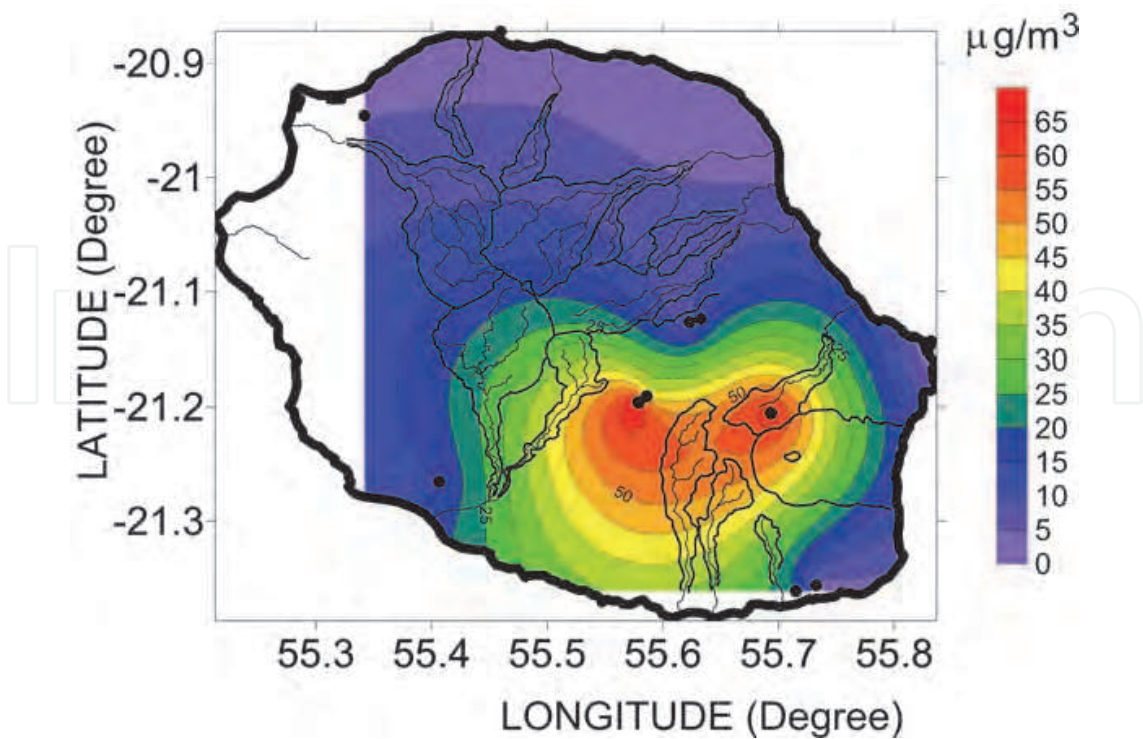
Fig. 4. Contour plot of the mean SO$_2$ concentration calculated by kriging interpolation method from thirteen measurement locations during 27th December 2005-3rd January 2006 period over Réunion Island (black circles : SO$_2$ sampling locations).
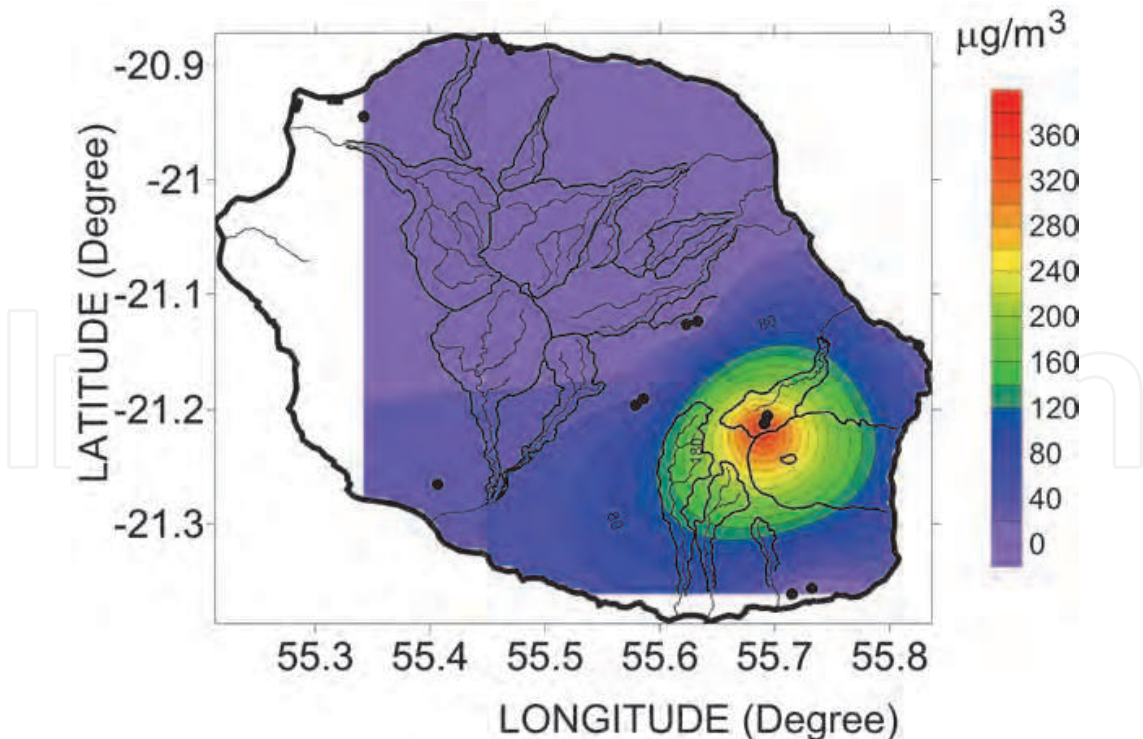

Fig. 5. Contour plot of the mean SO$_2$ concentration calculated by kriging interpolation method from thirteen measurement locations during 3rd January 2006-12th January 2006 period over Réunion island (black circles : SO$_2$ sampling locations).

4.2 Spatial SO₂ concentration distribution during early January 2006 eruption

The Figure 5 presents the plot of the spatial distribution of the mean SO_2 concentration obtained by passive diffusion samplers and automatic analysers during an eruption event which occurred from late December 2005 to mid-January 2006, i.e., from 3rd January 2006 to 12th January 2006. The highest SO_2 concentration (~ 370 µg/m³) is observed on the northern to south-western parts of the Piton de la Fournaise volcano. Interestingly, it may be seen that the high SO_2 levels are constrained in a mountainous sector with a very low density of population. The contaminated air masses follow gullies and rivers lane found in the vicinity of the volcano (on the north-western to southern part of it) to attain the littoral regions of the island. The comparison of the two figures (4 and 5) shows that, in spite of the relief and the meteorology, the source intensity is also a dominating factor which can explain the sulfur dioxide variability observed for these two eruptive episodes.

4.3 Spatial SO₂ concentration distribution during mid-April 2007 eruption

The Figure 6 presents the plot of the spatial distribution of the mean SO_2 concentration obtained by passive diffusion samplers and automatic analysers during an eruption event which occurred from early April 2007 to early May 2007, i.e., from 18th April 2007 to 26th April 2007. The highest SO_2 concentration (~ 190 µg/m³) is mainly concentrated on the northern to south-western parts of the Piton de la Fournaise volcano while moderate levels are also measured up to the southern to south-western part of the island.

Since the SO_2 surveillance in the vicinity of this volcano, it may be seen that during the previous eruptions, regularly the volcanic plumes are preferentially transported to the southern to north-western parts of Réunion island.
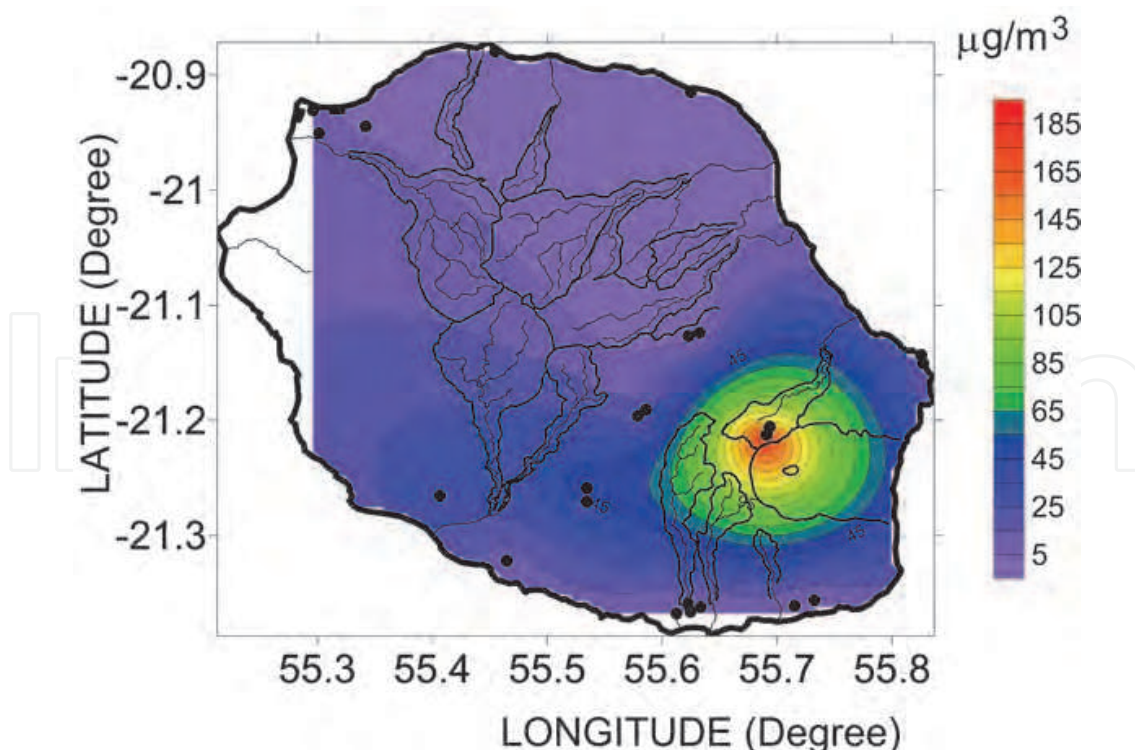

Fig. 6. Contour plot of the mean SO_2 concentration obtained by kriging interpolation method from twenty-three measurement locations during 18th April-26th April 2007 period over Réunion island (black circles : SO_2 sampling locations).

4.4 Temporal evolution of SO$_2$ concentration in 2006 and 2007

The Figure 7 presents the monthly mean SO$_2$ concentration measured by automatic analysers in atmospheric stations at different parts of Réunion island in 2006 and 2007. In absence of any eruption, the monthly mean SO$_2$ concentration exhibits low levels, varying in the 3-12 µg/m^3 range at all the monitoring sites.
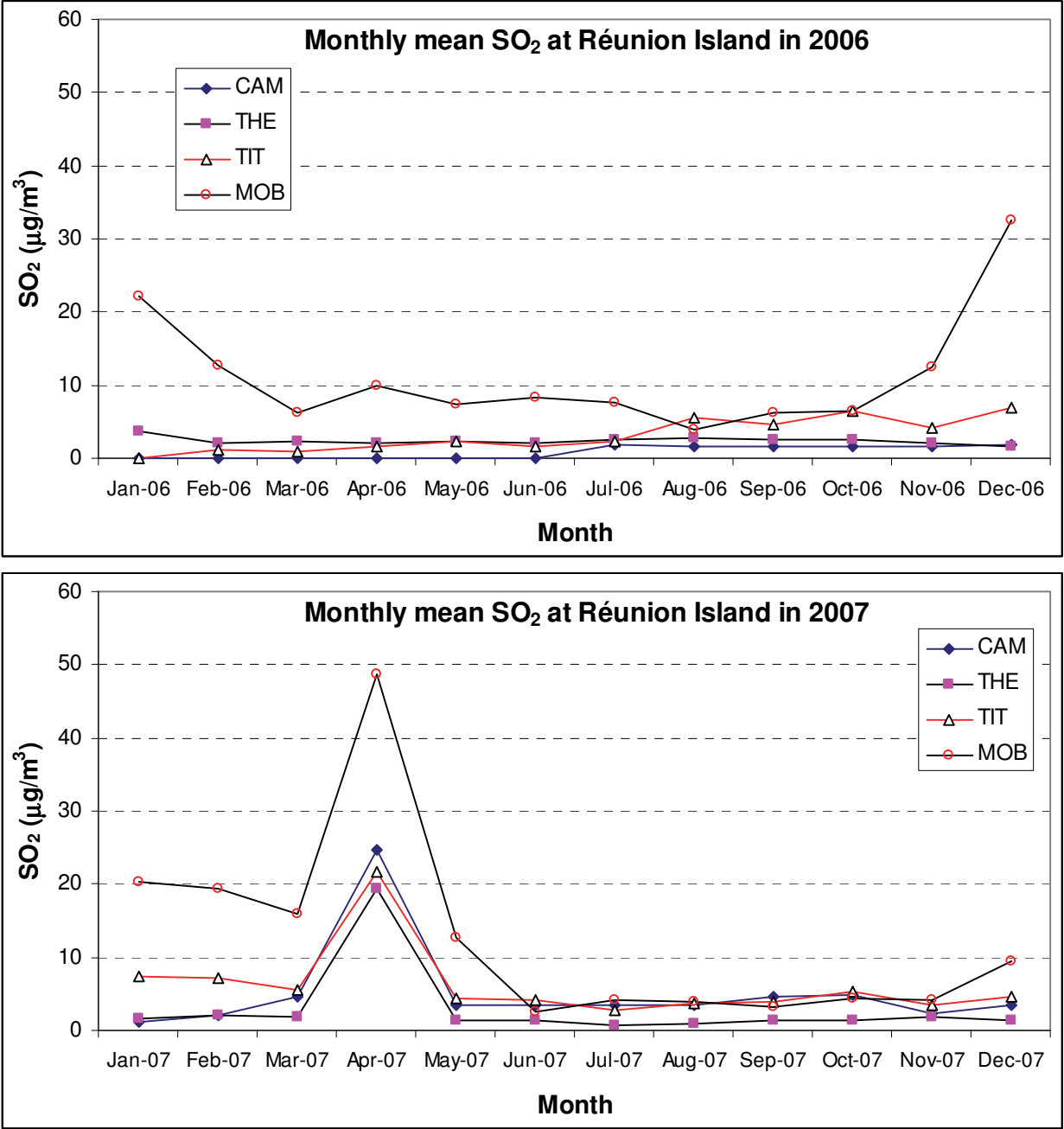

Fig. 7. Monthly mean SO$_2$ concentration measured continuously with automatic analysers at different atmospheric stations over Réunion island in 2006 and 2007.

The highest SO$_2$ concentration (~ 50 µg/m^3) is observed at the MOB station (which is closest to the Piton de la Fournaise volcano) while the other stations are also but less impacted by the SO$_2$ emitted in April 2007. This assessment is coherent with the results presented in Figure 6.

Importantly, it may be seen that the atmospheric stations located in the north-western parts of the island show low values while the MOB station exhibit high values during each eruption event registered in 2006 and 2007. The results also suggest a regional impact of the contaminants emitted during the Piton de la Fournaise volcano eruption and the implications on human health for the population exposed to atmospheric pollution.

4.5 Winds spatial distribution over Réunion island

Dynamical processes such as winds (direction and speed) have notable influence on atmospheric constituent variability. It is thus important to study the winds regime prevailing over the island in order to assess their influence on the SO_2 concentration variability. The Figure 8 presents the wind roses annual mean distribution over Réunion island, calculated from winds data collected over meteorological stations located in different parts of the island from 1976 to 1995 (Météo-France, 2000). It may be seen that the hilly landscape of the island plays an essential role in the winds distribution. On one hand, it contributes to strengthen the winds in certain sectors, and, on the other hand, to place certain regions under cover. The land/sea breezes as well as the slope breezes, the constituent of which is perpendicular in the coasts, are clearly evidenced on most of the meteorological stations. The local winds distribution induced by the important relief of the island, coupled with the easterlies prevailing regionally over the south-western Indian Ocean, notably contribute to the dispersion of the SO_2 over the island during and off eruption events.
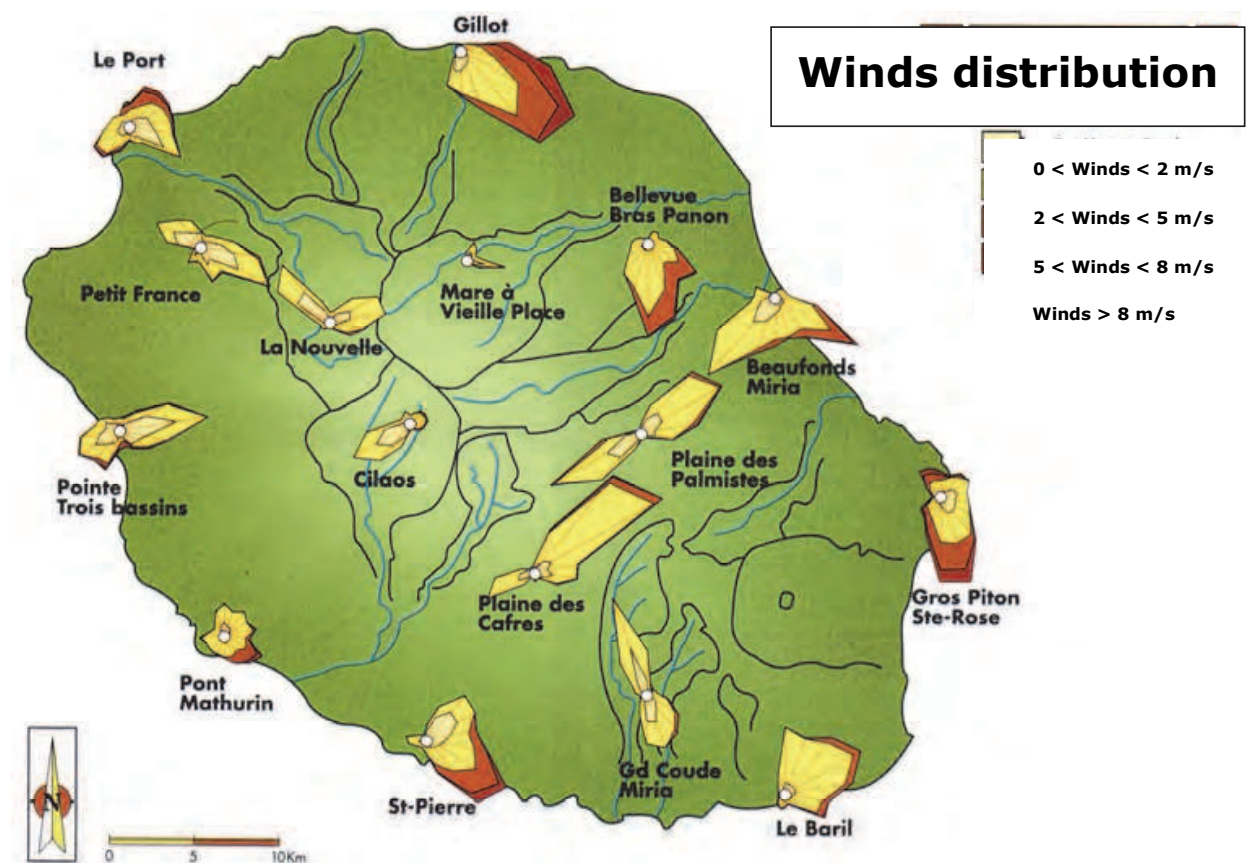

Fig. 8. Wind roses annual mean distribution illustrating the winds spatial distribution over Réunion island obtained from winds data collected from 1976 to 1995 (Source : Météo-France, 2000).

4.6 Spatial distribution of rainfall in early winter (April)

In order to gain more information about the spatial distribution and the temporal evolution of the SO_2 concentration; additional meteorological data collected over the island was also analysed. Figure 9 presents the spatial distribution of the monthly mean rainfall measured in April (from 1998 to 2008) over Réunion island. It may be seen that the maximum rainfall occurs in the southern to north-eastern regions, with a maximum rainfall of ~ 1 200 mm in the East of the island. A comparison with the 4 to 6 suggest that this parameter is the main factor which may explain the lower SO_2 levels observed in the south-eastern to the northern regions, especially during eruption events.
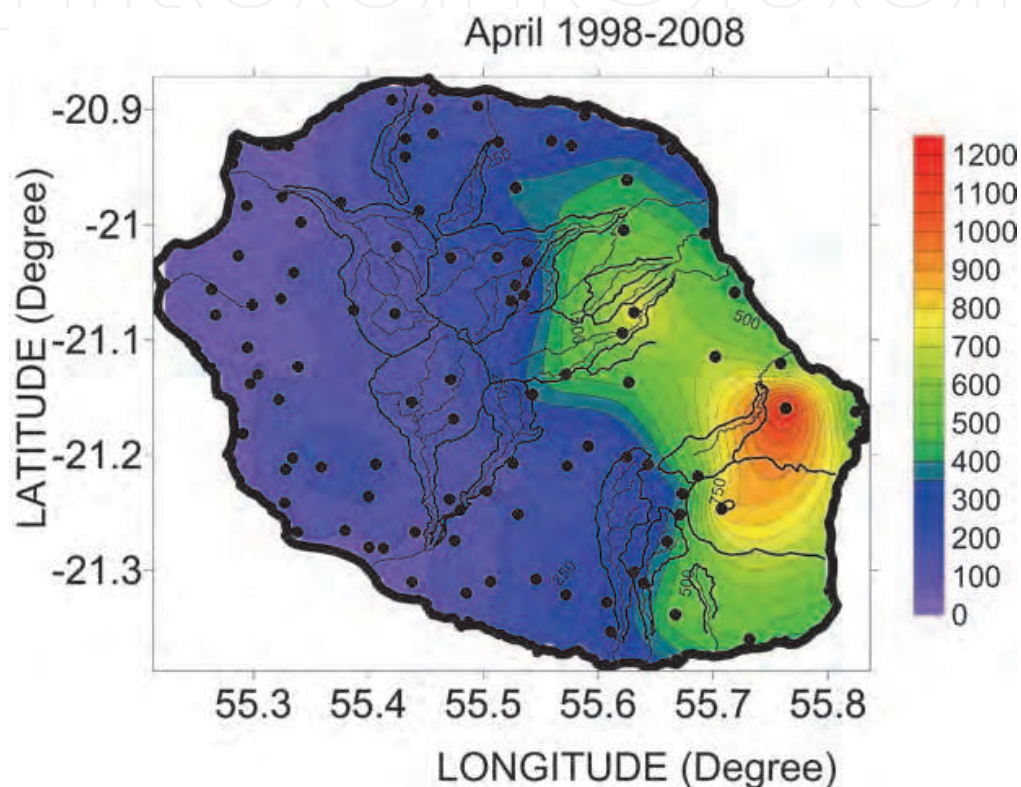
Fig. 9. Monthly mean rainfall measured in April from 1998 to 2008 at different parts of Réunion island (black circles : meteorological stations).

5. Conclusions

In this chapter the spatial distribution of SO_2 concentration and its temporal evolution during several eruptions of the Piton de La Fournaise volcano has been analysed, in conjunction with other parameters, such as seismic and meteorological data.

A good correlation has been established between the seismic variability and the SO_2 concentration variation in the vicinity of the volcano (Bhugwant et al., 2009).

The analysis of SO_2 data collected in parallel with meteorological parameters show that the rainfall influences notably the SO_2 spatial variability in particular over the eastern to northern regions of Réunion island, via scavenging processes.

The conjunction of the important relief of the island coupled with the winds (easterlies and land/sea breezes) also contribute to the spatial distribution and the temporal evolution of the SO_2 concentration measured at different parts of it.

Importantly, the results of several years of SO_2 measurements also show that the QO (Quality Objective) as well as the LV (Limit values for the protection of the ecosystems), based on an annual average, were not exceeded over the island during the 2005-2010 period. However, the SRI (Recommendation and information threshold) as well as the SA (alert threshold) was exceeded in some inhabited regions close to the volcano during previous eruptions, in particular during the April-May 2007 eruption (Bhugwant et al., 2009).

Recently, a preliminary epidemiological study showed that the SO_2 emitted during the eruption of the Piton de la Fournaise volcano might have a potential sanitary impact on the surrounding population. Consequently, this investigation should be carried out in order to establish quantitatively the links between atmospheric pollution induced by eruption events and sanitary impacts.

This preliminary work may be of interest in particular to epidemiologists (eg. to establish the sanitary impact on the surrounding population) and to decision-makers (eg. for crisis managements during eruption episodes).

A close collaboration between the various supervisory boards (ORA, OVPF and Météo-France) may help to establish a decision-making tool to the decision-makers, in particular, to draw up evacuation plans in case of pollution alerts. The recent tools deployed, i.e., the atmospheric data collected from the satellite since a few decades is also a supplement to the ground-based measurements, for the monitoring of atmospheric plumes during future eruptions of this active volcano.

6. Acknowledgements

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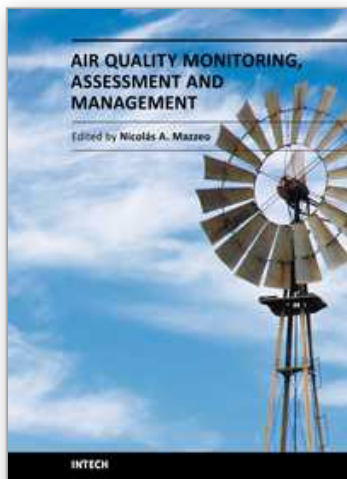
Air Quality Monitoring, Assessment and Management

Edited by Dr. Nicolas Mazzeo

Human beings need to breathe oxygen diluted in certain quantity of inert gas for living. In the atmosphere, there is a gas mixture of, mainly, oxygen and nitrogen, in appropriate proportions. However, the air also contains other gases, vapours and aerosols that humans incorporate when breathing and whose composition and concentration vary spatially. Some of these are physiologically inert. Air pollution has become a problem of major concern in the last few decades as it has caused negative effects on human health, nature and properties. This book presents the results of research studies carried out by international researchers in seventeen chapters which can be grouped into two main sections: a) air quality monitoring and b) air quality assessment and management, and serves as a source of material for all those involved in the field, whether as a student, scientific researcher, industrialist, consultant, or government agency with responsibility in this area.

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