Update of the volcanic SO_2 emission inventory in MOCAGE Chemistry-Transport Model and its impact on the atmospheric sulfur species budget

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Introduction & Context

Constraining volcanic emissions

Anthropogenic SO_2 emissions decrease $\rightarrow$ volcanic contribution to global sulfur emissions increase

$+$ Improvement in remote sensing measurements (satellite global coverage and higher sensitivity)

Objective : Estimate the relative contribution of volcanic sulfur emissions to the global budgets of chemical compounds (SO_2 and sulfate aerosols).

Tools : Volcanic SO_2 Emission Inventories

	Actual inventory	**New inventory**	
	Andres & Kasgnoc (1998)[1]	*Carn et al* (2016)[2]	*Carn et al* (2017)[3]
Time period	1970-1997	1978-2015	2005-2015
Emission type	continuous eruption	eruption	degassing
Data frequency per volcano	1 average flux over the 25 years	1 total flux quantity per day	1 average flux per year
Nb Volcanoes	43	119	91
Amount emitted	13 Tg	[0.2-5.9] Tg	[19.6-26.1] Tg
Injection parametrization	at model surface	from volcano vent to plume top	at volcano vent

. [1] https ://doi.org/10.1029/98JD02091

. [2] http ://dx.doi.org/10.1016/j.jvolgeores.2016.01.002

. [3] https ://doi.org/10.1038/srep44095

Simulations Description

Reference simulation over 2013

CTM MOCAGE with a 1°lat x 1°lon Global resolution

Meteorological forcing from ARPEGE

Emission inventories : anthropogenic (MaccCity), biomass burning (GFAS)

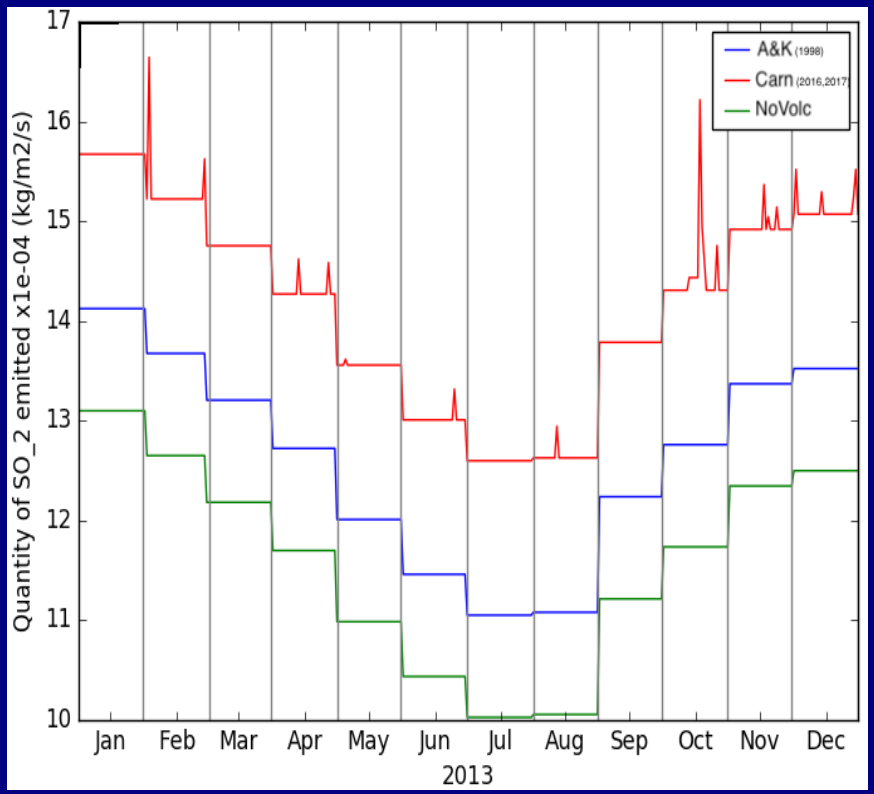
	Volcanic inventory	Altitude of injection
NOVOLC	none	none
REF	*Andres and Kasgnoc* (1998)	at the model surface
CARN	*Carn et al* (2016,2017)	at the model surface
CARNALTI	*Carn et al* (2016,2017)	altitude parametrization[1]

Objective :

- Improve MOCAGE definition of volcanic emissions.
- Assess its representation of the sulfur species budget in the atmosphere.

. [1] Details p.13

Simulations Description : 2013 emissions



NOVOLC :

Only anthropogenic emissions (monthly variation)

REF :

Anthropogenic emissions + constant volcanic emissions (7% of the total)

CARN & CARNALTI :

Anthropogenic emissions + variable volcanic emissions ($\sim$ 18% of the total)

Total eruptive emissions = 0.21 Tg

Total passive emissions = 23.53 Tg

Eruptive emissions « Passive emissions

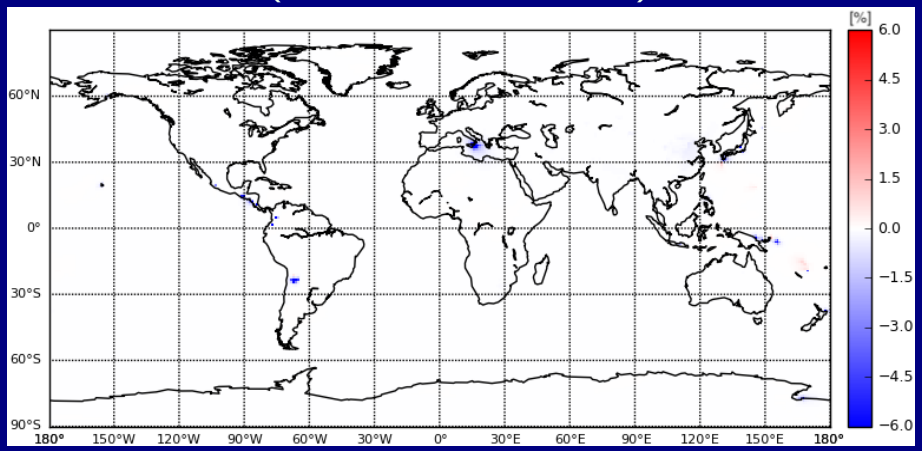
Overall Results

	Total Tropospheric Column			***Mean Surface Concentration***		
	SO_2 (mol/m^2)	Sulfate (mg/m^2)	$PM_{2.5}$ (mg/m^2)	SO_2 (mol/m^3)	Sulfate (mg/m^3)	$PM_{2.5}$ (mg/m^3)
	Annual mean concentration for each simulation					
REF	7.69e-6	3.25	57.6	7.71e-9	5.57e-4	1.266e-2
CARN	7.93e-6	3.52	57.9	8.21e-9	5.90e-4	1.268e-2
CARNALTI	8.27e-6	4.02	58.6	7.22e-9	5.87e-4	1.270e-2
	Relative difference between the different simulation					
CARN-REF	+3.1%	+9.8%	+0.6%	+6.5%	+5.9%	+0.2%
CARNALTI-REF	+7.3%	+29.1%	+2.1%	-6.4%	+5.4%	+0.3%
	Volcanic contribution to the total species concentration					
REF	+12%	+6.9%	+0.6%	+6.4%	+5.8%	+0.4%
CARN	+20.4%	+13.4%	+1.3%	+20.3%	+13.5%	+1.9%
CARNALTI	+23.6%	+21.2%	+2.7%	+14.4%	+19%	+1%

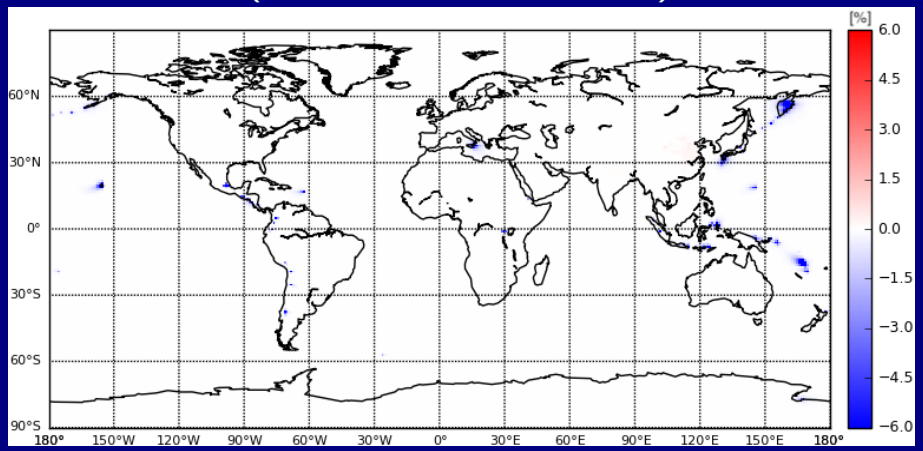
- Higher concentration in total columns with *Carn et al* (2016,2017) inventory.
- Higher concentration at the surface in CARN compared with REF (less quantity emitted) and CARNALTI (higher altitude of injection).
- Small impact on particulate matter ($PM_{2.5}$) concentration.
- Same conclusion on the volcanic contribution.

SO_2 Volcanic Impact and Contribution

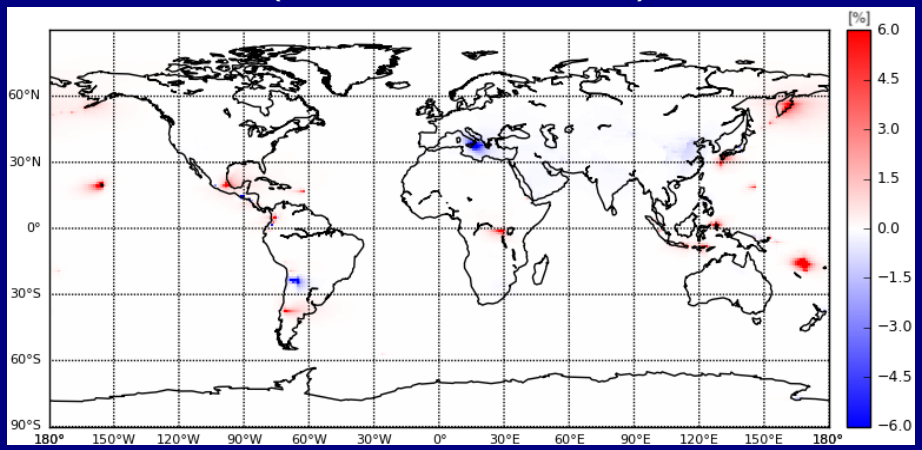
(a) Relative difference at the surface (CARNALTI-REF)



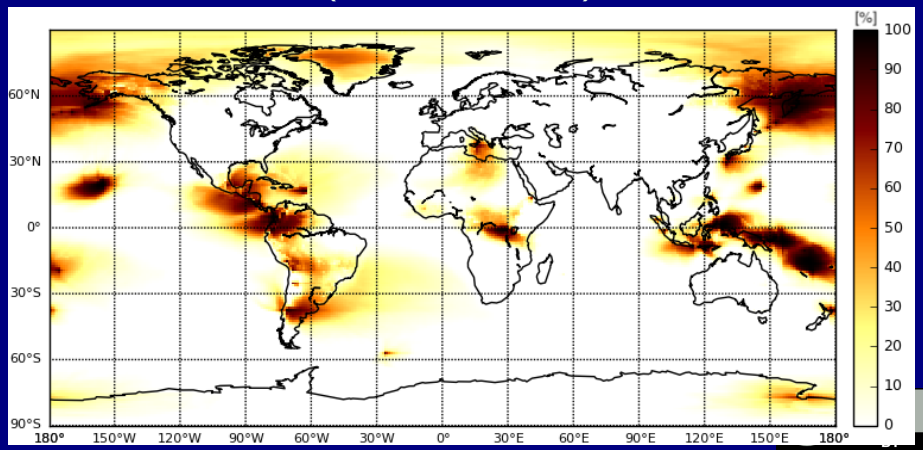
(b) Relative difference at the surface (CARNALTI-CARN)



(c) Relative difference on the total column (CARNALTI-REF)

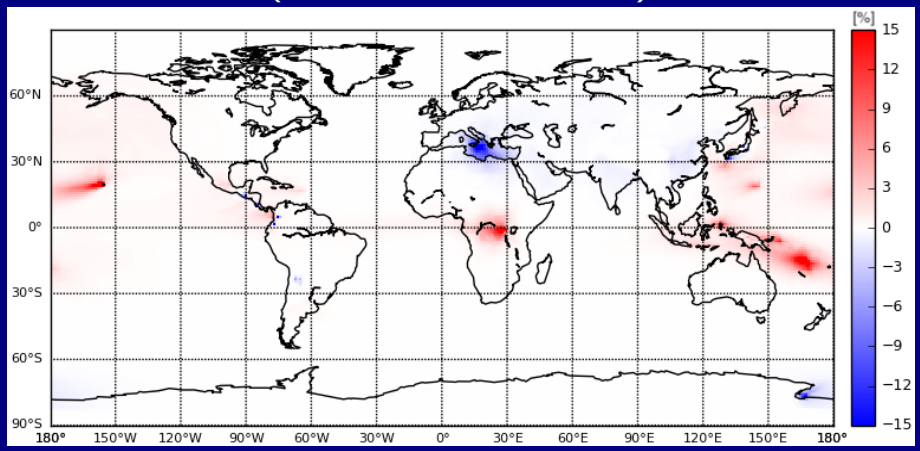


(d) Volcanic contribution (CARNALTI)

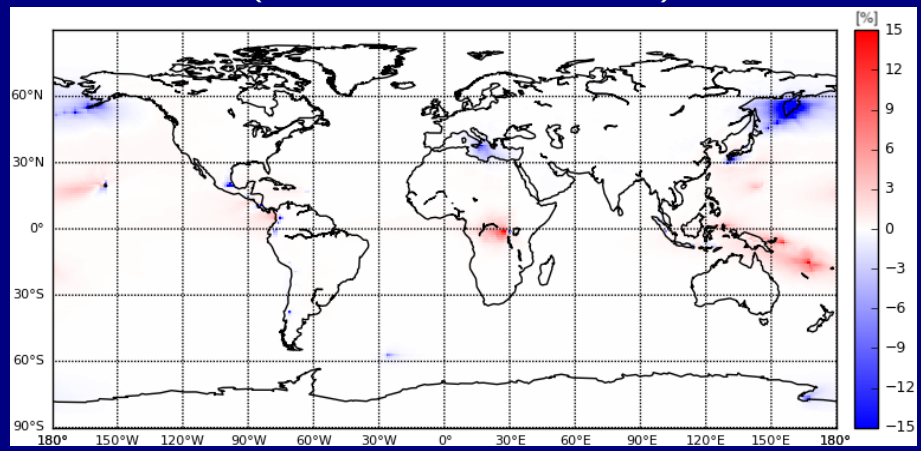


Sulfate Aerosol Volcanic Impact and Contribution

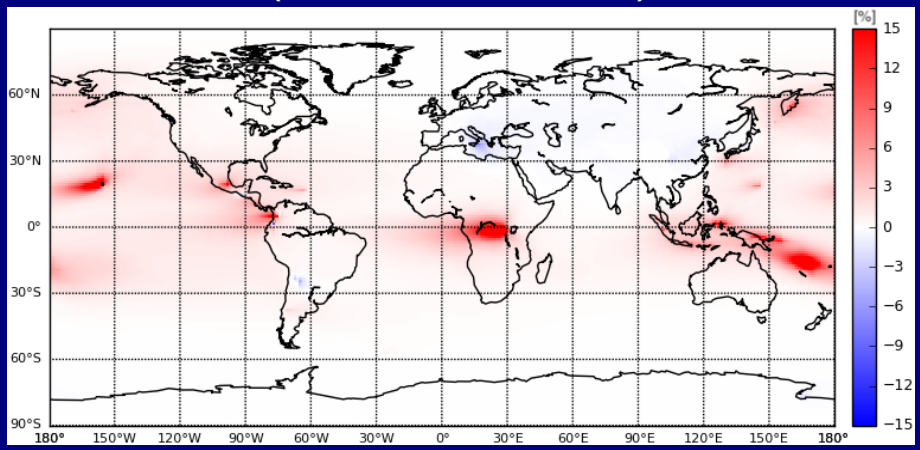
(a) Relative difference at the surface (CARNALTI-REF)



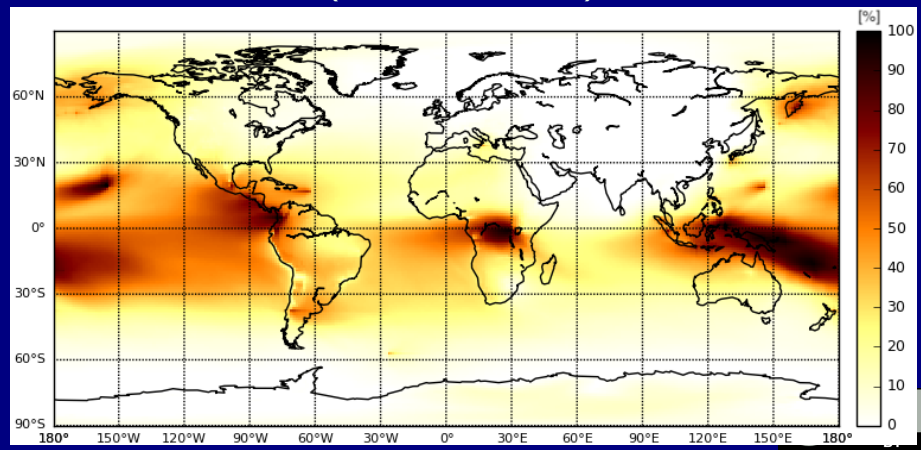
(b) Relative difference at the surface (CARNALTI-CARN)



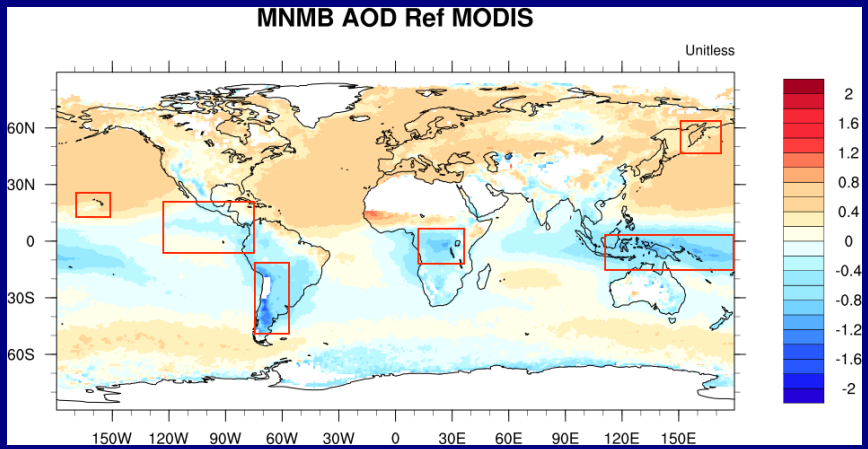
(c) Relative difference on the total column (CARNALTI-REF)

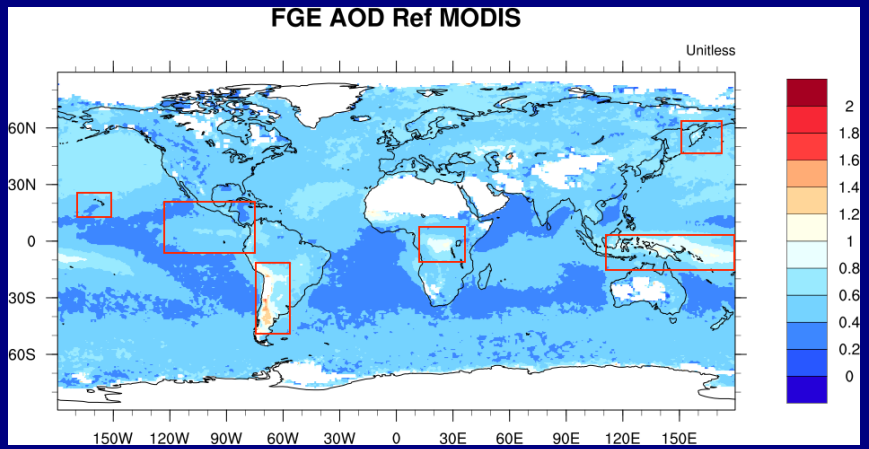


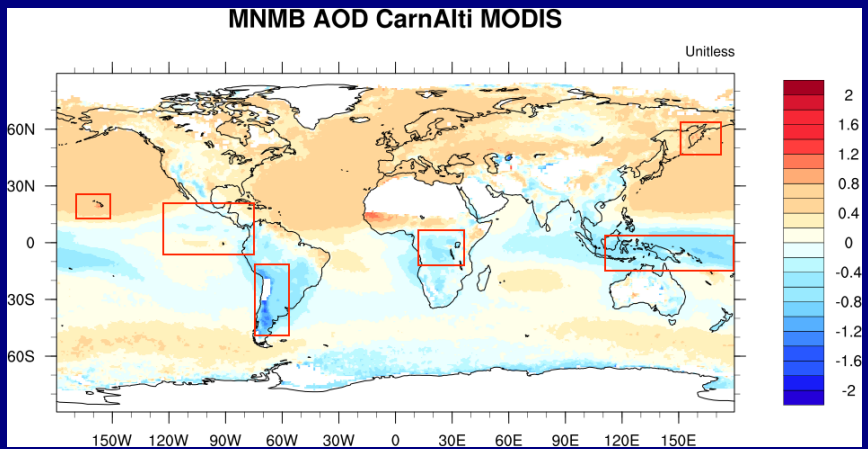
(d) Volcanic contribution (CARNALTI)

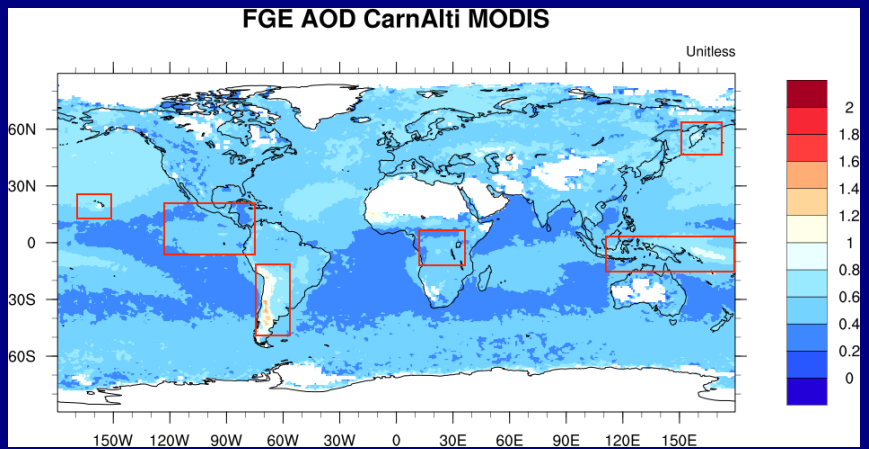


Validation with MODIS data









Validation : Improvement in CARNALTI simulation compared with REF simulation against MODIS AOD data.

Conclusion and Perspectives

Conclusions :

- More volcanic emission in the new inventory (+83%) $\rightarrow$ higher sulfur species concentration (+5-20%).
- New parametrization (injection in altitude) $\rightarrow$ better distribution on the vertical + less SO_2 concentration at the surface.
- Improvement in the global aerosol representation, against MODIS data, with the new inventory and the parametrization.

Perspectives :

- Same study with a finer resolution, in space (vicinity of the volcanoes) and time (monthly-averaged).
- Validate simulation with direct SO_2 observations (GOME-2, IASI,...).
- Look at the impact on the volcanic sulfur budget at the regional scale for a specific volcano (Etna).

Any questions ? Contact me :

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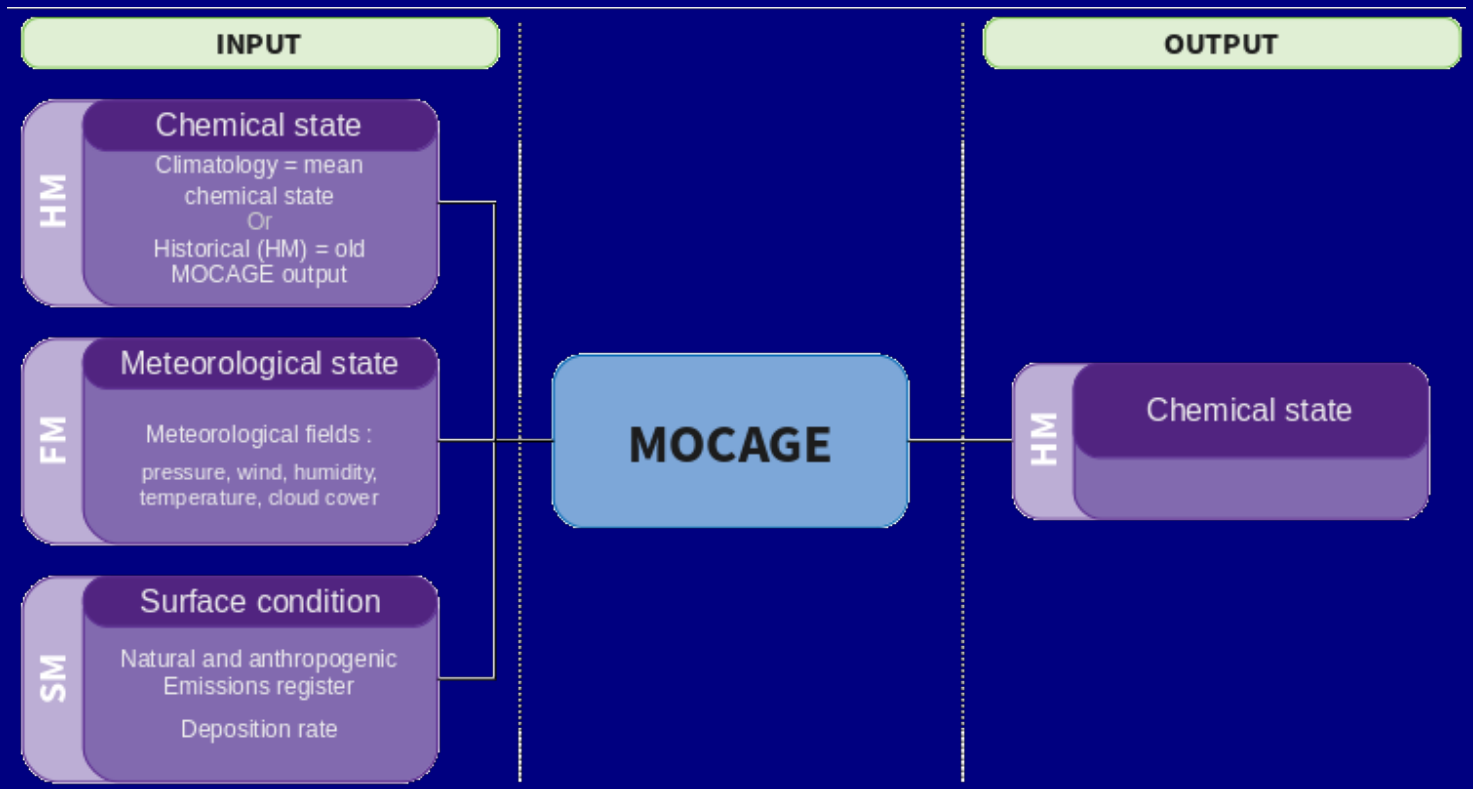
Tools : MOCAGE Chemistry-Transport Model

Supporting Information



- 47 σ-hybrid vertical levels from surface to 5hPa
- horizontal resolution from 0.1°lat x 0.1°lon to 2°lat x 2°lon
- chemical schemes : RACM for the troposphere and REPROBUS for the stratosphere

Parametrization : Volcanic Altitude of Injection

Supporting Information

New inventory database products :

Eruption → Altitude of the volcano + Altitude of the plume top

Passive degassing → Altitude of the volcano

Parametrization :

Eruption → from the volcano vent (L_{bot}) to the plume top (L_{top}) with an umbrella profil. Level of maximum of injection (L_{inj}) calculated as being at 75% of the plume top altitude.

Passive degassing → at the volcano vent (L_{bot}=L_{top})