A New Gas-Phase Scheme for Advanced Regional Climate Modelling with RegCM4

James M. Ciarlo` [1,2,3], Noel Aquilina [4], Susanna Strada [2], Ahmed Shalaby [5], Fabien Solmon [6]

1. Department of Geosciences, University of Malta, Msida, Malta
2. Earth System Physics Section, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
3. National Institute of Oceanography and Experimental Geophysics (OGS), Trieste
4. Department of Chemistry, University of Malta, Msida, Malta
5. Faculty of Forestry and Environmental Management, UNB, NB, Canada
6. LA, CNRS, Universite Paul Sabatier, OMP, Tolouse, France

MALTA GOVERNMENT MGSS SCHOLARSHIP SCHEME

ICTP

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International Workshop on ICTP Regional Climate Model: Applications over South Asia CORDEX Domain

22-28 February 2021

Motivation: Direct effects of SOAs

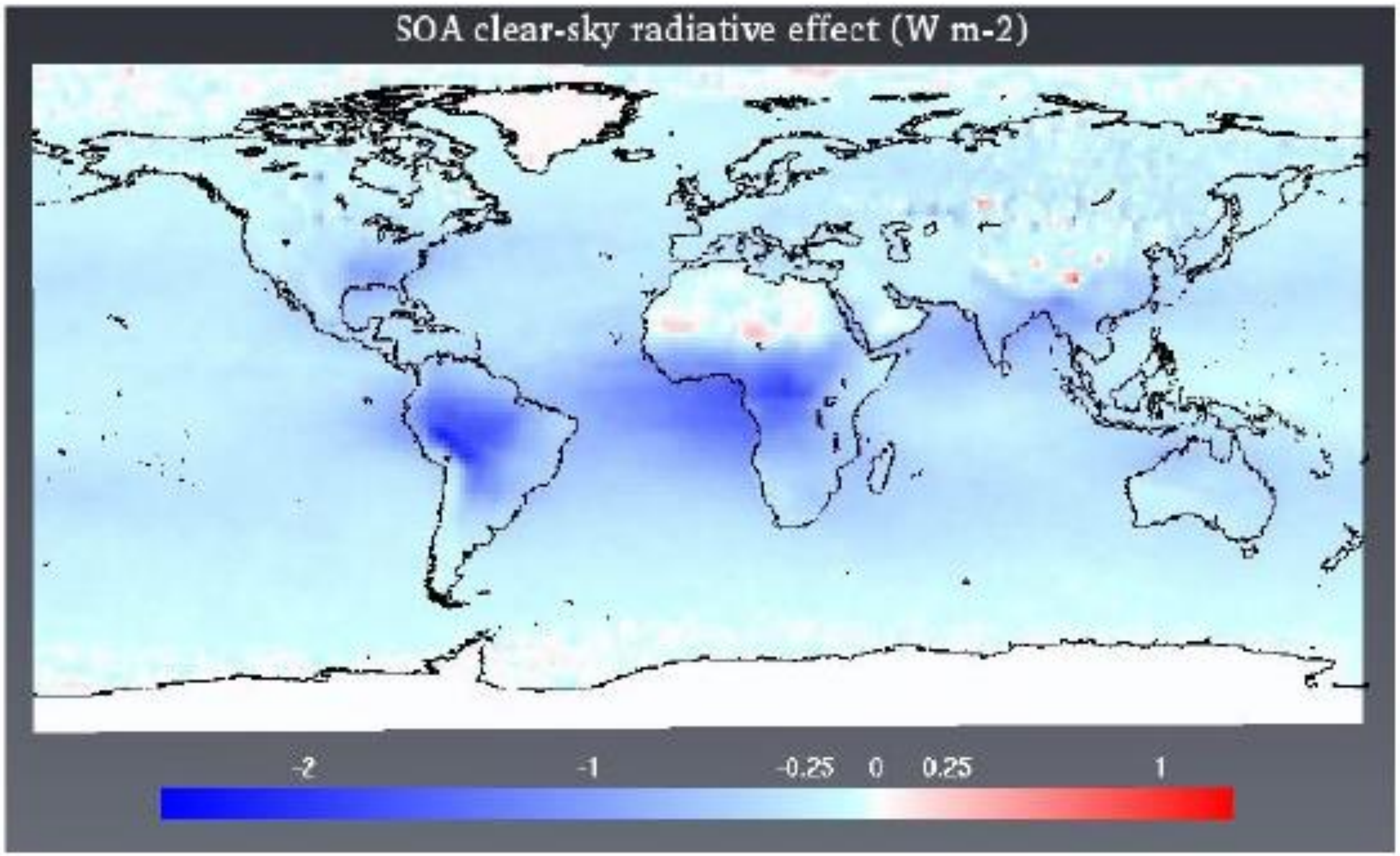


Figure 1.4: The annual direct SOA radiative forcing; obtained by calculating the difference in clear-sky top of atmosphere Sw flux between SOA and no SOA (O'Donnell *et al.*, 2011).

Motivation: Indirect effects of SOAs

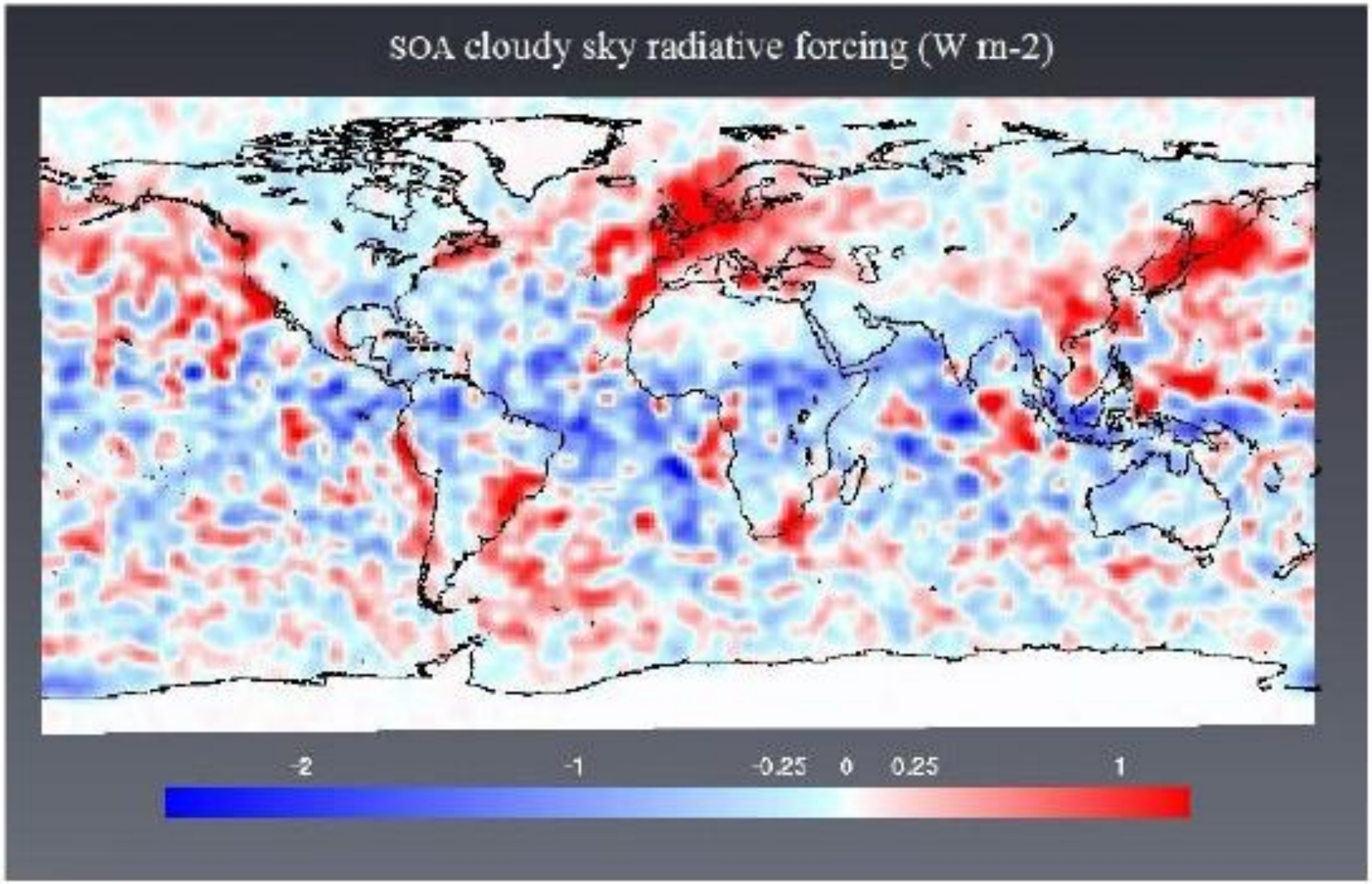
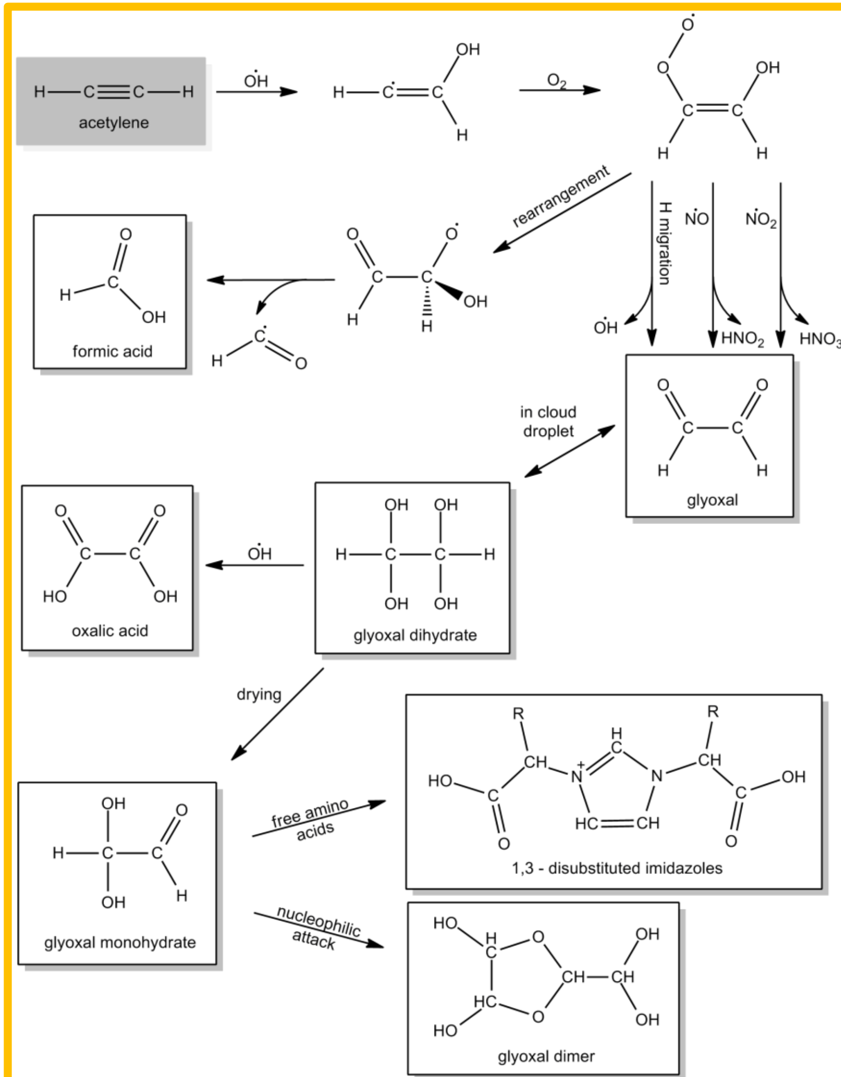
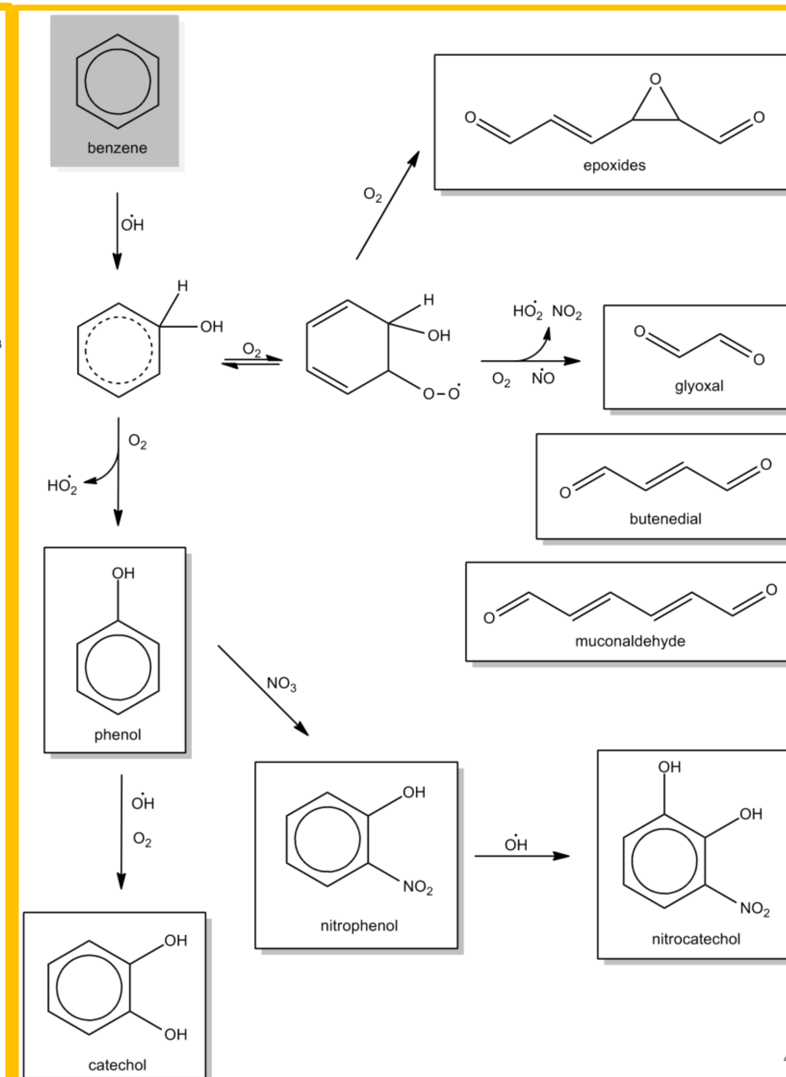


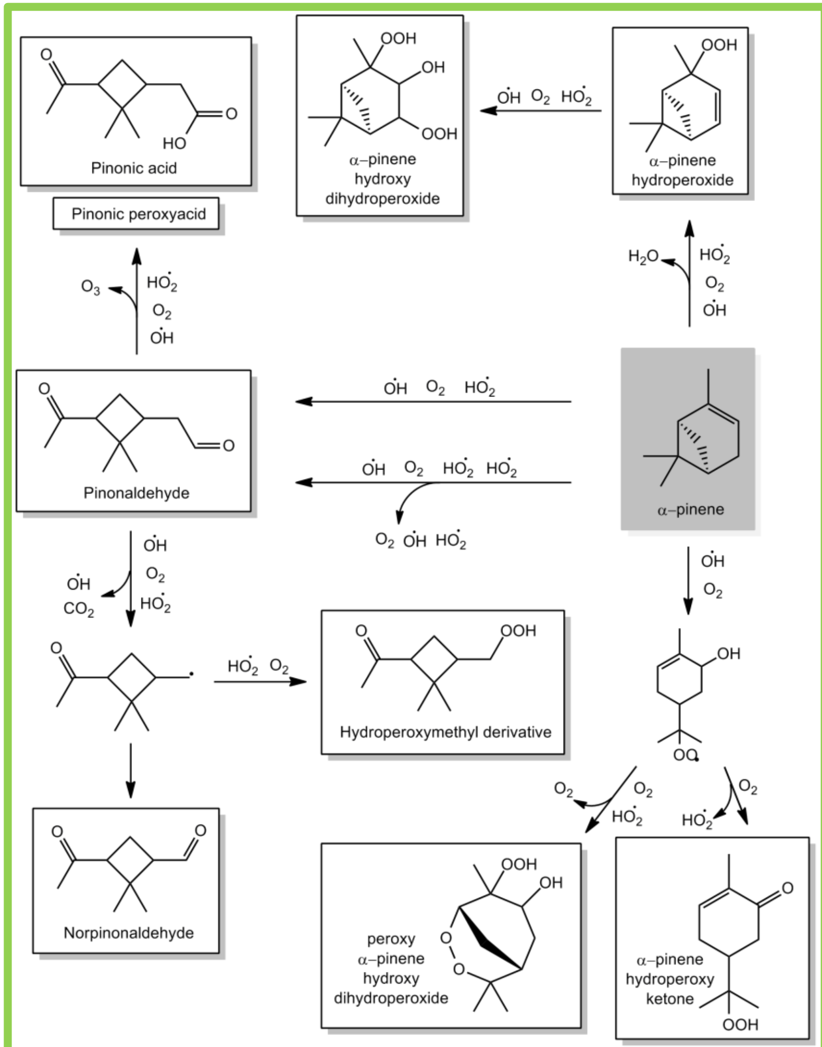
Figure 1.5: The annual indirect SOA radiative forcing; obtained using cloudy-sky radiative forcing (O'Donnell *et al.*, 2011).

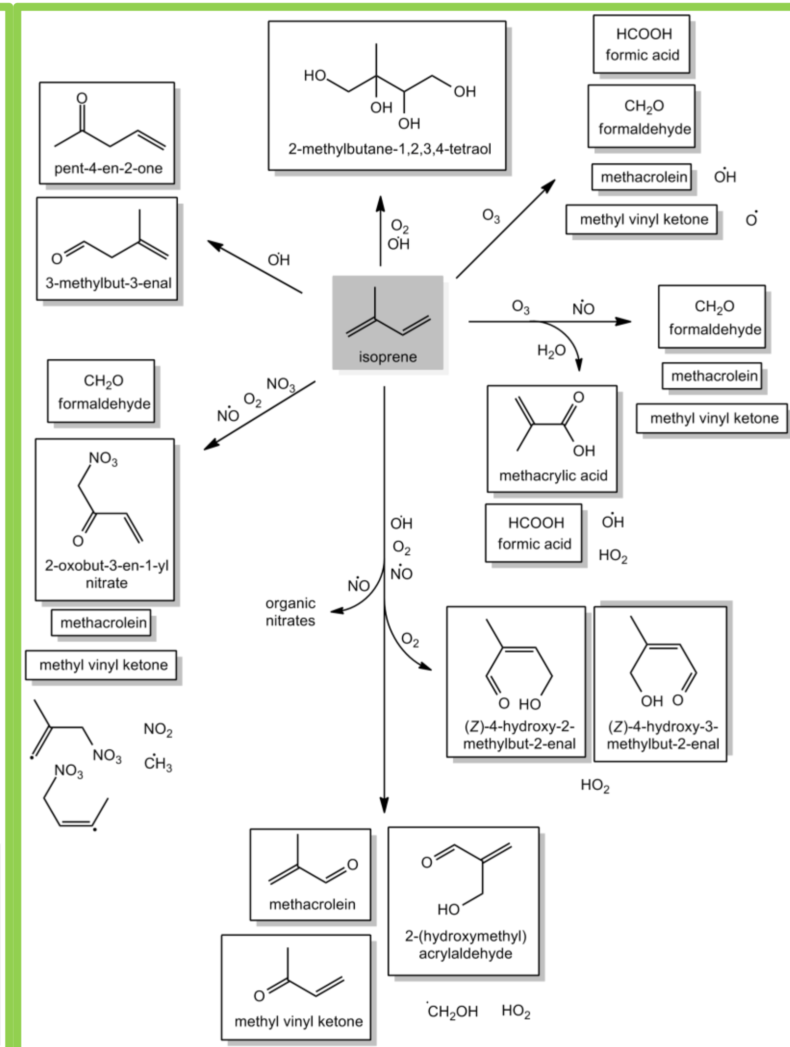
Gas-Phase reactions: Anthropogenic sources





Gas-Phase reactions: Biogenic sources





CB6-C Gas-Phase Scheme in RegCM4

	CBM-Z	**CB6-C**
variable species	57	77
reactions	124	216

- alternative to CBM-Z (Shalaby et al., 2012; Zaveri and Peters, 1999)
- Based on Carbon Bond Mechanism 6 (rev 2)
  (Yarwood et al., 2012; Ruiz and Yarwood, 2013; Goldberg et al., 2016)
- Reactions:
  - 95 similar chemical reactions;
  - additional isoprene products;
  - new oxidation mechanisms for formic acid.
- new chemical species:
  - pentane, ethyne, ethanol, acetic acids, methyl ethyl ketone, glyoxal, glycolaldehyde, benzene, nitrocresol, methacrolein, epoxides, and monoterpenes.

- **Chemical Boundary Conditions**
  - Model for Ozone and Related chemical Tracers (MOZART)
  - Climatology 1999-2009
  - Emmons et al. (2009)

CB6-C	MOZART data	Mf
Propane	Propane	3
Isoprene	Isoprene	0
Methacrolein	(Methyl vinyl ketone +Methacrolein+Hydroxycarbonyl)	4
Glycolaldehyde	Glycolaldehyde	4
Multifunc. nitrates	Organic nitrates	1
Isoprene nitrates	Isoprene+NO3 peroxy radical	1
Benzene	Toluene	0.29
Ethanol	Ethanol	1
Pinene	Pinene	1

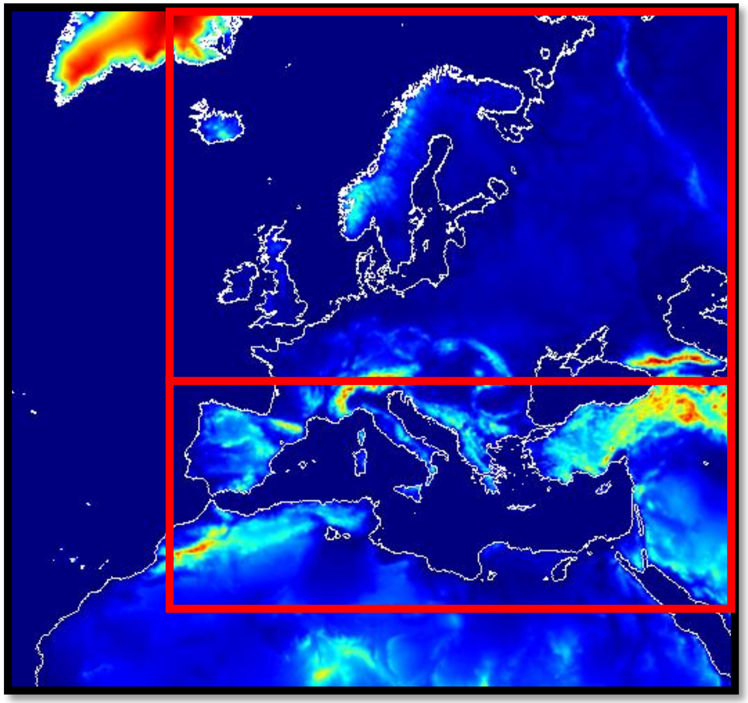
- **Emissions**
  - International Institute for Applied System Analysis (IIASA)
  - global emission database 1990 to 2010
  - Lamarque et al. (2010)
- **Photolysis Rates**
  - Madronich Tropospheric Ultraviolet (TUV) scheme
  - Madronich and Flocke (1999), Tie et al. (2003).
  - photolytic rates were assumed to be equal (or very similar) for chemicals with a similar composition

CB6-C	**J-val Source**
C3+ Peroxyacyl nitrate	Peroxyacyl nitrate
Butyl hydroperoxide	Methylhydroperoxide
Glycolaldehyde	Methacrolein
Methyl ethyl ketone	Acetone
(Z)-4-Hydroperoxy-3-methyl-2-butenal	Methylhydroperoxide
Nitro-cresols	Hydroxy/Alkyl nitrates
2-Pentenedial	Glyoxal
Butenedial	Glyoxal

CB6-C	**IIASA data**	**Mf**
Butene	Internal Olefins	7
Isoprene	Isoprene	0.05
Ethyne	Ethene	1.12
Ethanol	Ethene	0.82
Benzene	Toluene	0.29
Pinene	Isoprene	0.2

Domain & Simulation

- **Resolution:** 50 km
- **Chem Data:** MZCLM
- **SST data:** Weekly OISST
- **ICBC data:** NCEP/NCAR Reanalysis
- Time Period: 2003-2005
- Sub-regions:
  - Northern: 45 to 75 N
  - Southern: 30 to 45 N



- ICTP cluster 'Argo'
  - 60 (3 x20) processors
  - 63Gb memory

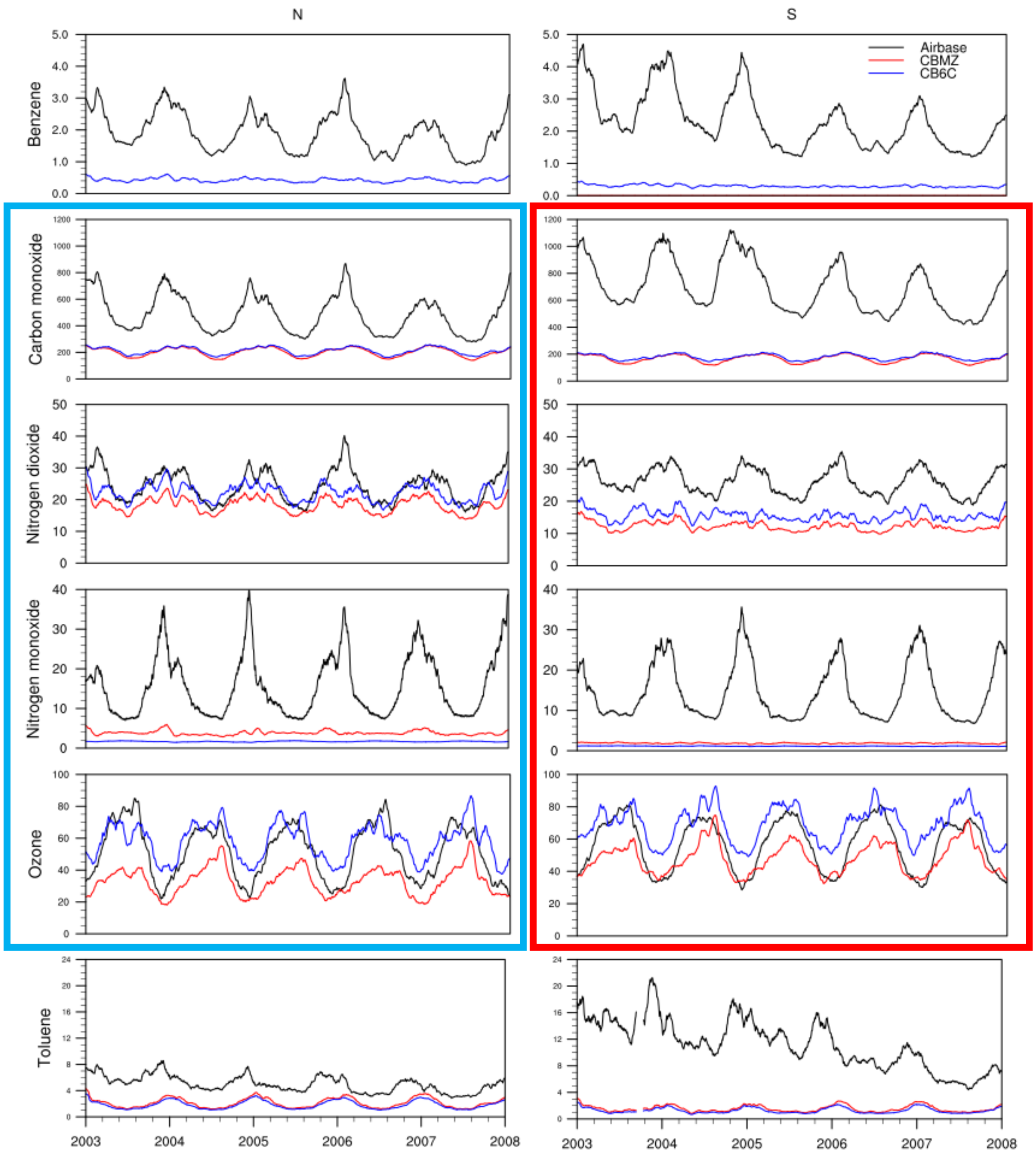
	CBM-Z	CB6-C	CB6-C Change
Sim. Time [/mon]	1.400 hr	2.092 hr	49.4 % slower
Output [/mon]	6.3 GB	9.4 GB	49.2 % bigger

Stations

- European Air quality Database (AirBase) station data

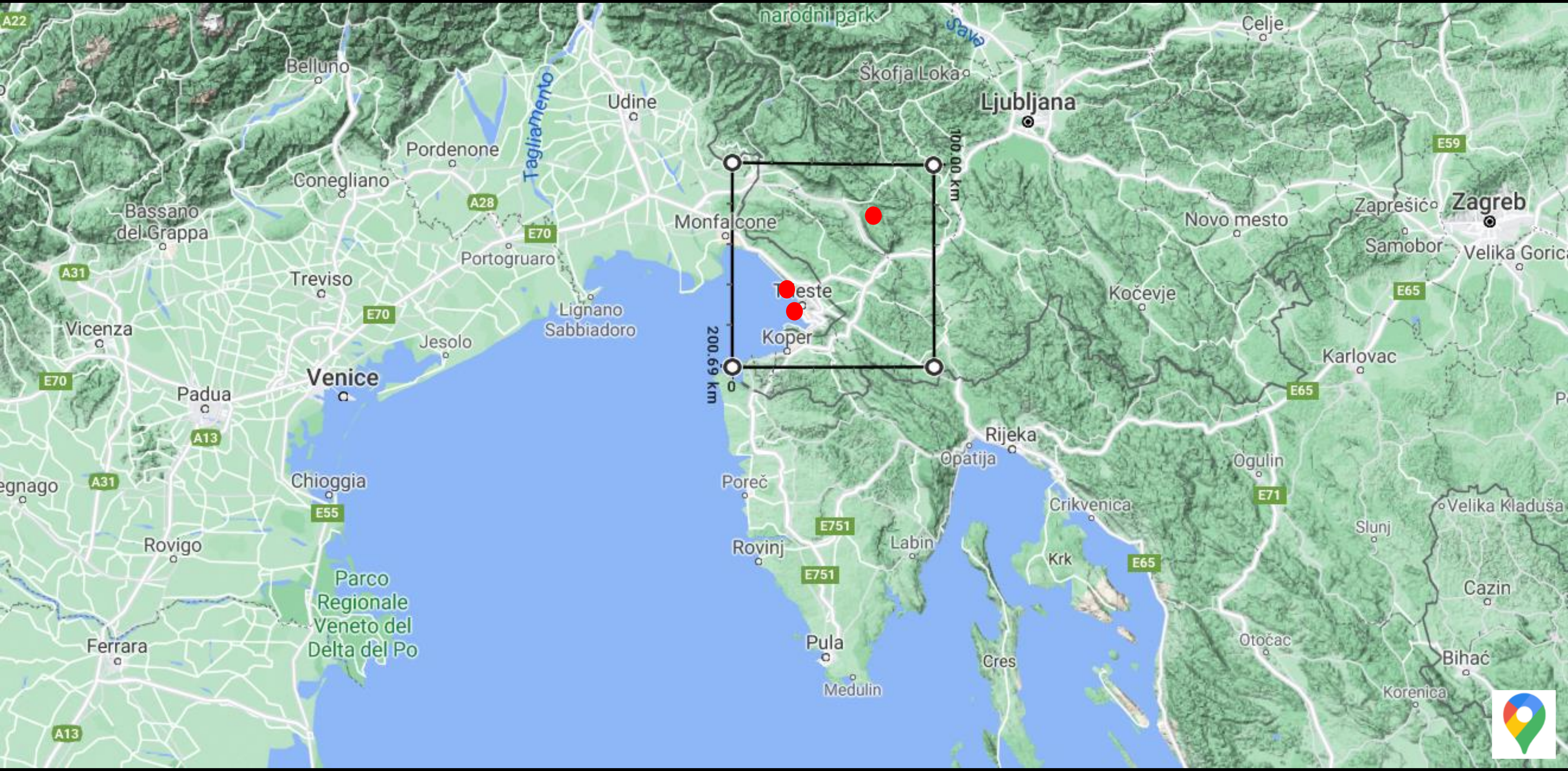
- Number of stations

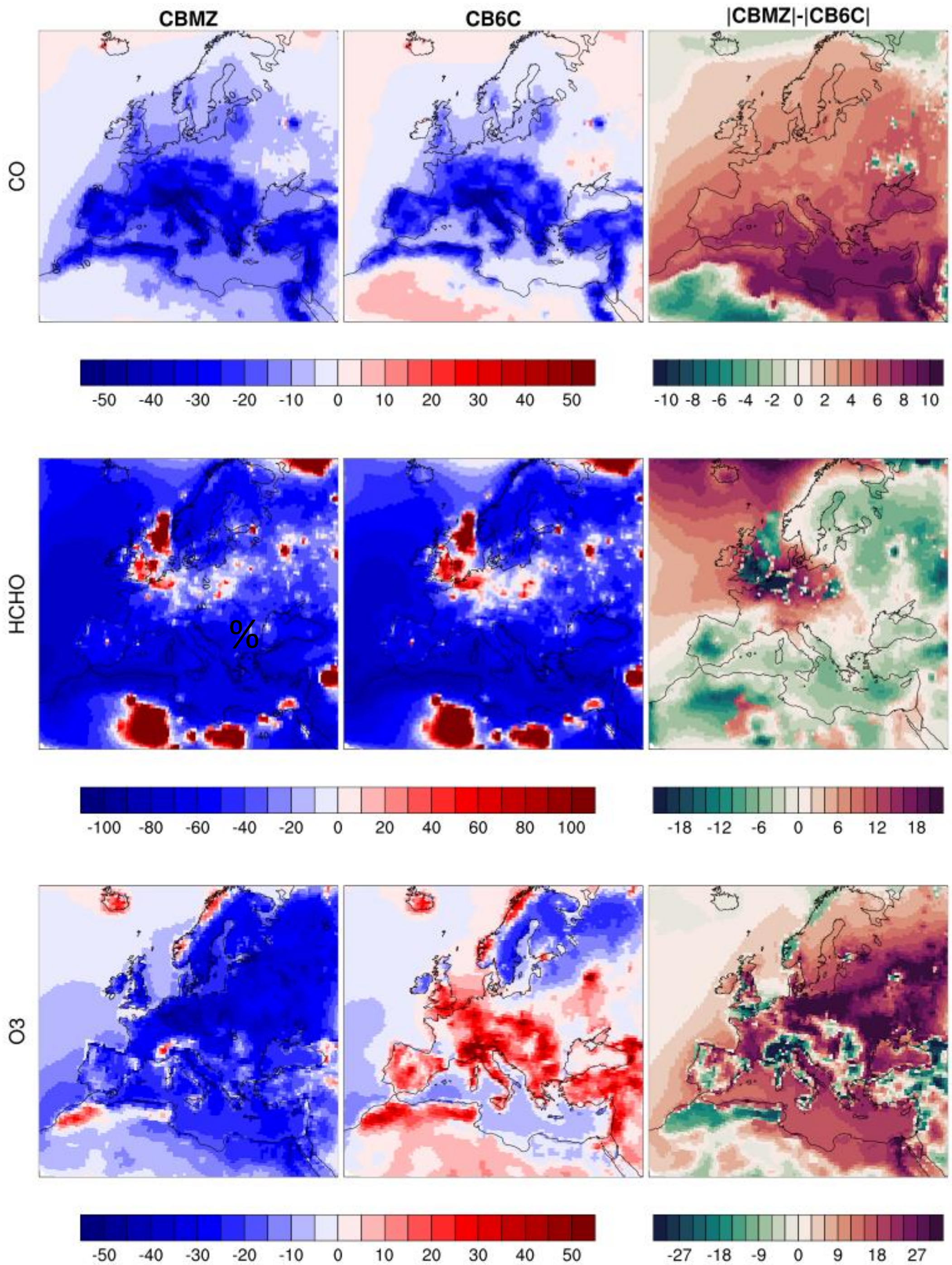
Chemical Species	N Min	N Mean	N Max	S Min	S Mean	S Max
Benzene	106	158.3	190	24	69.4	120
Carbon monoxide	**381**	**418.9**	**452**	***145***	***217.3***	***293***
Nitrogen dioxide	**801**	**927.3**	**1003**	***232***	***346.8***	***452***
Nitrogen monoxide	**401**	**523.3**	**643**	***140***	***245.2***	***349***
Ozone	**792**	**885.2**	**945**	***251***	***348.0***	***435***
Toluene	49	60.2	73	0	24.2	55



Inter-annual variability for surface concentration (ug/m^3) compared to the mean of all AirBase stations.

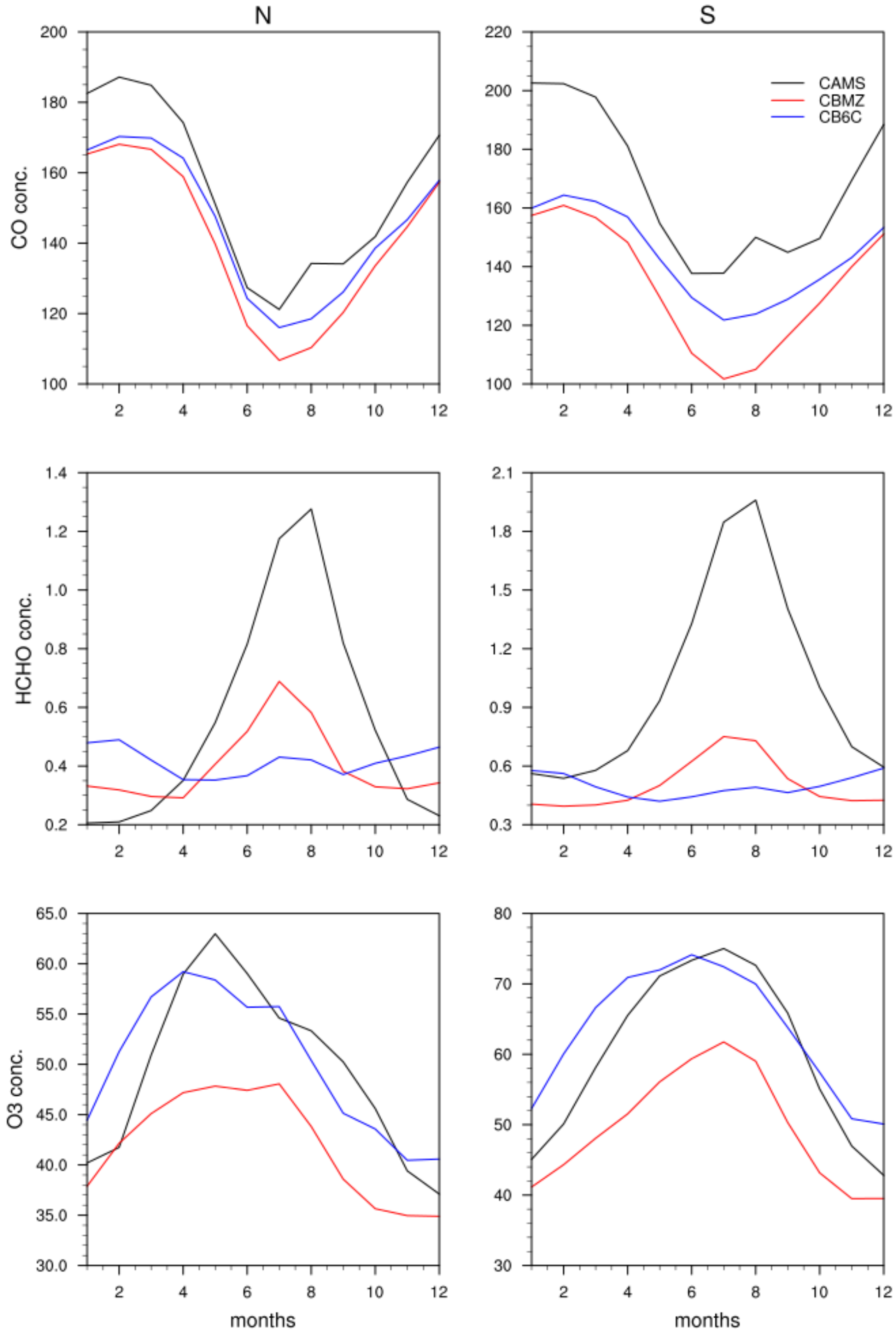
Comparing **stations** with **grid-cells**



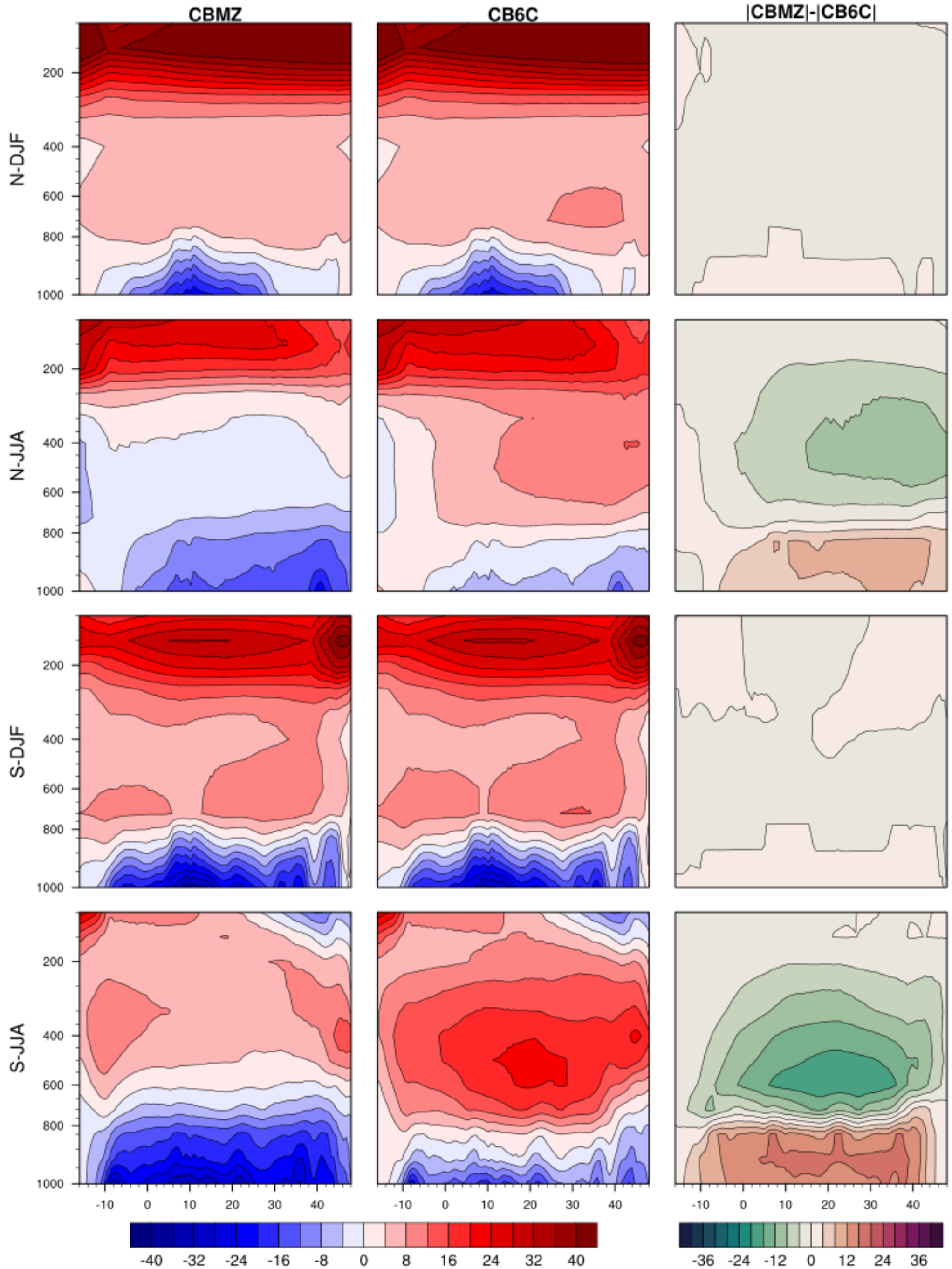


Relative bias (%) of the surface mixing ratio annual mean compared to CAMS data (Inness et al., 2019).

The right-most column shows the differences (%) between the absolute biases of the two models.



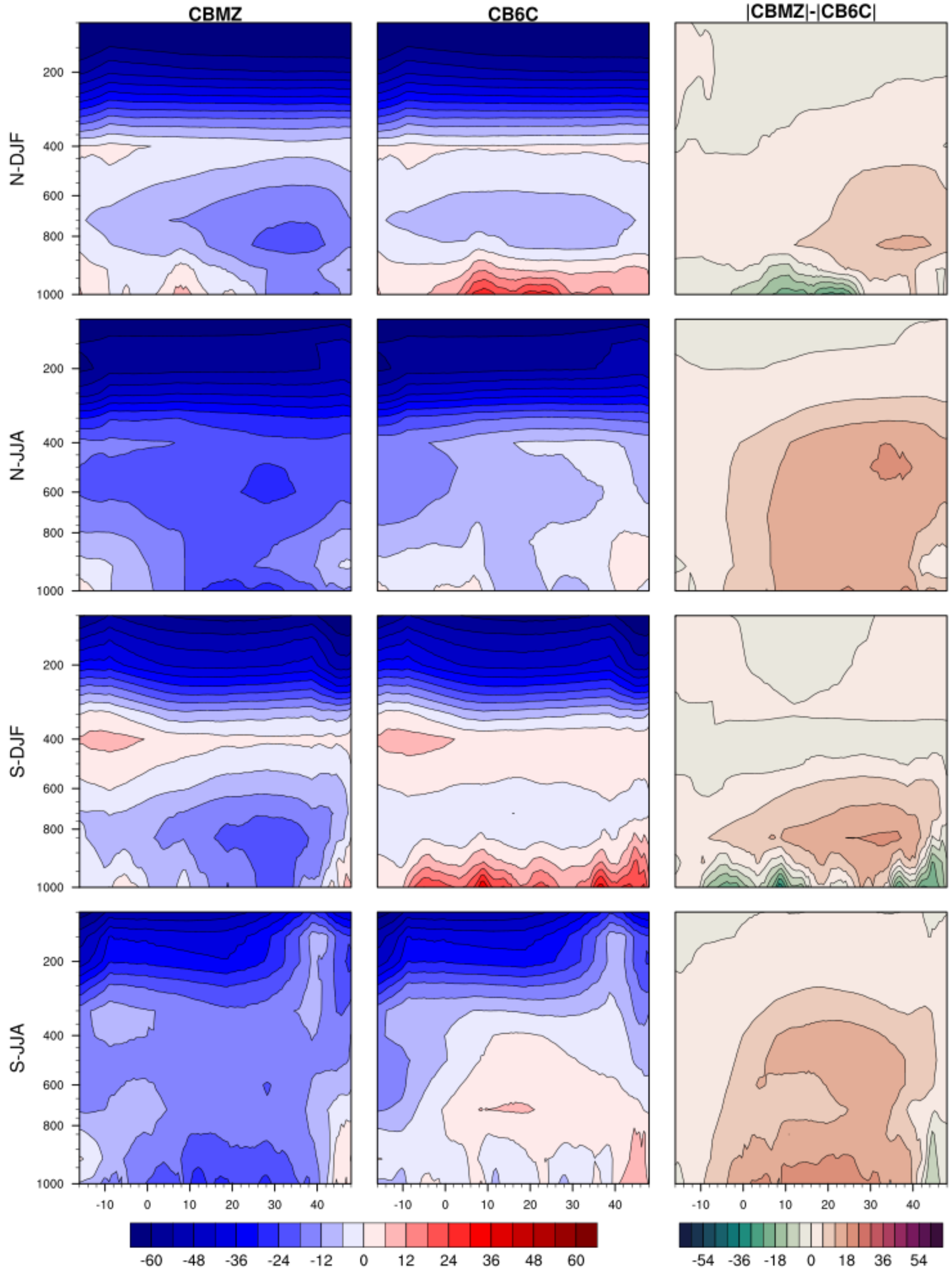
Annual cycle of surface concentration (ppb) spatial means compared to CAMS data.



Relative bias (%) of the vertical meridional means of carbon monoxide.

The right-
most column shows the differences (%) between the absolute biases.

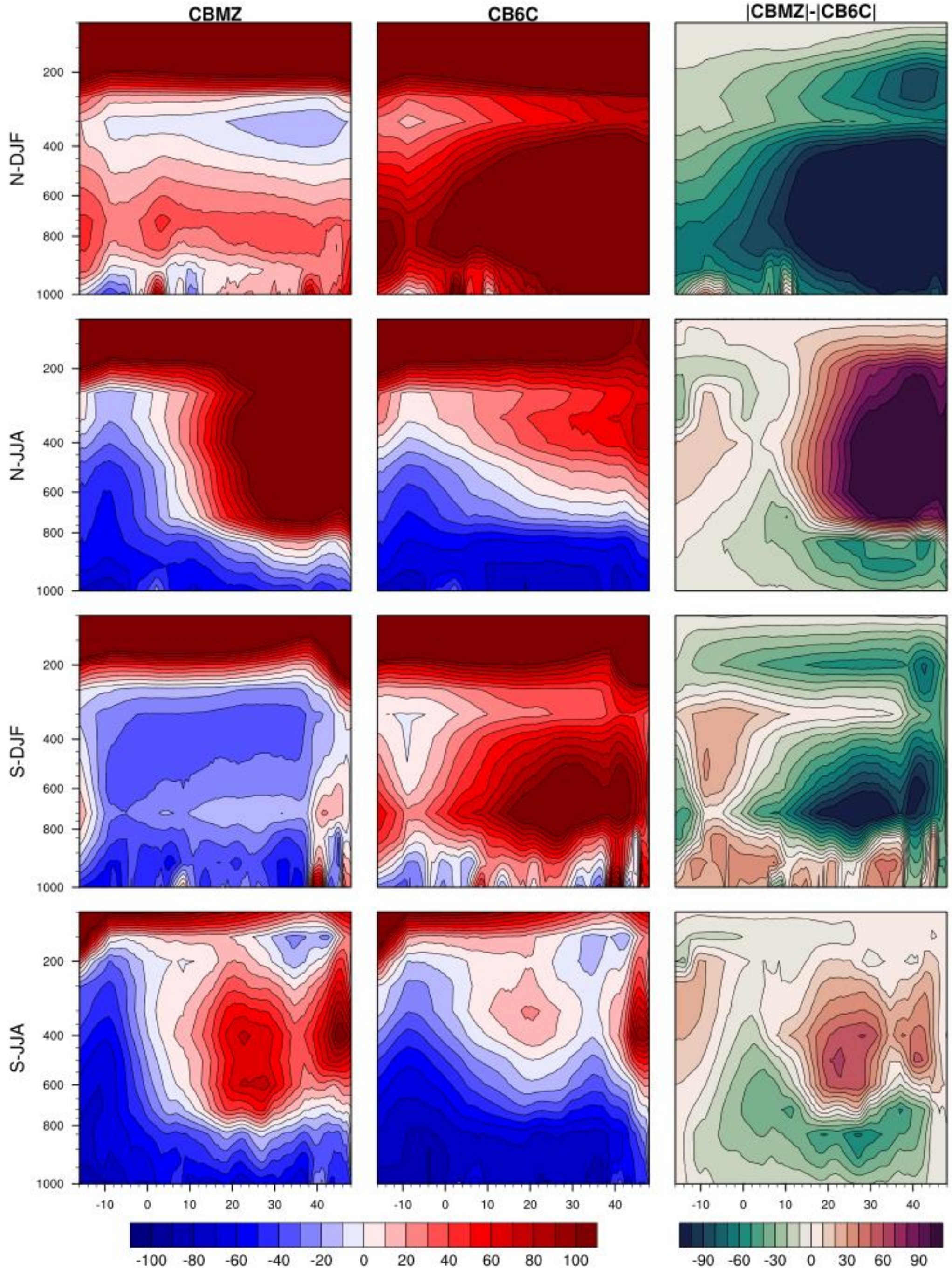
The pressure levels are expressed in hPa.



Relative bias (%) of the vertical meridional means of ozone.

The right-most column shows the differences (%) between the absolute biases.

The pressure levels are expressed in hPa.



Relative bias (%) of the vertical meridional means of formaldehyde.

The right-most column shows the differences (%) between the absolute biases.

The pressure levels are expressed in hPa.

Conclusions

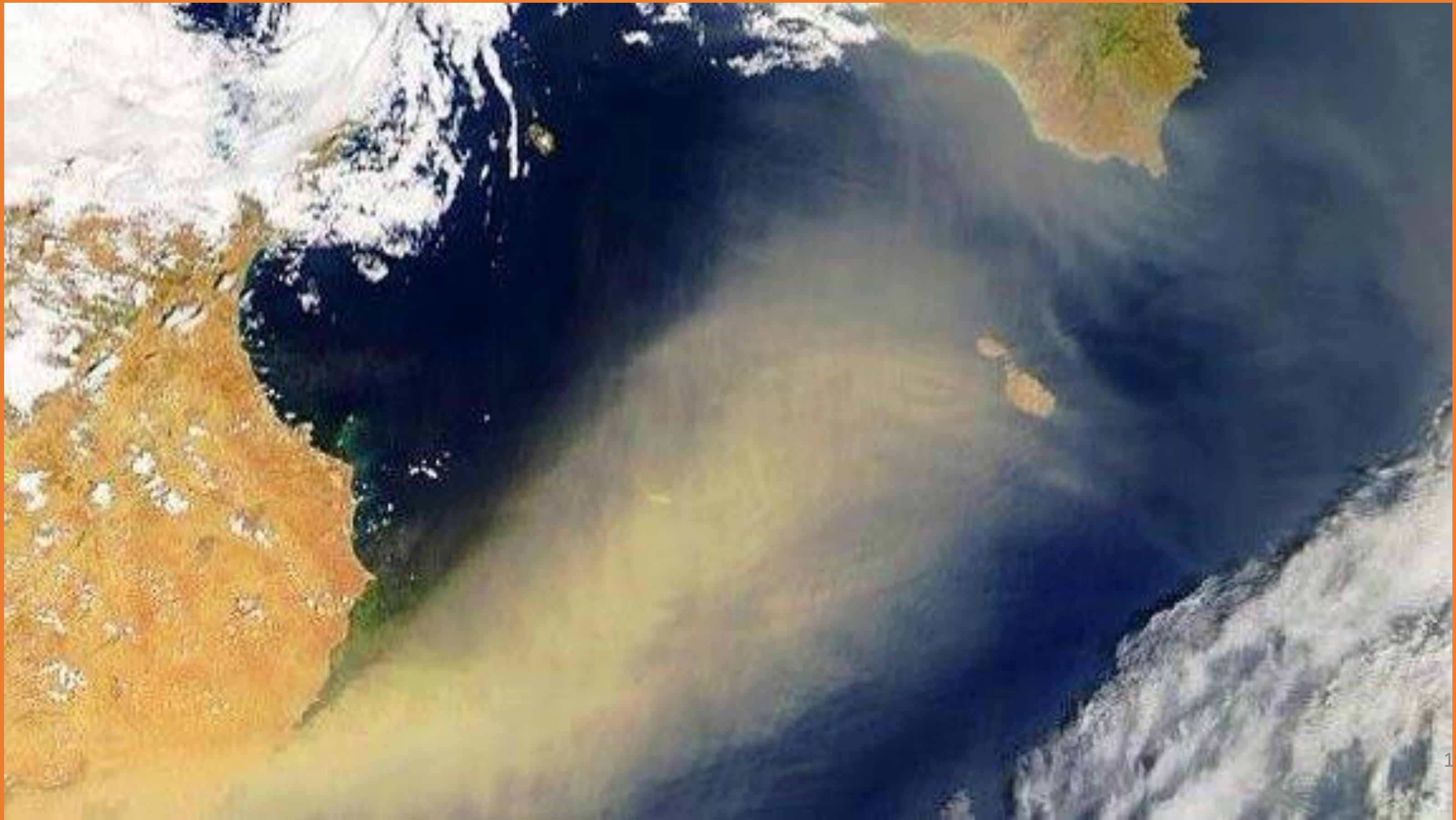
- Model is operational with reliable O_3 and CO products
- Formaldehyde and organic products require further tuning
  - Additional testing in progress…
- Next Step: Activation of SOA Module

$$\mathrm{G_p(g)} \xrightarrow{\text{oxidation}} \mathrm{G_s(g)} \xrightarrow[\text{evaporation}]{\text{condensation/dissolution}} \mathrm{G_s(aq)}$$

- Source:
  - Ciarlo` JM, et al. (*in review*). A Modified Gas-Phase Scheme for Advanced Regional Climate Modelling with RegCM4. Climate Dynamics.
- Model available at:
  - https://github.com/ciarloj/RegCM4.5-CB6C
  - Tutorial starting shortly…

Thank You

jciarlo@ictp.it



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