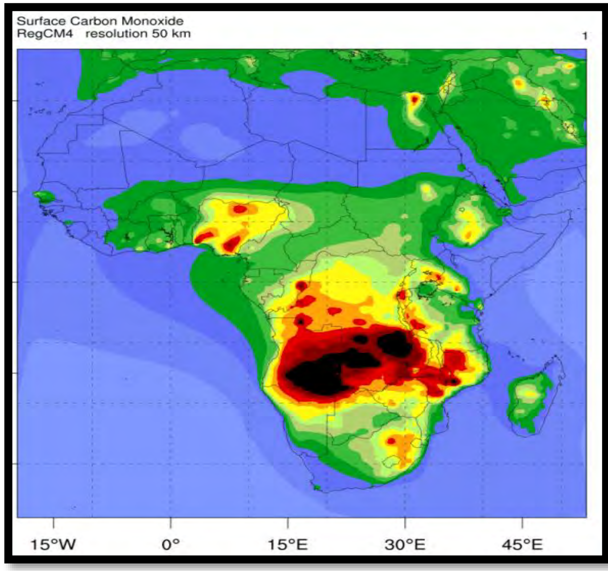
EGYPTIAN METEOROLOGICAL AUTHORITY

Seamless Prediction of Air Pollution in Africa



A. S. Zakey

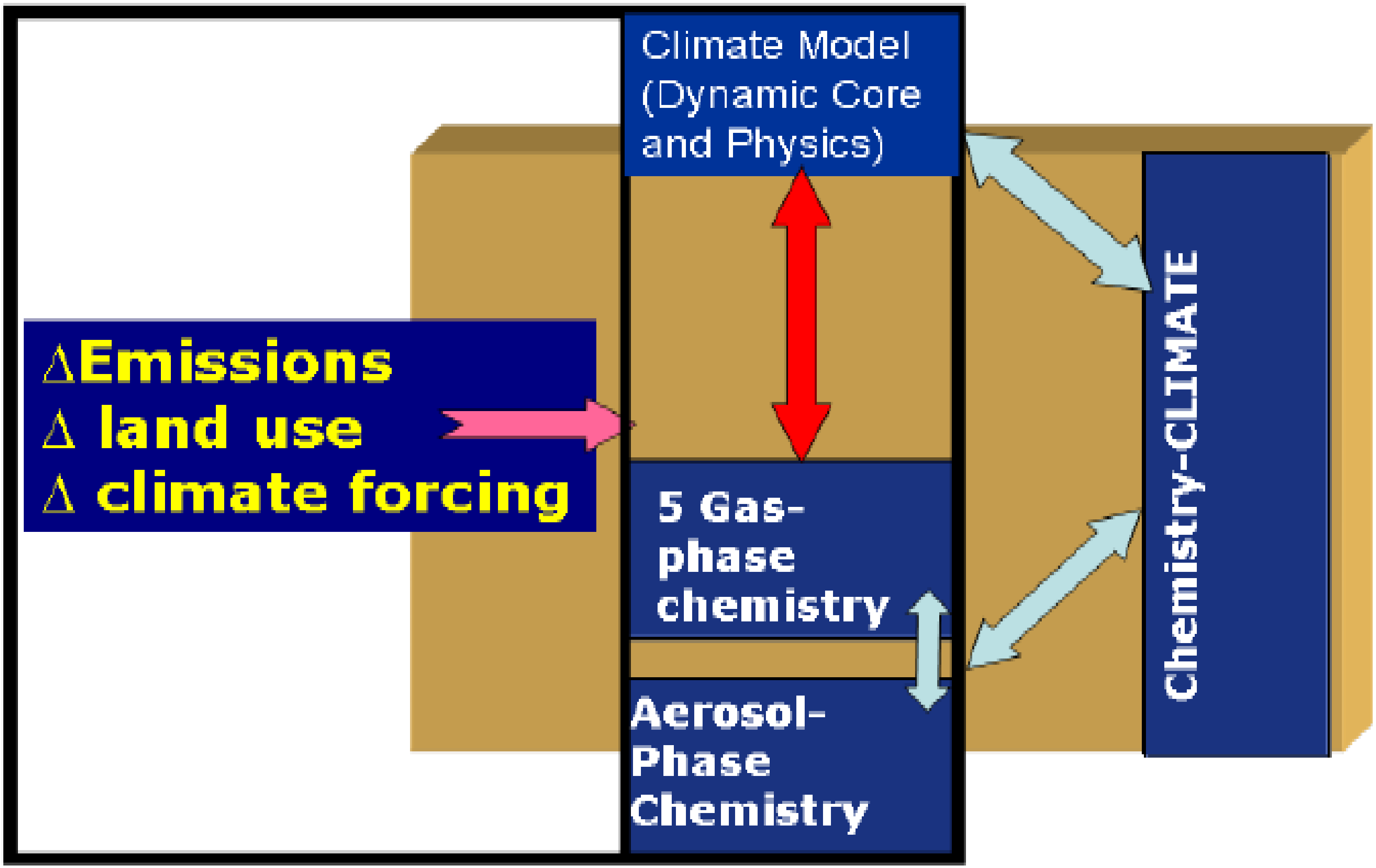
&

The RegCM Egyptian Team-work

The Egyptian Meteorological Authority

Seamless Prediction of Air Pollution in Africa, Nairobi,Kenya, 7-12 Obtober2019

On-line Integrated Regional Scale Climate Chemistry model RegCM-CHEM

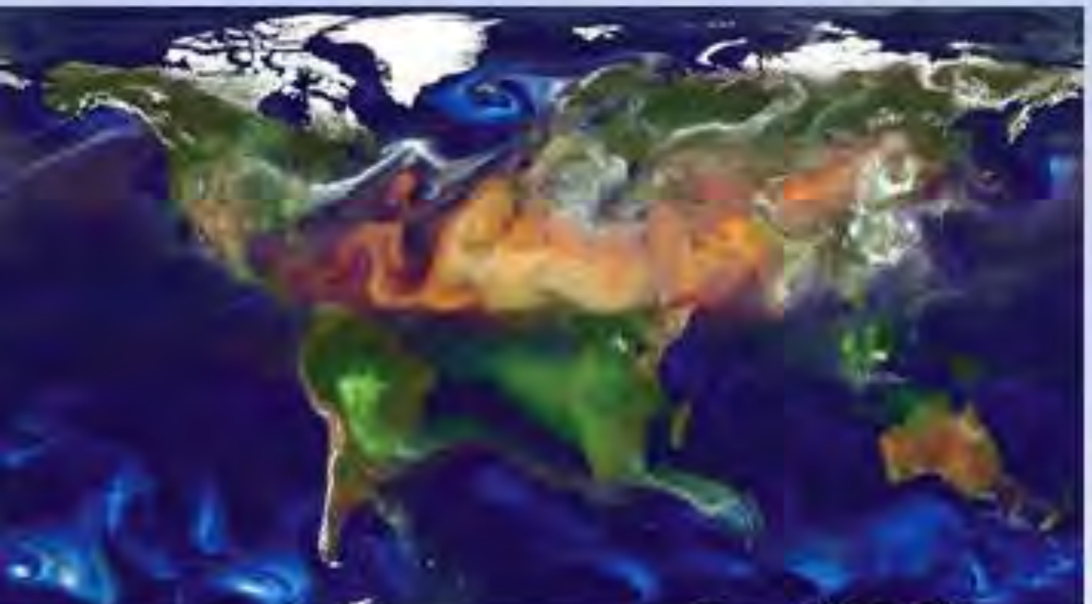


RegCM Coupled chemistry-climate model

Add prognostic tracer concentrations to the previous system .....

$$\frac{\partial \chi_i}{\partial t} = -\overline{V} \cdot \nabla \chi_i + F_H + F_V + T_{CUM} + S_{\chi_i} - R_{w,ls} - R_{w,cum} - D_{dep} + \sum Q_{p_i} - Q_{l_i}$$

Transport | Primary Emissions | Removal terms | Physico – chemical transformations



- **Anthropogenic aerosols**
- **Natural aerosols**
- **Photo-oxidant chemistry :**
  - O3 and precursors (anthropogenic, biogenic)
  - Secondary aerosols
- **Bio-aerosols (pollen)**

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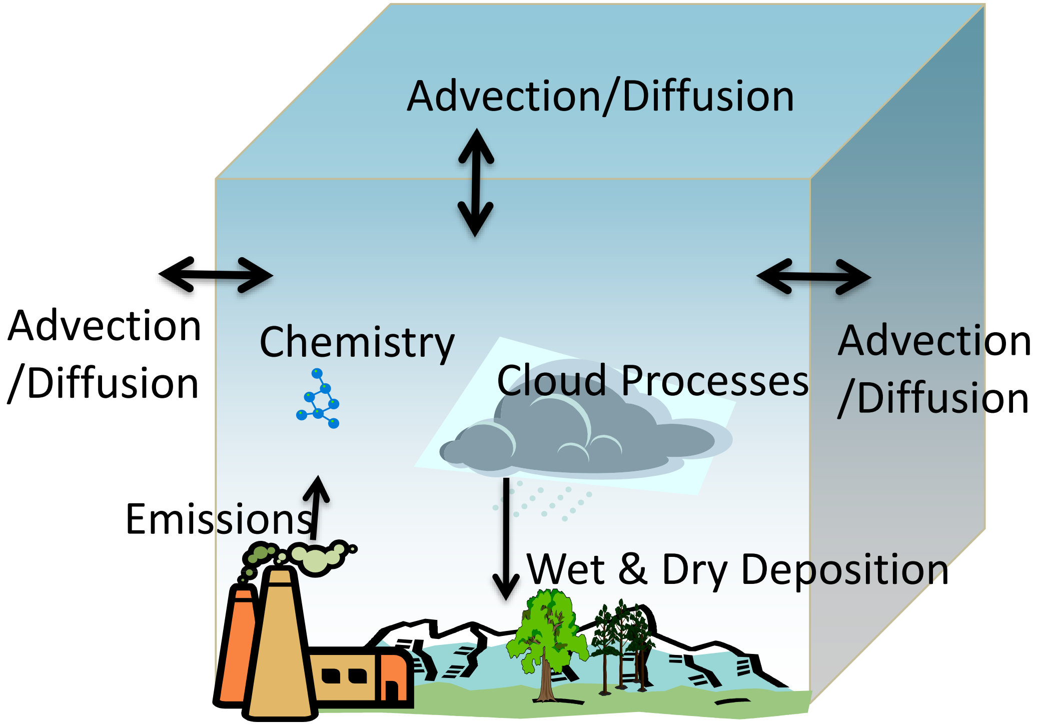
A grid cell view of atmospheric chemistry



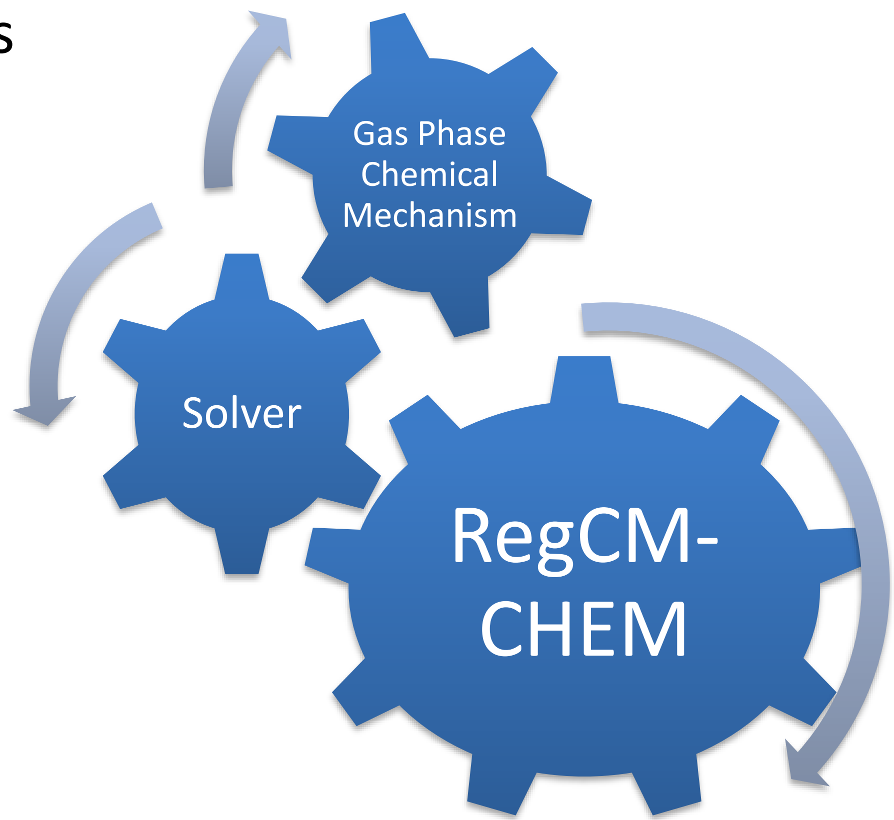
- What are the key processes for atmospheric chemistry?
- **Physical processes**: advection, diffusion, deposition, clouds & precip
- **Chemical processes**: emissions, gas-phase reactions, gas-to-particle conversion, aqueous chemistry, heterogeneous chemistry

RegCM-CHEM Gas-phase chemistry

- Incorporation of gas-phase chemistry requires:

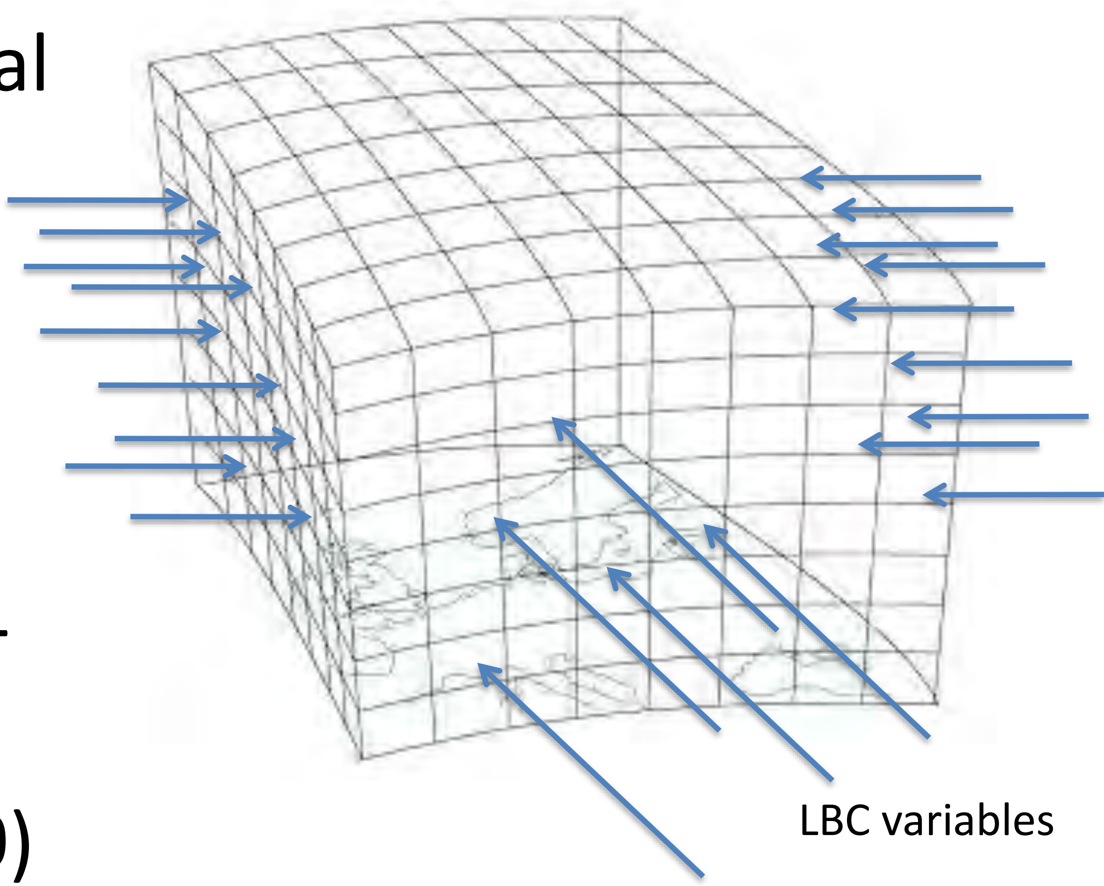
- Chemical mechanism (list of chemical reactions and species to include)
- Solver (numerical method to solve the chemical differential equations)

- Mechanism: CBMZ (Zaveri and Peters, 1999)
  - 53 species, 132 reactions
  - Developed for long-term simulations
- Solver: Radical Balance Method (RBM), Sillman



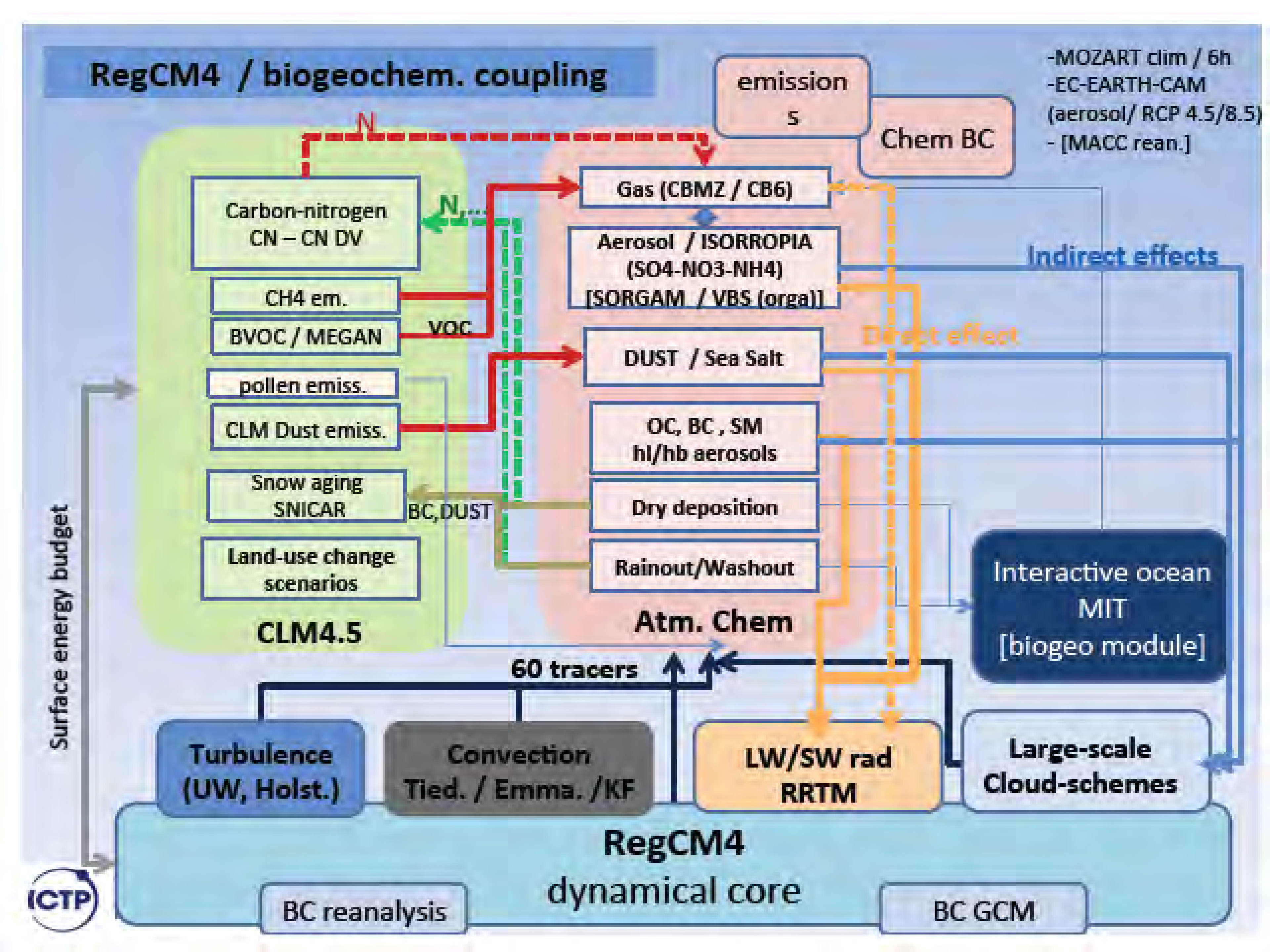
Lateral Boundary Conditions (LBC)

- Limited area runs require information provided to the lateral boundaries
- Meteorological: ERA-Interim global data, updated 6-hourly
- Chemical: MOZART monthly climatology (Emmons et al., 2010)



RegCM-CHEM: Model Description
Climate Core

- **Dynamics:**
  - MM5 Hydrostatic (Grell et al 1994)
  - Non-hydrostatic (MM5 or WRF, in progress)
- **Radiation:**
  - CCM3.6.6 (Kiehl 1996)
  - RRTM
- **Large-Scale Clouds & Precipitation:**
  - SUBEX (Pal et al 2000)
- **Cumulus Convection:**
  - Grell (1993) + FC80 Closure
  - Anthes-Kuo (1977)
  - MIT/Emanuel (1991)
  - Betts-Miller (1993)
  - STRACO (in progress)
- **Boundary Layer:**
  - Holtslag (1990)
- **Nesting:**
  - Numerous GCM/Reanalysis Interfaces
  - One-way nesting
- **Biogenic Emiss:**
  - MEGANE (Twffic, 2010)
- **Tracers/Aerosols:**
  - Qian et al (2001) – sulfur chem.
  - Solmon et al (2005) – BC/OC chem.
  - Zakey(2006,2008) – dust/ sea salt
  - Shalaby (2010) – gas-phase chem. (vectoized vers. By Ashraf Zakey)
- **Land Surface:**
  - BATS1e (Dickinson et al., 1993)
  - SUB-BATS (Giorgi et al., 2003)
  - CLM (Dai et al., 2003, Dai & Bi, in progress)
  - IBIS (Foley; Winter in progress)
- **Ocean Fluxes:**
  - BATS1e (Dickinson et al., 1993)
  - Zeng et al (1998)
  - Air-Sea Coupling (MITogcm, OASIS coupler, in progress)
- **Computations:**
  - User-Friendly
  - Multiple Platforms
  - Parallel Code


RegCM4 / biogeochem. coupling
emission
s
Chem BC
-MOZART clim / 6h
-EC-EARTH-CAM
(aerosol/ RCP 4.5/8.5)
- [MACC rean.]
N
N
Carbon-nitrogen
CN – CN DV
CH4 em.
BVOC / MEGAN
VOC
pollen emiss.
CLM Dust emiss.
Snow aging
SNICAR
BC,DUST
Land-use change
scenarios
CLM4.5
Gas (CBMZ / CB6)
Aerosol / ISORROPIA
(SO4-NO3-NH4)
[SORGAM / VBS (orga)]
Indirect effects
Direct effect
DUST / Sea Salt
OC, BC , SM
hl/hb aerosols
Dry deposition
Rainout/Washout
Atm. Chem
Interactive ocean
MIT
[biogeo module]
Surface energy budget
60 tracers
Turbulence
(UW, Holst.)
Convection
Tied. / Emma. /KF
LW/SW rad
RRTM
Large-scale
Cloud-schemes
RegCM4
dynamical core
BC reanalysis
BC GCM
ICTP

Sulfate-Nitrate-Ammonium formation via thermo equilibrium

RegCM-CHEM

1: Formation of H2SO4

2: ISORROPIA (Nenes et al.)

determine thermodynamical <u>equilibrium</u>

- semi-volatile compounds partition

- Speciation of the solution e.g. ammonium nitrate) + pH

Scavenging of gas (SO2/NOx) by the dust or sea salt particle

Dissolution kinetic of minerals : cations (Ca2+, K+, NA+) : new tracers

New thermodynamical equilibrium

Not yet implemented

Perspective biogeochem. coupling e.g. Fe

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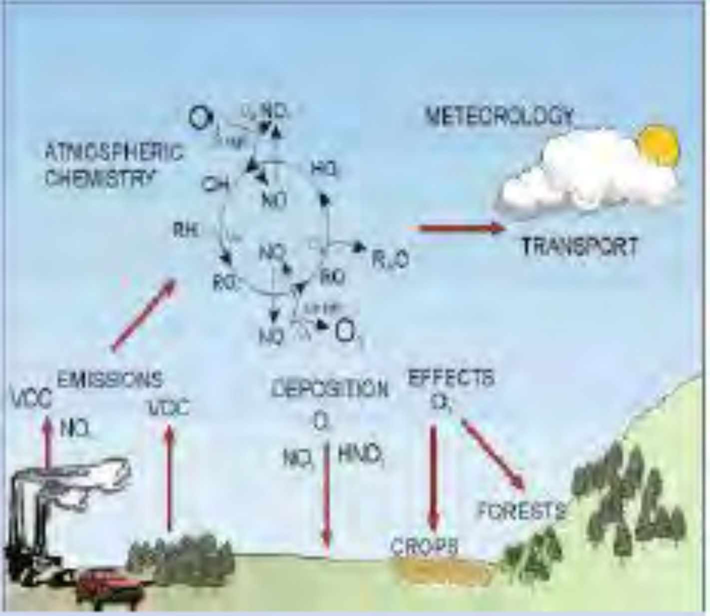
Gas phase chemistry

- **CBMZ / initially Shallaby et al., GMD, 2012**

  ODE Solver : now use KPP
  (check wikipedia ..)

  More tracer transported (SL adv)

  Boundary conditions :
  MOZART –clim 2000-2007
  MOZART 6h : for the period 2000-2009
  … soon to come : MACC reanalysis at 6h
  … MOCAGE / ARPEGE / hist +RCP at 6h



- **Developing branch :**

  CB6r2 / J. Ciarlo's PhD : allows a better representation of SOA precursors
  …. Yet to be merged … (try to catch up with Graziano …)

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The Main Products

- **Gases:** such as CO, O3, NOx, SO2
- **Aerosols:** such as SO4, BC, OC, ANH4, ANO3, Sea Salt and Dust
- **Optical properties of Aerosols:** such as Aerosol optical Depth, asymmetry parameter, and Radiative forcing.
- **Radiation:** such as short and long wave net radiation.
- **Indices related to air quality and health**: Air Quality Health Index and Ventilation index.
- **Common Meteorological parameters:** Air temperatures, precipitation, Relative humidity, wind, and mean sea level pressure, in addition to other many different variables.

Configuration of RegCM4-Africa

Parameter	
Meteorological field: Initial and Boundary conditions (ICBC)	ERA-entrim (with 1.5 degree resolution)
Dynamical Core	MM4 Hydrostatic (Giorgi et al., 1993a,b)
Radiation scheme	CCM3 (Kiehl, 1996)
Large-Scale Clouds & Precipitation scheme	SUBEX (Pal et al., 2000)
Cumulus convection scheme	Emanuel (1991) over Ocean & Land
Boundary Layer scheme	Modified Holtslag (Holtslag, 1990)
Land Surface model	BATS (Dickinson et al., 1993)
Interactive Aerosols	Organic and black carbon, SO4 (Solmon et al. 2006) Dust (Zakey et al. 2006) Sea salt (Zakey et al. 2008) (with feedback interactions)
GAS phase chemistry	CBMZ (Shalaby et al. 2011)

Area Configuration

Parameter	
Center latitude	00.00
Center longitude	17.00 E
Number of points in x-axis & y-axis	192 & 167
Projection	ROTMER (Rotated Mercator)
Horizontal resolution	50 km x 50 km
Vertical resolution	18 sigma-layers

RegCM-CHEM: Model Description
Chemistry Core

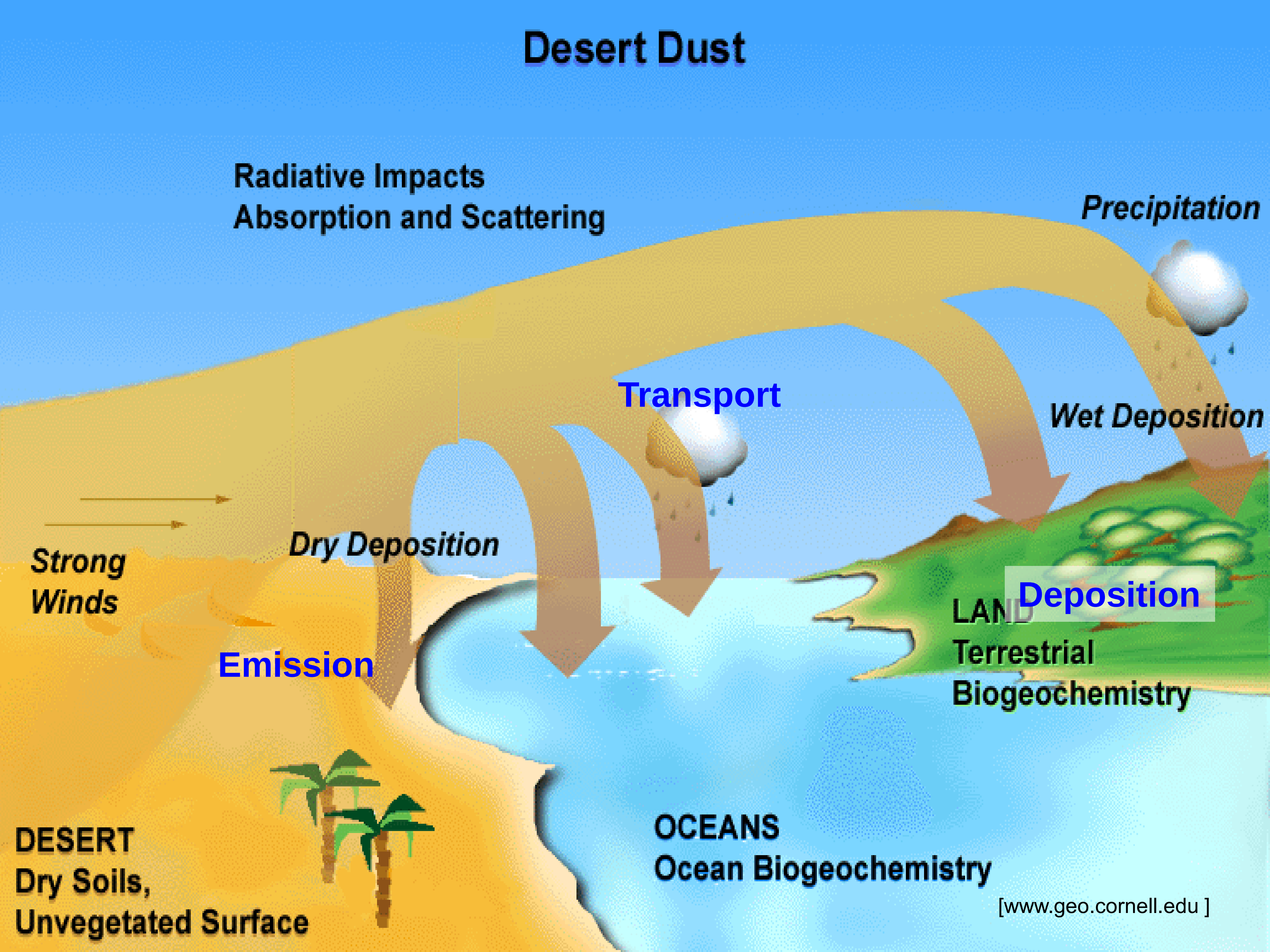
Chemistry:
Condensed CBM-Z gas-phase chemistry (Zaveri and Peters, 1999).

Solver:
Radical balance method (RBM) by (Sillman et al., 1991) and (Barth et al., 2002)

Photolysis rates:
Tropospheric Ultraviolet-Visible Model (Madronich and Flocke, 1999) with cloud cover correction by (Chang et al., 1987)

Dry deposition:

- "big leaf" multiple resistance model with aerodynamic, quasi-laminar layer, and surface resistance for 31 gaseous species.
- uptake resistance for vegetation, soil, water, snow and ice (20 land-use types).
- stomata and non-stomata resistances


Desert Dust
Radiative Impacts
Absorption and Scattering
Precipitation
Transport
Wet Deposition
Dry Deposition
Strong
Winds
Emission
Deposition
LAND
Terrestrial
Biogeochemistry
OCEANS
Ocean Biogeochemistry
DESERT
Dry Soils,
Unvegetated Surface
[www.geo.cornell.edu]

Aerosol dust modeling in RegCM-CHEM (Zakey et al., 2006 ACP)

Input parameters

Soil texture (12 types, USDA)

Soil erodible dry aggregates distribution (Shao et al. ,2002**)**

Land surface properties (BATS)

(roughness, soil humidity, cover fractions)

RegCM atmospheric variables

(surface wind, air temperature, air density)

DUST emission scheme

Zakey et al., 2006

Saltation (Marticorena et al. 1995)

Roughness and humidity correction

Sand-blasting (Alfaro et al., 1997, 2001)

Dust flux distribution

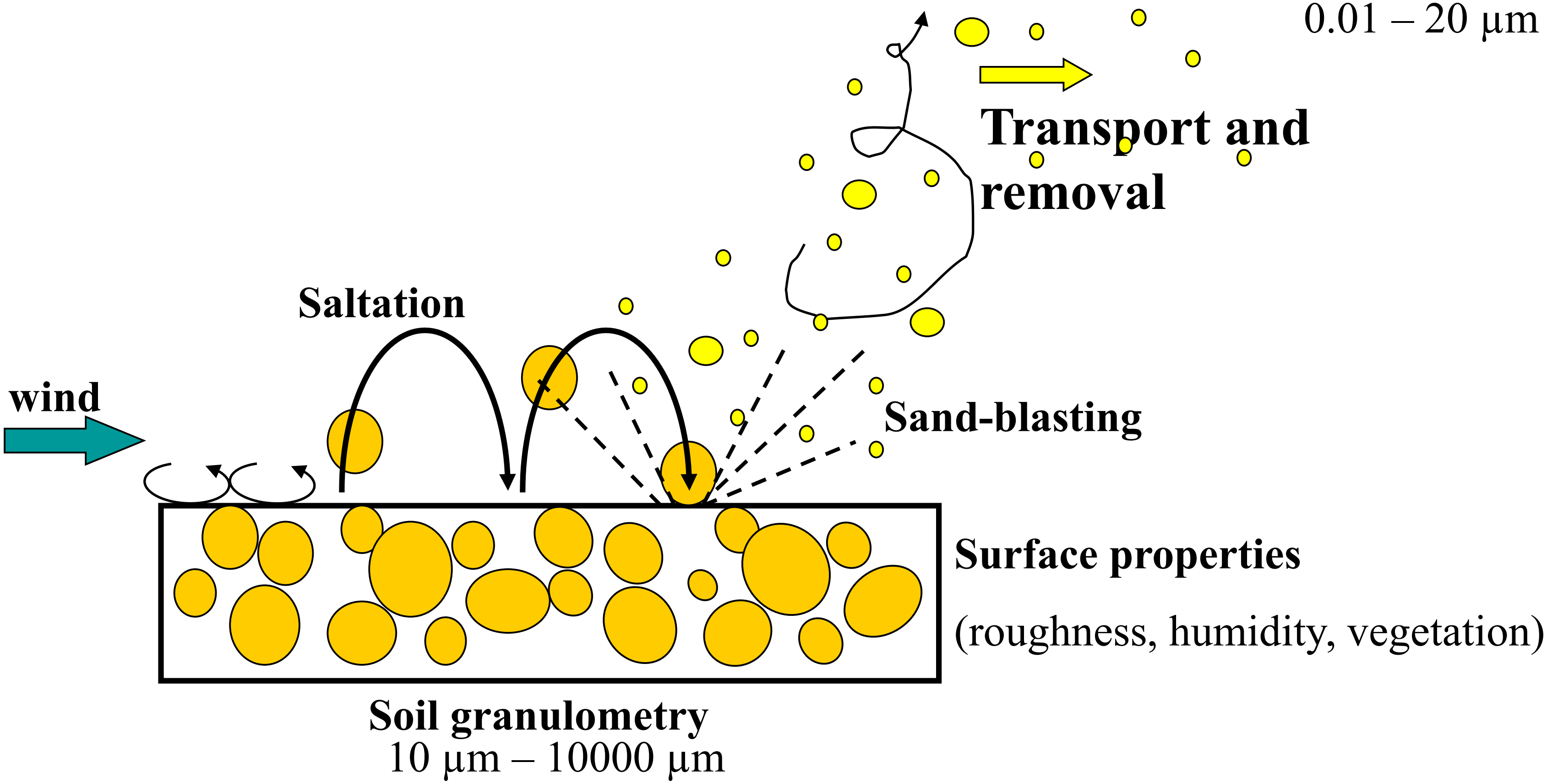
(3 log-normal emission modes)

Transport bins (up to 12), usually 4

Size dependent settling and surface déposition

AOP / radiation

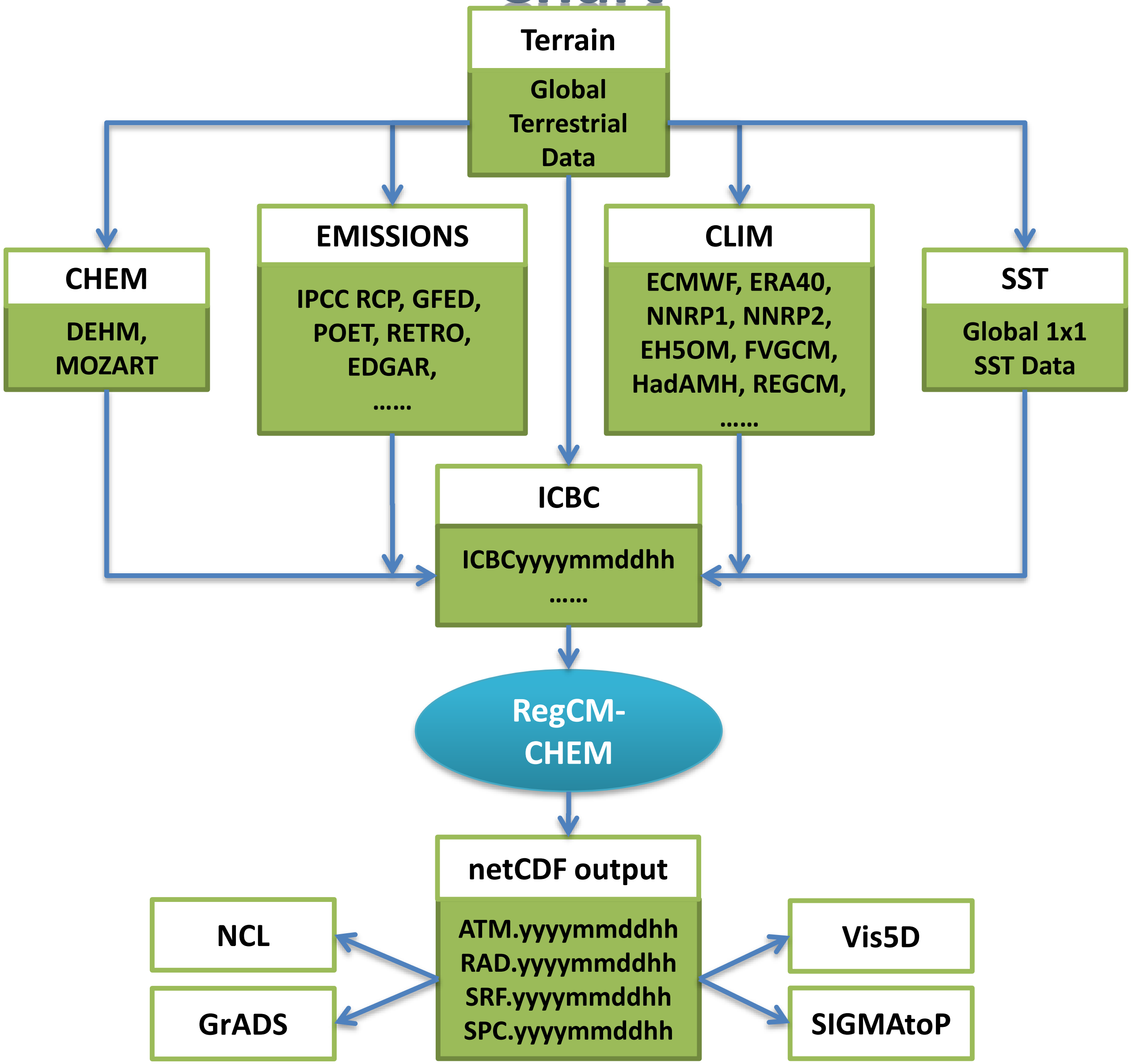
Regional climate modelling approach



Zakey et al., 2006

RegCM-CHEM

RegCM-CHEM : Modeling System Flow Chart



RegCM-CHEM setup

Global Climate Model EH5OM run (2000) res.: 1.875° x 1.875°	MOZART CHEM ICBCs	IPCC-RCP4.5 Emissions (2010) res.: 0.5° x 0.5°
Input parameters: surface pressure, geopotential, relative humidity, air temperature, wind velocity	**Input parameters:** O_3, H_2O_2, NO, NO_2, N_2O_5, HNO_3, SO_2, SO_4, CH_4, HCHO, CO, C2H_6, CH_3CHO, PAN, nC_4H_{10}, oXylene, Isoprene, NH_3, NH_4NO_3, ANIT, NH_4HSO_4, $NH_4{}^2SO_4$, CH_3OH, CH_3OOH, C_2H_5OH, C_2H_4, C_3H_6, C_3H_8, CH_3COCH_3, BIGENE, BIGALK, TOLUE, DMS	**Input parameters:** SO_2, CH_4, CO, NH_3, NO_x, OC, BC, acids, alcohols, benzene, butanes, chlorinated, esters, ethane, ethene, ethers, ethyne, formaldehyde, hexanes_and_higher_alkanes, ketones, other_alkanals, other_alkenes_and_alkynes, other_aromatics, pentanes, propane, propene, toluene, trimethyl_benzenes, xylene

EMISSION

RegCM-CHEM Emissions Preproc tool:

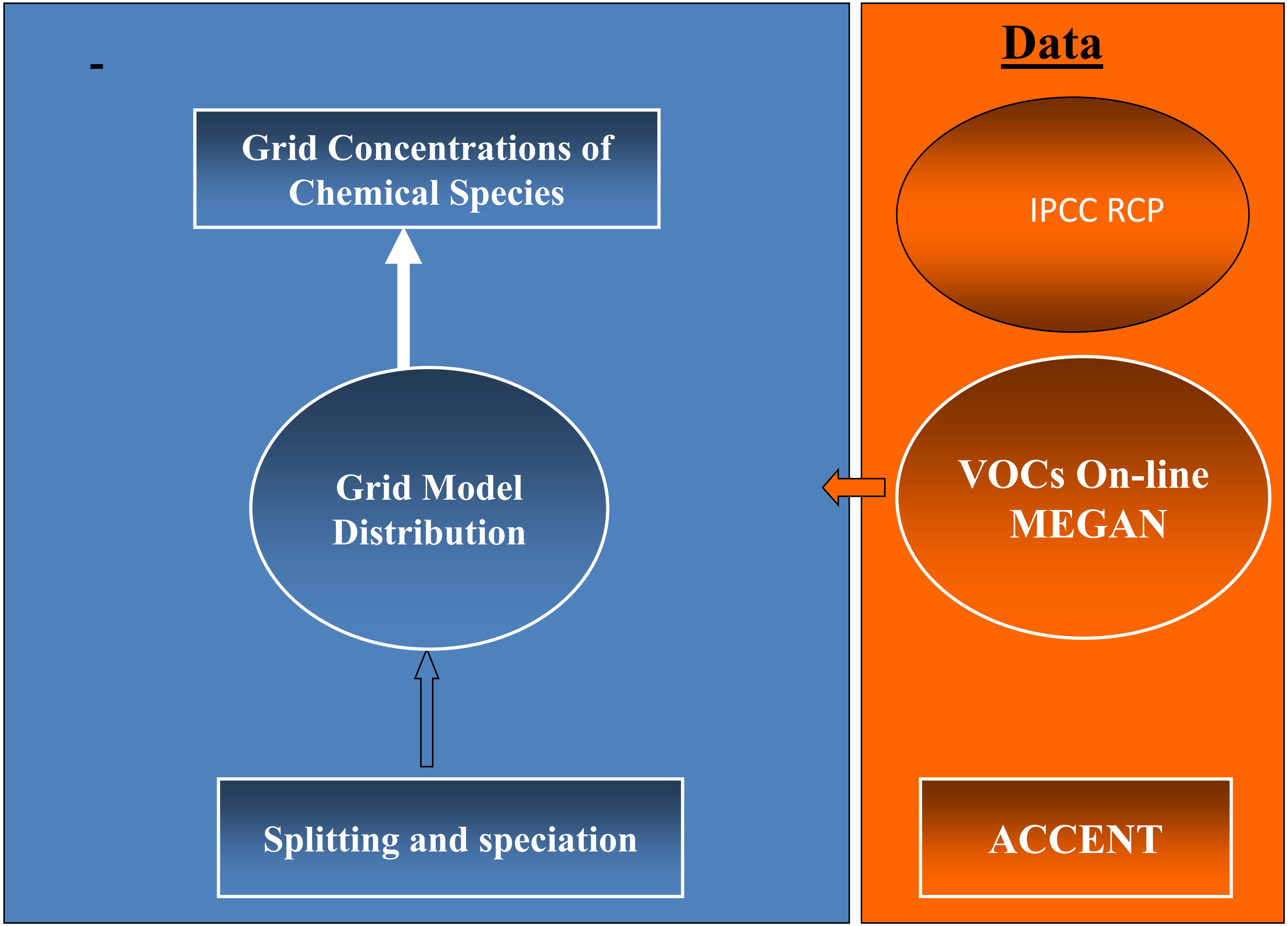
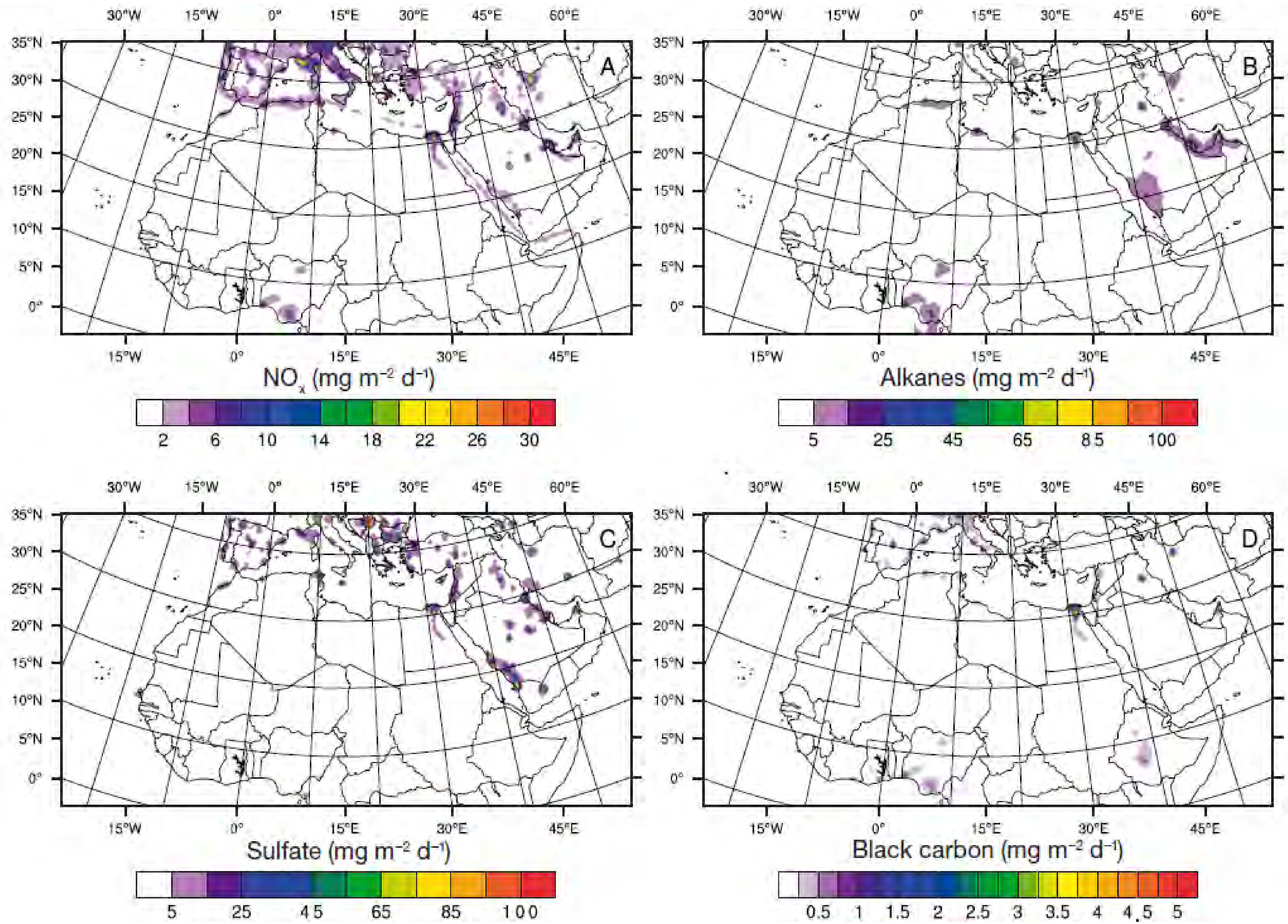
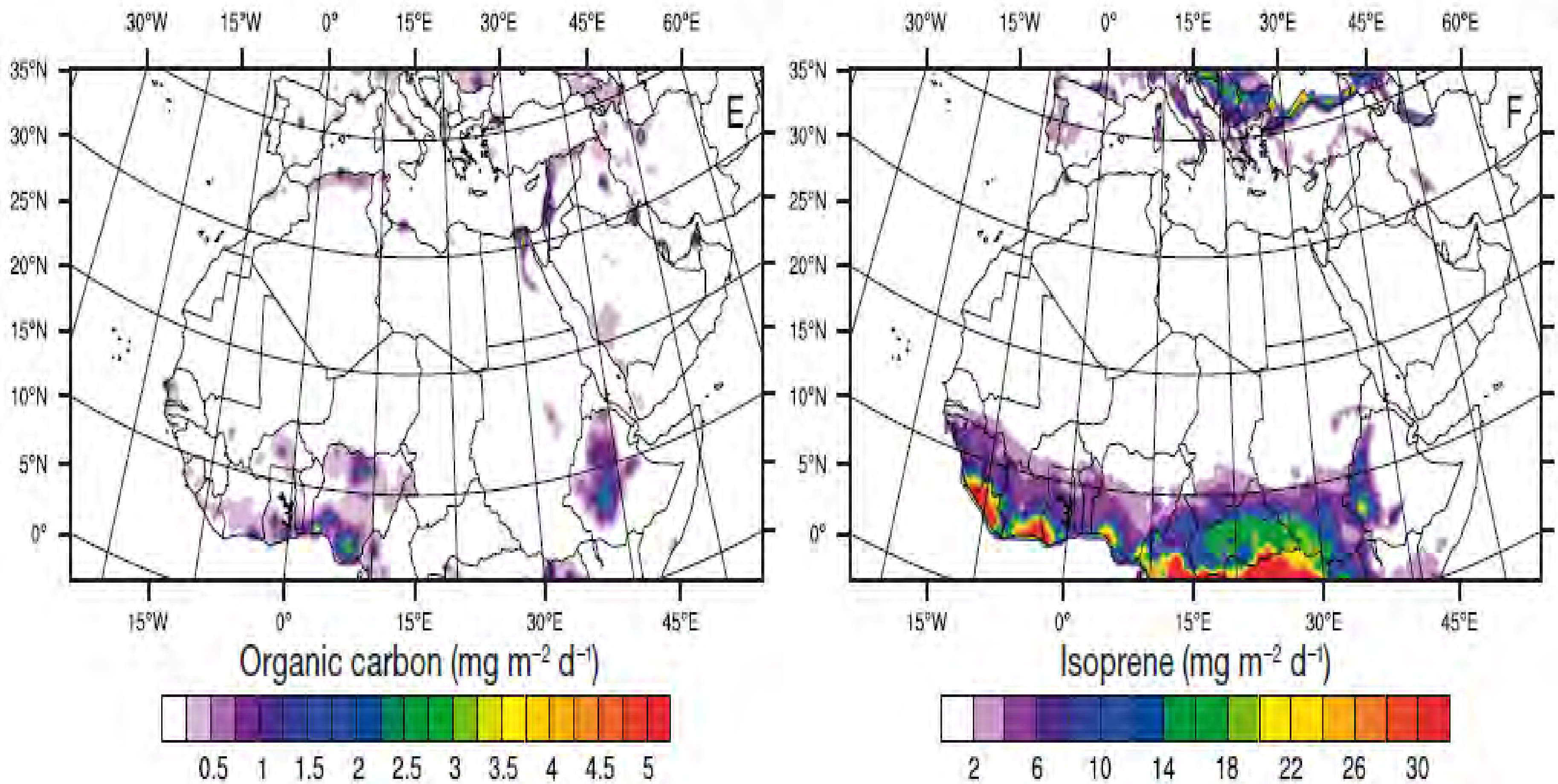


Table 1. Emissions inventories used to generate simulations of emissions of chemical compounds from different sources by the online, coupled regional chemistry–climate model RegCM4-CHEM for the Greater Cairo region. See Section 2.2. for explanations of abbreviations used to designate the inventories. The final column shows the abbreviations used to designate the same compounds in the condensed version of the Carbon Bond Mechanism (CBM-Z; Zaveri & Peters 1999) that is employed by this version of RegCM4-CHEM

Compound name	Compound abbreviation	Anthropogenic	Vegetation	Biomass burning	Ocean	CBM-Z map
Nitrogen oxides	NO_x	MACCity	POET	RETRO		NO
Carbon monoxide	CO	MACCity	POET	RETRO	POET	CO
Formaldehyde	HCHO	MACCity				HCHO
Acetone	CH_3COCH_3	MACCity				ALD2
Sulfur dioxide	SO_2	MACCity		EDGAR		SO2
Methane	CH_4	MACCity		RETRO		CH4
Ethane	C_2H_6	MACCity	POET	RETRO	POET	C_2H_6
Ethylene	C_2H_4	MACCity	POET	RETRO	POET	C_2H_4
Propane	C_3H_8		POET	RETRO	POET	PAR
Propene	C_3H_6	MACCity	POET	RETRO		OLT
Butane	C_4H_{10}	MACCity		POET		PAR
Butene	C_4H_8	MACCity				OLI
Isoprene	C_5H_8		MEGAN	POET	POET	ISOP
Toluene	C_7H_8	MACCity		RETRO		TOLU
Xylene	C_8H_{10}	MACCity		RETRO		XYL
Methanol	CH_3OH	MACCity	POET	POET		MOH
Ethanol	C_2H_5OH	MACCity		POET		MOH
Organic carbon	OC	MACCity		EDGAR		
Black carbon	BC	MACCity		EDGAR		

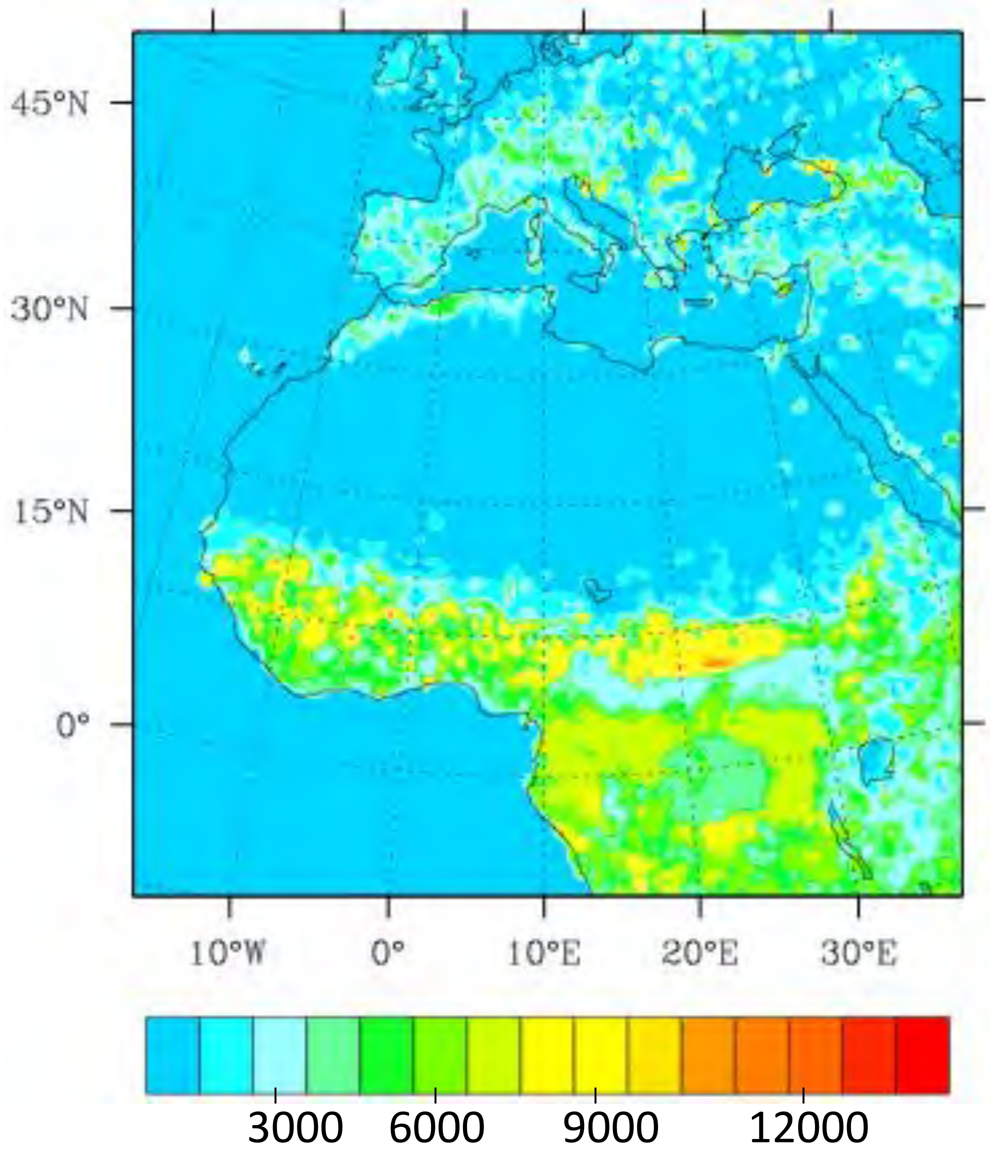


A
NOx (mg m-2 d-1)
2 6 10 14 18 22 26 30
B
Alkanes (mg m-2 d-1)
5 25 45 65 85 100
C
Sulfate (mg m-2 d-1)
5 25 45 65 85 100
D
Black carbon (mg m-2 d-1)
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5



Summer (JJA) emissions in the Mediterranean, Middle East and northern Africa averaged over 1998−2006 for (A) anthropogenic NO_x, (B) anthropogenic alkanes (including butanes, ethane and propane), (C) anthropogenic sulfate, (D) anthropogenic black carbon, (E) anthropogenic organic carbon, and (F) isoprene emissions. Panels (A) to (E) are based on the MACCity inventory and panel (F) on the online MEGAN-CLM emissions model

Emissions: Biogenic

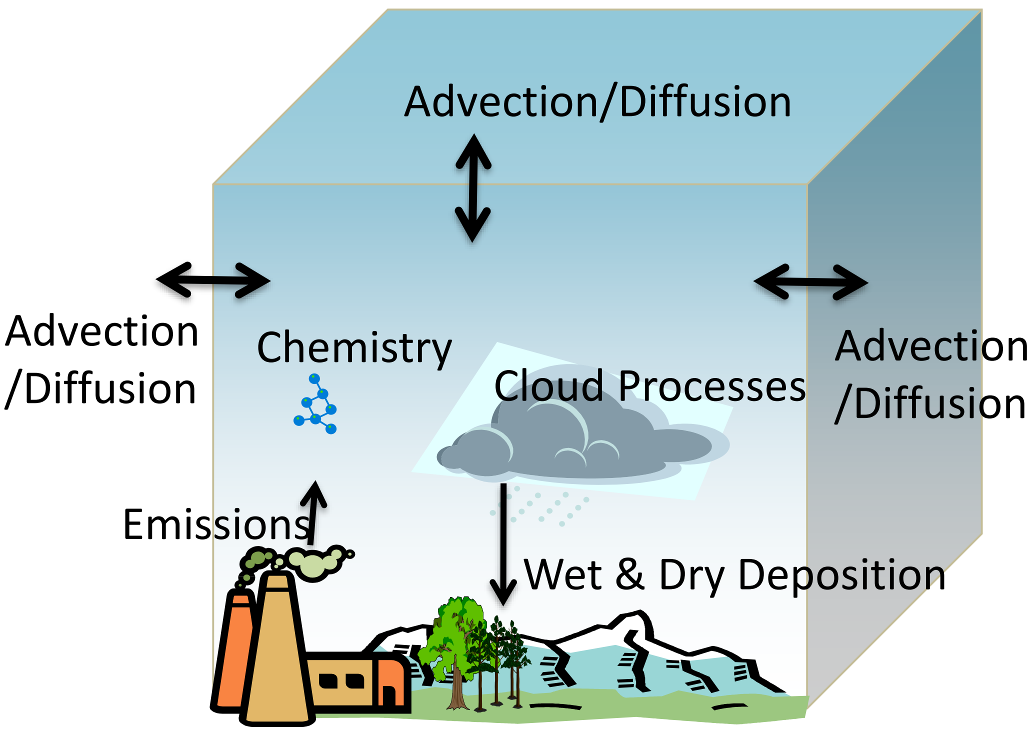


- MEGAN - Isoprene Emission Factor Map (ε)
- Baseline isoprene emission fluxes (μg m^{-2} hr^{-1})
- Modified for temperature, light, soil moisture, LAI, etc… (Ahmed T's talk Weds)

A grid cell view of atmospheric chemistry in RegCM-CHEM

- Representing this with the continuity equation

$$\frac{\partial c}{\partial t} = -v \times \nabla c + F_h + F_v + S - R_{dry} - R_{wet} + chem$$



- Large set of differential equations
- Varying lifetimes of chemical compounds makes this a “stiff” system

Cloud-Aerosol Interaction in RegCM4: Indirect effects of aerosols over Africa

Parameterization of autoconversion

1. The first parameterization depends on *Beheng (1994)* (or hereinafter the "BH" scheme), which based on *Lohmann and Feichter (1997)*
2. The second parameterization depends on *Tripoli and Cotton (1980)* (hereinafter, referred here as "TC" scheme).
3. The third parameterization of autoconversion parameterization (R6 scheme) of *Liu and Daum (2004),* which accounts for the dispersion effect of the cloud droplets *(Liu and Daum, 2004; Liu et al., 2004; Liu et al., 2007)*

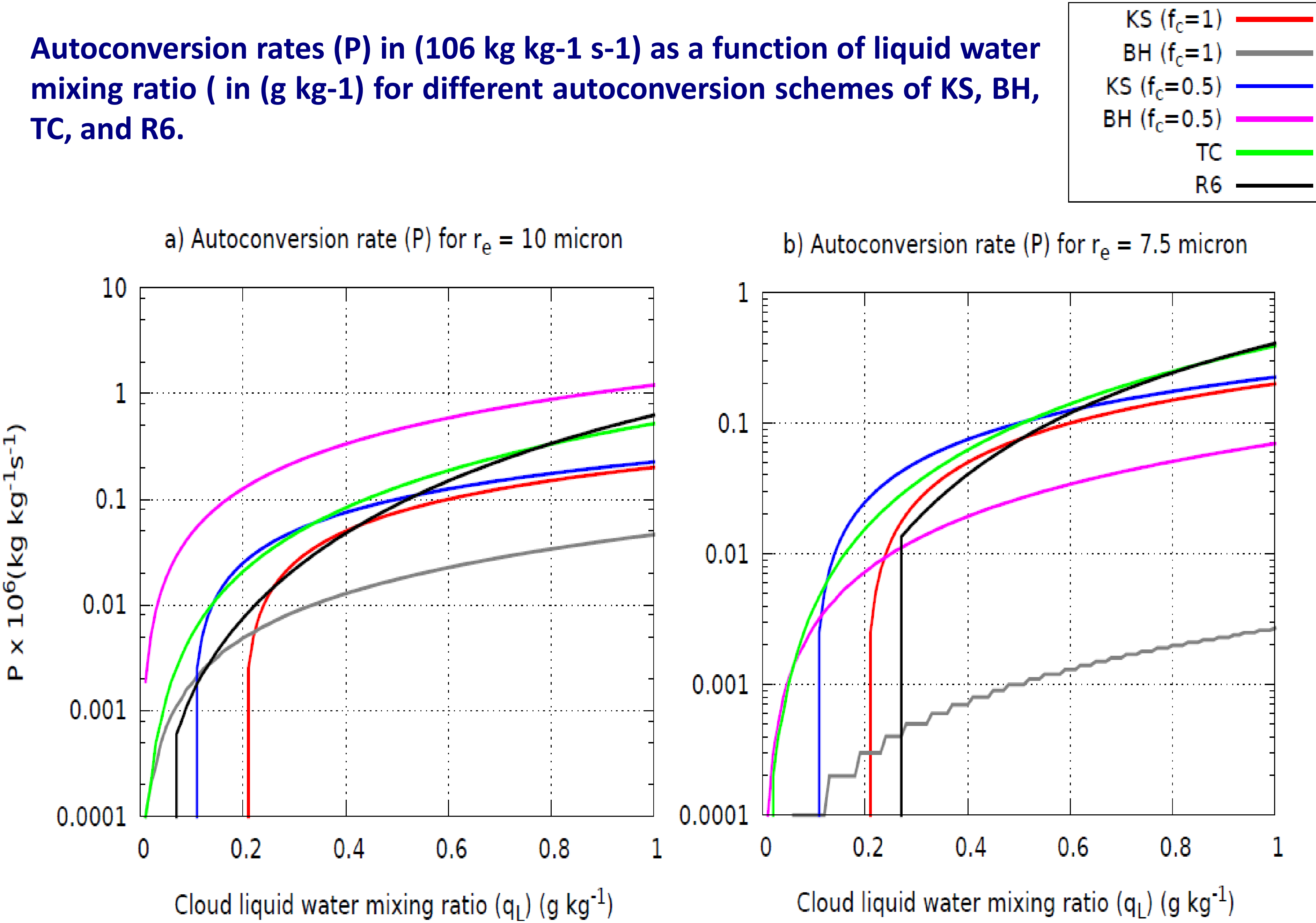
These three autoconversion schemes differ in their dependence on the total aerosol mixing ratio (x_{tot}), which relates to the effective radius (r_e), and on the liquid water content (w_L),

$$P \propto w_L^{4.7}\, x_{tot}^{-1.5} \quad \propto w_L^{1.4}\, r_e^{9.9}$$

$$P \propto w_L^{2.3}\, x_{tot}^{-0.15} \quad \propto w_L^{2}\, r_e$$

$$P \propto w_L^{3}\, x_{tot}^{-0.45} \quad \propto w_L^{2}\, r_e^{3}$$

Autoconversion rates (P) in (106 kg kg-1 s-1) as a function of liquid water mixing ratio (in (g kg-1) for different autoconversion schemes of KS, BH, TC, and R6.



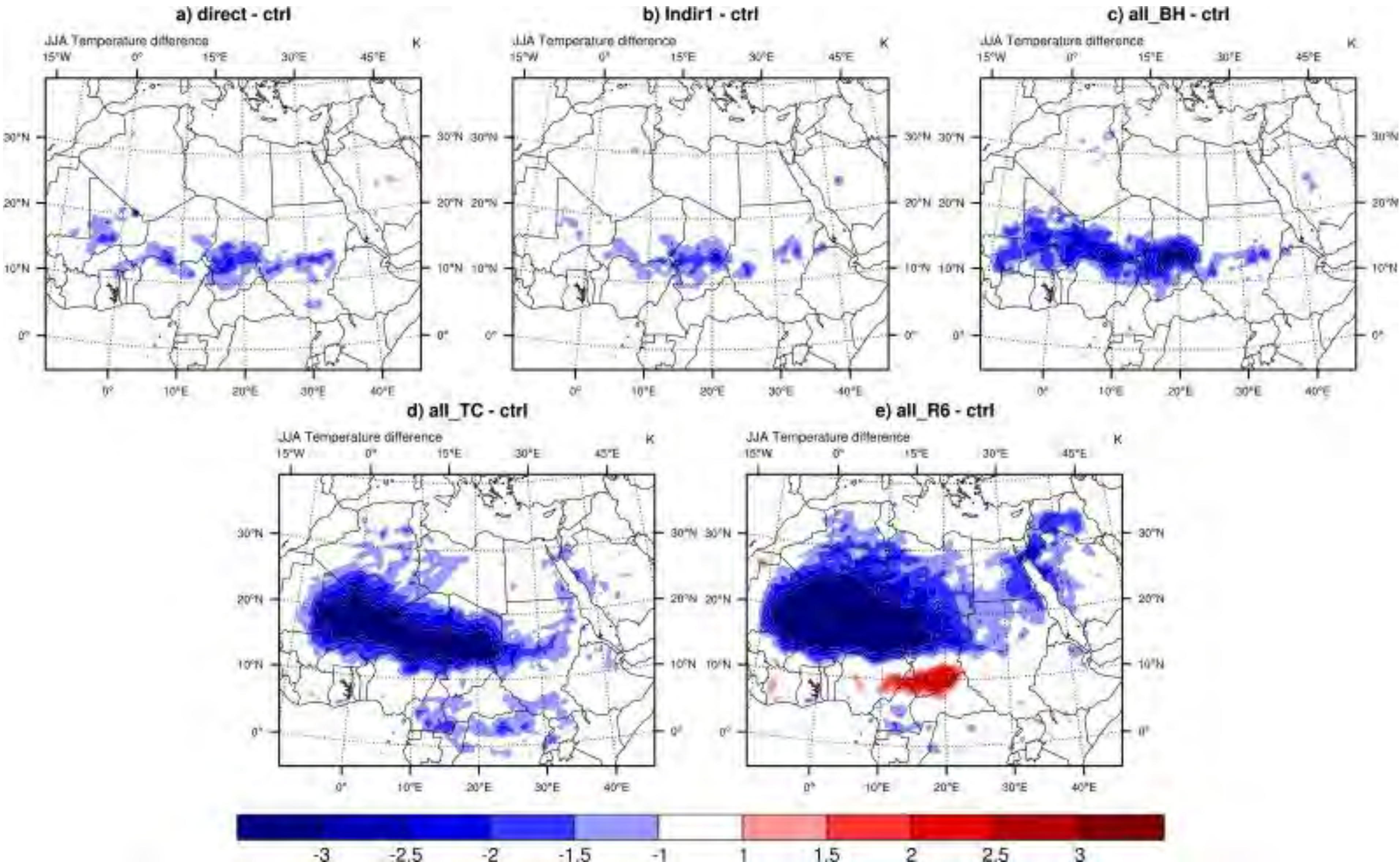
[1] All means (SO_4^{2-} + hydrophobic and hydrophilic OC and BC + 4 size bins of dust)

[2] The direct effects include all simulated aerosols

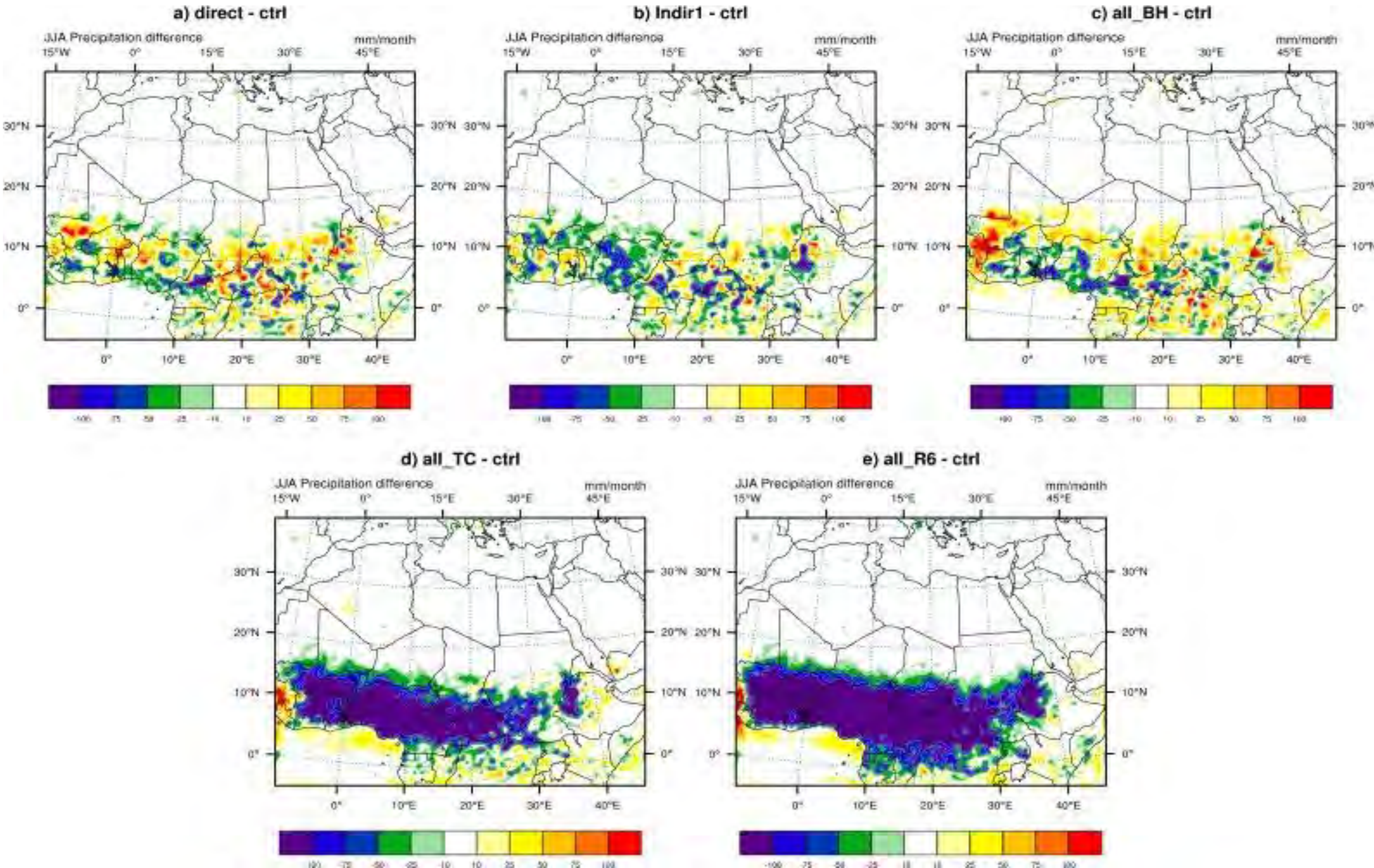
[3] The 1st and 2nd indirect effects include only SO_4^{2-} + hydrophilic OC and BC

Experiment	Autoconversion scheme	Aerosols	Effective radius of cloud droplets	Aerosol effect
ctrl	KS (Kessler, 1969)	none	Fixed (10μm)	none
ctrl_BH	BH (Beheng, 1994)	none	Fixed (10μm)	none
ctrl_TC	TC (Tripoli & Cotton, 1980)	none	Fixed (10μm)	none
ctrl_R6	R6 (Liu & Daum, 2004)	none	Fixed (10μm)	none
direct	KS	All [1]	Fixed (10μm)	Direct [2]
Indir1	KS	All	predicted	Direct + 1st indirect [3]
all_BH	BH	All	predicted	Direct + 1st + 2nd indirect
all_TC	TC	All	predicted	Direct + 1st + 2nd indirect
all_R6	R6	All	predicted	Direct + 1st + 2nd indirect

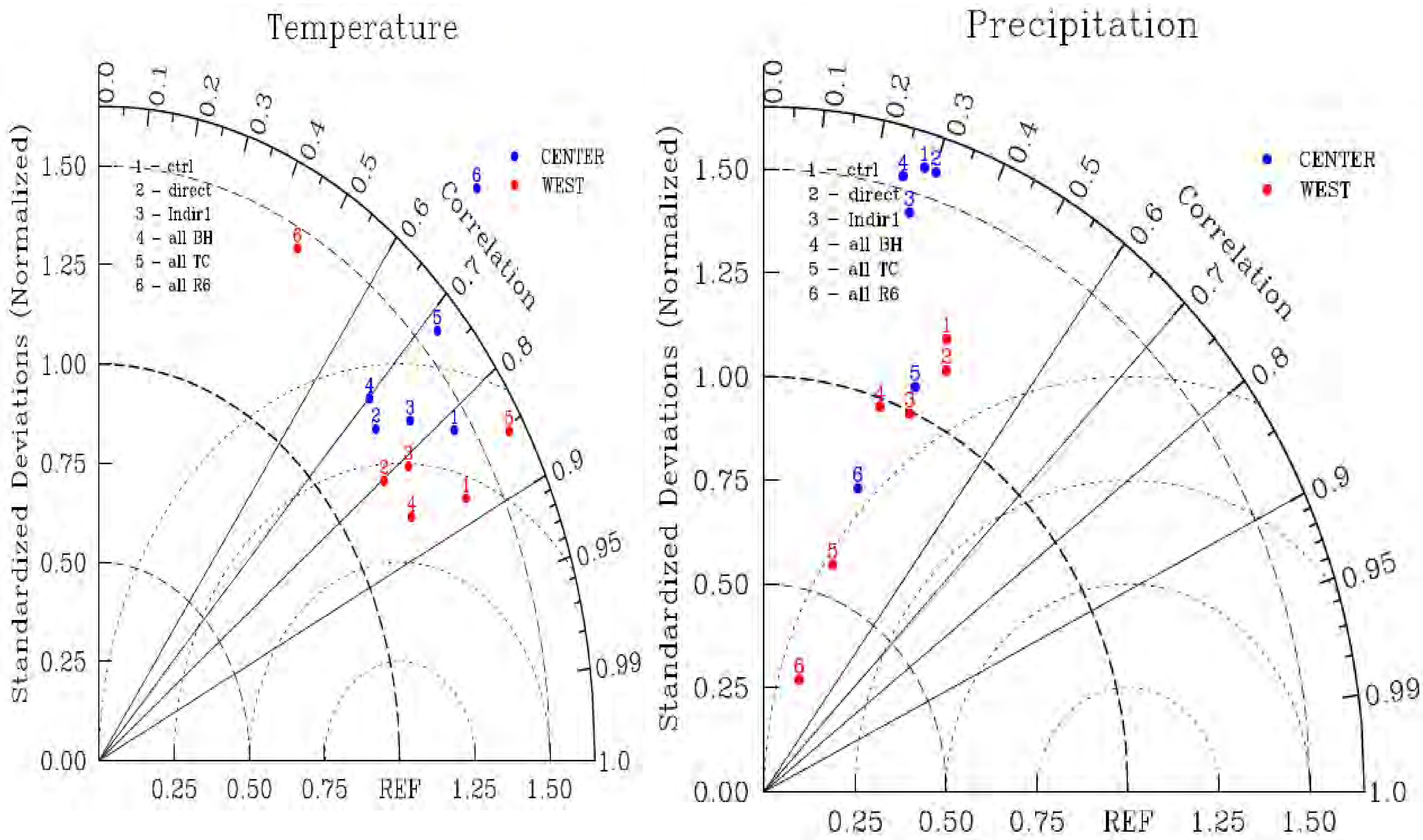
Changes in temperature (K) due to the experiments of a) direct, b) Indir1, c) all_BH, d) all_TC, and e) all_R6 relative to the experiment of ctrl, during JJA 20065



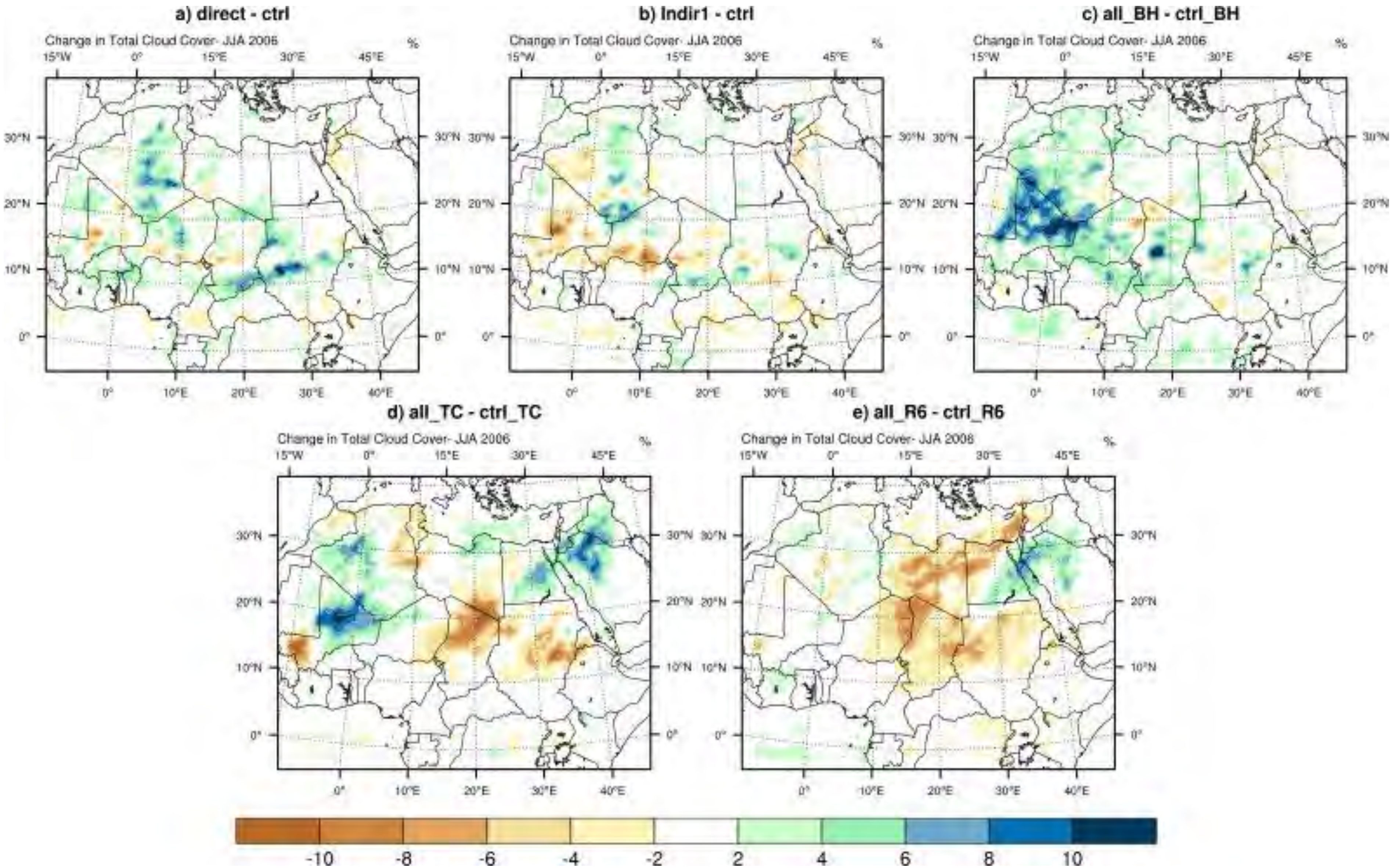
Changes in precipitation (mm month-1) due to the experiments of a) direct, b) Indir1, c) all_BH, d) all_TC, and e) all_R6 relative to the experiment of ctrl, during JJA 2006



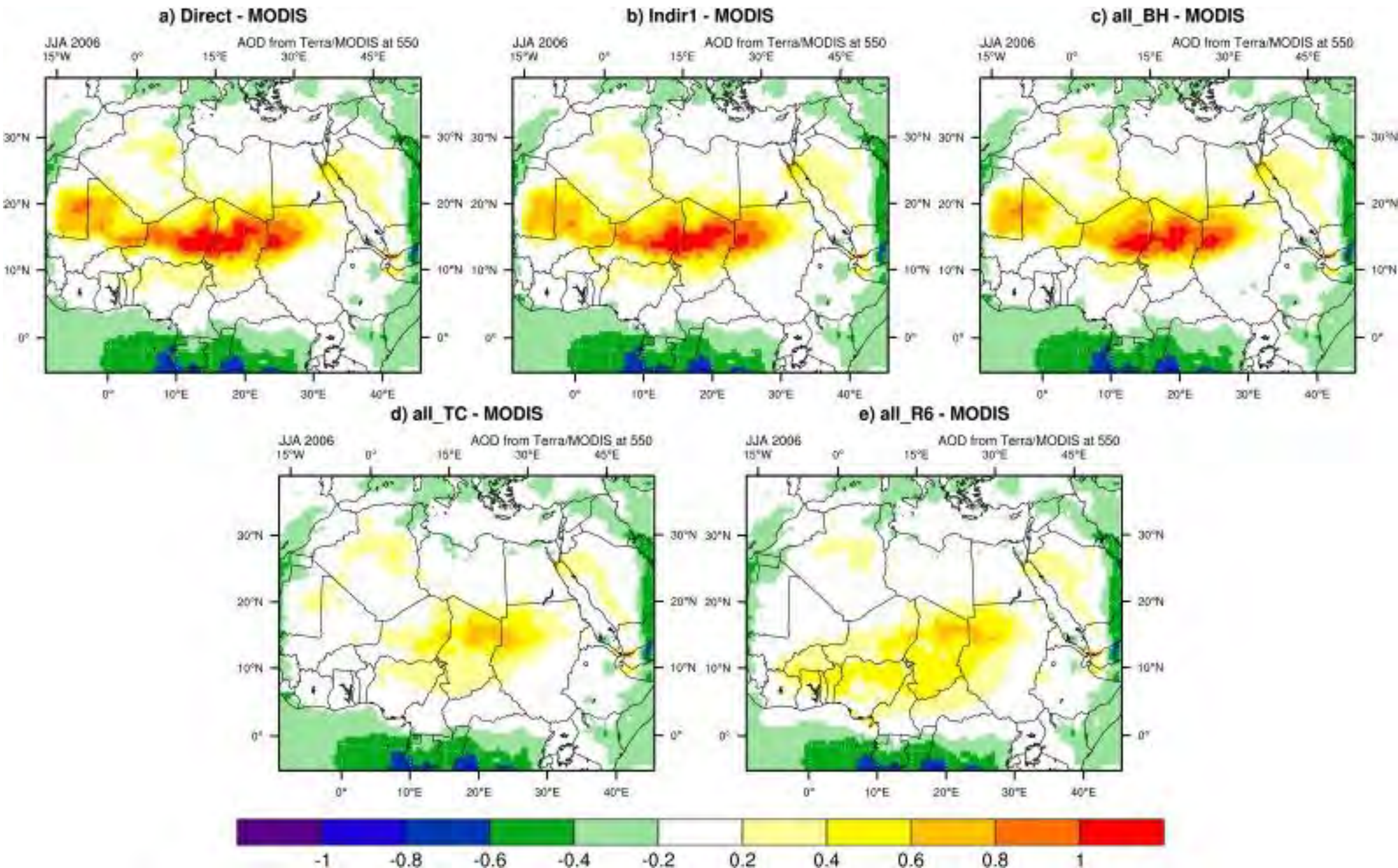
Taylor diagram for a) temperature and b) precipitation, over the West Africa (red points), and Central Africa (blue points) during JJA 2006.



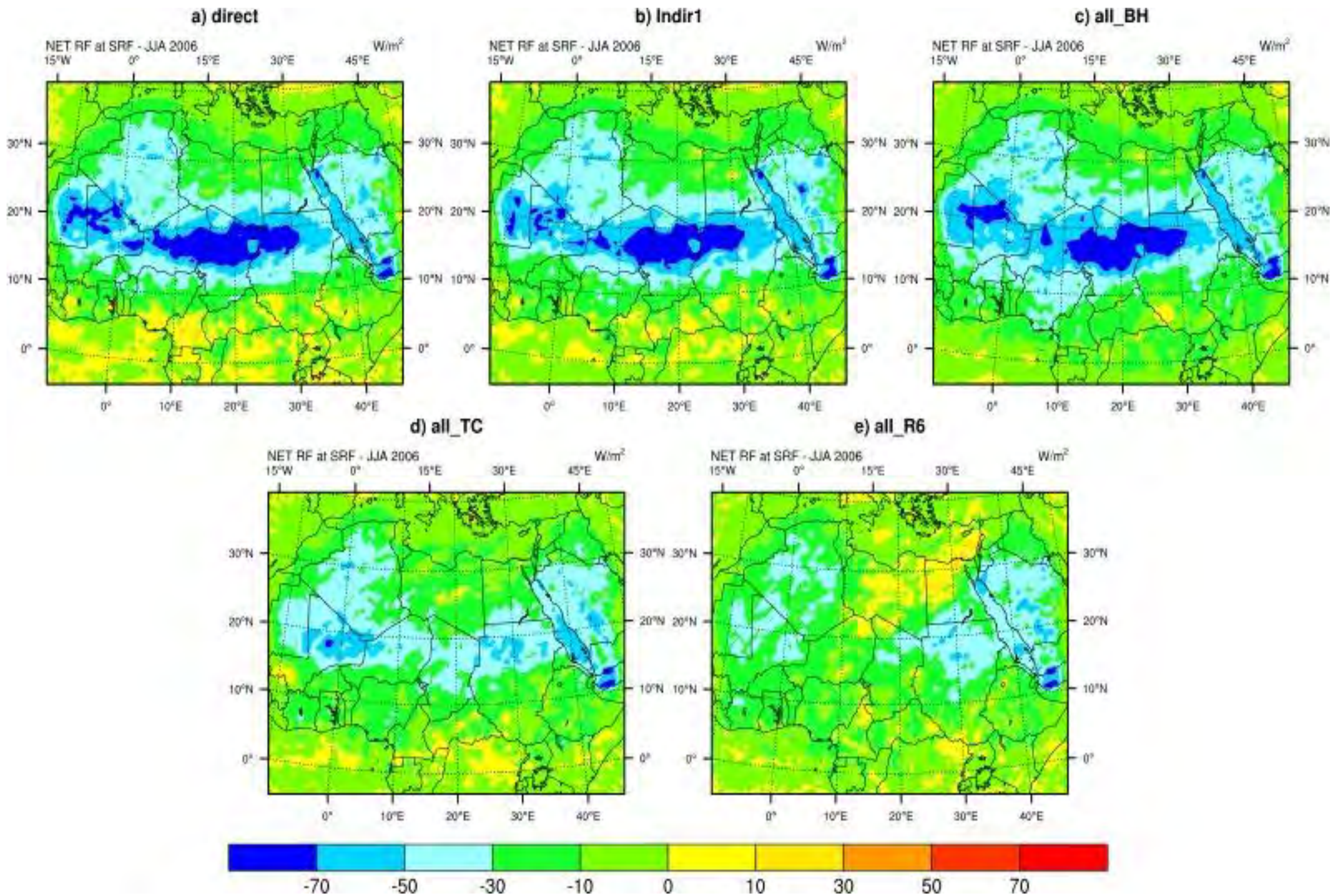
Changes in total cloud cover (%) due to the experiments of a) direct - ctrl, b) Indir1 – ctrl, c) all_BH – ctrl_BH, d) all_TC – ctrl_TC, and e) all_R6 – ctrl_R6, during JJA 2006.



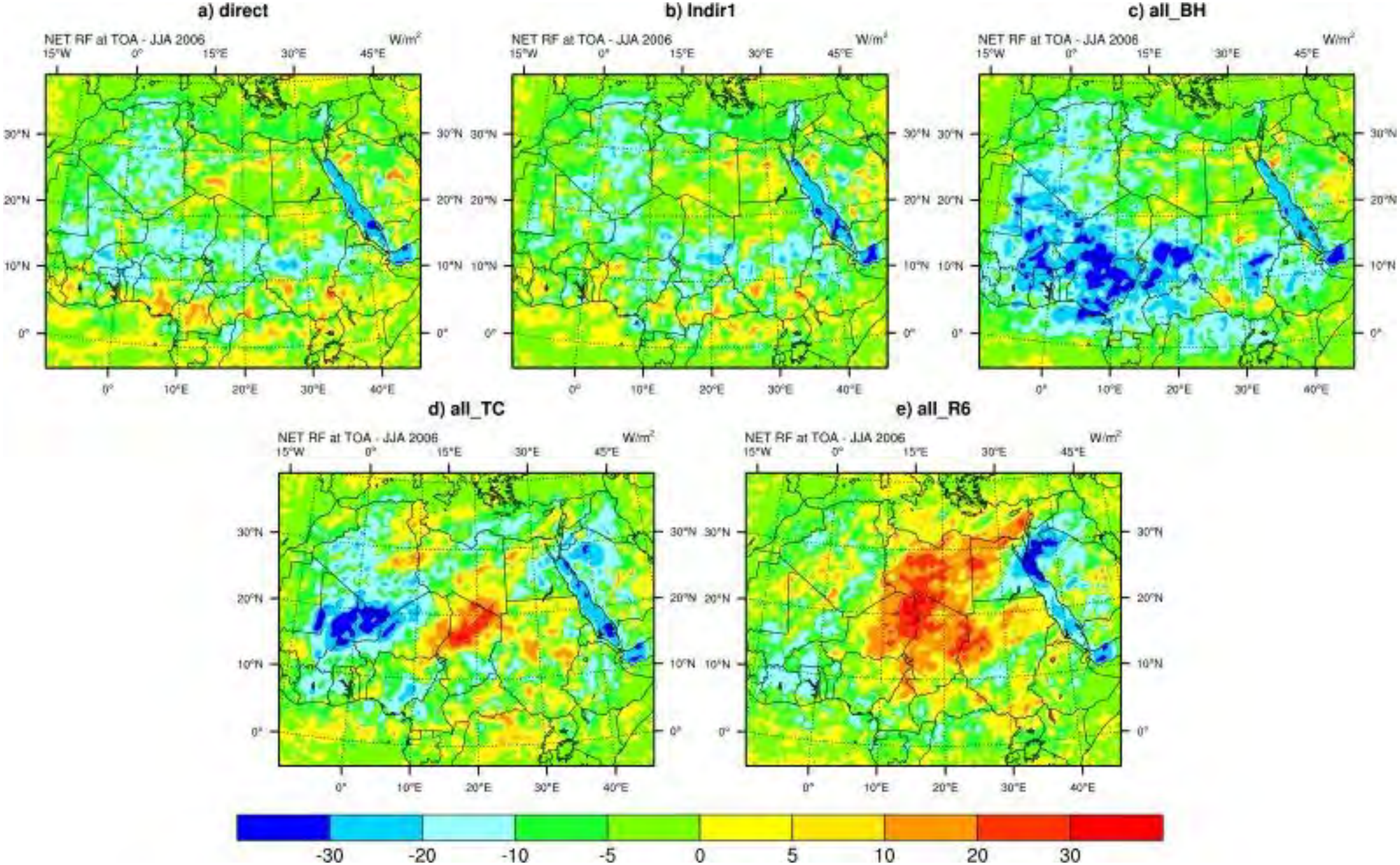
Changes in Aerosol optical depth (AOD) induced by a) direct, b) Indir1, c) all_BH, d) all_TC, and e) all_R6 relative to the AOD from Terra/MODIS at 550 nm, during JJA 2006



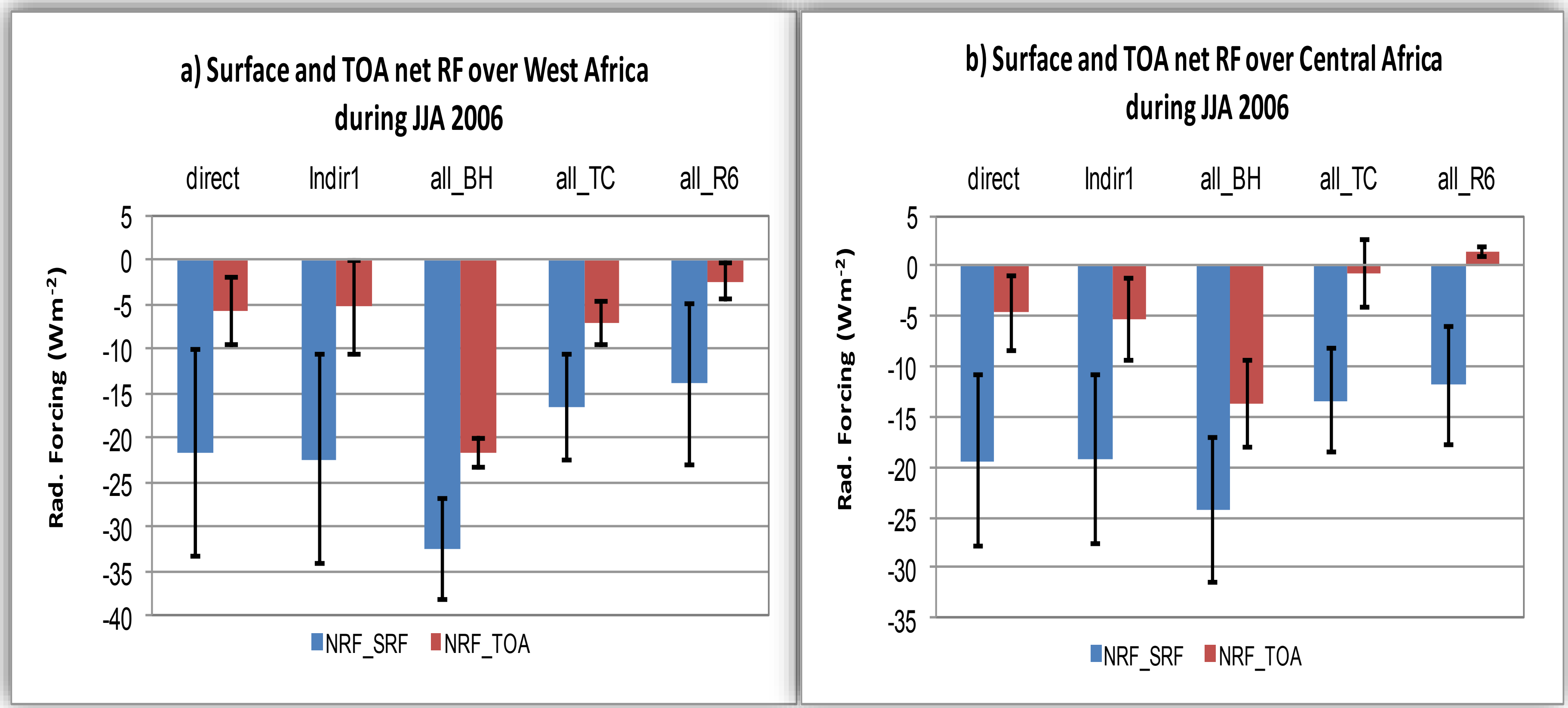
Simulated net radiative forcing (RF) at the surface (SRF) ($W m^{-2}$) induced by a) direct, b) Indir1, c) all_BH, d) all_TC, and e) all_R6 relative to their control runs, during JJA 2006.



Simulated net radiative forcing (RF) at the top of atmosphere (TOA) ($W\ m^{-2}$) induced by a) direct, b) Indir1, c) all_BH, d) all_TC, and e) all_R6 relative to their control runs, during JJA 2006.



Net Radiative forcing (shortwave and longwave) at the surface and TOA during JJA 2006 simulated by the different experiments (direct, Indir1, all_BH, all_TC, and all_R6) averaged over a) West Africa, and b) Central Africa, with error bars of standard deviation.

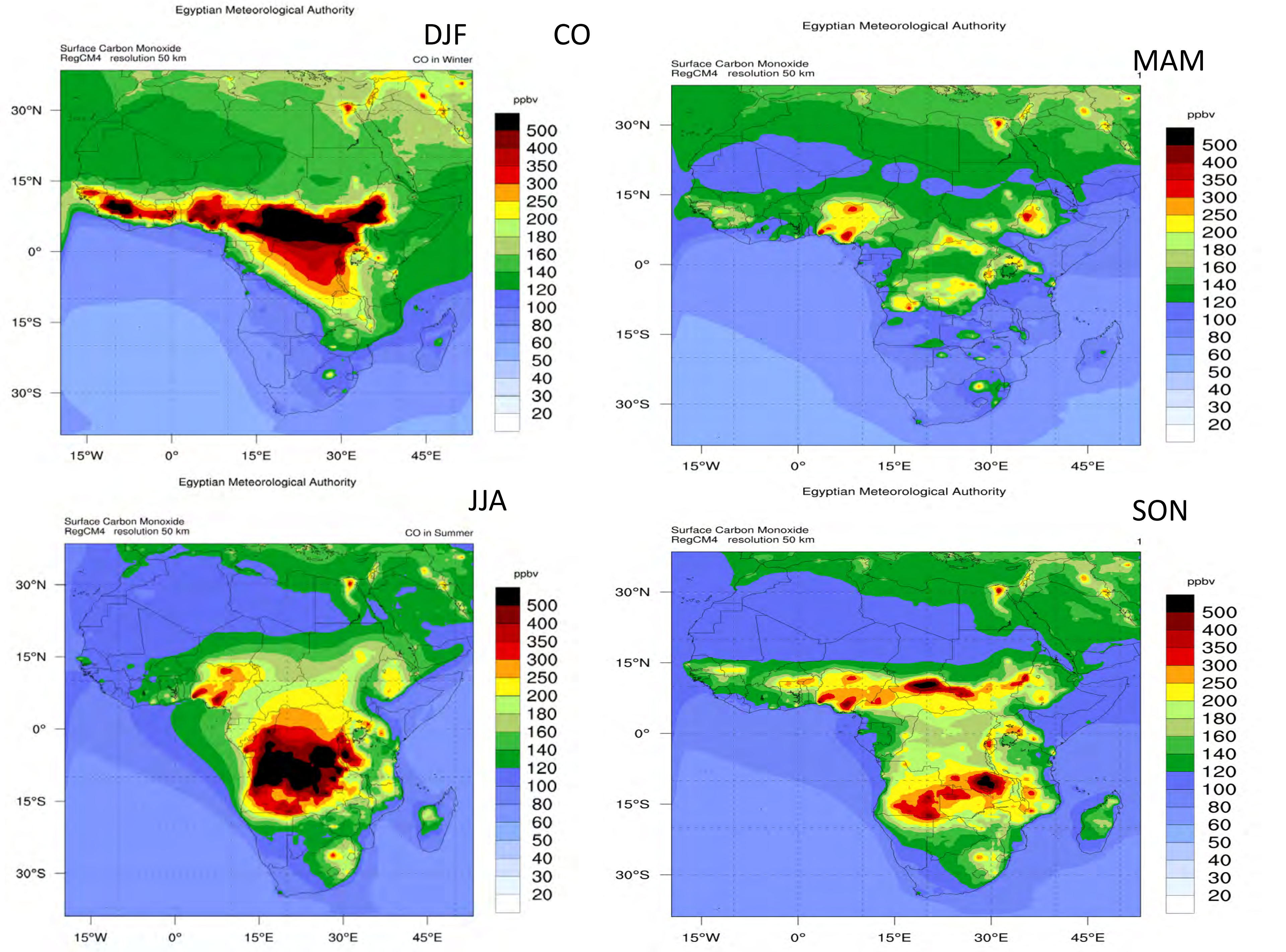


Seasonal means over West Africa and Central Africa for changing in cloud liquid water path (ΔCLWP), total cloud cover ΔTCLD, low cloud cover ΔLCLD, planetary albedo (ΔPALB), temperature (ΔT), total precipitation (ΔP), and latent heat flux (ΔLHF) due to direct, Indir1, all_BH, all_TC, and all_R6, relative to the control run (ctrl), averaging over the land only, during JJA 2006. The relative change in total cloud cover, planetary albedo, and precipitation is given in percent.

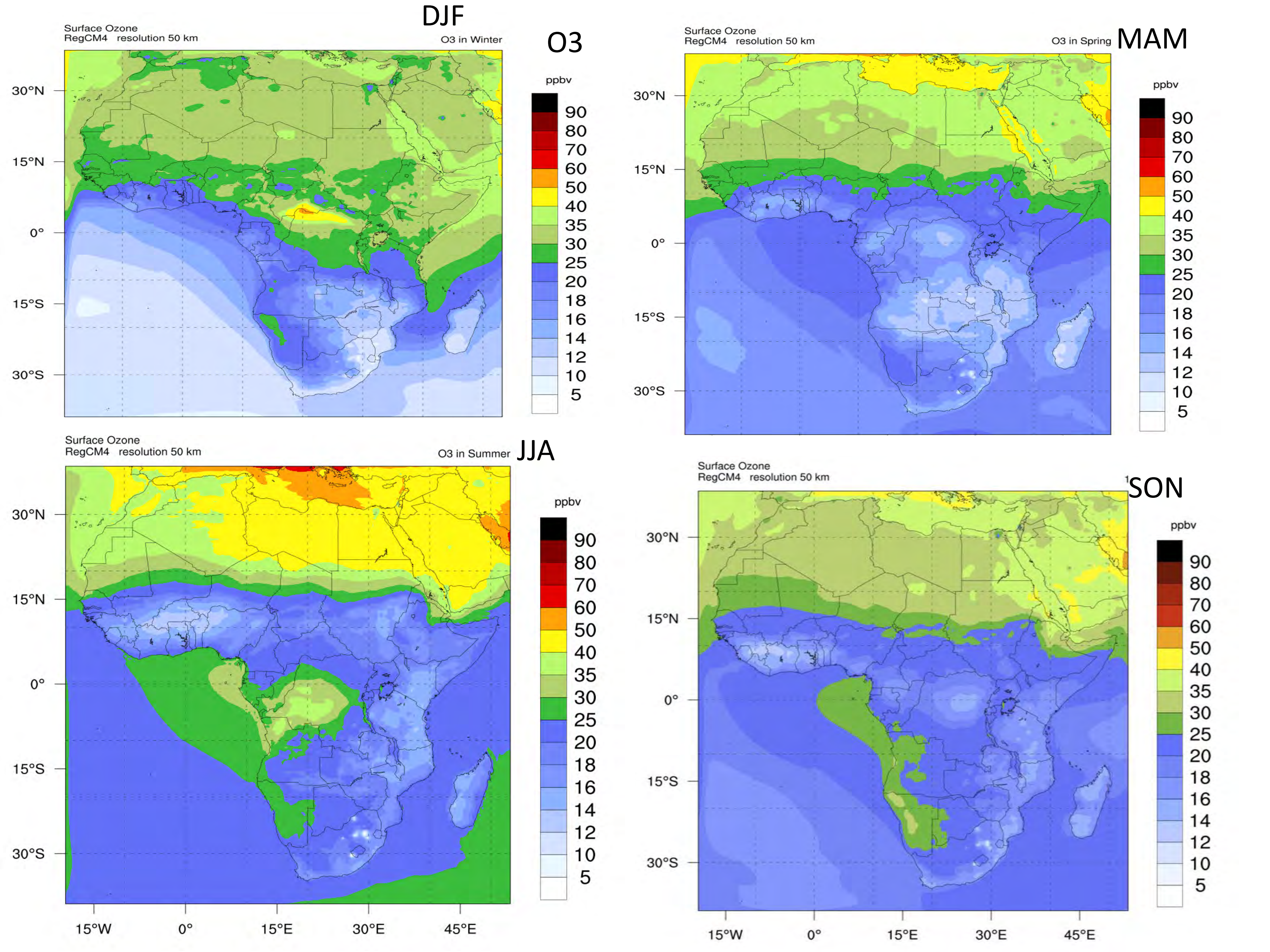
	direct	**Indir1**	**all_BH**	**all_TC**	**all_R6**
ΔCLWP(g/m2)	-04.37	-23.65	05.36	278.89	835.46
ΔTCLD (%)	00.53	-01.51	09.64	21.16	19.97
ΔLCLD (%)	03.15	00.18	06.81	-20.21	-58.51
ΔPALB (%)	04.02	05.27	12.14	41.84	49.62
ΔT (K)	-00.49	-00.48	-01.03	-01.21	-00.92
ΔLHF(W/m2)	-00.29	-00.54	-00.39	-03.67	-05.61
ΔP(mm/month)	-0.07(-0.04%)	-17.59(-10.02%)	-1.95(-01.11%)	-103.24(-58.83%)	-149.61(-85.25)

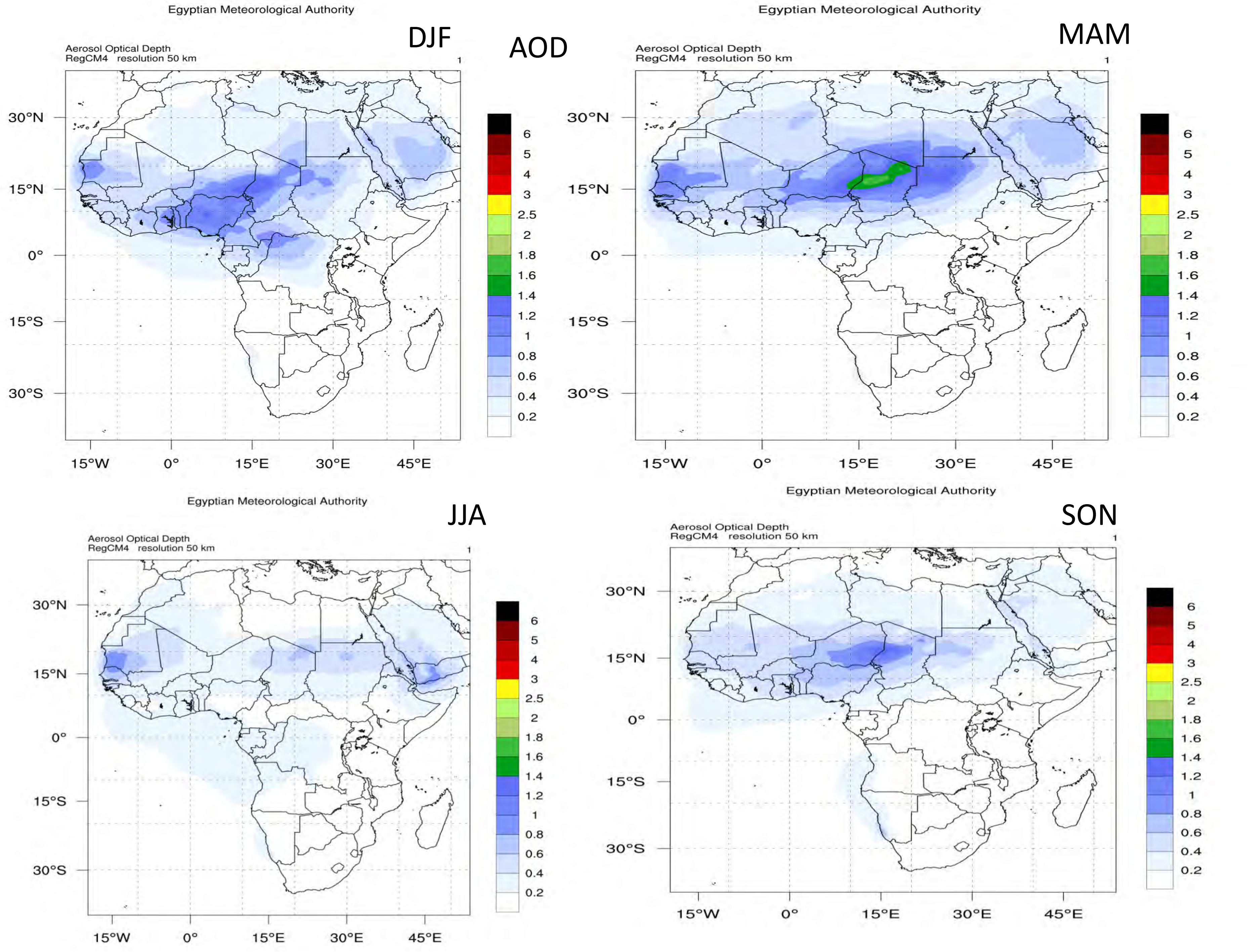
Central Africa

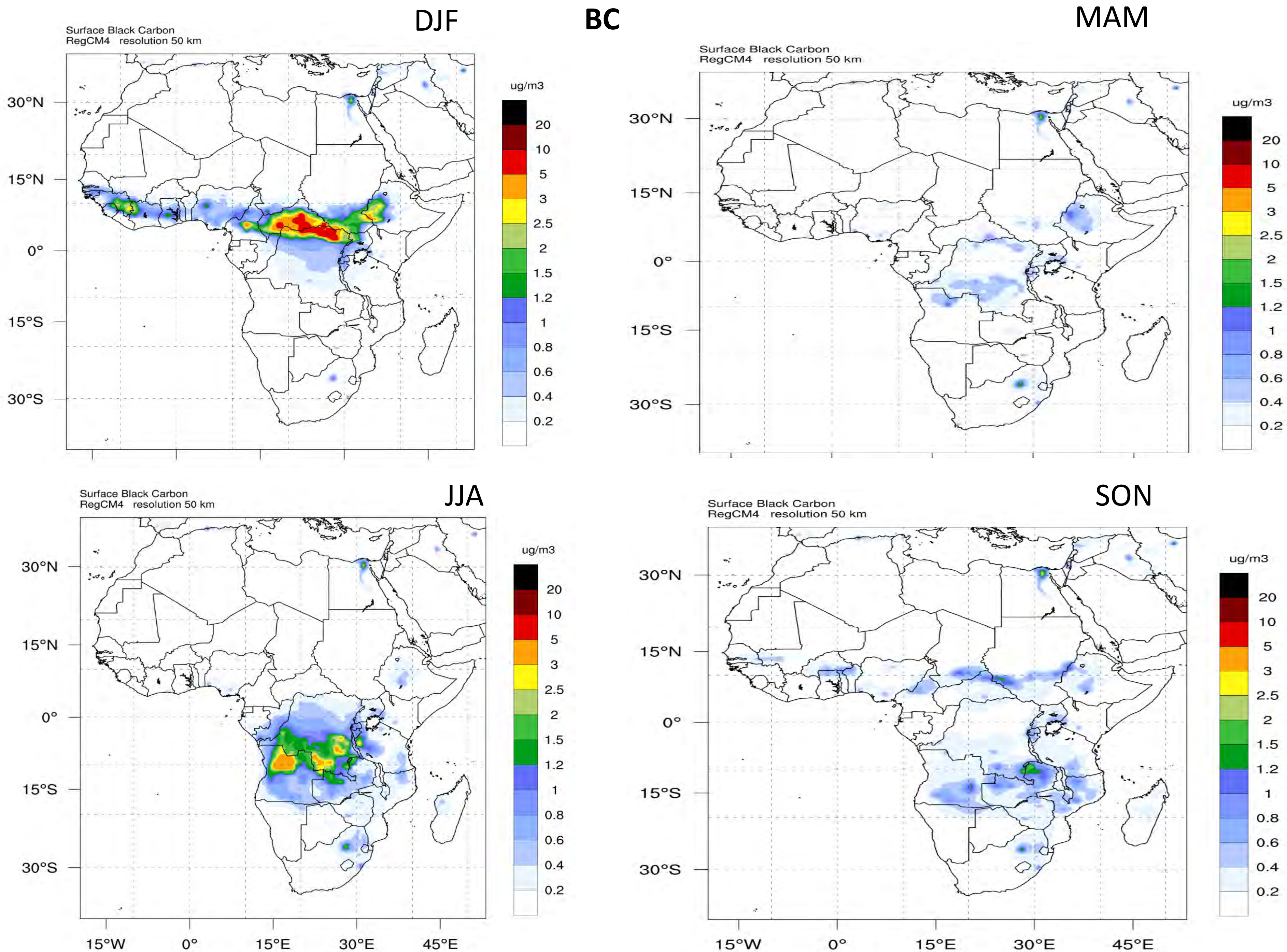
	direct	**Indir1**	**all_BH**	**all_TC**	**all_R6**
ΔCLWP(g/m2)	06.02	-11.66	39.58	04.36	-16.68
ΔTCLD (%)	01.47	-0.43	05.12	12.95	10.98
ΔLCLD (%)	06.17	01.47	05.22	-13.76	-41.73
ΔPALB (%)	02.37	03.84	04.50	25.68	33.64
ΔT (K)	-0.53	-00.48	-00.74	-01.20	-00.34
ΔLHF(W/m2)	00.11	-00.09	00.18	-01.43	-03.03
ΔP(mm/month)	09.09(5.74%)	-06.04(-3.82%)	08.26(05.22%)	-47.31(-29.00%)	-90.38(-57.13%)



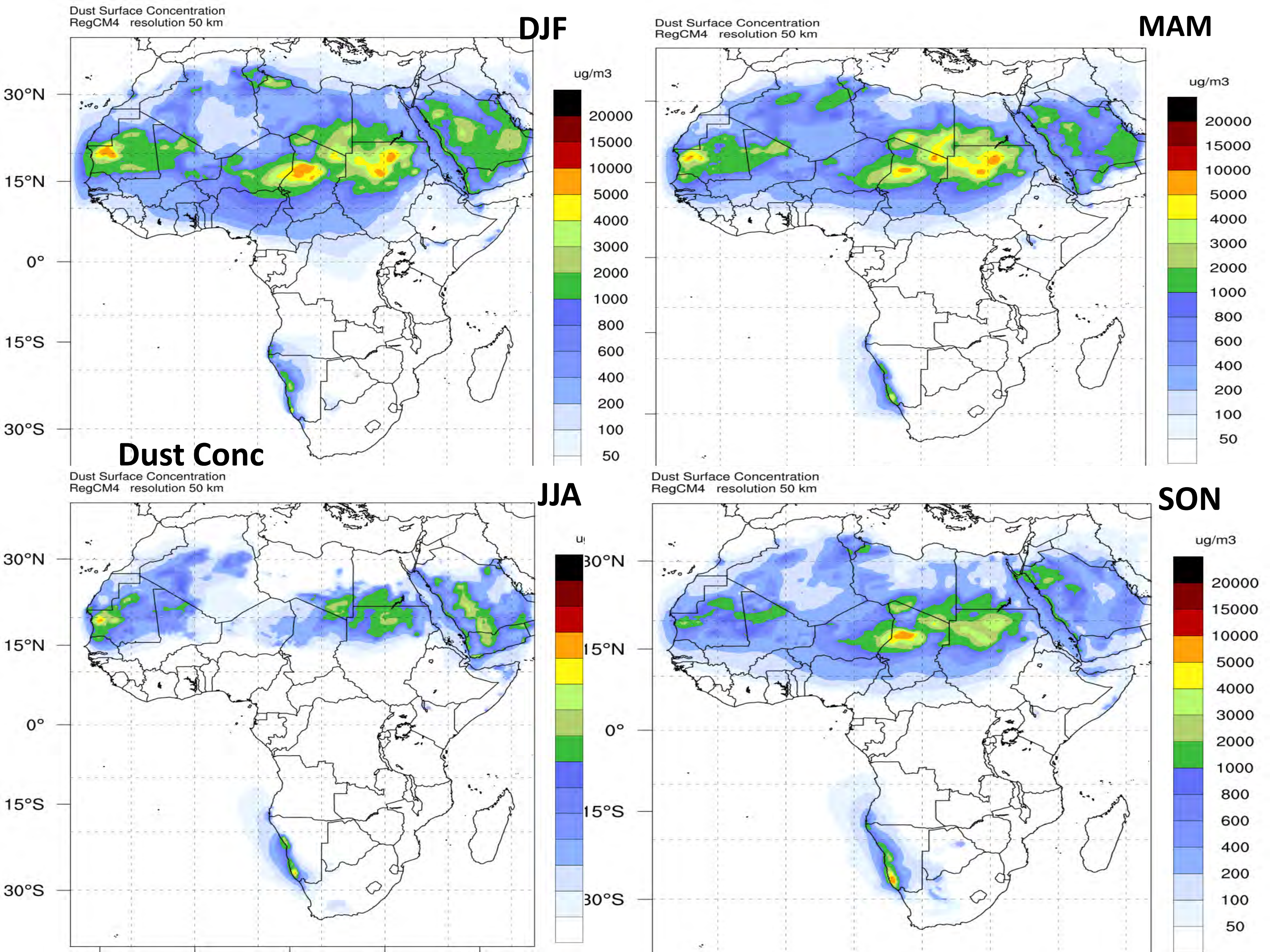
Egyptian Meteorological Authority
DJF
CO
Surface Carbon Monoxide
RegCM4 resolution 50 km
CO in Winter
ppbv
500
400
350
300
250
200
180
160
140
120
100
80
60
50
40
30
20
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E
Egyptian Meteorological Authority
MAM
Surface Carbon Monoxide
RegCM4 resolution 50 km
1
ppbv
500
400
350
300
250
200
180
160
140
120
100
80
60
50
40
30
20
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E
Egyptian Meteorological Authority
JJA
Surface Carbon Monoxide
RegCM4 resolution 50 km
CO in Summer
ppbv
500
400
350
300
250
200
180
160
140
120
100
80
60
50
40
30
20
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E
Egyptian Meteorological Authority
SON
Surface Carbon Monoxide
RegCM4 resolution 50 km
1
ppbv
500
400
350
300
250
200
180
160
140
120
100
80
60
50
40
30
20
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E

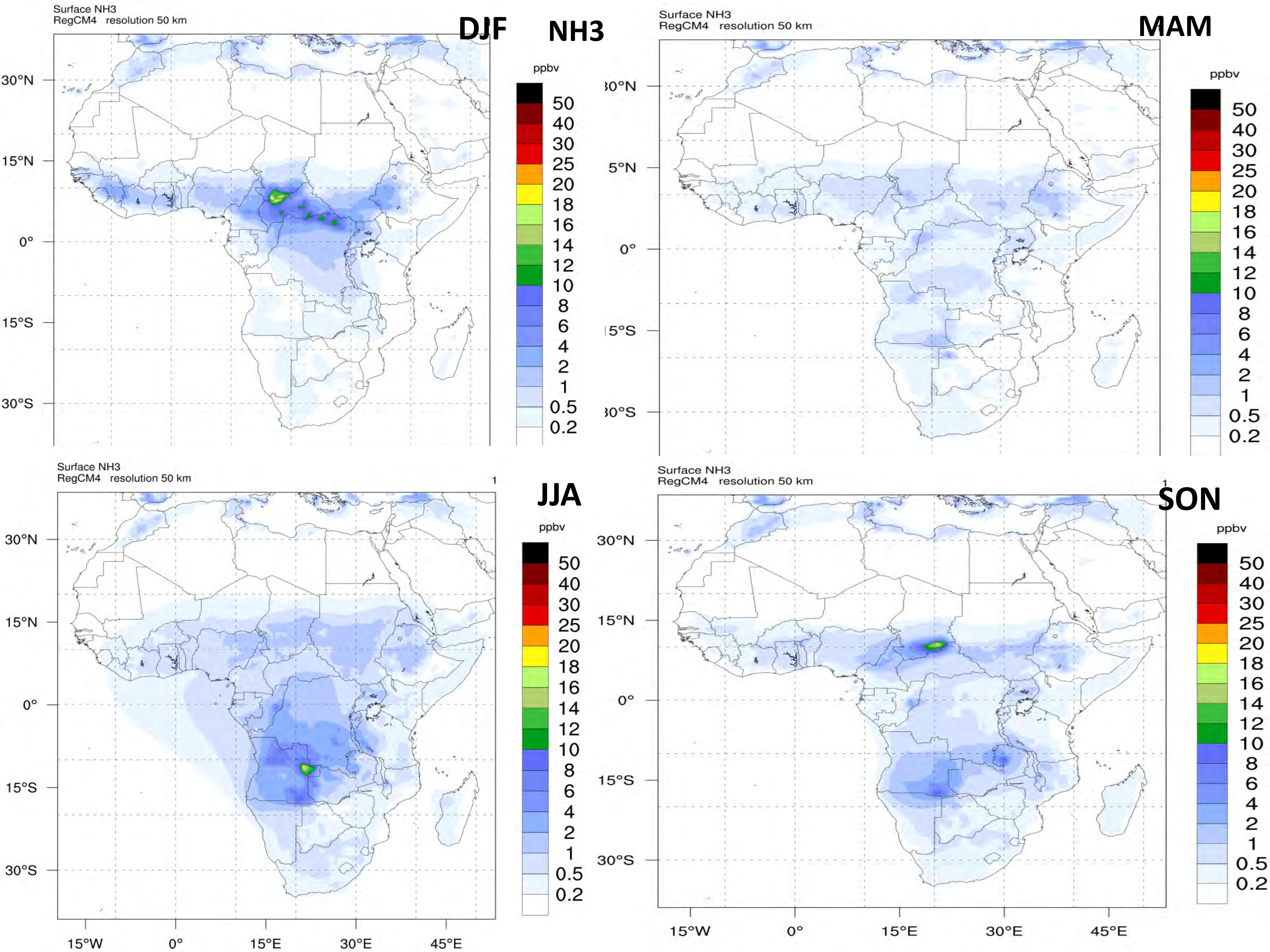

DJF
O3
MAM
JJA
SON
Surface Ozone
RegCM4 resolution 50 km
O3 in Winter
O3 in Spring
O3 in Summer
ppbv
90
80
70
60
50
40
35
30
25
20
18
16
14
12
10
5
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E


AOD
DJF
MAM
JJA
SON
Egyptian Meteorological Authority
Aerosol Optical Depth
RegCM4 resolution 50 km
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E
6
5
4
3
2.5
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2

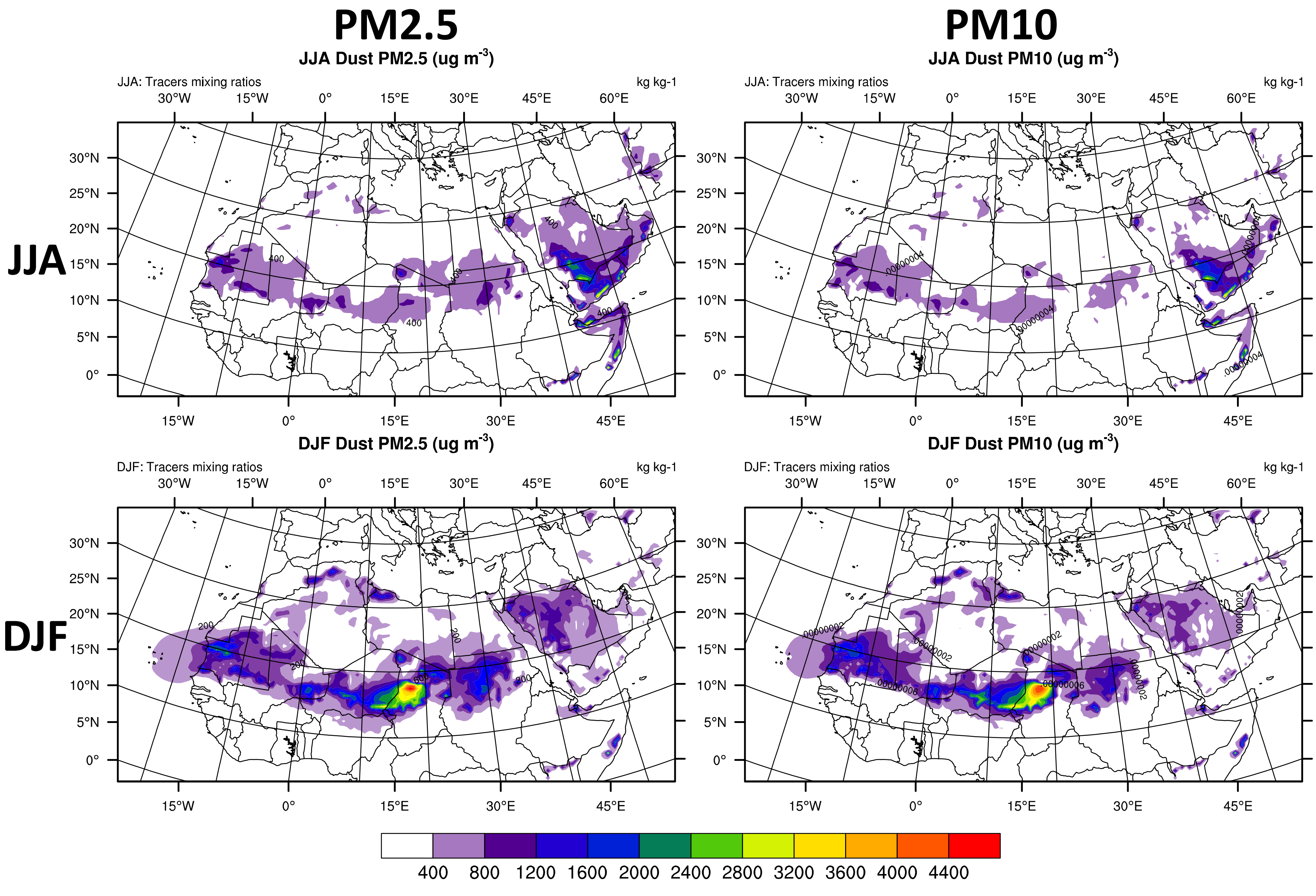


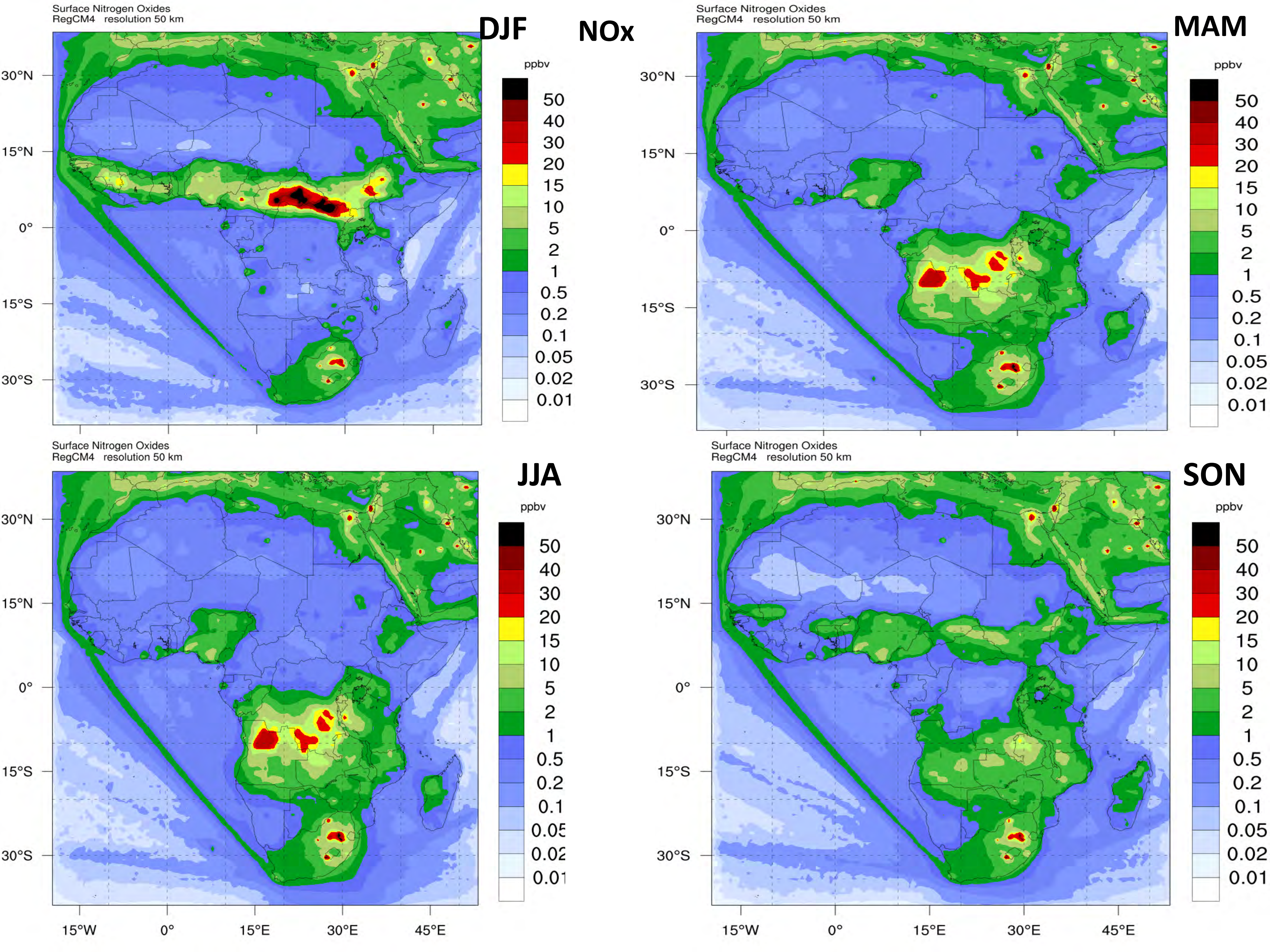
DJF
BC
MAM
JJA
SON
Surface Black Carbon
RegCM4 resolution 50 km
ug/m3
20
10
5
3
2.5
2
1.5
1.2
1
0.8
0.6
0.4
0.2
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E


Dust Conc
DJF
MAM
JJA
SON
Dust Surface Concentration
RegCM4 resolution 50 km
ug/m3
20000
15000
10000
5000
4000
3000
2000
1000
800
600
400
200
100
50
30°N
15°N
0°
15°S
30°S


Surface NH3
RegCM4 resolution 50 km
DJF
NH3
ppbv
50
40
30
25
20
18
16
14
12
10
8
6
4
2
1
0.5
0.2
MAM
JJA
SON
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E

Aerosol: Dust (RegCM-dust)

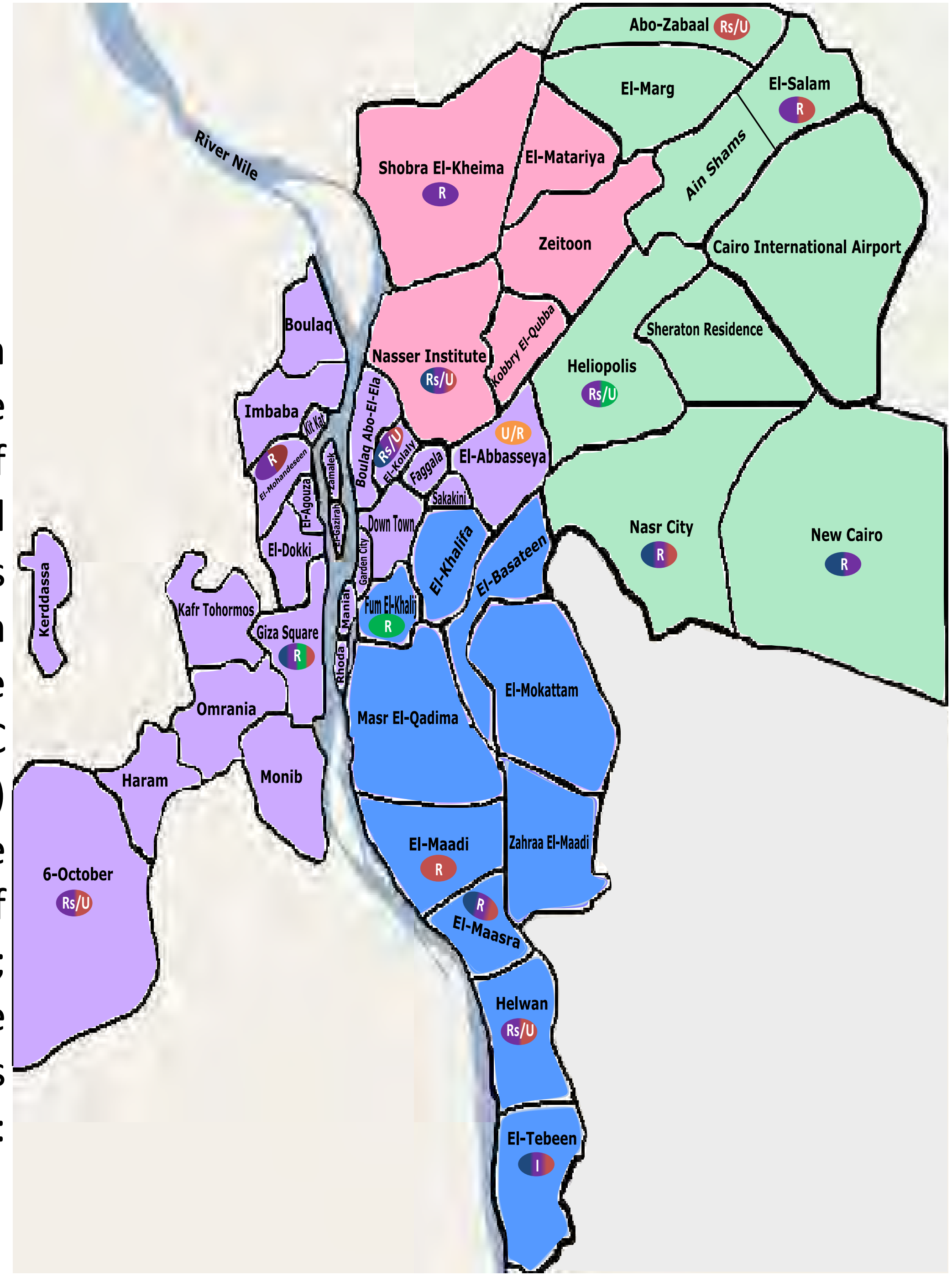




Surface Nitrogen Oxides
RegCM4 resolution 50 km
DJF
NOx
MAM
JJA
SON
ppbv
50
40
30
20
15
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
30°N
15°N
0°
15°S
30°S
15°W
0°
15°E
30°E
45°E

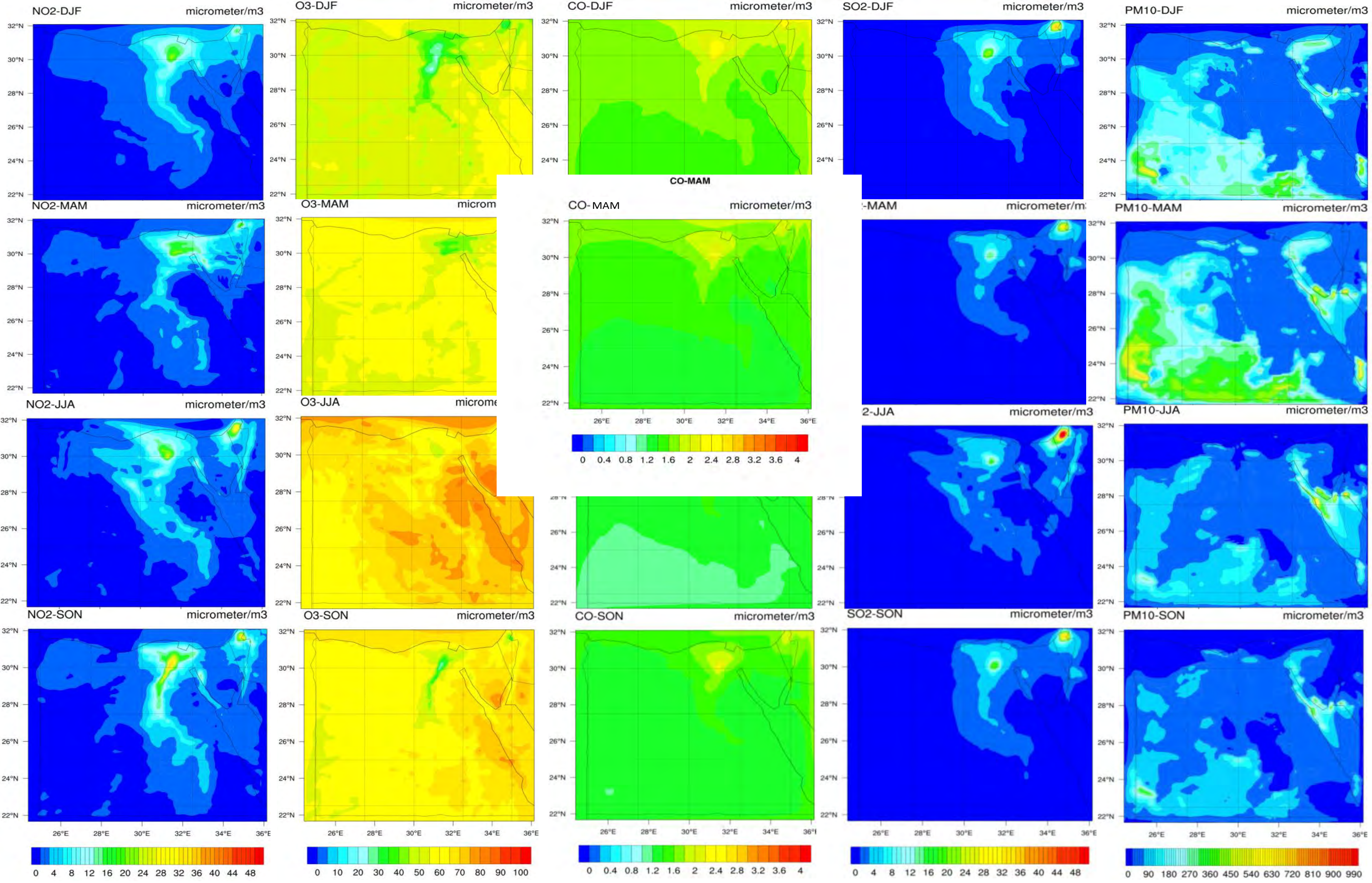
VALIDATION OF REGCM-CHEM4 MODEL BY COMPARISON WITH SURFACE MEASUREMENTS IN THE GREATER CAIRO (EGYPT) MEGACITY

map of GC region, showing the location of all the EEAA air quality stations. Note that in El-Abbasseya the instruments of the EMA and EEAA networks are installed in the same station. Only the stations with colored labels are the ones used in this study. The colored regions indicate the geographic location of the four GC sectors (north, south, east, and west) considered in the data analysis. The alphabetic symbols refer to the type of the station: R: Residential; Rs: Road side; I: Industrial; U: Urban. The colors of the symbols refer to the components measured by the station: red: SO_2; blue: NO_2; green: CO; orange: O_3; violet: PM10

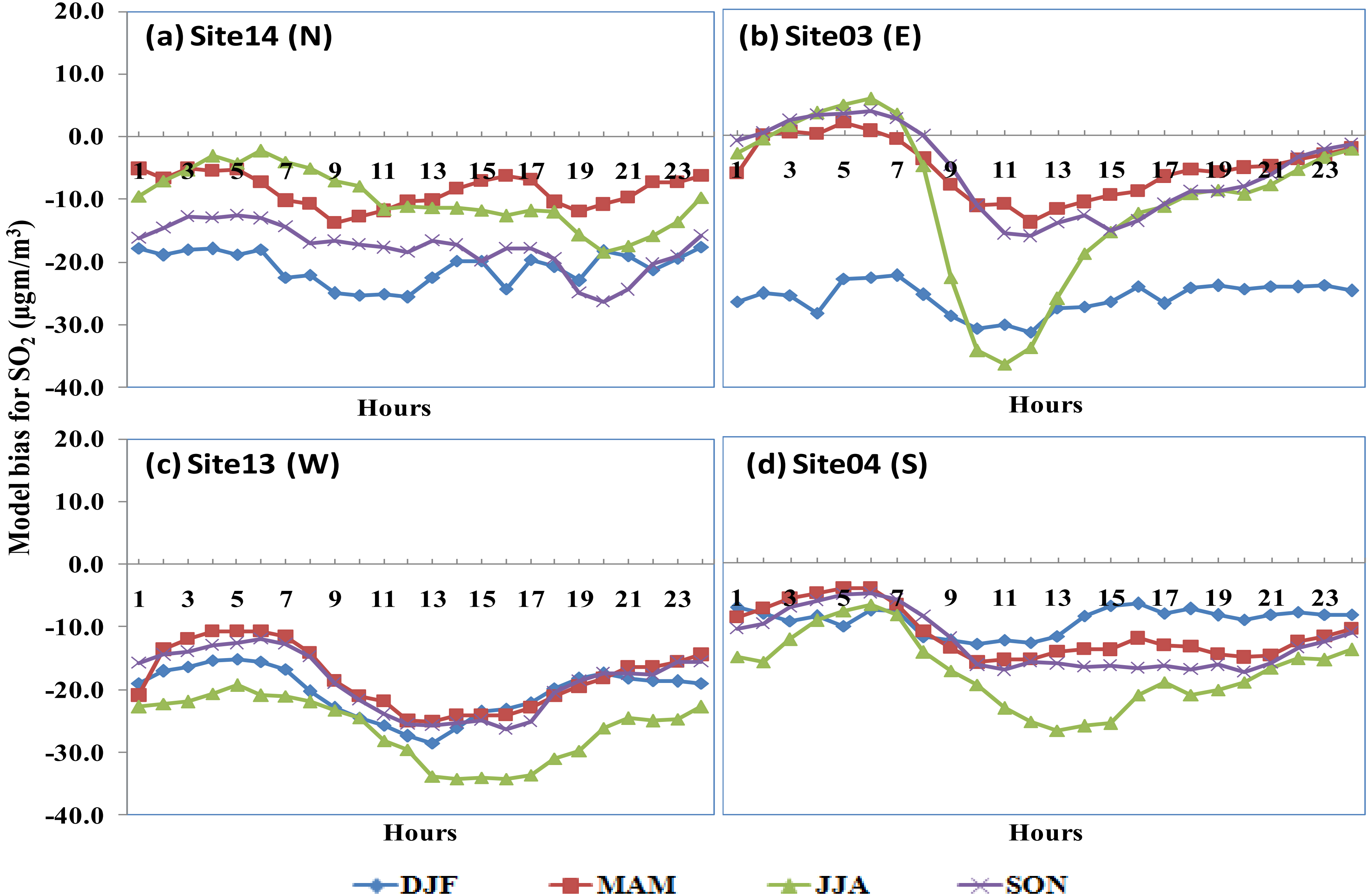


Site No.	Station Name	Measured pollutants	Coordinates		Station Type[b]	Location
			Lon.	Lat.		
1	El-Abbasseya[a]	O_3	31°17'	30°04'	U/R	W
2	El-Kolaly	SO_2, NO_2, PM10	31°14''	30°03'	Rs/U	W
3	Nasr City	SO_2, NO_2, PM10	31°19'	30°03'	R	E
4	El-Maadi	SO_2	31°16'	29°57'	R	S
5	El-Tebeen	SO_2, NO_2, PM10	31°17'	30°10'	I	S
6	Abo-Zabaal	SO_2	31°24'	30°14'	Rs/U	E
7	Helioplis	PM10, CO	31°21'	30°5'	Rs/U	E
8	Helwan	SO_2, PM10	31°20'	29°50'	Rs/U	S
9	Nasser Institute	SO_2, NO_2, PM10	31°15'	30°6'	Rs/U	N
10	New Cairo	NO_2, PM10	31°21'	30°2'	R	E
11	El-Maasra	SO_2, NO_2, PM10	31°17'	29°55'	R	S
12	6-October	SO_2, PM10	31°14'	30°03'	Rs/U	W
13	El-Mohandeseen	SO_2, PM10	31°12''	30°5'	R	W
14	El-Salam	SO_2, PM10	31°16'	30°7'	R	S
15	Giza Square	SO_2, NO_2, CO, PM10	31°12'	30°01'	R	W
16	Fum El-Khalij	CO	31°13'	30°1'	R	S
17	Shobra El-Kheima	PM10	31°14'	30°07'	R	N

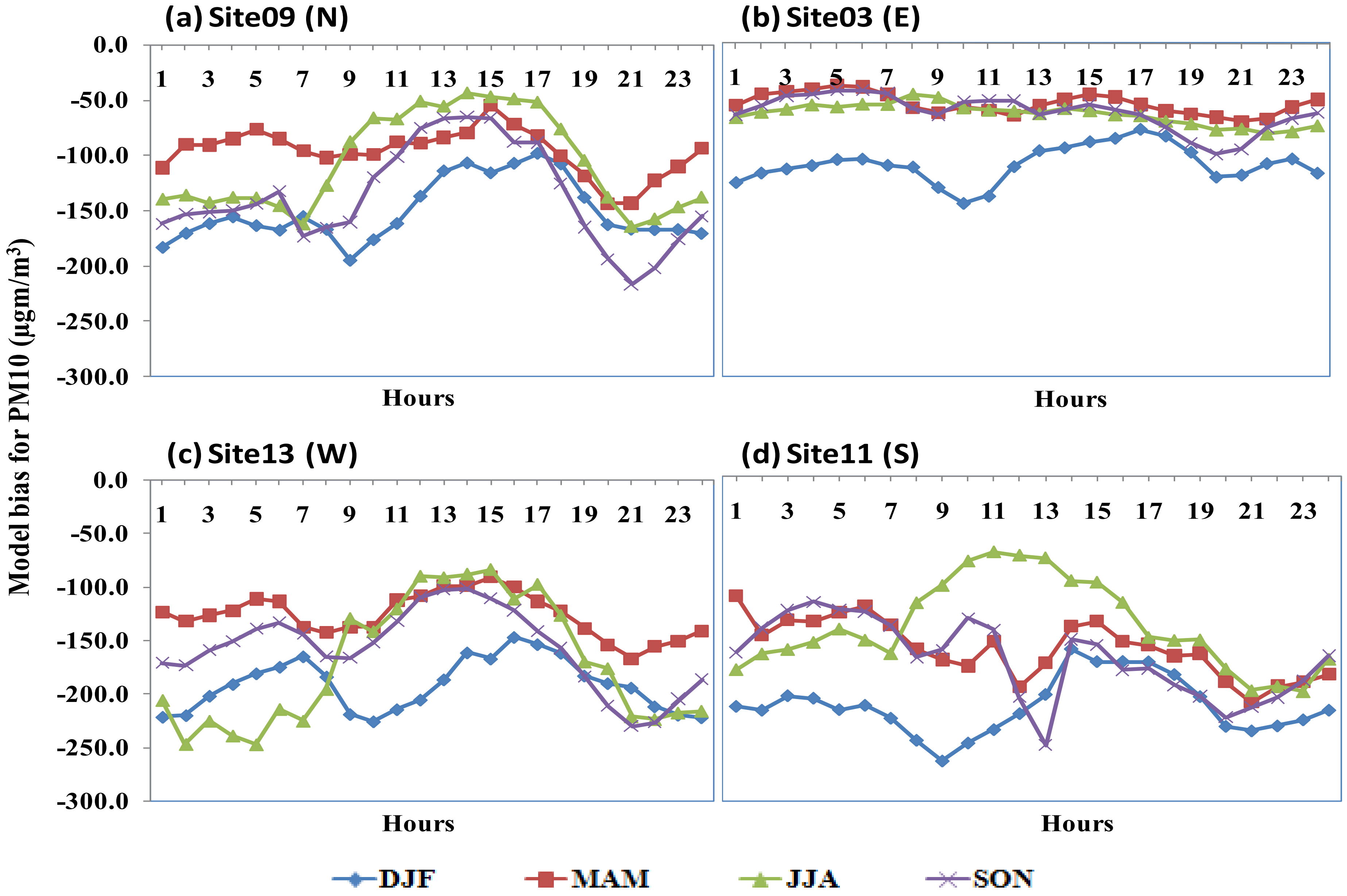
Measuring Stations with Their Coordinates, Monitoring Type, and Measured Pollutants Available for the Period of Study (Mostafa et al. 2018)



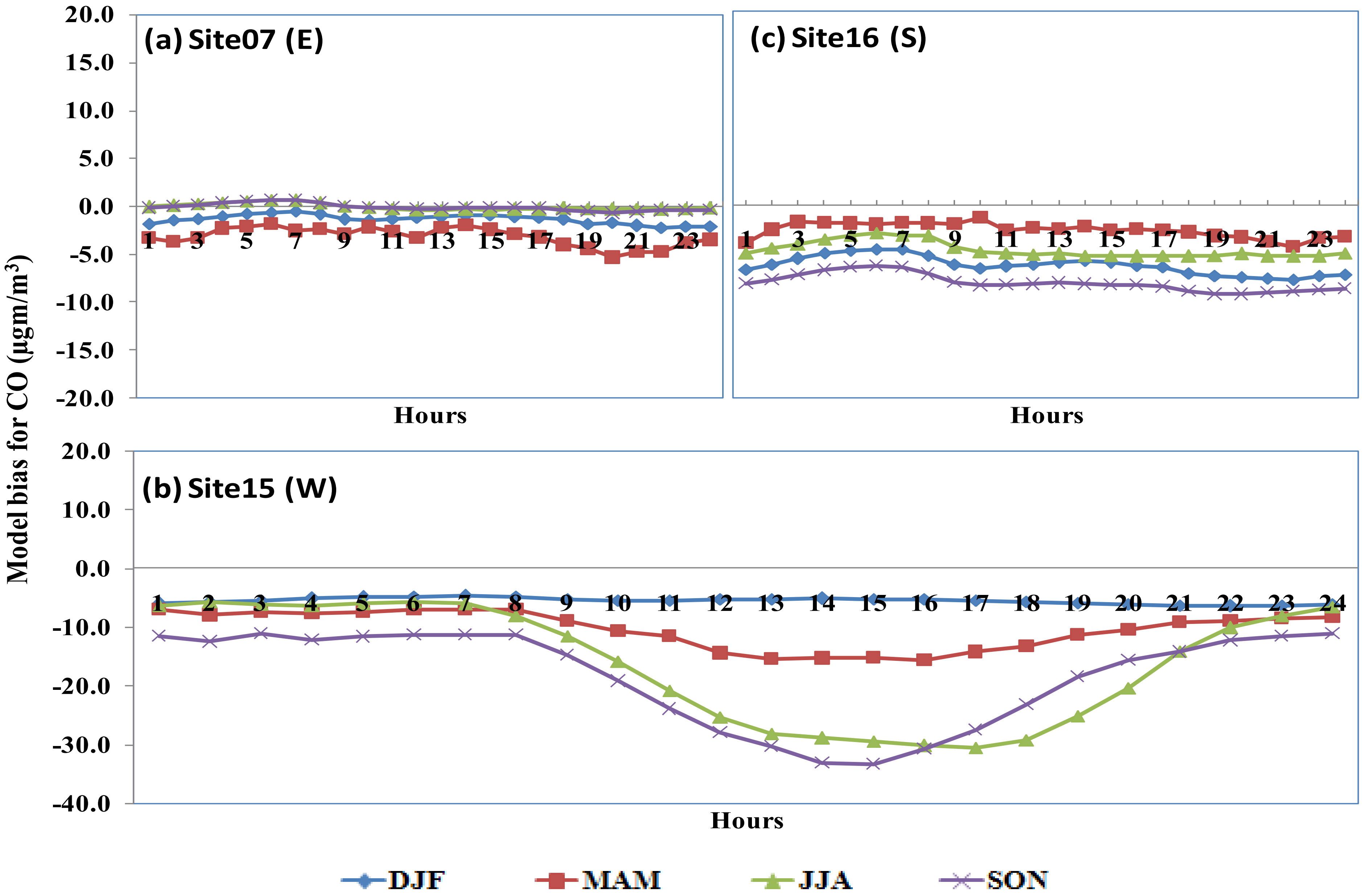
Seasonal variation of lowest model level of nitrogen dioxide, surface ozone, carbon monoxide, sulfur dioxide, and PM10 over Egypt



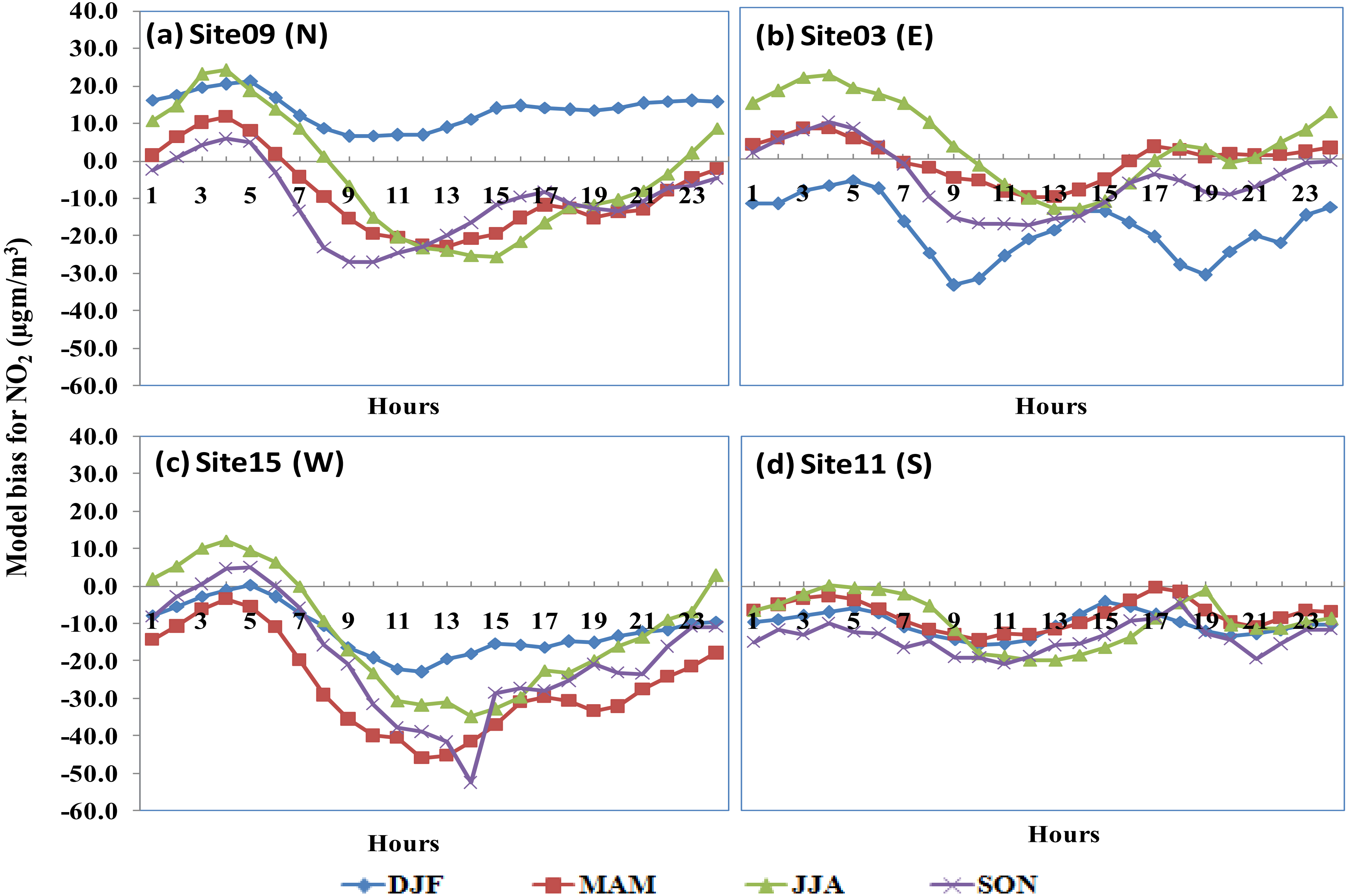
RegCM-CHEM4 Model bias (μg/m³) for 3-year seasonally averaged daily concentrations of SO_2 in (a) Site 14 (N), (b)Site 3 (E), (c) Site 13 (W), and (d) Site 4 (S)



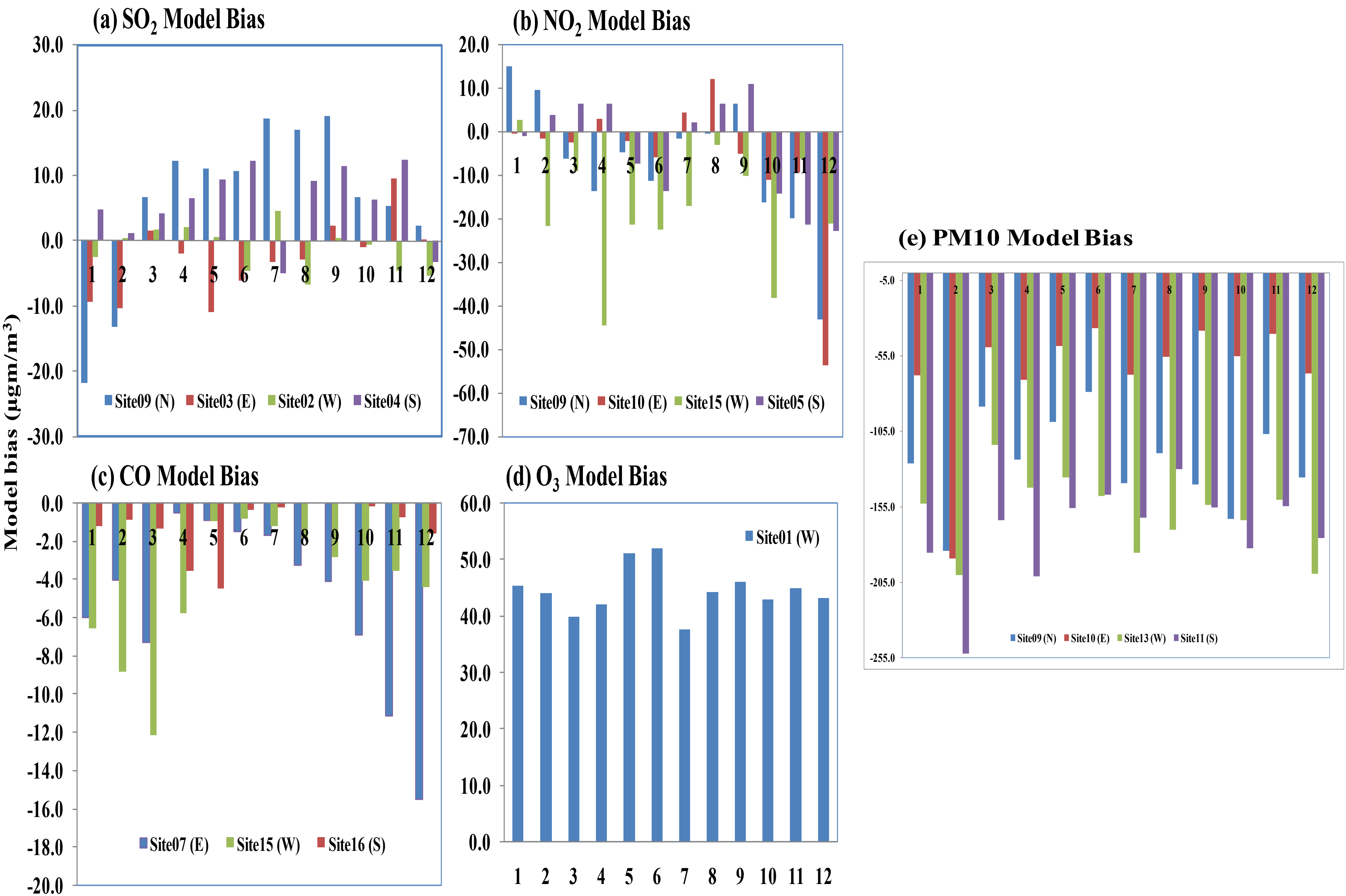
RegCM-CHEM4 Model bias (µg/m³) for 3-year seasonally averaged daily concentrations of PM10 in (a) Site 9 (N), (b) Site 3 (E), (c) Site 13 (W), and (d) Site 11 (S)



RegCM-CHEM4 Model bias (µg/m³) for 3-year seasonally averaged daily concentrations of CO in (a) Site 7 (E), (b) Site 15 (W), and (c) Site 16 (S)



RegCM-CHEM4 Model bias (µg/m^3) for 3-year seasonally averaged daily concentrations of NO_2 in (a) Site 9, (b) Site 11, (c) Site 15, and (d) Site 3



RegCM-CHEM4 Model bias (µg/m^3) for 3-year monthly averaged concentrations of SO_2, NO_2, CO,O_3, and PM10 at the available stations

Summary

The densely populated Greater Cairo (GC) region suffers from severe air quality issues caused by high levels of anthropogenic activities, such as motorized traffic, industries, and agricultural biomass burning events, along with natural sources of particulate matter, such as wind erosion of arid surfaces. Surface measured concentrations of particulate matter (PM10), sulfur dioxide (SO_2), and ozone (O_3) and its precursor's gases (nitrogen dioxide, NO_2; carbon monoxide, CO) were obtained for the GC region. The PM10 concentrations were found to exceed remarkably the Egyptian Guidelines (150 µg/m^3). These high levels of PM10 were recorded throughout 68% of the period of measurement in some industrial areas (El-Kolaly). The measured data of pollutants were used for both the evaluation of environmental pollution levels and the validation of the online integrated regional climate chemistry model "RegCM-CHEM4". Calculation of the bias between the model results and the measured data was used to evaluate the model performance in order to assess its ability in reproducing the chemical species over the area. The model was found to reproduce the seasonal cycle of the pollutants successfully, but with a large underestimation of the PM10 values. Validation of the RegCM-CHEM4 indicated that the emissions inventories of mobile sources and anthropogenic activities need to be improved especially with respect to local and regional activities in order to enhance air quality simulations over GC region.

Summary and Conclusion

1. At low cloud liquid water mixing ratio with large size of cloud droplets (r_e = 10 µm) or low aerosol concentrations, the autoconversion rate will be accelerated by BH scheme more than TC, R6, and KS, respectively.

2. At low in-cloud liquid water (≤ 0.1 g kg^{-1}) with smaller cloud droplets (r_e = 7.5µm) or high aerosol concentrations, the BH scheme will act faster than the other schemes, and as a consequence, the scheme of BH resulted in more precipitation than the others.

3. The inclusion of the direct and 1st indirect effects increased the cooling at the surface and TOA, which suppressed the precipitations over the west and central Africa.

4. With respect to precipitation, the simulations of all_R6 and all_TC had the minimum bias compared to the other simulations over the two domains.

5. With respect to temperature, all simulations have similar skills (RMS, correlation and normalized standard deviation), with the simulations of all_BH and ctrl resulted in the minimum bias (< 75%) over west and central domains, respectively, but all_R6 and all_TC had the lowest skills.

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THANK YOU FOR YOUR ATTENTION!


Conclusion – get on board (the 'bit' has left the station)
Any Questions
Thank You