ORDINE INTERPROVINCIALE DEI CHIMICI DELL'EMILIA ROMAGNA

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Ravenna 16·17·18 maggio 2018
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cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici

INQUINAMENTO ATMOSFERICO E CLIMA

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CMCC

Ringraziamenti:
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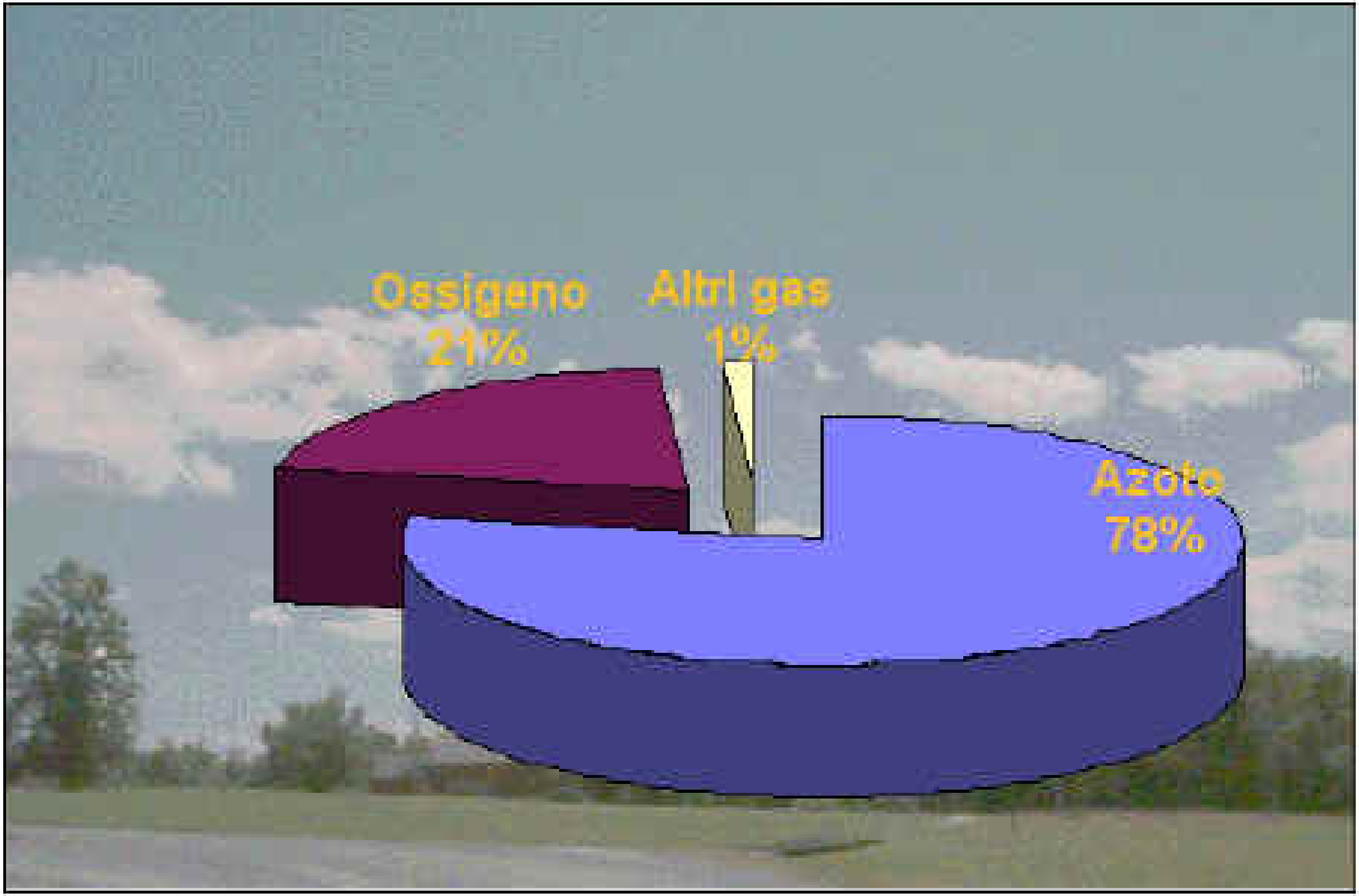
RER - Servizio Risanamento Atmosferico, Acustico e Elettromagnetico
(Katia Raffaelli, Carmen Carbonara)

Outline

1. Relazione tra meteo/clima e inquinamento atmosferico
2. Le tendenze dell’inquinamento atmosferico in E-R
3. Le tendenze del clima in E-R
4. Quale futuro ?

1. Relazione tra meteo/clima e inquinamento atmosferico

Atmospheric composition



COMPOSIZIONE DELL'ATMOSFERA AL SUOLO			
Gas	**Formula o simbolo**	**% in volume**	**GWP (20Y)**
Azoto	N_2	78,884	
Ossigeno	O_2	20,947	
Argo	Ar	0,934	
Vapore acqueo	H_2O	0,33	--
Biossido di carbonio	CO_2	0,032	1
Neo	Ne	0,00181	
Elio	He	0,0005	
Metano	CH_4	0,0002	21
Idrogeno	H	0,00005	
Cripto	Kr	0,000011	
Xeno	Xe	0,000008	
Ozono	O_3	0,000004	
Ossidi di azoto	NO, NO_2, N_2O	0,00003 (N_2O)	310 (N_2O)
Monossido di carbonio	CO	Tracce	
Ammoniaca	NH_3	Tracce	
Biossido di zolfo	SO_2	Tracce	
Solfuro di idrogeno	H_2S	Tracce	

Table 1–2 Principal gases of dry air

Constituent	Percent by Volume	Concentration in Parts Per Million (PPM)
Nitrogen (N_2)	78.084	780,840.0
Oxygen (O_2)	20.946	209,460.0
Argon (Ar)	0.934	9,340.0
Carbon dioxide (CO_2)	0.036	360.0
Neon (Ne)	0.00182	18.2
Helium (He)	0.000524	5.24
Methane (CH_4)	0.00015	1.5
Krypton (Kr)	0.000114	1.14
Hydrogen (H_2)	0.00005	0.5

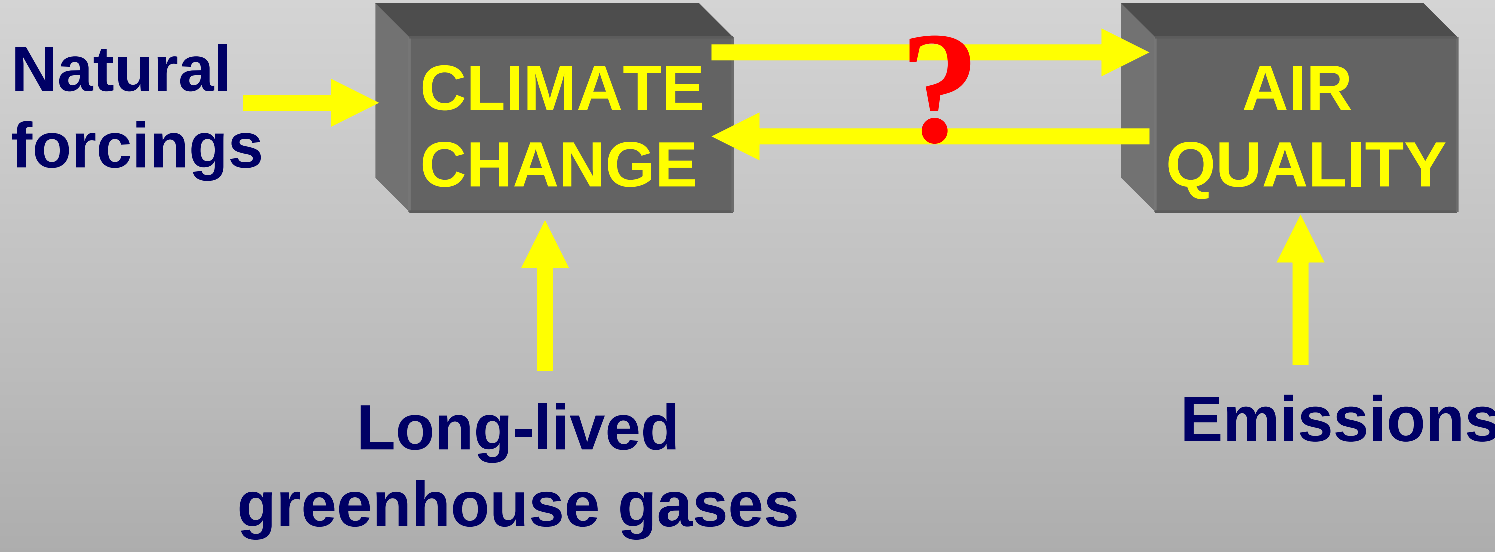
Inquinanti, aerosol e gas serra (esempi…)

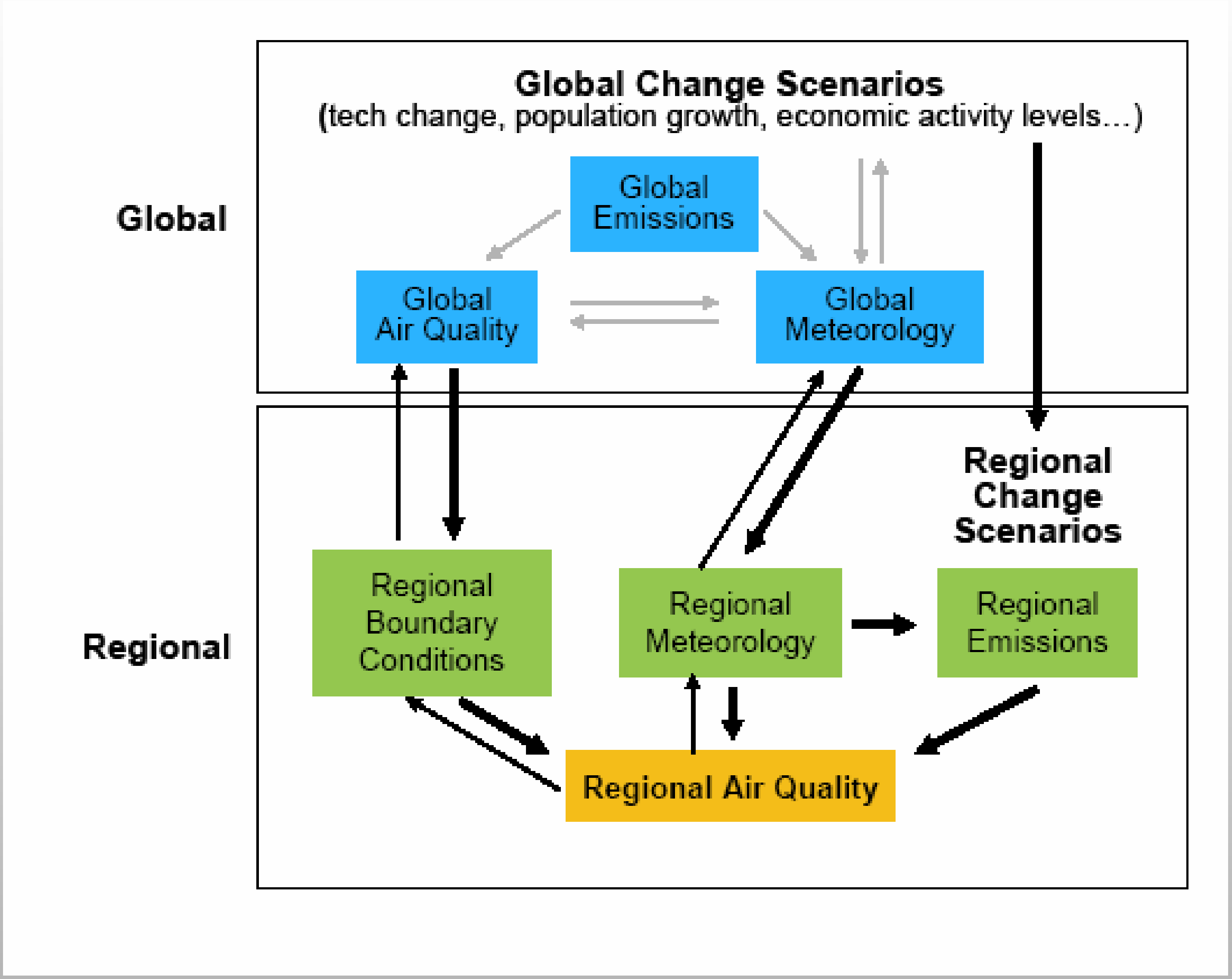
- **H_2O**
- **N_2O**
- **NO**
- **NO_2**
- **COV**
- **CO**
- **CO_2**
- **SO_2**
- **CH_4**
- **FREON ($CFCl_3$, ….)**
- **……..**

Cambiamento climatico e Qualità dell'Aria

L'aumento dei gas serra ha determinato un aumento della temperatura media globale, cambiamenti della circolazione atmosferica a scala grande, delle precipitazioni e delle condizioni meteorologiche anche alle scale regionali e locali

La qualità dell'aria è sensibile alle condizioni meteorologiche. Mutate condizioni climatiche producono impatti sulla qualità dell'aria (ozono, particolato ecc..). Ad esempio più alte temperature modificano la cinetica del particolato, l'altezza del PBL e quindi la qualità dell'aria





Fonte: Alice Gilliland, EPA, USA

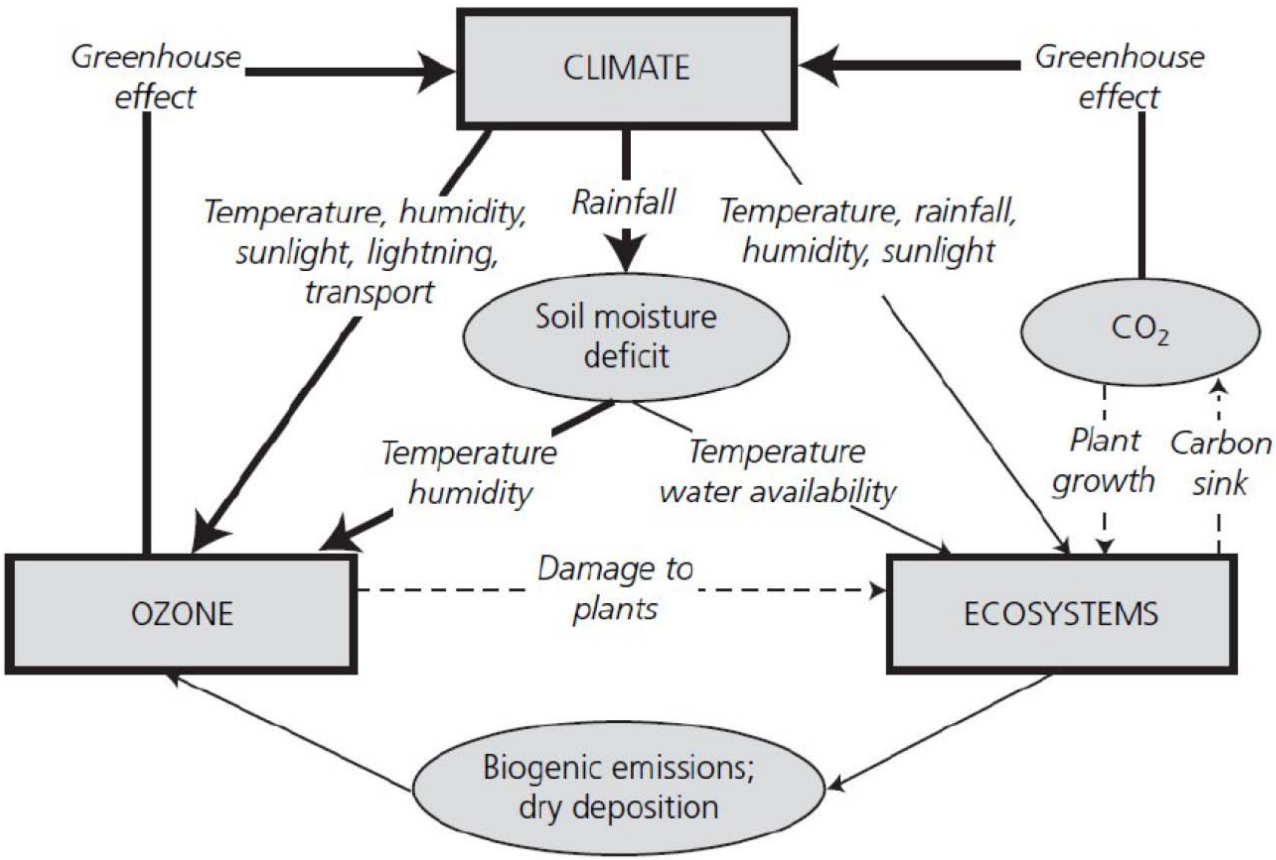


Figura 5: rappresentazione schematica delle relazioni tra cambiamenti climatici, parametri meteorologici e concentrazioni di ozono (da Chiesa 2013)

Come il Clima influenza la Qualità dell’aria

THE CLIMATE SYSTEM

The system can be divided into 5 essential components

ATMOSPHERE
(THE GAS ENVELOPE
very fast)

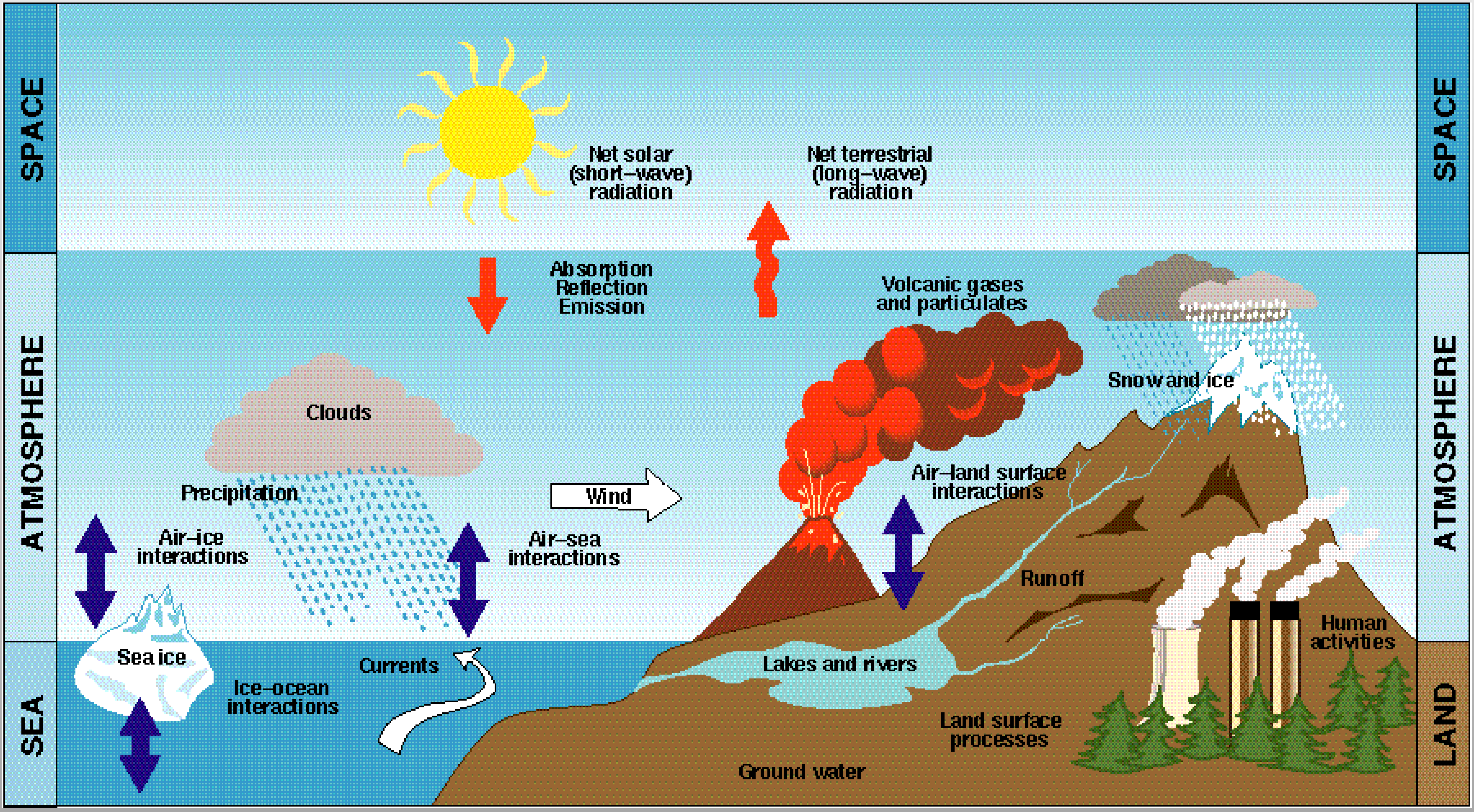
HYDROSPHERE
(OCEANS, SEAS, LAKES, RIVERS,
both fast and slow)

CRYOSPHERE
(SNOW, GLACIERS AND LAND AND SEA ICE
both fast and slow)

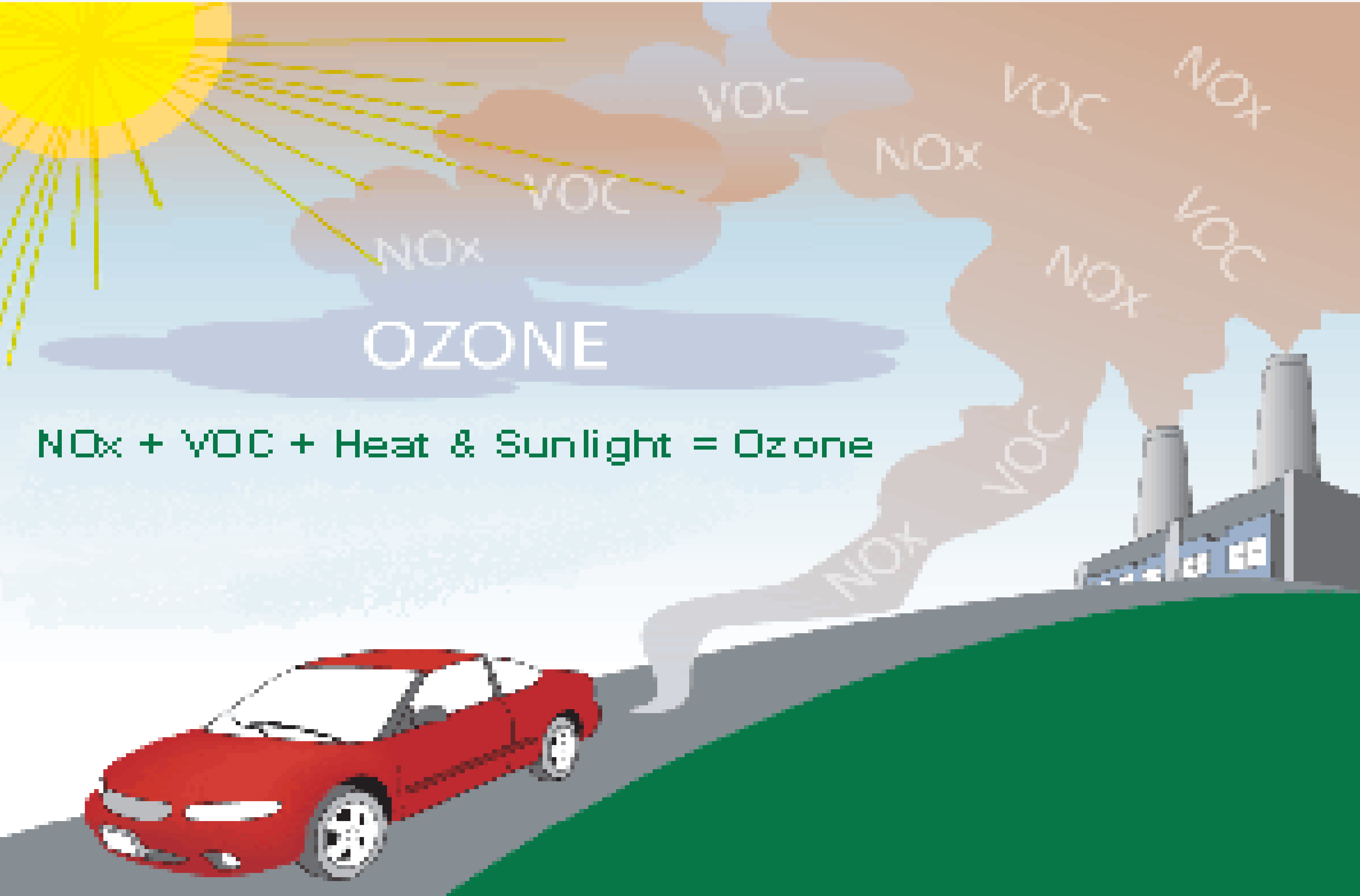
BIOSPHERE
(animal and vegetal world.
both fast and slow)

LITHOSPHERE
(SOLID EARTH,
very slow)

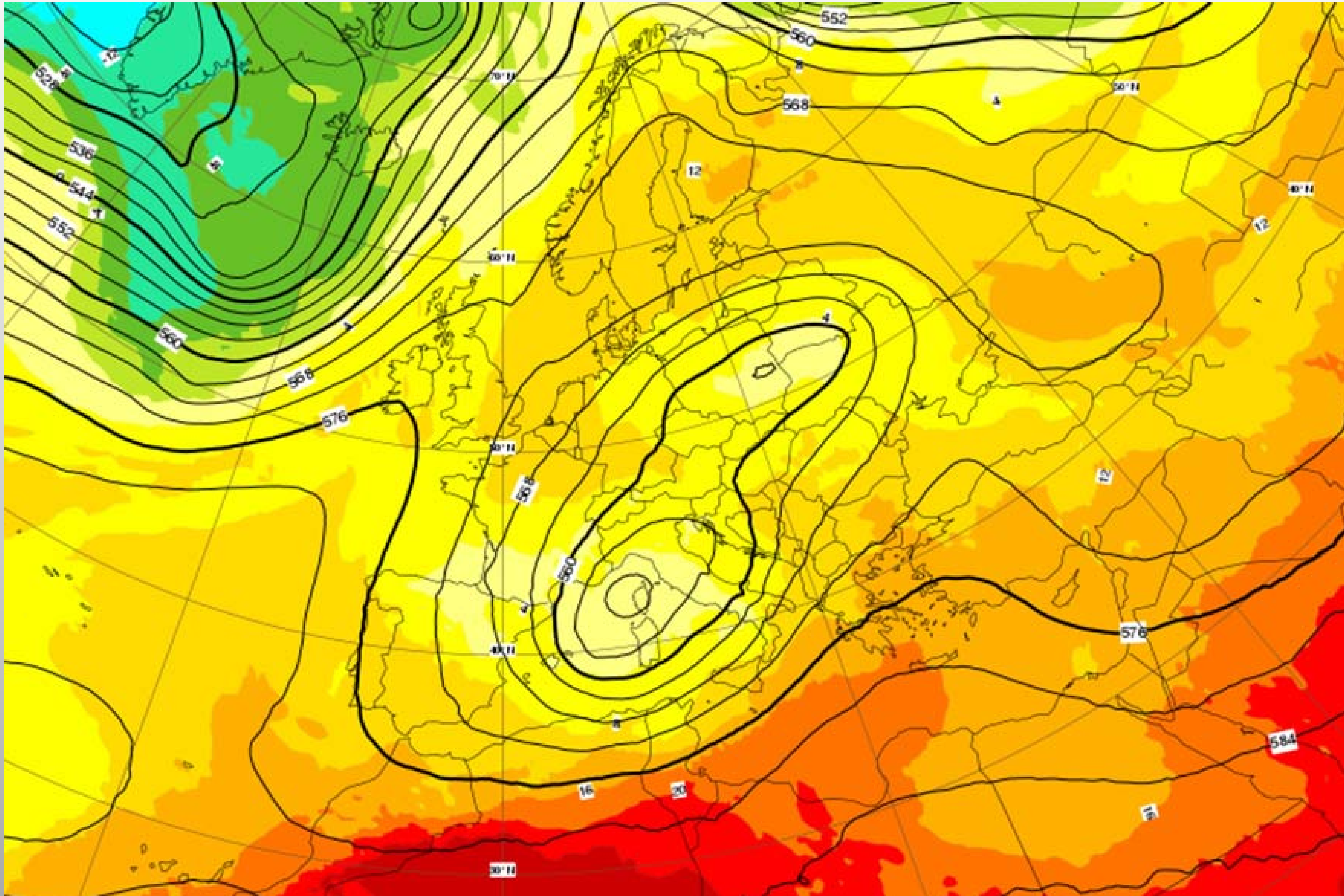
The Sun is the only important (external) energy source



How is Climate Change Affecting Air Quality?



Base time: Tue 15 May 2018 00 UTC Area: Europe
850 hPa temperature / 500 hPa geopotential



Cambiamento Climatico e Qualità dell’Aria

Esempi di interazione:

Aumento di temperatura (insolazione)..…..aumento di ozono e particelle secondarie

Stabilità verticale atmosfera……………...influenza la capacità
(riscaldamento ai bassi livelli) dell’atmosfera di disperdere gli inquinanti
> polveri sottili

Aumento di periodi di siccità…………....aumento delle polveri in generale

Aumento di frequenza di incendi……….aumento di particelle, ozono, monossido di carbonio, fuliggine

Come la Qualità dell’aria influenza il Clima

Climate Change Drivers

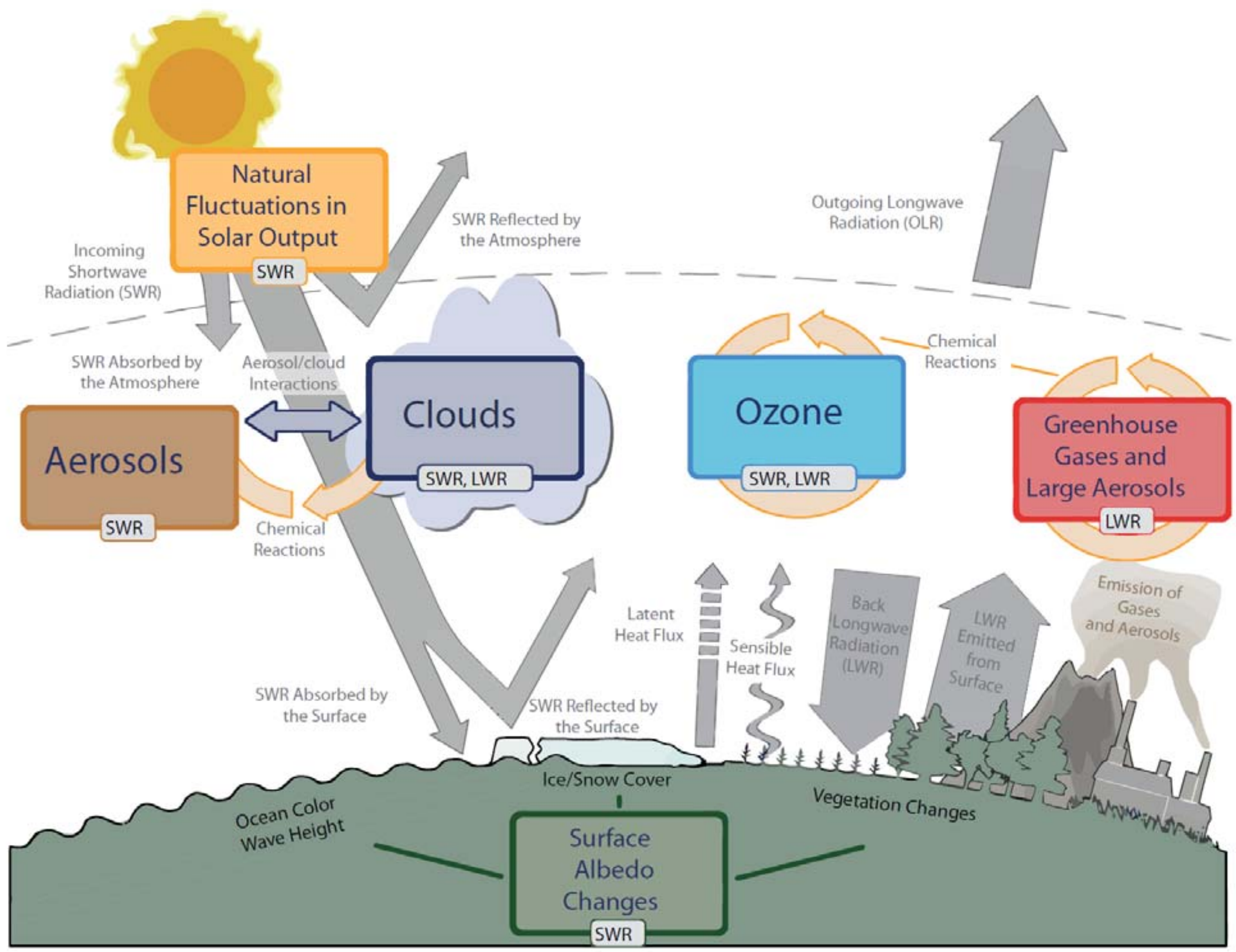


Figure 1.1 | Main drivers of climate change. The radiative balance between incoming solar shortwave radiation (SWR) and outgoing longwave radiation (OLR) is influenced by global climate 'drivers'. Natural fluctuations in solar output (solar cycles) can cause changes in the energy balance (through fluctuations in the amount of incoming SWR) (Section 2.3). Human activity changes the emissions of gases and aerosols, which are involved in atmospheric chemical reactions, resulting in modified O_3 and aerosol amounts (Section 2.2). O_3 and aerosol particles absorb, scatter and reflect SWR, changing the energy balance. Some aerosols act as cloud condensation nuclei modifying the properties of cloud droplets and possibly affecting precipitation (Section 7.4). Because cloud interactions with SWR and LWR are large, small changes in the properties of clouds have important implications for the radiative budget (Section 7.4). Anthropogenic changes in GHGs (e.g., CO_2, CH_4, N_2O, O_3, CFCs) and large aerosols (>2.5 μm in size) modify the amount of outgoing LWR by absorbing outgoing LWR and re-emitting less energy at a lower temperature (Section 2.2). Surface albedo is changed by changes in vegetation or land surface properties, snow or ice cover and ocean colour (Section 2.3). These changes are driven by natural seasonal and diurnal changes (e.g., snow cover), as well as human influence (e.g., changes in vegetation types) (Forster et al., 2007).

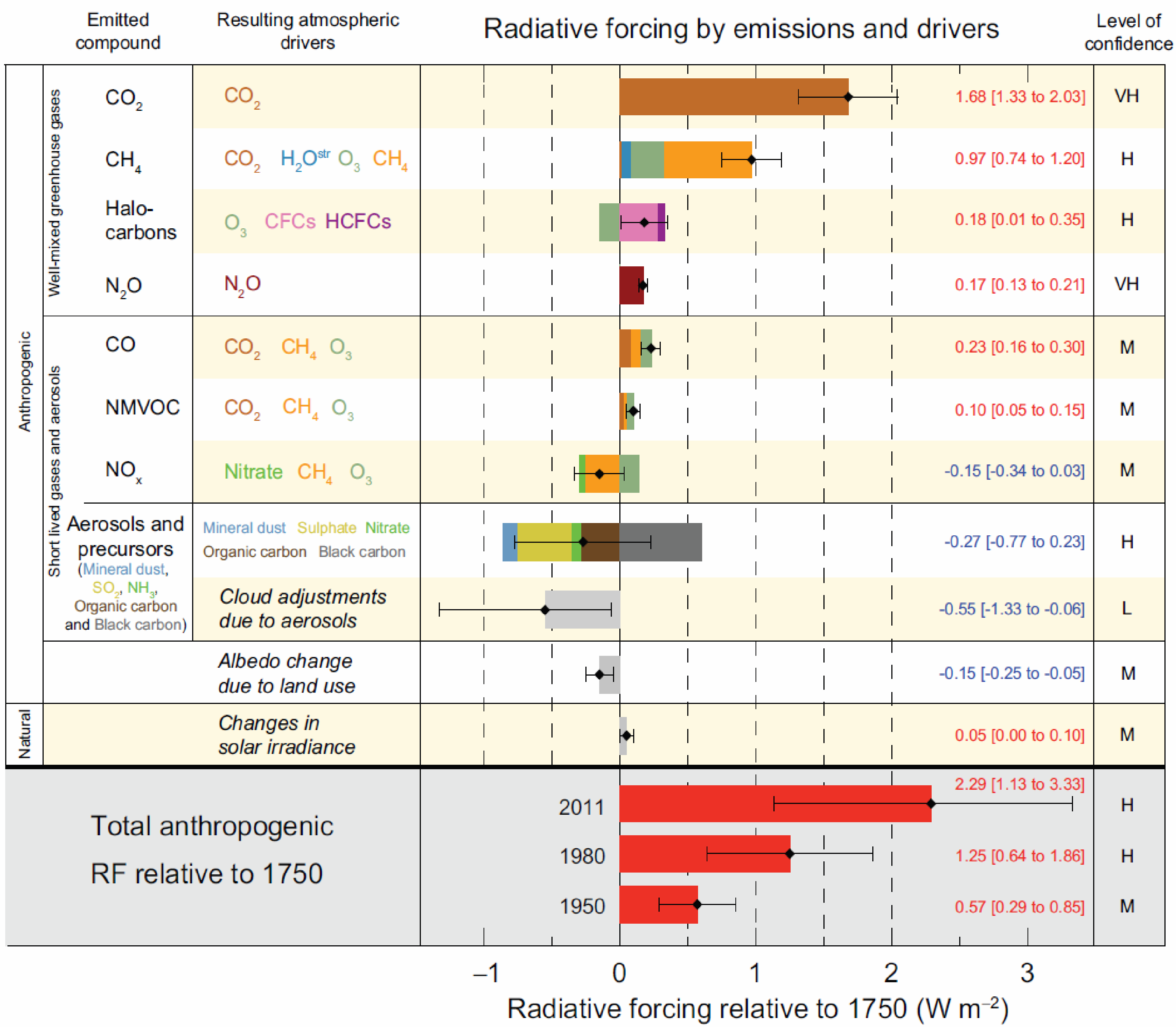
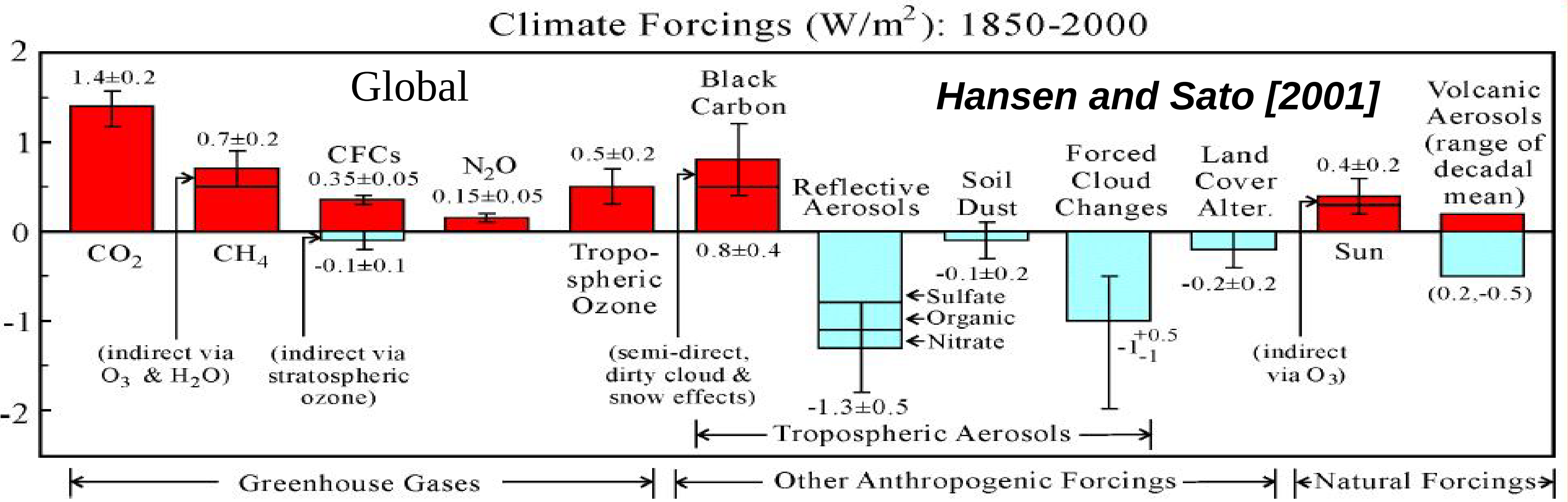


Figure SPM.5 | Radiative forcing estimates in 2011 relative to 1750 and aggregated uncertainties for the main drivers of climate change. Values are global average radiative forcing (RF14), partitioned according to the emitted compounds or processes that result in a combination of drivers. The best estimates of the net radiative forcing are shown as black diamonds with corresponding uncertainty intervals; the numerical values are provided on the right of the figure, together with the confidence level in the net forcing (VH – very high, H – high, M – medium, L – low, VL – very low). Albedo forcing due to black carbon on snow and ice is included in the black carbon aerosol bar. Small forcings due to contrails (0.05 W m–2, including contrail induced cirrus), and HFCs, PFCs and SF6 (total 0.03 W m–2) are not shown. Concentration-based RFs for gases can be obtained by summing the like-coloured bars. Volcanic forcing is not included as its episodic nature makes is difficult to compare to other forcing mechanisms. Total anthropogenic radiative forcing is provided for three different years relative to 1750.

EFFECTS OF AIR POLLUTANTS ON CLIMATE CHANGE



Air pollution - related greenhouse forcing: 0.5 (O_3) + 0.8 (BC) + 0.7 (CH_4)
= 2.0 W m^{-2}…larger than CO_2

Cooling from scattering anthropogenic aerosols: -1.3 (direct) – 1.0 (clouds)
= -2.3 W m^{-2} …would cancel half the warming

Global radiative forcing is not the whole story, pollutants also affect

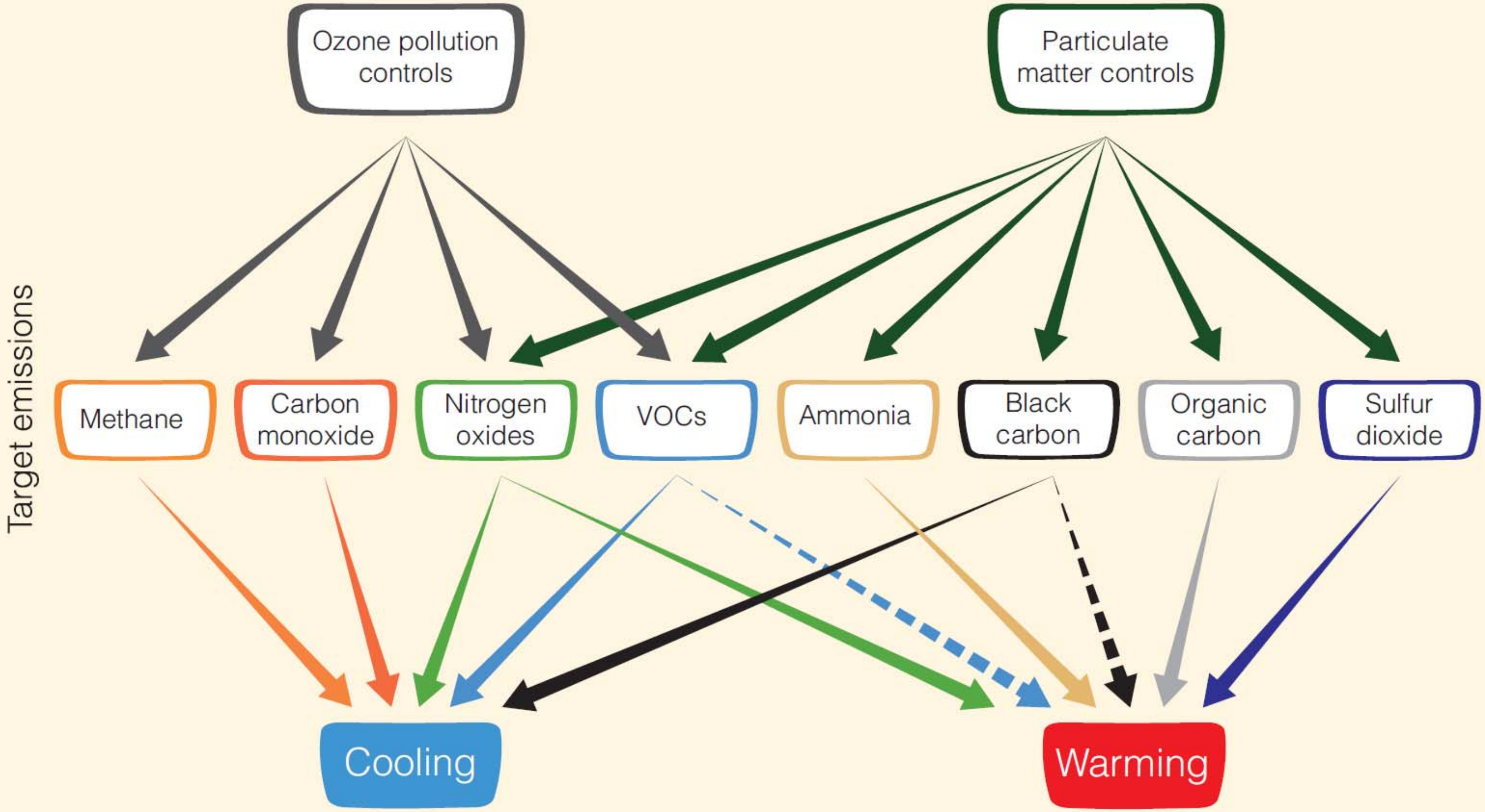
- **regional and surface forcing ⇨ regional climate change**
- **climate variables not quantified by radiative forcing (effect of aerosols on precipitation, of ozone on stratospheric temperatures…)**

Pollutant	Main sources	Effect on air quality and health	Effect on climate change
Particles – PM_{10} and $PM_{2.5}$	Burning fossil fuels (motor vehicles, electricity generation, dust, secondary processes, domestic heating, smoke from fires)	Increases in mortality, hospital admission, exacerbation of asthma etc, reduced visibility	Reflects (causing cooling) or absorbs (causing heating) sunlight depending on particle composition Affects radiation balance by influencing cloud formation
Ozone	Secondary pollutant	Increases in mortality, hospital admission, exacerbation of asthma etc, Reduced lung growth and lung function	Contributes to global warming
Carbon monoxide	Motor vehicles, electricity generation	Increases in mortality, hospital admissions mainly for cardiovascular disease, low birth weights premature delivery	Promotes formation of ozone (GHG).
Nitrogen oxides (NO_2, NO)	Burning fossil fuels (motor vehicles, electricity generation, shipping)	Increases in mortality, hospital admission, exacerbation of asthma, increased respiratory symptoms etc, Reduced lung growth and lung function	Promotes formation of ozone (GHG), forms secondary particles (nitrates – cause health effects and cooling of atmosphere)

Pollutant	Main sources	Effect on air quality and health	Effect on climate change
Carbon monoxide	Motor vehicles, electricity generation	Increases in mortality, hospital admissions mainly for cardiovascular disease, low birth weights premature delivery	Promotes formation of ozone (GHG).
Nitrogen oxides (NO_2, NO)	Burning fossil fuels (motor vehicles, electricity generation, shipping)	Increases in mortality, hospital admission, exacerbation of asthma, increased respiratory symptoms etc, Reduced lung growth and lung function	Promotes formation of ozone (GHG), forms secondary particles (nitrates – cause health effects and cooling of atmosphere)
CO_2	Burning fossil fuels (motor vehicles, electricity generation, air transport, shipping		GHG, increases plant growth when other factors are not limiting
CH_4	Natural gas leakage, agriculture, landfills	Promotes formation of ozone which affects health	GHG

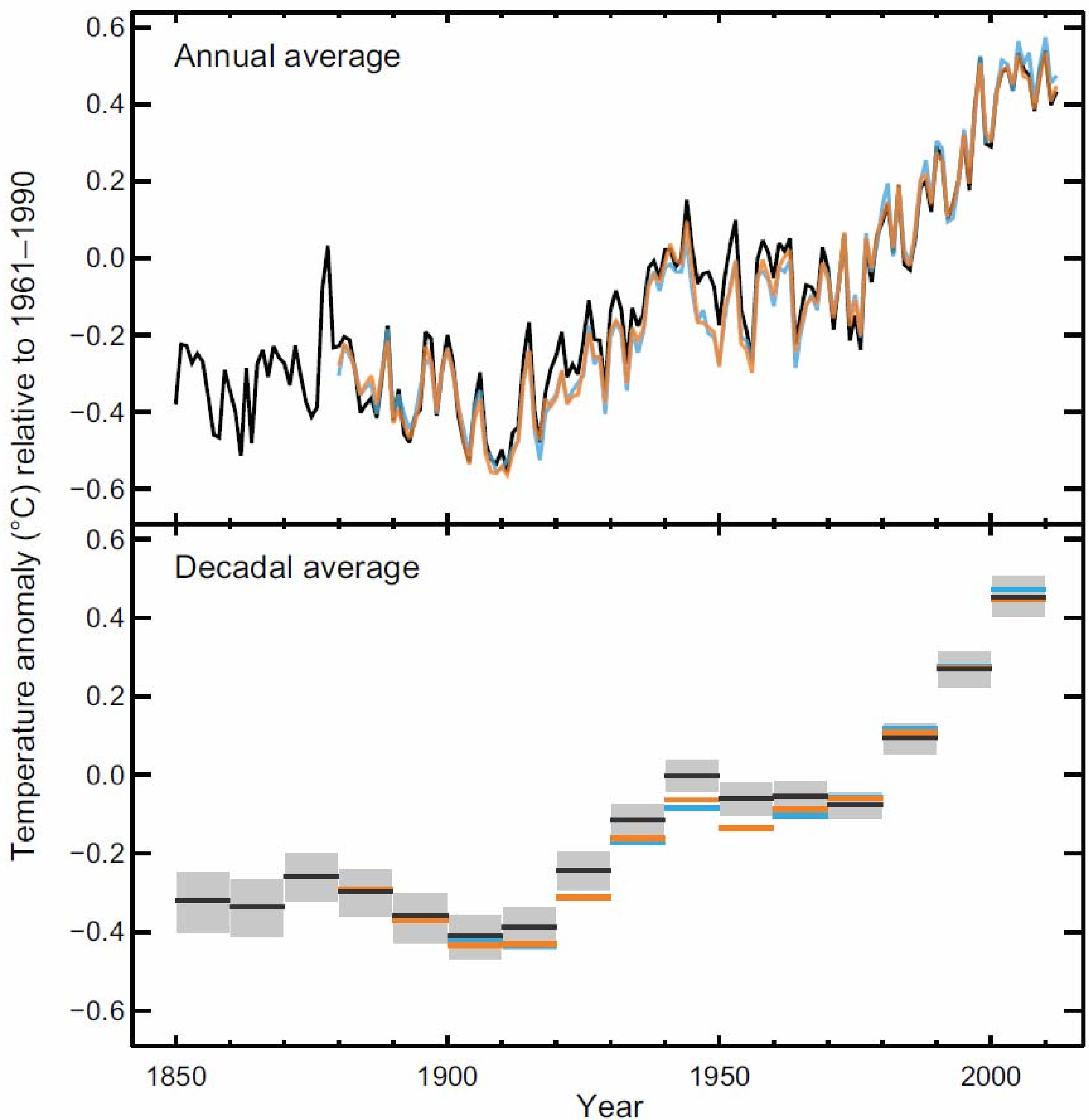
Pollutant	Main sources	Effect on air quality and health	Effect on climate change
VOCs (benzene, butane, isoprene etc)	Incomplete combustion, evaporation from solvent use, use and distribution of petrol, industry, vegetation	Range of health effects – eg., irritation through to cancer Promotes formation of ozone which affects health Promotes formation of secondary organic aerosol which affects health	Ozone – GHG SOA – causes cooling of the atmosphere

Come <u>il controllo della</u> qualità dell’aria (cioè della composizione chimica della nostra atmosfera) influenza il clima



FAQ 8.2, Figure 1 | Schematic diagram of the impact of pollution controls on specific emissions and climate impact. Solid black line indicates known impact; dashed line indicates uncertain impact.

(a) Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012



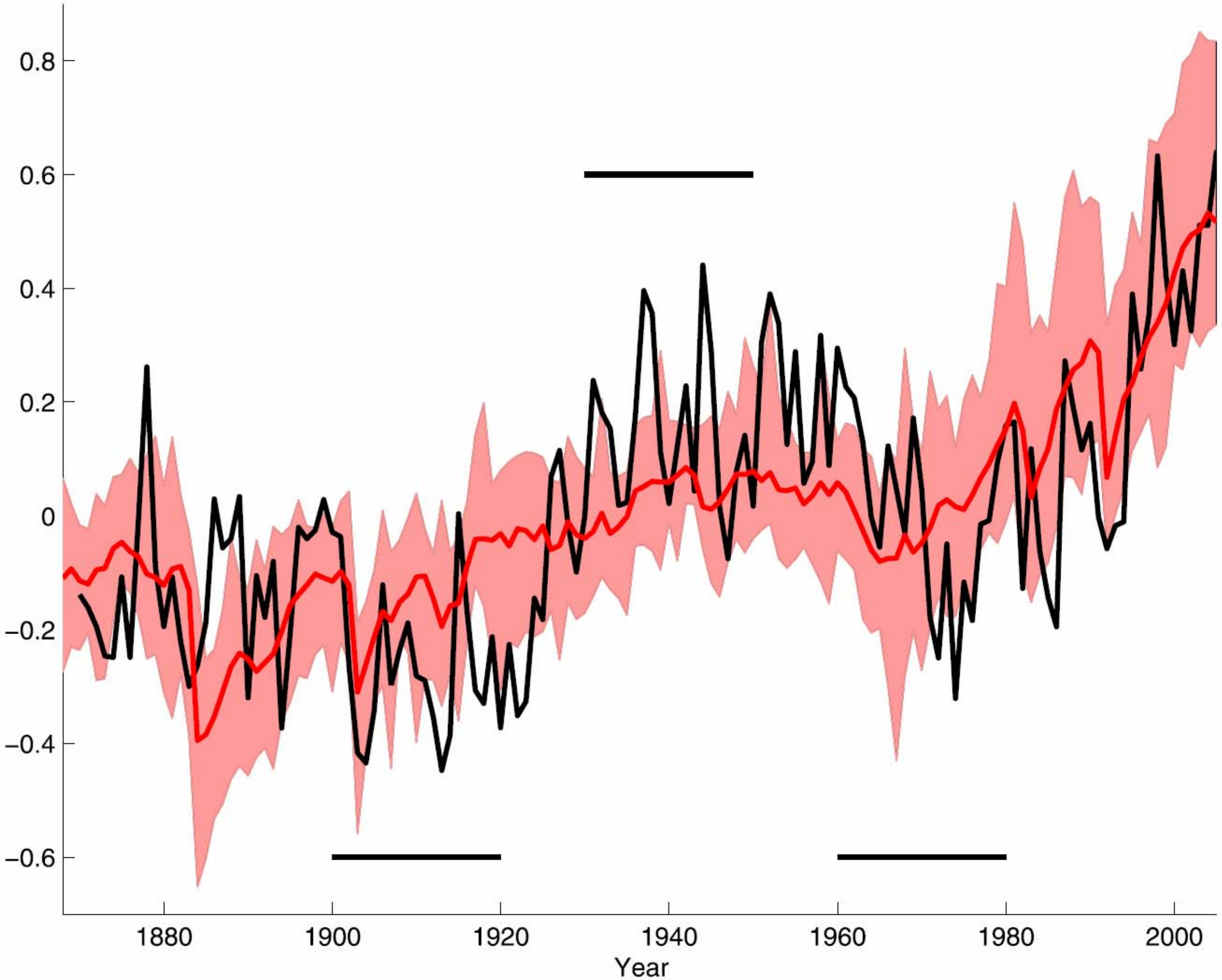


FIG. 1. Area-averaged North Atlantic (defined as 0°–60°N and 7.5°–75°W) SST anomalies relative to the 1870–2005 period, for an observational estimate (the HadISST dataset; solid black) and a multimodel ensemble of 13 CMIP5 historical integrations. The multimodel ensemble mean (MME) is in solid red, while light red shading represents the [min, max] envelope of the full multimodel historical ensemble. Thick black horizontal lines indicate the periods used to define the warm and cool phases of the observed SST variability.

2. Le tendenze dell’inquinamento atmosferico in E-R

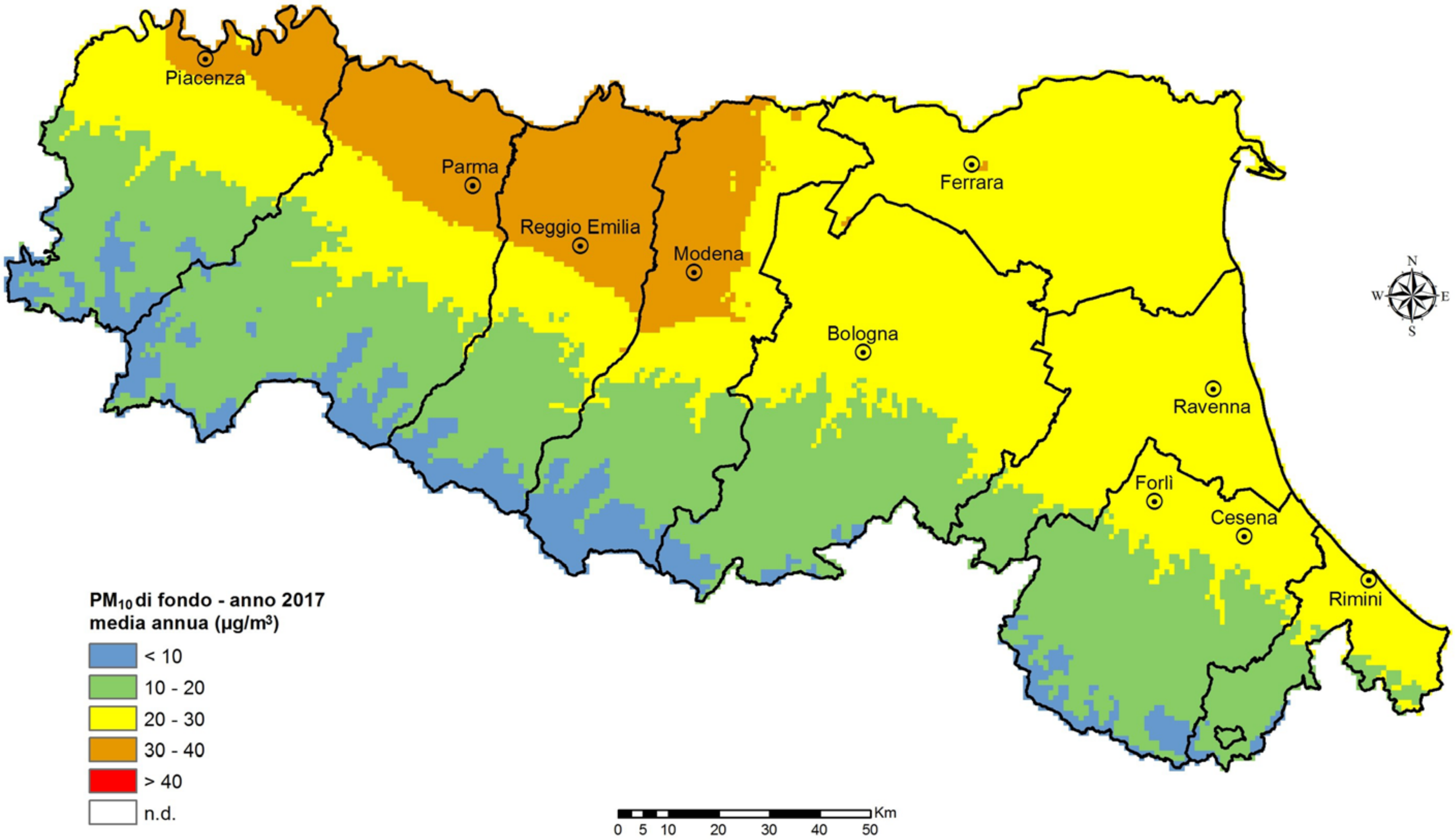
RegioneEmilia-Romagna

Piano
Aria
Integrato
Regionale
2020

Quadro conoscitivo

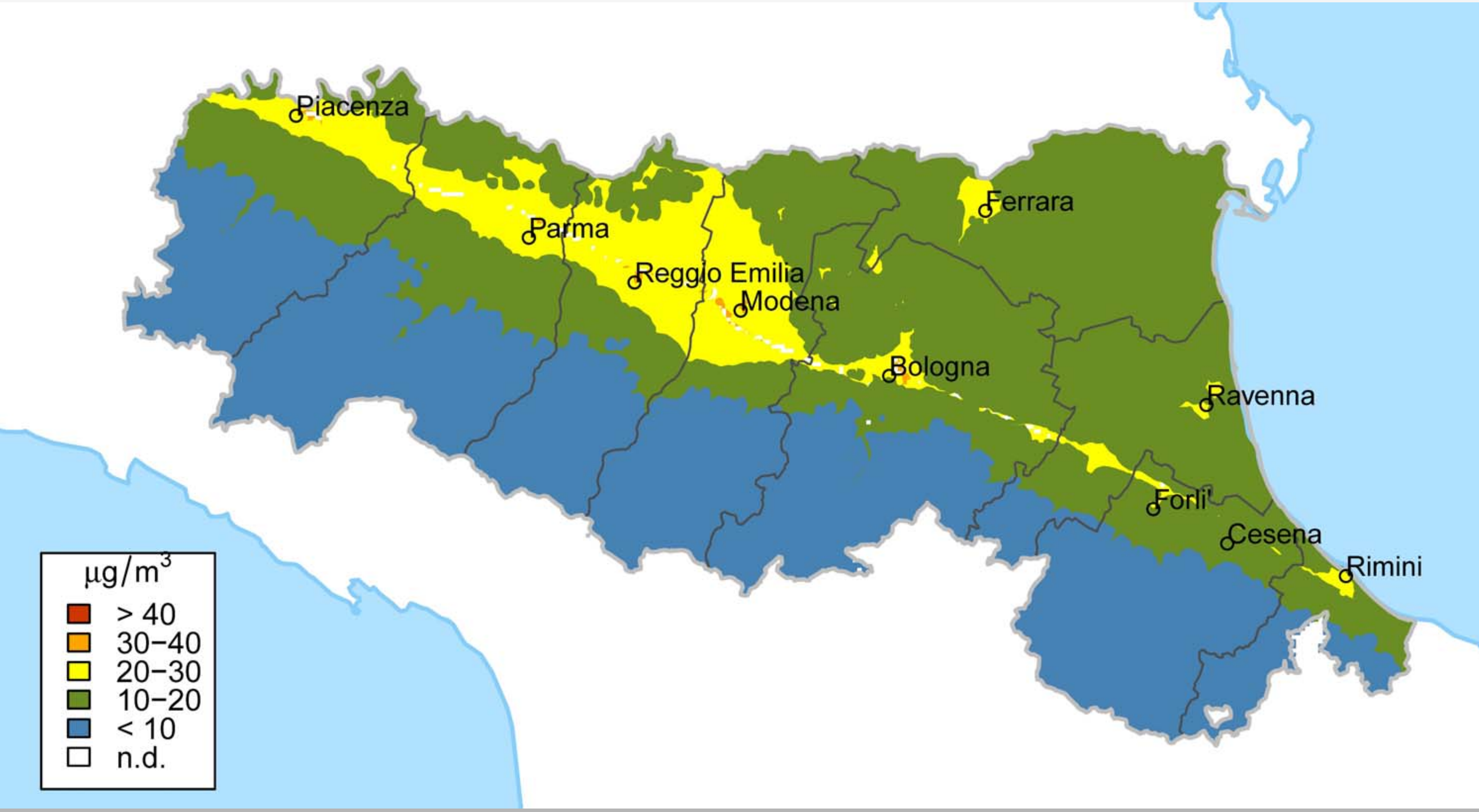
Piano Aria Integrato Regionale 2020

PM10 fondo



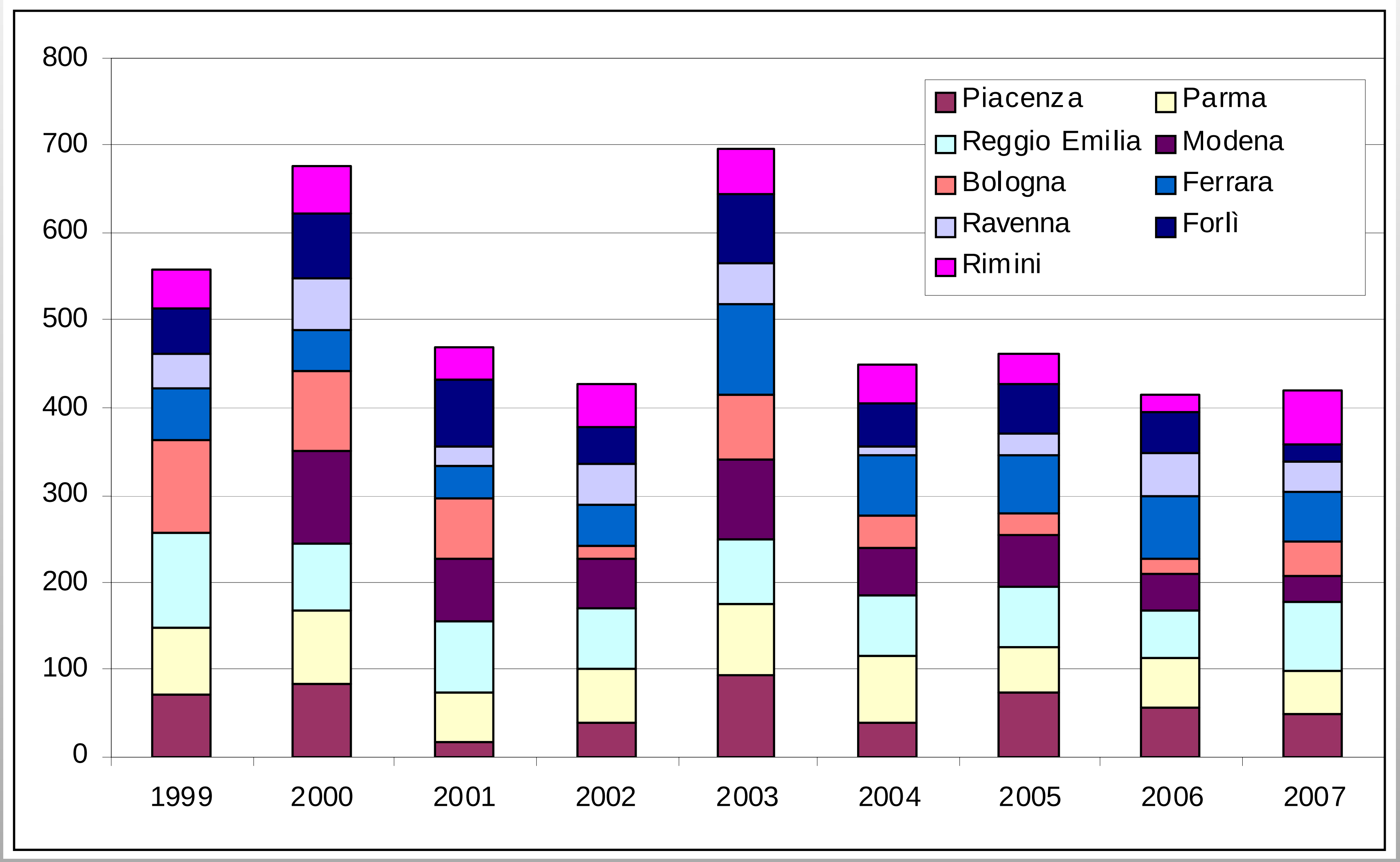
Piacenza
Parma
Reggio Emilia
Modena
Ferrara
Bologna
Ravenna
Forlì
Cesena
Rimini
N
W
E
S
PM10 di fondo - anno 2017
media annua (µg/m3)
< 10
10 - 20
20 - 30
30 - 40
> 40
n.d.
Km
0 5 10 20 30 40 50

NO_2

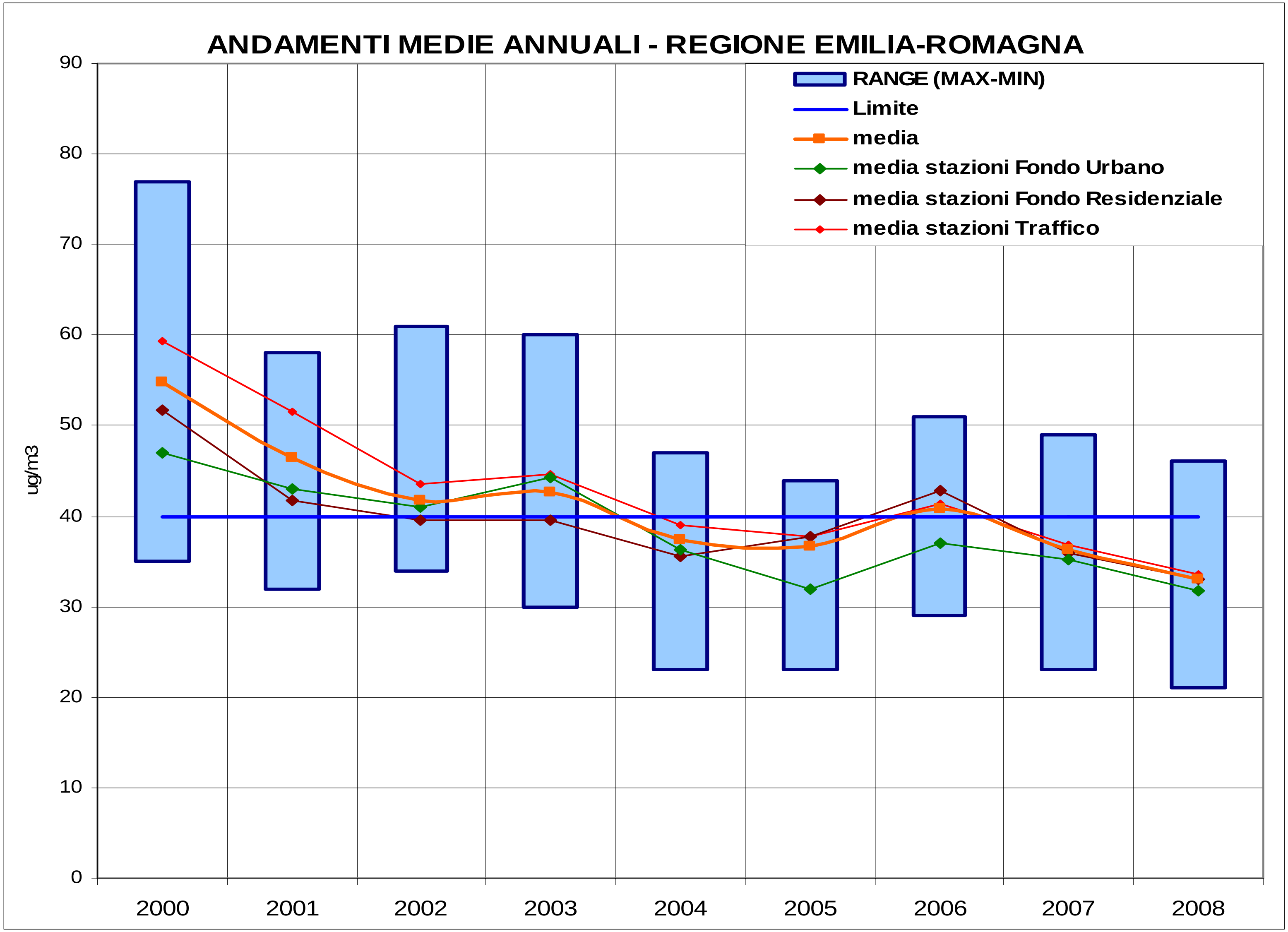


Piacenza
Parma
Reggio Emilia
Modena
Ferrara
Bologna
Ravenna
Forli'
Cesena
Rimini
µg/m3
> 40
30−40
20−30
10−20
< 10
n.d.

Inquadramento del problema in E-R
Variabilità inter-annuale dell'ozono

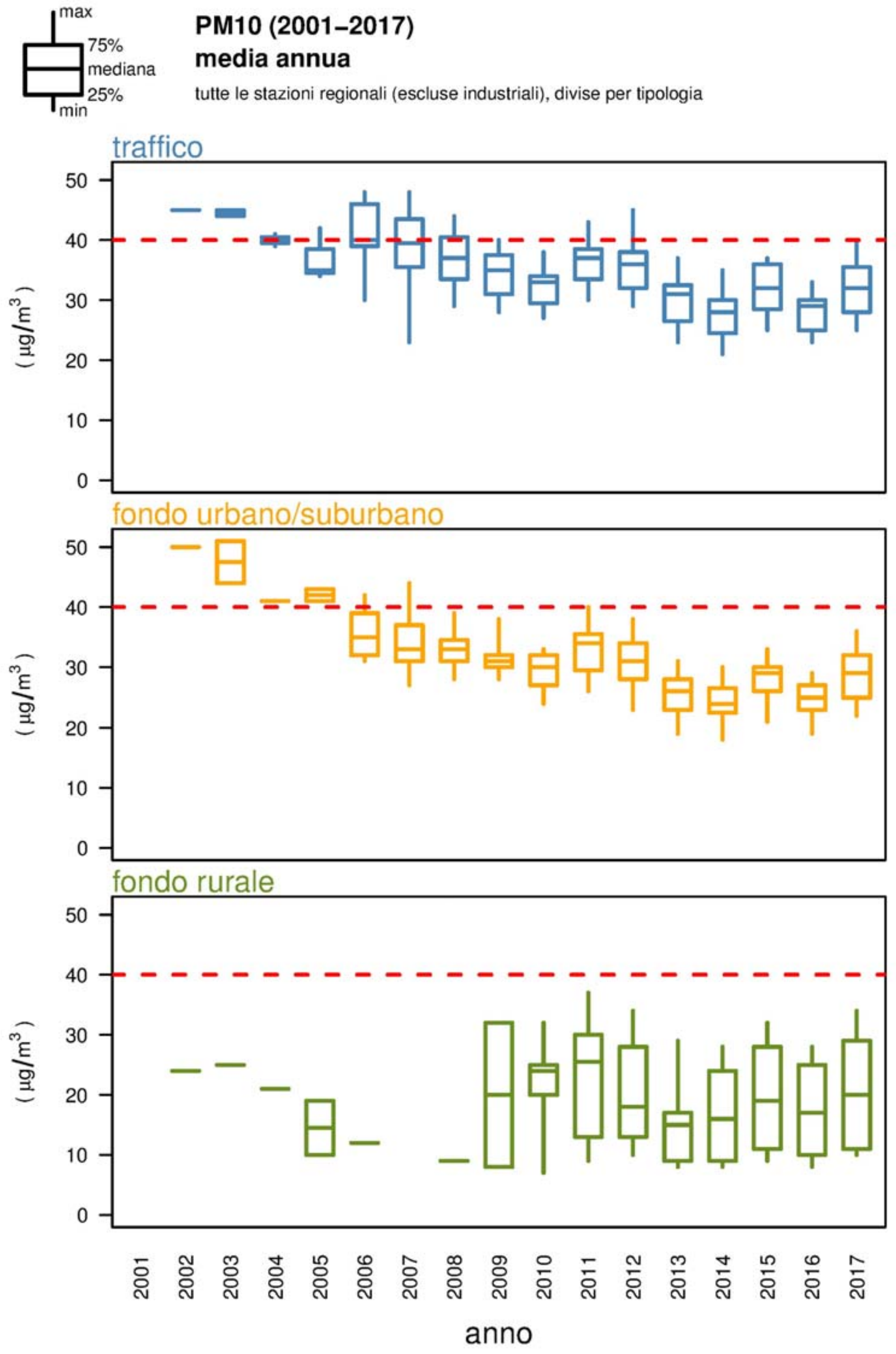


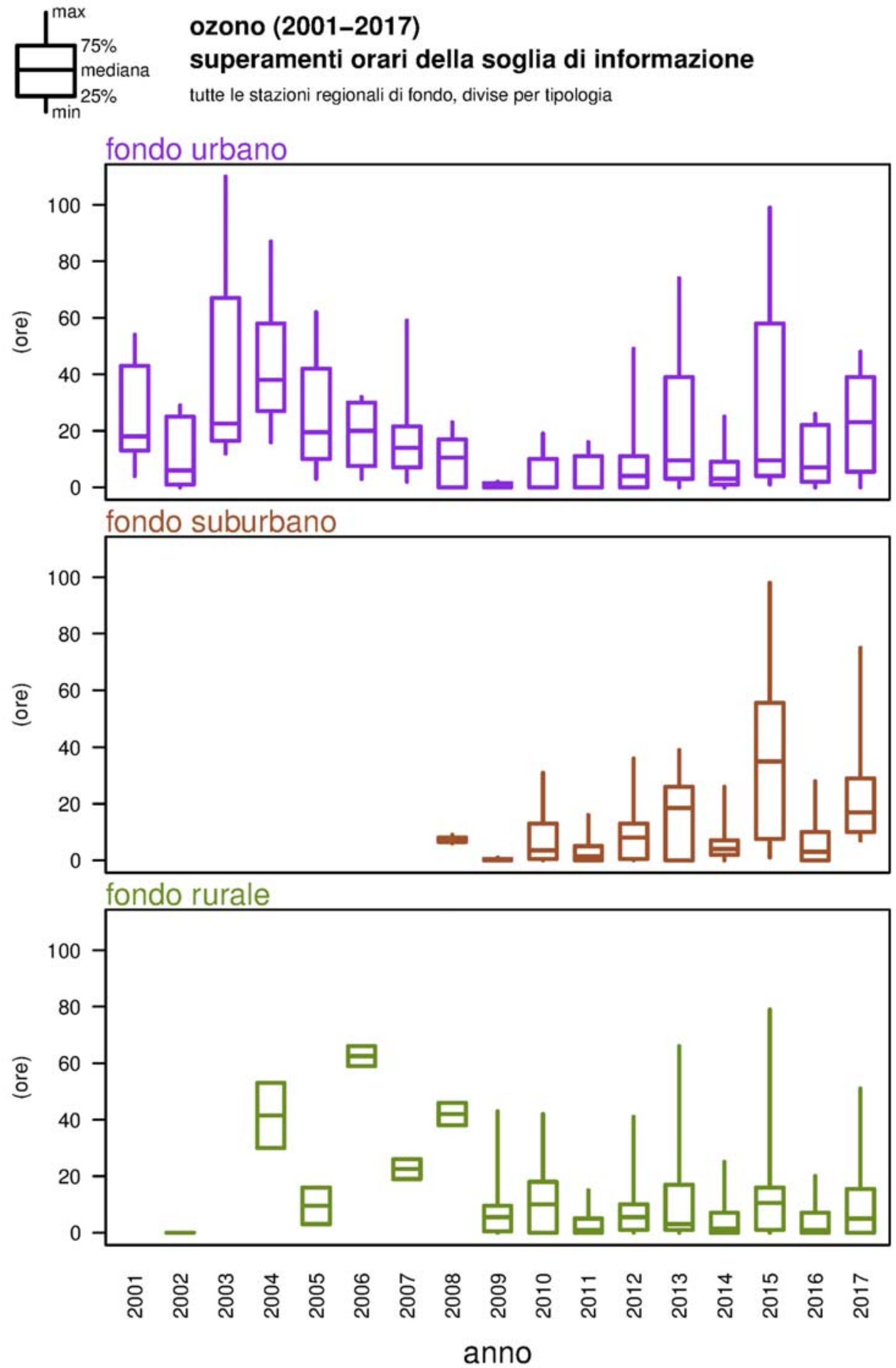
Inquadramento del problema in E-R
Variabilità interannuale del PM10



La verità è che:

la variabilità inter-annuale è dominata dai fattori meteo-climatici

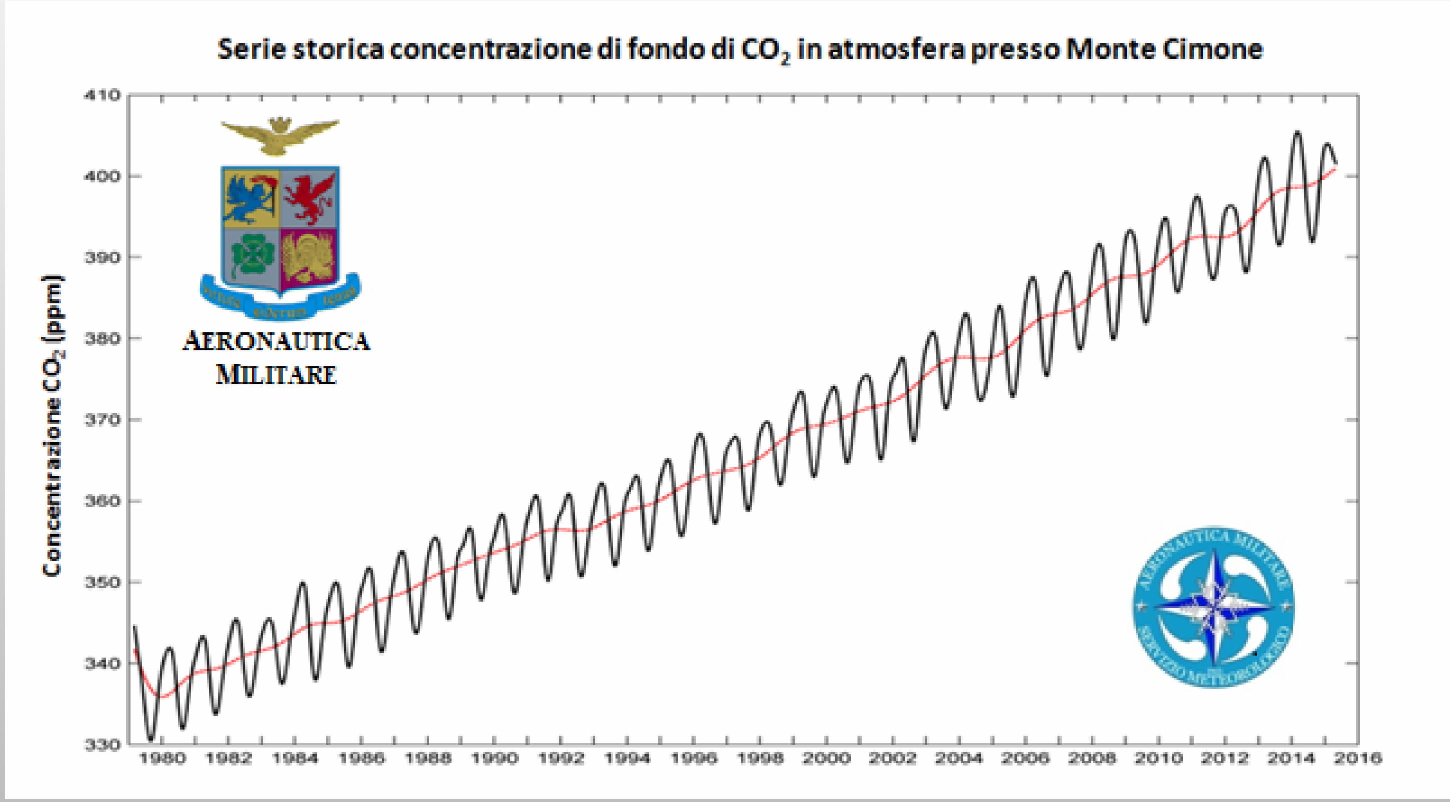

max
75%
mediana
25%
min
PM10 (2001–2017)
media annua
tutte le stazioni regionali (escluse industriali), divise per tipologia
traffico
fondo urbano/suburbano
fondo rurale
(µg/m3)
0
10
20
30
40
50
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
anno



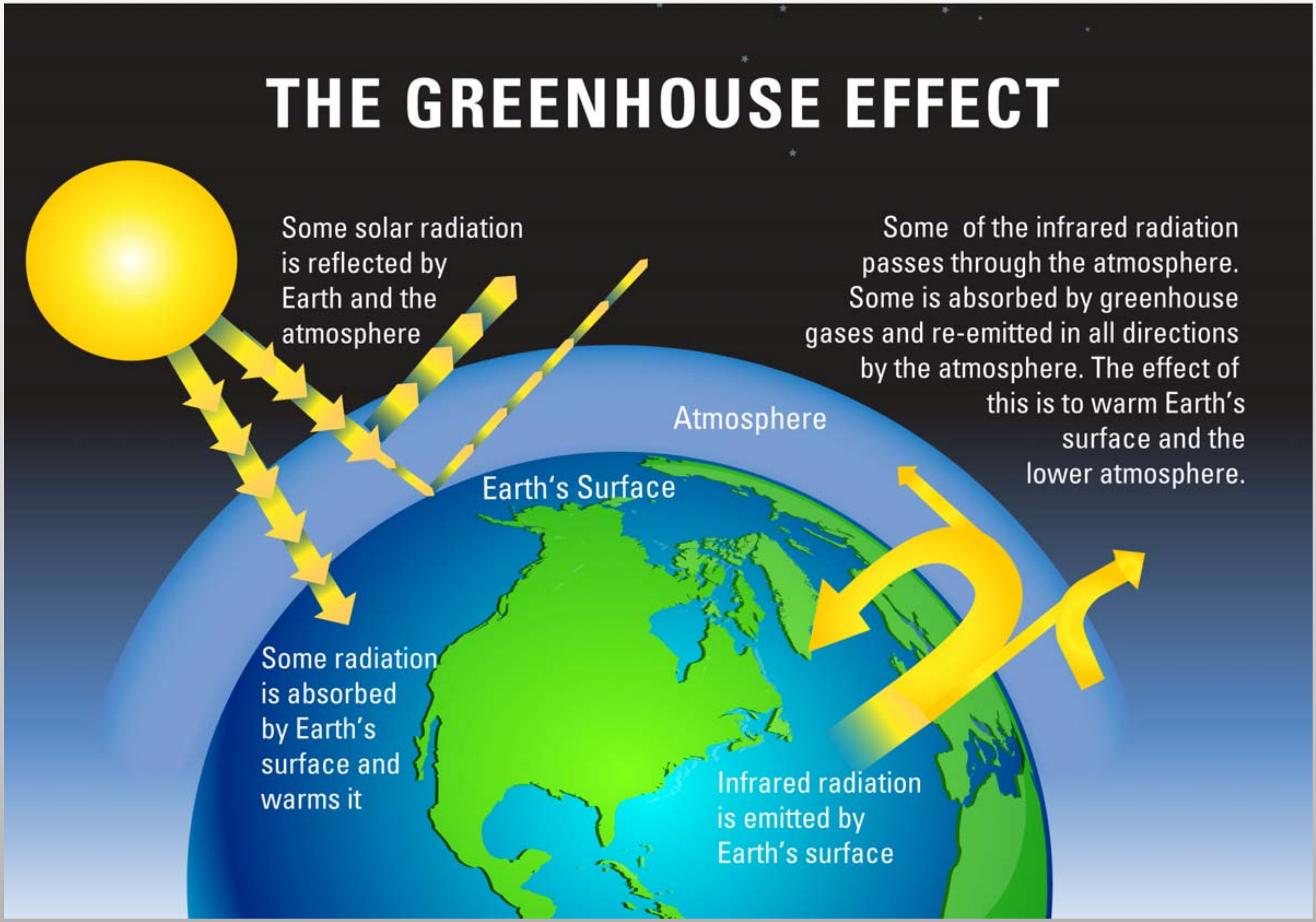
max
75%
mediana
25%
min
ozono (2001–2017)
superamenti orari della soglia di informazione
tutte le stazioni regionali di fondo, divise per tipologia
fondo urbano
fondo suburbano
fondo rurale
(ore)
0
20
40
60
80
100
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
anno

3. Le tendenze del clima in E-R

Monte Cimone CO_2 - Data source Italian Air Force



CO_2 never so high during the last million year or so!


THE GREENHOUSE EFFECT
Some solar radiation is reflected by Earth and the atmosphere
Some of the infrared radiation passes through the atmosphere. Some is absorbed by greenhouse gases and re-emitted in all directions by the atmosphere. The effect of this is to warm Earth's surface and the lower atmosphere.
Atmosphere
Earth's Surface
Some radiation is absorbed by Earth's surface and warms it
Infrared radiation is emitted by Earth's surface

How much has climate changed in Italy?

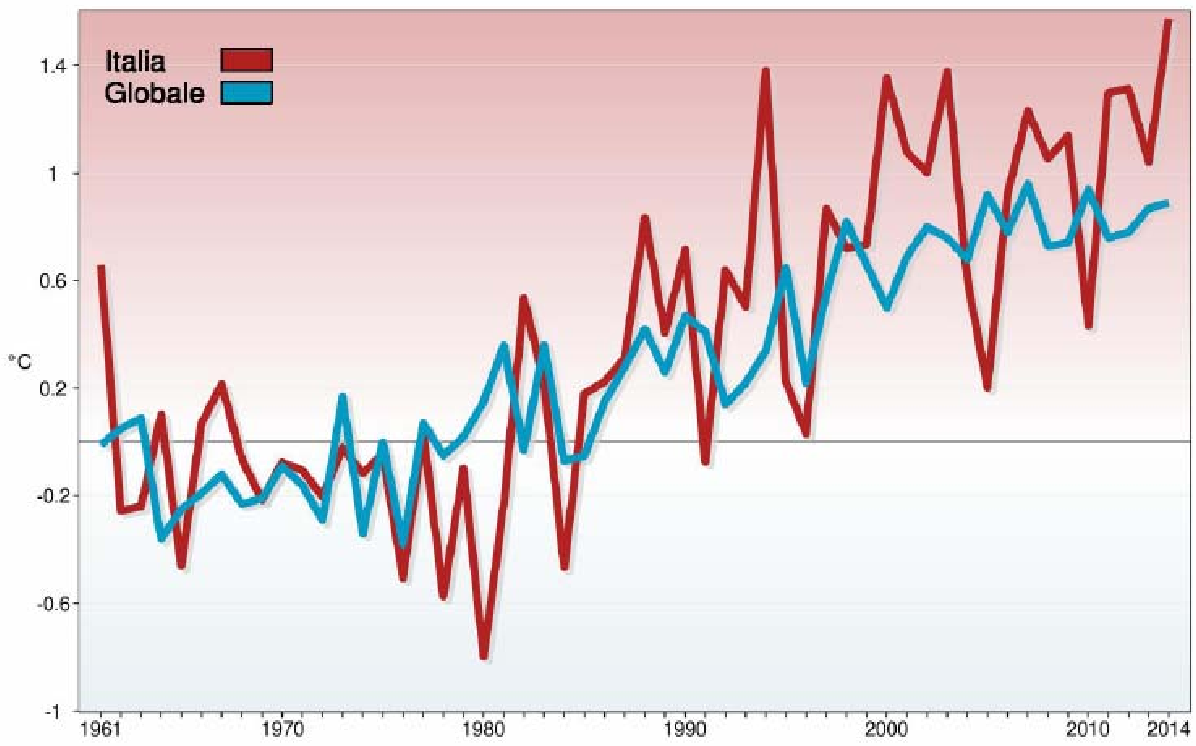
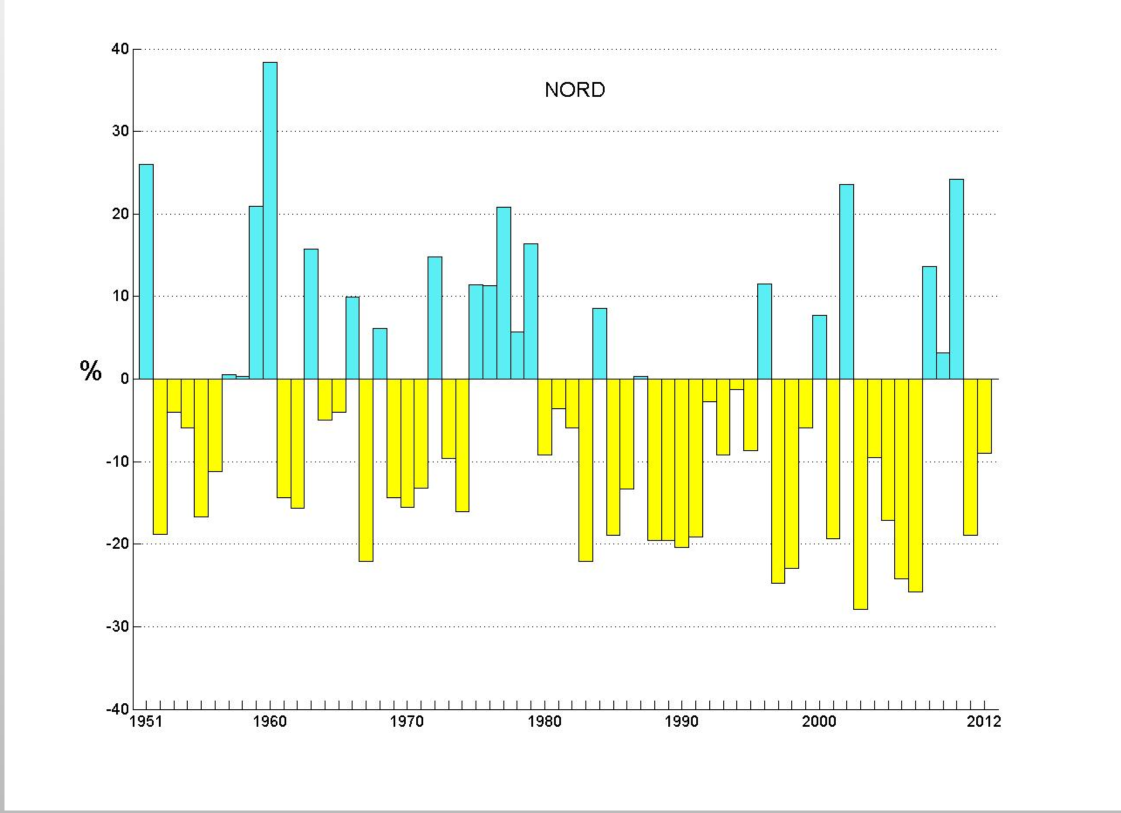


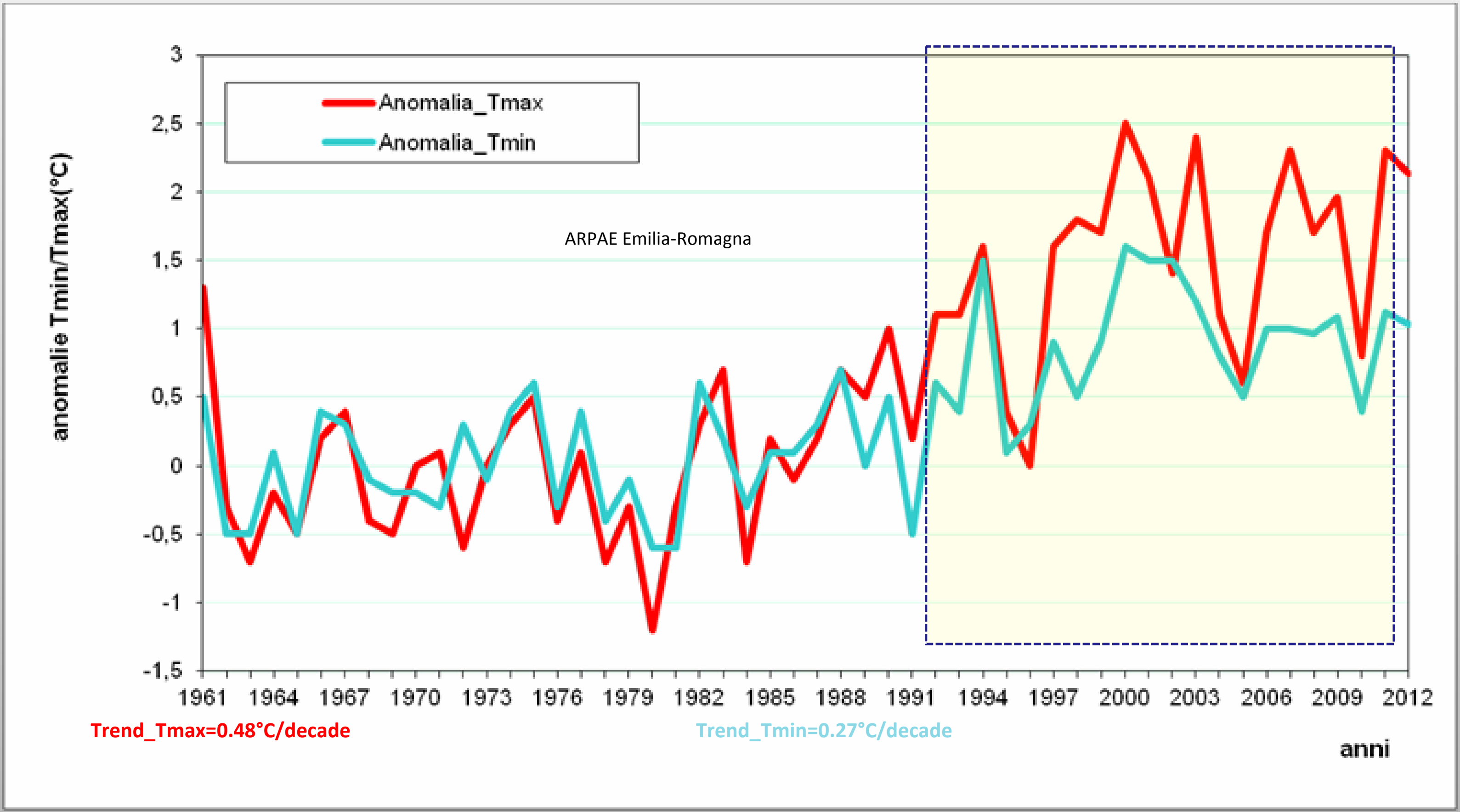
Figura 2.1: *Serie delle anomalie di temperatura media globale sulla terraferma e in Italia, rispetto ai valori climatologici normali 1961-1990. Fonti: NCDC/NOAA e ISPRA. Elaborazione: ISPRA.*

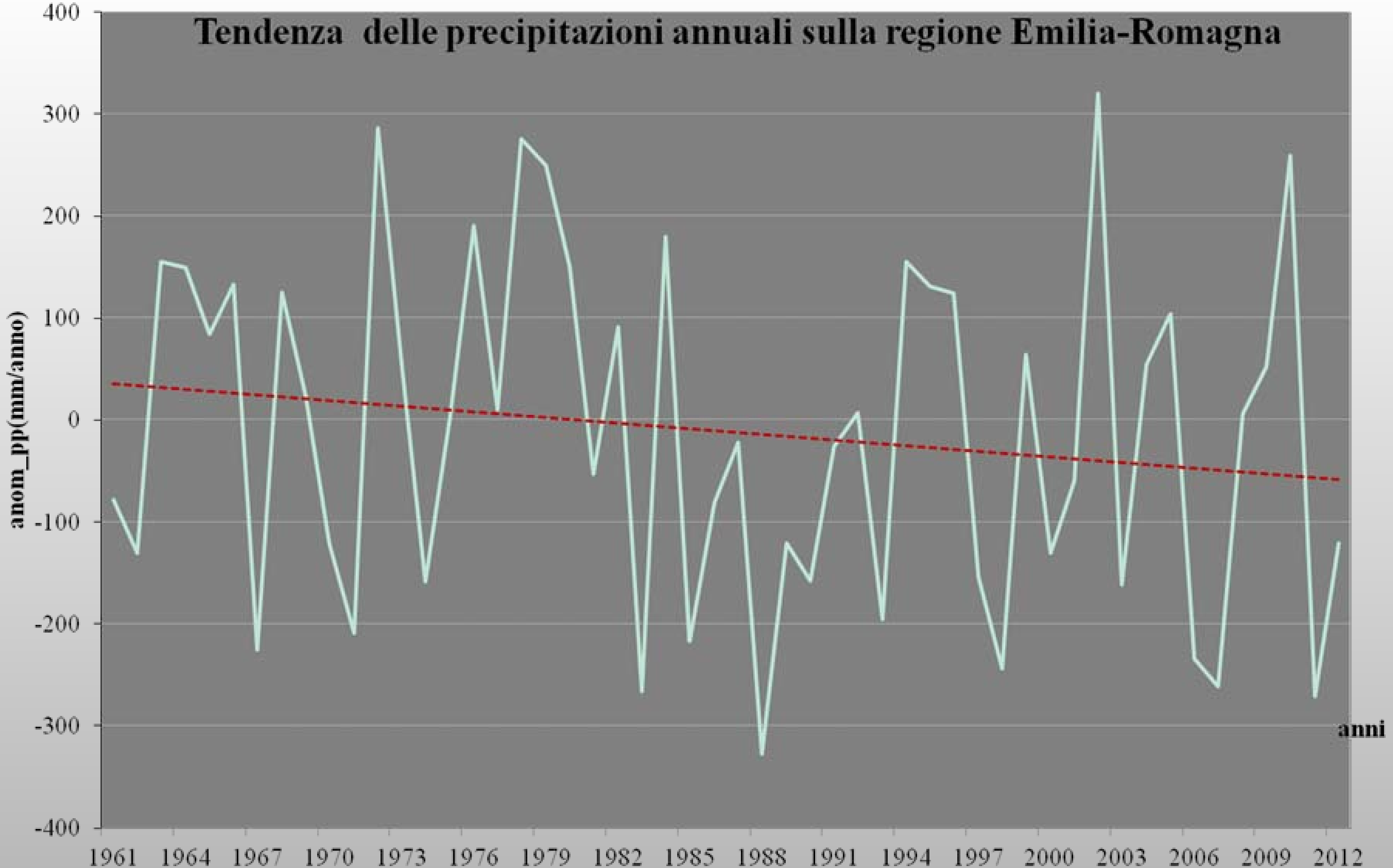
Cumulated precipitation anomaly in Northern Italy



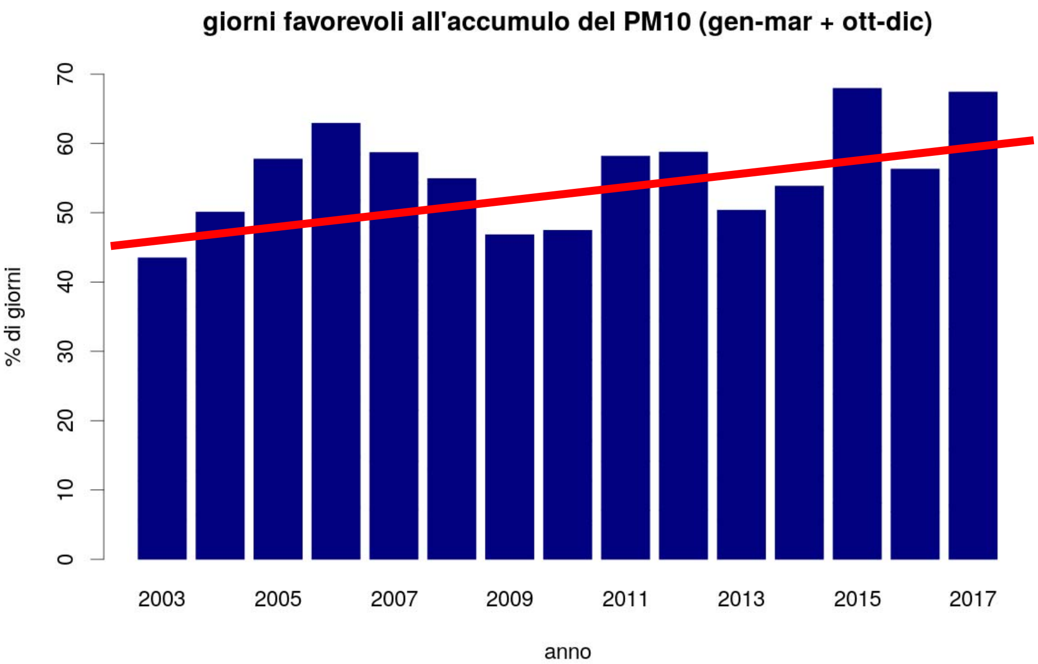
Fonte: Ispra

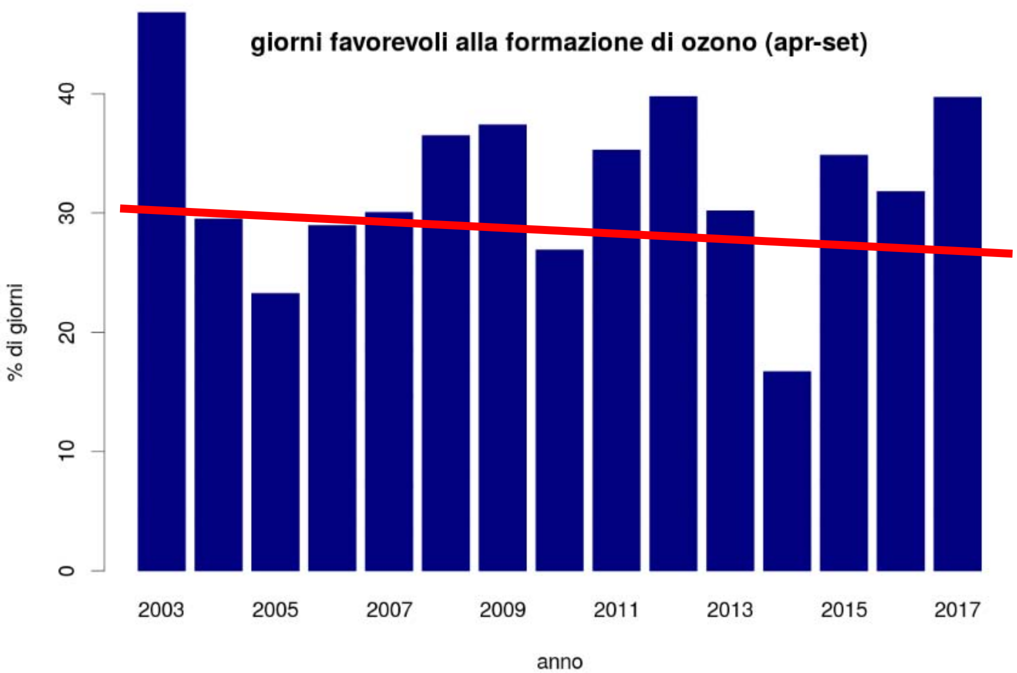
Climate Change in Emilia-Romagna: Tmax and Tmin





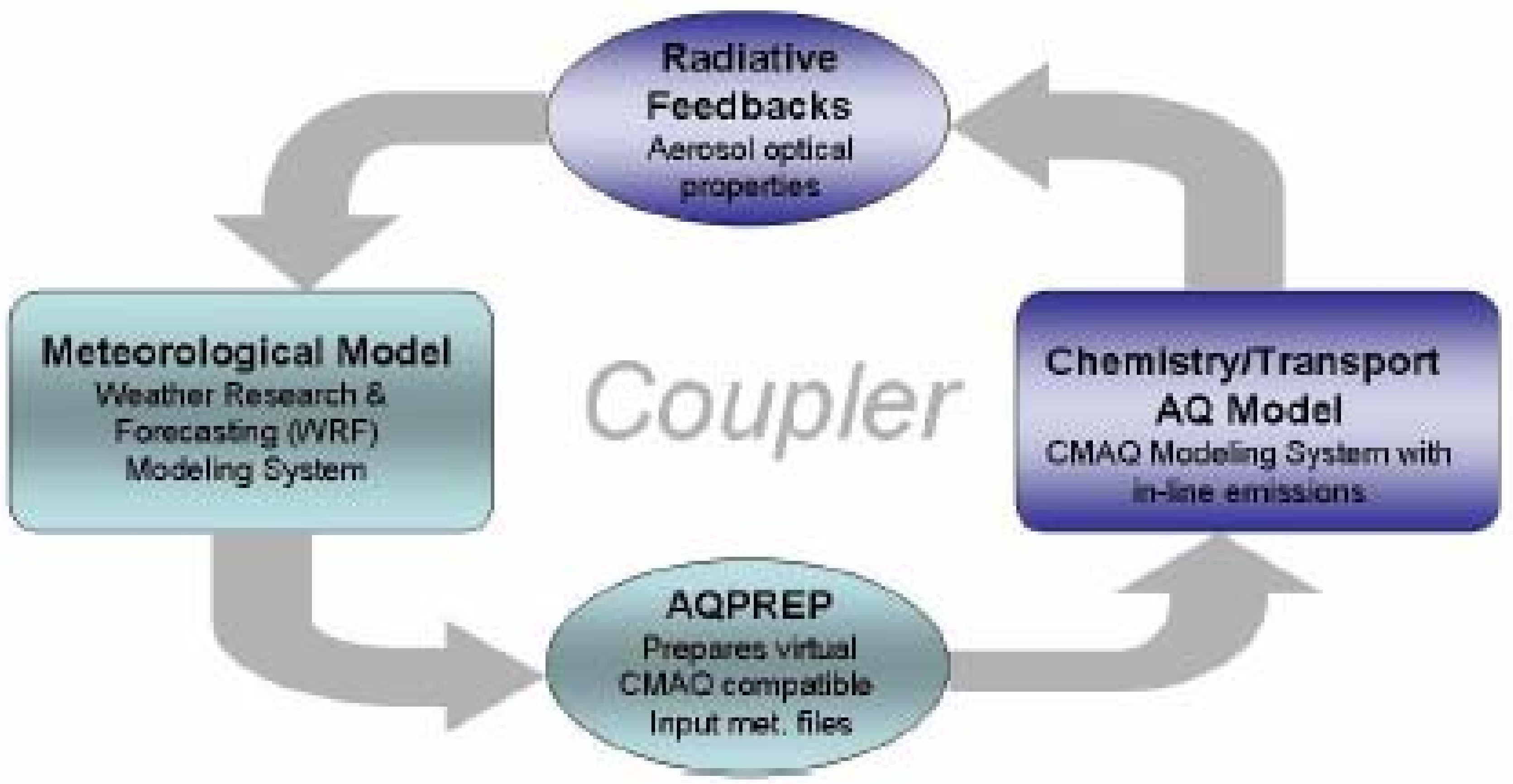
Dati ARPA Emilia-Romagna


giorni favorevoli all'accumulo del PM10 (gen-mar + ott-dic)
% di giorni
0
10
20
30
40
50
60
70
2003
2005
2007
2009
2011
2013
2015
2017
anno

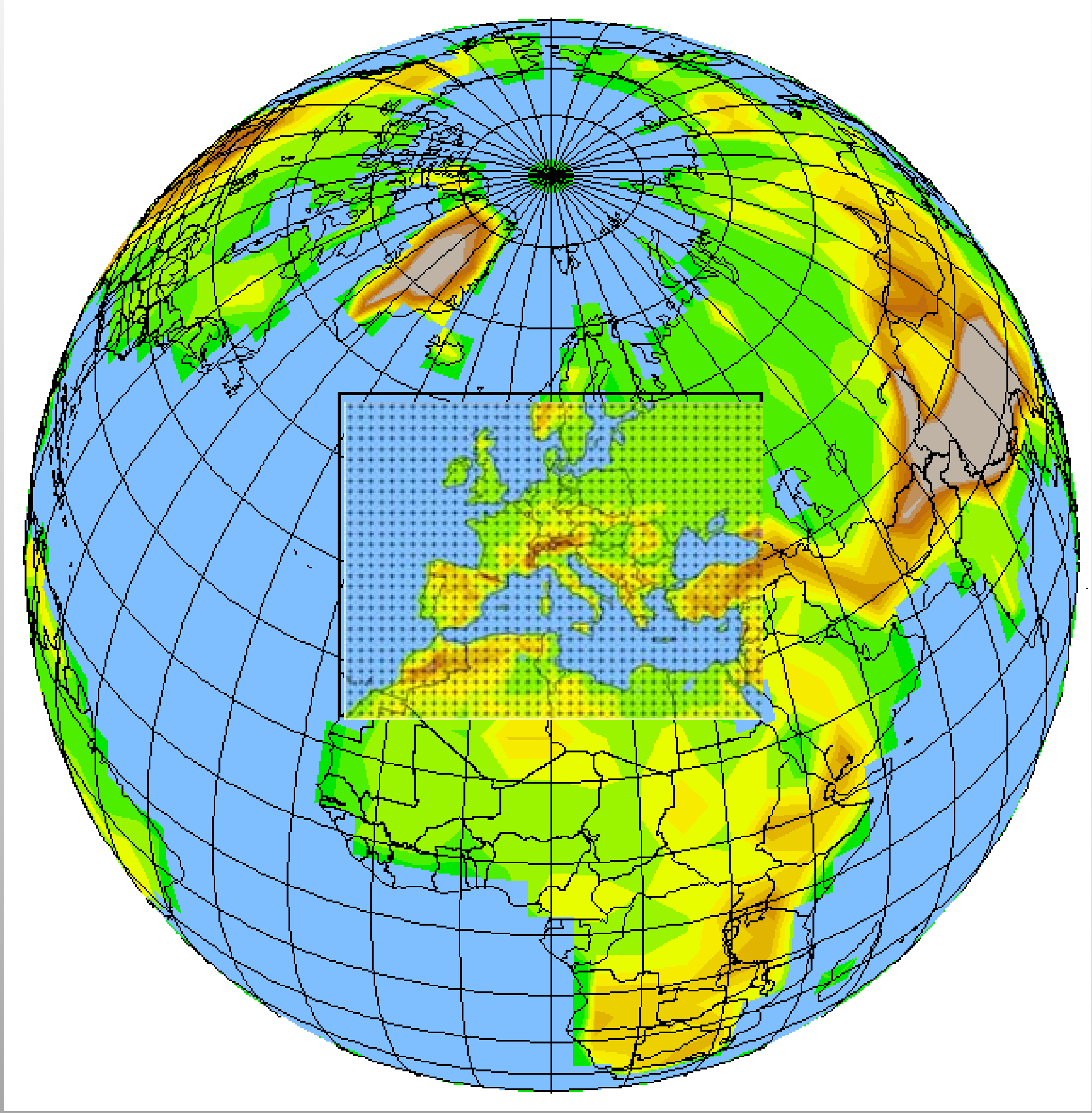

giorni favorevoli alla formazione di ozono (apr-set)
% di giorni
0
10
20
30
40
2003
2005
2007
2009
2011
2013
2015
2017
anno

4. Quale futuro ?

Accoppiamento modelli meteo-clima/modelli chimici



La modellistica del clima:
Modelli Globali (GCM) e Modelli Regionali (RCM)



L’Europa e il bacino del Mediterraneo

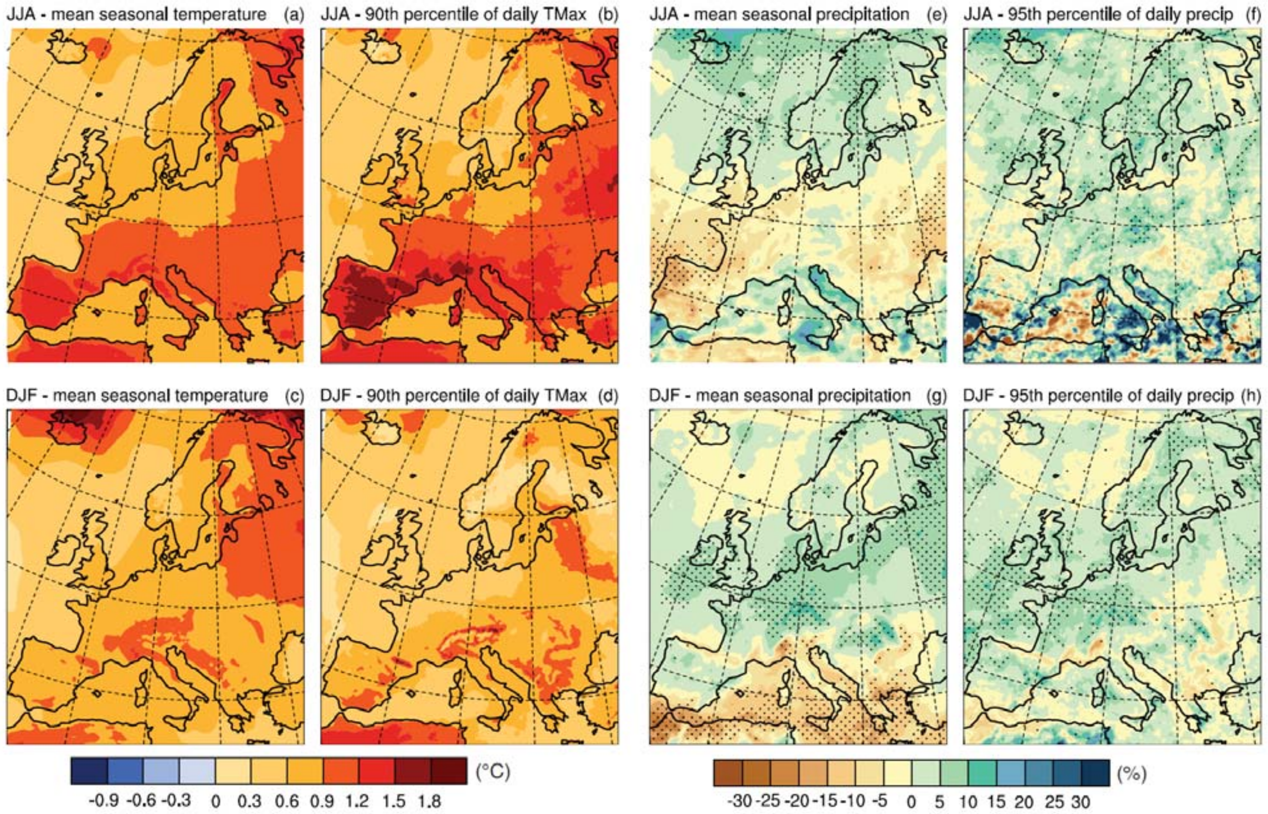


Figure 11.18 | European-scale projections from the ENSEMBLES regional climate modelling project for 2016–2035 relative to 1986–2005, with top and bottom panels applicable to June, July and August (JJA) and December, January, February (DJF), respectively. For temperature, projected changes (°C) are displayed in terms of ensemble mean changes of (a, c) mean seasonal surface temperature, and (b, d) the 90th percentile of daily maximum temperatures. For precipitation, projected changes (%) are displayed in terms of ensemble mean changes of (e, g) mean seasonal precipitation and (f, h) the 95th percentile of daily precipitation. The stippling in (e–h) highlights regions where 80% of the models agree in the sign of the change (for temperature all models agree on the sign of the change). The analysis includes the following 10 GCM-RCM simulation chains for the SRES A1B scenario (naming includes RCM group and GCM simulation): HadRM3Q0-HadCM3Q0, ETHZ-HadCM3Q0, HadRM3Q3-HadCM3Q3, SMHI-HadCM3Q3, HadRM3Q16-HadCM3Q16, SMHI-BCM, DMI-ARPEGE, KNMI-ECHAM5, MPI-ECHAM5, DMI-ECHAM5. (Rajczak et al., 2013.)

OZONO: 2030-2000

CLIMATE=solo clima
CLE=legislazione attuale
MFR=riduzione max fattibile
SRES=scenario pessimista
RCP=scenario ottimista

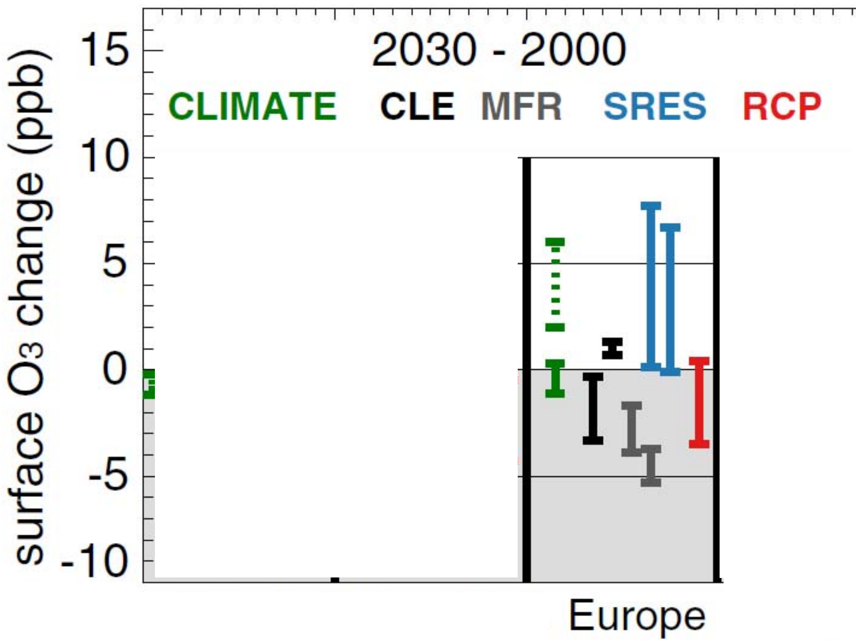


Figure 11.22 | Changes in surface O_3 (ppb) between year 2000 and 2030 driven by climate alone (CLIMATE, green) or driven by emissions alone, following current legislation (CLE, black), maximum feasible reductions (MFR, grey), SRES (blue) and RCP (red) emission scenarios. Results are reported globally and for the four northern mid-latitude source regions used by the Task Force on Hemispheric Transport of Air Pollution (HTAP, 2010a). Where two vertical bars are shown (CLE, MFR, SRES), they represent the multi-model standard deviation of the annual mean based on (left bar; SRES includes A2 only) the Atmospheric Composition Change: a European Network (ACCENT)/Photocomp study (Dentener et al., 2006) and (right bar) the parametric HTAP ensemble (Wild et al., 2012; four SRES and RCP scenarios included). Under Global, the leftmost (dashed green) vertical bar denotes the spatial range in climate-only changes from one model (Stevenson et al., 2005) while the green square shows global annual mean climate-only changes in another model (Unger et al., 2006b). Under Europe, the dashed green bar denotes the range of climate-only changes in summer daily maximum O_3 in one model (Forkel and Knoche 2006). (Adapted from Figure 3 of Fiore et al., 2012.)

Ozono, Europa, 2005 >>> 2105, vari scenari

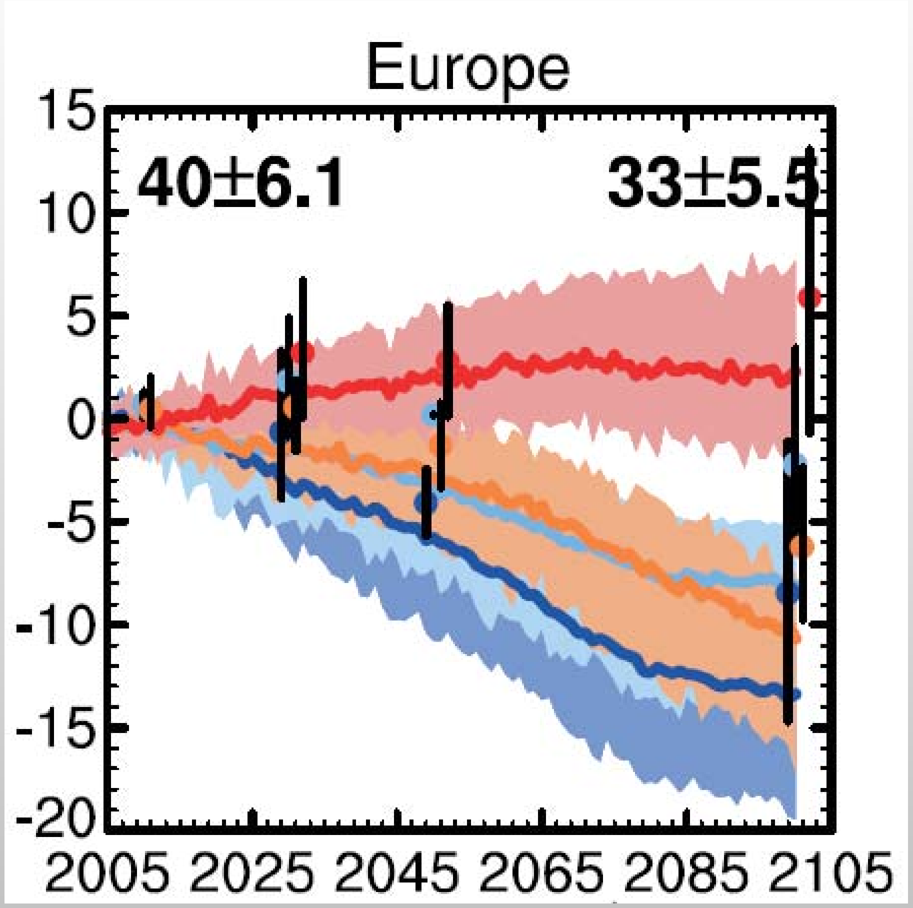
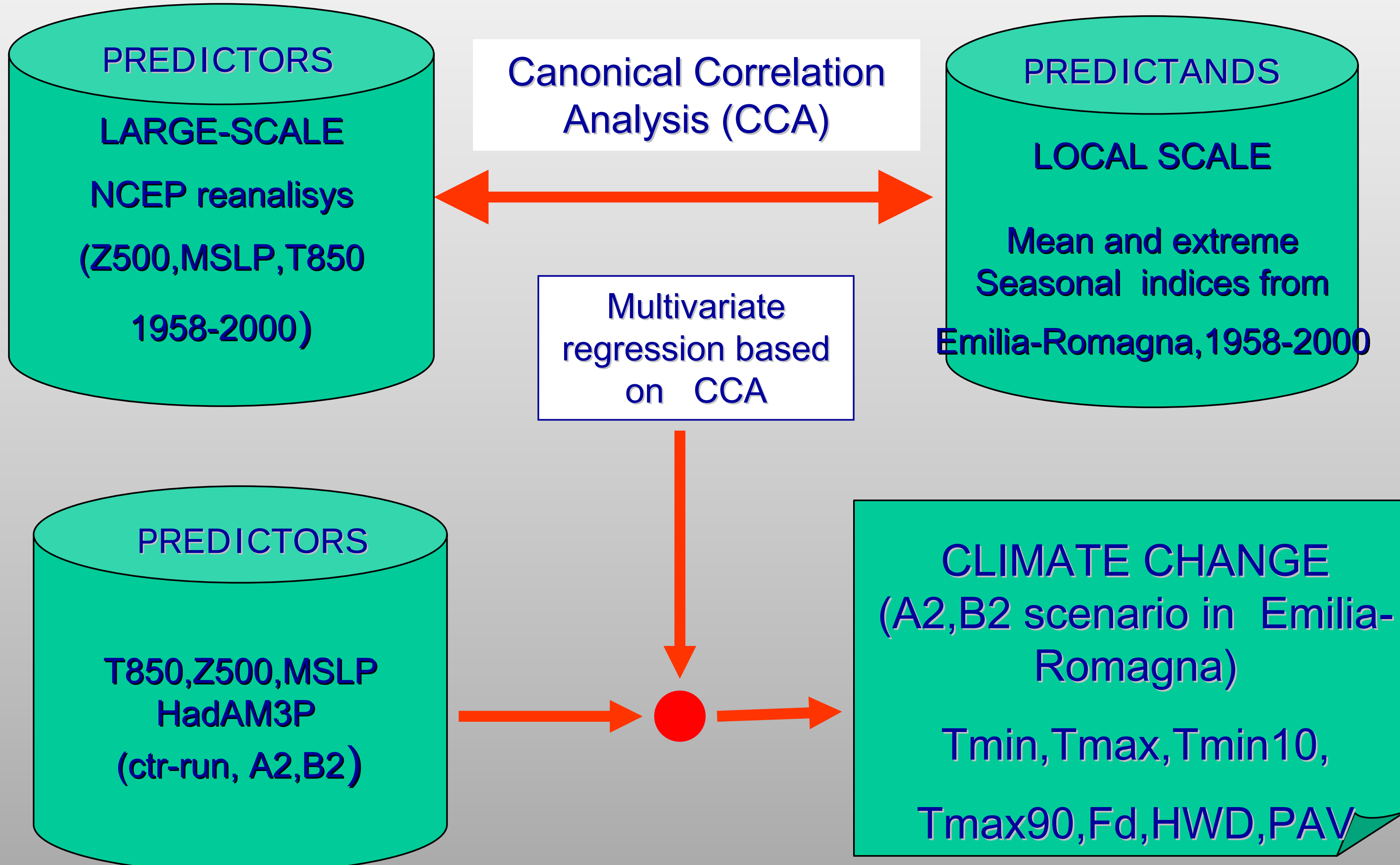
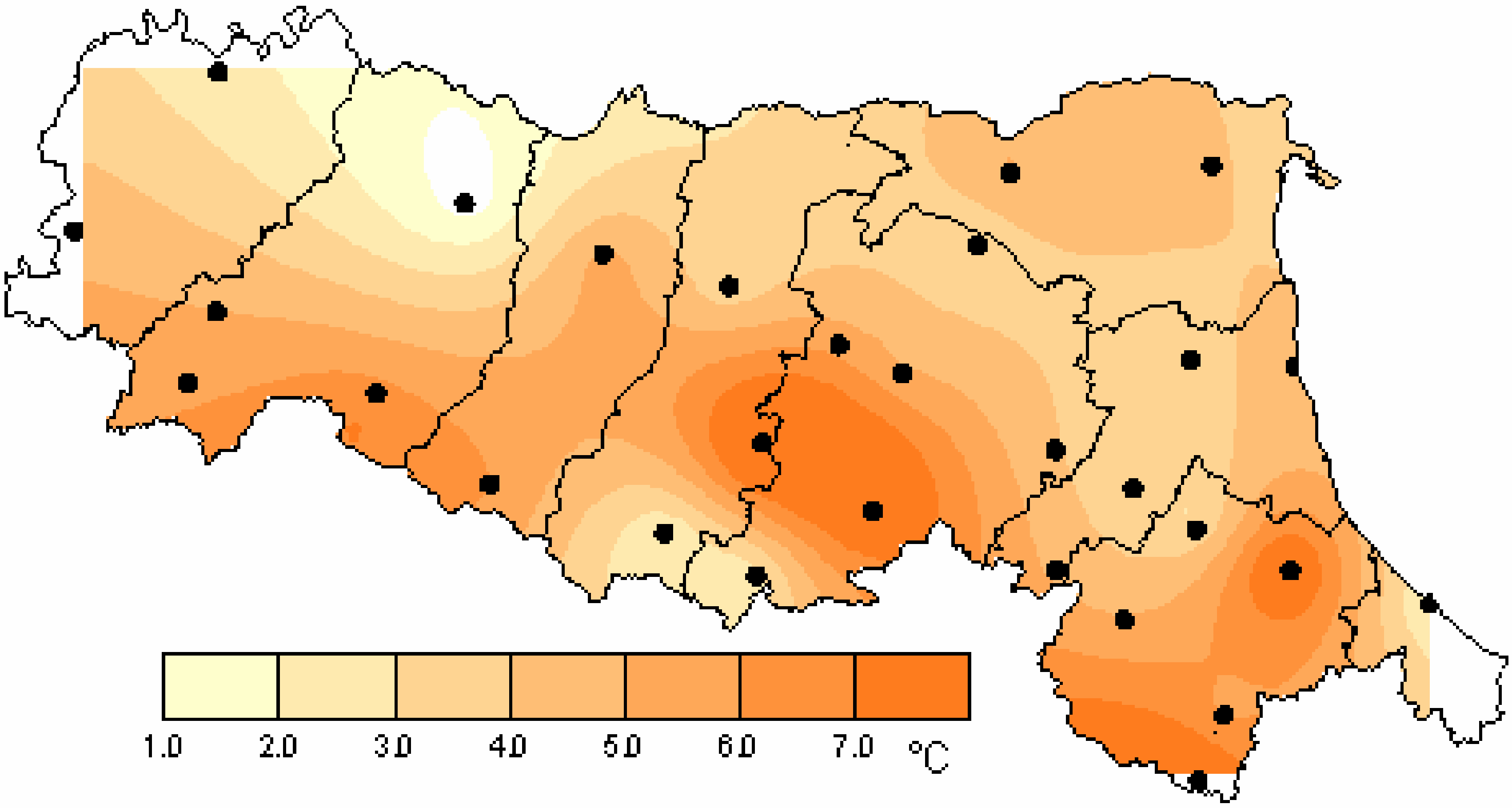


Figure 11.23a | Projected changes in annual mean surface O_3 (ppb mole fraction) from 2000 to 2100 following the RCP scenarios (8.5, red; 6.0, orange; 4.5, light blue; 2.6, dark blue). Results in each box are averaged over the designated coloured land regions. Continuous coloured lines and shading denote the average and full range of four chemistry–climate models (GFDL-CM3, GISS-E2-R, and NCAR-CAM3.5 from CMIP5 plus LMDz-ORINCA). Coloured dots and vertical black bars denote the average and full range of the ACCMIP models (CESM-CAM-superfast, CICERO-OsloCTM2, CMAM, EMAC-DLR, GEOSCCM, GFDL-AM3, HadGEM2, MIROC-CHEM, MOCAGE, NCAR-CAM3.5, STOC-HadAM3, UM-CAM) for decadal time slices centred on 2010, 2030, 2050 and 2100. Participation in the decadal slices ranges from 2 to 12 models (see (Lamarque et al., 2013)). Changes are relative to the 1986–2005 reference period for the CMIP5 transient simulations, and relative to the average of the 1980 and 2000 decadal time slices for the ACCMIP ensemble. The average value and model standard deviation for the reference period is shown in the top of each panel for CMIP5 models (left) and ACCMIP models (right). In cases where multiple ensemble members are available from a single model, they are averaged prior to inclusion in the multi-model mean. (Adapted from Fiore et al., 2012.)

Scendiamo ancora di scale: la regionalizzazione a scala locale



Emilia-Romagna: Cambiamenti climatici in temperatura (°C) (2070-2100 - 1960-1990)



In sintesi: uno sguardo al (possibile) clima futuro dell'Emilia-Romagna

- Ulteriore aumento delle temperature, massime, minime e medie
- Aumento dell'intensità e della durata delle "ondate di calore" (Heat Waves)
- Diminuzione del numero di giorni di gelo
- Lieve Diminuzione delle precipitazioni medie
- Aumento della probabilità di periodi siccitosi della durata di qualche anno

↓

- Aumento degli episodi di picchi di Ozono
- Aumento delle polveri connesse a meno precipitazioni e più periodi di "stagnazione"

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