Air Pollution Climate Change Health Impact Assessment

Multi-scale health impact assessment of air pollution under changing climate and emission conditions

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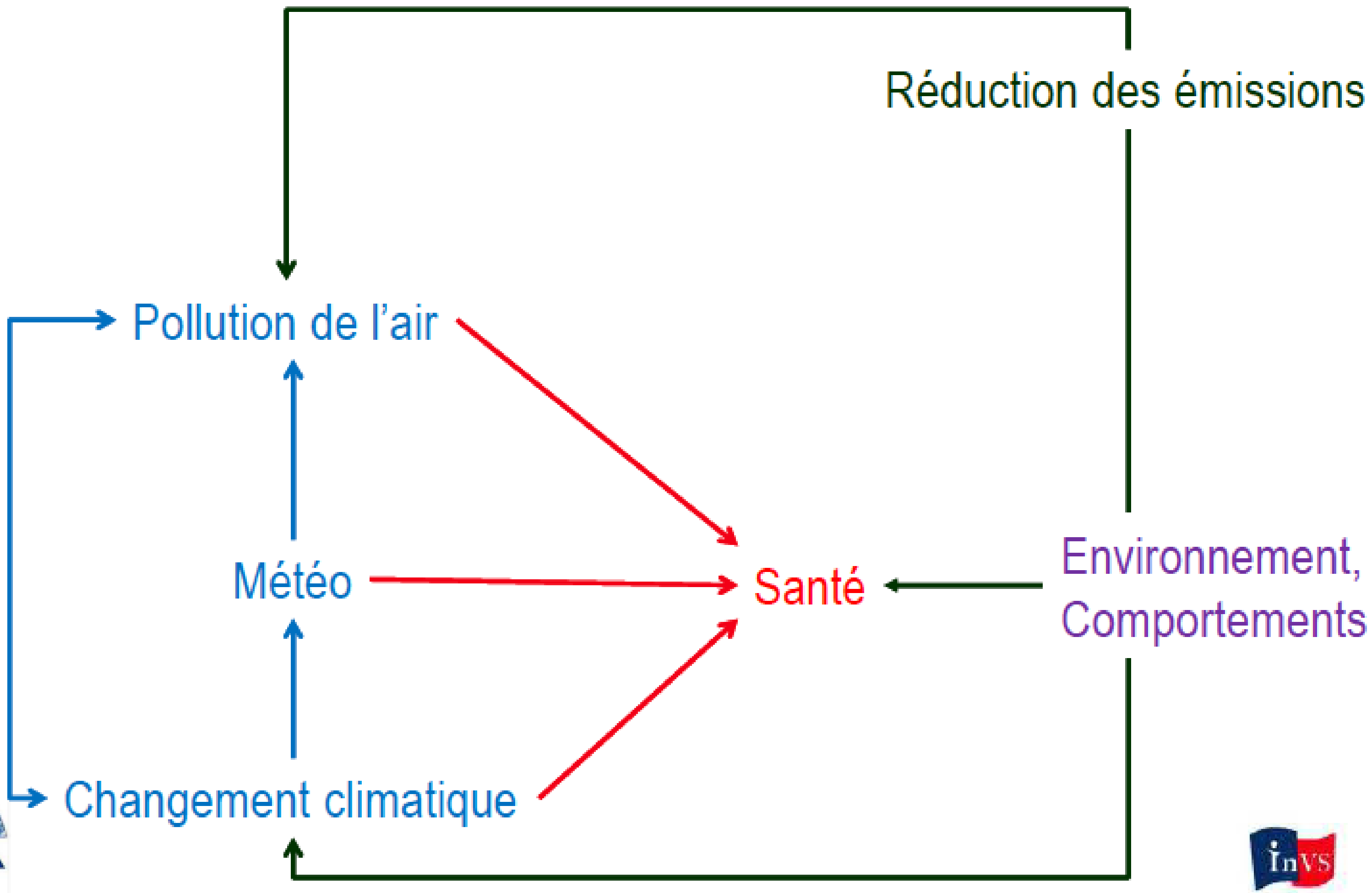
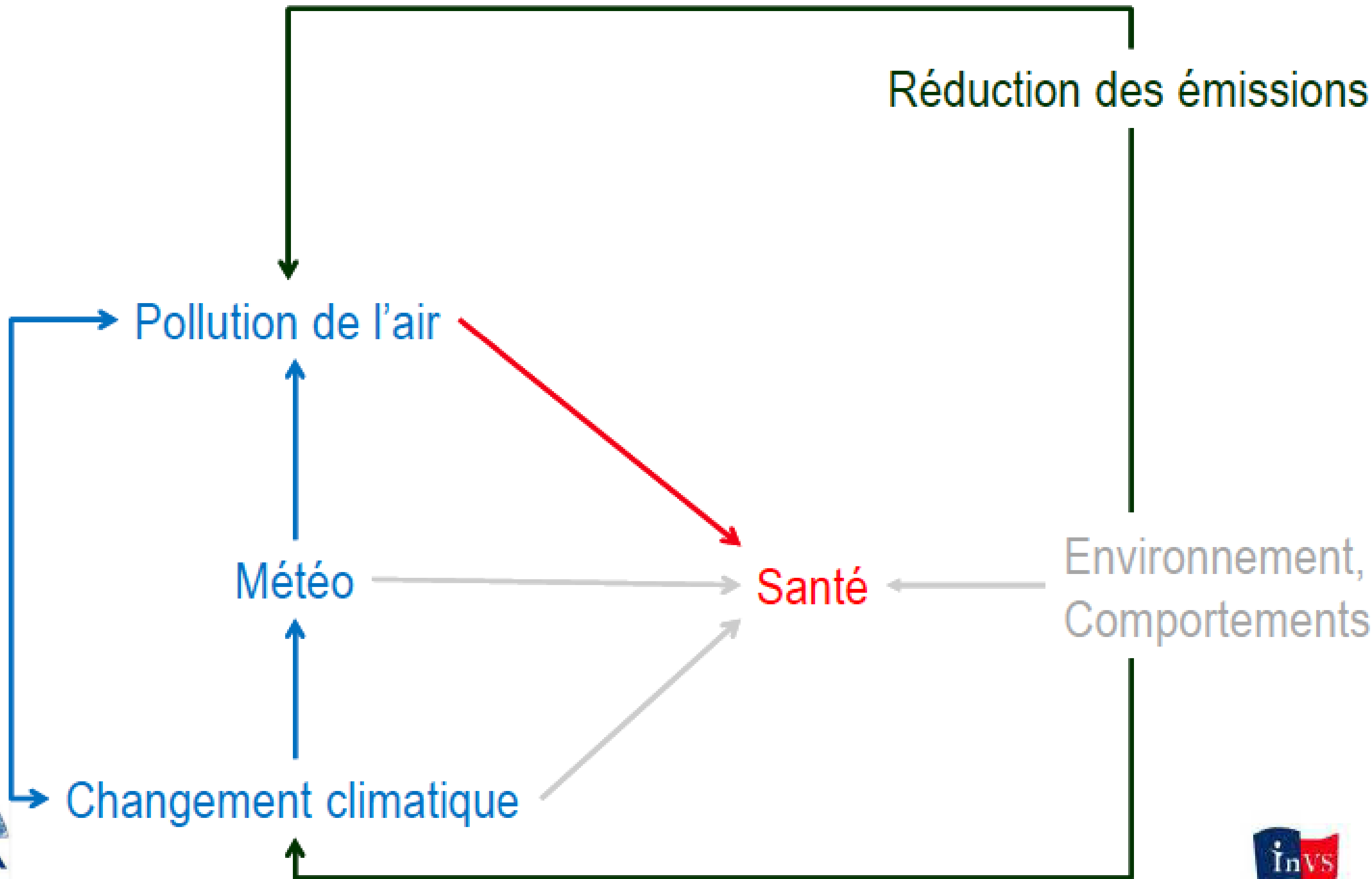
Long-Term Air Pollution and Health

- Long-term exposures to PM2.5 lead to premature deaths due to cardiovascular illness and lung cancer
  - Effects are well documented from multiple studies in the U.S. and Europe
- Long-term exposures to O3 may also lead to premature deaths due to respiratory causes
  - Evidence from just one study in the U.S.

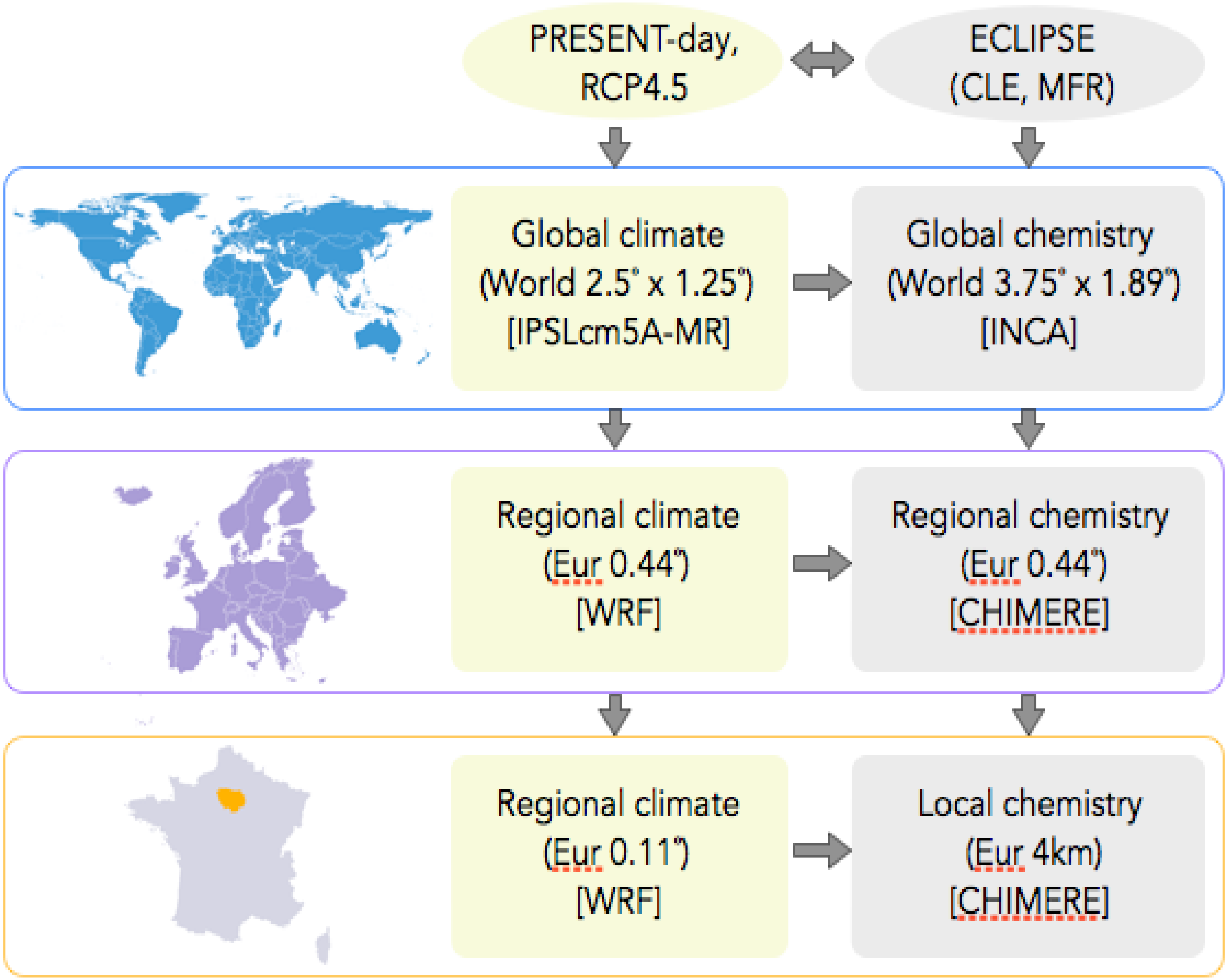
Climate-Pollution-Health Interactions

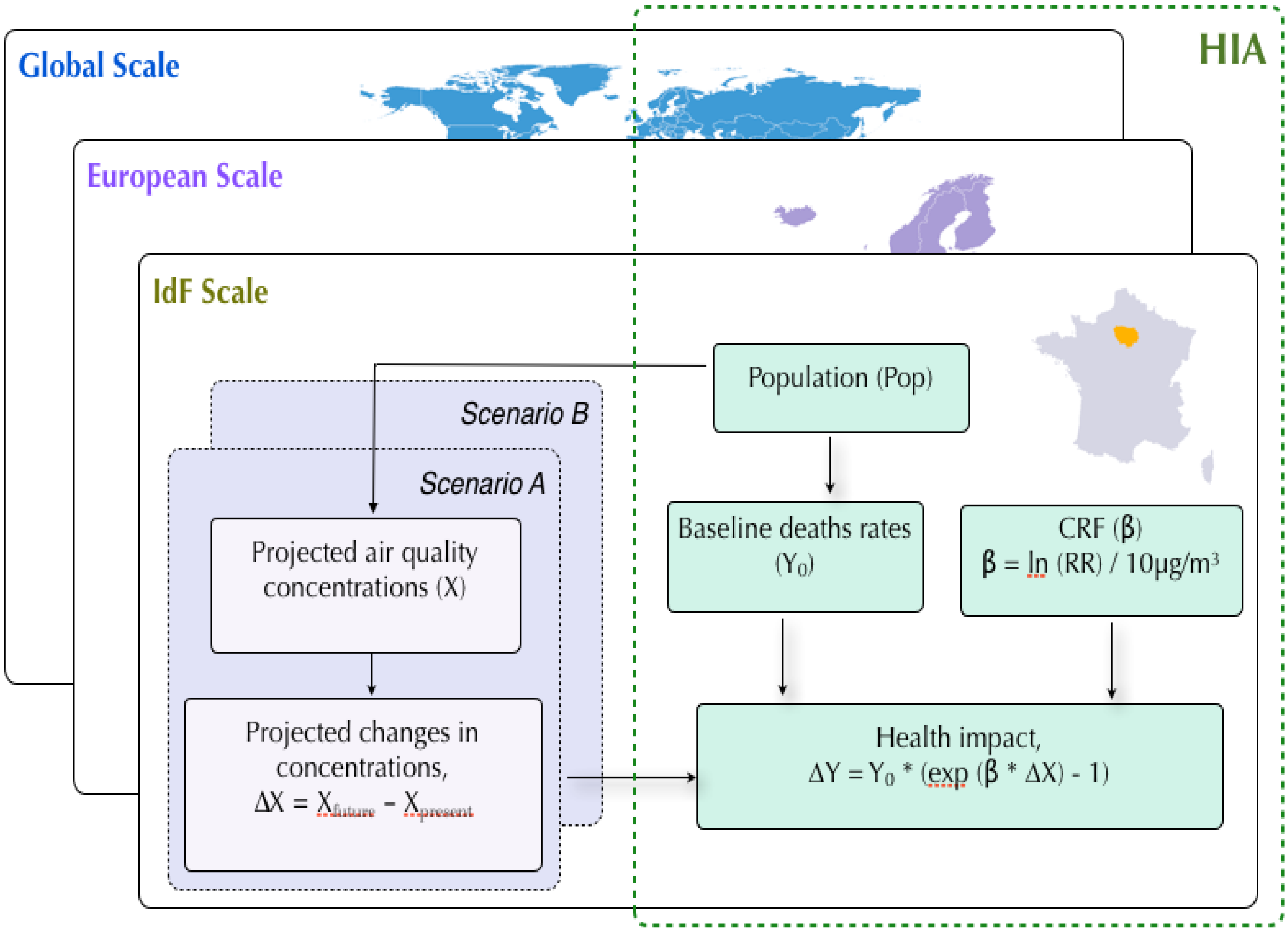


What do we quantify in ACHIA?



ACHIA Integrated Model Framework





Global Scale
European Scale
IdF Scale
HIA
Scenario B
Scenario A
Projected air quality concentrations (X)
Projected changes in concentrations,
ΔX = X_future - X_present
Population (Pop)
Baseline deaths rates (Y_0)
CRF (β)
β = ln (RR) / 10µg/m³
Health impact,
ΔY = Y_0 * (exp (β * ΔX) - 1)

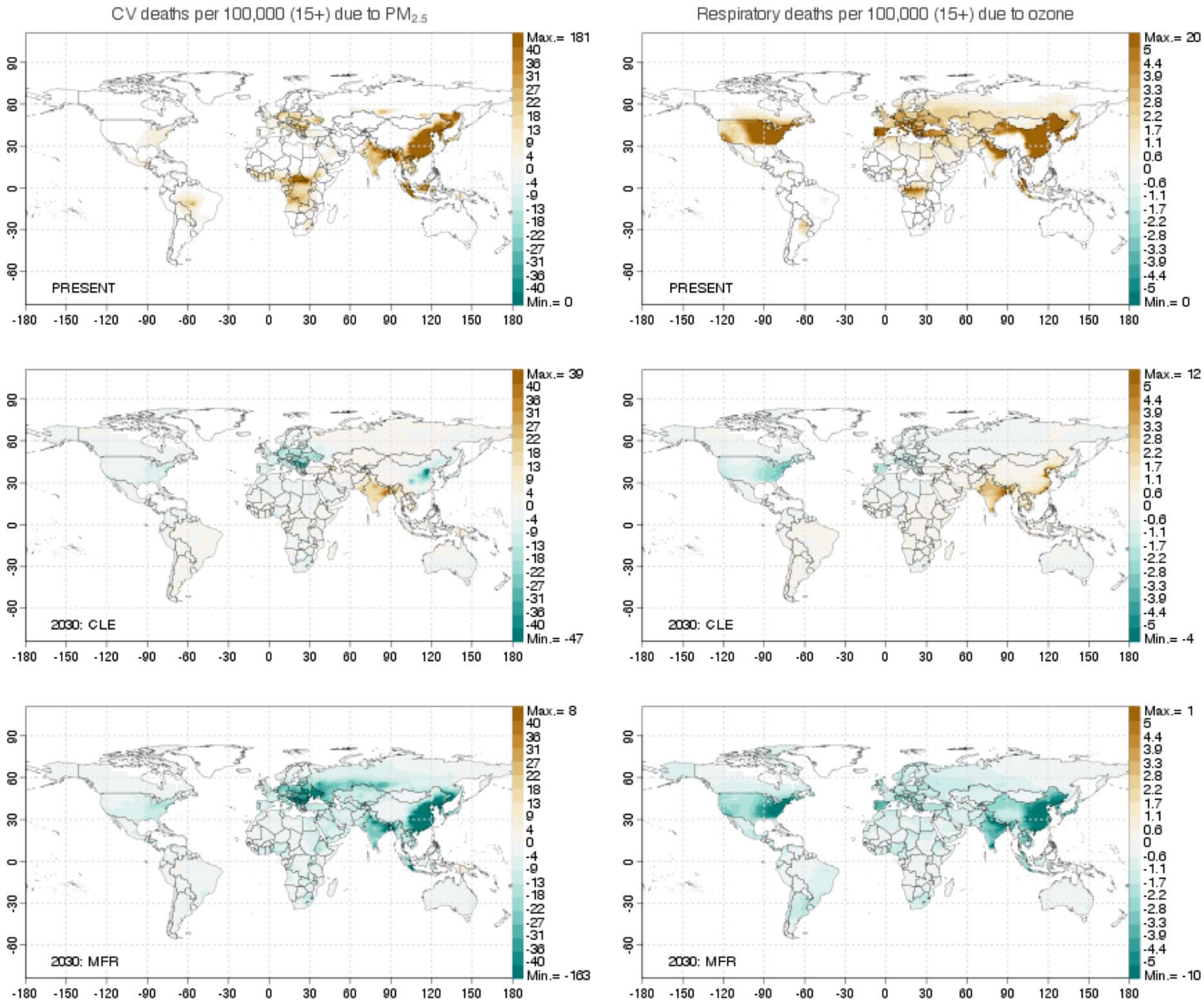
Integrated, multi-scale assessment framework

Domain/Scale	Scenarios	Time Horizon	Mortality outcomes and corresponding AP	CRF (relative risk per 10 μg/m^3)
Global/190x375km [LMDz-INCA]	ECLIPSE (CLE, MFR)	2030, 2050	CV: annual $PM_{2.5}$ Respiratory: summer (JJA) MDA8 ozone	$PM_{2.5}$: CV: **1.15** (95% CI: 1.04, 1.27) [ref. Hoek et al. 2013] O_3*: Respiratory: **1.02** (95% CI: 1.01,1.03) [ref. Jerrett et al. 2009]
Europe/50x50km [CHIMERE]		2030, 2050		
IdF/4x4km [CHIMERE]		2050		

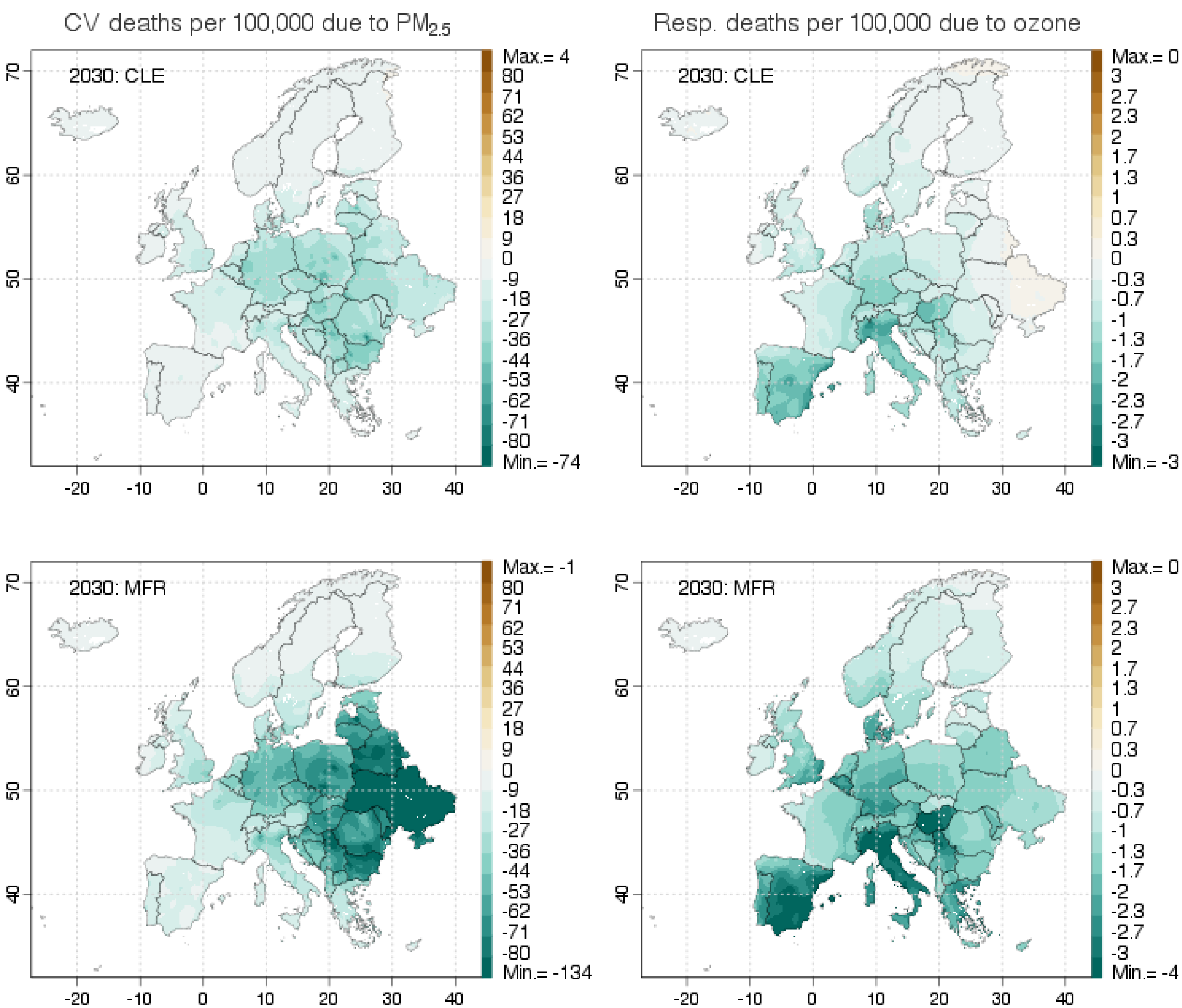
CLE – Emission reductions due to current legislation
MFR – Maximum feasible reductions of future emissions

Global Scale Effects of PM2.5 (left) and O3-related (right) on deaths per 100,000 in in 2005 (top), and in 2030 under CLE (middle) and MFR (bottom) scenarios.

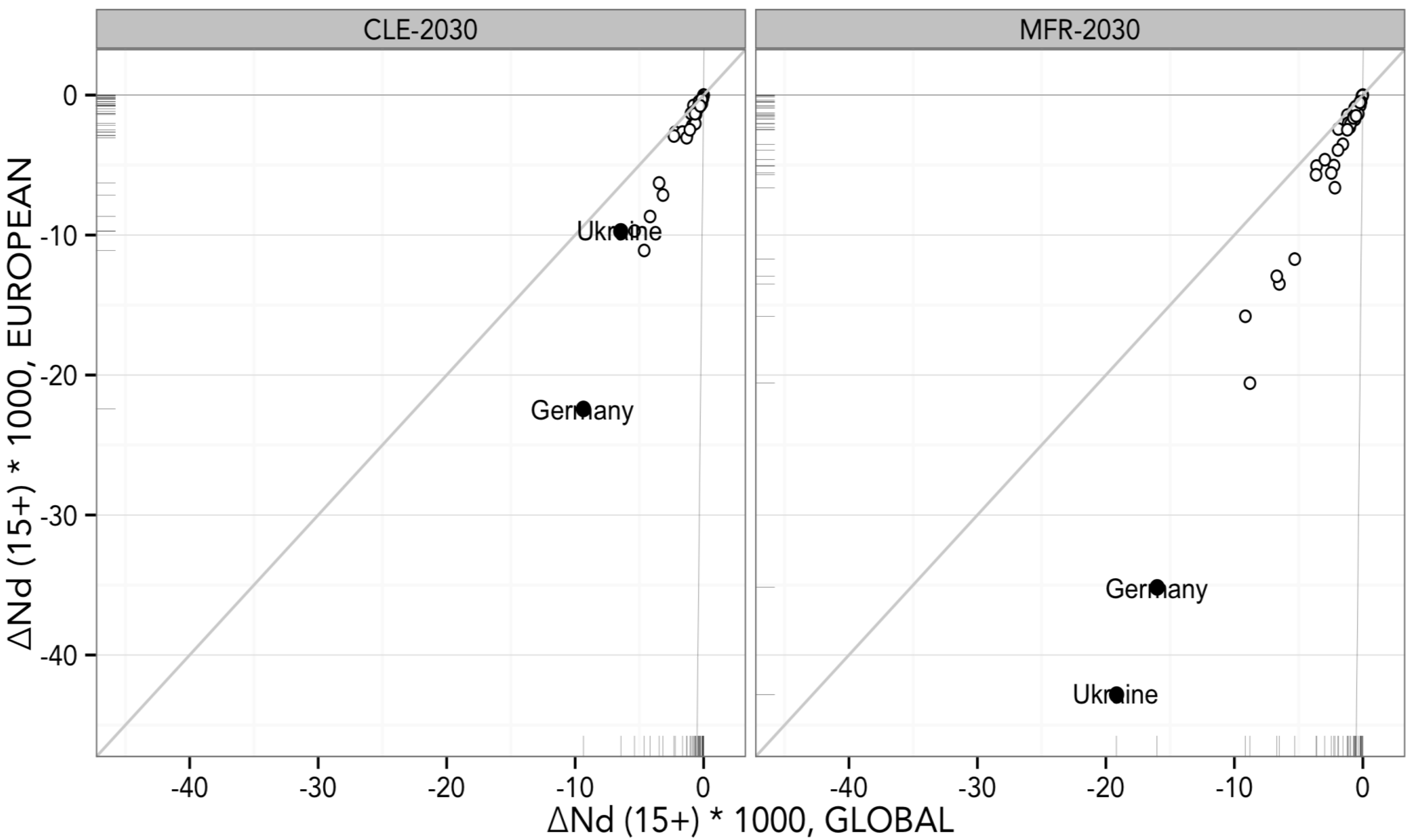
Brown=more deaths; Blue=less deaths.



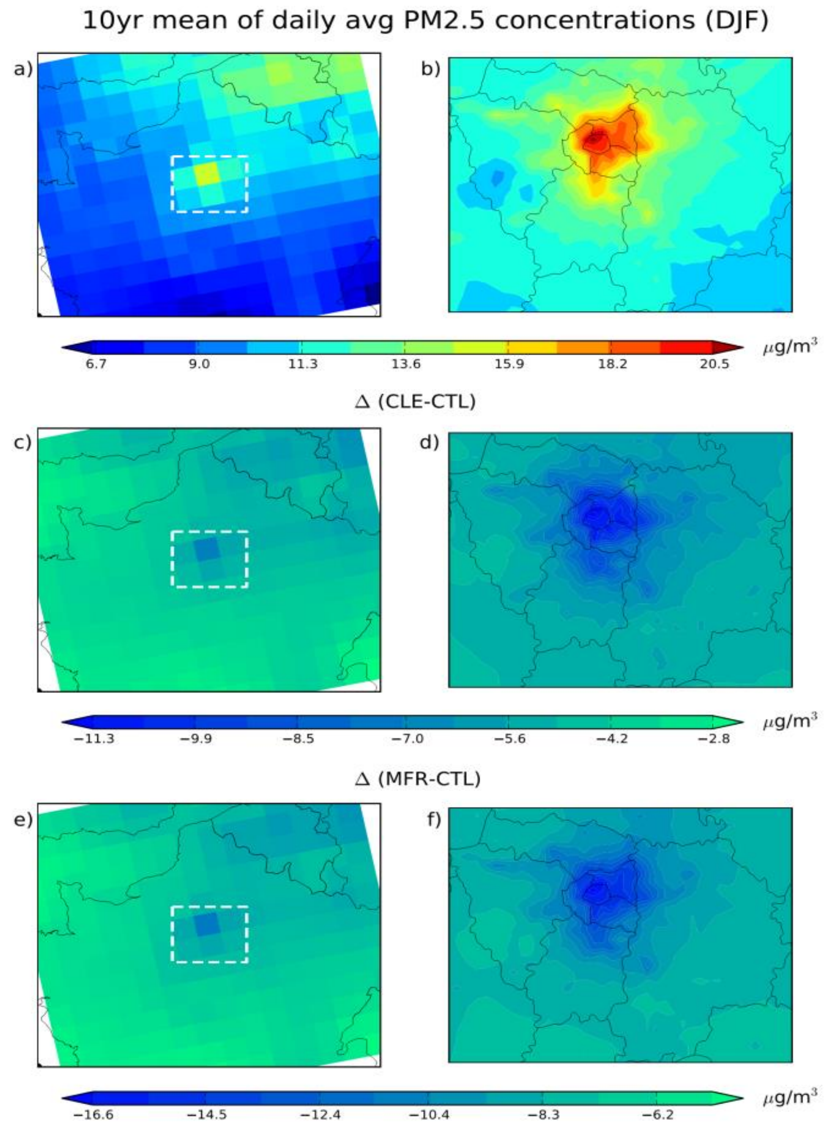
Projected European Scale changes in PM2.5- (left) and O3-related (right) deaths per 100,000 in 2030 under CLE (top) and MFR (bottom) scenarios.



Future changes in cardiovascular mortality (15+) * 1000 due to PM2.5 in 2030 under CLE and MFR scenarios on GLOBAL and EUROPEAN scales for 38 countries in Europe

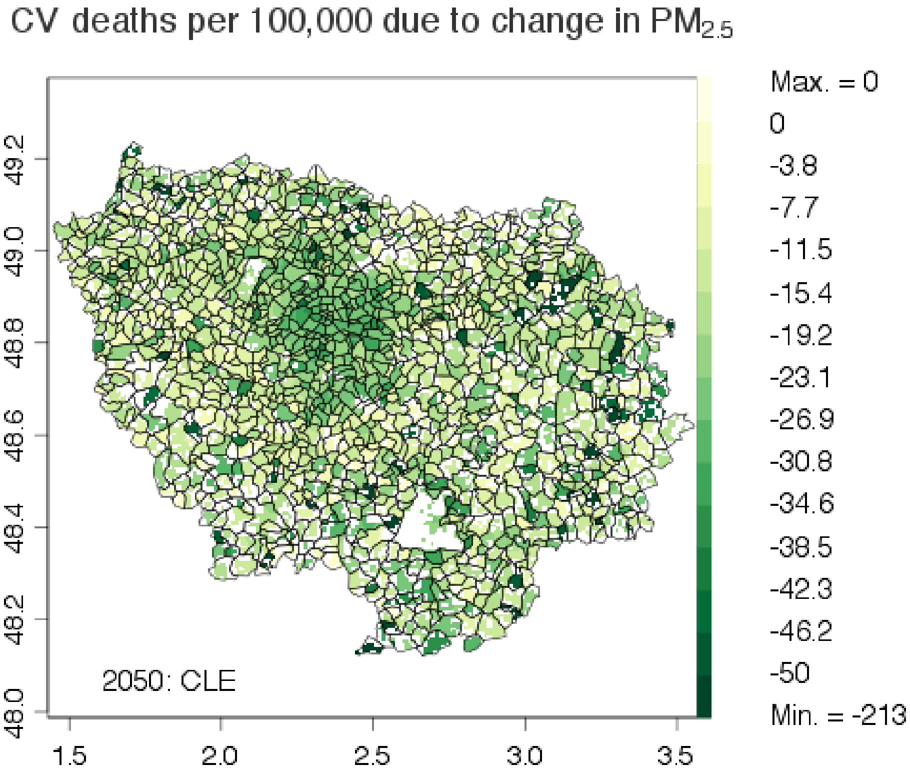


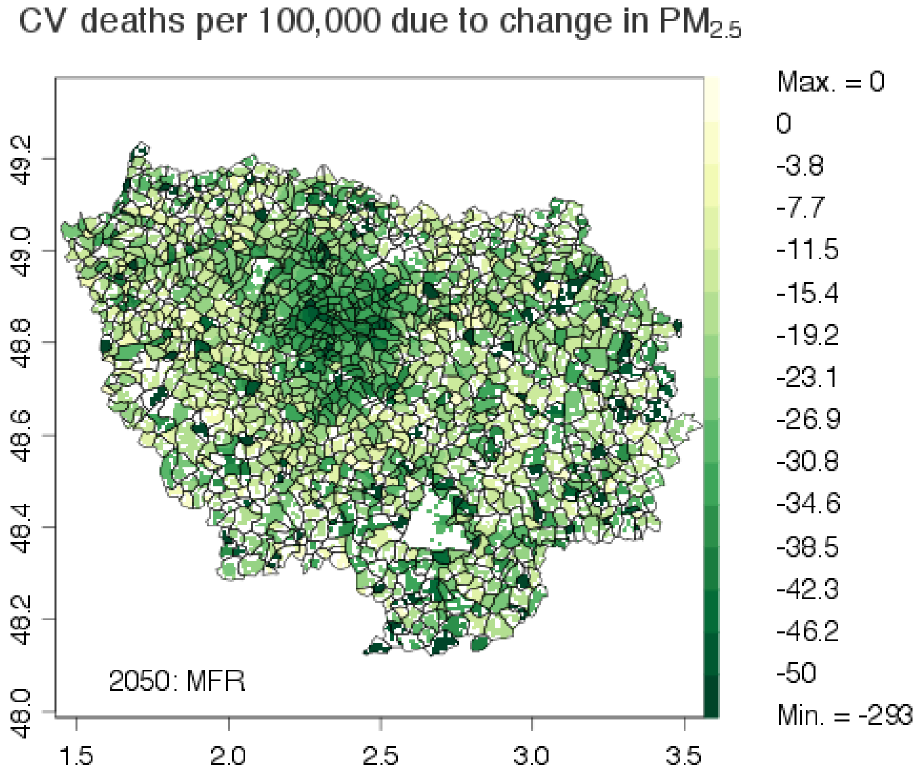
Wintertime $PM_{2.5}$ daily average fields ($\mu g/m^3$) for REG05º (left) and LOC4km (right) in the baseline simulation (top) and the differences between the changes by 2050 under the CLE (middle) and MFR (bottom) scenarios.



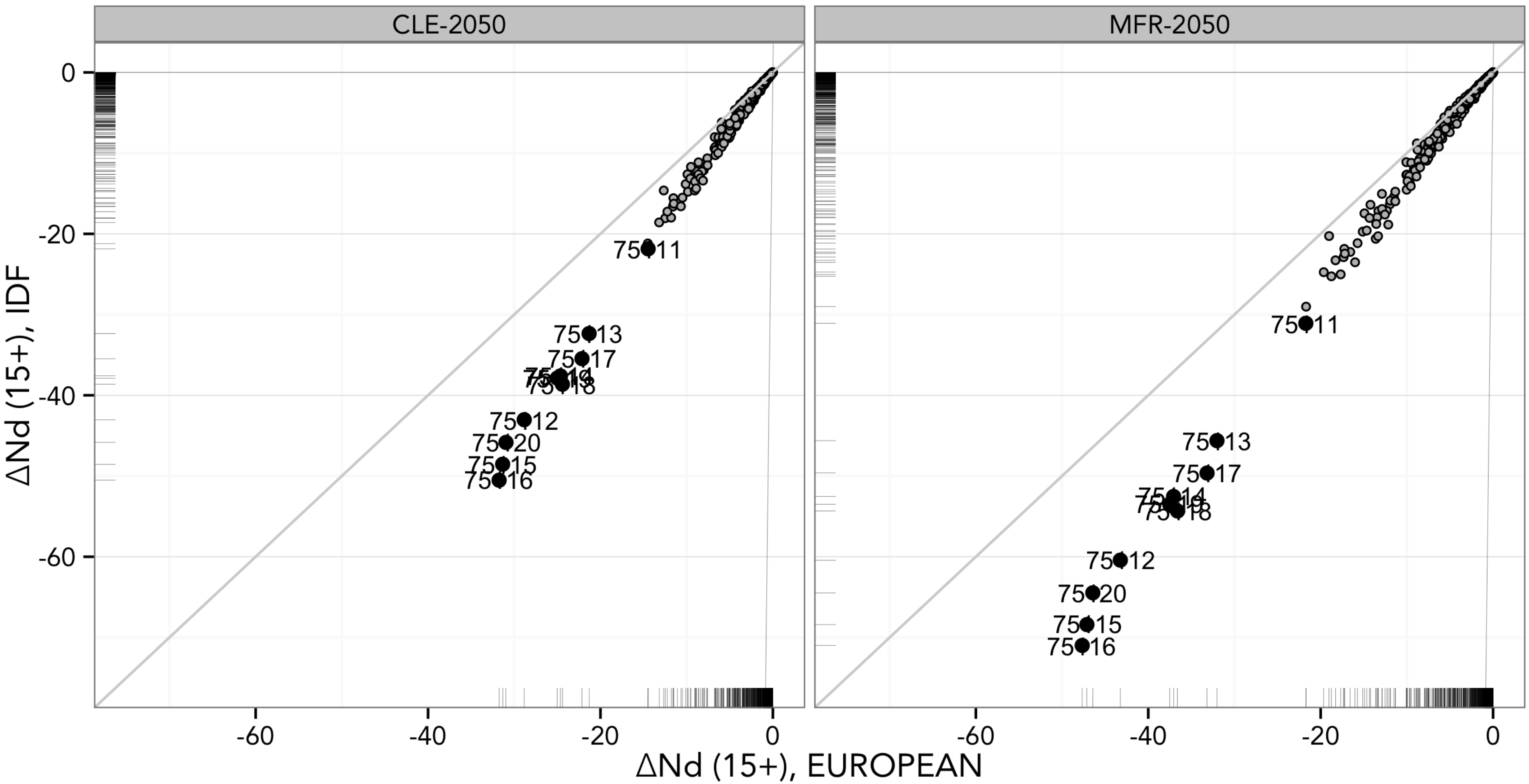
Projected changes in CV mortality death rates in 2050 relative to present in IDF using CLE (left) and MFR (right) scenarios

More red = less deaths





Scale comparison: IdF vs. European (changes in cardiovascular deaths in 2050 vs. present, CLE and MFR)



ACHIA - Highlights

- We were able to develop a consistent modeling framework for assessing health impacts of PM2.5 and O3 across three spatial domains and scales – global, European, Ile-de-France
- Differences in HIA results were observed across scales, highlighting value of multiple scales of analysis
- We successfully formed a multi-disciplinary team that was able to work jointly to address these questions

Direct Effect of Temperature on Mortality

nature climate change

LETTERS

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Projections of seasonal patterns in temperature-related deaths for Manhattan, New York

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Methods

- ***Historical Data***

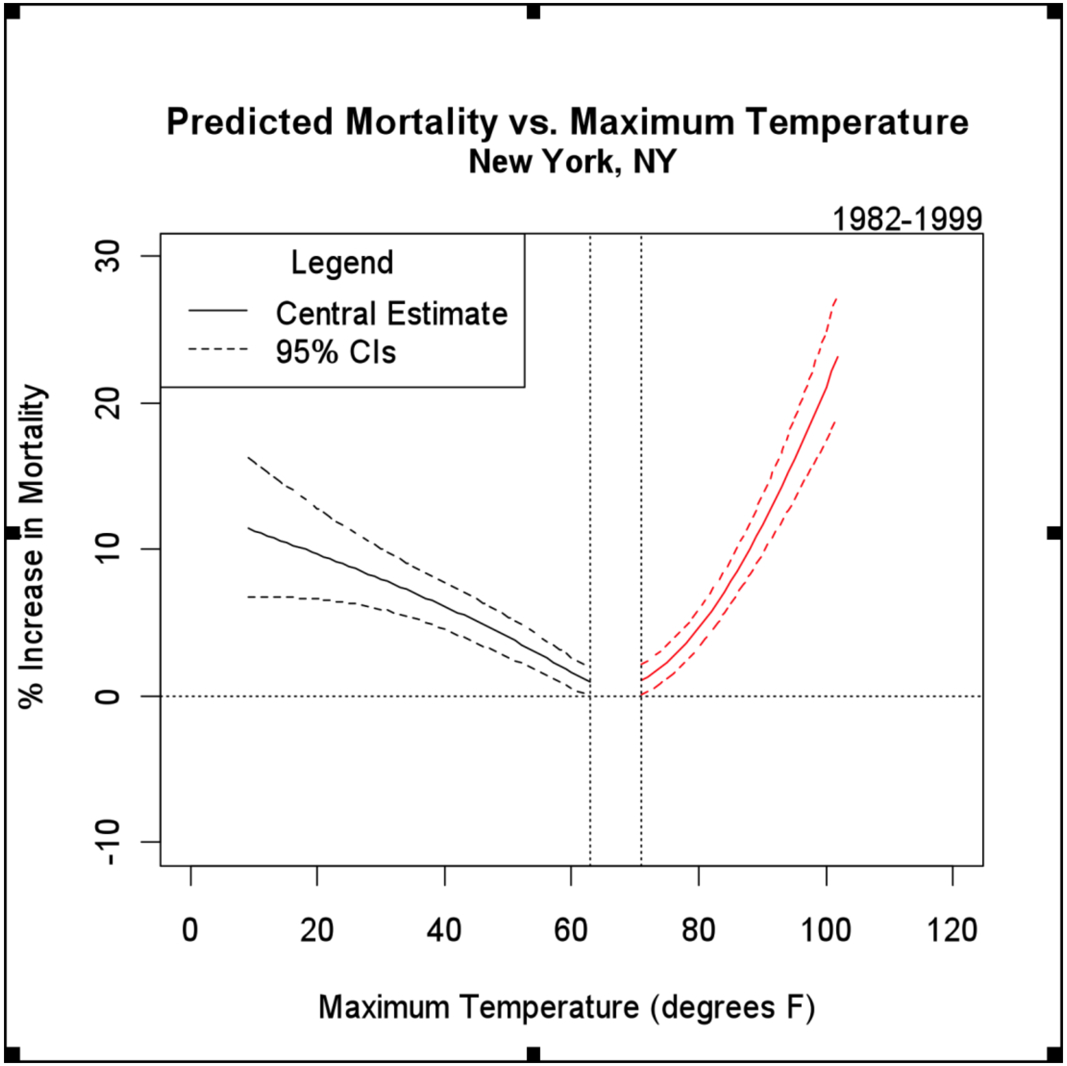
  Maximum daily temperature and daily mortality counts for New York county (Manhattan) from 1982 to 1999

- ***Statistical Modeling***

  Poisson GLM regression

daily mortality ~ natural spline(Temp$_{max_lag}$, 3df) + natural spline(time, 7df) + day of week indicator

Results: Exposure-Response Curve



Warm and cold effects fitted separately:

Lag 0 for warm effect
Lag 2 for cold effect

Assumed no effect for T range where 95% CI's crossed zero line

Future temperature modeling:

- Projected future Tmax using 32 combinations of global climate models and greenhouse gas emissions scenarios.
  - ***Two IPCC emissions scenarios (A2 and B1)***
  - ***16 Global Climate Models from IPCC 4th assessment report***
- Statistical downscaling to Central Park, NY station for 2020s, 2050s and 2080s. Baseline period is the 30 year climatological baseline of 1970 to 1999 (referred to here as "1980s")

Supplementary Table 1. Global Climate Models Used in This Study

Climate Model Acronym	Institution	Atmospheric Resolution (latitude × longitude)
BCCR	Bjerknes Center for Climate Research	1.9×1.9
CCSM	National Center for Atmospheric Research, USA	1.4×1.4
CGCM	Canadian Center for Climate Modeling and Analysis , Canda	2.8×2.8
CNRM	National Weather Research Center, METEO-FRANCE, France	2.8×2.8
CSIRO	CSIRO Atmospheric Research, Australia	1.9×1.9
ECHAM5	Max Planck Institute for Meteorology, Germany	1.9×1.9
ECHO-G	Meteorological Institute of the University of Bonn, Germany	3.75×3.75
GFDL-CM2.0	Geophysical Fluid Dynamics Laboratory, USA	2.0×2.5
GFDL-CM2.1	Geophysical Fluid Dynamics Laboratory, USA	2.0×2.5
GISS	NASA Goddard Institute for Space Studies	4.0×5.0
INMCM	Institute for Numerical Mathematics, Russia	4.0×5.0
IPSL	Pierre Simon Laplace Institute, France	2.5×3.75
MIROC	Frontier Research Center for Global Change, Japan	2.8×2.8
MRI	Meteorological Research Institute, Japan	2.8×2.8

Mortality Risk Assessment

$$\Delta Mortality = Y_0 \times ERF \times \Delta T$$

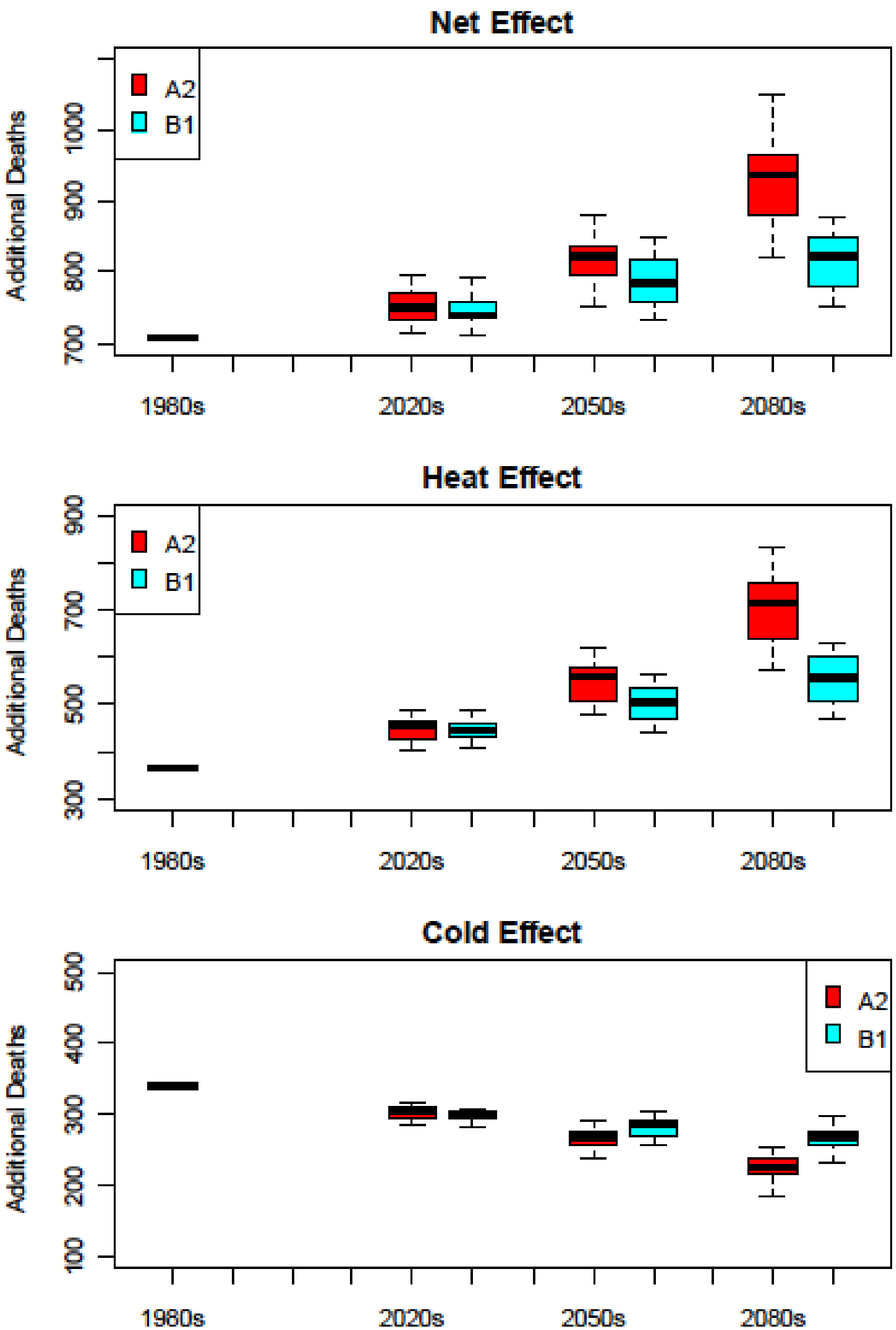
$\Delta Mortality$ is daily temperature-related deaths

Y_0 is baseline average daily death count

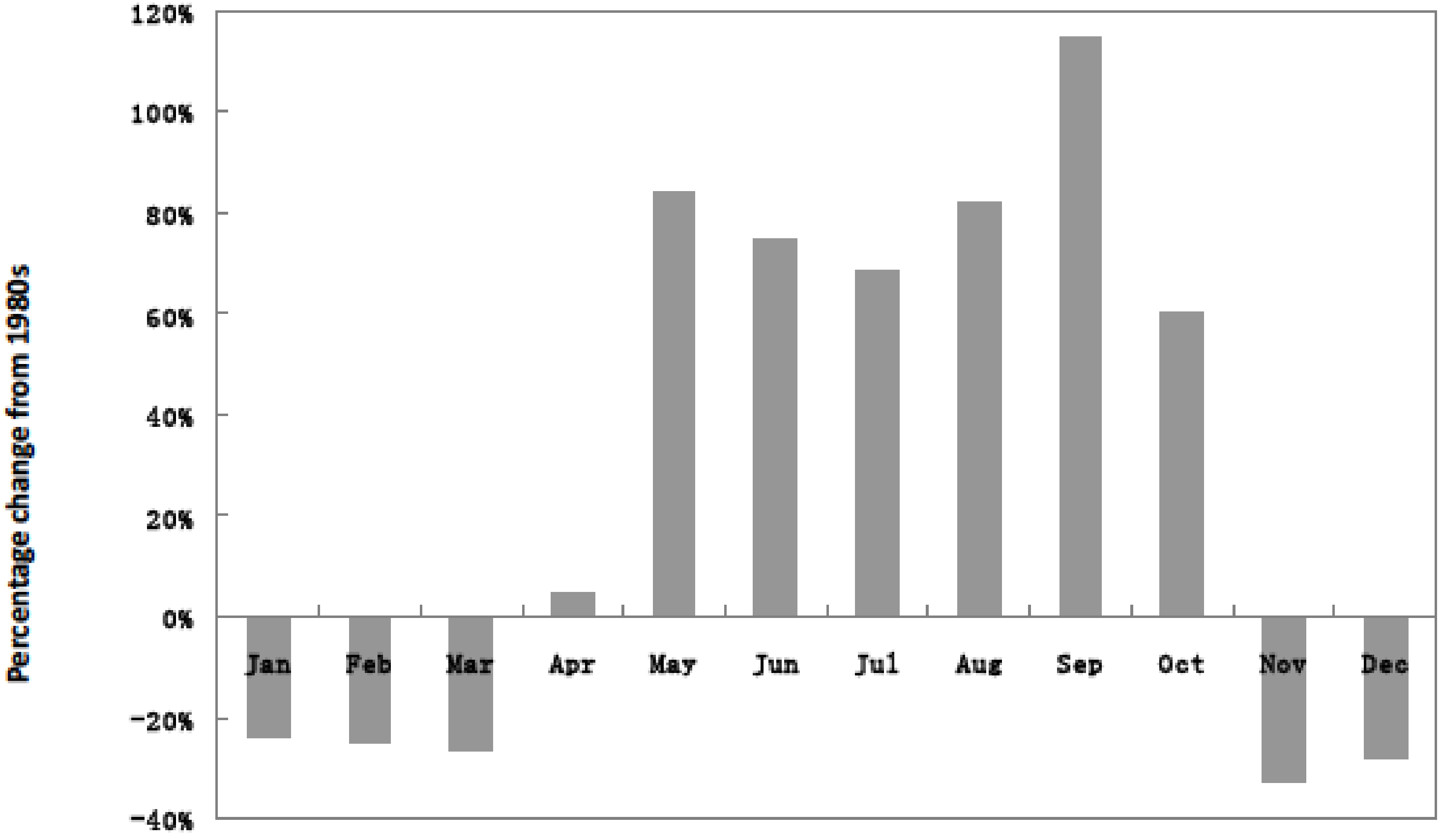
ERF (exposure response function) describes the non-linear percentage change in mortality per unit change temperature.

ΔT is daily observed for projected Tmax – the minimum mortality temperature (MMT)

Annual temperature-related deaths in baseline and future periods



Percent change (2080s vs. 1980s) in net temperature-related deaths, by month



Conclusions

- Daily mortality was associated with both cold and warm temperatures in an 18 year dataset from Manhattan
- We projected future mortality resulting from changing temperatures, based on 2 IPCC emissions scenarios and 16 climate models
- We saw small decreases in cold-related deaths and larger increases in heat-related deaths, yielding steady increases in net annual temperature-related deaths across decades
- Higher mortality impacts for higher GHG emissions scenario
- Climate has different effects across months
- But, we held population, ERF, and baseline death rate constant
  - Current work is exploring future population and adaptation scenarios