UNIVERSITY OF CAMBRIDGE

Cambridge Centre *for* Climate Science

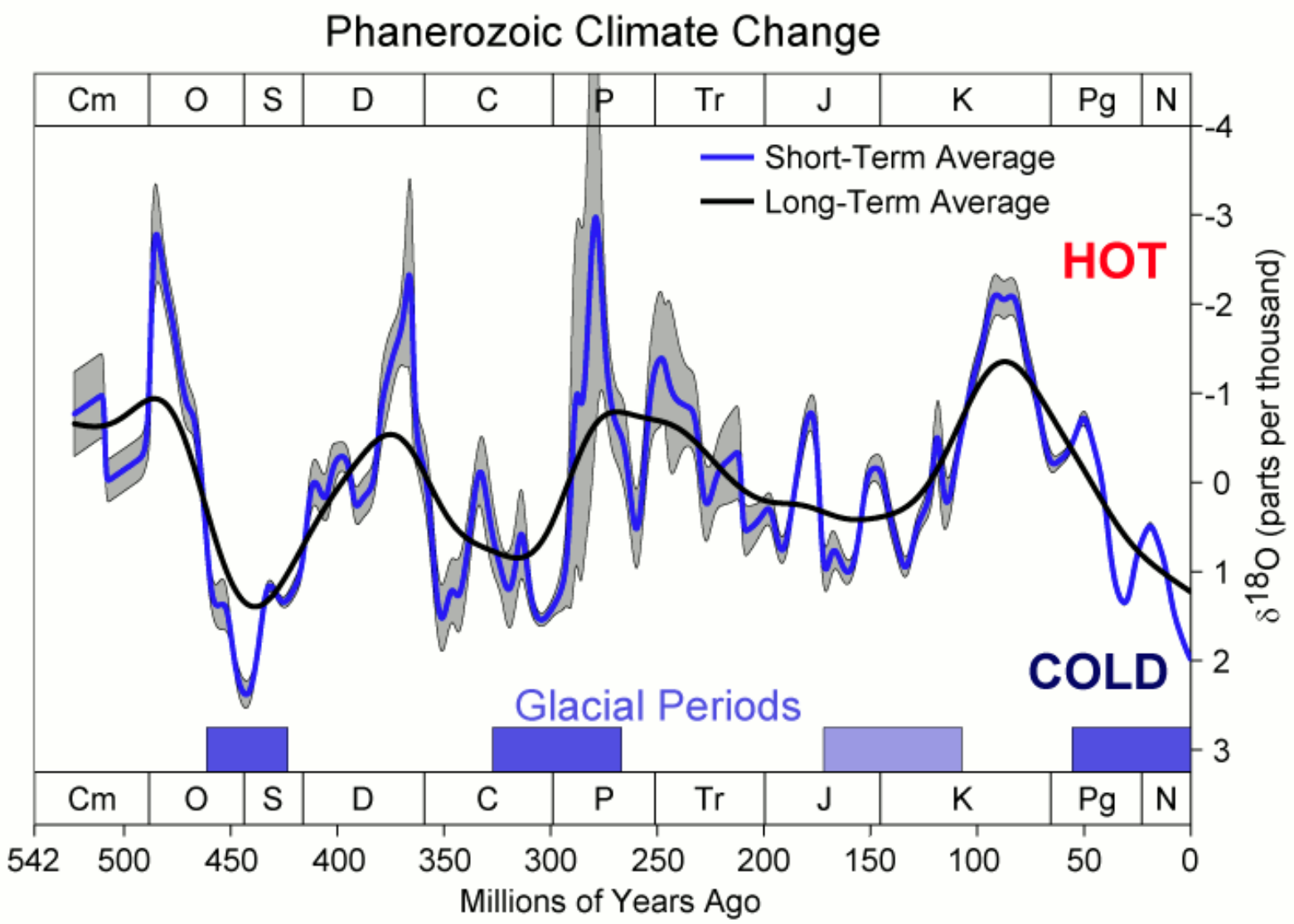
Towards the development of a community Earth system model.

Alexander T. Archibald.

Department of Chemistry, University of Cambridge & NCAS Climate

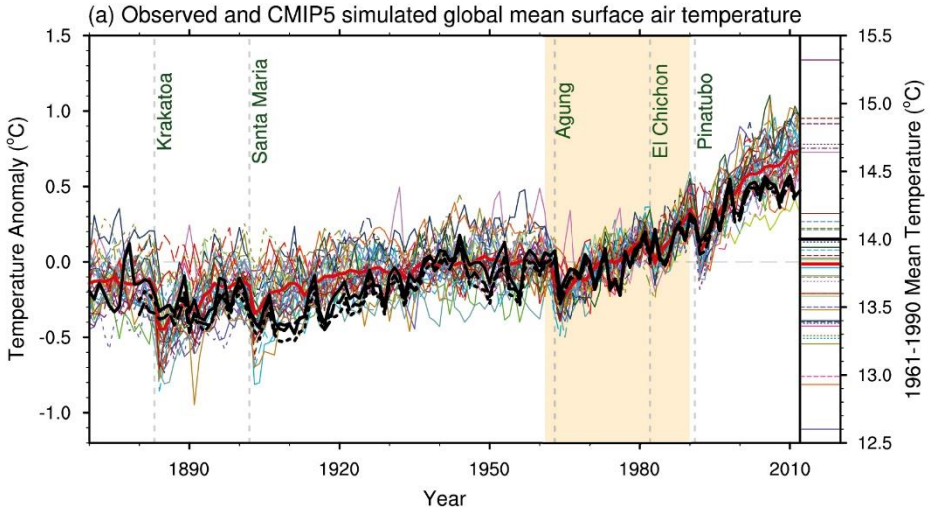
wholeSEM conference, University of Cambridge, Cambridge, UK
6th July 2015.

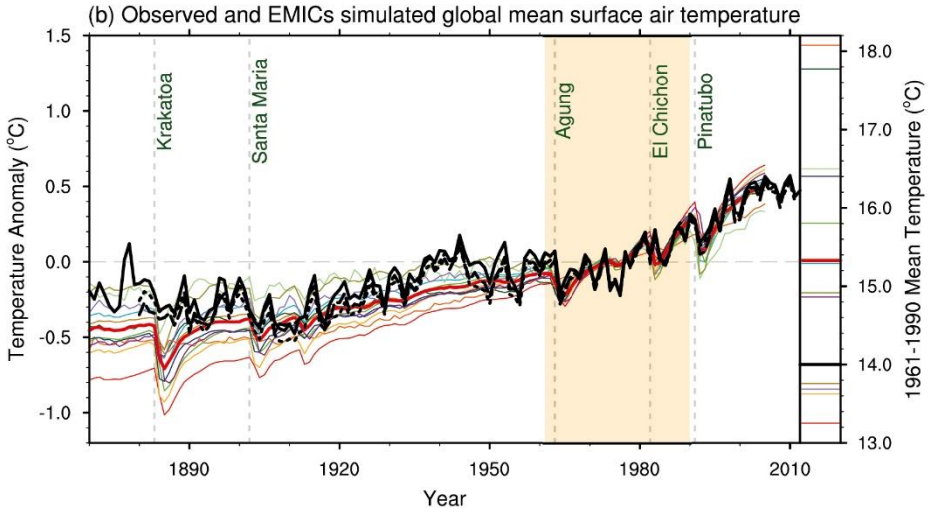
Climate changes from time to time.

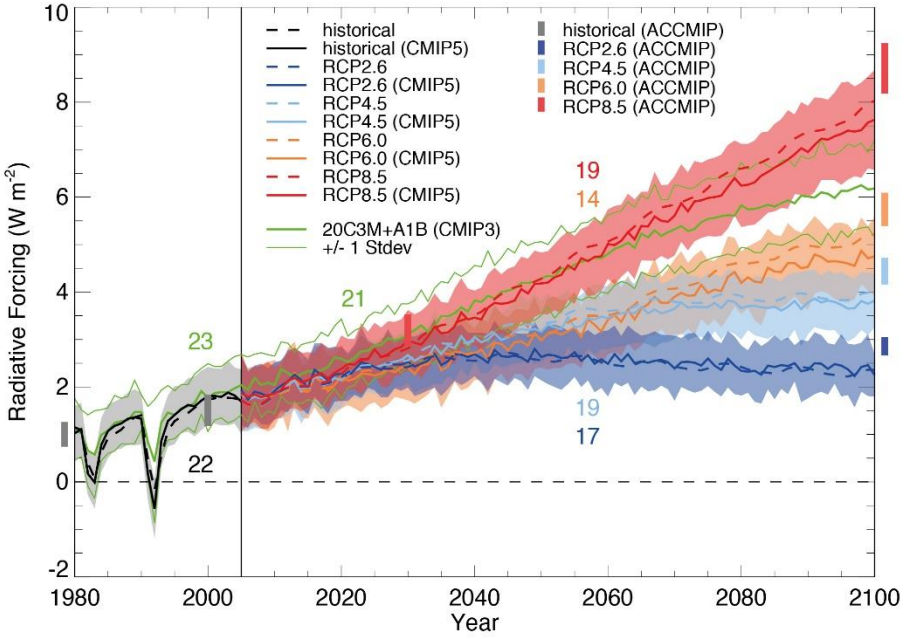


National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

But climate is changing rapidly - now.





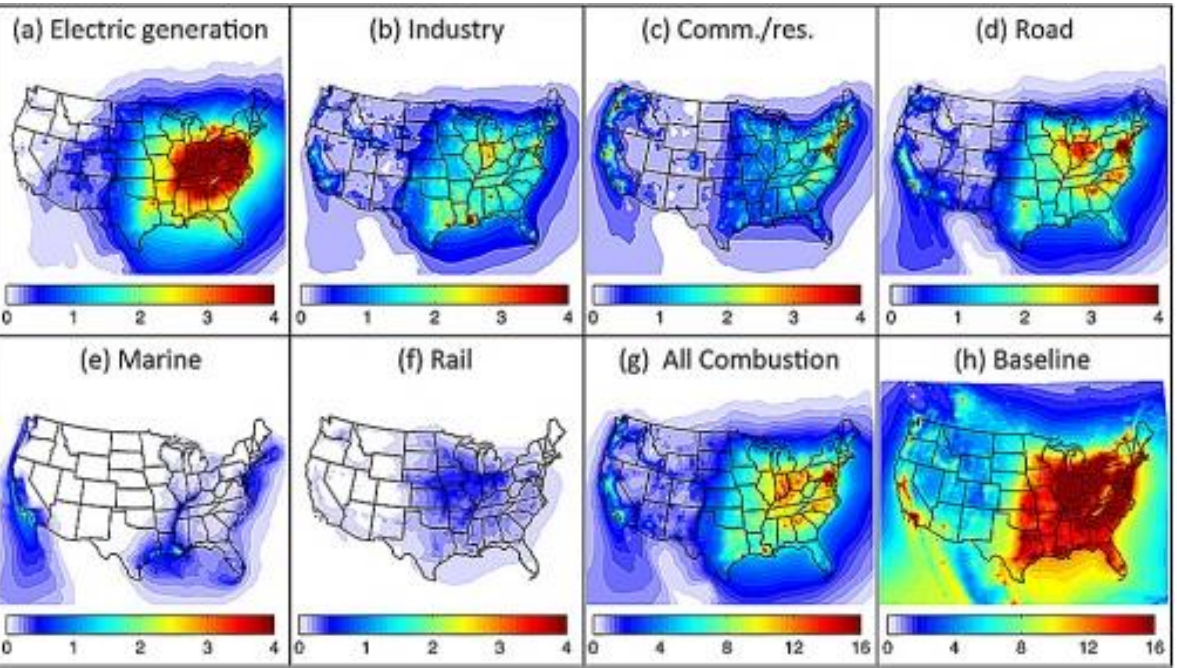


National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Air pollution is changing.


New Delhi 2014

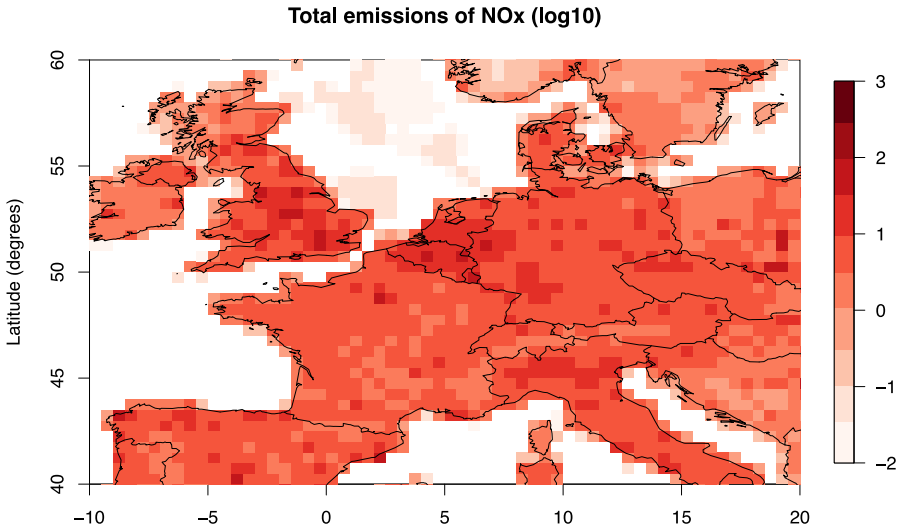

London 1952

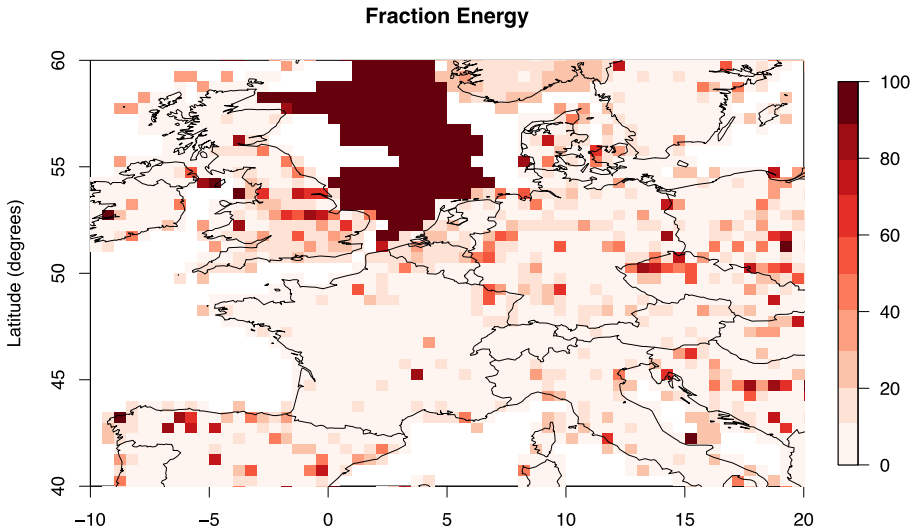


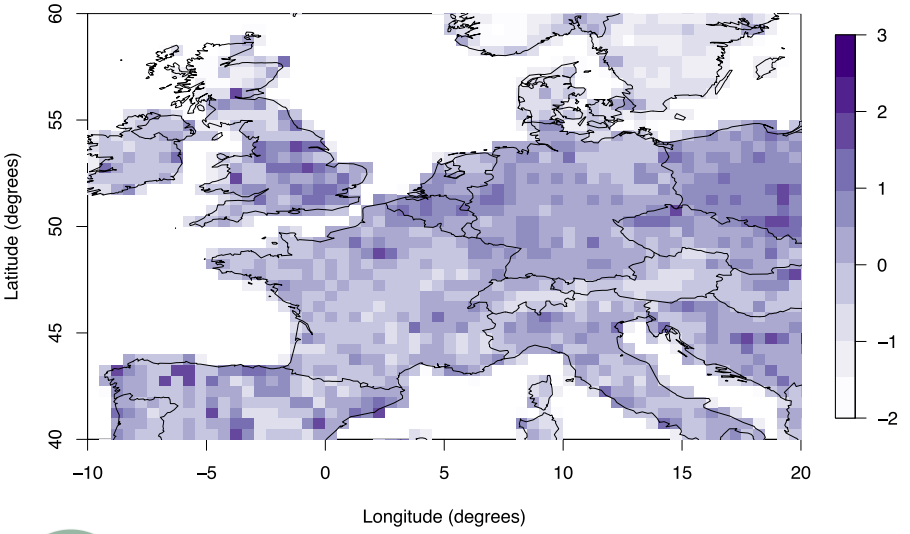
The sources, types and their geographical distributions of air pollution are changing.

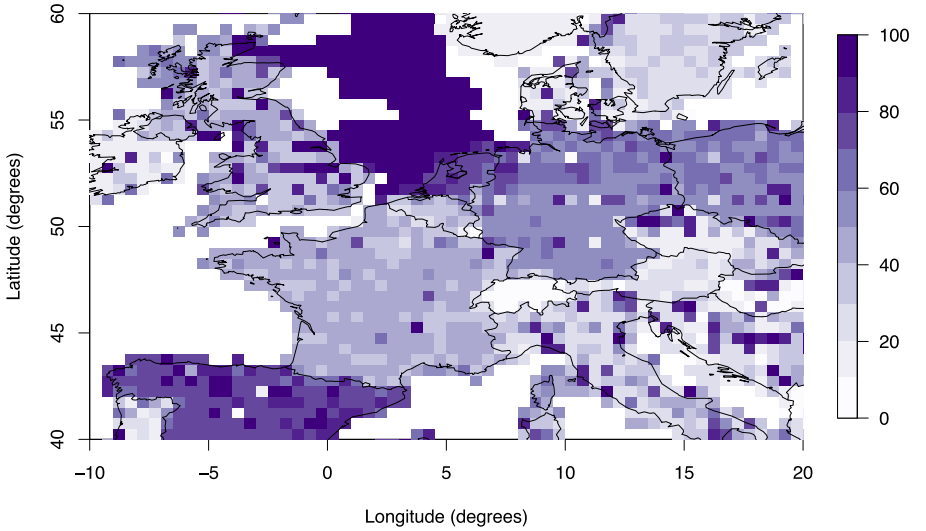
Air pollution one of the top “killers”
China: 500,000 /yr
USA: 200,000/yr
World: 7,000,000 /yr

The energy industry as a source.



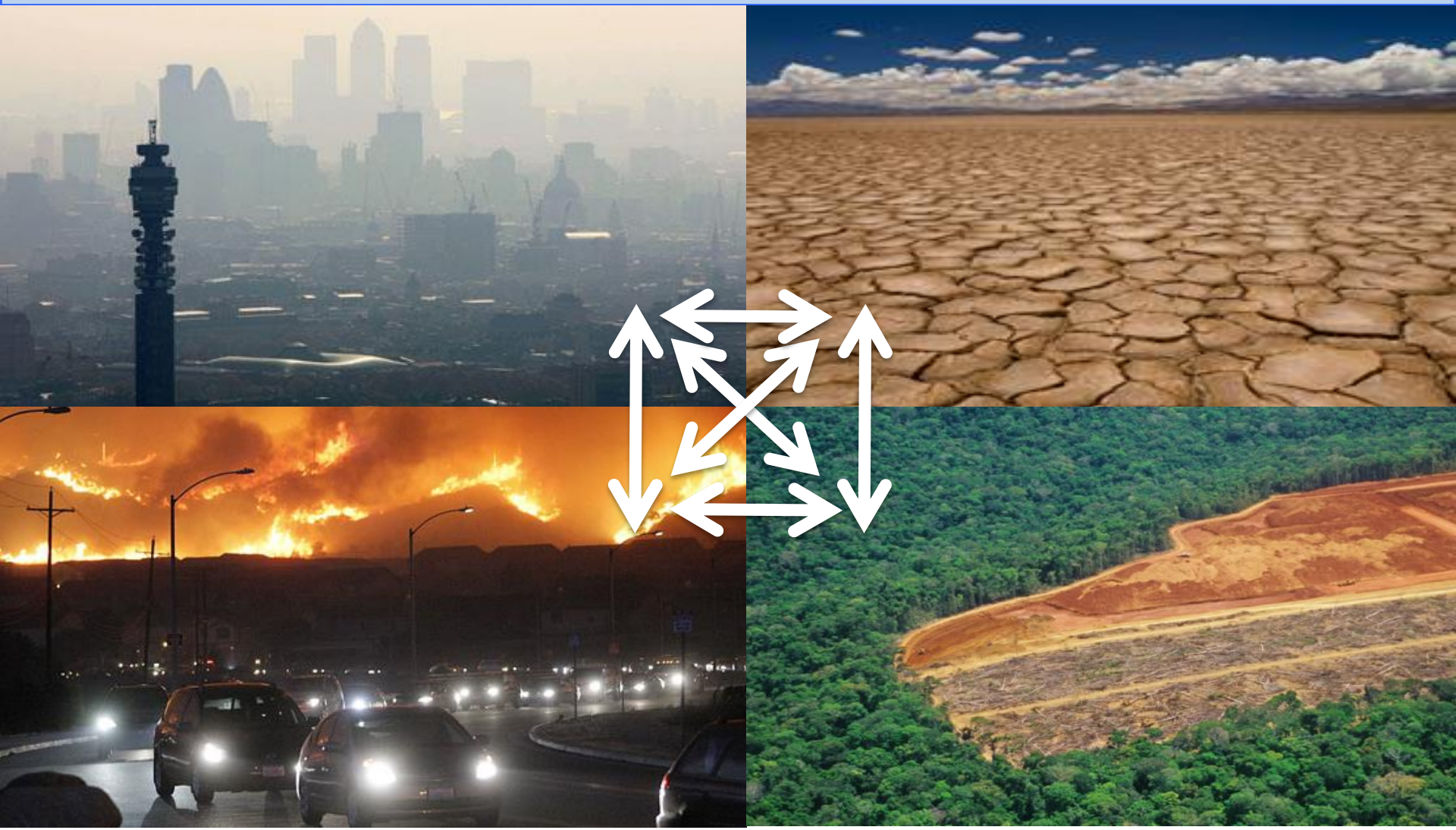






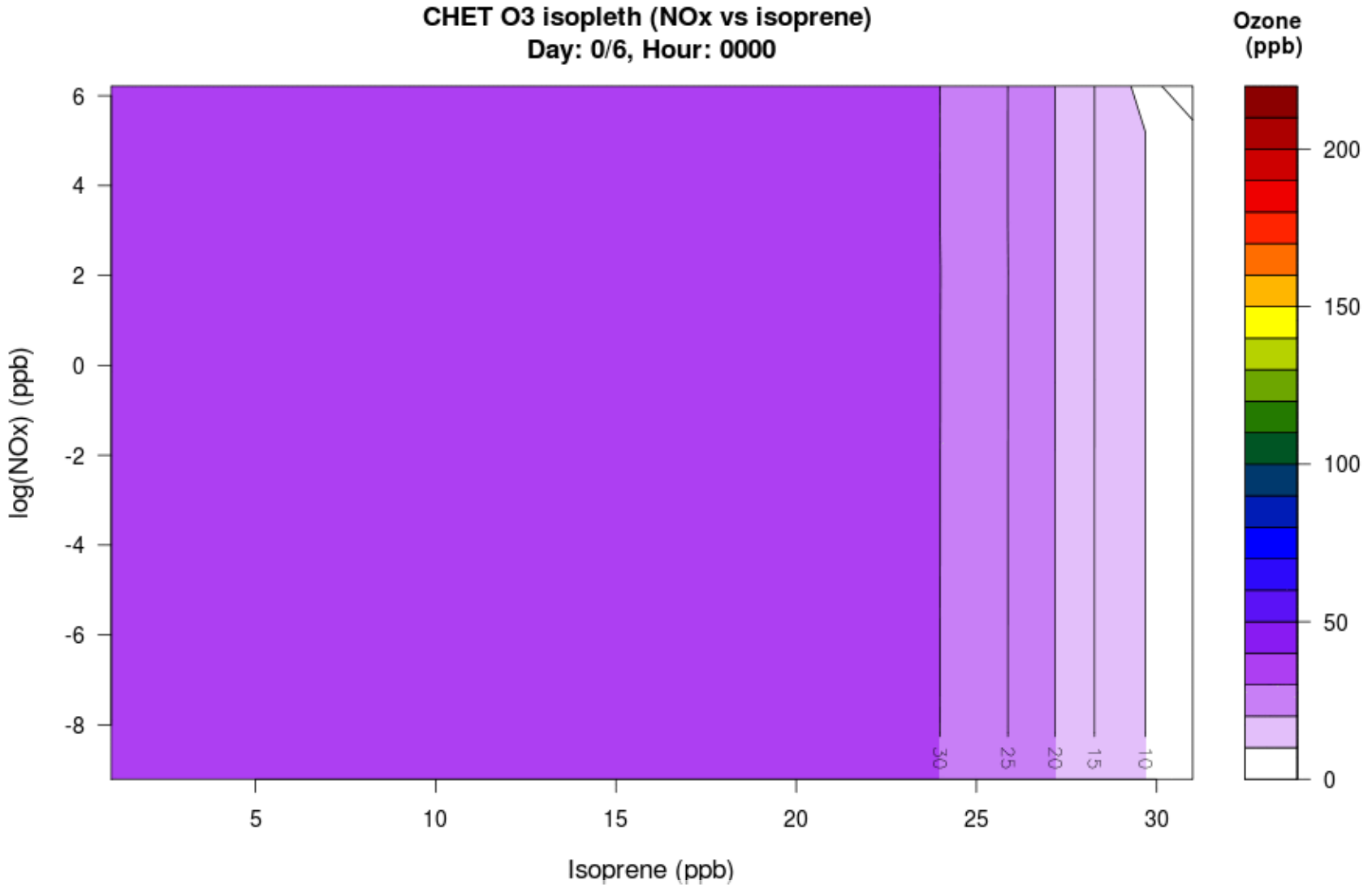
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

The problems we face are coupled.



National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

The problems we face are complex.



National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Development of atmospheric models

$$\frac{\mathrm{d}}{\mathrm{d}t} = \frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y} + w\frac{\partial}{\partial z} = \frac{\partial}{\partial t} + \mathbf{v}\cdot\nabla$$

$$\mathrm{dQ} = \mathrm{dU} + \mathrm{dW}$$

$$\bar{\mathbf{a}}_\mathrm{l} = \frac{\mathrm{d}\bar{\mathbf{v}}}{\mathrm{d}t} = \frac{\partial\bar{\mathbf{v}}}{\partial t} + (\bar{\mathbf{v}}\cdot\nabla)\,\bar{\mathbf{v}}$$

$$+\nabla\cdot(\mathbf{v}E) \approx \rho_\mathrm{a}\frac{\theta_\mathrm{v}}{T_\mathrm{v}}\frac{\mathrm{dQ}}{\mathrm{d}t}$$

$$\frac{\mathbf{F}_\mathrm{c}}{M_\mathrm{a}} = f\mathbf{k}\times\mathbf{v}$$

$$L = -\frac{u_*^3\bar{\theta}_\mathrm{v}}{kg(\overline{w'\theta'_\mathrm{v}})_\mathrm{s}} = \frac{u_*^2\bar{\theta}_\mathrm{v}}{kg\theta_*}$$

$$\frac{\mathbf{F}_\mathrm{g}}{M_\mathrm{a}} = \frac{\mathbf{F}_\mathrm{g}^*}{M_\mathrm{a}} + \frac{\mathbf{F}_\mathrm{r}}{M_\mathrm{a}} = -\nabla\Phi$$

$$E_\mathrm{p} = h\nu = \frac{hc}{\lambda}$$

$$\frac{\mathbf{F}_\mathrm{p}}{M_\mathrm{a}} = -\frac{1}{\rho_\mathrm{a}}\nabla p_\mathrm{a}$$

$$E_\lambda = I_\lambda\int_0^{2\pi}\int_0^{\pi}\sin\theta\,\mathrm{d}\theta\,\mathrm{d}\phi$$

$$\frac{\mathbf{F}_\mathrm{v}}{M_\mathrm{a}} = \frac{\eta_\mathrm{a}}{\rho_\mathrm{a}}\nabla^2\mathbf{v}$$

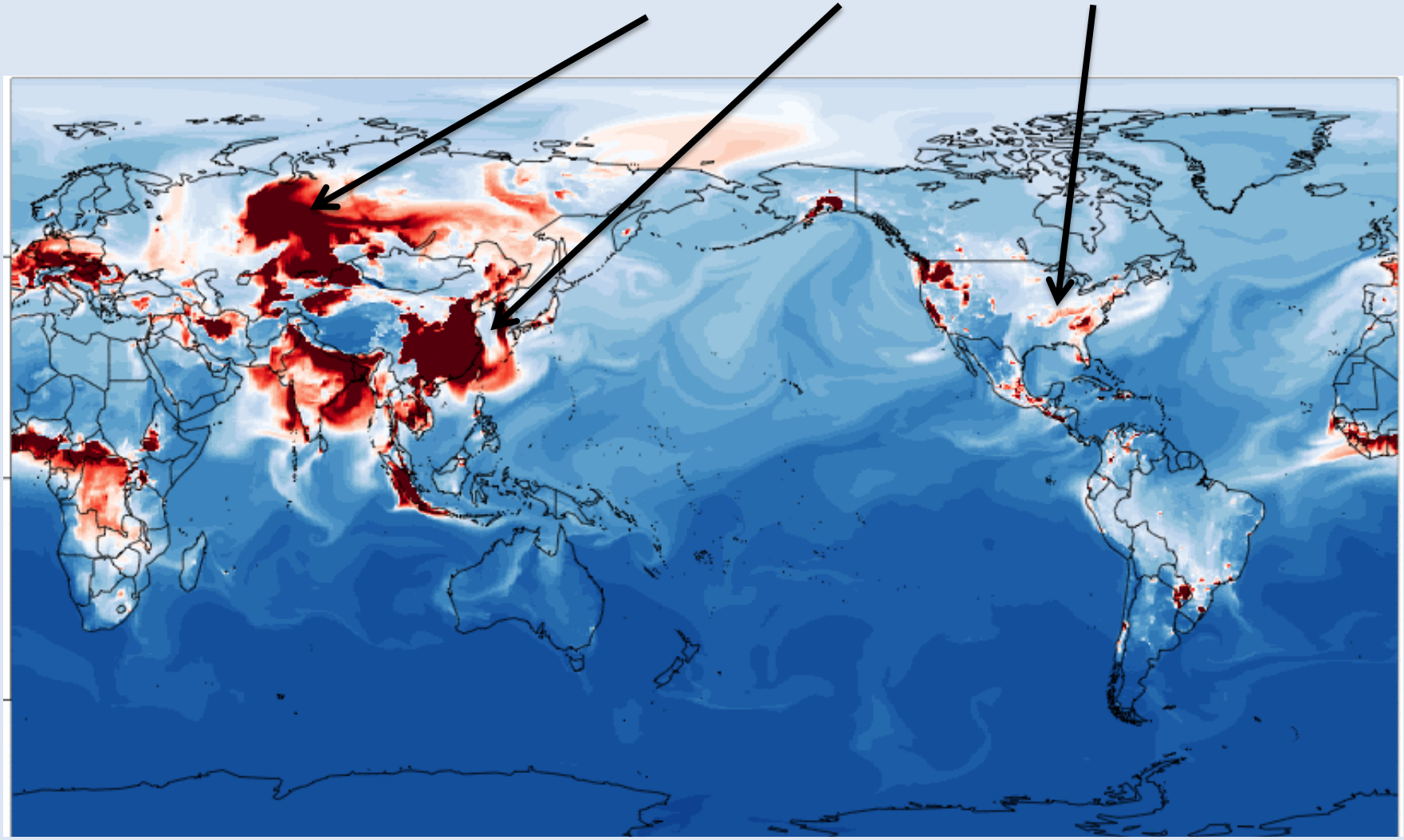
$$D_{\mathrm{p},i} = \frac{k_\mathrm{B}T}{6\pi r_i\eta_\mathrm{a}}G_i$$

$$\frac{\mathbf{F}_\mathrm{t}}{M_\mathrm{a}} = -\frac{1}{\rho_\mathrm{a}}(\nabla\cdot\rho_\mathrm{a}\mathbf{K}_m\nabla)\,\mathbf{v}$$

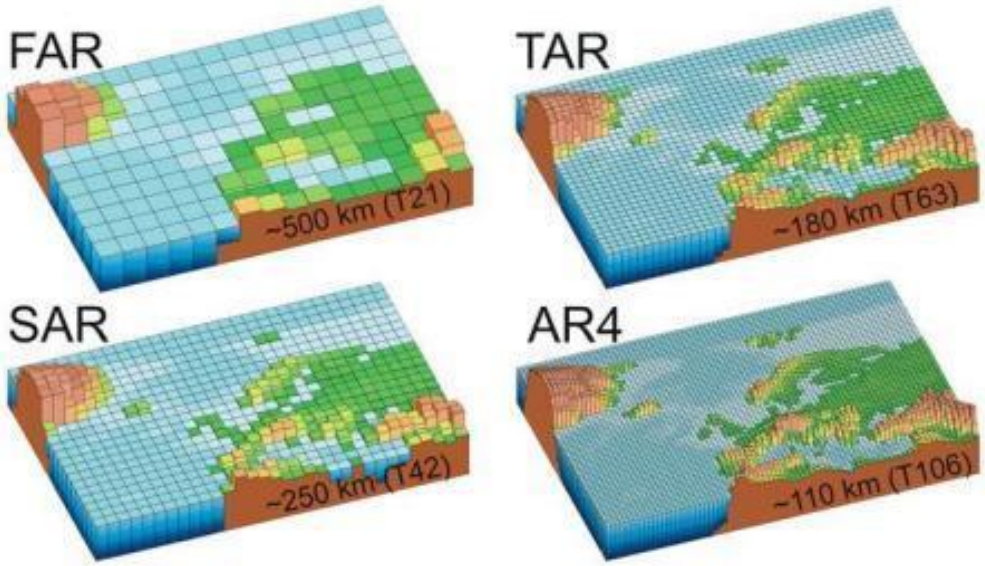
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

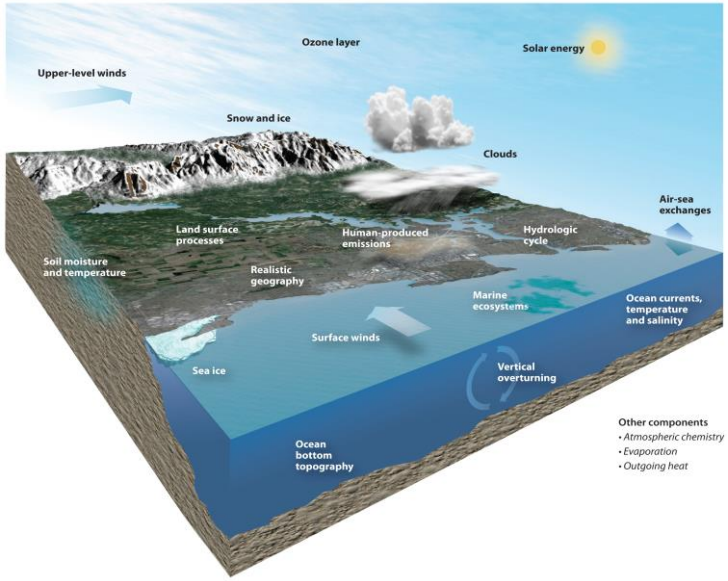
Numerical modelling of air pollution

Global simulation of carbon monoxide (CO) produced from incomplete combustion. Major sources include fires, industry, transport.

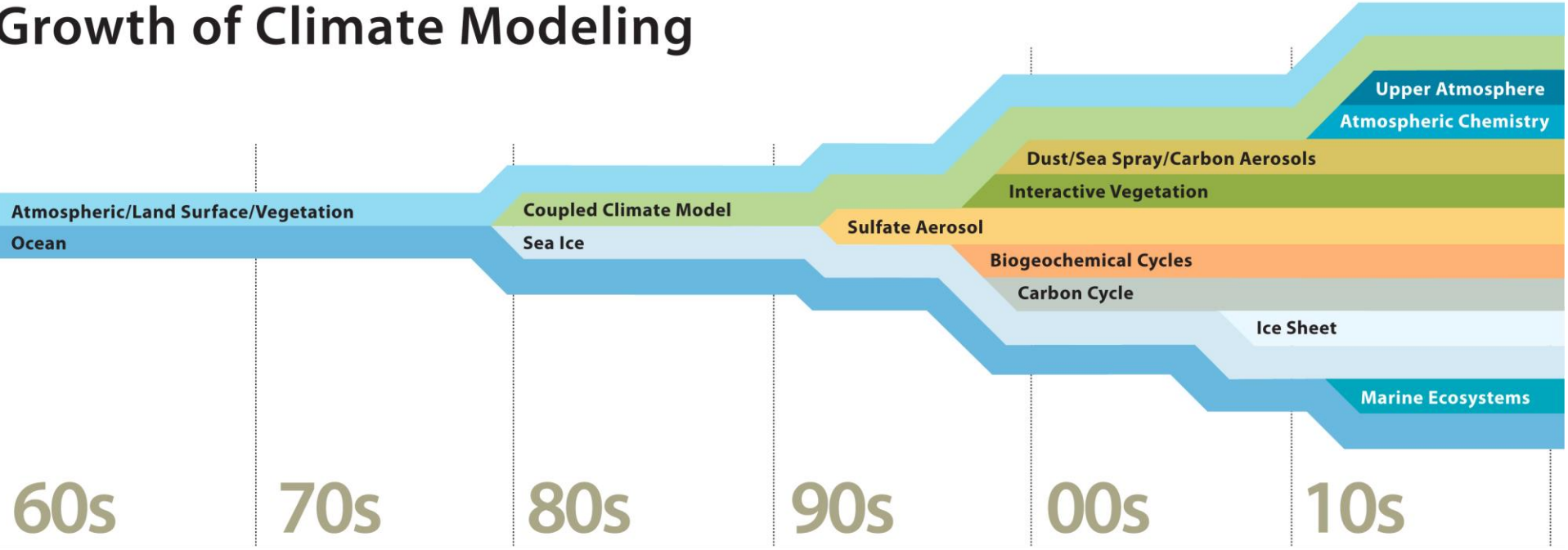


Towards models of the Earth system





Growth of Climate Modeling



Met Office | NERC SCIENCE OF THE ENVIRONMENT

JWCRP – a partnership in weather and climate research

UKESM (UK Earth System Model)

Overriding objectives:

- **To develop and apply a world-leading Earth System Model**
- **while growing a community of UK ESM scientists**

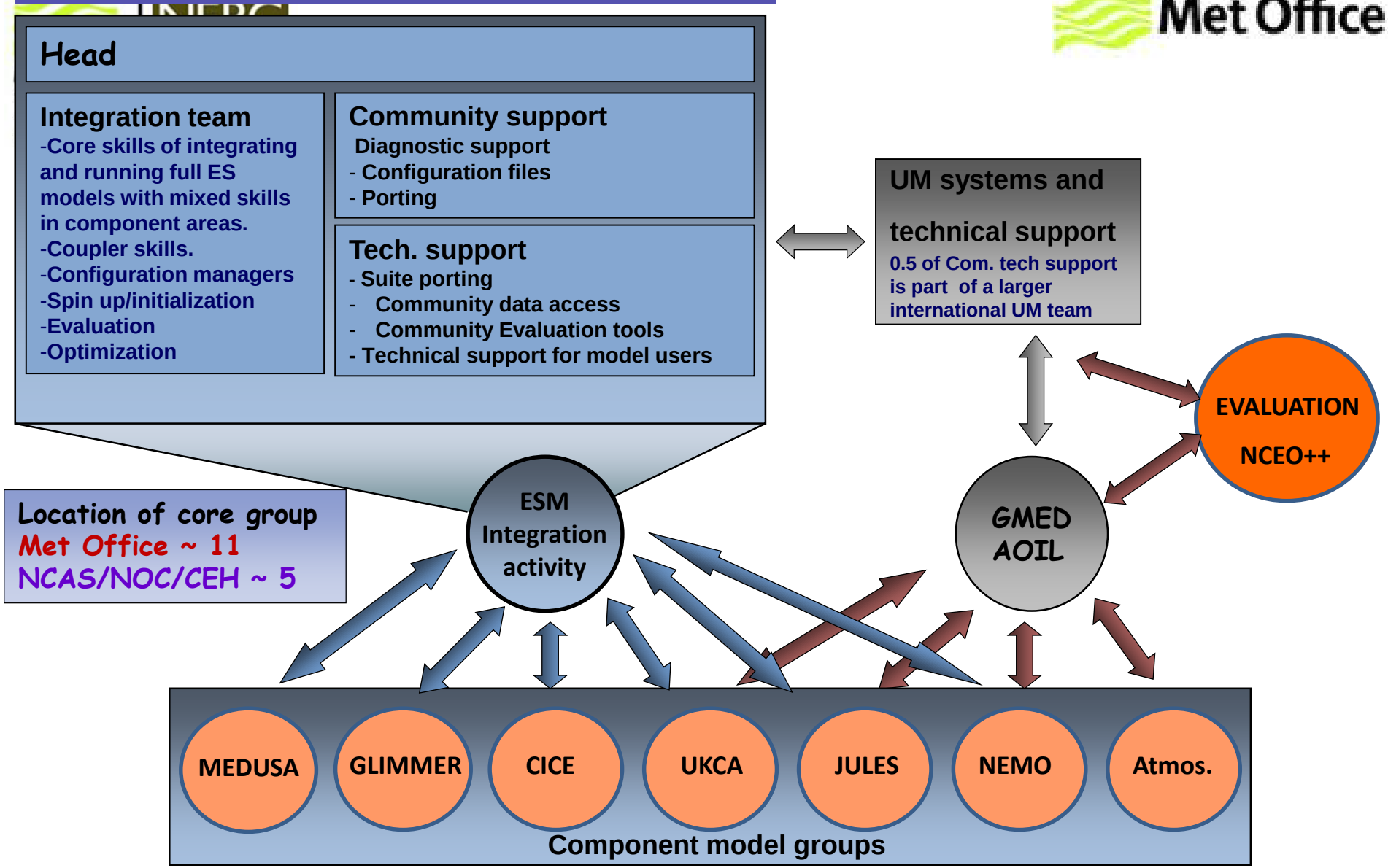
UKESM is a NERC/Met. Office collaboration, pooling expertise and resources around a common ESM development/evaluation effort.

UKESM has a core development team (of 16) funded equally by NERC & Met. Office and builds on other NERC/MO collaborations developing component models for the UM system (e.g. JULES, UKCA, NEMO etc)

The UKESM core group is responsible for putting together, applying & evaluating UKESM, building on the physical coupled model HadGEM.

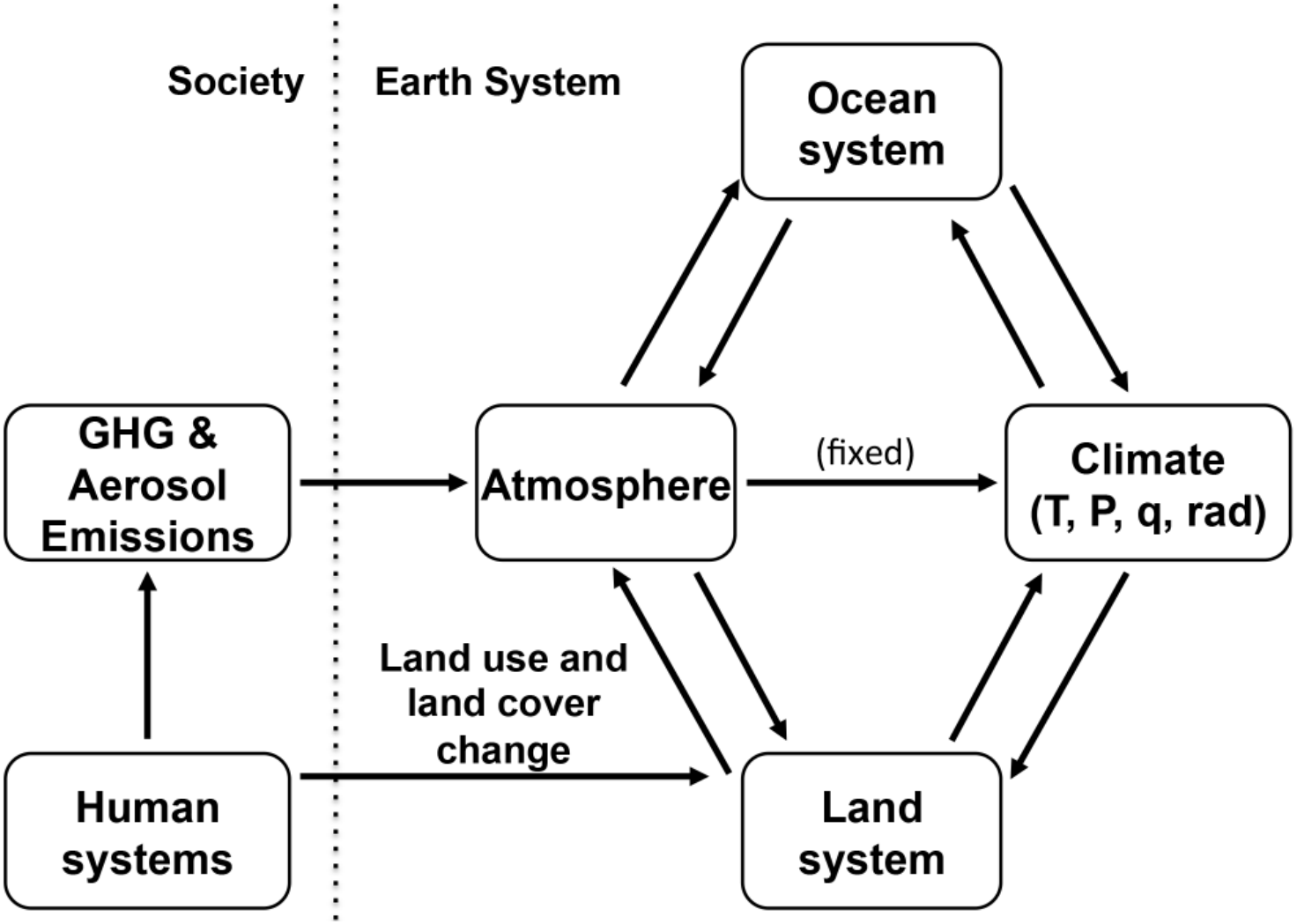
UKESM1 will be the UK community contribution to CMIP6

UKESM Core Group



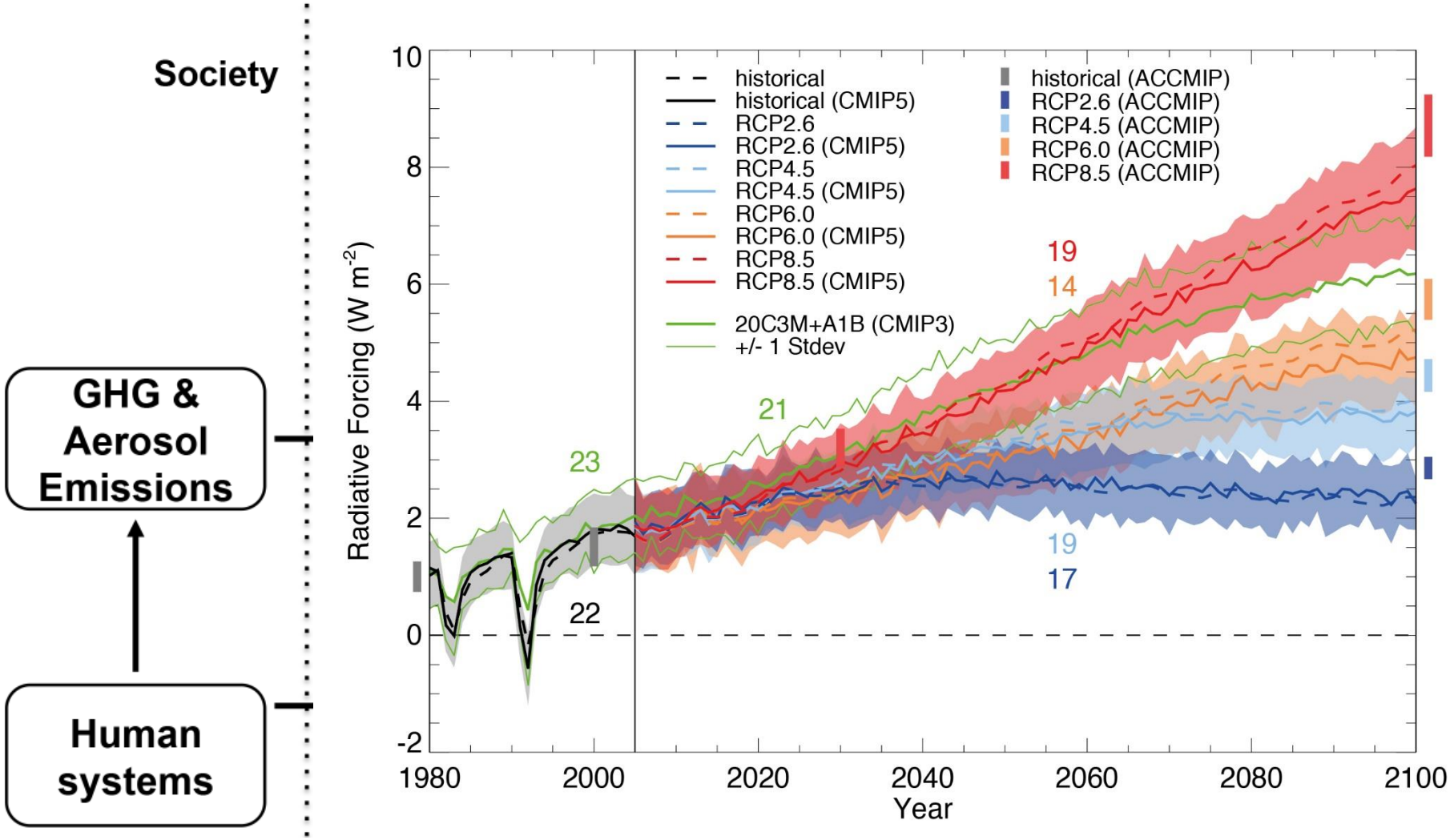
The core group integrates component developments into a full ESM

The limitation with ESM for projection



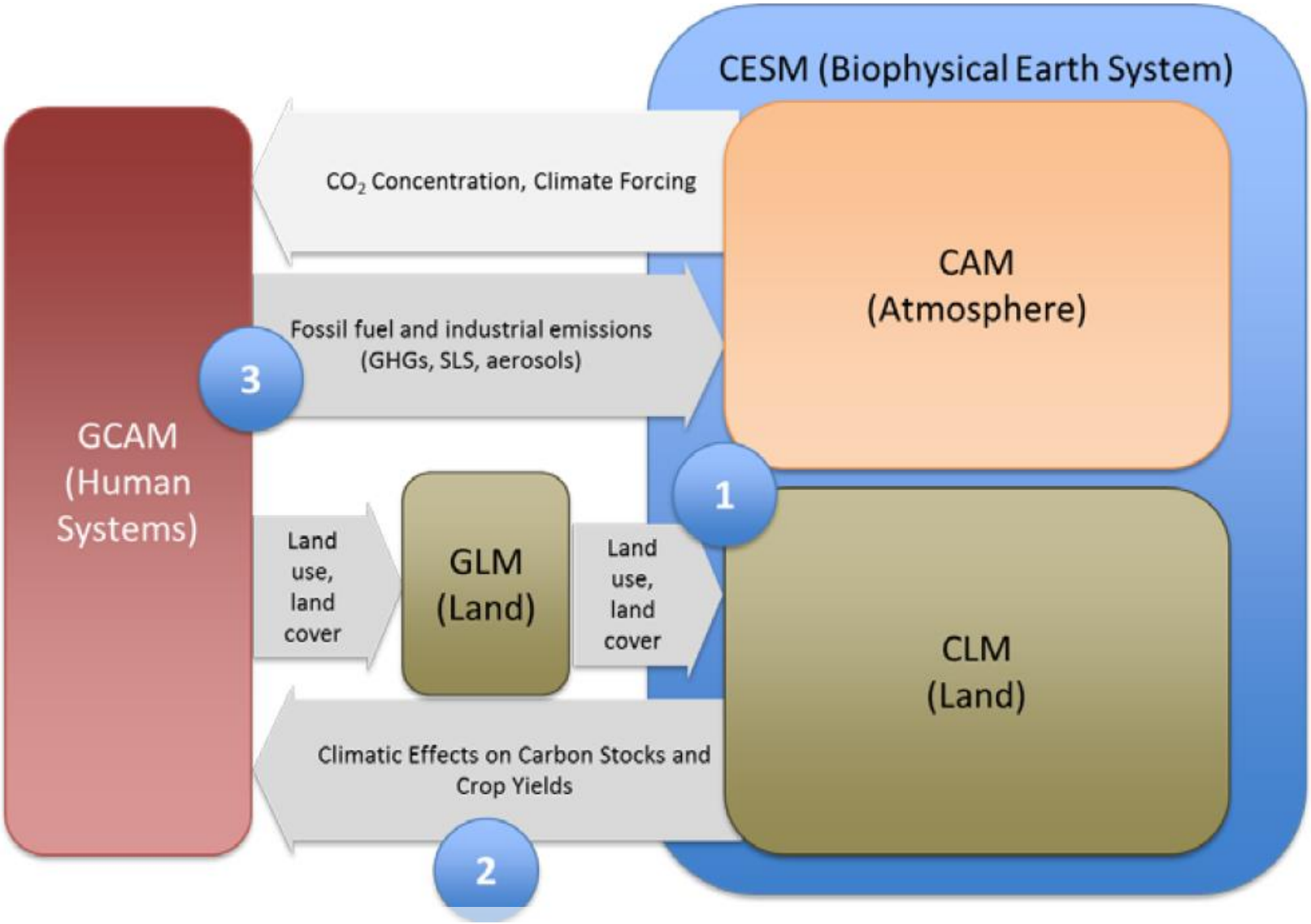
National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

The limitation with ESM for policy



National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

wholeSEM -> wholeESM



iESM (Collins et al., GMDD 2015)

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL