

# The importance of GRID computing in the investigation of climate and its change

**Eleni Katragkou**

[katragou@auth.gr](mailto:katragou@auth.gr)

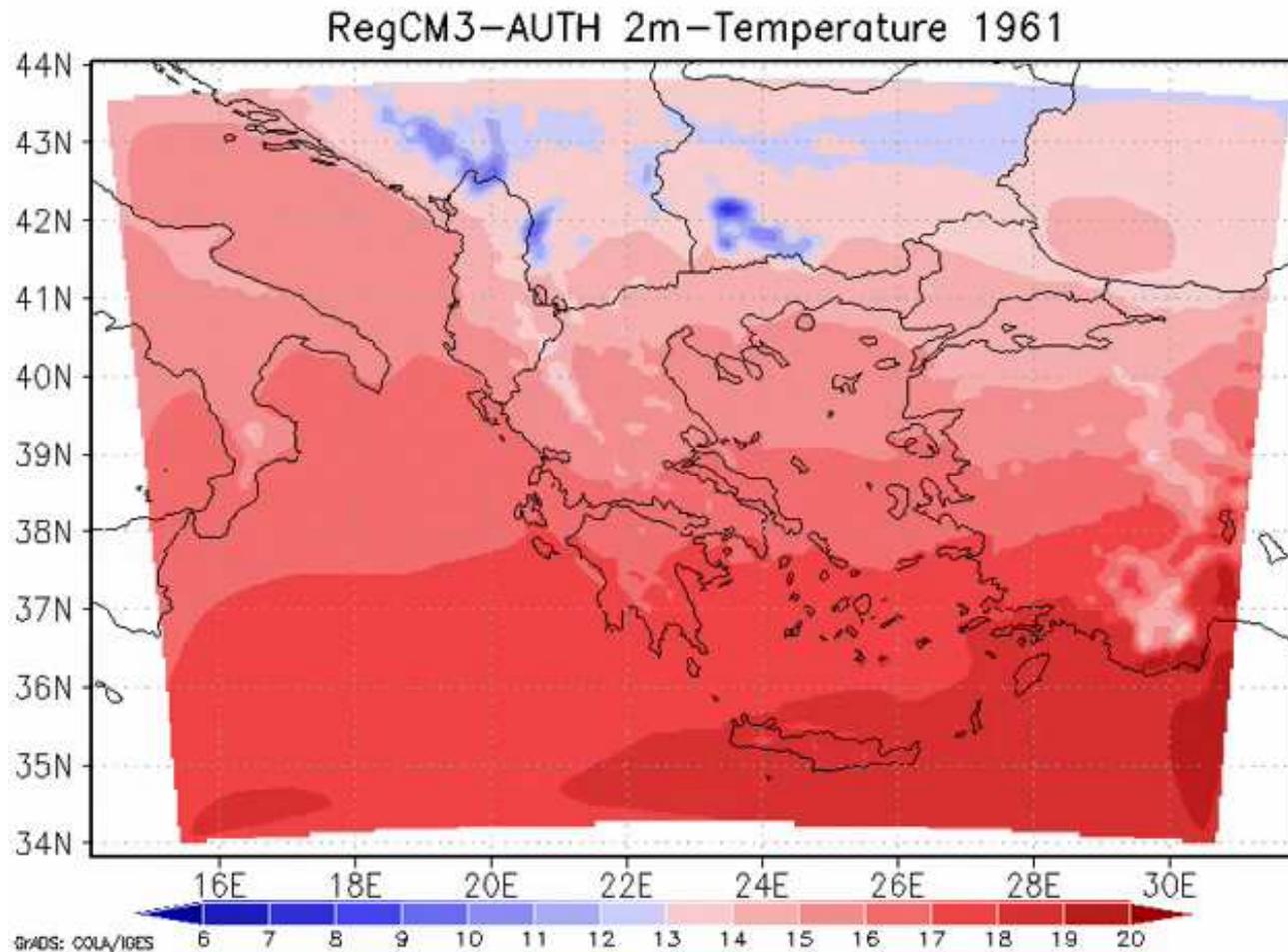
**Aristotle University of Thessaloniki**

**Department of Meteorology and Climatology**

**Greece**



# Part A: Climate and its change

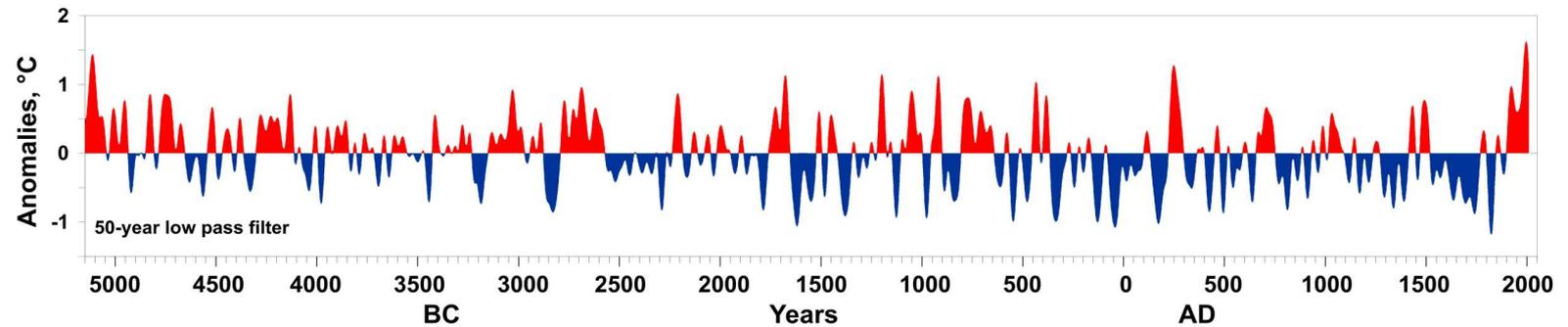


**Past and future surface temperatures over the Balkan Peninsula (1960-2100).**  
Regional climate simulations were performed at AUTH using EGI resources.  
More on [www.geoclima.eu](http://www.geoclima.eu)

# Paleoclimatology : determining past climate

Paleoclimatologists, based on *dendrochronology*, *fossils* and *ice-core data* have shown that global climate has undergone slow but continuous changes, throughout much of the earth's history, long before humanity came onto the scene.

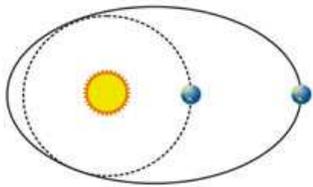
We know now that natural climate change is an inherent characteristic of climate.



# What causes climate to change

## Natural forcing

- Solar variation (Milankovitch theory)



Eccentricity



Obliquity



Precession

- Volcanic activity

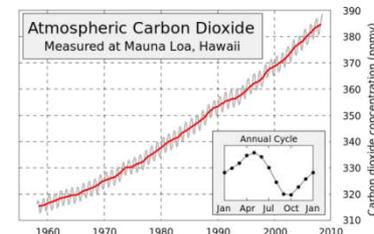


## Human forcing

- Changing landscape



- Anthropogenic emissions



# IPCC – Proving human induced climate change

- The **Intergovernmental Panel on Climate Change** (IPCC) is the leading international body for the assessment of climate change.
- One of the main IPCC activities is the preparation of comprehensive **Assessment Reports** about the state of scientific, technical and socio-economic knowledge on climate change, its causes, potential impacts and response strategies.
- *IPCC press release, Stockholm 23-26 September 2013 :*  
*“Multiple lines of evidence confirm that the extra heat being trapped by greenhouse gases is warming the Earth’s atmosphere, heating and acidifying the oceans, raising sea levels, and melting ice caps and glaciers. We are also seeing a change in weather patterns and extreme events such as heat waves, droughts and floods”.*
- More on the IPCC activities and reports on:  
[www.ipcc.ch/](http://www.ipcc.ch/)

# Components of the climate system



Atmosphere: **atmos**+sphere (ατμός=**vapor**)

Biosphere: **bio**+sphere (βίο=**life**)



Lithosphere: **litho**+sphere (λίθος=**rock**)

Cryosphere : **cryo**+sphere (κρύο=**cold**)



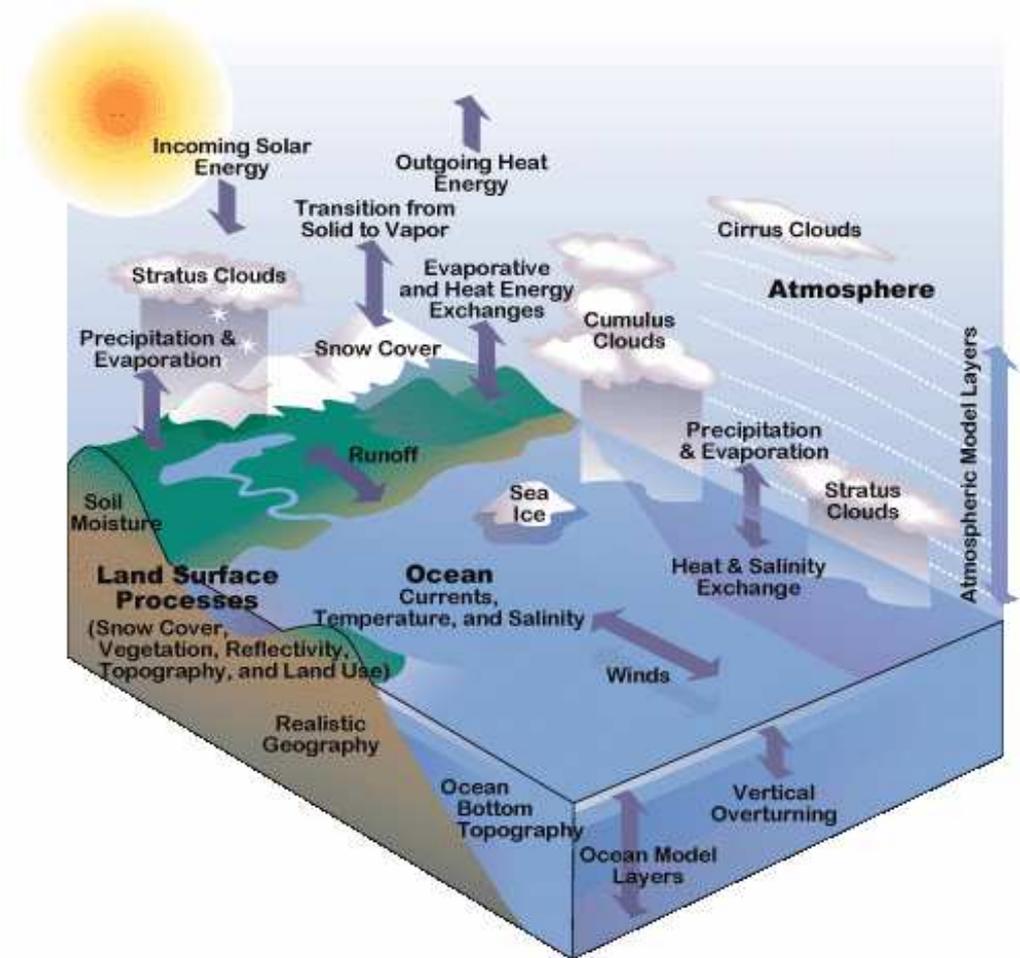
Hydrosphere: **hydro**+sphere (ύδωρ = **water**)

Human activity



# Part B: Modelling the climate system

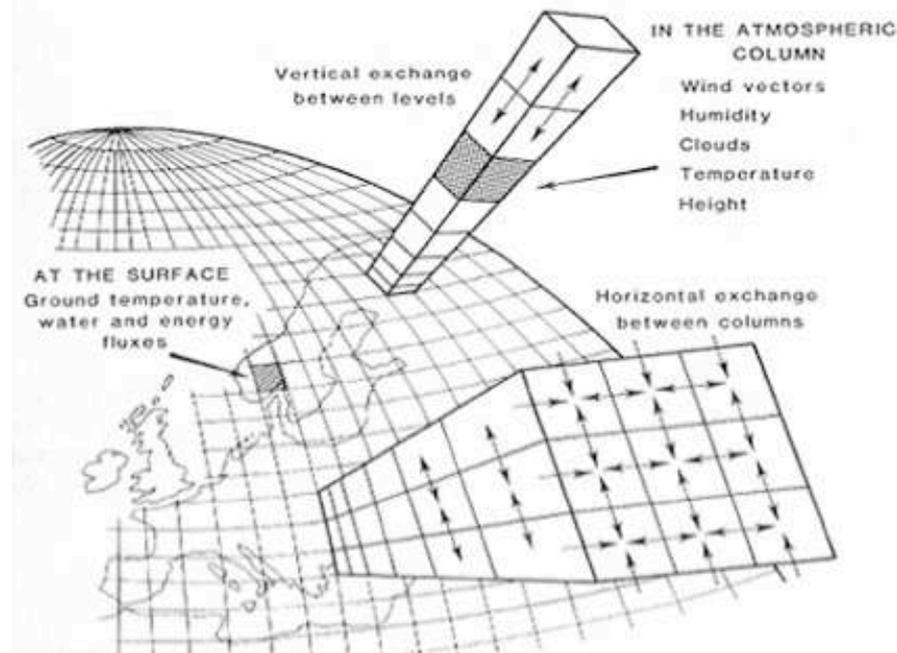
- Climate models that simulate the physical processes of the atmosphere are called **General Circulation Models (GCMs)**.
- GCMs use mathematics and the laws of physics to describe the general behaviour of the atmosphere.
- The primary earth system components that are simulated by a GCM include the atmosphere, oceans, land surface and the cryosphere.



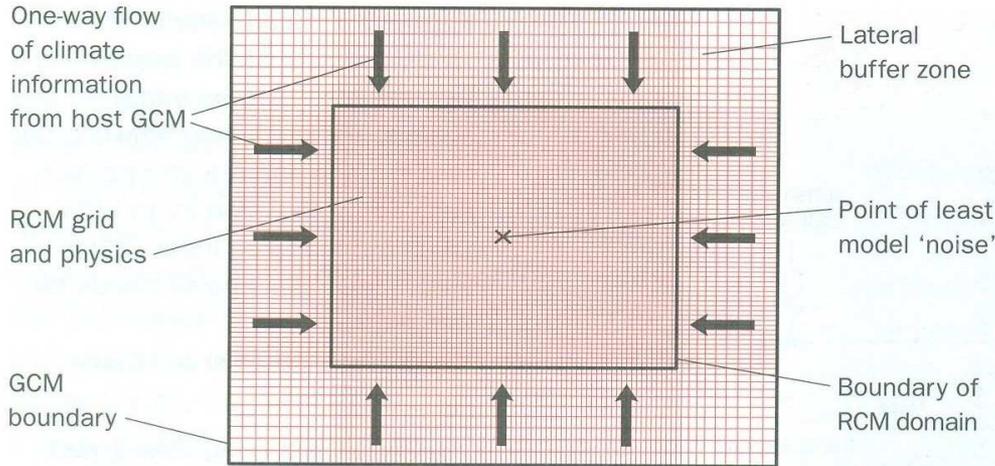
# Tools to assess climate: Climate models

- GCMs divide the atmosphere, oceans, and land into a **3-dimensional grid system**.
- **Differential equations** are used to relate fundamental physical quantities (Temperature, Pressure, Winds, Specific Humidity) to each other.
- Each equation is solved **at discrete grid points** on the earth's surface, at a fixed **time interval** (time-step) and **several vertical layers**, defined by the regular grid.
- The number of cells in the grid system is known as the "**resolution**". The more grid cells, the higher the resolution, and the more calculations that must be computed.

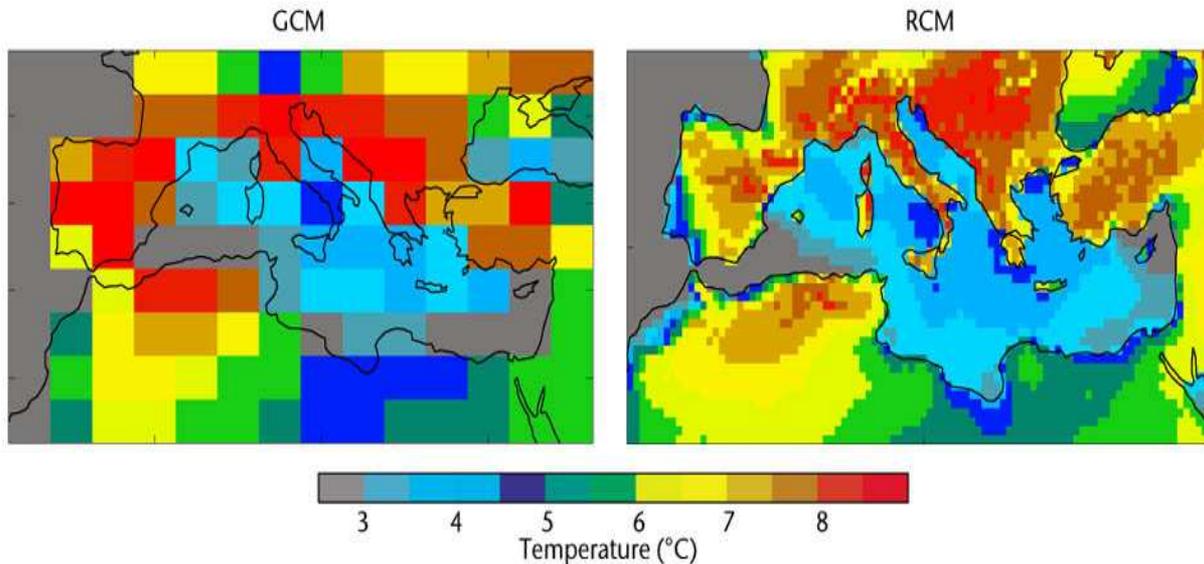
**Rule of thumb:**  
 **$2^3$  more CPU for**  
**a doubling of**  
**resolution**



# Regional Climate Models (RCMs)

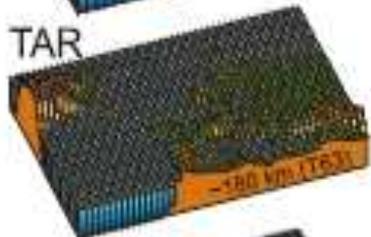
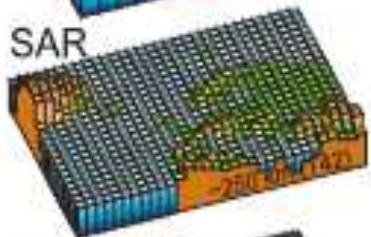
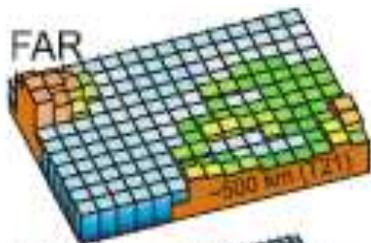


- An RCM can be nested through a lateral buffer zone to a GCM.
- This technique is called **Dynamical Downscaling**.
- Downscaling climate data is a strategy for generating regional relevant data of high resolution from GCMs.



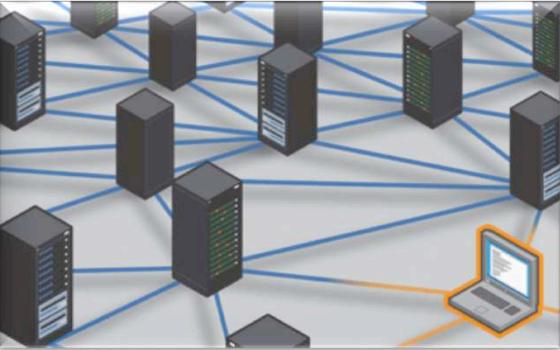
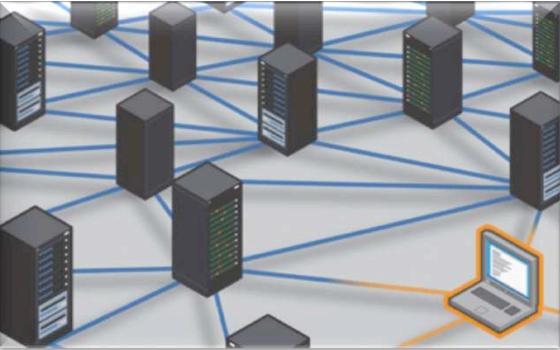
## Advances in the IPCC Assessment Reports

The advances in the Assessment Reports reflect the improved scientific knowledge in climate physics and the progress in computer science.



IPCC Assessment Report	Model resolution (Km)	Reporting Year
First (FAR)	500	1990
Second (SAR)	250	1995
Third (TAR)	180	2001
Fourth (AR4)	110	2007
Fifth (AR5)	<100 Km	2013/14

# Part C: GRID computing in atmospheric modeling



- **E**uropean
  - Over 35 countries
- **G**rid
  - Secure sharing of IT resources
- **I**nfrastructure
  - Computers (clusters)
  - Data
  - Applications
  - .... *and beyond!!*



# Story from the Grid:

Assessing the impact of climate change on surface ozone

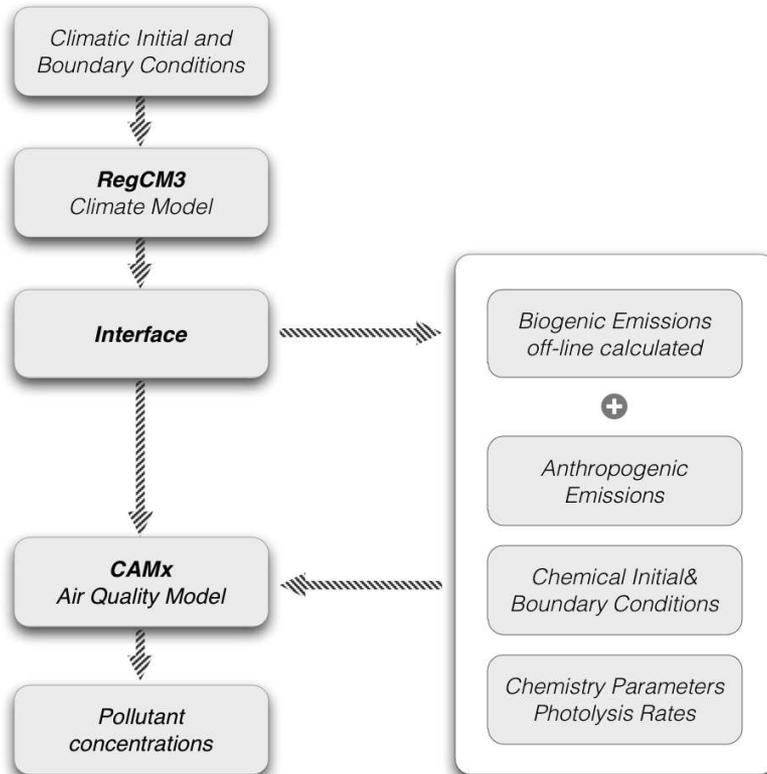


More on this EGI case study on:

<http://www.egi.eu/case-studies/ozone.html>

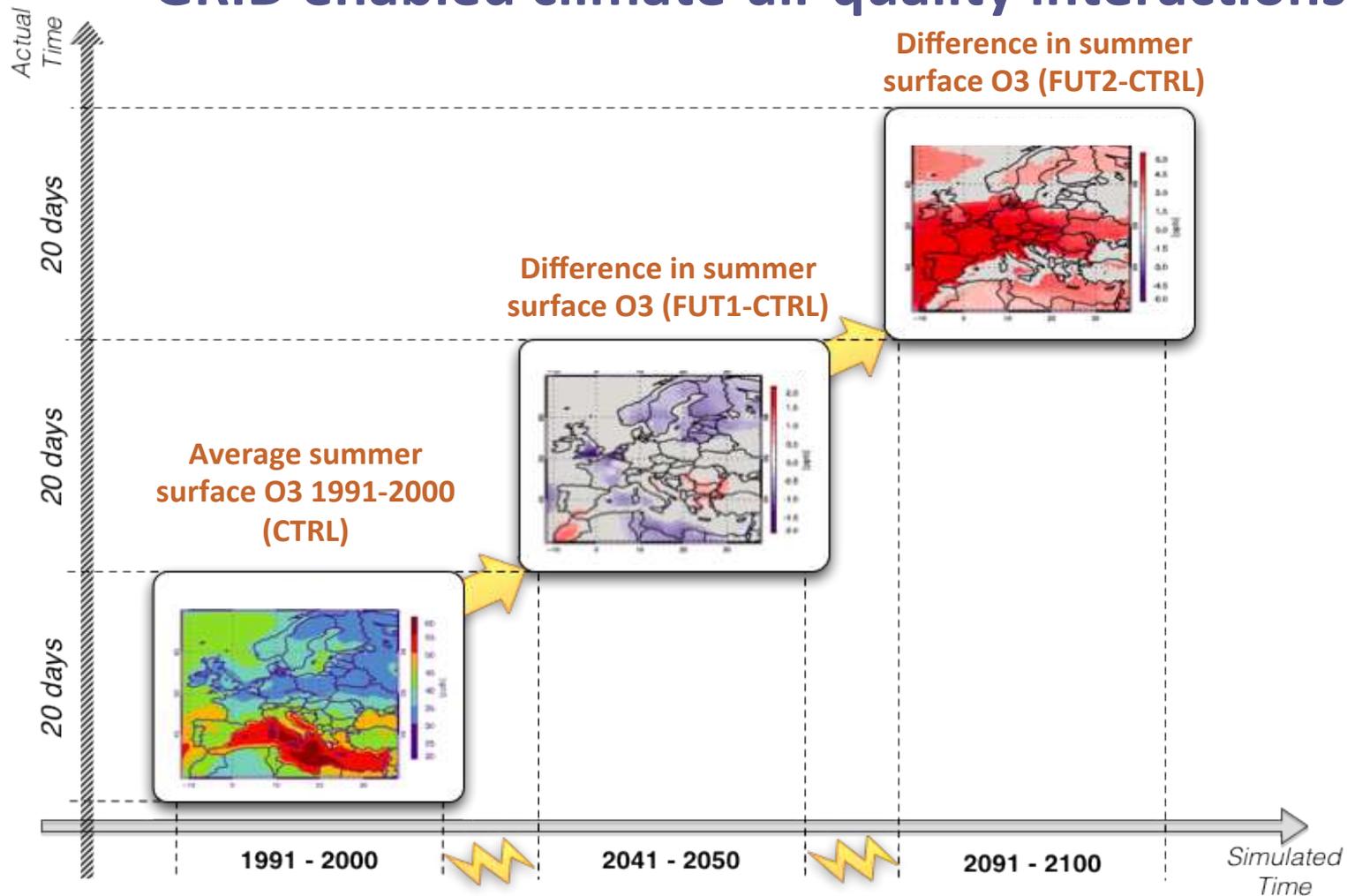


# GRID enabled climate-air quality interactions



- GCM forcing: ECHAM5
- **Regional Climate Model: RegCM3**
- **Air quality model: CAMx 5.3**
- Temporal coverage:
  - 1991-2000 (CTRL)
  - 2041-2050 (FUT1)
  - 2091-2100 (FUT2)
- Spatial coverage: Europe
- Temporal resolution: 3 hours
- Spatial resolution: 50 Km
- Storage: 1 TB for each 10 year time slice

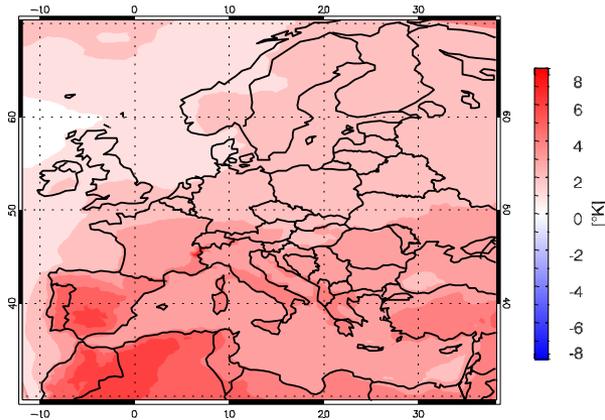
# GRID enabled climate-air quality interactions



Simulated average summer surface ozone (O<sub>3</sub>) in the control decade and statistical significant changes in surface O<sub>3</sub> in the two future decades. X axis denotes the simulated decade. Y axis denotes computational time needed for each simulation.

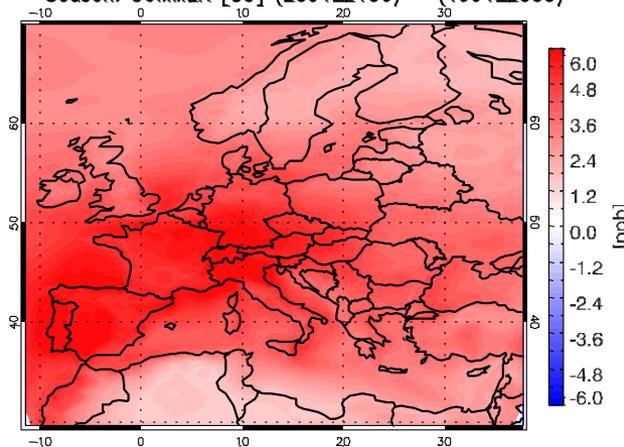
# GRID enabled climate-air quality interactions

Season: SUMMER [TEMP] (2091\_2100) - (1991\_2000)



The median of summer near **surface temperature** for whole Europe is 2.7 K higher at the end of the 21st century

Season: SUMMER [O3] (2091\_2100) - (1991\_2000)



Enhanced average **surface ozone** concentrations at the end of the 21st century especially over SW Europe, where the median of ozone increases by 6.2 ppb

# References

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# Acknowledgments

- European Grid Infrastructure (EGI) – EGI champions programme
- Department of Meteorology and Climatology, Aristotle University of Thessaloniki
- Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki
- Scientific computing centre, Aristotle University of Thessaloniki
- Greek research and technology network (GRNET)
- FP6 project CECILIA (Central and Eastern Europe Climate Change Impact and Vulnerability Assessment)
- AUTH Research Committee

## Useful links

- [www.egi.eu](http://www.egi.eu) (EGI)
- [www.egi.eu/community/egi\\_champions](http://www.egi.eu/community/egi_champions) (EGI Champions)
- [www.hellasgrid.gr](http://www.hellasgrid.gr) (HellasGRID)
- [www.ipcc.ch](http://www.ipcc.ch) (IPCC)
- [www.auth.gr](http://www.auth.gr) (AUTH)
- <http://www.epa.gov/ozone> (ozone-air quality)
- <http://www.hellasgrid.gr/2013/04/22/the-importance-of-grid-computing-in-the-investigation-of-climate-and-its-change/> (HellasGRID story)
- <http://www.egi.eu/news-and-media/videos/index.html> (Stories from the GRID)