Συμπόσιο Ψηφιακής Τεχνολογίας «20 χρόνια ΕΔΕΤ»

Ελένη Κατράγκου

Επίκουρη Καθηγήτρια
Τομέας Μετεωρολογίας Κλιματολογίας
Τμήμα Γεωλογίας
Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης
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Έρευνα και εκπαίδευση για το κλίμα και την κλιματική αλλαγή:

Η ΑΝΑΓΚΑΙΟΤΗΤΑ ΤΩΝ ΥΠΟΛΟΓΙΣΤΙΚΩΝ ΥΠΗΡΕΣΙΩΝ

Cray XC40 Anemos @ ECMWF

Πρόγνωση και Υπολογιστές

Το μαθηματικό πρόβλημα της πρόγνωσης

Η μελέτη του κλίματος είναι ένα μαθηματικό πρόβλημα τις βάσεις του οποίου έθεσαν οι Bjerknes (~1900) και Richardson (~1920), ορίζοντας τις θεμελιώδεις μαθηματικές εξισώσεις και το πλαίσιο για την αριθμητική τους επίλυση.

Vilhelm Bjerknes
1862-1951

Lewis Fry Richardson
1881-1953

Zonal (East-West) Wind:

$$\frac{\partial u}{\partial t} = \eta v - \frac{\partial \Phi}{\partial x} - c_p \theta \frac{\partial \pi}{\partial x} - z\frac{\partial u}{\partial \sigma} - \frac{\partial(\frac{u^2+v^2}{2})}{\partial x}$$

Meridional (North-South) Wind:

$$\frac{\partial v}{\partial t} = -\eta \frac{u}{v} - \frac{\partial \Phi}{\partial y} - c_p \theta \frac{\partial \pi}{\partial y} - z\frac{\partial v}{\partial \sigma} - \frac{\partial(\frac{u^2+v^2}{2})}{\partial y}$$

Temperature:

$$\frac{\delta T}{\partial t} = \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}$$

Precipitable Water:

$$\frac{\delta W}{\partial t} = u\frac{\partial W}{\partial x} + v\frac{\partial W}{\partial y} + w\frac{\partial W}{\partial z}$$

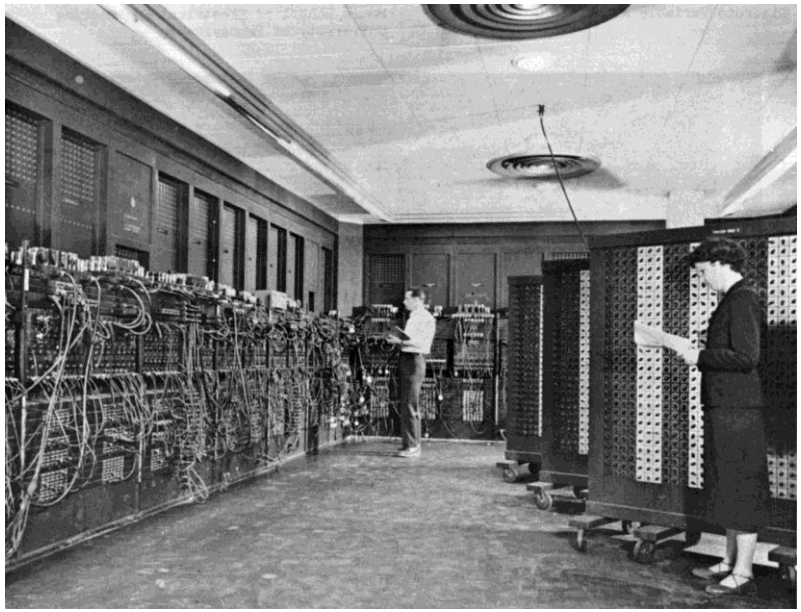
Air pressure:

$$\frac{\partial}{\partial t}\frac{\partial p}{\partial \sigma} = u\frac{\partial}{\partial x}x\frac{\partial p}{\partial \sigma} + v\frac{\partial}{\partial y}y\frac{\partial p}{\partial \sigma} + w\frac{\partial}{\partial z}z\frac{\partial p}{\partial \sigma}$$

Το υπολογιστικό πρόβλημα της πρόγνωσης

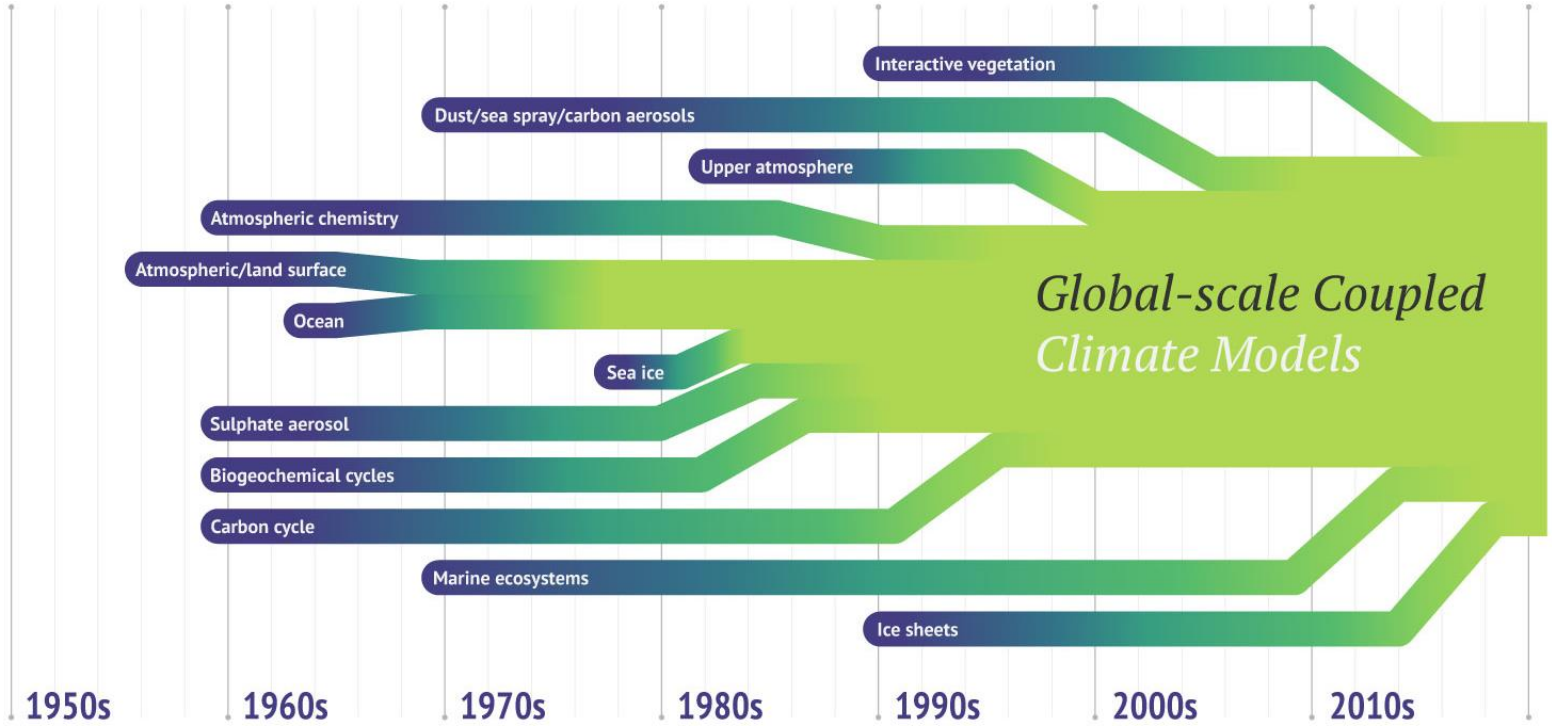
Το μαθηματικό πρόβλημα της πρόγνωσης παραμένει άλυτο μέχρι τη δεκαετία του ‘40 κατά την οποία σχεδιάζεται το πρώτο προγνωστικό μοντέλο και εκτελείται στον υπολογιστή ENIAC (~1945).

John von Neumann
1903-1957

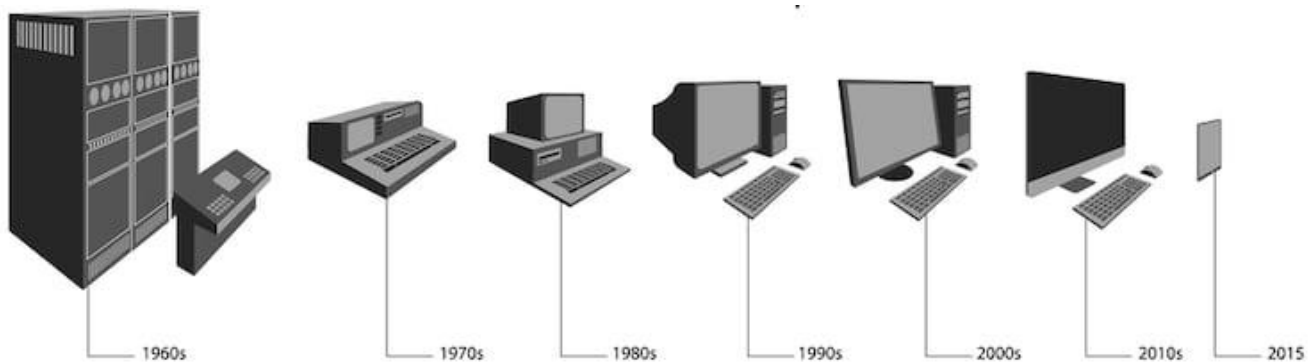


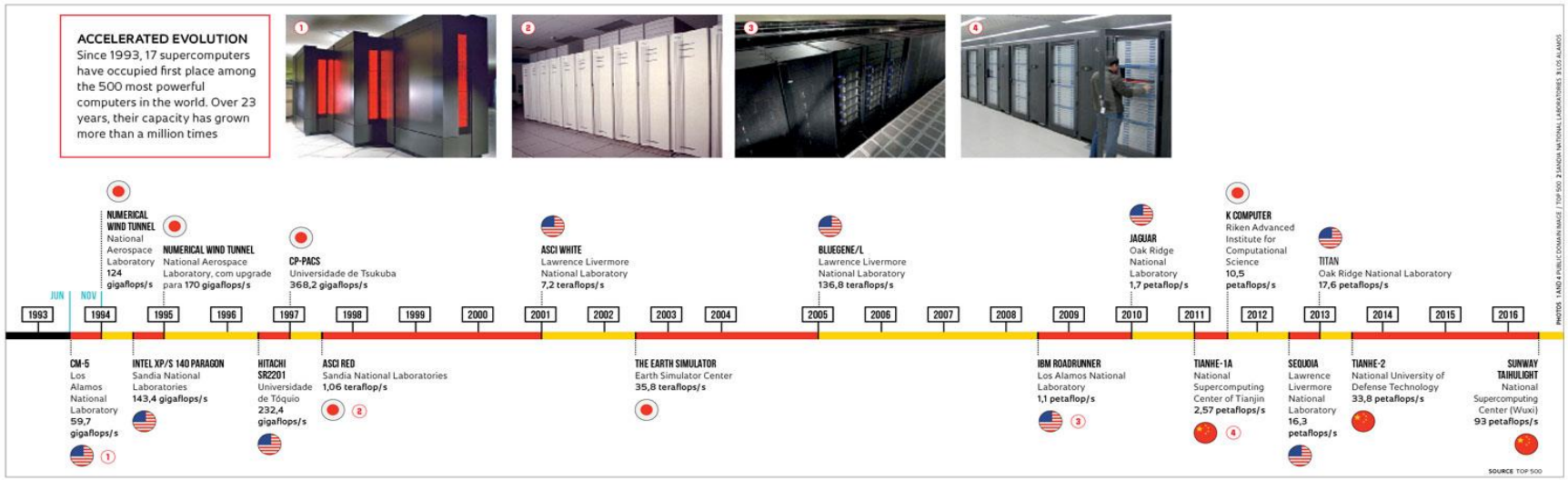
Glen Beck (background) and Betty Snyder (foreground) program ENIAC in BRL building 328. (U.S. Army photo)

Η εξέλιξη των κλιματικών μοντέλων …



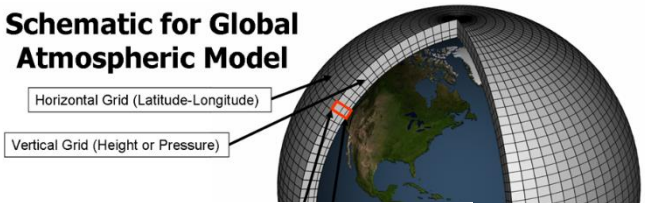
… προϋποθέτει την εξέλιξη των υπολογιστικών συστημάτων

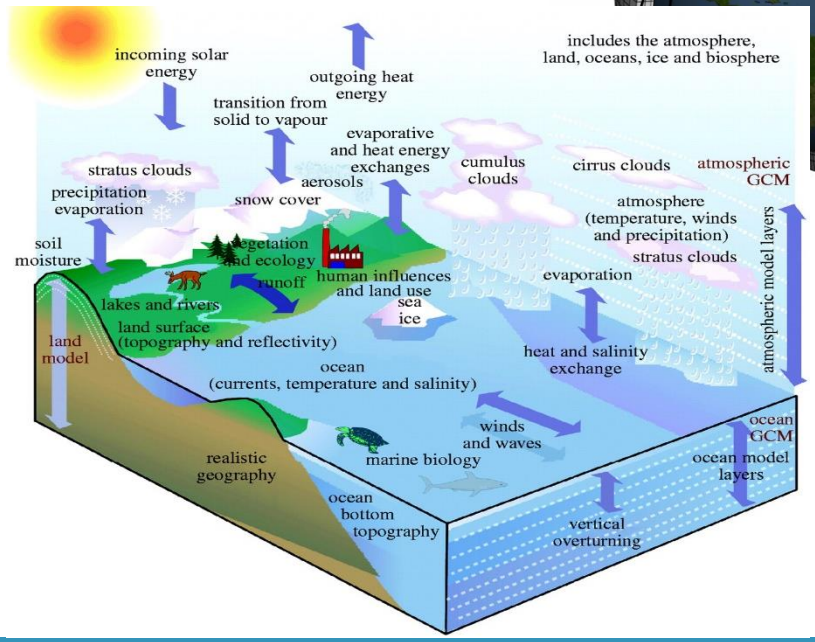




Γιατί είναι απαραίτητες οι υπολογιστικές υποδομές για την έρευνα του κλίματος;

- Αυξάνεται η χωρική ανάλυση των αριθμητικών μοντέλων
- Αυξάνεται η πολυπλοκότητα των αριθμητικών μοντέλων (περισσότερες φυσικές/χημικές/βιολογικές διεργασίες)





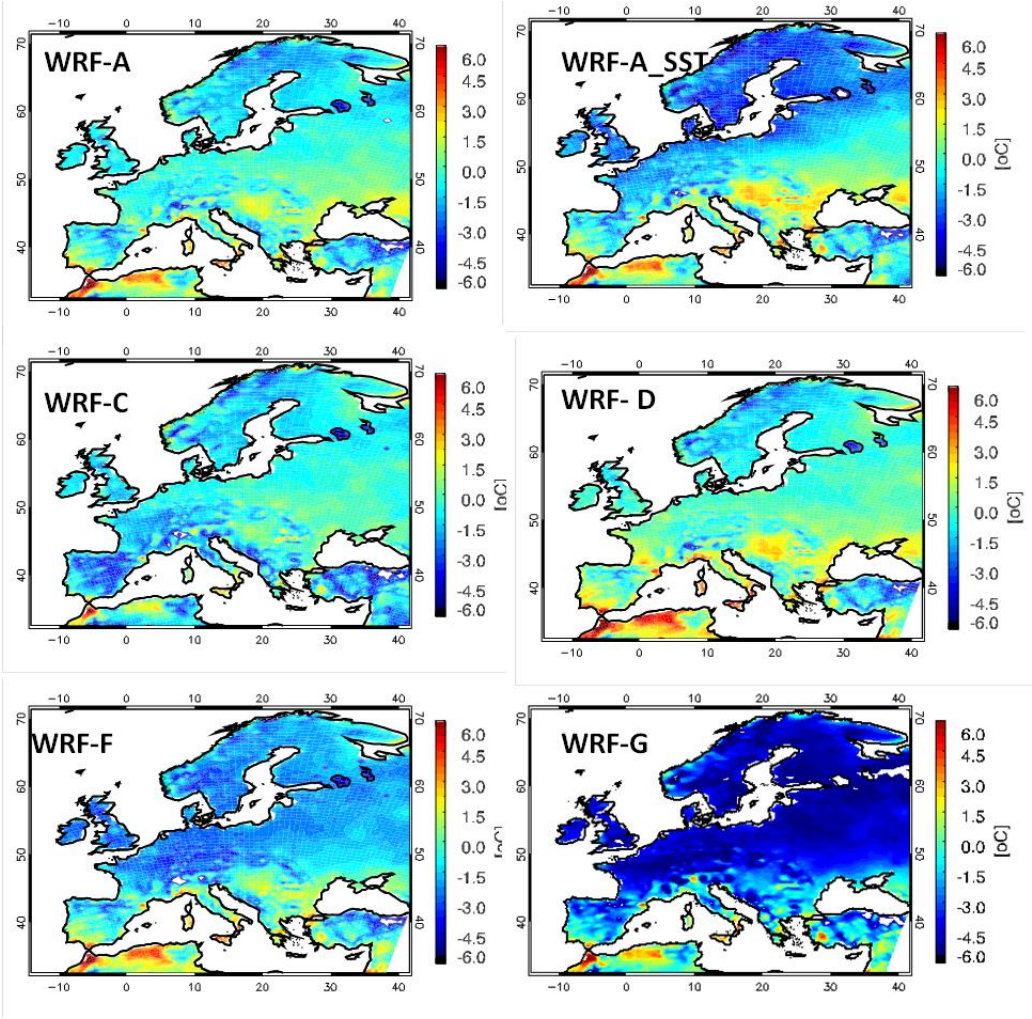
Computational time =

(operation per equation) x

(number of equations per grid box) x

(number of grid boxes) x

(number of time steps per simulations)



Χρήση υπολογιστικών υποδομών

Τομέας Μετεωρολογίας Κλιματολογίας ΑΠΘ

Ποιοι είμαστε

Στέργιος Κάρτσιος
Φυσικός
Υπ. Διδ.

Ελένη Κατράγκου
Φυσικός
Επικ. Καθηγ.

Βασίλης Παυλίδης
Φυσικός
Υπ. Διδ.

Μαρία Καρυπίδου
Γεωγράφος
Υπ. Διδ.

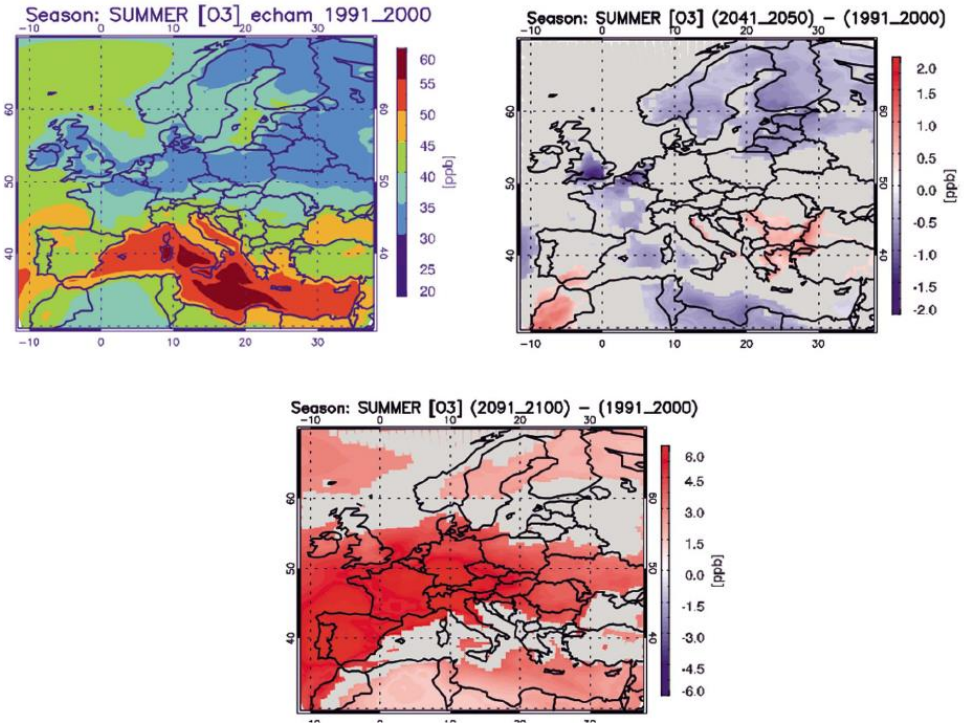
Γιάννης Σοφιάδης
Μαθηματικός
Υπ. Διδ.

Μετεωροσκοπείο, ΑΠΘ

Grid computing

RegCM3-CAMx regional climate-air quality simulations over Europe (Cecilia)

- Forcing: ECHAM5 GCM
- Spatial resolution: 50 Km
- Simulations: historical (1960-2000)
  A1B projection (2041-50; 2091-2100)

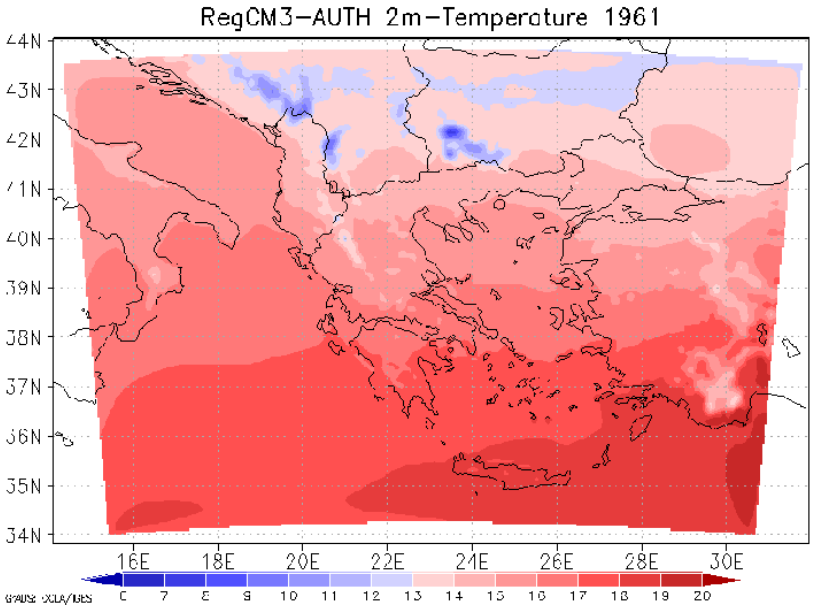


Katragkou et al., Future climate change impacts on summer surface ozone from regional climate-air quality simulations over Europe, *Journal of Geophysical Research, 116, D22307,* doi:10.1029/2011JD015899, 2011

Grid computing

RegCM3 climate projection over South East Europe (Geoclima)

- Forcing: RegCM@25Km
- Spatial resolution: 10 Km
- Simulations: historical (1960-2000)
  A1B projection (2001-2100)



Zanis P., **E. Katragkou**,… Transient high-resolution regional climate simulation for Greece over the period 1960–2100: evaluation and future projections, *Climate Research*, 64: 123–140, 2015.

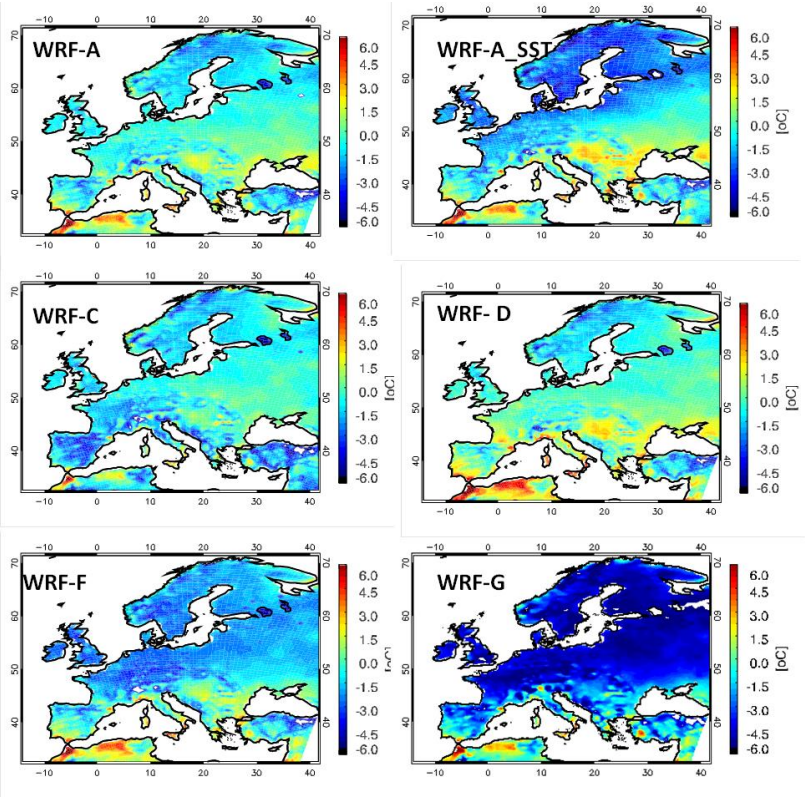
Grid computing

WRF-AUTH regional climate simulations over Europe (EURO-CORDEX)

- Forcing: ERA-interim
- Spatial resolution: 50 Km
- Simulations: hindcast (1990-2008)

✓ Switching to WRF regional climate model

✓ Becoming EURO-CORDEX participants



Katragkou et al., Regional climate hindcast simulations within EURO-CORDEX: evaluation of a WRF multi-physics ensemble, Geosci. Model Dev., 8, 603-618, https://doi.org/10.5194/gmd-8-603-2015, 2015.

Οι εφαρμογές στο HCP-ARIS του ΕΔΕΤ

- 1st production call: pr001020, 2015, **REGINA** (165.000 core hours)
  - *Regional climate simulations over Europe*
- 2nd production call: pr002046, 2016, **VERGINA** (1.400.000 core hours)
  - *Very high resolution regional climate simulations over Europe*
- 3rd production call: pr003005, 2017, **COPERATE** (1.900.0000 core hours)
  - *Convective permitting regional climate simulations*
- 5th production call: pr005025, 2018, **LUCE** (700.000 core hours)
  - *Impact of land use changes on regional and local climate in Europe*

- Preparatory/Development projects:
  - pa006006, 2016, (100.000 core hours): *Impact of aerosol on atmospheric radiation and clouds* (PI V. Pavlidis)
  - pa180201, 2018, (100.000 core hours): *Impact of land use changes on European climate using regional climate model* (PI I. Sofiadis)

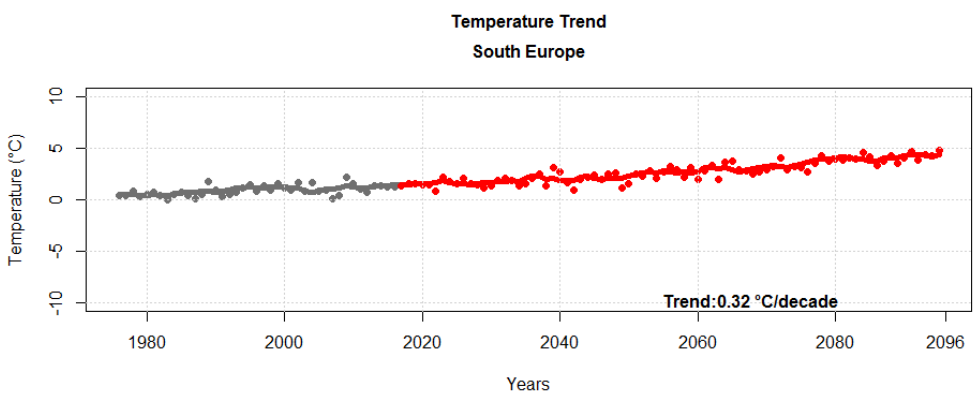
REGINA

NASA Goddard Institute for Space Studies

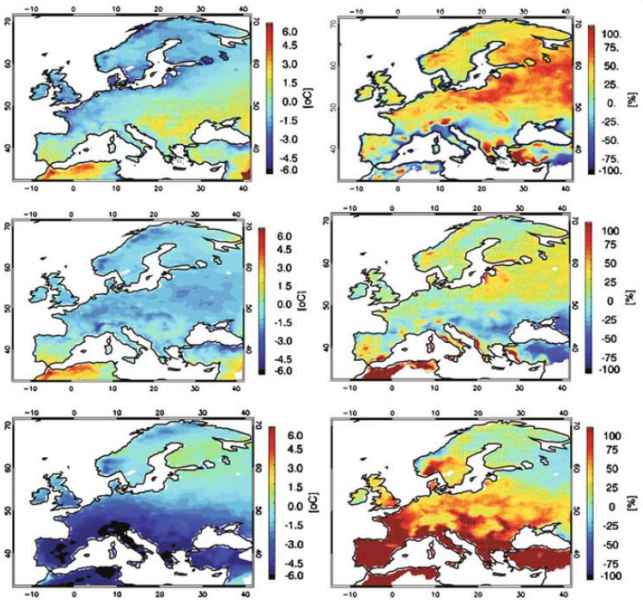
WRF-AUTH climate projection over Europe (0.44°)

- Forcing: NASA_GISS_E2 GCM
- Spatial resolution: 50 Km (Europe)
- Simulations: historical (1970-2005)

  RCP8.5 projection (2006-2100)



Sofiadis I. (2017) Climate change over Europe for the 21st century using regional climate simulation under scenario RCP8.5, MSc Thesis, School of Geology, AUTH.

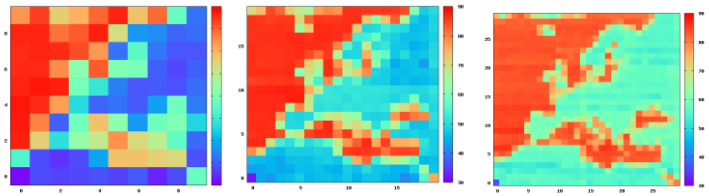


Katragkou et al. (2017) AUTH Regional Climate Model Contributions to EURO-CORDEX. In: Karacostas T., Bais A., Nastos P. (eds) Perspectives on Atmospheric Sciences. Springer Atmospheric Sciences. Springer, https://doi.org/10.1007/978-3-319-35095-0_106

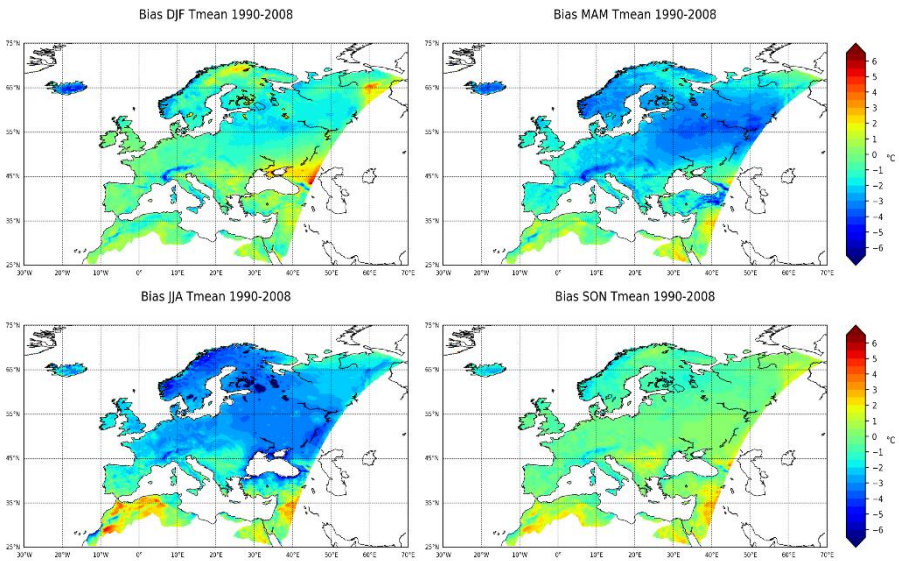
VERGINA

WRF-AUTH hindcast over Europe (0.11°)

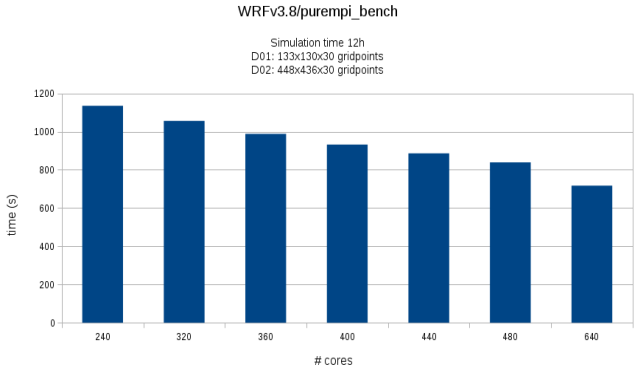
- Forcing: ERA-interim
- Spatial resolution: d01 50 Km; d02 12 Km
- Simulations: hindcast (1990-2008)



Dellis D., Waiting time (%) in each task (core) over a single domain 100 cores (left), 400 cores (middle), 900 (right)



Papakonstantinou Presvelou I. (2019) Evaluation of a high resolution (0.11°) regional climate simulation over Europe, MSc Thesis, School of Geology, AUTH.

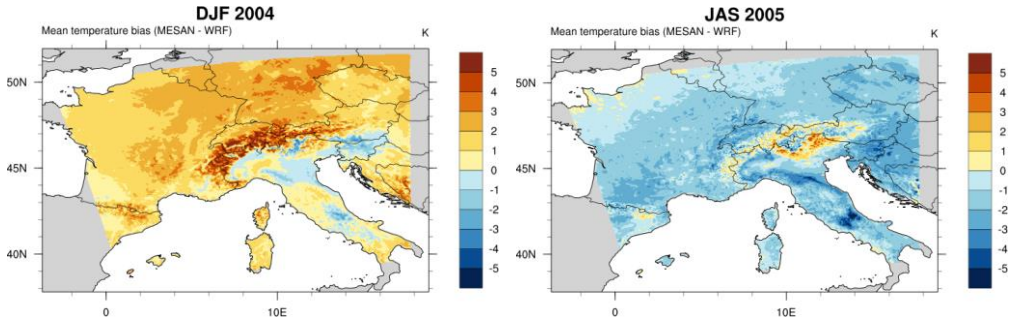


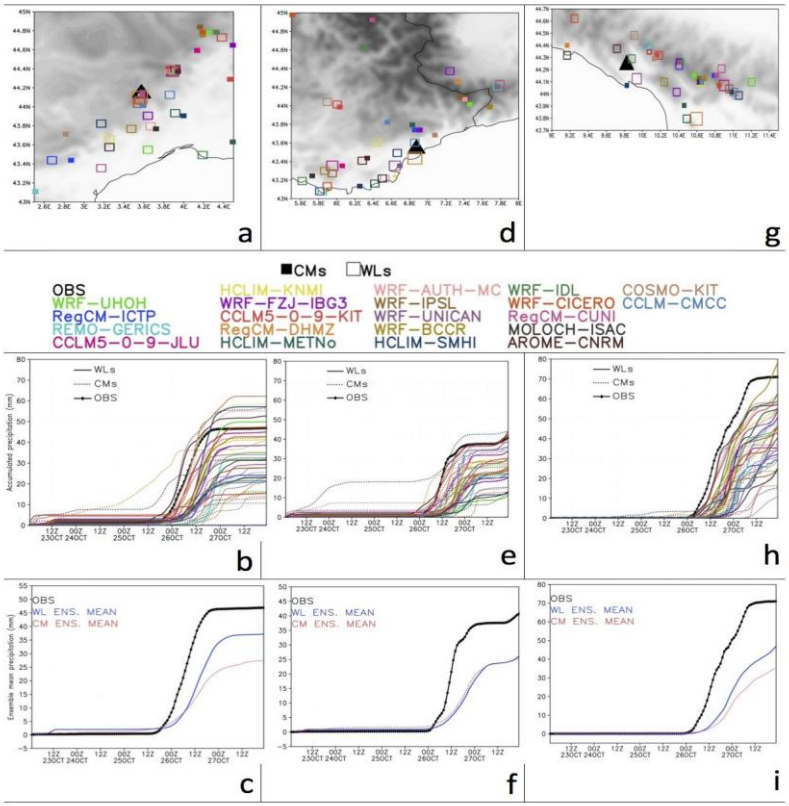
Kartsios S., Benchmarking WRF-AUTH @HPC-ARIS

COPERATE

WRF-AUTH hindcast & projection over the Alps

- Forcing: ERA-interim
- Spatial resolution: 12 Km (Europe) – 3 Km (Alps)
- Simulations: hindcast (2000-2015)
  - Time execution: ~42hrs per month (240 cores)
  - For 15 years: ~7.500hrs, 315 days
  - Total core hours: ~1.820.000



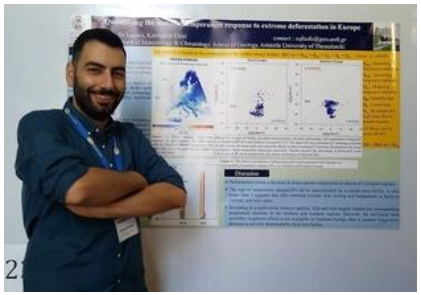


Coppola E., .. **S. Kartsios, E. Katragkou**, ...(2018) A first-of-its-kind multi-model convection permitting ensemble for investigating convective phenomena over Europe and the Mediterranean, *accepted in Climate Dynamics*

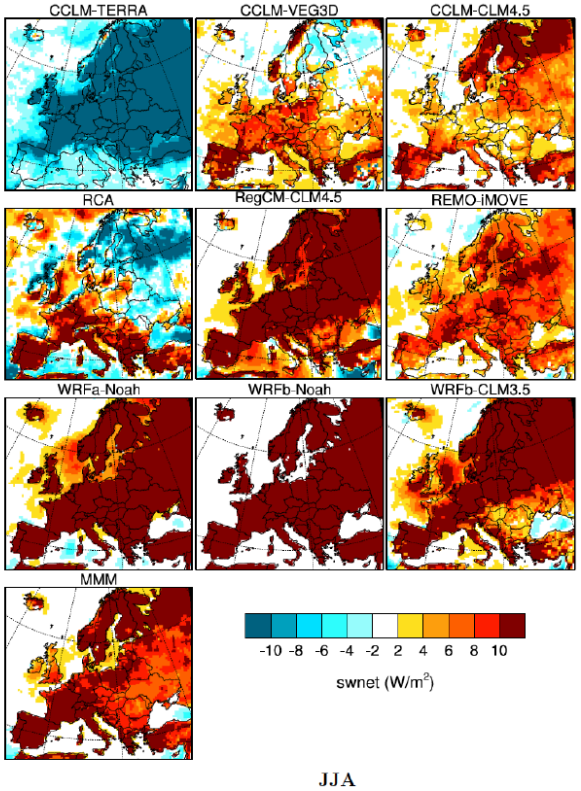
LUCE

WRF-AUTH hindcast over Europe (0.44°)

- Forcing: ERA-interim
- Spatial resolution: 50 Km
- Simulations: 3x hindcast (1986-2015)
  - Control
  - Maximum Forest
  - No forest



Sofiadis and Katragkou, Quantifying the summer temperature response to extreme deforestation in Europe, Medclivar 2018 Conference, Belgrade, Serbia 17-20/9/2018
(Best Poster Award)

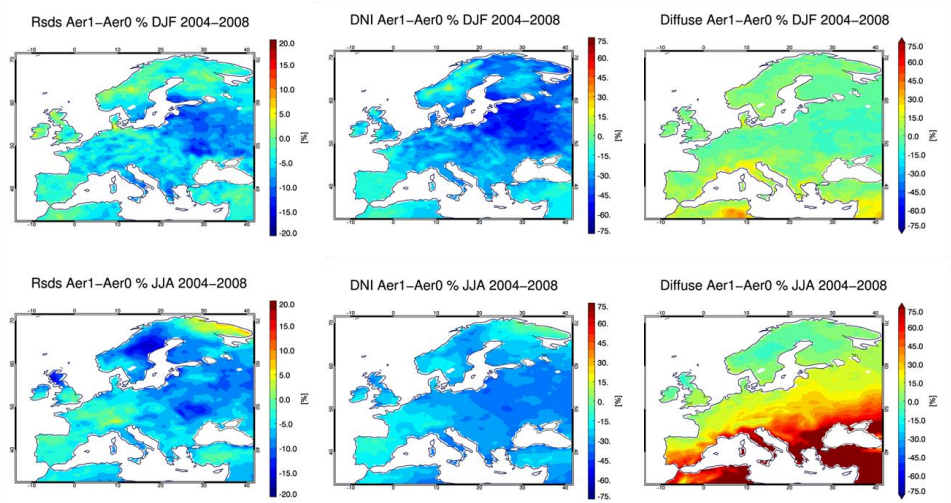


Davin E., … **I. Sofiadis, E. Katragkou**, … (2019) Biogeophysical impacts of re/afforestation in LUCAS: First results from the LUCAS intercomparison projects, *in preparation*

REMOT

WRF-AUTH hindcast over Europe (0.44°)

- Forcing: ERA-interim
- Spatial resolution: 50 Km
- Simulations: 7 x hindcast (2003-2008)



Simulation	Aer0	Aer1	Aer2	Aer2full	Aer2MACC	Aer0New	Aer3New
Microphysics scheme	Thompson regular	Thompson regular	Thompson regular	Thompson regular	Thompson regular	New Thompson Aerosol aware	New Thompson Aerosol aware
Aerosol option/source	-	aer_opt=1 Tegen	aer_opt=2 MACv1	aer_opt=2 MACv1	aer_opt=2 MACC	aer_opt=0 GOCART	aer_opt=3 GOCART

Pavlidis V., E. Katragkou., …. (2019) Sensitivity of radiation in aerosols in regional climate simulations over Europe, *in preparation*

Αποθηκευτικοί χώροι

2009 (Cecilia) 4 TB

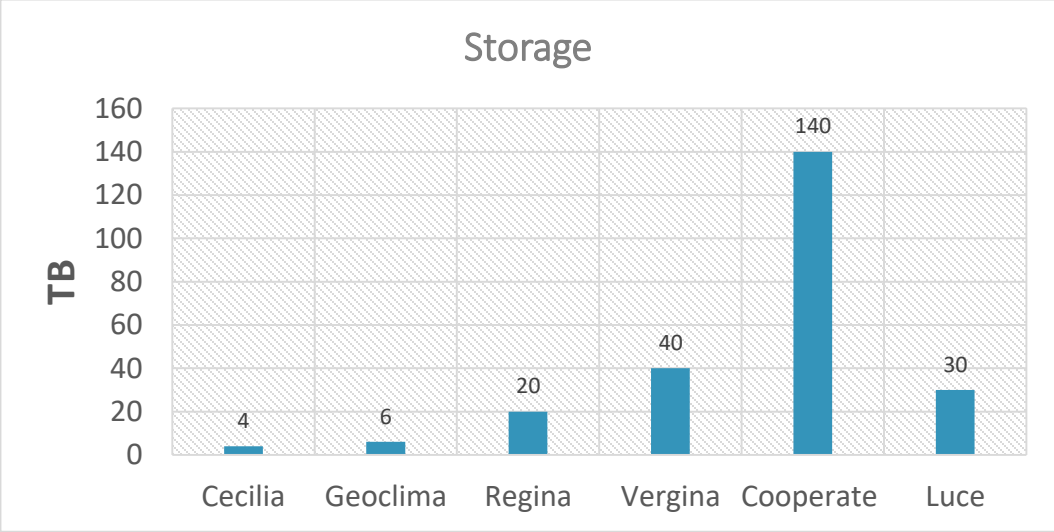
2013 (Geoclima) 6 TB

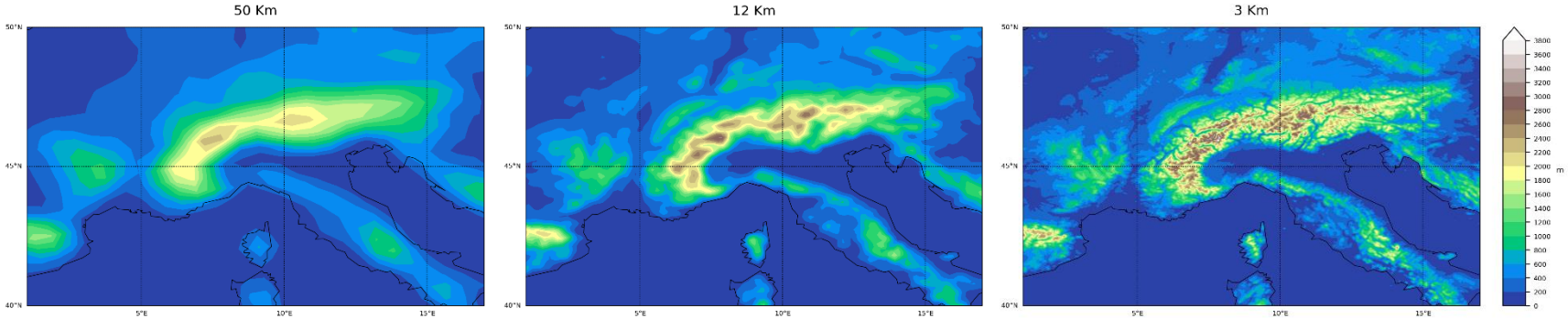
07/2015 (Regina) 20 TB

03/2016 (Vergina) 40 TB

11/2017 (Coperate) 140 TB

12/2018 (Luce) 30 TB μέχρι σήμερα





Storage repositories: The vi SEEM project

PRACE Summer of HPC 2017 HPC Ambassador Award:

Mahmoud Elbattah

PhD student at the National University of Ireland Galway (NUIG)

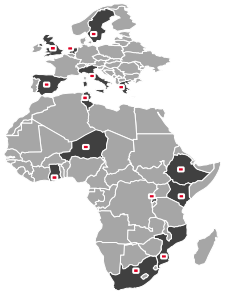
Automated Extraction of Metadata from Climate Simulations: Helping Researchers Share, Discover, and Use Data

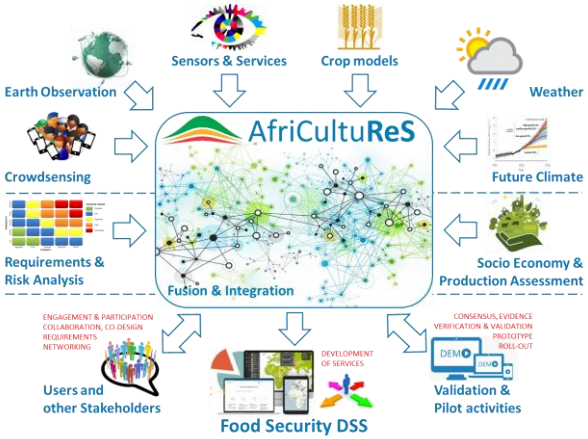
Mentors: E. Katragkou (AUTH), I. Liabotis (GRNET)

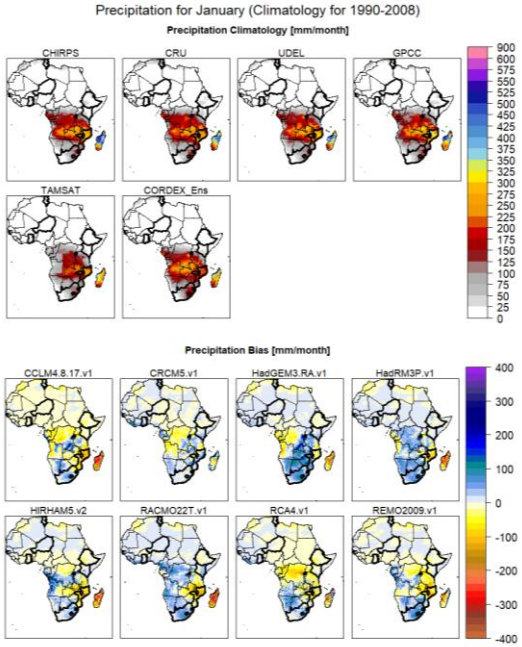
Κλιματικές υπηρεσίες

AfriCultuReS

H2020-SFS-2016-2017 Κλιματικές υπηρεσίες για επισιτιστική ασφάλεια σε αγροτικά συστήματα







GMV (lead, ES)	Centre Régional AGRHYMET (NE)
Aristotle University of Thessaloniki (GR)	CGIS – University of Rwanda (RW)
DRAXIS (GR)	CERSGIS – University of Ghana (GH)
HCP International (NL)	GeoSAS (ET)
Sapienza University of Rome (IT)	LocateIT (KE)
Swedish Meteorological and Hydrological Institute (SE)	Observatoire du Sahara et du Sahel (TN)
University of Cantabria (ES)	South African National Space agency (ZA)
University of Leeds (UK)	Eduardo Mondlane University (MZ)
University of Sheffield (UK)	

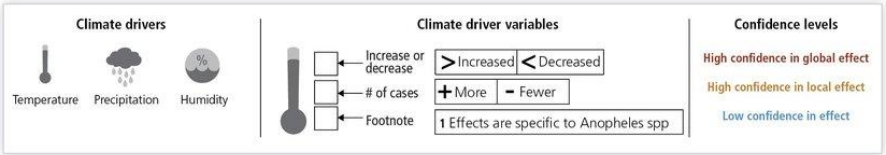
Karypidou M. (2019) Estimating errors and uncertainties of precipitation in regional climate simulations over Africa: investigation of physical processes, PhD Thesis, School of Geology, AUTH.

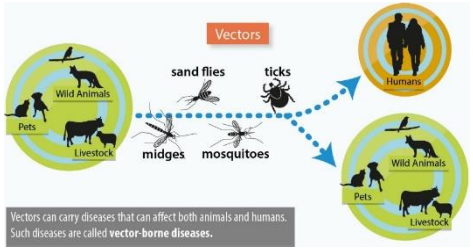
Κλιματικές υπηρεσίες

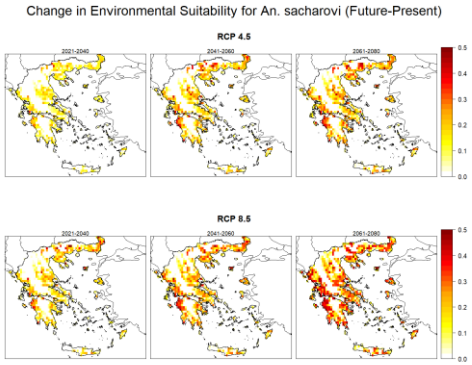
Επιχειρηματικότητα, Ανταγωνιστικότητα και Καινοτομία (ΕΠΑνΕκ)

Σύστημα έγκαιρης προειδοποίησης για τις μεταδιδόμενες ασθένειες από κουνούπια

Disease	Area	Cases per year	Climate sensitivity and confidence in climate effect	Key references
Mosquito-borne diseases				
Malaria	Mainly Africa, SE Asia	About 220 million		WHO (2008); Kelly-Hope et al. (2009); Alonso et al. (2011); Omumbo et al. (2011)
Dengue	100 countries, esp. Asia Pacific	About 50 million		Beebe (2009); Pham et al. (2011); Astrom et al. (2012); Earnest et al. (2012); Descloux (2012)
Tick-borne diseases				
Tick-borne encephalitis	Europe, Russian Fed., Mongolia, China	About 10,000		Tokarevich et al. (2011)
Lyme	Temperate areas of Europe, Asia, North America	About 20,000 in USA		Bennet (2006); Ogden et al. (2008)
Other vector-borne diseases				
Hemorrhagic fever with renal syndrome (HFRS)	Global	0.15–0.2 million		Fang et al. (2010)
Plague	Endemic in many locations worldwide	About 40,000		Stenseth et al. (2006); Ari et al. (2010); Xu et al. (2011)





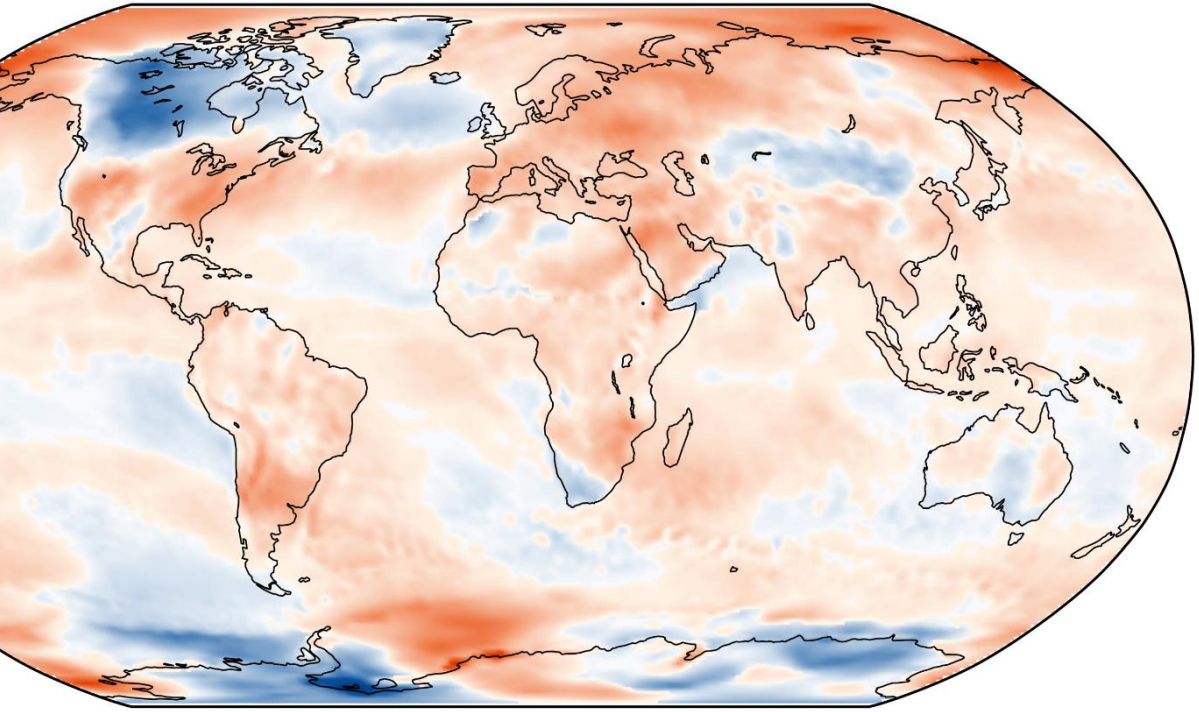


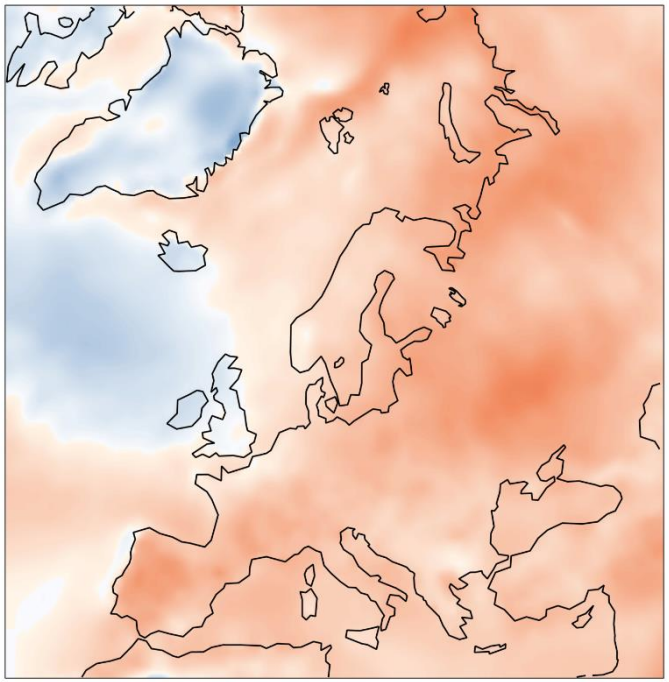
Karypidou M et al. (2019) The employment of correlative and mechanistic models for the assessment of regions in risk of malaria, *in preperation*

Τι θα χρειαστούμε στο άμεσο μέλλον

- Οι απαιτήσεις σε υπολογιστικούς πόρους (HPC) για τη μελέτη του κλίματος θα αυξηθούν ακόμα περισσότερο καθώς τα κλιματικά μοντέλα του μέλλοντος θα απαιτούν σύζευξη της ατμόσφαιρας-εδάφους με ωκεανούς, δυναμική βλάστηση, αναλυτική χημεία κτλ.
- Οι απαιτήσεις σε αποθηκευτικούς χώρους θα αυξηθούν καθώς η ανάγκη για υψηλότερης χωρικής/χρονικής ανάλυσης πληροφορία θα είναι απαραίτητη για τις μελέτες εκτίμησης επιπτώσεων της κλιματικής αλλαγής.
- Για παροχή κλιματικών υπηρεσιών θα αυξηθεί η ζήτηση σε υπηρεσίες cloud, ιδιαίτερα σε συνδυασμό με τα εργαλεία και τις υπηρεσίες που «χτίζει» η Ευρωπαϊκή κοινότητα (*Copernicus Data and Information Access Services – DIAS, Copernicus Climate Data Store - CDS*).

Surface air temperature anomaly for September 2018 relative to 1981-2010





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IMPLEMENT

Σας ευχαριστώ για την προσοχή σας!