CLIMATE CHANGE IMPACTS AND ADAPTATION OPTIONS FOR TRANSPORT NETWORKS IN GREECE

International Conference on Adaptation of Transport Networks to Climate Change, Alexandroupolis, Greece, 25-26/06/2012
United Nations Economic Commission for Europe

Dr. Evangelos Mitsakis

Centre for Research and Technology Hellas

Hellenic Institute of Transport

Post-doctoral researcher

Head of Lab Transport Systems Analysis & Optimization

Head of Unit Int'l cooperation

CERTH-HIT experience in climate change impacts' assessment

- WEATHER project (FP7), 2009-2012
  Weather Extremes: Assessment of Impacts on Transport Systems and Hazards for European Regions
- Study for the Bank of Greece, 2009-2011
  Climate Change Impacts Study for Greece
- MOWE-IT (FP7), 2012-2015
  Management of weather events for transport systems

HELLENIC INSTITUTE OF TRANSPORT

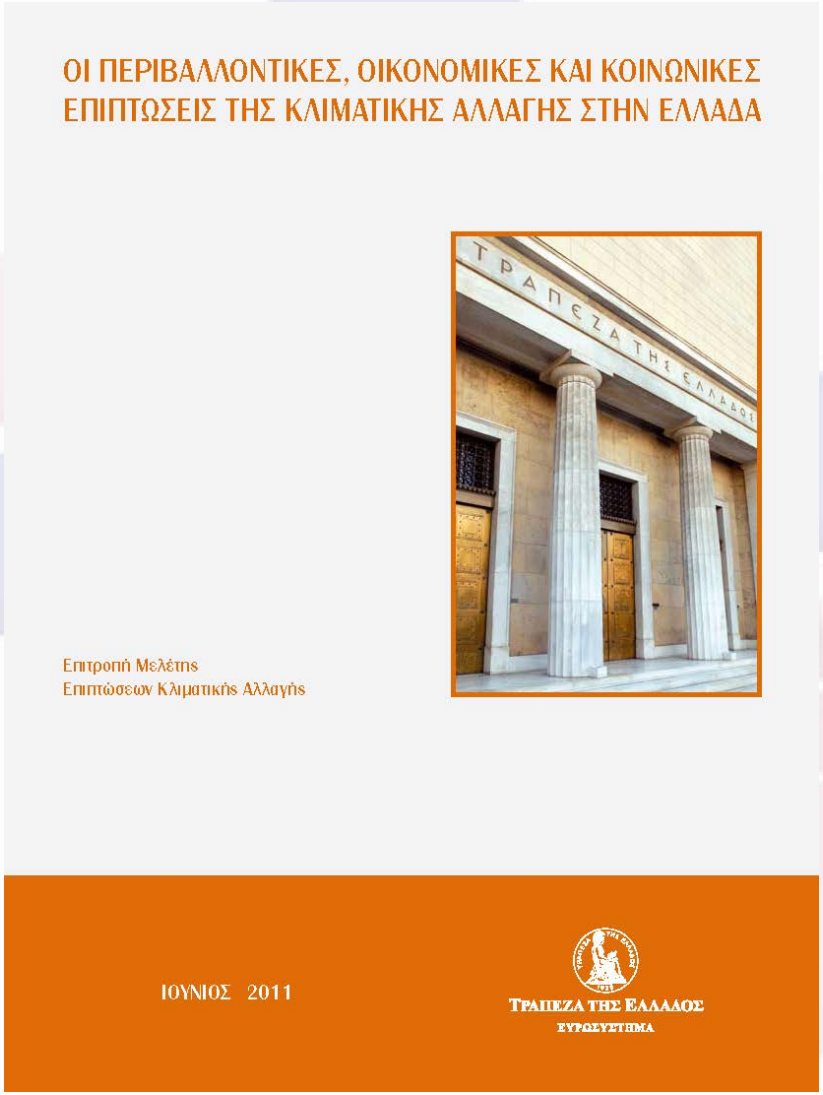
CENTER FOR RESEARCH AND TECHNOLOGY HELLAS

What is currently requested by climate change impact assessment studies for transportation engineers?

- Cooperation with meteorologists
- Cooperation with transport economists
- Cooperation with policy makers
- Cooperation with entities responsible for financing transport network infrastructures & systems

- Projection of impacts on transport networks
- Risk/Vulnerability/Criticality assessment of transport networks
- Quantification of impacts at network level in order to estimate costs

Bank of Greece Study: Environmental, economical and social impacts of climate change in Greece



BANK OF GREECE
EUROSYSTEM
CLIMATE CHANGE IMPACTS STUDY COMMITTEE

Bank of Greece Study: Transport sector team members

- Prof. George Giannopoulos
- Dr. Evangelos Mitsakis
- Ms. Eliza Gagatsi MSc
- Mr. Josep-Maria Salanova MSc

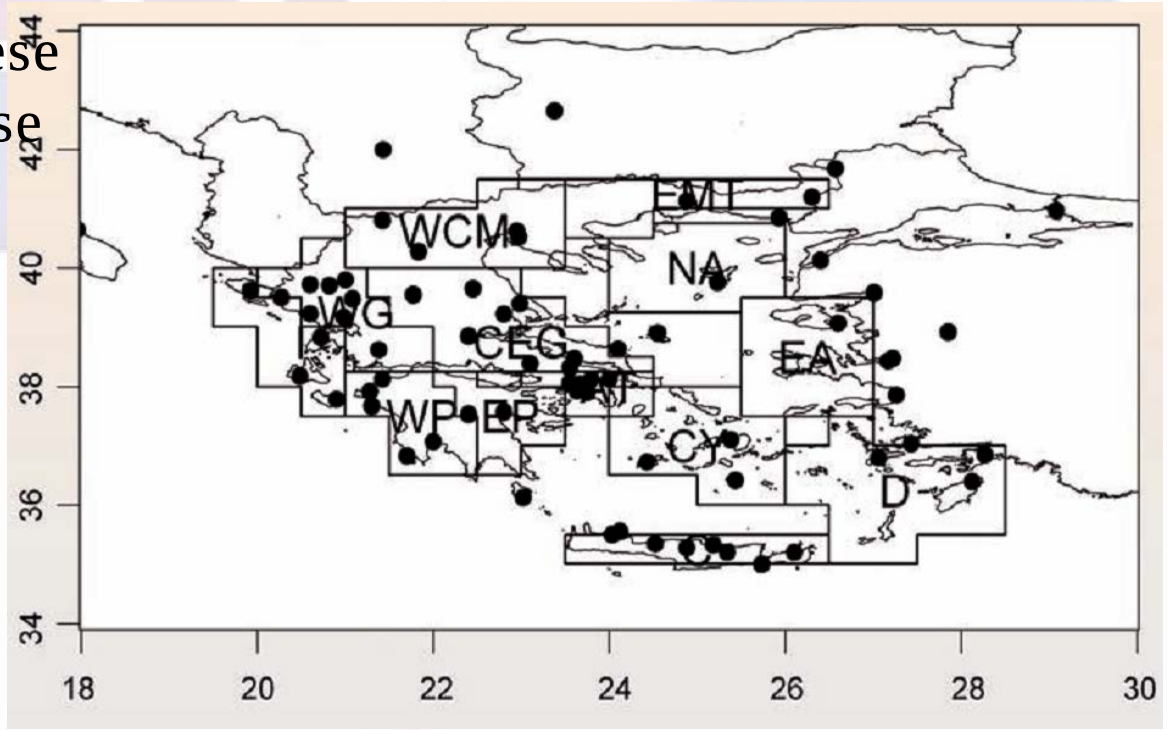
Bank of Greece Study: Environmental, economical and social impacts of climate change in Greece

- Analysis of climate in Eastern-Mediterranean and Greece
- Risk- and impact assessment
  - Water systems
  - Sea level rise
  - Fishery and aquacultures
  - Agriculture
  - Forestry
  - Biodiversity and ecosystems
  - Tourism
  - Built environment
  - **Transport**
  - Health
  - Mining
- Economics of climate change
- Towards a low carbon economy
- Conclusions and strategies for managing climate change

Bank of Greece Study: Climatic data

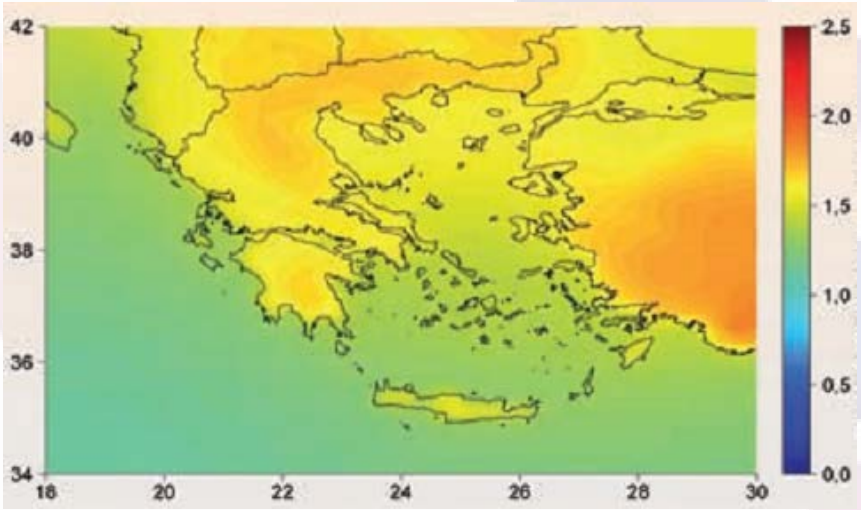
The 13 climate zones of Greece:

- Western Greece
- Central and Eastern Greece
- Western and Central Macedonia
- Eastern Macedonia & Thrace
- Western Peloponnese
- Eastern Peloponnese
- Attica
- Crete
- Dodekanisa
- Cyclades
- Eastern Aegean
- Northern Aegean
- Ionian

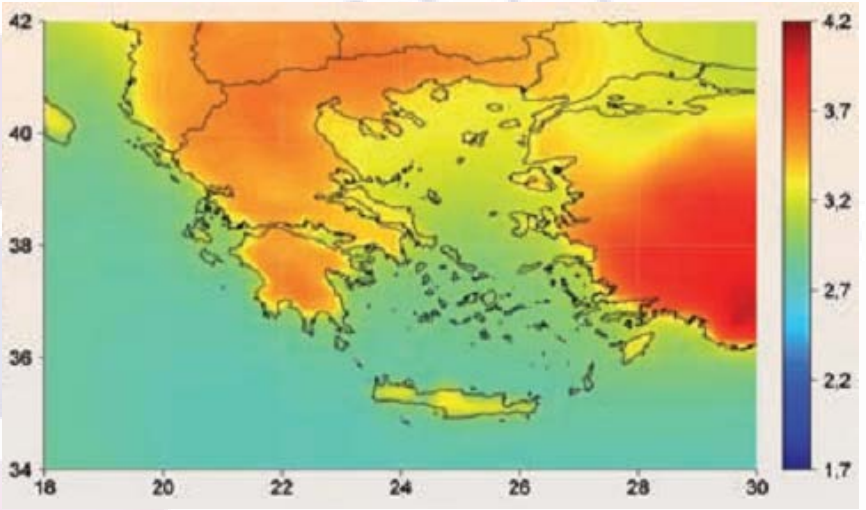


Bank of Greece Study: Climatic data

Mean air temperature difference



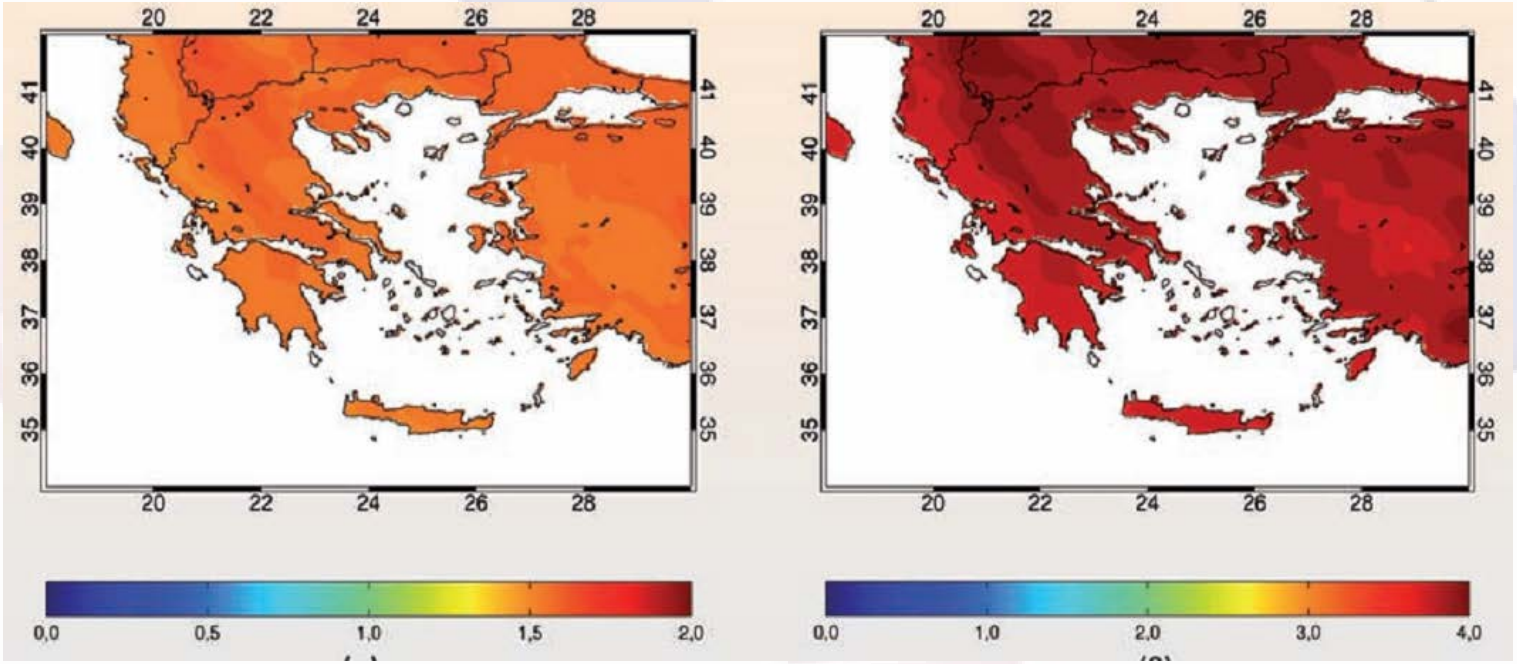
2021-2050



2071-2100

Bank of Greece Study: Climatic data

Mean minimum winter temperature difference

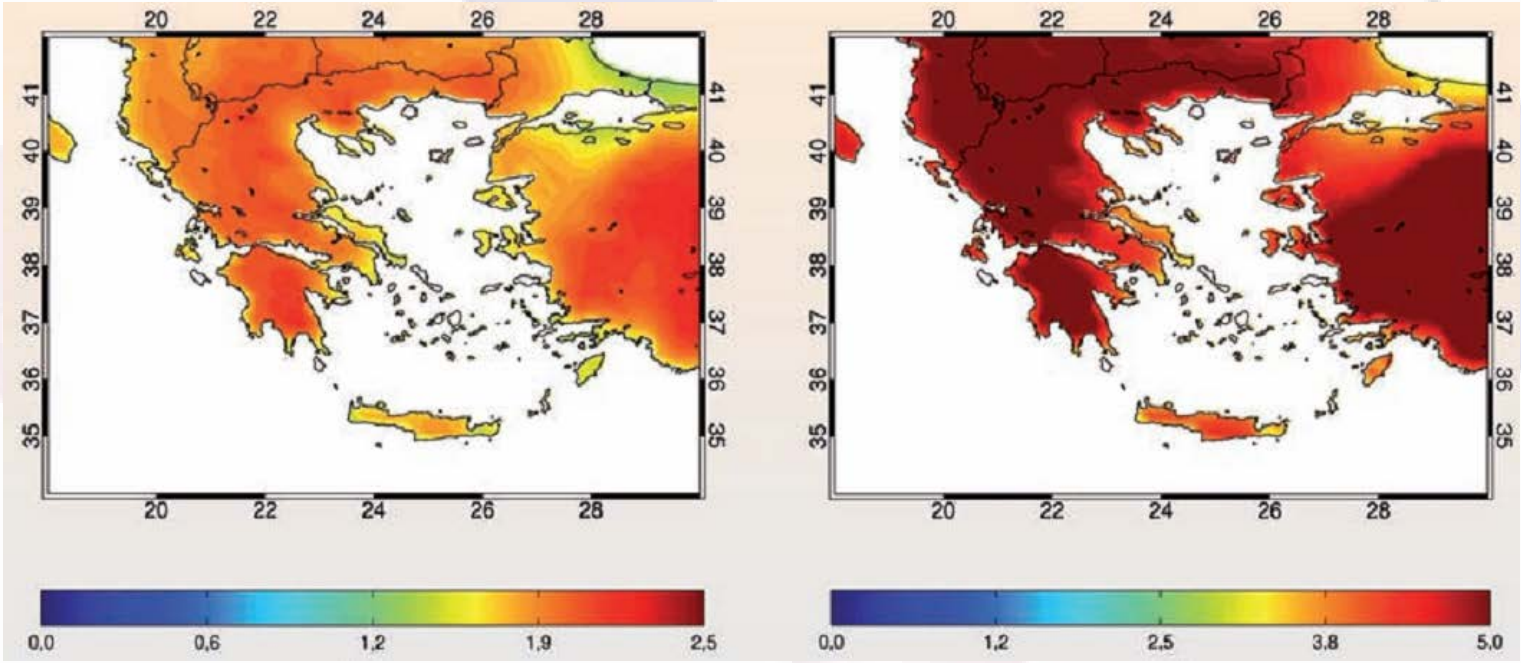


2021-2050

2071-2100

Bank of Greece Study: Climatic data

Mean maximum summer temperature difference

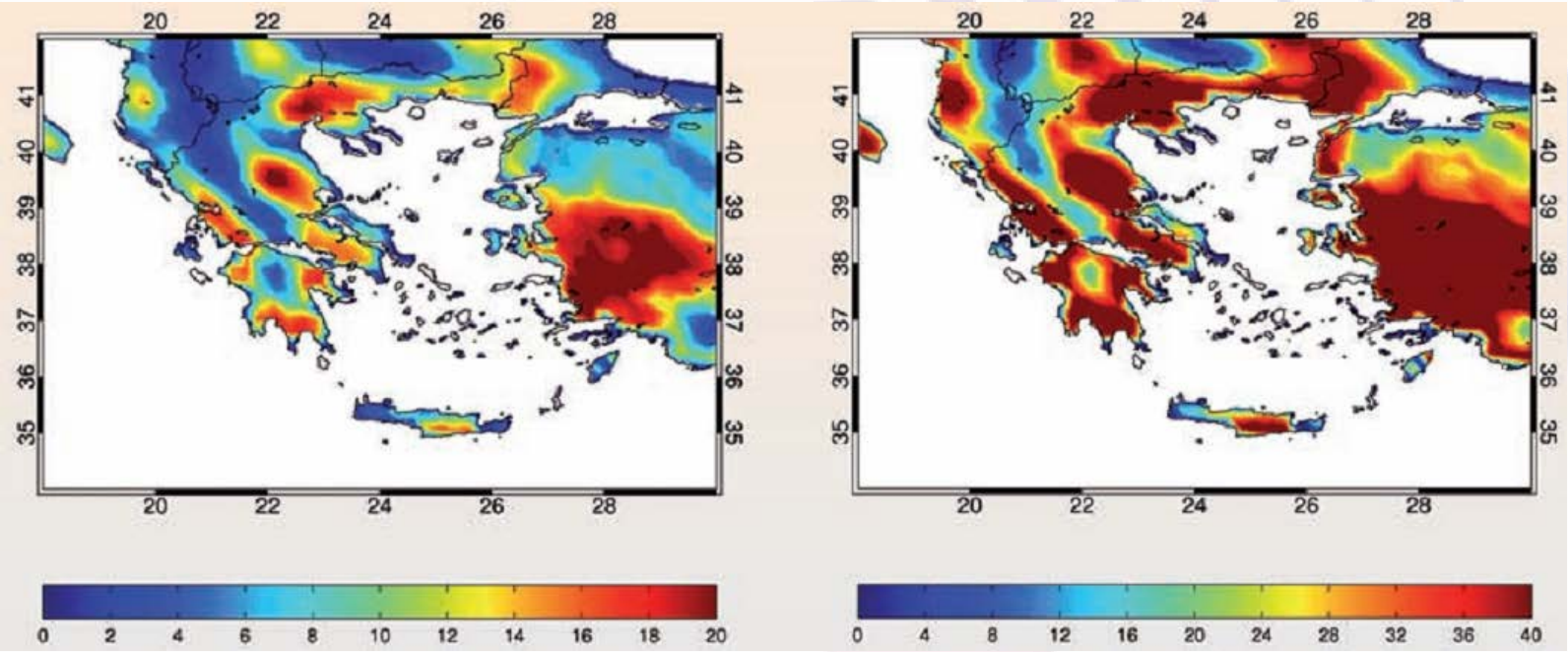


2021-2050

2071-2100

Bank of Greece Study: Climatic data

Difference in number of days with maximum temperature > 35°C

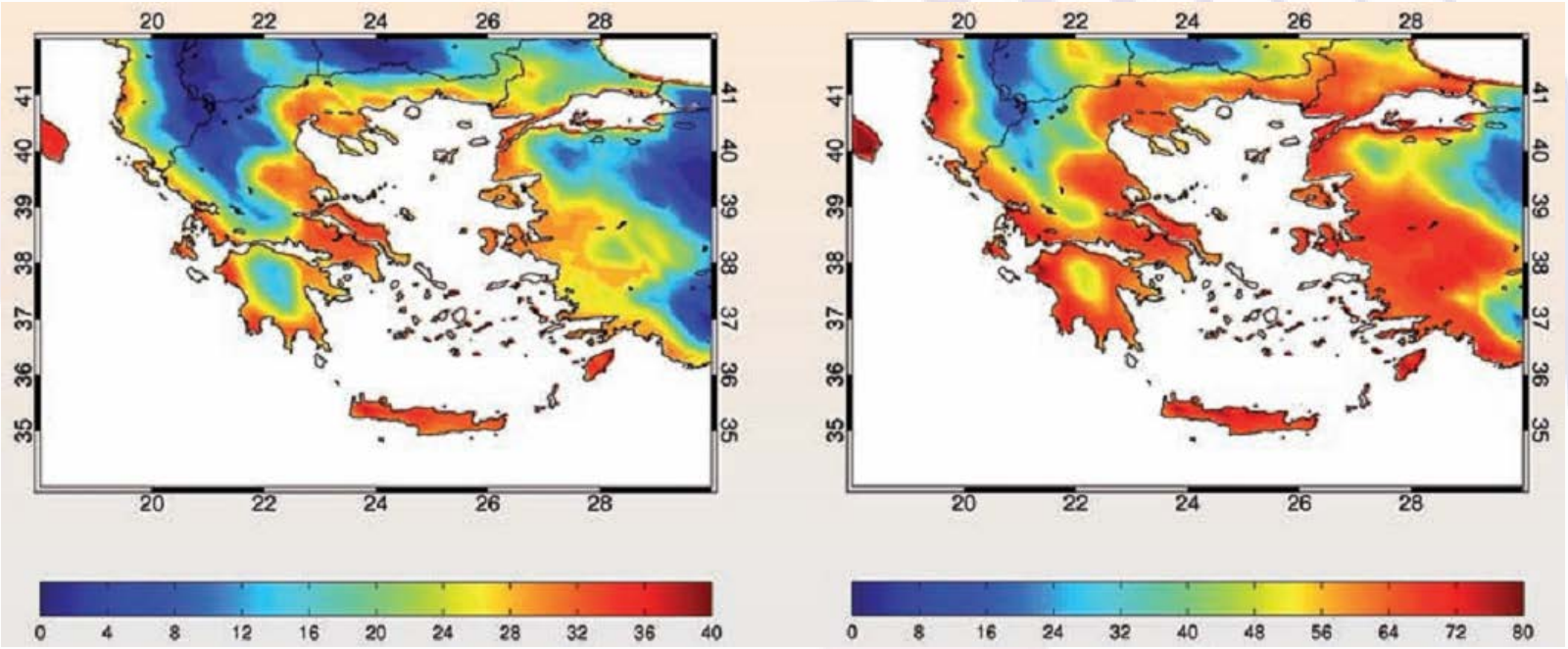


2021-2050

2071-2100

Bank of Greece Study: Climatic data

Difference in number of days with minimum temperature < 20°C

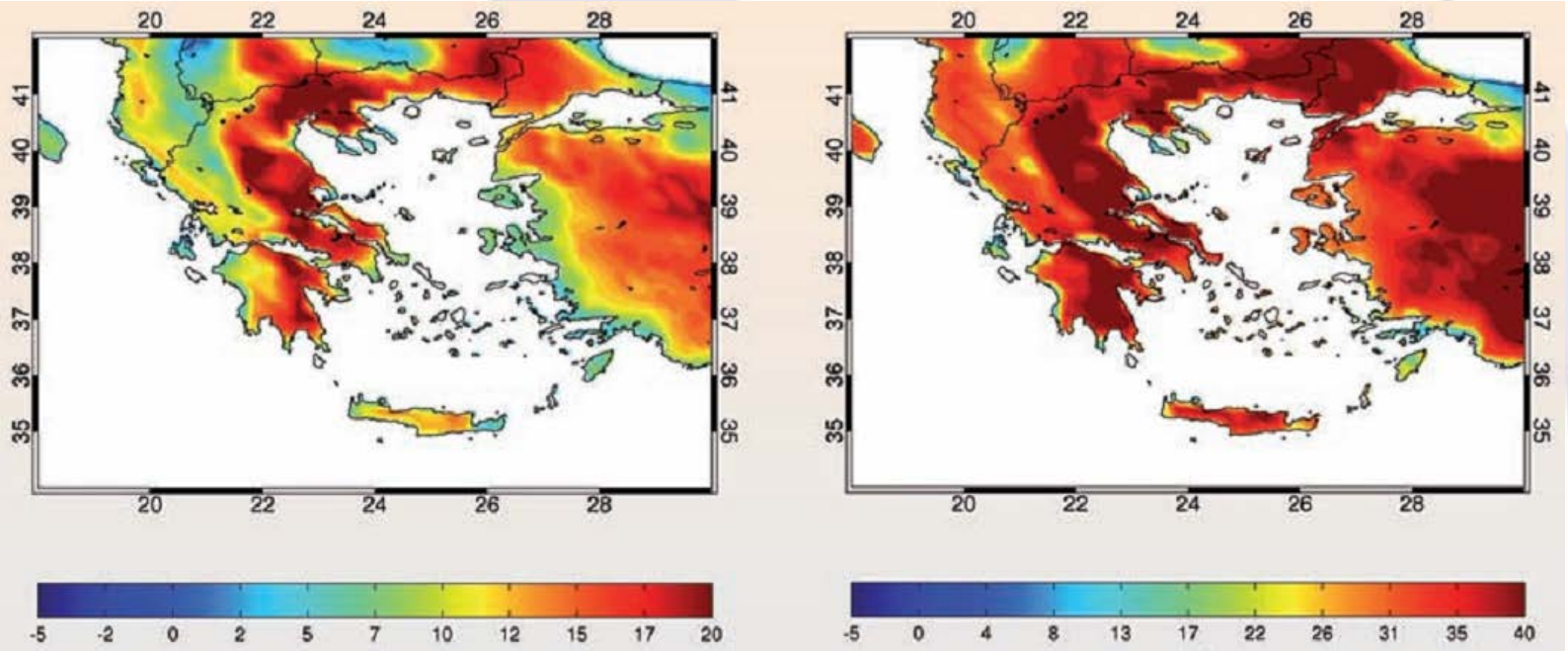


2021-2050

2071-2100

Bank of Greece Study: Climatic data

Difference in number of days with increased risk for fires



2021-2050 2071-2100

Bank of Greece Study: Transport sector methodology

- Step 1: Recording of the transport network at the national level and prioritization based on the vulnerability assessment of its attributes (infrastructure and services)
- Step 2: Forecasting of future transport demand
- Step 3: Impact and cost assessment of climate change for the transport sector
- Step 4: Qualitative evaluation of impacts – Suggestions and measures for adaptation & mitigation – General conclusions
- Step 5: Policy recommendations

Bank of Greece Study: Transport sector impacts studied

Adaptation

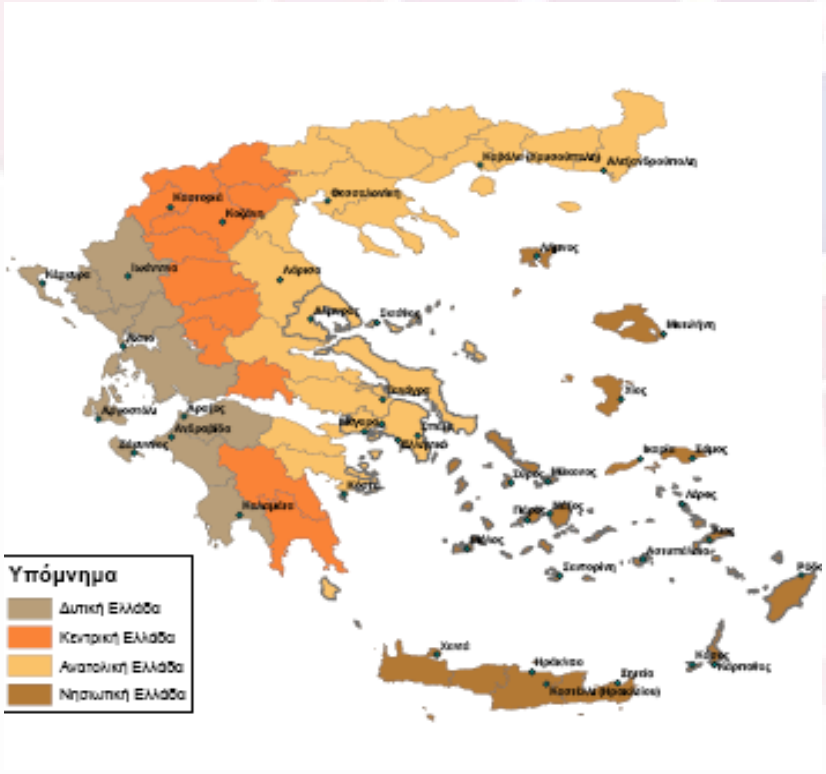
- Restructuring (reconstructing and repairing) of transport infrastructure due to natural hazards caused from climate change
- Protection of the existing infrastructure from the sea level rise, floods and other similar impacts
- Increasing needs of transport infrastructure maintenance
- Negative impacts in operation and reliability of the transport system due to delays, unscheduled changes in itineraries and/or other services

Mitigation

- Technologies, measures and policies for the de-carbonisation of the transport sector

Step 1: Recording of the transport network at the national level (1/3)

- Four (4) zones (Western, Central, Eastern και Island)
- Recording of road (national and regional) network, rail network and the network of main ports and airports for each zone



Transport system characteristics of Greece *(source: TRANSTOOLS, 2005)*		
Road network	**National**	**Regional**
	1.869,39km	**7.664,68km**
Rail network	**2.530km**	
Main airports	**43**	
Main ports	**119**	

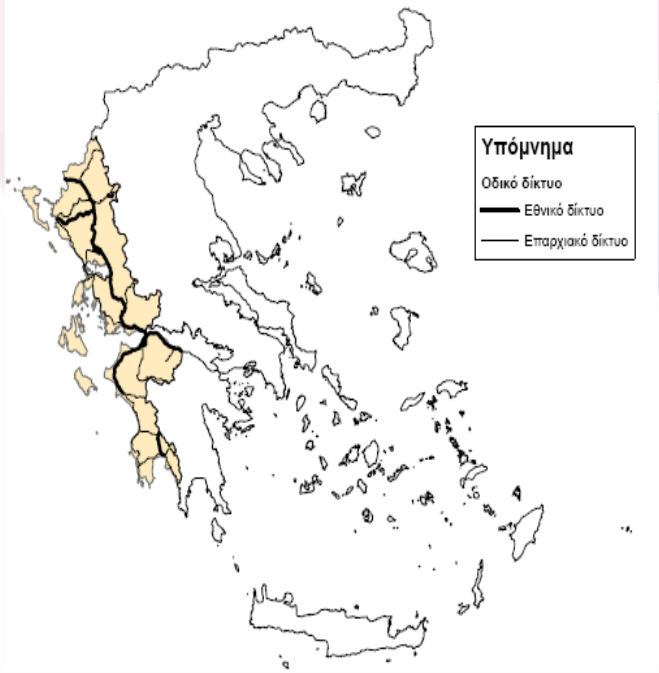
Step 1: Recording of the transport network at the national level (2/3)

- Network vulnerability per zone

Zone 1: Western Greece	Percentage (%) of road transport networks within 50 meters from coast line	**National: 1,41**	**Rural: 1,93**
	Percentage (%) of rail transport networks within 50 meters from coast line	**2,65**	
	Number of air ports at sea level	**1 (I. Kapodistrias, Corfu)**	
Zone 2: Central Greece	Percentage (%) of road transport networks within 50 meters from coast line	**National: -**	**Rural: 0,76**
	Percentage (%) of rail transport networks within 50 meters from coast line	**0**	
	Number of air ports at sea level	**0**	
Zone 3: Eastern Greece	Percentage (%) of road transport networks within 50 meters from coast line	**National: 1,53**	**Rural: 1,92**
	Percentage (%) of rail transport networks within 50 meters from coast line	**0,61**	
	Number of air ports at sea level	**2 (Macedonia Int'l Airport Thessaloniki), (Skiathos Airport)**	
Zone 4: Islands	Percentage (%) of road transport networks within 50 meters from coast line	**6,64**	
	Percentage (%) of rail transport networks within 50 meters from coast line	**0**	
	Number of air ports at sea level	**1 (Heraklion Int'l Airport)**	

Step 1: Recording of the transport network at the national level (3/3)

- Example for the zone of Western Greece



Transport system characteristics of Western Greece Zone		
Road network	**National**	**Regional**
	353,90 km	1.454,18 km
Rail network	453 km	
Main airports	8	
Main ports	19	

Quantitative figures of "vulnerability:

- ***Percentage of road network in a distance of 50 meters from the sea (and of the same altitude): 1,41% of the national road network and 1,93% of the regional network.***
- ***Percentage of rail network in a distance of 50 meters from the sea (and of the same altitude): 2,65%***
- ***No of airports in the sea level: 1 (Airport of Kerkyra Island).***

Qualitative assessment of critical infrastructure

Step 2: Forecasting of future transport demand

Passenger transport	Road (in billions km / year)		Rail (in billions passengers km/ year)	Air (in millions passengers/ year)	Maritime (in millions passengers/ year)
	National network	Regional network			
Base year	12,9	8,7	1,9	38,7	86
2015	14,6	9,9	2,0	43,9	98
2030	18,6	12, 5	2,3	54,0	122
2050	23,5	17,2	2,0	70,0	130

Freight transport	Road (in billions tons km/year)	Rail (in billions tons km/year)	Air (in '000 tons/year)	Maritime (in millions tons/year)
Base year	25,6	0,7	130	151
2015	29,5	0,8	151,3	189
2030	38,6	1,0	194,8	267
2050	55,1	1,4	272,9	350

Step 3: Cost assessment of climate change for the transport sector in Greece: Types of impacts (1/2)

Road & Rail transport

- Costs for the redesign of the road and rail networks, which are within a short distance from the coastline, due to sea level rise
- Costs for restructuring and repairing of road and rail network infrastructures, due to increased frequency and severity of floods
- Savings, due to reduced de-icing works
- Costs associated with delays/disruptions of transport services (related to value of time)

Step 3: Cost assessment of climate change for the transport sector in Greece: Types of impacts (2/2)

Maritime transport

- **Infrastructures:**
  - Costs associated with damages of quays, due to sea level rise
  - Costs associated with quays elevation
- **Services:**
  - Costs associated with delays/disruptions of transport services (related to value of time)

Step 3: Costs due to infrastructures' restructuring, repairing and maintenance

Type of impact	Scenario:	2050 NO ADAPTATION	2050 MODERATE ADAPTATION	2050 HIGH ADAPTATION	2100 NO ADAPTATION	2100 MODERATE ADAPTATION	2100 HIGH ADAPTATION
Temperature increase	Road	150 mil € / year	100 mil € / year	50 mil € / year	300 mil € / year	200 mil € / year	100 mil € / year
	Rail	37 mil € / year	30 mil € / year	20 mil € / year	75 mil € / year	55 mil € / year	40 mil € / year
Sea level rise	Road	3 bil € flat	3 bil € flat	3 bil € flat	-	-	-
	Rail	0,3 bil € flat	0,3 bil € flat	0,3 bil € flat	-	-	-
	Maritime	0,6 bil € flat	0,6 bil € flat	0,6 bil € flat	-	-	-
Flooding	Road	200 mil € / year	120 mil € / year	60 mil € / year	300 mil € / year	200 mil € / year	85 mil € / year
	Rail	-	-	-	-	-	-
Benefits due to snowfall reduction	Road	-40 mil € / year	-25 mil € / year	-15 mil € / year	- 80 mil € / year	-50 mil € / year	-30 mil € / year
	Rail	-0,1 mil € / year	-0,07 mil € / year	-0,05 mil € / year	-0,2 mil € / year	-0,15 mil € / year	-0,1 mil € / year
TOTALS		346 mil € / year & 4 bil € flat	225 mil € / year & 4 bil € flat	115 mil € / year & 4 bil € flat	594,8 mil € / year	405 mil € / year	195 mil € / year

Step 3: Annual cost of transport delays

Scenarios	TOTAL ANNUAL COSTS (Road & Rail) (Bil. € / year)
2050 (with no adaptation)	9,91
2050 (moderate adaptation)	4,304
2050 (with high adaptation)	1,401
2100 (with no adaptation)	28,031
2100 (with moderate adaptation)	9,311
2100 (with high adaptation)	4,204

Step 4: Quantitative impact assessment (example 1/2)

Expected change / climate event		Road transport	Infrastructure / Service	Type of impact – Costs
1	**Mean Temperature increase**	Higher demand for air conditioning of vehicles	Service	Negative impact (Increased costs and energy)
		Demand for heating	Service	Positive impact (Reduced costs and energy)
		Changes in the demand for transport	Service and Infrastructure	Cannot be directly estimated. Most probably with negative impact, due to a possible shift of travelers to road transport (because of low service quality provided by public transport)
		Overheating of vehicles and tire wearing	Service	Negative impact (increased costs for vehicles' and tires' maintenance)
		Restrictions associated with the periods of works execution (maintenance and repairing of infrastructures), due to personnel's' health and safety issues	Infrastructure	Negative impact (restrictions for work usually apply for temperatures above 29.5°C)

Step 4: Quantitative impact assessment (example 2/2)

Expected change / climate event		Road transport	Infrastructure / Service	Type of impact - Costs
2	**Increased frequency of high or very high temperature events**	Increased pavement damages	Infrastructure	Negative impact (related to increased infrastructure maintenance costs)
		Increased damages of structural elements of the infrastructures (due to e.g. thermal expansion/contraction of bridges or pavements)	Infrastructure	Negative impact
		Reduced level of comfort for private vehicle drivers and passengers	Service	Negative impact
		Reduced level of comfort for public transport passengers and personnel	Service	Negative impact

Step 5: Policy measures for prevention and handling of climate change impacts (Adaptation) Scenario of moderate adaptation, example of all transport means

Climate change event:	***Transport policies for:***	
	Mitigation *(all transport means)*	***Adaptation*** *(all transport means)*
Mean temperature increase	Implementation of policies for reducing greenhouse gas emissions for all transport means, with emphasis on: A) Improved internal combustion engines with reduced CO_2 emissions below 120 gr/km for freight and passenger transport. B) Hybrid vehicles. C) Incentives to promote the use of EVs and hydrogen cell fuels, when technically mature (~2015) D) Incentives and infrastructures for increased use of public transport E) Demand & mobility management measures	A) Measures for reduced use of private vehicles (focus on vehicles with less than 2 travelers). B) Measures for the reduction of negative impacts due to the increased use of air conditioning in all types of vehicles (use of existing research results and existing systems, or systems to be developed in the near future).

Step 5: Policy measures for prevention and handling of climate change impacts (Adaptation) Scenario of moderate adaptation, example of all transport means

Climate change event:	***Transport policies for:***	
	Mitigation *(all transport means)*	***Adaptation*** *(all transport means)*
Increased frequency of high or very high temperature events	Implementation of policies for reducing greenhouse gas emissions for all transport means, with emphasis on: A) Improved internal combustion engines with reduced CO2 emissions below 120 gr/km for freight and passenger transport. B) Hybrid vehicles. C) Incentives to promote the use of EVs and hydrogen cell fuels, when technically mature (~2015) D) Incentives and infrastructures for increased use of public transport E) Demand & mobility management measures	A) Elaboration of plans for predefined and well organized traffic restrictions in urban areas during high temperature peak periods. B) Quick check programs for targeted pavement maintenance, in order to minimize damages. C) R&D for new types of pavements (increased durability at high and very high temperatures). D) Programing and re-planning of rail schedules, taking into account expected events of high or very high temperatures and related restrictions that apply for maximum velocity and allowable carried weight due to safety reasons.

Bank of Greece study: Groups of suggested policy measures

- Institutional – Organizational
- Technical – Technological
- Environmental
- Economical

Bank of Greece study full report and sectoral studies

http://www.bankofgreece.gr/Pages/el/klima/results.aspx

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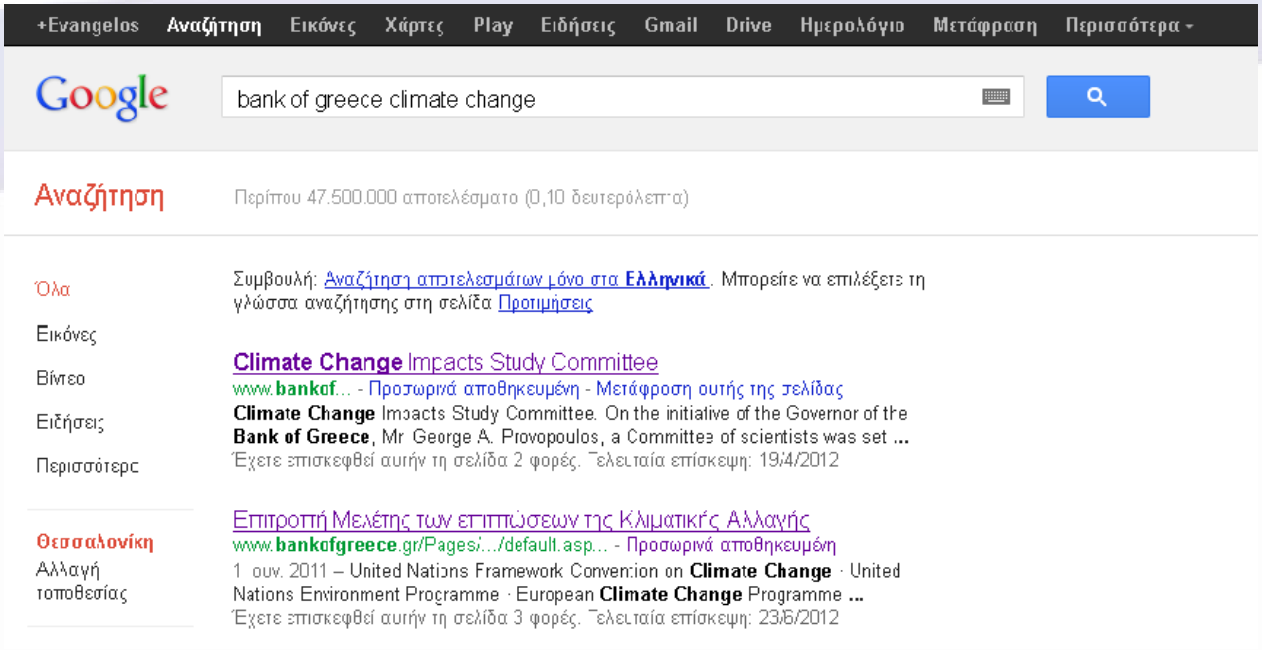

Thank you for your attention
Ευχαριστώ για την προσοχή σας

Dr. Evangelos Mitsakis
Post-doctoral researcher
Centre for Research and Technology Hellas
Hellenic Institute of Transport
emit@certh.gr
+302310498459