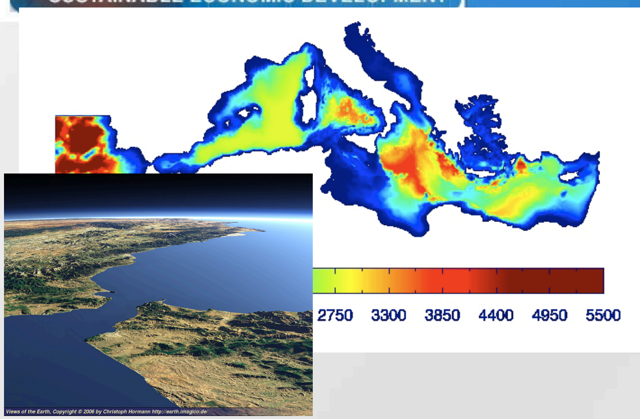
ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Analysis and simulations of climate change in the Mediterranean region for the development of a strategy of adaptation and mitigation



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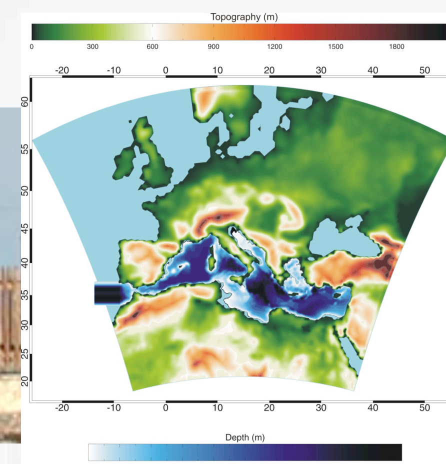
ENEA

Energy and Environment Modeling, ENEA Technical Unit

(UTMEA, *http://utmea.enea.it/*)

CR Casaccia, Rome (Italy)

with the contribution of F. Antonioli, S. Calmanti, A Carillo, A. Dell'Aquila, C. Di Palo, A. Di Sarra, G. Pisacane, PM Ruti, MV Struglia



ENEA-UTMEA mission:

✓**To understand and predict changes in Earth's environment by:**

The **analysis** of in situ and satellite data and developing numerical **climate modeling** of the Earth Systems and in particular of the **Mediterranean Region;**

✓**To conserve and manage natural resources by:**

The development of modeling tools/technological platform **to fill the gap** between **RD&D results** and **market applications;**

✓**To meet economic, social, and environmental needs by:**

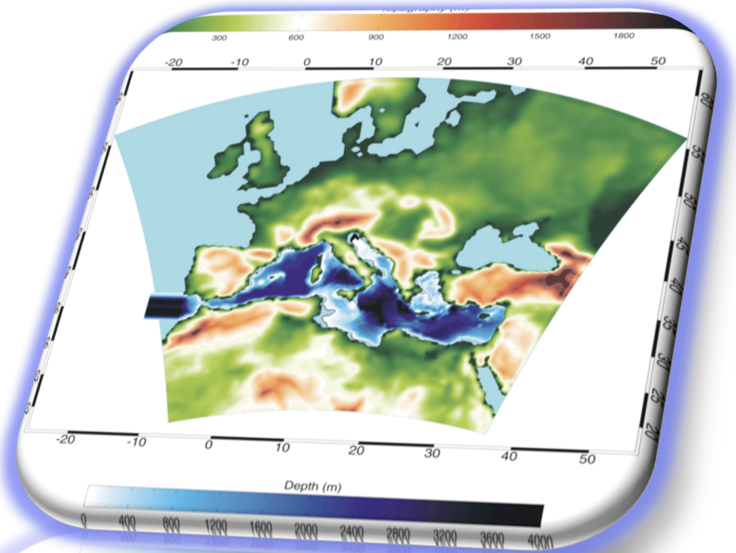
Elaboration of integrated mitigation and adaptation strategies to mitigate the effects of climate change and to **keep citizens informed** of the changing environment around them;

The UTMEA Laboratories

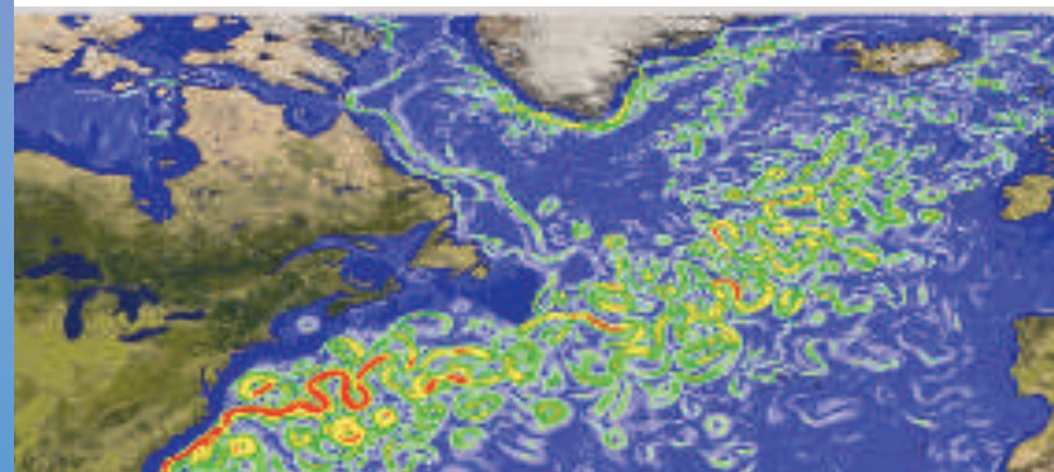
- ✓ **UTMEA-TER**
- *Earth Observations and Analysis*
- ✓ **UTMEA-CLIM**
- *Climate Modelling and Impacts*
- ✓ **UTMEA-CAL**
- *Computing and Technologic Infrastructures*
- ✓ **UTMEA-MACC**
- *Adaptation to Climate Change*

Contents

- ✓ **Protheus Earth System**
- ✓ **The Mediterranean case**
- ✓ **Future climate scenarios and impacts**
- ✓ **technologies for adaptation**



“CRUCIAL EXPERIMENTS”



A strict application of the scientific method requires a process of isolation of constituent subsystems and experimental verification of a hypothesis. **For the climate system, this is only possible by using numerical models.** Such models have become the central pillar of the quantitative scientific approach to climate science because they allow us to perform “crucial” experiments under the controlled conditions that science demands. **Sometimes crucial experiments are …like the quest for the Higgs boson currently going on at CERN.**

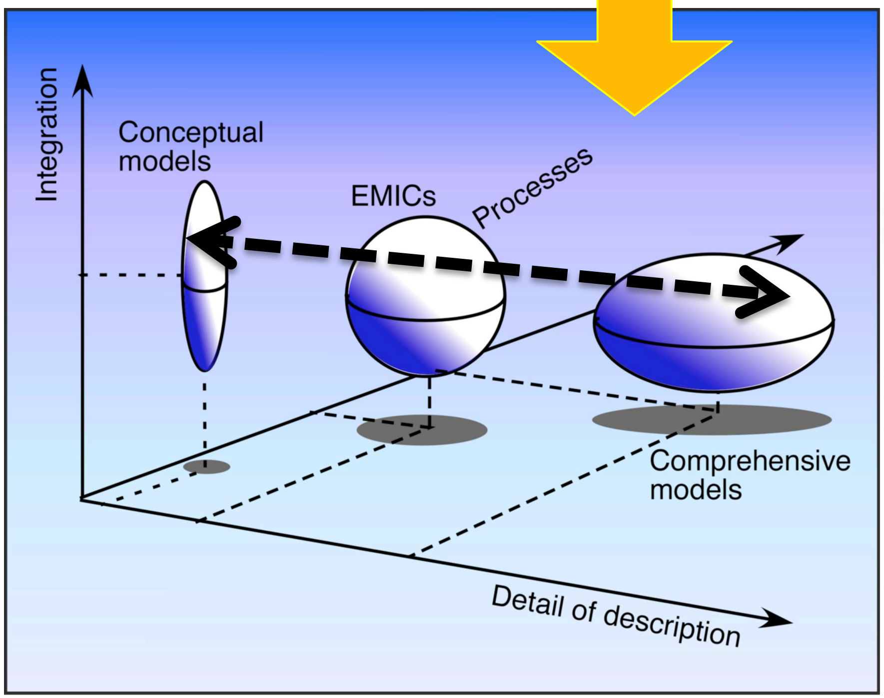
Protheus: a Regional Coupled System for climate change assessment in the Mediterranean region

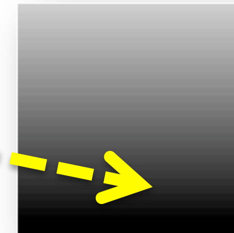
The PROTHEUS

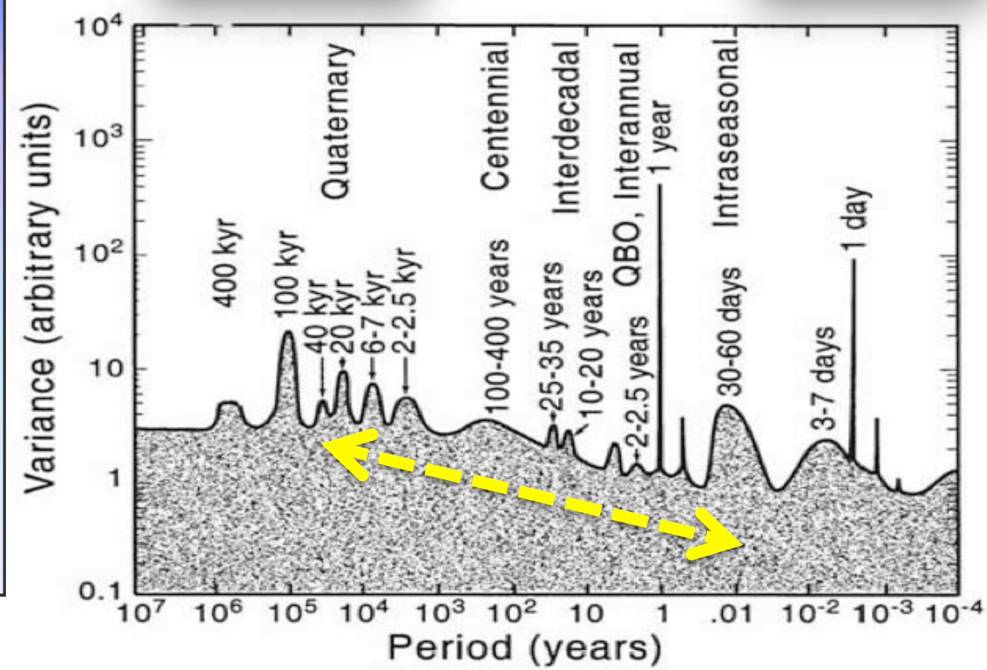
Group

Views of the Earth, Copyright © 2006 by Christoph Hormann http://earth.imagico.de/

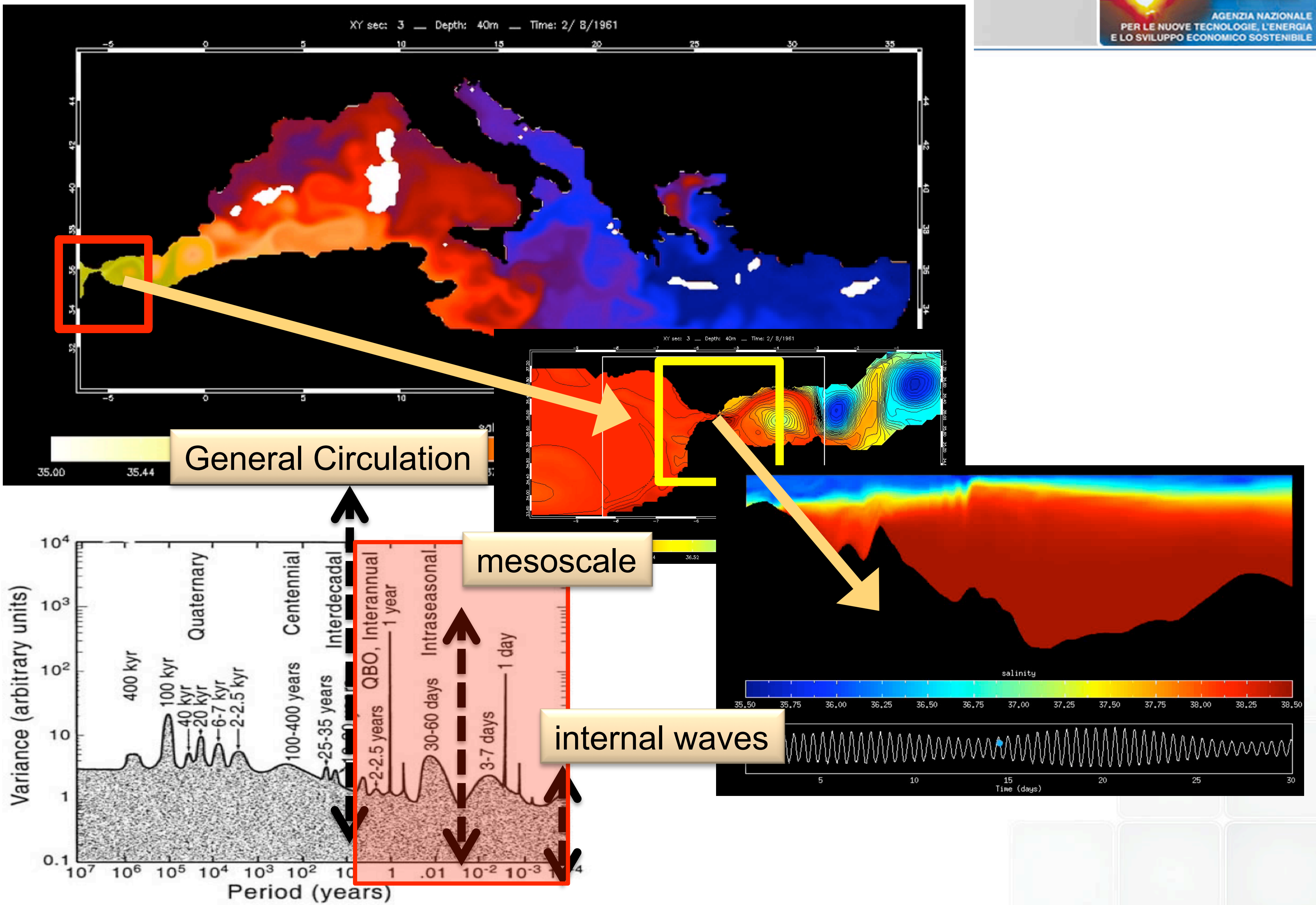
TEMPORAL SCALE INVOLVED IN CLIMATE SYSTEM AND MODELLLING SIMULATIONS: THE MEDITERRANEAN CASE



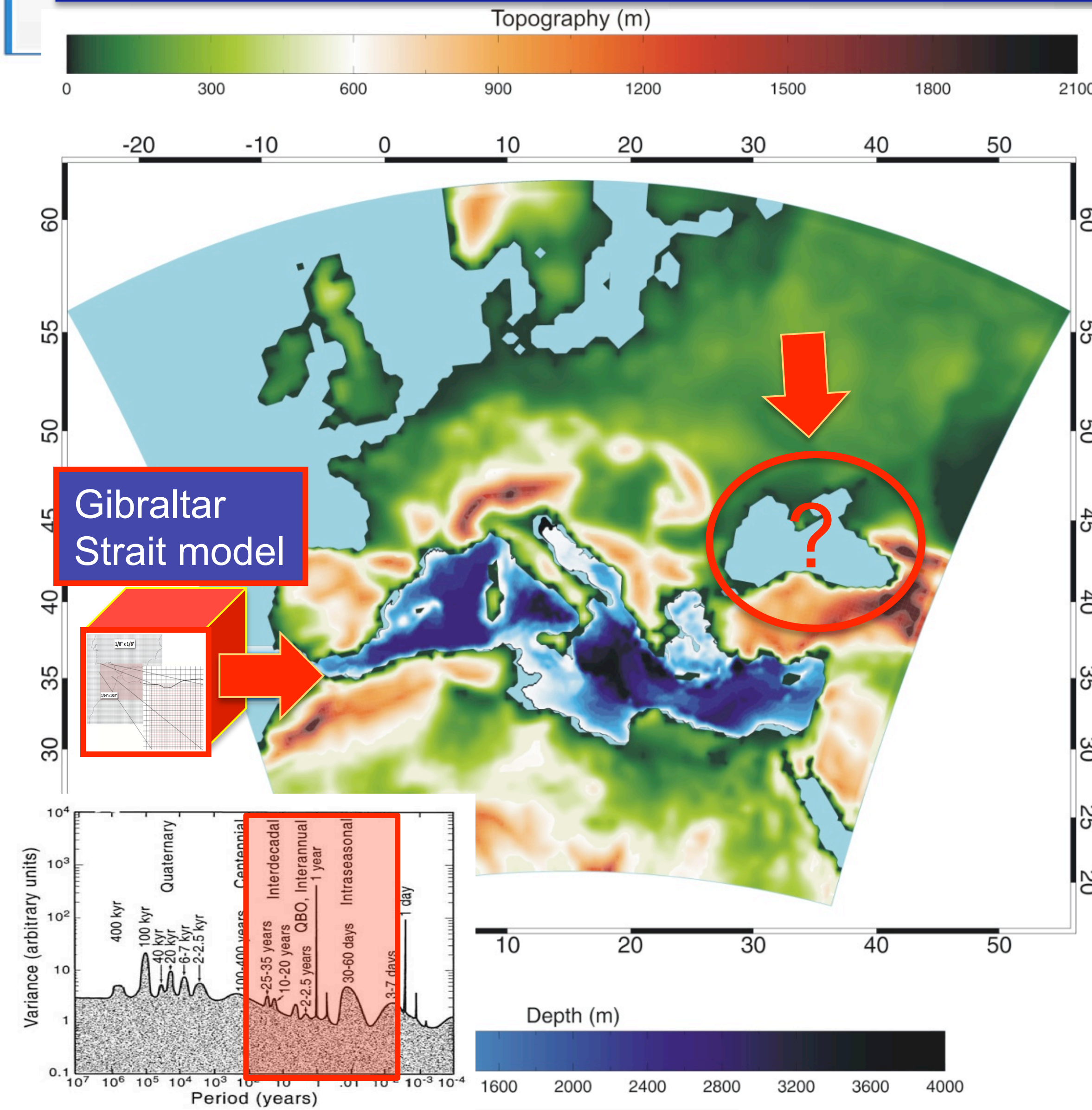




Mediterranean ocean circulation



PROTHEUS Model



Model domain

Model components

RegCM3

18 sigma vertical levels

30 Km horizontal resolution

BATS + IRIS

BATS: Biosph.-Atmosph. Transfer Scheme

IRIS: interactive RIvers Scheme

SST

OASIS 3
Freq. 6h

HF-WF-Wind

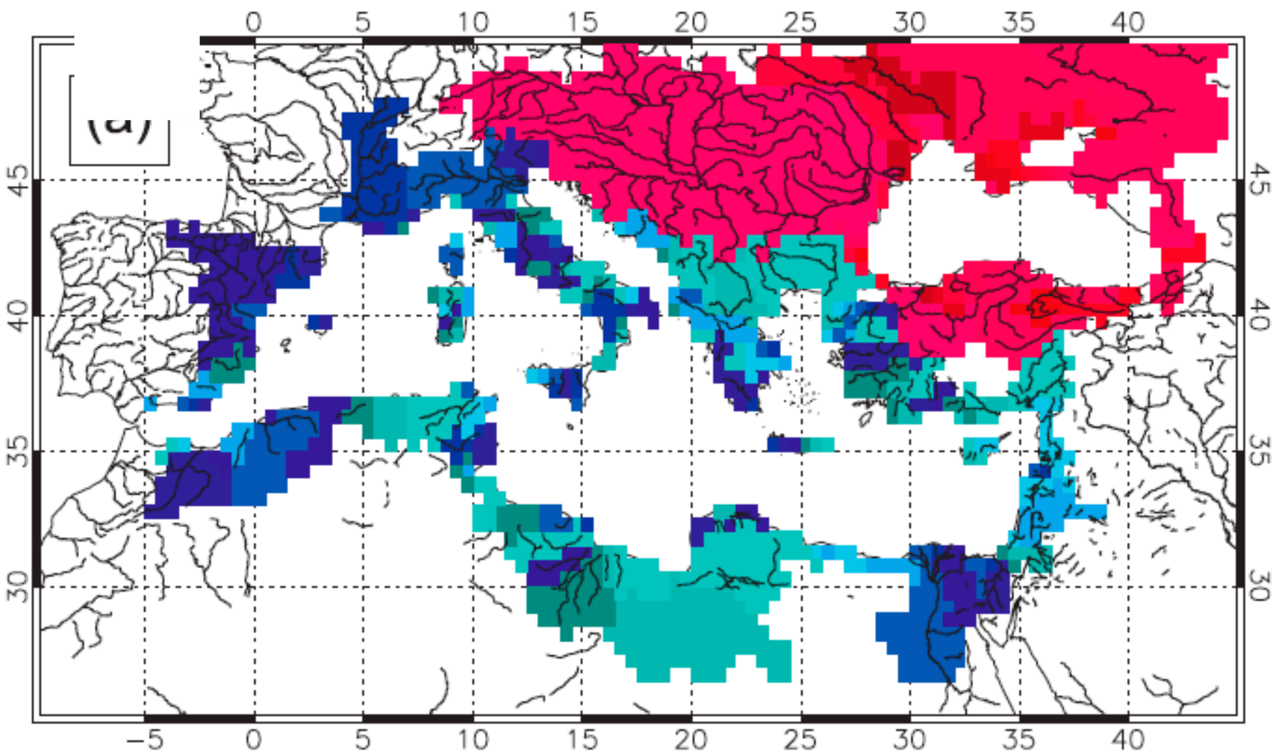
MedMIT

42 zeta vertical levels (partial cell)

1/8° x 1/8° horizontal resolution

PROTHEUS Model

River discharge is calculated from the surface runoff provided by the land-surface scheme of RegCM using the **TRIP Total Runoff Integrated Pathaway database** that condenses all available information about global river channel network.



The figure shows reconstructed catchment basin for each river falling into the Mediterranean Sea. Blu for rivers discharging directly into the Mediterranean and red for rivers that discharge into the Black Sea.

River modelling (future version) in Protheus

PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Regional model
Vertical balance of water fluxes in land-vegetation module

daily total runoff fields

river routing model (CCNY-NY)

Bi-dimensional field of river discharge

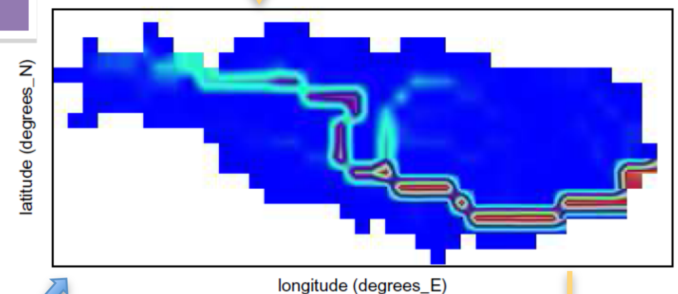
monthly total runoff fields

In collaboration with the City College of New York, the NASA Jet Propulsion Laboratory and the World Wildlife Fund

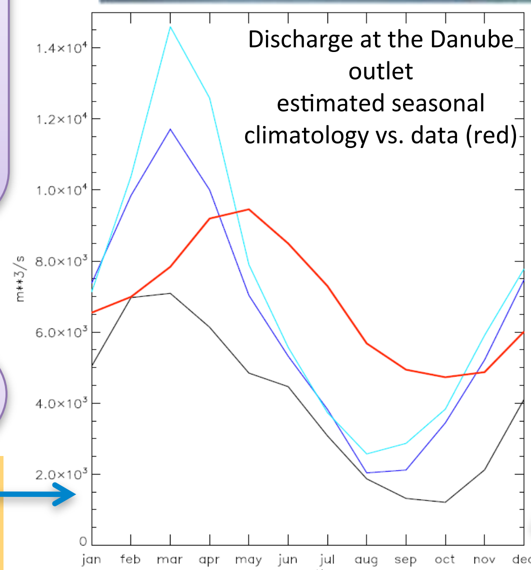
Inverse distance interpolation (IDI) on a lat/lon grid reconstruction of hydrographic basins
(Oki and Sud,1998 *Earth Interactions*, 2)

Estimate of monthly mean discharge at the river mouth

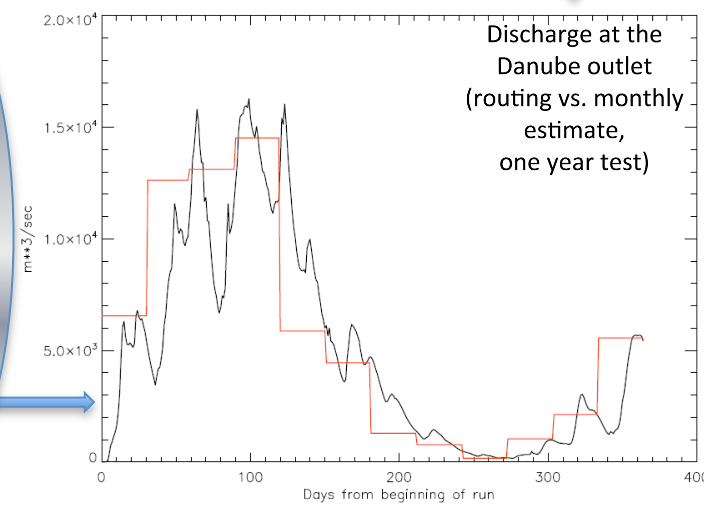
G.Pisacane, M.V.Struglia and B. Fekete, in preparation



Range of outflow: -33.3959 to 10456.6 m3/s
Range of longitude: 9.25 to 29.25 degrees_E
Range of latitude: 42.25 to 50.25 degrees_N



DANUBE



PROTHEUS Validation: Present climate simulation

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Simulation details

Lateral BC

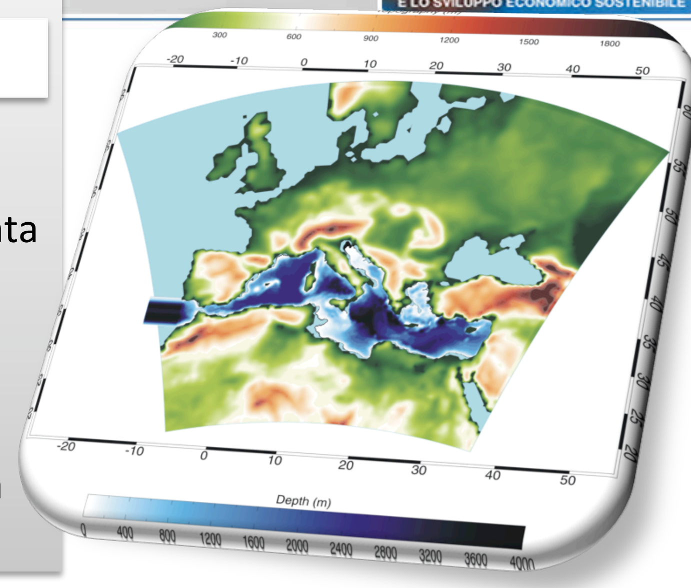
○ERA40 reanalysis 1958-2000

SST (Atlantic Box)

○GISST - Global Sea Ice Coverage and Sea Surface Temperature data -Met Office

Ocean initialization

○The oceanic component is initialized with MEDATLAS II data (MEDAR Group, 2002), then a 40 year spin-up is performed using a 3D relaxation of T and S to the climatological values.



Comparison with:

- **Stand-alone** configuration of the atmospheric model RegCM3 (forced by GISST data)
- **ERA40** Reanalysis
- **Observational datasets**

  OISST (daily 1/16°x1/16° SST for the period 1985-2000, Marullo et al. 2007)

  HOAPS (Hamburg Ocean Atmosphere Parameters and fluxes from Satellite data)

  CRU (Climatic Research Unit, UK)

  GPCP (Global Precipitation Climatology Project)

PROTHEUS Validation: Present climate simulation

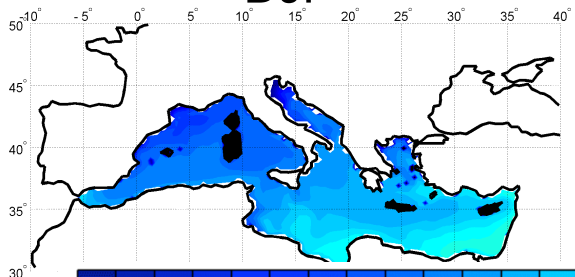
PROTHEUS SST Climatology vs. Observations

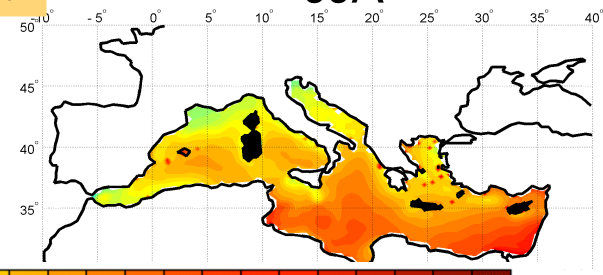
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

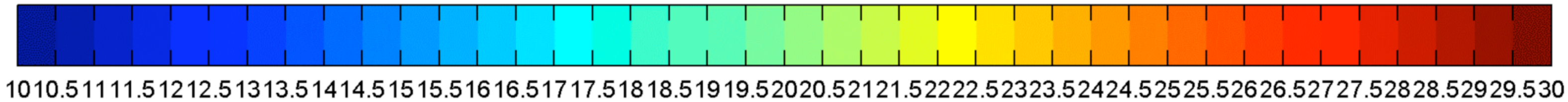
Artale et al., Climate Dynamics, 2009

DJF | JJA

PROTHEUS

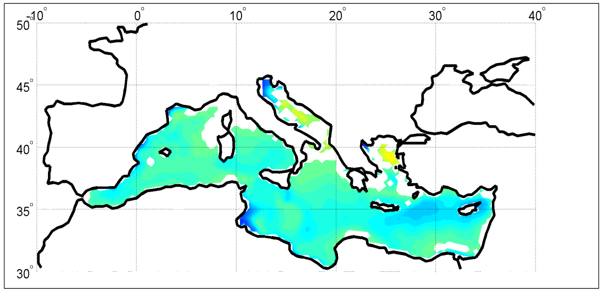


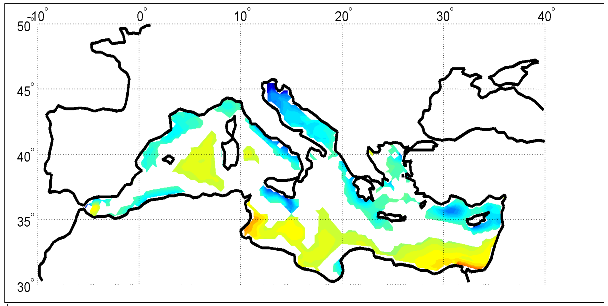




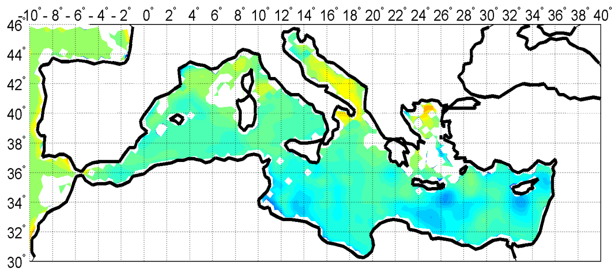
Temperature (°C)

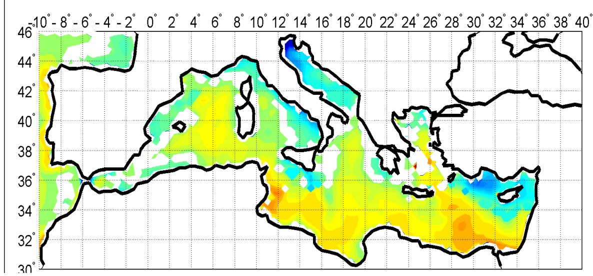
PROTHEUS-GISST



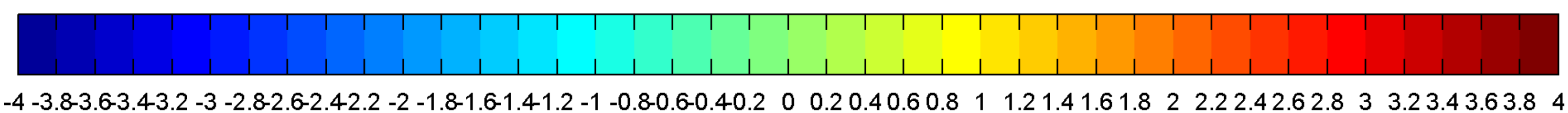


PROTHEUS-OISST





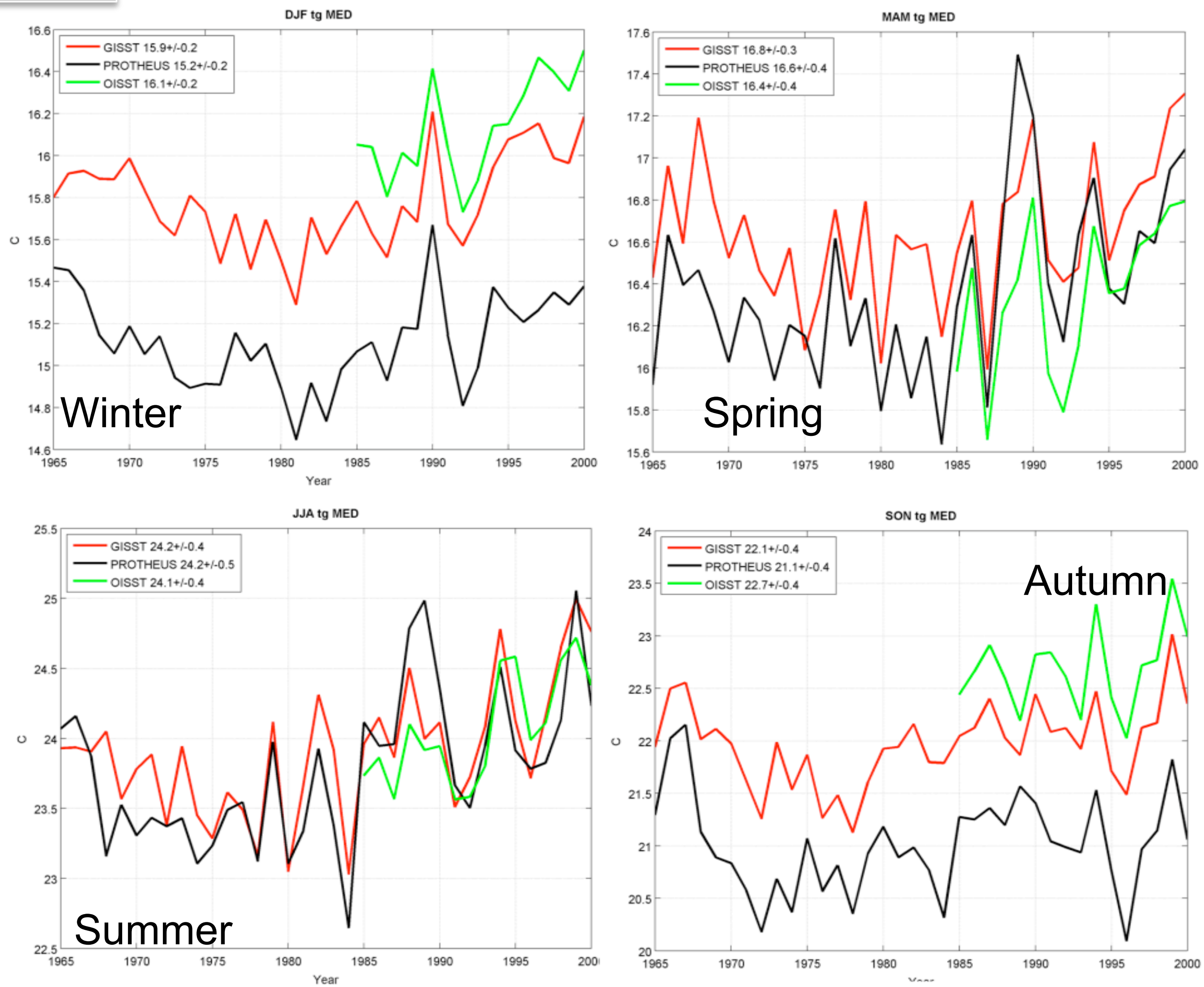
Temperature (°C)



PROTHEUS Validation: Present climate simulation

GISST
OISST
PROTHEUS

PROTHEUS SST Climatology vs. Observations (TEMPERATURE)



PROTHEUS Validation: Present climate simulation

Precipitation over land CLIMATOLOGY

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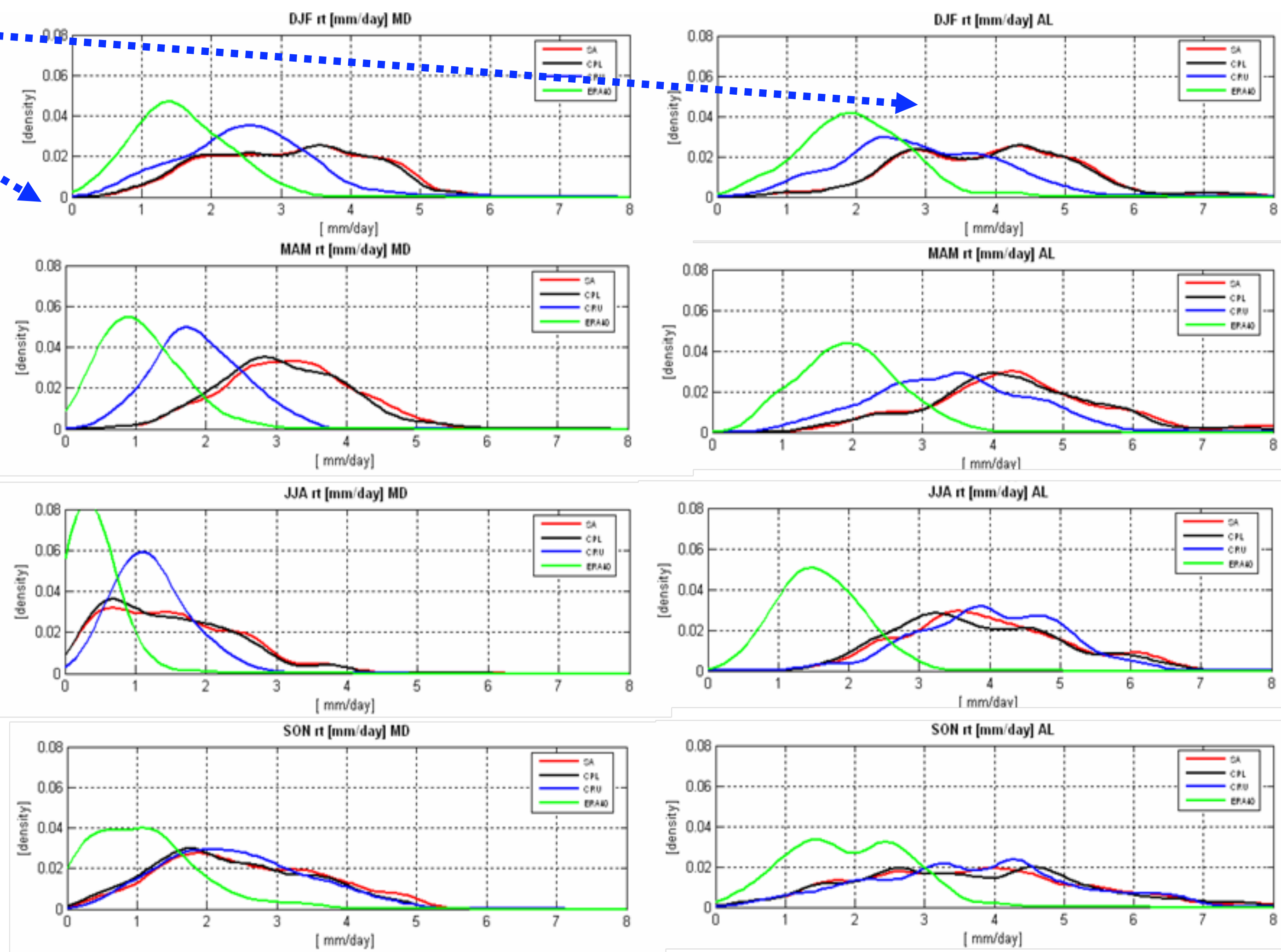
Fig. 4 European sub-areas

Area	West	East	South	North
1 (BI) British Isles	-10	2	50	59
2 (IP) Iberian Peninsula	-10	3	36	44
3 (FR) France	-5	5	44	50
4 (ME) Mid-Europe	2	16	48	55
5 (SC) Scandinavia	5	30	55	70
6 (AL) Alps	5	15	44	48
7 (MD) Mediterranean	3	25	36	44
8 (EA) Eastern Europe	16	30	44	55

MD AL



ERA40

CRU

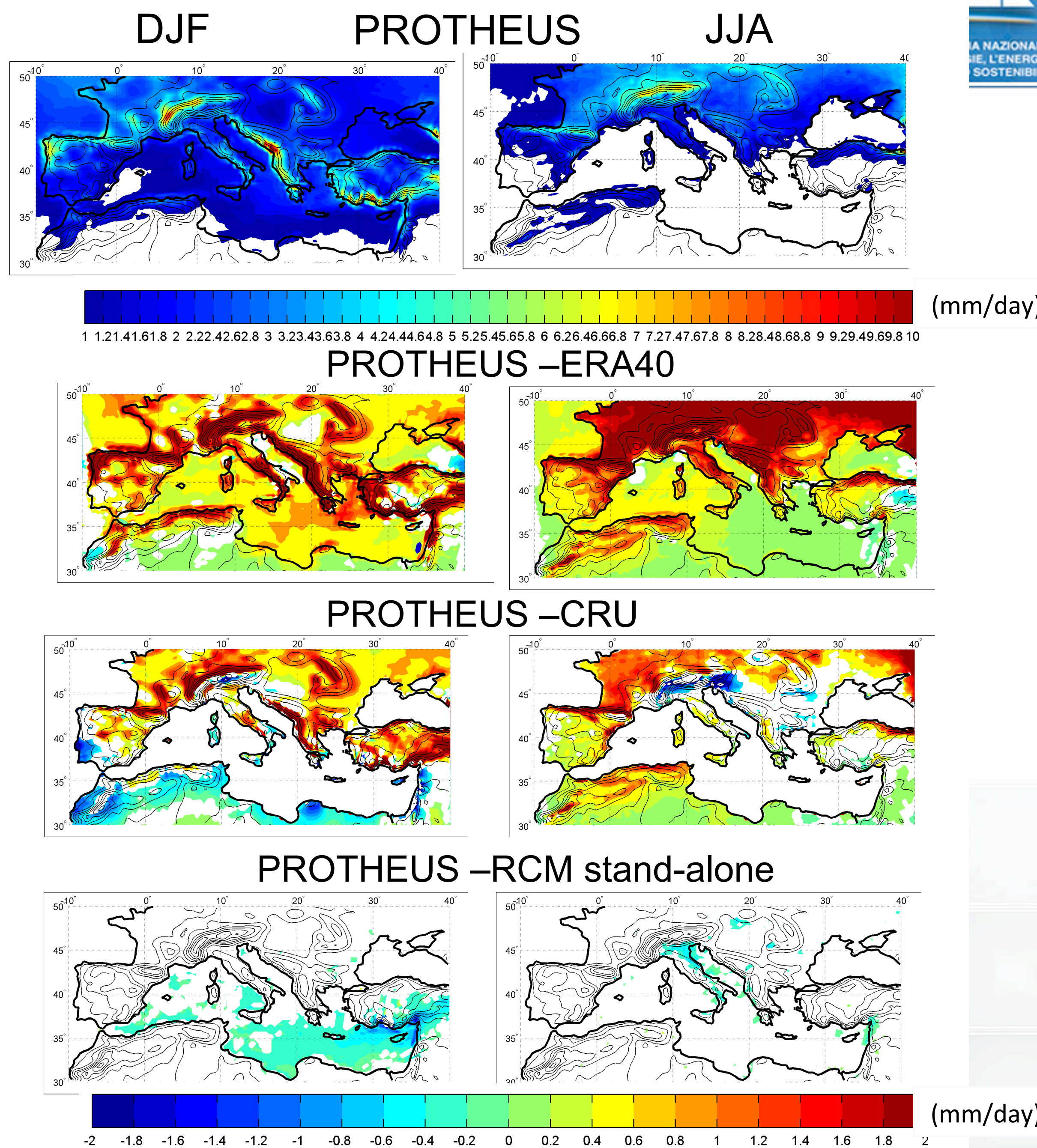
PROTHEUS

RegCM-SA

PROTHEUS Validation: Present climate simulation

Precipitation

CLIMATOLOGY



Precipitation

CLIMATOLOGY

differences

ENEA
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Present Climate Simulation : Major results

- 40-year simulation driven by ERA40 reanalysis at BC
- Realistic features reproduced (atmospheric circulations, land surface climate, ocean SST, ocean surface circulations and air-sea fluxes)
- The coupling does not affect the bulk characteristics of the atmospheric model
- The coupled model is capable of significantly improve the description of air-sea interactions in terms of sensible and latent heat, **especially at small scales and for intense events**
- Sea level anomalies correctly reproduced

PROTHEUS SCENARIO Simulation

Simulation characteristics:

Boundary condition from ECHAM5-MPIOM run performed in ENSEMBLES project:

20C3M: 1951-2000 climate of the 20th Century experiment

SRES A1B: 2001-2051 720 ppm stabilization experiment

Impose SRES A1B conditions and initialize with conditions from the end of the 20C3M simulation.

ECHAM5-MPIOM model characteristics:

Atmosphere (ECHAM5; Roeckner et al., 2003) resolution: T63 L32

Ocean (Marsland et al., 2003) resolution: 1. deg, conformal mapping grid with grid poles over Greenland and Antarctica, 41 vertical levels

BC for MITgcm

Temperature and salinity are relaxed in the Atlantic box to climatological monthly Levitus data in the present climate simulation and to monthly mean anomalies obtained from the oceanic component of the coupled global run in the scenario simulation.

PROTHEUS SCENARIO Simulation

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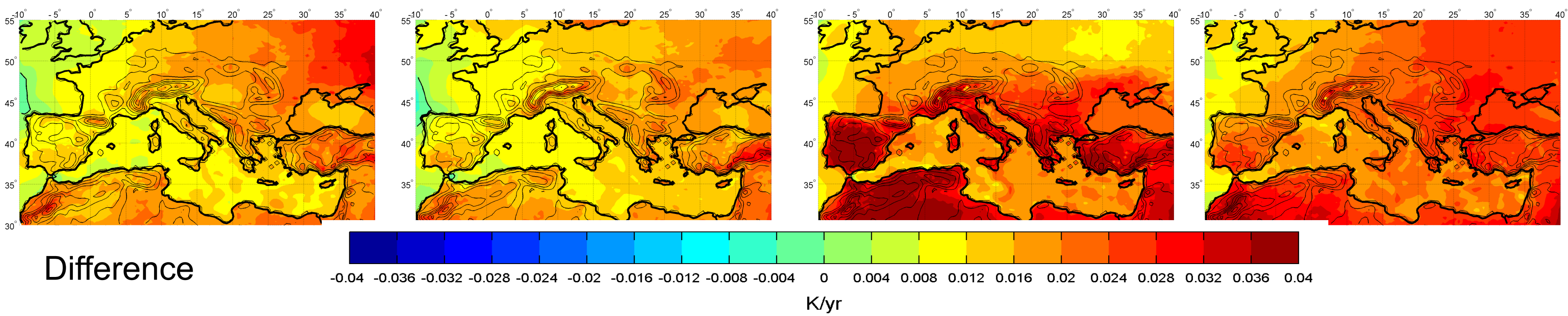
AGENZIA NAZIONALE
PER LE NUOVE TECNOLOGIE, L'ENERGIA
E LO SVILUPPO ECONOMICO SOSTENIBILE

•Several Scenario Simulation planned (METEO-FRANCE, ECHAM5-MPIOM,…)

•**Simulation already performed:** 1951-2050 ECHAM5-MPIOM at BC (20c3m for 1951-2000 and SRESA1B for 2001-2050), at the moment we are preprocessing the ARPEGE simulation

PROTHEUS
trend

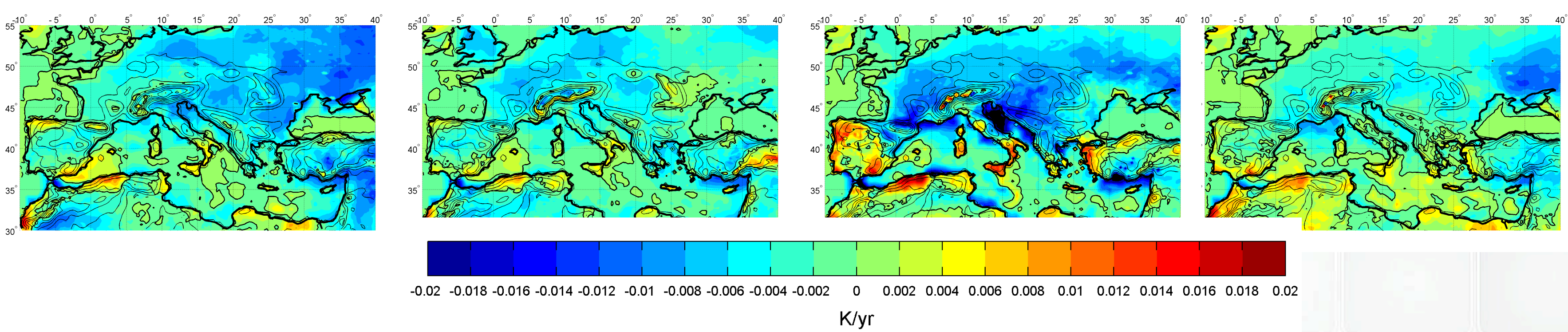
Trend Analysis :Surface Temperature



Difference

PROTHEUS-ECHAM5

DJF MAM JJA SON



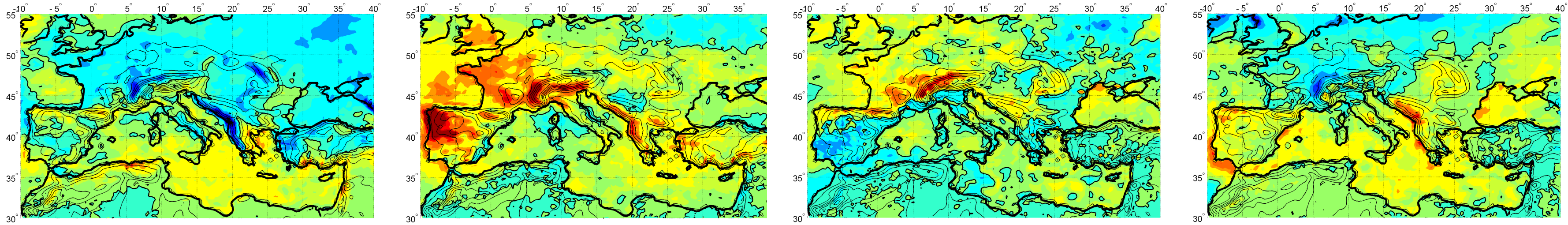
PROTHEUS SCENARIO Simulation: preliminary analysis

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

E-P FLUX TREND

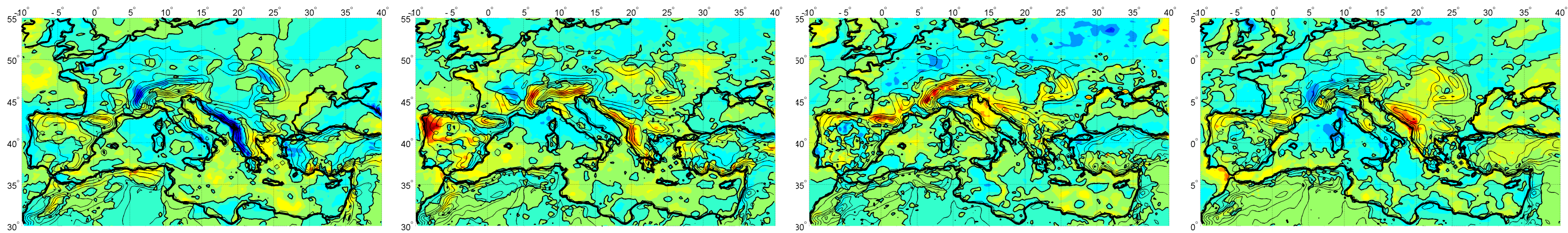
PROTHEUS trend

DJF | MAM | JJA | SON

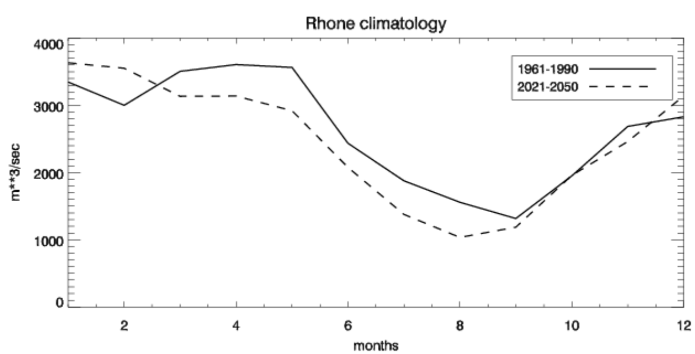


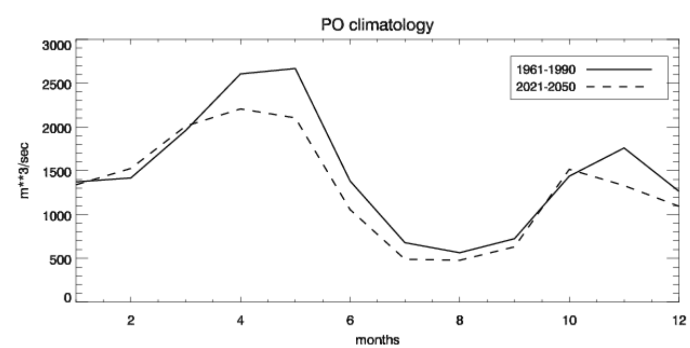
Difference

PROTHEUS-ECHAM5



River Discharge





SST averaged over the whole basin in Summer

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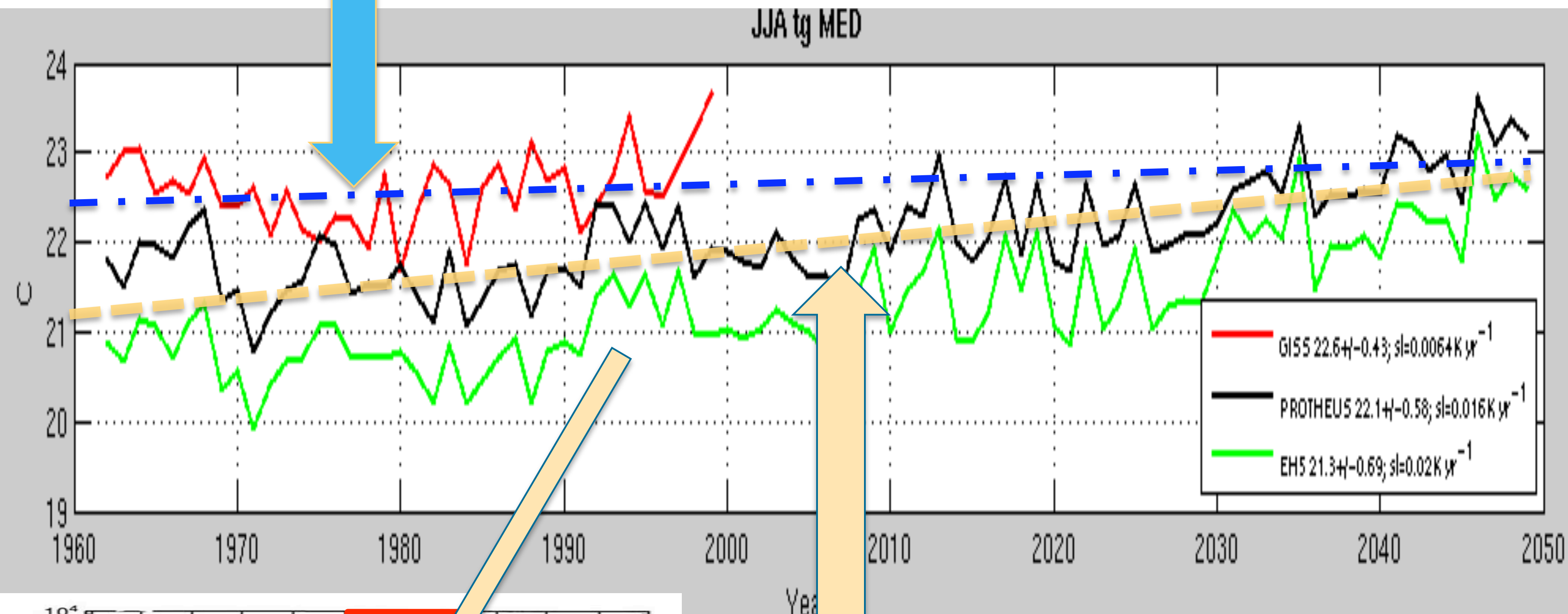
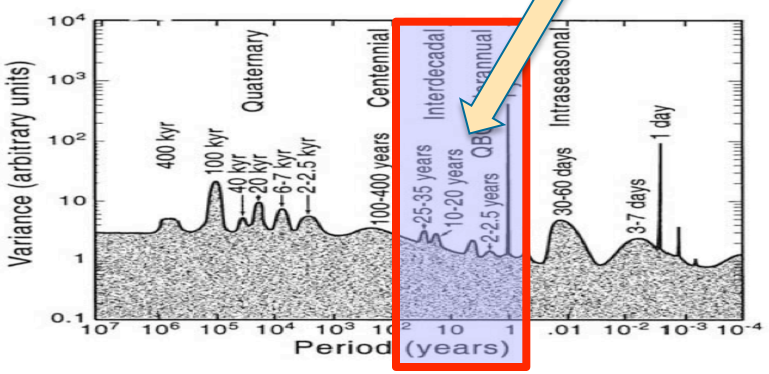
0.02-0.03/decade from the past observation or 0.06/decade for the last 50 yrs





0.16/decade from our scenario

Impact for future scenario of the Mediterranean Region

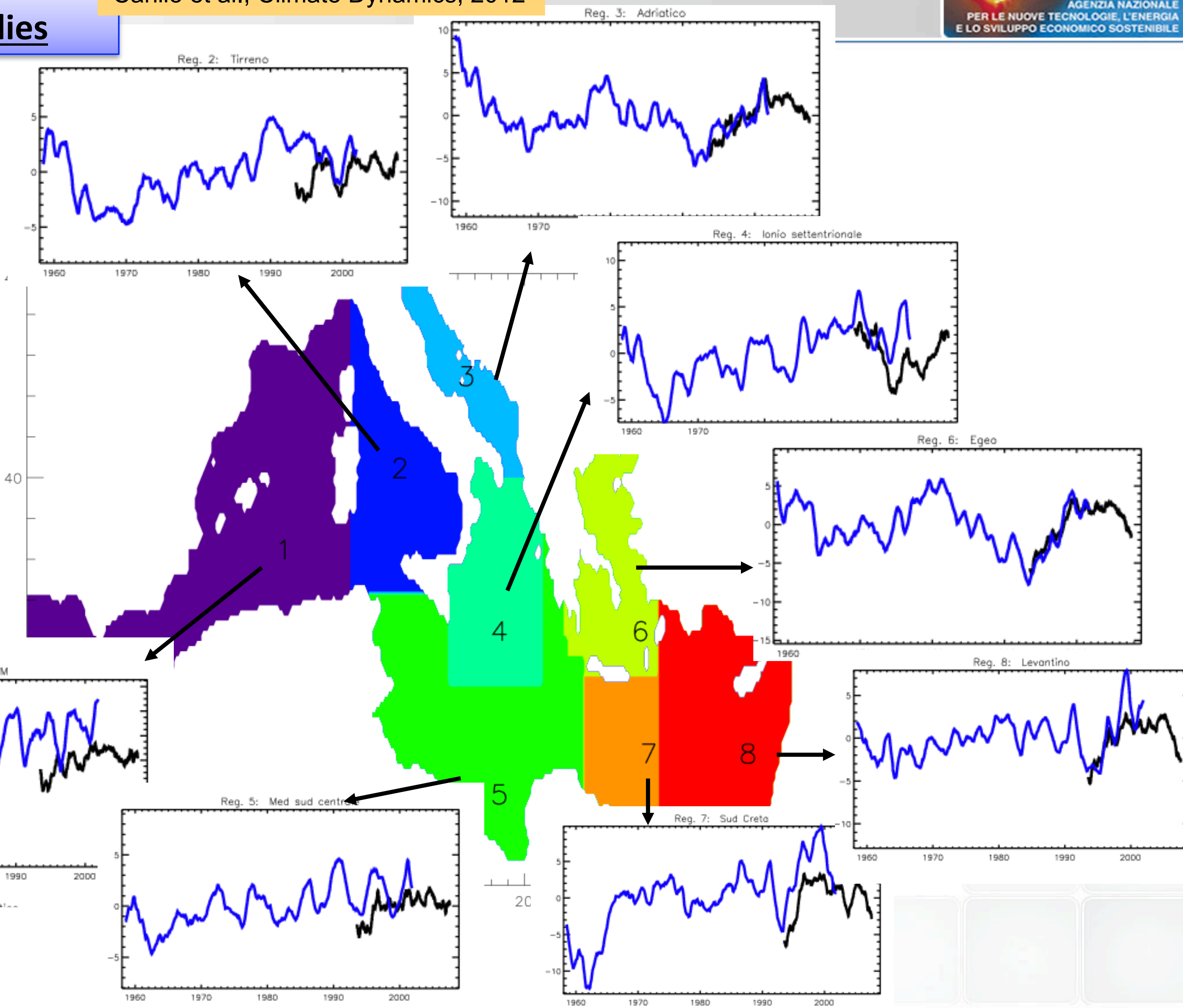
- SLR
- Aridity Index
- Snow cover
- Total runoff
- Olive system
- Land-cover change

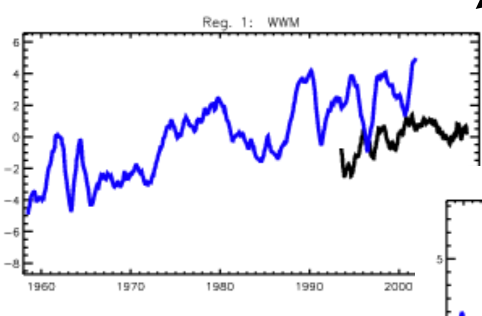
PROTHEUS Validation: Present climate simulation

Carillo et al., Climate Dynamics, 2012

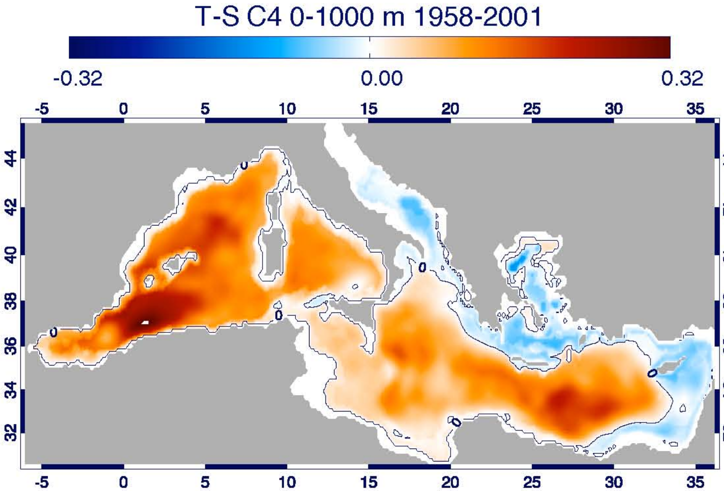
Sea Level Anomalies

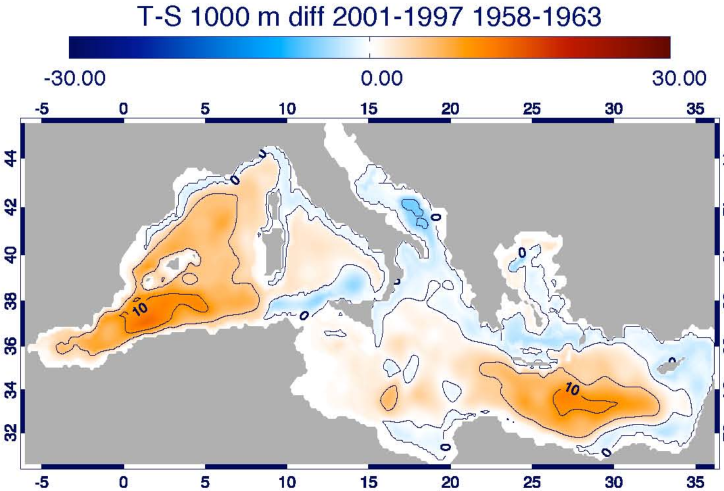
Total sea level anomalies for the Mediterranean sub-basins. Values computed from PROTHEUS ERA40 run (blu line) & altimeter data (black line).

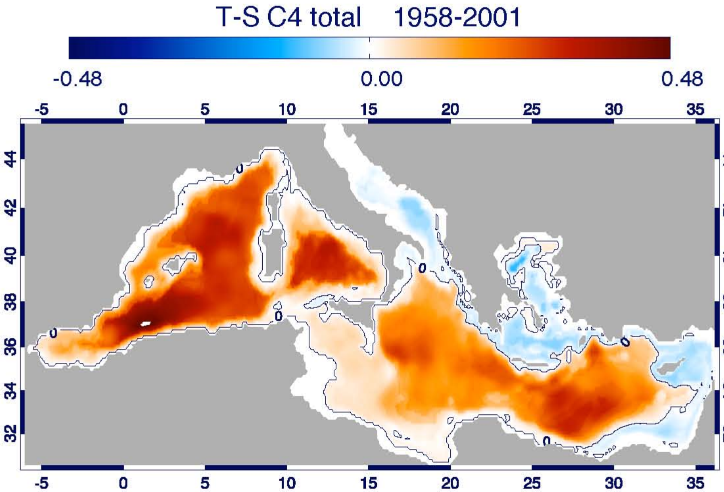


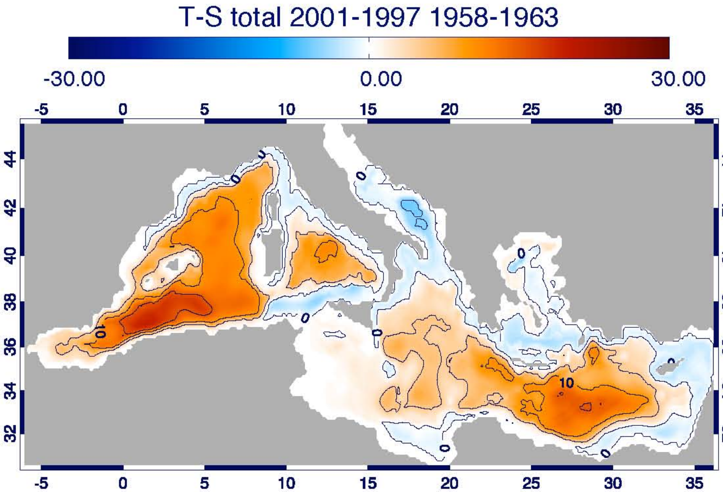


Sea level trend

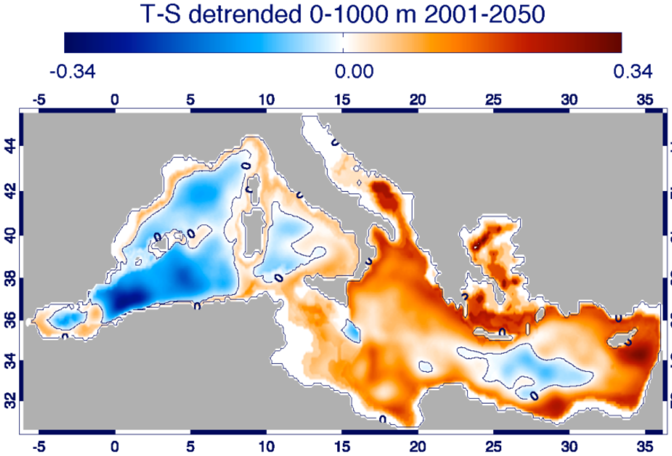


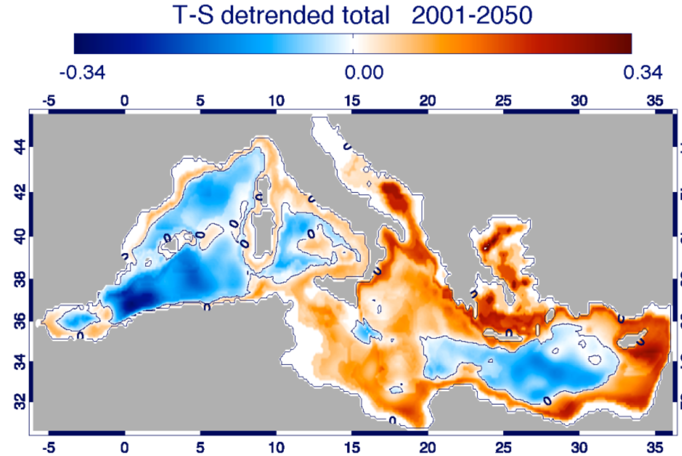


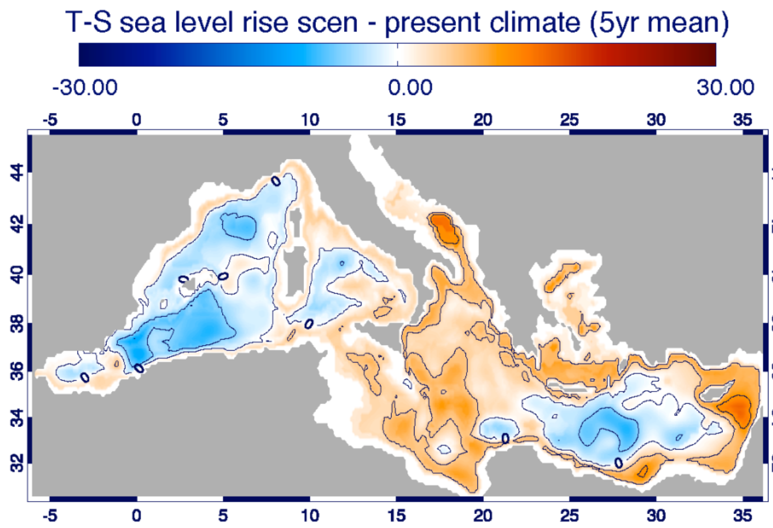




Sea level trend for the scenario period







Caveat for intepreting the western basin due to uncertainties related to the Atlantic water inflow

The Ionian and Adriatic Sea will experience the strongest sea level rise after 2040

PROTHEUS SCENARIO simulations

BC for MITgcm

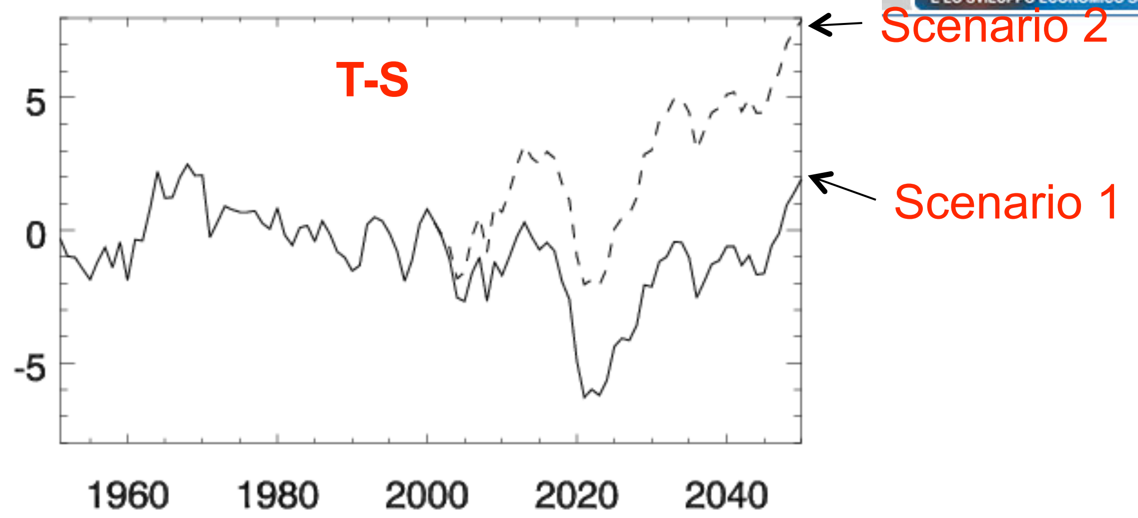
Scenario 1

Temperature and salinity are relaxed in the Atlantic box to monthly mean values. These values are obtained adding to the climatological data the tracers anomalies derived from the global coupled model and computed respect to the present climate simulation.

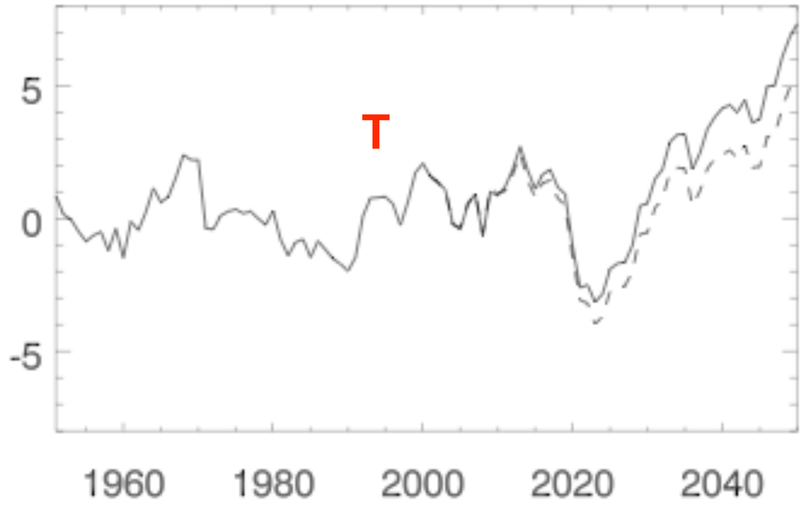
Scenario 2

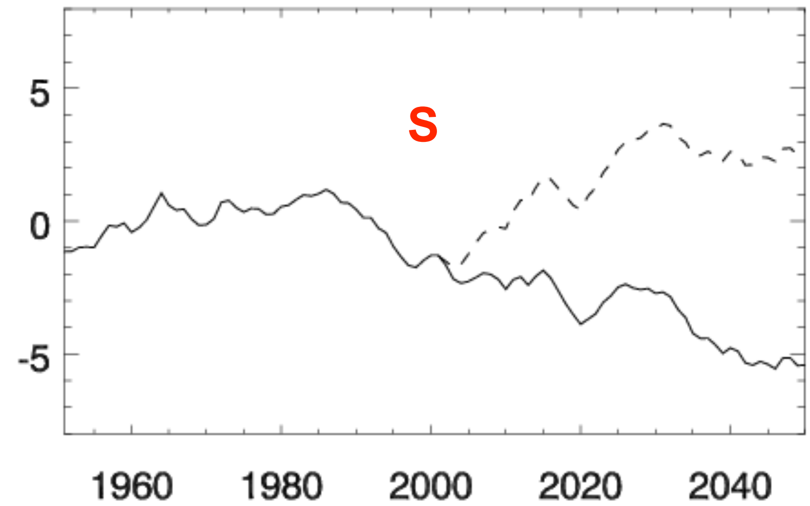
Temperature and salinity are relaxed in the Atlantic box to monthly mean values obtained from the coupled global run.

Steric sea level trend

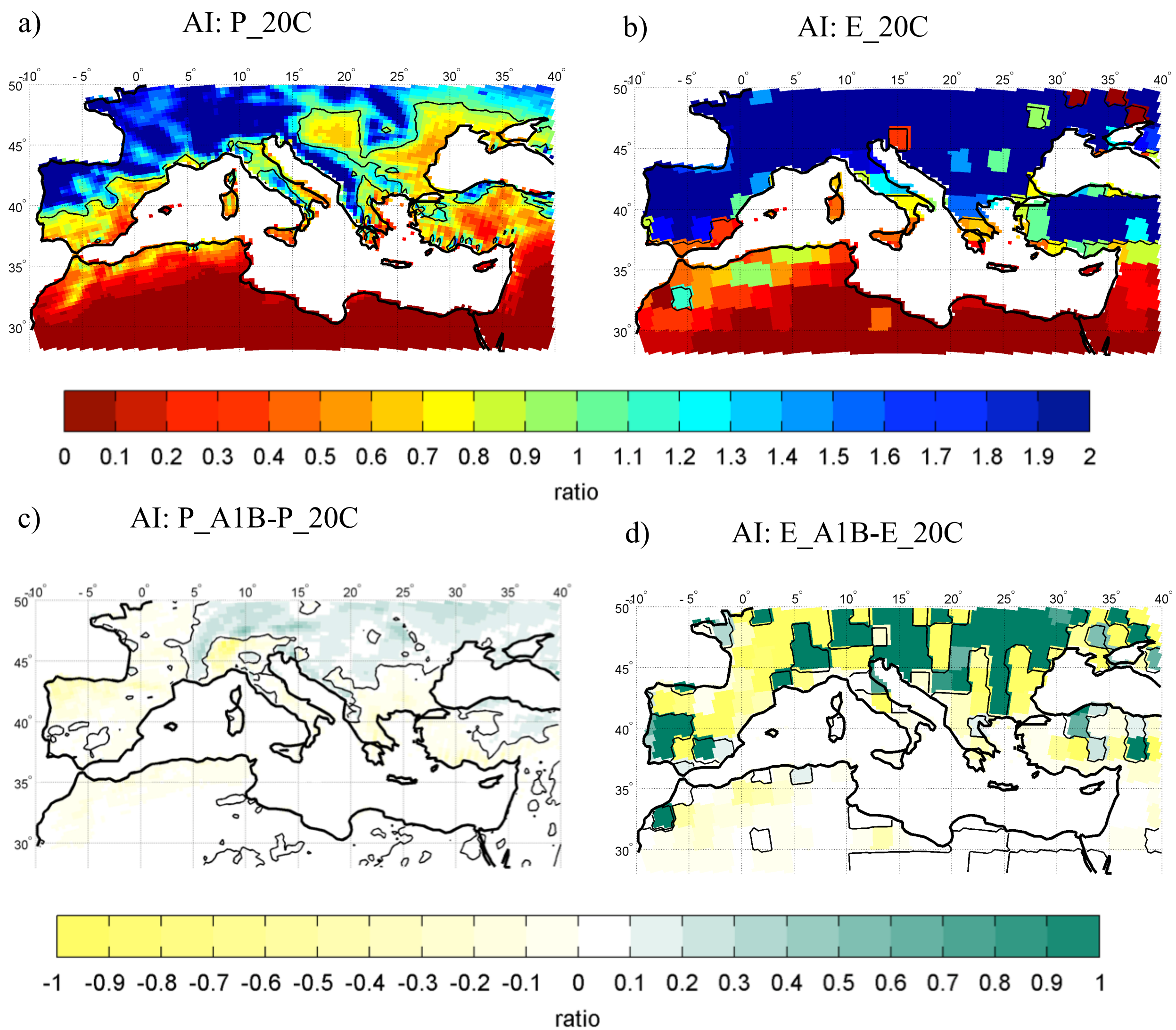


Linear trend computed over the present climate run (1950-2000) has been subtracted





The Aridity Index is defined by the ratio: AI = pr/PET, annual cumulated precipitation/annual potential evapotranspiration

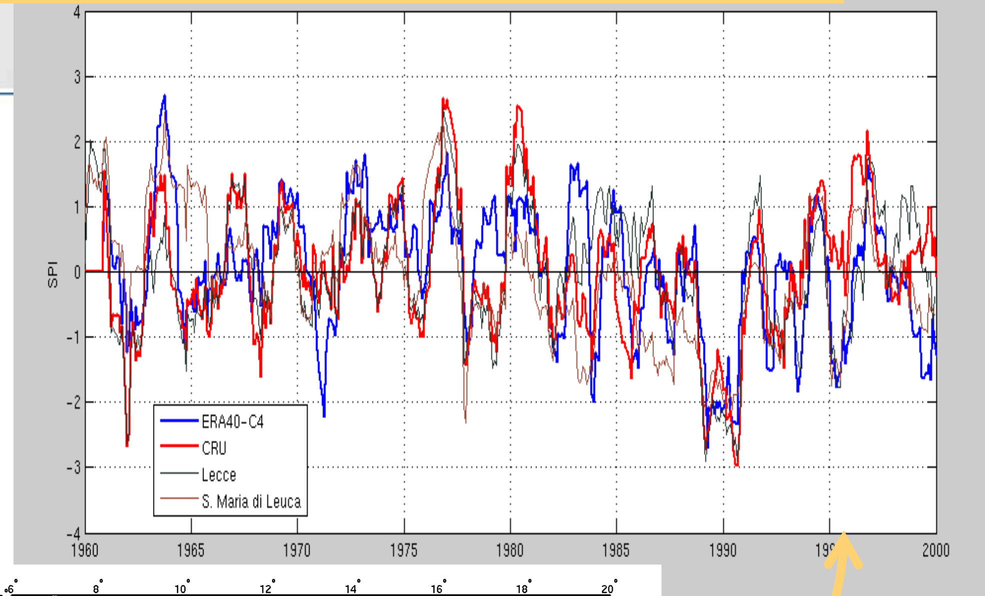


Aridity Index: AI in PROTHEUS and ECHAM5/ MPI-OM simulations. a-b) Mean values in P_20C and E_20C, respectively. The solid lines here pertain to the *AI=1* contours. As usual, we consider the reference period 1961-1970. (c-d) *AI* changes (A1B-20C) . The solid lines here pertain to the zero difference contours. The global driver patterns are reported onto the PROTHEUS grid to make the comparison easier.

Climate reconstruction 1961-2000,PROTHEUS System

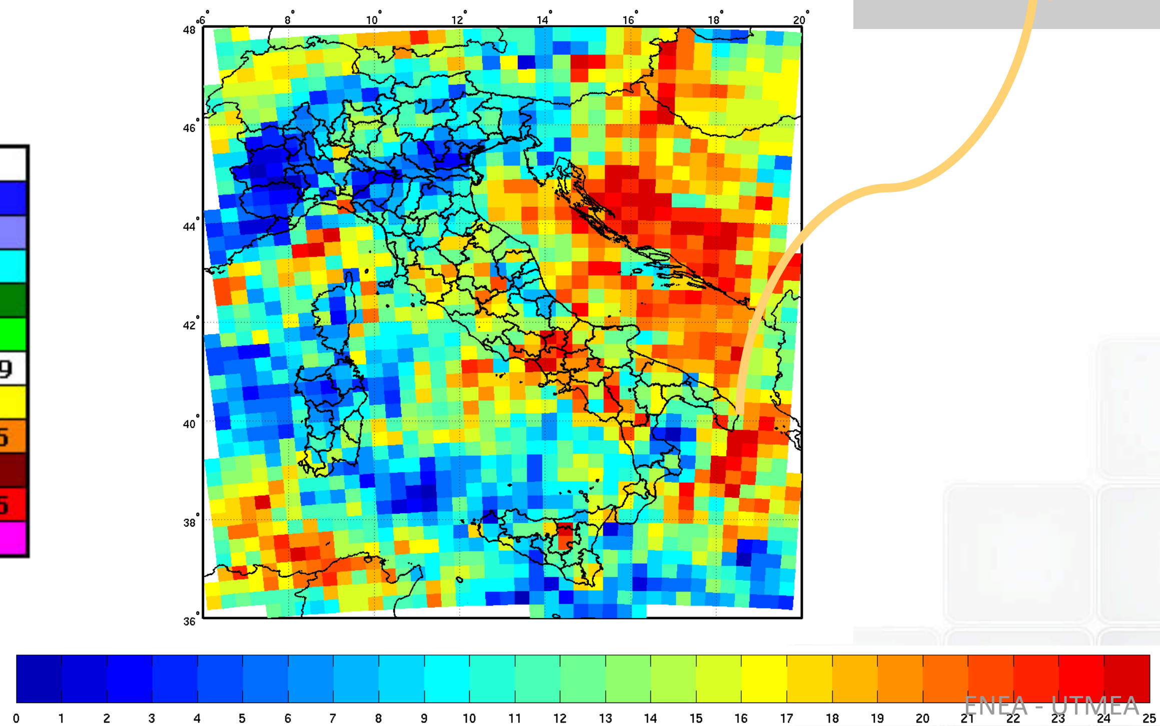
SPI drought index calculated at 12 months:

A prolonged lack of rain for many months will have effects on river flows, while on the scale of one to two years will impact on the availability of water in aquifers.



Numero mesi con SPI 12mesi <-2

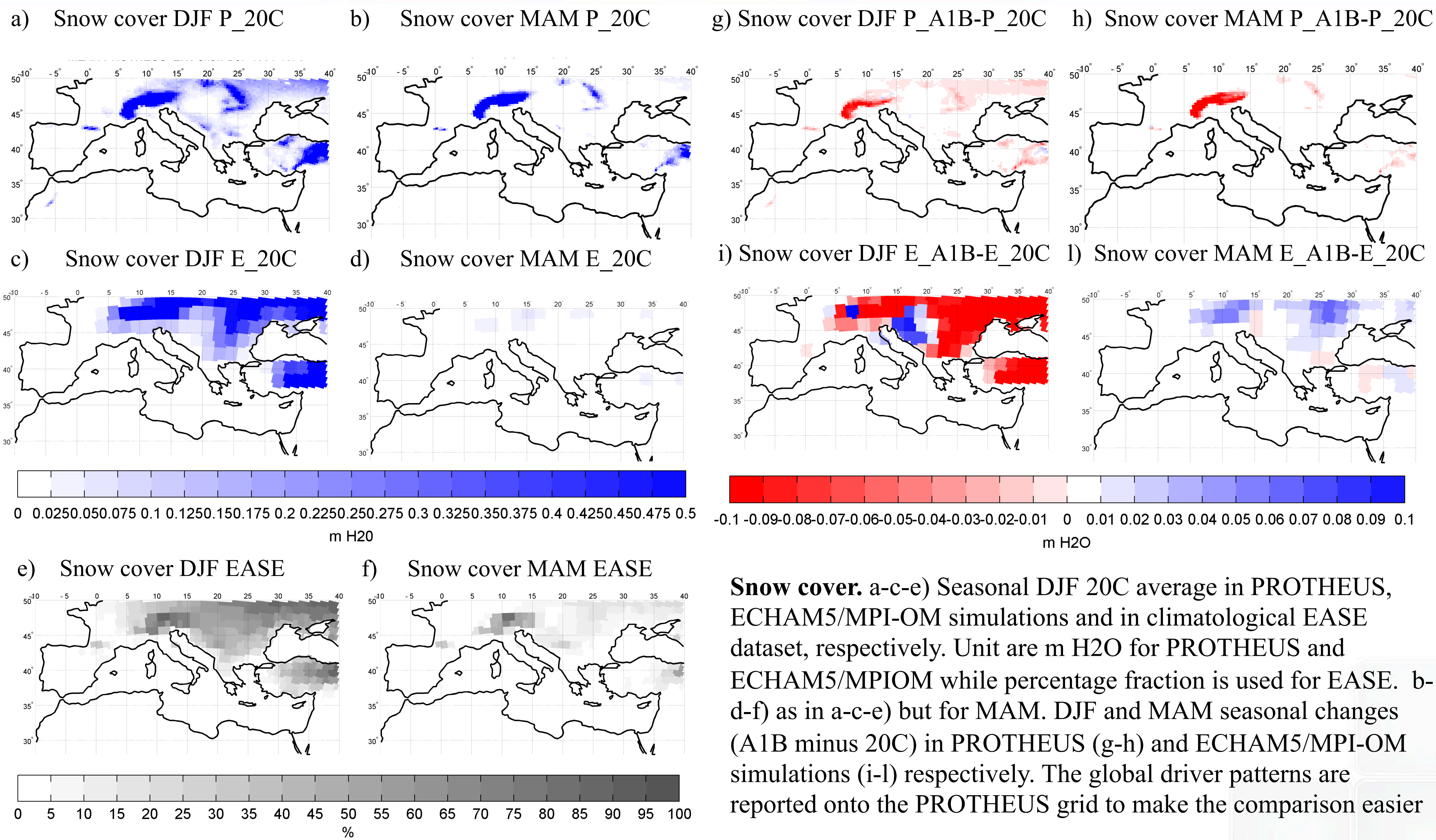
Classe	Indice SPI
Grave >2	>3
	da 2.5 a 2.99
	da 2 a 2.49
Severamente umido	da 1.50 a 1.99
Moderatamente umido	da 1 a 1.49
Vicino al normale	da -0.99 a 0.99
Moderatamente siccitoso	da -1.49 a -1
Severamente siccitoso	da -1.99 a -1.5
Estremamente siccitoso < -2	da -2.49 a -2
	da -2.99 a -2.5
	<-3



ENEA - UTMEA

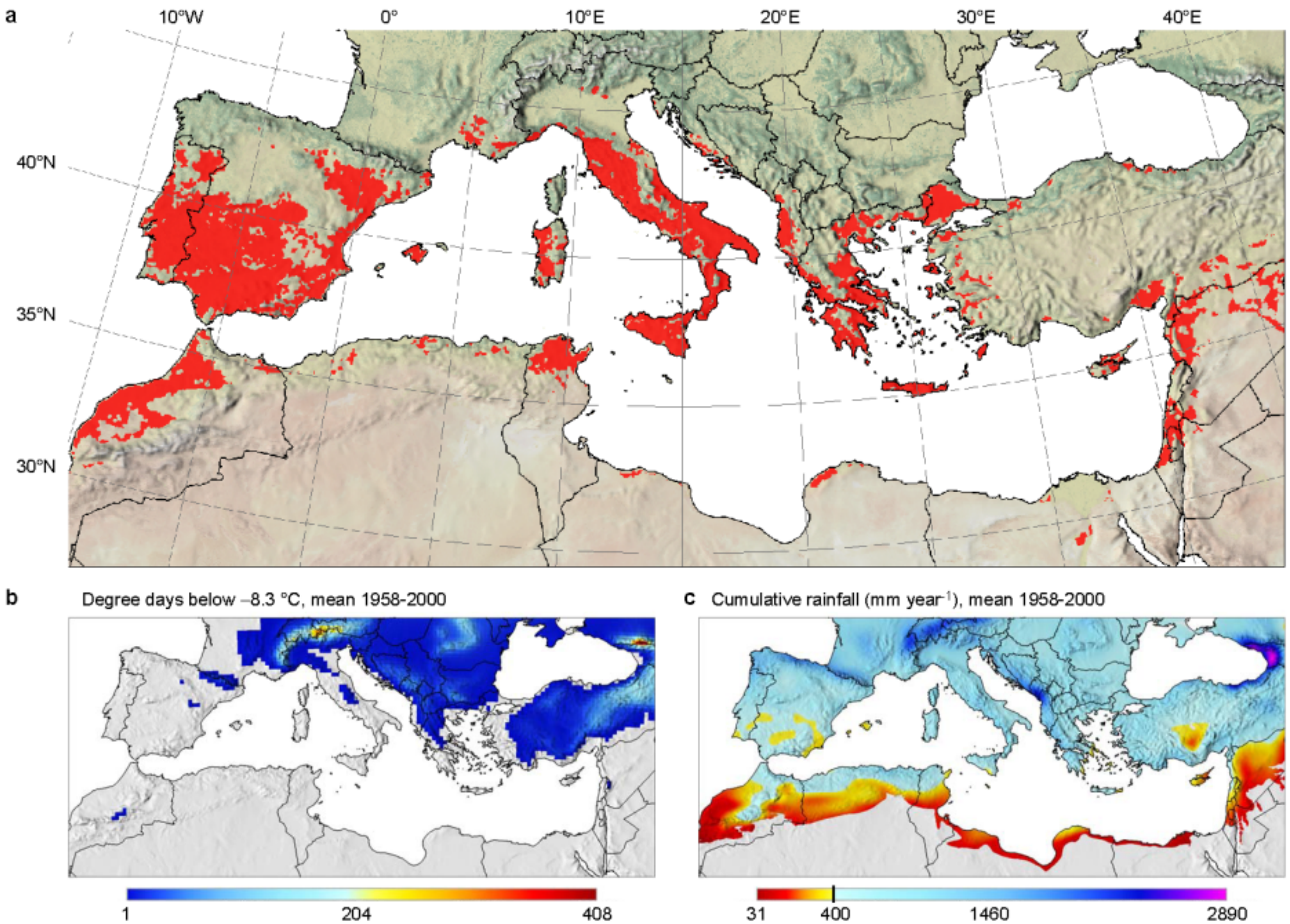
SNOW COVER

ENEA
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

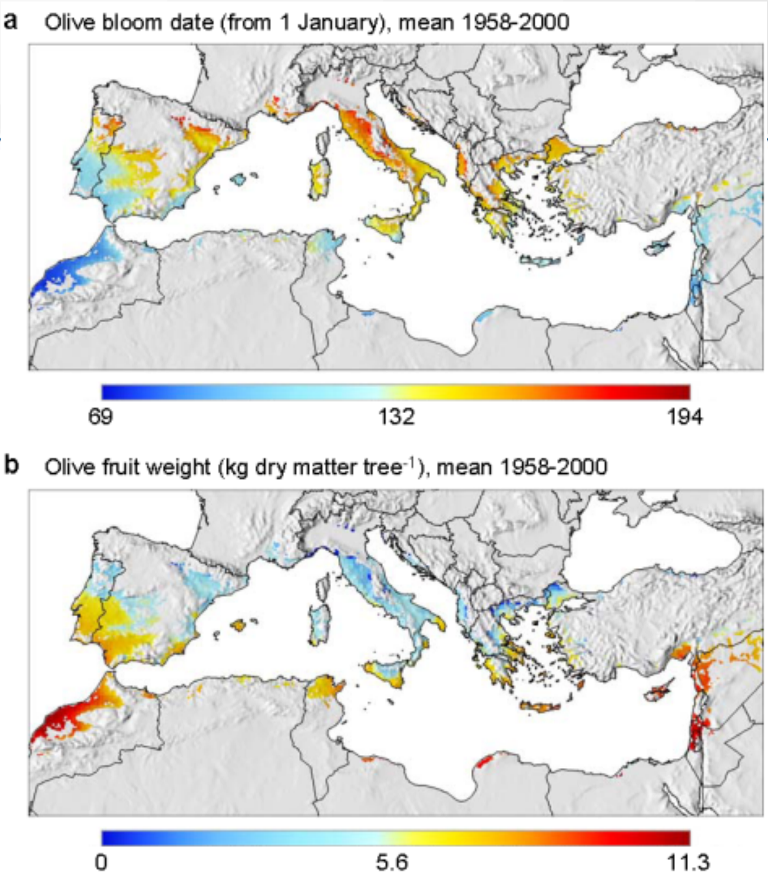


Snow cover. a-c-e) Seasonal DJF 20C average in PROTHEUS, ECHAM5/MPI-OM simulations and in climatological EASE dataset, respectively. Unit are m H2O for PROTHEUS and ECHAM5/MPIOM while percentage fraction is used for EASE. b-d-f) as in a-c-e) but for MAM. DJF and MAM seasonal changes (A1B minus 20C) in PROTHEUS (g-h) and ECHAM5/MPI-OM simulations (i-l) respectively. The global driver patterns are reported onto the PROTHEUS grid to make the comparison easier

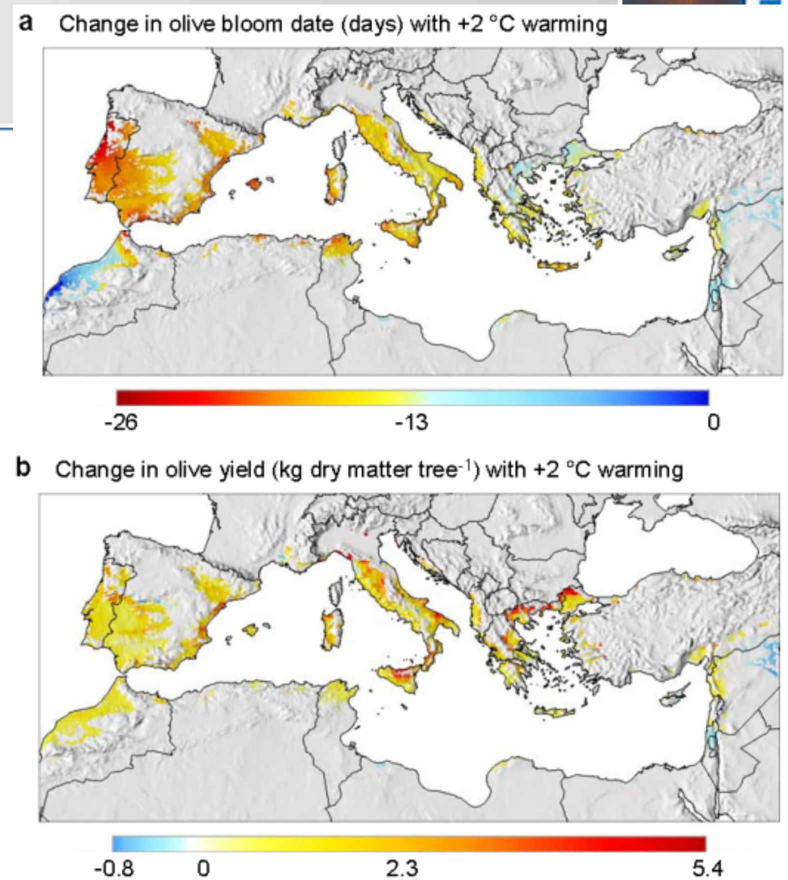
Effects of present and warming climate on olive systems in the Mediterranean basin



Observed distribution and climatic favorability of olive in the Mediterranean basin. a) Observed olive growing area (red) superimposed on a shaded relief showing satellite-derived land cover. b,c) Mean degree days below -8.3 °C (lower thermal threshold for olive) (b) and mean yearly rainfall (mm y-1) (c) for the period 1958-2000 based on the PROTHEUS present climate dataset. In (c) only non desert ecological zones are mapped and a value of 500 mm y-1 is indicated as a reference precipitation amount above which commercial yields are expected for olive under rain fed conditions.



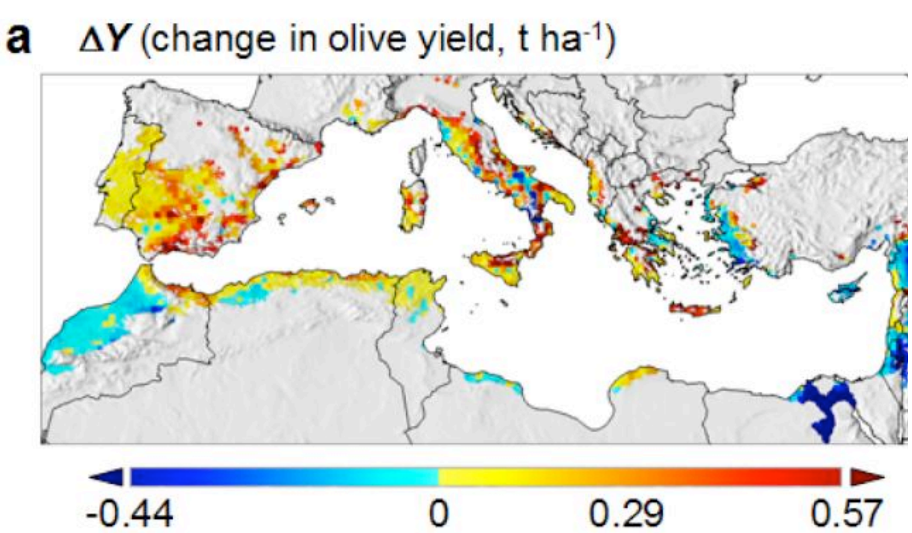
Simulated olive dynamics in the Mediterranean basin. a,b) Mean bloom date (a) (days from 1 January) and mean yield (kg dry matter tree-1) (b) for the period 1958-2000. (based on PROTHEUS)

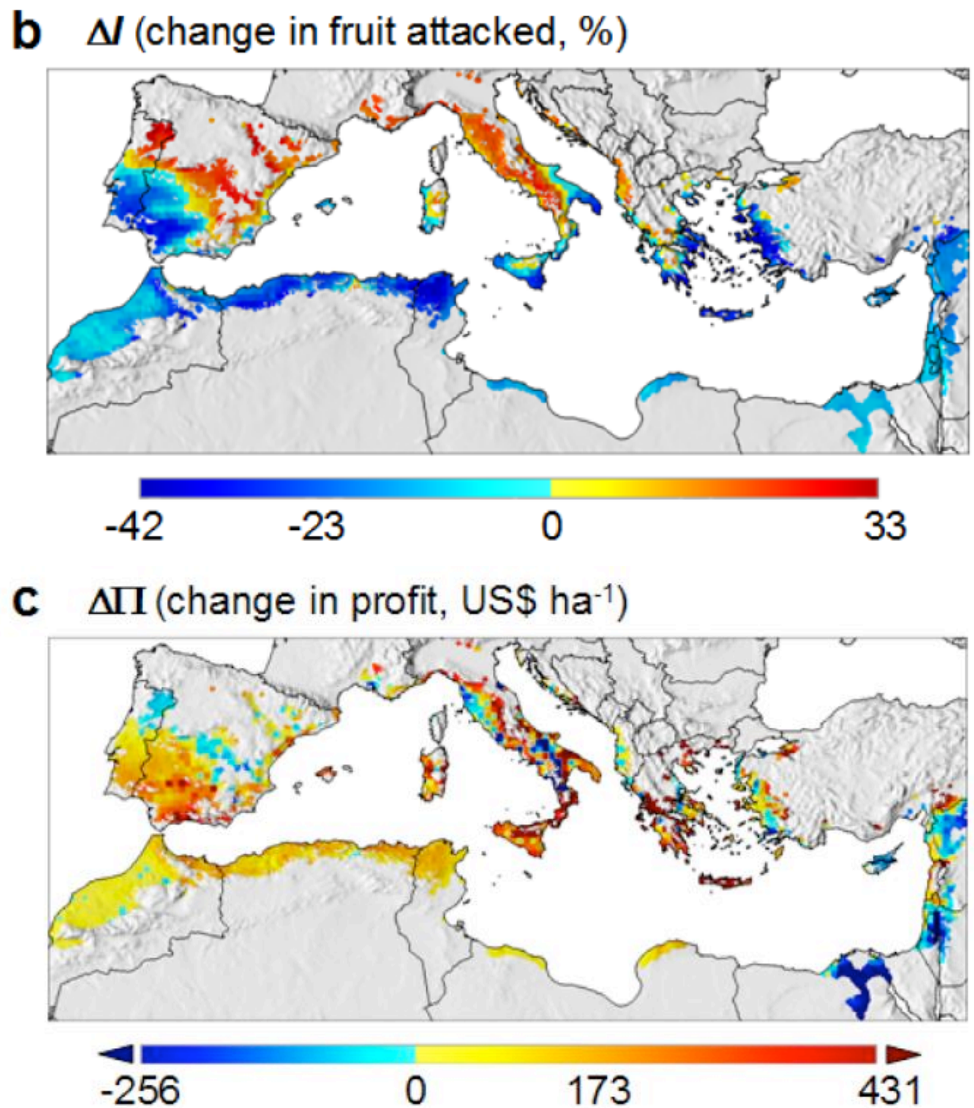


Mapping the effects of a +2 °C climate warming scenario on olive and olive fly in the Mediterranean basin. a) Advancement of olive bloom date (days). b) Change in olive yield (kg dry matter tree-1). (based on PROTHEUS)

Luigi Ponti, Andrew Paul Gutierrez, Paolo Michele Ruti, Alessandro Dell'Aquila

Terrestrial ecosystems: the case of the olive (Ponti et al, 2012)





a) Forecast of climate change in olive production (t / ha)
b) infestation% of fruit attacked c) variation of profit (U.S. $ / ha)

Data produced using the A1B scenario, simulations Protheus

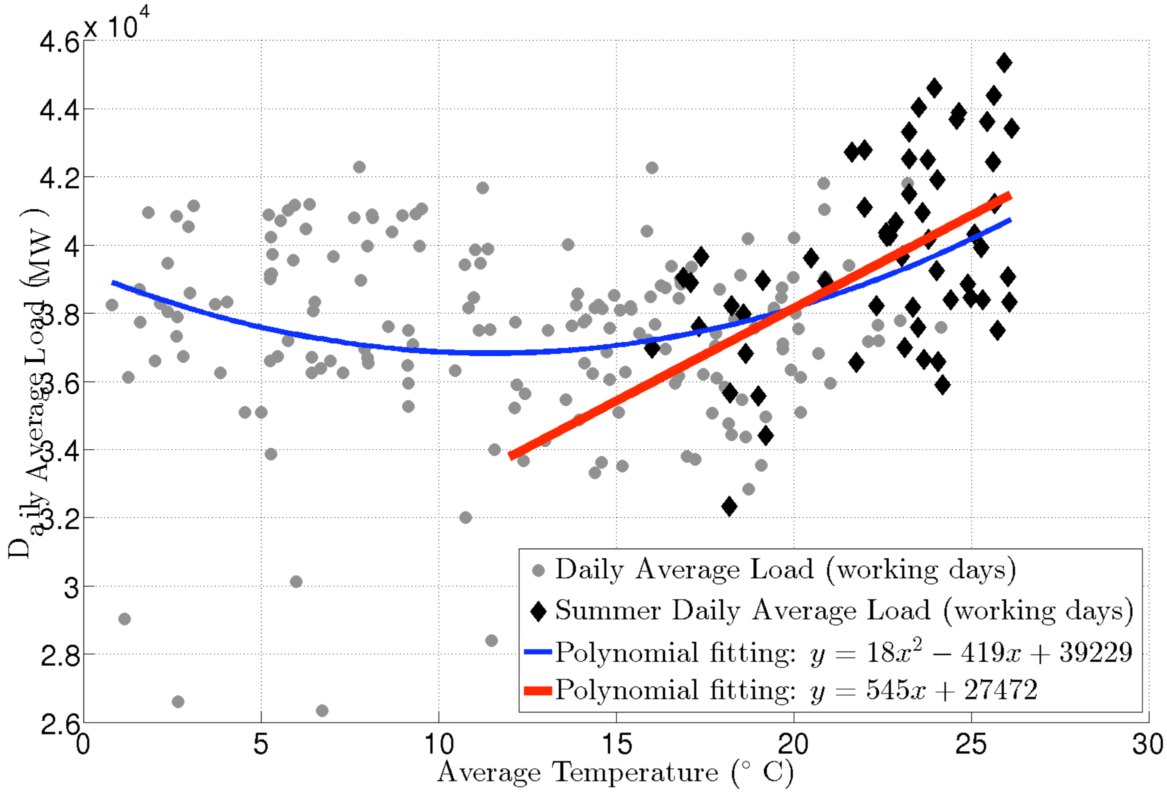
We find that regional patterns of olive and olive fly under present climate are consistent with field observations.
Climate warming increases olive yields especially in presently unfavorable areas where also olive fly is enhanced via bottom-up effects from the plant.

Surprisingly, climate warming reduces olive fly abundance in areas of present high favorability to the pest despite concurrent increases in olive yield.

We propose that by including species interactions as driven by Mediterranean climate data of unprecedented detail, our multitrophic analysis overcomes a major deficiency in current regional assessments of climate effects on ecosystems.

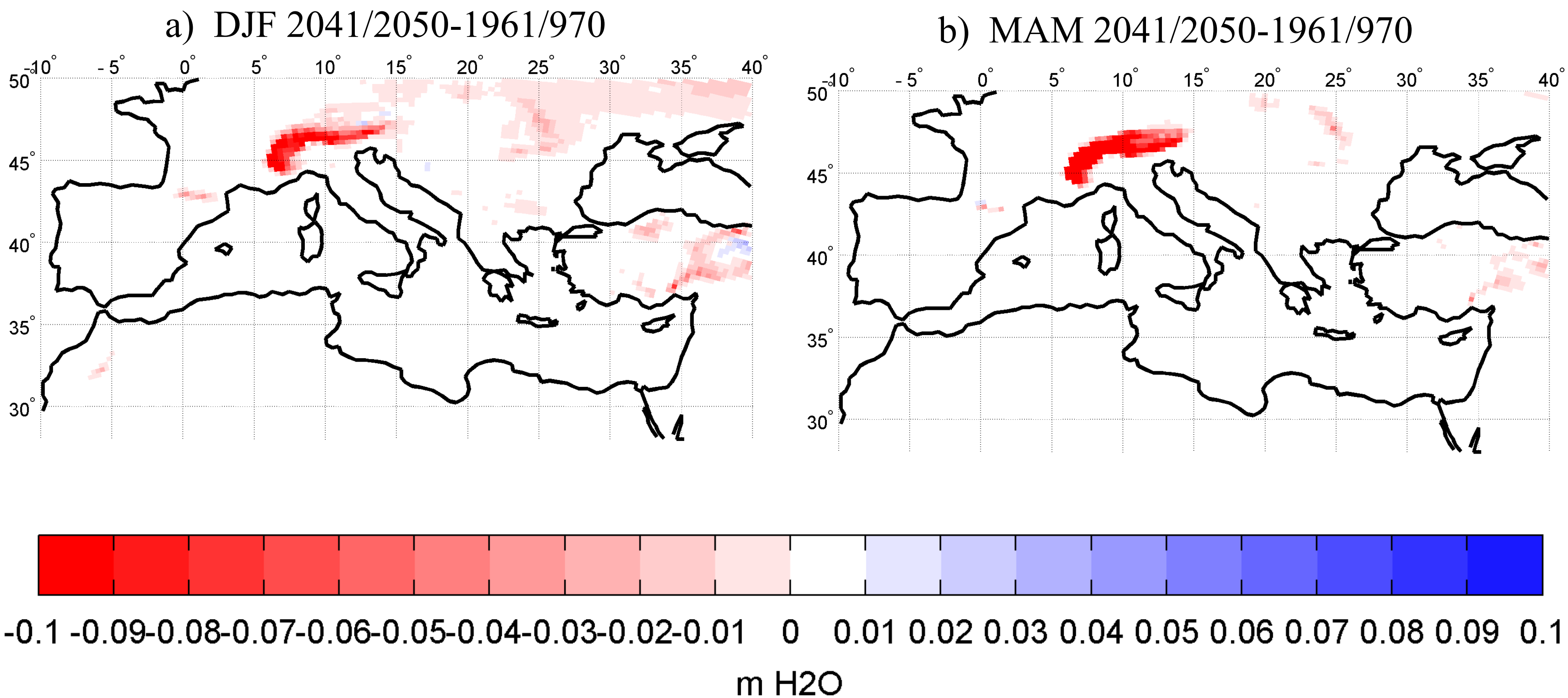
ENERGY - Electricity Network Loading

(Ruti – De Felice, Energy and Climate, Springer 2012)



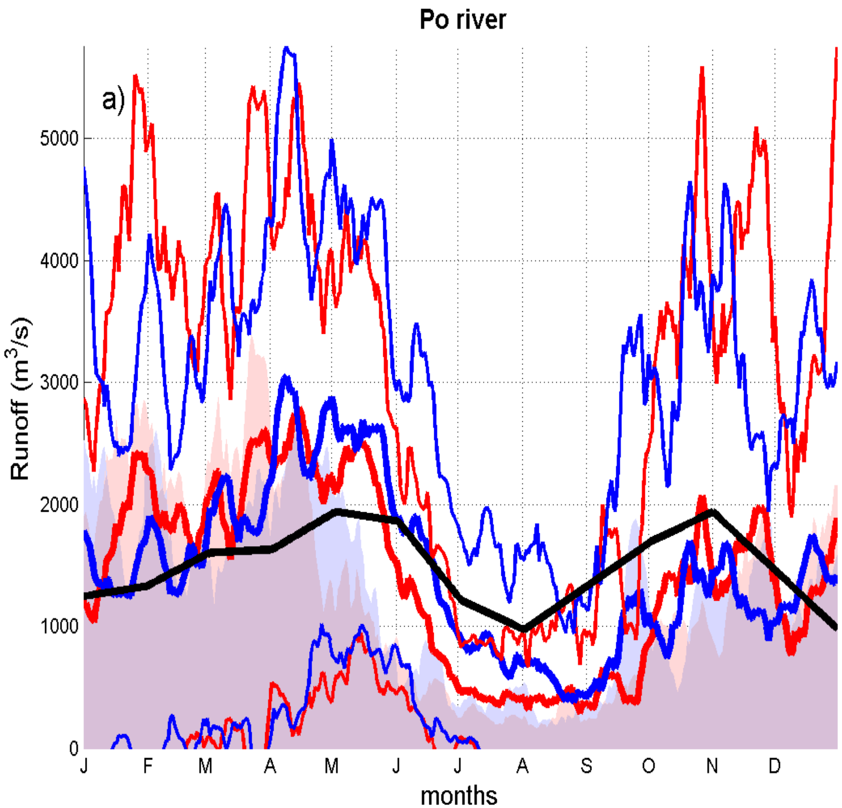
This figure shows the relation between network load and temperature for the summer. This report is used to evaluate the network impact of temperature trends for the next 20-40 years old.

TOURISM - snow cover (Dell'Aquila et al., 2012 Climate Research)



Future climate projections obtained with the energy scenario IPCC SresA1B.
Model PROTHEUS. This signal on the snow cover is not present in the global models used to force PROTHEUS

Impatti Idrologici



Controllo 1961-1970 ±σ

Scenario A1B 2041-2050 ±σ

Climatologia osservata

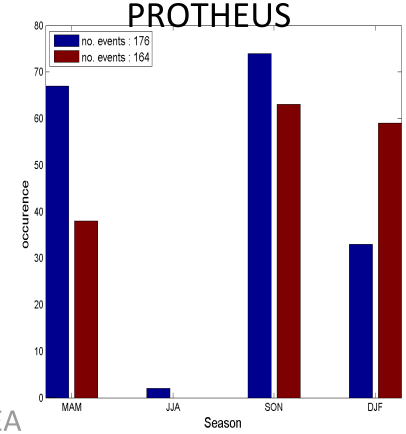
Variabilità del modello globale forzante ECHAM5

Controllo 1961-1970

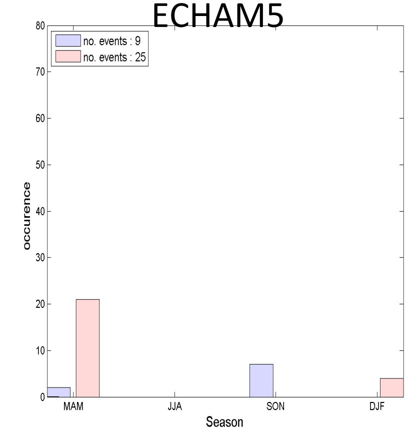
Scenario A1B 2041-2050

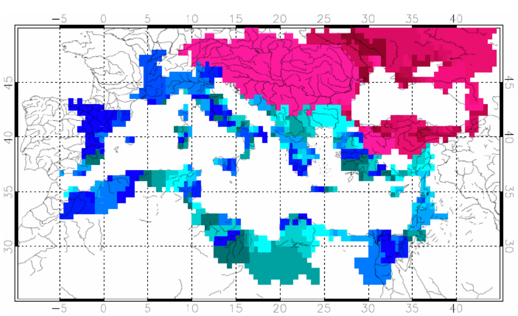
Distribuzione stagionale degli eventi intensi (I > Ī + 2σ)

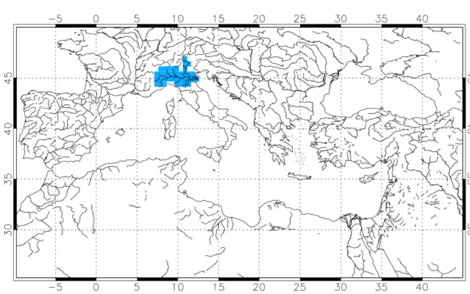
PROTHEUS



ECHAM5

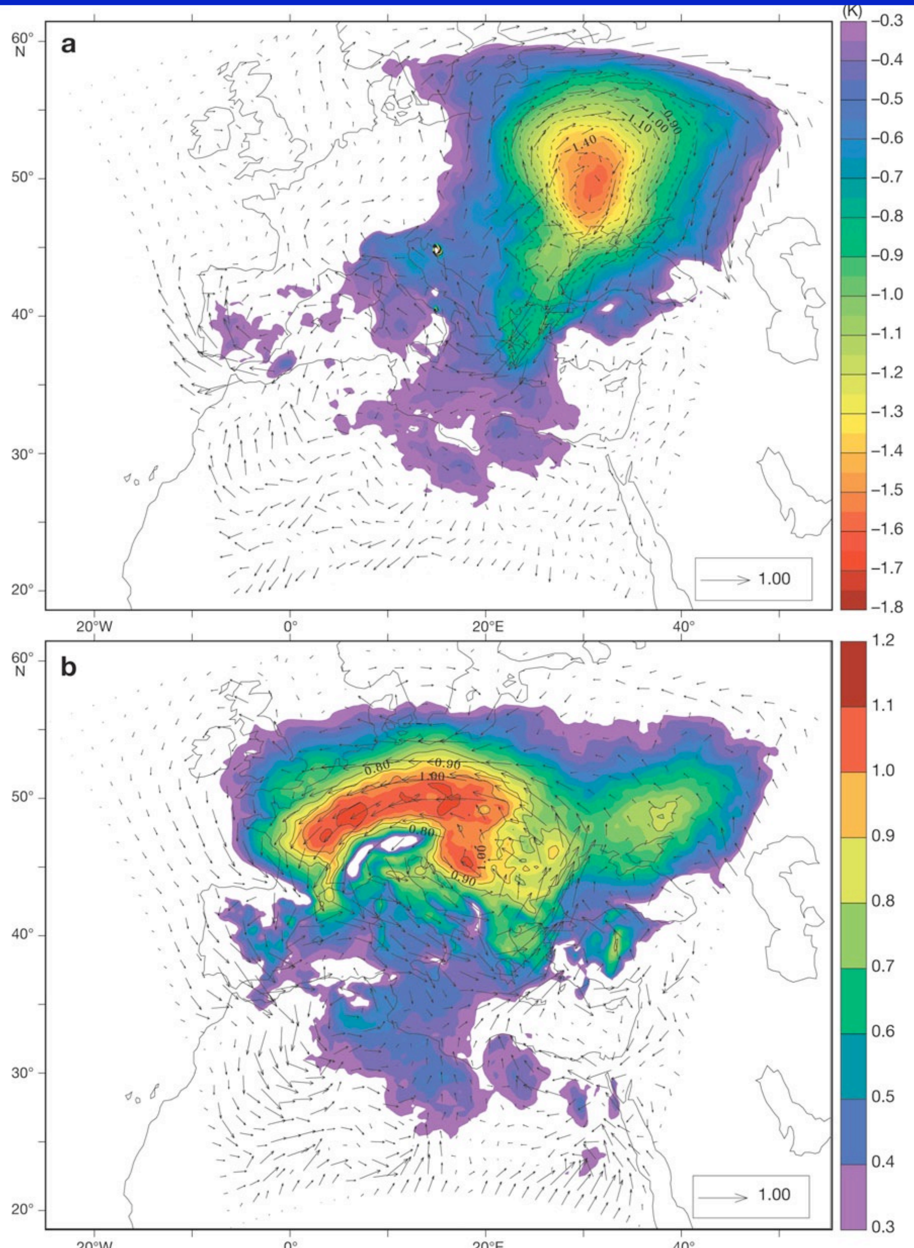






ENEA - UTMEA

Modelling the effects of land-cover changes on surface climate in the Mediterranean region



Differences in horizontal wind vectors (arrows, m s–1) and temperature (color scale, K) at 960 hPa over the summer season (June–August) between the control run and the (a) deforestation and (b) afforestation simulations. The contour lines indicate where these differences are statistically significant (*t*-test, $p < 0.01$)

Some Conclusion

From a review of all available data set for the Mediterranean Sea we found an warming trend of 0.022 °C/decade in SST over the last 150 yrs, moreover in the Gulf of Cadiz the MOW displays a trend of 0.16 °C/decade and 0.05/decade in salinity over the last 50 yrs;

The coupled model (Protheus System) predicts significant interannual variability including EMT and acceleration of warming in particular after the 2020 with an average value of 0.16 °C/decade; the steric sea level trend ranges in the basin from -0.32 cm/yr to 0.34 cm/yr , with a mean over the Mediterranean of 0.028 cm/yr . A strong increase in the sea level trend due to the thermal component is observed in the second part of the 50 year simulation.

Protheus simulation analysis shows significant differences in the occurrence and in the patterns of intense rainfall episodes between the downscaling and the global driver. In particular a more accurate description of complex orography surrounding the Mediterranean Sea, as well as of land surface processes, produces more organized patterns in the tendency of key impact indicators such as the aridity index and the snow cover.

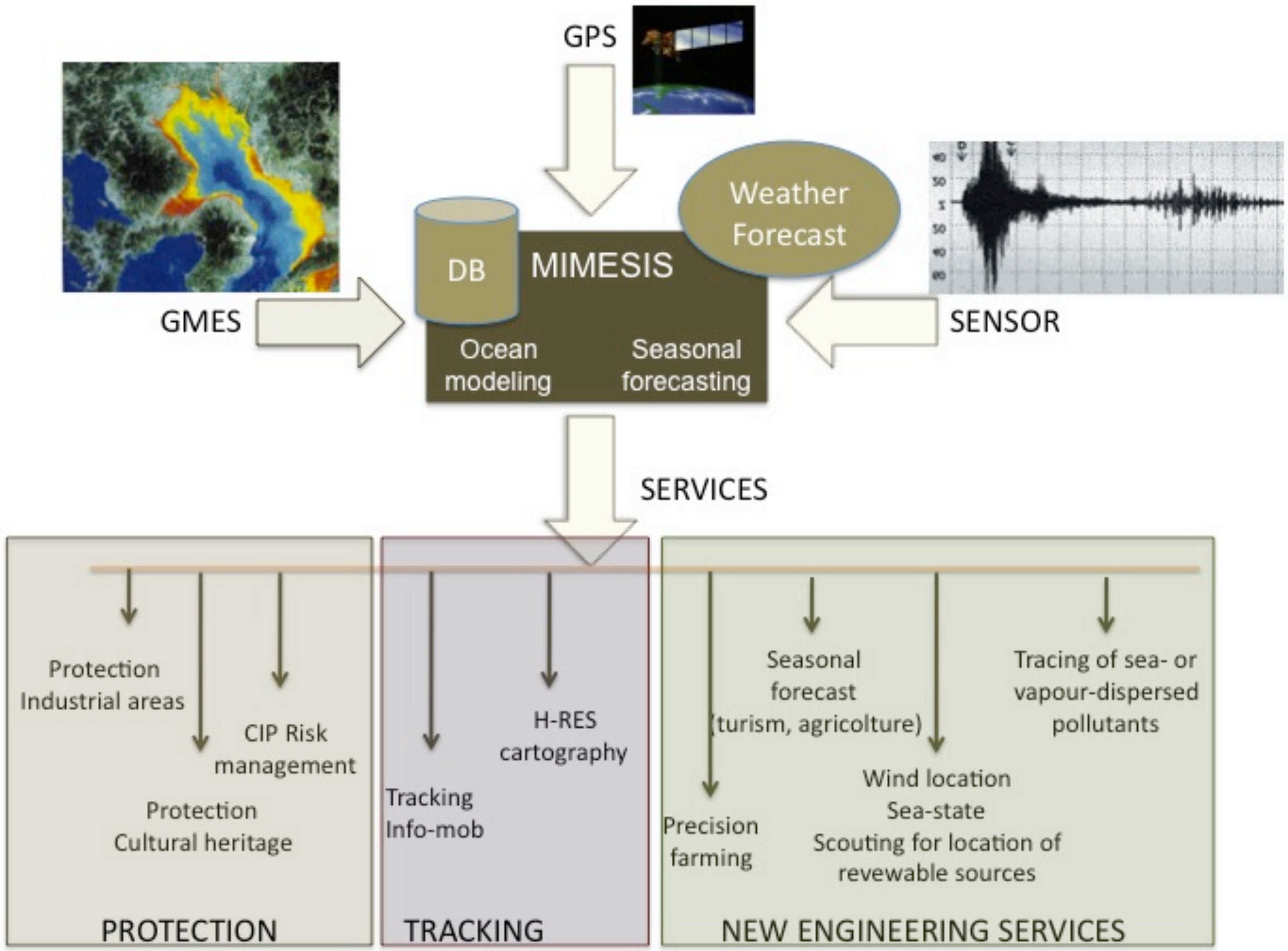
TECHNOLOGY FOR ADAPTATION

Description of the technology

ENEA are developing a modeling tool, technological platform (e.g. MIMESIS) and many other scientific instruments in the context of Security & Environment in order to respond to the Grand Challenge of the connection between the environmental sciences (including climate) and the development of new technologies for the adaptation of infrastructures to the complex human-environment interactions in the special framework of the low-carbon society.

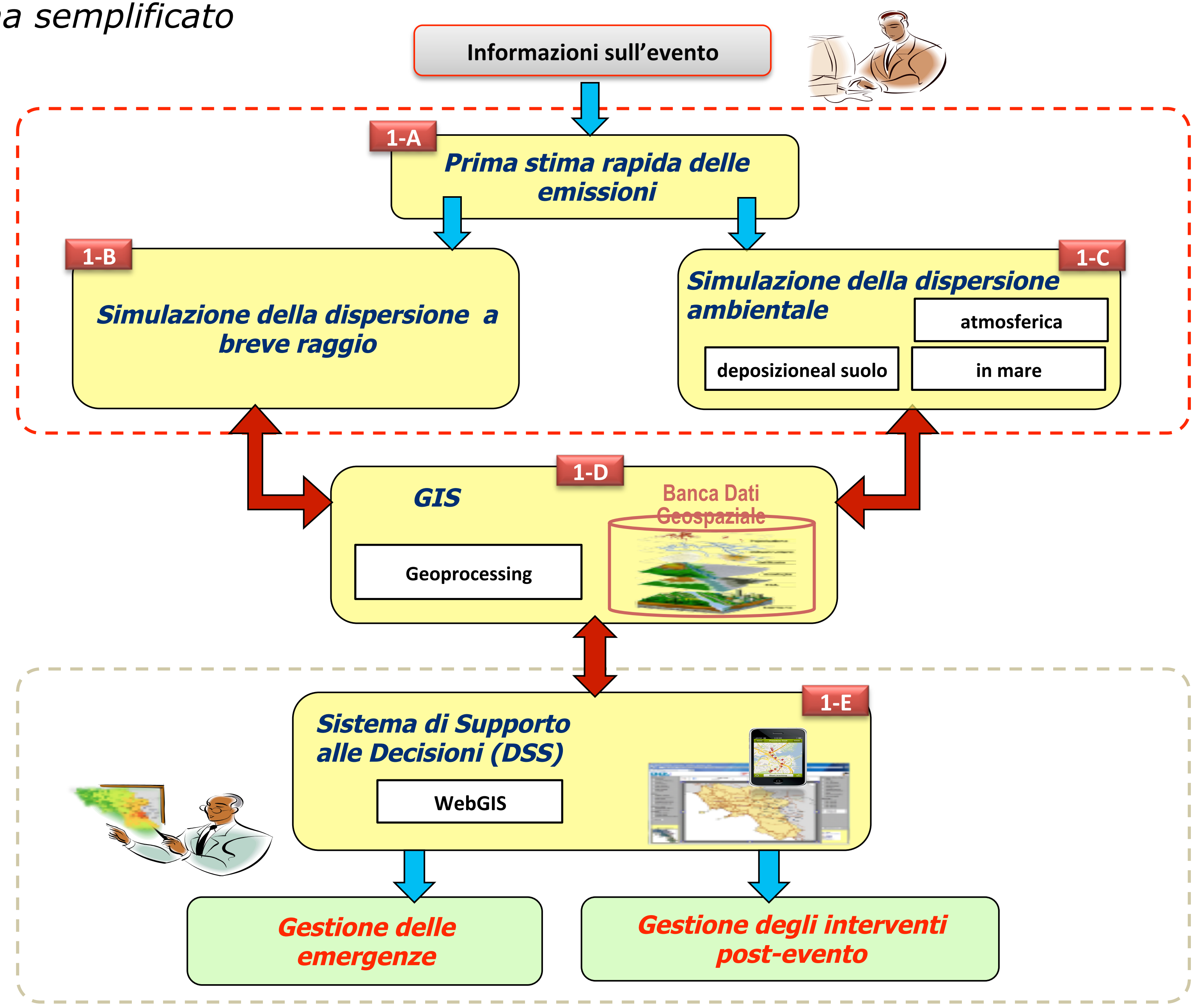
GIS database with regional data (geophysical, meteo-climatic, economical, industrial, Cis elements data) is constantly analyzed and crisis scenarios are predicted on the bases of weather prediction. The impact of Crisis scenarios on CI services are evaluated through the use of CI domain (or federated) simulators

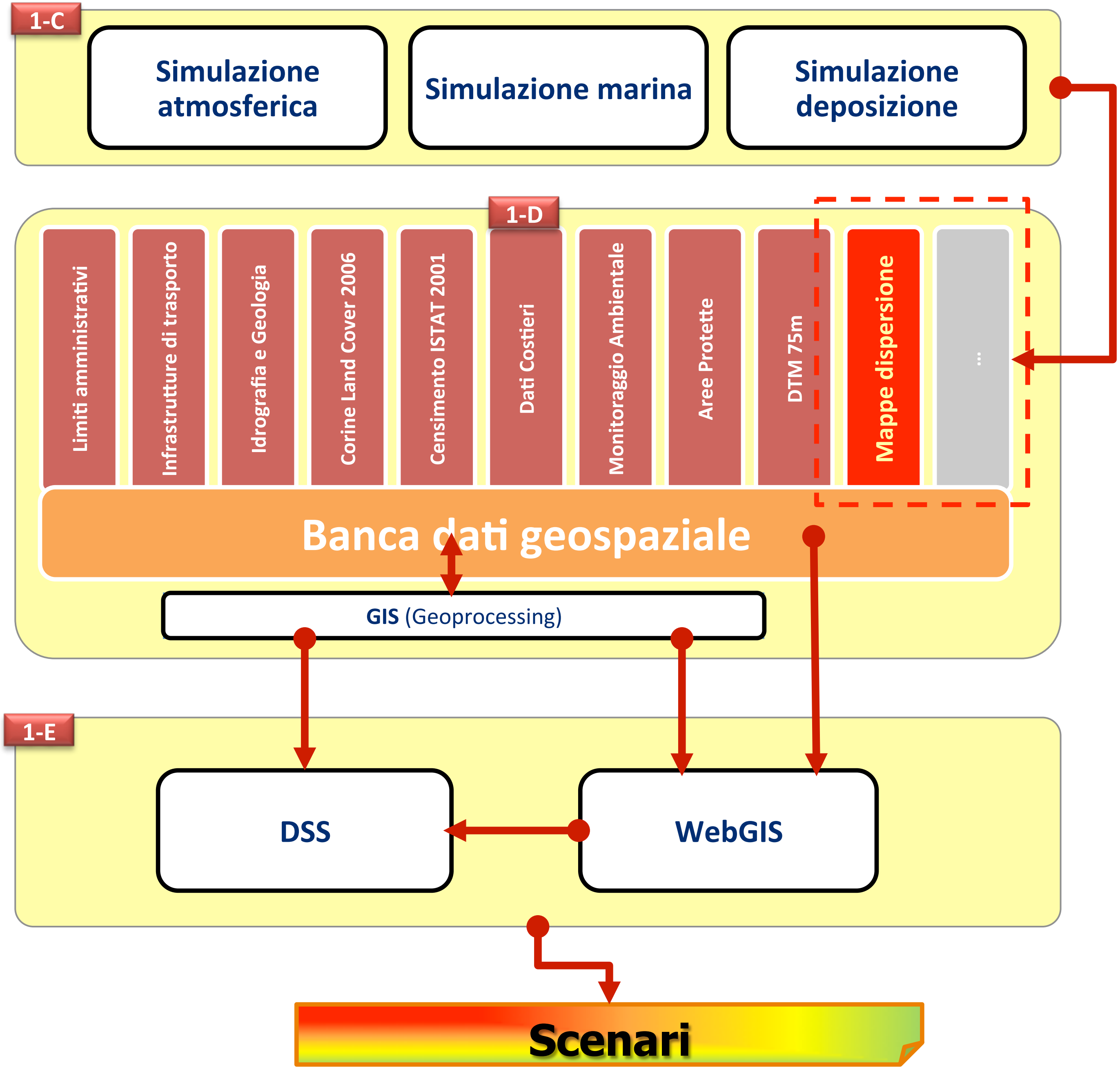
MIMESIS PLATFORM



DIFURAD

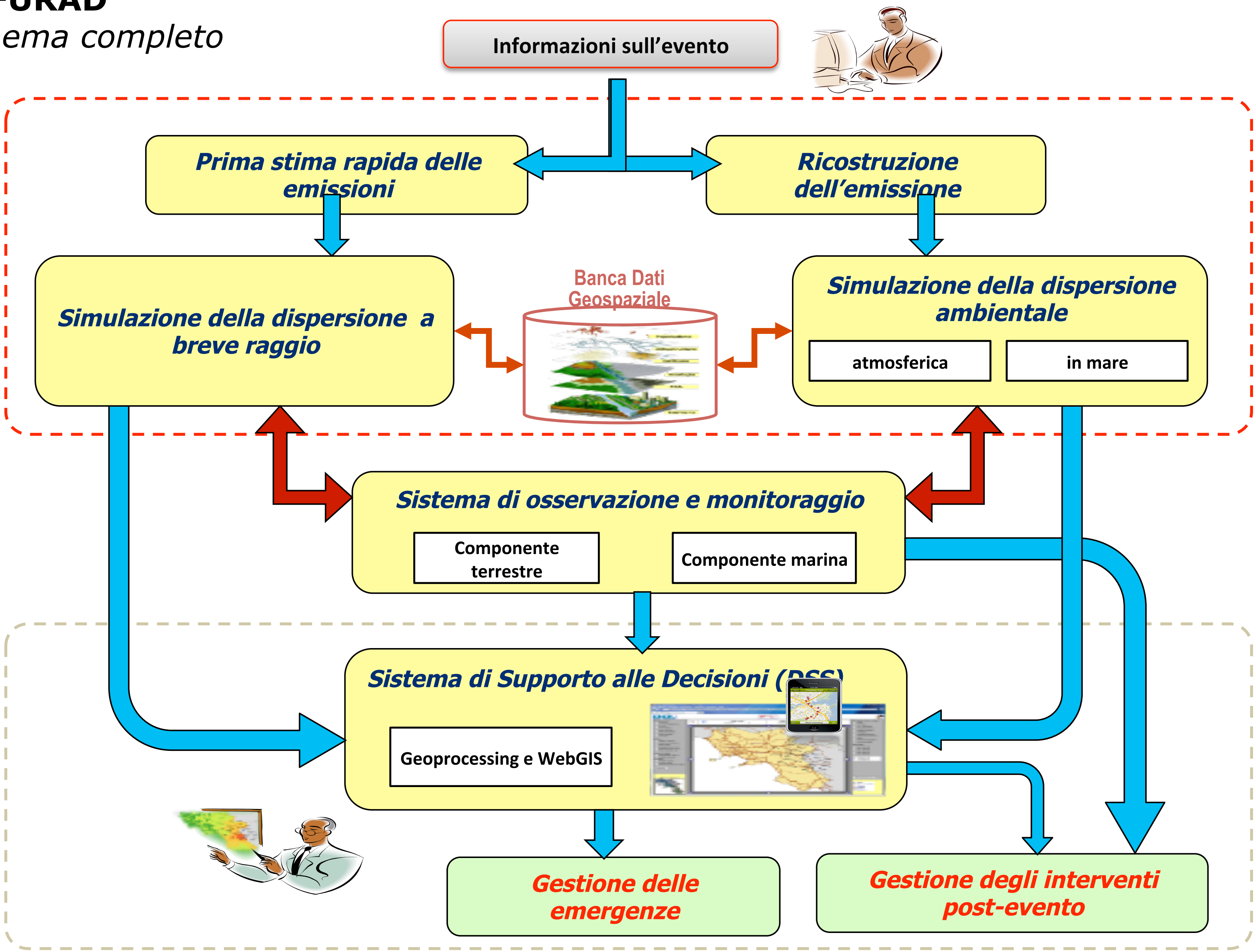
Schema semplificato



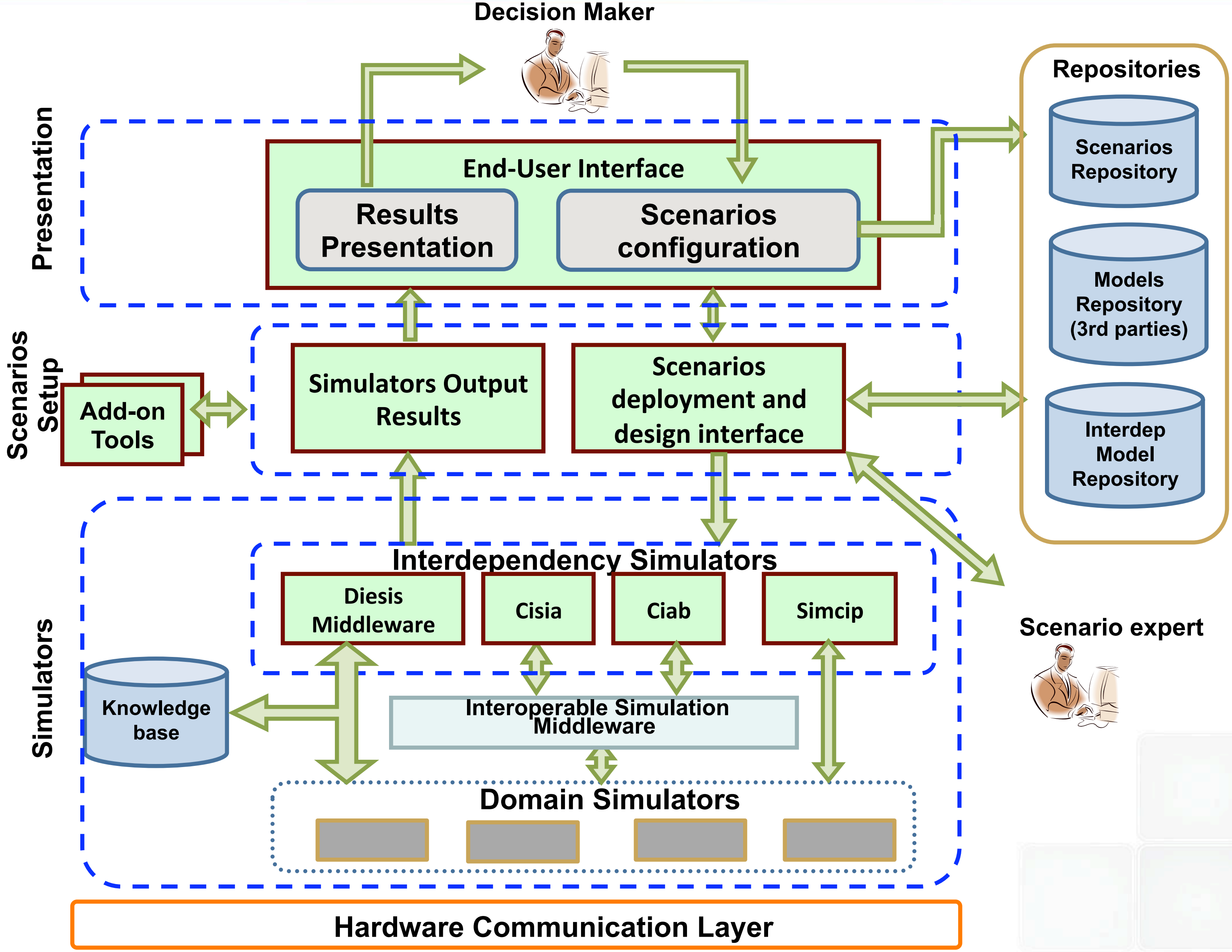

1-C
Simulazione atmosferica
Simulazione marina
Simulazione deposizione
1-D
Limiti amministrativi
Infrastrutture di trasporto
Idrografia e Geologia
Corine Land Cover 2006
Censimento ISTAT 2001
Dati Costieri
Monitoraggio Ambientale
Aree Protette
DTM 75m
Mappe dispersione
…
Banca dati geospaziale
GIS (Geoprocessing)
1-E
DSS
WebGIS
Scenari

DIFURAD

Schema completo



ENEA Modeling and Simulation Platform Architecture




Thanks for your attention !!