

The evolution of Etesians: Trends in 20th century and future projections

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Abstract The etesians are northern sector winds of the lower atmosphere and of the most persistent regional wind systems. They prevail over the Aegean Sea during summer and early autumn, contributing to decreasing surface temperature during summer and to regulating the concentration of the pollutants to the SE Mediterranean. This study investigates past and future (21st century) trends of etesian days and wind speed distributions in global and regional simulations undertaken within the Coupled Model Intercomparison Project Phase 5 (CMIP5) and Coordinated Regional Climate Downscaling Experiment (CORDEX). Historical simulations are compared to reanalysis datasets. Our analysis is focused on changes in month August. The findings suggest the presence of a future inter-model variability for etesians days and wind speed distribution for models used here.

1 Introduction

The etesians are northern sector winds blowing in the Aegean basin during the summer and early autumn, from June to September (Repapis et al. 1978; Tritakis 1982; Kallos et al. 1998; Anagnostopoulou al., 2013). They blow in the lower troposphere and consist one of the most permanent wind system. They prevail in north direction in the central and south Aegean, and become northwesterly near the south-western Turkish coasts (Kotroni et al. 2001). The maximum frequency of the EW is observed in July and August in the eastern Mediterranean (Carapiperis 1951; Maheras 1980; Makrogiannis and Dikaiakos 1990). The topography provides a channel and increases the north direction for the winds in the region of SE Mediterranean (Poupkou et al. 2011). The main cause for the etesians is the synoptic circulation (the low pressure in SE Mediterranean and the high pressure in Balkan Peninsula and Central Europe). They are important climatic elements because they moderate the summer temperatures and regulate the concentration of pollutants in the SE Mediterranean (Metaxas and Bartzokas 1994). Also they cause problems to sea transport in the Aegean Sea during the high touristic season (Koletsis et al. 2009). There have been previous studies

focusing on the connection between etesians and Indian Monsoon (Tyrllis et al. 2012; Dafka et al. 2015), the High pressure of Azores (Prezerakos 1994) and the summer phase of North Atlantic Oscillation (Chronis et al. 2011).

In this study we analyze the frequency and amplitude of the etesians during the period 1950 to 2100. We use Earth System model simulations (ESMs) available from the Coupled Model Intercomparison Project Phase 5 CMIP5, of the Intergovernmental Panel on Climate Change (IPCC) and from Coordinated Regional Climate Downscaling Experiment (CORDEX), a project with emphasis on evaluating and improving regional climate downscaling models and techniques. It also focuses on better understanding relevant regional climate phenomena, their variability and changes, (through downscaling). Our study is focused on the month of August as it is the most intense month for the etesians. Simulated results are compared to the ERA-Interim Reanalysis Dataset. We focus here on three models (CNRMCM5, IPSMCM5 and MPIESMLR) used in both Cordex and CMIP5 (historical and RCP8.5) simulations. We test the evolution of the number of Etesian days and wind intensity for the future and we compare results between CMIP5 and CORDEX simulations for the single ensemble member r1i1p1, with the same initialisation, physics and time of the control run. Our analysis shows an increase in the number of etesian days for the 21st century, in most cases statistically insignificant. It is shown that results of the analysis using CORDEX simulations are closer to the ERA-Interim analysis than using CMIP5 simulations.

2. Data and Methodology

2.1 Data

We analyzed simulations from CMIP5 and CORDEX projects. The scenarios used here are the historical scenario (1950-2005) and the RCP8.5 for the future from CMIP5 simulations, together with the historical and RCP8.5 scenarios from the CORDEX simulations. The spatial analysis used here for CORDEX simulations is $0.11 \times 0.11^\circ$. We also analyzed the etesians from the ERA-Interim reanalysis for the period 1979-2013. The table 1 provides a short description of the datasets used.

2.2 Methodology

We focus our analysis on the month August because the Era-Interim reanalysis dataset presents the greatest frequency of etesians in this month. The criterion to classify a day as etesian day is based on a metric that takes into account the 50% of wind speed distribution during the period 1970-2000 (critical wind speed) and the direction of the winds between NE to NNW for each simulation. We choose a reference point to be at 37.5°N and 25.0°E . When the mean daily wind speed in this point is greater or equal to critical wind speed and wind direction is between NE to NNW, then a day is classified as an etesian wind day. For the CMIP5

simulations data were regridded to a common grid, and the domain covering the SE Mediterranean is used (10°N- 45°N and 5°E to 60°E). For the CORDEX simulations we choose the grid point which is the nearest to reference point. The domain includes the area between 30°N- 45°N and 15°E to 35°E. For three of the CMIP5 models, namely CNRM-CM5, IPSL-CM5A-MR and MPI-ESM-LR we analyze the SLP for the extended domain of SE Mediterranean (20°N- 60°N and 0°E to 80°E). For the period 1950-2005 we examined the relation of SLP centers of NW Balkan (40°N- 45°N and 20°E to 25°E) and the SE Mediterranean (38°N- 42°N and 30°E to 40°E) with the etesian days changes. Also we calculated the evolution and the wind distribution of etesian days for past (1950-2005) and for future (21st century) periods.

Table 1. The CMIP5 and CORDEX simulations. In bold the simulations for ensemble r1i1p1 we are used for our comparison between Cordex and CMIP5 simulations are highlighted

Project	CMIP5		CORDEX
Period / Scenario	Historical (1950-2005)	RCP8.5 (2006-2100)	Historical and RCP 8.5
Simulations	CNRM-CM5(1950-2005)	CNRM-CM5	RCA4-CNRMCM5(1970-2100)
	HADGEM2-CC(1958-2005)	IPSL-CM5A-MR	HIRAM-ECEARTH(1951-2100)
	HADGEM2-ES(1950-2005)	MPI-ESM-LR	RCA4-ECEARTH(1971-2100)
	HIRAM-GFDLC180(1979-2008)	MPI-ESM-MR	RACMO-ECEARTH(1950-2100)
	IPSL-CM5A-MR(1950-2005)	MPI-ESM-LR	CCLM4-CNRMCM5(1950-2100)
	MPI-ESM-MR(1950-2005)	HadGEM2-CC	RCA4-IPSLCM5(1970-2100)
	MPI-ESM-MRamip(1979-2008)	CanESM2	RCA4-MPIESMLR(1970-2100)
	MPI-ESM-LR(1950-2005)		
	MPI-ESM-LRamip(1979-2008)		
	CanESM2(1979-2005)		
Reanalysis	ERA-Interim Reanalysis dataset (1979-2013)		

Results

Models from CMIP5 underestimate the frequency of the etesian days compared to reanalysis, showing no significant change over the whole period. Analysis of the CORDEX data shows similar frequencies of the number of days as in the ERA-Int. dataset, in better overall comparison to the reanalysis than the comparison of reanalysis to CMIP5. Fig. 1 presents the number of etesian days in August for 1950-2005. For CMIP5 simulations and reanalysis the PSL centers in SE Mediterranean (L) and NW Balkan (H) are the main cause for the EW in Aegean. The number of etesian days and the difference between PSL centers present Pearson coefficient between 0.6-0.9.

The mean wind speed difference between 2070-2100 and 1970-2000 for the CORDEX simulations increases about 0.5-1.5 m/s (statistical significant for simulations RCA4-MPIESMLR and RACMO-ECEART). For CMIP5 models the

difference increases about 0.2-0.5m/s (statistical insignificant) excluding IPSLCM5AMR (presents decrease by about 0.5 m/s) (Fig. 2). The etesian days' frequencies are increased for CORDEX compared to CMIP5 simulations (approximately 30%). Table 2 presents the frequency of etesian days between periods 2070-2100 and 1970-2000. The frequencies' difference between two periods for RCA4-MPIESMLR, HIRAM-ECEARTH and RACHMO-ECEARTH is statistically significant.

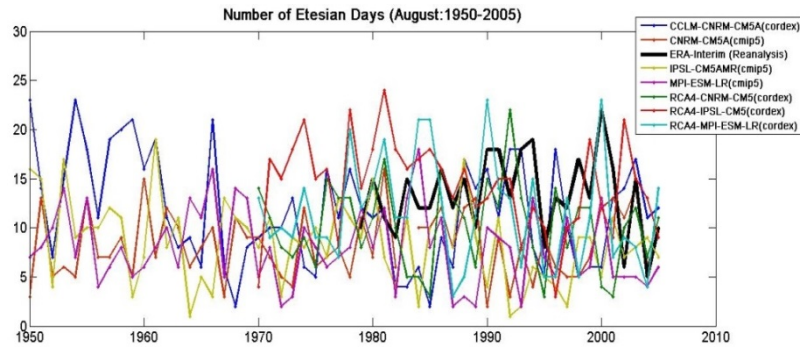


Fig. 1. The number of etesian days in August for 1950-2005 for all data sets used here.

Table 2. Etesian days frequency for periods 1970-2000 and 2070-2100 for Cordex and CMIP5 simulations.

Project	Simulation (ensemble member r1i1p1)	Period		Etesian Days diff. between periods	stat. signif. at 5%
		1970-2000	2070-2100		
CORDEX	RCA4-IPSLCM5	46,41%	45,79%	-0,1922	-
	CCLM-CNRMCM5	32,67%	42,04%	2,9047	-
	RACMO-ECEARTH	40,37%	51,82%	3,5495	↑
	RCA4-ECEARTH	42,47%	47,14%	1,4477	-
	HIRAM-ECEARTH	41,94%	54,11%	3,7727	↑
	RCA4-CNRMCM5	33,71%	40,17%	2,0026	-
	RCA4-MPIESMLR	38,92%	55,36%	5,0964	↑
CMIP5	MPI-ESM-LR	25,75%	28,51%	0,8556	-
	IPSL-CM5A	26,74%	19,36%	-2,2878	-
	CNRM-CM5	27,39%	33,23%	1,8104	-

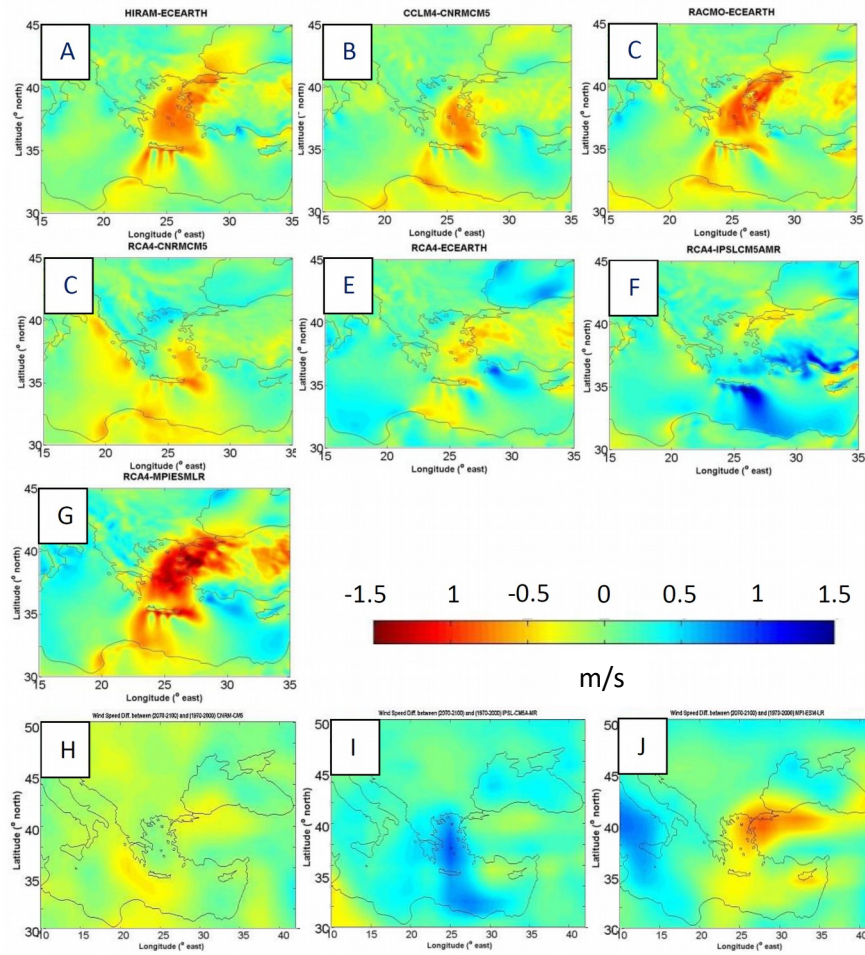


Fig 2. Mean Wind Speed difference between periods 2070-2100 and 1970-2000: 1. Maps from A to G - CORDEX simulations (r1i1p1) 2. Maps from H to J – CMIP5 simulations (r1i1p1)

Conclusion

All models studied here run under CMIP5 historical scenario were found to underestimate the frequency of etesian days in August in comparison to ERA-Interim. Results from the analysis of CORDEX simulations, on the other hand, show a much closer comparison to ERA-Interim with respect to the etesian day's frequency.

For CORDEX simulations our analysis shows changes in the number of etesian days and wind speed distributions mainly during 2070-2100 when

compared to both the past period 1970-2000 and the period 2010-2040. The increases in frequency and wind speed of etesian days during August are found in all models examined here (exception constitutes IPSLCM5A simulation) (Table 2).

The frequencies of etesian days for periods 2070-2100 and 1970-2000 are increased for CORDEX compared to CMIP5 simulations about 20-30% for the models used here. The mean wind speed difference between two periods for CORDEX simulations increase about 0.5-1.5 m/s and 0.2-0.5 m/s for CMIP5 simulations) excluding IPSLCM5AMR simulation (decreasing of frequency and wind speed between two periods) (Fig. 2).

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References

- Anagnostopoulou C., Zannis P., Katragou E., Tegoulas I., Tolika K., Recent Past and Future Patterns of the Etesian Winds based regional scale climate model simulations *Clim Dyn* (2014) 42:1819–1836, doi 10.1007/s00382-013-1936-0
- Karapiperis L (1951) On the periodicity of Etesian in Athens. *Weather* 6:378–379
- Chronis, Themis, Dionysios E. Raitsos, Dimitris Kassis, Athanassios Sarantopoulos, 2011: The Summer North Atlantic Oscillation Influence on the Eastern Mediterranean. *J. Climate*, **24**, 5584–5596. doi: <http://dx.doi.org/10.1175/2011JCLI3839.1>
- Kallos G, Kotroni V, Lagouvardos K, Papadopoulos A (1998) On the long range transport of air pollutants from Europe to Africa. *Geophys Res Lett* 25:619–622. doi:10.1029/97GL03317
- Metaxas DA, Bartzokas A (1994) Pressure covariability over the Atlantic, Europe and N. Africa. Application: Centers of Action for Temperature, Winter Precipitation and Summer Winds in Athens, Greece. *Theor Appl Climatol* 49:9–18. doi:10.1007/BF00866284
- Poupkou A, Zannis P, Natsios P, Papanastasiou D, Melas D, Tourpali K, Zerefos C, Present Climate Trend Analysis of the etesian Winds in Aegean Sea., *Theor Appl Climatol* (2011) 106:459–472 doi 10.1007/s00704-011-0443-7
- Tyrlis E, Levievel Jos, Steil B, The Summer Circulation over the Eastern Mediterranean and middle East: influence of the South Asian monsoon., *Clim Dyn* (2013) 40:1103–1123 DOI 10.1007/s00382-012-1528-4
- Maheras P (1980) The problem of Etesians [Le probleme des Etesiens]. *Mediterranée* 40:57–66
- Makrogiannis TJ, Dikaiakos JC (1990) Large scale patterns of atmospheric circulation anomalies associated to long spells of etesian wind-days over Greece. In: Brazdil R (ed) *Climatic change in the historical and the instrumental periods*. Mararyk University, Brno, pp 307–309
- Stella Dafka, Elena Xoplaki, Andrea Toreti, Prodromos Zanis, Evangelos Tyrlis, Christos Zerefos, Juerg Luterbacher, The Etesians: from observations to reanalysis, *Clim Dyn* DOI 10.1007/s00382-015-2920-7
- Tritakis BP (1982) Etesians distribution within the Bartel rotations no. 1938–2027 (1975–1981). *Geophys Res Lett* 9:1225–1226. doi:10.1029/GL009i011p01225
- Repapis C, Zerefos C, Tritakis B (1978) On the Etesians over the Aegean. *Proceedings of the Academy of Athens* 52:572–606
- Logothetis Ioannis, Thesis: “The Etesian winds over Aegean Sea in the 21st century from Earth System Model (ESM) simulations”, Thessaloniki 2014, <http://ikee.lib.auth.gr/record/135159/files/GRI-2014-13150.pdf>