The Abdus Salam International Centre for Theoretical Physics

2210-11

MedCLIVAR Workshop on: "Scenarios of Mediterranean Climate Change under Increased Radiative Active Gas Concentration and the Role of Aerosols

23 - 25 September 2010

The topic of dimming and brightening with a link to the NAO in the Mediterranean

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Influence of NAO and clouds on dimming and brightening in Europe

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ICTP MedCLIVAR Workshop
23-25 Sep 2010

Outline

1. Background and Motivation
2. Dataset - GEBA
4. Results –

   3.1 Annual and seasonal trends

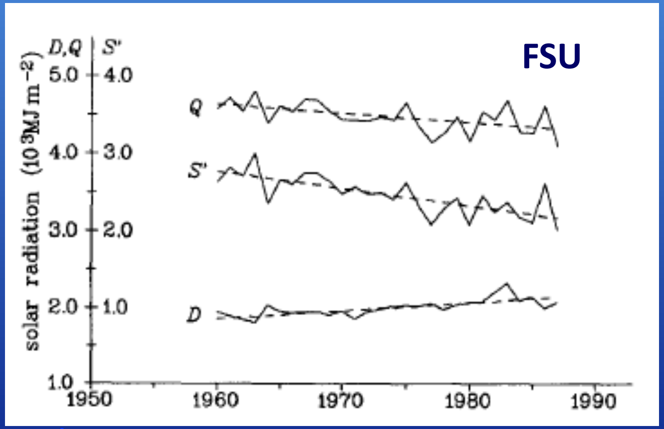
   3.2 Seasonal connection with aerosols and circulation patterns

4. Conclusions

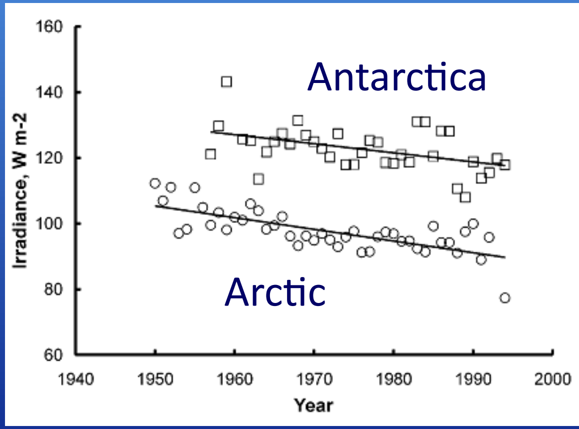
Decadal Variations of SW Radiation

Global dimming

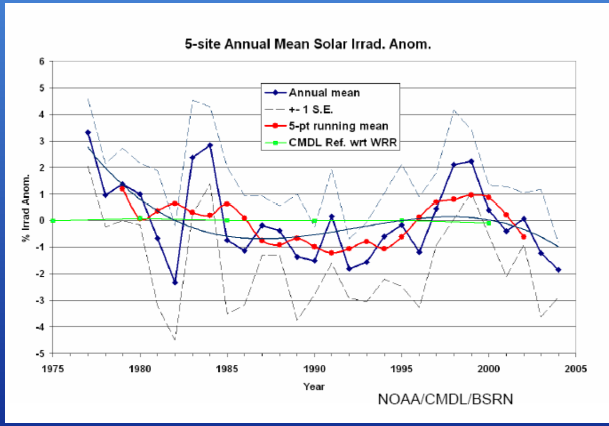
- Late 1980s: first evidences of decrease in surface solar radiation between 1950s-1990s (e.g. Ohmura and Lang, 1989)
- Estimated linear changes between 2% and 10% decade^{-1} (Stanhill and Cohen 2001)
- Liepert (2002) estimated a decrease of 7 Wm^{-2} over global land sites during the 1961-1990 period



Abakumova et al. (1995)



Stanhill and Cohen (2001)



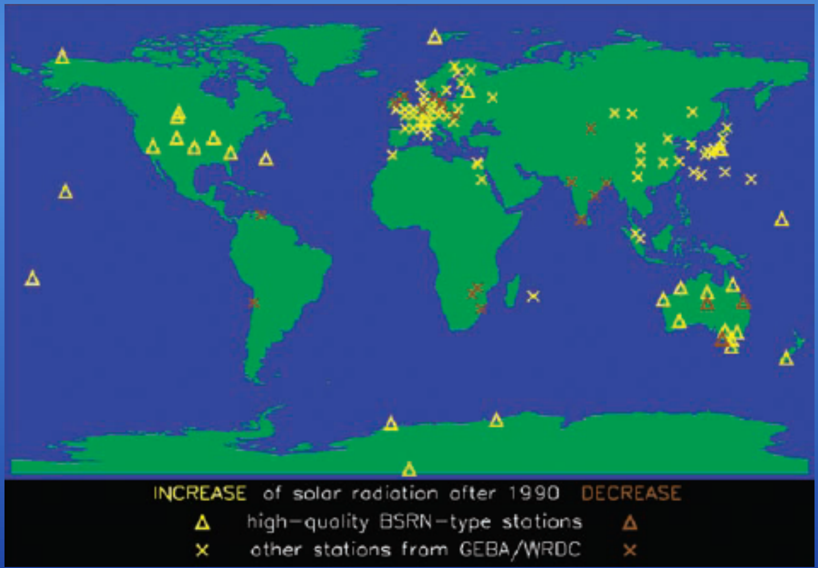
Dutton et al. (2006)

Decadal Variations of SW Radiation

Global brightening

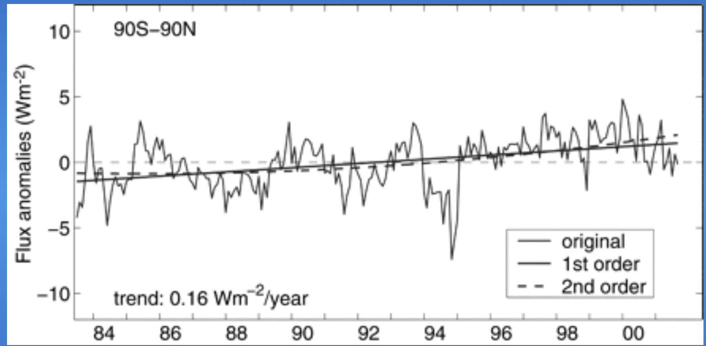
- Since late 1980s a reversal in this trend has been detected in many regions of the world using surface and remote sensing observations

1992-2002

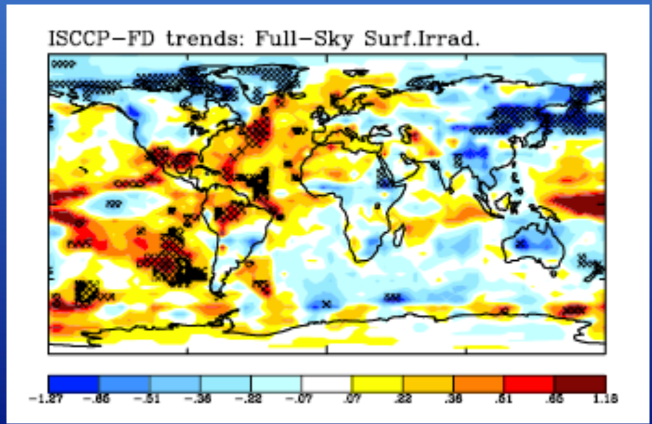


Wild et al. (2005)

Land and Ocean (1983-2001)



Pinker et al., 2005



Romanou et al. (2007)

Decadal Variations of SW Radiation

Global Satellite Data

Table 2. Slopes of Best Fit Lines to Various SRB Version 2.8 Mean All-Sky Shortwave Downward Flux Time Series and Results From Other Global Satellite Studies[a]

Period	Source	Region	Trend	95% CI T	95% CI
July 1983 to June 2004	SRB 2.8	global	0.25	[−0.08, 0.58]	[−0.41, 0.91]
July 1983 to June 2001	SRB 2.8	global	0.88	[0.48, 1.28]	[0.10, 1.66]
1983–2001	*Pinker et al.* [2005]	global	1.6		
1984–2000	*Hatzianastassiou et al.* [2005]	global	2.4		
July 1983 to July 1991	SRB 2.8	global	−2.51	[−3.62, −1.39]	[−4.68, −0.34]
		ocean	−1.17		[−3.40, 1.06]
		land	−5.58		[−8.19, −2.97]
		NH	−3.21		[−5.99, −0.44]
		SH	−1.80		[−4.81, 1.21]
July 1991 to October 1999	SRB 2.8	global	3.17	[1.90, 4.43]	[0.67, 5.66]
		ocean	5.32		[1.80, 8.85]
		land	−0.82		[−2.65, 1.02]
		NH	4.24		[1.72, 6.77]
		SH	2.09		[−0.97, 5.14]
October 1999 to June 2004	SRB 2.8	global	−5.26	[−7.87, −2.66]	[−9.89, −0.63]
		ocean	−7.56		[−14.02, −1.10]
		land	−0.50		[−4.35, 3.36]
		NH	−5.39		[−11.41, 0.62]
		SH	−5.14		[−13.03, 2.76]

[a]Trend is the best fit slope of the data, in W m^{-2} $decade^{-1}$; 95% CI T is the 95% confidence interval of the trend from standard Student's T test; and 95% CI is the 95% confidence interval of the trend accounting for correlation, both in W m^{-2} $decade^{-1}$.

Hinkelman et al. (2009)

Decadal Variations of SW Radiation

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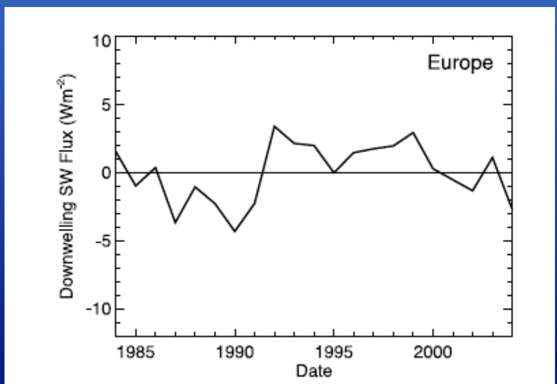
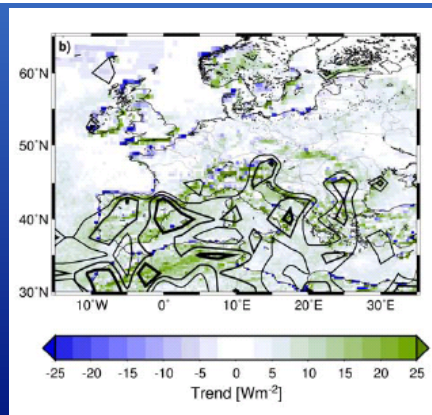
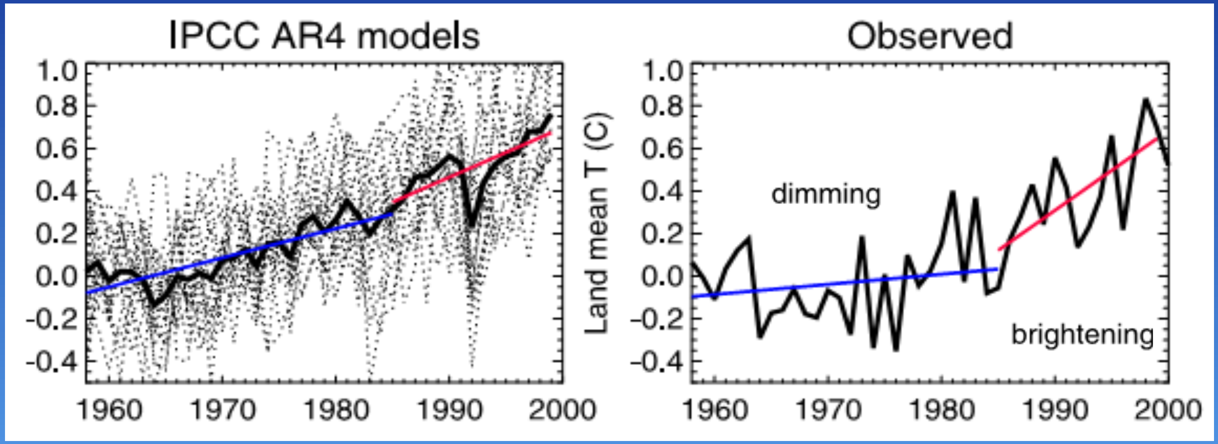


NASA SRB (1983-2004)
Hinkelman et al. (2009)

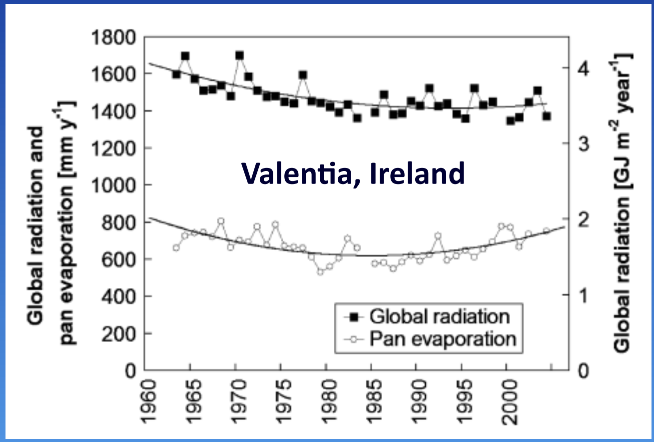


ISCCP DX (1984-2000)
Petrenz et al. (2007)

Impact of Dimming/Brightening



Wild (2009)



Stanhill and Möller (2008)

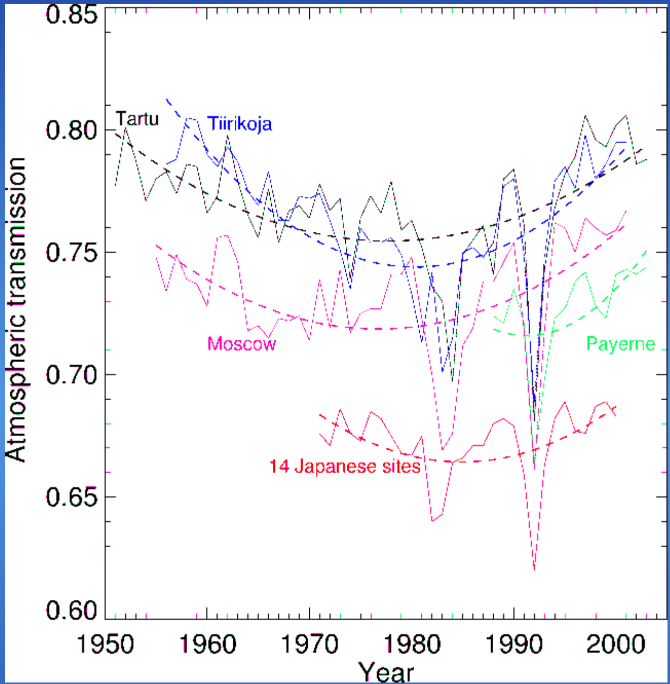
- Impact on **surface temperature** and global warming (e.g. Wild, 2009)

- Impact on components and intensity of the **hydrological Cycle -** evaporation (e.g. Roderick and Farquart, 2002; Stanhill and Möller, 2008; Teuling et al., 2009)

- Impact on the **terrestrial biosphere** and **carbon cycle** (e.g. Mercado et al., 2009)

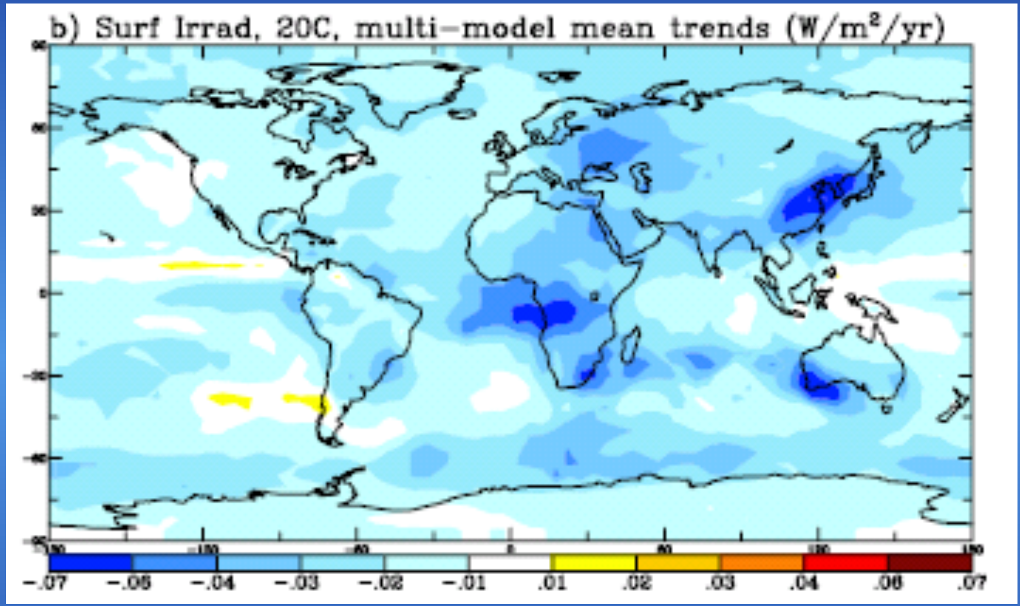
Causes of Dimming/Brightening

Atmospheric transmission
1950-2002



Wild et al. (2005)

IPCC multi-model mean shows decline mostly over land areas (20c)

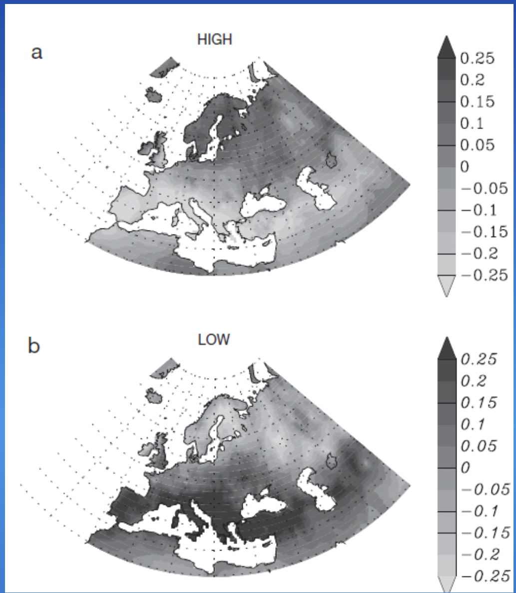


Romanou et al. (2007)

- Transmissivity of the Earth's atmosphere due to changes in concentrations of **aerosols** as a consequence of anthropogenic emissions are considered the most likely cause
- It has also been found that the dimming/brightening periods may be linked to changes in **cloud cover**

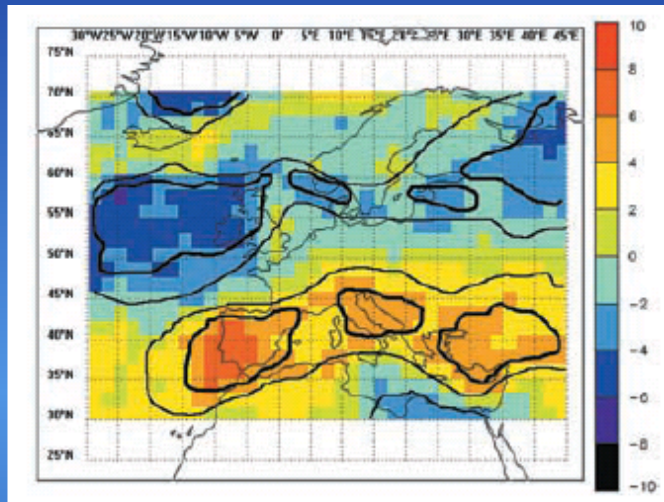
NAO Influence in Europe

Cloud Cover



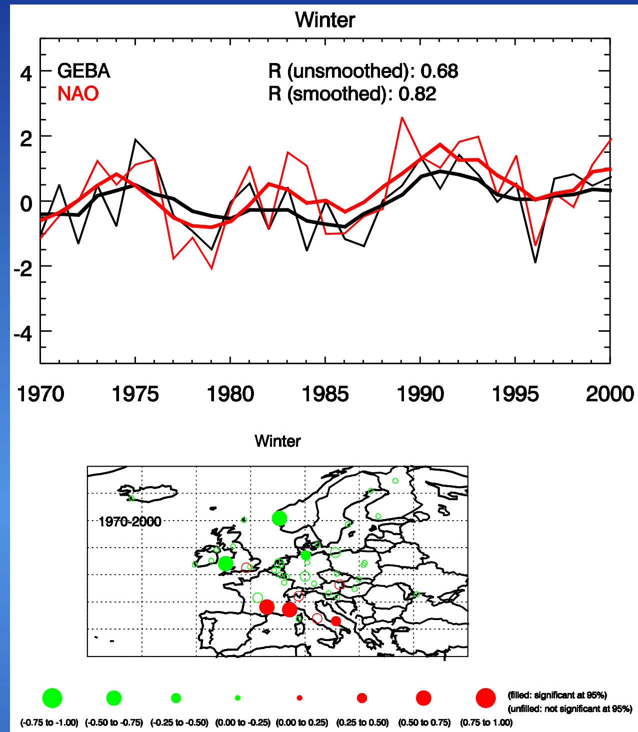
Trigo et al. (2002)

SW Radiation and NAO



Pozo-Vazquez et al. (2004)

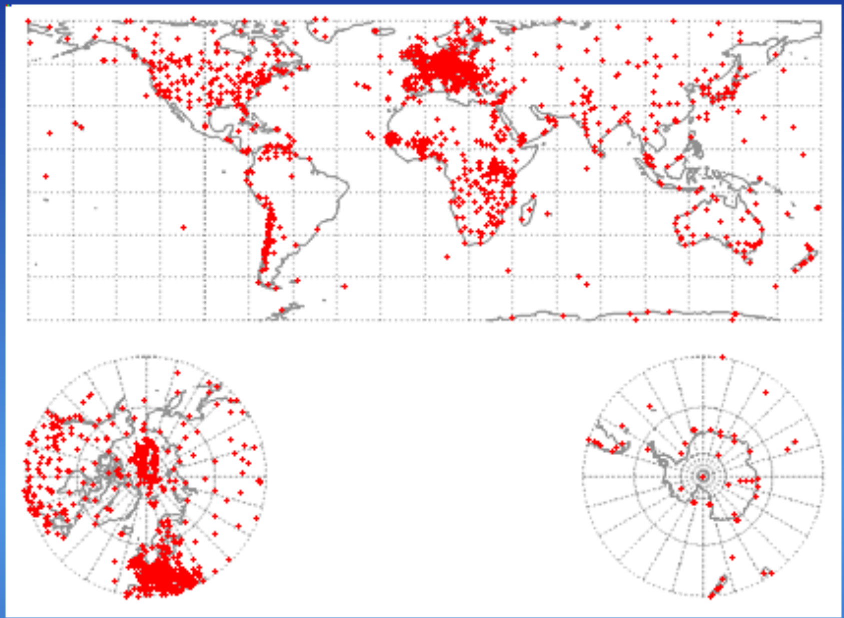
SW Radiation and NAO



Chiacchio and Wild (2010)

- Important to analyze SW radiation and their relationship to circulation patterns
- Previous studies found a strong influence of the NAO on winter radiation (Pozo-Vazquez et al., 2004; Chiacchio and Wild, 2010) and cloud cover (Trigo et al., 2002; Lolis, 2009) variability over the European region
- A systematic analysis over the Mediterranean area, including other teleconnection patters and other seasons, is still lacking

Global Energy Balance Archive (GEBA)



total of 2500 stations and 450,000 monthly mean values of different surface energy parameters

station history of these sites are also included in this database

First version was implemented in 1988 (Ohmura et al. 1989)

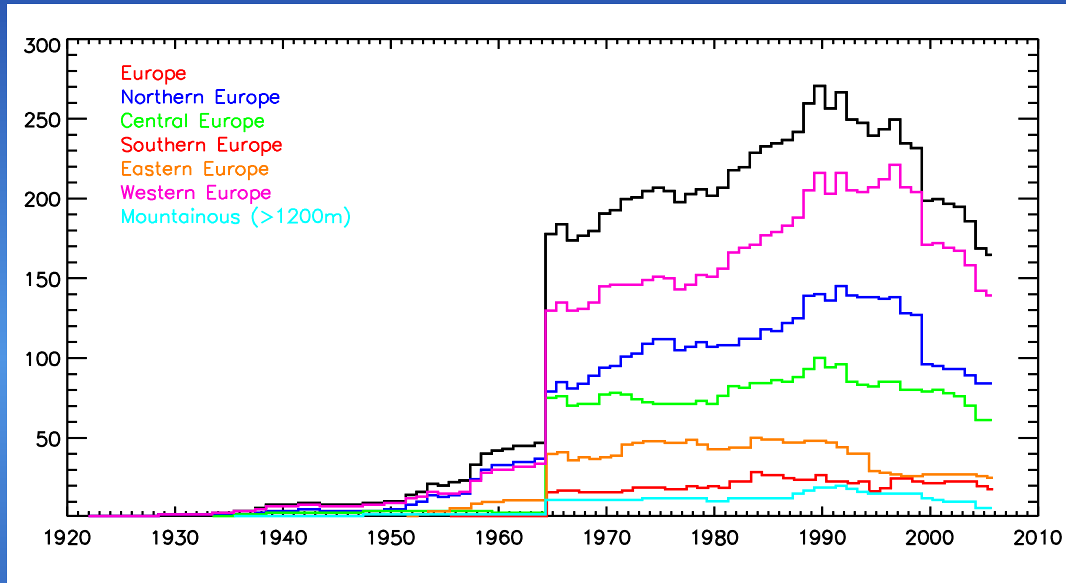
Uses of the GEBA dataset:

- studying the surface energy balance
- validating satellite radiation algorithms
- validating of energy fluxes simulated from general circulation models
- providing data for industrial applications

Update of GEBA

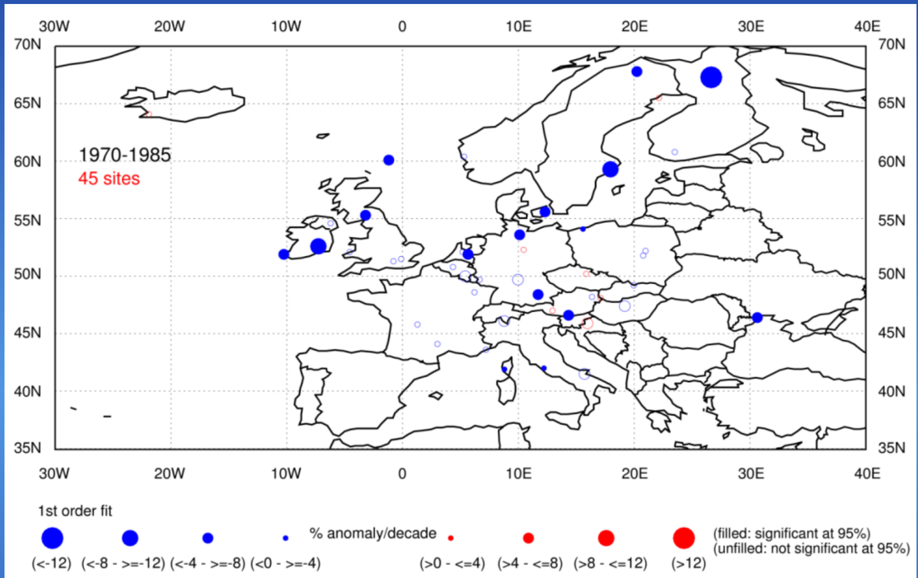
Radiative Parameters in GEBA:

Global radiation
Direct solar radiation
Diffuse sky radiation
Albedo
Reflected short-wave radiation
Long-wave incoming radiation
Longwave outgoing radiation
Longwave net radiation
Radiation balance
Sensible heat flux
Latent heat of melt
UV radiation
Absorbed short-wave radiation
Sum of outgoing short-and long-wave radiation
Sum of latent and sensible heat flux

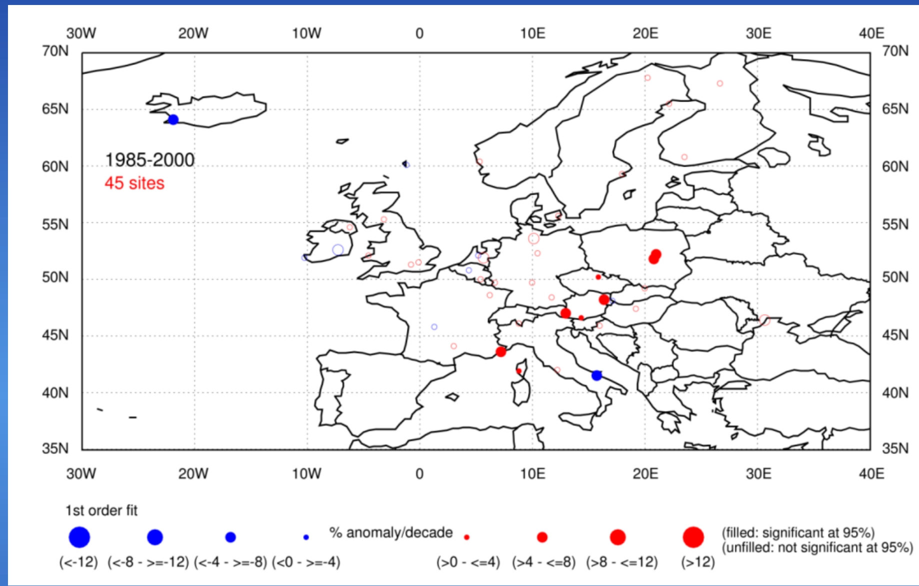


Trends of SW Radiation over Europe

1970-1985



1985-2000



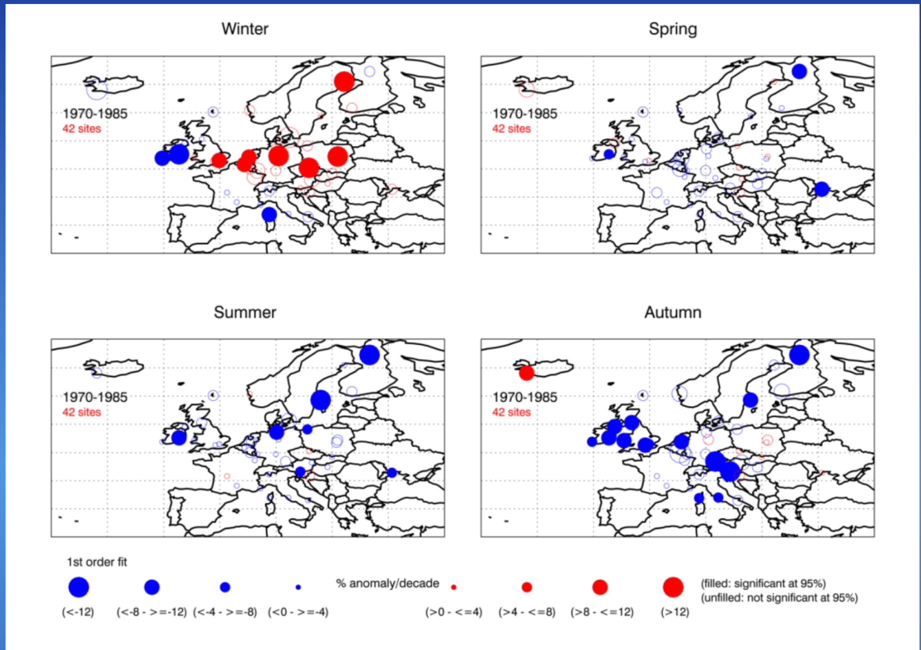
Annual 1970-1985 (% decade^{-1})	**-3.0**

Annual 1985-2000 (% decade^{-1})	+0.3

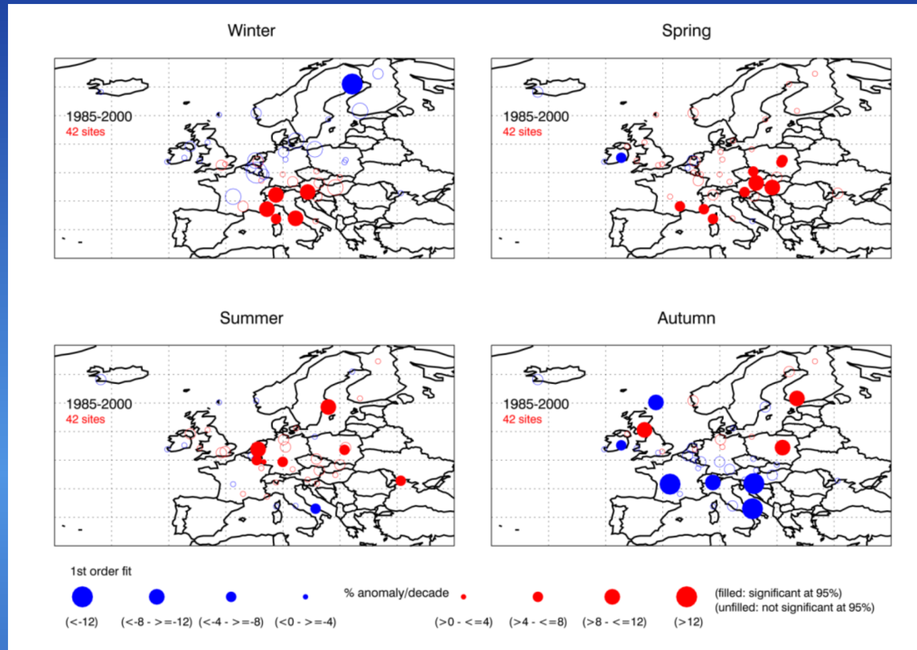
Chiacchio and Wild (2010)

Trends of SW Radiation over Europe

1970-1985



1985-2000



Winter (% dec^{-1})	+0.5
Spring	-2.4
Summer	-3.2
Autumn	**-2.5**

Winter (% dec^{-1})	+0.5
Spring	+1.6
Summer	+0.9
Autumn	**-2.5**

Chiacchio and Wild (2010)

Correlation of Solar Radiation and NAO

	1970-2000	1970-2000 (running avg)	1970-1985	1970-1985 (running avg)	1985-2000	1985-2000 (running avg)
Europe	0.26	0.34	0.29	0.23	0.09	0.16
	0.37	0.29	0.45	0.36	0.34	0.44
	0.62	**0.62**	0.56	0.61	**0.75**	0.45
	0.32	**0.42**	0.07	**-0.60**	0.42	**0.57**
S. Europe	**0.68**	**0.82**	0.56	0.60	**0.74**	**0.95**
	0.29	0.10	0.31	0.42	0.27	-0.30
	-0.15	-0.07	-0.06	0.08	-0.36	-0.47
	0.30	**0.58**	0.28	-0.26	0.09	0.47
N. Europe	-0.34	**-0.52**	-0.11	-0.15	-0.57	-0.59
	0.29	0.30	0.36	0.28	0.27	0.59
	0.66	**0.72**	0.59	**0.65**	**0.79**	**0.66**
	0.21	0.06	0.11	**-0.66**	**0.55**	**0.63**

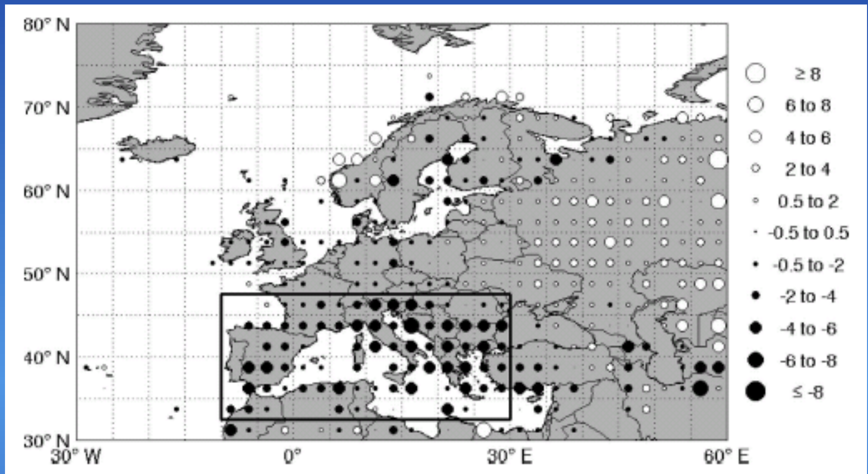
Chiacchio and Wild (2010)

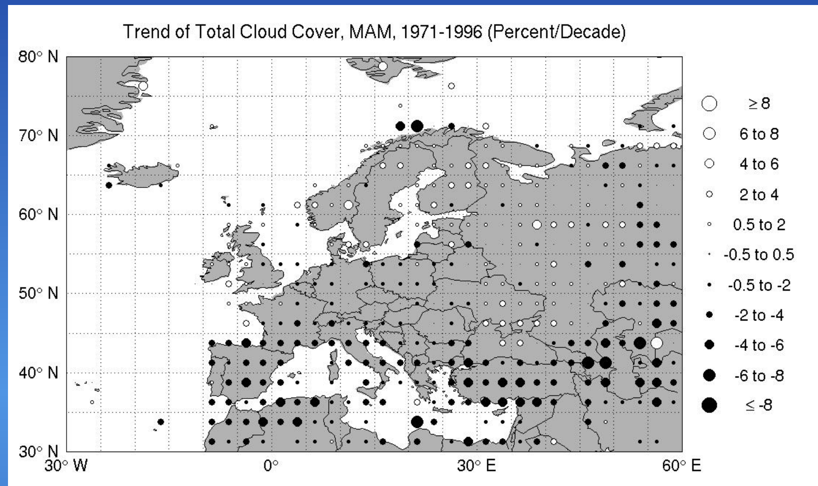
Correlation becomes stronger in low-frequency variability with a maximum in winter and autumn in Southern Europe

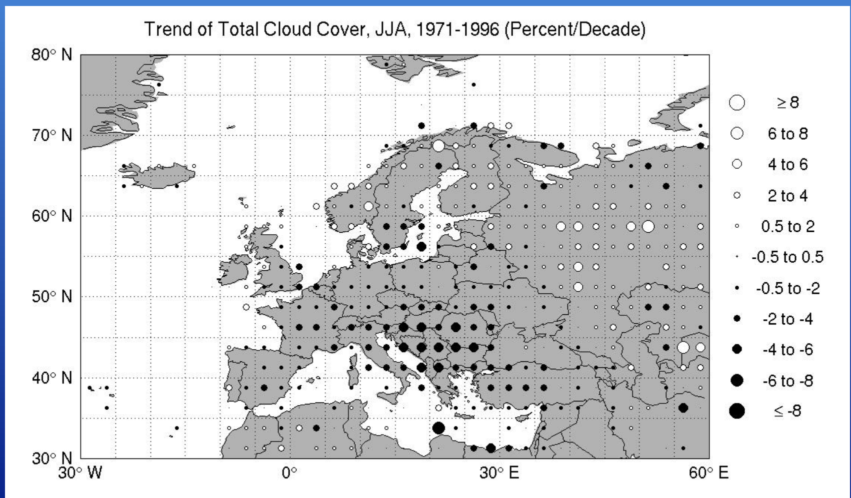
Decadal Variations in Seasonal Cloud Cover

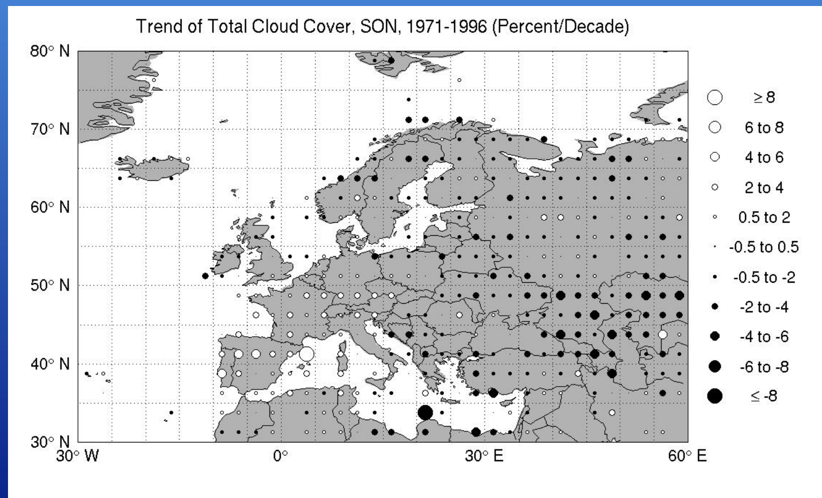
Decrease is strongest over Mediterranean in winter

Stephen Warren (personal comm.)









Solar Radiation and Cloud Cover

1971-1996

Season	Europe	Europe (running avg)	S. Europe	S. Europe (running avg)	N. Europe	N. Europe (running avg)
DJF	**-0.55**	-0.15	**-0.80**	**-0.75**	**-0.37**	0.12
MAM	**-0.81**	**-0.56**	**-0.57**	-0.27	**-0.88**	**-0.77**
JJA	**-0.85**	**-0.65**	**-0.57**	0.07	**-0.93**	**-0.81**
SON	**-0.70**	**-0.55**	**-0.80**	**-0.66**	**-0.63**	**-0.48**

Chiacchio and Wild (2010)

Correlation weakens in low-frequency variability

Solar radiation variability is governed by cloud cover in Southern Europe in winter and autumn and in Northern Europe during spring and summer

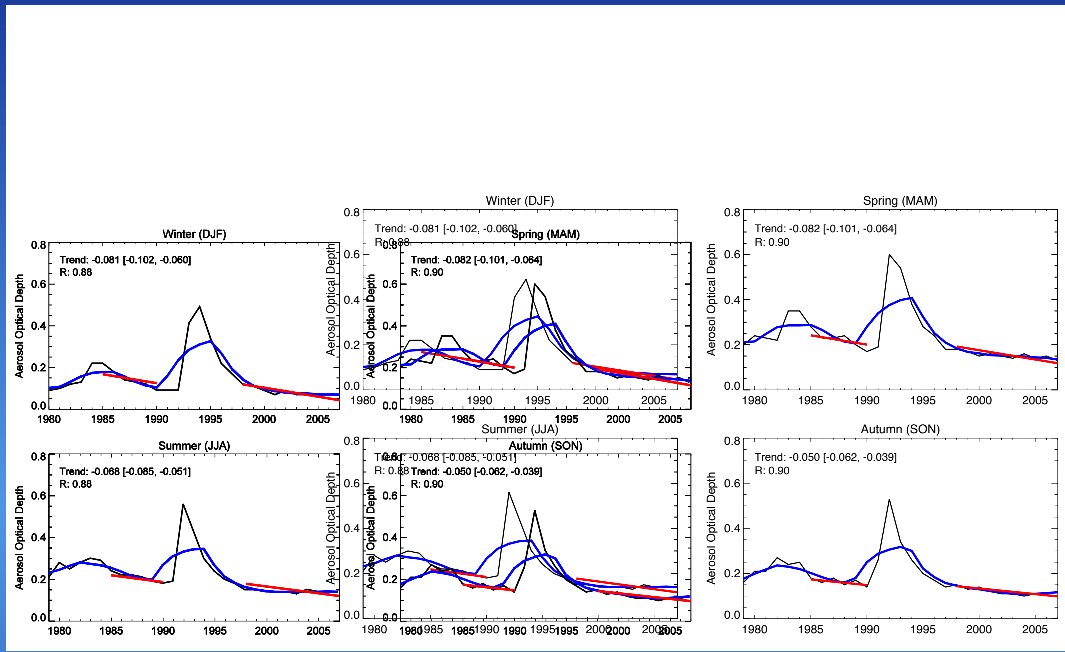
GOCART Model

(Goddard Chemistry Aerosol Radiation and Transport model):

- Simulate aerosol optical thickness from various types of aerosols: sulfur, dust, sea-salt, black carbon (BC), organic carbon (OR)
- Horizontal resolution of 2° latitude x 2.5° longitude and 20-30 vertical sigma layers
- Assimilated meteorological fields are generated from the Goddard Earth Observing System Data Assimilation System (GEOS DAS)
- Dust and biomass burning emissions are incorporated into the model
- Output: aerosol composition and distribution, optical thickness, radiative forcing

Decadal Variations of AOD in Europe

GOCART model (1979-2007)   Europe

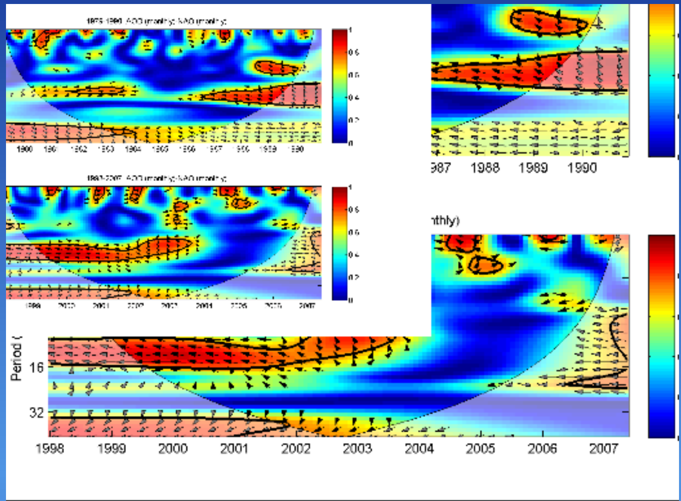


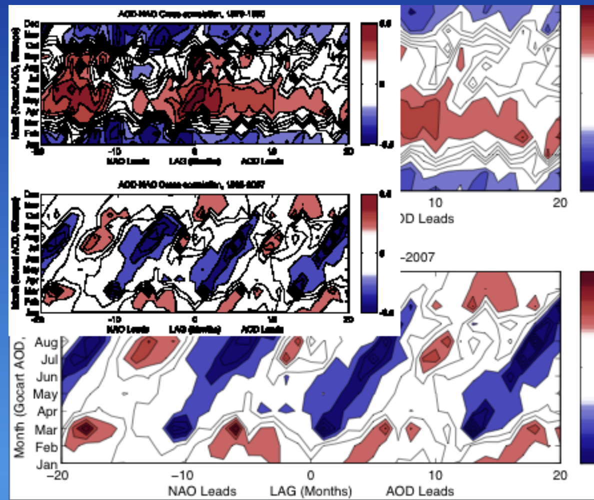
Chiacchio et al. (submitted)

AOD changes (%) (1985-2007)

Region	Annual Sulfate/Total	Winter (DJF) Sulfate/Total	Spring (MAM) Sulfate/Total	Summer (JJA) Sulfate/Total	Autumn (SON) Sulfate/Total
Europe	**-69/-41**	**-115/-69**	**-69/-39**	**-60/-39**	**-59/-37**
Northern Europe	**-73/-46**	**-132/-77**	**-76/-46**	**-57/-42**	**-64/-44**
Southern Europe	**-63/-35**	**-99/-54**	**-61/-30**	**-60/-33**	**-57/-34**
Western Europe	**-65/-33**	**-129/-70**	**-67/-34**	**-48/-26**	**-60/-35**
Eastern Europe	**-75/-50**	**-111/-70**	**-76/-49**	**-71/-53**	**-64/-42**

Sulfate AOD and NAO





Strong and significant anti-phase relationship most pronounced in the late 1980s.

Chiacchio et al. (submitted)

No major lead or lag by AOD or NAO. However, a seasonal relationship exists between AOD and NAO with a negative correlation in winter and positive in summer.

Teleconnection Patterns

- **North Atlantic Oscillation (NAO) –** obtained from the Climate Research Unit (Gibraltar – SW Iceland, Jones et al., 1997)

- **Mediterranean Oscillation (MO)** – one of the most important regional low-frequency patterns affecting precipitation in this region with anticyclone in the western Mediterranean and a depression in the eastern Mediterranean (Conte, 1989)

- **North Sea-Caspian Pattern** (NCP) – upper level (500 hPa) difference in geopotential heights; teleconnection affecting the area north of the Mediterranean between the North Sea and Caspian (Kutiel and Benaroch, 2002)

Multiple Linear Regression Model

• Analysis is performed on SW radiation from GEBA data in 45 stations across Europe (1970-2000)

• Cloud cover is analysed from measurements for 32 stations. Cloud cover is taken from Carbon Dioxide Information Anaylsis Center (CDIAC, C.J. Hahn and S.G. Warren) for the period 1971-1996

• Effect of cloud cover is studied using a **generalized linear model (GLM)** where it acts as a covariate:

$$Y^j = (Y_1{}^j{}_{DJF}, Y_1{}^j{}_{MAM}, Y_1{}^j{}_{JJA}, \ldots, Y_n{}^j{}_{MAM}, Y_n{}^j{}_{JJA}, Y_n{}^j{}_{SON}),$$

$$C^k = (C_1{}^k{}_{DJF}, C_1{}^k{}_{MAM}, C_1{}^k{}_{JJA}, \ldots, C_n{}^k{}_{MAM}, C_n{}^k{}_{JJA}, C_n{}^k{}_{SON}),$$

(SW radiation is at station j and cloud cover at station k, n = 26 years)

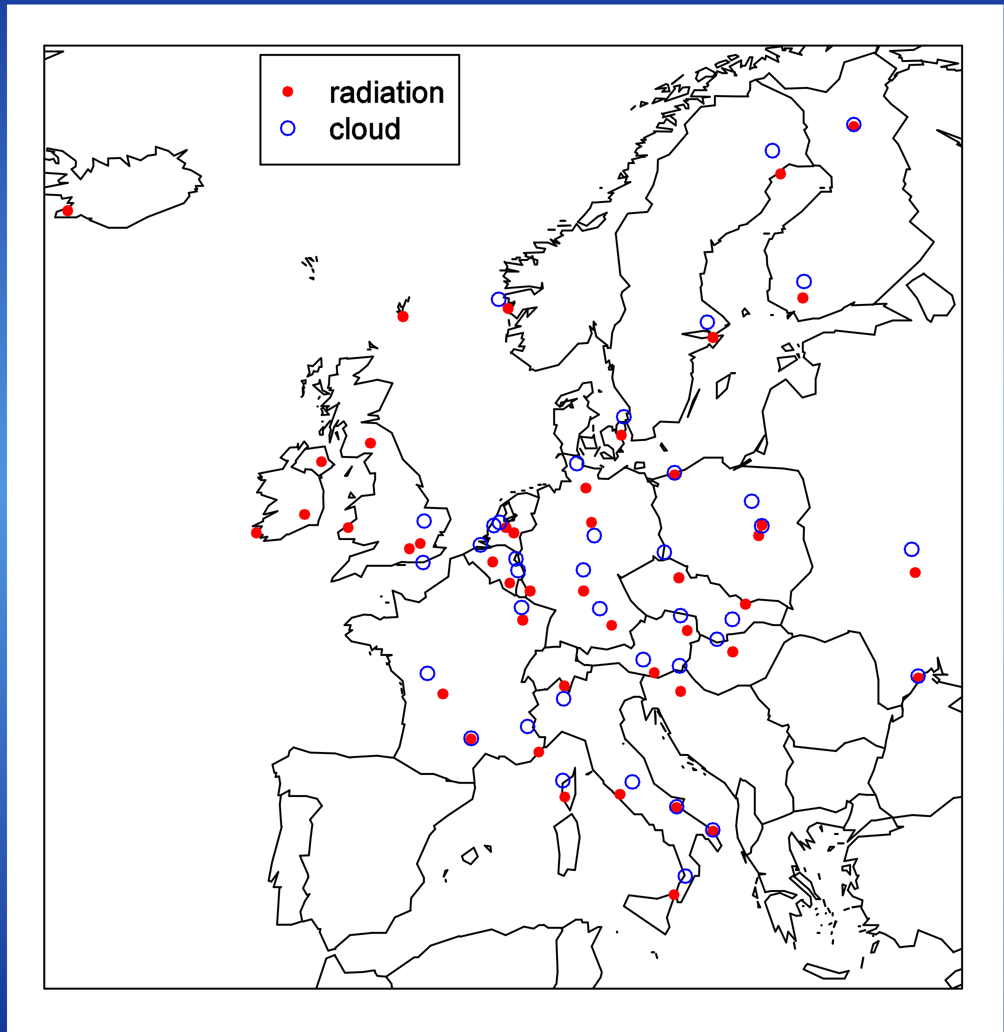
Cloud cover effect is quantified with this model:

$$Y_j \text{ Normal}(\mu, \sigma), \quad \mu = \beta_0 + \beta_1 C^k + \beta_2 DJF + \beta_3 MAM + \beta_4 JJA$$

Circulation effects are quantified through the following model:

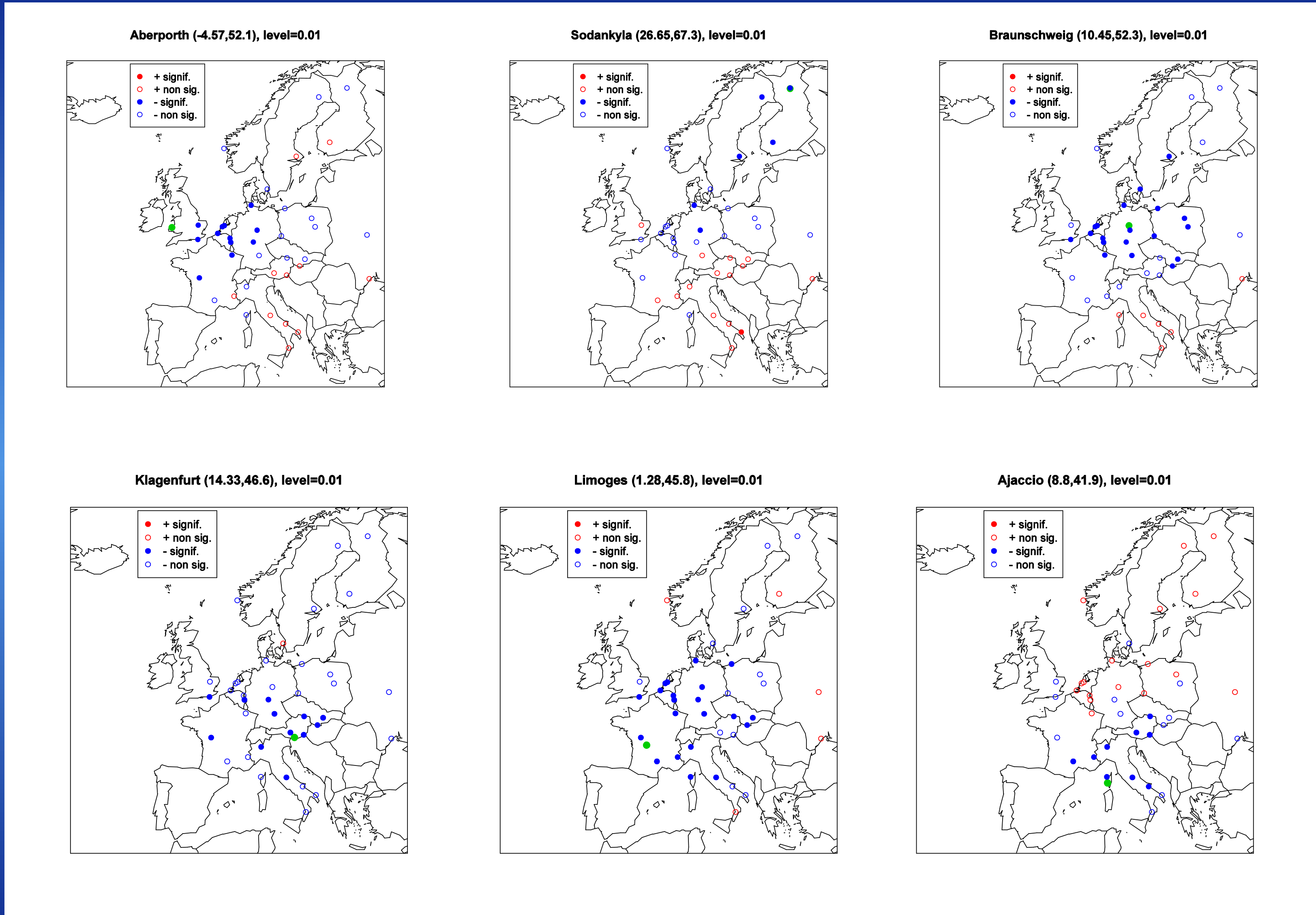
$$Y_j \text{ Normal}(\mu, \sigma), \quad \mu = \beta_0 + \beta_1 NAOI + \beta_2 MOI + \beta_3 NCPI + \beta_4 DJF + \beta_5 MAM + \beta_6 JJA$$

Location of Station Measurements



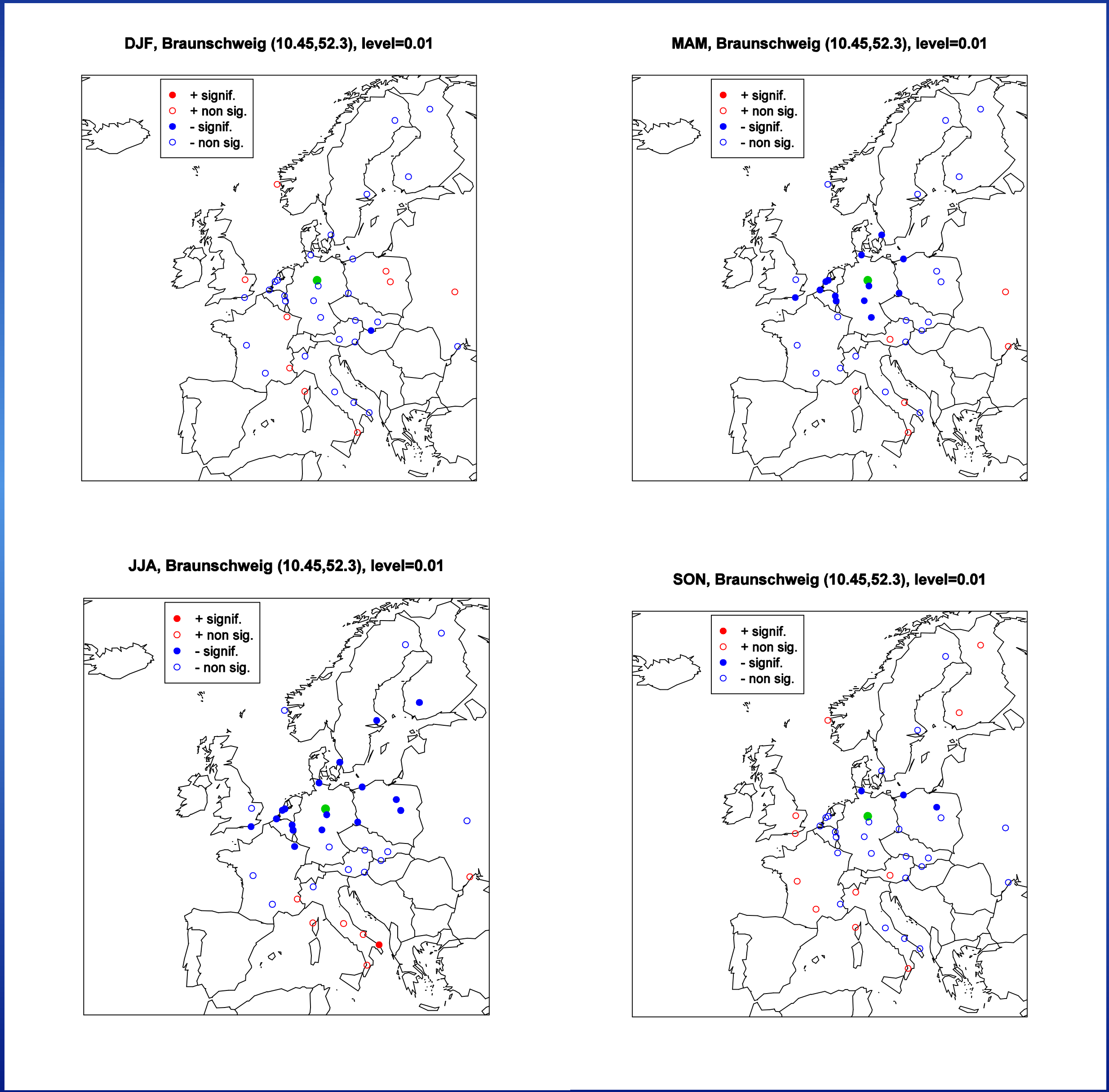
GEBA and Cloud Cover Stations

Cloud Cover Effect on SW Radiation



Size of area of significance gives a measure of spatial dependence of cloud cover on the SW radiation with a negative effect

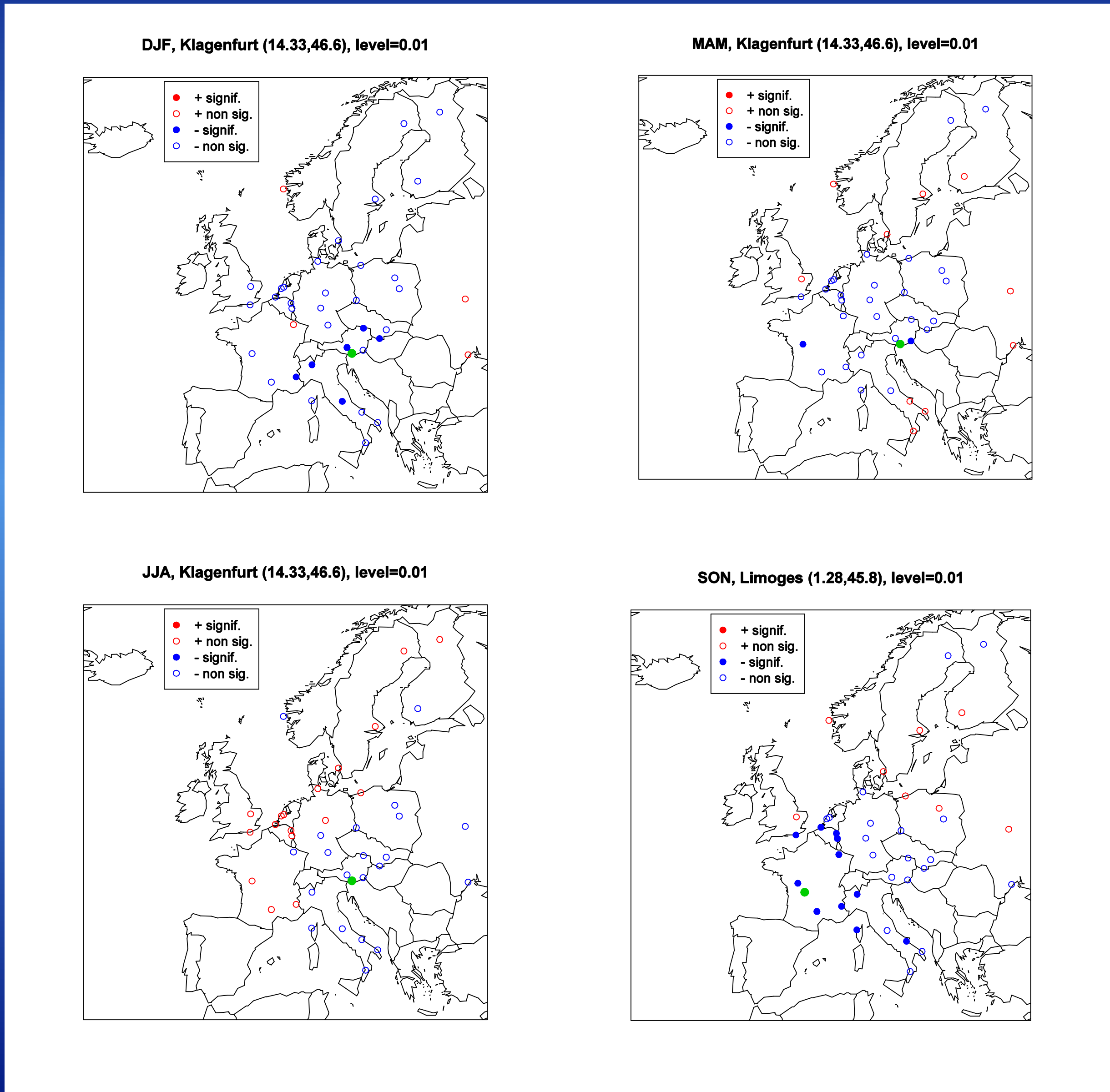
Seasonal Cloud Cover Effect on SW Radiation



Testing for cloud effects in **Central Europe** in DJF, MAM, JJA, SON

Strongest cloud cover effects in MAM and JJA

Seasonal Cloud Cover Effect on SW Radiation

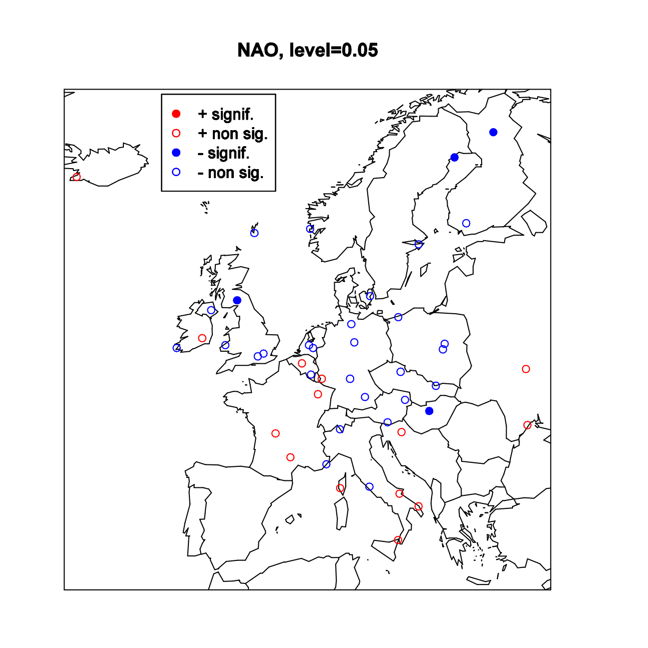


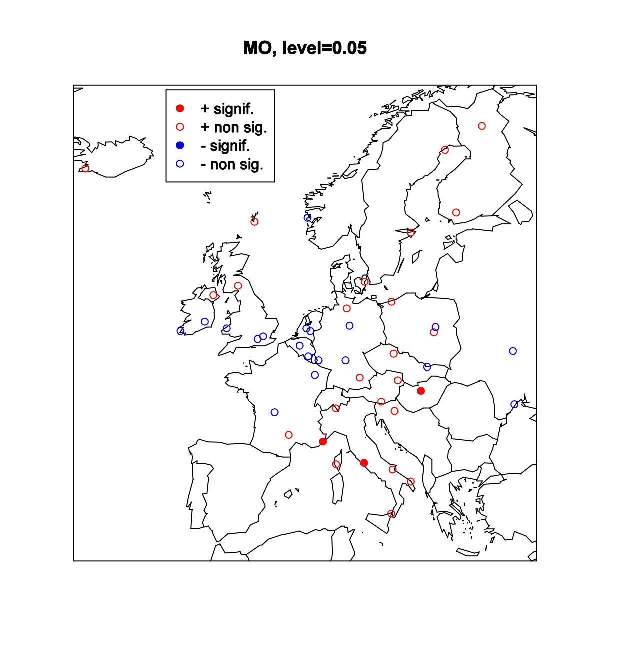
Testing for cloud effects in **Southern Europe** in DJF, MAM, JJA, SON

Strongest cloud cover effects in DJF and SON

Circulation Effect on SW Radiation

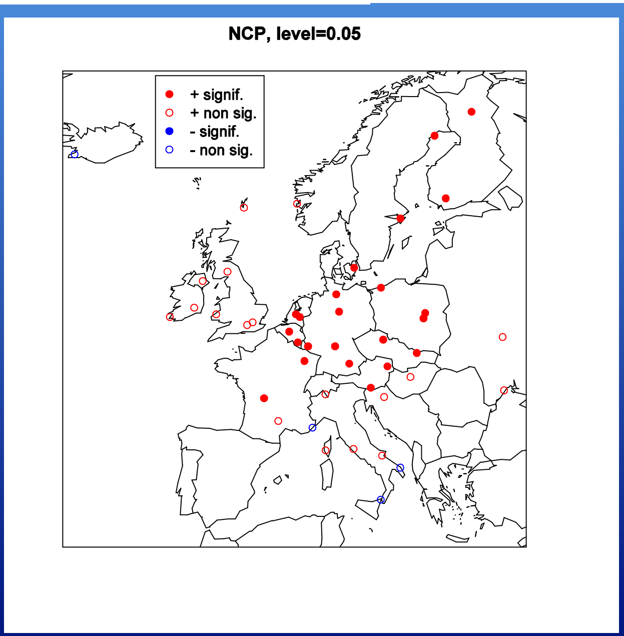
NAO





MO

NCP



Sign of the coefficients β_1, β_2, β_3 from the statistical model corresponds to the 3-monthly NAO, MO, and NCP indices

Conclusions

- Trend analysis of solar radiation show dimming and brightening in the annual, spring and summer mean time series
- Winter and autumn solar radiation trends are mainly due to NAO through the modification of cloud cover in Southern Europe
- Spring and summer trends are attributable to cloud cover in Northern Europe
- Cloud cover and solar radiation relationship weakens in the low-frequency variability while solar radiation and NAO show a strengthening, suggesting that other effects such as aerosols may play a role and interfering with NAO
- Seasonal dependence between sulfate AOD and NAO variability with positive correlation in winter and negative in summer
- NAO effects on SW radiation revealed dipole pattern in winter; mostly positive effects from MO in Mediterranean in winter; NCP has a strong positive effect in Central to Northern Europe mostly during spring and summer