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31 May - 11 June, 2010

On the direct effects of anthropogenic aerosols on European climate with RegCM3

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ΑΡΙΣΤΟΤΕΛΕΙΟ
ΠΑΝΕΠΙΣΤΗΜΙΟ
ΘΕΣΣΑΛΟΝΙΚΗΣ

On the direct effects of anthropogenic aerosols on European climate with RegCM3

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Fifth ICTP Workshop on the Theory and Use of Regional Climate Models
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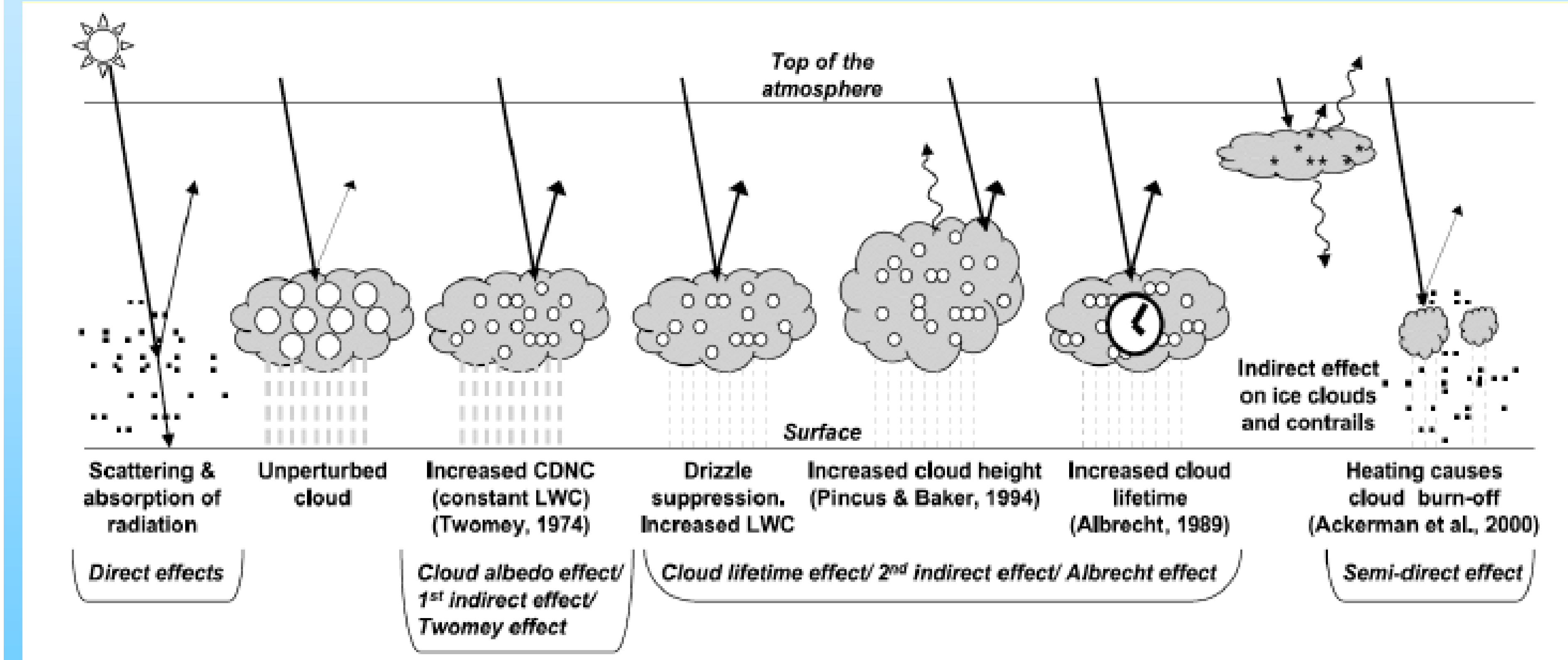
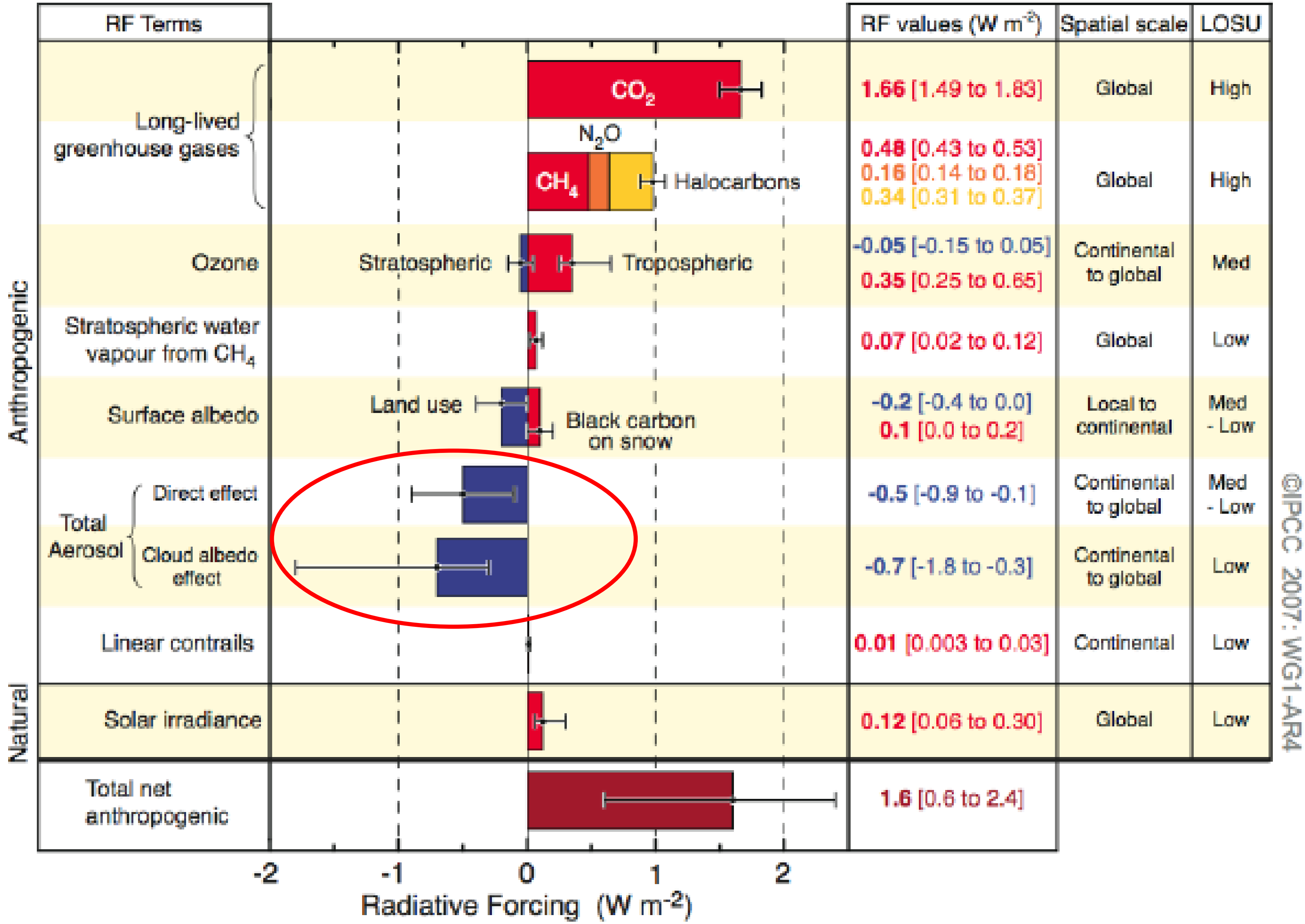
Aerosol direct and indirect effects



Radiative Forcing Components



Aerosols in RegCM3

- **General approach** ⇔ Tracer model / RegCM3
  (from Giorgi et al.,2002; Qian et al.,2001)

$$\frac{\partial \chi}{\partial t} = -\overline{V} \cdot \nabla \chi + F_H + F_V + T_{CUM} + S_\chi - R_{w,ls} - R_{w,cum} - D_{dep} + \sum Q_p - Q_l$$

Transport | Primary Emissions | Removal terms | Physico – chemical transformations

Strongly dependent on the nature of the tracer (Primary Emissions, Removal terms, Physico – chemical transformations)

- **Particles and chemical species considered ("anthropogenic compounds")**

SO_2 ⇔ SO_4^{-}
-

BC (soot) → Hydrophilic ⇕ Hydrophobic

6 Tracers

OC_T (primary + secondary) → Hydrophilic ⇕ Hydrophobic

RegCM3/aerosol simulations

Two 12-year RegCM3/aerosol simulations were performed for the period 1996-2007 :

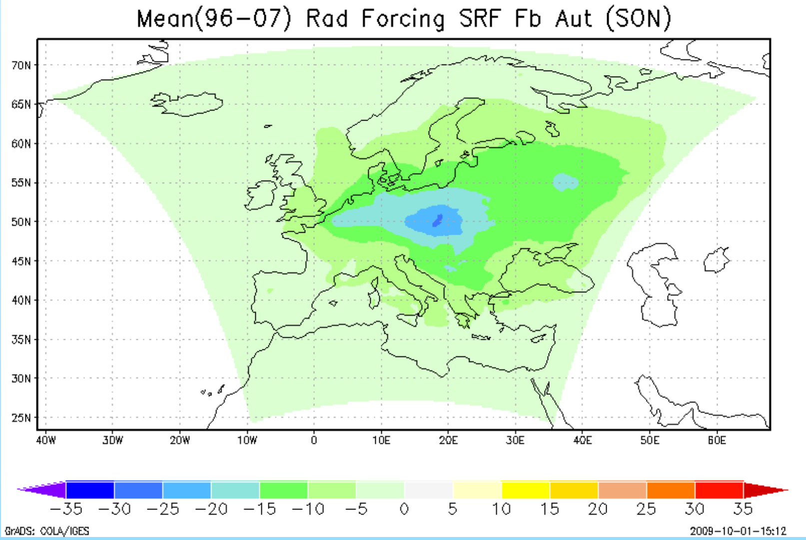
a) **The control run (Crun) with the chemical tracers only being transported**
b) **The aerosol feedback run (AFrun) including the direct aerosol feedback on the shortwave radiation**

Lateral boundary conditions: NCEP-DOE AMIP-II Reanalysis dataset

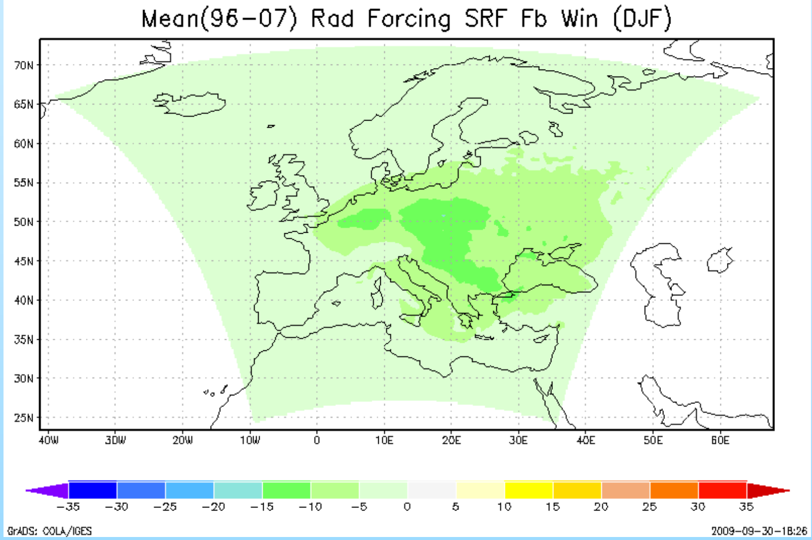
Domain: European domain with 50 km x 50 km resolution (18 layers up to 50 hPa)

Radiative forcing

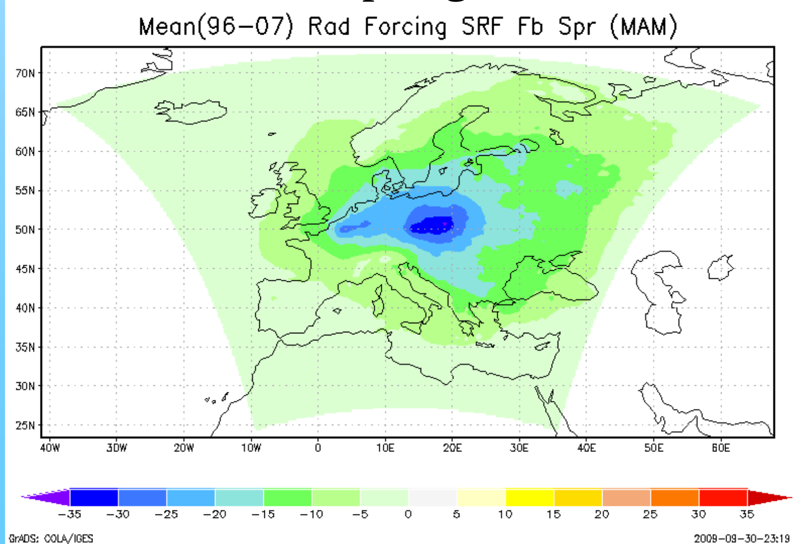
autumn



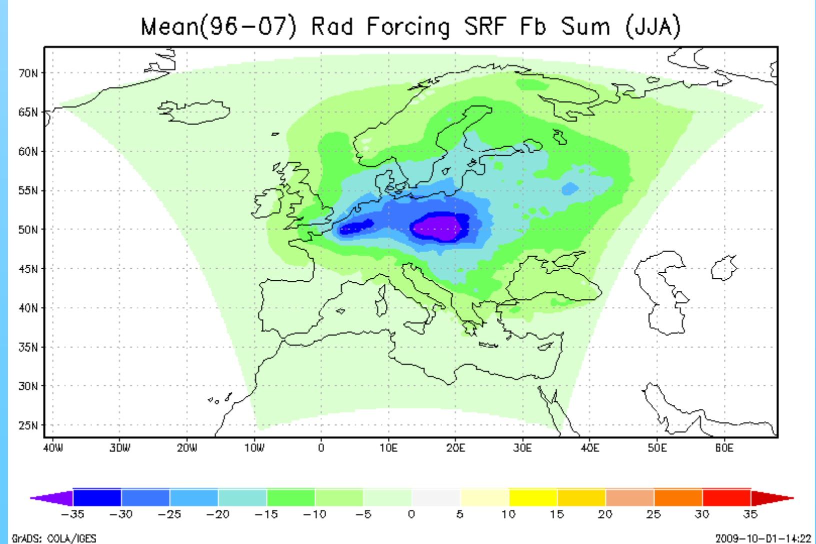
winter



spring

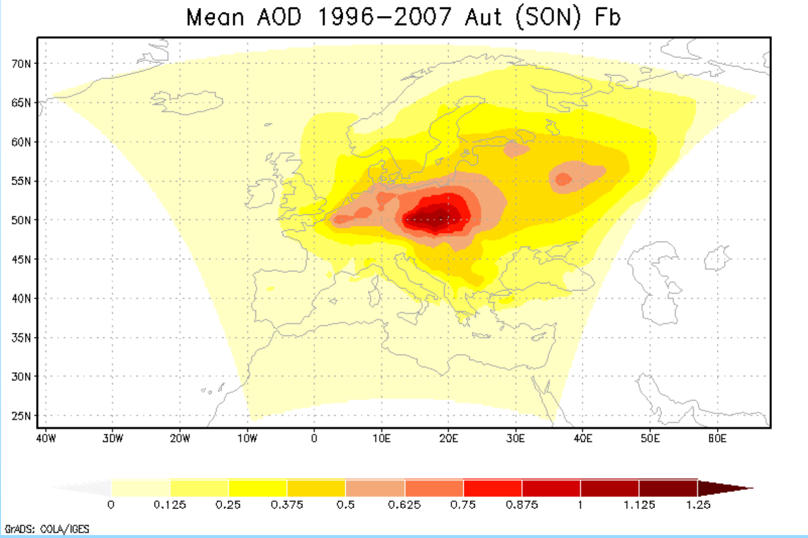


summer

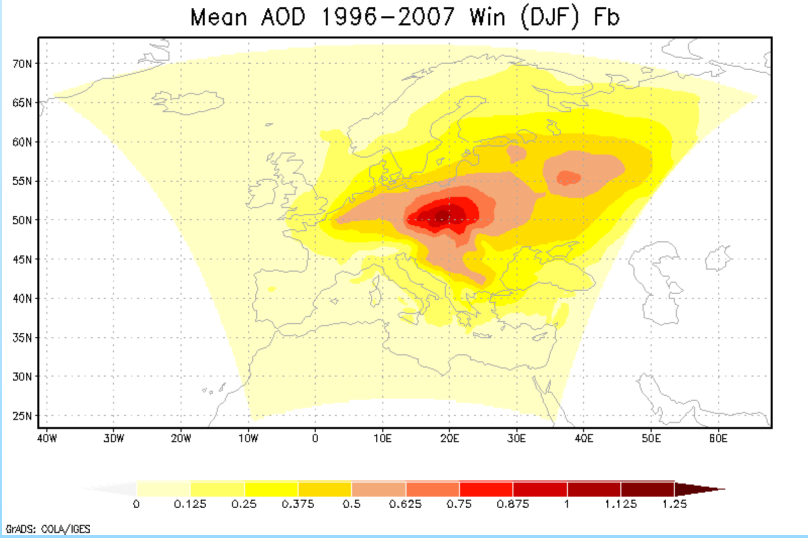


AOD values

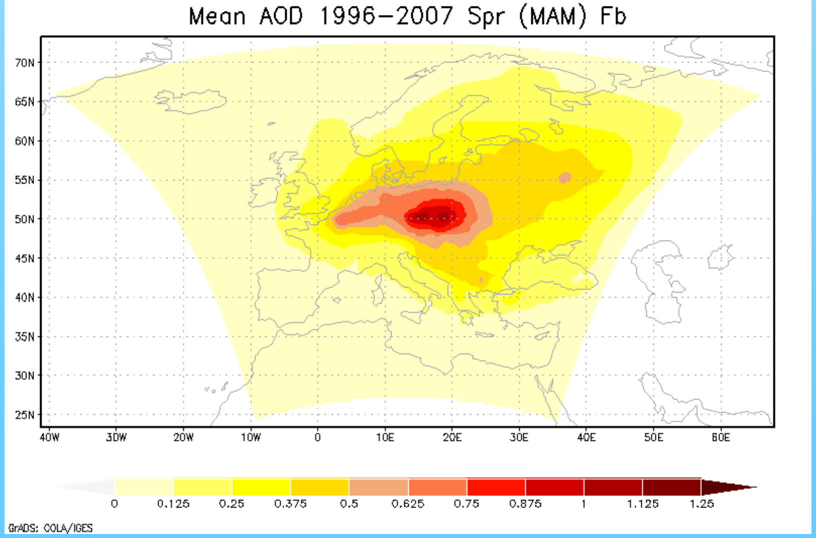
autumn



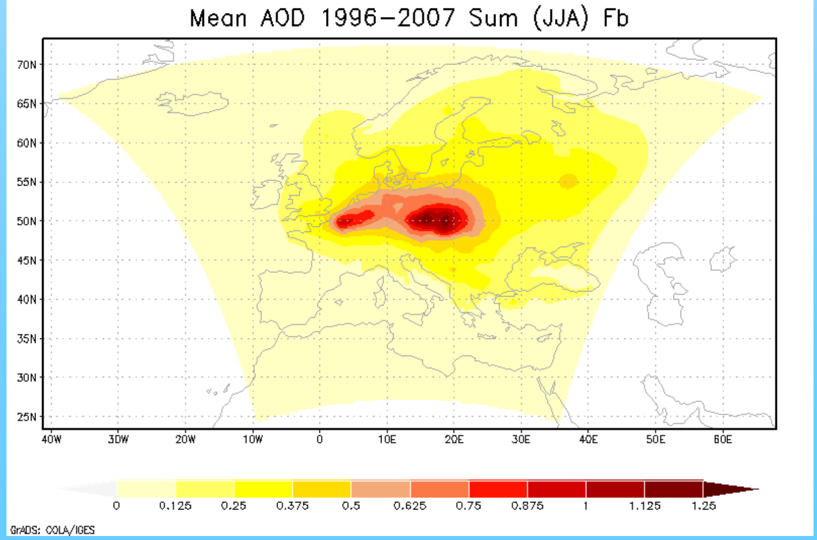
winter



spring



summer



MODIS (2000-2007)

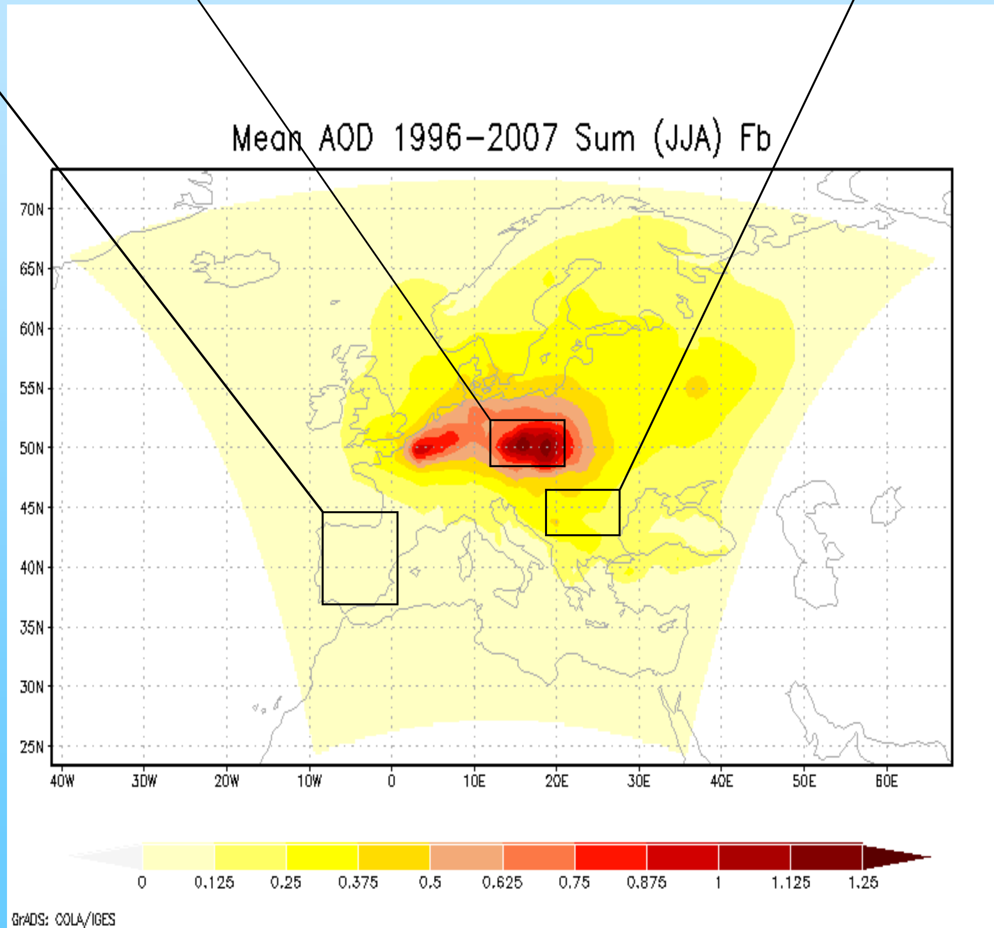
0.19

MODIS (2000-2007)

0.24

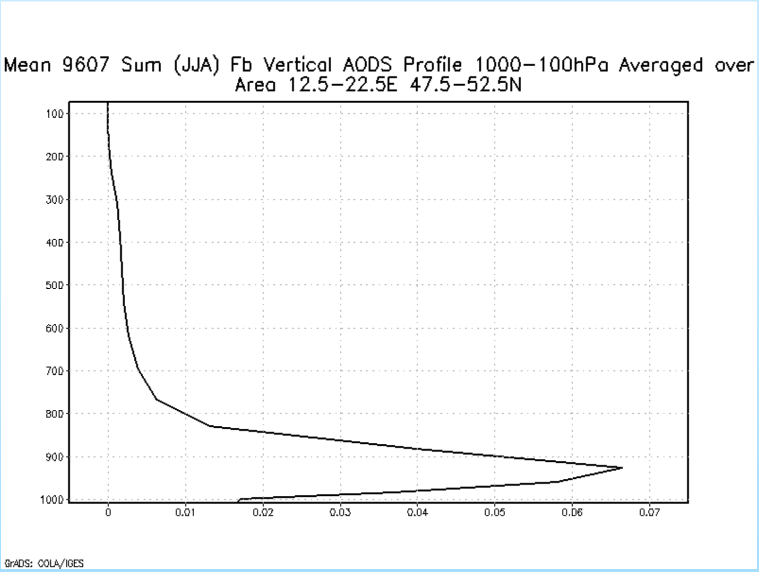
MODIS (2000-2007)

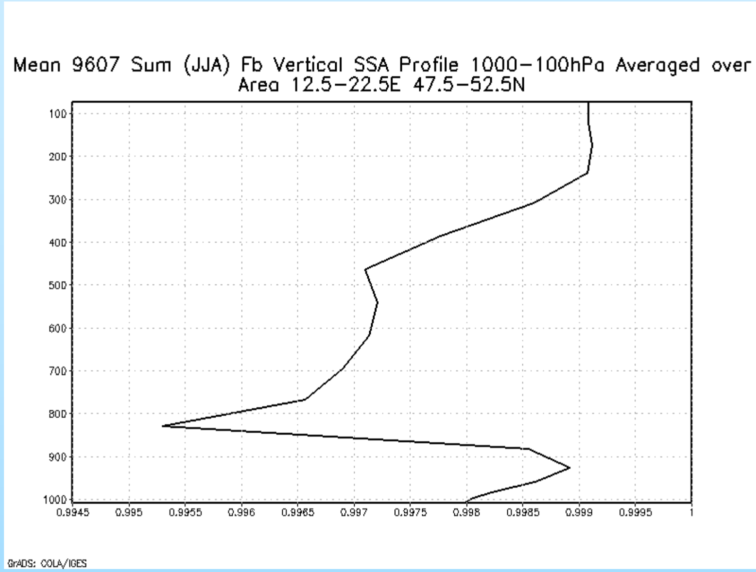
0.23

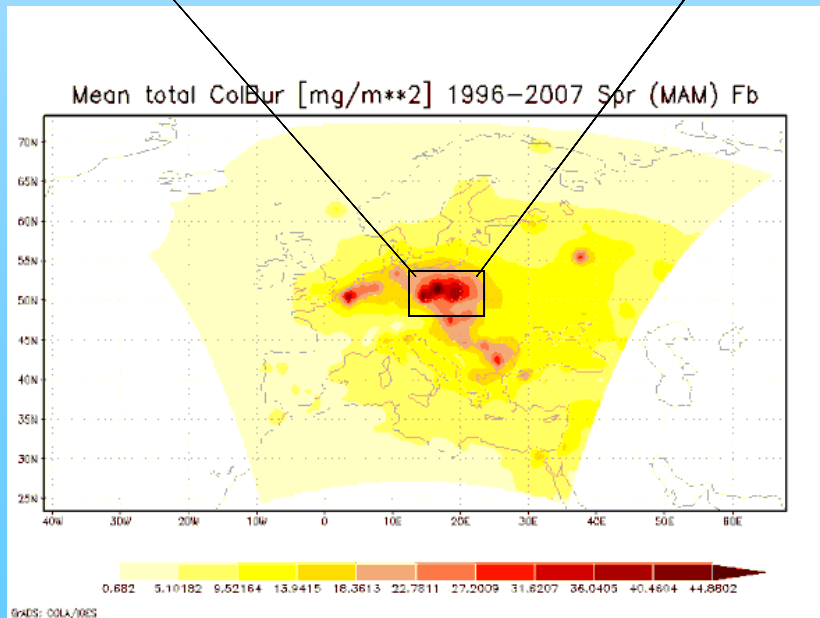


Aerosol extinction

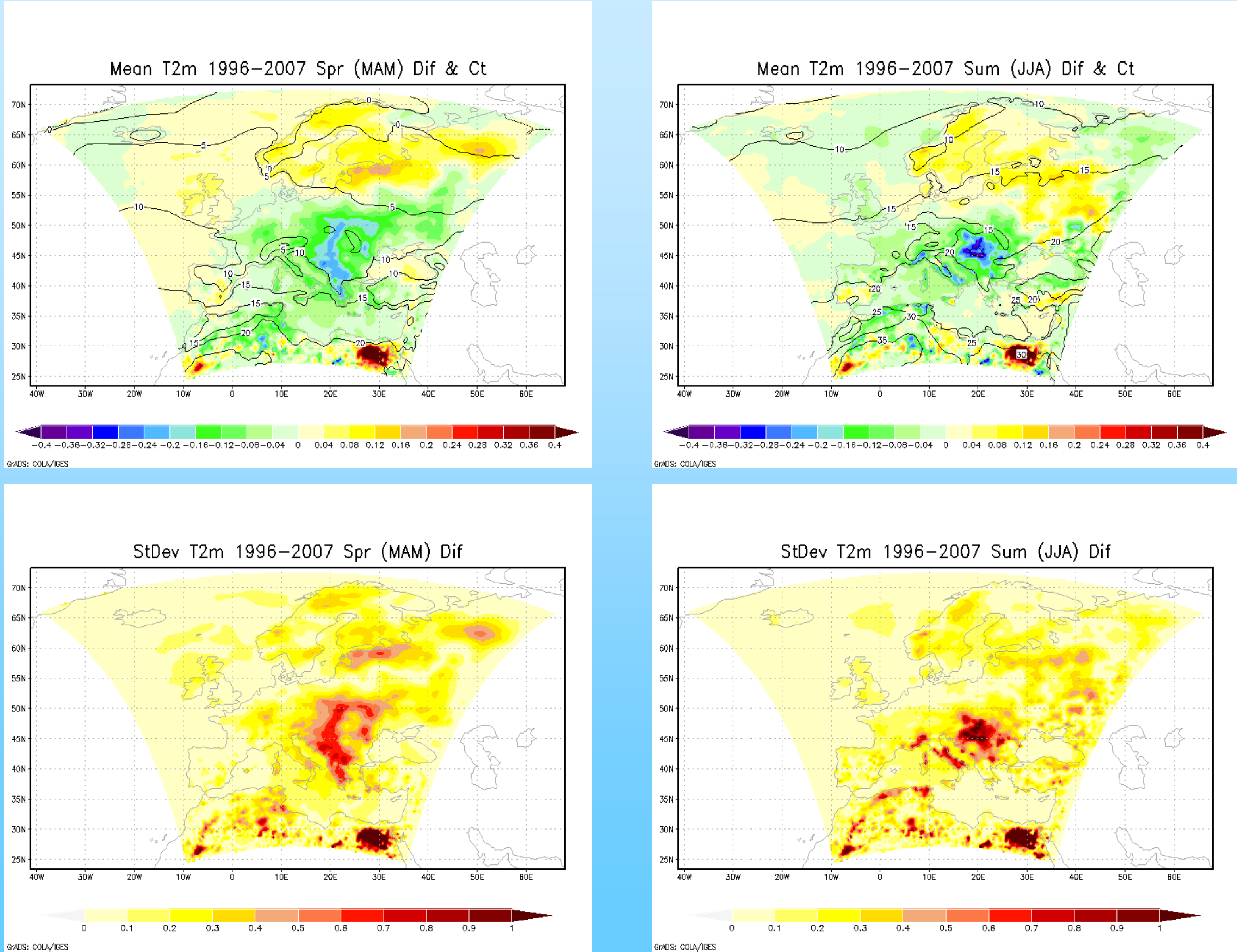
Single scattering albedo

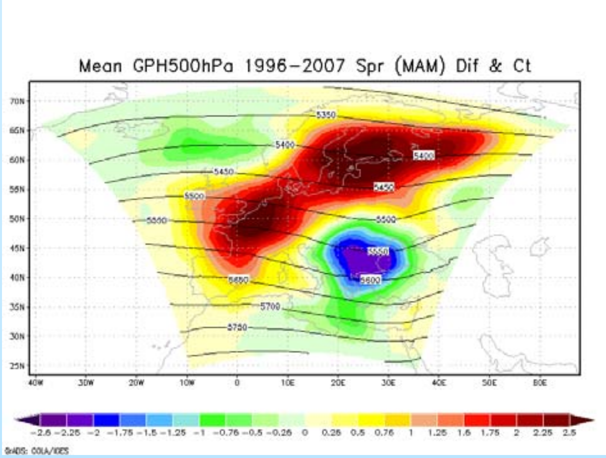


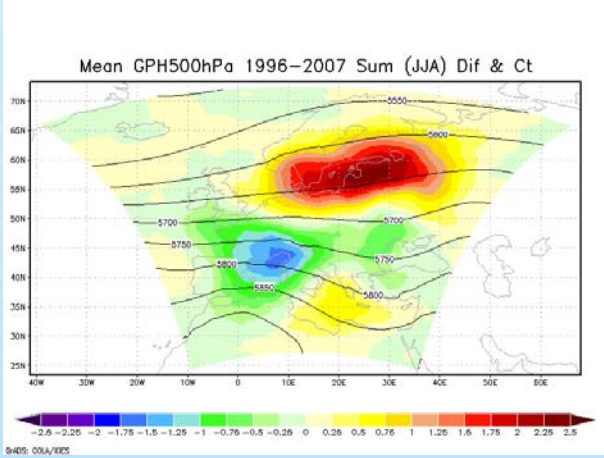




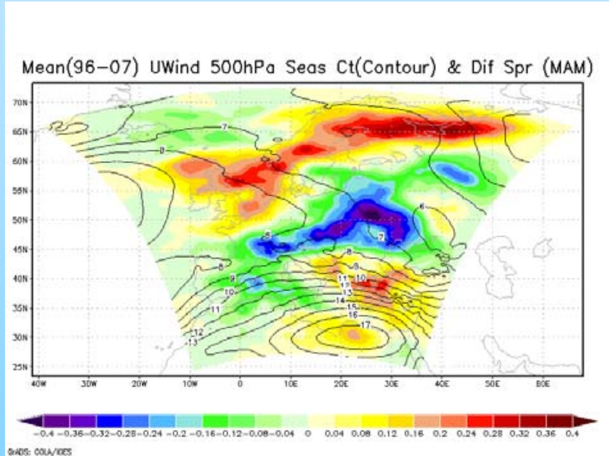
Temperature difference

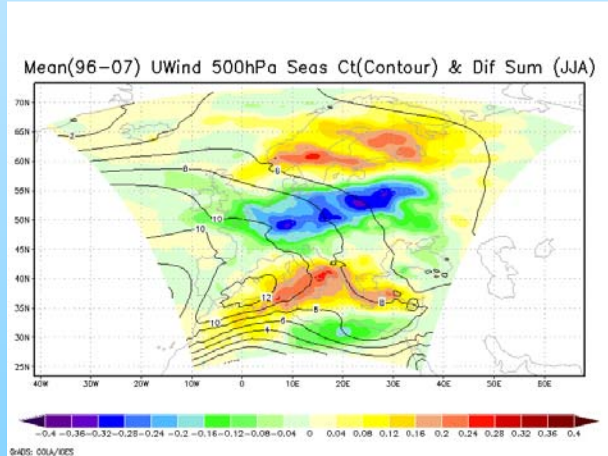




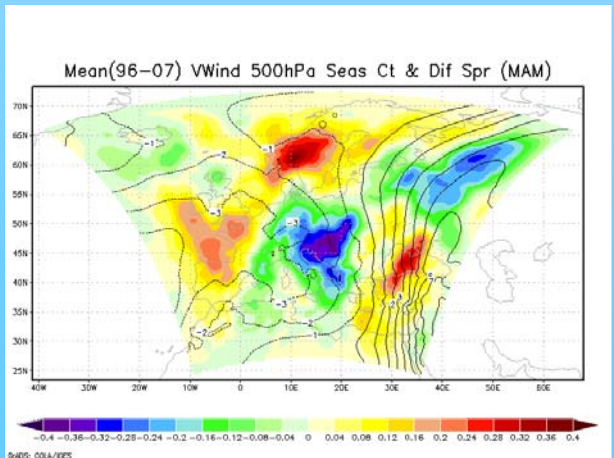


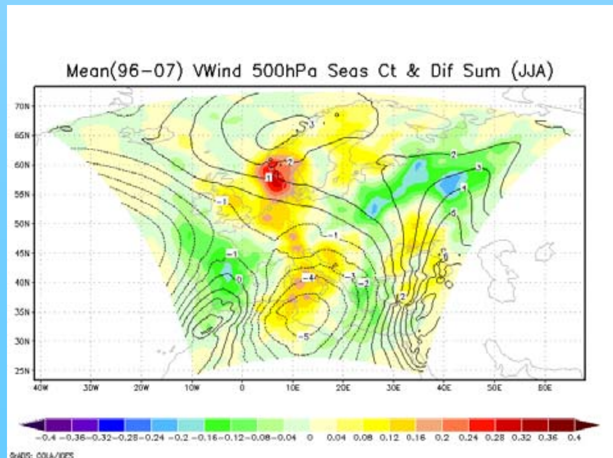
Geopotential Height differences AFrun-Crun at 500 hPa over 1996-2007





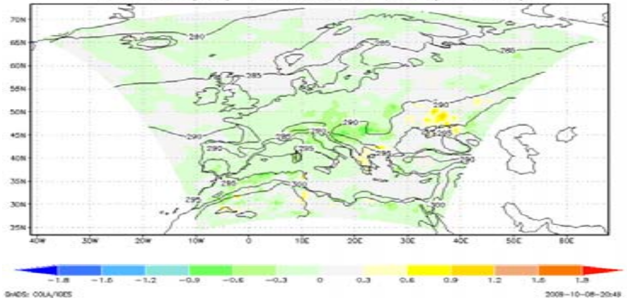
Zonal wind differences AFrun-Crun at 500 hPa over 1996-2007



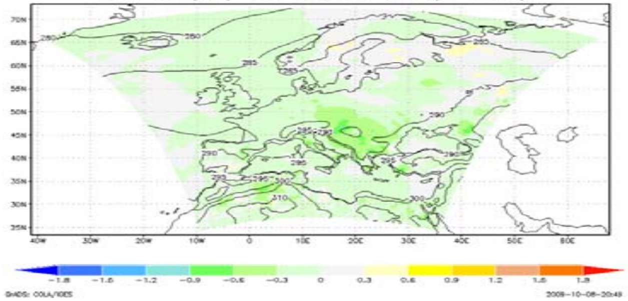


Meridional wind differences AFrun-Crun at 500 hPa over 1996-2007

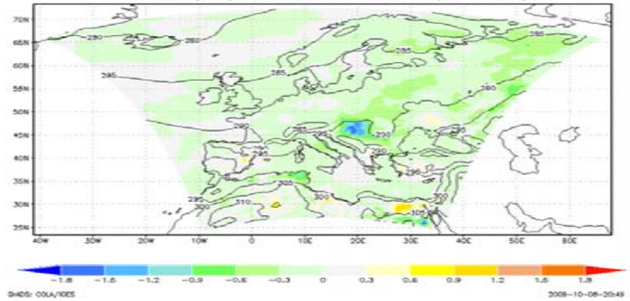
Summer (JJA) T2m 1996 Dif & Fb(Contours)



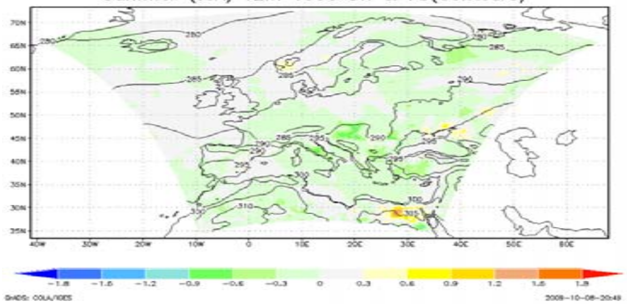
Summer (JJA) T2m 1997 Dif & Fb(Contours)



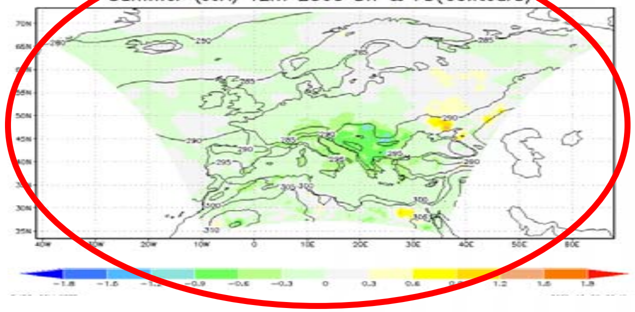
Summer (JJA) T2m 1998 Dif & Fb(Contours)



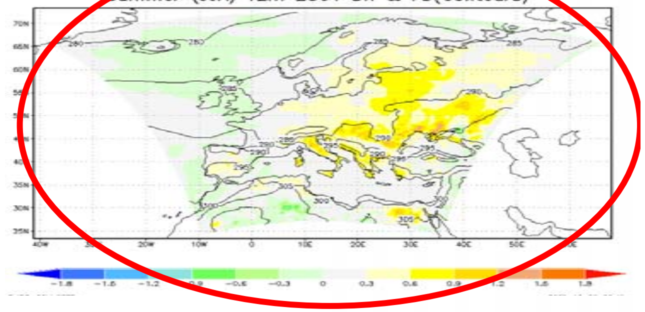
Summer (JJA) T2m 1999 Dif & Fb(Contours)



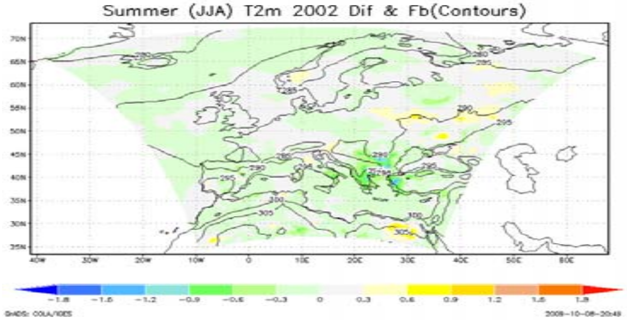
Summer (JJA) T2m 2000 Dif & Fb(Contours)



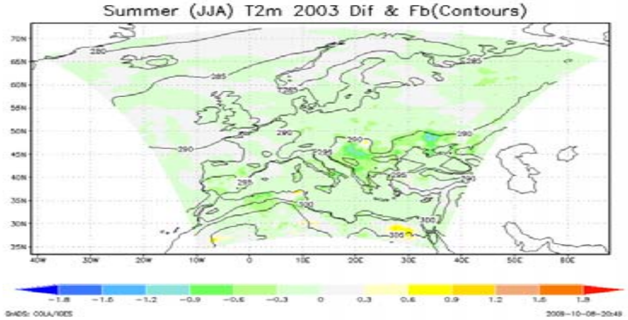
Summer (JJA) T2m 2001 Dif & Fb(Contours)



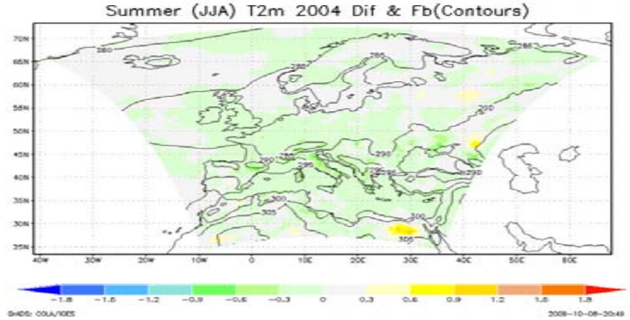
Summer (JJA) T2m 2002 Dif & Fb(Contours)



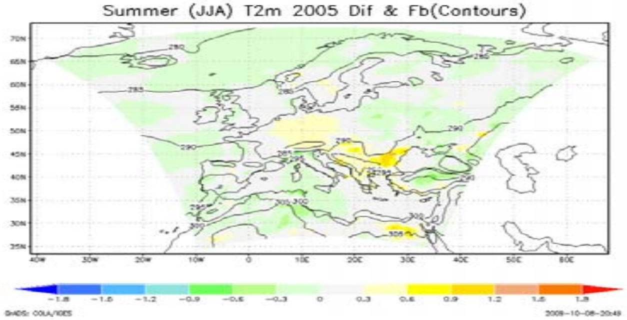
Summer (JJA) T2m 2003 Dif & Fb(Contours)



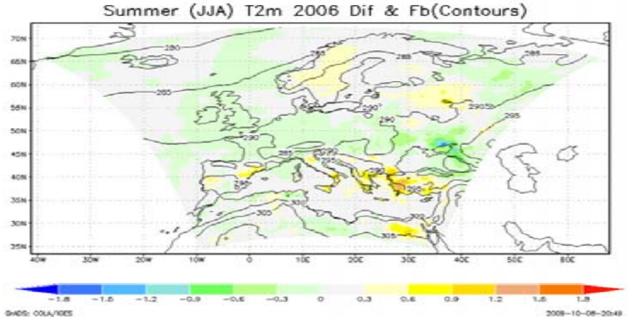
Summer (JJA) T2m 2004 Dif & Fb(Contours)



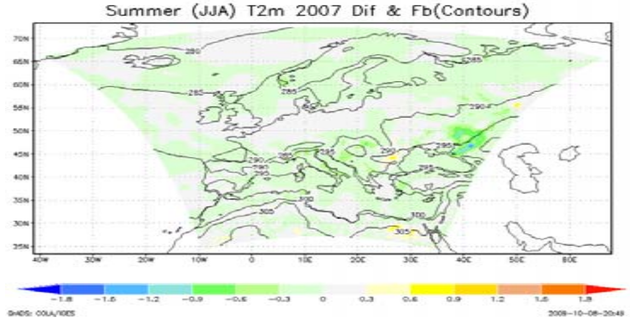
Summer (JJA) T2m 2005 Dif & Fb(Contours)



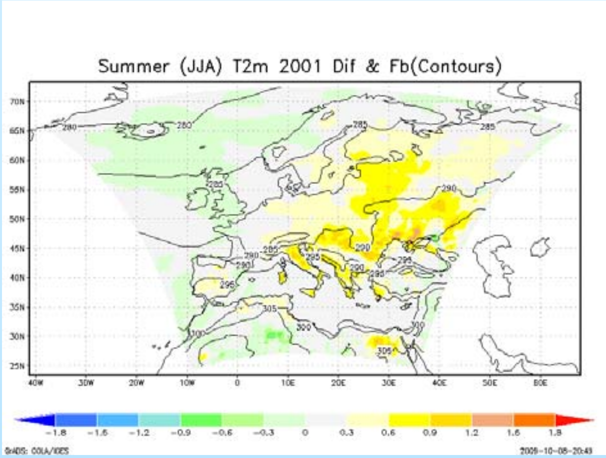
Summer (JJA) T2m 2006 Dif & Fb(Contours)

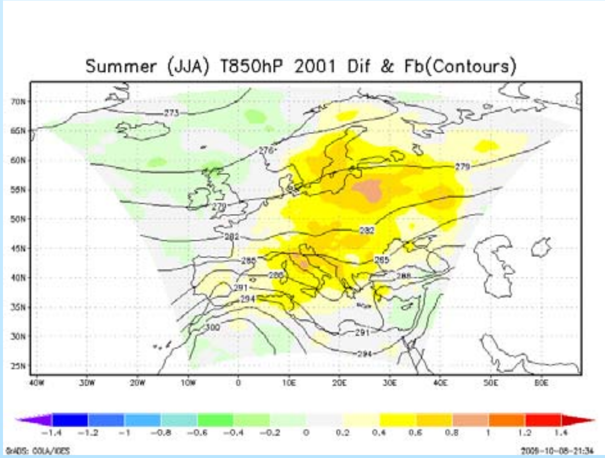


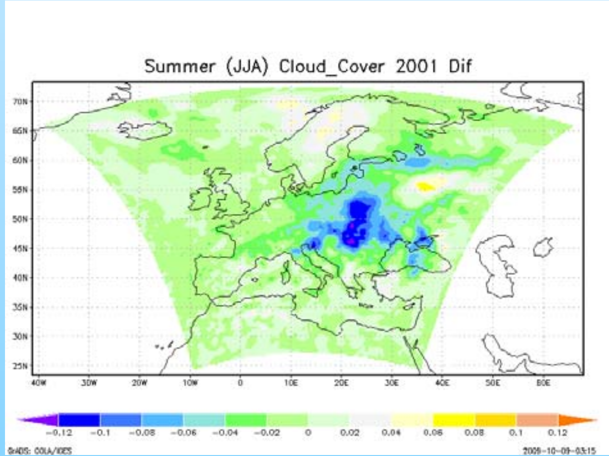
Summer (JJA) T2m 2007 Dif & Fb(Contours)

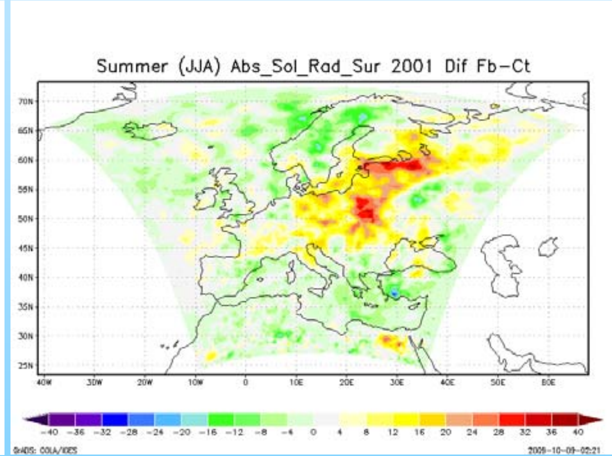


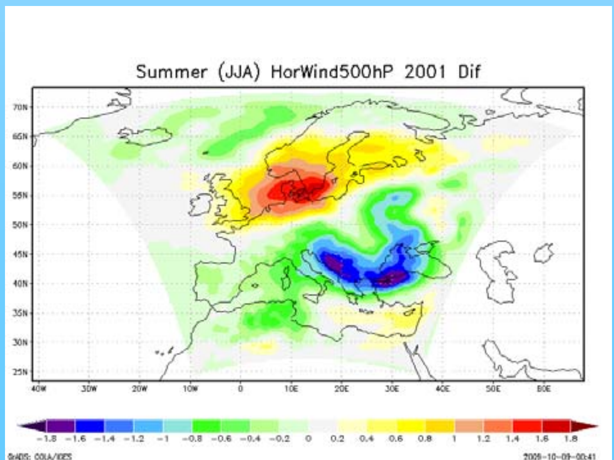
Summer 2001

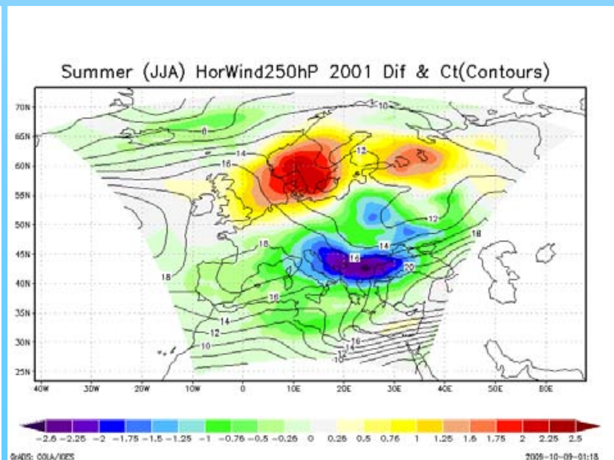

Summer (JJA) T2m 2001 Dif & Fb(Contours)

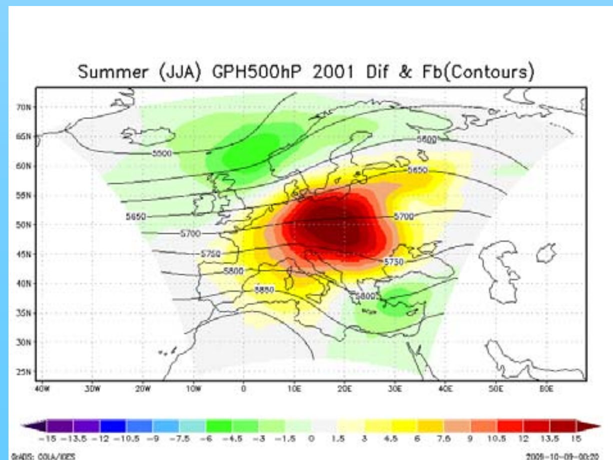

Summer (JJA) T850hP 2001 Dif & Fb(Contours)


Summer (JJA) Cloud_Cover 2001 Dif

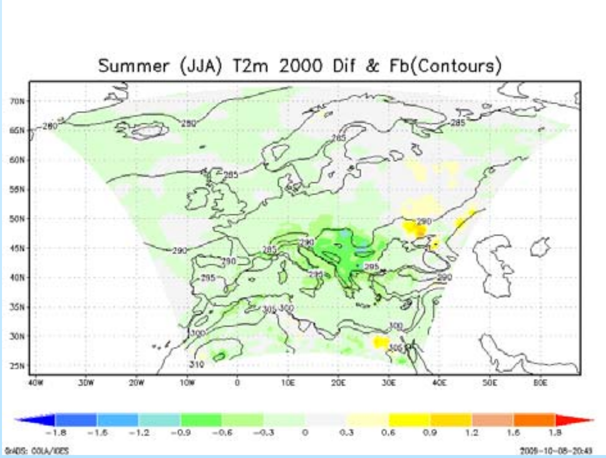

Summer (JJA) Abs_Sol_Rad_Sur 2001 Dif Fb-Ct


Summer (JJA) HorWind500hP 2001 Dif


Summer (JJA) HorWind250hP 2001 Dif & Ct(Contours)


Summer (JJA) GPH500hP 2001 Dif & Fb(Contours)

Summer 2000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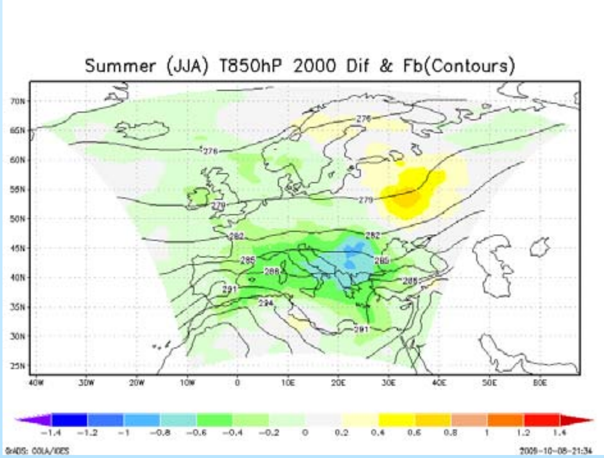
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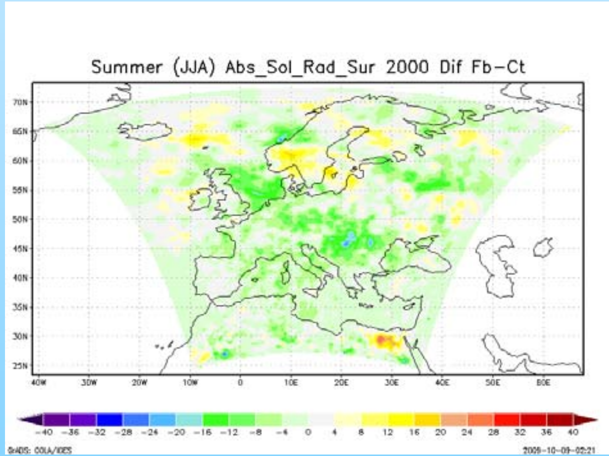
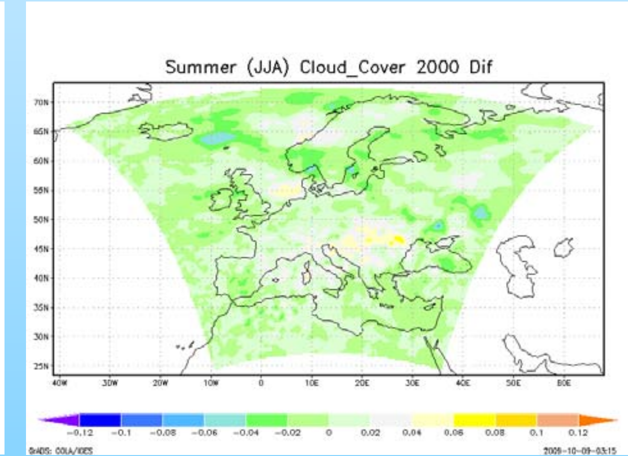
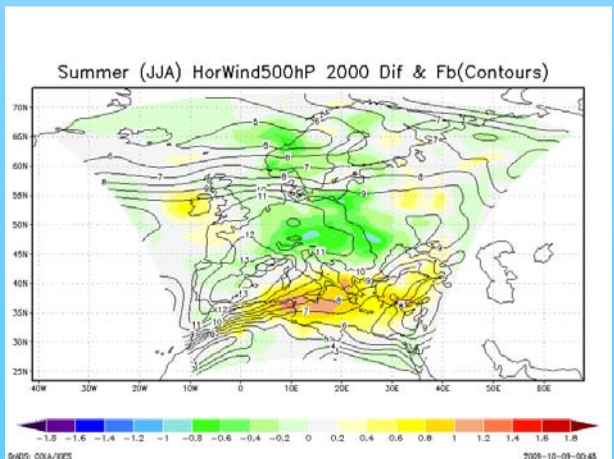
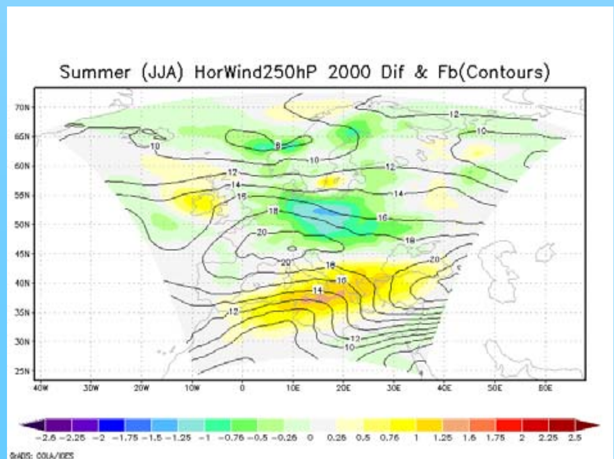
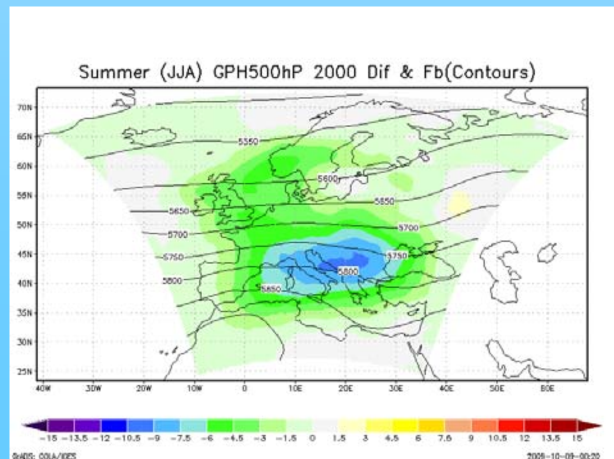
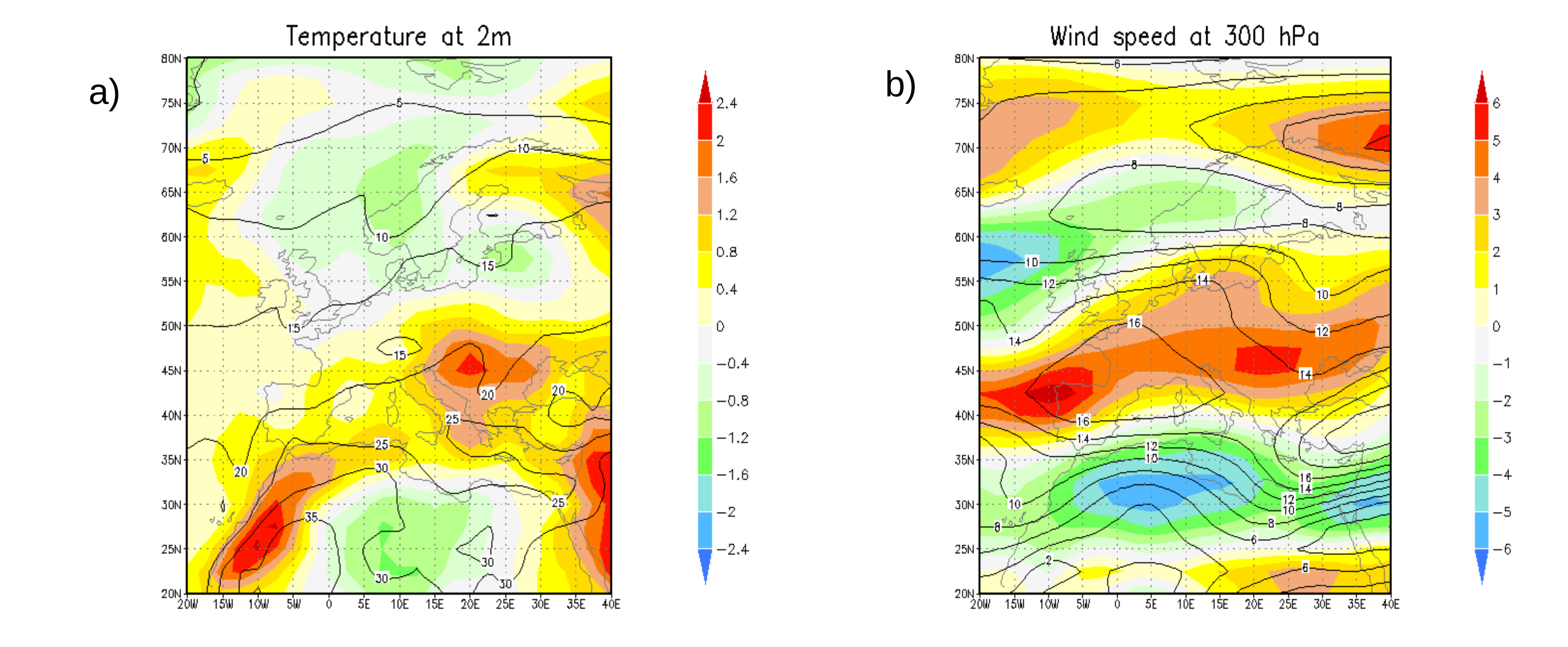

Summer (JJA) Abs_Sol_Rad_Sur 2000 Dif Fb-Ct


Summer (JJA) Cloud_Cover 2000 Dif

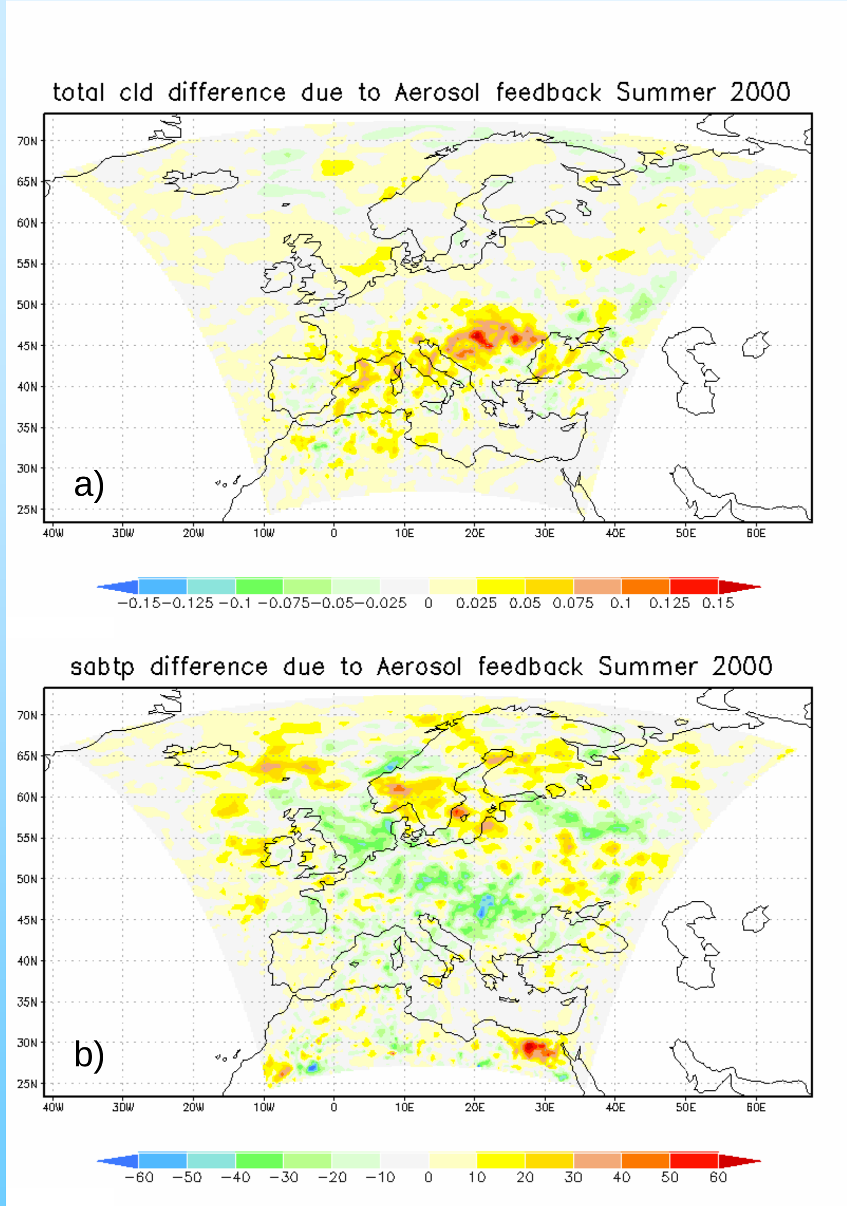

Summer (JJA) HorWind500hP 2000 Dif & Fb(Contours)


Summer (JJA) HorWind250hP 2000 Dif & Fb(Contours)

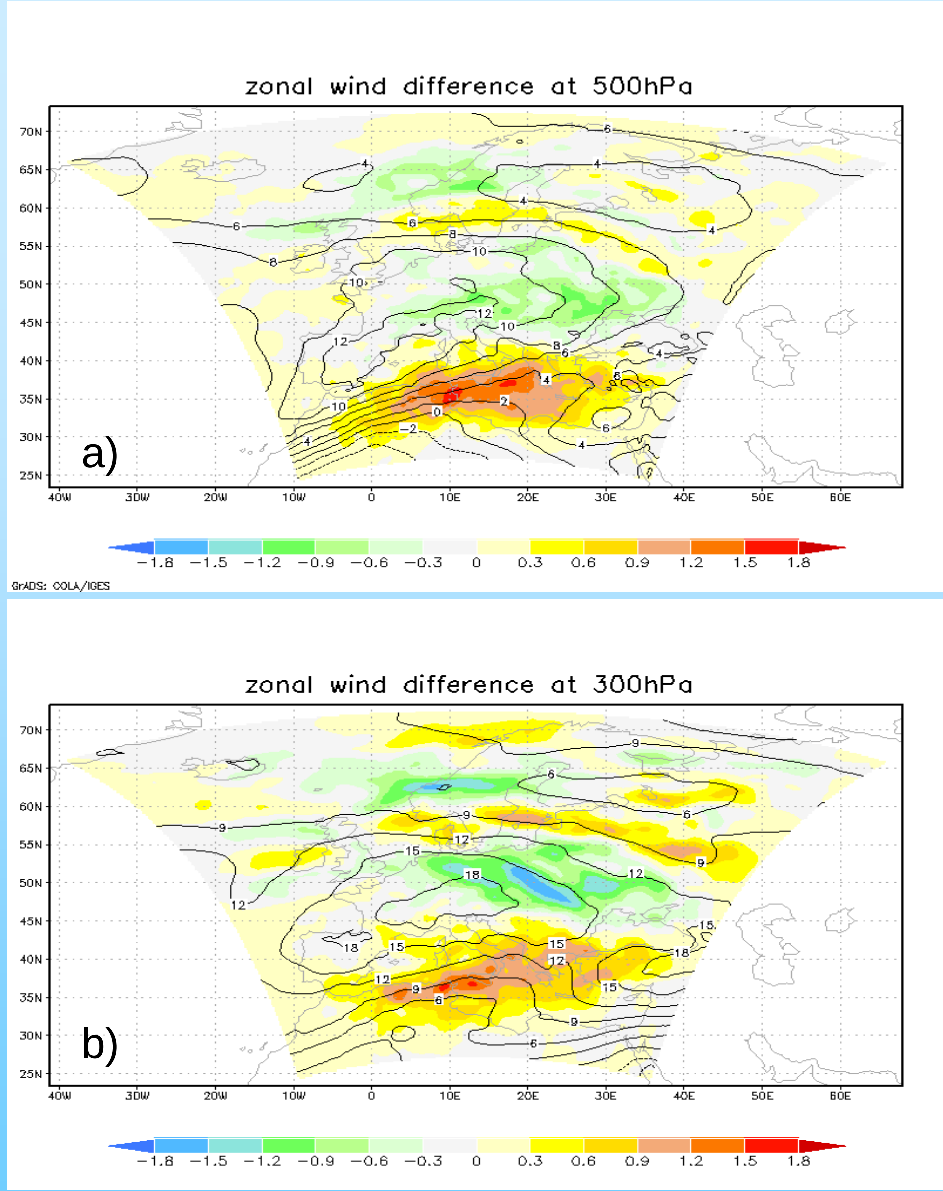

Summer (JJA) GPH500hP 2000 Dif & Fb(Contours)



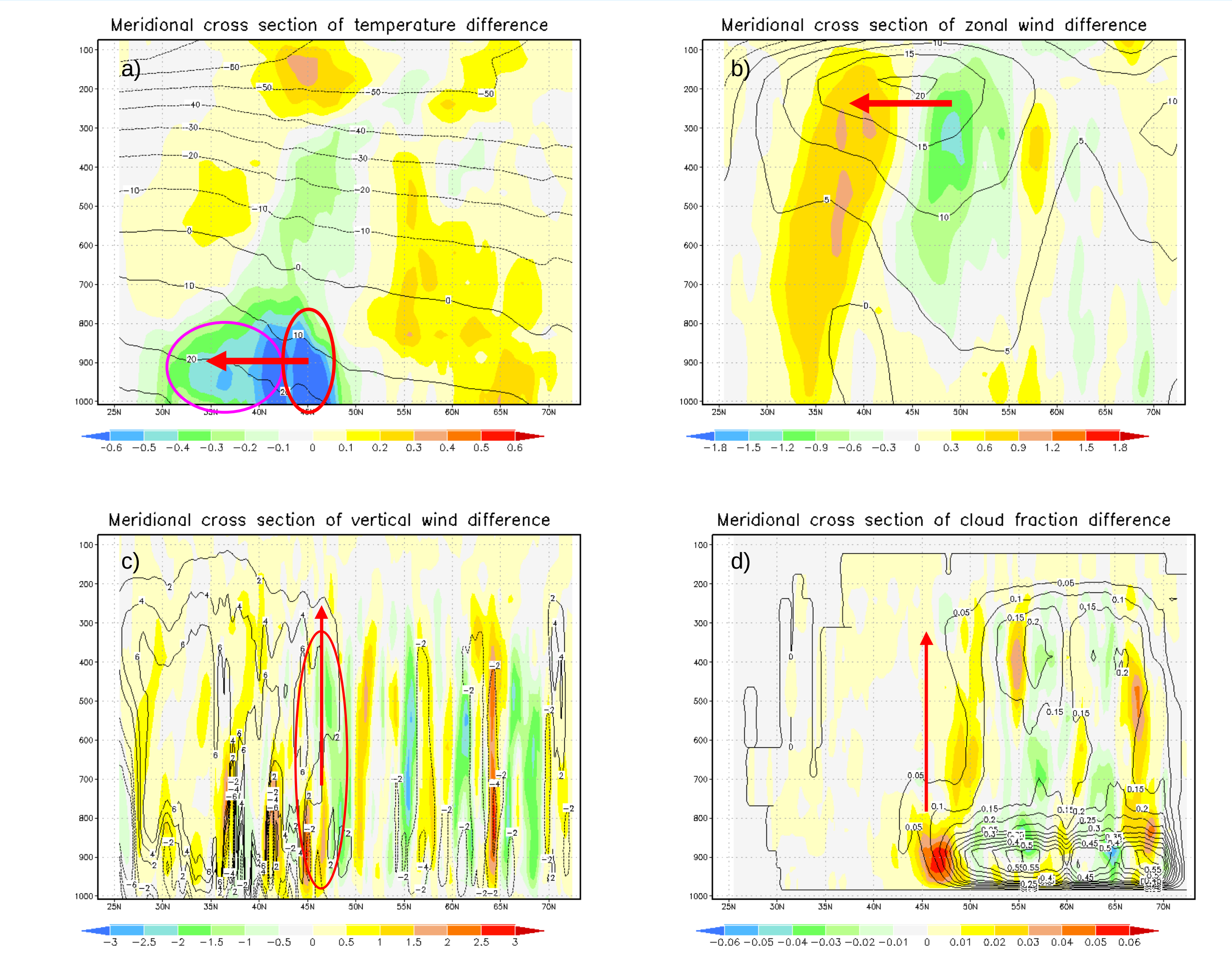
Anomalies of summer 2000 from the summer climatic mean over the period 1961-1996 for a) near surface air temperature and b) wind speed at 300 hPa. The contour lines denote the mean values of summer 2000.



Seasonal mean fields in summer for the year 2000 of the difference AFrun-Crun RegCM3 aerosol simulations due to aerosol feedback in a) total column fractional cloud cover (%) and b) surface absorbed solar radiation (W/m^2).



Seasonal mean fields in summer for the year 2000 of the difference AFrun-Crun RegCM3/aerosol simulations due to aerosol feedback in zonal wind at 500 hPa (a) and 300 hPa (b). The units are in m/s.



Mean summer (for the year 2000) meridional cross sections averaged over the longitudinal zone 20^{o}E-30^{o}E of the difference AFrun-Crun RegCM3/aerosol simulations due to aerosol feedback in a) air temperature (^{o}C), b) zonal wind (m/s), c) vertical wind (10^{-5} hPa/s) and d) cloud fraction (dimensionless).

Key points

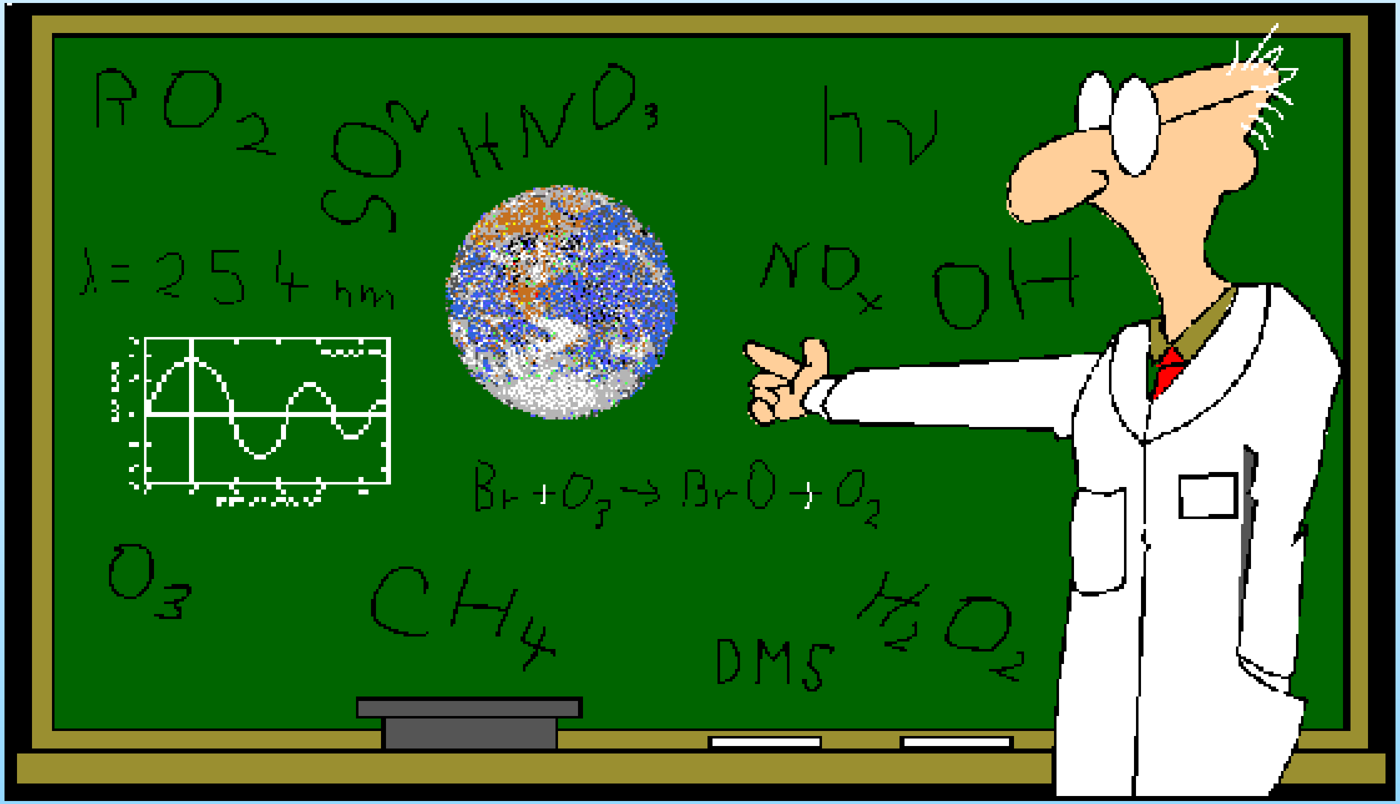
- The direct effect of anthropogenic aerosols induces a small near surface temperature differences (decreases) for the overall period 1996-2007 with the largest effects seen in spring and summer when RF values are more negative.

- The pattern of the regional aerosol induced changes of the near surface temperature is mainly arisen through the aerosol induced changes of the atmospheric circulation and is not spatially collocated with the pattern of the aerosol induced surface radiative forcing.

- A common feature in the aerosol induced changes in atmospheric circulation for spring and summer is a small decrease of the westerly zonal wind in the latitudinal belt 45^{o} N-55^{o} N.

- Greater near surface temperature differences seen from year to year as the aerosol radiative forcing interacts in a complex way with the specific atmospheric circulation patterns of each year. The effect on circulation patterns becomes moderate in the long-term mean.

- A southward shift of the subtropical jet stream seems to play a dominant role for the decrease in near surface air temperature over Southeastern Europe and the Balkan Peninsula for summer 2000.



Thanks for your attention

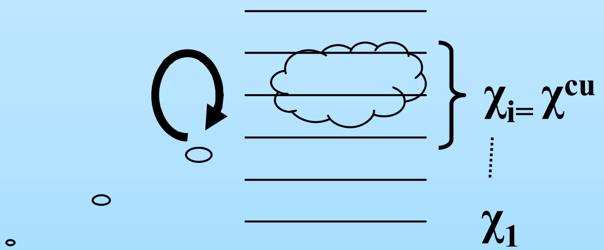
Aerosols processes

- **Transport of tracers**

  Advection / diffusion ⟺ Cloud mmr (mm5 options)

- **Convective transport**

  Simple mixing hypothesis



- **Wet removal by large scale rainfall:**

$$R_{w,ls} = \chi f_{sol}(\chi) \frac{1-\exp\left(-\Delta t / \tau_{w,ls}\right)}{\Delta t}$$

(Giorgi et al., 1989)

- **Wet removal by cumulus convective rainfall:**

$\tau_{w,cum} \sim 20\text{min}$

$$R_{w,cum} = \chi f_{cum}\, f_{sol}(\chi) \frac{1-\exp\left(-\Delta t / \tau_{w,cum}\right)}{\Delta t}$$

- **Dry deposition : prescribed deposition velocities (nature tracer / surface)**

Aerosols processes

- **Sulfur Aerosol Model** (Kasibhalta et al., 1997, Qian et al., 2001)

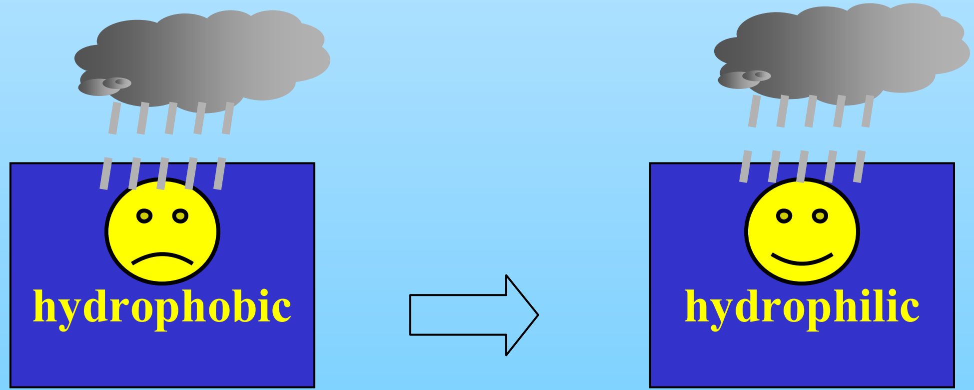
Gas phase: $SO_2 + OH \rightarrow SO_4^{2-} + HO_2$

Aqueous phase: $HSO_3^- + H_2O_2 \rightarrow SO_4^{2-} + 2H^+ + HO_2$

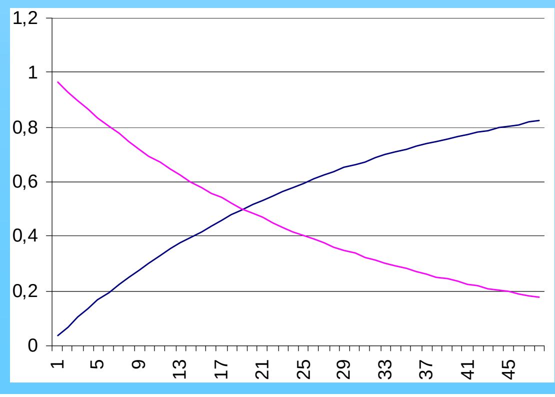
[OH] : constant profile + diurnal evolution (max for $\cos\theta = 1$)

- **Aging of carbon aerosol**
(Cooke et al.,1999)

Simple approach :



τ_{aging}= 1,15 days



Deposition (dry, wet)

Optical properties

CCN

Carbon aerosol (Liousse et al.,1996)

- BC
- $OC_{tot} = OC_{prim} + OC_{sec}$

Emission factors method

➡ Fossil fuel : 1995, 1 deg, annual

➡ Biomass burning : 80-90's

3.75*5 deg, monthly

- Forest
- Savanna
- Agriculture
- Cleaning
- Domestic fires

Injection height

- Hydrophobicity at the emisson

	BC	**OC_{tot}**
	**80 %**	**50 %**
	**20 %**	**50 %**

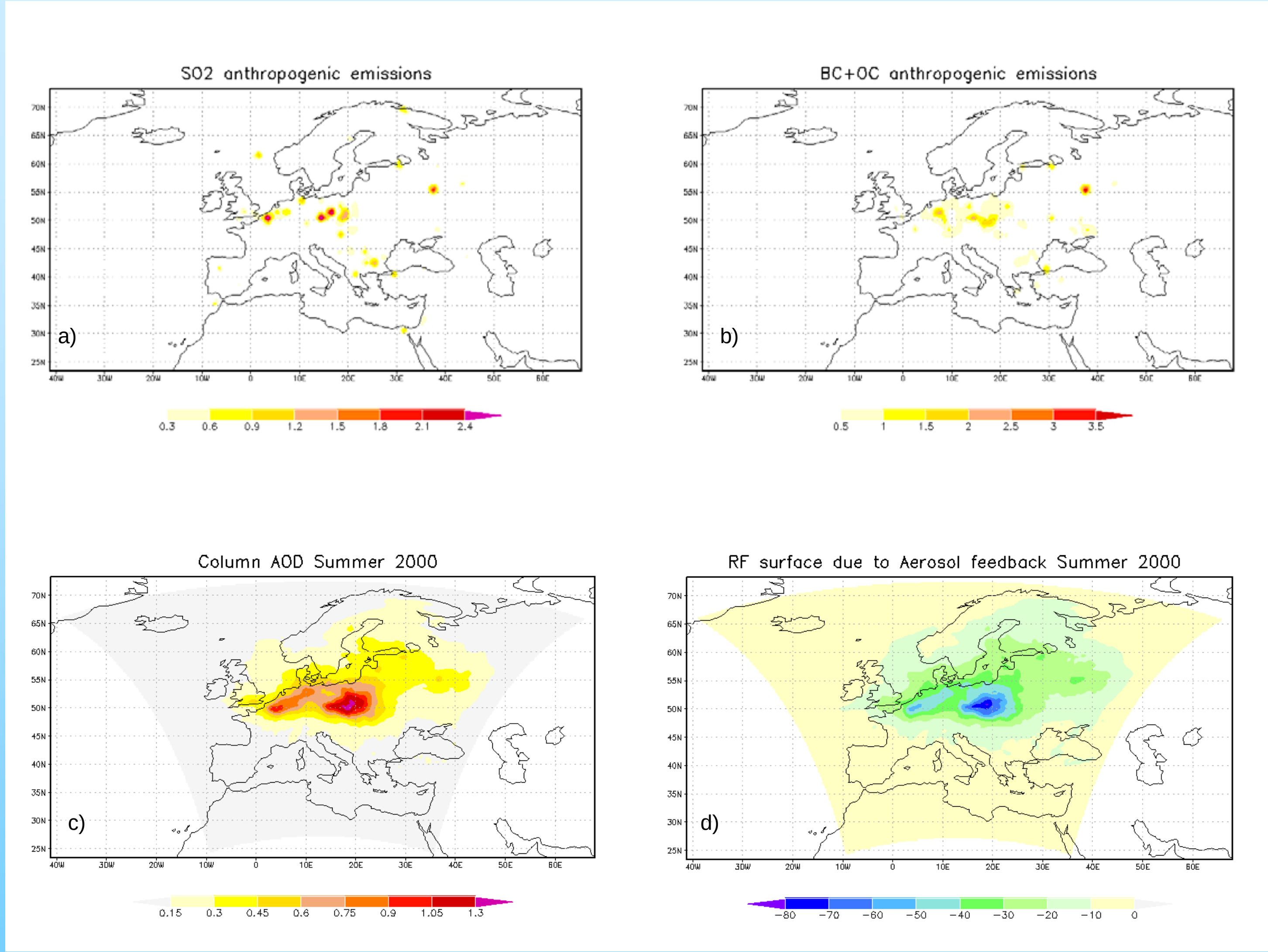
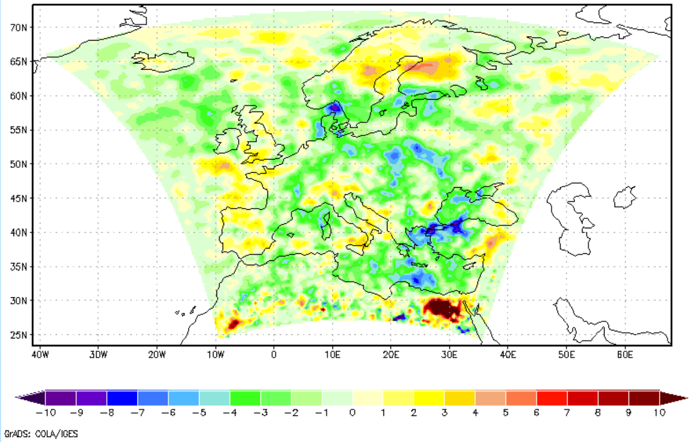
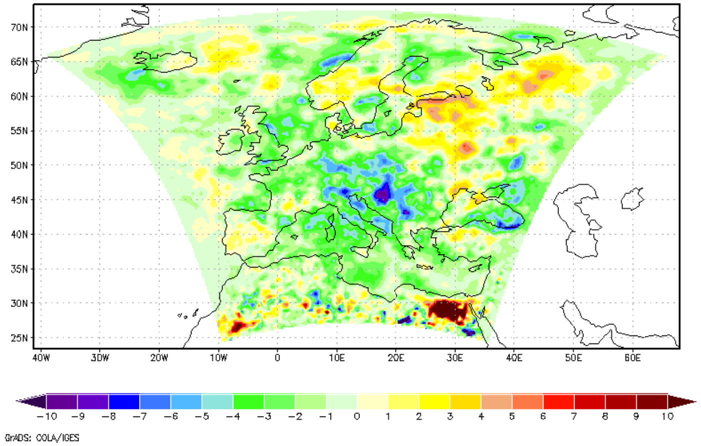


Figure 2. a) Anthropogenic emission of a) SO2 (in 10-9 kg m-2 s-1) and b) the sum of black and organic carbon (in 10-12 kg m-2 s-1). Seasonal mean fields in summer of the year 2000 of c) the aerosol optical depth and d) the surface radiative forcing (in W/m2) due to anthropogenic aerosols (carbonaceous particles and sulphates) obtained from the RegCM3/aerosol simulations.

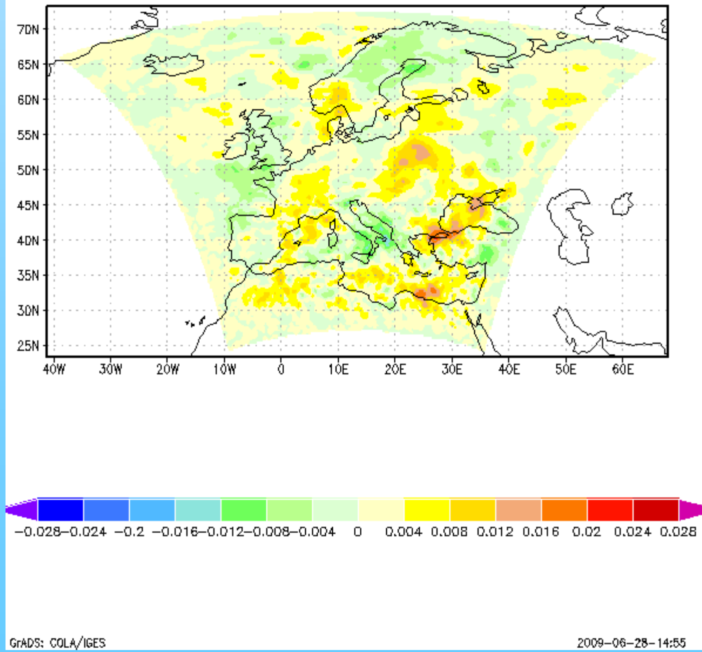
Mean Rad_Budget_Surface 1996–2007 Spr (MAM) Dif



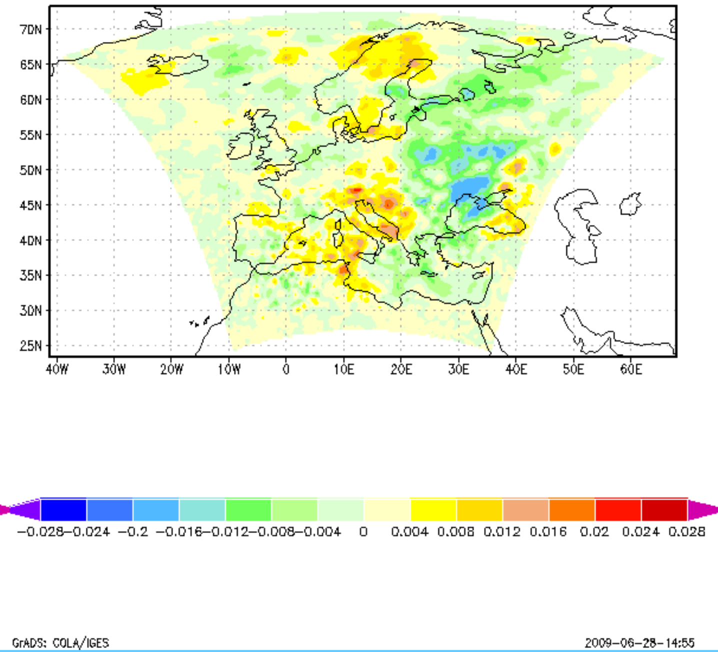
Mean Rad_Budget_Surface 1996–2007 Sum (JJA) Dif

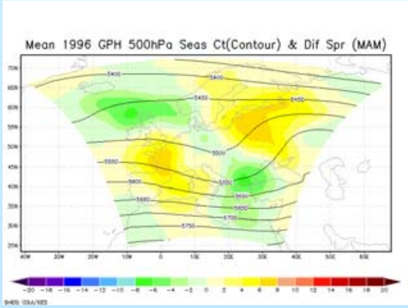


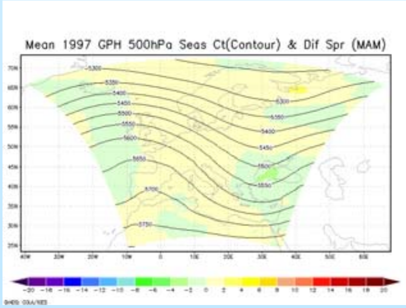
Mean(96–07) DTCCFC SeasDif(Fb–Ct) Spr (MAM)

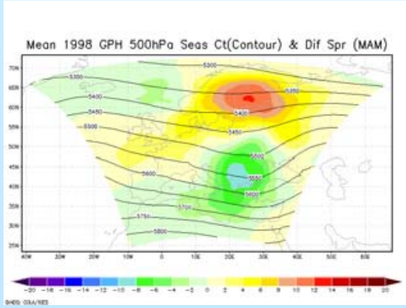


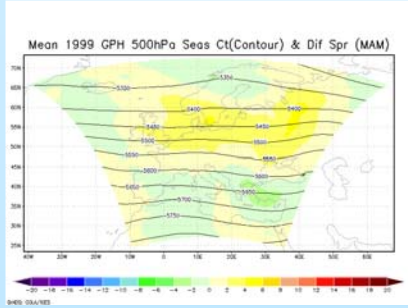
Mean(96–07) DTCCFC SeasDif(Fb–Ct) Sum (JJA)

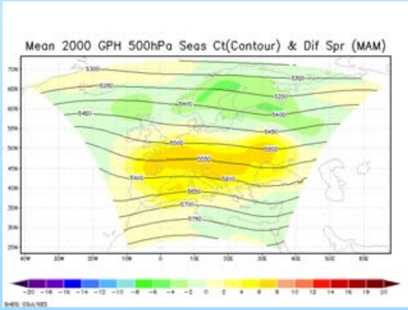


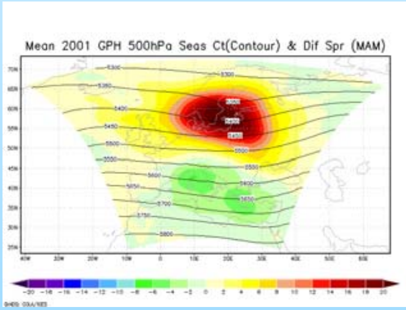

Mean 1996 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

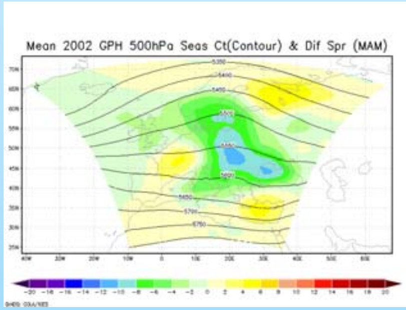

Mean 1997 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

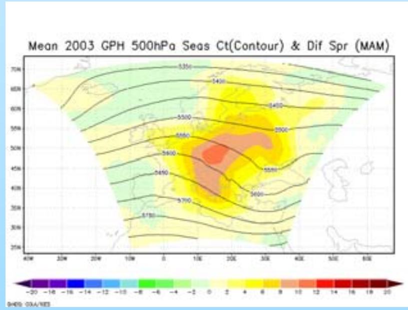

Mean 1998 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

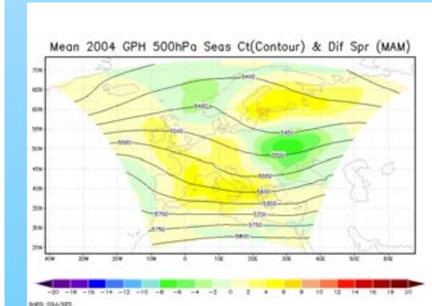

Mean 1999 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

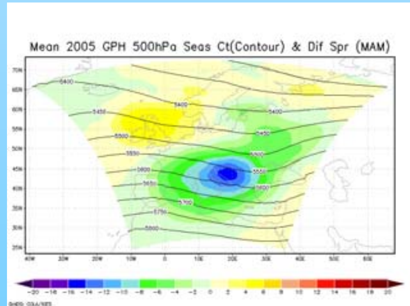

Mean 2000 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)


Mean 2001 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)


Mean 2002 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)


Mean 2003 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)


Mean 2004 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)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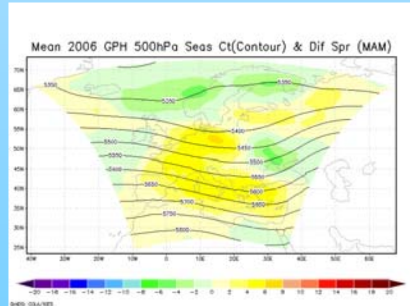
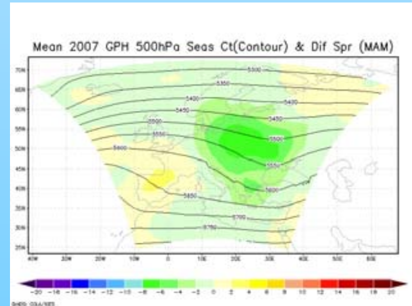
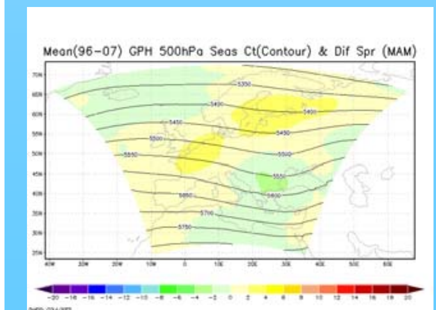
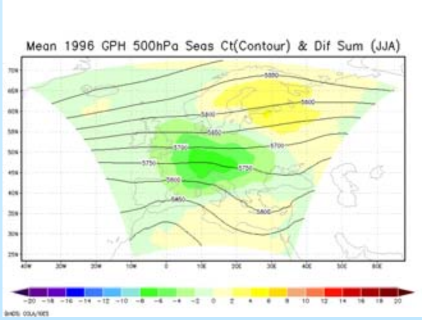
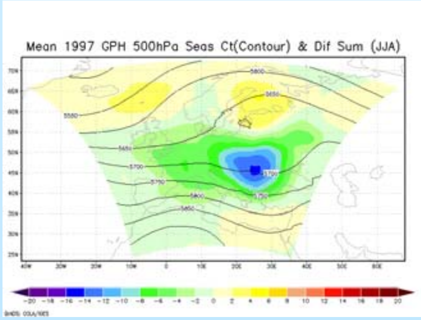
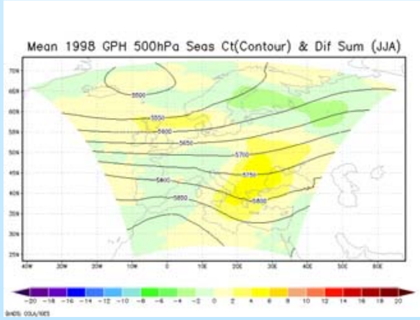

Mean 2006 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

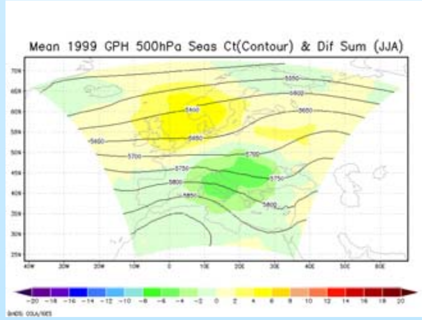

Mean 2007 GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

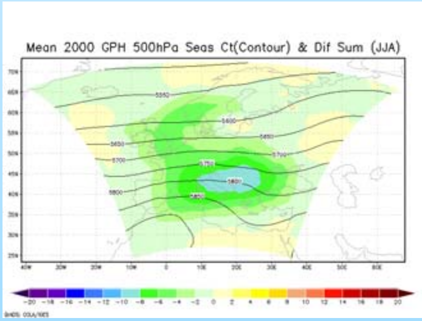

Mean(96-07) GPH 500hPa Seas Ct(Contour) & Dif Spr (MAM)

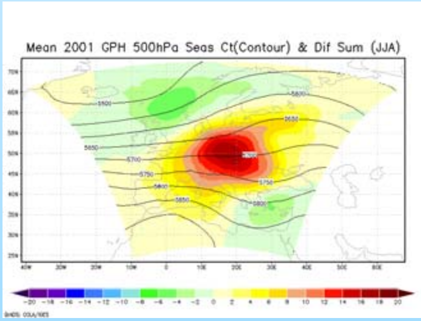

Mean 1996 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)

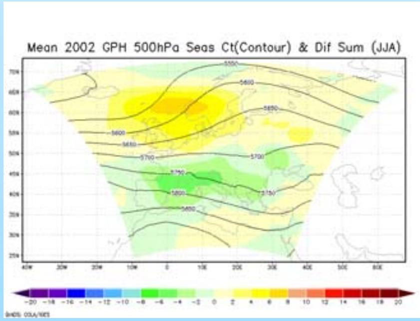

Mean 1997 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean 1998 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean 1999 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean 2000 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean 2001 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)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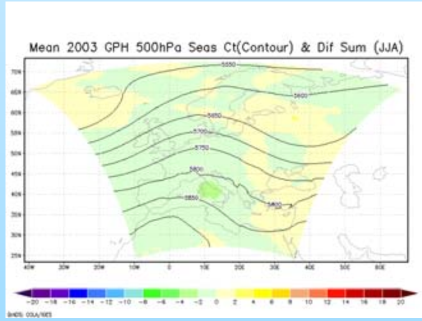
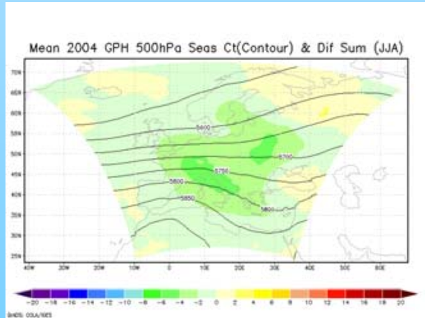
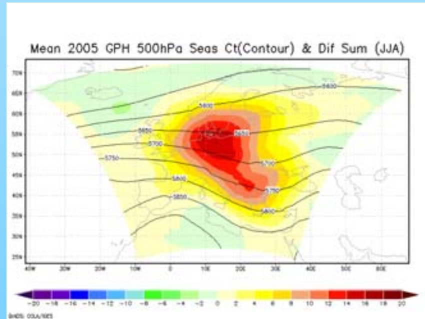
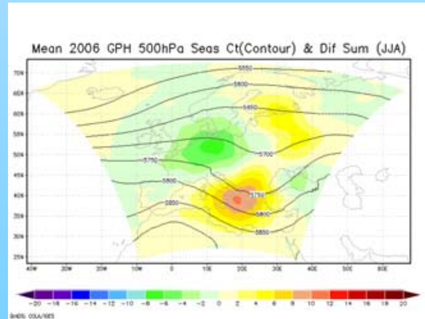

Mean 2003 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean 2004 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean 2005 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)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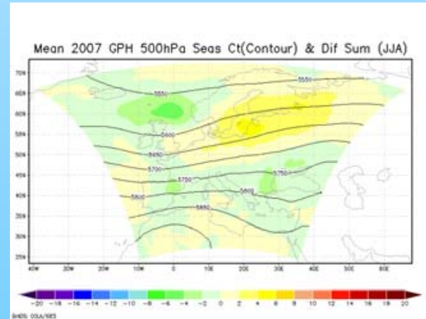
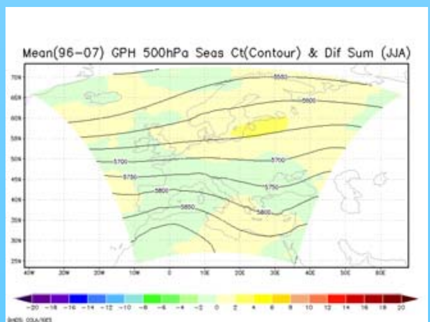
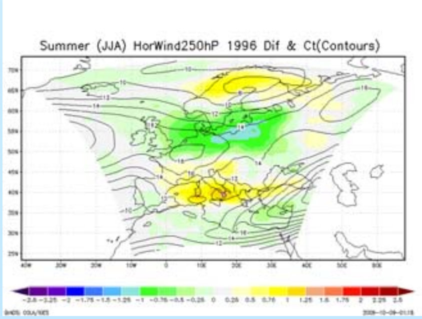
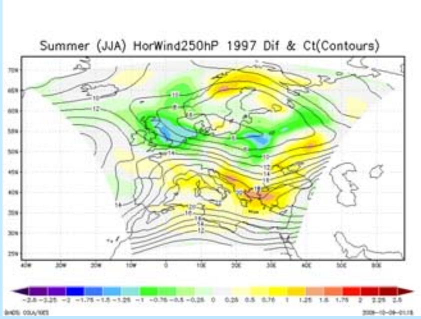
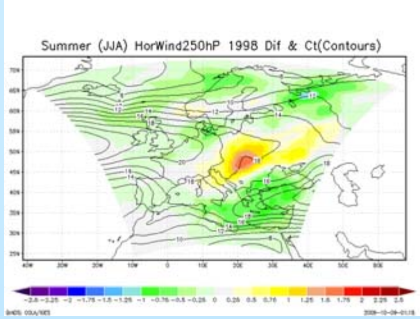

Mean 2007 GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Mean(96-07) GPH 500hPa Seas Ct(Contour) & Dif Sum (JJA)


Summer (JJA) HorWind250hP 1996 Dif & Ct(Contours)


Summer (JJA) HorWind250hP 1997 Dif & Ct(Contours)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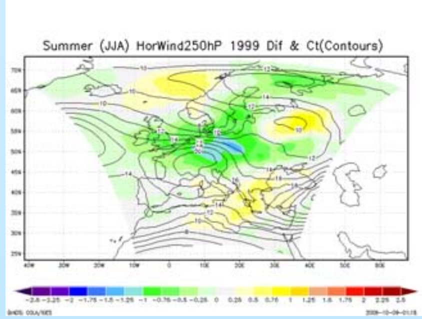
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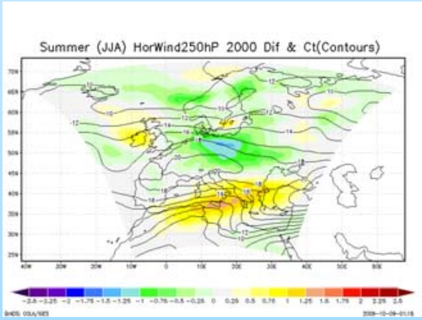
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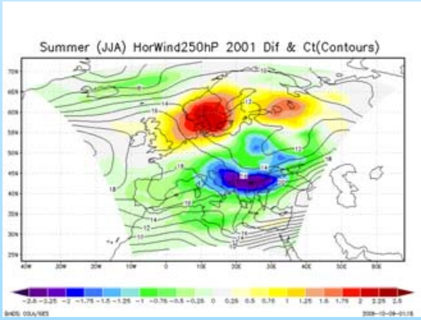
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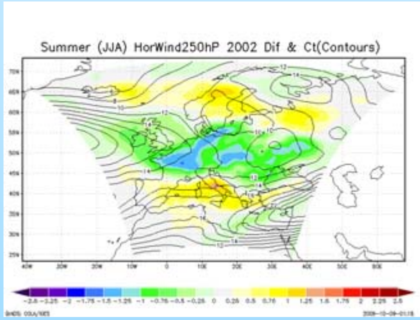
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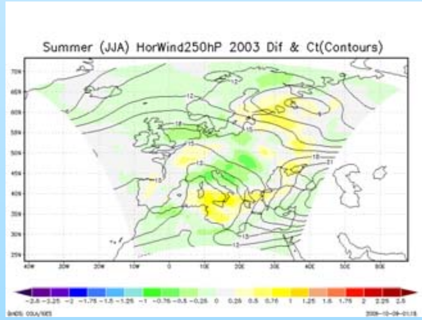
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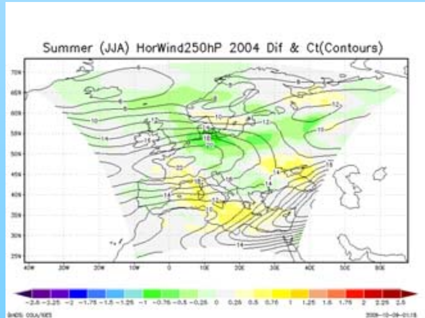
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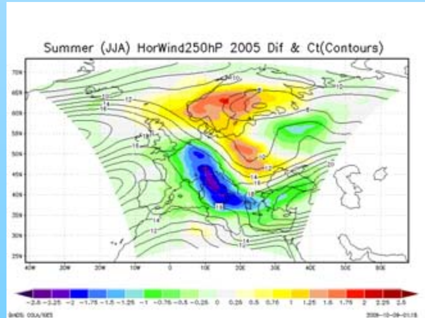
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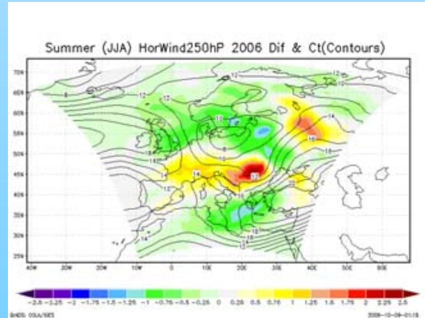
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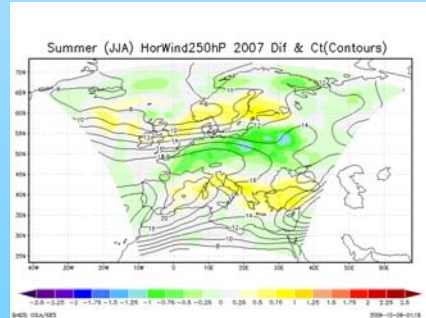
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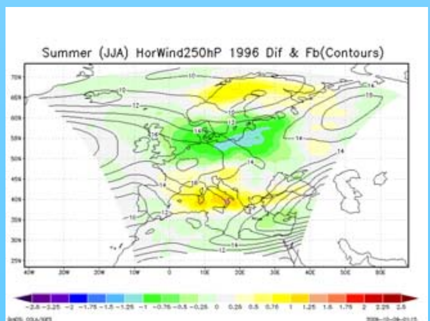
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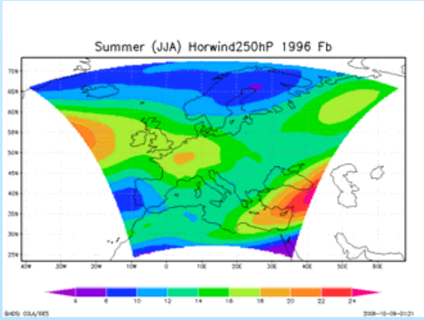
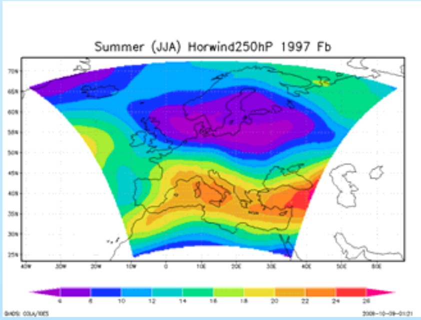

Summer (JJA) Horwind250hP 1996 Fb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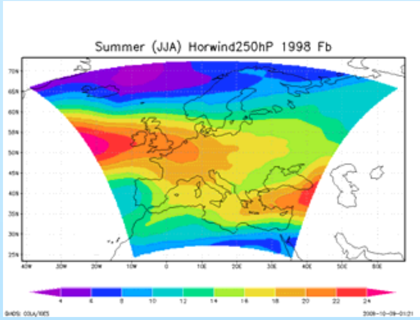
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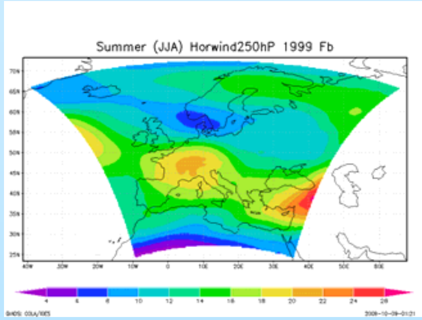
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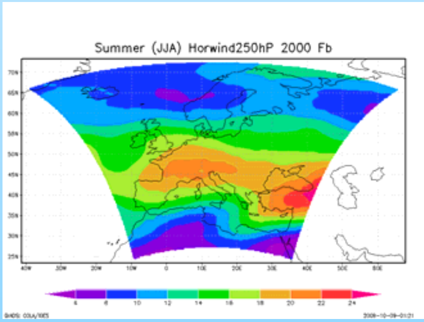
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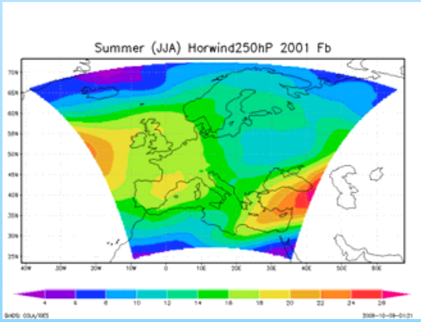
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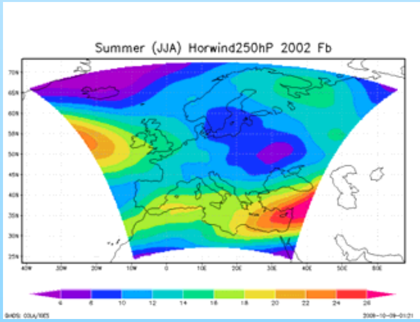
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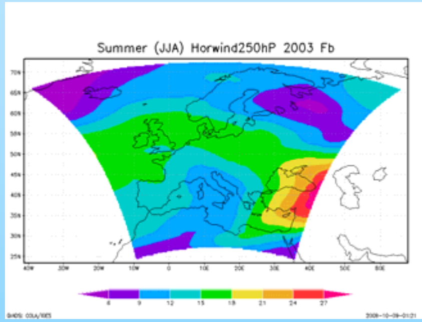
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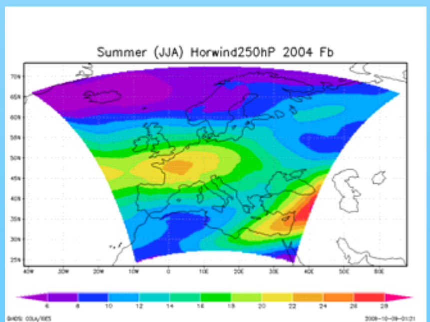
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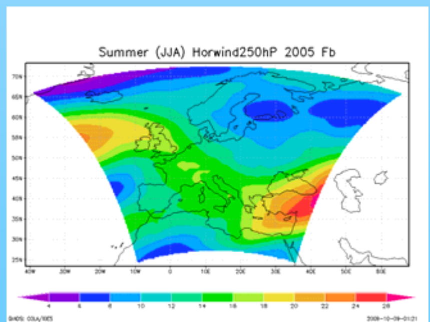
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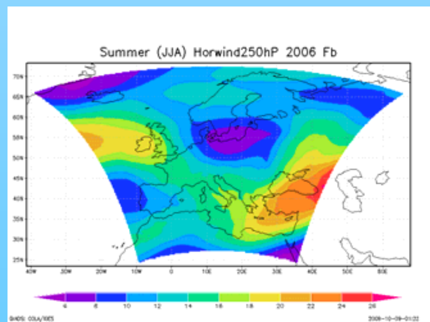
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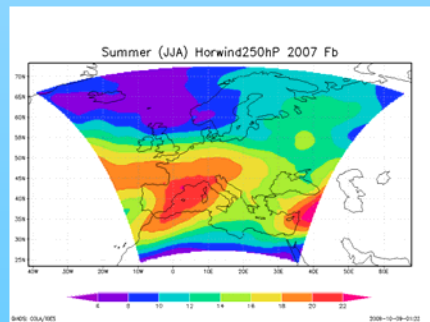
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