





Variazioni dell'ozono colonnare sopra l'Europa occidentale dovute alla deplezione nell'Artico durante la primavera 2011



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V Convegno nazionale: “Il controllo degli Agenti Fisici: ambiente, salute e qualità della vita”, 6 – 8 giugno, 2012, Novara

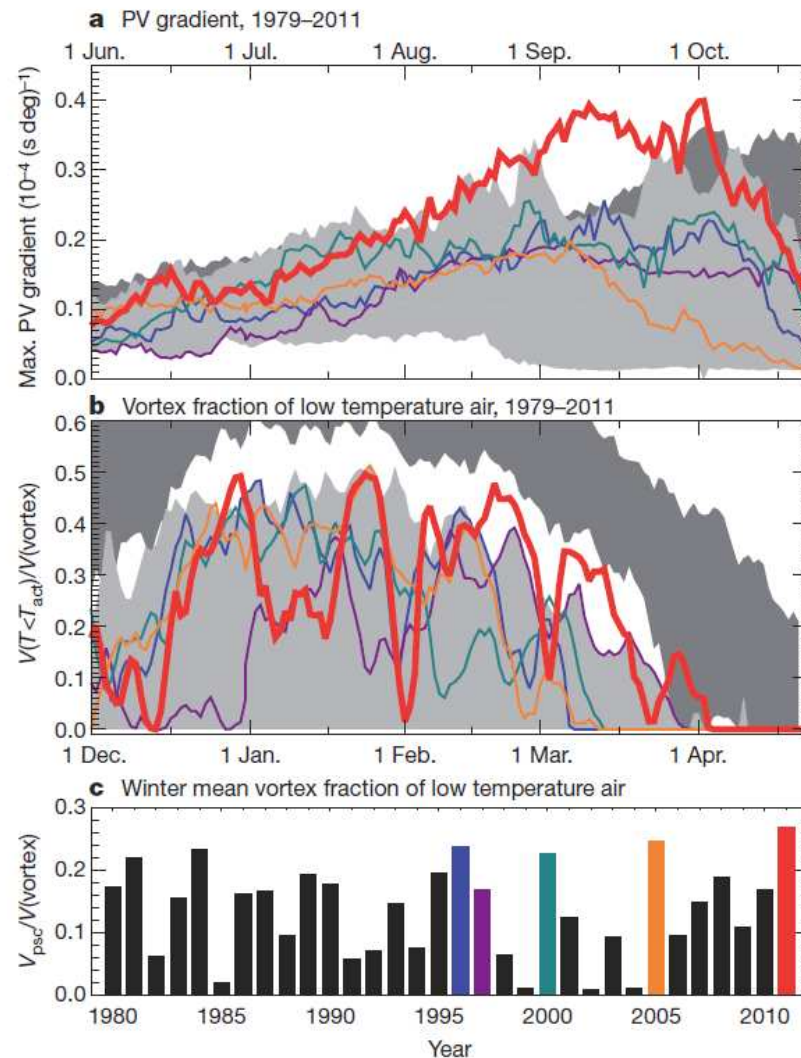


Figure 1 | Meteorology of the Arctic lower stratosphere. a, Vortex strength (as indicated by maximum potential vorticity⁴⁹ (PV) gradients) at 460 K potential temperature (~ 18 km altitude, ~ 65 hPa level). b, Fraction of vortex volume at potential temperatures between 390 and 550 K with a temperature less than the chlorine activation threshold (T_{act}). Light (dark) grey shading shows range of Arctic (Antarctic) values for 1979–2010. Antarctic dates are shifted by six months (top axis in a) to show the equivalent season. c, Winter mean V_{psc} during the past 32 years, expressed as a fraction of vortex volume. Red, orange, green, purple and blue lines/bars show the 2010–11, 2004–05, 1999–2000, 1996–97 and 1995–96 Arctic winters, respectively.

I parametri dei vortici Artico ed Antartico secondo

Manney, G.L. et al. Unprecedented Arctic ozone loss in 2011. *Nature*, 478, 469 – 475, 2011

La curva rossa rappresenta i valori del 2011

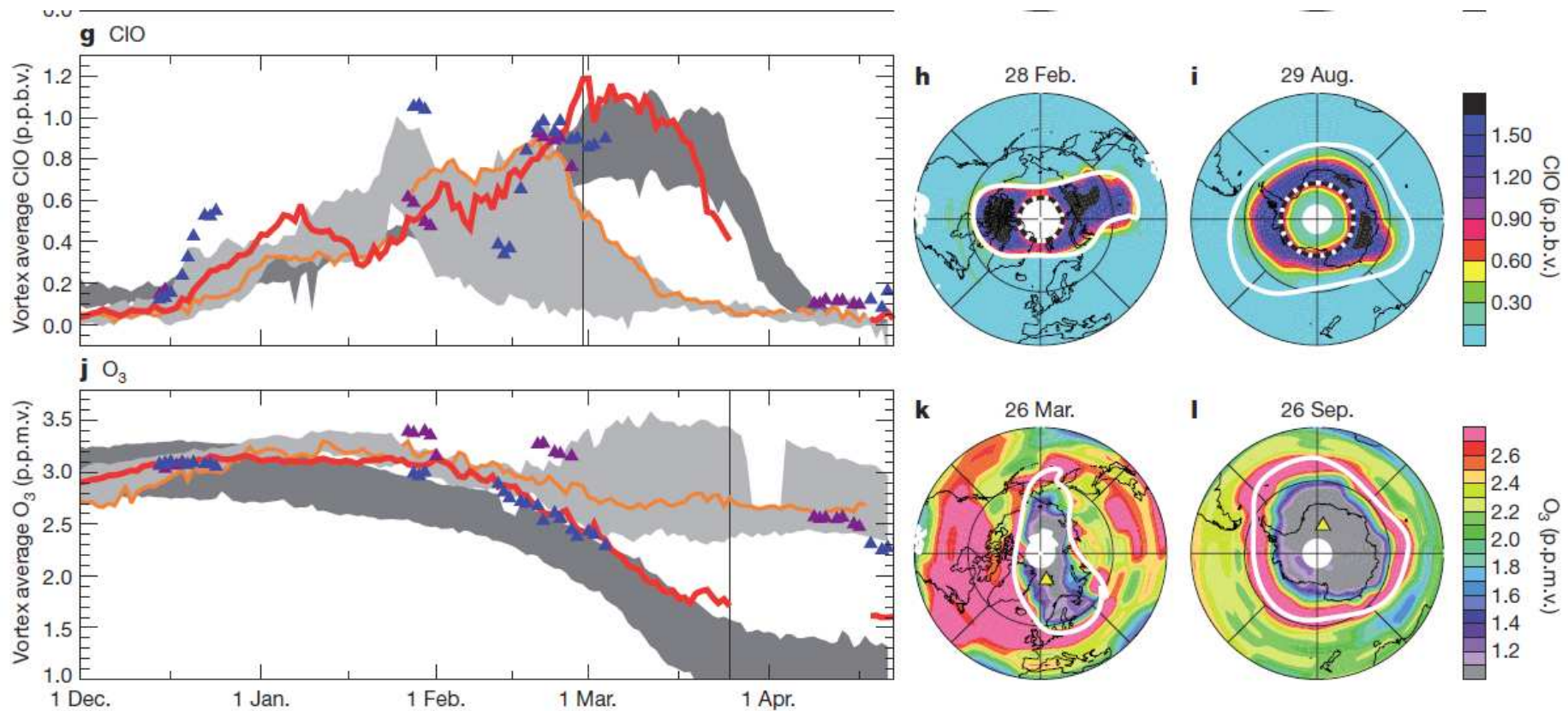
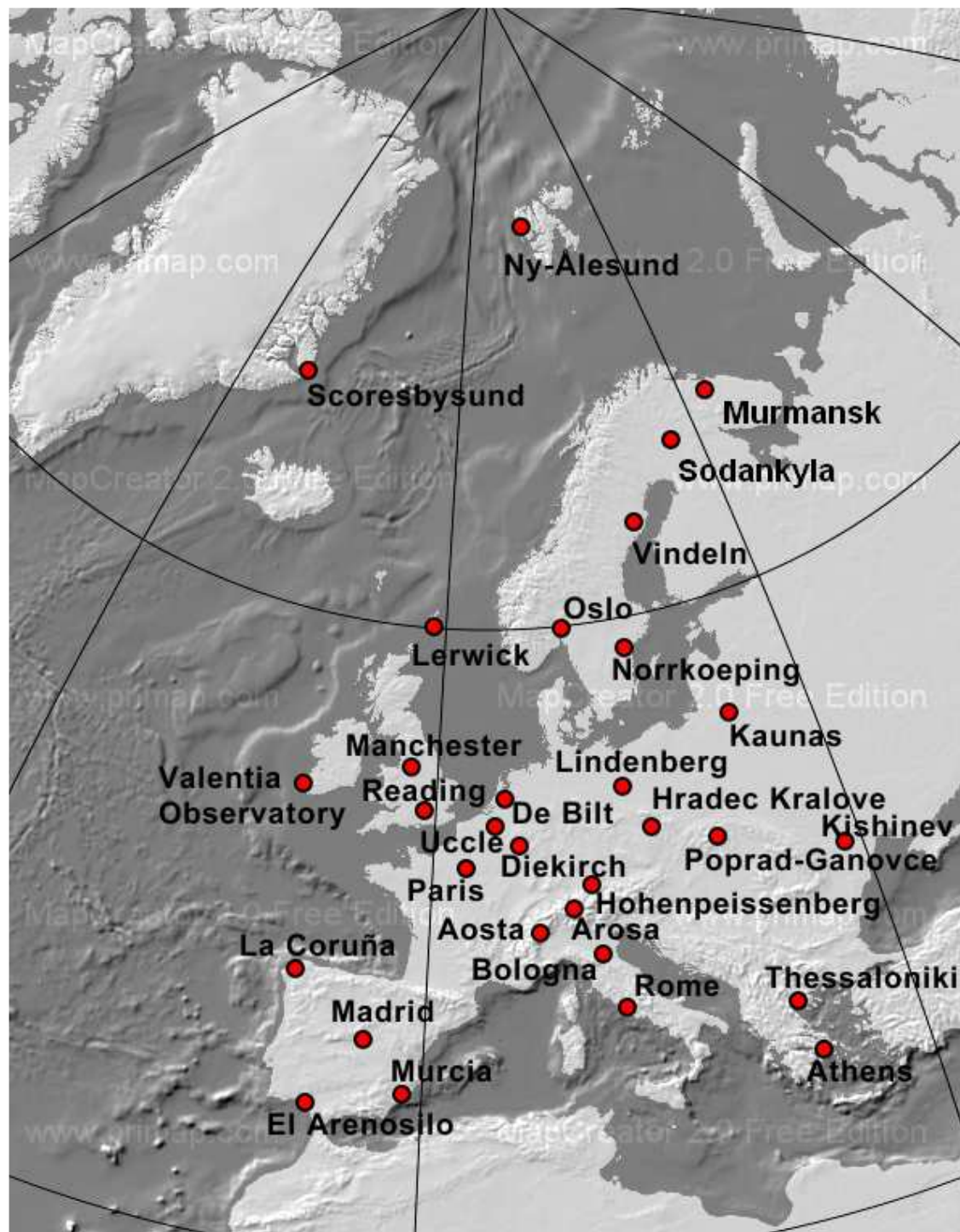


Figure 2 | Chemical composition in the lower stratosphere. a–l, Maps (right) and vortex-averaged time series (left) at 485 K potential temperature (~ 20 km, ~ 50 hPa) for four different gases: HNO_3 (a, b, c), HCl (d, e, f), ClO (g, h, i) and O_3 (ozone; j, k, l); mixing ratios from Aura MLS are shown. Averaging for the time series is done within the white contour shown on the maps. Blue (purple) triangles on time series, 1995–96 (1996–97) values from UARS MLS. Line colours/shading as in Fig. 1, but shading is for Aura MLS measurements from

2005–10. Antarctic dates are shifted by six months (top axis on time series) to show the equivalent season. Vertical lines show dates of maps in 2011 (2010) in the Arctic (Antarctic). Black overlays on HNO_3 maps, T_{act} (~ 196 K at this level); HNO_3 may be sequestered in PSCs at lower temperatures. Dotted black/white contour on ClO maps, 92° SZA, poleward of which measurements were taken in darkness. Yellow/black triangles on ozone maps, locations of the profiles in Fig. 3.

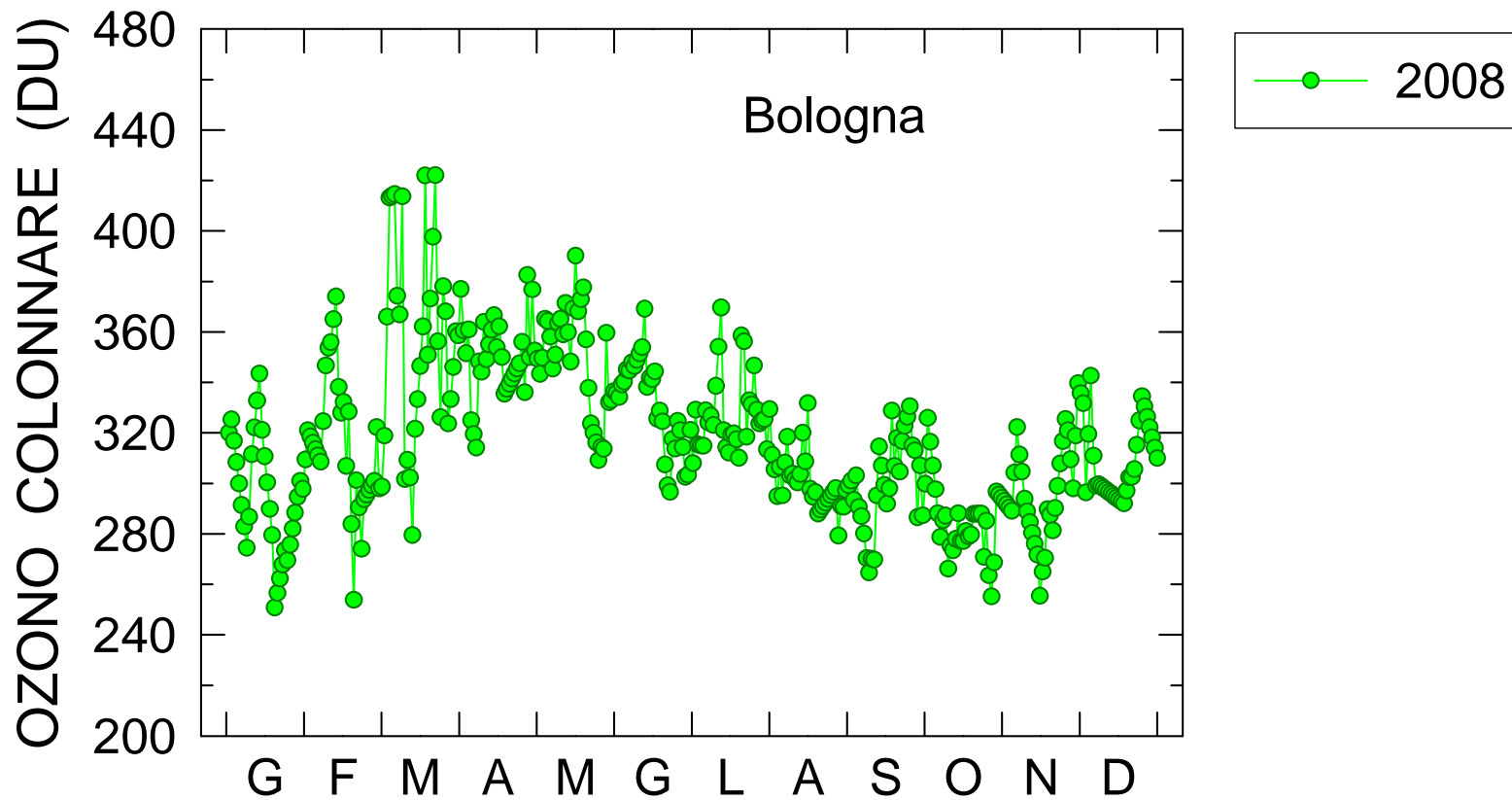
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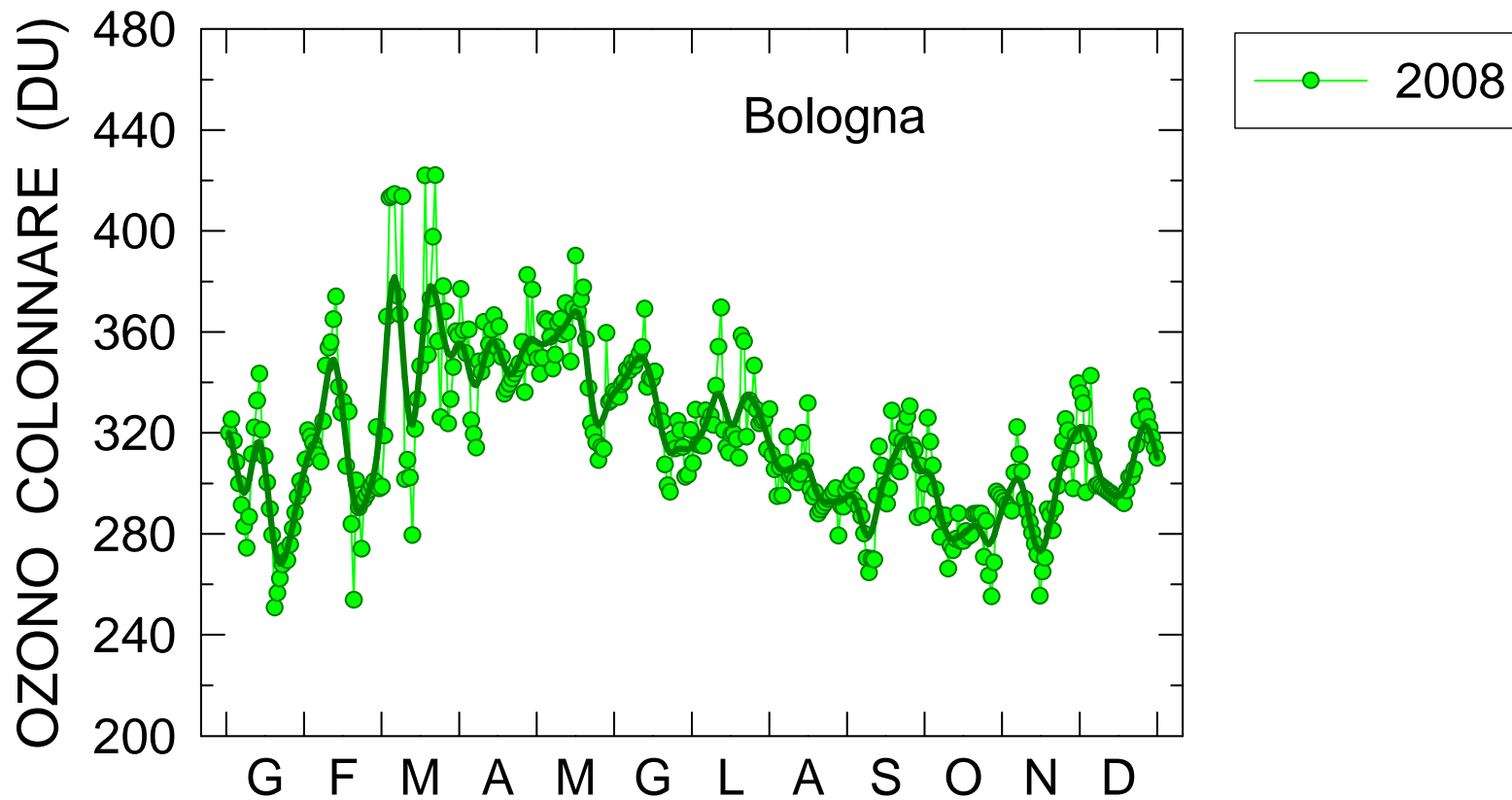
Per studiare l'effetto della deplezione dell'ozono colonnare nell'Artico durante la primavera 2011 sull'ozono alle medie latitudine sono stati analizzati i dati misurati in 31 stazioni in superficie.

Lo studio considera il periodo tra 2000 e 2011 per avere una base di confronto tra il comportamento dell'ozono nel 2011 e quello negli anni recenti.

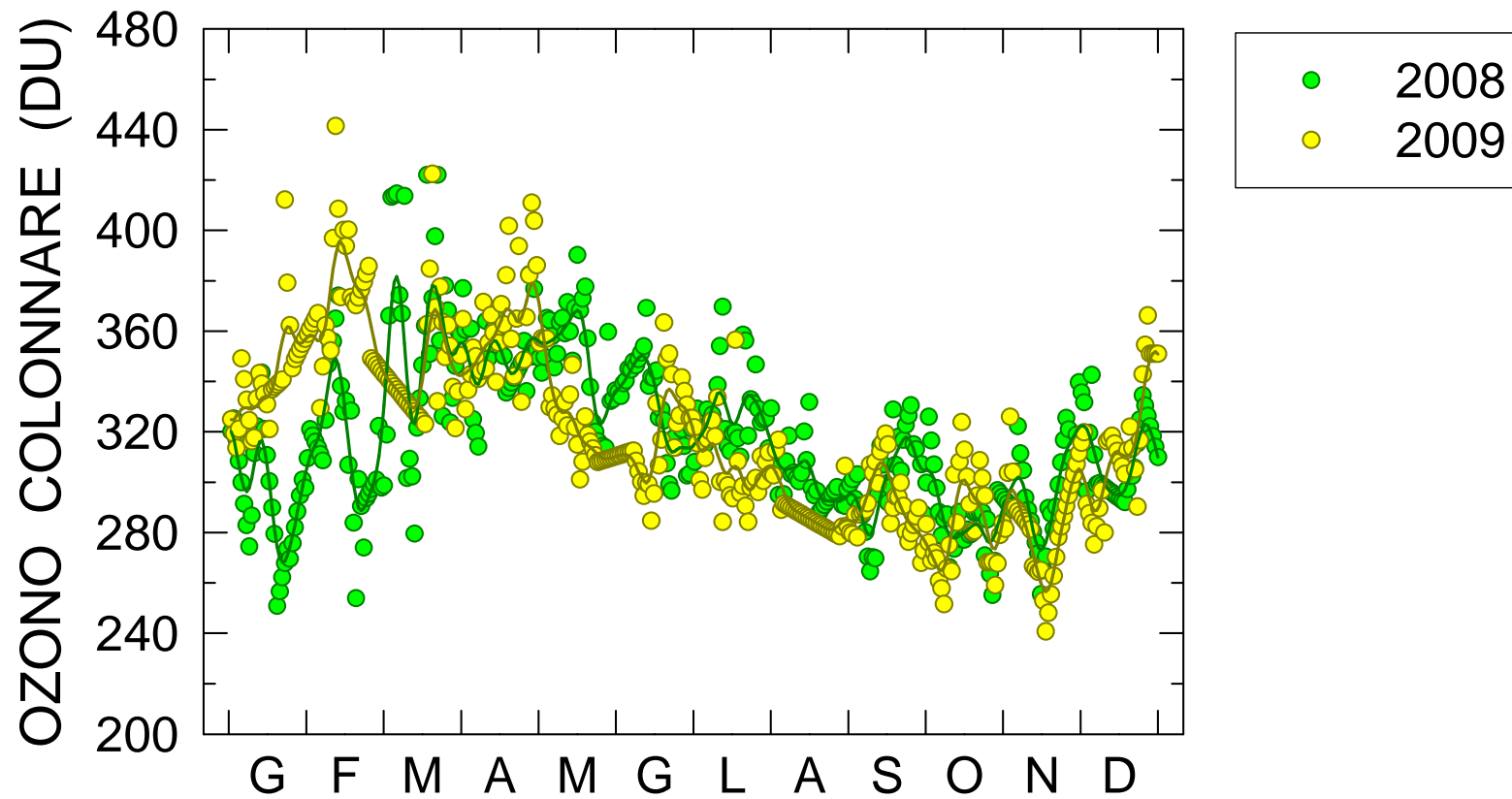
All'inizio proseguiamo il trend meridionale dell'ozono colonnare durante l'evento.



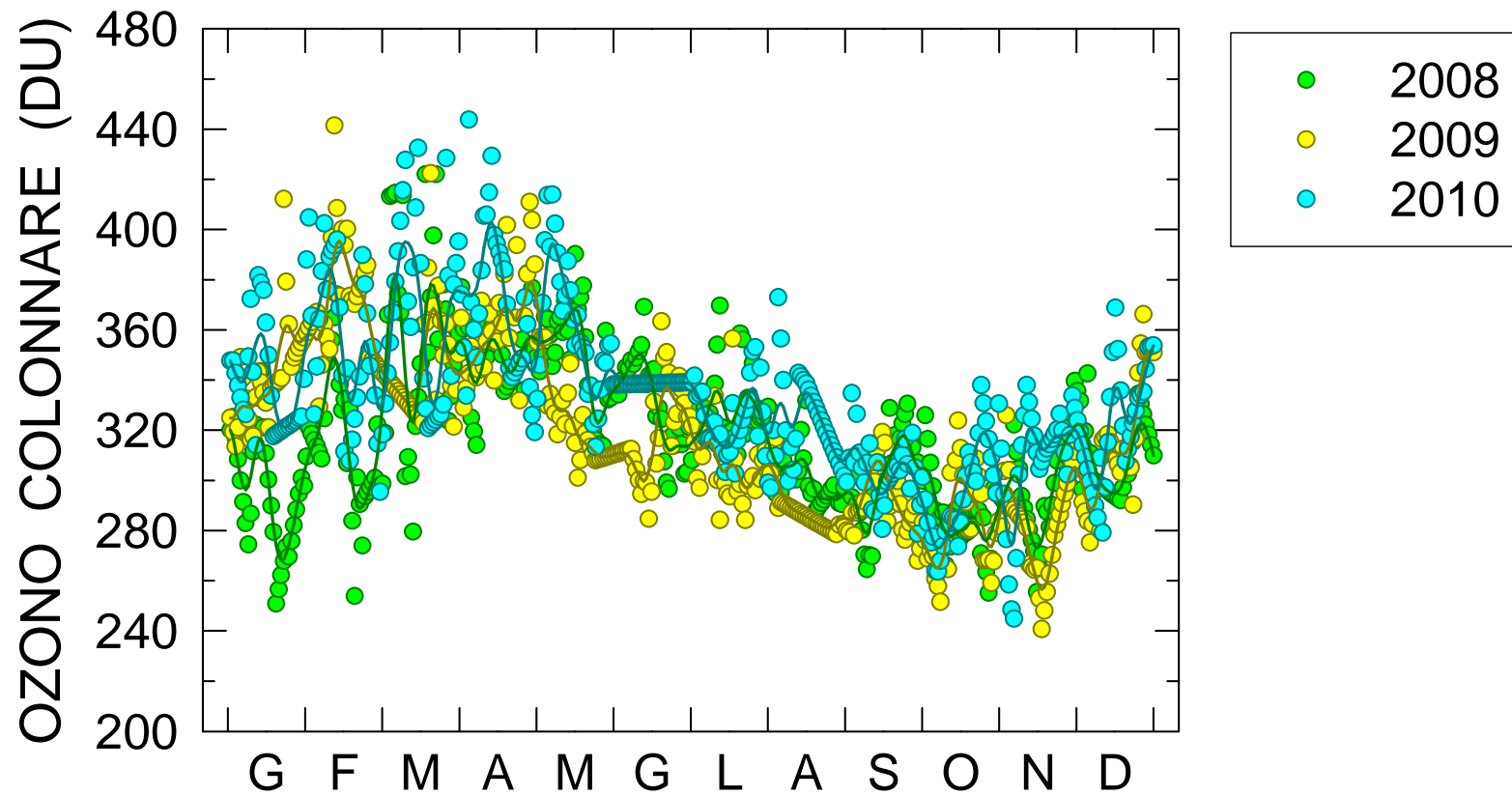
Questi sono i valori giornalieri dell'ozono colonnare in funzione del tempo espresso in giorni. Al fine di filtrare la variabilità giornaliera i dati sono stati lisciati usando la media mobile con una finestra temporale di 6 giorni. La finestra è scelta in modo che i dettagli delle variazioni sulla scala mensile non vadano perduti. Il metodo è stato iterato 3 volte al fine di raggiungere un risultato soddisfacente



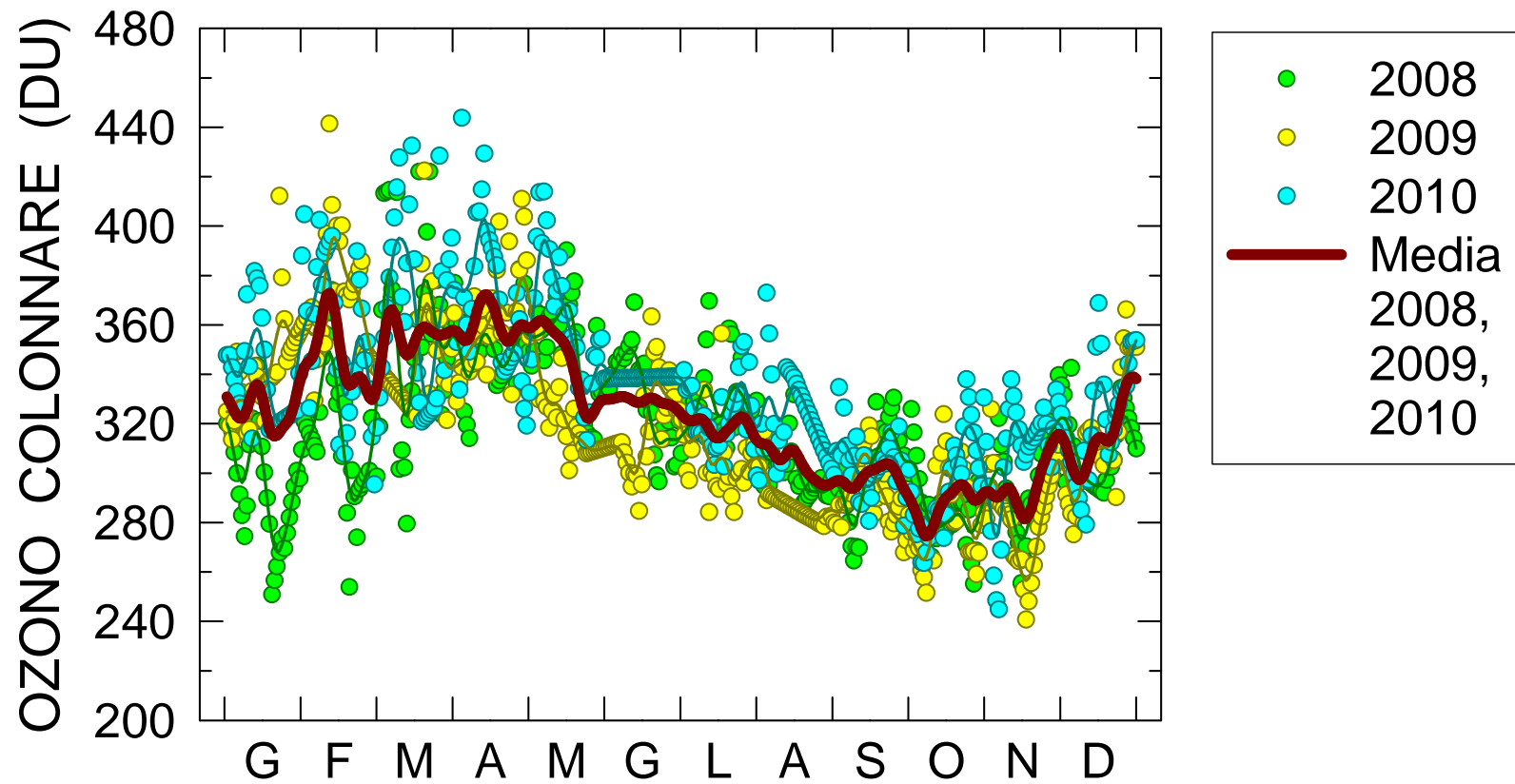
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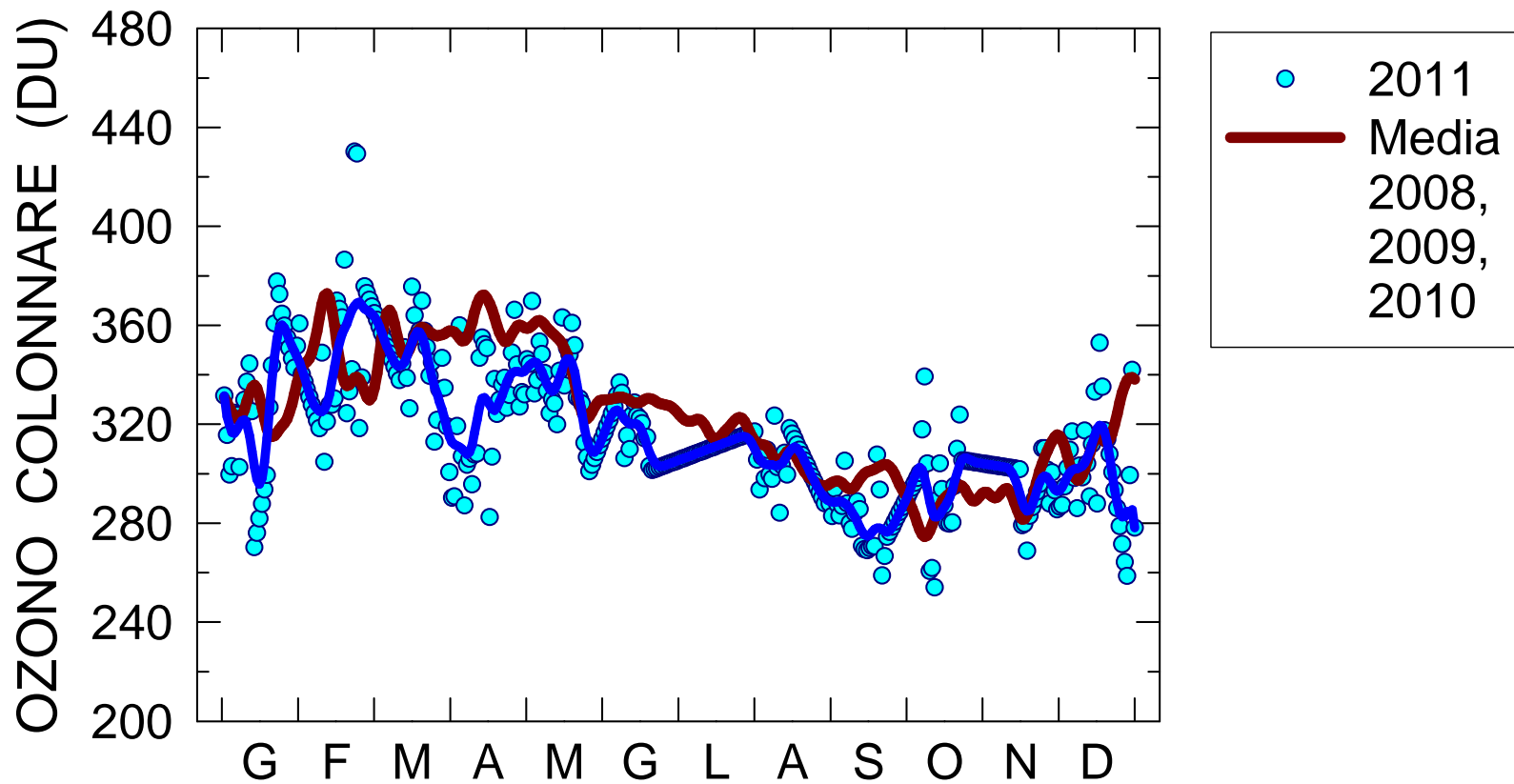
A parte i dati dal 2008, nello stesso modo si trattano i dati dal 2009 e 2010.



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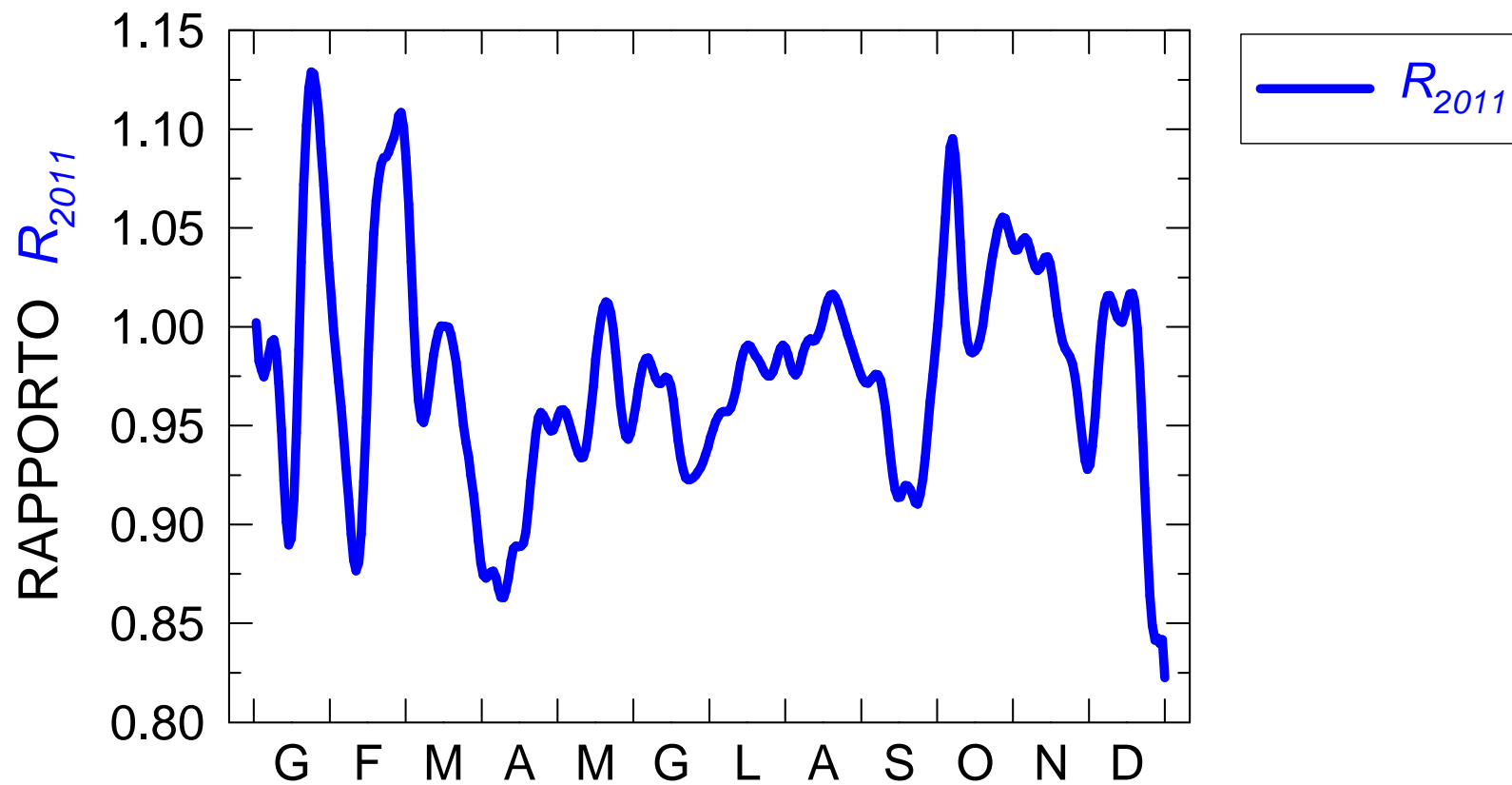


Infine, si trova l'andamento medio

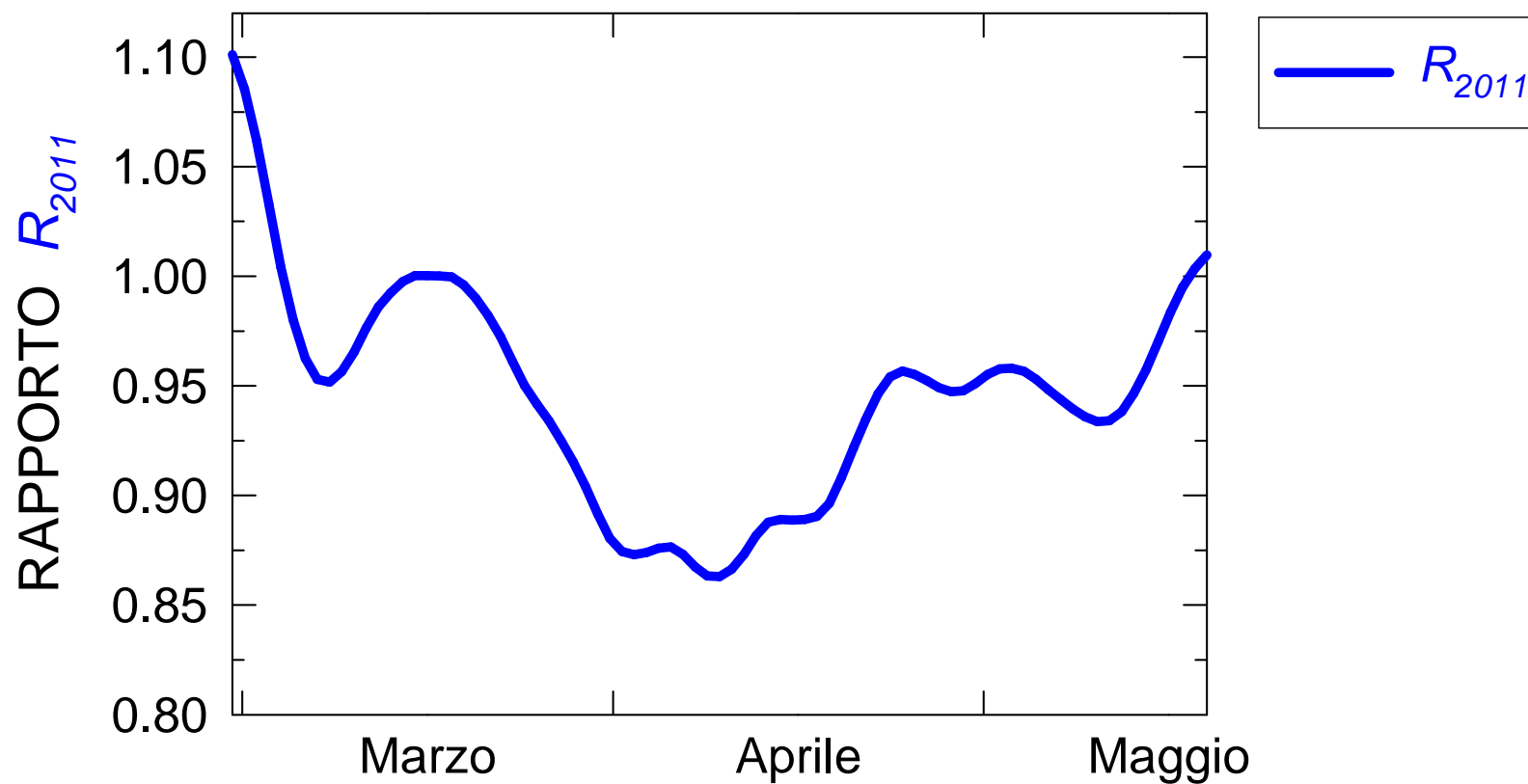


Infine, si trova l'andamento medio che servirà come una base dell'estimo delle variazioni di ozono colonnare durante il 2011. Per mettere in evidenza l'eventuale impatto della deplezione dell'ozono colonnare nella regione artica nella primavera 2011 sulle medie latitudini è stato introdotto il parametro $R_{2011}(t)$ definito come

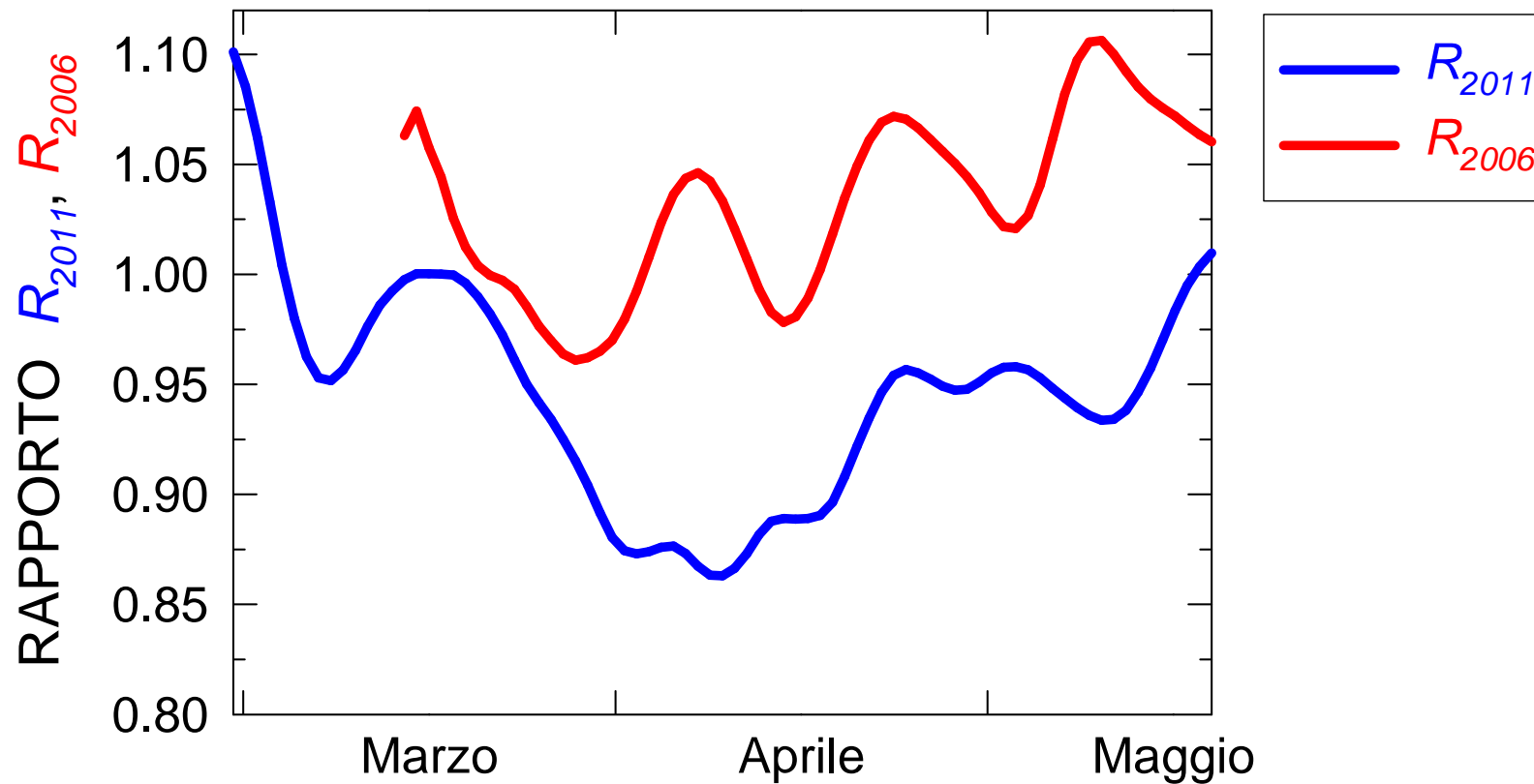
$$R_{2011}(t) = \frac{Q_{2011}(t)}{Q_M(t)}$$



Così definito, il rapporto $R_{2011}(t)$ evidenzia le variazioni del contenuto colonnare di ozono nel 2011 rispetto ai tre anni precedenti.

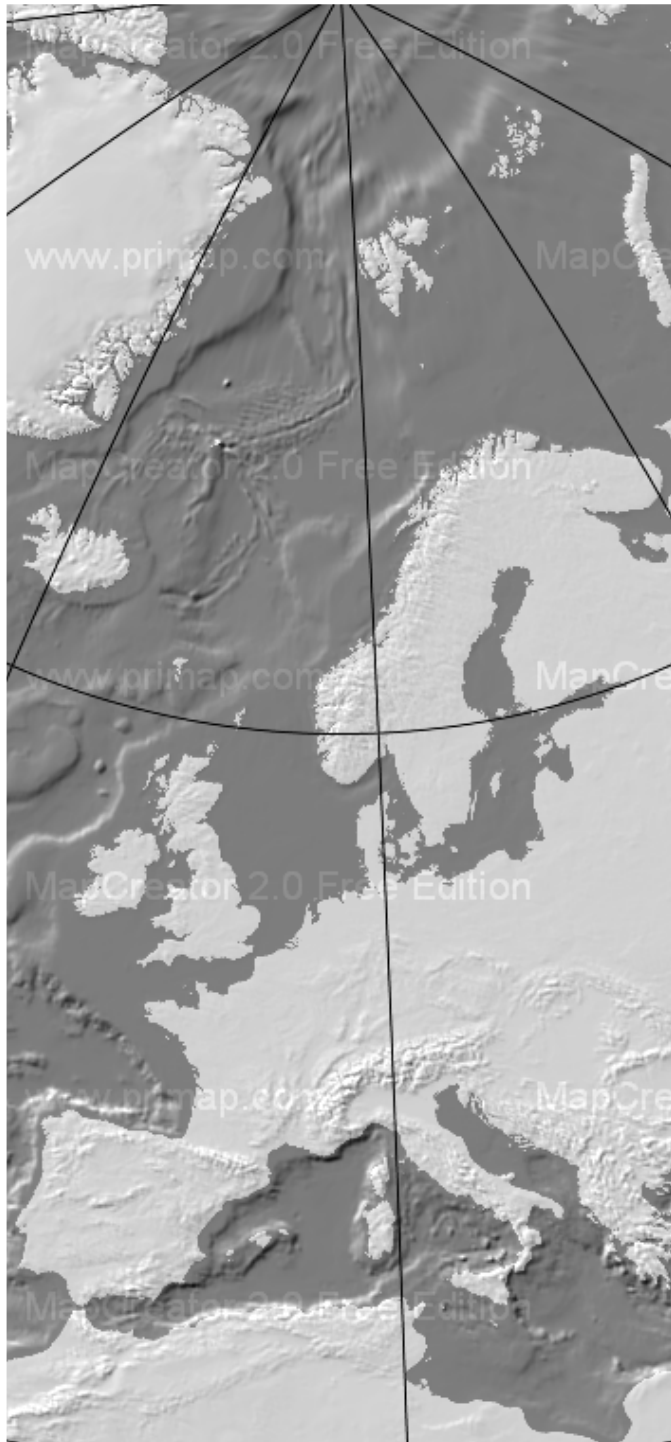


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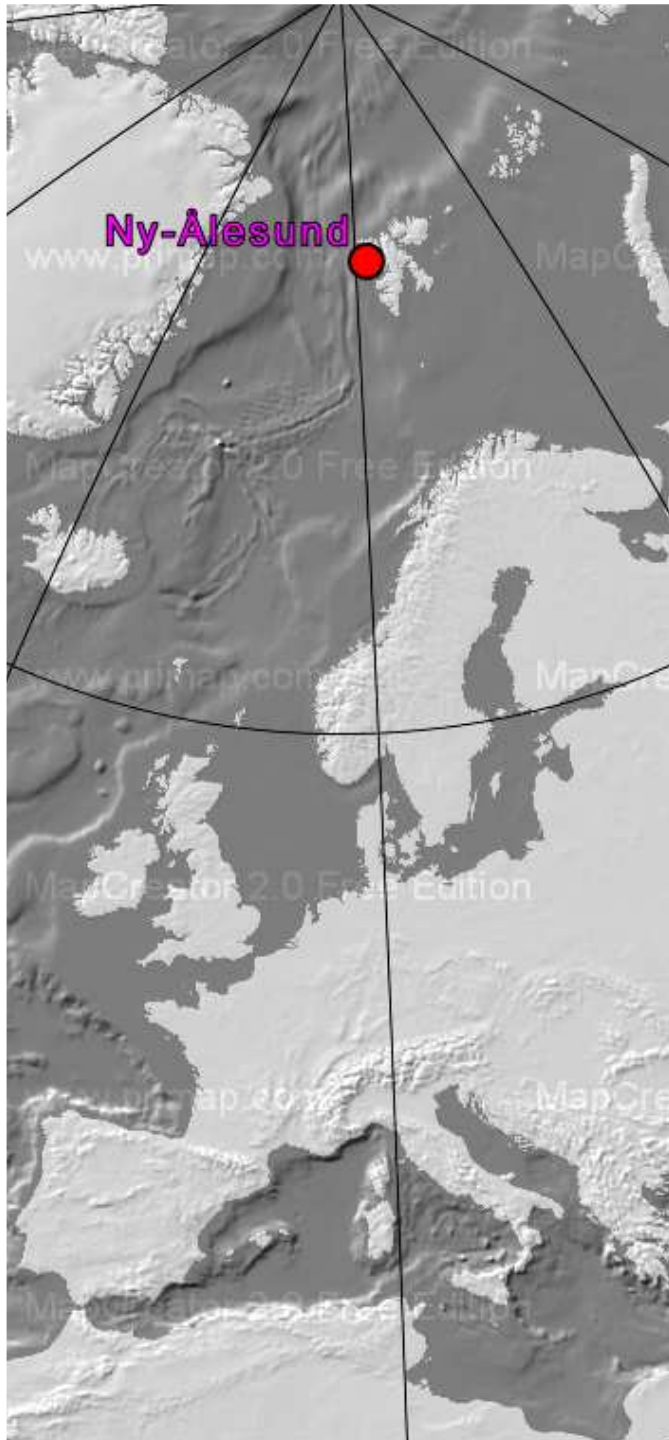
Il comportamento del rapporto è stato confrontato con quello calcolato per un altro anno (2006 o 2007 a seconda della disponibilità dell'intero data set) sostituendo nella formula i valori di $Q_{2006/2007}(t)$ a quello di $Q_{2011}(t)$:

$$R_{2006/2007}(t) = \frac{Q_{2006/2007}(t)}{Q_M(t)}$$

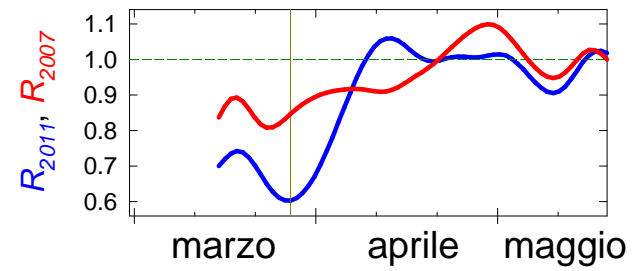


**Comportamento dei rapporti
intorno al meridiano 10°E**

$$R_{2006,2007,2011}(t)$$

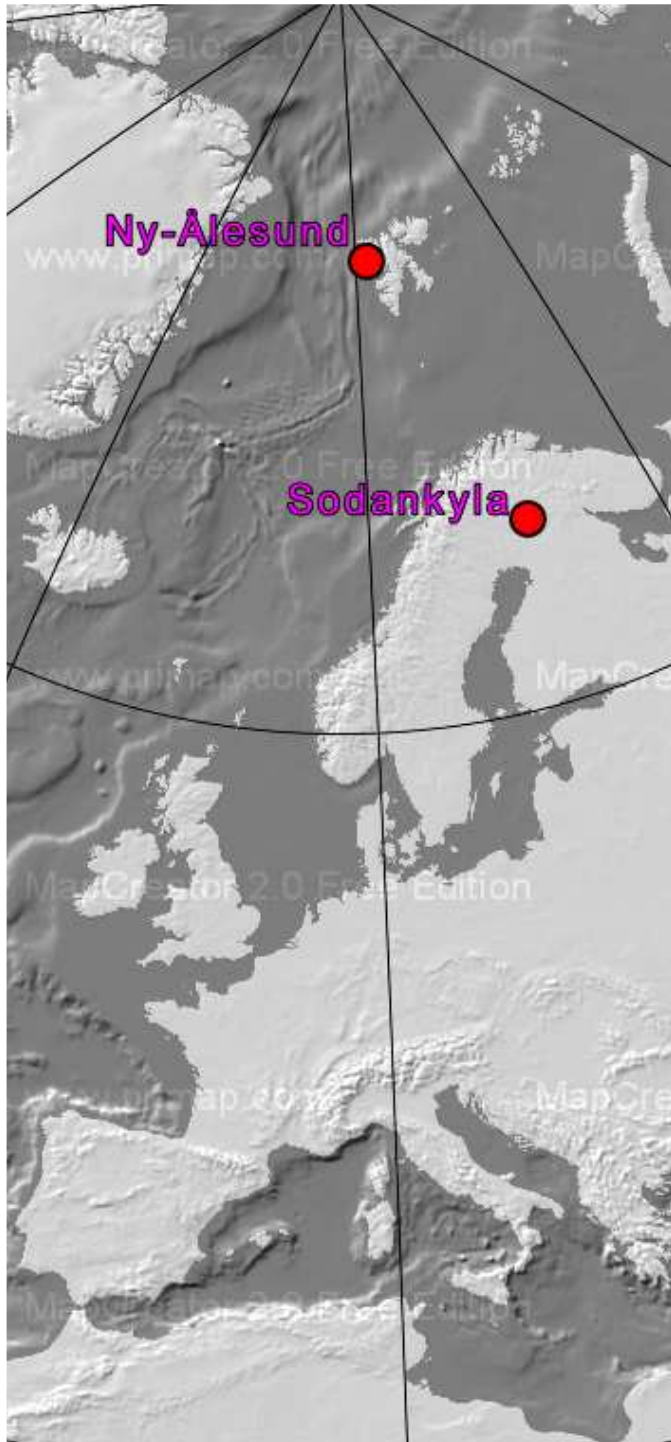


Comportamento dei rapporti intorno al meridiano 10°E



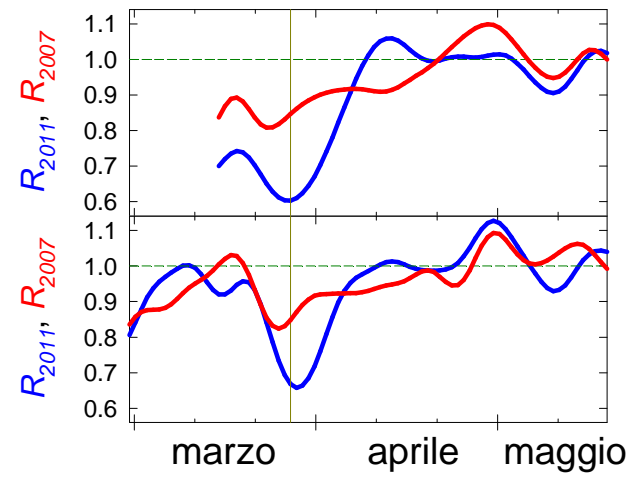
$$R_{2006,2007,2011}(t)$$

78°56'N



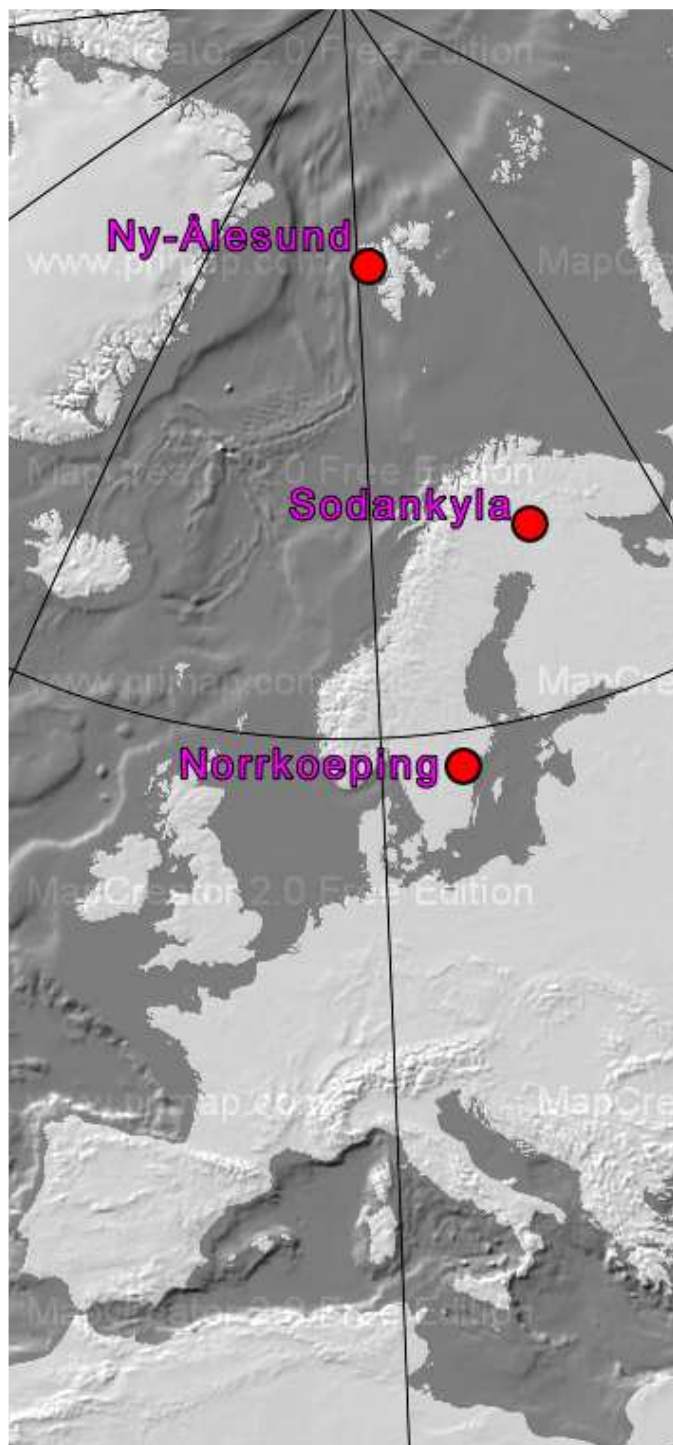
Comportamento dei rapporti intorno al meridiano 10°E

$$R_{2006,2007,2011}(t)$$



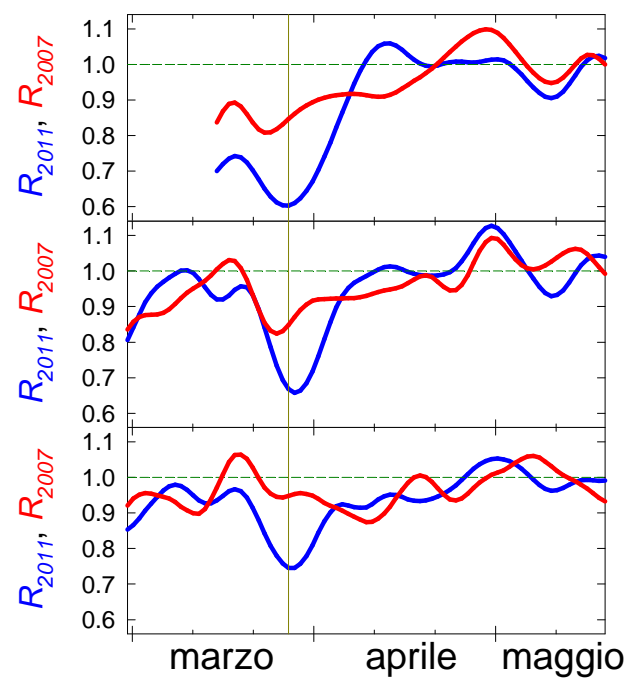
78°56'N

67°30'N



Comportamento dei rapporti intorno al meridiano 10°E

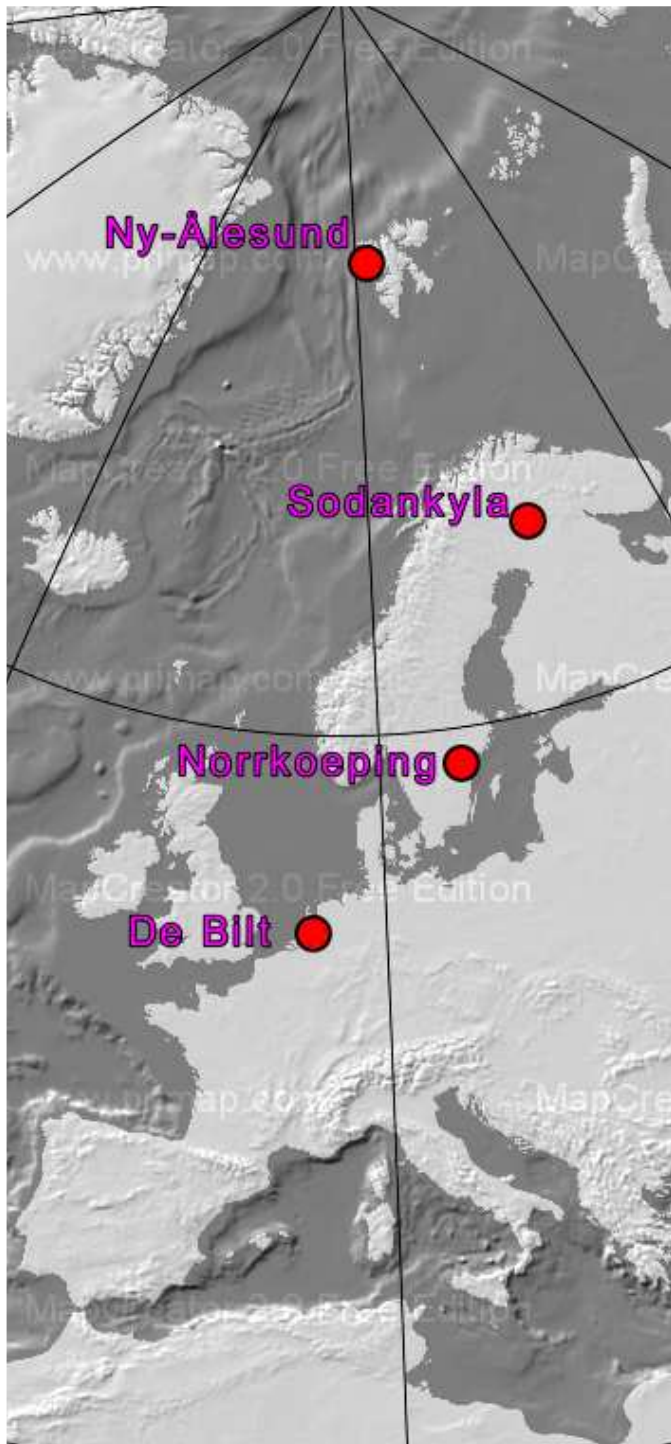
$$R_{2006,2007,2011}(t)$$



78°56'N

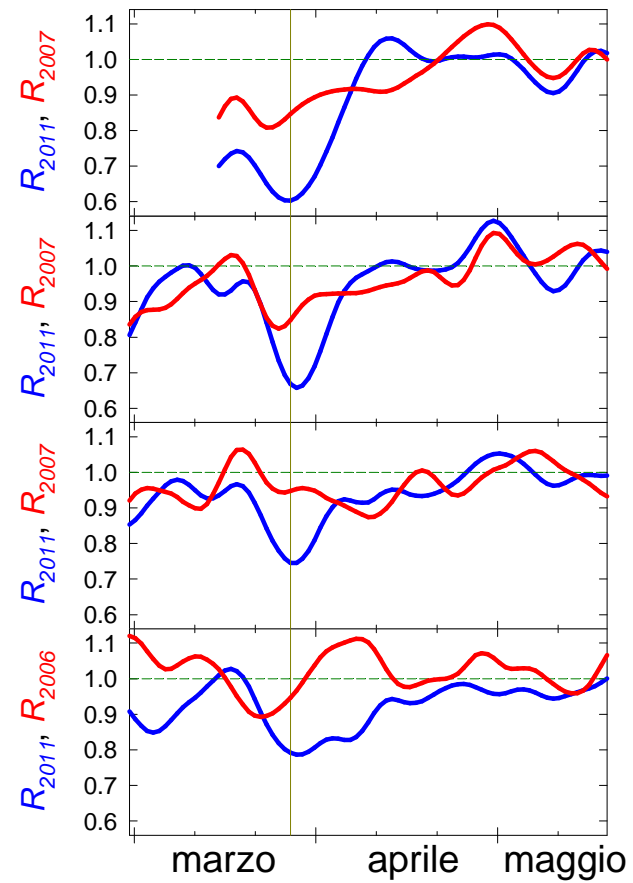
67°30'N

58°35'N



Comportamento dei rapporti intorno al meridiano 10°E

$$R_{2006,2007,2011}(t)$$

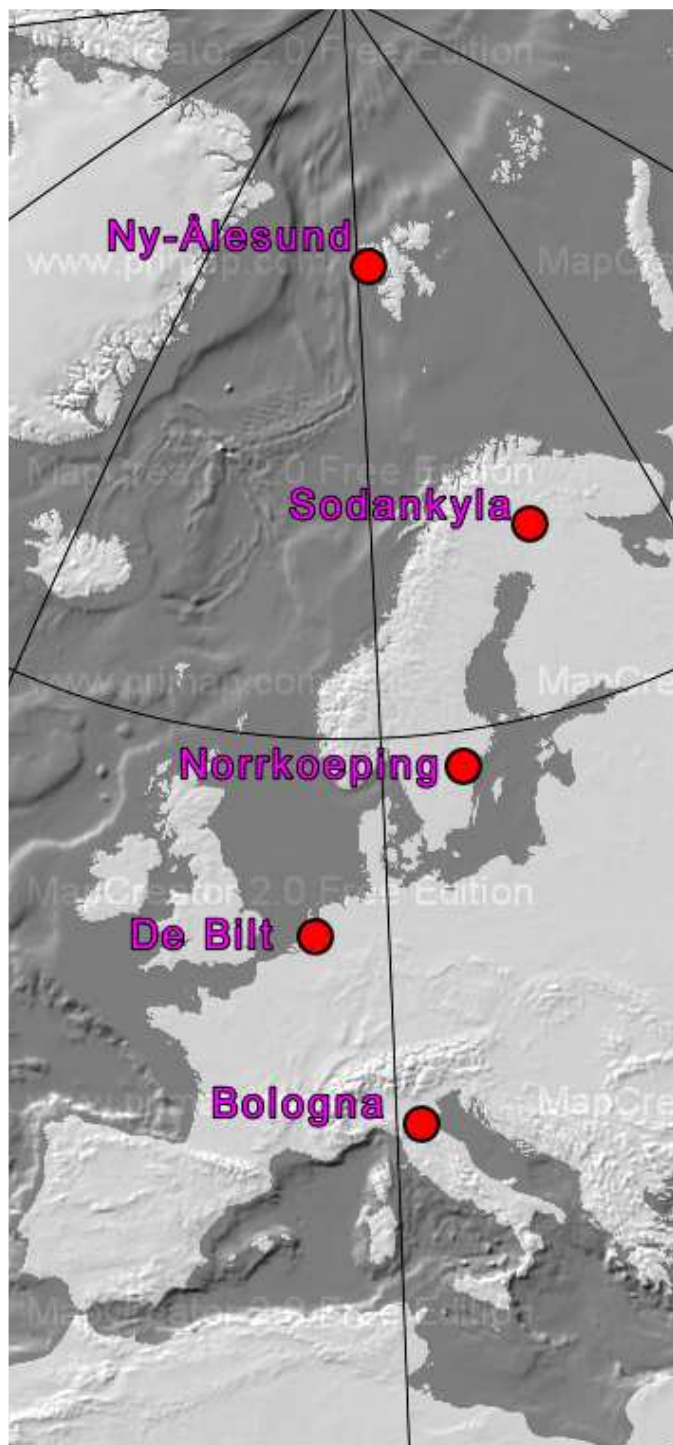


78°56'N

67°30'N

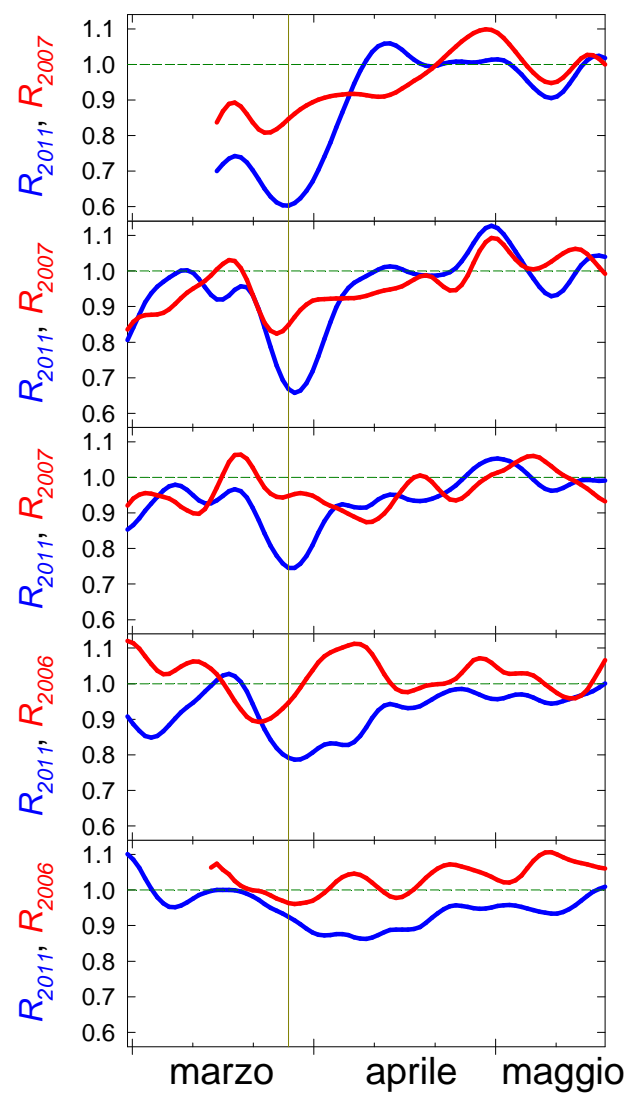
58°35'N

52°06'N



Comportamento dei rapporti intorno al meridiano 10°E

$$R_{2006,2007,2011}(t)$$



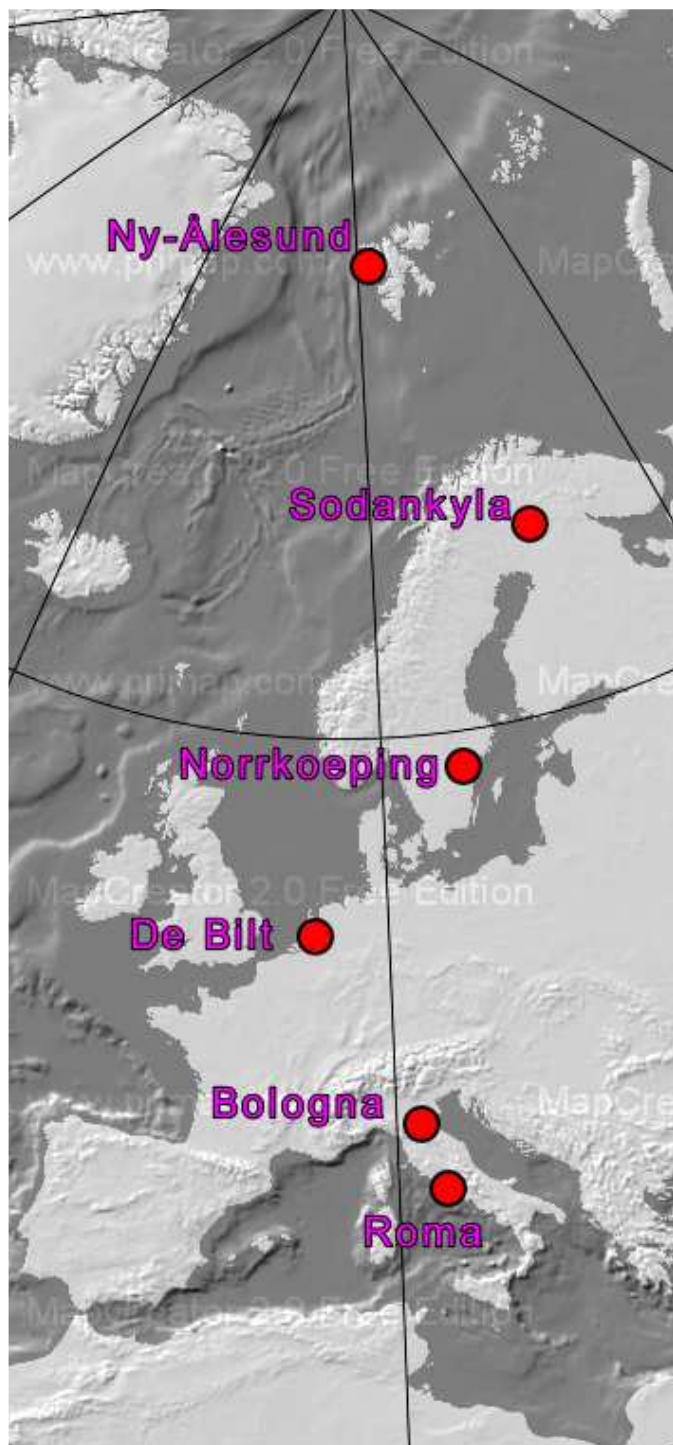
78°56'N

67°30'N

58°35'N

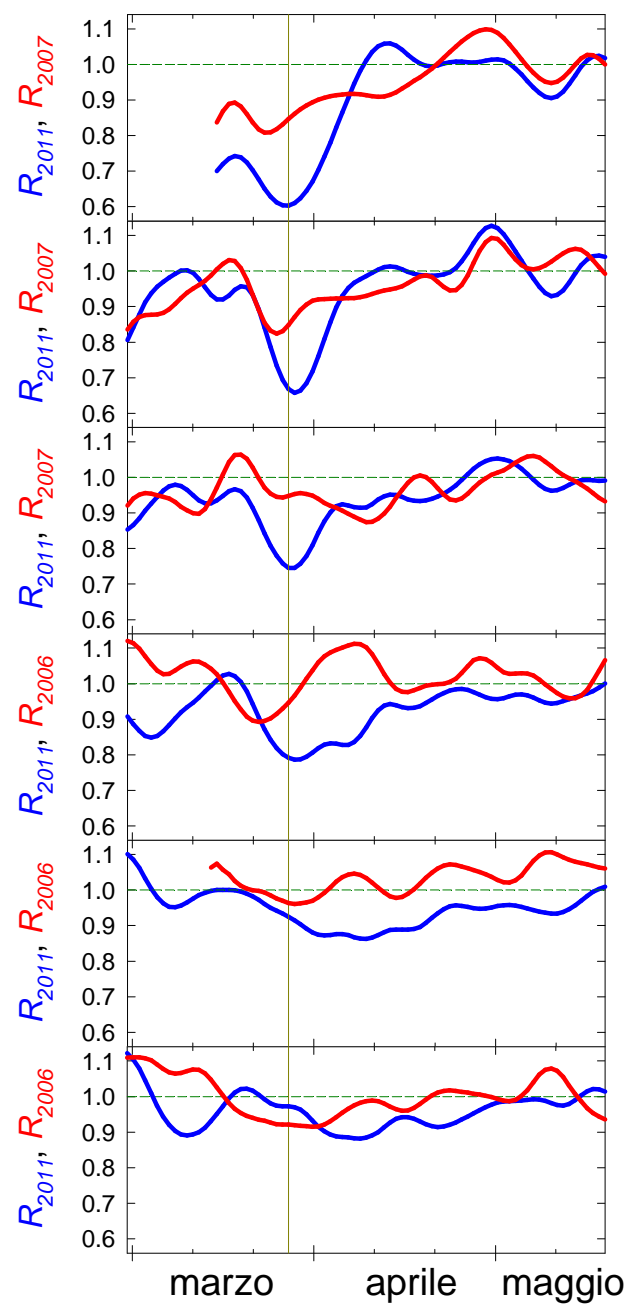
52°06'N

44°31'N



Comportamento dei rapporti intorno al meridiano 10°E

$$R_{2006,2007,2011}(t)$$



78°56'N

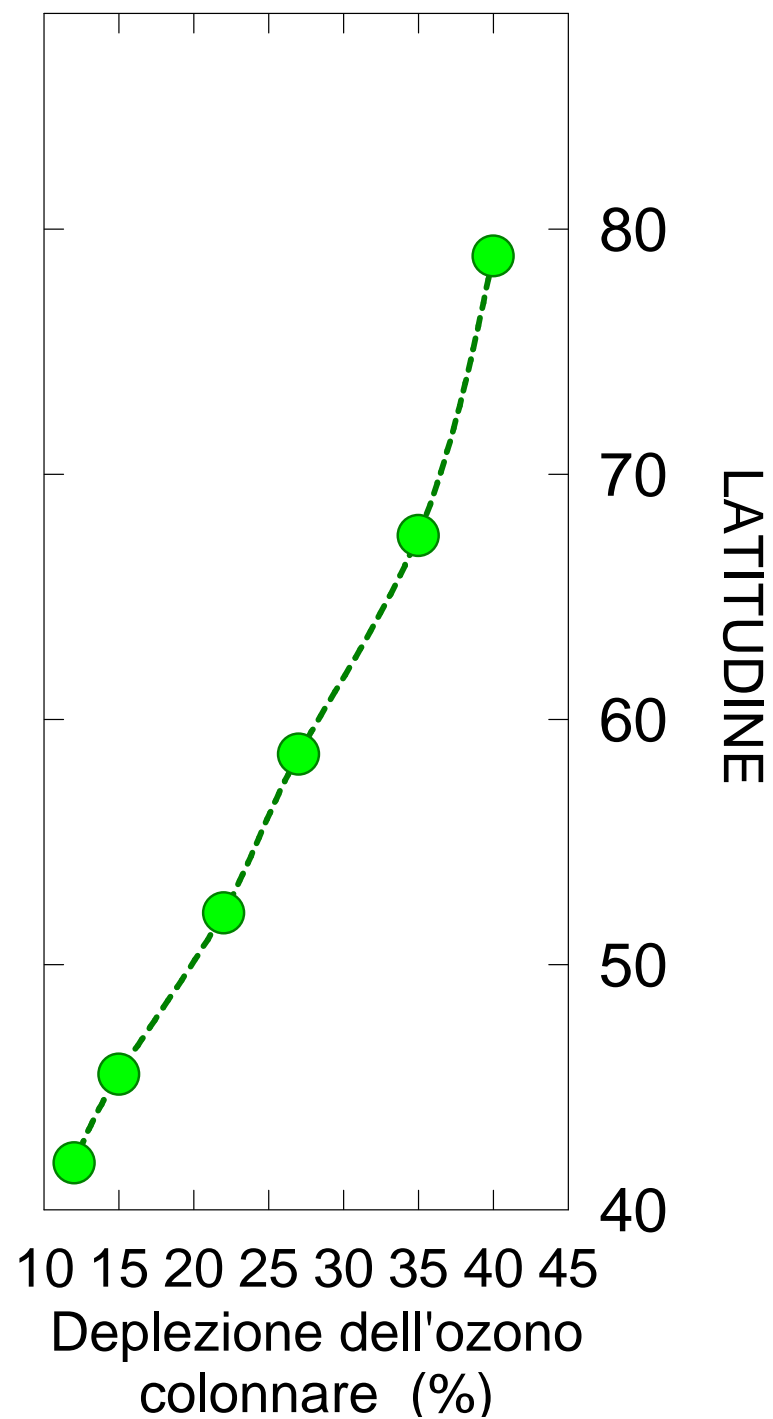
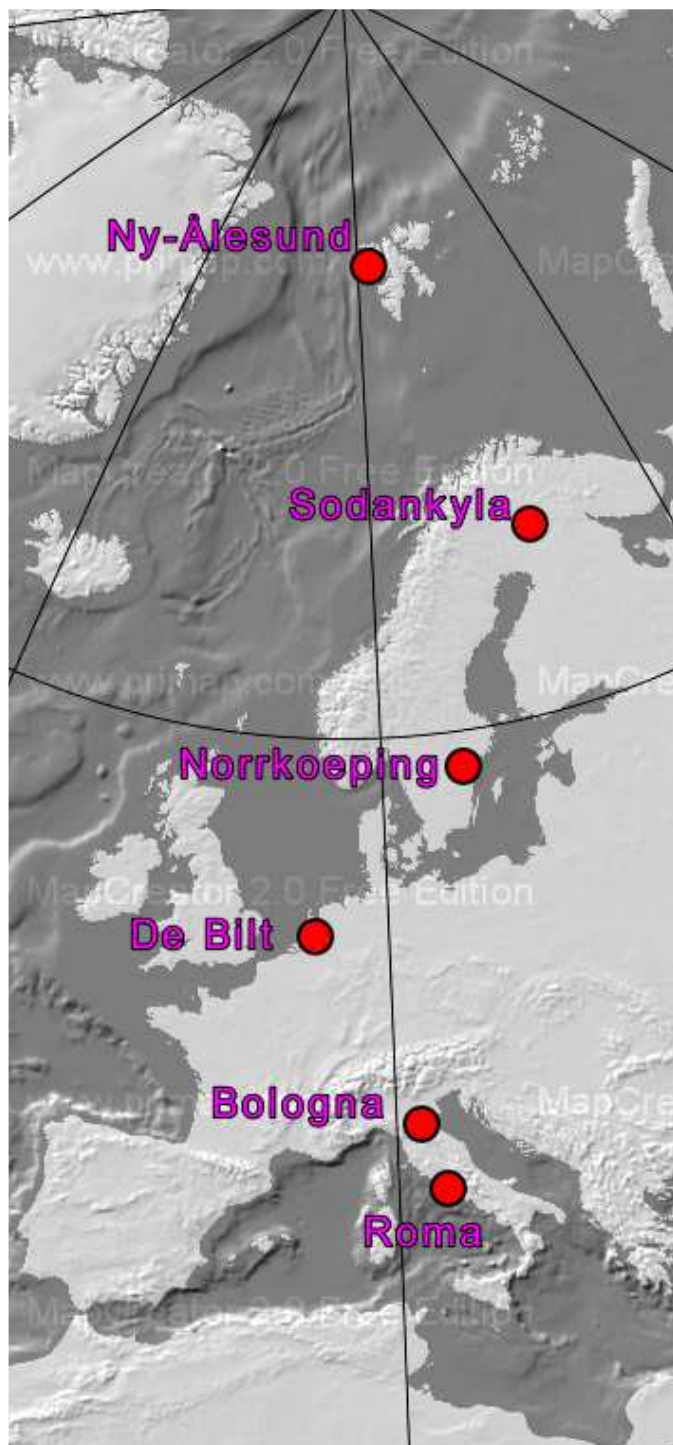
67°30'N

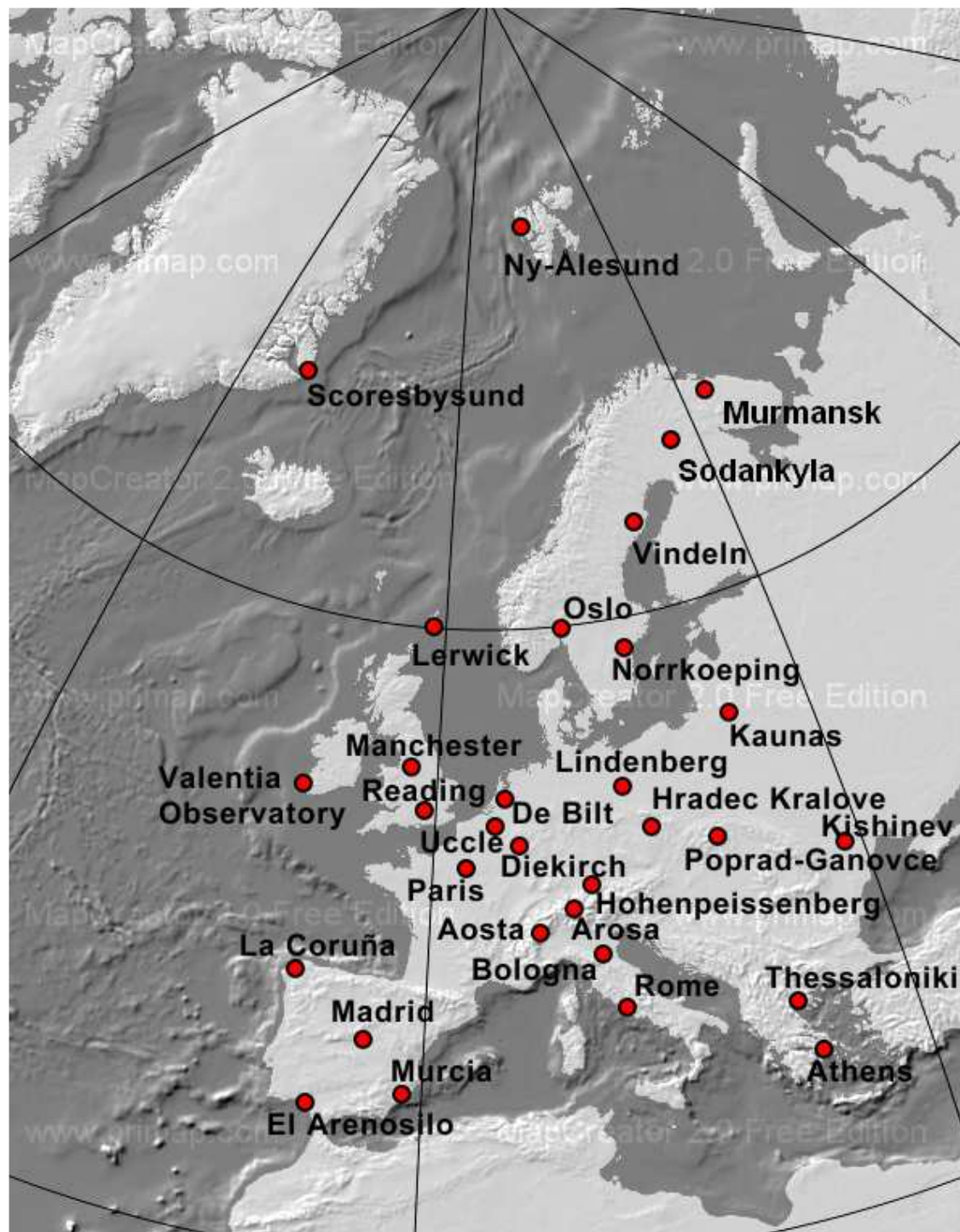
58°35'N

52°06'N

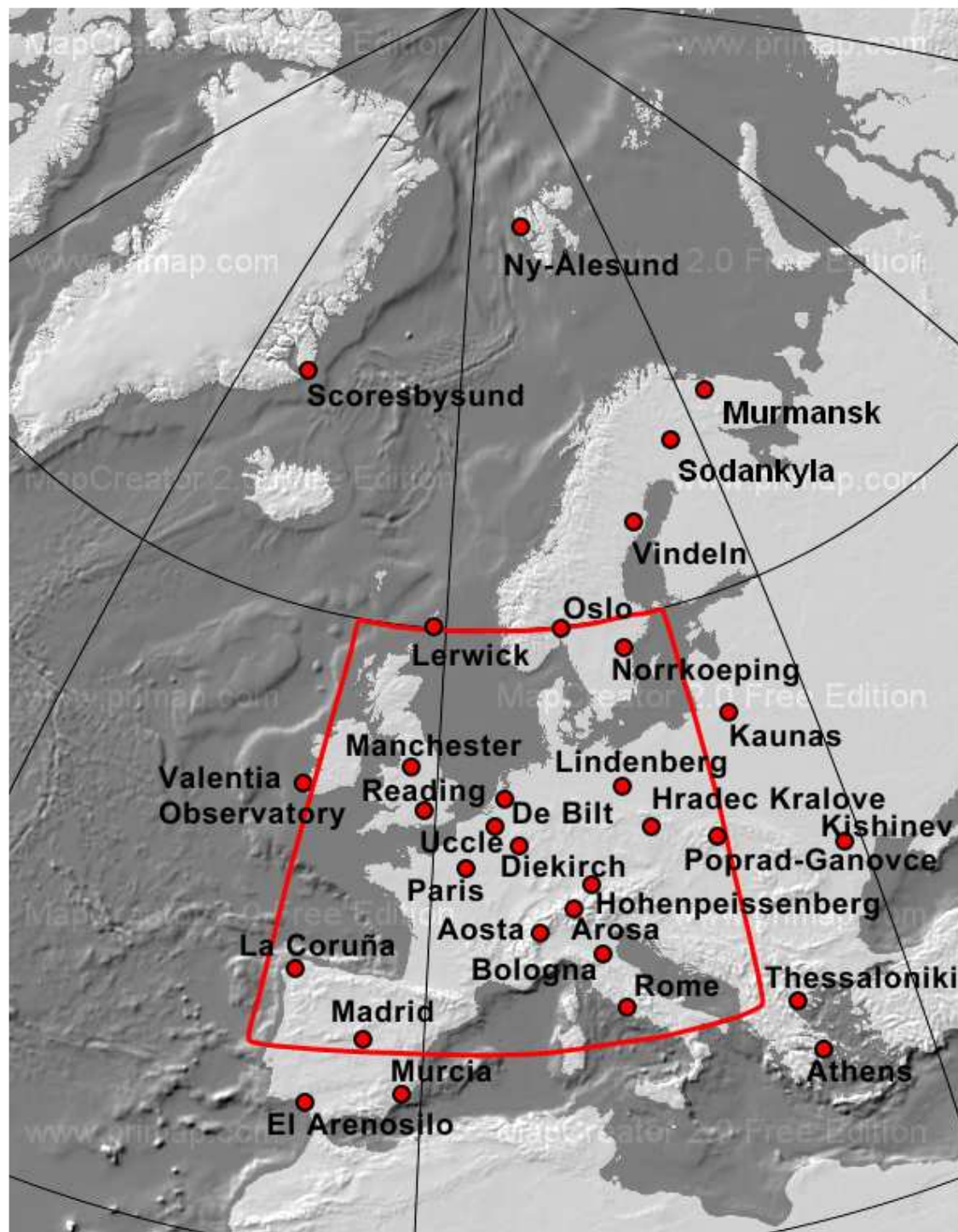
44°31'N

41°51'N

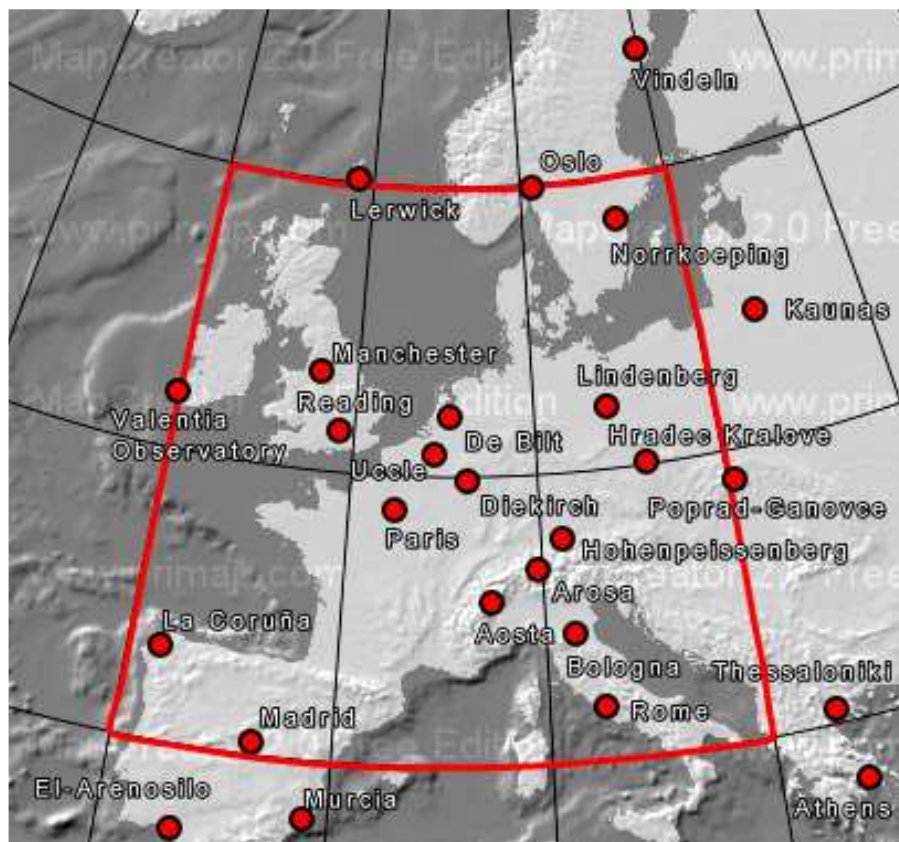




**Nel passo successivo
l'analisi è stata confinata
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misura di ozono
colonnare**



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modo relativamente
omogeneo da stazioni di
misura di ozono
colonnare che si
estende tra le longitudini
10°W e 20°E e le
latitudini 40°N e 60°N**

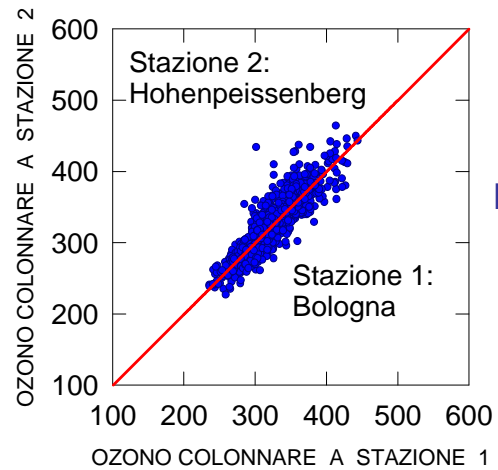


Nel settore selezionato, a partire dai dati misurati dalle stazioni, la distribuzione spaziale dell'ozono colonnare è stata ottenuta utilizzando il metodo di Shepard (1968), che porta ad un *dataset* con risoluzione di 2.5° in longitudine e in latitudine dove l'ozono colonnare si definisce come:

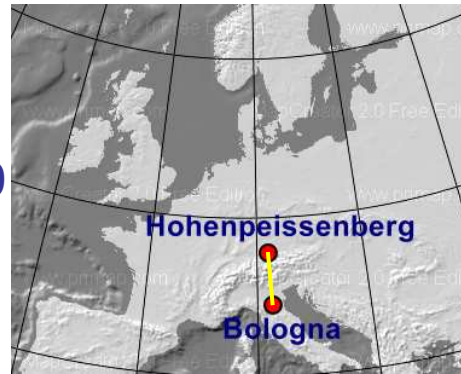
$$Q(\varphi, \lambda, t) = \frac{\sum_{i=1}^N Q_{S_i}(t) / d_i^2}{\sum_{i=1}^N 1 / d_i^2} ,$$

dove $Q(\varphi, \lambda, t)$ è l'ozono nei nodi della griglia al latitudine φ e longitudine λ nel momento t , $Q_{S_i}(t)$ è l'ozono misurato nella stazione S_i e d_i è la distanza tra il punto (φ, λ) e la stazione S_i in chilometri che si calcola tramite la formula di Lambert.

Coefficiente di correlazione dei dati di diversi stazioni situati a distanza di:

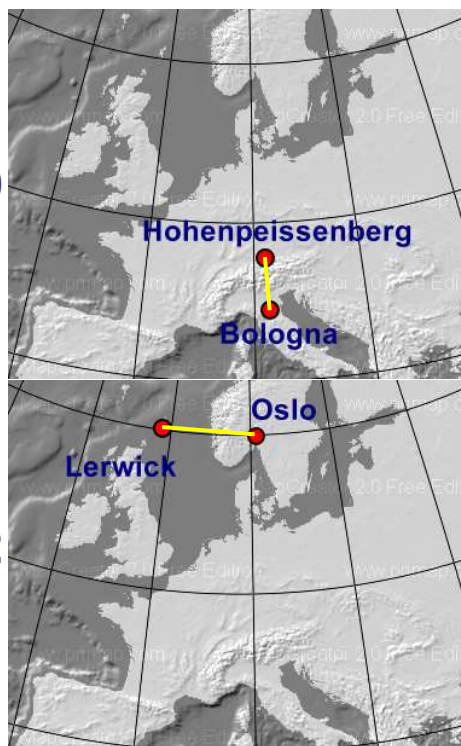
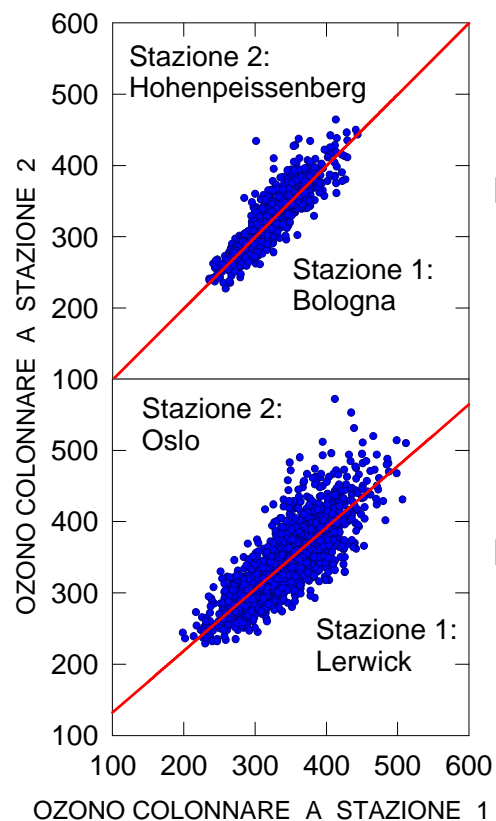


$r = 0.90$

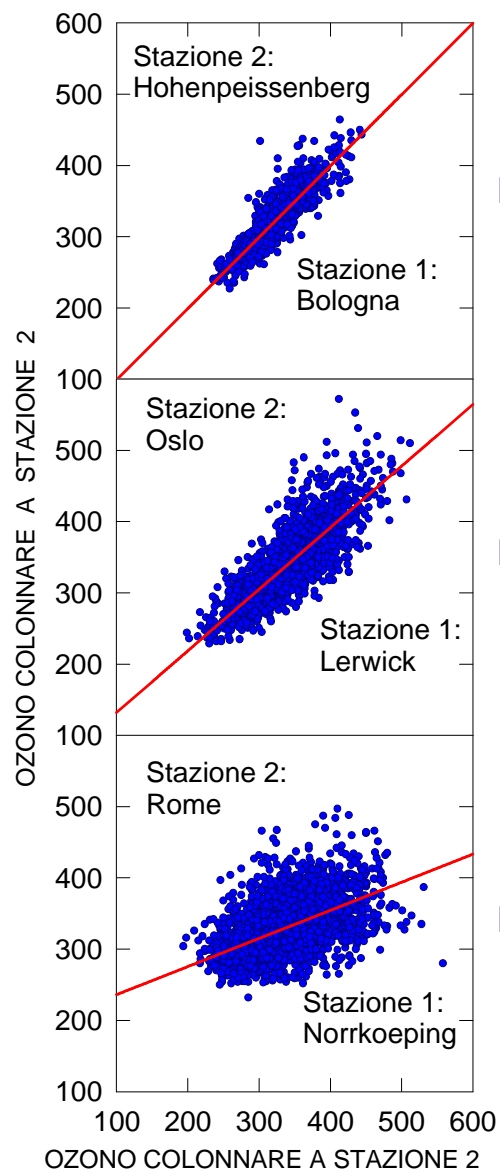


365 km

Coefficiente di correlazione dei dati di diversi stazioni situati a distanza di:



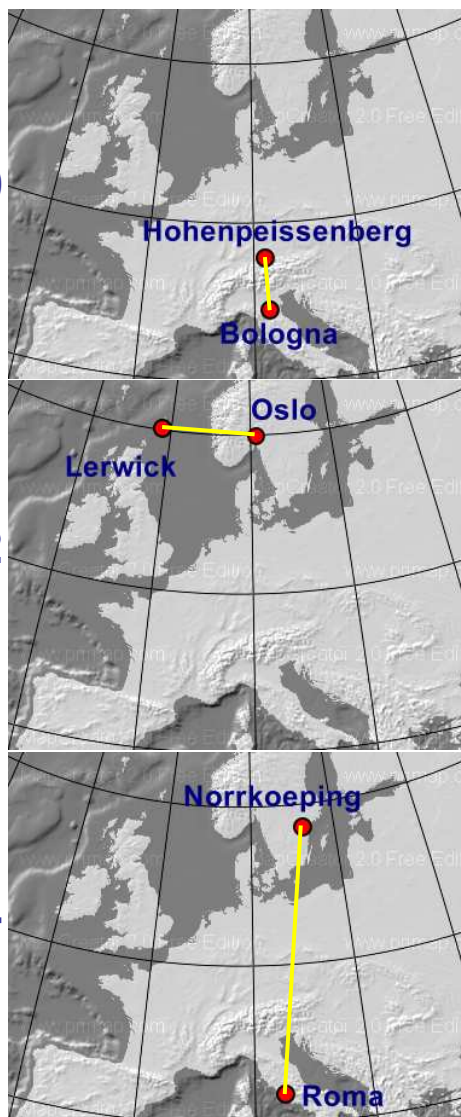
Coefficiente di correlazione dei dati di diversi stazioni situati a distanza di:



$r = 0.90$

$r = 0.82$

$r = 0.54$

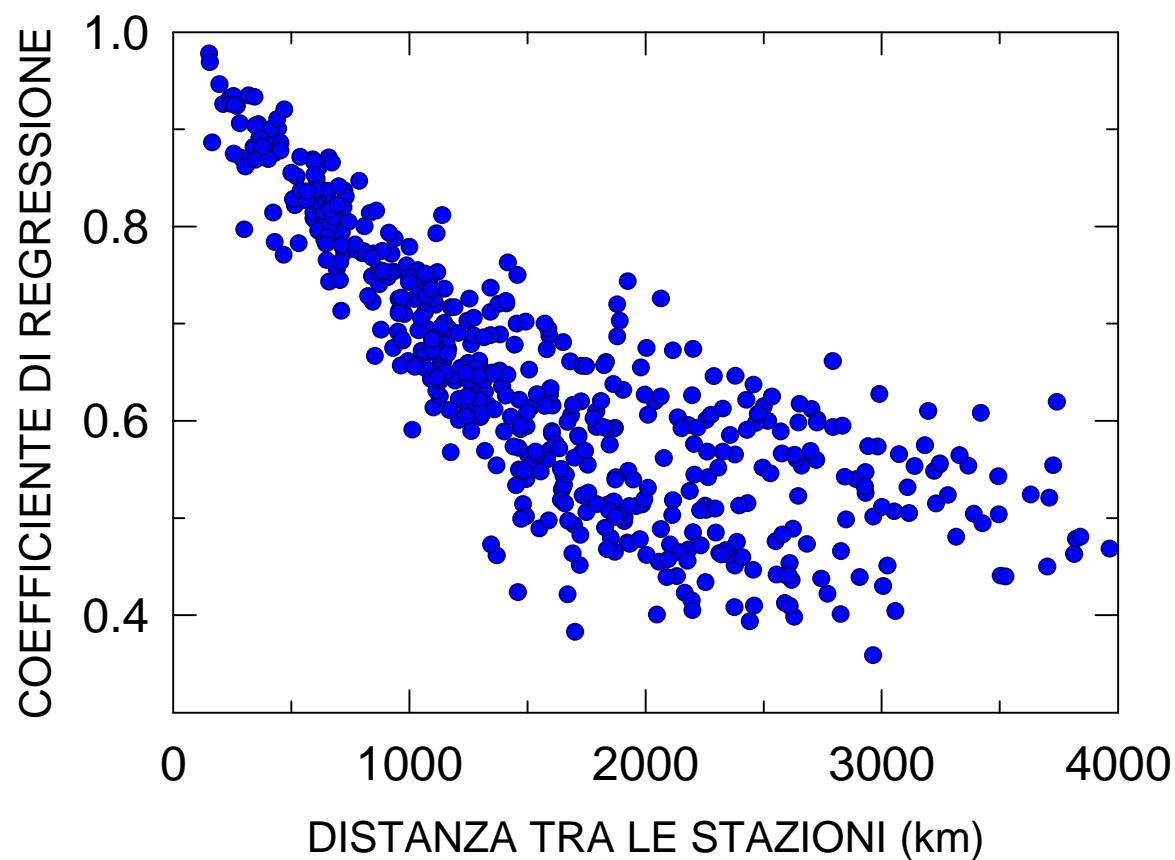


365 km

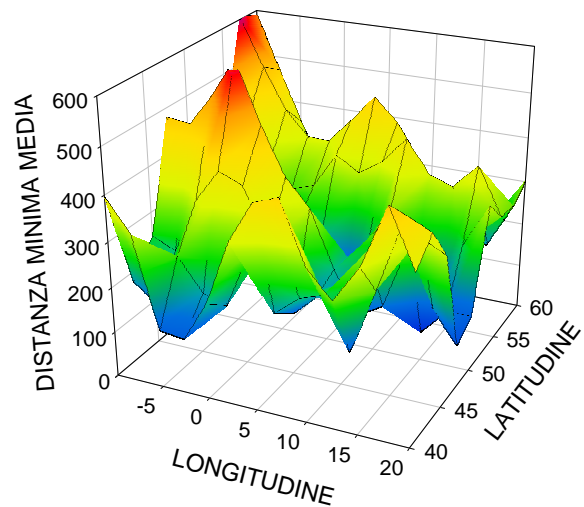
663 km

1872 km

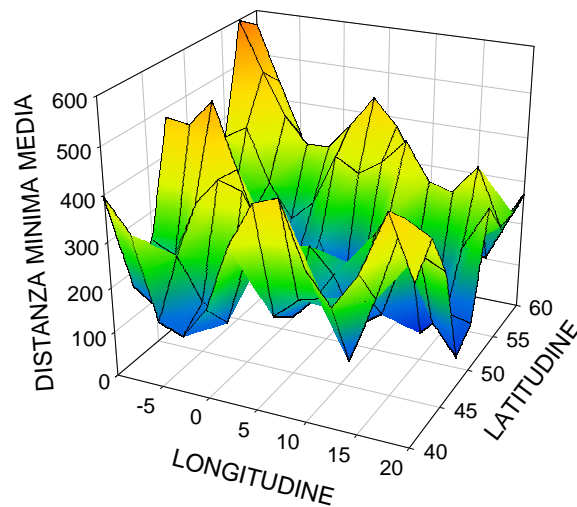
Coefficiente di regressione tra i dati dell'ozono colonnare forniti da tutte le coppie possibili delle stazioni considerate in funzione della distanza presente fra di loro.



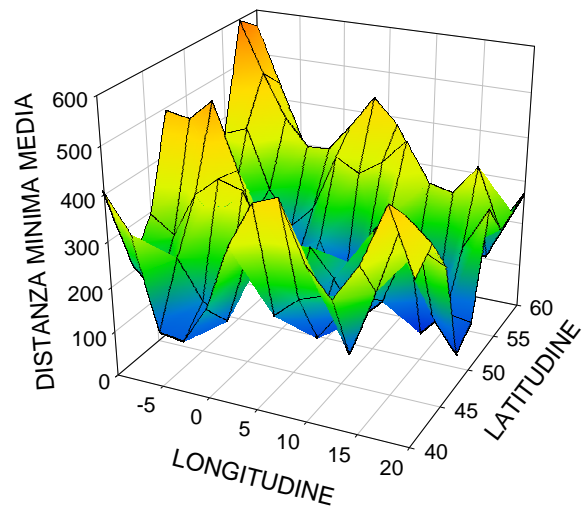
2001



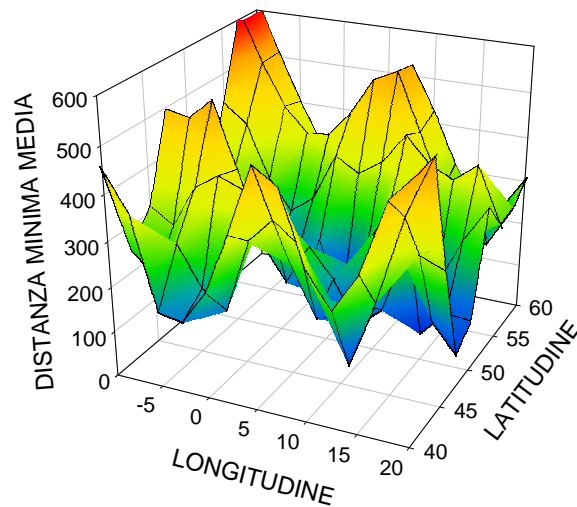
2006



2010

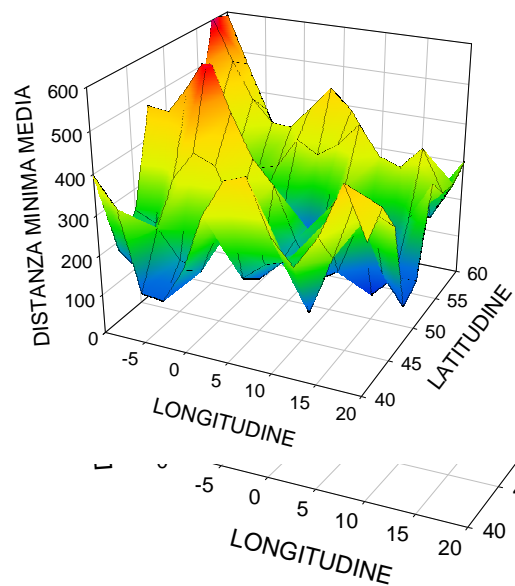


2011

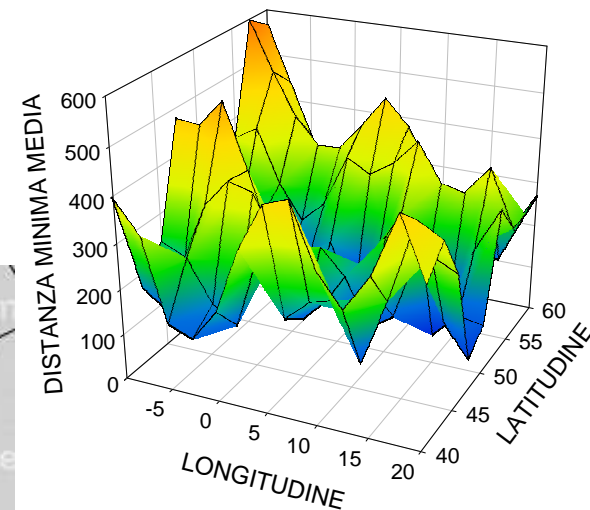
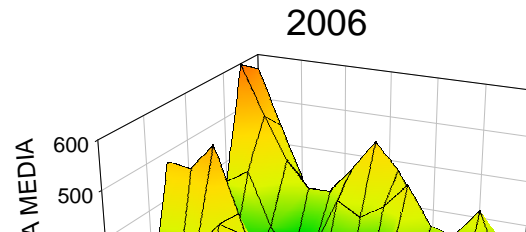


Distribuzione
delle distanze (in
chilometri) tra
ogni nodo della
griglia e la
stazione più
vicina.

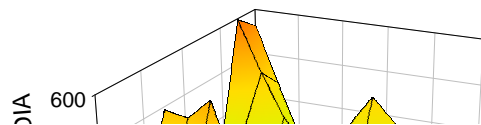
2001



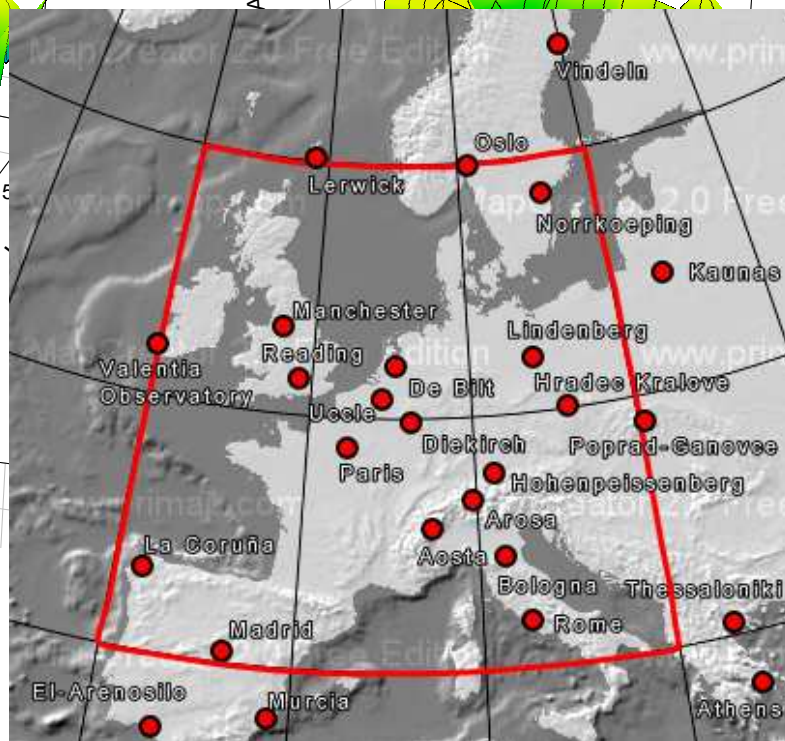
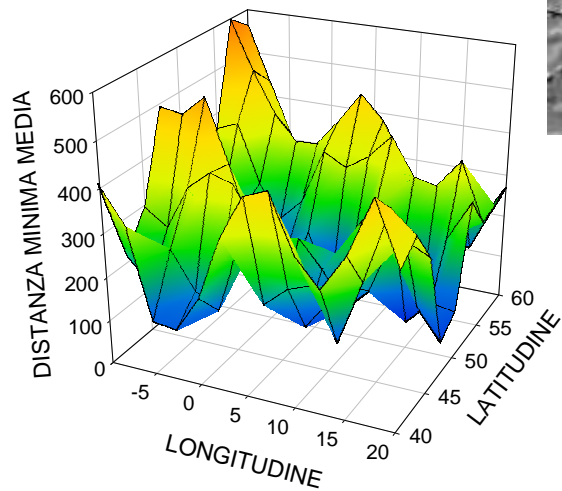
2006



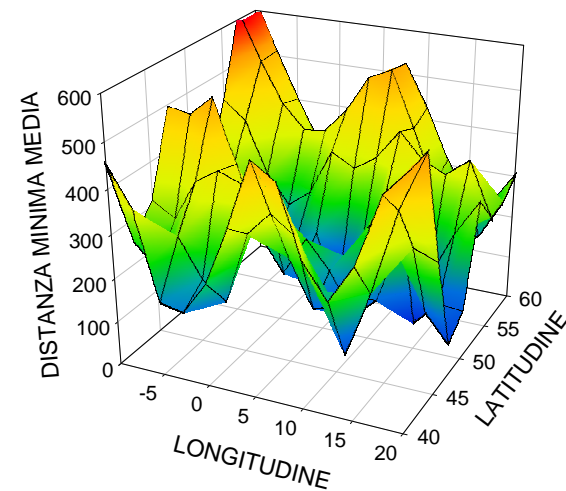
2010



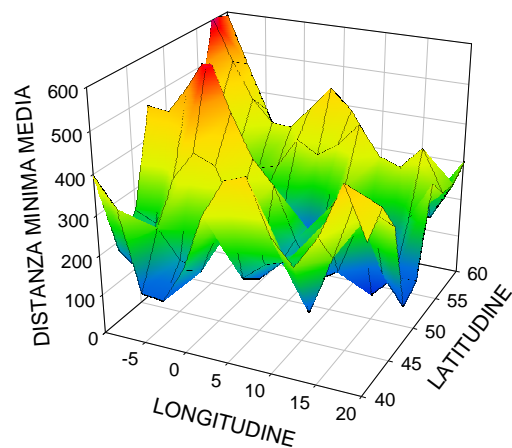
2010



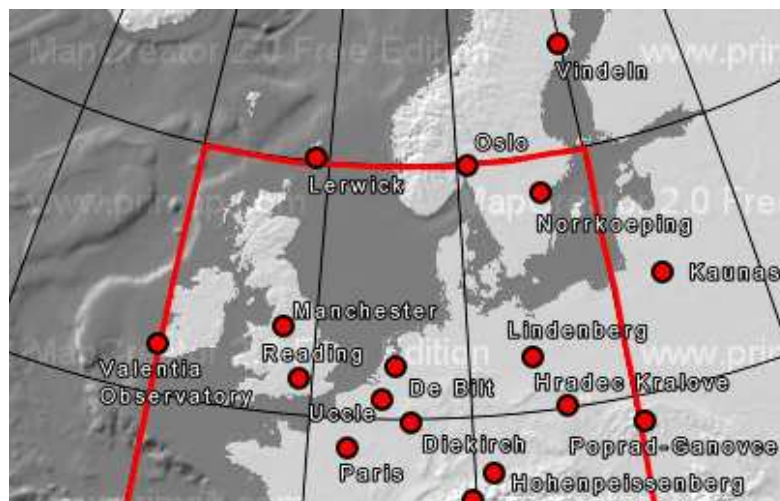
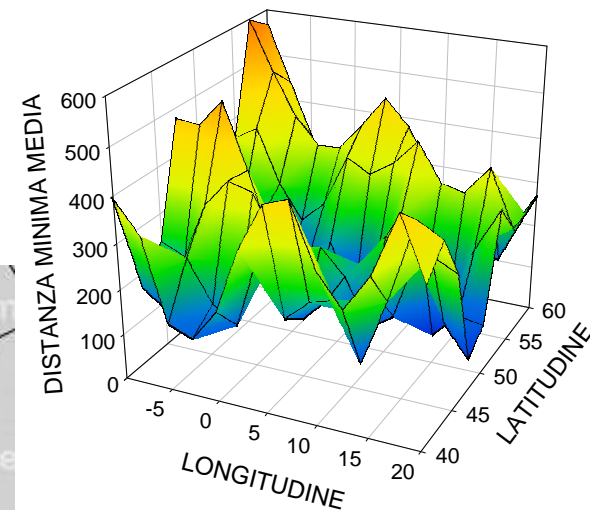
2011



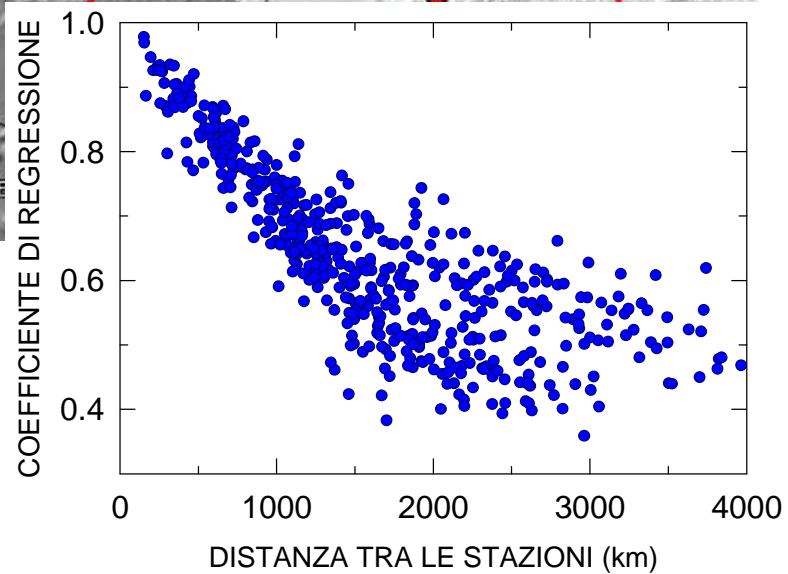
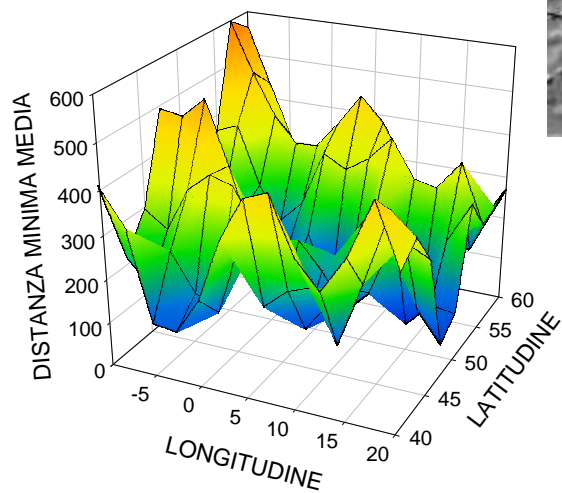
2001



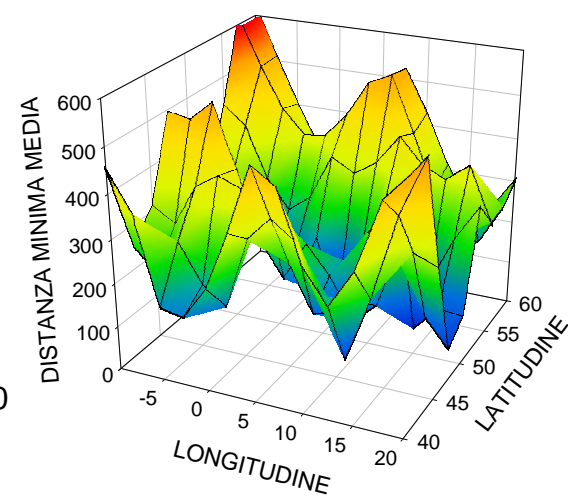
2006



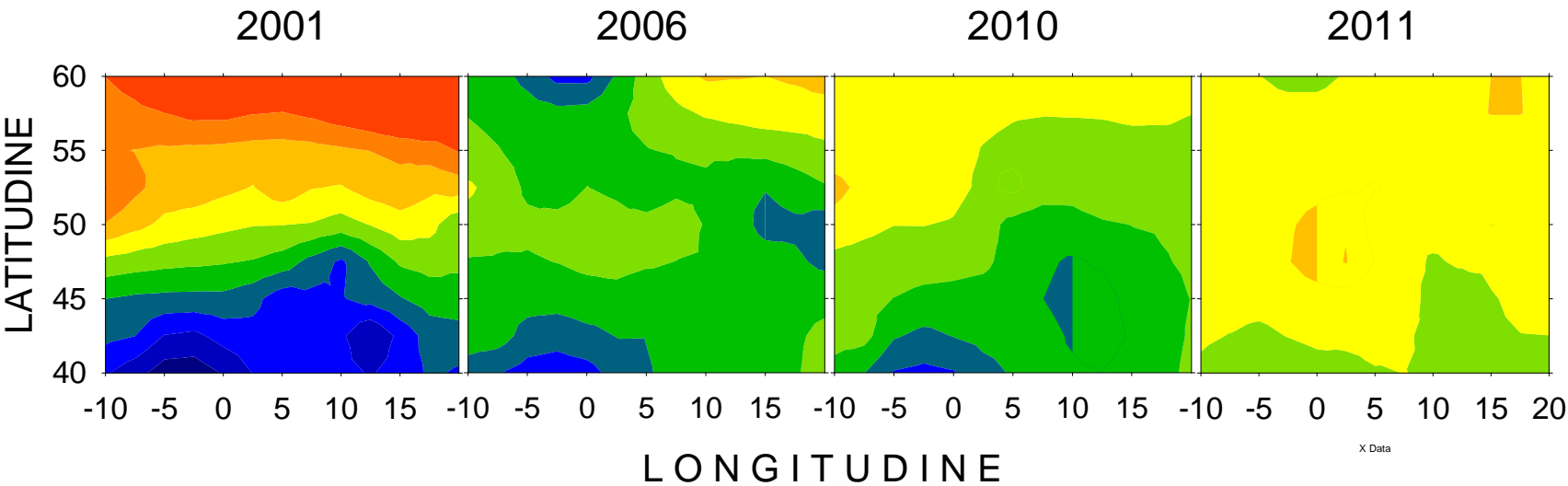
2010



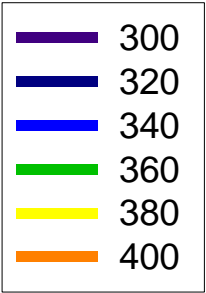
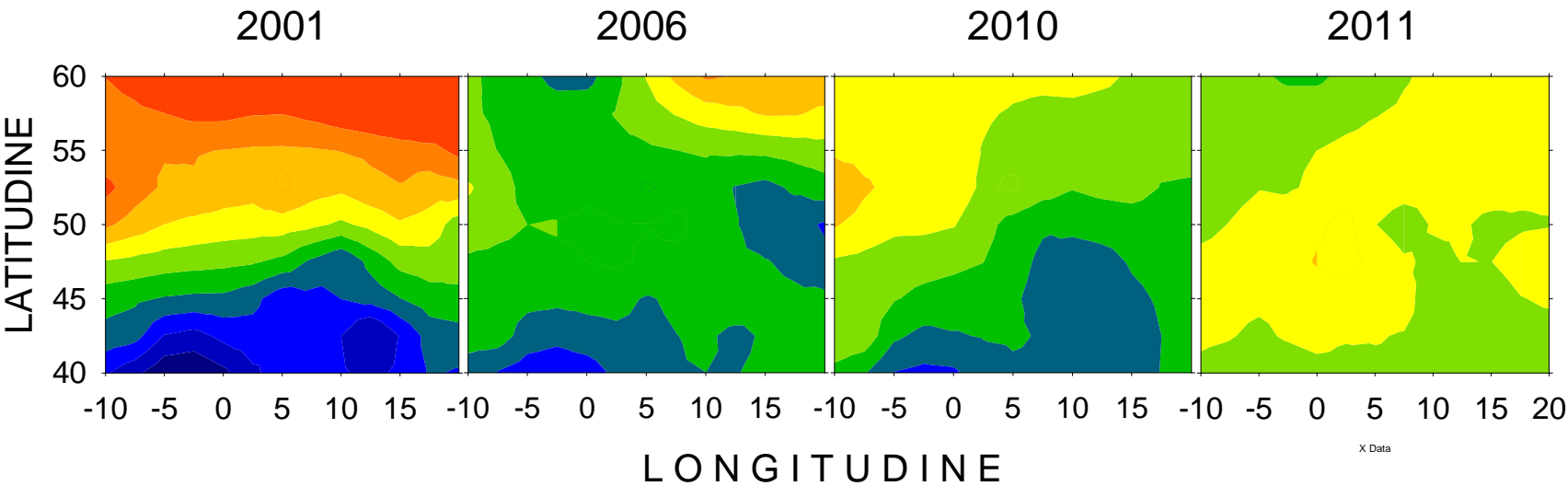
2011



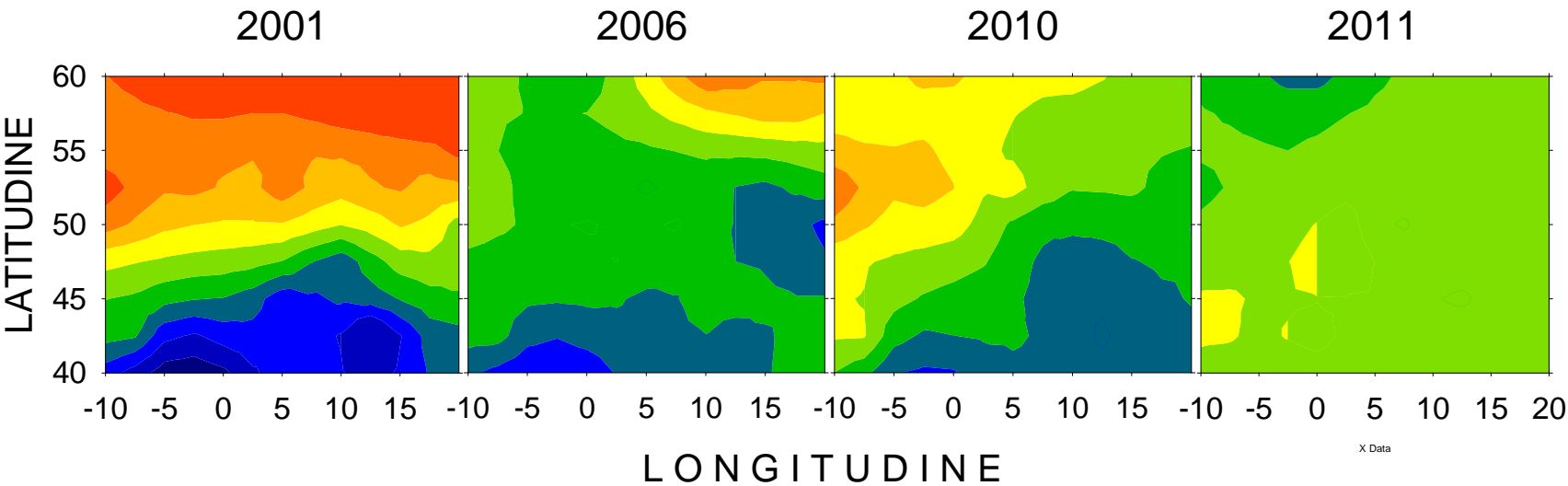
20 Marzo



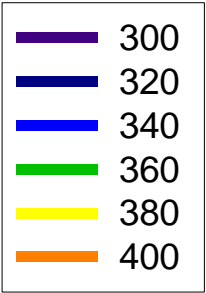
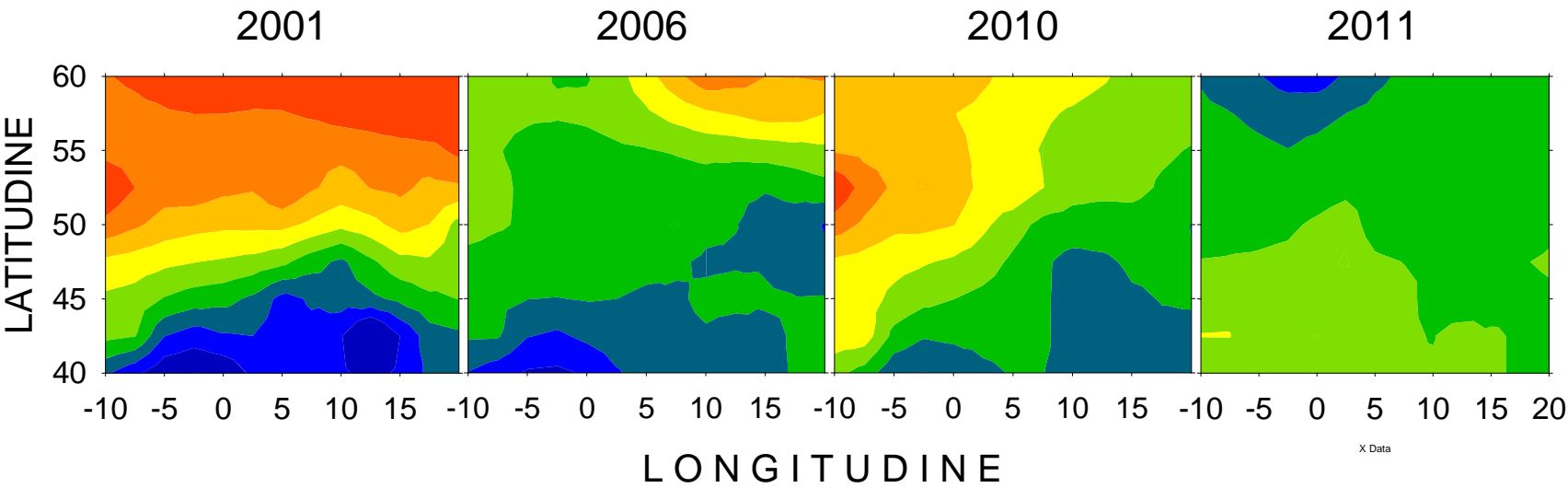
21 Marzo



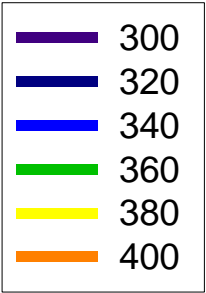
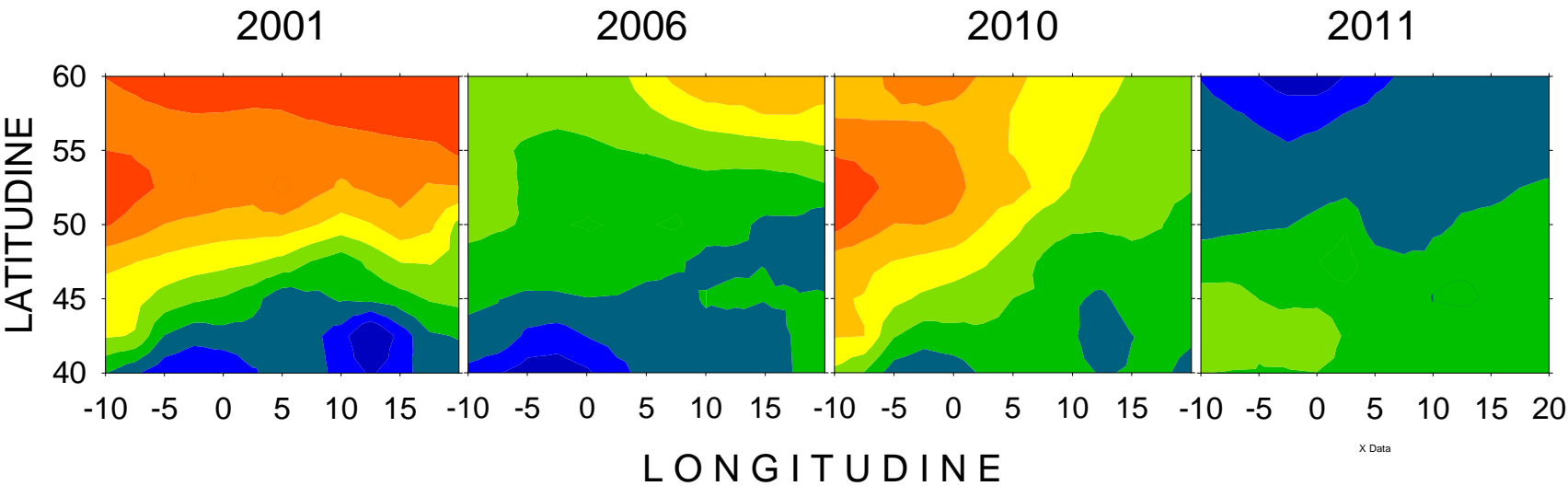
22 Marzo



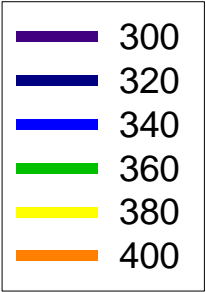
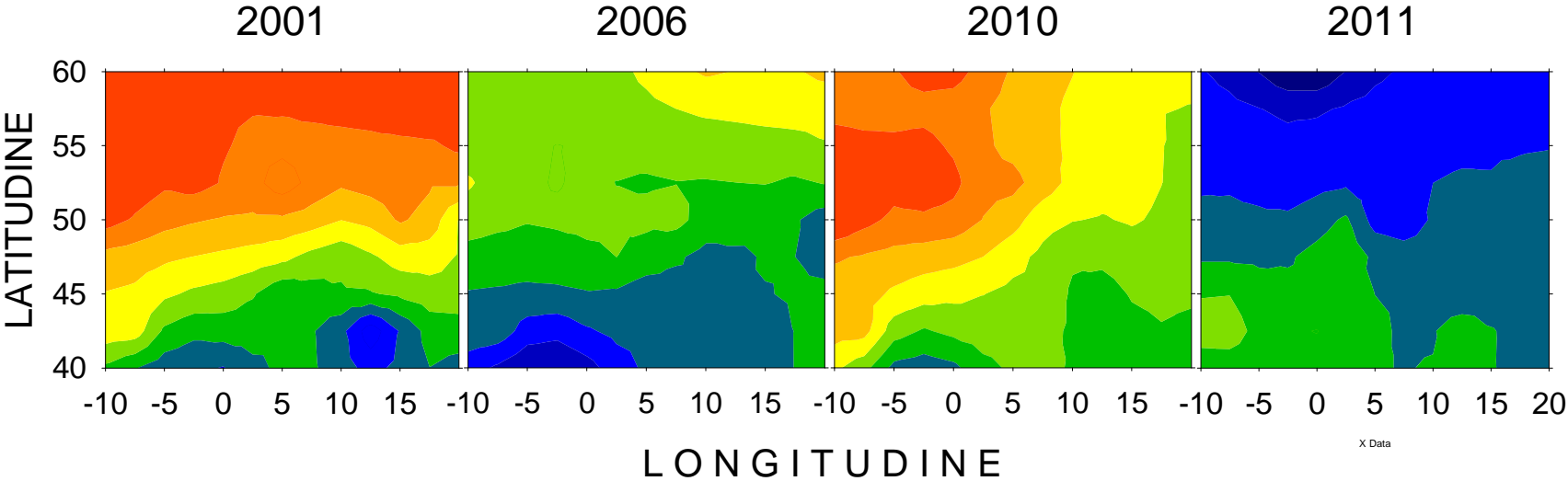
23 Marzo



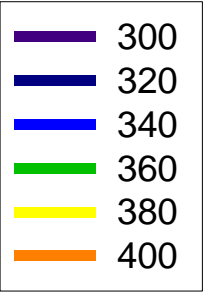
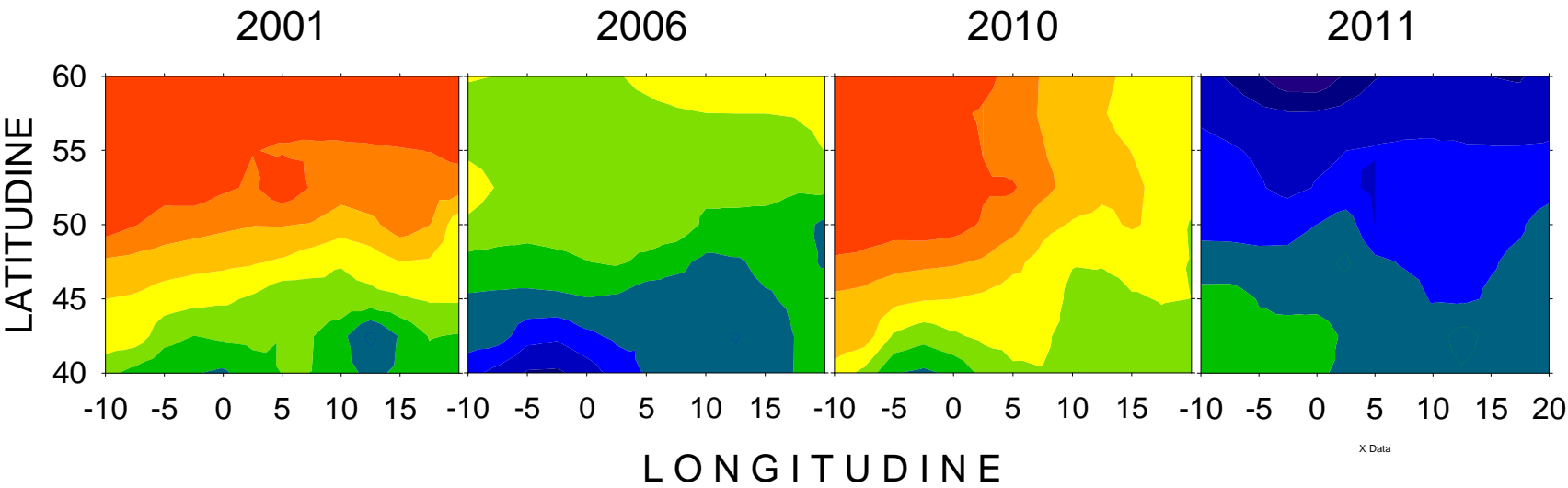
24 Marzo



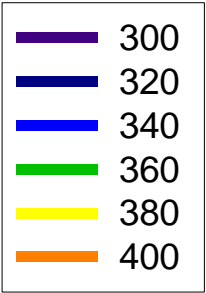
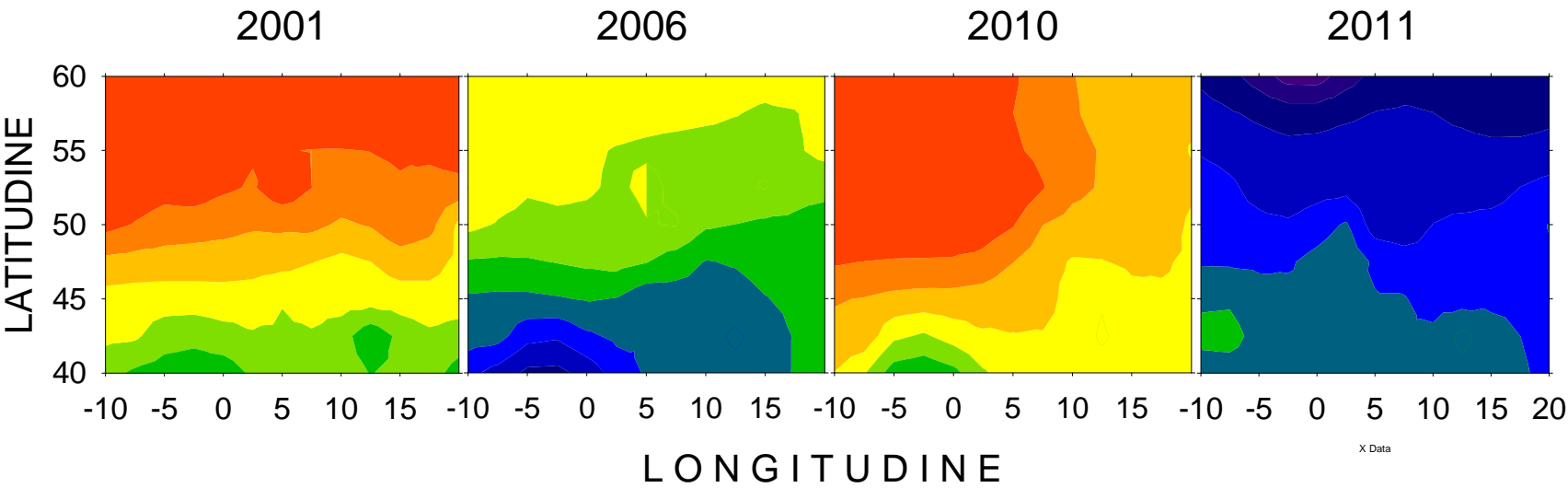
25 Marzo



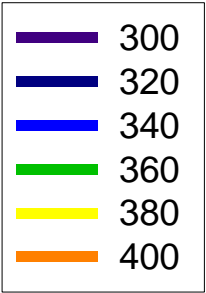
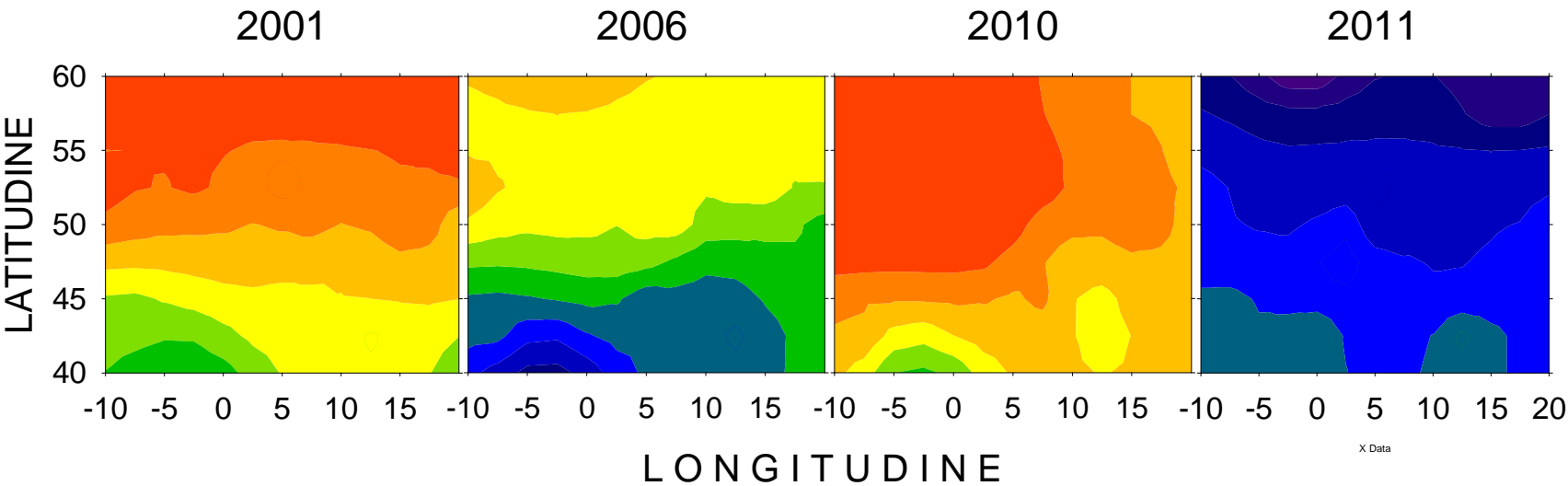
26 Marzo



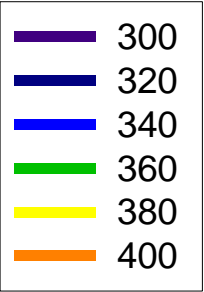
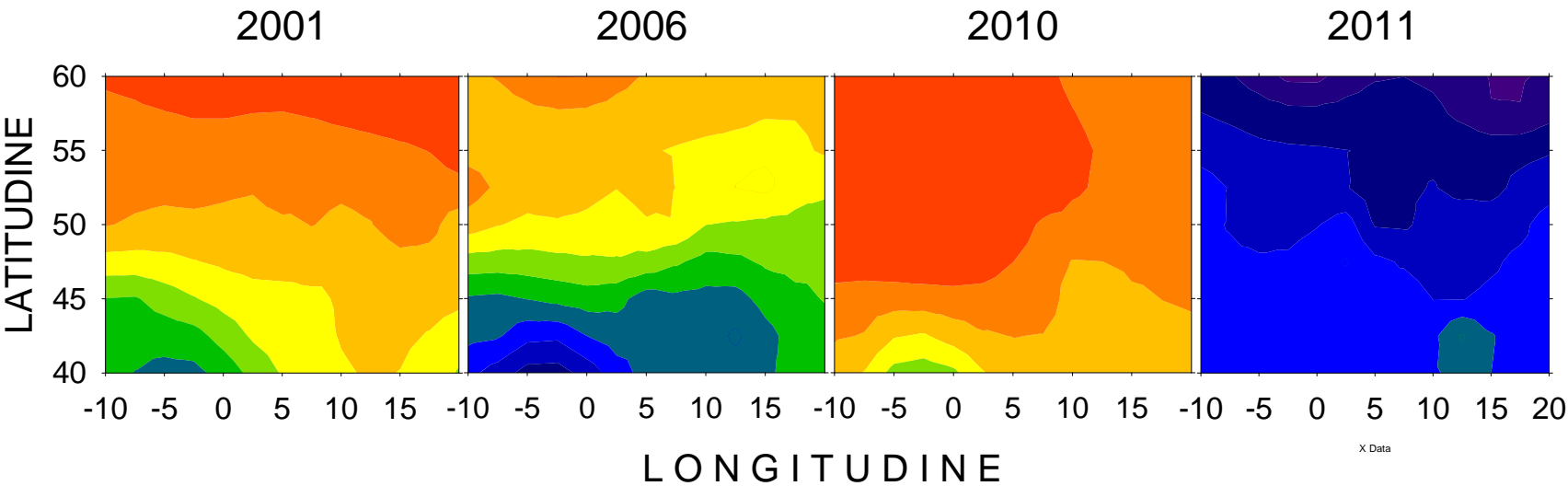
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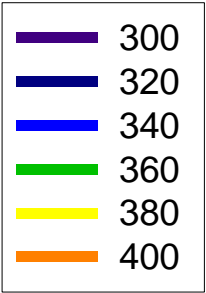
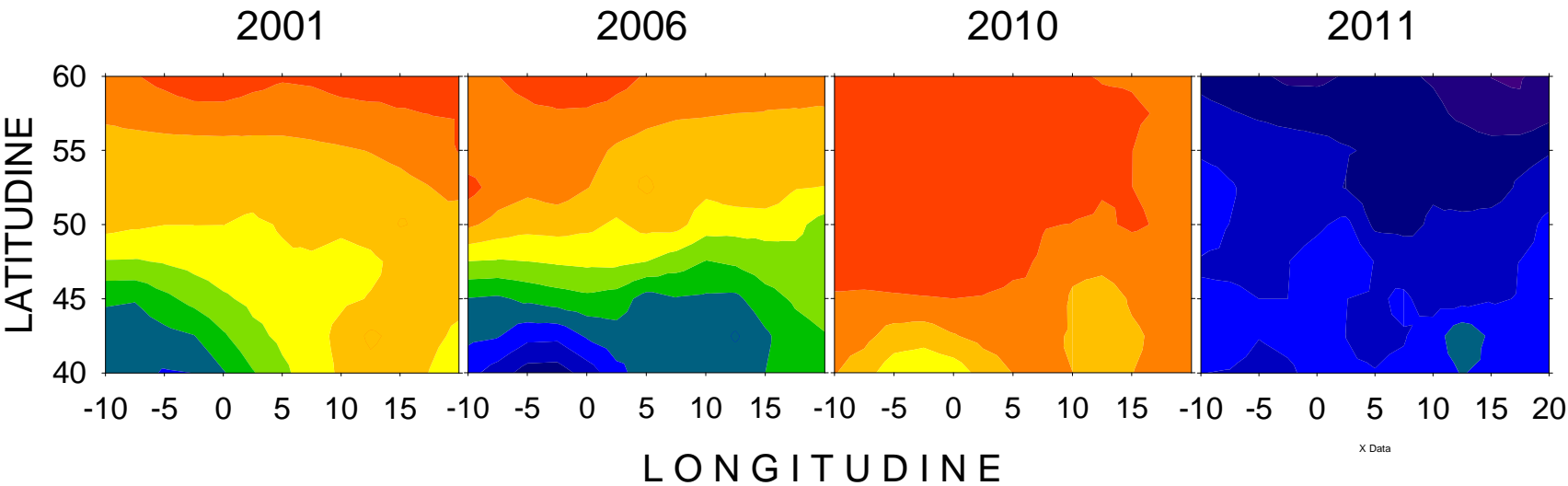
28 Marzo



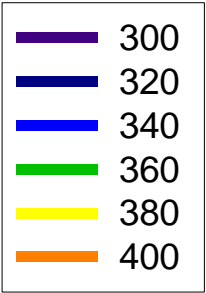
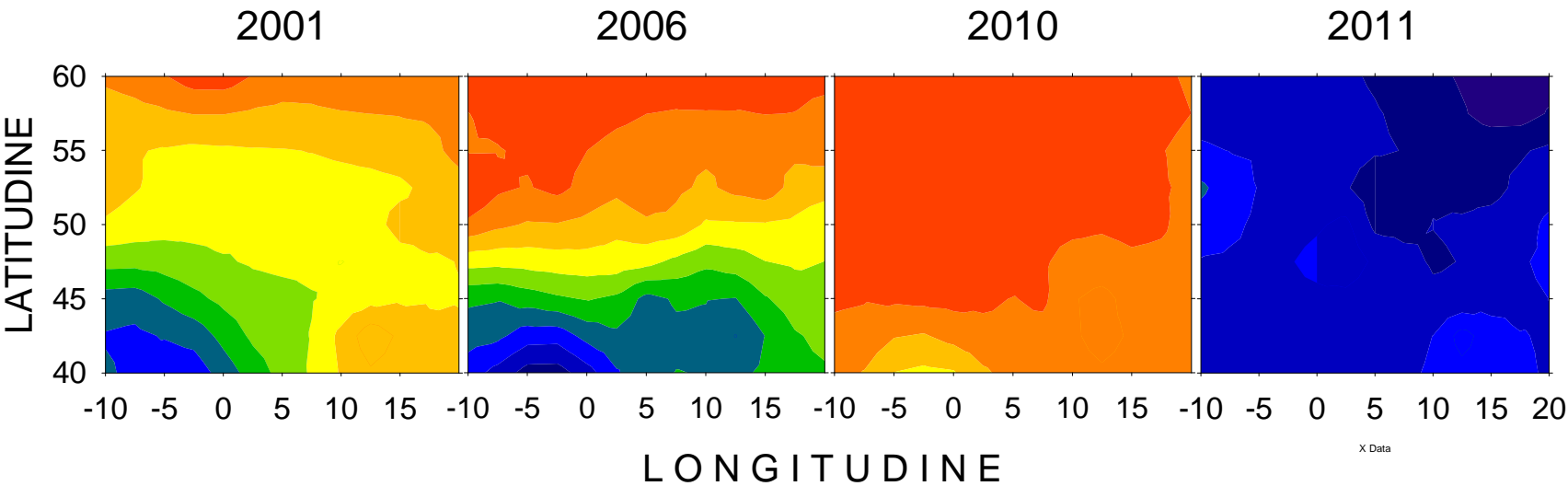
29 Marzo



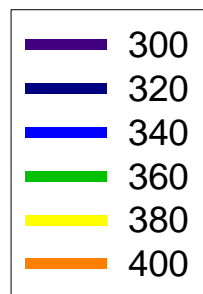
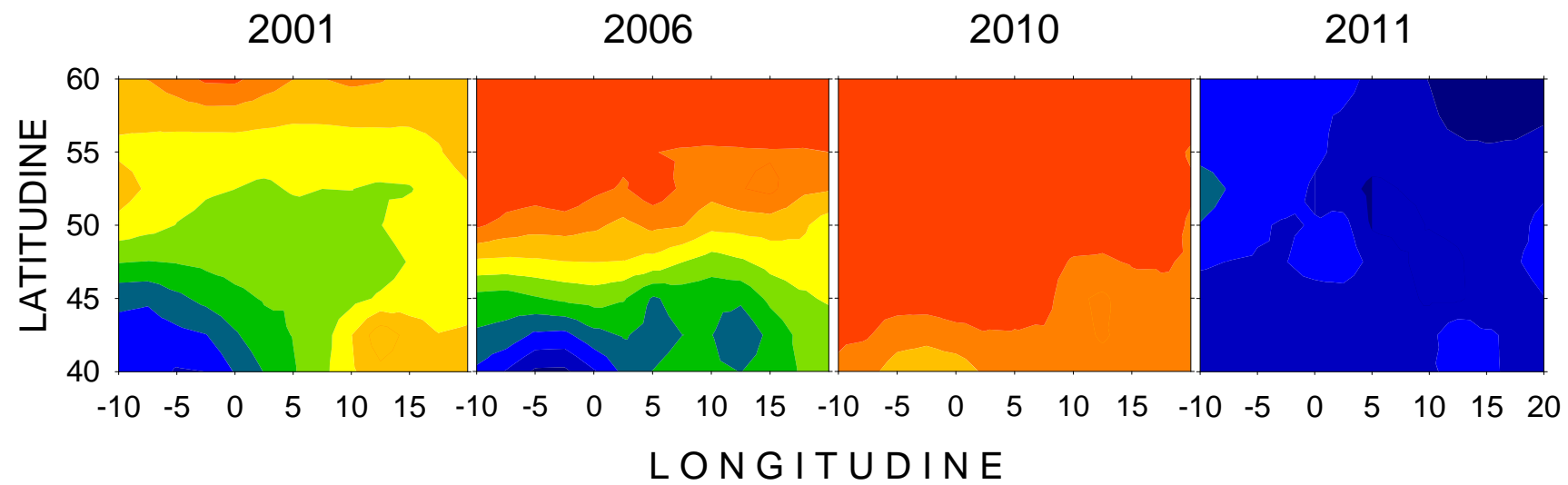
30 Marzo



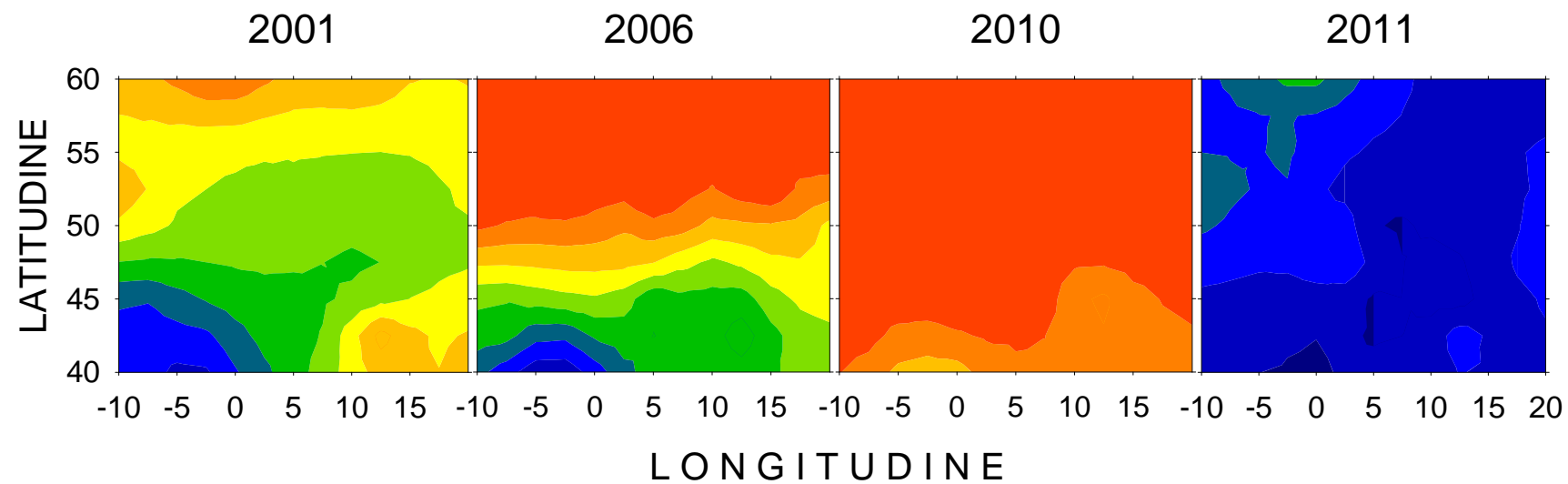
31 Marzo



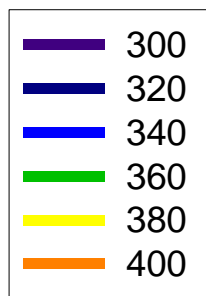
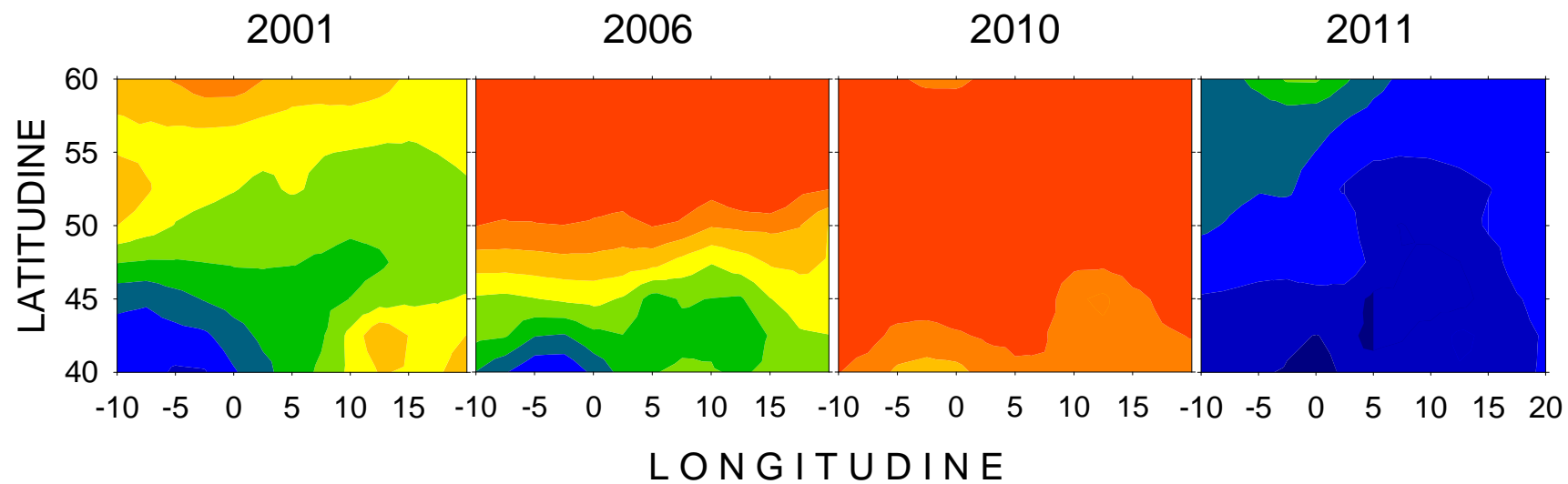
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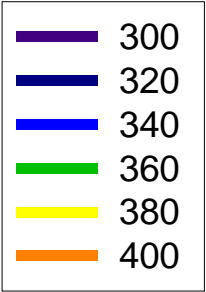
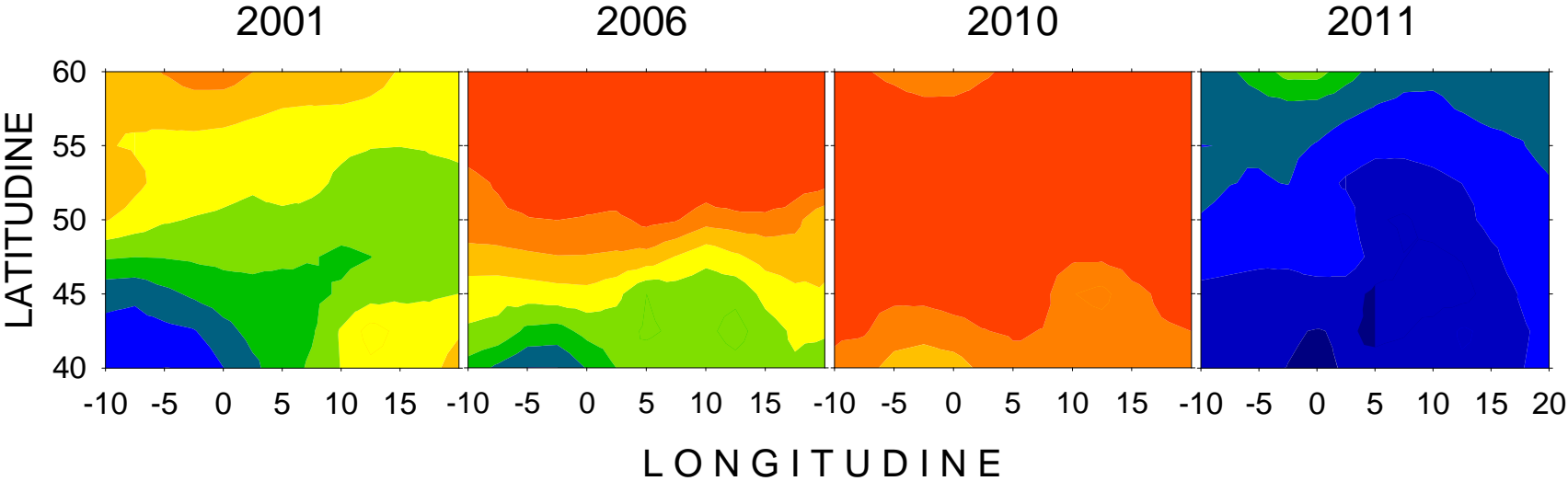
2 Aprile



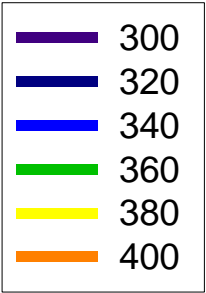
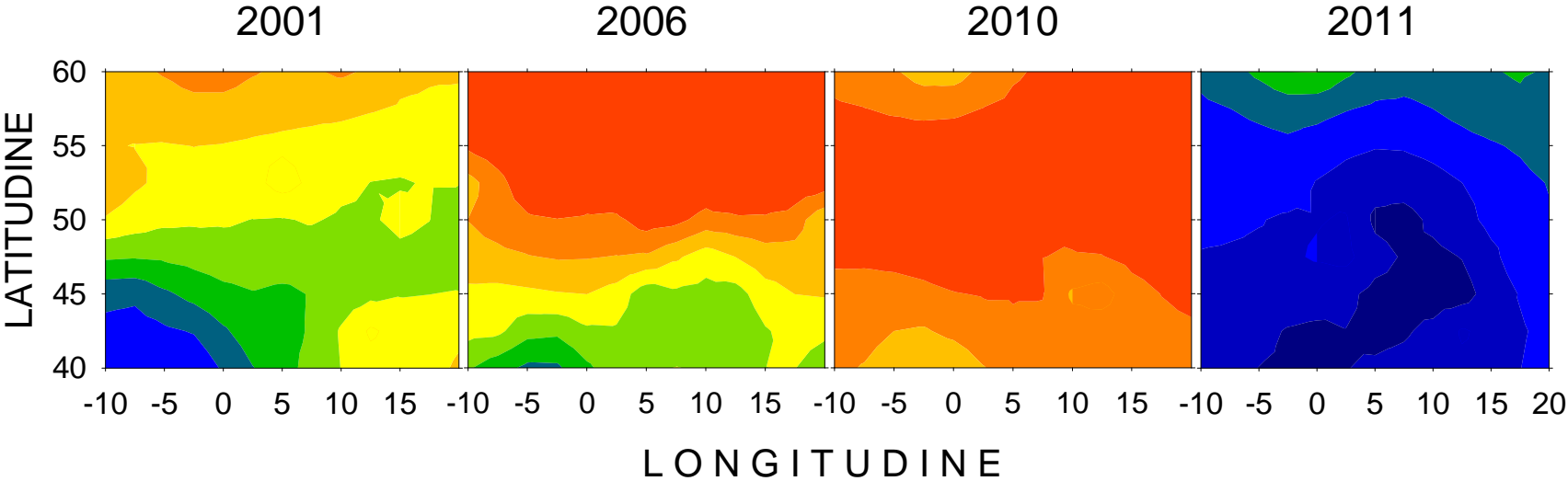
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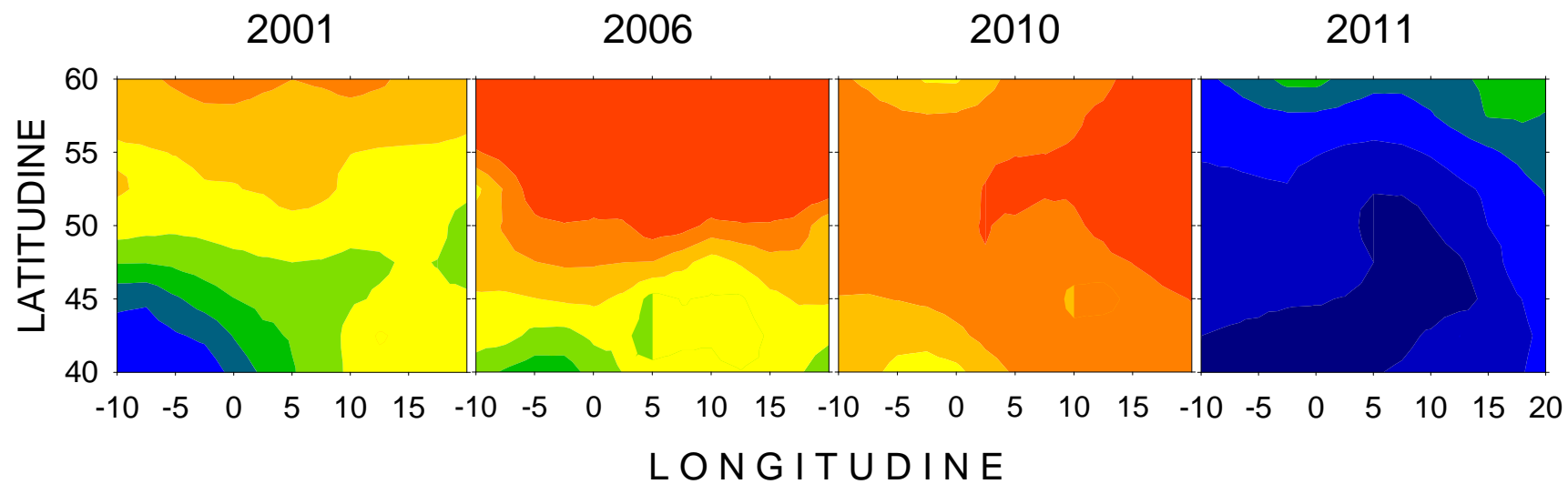
4 Aprile



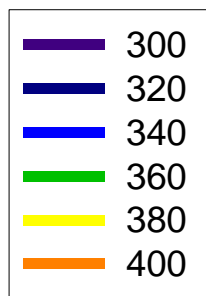
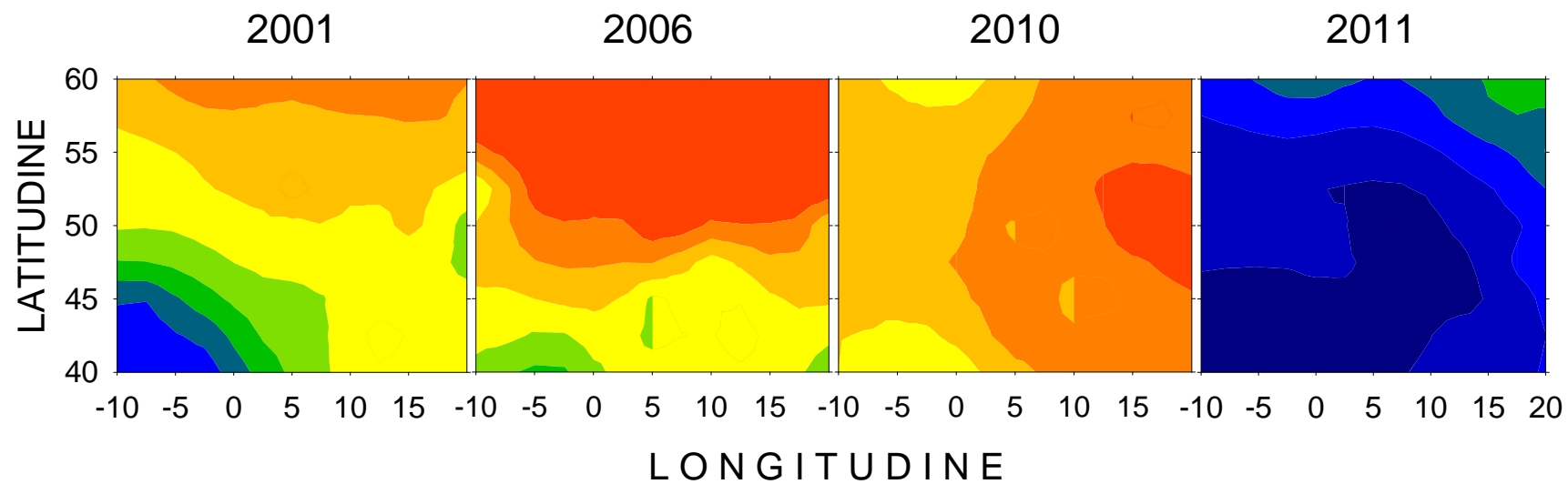
5 Aprile



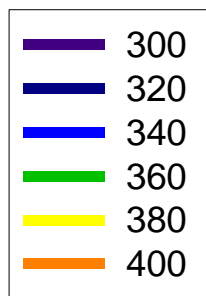
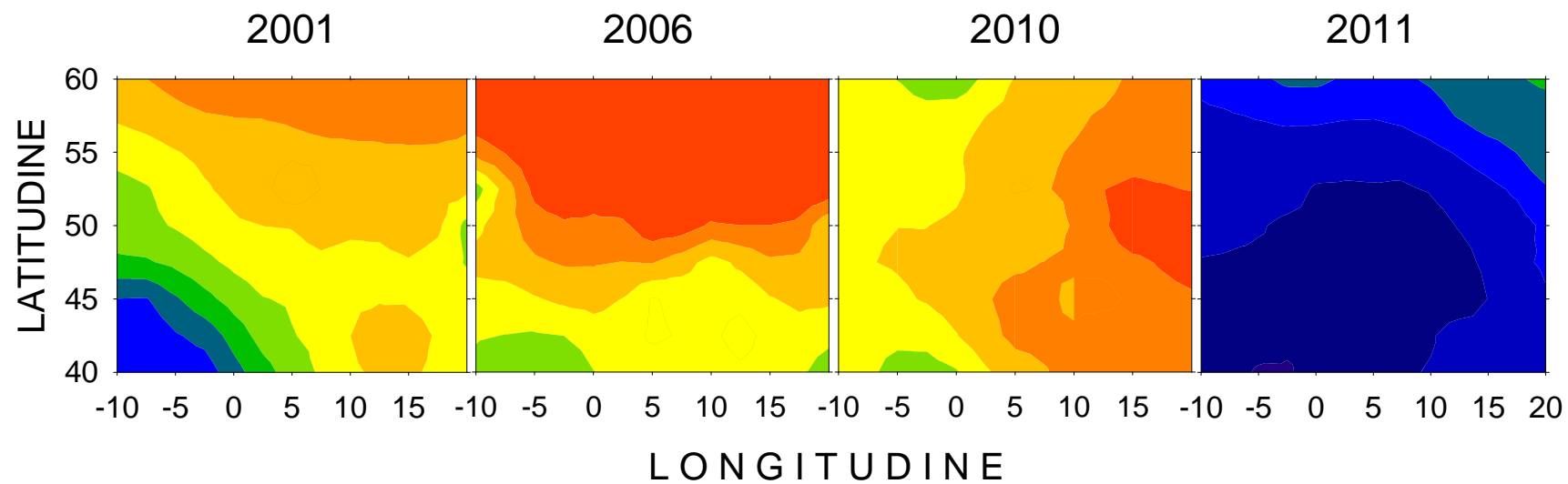
6 Aprile



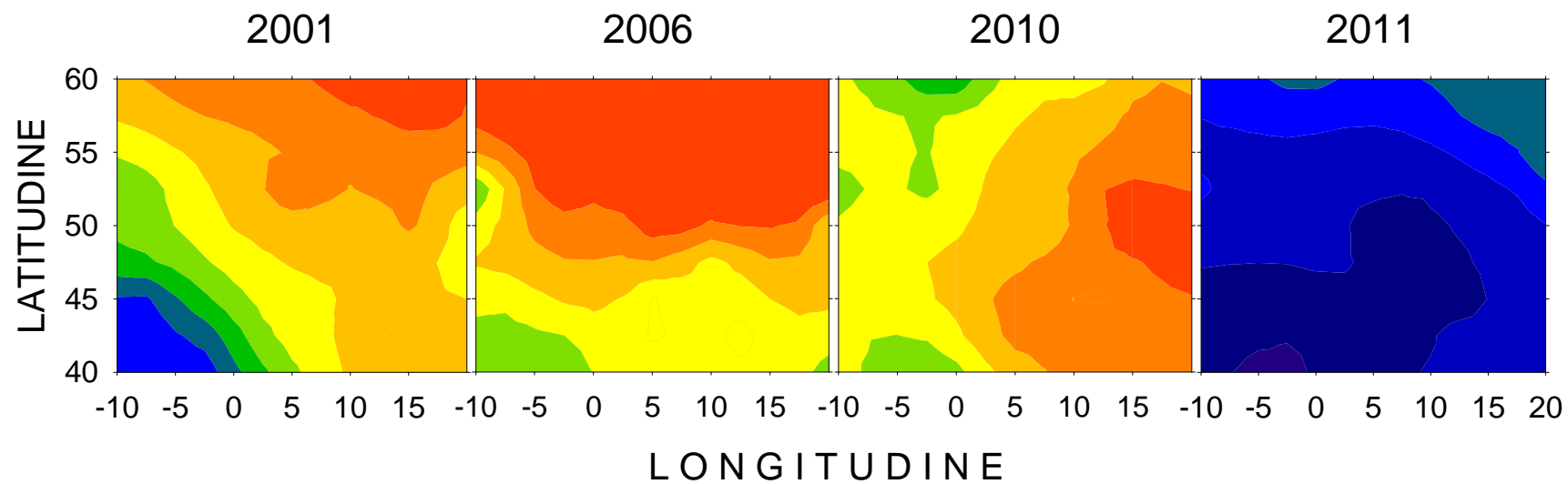
7 Aprile



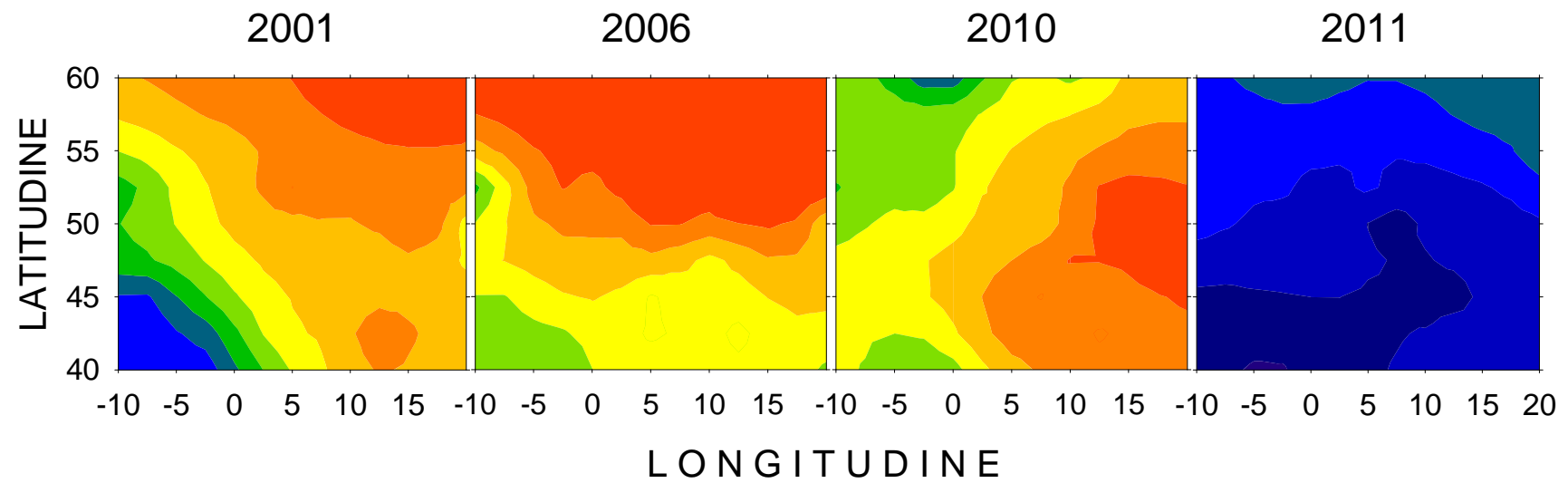
8 Aprile



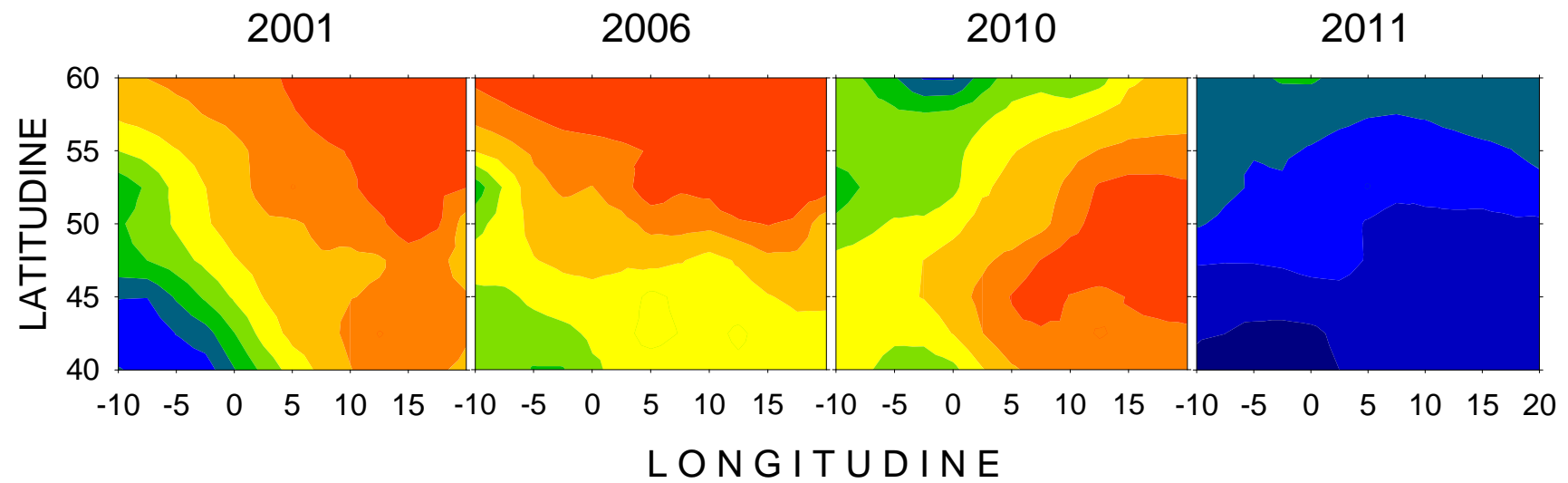
9 Aprile



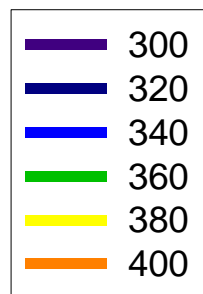
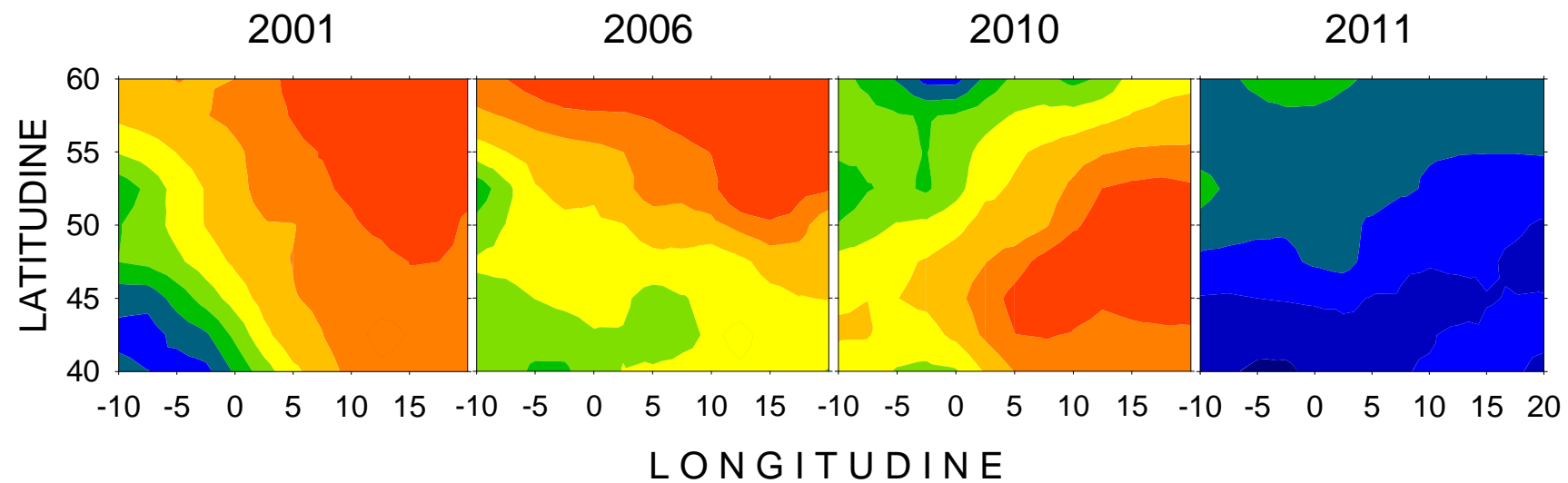
10 Aprile



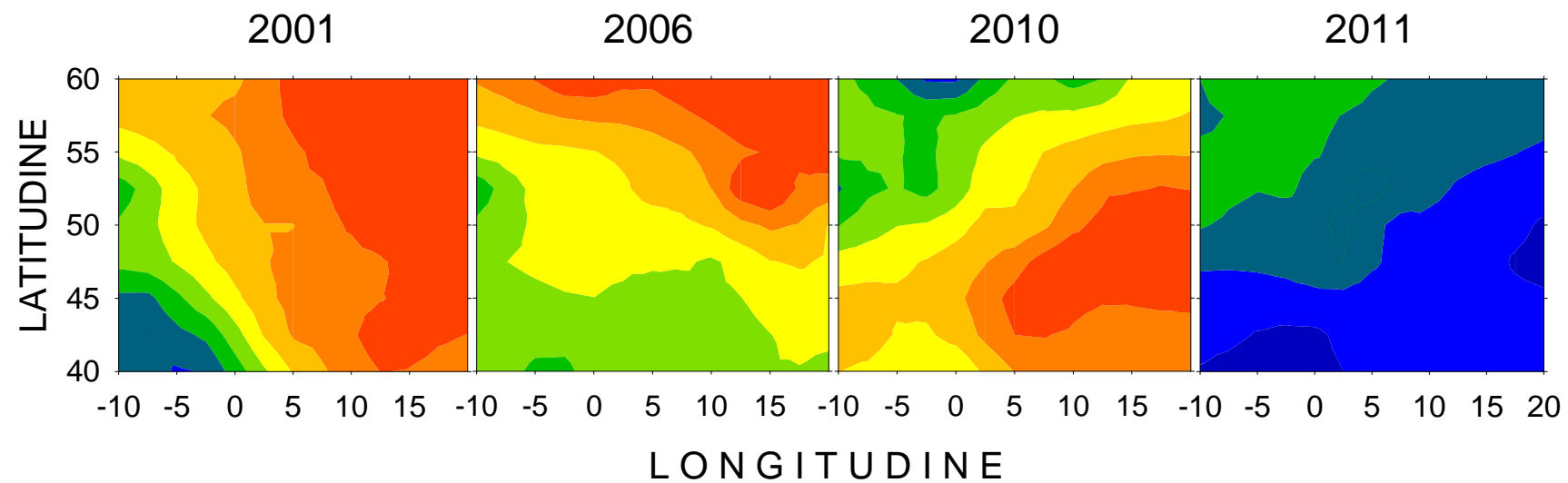
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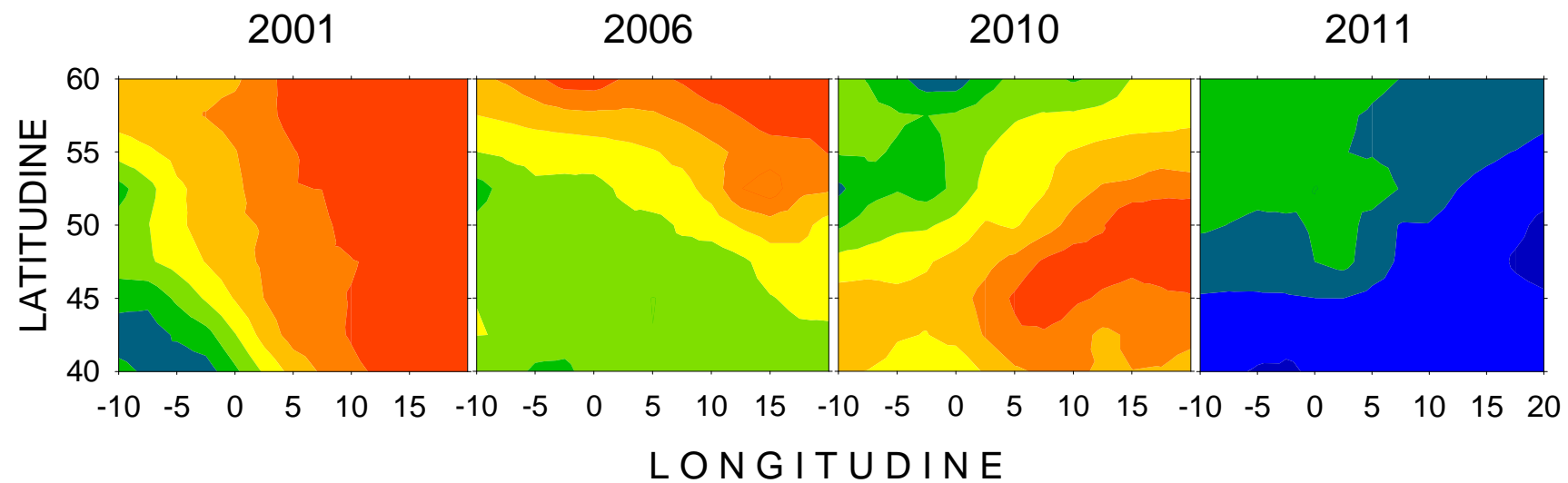
12 Aprile



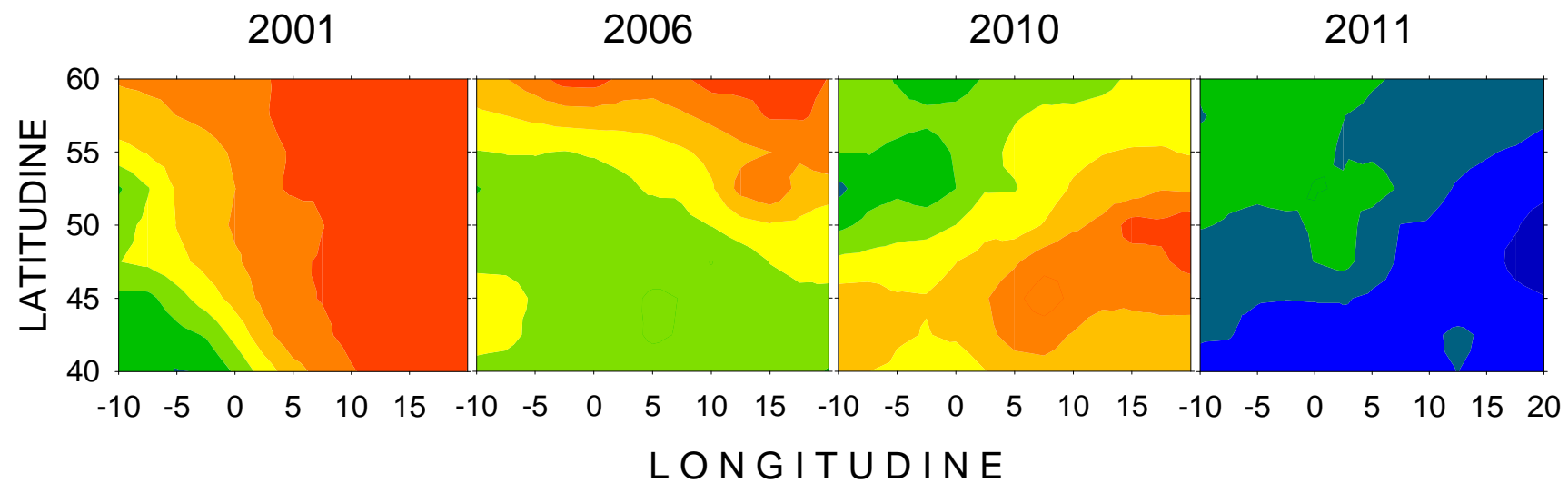
13 Aprile



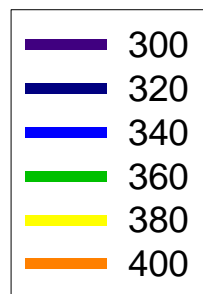
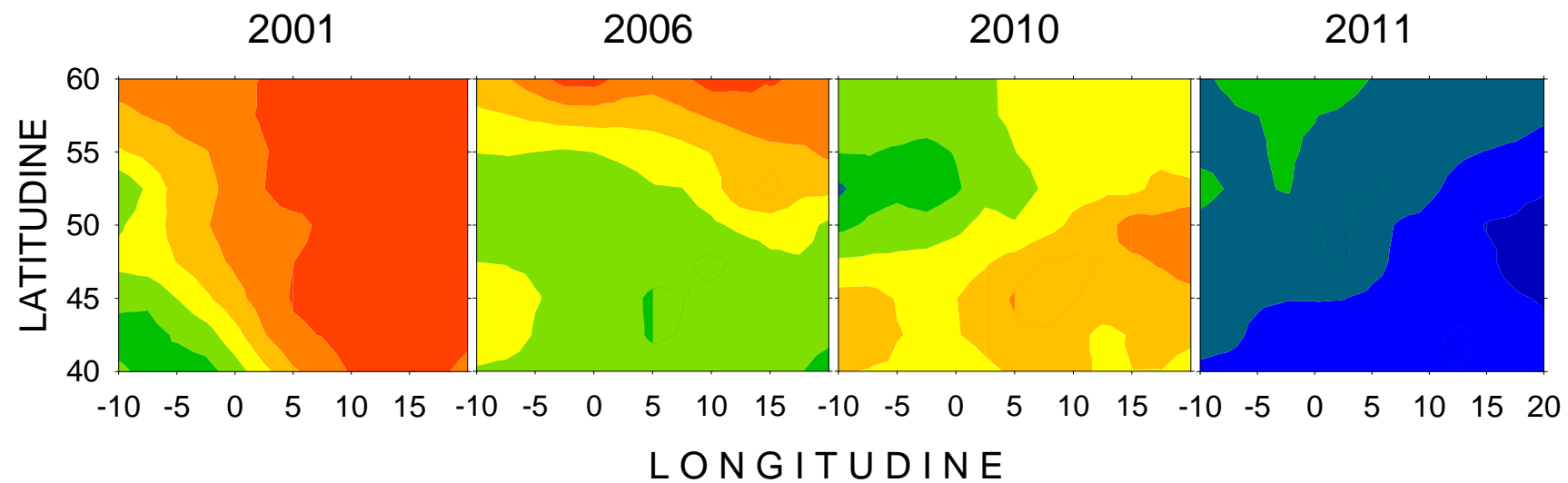
14 Aprile



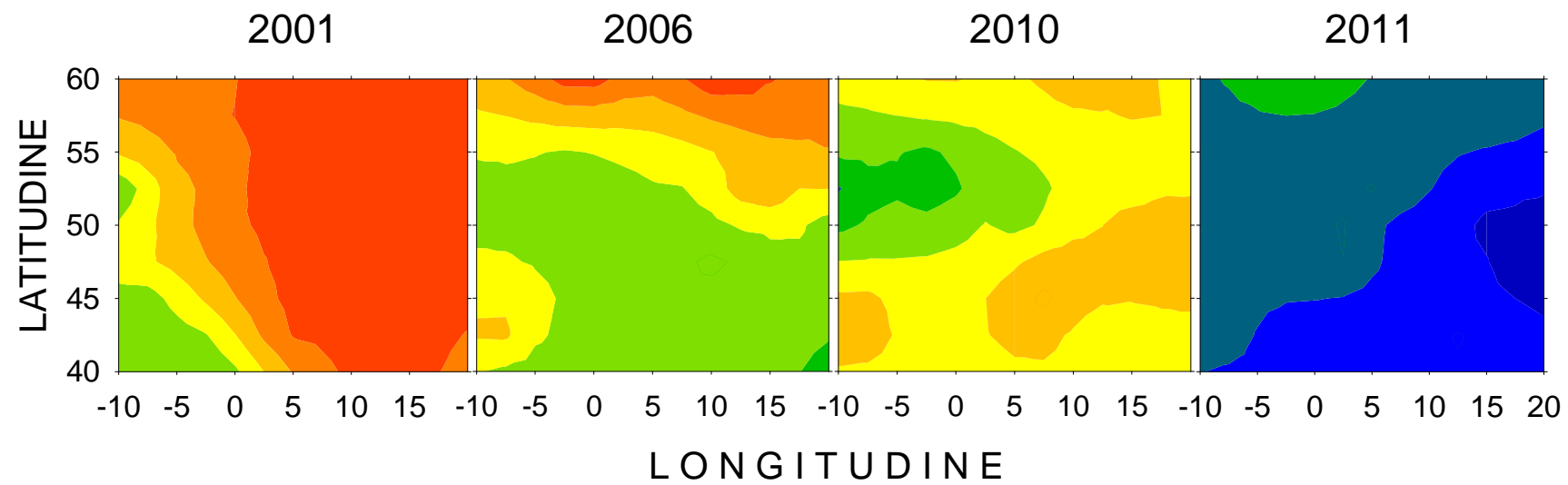
15 Aprile



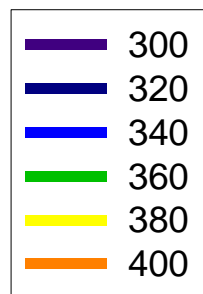
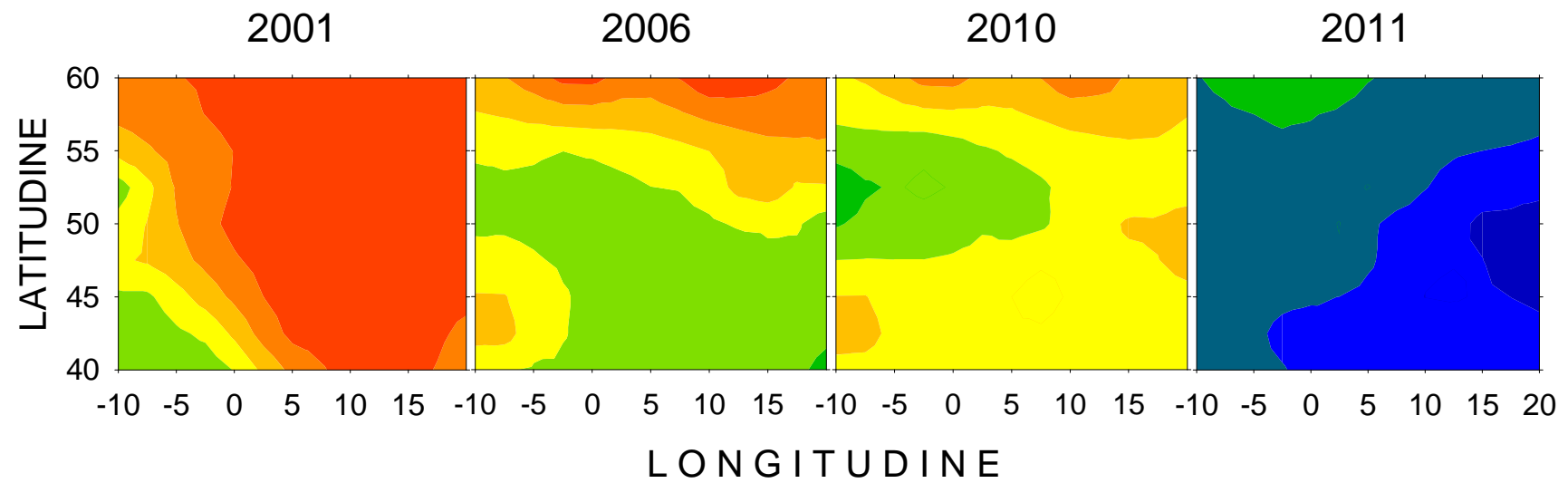
16 Aprile



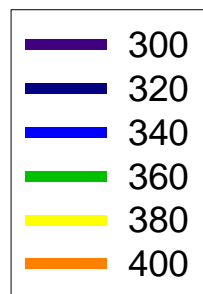
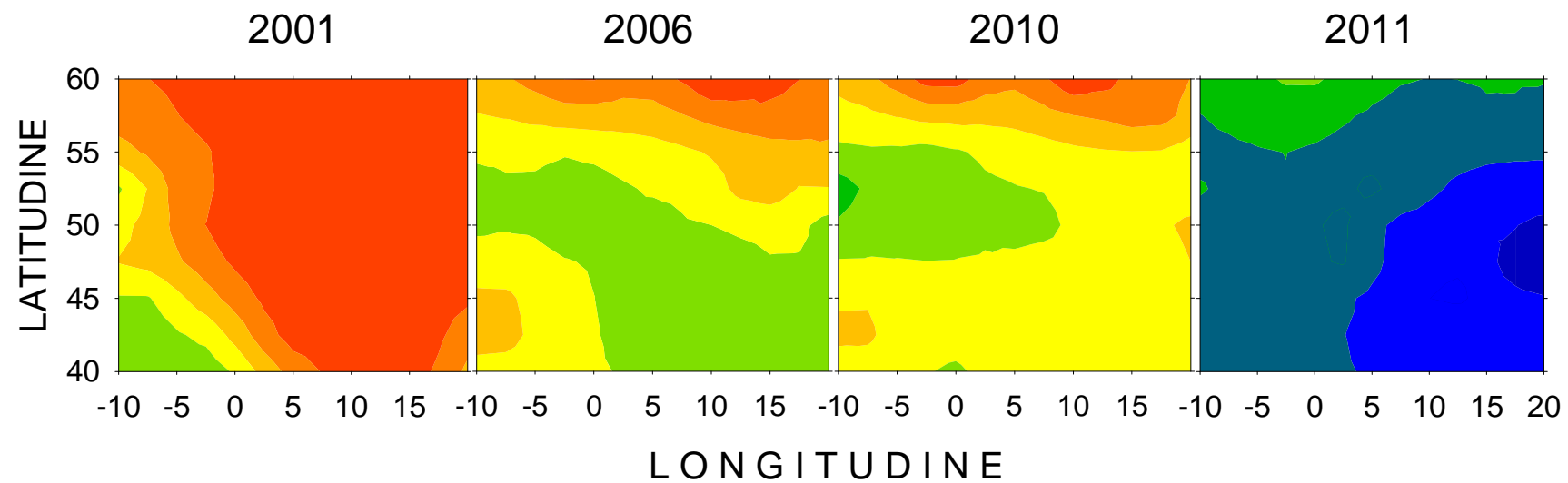
17 Aprile



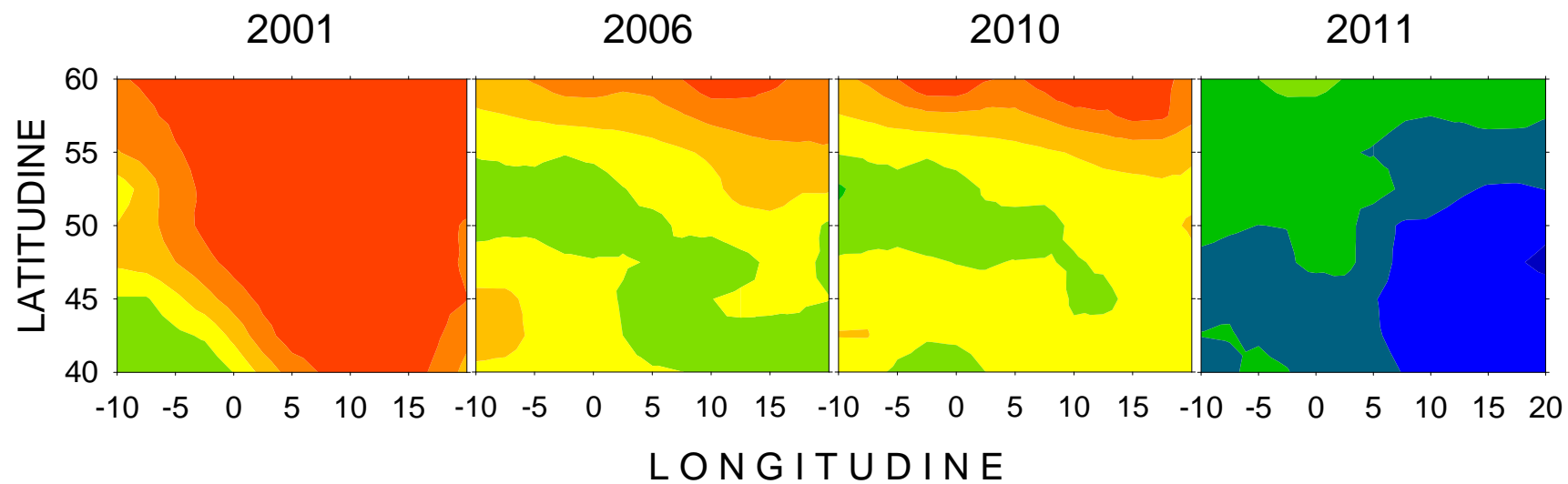
18 Aprile



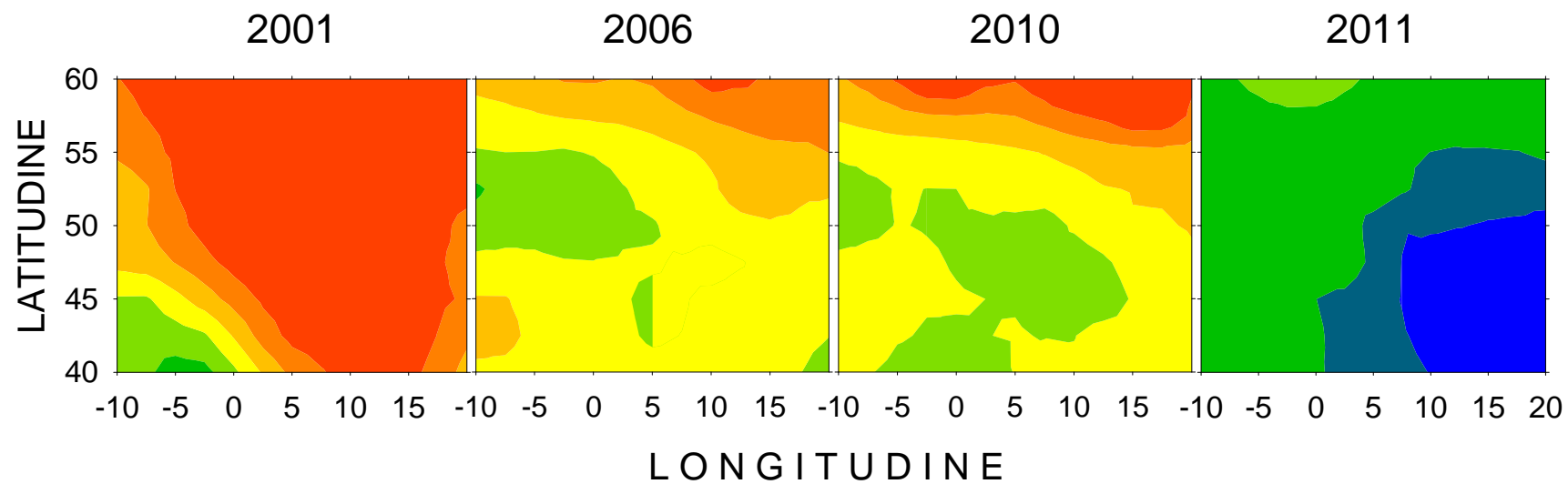
19 Aprile



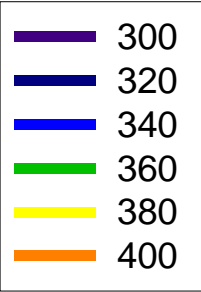
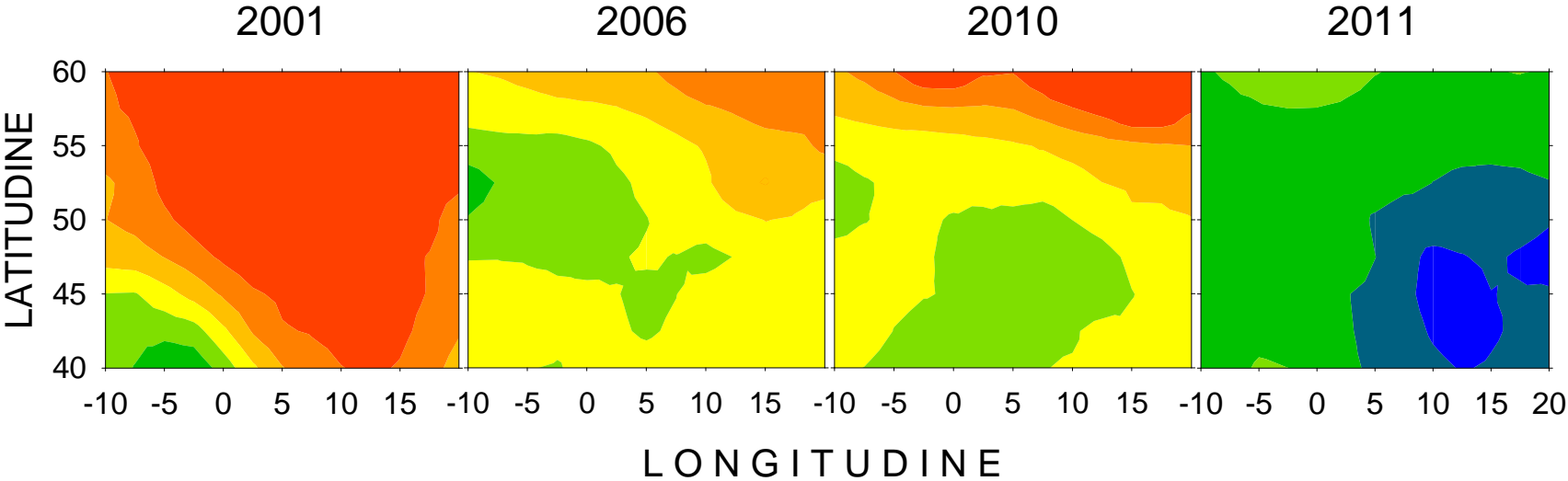
20 Aprile



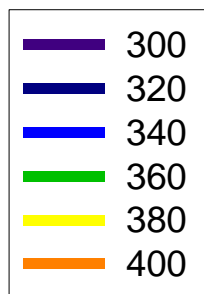
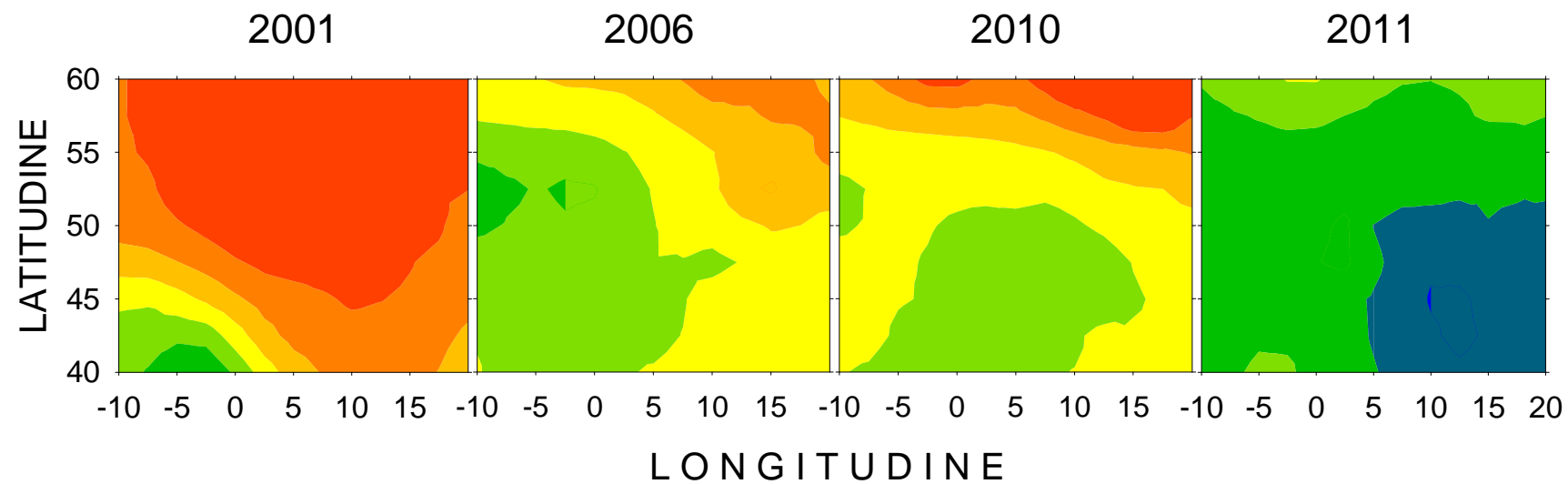
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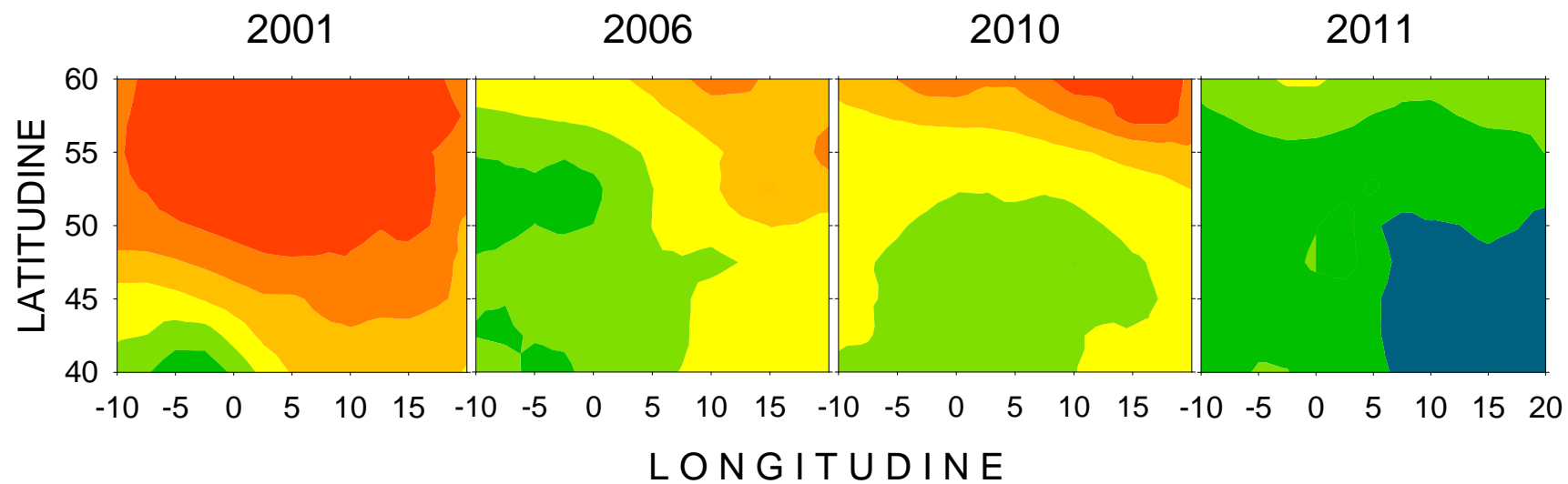
22 Aprile



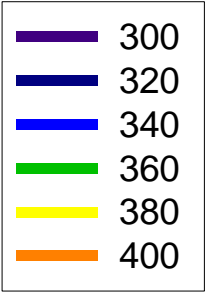
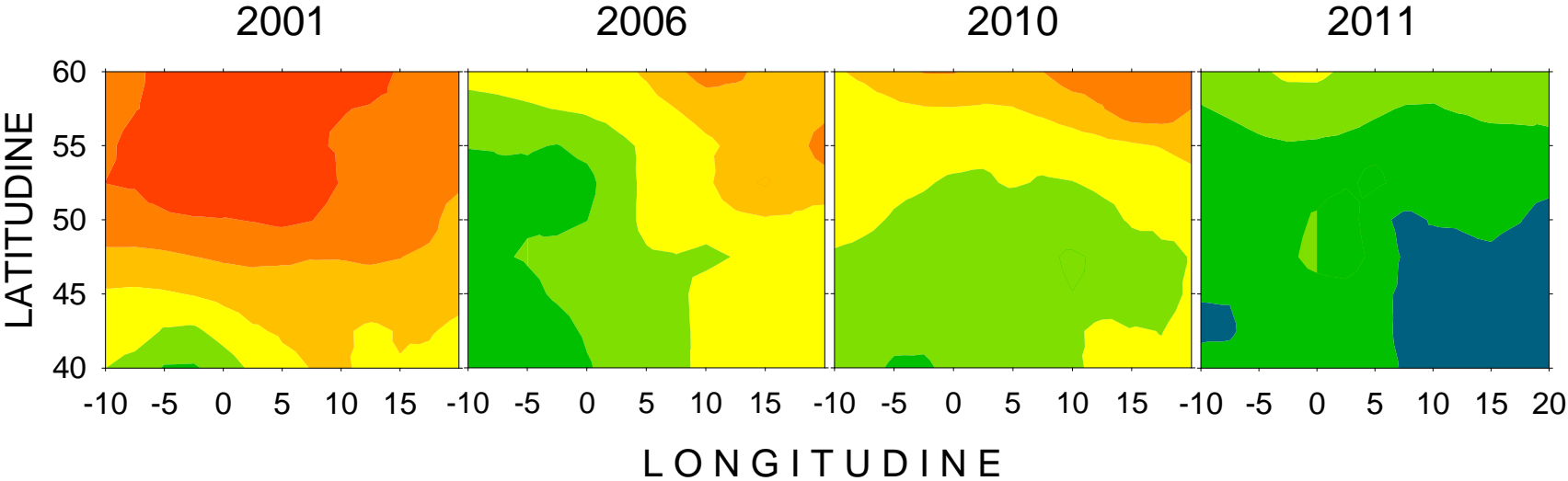
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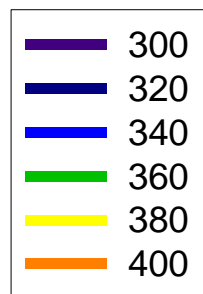
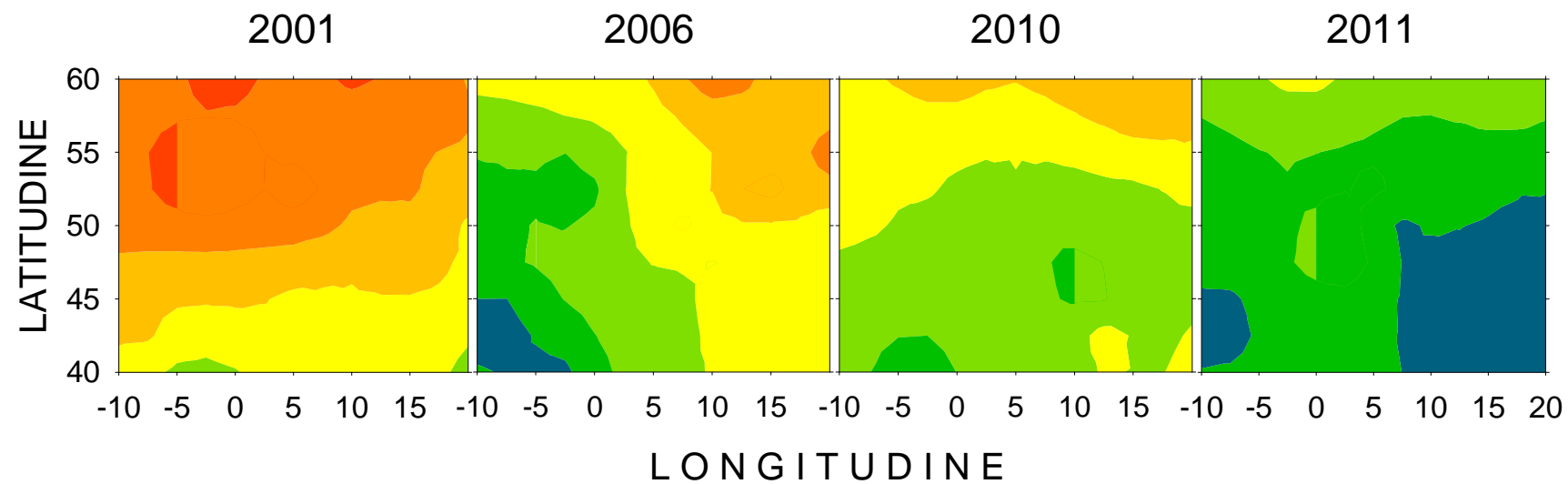
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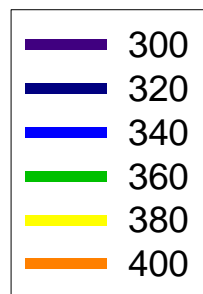
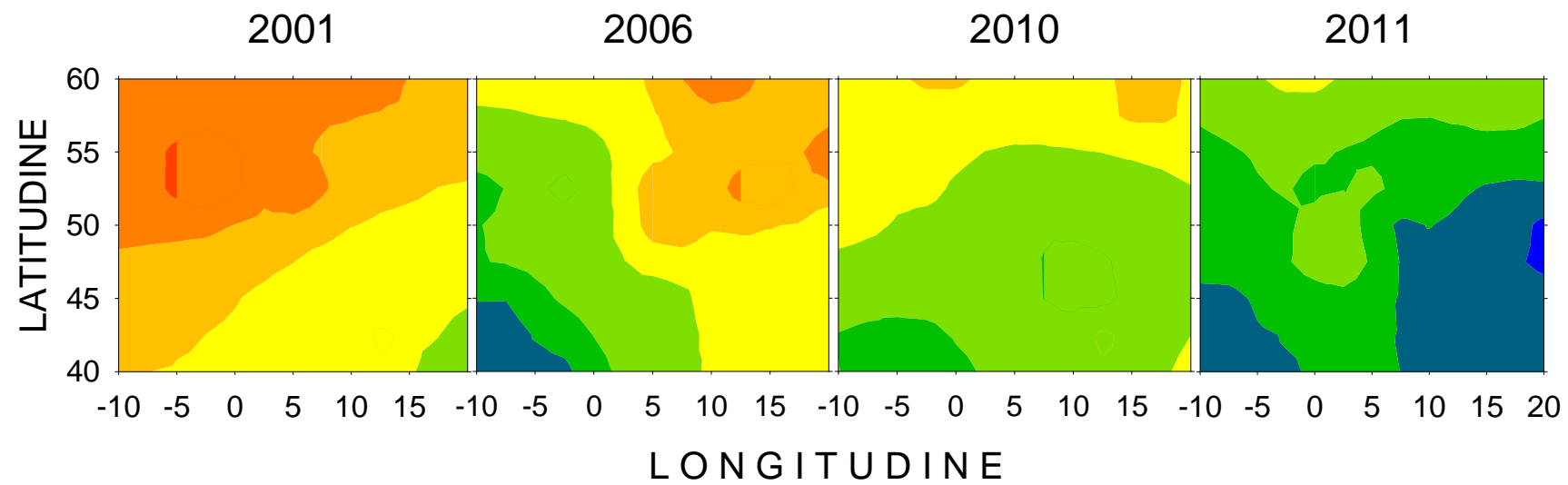
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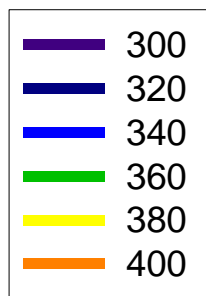
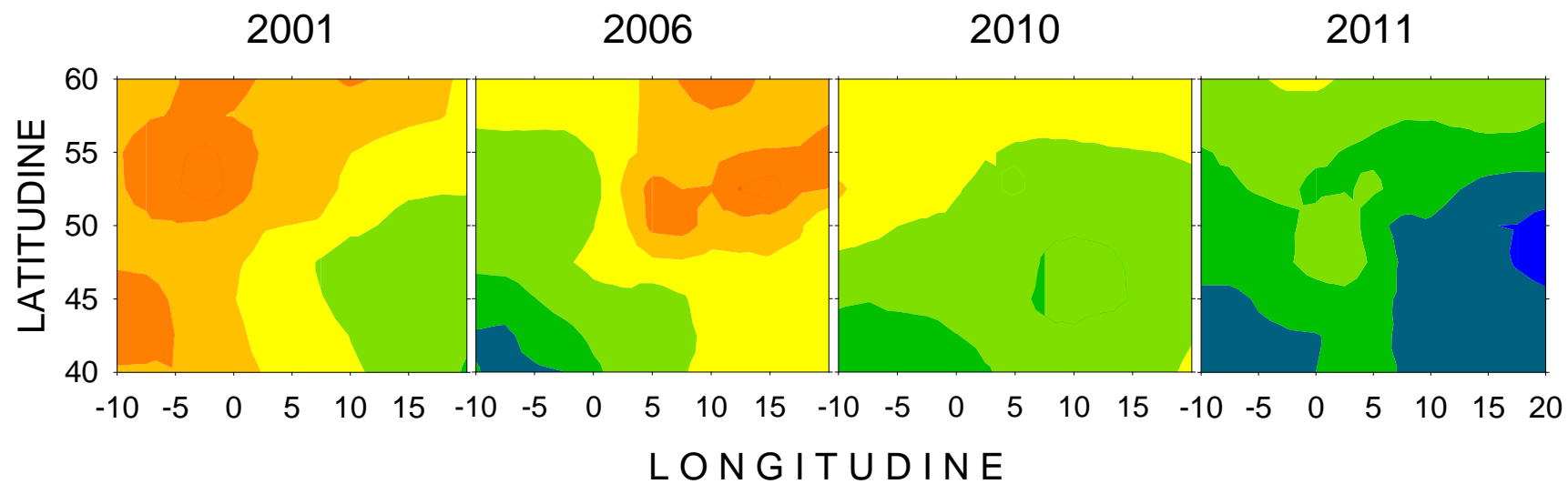
26 Aprile



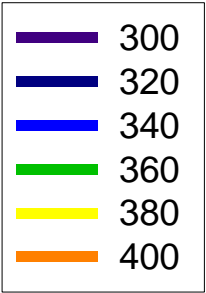
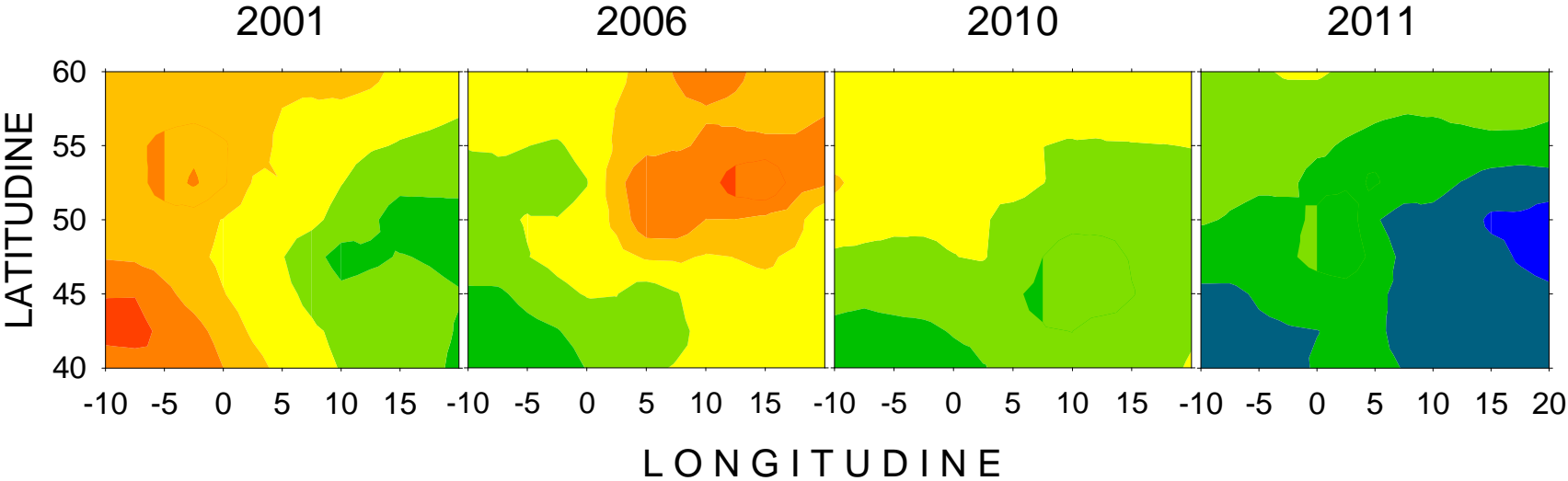
27 Aprile



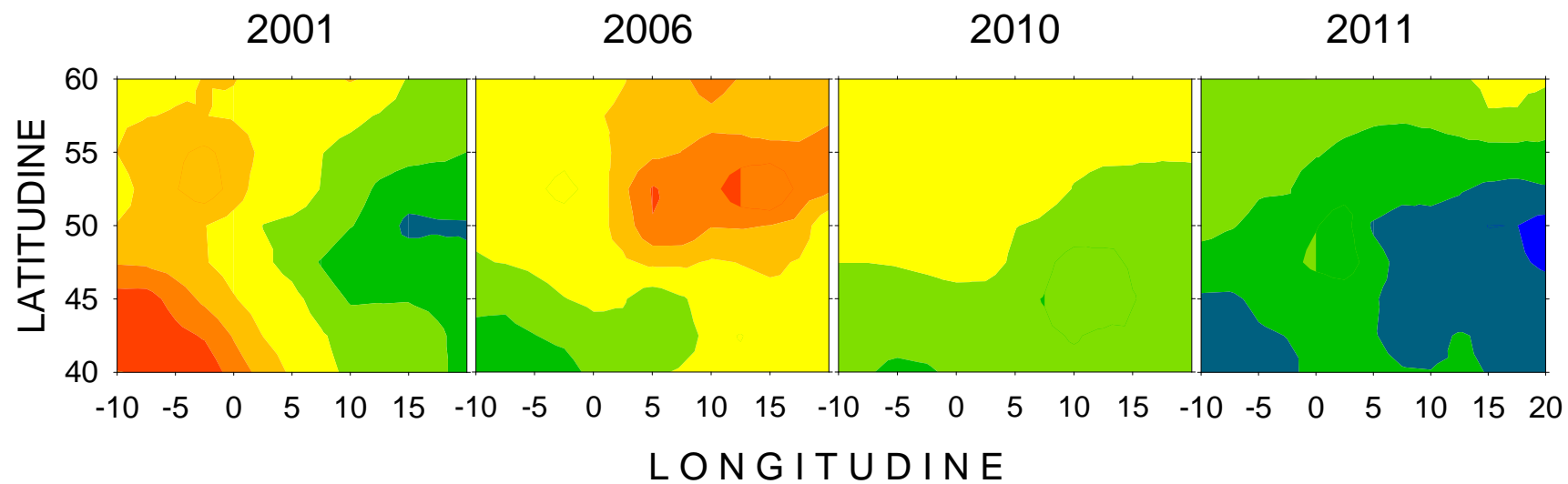
28 Aprile

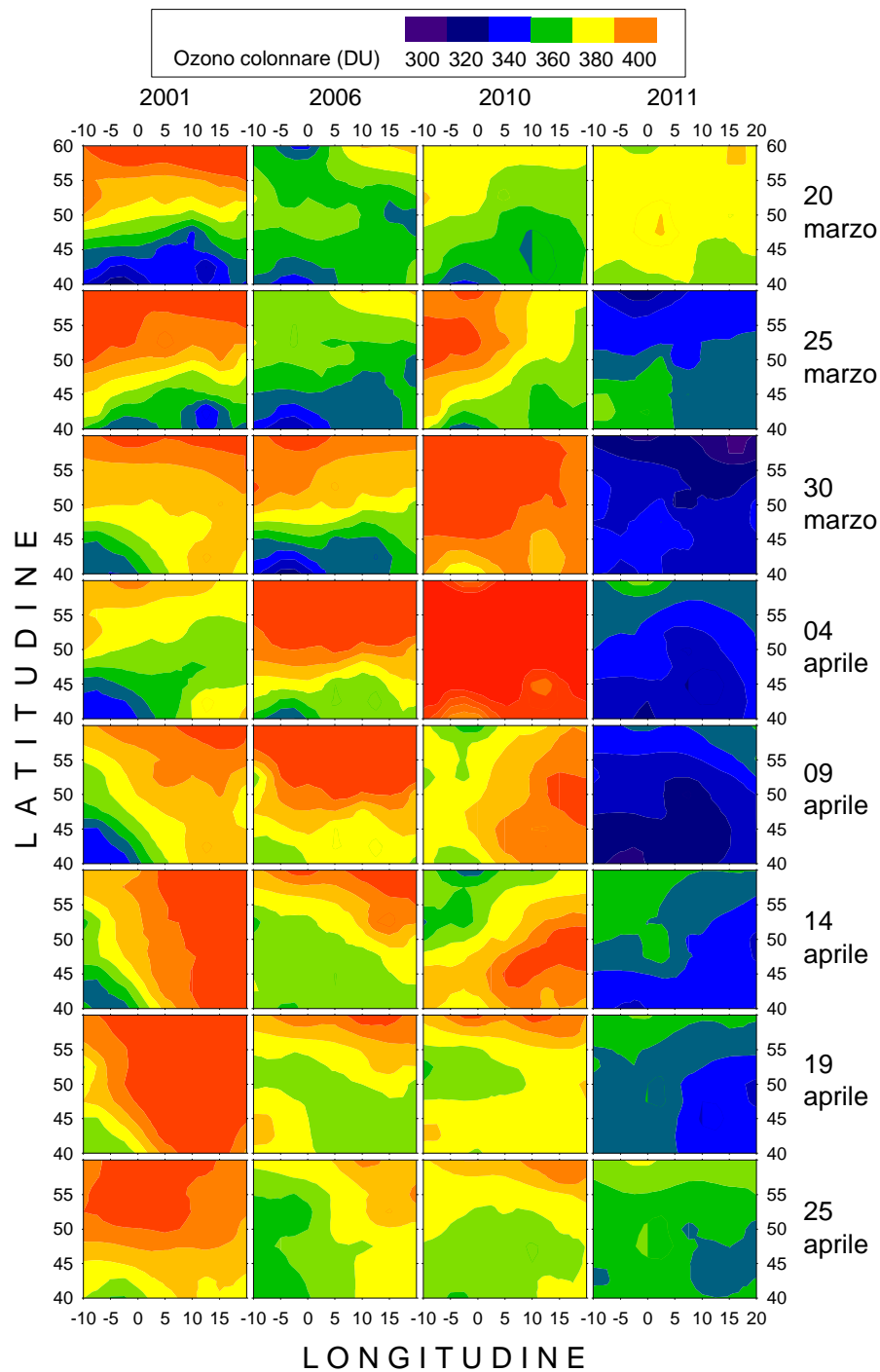


29 Aprile



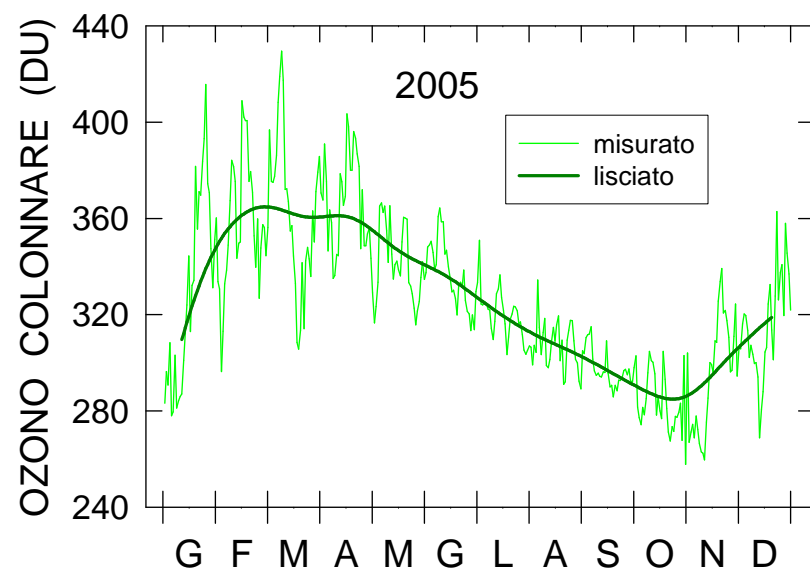
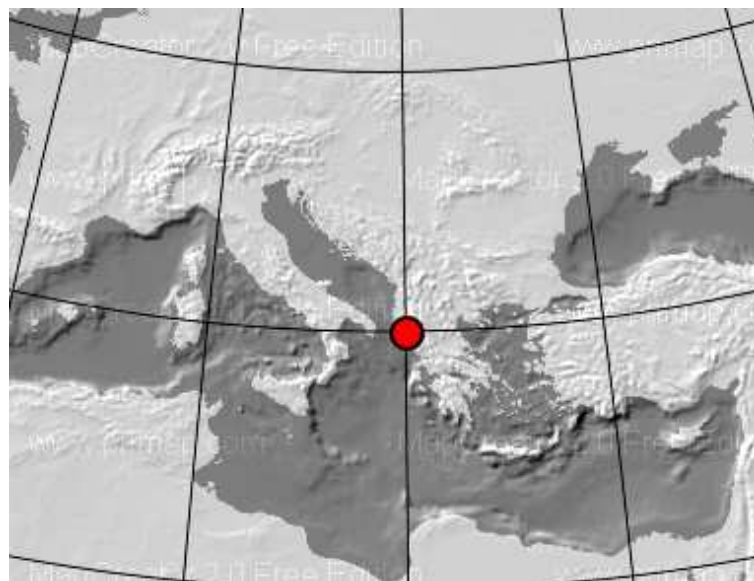
30 Aprile



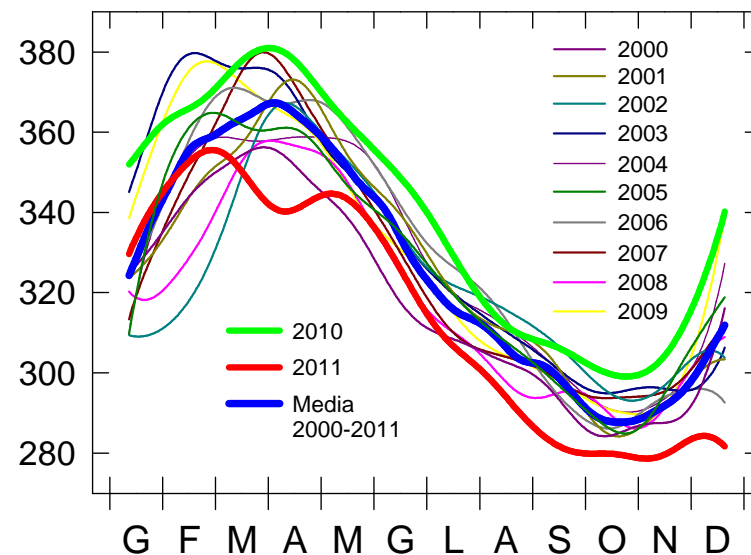
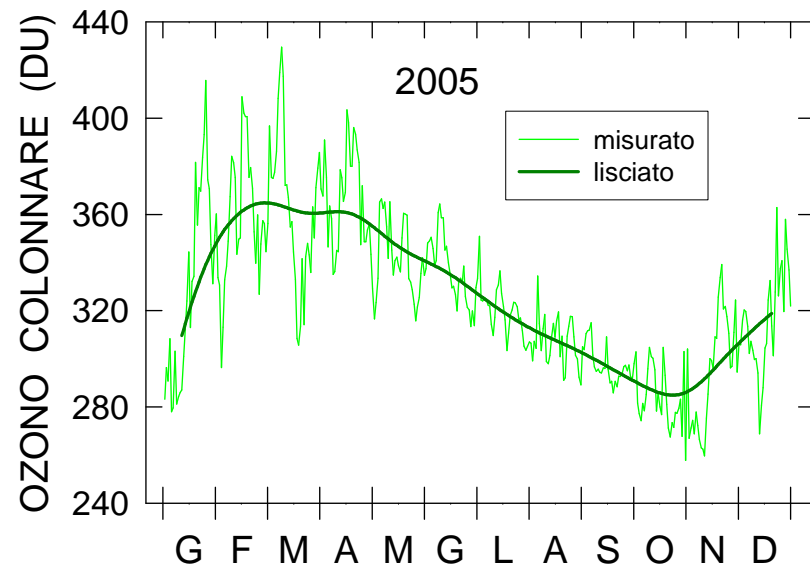
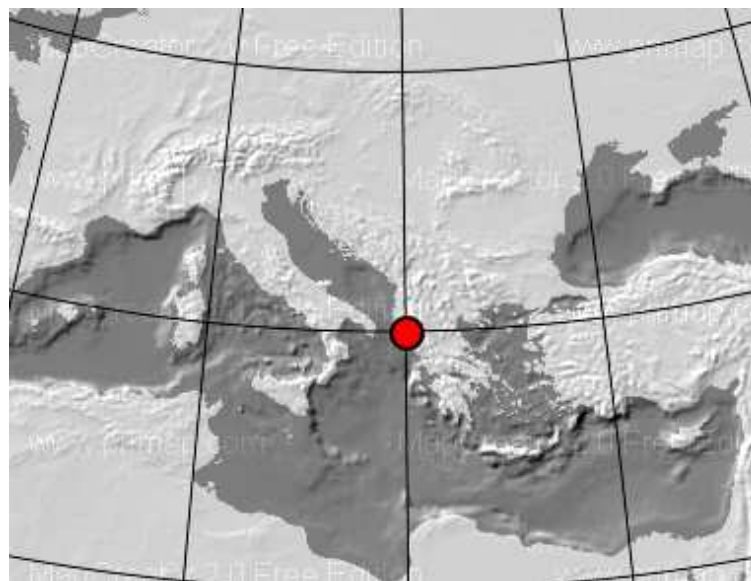


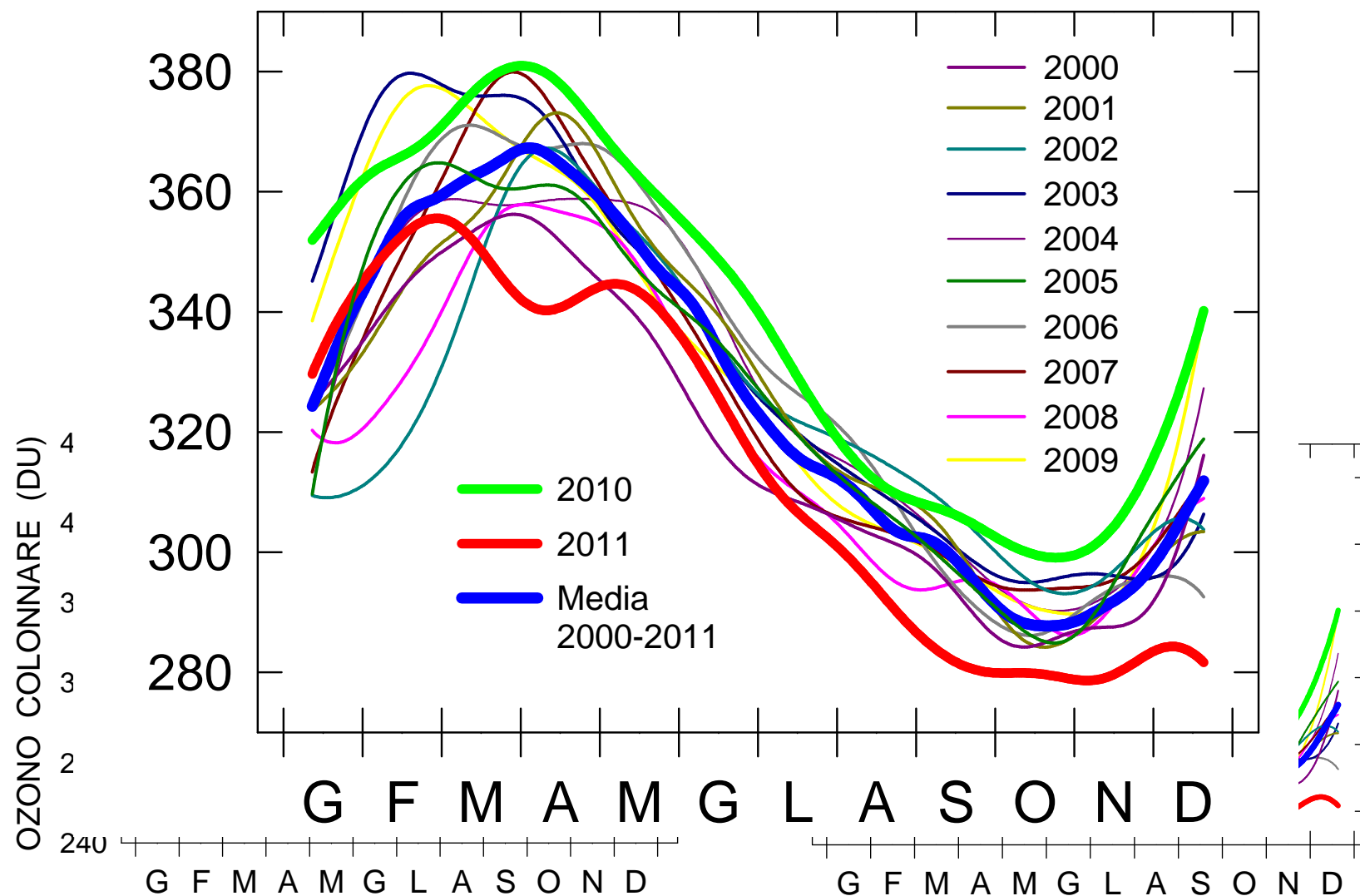
La distribuzione dell'ozono colonnare sul settore selezionato per diversi giorni, indicati a destra di ogni riga, nel periodo tra 20 marzo e 25 aprile per diversi anni, segnalati sopra ogni colonna.

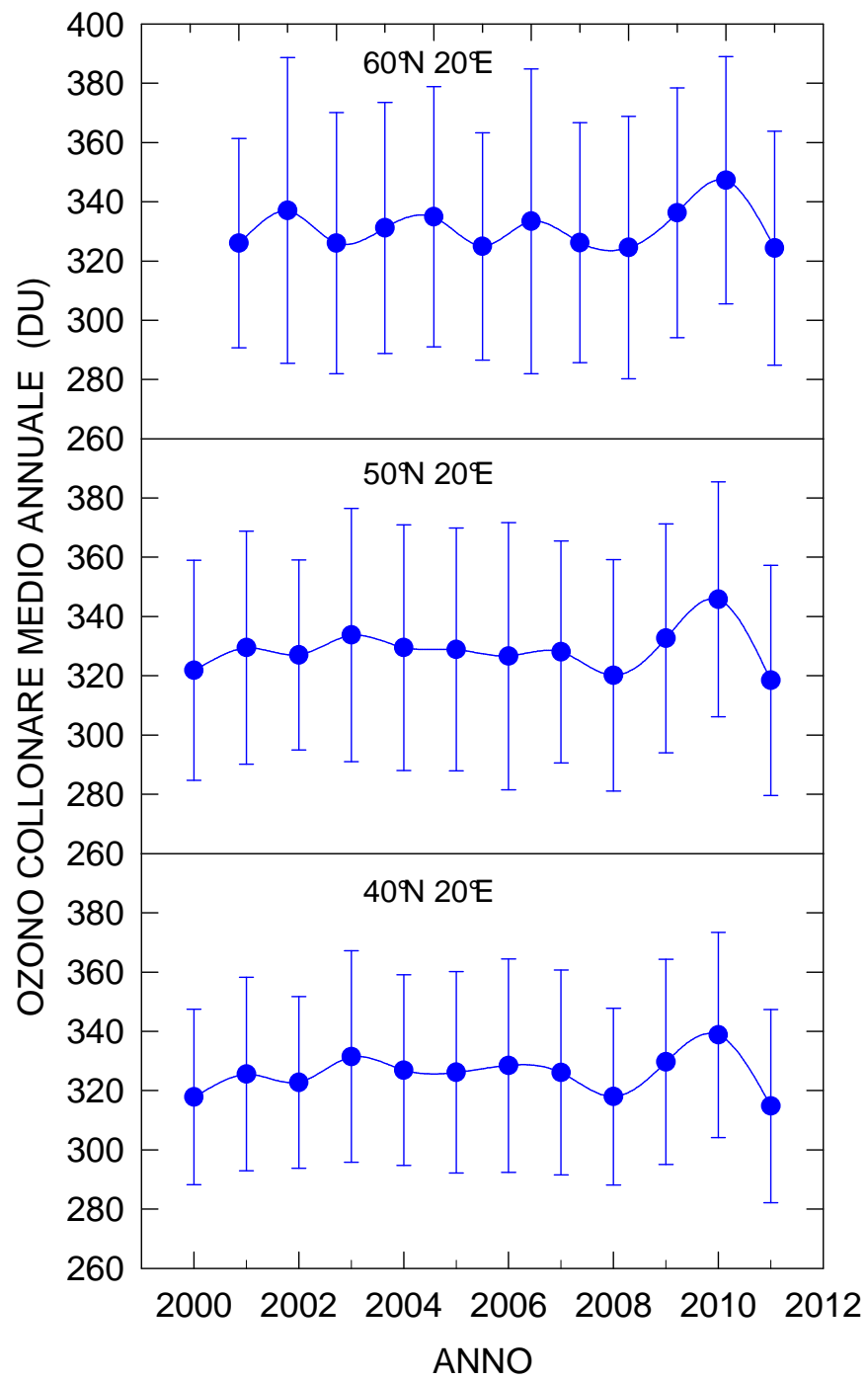
Il trend annuale
dell'ozono
colonnare.

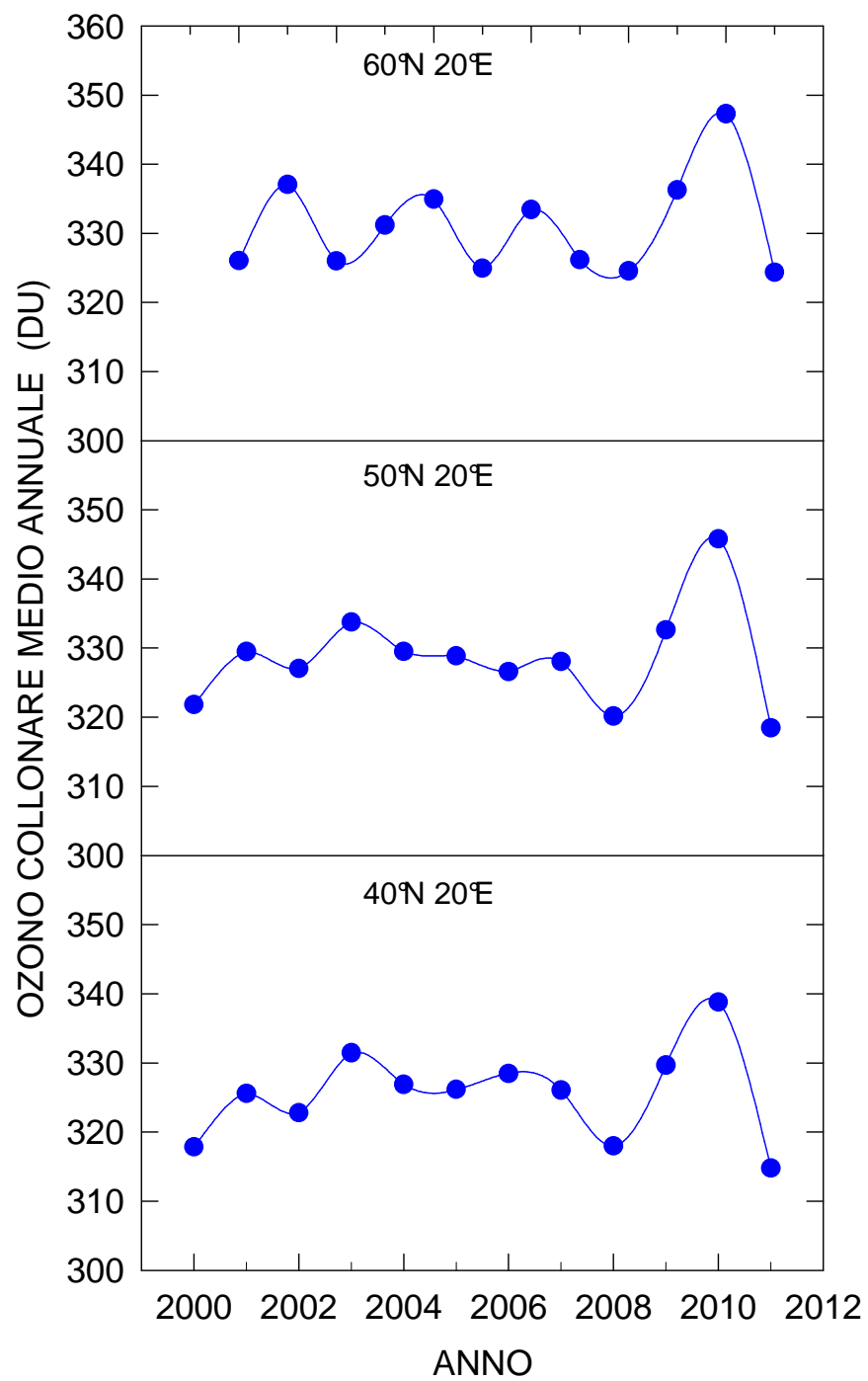


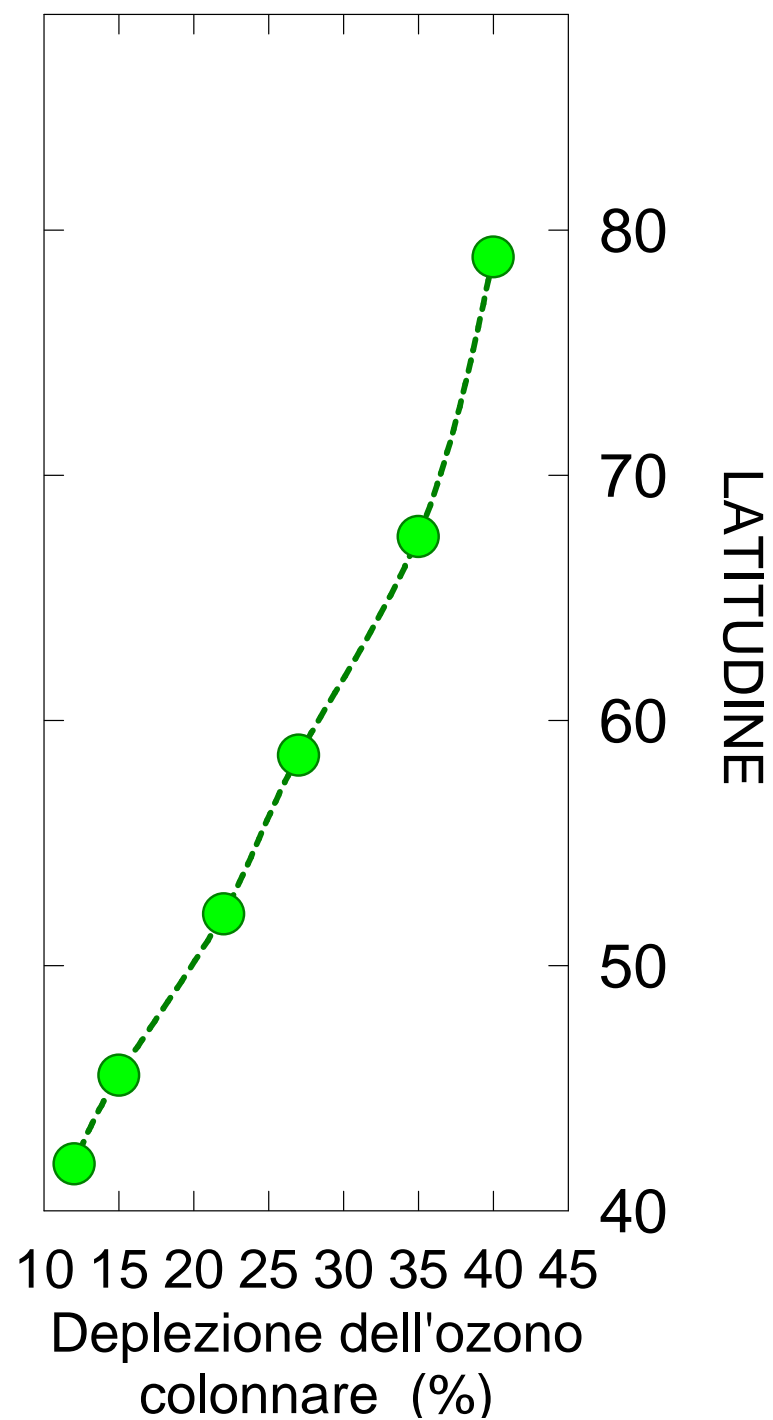
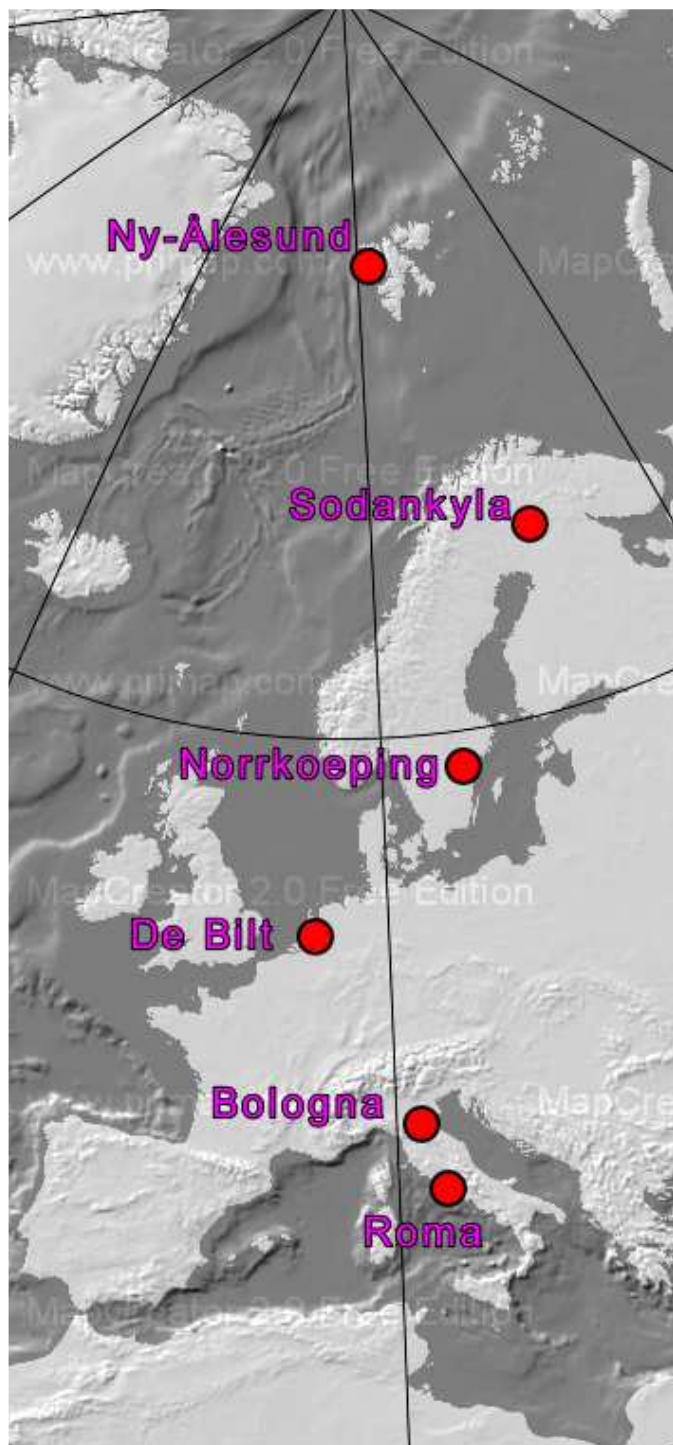
Il trend annuale
dell'ozono
colonnare.











La variazione dell'irradianza solare UV biologicamente efficace derivante dalla variazione di ozono colonnare, si può esprimere attraverso "Radiation Amplification Factor"

$$RAF = - \frac{\frac{\Delta F}{F}}{\frac{\Delta Q}{Q}} .$$

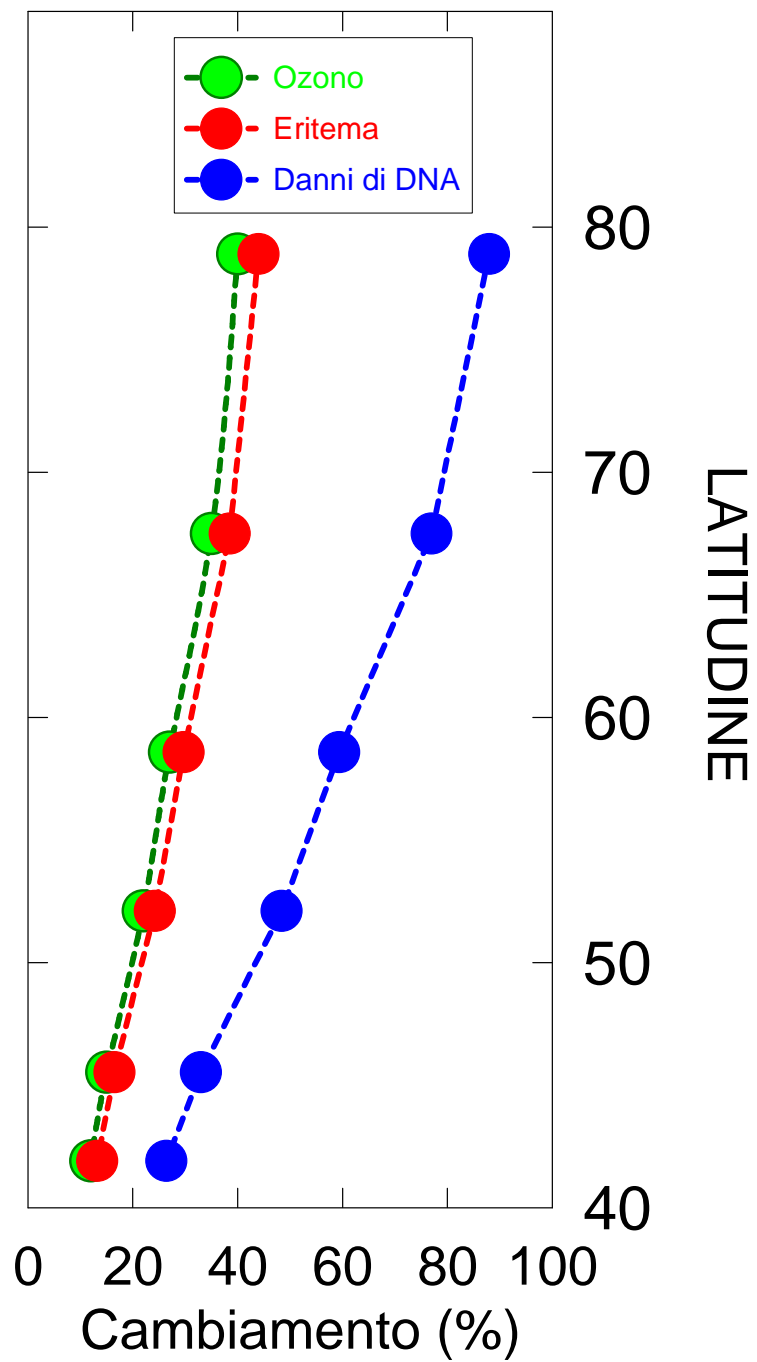
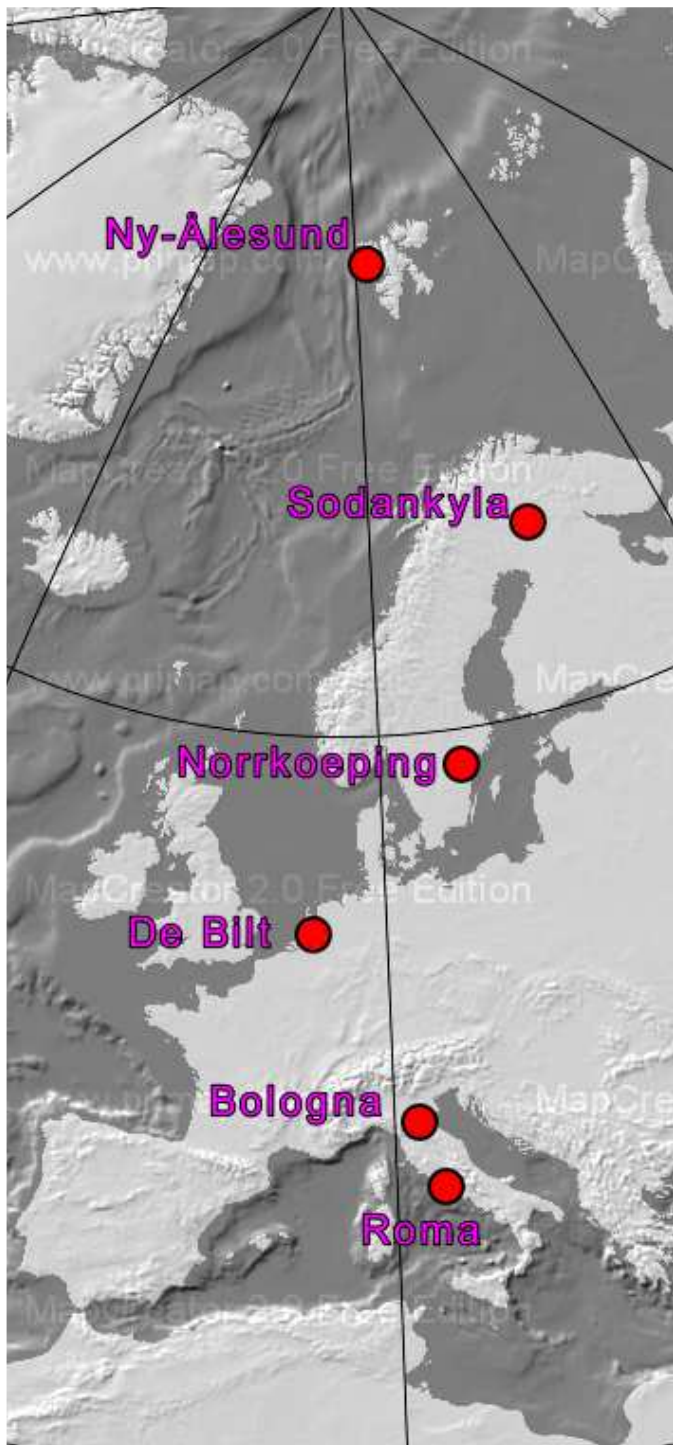
Questo parametro indica l'aumento percentuale dell'irradianza biologica che si ottiene con l'abbassamento del 1% dell'ozono colonnare.

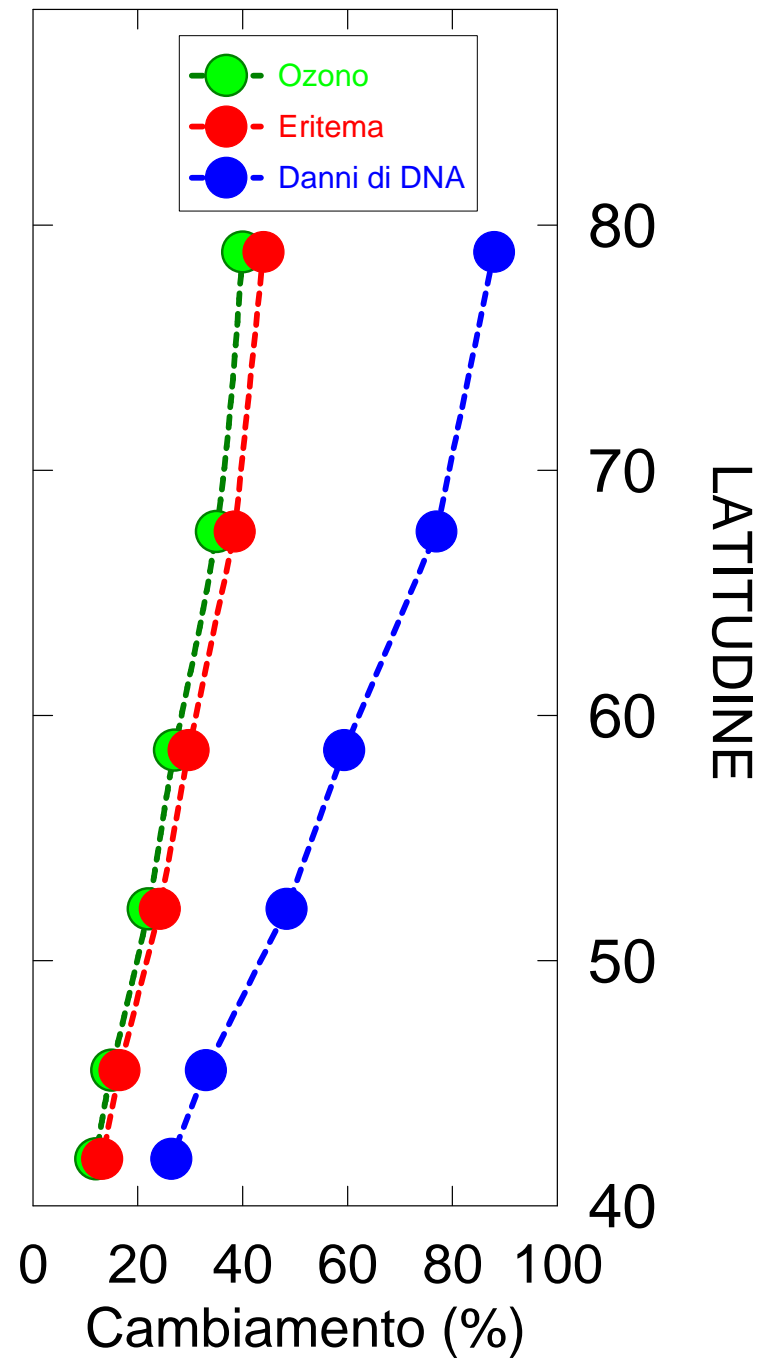
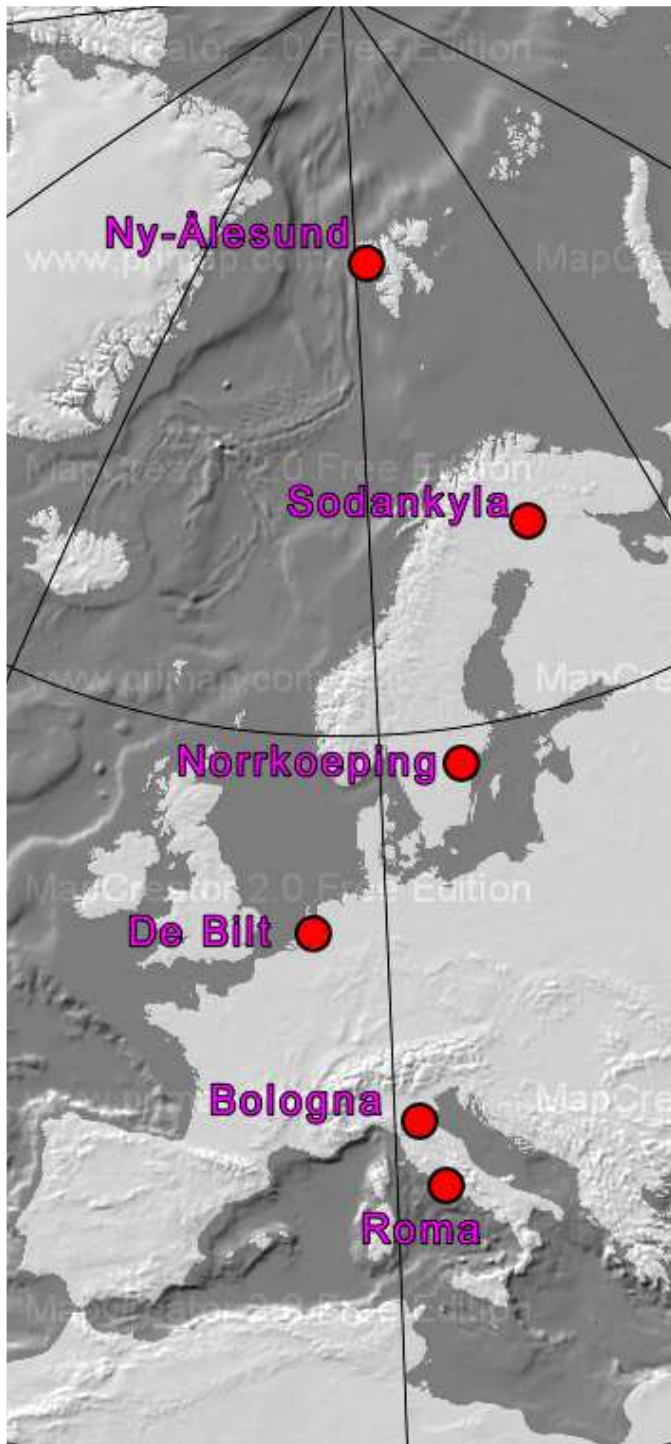
Eritema

$$RAF = 1.1$$

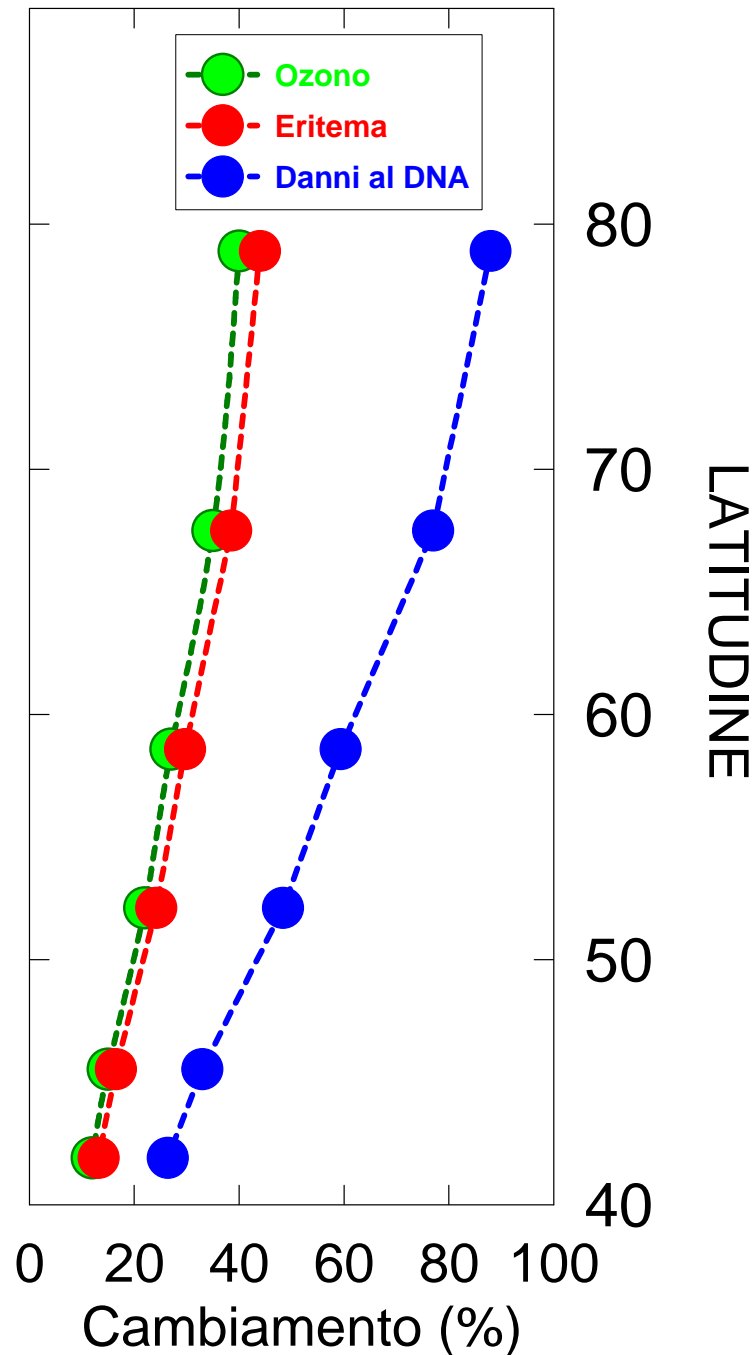
L'effetto di danneggiamento del DNA

$$RAF = 2.2$$





Dose giornaliera media per il periodo che va dal 27 marzo al 10 aprile:



Eritema

Danni al DNA

a Ny-Ålesund (80°N)

370 J m⁻²

1.6 J m⁻²

Aumenta con 44%,
quindi con

Aumenta con 88%,
quindi con

163 J m⁻²

1.4 J m⁻²

1 MED (fototipo I) = 200 J m⁻²

1 MED (fototipo II) = 250 J m⁻²

a Bologna (44°N)

1600 J m⁻²

17 J m⁻²

Aumenta con 17%,
quindi con

Aumenta con 33%,
quindi con

272 J m⁻²

5.6 J m⁻²

Gli autori ringraziano gli ascoltatori per l'attenzione e il personale di World Ozone and Ultraviolet Radiation Data Center (WOUDC) e tutte le Agenzie Europee che forniscono i dati usati nello studio.

