Surface UV simulations in the 21st century

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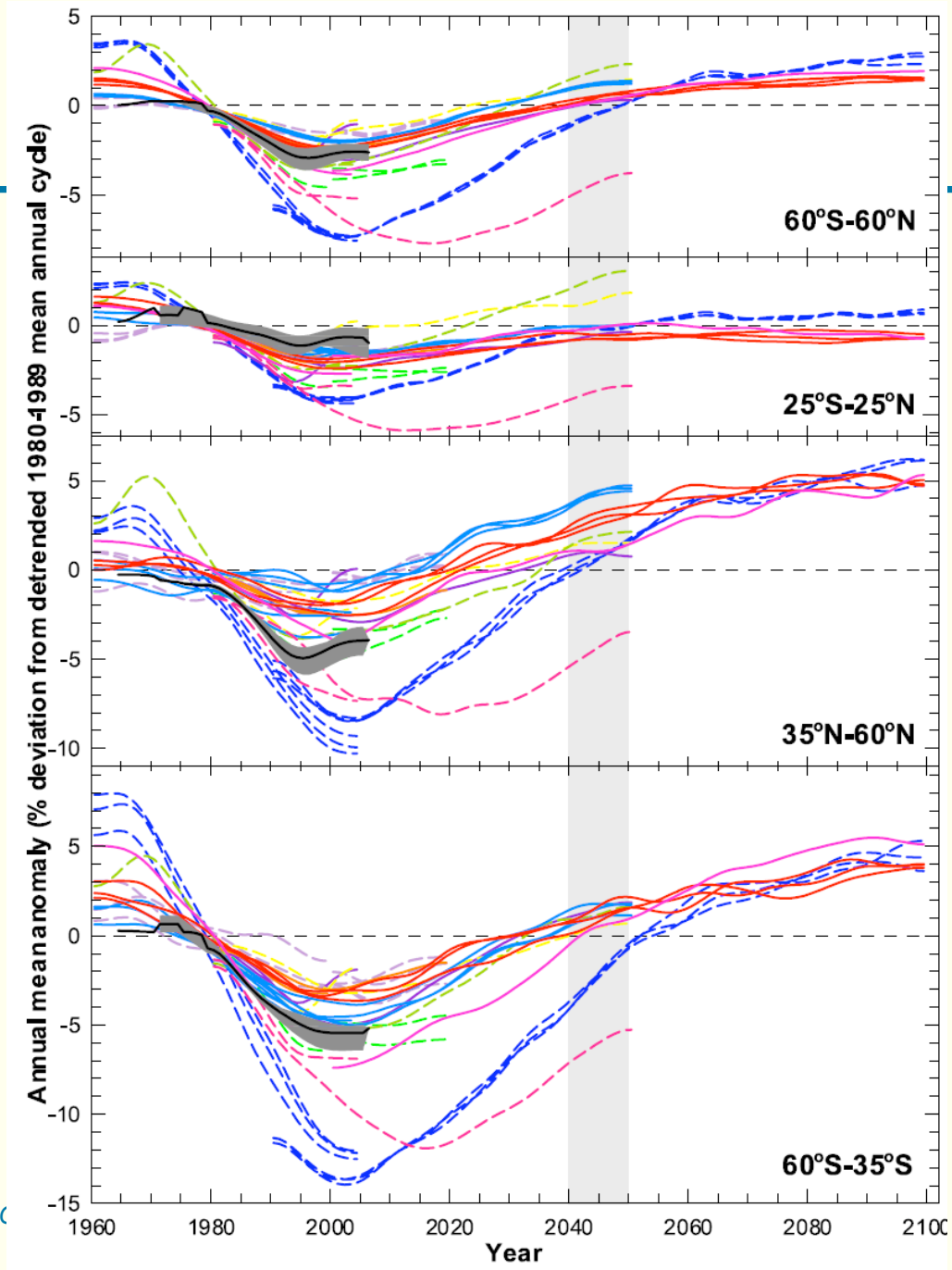
thanks to
SCOUT-O_3 A1 and CCMVal PIs

Simulations of future UV irradiance

- Parameters that may affect future UV levels:
  - Ozone (column and profile)
  - Clouds
  - Aerosols
  - Anthropogenic UV absorbing constituents (e.g. air pollutants)
  - Surface reflectivity
  - Temperature profile
- UV calculations with LibRadTran (Mayer and Kylling, 2005)
- Inputs from CCMs (monthly averages) :
  - Ozone total column
  - Ozone and Temperature profiles (zonal means)
  - All other factors were assumed constant
- Output:
  - Erythemal UV irradiance at local noon for the 15th of each month
  - Calculations were done for the zonal averages

Climate Chemistry Models

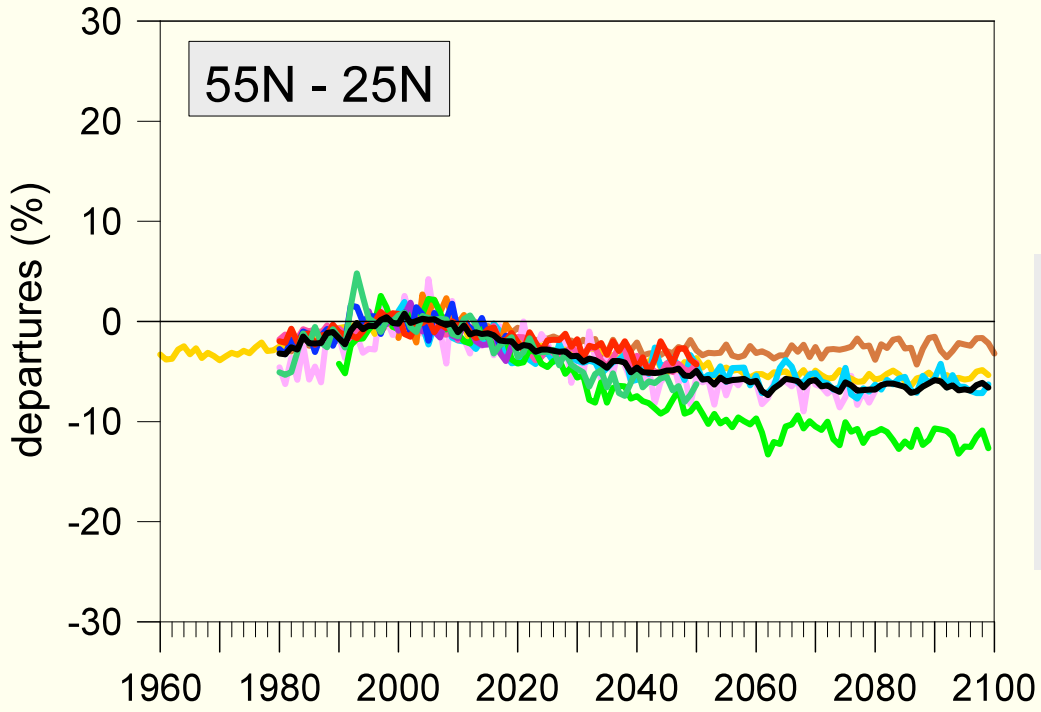
Model	Domain /resolution	Runs	References
AMTRAC	2° x 2.5° 48L, 0.0017 hPa	3×REF2, 1990 – 2099	Austin et al. [2006] Austin and Wilson [2006]
CCSRNIES	T42 34L, 0.01 hPa	1×REF2, 1980 – 2099	Akiyoshi et al. [2004]; Kurokawa et al. [2005]; Shiogama et al. [2005]
CMAM	T32 71L, 0.0006 hPa	3×REF2, 1960 – 2099	Beagley et al. [1997] de Grandpré et al. [2000]
E39C	T30 39L, center at 10 hPa	3×SCN2, 2000 – 2019	Dameris et al. [2005, 2006]
GEOSCCM	2° x 2.5° 55L, 0.01 hPa	1×REF2, 2000 – 2099	Stolarski et al. [2006b]
MAECHAM4/CHEM	T30 39L, 0.01 hPa	1×REF2, 2000 – 2019	Manzini et al. [2003] Steil et al. [2003]
MRI	T42 68L, 0.01 hPa	1×REF2, 1980 – 2099	Shibata and Deushi [2005] Shibata et al. [2005]
SOCOL	T30 39L, 0.1 hPa	1×REF2, 1980 – 2050	Egorova et al. [2005] Rozanov et al. [2005]
ULAQ	10° x 22.5 26L, 0.04 hPa	1×REF2, 1980 – 2050	Pitari et al. [2002]
UMSLIMCAT	2.5° x3.75° 64L, 0.01 hPa	1×REF2, 1980 – 2020	Tian and Chipperfield [2005]
WACCM (v.3)	4° x 5° 66L, 4.5x10-6 hPa	3×REF2, 1980 – 2050	Garcia et al. [2006]



WMO assessment 2006

SPARC 4th C

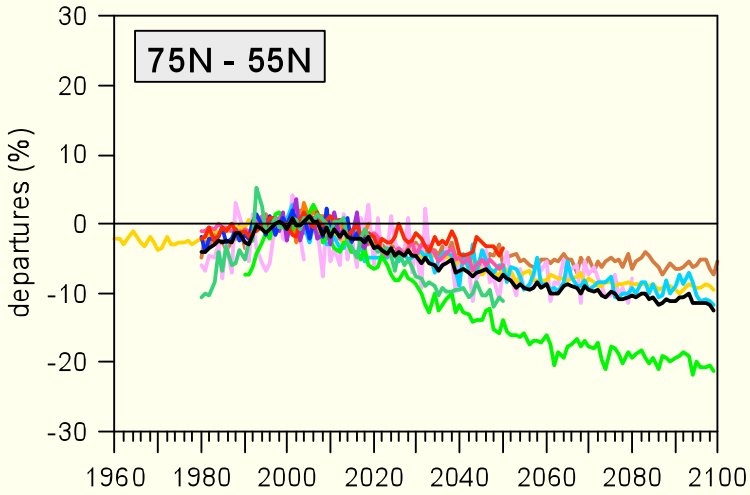
Simulations of erythemal irradiance

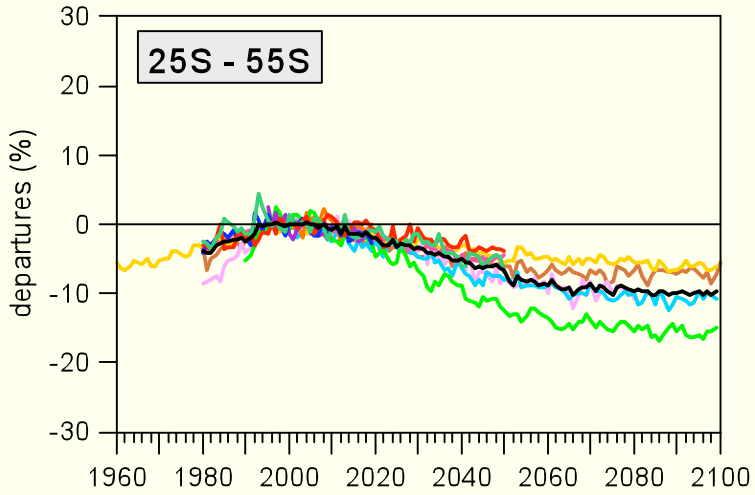


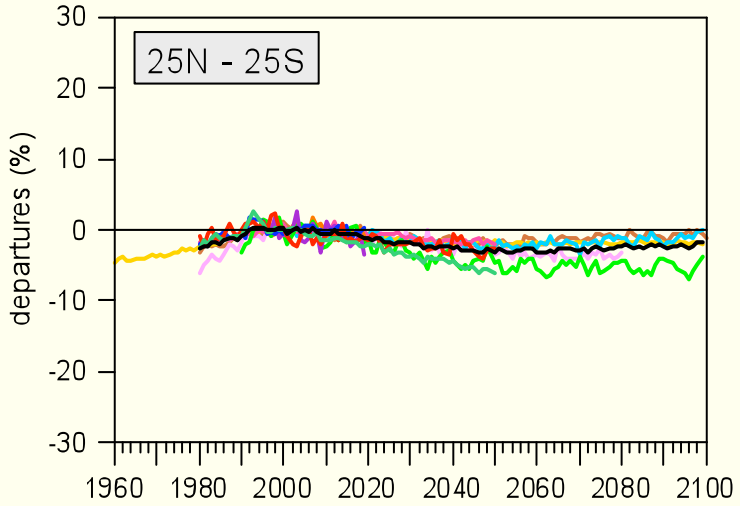
ccsrnies
geosccm
maecham4/chem
mri
socol
ulaq
umslimcat
amtrac_e
cmam_e
e39c_e
waccm_e
model average

- UV calculations for clear skies and at local noon (Libradtran)
- Simulations are shown only as changes and not as absolute values
- Departures were calculated relative to the mean of years 1996-2005

Changes in erythemal irradiance







ccsrnies
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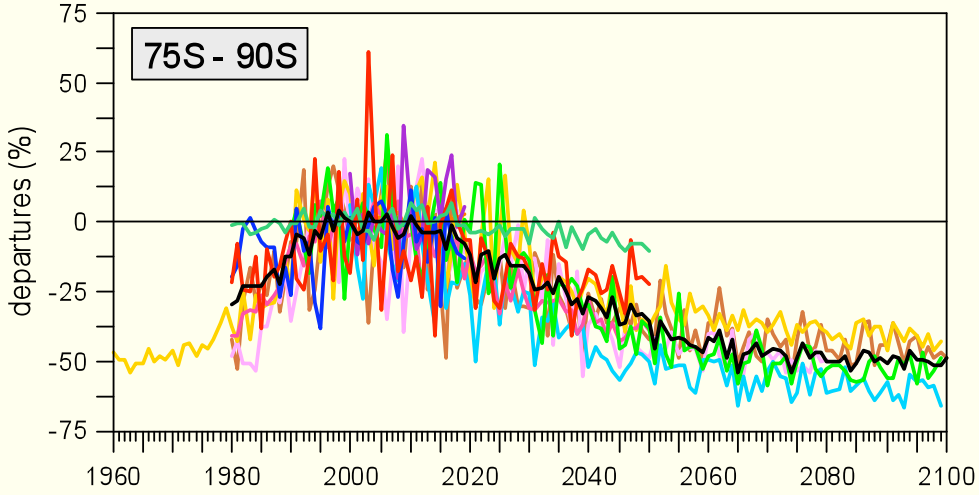
model average

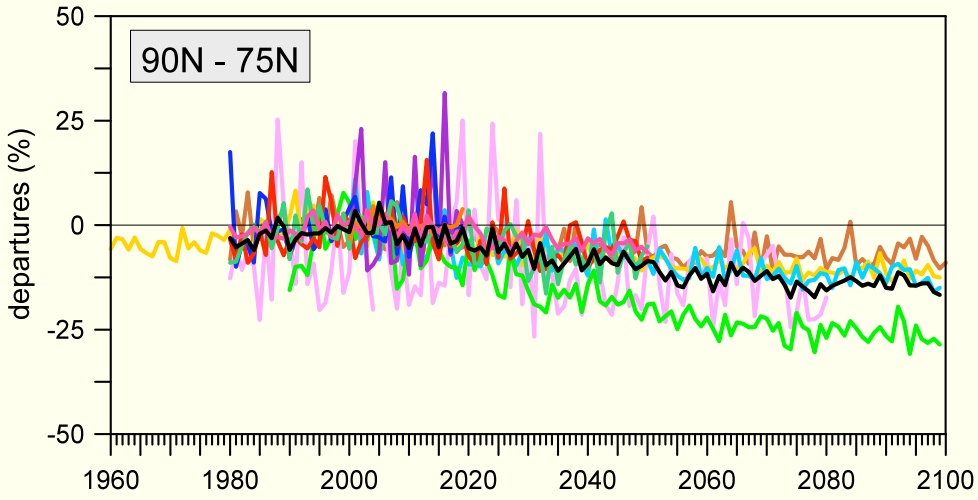
Cloudless skies
Local Noon

Changes in erythemal irradiance



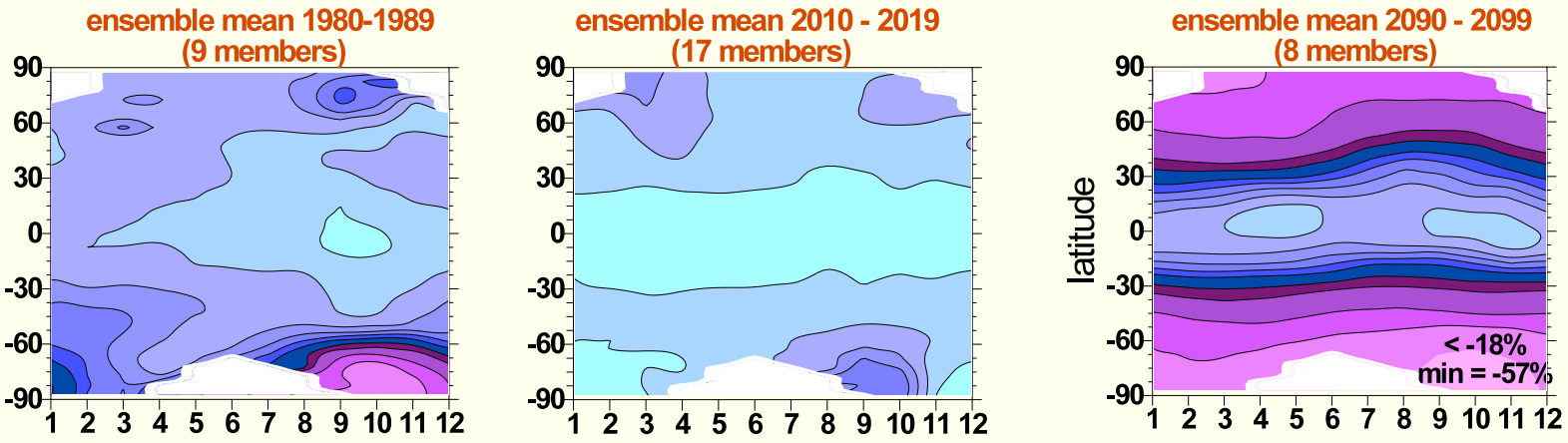
October-November average

March-April average



Cloudless skies
Local Noon

Decadal averages of changes in erythemal irradiance



Cloudless skies

Local Noon

Conclusions - I (clear skies)

- Cloud-free erythemal irradiance decreases after 2020 at the high latitudes of both hemispheres. Changes in the tropics are smaller but still negative.
- The predicted ozone recovery for the next few decades is reflected in the monotonic reduction of the erythemal irradiance after about year 2010.
- The highest surface UV levels have been calculated for the period 1990 – 2010, when ozone is predicted to have reached its minimum.
- The negative departures of irradiance in the 1980s and early 1990s result from the fact that total ozone had not reached its minimum until early 2000s.

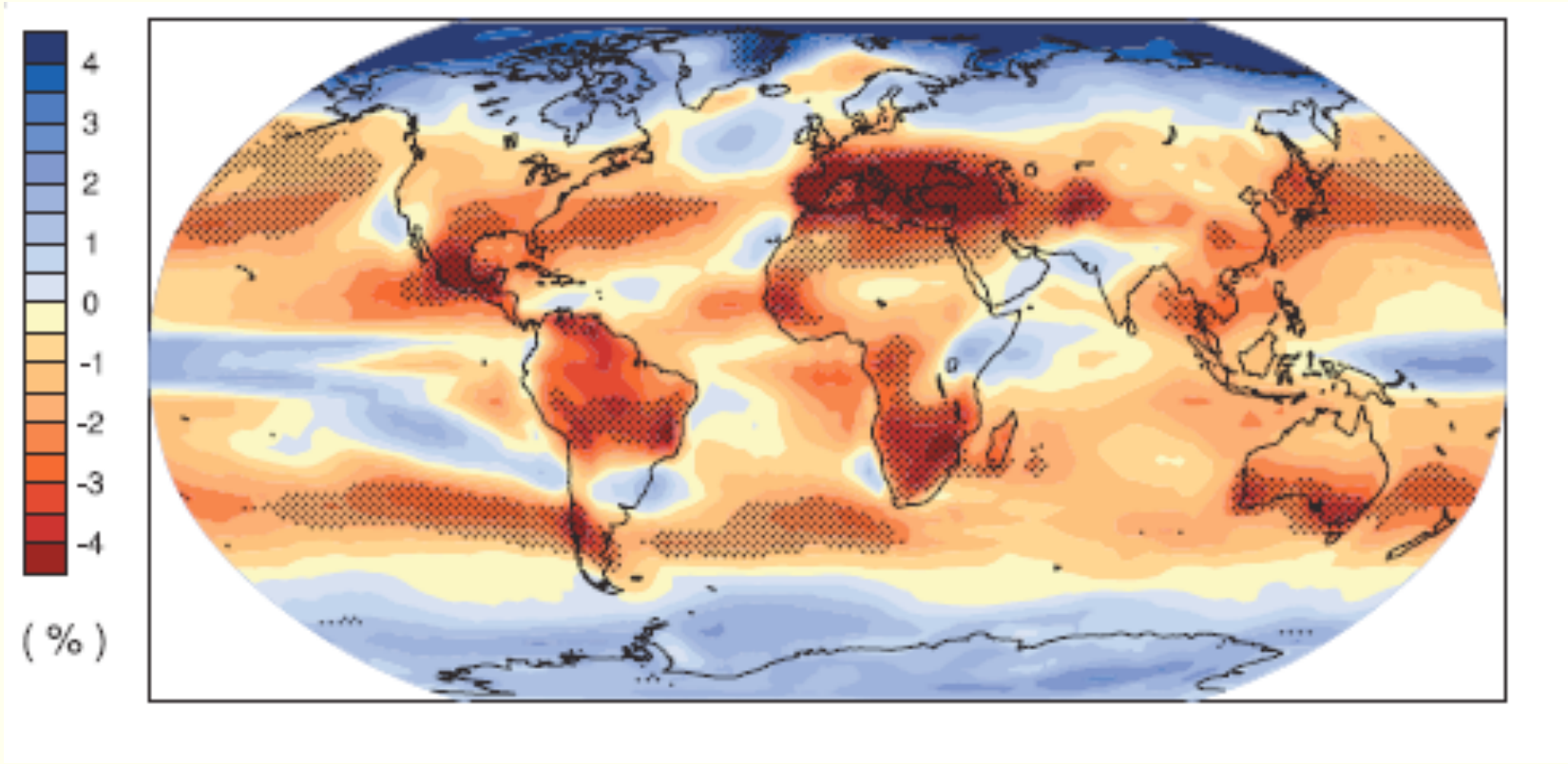
The above are presented in Tourpali et al., ACPD, 8, 13043-13062, 2008

But...

- Future UV levels are likely to be affected by other factors influenced by climate change, such as cloudiness, aerosols and surface albedo.
- Therefore the predicted changes towards the mid of the 21st century due to ozone only may change substantially, even in sign, depending on season and latitude.

Change in cloud cover

Mean of 2080 - 2099 relative to 1980 - 1999



SRES A1B scenario, IPCC AR4WG1 – Meehl et al., 2007

Surface UV simulations under all skies

- Input from CCMs (monthly averages) : Ozone total column
  (interpolated to 5°x5°)

  5 models, 9 ensemble members
- Output I: Clear-sky erythemal irradiance (in 5°x5°grid)
  at local noon for the 15th of each month
- Cloud information from GCMs (IPCC AR4)
  - Surface SW radiation under clear skies
  - Surface SW radiation under all skies
  - Calculation of SW Cloud Modification Factor (CMF_{SW})
  - Conversion of SW CMF to UV CMF

All data for the period 2001 - 2100

Cloud transmittance (or CMF) from shortwave to UV

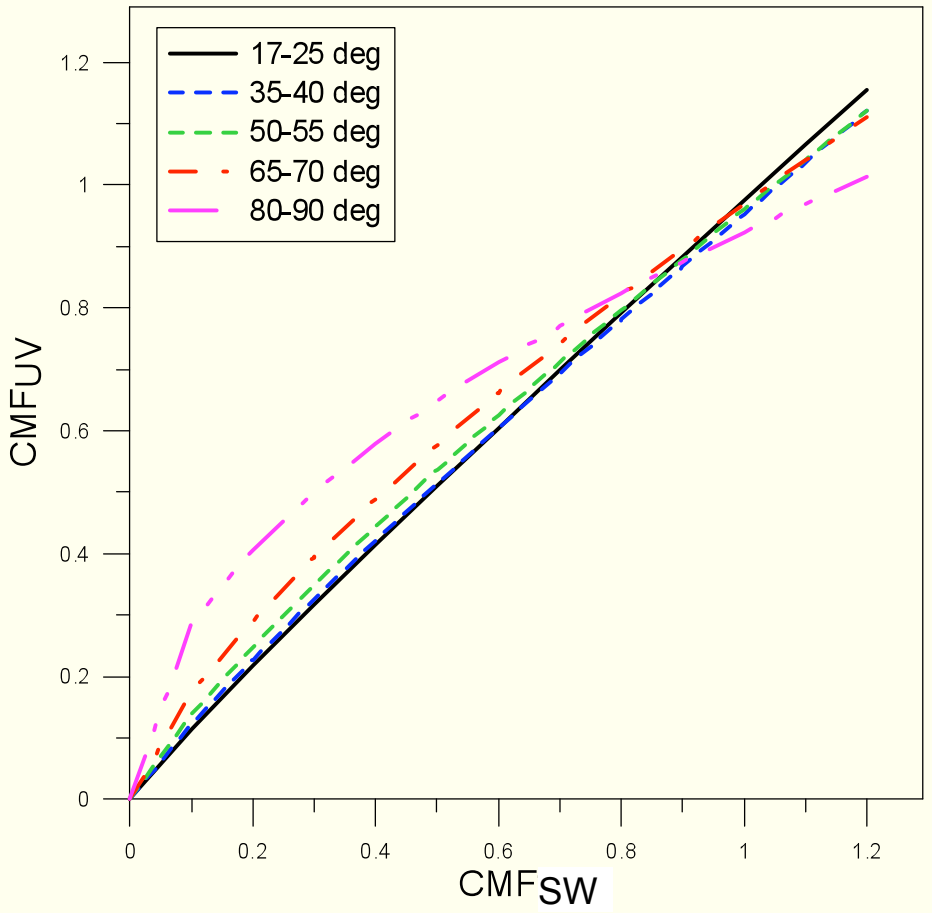
$$CMF = \frac{irradiance_{all\ skies}}{irradiance_{cloudless}}$$

Empirical relations:

$$CMF_{UV} = b(\theta) * (CMF_{SW})^{a(\theta)}$$

RTM lookup tables:

$$CMF_{SW} \rightarrow CMF_{UV}$$



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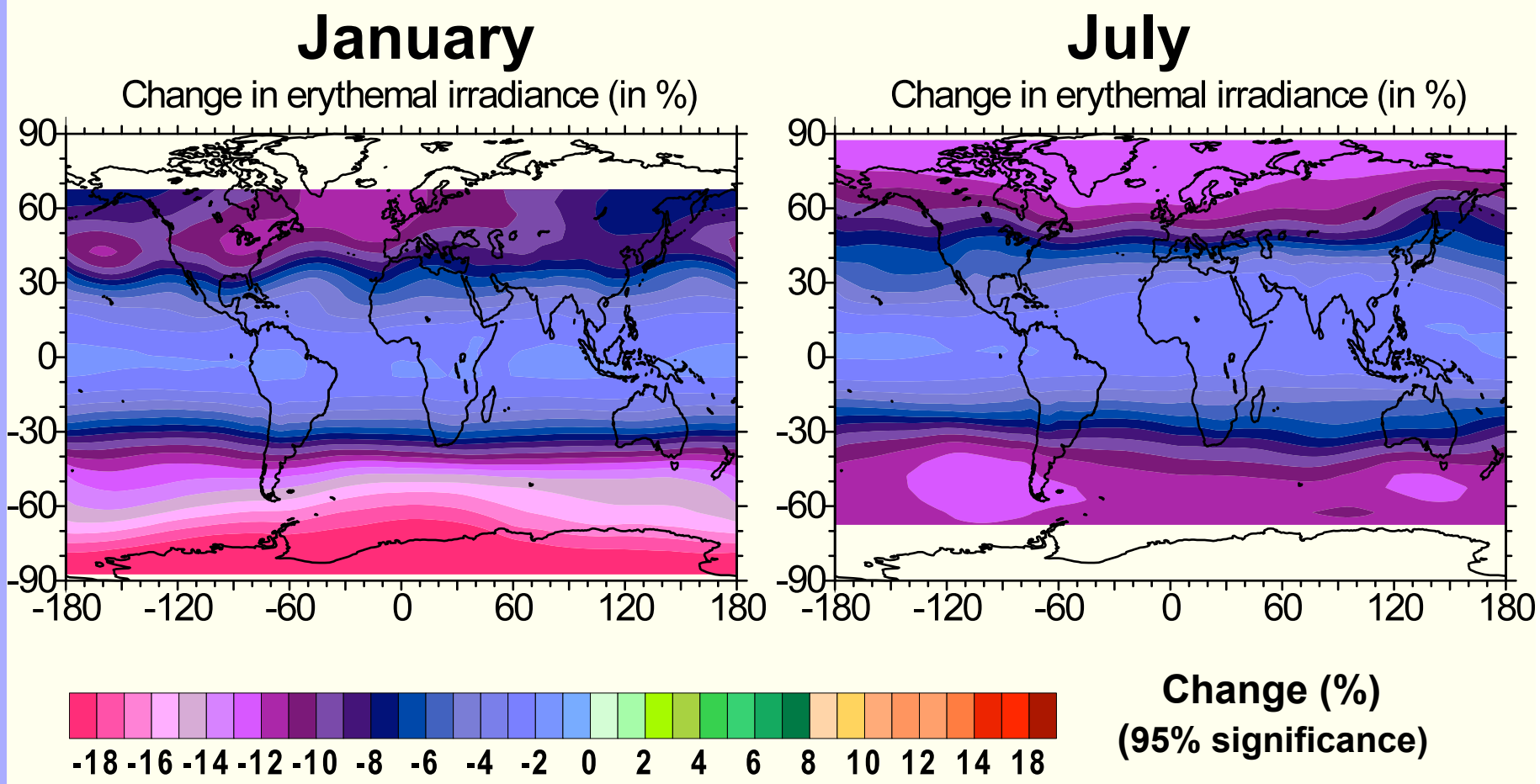
All data for the period 2001 – 2100

- Final output:

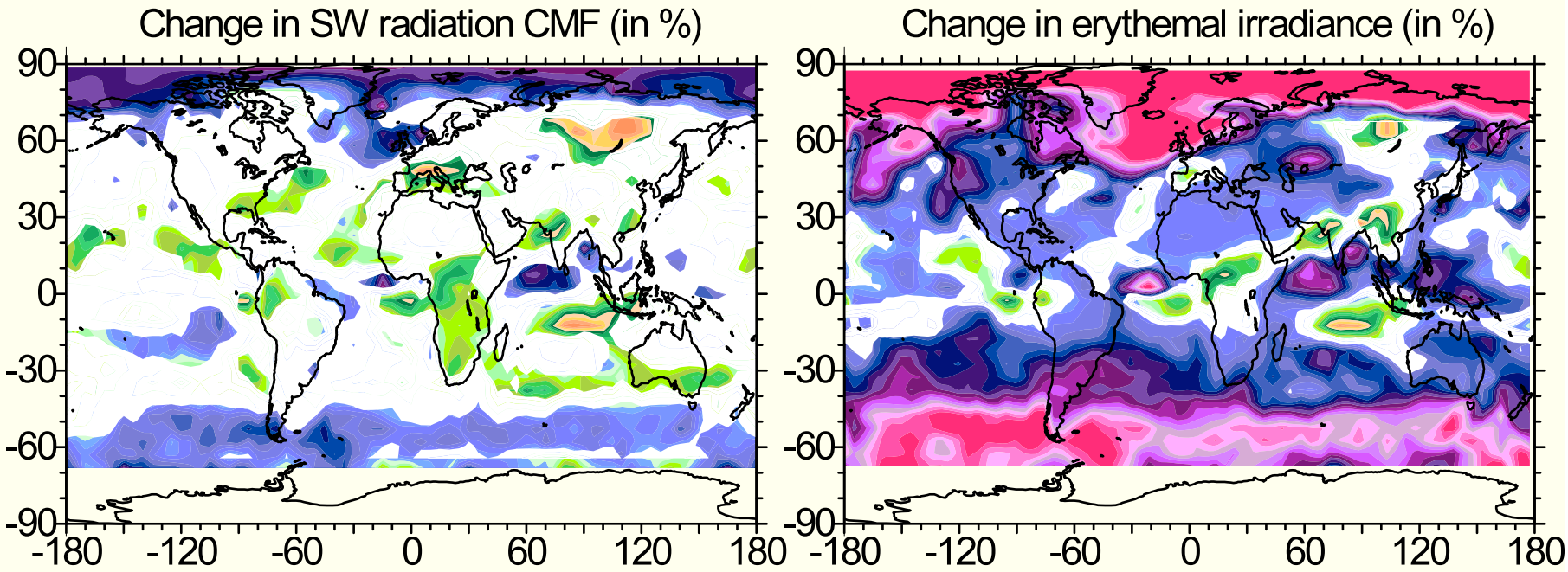
  Erythemal irradiance (in 5°x5° grid) under all-sky conditions

Surface erythemal irradiance (clear skies)
Mean of 2081 - 2100 relative to 2001 - 2020



Surface erythemal irradiance (all skies)
Mean of 2081 - 2100 relative to 2001 - 2020

July

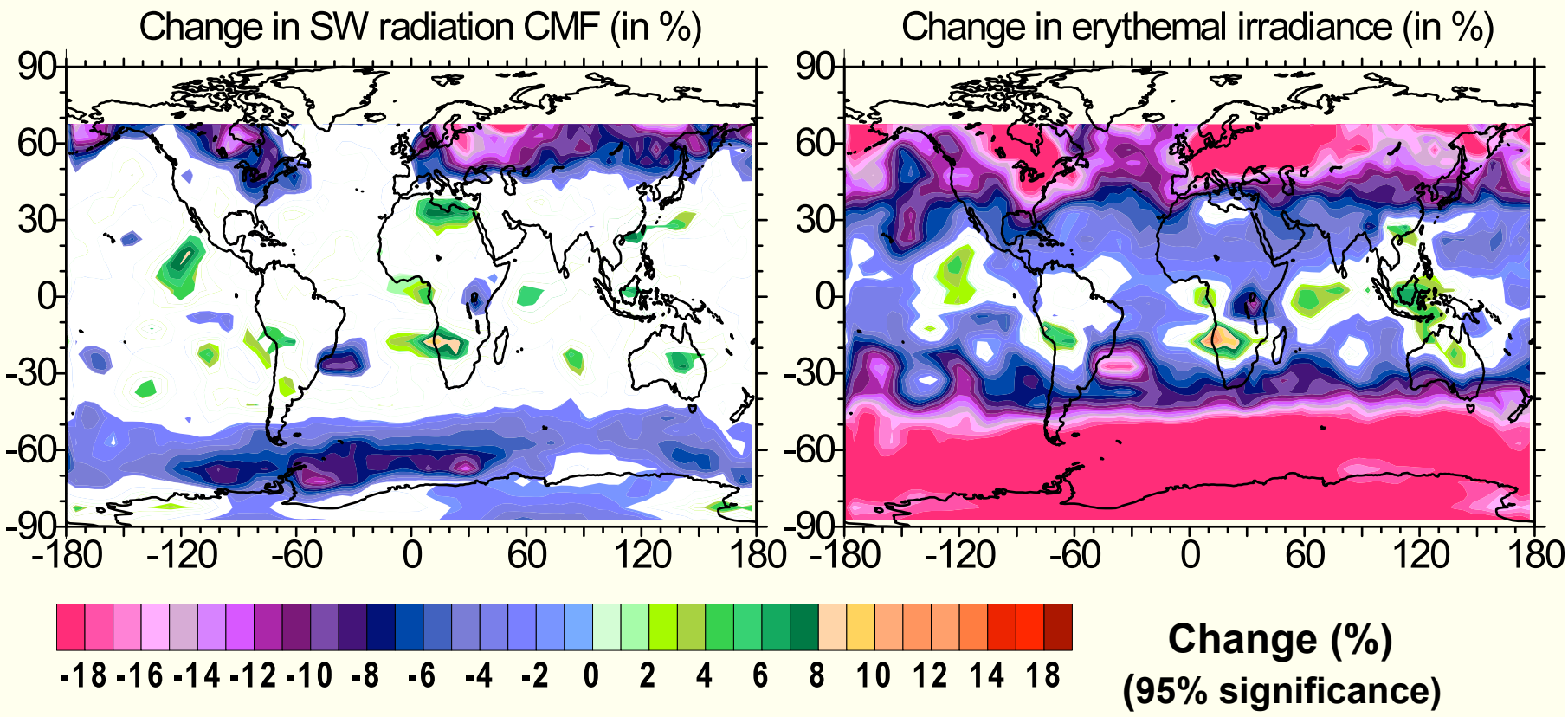


AR4 ECHAM5-Runs based on the IPCC-SRES A1B scenario

data source: WCRP CMIP3 multi-model dataset

Surface erythemal irradiance (all skies)
Mean of 2081 - 2100 relative to 2001 - 2020

January



AR4 ECHAM5-Runs based on the IPCC-SRES A1B scenario

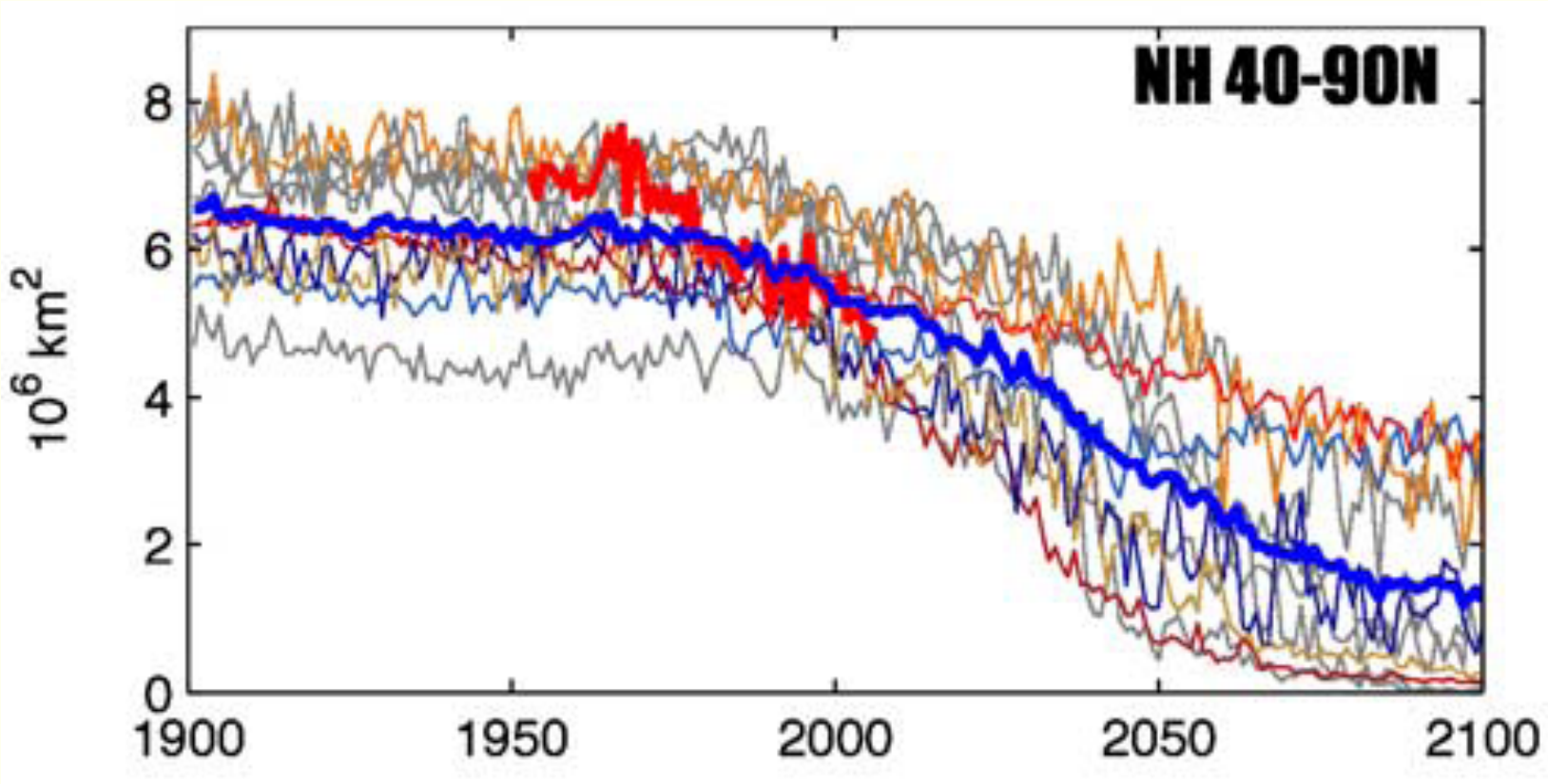
data source: WCRP CMIP3 multi-model dataset

Conclusions – II (all-sky conditions)

- Changes in surface UV between the first and the last 2-decades of the 21st century due to ozone and cloud variations show:
  - Large reductions at high latitudes (mainly due to ozone recovery)
  - Moderate reductions (~2-5%) at mid-latitudes
  - Localized increases in the tropical zone
- Accuracy of calculations and significance are expected to improve as cloud information (surface SW radiation levels) becomes available from CCMs in a lat-lon scale
- Accounting for surface reflectivity changes will further refine the simulations

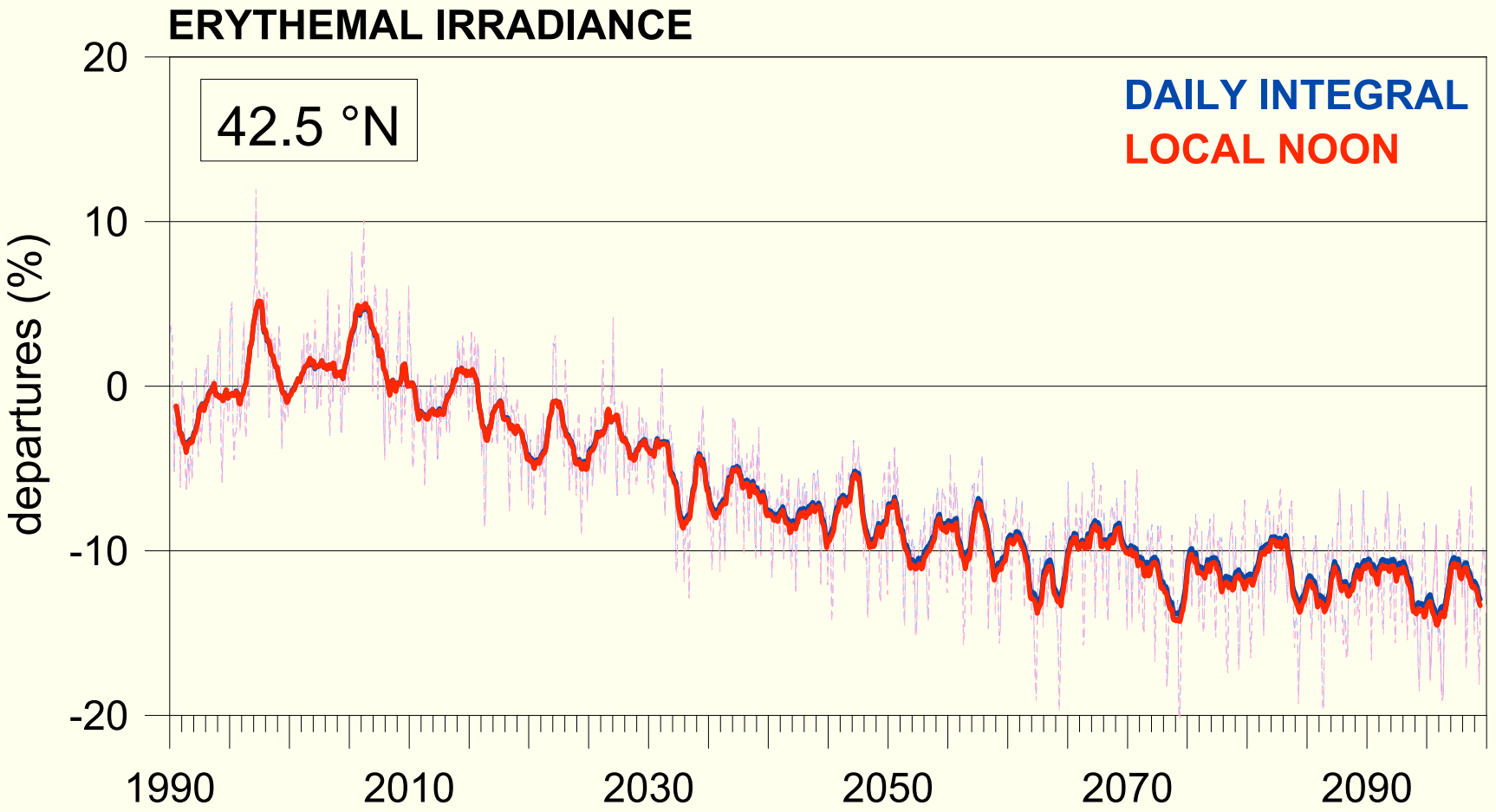
Thank you!

Simulated summer sea ice area



Overland & Wang, GRL, 2007

Daily erythemal irradiance



Daily erythemal irradiance