Klima wird von Spurenstoffen dominiert - die Luftqualität ebenso

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Max-Planck-Institut für Meteorologie, Hamburg

Vortrag bei der Kommission Klima und Luftqualität der Österreichischen Akademie der Wissenschaften

Wien, 28. November 2013

Was wir früher im Winter hatten, haben die Chinesen jetzt auch
12. Januar 2013, Peking

Was ist Klima?

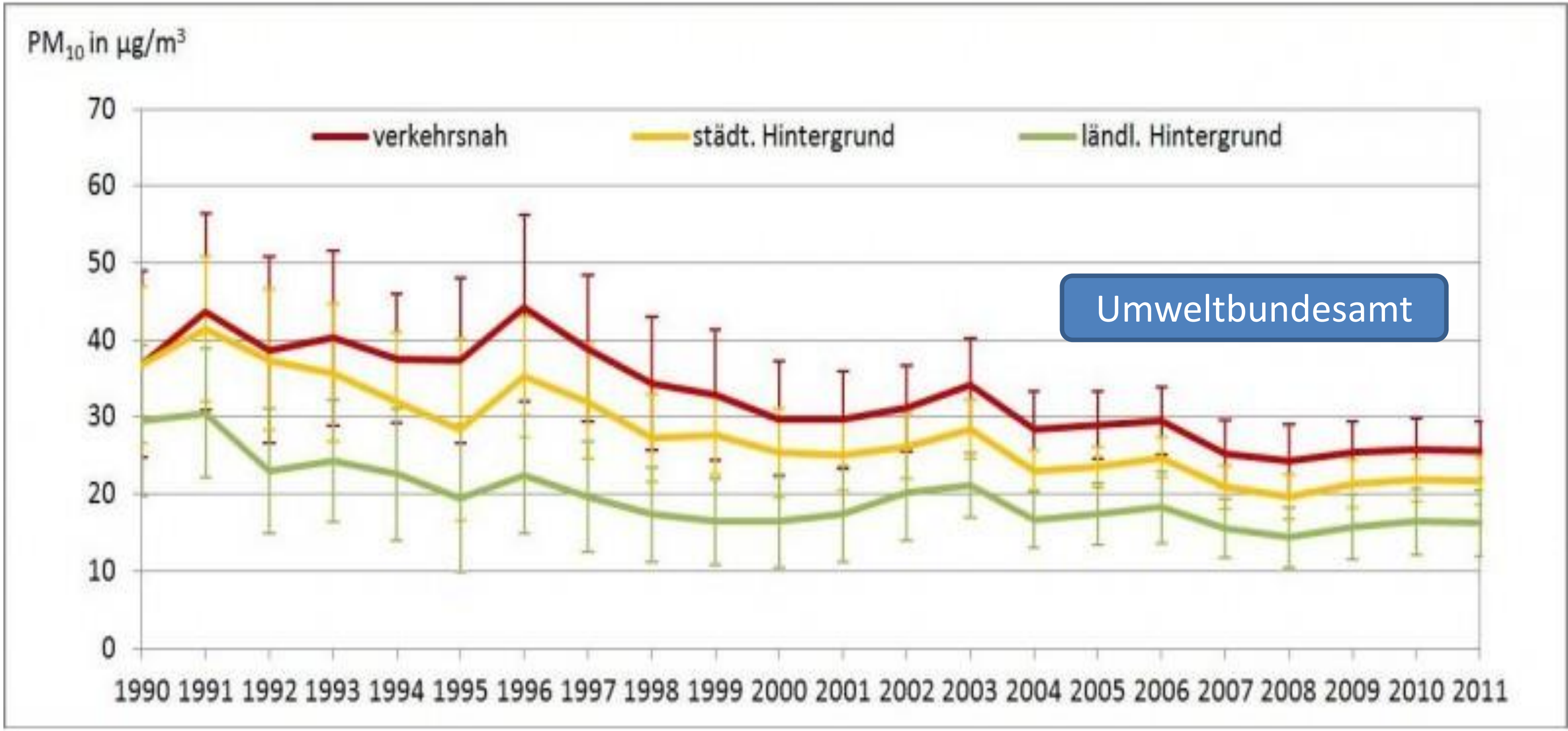
Das **Klima** steht als Begriff für die Gesamtheit aller meteorologischen Vorgänge, die für den durchschnittlichen Zustand der Erdatmosphäre an *einem* Ort verantwortlich sind. Oder anders ausgedrückt: Klima ist die Gesamtheit aller an einem Ort möglichen Wetterzustände, einschließlich ihrer typischen Aufeinanderfolge sowie ihrer tages- und jahreszeitlichen Schwankungen. Das Klima wird dabei jedoch nicht nur von Prozessen innerhalb der Atmosphäre, sondern vielmehr durch das Wechselspiel aller Sphären der Erde (Kontinente, Meere, Atmosphäre) sowie der Sonnenaktivitäten (Eiszeiten) u.a Einflüsse wie z.B. Erdbahnänderungen geprägt.

Was ist Luftqualität?

Sie ist in der EU von

RICHTLINIE 2008/50/EG DES EUROPÄISCHEN PARLAMENTS UND DES RATES
vom 21. Mai 2008 über Luftqualität und saubere Luft für Europa bestimmt.
Sie hat in den letzten Jahrzehnten in Europa zugenommen, insbesondere nach dem Zusammenbruch des Ostblocks.

Partikelbelastung der Luft (PM_{10}) in Deutschland seit 1990

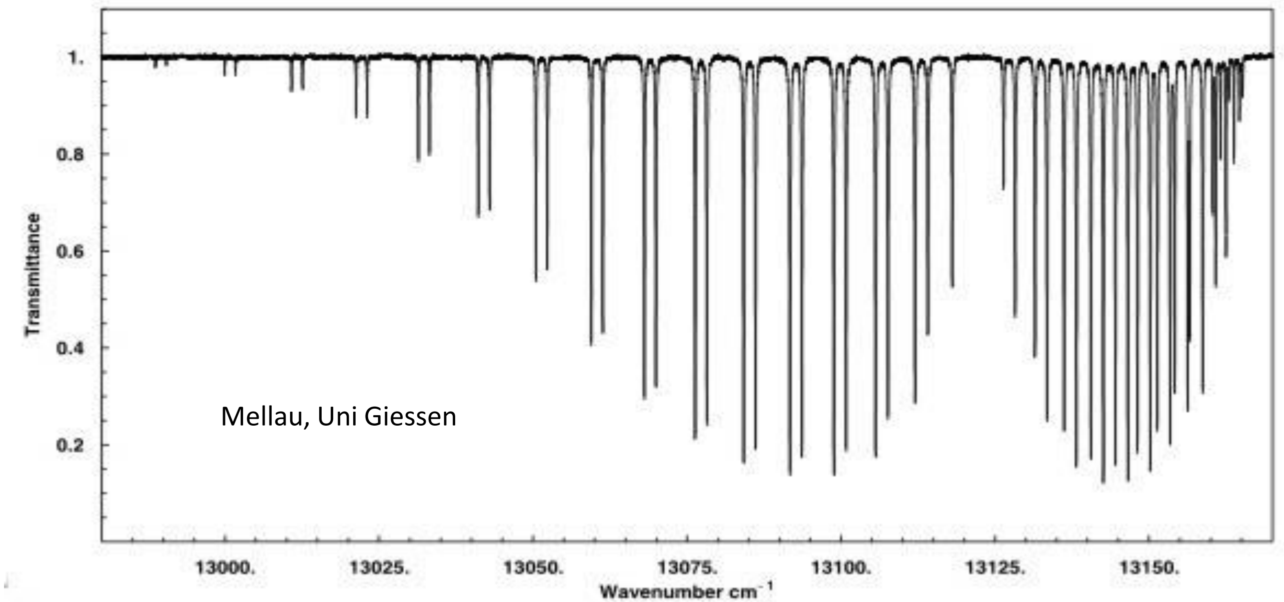


Die Schadstoffbelastung der Luft nahm seit Beginn der 1990er-Jahre deutlich ab. Seit Anfang dieses Jahrzehnts gibt es trotz kontinuierlich verminderter Emissionen keinen eindeutig abnehmenden Trend der Belastung durch Feinstaub, Stickstoffdioxid und Ozon in Deutschland mehr.

Warum sind die Hauptbestandteile der Luft kaum für das Klima bedeutsam?

- **Weil 99,96 Prozent der trockenen Luft - Stickstoff, Sauerstoff und Argon - kein elektrisches Dipolmoment haben.**
- **Ein nur schwaches magnetisches Dipolmoment verursacht bei dem Sauerstoffmolekül einige, gemessen an der Konzentration aber nur schwache, Absorptionsbanden**

Klima und Luftqualität werden gemeinsam von winzigen Beimengungen der Luft dominiert.

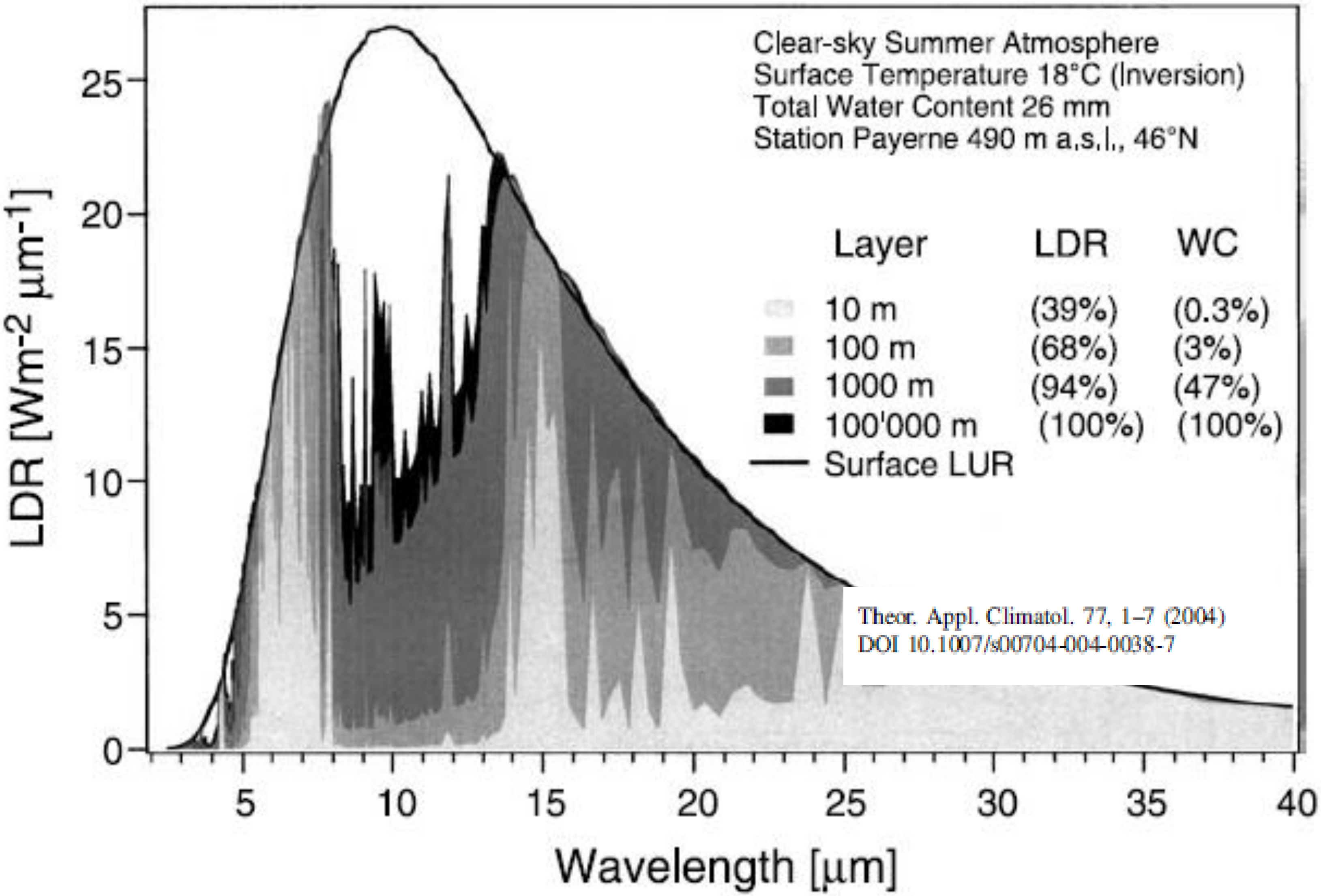


Die Reihung der Bedeutung einzelner Gase für den natürlichen Treibhauseffekt der Erdatmosphäre

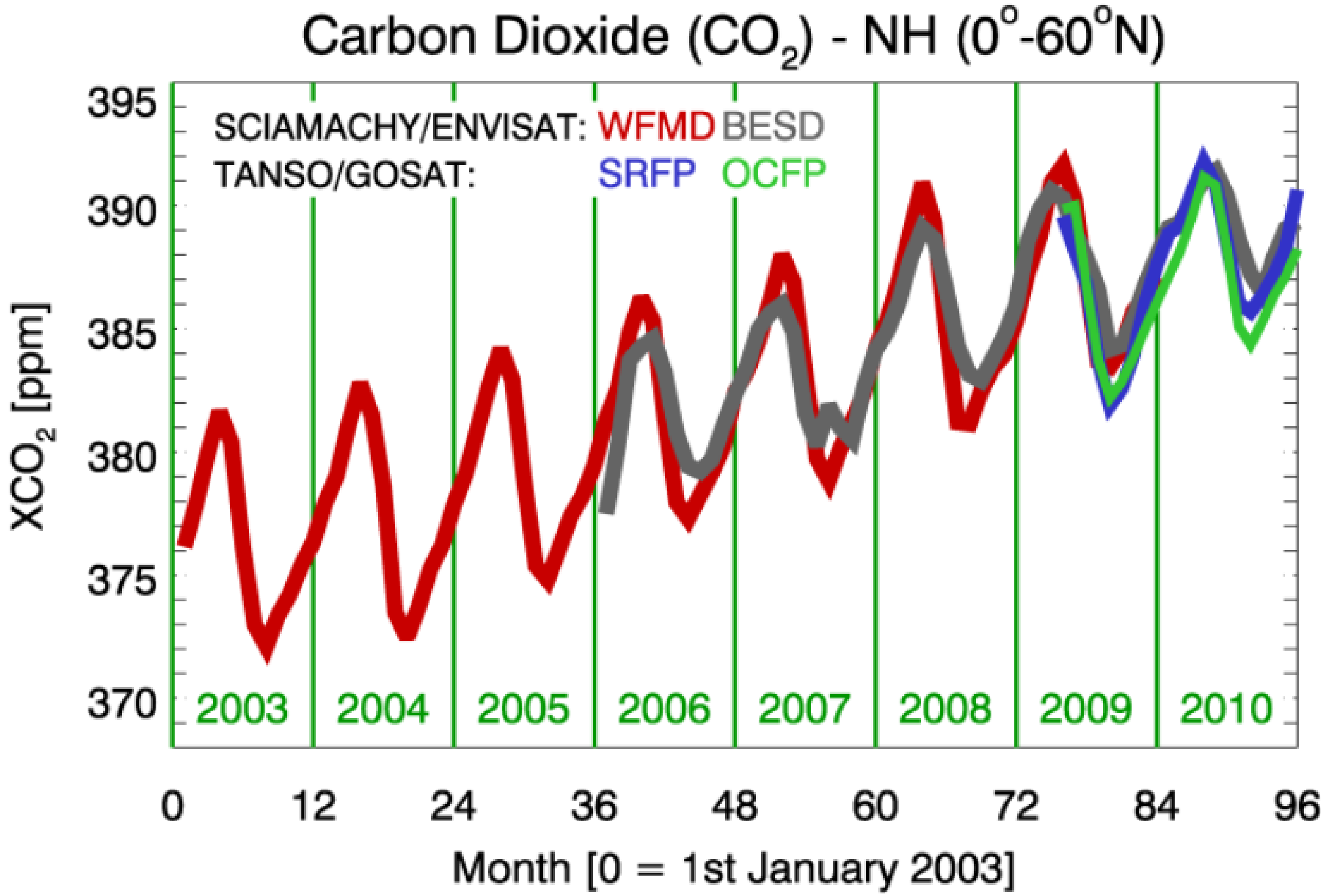
- *Wasserdampf (etwa 2/3)*
- *Kohlendioxid (etwa 1/5)*
- *Ozon (etwa 1/10)*
- *Distickstoffoxid (etwa 1/30)*
- *Methan (etwas unter 1/30)*
- *(Kohlenmonoxid (direkt fast unbedeutend, jedoch über Chemie der Atmosphäre))*
- *(Stickstoff (fast bedeutungslos))*
- *(Sauerstoff (fast bedeutungslos))*

Spectral longwave downward radiation flux density (LDR) in Payerne ***(Philipona et al. (2004)***

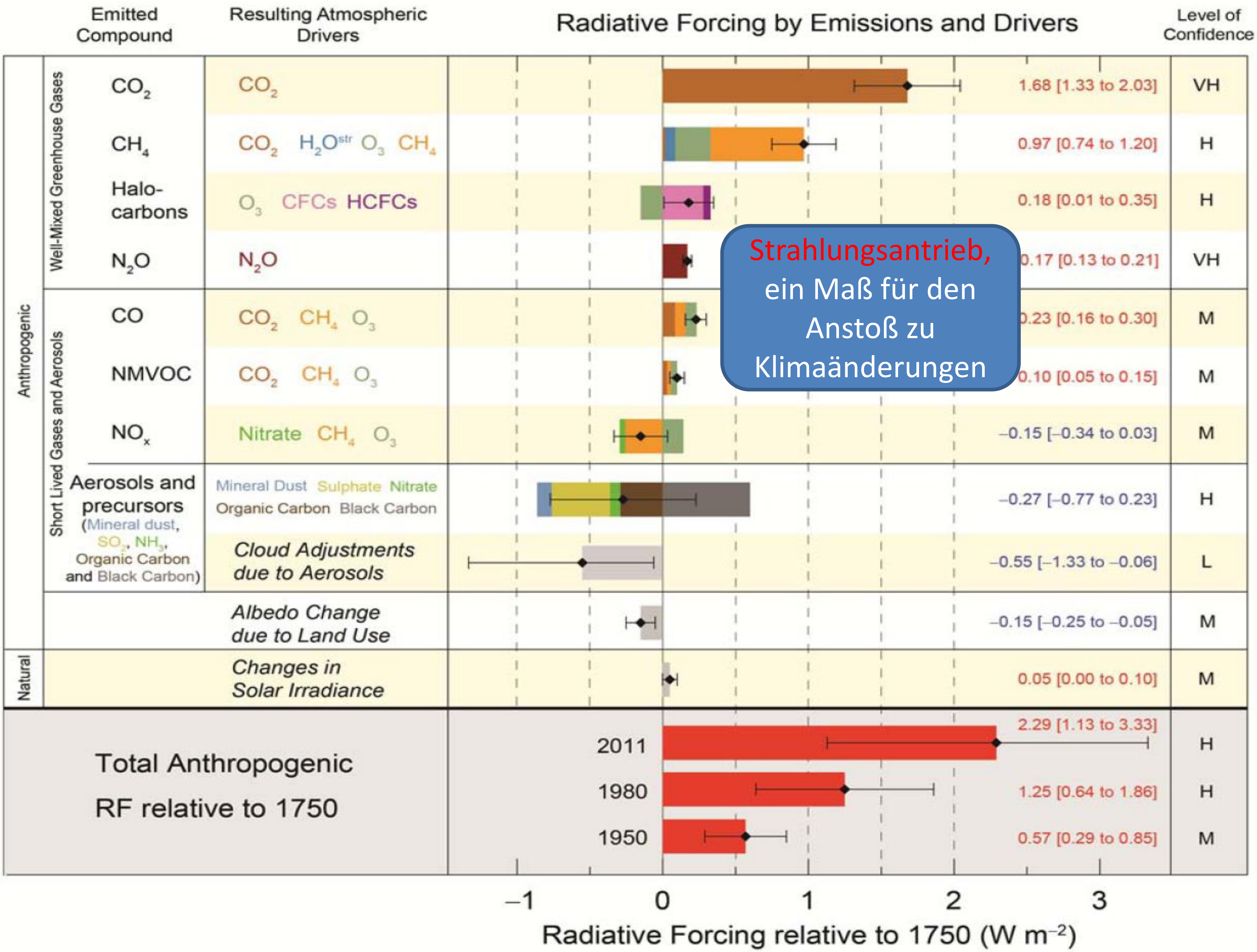
Spektrale langwellige Strahlungsflussdichte (LDR) in Payerne



Theor. Appl. Climatol. 77, 1–7 (2004)
DOI 10.1007/s00704-004-0038-7

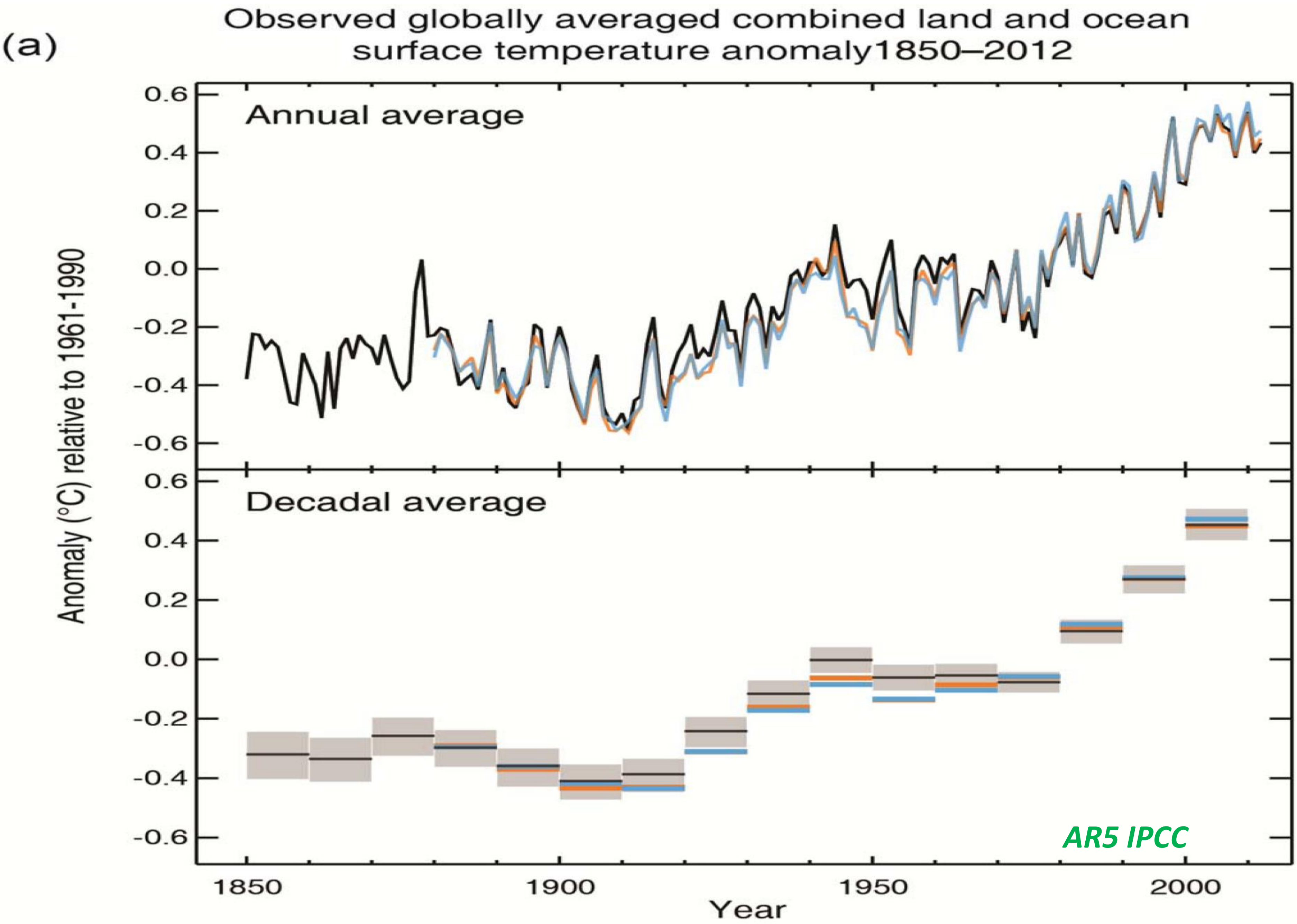


Buchwitz et al. 2012

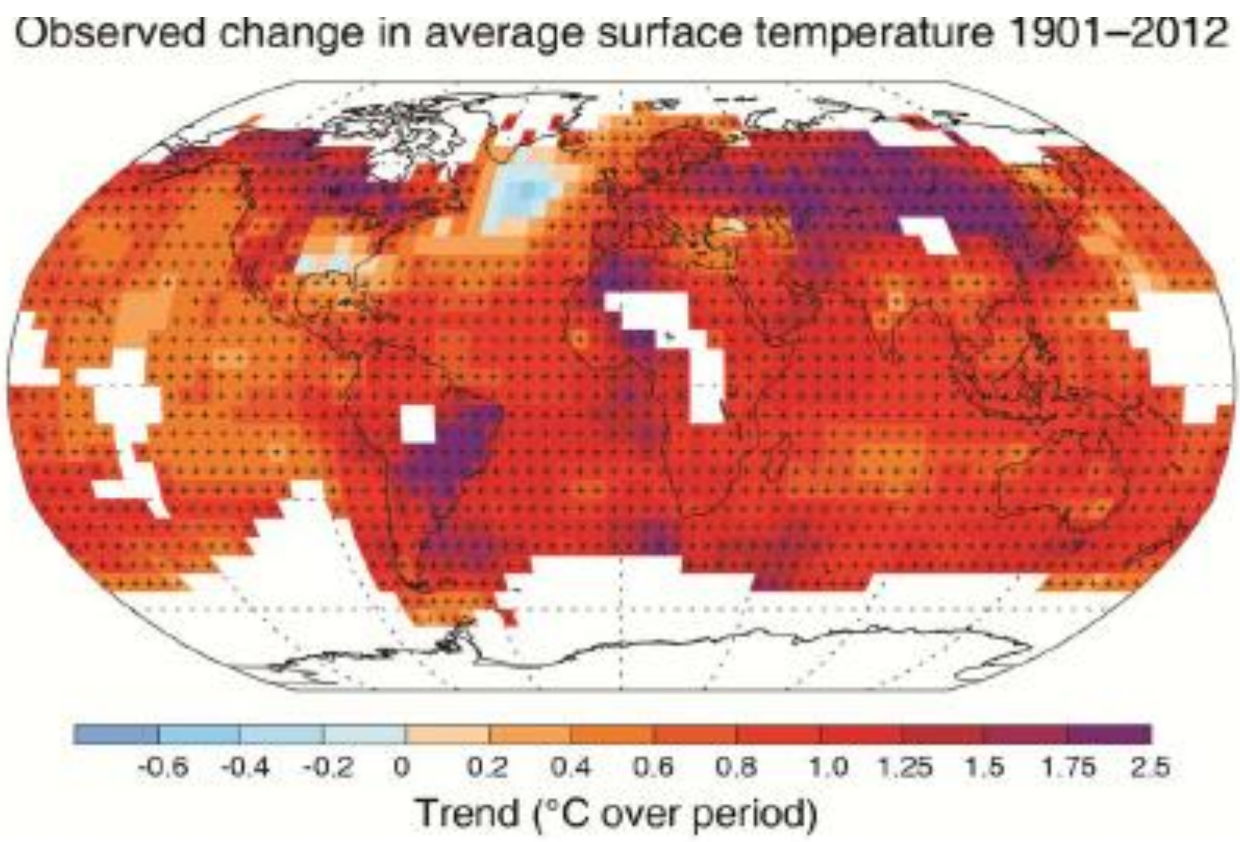


Emitted Compound
Resulting Atmospheric Drivers
Radiative Forcing by Emissions and Drivers
Level of Confidence
Anthropogenic
Well-Mixed Greenhouse Gases
CO_2
CO_2
1.68 [1.33 to 2.03]
VH
CH_4
CO_2 H_2O^{str} O_3 CH_4
0.97 [0.74 to 1.20]
H
Halo-carbons
O_3 CFCs HCFCs
0.18 [0.01 to 0.35]
H
N_2O
N_2O
0.17 [0.13 to 0.21]
VH
Short Lived Gases and Aerosols
CO
CO_2 CH_4 O_3
0.23 [0.16 to 0.30]
M
NMVOC
CO_2 CH_4 O_3
0.10 [0.05 to 0.15]
M
NO_x
Nitrate CH_4 O_3
−0.15 [−0.34 to 0.03]
M
Aerosols and precursors (Mineral dust, SO_2, NH_3, Organic Carbon and Black Carbon)
Mineral Dust Sulphate Nitrate Organic Carbon Black Carbon
−0.27 [−0.77 to 0.23]
H
Cloud Adjustments due to Aerosols
−0.55 [−1.33 to −0.06]
L
Albedo Change due to Land Use
−0.15 [−0.25 to −0.05]
M
Natural
Changes in Solar Irradiance
0.05 [0.00 to 0.10]
M
Total Anthropogenic RF relative to 1750
2011
2.29 [1.13 to 3.33]
H
1980
1.25 [0.64 to 1.86]
H
1950
0.57 [0.29 to 0.85]
M
−1
0
1
2
3
Radiative Forcing relative to 1750 ($W m^{-2}$)
Strahlungsantrieb, ein Maß für den Anstoß zu Klimaänderungen

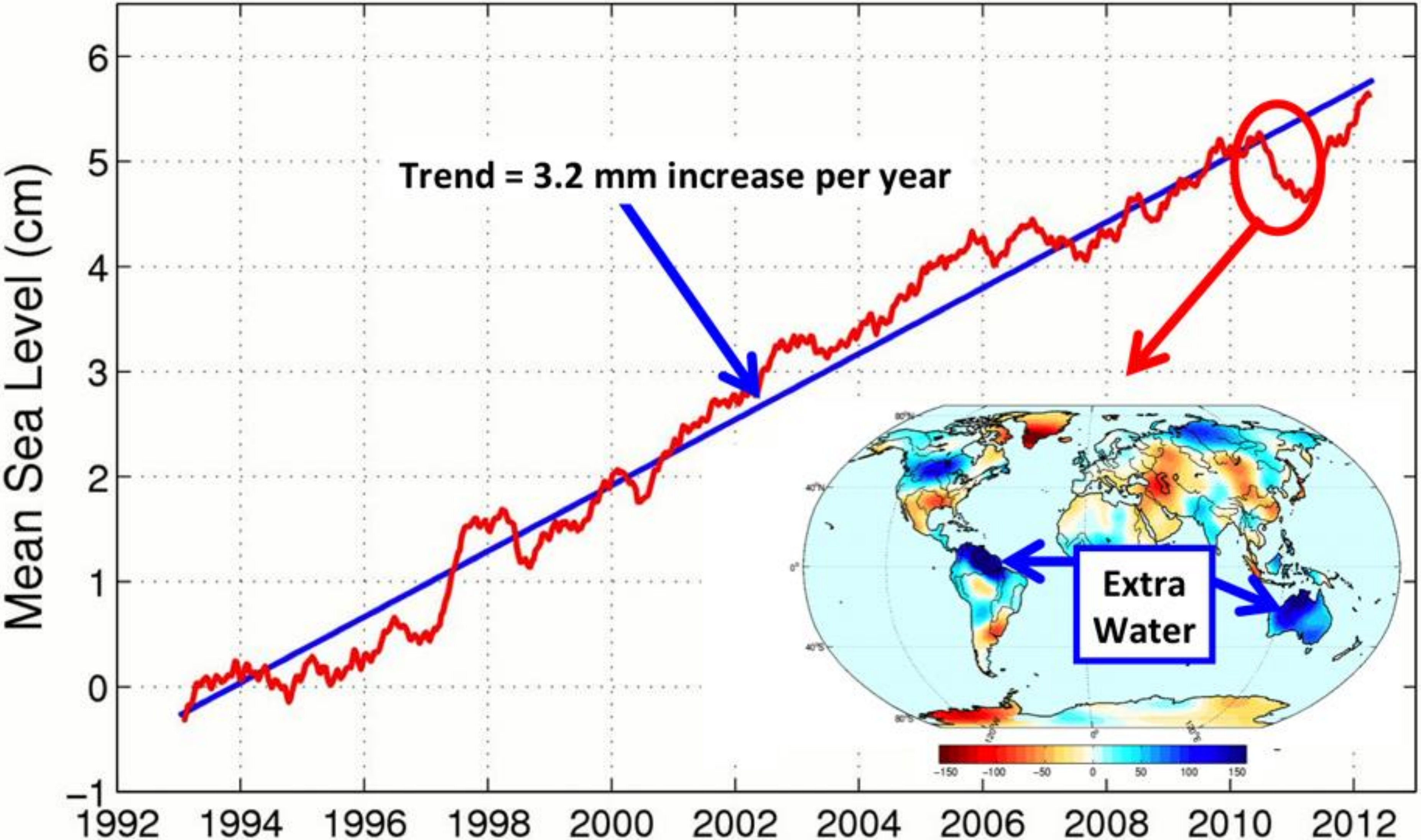
Mittlere globale Temperaturänderungen seit 1850



Erwärmung oder Abkühlung seit 1901



Meeresspiegeländerungen, seit diese von Satelliten aus genauer beobachtet werden können

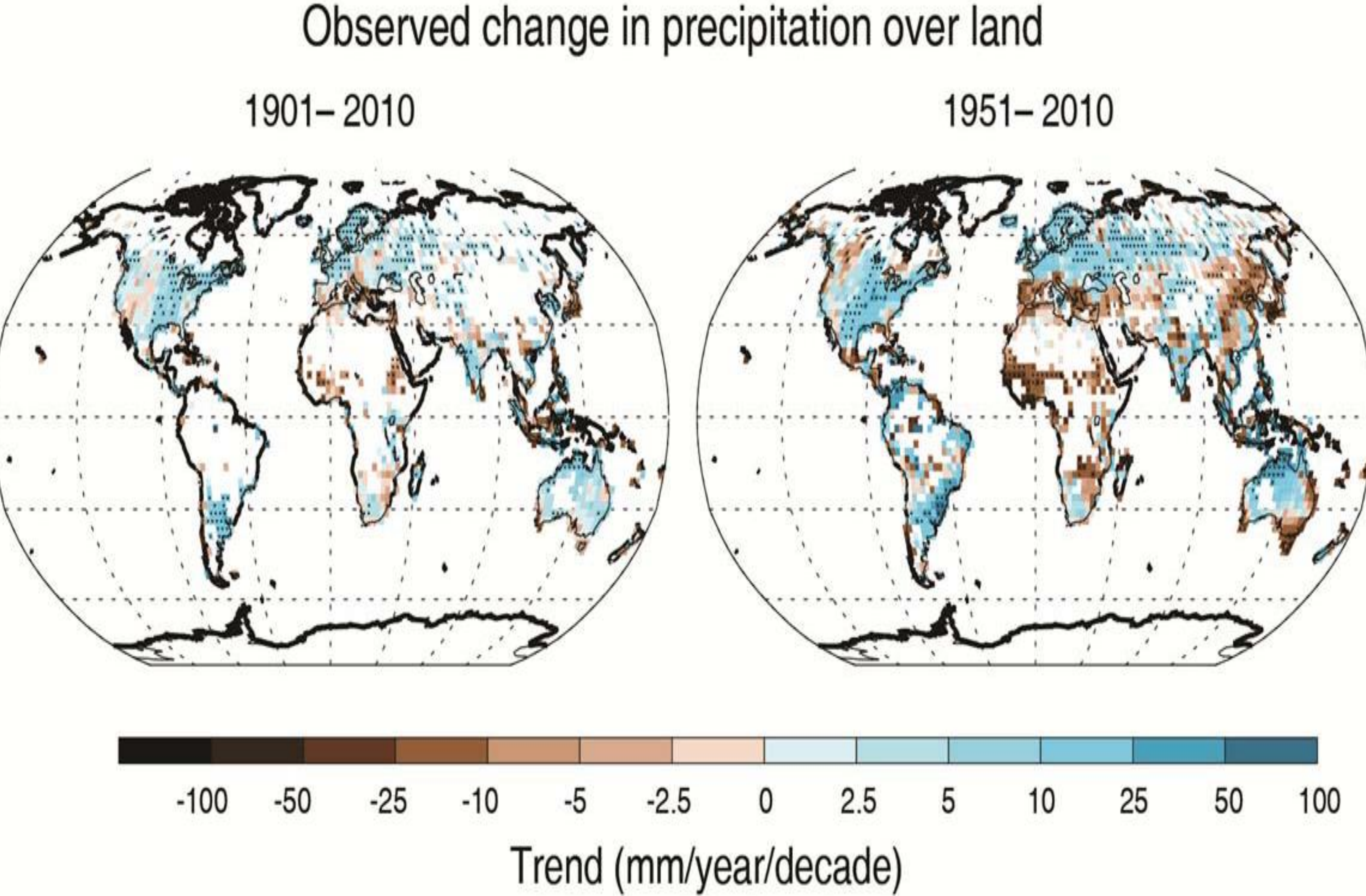


Sea Level Change

It is very likely that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm yr^{-1} between 1901 and 2010, 2.0 [1.7 to 2.3] mm yr^{-1} between 1971 and 2010 and 3.2 [2.8 to 3.6] mm yr^{-1} between 1993 and 2010. Tide-gauge and satellite altimeter data are consistent regarding the higher rate of the latter period. It is likely that similarly high rates occurred between 1920 and 1950

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia (high confidence) *IPCC AR5*

Niederschlagsänderungen über Landgebieten



An operational Meteorological Satellite as the air chemistry sensor

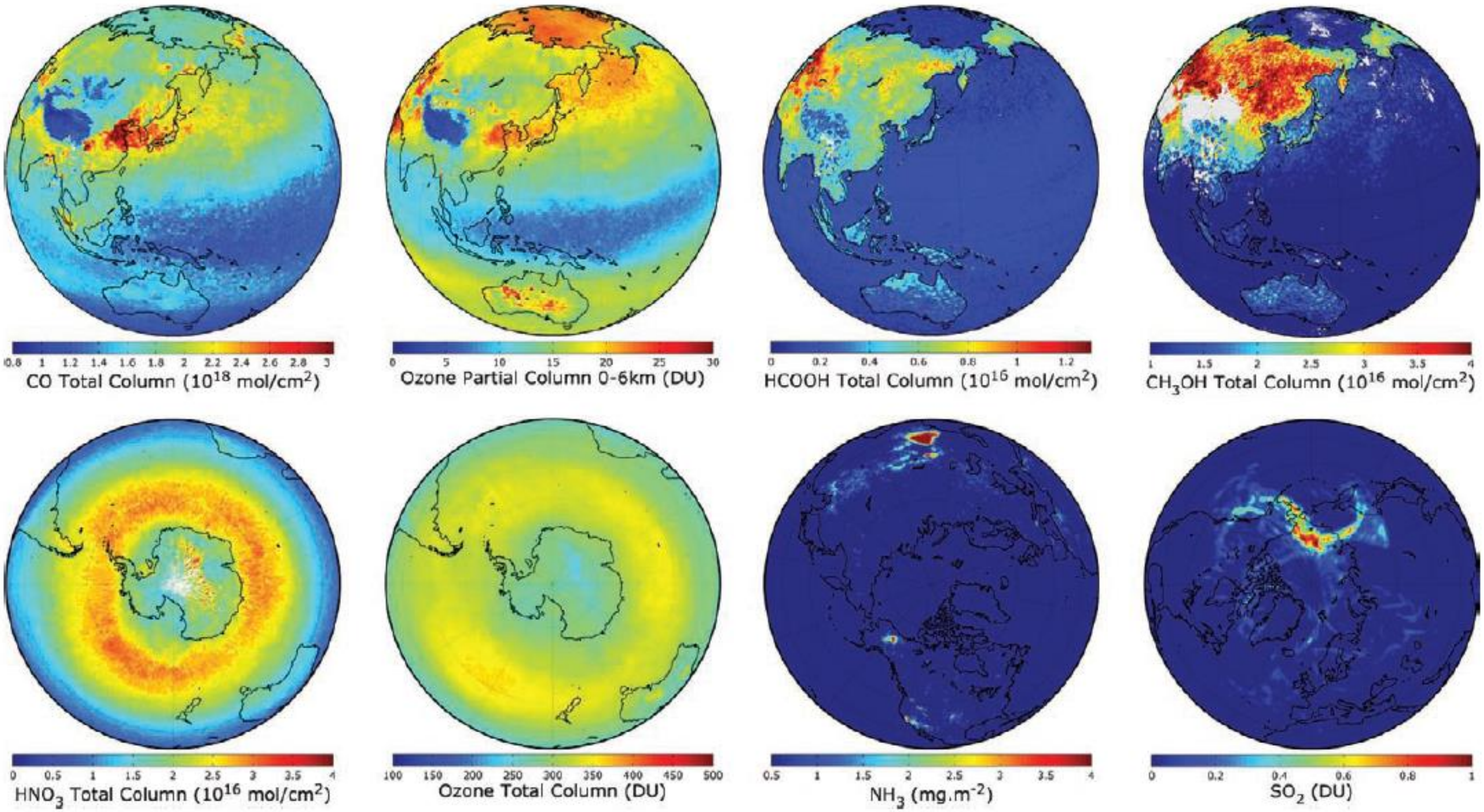
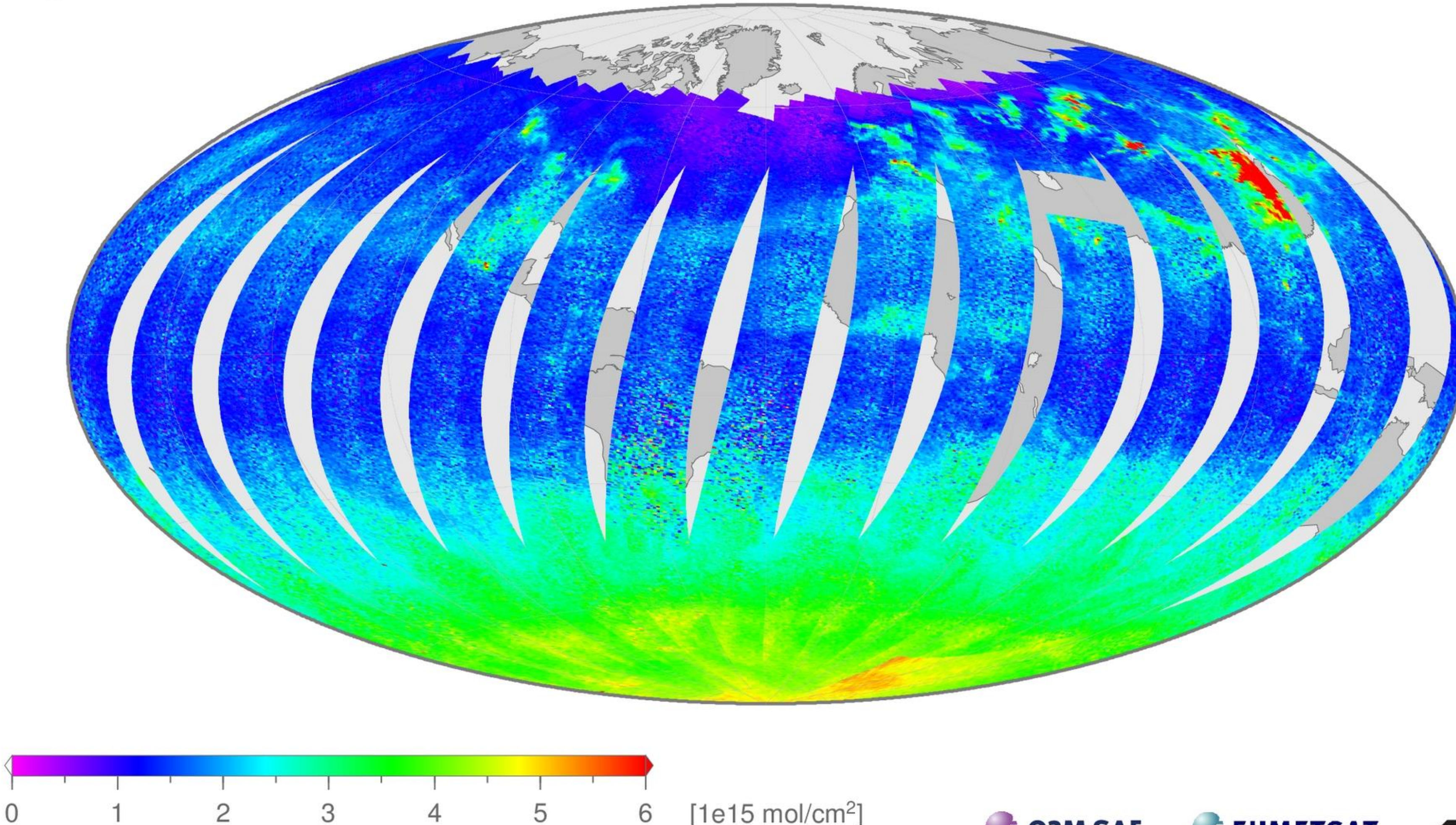


FIG. 9. Trace gas distributions retrieved from IASI spectra, averaged over 1 month of observations in Jul 2008. (top) Total columns for the chemistry gases carbon monoxide, ozone (tropospheric column), formic acid, and methanol. (bottom left) Polar projection over the Antarctic of ozone and nitric acid total columns, prior to the development of the ozone hole. (bottom right) Arctic projection showing hotspots of ammonia over continental areas and the SO_2 plume following Okmok eruption.

NO_2

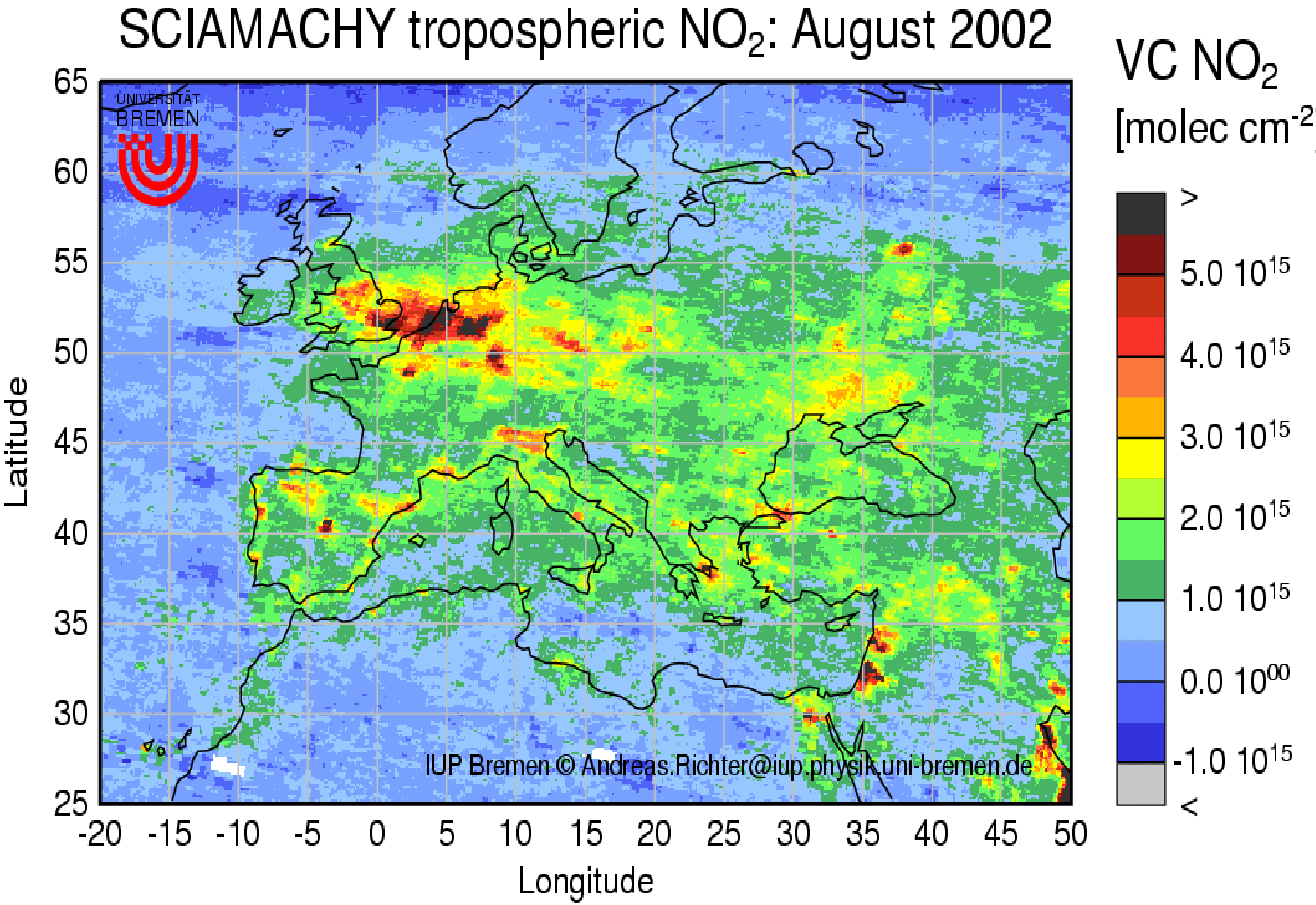
Nitrogen Dioxide total column

Acquisition Time	Sensor	Plot Range	Algorithm
18-DEC-2012 00:02:54	GOME-2	0.0 : 21.3	GDP 4.6
18-DEC-2012 23:45:59	MetOp-B	2.8 ± 1.4	UPAS 1.3.7



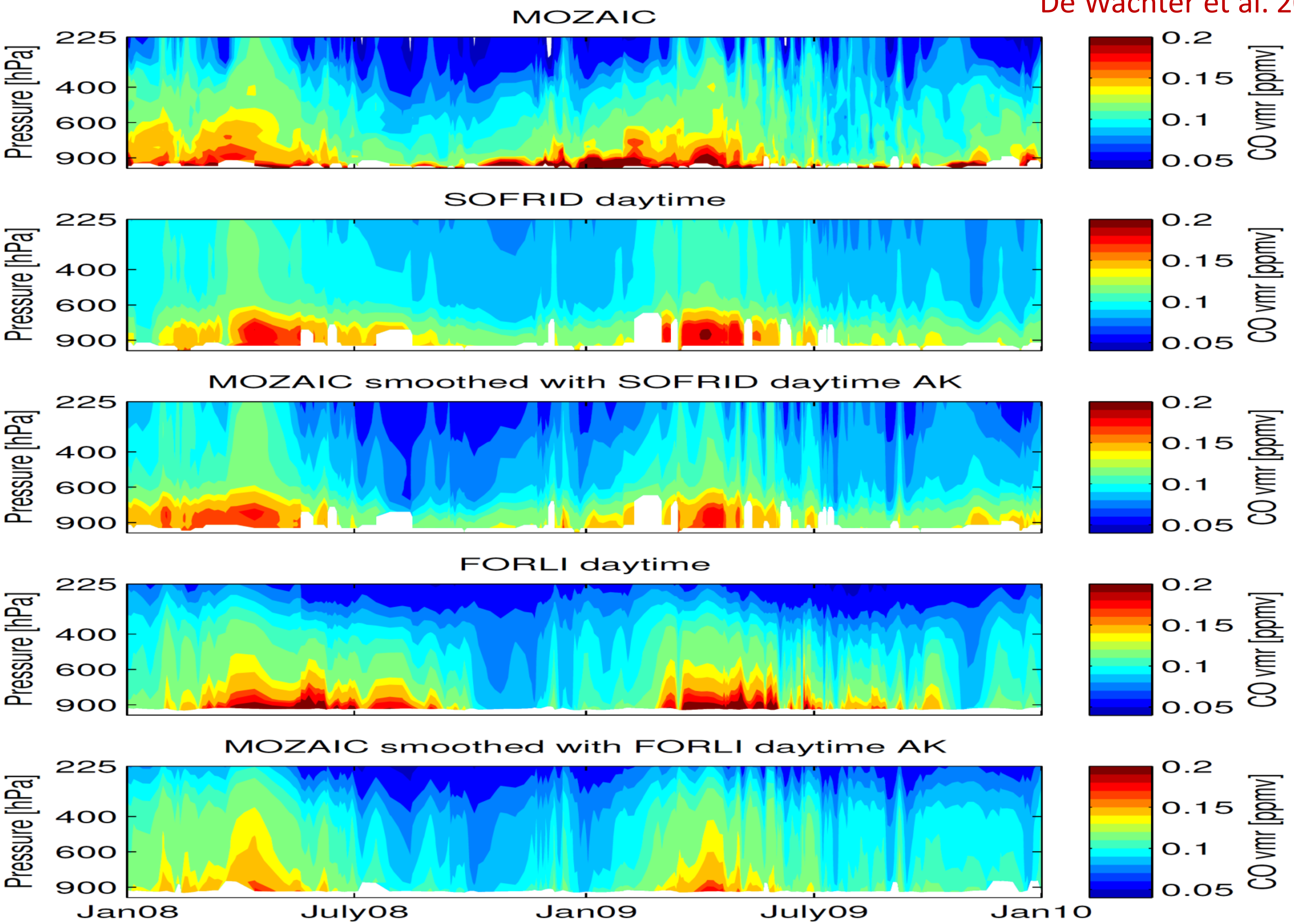
O3M SAF EUMETSAT DLR

http://atmos.eoc.dlr.de/gome2b


SCIAMACHY tropospheric NO2: August 2002
VC NO2
[molec cm-2]
>
5.0 10^15
4.0 10^15
3.0 10^15
2.0 10^15
1.0 10^15
0.0 10^00
-1.0 10^15
<
Latitude
65
60
55
50
45
40
35
30
25
Longitude
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
UNIVERSITÄT
BREMEN
IUP Bremen © Andreas.Richter@iup.physik.uni-bremen.de

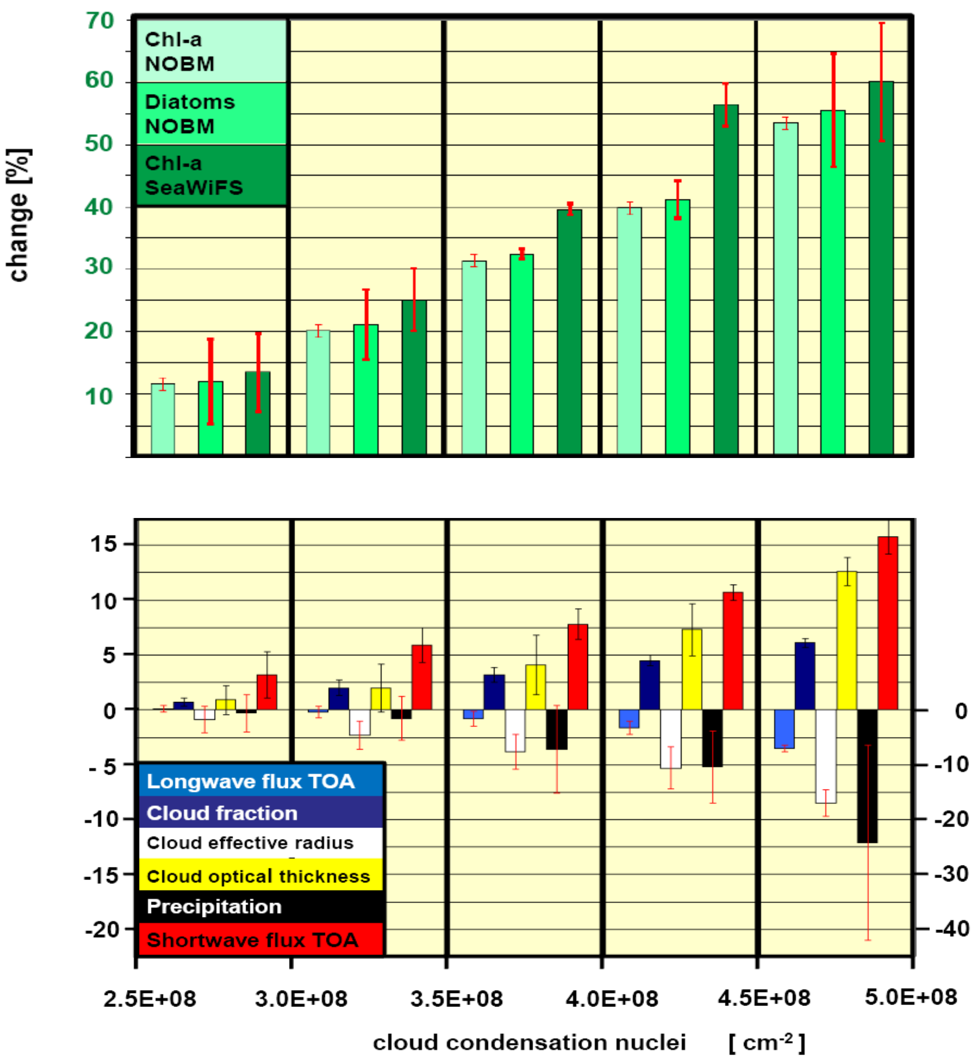
Grobe Vertikalprofile eines Spurengases (CO) beobachtet mit einem Sensor (IASI) an Bord eines operationellen meteorologischen Satelliten über Frankfurt

De Wachter et al. 2012



b

Ein Beispiel für die Wirkung von Spurengasen auf die Lufttrübung und die Wolken



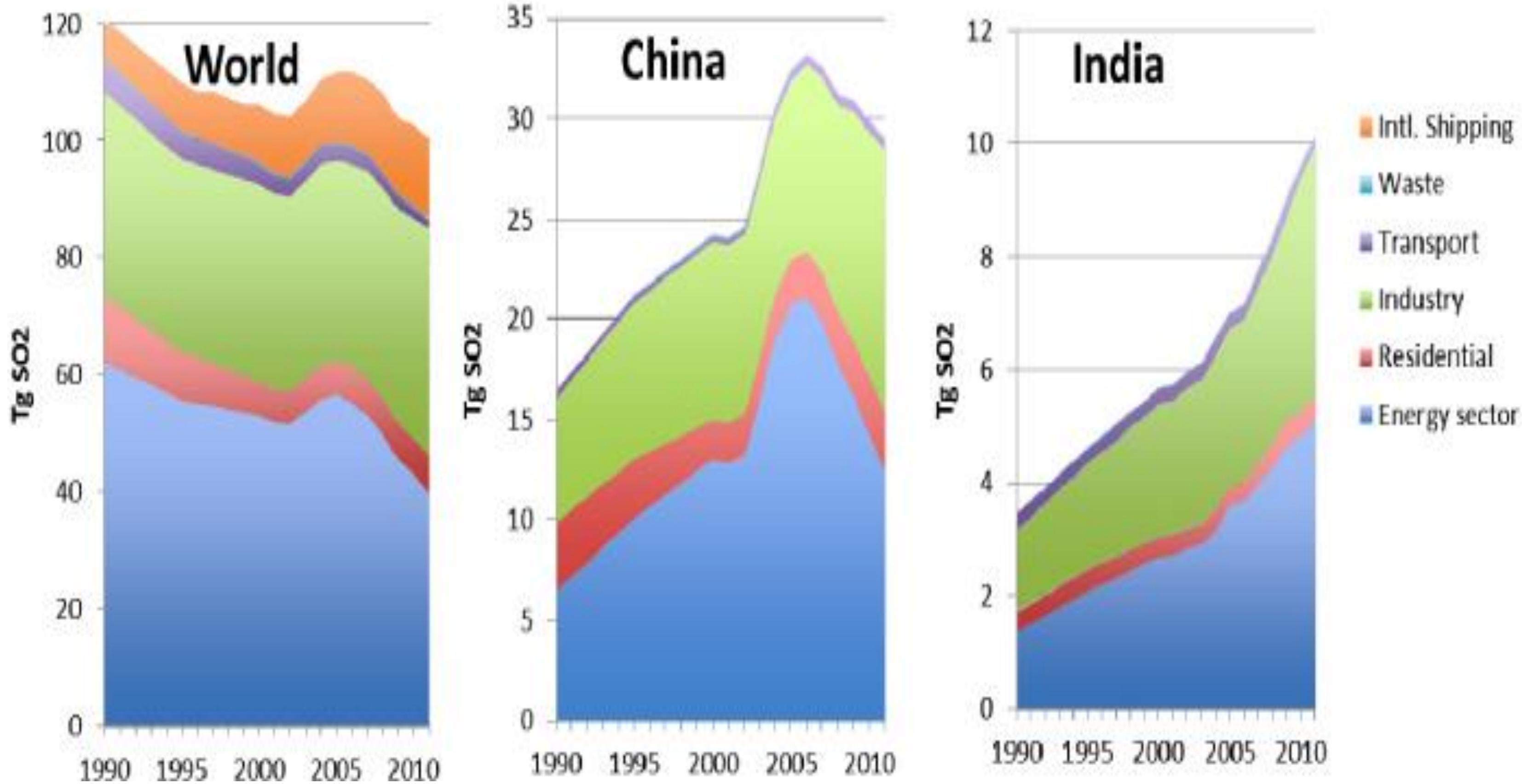
Phytoplankton changes clouds and precipitation over the Southern Ocean

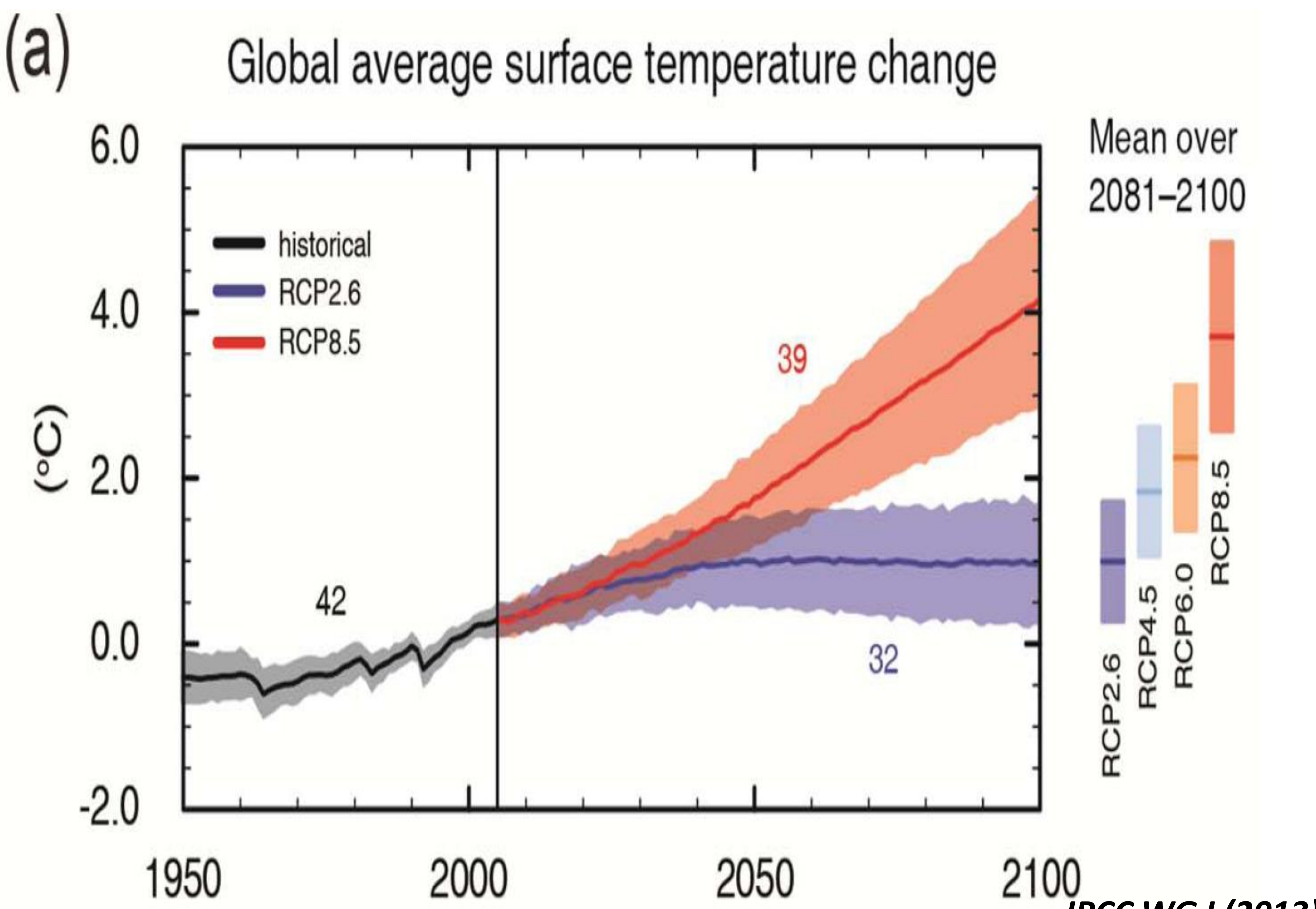
FIGURE 1: Changes (in %) of chlorophyll-a concentration (Chl-a) from SeaWiFS and NASA Ocean Biogeochemical Model (NOBM), diatom concentration ($C_{diatoms}$) from NOBM (upper part, a), cloud effective radius for water clouds (R_e) from MODIS (in white, left ordinate), cloud fraction (C_f) from MODIS-TERRA (in dark blue, left ordinate), cloud optical thickness for water clouds (τ) from MODIS-TERRA (in yellow, left ordinate), upward shortwave radiative flux (SWF_U, in red, left ordinate) and upward longwave radiative flux (LWF_U, in light blue, left ordinate) at top-of-atmosphere from CERES and precipitation amount (P, in black, right ordinate) from HOAPS-3 (lower part, b) relative to the three year mean range in CCN number per cm^2 from $2.0x10^8$ to $2.5x10^8$ (Chl-$a_{SeaWiFS}$ =0.31mg/m^3, Chl-a_{NOBM} =0.30mg/m^3, $C_{diatoms}$ =0.29mg/m^3,R_e=13.9µm , C_f=89% , τ=13.2 , SWF_U=326W/m^2, LWF_U=220W/m^2, P=55mm/month) for 2003, 2004 and 2005. The standard deviation is also shown. The relative changes are calculated for a grid size of 1^0 longitude and 1^0 latitude within the latitude belt of 45^0S-65^0S. Results are shown for five intervals ranging from $2.5x10^8$ – $3.0x10^8$, $3.0x10^8$ – $3.5x10^8$, $3.5x10^8$ – $4.0x10^8$, $4.0x10^8$ – $4.5x10^8$ CCN/cm^2. While Chl-$a_{SeaWiFS}$, Chl-a_{NOBM} , C_{diatom}, C_f, τ and SWF_U are increasing with increasing CCN, the values for R_e and LWF_U and P are decreasing.

Krueger and Grassl (2011), GRL

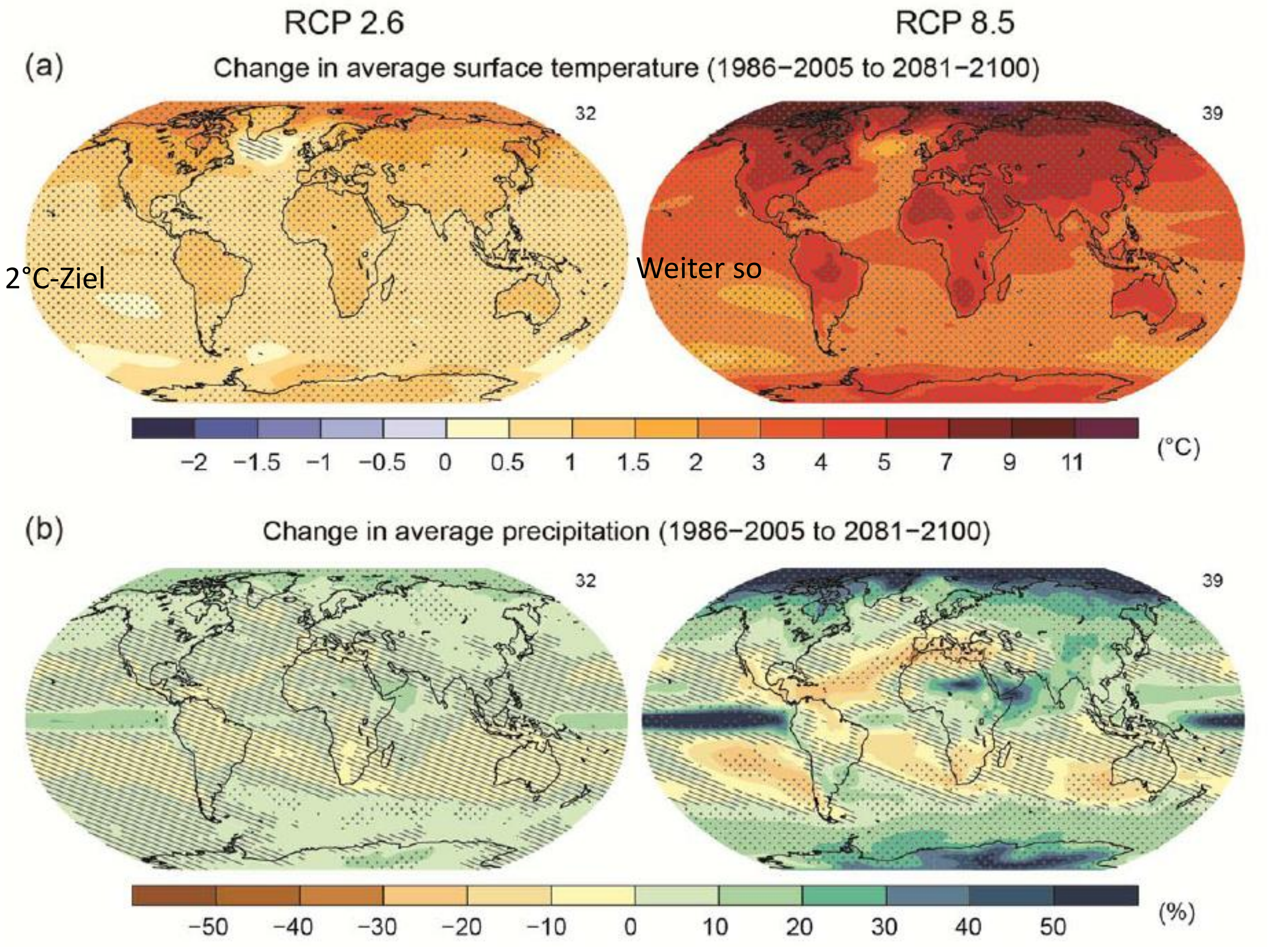
Schwefeldioxid-Emissionen weltweit und bei den stärksten Emittenten   *(ein Hoffnungsschimmer?)*

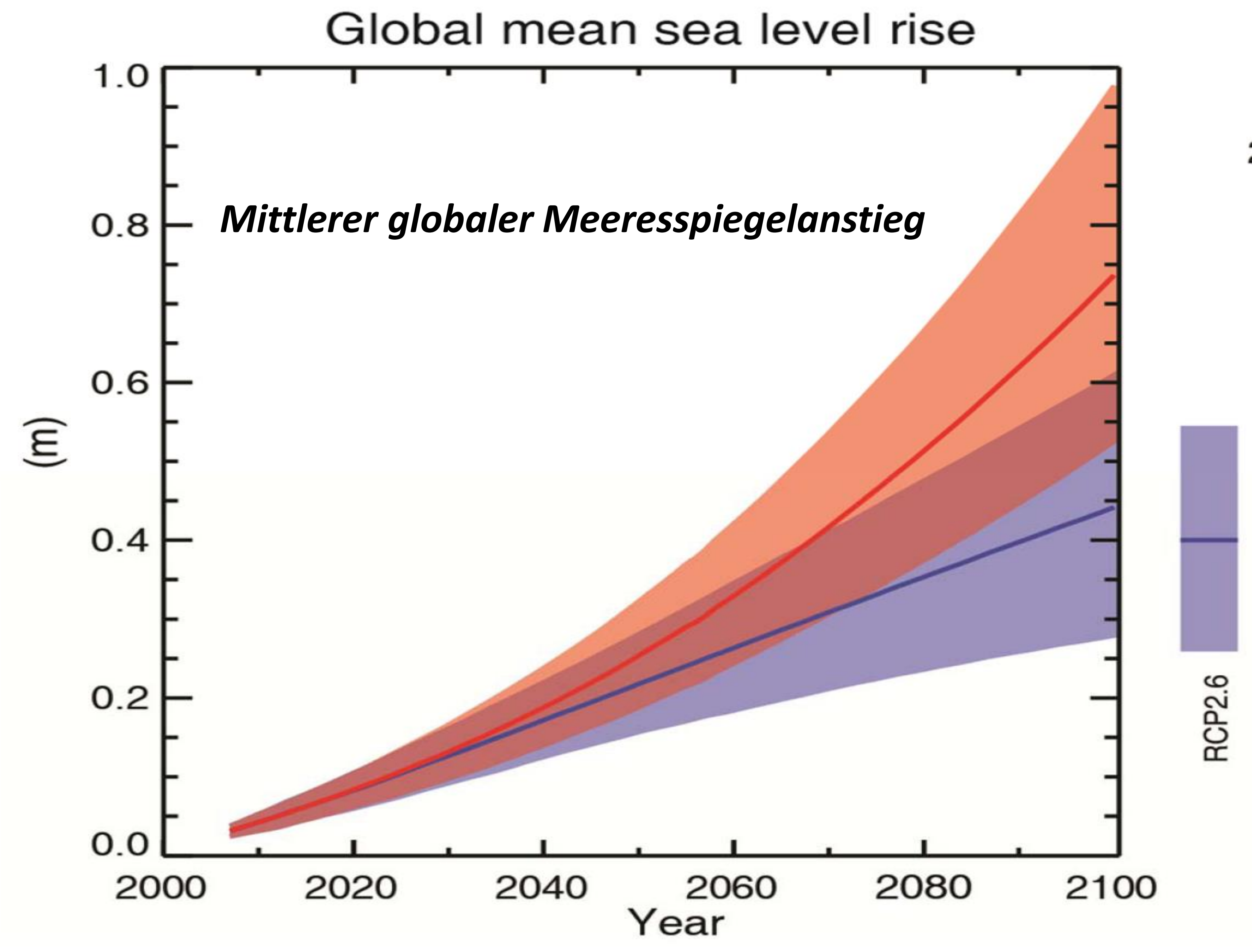
Figure 1 from Z Klimont et al 2013 Environ. Res. Lett. 8 014003





IPCC WG I (2013)


RCP 2.6
RCP 8.5
(a)
Change in average surface temperature (1986−2005 to 2081−2100)
32
39
2°C-Ziel
Weiter so
−2 −1.5 −1 −0.5 0 0.5 1 1.5 2 3 4 5 7 9 11
(°C)
(b)
Change in average precipitation (1986−2005 to 2081−2100)
32
39
−50 −40 −30 −20 −10 0 10 20 30 40 50
(%)



Global mean sea level rise
Mittlerer globaler Meeresspiegelanstieg
1.0
0.8
0.6
0.4
0.2
0.0
(m)
2000
2020
2040
2060
2080
2100
Year
RCP2.6

Eine neue zentrale Frage für die Wissenschaft:

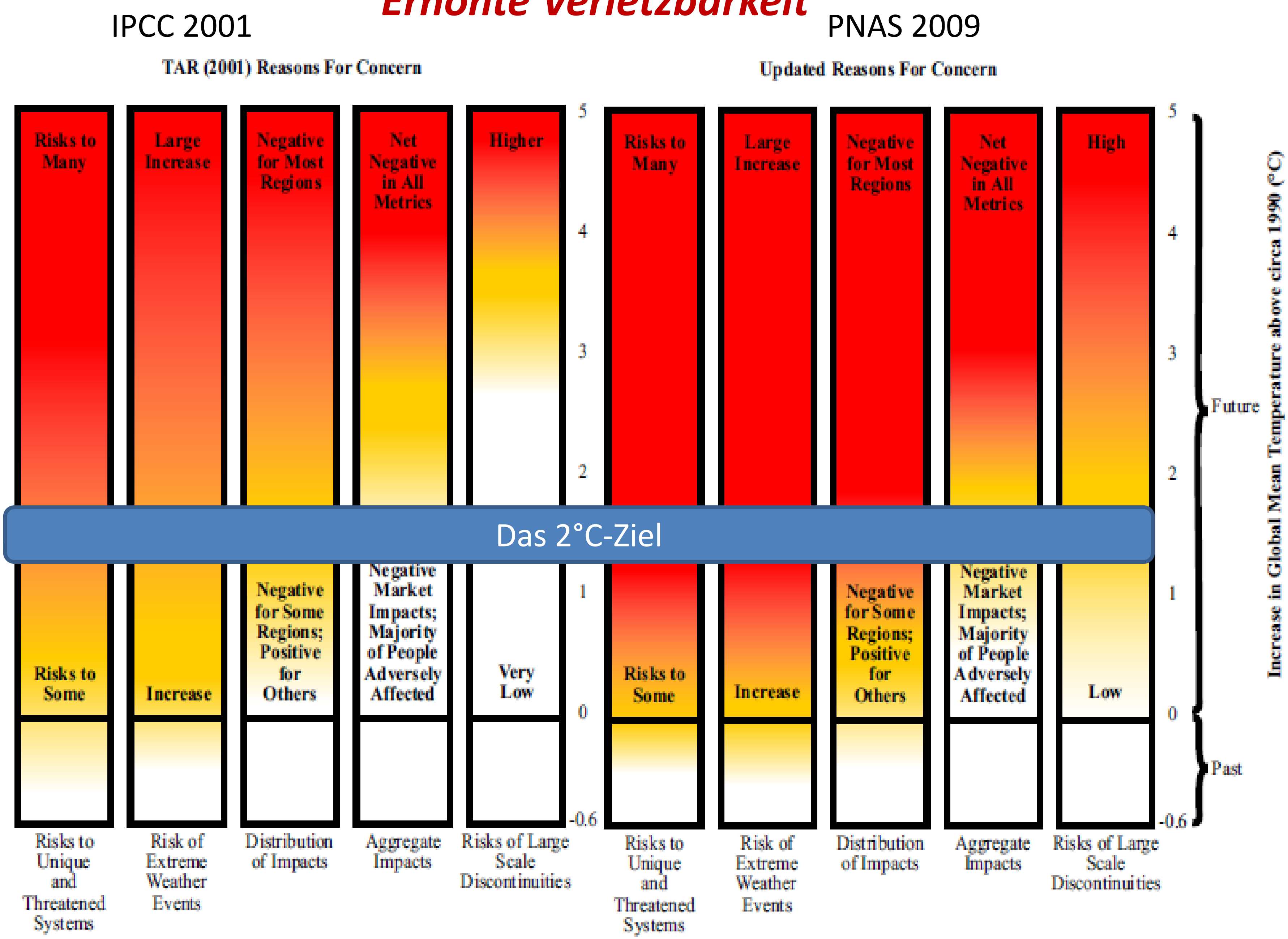
Wie lange hält der erhöhte Treibhauseffekt an?

In der Klimageschichte der letzten Million Jahre galt:

Mittlere Erwärmung oder Abkühlung von 1°C ist gleich-bedeutend mit etwa 20 m Meeresspiegeländerung bei über Jahrtausende anhaltendem Antrieb

Wie viel davon wird in den kommenden Jahrhunderten realisiert?

Erhöhte Verletzbarkeit



Fazit

Klimapolitik bestimmt darüber, ob wir eine Nachhaltige Entwicklung schaffen

Fast alle Klimaschutzmaßnahmen erhöhen die Luftqualität und sind damit auch gesundheitspolitisch wohltuend

Wir sollten Luftreinhalte- und Klimapolitik möglichst gemeinsam betreiben

Die Wirkungen des Zwischenstaatlichen Ausschusses über Klimaänderungen (IPCC)

1. Bericht: 1990	***Forderung nach UNFCCC***
Zwischenbericht 1992	***Zeichnung der UNFCC***
2. Bericht: 1995	***Kyoto-Protokoll formuliert***
3. Bericht: 2001	***Kleingedrucktes für Kyoto-Protokoll***
4. Bericht: 2007	***20, 20, 20 der EU bis 2020***
5. Bericht: 2013	***?***

Ad-hoc Study Group on Carbon Dioxide and Climate Report to the Climate Research Board , Assembly of Mathematical and Physical Sciences, National Research Council , USA, 1979

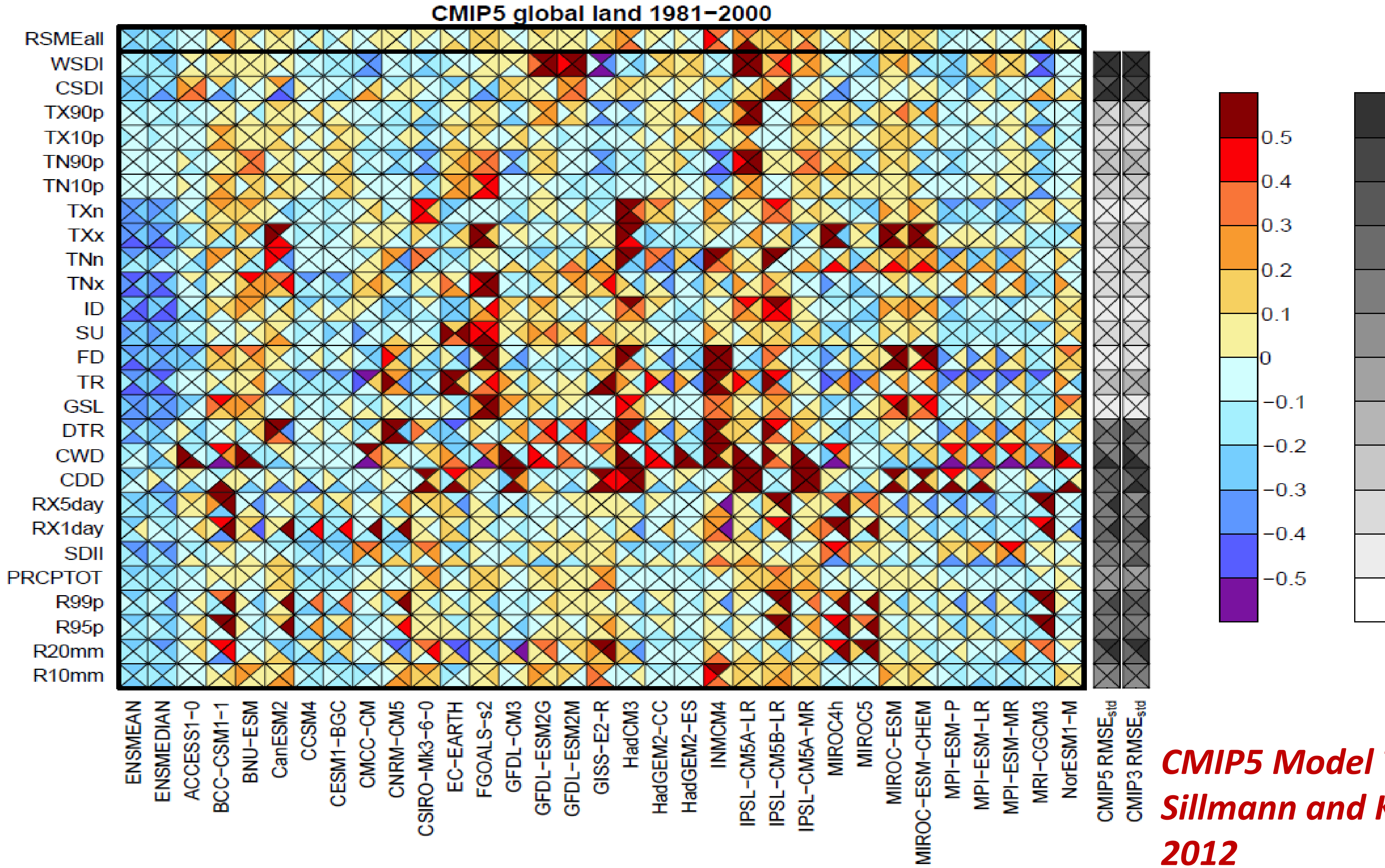
The conclusions of this brief but intense investigation may be comforting to scientists but disturbing to policymakers. If carbon dioxide continues to increase, the study group finds no reason to doubt that climate changes will result and no reason to believe that these changes will be negligible. The conclusions of prior studies have been generally reaffirmed. However, the study group points out that the ocean, the great and ponderous flywheel of the global climate system, may be expected to slow the course of observable climatic change. A wait-and-see policy may mean waiting until it is too late.

1979 National Research Council Report

"When it is assumed that CO2 ... is doubled ... the more realistic modeling efforts predict a global surface warming of 2 to3.5°C"

Through this report the enhanced greenhouse effect enters the political arena prior to the First World Climate Conference in 1979, which called for a World Climate Programme, whose research component became the well-known World Climate Research Programme (WCRP)

Can Climate Models Correctly Calculate Recent Climate ?



CMIP5 Model Test
Sillmann and Kharin 2012

Figure 10. The "portrait" diagram of relative spatially averaged RMS errors in the 1981–2000 climatologies of temperature and precipitation indices simulated by the CMIP5 models with respect to the four reanalyes, ERA40 (left triangle), ERAinterim (upper triangle), NCEP1 (right triangle) and NCEP2 (lower triangle). The RMS errors are spatially averaged over gobal land grid points. The top row indicates the mean relative RMSE across all indices for a particular model and the gray-shaded columns on the right side indicates the standardized median $RMSE_{median,std}$ for CMIP3 and CMIP5 (see text for details).

Global Energy Flows W m⁻²

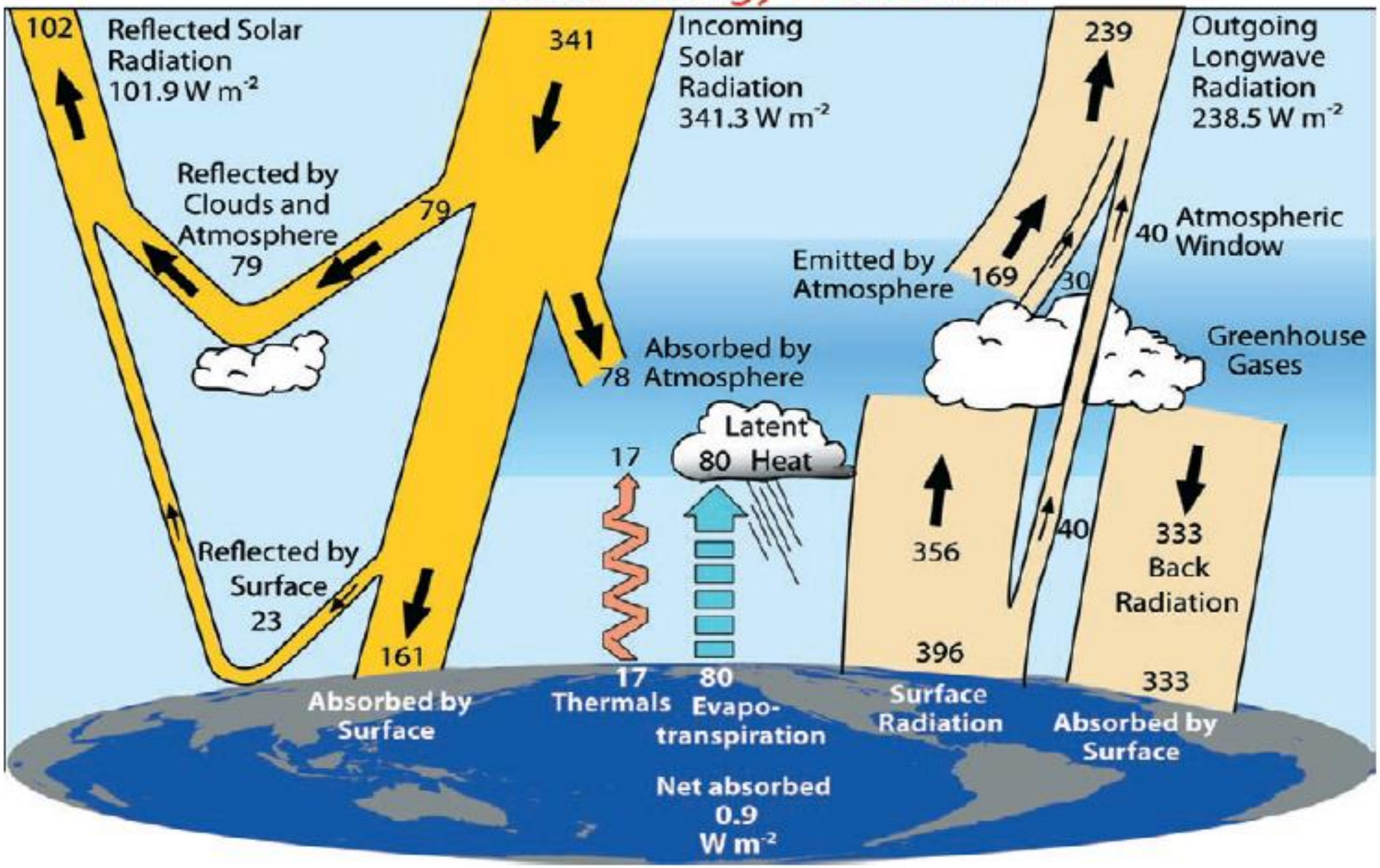


FIG. 1. The global annual mean Earth's energy budget for the Mar 2000 to May 2004 period (W m^{-2}). The broad arrows indicate the schematic flow of energy in proportion to their importance.

Trenberth et al., 2009

1796

Jean Baptiste Joseph Fourier
1768 – 1830

He was a scientist, politician, twice a prisoner and needed 15 years to publish his famous academy lectures of 1807, reshaped into a book, in 1822. Also his most frequently cited publication of 1827 with respect to the greenhouse effect is just a reprint of a publication in 1824.

Fourier (1824): *“La transparence des eaux et celle de l’air paraissent concourir à augmenter le degré de chaleur acquise, parce que la chaleur lumineuse affluente pénètre assez facilement dans l’intérieur de la masse, et que la chaleur obscure sort plus difficilement suivant une route contraire”.*

Translation by the author:
Both the transparency of water and air seem to compete to augment the heat absorbed because the incoming visible heat penetrates rather easily into the interior of the mass but the invisible heat escapes more difficult.

Fourier, J (*1824*): "Remarques Générales sur les Températures du Globe Terrestre et des Espaces Planétaires". Annales de Chimie et de Physique 27: 136–67.

Claude Servais Mathias Pouillet
16 February 1791 – 14 June 1868

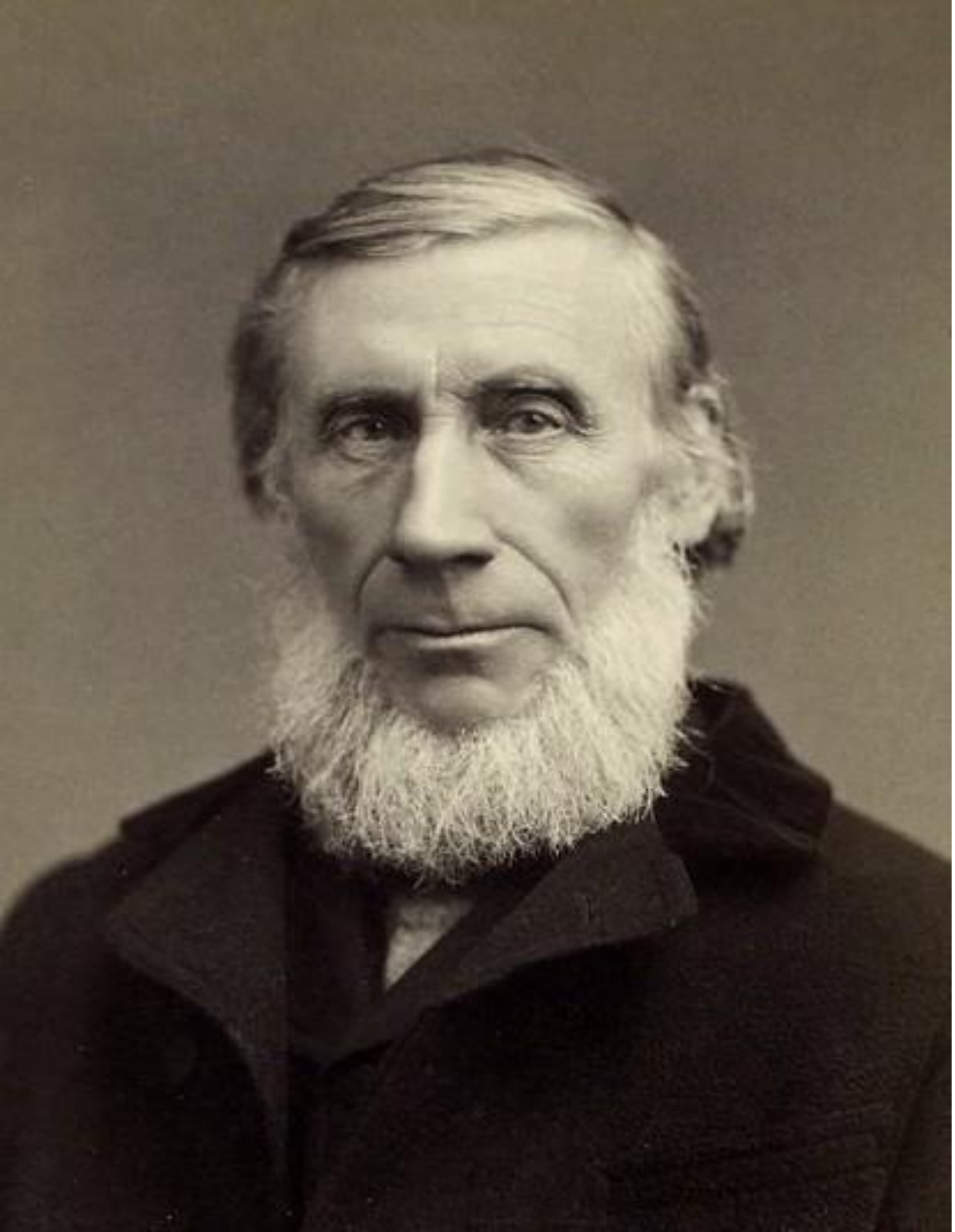
His first estimate of solar irradiance at TOA using the pyrheliometer he had constructed was 1228 W/m^2

Claude Servais Mathias Pouillet *(1791-1868), professor of physics at the Sorbonne and member of the French Academy of Science, has constructed the first pyrheliometer, an instrument that measured the quantity of heat received from the sun. He made early estimates of the thermal equivalent of solar radiation outside of the atmosphere, or the so-called solar constant, and provided* ***the first estimates of the role of water vapor for the greenhouse effect.***

"Mémoire su la chaleur solaire, sur les pouvoirs rayonnants et absorbants de l'air atmosphérique, et sur les températures de l'espace," by Pouillet, Claude S. M (1838) Comptes Rendus de l'Académie des Sciences 7, no. 2, 24-65.

Translation into English by Richard Taylor, "Memoir on Solar Heat, the Radiative Effects of the Atmosphere, and the Temperature of Space," *Scientific Memoirs* **4** (London: Taylor and Francis, 1846)

Assessed on 02 08 12 from the
National Science Digital Library (NSDL)



John Tyndall
2 August 1820 –
4 December 1893
Experimental Physicist

He was the first to publish a "modern" version of the definition of the greenhouse effect based on his own lab measurements of the transmission of many gases, among them water vapour

In 1863 Tyndall wrote:

"The solar heat possesses the power of crossing an atmosphere, but, when the heat is absorbed by the planet, it is so changed in quality that the rays emanating from the planet cannot get with the same freedom back into space. Thus the atmosphere admits the entrance of the solar heat but checks its exit, and the result is a tendency to accumulate heat at the surface of the planet"

John Tyndall (1863): On the transmission of heat of different qualities through gases of different kinds; Proceedings of the Royal Institute of Great Britain 3: 158

Svante August Arrhenius
19 February 1859 – 2 October 1927

The first to talk about anthropogenic climate change caused by an enhanced greenhouse effect of the atmosphere was the Swede Svante Arrhenius. He used the knowledge of carbon dioxide absorption bands published by Langley to argue that increased combustion of coal – at that time mainly in Great Britain – may lead to higher surface temperatures. He stated: ***'[…] if the quantity of carbonic acid [CO_2] increases in geometric progression, the augmentation of the temperature will increase nearly in arithmetic progression' (Arrhenius 1896).***

Svante Arrhenius (1896): On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground ; Philosophical Magazine and Journal of Science, Series 5, Volume 41, April 1896, pages 237-276.

Guy Stewart Callendar
February 1898 - October 1964

He developed the first full theory of anthropogenic climate change (most of his colleagues, however, did not accept it during his life-time).

THE ARTIFICIAL PRODUCTION OF **CARBON DIOXIDE**
AND ITS INFLUENCE ON TEMPERATURE

By G. S. CALLENDAR
Steam technologist to the British Electrical **and Allied Industries** Research Association, communicated by Dr. G. M. B. **DOBSON F.R.S.)**

[Manuscript received May 19, 1937-read February 16, 1938.

SUMMARY

By fuel combustion man has added about 150,000 million tons of carbon dioxide to the air during the past half century. The author estimates from the best available data that approximately three quarters of this has remained in the atmosphere. The radiation absorption coefficients of carbon dioxide and water vapour are used to show the effect of carbon dioxide on " sky radiation." From this the increase in mean temperature, due to the artificial production of carbon dioxide, is estimated to be at the rate of 0.003°C per year at the present time. The temperature observations at 100 meteorological stations are used to show that world temperatures have actually increased at an average rate of 0.005°C per year during the past half century.   (QJRMS,1938)

Guy Stuart Callendar added a year later:

'As man is now changing the composition of the atmosphere at a rate which must be very exceptional on the geological time scale, it is natural to seek for the probable effects of such a change. From the best laboratory observations it appears that the principal result of increasing carbon dioxide [...] would be a gradual increase in the mean temperature of the colder regions of the Earth'.

Callendar, G. S. (1939): The composition of the atmosphere through the ages. *Meteorological Magazine* 74: 33–39.