

Remote Sensing van de Atmosfeer

WND conferentie, 2016

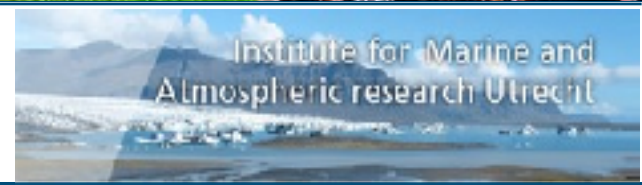
Prof. Maarten Krol
SRON, WU, IMAU



WAGENINGEN UNIVERSITY
WAGENINGEN UR

SRON

Netherlands Institute for Space Research



Institute for Marine and
Atmospheric research Utrecht

Inhoud

- “remote sensing”: definitie
 - Afhankelijk van de golflengte van het licht
 - Verschillende meetconfiguraties
 - Terug-rekenen
- Toepassingen
 - Ozon (“het gat in de ozonlaag”)
 - Stikstofdioxide (vervuiling aan de grond)
 - Koolmonoxide (Vervuiling door b.v. bosbranden)
 - Kooldioxide (Broeikasgas, uitstoot, opname)
 - Fluorescentie

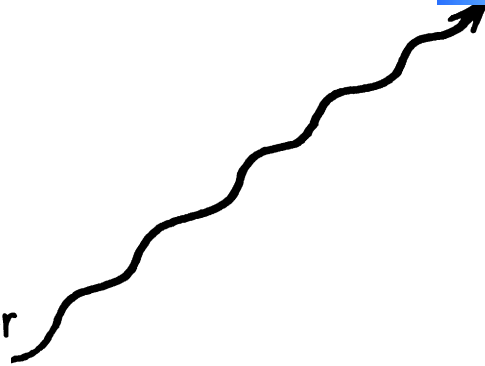
Stephens et al., Remote Sensing of the Lower Atmosphere, 1994

Principe van Remote Se

Gebruik maken van zonlicht dat wordt verstrooid door de aarde en haar atmosfeer



Transmitter



Scatterer



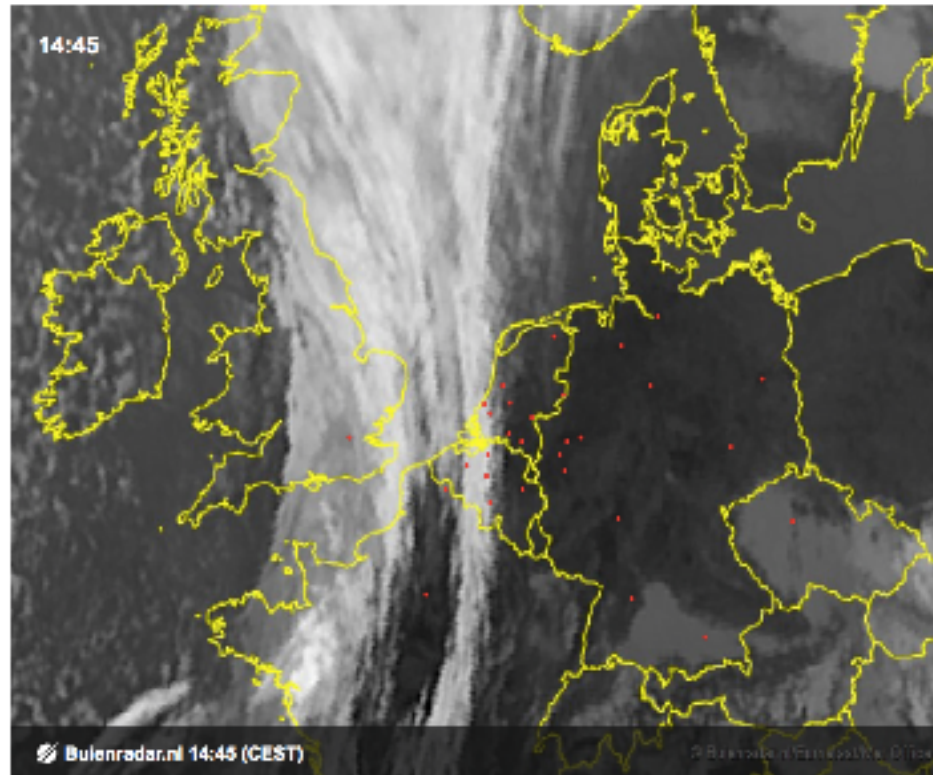
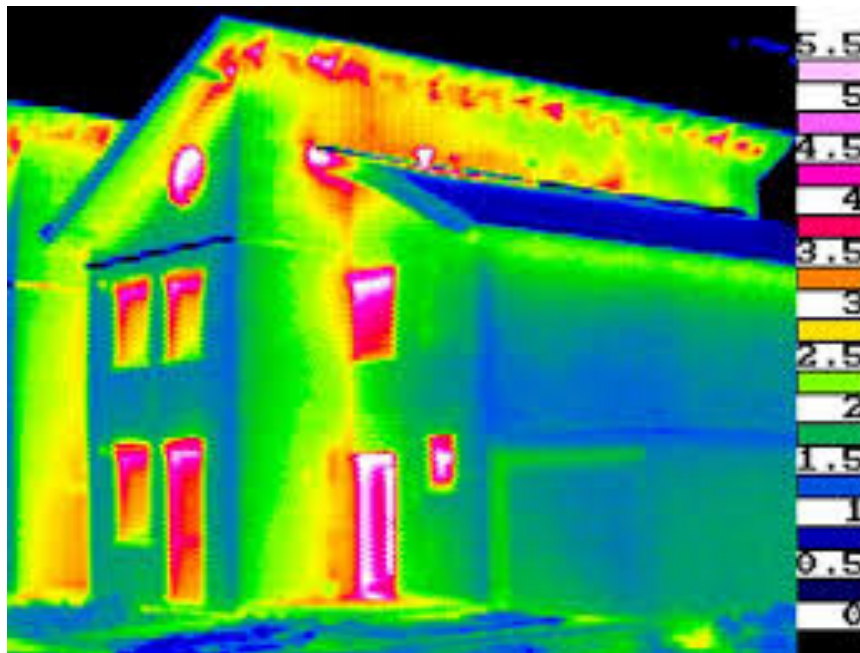
Receiver



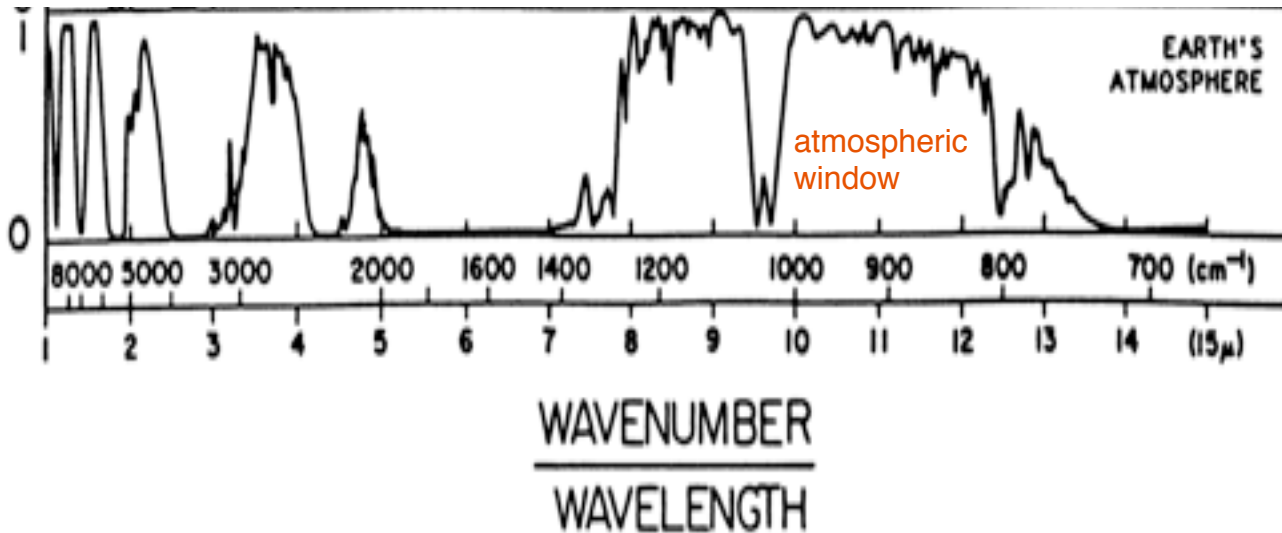
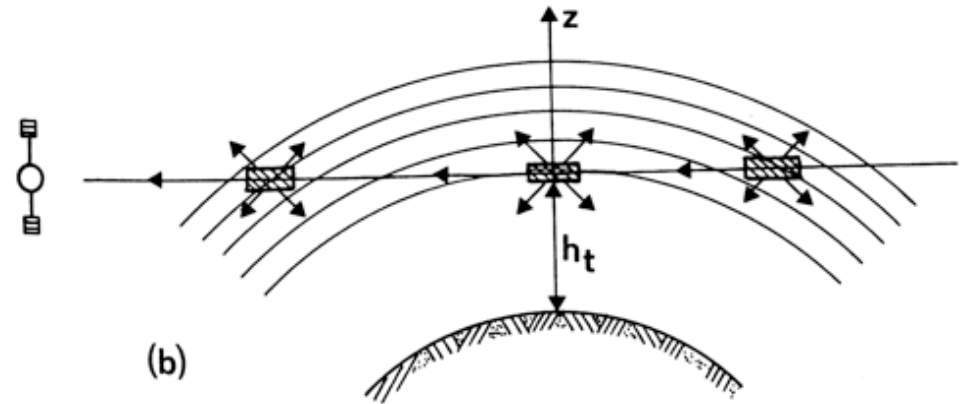
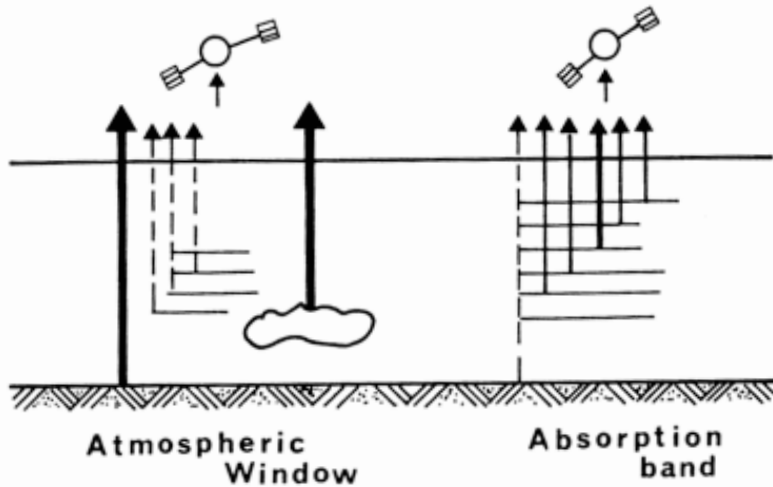
Type Remote Sensing

- Actief
 - Gebruik van een controleerbare energiebron (b.v. radar)
- Passief
 - Meet uitgezonden of gereflecteerde straling
- Kijk-geometrie
 - Nadir (naar beneden kijkend)
 - Limb (door de atmosfeer heen kijkend)

Gebruik maken van de warmtestraling die door de aarde wordt uitgestraald



Voorbeeld: Infrarode straling



1: volledig transparant

0: opaque

Retrieval (terug-rekenen)

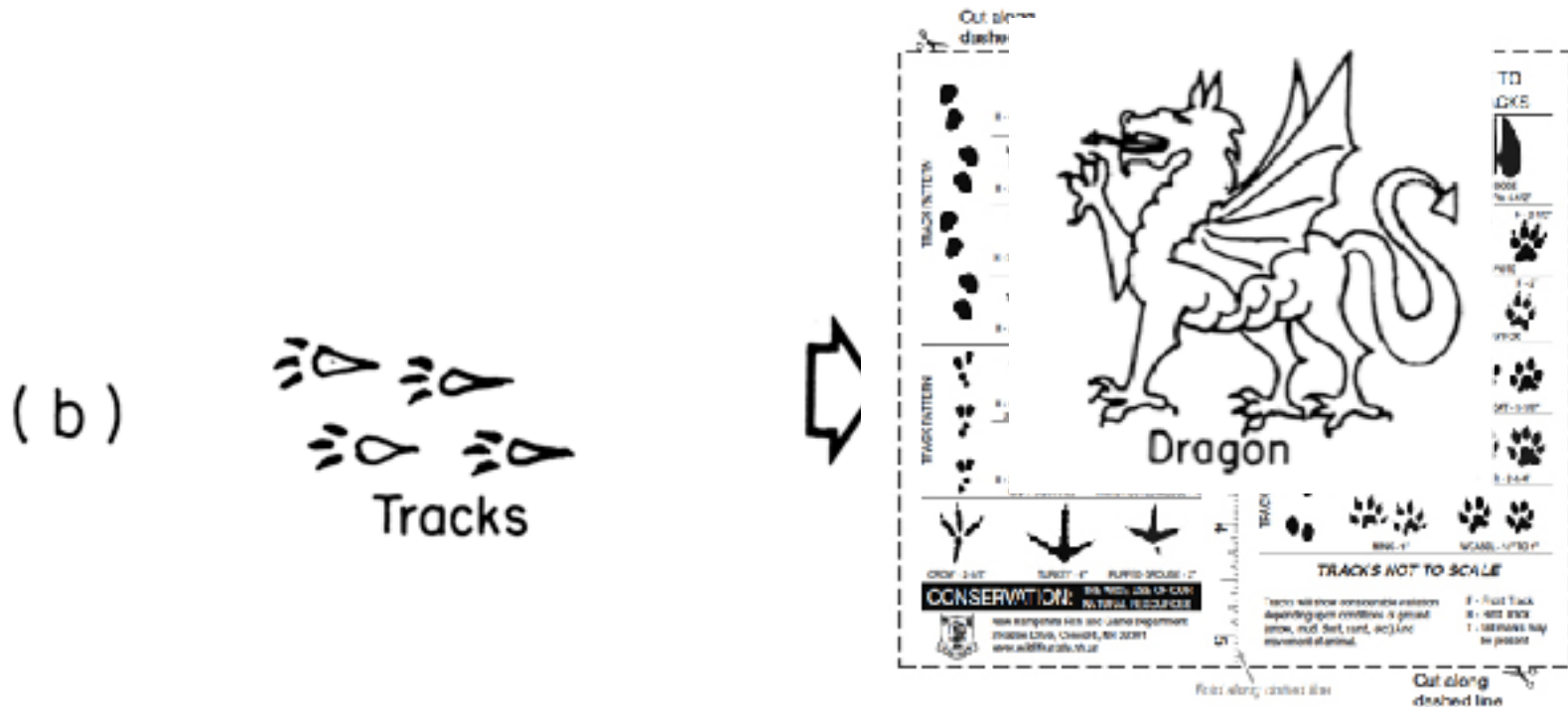
Karakteristiek voor Remote Sensing



“Forward problem”

Retrieval (terug-rekenen)

Karakteristiek voor Remote Sensing



“Inverse problem”

Retrieval “Problems”:

- niet-unieke oplossing
- instabiliteiten
- gevoeligheid voor meetfout

$$y_i + \epsilon_i = \int K_i(z)x(z)dz$$

Meting fout Integraal functie

$$y_i = \int K_i(z)x(z)dz$$
$$\mathbf{y} = \mathbf{Kx}$$

Retrieval Problems

$$\begin{array}{|c|c|} \hline 1.0 & 1.0 \\ \hline 2.0 & 2.000001 \\ \hline \end{array} \quad \begin{array}{|c|} \hline 1.0 \\ \hline 1.0 \\ \hline \end{array} = \begin{array}{|c|} \hline 2.0 \\ \hline 4.000001 \\ \hline \end{array}$$

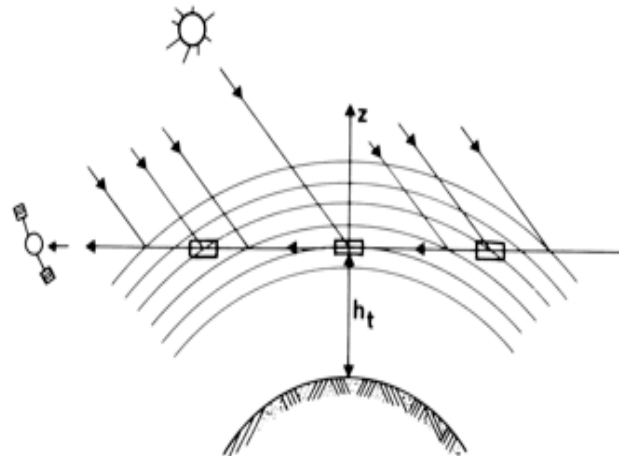
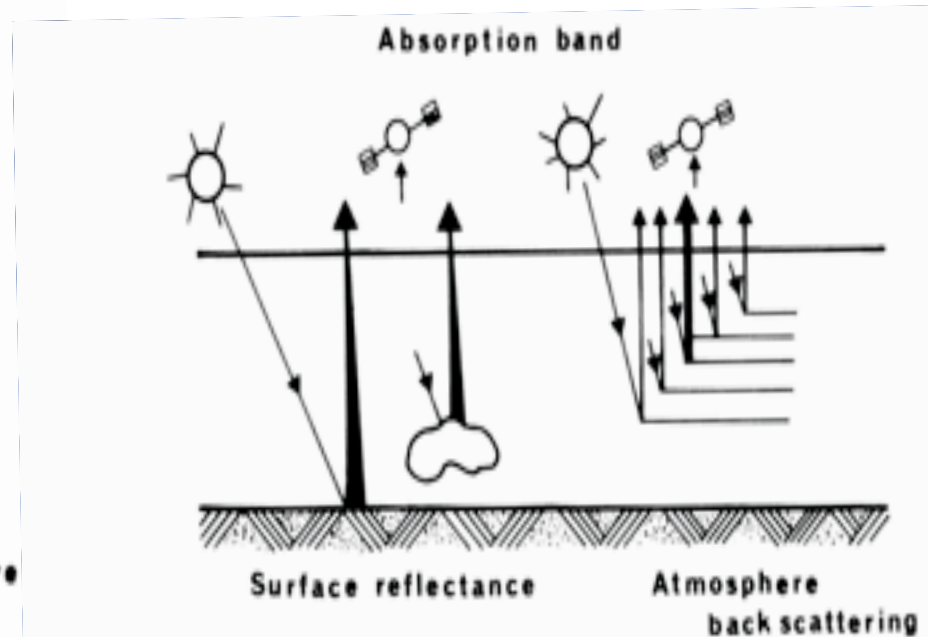
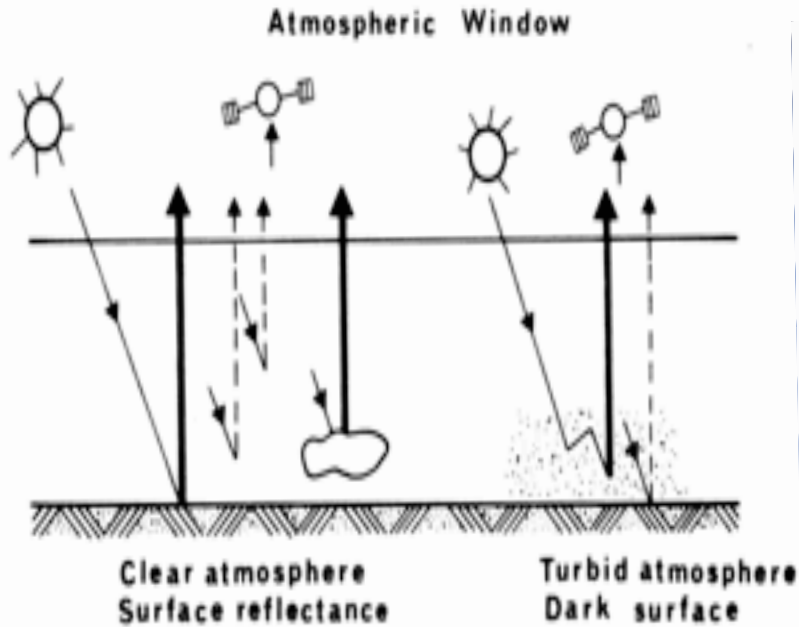
$K \quad x \quad = \quad y$

Voorwaarts probleem

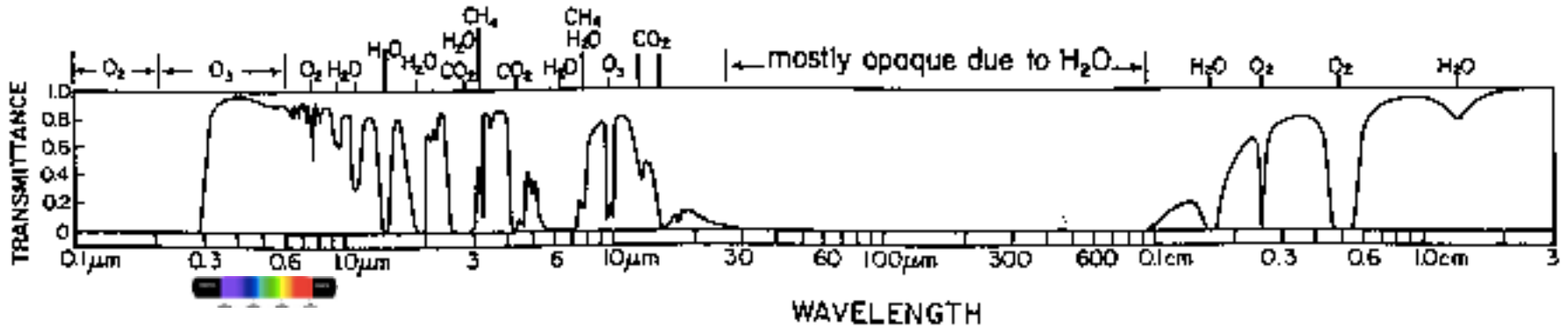
$$\begin{array}{|c|} \hline y_m \\ \hline 2.0 \\ \hline 4.0 \\ \hline \end{array} = \begin{array}{|c|c|} \hline 1.0 & 1.0 \\ \hline 2.0 & 2.000001 \\ \hline \end{array} \begin{array}{|c|} \hline x_1 \\ \hline x_2 \\ \hline \end{array}$$
$$\begin{array}{|c|} \hline x_1 \\ \hline x_2 \\ \hline \end{array} = \begin{array}{|c|} \hline 2 \\ \hline 0 \\ \hline \end{array}$$

Inversie probleem

Het meten van teruggekaatst zonlicht

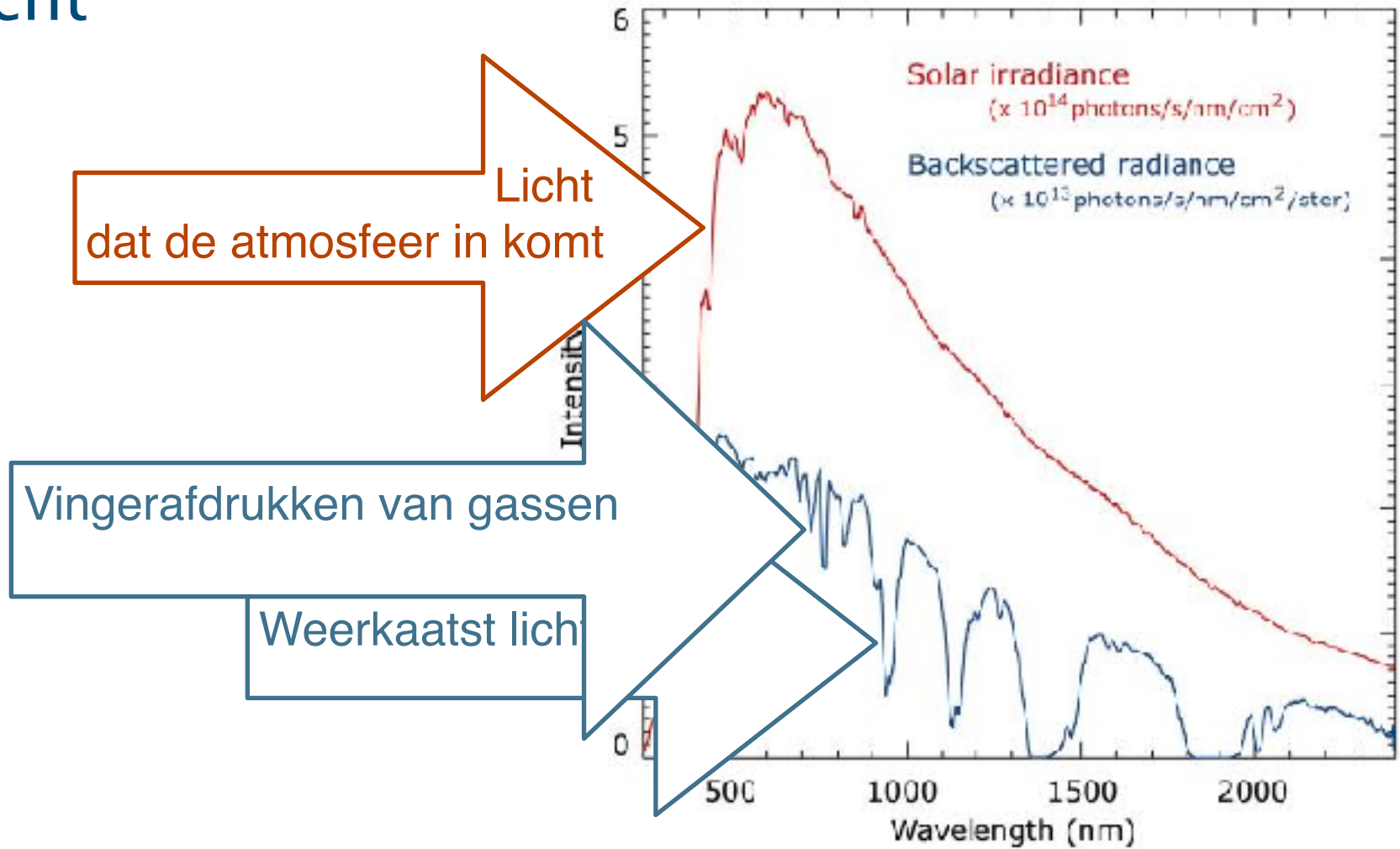


Afhankelijk van de atmosferische eigenschappen

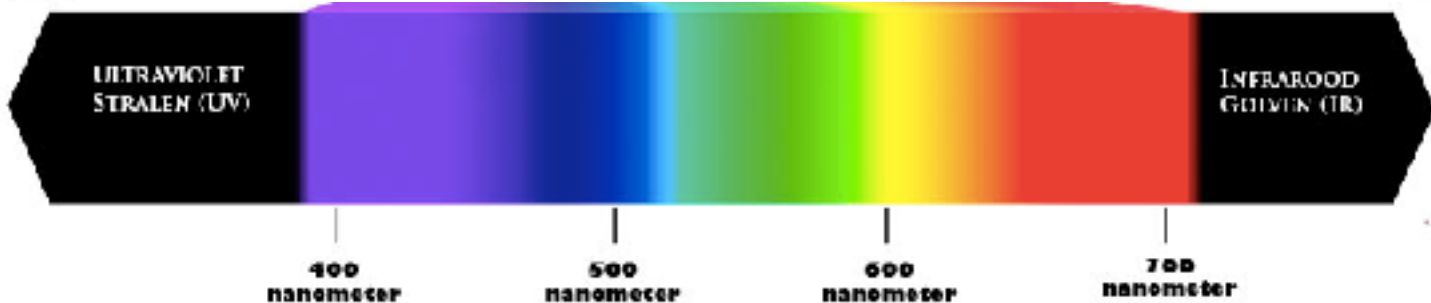
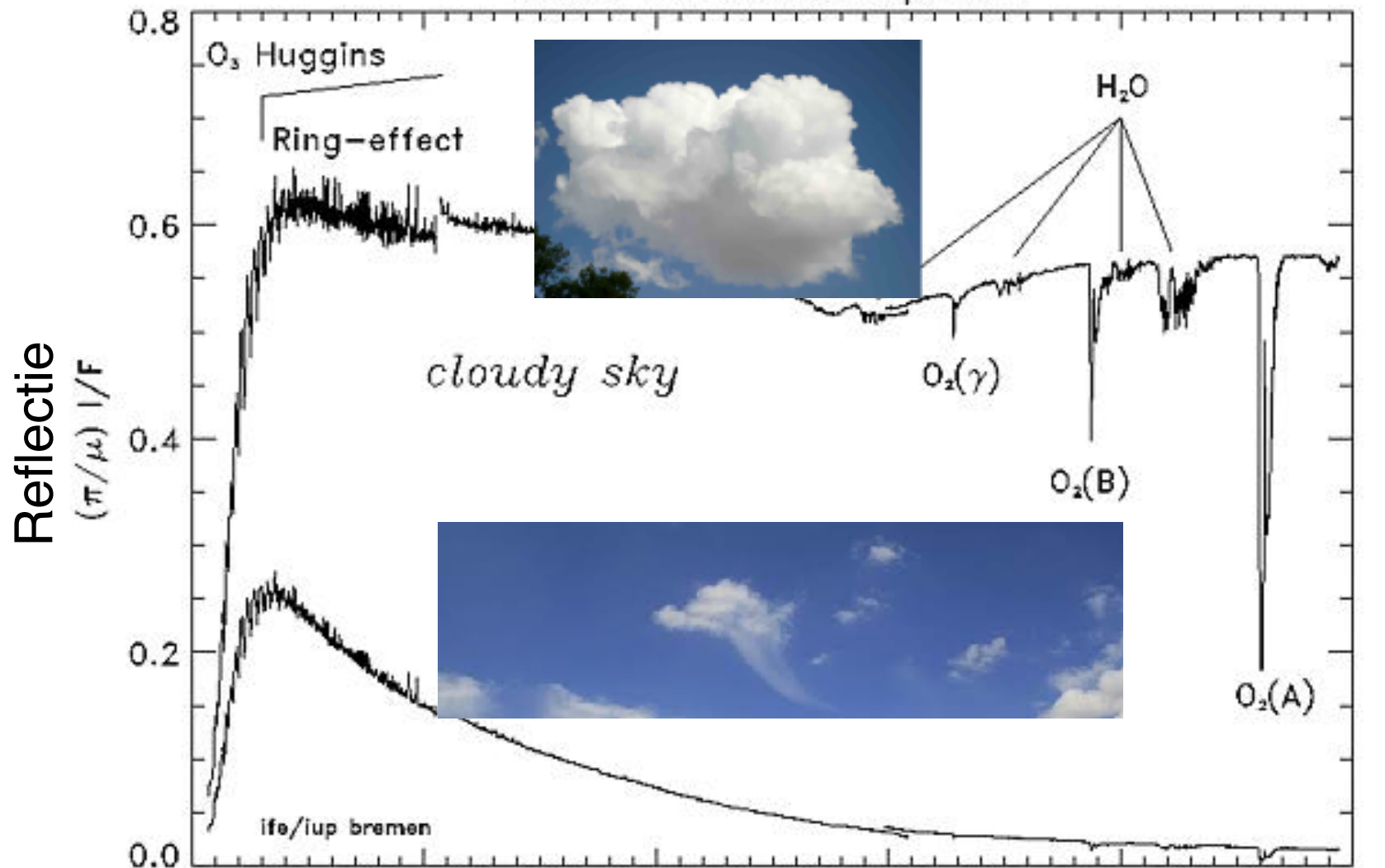


UV SWIR TIR
zichtbaar

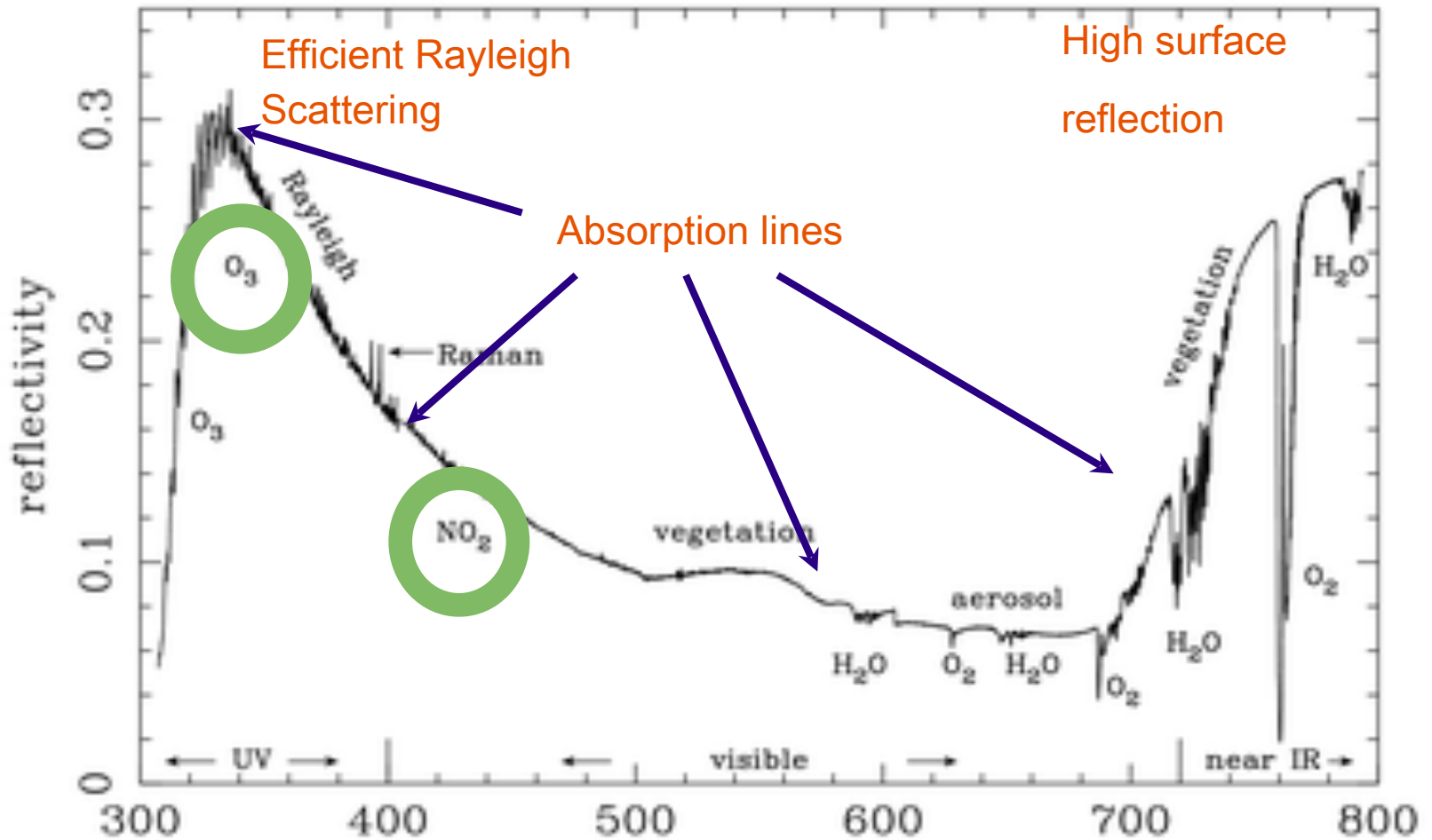
Satellieten die meten in het UV en zichtbare licht



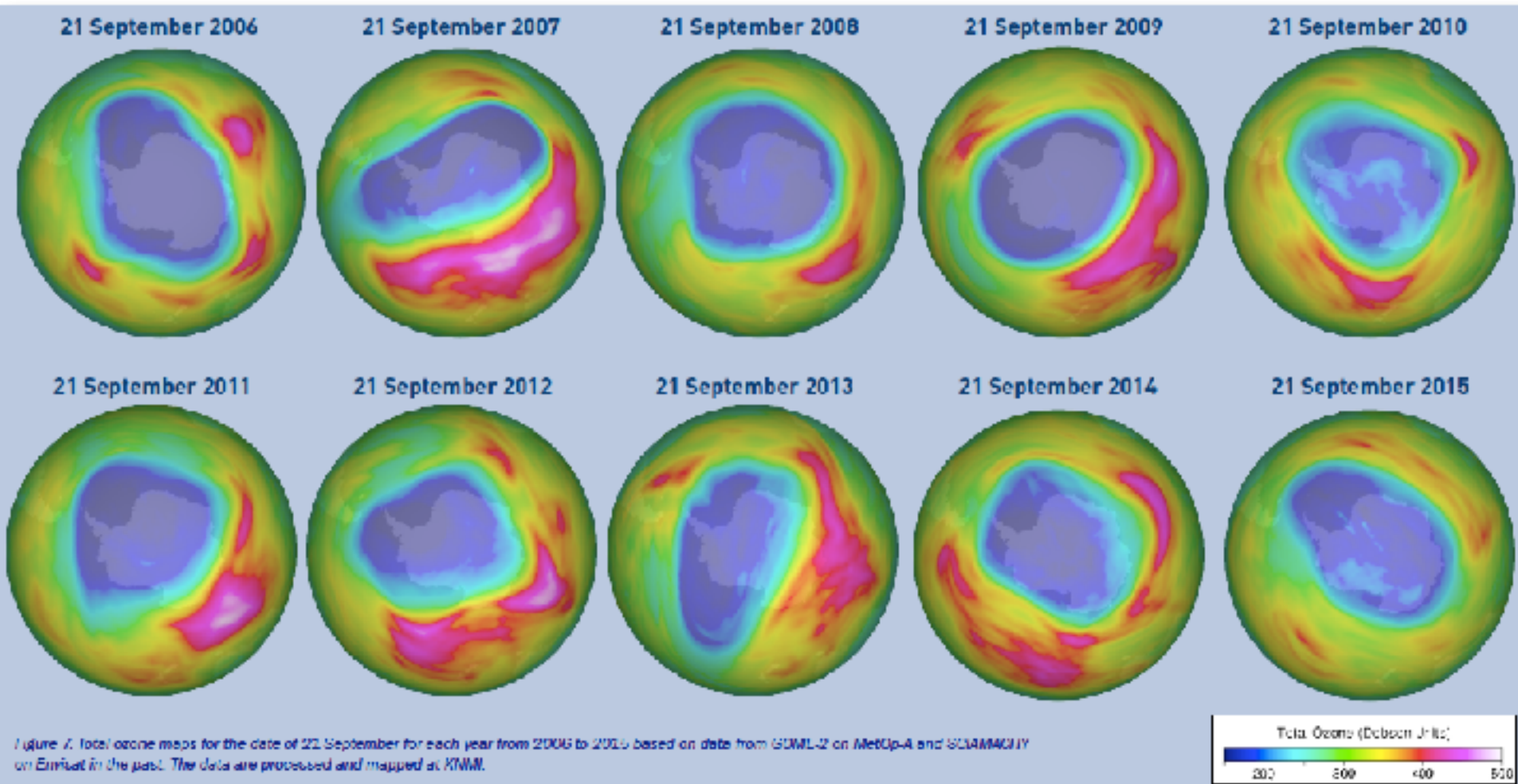
GOME Earthshine Spectra



Solar Radiation/Earth radiation

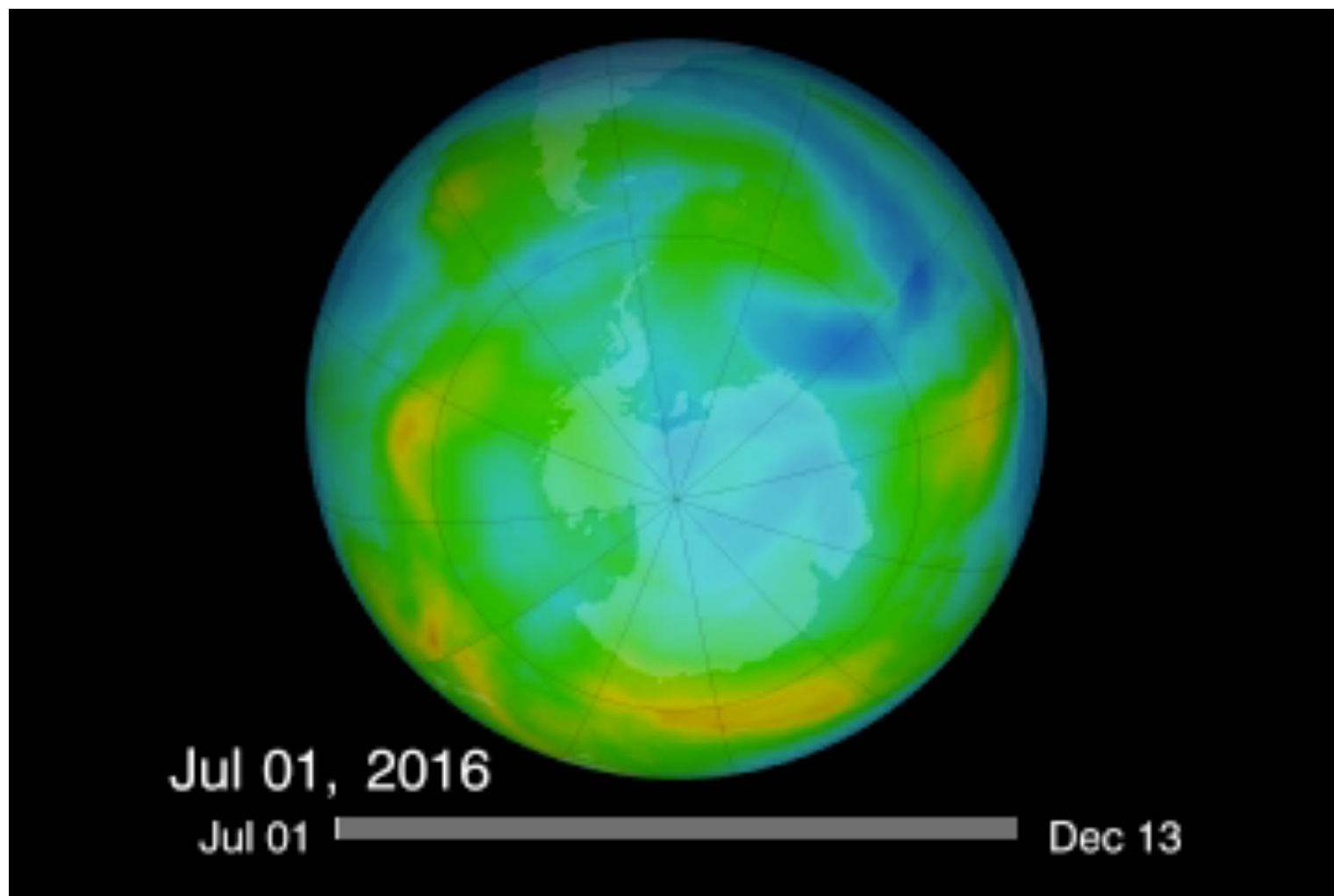


Wordt het ozongat kleiner?



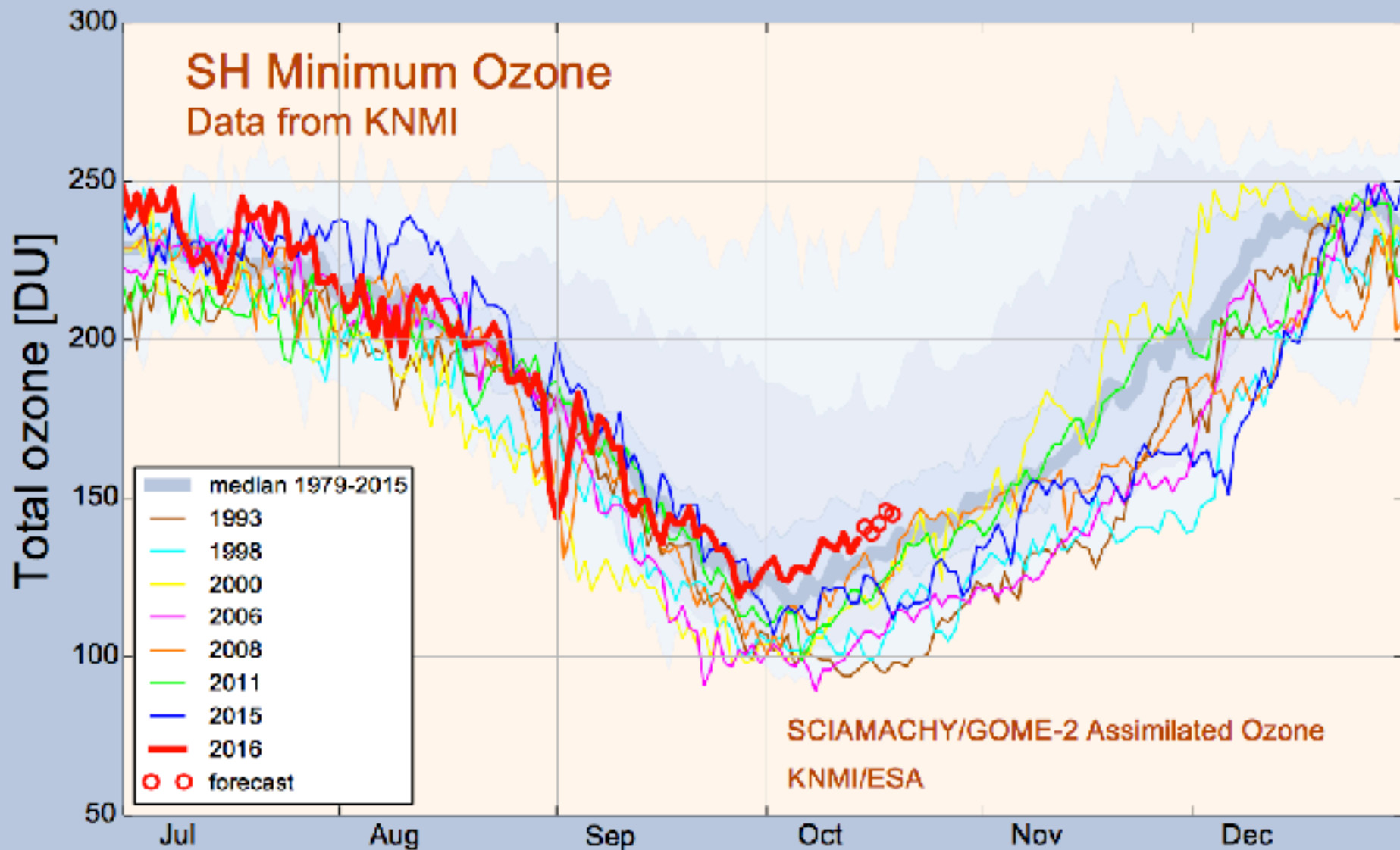
WMO arctic ozone bulletin 2, 2015

Jaarlijks gat in de ozonlaag:



Herstel? Verwacht in 2050

WMO arctic ozone bulletin 2, 2016



Stikstofdioxide vanuit de ruimte (SCIAMACHY)

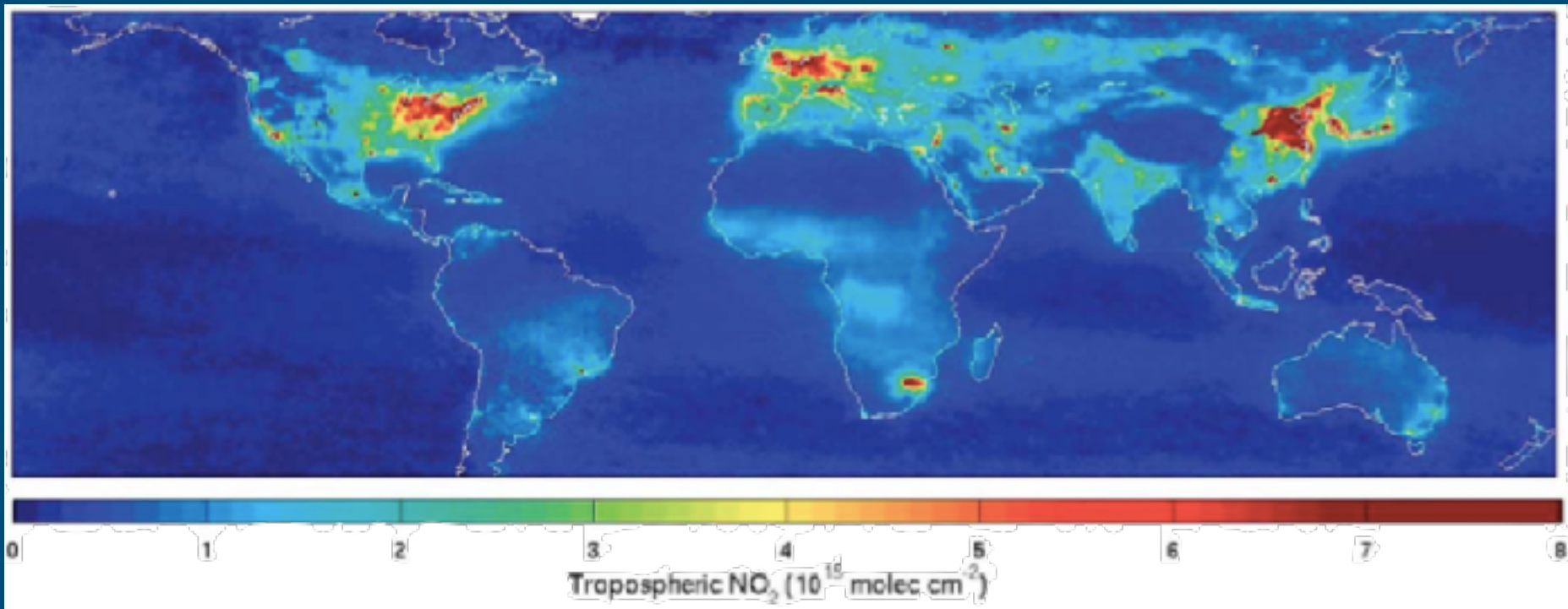
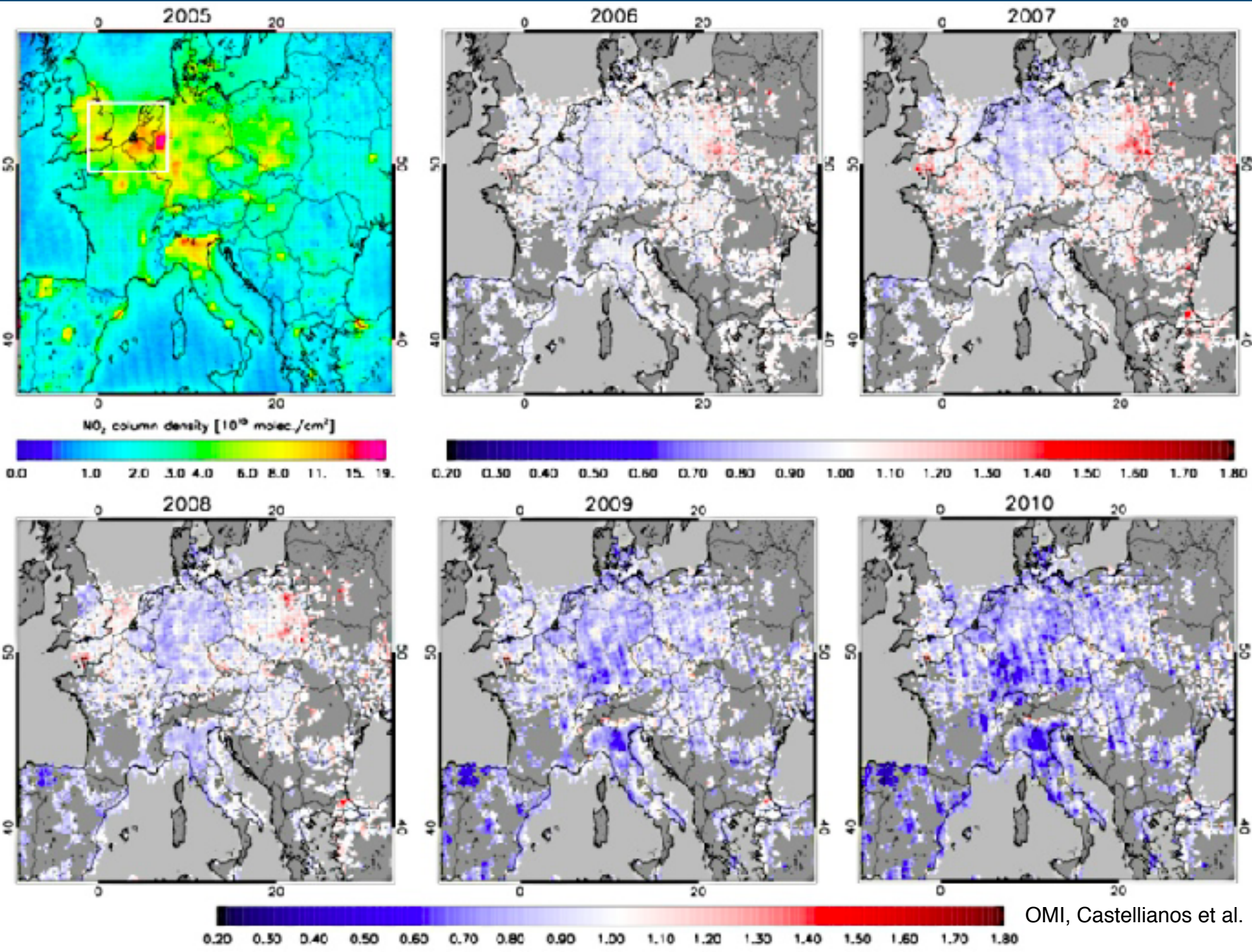


FIG. 5. Tropospheric NO₂ columns retrieved by Martin et al. (2006) from the SCIAMACHY satellite instrument for Jan 2003 - Dec 2005 inclusive.





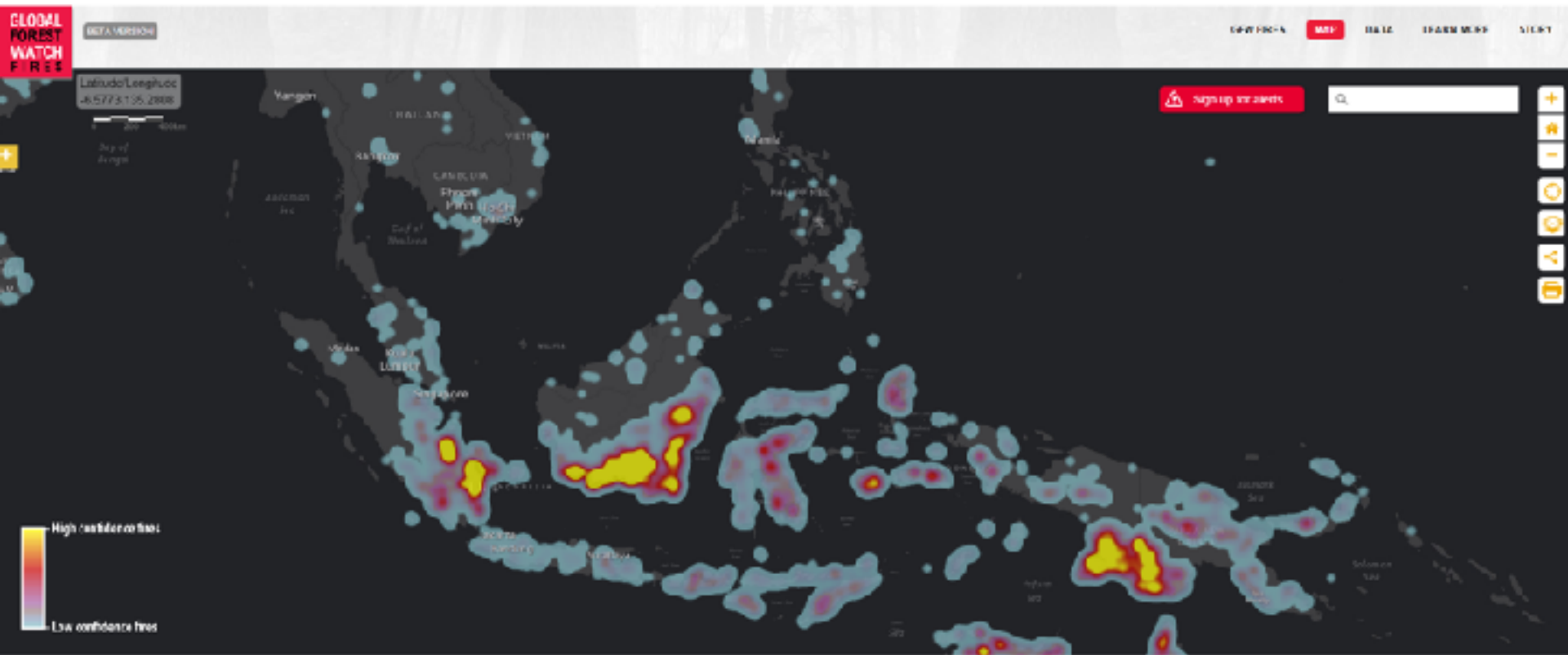
Koolmonoxide (CO)

- Komt vrij bij incomplete verbranding
 - Verkeer
 - Industrie
 - Bosbranden
- CO kan goed met satellieten gemeten worden
 - nu meestal in het IR (IASI instrument)
 - TROPOMI (juni 2017) gaat CO in SWIR meten
- Data-assimilatie:
 - Aanpassen van de CO-uitstoot in het model totdat we de satelliet-metingen reproduceren



An Indonesian woman rides a motorbike amid thick haze in Palangkaraya, Central Kalimantan province, Indonesia. Photograph: Hugo Hudoyoko/EPA

INDONESIA FIRES CONCENTRATED IN SUMATRA, KALIMANTAN AND PAPUA

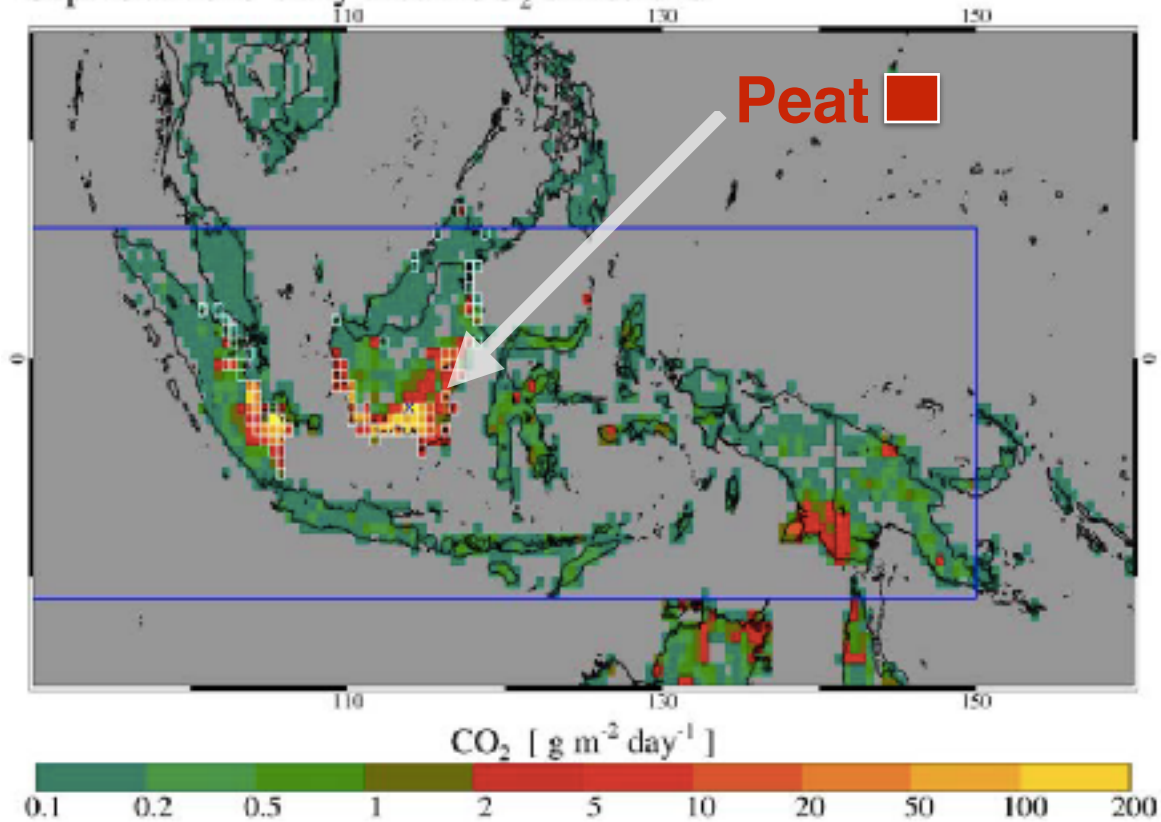


fires.globalforestwatch.org

 WORLD RESOURCES INSTITUTE

Grote bron van CO₂ (dat ligt opgeslagen in “Veen” (Peat))

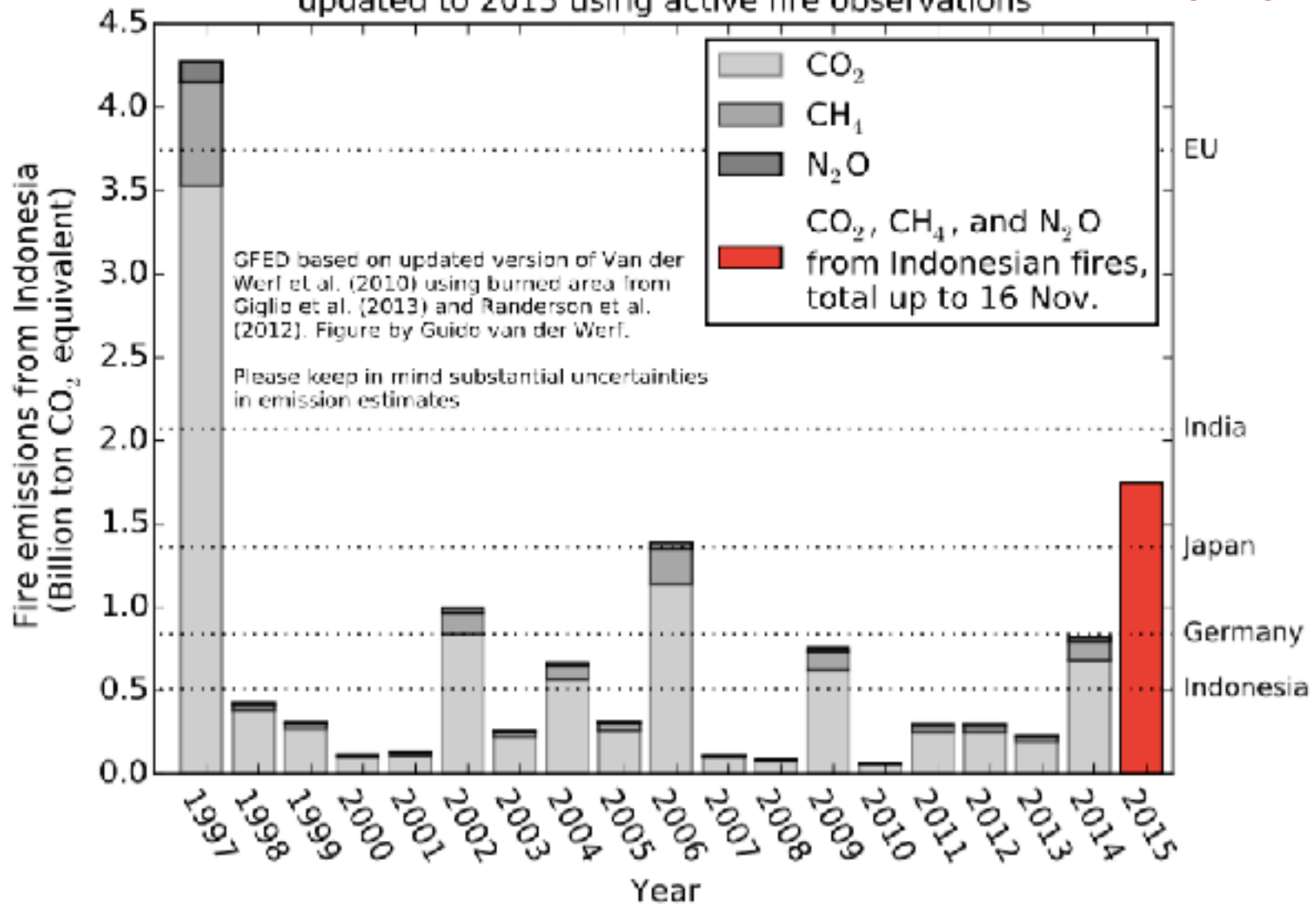
Sept-Oct 2015 daily mean CO₂ emissions



Huijnen et al., 2016,
Nature Scientific Reports

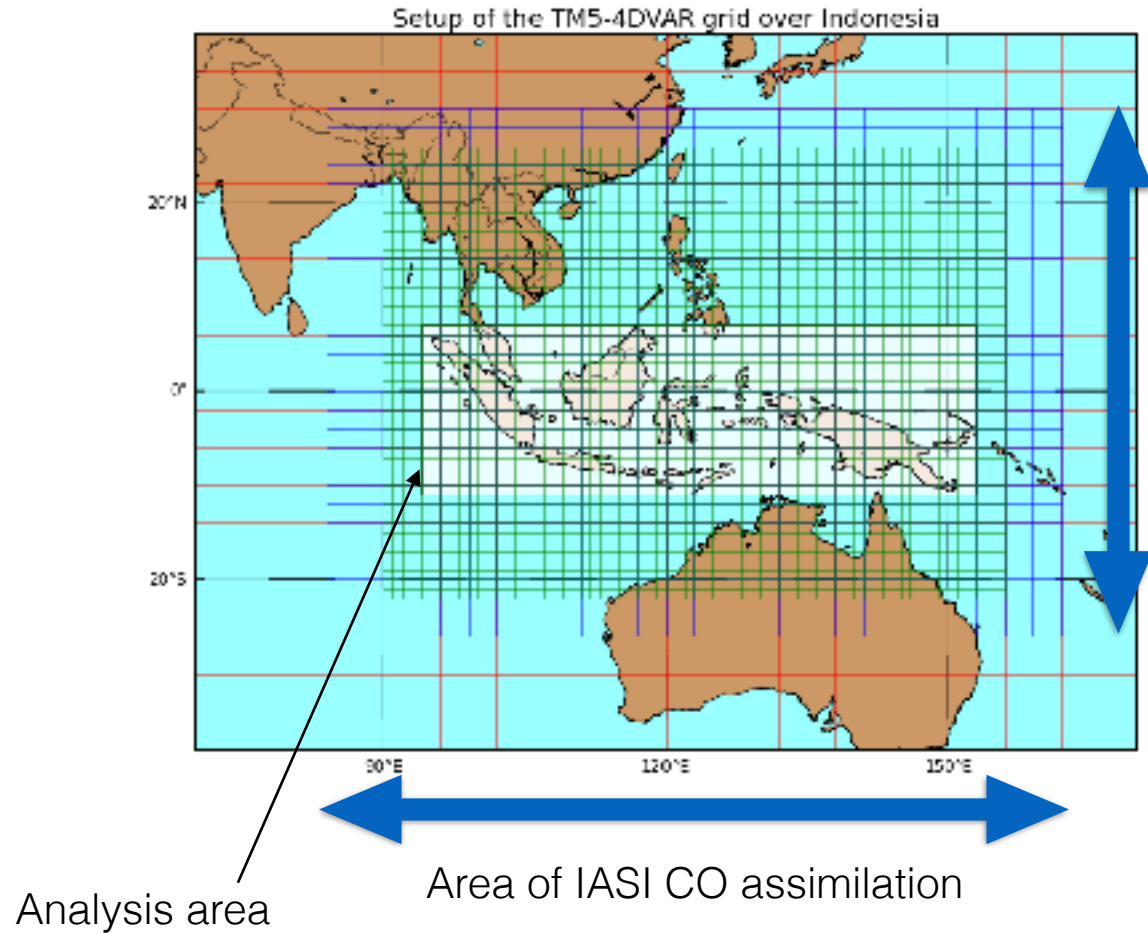
1.7 Pg CO₂ =
0.46 Pg C

Global Fire Emissions Database (GFED)
updated to 2015 using active fire observations



Fossil fuel CO₂ emissions for various countries in the year 2013 based on the EDGAR database

Model systeem voor het bepalen van CO emissies:

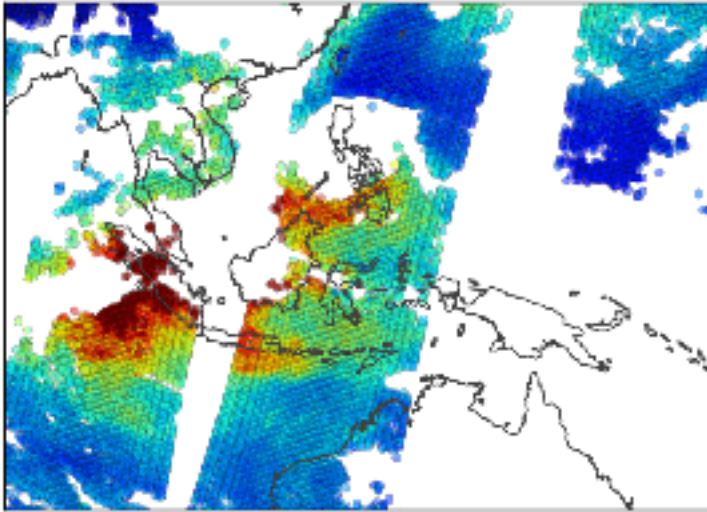


CO totale kolommen

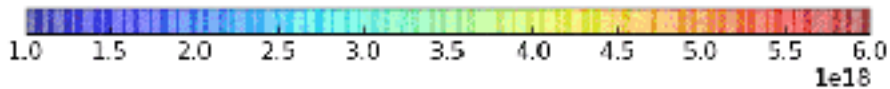
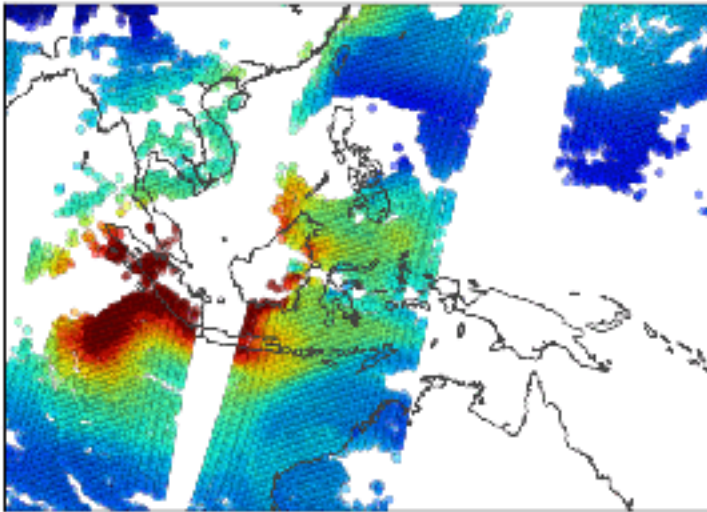
Satelliet waarnemingen

Model met geoptimaliseerde CO uitstoot

IASI columns (#/cm2) (month,day)(10,1)

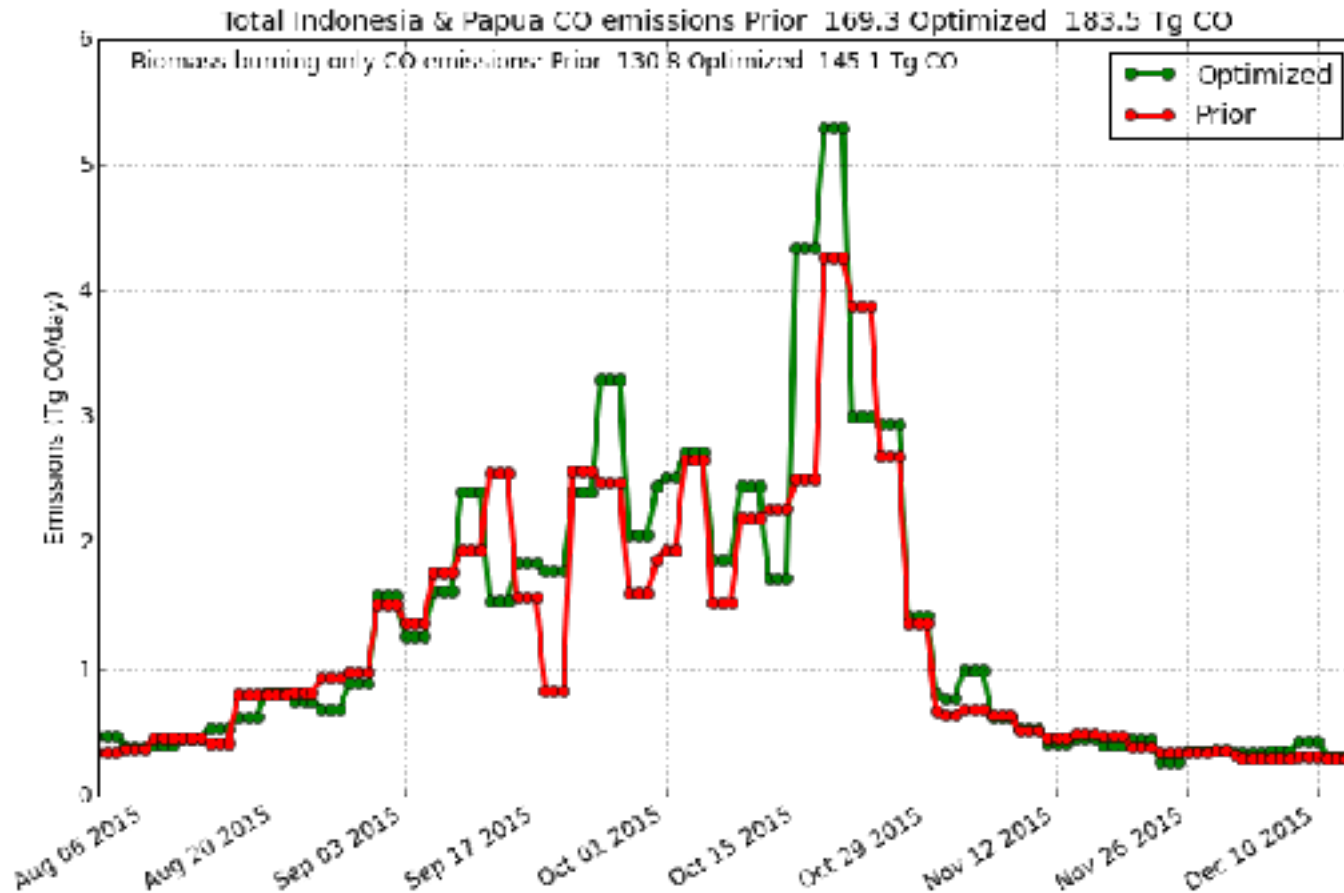


poste Modeled columns (#/cm2) (month,day)(10,1)

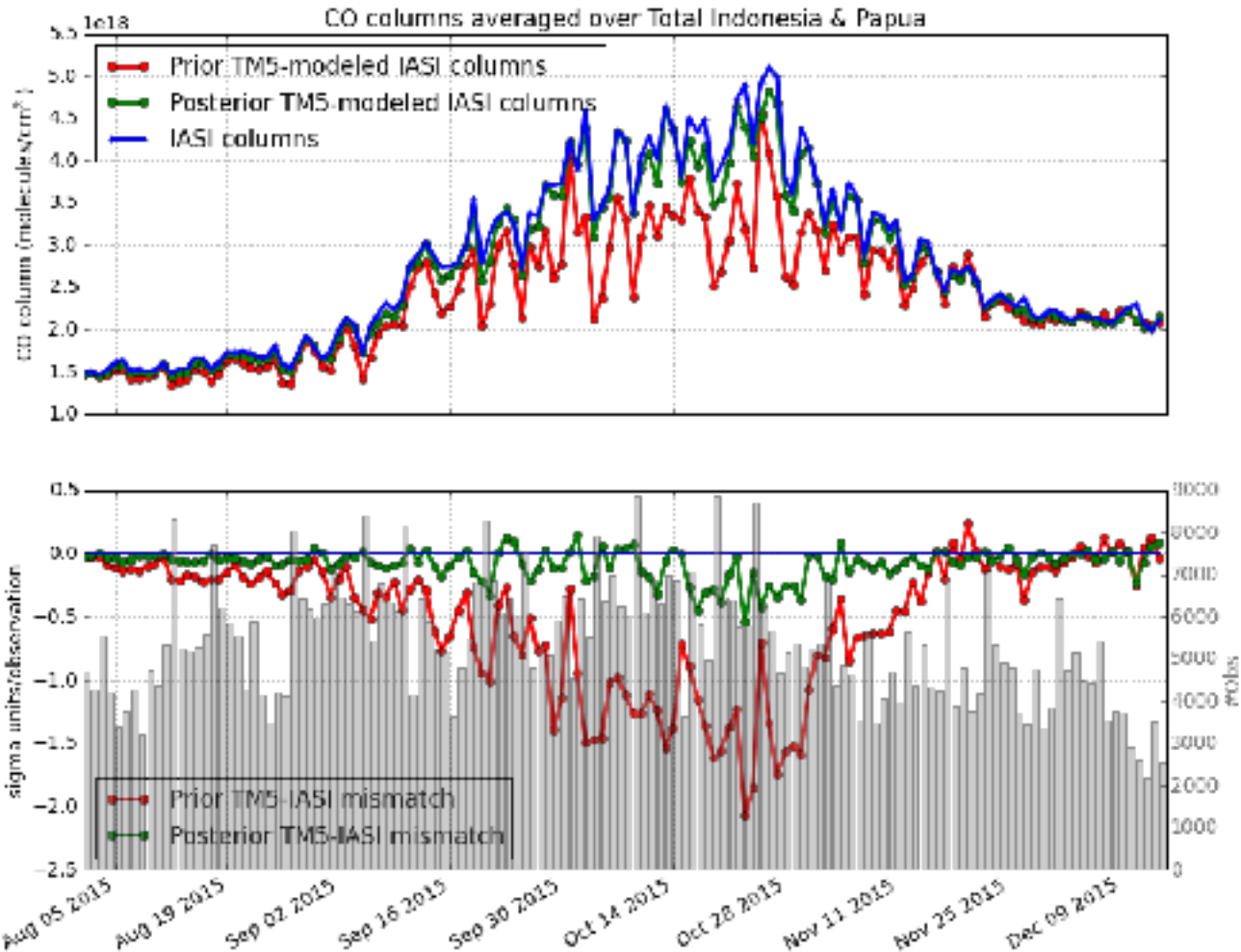


6×10^{18} molecules CO cm^{-2} = 280 ppb

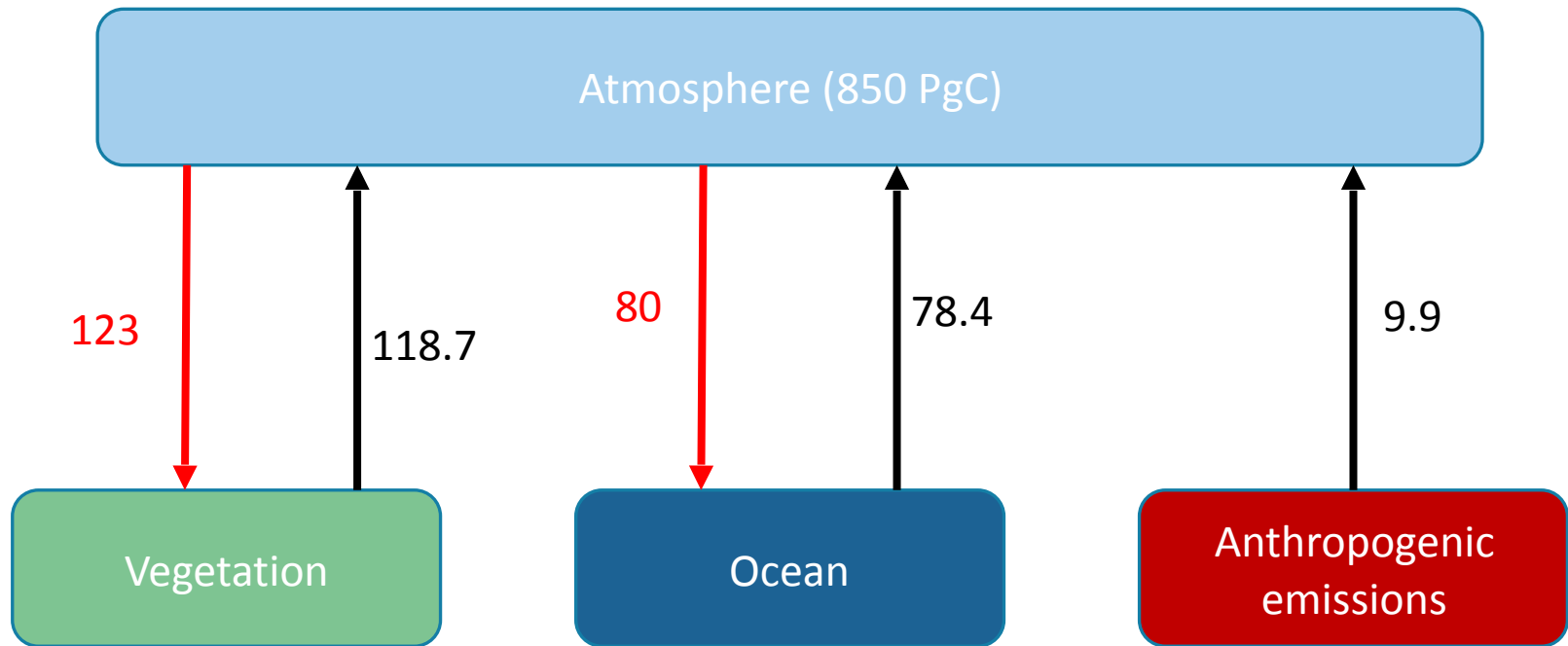
Total Indonesia & Papua



Total Indonesia & Papua



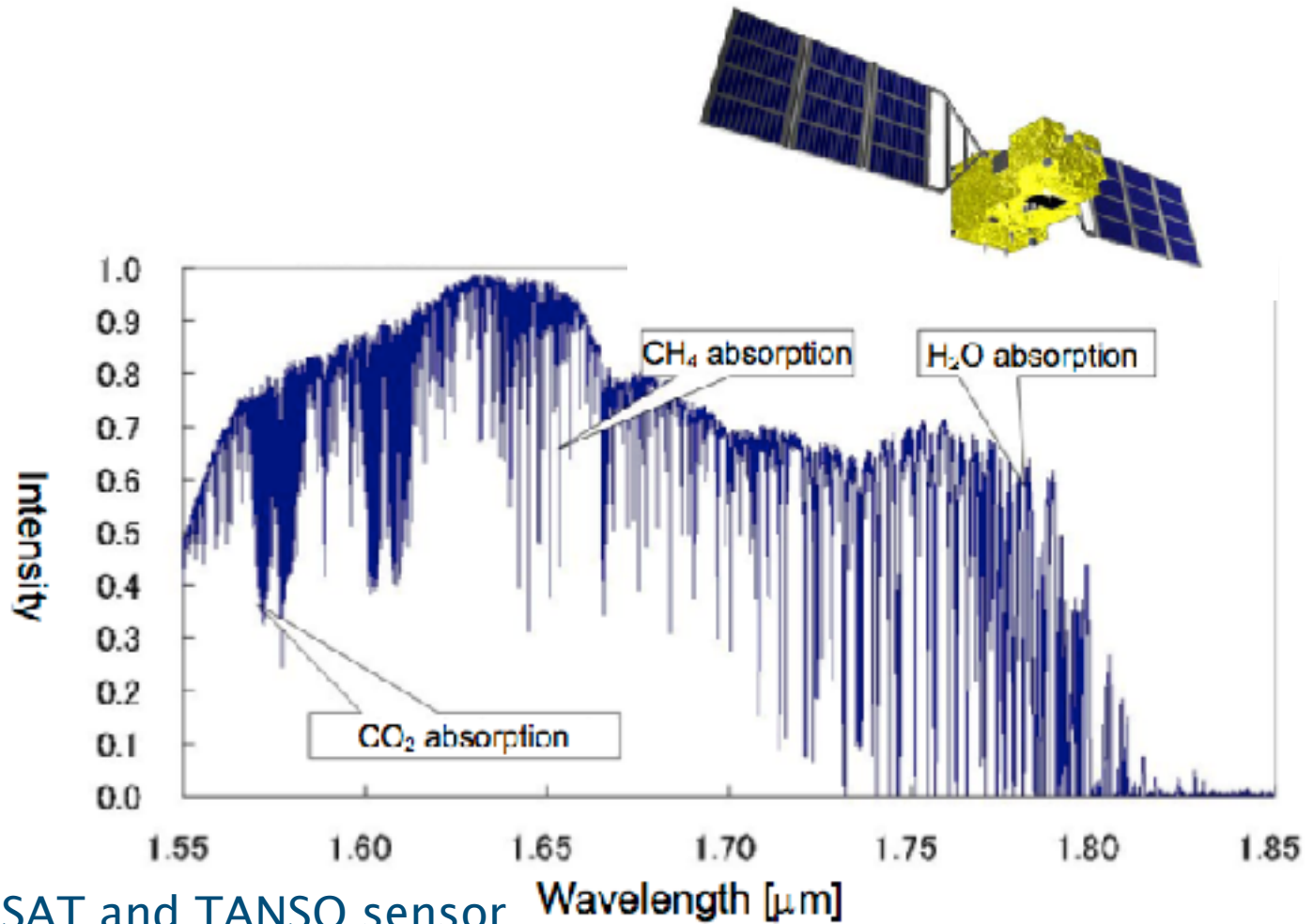
The Global Carbon Budget



Units are in PgC / yr

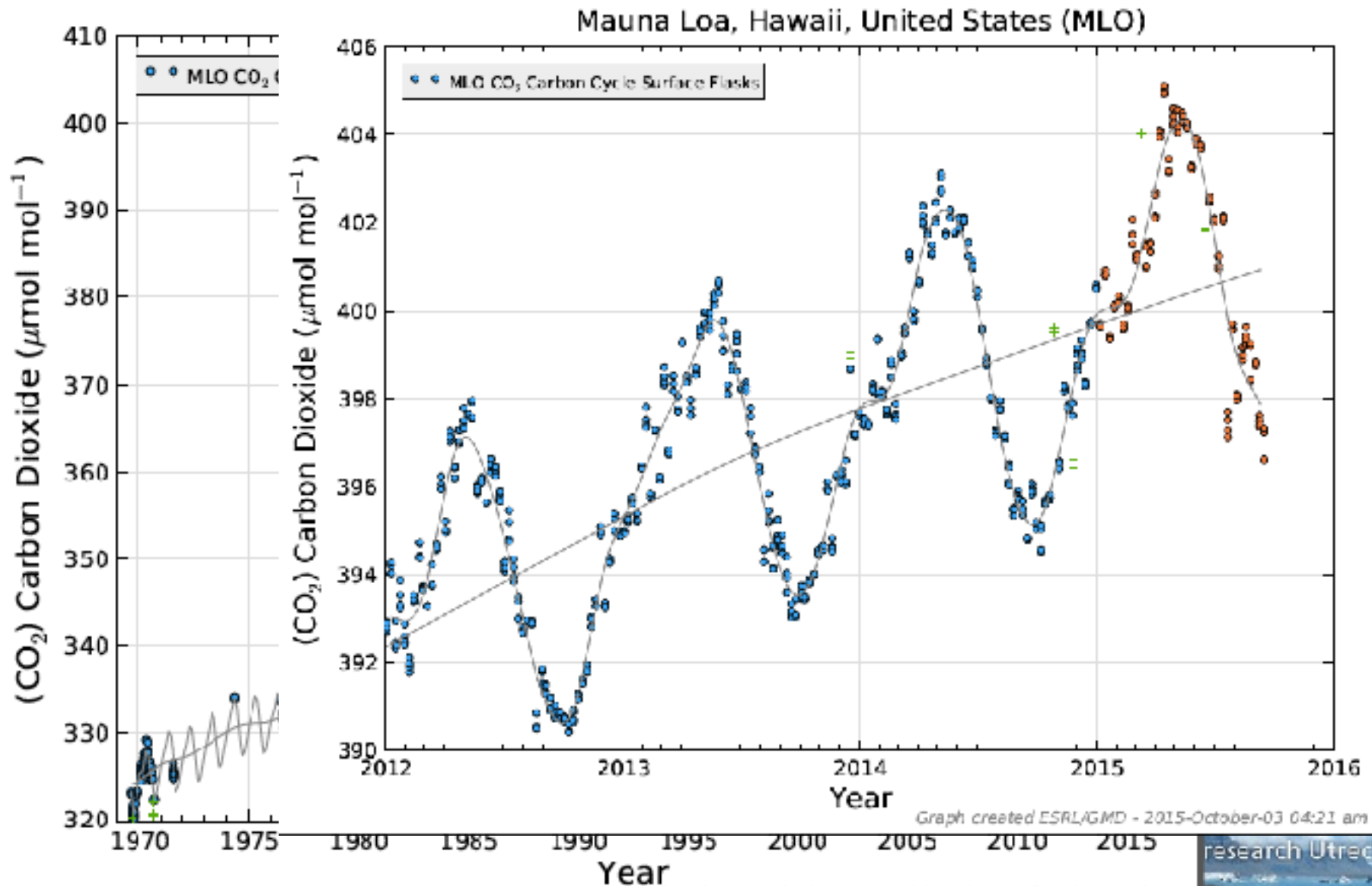
Kunnen we broeikasgassen zien vanuit de ruimte?

JA

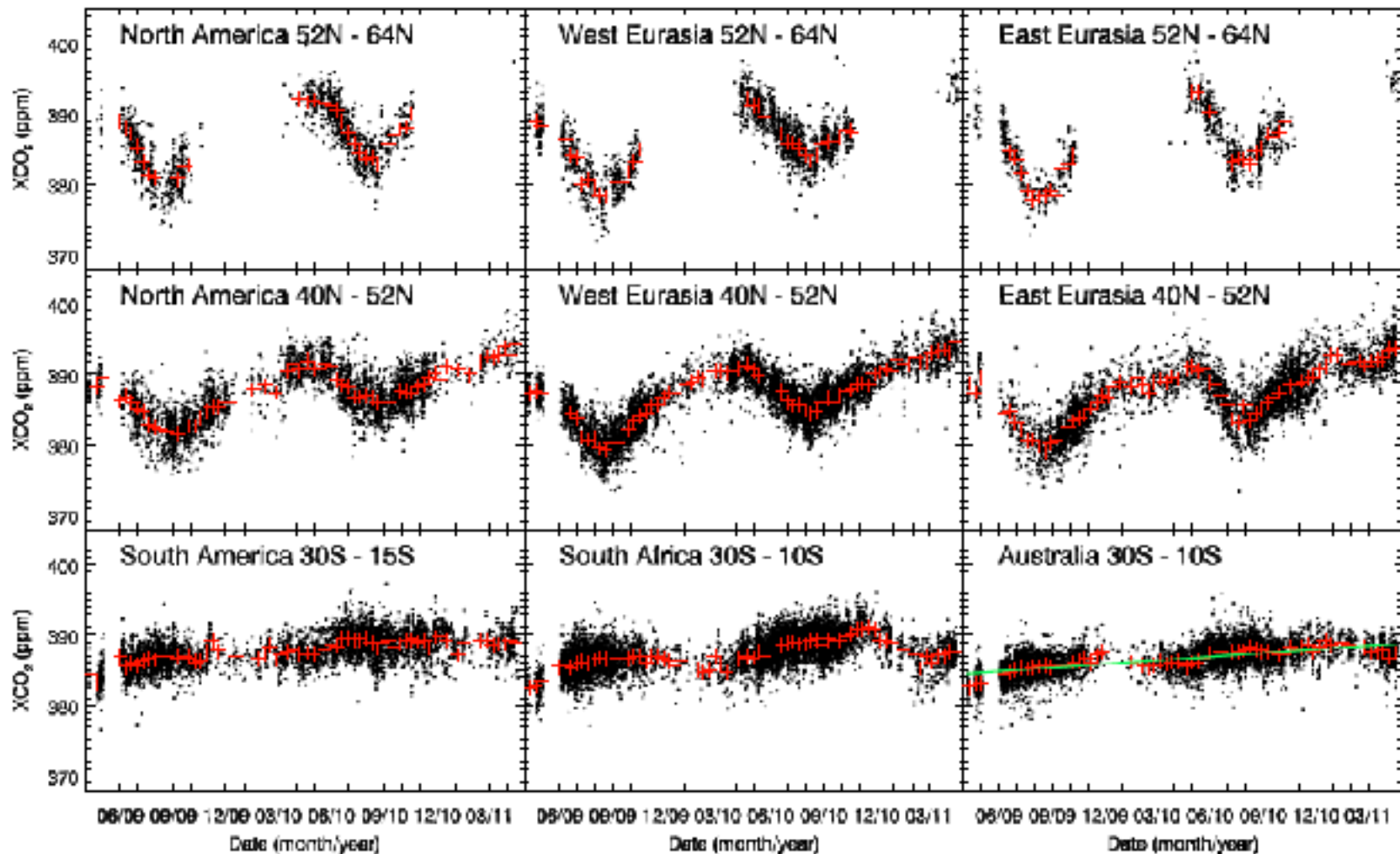


from: outlines of GOSAT and TANSO sensor

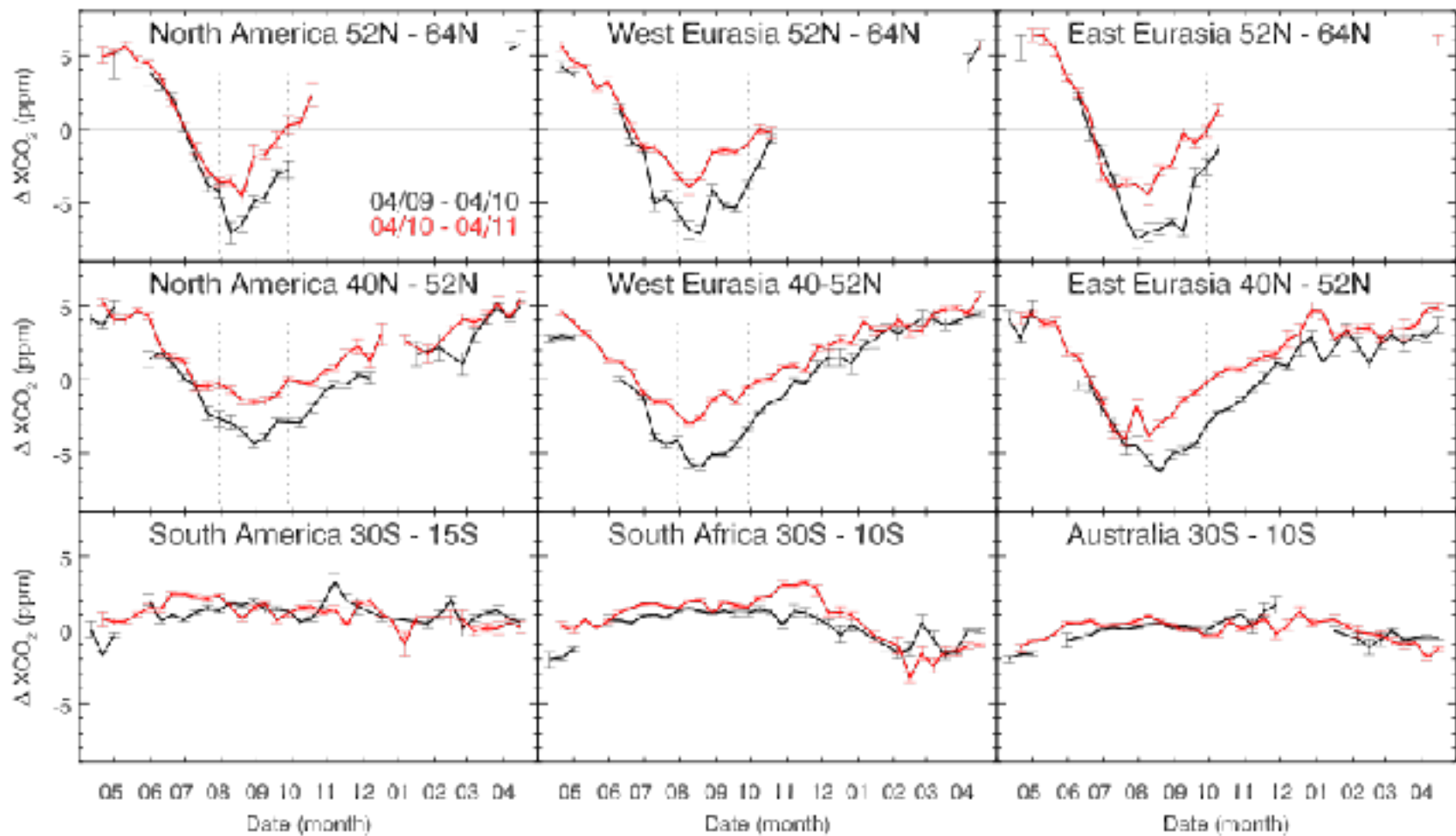
Kooldioxide (CO₂) (grondmetingen)



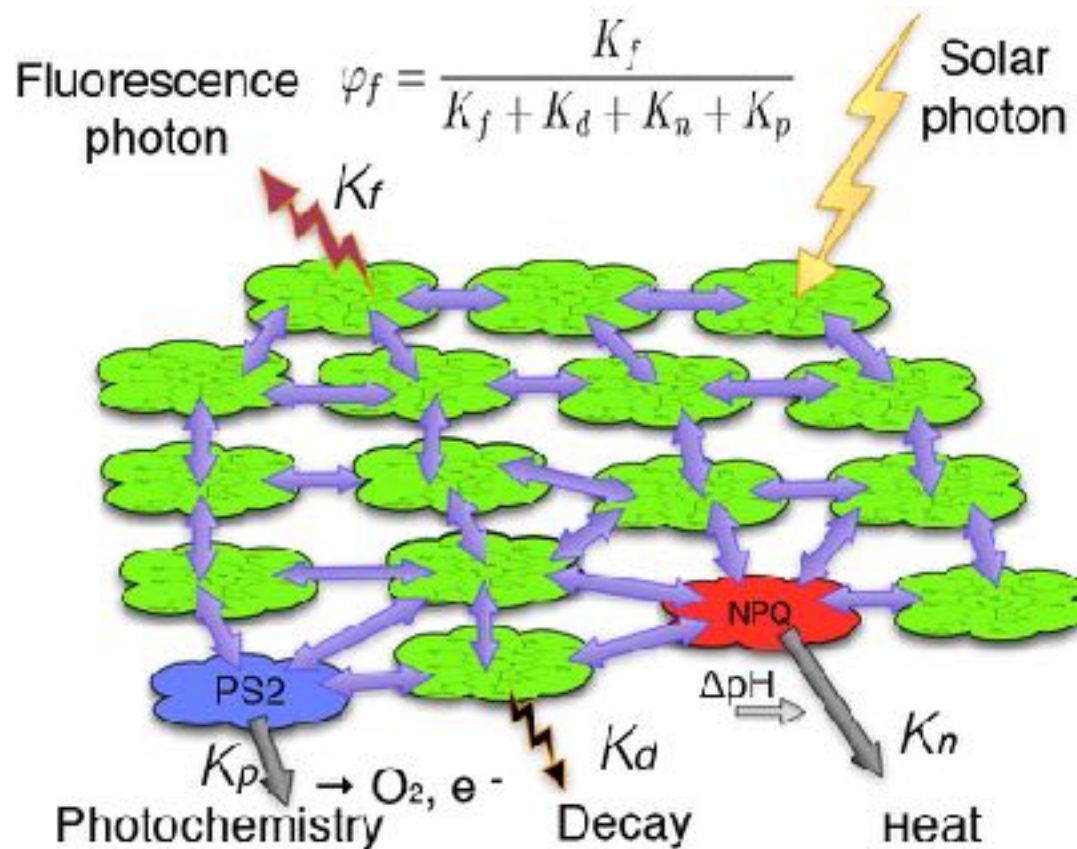
Toepassing GOSAT CO₂ data



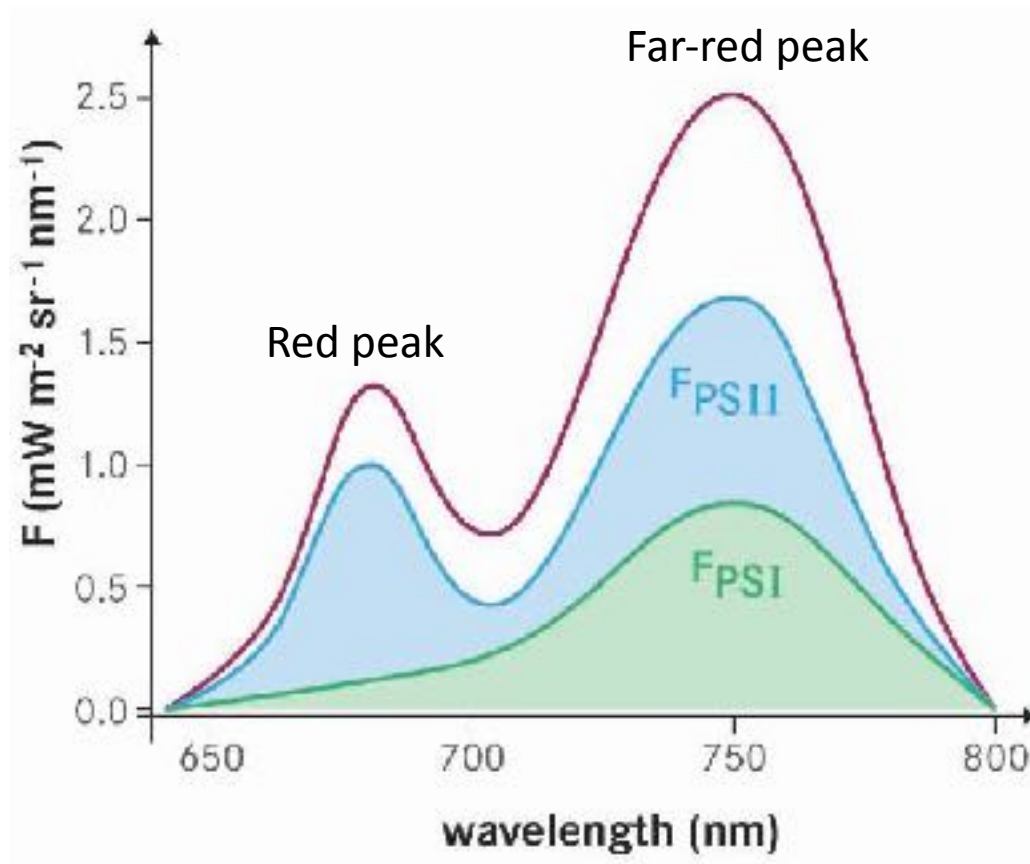
Toepassing GOSAT CO₂ data



Sun-Induced Fluorescence (SIF) at leaf-level

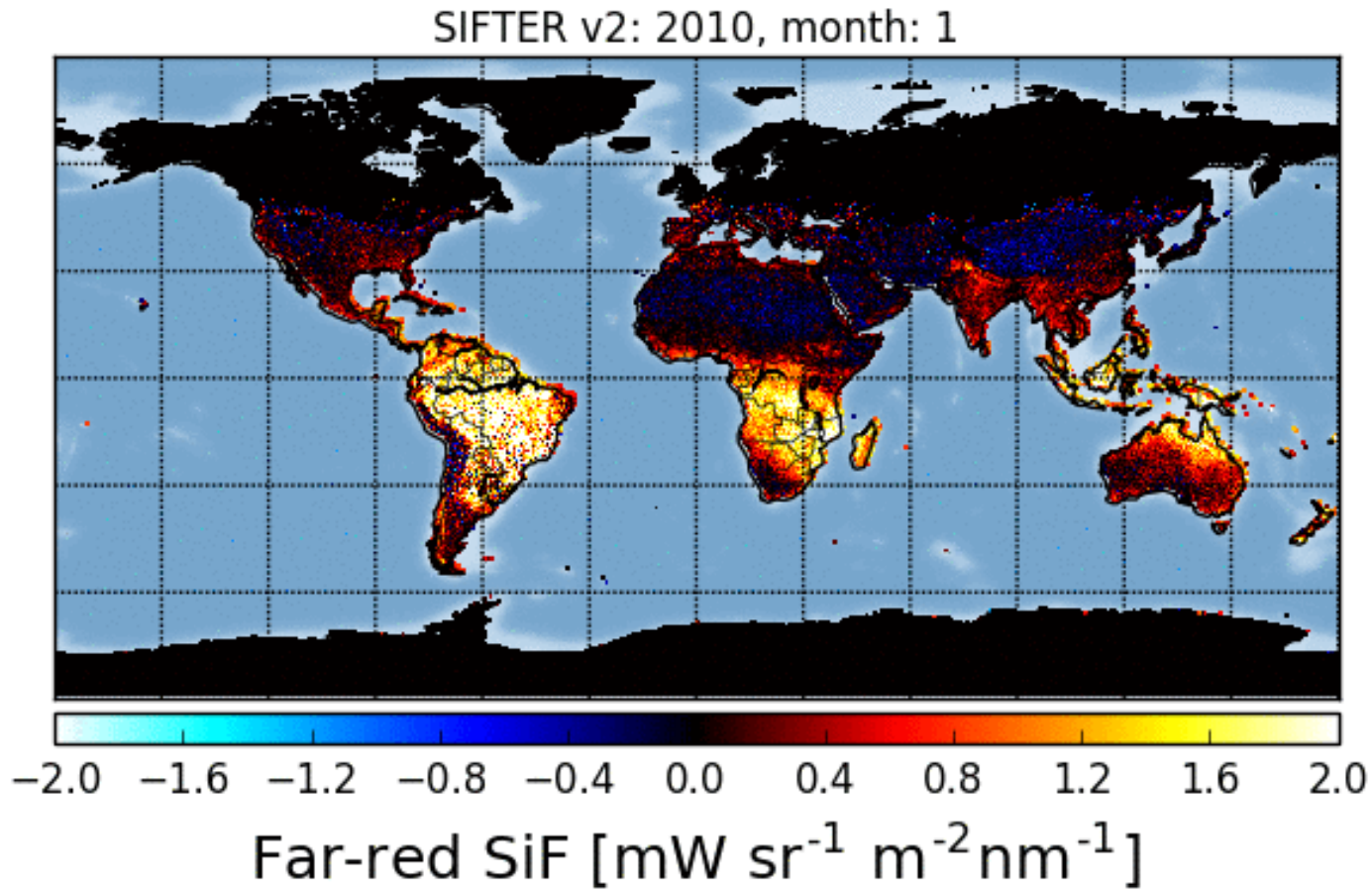


Sun-Induced Fluorescence (SIF) at leaf-level



ESA, 2015

Fluorescence - Temporal



Erik van Schaik, WUR/KNMI

Samenvatting

- Met satellieten kunnen we veel te weten komen over de samenstelling van onze atmosfeer:
 - Monitoren van het herstel ozonlaag
 - Meten hoe de uitstoot vervuiling verandert
 - Beter bepalen van de uitstoot van branden
 - Kijken op plaatsen waar we geen grondmetingen doen
- In 2017 wordt TROPOMI gelanceerd