

# Klimaatgassen en de oceaan, van puntmeting naar wereldwijde schatting



**Dr. Lonneke Goddijn-Murphy**



**Klimaatgassen en de oceaan,  
van puntmeting naar wereldwijde schatting**

**Achtergrond**

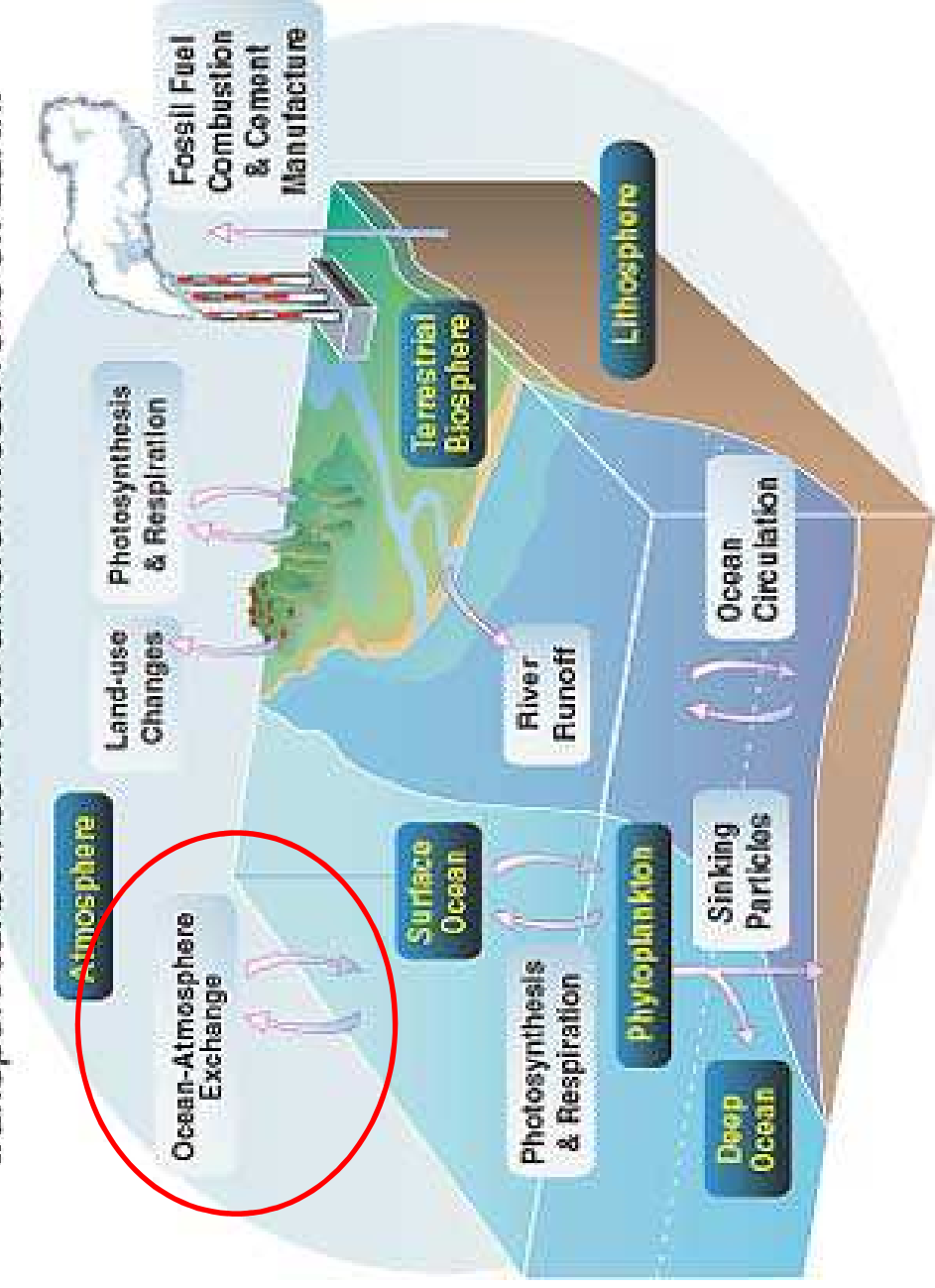
**Uitdagingen**

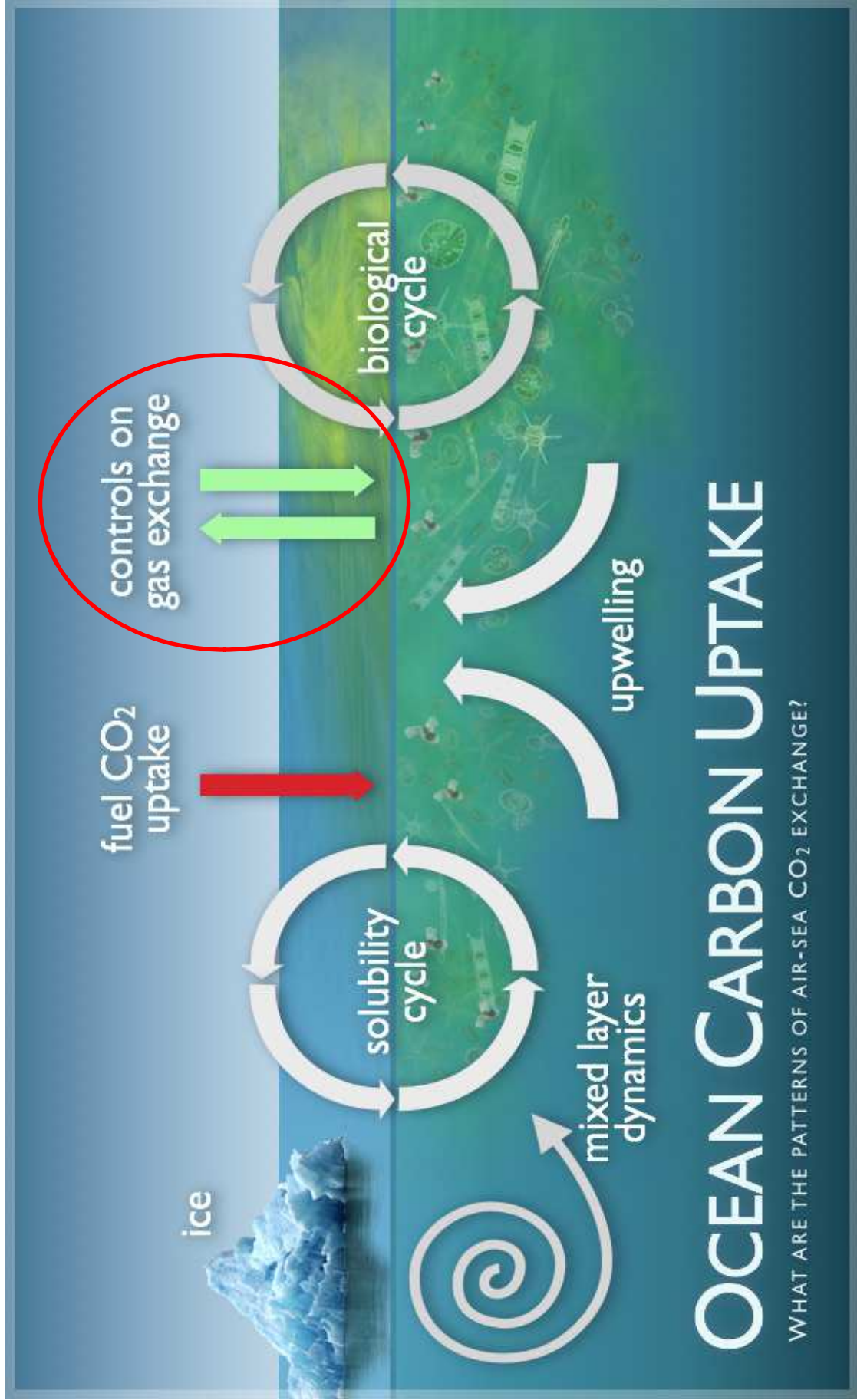
**Wiskundige oplossingen**

**Lonneke Goddijn-Murphy**

## The Global Carbon Cycle

A network of interrelated processes that transport carbon between different reservoirs on Earth.





# OCEAN CARBON UPTAKE

WHAT ARE THE PATTERNS OF AIR-SEA CO<sub>2</sub> EXCHANGE?



# Gas Flux Vergelijking

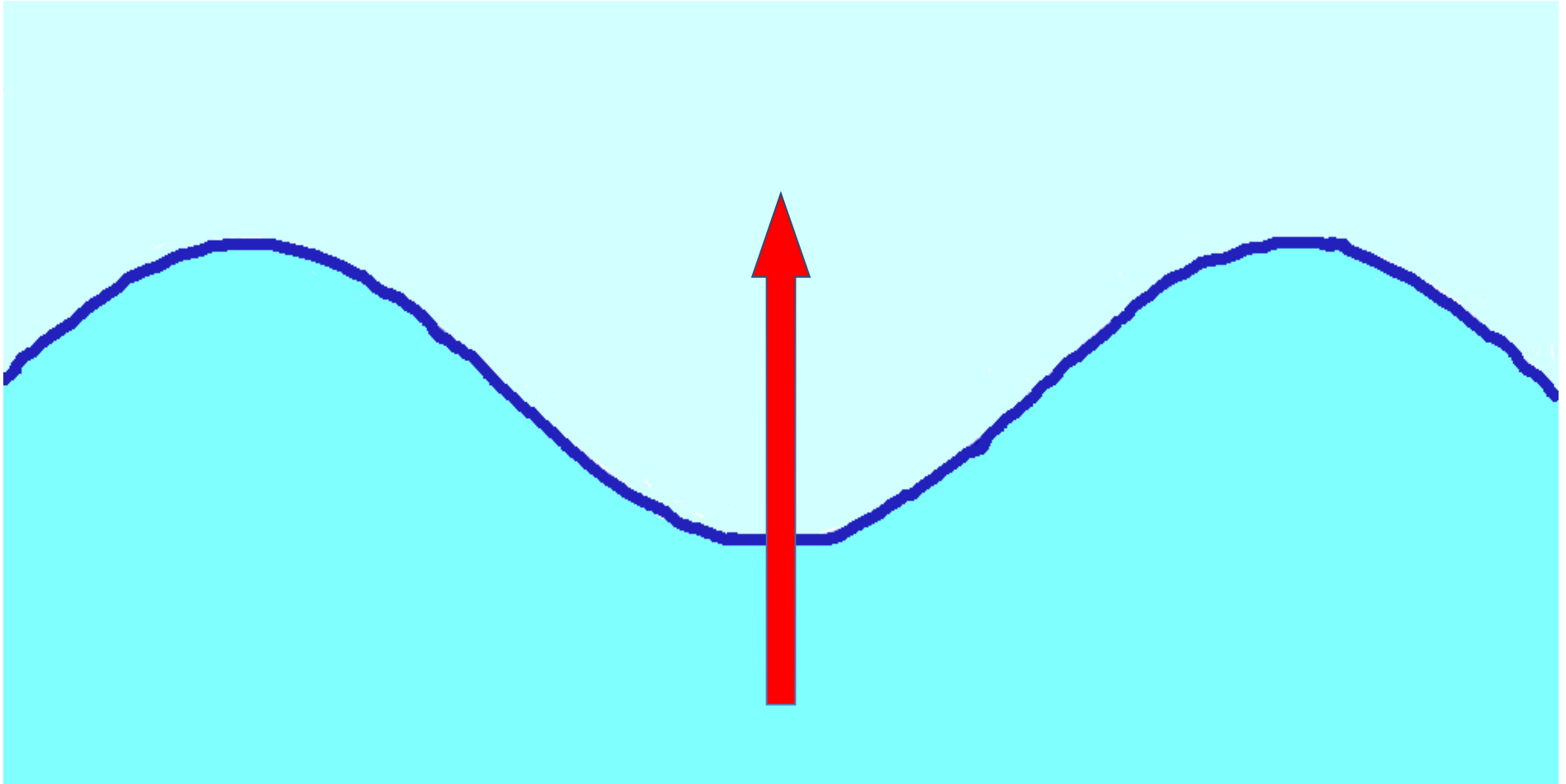
$$F = k \cdot \Delta C$$

$F$  = gas flux [g/(m<sup>2</sup>s)]

$k$  = gas uitwisselings snelheid parameter [cm/s]

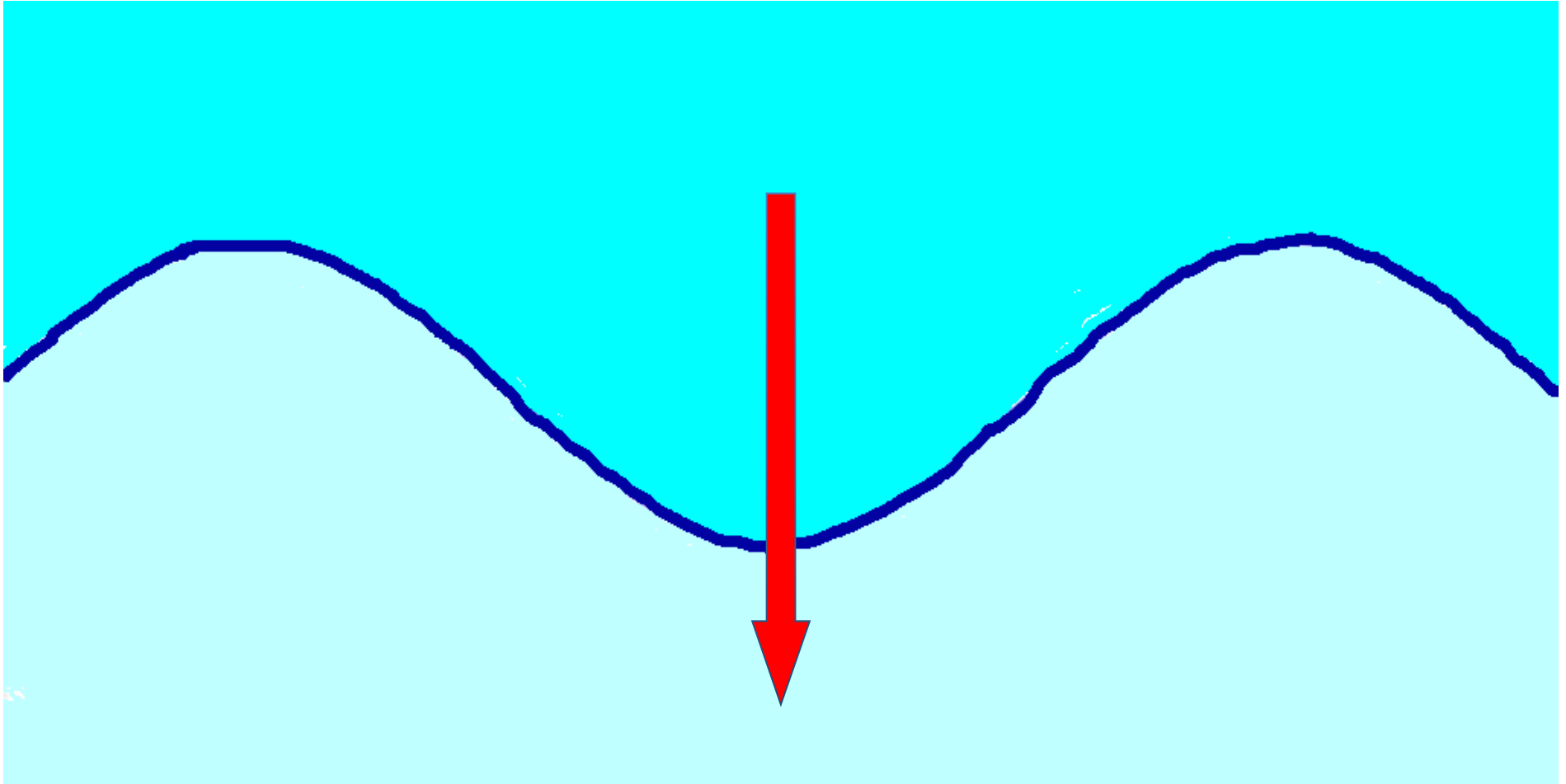
$\Delta C$  = concentratie verschil in atmosfeer - zee [g/m<sup>3</sup>]

# Gas Flux



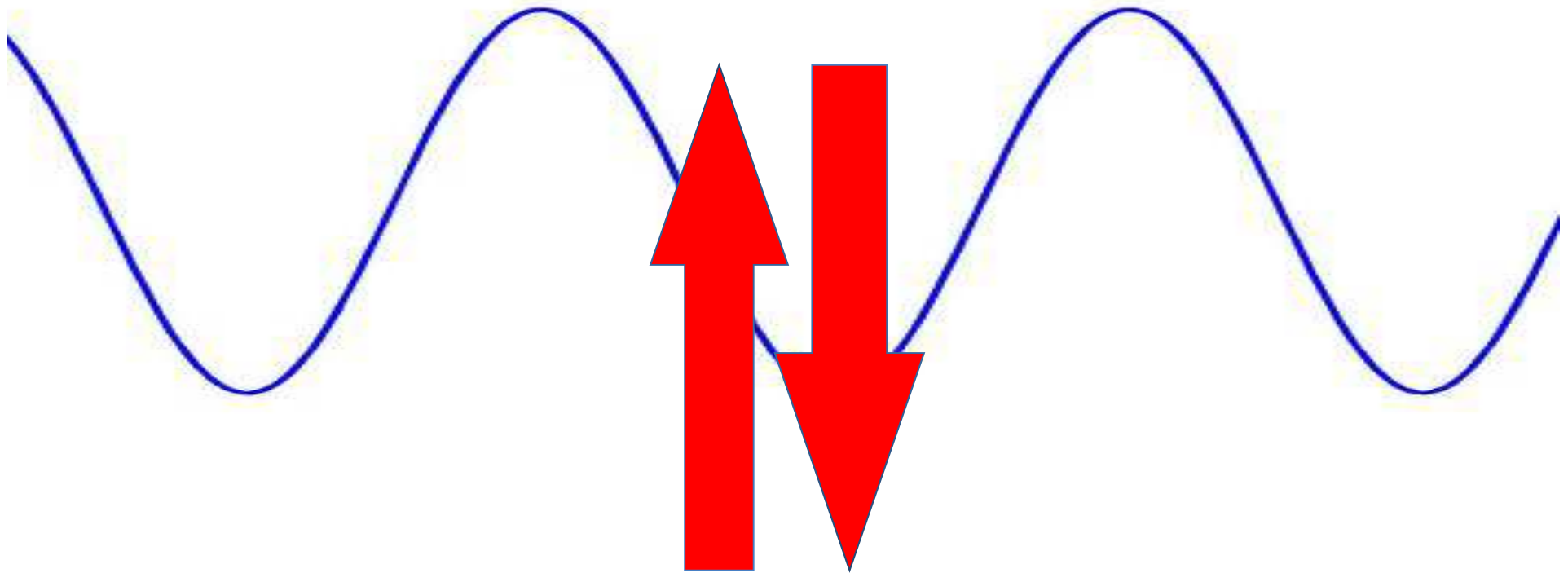
$\Delta C$ : hogere gas concentratie in zee

# Gas Flux



$\Delta C$ : lagere gas concentratie in zee

# Gas Flux



$k$ : steilere golven geeft grotere  $k$



# Gas Flux Vergelijking

$$F = k \cdot \Delta C$$

$F$  = gas flux [g/(m<sup>2</sup>s)]

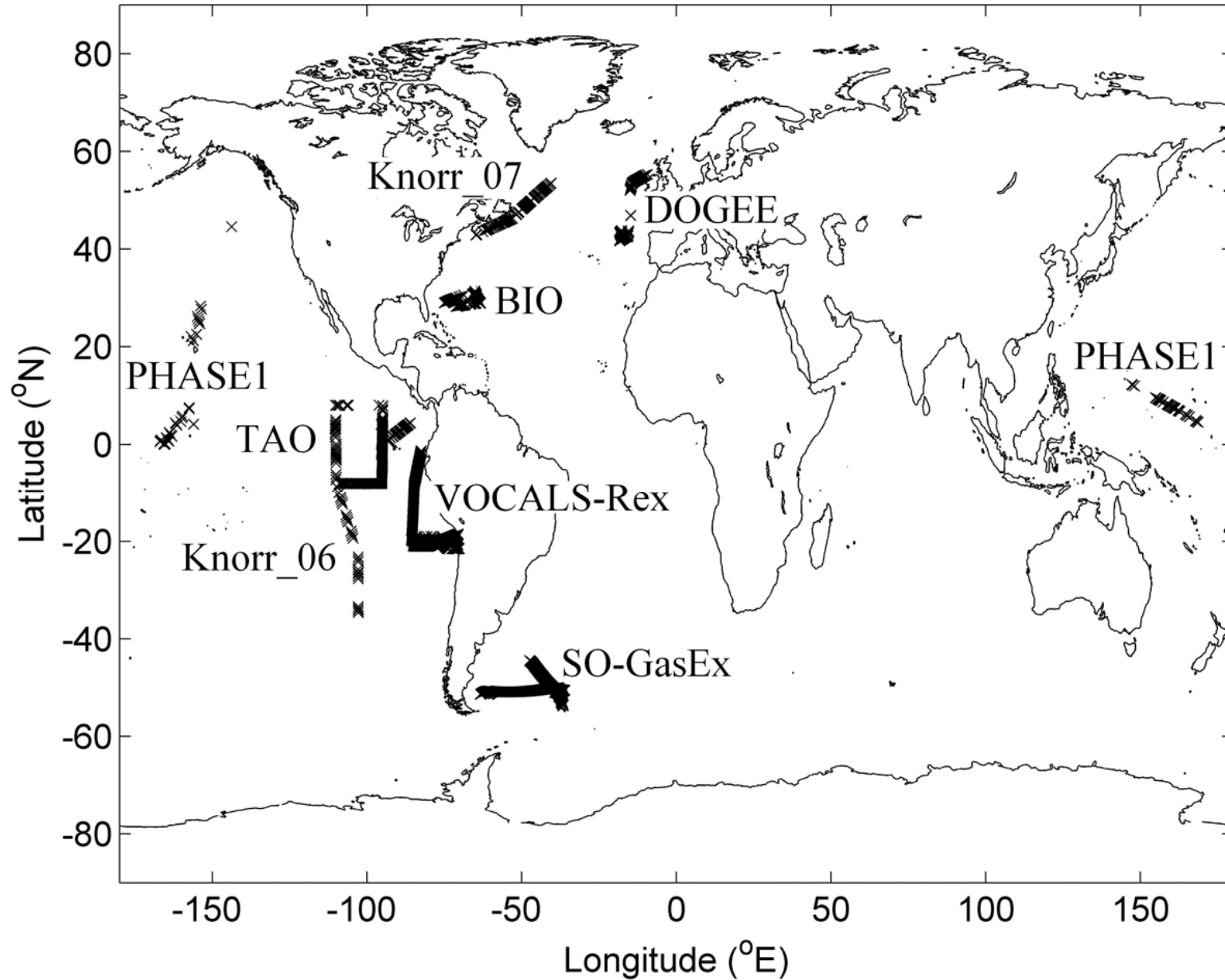
$k$  = gas uitwisselings snelheid parameter [cm/s]

$\Delta C$  = concentratie verschil in atmosfeer - zee [g/m<sup>3</sup>]

# *K* metingen in het veld

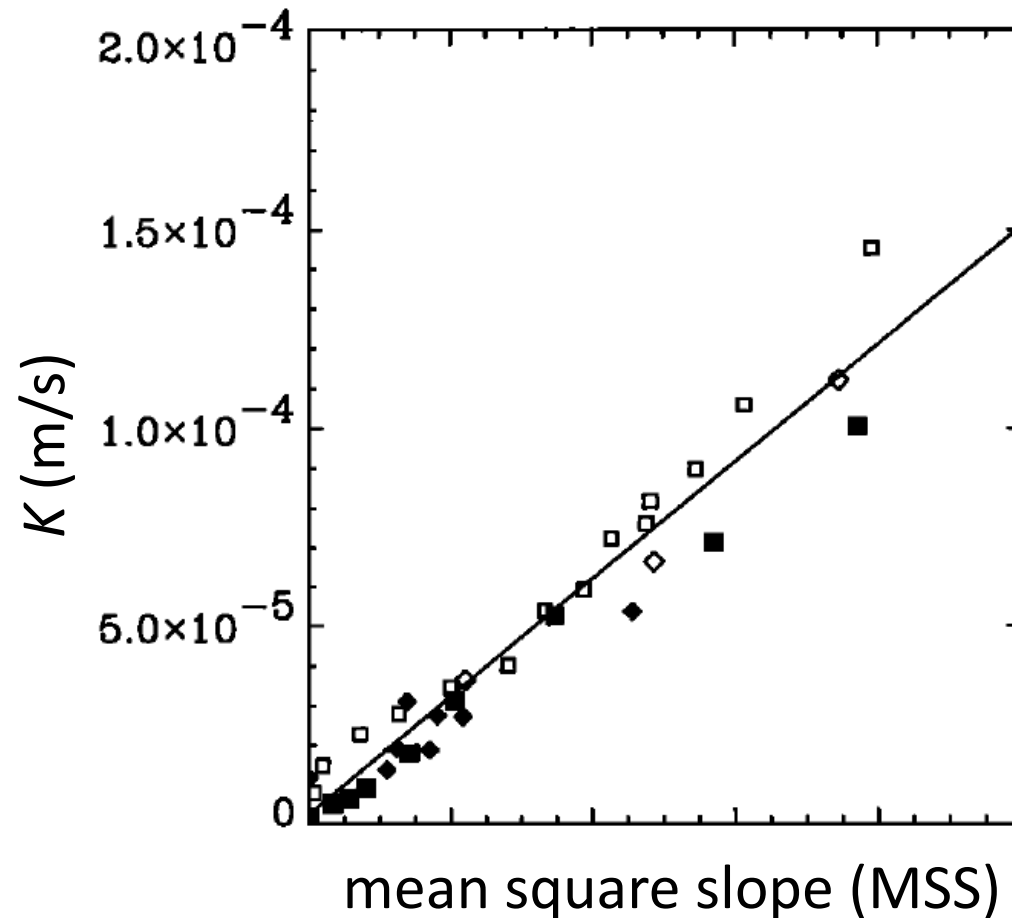


# K metingen in het veld



# $K$ metingen in het lab

[Bock et al., 1999]



$k$ : steilere golven geeft grotere  $k$





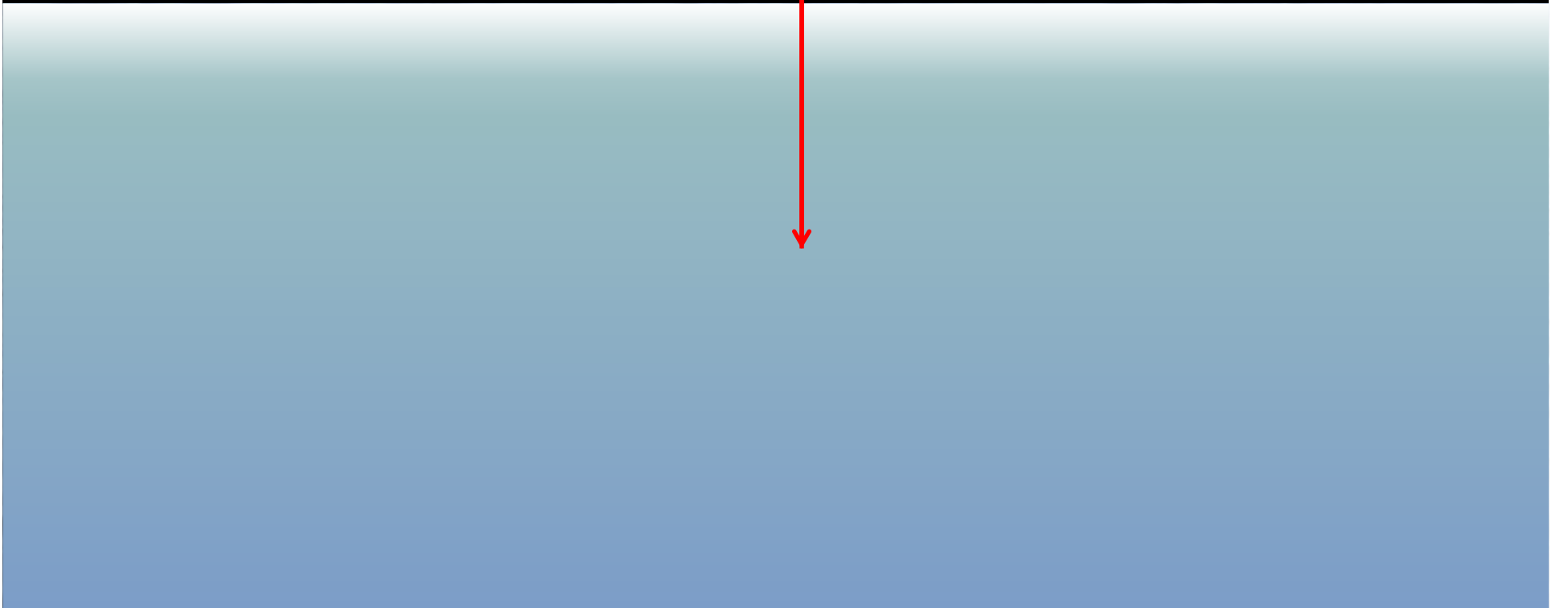
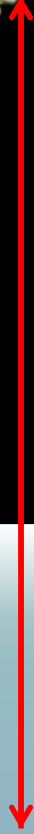
***K*** metingen boven de oceaan

metingen van de  
mean square slope, **MSS**,

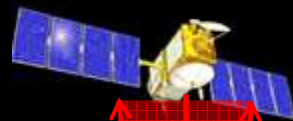




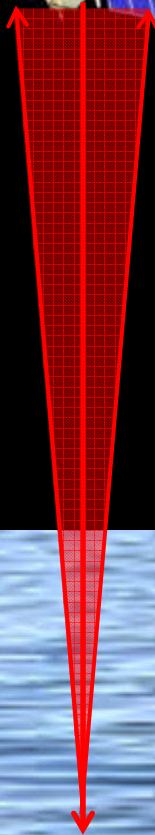
microwave



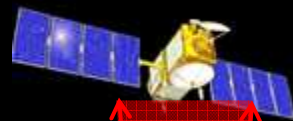




microwave







backscattering  
coefficient,  $\sigma$

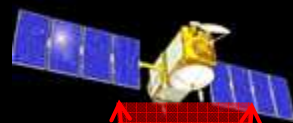
MSS  $\uparrow$

$\sigma$   $\downarrow$

$1/\sigma$   $\uparrow$

$K$   $\uparrow$





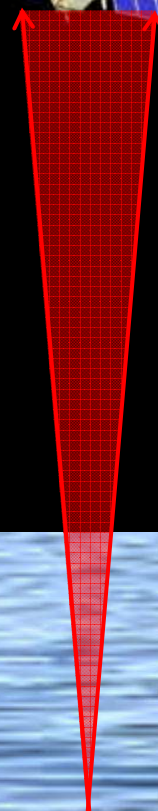
backscattering  
coefficient,  $\sigma$

MSS  $\uparrow$

$\sigma$   $\downarrow$

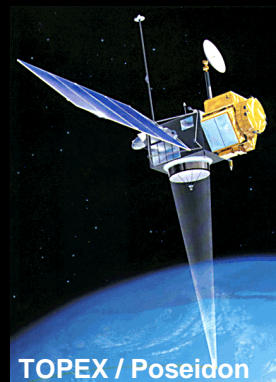
$1/\sigma$   $\uparrow$

$K$   $\uparrow$



# Satellieten met altimeters

## afgelopen 20 jaar





**Ku-band microwaves:**



**Worden verstrooid door objecten  $> 6.3$  cm**

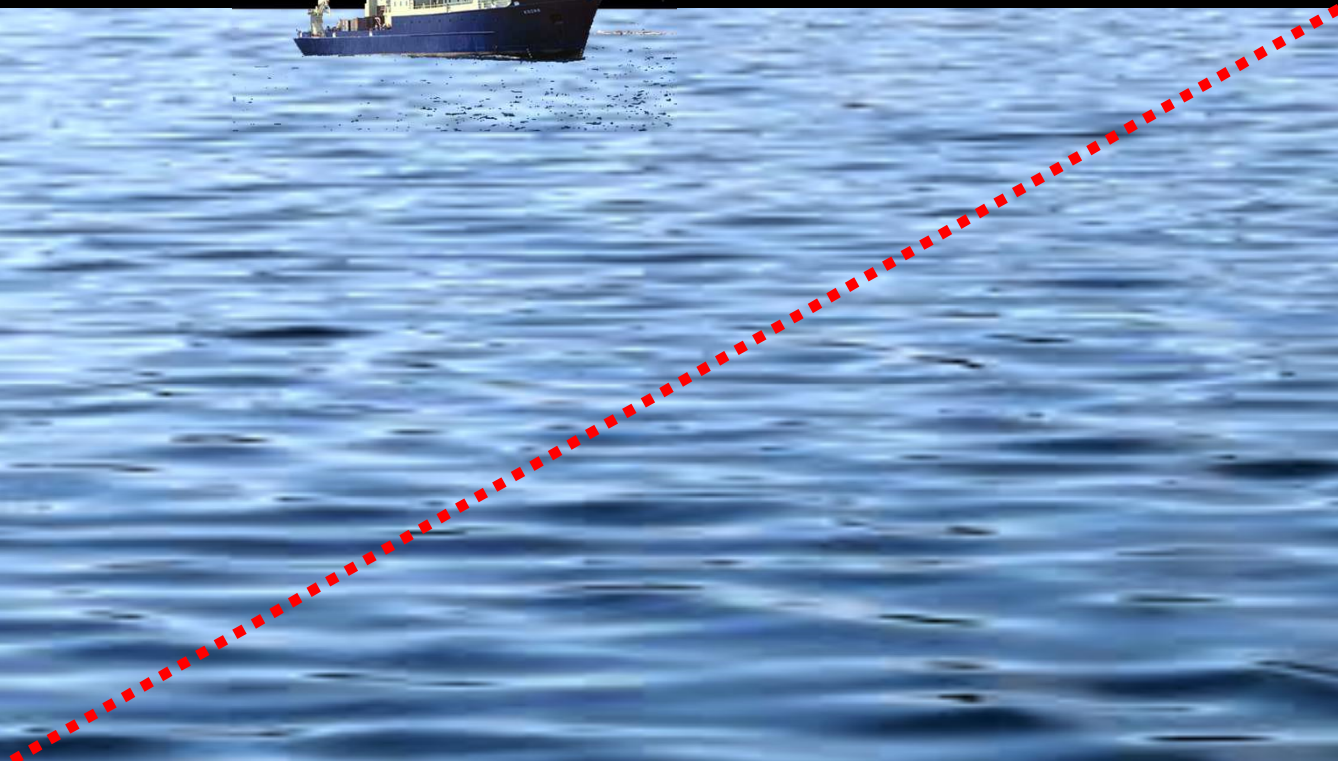


$\Delta t < 6 \text{ hr}$     $\Delta x < 0.5^\circ$



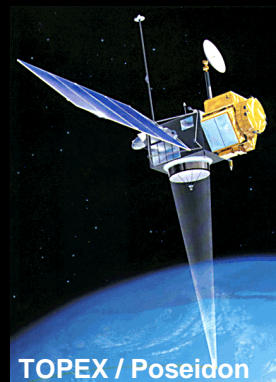
$\sigma_{\text{Ku}}$

$K$



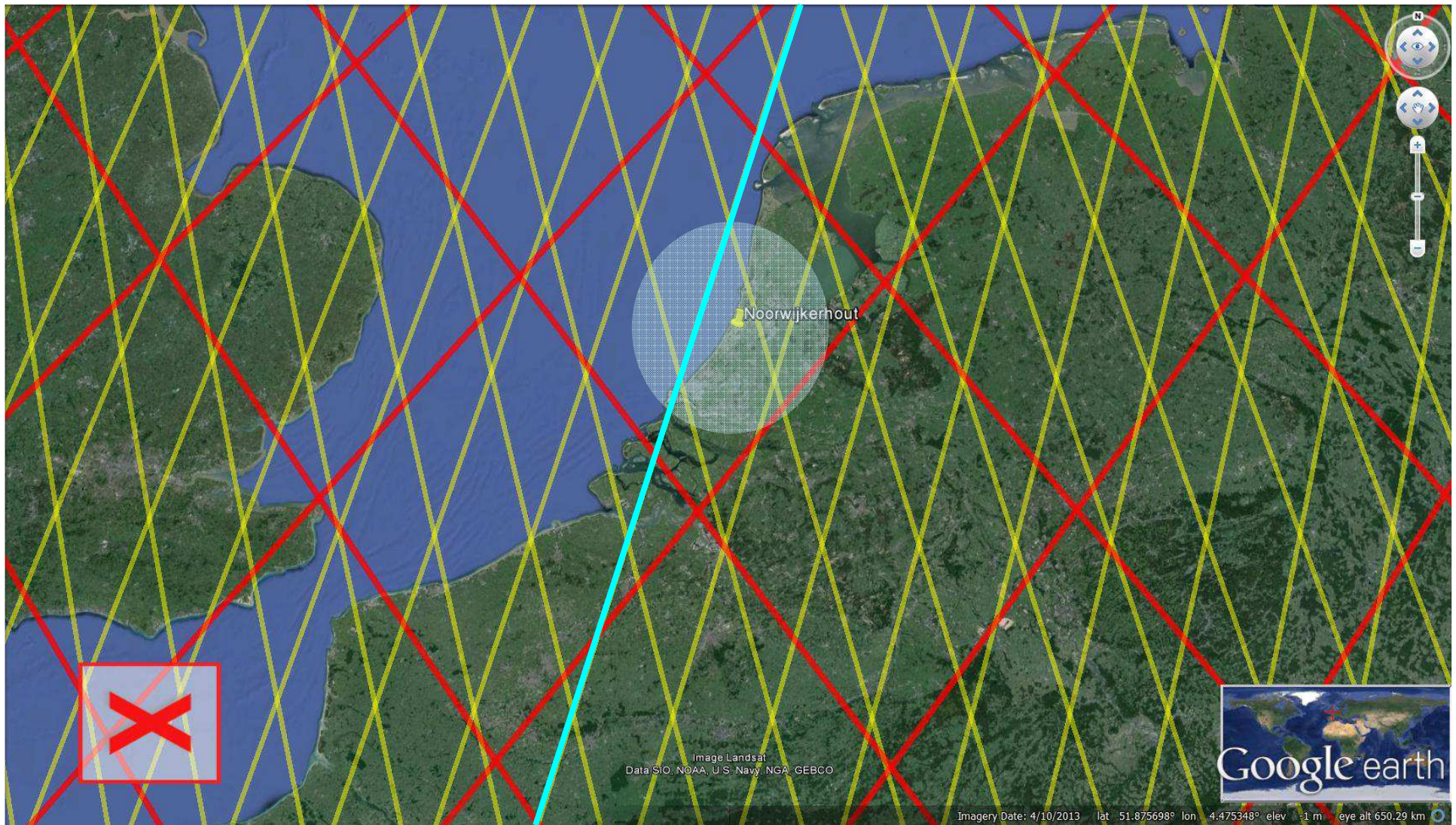
# Satellieten met altimeters

## op dit moment





30-Jan-2015 18:31:37



Jason-2

SARAL/AltiKa



$\Delta t < 6 \text{ hr}$     $\Delta x < 0.5^\circ$     $N = 179$

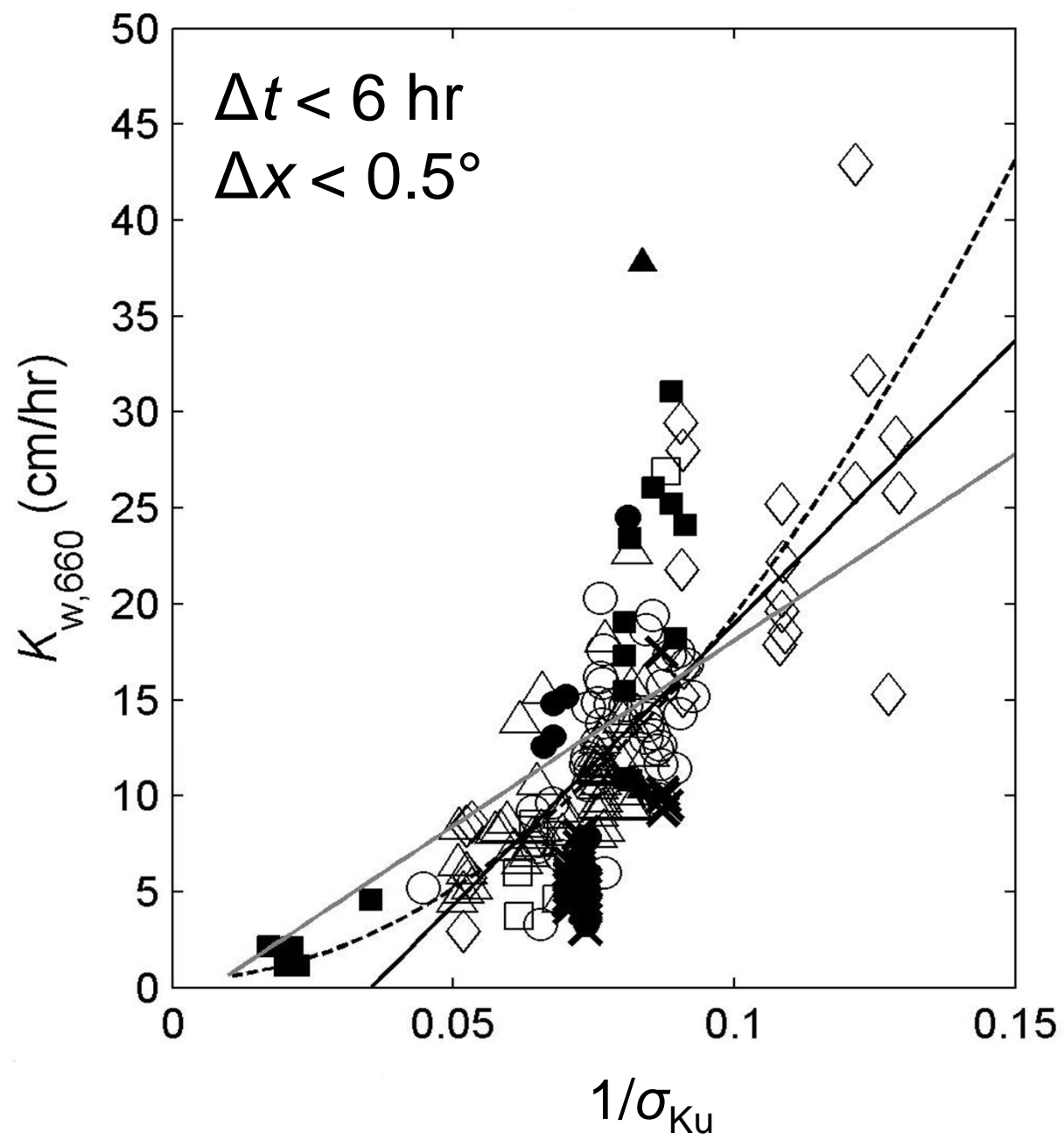


$\sigma_{\text{Ku}}$

$K$







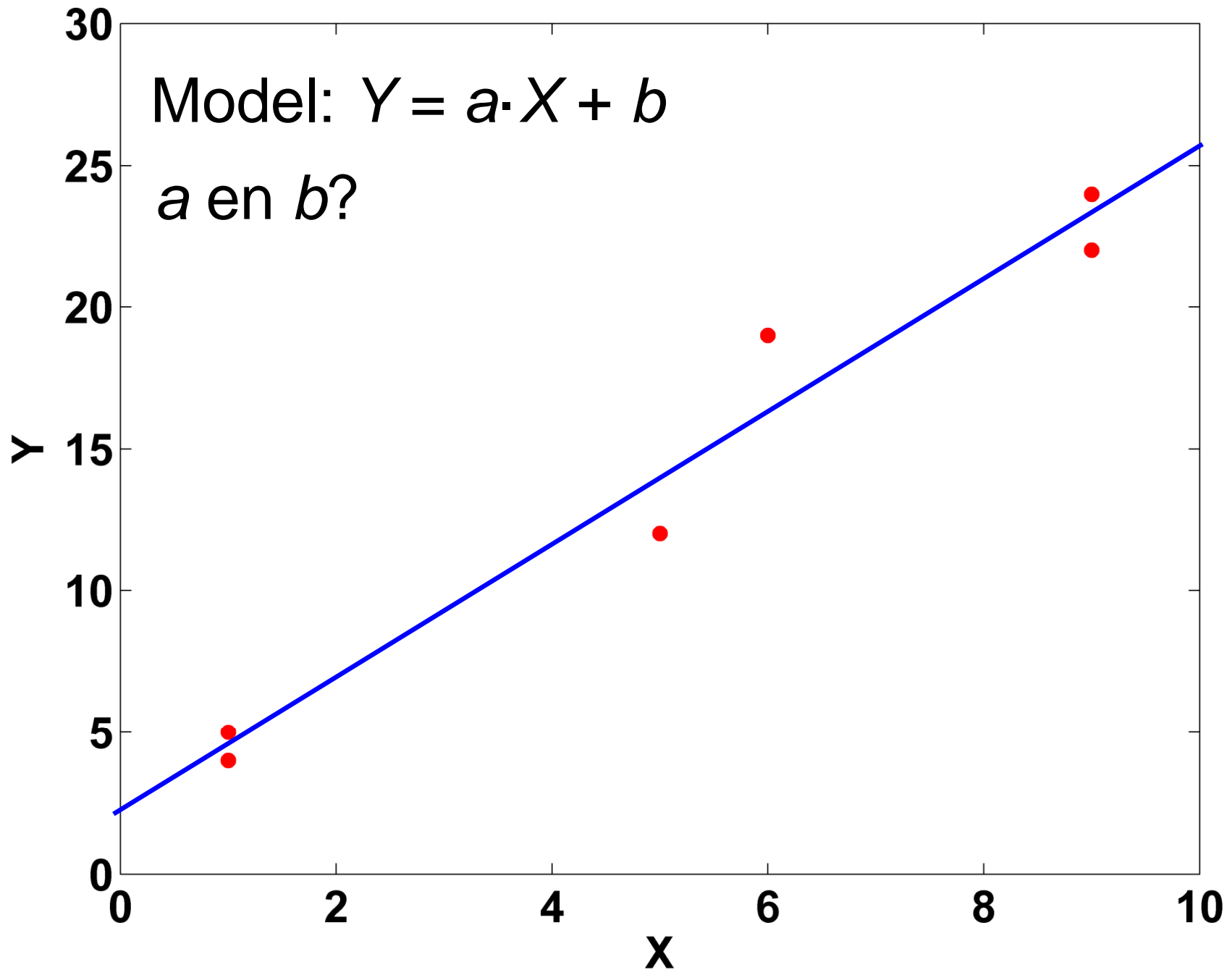
# Kleinste kwadraten methode

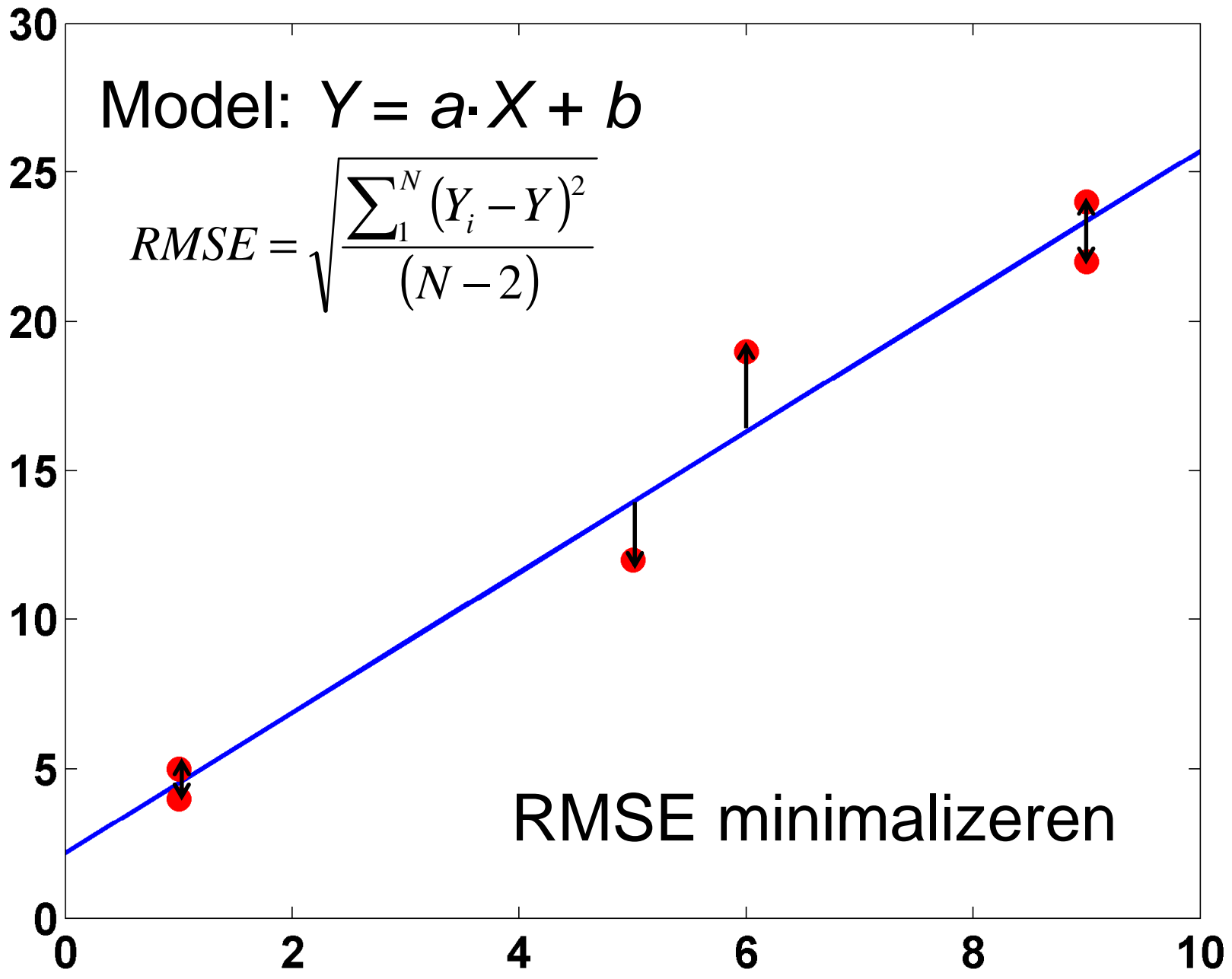
Deze methode bepaalt de  
'best passende' curve door de  
kwadratische afwijkingen te  
minimalizeren

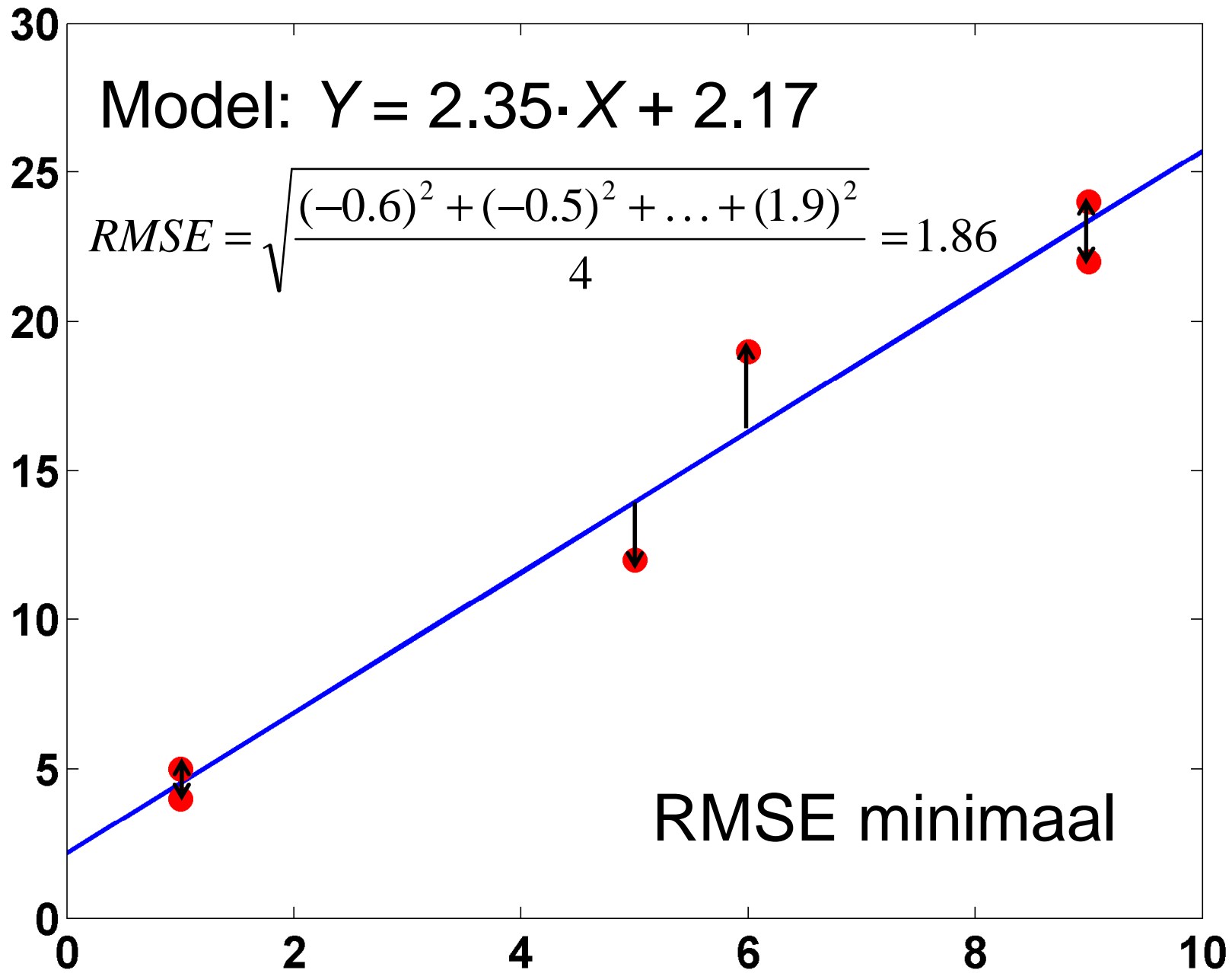
# Kleinste kwadraten voorbeeld

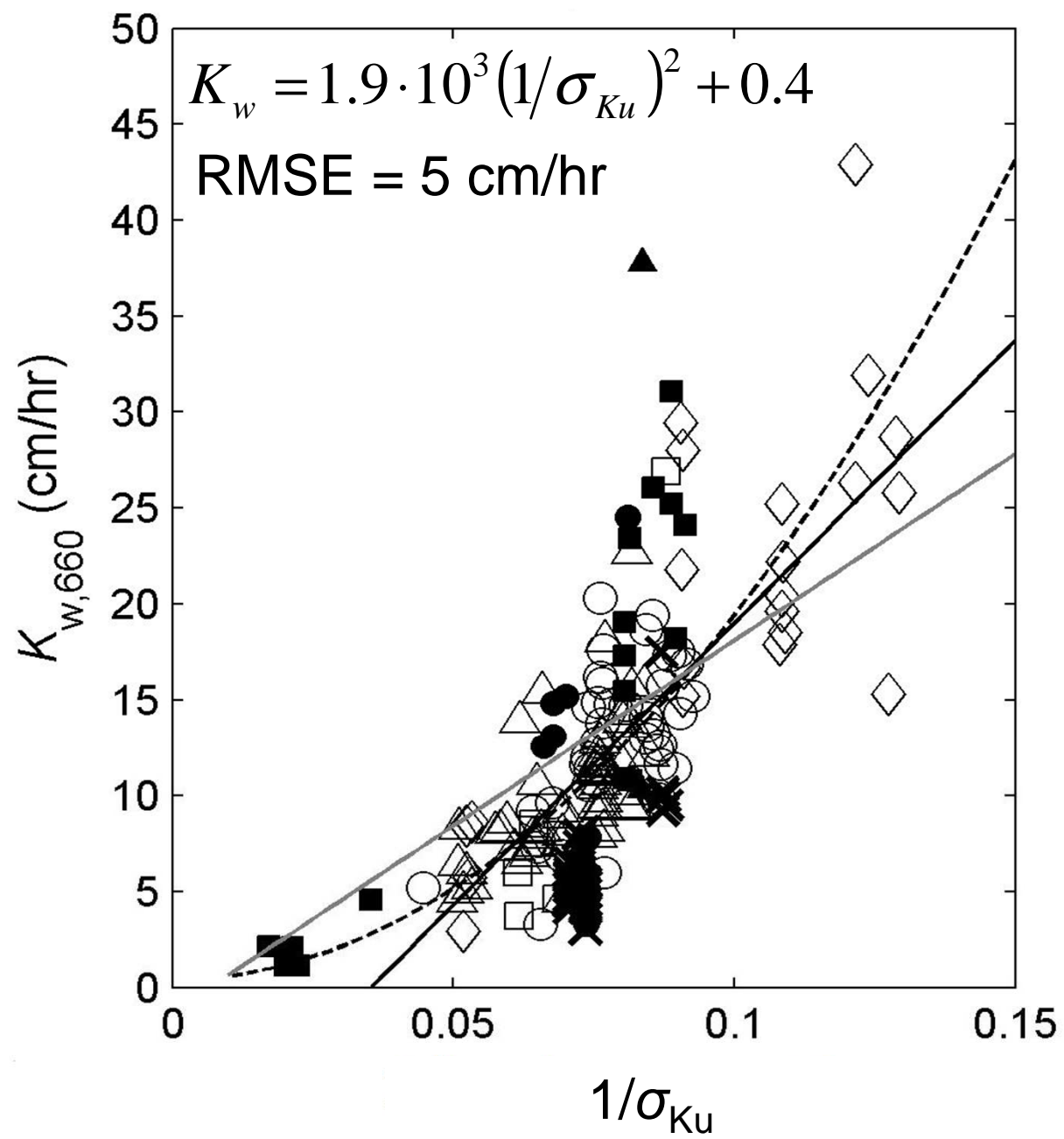
Voorbeeld dataset

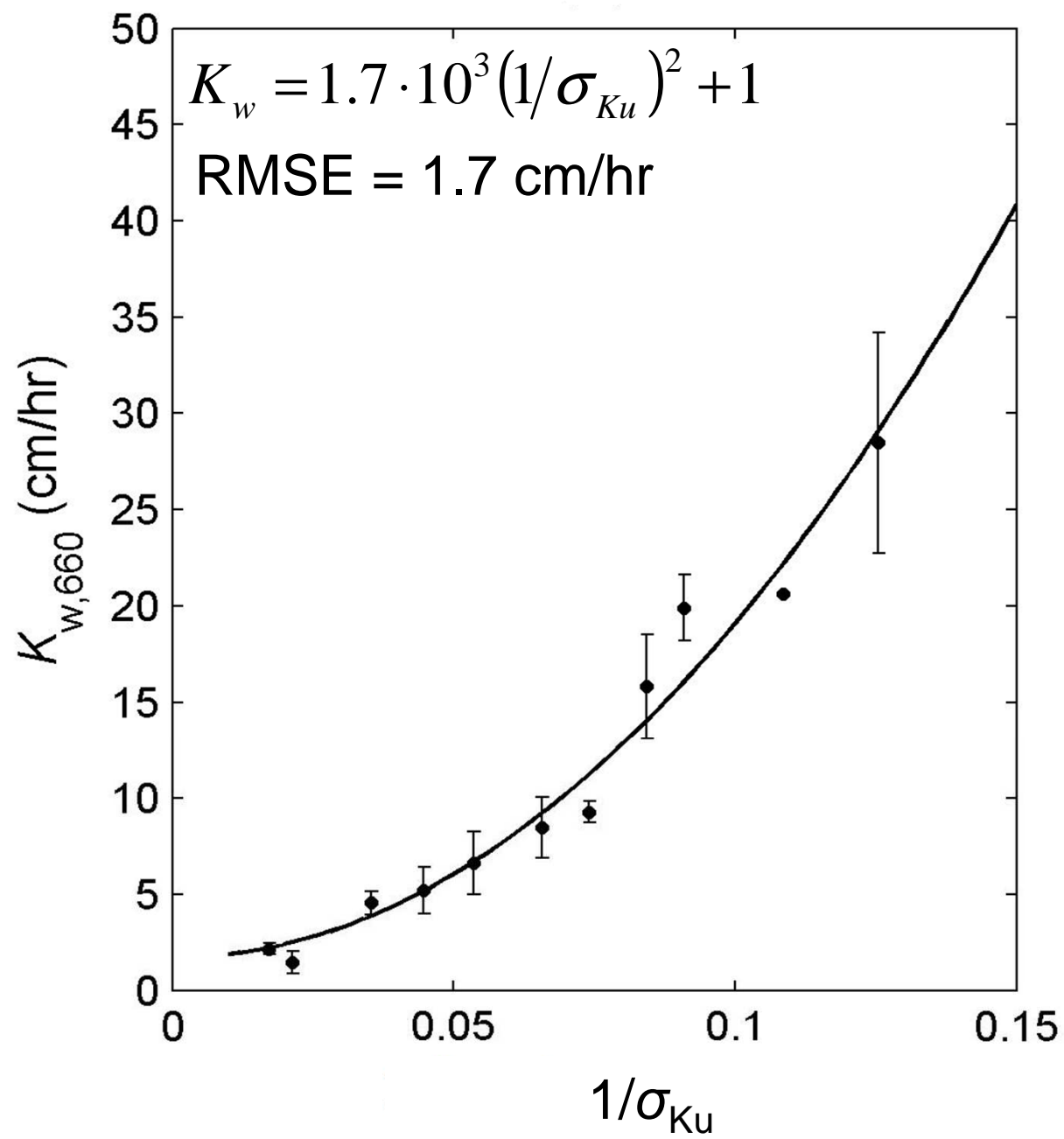
$X_i$	$Y_i$
9	24
1	5
9	22
6	19
1	4
5	12

















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**C-band microwaves:**

worden verstrooid door objecten  $> 16.5$  cm



Het **verschil** tussen het signaal van



**Ku-band** en van **C-band**

is een maat voor golven van **6.3 – 16.5 cm**



$$\Delta t < 6 \text{ hr}$$

$$\Delta x < 0.5^\circ$$

$$N = 62$$

 $\sigma_{Ku}$  $\sigma_C$  $K$ 

$\Delta t < 6 \text{ hr}, \Delta x < 0.5^\circ:$

$N = 62$

Geen verschil tussen  
2-band en 1-band algorithm

$\Delta t < 2 \text{ hr}$ ,  $\Delta x < 0.5^\circ$ :

$N = 29$

2-band lijkt beter dan 1-band  
algorithm



$\Delta t < 2 \text{ hr}$ ,  $\Delta x < 0.5^\circ$ :

$N = 29$

Echter, het verschil is klein  
en er is veel spreiding in de  
data

**Is verbetering significant?**



# Bootstrap methode

Deze methode maakt **synthetische datasets** door random selecteren van de orginele data set **met teruglegging**.

# Bootstrap methode

Op aldus gecreerde groot aantal synthetische datasets kan statistische analyse toegepast worden.

# Bootstrap methode

We geven nu een voorbeeld van de bootstrap techniek met behulp van 6 data-paren

$$\begin{array}{ccccccc} & & & & & & y_4 = 19 \\ & & & & x_4 = 6 & & \\ & & x_1 = 9 & & & & \\ & & & y_1 = 24 & & & \\ & & & & x_5 = 1 & & y_5 = 4 \\ x_2 = 1 & & y_2 = 5 & & & & \\ & & & & & x_6 = 5 & \\ x_3 = 9 & & & y_3 = 22 & & & y_6 = 12 \end{array}$$

# Bootstrap voorbeeld

## Voorbeeld dataset

$x_1 - y_1$

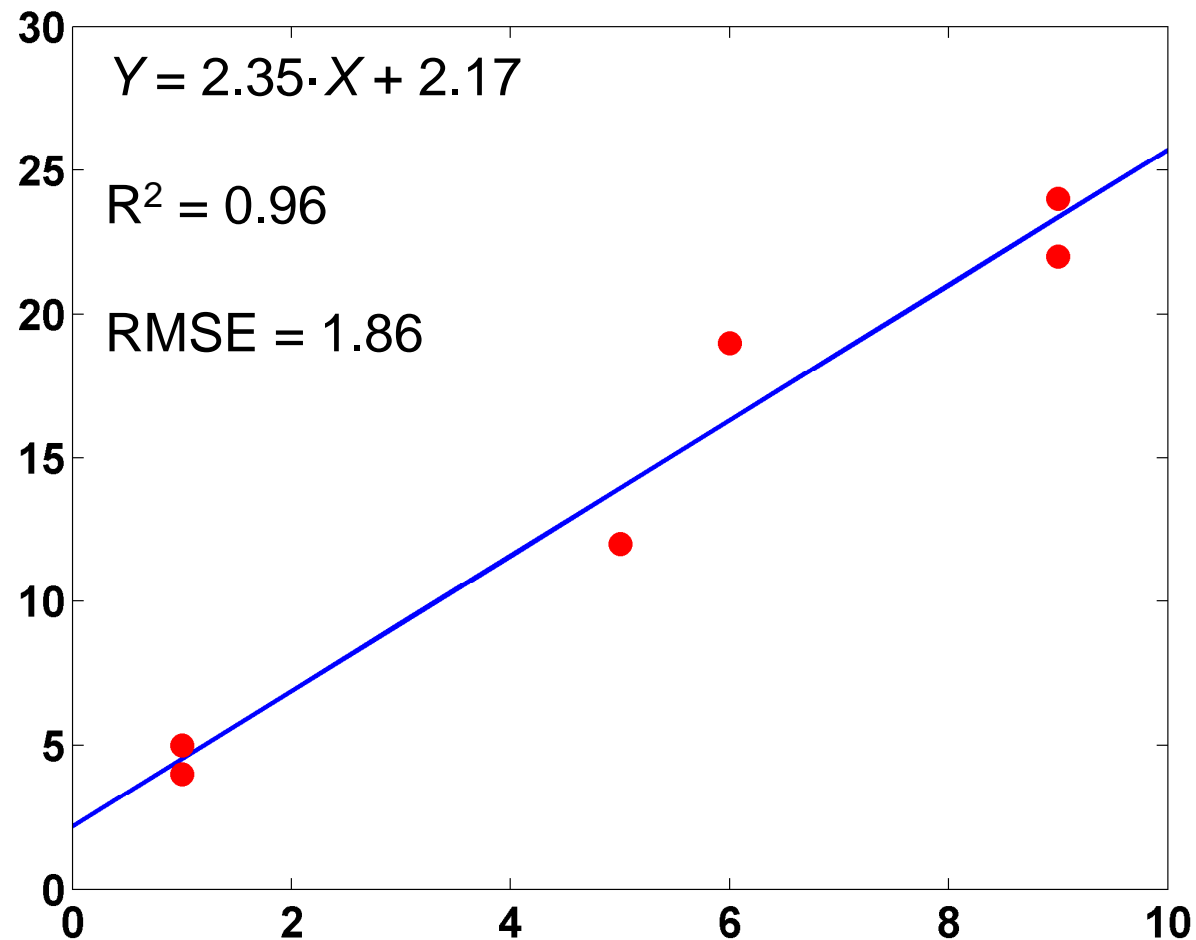
$x_2 - y_2$

$x_3 - y_3$

$x_4 - y_4$

$x_5 - y_5$

$x_6 - y_6$



# Bootstrap voorbeeld

## Bootstrap 1

$x_3 - y_3$

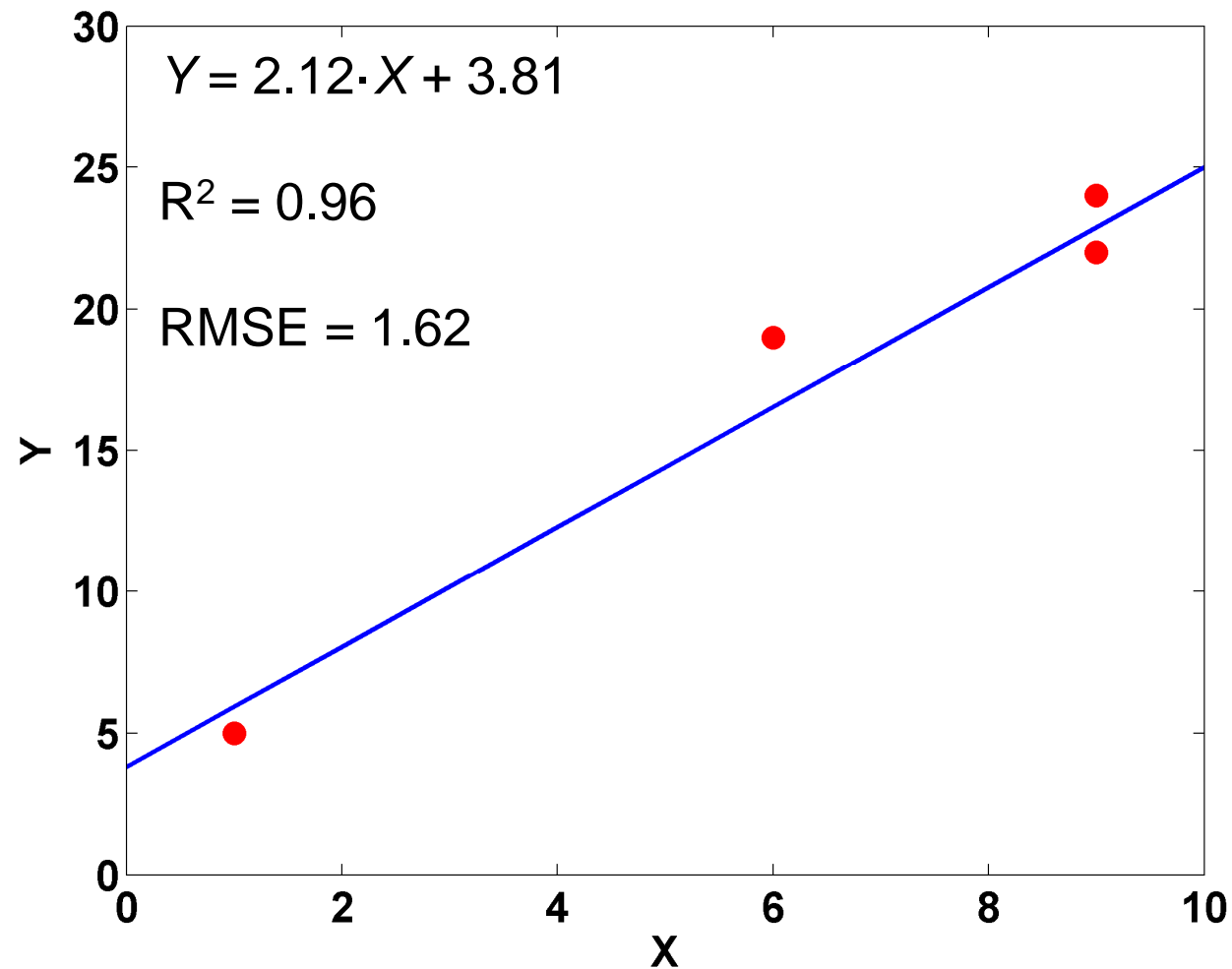
$x_3 - y_3$

$x_1 - y_1$

$x_2 - y_2$

$x_4 - y_4$

$x_3 - y_3$



# Bootstrap voorbeeld

## Bootstrap 2

$x_1 - y_1$

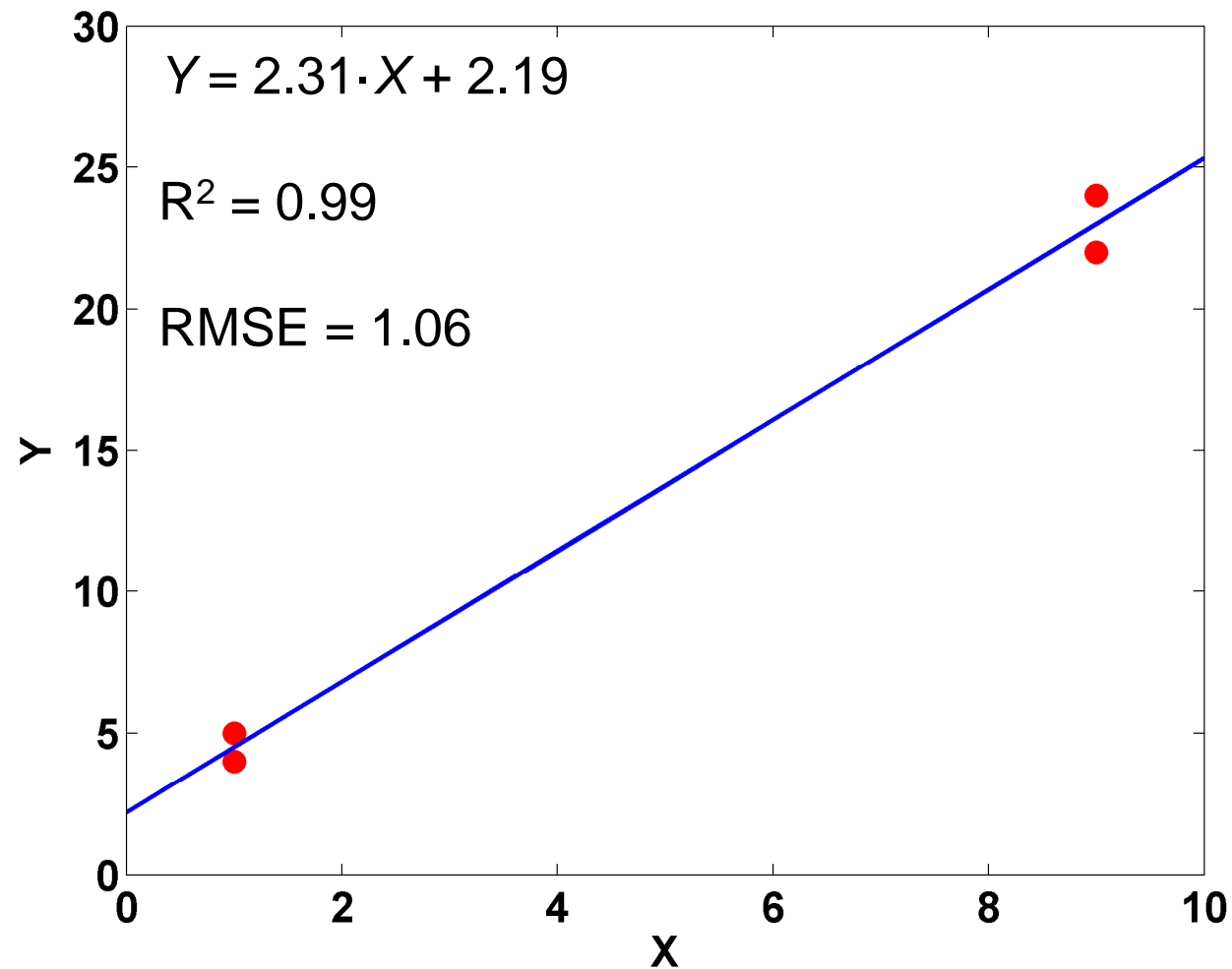
$x_3 - y_3$

$x_5 - y_5$

$x_2 - y_2$

$x_1 - y_1$

$x_3 - y_3$





# Bootstrap voorbeeld

## Bootstrap 3

$x_6 - y_6$

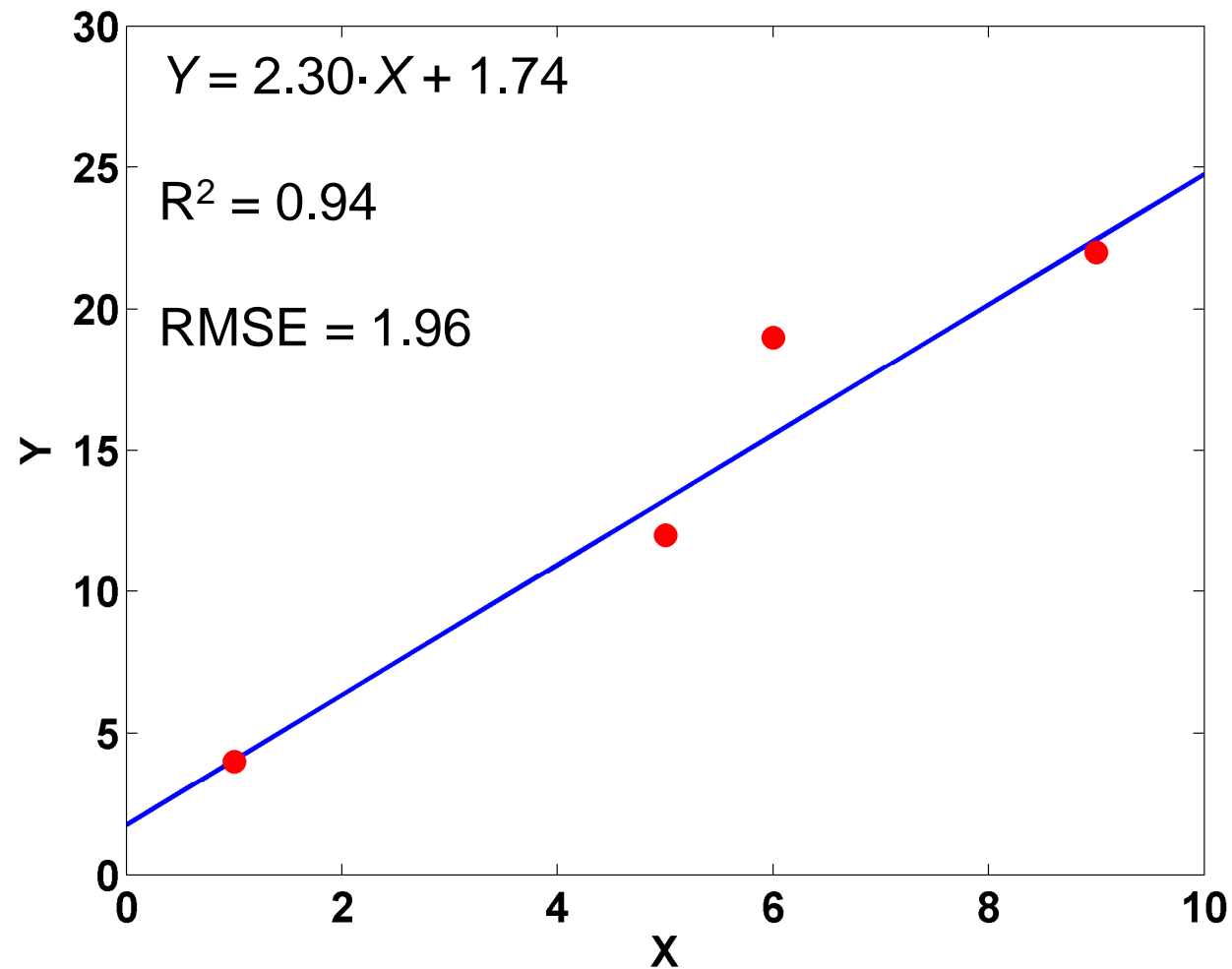
$x_4 - y_4$

$x_5 - y_5$

$x_3 - y_3$

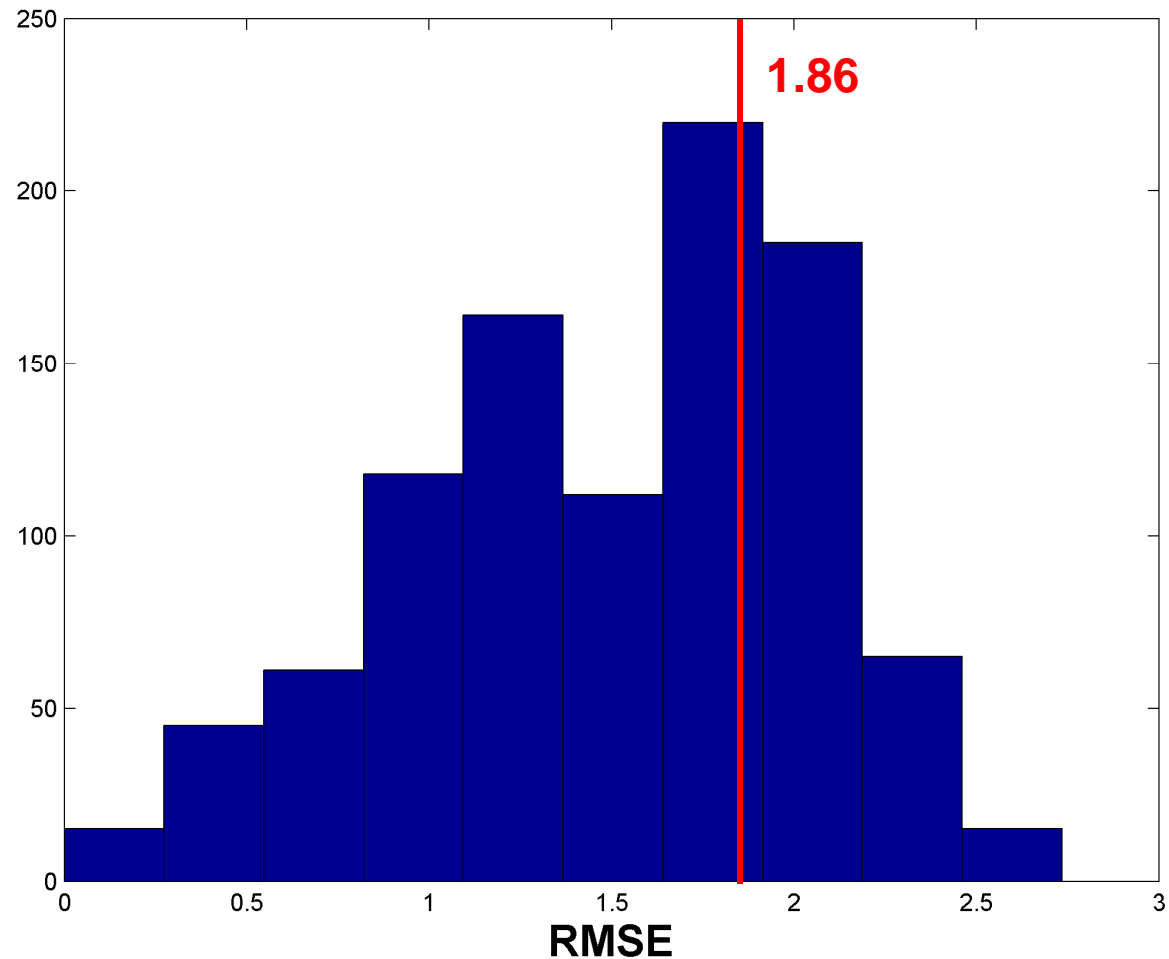
$x_3 - y_3$

$x_6 - y_6$



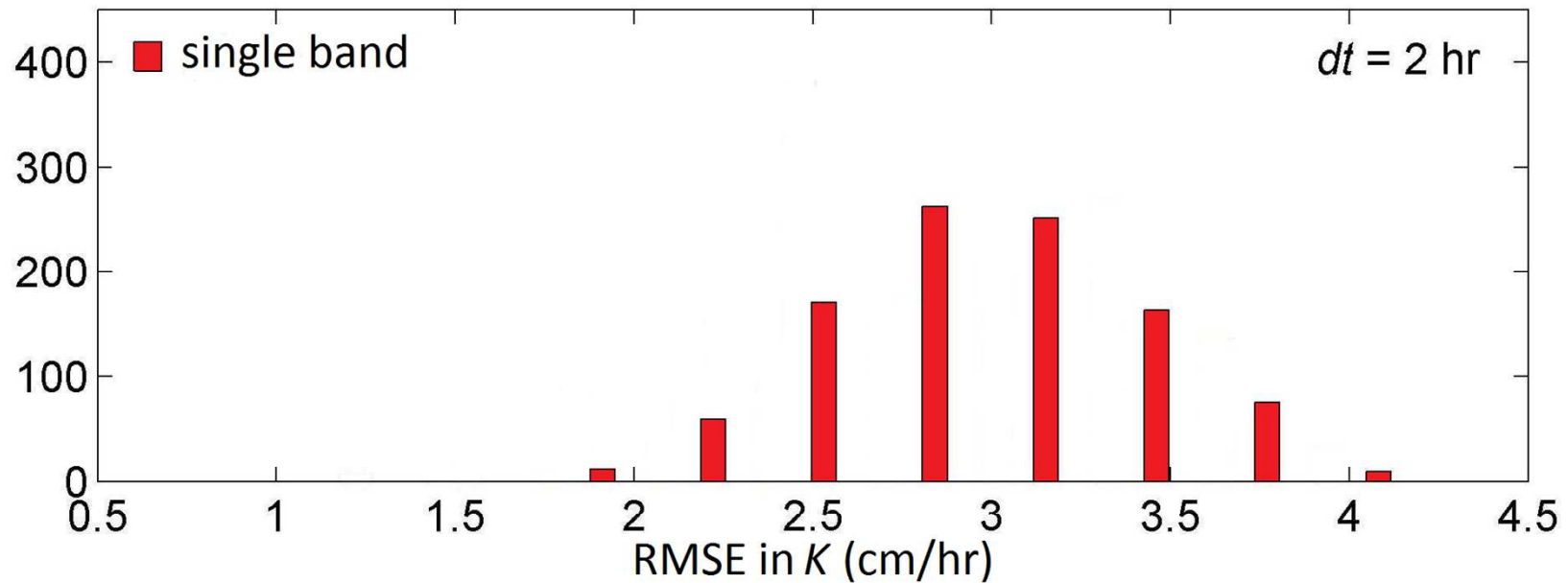
# Bootstrap 6 vb data paren

Histogram van RMSE for 1000 bootstraps



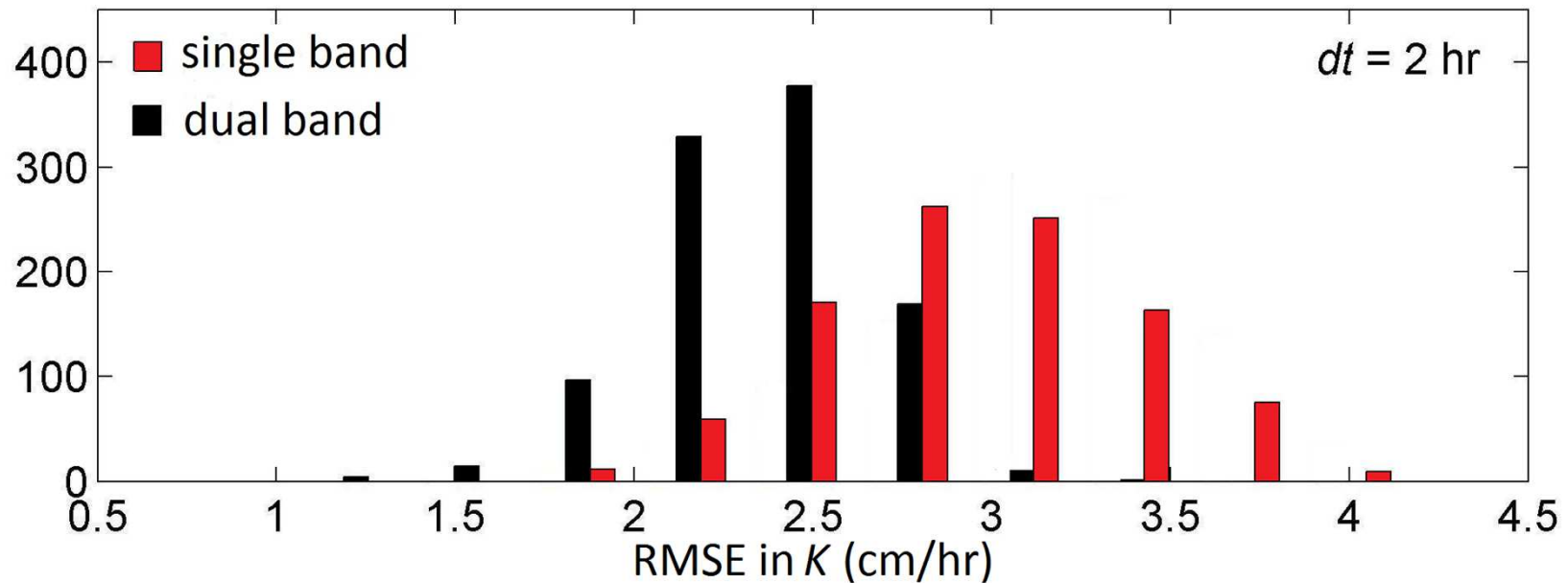
# Bootstrap de 29 data paren

## Histogram for 1000 bootstraps



# Bootstrap de 29 data paren

## Histogram for 1000 bootstraps



# Gas Flux Vergelijking

$$F = k \cdot \Delta C$$

$F$  = gas flux [g/(m<sup>2</sup>s)]

**$k$  = gas uitwisselings snelheid parameter [m/s]**

$\Delta C$  = concentratie verschil in atmosfeer - zee [g/m<sup>3</sup>]



# Gas Flux Vergelijking

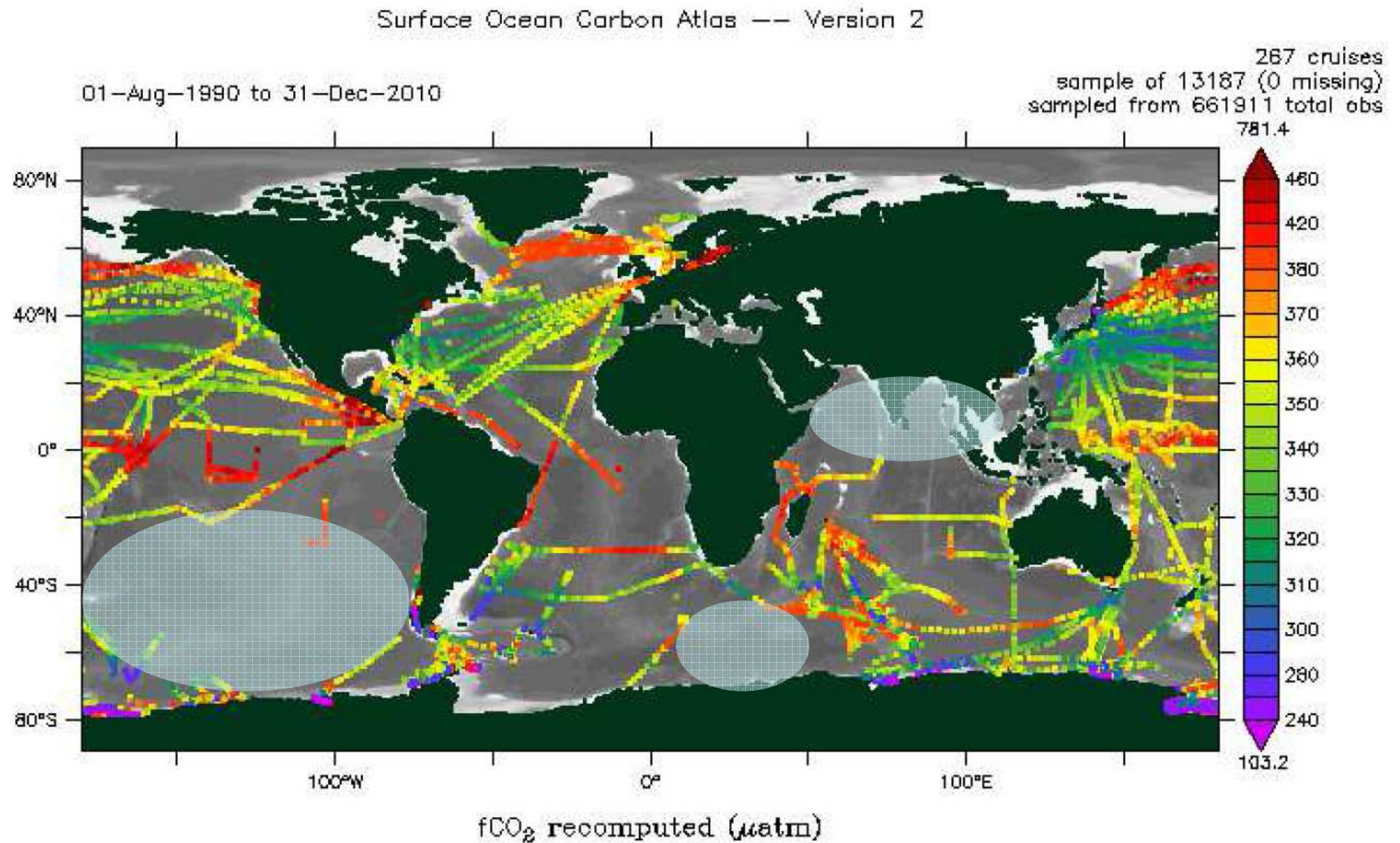
$$F = k \cdot \Delta C$$

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$k$  = gas uitwisselings snelheid parameter [m/s]

$\Delta C$  = concentratie verschil in atmosfeer - zee [g/m<sup>3</sup>]

# Alle januari metingen in 20 jaar



# Kriging

Horizontale interpolatie

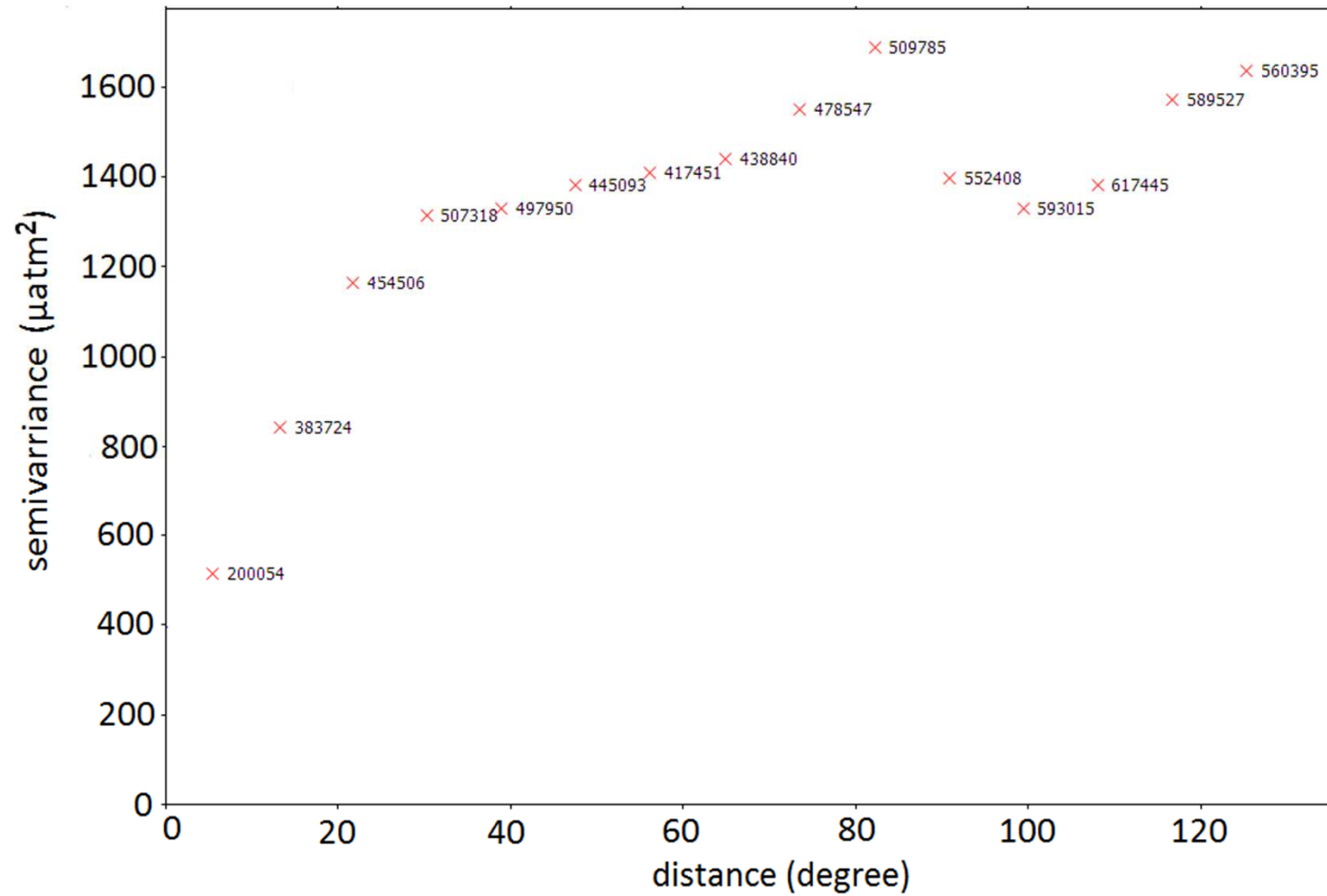
Alleen de data zelf wordt gebruikt

Variogram beschrijft de trend

Voor elk punt onzekerheid berekend

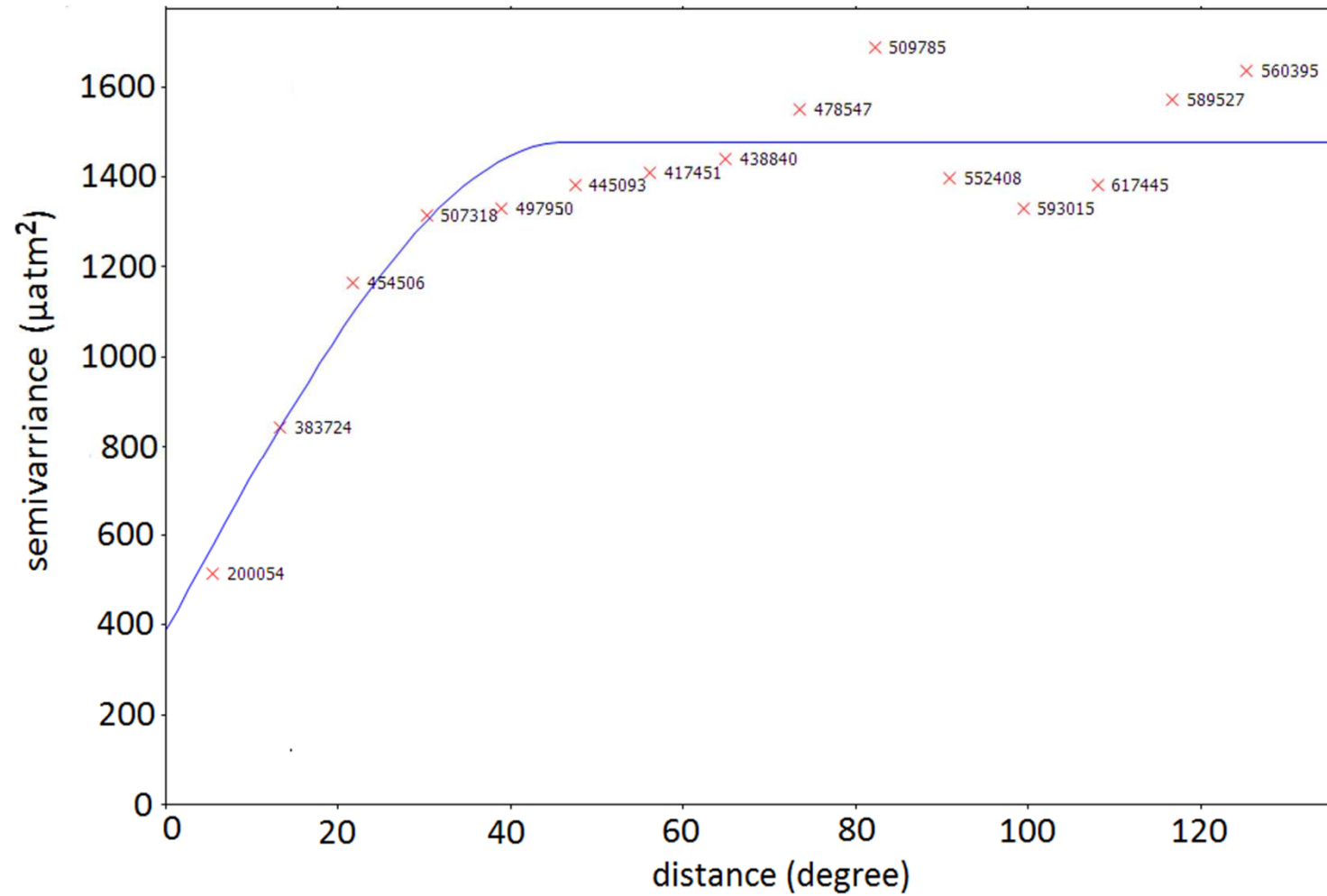
# Kriging

## Variogram voor januari



# Kriging

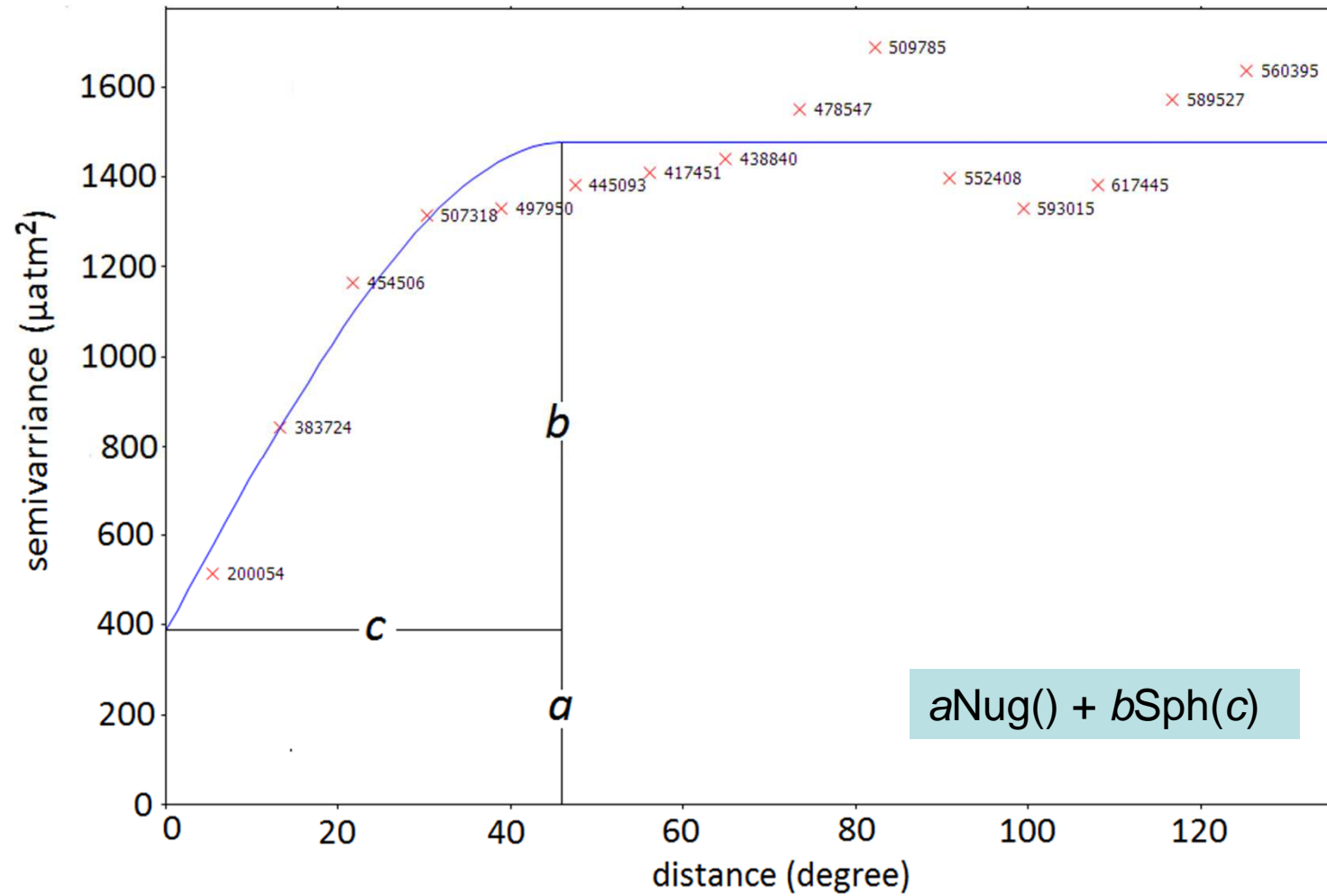
## Variogram voor januari





# Kriging

## Variogram voor januari



# Kriging

## Ordinary block kriging

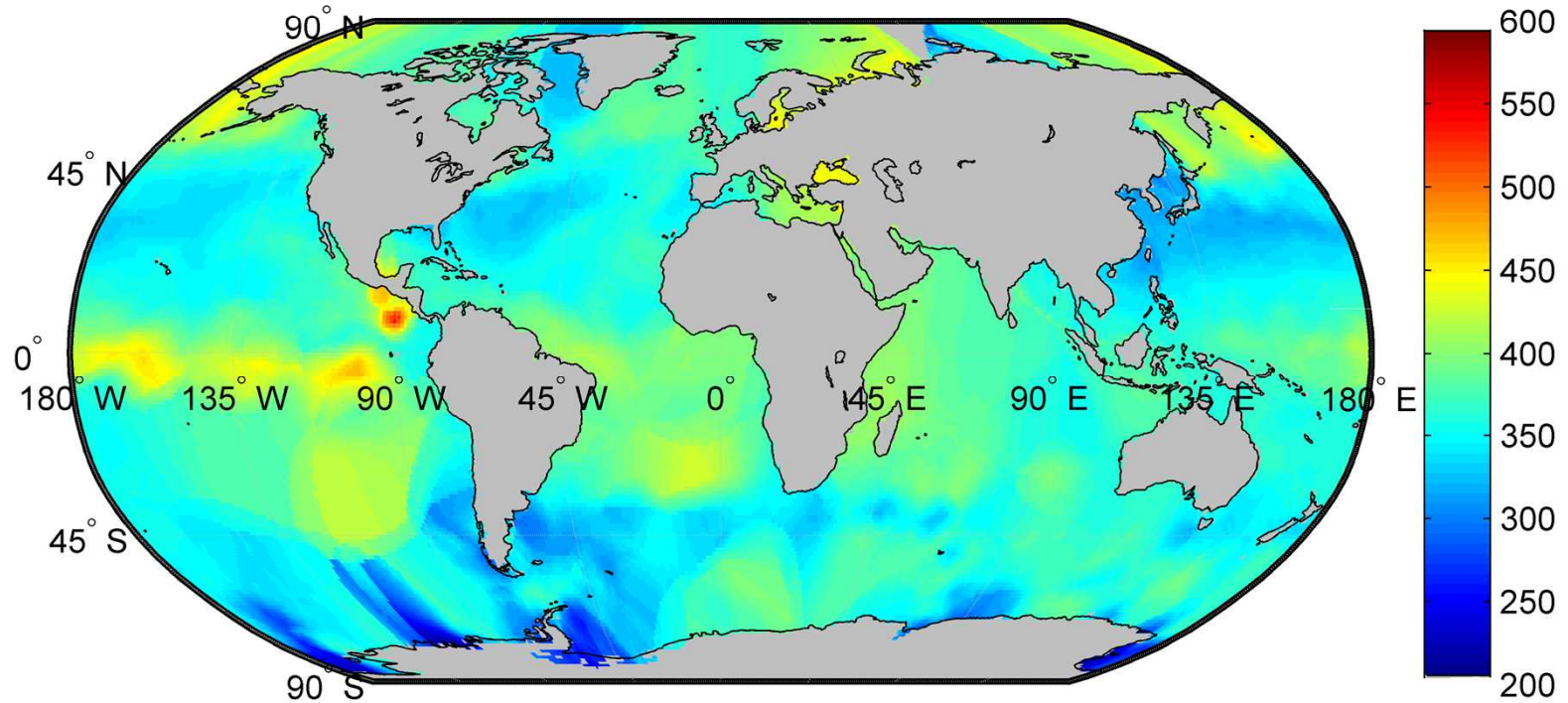
$1^\circ \times 1^\circ$  roosterpunten van de oceanen

radius =  $60^\circ$ , max = 20, min = 4

Na het selecteren van alle data punten op een afstand van  **$60^\circ$**  of minder worden de **20** dichtstbijzijnde punten gekozen en als er minder dan **4** punten zijn gevonden blijft het roosterpunt leeg

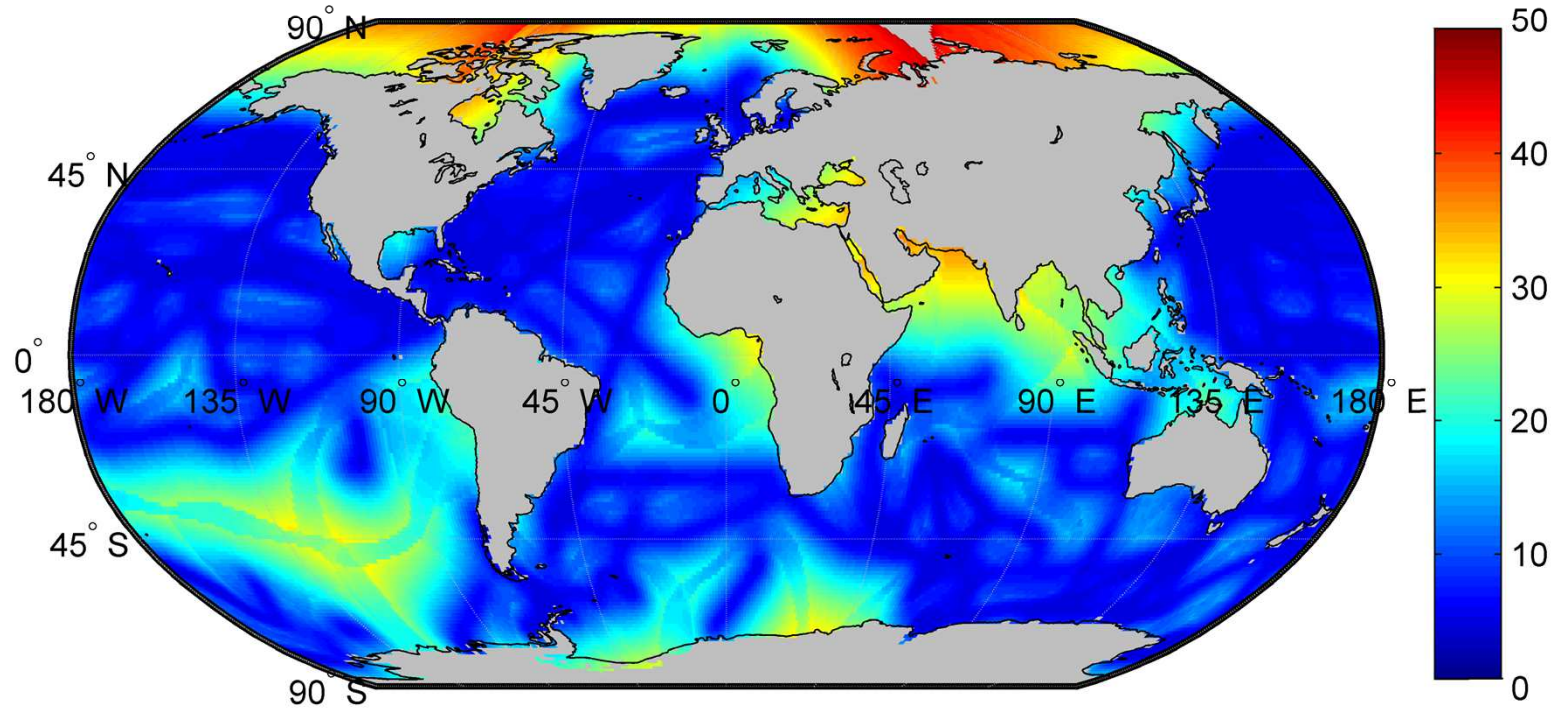
Daarna worden de roosterpunten glad gestreken door te middelen over  $5^\circ \times 5^\circ$  grote blokken

mean of  $f_{\text{CO}_2, \text{cl}}$  ( $\mu\text{atm}$ ) from SOCAT V2



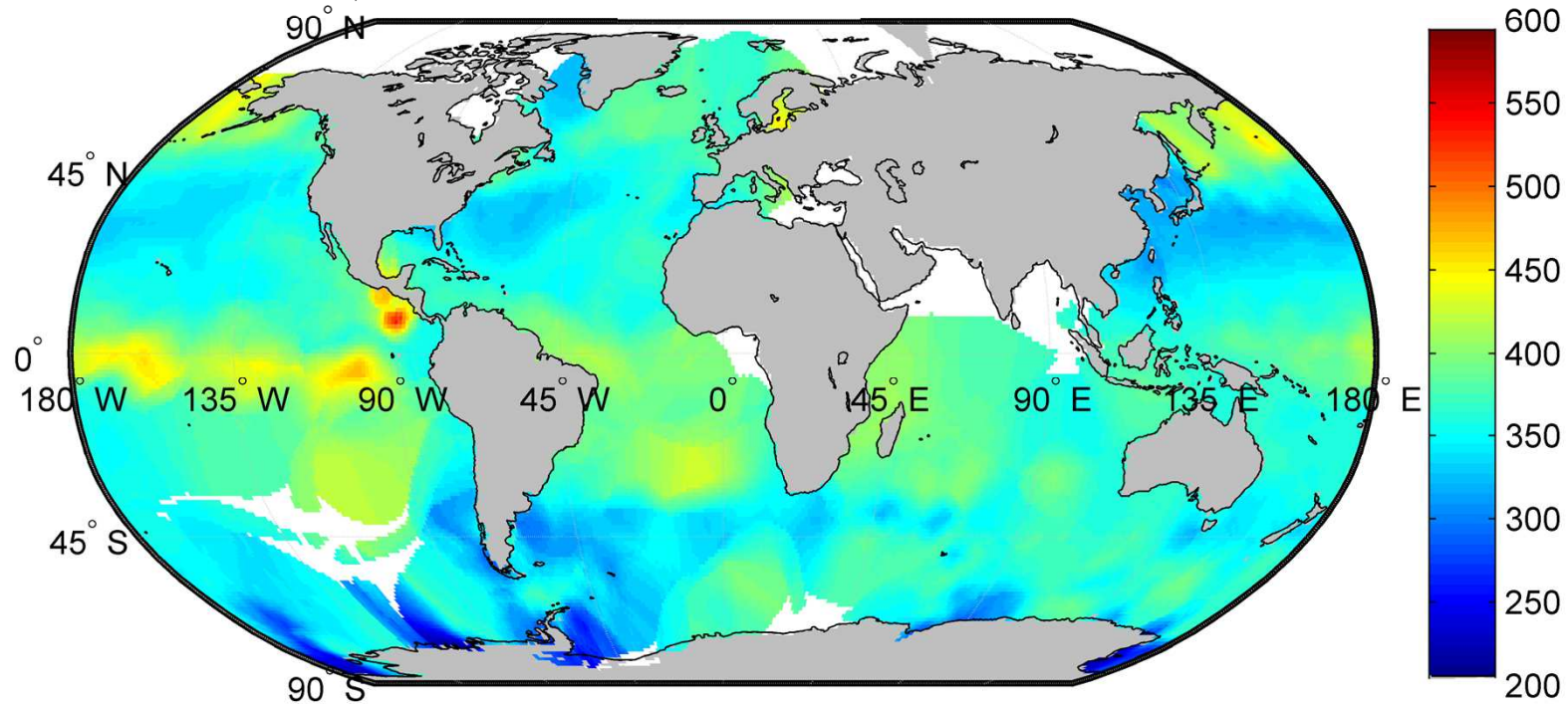
January

std of  $f_{\text{CO}_2,\text{cl}}$  ( $\mu\text{atm}$ ) from SOCAT V2



January

mean of  $f_{\text{CO}_2, \text{cl}}$  ( $\mu\text{atm}$ ) from SOCAT V2  
voor  $\text{std} > 25 \mu\text{atm}$



January

# Gas Flux Vergelijking

$$F = k \cdot \Delta C$$

$F$  = gas flux [g/(m<sup>2</sup>s)]

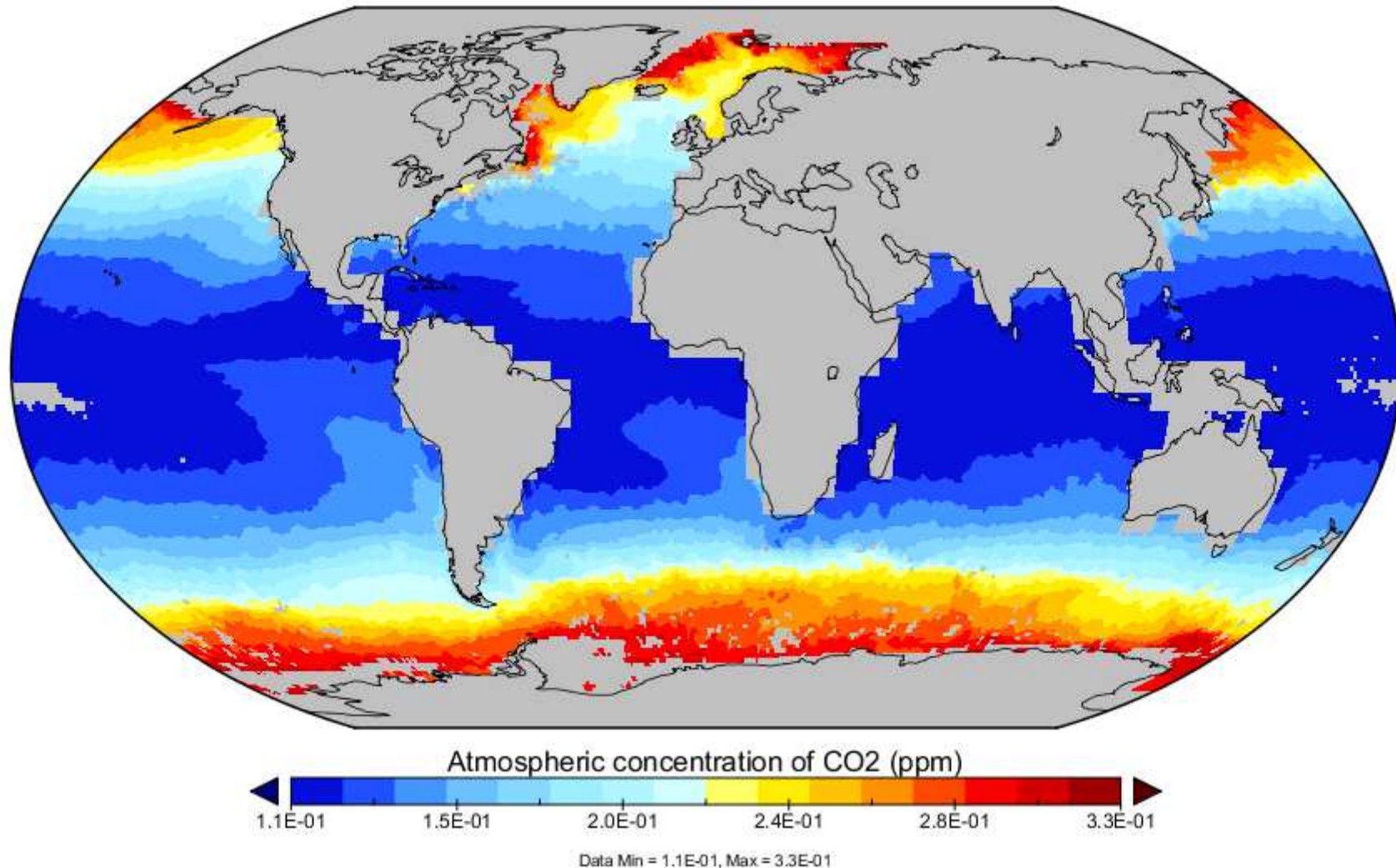
$k$  = gas uitwisselings snelheid parameter [m/s]

$\Delta C$  = concentratie verschil in atmosfeer - zee [g/m<sup>3</sup>]



# January - CO<sub>2</sub> in de atmosfeer

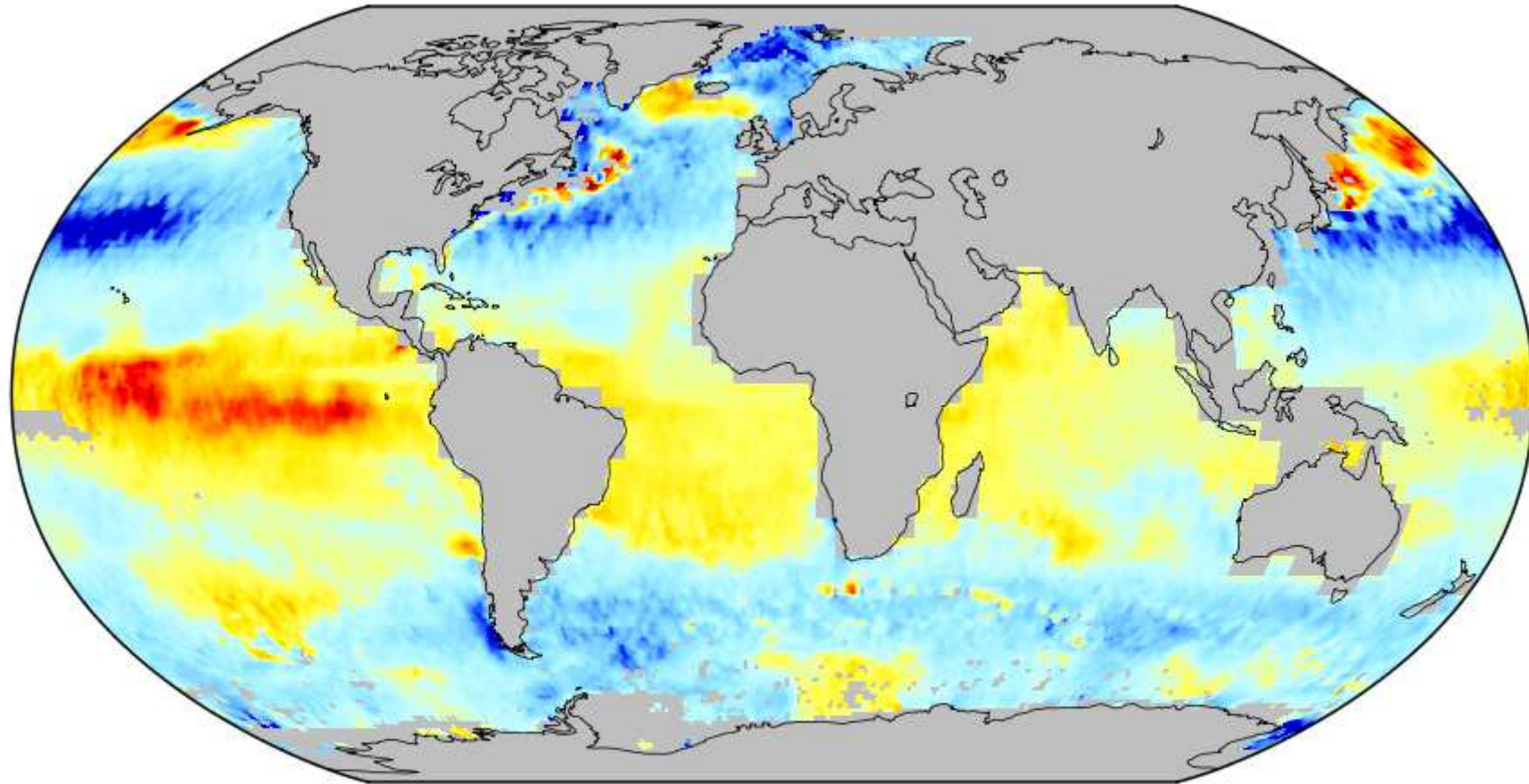
Atmospheric concentration of CO<sub>2</sub>



Fractions from the NOAA ESRL Carbon Cycle Cooperative Global Air Sampling Network. Data Path: [ftp://aftp.cmdl.noaa.gov/data/trace\\_gases/co2/flask/surface/](ftp://aftp.cmdl.noaa.gov/data/trace_gases/co2/flask/surface/)

# January - Air-sea CO<sub>2</sub> net flux

January



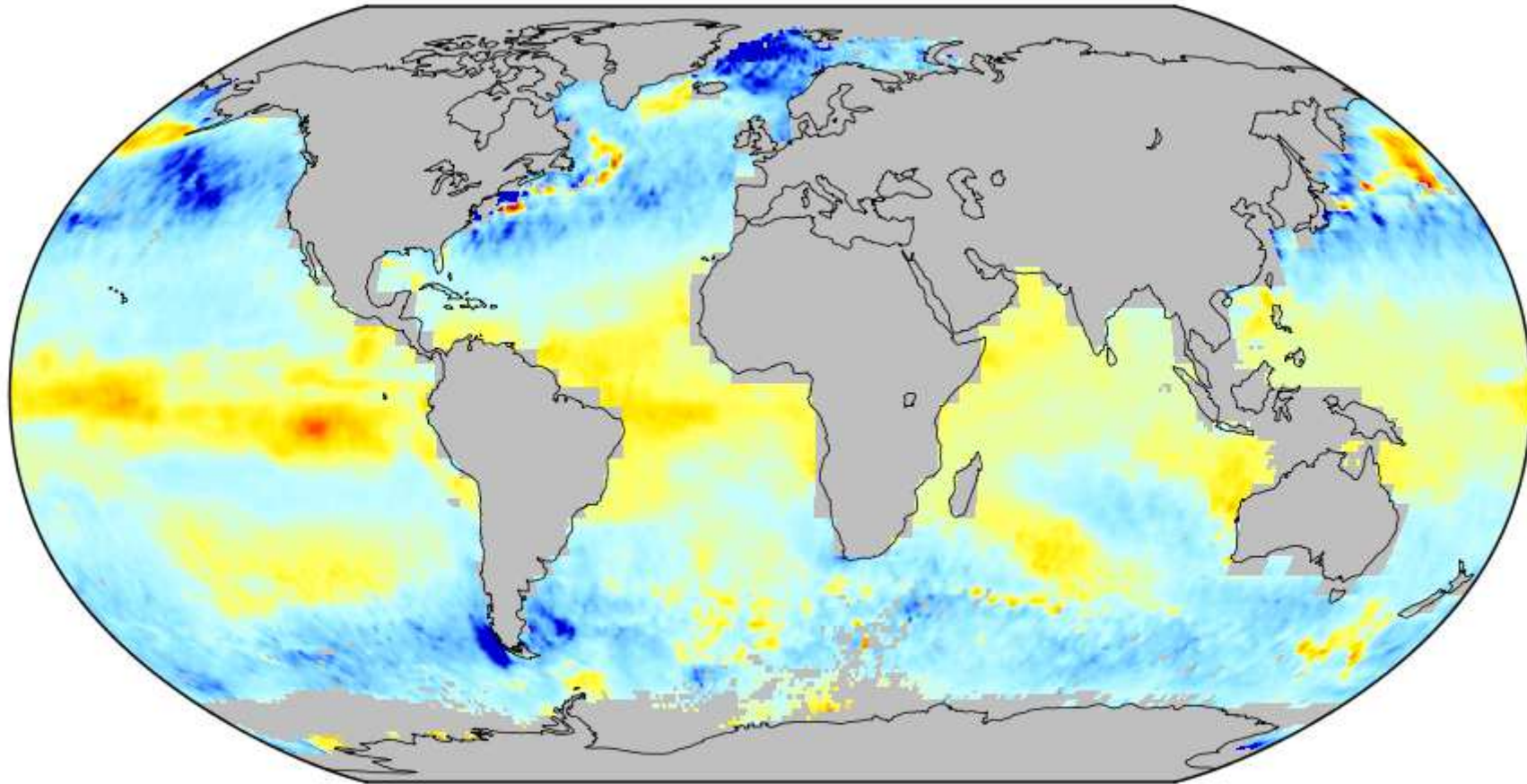
Air-sea CO<sub>2</sub> flux using the kH06 Ho et al., 2006 gas transfer velocity (k) (g C m<sup>-2</sup> day<sup>-1</sup>)





# Air-sea CO<sub>2</sub> net flux

December



Air-sea CO<sub>2</sub> flux using the kH06 Ho et al., 2006 gas transfer velocity (k) (g C m<sup>-2</sup> day<sup>-1</sup>)



# Air-sea CO<sub>2</sub> flux, totaal

Voor het jaar 2000 de jaarlijkse, globale, geïntegreerde net flux was

$-2.0 \pm 1.0$  Pg C/jaar

[*Takahashi, 2009*]

# Global Carbon Cycle

