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The retrieval of air-sea gas transfer velocity from space using the hybrid model

Lonneke Goddijn-Murphy, David Woolf, Adrian Callaghan, Christa Marandino

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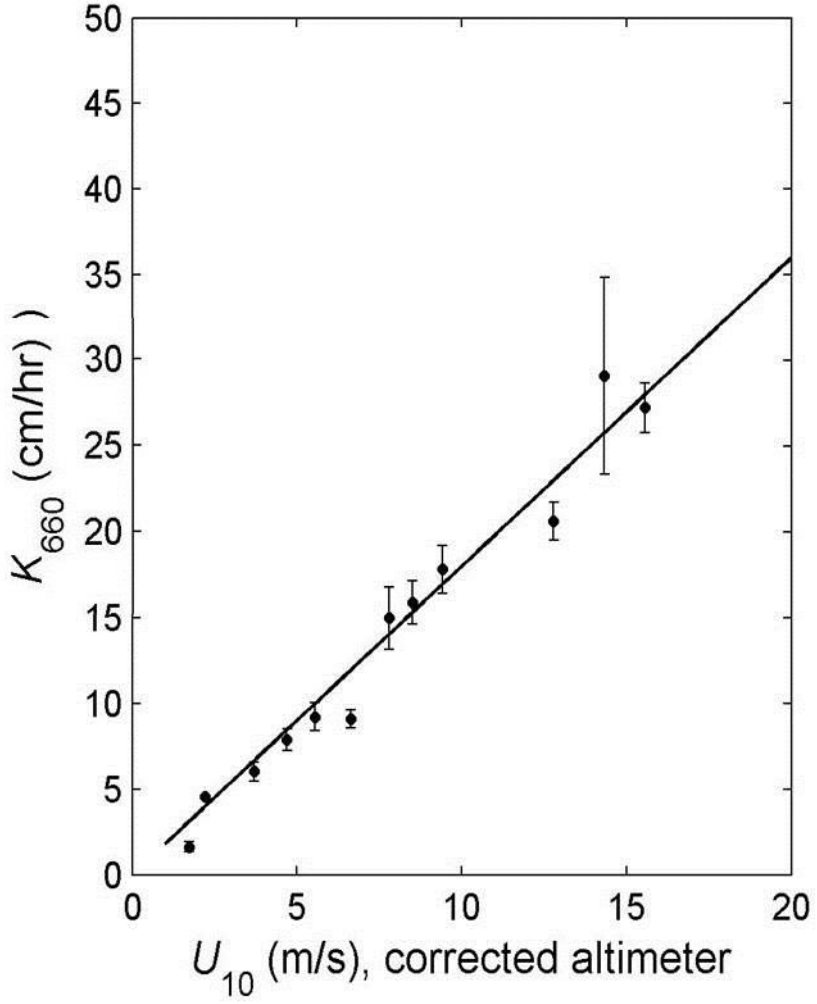
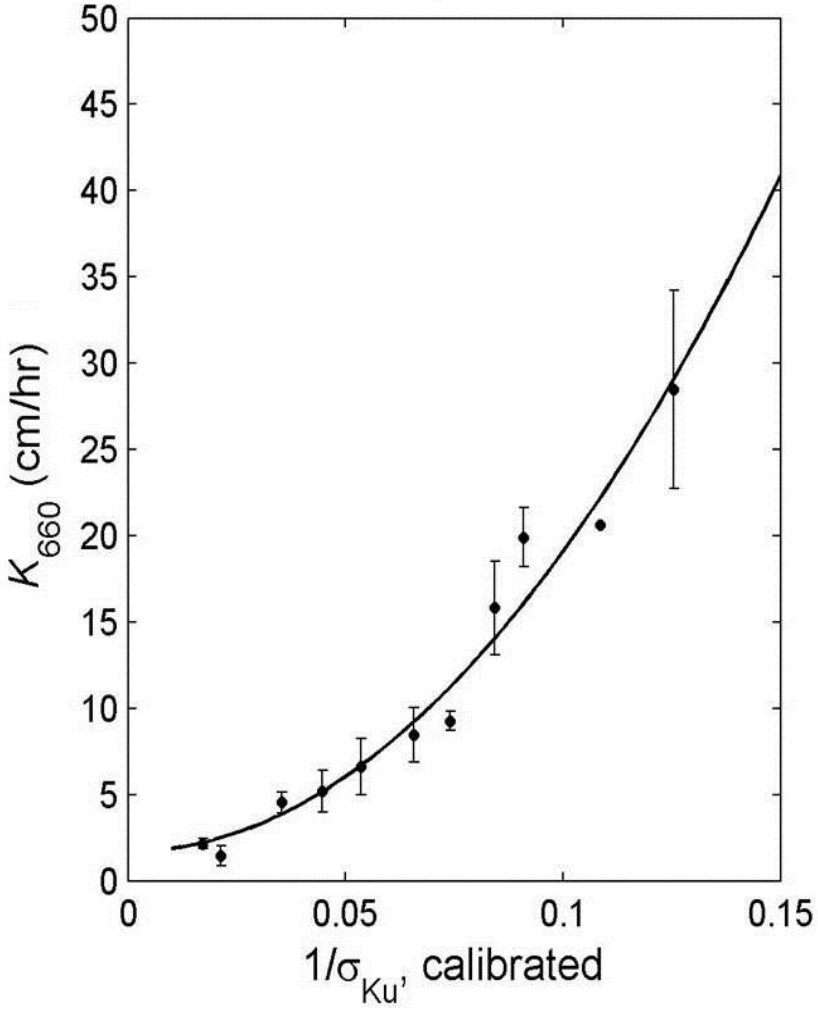
K_{660} measurements for DMS – satellite altimeter U_{10}



$$K_{660} = 2.1 \cdot U_{10,al} - 2.8$$

(R^2 = 0.53; *RMSE* = 4.9)

K_{660} measurements for DMS – satellite altimeter σ_{Ku}



$$K_{660} = 0.4 + \frac{1.9 \cdot 10^3}{\sigma_{Ku}^2}$$

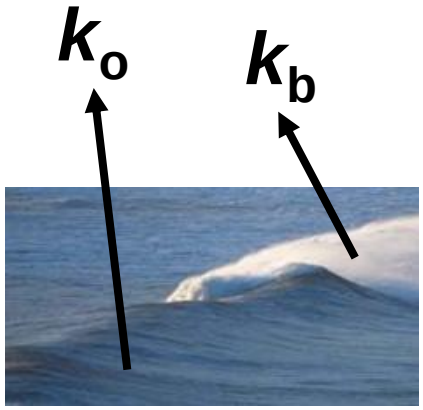
(R^2 = 0.52; *RMSE* = 5.0)

Hybrid model:

$$k_w = k_o + k_b$$

Two parallel pathways expressed as separate

and additive contributions to the total kinetic rate



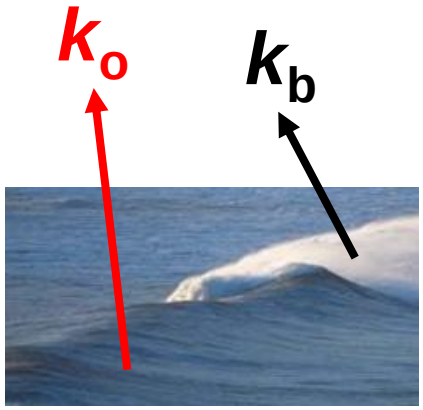
Hybrid model:

$$k_w = k_o + k_b$$

k_o direct gas transfer through the unbroken surface

described by ordinary molecular and turbulent transfer

$$k_{o,1} = k_{o,2}\left(\frac{Sc_1}{Sc_2}\right)^{-0.5}$$



Hybrid model:

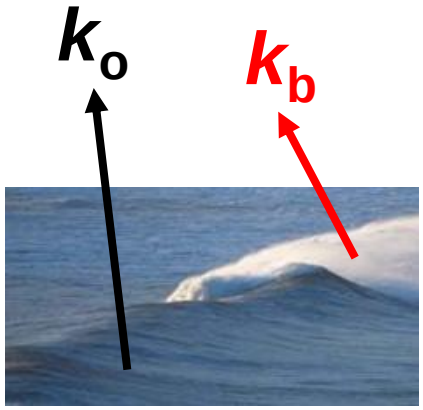
$$k_w = k_o + k_b$$

k_b gas transfer through bubbles

from **bubble models** (Woolf *et al.*, 2007) and ***W***

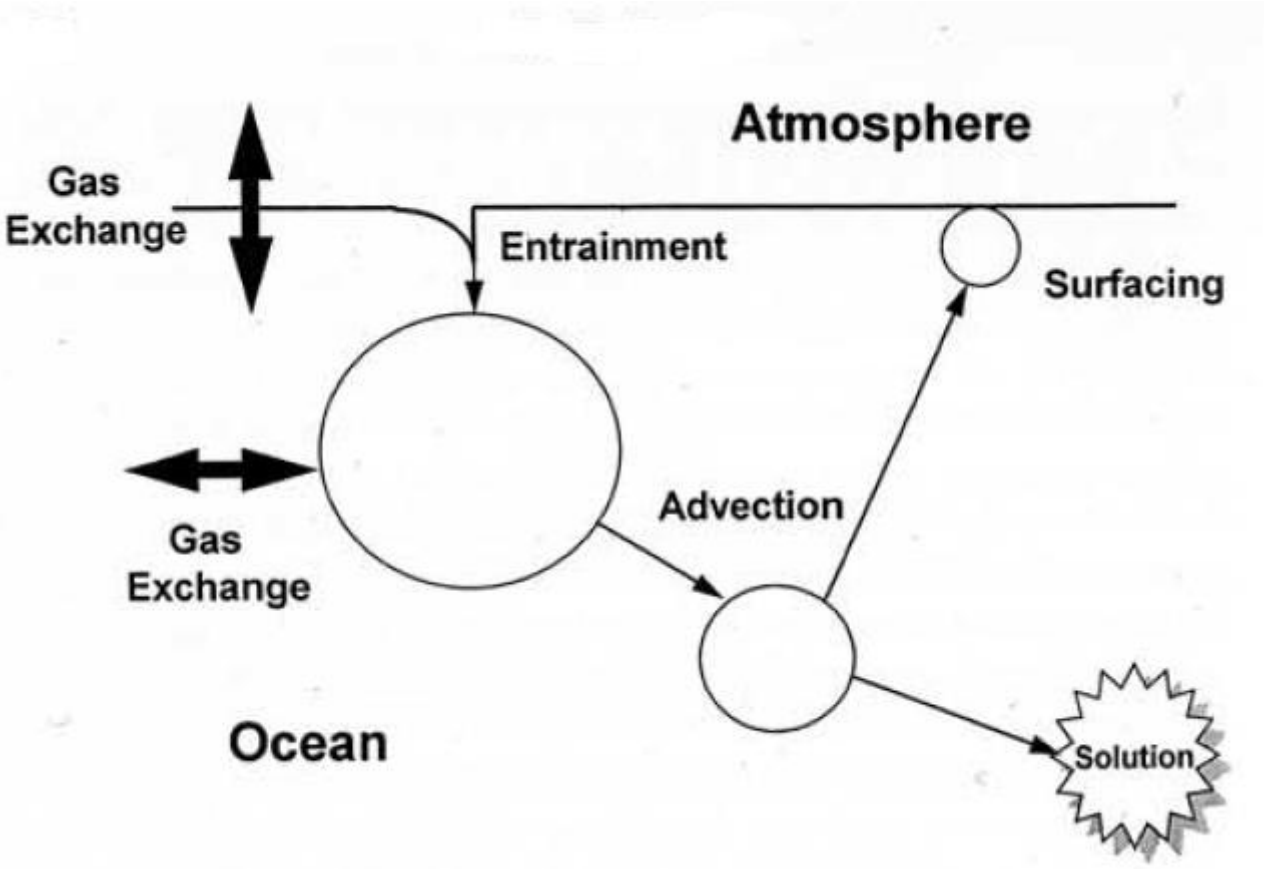
Whitecap coverage, *W*

- Measurements
- Models
- Parameterizations



$$k_b = k_{mod} W\%$$

Bubble model



(Woolf, 1997)

Bubble model

Gas characteristics

- Ostwald solubility, α
- Schmidt number, Sc

Plume characteristics

- Volume flux of bubbles
- Breadth of bubble plume
- Bubble interaction

Bubble interaction

1) Independent bubble model

Bubbles exchange gas with surrounding water independently of each other

$$k_b = k_{ind} W\%$$

2) Dense plume model

A collective effect of the gas exchange of bubbles on surrounding water

$$k_b = k_{void}(v) W\%$$

v = void fraction

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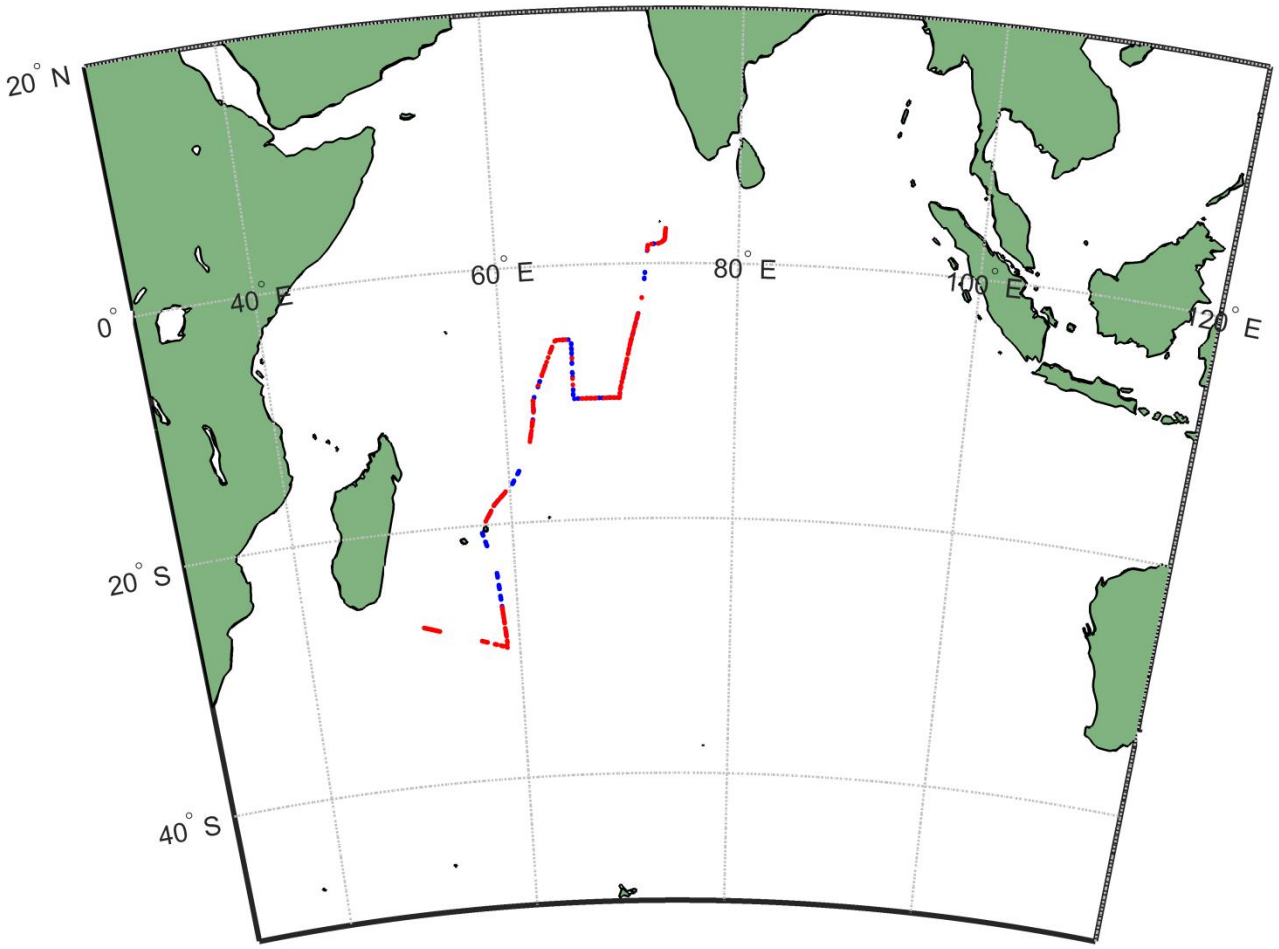
air-sea flux measurements using EC Indian Monsoon, July-August 2014



DMS CO_2

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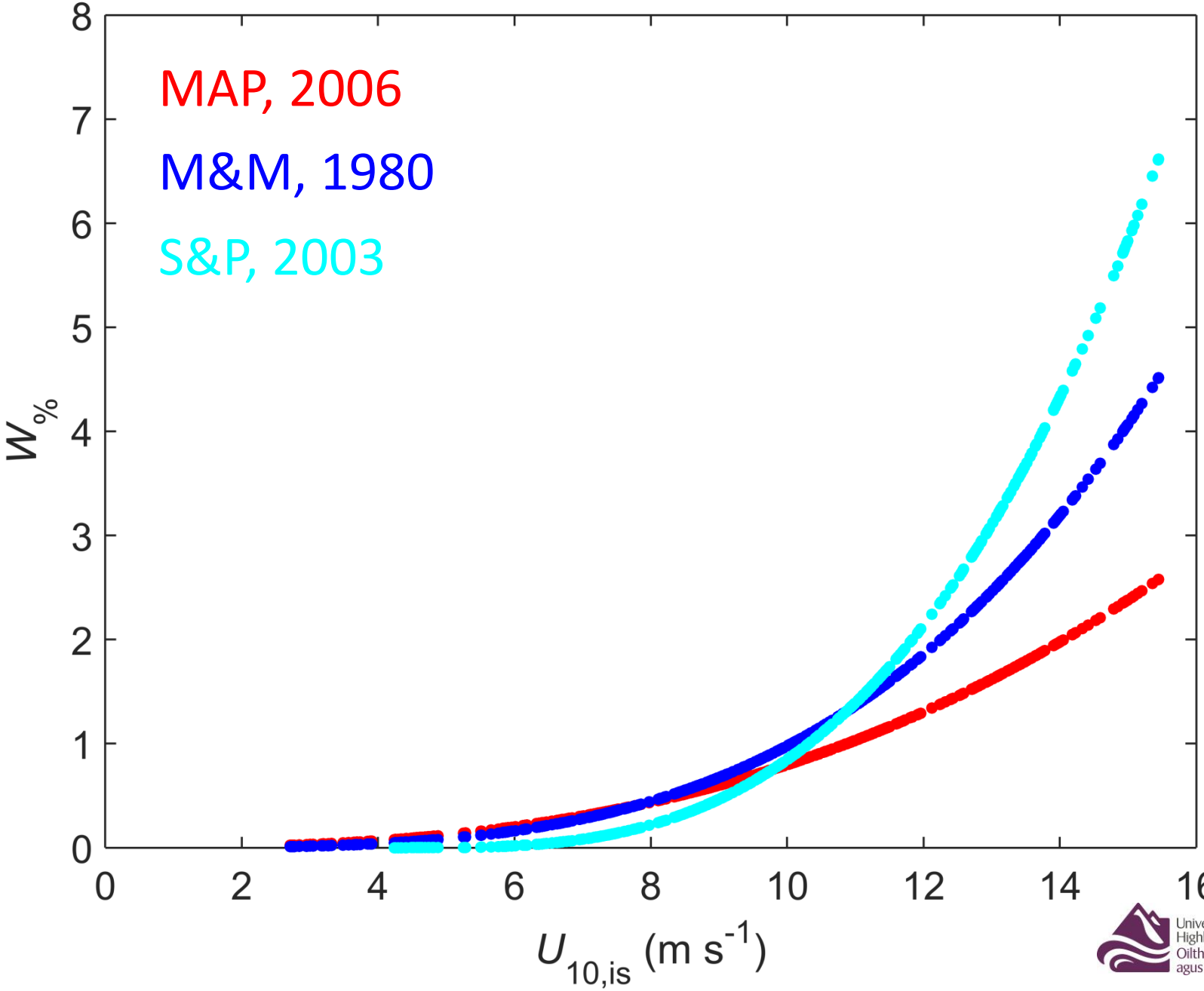
Empirical whitecap parameterizations



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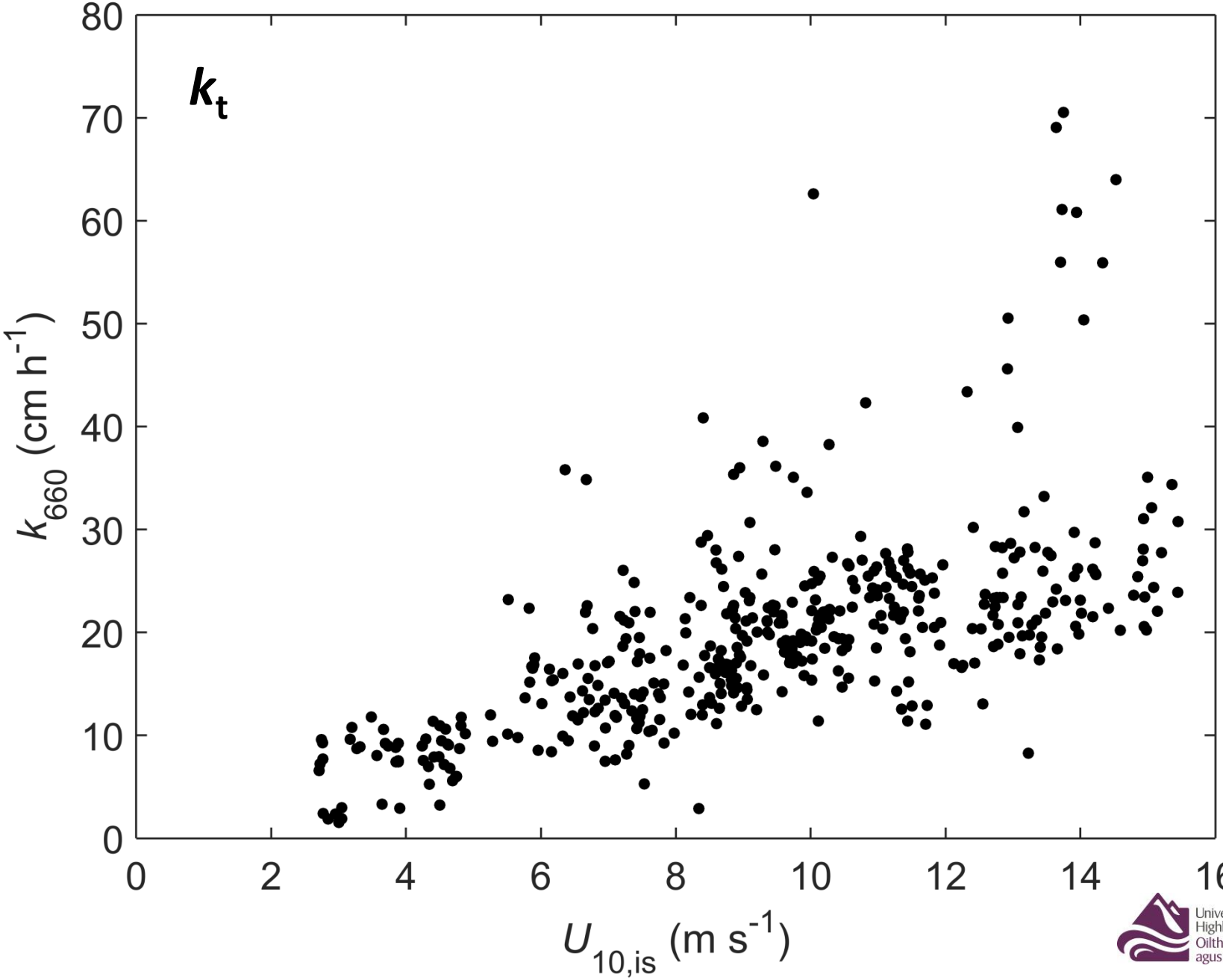

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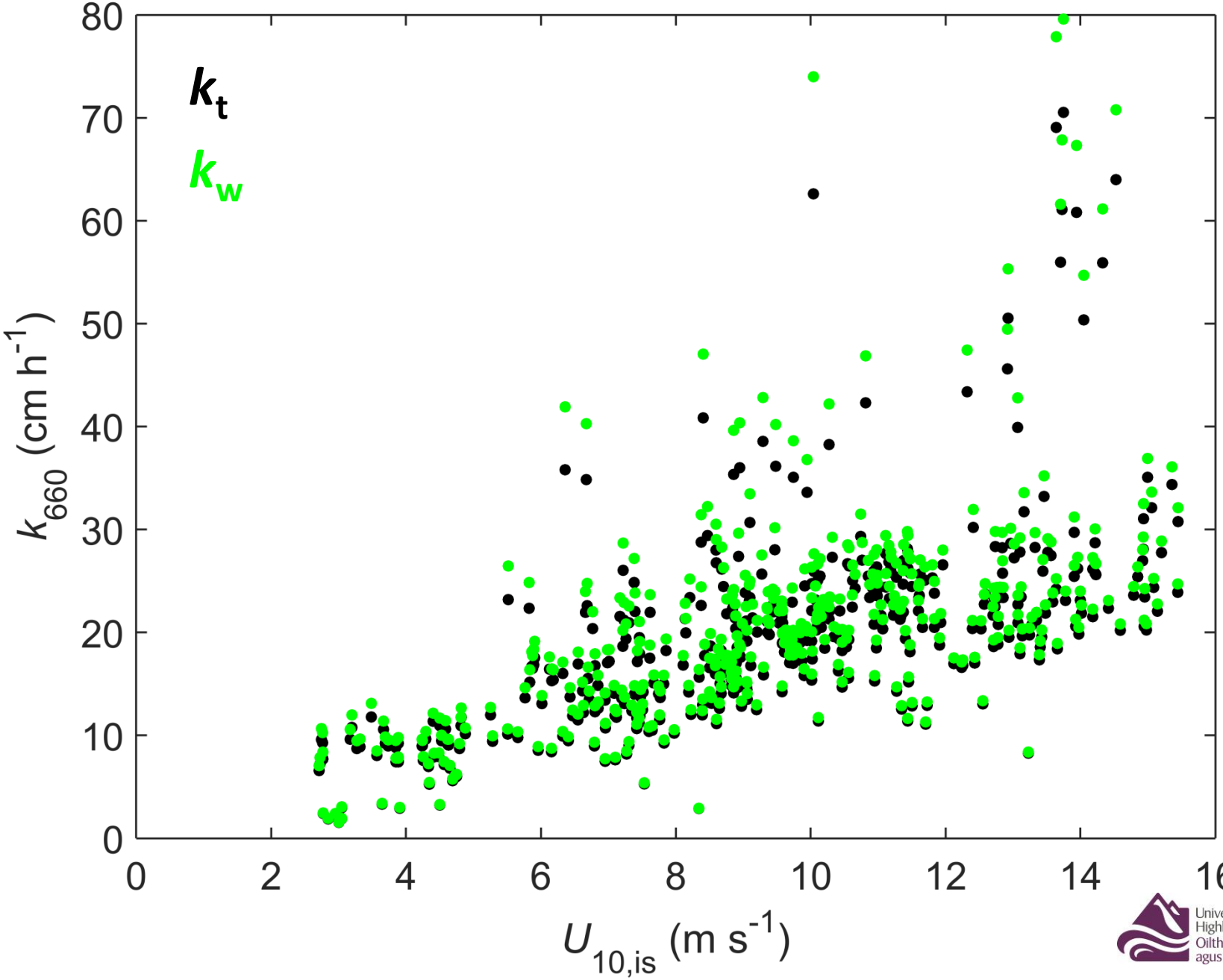

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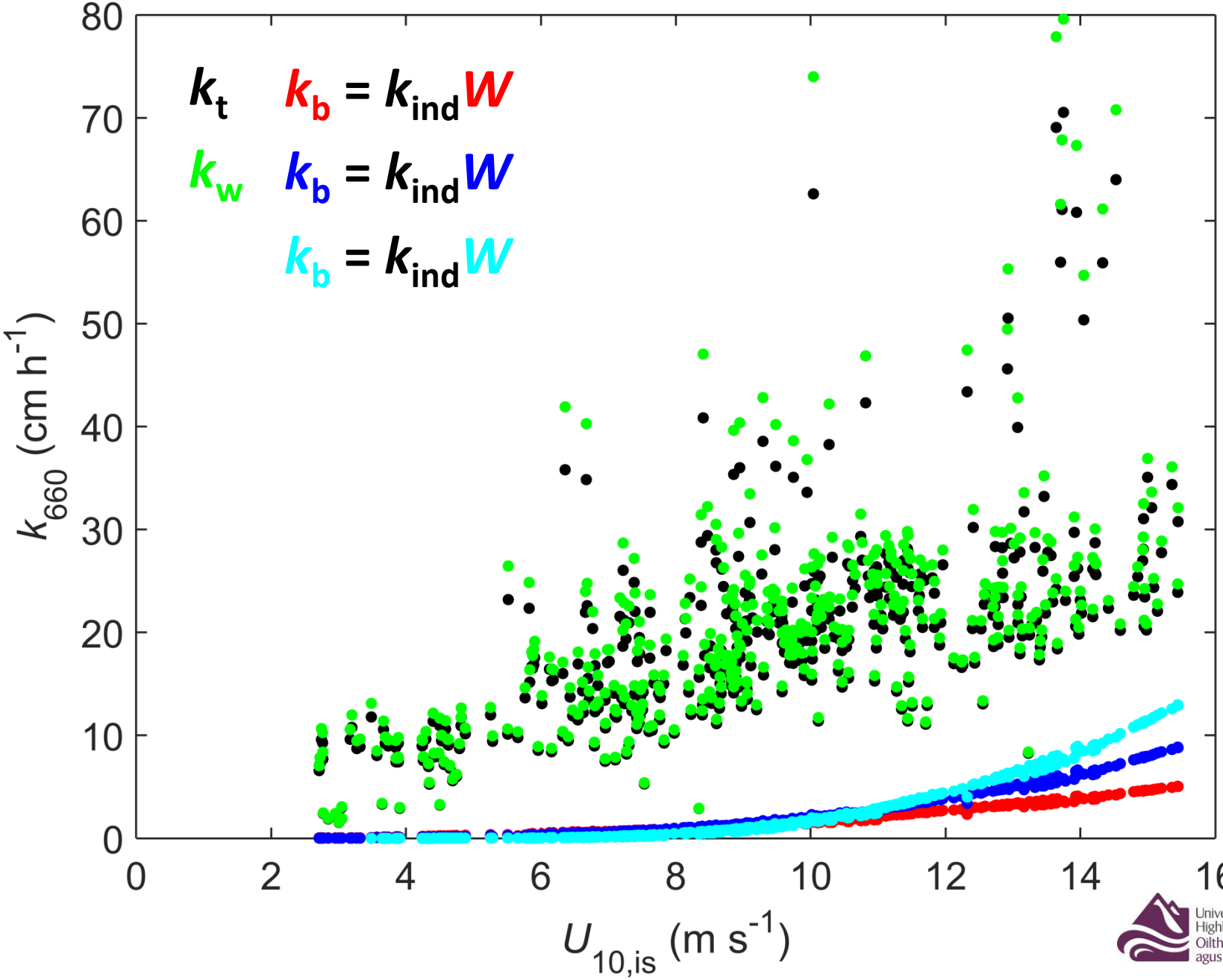

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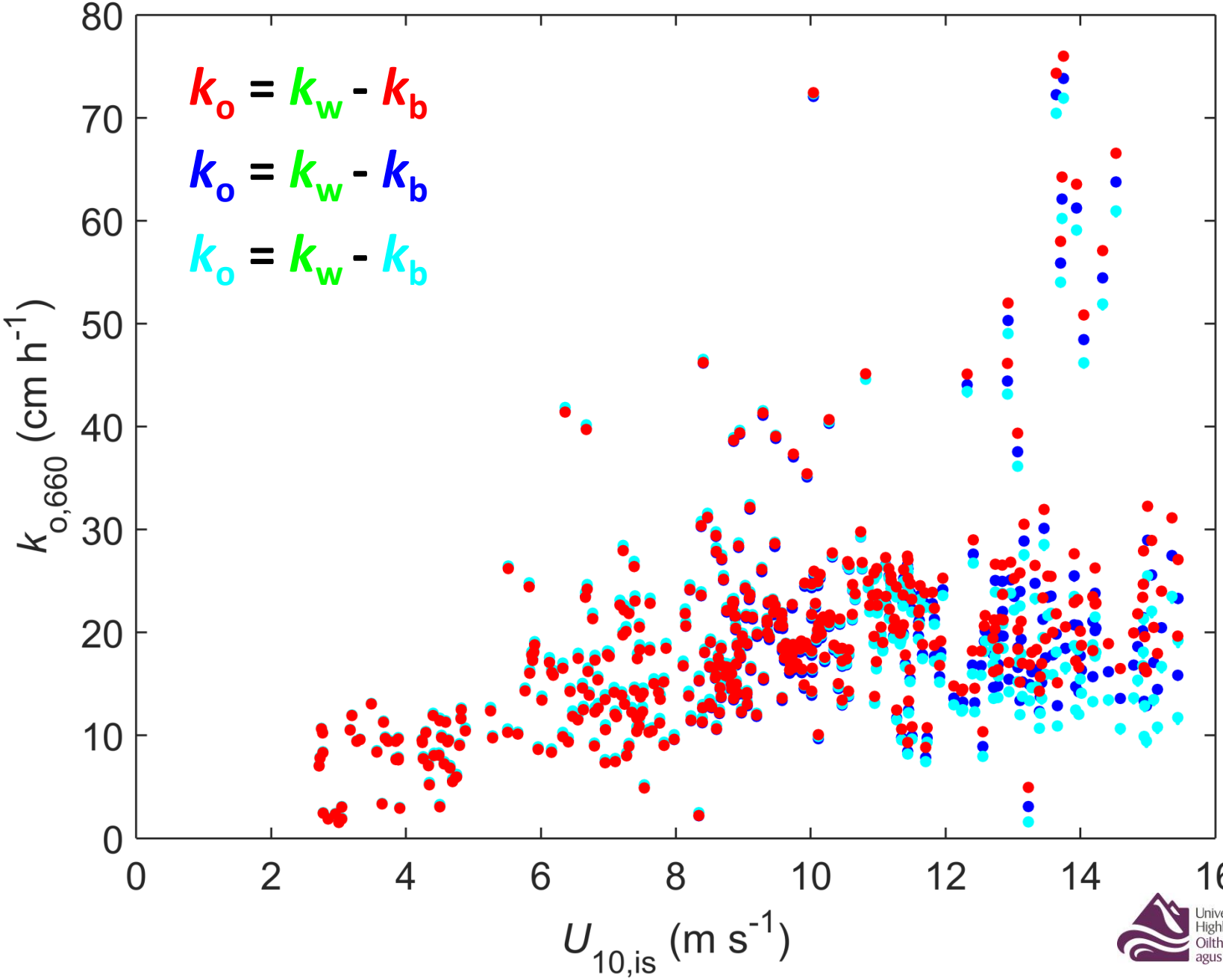

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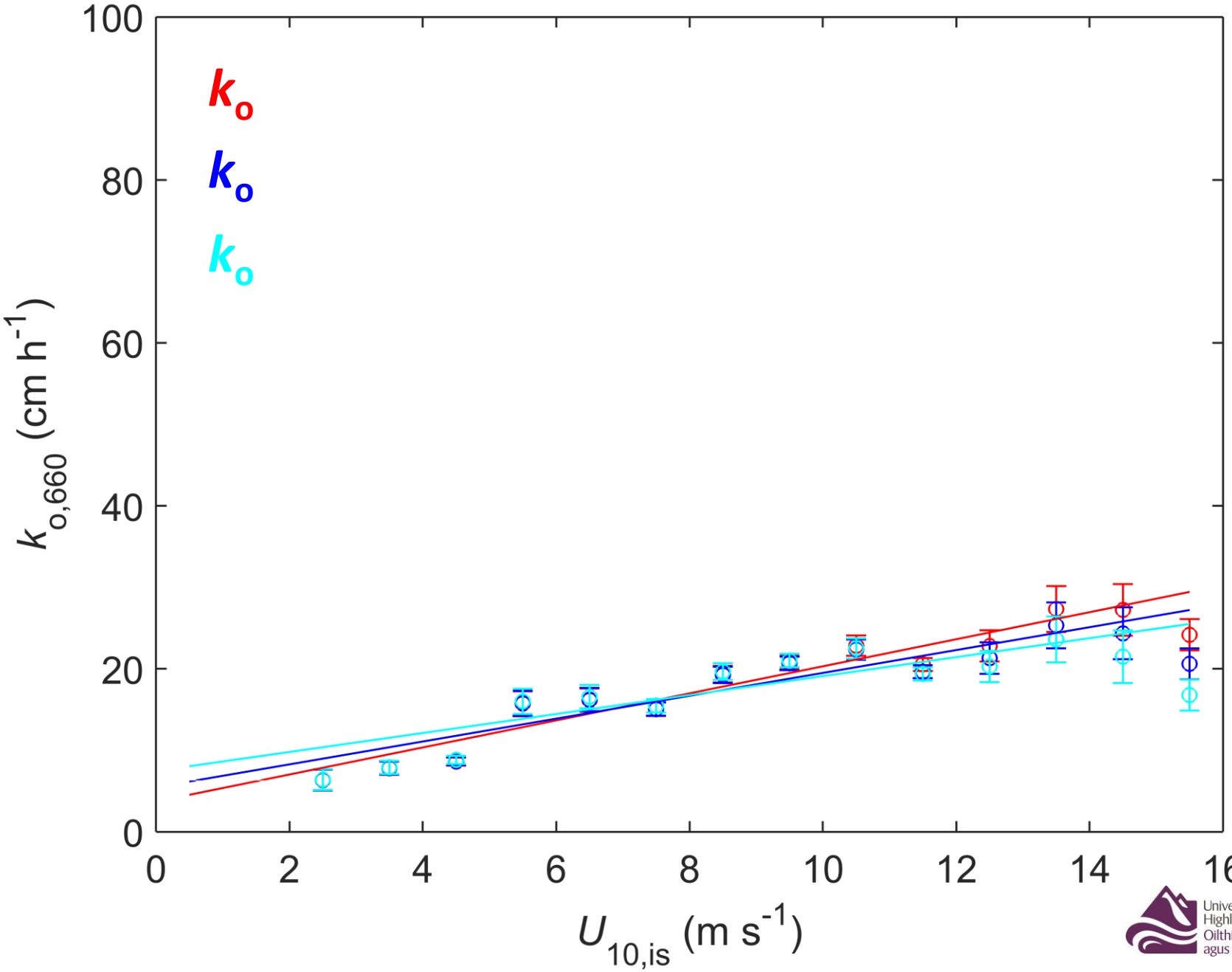

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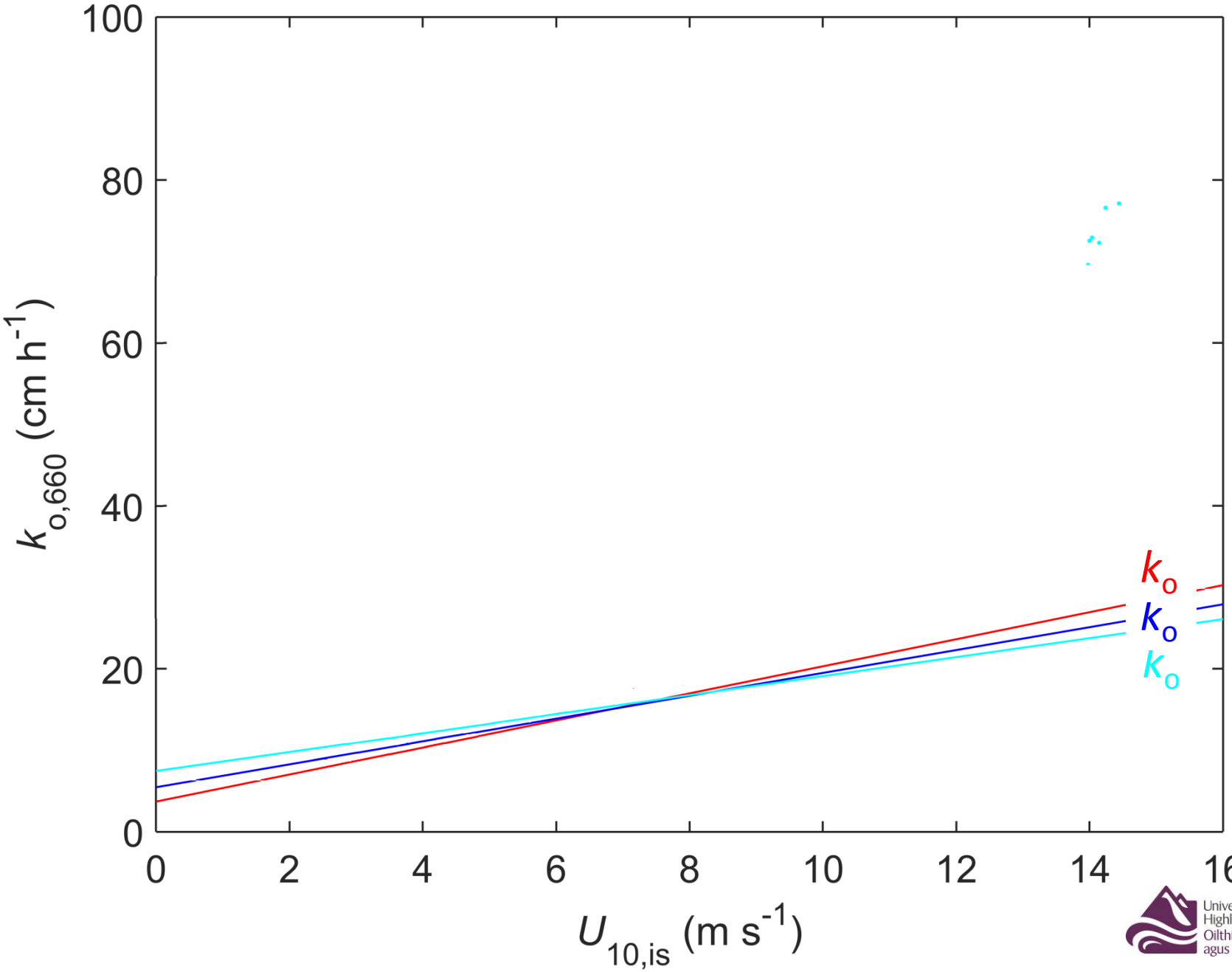
CO_2



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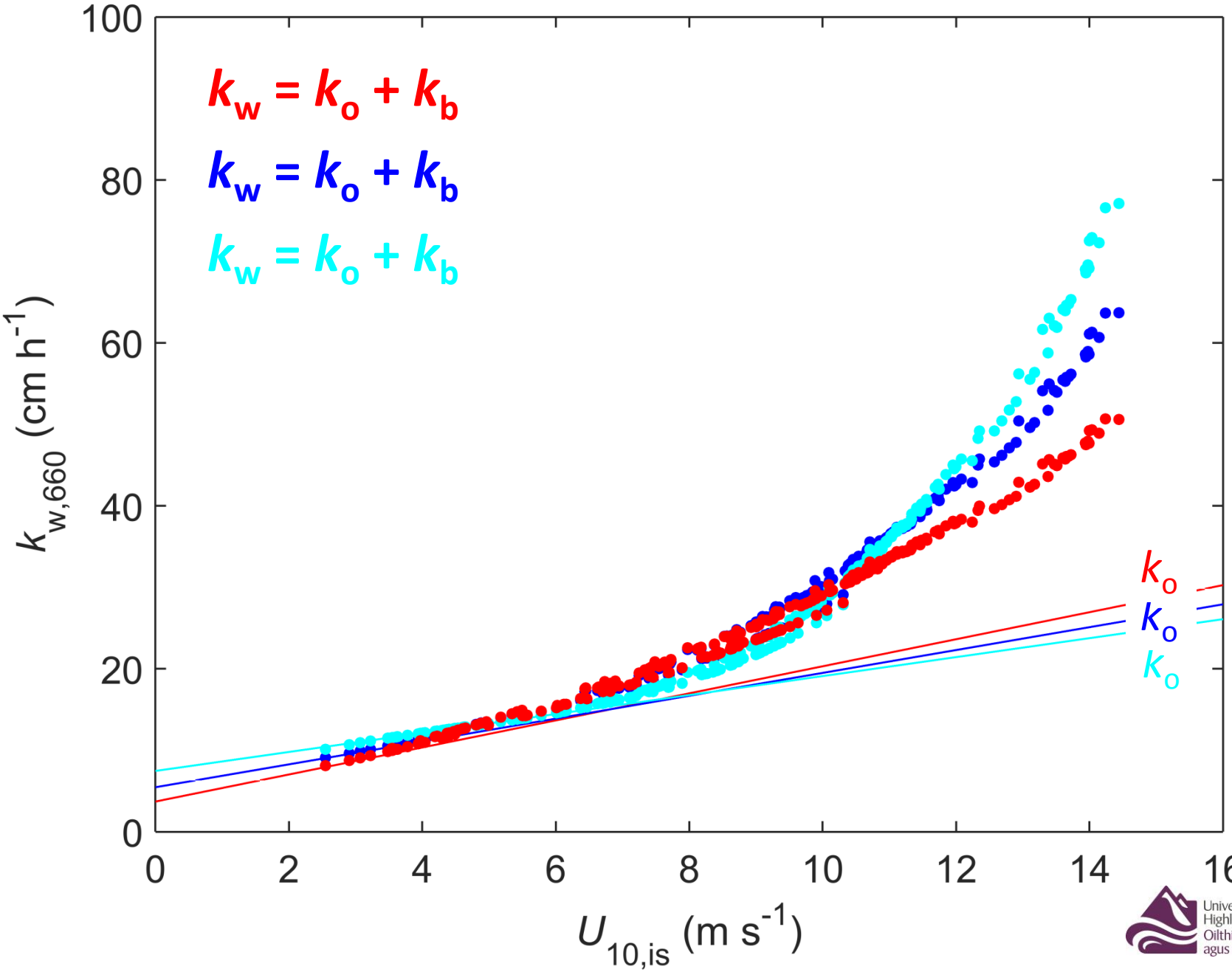
CO_2



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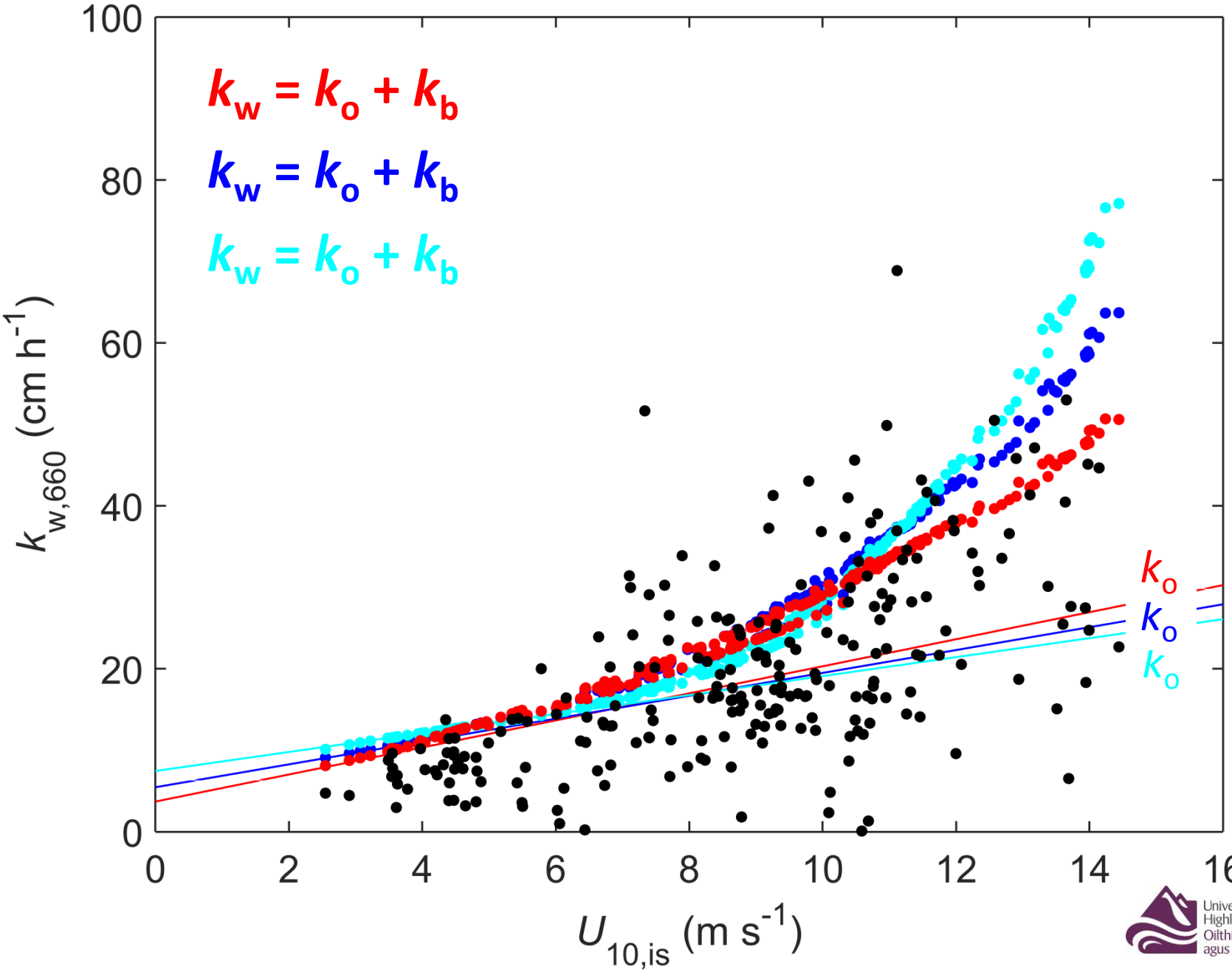
CO_2



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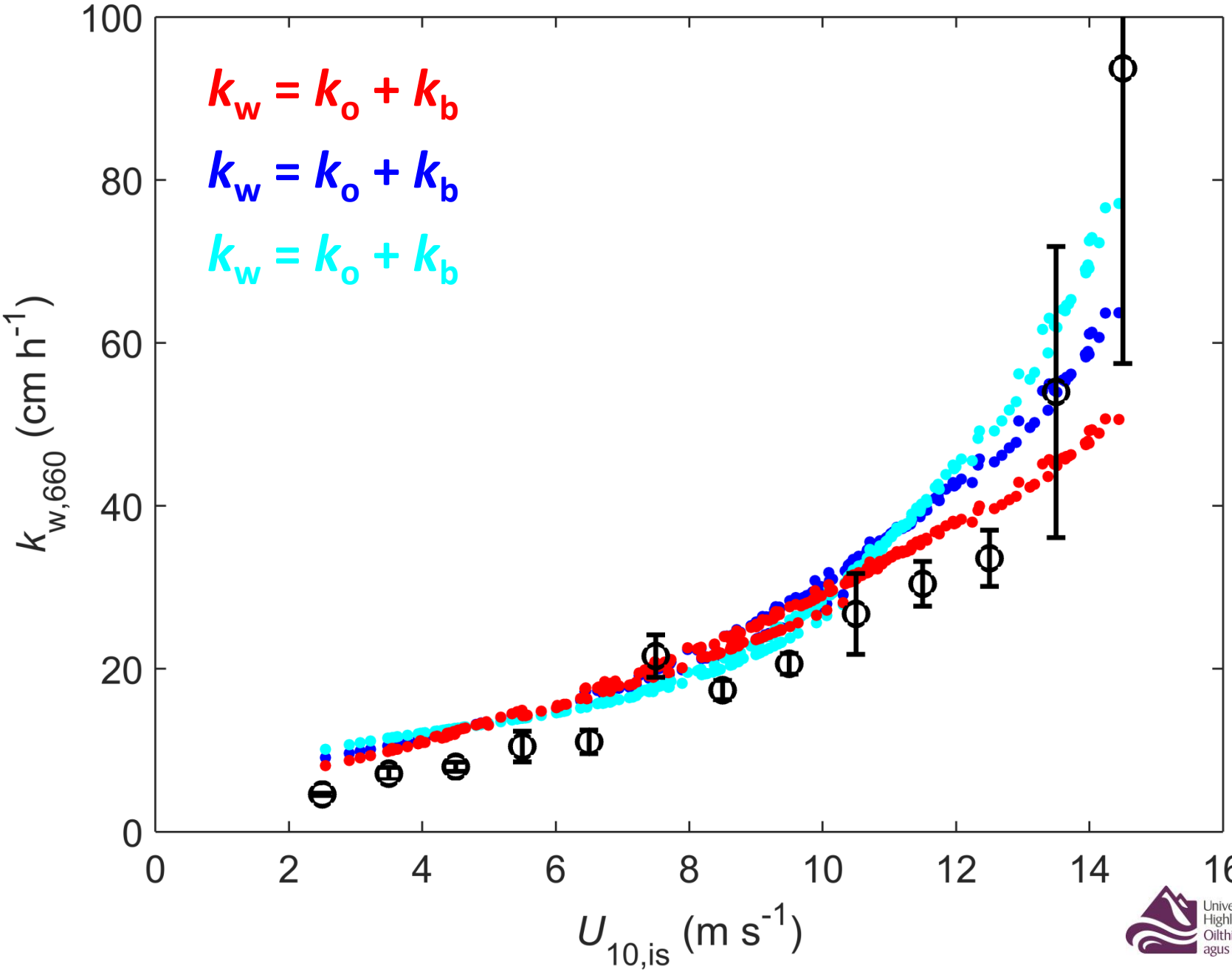
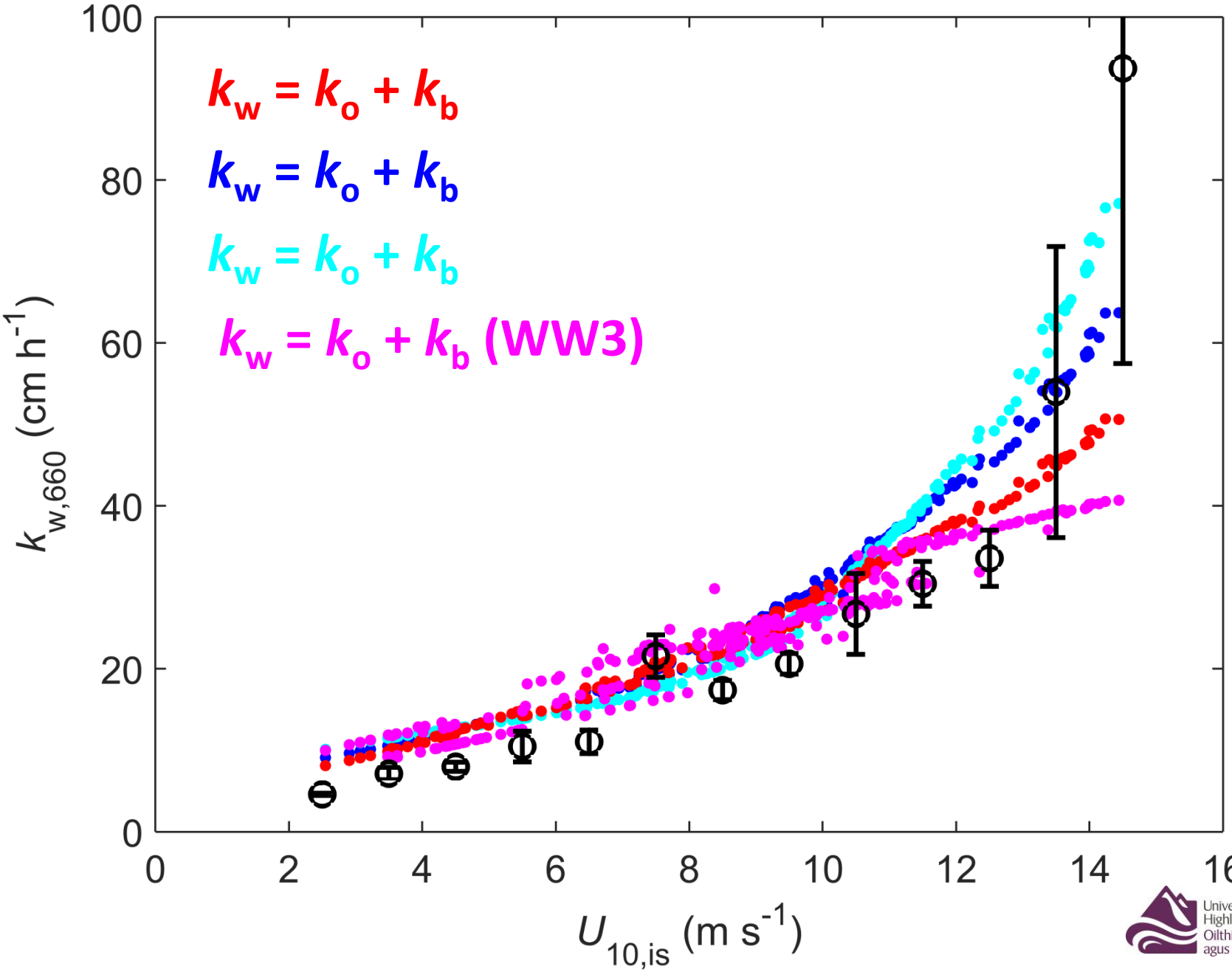
CO_2


$k_w = k_o + k_b$
$k_w = k_o + k_b$
$k_w = k_o + k_b$
$k_{w,660}$ (cm h^{-1})
$U_{10,is}$ (m s^{-1})
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16

CO_2


$k_w = k_o + k_b$
$k_w = k_o + k_b$
$k_w = k_o + k_b$
$k_w = k_o + k_b$ (WW3)
$k_{w,660}$ (cm h^{-1})
$U_{10,is}$ (m s^{-1})
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16

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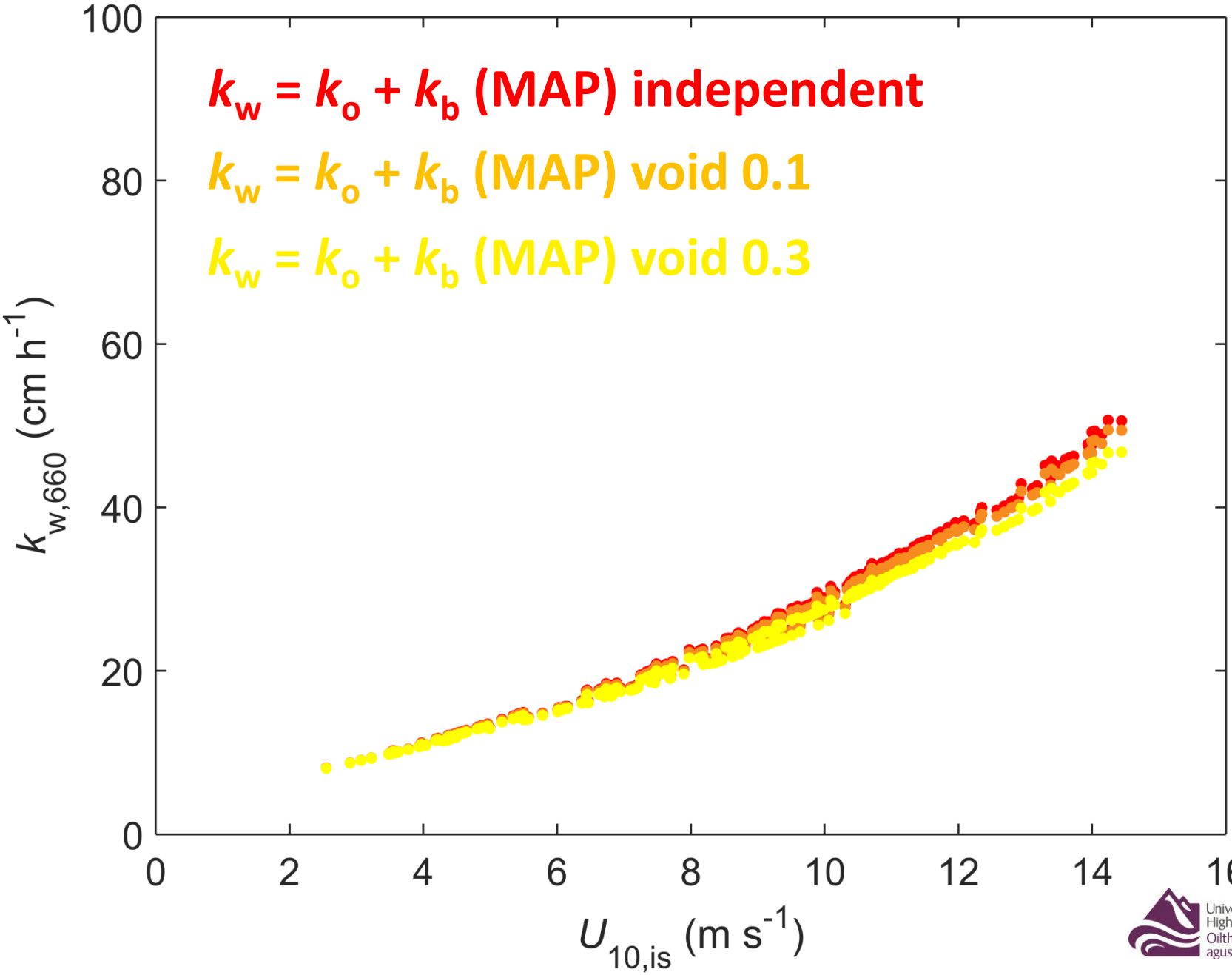

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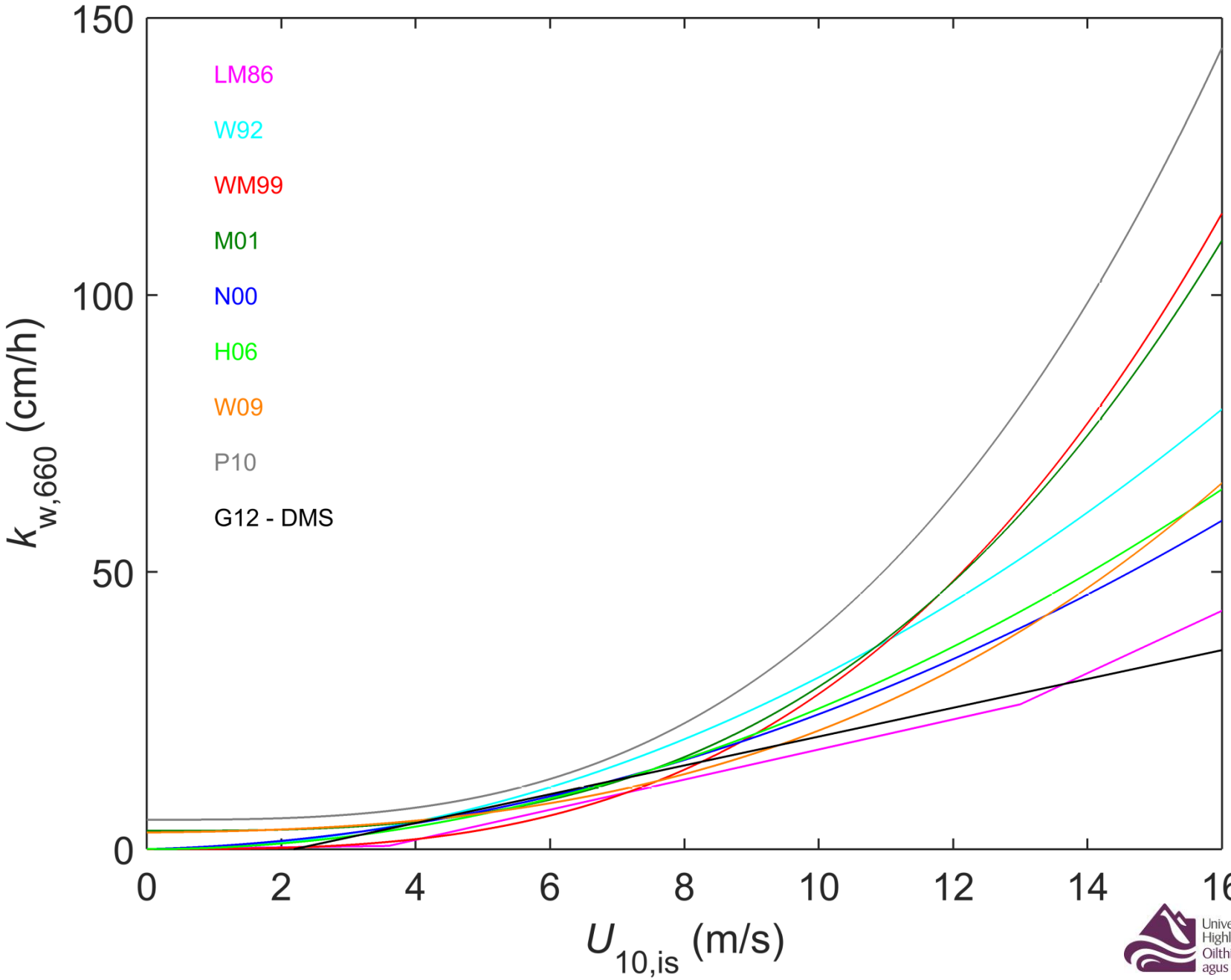
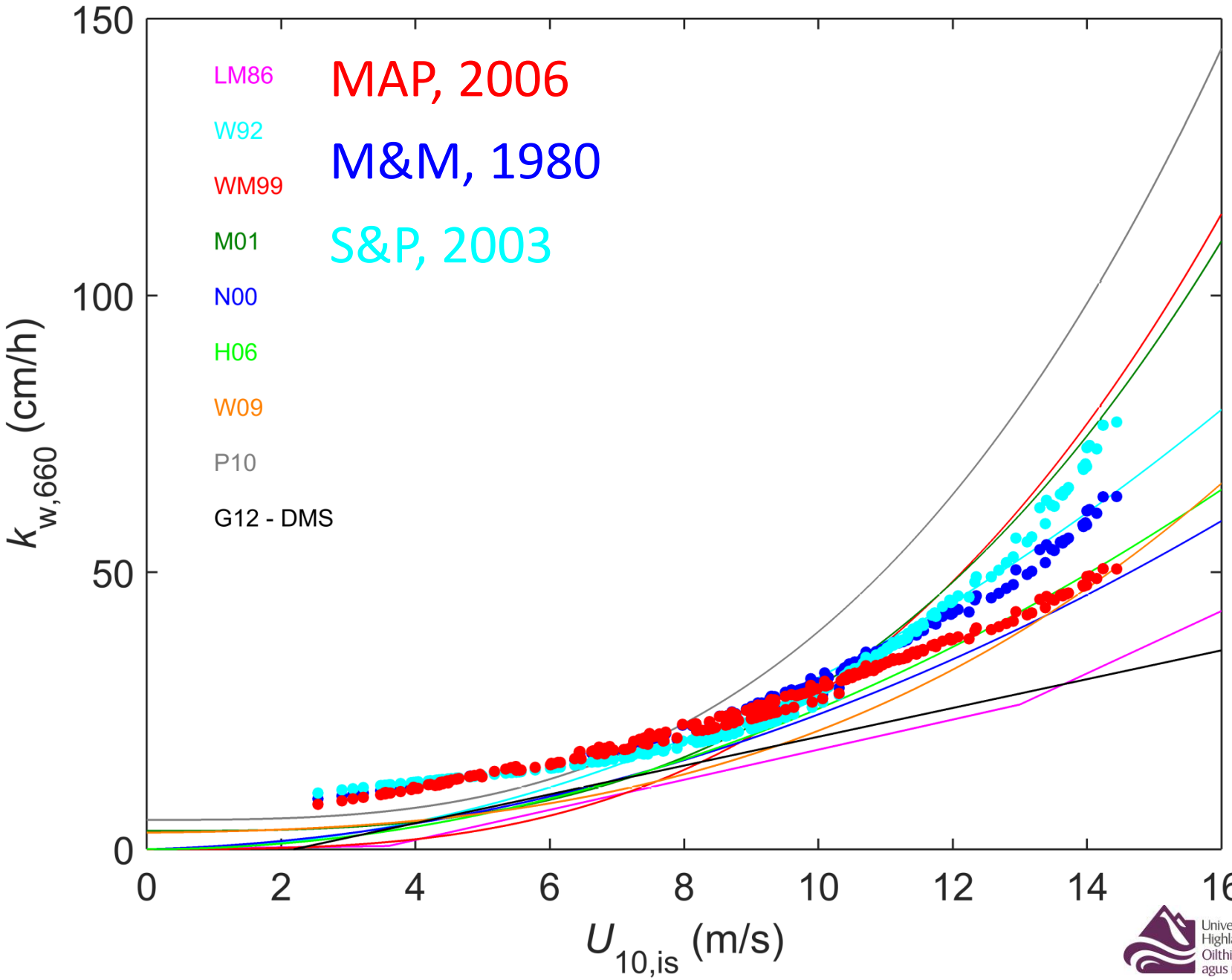
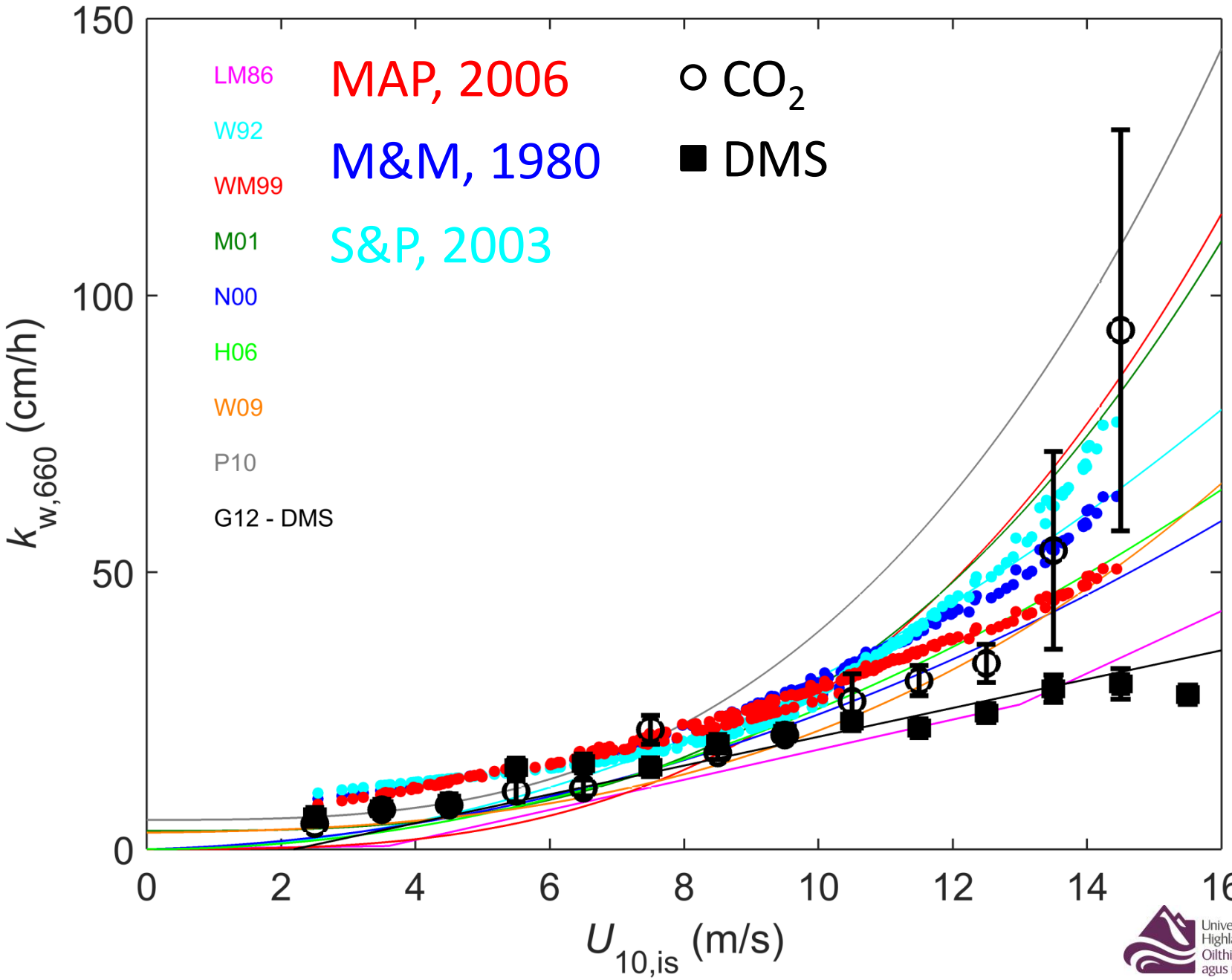
Known empirical relationships




150
100
50
0
0
2
4
6
8
10
12
14
16
$k_{w,660}$ (cm/h)
$U_{10,is}$ (m/s)
LM86
W92
WM99
M01
N00
H06
W09
P10
G12 - DMS
MAP, 2006
M&M, 1980
S&P, 2003


150
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2
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10
12
14
16
$k_{w,660}$ (cm/h)
$U_{10,is}$ (m/s)
LM86
W92
WM99
M01
N00
H06
W09
P10
G12 - DMS
MAP, 2006
M&M, 1980
S&P, 2003
CO_2
DMS

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The retrieval of air-sea gas transfer velocity from space using the hybrid model

k_o from satellite altimeter σ_{Ku}, (and σ_C) or U_{10}

k_b from bubble model and W

W from satellite U_{10}, brightness temperature, or model

Applicable to any gas

$$k_w = k_o + k_b$$

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Bubble model

Key assumptions and simplifications

Bubbles rise after injection to a shallow depth

Each bubble rises freely at terminal velocity for only 0.1 m

Free and mobile bubble surface, i.e. “clean” bubbles

The assumed bubble distribution