Evaluation of the NOAA/COARE Air-Sea Gas Transfer Parameterization using GasEx Data

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Parameterization and Micrometeorological Measurement of Air-Sea Gas Transfer

- 2000: Fairall, Hare, Edson, and McGillis

Boundary-Layer Meteorology, 96, p 63-105

Direct Covariance Air-Sea CO_2 Fluxes

- 2001: McGillis, Edson, Hare, and Fairall

Journal of Geophysical Research, 106,
pp 16729-16745

NOAA
R104

$$\text{Flux} = k \ \alpha \ \Delta fCO_2$$

k = transfer velocity

α = solubility

ΔfCO_2 = fugacity difference across the interface

- $k = 0.31\ U^2$ Wanninkhof 1992

- $k = 0.17\ U$ ($U < 3.6$ ms-1)
  $k = 2.85\ U - 9.65$ ($3.6 < U < 13$ ms-1)
  $k = 5.9\ U - 49.3$ ($U > 13$ ms-1)
  Liss-Merlivat 1986

- $k = 3.3 + 0.026\ U^3$ McGillis et al. 2001

$$\text{Flux} = k_s \left(\alpha_w \, fCO_{2w} - \alpha_s \, fCO_{2a} \right)$$

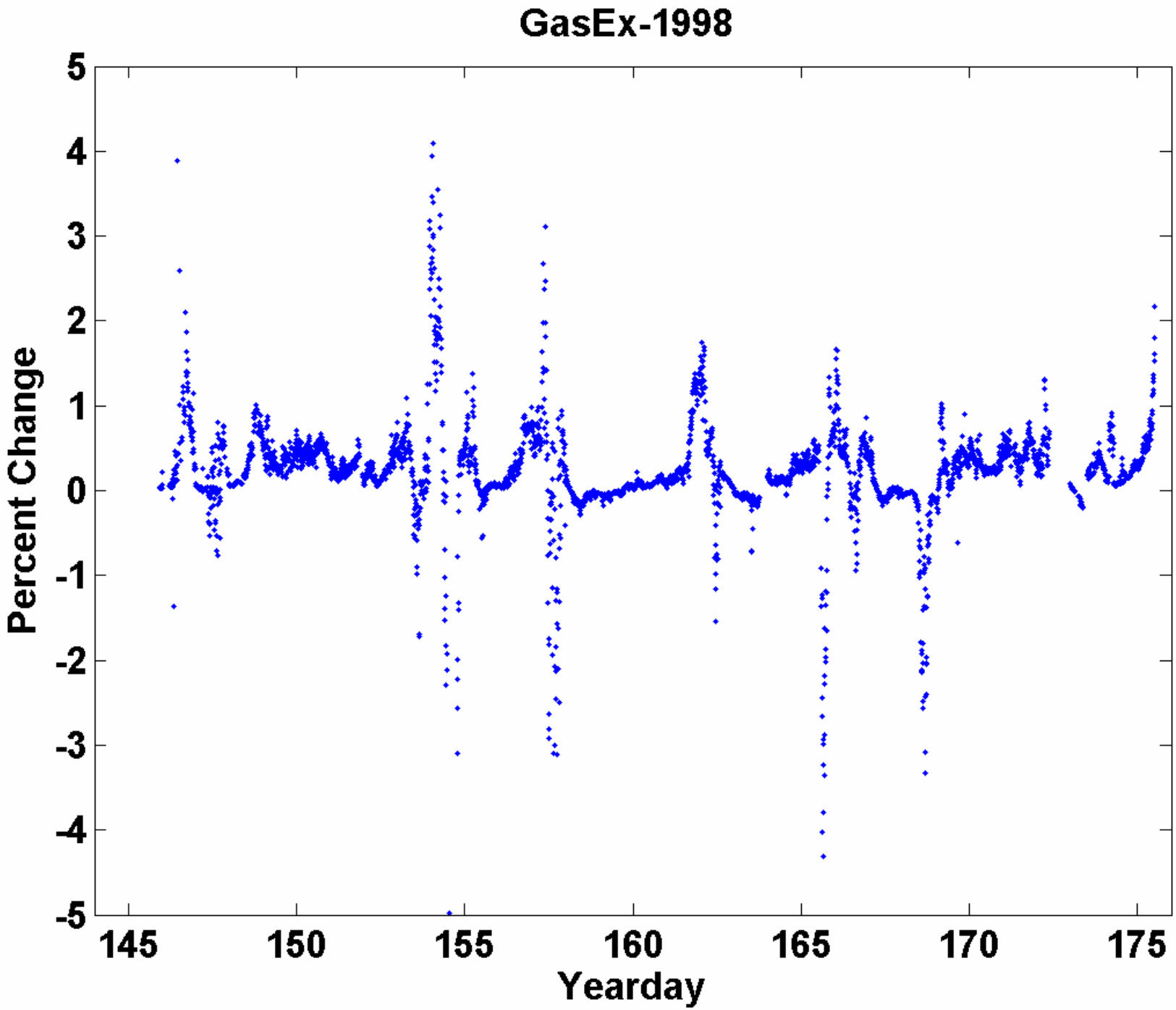
k_s = transfer velocity at the interface

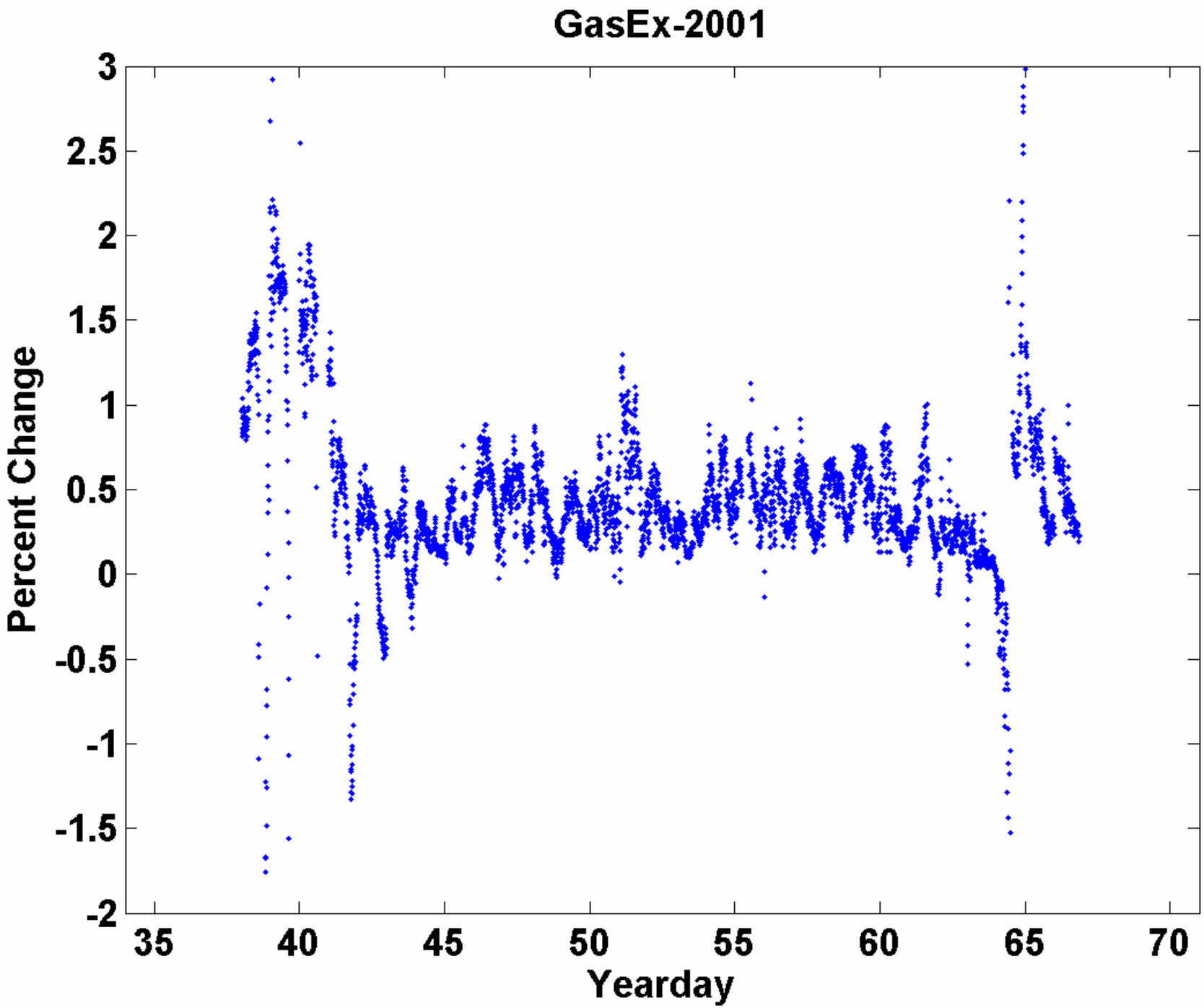
α_w = solubility in the bulk water

α_s = solubility at the interface

fCO_{2w} = fugacity in the bulk water

fCO_{2a} = fugacity in the air


GasEx-1998
Percent Change
Yearday
5
4
3
2
1
0
-1
-2
-3
-4
-5
145
150
155
160
165
170
175


GasEx-2001
Percent Change
Yearday
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
35
40
45
50
55
60
65
70

Whitecap Contribution

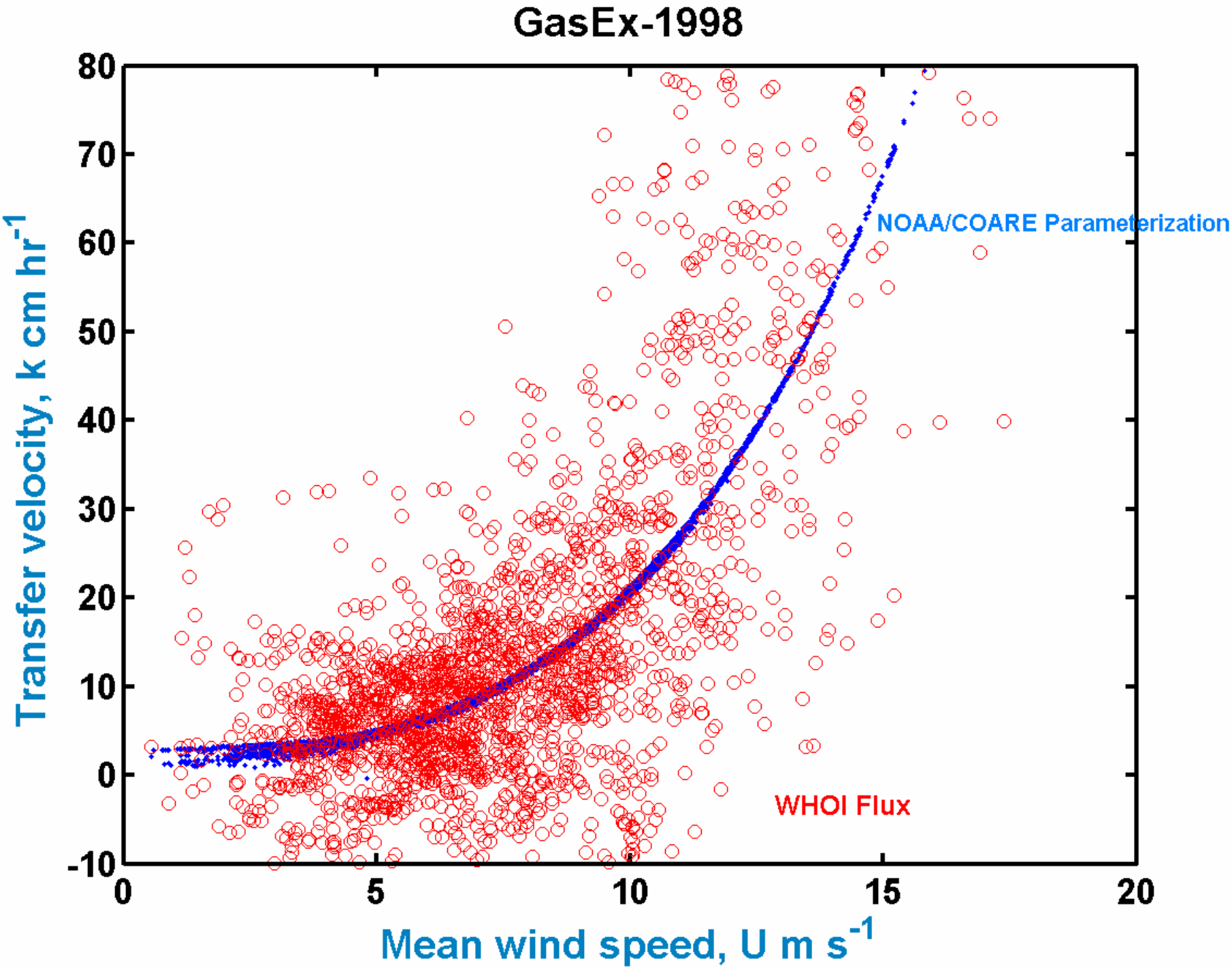
Bubbles, Enhanced Turbulence

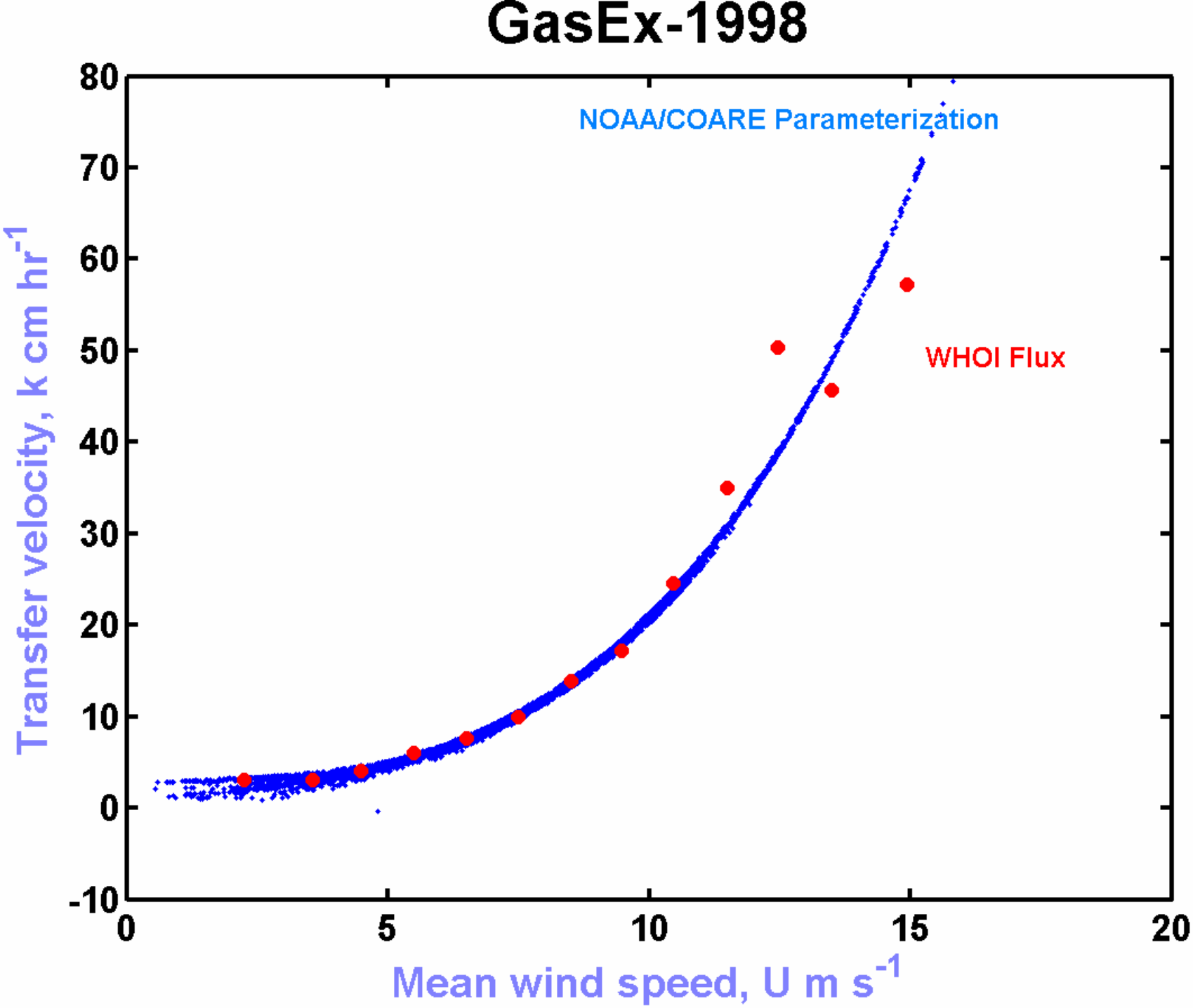
Woolf, 1997

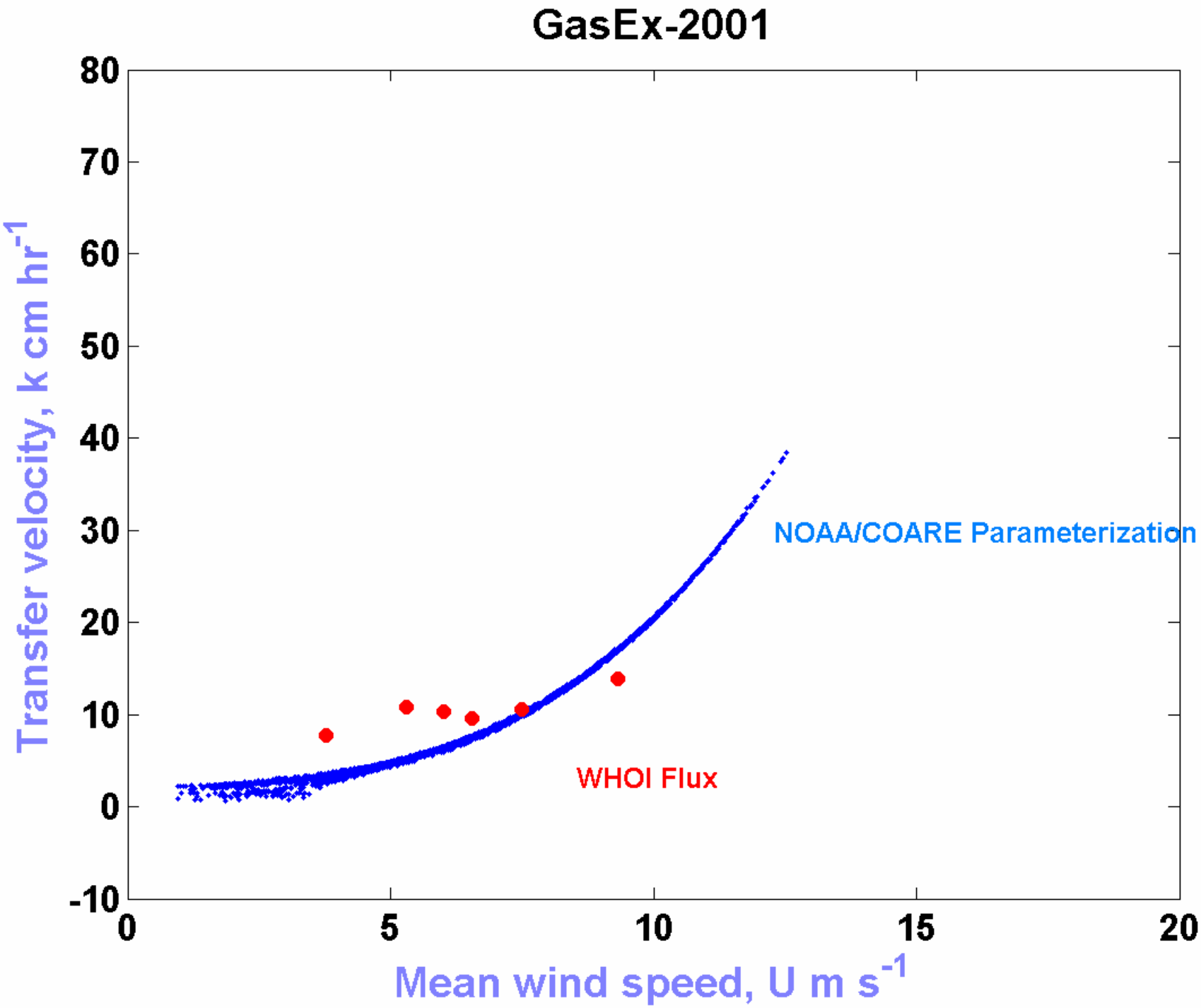
- $k_{bb} = V\, f\, \alpha^{-1} \left[1 + \left(e\, \alpha\, Sc^{-1/2} \right)^{-1/n} \right]^{-n}$

$f = B\, U^{3.4}$

V, e, n, and B are constants


GasEx-1998
Transfer velocity, k cm hr-1
Mean wind speed, U m s-1
NOAA/COARE Parameterization
WHOI Flux
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20


GasEx-1998
NOAA/COARE Parameterization
WHOI Flux
Transfer velocity, k cm hr-1
Mean wind speed, U m s-1
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20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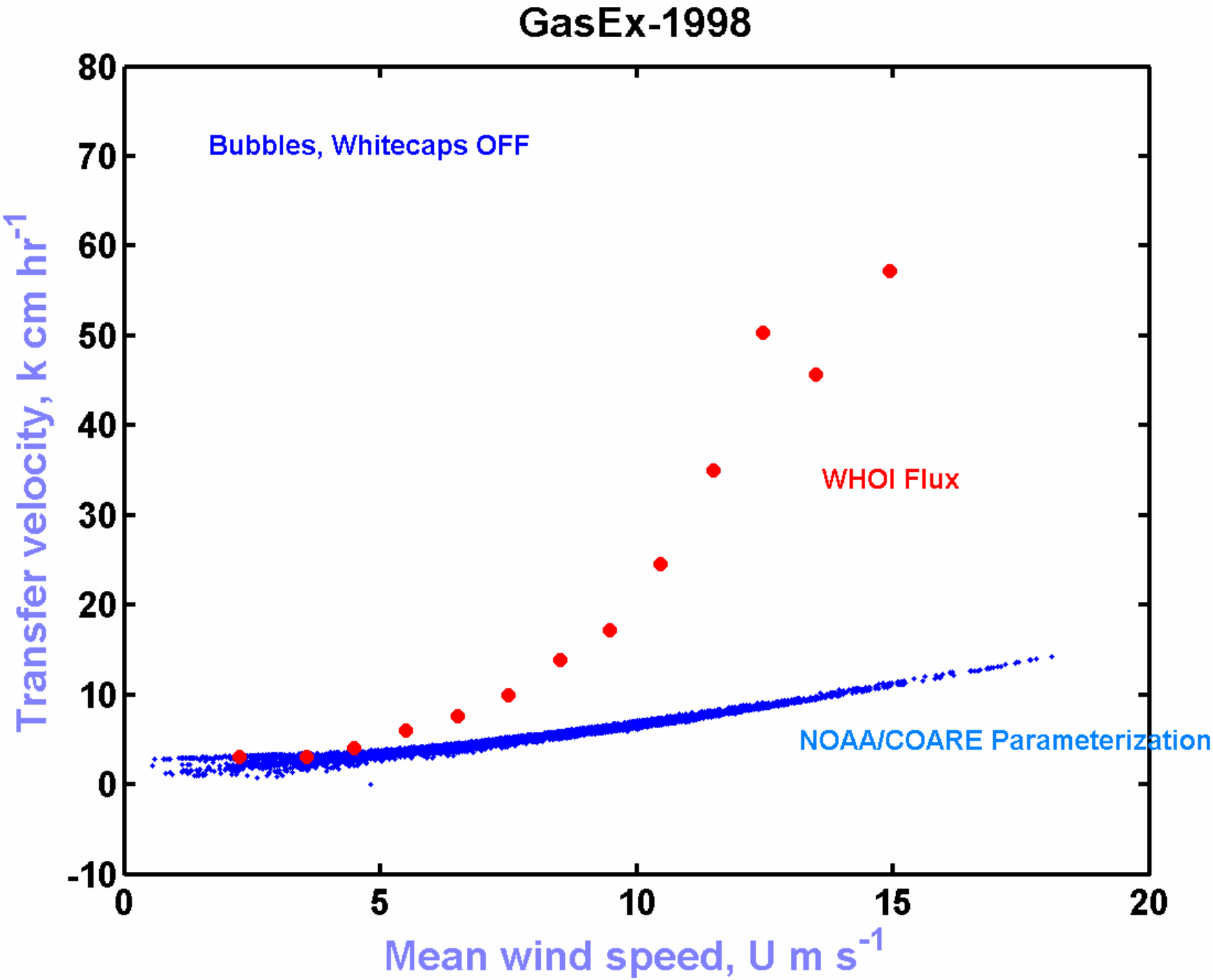
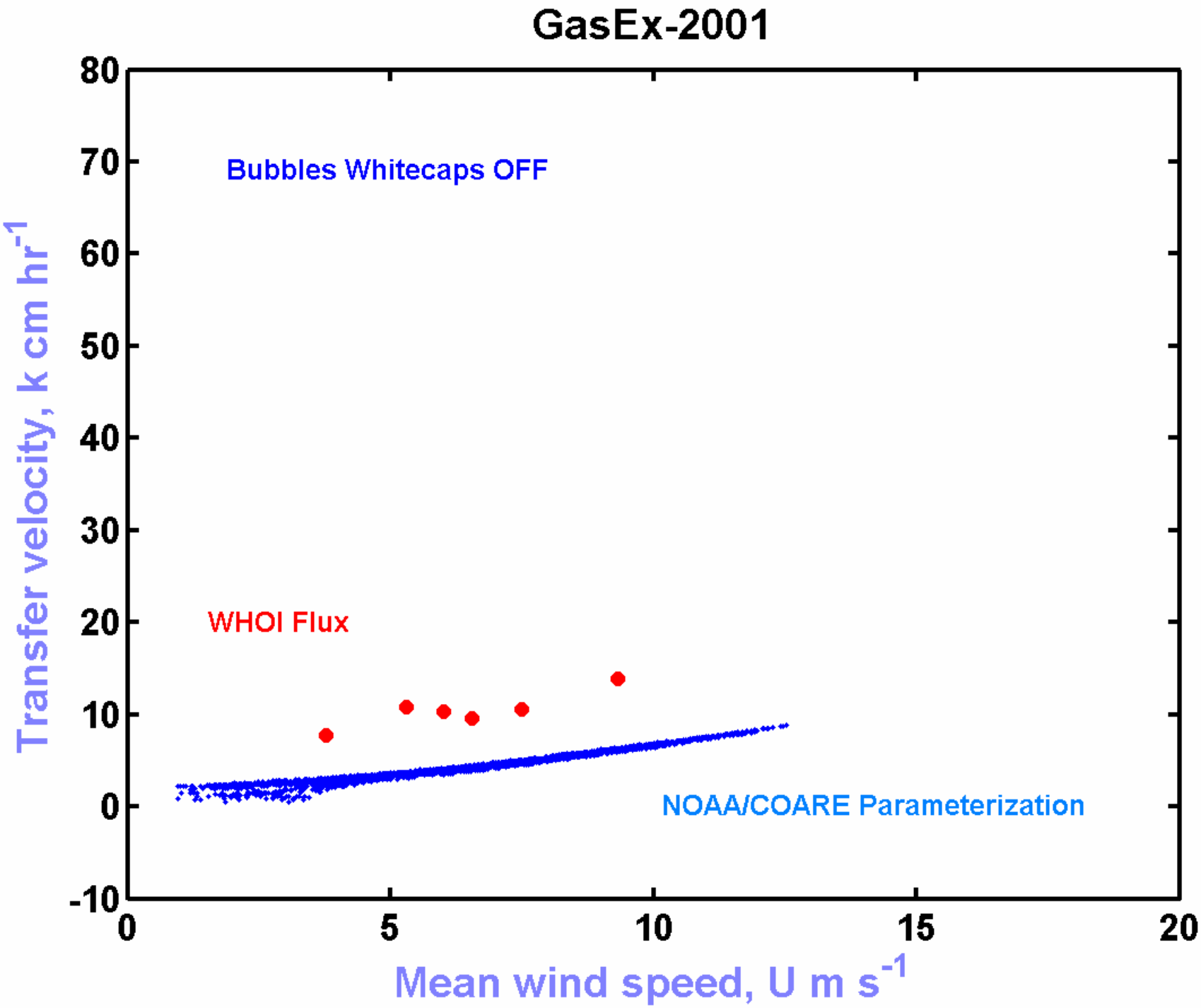
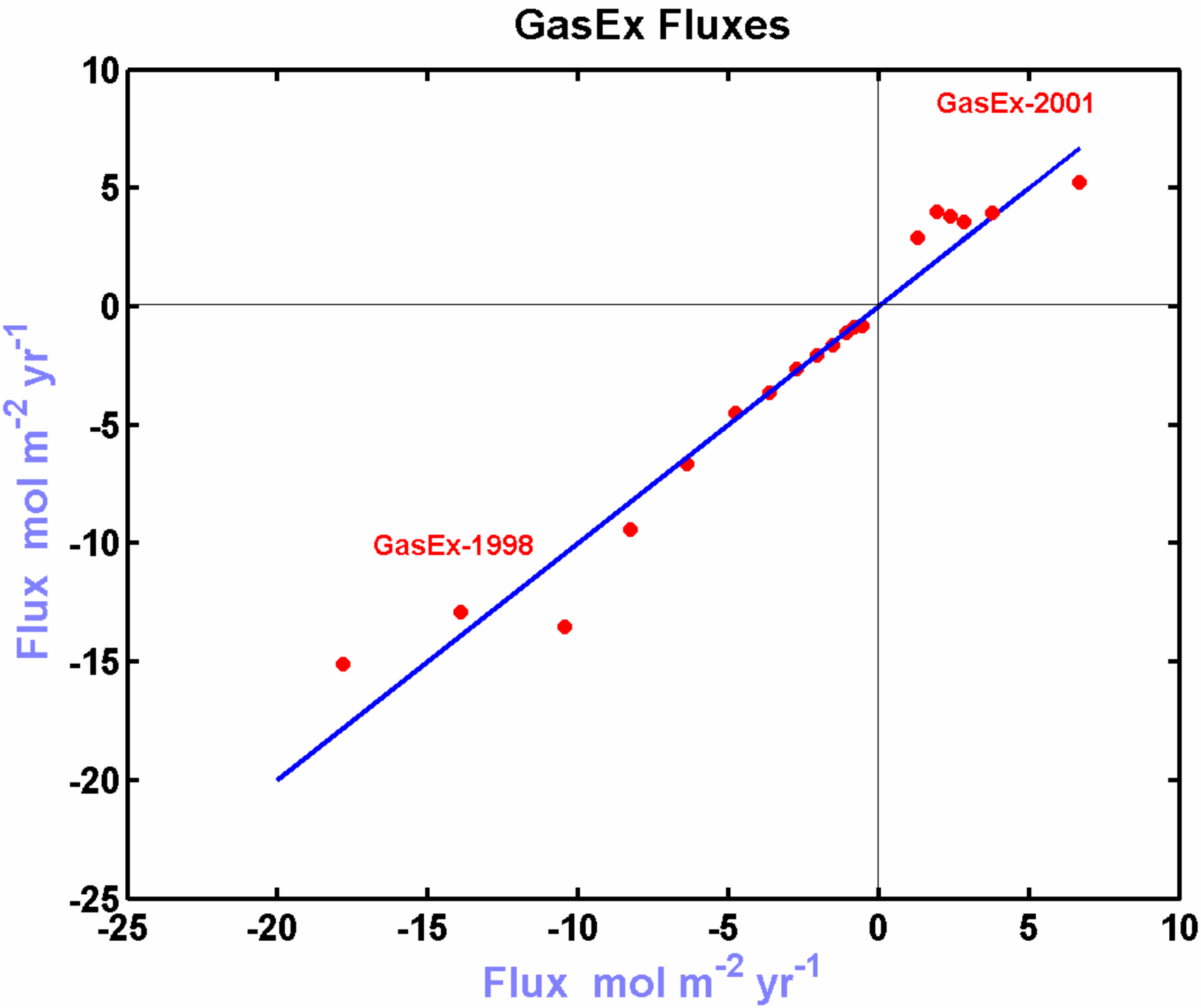
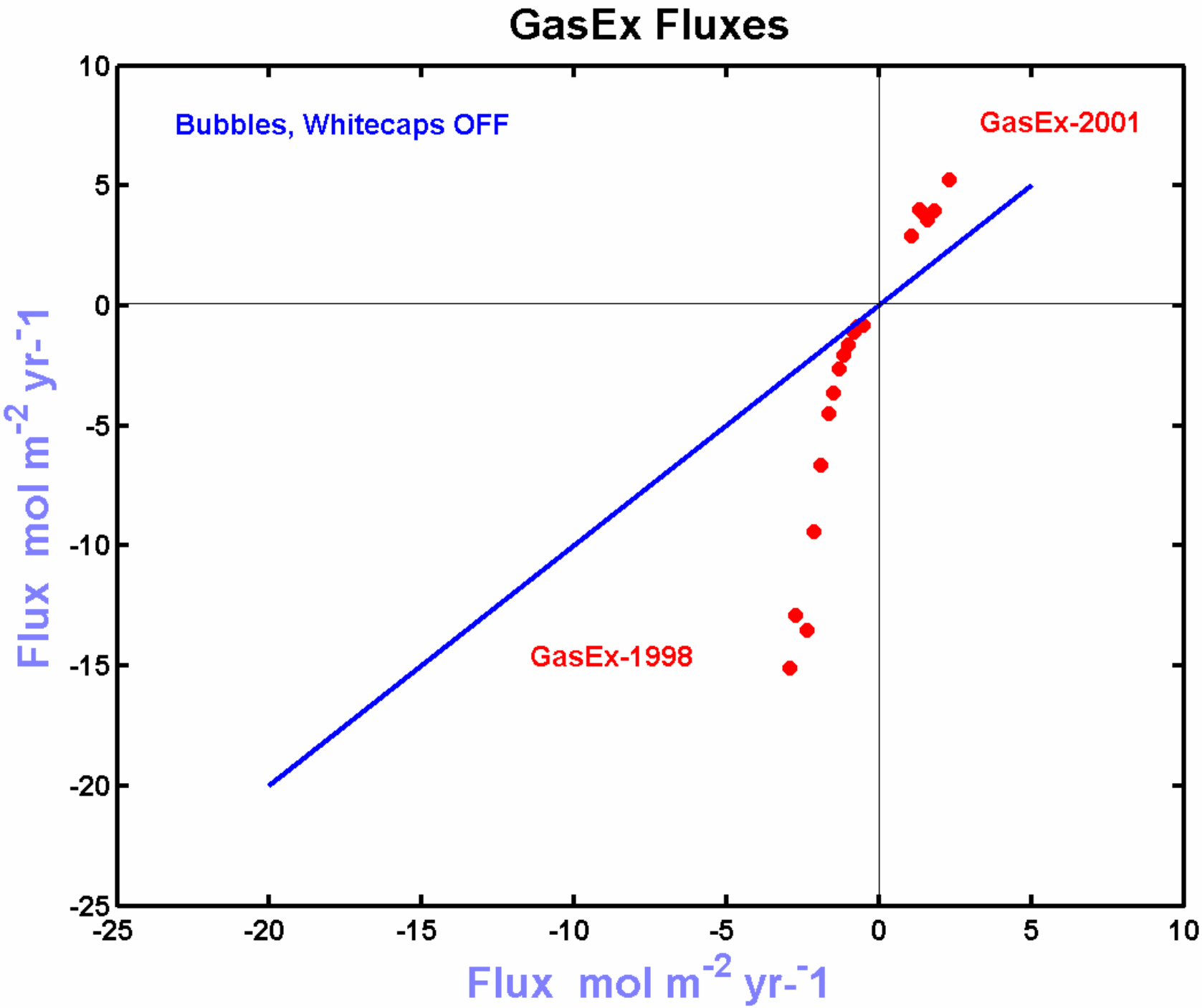
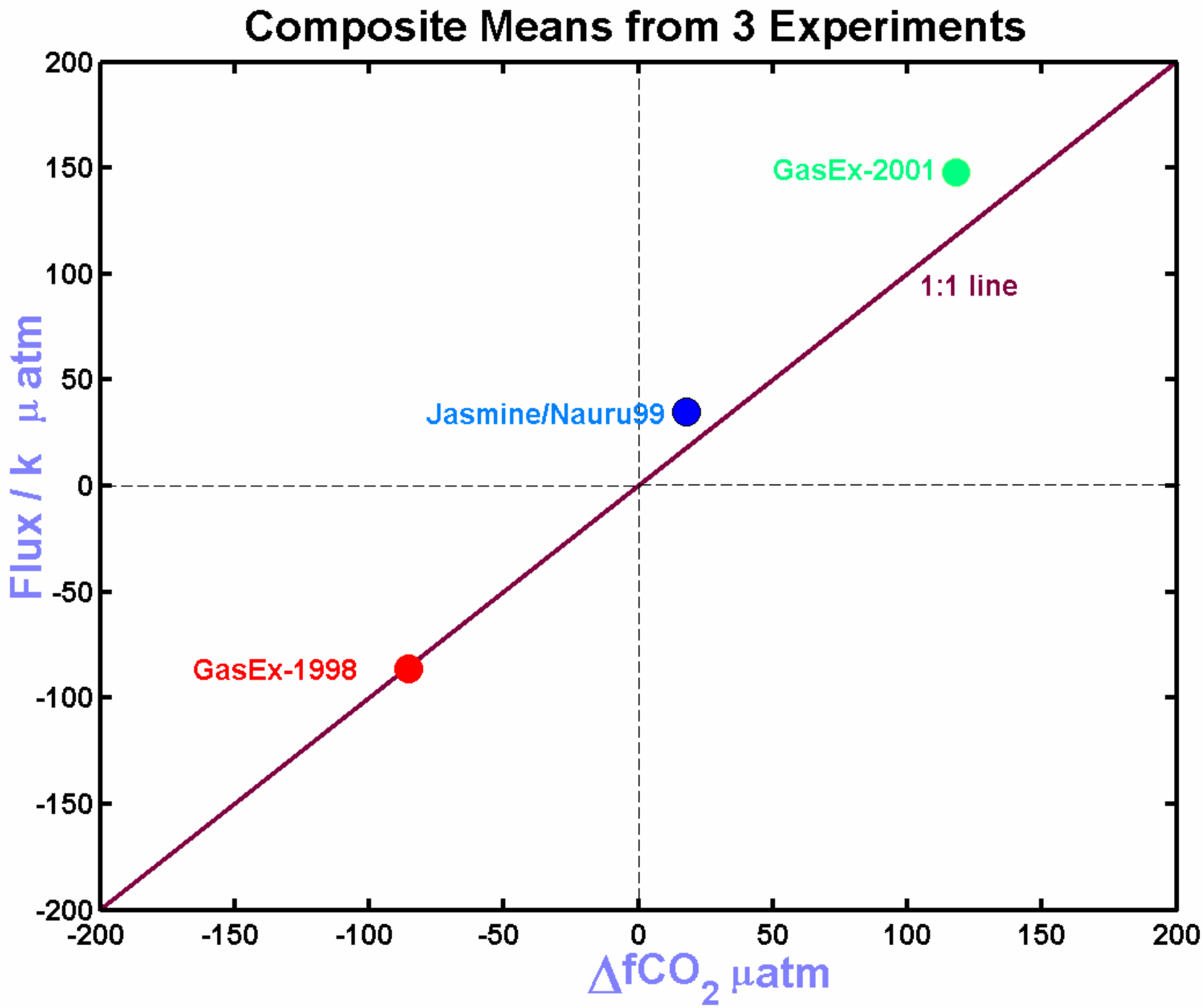
Mean wind speed, U m s-1
NOAA/COARE Parameterization
WHOI Flux
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20

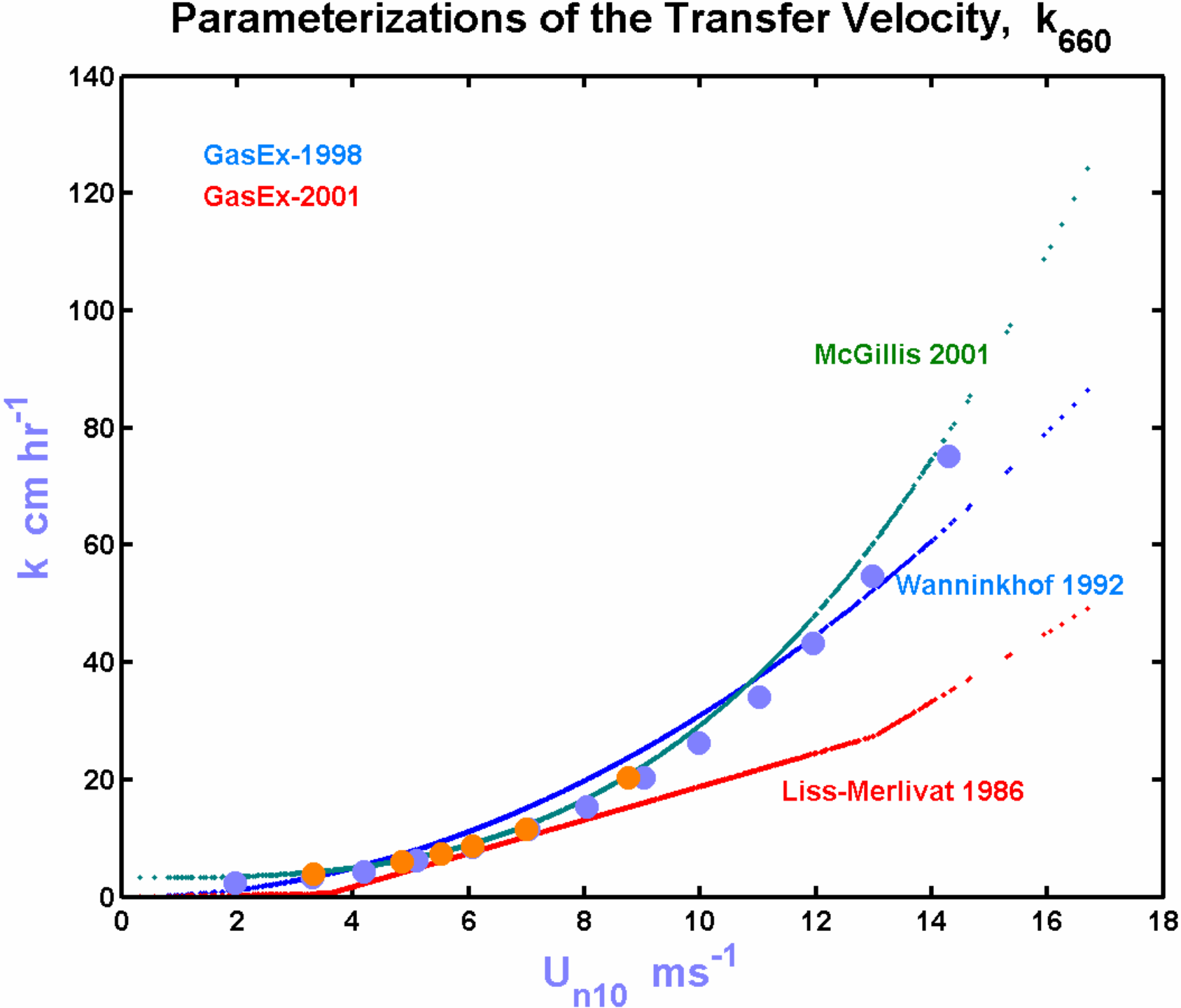

GasEx-1998
Bubbles, Whitecaps OFF
WHOI Flux
NOAA/COARE Parameterization
Transfer velocity, k cm hr-1
Mean wind speed, U m s-1
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20


GasEx-2001
Bubbles Whitecaps OFF
WHOI Flux
NOAA/COARE Parameterization
Transfer velocity, k cm hr-1
Mean wind speed, U m s-1
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20


GasEx Fluxes
GasEx-2001
GasEx-1998
10
5
0
-5
-10
-15
-20
-25
-25
-20
-15
-10
-5
0
5
10
Flux mol m-2 yr-1
Flux mol m-2 yr-1


GasEx Fluxes
Bubbles, Whitecaps OFF
GasEx-2001
GasEx-1998
Flux mol m-2 yr-1
Flux mol m-2 yr-1
10
5
0
-5
-10
-15
-20
-25
-25
-20
-15
-10
-5
0
5
10


Composite Means from 3 Experiments
GasEx-2001
1:1 line
Jasmine/Nauru99
GasEx-1998
Flux / k μ atm
ΔfCO2 μatm
200
150
100
50
0
-50
-100
-150
-200
-200
-150
-100
-50
0
50
100
150
200


Parameterizations of the Transfer Velocity, k660
GasEx-1998
GasEx-2001
McGillis 2001
Wanninkhof 1992
Liss-Merlivat 1986
k cm hr-1
Un10 ms-1
0
20
40
60
80
100
120
140
0
2
4
6
8
10
12
14
16
18

NOAA/COARE Parameterization

- Tuning of the model coefficients to match 1998 flux data requires:
  - Soloviev & Schlüssel coefficient decrease by a factor of ~3
  - Woolf coefficient increase by a factor of ~2

Parameterization of GasEx-1998 and GasEx-2001

- Different regimes with physics not adequately captured (simplified ocean physics)
- Biological processes and/or surfactant effects
- Opposite direction of ΔfCO_2 ?
- More studies are required

NOAA/COARE Parameterization

- Details to study:
  - Does the model capture the physics?
  - Comparison with ETL/WHOI/RSMAS open-path data
  - Wave, whitecap, bubble, and surface parameterization adjustments
  - More Quality Data!