# The role of tropical cyclones on the global $CO_2$ flux: an observation based approach

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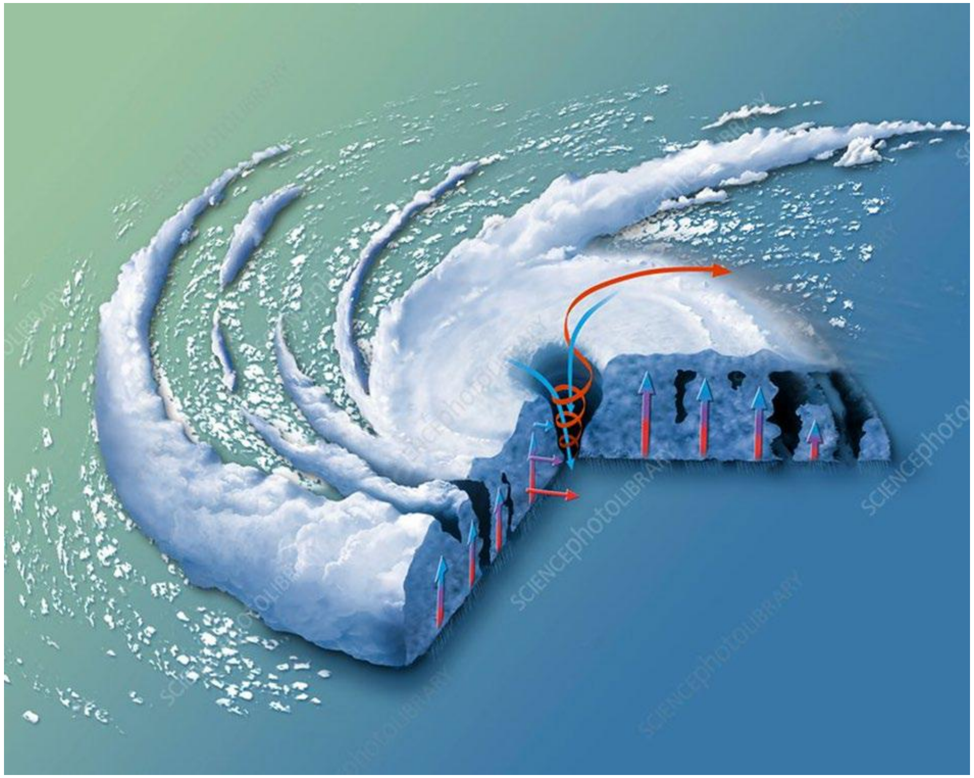
# Tropical cyclones



- Rapidly rotating storms
- Form over bodies of warm water
- High wind speeds
- Low pressure core
- Local Ekman pumping
- Heavy rainfall

# Extreme weather events in observation based flux estimates

- Global fluxes are often made at monthly resolution on 1° x 1° grids.
- Extreme weather events are infrequent and occur on the order of days to weeks.
- To capture wind speed variability, the second moment $<U_{10}^2>$ of the monthly averaged 6-hourly 0.25° winds are used.

# How do tropical cyclones impact flux

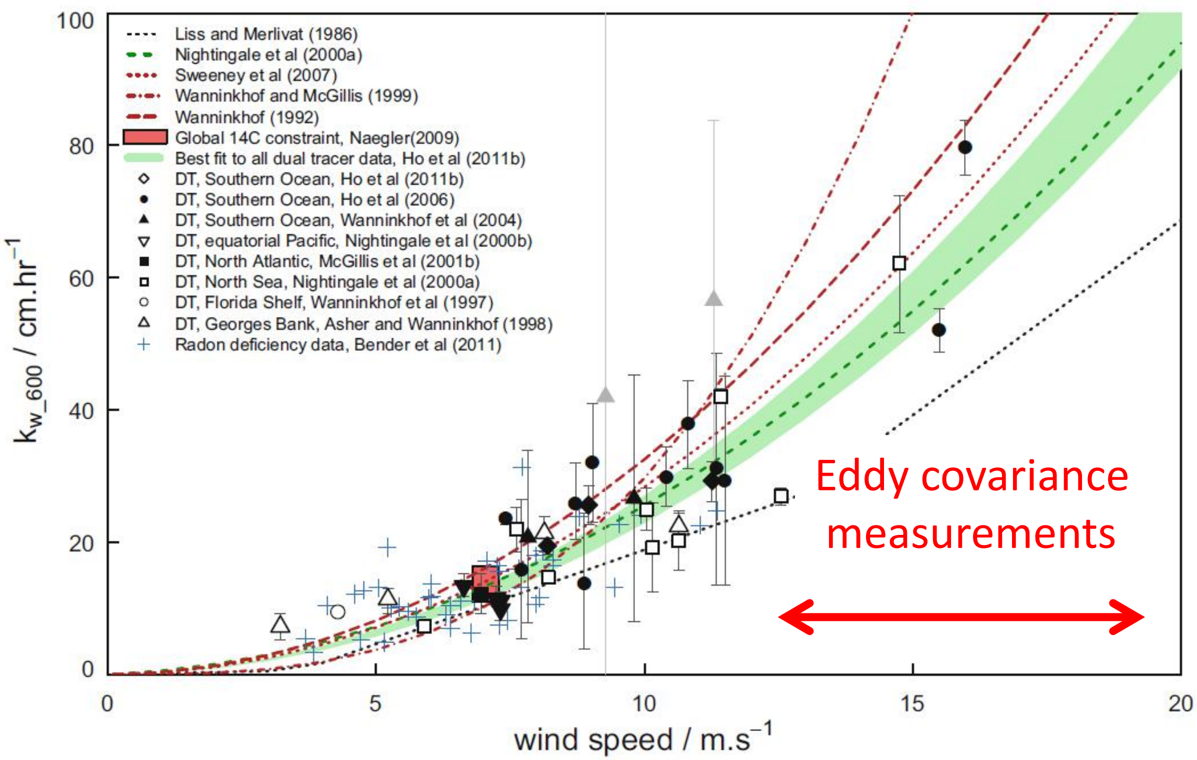
$$FCO_2 = k\, k_0 \,(pCO_{2\,(sea)} - pCO_{2\,(air)})$$

1. High wind speeds
2. Changes to SST
3. Changes to SSS
4. Changes to atmospheric pressure
5. Precipitation
6. Upwelling of nutrients and DIC

# Gas exchange parameterisations at high wind speeds

## Saffir–Simpson scale

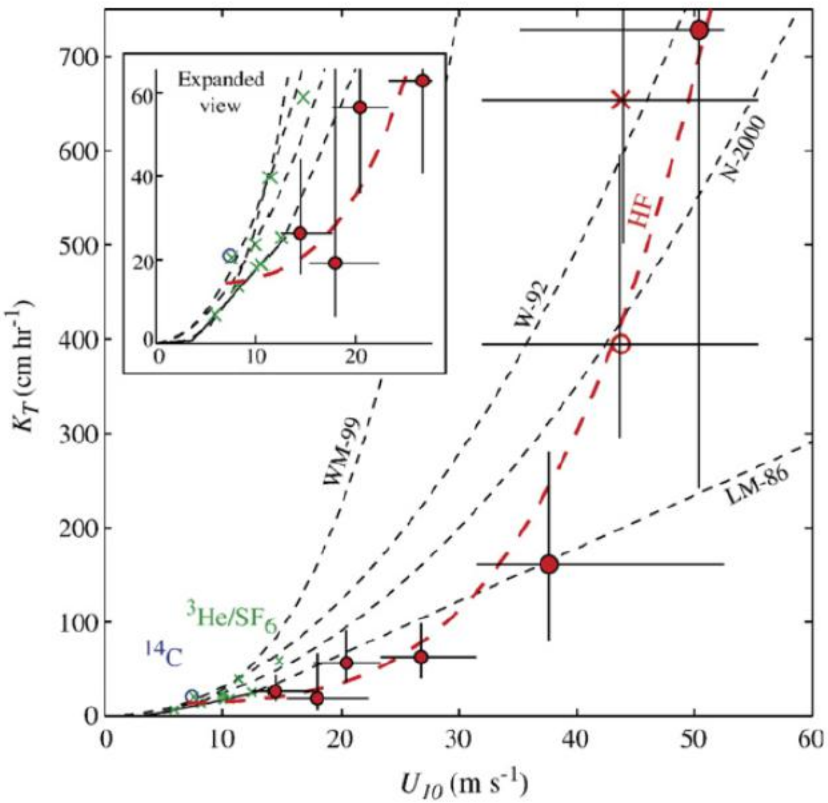
| | |
|---|---|
| Five | ≥ 70 m/s |
| Four | 58–70 m/s |
| Three | 50–58 m/s |
| Two | 43–49 m/s |
| One | 33–42 m/s |
| Tropical storm | 18–32 m/s |
| Tropical depression | ≤ 17 m/s |



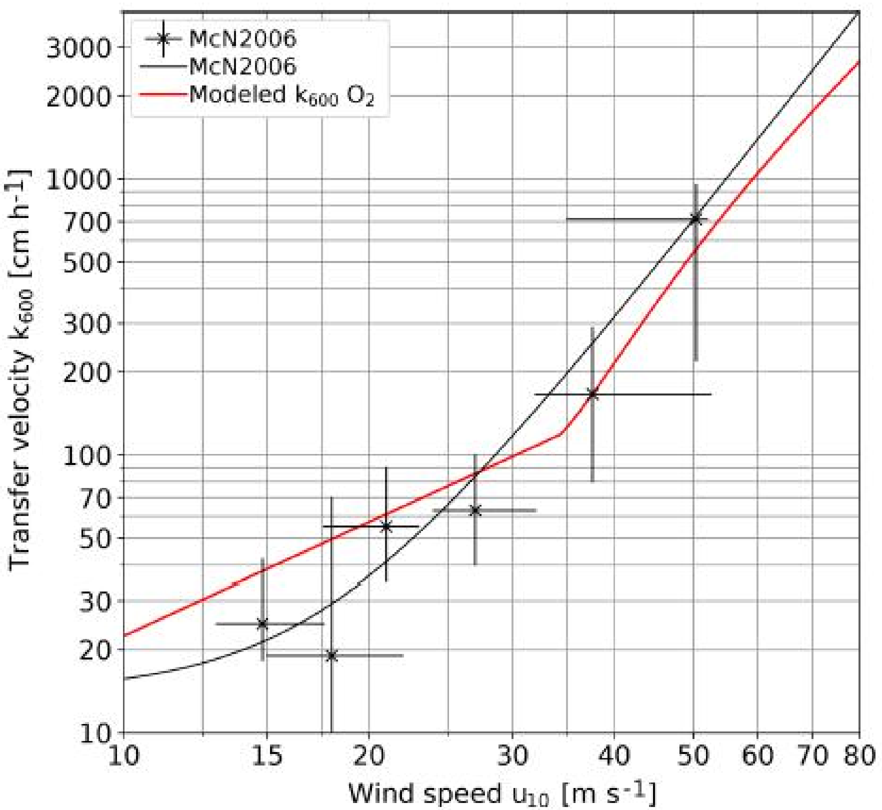

(Garbe *et.al* 2014).

# Gas exchange parameterisations at high wind speeds

$k = 14 + 0.0002925 * (U_{10})^{3.742}$




(McNeil & D'Asaro 2006).




(Krall *et.al* 2019).

# Previous estimates

A number of studies have used *in situ* pre and post storm data to infer the impact of individual storms on the flux.

A comprehensive approach is needed to address all the competing factors.

Levy *et.al* 2012 use a modelling approach to estimate the impact on the flux for all the storms using a storm atlas.

# MAXSS Atlas

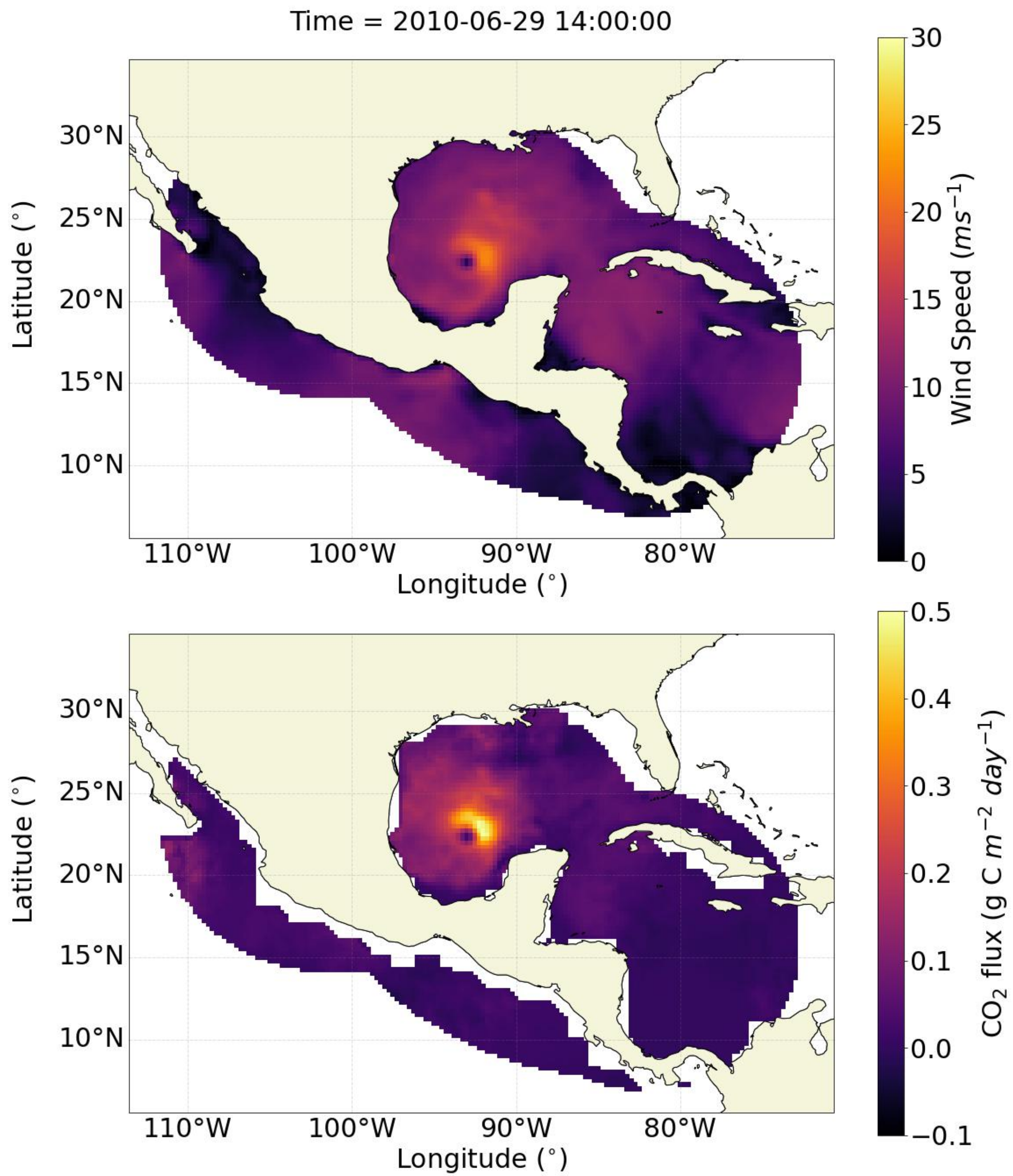
Advancements in remote sensing and reanalysis products mean it is possible to attempt an observation based estimate.

The Marine Atmosphere eXtreme Satellite Synergy (MAXSS) storm Atlas includes observational data for every storm from 2010 – 2020.

# MAXSS ATLAS contents

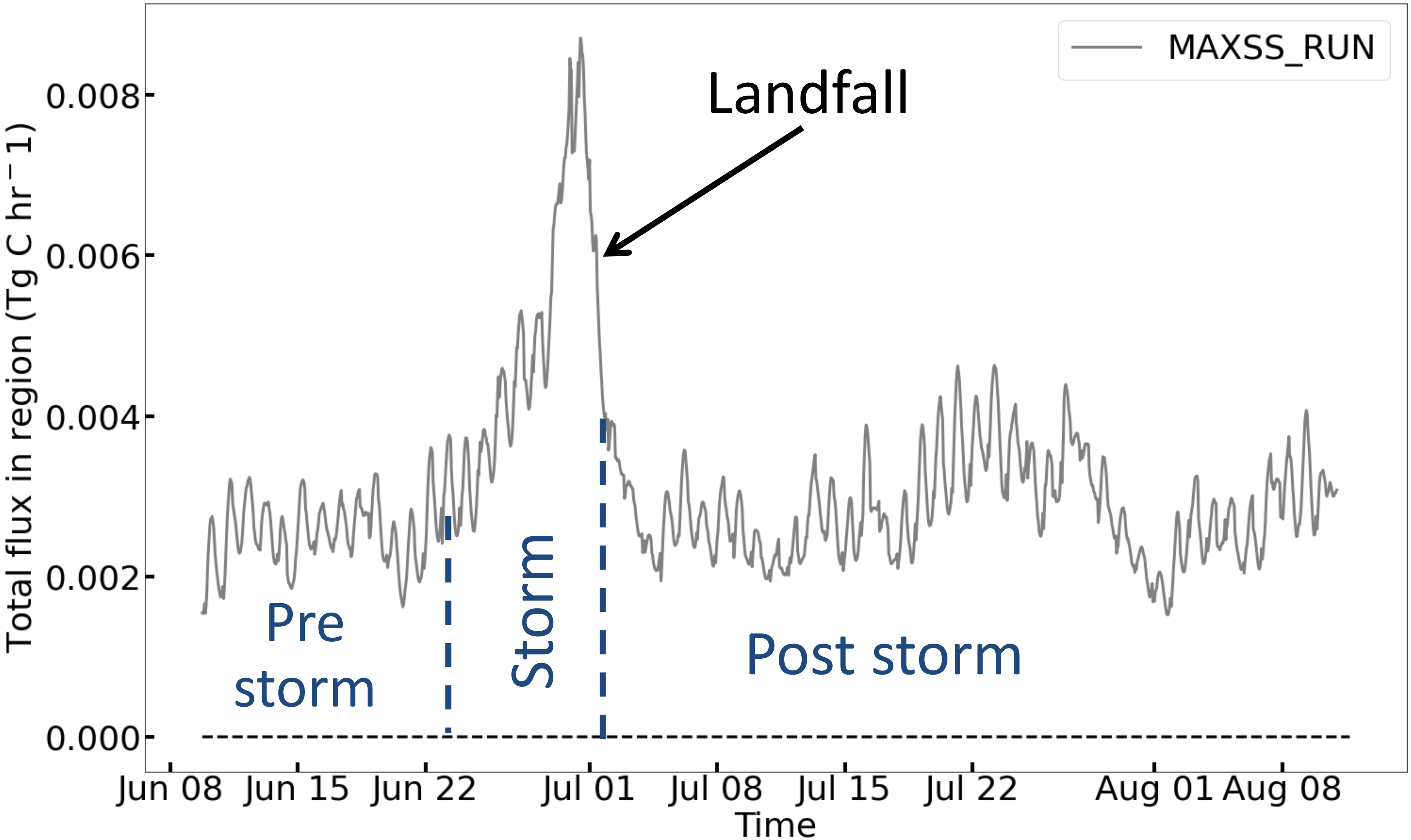
- Wind –MAXSS L4- hourly – grid size 0.25 degree
- SST –ESACCI - daily
- SSS – ESACCI - weekly
- Pressure - ERA5 – hourly reanalysis
- Precipitation – ERA5 – hourly reanalysis

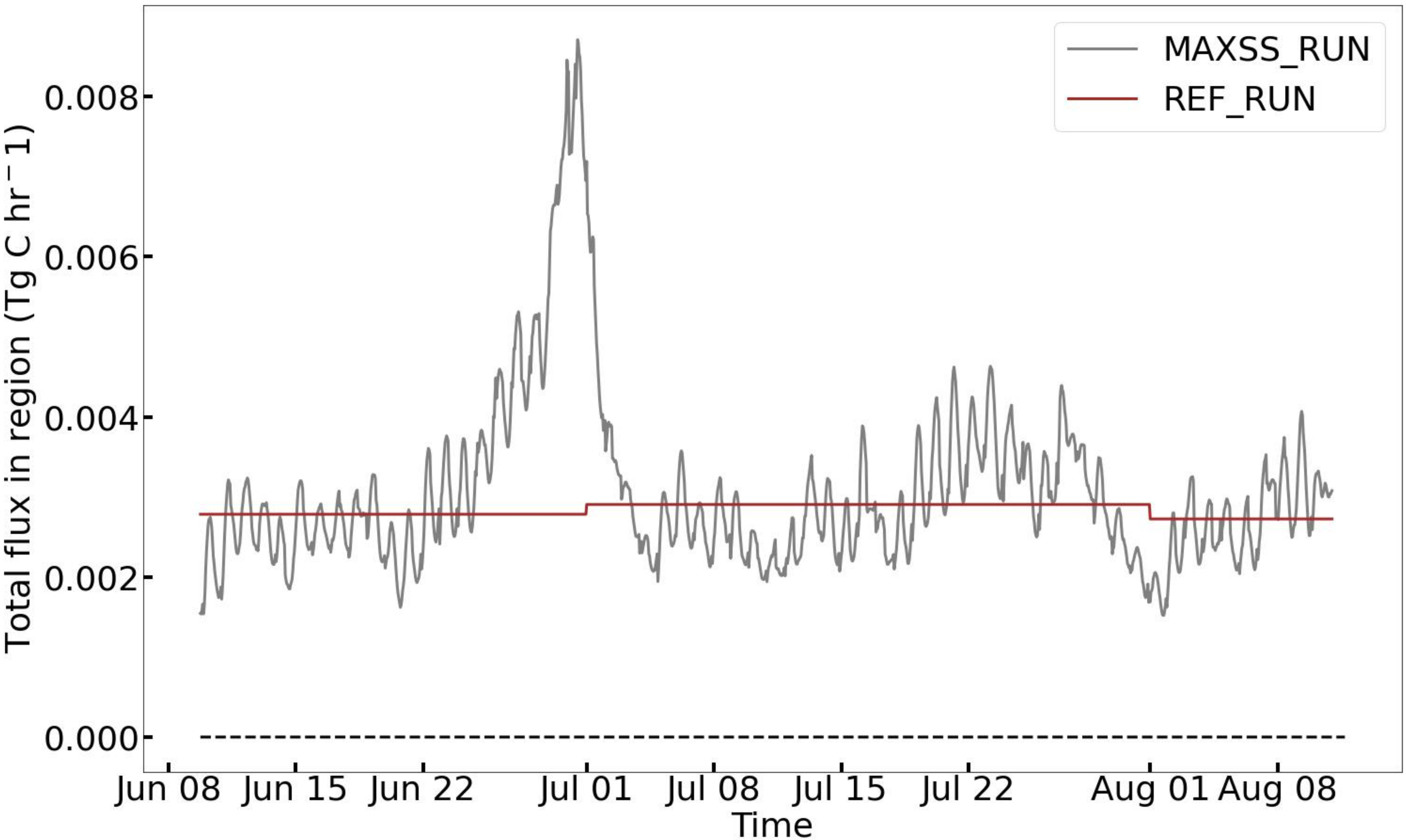
- pCO2 data – Woolf 2019 - monthly
- atmospheric pCO2 data – NOAA -monthly


Time = 2010-06-29 14:00:00
30°N
25°N
20°N
15°N
10°N
Latitude (°)
110°W
100°W
90°W
80°W
Longitude (°)
Wind Speed ($ms^{-1}$)
0
5
10
15
20
25
30
$CO_2$ flux (g C $m^{-2}$ $day^{-1}$)
−0.1
0.0
0.1
0.2
0.3
0.4
0.5

# Video plays here.

# How does the integrated flux change over time?

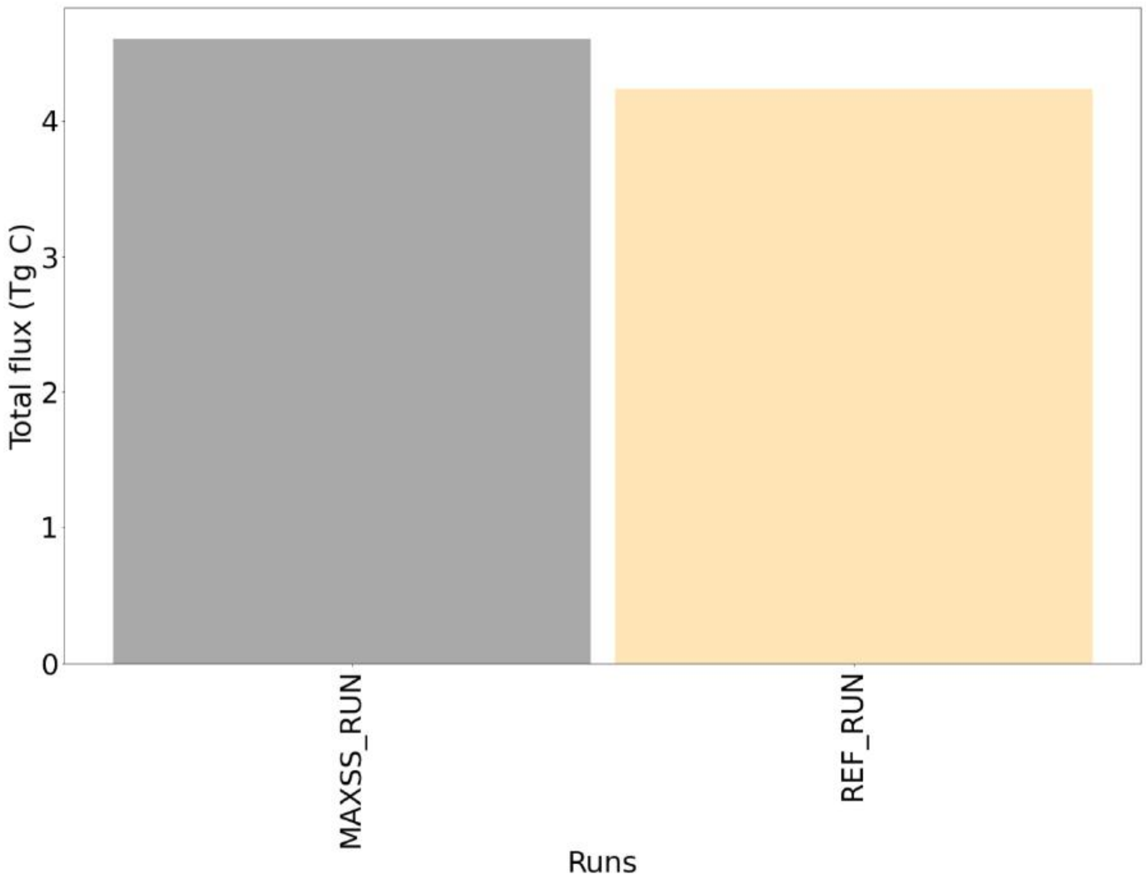




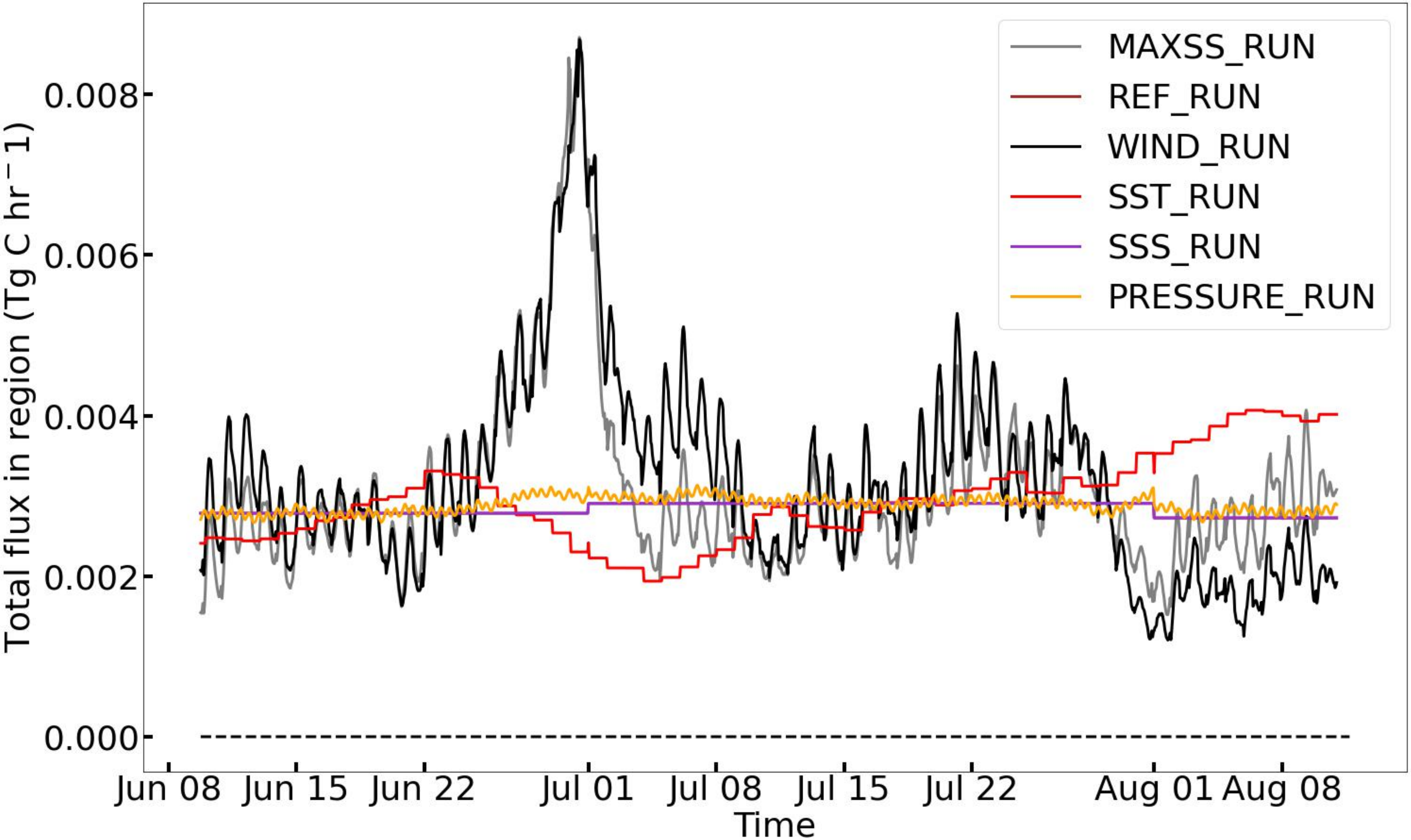
MAXSS_RUN
REF_RUN
0.008
0.006
0.004
0.002
0.000
Total flux in region (Tg C hr⁻1)
Jun 08
Jun 15
Jun 22
Jul 01
Jul 08
Jul 15
Jul 22
Aug 01
Aug 08
Time

# What is the net impact of the TC

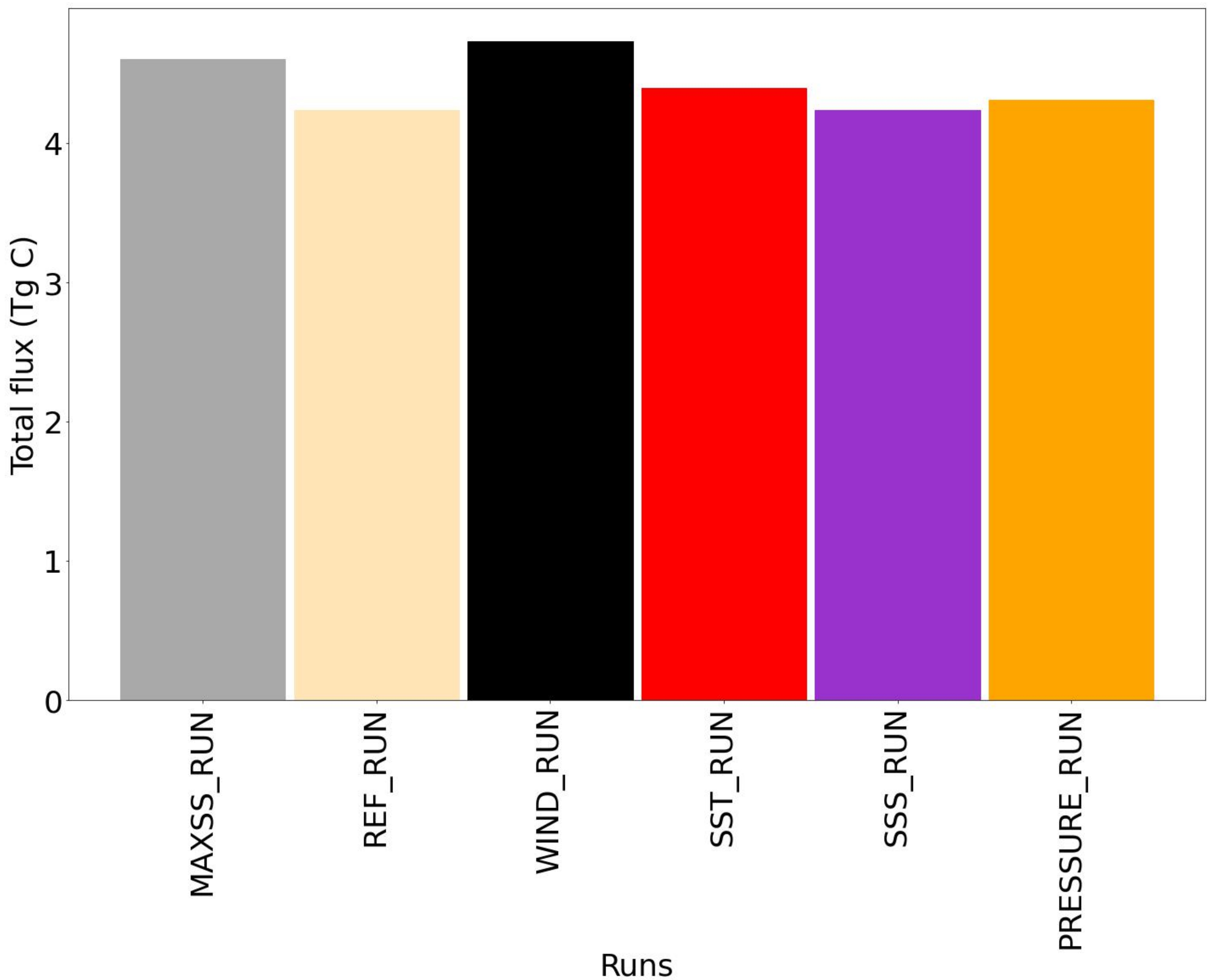
Net impact = $\int_{t=end}^{t=1} MAXSS\_RUN - \int_{t=end}^{t=1} MAXSS\_REF$




Net impact = 0.37 Tg C



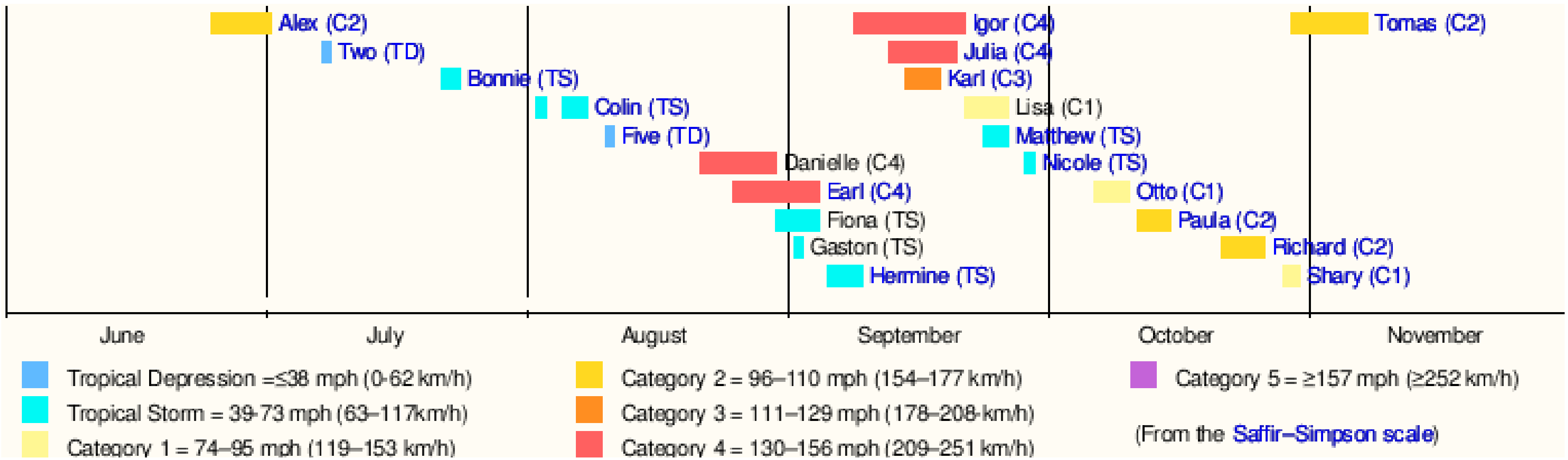
MAXSS_RUN
REF_RUN
WIND_RUN
SST_RUN
SSS_RUN
PRESSURE_RUN
0.008
0.006
0.004
0.002
0.000
Total flux in region (Tg C hr$^{-1}$)
Jun 08
Jun 15
Jun 22
Jul 01
Jul 08
Jul 15
Jul 22
Aug 01
Aug 08
Time



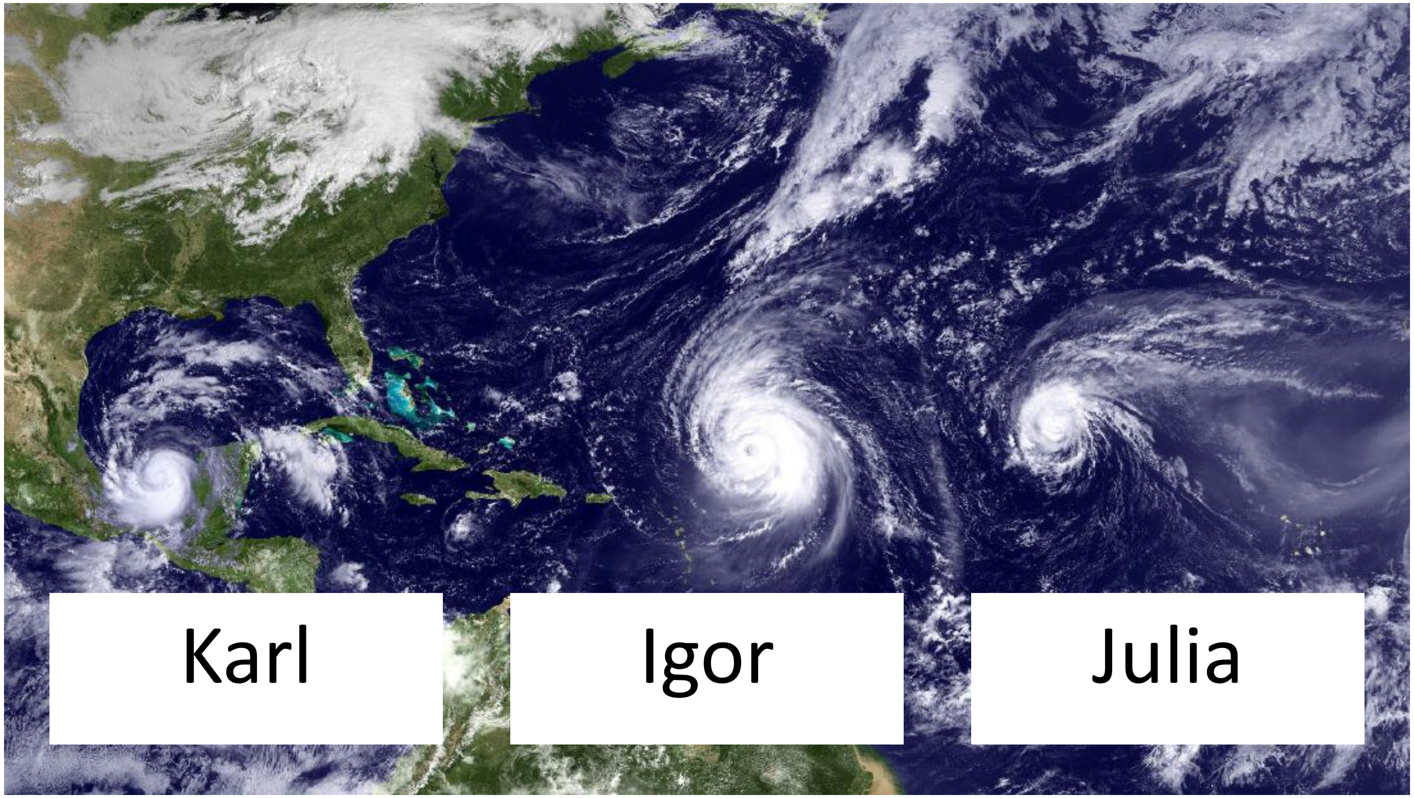
Total flux (Tg C)
0
1
2
3
4
MAXSS_RUN
REF_RUN
WIND_RUN
SST_RUN
SSS_RUN
PRESSURE_RUN
Runs

# Conclusions

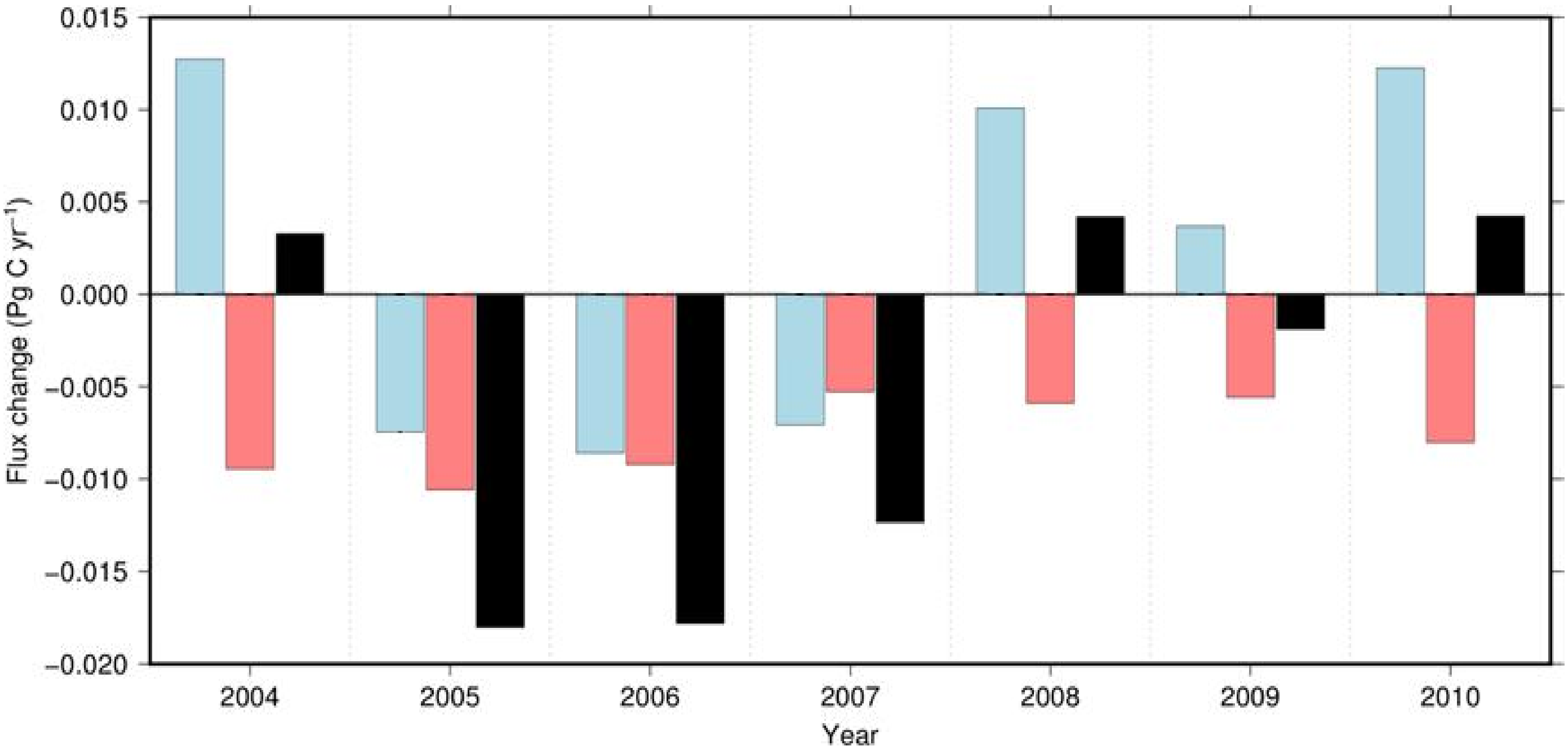
- Framework developed for calculating the flux of tropical cyclones.
- Can calculate the net impact of the storm and can attribute the contribution from different drivers.
- Season, storm location, storm duration and storm intensity are important.



Alex (C2)
Two (TD)
Bonnie (TS)
Colin (TS)
Five (TD)
Danielle (C4)
Earl (C4)
Fiona (TS)
Gaston (TS)
Hermine (TS)
Igor (C4)
Julia (C4)
Karl (C3)
Lisa (C1)
Matthew (TS)
Nicole (TS)
Otto (C1)
Paula (C2)
Richard (C2)
Shary (C1)
Tomas (C2)
June
July
August
September
October
November
Tropical Depression =≤38 mph (0-62 km/h)
Tropical Storm = 39-73 mph (63–117km/h)
Category 1 = 74–95 mph (119–153 km/h)
Category 2 = 96–110 mph (154–177 km/h)
Category 3 = 111–129 mph (178–208 km/h)
Category 4 = 130–156 mph (209–251 km/h)
Category 5 = ≥157 mph (≥252 km/h)
(From the Saffir–Simpson scale)

Karl
Igor
Julia



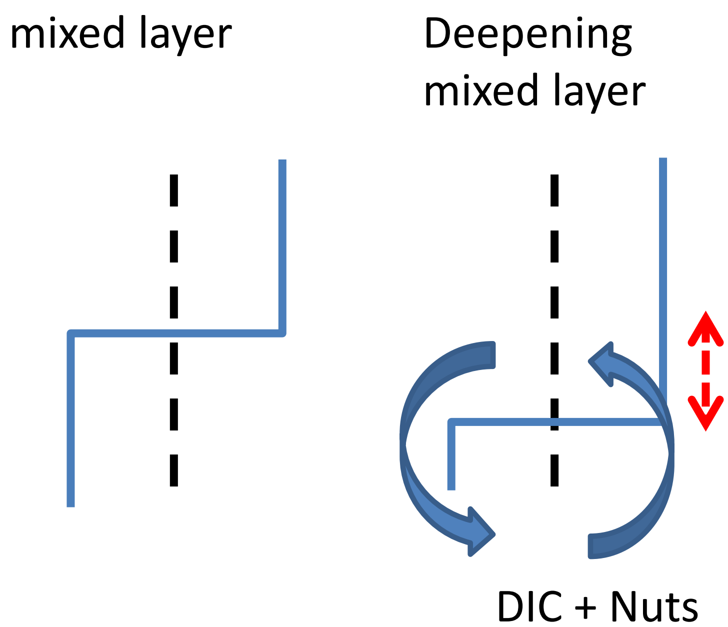

Interannual change in air-sea flux of $CO_2$ (in PgC $yr^{-1}$) due to $DpCO_2$ (blue), wind speed (black) and cold wake (red).

(Schuster & Jones 2017) – Unpublished Oceanflux results

# Updates to the Atlas

- CD or U* will be included in the next version of the Atlas .
- We can then include high wind parameterisations (Krall *et.al* 2019) & (Deike *et.al* 2018).
- Include rain effects (Harrison *et.al* 2012).

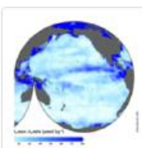
# What about upwelling?




A global monthly climatology of total alkalinity: a neural network approach

Daniel Broullón[1], Fiz F. Pérez[1], Antón Velo[1], Mario Hoppema[2], Are Olsen[3], Taro Takahashi[4], Robert M. Key[5], Toste Tanhua[6], Melchor González-Dávila[7], Emil Jeansson[8], Alex Kozyr[9], and Steven M. A. C. van Heuven[10]

31 Jul 2019



A global monthly climatology of oceanic total dissolved inorganic carbon: a neural network approach

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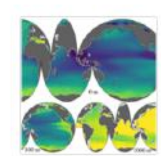

# Thankyou for listening

# Any questions?