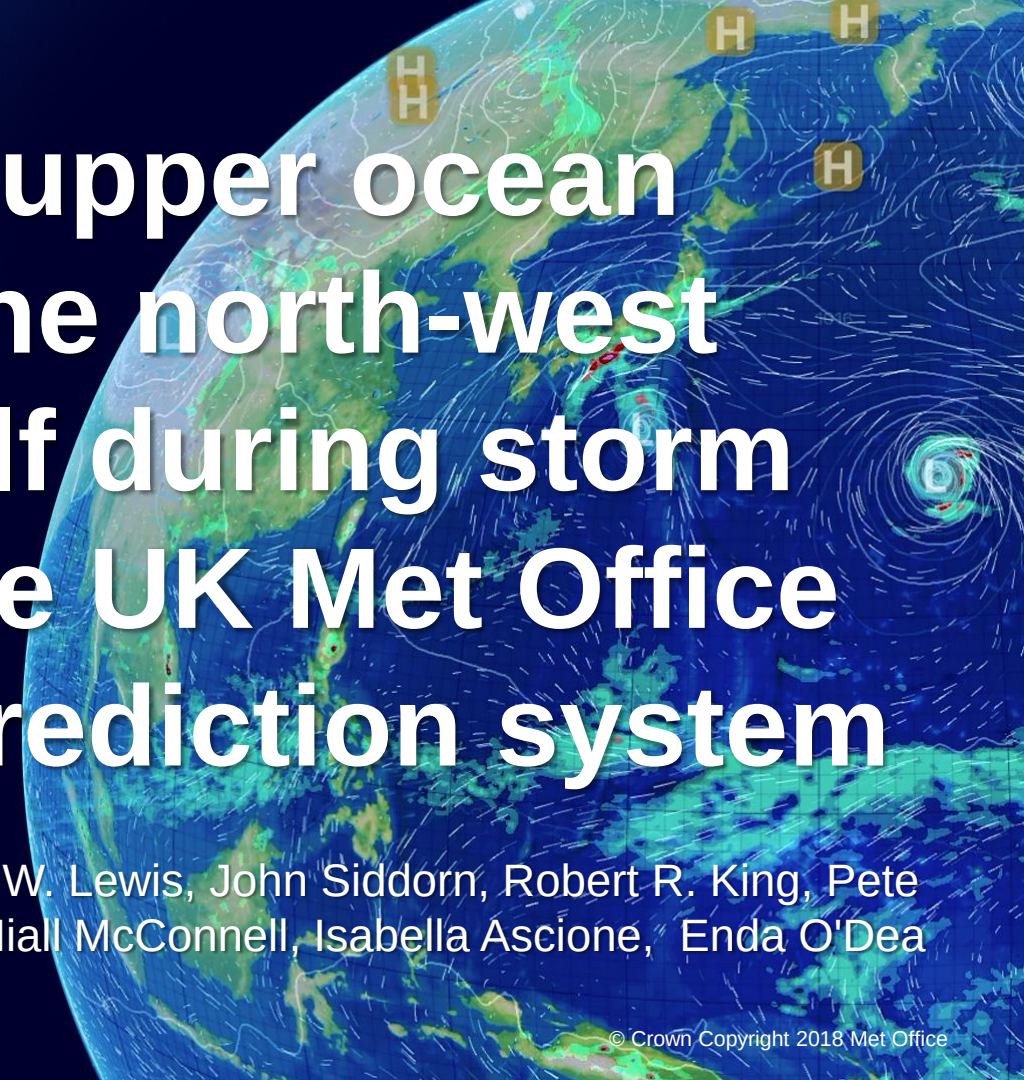
Met Office

Modelling the upper ocean dynamics of the north-west European shelf during storm events with the UK Met Office ocean-wave prediction system



Diego Bruciaferri, Marina Tonani, Huw W. Lewis, John Siddorn, Robert R. King, Pete Sykes, Juan M. Castillo, Andy Saulter, Niall McConnell, Isabella Ascione, Enda O'Dea

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Aim of the study

1. Quantify the impact of ocean-wave coupling on the accuracy of the simulation of the surface dynamics during extreme events on the NW European shelf and the NE Atlantic.

2. Assess the sensitivity of ocean-wave coupling to the temporal resolution of the atmospheric forcing.

3. Investigate the relative impact on the surface dynamics of

    - The modification of the surface wind stress by wave growth and dissipation
    - The Stokes-Coriolis force
    - A wave height dependent ocean surface roughness

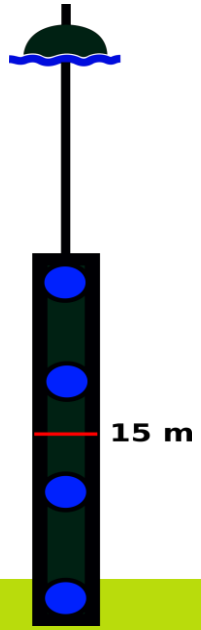
4. Identify possible issues in the current coupling approach and future development strategies.

Methodology

1. Simulation of drifter trajectories during 4 storms occurred in winter (JFM) 2016

2. We use CMEMS 2016 drifter observations. They include two types of drifter:

SVP with drogue



SVP which has lost the drogue
(effectively is an iSphere)

Drifter Trajectories

iSphere:

$$\frac{d\vec{x}}{dt} = \overrightarrow{u_E}\Big|_{\text{surf}} + \overrightarrow{u_S}\Big|_{\text{surf}} + \overrightarrow{u_W}$$

SVP:

$$\frac{d\vec{x}}{dt} = \overrightarrow{u_E}\Big|_{15m} + \overrightarrow{u_S}\Big|_{15m}$$

where

$\overrightarrow{u_E}\Big|_{surf}$ is the velocity of Eulerian ocean currents at the surface

$\overrightarrow{u_E}\Big|_{15m}$ is the velocity of Eulerian ocean currents at a depth of 15m

$\overrightarrow{u_S}\Big|_{surf}$ is the Stokes' drift at the surface

$\overrightarrow{u_S}\Big|_{15m}$ is the Stokes' drift at a depth of 15m

$\overrightarrow{u_W}$ is the wind drag velocity (leeway-drift velocity) at the surface

Drifter Trajectories

iSphere:

$$\frac{d\vec{x}}{dt} = \overrightarrow{u_E}\Big|_{\text{surf}} + \overrightarrow{u_S}\Big|_{\text{surf}} + \overrightarrow{u_W}$$

SVP:

$$\frac{d\vec{x}}{dt} = \overrightarrow{u_E}\Big|_{15m} + \overrightarrow{u_S}\Big|_{15m}$$

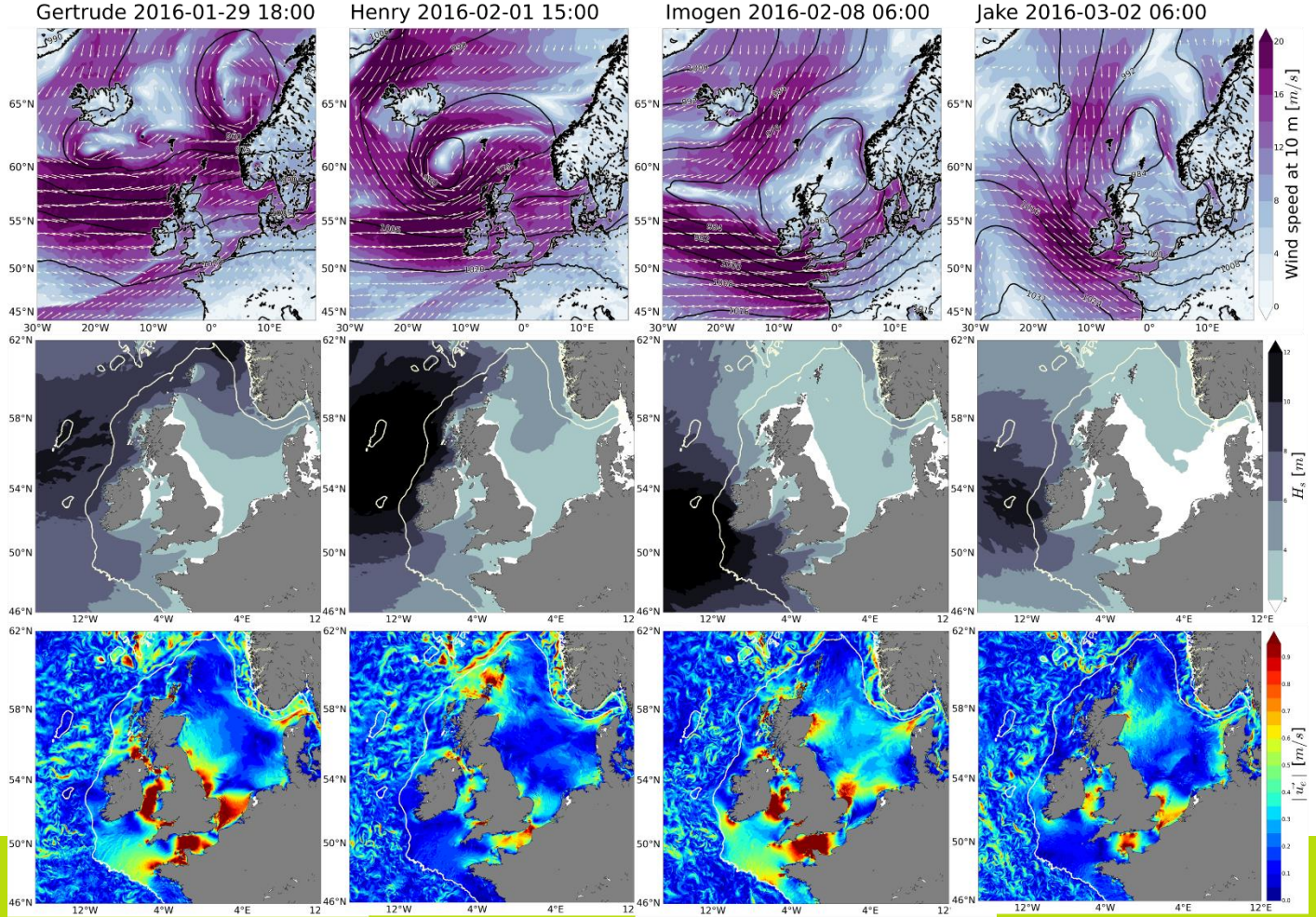
For some drifter there is no information regarding the presence or not of the drogue:

We simulate those drifters assuming they are either SVP or iSphere-like and then we choose the setting which gives the best performance

STORMS WINTER 2016

Storm	Dates active	Highest wind gust [km/h]	Lowest pressure [hPa]	Casualties	Damages
Gertrude	29-30 Jan	169	948	0	≥ £80 million (≥ €90 million)
Henry	1-2 Feb	140	944	0	≥ £80 million (≥ €90 million)
Imogen	8 Feb	154	962	0	≥ £80 million (≥ €90 million)
Jake	1-4 Mar	134	989	0	Unknown

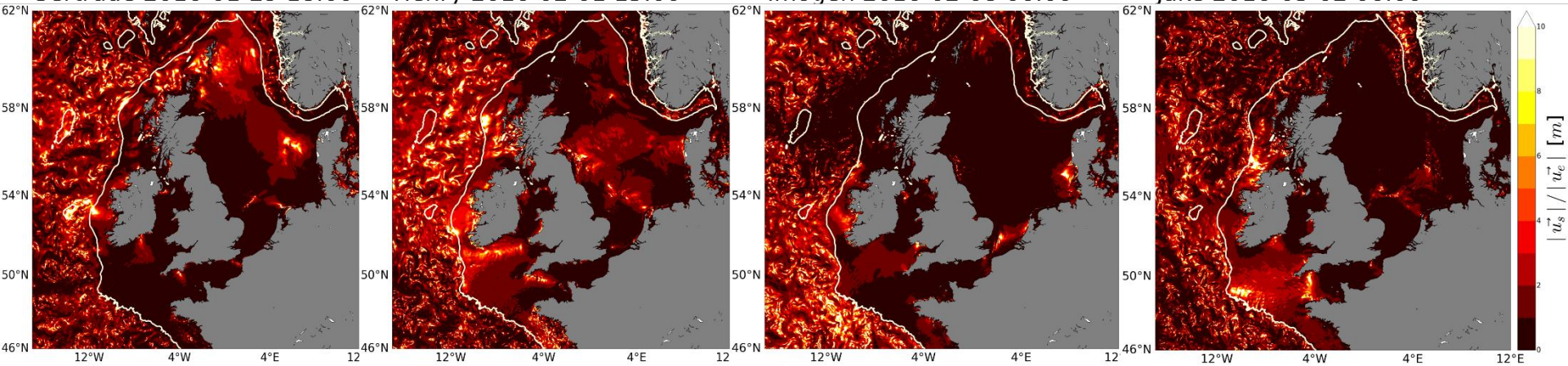
METEO-MARINE WEATHER CONDITIONS



THE IMPORTANCE OF THE STOKES' DRIFT

Ratio $\frac{|\overrightarrow{u_s}|}{|\overrightarrow{u_e}|}$

Gertrude 2016-01-29 18:00 | Henry 2016-02-01 15:00 | Imogen 2016-02-08 06:00 | Jake 2016-03-02 06:00



IDENTIFYING DRIFTERS' TRAJECTORIES DURING THE STORM

For each drifter of CMEMS winter 2016 dataset:

1. Consider the time window when the storm has been recorded as active on the NW shelf (previous table)

2. Extend that time window by considering the previous and the following days of its limit

3. Interpolate modeled Hs fields along the trajectory of the drifter for the identified period

The result is a timeseries of the Hs along each drifter trajectory during each storm.

IDENTIFYING DRIFTERS' TRAJECTORIES DURING THE STORM

For each Hs timeseries:

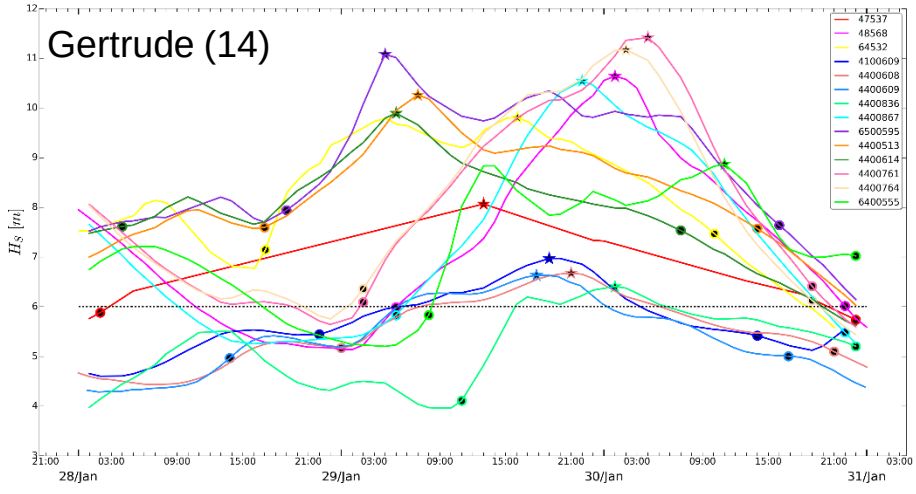
1. Compute the **peak** as the record of the timeseries where $Hs > Hs_{99}$ (Masselink et al. 2016), where Hs_{99} is the 1% exceedance Hs (i.e. the Hs with a value which is exceeded in the timeseries only 1% of the time)

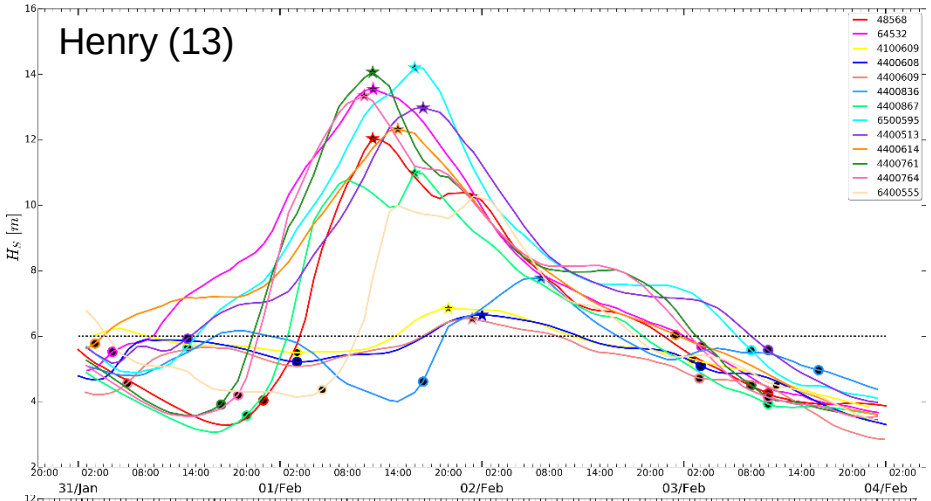
2. Compute the **beginning** of the along-drifter storm as the record of the Hs timeseries occurred **before** the peak of the storm which is nearest in time to the occurrence of the peak and with $Hs < Hs_{30}$ (i.e. the Hs with a value which is exceeded in the timeseries 70% of the time)

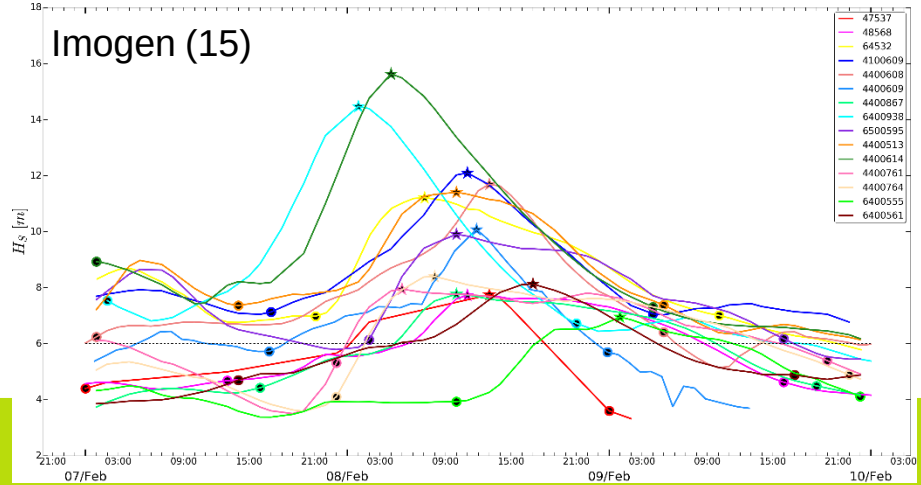
3. Compute the **end** of the along-drifter storm as the record of the timeseries occurred **after** the peak of the storm which is nearest in time to the occurrence of the peak and with $Hs < Hs_{30}$

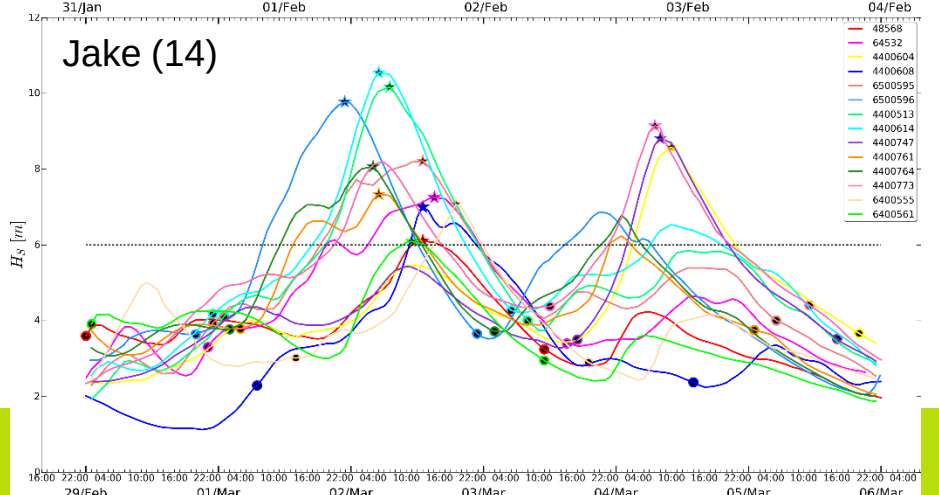
The aim of this study is to assess the effect of ocean-wave coupling during storm events: therefore, we consider only the drifters with a peak of the Hs timeseries larger than 6 m.

IDENTIFYING DRIFTERS' TRAJECTORIES DURING THE STORM

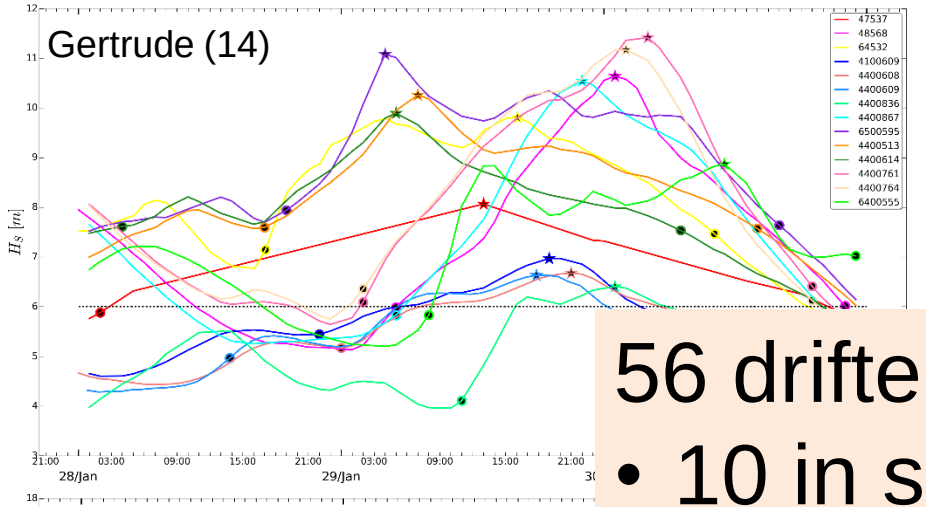


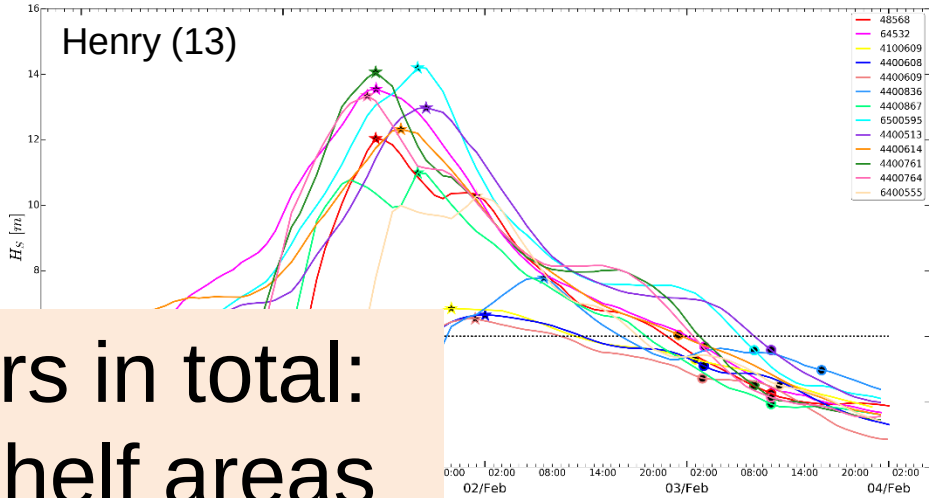






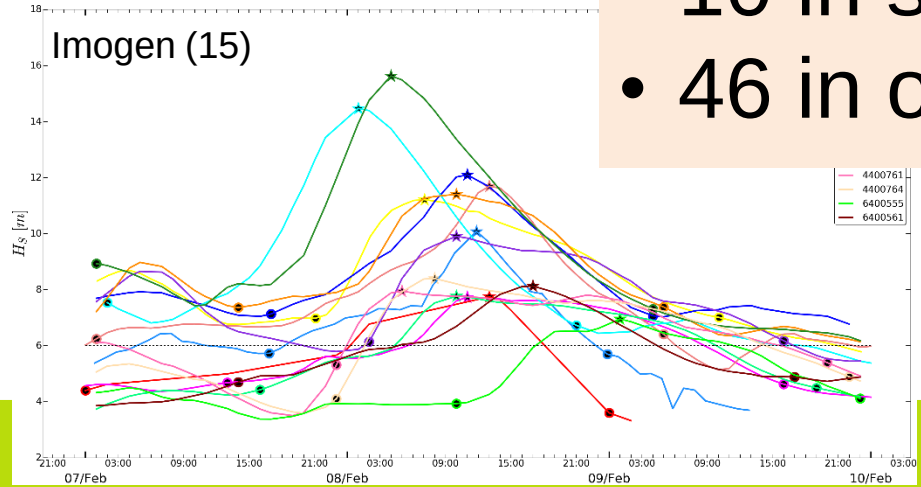
IDENTIFYING DRIFTERS' TRAJECTORIES DURING THE STORM

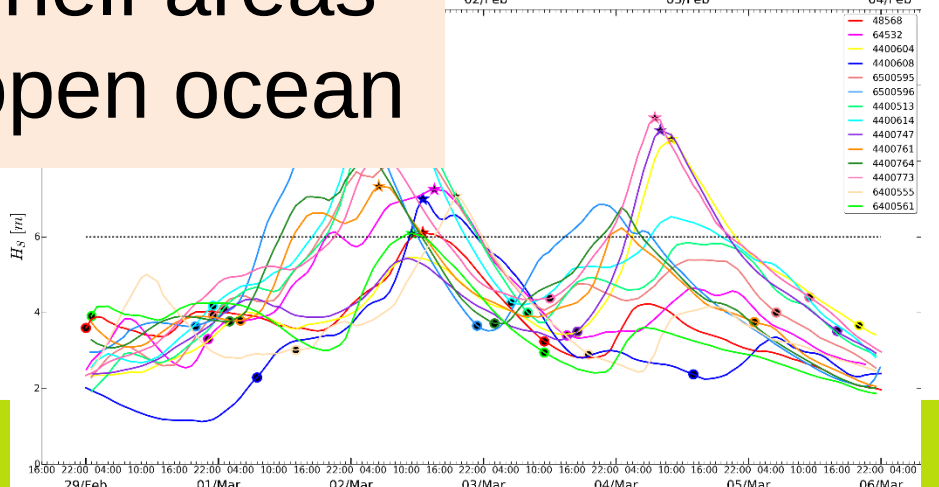




56 drifters in total:

- 10 in shelf areas
- 46 in open ocean





The UK MO ocean-wave coupled system

The Coupled ocean-wave forecasting system includes the following components:

1. **Ocean Forecasting system:**

   - NEMO v3.6 hydrodynamic code (Madec et al 2016)
   - 3DVar NEMOVAR (SST, T&S profiles)
   - 1.5 km horizontal resolution (AMM15 configuration)
   - 51 hybrid z*-s levels (Siddorn and Furner 2012)
   - Details in Graham et al. 2018 and Tonani et al 2018

2. **Wave Forecasting system:**

   - WWIII-vl4.18 (Tolman and WW3DG, 2014)
   - Rotated SMC grid with variable resolution (3 to 1.5 km) (Li, J.G. 2011)
   - Details in Saulter et al. 2016

The UK MO ocean-wave coupled system

Surface waves affect Eulerian ocean currents through the following physical mechanisms (details in Lewis et al. 2019a,b):

1. STOKES-CORIOLIS FORCING

- **Stokes' drift:** mean Lagrangian transport induced by surface waves in their direction of propagation (Stokes 1847, Phillips 1977)

- The interaction between the planetary vorticity and the Stokes' drift yields an additional force on the wave averaged Eulerian momentum equation (Hasselmann 1970)

$$\frac{D\boldsymbol{u}}{Dt} + f\hat{\boldsymbol{z}} \times (\boldsymbol{u} + \boldsymbol{u_s}) = -\frac{1}{\rho}\boldsymbol{\nabla} p \; - g\,\hat{\boldsymbol{z}} + \boldsymbol{F}$$

In the UK MO coupled system the $\boldsymbol{u_s(0)}$ at the surface is computed by the wave model. The 3D $\boldsymbol{u_s}$ is computed using $\boldsymbol{u_s(0)}$ and Brievik et al 2016 parameterization.

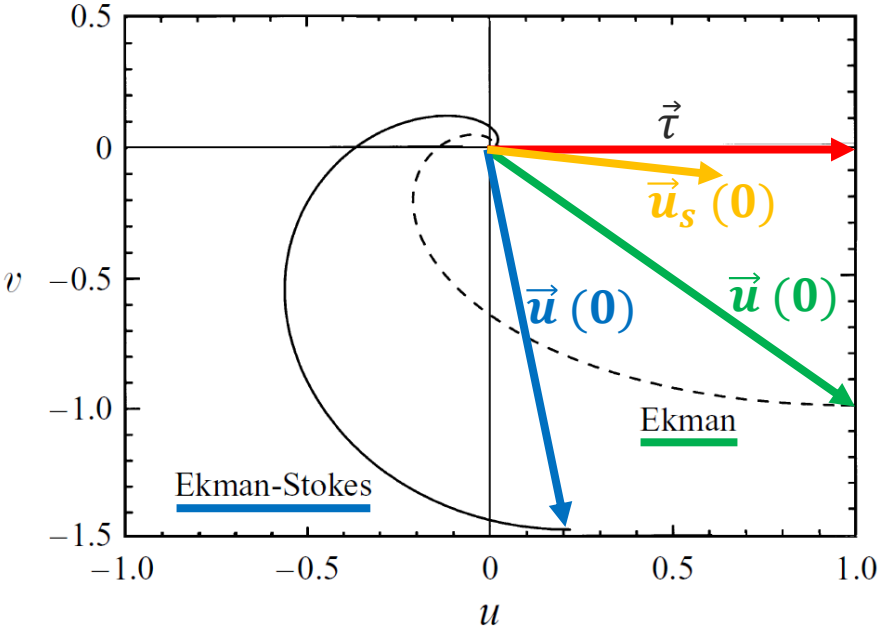
The UK MO ocean-wave coupled system

1. STOKES-CORIOLIS FORCING (continue)

- Classical Ekman problem modified for the Stokes-Coriolis forcing (McWilliams et al 1997, Polton et al. 2005):

$$f\hat{\boldsymbol{z}} \times (\boldsymbol{u} + \boldsymbol{u_s}) = K_m \frac{\partial\, u}{\partial^2 z}$$

The Stokes' Coriolis force adds an additional veering to the upper-ocean currents



The UK MO ocean-wave coupled system

2. SURFACE WIND STRESS MODIFIED BY GROWING SURFACE WAVES

The stress felt by the ocean is given by (e.g Komen et al. 1994, Janssen 2004)

$$\tau_o = \tau_a - \tau_{gw} - \tau_{bw}$$

where

- τ_o is the stress felt by the Eulerian ocean
- τ_a is the total wind stress at the ocean surface
- τ_{gw} is the fraction of the momentum from the atmosphere used for waves growing
- τ_{bw} is the momentum released to the ocean through wave breaking

In the UK MO coupled system, τ_{gw} and τ_{bw} are computed by the wave model.

The UK MO ocean-wave coupled system

3. WAVE DEPENDENT SEA SURFACE ROUGHNESS

- The sea surface roughness z_0 is the length scale at which the high surface turbulent mixing occurs (e.g. Craig and Banner 1994, Mellor and Blumberg 2004)

- Rascle et al (2008) associated z_0 to the wind-sea H_s :

$$z_0 = a\, H_s \quad \text{, with } a = 1.3$$

In the UK MO coupled system, the wind-sea H_s is computed by the wave model.

The UK MO ocean-wave coupled system

Ocean currents affect waves propagation causing refraction, energy bunching and frequency shifting. The action density balance equation solved by WWIII reads

$$\frac{\partial N}{\partial t} + \nabla_x \cdot \dot{\mathbf{x}} N + \frac{\partial}{\partial k}\dot{k} N + \frac{\partial}{\partial \theta}\dot{\theta} N = \frac{S}{\sigma} ,$$

$$\dot{\mathbf{x}} = \mathbf{c}_g + \mathbf{U} ,$$

$$\dot{k} = -\frac{\partial \sigma}{\partial d}\frac{\partial d}{\partial s} - \mathbf{k} \cdot \frac{\partial \mathbf{U}}{\partial s} ,$$

$$\dot{\theta} = -\frac{1}{k}\left[\frac{\partial \sigma}{\partial d}\frac{\partial d}{\partial m} + \mathbf{k} \cdot \frac{\partial \mathbf{U}}{\partial m}\right]$$

Ocean-wave coupling does not add any further ocean currents' effect to the wave action density governing equation

COUPLING ENTERS IN THE ACTION BALANCE EQUATION ONLY THROUGH A WAVE-MODIFIED EULERIAN CURRENT

Numerical experiments

1. Drifters' trajectories are simulated using OpenDrift Lagrangian model (Dagestad et al., 2018).

2. For iSphere-like drifters, the evolution of the drifter position is computed according to

$$\frac{d\vec{x}}{dt} = \overrightarrow{u_E}(\vec{x}) + \overrightarrow{u_S}(\vec{x}) + \overrightarrow{u_W}(\vec{x})$$

where $\overrightarrow{u_E}$ and $\overrightarrow{u_S}$ are the velocities of Eulerian ocean currents and the Stokes' drift computed at 0.5 m (first AMM15 level) and $\overrightarrow{u_W}$ is the leeway velocity defined as

$$\overrightarrow{u_W}(\vec{x}) = \gamma\, \overrightarrow{U_{10}}$$

with $\overrightarrow{U_{10}}$ the wind velocity at 10 m and $\gamma = 0.01$ (Rohrs et al 2012, De Dominicis et al. 2016).

3. For SVP drifters $\overrightarrow{u_E}$ and $\overrightarrow{u_S}$ are computed at 15m and the leeway of the wind is assumed to be nihil ($\overrightarrow{u_W}$ = 0)

4. The Stokes' drift at 0.5 and 15 m is computed using the Breivik et al. 2016 approximation.

5. Time integration is performed using a 4th order Runge-Kutta scheme with a time-step of 60 min.

6. No explicit diffusion

Numerical experiments

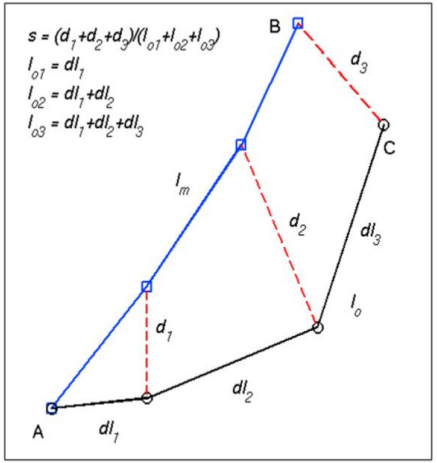
- The accuracy of the numerical results is quantified using Liu & Weisberg 2011 metric:

- **Skill score** *ss(t_i)*: it evaluates the separation between drifter and model trajectory along their entire path, normalized by the total path length.
  It is defined as

$$ss(t_i) = \begin{cases} 1 - \dfrac{s(t_i)}{n} & , s(t_i) \le n \\ 0 & , s(t_i) > n \end{cases}$$

with

$$s(t_i) = \frac{\sum_{i=1}^{N} d\,(t_i)}{\sum_{i=1}^{N} l_o\,(t_i)}$$



where $l_o(t_i)$ is the length of the observed trajectory at time t_i , $d(t_i)$ is the distance between the observed and the simulated drifter position at time t_i , N is the total number of observed drifter positions and n=1 is a tolerance threshold.

- ss = 1 → perfect fit between observation and simulation
- ss = 0 → model simulations have no skill.

Numerical experiments

Drifter trajectories are simulated combining the following forcing data:

1. **Wind velocity data**
   - ECMWF-3H
   - ECMEWF-1H

2. **Ocean currents and Stokes' drift data**
   - from a number of trials of the UK MO ocean-wave coupled forecasting system run with different levels of coupling (from uncoupled to fully coupled mode) and different atmospheric forcing.

Numerical experiments

Trial name	Ocean-Wave coupling	Atmospheric forcing	Simulation period
CT3H	OFF	ECMWF-3H	01-01-2016 10-03-2016
OW3H	ON - FULL	ECMWF-3H	01-01-2016 10-03-2016
OW1H	ON - FULL	ECMWF-1H	01-01-2016 10-03-2016
CT1H	OFF	ECMWF-1H	01-01-2016 10-02-2016
SC1H	ON - only Stokes-Coriolis	ECMWF-1H	01-01-2016 10-02-2016
TW1H	ON - only wind stress	ECMWF-1H	01-01-2016 10-02-2016
WR1H	ON - only sea surf. roughness	ECMWF-1H	01-01-2016 10-02-2016

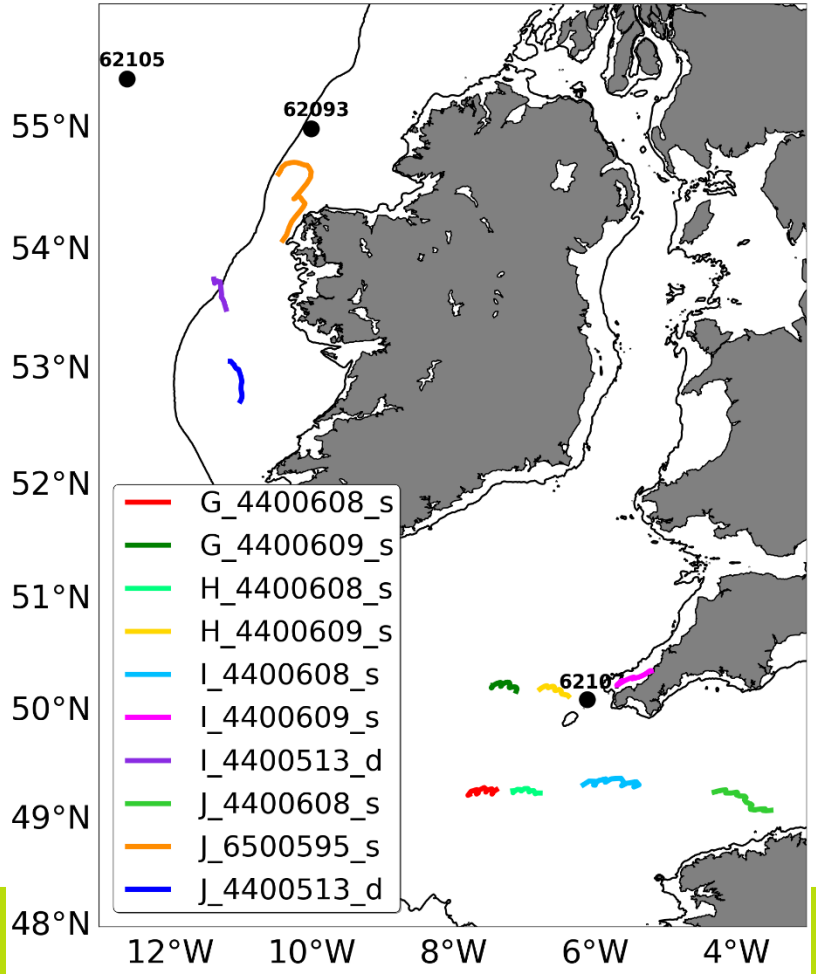
RESULTS

(In this presentation we are going to present only the results for the drifters on the shelf since the analysis for the open-ocean is still on going)

How does our Lagrangian modelling approach work in shelf areas?

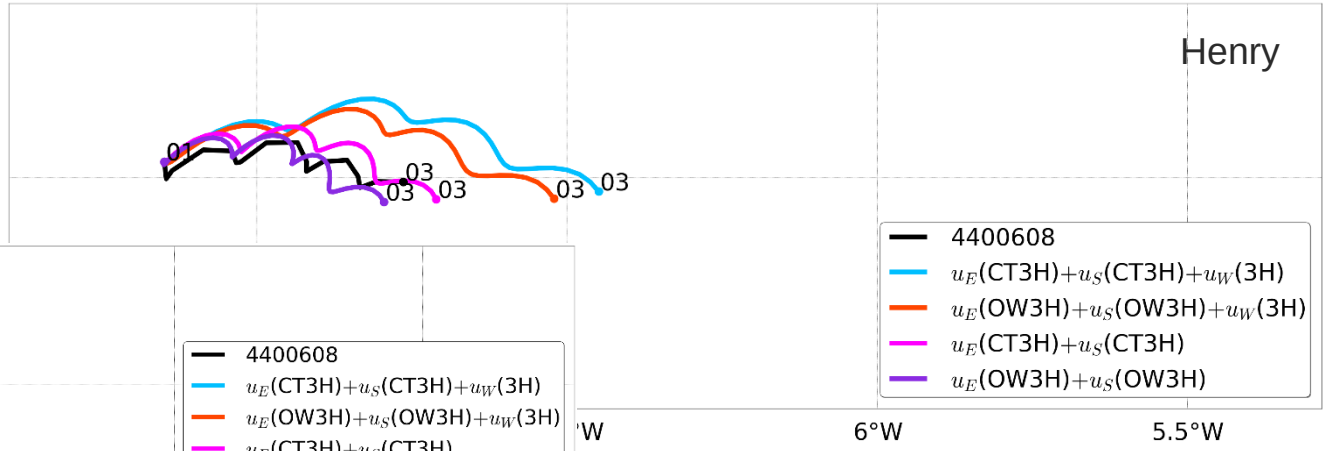
SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

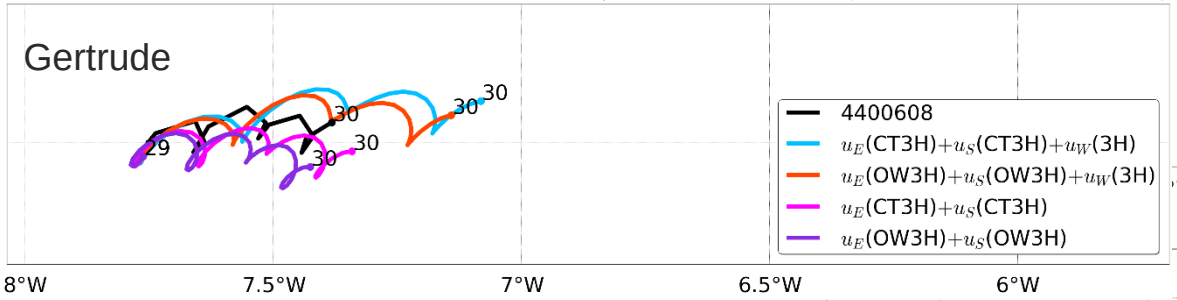
62105, 62093 and 62107 are available wave buoy for this period

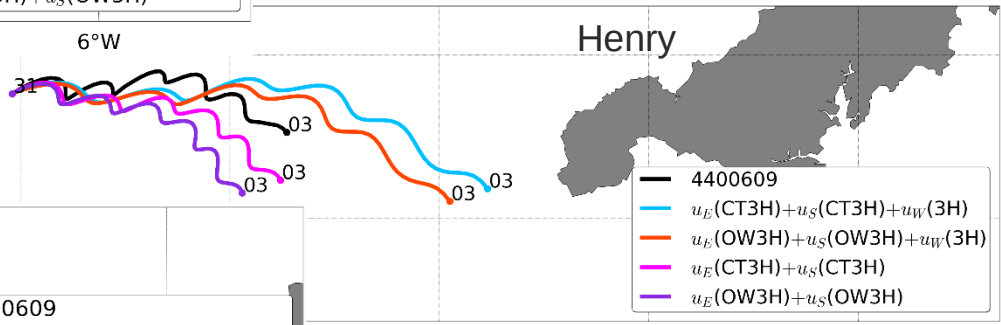


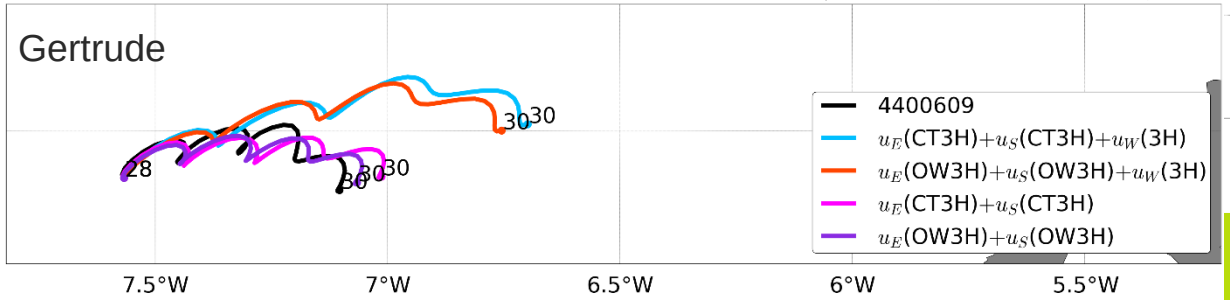
SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

SURFACE DRIFTERS



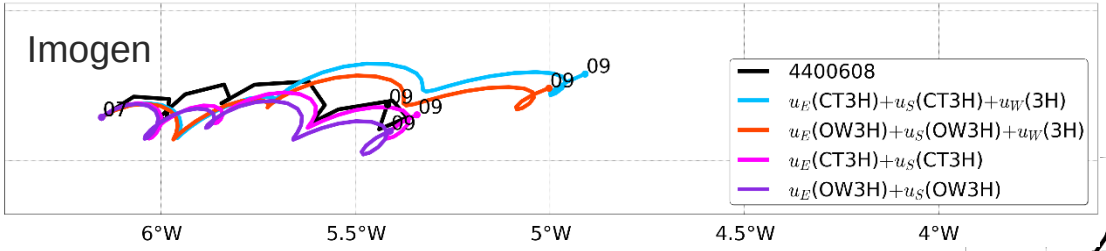


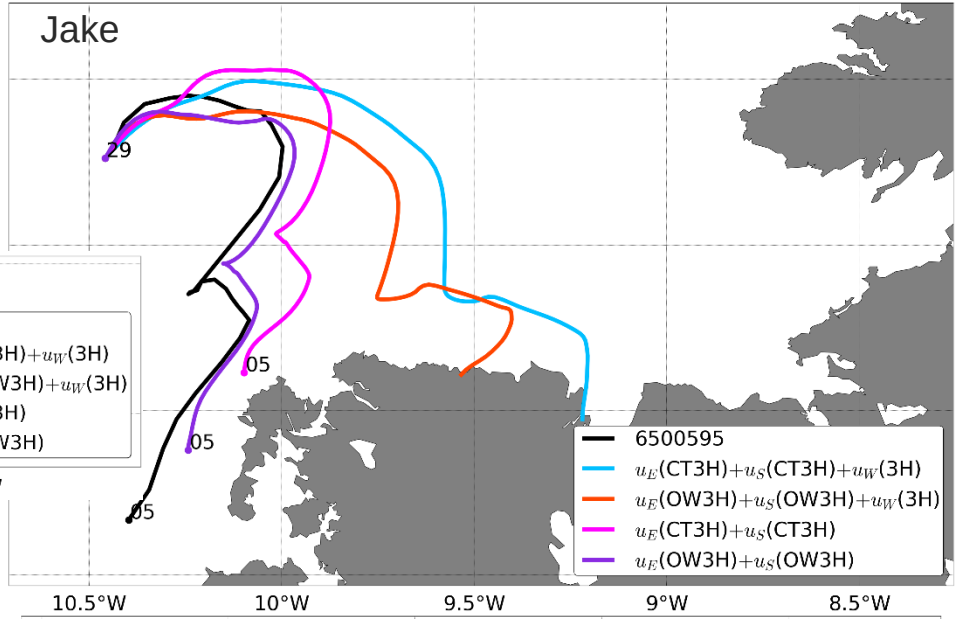


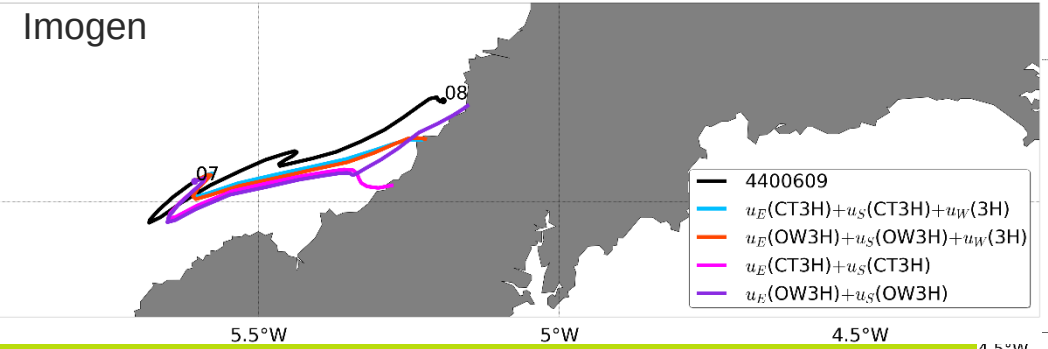


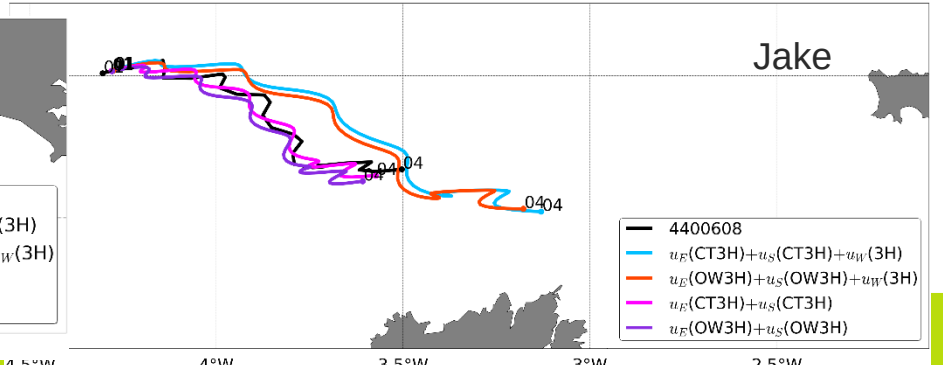
SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

SURFACE DRIFTERS









SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

SURFACE DRIFTERS

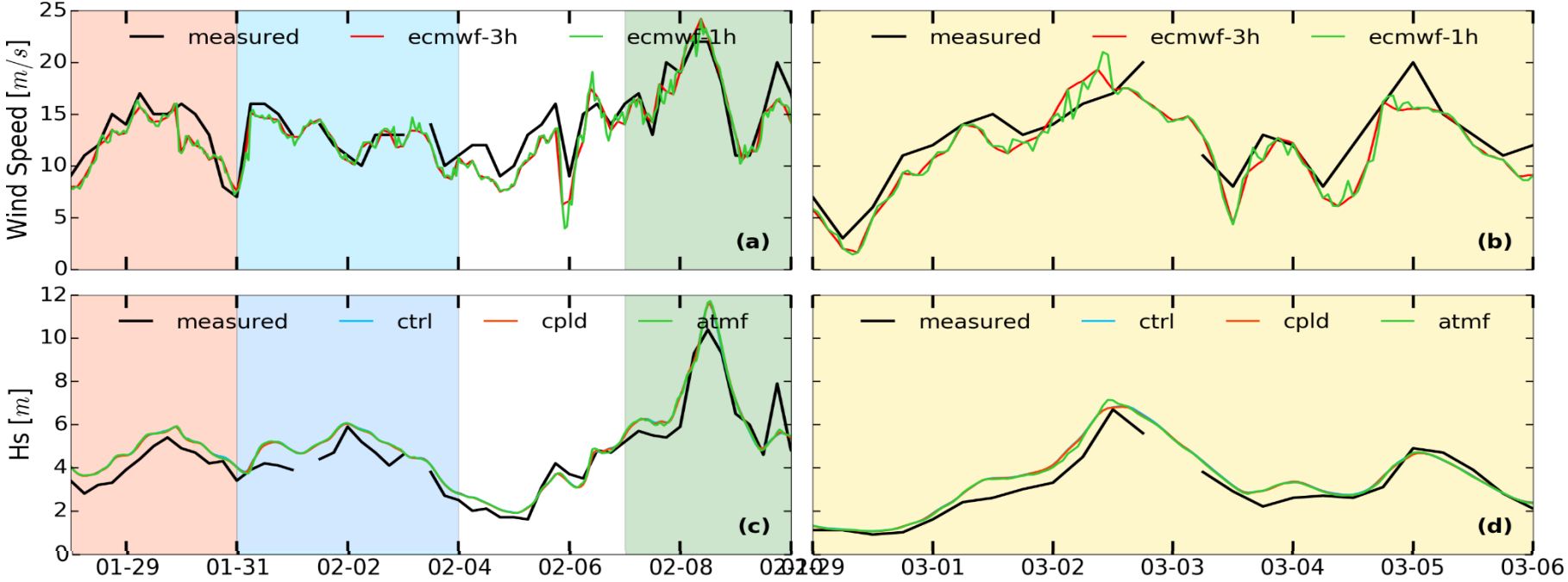
1. Generally, the simulated drifters' trajectories are overestimated with respect to the observed ones – the simulated drifters' velocities are faster than the real ones.

2. When the leeway of the wind is not taken into account (uW is not used), the simulated trajectories agrees much more with the observed ones (higher ss for both CTRL and CPLD).

CAN WE EXPLAIN WHY ?

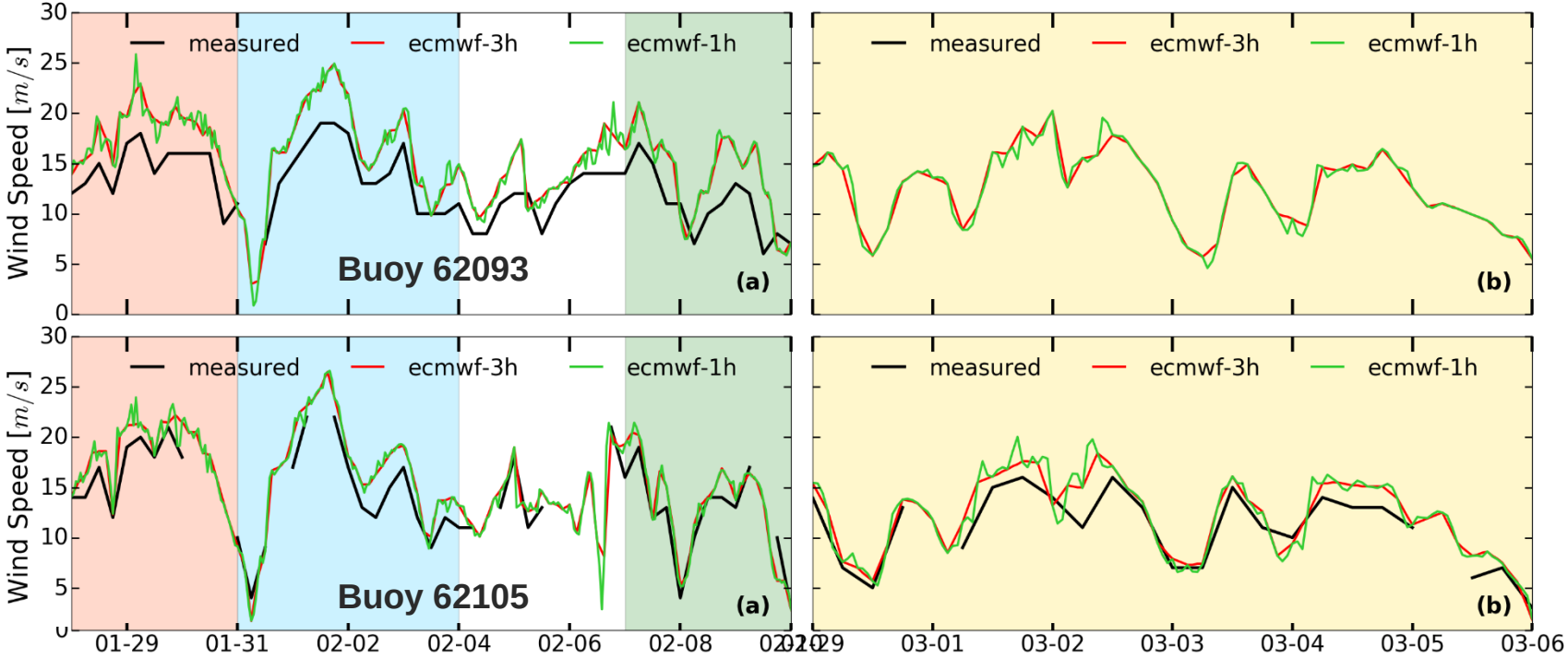
SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

Buoy 62107



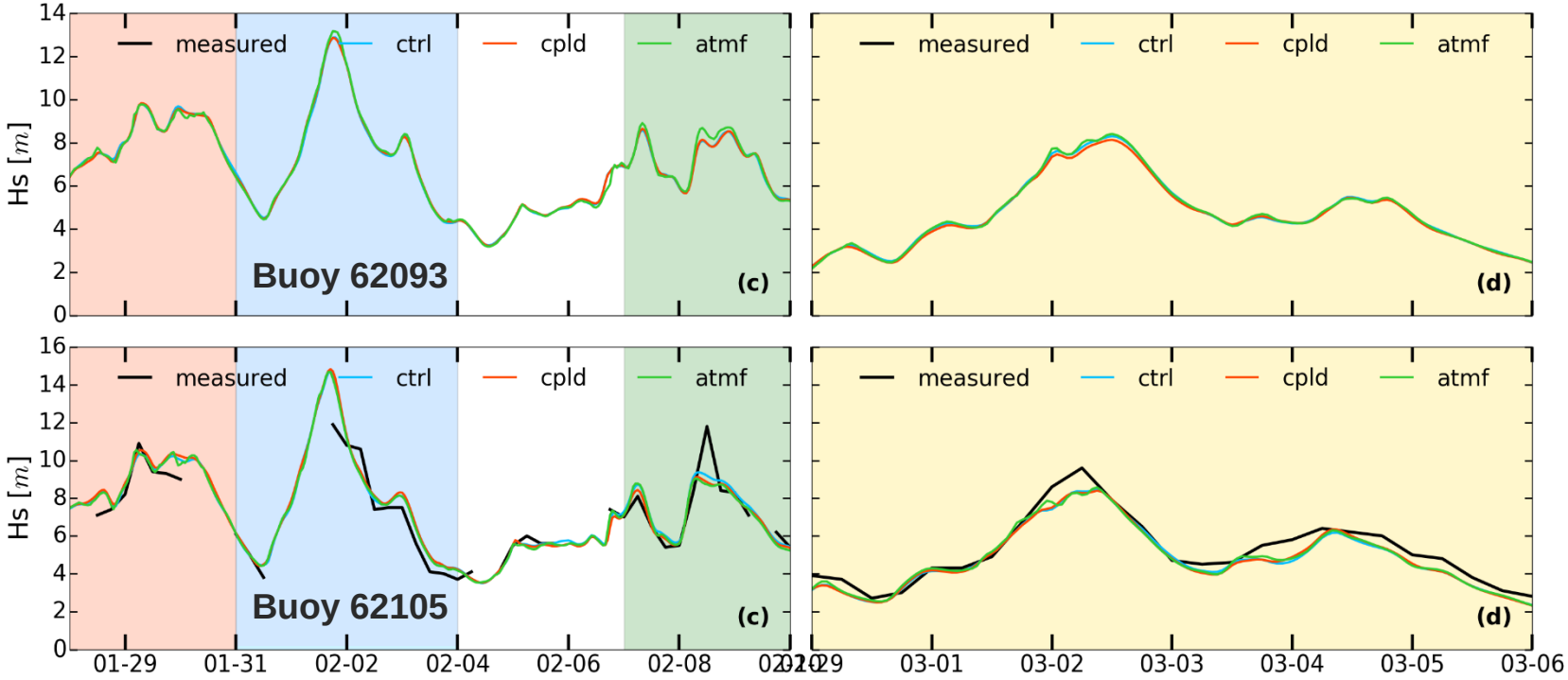
- **Wind quite good**, slightly underestimates the strongest events. Overestimation (or under sampling?) of strong event during 8th of February (Imogen).
- **Hs overestimated, especially during strongest events** -> Stokes' drift overestimated also

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF



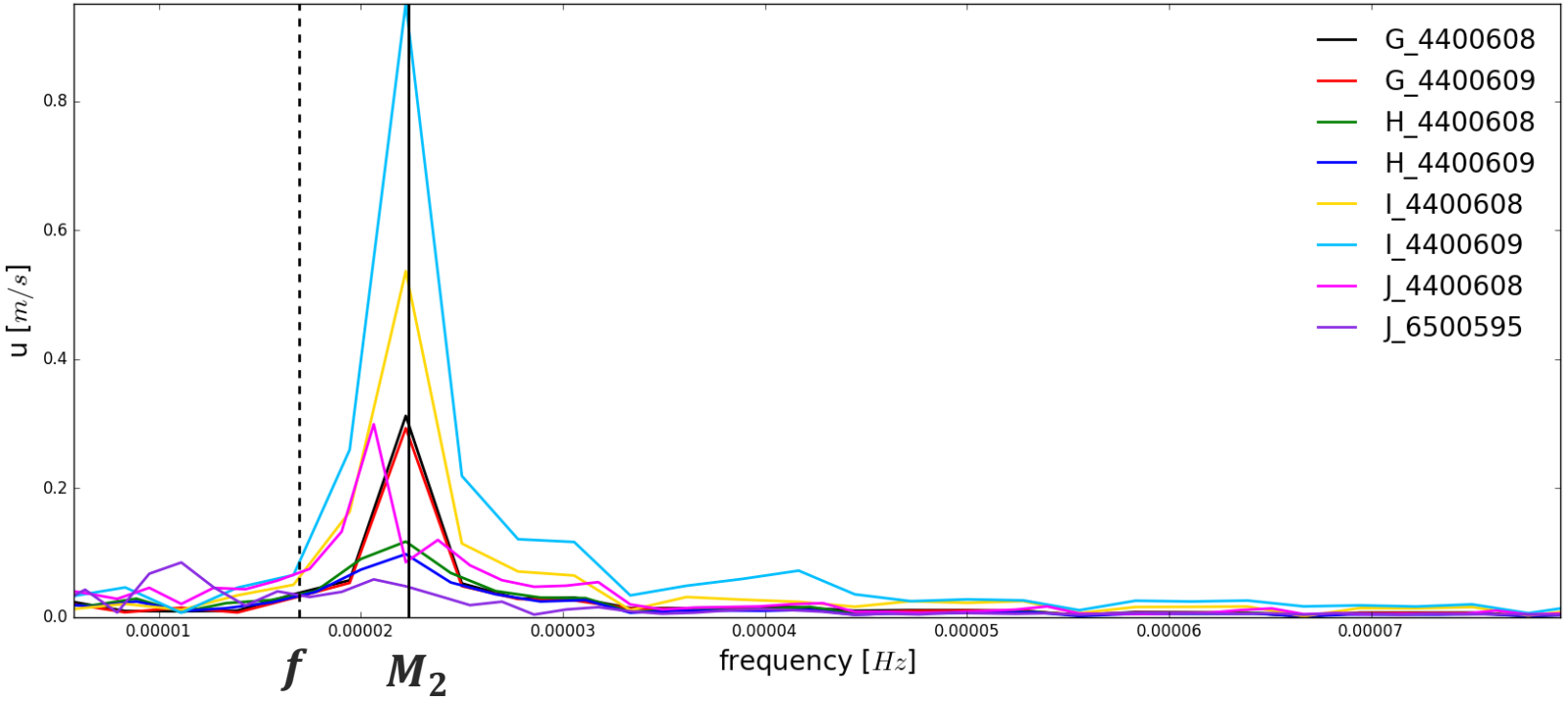
- ECMWF wind importantly overestimates observations in both buoys for storms Gertrude, Henry and Imogen.
- Timeseries of both model and observation signals correlate very well -> **we can expect overestimation of wind forcing also in location of buoy 62093 for storm Jake.**

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF



- During storm Jake, Hs of buoy 62105 slightly underestimates the observed signal.
- Hs model timeseries extracted at the location of the buoys correlate very well.
- The importance of locally generated wind-waves and swell in both location is very similar.
- **We can expect observed Hs of buoy 62093 to be very similar to the one of buoy 62105.**

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF



- Velocity-frequency spectrum of ocean currents sampled during the storm events where drifters where observed.
- **Ocean currents are mainly tidal**: velocity-frequency maxima at M2 frequency.

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

For drifters 4400608 (storms Gertrude, Henry, Imogen, Jake), 4400609 (storms Gertrude and Henry) and 6500595 (storm Jake) :

1. Buoy 62107 (close to drifters 4400608 and 4400609) shows that:
   - during the storms the Stokes' drift might be overestimated (see Hs), especially during the strongest events.
   - the wind is reasonably well reproduced, with a small negative bias especially during the strongest events.

2. Buoys 62093 and 62105 (close to drifter 650095 during storm Jake)
   - during the storm Jake the Stokes drift might be slightly underestimated (see Hs), especially during the strongest events.
   - The wind is likely to be overestimated.

We conclude that:

- the errors in the Lagrangian simulations when using also the leeway of the wind are probably due to inaccuracies in the wind and/or the Stokes' Drift forcing.

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

In the case of the coastal drifter 4400609 during storm Imogen:

1. Buoy 62107 shows that in the area of drifter 4400609 the wind agrees well with obs., being slightly overestimated only during the strong event of the 8th of February. There are indications that Hs might be overestimated during the simulated period (7-9 Feb).

We conclude that

The errors in the Lagrangian simulation might be linked to inaccuracies affecting the wave forcing.

In coastal areas, biases in wind and wave simulations are in agreement with literature (e.g. Arduhin et al. 2006, Ponce et at 2008, Christakos et al 2020):

1. coarse resolution wind does not resolve orography properly -> large errors close to the coast
2. Wave-wave interaction not properly represented

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

Currents are mainly tidal. In shallow areas (< 200m)

1. the wave-enhanced turbulence at the sea bed (higher bed stress) can have a significant effect upon currents, directly reducing near bed currents but also affecting surface flow and tidal elevation through non-linear interactions (e.g. Davies and Lawrence 1995).

2. the enhanced levels of turbulence associated with the wind and the wind-induced currents significantly influence the profile of the M2 tidal current, and also affect the higher tidal harmonics (e.g Davies and Jones 1994, Davies et al 2000).

It is likely that

1. Errors in the wind field affected also the ocean currents, both directly (i.e. the wind-induced circulation) or via non-linear interactions with the tidal flow.

2. For coastal drifters, including enhanced wave-induced turbulence at the bottom might be also particularly important.

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

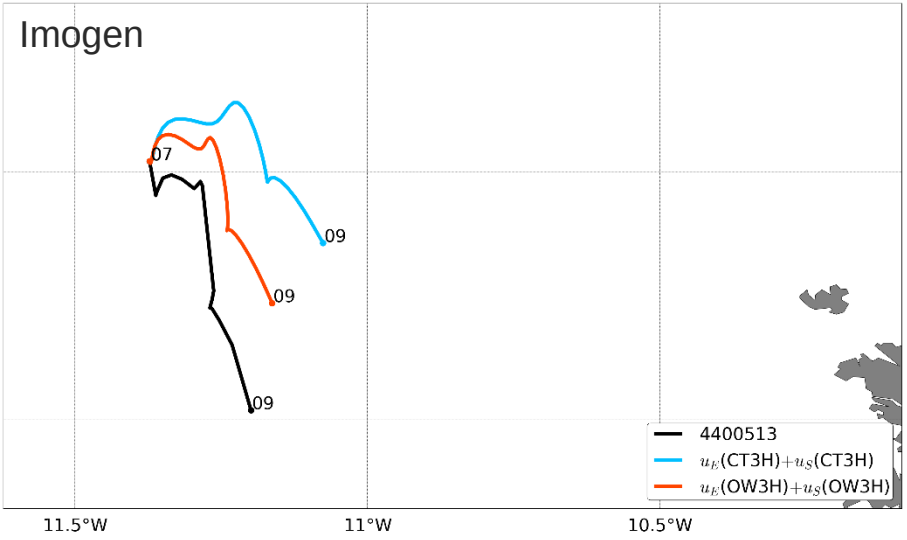
STORM	DRIFTER	ss CT3H-CT3H-W3H	ss OW3H-OW3H-W3H	ss CT3H-CT3H	ss OW3H-OW3H
GERTRUDE	4400608	0.6	0.68	0.86	0.82
GERTRUDE	4400609	0.57	0.59	0.91	0.92
HENRY	4400608	0.34	0.45	0.76	0.79
HENRY	4400609	0.54	0.6	0.87	0.84
IMOGEN	4400608	0.74	0.77	0.86	0.83
IMOGEN	4400609	0.22	0.26	0.6	0.66
JAKE	4400608	0.76	0.78	0.83	0.85
JAKE	6500595	0.47	0.57	0.79	0.89
TOT		0.53	0.59	0.81	0.83

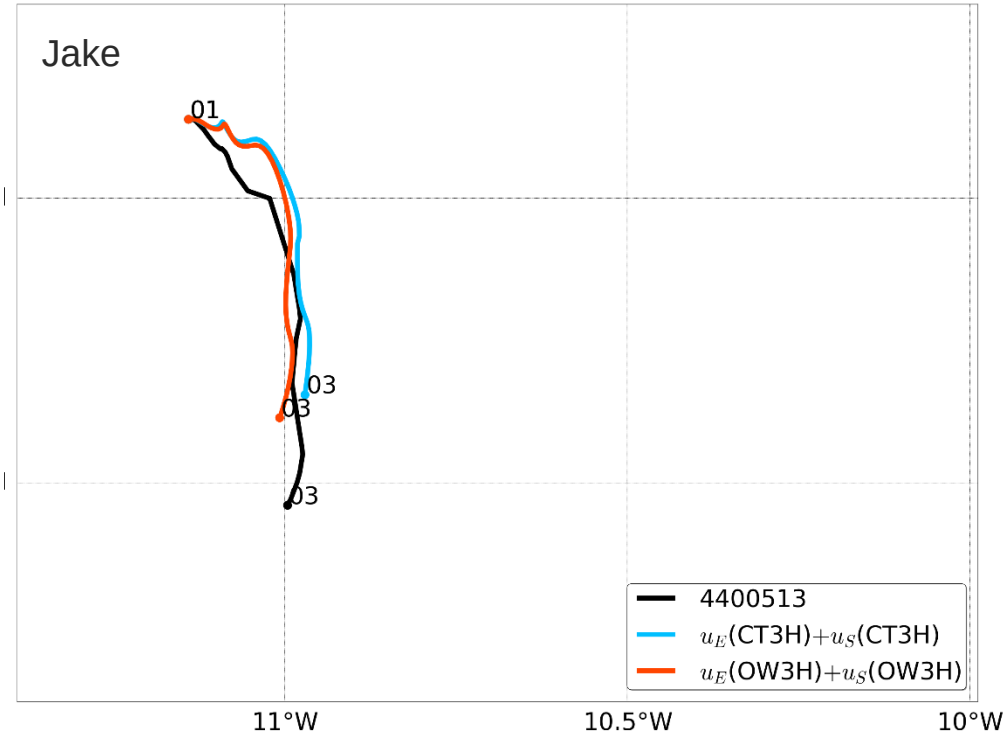
- The ss is significantly improved when the wind drag is not taken into account.
- We showed that the errors can be linked to inaccuracies in the forcing (mainly wind and waves) in shelf and coastal areas, in agreement with previous studies (e.g. Christakos et al 2020).

We decide that for drifters on the shelf we will assess the effect of coupling not using uW.

SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

15m DRIFTERS





SIMULATING DRIFTER TRAJECTORIES ON THE SHELF

15m DRIFTERS

1. The simulated trajectories of drifter 4400513 during Imogen and Jake storms underestimate the observed ones – the simulated drifter velocities are slower than the real ones.

2. This might be due to:
   - Inaccuracies in the wind-driven currents – storm physics is underestimated
   - Not representation of wind drag below the surface during extreme events – is it reasonable to assume that the drogue does not feel the strong wind during storms?

What is the effect of ocean-wave coupling on the shelf?

THE EFFECT OF COUPLING ON THE SHELF

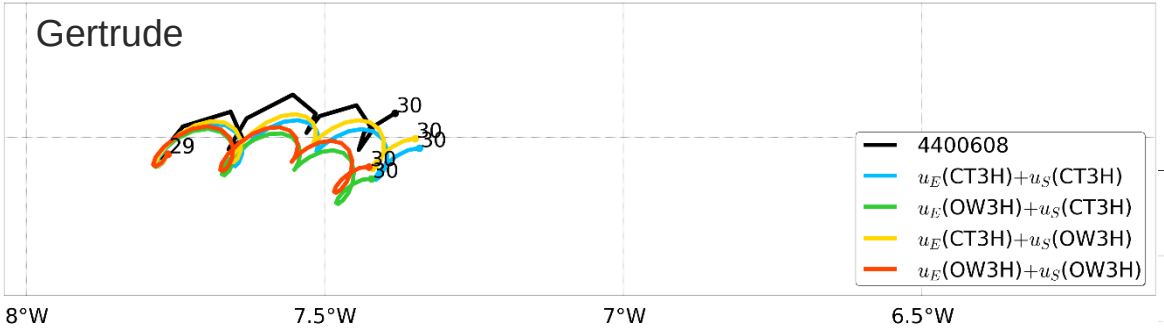
STORM	DRIFTER	TYPE	ss CT3H-CT3H	ss OW3H-OW3H	ss CT3H-OW3H	ss OW3H-CT3H
GERTRUDE	4400608	surf	0.86	0.82	0.89	0.8
GERTRUDE	4400609	surf	0.91	0.92	0.93	0.89
HENRY	4400608	surf	0.76	0.79	0.73	0.81
HENRY	4400609	surf	0.87	0.84	0.89	0.81
IMOGEN	4400608	surf	0.86	0.83	0.87	0.81
IMOGEN	4400609	surf	0.6	0.66	0.62	0.62
IMOGEN	4400513	15m	0.16	0.4	0.14	0.42
JAKE	4400608	surf	0.83	0.85	0.82	0.85
JAKE	6500595	surf	0.79	0.89	0.76	0.88
JAKE	4400513	15m	0.56	0.62	0.54	0.64
TOT			0.72	0.76	0.72	0.75

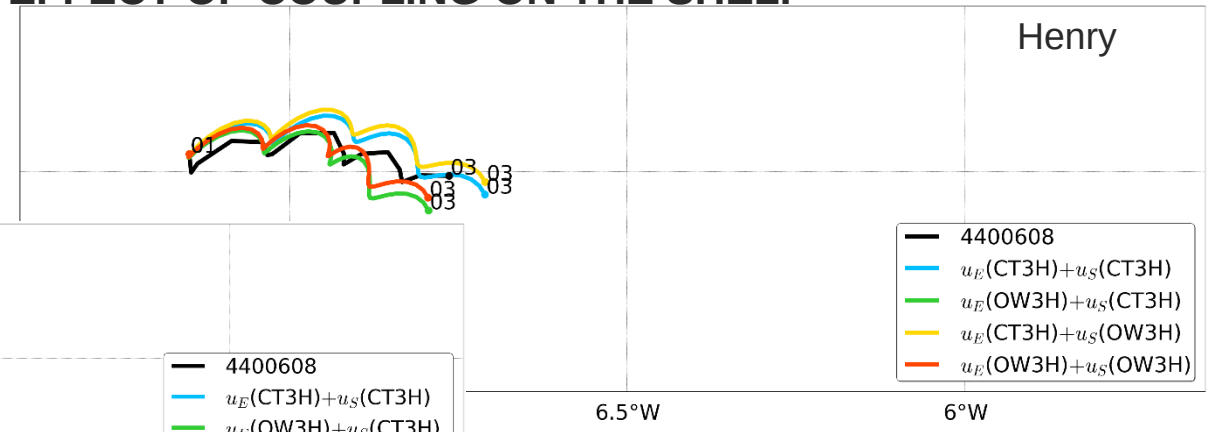
1. On average, using forcing fields from an ocean-wave coupled system (OW3H-OW3H) results in a moderate higher ss (+ 4%) wrt using forcings from an uncoupled system (CT3H-CT3H).

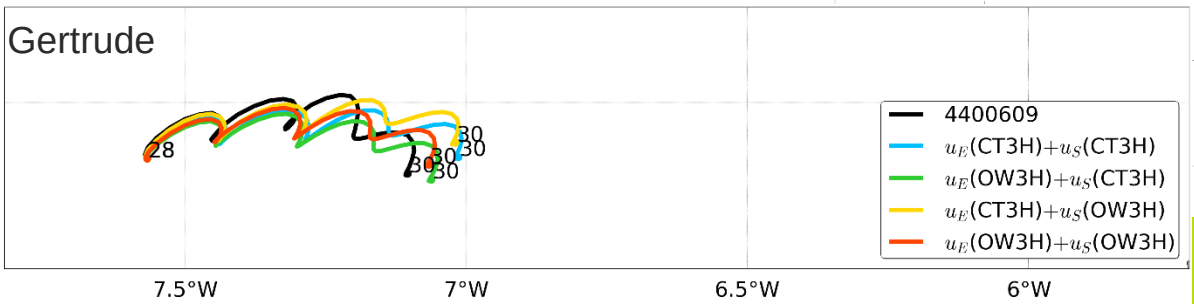
2. In coastal areas (H <~ 50m) coupling can improve ss up to 6%.

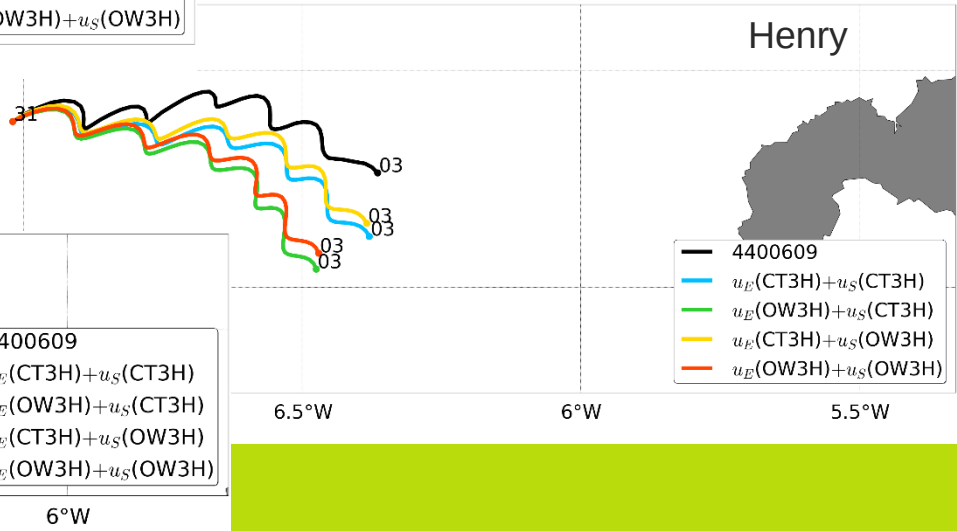
THE EFFECT OF COUPLING ON THE SHELF

SURFACE DRIFTERS

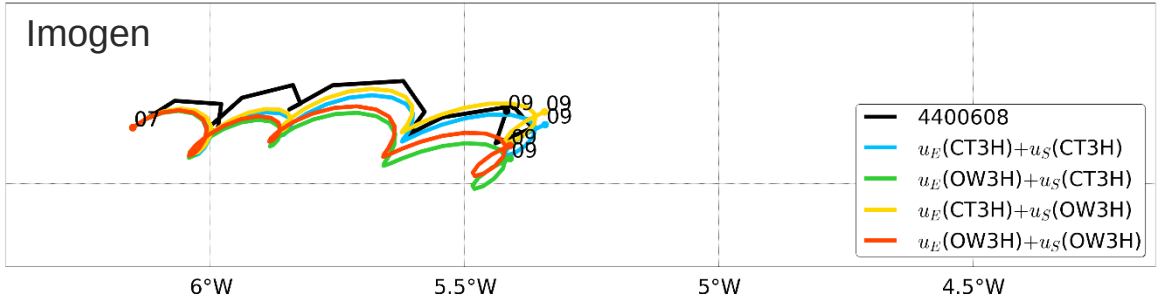


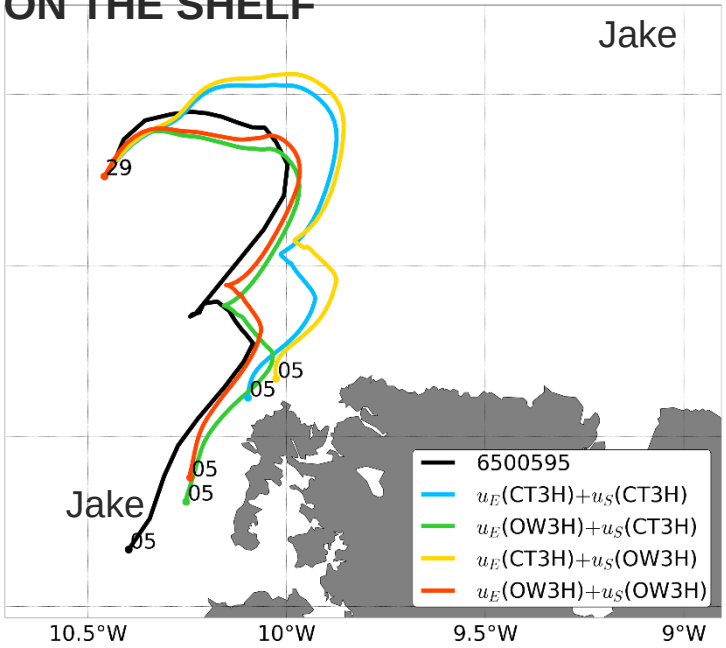


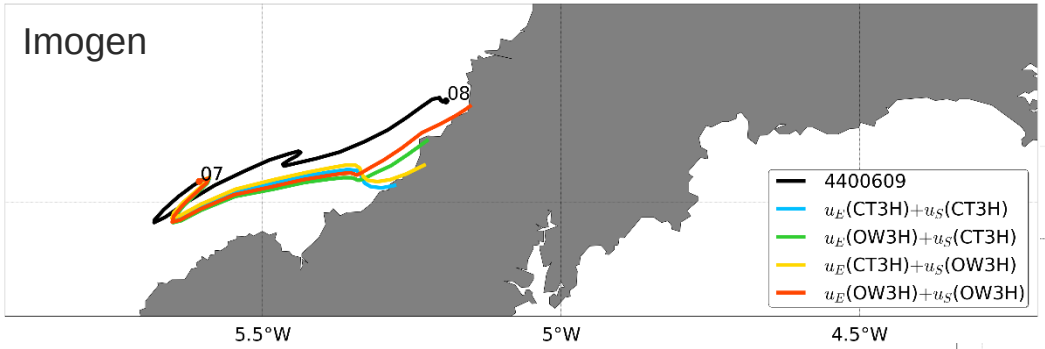


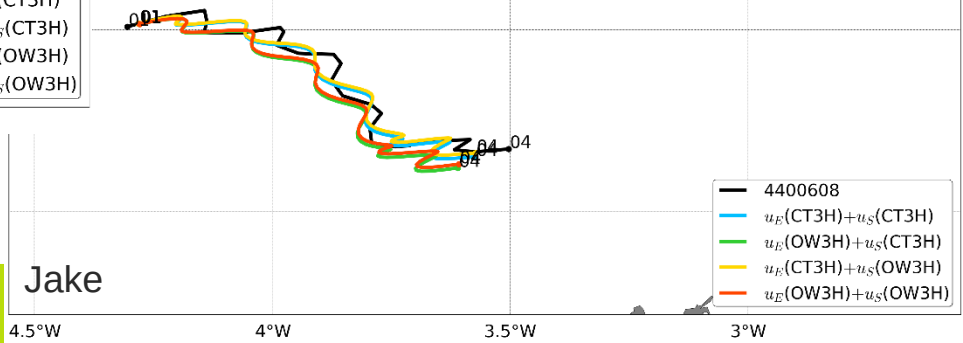


THE EFFECT OF COUPLING ON THE SHELF





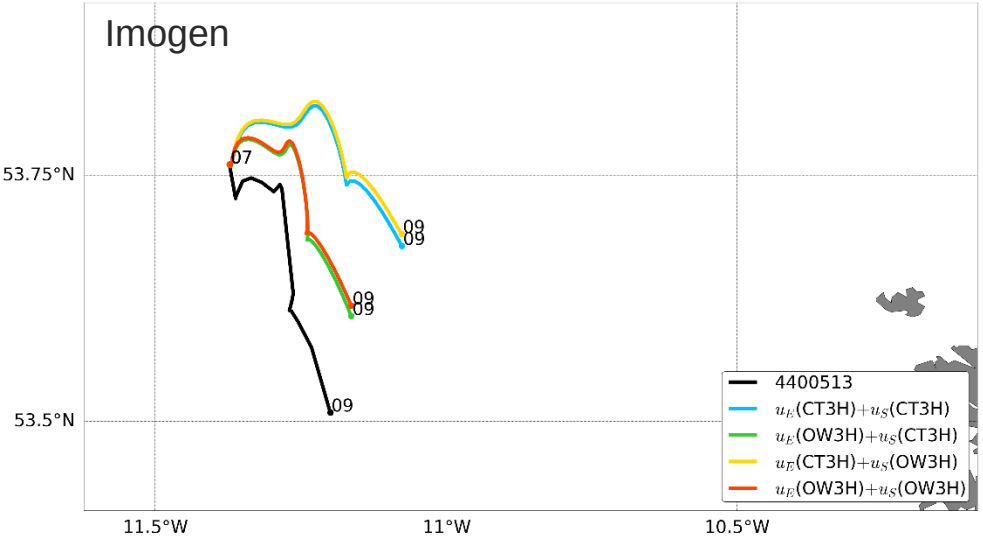


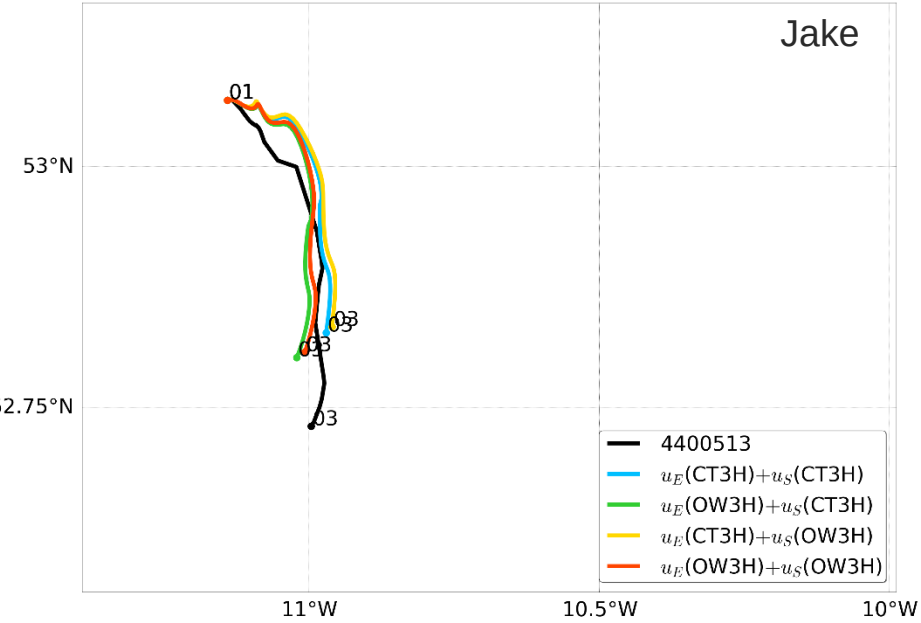


SURFACE DRIFTERS

THE EFFECT OF COUPLING ON THE SHELF

15m DRIFTERS





THE IMPACT OF COUPLING ON OCEAN CURRENTS

1. On average, the effect of ocean-wave coupling on the eulerian currents seems to be the most important:
   - OW3H-CT3H - CT3H-CT3H = +3%
   - OW3H-OW3H - CT3H-OW3H = +4%

2. Dynamically, an ocean current computed using a coupled system seems to deflect the trajectory of the simulated drifter to the right wrt the one using a current from an uncoupled model -> the Stokes'-Coriolis force seems to be a good candidate to explain this

THE IMPACT OF COUPLING ON THE STOKES' DRIFT

1. On average, the effect of ocean-wave coupling on the Stokes' drift seems to be negligible (CT3H-OW3H - CT3H-CT3H = 0%) or to slightly improve the ss (OW3H-OW3H - OW3H-CT3H = 1%).

2. In general, the trajectories of CT3H-OW3H and OW3H-OW3H are deflected with respect to the ones of CT3H-CT3H and OW3H-CT3H.

3. In order to elucidate better this mechanism, we simulate the trajectories of the drifters using only uS(CT3H) or uS(OW3H) or uW(3H).

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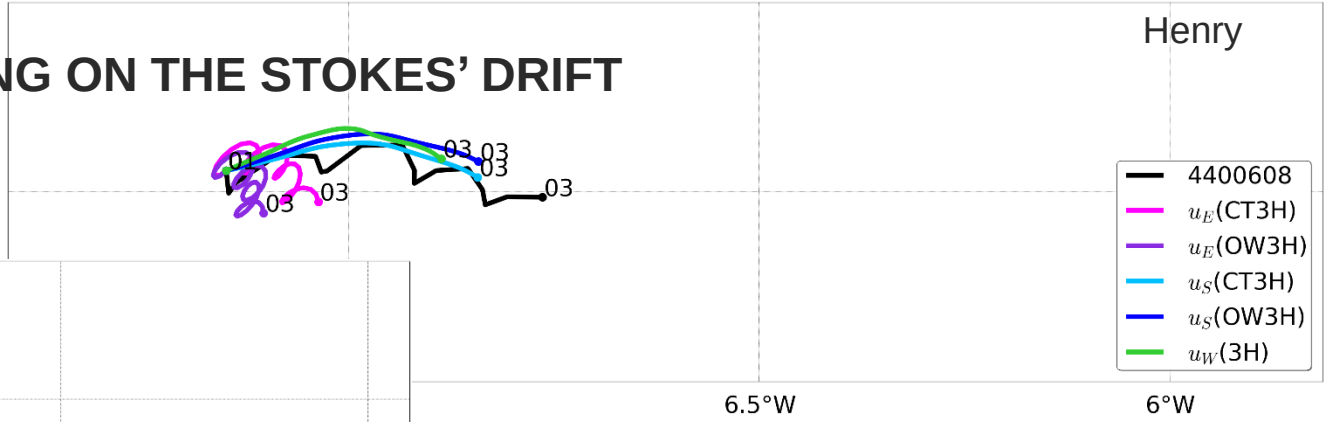
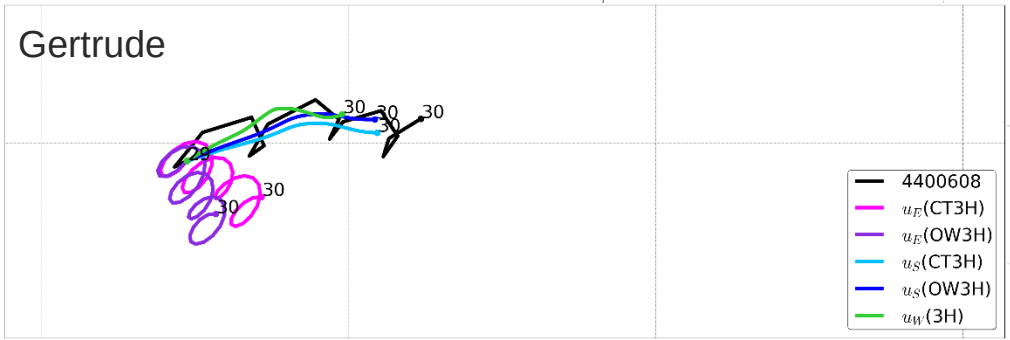
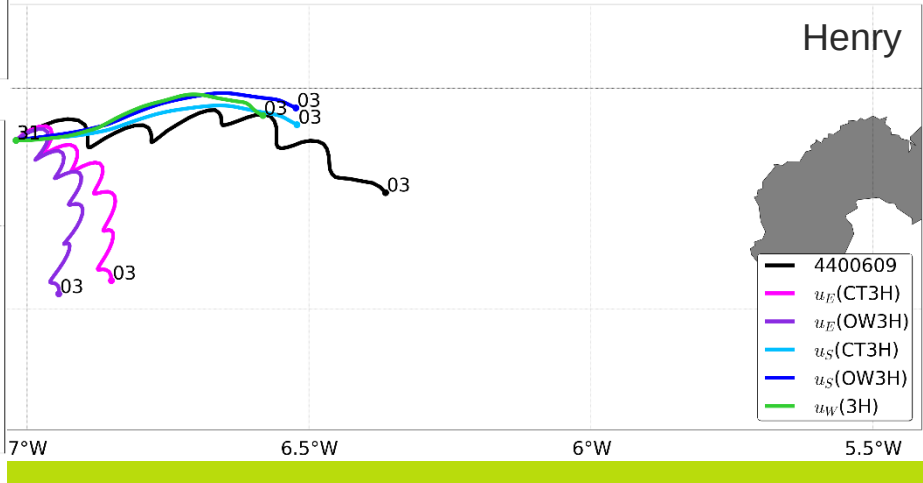
THE IMPACT OF COUPLING ON THE STOKES' DRIFT

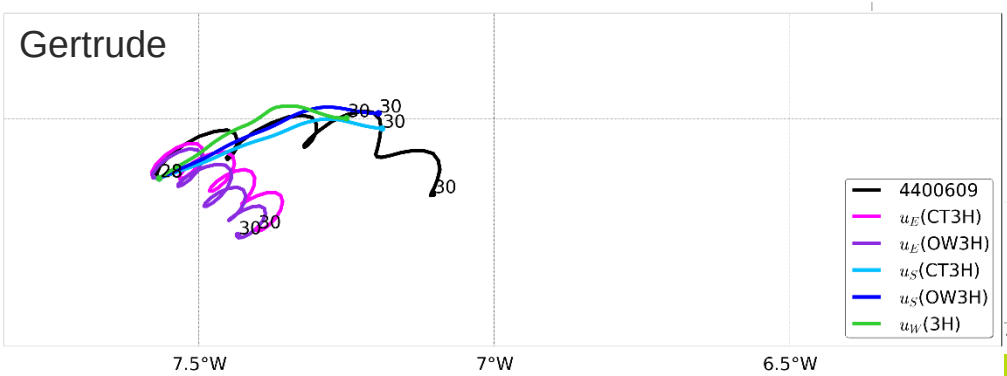
THE EFFECT OF COUPLING ON THE SHELF





SURFACE DRIFTERS





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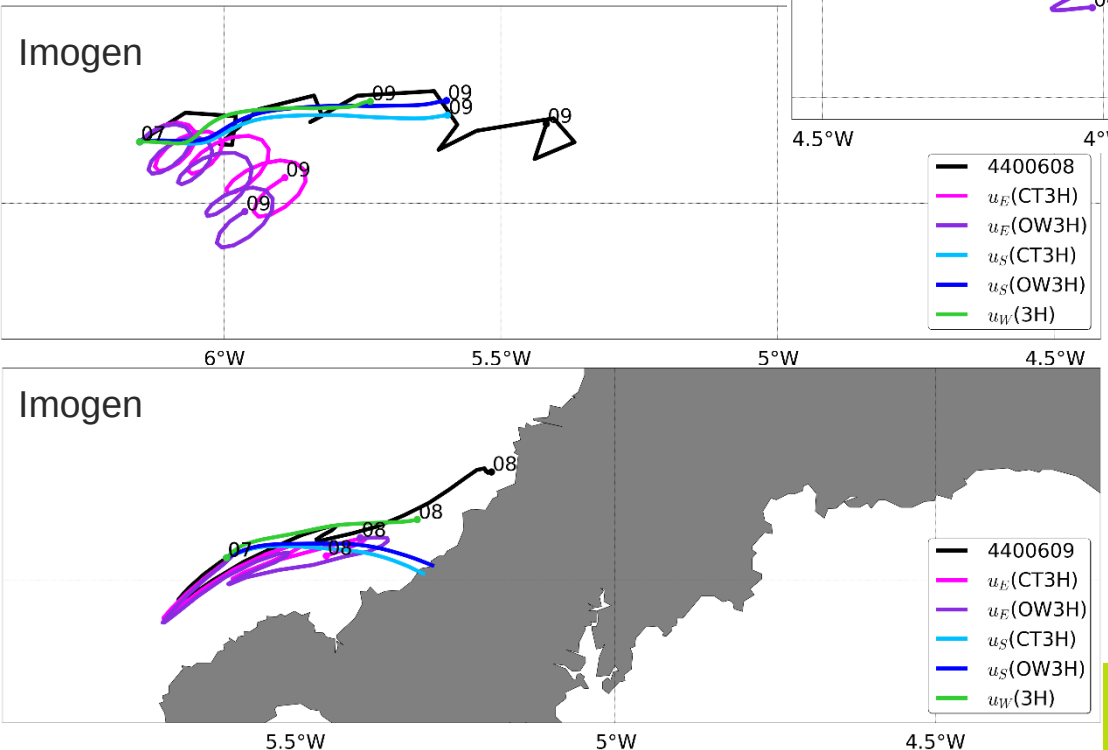
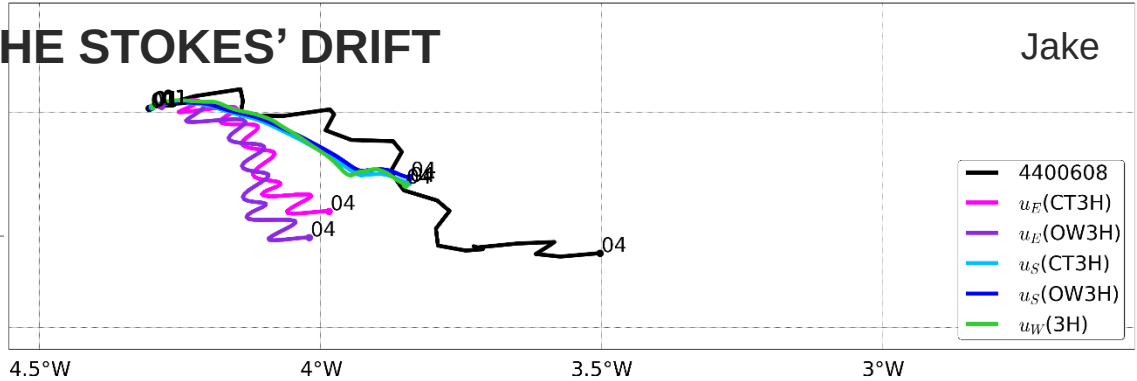
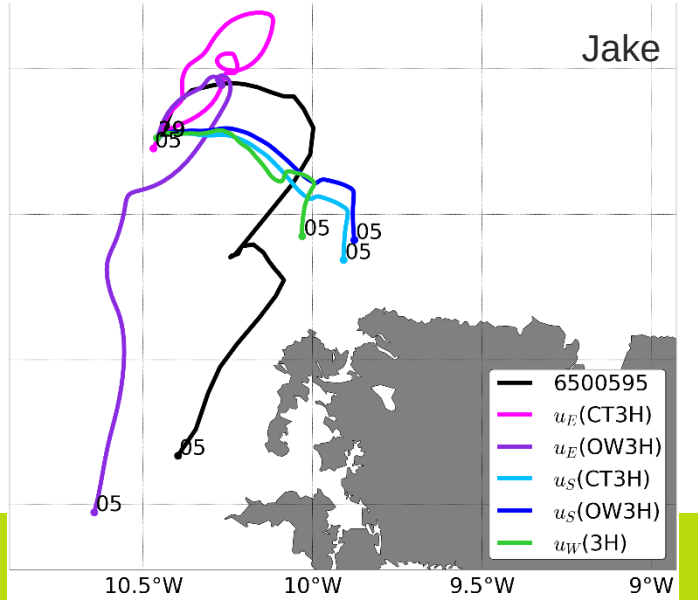
THE EFFECT OF COUPLING ON THE SHELF

THE IMPACT OF COUPLING ON THE STOKES' DRIFT

SURFACE DRIFTERS

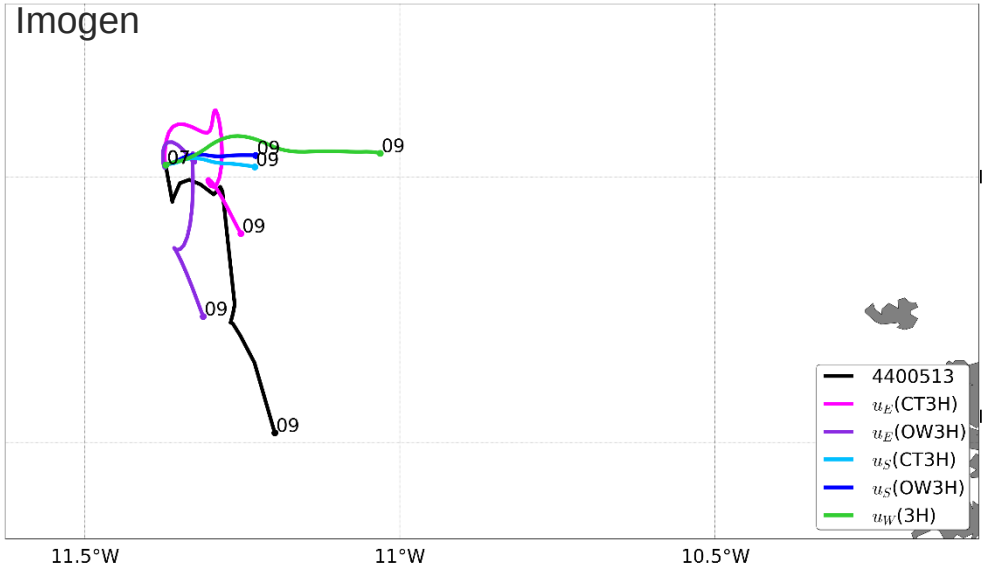


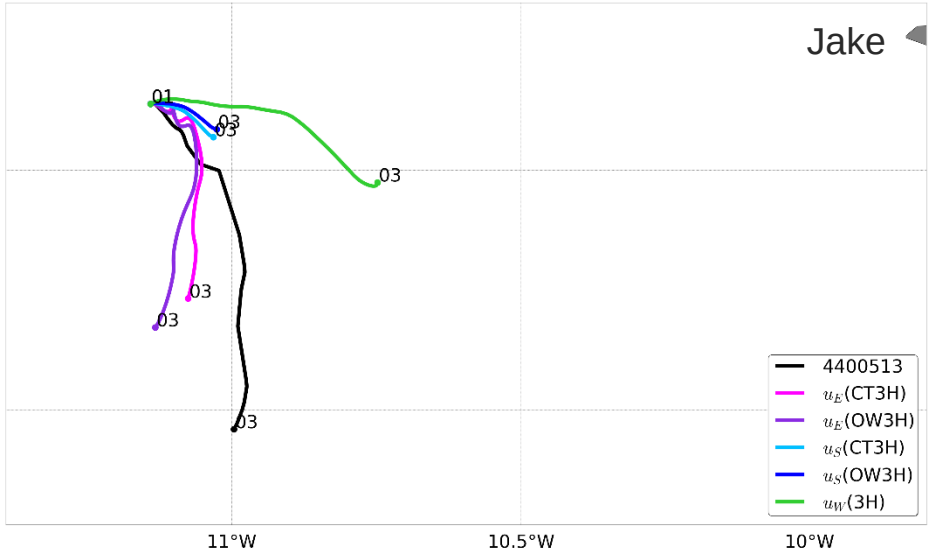




THE IMPACT OF COUPLING ON THE STOKES' DRIFT

15m DRIFTERS





THE IMPACT OF COUPLING ON THE STOKES' DRIFT

STORM	DRIFTER	ss uS(CT3H)	ss uS(OW3H)
GERTRUDE	4400608	0.76	0.82
GERTRUDE	4400609	0.78	0.85
HENRY	4400608	0.8	0.85
HENRY	4400609	0.9	0.9
IMOGEN	4400608	0.78	0.78
IMOGEN	4400609	0.66	0.72
IMOGEN	4400513	0.35	0.36
JAKE	4400608	0.86	0.86
JAKE	6500595	0.87	0.86
JAKE	4400513	0.21	0.21
TOT		0.70	0.72

1. We compute the ss of uS(CT3H) and uS(OW3H) simulations wrt to the results obtained moving the drifter only with the wind drag, i.e. uW(3H)

2. ss of uS(OW3H) > ss of uS(CT3H): the Stokes' drift simulated with a coupled system is deflected to be more aligned with the wind direction (in agreement with observations from Clarke et al. 2018).

SENSITIVITY OF THE COUPLING TO THE ATMOSPHERIC FORCING

What is the sensitivity of ocean-wave coupling to the temporal resolution of the atmospheric forcing?

SENSITIVITY OF THE COUPLING TO THE ATMOSPHERIC FORCING

STORM	DRIFTER	TYPE	SS OW3H-OW3H	SS OW1H-OW1H	SS OW3H-OW1H	SS OW1H-OW3H
GERTRUDE	4400608	surf	0.82	0.83	0.83	0.83
GERTRUDE	4400609	surf	0.92	0.9	0.92	0.9
HENRY	4400608	surf	0.79	0.78	0.79	0.78
HENRY	4400609	surf	0.84	0.83	0.84	0.83
IMOGEN	4400608	surf	0.83	0.85	0.82	0.85
IMOGEN	4400609	surf	0.66	0.73	0.68	0.72
IMOGEN	4400513	15m	0.4	0.65	0.39	0.65
JAKE	4400608	surf	0.85	0.81	0.85	0.82
JAKE	6500595	surf	0.89	0.8	0.89	0.79
JAKE	4400513	15m	0.62	0.48	0.62	0.48
TOT			0.76	0.77	0.76	0.77

SENSITIVITY OF THE COUPLING TO THE ATMOSPHERIC FORCING

1. No effect on the Stokes' drift:
   - OW3H-OW3H - OW3H-OW1H = 0%
   - OW1H-OW3H - OW1H-OW1H = 0%

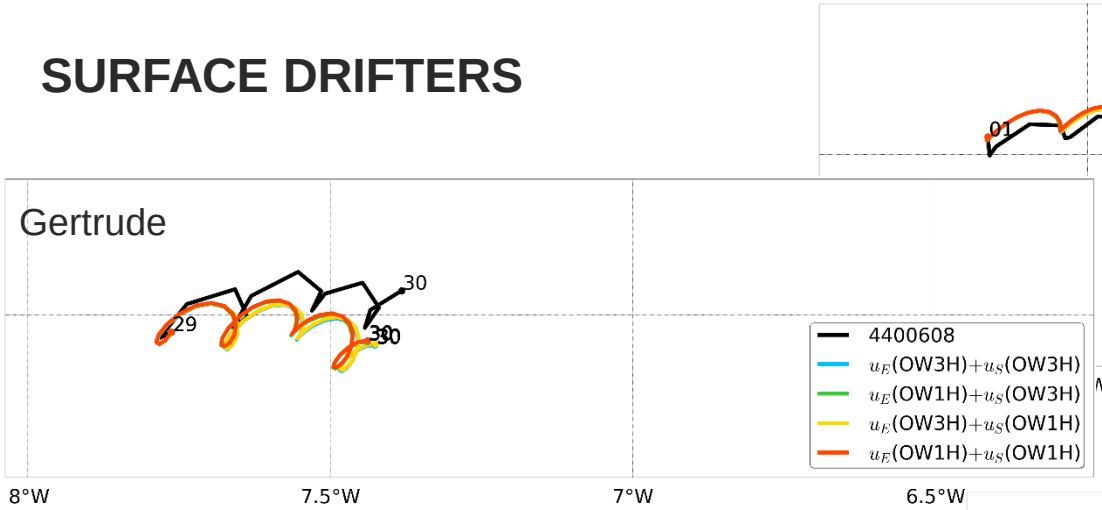
   This is confirmed from wave verification

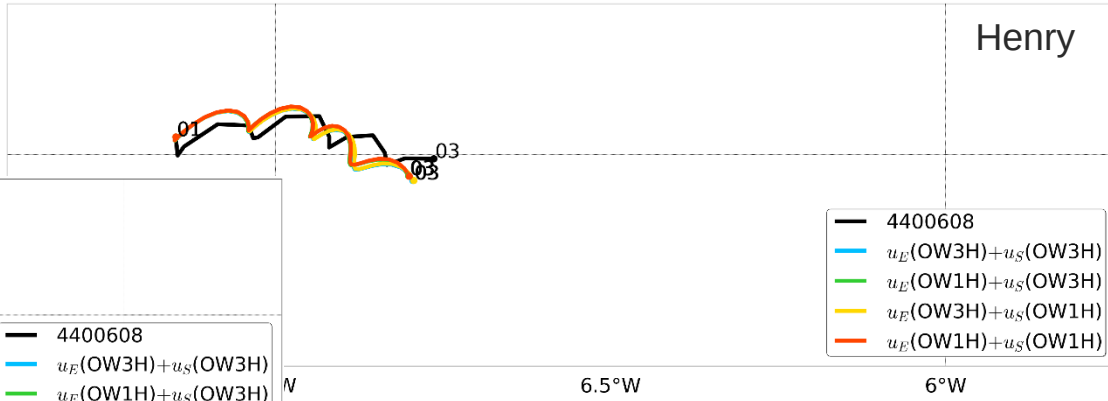
2. On average, using the atmospheric forcing with higher temporal resolution seems to have a slightly positive effect on Eulerian currents:
   - OW1H-OW3H - OW3H-OW3H = +1%
   - OW1H-OW1H - OW3H-OW1H = +1%

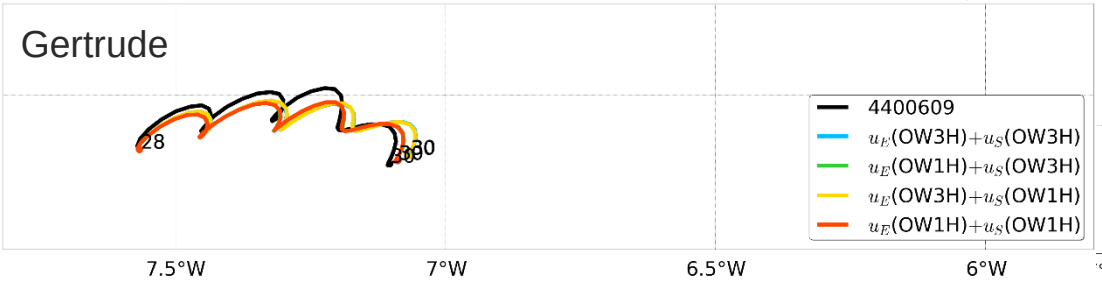
3. However, there is not a clear tendency. It seems that if the 3h-wind has large errors, then the 1h-wind make things worst (see drifter J_6500595_s and buoy 62093) and viceversa (see drifter I_4400513_d).

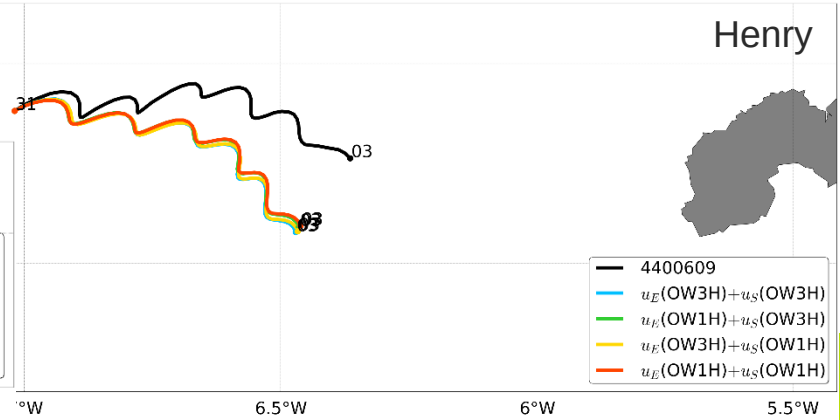
SENSITIVITY OF THE COUPLING TO THE ATMOSPHERIC FORCING

SURFACE DRIFTERS



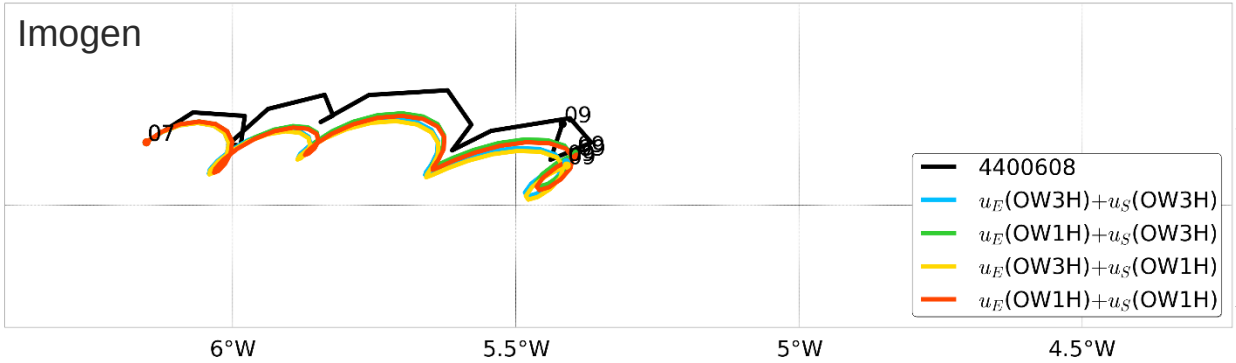


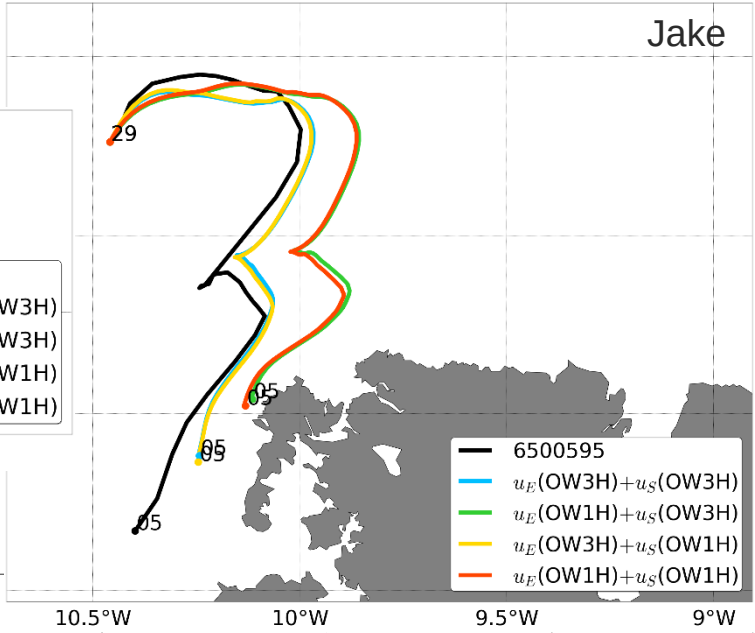


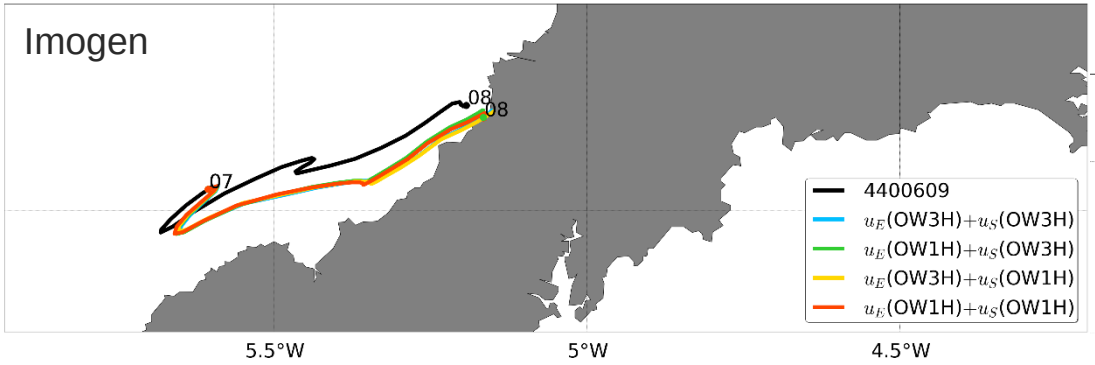


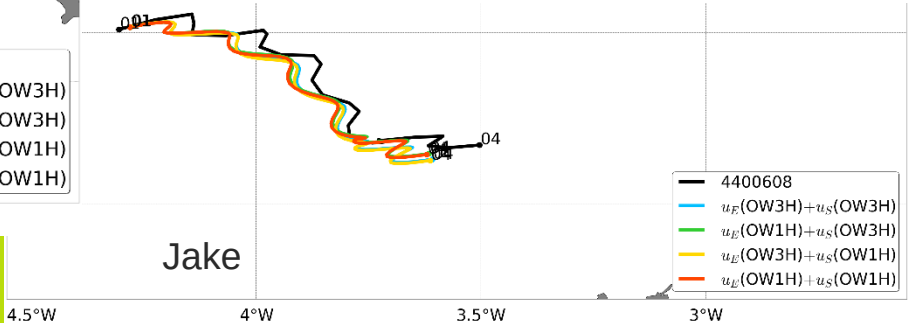
SENSITIVITY OF THE COUPLING TO THE ATMOSPHERIC FORCING

SURFACE DRIFTERS



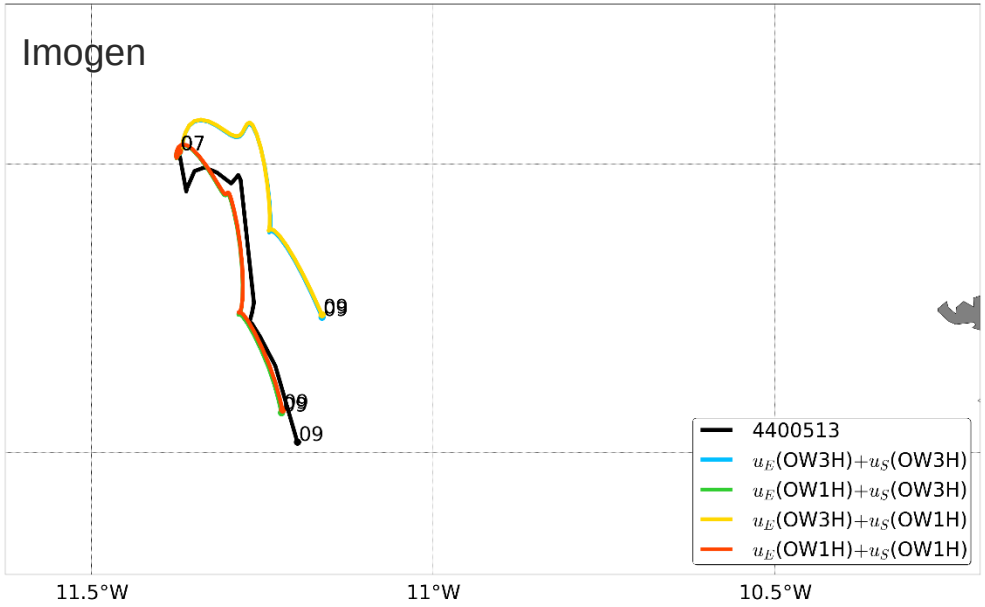


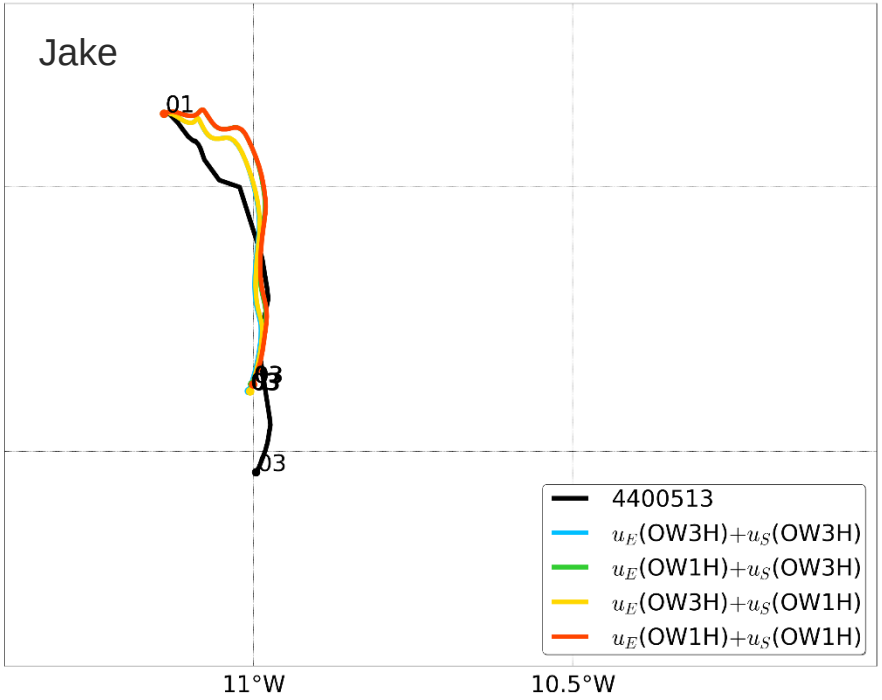




SENSITIVITY OF THE COUPLING TO THE ATMOSPHERIC FORCING

15m DRIFTERS



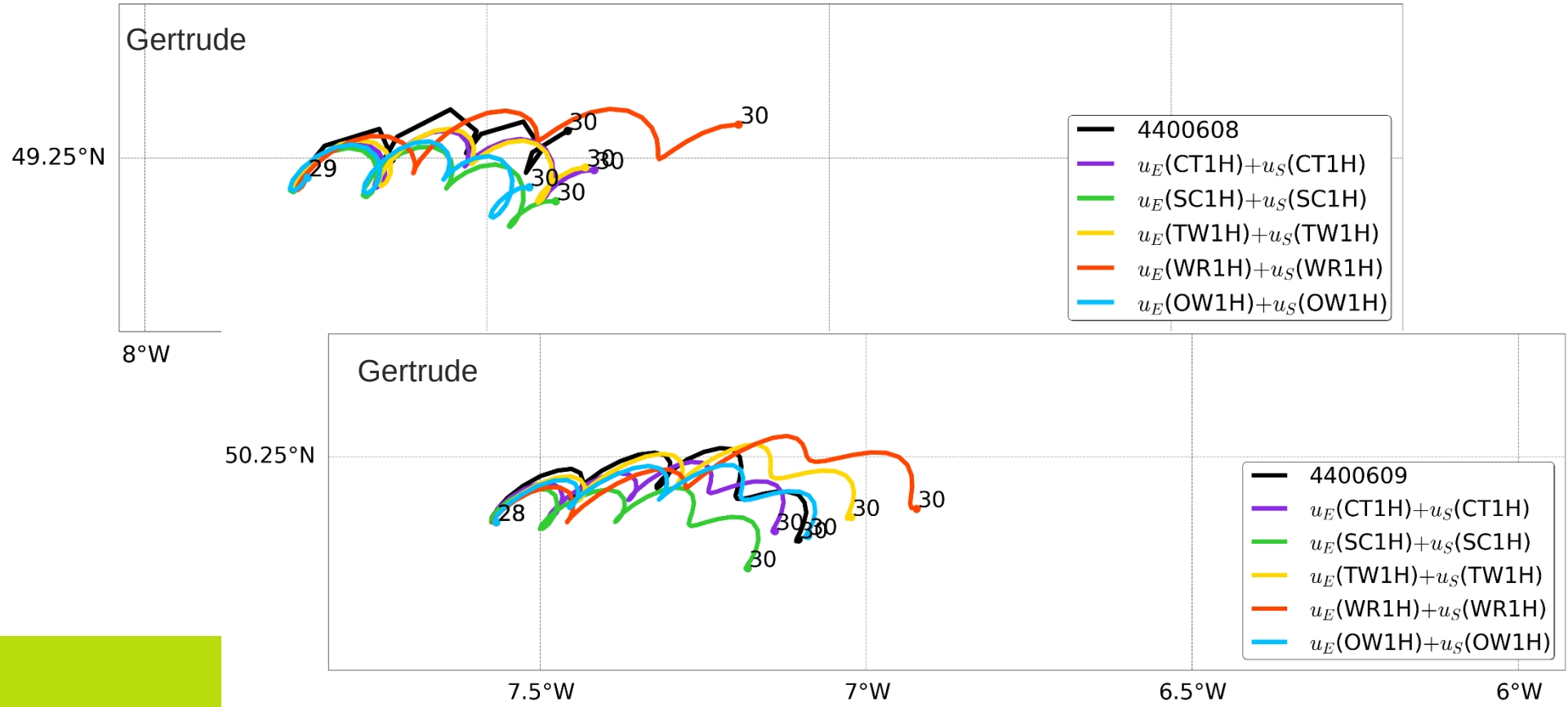


What is the relative impact of each single wave-current interaction ?

THE IMPACT OF EACH WAVE-CURRENT INTERACTION

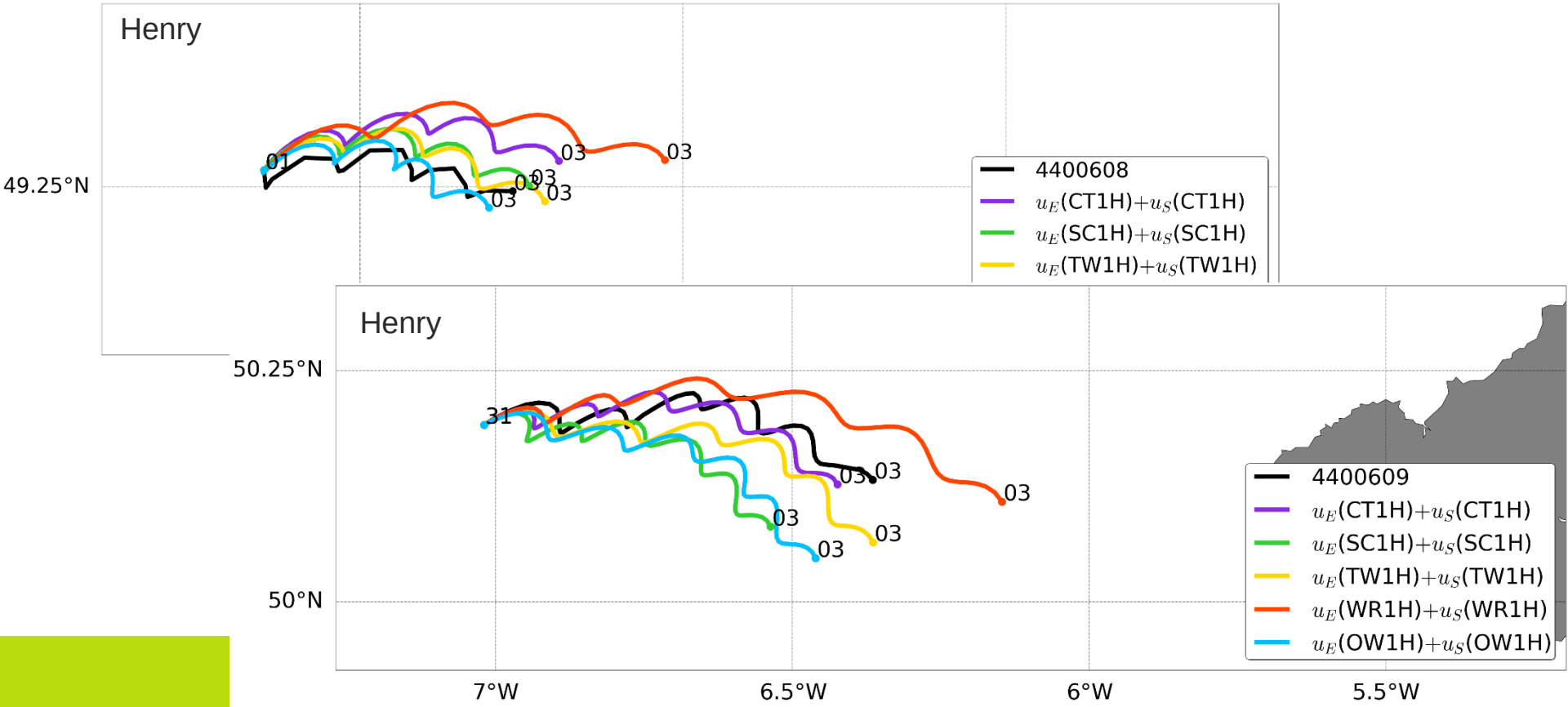
STORM	DRIFTER	TYPE	SS CT1H-CT1H	SS SC1H-SC1H	SS TW1H-TW1H	SS WR1H-WR1H	SS OW1H-OW1H
GERTRUDE	4400608	surf	0.88	0.8	0.91	0.8	0.83
GERTRUDE	4400609	surf	0.78	0.71	0.91	0.79	0.9
HENRY	4400608	surf	0.64	0.73	0.74	0.45	0.78
HENRY	4400609	surf	0.82	0.72	0.87	0.83	0.83
IMOGEN	4400608	surf	0.85	0.79	0.89	0.81	0.85
IMOGEN	4400609	surf	0.69	0.75	0.65	0.56	0.73
IMOGEN	4400513	15m	0.46	0.47	0.39	0.42	0.65
TOT			0.73	0.71	0.77	0.67	0.80

THE IMPACT OF EACH WAVE-CURRENT INTERACTION

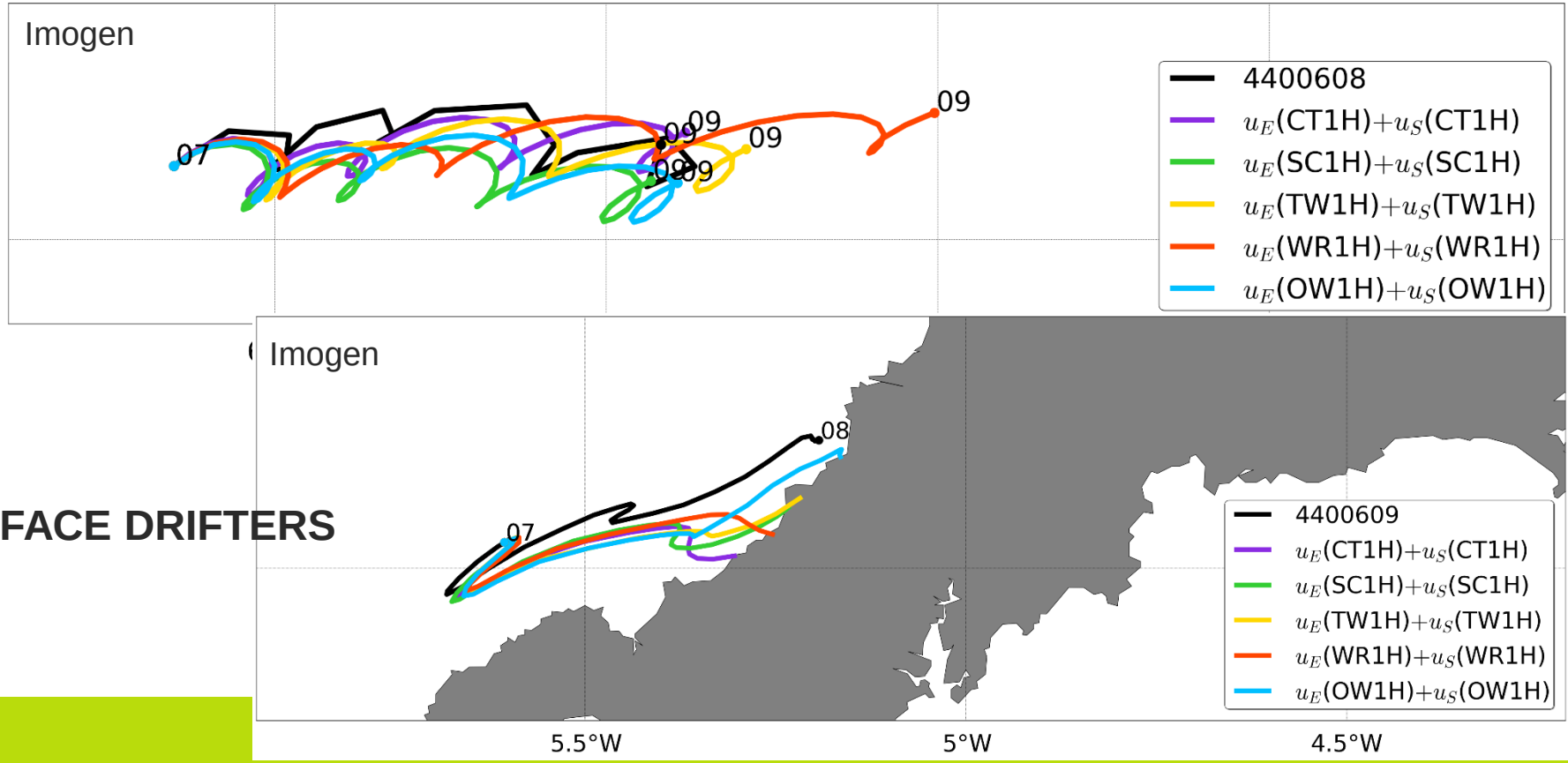


THE IMPACT OF EACH WAVE-CURRENT INTERACTION

SURFACE DRIFTERS



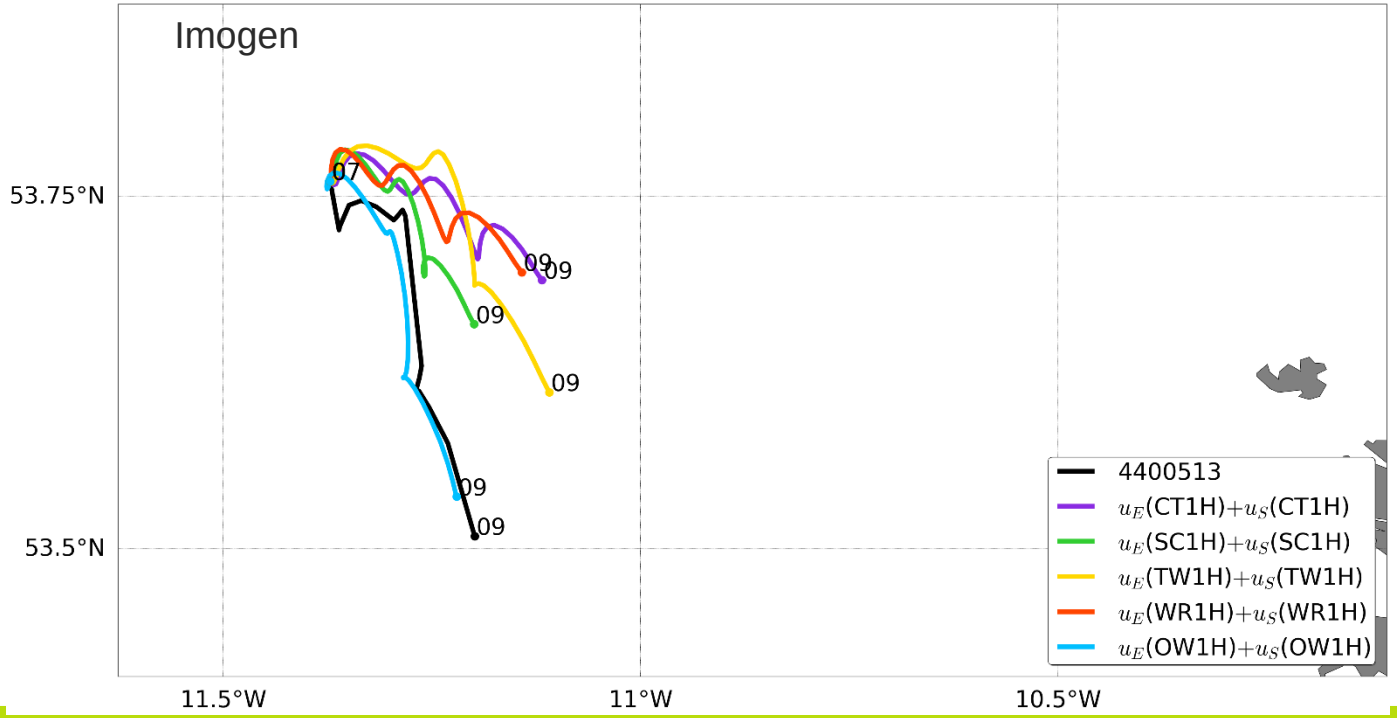
THE IMPACT OF EACH WAVE-CURRENT INTERACTION



SURFACE DRIFTERS

THE IMPACT OF EACH WAVE-CURRENT INTERACTION

15m DRIFTER



THE IMPACT OF EACH WAVE-CURRENT INTERACTION

1. The highest ss is obtained with currents and Stokes' drift from the fully coupled system (OW1H-OW1H)

2. The wind stress felt by the ocean modified for wave growth (TW1H-TW1H) seems to be the most important wave effect

CONCLUSION

We have found that when simulating drifter trajectories on shelf areas during storm events:

1. Due to inaccuracies of the forcings (mainly wind and wave), the trajectories of surface drifters are better simulated without taking into account the wind leeway.

2. In general, ocean-wave coupling improves ss (+4%):
   - Coupling improves mainly ocean currents (~+3%)
   - Coupling slightly improves Stokes' drift (~+1%), generally deflecting the wave-induced current to be more aligned with the wind direction

3. Increasing the temporal resolution of the atmospheric forcing has very low impact on the coupling:
   - No effects on Stokes' drift
   - Some improvements on currents: are coupling-related or only ocean-related?

4. Modifying the wind stress for wave growing seems to be the most important wave-current interactions