

The interaction of surface heterogeneity and mesoscale circulations with the Boundary Layer structures (UMBRELLA Project)

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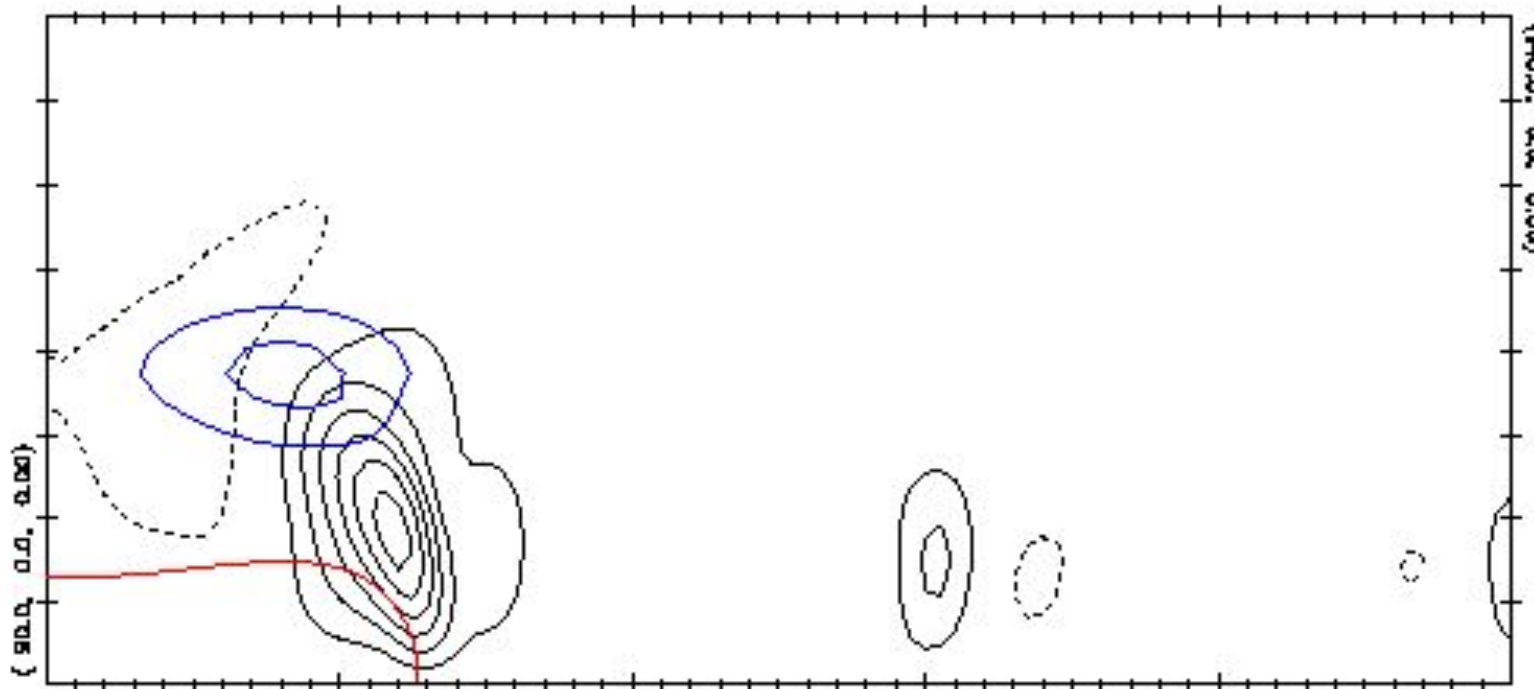
- Investigate the model (high res MetUM)'s ability to simulate the interaction between the sea breeze front and boundary layer rolls in the presence of orography.
- Compare results at different resolutions: 100m, 200m, 300m and 2.2km. – Compare coherent features identified in the selected case with those at coarser resolutions.
- Compare the representation of the BL rolls identified in the models with the WesCON observations (DIMONA aircraft data).

Investigate the model's ability to simulate the interaction between the sea breeze front and boundary layer rolls in the presence of orography



Boundary layer rolls play a key role in the initiation and modulation of convection along a sea breeze

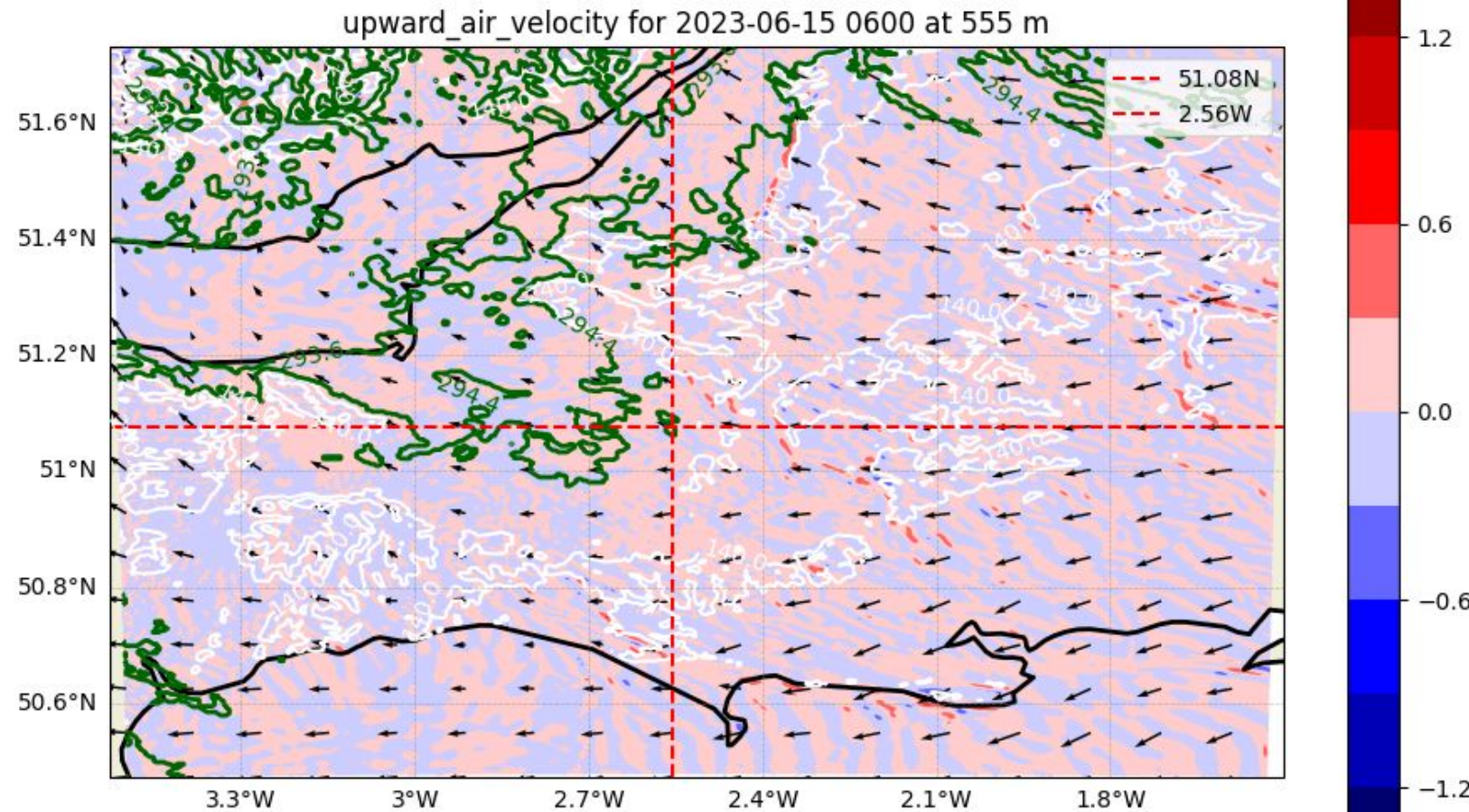
Convection is enhanced (suppressed) at frontal locations where BL roll updrafts (downdrafts) intersect. (Dailey and Fovell, 2001; Fovell, 2004)



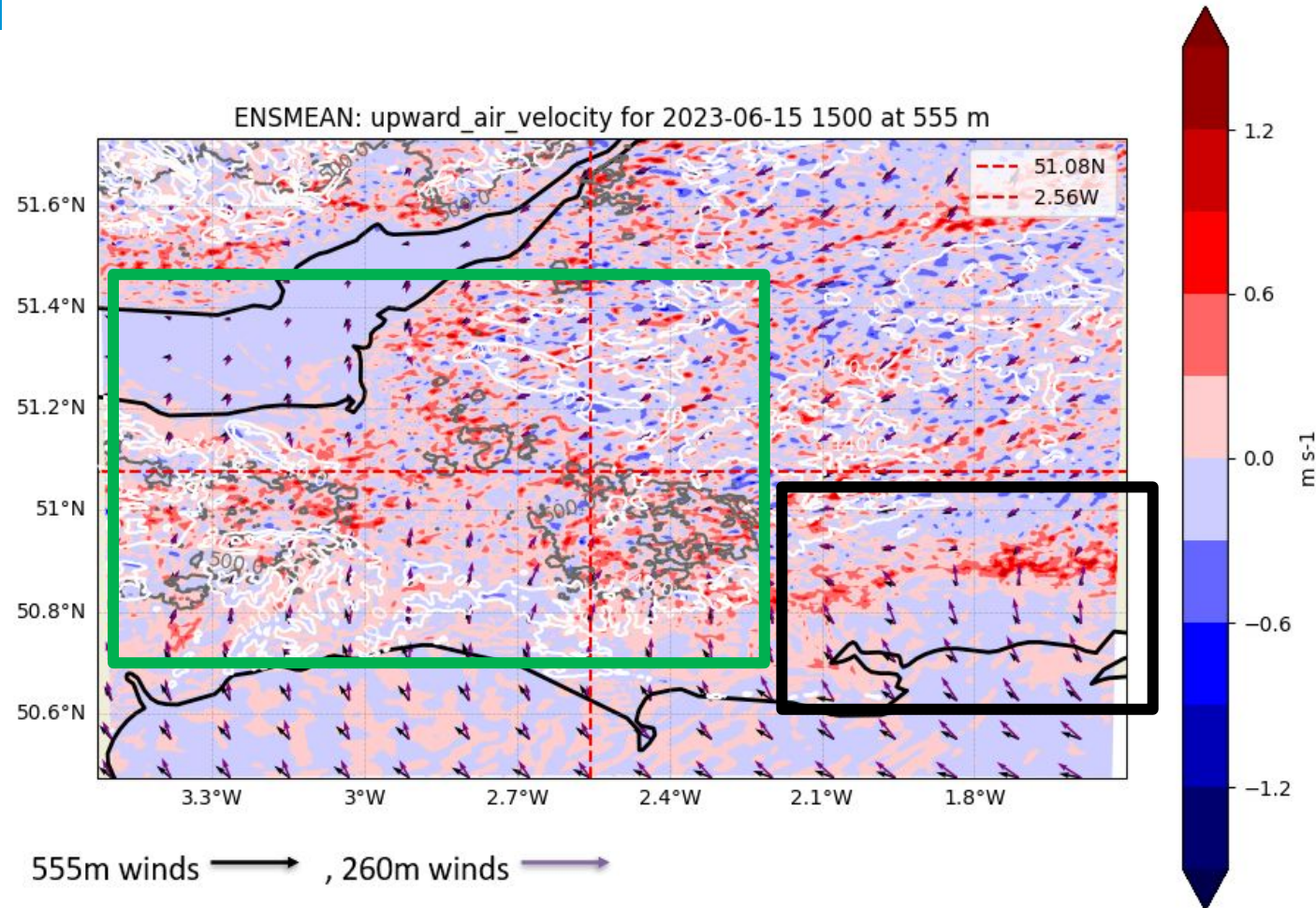
Investigate the model's ability to simulate the interaction between the sea breeze front and boundary layer rolls in the presence of orography



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- Sea breeze is initiated at 10am due to surface heating
- The surface heating leads to the formation of BL rolls.
- Clouds begin to form later in the day (grey contours)
- Low potential temperatures (dark green contours)
- Rolls form in morning. Transition to more cellular BL structure later in the day. Passage of sea breeze suppresses rolls.



- Investigate the role of small scale topography and surface heterogeneity in the initiation of convection. – Does this impact the timing and location of convection? (15 June 2023)

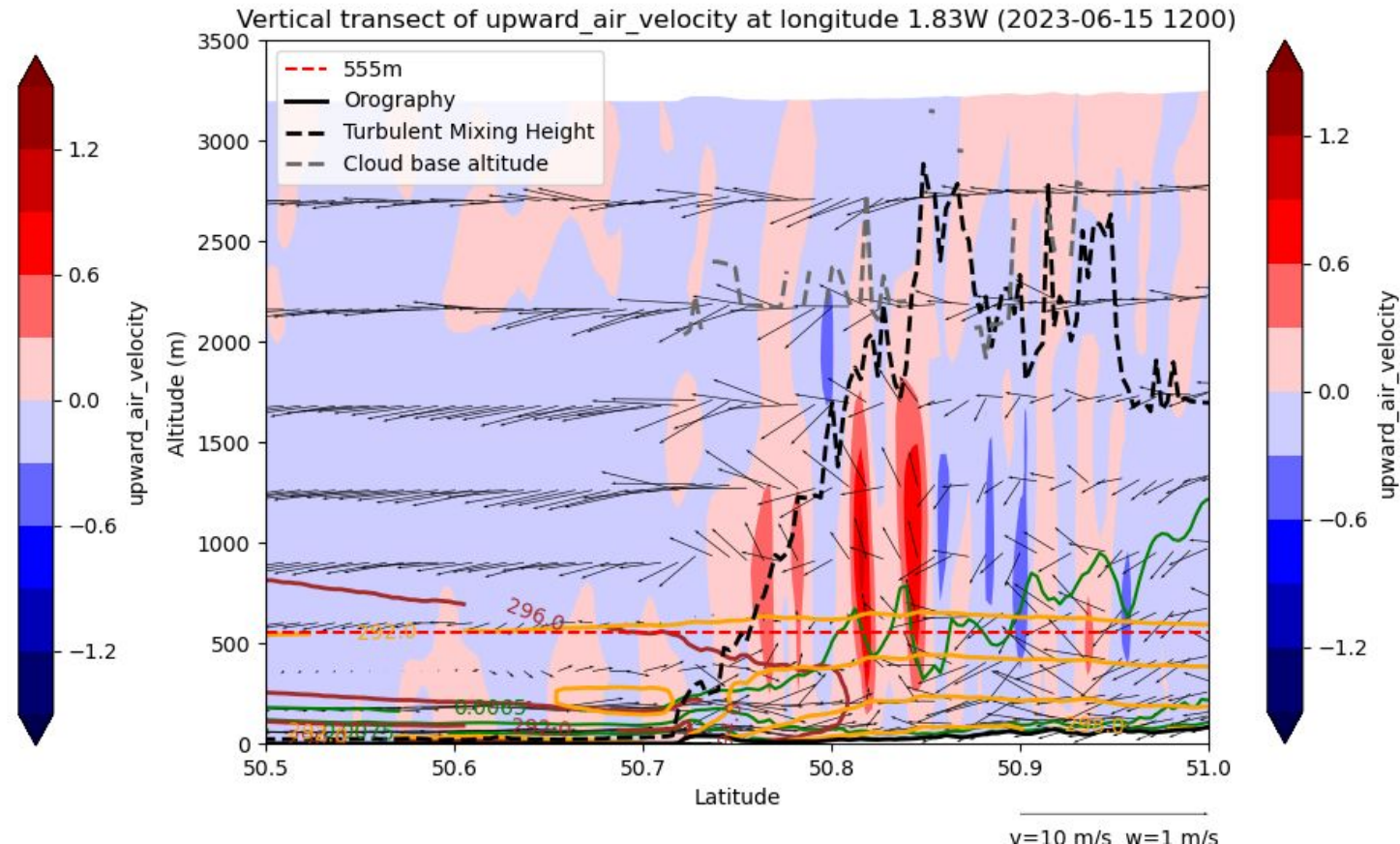
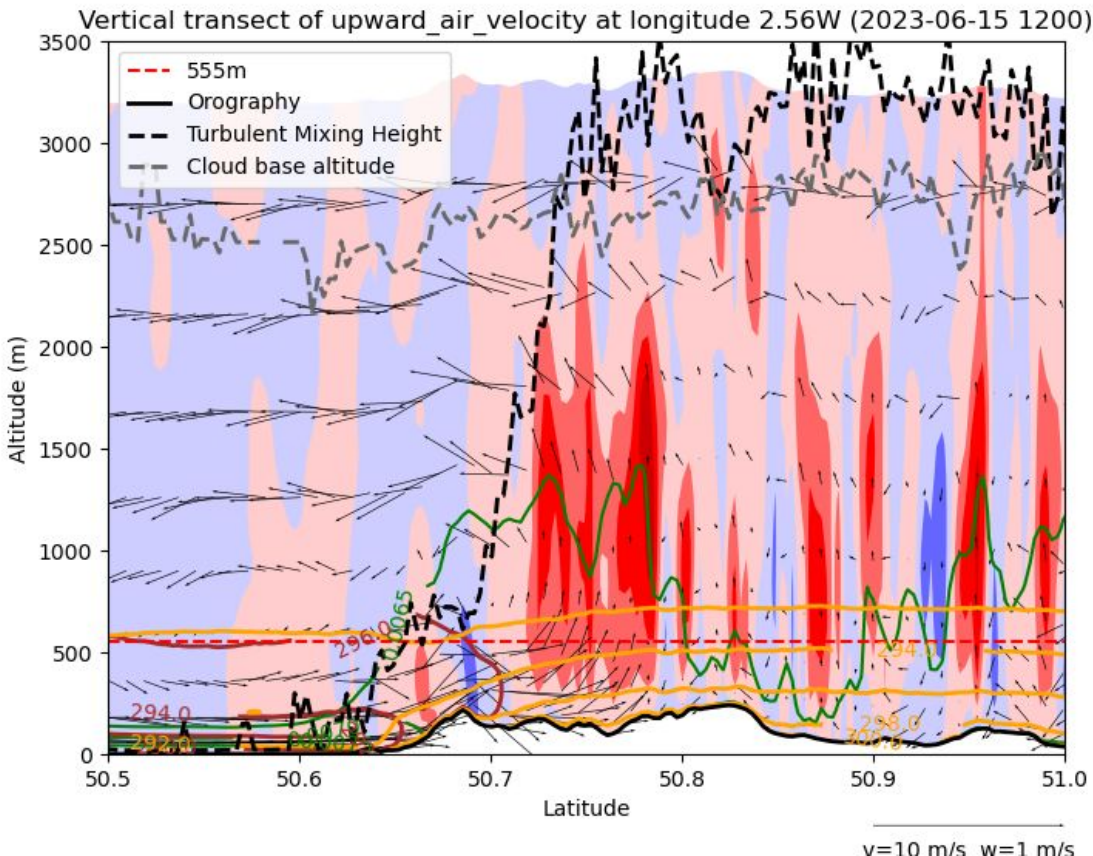
The role of small scale orography and surface heterogeneity in the initiation of convection (15 June, Fovell and Dailey, 2001) UNIVERSITY OF LEEDS



Although the sea breeze front propagates faster in the weak convection region, it doesn't result in a deep vertical mixing

Strong convection region

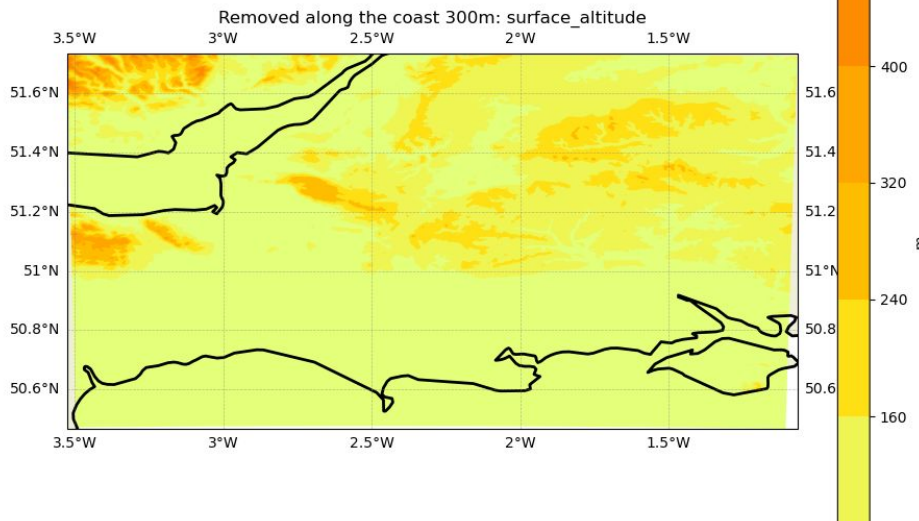
- **Weak convection region**



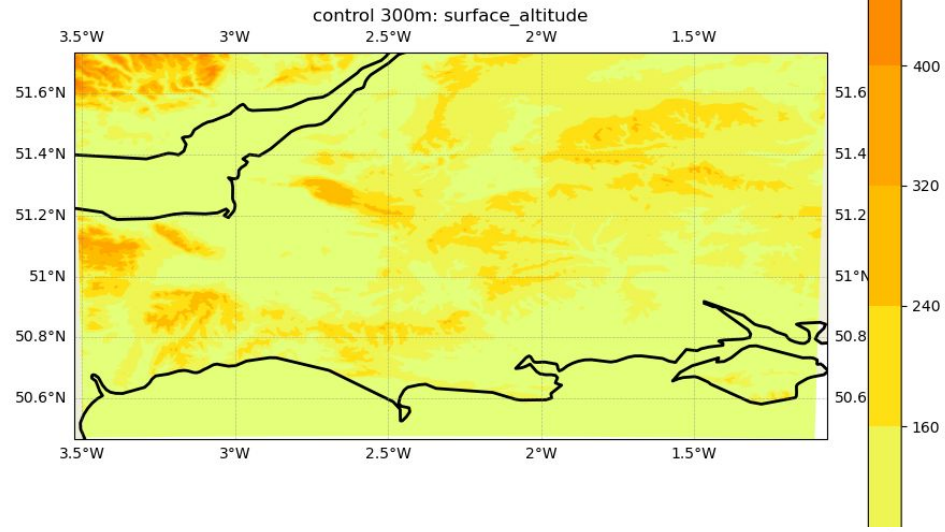
Orography Experiments (15 June)



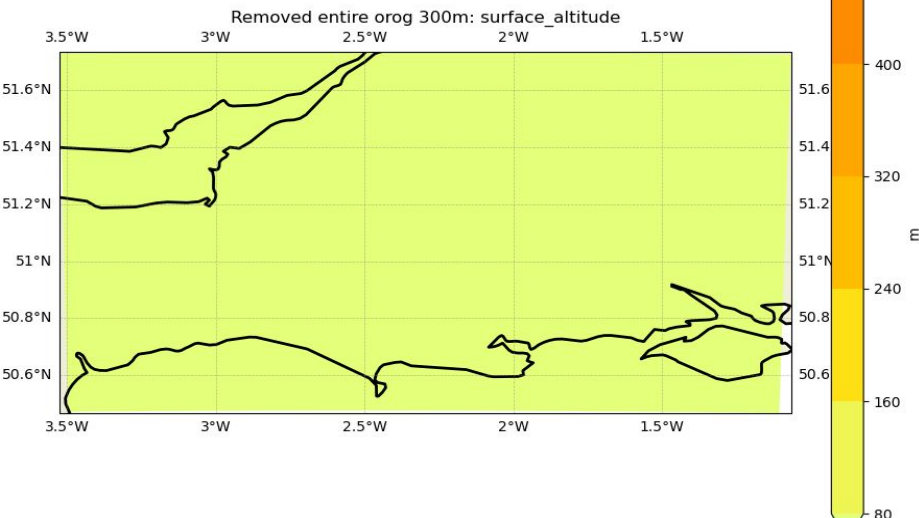
Removed orography along the coast



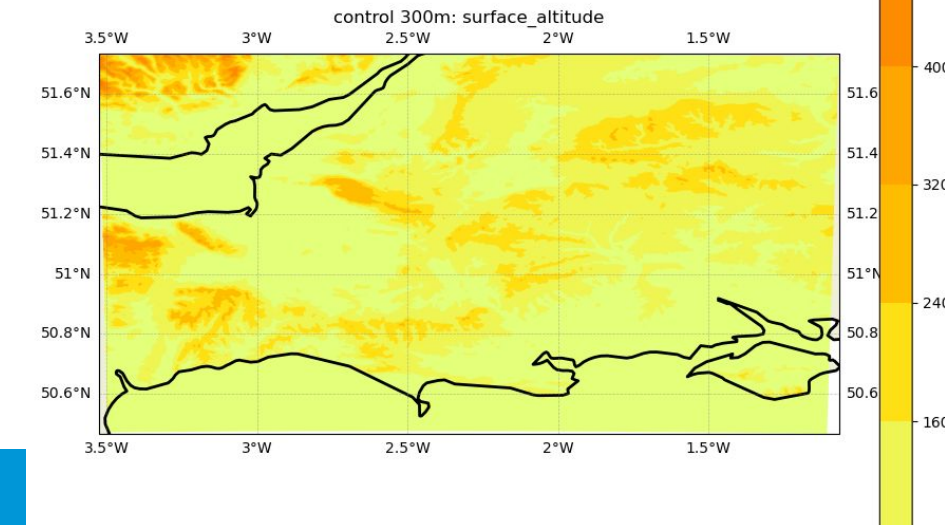
Control



Removed entire orography



Control



- Two Experiments:
- Orography removed along the coast
- Entire orography removed

Orography experiments (15 June)

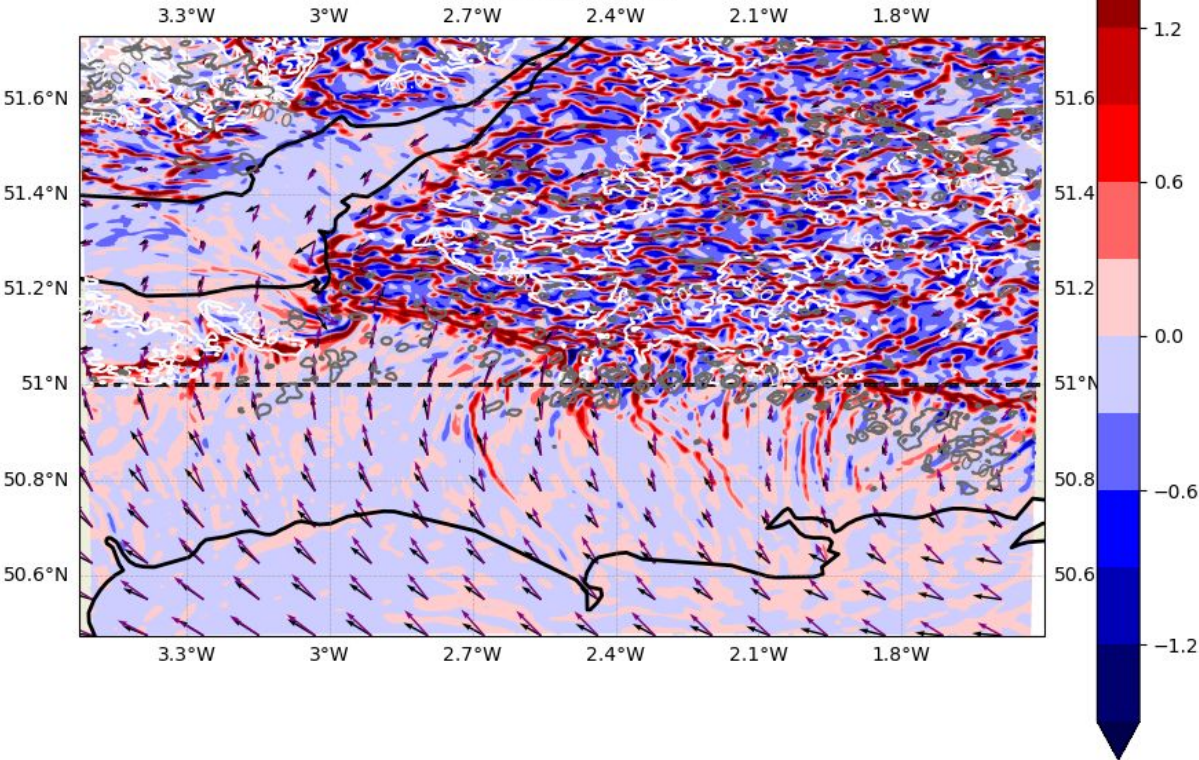


Removed orography along the coast

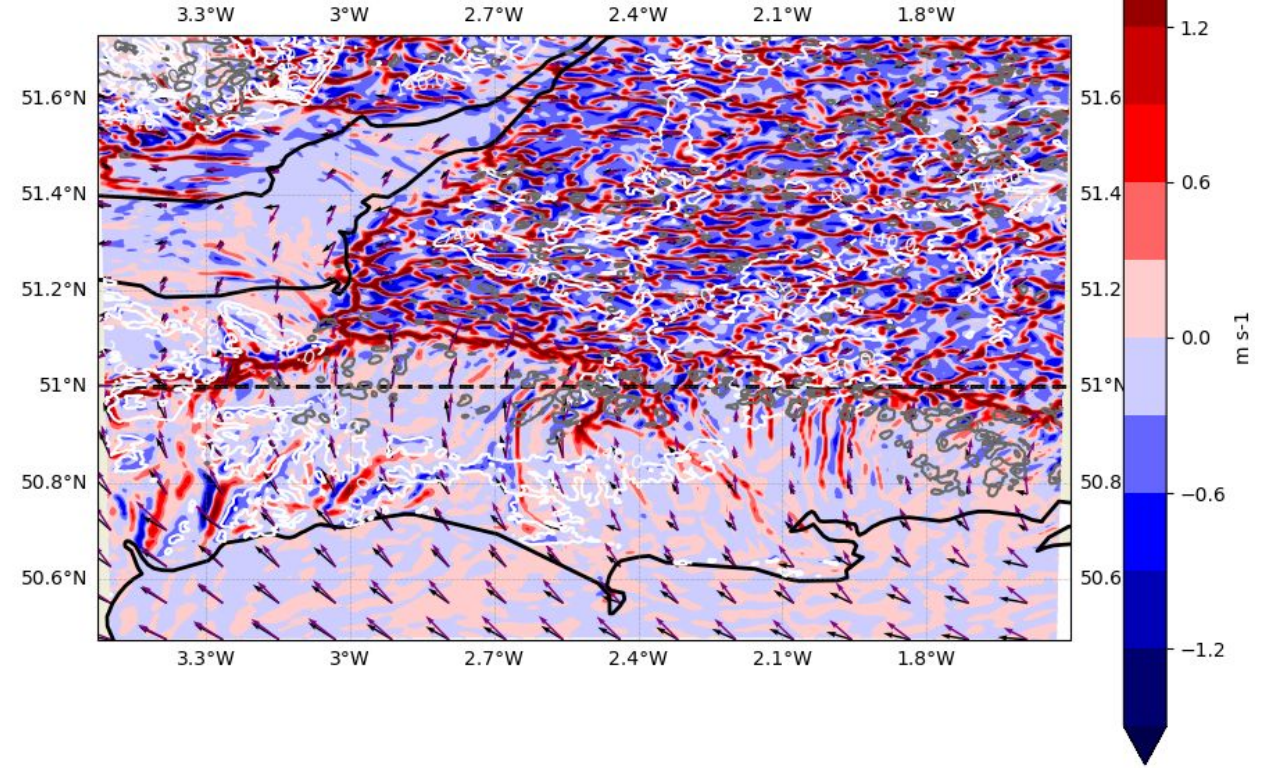
Control


The sea breeze front propagates slightly faster when orography is removed along the coast

Removed along the coast 300m: upward_air_velocity for 2023-06-15 15:05 UTC
Wind at level 555m



control 300m: upward_air_velocity for 2023-06-15 15:05 UTC
Wind at level 555m



555m winds  , 260m winds 

Orography experiments (15 June)



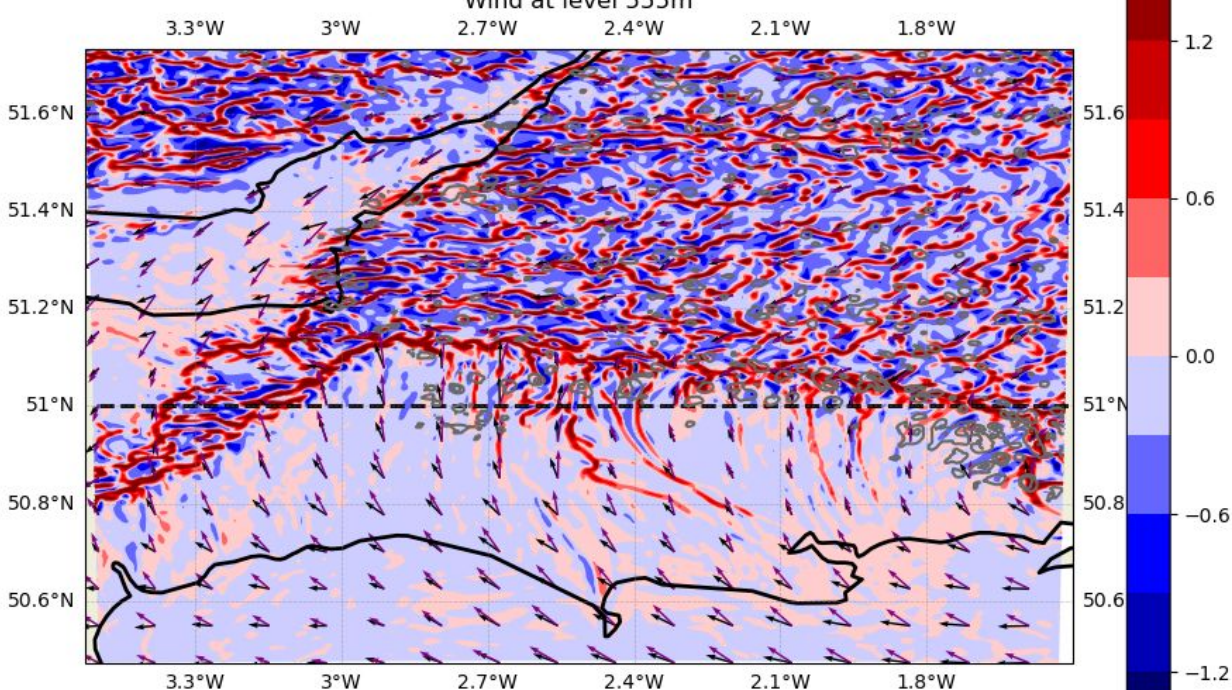
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Removed entire orography

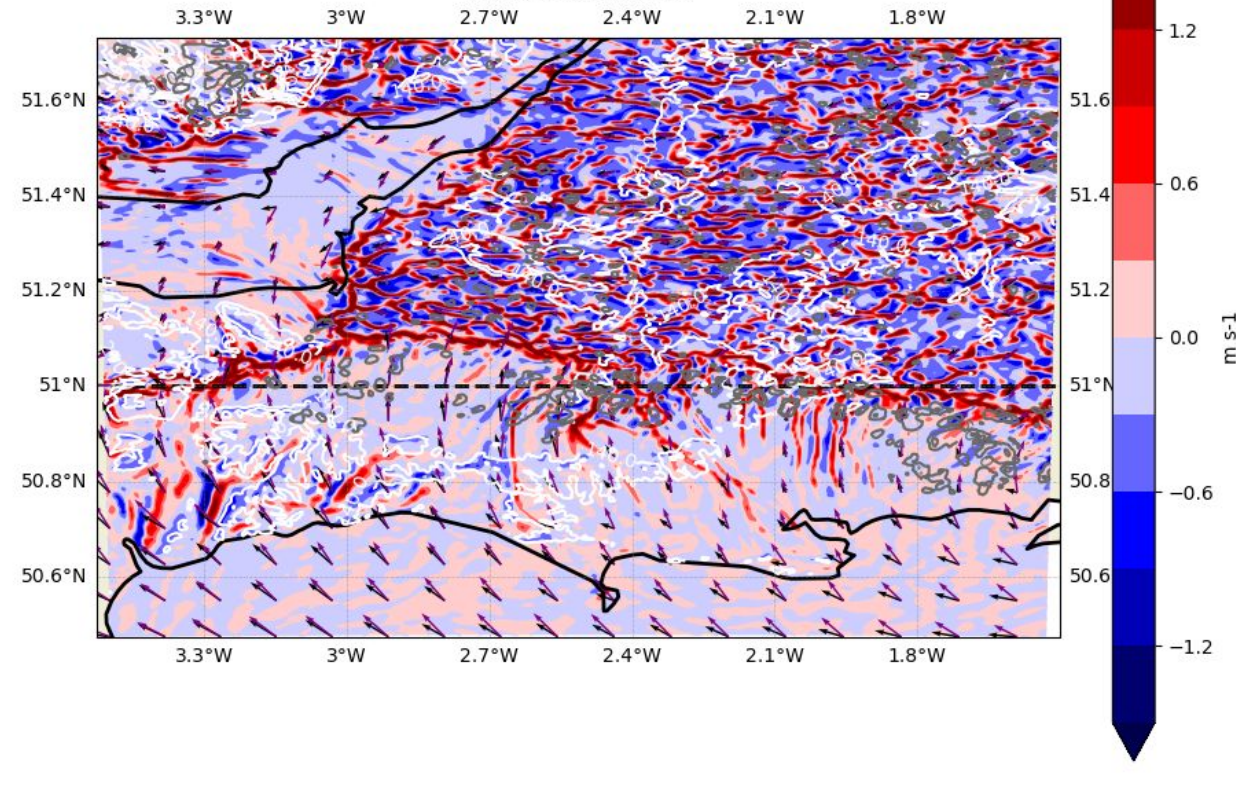
Control

The sea breeze front propagates slightly faster in regions without orography. The presence of orography slows down the propagation. The orientation of the upper-level (555m) winds (black arrows) changes slightly and slows down the propagation speed

Removed entire orog 300m: upward air velocity for 2023-06-15 15:05 UTC
Wind at level 555m



control 300m: upward air velocity for 2023-06-15 15:05 UTC
Wind at level 555m



555m winds \longrightarrow , 260m winds \longrightarrow

Orography experiments- Vertical transect (15 June)



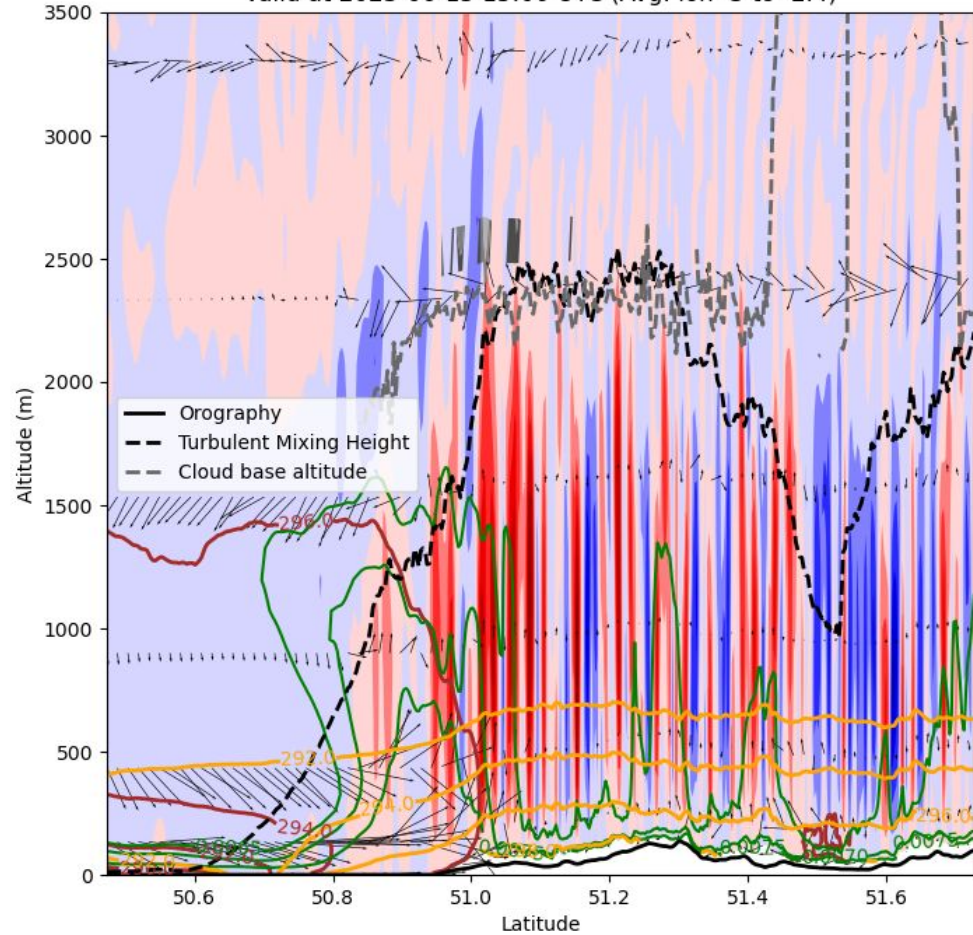
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Removed orography along the coast

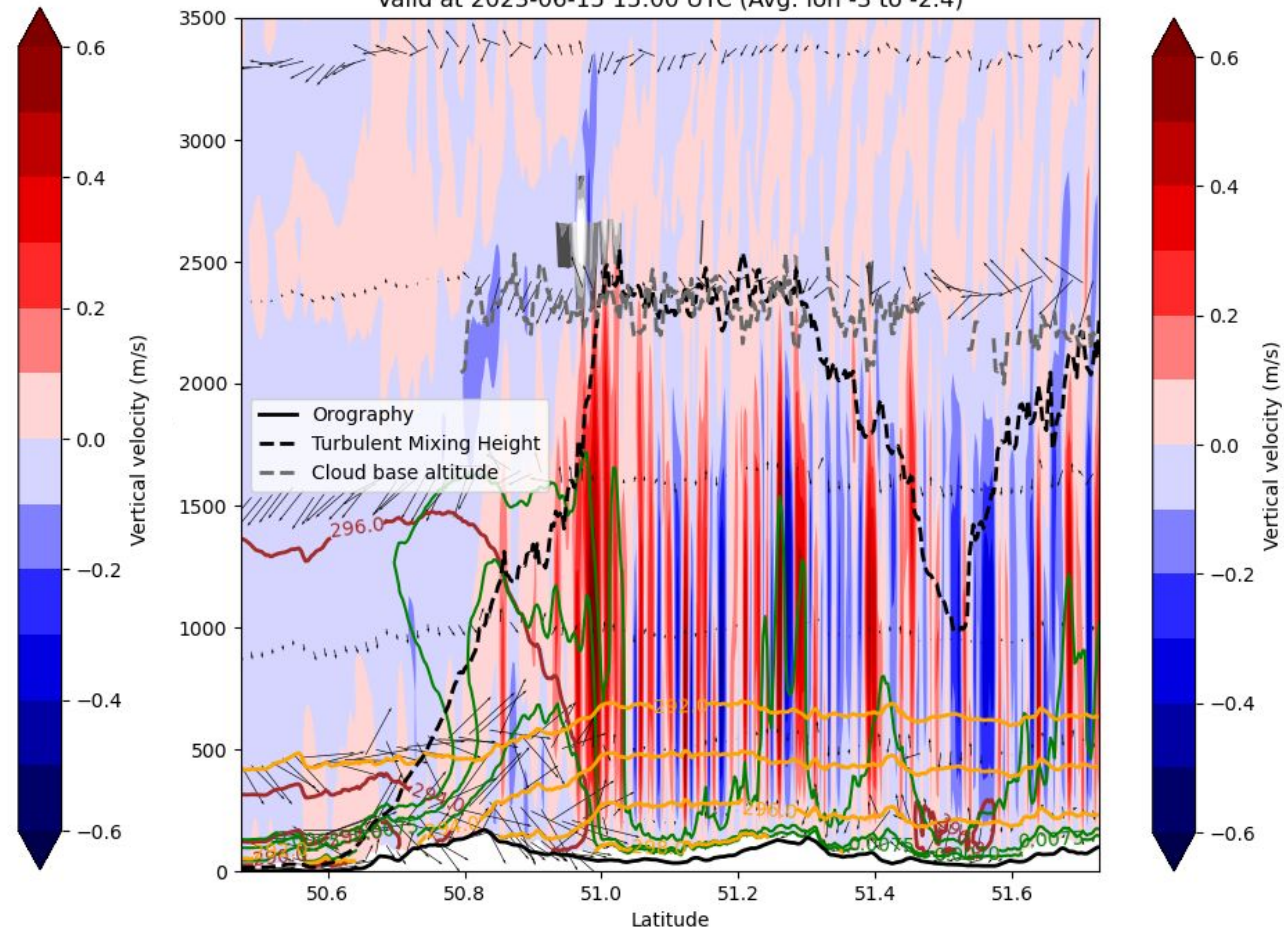
Deeper cloud is seen in the experiment with orography. The w wind ahead of the sea breeze front is higher with orography

Control

Vertical transect of Vertical velocity (coastal orog removed)
Valid at 2023-06-15 15:00 UTC (Avg: lon -3 to -2.4)



Vertical transect of Vertical velocity (control)
Valid at 2023-06-15 15:00 UTC (Avg: lon -3 to -2.4)



v=10 m/s, w=1 m/s

v=10 m/s, w=1 m/s

Orography experiments- Vertical transect (15 June)



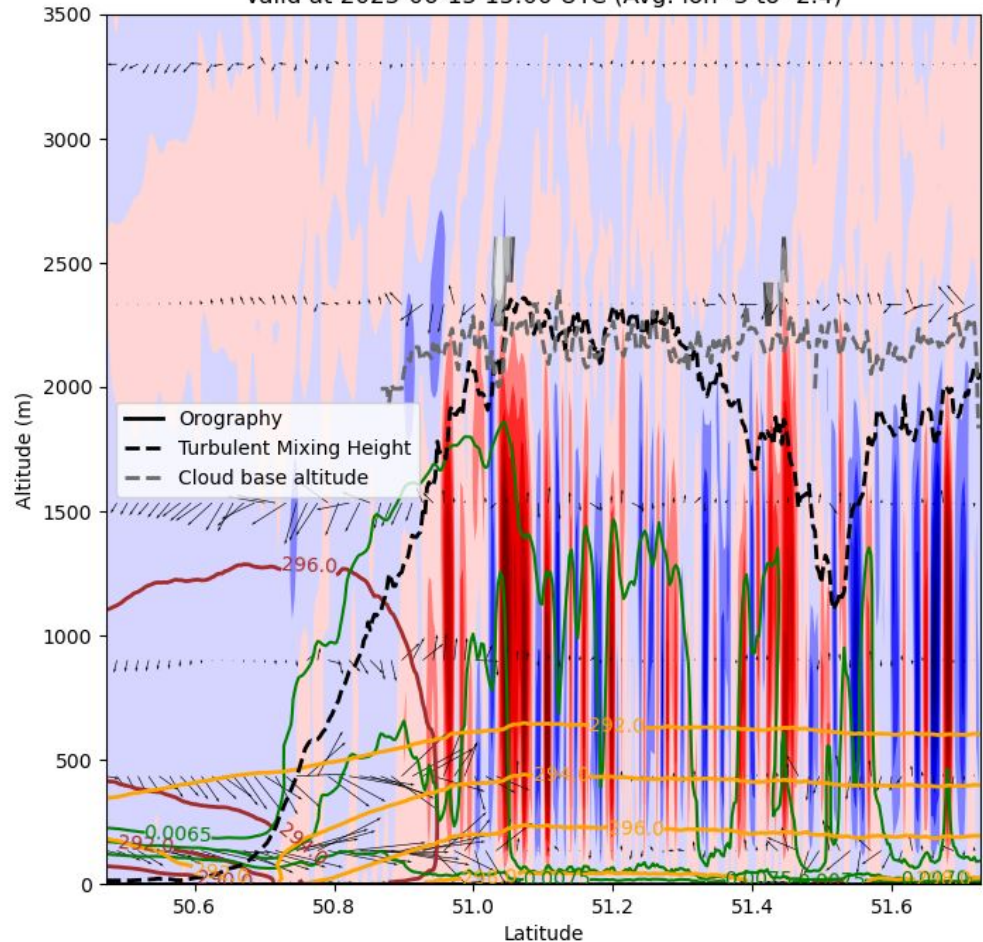
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Removed entire orography

Deeper cloud is seen in the experiment with orography. Specific humidity is slanted backwards with orography

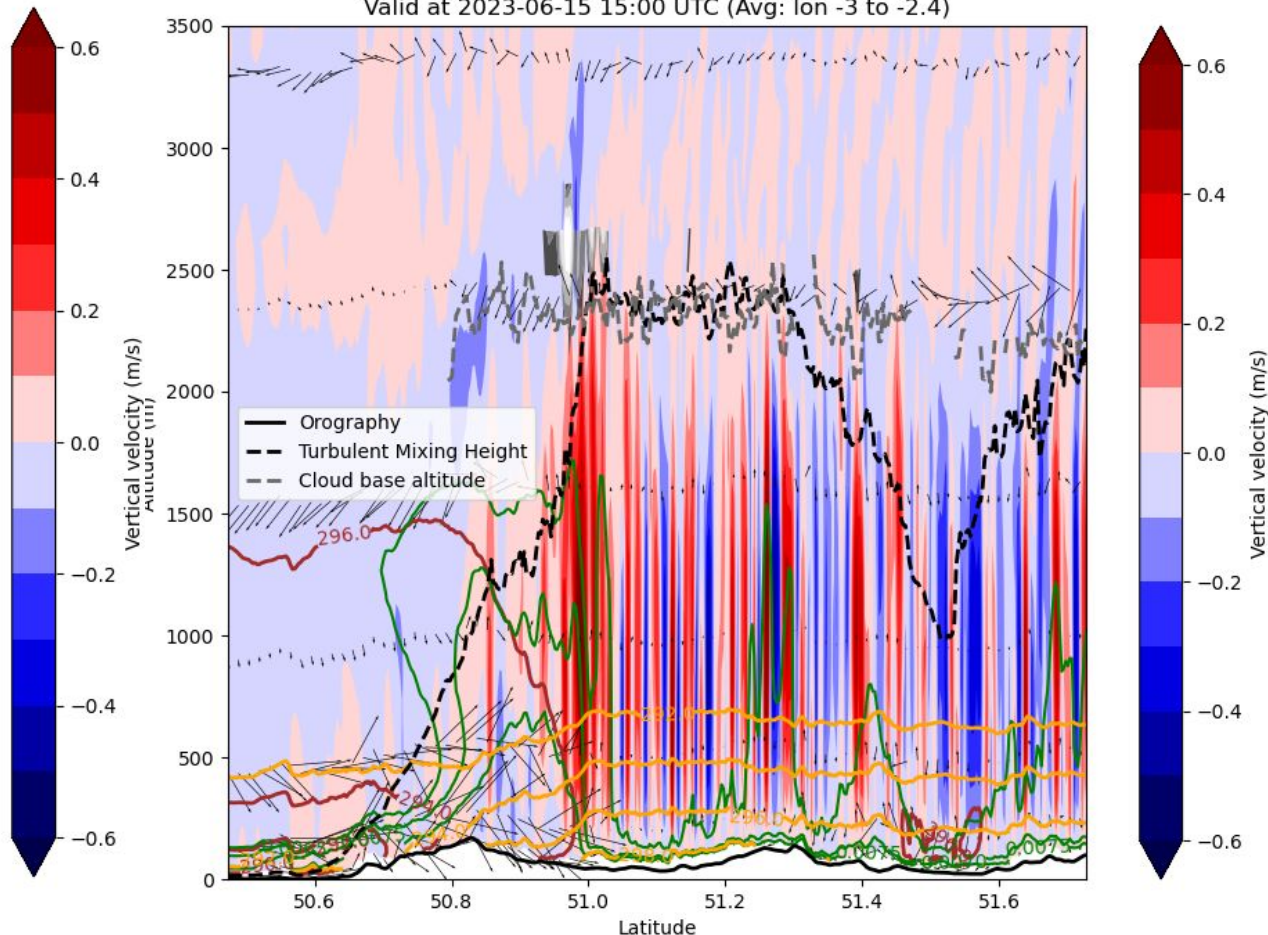
Control

Vertical transect of Vertical velocity (removed entire orog)
Valid at 2023-06-15 15:00 UTC (Avg: lon -3 to -2.4)



v=10 m/s, w=1 m/s

Vertical transect of Vertical velocity (control)
Valid at 2023-06-15 15:00 UTC (Avg: lon -3 to -2.4)



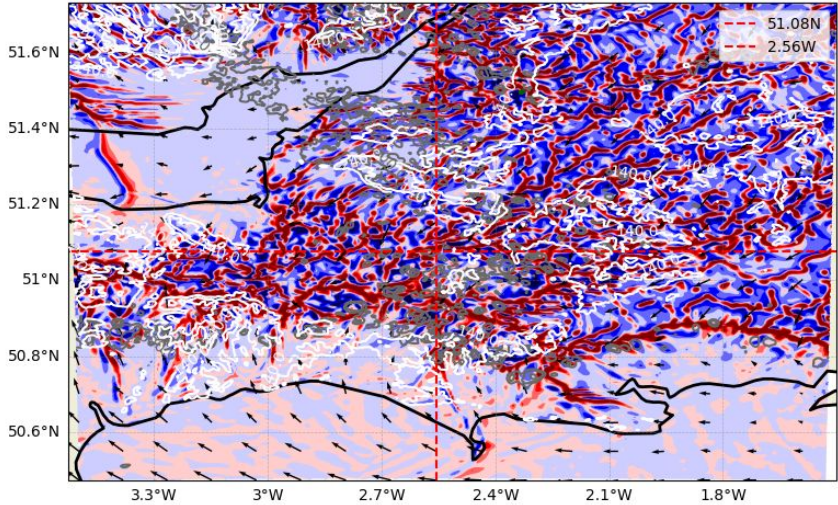
v=10 m/s, w=1 m/s

Compare results at different resolutions (15 June, ens23)



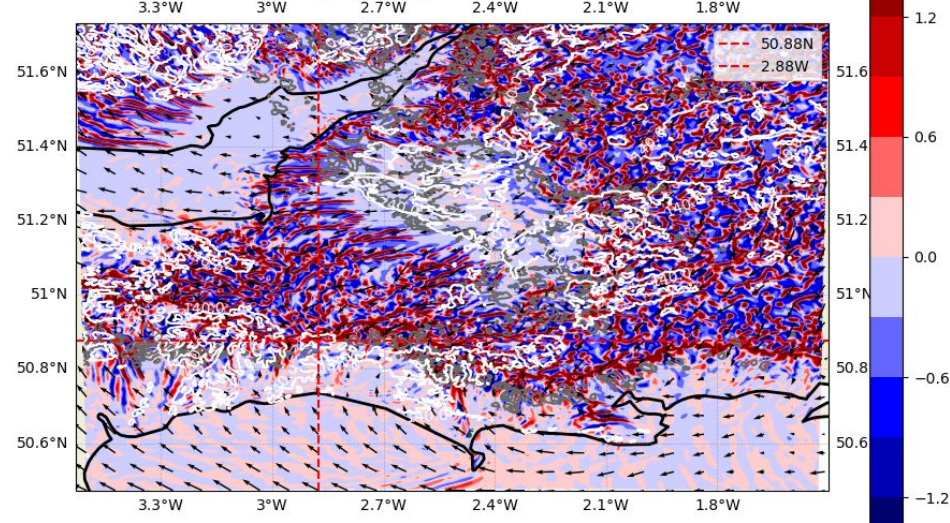
300m

upward_air_velocity for 2023-06-15 1400 at 555 m



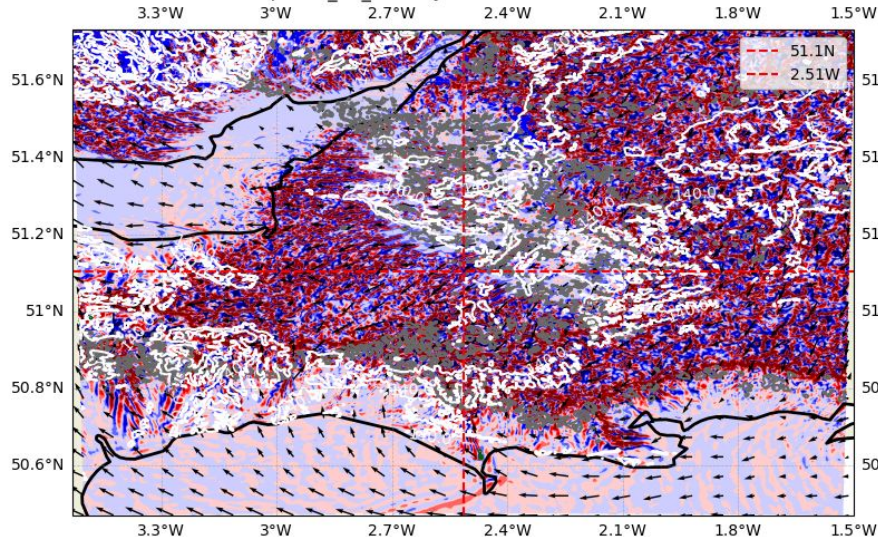
200m

200m: upward_air_velocity for 2023-06-15 1400 at 525 m



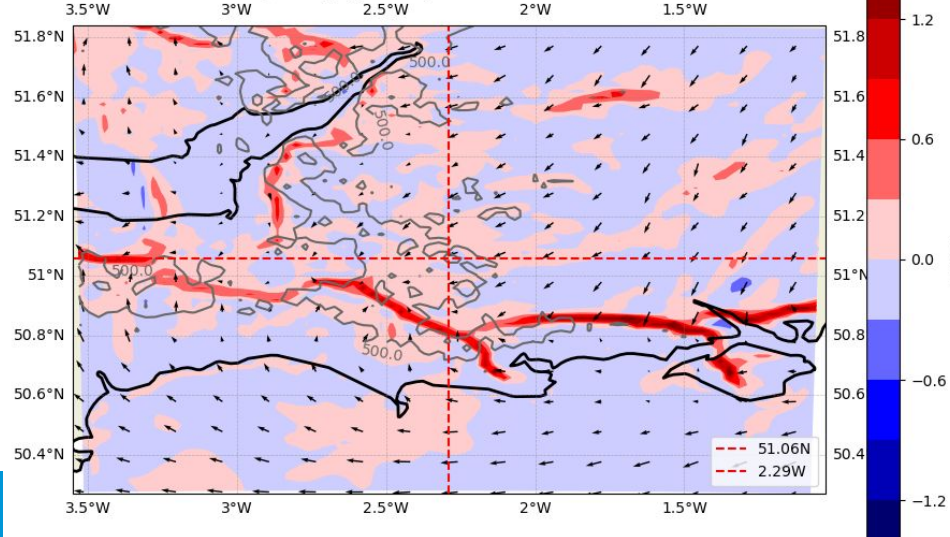
100m

100m: upward_air_velocity for 2023-06-15 1400 at 525 m



2.2km

2.2km: upward_air_velocity for 2023-06-15 1400 at 555 m



Coarse grained to 2.2km (15 June)- ens23

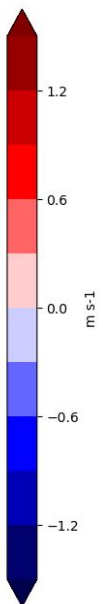
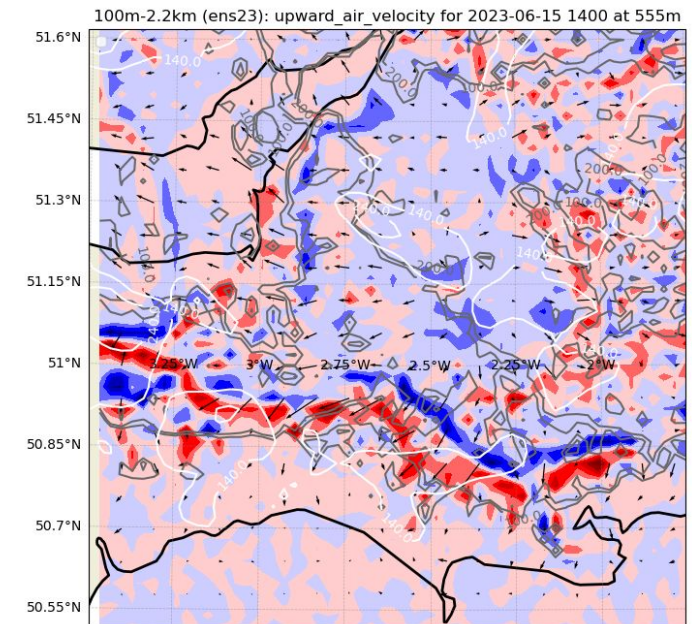
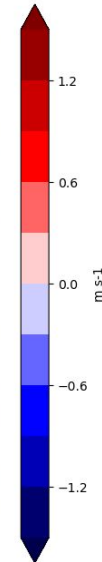
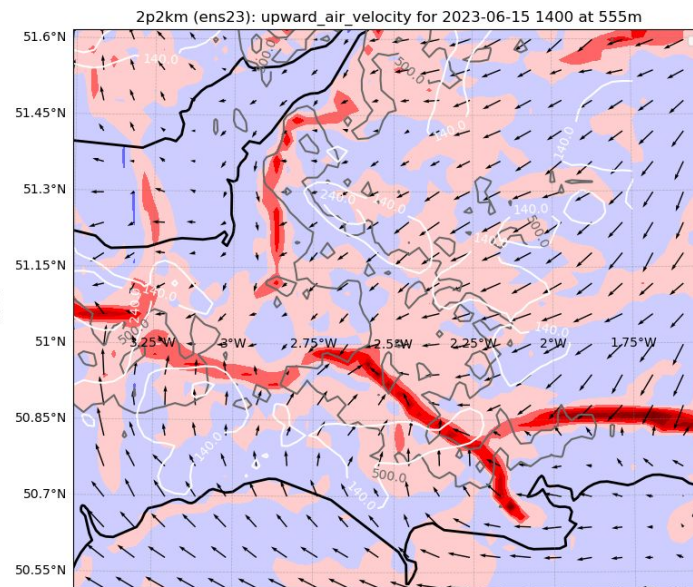
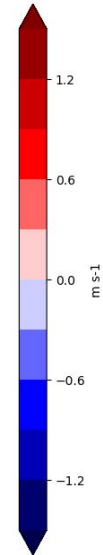
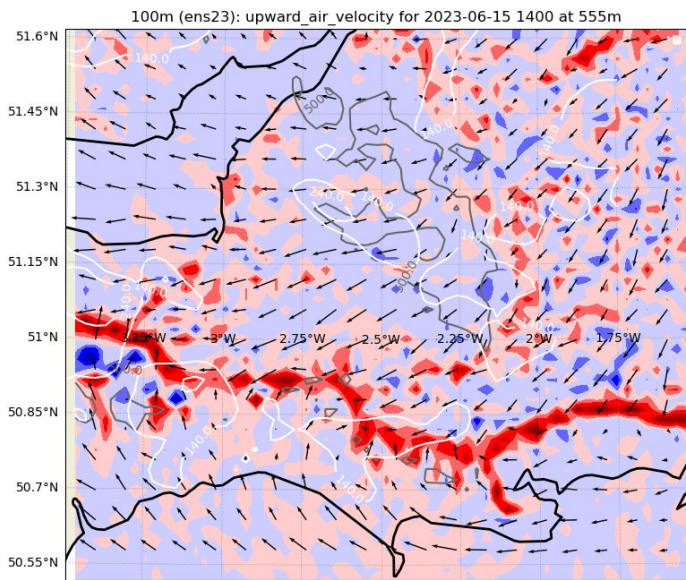


ens23 main features: 2.2km sea breeze front propagates slightly faster

100m

• 2.2km

100-2.2km



Coarse grained to 2.2km (15 June)- ENSMEAN



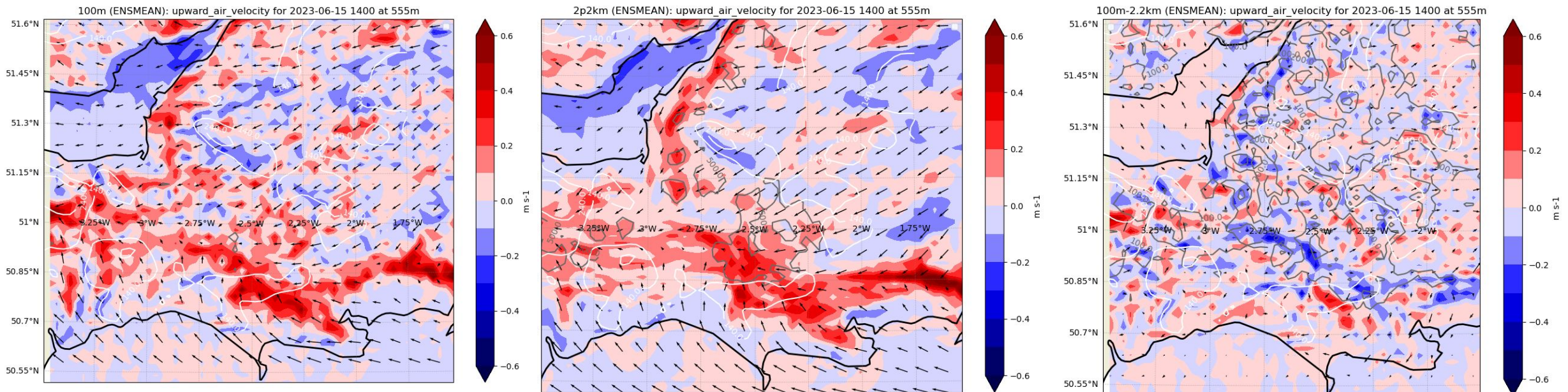
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ENSMEAN main features: the 2.2km model has stronger winds (u,v) and stronger magnitudes of w than the 100m. The sea breeze front therefore propagates slightly faster in the 2.2km

100m

• 2.2km

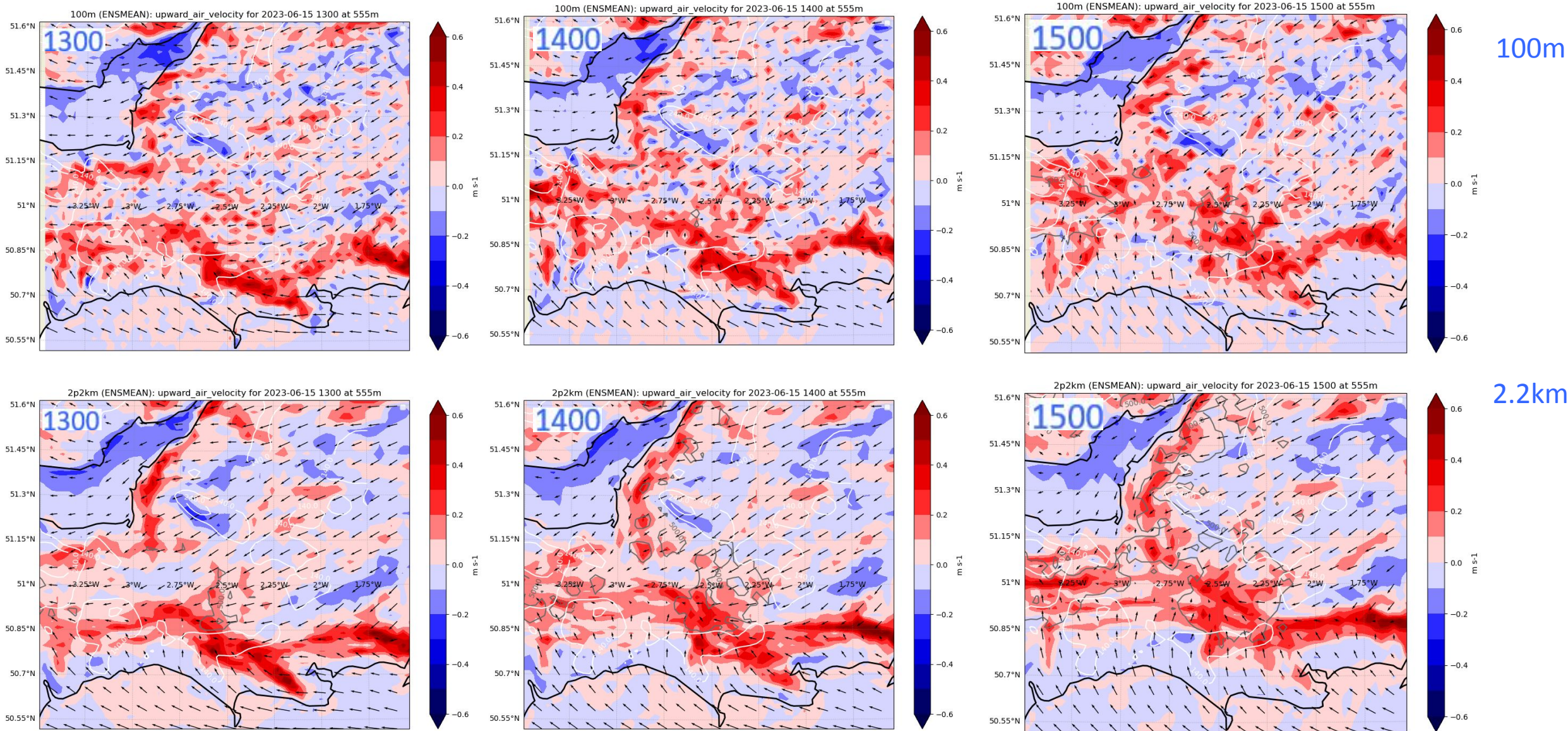
100-2.2km



Coarse grained to 2.2km (15 June)- ENSMEAN temporal evolution (Clouds developed earlier in 2.2km)



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100m

2.2km

ENSMEAN main features: significant clouds developed 1 hour earlier in the 2.2km

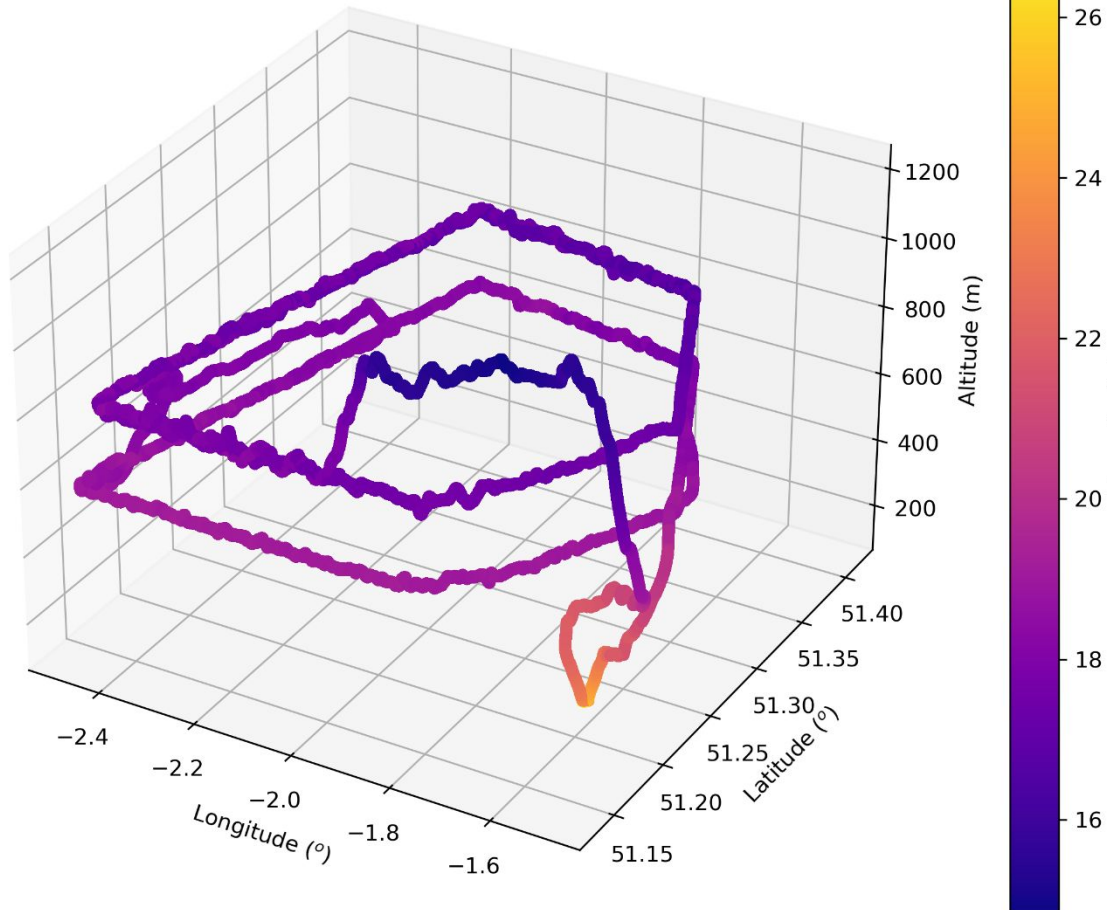
- Compare the representation of the BL rolls identified in the models with the WesCON observations (DIMONA HK36 aircraft data).



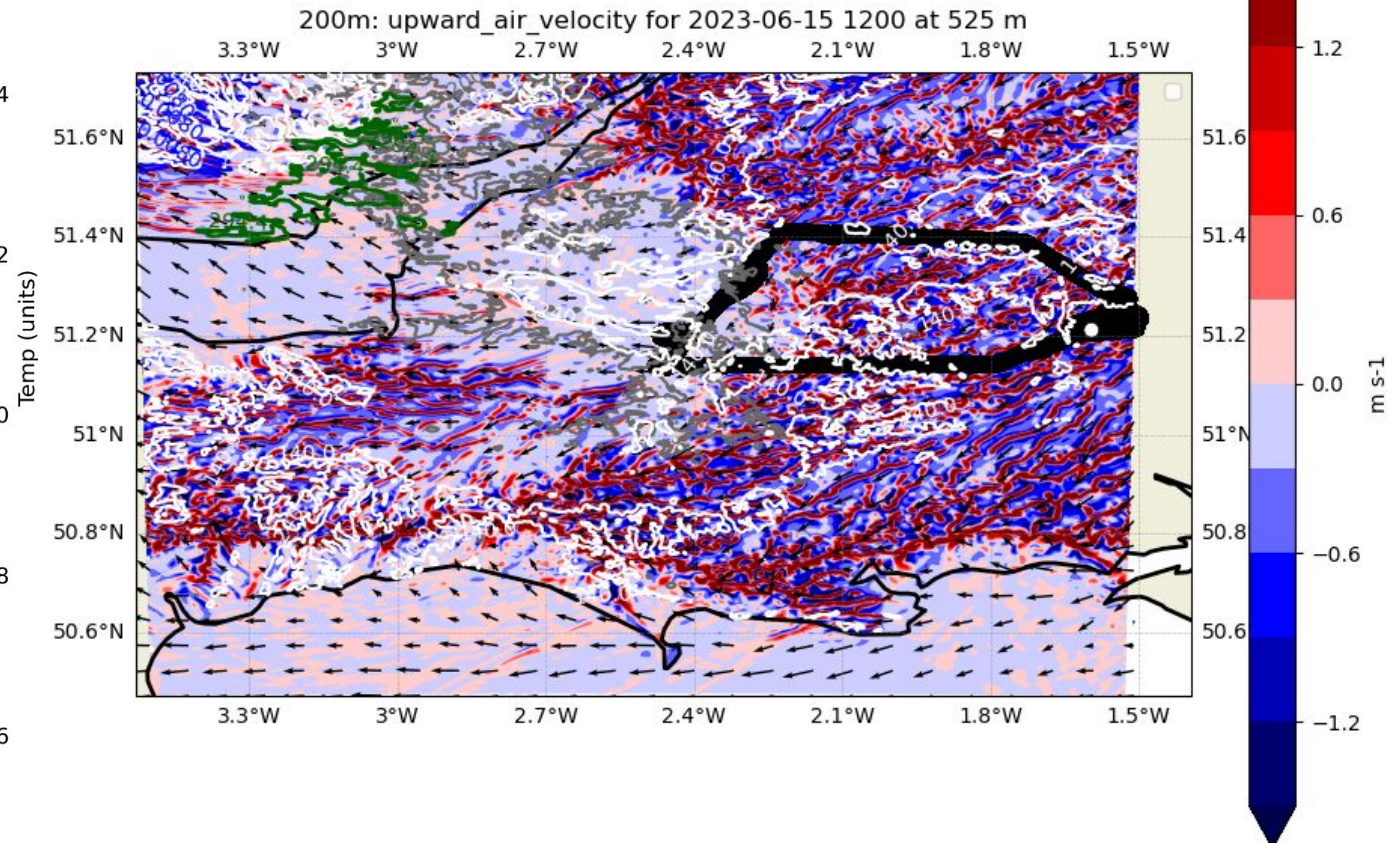


Dimona

DIMONA Aircraft Data 3D Plot - Temp



- Map



Dimona aircraft data (20230615) -2.2km vs 100m 1200



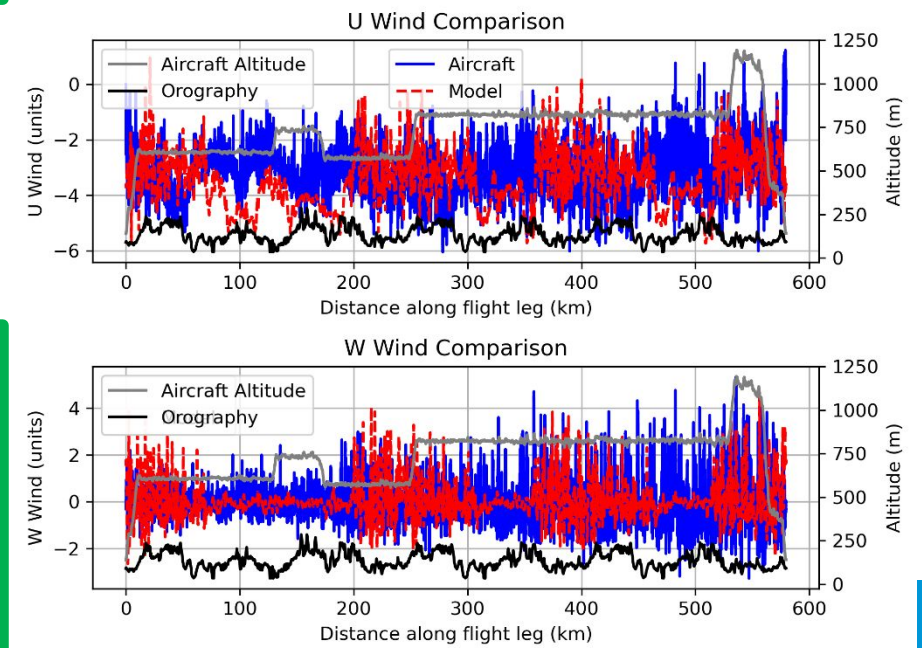
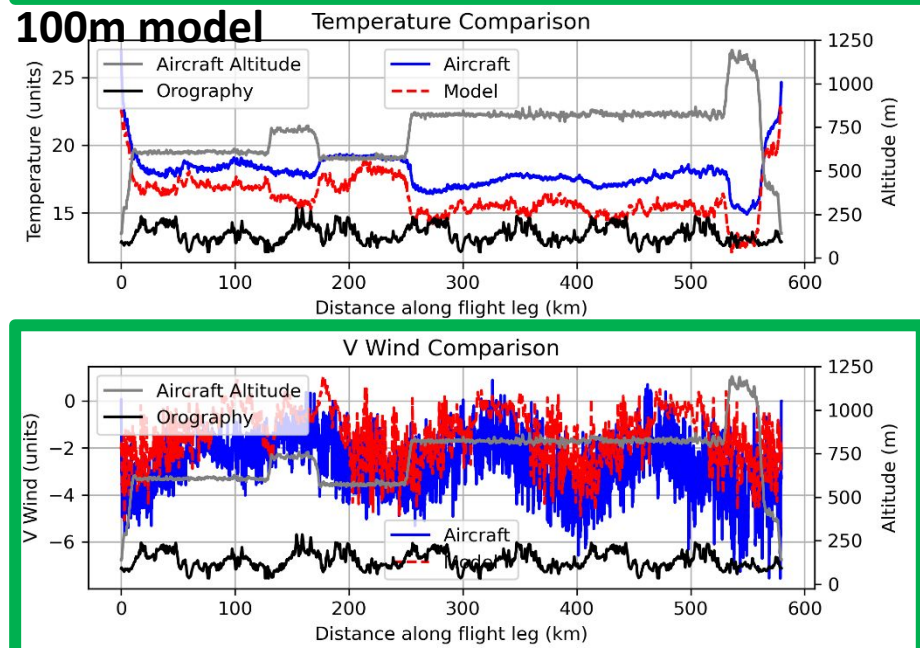
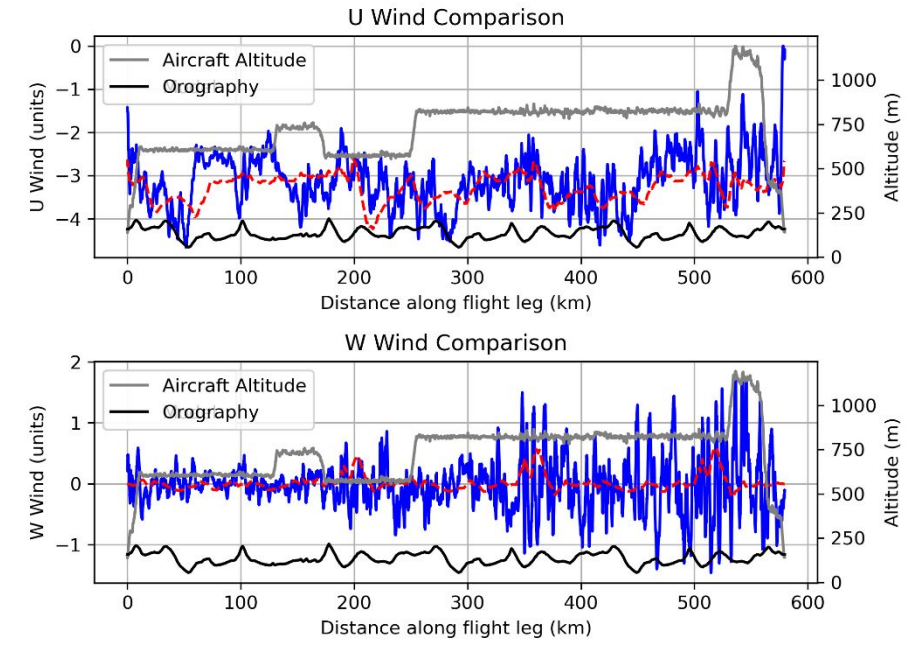
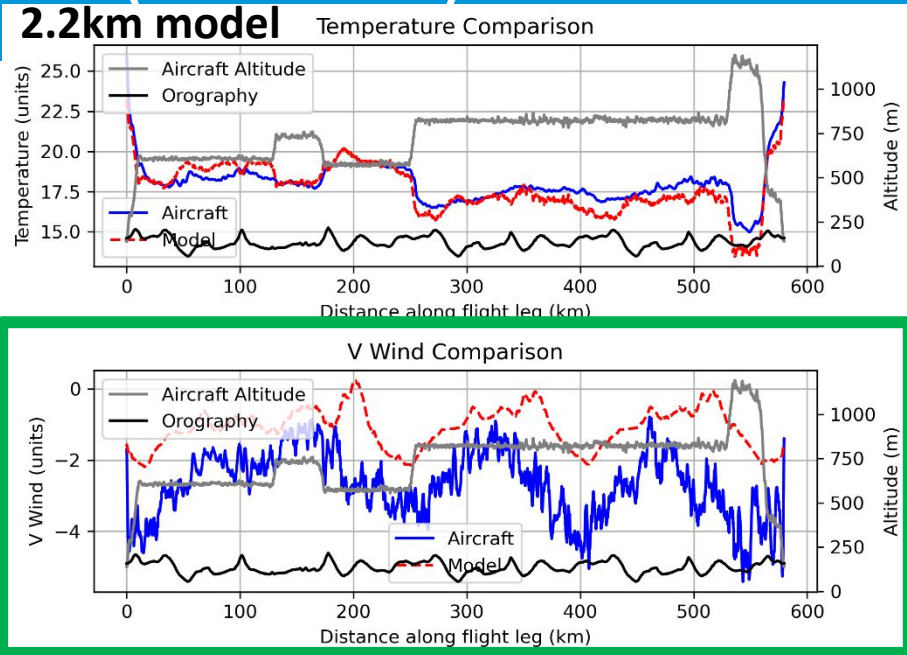
The 100m model performs better with the aircraft data than the 2.2km model.

The 2.2km model:

- Overestimates v winds
- (possibly explains the faster sea breeze front)

Model – red
Aircraft - blue

NB: The aircraft data has been smoothed to the resolution of each model.



Interaction between the BL rolls and sea breeze in the presence of orography:

- Specific humidity increases ahead of the sea breeze front (due to ascent ahead of the front)
- Sea breeze front propagates slightly faster when orography is removed
- Sea breeze front + orography results in more vertical mixing (as compared to sea breeze front on a flat land).

Comparison across resolutions:

- the 2.2km model has stronger winds (u,v) and stronger magnitudes of w than the 100m
- The sea breeze front propagates slightly faster in the 2.2km.

Comparison with observation:

- The sub-km models reproduce boundary layer rolls with similar wavelengths and amplitudes to the DIMONA HK36 aircraft data
- 2.2km overestimates the v winds and therefore potentially overestimates the sea breeze