living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE
OF OUR PLANET FROM SPACE

EUMETSAT ECMWF EUSPA

Harmony in an Earth System Model (ESM) 2.0 and Digital Twin Earth (DTE) context

Aurhor

date

Earth system approach: Hasselmann's holistic view (1990)

The reduction of ocean anoxia is key to control the influence of climate or the sea level on the rate of organic matter burial, thereby stabilizing the carbon cycle, global climate and atmospheric oxygen levels :

Oxygen accumulation in the atmosphere is ultimately a by-product of the burial of organic matter produced via oxygenic photosynthesis

<u>WCRP Strategic Plan (2020)</u>: the development of a new generation of coupled Earth system models that explicitly represent global storms, deep convection, ocean eddies and land-atmosphere interactions (1 km scale) and that provides information with reliable regional precision.

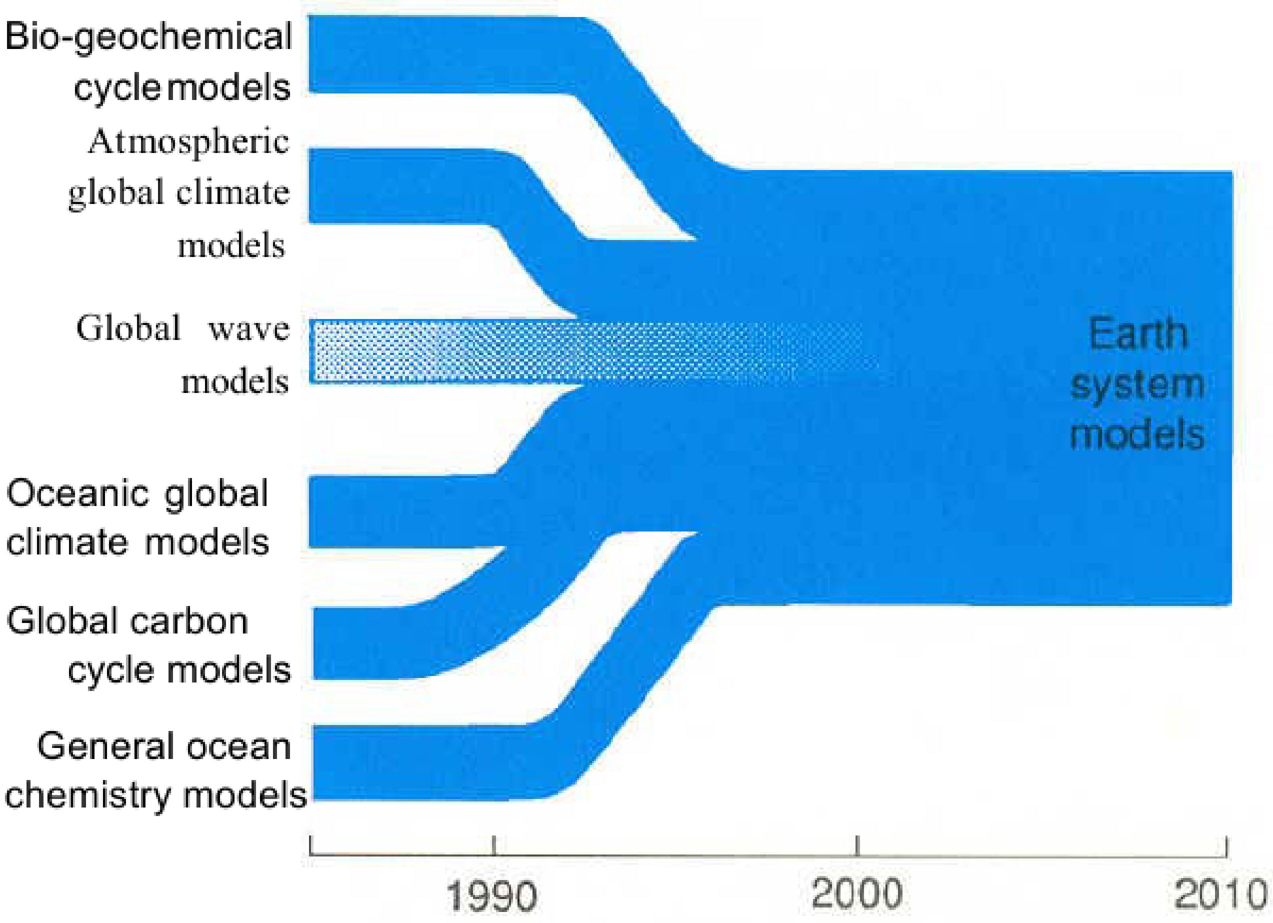
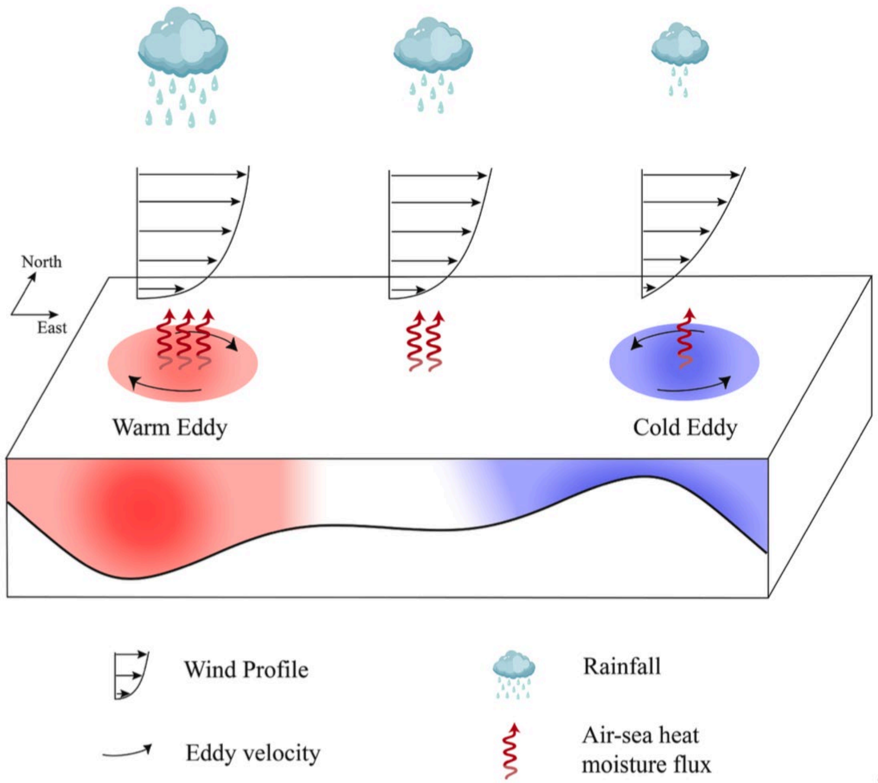
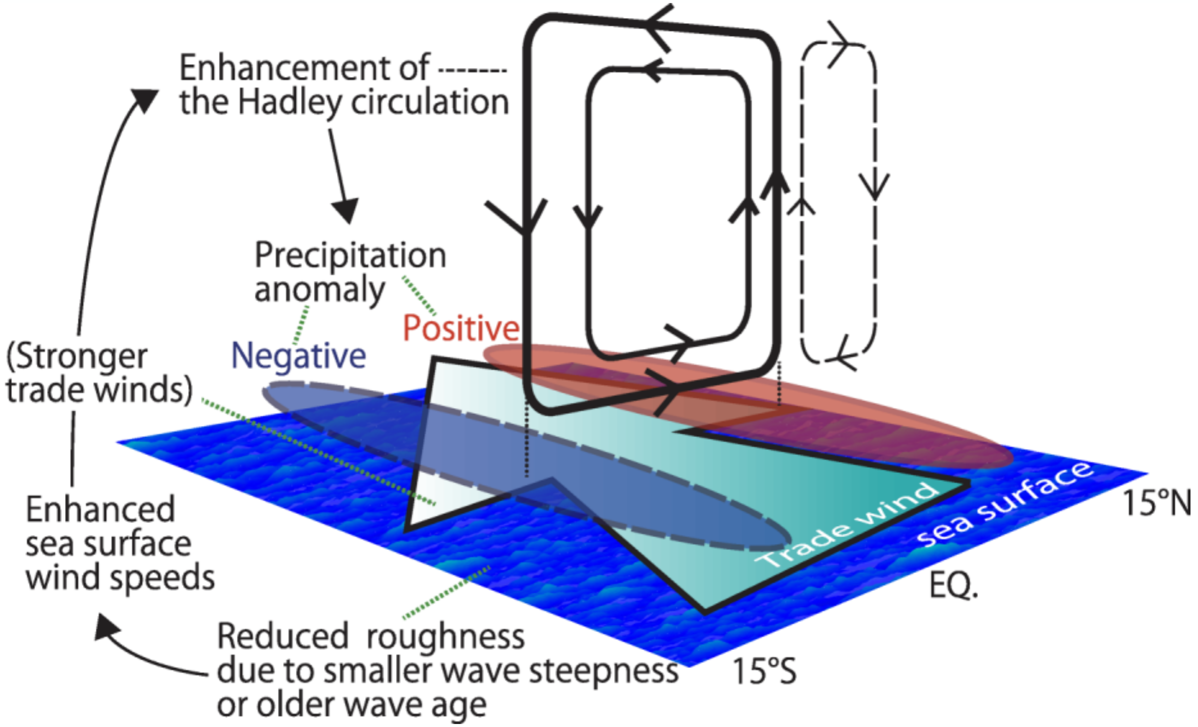


Figure 1. Future role of wave models as an essential coupling component for ocean-atmosphere-carbon-cycle modets developed in the context ot the World Climate and Global Change programs.

Earth system complexity: Ocean-Atmosphere, local and non-local multi-scale interactions

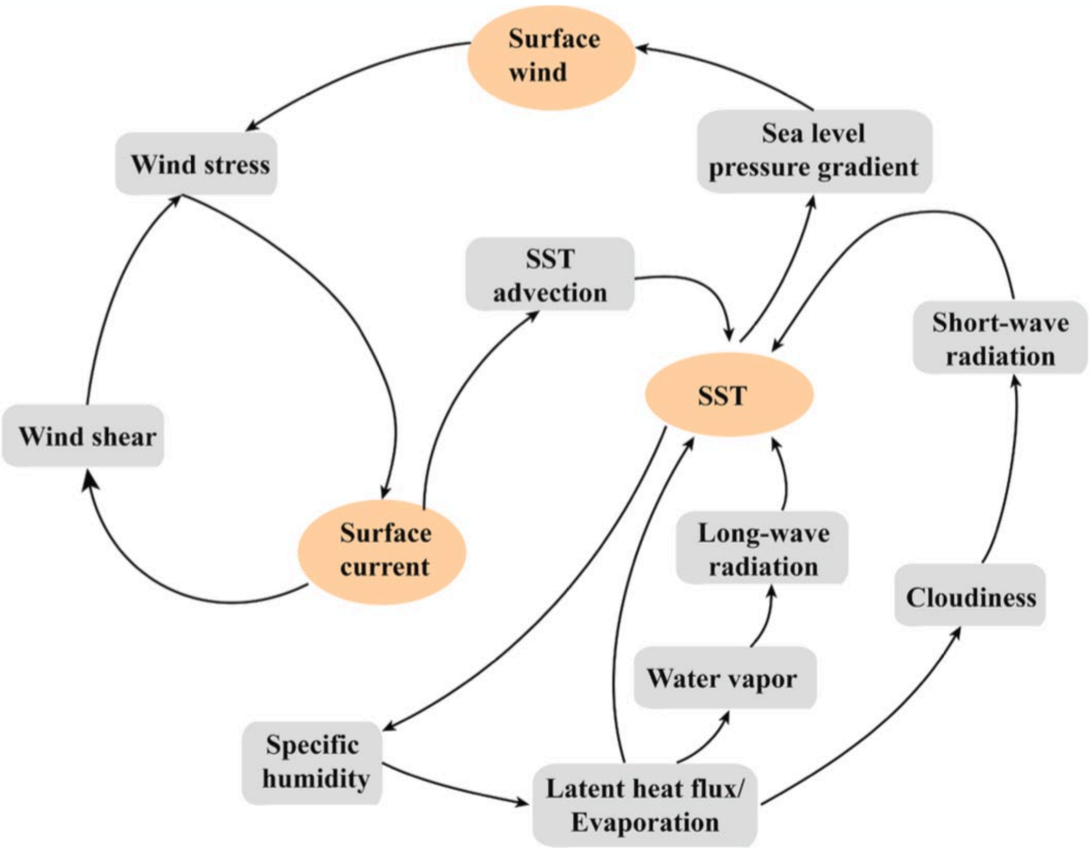


Long-term impacts of ocean wave-dependent roughness on global climate systems

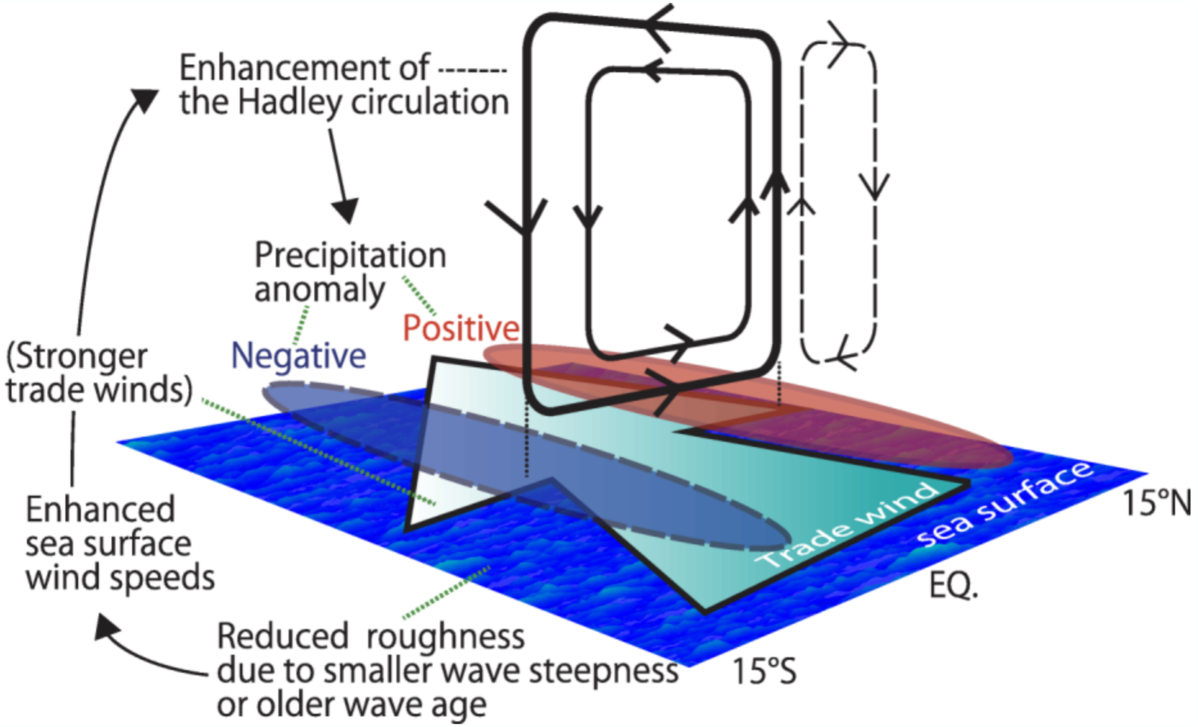


WRCP (P. Brasseur): 2028, an International Earth System Year, with intensive observational and modeling activities to investigate the complexity of planetary dynamics

Earth system complexity: Ocean-Atmosphere, local and non-local multi-scale interactions



Long-term impacts of ocean wave-dependent roughness on global climate systems



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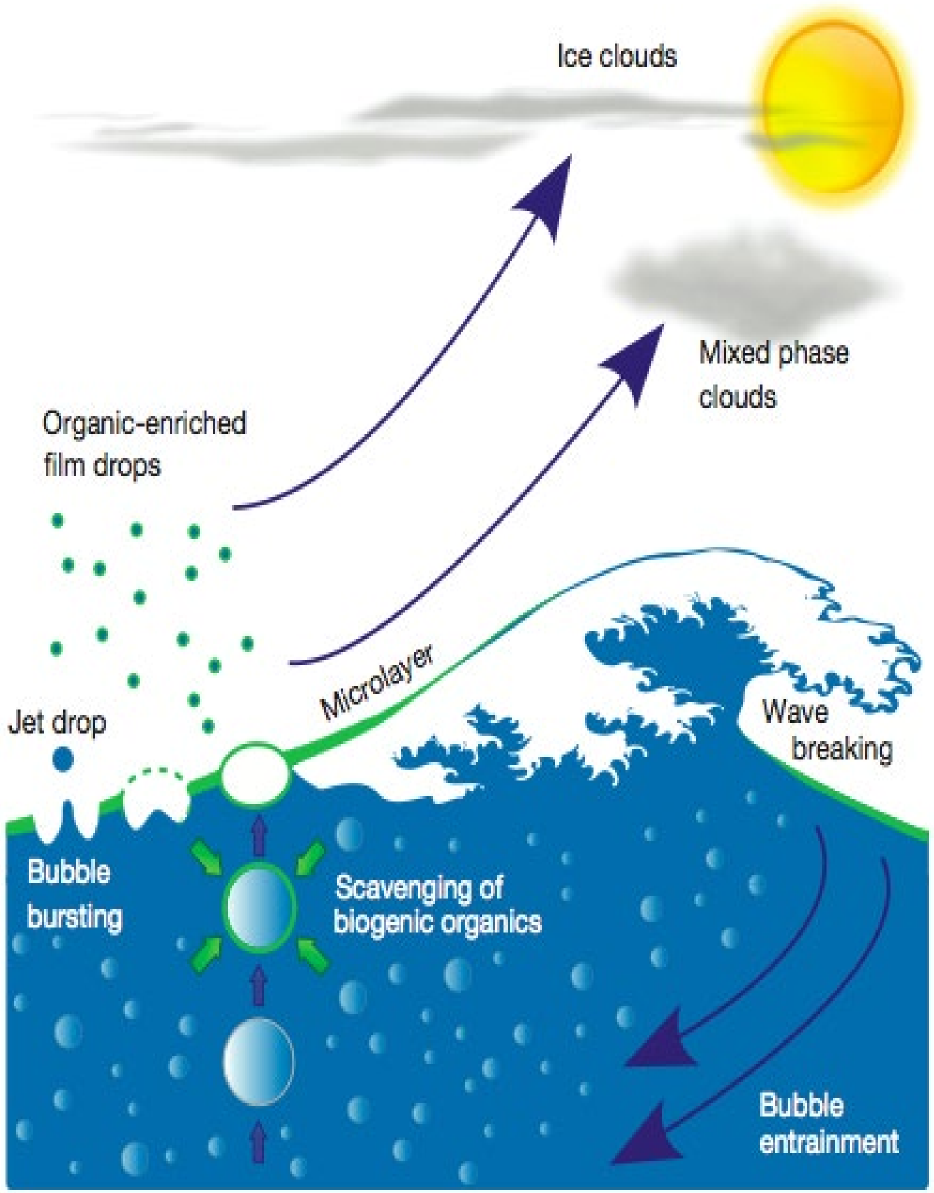
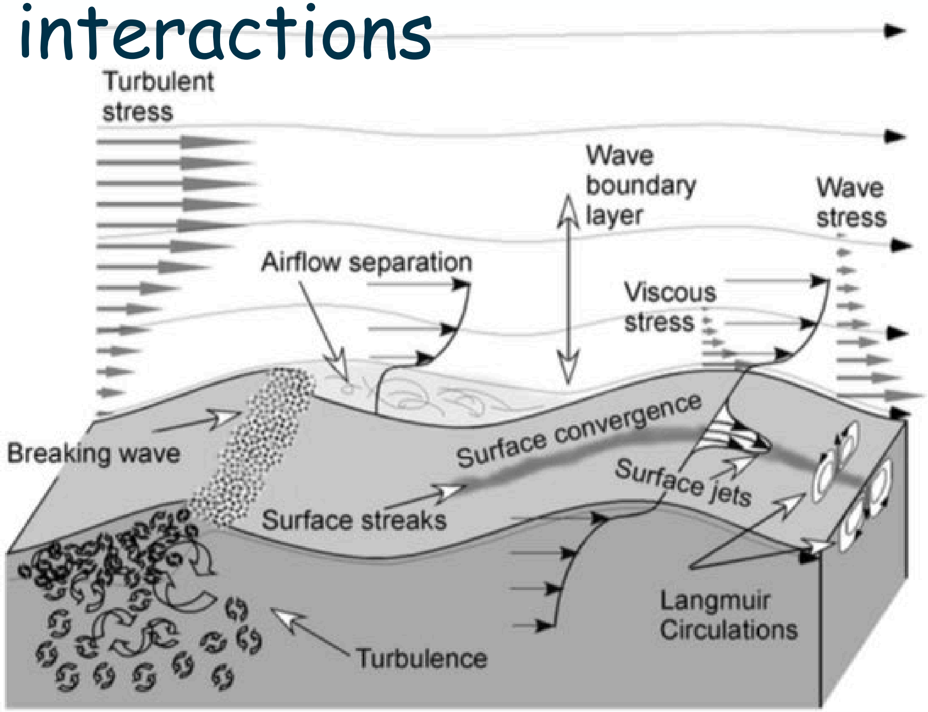


Sea-spray aerosol particles enriched in organic material are possibly generated when the air-sea interface is bursting

Earth system log-jam: the air-sea interface, local and non-local multi-scale interactions



Numerical models are not totally able to describe all rules governing real-world multi-scale interactions, data-driven (physically-constrained) methods are now promoted to bridge the known physics and observations. Deep learning models if trained on observations can mitigate certain biases in current state-of-the-art weather models.

How to reproduce effects of unresolved scales on the resolved large scales ?

Harmony combined-observations : Reference data at very high resolution to calibrate/emulate sub-grid model parameterizatons

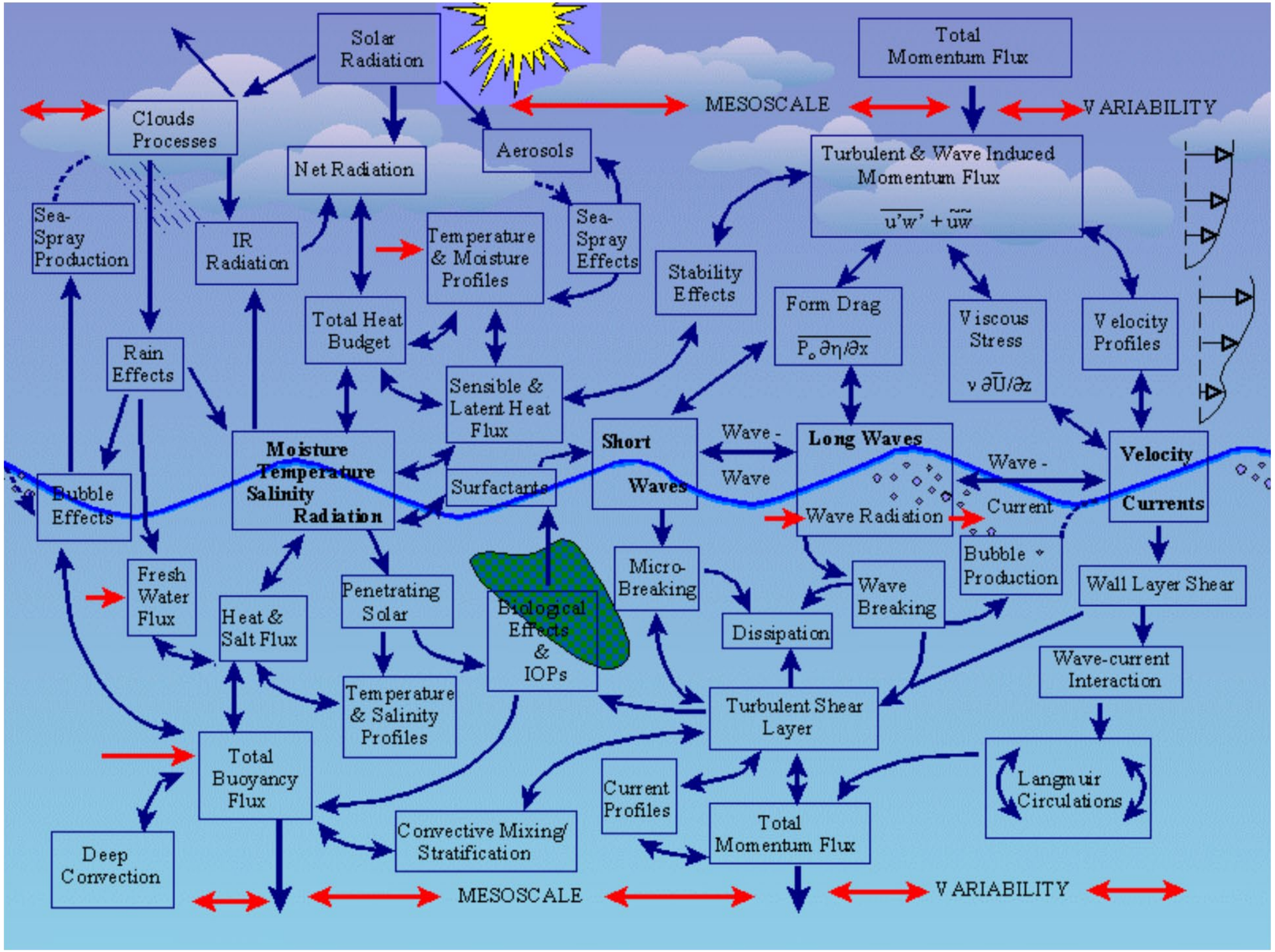
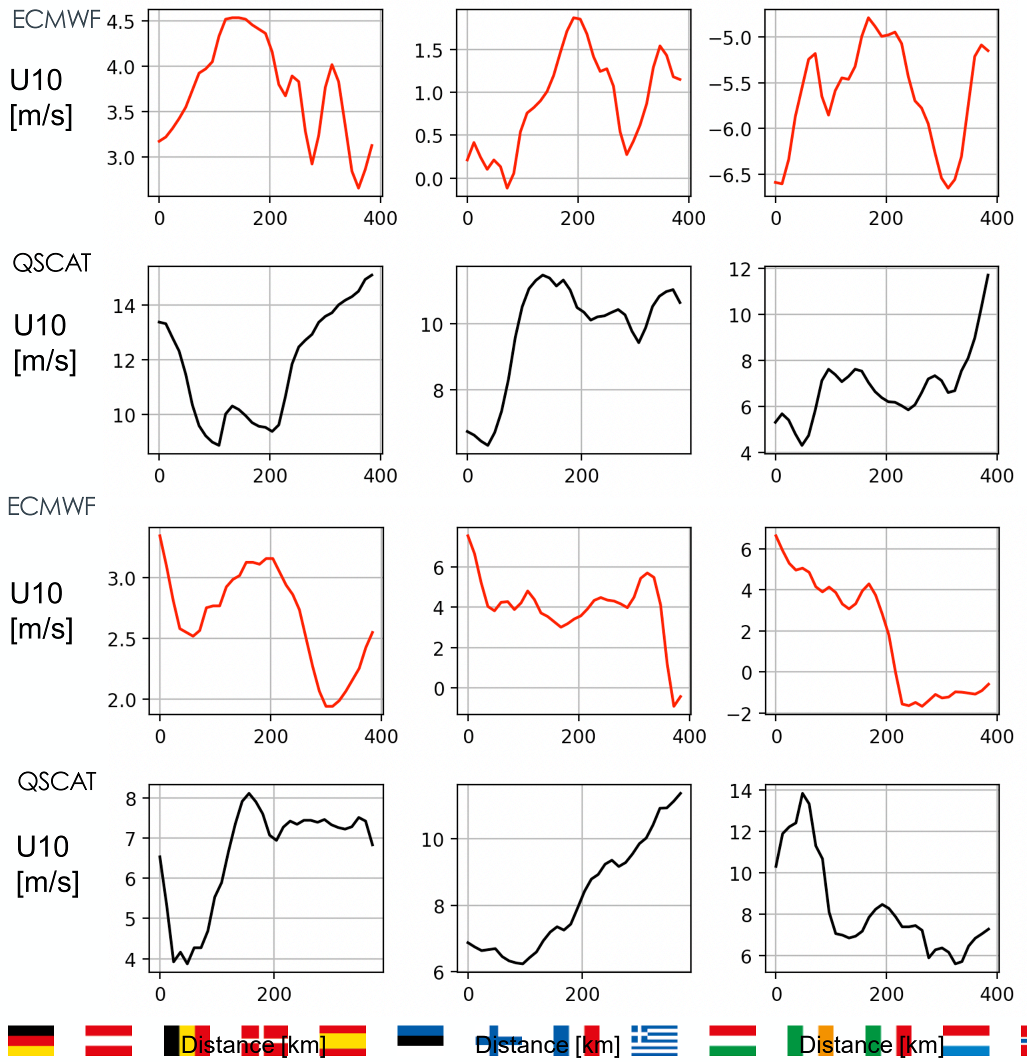


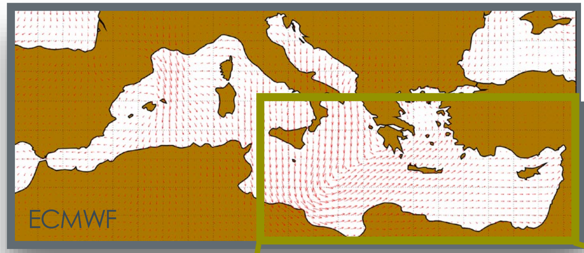
Figure 2. Some of the processes that govern the transfer of heat, mass, and momentum within the coupled boundary layers.

Statistical Characterisation of Observed vs Modelled Wind Properties

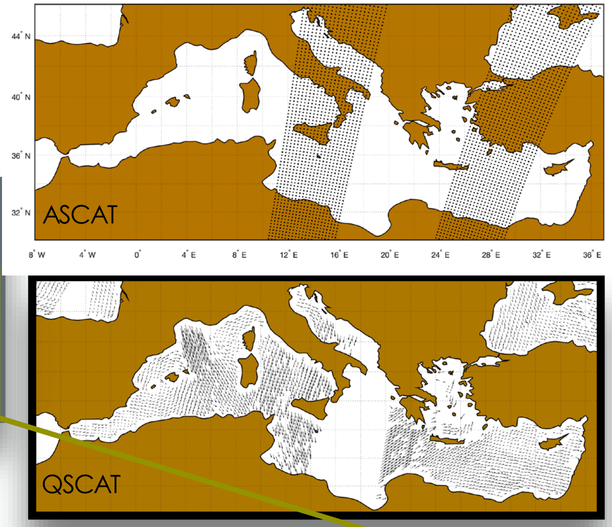
Random Samples



GRIDDED MODELING PRODUCT
(i.e., model analysis and forecast)
02-02-2005
6:00HR

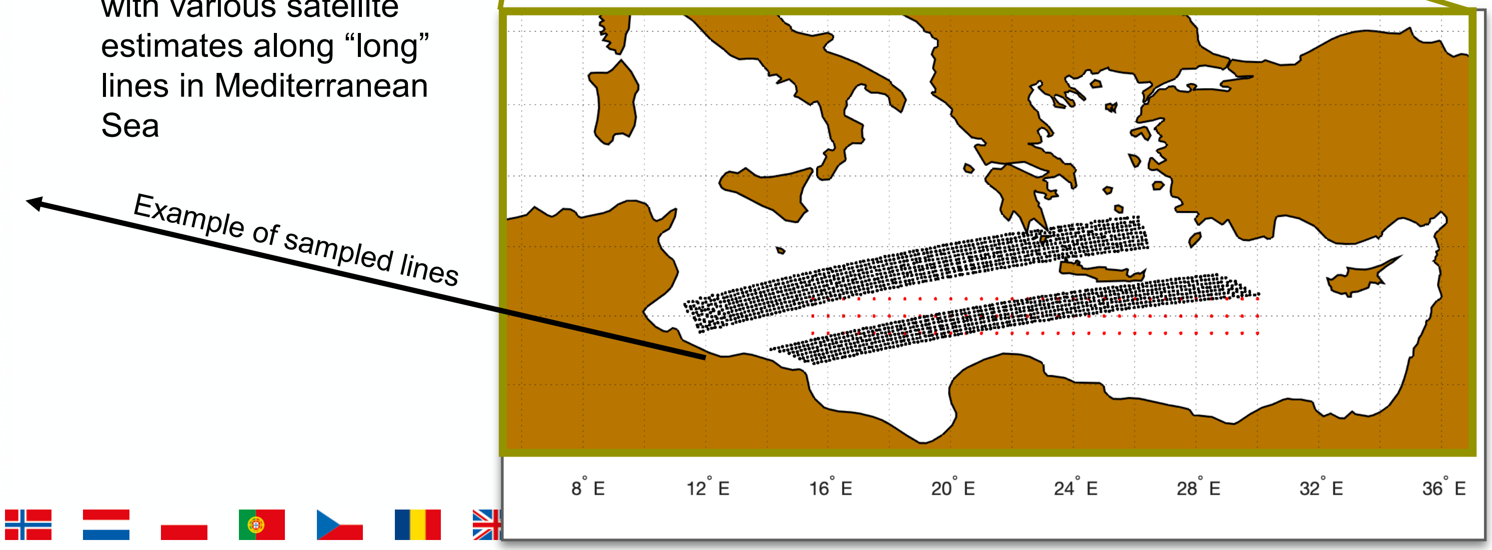


SATELLITE ESTIMATES
(HARMONY-like SVW measurements)
02-02-2005
6:00/9:00HR



- Surface winds statistics from ECMWF analysis with various satellite estimates along “long” lines in Mediterranean Sea

QSCAT vs ECMWF



Statistical Characterisation of Observed vs Modelled Wind Properties

ECMWF analysis, Mediterranean Sea

ASCAT (METOP-A), 2013, Mediterranean Sea

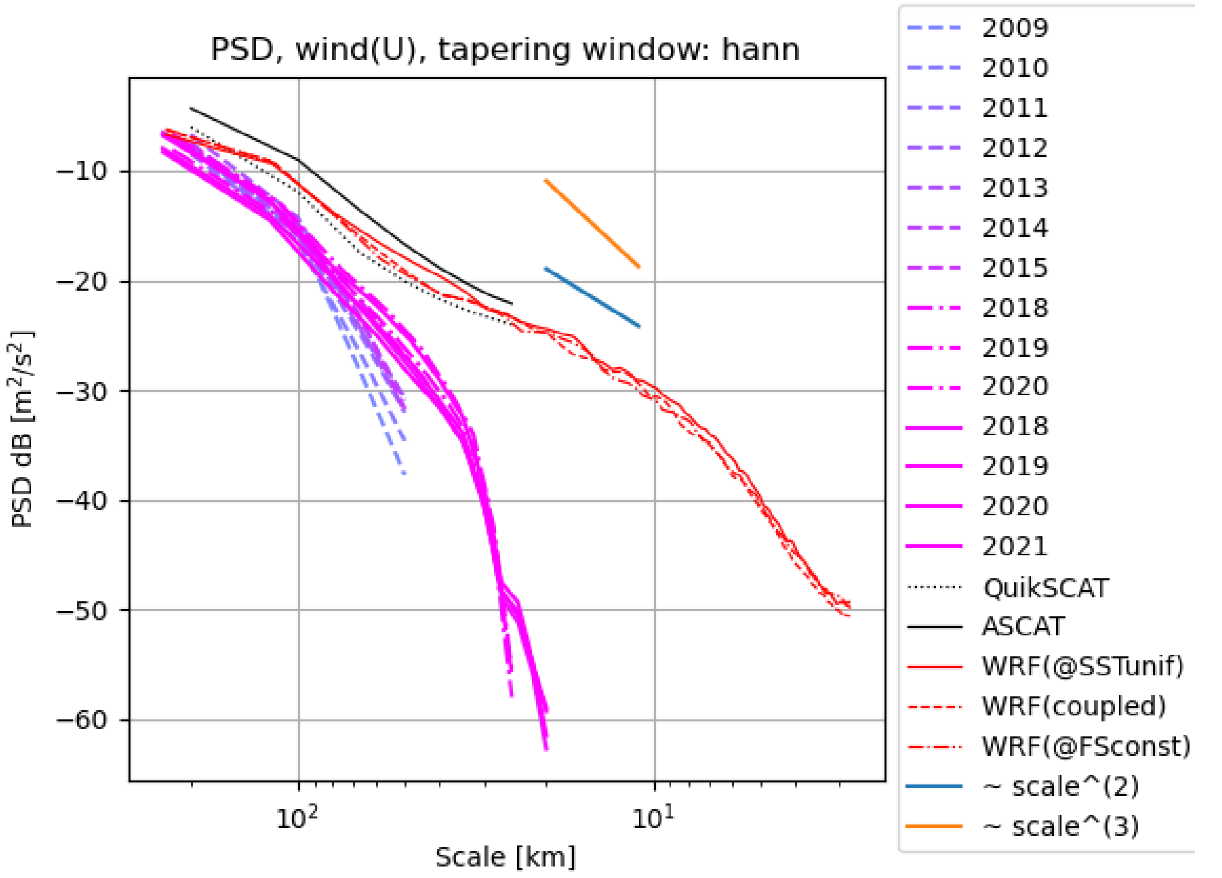
QuikScat, 2005, Mediterranean Sea

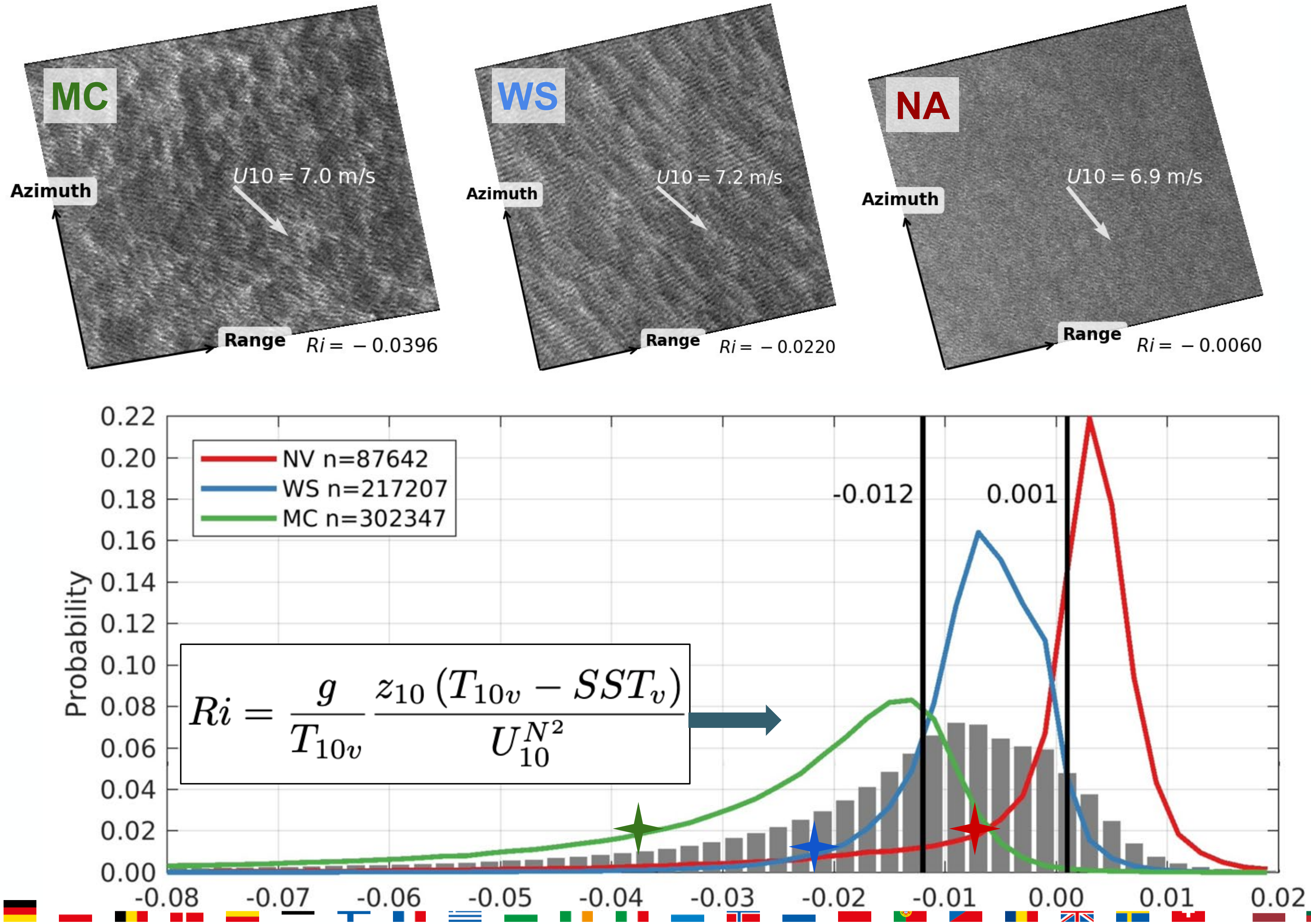
Med Sea, averages of PSD computed over 240 km lines

WRF Winds Time window: 2014-10-06 to 2014-10-10.

Region of interest: Ligurian Sea (domain-03).

Grid resolution: 1.4 km.





$$Ri = \frac{g}{T_{10v}} \frac{z_{10}\left(T_{10v} - SST_v\right)}{U_{10}^{N^2}}$$

Unstable

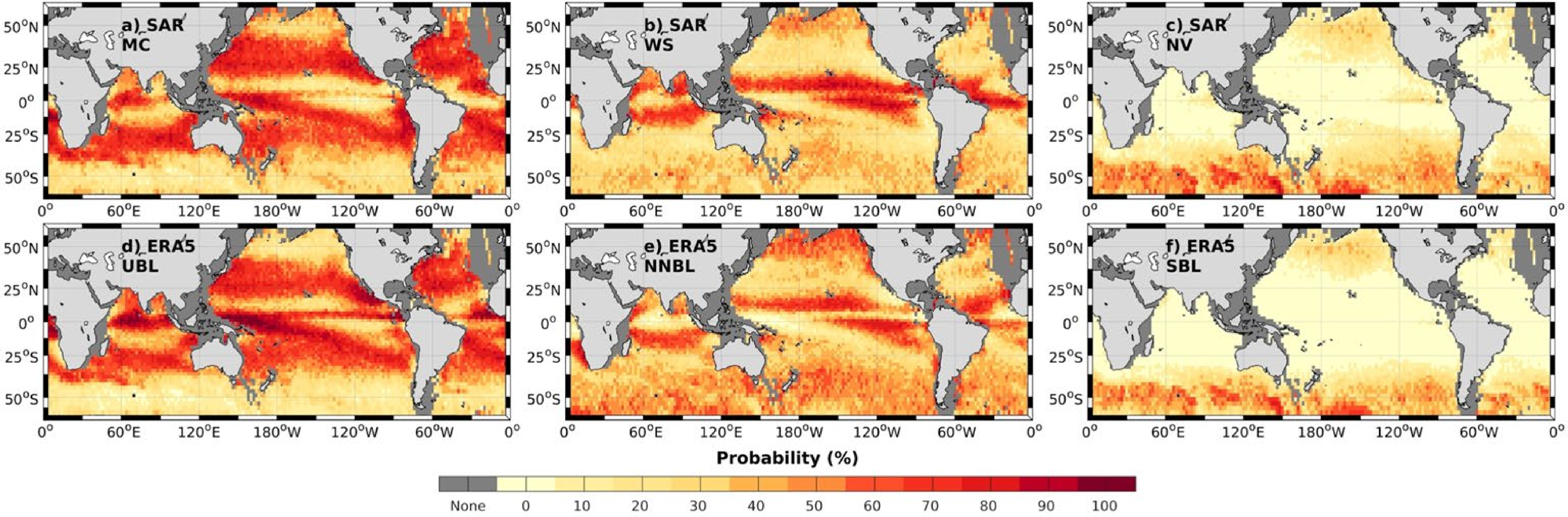
- more negative Ri
- favorable for MC

Near-neutral

- weakly negative Ri
- favorable for WS

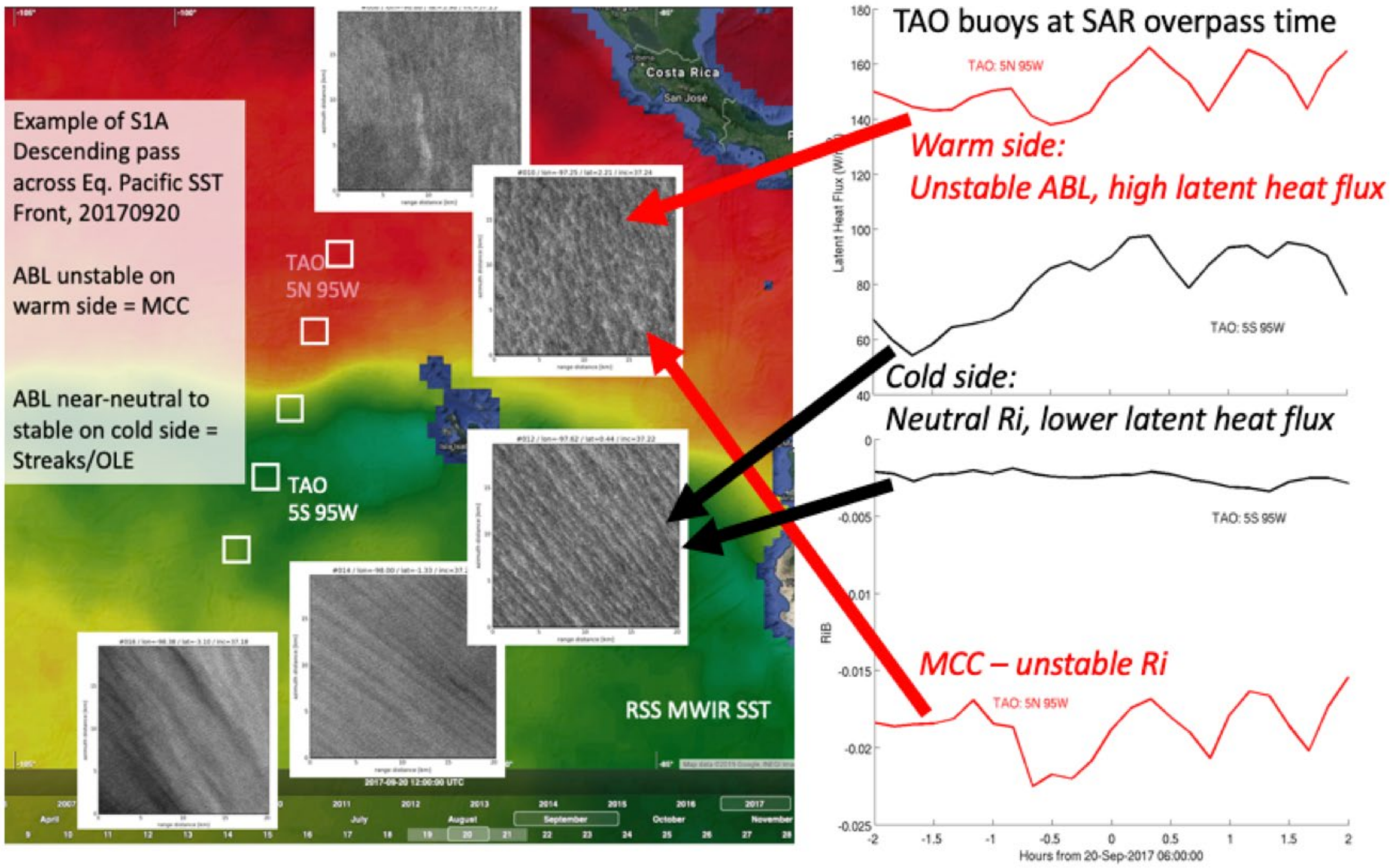
Stable

- positive Ri
- only turbulence left

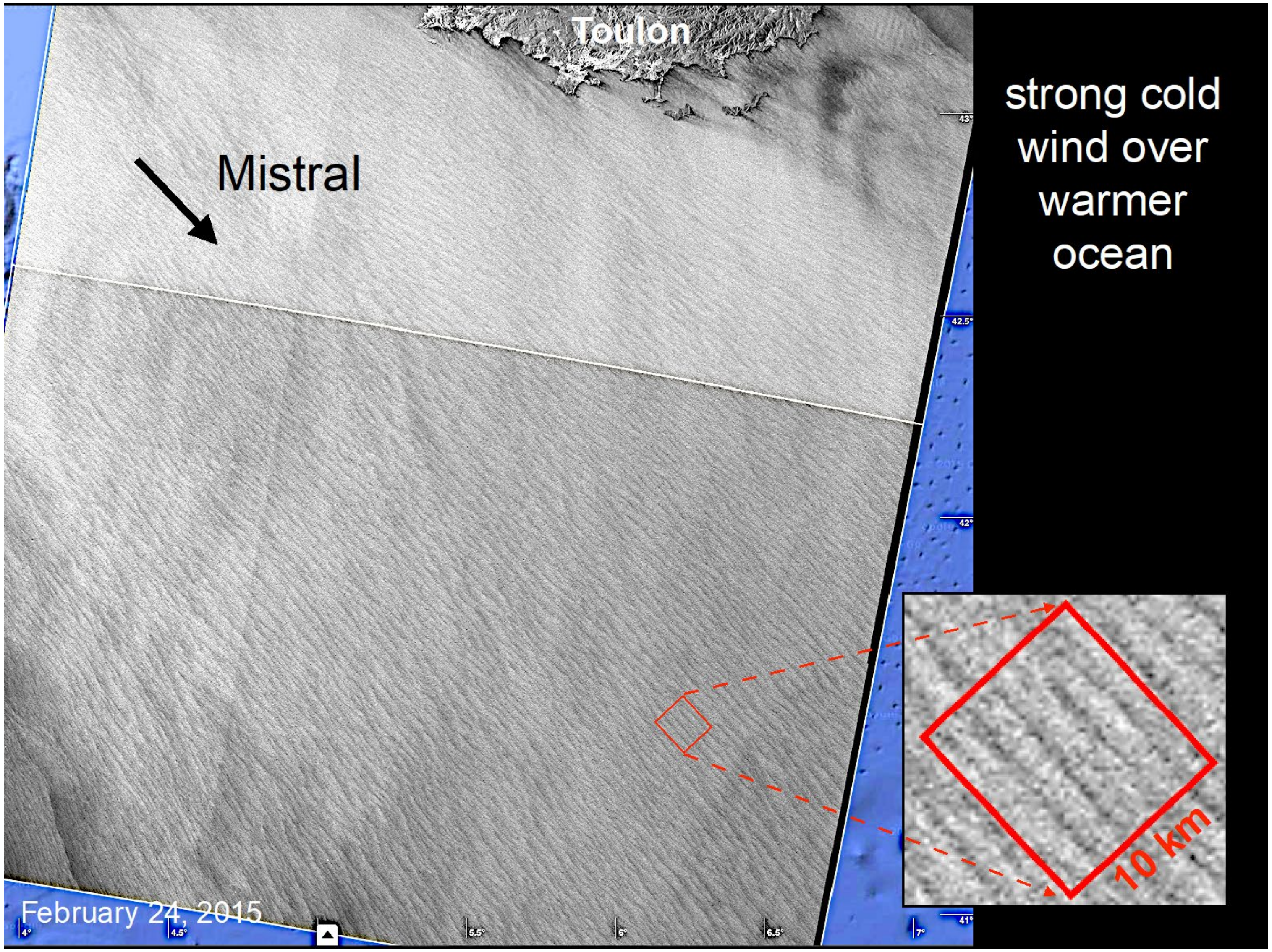


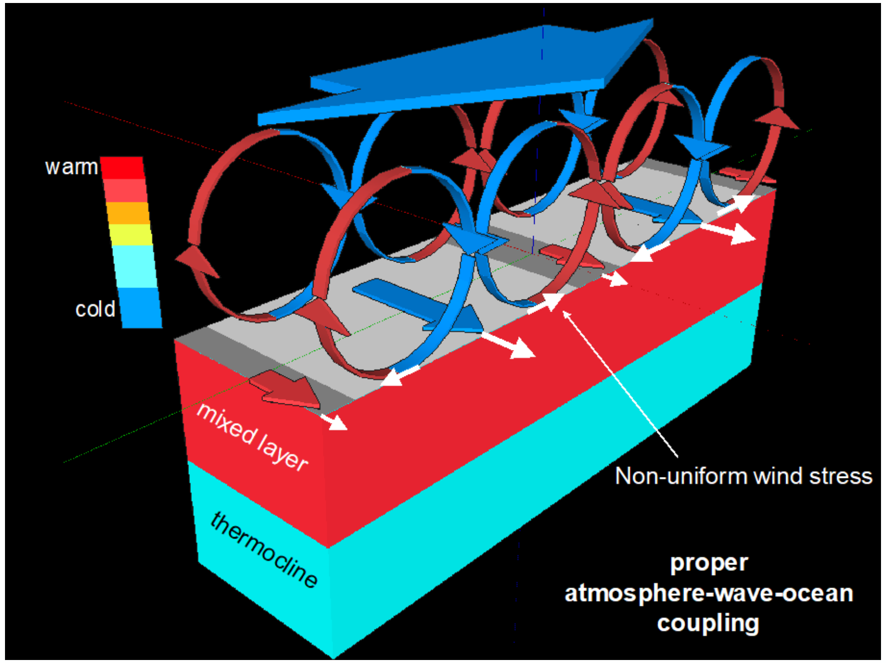
- SAR-observed **MABL structure** links closely to the **ERA5-estimated Ri**
- Nature transitions from **MC (unstable)** to **WS (neutral)**, and to **NV (stable)**

  Significant impacts on wind-only air-sea parameterization



Five along-pass Sentinel 1A WV2 images across E. Pacific SST front with coincident TAO buoy estimates of bulk Richardson number and latent heat flux. Illustrates typical ABL transitions observable in space and time using these SAR roughness data.


Toulon
Mistral
strong cold wind over warmer ocean
10 km
February 24, 2015


warm
cold
mixed layer
thermocline
Non-uniform wind stress
proper atmosphere-wave-ocean coupling

LES simulations of trade wind cumuli using MesoNH

EUREC4A field campaign, Jan-Feb 2020, Barbados (Bony et al 2017, Stevens et al 2021)

Case of the 13/02/2020, mean wind ~10 m/s

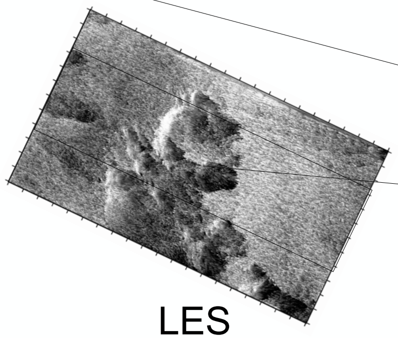
Useful domain: 200 x 120 km x 4000 m at 100-m horizontal resolution ; 100 vertical levels with resolution between 10 m (surface) and 100 m.

Atmospheric forcing (initial and open boundary conditions): AROME 1.3-km with oceanic 1D OML (Beucher at al. 2022) at 1-h

Surface forcing (SST): AROME surface analysis, no time evolution

1-moment microphysical scheme ICE3, 3D turbulence scheme with Deardorff mixing length, interactive radiative scheme.

LES simulations of trade wind cumuli using Meso-NH



LES simulation (MN Bouin et al)

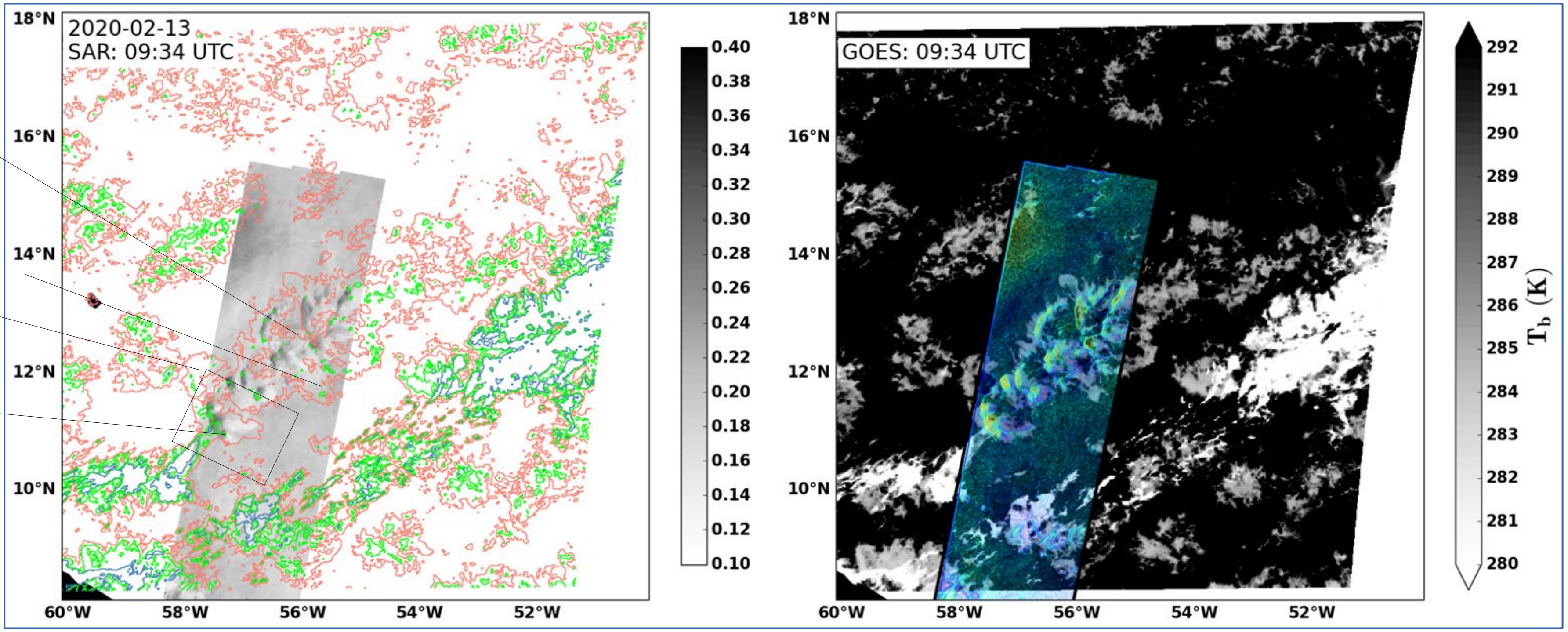
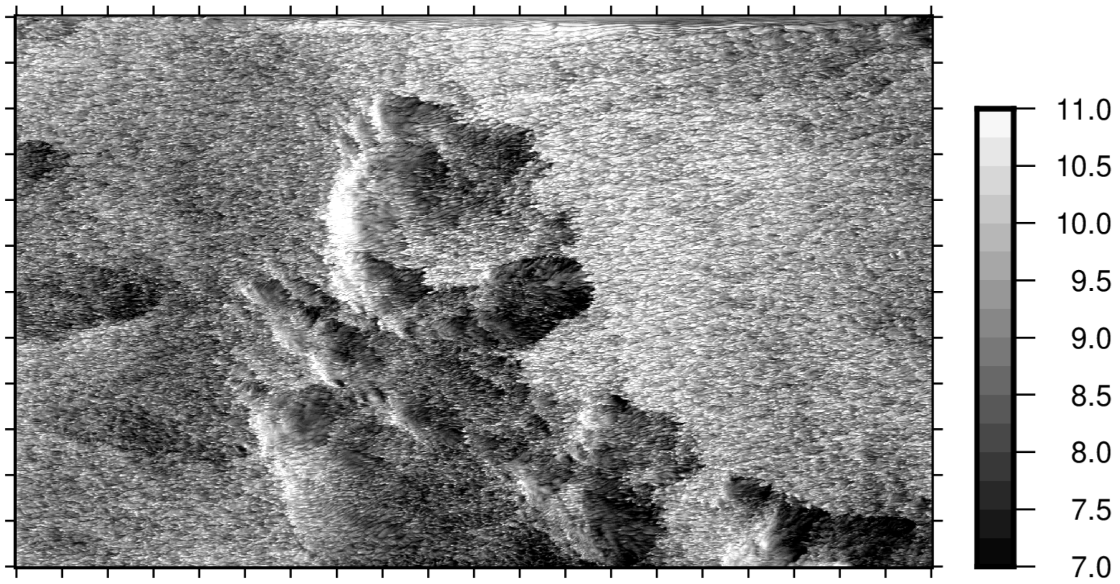


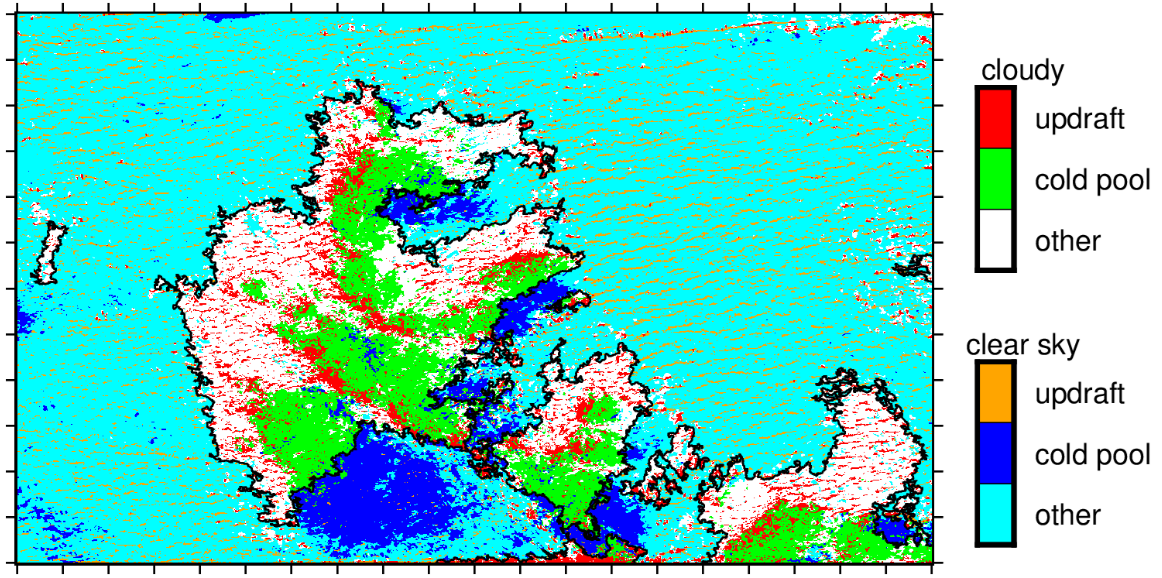
Figure P.E. Brilouet

Sentinel-1A wide swath + GOES-16 brightness temperature 13/02/2020 at 09:34 UT

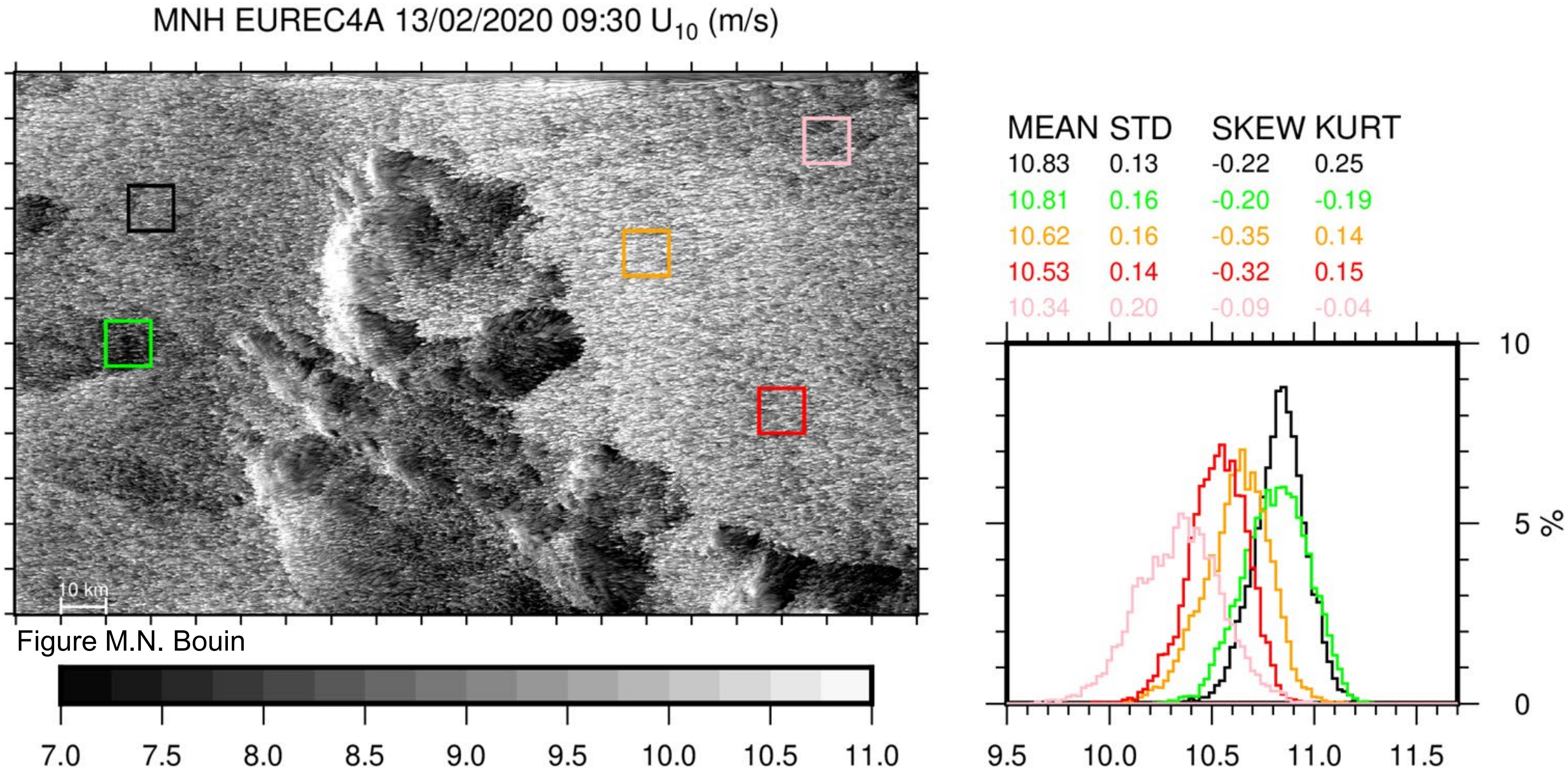
(BT contours: red = 292 K, green = 287 K, blue = 280 K)

LES simulations – outputs – surface wind + processes



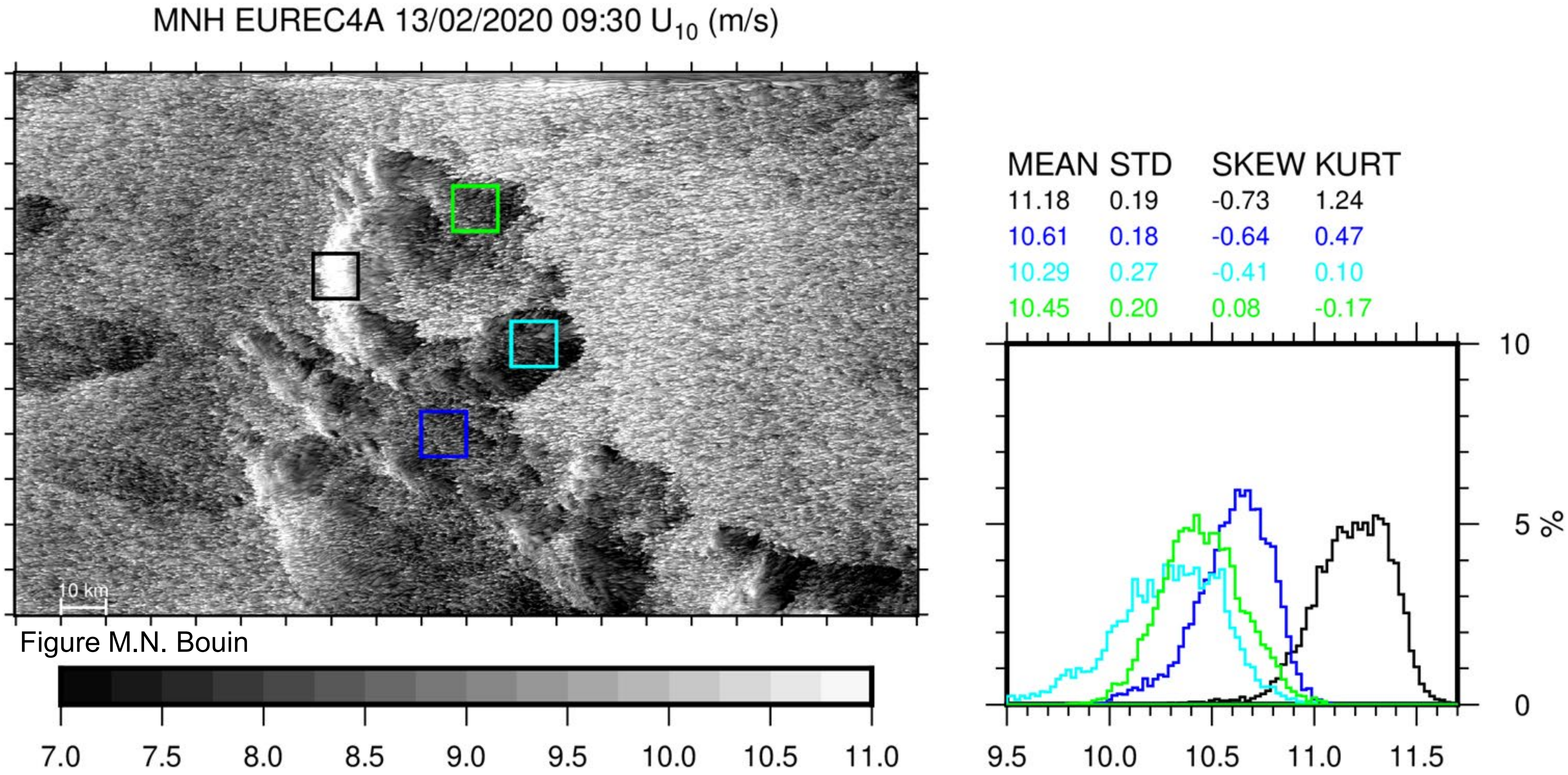


LES simulations – surface wind distribution – clear sky



MEAN	STD	SKEW	KURT
10.83	0.13	-0.22	0.25
10.81	0.16	-0.20	-0.19
10.62	0.16	-0.35	0.14
10.53	0.14	-0.32	0.15
10.34	0.20	-0.09	-0.04

LES simulations – surface wind distribution – clouds



MEAN	STD	SKEW	KURT
11.18	0.19	-0.73	1.24
10.61	0.18	-0.64	0.47
10.29	0.27	-0.41	0.10
10.45	0.20	0.08	-0.17

Earth system complexity: Harmony combined observations to provide very high resolution quantitative estimates of Ocean-Atmosphere, local and non-local interactions

WRCP (P. Brasseur): 2028, an International Earth System Year, with intensive observational and modeling activities to investigate the complexity of planetary dynamics

A main grand Challenge is that a DTO must serve to improve our capabilities to estimate What is going on, to improve model parameterizations, to anticipate so What and What if questions: Extreme events and trend amplifications, defined as results of the synergistic action between low probability events and dynamics

Reference data at very high resolution are absolutely needed, and will directly serve calibration/emulation of sub-grid processes (to assess impacts on resolved scales)