Overview of the EUREC^{4}A field campaign

- Recap of the main objectives
- Present status of facilities
- Present status of planning

EUREC^{4}A Planning workshop, Paris, 24 Sept 2019

1. Recap of the main scientific objectives

EUREC^{4}A: A field campaign to elucidate the couplings between clouds, convection and circulation

Sandrine Bony · Bjorn Stevens · Felix Ament · Sebastien Bigorre · Patrick Chazette · Susanne Crewell · Julien Delanoë · Kerry Emanuel · David Farrell · Cyrille Flamant · Silke Gross · Lutz Hirsch · Johannes Karstensen · Bernhard Mayer · Louise Nuijens · James H. Ruppert Jr. · Irina Sandu · Pier Siebesma · Sabrina Speich · Frédéric Szczap · Julien Totems · Raphaela Vogel · Manfred Wendisch · Martin Wirth

August 28, 2017

Surveys in Geophysics (2017)

1. Recap of the main scientific objectives

EUREC^{4}A: A field campaign to elucidate the couplings between clouds, convection and circulation

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Surveys in Geophysics (2017)

During the last years,

additional objectives have emerged

EUREC^{4}A Early Career Scientist Meeting 23. Sept. 2019

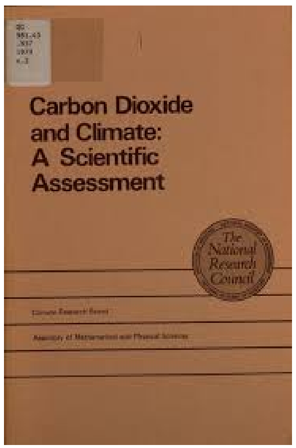
room 107 (https://eurec4a.sciencesconf.org/resource/acces)

9:00	Welcome	
9:10	Overview of the EUREC^{4}A experiment	Sandrine Bony
9:40	The role of ECS in EUREC^{4}A	Bjorn Stevens
10:00	Who is who	
10:15	Combining microwave radiometer and differential absorption radar for water vapor profiling in the cloudy trade wind environment	Sabrina Schnitt
10:30	Case study analysis on precipitation detection in model and observation: how to to compare using PAMTRA	Claudia Acquistapace
10:45	**coffee/tea break**	
11:15	Development and mixing of moist convection	Thibaut Dauhut
11:30	Humidity and ice clouds in the upper troposphere	Theresa Lang
11:45	Capturing water vapor variability in satellite retrievals during EUREC^{4}A	Marc Prange
12:00	Gravity waves and convection	Claudia Stephan
12:15	Discussion	
12:30	**lunch break**	
14:00	Diurnal cycle of tradewind cumuli	Jessica Vial
14:15	Influence of the large-scale environment on cloudiness	Geet George
14:30	The effect of mesoscale eddies on air-sea interactions	Yanxu Chen
14:45	Measuring the mass flux of tropical shallow cumulus clouds	Marcus Klingebiel
15:00	Estimating the shallow convective mass flux from the sub-cloud layer mass budget	Raphaela Vogel
15:15	A (future) tool for setting up LES/SCM simulations	Steven Boeing
15:30	**coffee/tea break**	

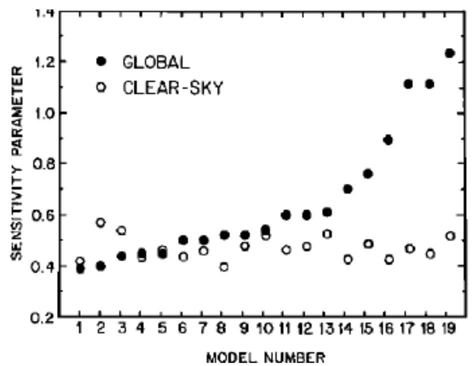

How sensitive is the Earth's climate?

Some historical context...

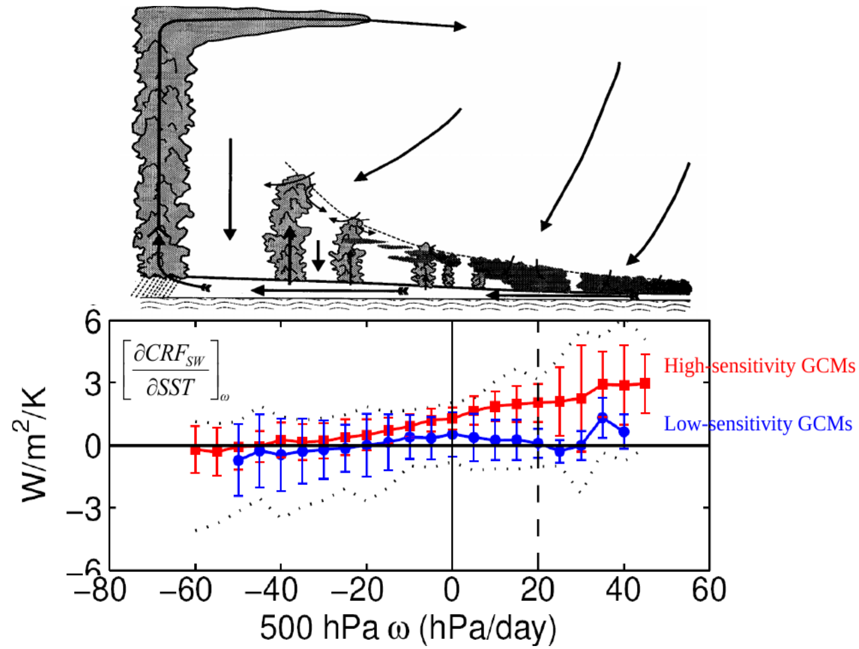
1979 : Charney report
ECS : 1.5-4.5C



1989 : Bob Cess (FANGIO)
Cloud feedbacks are the problem

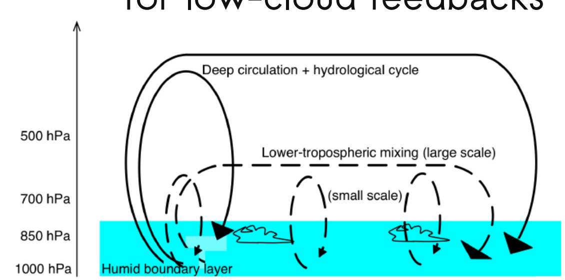


1999-2006 : CFMIP, CMIP, IPCC-AR4 :
Low-cloud feedbacks are the problem

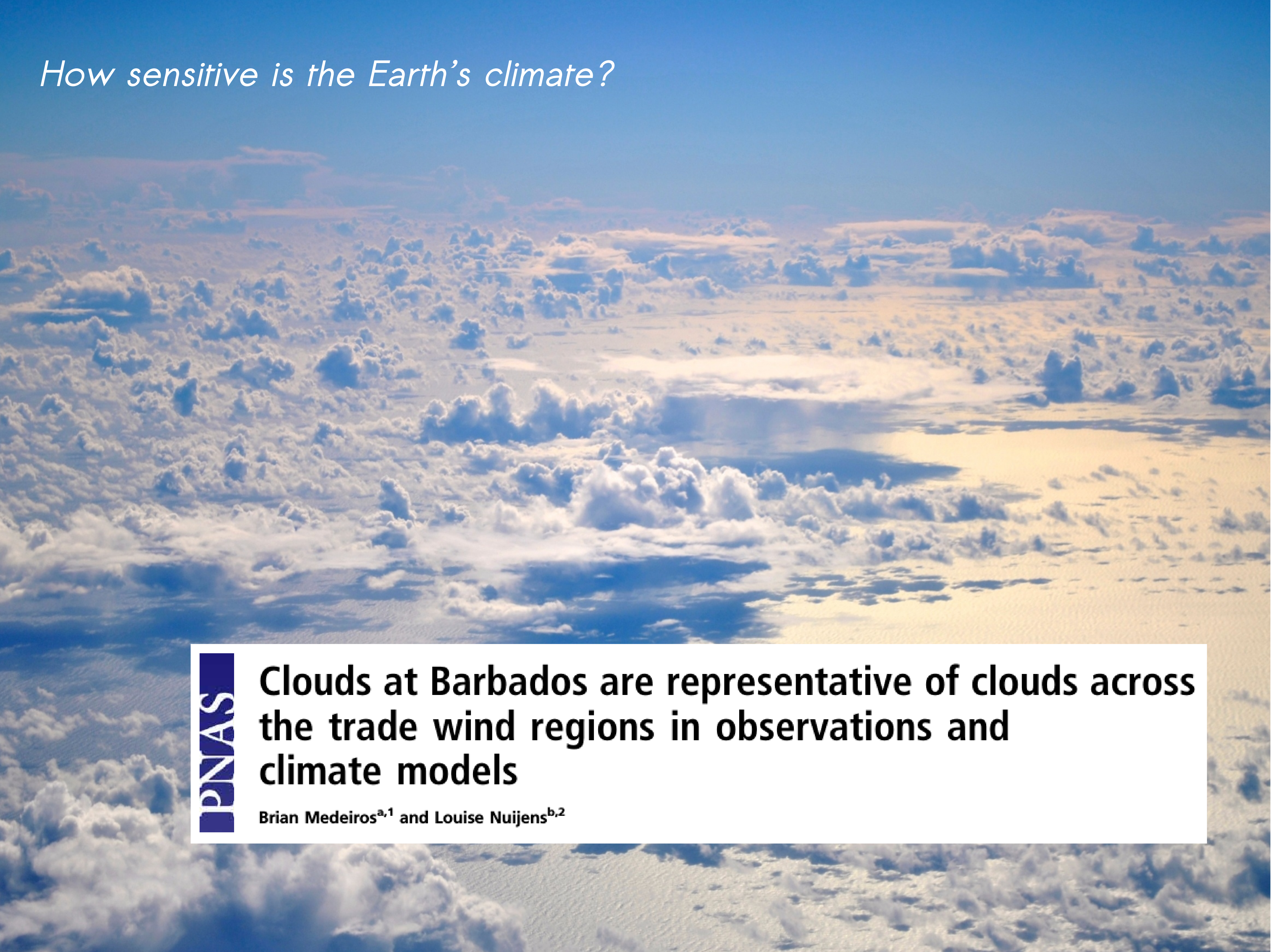


2010 : MPI-CIMH set up the
Barbados Cloud Observatory

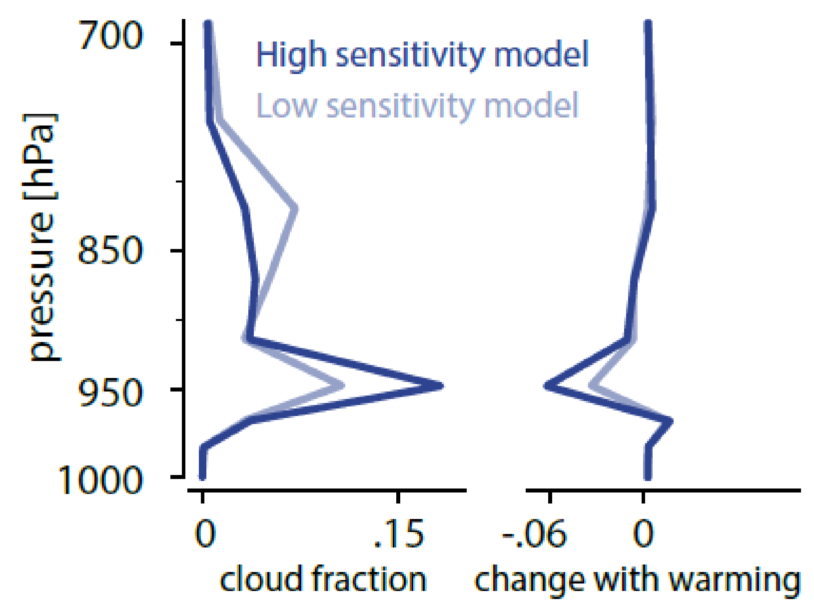
2010-2015 : EUCLIPSE :
cloud-circulation coupling critical
for low-cloud feedbacks



EUREC4A
WCRP World Climate Research Programme


How sensitive is the Earth's climate?
PNAS
Clouds at Barbados are representative of clouds across the trade wind regions in observations and climate models
Brian Medeiros[a,1] and Louise Nuijens[b,2]

How sensitive is the Earth's climate?

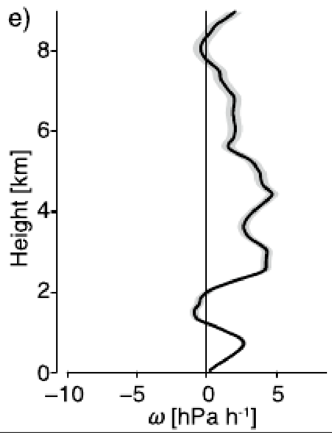


High climate sensitivity models predict a dessication of clouds at their base, that depends on the strength of vertical mixing im the lower troposphere

What controls trade-wind cloudiness ?

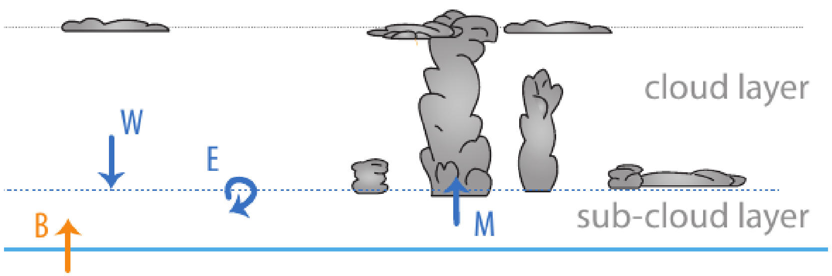
Low-cloud-controlling factors

- Lower-tropospheric mixing
- Large-scale vertical motion
- Inversion strength
- Surface wind & turbulence
- Free-tropospheric humidity
- Sea surface temperature



Cloud properties

(macrophysical, microphysical, radiative)



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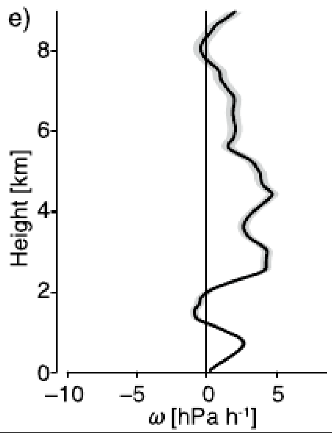

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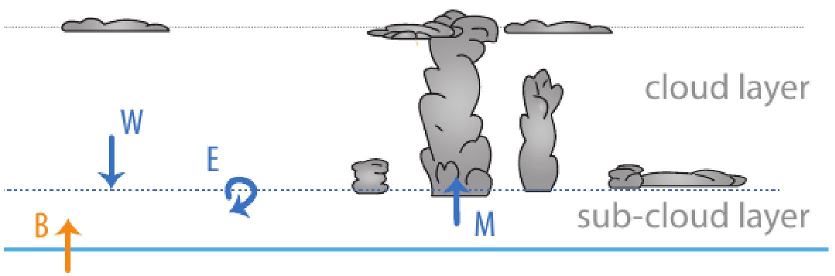
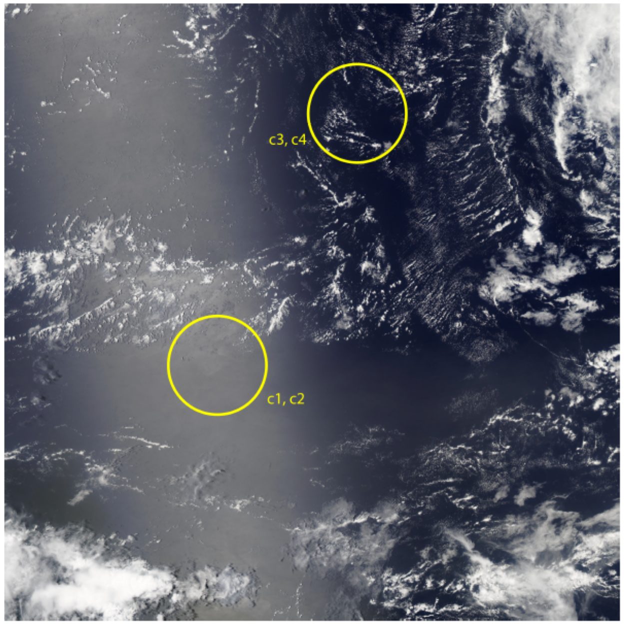
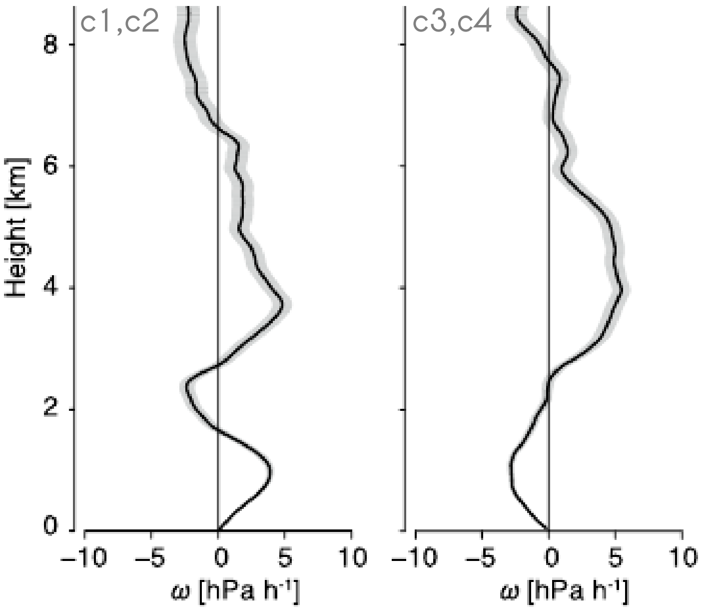


→ Characterization of the large-scale environment in which the clouds form :





Vertical profiles of T, q, P, u, v, mass divergence and area-averaged vertical motion will be measured with dropsondes

George et al

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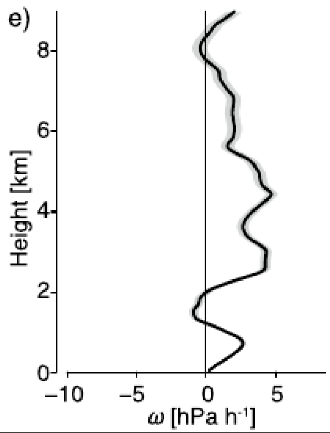

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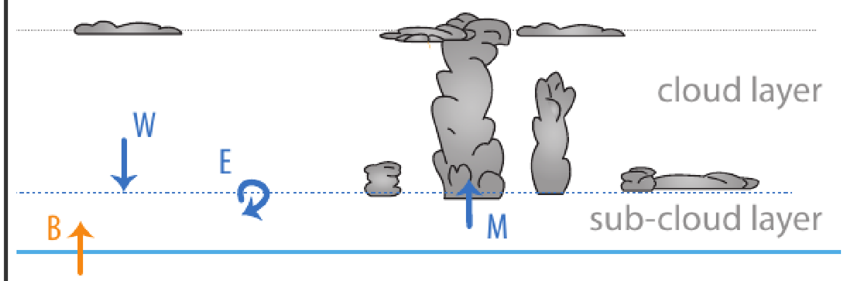


→ Quantification of the lower-tropospheric mixing by convection:

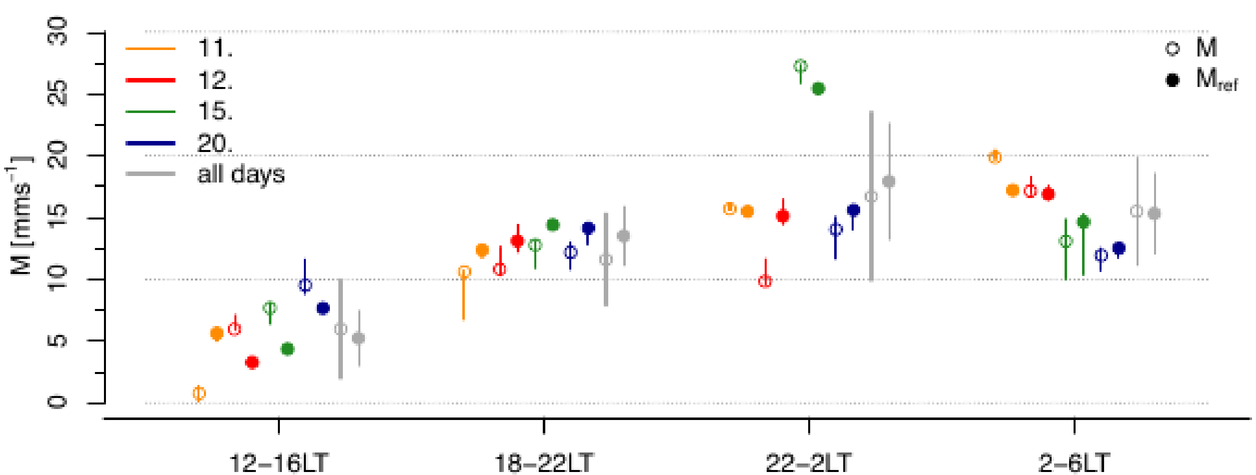


Fig. Comparison of mass budget M and core-sampled M_{ref}.

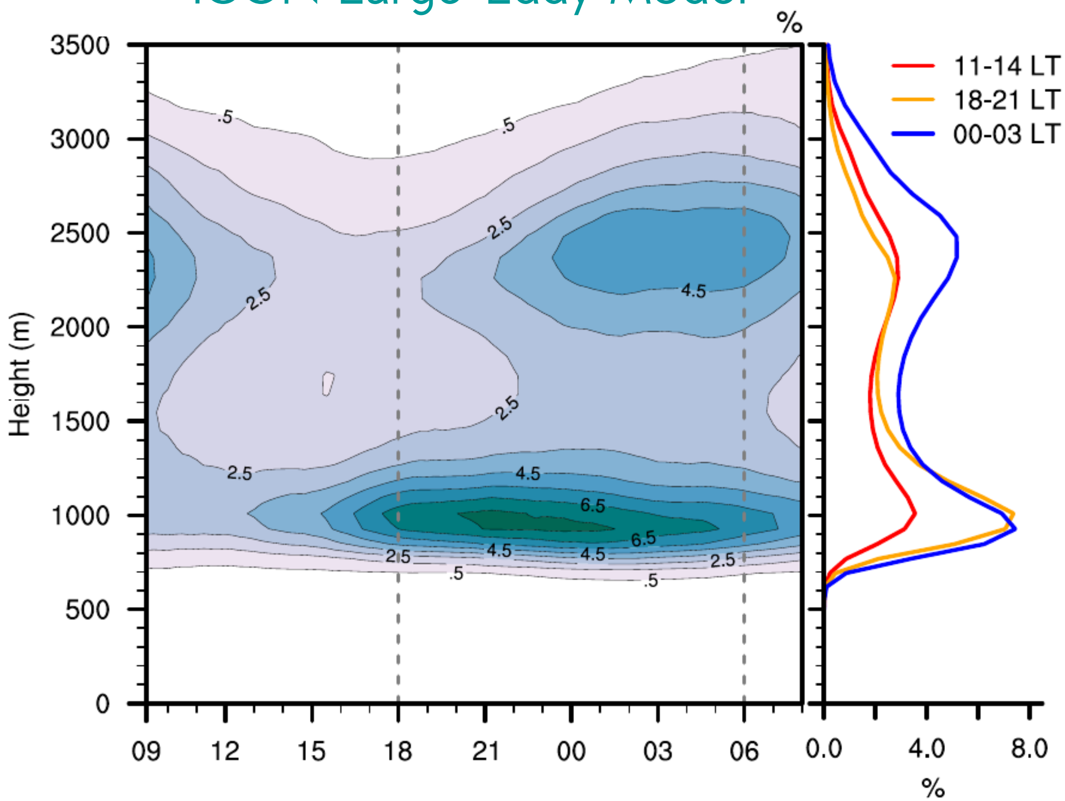
The convective mass flux at cloud base can be estimated from the mass budget of the subcloud layer

Vogel et al (2019)

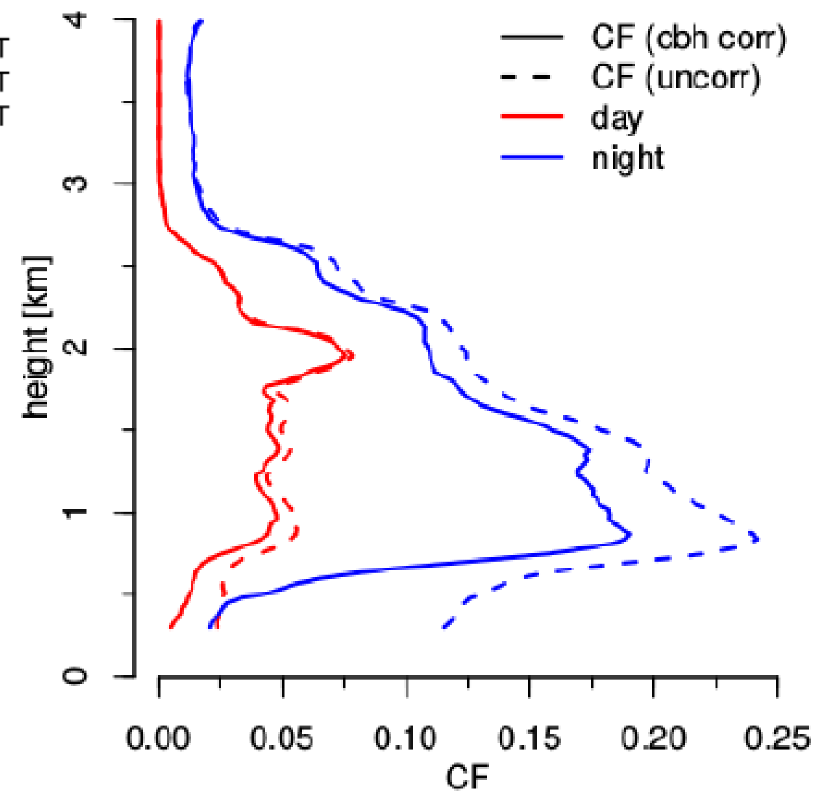
Diurnal cycle

Vertical distribution of cloud fraction

ICON Large-Eddy Model

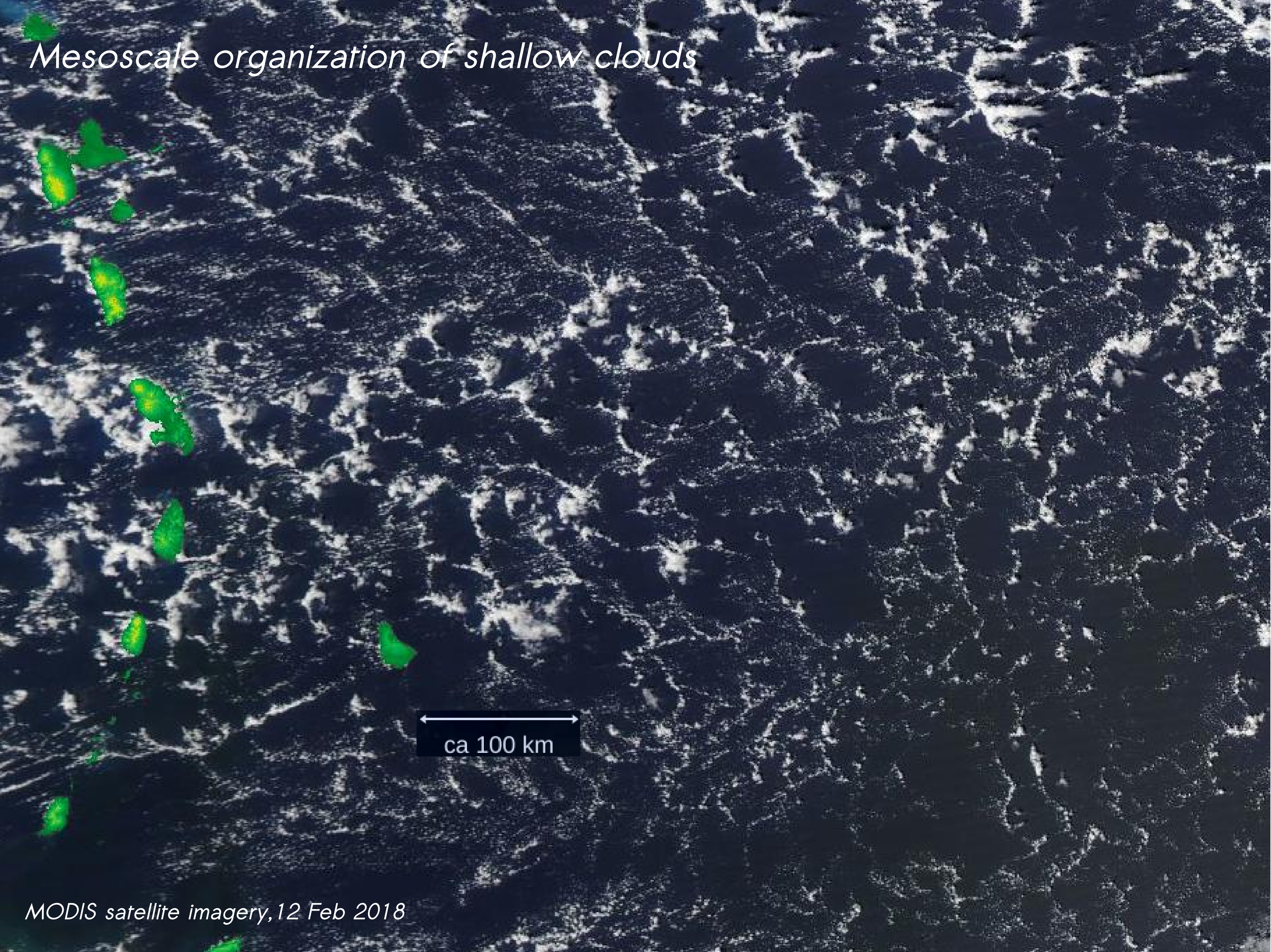


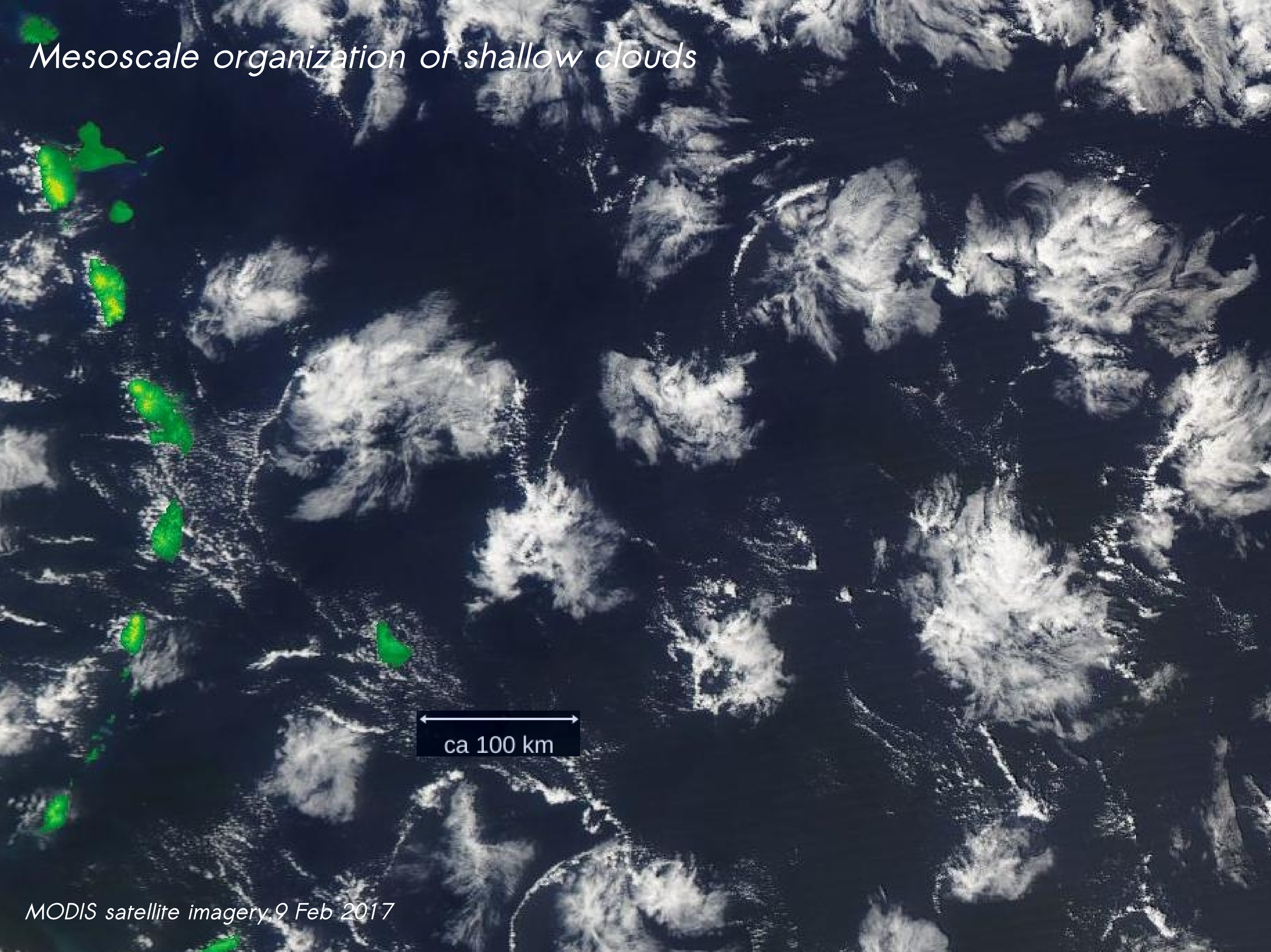
Barbados Cloud Observatory



→ A forced variability to be understood (turbulence, convection, radiation, LS dynamics)

Vial et al. (2019)


Mesoscale organization of shallow clouds
ca 100 km
MODIS satellite imagery,12 Feb 2018


Mesoscale organization of shallow clouds
ca 100 km
MODIS satellite imagery, 9 Feb 2017

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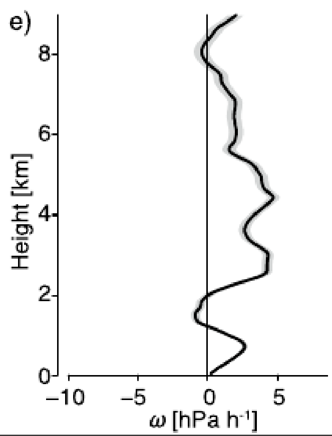
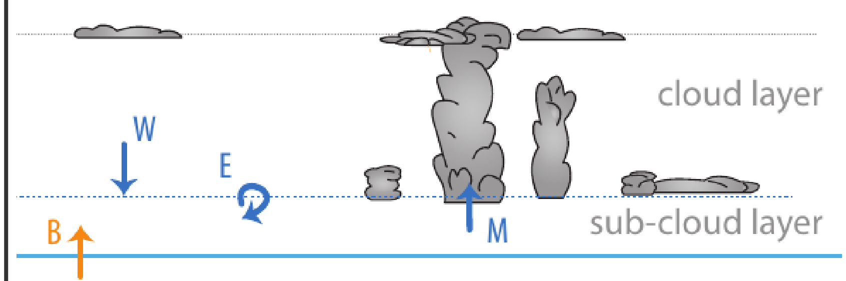
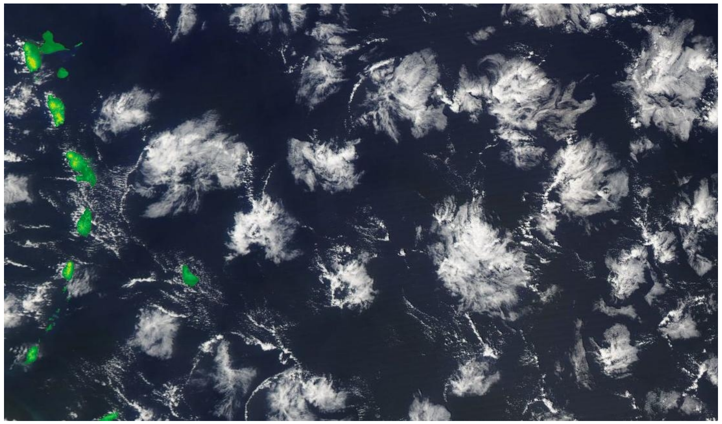


Cloud properties

(macrophysical, microphysical, radiative)

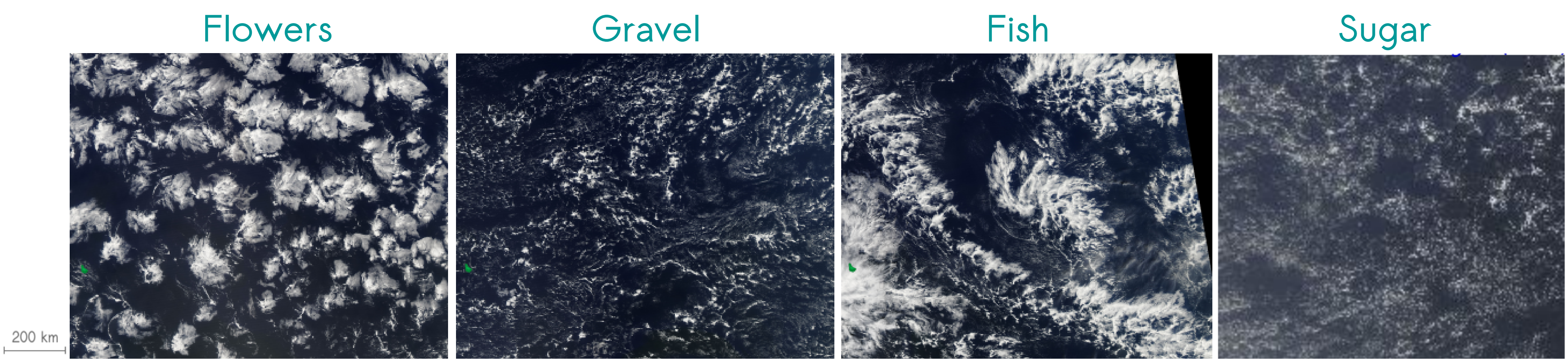


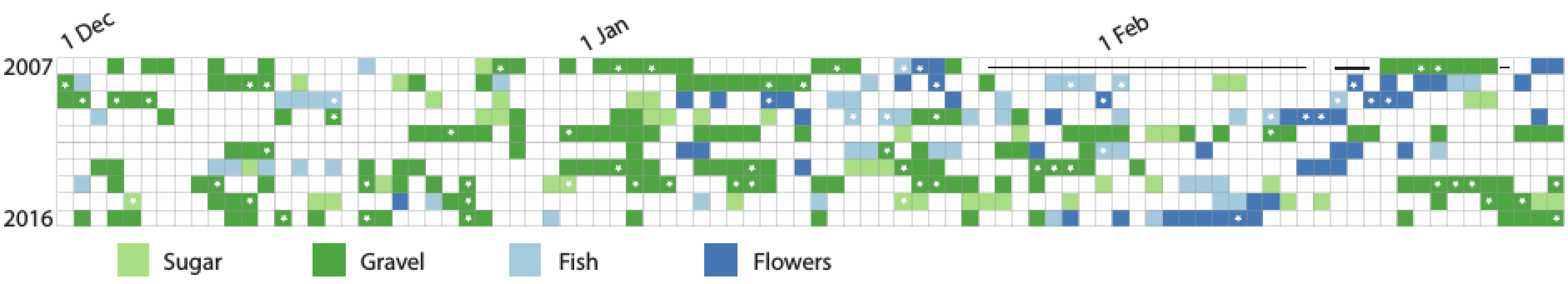
Mesoscale organization



Mesoscale organization of shallow clouds

Most prominent cloud patterns during winter





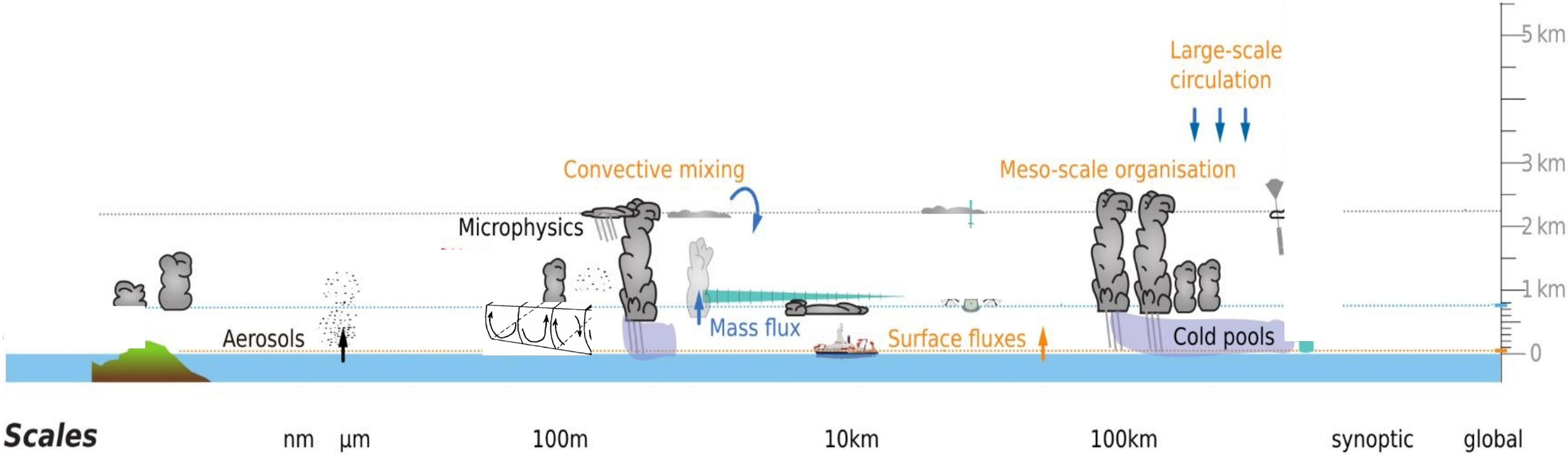
→ Drivers of the mesoscale organization of convection ?

→ Dependence on the large-scale environment, on subcloud-layer characteristics ?

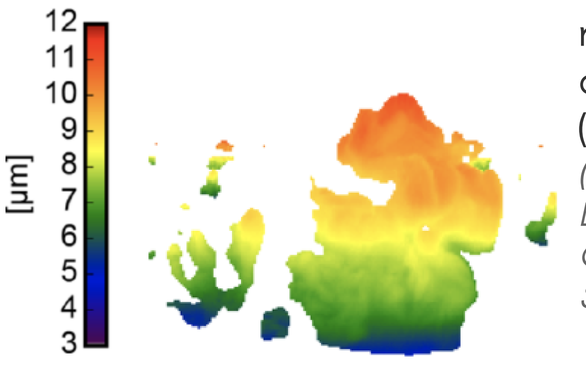
→ Impact on cloud properties?

Bony, Denby, Rasp, Schulz, Siebesma, Stevens et al.

Turbulence, Aerosols, Microphysics and Convective dynamics



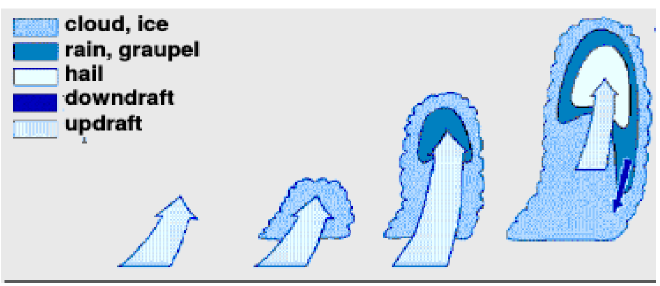
EUREC4A-UK (Blyth, Boeing, Parker et al)



DLR & LMU (Ewald & Mayer)

Particles : aerosols (size, nature, concentration), cloud droplets (size, (concentration)

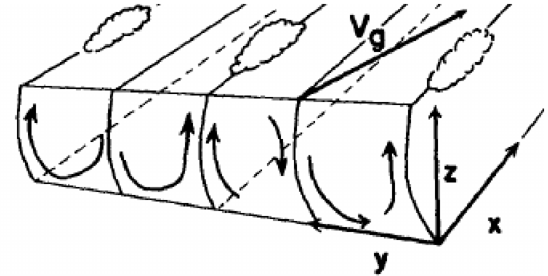
(Bodenschatz, Chazette, Delanoë, Feingold, Naumann, Quinn, Schwarzenboeck, Schröder et al)



PoldiRad (Hagen)

Development of rain and downdraughts, life cycle of precipitation cells, cold pools, gust fronts, detrainment layer

(Acquistapace, Hagen, Klingebiel, Konow, Naumann, Zuidema et al)

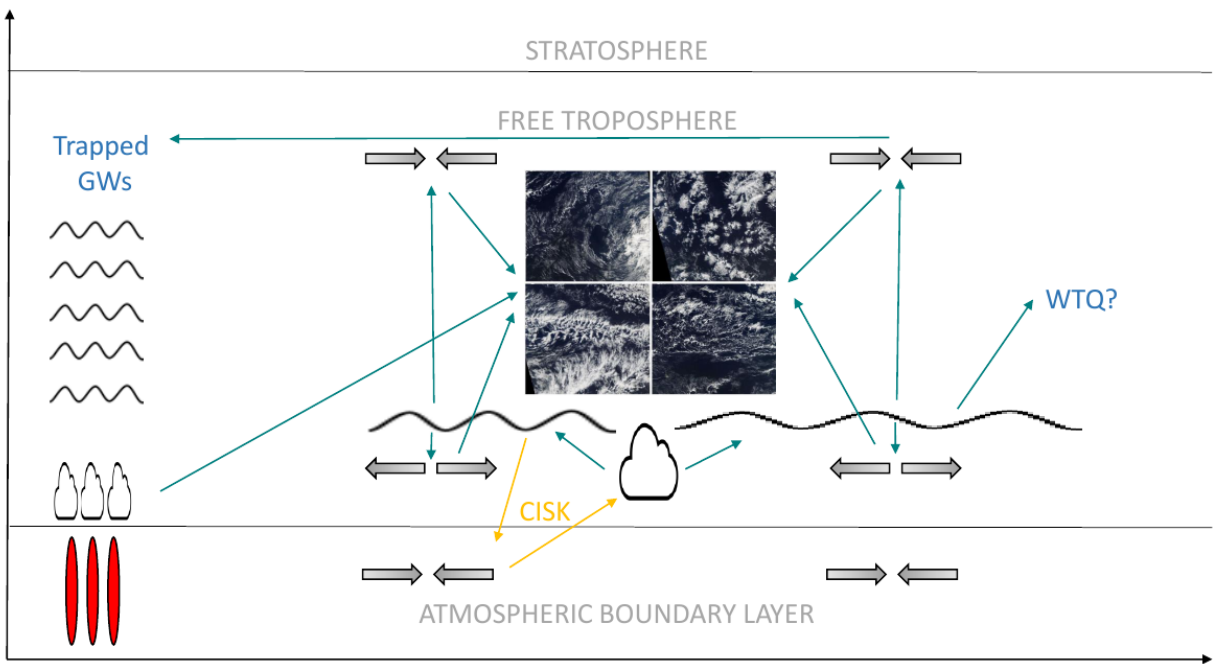


Turbulence within the subcloud layer (coherent structures, along wind and cross wind)

(Brilouet, Lothon, Malinowski et al)

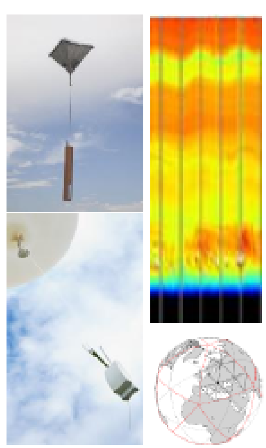
Waves - clouds interactions

- What is the composition of the waves background ?
- Discrete, continuous ?
- What does it depend on ?
- How do clouds couple to waves on different scales ?



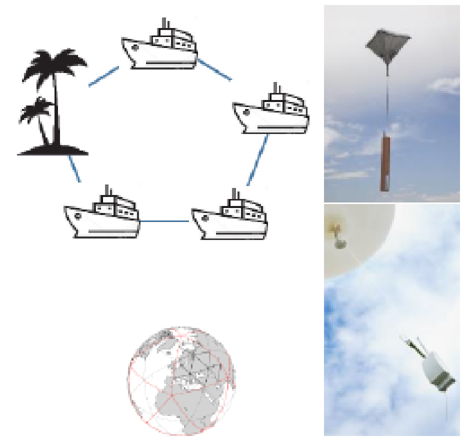
Stephan, Bellenger, de Szoeke et al.

cloud scale (5-30 km)

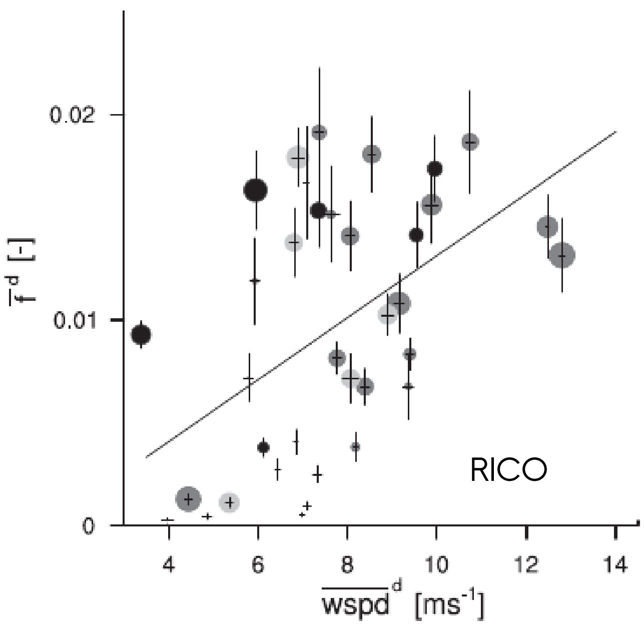


mesoscale (200 - 600 km)

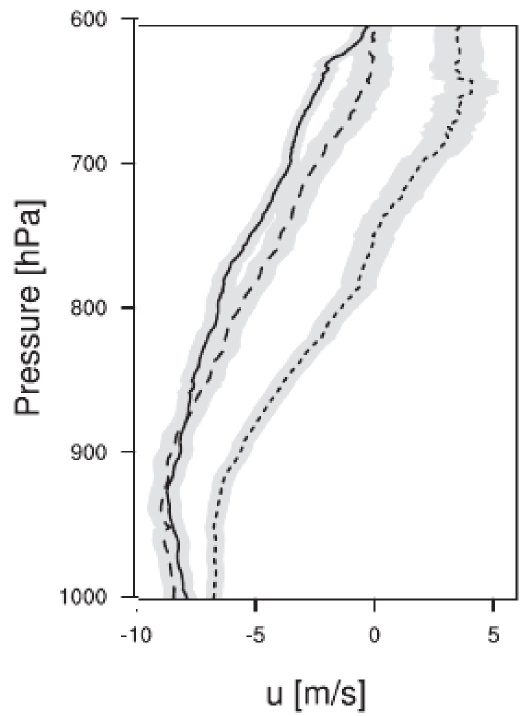
synoptic scale (*O* 1000 km)



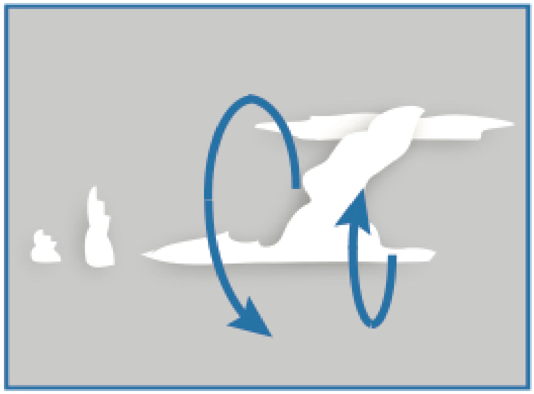
What controls the characteristics of the trade winds?



Nuijens et al., J. Clim (2009)



Interaction between clouds and wind ?
(momentum transport)



CloudBrake

→ Understand the coupling between wind and clouds

→ What controls the vertical profile of wind?

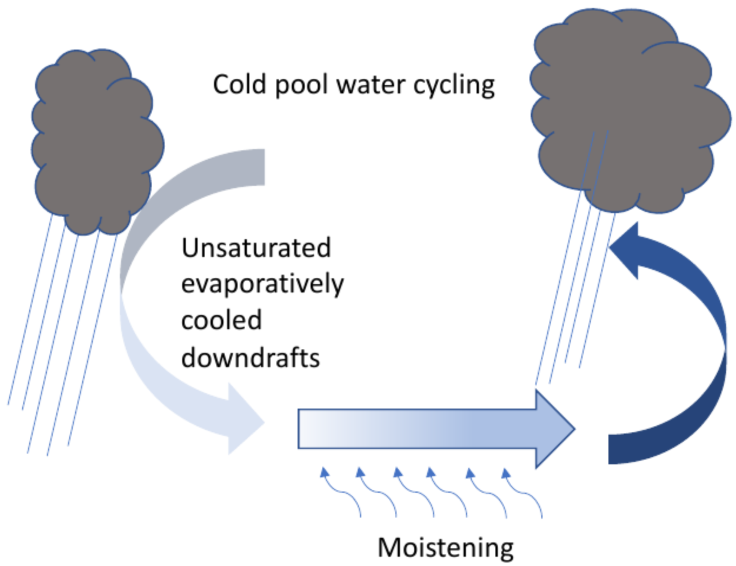
→ implications for wind energy production, cold pools structure, etc

Farrell, Forde, Nuijens, Sandu et al.

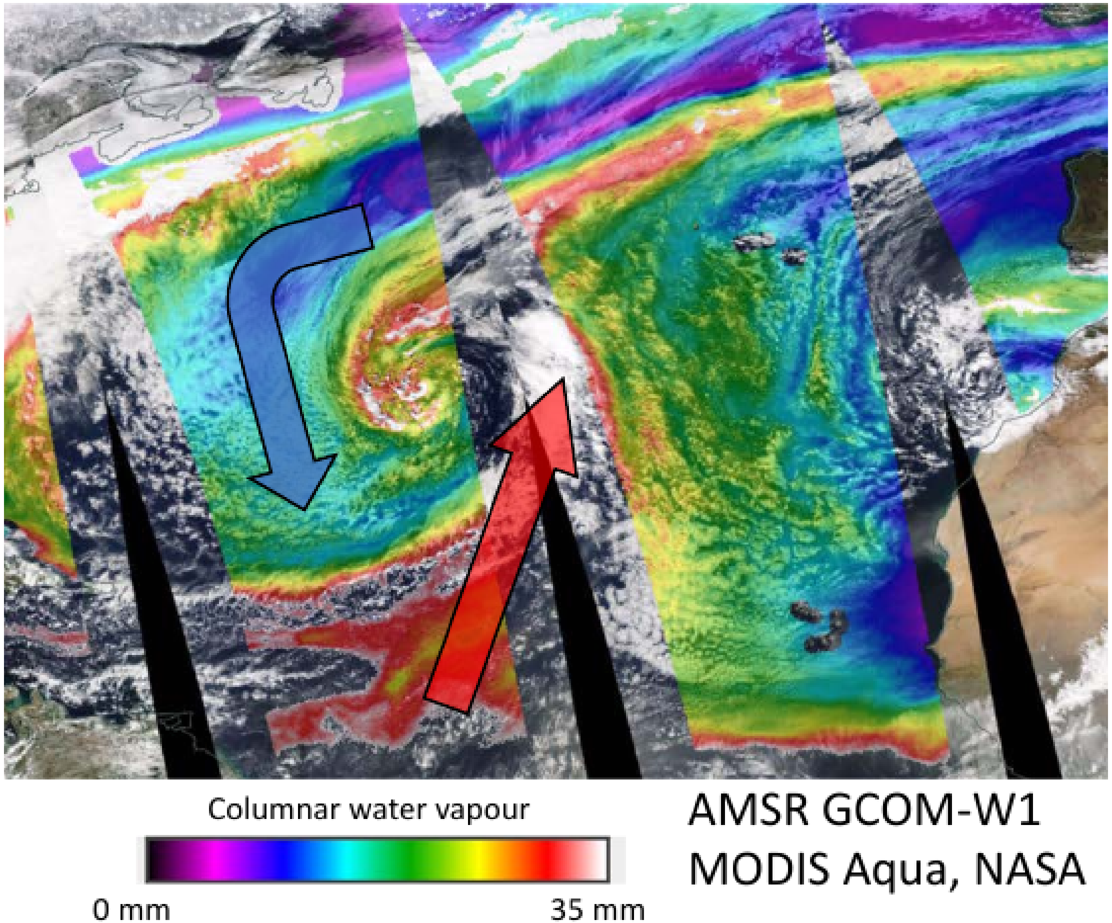
What controls the water budget of the boundary-layer?

Determine the relative influences of :

- Surface evaporation
- Unsaturated downdrafts
- Turbulent entrainment
- Extratropical intrustions



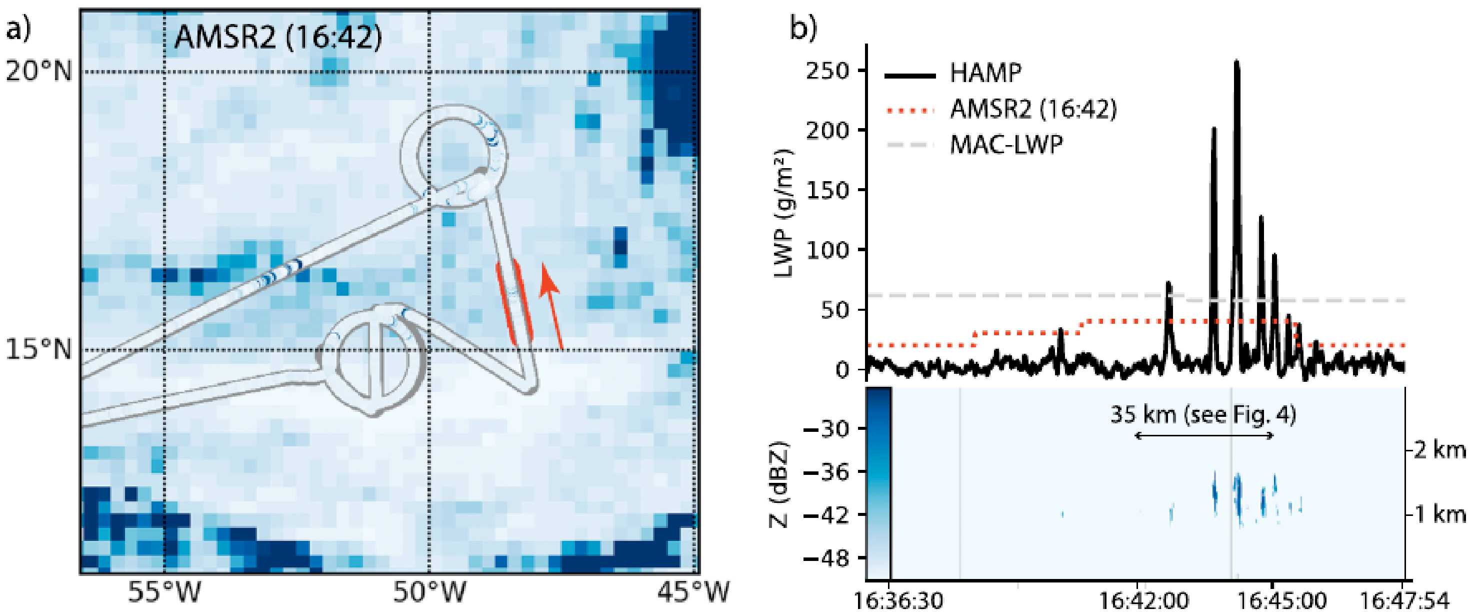
Aemisegger, Flamant, Galewsky, Noone, Pfahl, Reverdin, Risi, Sodemann, Villiger, Wirth et al.

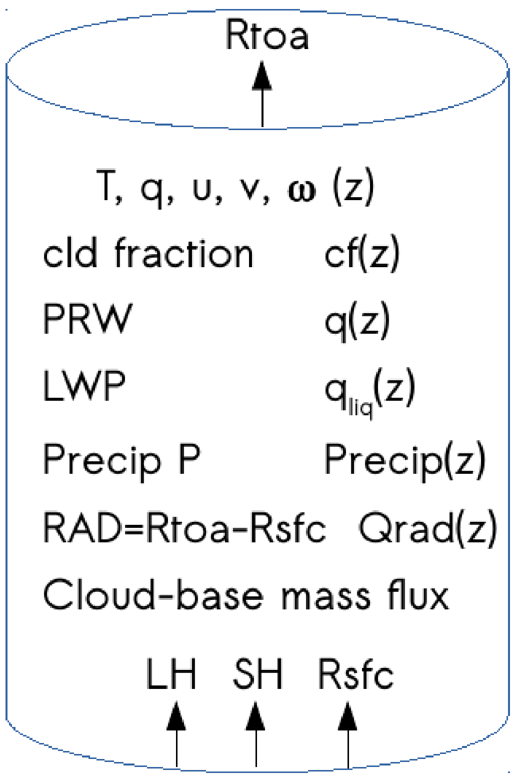


→ inferred from the water isotopic composition (δHDO, $\delta H_2{}^{18}O$)

→ MSE budgets will be assessed as well *(Emanuel)*

Satellite validation and retrievals ; Water and energy budgets

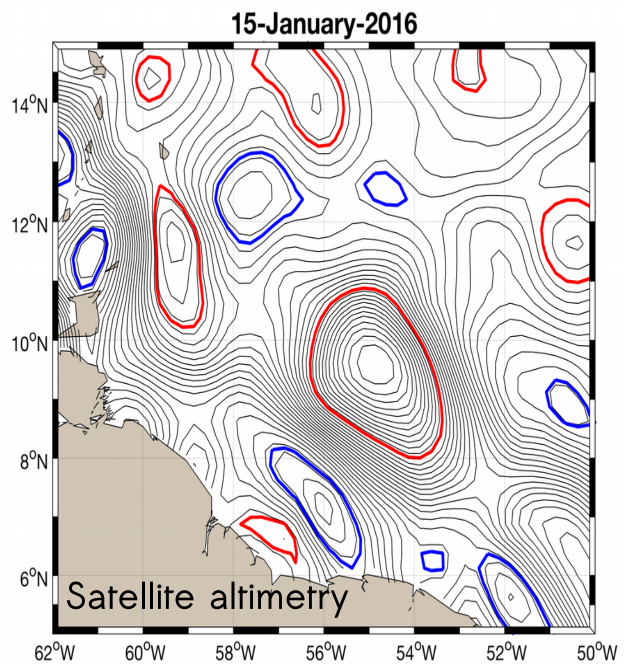




- Local & statistical evaluation of satellite retrievals (AMSR2, GPM, ADM-Aeolus..)
- Water and energy budgets of the atmospheric column

Buehler, Crewell, Delanoë, Gross, Jacob, Mace, Mayer, Pincus, Schnitt, Wendish et al.

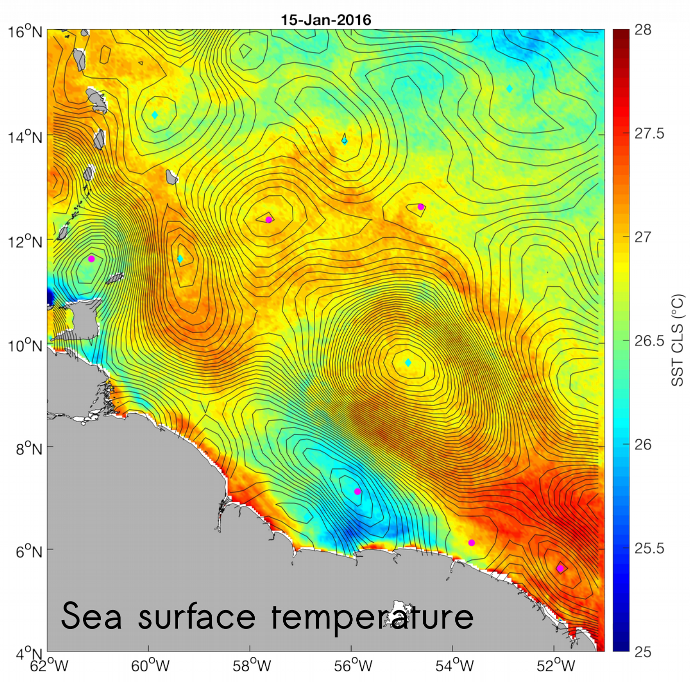
Ocean-Atmosphere interactions and ocean (sub)mesoscale processes

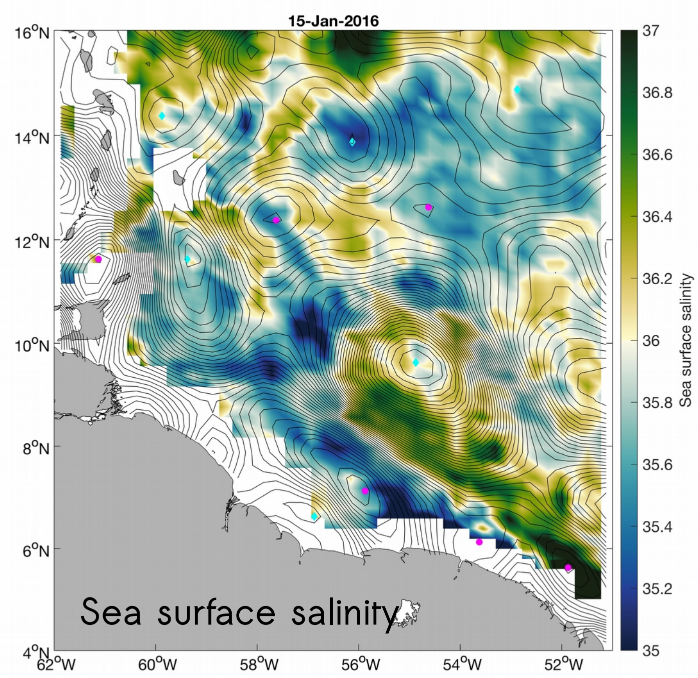


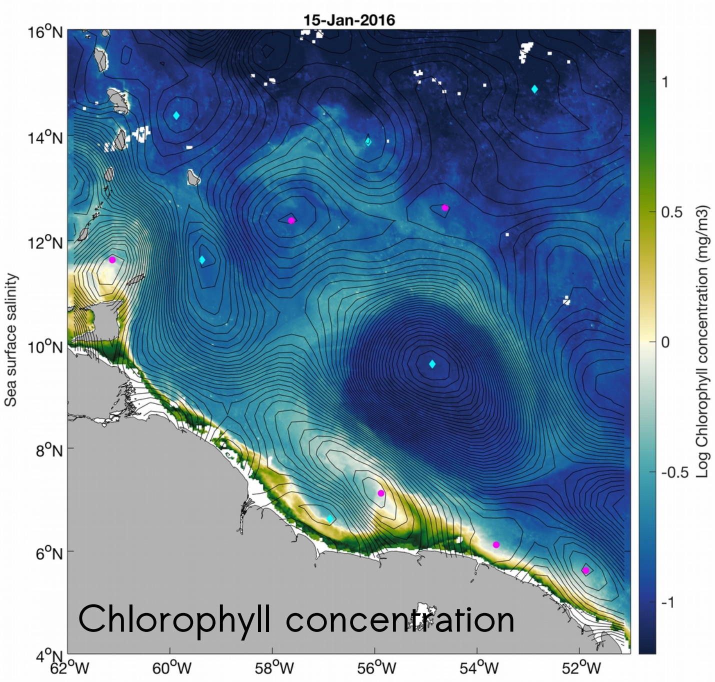
Will observe, simulate and advance understanding of:

- Oceanic and atmospheric boundary layers
  - → diurnal cycle of the ocean-atmosphere coupled system ?
- Mesoscale ocean eddies, submesoscale (10m-10km) and mesoscale (10km-500km) structures
  - → their evolution and impact on the ocean structure ?
  - → their contribution to air-sea interactions ?
  - → their interaction with atmospheric convection ?

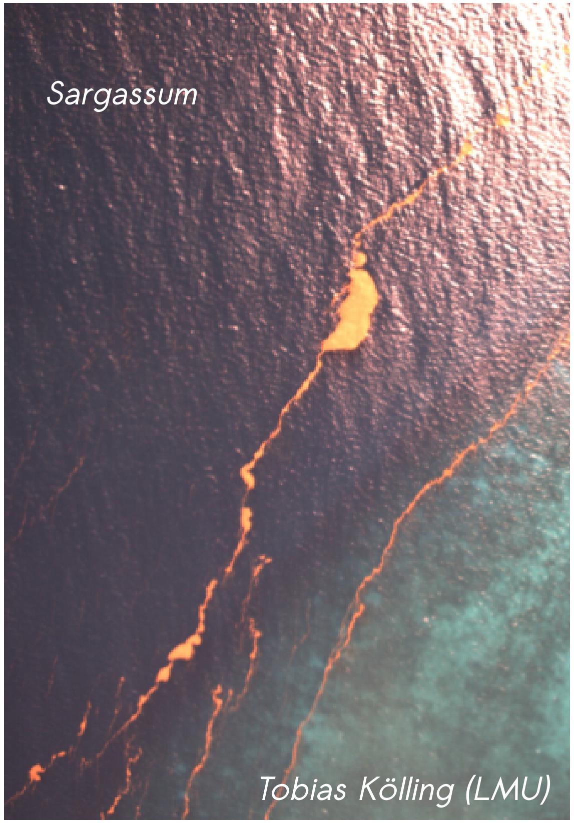
Karstensen, Speich, Chen, Couvreux, et al ; ATOMIC





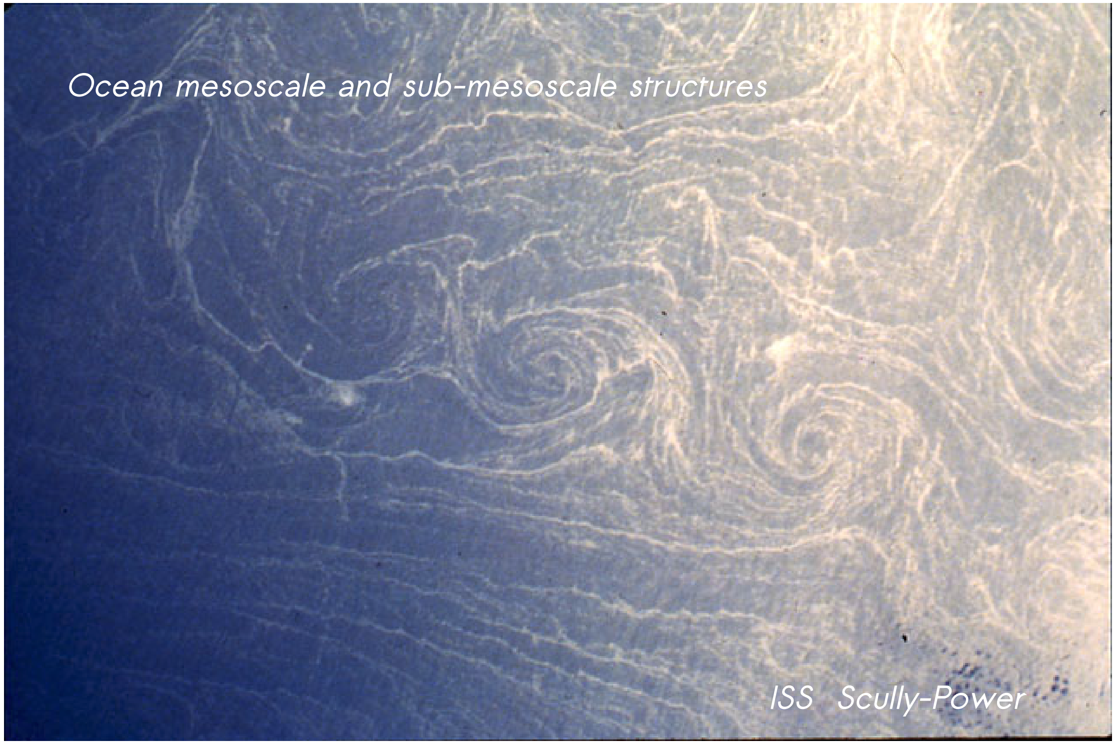


Ocean-Atmosphere interactions and ocean (sub)mesoscale processes



- How to mesoscale and sub-mesoscale processes influence clouds, ocean mixing, nutrients, air-sea exchanges of heat, momentum & CO_2?

- At what amplitude and scale does the atmospheric boundary layer 'feel' ocean surface heterogeneities ?

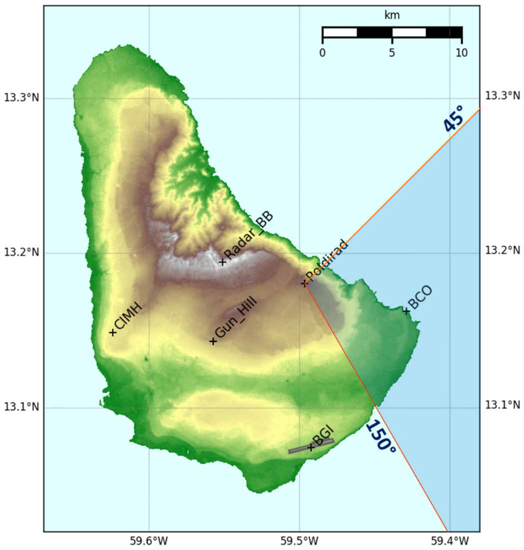


McWilliams, Redelsperger, Renault, et al.

2. Present status of the facilities

Barbados Cloud Observatory (since 2010)

Barbados Cloud Observatory (since 2009) and PoldiRad



Radars

- High-powered (2m dish) K-band polarized cloud radar, CORAL.
- W-band vertically staring polarized cloud radar (Rumba)
- PolidRad (C-band) high power, polarized scanning radar)
- Micro-rain radar (vertically staring radar disdrometer)

Lidars

- High-powered water vapor Raman lidar, CORAL. (25 km range)
- 2 wind lidars (vertical and horizontal, range ca 1 km)
- Ceilometer

Meteorology

- Microwave radiometer
- Standard Met and Broadband Irradiances (direct and indirect)
- Aerosol sampling and CCN measurements

Ewald, Forde, Hagen, Hirsh, Jensen et al.

Aircraft

ATR-42
(SAFIRE, FR)

G-5 HALO
(DLR, DE)

WP-3D
(NOAA, USA)

TwinOtter
(BAS, UK)

C-26A
(RSS, Barbados)

Large-scale environment :
- dropsondes (HALO, P3)
- water vapor lidar (HALO)
- passive radiometers (HALO)
- meteorology

In-situ particles and cloud properties:
- particle sizes : 60 nm - 1280 µm (ATR) ;
0.5 µm - 6200 µm (P3); 10 nm - 1900 µm (TO)
- cloud water content (ATR, TO)

Remotely-sensed particle properties :
- cloud radars (ATR <u>horiz+vertical</u>, HALO, P3)
- backscatter lidar (ATR horiz, HALO)
- microwave radiometers (HALO, P3)

Turbulence :
- eddy covariances for enthaply, momentum (ATR, TO)
- doppler spectrum from radar (ATR, HALO)

Precipitation:
- scanning precip radar (P3)

Water isotopes :
- in the atmosphere (ATR, P3)

Radiation :
- broadband LW, SW fluxes (ATR, HALO, TO)
- spectrometers (HALO)
- imagers and cameras (ATR, HALO, TO)

Sea surface temperature:
ATR, HALO, P3

Research Vessels

Atalante (A, FR)

Maria S Merian (MSM, DE)

Meteor (M, DE)

Ron Brown (RB, USA)

+ Barbados Defense Force ?

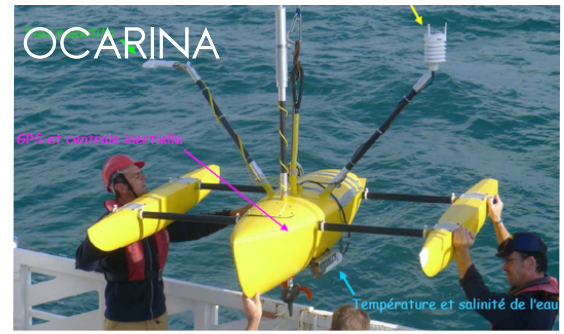
Atmospheric Profiling
- UAS, Cloud-Kite or Quad Copters (M, MS
- W-band cloud radar (M, MSM, RB)
- Raman Lidear (M, MSM)
- Radio Sondes (A, M, MSM, RB)
- Microwave Radiometer (M, MSM, RB)
- Sun photometer (A, M, MSM)
- Wind lidar (M, RB)

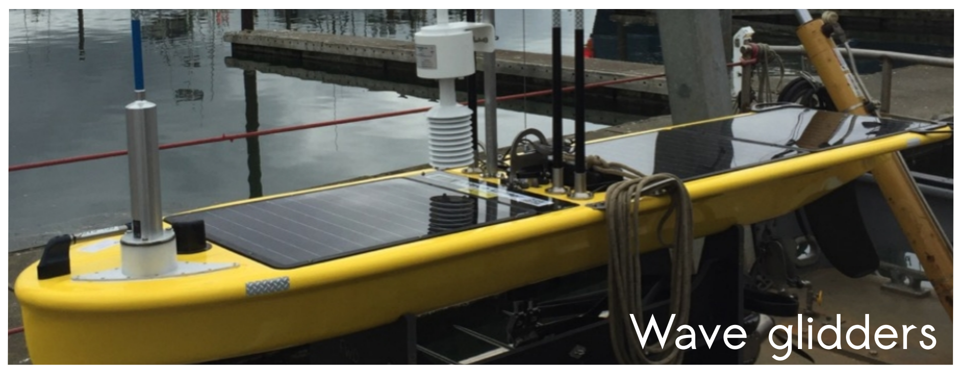
Near surface air measurements
- Standard Met (A, M, MSM, RB)
- Enthalpy and momentum eddy co-variance (M & RB)
- Isotopic Measurements (A, M, & RB)
- CO_2 fluxes (MSM)
- Disdrometer (M, MSM)
- Broadband SW & IR (M, MSM), Hyperspectral IR (RB)
- Aerosol (M, RB)

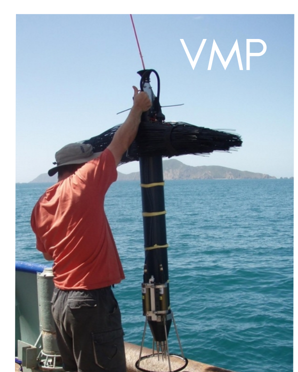
Ocean Profiling
- Standard Ocn., incl. CTDs (A, M, MSM, RB)
- Gliders (A, M, MSM, RB) & Drifters (M, MSM, RB)
- Biology (Nitrogen Fixation, Amonia Oxidation M, MSM)
- ADCP (MSM,
- Multibeam Echo Sounder (MSM)
- Moving vessel profiler — towed buoy (MSM)
- Microstructure sonde (MSM)
- X-band WaveRadar (MSM)
- Upper ocean pCO2 (MSM)

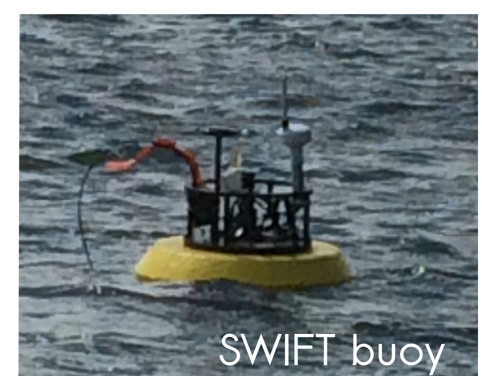
A blooming of autonomous observing systems

DJI Mavic Pro

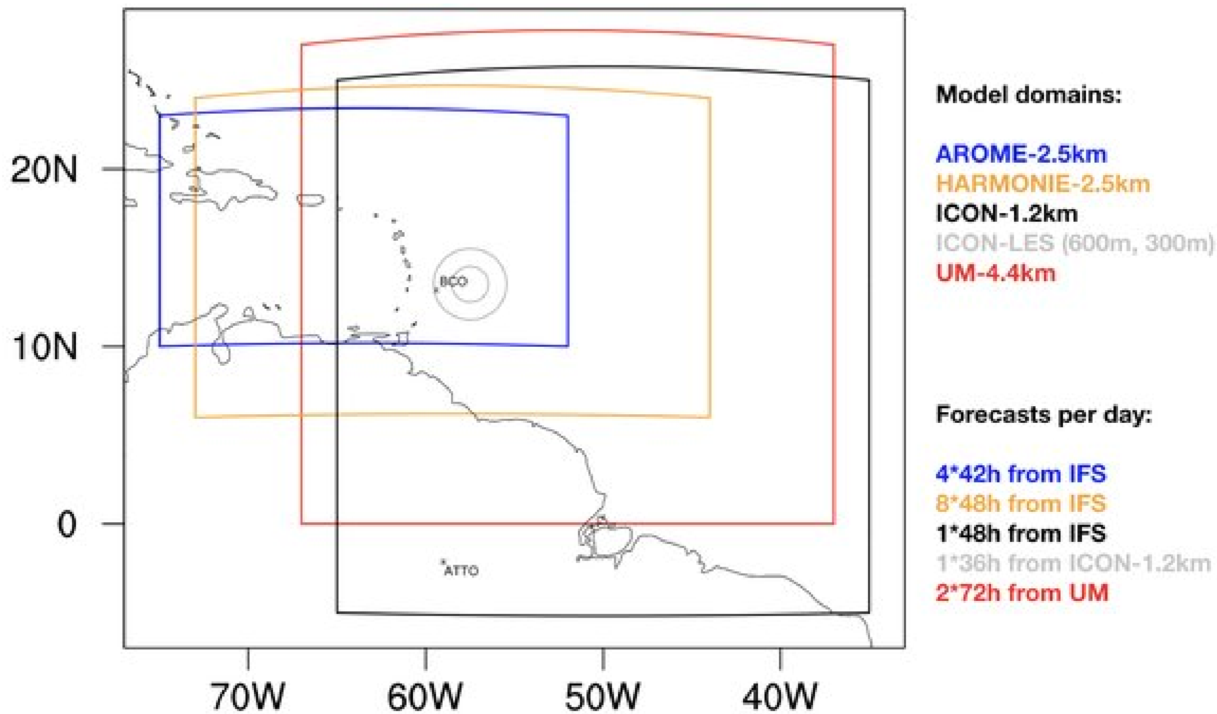




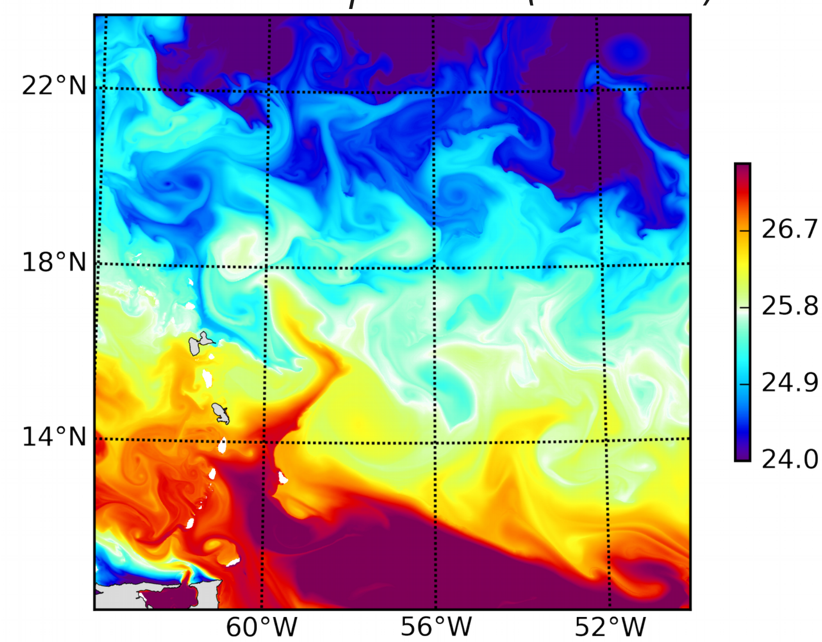




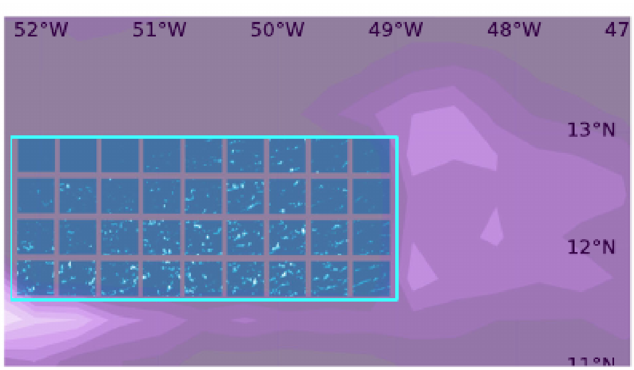
Atmospheric and oceanic modelling (from local to global)



Sea Surface Temperature (CROCO)



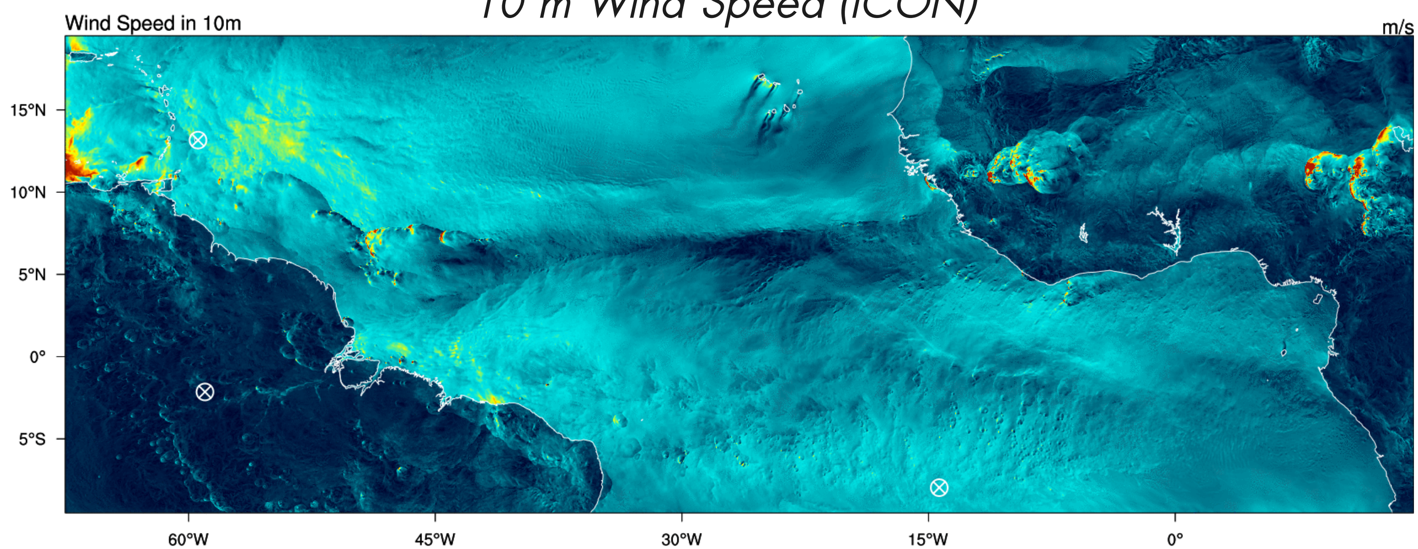
Jonathan Gula (LOPS, Brest)



coupled DALES domains (12.8 x 12.8 km^2) in the IFS

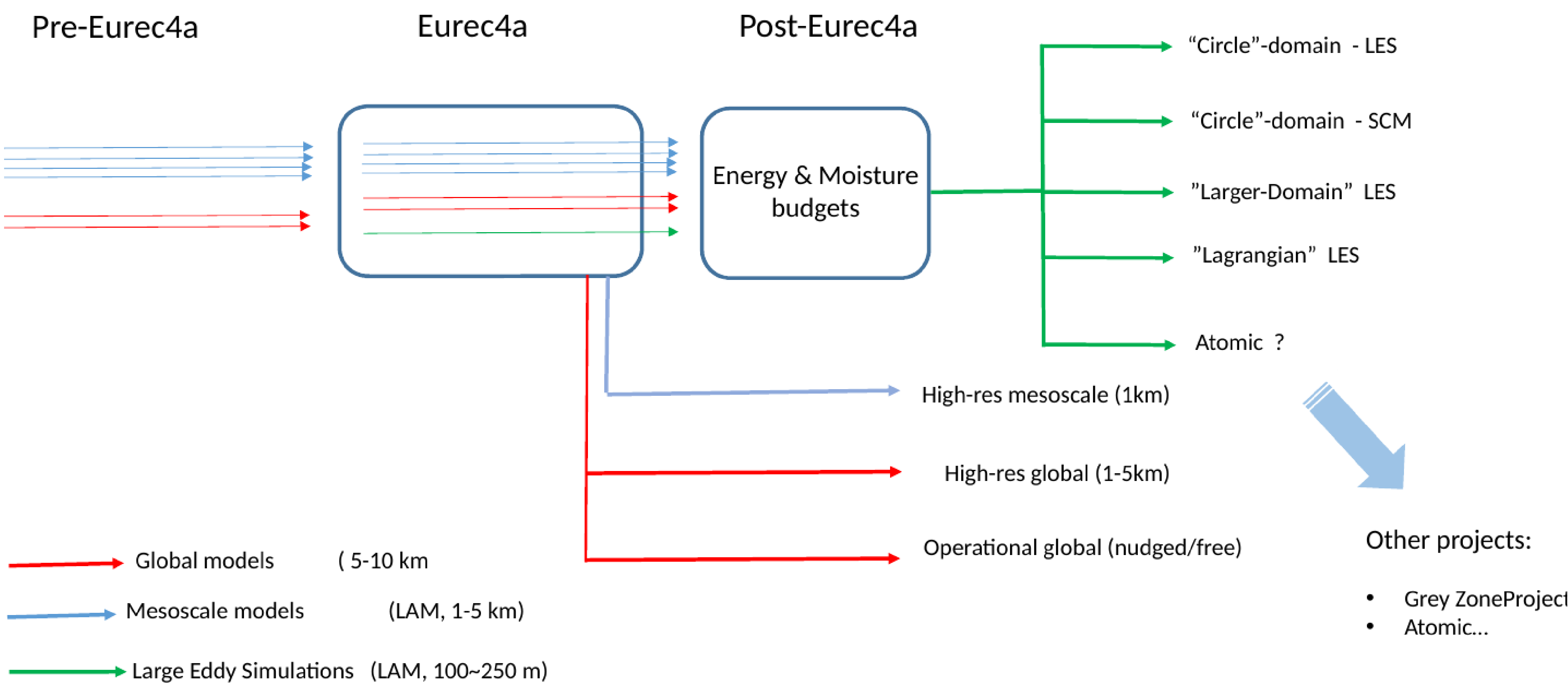
Pier Siebesma (TUD)

10 m Wind Speed (ICON)



Daniel Klocke (DWD) and Matthias Bruek (MPI)

Modeling activities: before, during, after EUREC^{4}A



Couvreux, Klocke, Musat, Schemann, Siebesma et al.

Pre-EUREC^{4}A : outputs from operational forecasts

→ a list of outputs has been proposed

→ files will be shared (AERIS ftp server)

→ quick-looks will be made (scripts welcome) and posted on the campaign website

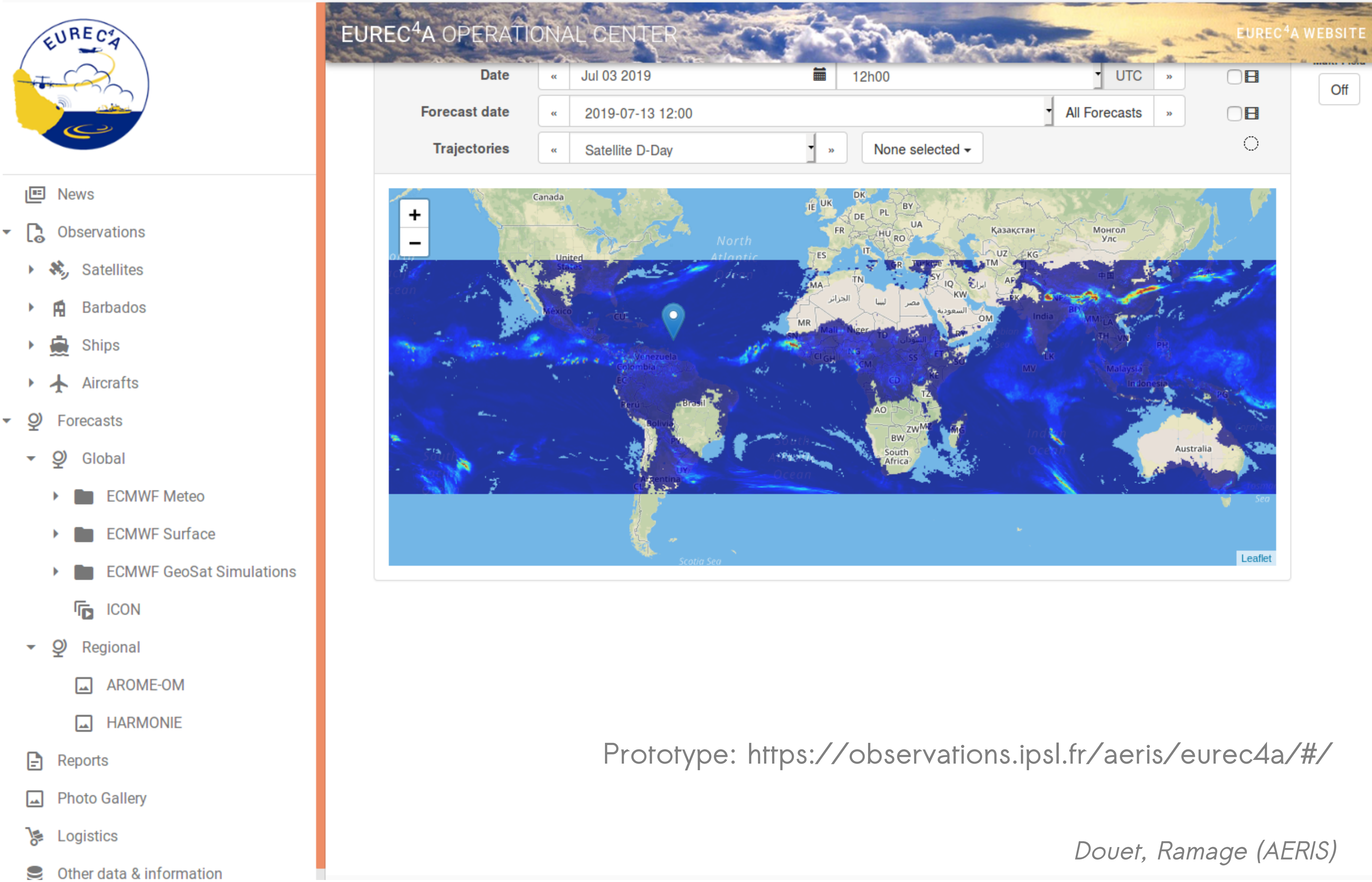
Table 2: required 2D Output (60 min interval)for quicklooks. In ICON both CAPE and CIN are computed with respect to the mean properties of a surface layer parcel.

Variable	Long Name	Units
$U_{10\mathrm{m}}$	Zonal wind at 10 m	$\mathrm{m\,s^{-1}}$
$V_{10\mathrm{m}}$	Meridional wind at 10 m	$\mathrm{m\,s^{-1}}$
P_{sfc}	Surface pressure	K
$\int q_{\mathrm{v}} \rho \, \mathrm{d}z$	Vertically integrated specific humidity	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{c}} \rho \, \mathrm{d}z$	Vertically integrated cloud water	$\mathrm{kg\,m^{-2}}$
$\int q_{\mathrm{i}} \rho \, \mathrm{d}z$	Vertically integrated cloud ice	$\mathrm{kg\,m^{-2}}$
C	Vertically projected cloud cover	–
R	Surface precipitation (accumulated)	$\mathrm{kg\,m^{-2}}$
CAPE	Convective available potential energy	$\mathrm{J\,m^{-2}}$
CIN	Convective inhibition	$\mathrm{J\,m^{-2}}$

Table 3: required fields (60 min interval) for quicklooks

Variable	Long Name	Units	level
U	Zonal wind at 10 m	$\mathrm{m\,s^{-1}}$	925, 850, 500, 200hPa
V	Meridional wind at 10 m	$\mathrm{m\,s^{-1}}$	925, 850, 500, 200hPa
θ	Potential temperature	K	925, 850, 500hPa
θ_e	Equivalent potential temperature	K	925, 850, 500, 200hPa
T	Temperature	K	925, 850, 500hPa
q_v	water vapor specific humidity	–	925, 850, 500hPa
RH	relative humidity	–	925, 850, 700, 500hPa
ω	vertical pressure velocity	Pa s^{-1}	925, 850, 500hPa

EUREC4A website for operations



Prototype: https://observations.ipsl.fr/aeris/eurec4a/#/

Douet, Ramage (AERIS)

Post-EUREC^{4}A : simulation proposals

- Global models (full EUREC4A period, NWP free/nudged runs)
- Mesoscale models (1-5 km, full EUREC4A period, common domain, free / hindcasts)
- Large-Eddy simulations (circle simulations, large-circle simulations, lagrangian cases)

+ 'climate change'-like perturbations *(Schär et al.)*

EUREC⁴A

Lots of objectives and many facilities

→ Important to look at the experiment as a whole without loosing sight of the big picture

How do clouds interact with their environment ?

macrophysics
microphysics, patterns, turbulence

LS vertical motion, convective mixing, thermodynamics
waves, shear, organization, ocean, aerosols

→ Common playground (connexions easier)

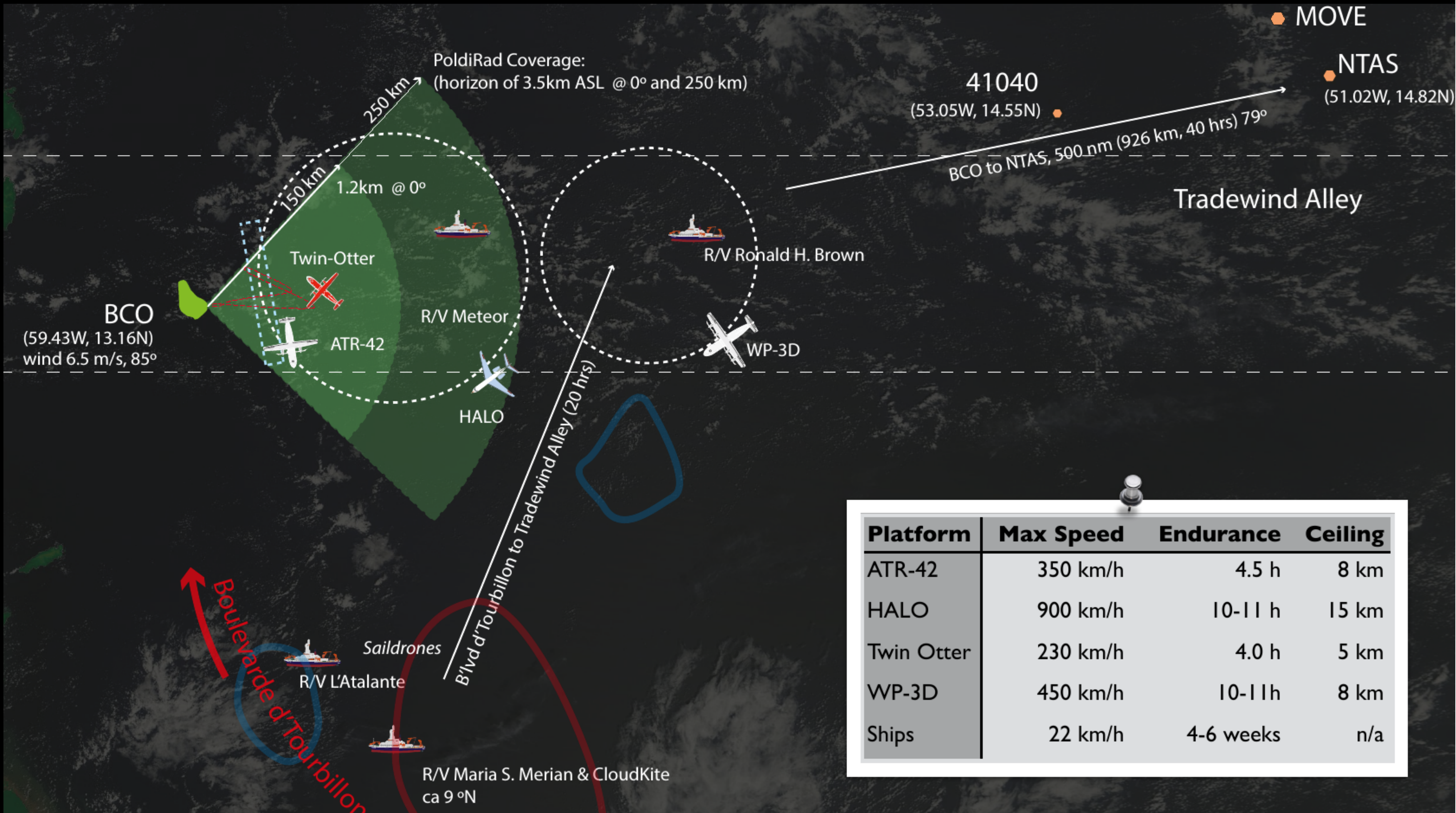
+ the simplest and most repetitive plans, the better (comparison of the different days)

Parallel play

Cooperative play

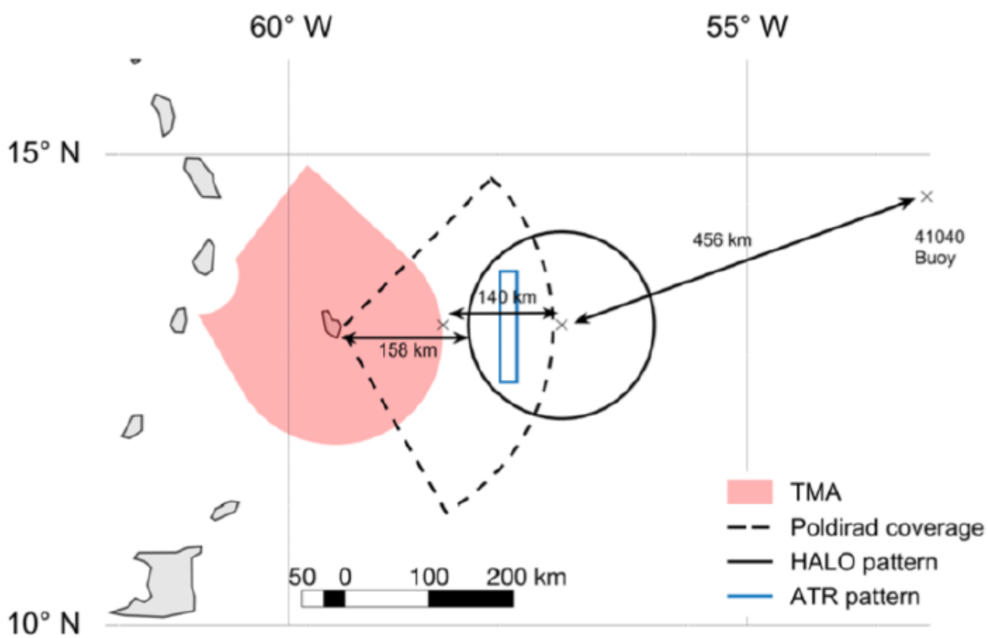
3. Present status of planning

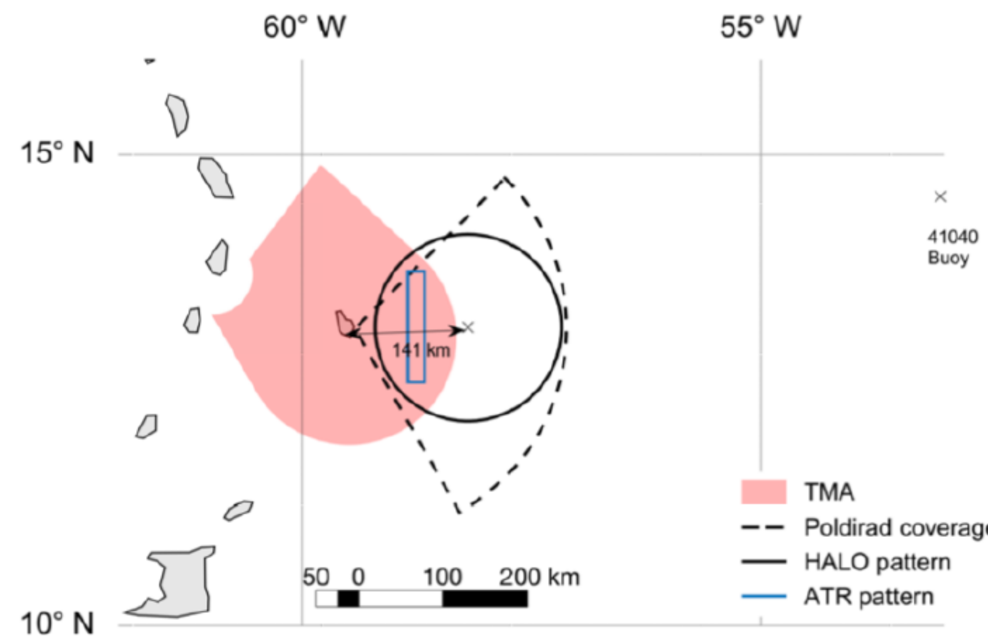
Envisionned area of operations



Platform	Max Speed	Endurance	Ceiling
ATR-42	350 km/h	4.5 h	8 km
HALO	900 km/h	10-11 h	15 km
Twin Otter	230 km/h	4.0 h	5 km
WP-3D	450 km/h	10-11h	8 km
Ships	22 km/h	4-6 weeks	n/a

Airspace and Airport Limitations

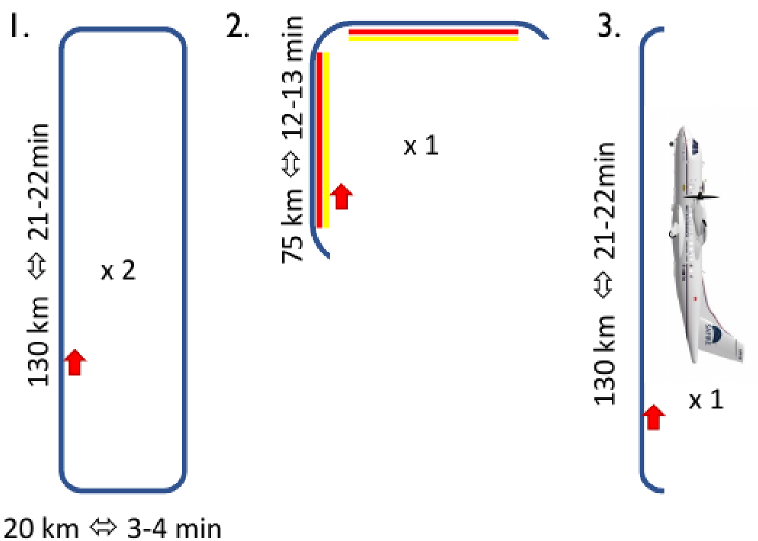




- Plan to fly regular 'weekly' schedule, with three flights per week & staggered departure times.
- Airspace restrictions (2.5 km to 7.5 km) may influence where sondes can be launched.
- Work is planned for the runway, which could imply airport closures, and limits on landing and takeoff times.
- GAIA winter schedule (major airlines arrival & departures) may influence choice of flight days, take-off/landing times and refueling schedule.

	Sunrise (LT)	Sunset (LT)	Sunrise (UTC)	Sunset (UTC)
20. Jan 2020	0625	1753	1025	2153
20. Feb 2020	0619	1805	1019	2205

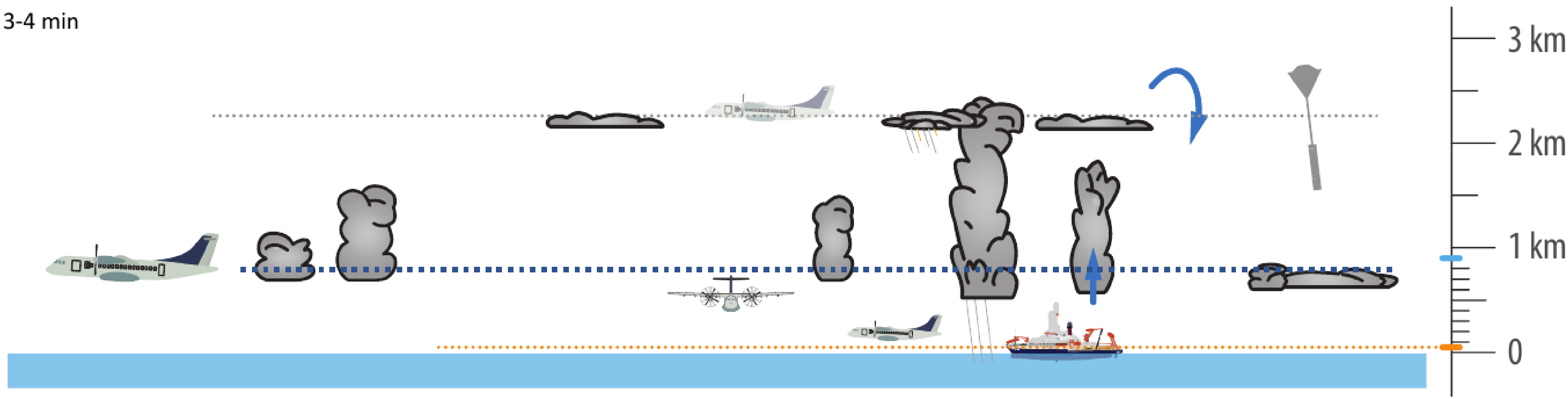
ATR-42 flight plans



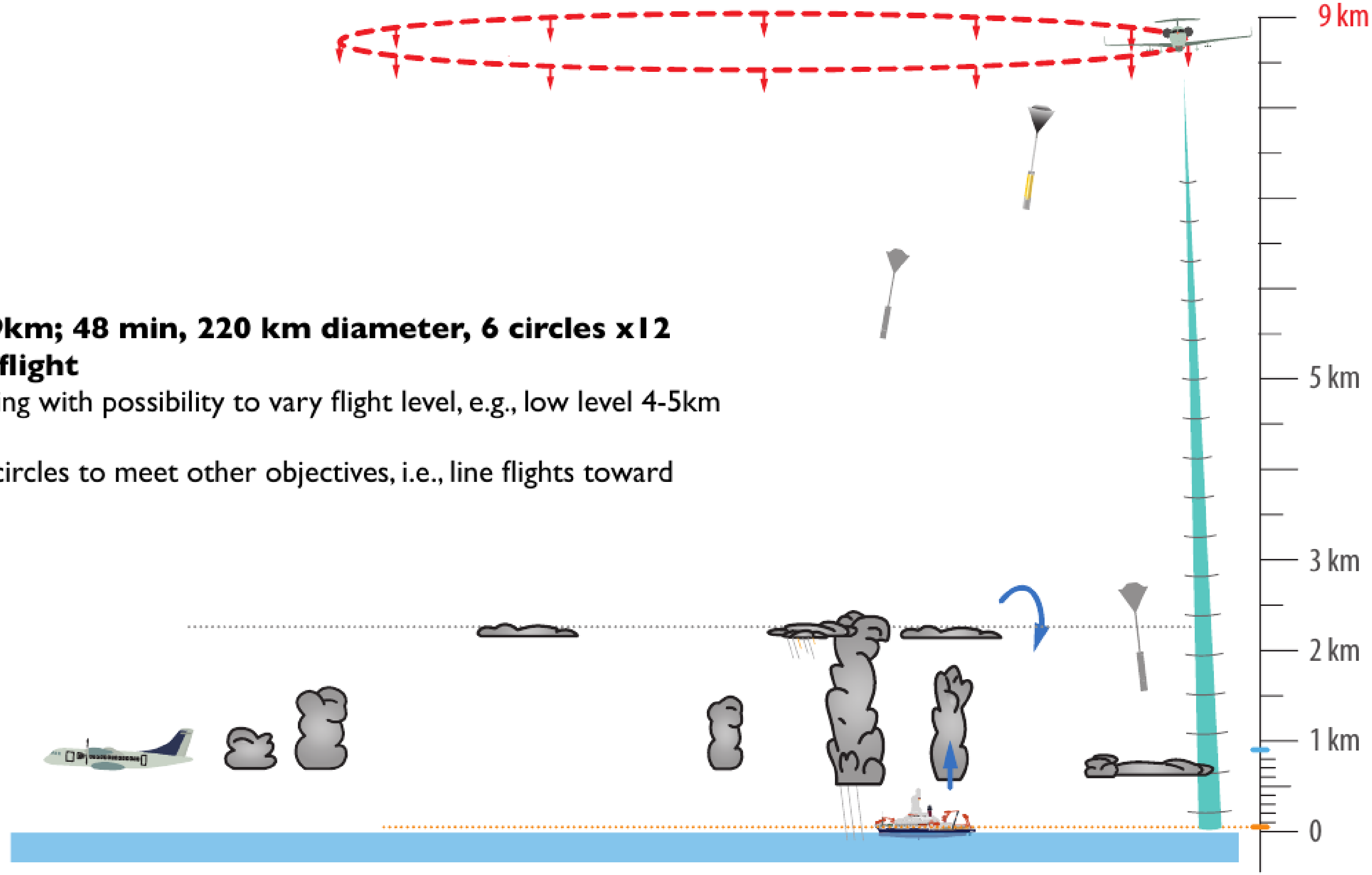
1. **Cloud base rectangles just above cloud base — how to determine this flight level?**
2. **Wind parallel and perpendicular legs at 350 (FL11) m and 500 m (FL16) in sub-cloud layer**
3. Stratiform cloud layer legs at 2.5 km (FL82) with possible roll

Notes:

- Two (4.5 hr) flights per day
- Top-down patterns to minimize sea-spray influence on sensors
- Horizontal lidar and radar remote sensing for cloud-base cloud amount



HALO flight plans



- **Circles, presently planned for 9km; 48 min, 220 km diameter, 6 circles x12 sondes, yielding 72 sondes per flight**
- Two additional circles for remote sensing with possibility to vary flight level, e.g., low level 4-5km circle for better radar/lidar sensitivity
- Possible substitution of non-sounding circles to meet other objectives, i.e., line flights toward buoy or satellite overpass.

Notes:

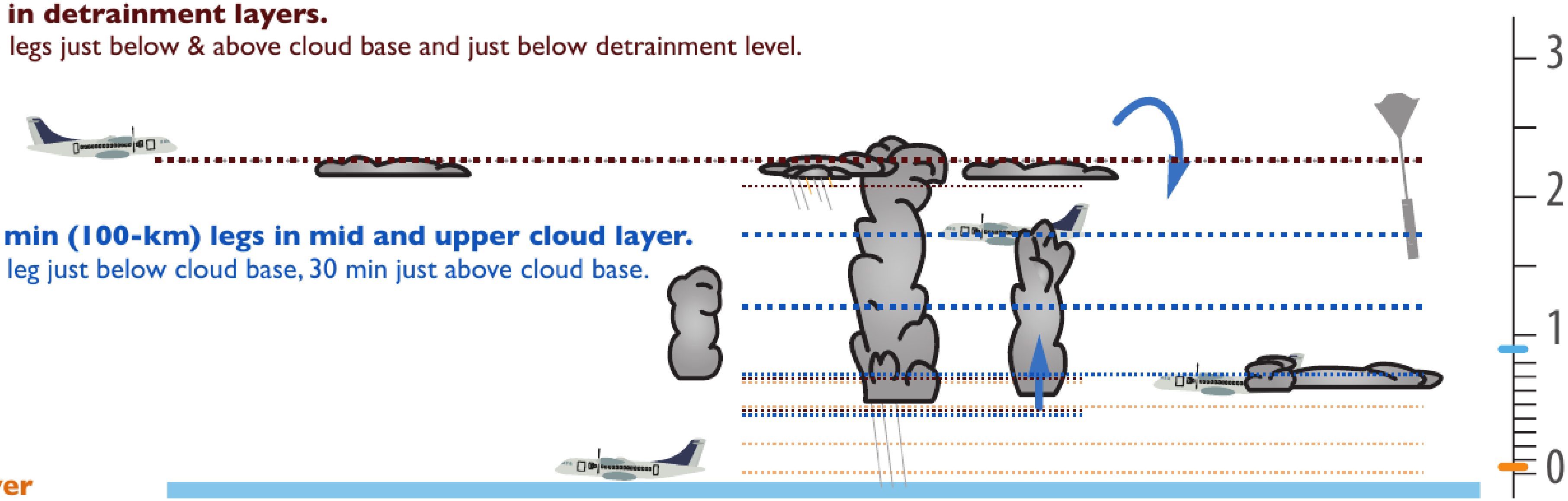
- For a wind-speed of 8 m/s, in 8 h the air moves across the diameter of a circle (230 km)
- Area of a 110 km radius circle 38 000 km2; 8 circles with a 7 km field of view map out the same area. Hence HALO's downward looking imagers can map out the area of a circle in the course of a flight.

Twin-Otter flight plans

1. Detrainment layer

a. 150 min legs in detrainment layers.

b. 15 min (50-km) legs just below & above cloud base and just below detrainment level.



2. Cloud layer

a. repeated 30 min (100-km) legs in mid and upper cloud layer.

a. 15 min (50-km) leg just below cloud base, 30 min just above cloud base.

3. Sub-cloud layer

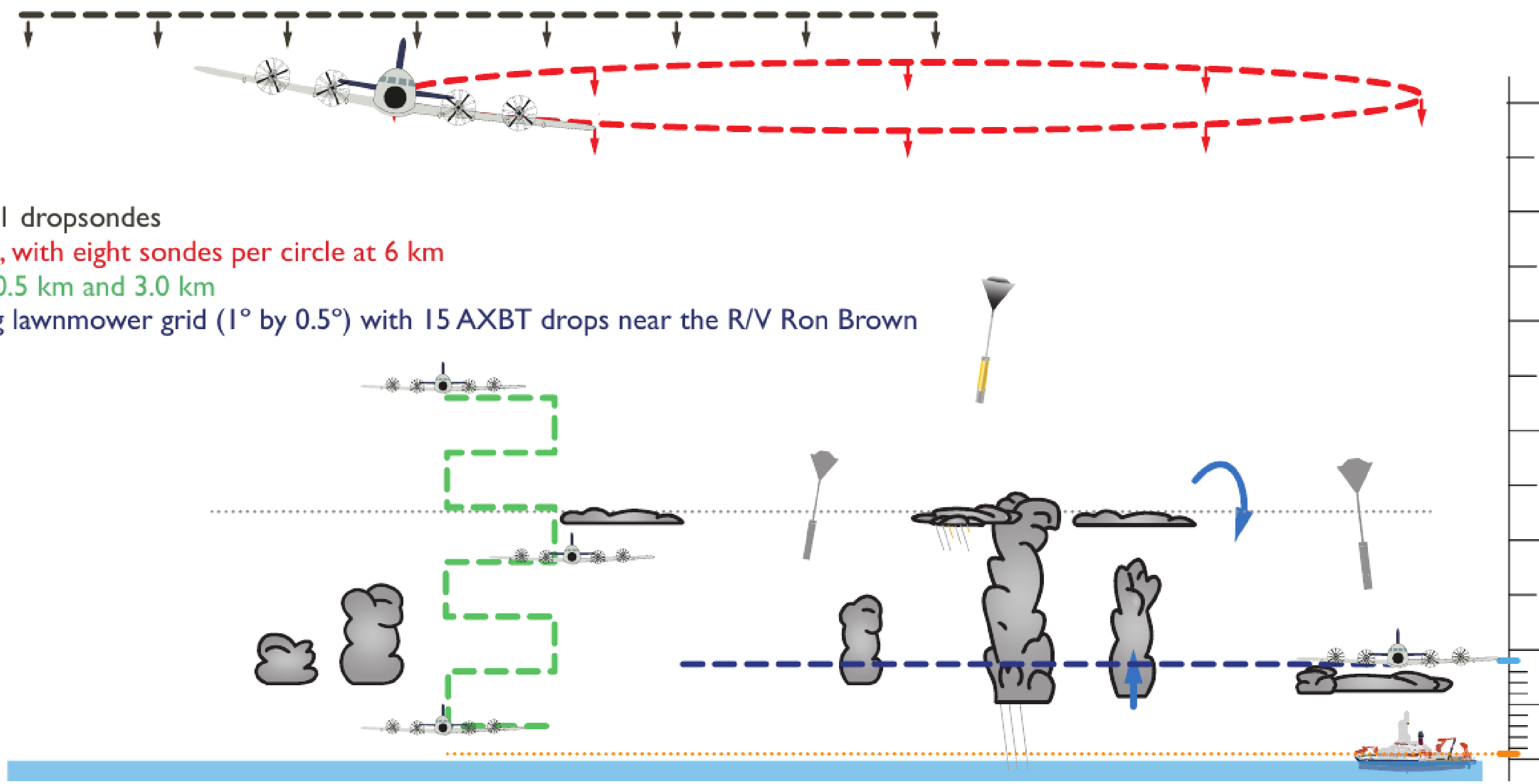
a. 15 min (50-km) leg just above cloud base.

b. 30 min (100-km) legs just above cloud base, at lowest safe flight level and midway through the sub cloud layer.

Notes:

- Each flight concentrates on one pattern, with two (3 and 4hr) flights a day.
- Most flights will use the ferry to target to make a sounding.
- All patterns provide cloud base sampling.
- Most patterns will try to optimize cloud penetrations while maintaining rough course (non-random sampling).

WP-3D flight plans

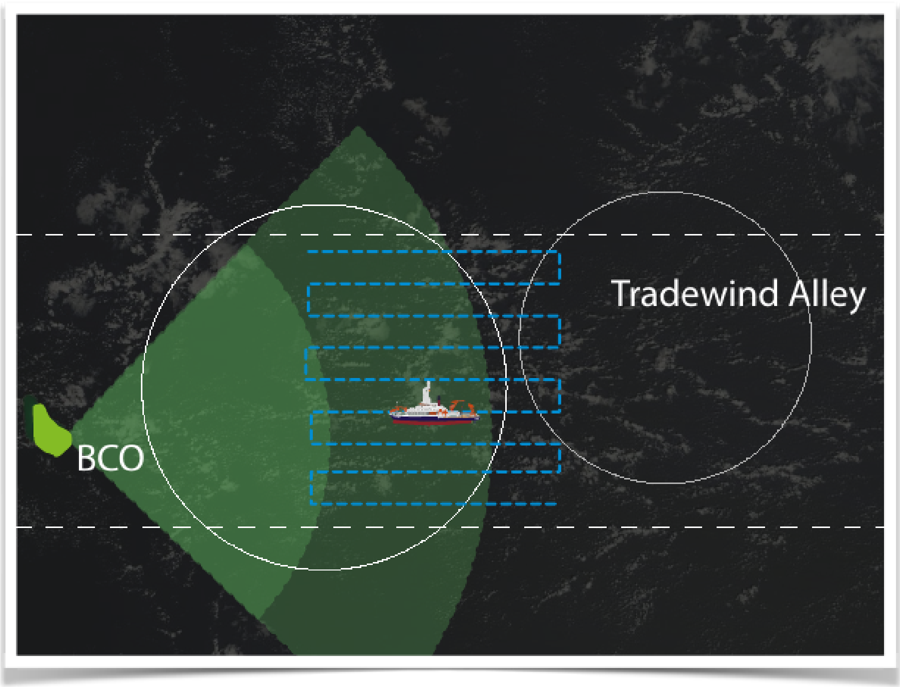


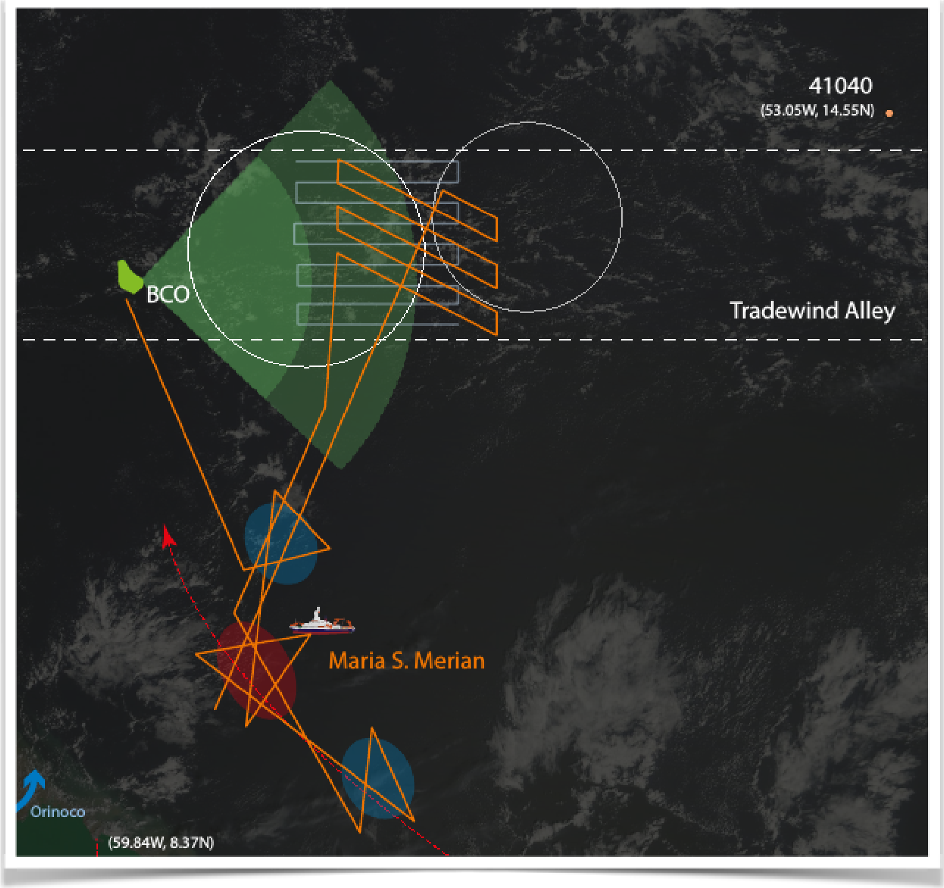
- Long ferries at 6 km with 11 dropsondes
- Two 1.5° circles, and ferries, with eight sondes per circle at 6 km
- Stepped profiling between 0.5 km and 3.0 km
- Long cloud based legs along lawnmower grid (1° by 0.5°) with 15 AXBT drops near the R/V Ron Brown

Notes:

- WP-3D may fly night flights
- Intends to combine all patterns in each flight
- Orientation of lawnmower patterns open, as is range of stepped profiles

R/V Meteor & R/V Maria S. Merian





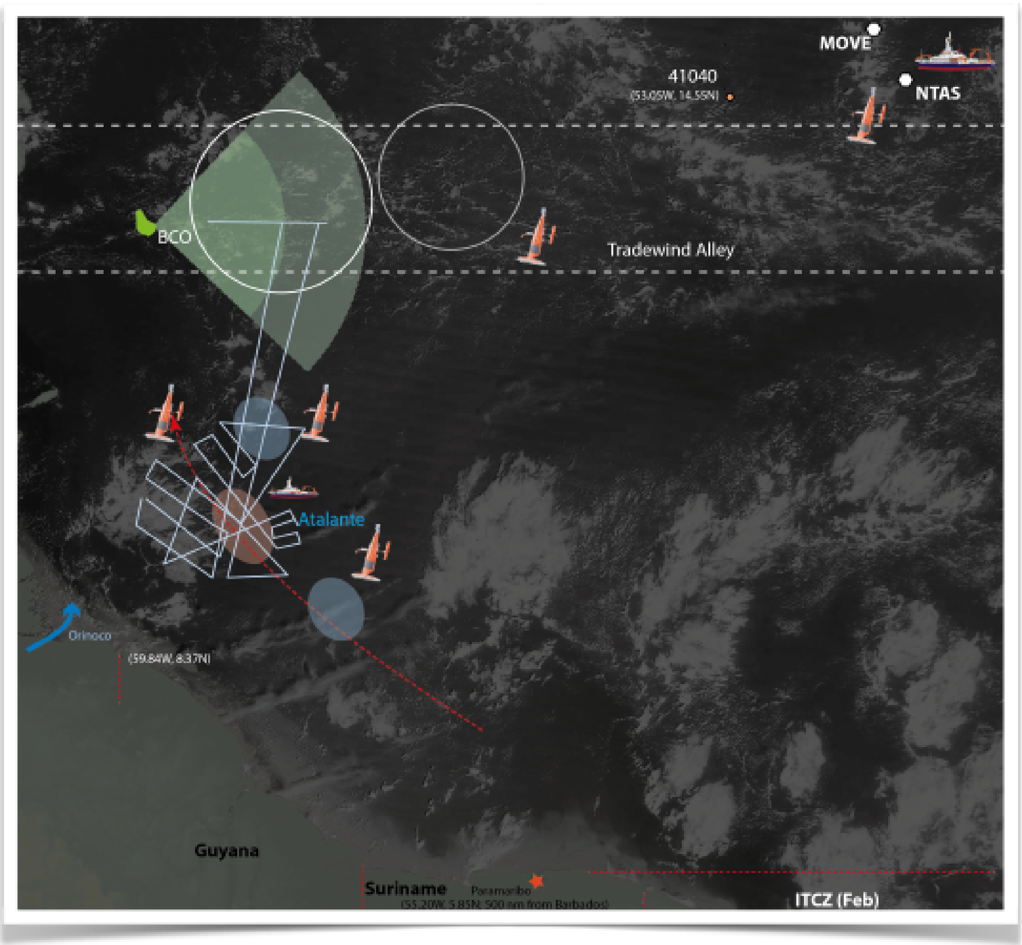
Meteor: Lawnmower grids in Tradewind Alley

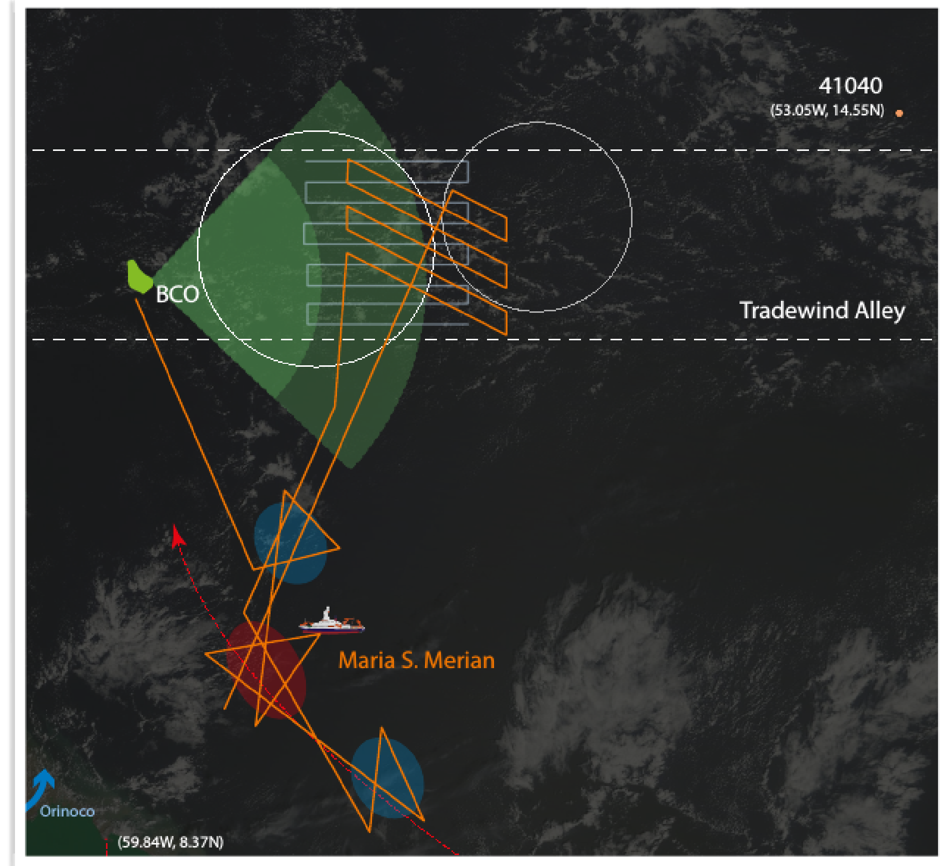
- 150 km E-W Transects.
- Length determined to repeat pattern 4 times

Maria S Merian

- Mostly sampling eddies SSE of Barbados
- 1-week (Arr. Jan 30, Dep. Feb 5?) intercomparison in Tradewind Alley (transit time 1day each way).
- Most likely to pair with other ships.

R/V Atalante & R/V Maria S. Merian





Atalante

- Mostly sampling eddies & filaments SSE of Barbados
- Sometime in pair with other Merian and available other ships.
- Time spent to pair with the 5 sail drones

Maria S Merian

- Mostly sampling eddies SSE of Barbados
- 1-week (Arr. Jan 30, Dep. Feb 5?) intercomparison in Tradewind Alley (transit time 1day each way).
- Most likely to pair with other ships.

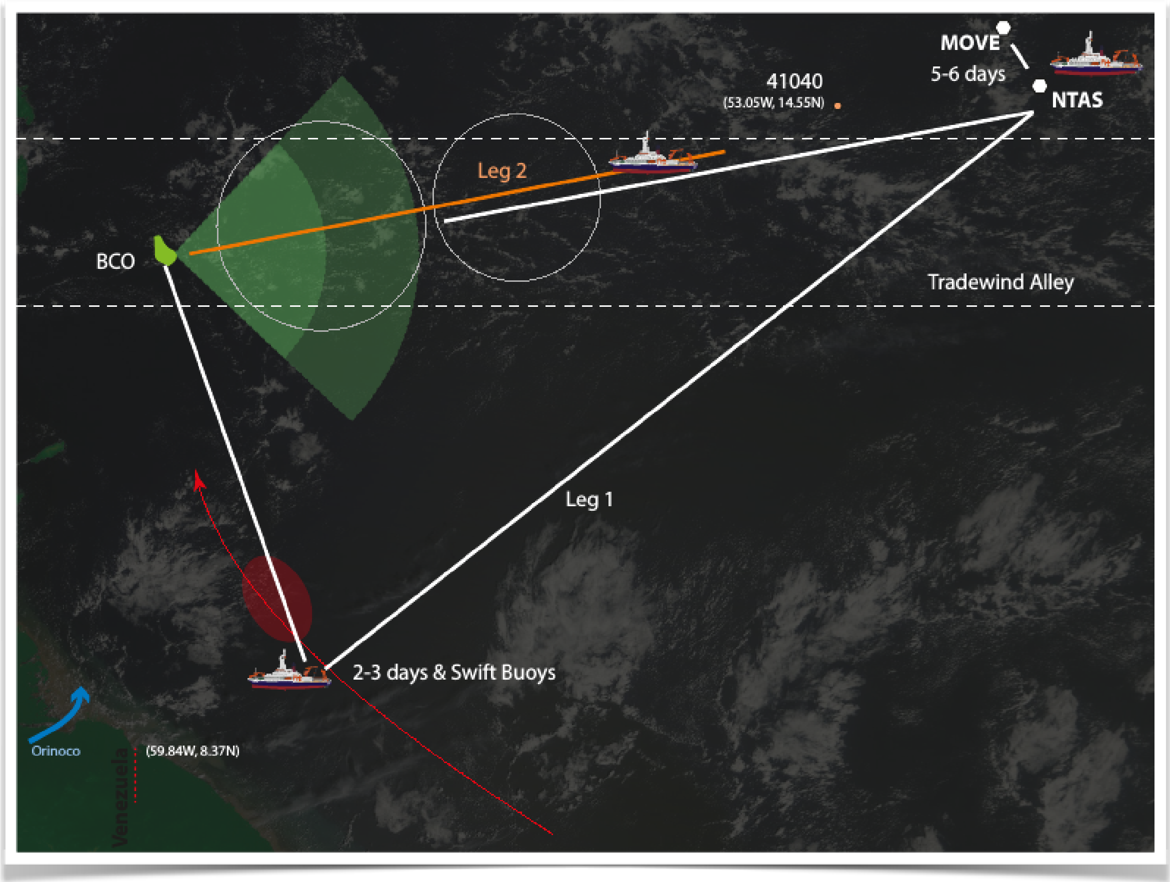
R/V Ronald H. Brown (2 legs)

Leg 1 (Jan 6 - Jan 26)

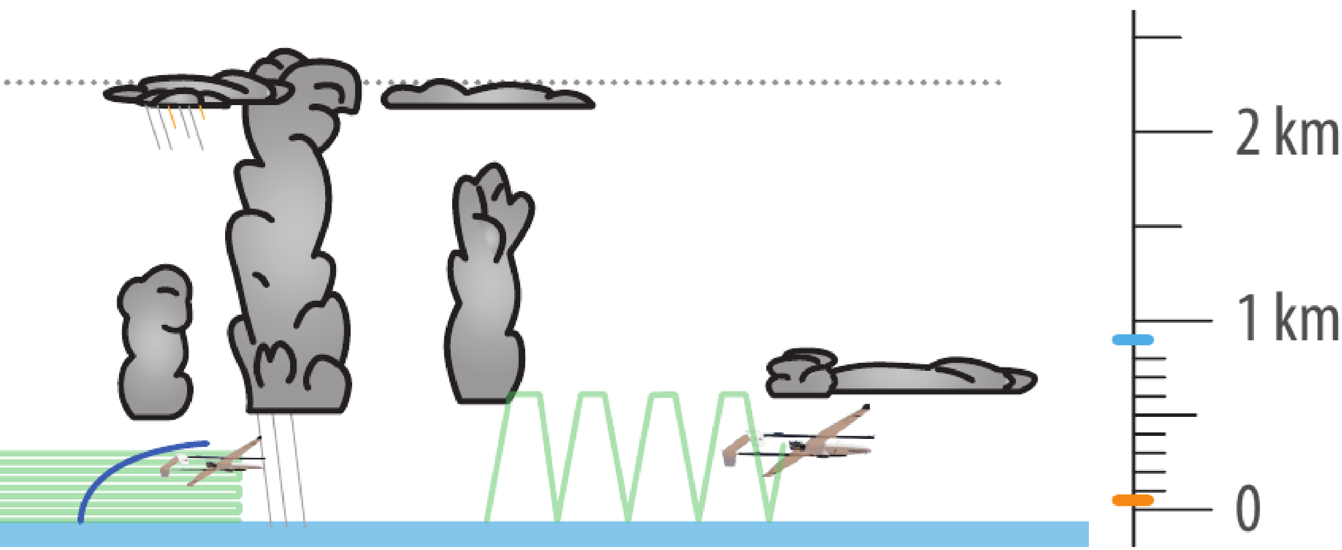
- Measure active eddy region SE of Barbados for (2-3 d).
- Service NTAS and MOVE buoys (5-6 d)
- Work line between NTAS and HALO circle

Leg 2 (Jan 28 - Feb 13)

- Intercomparison with BCO & Other Platforms
- Work line between NTAS and HALO circle.



R/V Ronald H. Brown (UAS flights)



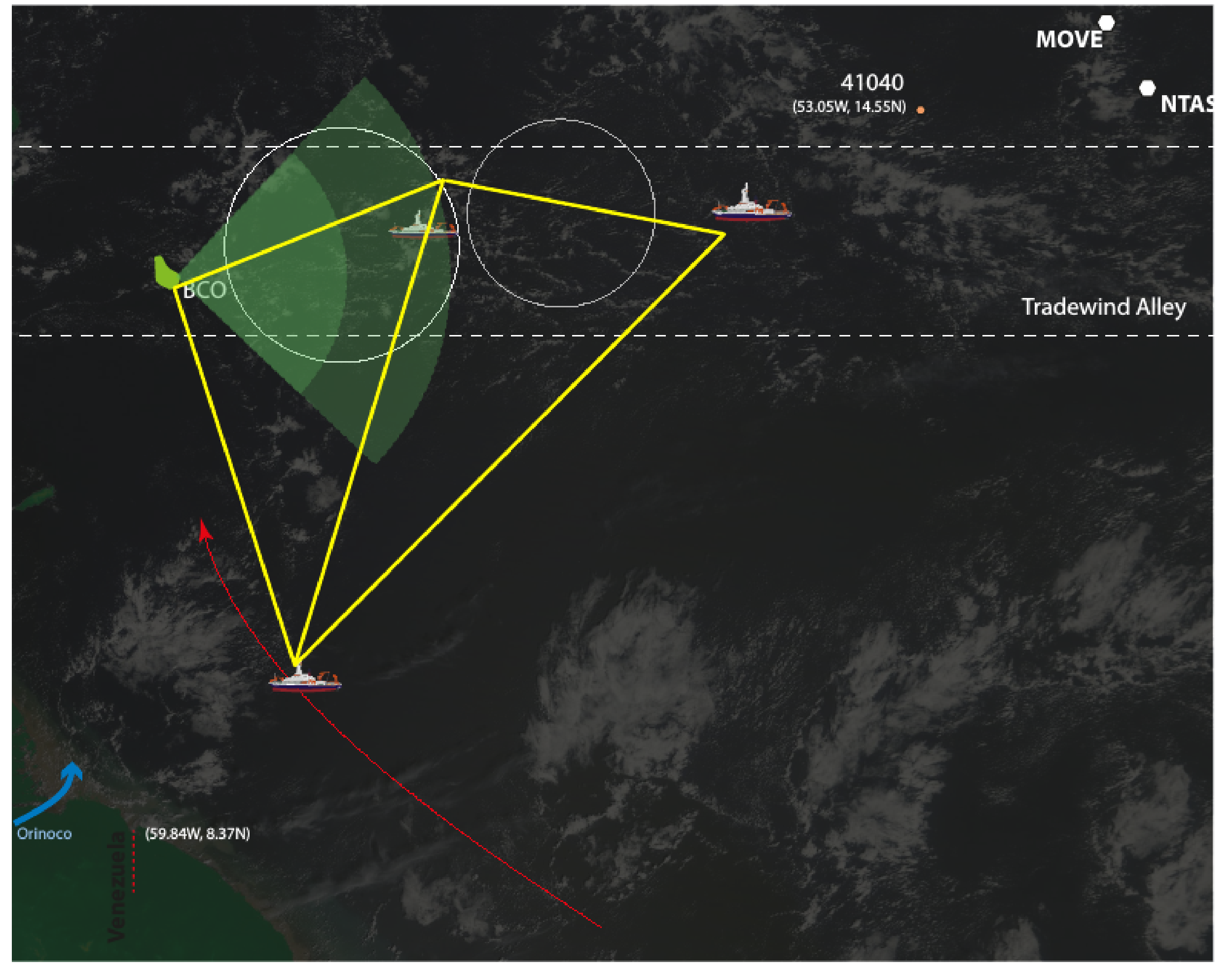
2. Coldpool Stacks
a. 10 km legs at 60 m height intervals

1. Subcloud layer profiling
a. 40 min at top of sub-cloud layer
b. 20 min (200 ft/min) ascent/descents

Upper Air Network (~1000 dropsondes, 930 radiosondes)

Notes

- HALO Dropsondes, 72 /flight; WP-3D # Uncertain, 8 per circle, 6 per Ferry?
- Radiosondes all Vaisala; training session in early October
- 240 Sondes (Meteor & Ron Brown); 180 Sondes (BCO & Maria S. Merian); 90 Sondes (L'Atalante)
- Intensive overlap Period 25 days



Time Windows

Platform	Availability	Harbor/Arrival
ATR-42	20 Jan – 15 Feb	Arrival Jan 11th
HALO	20 Jan - 15 Feb	Arrival Jan 18th
Twin Otter	20 Jan - 16 Feb	
WP-3D	15 Jan - 15 Feb	
R/V L'Atalante	18 Jan - 19 Feb	Jan 16*, Jan 18
R/V Maria S Merian	17 Jan - 17 Feb	Jan 14
R/V Meteor	18 Jan - 20 Feb	Jan 12-14, 17
R/V Ronald H Brown	06 Jan - 13 Feb	Jan 26-28

*Pointe-à-Pitre

Mon	Tue	Wed	Thr	Fri	Sat	Sun
Jan 6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	**21**	**22**	**23**	**24**	**25**	26
27	**28**	**29**	**30**	**31**	**Feb 1**	**2**
3	**4**	**5**	**6**	**7**	**8**	**9**
10	**11**	**12**	**13**	14	15	16
17	18	19	20			

EUREC^{4}A

7 Break Out Groups

1. Flight Planning
2. Ship Schedules
3. Soundings
4. Modelling
5. Data Products
6. Logistics
7. Outreach