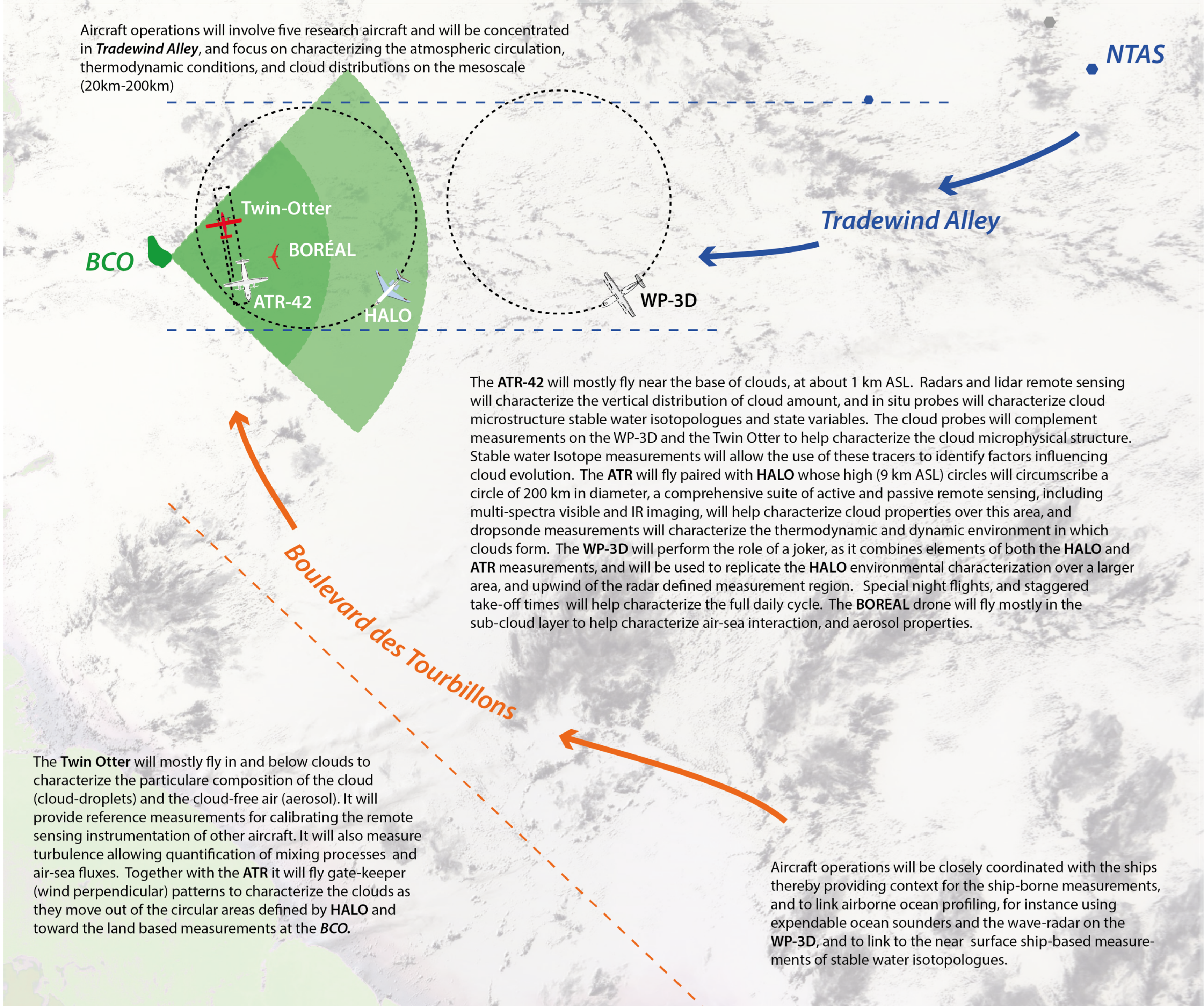
EUREC4A/ATOMIC *flight planning*

The flight planning group

Aircraft setup

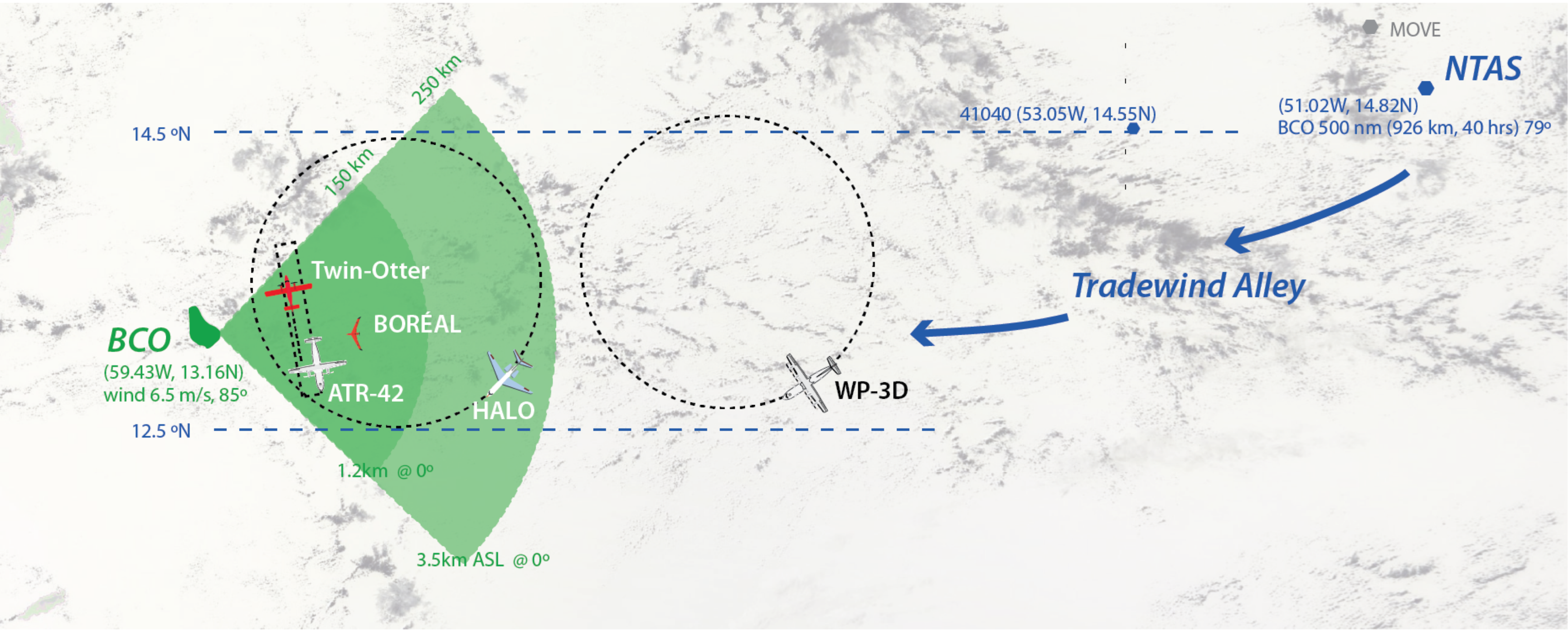
Aircraft operations will involve five research aircraft and will be concentrated in ***Tradewind Alley***, and focus on characterizing the atmospheric circulation, thermodynamic conditions, and cloud distributions on the mesoscale (20km-200km)



The **ATR-42** will mostly fly near the base of clouds, at about 1 km ASL. Radars and lidar remote sensing will characterize the vertical distribution of cloud amount, and in situ probes will characterize cloud microstructure stable water isotopologues and state variables. The cloud probes will complement measurements on the WP-3D and the Twin Otter to help characterize the cloud microphysical structure. Stable water Isotope measurements will allow the use of these tracers to identify factors influencing cloud evolution. The **ATR** will fly paired with **HALO** whose high (9 km ASL) circles will circumscribe a circle of 200 km in diameter, a comprehensive suite of active and passive remote sensing, including multi-spectra visible and IR imaging, will help characterize cloud properties over this area, and dropsonde measurements will characterize the thermodynamic and dynamic environment in which clouds form. The **WP-3D** will perform the role of a joker, as it combines elements of both the **HALO** and **ATR** measurements, and will be used to replicate the **HALO** environmental characterization over a larger area, and upwind of the radar defined measurement region. Special night flights, and staggered take-off times will help characterize the full daily cycle. The **BOREAL** drone will fly mostly in the sub-cloud layer to help characterize air-sea interaction, and aerosol properties.

The **Twin Otter** will mostly fly in and below clouds to characterize the particulare composition of the cloud (cloud-droplets) and the cloud-free air (aerosol). It will provide reference measurements for calibrating the remote sensing instrumentation of other aircraft. It will also measure turbulence allowing quantification of mixing processes and air-sea fluxes. Together with the **ATR** it will fly gate-keeper (wind perpendicular) patterns to characterize the clouds as they move out of the circular areas defined by **HALO** and toward the land based measurements at the *BCO.*

Aircraft operations will be closely coordinated with the ships thereby providing context for the ship-borne measurements, and to link airborne ocean profiling, for instance using expendable ocean sounders and the wave-radar on the **WP-3D**, and to link to the near surface ship-based measurements of stable water isotopologues.



MOVE
NTAS
(51.02W, 14.82N)
BCO 500 nm (926 km, 40 hrs) 79º
41040 (53.05W, 14.55N)
14.5 ºN
12.5 ºN
250 km
150 km
Twin-Otter
BORÉAL
ATR-42
HALO
WP-3D
BCO
(59.43W, 13.16N)
wind 6.5 m/s, 85º
1.2km @ 0º
3.5km ASL @ 0º
Tradewind Alley

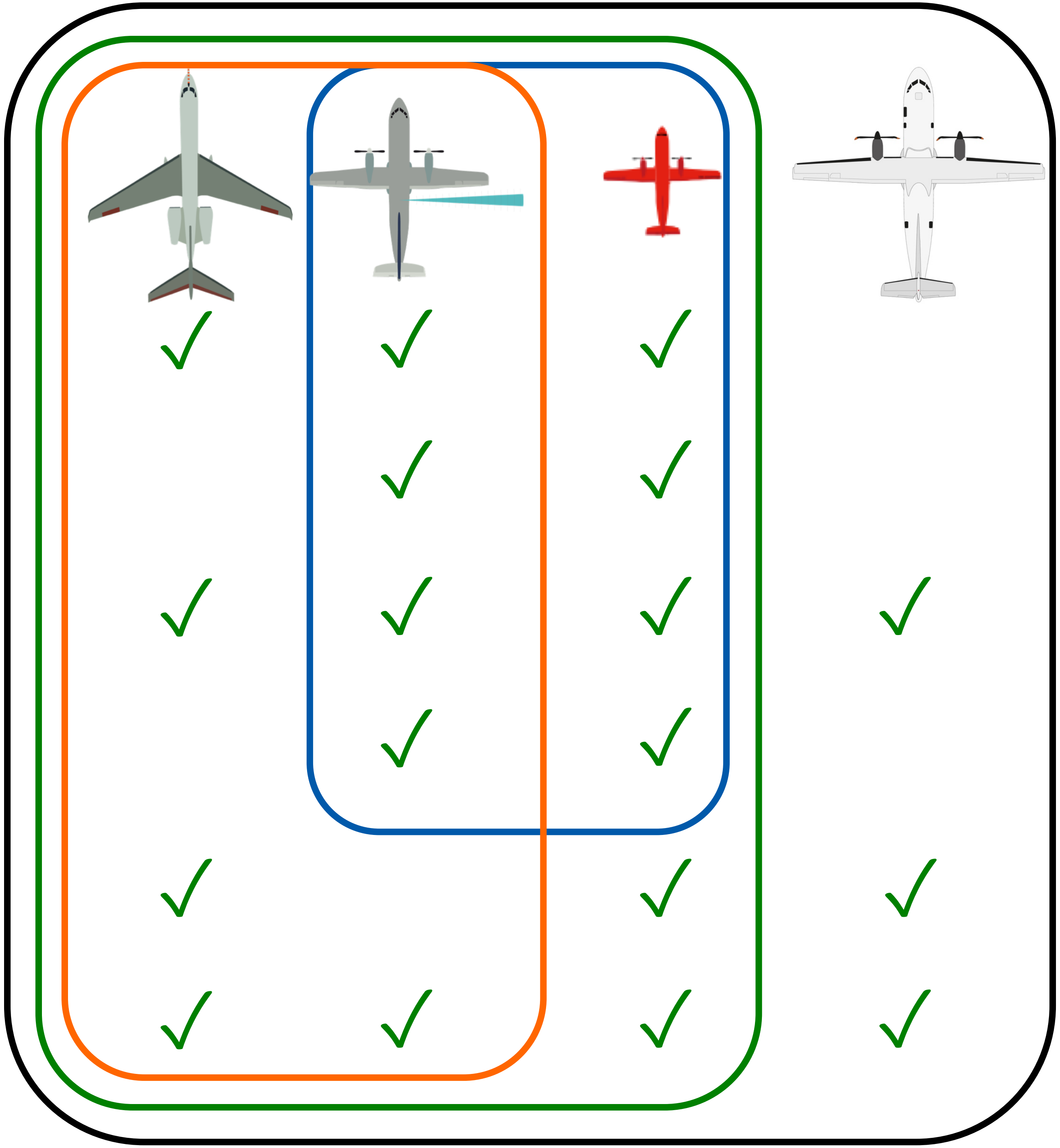
Scientific Objectives

Benefits of coincidence

Scientific Objectives

Benefits of coincidence

- **Mass flux (cloud base to detrainment)**
  → “Common area” for HALO/ATR/TO (HAT)
- **Boundary layer fluxes**
  → ATR/TO same track, different levels
- **Diurnal cycle (statistics)**
  → Shifted HAT schedules + W-P3 night flights
- **Warm rain processes**
  → TO at different levels, coordinated with ATR radar/lidar (following or offset)
- **Mesoscale organization / Cold pools**
  → Leg along BCO-NTAS / super-curtain
- **Calibration / Validation**
  → “Super curtain” after take-off



Instrument Needs

Calibration and Validation

- **Validate VELOX SST (HALO and SHIPS)**
  - Fly straight legs (5-10 min) at different altitudes over same position to test influence of atmosphere between instrument and sea surface (once)
  - Collocate with sea surface measurements from buoy and/or ships
- **Calibrate SMART, Velox and BARCARDI (HALO)**
  - Radiation rectangle with clear sky above (once)
  - Boresight calibration (once)
- **Cloud radar calibration and sensitivity intercomparison (ALL)**
  - Calibration roll maneuvers (end of each flight)
  - Circle with known sea level wind speed e.g. bouy or W-P3D (once)
  - Overflights with HALO/ATR over shipborne cloud radars (during super-curtains / HALO excursions)
- **Insitu - Insitu intercomparisons (during super-curtains after take-off) (ATR/TO)**

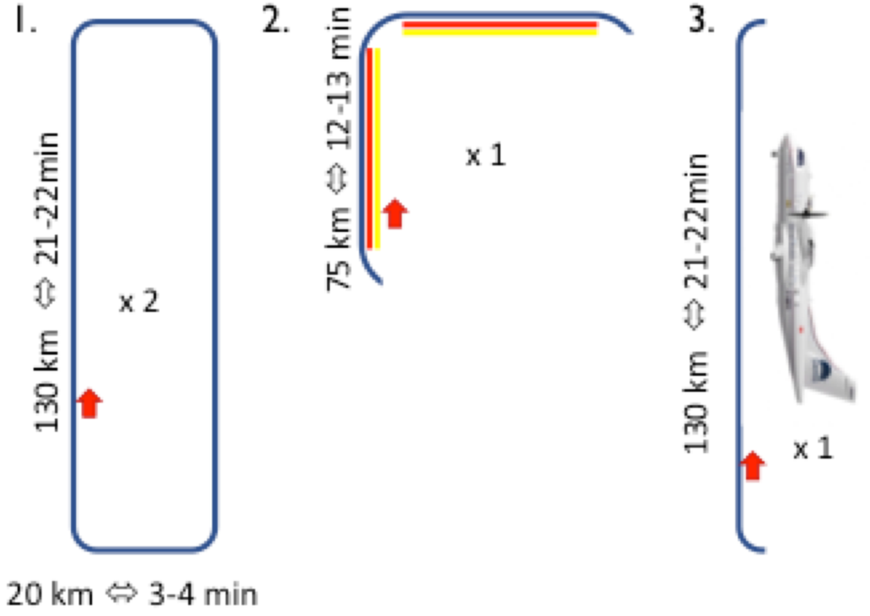
Scientific Objectives
HALO specific

No.	aim	how?	who?
1	Provide context; how representative are the circles at their location; spatial variability of water vapor in free troposphere	Long legs (e.g. upstream), over moisture gradients to buoy and/or ships	WALES
2	Daylight measurements (for visible instruments)	Fly as much during daylight as possible	SpecMacs
3	Testing retrievals of SpecMacs	ATR HALO collocation with ATR in HALO's shadow	SpecMacs
4	Characterization of the large scale cloud structure (cloud fraction, cloud size distribution, degree of clustering) with respect to VELOX, specMACS, HAMP	MODIS and AVHRR collocation in the afternoon	SMART/Velox/ HAMP
5	Validation of SST measurements	Flying at different altitudes to test influence of atmosphere between instrument and sea surface; Collocated sea surface measurements from buoy and/or ships	Velox
6	Calibrate SMART and Velox	Fly calibration pattern	SMART/Velox
7	Assessment of satellite derived LWP and rain	GPM underflights	HAMP
8	Instrument assessment	Comparison flight with P3; comparison with ship measurements	
9	Development of rain from shallow convection	Check for precipitating clouds; adjust flight pattern if needed; gradient legs	HAMP
10	Radar comparison (HAMP, BCO, Poldirad, Ships)	BCO overpasses (possibly best before landing)	HAMP/Poldirad
		Flying above cirrus that is upstream of BCO	HAMP/Ships
11	Testing BACARDI	Flying above below and through cirrus	BACARDI
12	Representativeness of different cloud masks from airborne and spaceborne instruments	All flight pattern ok, access to satellite images	SMART
13	Water vapor distribution between clouds	Low approach (ca. 5 km for 15-20 min) to Barbados	WALES

Flight plans

Platform priorities (recap)

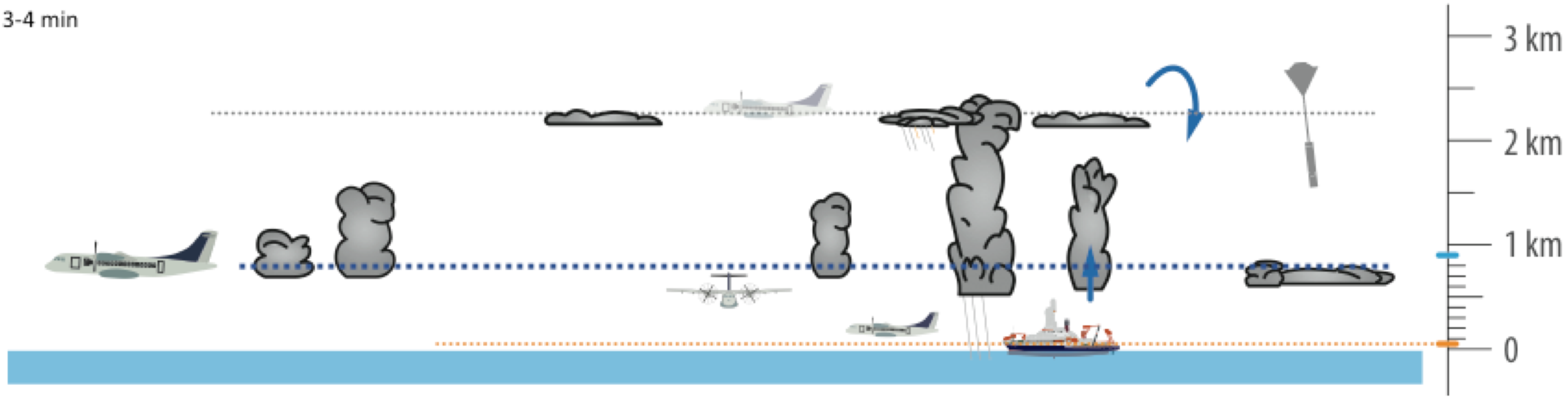
ATR-42 flight plans



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



Twin-Otter flight plans

1. Detrainment layer

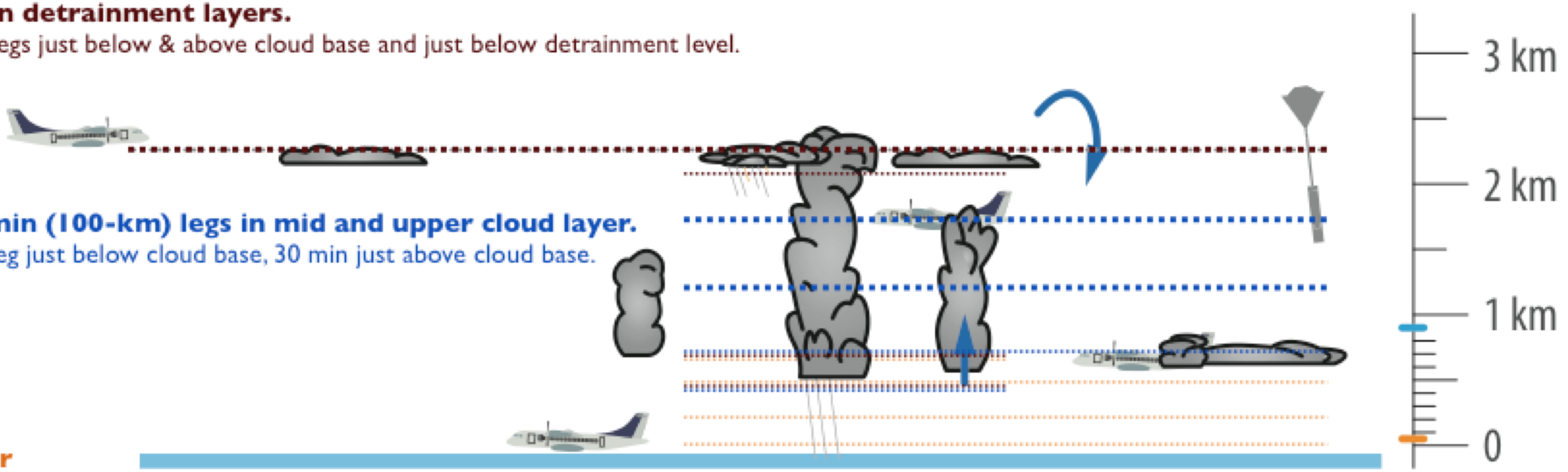
a. 150 min legs in detrainment layers.

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

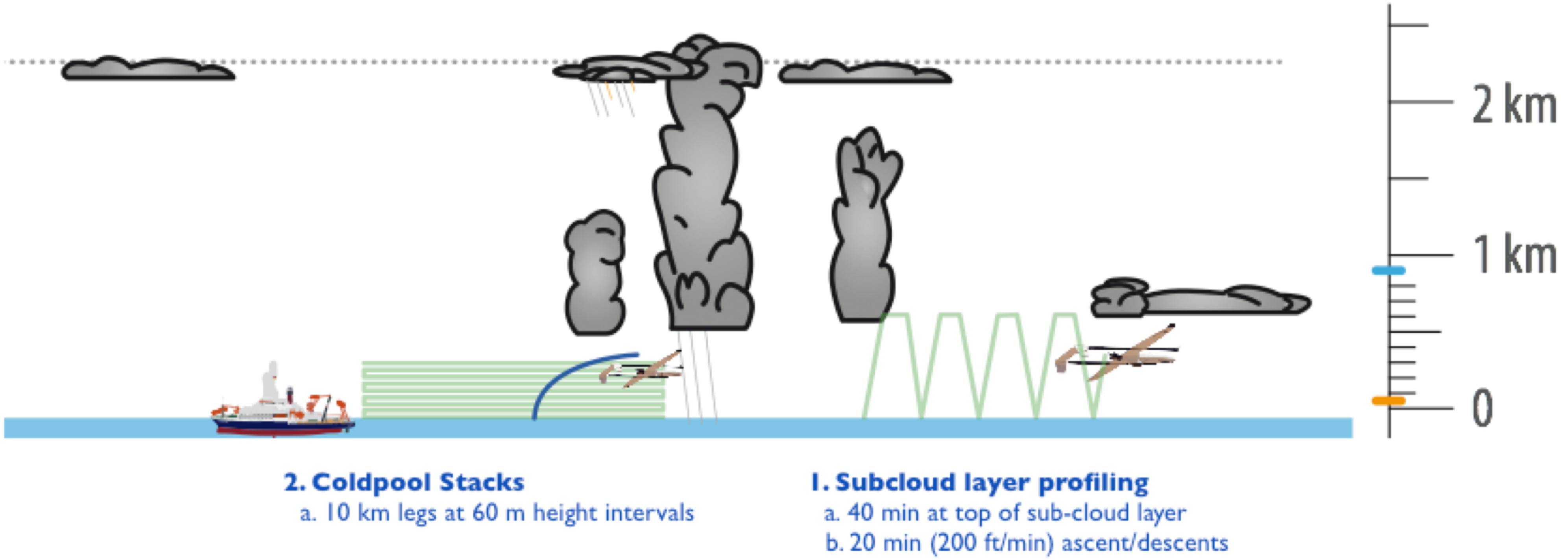
a. 15 min (50-km) leg just above cloud base.

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

Notes:

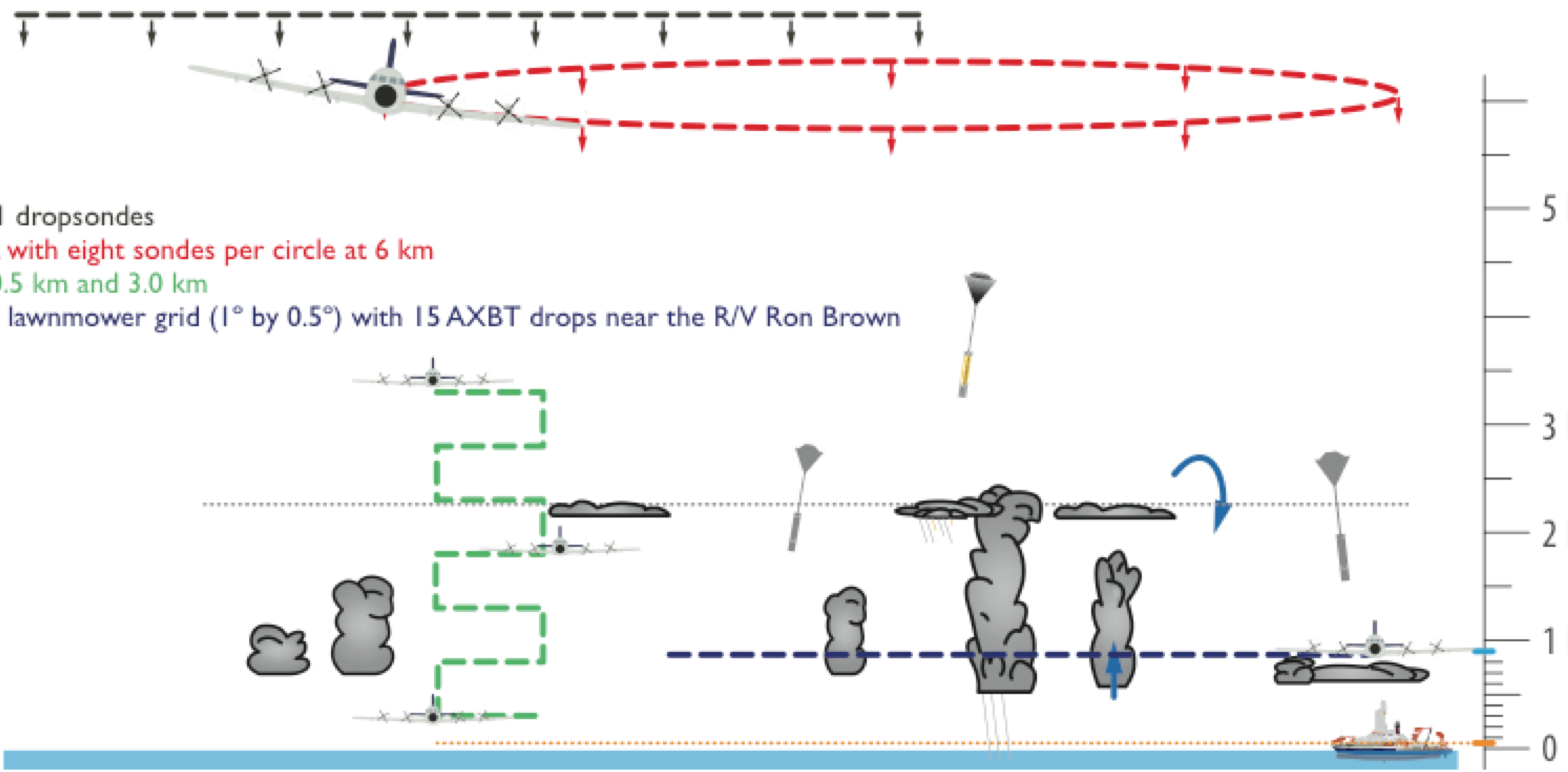
- Each flight concentrates on one pattern, with two (3 and 4hr) flights a day.
- Most flights will use the ferry to target to make a sounding.
- All patterns provide cloud base sampling.
- Most patterns will try to optimize cloud penetrations while maintaining rough course (non-random sampling).

BOREAL flight plans (or other drones)



- L-shape curtain with 50 km legs on each side at four altitudes (40, 80, 200, 500 m.asl) to focus on structure of sub-cloud layer.
- Profile to 2500m.asl, curtain flight with 75 km legs perpendicular to wind at 5 or 6 altitudes for cold pool characterization.

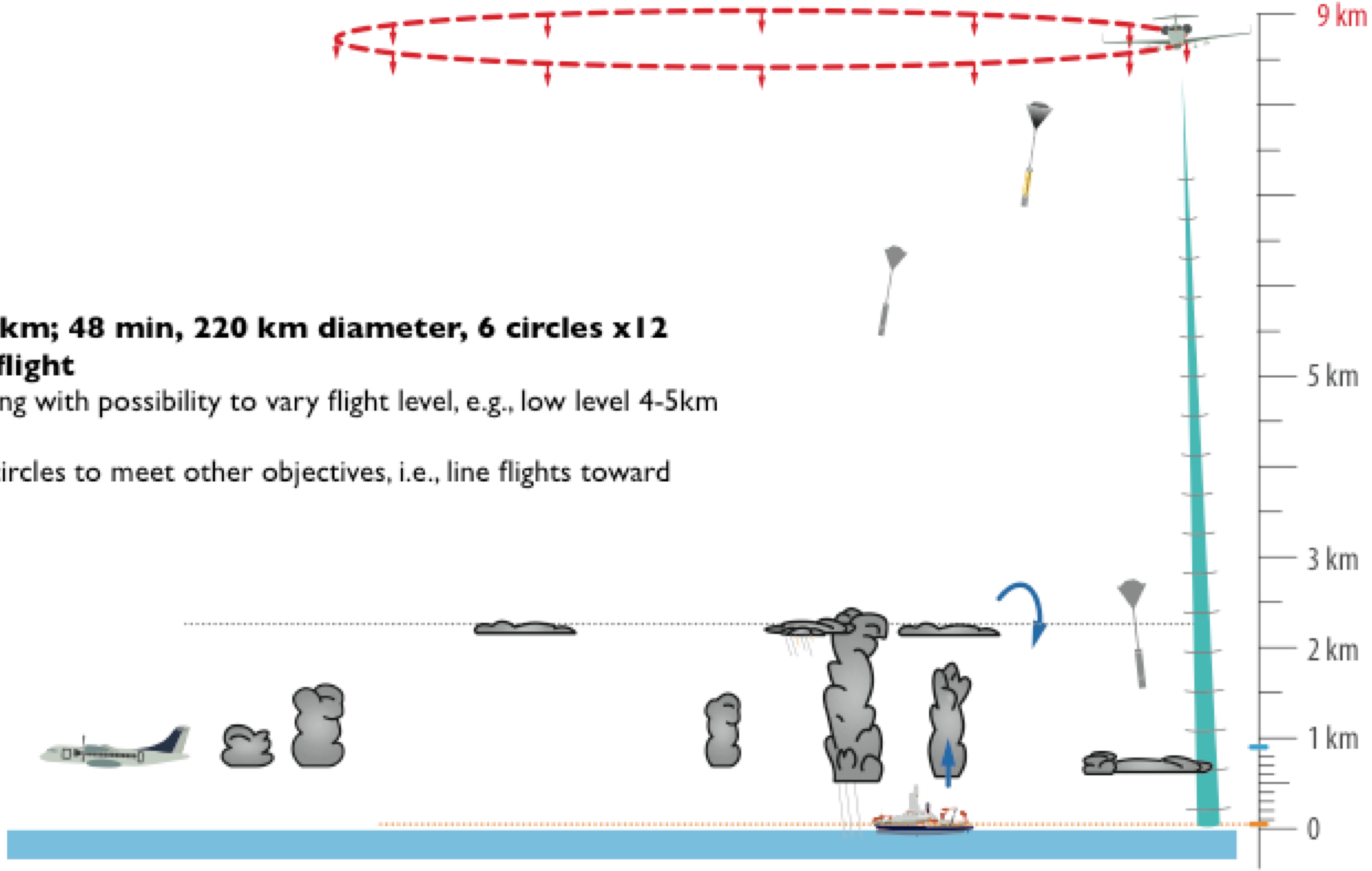
WP-3D flight plans



- 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

HALO flight plans



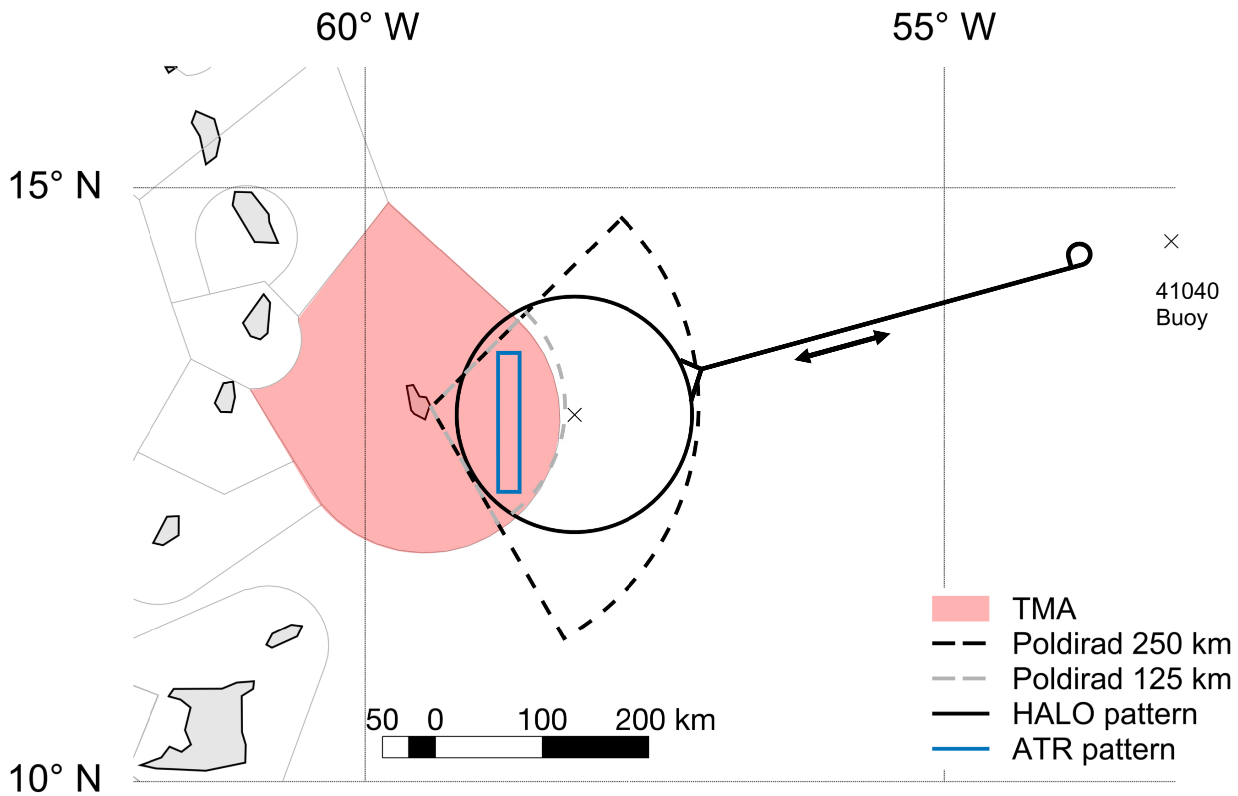
- **Circles, presently planned for 9km; 48 min, 220 km diameter, 6 circles x12 sondes, yielding 72 sondes per flight**
- Two additional circles for remote sensing with possibility to vary flight level, e.g., low level 4-5km circle for better radar/lidar sensitivity
- Possible substitution of non-sounding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

HALO flight plans

- **Circles** at 9 km, 48 min, 90 km radius, 6 circles x 12 sondes simultaneously with flights of ATR and Twin Otter
- **“Alley Walk”** during refueling of ATR and TO: long leg along Tradewind Alley
  - Provide context for circles (wind shear)
  - Aerosol layers transported from Africa
  - Predictable for ships for intercomparison
  - Dropsondes
- **Approach to TBPB**: at around 5 km for approximately
  20 minutes for high resolution radar/lidar measurements
- Some **BCO overpasses** upon return
- **Calibration** patterns for SMART, VELOX, HAMP (once in beginning of campaign)



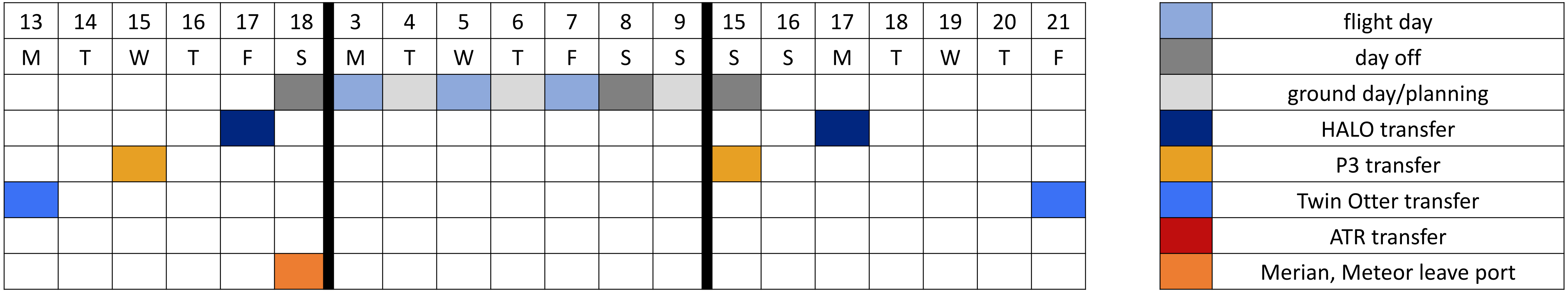
Flight schedules

Temporal coordination

Flights schedules

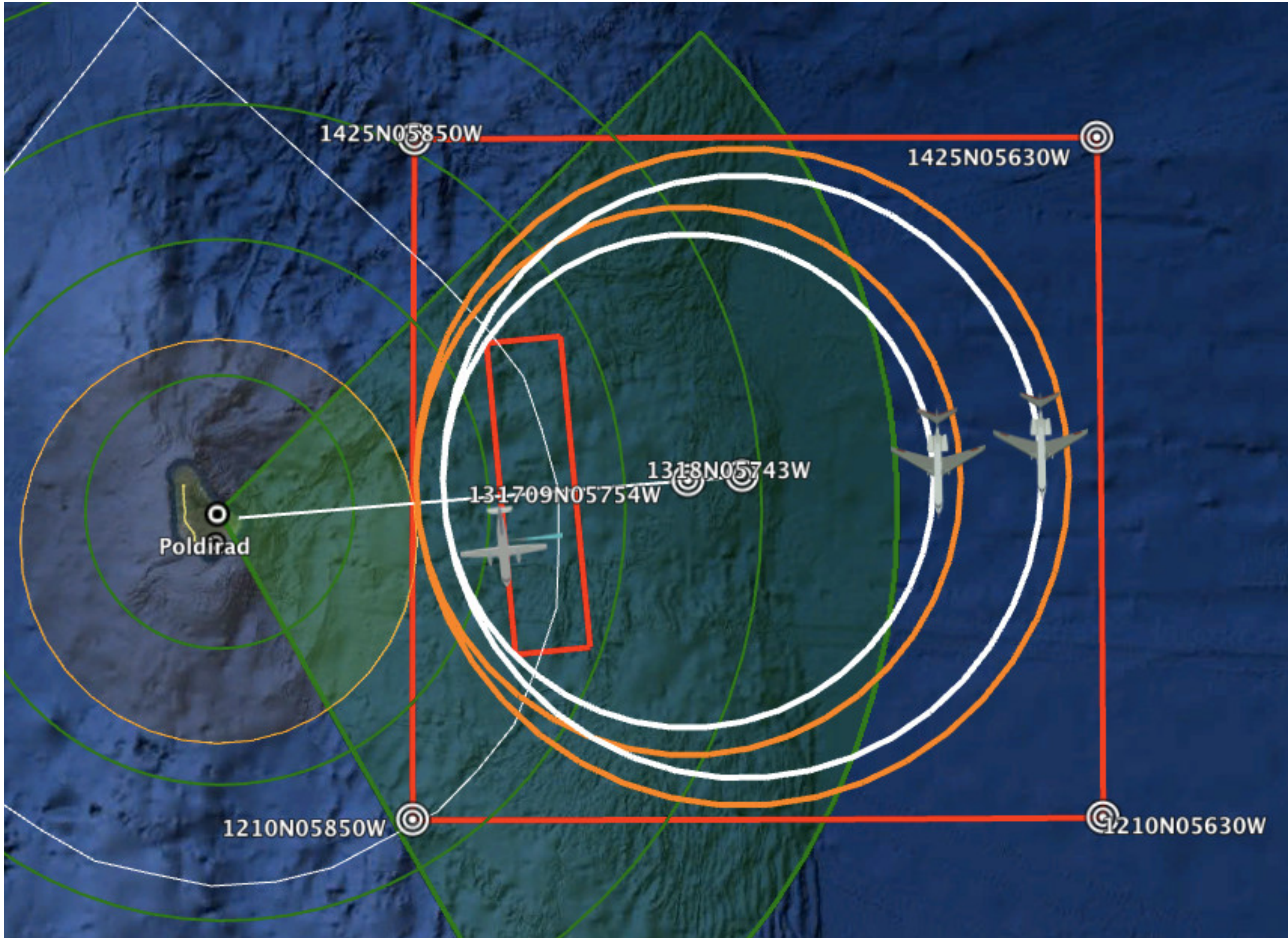
Temporal coordination

- Three different take-off times for HALO, ATR, Twin Otter:
  - 05, 08, 11 LT
  - Three days a week (exact days have to be cleared with Barbados airport)
  - Ideally, we could schedule the flights to coincide with satellite overpasses
- TO more focus on daytime flights, but could also do nighttime (but no subcloud layer flights)
- For diurnal cycle measurements it could be interesting to leave earlier than 08 LT (e. g. 06 LT); but it takes time for the aircraft to reach the area and for the instruments to be operational
- W-P3D might do one week of nighttime flights with take-off around 20 LT



Aircraft Operations Area

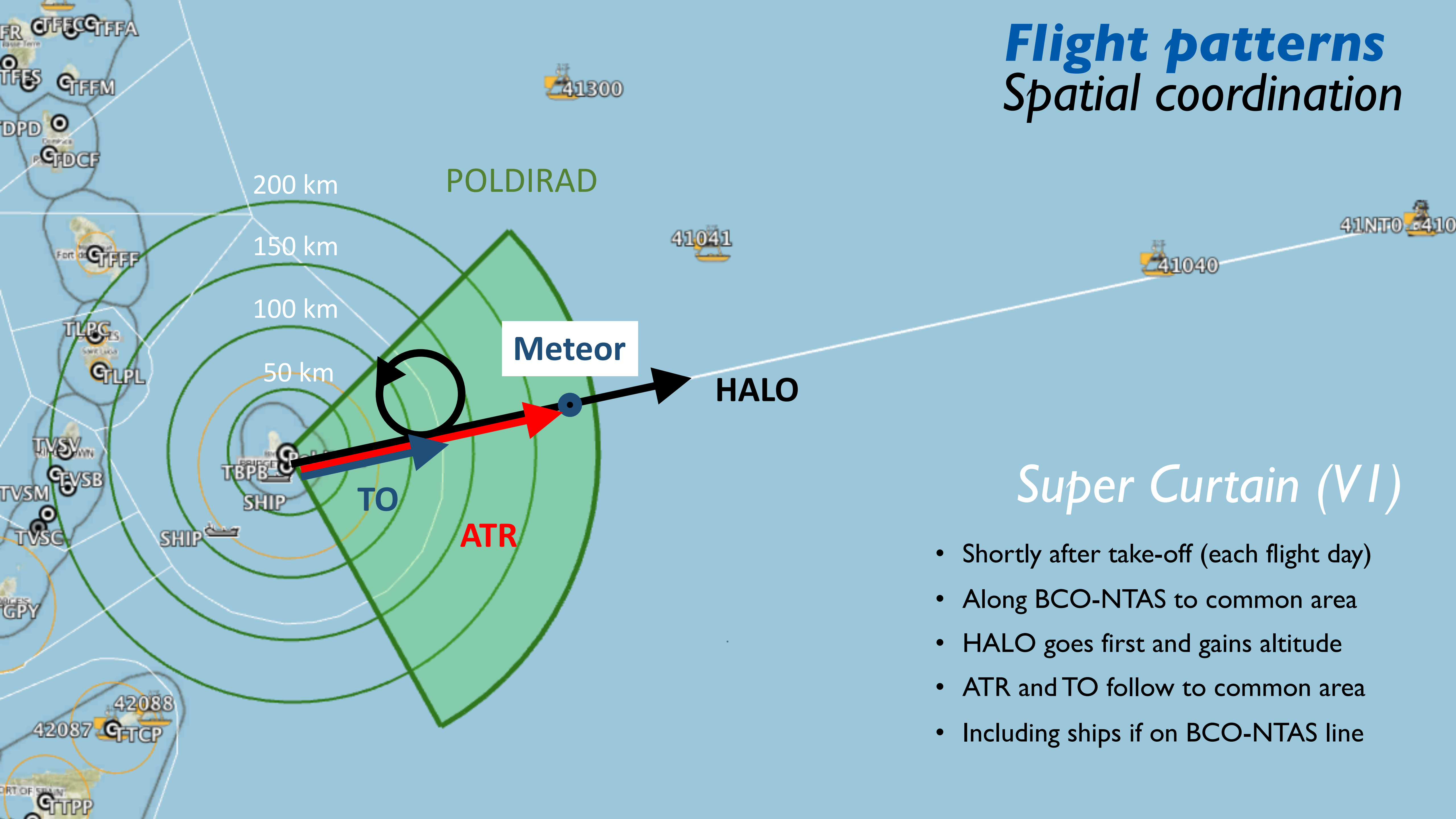
- Airspace has been requested via NOTAM
- Area inside
  1425N 05630W
  1425N 05850W
  1210N 05630W
  1210N 05850W
  between surface and unlimited will be cleared for EUREC4A/ATOMIC operations
- Sondes can be launched inside this airspace
- White circles: two possible HALO circles (90 km and 110 km radius)
  Yellow circle: 5 NM buffer zone around possible HALO circles to account for dropsonde drift



Flight patterns

Spatial coordination

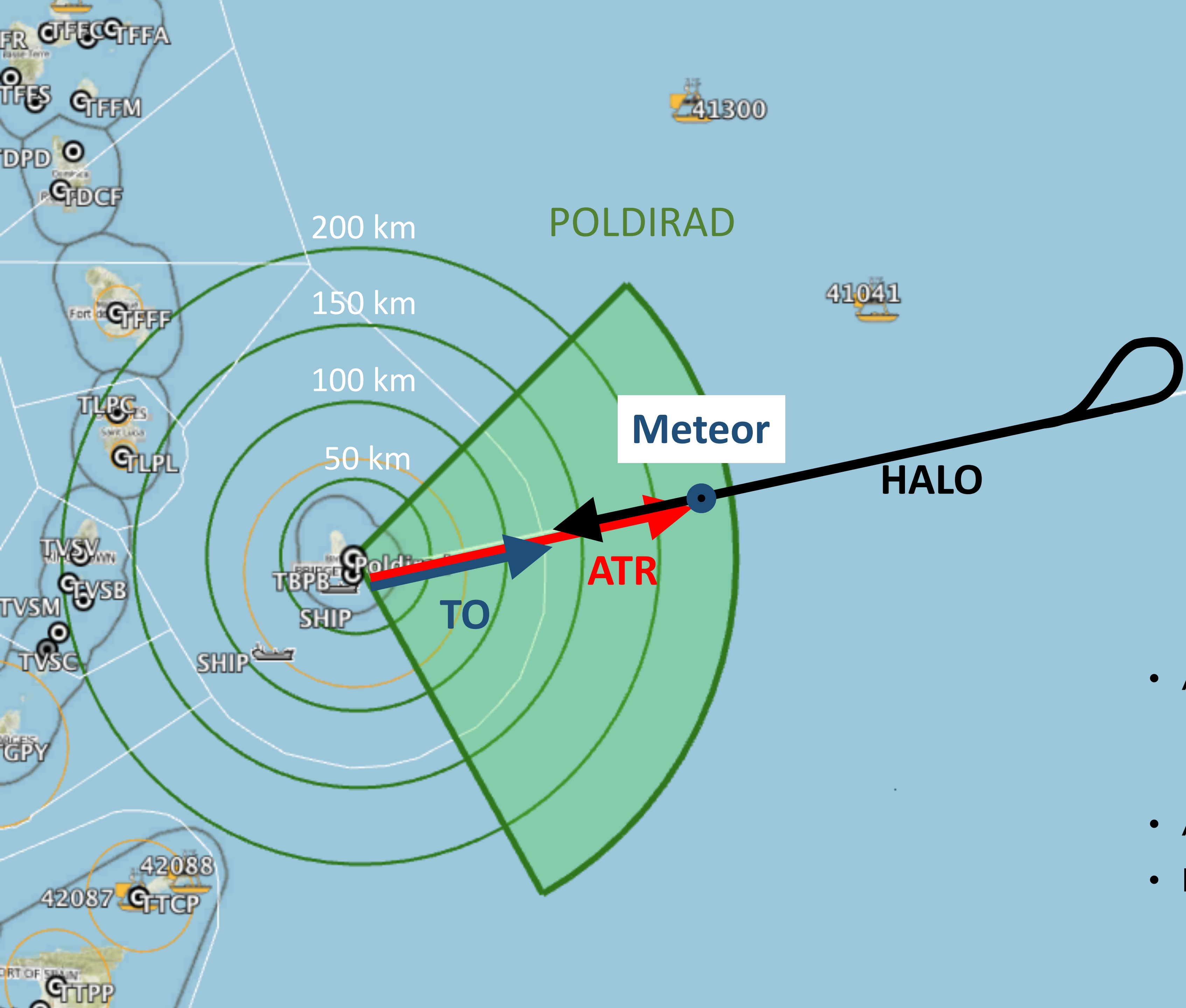
Flight patterns
Spatial coordination



Super Curtain (V1)

- Shortly after take-off (each flight day)
- Along BCO-NTAS to common area
- HALO goes first and gains altitude
- ATR and TO follow to common area
- Including ships if on BCO-NTAS line

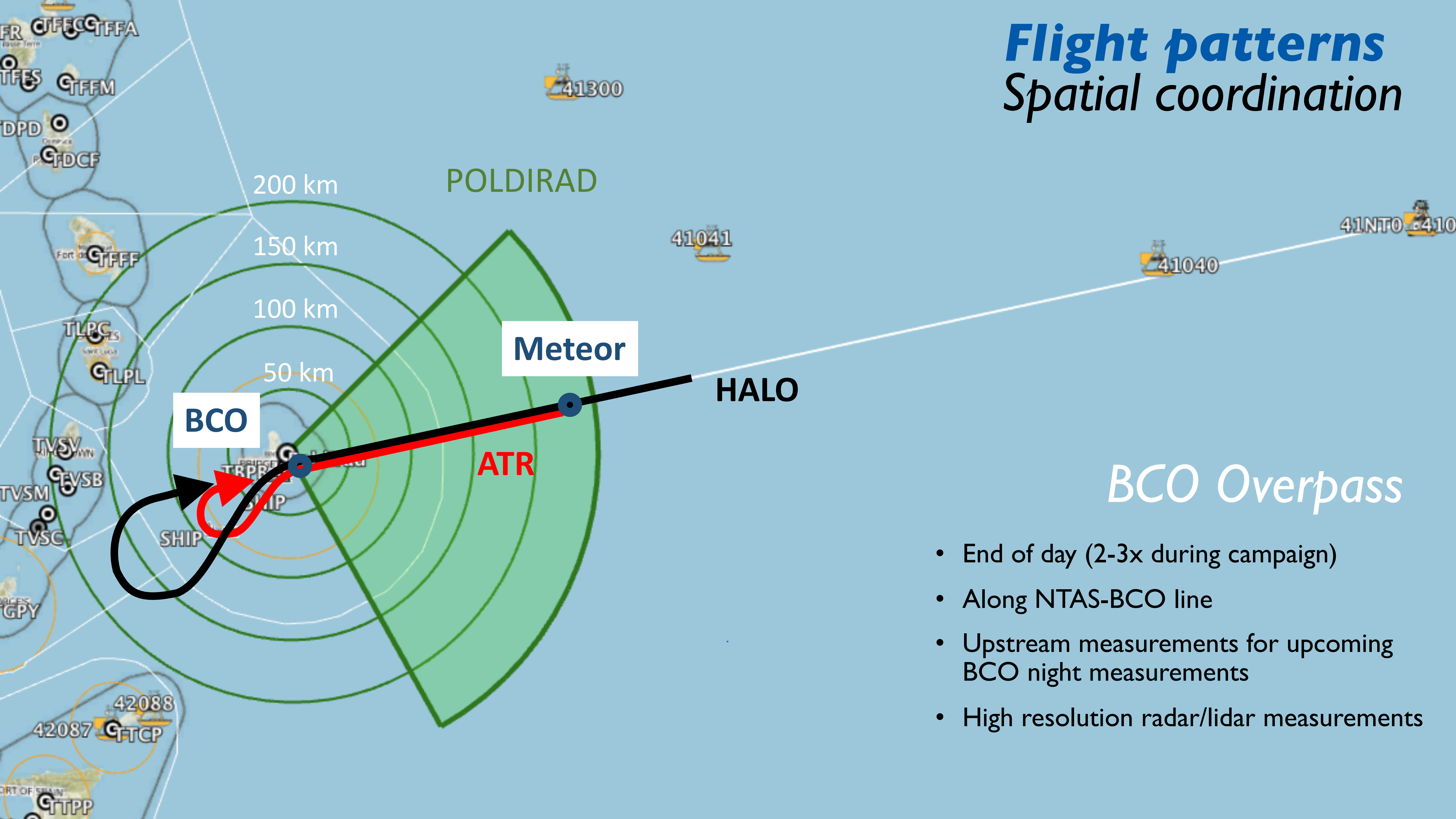
Flight patterns
Spatial coordination



Super Curtain (V2)

- After take-off or after refueling
  - If HALO take-off (has to be) earlier
  - Or as HALO excursion pattern
- As kick-off for operation in common area
- Including ships if on BCO-NTAS line

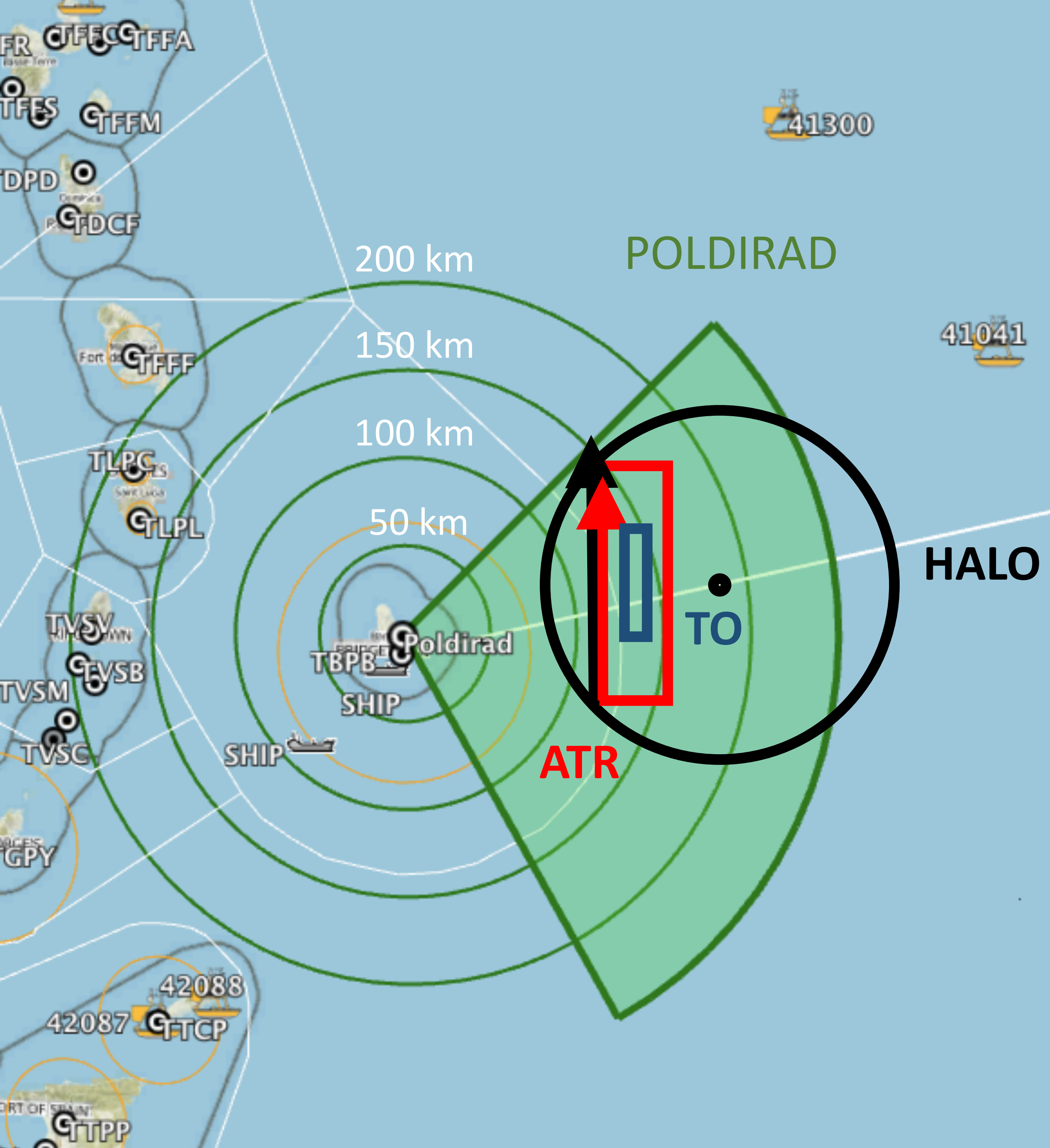
Flight patterns
Spatial coordination



BCO Overpass

- End of day (2-3x during campaign)
- Along NTAS-BCO line
- Upstream measurements for upcoming BCO night measurements
- High resolution radar/lidar measurements

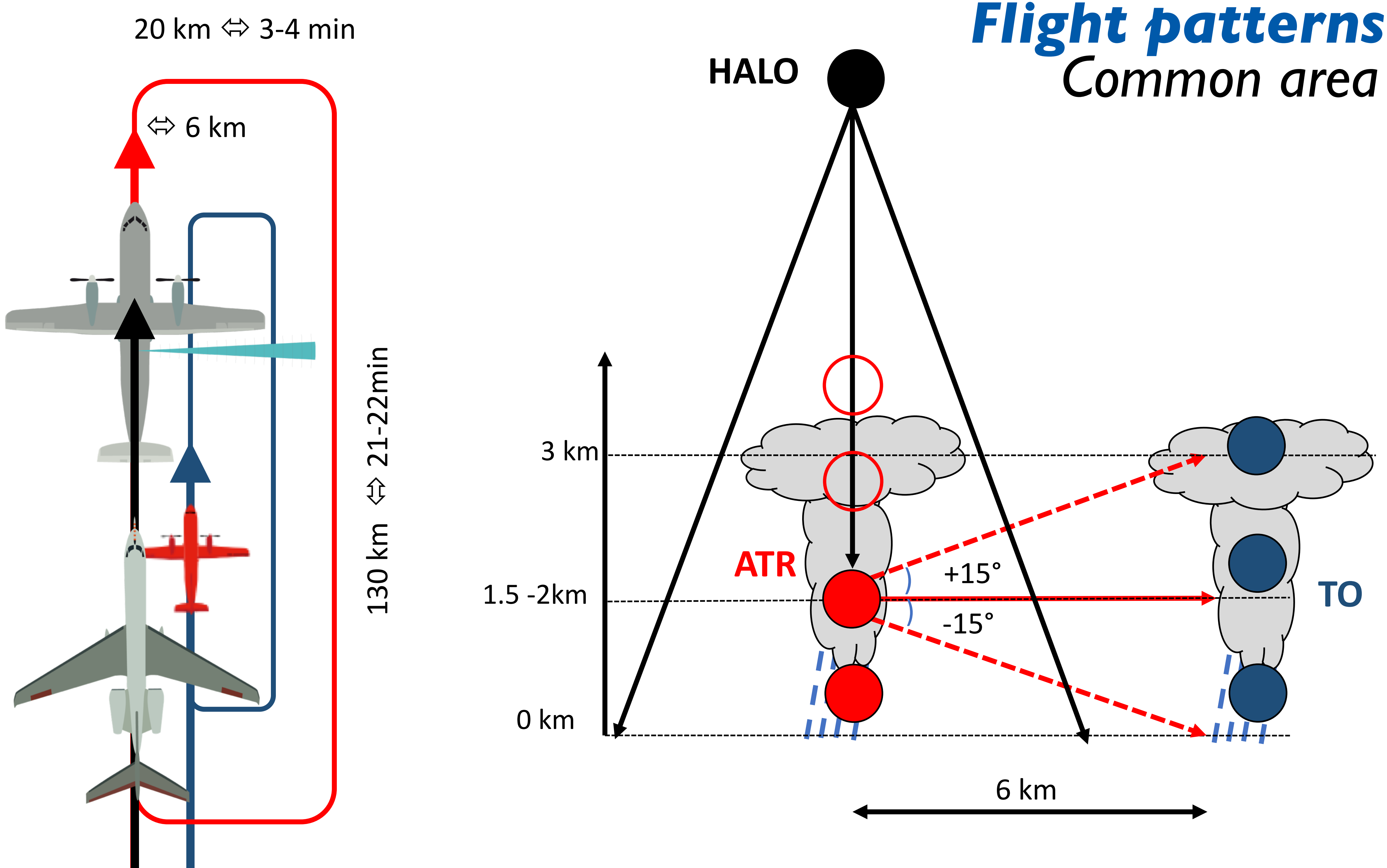
Flight patterns
Spatial coordination



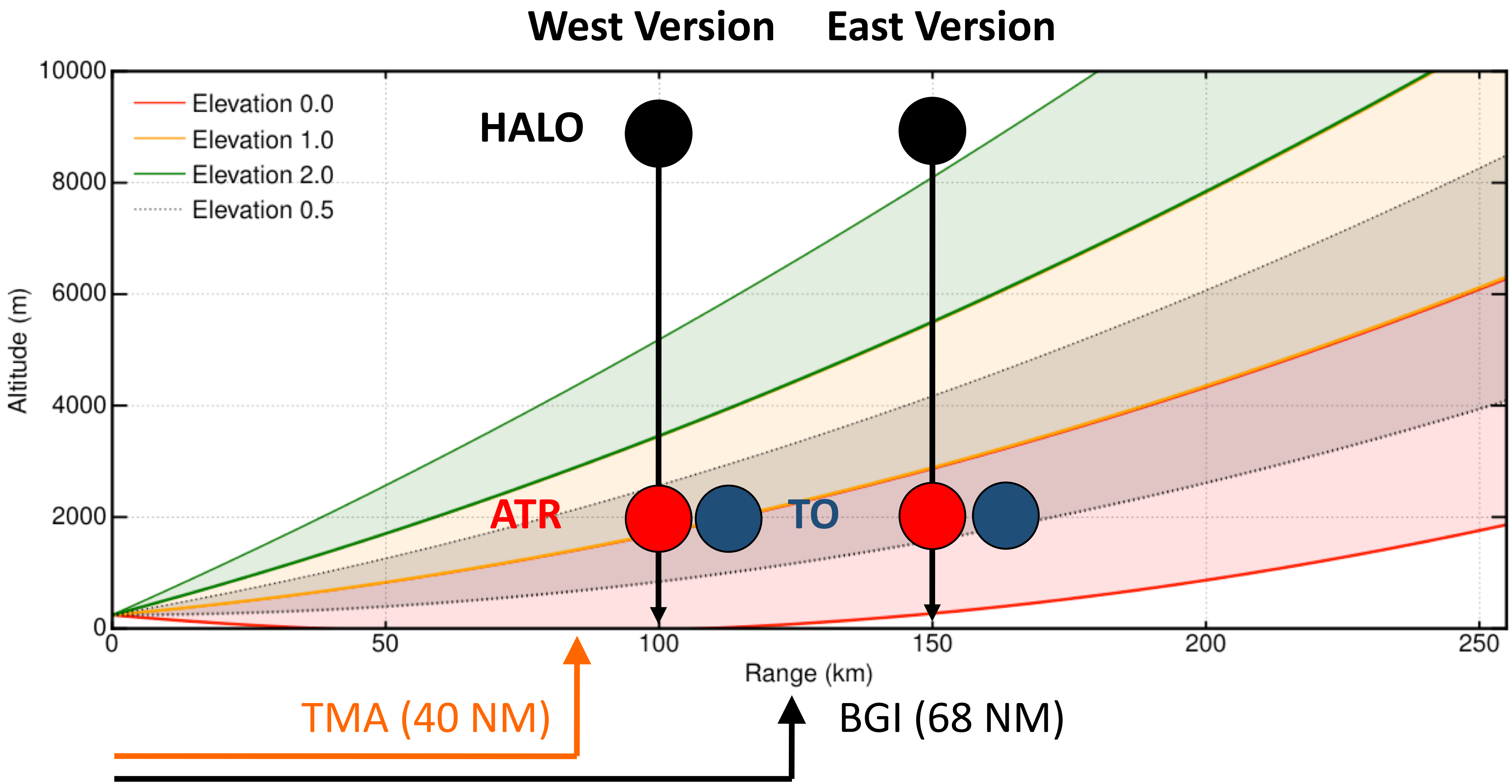
Common area

- Core pattern (massflux / closure studies)
- On all flight days (AM + PM flights)
- Close tandem of HALO / ATR
- Twin Otter will join as often as possible
- Key request: flattened HALO circle

Flight patterns
Common area



Flight patterns
Common area (POLDIRAD)



Open issues
Known unknowns

Airport limitations

- Plan to fly regular 'weekly' schedule with three flights per week & staggered departure 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

Aircraft limitations

Common area (closure studies) + Super curtain

- Location, duration, specific plans for calibration patterns
- Refuel @ around 4 pm might be an issue – take-off at noon therefore not optimal
- TO is happy to fly with ATR42
  - could fly inside the ATR42's pattern

  → vertical separation at least 1000ft

Aircraft limitations

Night time flights (Diurnal cycle)

- ATR, TO: Interest / feasibility for night-time flights?
- TO: How far in advance will flight plans be fixed?
- W-P3D could fly night-time (take off 8pm) – 3 flights for one week?
- TO and ATR42 could fly at night but with restriction in terms of lowest altitude (adv more stat during night / cons change in stat + logistic)

Open questions

Twin-Otter specific

Points to consider.

1. Include a profile except perhaps in the BL-focus flights. Time is a factor.
2. Divide flights into two categories of sampling and three vertical regions.
   Suggest we focus on one region per flight.
3. It may be possible to have two flights per day: e.g. first of 4 hrs and second 3 hrs.

Categories

1. Study of "single cloud": e.g. for flowers, but also for developing clouds in other regimes
2. Quasi-statistical flying, in more-or-less straight line, or along a curve (fish), but diverting to target clouds if necessary