CuPIDO flight strategy

an update based on the July 2004 UWKA facility request

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Flight schedule:

The facility request says that the flights are generally between 7 am – 1 pm LT. The ideal is that the King Air is airborne just before the first cumulus develops over the mountain. Normally, just one flight will be conducted in a day. Exceptionally, a second flight is possible, e.g. because the first flight was aborted because the anticipated cumuli did not develop (yet), or because a succession of towering cumuli never evolves into the cumulonimbus stage.

On a daily basis, research flights may be focused either towards intense investigation of cumulus dynamics or towards large-scale convection evolution and environmental modification. The latter might require circling the mountain range multiple times (and multiple flight levels) to document changes in valley and environmental meteorological parameters (see Section B.), and the use of along-wind extended legs at multiple levels. Cumulus dynamics should be promoted when little vertical shear, low winds aloft, and large instability are present.

A. Cumulus dynamics/microphysics patterns (Fig 1)

(i) short-leg **Racetrack** (Fig 1c)**,** **Rosette** (Fig 1b), and **90-270°** (Fig 1d) patterns

<u>objective</u>: to study fundamental cumulus dynamics and cloud processes
These patterns will consume most of the flight time on a majority of flights.

Rosettes are not ideal for cumulus dynamics, since clouds are not axisymmetric and thus the temporal evolution is lost. Assembling images from displaced two-dimensional planes introduces more unknowns in the interpretation of the three-dimensional mechanics of the clouds due to the extra dimension of time. <u>Rosette patterns are thus recommended only for statistical sampling of thermodynamic conditions and assessment of cloud variable vertical profiles</u>.

Racetracks and **90-270°** repeated traverses are ideal to assess the fluid-dynamic evolution within cumulus, also they can be combined with parallel passes outside the cloud with the radar scanning horizontally or alternatively with side-down profiling passes. Racetracks and 90-270° traverses should be conducted at a fixed heading, either <u>parallel</u> to the mean (in the cloud layer) wind direction or in a <u>cross-wind</u> direction.

Temporal (rather than just statistical) *sampling is essential*. In *the initial stages of evolution* the continental cumuli will likely be only marginally detectible by the WCR, and the strategy is to characterize the subcloud layer at about **200 m below cloud base**, mostly relying on on-board instruments. Estimated flight-segment required time: *10-15 minutes*. The WCR will be run in up/down profile mode (scanning a vertical plane above and below flight level) that allows, in case of scatterers such as insects or other types of debris be present, to verify the occurrence of buoyant plumes and the continuity of updrafts from the surface up into the cloud. The thermodynamic assessment of the subcloud airmass will be used in post-processing in an effort to predict the adiabatic liquid water path and microphysical quantities against the real data coming from penetrations across the cloud. Entrainment assessment calculations will also rely on these data.

The next phase consists of penetrations **at 200 m above cloud base**. The WCR will be run in side-forward/ down/ up modes, scanning a vertical plane above and below the aircraft and a starboard horizontal one. We foresee to find good data for droplet activation problem closure and to be able to characterize the kinematics of cloud base (convergence, updraft strength and location). Estimated flight segment time: *10 minutes*.

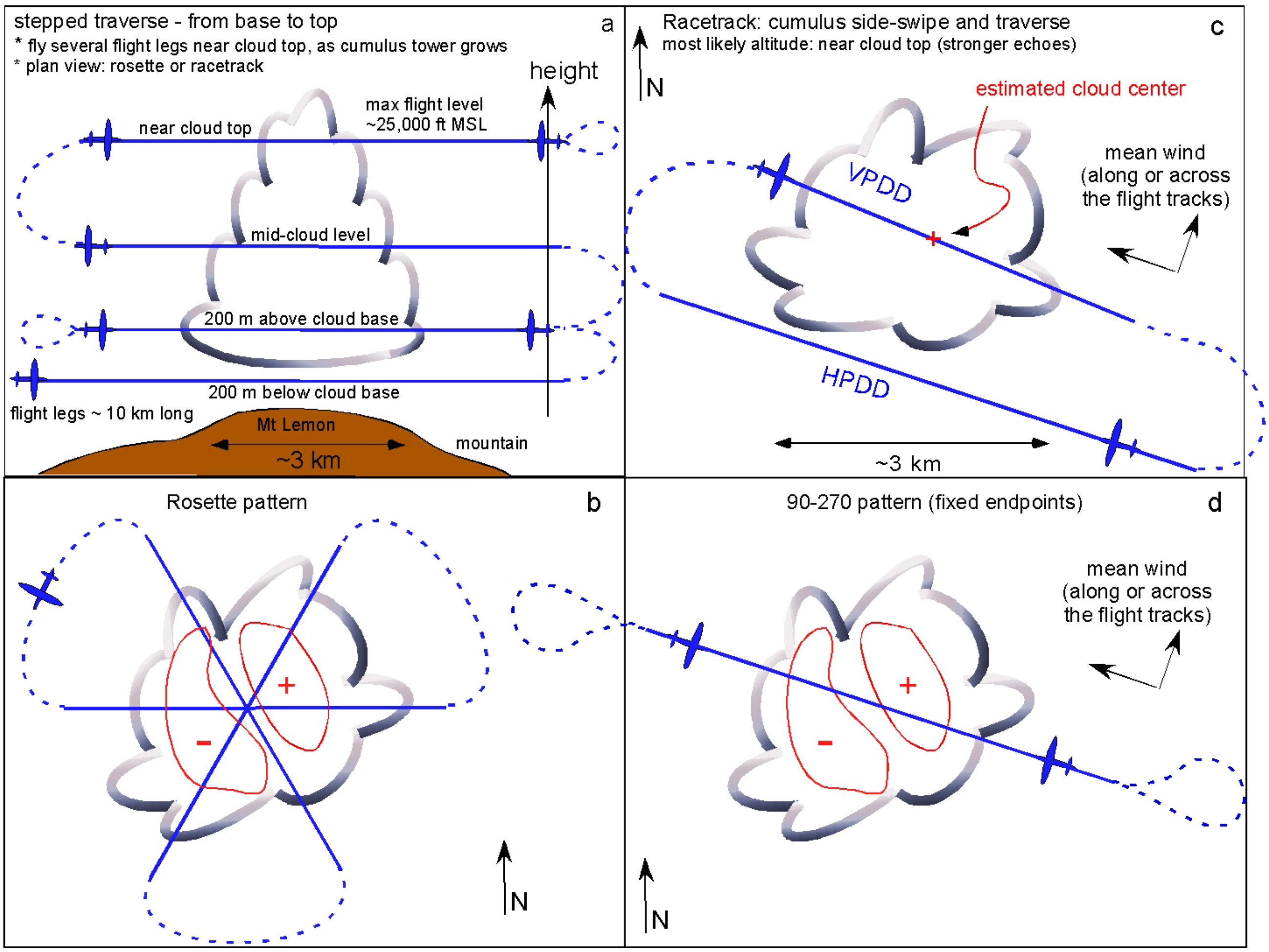

Fig 1. Cumulus penetration patterns. (a) Vertical transect showing a base-to-top stepped traverse. This traverse can be done as a racetrack (c), a rosette (b), or a quick 90-270°.

As the cloud develops into a weak congestus, fixed heading cloud traverses (Fig 1c) will be executed **near cloud top** in VPDD mode. If the cloud depth is larger than 500m, the ideal aircraft position would be at or just above cloud top. Cloud top may outclimb flight level allowing *HPDD passes grazing the edges alternated by VPDD or side-down modes* (Racetrack, see Fig 1c) penetrating the cloud. Estimated required time: *20 minutes*. <u>Cloud-top maximum rate of climb can be estimated at 1000ft/min</u> (maximum expected updraft speed on the order of 10 m/s). Two successive traverses (or a penetration + one grazing pass) may require up to 2 minutes. The thermal core would rise at most by 2000 ft, allowing ideally to first scan the leading edge and then to sample the convergence region at the trailing edge of the main thermal. If more time is required, because of the cloud lateral extent, the cloud-top rate of rise is likely to be less.

The **mature congestus stage** is defined as a cloud depth between 1-3.5 km (3.3-11.5 kft). At this stage a further up/down/side penetration and/or HPDD will be executed at the same altitude, likely a *mid-depth level*. Then the aircraft will climb again to the top of the tower and complete passes in VPDD and HPDD. Estimated required time: *20 minutes*.
Alternating between HPDD passes and penetrations in VPDD or up/down mode is needed for the spatial collocation of the various features in the horizontal plane with respect to the updraft/downdraft regions. All flight legs should maintain the same orientations, along the shear vector if shear is present, or a cross-wind direction in case of cumulus dynamics focus.

The maximum flight level ever requested will be 25 kft. Cumuli rising well above that level may rapidly evolve into cumulonimbi (with lightning), and therefore should not be targeted.

B. Cumulus – environment interaction and Catalina circumnavigation

(i) **boxes and long-leg tracks along the mean wind** (Fig 2)

objectives: (a) to study the modification of the mid-troposheric environment by the successive cumulus pulses; (b) to examine and assess overall cumulus (cluster) evolution at a given level (high-pulsewidth HBDD).

These patterns may dominate the flight legs on a few flights. This pattern is preferred when a clear prevailing wind exists, leading to a clear detrainment zone and possible multiple clouds towering at increasing height. Either 20-40 km long legs (racetrack or 90-270°) or smaller boxes encompassing all cumuli over the Catalinas will be flown. One or several flight levels will chosen near the estimated level of maximum detrainment, in order to assess how the cumuli affect the environment. A secondary flight level is just below cloud base, in order to assess the variability of the inflow environment.

(ii) **fixed-track low-level Catalina circumnavigation** (Fig 3)

objectives: (a) to estimate the net horizontal convergence of mass, water vapor, heat and momentum in the convective boundary-layer within the flight loop before, during, and after convective initiation; (b) to estimate the vertical surface sensible and latent heat fluxes along the flight loop.

- One flight is to be entirely dedicated to this.
- Circumnavigation is recommended both before and after the cumulus penetration work, (before) if the sky is still clear, and (afterwards) if the cumulonimbus remains over the mountain and can readily be circumnavigated.
- flight level: 1000 ft AGL. A single flight level is chosen to maximize temporal comparability. A low level is chosen to sample the CBL as early as possible and to allow combined use of UWKA/PAM data. A height AGL is used because of the large along-track MSL height variations.
- One ~100 km circle around the mountain (Fig 3) takes ~19 minutes.

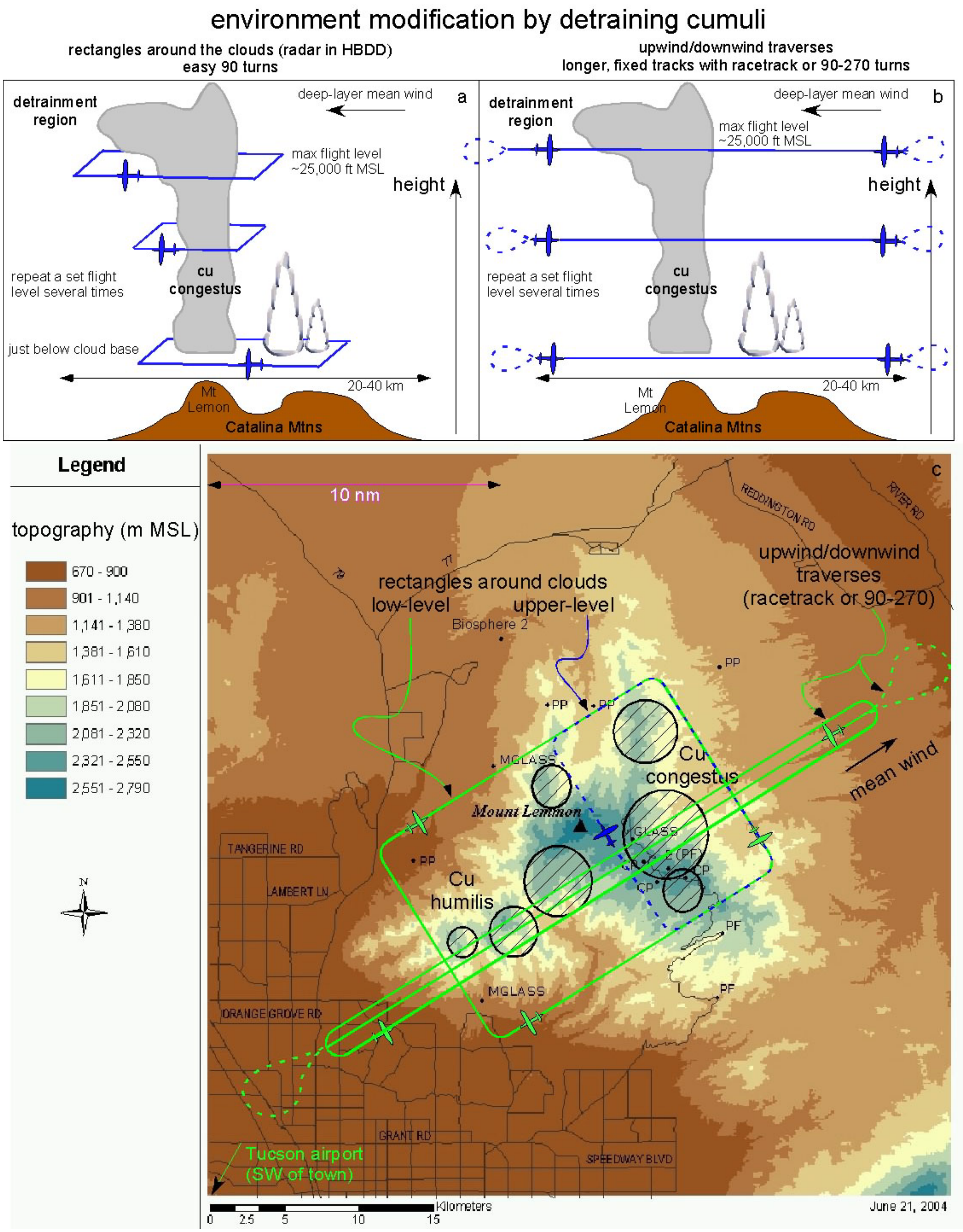

Fig 2. Modification of the environment by detraining cumuli. (a) box pattern, in clockwise direction to allow WCR coverage; (b) upwind/downwind traverses; (c) map display of (a) and (b).

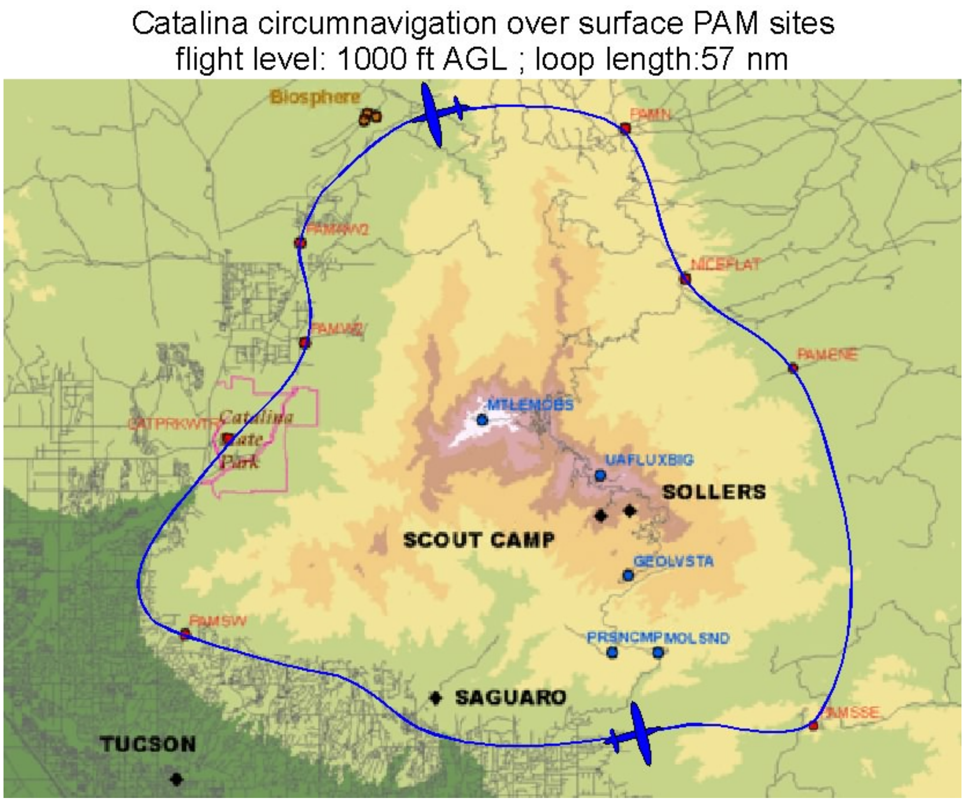

Fig 3: Catalina circumnavigation over the surface sites at 1000 ft AGL.