Aerosols @ HALO

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Outline

Research Motivation

- ***background & challenges***

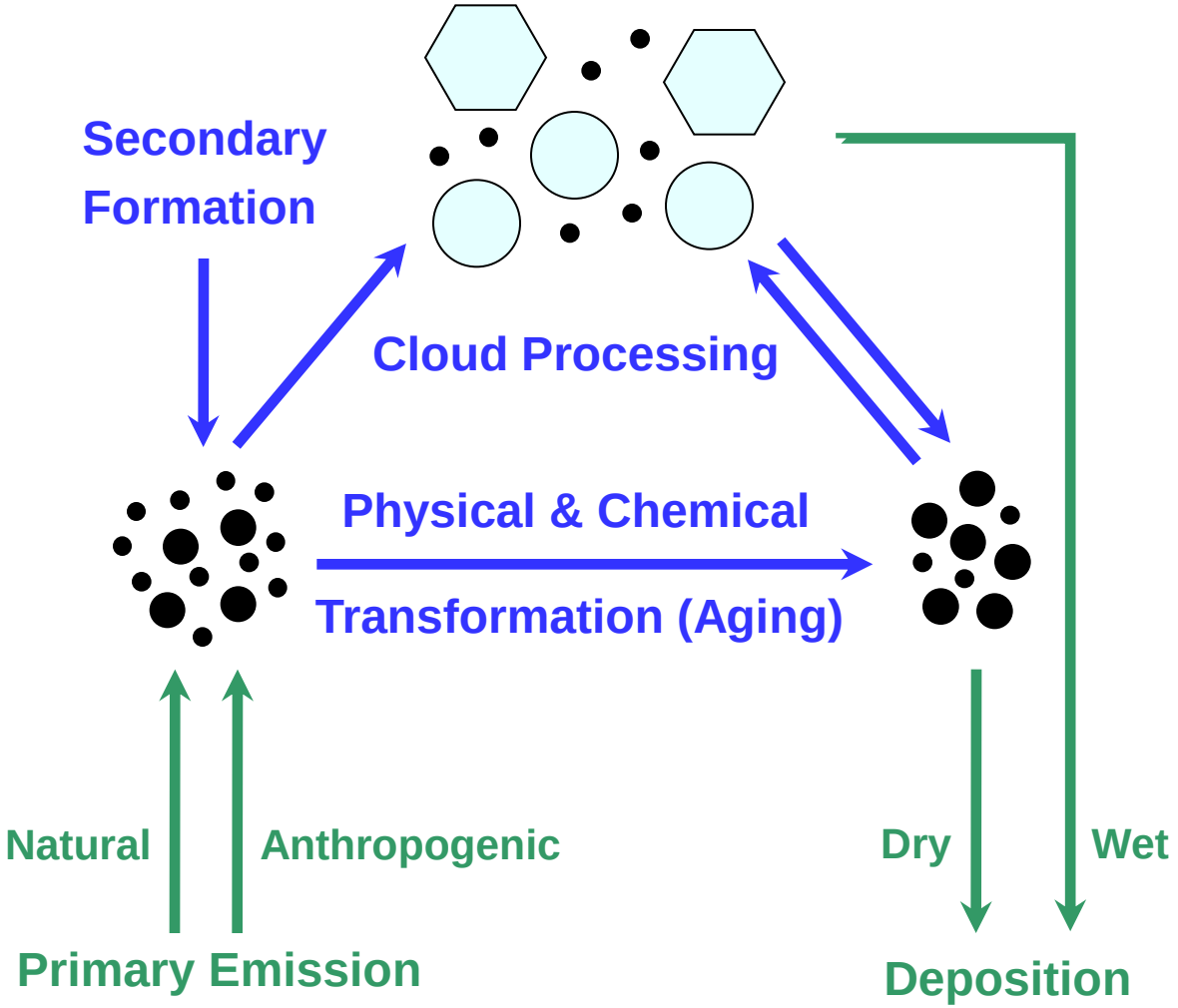
HALO - Why & How ?

- ***opportunities & perspectives***

Demo Missions

- ***ACRIDICON***
- ***ML-CIRRUS***

Aerosol Cycling & Effects



Atmosphere & Climate

- clouds & precipitation
- trace gases
- radiation

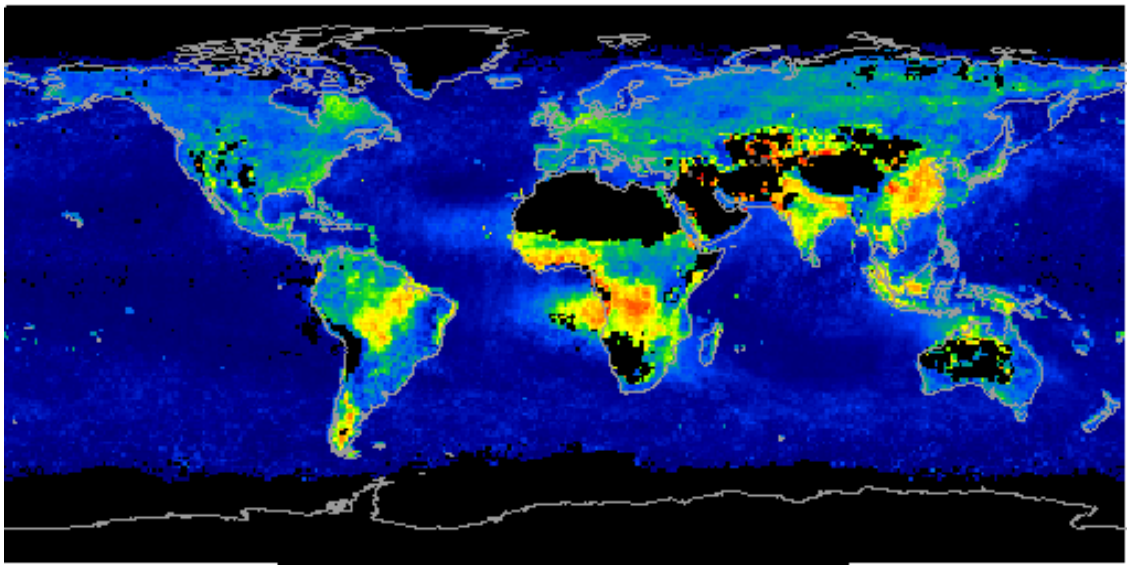
Quantitative Description & Human Influence ?

- human, animal & plant diseases
- spread of organisms & ecosystems

Biosphere & Public Health

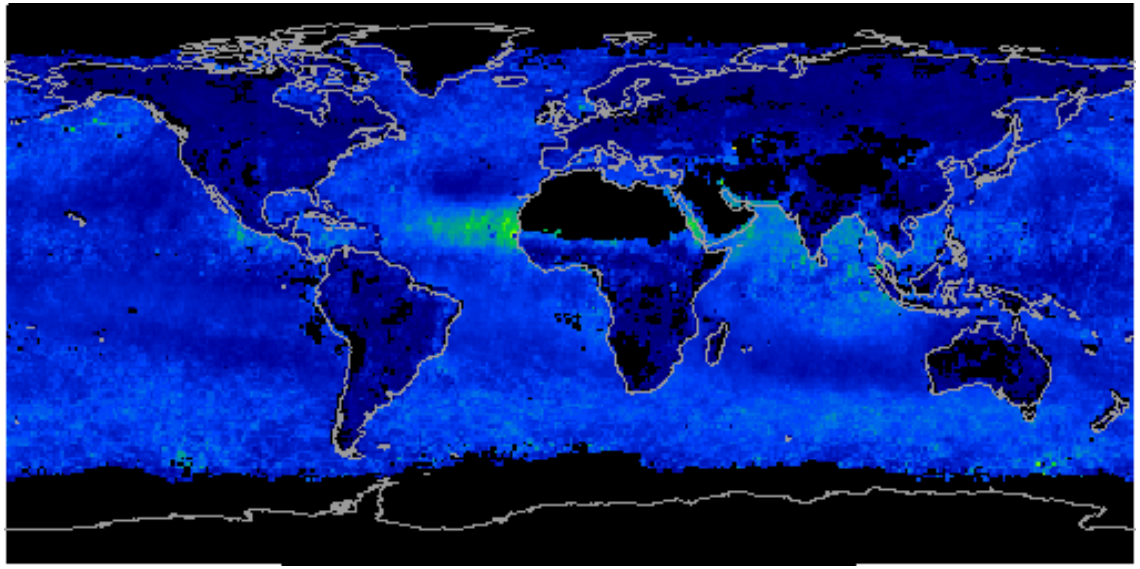
Pöschl 2005, Fuzzi 2006

Global Abundance & Remote Sensing



Fine Aerosol (< 1 μm)

- Combustion
  (biomass & fossil fuel)
- Photochemistry
  (natural & anthropogenic precursors: SO2, HC, etc.)



Coarse Aerosol (> 1 μm)

- Sea Salt
- Mineral Dust
- Biological Particles

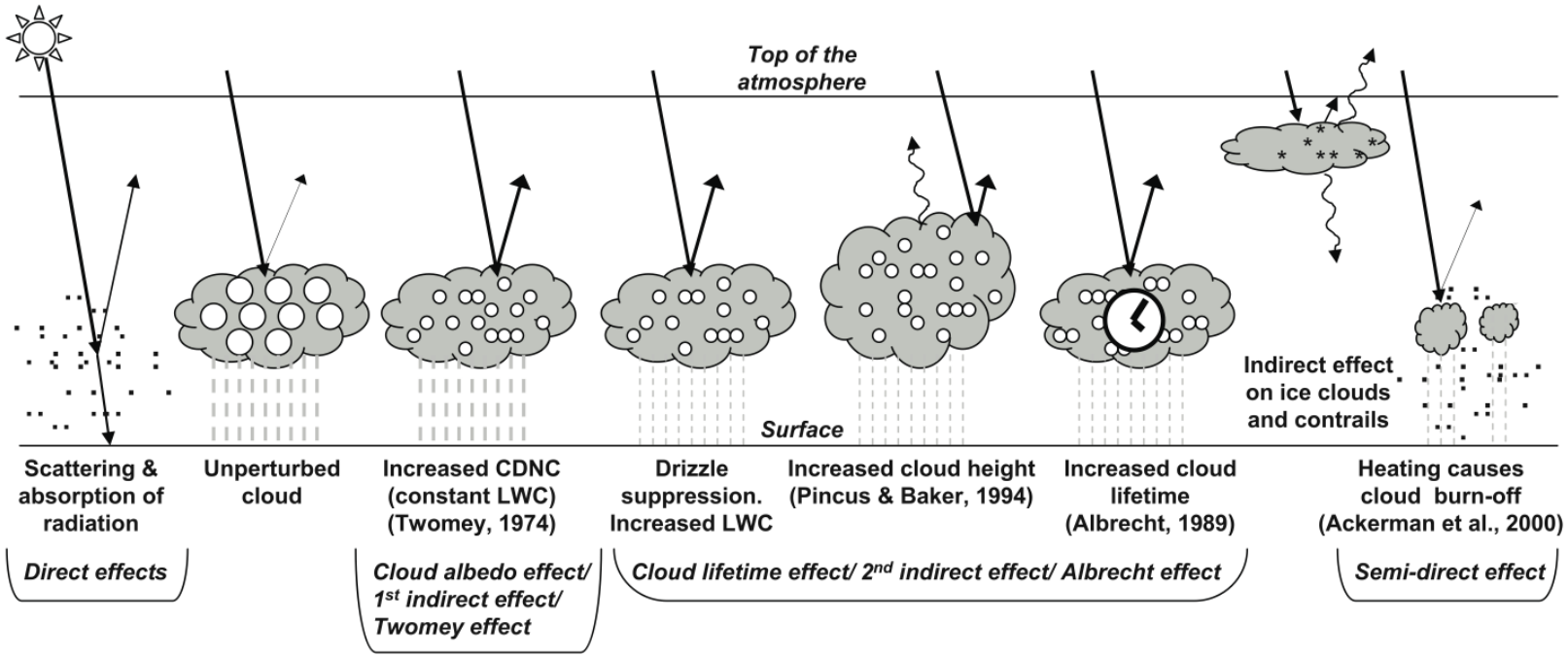
Composition & Profiles ?

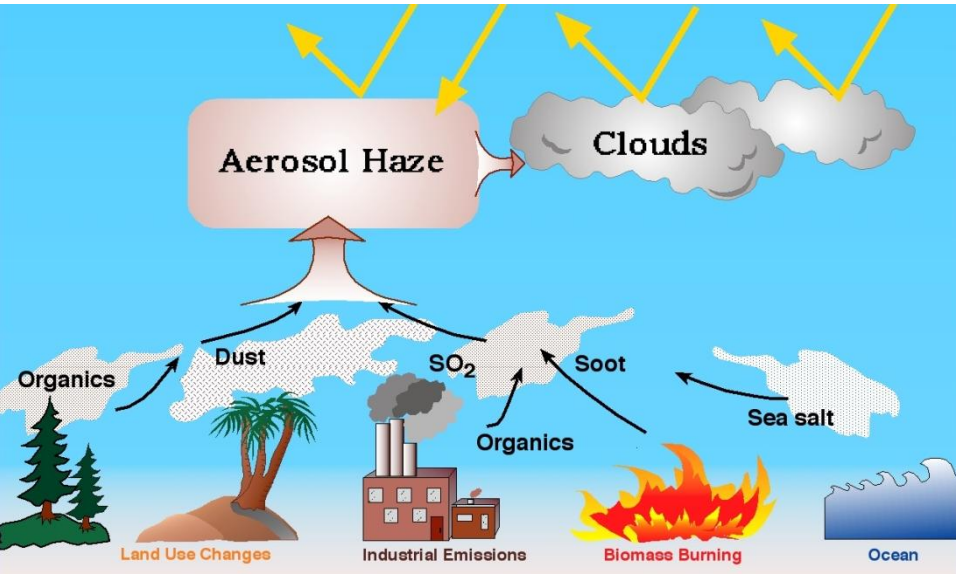
Accuracy & Validation?

Blue → ***Red*****:** *increasing optical depth & particle abundance*

Rudich 2001 (NASA-MODIS)

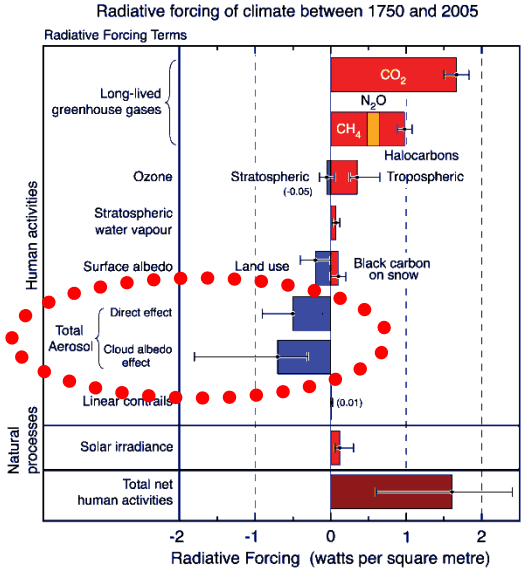
Radiative Forcing of Climate





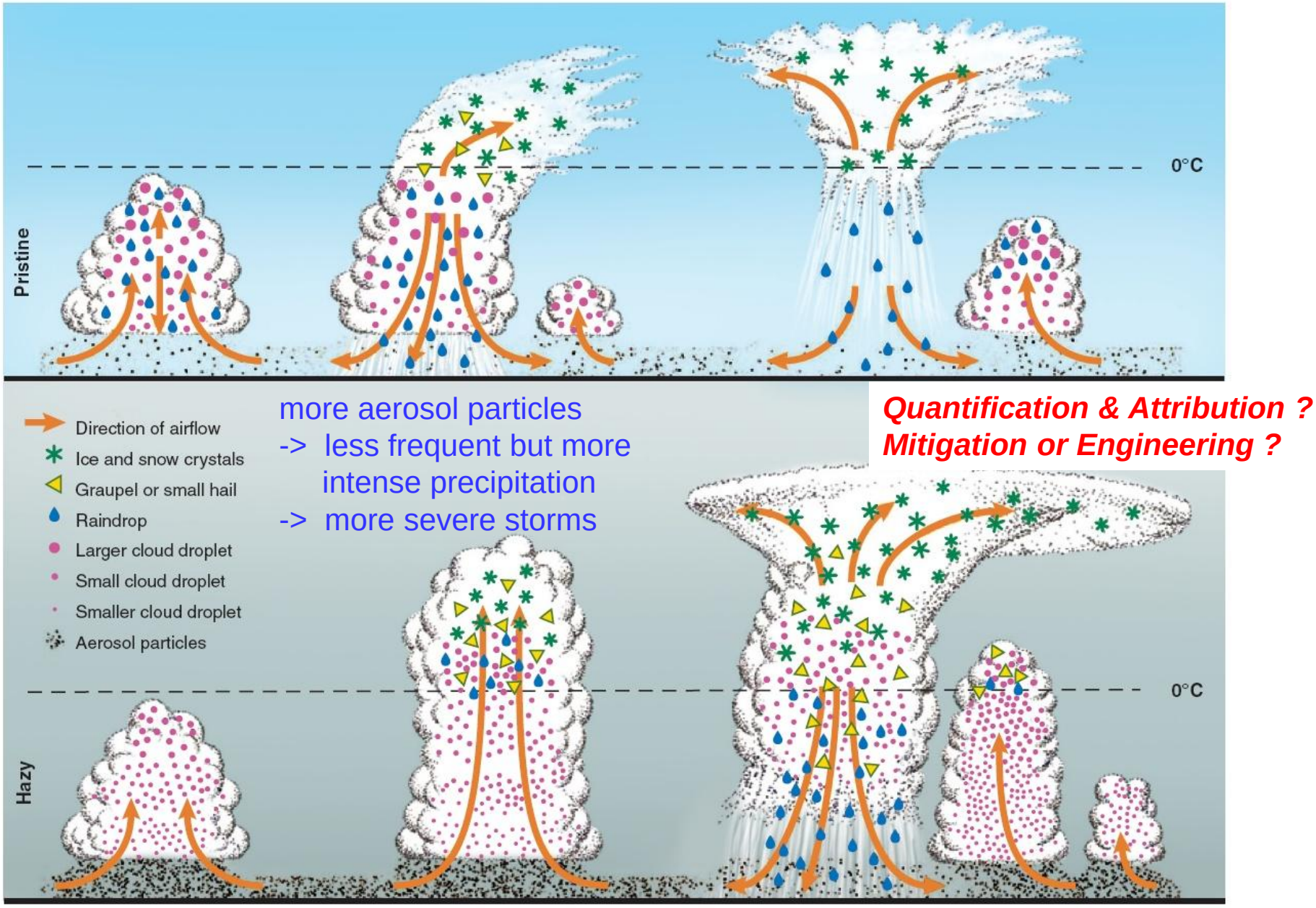
Quantification & Attribution ?

Mitigation or Engineering ?



IPCC 2007

HALO Hydrological Cycle & Heavy Weather



Quantification & Attribution ?
Mitigation or Engineering ?

Rosenfeld 2008

HALO - Why & How ?

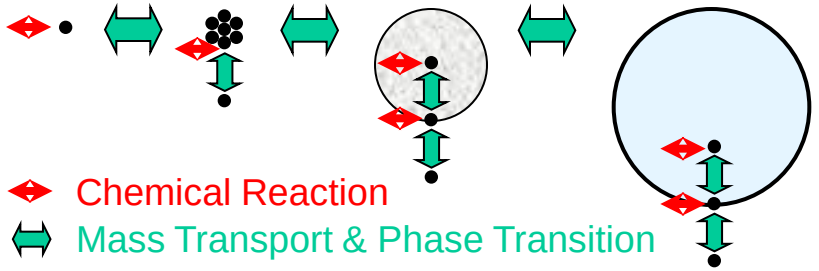
Opportunities: high altitude, long range, large payload

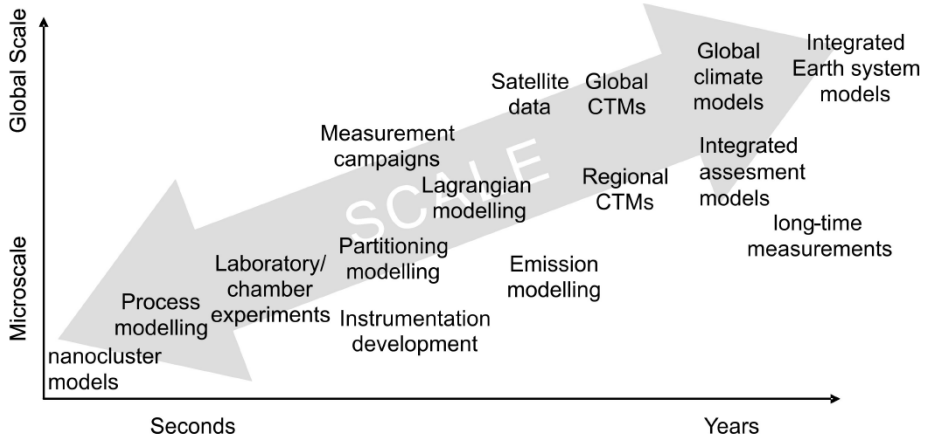
- Profile troposphere & reach UT/LS
- Combine in-situ & remote sensing of gases, aerosols, clouds & precipitation
- Cover wide spatial & temporal scales

Perspectives

Advance & validate remote sensing
of gases, aerosols & clouds
(ground-based & satellite)

Quantify multiphase processes
in cirrus clouds & deep convection
(aerosol-cloud-precipitation)





Demo Missions

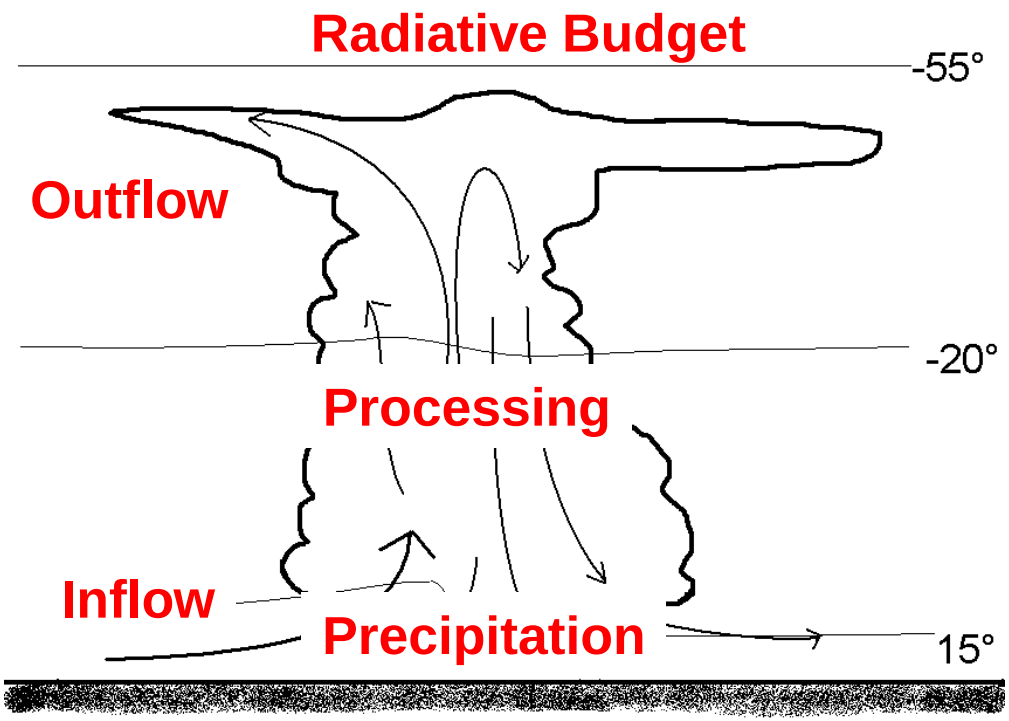
ACRIDICON, ML-CIRRUS
(NARVAL, NEPTUN, etc.)

Pöschl 2005, Fuzzi 2006, Kulmala 2009

Aerosol, Cloud, Precipitation, and Radiation Interactions and Dynamics of Extra-Tropical Convective Cloud Systems

Key Questions

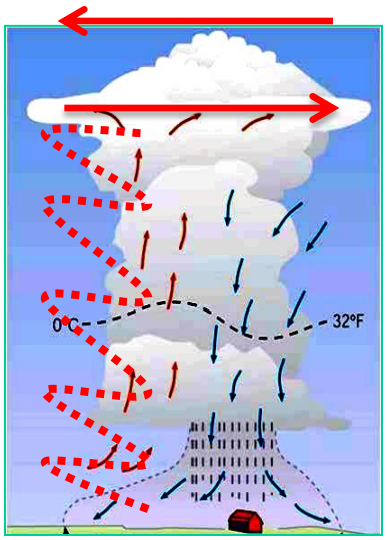
- Does the interaction of aerosols with clouds & precipitation significantly influence the **formation & dynamics of convective cloud systems & the vigor of heavy weather events** (hail and rainstorms)?
- Can these effects induce substantial changes in the **global circulation of the atmosphere, the Earth's energy budget, and climate**?

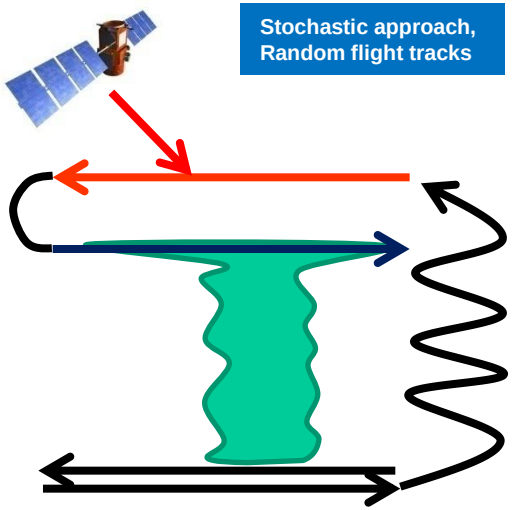


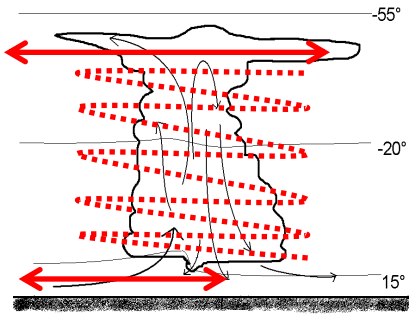
- What are the characteristic physical & chemical properties of **aerosol & cloud particles** in convective clouds, and how do they change in the course of **cloud evolution**?
- What are the effects of convective cloud systems on the solar and terrestrial radiation budget, and what is the **3-dimensional microphysical structure of convective clouds**?

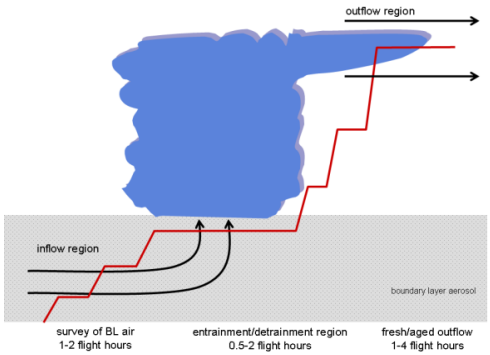
Mission Types

1. **Cloud Vertical Evolution**
   (Cloud Profiling)
2. **Aerosol Processing**
   (Inflow, Outflow)
3. **Satellite Validation**
   (Cloud Products)
4. **Vertical Transport & Mixing**
   (Artificial Tracer)





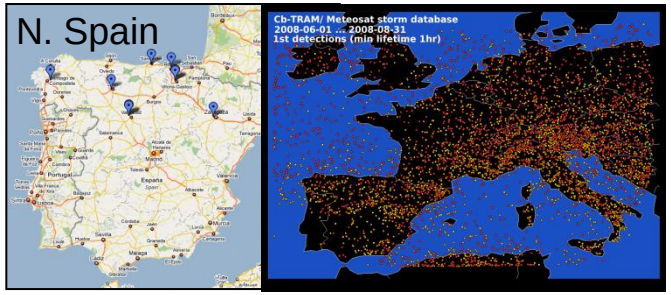




→ ***Contrast of pristine & polluted conditions***

→ ***Comparison of different thermodynamic conditions***

→ ***Comprehensive measurement of aerosol, cloud & radiation parameters:***
particle size distributions, CCN, IN, BC, LWC, IWC, LWP, IWP, backscatter, gas tracers (nat./art.), etc.



Formation, Lifetime, Properties and Radiative/Chemical Impact of Mid-Latitude Cirrus Clouds

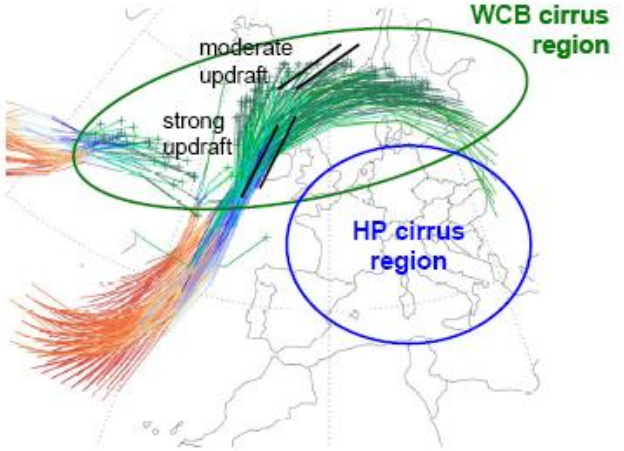
General Objectives

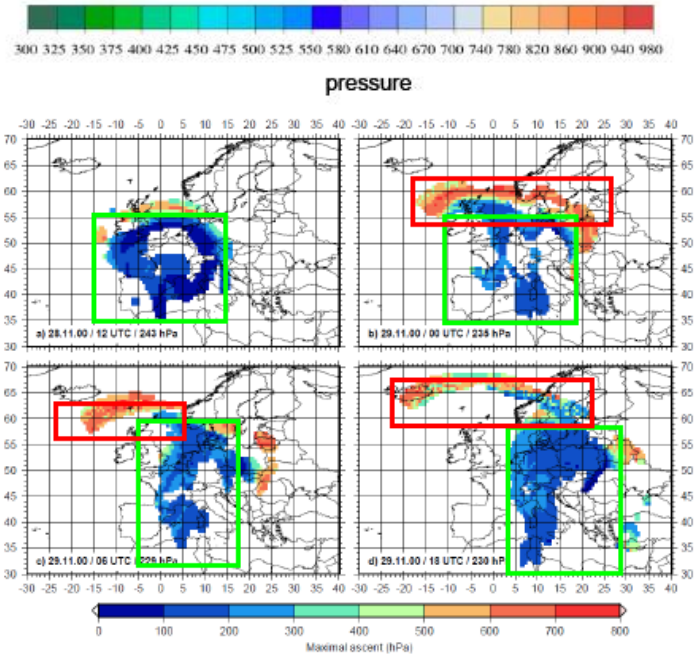
- Investigate the **indirect aerosol effects on cirrus clouds**. Quantify the contributions of aerosol particles from surface sources and aviation (including contrails). Clarify (microphysical) mechanisms for cirrus formation.
- Characterise the changes of cirrus cloud properties during their life cycle and the **effects of cirrus on radiation**.
- Characterise the **distribution and occurrence of ice-supersaturated regions** (forecast of persistent contrail/cirrus). Quantify the distribution of UT/LS water vapor inside and outside of ice-supersaturated regions and in the vicinity of cirrus clouds.
- Evaluate the **cirrus/aerosol impact on trace gas fields** (e.g. reactive nitrogen species, halogens, water, ozone). Investigate the impact of aircraft emissions on the composition of the UT/LS region including reactions on particles.
- **Validate space-borne instruments** for the measurement of cirrus cloud properties and water vapour (e.g., MSG, CALIPSO, MetOp, Earth-CARE, CESUR, Space-WAVES, MIPAS, MLS, IASI) with special emphasis on cloud microphysics and radiative forcing.

HALO

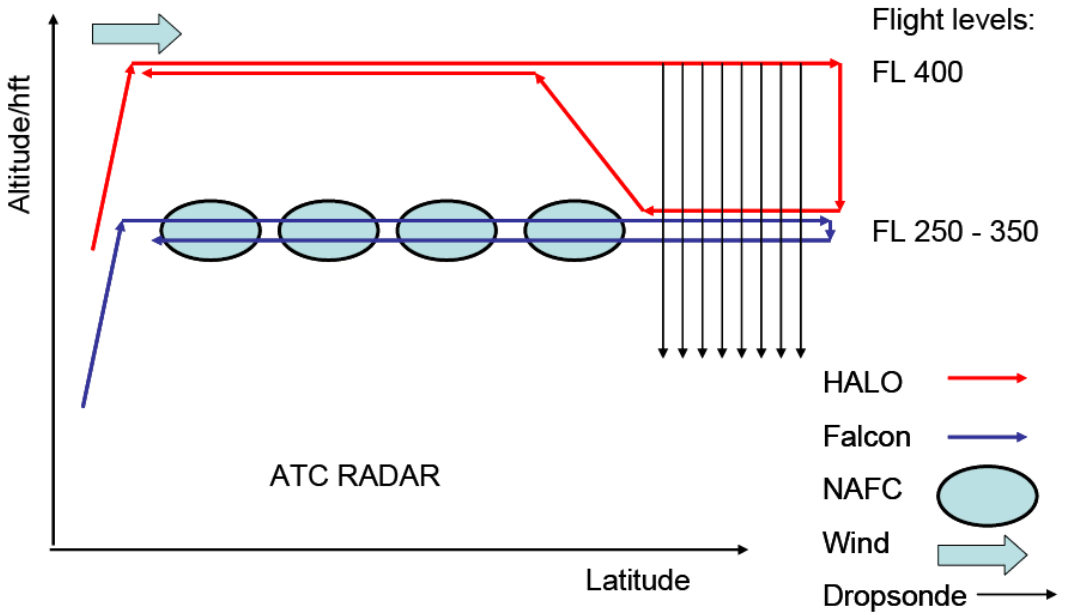
ML-CIRRUS

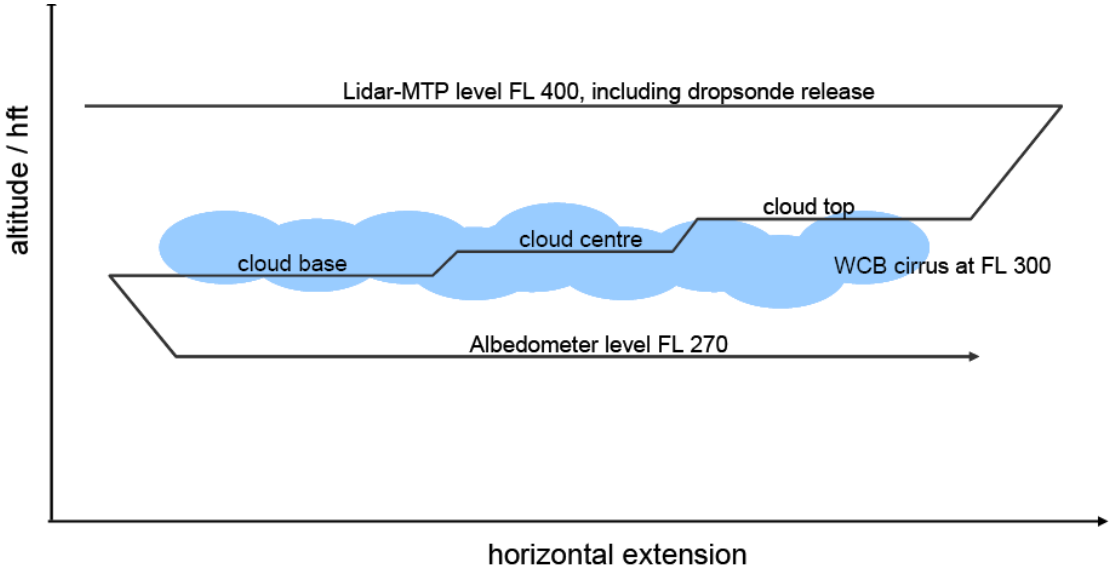
Measurement Regions





Flight Patterns





Aerosols @ HALO

Opportunities: high altitude, long range, large payload

- Profile troposphere & reach UT/LS
- Combine in-situ & remote sensing of gases, aerosols, clouds & precipitation
- Cover wide spatial & temporal scales

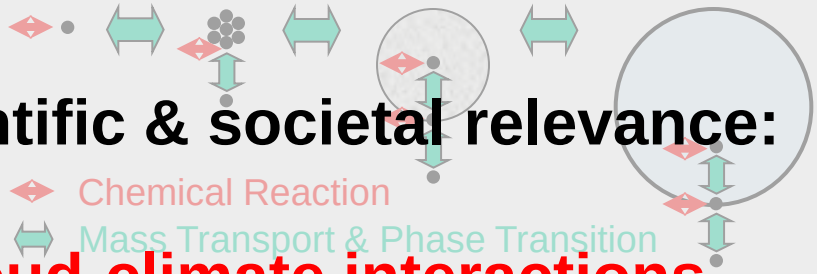
Perspectives

Address & validate remote sensing of gases, aerosols & clouds *(ground-based & satellite)*

Quantify multiphase processes in cirrus clouds & deep convection *(aerosol-cloud-precipitation)*

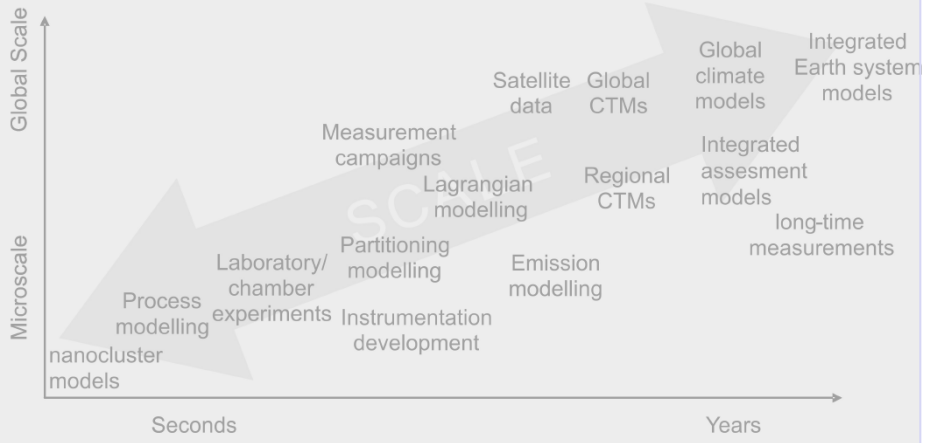
Demo Missions

ACRIDICON, ML-CIRRUS *(NARVAL, NEPTUN, etc.)*



Address challenge of high scientific & societal relevance:

Elucidate & quantify aerosol-cloud-climate interactions



HALO ACRIDICON: Specific Objectives

Mission Type 1: Cloud Vertical Evolution (Cloud Profiling)

- Evolution of cloud base drop size distribution (DSD).
- DSD & height above cloud base for onset of warm rain.
- Height and temperature warm rain can reach before freezing.
- Extent of warm rainout before freezing w/o freezing heat release.
- Amount of cloud water below and above onset of warm rain.
- Amount of supercooled water depending on updraft & temp.
- Rain initiation: coalesc. of mod. DSD into drizzle & rain drops vs. rain embryos formed on isolated giant CCN.
- Initiation of convective ice hydrometeors: Freezing rain drops or riming of nucleated ice crystals?
- Extent of cloud electrification?
- Formation of snow aggregates: where & when?
- Hydrometeor growth in the anvil: extent & mechanisms?

Mission Type 2: Aerosol Processing (Inflow, Outflow)

- Compare particles and trace gases in inflow & outflow,
- Study vertical redistribution of aerosols by convective systems,
- Investigate particle formation & evolution of aerosol properties
- Assess cloud processing of aerosol particles (esp. soot/BC)

Mission Type 3: Satellite Validation (Cloud Products)

- Compare quantities directly measured by satellite and airborne instrumentation (solar radiance, microwave radiance, radar reflectivity and lidar backscatter) to estimate uncertainties in satellite calibration.
- Validate cloud products such as cloud optical thickness, particle diameter, liquid and ice water path, and phase derived by retrieval algorithms applied to both airborne & satellite data.

Mission Type 4: Vertical Transport & Mixing (Artificial Tracer)

- Study vertical mass transport associated with deep convection
- Characterize type and degree of pollution in the air masses where convection occurs
- Quantify redistribution & scavenging of air pollutants

HALO ACRIDICON: Measurement Parameters

Aerosol particles: SD, BC, CCN, IN, composition, mixing state, hygroscopicity, backscatter, depolarisation

Cloud particles/nuclei: SD, LWC, IWC

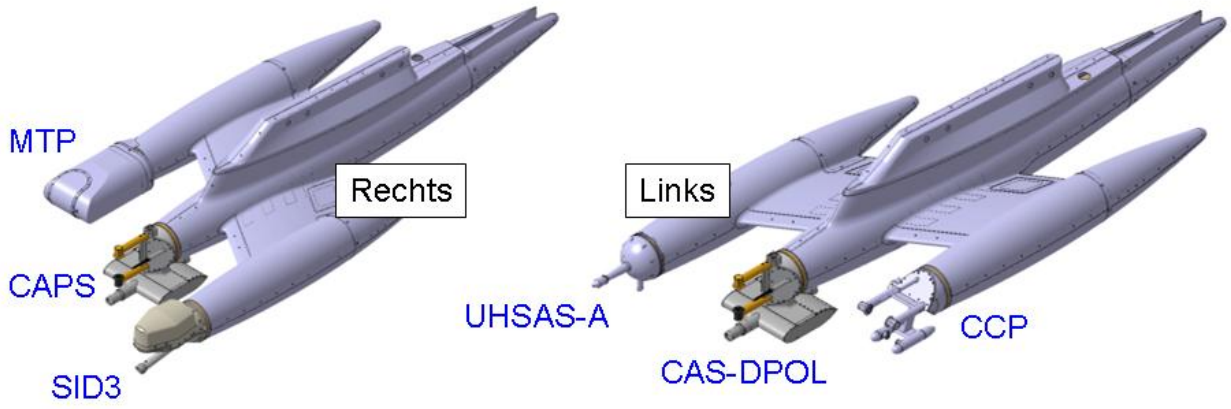
Radiation: spectral radiometers, lidar, DOAS, LWP, IWP, RWP, SWP, GWP, humidity and temperature profiles,
vertical hydrometeor classification.

Precipitation/dynamics: radar

Trace gases: CO, O3, SO2, NOx, NOy, PFC, CH2O NO2, HONO, BrO, IO, OIO, O2 und O4, H2O (Gas)

Inlets: CVI, MAI, HASI (sub-µm and µm)

Wing station probes: CAPS, CAS-DPOL, CCP, MTP, SID-3, UHSAS-A



HALO ML-CIRRUS: Specific Questions

A) Aerosol-cirrus interactions

- Is it possible to unambiguously identify an indirect effect of heterogeneous ice nuclei (from natural or anthropogenic sources) on cirrus cloud properties?
- Can we proof an indirect aerosol effect from aviation on cirrus?
- How do ageing processes (classified by in-cloud ice saturation ratio and distance of sampling point to cloud edge, top and base) influence the microphysical and optical properties of cirrus clouds and how do cirrus affect the interstitial aerosol ?

B) Water vapour supersaturation and transport

- What is the horizontal and vertical extent of ice supersaturated regions in the upper troposphere and lowermost stratosphere in different meteorological conditions from cloud scale to synoptic scale?
- Which processes generate ice supersaturation?
- Is it possible to quantify the amount of water in the form of vapour and cirrus ice entering the mid-latitude lowermost stratosphere across the tropopause in quiescent regions, over storm tracks, and over convective regions ?
- Does particle sedimentation lead to a significant redistribution of water vapour and other trace gases in mid-latitudes?

C) Radiative transport and radiative forcing

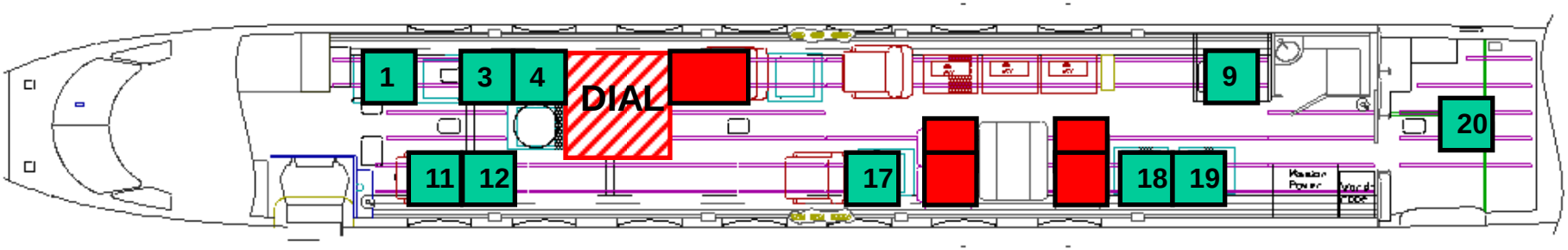
- Can we obtain closure on the radiative forcing exerted by a selected cirrus cloud type (frontal cirrus, also anvils, subvisible cirrus, contrail cirrus) by measuring the spatial-temporal evolution of its properties in situ and from space?
- Is there any threshold optical cirrus property above which the ice crystal morphology looses significance in determining the instantaneous radiative forcing of cirrus clouds ?

D) Implications for heterogeneous chemistry

- What is the distribution of nitrogen oxides and chlorine reservoir species in regions with cirrus clouds?
- Can we better quantify halogen activation on cold aerosol and ice crystals?
- Are there observable differences in the trace gas concentrations in clear sky, contrail cirrus and cirrus clouds?

HALO

ML-CIRRUS: Instrumentation



Rack #5, 6, 14, 15	DIAL: Water vapour profiles, aerosol extinction profiles
Rack #1	CVI + residuals microphysics
Rack #3	ALABAMA: aerosol mass spectrometer
Rack #4	FINCH: Ice nuclei counter
Rack #9	SP-2; soot particles, SMART: radiance, irradiance
Rack #11	NO_y
Rack #12	Water vapour instruments: FISH, HAI, ISOWAT
Rack #17	AIMS: Chemical ionisation mass spectrometer
Rack #18	Aerosol microphysics
Rack #19	AMTEX: O_3, CO, Tracer experiment
Rack #20	Dropsondes, Tracer experiment

<u>Wing-mounted instruments:</u>

Aerosol microphysics	UHSAS, CAS-D
Cloud microphysics	CAPS, SID, CCP
Temperature profile	MTP