Free Troposphere Flows and Turbulence

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Mountain winds and turbulence

Main scientific frontiers:

- Coupling of waves & BL flows
- Prediction and understanding of high-amplitude downslope wind storms
    - Impact of upwind precipitation, surface heating, and details of terrain (gap flows)
    - Transition from laminar wave flow to turbulent flow on the lee side
- Characterization of low-level wave breaking, boundary-layer separation, turbulence in (sub)rotors
- Upper-level (usually UTLS) wave breaking and mixing: causes and fine-scale characteristics
- Vertical fluxes by orographic gravity waves
    - Parameterization of gravity-wave drag in models
- Processes in proximity of steep terrain

Turbulence in Clouds

Main scientific frontiers:

Impact of large, coherent eddies and microscale turbulence on cloud microphysics (nucleation, droplet broadening, precip formation)

Large eddies affect RH, coupling strength with underlying surface, entrainment ...

Microscale turbulence affects particle interaction and precip growth

Entrainment and mixing, incl. turbulent transport of aerosols into clouds

Warm clouds**:** Impact on collision/coalescence

Mixed-phase clouds**:** impact of turbulence on ice-initiation and on longevity of cloud regime

Ice clouds: Role of gravity waves in ice nucleation and microphysical variability

Measurements: 3D wind and turbulence, cloud microphysics (LWC and IWC, concentration), ice nuclei, water vapor mixing ratio within cloud, rapid cloud-scale radar measurements, surface fluxes, turbulence

Clear-air turbulence (CAT)

Main scientific frontiers:

Direct sources of CAT

How do gravity waves induce turbulence? How does this energy cascade to aircraft-influencing scale (10 m – 1 km)?

Role of remote deep convection on CAT

Role of jet and tropopause folds on CAT

Global climatology of CAT

CAT predictability? Relevant model diagnostics?

Thorough model diagnostic analysis based on good observational case studies (with dropsondes)

Measurements: Vertical turbulence, wind structure, and stability at the mesoscale and

Instrumentation

Available (in LAOF pool or user-supplied)
Experimentally available, not thoroughly tested
Presently not available (In design or development)

Mountain winds, precip and turbulence: Doppler lidars & radars across complex terrain, profiling airborne radars, radars with rapid-scan capability, disdrometers and gauges, wind profilers

Turbulence in Clouds: Doppler lidars & profiling and polarimetric scanning cloud radars, *in situ* aircraft, airborne phased array radar, rapid scan radar, UAVs, slowly-moving airborne platforms

Clear-air turbulence: radiosondes, driftsondes with a curtain, UAVs, lidars, in-situ observations from aircraft, nano driftsondes (eMotes), EDR measurement on commercial aircraft fleet, laser air motion system (LAMS)

Free troposphere flow and Turbulence: instrument priority: airborne

	Instrument type	orographic	in-cloud	CAT
Aircraft in situ	cloud imaging and size spectra probes		✓	
	3D spatial arrangement of cloud particles (eg Holodec)		✓	
	3D winds and turbulence	✓	✓	✓
	Turbulence on commercial aviation fleet	✓		✓
Aircraft remote	profiling or scanning Doppler radars	✓	✓	
	rapid radars (phased-array or other rapid scan technique)	✓	✓	
	Backscatter lidars (Doppler)	✓		
	water vapor, temperature, LWP (Raman, DIAL, radiometric)			
	3D turbulence *near* aircraft (e.g., laser air motion system)	✓	✓	

Free troposphere flow and Turbulence: instrument priority: airborne

	Instrument type	orographic	in-cloud	CAT
UAS (lower level, slower than manned A/C)	In situ meteorology	✓		✓
	Other probes (turbulence, cloud microphysics) - better stats in rather small region	✓	✓	
Balloon systems	Radiosondes, dropsondes	✓	✓	✓
	Enhanced radiosondes (LW, video …)		✓	
	Zero buoyancy Lagrangian drift sondes (maybe with in situ instruments tethered below)		✓	✓
	Nano drift sondes (e.g., eMotes, Cicadas)	✓		✓

Free troposphere flow and Turbulence: instrument priority: ground-based

	Instrument type	orographic	in-cloud	CAT
In situ	met stations, flux towers	✓	✓	
	precipitation (gauges, parsivel or video-disdrometer, …)	✓	✓	
remote	Profiling radars (from mm wave to wind profilers)	✓	✓	✓
	Scanning radars	✓		
	Rapid scan radars (phased array ...)		✓	
	Water vapor, temperature profiles (Radiometer, AERI, …)	✓		
	Profiling lidar, ceilometer		✓	
	Doppler lidars- profiling or scanning	✓		✓