Towards Operational Boundary-Layer Profiling -- with a Focus on Water Vapor

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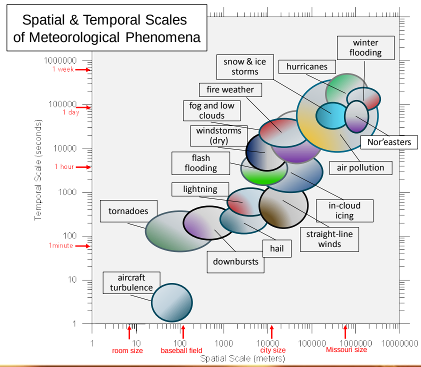

Adapted from T. Schlatter in NRC, 2009: "Observing Weather and Climate from the Ground Up"

Unmet Observing Requirements for Mesoscale Definition & 48h Prediction (1/3)

| = 3km range

Phenomena	Meteorological Parameters	Measurement Resolution		
		Δr(km)	Δt (h)	Δz and z_{max} (km)
Flooding (large scale)	T, q, V, pp	50	3	0.2 / 5.0 (60%)
Nor'easters	SST, T, q, V	10-50	3-12	0.1 / 12.
Snow- & ice storms	T, q, V, pp	30	2	0.1 / 5.0
Hurricanes & tropical storms	T, q, V, SST, pp	10-100	3-6	0.2 / 16.
Air pollution	T, q, V	5-30+	0.25-0.5	.05 / 3.0 (100%)
Toxic spills/releases	T, q, V, pp	1-15	0.1-0.25	.05 / 3.0
Fog and low clouds	T, q, V	25	0.25	.03 / 3.0

Key: temperature (T); moisture (q); winds (V); precipitation (pp); pressure (p); insolation (I); hydrometeor mixing ratio (HMR); sea surface temperature (SST); soil moisture [q(s)]

adapted from: NRC, 2009: "Observing Weather and Climate from the Ground Up"

Unmet Observing Requirements for Mesoscale Definition & 48h Prediction (2/3)

| = 3km range

Phenomena	Meteorological Parameters	Measurement Resolution		
		Δr(km)	Δt (h)	Δz and z_{max} (km)
Lightning	T, q, V, q(s), spherics	2	0.25	0.1 / 3.0
Flash floods	T, q, V, q(s), pp	20-50	0.25 - 2	0.1 / 12.
Hail	T, q, V, HMR	20-50	0.25-2	0.1 / 12.
Straight-line damaging winds	T, q, V	1	5	0.1 / 12.
Tornadoes (pre-storm environment)	T, q, V	50	1	0.2 / 6.0
Tornadoes (non-supercell)	T, q, V	0.5	0.06	0.1 / 3.0
Downslope windstorms (pre-storm env.)	T, q, V	100	3	0.2 / 15.

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Unmet Observing Requirements for Mesoscale Definition & 48h Prediction (3/3)

| = 3km range

Phenomena	Meteorological Parameters	Measurement Resolution		
		Δr(km)	Δt (h)	Δz and z_{max} (km)
Downslope windstorms (local variability)	T, q, V	1	0.25	0.1 / 15
Pressure-gradient windstorms	T, q, V, p	100	6.	0.5
Fire weather	T, q, V, I	1	0.25	0.1 / 5.0
In-cloud icing	T, q, V, HMR	5	1.	0.1
Downbursts	T, q, V, HMR	1	0.017	.2 / 8.0
Clear air turbulence	T, q, V	1	0.017	.05

Key: temperature (T); moisture (q); winds (V); precipitation (pp); pressure (p); insolation (I); hydrometeor mixing ratio (HMR); sea surface temperature (SST); soil moisture [q(s)]

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Types of LT Meteorological Profiling Systems

Types of LT Profiling Systems	Radio(up) - and Dropsondes	T/AMDAR/UAS	Sodar	Lidar	μwave profiler	Radar	μwave & IR sounders
In Situ Systems	X	X					
Remote Sensing Systems							
- Active			X	X	X	X	
- Passive							X
Platforms							
- Stationary (sfc)	X		X	X	X	X	X
- Aircraft	X	X		X		X	X
- Balloons	X					(X)	
- Ships	X		X	X	X	X	X

water vapor profiling systems

Types of LT Meteorological Profiling Systems

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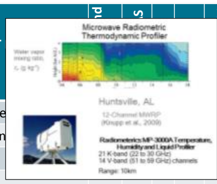
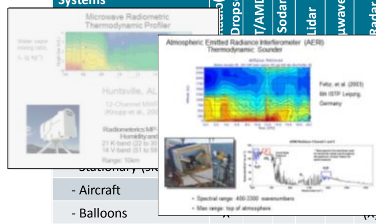
In Situ Syste							
Remote Sen							
- Active					X	X	
- Passive							X
Platforms							
- Stationary (sfc)	X		X	X	X	X	X
- Aircraft	X	X		X		X	X
- Balloons	X					(X)	
- Ships	X		X	X	X	X	X



water vapor profiling systems

Types of LT Meteorological Profiling Systems

Types of LT Profiling Systems	o(up) - and Dropsondes	T/AMDAR/UAS	Sodar	Lidar	µwave profiler	Radar	µwave & IR sounders
							X
							X
- Aircraft							X
- Balloons							
- Ships	X		X	X	X	X	X



water vapor profiling systems

Types of LT Meteorological Profiling Systems

Types of LT Profiling Systems	up) - and ondes	AR/UAS		Lidar			
In Situ Sy							
Remote							
- Activ				X			
- Passi							
Platform							
- Static				X			
- Aircra				X			
- Balloons	X					(X)	
- Ships	X		X	X	X	X	X

Raman lidar systems detect selected species by monitoring the wavelength-shifted molecular return produced by vibrational Raman scattering from the water vapor molecules.

The ratio of the signal at the water-vapor wavelength to the signal at the nitrogen wavelength, is (almost) directly proportional to the water-vapor mixing ratio.

Operate in the UVA, UVB and visible wavelengths.

Differential Absorption Lidar (DIAL) uses two wavelengths: one is in the maximum of the absorption line of water vapor, and a second wavelength is in the region of low absorption (i.e. high transmission).

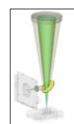
The two wavelengths are selected so that the aerosol optical properties are the same at these wavelengths.

Subtracting the measurements at two wavelengths, yields the water vapor density as a function of range.

Typically operate in the near-IR wavelengths.

The Prototype Vaisala DIAL System

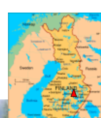
Goal: provide economical, operational PBL water vapor profiles
Semiconductor laser source
Wavelength region: Sub-micron; Dual wavelength
Operating Mode: Pulsed
Power: Class 1M eye safety
Pulse Repetition Rate: 10 kHz
Vaisala ceilometer type telescope design
Overlap optimized for near and far fields
Nominal max. range: 3km
Nominal range res.: 100m
24/7 unattended, all-weather operation

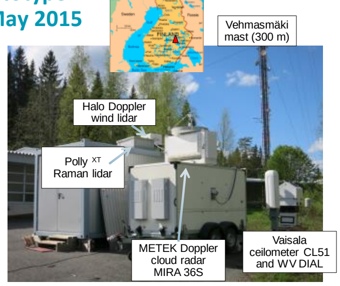


Vaisala WV DIAL Prototype at the DWD Meteorological Observatory, Lindenberg, Germany

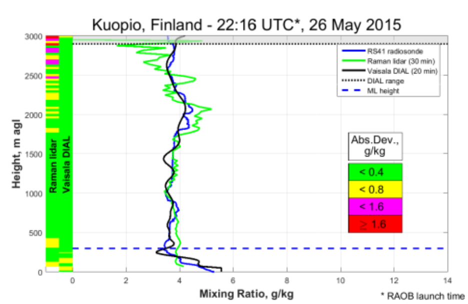
Vaisala WV DIAL Prototype – Kuopio Campaign, May 2015

- The Finnish Meteorological Institute hosted a measurement campaign in the vicinity of Kuopio, in centralFinland (UTC+2)
- 3 Vaisala RS41 radiosondes were launched daily
- During the final two evenings, there were hourly RS41 launches

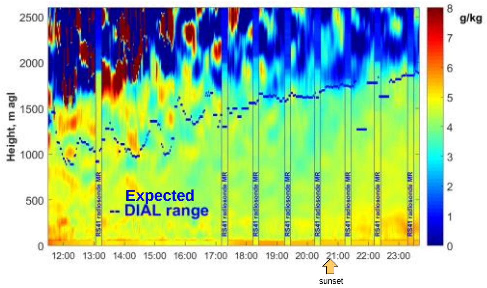




Vaisala Prototype WV DIAL – Preliminary Performance



Kuopio Campaign – Vaisala DIAL Mixing Ratio 11:30 – 23:40 UTC, 27 May 2015



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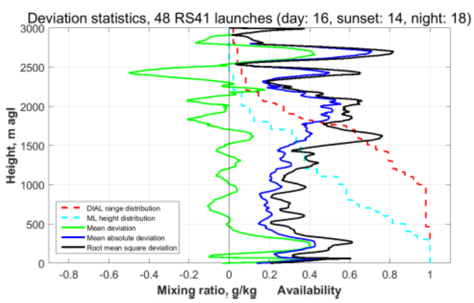
Kuopio Campaign – DIAL vs. Radiosonde Statistics



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