MLH from MWR

a quick review

WG3 Chairs:

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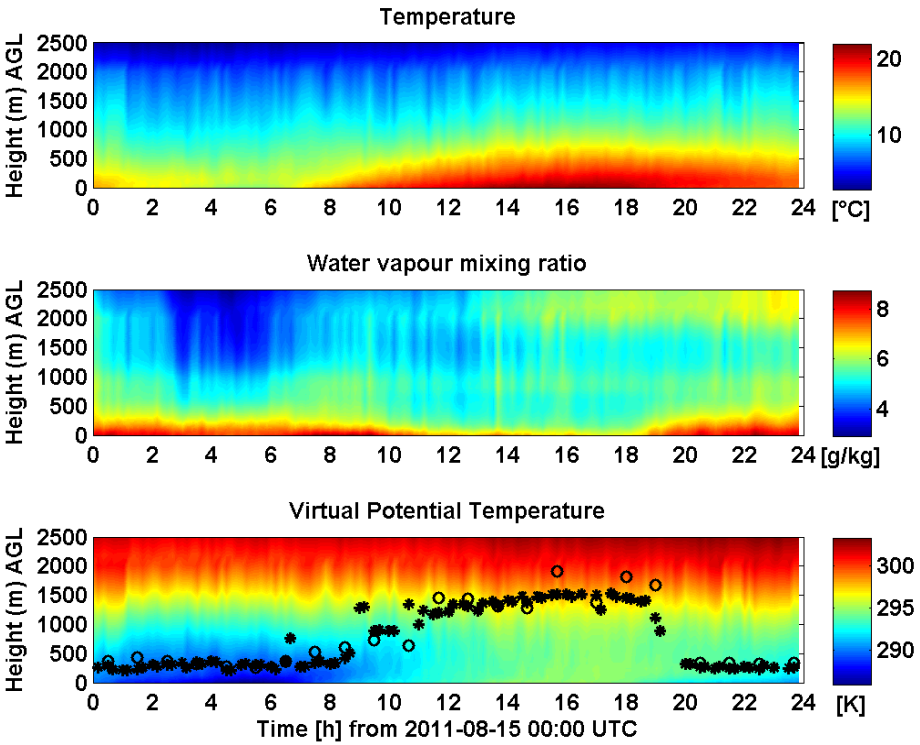
What ground-based MWR provide?

- Ground-based MWR provide T and H profiles
  - High temporal resolution (~1 min),
  - Low-to-moderate vertical resolution,
  - Information mostly residing in the PBL



Mixing Layer Height (MLH) retrievals

MLH definition (Seibert et al. 2000): "the height of the layer adjacent to the ground over which pollutants emitted within this layer or entrained into it become vertically dispersed by convection or mechanical turbulence"

Methods based on *T and H* profiles*

- Parcel Method (PM)
- Surface-Based Temperature Inversion (SBTI)
- Gradient Method (*Liu and Liang Method*)

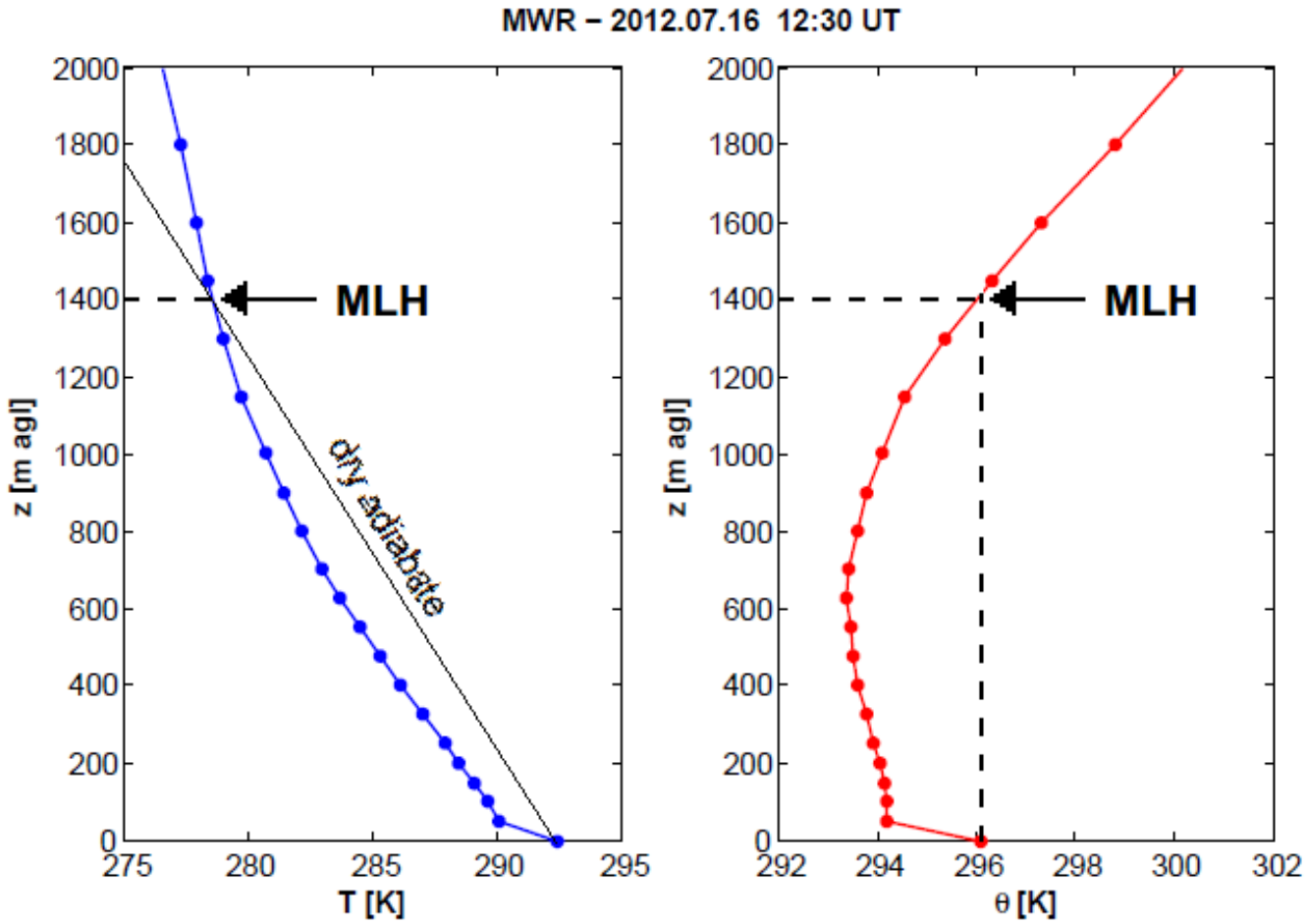
Methods based on *Tb*

- Direct Method (Tb → MLH)

*Collaud et al., 2014; Seibert et al., 2000; Seidel et al., 2010.

Parcel Method (PM)

PM* defines the MLH as the elevation to which an air parcel with ambient surface *T* can rise adiabatically from the ground.

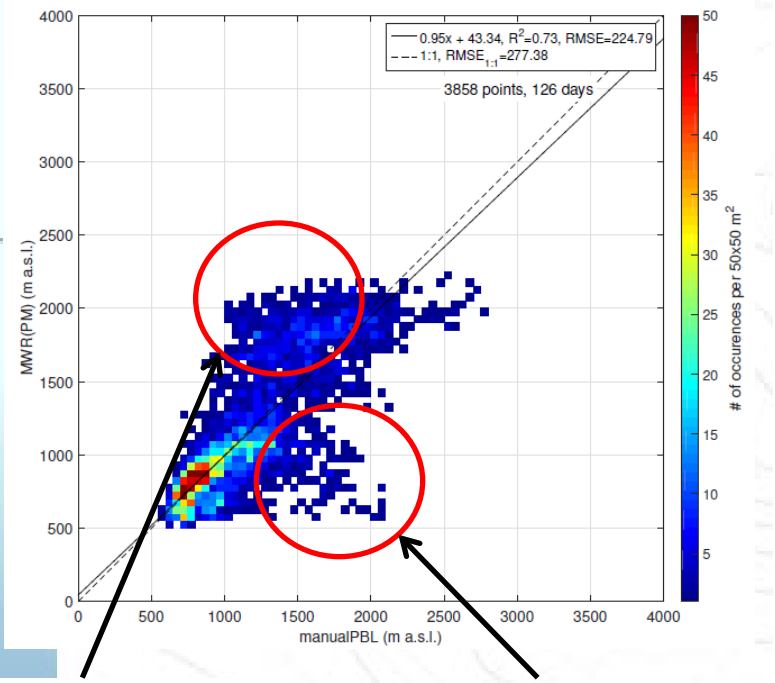


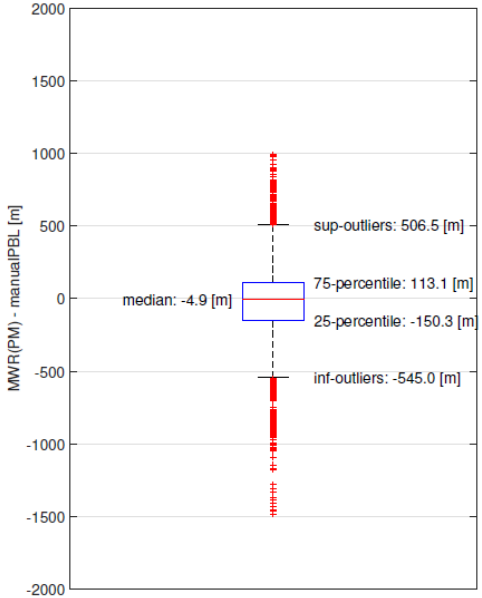
* Holzworth, 1964; Fisher et al., 1998

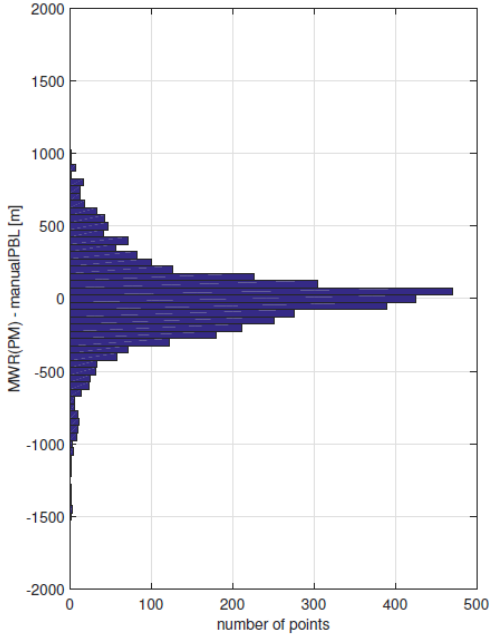
PM validation versus ManualPBL

Courtesy of Meteoswiss (A. Haefele)

Authors: Y. Poltera, M. Hervo, G. Martucci, A. Haefele







Morning:
PM rises faster than aerosol layer

Afternoon:
PM decays faster than aerosol layer

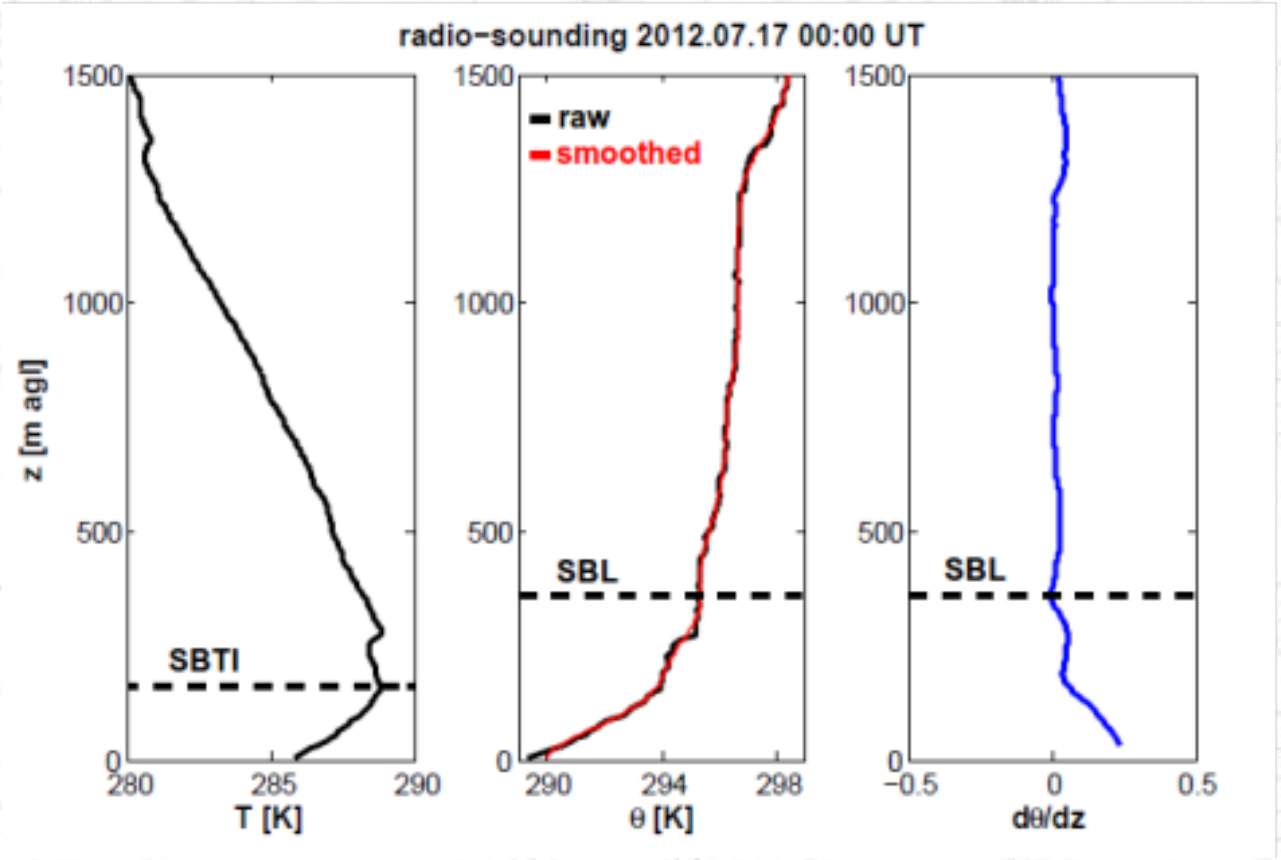
- **Zero bias (median = -5 m)**
- **Important scatter (iqr = 260 m)**
  - **Differences in physical processes (thermal structure versus actual mixing)**
  - **Biases in MWR T profile**

Parcel Method (PM)

- Advantages:
  - It only needs T (or T and H) → θ or θ_v
  - An estimate of the MLH uncertainty is obtained by varying Ts±0.5 K, resulting in 50-150 m
- Limitations:
  - Ts is critical (it needs a precise measurement)
  - It can only be applied to unstable conditions (Convective BL)

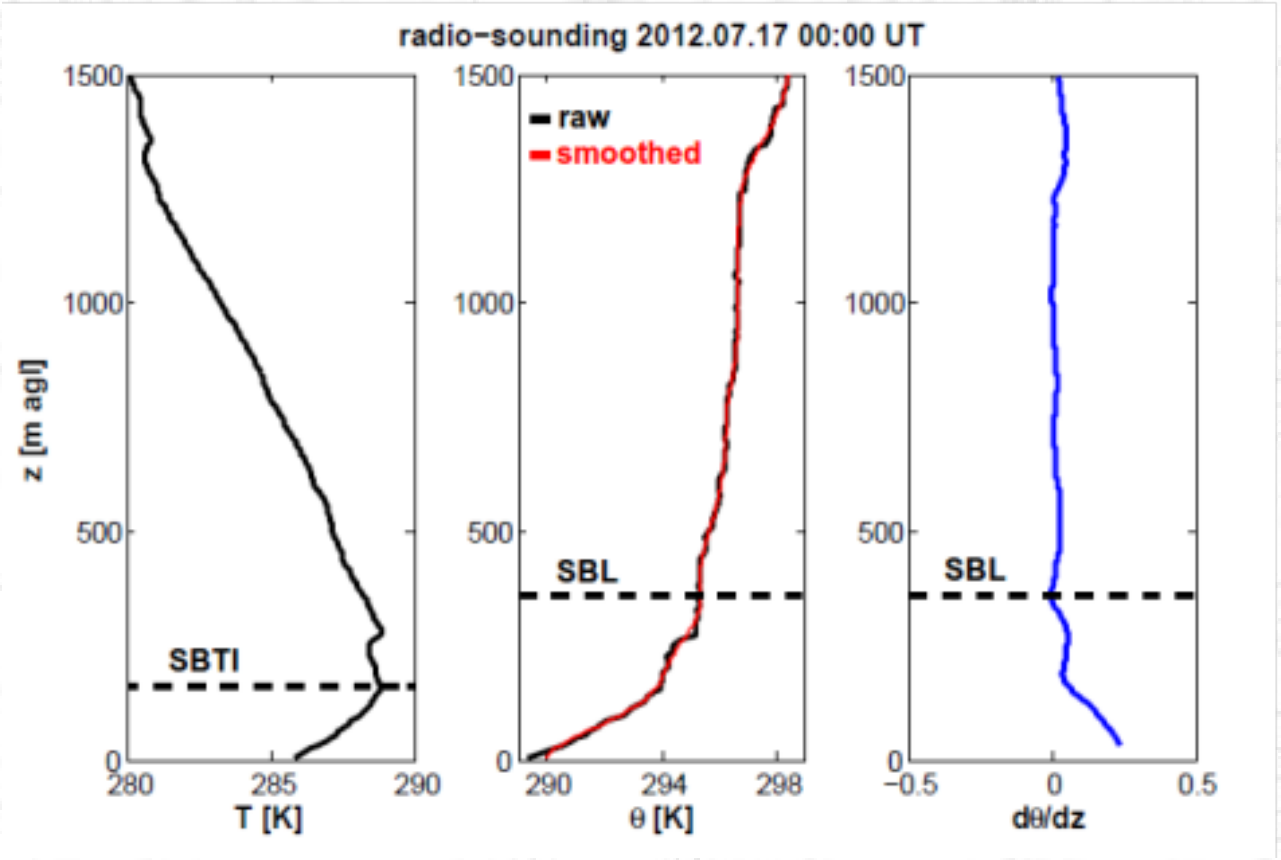
Stable BL (SBL)

- A surface-based *T* inversion is a clear indicator of a SBL
- The Surface-Based Temperature Inversion (SBTI) method computes the height of the surface-based *T* inversion
  - where *T* first decreases with elevation (dT/dz=0)



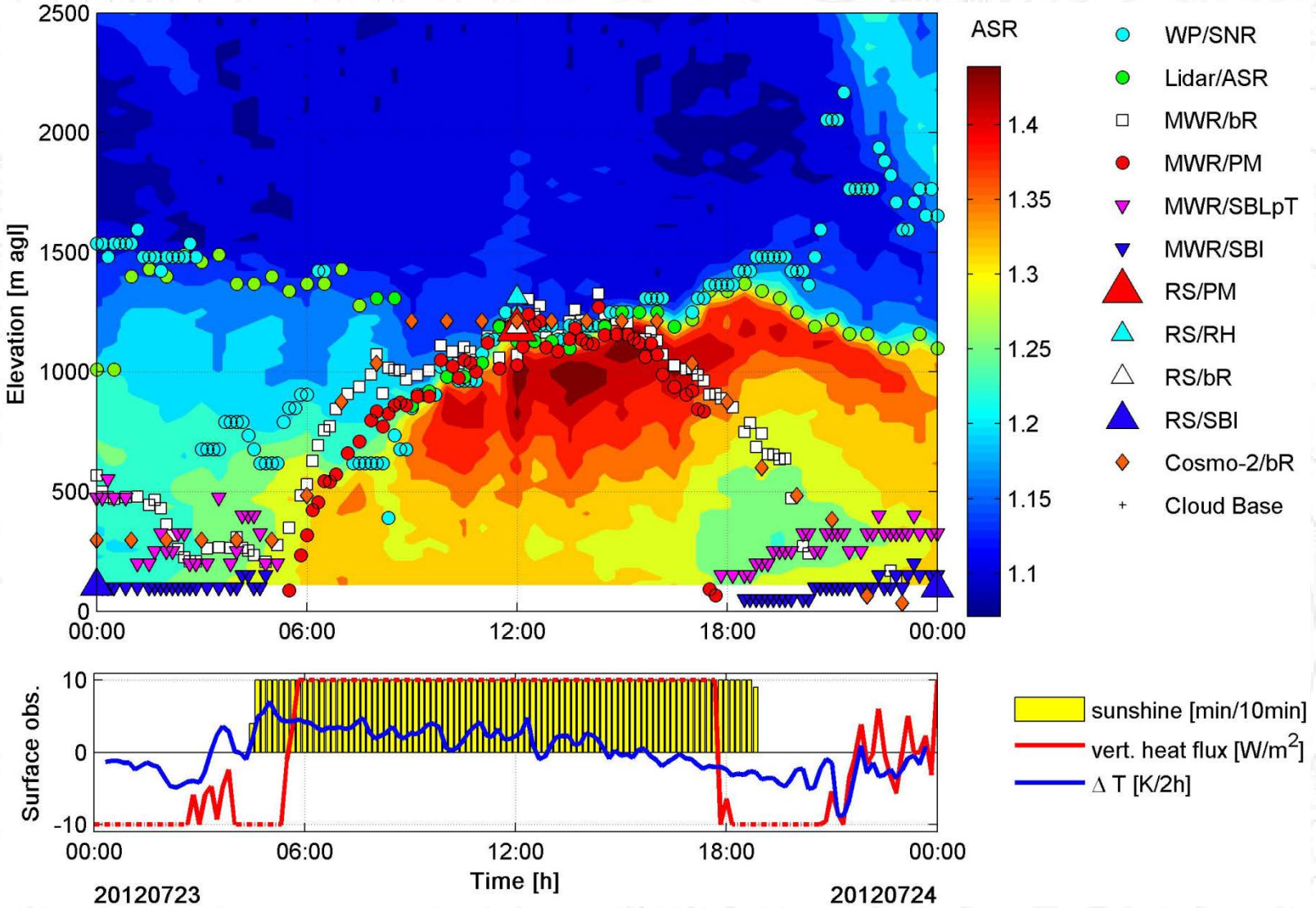
Stable BL (SBL)

- Another approach is to compute the SBL as the height at which the gradient of θ vanishes, i.e. dθ /dz=0
- SBL is higher than SBTI since the gradient is still positive at the height of the surface-based *T* inversion



PM+SBL+SBTI

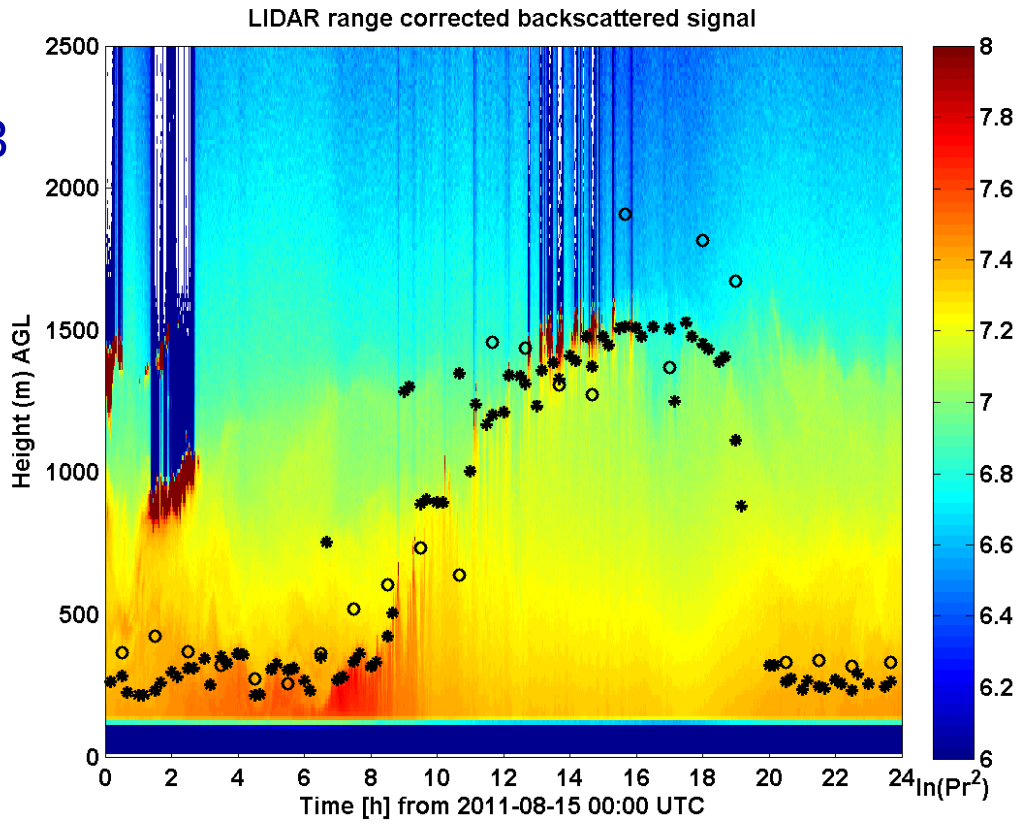
Validation at Meteoswiss (Collaud-Coen et al., ACP, 2014)



Direct Method (Tb → MLH)

- Direct estimate from MWR Tb
  - Multivariate Regression
  - Reference for training: STRAT+ (lidar)

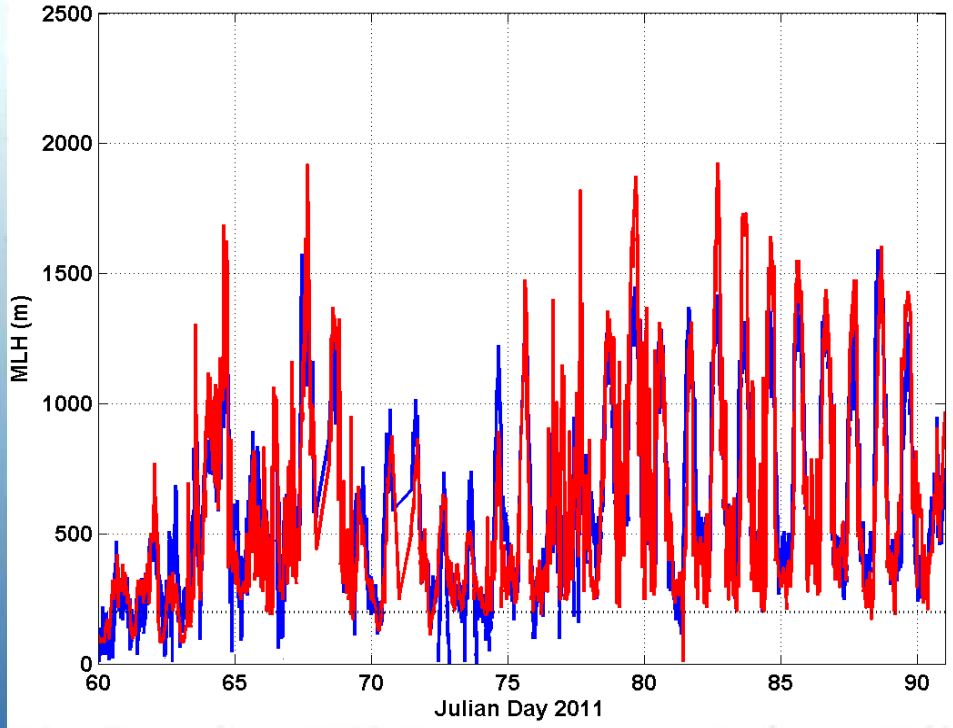
Cimini et al., AMT, 2013

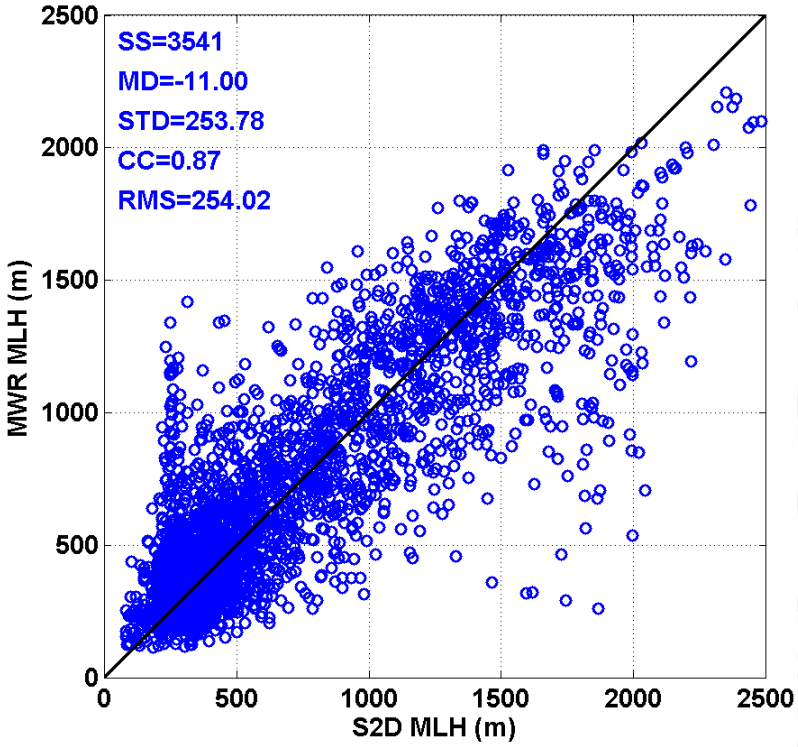


Direct Method (Tb → MLH)

- Validated against independent lidar data

Cimini et al., AMT, 2013

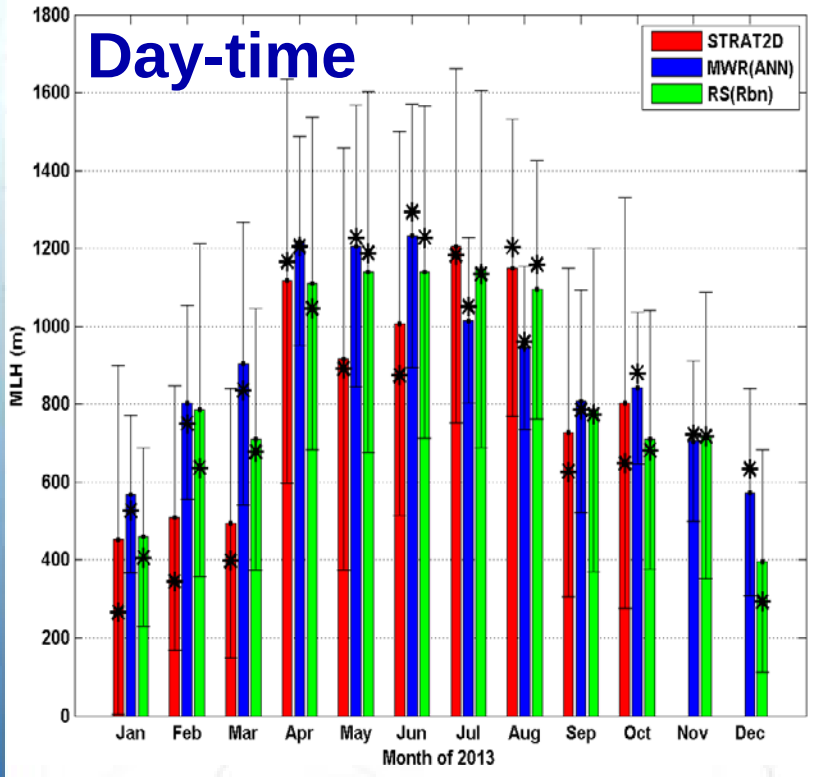


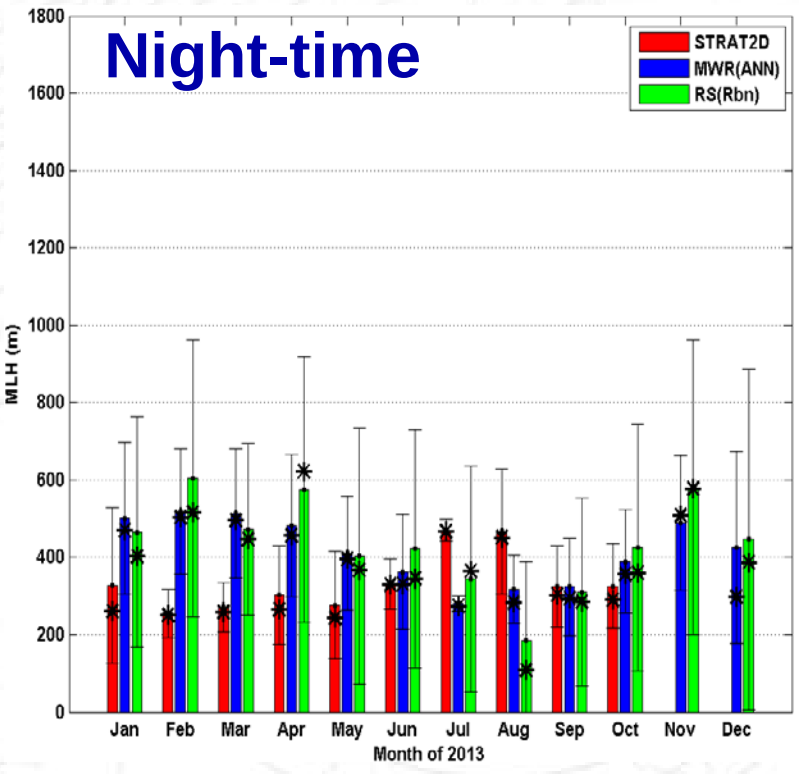


Direct Method (Tb → MLH)

- Direct estimate from MWR Tb
  - Neural Networks
  - Reference for training: RS

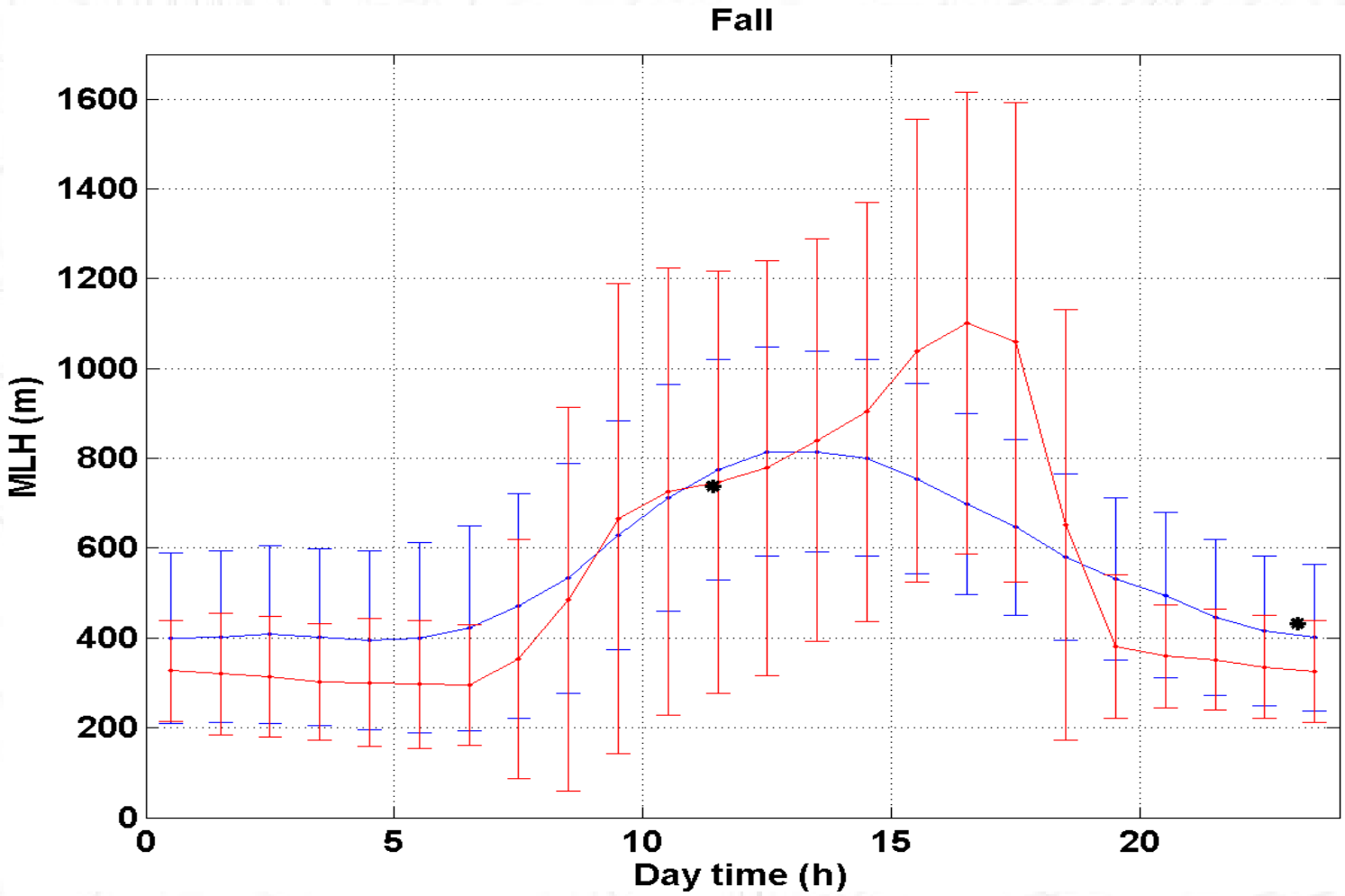
This could be easily implemented as a MWR retrieval product





Direct Method (Tb → MLH)

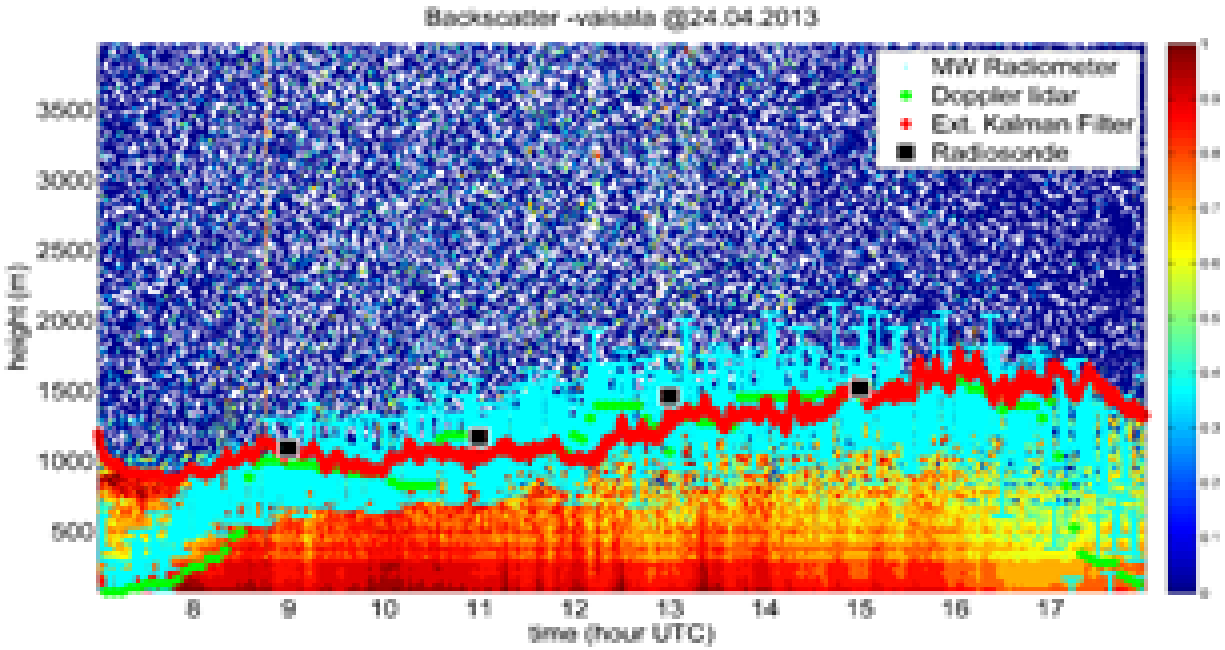
- NN trained with RS: problem with afternoon MLH peak



Combined method (MWR + Lidar)

- MWR and Lidar synergy
  - Contribution from J-L. Rascado, M.J. Costa (U. Granada/Evora)
- Extended Kalman Filter
  - Contribution from U. Saeed, F. Rocadenbosch (UPC), S. Crewell (U. Cologne)

SYNERGETIC MIXING-LAYER HEIGHT



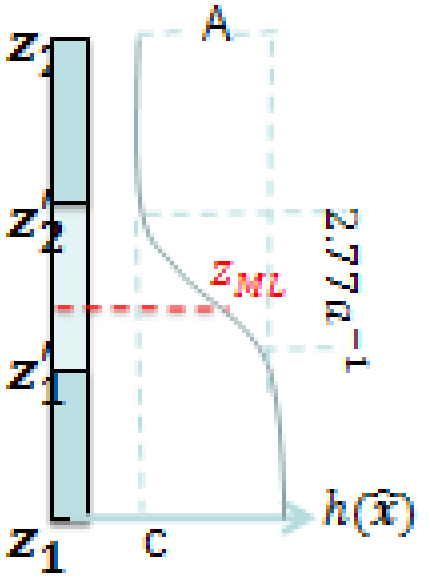
Courtesy of U. Saeed (UPC)

$$h(\hat{x}) = \frac{A}{2}\left\{1 - erf\left[\frac{a}{\sqrt{2}}(z - z_{ML})\right]\right\} + c\ *$$

- State vector: $\hat{x} = (z_{ML}, a, A, c)$

where $\hat{z}_{ML}$: MLH., a: scaling factor related to EZ., A: total backscatter coeff., c: molecular background.

- z_1, z_1', z_2', z_2 are the EKF fitting ranges set by MWR estimates.

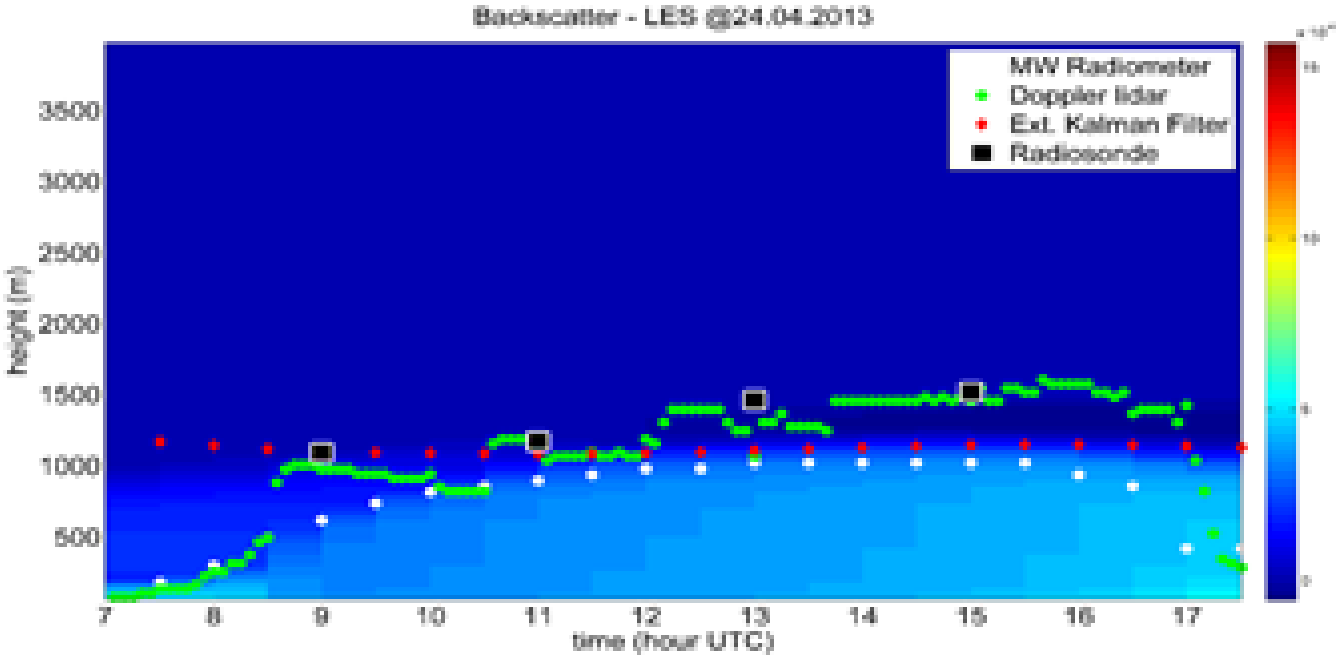


"D. Lange, J. Tiana-Alsina, U. Saeed, S. Tomás and F. Rocadenbosch, "Atmospheric-boundary-layer height monitoring using a Kalman Filter and backscatter lidar returns," IEEE Transactions on Geoscience and Remote Sensing, DOI: 10.1109/TGRS.2013.2284110, 52(8):4717–4728 (2014).

SYNERGETIC MIXING-LAYER HEIGHT

Simulated data

- Dutch Atmospheric Large-Eddy Simulation (DALES) model for BL studies
- Provides a virtual laboratory to test algorithms without the shortcomings of instruments.
- Effect of instrumental errors on the retrieved products from instrumental measurements can be studied.



- Similar approach for stable boundary-layer height has been developed and is under validation phase!

Summary

- MWR can be used to estimate MLH
  - Parcel method (unstable conditions)
  - SBL and SBTI (stable conditions)
  - Bulk Richardson method
  - Direct method (Tb → MLH, regression or neural networks)

- Good agreement is found with other methods
  - R=0.85-0.87; RMS=~250 m; Bias<10m; wrt lidar estimates
  - part of the differences are due to different definition/tracer.

Bottom line

- MWR is complementary to other methods and shall be considered in a multisensor synergetic retrieval of MLH.

Thank you very much for your attention!!

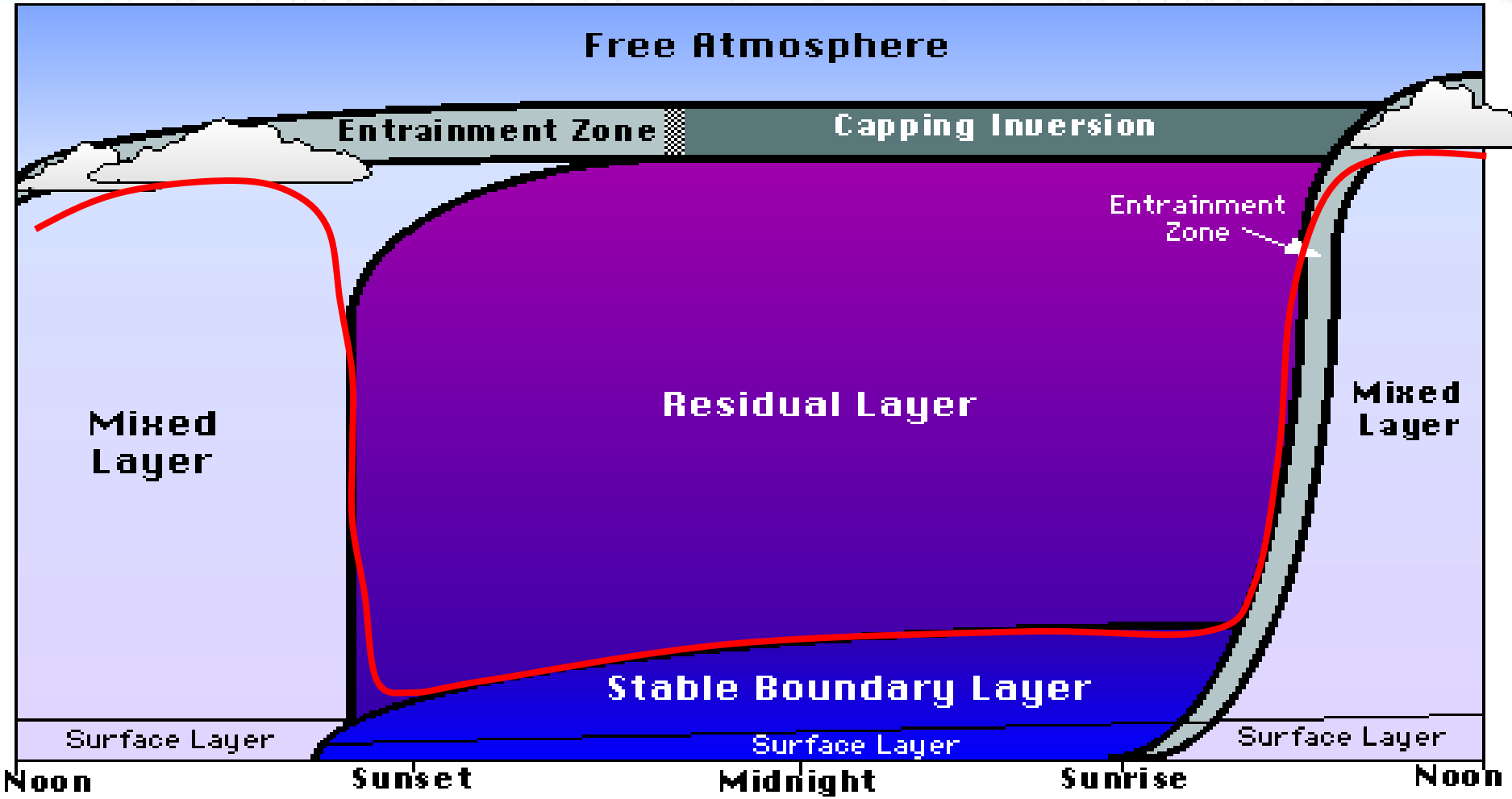
Relevant publications

- Cimini, De Angelis, Dupont, Pal, and Haeffelin: Mixing layer height retrievals by multichannel MWR observations, Atmos. Meas. Tech., 2013.

- Collaud Coen, M., Praz, C., Haefele, A., Ruffieux, D., Kaufmann, P., and Calpini, B.: Determination and climatology of the planetary boundary layer height by in-situ and remote sensing methods as well as the COSMO model above the Swiss plateau, Atmos. Chem. Phys. Discuss., 14, 15419-15462, doi:10.5194/acpd-14-15419-2014, 2014.

- Seibert, P., Beyrich, F., Gryning, S. E., Joffre, S., Rasmussen, A., and Tercier, P.: Review and intercomparison of operational methods for the determination of the mixing height, Atmos. Environ., 34, 1001–1027, 2000.

- Seidel, D. J., Ao, C. O., and Li, K.: Estimating climatological planetary boundary layer heights from radiosonde observations: Comparison of methods and uncertainty analysis, J. Geophys. Res., 115, D16113, doi:10.1029/2009JD013680, 2010.



Structure of Planetary Boundary Layer

adapted from Stull, 1988.

Potential Temperature

The **potential temperature** of a air parcel at pressure P is the temperature that the parcel would acquire if adiabatically brought to a standard reference pressure Po, usually 1000 mb.

$$\theta = T\left(\frac{P_0}{P}\right)^{R/c_p},$$

where T is the absolute temperature (in K) of the parcel, R is the gas constant of air, and cp is the specific heat capacity at a constant pressure.

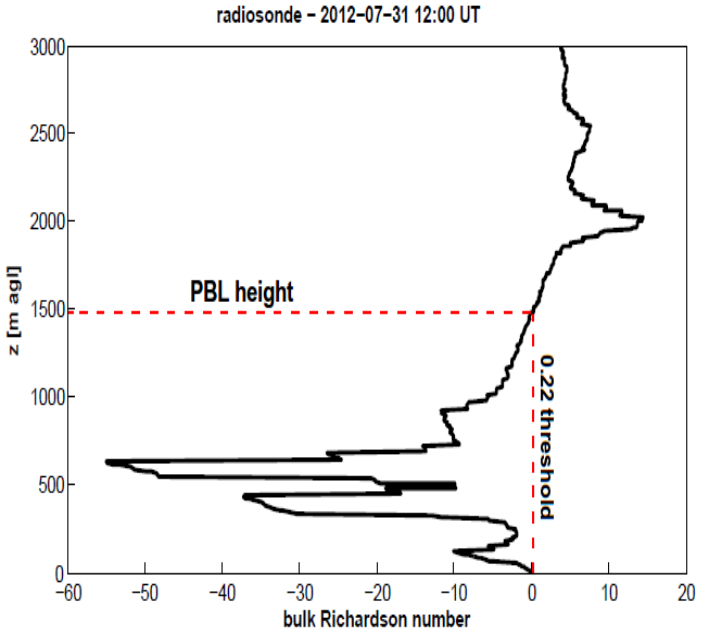
Bulk Richardson Method

- Ri is a dimensionless number relating vertical stability and vertical wind shear (ratio of convective and wind shear produced turbul.)

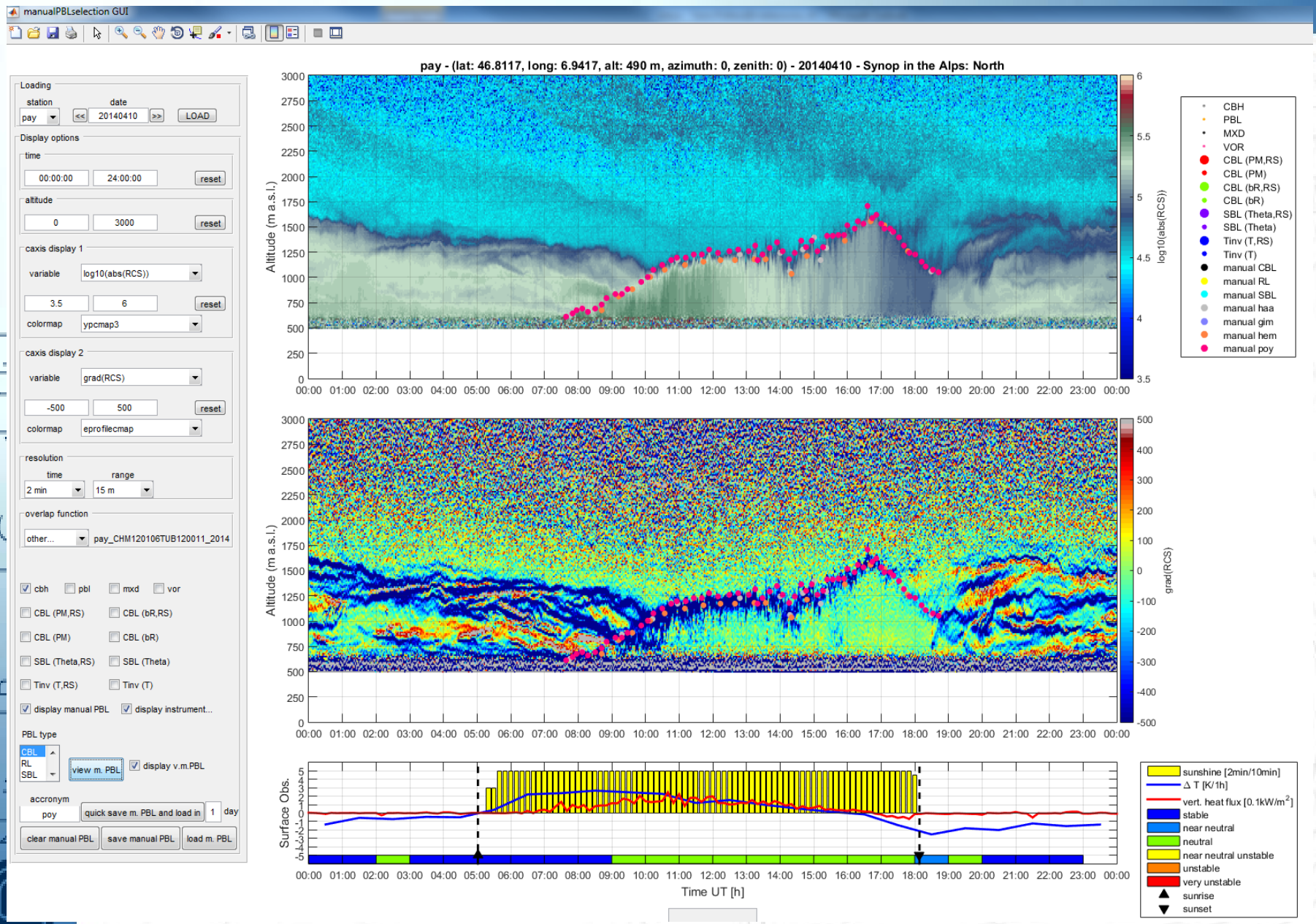
$$Ri = \frac{g\Delta\theta_v/\theta_v}{[(\Delta U)^2 + (\Delta V)^2]/\Delta Z}$$

- High values indicate unstable and/or weakly sheared conditions;
- Low values indicate weak instability and/or strong vertical shear.

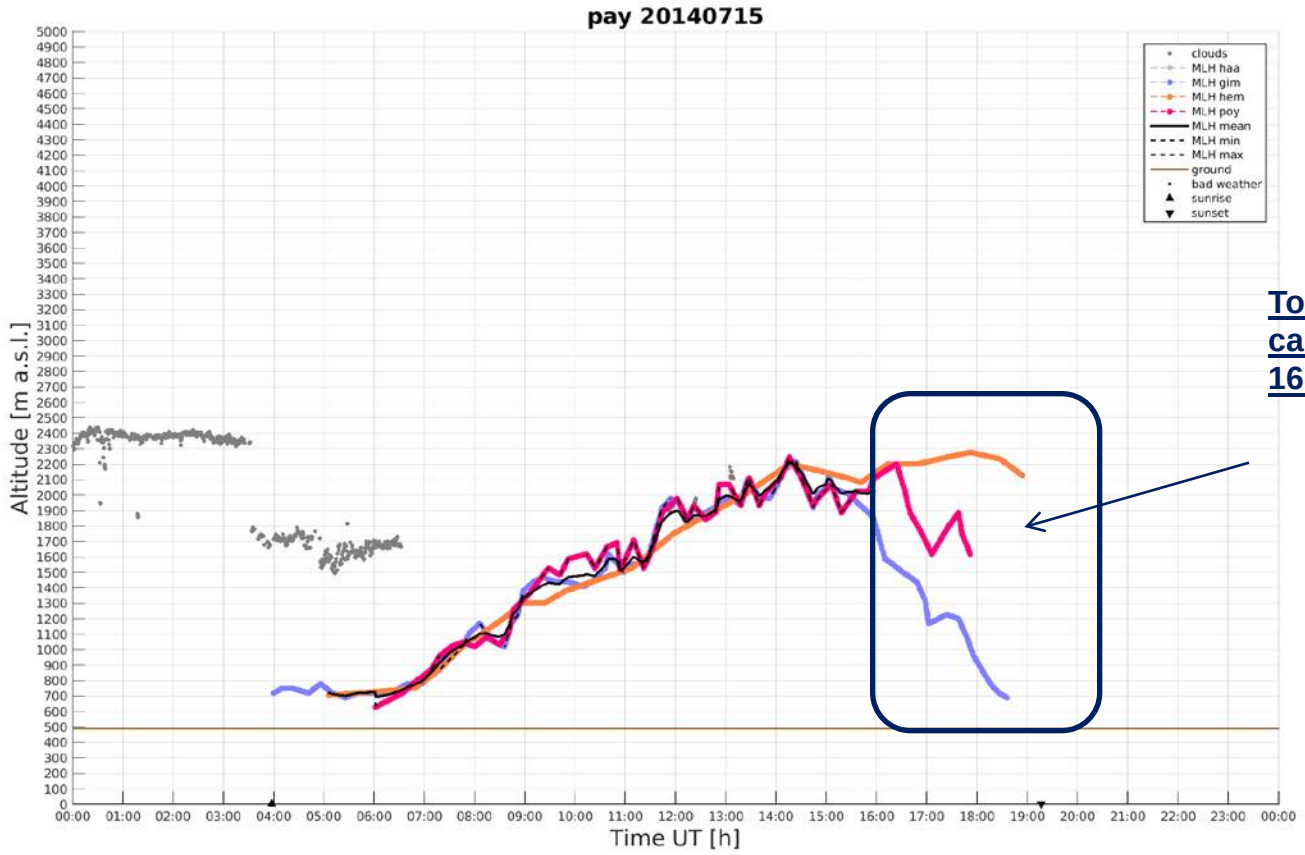
- PBL height corresponds to first elevation for which Rib is greater than a critical threshold (0.22 or 0.33 for day and night conditions



ManualPBL detection interface



ManualPBL consensus



Too high dispersion to calculate reference after 16h

Calculation of reference:

- zones without precipitation or fog ; sunrise to sunset
- dispersion @ altitude *h* <= 0.1*h*+100 m
- days processed: 5, 10, 15, 20, 25, 30 of all months 2014 & full months of Jan, Mar, Jul, Oct 2014