Assessment and improvements of STRAT applied to ceilometer measurements for non-supervised atmospheric classification

J.A. Casquero-Vera[1,2] , Bravo-Aranda J.A.[1,2], Cazorla, A[1,2]., Alados-Arboledas L.[1,2]

[1]Andalusian Institute for Earth System Research (IISTA), University of Granada, Autonomous Government of Andalusia, Granada, Spain
[2]University of Granada, Granada, Spain

juacasver@correo.ugr.es

Identification of cloud, aerosol and molecular regions in the atmospheric column is relevant for the atmospheric research. To this aim, Morille et al. [2007] developed the STRucture of ATmosphere (STRAT) software using single-wavelength vertical backscatter signal from lidar systems providing successful results. However, continuous operation of dense lidar networks is prohibitive due to the cost and the requirement of qualified staff. In this regard, ceilometers seems to be a good alternative despite their lower signal-to-noise ratio in comparison with lidar systems. Thus, STRAT is adapted and applied to ceilometer measurements (Jenoptik CHM15k Nimbus) in this work. The appropriate values of the user-defined STRAT thresholds were optimized by comparison of STRAT results with correlative lidar measurements. Additionally, some improvements are implemented in order to solve misclassification problems associated to the low signal-to-noise ratio of ceilometer data. Our results show that the use of automatic algorithm for atmospheric classification is very useful to retrieve atmospheric structure information in ceilometer networks with affordable cost.

INSTRUMENTATION AND EXPERIMENTAL SITE

Ceilometer (Jenoptick CHM-15k Nimbus)

- Nd:YAG – 1064nm
- Energy/pulse: $8\ \mu J$
- Frequency of pulses: $6{,}5\ kHz$
- Overlap > *80 %* at *480 m*

Lidar Raman LR 321 D400

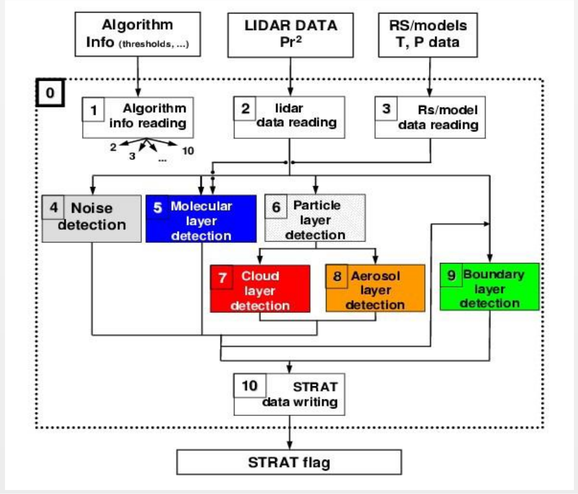
- Nd:YAG – 1064, 532 and 355 nm
- Energy/pulse: 110, 65 and 60 mJ
- Frequency of pulses: 10 Hz
- Overlap > *80 %* at *400 m*

Experimental site

- Granada (37,16º N, 3,58ºW, 680 a.s.l.)
- Non-industrialized medium size city
- Situated in a natural valley surrounded by mountains (1000-3350 m a.s.l.)
- Mediterranean-continental climate
- Main aerosols sources: traffic, Saharan dust and biomass burning aerosols (in summer)

METHODOLOGY

- Pre-processing ceilometer data: temporal and spatial averages (10 min. and 30 metres)
- Stages in STRAT (Morille et al. [2007]):
  - Noise detection: determine regions with low signal-to-noise ratio.
  - Molecular detection: determine regions where the particles concentration is low enough to assume molecular conditions.
  - Particles detection: determine regions affected by clouds or aerosol.
  - Cloud-particles distinction.
  - Boundary layer detection (MLD-Mixed Layer Depth)

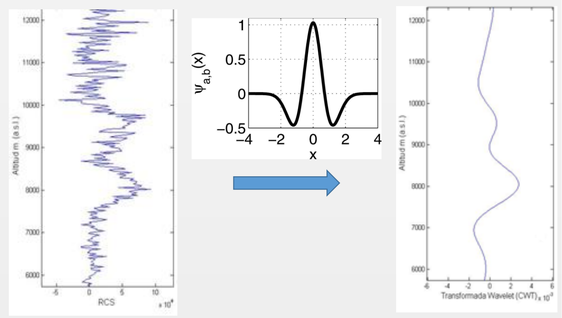


- Layering is determined by continuous wavelet transform (Mexican Hat) (Morille et al. [2007])

$$\Psi_{a,b}(r) = \frac{1}{\sqrt{a}}\Psi\left(\frac{x-b}{a}\right)$$

a: dilation (wavelet width)
b: range

$$CWT_{a,b}(r,t) = \sum_{r} P(r,t)\psi_{a,b}(r)$$



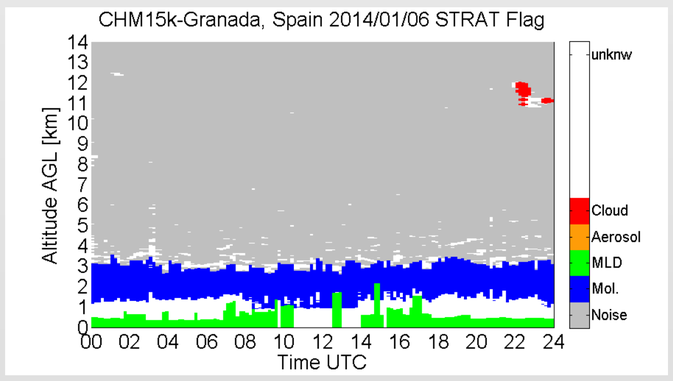
APPLICATION OF STRAT

Running STRAT requires the selection of different thresholds for different evaluations functions that depend on instrument features. In this sense , the low signal-to-noise ratio of ceilometers represents a challenge and some internal modifications of STRAT are necessary to provide a successful classification. In the following we present a short description of the suggested improvements, illustrated by means of appropriate study cases.

- **MOLECULAR DETECTION IMPROVEMENT:**

Cases with low aerosol load has been used to test the molecular detection.

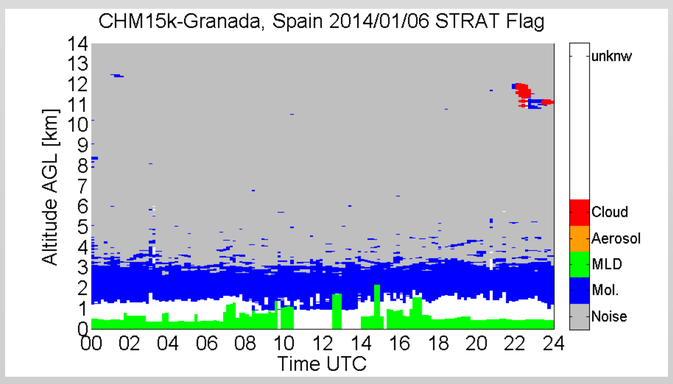
Without particles improvements



x It is clear that there is room of improvement to reduce Unknown layer. Thus, considering that STRAT uses an atmospheric profile for the whole day, we propose the use of hourly atmospheric profiles tuning the reference atmosphere to surface meteorological conditions.

✓ **The use of hourly atmospheric profiles tuned to surface meteorological conditions improves the molecular detection**

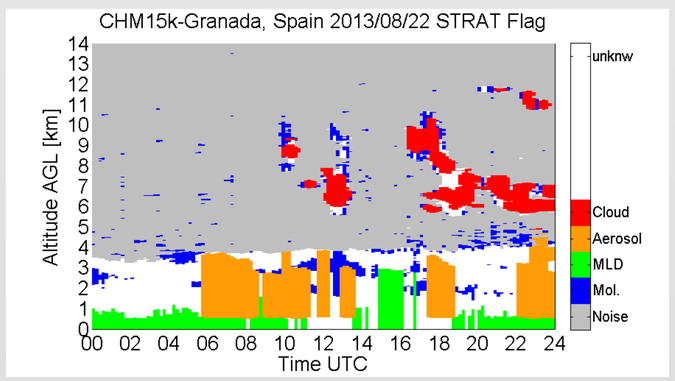
With molecular improvements



- **PARTICLE DETECTION IMPROVEMENT:**

x Dilation is not an external threshold and should be modified for each instrument
x STRAT bases its analysis on the use of the raw signal

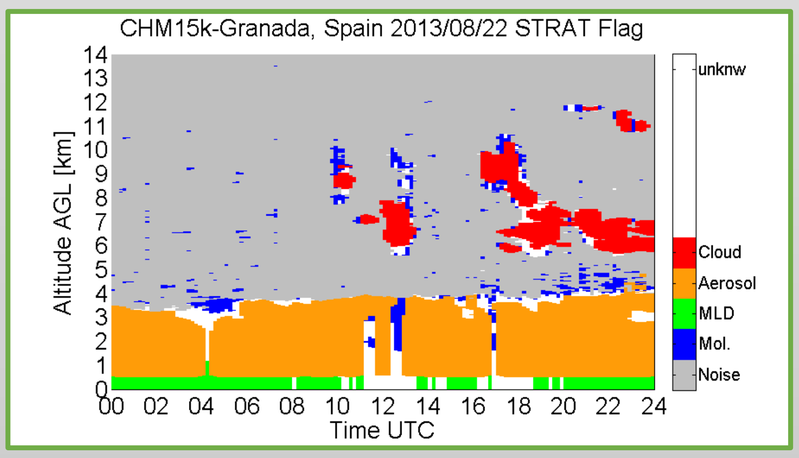
With molecular improvements
Without particles improvements



After several test applied to STRAT some modification has been proposed:

✓ **We increment the dilation to reduce the problem with noise**
✓ **Particles analysis based on RCS instead of Raw signal**
✓ **We suggest new criterions for the discrimination of particle layers**

After all improvements



CONCLUSION

We explored the use of the STRucture of ATmosphere (STRAT) software for atmospheric classification with ceilometers. Several changes have been applied to STRAT in order to reduce the non-classified areas ("unknw" class). On one hand, the use of hourly atmospheric profiles reduces the non-classified regions in the molecular detection. On the other hand, in order to reduce the influence of noise in the particles detection the dilation in the wavelet transform is modified and the analysis are based on the Range Corrected Signal instead of the raw signal.
We evidence the impact of the improvements in the detection of molecular and particles layers by a comparison between STRAT results with ceilometer and LIDAR studies, during the same time period.

ACKNOWLEDGEMENTS

This work was supported by the Spanish Ministry of Economy and Competitiveness through project CGL2013-45410-R Mr. Casquero-Vera was funded under grant of internal formation program –University of Granada

REFERENCES

Morille et al. [2007], *J. Atmos. Oceanic Technol.*, 24, 761–77