Critical Liquid Water Path as a possible indicator of Fog Dissipation

F. Toledo (LMD/MODEM), E.G. Waersted, M. Haeffelin (IPSL/CNRS) , J-C. Dupont (IPSL/UVSQ)

Contact: felipe.toledo@lmd.polytechnique.fr

IFDA Taiwan 2019

SIRTA Site Instrumental de Recherche par Télédétection Atmosphérique

1. The Critical Liquid Water Path (CLWP)

- The CLWP is a measure of the minimum amount of Liquid Water Path (LWP) needed for a cloud to reach the surface.
- The CLWP depends on the cloud's temperature, pressure, cloud top height and subadiabaticity profile.
- It was originally applied to detect fog from satellite cloud observations [1].
- Recent research has discovered that the CLWP could be a main indicator of fog dissipation tendency [2].

2. CLWP calculation

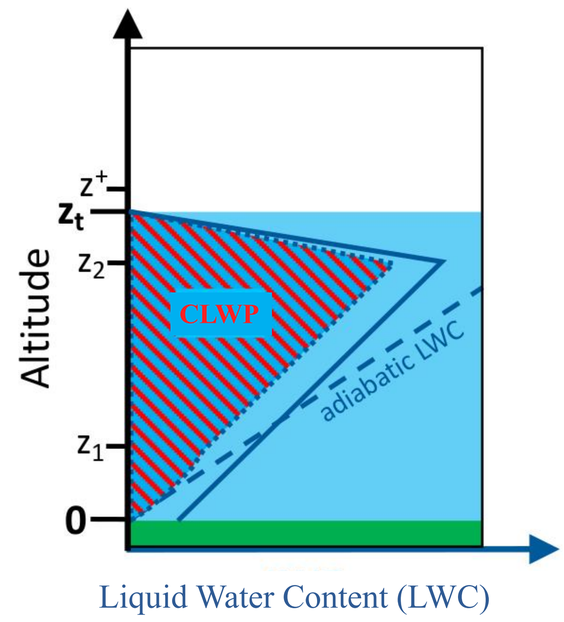
$$CLWP = \int_{z=0}^{z=z_1} (1-\beta_0 z)\cdot LWC_{ad}^{*}(z)\,dz + \int_{z=z_1}^{z=z_2} (1-\beta_0)\cdot LWC_{ad}^{*}(z)\,dz + \int_{z=z_2}^{z=z_t} \frac{z_t - z}{z_t - z_2}\cdot LWC_{ad}^{*}(z_2)\,dz$$

β_0: Fog subadiabaticity

z_1: Ground coupling parameter [m]

z_2: Cloud-top entrainment parameter [m]

β_0, z_1 and z_2 are determined following the procedure published in [2]



z_t: Cloud Top Height [m]

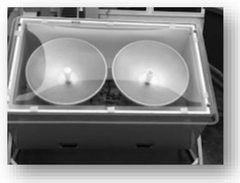
$LWC_{ad}^{*}(z)$: Adiabatic Liquid Water Content profile, starting from zero at the Surface [Kg/m3]

3. Ground based fog observations

Fog observations are performed at the atmospheric observatory SIRTA, located in Palaiseau, France [3]. Fog events are frequent at the site during the winter season.

The SIRTA has over 100 instruments on-site, including a profiling mast, ceilometers, particle spectrometers, wind profilers, etc.

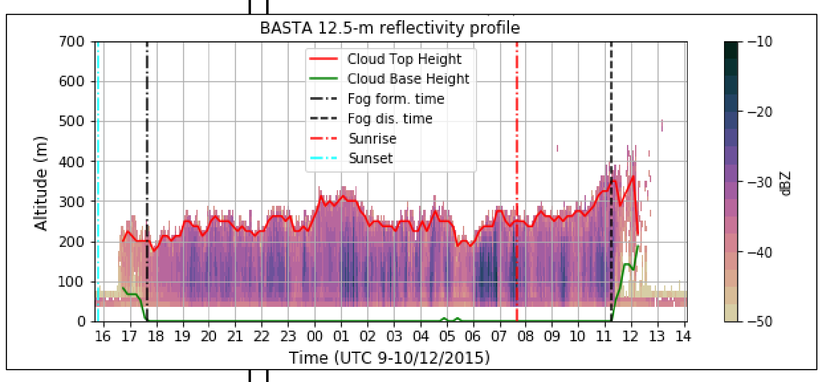
Main instruments used in this study:



Cloud Radar BASTA [4]
- Fog reflectivity profile
- Cloud Top Height

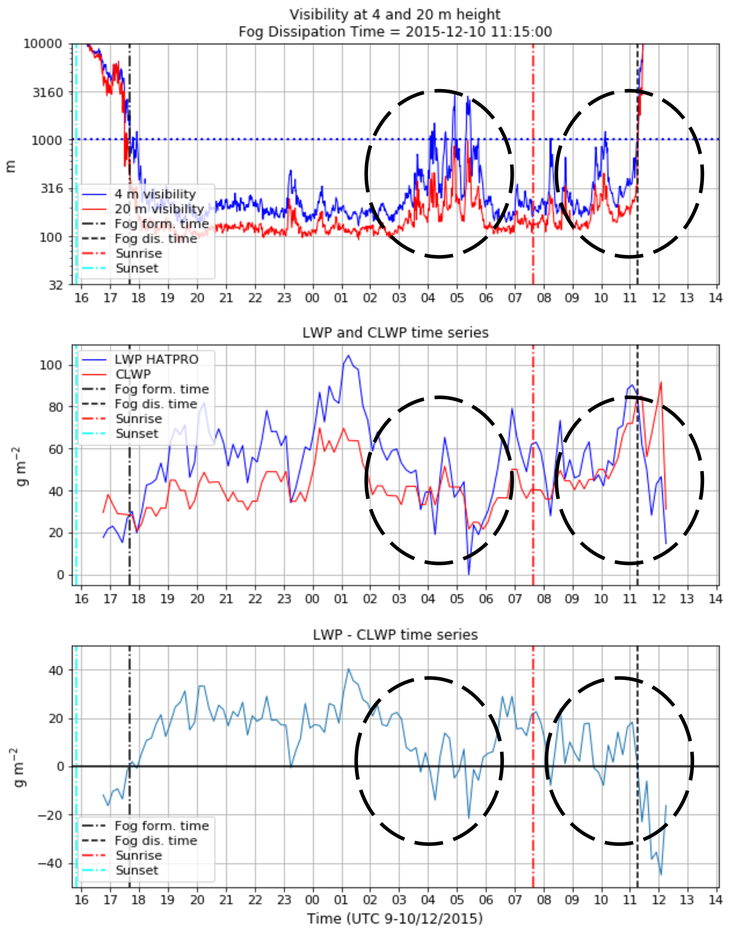
Microwave Radiometer HATPRO [5]
- Liquid Water Path
- Temperature and humidity profiles

Visibility meter
- Fog formation and dissipation time



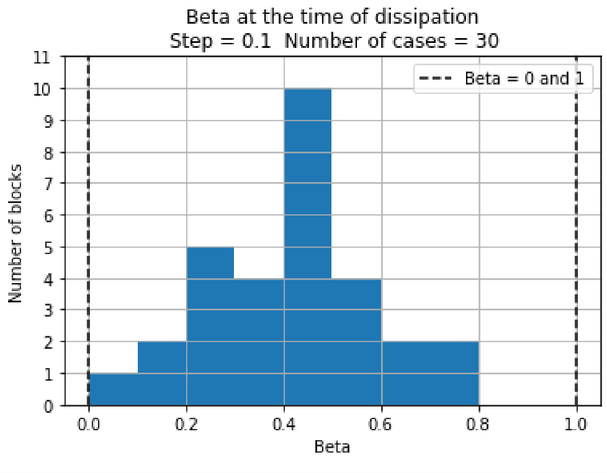
4. Example

- Fog case of December 9-10, 2015
- CLWP increases with temperature and CTH
- When the fog LWP decreases near the CLWP value visibility increases
- At fog dissipation, CLWP grows rapidly and surpasses the observed LWP



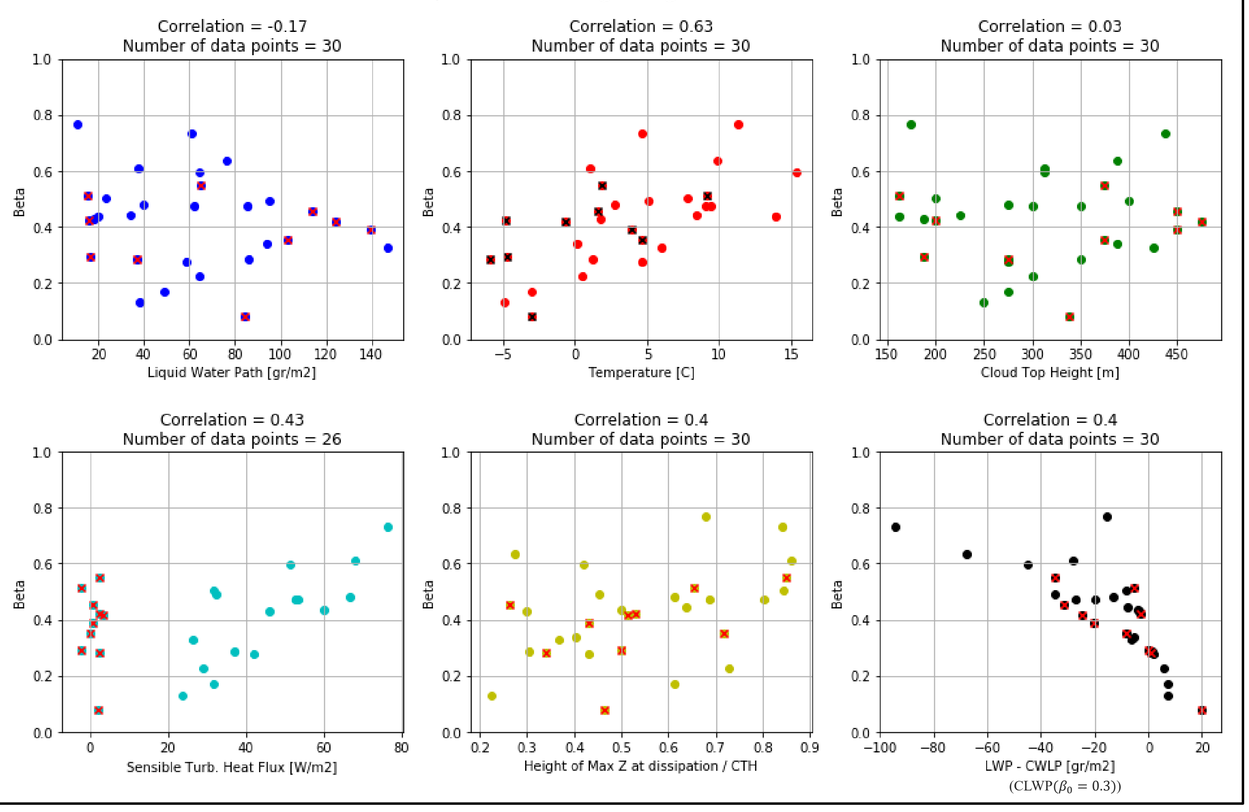
5. CLWP study: Subadiabaticity Statistics

- An accurate estimation of β_0 (Beta) is essential to correctly estimate the CLWP
- β_0 can be retrieved by matching the CLWP with fog's LWP at dissipation time
- 30 fog events studied



β_0 vs other fog parameters at dissipation time

Events with dissipation occurring at night are indicated with crosses



Conclusions

- Changes in the difference between LWP and CLWP are linked to changes in fog's visibility.
- The observed β_0 value varies from 0 to 0.8, with median of 0.4, slightly larger than 0.3, a value widely used in literature.
- Temperature and Surface Heat Fluxes are shown to be related with the value of β_0.
- Further research in fog subadiabaticity is a crucial step before applying this method on fog dissipation forecasting.

[1] Cermak, Jan, and Jörg Bendix. "Detecting ground fog from space–a microphysics-based approach." International Journal of Remote Sensing 32.12 (2011): 3345-3371.

[2] Wærsted, Eivind. Description des processus physiques pilotant le cycle de vie de brouillards radiatifs et des transitions brouillard–stratus basé de modèles conceptuels. Diss. Université Paris-Saclay, 2018.

[3] Haeffelin, M., et al. "PARISFOG: shedding new light on fog physical processes." Bulletin of the American Meteorological Society 91.6 (2010): 767-783.

[4] Delanoe et al., BASTA: A 95-GHz FMCW Doppler Radar for Cloud and Fog Studies, Journal of Atmospheric and Oceanic Technology, American Meteorological Society, 33 (5), 1023-1038, doi:10.1175/JTECH-D-15-0104.1, 2016.

[5] Rose, Thomas, et al. "A network suitable microwave radiometer for operational monitoring of the cloudy atmosphere." Atmospheric Research 75.3 (2005): 183-200.

We would like to thank MODEM and the French National Association for Scientific Research (ANRT) for funding and supporting this project. Additionally, we would like to thank the technical and computer staff of SIRTA Observatory for taking the observations and making the data set easily accessible.