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DOE/SC-ARM-TR-242

Lifting Condensation Level Height (LCL Height) Value-Added Product Report

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April 2020

ARM

DISCLAIMER

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Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

ARM	Atmospheric Radiation Measurement
LASSO	LES ARM Symbiotic Simulation and Observation
LCL	lifting condensation level
LES	large-eddy simulation
MAWS	meteorological automatic weather station
MET	surface meteorological system
NetCDF	Network Common Data Form
OKM	Oklahoma Mesonet
SGP	Southern Great Plains
VAP	value-added product

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1.0 Introduction

The lifting condensation level height (LCL, m) is determined from continuous surface-air observations of relative humidity and temperature as the altitude where the surface-air moisture equals saturation following a dry-adiabatic ascent. Values are computed from surface meteorological observations for 16 facilities belonging to the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility Southern Great Plains (SGP) atmospheric observatory and for 133 Oklahoma Mesonet (OKM) stations.

The LCL Height Value-Added Product (VAP) was developed for use by the Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation (LASSO) project (Gustafson et al. 2016, 2017, 2018, 2020).

2.0 Input Data

The LCL VAP takes in data from ARM surface meteorology systems (MET) (Ritsche 2011) at 16 facilities in north central Oklahoma. The systems use conventional in situ sensors to collect 1-min observations of temperature, relative humidity, pressure, wind speed, wind direction, and precipitation. In the event that a MET data file for a day is unavailable for SGP E13, the meteorological automatic weather station (MAWS) data (Holdridge and Kyrouac 2017) at SGP C1 is used.

The LCL VAP also takes in 5-min time resolution meteorological data provided by the OKM stations (sponsored by the University of Oklahoma and Oklahoma State; Brock et al. 1995).

Table 1. Input variables.

<table>
<tr><th colspan="2">Input Variables for ARM SGP facilities</th></tr>
<tr><th>met.b1</th><th>mawsC1.b1
(if metE13.b1 is not available)</th></tr>
<tr><td>alt
atmos_pressure
lat
lon
rh_mean
temp_mean</td><td>alt
atmospheric_pressure
lat
lon
atmospheric_relative_humidity
atmospheric_temperature</td></tr>
<tr><th colspan="2">Input Variables for OKM stations</th></tr>
<tr><th colspan="2">05okm.b1</th></tr>
<tr><td colspan="2">alt
pres
lat
lon
rh
tdry_1_5m
platform</td></tr>
</table>

3.0 Algorithm and Methodology

The data flow of the LCL VAP is depicted in Figure 1. For each ARM facility, if there is a met.b1 data file for the day, the LCL is computed from that data. For the SGP E13 facility, if there is no met.b1 data file for a particular day, the maws.b1 datastream for SGP C1 is used. For all OKM stations, the 05okm.b1 datastream is used.

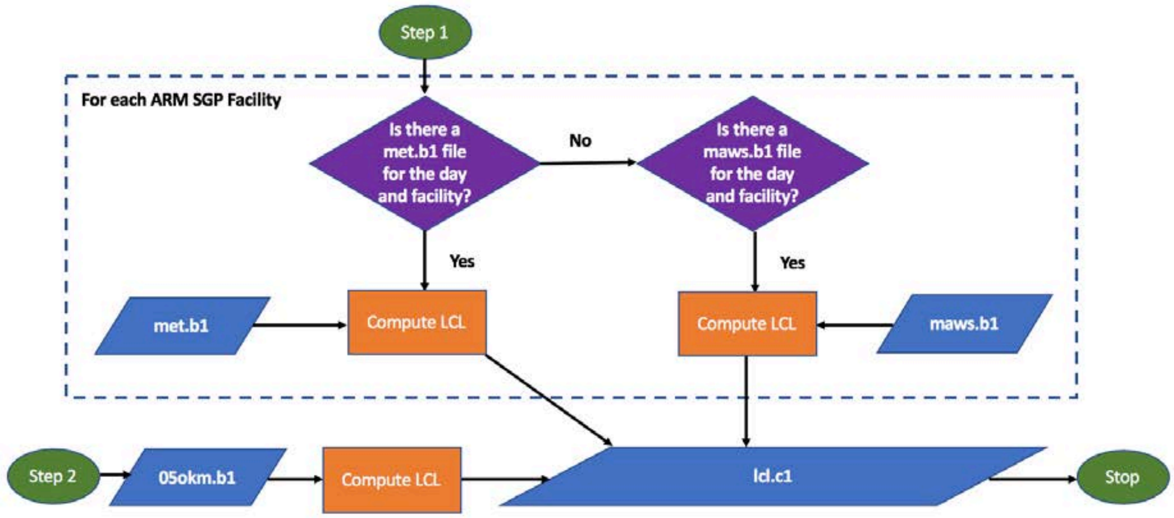

Figure 1. Flowchart describes the processing of a 24-hour period (1 day) of surface meteorological data.

A parcel method is adopted to determine LCL as the height at which the parcel water vapor mixing ratio q_v reaches parcel saturation water vapor mixing ratio q_{vs}, thus:

$$z_{LCL} = z\,(q_v = q_{vs})$$

where z_{LCL} is LCL height, and z is parcel height.

In the adiabatic air parcel, the initial water vapor mixing ratio is conserved whereas temperature T and pressure p decrease, respectively, following dry adiabatic lapse rate:

$$\frac{dT}{dz} = -\frac{g}{c_p}$$

and hydrostatic equilibrium:

$$\frac{dp}{dz} = -\rho g$$

where g is gravitational acceleration, c_p is the specific heat constant, and ρ is air density that is also a function of T and p.

Following the temperature and pressure changes, the saturation water vapor is calculated by:

$$q_{vs}(p,T) = 0.622 * \frac{e_s(T)}{p - e_s(T)}$$

where e_s is saturation vapor pressure given by a variation of Teten's approximation:

$$e_s(T) = 6.11 \times 10^{\frac{7.5\,T_C}{237.7+T_C}}$$

where $T_C = T - 273.15$ is temperature in Celsius.

The implemented algorithm is explained in Figure 2. For each 0.5 m increment in z, the thermodynamic state of the parcel (T, p and ρ) is updated, and the parcel q_{vs} is then evaluated against q_v until the parcel q_{vs} becomes smaller than q_v and the LCL height is determined.

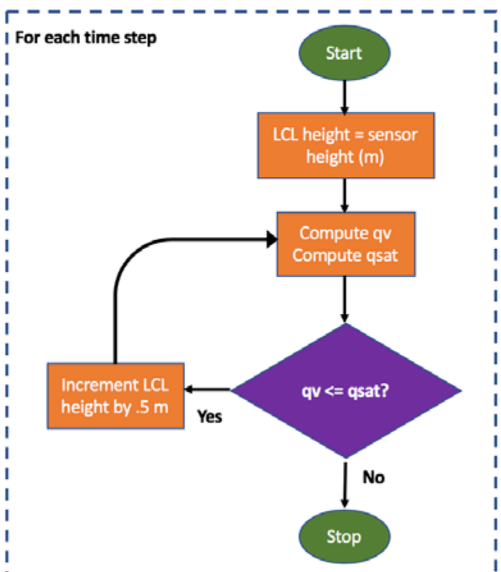

Figure 2. Flowchart describes the LCL algorithm as performed for each time step.

4.0 Output Data

This VAP outputs a daily NetCDF file containing 1-min time resolution estimates of LCL heights for each SGP facility and effective 5-min time resolution estimates of LCL for the OKM stations. Included also are the temperature, relative humidity, and pressure used to compute LCL, as well as the latitude, longitude, and altitude of each SGP facility or OKM station.

Table 2. Major output variables.

Datastream lcl.c1 fields
lcl (time, stations)
temperature (time, stations)
relative_humidity (time, stations)
pressure (time, stations)

5.0 Summary

The LCL Height VAP computes lifting condensation level heights for the ARM SGP facilities and the OKM stations. The VAP is being used to evaluate shallow convection LES models at the ARM SGP through the LASSO project.

6.0 Example Plots

Quicklook images are produced for each day of LCL processing. Figure 3 presents a sample output.

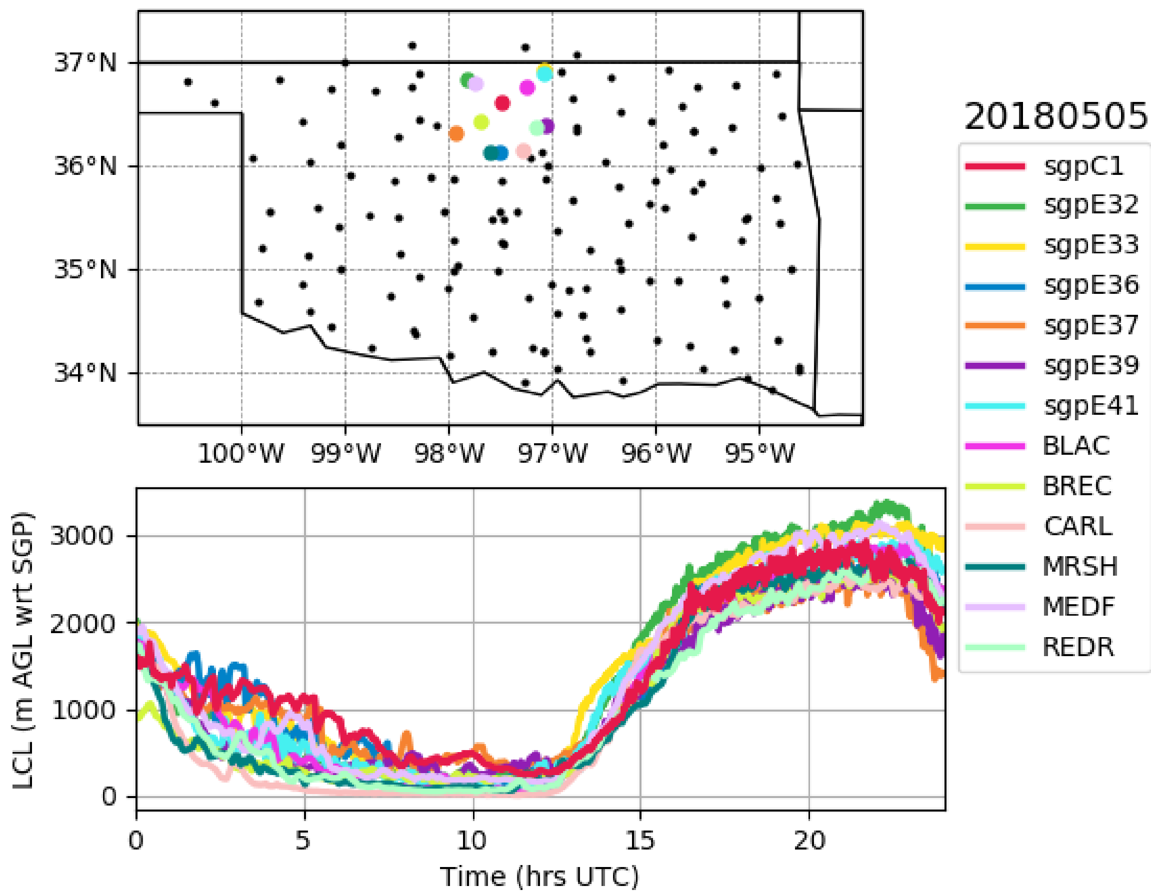

Figure 3. Quick look image produced by the LCL VAP on 20180505. For each black and colored dot on the map of Oklahoma, an LCL time series is computed. The time series plot only shows the LCLs for the colored dots on the map, which are the stations/facilities within 60 km of SGP C1, for which names are indicated in the legend. The time series of LCLs are in meters above ground level with respect to the height of SGP C1.

7.0 References

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