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Small Unmanned Aircraft System (sUAS) Measurements at the Oliver Springs Airport

E. J. Dumas[1]

T. R. Lee[1]

T. J. Schuyler[1]

M. Buban[1]

B. Baker[1]

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National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Air Resources Laboratory

Corresponding Author: Ed.Dumas@noaa.gov

1 NOAA/ARL, 5830 University Research Court, College Park, MD

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List of Abbreviations and Acronyms

Abbreviation	Acronym
AGL	Above ground level
AOC	Aircraft Operations Center
ARL	Air Resources Laboratory
ATDD	Atmospheric Turbulence and Diffusion Division
COA	Certificate of Authorization
FAA	Federal Aviation Administration
ftp	file transfer protocol
GPS	Global positioning system
LDT	Local daylight time
MATLAB©	Matrix Laboratory
MSL	Mean sea level
NOAA	National Oceanic and Atmospheric Administration
OMAO	Office of Marine and Aviation Operations
OSI	Oliver Springs airport
PIC	Pilot-in-command
sUAS	small Unmanned aircraft system
T/RH	Temperature and relative humidity
UTC	Universal coordinated time
VO	Visual observer

Abstract

This report describes the operation of NOAA/ARL/ATDD's Meteomatics Meteodrone SSE small Unmanned Aircraft System (sUAS) at the Oliver Springs Airport in Oliver Springs, TN during 2020. The Meteodrone was used to measure profiles in the lower atmospheric boundary layer on a daily basis from August, 2020 through December, 2020. During this operational study, typically eight Meteodrone flights were made from ½ hour after sunrise at ½ hour intervals on a given day to measure vertical profiles of air temperature, relative humidity, air pressure, wind speed, and wind direction from the surface to approximately 700 meters AGL. Datasets from these aircraft flights were processed and provided in near real-time to the Morristown National Weather Service office. The datasets have also been archived on ATDD's ftp site and are publicly available.

Introduction

NOAA's Air Resources Laboratory, Atmospheric Turbulence and Diffusion Division (NOAA/ARL/ATDD) entered into an agreement on 21-Mar-19 with the Oliver Springs Airport (OSI) in Oliver Springs, TN to perform research flights of its small UAS aircraft at that location. The airport is located within a 15 minute drive of the ATDD office in Oak Ridge and makes a convenient location for ATDD personnel to perform routine sUAS flights. Also, OSI is a sparsely used airport with a 2800 foot x 200 foot grass runway and surrounding open fields that provide adequate space to perform sUAS flights.

The goal of this research is to better understand the dynamics of the early morning transition of the boundary layer from stable to unstable conditions in complex terrain. Each sUAS flight was performed in the early morning hours of each day, with some flights beginning at sunrise, and others ½ hour after sunrise and continuing at ½ hour intervals until 8 flights had been accomplished. Each flight lasted approximately 10 minutes, and a total of 241 flights were flown on 31 days between 20-Aug-20 and 10-Dec-20.

Data were collected using a Meteomatics Meteodrone SSE small Unmanned Aircraft System (sUAS) owned by NOAA/ARL/ATDD. The SSE is a six-rotor vehicle capable of vertical takeoff and landing. It has a wingspan of approximately 0.4 m and carries a payload of custom-built meteorological sensors into the atmosphere in a specially designed housing to allow the sensors to be adequately ventilated during ascent and descent. The aircraft is operated by a remote pilot-in-command (PIC) who controls the aircraft and is aided by a visual observer (VO) who maintains visual line of sight on the aircraft at all times while it is in flight and scans for any air traffic that might conflict with the sUAS mission. The PIC monitors telemetry transmitted to the flight control system while the aircraft is in flight. The sUAS is operated within visual line of sight of the PIC and VO and is limited to altitudes of 1000 m above ground level (AGL) by a Federal Aviation Administration (FAA) Certificate of Authorization (COA) that ATDD has for this location. This sUAS is instrumented to make measurements of air temperature, relative humidity, atmospheric pressure, wind speed, and wind direction and record these measurements at approximately 4 Hz while the aircraft flies.

The flight profile for each flight is to climb upward at constant velocity, usually 3 m/s, until reaching the highest altitude that the aircraft can still be seen with the unaided eye. During this climb, the aircraft maintains its position over the takeoff point. This particular aircraft can be seen with the unaided eye up to about 700 m AGL under most meteorological conditions. After reaching this maximum altitude, the PIC commands the aircraft to begin descending at approximately 3 m/s until it is within a few meters of the ground. At this point the PIC executes a landing using manual control input. Most flights take approximately 10 minutes to execute.

Data is automatically recorded onboard the aircraft during flight and then downloaded to a portable computer after the aircraft is safely on the ground. Data is then uploaded to Meteomatics for processing, and then a processed file downloaded from Meteomatics. After more quality control processing and data conversion, the final processed data is uploaded to ATDD's file transfer protocol (ftp) site for use by various external partners.

Additional data is collected by a meteorological tower installed at the Oliver Springs Airport site. The meteorological quantities measured by this tower are wind direction, wind speed, peak wind gust, air temperature, relative humidity, dew point temperature, air pressure, density altitude, data logger panel temperature, and data logger battery voltage. Data is stored once per minute and archived on the ATDD ftp site.

The Meteomatics Meteodrone SSE is shown in Figure 1 flying at the Oliver Springs Airport in Oliver Springs, Tennessee during an operational flight for this study.

Figure 1: Meteomatics Meteodrone SSE flying at the Oliver Springs Airport in Oliver Springs, TN.

Table 1: Summary of Meteomatics Meteodrone SSE flights made at OSI during 2020. Note that local daylight time is UTC-5 hours and local standard time is UTC-5 hours. Additionally, local time changed from daylight savings (UTC-4 hours) to standard time (UTC-5 hours) on November 1, 2020

Date	Local Sunrise (UTC)	Number of Profiles	First Profile (UTC)	Last Profile (UTC)
20-Aug-20	1100	8	1104	1437
21-Aug-20	1100	8	1105	1434
24-Aug-20	1103	8	1106	1434
25-Aug-20	1103	8	1107	1435
26-Aug-20	1104	8	1104	1432
27-Aug-20	1105	8	1105	1434
31-Aug-20	1108	8	1103	1434
1-Sep-20	1109	8	1105	1435
2-Sep-20	1110	8	1101	1433
3-Sep-20	1110	8	1104	1434
4-Sep-20	1111	8	1104	1434
8-Sep-20	1114	8	1120	1450
9-Sep-20	1115	3	1124	1319
16-Sep-20	1120	8	1150	1520
23-Sep-20	1126	8	1205	1535
30-Sep-20	1131	8	1204	1534
7-Oct-20	1137	8	1201	1535
13-Nov-20	1212	8	1249	1619
16-Nov-20	1215	8	1249	1619
17-Nov-20	1216	8	1249	1619
18-Nov-20	1217	8	1249	1619
24-Nov-20	1223	8	1250	1619
25-Nov-20	1224	8	1249	1619
30-Nov-20	1228	8	1304	1633
1-Dec-20	1229	8	1305	1634
2-Dec-20	1230	8	1304	1634
3-Dec-20	1231	8	1304	1634
7-Dec-20	1235	8	1304	1634
8-Dec-20	1235	8	1304	1634
9-Dec-20	1236	8	1304	1634
10-Dec-20	1237	6	1304	1534

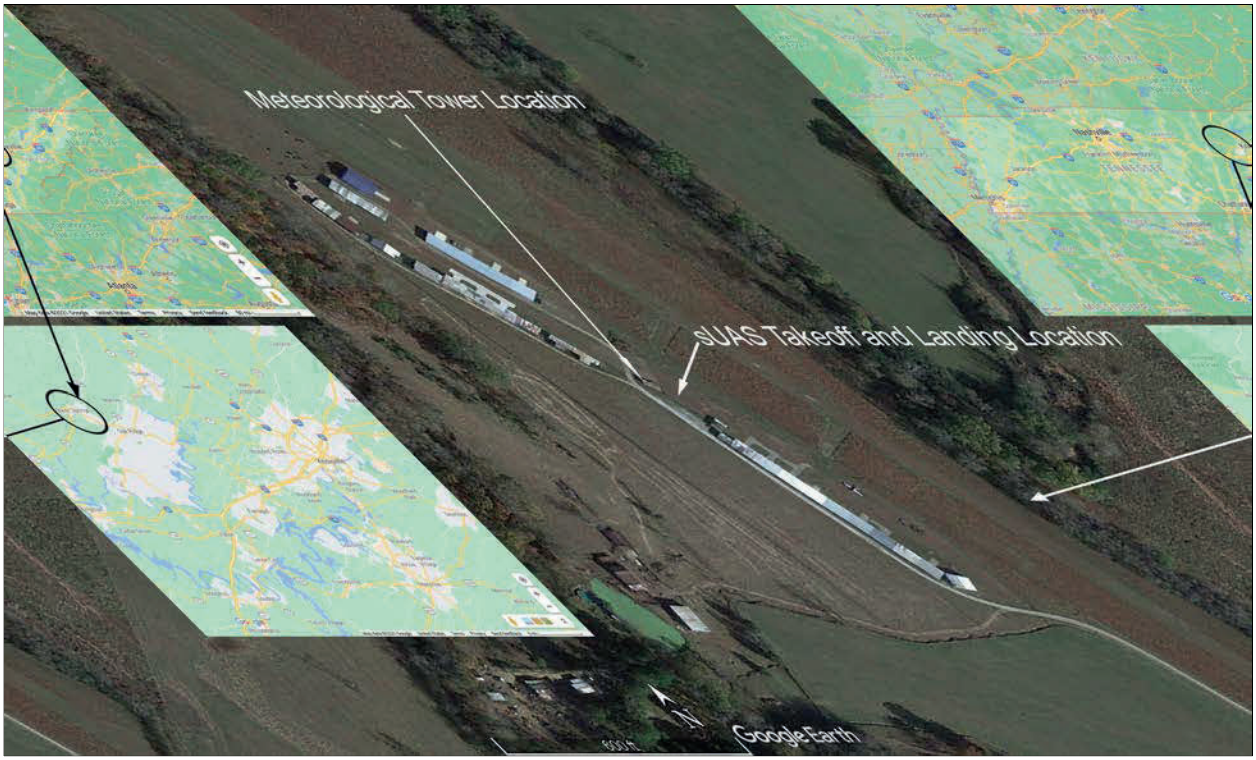

Figure 2: Map showing the Meteomatics Meteodrone SSE flight location and meteorological tower location at OSI.

Instrument Description

Meteomatics has built custom instruments to measure air temperature, relative humidity, and atmospheric pressure onboard the Meteomatics Meteodrone SSE aircraft during flight. The temperature and relative humidity (T/RH) instruments were calibrated prior to use in ATDD's temperature and humidity chamber to verify their accuracy and precision. The instruments are self-contained in a custom housing that allows the temperature, relative humidity, and pressure sensors to be ventilated as the aircraft climbs and descends. Using onboard GPS and inertial sensors, the control inputs needed to maintain the flightpath of the aircraft are used to calculate the ambient wind speed and direction as the aircraft ascends and descends. All data is recorded on a storage device inside the aircraft during flight. The specifications for each sensor are shown in Table 2.

Table 2: Meteomatics Meteodrone SSE meteorological sensor specifications

	Humidity	Temperature	Pressure	Wind Speed	Wind Direction
Type	Capacitive	Bead Thermistor	Piezo resistive	A/C flight path	A/C flight path
Range	0-100% RH	-95°C to +50°C	10-1200 hPa	0-40 m/s	0-360°
Response time	< 4 sec	< 1 second	250 ms	< 250 ms	< 250 ms
Accuracy	< 2% RH	±0.1 K	±0.1 hPa	< 1 m/s	< 10°
Storage freq	4 Hz	4 Hz	4 Hz	4 Hz	4 Hz

For more information please visit www.meteomatics.com

Data Collection and Processing

Data from the Meteomatics meteorological sensors were stored on-board the Meteodrone SSE during flight. Following each flight, data from the meteorological sensors were downloaded onto a laptop computer for post-processing.

Post-processing began by converting the Meteomatics data from its native CSV format to the NSP format used by the National Weather Service. This conversion was done using custom MATLAB© software. Finally, the data were plotted and visually inspected to provide an initial level of quality control prior to being archived onto the ATDD ftp site.

Data Format

The Meteomatics Meteodrone SSE CSV data file has the following format:

Line 1 - UTC time, file source, aircraft serial number

Lines 2-end: Latitude, longitude, GPS altitude, air temperature, dew point, relative humidity, air pressure, wind speed, wind direction

The UTC time is the time that the profile starts in Universal Coordinated Time. The file source is the location where the file is stored on the local computer. The GPS altitude is measured with respect to GPS referenced sea level. It should be noted that this file contains data from only the ascending portion of the flight at height intervals of approximately 1.5 meters.

The OSI meteorological tower instruments are listed in Table 3 and the data file has the following columns:

Date, time, Julian day, air pressure, air temperature 1, air temperature 2, dew point temperature, wind speed, wind direction, panel temperature, battery voltage

Table 3: OSI Meteorological Tower Instruments

Variable	Units	Instrument	Height AGL
Time, Panel Temp, Battery Voltage	ºC, VDC	Campbell Scientific CR23X	1.57 m
Air Pressure	mb	Vaisala PTB101B Barometric Pressure Sensor	1.57 m
Air Temperature 1*	ºC	Thermometrics PRT	5.18 m
Air Temperature 2*	ºC	Vaisala Humicap HM110	5.18 m
Dew Point Temperature*	ºC	Vaisala Humicap HM110	5.18 m
Wind Speed	m/s	RM Young 05103	5.79 m
Wind Direction	º	RM Young 05103	5.79 m

*These instruments are housed in a MetOne 076B aspirated shield 5.18 m above the ground.

Data from the OSI tower instruments is recorded by the Campbell CR23X and stored once per minute. Real-time OSI meteorological tower data are available at http://www.eddumas.com/osi/ Archived data from the OSI meteorological tower are available at ftp://ftp.atdd.noaa.gov/pub/GEWEX/OSI/

Acknowledgements

ATDD wishes to thank Mark Rogers of NOAA/OMAO/AOC for his assistance in securing the FAA COA that has allowed this work to be possible.

Appendix A – Catalog of OSI data from Meteomatics Meteodrone SSE flights in 2020

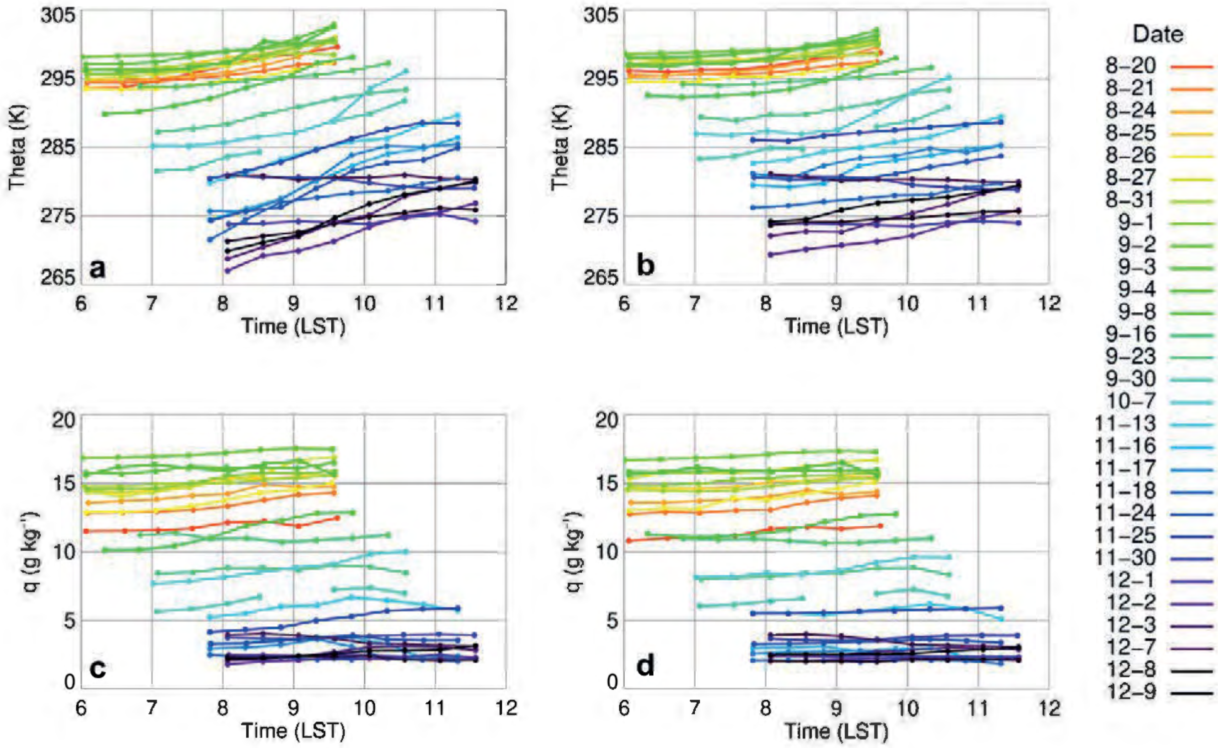

Figure A1: (a) 10-m and (b) 100-m potential temperature obtained from sUAS observations as a function of time of day colored as a function of day in 2020. Same for (c) and (d) but for specific humidity (*q*).

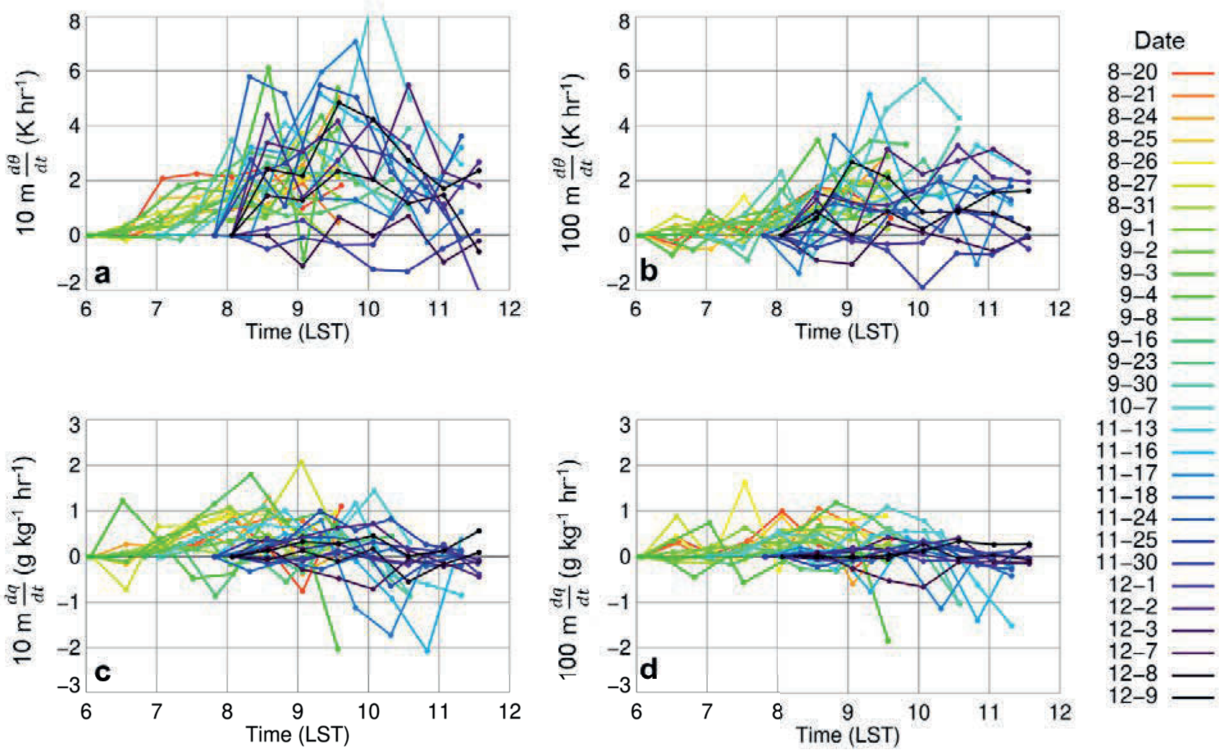

Figure A2: (a) 10-m and (b) 100-m potential temperature change (i.e., $d\theta/dt$) obtained from sUAS observations as a function of time of day colored as a function of day in 2020. Same for (c) and (d) but for specific humidity change (i.e., dq/dt).

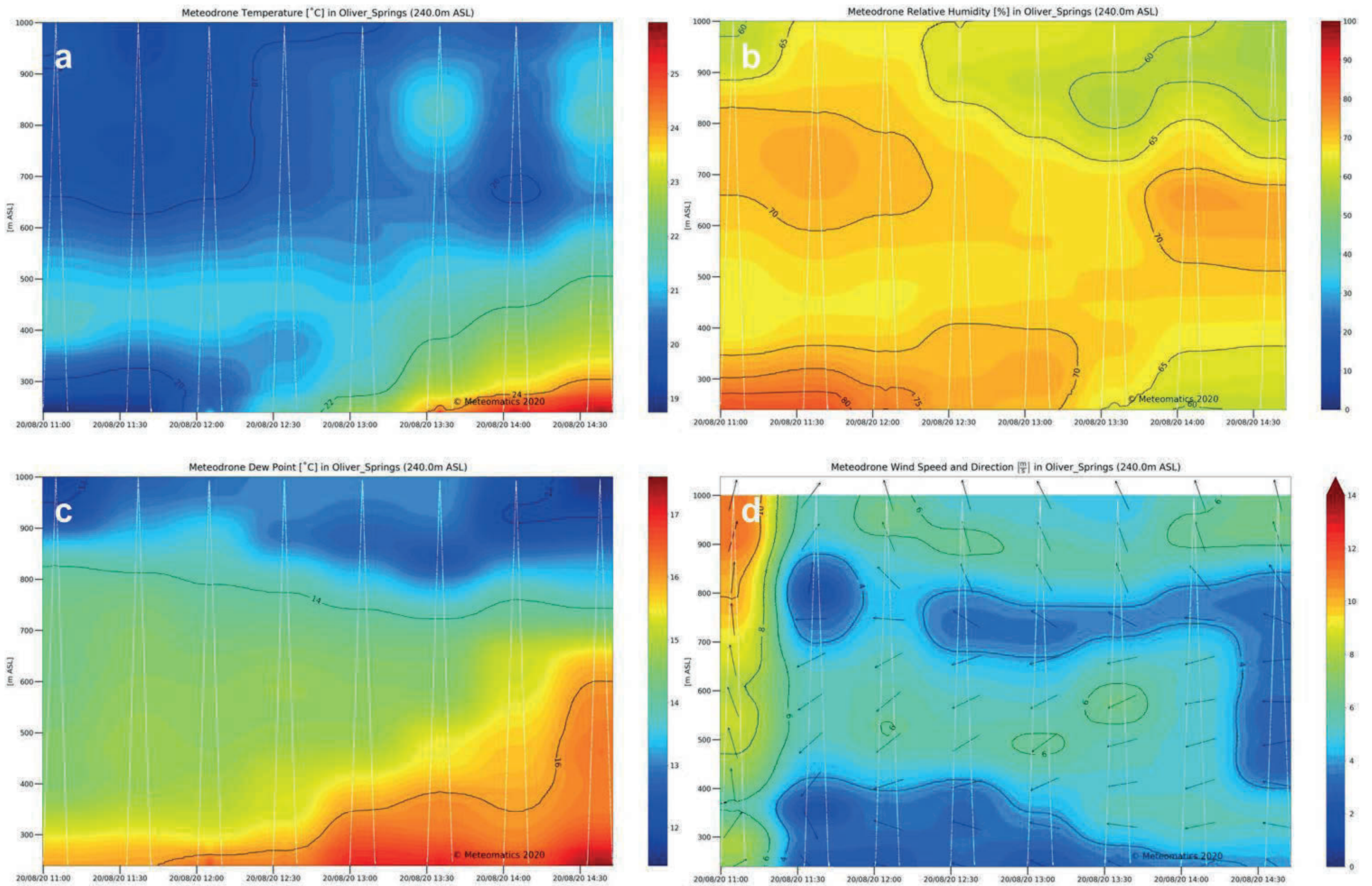

Figure A3: Sample Meteomatics Meteodrone SSE time-height cross-section for (a) air temperature, (b) relative humidity, (c) dew point temperature, and (d) wind speed and direction as a function of time after sunrise and altitude above ground from 20 August 2020. Individual aircraft paths can be seen in the white, and all times are in UTC.

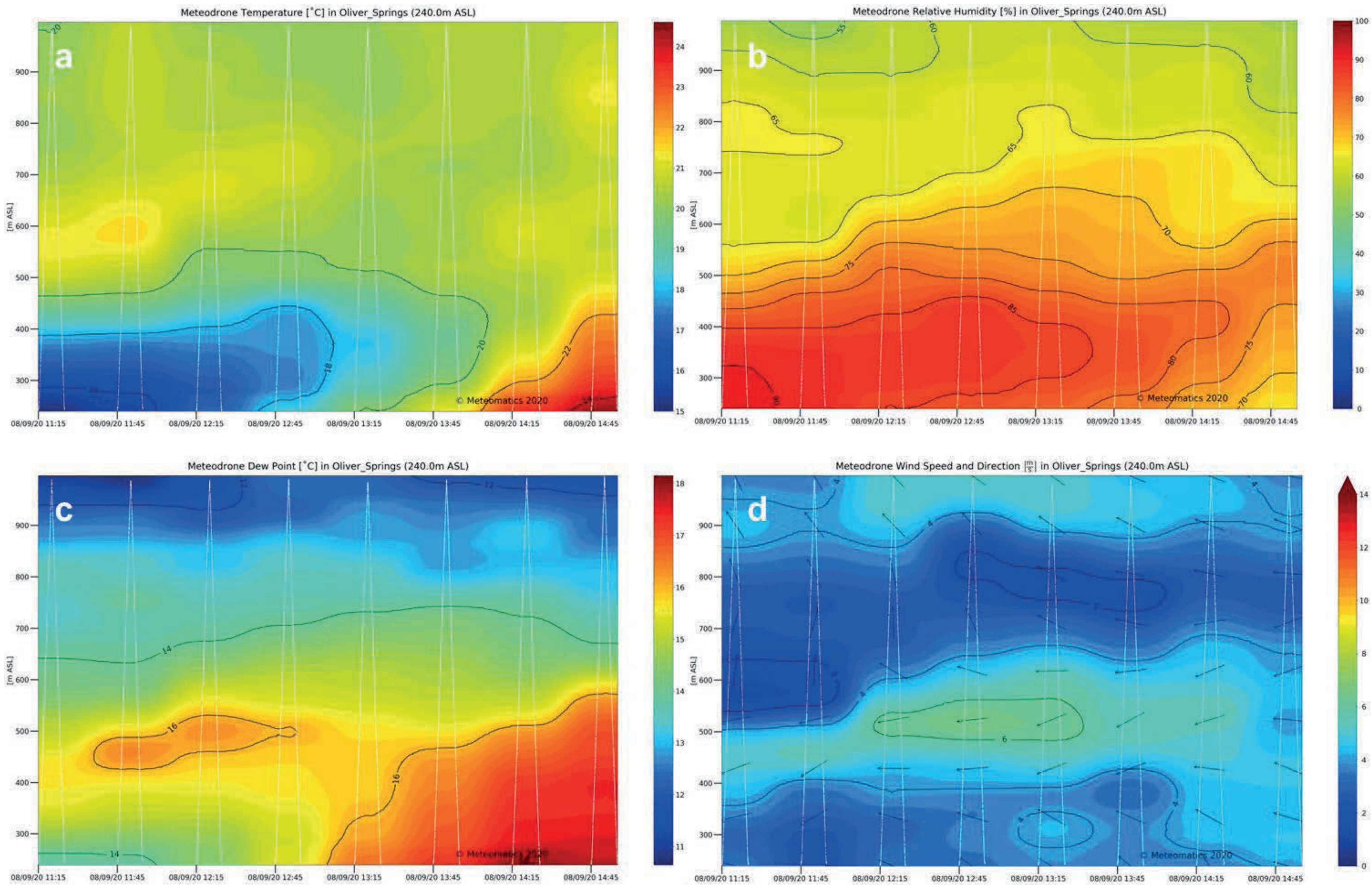

Figure A4: Same as Figure A3 but for 8 September 2020.

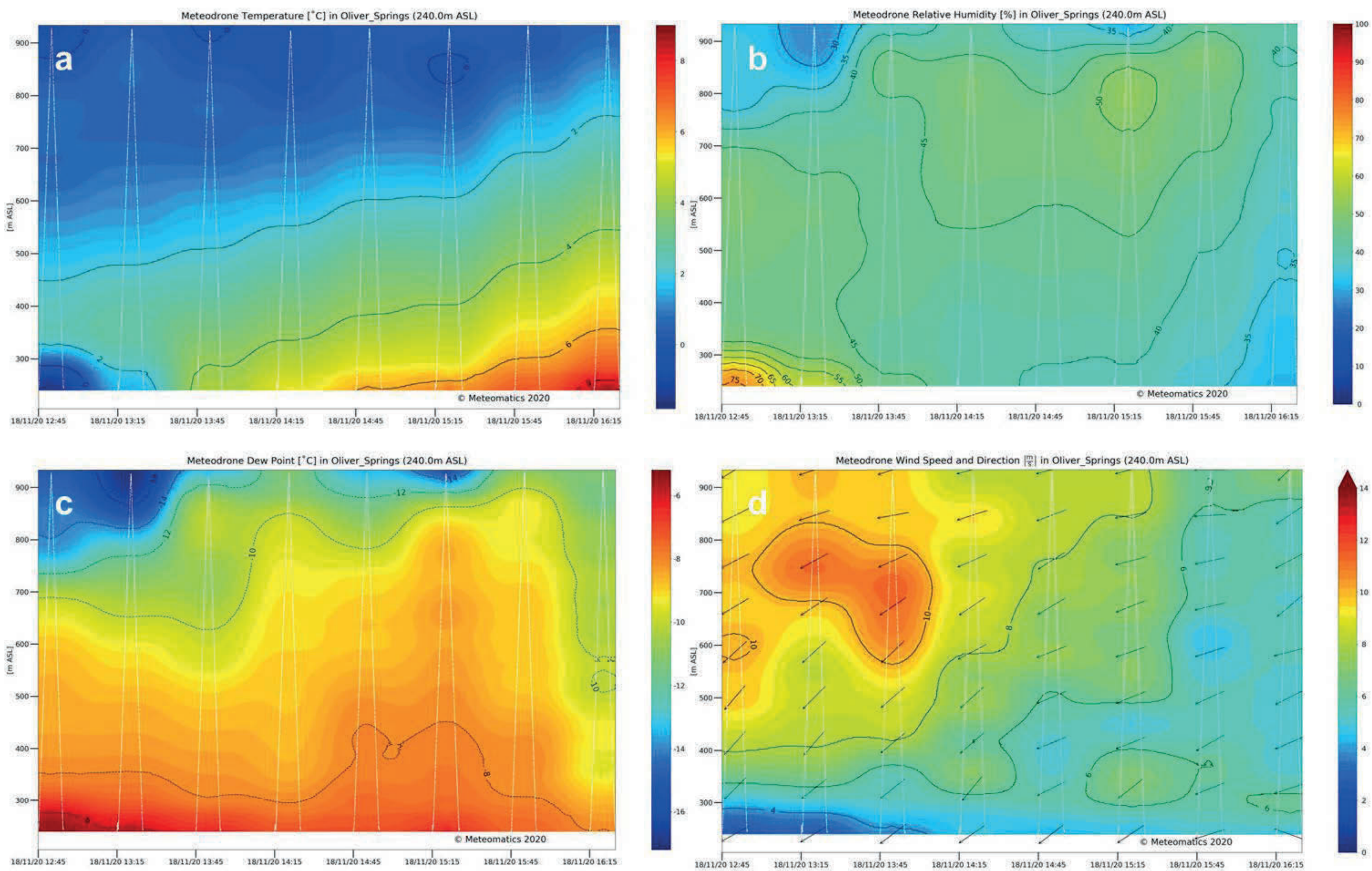

Figure A5: Same as Figure A3 but for 18 November 2020.

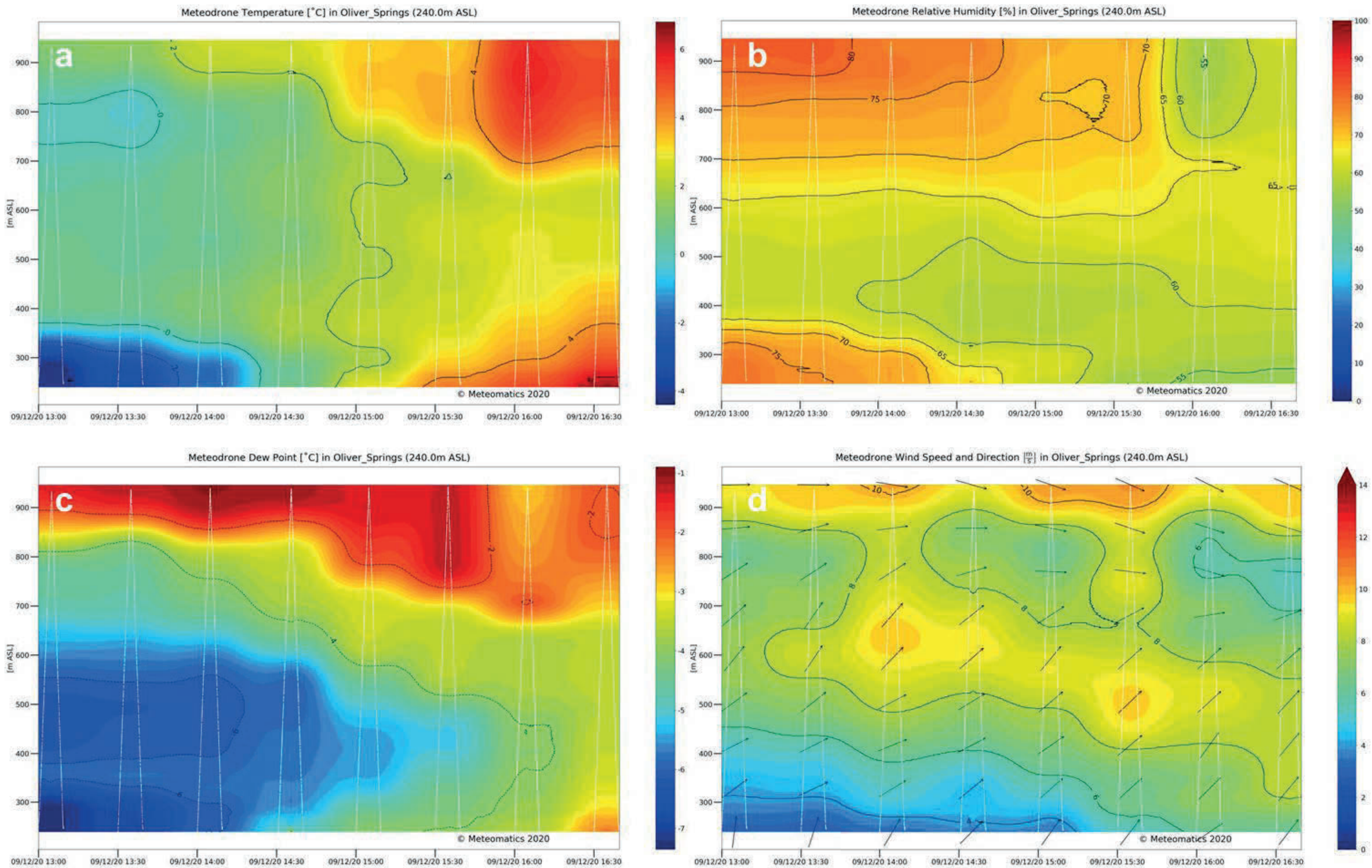

Figure A6: Same as Figure A3 but for 9 December 2020.

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