ARABLE

ARABLE MARK 2 MEASUREMENTS

SENSOR MEASUREMENTS

MEASURED WITH ARABLE MARK 2

MEASUREMENT	UNITS	RANGE	ACCURACY
Air temperature enhanced by machine learning algorithms	°C or °F	Calibrated -18° C to 45° C	±0.8° C within calibrated range ±1.5° C outside calibrated range
Relative humidity	%	1-100%	±5%
Pressure	kPa or mBar	50 kPa to 110 kPa absolute pressure; tested 95 kPa to 102 kPa	±0.5 kPa
Precipitation - rain and mixed drizzle/rain (sleet, snow, and hail excluded) enhanced by machine learning algorithms	mm or in	0 to 100 mm/hr	±6%
Blue spectral waveband - upwelling/downwelling	$W\ m^{-2}\ nm^{-1}$	420-480 nm	
Green spectral waveband - upwelling/downwelling	$W\ m^{-2}\ nm^{-1}$	490-560 nm	
Yellow spectral waveband - upwelling/downwelling	$W\ m^{-2}\ nm^{-1}$	560-610 nm	
Red spectral waveband - upwelling/downwelling	$W\ m^{-2}\ nm^{-1}$	640-700 nm	
Red edge spectral waveband - upwelling/downwelling	$W\ m^{-2}\ nm^{-1}$	730-760 nm	
NIR (near infra-red) spectral waveband - upwelling/ downwelling	$W\ m^{-2}\ nm^{-1}$	800-855 nm	
NIR (near infra-red) spectral waveband - upwelling/ downwelling	$W\ m^{-2}\ nm^{-1}$	920-965 nm	
Shortwave (visible light) energy	$W\ m^{-2}$	300-2,500 nm	
Longwave energy	$W\ m^{-2}$	8,000-14,000 nm	

SENSOR MEASUREMENTS

MEASURED WITH ARABLE BRIDGE

MEASUREMENT	DEFINITION	UNITS
Wind speed	Wind speed from a Davis cup anemometer	m s^{-1} or km h^{-1} or mi h^{-1}
Wind direction	Wind direction from a Davis cup anemometer, set at true north	deg
Soil moisture	Millimeters of water per 10 cm, equal to a volumetric fraction of water content	%
Soil salinity	Volumetric ion content of the water in the soil	unitless
Soil temperature	Soil temperature per 10 cm	°C

DERIVED MEASUREMENTS

SPECTRAL REFLECTANCE

Arable's reflectance values are a ratio of upwelling and downwelling measurements. Daily values are computed from the average of spectral measurements taken one hour before and after local solar noon, and are used to calculate the spectral indices below.

NDVI - NORMALIZED DIFFERENCE VEGETATION INDEX

The normalized difference vegetation index is a generalized index to evaluate green vegetation's overall vigor and is broadly correlated to the canopy leaf area index (LAI). The calculation is performed using the NIR and red band reflectances. This is based on the papers by Tucker, 1979; Rouse et al., 1974

CI - CHLOROPHYLL INDEX (GREEN BAND FORMULATION)

Chlorophyll index is a spectral index correlated with nitrogen uptake during peak greenness. The calculation is performed using the spectral reflectances around 560 nm and 870 nm. This is based on the paper by Gitelson and Merzlyak (2005).

PRECIPITATION

Precipitation (mm h^{-1} or mm d^{-1}) is measured by detecting the acoustic signal caused by the power intensity of rainfall droplets. Each droplet resonates at a distinct frequency, allowing Arable's unique algorithms to predict droplet size. The distribution of droplet sizes determines the overall precipitation rate and accumulated amount. This process is enhanced by employing classification and regression machine learning (ML) models. Precipitation hours are defined as the number of hours with more than 0.1 mm of precipitation.

ET - EVAPOTRANSPIRATION

Evapotranspiration (mm h^{-1} or mm d^{-1}) is the hypothetical value under a grass reference surface. We use Arable's unique ML model to predict ET, which makes use of the hyper-localized measurements taken by the Mark 2. The feature inputs into this ML model are similar to those inputs required for physical models, like the FAO Penman-Monteith method, but we achieve greater accuracy using the ML model, which is able to correct for errors and capture patterns that inflexible physical models do not. As a backup, when the ML model cannot be applied (only under rare circumstances), we use the FAO Penman-Monteith method with the Dong et.al net radiation approach.

DERIVED MEASUREMENTS

ETc - CROP (CANOPY) EVAPOTRANSPIRATION

Crop-specific evapotranspiration (mm h^{-1} or mm d^{-1}) is the theoretical ET multiplied by the crop coefficient (Kc_{NDVI}). This value represents water losses specific to the canopy as opposed to that lost across the field (cover crop, soil).

KC_{NDVI} - NDVI DERIVED CROP COEFFICIENT

The crop coefficient is derived from the vegetation cover as measured by NDVI using Arable's spectrometers. Given that NDVI is specific to the crop, Kc_{NDVI} represents the actual conditions of the crop canopy.

TDEW - DEW POINT TEMPERATURE

Dew point temperature (°C) is the temperature point where the air will saturate with water vapor, below which condensation will form on surfaces. It is computed using the actual vapor pressure, which is itself the result of the saturation vapor pressure multiplied by the relative humidity. This is based on the papers from Bosen (1958); Jensen et al. (1990).

VPD - VAPOR PRESSURE DEFICIT

Vapor pressure deficit (kPa) is the difference -- or deficit -- between the amount of moisture in the air and how much moisture the air can hold when it is saturated. VPD is recognized as the evaporative driving force for water transport.

LFW - LEAF WETNESS

Hourly leaf wetness is binary, where 1 is defined as wet and 0 as dry. If any length of time within a given hour is deemed wet, then that entire hour is classified as 1. Daily leaf wetness represents the number of whole hours that were defined as wet, determined by summing the results of each hour. Arable's unique model predicts leaf wetness based on measured relative humidity, precipitation, dew point temperature, and surface temperature.

GDD - GROWING DEGREE DAYS

Growing degree days (°C-day or °F-day) measure how much heat a crop has received during the season. Since temperature influences many biological processes that determine health and vigor, GDD is strongly correlated to plant development. It is a calculation that represents the passage of physiological time based on temperature. Different biological thresholds and the start of accumulation dates are used for each crop and varietal. Cumulative growing degree days (CGDD) are the sum of GDDs since the beginning of the season, as specified by the user.

SLP - SEA LEVEL PRESSURE

Sea level pressure (kPa) is empirically derived from the measured pressure, air temperature, and elevation, as well as from the gravitational acceleration and gas constants.

CWD - CROP WATER DEFICIT

Crop water deficit (mm d^{-1}) is the amount of daily water required by the crop, accounting for water inputs and outputs. Precipitation and irrigation amounts define water inputs, and the water lost to crop-specific evapotranspiration defines water outputs.

SUNSHINE DURATION

Sunshine duration (hrs) is the length of time each day where direct solar irradiance is greater than 120 W m^{-2}. This is based on the World Meteorological Organization (WMO) WMO guidelines.