# OASIS98 Soil Measurements Report

For OASIS98 three sets of soil sensors were deployed. The three sites were in the vicinity of the radiation array within cable reach of the Campbell. Each soil sensors set was within a 1 m circle, with neither sensors nor cables interfering with each other.

Each set of soil sensors consisted of:

one heat flux plate, inserted 8 cm deep, horizontal, with white dot uppermost

one soil temperature probe, inserted at 45 degrees from 1 - 8 cm

one TDR moisture sensor, inserted 4 cm deep, horizontal

To insert the heat flux plate a trench was dug 8 cm deep, ~5- 8 cm wide, and 20 cm long. At the bottom and end of the trench a slot was made with a screw driver and insert the heat flux plate. The cable was lead horizontally away from the plate and up and out of the other end of the trench. The trench was refilled and recompacted to the original state.

The soil temperature probe was inserted using a screw driver to make a 45 degree 15 cm deep hole and the temperature probe was pushed into the hole. The cable was lead away from the sensor.

The TDR moisture sensor was inserted by digging a trench 8 cm deep, ~ 10 cm wide and 30 - 40 cm long. Holding the sensor at the 4 cm depth, with the prongs horizontal just penetrating the face of the trench and maintaining the prongs level, the prongs were forced into the face of the trench.

**BRIEF HISTORY OF THE SOIL SENSORS.** The soil sensors were installed on 20 Jun''98 (see Logbook #14). After the NCAR sensors were installed they were merely left to “settle in”. The OKMN sensor installations were well-wetted with several gallons of water to assist in the “settling in”. It was noted that the data from the #1 set of NCAR heat flux, temperature and soil moisture sensors were out of line with the other two sets. On 7 Jul the #1 set of sensors were reinstalled (see Logbook #97). This improved the heat flux and temperature data but not the soil moisture data.

At each site soil samples were taken to calibrate the TDR moisture sensor. Three basic methods were used to obtain soil samples:

**Pit.** A hole was dug ~ 20 cm deep. One face was squared off. a line was scoured across the face at the 6 cm level. Dirt was scraped from the 0 - 6 cm level and loaded into a Tupperware container. Care was taken to acquire a representative sample. In the trailer the dirt was homogenized and three ~25 g aliquots were loaded into Al foil cups. The fresh weight was measured, the dirt was baked at 110$^{o}$C for 24 hours and then the dry weight was measured.

**Core.** The soil corer was assembled with the core sleeves. Two 3 cm sleeves were inserted at the top of the barrel, with the other sleeves below. The corer was driven into the soil using the slide hammer, the corer was loosened by rocking the handle from side to side and the corer was withdrawn. In the trailer the core sleeves were pushed out of the barrel and the bottom, > 6 cm, sample discarded. The contents of the top two 3 cm sleeves was emptied into an Al foil dish. The fresh weight was determined, the dirt was baked at 110$^{o}$C for 48 hours and then the dry weight measured.

**Volume of soil collected using corer = cross section of sleeve x 6 cm = 137 cm$^3$**

**Clod**. A chunk of undisturbed soil measuring ~ 20 cm x 20 cm x 15 cm deep was dug up and taken into the trailer. Using a keyhole saw, the chunk was squared off and several rectangular prisms, 6 cm deep by ~3 cm x ~3 cm were cut. and these clods were loaded into an Al foil dish. The fresh weight was determined, the clod was baked at 110$^{o}$C for 48 hours and the dry weight measured. Melted parwax was dribbled over the clod to water-proof it. The clod was suspended by a thread from the hook underneath the balance. A beaker of water was raised to immerse the clod. The weight in air and the weight immersed in water were determined. The bouyancy excerted upon the clod is equal to the volume of water displaced. This is equal to the volume of the clod. The additional wax does not make any difference as long as the volume of the clod is not affected.

**Volume of soil in clod = (wt of clod in air - wt of clod suspended in water)/density of water**

The gravimetric water fraction, **gwf**, is determined by weighing a soil sample fresh, and then after baking to dryness.

**gwf = (Mass of water)/(Mass of soil) = (Fresh wt - Dry wt)/( Drywt)**

The bulk density, Dens, of the soil is determined from the dry weight of an aliquot of the soil and the in situ volume of that aliquot. The dry weight of an aliquot is easilly determined but the in situ volume is more difficult to determine. My preference is using the clod method because the corer tends to introduce cracks and voids leading to an lower density.

**Dens = (Mass of soil)/(Volume of soil) = (Dry wt)/(Volume of soil)**

The volumetric water fraction, **vwf**, is the gravimetric water fraction multiplied by the density of the soil. (see below)

**vwf = gwf x Dens**

# Relationships involved in soil measurements

| | |
|---|---|
| Dry | soil dry mass, g |
| Fresh | soil wet mass, g |
| Diff | soil wet mass -soil dry mass = soil water mass, swm , g |
| Vol | in situ volume of soil, cm3 |
| Dens | in situ density of dry / moist soil. Assumes soil does not swell nor shrink , g cm-3 |
| mindens | density of the mineral grains, g cm-3 |
| waterdens | density of water = 1.0 g cm-3 |
| soil water mass, swm | mass of water in a volume of soil = (Fresh - Dry), g |
| soil mineral mass, smm | mass of mineral in a volume of soil, g |
| soil organic mass, som | mass of organic material in a volume of soil (we normally ignore this component), g |
| gwf | gravimetric water fraction = soil water mass/soil dry mass = (Dry - Fresh ) / Dry |
| vwf | volumetric water fraction = gwf * Dens |

| | | |
|---|---|---|
| gwf | = | $M_{water}$ / $M_{dry\ soil}$ |
| $Vol_{water}$ | = | $M_{water}$ / $Density_{water}$ |
| $Vol_{dry}$ | = | $M_{dry\ soil}$ / $Density_{dry}$ |
| vwf | = | $Vol_{water}$ / $Vol_{dry}$ |

$= M_{water} / M_{dry\ soil} * Density_{dry} / Density_{water}$

$= gwf * Density_{dry} / Density_{water}$

$= gwf * Density_{dry}$

vwf $=$ **gwf * Dens**

# Determination of mineral density for the OASIS98 soil

A few hundred grams of soil were dug from the depth 0-6 cm.

Soil was pulverized with a hammer and seived through a window screen mesh.

Using five vials to obtain multiple determination:

Three-quarters filled with dry soil, weigh = $\mathbf{M_{min}}$

Water added until soil was saturated, syringing out any excess, weigh = $\mathbf{M_{wet}}$

Level marked and afterwards filled with water to this same level and weighed = $\mathbf{M_T}$ = $V_T$

$V_{interstsit} = M_{interstit} = (M_{wet} - M_{min})$

$V_{min} = (V_T - V_{interstit}) = (M_T - M_{interstit}) = (M_T - (M_{wet} - M_{min})$

Mindens = $M_{min} / V_{min} = \mathbf{M_{min} / M_T - (M_{wet} - M_{min})}$

Measurements in lab, 18 - 19 Aug''98

| | **Glass beads** | | **OASIS98 soil** | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| $M_{min}$ | 37.4 | 33.5 | 33.5 | 30.3 | 30.6 |
| $M_{wet}$ | 46.2 | 41.7 | 47.3 | 42.6 | 42.8 |
| $M_T$ | 22.5 | 20.6 | 29.1 | 26.5 | 26.5 |
| $(M_{wet} - M_{min})$ | 8.8 | 8.2 | 13.8 | 12.4 | 12.2 |
| $(M_T - (M_{wet} - M_{min}))$ | 13.7 | 12.4 | 15.3 | 14.1 | 14.3 |
| $M_{min} / (M_T - (M_{wet} - M_{min}))$ | 2.73 | 2.70 | 2.19 | 2.14 | 2.14 |
| Mindens ($g.cm^{-3}$) | 2.72 | | 2.16 | | |

Note that the glass beads came from EMCO in Germany, and I don‘t have the density. However, The Rubber Book gives 2.4 - 2.8 g.cm-3 as the range for glass densities, so I trust the values measured.

These values were extracted from the OASIS98 logbook. The values were compared to the original notes in my notebook and the arithmetic was rechecked

**TABLE 1** Soil sample data

| **Date** | **Prs** | **Styl** | **Dpt cm** | **Fresh g** | **Dry g** | **Diff g** | **Wxd g** | **Imr g** | **Vol $cm^3$** | **gwf** | **Dens $g/cm^3$** | **vwf D= 1.42** | **Bestvalues vwf** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26Jun | SS | core | 0-4 | 118.1 | 111.7 | 6.4 | | | 91 | 0.057 | 1.23 | 0.081 | |
| | | | 0-6 | 191.4 | 180.7 | 10.7 | | | 137 | 0.059 | 1.32 | 0.084 | 0.084 |
| 5Jul | TD | core | 0-6 | 25.6 | 24.6 | 1.0 | | | ~ | 0.041 | | 0.058 | |
| | | | | 20.7 | 19.9 | 0.8 | | | ~ | 0.040 | | 0.057 | 0.057 |
| | | | | 24.3 | 23.4 | 0.9 | | | ~ | 0.039 | | 0.055 | |
| 5Jul | TD | clod | 0-3 | ~ | 59.2 | ~ | 64.1 | 25.1 | 39.0 | ~ | 1.52 | | |
| | | | 3-6 | ~ | 120.3 | ~ | 136.4 | 50.4 | 86.0 | ~ | 1.40 | | |
| 7Jul | TD | core | 0-6 | 173.9 | 168.7 | 5.2 | | | 137 | 0.031 | 1.23 | 0.044 | 0.044 |
| 8Jul | TD | core | 0-3 | 83.3 | 69.1 | 14.2 | | | ~ | 0.205 | | 0.291 | |
| | | | 3-6 | 88.6 | 80.5 | 8.1 | | | ~ | 0.101 | | 0.143 | |
| 12Jul | TD | pit | 0-6 | 19.3 | 18.4 | 0.9 | | | ~ | 0.049 | | 0.070 | |
| | | | | 21.2 | 20.2 | 1.0 | | | ~ | 0.050 | | 0.071 | 0.070 |
| | | | | 22.0 | 21.0 | 1.0 | | | ~ | 0.048 | | 0.068 | |
| 12Jul | TD | core | 0-6 | 184.0 | 173.3 | 10.7 | | | 137 | 0.062 | 1.26 | 0.088 | |
| 14Jul | TD | pit | 0-6 | 20.6 | 19.9 | 0.7 | | | ~ | 0.035 | | 0.050 | |
| | | | | 27.4 | 26.5 | 0.9 | | | ~ | 0.034 | | 0.048 | |
| | | | | 32.5 | 31.4 | 1.1 | | | ~ | 0.035 | | 0.050 | |
| 14Jul | TD | core | 0-6 | 183.0 | 175.8 | 7.2 | | | 137 | 0.041 | 1.28 | 0.058 | |
| 14Jul | TD | clod | 0-6 | 134.0 | 129.2 | 4.8 | 139.1 | 49.5 | 89.6 | 0.037 | 1.44 | 0.053 | |
| | | | | 118.8 | 114.2 | 4.6 | 121.8 | 41.6 | 80.2 | 0.040 | 1.42 | 0.057 | 0.052 |
| | | | | 83.6 | 81.0 | 2.6 | 87.7 | 30.6 | 57.1 | 0.032 | 1.42 | 0.045 | |
| 18Jul | TD | pit | 0-6 | 24.6 | 23.6 | 1.0 | | | ~ | 0.042 | | 0.060 | |
| | | | | 25.7 | 24.7 | 1.0 | | | ~ | 0.040 | | 0.057 | |
| | | | | 26.2 | 25.2 | 1.0 | | | ~ | 0.040 | | 0.057 | |
| 18Jul | TD | core | 0-6 | 174.6 | 168.3 | 6.3 | | | 137 | 0.037 | 1.23 | 0.053 | |
| 18Jul | TD | clod | 0-6 | 222.6 | 214.1 | 8.5 | 233.4 | 80.0 | 153.4 | 0.040 | 1.40 | 0.057 | 0.059 |
| | | | | 137.3 | 131.7 | 5.6 | 143.2 | 50.0 | 93.2 | 0.043 | 1.41 | 0.061 | |
| 30Jul | JM | core | 0-6 | 186.2 | 180.9 | 5.3 | | | 137 | 0.029 | 1.32 | 0.041 | |
| 30Jul | JM | clod | 0-6 | 225.4 | 220.3 | 5.1 | 233.9 | | | 0.023 | | 0.033 | 0.037 |
| | | | | 143.6 | 139.7 | 3.9 | 151.6 | | | 0.028 | | 0.040 | |
| 5Aug | JM | pit | 0-6 | 34.9 | 33.6 | 1.3 | ~ | ~ | ~ | 0.037 | | 0.053 | |
| | | | | 31.4 | 30.2 | 1.2 | ~ | ~ | ~ | 0.040 | | 0.057 | 0.056 |
| | | | | 24.9 | 23.9 | 1.0 | ~ | ~ | ~ | 0.040 | | 0.057 | |
| 5Aug | JM | core | 0-6 | 178.3 | 178.2 | 0.1 | ~ | ~ | 137 | 0.0006 | | | |
| | | clod | 0-6 | 152.5 | 154.1 | -ve | | | | | | | |
| | | | 0-6 | 161.2 | 161.8 | -ve | | | | | | | |

Note that a value for Dens = 1.42 g/ $cm^3$ was used throughout to calculate the vwf.. This value of

$1.42\ g/cm^3$ was derived from the clod method. The clod method is more credible than the corer method for this friable soil which tended to fracture and form cracks when the corer was used.

# Calibration of CSI vwf response using Manual results

From the gravmoist/bulkdens data a limited number of vwf values were available.
For times corresponding to these vwf values the raw CSI msec data, Mp., were extracted.

| Date/Time | Manual, vwf | CSI (1) msec | CSI (2) msec | CSI (3) msec |
|---|---|---|---|---|
| 1998, Jun 26, 10:30 | 0.084 | 0.876 | 0.886 | 0.883 |
| 1998, Jul 5, 10:30 | 0.057 | 0.850 | 0.867 | 0.865 |
| 1998, Jul 7, 10:30 | 0.044 | 0.848 | 0.864 | 0.862 |
| 1998, Jul 12, 10:30 | 0.070 | 0.872 | 0.903 | 0.900 |
| 1998, Jul 14, 10:30 | 0.052 | 0.853 | 0.881 | 0.879 |
| 1998, Jul 18, 10:30 | 0.059 | 0.835 | 0.862 | 0.860 |
| 1998, Jul 30, 10:30 | 0.037 | 0.802 | 0.841 | 0.840 |
| 1998, Aug 5, 10:30 | 0.056 | 0.811 | 0.846 | 0.846 |

The relationship:

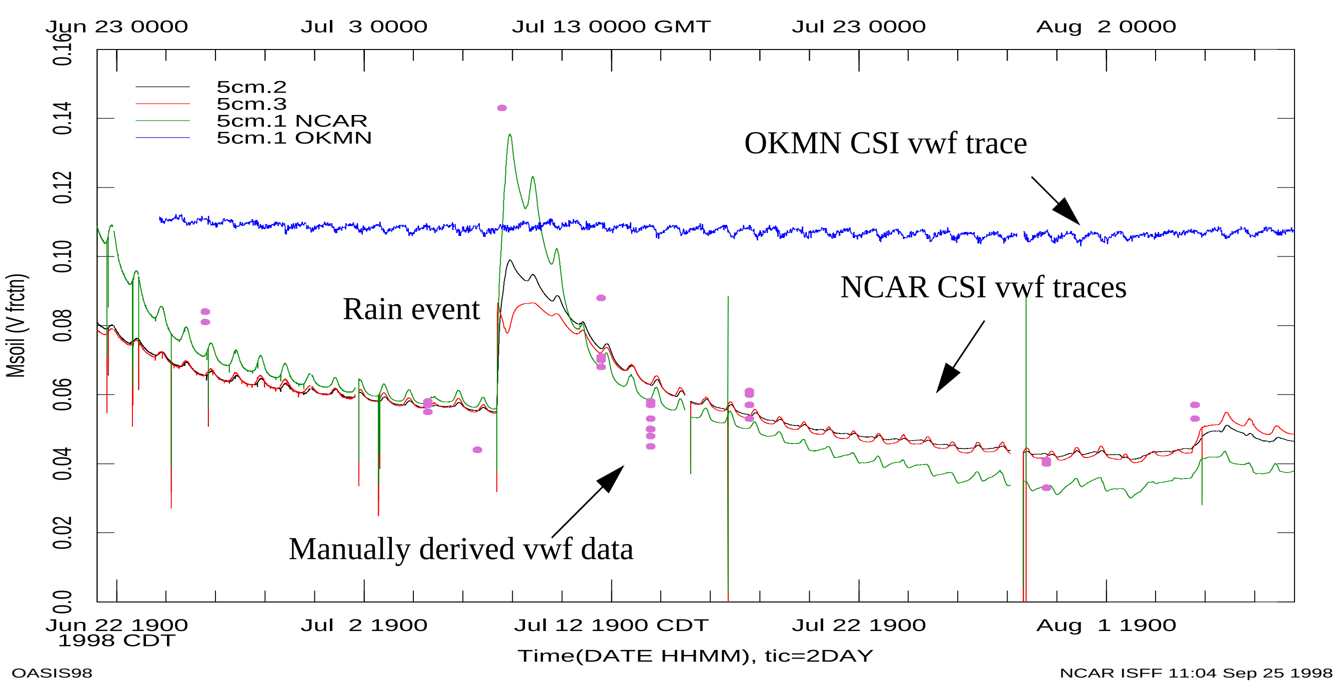
$$vwf(manual) = a_0 + a_1*CSI(\#) + a_2*CSI(\#)^2$$

was analysed, using Splus function, lm(), and the coefficients for the polynomial were extracted.
For the OASIS98 program the following coefficients were found to be:
These coefficients were then applied to the CSI(#) raw time data and continuous traces of

**TABLE 2**

| | CSI(1) | CSI(2) | CSI(3) |
|---|---|---|---|
| $a_0$ | 0.08852222 | -1.294723 | -2.248838 |
| $a_1$ | -0.61869700 | 2.612943 | 4.794257 |
| $a_2$ | 0.68604872 | -1.215597 | -2.460459 |

vwf(CSI(1)), vwf(CSI(2)) and vwf(CSI(3) were generated



# Conclusions

For the OASIS98 deployment the default value for the soil parameters should be replaced by the OASIS98 specific values.

Bulk density = 1.42 g. $cm^{-3}$

Mineral density = 2.16 g. $cm^{-3}$

The volumetric water fraction for the OASIS98 soil is well defined by the NCAR CSI traces when the CSI sensors are calibrated to the local soil using manually derived gravimetric soil moisture and bulk density values.

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