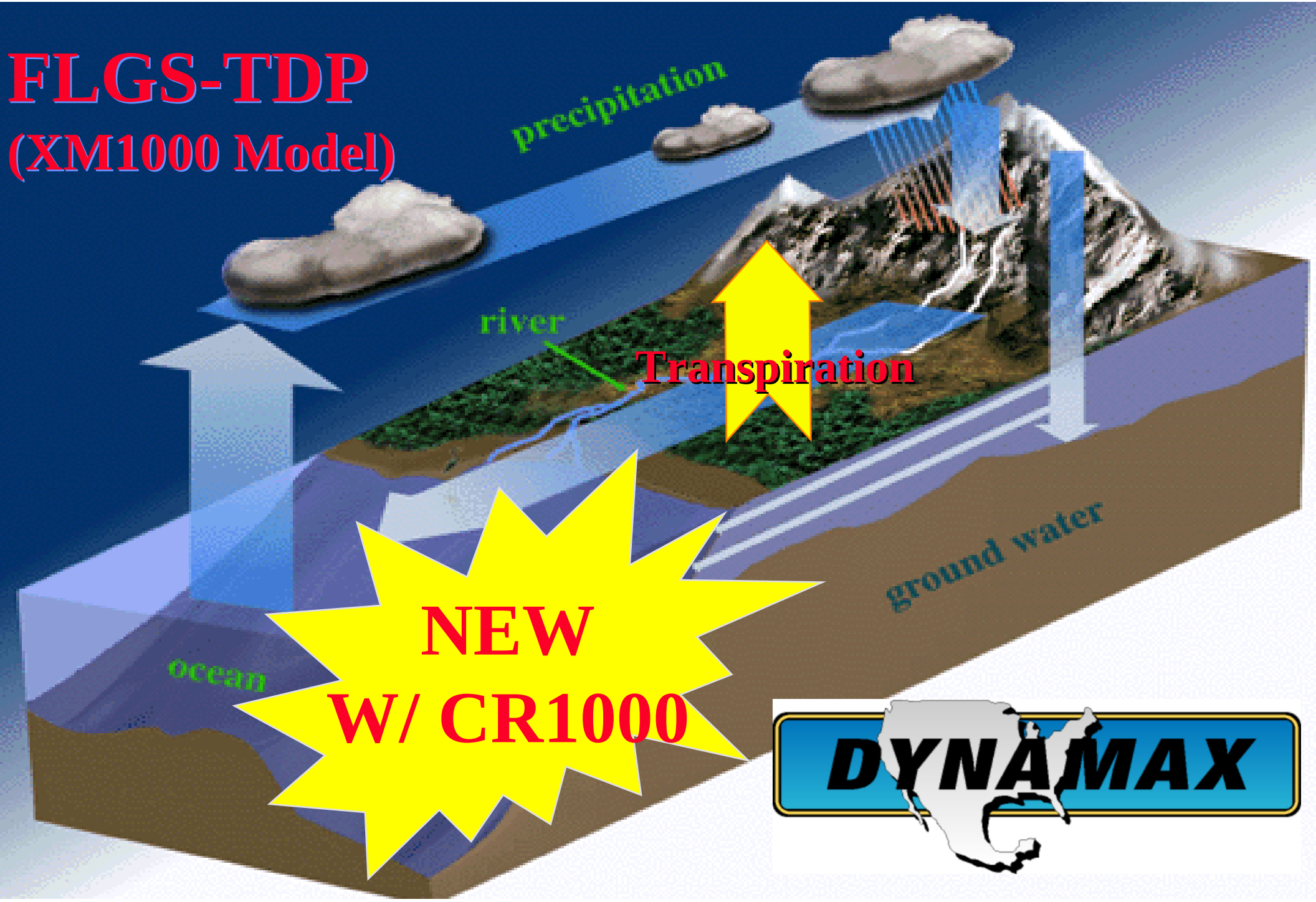

FLGS-TDP
(XM1000 Model)
precipitation
river
Transpiration
ground water
ocean
NEW
W/ CR1000
DYNAMAX

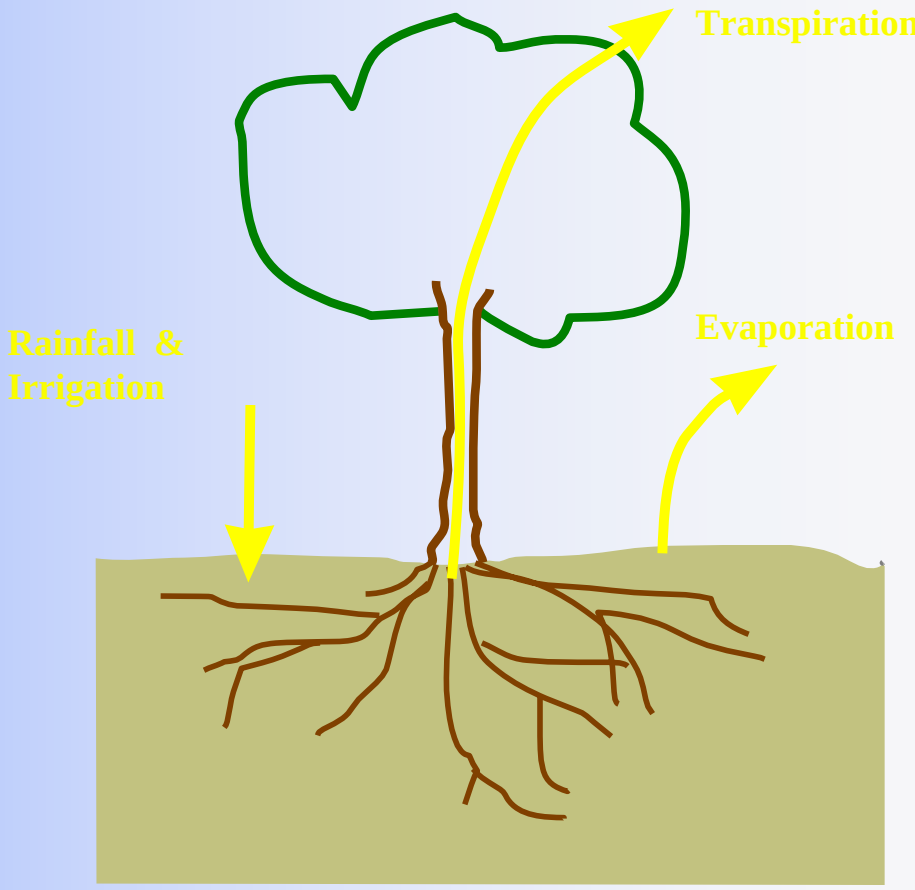
Overview

- TDP Sap velocity sensor
- TDP Principle of Measurement
- Installation Procedures and tips
- FLGS-TDP (XM1000 Model)
- Specifications
- Features & Benefits
- Programming and data format
- Applications

What Are We Measuring?

- **Transpiration**

"The evaporation of water from plants occurring primarily at the leaves through open stomata during the process of CO_2 gas exchange during photosynthesis"



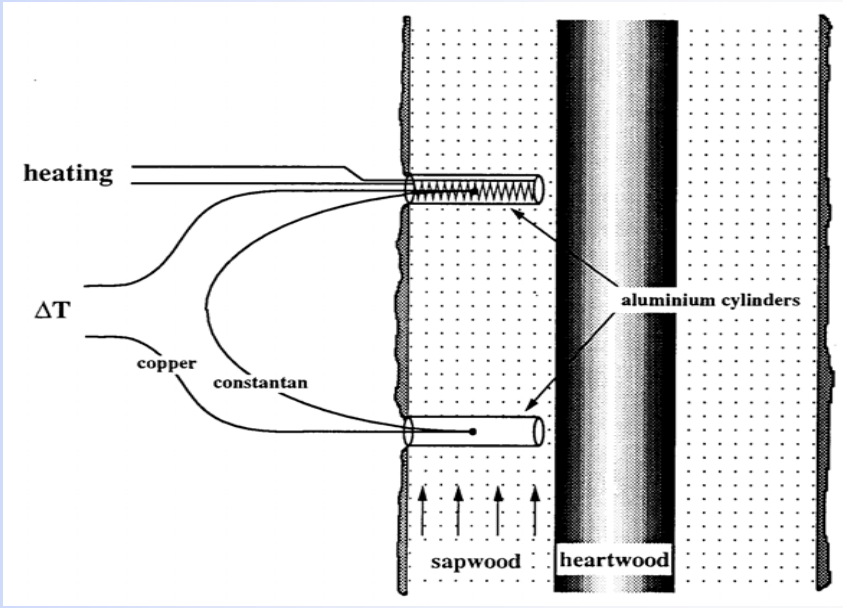
Factors that affect Transpiration

- **Light -** Stimulates Stomatal opening & leaf warming.
- **Temp-** At 30 ^{O}C a plant may transpire 3 times faster than at 20 ^{O}C
- **Humidity -** Increases the diffusion gradient between the ambient air & leaf
- **Wind -** Decreased leaf boundary layer resistance.
- **Soil Water -** When absorption of water by the roots fails to meet transpiration, loss of turgor & stomatal closure occurs.

DYNAMAX

Thermal Dissipation Sap Velocity

- Probe consists of two needles
  - –(-) Reference T-Type Thermocouple
  - –(+) T-Type Thermocouple & Heater



- NO FLOW Conditions

  Maximum dT occurs when the needle is hottest
- HIGH FLOW Conditions

  Minimum dT occurs when the needle is coolest
- Auto Zero (dTM)

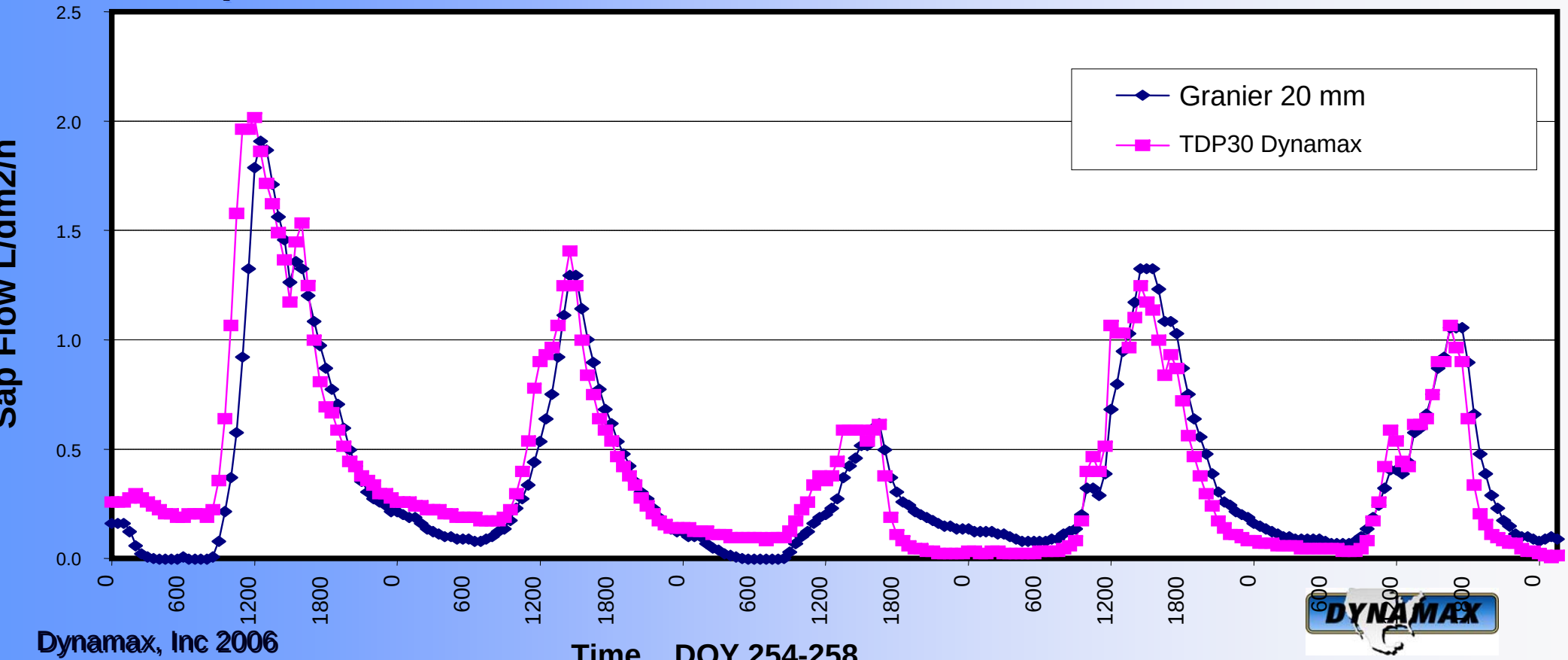
  Maximum dT is recorded and averaged pre-dawn

  i.e. the zero flow set point.

TDP Principle

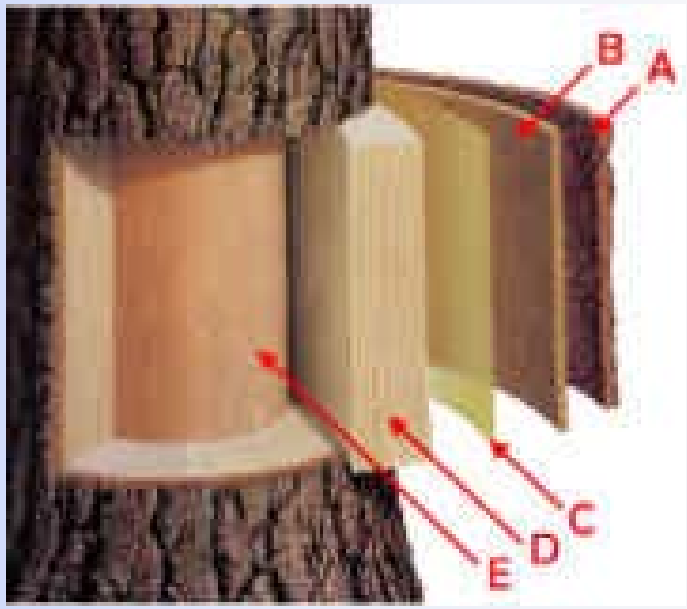
- Calculate Dimensionless Variable K
  - K=(dTm - dT)/dT
- Calculate Velocity V
  - V= 0.000119 * K ^ 1.231 (m/s)
- Calculate Area of Sapwood
- multiply to obtain volume flow
  - Sapflow =A * V

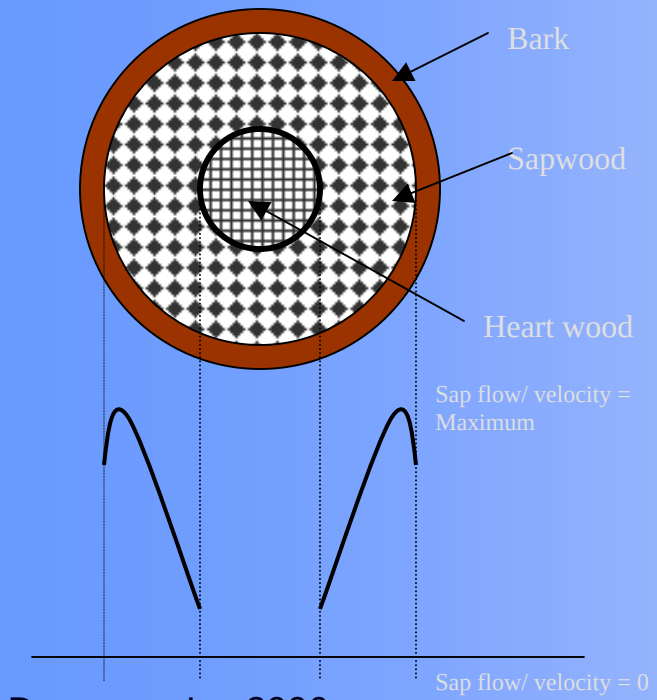
- Dynamax Improvements
  - Smaller Needles
  - Internally mounted heater
  - Teflon Coated Probes
- *Grainer concluded the smaller diameter of DYNAMAX design is pivotal to improved responsiveness of DYNAMAX TDP probes over his original prototype.*



Sapwood Area

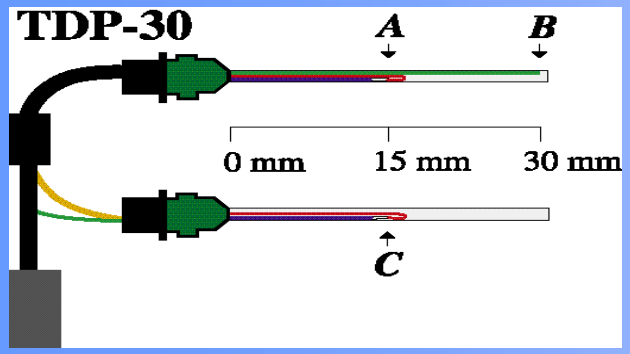
- **(A) Outer Bark**
  (B) Inner Bark
  (C) Cambium Layer
  (D) Sapwood
  (E) Heartwood
- Only the Sapwood conducts water
- Only the sapwood needs to be measured.





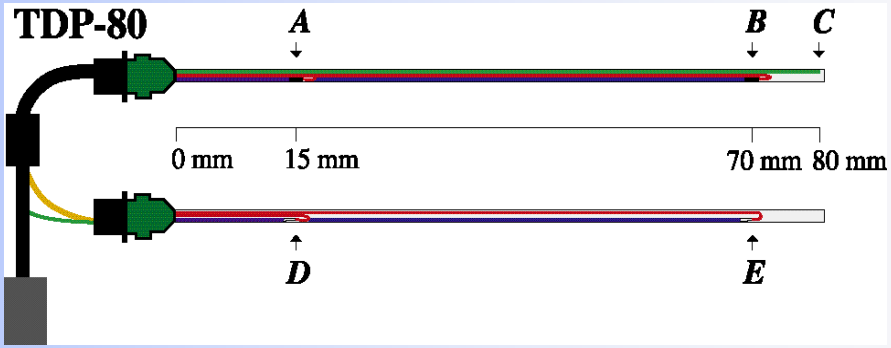
- Methods to determine sapwood area
  - Die-test
  - Using Incremental core
  - Analytical methods
    - Establish Statistical relationship
    - $S_A = -0.0039 + 0.59\ S_T$
  - Other Methods

TDP Specifications



A- Thermocouple #1
B- Heater
C-Reference Thermocouple

Model	TDP-30
Length	30mm
Diameter	1.2 mm
T-Type T/C's	1 ea
Probe Spacing	40 mm
Power	0.15 to 0.2 w
Cable Standard	10ft/ 5 cond
Heater Resistance	45 Ohms
Operating Volts	3.0 V @~8°C
Signal Out	40 uV/°C



A- Thermocouple #1

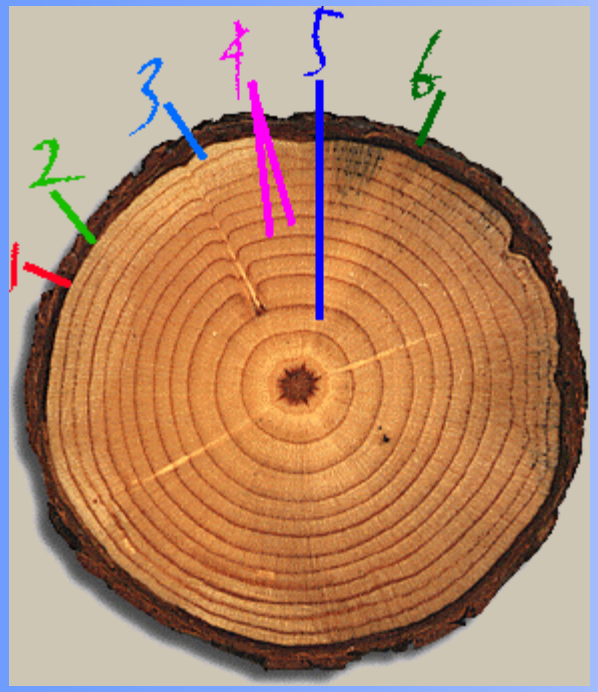
B- Thermocouple #2

C- Heater

D- Reference Thermocouple

E- Reference Thermocouple

How Many Sensors Not How Long!



- Uniform Growth Conditions

- Non-uniform Growth Conditions

Features and Benefits

Features

- INRA research(Granier) design
- CR1000 Logger
- Verified & supported math
- Two needles epoxy sealed
- Teflon coated probes
- International License
- Multiple probe size
- One differential channel
- Low voltage operation

Benefits

- Continuous Sap Velocity
- Simple data calculation/analysis
- Durable, Reusable Design
- Real-Time Data Acquisition
- Monitor multiple trees
- Monitor large trees
- Universal logger compatibility
- Easy voltage regulation

Installation Procedure

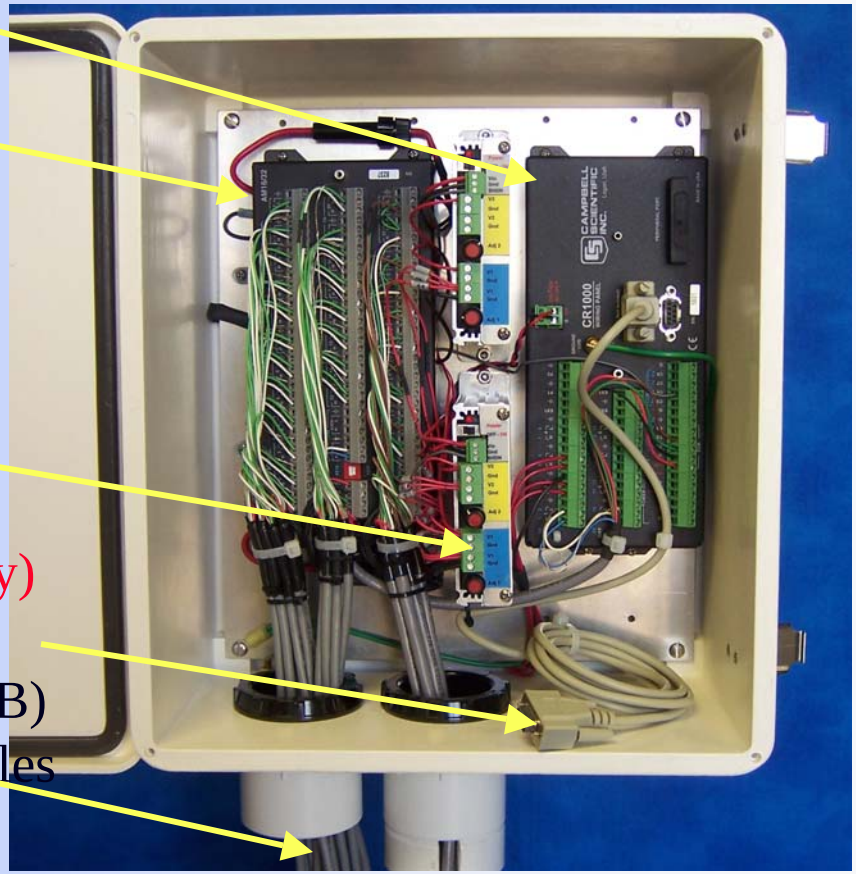
1. **Prepare the Probe Site:**
   - **Select a height 1-2 meters above the ground**
   - **Remove old rough bark to cambium layer. 4cm wide and 10 cm tall**
2. **Drill Holes:**
   - **Place the Drilling Jig flat on the prepared surface**
   - **Drill a holes**
3. **Install Probes:**
   - **Insert the heater in the top hole & the reference in the bottom**
   - **Insert needles slowly and gradually**
   - **Tape cables to the tree for support**
4. **Insulation:**
   - **Install a water proof seal around the needles**
   - **Secure Foam Quarter spheres around probes**
   - **Install thermal insulation using reflective foam Bubble Wrap**
5. **Probe Removal:**
   - **Do NOT pull on the base of the needle, Never use Claw hammers or long Levers**
   - **Always use the supplied nail removing Pry-bar**

FLGS-TDP (XM1000 Model)

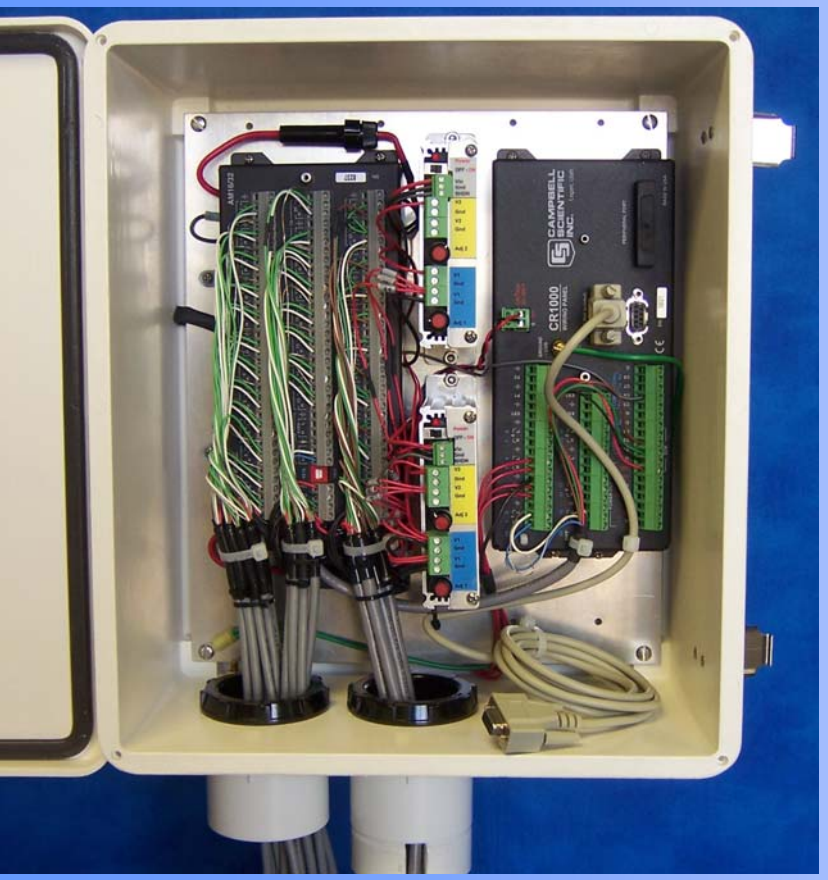
- New CR1000 Logger
- New AVRD (High-current & High-efficiency)
- Simple programming using CRBasic or your favorite text editor
- PC400 logger support software
- Logger Net for advanced applications – with scheduling and networks
- Enter sensor, system and field parameters in the logger program
- .csv formatted data in different files/ tables
- Sap velocity, sap flow, daily accumulators calculated in the logger.
- Excel recalculation spread sheet

FLGS – TDP Specifications

Datalogger : CR1000 logger
Base Inputs : 8 Differential-Analog
Expansion : AM16/32 Relay Multiplexer
Total Inputs : 32 Differential-Analog
Capacity : 32 TDP10/ 30/50
16 TDP80, 10 TDP100
Range : +/- 2.5 mV
Resolution : 0.33 uV
Voltage : AVRD 0 -10 V, 5A ea.
(High-efficiency, High-Current)
Base Memory : 2 MB (200 days memory capacity)
Optional Memory : 4Mb
Communications: 9-PIN Male RS232 (optional USB)
Sensor Cables : 8’ long assembled, extension cables in steps of 25’
Dimensions : 43 x 35 x 16 cm
Program : Using CRBasic
Software : PC400,
FLGS-TDP CDROM w/ programs

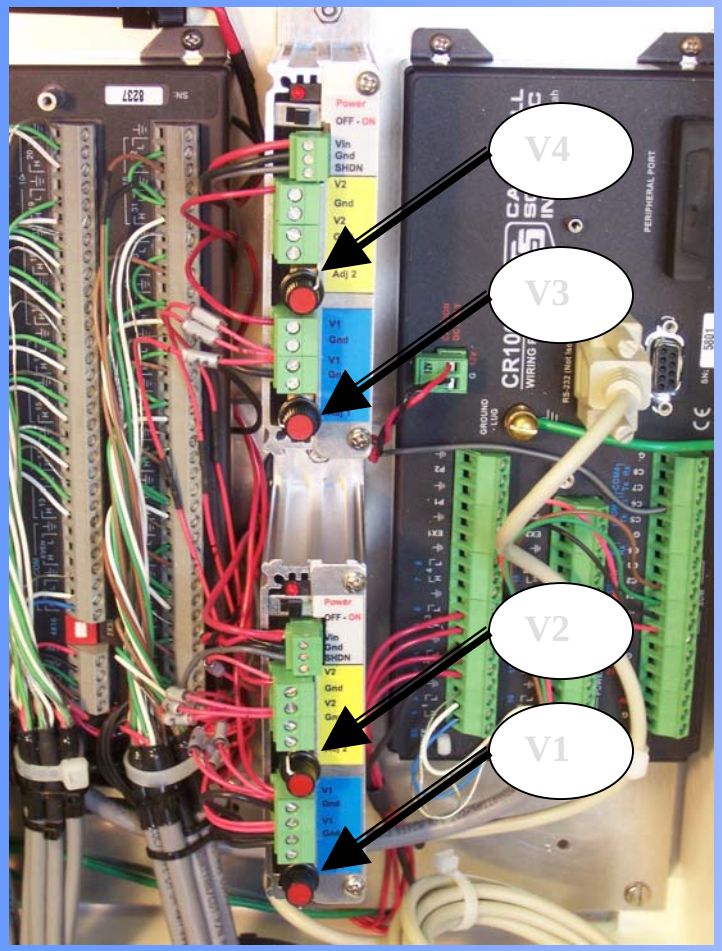


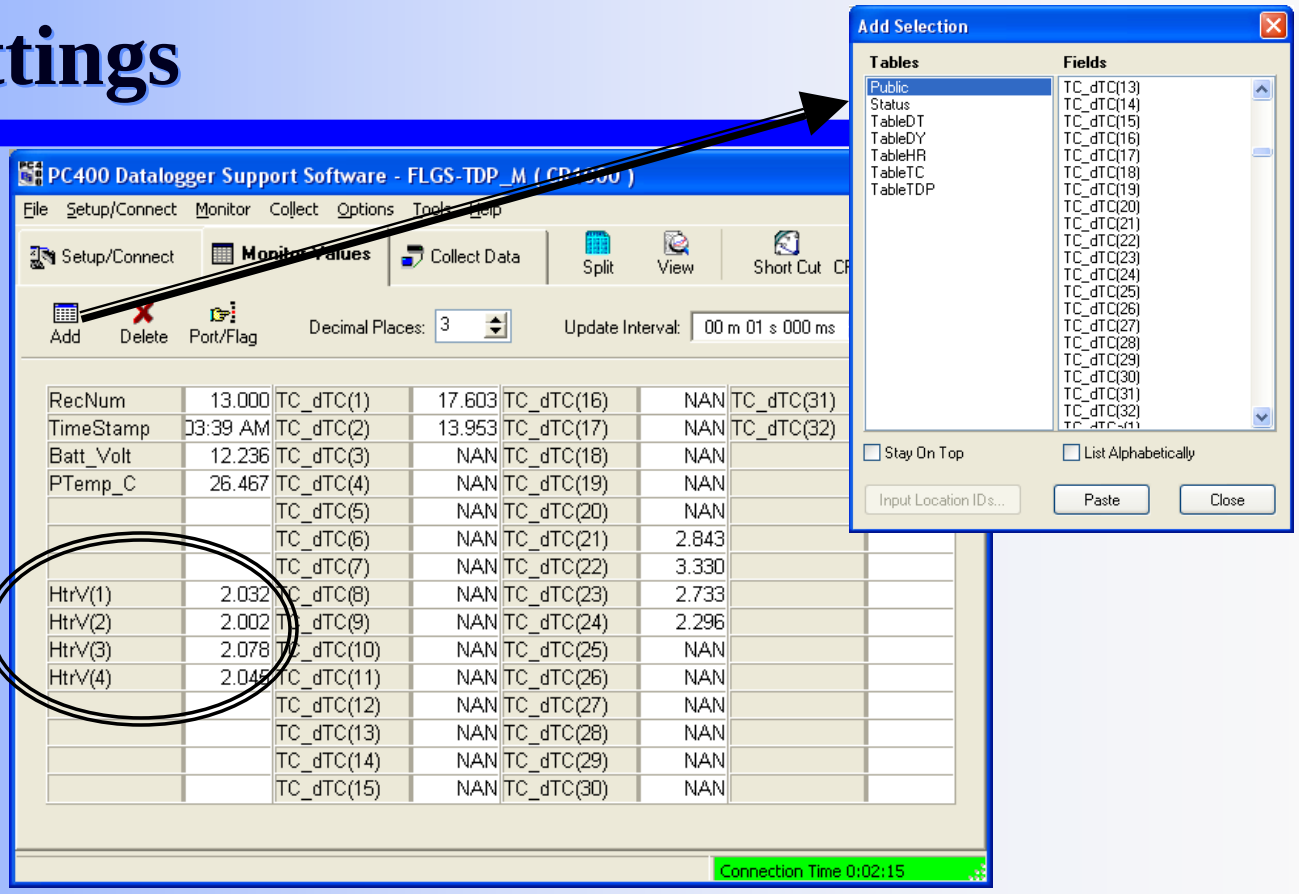
Features & Benefits



- Real time sap flow calculations
- Up to 32 Sap Velocity Measurements
- Thermocouple sapflow v/s plant sapflow
- Daily accumulated stored in memory
- Sap flow indexing
- Water usage, daily accumulators
- Expandable up to 128 TDP measurements or a combination of sap flow and weather station using secondary multiplexer systems.
- Easy, Accurate and Portable System
- For Field or Greenhouse Applications
- Sap flow calculation spread sheets
- Data analysis support

Sensor Power Settings

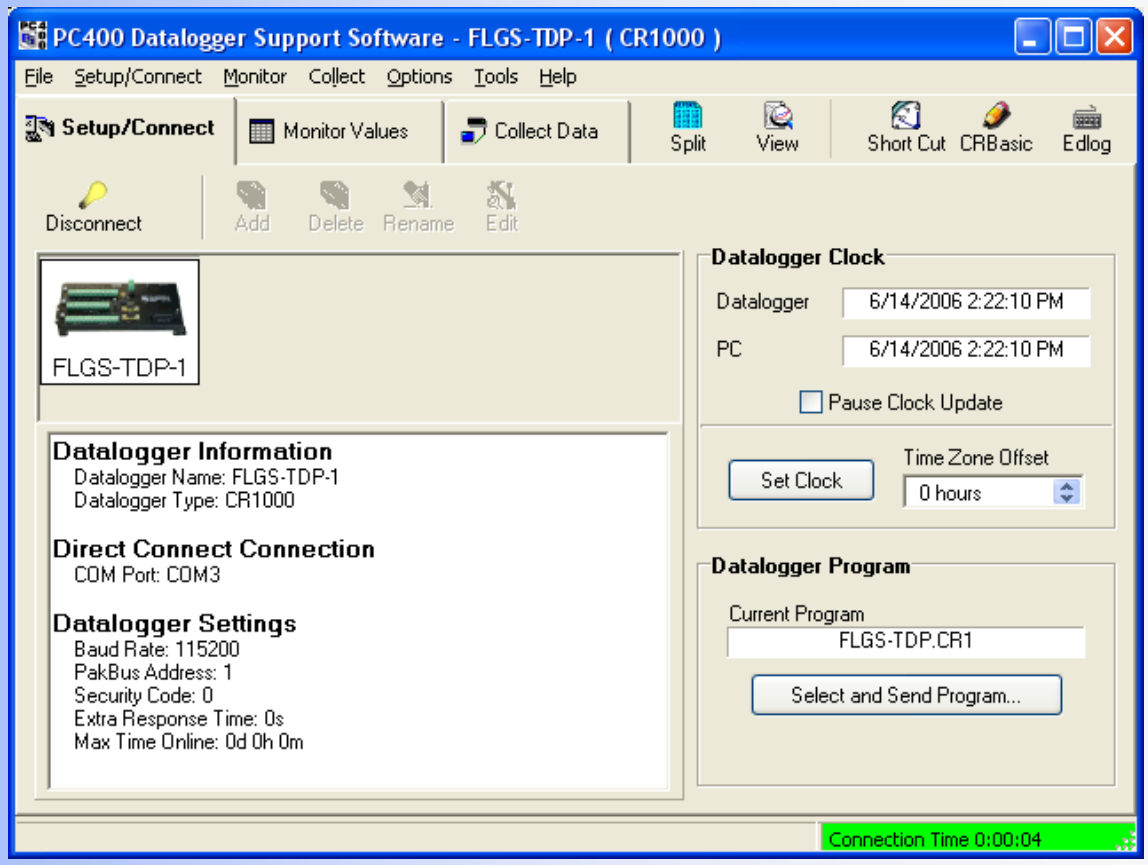




- Check AVRDC adjustments (V1 to V4) using
  - The Maintenance Maint.dld program
  - Numerical Display option (LoggerNet / PC400)
  - Voltmeter

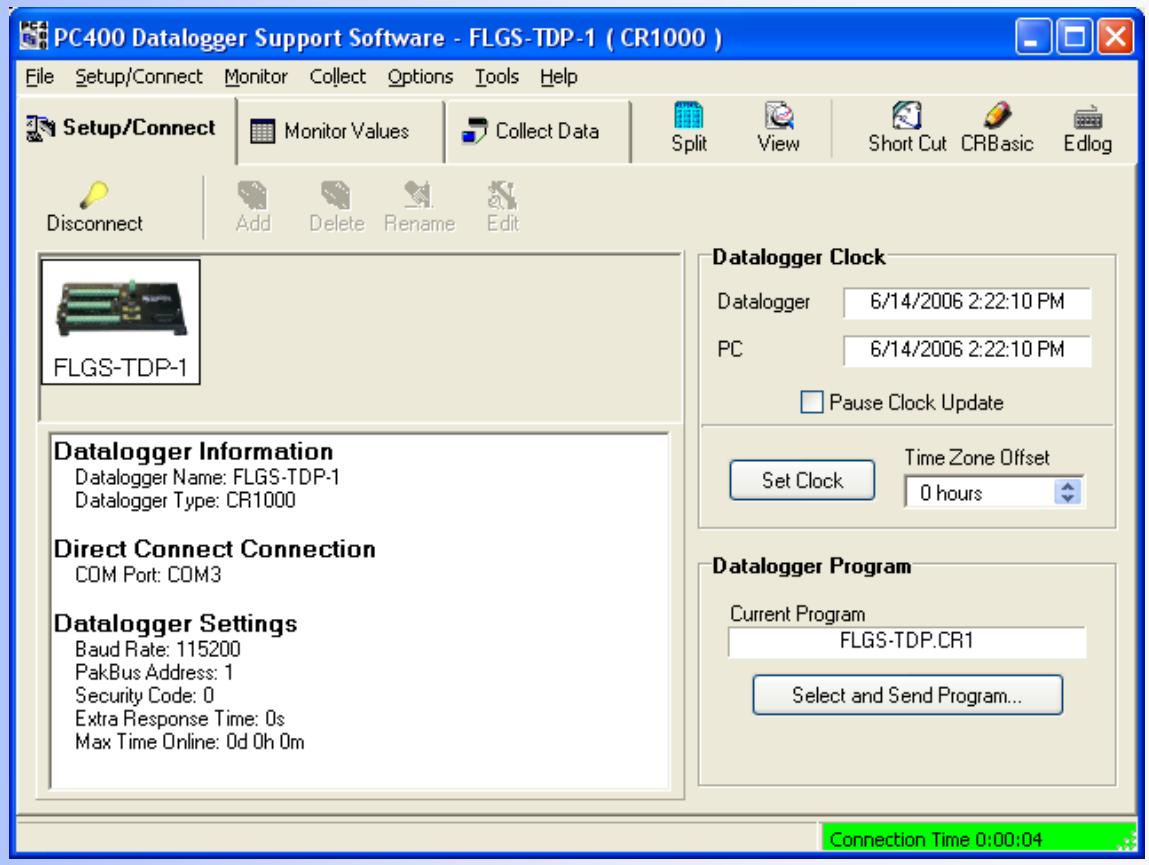
Software: Setup Logger

- PC400 software
- Add Device, select CR1000
- (Optional)Change Data logger name to custom “FLGS-TDP”
- Easy to use software interface



Software: Connect to Logger

- Connect
- Set Datalogger Clock
- Associate Program v/s send program
- Monitor Values
- Collect Data



System Programming

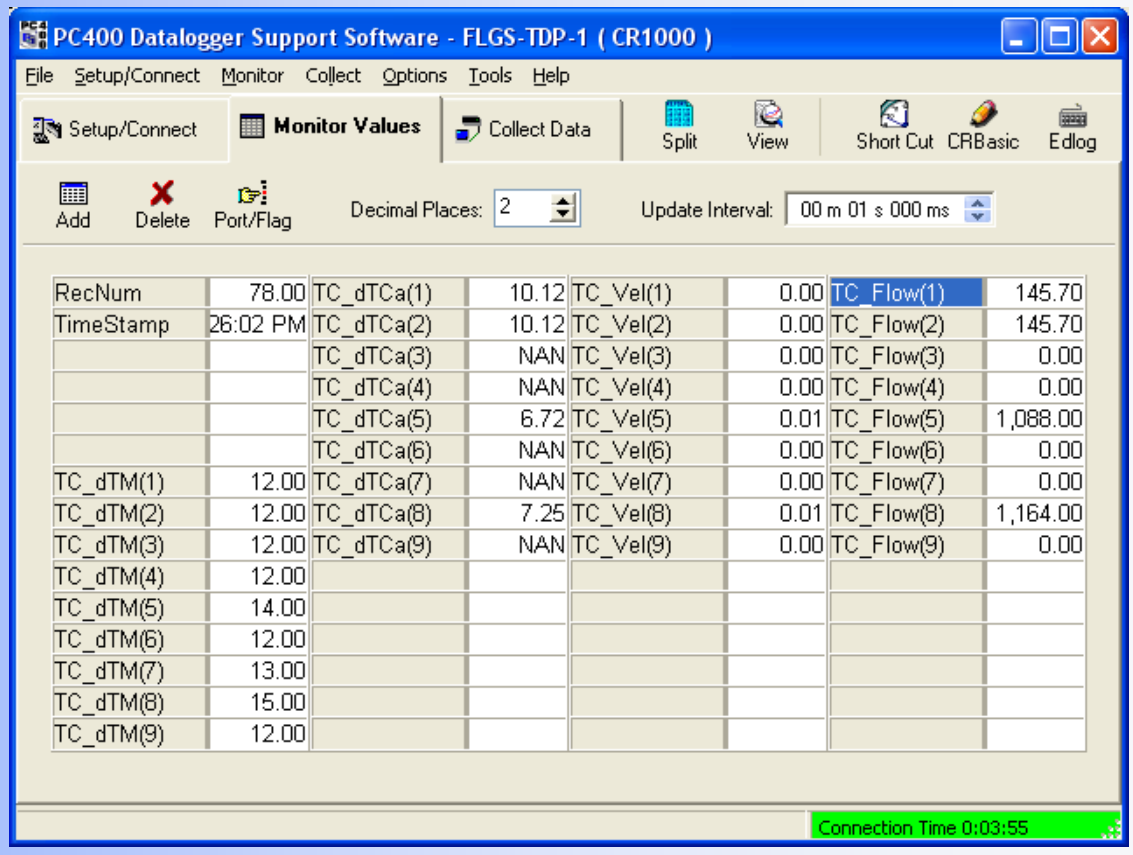
Constant Name	Units	Value		Range	Remarks
		Default	Maintenance		
INT_SCAN	Sec	60	5	0 – 60	Interval between sensor measurements
INT_AVG	Minutes	60	1	0 – 60	Log/ storage interval
NUM_TDP	Number	32	32	0 – 32	Numberof TDP sensors
NUM_TC	Number	32	32	0 – 32	Number of thermocouple/ measurements among all the TDP sensors
DTMIN	Deg C	0.2	0.2	0 – 3	DT below which data is ignored
WARMUP_MIN	Minutes	60	1	0 – 120	Sensor warmup time
FIELDINDEX	Sq. cm	1	1	Area sq.cm	Average field index (stem area/ sapwood area/ LAI)
FLAG_INDEX_EN		0	0	0 or 1	scaling flag (1-Enable)
FLAG_VOTE_EN		0	0	0 or 1	voting flag (1-Enable)
PS_ENABLE		1	0	0 or 1	Power save flag (1-Enable)
PS_START	Number	1260	1260	0 – 1440	Power save start time
PS_STOP	Number	300	300	0 – 1440	Power save stop time
ZERO_ENABLE		1	0	0 or 1	Auto-zero flag (1-Enable)
ZERO_STARTHOUR	Hour	2	2	0 – 24	Auto zero start hour
ZERO_STOPHOUR	Hour	5	5	0 – 24	Auto zero stop hour
ZERO_DAYINT	Number	3	3	0 – 10	Interval between auto zero performing days.

Syntax of a TDP sensor definition in FLGS-TDP is

InputTDP# = "TDP Type, Index Area, dTM1, SA1, dTM2, SA2, dTM3, SA3"

Software: Numeric Display

- Add
- Select variables to be displayed
- Select Cell
- Paste



Data Format

Table Name	Description	Variables
Status	Data loggers status table	
Public	Programs public table, contains all the public variables at any given time	
TableDT	Table of differential temperatures between the logging events	DT(1) – DT(32)
TableTC	Table containing differential temperature and sap flow calculation variables for all the thermocouples, battery voltage, panel temperature, heater voltages	JDAY JHM dTC(1) – dTC(32) dTM(1) – dTM(32) Vel(1) – Vel(32) Flow(1) – Flow(32) Status(1) – Status(32) HtrV(1) – HtrV(4) Batt_Volt PTemp_C
TableTDP	Table containing calculated sap flow data and indexed sap flow data along with statuses for all the TDP sensors	JDAY JHM TDP_Flow(1) – TDP_Flow(32) TDP_FlowIx(1) – TDP_FlowIx(32) TDP_Status(1) – TDP_Status(32)
TableHR	Table containing accumulated total hourly sap flow from all the sensors	JDAY JHM Hr_Flow
TableDY	Table containing accumulated total daily sap flow from all the sensors	JDAY DY_Flow

TableDT – The raw DT, differential temperatures with date and time stamps.

TableTC – Raw sensor temp signals, maximum dT @zero; Velocity, flow, and status

TableTDP – Computed hourly flow rates, indexed sap flow, and sensor status

TableHR – An indexed sap flow for all sensors combined

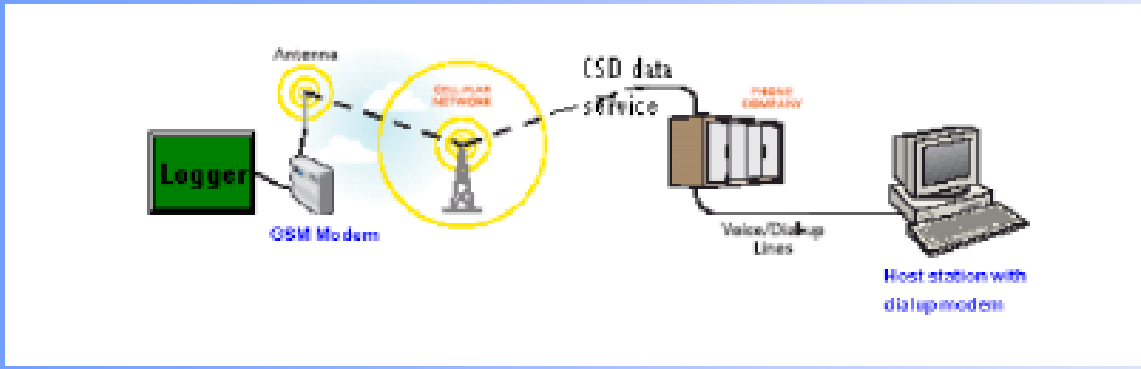
TableDY – Accumulated daily sap flow with one daily total, a day by day report.

DYNAMAX

Communications: RFMX

- Programmable using software
- **900MHz / 2.4 GHz**
- Distances - **40 Miles/ LOS with directional antenna; 14 Miles/ LOS**
  - Use of Repeater for longer designs
  - Antenna and surge protector design
- Power supply - 9 Volt DC; Solar panel/battery power design for remote site
  - Sleep mode option
- Software programmable radio modules
- 7 independent channels
- **Point-point, Point-multipoint, Multi-network** communication features
  - Module and channel selection for multi-point and multi-network operation
- Approved FCC, Industry Canada

Communications: GSM



- Software setup for base modem and remote modem
- Transparent operation
- Low power
- Connect to any location with Cellular wireless network

Communications: Network

- Point-Point, Point-multipoint configurations
- Transparent operation
- Low power
- Connect to any location with Cellular wireless network
- Hybrid network of CR1000 loggers using GSM, RFMX and serial communication cable.
- Integrated communication kit with antenna and accessories

Sap Flow Applications

Water Balance

Plant transpiration

Disease Effects

Fertilizer Efficacy

Greenhouse Management

Irrigation Scheduling

Phytoremediation

Global Climate Change

Water Balance Research

- **Perform Water Balances**
- **Watershed Studies**

Transpiration Research

- How much water do plants use?
- Measure plant stress
- Fertility effects on plants
- Varietal differences

- University Plant Scientists
- Plant Physiologists
- Environmental Engineers - Ecologists
- USDA-AG Research Service
- Agri-chemical Companies
- Forestry Research

Dr. Stan Wullschleger

Oak Ridge National Lab

Environmental Services Division

Oak Ridge Tennessee USA

www.ornl.gov

Whole-plant water flux in under story red maple exposed to altered precipitation regimes. Tree Physiology 18, pages 71-79 1998

Phytoremediation of Pollution

In-situ risk reduction of contaminated soils / water with living green plants - Extraction = K * T

- **How much pollutants do plants take up?**
  - **Stabilize - immobilize contaminants**
  - **Voltilize - transpire & reduce compounds**
  - **Extraction - uptake of metals**
  - **Rhizofiltration**
- **Measure plant stress - due to toxicity**
- **Variety differences, species selections**
- **Tree based containment of contaminated water plume, hydraulic barrier**

Examples
TNT, Chemical – Bio - warfare
CFC, Cleaners, Solvents, MTBE
Lead, Mercury, Radioactive
DNAPL, Oil, MTBE

K = Concentration in Water , T = Transpiration rate,

CFC = Clorofluorocarbon, DNAPL=dense non-aqueous phase liquids,

MTBE = gasoline additive - oxidant

Global Climate Change Research

- Open Chamber Research for Elevated CO2
- Study plant water relations in high CO2 conditions
- CO2 Flux =f(Transpiration)
  - Carbon sink credits
  - T = f (CO2 Concentration)
- Environmental Protection Agency
- AMERIFLUX - Carbon flux Network - Fluxnet - Euroflux
- NASA
- Energy Department - DOE