A possibility for correcting SWdn measurements for aircraft tilt.

Chuck Long

PNNL

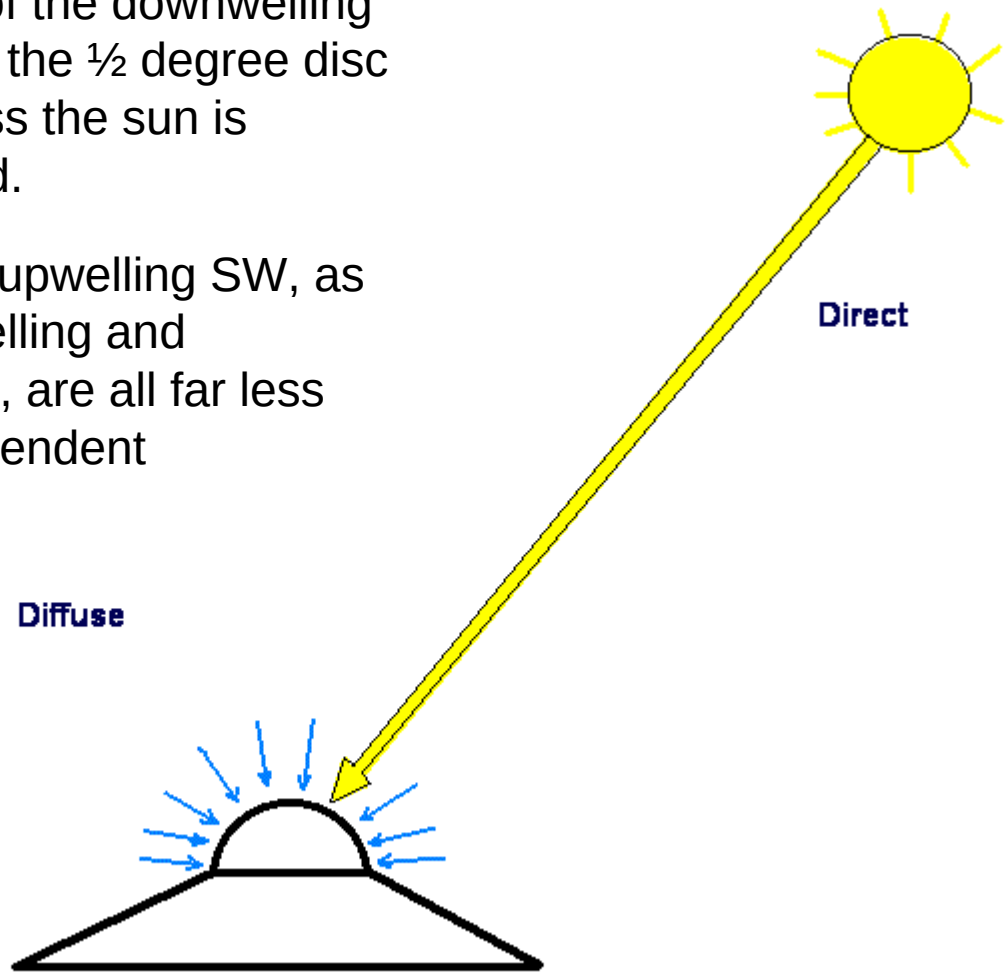
ARM Atmospheric Radiation Measurement

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

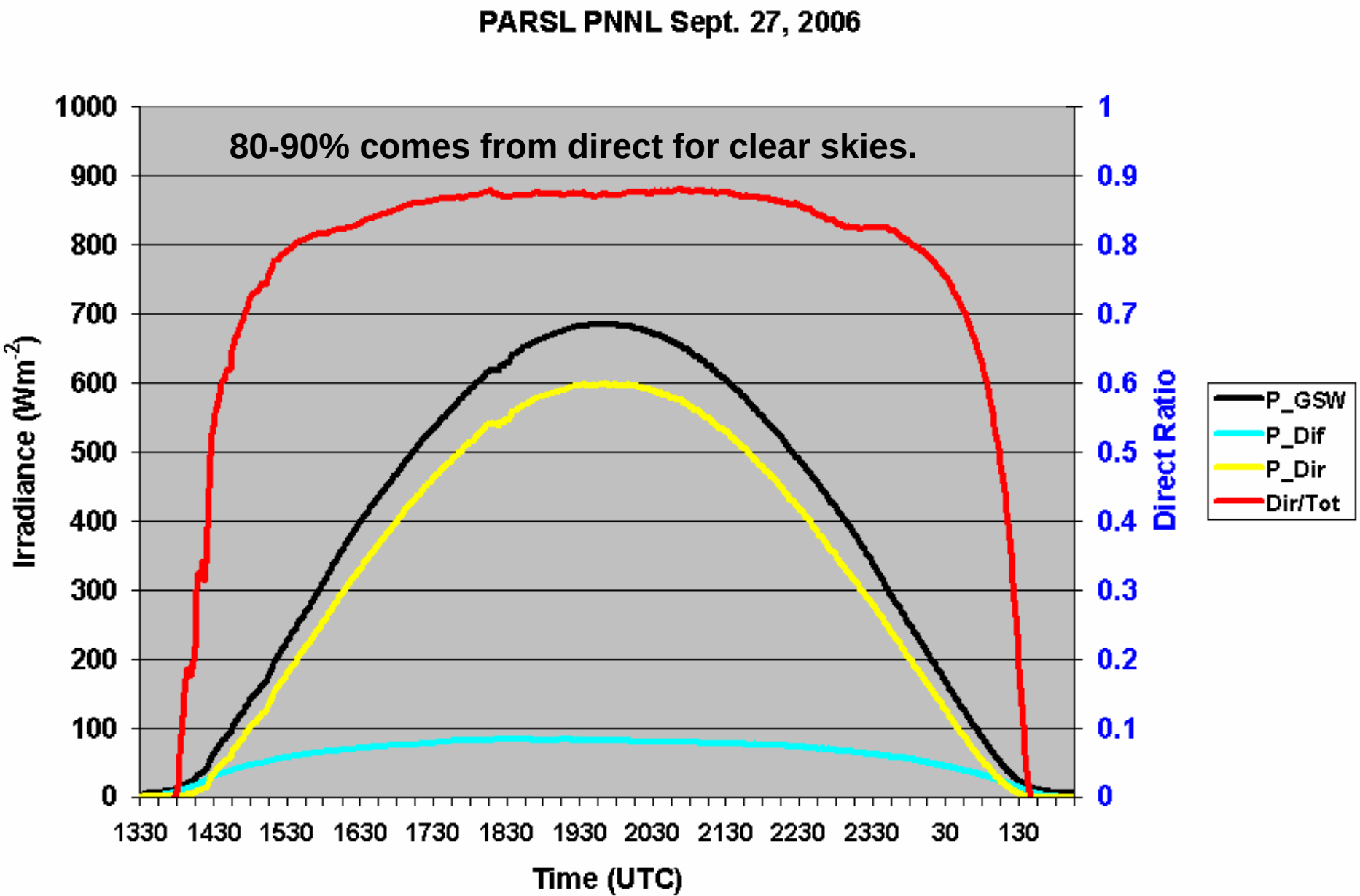
The problem:

A large portion of the downwelling SW comes from the ½ degree disc of the sun, unless the sun is blocked by cloud.

The diffuse and upwelling SW, as well as the upwelling and downwelling LW, are all far less directionally dependent measurements.



The problem:


PARSL PNNL Sept. 27, 2006
80-90% comes from direct for clear skies.
Irradiance (Wm-2)
Direct Ratio
Time (UTC)
1000
900
800
700
600
500
400
300
200
100
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1330
1430
1530
1630
1730
1830
1930
2030
2130
2230
2330
30
130
P_GSW
P_Dif
P_Dir
Dir/Tot

Lessons from ARESE

- Flux divergence measurements require very good accuracy
- Aircraft pitch and roll have a significant negative impact on the SWdn measurements
- Correcting for rapidly changing off-level tilt with only total SWdn measurements is difficult

Stabilization

- ARM UAV has tried a stabilization platform
- When it works, it works very well
- Problems with reliability
- Chews up a significant amount of payload capacity/volume
- Thus not suitable for small UAVs, etc.

Correction for tilt

- Similar to ship and buoy deployments
  - Though tilt changes not as rapid
- The tilt is primarily a problem for the Direct component only
- In order to better correct for tilt, need to know what portion of the Total SW is from the Direct component
  - Weight the amount of correction by Dir/Tot ratio

Possible solution:

- Total and Diffuse SW are needed for the Flux Analysis methodology
- I have been looking for years for a way to get these data at sufficient accuracy for small, dependable, low power, remotely deployable systems
- Two years ago I ran across a radiometer from Delta-T, UK
- Have been working with them…

SPN-1 Radiometer

- Eliminates need for sun-relative azimuthal orientation
- About same size as PSP or CM22
- Measures Total and Diffuse SW with no moving parts

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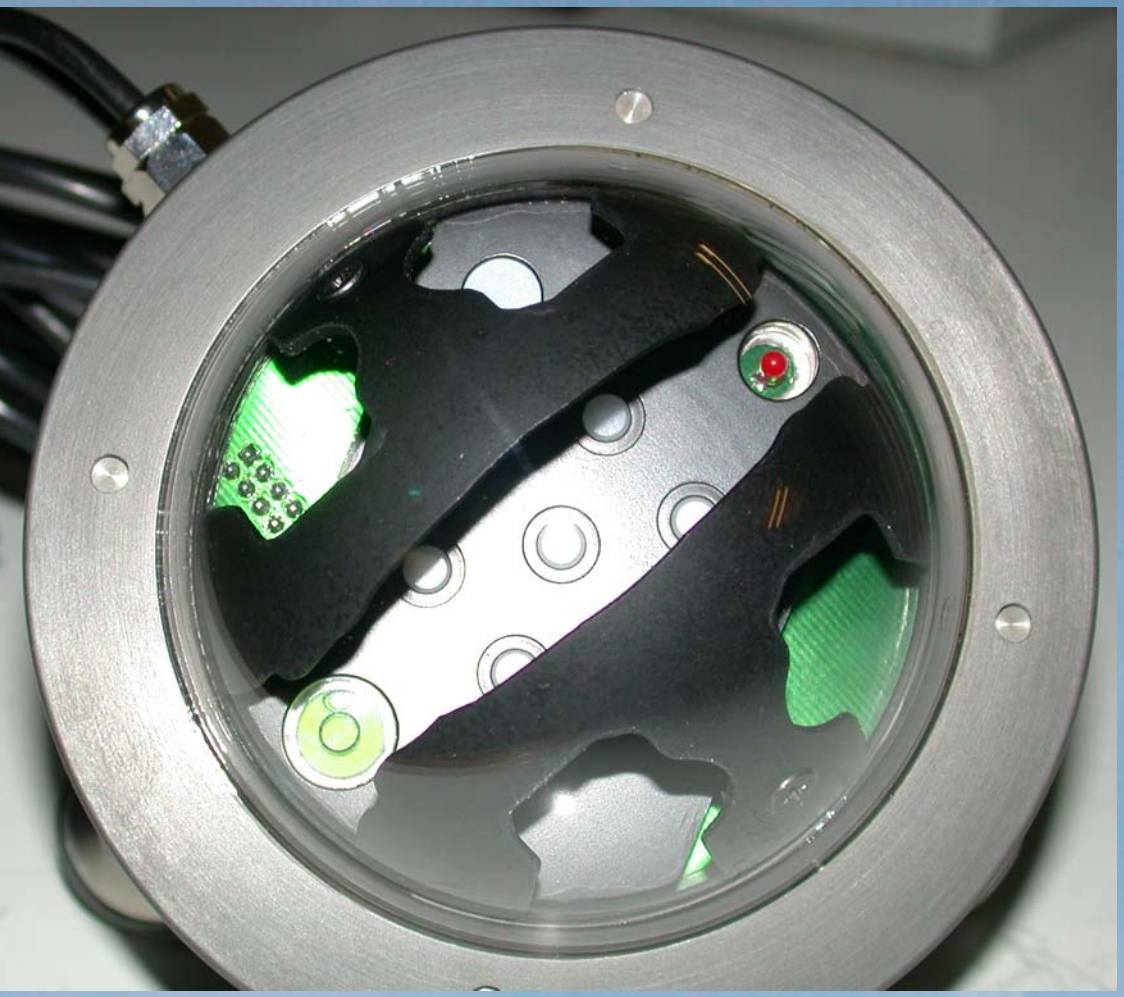
SPN-1 Radiometer



- Uses 7 detectors and a patented shading pattern
- Weighs 940 g

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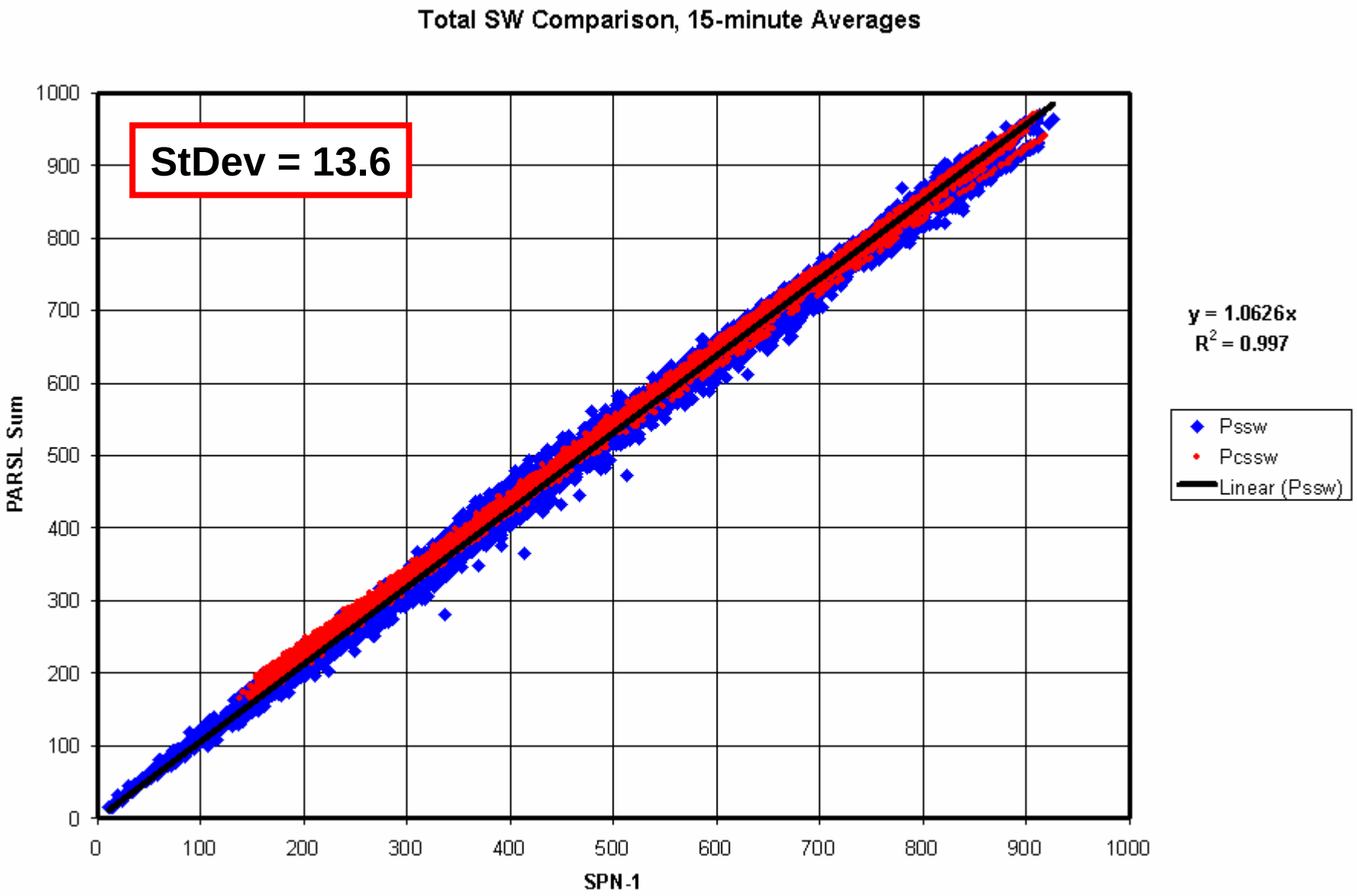
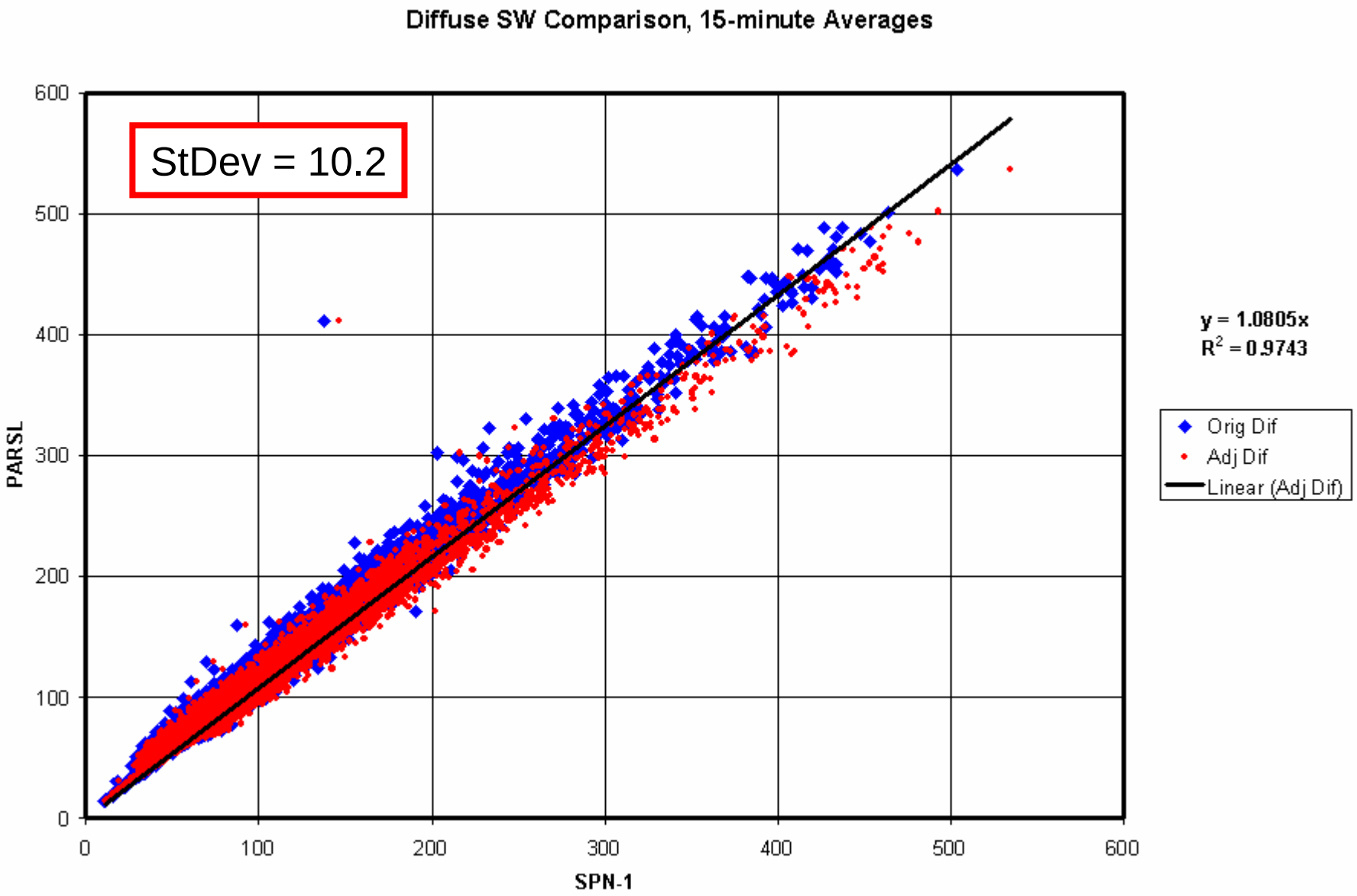
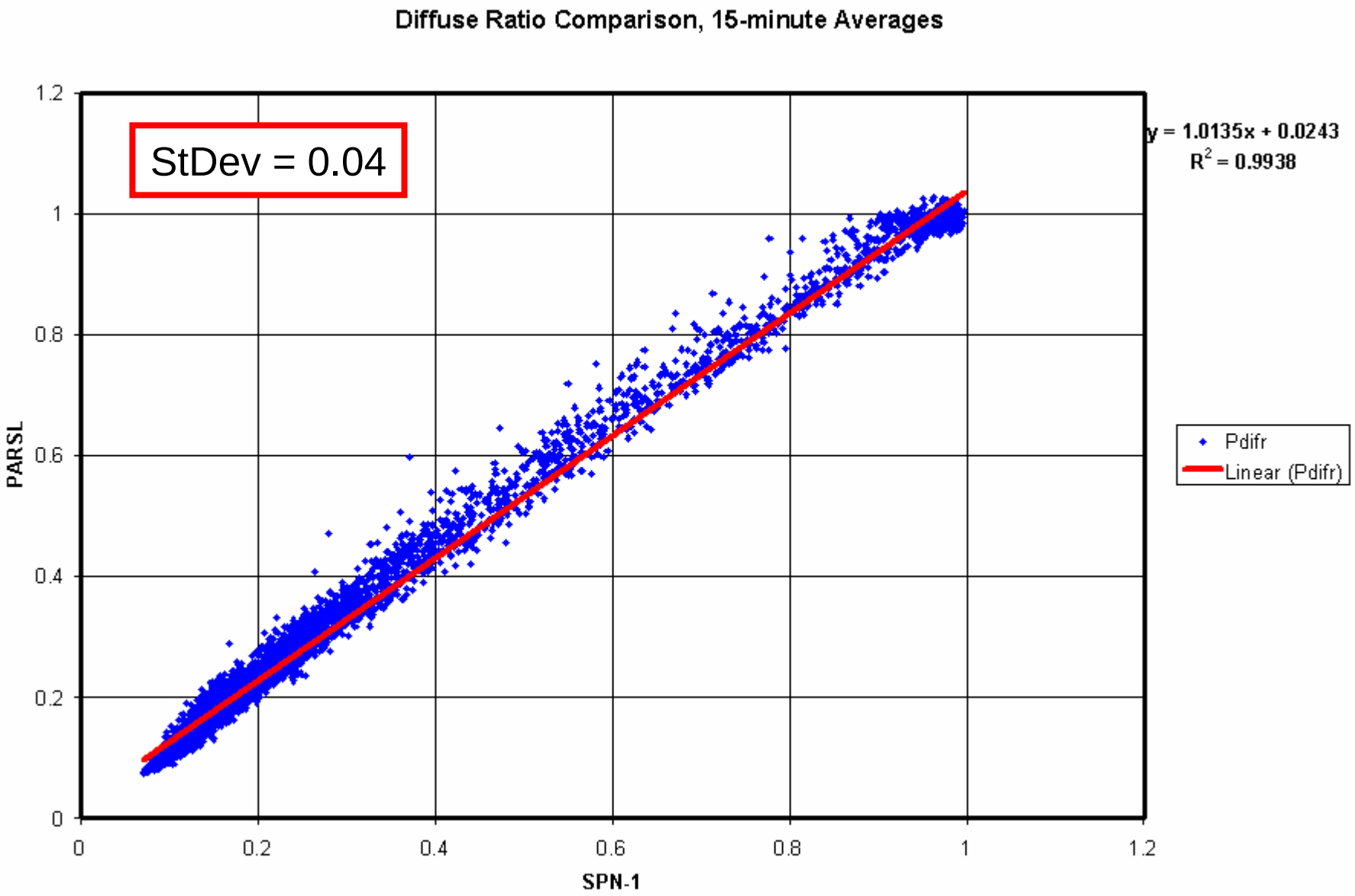
Relative accuracy



Relative accuracy



Relative accuracy



SPN1 Specs

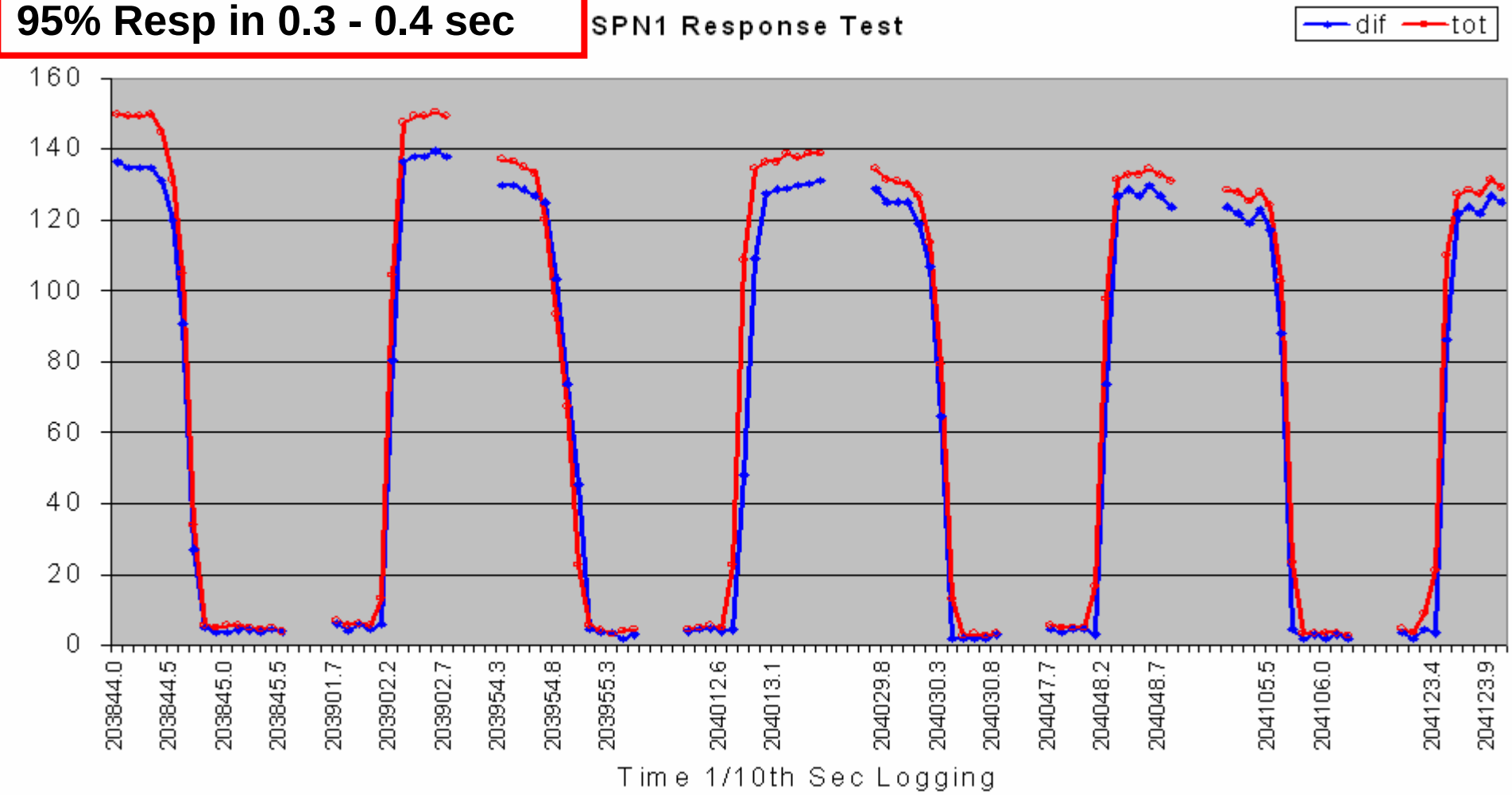
Specifications

WMO Classification	Matches "WMO Good Quality Pyranometer" classification
Overall accuracy: Global (Total) and Diffuse radiation	±5% Daily integrals ±5% ±10 $W.m^{-2}$ Hourly averages ±8% ±10 $W.m^{-2}$ Individual readings *Accuracy figures give 95% confidence limits, i.e. 95% of individual readings will be within stated limits under normal climatic conditions.*
Resolution	0.6 $W.m^{-2}$ = 0.6mV
Range	0 to >2000 $W.m^{-2}$
Analogue output sensitivity	1mV = 1 $W.m^{-2}$
Analogue output range	0-2500mV
Sunshine status threshold	120 $W.m^{-2}$ in the direct beam
Accuracy: Sunshine status	±10% sun hours with respect to the threshold
Accuracy: Cosine Correction	±2% of incoming radiation over 0-90° Zenith angle
Accuracy: Azimuth angle	± 5% over 360° rotation
Temp coefficient	± 0.02% per °C typical

Temperature range	-20 to + 70°C
Recalibration / stability	Factory recalibration recommended every 2 years.
Response time	< 200ms
Spectral Response	400-2700nm
Spectral sensitivity variation	10% typical
Non-linearity	<1%
Tilt response	Negligible errors
Zero offsets	<3 $W.m^{-2}$ for a change of 5°C/hr in ambient temperature <3 $W.m^{-2}$ dark reading
Latitude capability	-90° to +90°
Environmental	IP67 sealing
Sunshine status output	No sun = open circuit Sun = short circuit to ground
Power requirement	2mA (excluding heater power), 5V – 15V DC
Heater power	12V – 15V DC, up to 1.5A
Heater control	Continuously variable up to 20W output for external temperatures below 0°C
Lowest snow & ice-free temperatures (with heater in use)	-20°C at 0 m/s wind speed -10°C at 2 m/s wind speed
Mounting options:	3 x M5 tapped holes in base; 108mm pcd, 120°spacing
Size & weight	140mm dia x 100mm (h), 940g

SPN1 Response Time

95% Resp in 0.3 - 0.4 sec



Response Times

- SPN-1 response time, 95%:
  - 0.3 - 0.4 sec.
- K&Z CM-22 response time, 95%:
  - 5 sec.
- Eppley PSP response time, (1/e, 69%):
  - 1 sec.
  - (2 - 3 sec. for 95%)

Summary: Thoughts

- Use in ADDITION to total SWdn radiometer
  - For obtaining measurements of the Dir/Total SW ratio for corrections
  - Faster response times useful for relative changes not captured by CM22, PSP
  - Light weight, suitable for some smaller UAVs?

Other issues:

- Temperature
  - IR loss offsets
    - Equip with case/dome thermistors and measure
  - Thermal linearity
    - Covering 35 through -100 C range
    - Need to characterize thermal characteristics and apply in post-processing
- Frosting, etc.?