



2019

# **HERRAMIENTAS PARA LA INVESTIGACIÓN EN METEOROLOGÍA**

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**PONENTE EN LA SEMANA CIENTÍFICA DE LA UNALM**



# **Instrumental Agrometeorológico**

- **Sensor de Temperatura**
- **Sensor de Humedad**
- **Sensor de Presión**
- **Piranómetro**
- **Pluviómetro**
- **Geotermómetro**
- **Humedad del suelo**
- **\* Sensor Infrarrojo**

## **Objetivo**

**Elaborar, calibrar y validar una estación agrometeorológica de bajo costo usando la plataforma Arduino**



# METODOLOGÍA

## Área de desarrollo

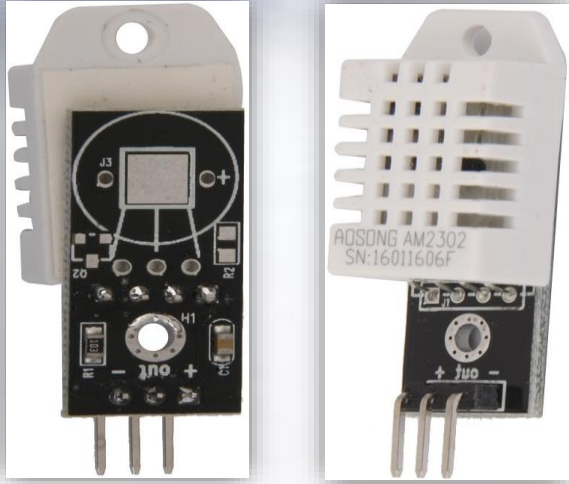


## Datos

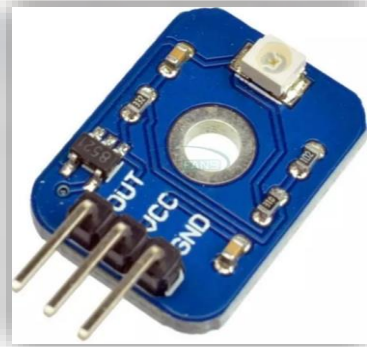
instrumental2: Bloc de notas	
Archivo	Edición Formato Ver Ayuda
fecha,BMPTEMP,PRESIONBMP,DHTTEMP,DHTHUMEDAD,PP,HS,valor_sensor,tension_Rs,vo1,res1,temp1,vo2,res2,temp2,vo3,res3,temp3,vo4,res4,temp4	
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# DHT22 (Temperatura y humedad)



# ML8511 (RADIACIÓN\*)

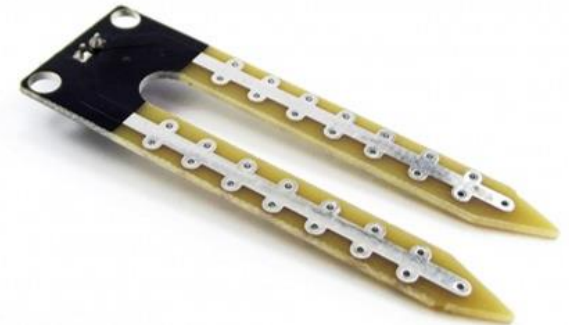
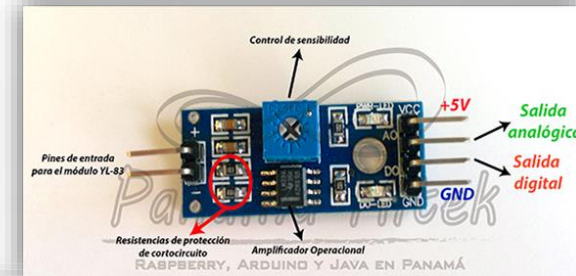
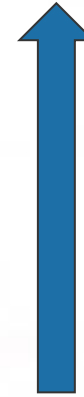


# GEOTERMÓMETRO



# Water Sensor SL067 (PRECIPITACIÓN)

4 cm



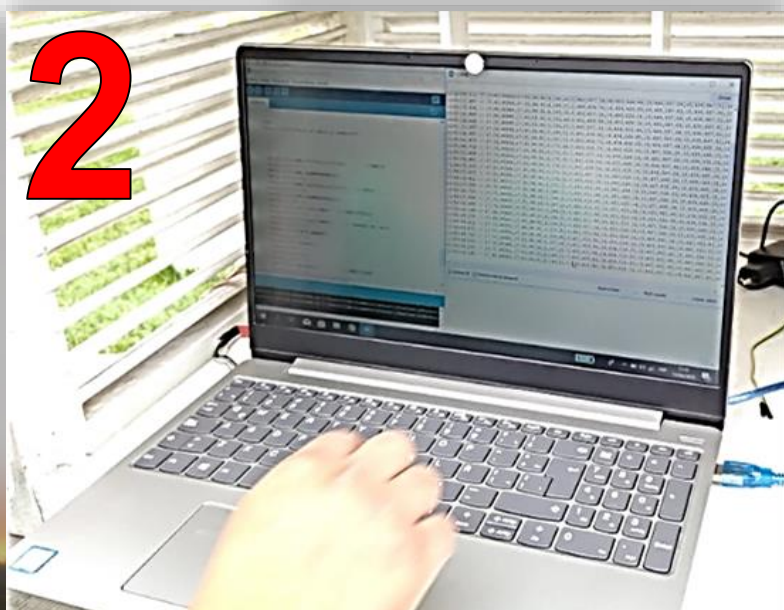
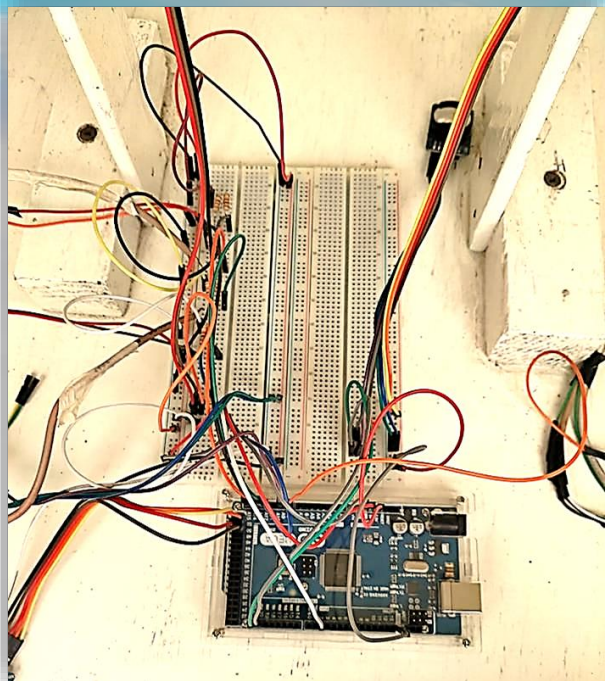
# SEN-HUS YL-69 (Higrómetro)

# BMP180 (PRESIÓN)





# PROCEDIMIENTO



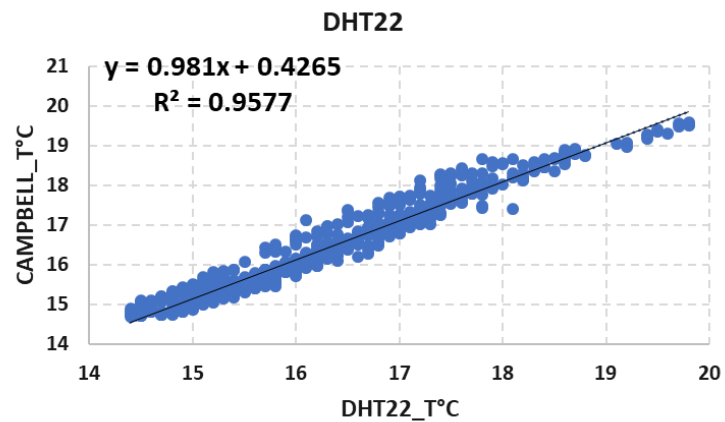
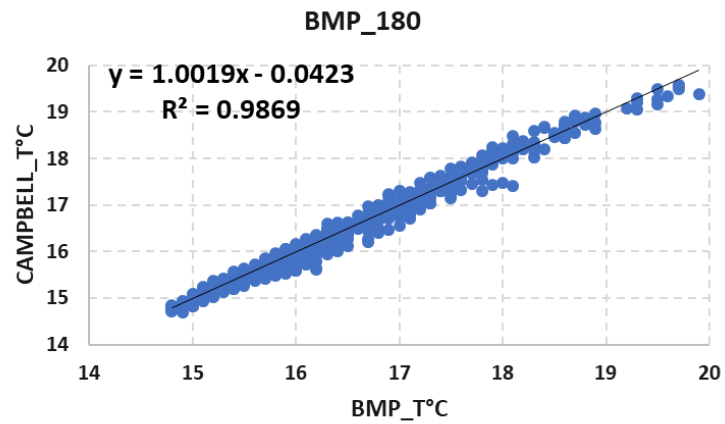


# OBTENCIÓN DE INFORMACIÓN

## CAMPBELL CR300



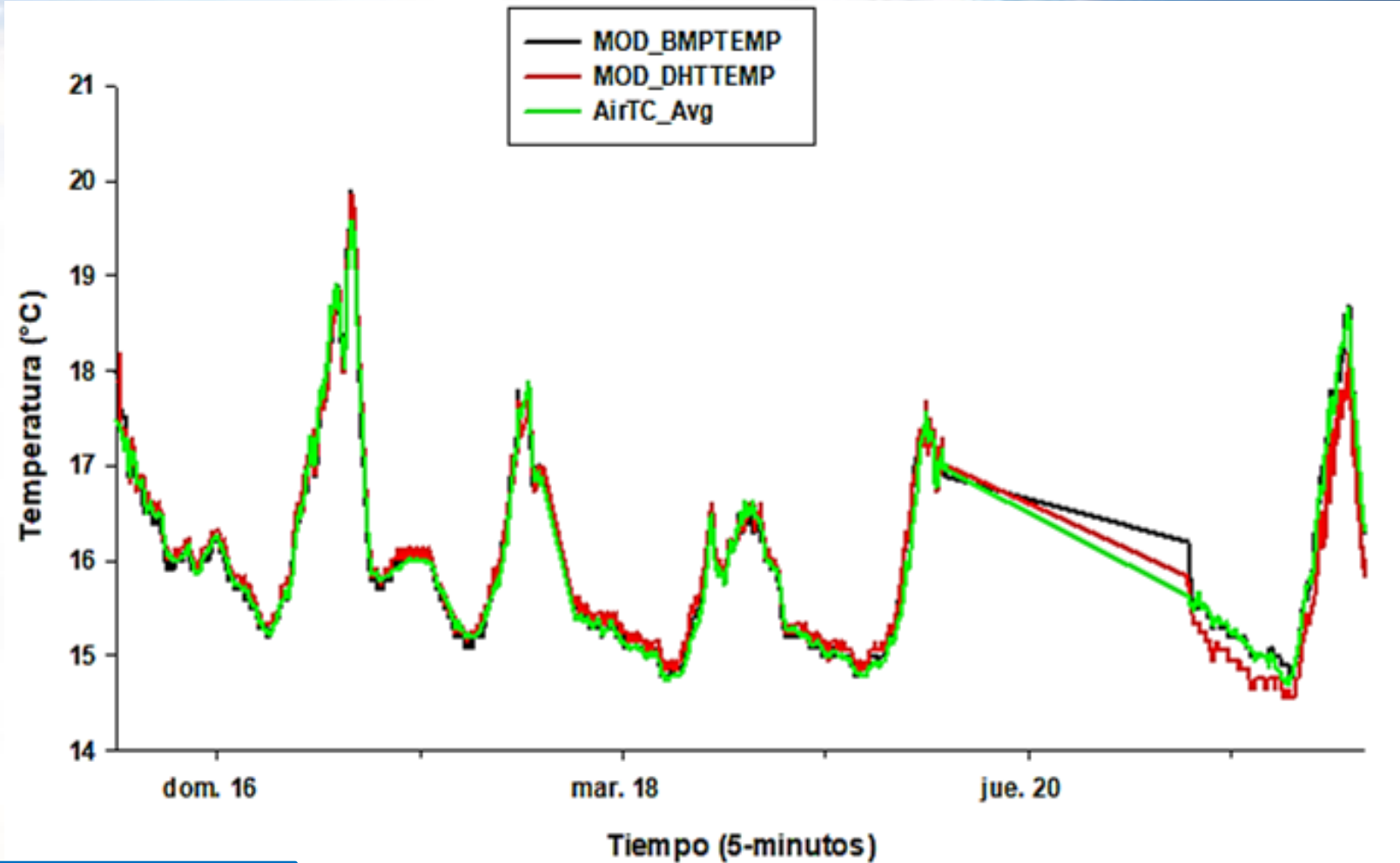
# SENSOR DE TEMPERATURA



```
data: temp$BMPTMP and temp$AirTC_Avg
t = 321.98, df = 1375, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.9927038 0.9940906
sample estimates:
cor
0.9934335
```

Pearson's product-moment correlation

```
data: temp$DHTTEMP and temp$AirTC_Avg
t = 176.45, df = 1375, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.9762668 0.9807476
sample estimates:
cor
0.978623
```



**CALIBRACIÓN**

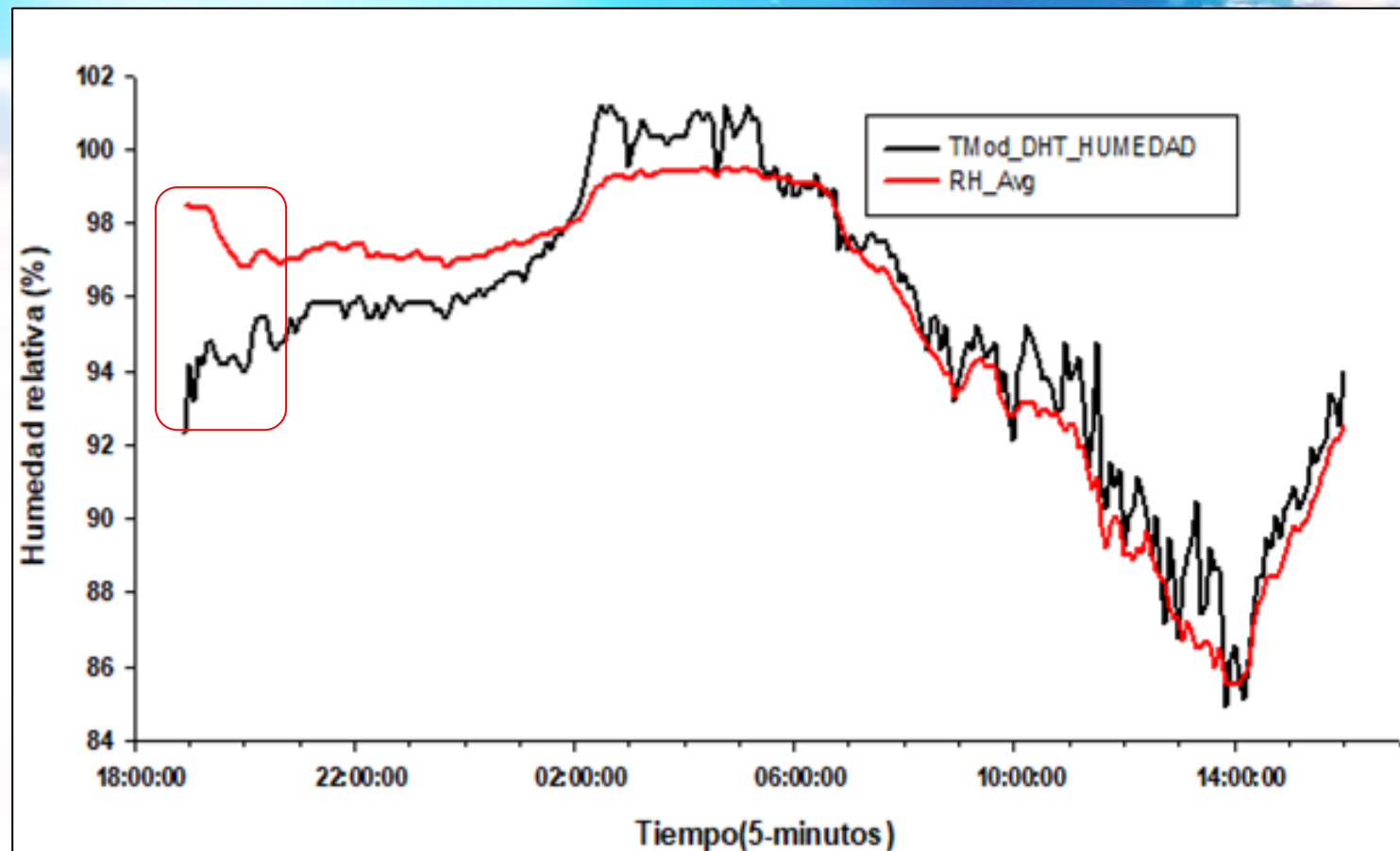
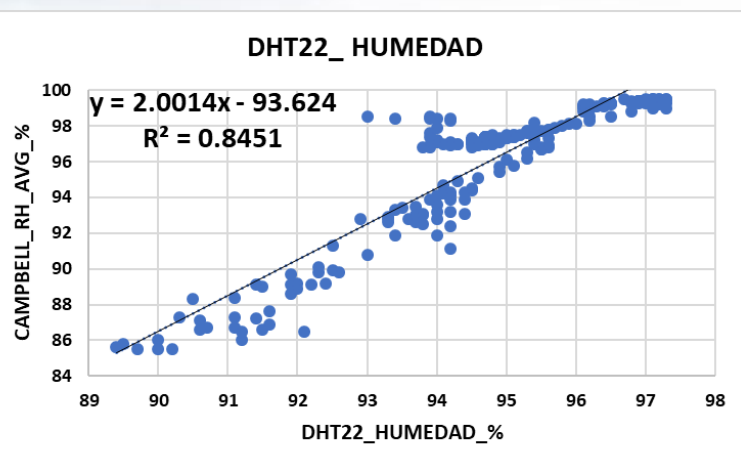
**VALIDACIÓN**

	BMP_180	DHT22
BIAS	0.03	0.48
RMSE	8.54	2.00
r	0.99	0.99



# SENSOR DE HUMEDAD

## CALIBRACIÓN



```
> cor.test(humedad$Mod_DHT_HUMEDAD,humedad$RH_Avg, method = "pearson")
```

Pearson's product-moment correlation

data: humedad\$Mod\_DHT\_HUMEDAD and humedad\$RH\_Avg

t = 35.572, df = 232 **p-value < 2.2e-16**

alternative hypothesis: true correlation is not equal to 0

95 percent confidence interval:

0.8967478 0.9370479

sample estimates:

cor

**0.9192734**

## VALIDACIÓN

RMSE 1.02

BIAS 1.04

r 0.97

```
> cor.test(hum_val$Mod_DHT_HUMEDAD,hum_val$RH_Avg, method = "pearson")
```

Pearson's product-moment correlation

data: hum\_val\$Mod\_DHT\_HUMEDAD and hum\_val\$RH\_Avg

t = 18.558, df = 18 **p-value = 3.492e-13**

alternative hypothesis: true correlation is not equal to 0

95 percent confidence interval:

0.9361921 0.9902043

sample estimates:

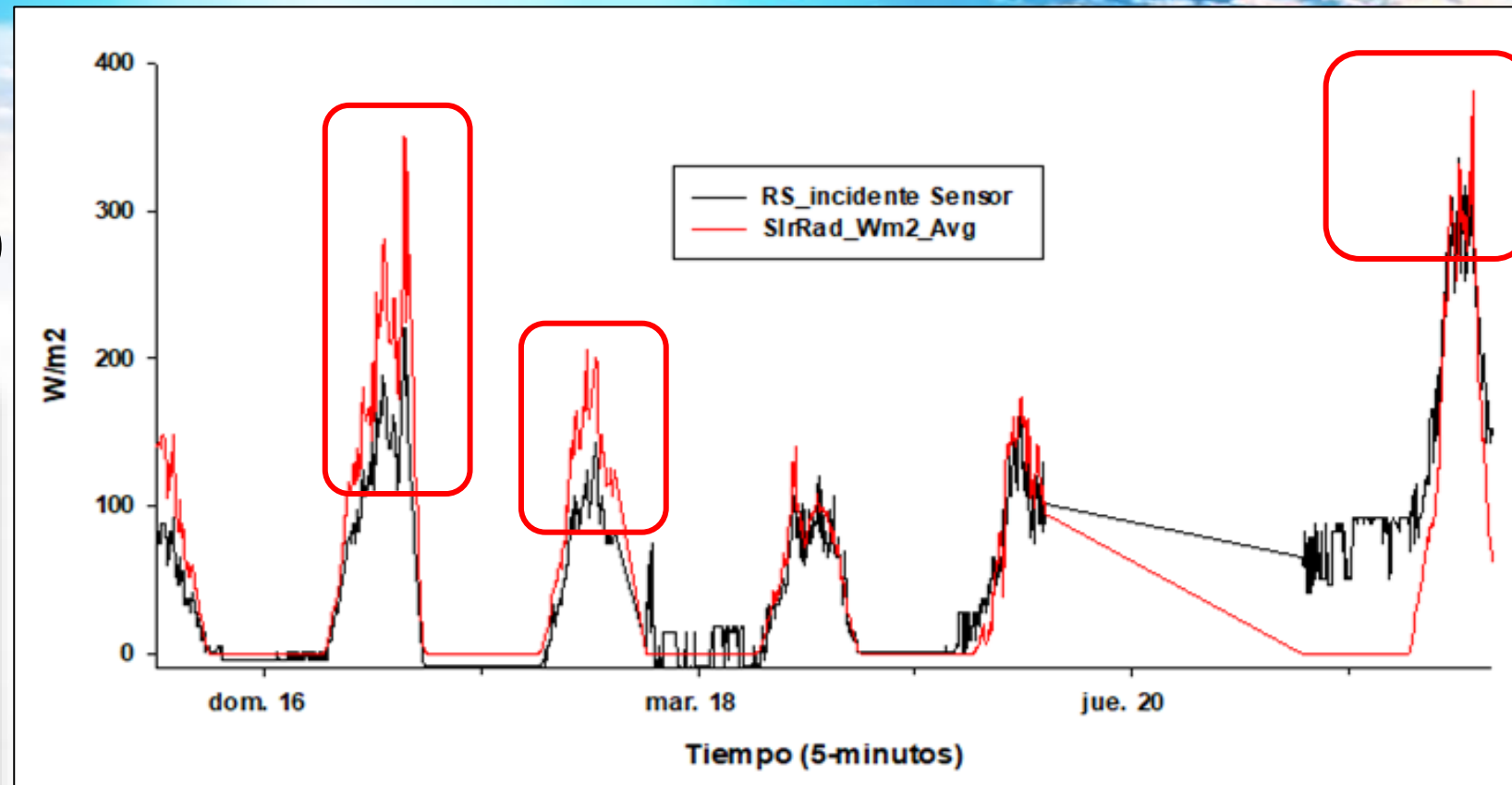
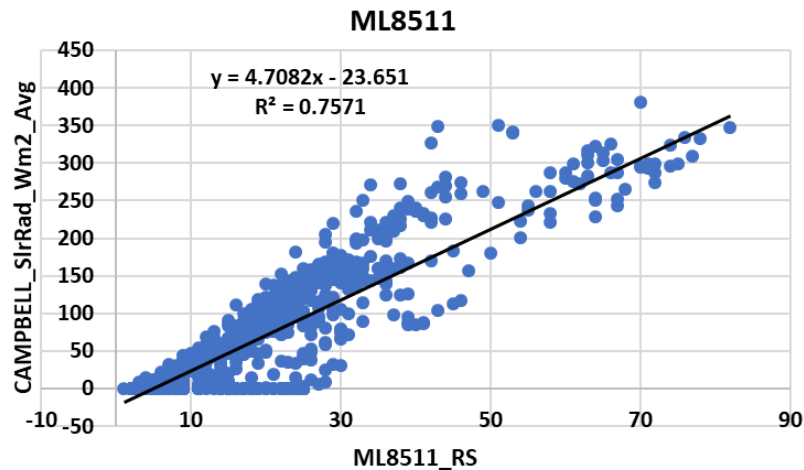
cor

**0.9748483**



# PIRANÓMETRO

## CALIBRACIÓN



## VALIDACIÓN

RMSE	0.02
BIAS	-60.28
r	0.91

```
> cor.test(rad$RS_incidente, rad$SlrRad_wm2_Avg)
```

Pearson's product-moment correlation

data: rad\$RS\_incidente and rad\$SlrRad\_wm2\_Avg  
t = 9.2915, df = 18, p-value = 2.733e-08  
alternative hypothesis: true correlation is not equal to 0  
95 percent confidence interval:  
0.7818708 0.9640903  
sample estimates:  
cor  
0.909656

```
> cor.test(rad$RS_incidente, rad$SlrRad_wm2_Avg, method = "pearson")
```

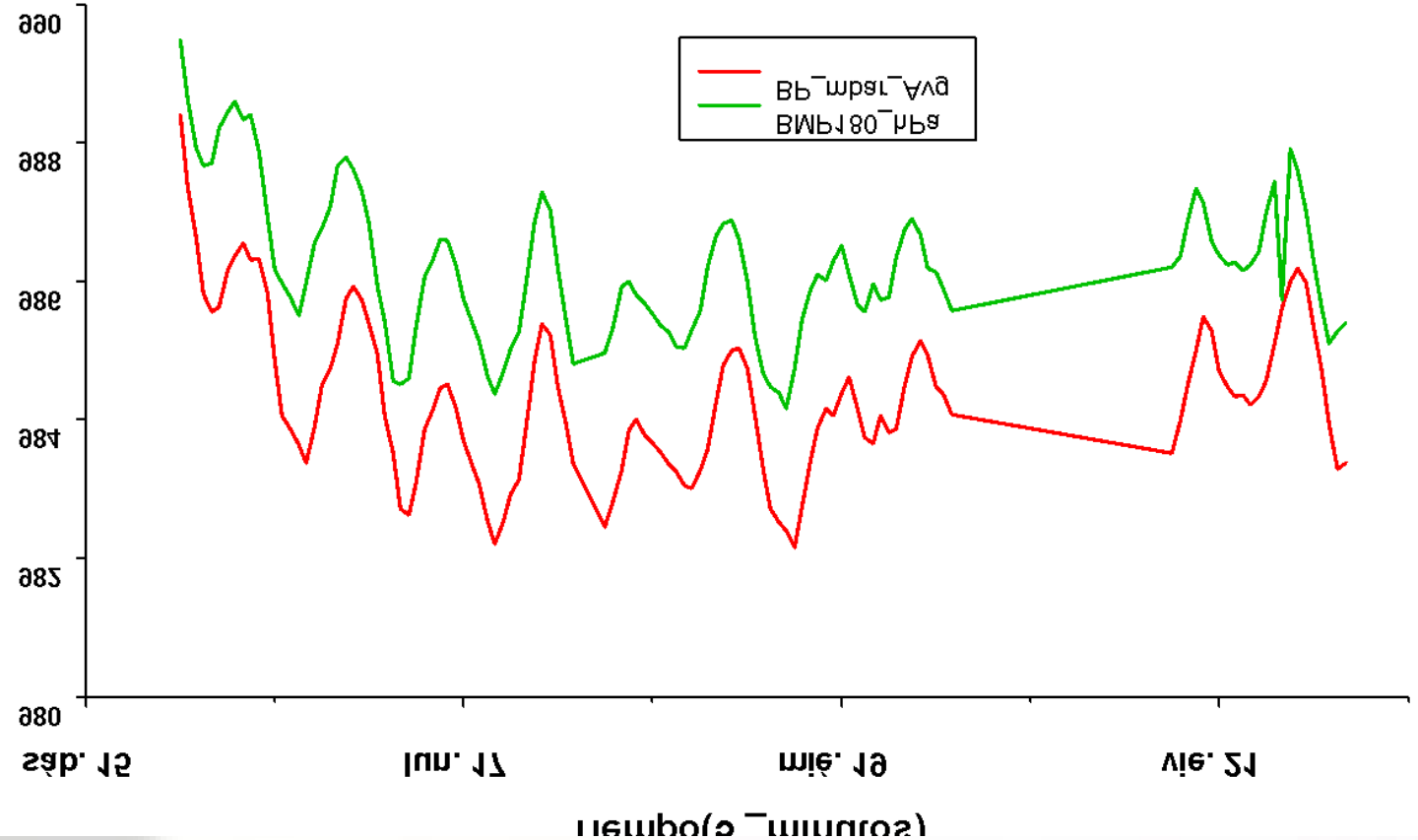
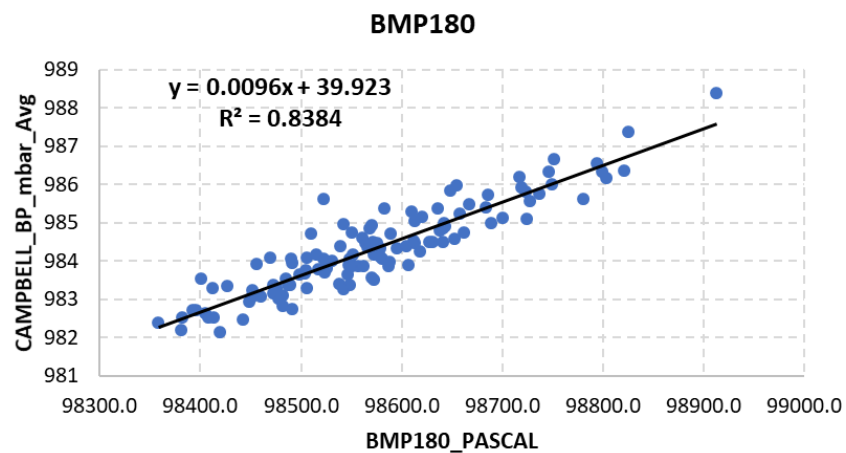
Pearson's product-moment correlation

data: rad\$RS\_incidente and rad\$SlrRad\_wm2\_Avg  
t = 64.977, df = 1355, p-value < 2.2e-16  
alternative hypothesis: true correlation is not equal to 0  
95 percent confidence interval:  
0.8565230 0.8824366  
sample estimates:  
cor  
0.8700797



# SENSOR DE PRESIÓN ATMOSFÉRICA

## CALIBRACIÓN



## VALIDACIÓN

BIAS	-1.64
RMSE	1.74
r	0.74

```
> cor.test(pre$BP_mbar_Avg,pre$MOD_BMP180)

Pearson's product-moment correlation

data:  pre$BP_mbar_Avg and pre$MOD_BMP180
t = 3.8402, df = 12, p-value = 0.002352
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.3497405 0.9132976
sample estimates:
      cor 
0.7425319
```

```
> cor.test(data$PRESIONBMP_promedio,data$presion_sensor, method = 'pearson')
```

Pearson's product-moment correlation

```
data: data$PRESIONBMP_promedio and data$presion_sensor
t = 24.634, df = 117, p-value < 2.2e-16
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.8807840 0.9405977
sample estimates:
```

```
cor
0.9156197
```

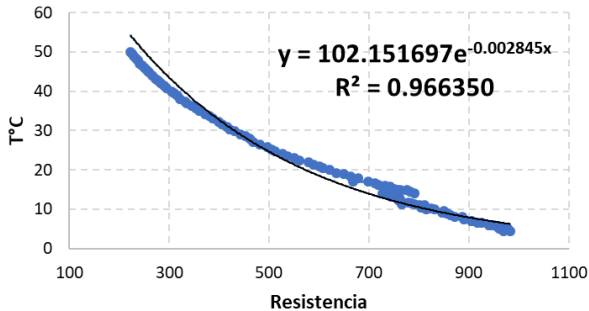


# GEOTERMÓMETRO

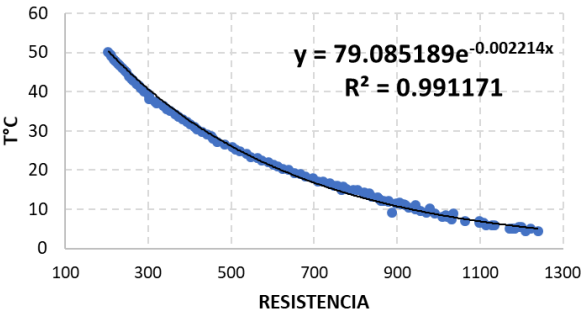
## CALIBRACIÓN EN CAMPO

### CALIBRACIÓN EN LABORATORIO

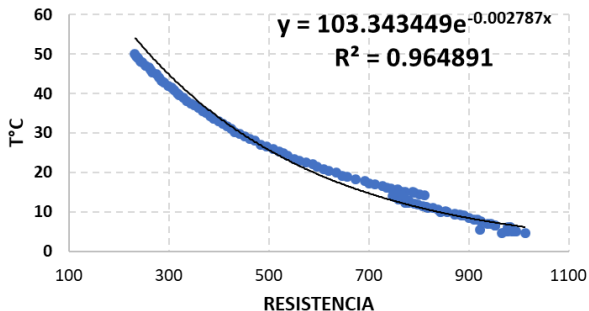
NARANJA



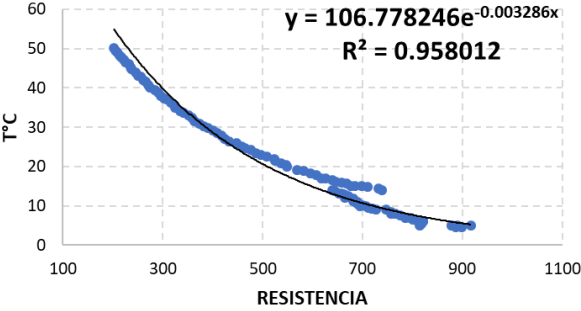
VERDE



MARRON

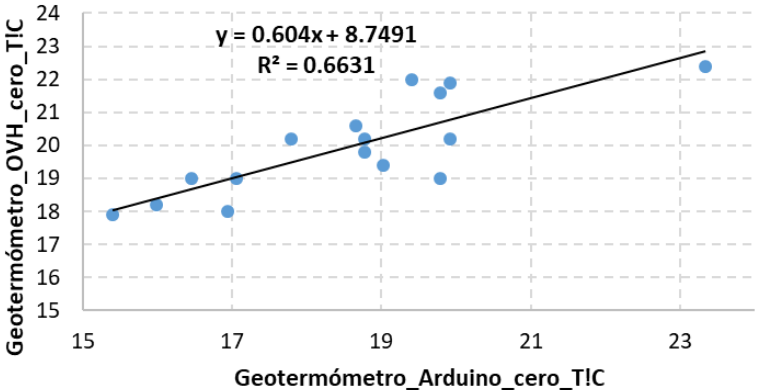


AZUL

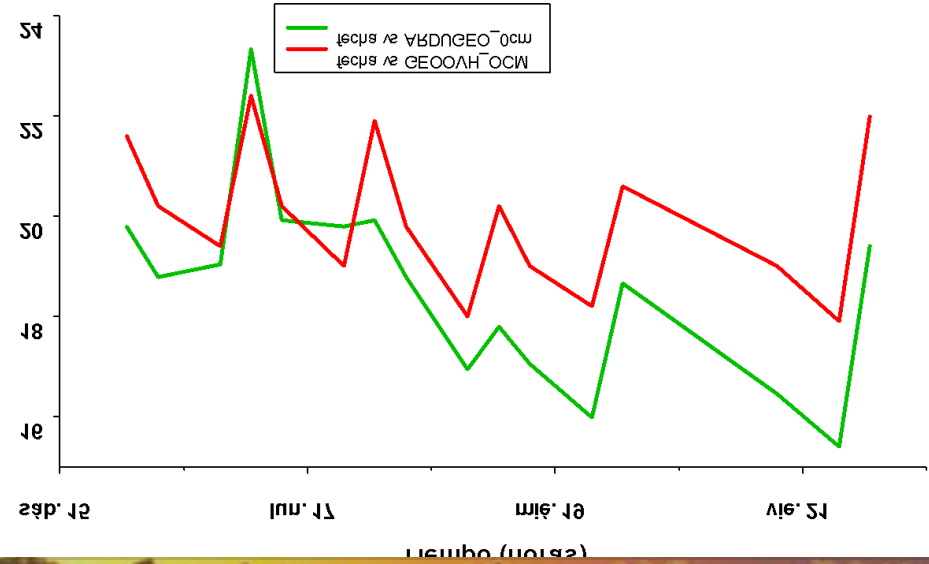


	r
Naranja	0.9931
Verde	0.9985
Marrón	0.9938
Azul	0.9908

Geotermómetro\_0\_cm

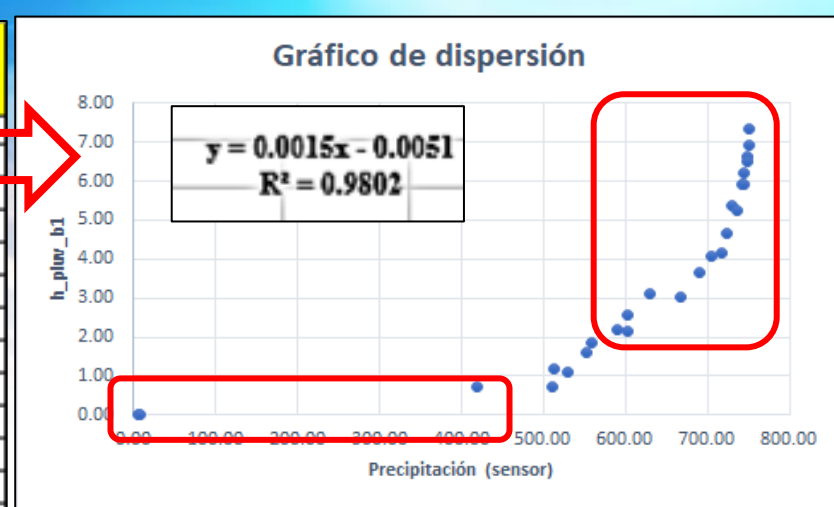


Los siguientes niveles salió erróneo





precipitacion	altura mm	h_pluv_b1	h_pluv_b2	Vol_prob eta(cm2+ mm)
7.00	0.00	0.00	0.00	0.00
9.00	0.00	0.00	0.00	0.00
420.00	1.60	0.71	4.07	320.00
512.00	1.60	0.71	4.07	320.00
514.00	2.70	1.19	6.88	540.00
529.00	2.50	1.11	6.37	500.00
553.00	3.65	1.61	9.29	730.00
559.00	4.20	1.86	10.70	840.00
590.00	5.00	2.21	12.73	1000.00
602.00	5.80	2.56	14.77	1160.00
602.00	4.85	2.14	12.35	970.00
631.00	7.00	3.09	17.83	1400.00
667.00	6.85	3.03	17.44	1370.00
691.00	8.30	3.67	21.14	1660.00
704.00	9.20	4.07	23.43	1840.00
717.00	9.45	4.18	24.06	1890.00
723.00	10.55	4.66	26.87	2110.00
729.00	12.20	5.39	31.07	2440.00
736.00	11.90	5.26	30.30	2380.00
742.00	13.40	5.92	34.12	2680.00
745.00	13.35	5.90	34.00	2670.00
745.00	14.05	6.21	35.78	2810.00
748.00	15.00	6.63	38.20	3000.00
749.00	14.70	6.50	37.43	2940.00
750.00	16.60	7.34	42.27	3320.00
751.00	15.70	6.94	39.98	3140.00



## Pluviómetro

```
> cor.test(precipitacion, h_pluv_b1, method = "spearman")
```

Spearman's rank correlation rho

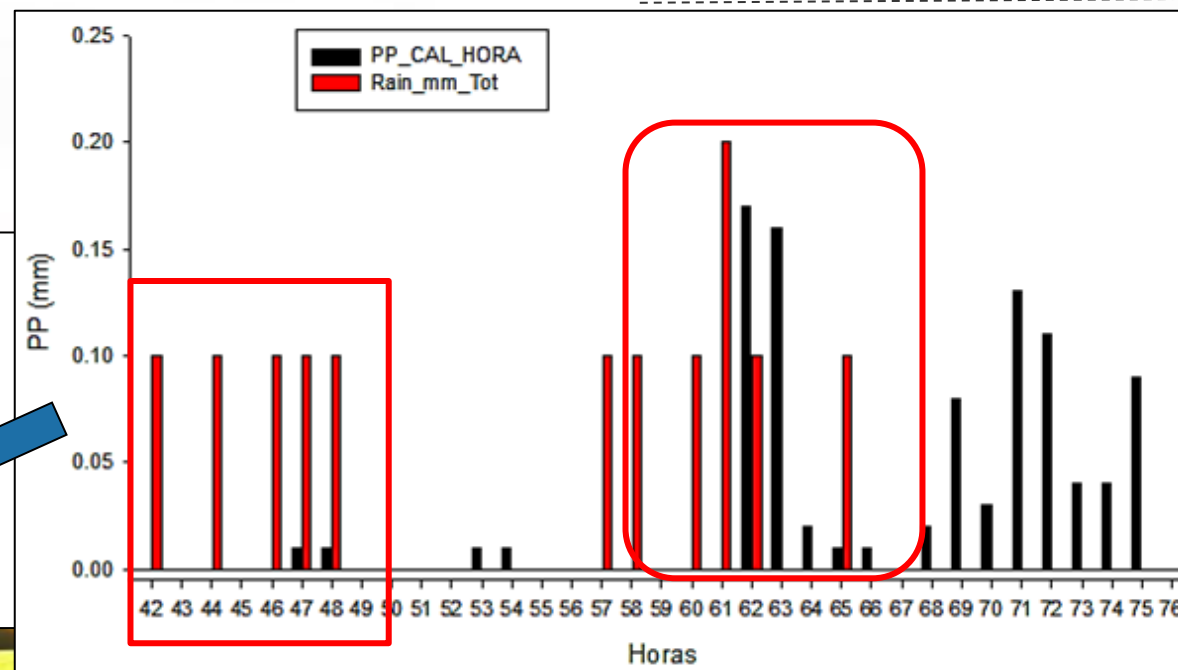
data: precipitacion and h\_pluv\_b1

S = 18.012, p-value < 2.2e-16

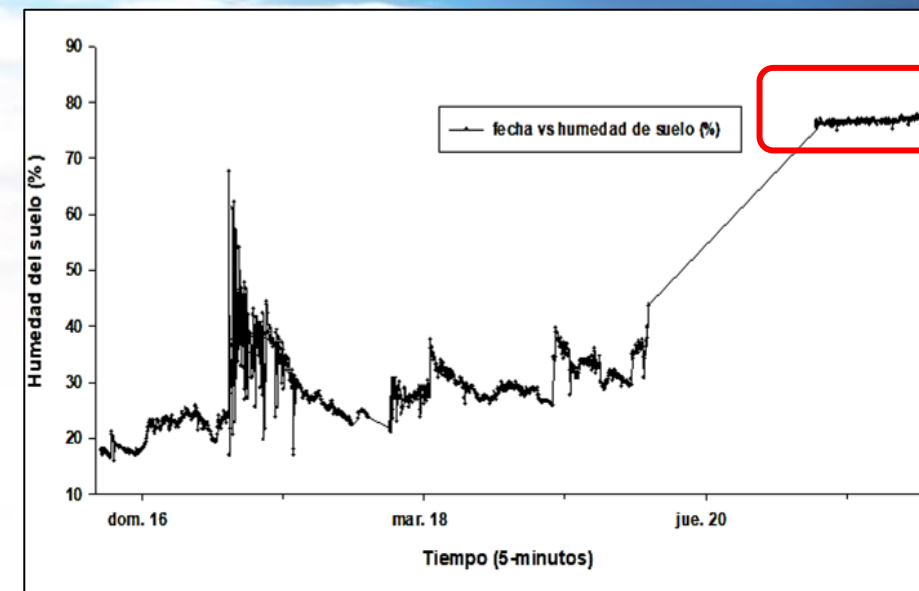
alternative hypothesis: true rho is not equal to 0

sample estimates:

rho  
0.9938419



## HIGRÓMETRO

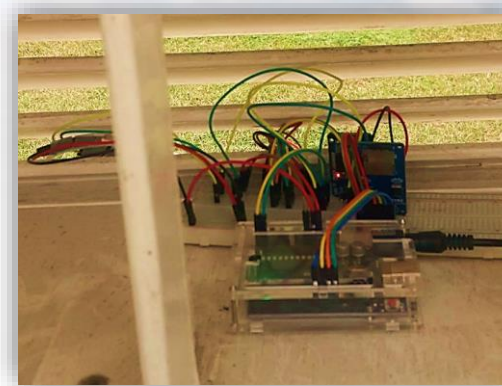




# SENSORES INFRARROJOS

Lo que elaboré en prácticas

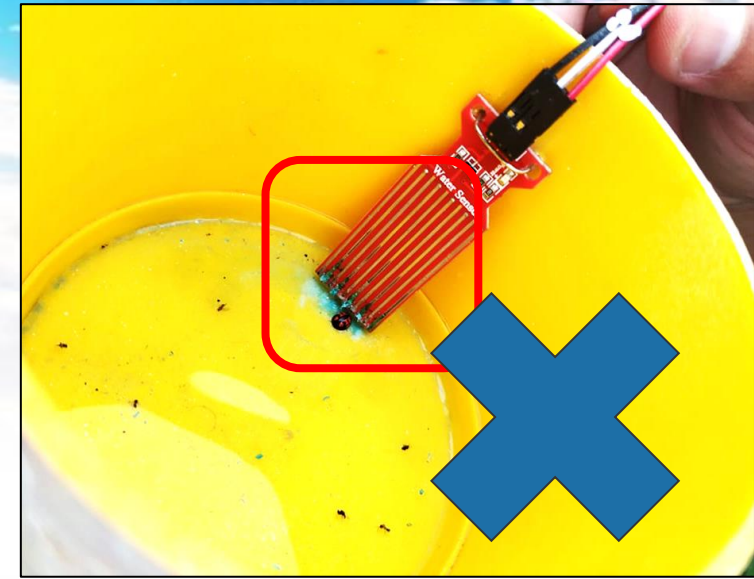
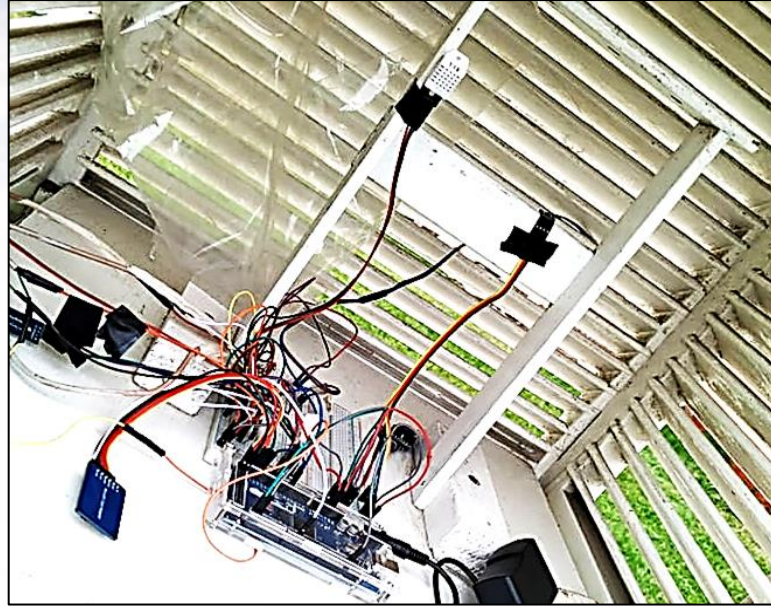
Lo que desarrollo actualmente



MLX90614



# RECOMENDACIONES





# CONCLUSIONES

- Los sensores de bajo costo de temperatura, humedad, presión y radiación presentan una alta correlación en comparación con los sensores de la estación automática Campbell CR 300, aunque el geotermómetro en sus cuatro niveles (0cm,5cm,20cm y 40cm) obtuvo una mejor respuesta en el primer nivel.
- El pluviómetro presentó una alta correlación, sin embargo no presentó una óptima respuesta para los eventos de precipitación, por otro lado el sensor de humedad del suelo no presentó el comportamiento esperado.





**GRACIAS**