Version 1.1 May 17, 2016

Surface Meteorological and Air-Sea Flux Time Series from the WHOI Bay of Bengal Mooring

This readme file provides information about the meteorological and air-sea flux time series collected from a surface mooring in the northern Bay of Bengal from December 2014 to January 2016. We encourage use of these data. When using the data please acknowledge its source.

The surface mooring was deployed by investigators Dr. J. T. Farrar and Robert A. Weller of the Upper Ocean Processes Group of the Woods Hole Oceanographic Institution (WHOI). R. Weller and J. T. Farrar were supported by the U.S. Office of Naval Research, Grant N00014-13-1-0453. The deployment of the WHOI mooring was done by RV *Sagar Nidhi* and the recovery by RV *Sagar Kanya*; the help of the crew and science parties is gratefully acknowledged as is the ongoing support at NIOT in Chennai and by other colleagues in India of this mooring work.

Supporting technical information about the mooring including a mooring diagram and a log of the mooring deployment can be found at http://uop.whoi.edu/projects/Bengal/index.html

The reference that should cited in conjunction with the use of the surface meteorological and air-sea flux data from the WHOI buoy is:

Weller, R. A., J. F. Farrar, J. Buckley, S. Mathew, R. Venkatsen,S. Lekha, Dipanjan, N.S. Kumar, N. P. Kumar, 2016: Air-sea interaction in the Bay of Bengal. *Oceanography,* submitted.

For the surface meteorology, four files have been prepared. The meteorological sensors on the buoy yield one-minute boxcar averages. The primary meteorological instrumentation is the ASIMET package (Hosom et al., 1995), and the best data from the sensors of two ASIMET packages together with a redundant Vaisala WXT 520 have been selected to make a single best basic, one-minute time series of surface meteorology. These data are as taken by the sensors, at the height of the sensors above the waterline of the buoy (Table 1). The one-minute meteorological time series are then used to make one-hour meteorological time series, with the time word associated with the center of the hour, one-day meteorological time series, with the time word associated with the center of the day, and one-month meteorological time series, with the time word associated with the center of the month.

The one-minute surface meteorological time series are then used with bulk formulae, including the TOGA COARE formulae version 3.0 (Fairall et al, 2003), to make one-minute time series of the air-sea fluxes of heat, freshwater, and momentum. In computing the fluxes, the wind velocity relative to the sea surface is required, and we use a 2m deep ocean velocity record from an upward-looking Acoustic Doppler Current Profiler (ADCP) to compute the relative wind velocity. This, we also share here the 2m deep current. The one-minute fluxes in turn are used to make one-hour time series of the air-sea fluxes, one-day time series of the air-sea fluxes, and one-month time series of the air-sea fluxes.

The Files and the Variables

Four surface meteorology files are provided in both Matlab (.mat) and NetCDF (.nc) formats:

beng1_met_60s.mat Bengal_1_D_M-60s.nc	one-minute surface meteorology at the sensor heights
beng1_met_1hr.mat Bengal_1_D_M-1hr.nc	one-hour surface meteorology at the sensor heights
beng1_met_1d.mat Bengal_1_D_M-1d.nc	one-day surface meteorology at the sensor heights
beng1_met_1mnth.mat Bengal_1_D_M-1mnth.nc	one-month surface meteorology at the sensor heights

Four air-sea flux files are provided in both Matlab (.mat) and NetCDF (.nc) formats. In these files in addition to the air-sea fluxes, there are air temperature and humidity adjusted to 2 m and wind velocity to 10 m:

beng1_flux_60s.mat Bengal_1_D_F-60s.nc	one-minute air-sea fluxes
beng1_flux_1hr.mat Bengal_1_D_F-1hr.nc	one-hour air-sea fluxes
beng1_flux_1d.mat Bengal_1_D_F-1d.mat	one-day air-sea fluxes
beng1_flux_1mnth.mat Bengal_1_D_F-1mnth.nc	one-month air-sea fluxes

In addition, as mentioned above, the 2 m deep ocean velocity data are provided:

nortek_2mbin_4flux.mat
Bengal_1_D_surfV.nc

Further descriptions of the variables in each file are provided in the attached appendices, Appendix I for Matlab files and Appendix II for NetCDF files.

Notes on Processing

For a very high level summary, the following steps are taken in the preparation of the best basic one-minute surface meteorological time series

1. Both data logger clocks are checked and adjusted accordingly. The final time series data are from Dec 08, 2014 10:00:00 to Jan 29, 2016 04:00:00.

2. Sensor returns are compared between the two loggers and with the stand alone Vaisala WXT meteorological instrument (wind velocity, barometric pressure, air temperature and humidity, and rain) and stand alone Lascar temperature and humidity logger.

3. The logger with the better return rate is identified and chosen as the basic data for each of the variables.

4. The spiky points and problematic segments are flagged and replaced by good points from the other data logger (when available).

5. Finally, all fixed time series for each of the variables are combined to form the best one-minute surface meteorological time series.

The detailed processing steps are summarized in Appendix III.

Points of Contact

Feedback on data quality issues is welcomed. To provide that or to seek further information, please contact Tom Farrar (jfarrar@whoi.edu) or Bob Weller (rweller@whoi.edu)

References

Fairall, C. W., E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson. 2003. Bulk paramterization of air-sea fluxes: updates and verification for the COARE algorithm. *Journal of Climate* 16: 571-591.

Hosom, D.S., R.A. Weller, R.E. Payne and K.E. Prada. 1995. The IMET (improved meteorology) ship and buoy systems. *Journal of Atmospheric and Oceanic Technology* 12:527-540.

Appendix I – Matlab files

For the surface meteorological files:

```
>> who
Your variables are:
met
atmp        currentdepth  magvar       relwndn     swspd      zatmp_in
bpr         curspd        mday         relwspd     wdir       zhum_in
cond        experiment    meta         sal         wnde       zsst_in
curdir      hrh           prate        sh          wndn       zwspd_in
cureast     lat           prate_units  sigma       wspd
curnorth    lon           relwdir      sst         yday
current_sn  lwr           relwnde      swr         year
```

atmp = air temperature, °C
bpr = barometric pressure, hPa
cond = seawater conductivity from SBE 37 on bridle, S/m
curdir = direction water velocity flows toward used to compute relative wind velocity, ° true
cureast = eastward current, + to the east, m/s
curnorth = northward current, + to north, m/s
current sn = serial number of current meter used for surface velocity
currentdepth = depth of current meter used for surface velocity, m
curspd = speed of current used for surface velocity, m/s
experiment = project name
hrh = relative humidity, %
lat = latitude
lon = longitude
lwr = incoming longwave radiation, W/m^2
magvar = magnetic variation at site applied to correct compasses, °
mday = matlab time, days
meta = metadata
prate = rain rate, mm/hr
prate_units = units for prate
relwdir = direction the vector of the wind relative to the surface current flows toward, °
relwnde = east wind component, relative to surface current, + to east, m/s
relwndn = northward wind component, relative to surface current, + to north, m/s
relwspd = speed of vector wind relative to surface current, m/s
sal = salinity, from SBE 37 on bridle, psu
sst = temperature from SBE 37 on bridle, °C
swr = incoming shortwave radiation, W/m^2
swspd = scalar wind speed, from scalar average over interval, m/s
wdir = measured direction wind velocity flows toward, °
wnde = measured eastward wind velocity component, + to east, m/s
wndn = measured northward wind velocity component, + to north, m/s

wpsd = measured wind speed, from vector average over interval, m/s
yday = time in days relative to deployment year, note yday=1.5 for Jan 1 noon of deployment year
year = deployment year
zatmp_in = height above sea surface of air temperature sensor, m
zhum_in = height above sea surface of relative humidity sensor, m
zsst_in = depth below sea surface of sea surface temperature sensor, m
zwspd_in = height above sea surface of wind sensor, m

For the air-sea fluxes:
>>who
Your variables are:
Your variables are:

```
CE     Z0q           experiment  qq_h       taue       wbar      zhum_out
CH     Z0t           jcool       qstar      taumag     wg        zsst_in
QB     albedo        jwarm       rough      taun       ws_h      zwspd_in
QH     current_sn    lat         roughlen   tk_pwp     yday      zwspd_out
QN     currentdepth  lon         stability  tkt        year
Ql     drag          magvar      ta_h       tskin      zatmp_in
Qr     dt_wrm        mday        tau_r      tstar      zatmp_out
Qs     dter          meta        taudir     ustar      zhum_in
```

CE = bulk formulae coefficient for latent heat
CH = bulk formulae coefficient for sensible heat
QB = sensible heat flux, W/m^2
QH = latent heat flux, W/m^2
Ql = net longwave heat flux, W/m^2
QN = net heat flux, + is heat into ocean, W/m^2
Qr = rain heat flux, W/m^2
Qs = net shortwave heat flux, W/m^2
experiment = project name
lat = latitude
lon = longitude
magvar = magnetic variation at site applied to correct compasses, °
meta = metadata
mday = matlab time, days
yday = time in days relative to deployment year, note yday=1.5 for Jan 1 noon of deployment year
zatmp_in = air temperature sensor height above sea surface, m
zatmp_out = air temperature interpolated using bulk formulae to this height, m (usually 2m)
ta_h = air temperature at height zatmp_out, °C
zhum_in = air humidity sensor height above sea surface, m
zhum_out = air humidity interpolated using bulk formulae to this height, m (usually 2m)
qq_h = specific humidity at height zhum_out, g/Kg
zwpsd_in = wind velocity sensor height above sea surface, m

zwspd_out = wind velocity interpolated used bulk formulae to this height, m (usually 10m)
wspd_h = wind speed at height zwspd_out, m/s
zsst_in = depth of measured sea surface temperature, m
tskin = sst, interpolated with COARE algorithm to skin temperature, °C
taumag = magnitude of wind stress computed using absolute wind velocity, N/m^2
taudir = direction of wind stress vector computed using absolute wind velocity, °
taue = absolute wind stress, eastward component, + to east, N/m^2
taun = absolute wind stress, northward component, + to north, N/m^2

other variables record settings for use with COARE version 3.0 formula and results from running COARE bulk formulae code

For the 2 m ocean current file:
>> who
2m nortek
Your variables are:

```
curdir    depth     experiment  lon       meta      note      yday
curspd    east      lat         mday      north     sn        year
```

curdir = ocean current direction, °
curspd = ocean current speed, m/s
depth = depth of current, m
east = eastward component of current, + towards east, m/s
experiment = project name
lat = latitude
lon = longitude
mday = matlab time, days
meta = metadata
north = northward component of current, + towards north, m/s
note = indicates source and use for computing wind relative to sea surface
sn = serial number of instrument
yday = time in days relative to deployment year, note yday=1.5 for Jan 1 noon of deployment year

Metadata for .mat files

```
% Bengal1_met_meta.m
% this gets all the metadata for individual buoy deployment, including
module SNs and
% sensor heights

    meta.global.SN = '1';  % note: string

    % QC and Cell_methods are the same for all variables.
    meta.variable.QC_indicator=8;
    meta.variable.QC_procedure=5;
    meta.variable.cell_methods='time:point depth:point';

    meta.variable.RELH.SN='sys2/213';
    meta.variable.RELH.sensor_height=3.02; %+0.8 included

    meta.variable.AIRT.SN='sys2/213';
    meta.variable.AIRT.sensor_height=3.02;

    meta.variable.ATMS.SN='sys1/240';
    meta.variable.ATMS.sensor_height=3.11;

    meta.variable.TEMP.SN='sys2/5994';
    meta.variable.TEMP.sensor_height =-0.7; %-1.5+0.8

    meta.variable.UWND.SN='sys2/329';
    meta.variable.UWND.sensor_height=3.47;

    meta.variable.VWND.SN='sys2/329';
    meta.variable.VWND.sensor_height=3.47;

    meta.variable.SW.SN='sys1/268';
    meta.variable.SW.sensor_height=3.62;

    meta.variable.LW.SN='sys1/265';
    meta.variable.LW.sensor_height=3.62;

    meta.variable.RAIN.SN='wxt/007';
    meta.variable.RAIN.sensor_height=3.40;
```

Appendix II – NetCDF files

Surface meteorology

```
%% Variables and attributes:

nc{'lon'}.units = ncchar(''degrees longitude\0'');
nc{'lon'}.epic_code = nclong(501);

nc{'lat'}.units = ncchar(''degrees latitude\0'');
nc{'lat'}.epic_code = nclong(500);

nc{'depth'}.units = ncchar(''meters\0'');
nc{'depth'}.epic_code = nclong(3);

nc{'time'} = nclong('time'); %% 539440 elements.
nc{'time'}.units = ncchar(''days\0'');

nc{'time2'} = nclong('time'); %% 539440 elements.
nc{'time2'}.units = ncchar(''milliseconds\0'');
nc{'time2'}.epic_code = nclong(624);

nc{'wnde'}.long_name = ncchar(''east wind\0'');
nc{'wnde'}.units = ncchar(''m/s\0'');

nc{'wndn'}.long_name = ncchar(''north wind\0'');
nc{'wndn'}.units = ncchar(''m/s\0'');

nc{'wavg'}.long_name = ncchar(''scalar averaged wind speed\0'');
nc{'wavg'}.units = ncchar(''m/s\0'');

nc{'wnds'}.long_name = ncchar(''wind speed\0'');
nc{'wnds'}.units = ncchar(''m/s\0'');

nc{'wndd'}.long_name = ncchar(''wind direction\0'');
nc{'wndd'}.units = ncchar(''degrees\0'');

nc{'atmp'}.long_name = ncchar(''air temperature\0'');
nc{'atmp'}.units = ncchar(''degC\0'');

nc{'stmp'}.long_name = ncchar(''sea temperature at about 0.6m depth\0'');
nc{'stmp'}.units = ncchar(''degC\0'');

nc{'hrh'}.long_name = ncchar(''relative humidity\0'');
nc{'hrh'}.units = ncchar(''%\0'');
```

Air-sea flux

```
%% Variables and attributes:

nc{'lon'} = ncfloat('lon'); %% 1 element.
nc{'lon'}.units = ncchar(''degrees longitude'');

nc{'lat'} = ncfloat('lat'); %% 1 element.
nc{'lat'}.units = ncchar(''degrees latitude'');

nc{'depth'} = ncfloat('depth'); %% 1 element.
nc{'depth'}.units = ncchar(''meters'');

nc{'time'} = nclong('time'); %% 539440 elements.
nc{'time'}.units = ncchar(''days'');

nc{'time2'} = nclong('time'); %% 539440 elements.
nc{'time2'}.units = ncchar(''milliseconds since midnight'');

nc{'QB'}.long_name = ncchar(''sensible heat flux'');
nc{'QB'}.units = ncchar(''W/m^2'');

nc{'QH'}.long_name = ncchar(''latent heat flux'');
nc{'QH'}.units = ncchar(''W/m^2'');

nc{'Qs'}.long_name = ncchar(''net shortwave radiation'');
nc{'Qs'}.units = ncchar(''W/m^2'');

nc{'Ql'}.long_name = ncchar(''net longwave radiation'');
nc{'Ql'}.units = ncchar(''W/m^2'');

nc{'QN'}.long_name = ncchar(''net heat flux'');
nc{'QN'}.units = ncchar(''W/m^2'');

nc{'taue'}.long_name = ncchar(''east wind stress'');
nc{'taue'}.units = ncchar(''N/m^2'');

nc{'taun'}.long_name = ncchar(''north wind stress'');
nc{'taun'}.units = ncchar(''N/m^2'');

nc{'taumag'}.long_name = ncchar(''wind stress magnitude'');
nc{'taumag'}.units = ncchar(''N/m^2'');

nc{'taudir'}.long_name = ncchar(''wind stress direction'');
```

```
nc{'taudir'}.units = ncchar(''degrees'');

nc{'ws_h'}.long_name = ncchar(''adjusted wind speed at 10.0m'');
nc{'ws_h'}.units = ncchar(''m/s'');

nc{'qq_h'}.long_name = ncchar(''adjusted specific humidity at 2.0m'');
nc{'qq_h'}.units = ncchar(''g/kg'');

nc{'ta_h'}.long_name = ncchar(''adjusted air temperature at 2.0m'');
nc{'ta_h'}.units = ncchar(''degC'');

nc{'tskin'}.long_name = ncchar(''skin temperature'');
nc{'tskin'}.units = ncchar(''degC'');

nc{'stability'}.long_name = ncchar(''stability'');
nc{'stability'}.units = ncchar(''nondimensional'');

nc{'ustar'}.long_name = ncchar(''ustar'');
nc{'ustar'}.units = ncchar(''m/s'');

nc{'drag'}.long_name = ncchar(''drag coef'');
nc{'drag'}.units = ncchar(''nondimensional'');

nc{'rough'}.long_name = ncchar(''roughness reynolds number'');
nc{'rough'}.units = ncchar(''nondimensional'');

nc{'roughlen'}.long_name = ncchar(''roughness length'');
nc{'roughlen'}.units = ncchar(''m'');

nc{'wg'}.long_name = ncchar(''gustiness factor'');
nc{'wg'}.units = ncchar(''m/s'');

nc{'tau_r'}.long_name = ncchar(''momentum flux due to rain'');
nc{'tau_r'}.units = ncchar(''N/m^2'');

nc{'wbar'}.long_name = ncchar(''Webb mean vertical velocity'');
nc{'wbar'}.units = ncchar(''m/s'');

nc{'Qr'}.long_name = ncchar(''rainfall heat flux'');
nc{'Qr'}.units = ncchar(''W/m^2'');

nc{'qstar'}.long_name = ncchar(''humidity scaling parameter'');
nc{'qstar'}.units = ncchar(''kg/kg'');
```

```
nc{'tstar'}.long_name = ncchar(''temperature scaling parameter'');
nc{'tstar'}.units = ncchar(''deg C'');

nc{'CH'}.long_name = ncchar(''transfer coefficient for heat'');
nc{'CH'}.units = ncchar(''nondimensional'');

nc{'CE'}.long_name = ncchar(''transfer coefficient for moisture'');
nc{'CE'}.units = ncchar(''nondimensional'');

nc{'RT'}.long_name = ncchar(''roughness Reynolds number for temperature'');
nc{'RT'}.units = ncchar(''nondimensional'');

nc{'RQ'}.long_name = ncchar(''roughness Reynolds number for moisture'');
nc{'RQ'}.units = ncchar(''nondimensional'');

nc{'Z0t'}.long_name = ncchar(''roughness length for temperature'');
nc{'Z0t'}.units = ncchar(''nondimensional'');

nc{'Z0q'}.long_name = ncchar(''roughness length for humidity'');
nc{'Z0q'}.units = ncchar(''nondimensional'');

nc{'dt_wrm'}.long_name = ncchar(''total warm layer temperature difference'');
nc{'dt_wrm'}.units = ncchar(''degC'');

nc{'dter'}.long_name = ncchar(''cool skin temperature difference'');
nc{'dter'}.units = ncchar(''deg C'');

nc{'tk_pwp'}.long_name = ncchar(''thickness of warm layer\0units\0\0\0'');
nc{'tk_pwp'}.units = ncchar(''m\0\0\0c'');


nc{'sh'}.long_name = ncchar(''specific humidity\0'');
nc{'sh'}.units = ncchar(''g/kg\0'');

nc{'srad'}.long_name = ncchar(''shortwave radiation\0'');
nc{'srad'}.units = ncchar(''W/m^2\0'');

nc{'lrad'}.long_name = ncchar(''longwave radiation\0'');
nc{'lrad'}.units = ncchar(''W/m^2\0'');

nc{'bpr'}.long_name = ncchar(''barometric pressure\0'');
nc{'bpr'}.units = ncchar(''mbar\0'');

nc{'sal'}.long_name = ncchar(''salinity from about 0.6m depth\0'');
```

```
nc{'sal'}.units = ncchar(''PSU\0'');

nc{'sigma'}.long_name = ncchar(''density (sigma-theta) from about 0.6m depth\0'');
nc{'sigma'}.units = ncchar(''kg/m^3\0'');

nc{'cureast'}.long_name = ncchar(''near-surface east current\0'');
nc{' cureast'}.units = ncchar(''m/s\0'');

nc{'curnorth'}.long_name = ncchar('''near-surface north current\0'');
nc{' curnorth'}.units = ncchar(''m/s\0'');

nc{'relwnde'}.long_name = ncchar(''east wind relative to near-surface current\0'');
nc{'relwnde'}.units = ncchar(''m/s\0'');

nc{'relwndn'}.long_name = ncchar(''north wind relative to near-surface current \0'');
nc{'relwndn'}.units = ncchar(''m/s\0'');

nc{'curspd'}.long_name = ncchar(''current speed\0'');
nc{'curspd'}.units = ncchar(''m/s\0'');

nc{'curdir'}.long_name = ncchar(''current direction\0'');
nc{'curdir'}.units = ncchar(''degrees\0'');

nc{'curdepth'}.long_name = ncchar(''current depth\0'');
nc{'curdepth'}.units = ncchar(''m\0'');
```

Appendix III - Bay of Bengal 1 Surface Met and Flux Processing Procedures

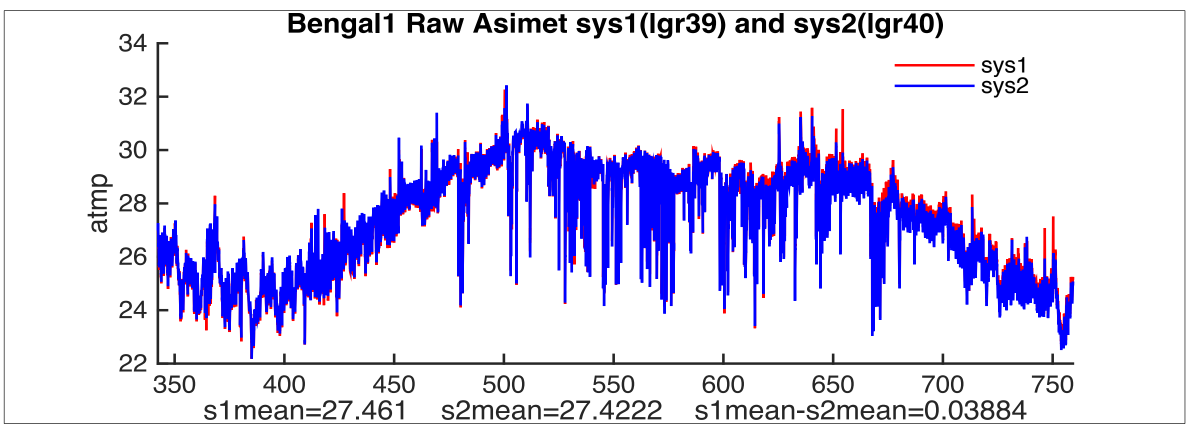
Data source:
Raw data logger files from the two ASIMET systems in the buoy
infile1='bengal1_lgr39.mat';
infile2='bengal1_lgr40.mat';

I. Surface Met Processes

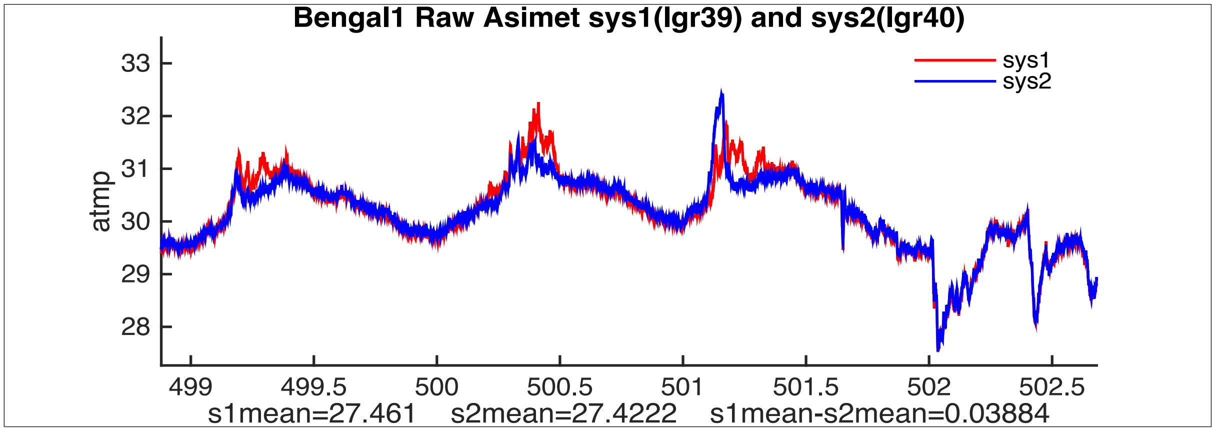
1. Checking overall logger data quality

The goal is to obtain an overall view of the data returns from both loggers. Data from sys1 and sys2 are plotted for the listed variables within the deployment time. Some variables are also checked against standalones (when available).

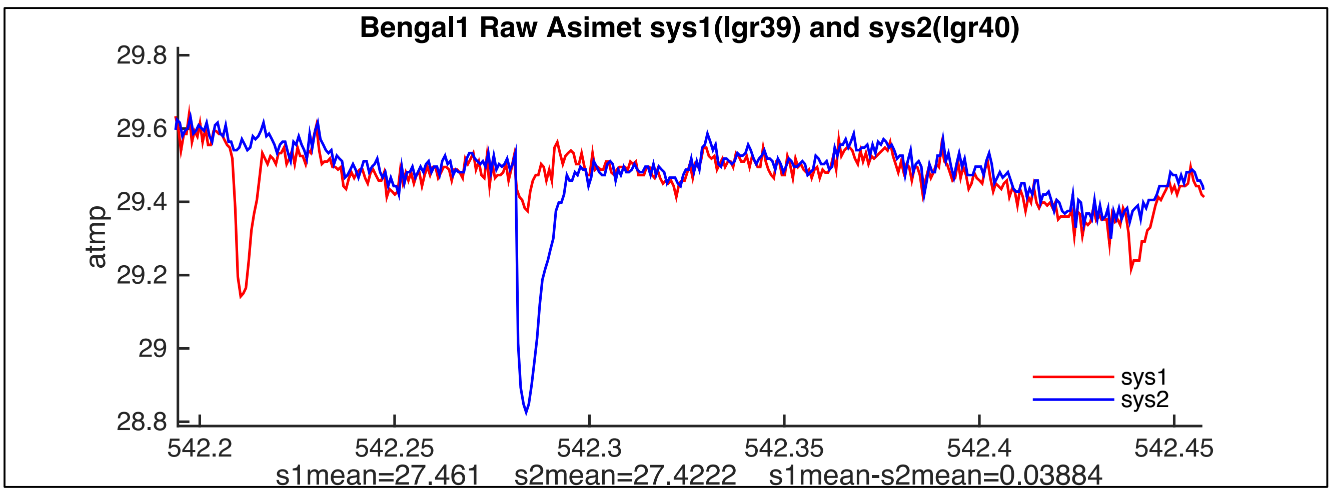
```
varn={'atmp','hrh','bpr','sst','cond','swr','lwr','precip','wnde','wndn','wspd','vane','compass'};
st=datenum(2014, 12, 08, 10, 0, 0)
ed=datenum(2016, 01, 29, 04, 0, 0)
```



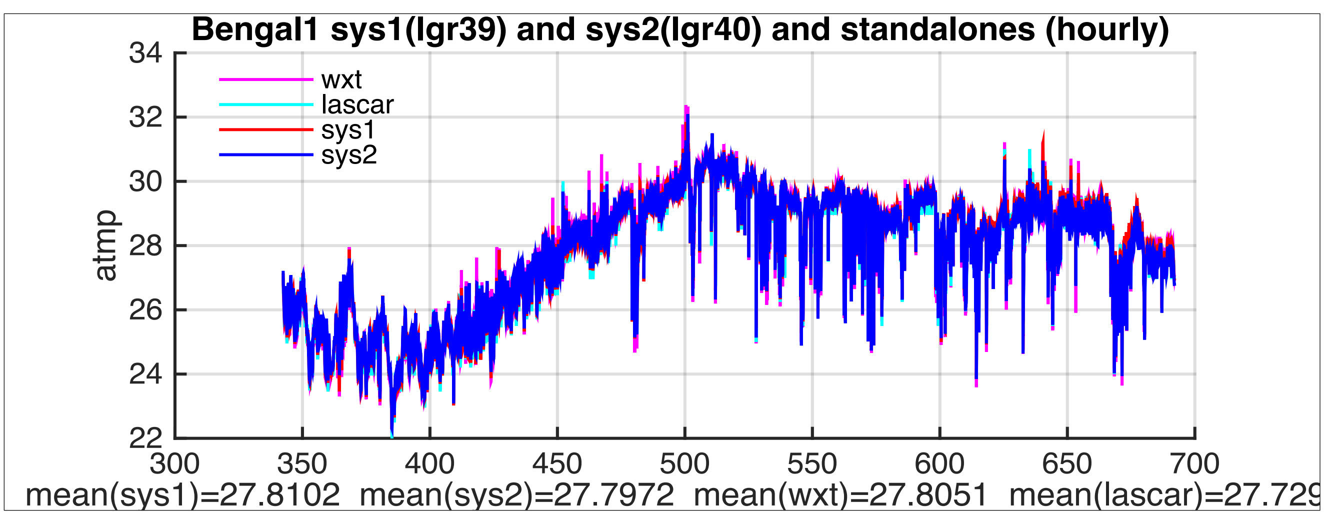
ATMP: Both loggers look good over all.



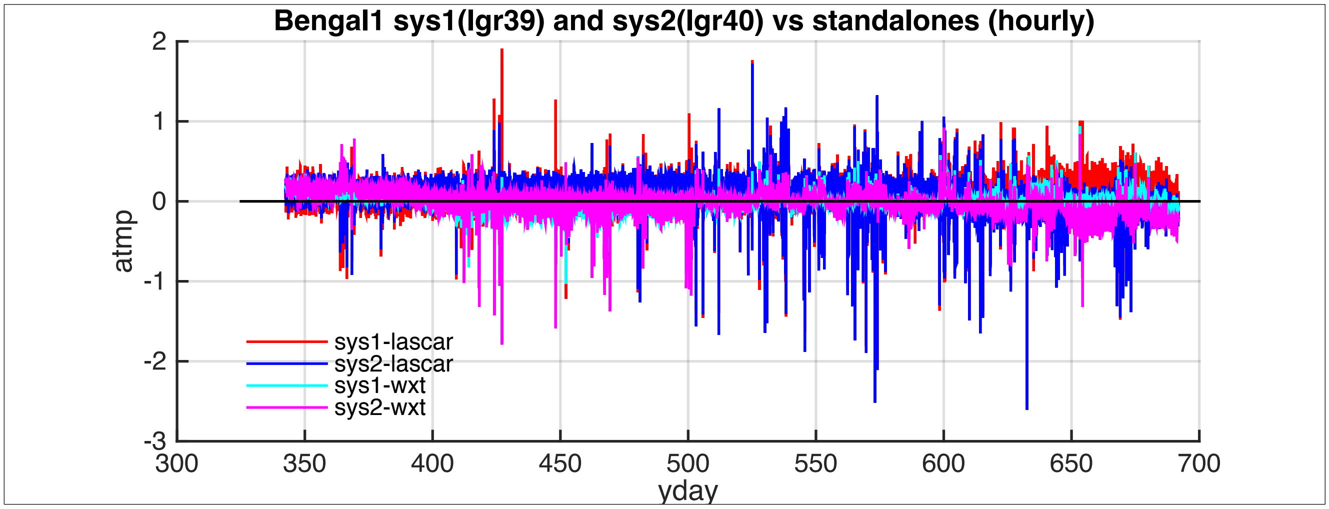
ATMP: Section showing low wind daytime sensor overheating.



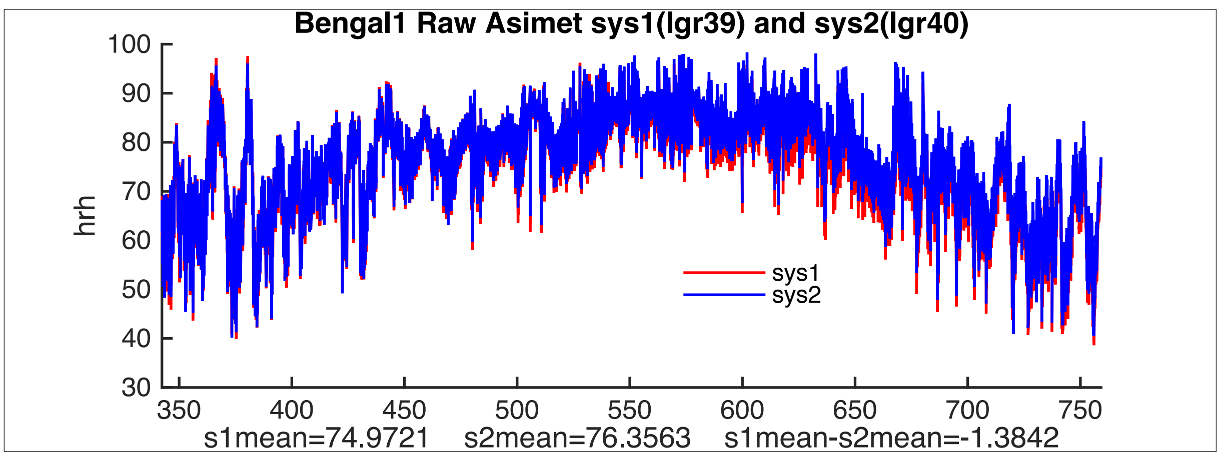
ATMP: Section showing sudden drops.



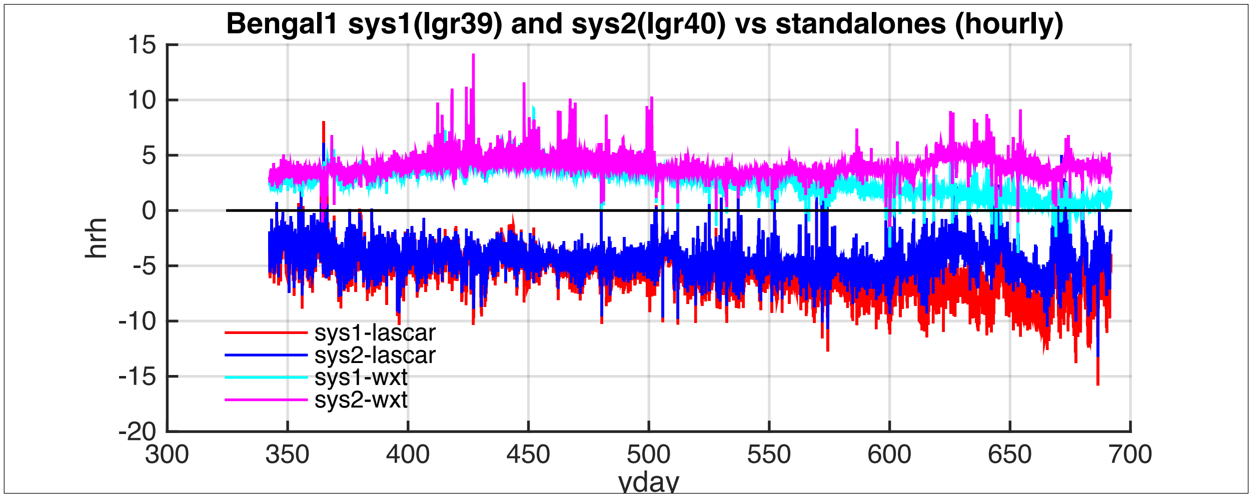
ATMP: Compare loggers with standalone WXT and Lascar.



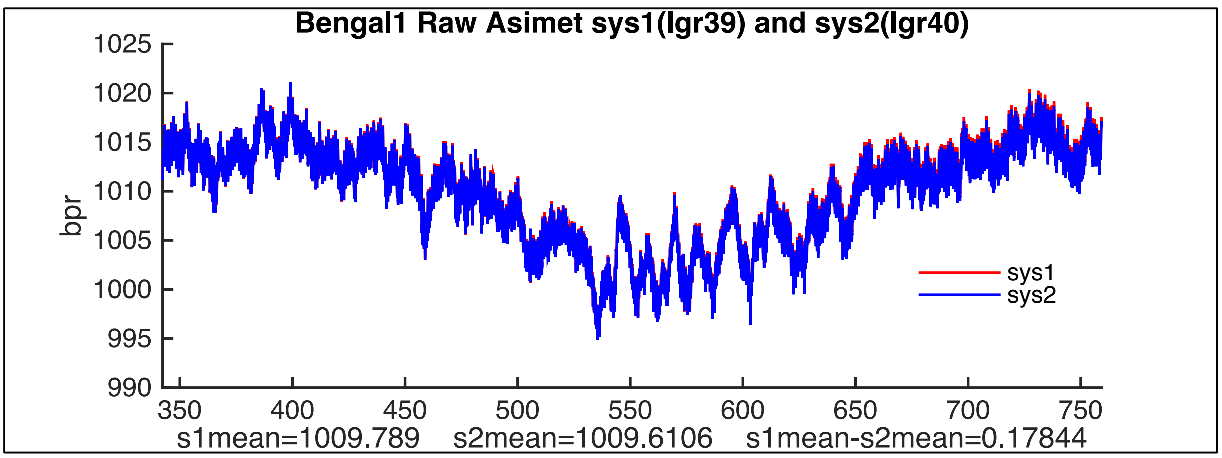
ATMP: Check the differences between logger and the standalones to help identify offsets or drifts.



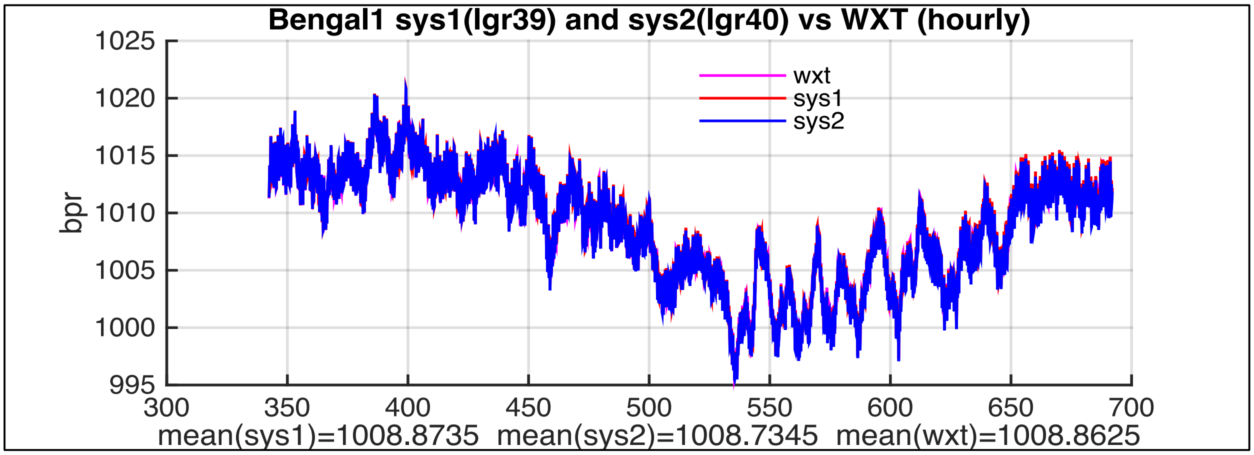
HRH: Both loggers look good overall, sys1 starts to drift below sys2 after yday 575.



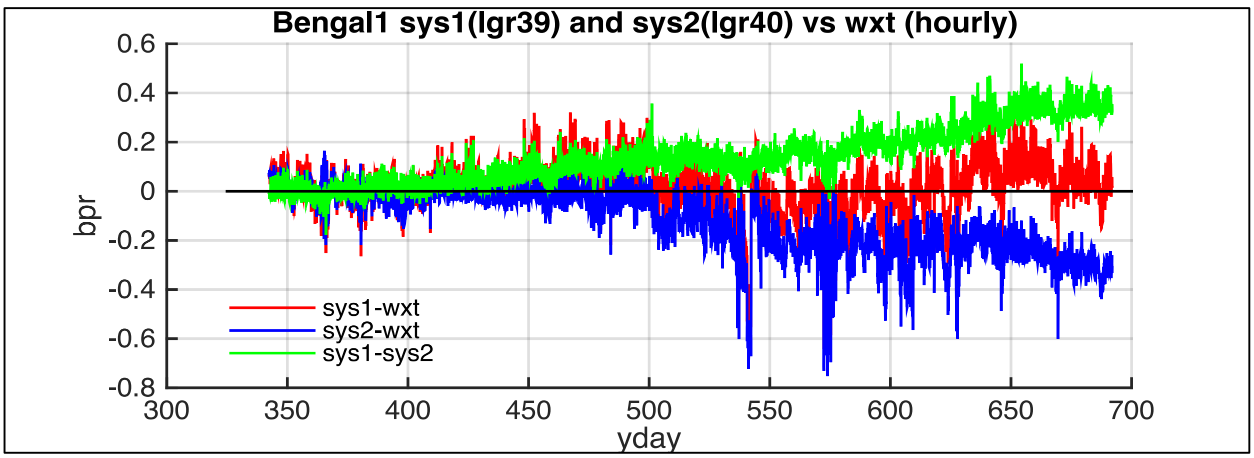
HRH: Check the differences between logger and the standalones; sys1 drifts downwards.



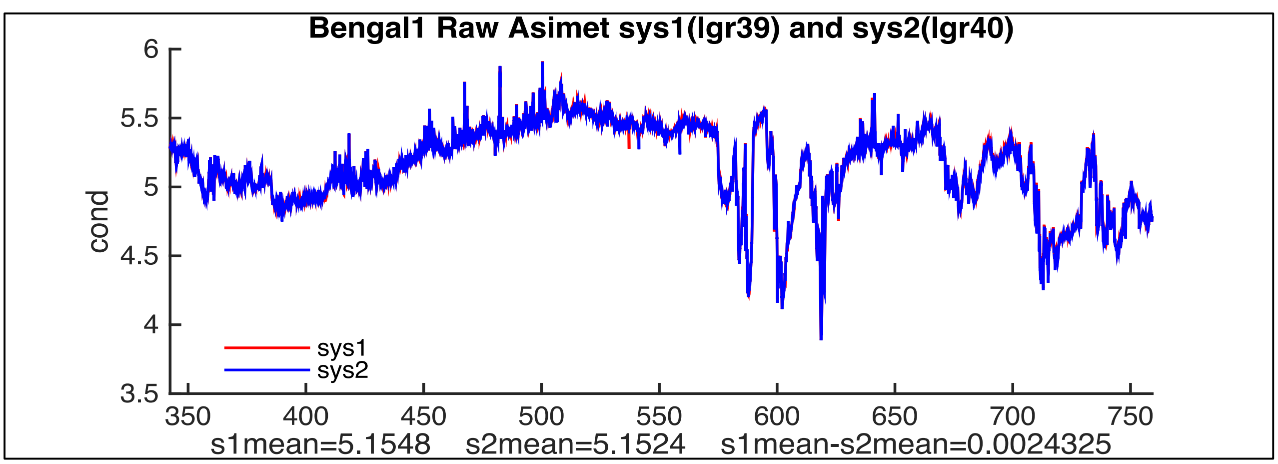
BPR: Both loggers look good.



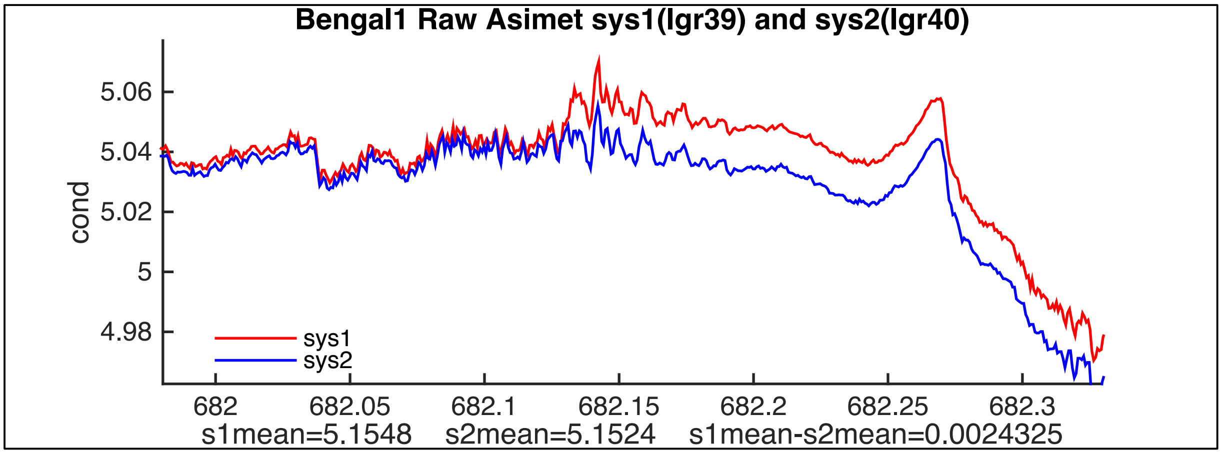
BPR: Compare loggers with standalone WXT.



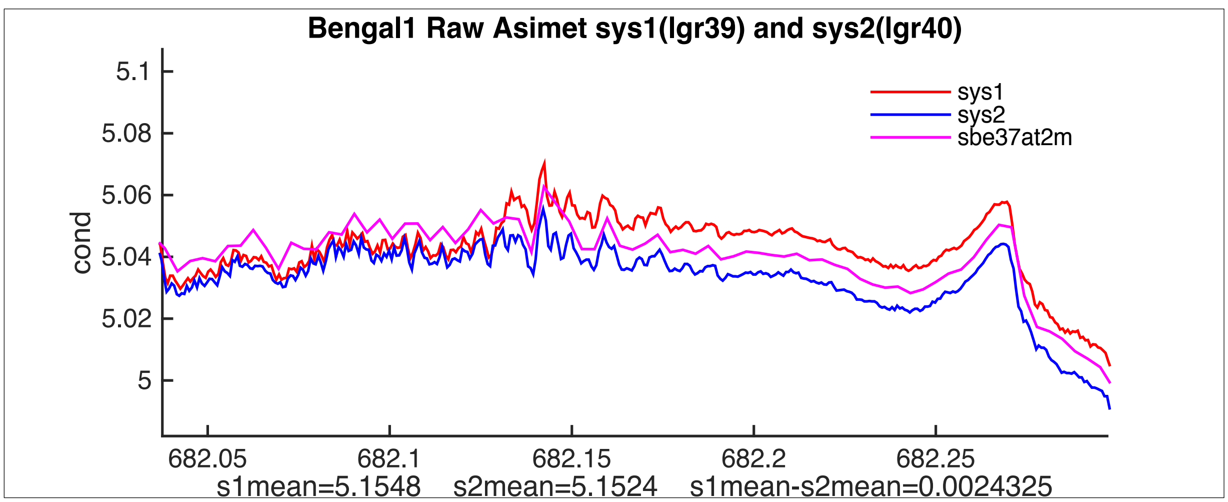
BPR: Check the differences between logger and standalone wxt; sys2 drifts downwards.



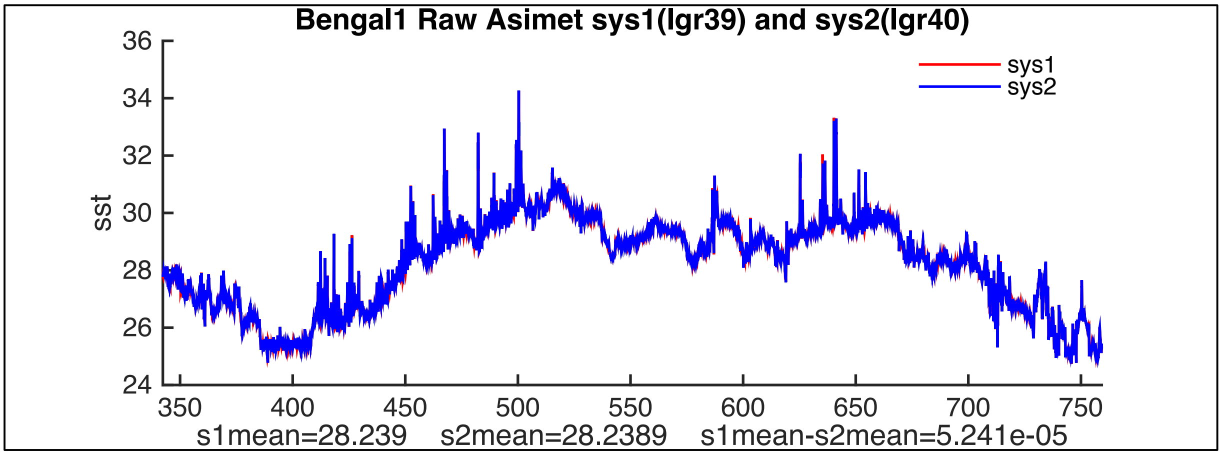
COND: Both loggers look good over all.



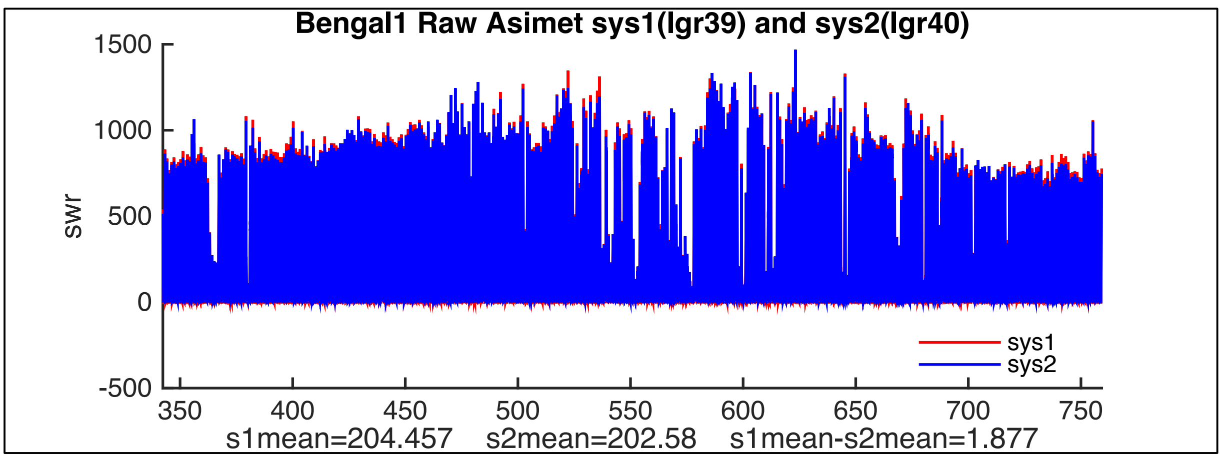
COND: However, sys1 returns much higher value than sys2 after yday 682.



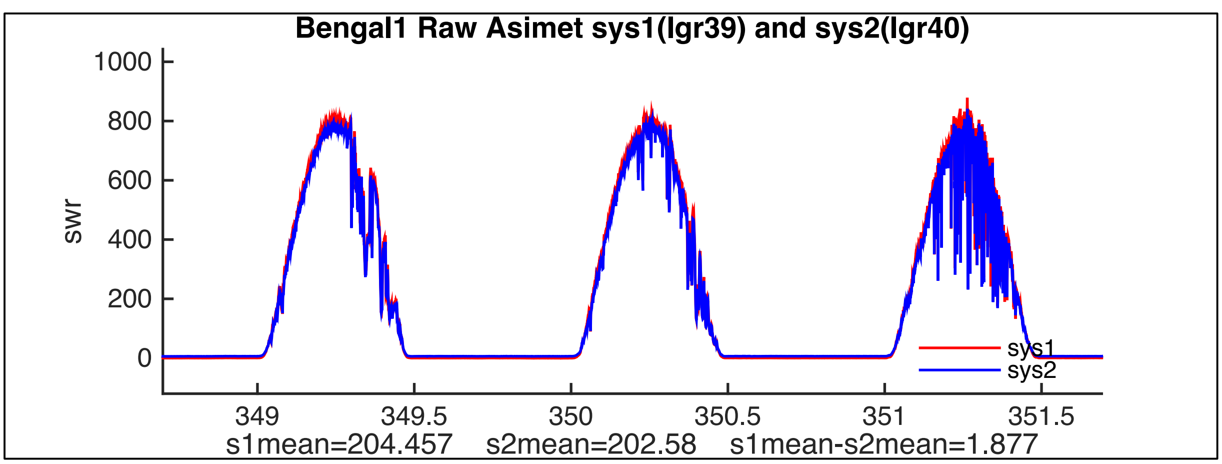
COND: Compare with SBE37 at 2.3m; sys2 looks good.



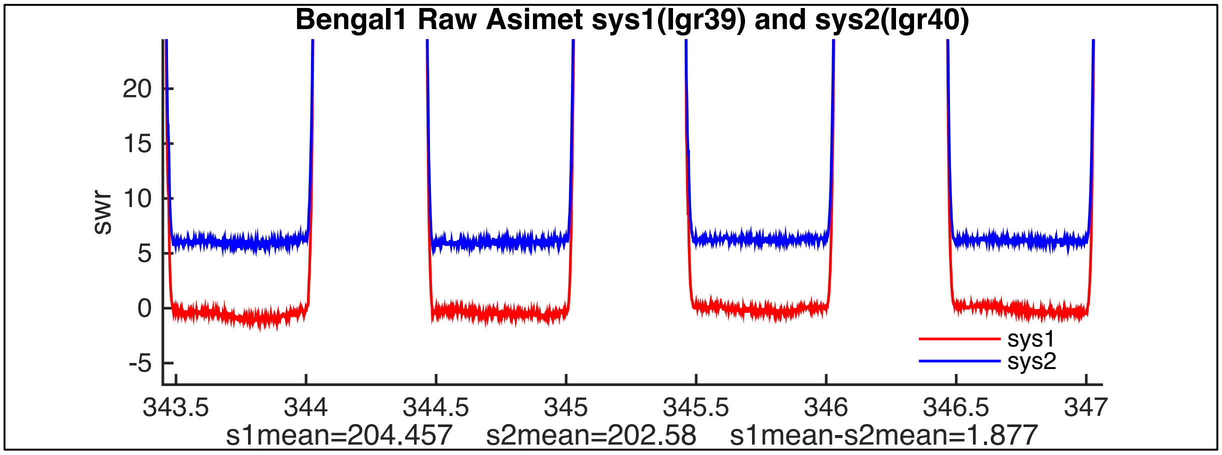
SST: Both loggers look good.



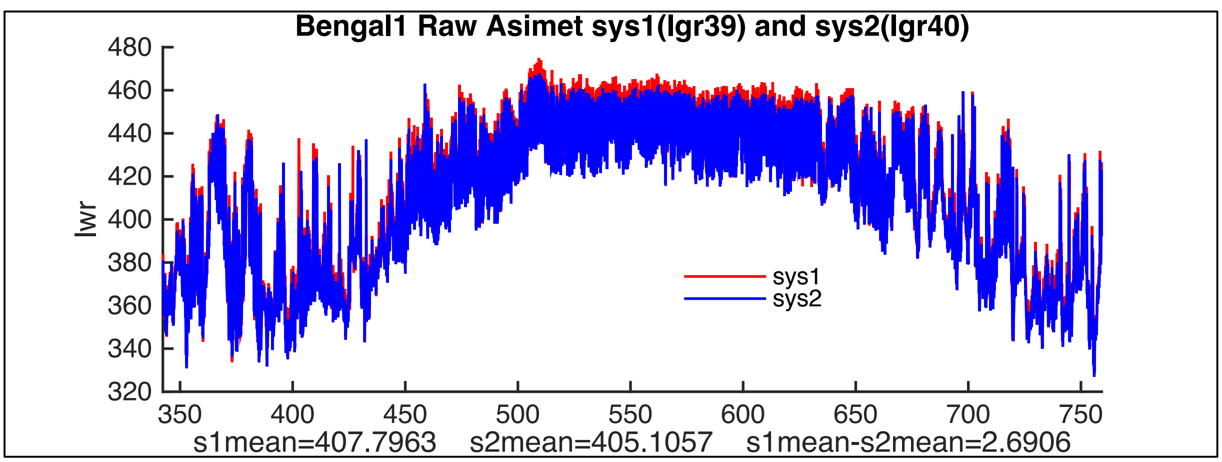
SWR: Both loggers look good overall.



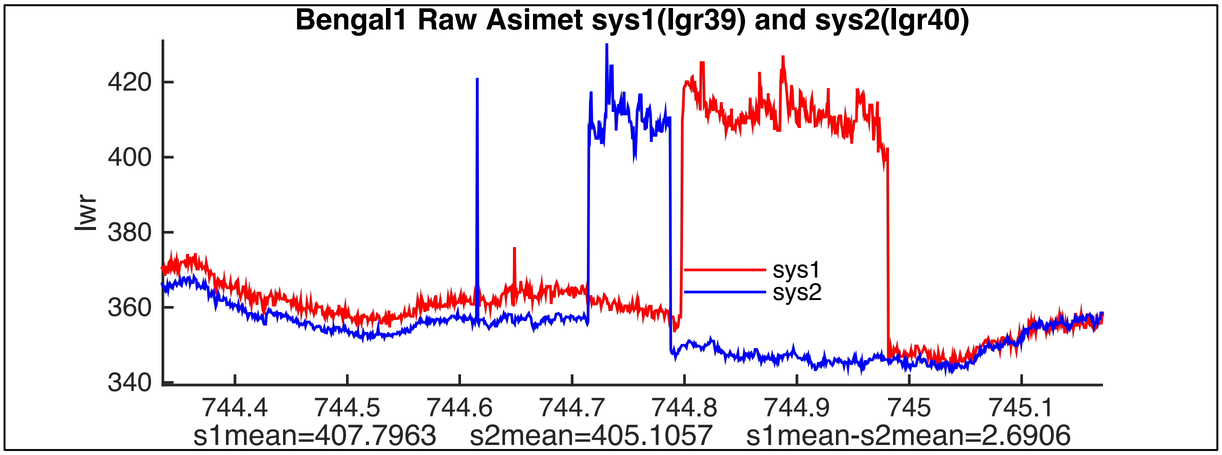
SWR: Daytime sys1 and sys2 agree well.



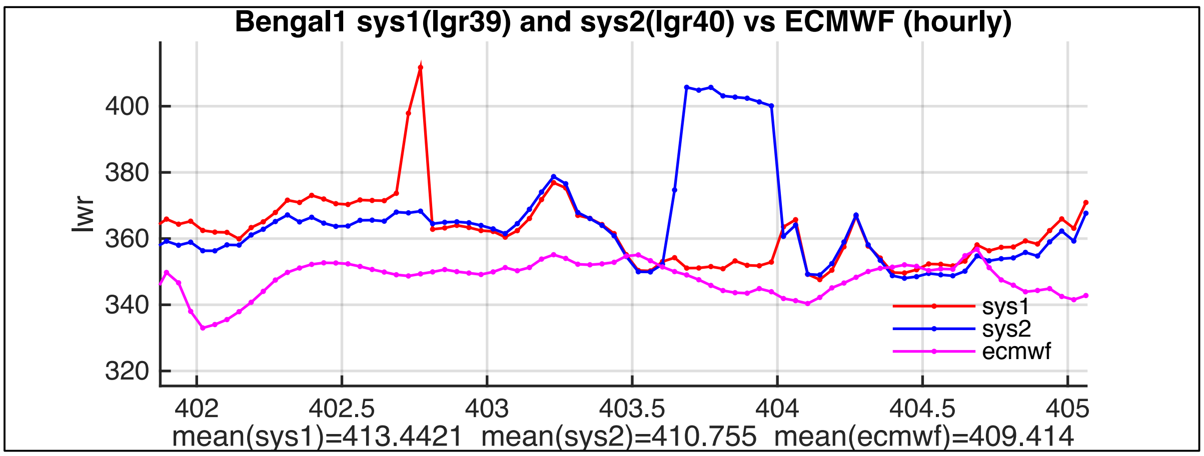
SWR: However, sys2 during nighttime is 6W/m2 above zero.



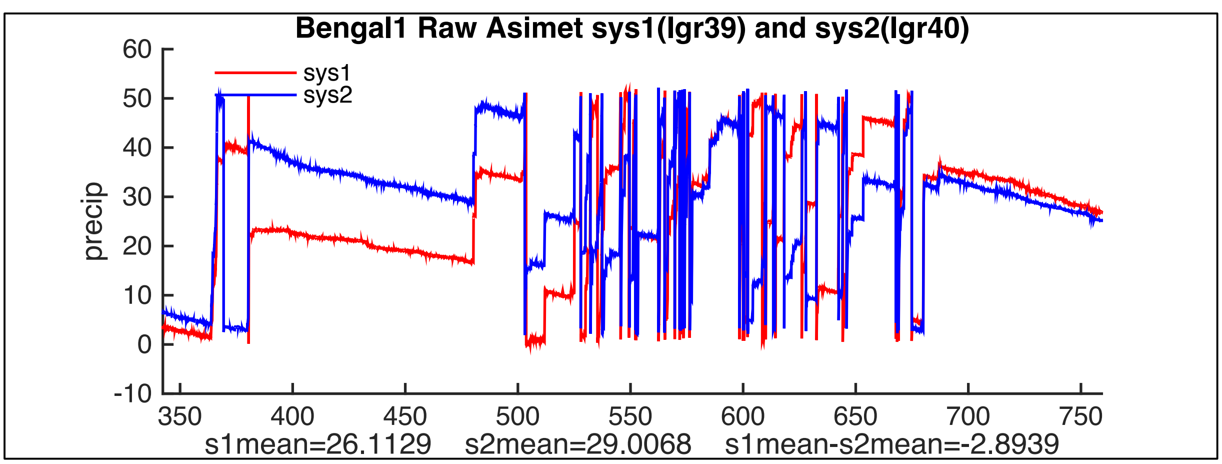
LWR: Both loggers look good overall.



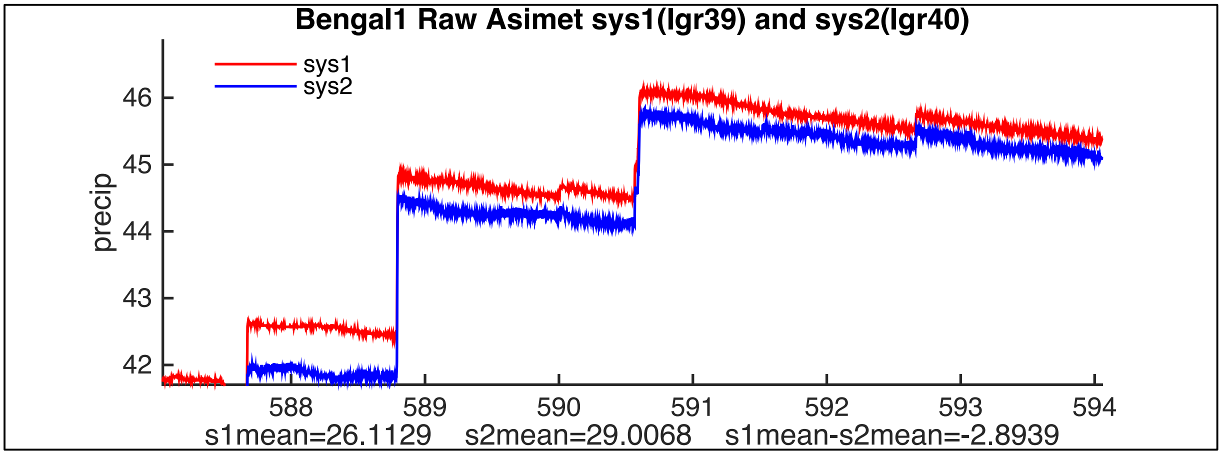
LWR: Section showing lwr spikes in both loggers.



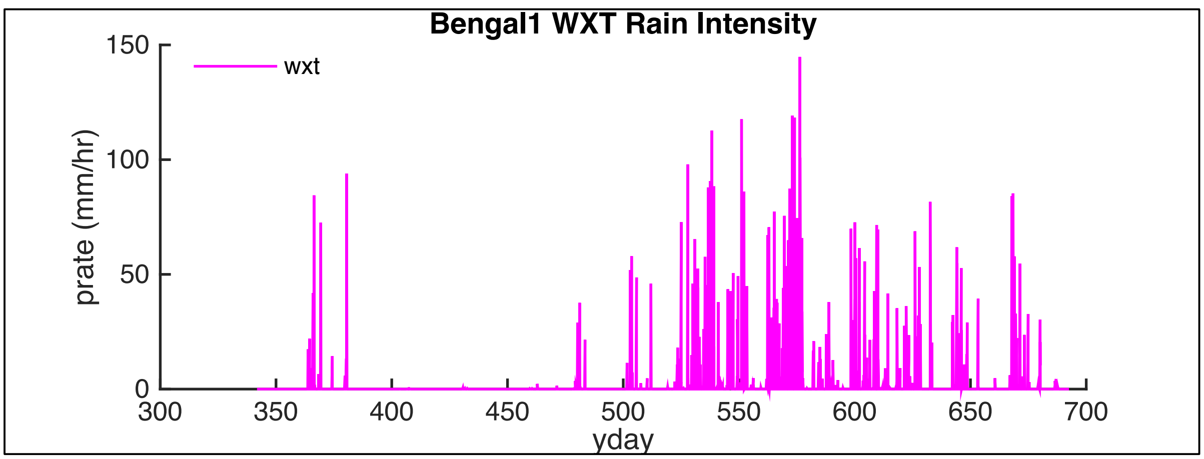
LWR: Compare with ECMWF; the spikes could be caused by birds standing on the sensors.



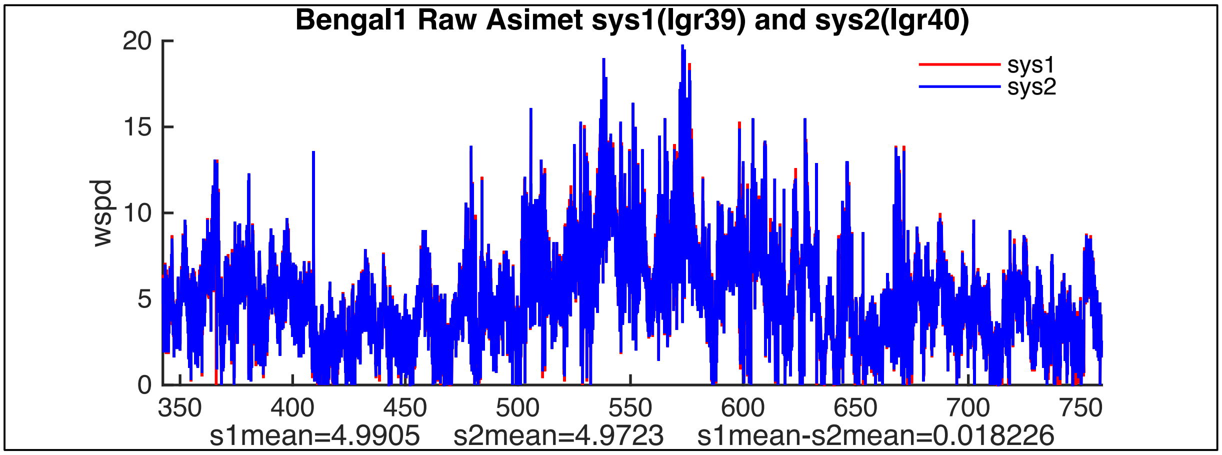
PRECIP: Both loggers look good.



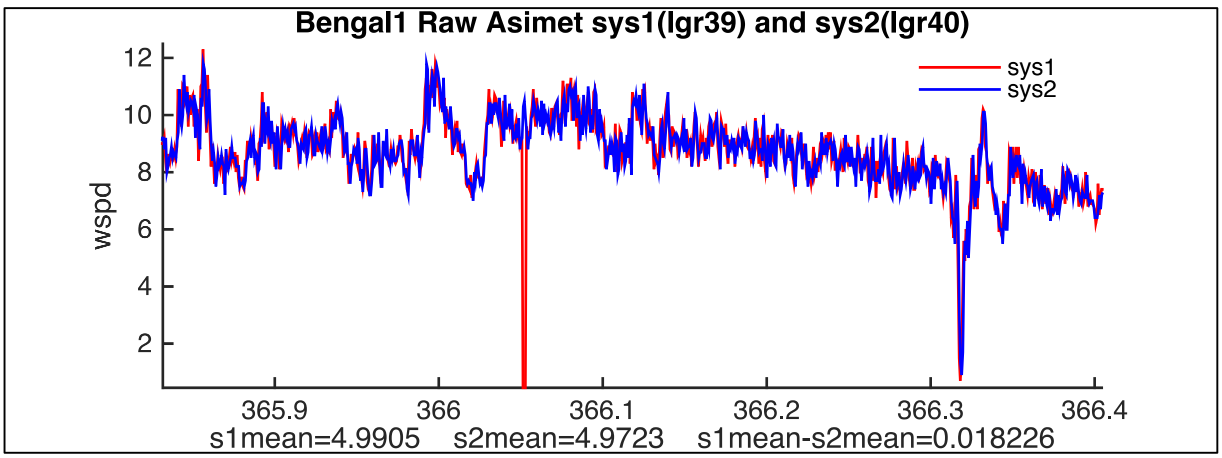
PRECIP: Section showing small spikes in the returns.



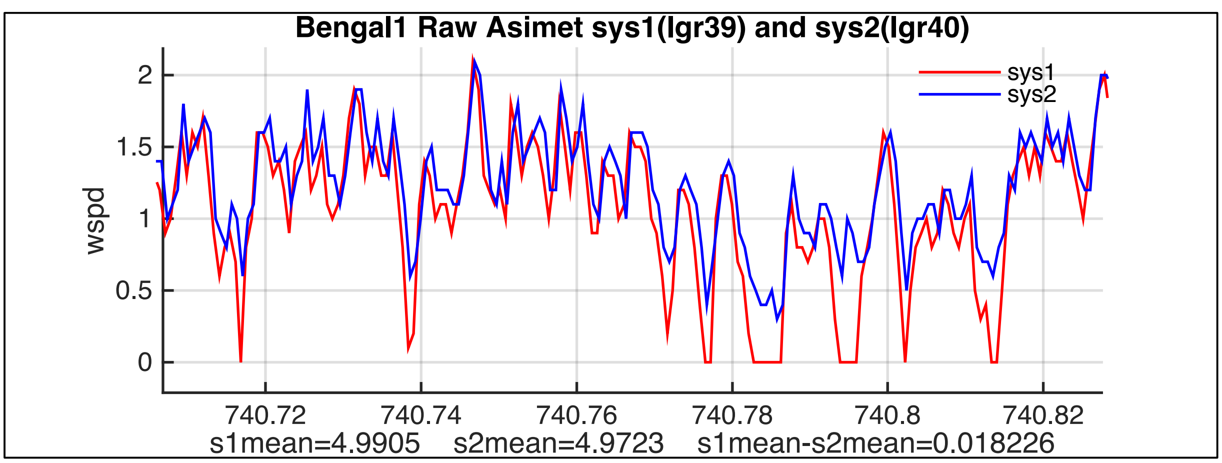
PRECIP: Standalone WXT's prlev failed after mid-way, but WXT's prate is good until yday 688.



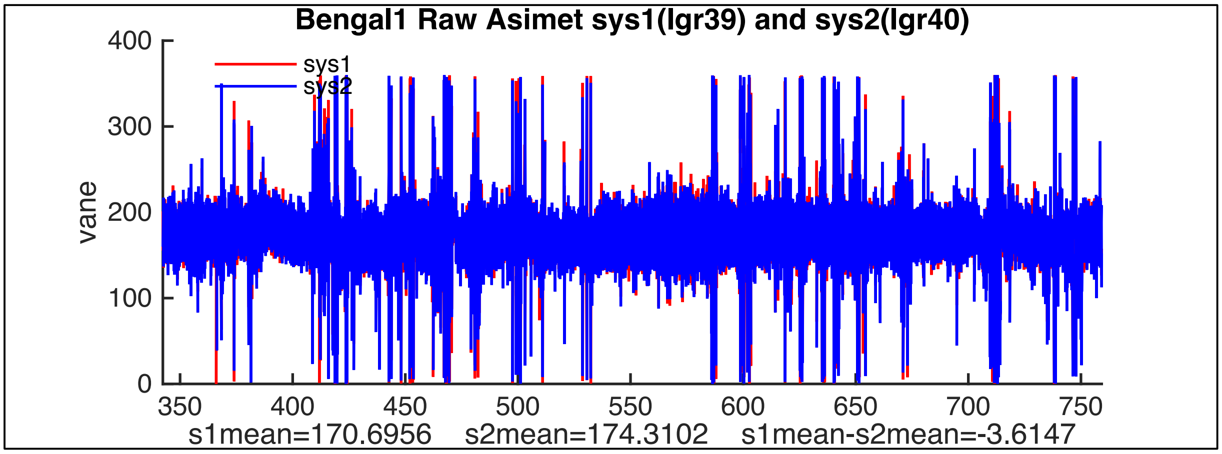
WSPD: Both loggers look good.



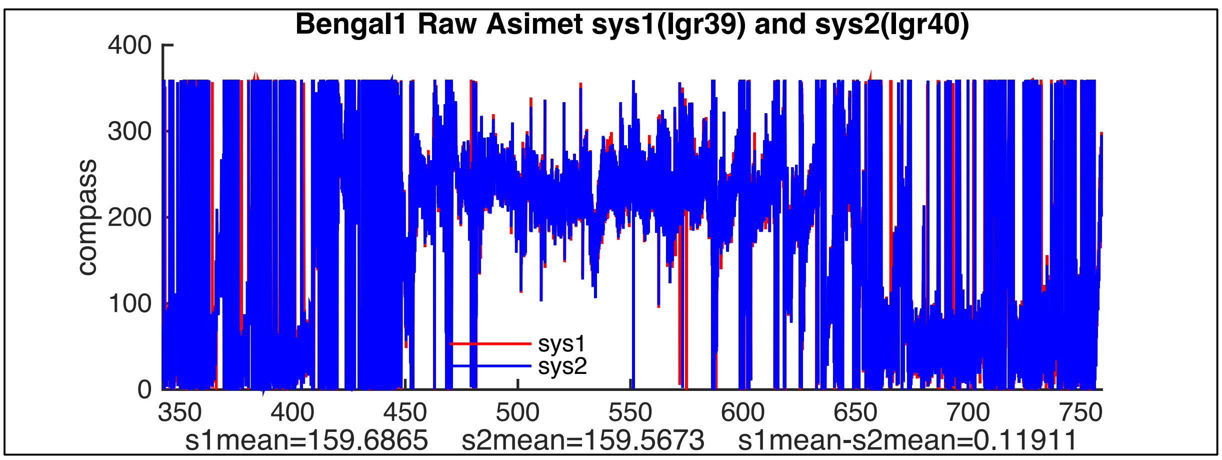
WSPD: Section showing sharp sensor spikes in sys1; sys2 has fewer spikes.



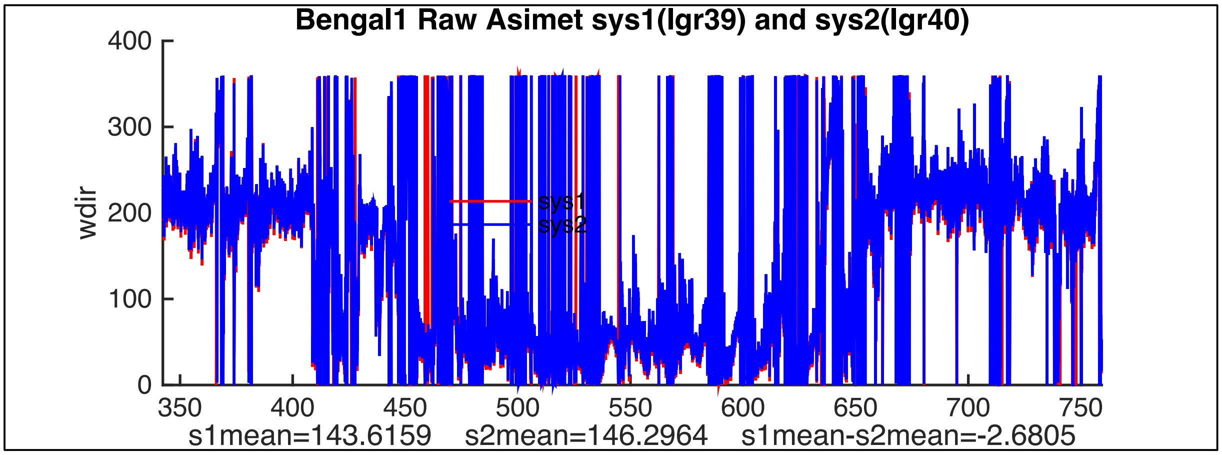
WSPD: Section showing sys1 has lower (and near zero) returns than sys2.



VANE: Both loggers look good.



COMPASS: Both loggers look good.



WDIR (VANE+COMPASS): Both loggers look good.

2. Selecting baseline data for each of the variables:

- ATMP: sys2-lgr40 is picked as baseline data since it has much less overheating problems during the days when wind speed drops below 4m/s.
- HRH: sys2-lgr40 is picked as baseline data; sys1-lgr39 drifts downwards by about 3% by the end of the deployment.
- BPR: sys1-lgr39 is picked as baseline data; sys2-lgr40 drifts downwards by about 0.4mbar by the end of the deployment.
- COND: sys2-lgr40 is picked as baseline data; sys1-lgr39 jumps after yday 682.
- SST: sys2-lgr40 is picked as baseline data to go along with sys2-lgr40's cond.; sys1-lgr39's sst is also good.
- SWR: sys1-lgr39 is picked as baseline data; sys2-lgr40's nighttime reading is about 6W/m2 higher than zero through out the entire deployment.
- LWR: sys1-lgr39 is picked as baseline data; sys2-lgr40 is good but has more spike segments.

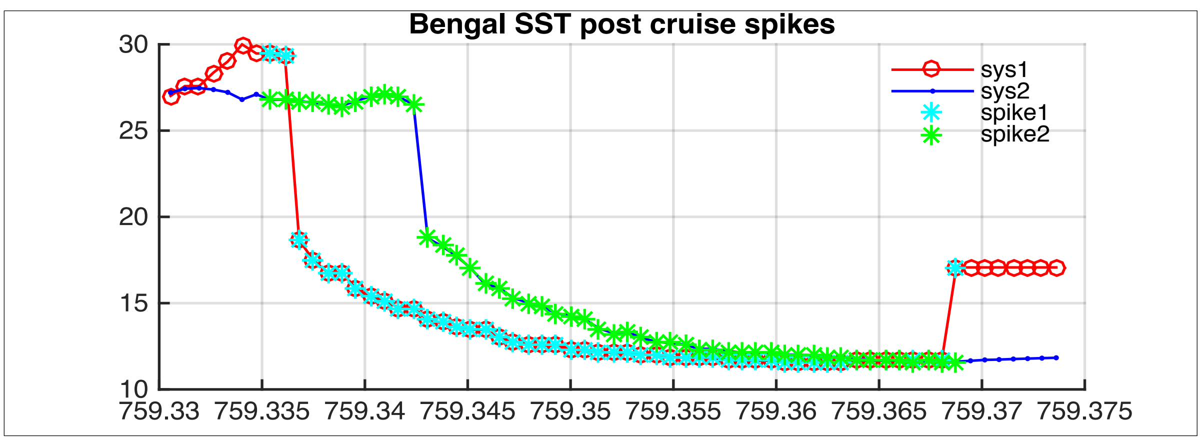
- PRECIP: wxt07's prate is picked as baseline data before yday 688, and the combined logger prate is used from yday 688 to the end.

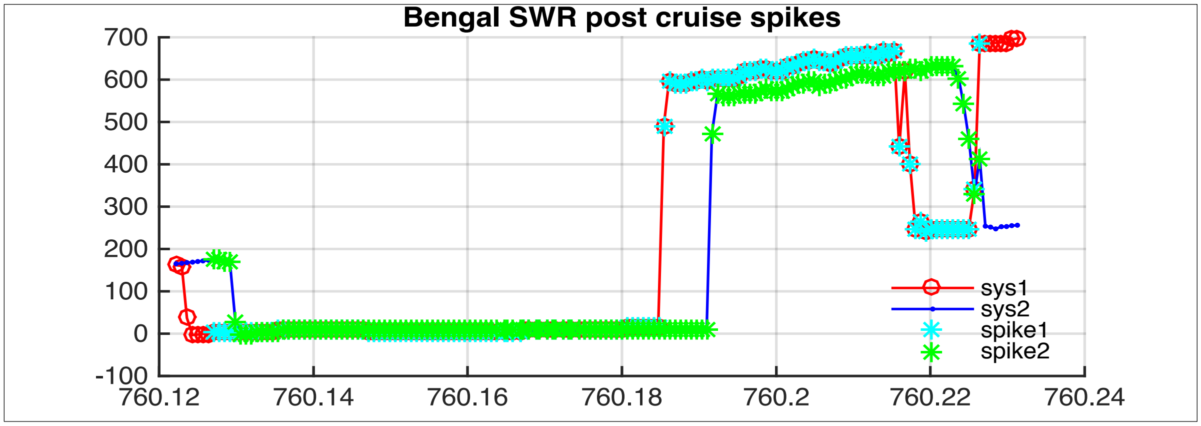
- WSPD: sys2-lgr40 is picked as baseline data; sys1-lgr39 is good but has more drop to zero spikes.

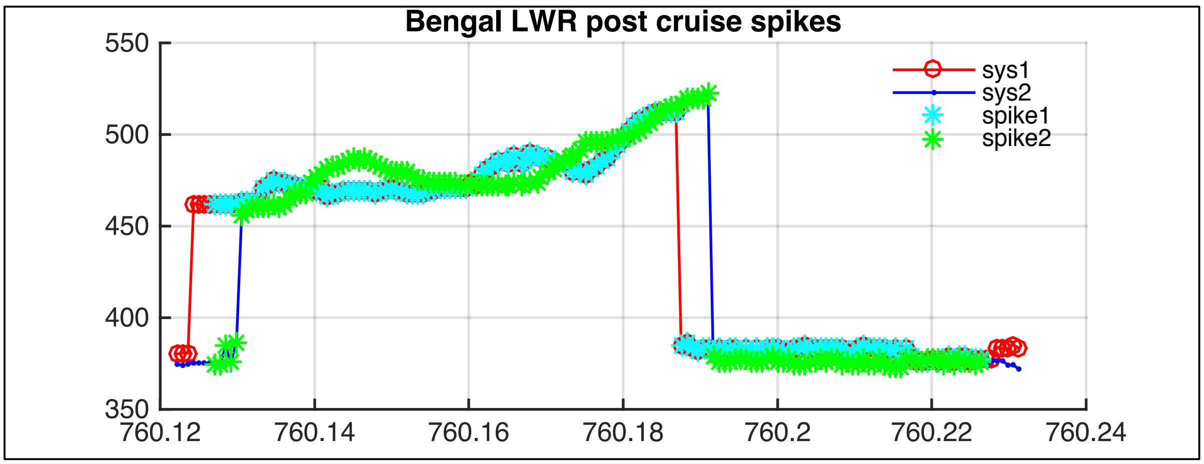
- WDIR: sys2-lgr40 is picked as baseline data to go along with sys2-lgr40's wspd; sys1-lgr39's wdir is also good.

3. *Checking logger clocks with post-cruise TIME SPIKES (in BoB1_Recovery.xls file).*

- Post-cruise time spikes were performed for sst, swr, and lwr after buoy recovery; the plots below show that sys1's clock is about 1 minute off and sys2's clock is about 9 minutes fast.





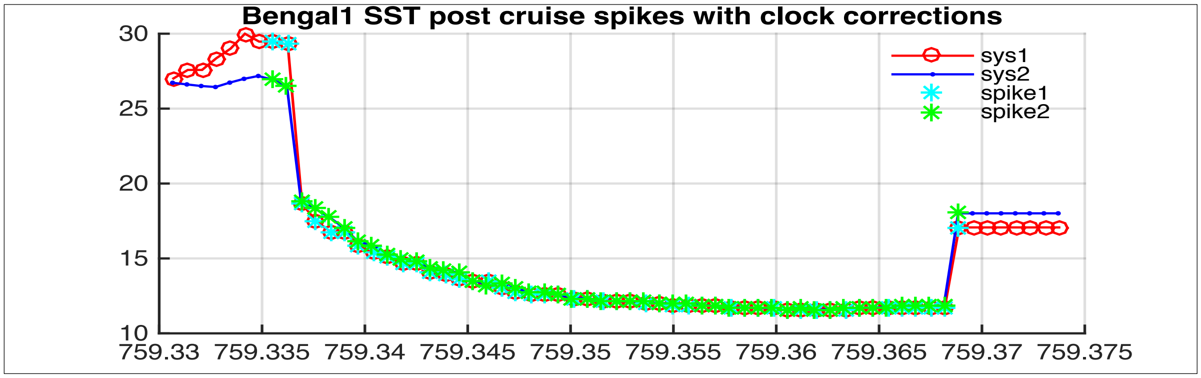


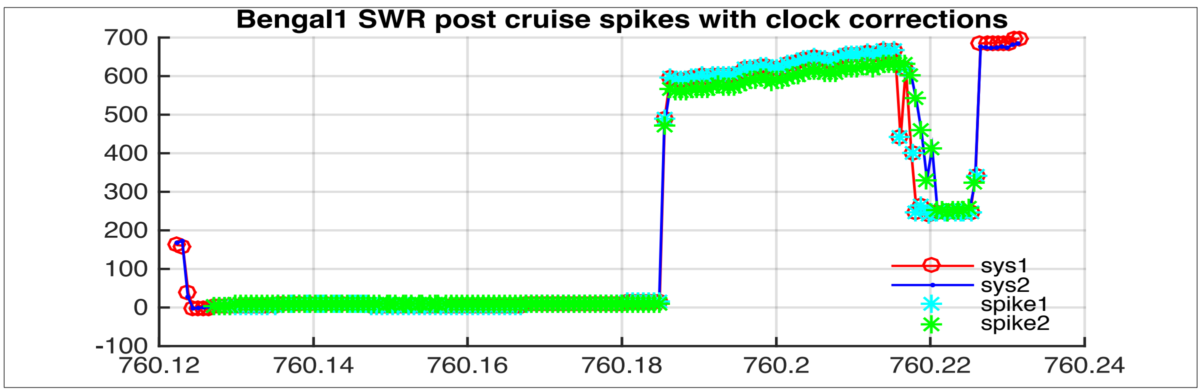
- Adjusting Logger Clocks

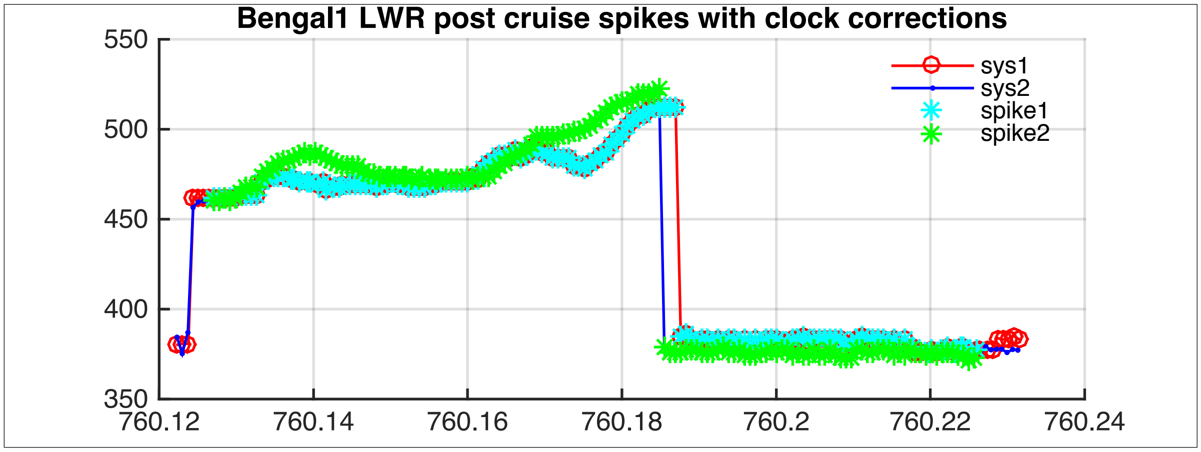
```
Ti=l1.mday;
Ta=[datenum(2014,12,08,08,30,0) datenum(2016,01,30,08,23,25)];
Tinstr=[datenum(2014,12,08,08,30,0) datenum(2016,01,30,08,23,13)];
Tcor=clock_drift(Ti,Ta,Tinstr,1);
% replace yday of l1 with the corrected Tcor
l1.yday=Tcor-datenum(year,1,0);

Ti=l2.mday;
Ta=[datenum(2014,12,08,08,30,0) datenum(2016,01,30,08,26,15)];
Tinstr=[datenum(2014,12,08,08,30,0) datenum(2016,01,30,08,35,08)];
Tcor=clock_drift(Ti,Ta,Tinstr,1);
% replace yday of l2 with the corrected Tcor
```

l2.yday=Tcor-datenum(year,1,0);

- Re-check logger clocks after time correction, both logger clocks are in good alignment







4. Comparing the mean values of the two loggers for the listed variables over the deployment

The means for the listed variables within the deployment time and expected ranges are calculated; out of data [max and min] range points are set to NaN before the average.

```
varn ={'atmp', 'hrh', 'bpr', 'lwr', 'swr',...
    'sst', 'cond', 'sal', 'wnde', 'wndn', 'wspd', 'precip', 'vane', 'compass', 'wdir'};
```

```
maxv=[35, 120, 1025, 500, 1650, 38, 6.5, 35,  20,  20, 25, 60, 365, 365, 365];
minv=[15,  30,  950,  280,   -10,  20,  3,   25, -20, -20,  0, -10,  -5,   -5,   -5];
```

variable	sys1mean	sys2mean	s1mean-s2mean	range(min,max)
atmp	27.4610	27.4222	0.039	(22.18, 32.42)
hrh	74.9721	76.3563	-1.384	(38.62, 98.34)
bpr	1009.7890	1009.6106	0.178	(994.88,1021.15)
lwr	407.7963	405.1057	2.691	(326.90,475.00)
swr	204.4570	202.5800	1.877	(-7.60,1468.40)
sst	28.2390	28.2389	0.000	(24.74, 34.27)
cond	5.1548	5.1524	0.002	(3.89, 5.91)
sal	31.6209	31.6043	0.017	(25.00, 34.13)
wnde	0.7993	0.8147	-0.015	(-12.82, 19.50)
wndn	0.3553	0.2627	0.093	(-14.23, 14.67)
wspd	4.9905	4.9723	0.018	(0.00, 19.79)
precip	26.1129	29.0068	-2.894	(-0.09, 52.18)

vane	170.6956	174.3102	-3.615	(0.00,359.90)
compass	159.6865	159.5673	0.119	(0.00,359.90)
wdir	143.6159	146.2964	-2.681	(0.00,359.95)

5. *Comparing logger data with ship met during buoy recovery*

Pre-cruise ship data has been compared to logger returns, they agree well.
However, there is no ship data available for making comparisons during buoy recovery.

6. *Data quality checking for each of the variables*

a) For each variable, set the picked baseline data as basic value, and set the other logger as backup data.

b) Set outside range points or segments to NaN.

c) Apply magvar to wind direction and east and north components.

d) Re-grid both loggers to the same new even time grid.

e) Fix spikes and problematic segments:

- For each variable: spikes and problematic segments are flagged and set to NaN first; then these flagged points are replaced by good points from the backup logger with offset adjusted when necessary.

- For atmp: overheating days are first identified (when atmp differs between the loggers is greater than 0.4 degrees during the day and the wind speed is less than 4m/s); overheated daytime atmp is replaced by the lower atmp from the back up logger; standalone wxt and lascar atmp are also used to help confirming the overheating among the sensors.

- For hrh: spikes are flagged and fixed; no bias adjustment is performed.

- For lwr: spikes causing by birds are identified (when the hrh differs between the loggers is greater than 20w/m2); flagged lwr value is replaced by the lower lwr from the backup logger.

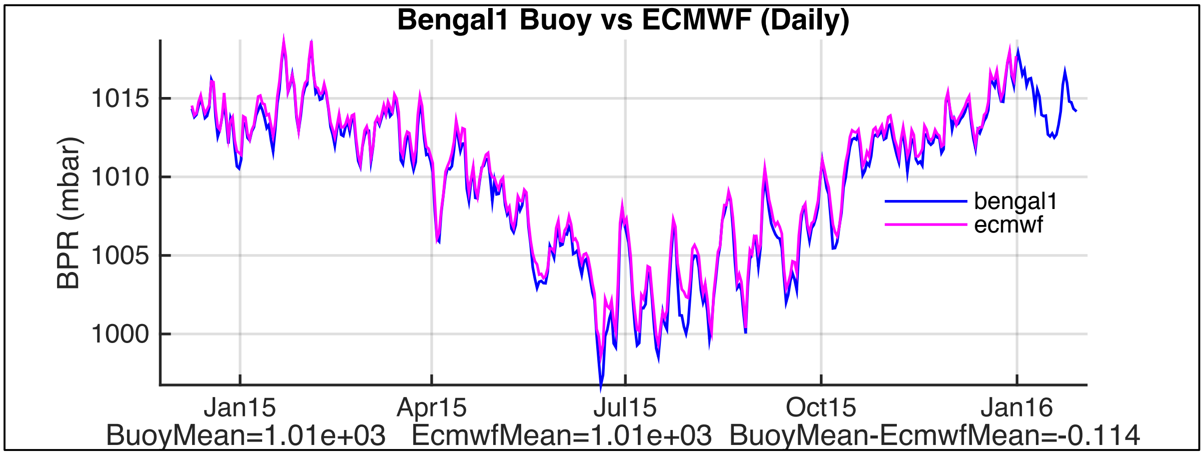
- For swr: spikes caused by birds are identified (when the swr differs between the two loggers is greater than 100w/m2 during the daytime); flagged swr is replaced by the higher swr from the backup logger; clearsky swr is calculated to help set the night time swr to zero.

- For cond: spikes, and drop and jump segments are identified and flagged; the flagged values are adjusted or replaced by the good points from the backup logger.
- For wind: spikes are identified (when both wnde and wndn drop to zero); the flagged points are replaced by good points from the backup logger;
- For precip: wxt07's rain rate is used before it failed on yday 688; then the combined logger precip is added to the data from 688 to the end of the deployment.
- For each variable: if the flagged points can not be replaced by the backup data, they are linearly interpolated by good neighboring data points.
- For each variable: all fixed and replaced points are plotted and rechecked to make sure the corrections/replacements/interpolations are intended.

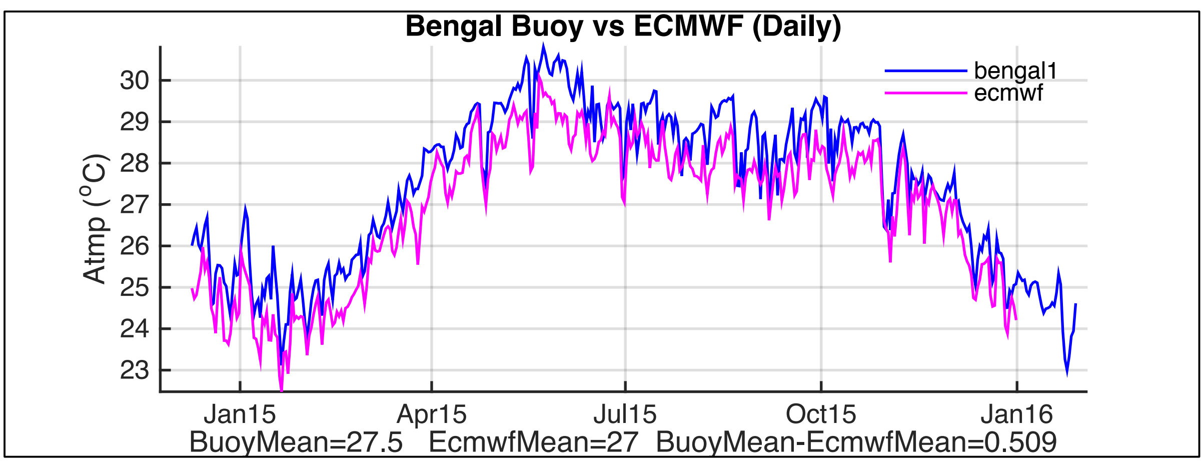
f) Finally, all fixed time series for each of the variables are combined to form the best one minute surface meteorological time series

7. *Averaged* files

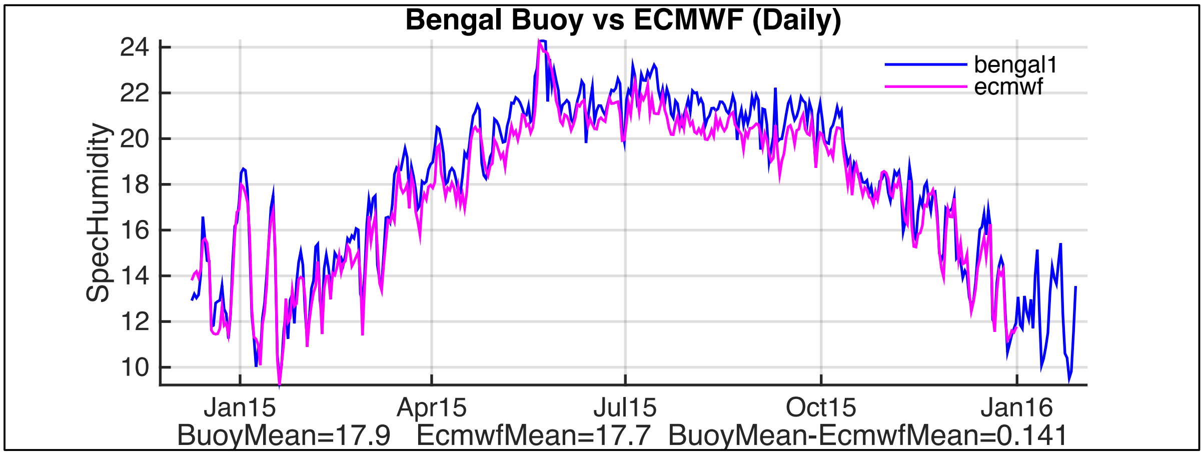
Finally, the hourly, daily, and monthly averages are calculated from quality checked one minute surface met for each of the variables. They are compared with model ECMWF outputs. Any unexpected changes or variations in met data are checked again.



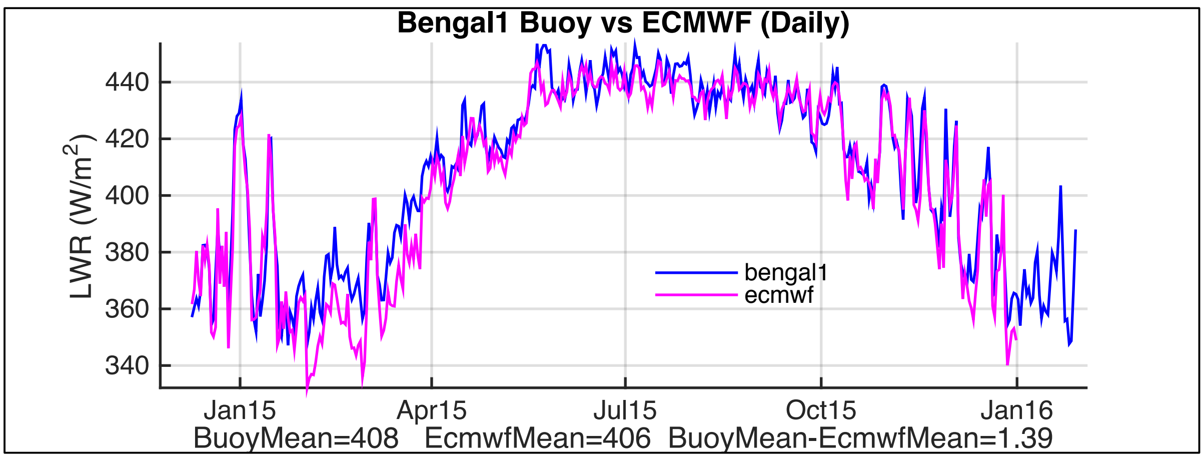
BPR: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



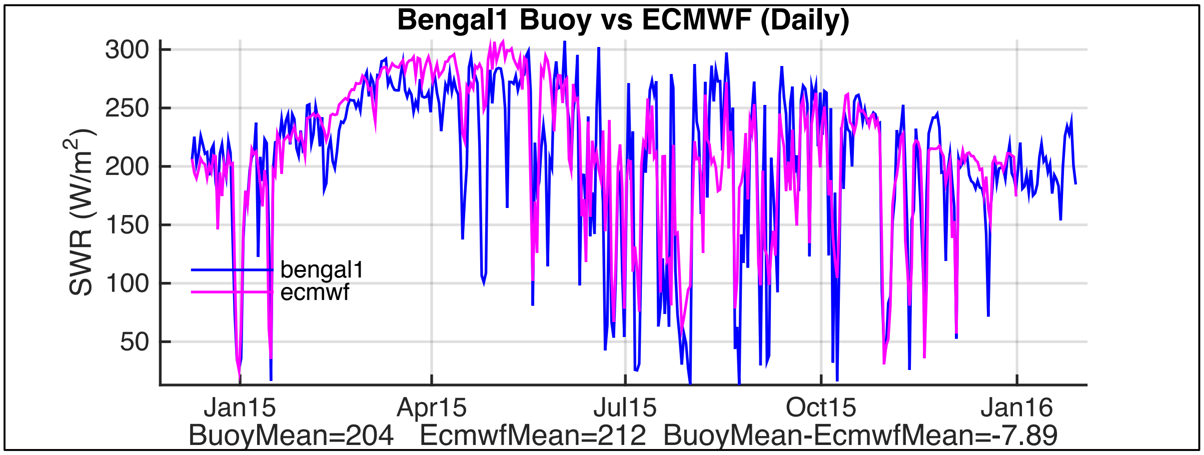
ATMP at 2m: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



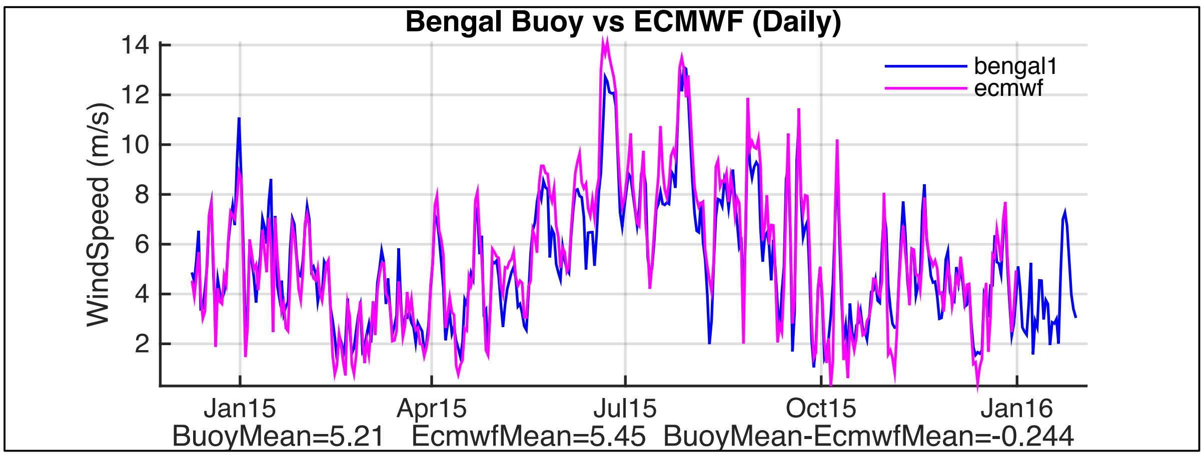
SH at 2m: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



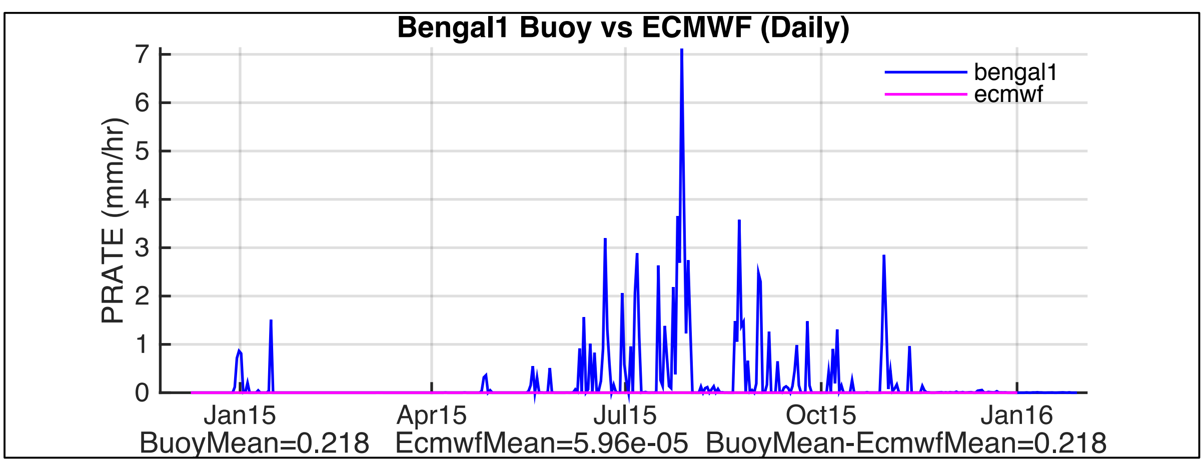
LWR: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



SWR: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



WSPD at 10m: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



RAIN RATE: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.

II. Flux calculation based on quality checked surface met results

1. Subsurface Nortek current meter (Aquapro 11437) returns at 2m are used to calculate the relative wind speed (wind at sensor height – current at 2m depth). The current data and its time are checked and adjusted before the relative wind calculation.

2. Coare flux algorithm (in matlab) version 3.0a (last modified on Jan19, 2006) is used for fluxes calculation.

   a) Input variables and parameters (from quality checked one minute met file):

   year, lat, lon, yday, relwspd, relwdir, wdir, sst, atmp, bpr, sh, swr, lwr, prate

   jcool=1; jwarm=1; albedo=0.055;

   deck_height=0.80; % meters

   zatmp_in=2.22 + deck_height;
   zhum_in=2.22 + deck_height;
   zwspd_in=2.67 + deck_height;
   zsst_in=1.5 - deck_height;

   zwspd_out = 10.0; % adjusted height for output wind
   zatmp_out = 2.0; % adjusted height for output atmp and humidity
   zhum_out = 2.0;

   b) Output variables and parameters (saved to one minute flux file):

   mday, year, yday, magvar, procdate, lat, lon, current_sn, currentdepth,
   atmp, sh, bpr, swr, lwr, sst, prate, relwspd, relwdir wdir,
   zwspd_in, zatmp_in, zhum_in, zsst_in,

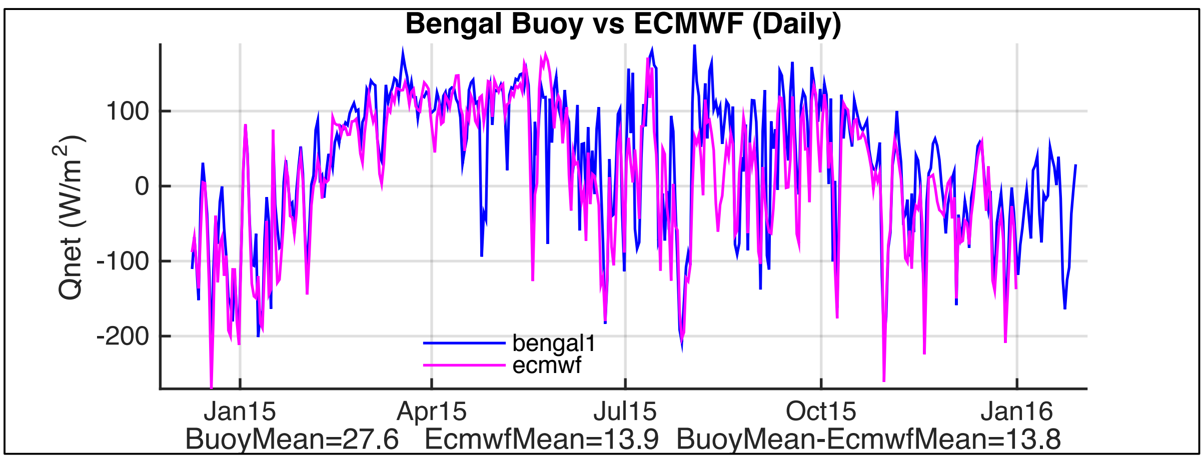
   QB, QH, Qs, Ql, QN, taumag, taudir, taue, taun, ws_h, qq_h, ta_h, tskin,
   Stability, ustar, drag, wg, wbar, Qr, tau_r, rough, roughlen,
   qstar, tstar, CH, CE, Z0t, Z0q, dt_wrm, dter,

tk_pwp, tkt, zwspd_out, zatmp_out, zhum_out, jcool, jwarm, albedo

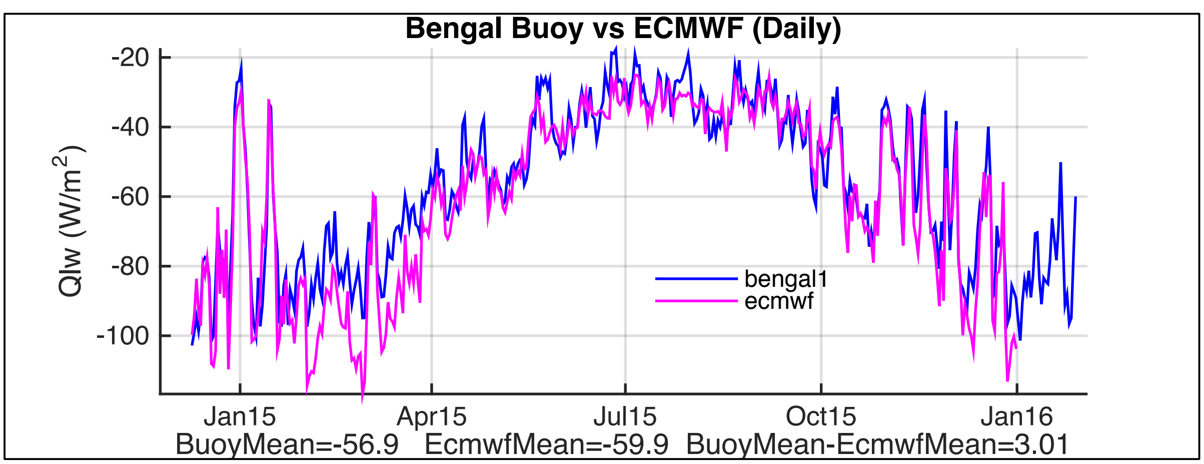
3. The hourly, daily, and monthly averages are calculated from one minute flux results for each of the variables, all flux time series are saved on buoy2_hd in folder:

/buoy2_hd/users/shared/projects/Bengal/Bengal1/BoBForDistribution/met_flux/

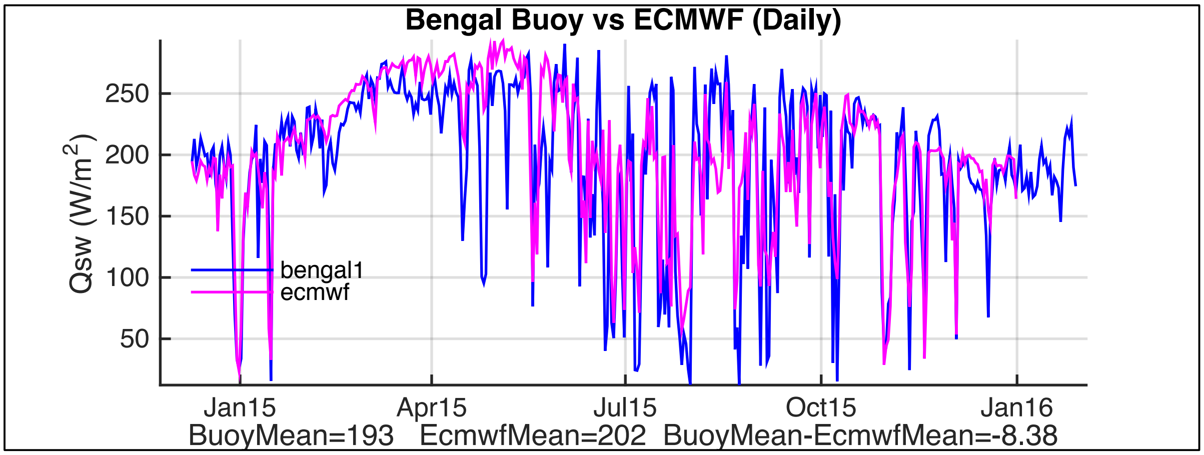
4. The daily fluxes are plotted against model ECMWF outputs at Bay of Bengal site:



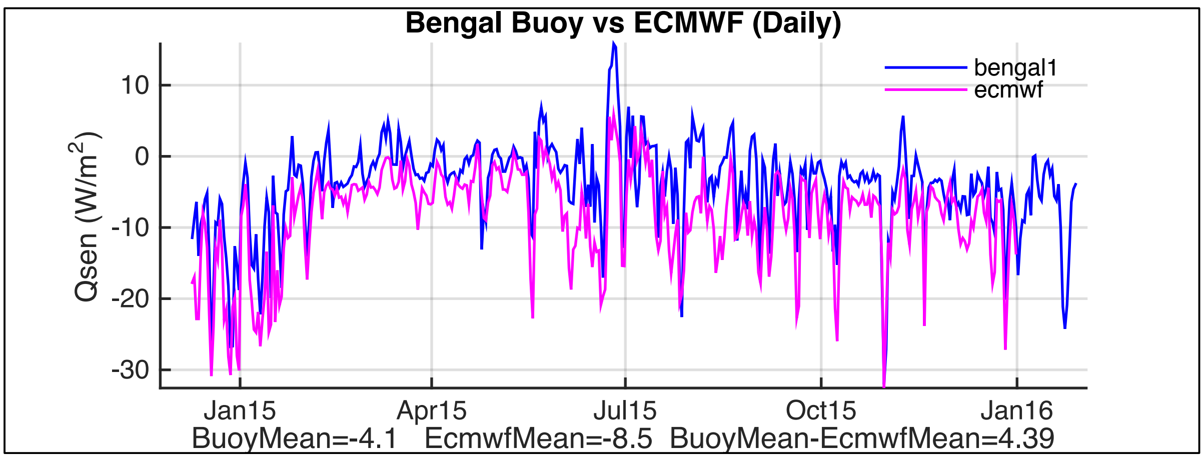
Qnet: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



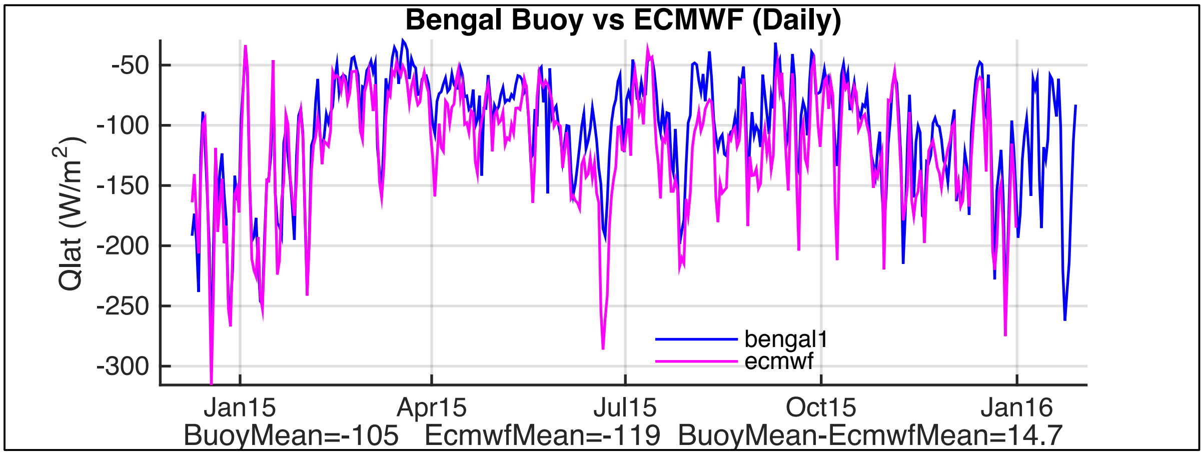
Qlw: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



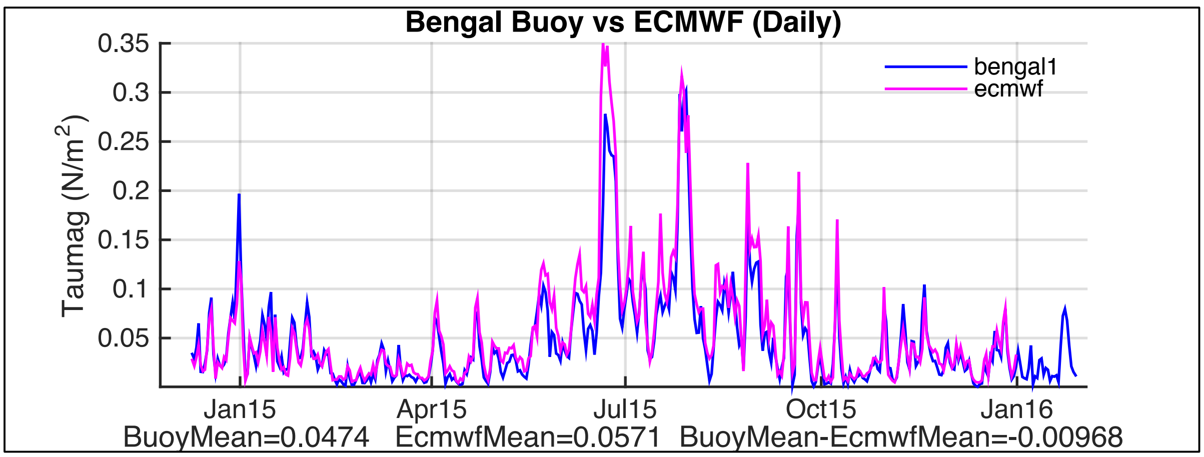
Qsw: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



Qsen: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



Qlat: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.



Taumag: Bay of Bengal Buoy vs model ECMWF from Dec 09, 2014 to Jan 28, 2016.