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Direct/bulk fluxes from the 2004 NOAA ICART/NEAQS Cruise
Version C

The data file contains computations of bulk meteorological variables and fluxes derived the ETL system based on preliminary analysis done during the NEAQS 2004 cruise in the coastal area of New Hampshire and Maine (43N 70 W). Most quantities given are subject to future modification based on accounting for other sources of data and revised calibrations.

The first release of turbulent and bulk fluxes for the ICART/NEAQS cruise. This document is the Readme for *crus_hr.txt* and *crus_10.txt* files where 'crus'= is described below. The *_hr* refers to hourly averages; the *_10* to 10-minute averages.

The data files *crus_hr.txt* and *crus_10.txt* contain measurements of turbulent and radiative fluxes plus bulk meteorological variables from the R/V Ronald H. Brown in various legs of the New England cruise of the summer of 2004. The files also contain bulk estimates of the turbulent fluxes computed using a recently updated version (3.0) of the COARE flux algorithm (see ftp://ftp.etl.noaa.gov/user/cfairall/bulkalg/ for documentation). Most quantities have been subjected to one round of intercomparison/calibration scrutiny; however, there may be future modifications based on accounting for other sources of data and revised calibrations. Both direct (covariance) and inertial-dissipation (ID) turbulent flux calculations are included in this present data.

The files are 51 columns; lengths depend on the length of the data sets (hours column in table above gives length for the _hr data). Following the decimal julian date, the next 10 columns are mean variables from the ETL system; the last 8 columns are similar data from the ships sensors. Columns 12-21 are turbulent fluxes (covariance, ID, and bulk); columns 22-23 the radiative fluxes and 24 the rain rate. Columns 25-28 are turbulence data quality indicators; 29-32 turbulent structure function parameters (indices of small-scale turbulence in the inertial subrange). Columns 33-34 are the minor (rain and Webb) heat flux components; 35-36 the latitude and longitude; 37-39 the heights of the ETL wind, temperature, and humidity mean sensors. The data columns are presently labeled and numbered at the top (first two rows). Delete the first two rows and restore as a .txt file so they can be directly acquired with a MATLAB 'load' statement.

```
x=load('your_local_directory\crus_hr.txt');%read file with hr-average data;
set your local directory
```

The columns are as follows:

```
   jdy=x(:,1);%julian day at beginning of time average
   ushp=x(:,2);%doppler log, SCS (m/s)
   U=x(:,3);%true wind,ETL sonic (m/s)
   dir=x(:,4);%true wind direction, ETL sonic (deg)
   urel=x(:,5);%relative wind speed, ETL (m/s)
   reldir=x(:,6);%relative wind direction (from),clockwise rel ship's bow, ETL
      sonic (deg)
```

```
head=x(:,7);%ship heading, deg clockwise rel north, SCS laser ring gyro
   (deg)
tsnk=x(:,8);%sea snake temperature, ETL, 0.05 m depth (C)
ta=x(:,9);%air temperature, ETL (C)
qse=x(:,10);%sea surface specific humidity, from snake (g/kg)
qa=x(:,11);%air specific humidity, ETL (g/kg)
hsc=x(:,12);%sensible heat flux, covariance, ETL sonic anemometer(W/m^2)
hsib=x(:,13);%sensible heat flux, ID, ETL sonic anemometer(W/m^2)
hsb=x(:,14);%bulk sensible heat flux, (W/m^2)
hlc=x(:,15);%latent heat flux, covariance, (W/m^2)
hlib=x(:,16);%latent heat flux, ID, (W/m^2)
hlb=x(:,17);%bulk latent heat flux, W/m^2 (includes Webb et al. correction)
taucx=x(:,18);%covariance streamwise stress, ETL sonic anemometer (N/m^2)
taucy=x(:,19);%covariance cross-stream stress, ETL sonic anemometer (N/m^2)
tauib=x(:,20);%ID streamwise stress, ETL sonic anemometer (N/m^2)
taub=x(:,21);%bulk wind stress along mean wind, (N/m^2)
rs=x(:,22);%downward solar flux, ETL units (W/m^2)
rl=x(:,23);%downward IR flux,  ETL units (W/m^2)
org=x(:,24);%rainrate, ETL STI optical rain gauge, uncorrected (mm/hr)
J=x(:,25);%ship plume contamination index
sigoph=x(:,26);%standard deviation of ophir fast hygrometer clear channel
tiltx=x(:,27);%flow tilt at ETL sonic anemometer, earth frame
Jm=x(:,28);%ship maneuver index
ct=x(:,29);%ct^2 (K^2/m^.667)
cq=x(:,30);%cq^2 ((g/kg)^2/m^.667)
cu=x(:,31);%cu^2 ((m/s)^2/m^.667)
cw=x(:,32);%cw^2 ((m/s)^2/m^.667)
hrain=x(:,33);%rain heat flux,Gosnell et al 1995, JGR, 18437-18442, (W/m^2)
hlwebb=x(:,34);%correction to measured latent heat flux, Webb et al.
   1980,QJRMS, 85-100
lat=x(:,35);%latitude, deg  (SCS pcode)
lon=x(:,36);%longitude, deg (SCS pcode)
zu_etl=x(:,37);%height of mean wind sensor, 17.7 m
zt_etl=x(:,38);%height of mean air temperature sensor, 15.5 m
zq_etl=x(:,39);%height of mean air humidity sensor, 15.5 m
%*****   ships imet and scs data
sog=x(:,40);%speed over ground, SCS gps, (m/s)
U_scs=x(:,41); %true wind speed, imet propvane anemometer (m/s)
dir_scs=x(:,42);%true wind direction (from),clockwise rel north, imet,(deg)
cog=x(:,43);%%course over ground, SCS gps, (m/s)
tsg=x(:,44);%tsg water temperature, 5 m depth, (C)
ta_im=x(:,45);%imet air temperature (C)
qs_tsg=x(:,46);%imet bulk water specific humidity (g/kg)
qa_im=x(:,47);%imet air specific humidity, (g/kg)
rs_im=x(:,48);%imet solar flux, (W/m^2)
rl_im=x(:,49);%imet IR flux (W/m^2) – not connected for neaqs
hl_lic=x(:,50);%LICOR latent heat flux (W/m^2)
wco2_lic=x(:,51);%LICOR CO2 flux, (micatm m/s)
```

The data in this file comes from three sources: The ETL motion-correct flux package [sonic anemometer acquired at 20.83 Hz, OPHIR fast hygrometer acquired at 20 Hz, LICOR fast hygrometer and fast CO2 acquired at 10 Hz, and 6-component motion measurements acquired at 10 Hz), the ships SCS system (acquired at 2 sec intervals), and the ETL mean measurement systems (sampled at 10 sec and averaged to 1 min). The sonic is 5 channels of data; the SCS file is 13 channels, and the ETL mean system is 16 channels. A series of programs are run that read these data files, decode them, compute covariance, variances, spectra, etc. at 10-min time resolution. A set of 10-min process files are written for each cruise. One particular file, crus_da.dat consists of 164 columns of 10-min data including the turbulent and mean variables used here. A final program reads the crus_da.dat files, applies various corrections, computes the ID and bulk fluxes and the data quality indices, and writes the crus_10.txt files. This program also contains routines that average the data to fixed one-hr time intervals, computes the ID and bulk fluxes from one-hr means, and writes the crus_hr.txt files. Note, that in the case of the turbulent variables (covariances, variances, structure function parameters) only 10-min values that pass the data indicator criteria are used in the one-hr average.

Further experimental details are as follows:

True wind speed is computed from the sonic anemometer using the ship's Laser ring gyro and the odec doppler log; thus, it is interpreted as the speed relative to the water. Some modest eyeball flow distortion corrections to the relative wind components have been used in an attempt to reduce the transitions when stopping for stations.

Air temperature and humidity are from the ETL (aspirated Vaisala HMP-235). Final values are good to about 2% RH and 0.2 C.

At various times during some cruises the seasnake was removed from the water, in which case the ship's thermosalinograph, corrected for any warm layer effects, was substituted. Sea surface temperature measurements often showed contamination by the ship during stops and maneuvers at stations. The sensor was airborne a lot when the ship was underway in the stronger wind/rougher sea days and the accuracy under those conditions is uncertain.

Longwave flux was obtained from 2 Eppley PIR units, logged and computed as per Fairall et al. Jtech, 1998.

Shortwave flux was obtained from 2 Eppley PSP units. The original values were increased 5% based on intercomparisons with the BNL PRP.

The rainrate was obtained from the ETL STI optical raingauge. Note, this is model org-815 - not the mini-org used on COARE. No correction for cosine response has been attempted. There was a +0.1 to 0.4 mm/hr bias that has been removed.

Bulk estimates of air sea fluxes were computed using the COARE bulk algorithm version 3.0.

Turbulent fluxes were computed from motion-corrected time series of fast sensors. Covariance latent heat fluxes were obtained by cross-correlating the motion-corrected vertical velocity with fast humidity fluctuations from an OPHIR IR hygrometer. The turbulent fluctuations from the OPHIR were scaled by the mean ratio of the OPHIR humidity to the ETL Vaisala humidity. An additional scaling factor (4.5% increase) was used to account for the physical separation of the OPHIR and the sonic. Using a right-handed coordinate system with x boward, y to the port, and z up, the displacement vector from the OPHIR to the sonic is (1.0, 0.69, 1.57) m. We used Kristensen et al. (*J. Atmos. Oceanic Tech.*, **14**, 814-821, 1997) to estimate the correlation loss.

Because the IR hygrometers detect water vapor mass concentration (rho_v in kg/m^3), their water vapor - velocity correlations must be corrected as per Webb et al

Hlatent = Le <w’ rho_v’> + hl_webb

The values given for covariance and ID latent heat fluxes in the file are Le<w’ rho_v’>. Values for hl_webb are included in column 34. This should be applied to the covariance and ID values. It is already included in the bulk values given here.

Sensible heat flux was computed from vertical velocity - sonic temperature covariance. The humidity contribution to sonic temperature was removed using the bulk latent heat flux.

Both latent and CO2 fluxes are computed from the LICOR-7500 open path IR sensor. This sensor was out of calibration for *mean* humidity (70% high) and *mean* CO2 (15% high). We don’t have enough experience with this sensor to know the significance of this. Fluxes are based on the variations instead of the means, so fluxes are not affected by offsets. Note, the CO2 fluxes have been corrected for the humidity Webb effect but not for the temperature Webb effect.

Simple data quality indicators have been use to edit the turbulence data. At each 10-min time step, values for ID turbulence variables were computed if the following criteria were met:

```
jj=find((reldir<90 | reldir>270) & sig_h<8 &sig_u<2 &sp2<2  & org<5 &
sqrt(ww)./ugw<.55+.002*U.^2 & sqrt(vv)./ugu<1.1);
```

reldir is the relative wind direction
sig_h the standard deviation of ship heading (deg)
sig_u the standard deviation of the ship speed
sp2 the standard deviation of cross-ship motion corrections
org the rainrate
ww the vertical velocity variance
vv the cross stream velocity variance

Otherwise, the ID variables were set to NaN (not a number). In processing the 10-min data to one-hr averages, only the jj rows were used in averaging the turbulence variables. If there were no valid values in the 1-hr interval, the turbulence variables were set to NaN. The criteria given above were subdivided to be approximately compatible with indices used in the past:

```
J=ones(length(jdy),1);
ii=find(sqrt(ww)./ugw<.55+.002*U.^2 & sqrt(vv)./ugu<1.1);
J(ii)=0;
jm=3*ones(length(jdy),1);
ij=find(sig_h<8 & sig_u<2 & sp2<2);
jm(ij)=sig_u(ij);
```

*A value of *J*=0 implies no ship contamination.
*A value of *jm*<3 implies no significant maneuver during the average.

Sigoph is an index of salt or rain contamination on the fast hygrometer (OPHIR) optics. Values for fluxes begin to be affected when *sigoph* exceeds 20 although a threshold of 50 gives acceptable data. The OPHIR performed poorly on this cruise because of internal water condensation. We recommend using the LICOR humidity fluxes.

*Turbulent fluxes are computed by converting the anemometer 3-component velocities to fixed earth coordinates, correcting the fast time series for ship motion, and re-setting the coordinate system normal to the 10-min mean flow through one rotation about the original vertical and one tilt. The variable *tiltx* gives the tilt used for the computation. Experience shows that tilts greater than about 10 deg give questionable fluxes.