NOAA COARE Marine Ozone Deposition Velocity Parameterization

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4 Feb 2005

Background

The flux of ozone to the surface is characterized by a deposition velocity, V_d,

$$Flux = -V_d * X(z)$$

where X(z) is the concentration of ozone at some height, z, above the water surface. The deposition velocity is represented as the sum water side (subscript *w*) and air side (subscript *a*) resistances (Fairall et al., 2000)

$$V_d = (R_w / \alpha + R_a)^{-1}$$

where α is the dimensionless solubility. The resistances in the fluids are computed from the turbulent transport budget equation for the gas in the water and air. Because ozone is destroyed by chemical reaction in the water, the equation looks like

$$\frac{\partial}{\partial z}[(D_w + \kappa u_{*w} z)\frac{\partial X_w}{\partial z}] = C_{xy} Y_w X_w = a X_w$$

where D_w is the diffusion coefficient of the gas in water, u_{*w} the friction velocity in water, κ the von Karman constant, and *a* the reaction time-scale for ozone.

If a is sufficiently large, then all ozone is destroyed in the molecular sublayer and the influence of turbulence is negligible. In that case, Garland et al. (1980) have shown that

$$R_w = R_{w0} = 1/\sqrt{a D_w}$$

If we don't neglect turbulence then the general solution to the equation is

$$R_w = R_{w0} K_0(\xi) / K_1(\xi)$$

where K_n are modified Bessel functions of order n and

$$\xi = \frac{2}{\kappa u_{*w} R_{w0}}$$

Parameterization

A simple program, *cor30_ks_oz.m*, has been written in Matlab to implement the parameterization. The algorithm accepts input in the form

x=[U ts ta qa rl zi press zu usr hsb hlb aoz alph scw];

where
U=x(1);%wind speed, m/s
ts=x(2);%water temperature, C
ta=x(3);%air temperature, C
qa=x(4);%specific humidity, g/kg
Rl=x(5);%downward IR flux, W/m^2
zi=x(6);%atmospheric inversion height, m
P=x(7);%atmospheric pressure, mb
zu=x(8);%height of the wind speed data, m
usr=x(9);%friction velocity, m/s
hsb=x(10);%sensible heat flux, W/m^2
hlb=x(11);%latent heat flux, W/m^2
aoz=x(12);%Ozone reaction rate time scale, s^-1
alph=x(13);%Ozone dimensionless solubility
scw=x(14);%Ozone schmidt number in water

The program returns a vector that gives the deposition velocity variables:

y=[rwo ra rw vdo vd phi];

where
R_{wo}=y(1);%No turbulence ocean resistance, Garland et al, 1980 JGR, vol 85
R_a=y(2);%atmos resistance
R_w=y(3);%ocean resistance with turbulence
Vdo=y(4);%dep velocity, no ocean turb
V_d=y(5);%dep velocity, with ocean turb
phi=y(6);%buoyancy effect on ocean transfer

In matlab the program is executed as y=*cor30_ks_oz*(x);

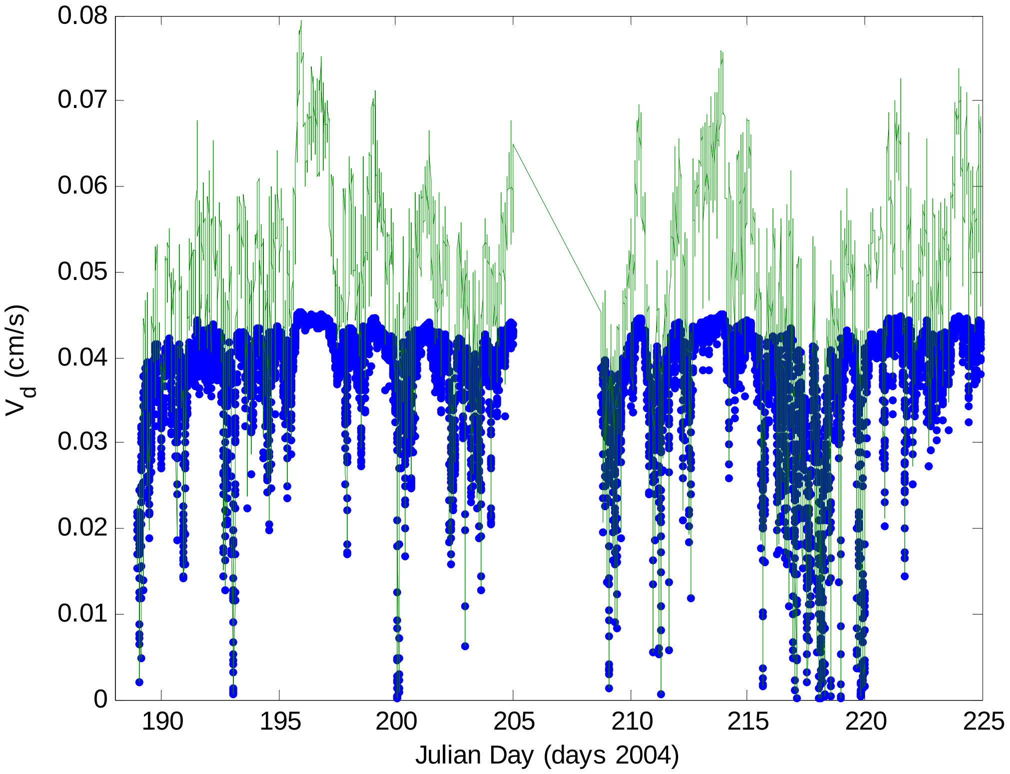
Sample Program

A sample program is provided to demonstrate the parameterization code. This program, *ozonedep_rhb_neaqs_04,* reads data in from a recent field program (the NEAQS study on the Ronald H. Brown conducted off New England in the summer of 2004) and computes ozone deposition velocity time series. This particular program uses the COARE 3.0 conventional turbulent flux algorithm to obtain values for friction velocity and sensible and latent heat fluxes. However, any source of such data is allowable. Just substitute your own.

Note that in the beginning of *ozonedep_rhb_neaqs_04* I have set specific values for a, solubility, Schmidt number, atmospheric pressure, and PBL depth. You are free to select your own values for these. The code can be changed to make any of these variables a time series also.

```
aoz=1e3;%waterside reaction rate, s^-1
H=3;%henry constant = 1/alpha
alph=1/H;%dimensionless solubility
scw=500;%water side schmidt #
press=1010;
zi=600;
```

The program should produce a time series figure as given below. The green line is the full parameterization and the blue dots the no-turbulence values.



This is an unusual data set because there are many cases with air much warmer than water. In some cases this causes the atmospheric resistance to be very high.