# ETL SURFACE FLUX PARAMETERIZATIONS

Parameterizations are mathematical simplifications of physical processes. In meteorology and oceanography, a loose distinction is made between models and parameterizations. The term *Models* usually refers to time integrations of physical conservation equations which are normally expressed as rate relationships. For example, the Navier-Stokes equation describes the conversation of momentum in a fluid and is used to model the time evolution of the wind speed profile as a classic weather forecast mechanism. The term *Parameterization* usually refers to a simple mathematic formula expressing some desired variable in terms of other parameters of the system that are known through measurement or are 'realized' within a *Model*. Parameterizations are normally used when a variable is of interest only internally to a model, or the process is so complicated it can only be practically represented statistically, or we lack an essential measured property and must estimate it from properties that are measured. Here we will be discussing turbulent and radiative fluxes at the surface. In some cases these quantities are only of internal interest (the public is interested in a forecast of air temperature but no in heat flux) or the fluxes themselves are an actual focus (e.g., the take up of atmospheric carbon dioxide by the ocean).

To place this concept in perspective, consider the way weather and climate models compute 'forecasts'. This is done by time integrations of rate equations (i.e., expressions of conservation) for the relevant variables. For example, atmospheric temperature is forecast by dividing the atmosphere into gridboxes and computing the time evolution of the *average* temperature, $<\theta>$ within each box

$$\frac{\partial < \theta >}{\partial t} = - < U > * \nabla < \theta > - \frac{\partial(< w'\theta' > - < R_n > /(\rho c_p))}{\partial z} + < Q_\theta >$$

where the brackets (<>) denote an average over the gridbox volume, U is the wind vector, $R_n$ the net radiative flux (+ downward), $Q_s$ is some other source of heat, and $\rho c_p <w'\theta'>$ is the turbulent transport of heat in the vertical direction (z) associated with vertical air motions of velocity w. This follows the convention of separating temperature, $\theta$, into its volume average component, $<\theta>$, and fluctuations, $\theta'$, distributed within the grid volume

$$\theta = < \theta > + \theta'$$

Whereas $<U>$ and $<\theta>$ are, in principal, known by integration of this equation, the subgrid scale fluctuations and their correlations are not known. The essence of parameterization in this context is representing the turbulent flux $<w'\theta'>$ in some realizable fashion

$$< w'\theta' > = Function(< U >, < \theta >, etc)$$

The terminology often used in modeling circles is that $<U>$ is resolved (i.e., computed on the grid volume) and U' is unresolved or *subgrid scale*.

Subgrid scale terms must be parameterized in terms of resolved scale variables. For example, the heat flux <u>at the surface</u> can be approximated by

$$< w'\theta' >= C_H < U > (< \theta_o > - < \theta >)$$

where $<\theta_o>$ is the mean surface temperature and $C_H$ is an empirical coefficient that depends principally on the nature of the surface and atmospheric stability.

Another example is the net radiative flux at the surface, which we can represent as the sum of solar and IR components

$$R_{no} = R_{s\downarrow} - R_{s\uparrow} + R_{l\downarrow} - R_{l\uparrow}$$

For example, the downward IR flux can be computed by specifying the profile of temperature and the various IR absorbing materials in the atmospheric column above the surface

$$R_{l\downarrow} = \sigma \int_o^\infty < T(z) >^4 \frac{\partial \varepsilon(z)}{\partial z} dz$$

where σ is the Stefan-Boltzmann constant and ϵ the emissivity of the absorbers in the path from the surface to height z. This is strongly affected by clouds, but in clear skies is dominated by water vapor and ozone. Downward IR flux can now be computed very accurately if detailed profile information is available. In the weather/climate model context, the profile is usually fairly well known in terms of the resolved scale profiles of temperature and moisture. Clouds are the major problem because there is considerable subgrid scale variability that is very difficult to parameterize.

In models that don't supply full specification of atmospheric profiles and in many measurement programs, detailed information is not available (i.e., a simple meteorological buoy in the middle of the Pacific Ocean), then approximations are used that are based on simplifications of this equation.

$$R_{l\downarrow} = \sigma T_{rad}^4 \int_o^\infty \frac{\partial \varepsilon}{\partial z} dz = \sigma T_{rad}^4 \varepsilon_\infty = \sigma T_{eff}^4 \varepsilon_{eff}$$

where $T_{rad}$ is an effective radiating temperature and $\epsilon_\infty$ the total column longwave emissivity. Whereas $T_{rad}$ and $\epsilon_\infty$ are computed from the specification of the atmospheric column, $T_{eff}$ and $\epsilon_{eff}$ are parameterizations. Both of theses parameters must be expressed in terms of known quantities such as the near-surface air temperature and humidity or the column integrated water vapor density (precipitable water). This is an example of the *measurement* parameterization problem - we have a set of data that doesn't contain all the information we need so we must estimate missing pieces using what we do have.

In this document we will illustrate several parameterizations that have been developed at ETL. They are organized by parameterizations of turbulent fluxes, radiative fluxes, and sea spray fluxes. The turbulent flux parameterizations span air-sea, air-ice/snow, and air-land with representations for the standard meteorological fluxes (momentum, sensible heat, and latent heat) and trace gases (primarily CO2 but also other gases). The radiative flux parameterizations are for IR and solar fluxes with clear skies or simple overcast conditions where cloud properties

are specified. The sea spray parameterization is intended for use in models (e.g., MM5) to supplement the existing turbulent parameterizations.