Forecasting Local Temperature Changes

A. Temperature Tendency Equation

Suppose you were trying to make a general concept expression for the temperature change expected locally at a weather station. There are two general ways for the temperature at a weather station to change: (a) the wind brings air parcels with a different temperature to the weather station, replacing the air parcels that are there, which move out; and, (b) change the temperature of all air parcels around that weather station by a diabatic effect, such as conductional heating or radiational cooling etc. (a) is referred to as temperature advection and (b) is referred to as the material change, diabatic changes affecting all air parcels.

Local Temperature Change = Material (Air Parcel) Temperature Change + Temperature Change Due to Advection

Using algebraic symbols

$$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels} + (-V\ \Delta T/\Delta s - w\ \Delta T/\Delta z) \qquad (1)$$

where $(-V\ \Delta T/\Delta s)$ is the temperature change to horizontal advection and s $(- w\ \Delta T/\Delta z)$ is the temperature change due to vertical advection.

At the very bottom of the atmosphere, vertical motions are zero. Hence, if the weather station is at the ground equation (1) becomes simplified.

$$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels} + (-V\ \Delta T/\Delta s) \qquad (2a)$$

$$(\Delta T/\Delta t)_{local} = (\Delta T/\Delta t)_{all\ air\ parcels} - V\ \Delta T/\Delta s \qquad (2b)$$

This is known as the Simplified Temperature Tendency equation.

The left hand side is often referred to as the local change (meaning at a spot fixed with respect to the earth) and also is known as the Eulerian change. The term to the immediate right of the equals sign is called the material (or total) change is also known as the Lagrangian change. The Eulerian (local) change is measured by a thermometer at a fixed location, and the Lagrangian change by a thermometer always staying with the air parcels, whether they are moving or not.

B. Simplified Temperature Tendency Equation

The Lagrangian (or total or material) change can occur for a number of reasons, but the biggest and most obvious one relates to diabatic temperature changes that occur, basically, because the sun comes up in the morning and goes down at night.

When strong fronts come through or, even, when smaller scale features like sea-breeze boundaries or outflow boundaries come through, short term local changes are dominated by the horizontal advection term. This is because for such short time frames the Lagrangian change is two to three orders of magnitude smaller than the advection term for those cases.

It's important to retain the minus sign in the horizontal temperature advection when you do calculations. But for now, neglecting the Lagrangian change in the equation results in

$$(\Delta T/\Delta t)_{local} = -V\, \Delta T/\Delta s \qquad (3)$$

This is known as the Simplified Temperature Tendency equation. It's a simple yet accurate way to assess the temperature changes expected at a station just knowing the wind speed and the temperature gradient (assessed from isotherms) in the region.