2.1 Discrete vertical grid

As part of the numerical development in this chapter, we have need to describe how discrete fields are placed on a vertical grid, and how finite difference operations are performed. A vertical column generally has time dependent positions of the discrete fields, distances between the positions, and thicknesses of the cells over which the discrete fields are defined. Generality is necessary for models where grid cell thicknesses are functions of time, and CVMix allows for such freedom.

Figure 2.4 provides a schematic of the conventions for a tracer column used by CVMix modules. The conventions are motivated by those used in MOM, POP, and MPAS-ocean, yet some details may differ slightly. The calling model must provide to CVMix sufficient information to fill all the arrays in this figure. A summary of the choices made in developing this figure are as follows.

- VERTICAL COORDINATE: The vertical coordinate z increases upward and extends from the ocean bottom at $z = -H(x,y)$ to the sea surface at $z = \eta(x,y,t)$.
- TRACER CELL ARRAYS: Tracer cell arrays are labelled with the discrete index `kt`, and have dimensions `nlevs`. The index `kt` increases downward starting from the ocean surface. The number of levels, `nlevs`, is a function of the column label, `ic`, with only wet points included in CVMix column. Examples of tracer cell arrays include temperature, salinity, density, thermal expansion coefficient, and haline contraction coefficient.
- W-CELL OR INTERFACE ARRAYS: W-cell or interface arrays are labelled with the discrete index `kw`, and have dimensions `nlevs+1`. The index `kw` increases downward starting from the ocean surface. The notation "w-cell" originates from the continuity equation, in which the vertical velocity component, w, transfers mass across the vertical interfaces of tracer cells.

  Examples of w-cell or interface arrays are diffusivity, viscosity, vertical tracer derivatives, buoyancy frequency, and Richardson number. For most w-cell arrays, both the top interface at `kw=1` and bottom interface at `kw=nlevs+1` have zero values. Nonetheless, we choose to allocate these arrays for flexibility across models where conventions may differ, and for consistency with how arrays are allocated in Fortran.
- TRACER CELL THICKNESS: The rectangular boxes in Figure 2.4 represent tracer cells whose thickness is measured by the array element `dzt(kt)` with units of meter. This array has dimensions `dzt(nlevs)`.
- DISTANCE FROM OCEAN SURFACE TO TRACER CELL POINT: The distance (in meters) from the tracer cell point to the ocean surface is given by the array element `zt(kt)`. This array has dimensions `zt(nlevs)`.
- W-CELL THICKNESS OR TRACER POINT SEPARATION: The array `dzw` has dimensions `dzw(nlevs+1)`. The array element `dzw(kw=1)` measures distance (in meters) from the top of the top tracer cell to the tracer point `T(kt=1)`, and array element `dzw(kw=nlevs+1)` measures the distance from the bottom tracer point `T(kt=nlevs)` to the bottom of the bottom tracer cell. Intermediate elements of `dzw` measure the distance between tracer points, or equivalently the thickness of a w-cell.
- DISTANCE FROM OCEAN SURFACE TO INTERFACE: The distance from the tracer cell interface, or the w-point, to the ocean surface is given by the array element `zw(kw)`. This array has dimensions `zw(nlevs+1)`.

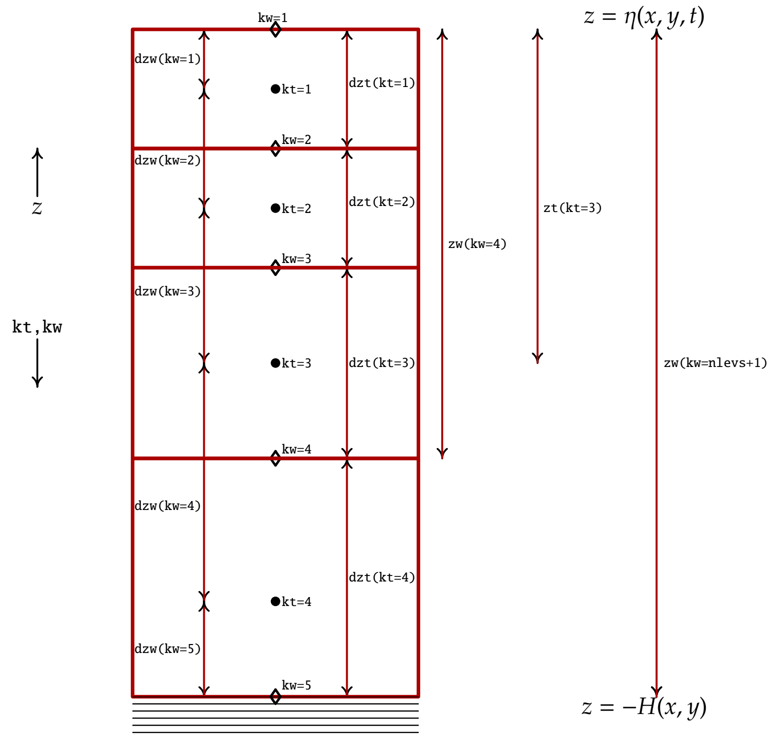

Figure 2.1: Schematic of a discrete vertical column used in CVMix modules, with the surface at $z = \eta(x, y, t)$ and bottom at $z = -H(x, y)$. The vertical coordinate z increases upward, whereas the discrete vertical indices `kt` and `kw` increase downward. CVMix code assumes distances and thicknesses are in units of meters. The rectangular boxes represent tracer cells in the ocean model. The array element `dzt(kt)` measures the thickness of a tracer cell. This array has dimensions `dzt(nlevs)`, where `nlevs` is the number of wet cells in a particular column. For this particular example, `nlevs` = 4. The array `dzw` has dimensions `dzw(nlevs+1)`. The array element `dzw(ik=1)` measures the distance from the top of the top tracer cell to the tracer point `T(k=1)`, and array element `zw(kw=nlevs+1)` measures the distance from the bottom tracer point `T(k=nlevs)` to the bottom of the bottom tracer cell. Intermediate elements of `dzw` measure the distance between tracer points, or equivalently the thickness of w-cells. The distance from the ocean surface to a tracer point is measured by the array element `zt(kt)`, and the distance to the interface is measured by `zw(kw)`. The total thickness of a column is `zw(nlevs+1)`, and it is generally time dependent, as are all of the grid distances `dzt` and `dzw`. Arrays that are defined at the interface, such as buoyancy frequency, Richarson number, diffusivity, viscosity, have vertical indices `kw`. Arrays defined at the tracer cell point, such as temperature, salinity, and density, have vertical indices `kt`.