EDITORIAL

Adoption of Système International (SI) Units in AMS Publications

Beginning with the 1975 issues of AMS journals, editors will enforce usage of the International System of Units (Système International d'Unites—SI). Basic units are the meter (m), kilogram (kg), second (s), and the kelvin (K) denoting thermodynamic temperature. MONTHLY WEATHER REVIEW authors are urged to use SI units beginning now, to avoid delays if manuscripts have to be returned for conversion. The new policy is described in full in the August 1974 issue of BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY.

Some advantages of the SI. Metric units have been widely used in meteorology for decades, and the advantages need not be recounted. Often, a mixture of units has been used: for example, the same article might express wind speed in m/sec, kinetic energy in ergs, and heat energy in terms of calories; and distances in terms of degrees latitude, kilometers, statute miles, or nautical miles. Energy exchanges are often specified in cal cm^{-2} min^{-1}, erg cm^{-2} sec^{-1}, langleys per minute or per day, kilocalories per square centimeter per year, or in a variety of other forms.

This lack of conformity and consistency in the use of units demands mental gymnastics on the part of the reader who encounters a given unit when he is accustomed to another, and leads to the possibility of error when numerical conversions are made. A principal advantage of SI units is that they form a *coherent system*, in which combinations of SI units form other SI units.

One of the main changes from earlier practice will be in the use of energy units. The calorie (not related to the metric system, but to the properties of water) is not recognized in the SI. This policy formally acknowledges the principle established by Joule and others in the mid-19th Century, namely, the mechanical equivalence of heat and its interchangeability with other forms of energy (enunciated in the context of atmospheric processes by V. Bjerknes around the turn of the century). This feature of the SI will minimize the

TABLE 1. Examples of SI derived units.

Quantity	Name	In terms of SI base units[a,b]	Symbol For special name[b]	In terms of other units[a,b]
area	square meter	m^2	—	—
volume	cubic meter	m^3	—	—
speed, velocity	meter per second	$m \cdot s^{-1}$	—	—
acceleration	meter per second squared	$m \cdot s^{-2}$	—	—
divergence; vorticity	per second	s^{-1}	—	—
wavenumber	1 per meter	m^{-1}	—	—
geopotential; dynamic height	meter squared per second squared	$m^2 \cdot s^{-2}$	—	—
density	kilogram per cubic meter	$kg \cdot m^{-3}$	—	—
specific volume	cubic meter per kilogram	$m^3 \cdot kg^{-1}$	—	—
frequency	hertz	s^{-1}	Hz	—
force	newton	$m \cdot kg \cdot s^{-2}$	N	—
pressure; stress	pascal	$m^{-1} \cdot kg \cdot s^{-2}$	Pa	$N \cdot m^{-2}$
energy	joule	$m^2 \cdot kg \cdot s^{-2}$	J	$N \cdot m$
power	watt	$m^2 \cdot kg \cdot s^{-3}$	W	$J \cdot s^{-1}$
dynamic viscosity	pascal second	$m^{-1} \cdot kg \cdot s^{-1}$	—	$Pa \cdot s$
moment of force	meter newton	$m^2 \cdot kg \cdot s^{-2}$	—	$N \cdot m$
heat flux density	watt per square meter	$kg \cdot s^{-3}$	—	$W \cdot m^{-2}$
entropy	joule per kelvin	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$	—	$J \cdot K^{-1}$
gas constant, universal	joule per kelvin	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$	—	$J \cdot K^{-1}$
specific heat capacity	joule per kilogram kelvin	$m^2 \cdot s^{-2} \cdot K^{-1}$	—	$J \cdot kg^{-1} \cdot K^{-1}$
specific energy	joule per kilogram	$m^2 \cdot s^{-2}$	—	$J \cdot kg^{-1}$
thermal conductivity	watt per meter kelvin	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$	—	$W \cdot m^{-1} \cdot K^{-1}$
energy density	joule per cubic meter	$m^{-1} \cdot kg \cdot s^{-2}$	—	$J \cdot m^{-3}$
angular velocity[c]	radian per second	$rad \cdot s^{-1}$	—	—

[a] Use of the centered dot indicating multiplication of units is encouraged, but it may be omitted (with a space instead) where this does not lead to ambiguity. Also see paragraph on *Alternative expressions of units*.
[b] Note that unit symbols derived from proper names are capitalized.
[c] The radian (nondimensional) is a supplementary unit of the SI.

TABLE 2. Most common prefixes for decimal multiples and submultiples of SI units.

Multiple	Prefix	Symbol	Sub-multiple	Prefix	Symbol
10^6	mega	M	10^{-1}	deci	d
10^3	kilo	k	10^{-2}	centi	c
10^2	hecto	h	10^{-3}	milli	m
10^1	deka	da	10^{-6}	micro	μ

burden of conversion constants, since internal (heat), potential, and kinetic energy changes, and work by pressure forces, are all expressed in the same units.

SI units, symbols, and common constants. An exhaustive listing of SI units is given in the BAMS article cited above, including units of electricity, magnetism, and illumination. MONTHLY WEATHER REVIEW contributors and readers will find it convenient to refer to Table 1, which lists SI derivative units most used by meteorologists dealing with atmospheric motions and thermodynamics. The most commonly used decimal prefixes are given in Table 2.

Some of the principal thermodynamic constants are listed in Table 3, in terms of SI units. Most of these "constants" are really variable, and their precise values at different temperatures should be sought in such sources as the *Smithsonian Meteorological Tables.*

Presentation of tables and graphs. In the presentation of tabular data or graphs, SI units should be used unless there is a defensible reason for employing other units. Where diagrams are reproduced from earlier works, the necessary conversion may be done by substitution of a new abscissa or ordinate scale (or, if preferred, an SI-unit scale in addition to the scale of units in the original diagram). If extensive tables are reproduced, these may be retained in their original form if in metric units (such as CGS), although, in general, conversion to SI units is preferred.

TABLE 3. Thermodynamic constants.[a]

Physical quantity	Symbol	Value
Specific heat		
liquid water at 15°C (pure)[b]	c_w	4.186×10^3 J kg^{-1} K^{-1}
ice (at 0°C)	c_i	2.106×10^3 J kg^{-1} K^{-1}
dry air at constant pressure[c]	c_p	1.005×10^3 J kg^{-1} K^{-1}
dry air at constant volume[d]	c_v	0.718×10^3 J kg^{-1} K^{-1}
water vapor at constant pressure[e]	c_{pv}	1.846×10^3 J kg^{-1} K^{-1}
water vapor at constant volume	c_{vv}	1.386×10^3 J kg^{-1} K^{-1}
Gas constant for dry air	R	0.287×10^3 J kg^{-1} K^{-1}
Latent heat (phase change at 0°C)		
of condensation[f]	L	2.501×10^6 J kg^{-1}
of fusion[e]	L_f	0.334×10^6 J kg^{-1}
of sublimation[e]	L_s	2.834×10^6 J kg^{-1}

[a] Values taken from *Smithsonian Meteorological Tables*, 6th Revised Edition (R. J. List, Ed.). For conversion from source material giving values in terms of caloric units, note that 1 15° g cal = 4.1855 J (recommended in WMO *International Tables*).

[b] Decreases nonlinearly with increasing salinity of sea water, being 3.931×10^3 J kg^{-1} K^{-1} at a salinity of 30‰.

[c] For moist air, $c_p=(1+0.90q)c_{pd}$, where c_{pd} is specific heat of dry air and q is specific humidity.

[d] For moist air, $c_v=(1+1.02q)c_{vd}$.

[e] For variation with temperature, see *Smithsonian Tables*.

[f] $L=(2.500-0.0024t)\times10^6$ J kg^{-1}, where t is Celsius temperature.

TABLE 4. Non-SI units in use with SI units.

Name	Symbol	Value of SI Unit
minute	min	1 min = 60 s
hour	h	1 h = 60 min = 3600 s
day	d	1 d = 24 h = 86,400 s
degree	°	1° = (π/180) rad
liter	ℓ*	1 ℓ = 1 dm^3 = 10^{-3} m^3
tonne	t	1 t = 10^3 kg

* Because the typewritten "ell" is the same as the arabic numeral "one," authors should use the script "ell" (ℓ) as the symbol for liter in their manuscripts.

Alternative expressions of units. The new policy permits some flexibility in statement of units, so long as ambiguity is avoided. Use of the solidus (/) is permitted, but is generally not advantageous when complex combinations of units are employed. Thus authors may express speed in terms of m/s or m s^{-1} according to their preference, and acceleration as m/s^2 or m s^{-2}. Multiple use of the solidus is never justified. Thus, for example, the physical unit for specific heat (joule per kilogram per kelvin) may be written

$$\mathrm{J\ kg^{-1}\ K^{-1}} \quad \text{or} \quad \mathrm{J/(kg\ K)}$$

but not

$$\mathrm{J/kg/K} \quad \text{or} \quad \mathrm{J/kg\ K}.$$

Exceptions. The International Committee on Weights and Measures (CIPM), while recommending the SI, recognized that some users will wish to employ certain units which, although not part of SI, are important and widely used. (For example, cloud physicists may prefer to express particle populations in terms of "per liter"). In general, the use of non-SI units for time, in stating physical quantities, is to be avoided.

The AMS permits use of some units not recommended by the CIPM. While the pascal (Pa) is the recommended unit of pressure, the millibar is permitted (1 mb = 1 hPa). Stress should be expressed in pascals (1 Pa = 10 dyn/cm^2). Since decimal prefixes may be employed, vertical velocity may still be expressed as cm/s, m/s or, in the pressure-coordinate system, microbars per second (μb/s).

Use of some non-metric units such as knots (kt) is allowed for a limited time, because of the familiarity of this unit and the fact that basic winds-aloft data are at present given in knots. Where wind speeds are discussed in the context of (say) kinetic energy, SI units should be used consistently throughout the text. Statute miles should never be used, nor, in general, other English measures. The degree Celsius (°C) is permitted by SI, but the degree Fahrenheit (°F) is proscribed. The AMS allows use of degrees Fahrenheit in suitable contexts, however. An example is in discussions of surface temperature forecasts, pending adoption by weather services of the degree Celsius in surface observations and public forecasts. Other exceptions may be justified in articles communicating meteorological information to readers in other disciplines that have not adopted the SI, but that is not generally relevant to articles in MONTHLY WEATHER REVIEW.

Additional remarks. Examination of the "rules" outlined above will show that MWR contributors still have considerable flexibility in their choice of units. This should not be taken as a license to circumvent the intent of adopting the SI. This intent is to enforce usage not just of metric units, but of SI units that have the advantage of *coherency* (the property that multiplication or division of SI units by other SI units will produce an expression in SI units, as in Table 1). This editor feels that while the use of decimal prefixes or the non-SI units in Table 4 is sometimes justifiable, part of the advantage is lost if this option is used indiscriminately. Thus, e.g., the expression of energy flux in terms of W/m^2 rather than the (also permitted) forms mW/cm^2 or $J\ m^{-2}\ d^{-1}$ is obviously advantageous. Authors should make every effort to promote the adoption of a uniform system of units by adhering to SI units unless there is a substantial reason for using variants.—*Chester W. Newton*