WEATHER TO FLY

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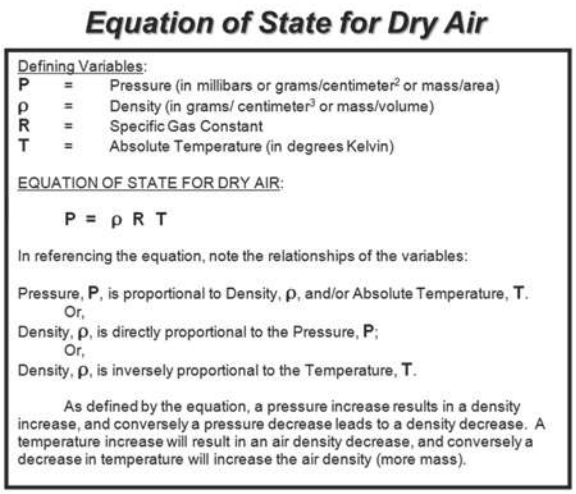
Convergence along a Sea Breeze Front

Introduced in the April issue of Soaring, convergence in the atmosphere's airflow provides a mechanism for providing useful lift for a soaring pilot. The classic example in soaring aviation texts for convergence lift is often illustrated as that associated with a sea breeze. This article will be a simple review of the development of a sea breeze and its associated convergence lift.

In its constant attempt to achieve equilibrium in regard to any density or pressure differences, atmospheric motion or wind results. As a thermal property of a substance, specific heat is the ability of that substance to absorb and store energy without raising its sensible temperature. In regard to the incoming energy absorption of various surfaces and compounds along coastlines or adjacent to large lakes, the specific heat of water is the highest of common compounds when compared to that of typical earth along coastal sections (water's specific heat is approximately 4.5 times higher). At the same latitude and under the influence of the same upper air synoptic weather pattern and its general atmospheric temperature profile, incoming solar energy results in differing surface temperatures due to the aforementioned water and surface-specific heat differences, along with other thermal-influencing properties such as coloration and texture.

As a simplified initial state of the atmosphere at dawn, envision one where the air immediately above the sea and land are the same in temperature and the isobars of pressure aloft are parallel to the surface. As pressure is defined as the weight of the air molecules above us, the isobars decrease in magnitude with an increase in altitude (See ***Diagram #1: "Initial Atmosphere Pressure Pattern"***). In such a simplified model, with no temperature or density differences, there is no wind (pressure gradient = 0.0 mb). The *Equation of State for Dry Air* describes the relationship of mass, pressure, and density (See ***Text Box #1: "Equation of State for Dry Air"***). After dawn, incoming solar energy begins to add energy to all surfaces, water, and land. However, the ocean remains relatively steady in temperature with the water's tremendous capacity to store energy, while the land with a low specific heat and as a poor conductor heats much more quickly than the adjacent ocean. With higher surface temperatures, air immediately next to the land warms by conduction, and subsequently, the lower atmosphere warms by the convection mixing process. The generation of the lower atmosphere thermal mixing occurs and mass is transported upward in the thermal process *thereby raising the pressure at some altitude aloft over the land* in contrast to that pressure over the ocean at the same altitude. Pressure lowers at the surface of the land with the loss of vertically transported air along with the lowering of the density of the air due to the sensible warming. Subsequently, this early, weak thermal mixing of the air results in a change the orientation of the initial pressure pattern placing higher pressure aloft over the land in comparison to a point over the ocean. Concurrently, and, again, with far less change in the sensible temperature of the ocean (or large lake), the density of the air over the water is relatively unchanged. With a density gradient at the lowest levels of the atmosphere from over the ocean to over the land, subsequently atmospheric pressure *at the surface over the water is higher* than surface pressure over the land. As a result, an onshore (ocean-to-inland) pressure gradient develops (See ***Diagram #2: "Resultant Sea Breeze Pressure Pattern"***).

Empirical evidence shows that air movement can begin with as little as a 2 degree Fahrenheit difference in temperature. Thus, a thermally induced onshore breeze is observed at the surface. Since a sea breeze is a closed circulation, aloft the pressure gradient favors a return (although much weaker) land-to-ocean



Equation of State for Dry Air

Defining Variables:

P = Pressure (in millibars or grams/centimeter^2 or mass/area)
ρ = Density (in grams/ centimeter^3 or mass/volume)
R = Specific Gas Constant
T = Absolute Temperature (in degrees Kelvin)

EQUATION OF STATE FOR DRY AIR:

$$P = \rho R T$$

In referencing the equation, note the relationships of the variables:

Pressure, **P**, is proportional to Density, **ρ**, and/or Absolute Temperature, **T**.
Or,
Density, **ρ**, is directly proportional to the Pressure, **P**;
Or,
Density, **ρ**, is inversely proportional to the Temperature, **T**.

As defined by the equation, a pressure increase results in a density increase, and conversely a pressure decrease leads to a density decrease. A temperature increase will result in an air density decrease, and conversely a decrease in temperature will increase the air density (more mass).

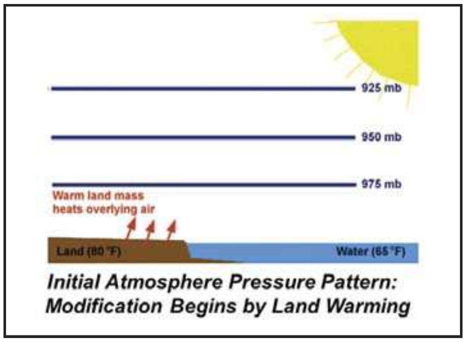


Diagram #1: Initial Atmosphere Pressure Pattern

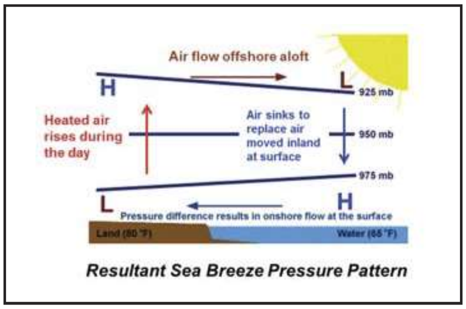


Diagram #2: Resultant Sea Breeze Pressure Pattern airflow (See ***Diagram #3: "Sea Breeze Circulation"***). A typical sea breeze has its onshore wind flow beginning by midmorning at the immediate coastline and reaches 20 miles inland by early afternoon. With incoming solar energy received per unit area getting stronger during the morning through midday, the surface onshore pressure gradient continues to get stronger, and the sea breeze front continues to push inland with time passage through the afternoon hours (See ***Diagram #4: "Sea Breeze Inland Movement with Time"***).

Because of the differing air mass characteristics and discontinuities across the "front," the sea breeze front is analogous to a synoptic scale front. The air being replaced over a given point inland along a coastal plain or valley reflects the characteristics of the maritime or large lake source region with its lower surface temperature and higher humidity characteristics. The common characteristics of a sea breeze front passage includes a sharp temperature drop, wind shift, wind speed increase, gusty wind, and a rise in relative humidity. The passage of a sea breeze front is also marked by a sudden pressure rise (pressure discontinuity), the presence of a line of haze marking the boundary between land and sea air, and a rise in dew point temperature.

Because of the speed of convergence (Reference: April 2012 "*Soaring*," '*Weather To Fly*') at the leading edge of the sea breeze, the upward vertical motion results in useful lift for the soaring pilot (See ***Diagram #5: "Sea Breeze Convergence Lift Zone"***). The magnitude of the upward vertical motion along the sea breeze front is a function of several factors, including but not limited to, the instability of the air mass ahead of the front, the speed of the front, the speed of the wind, and the vertical depth of the maritime influence. Suffice it to say that the push of the maritime air inland against the resident air over the land provides lift. There are a couple of factors associated with the sea breeze front, as a convergence line, that may place an unwary soaring pilot in an unplanned situation. Since the sea breeze front initially develops at the coastline and moves inland with the passage of time in its typical diurnal pattern, a soaring pilot using thermals for lift at a gliderport along a coastal plain in the morning hours would transition to the steady lift along the sea breeze frontal convergence line when passage occurs. Frequently, the lifting action associated with the sea breeze front or convergence line often will be marked and enhanced by the development of a line of cumulus in an otherwise "blue" or clear air mass.

Some typical characteristics of a sea breeze front are as follows:

- The rate-of-advance of the sea breeze is a function of the density difference across the front. Typically, the advance is from 4 to 8 knots but higher values reach 15 knots;
- The temperature difference across the sea breeze front is often on the order of 15 degrees Fahrenheit over a distance of 20 miles;
- The sea breeze has wind speeds typically from 8 to 15 knots with higher speeds up to 28 knots;
- The depth of the sea breeze circulation is a function of the coastal marine layer and will vary from 1000 feet(330m) to 3000 feet(1km) mean sea level in altitude;
- Lift rates along such a convergence line (heavily influenced by terrain features) are typically in the 200 to 400 feet per minute (FPM) range. However, other influences such as terrain channeling and especially inland air mass instability can increase soaring lift rates along such a modified convergence line to over 1000 FPM, and,
- Inland penetration of the sea breeze varies tremendously because of terrain features. Inland distances, with questions also involving the definition of 'maritime' air, vary from 3 miles to 125 miles with the sea breeze circulation effects also observed 60 miles from the coastline over the ocean [Reference: Round].

If a pilot chooses to soar the inland moving convergence line, at least two negative soaring properties of a sea breeze front must be overcome in order to return to the departure gliderport: 1) A strong headwind in the maritime influenced boundary layer to reach the gliderport (See ***Diagram #4: "Sea Breeze Inland Movement with Time"***); and, 2) A change to weaker or even total elimination of thermals to use for cross-country flight back to the gliderport due to the presence of cool air at the lower levels. This cool air advection behind the sea breeze front at the lowest levels weakens the vertical temperature lapse rate and provides a low-

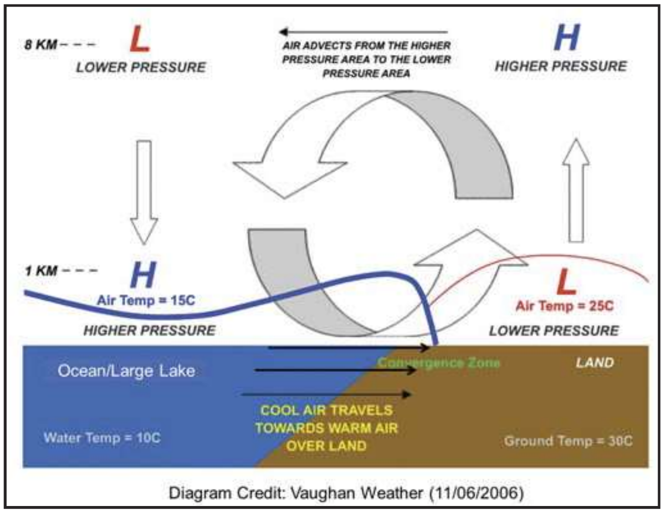


Diagram Credit: Vaughan Weather (11/06/2006)

Diagram #3: Sea Breeze Circulation

Map Courtesy: Google; Map Data 2012

Diagram #4: Sea Breeze Inland Movement with Time level "capping" temperature inversion at the transition from the maritime air to the general air mass aloft (See ***Diagram #6: "Sea Breeze Vertical Temperature Profile"***). An afternoon weather satellite image of Florida clearly shows the influence of the sea breeze as it changed the resident land air mass with its thermal-generated cumulus cloud field to that of a cleared, stable maritime air mass along the coastlines (See ***Picture #1: "Florida Sea Breeze"***). Depending upon atmospheric instability and moisture presence in the resident air mass ahead of the front, sea breeze fronts often result in a third negative property, the development of deep convection due to the initiating lift mechanism of the frontal convergence line (See ***Picture #2: "Southeast Texas Gulf Coast Sea Breeze***). Whether it is truly marine air with its moisture content and reflecting the ocean surface temperature that defines its maritime origins or marine air that has become modified in its inland push and no longer has its initial marine moisture and temperature characteristics, the influence of a coastal sea breeze can be realized far inland. For example, local meteorologists do not consider the increase in wind speeds observed at Uvalde, Texas, around 11 PM CDT as the passage of a sea breeze front. However, the influence of a push of maritime air from the southeast Texas Gulf Coast sea breeze front results in the aforementioned action well downstream over interior, south-central Texas even if the air directly involved in that action is not 'maritime' in nature. Interior convergence lines will be discussed in future articles of "Weather to Fly."

The closed, thermal-induced circulation system that drives a sea breeze front has been discussed. The relationship of temperature, pressure, and density continues to be a driving force for air motion that results in convergence that is useful for soaring flight. The sea breeze front and its variants are examples of convergence with more examples of convergence types to be discussed.

References

[1] "***AC 00-6A; Aviation Weather***"; DOT/FAA/Government Printing Office, 1975.

(also available on-line: http://www.srh.noaa.gov/faa/pubs.html)

[2] Round, Lt. Robert D. Thesis: "Climatology and Analysis of the Monterey Bay Sea Breeze." Naval Postgraduate School, Monterey, CA. September 1993.

[3] Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Weather World 2010 Project™. < http://ww2010.atmos.uiuc.edu/ >

[4] Bewley, Jennifer. "The Relationship between the Satellite Cloud Edge, the Radar Thin Line, and the Surface Indicated Sea Breeze Front along the East Coast of Florida". Department of Marine and Environmental Sciences, Florida Institute of Technology, Melbourne, FL. June 2004.

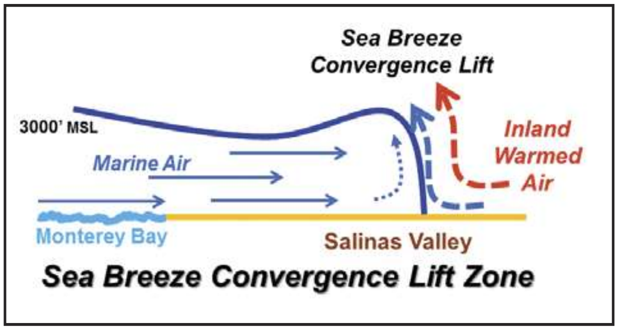


Diagram #5: Sea Breeze Convergence Lift Zone

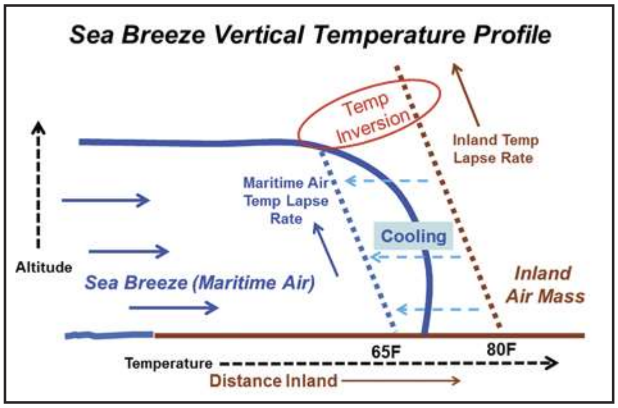
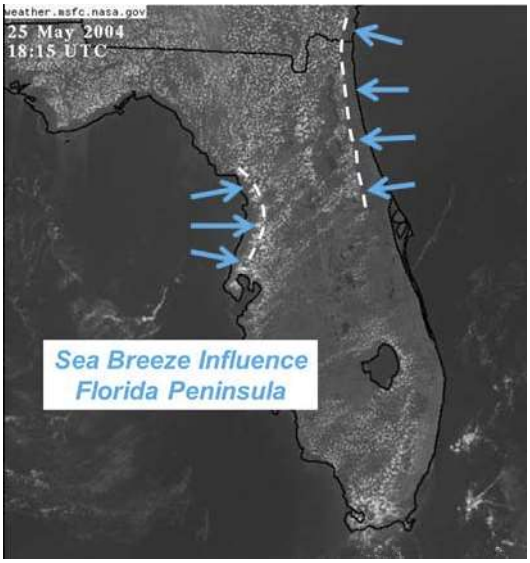
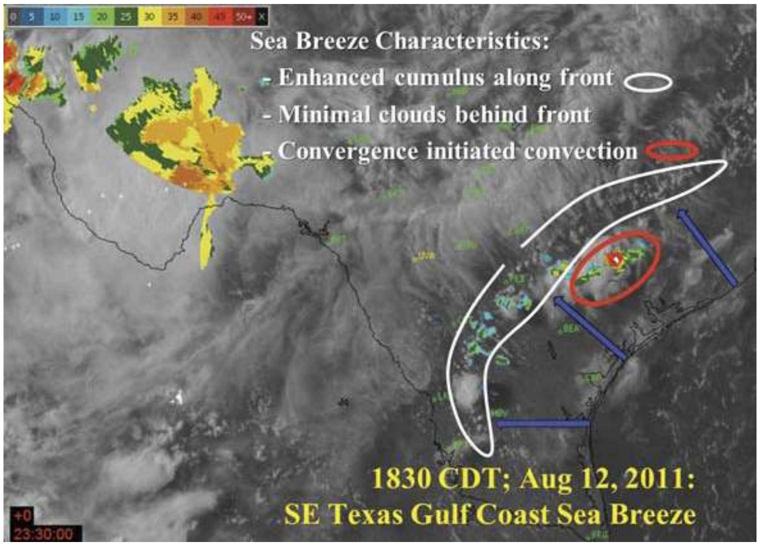


Diagram #6: Sea Breeze Vertical Temperature Profile



Florida Sea Breeze



SE Texas Gulf Coast Sea Breeze