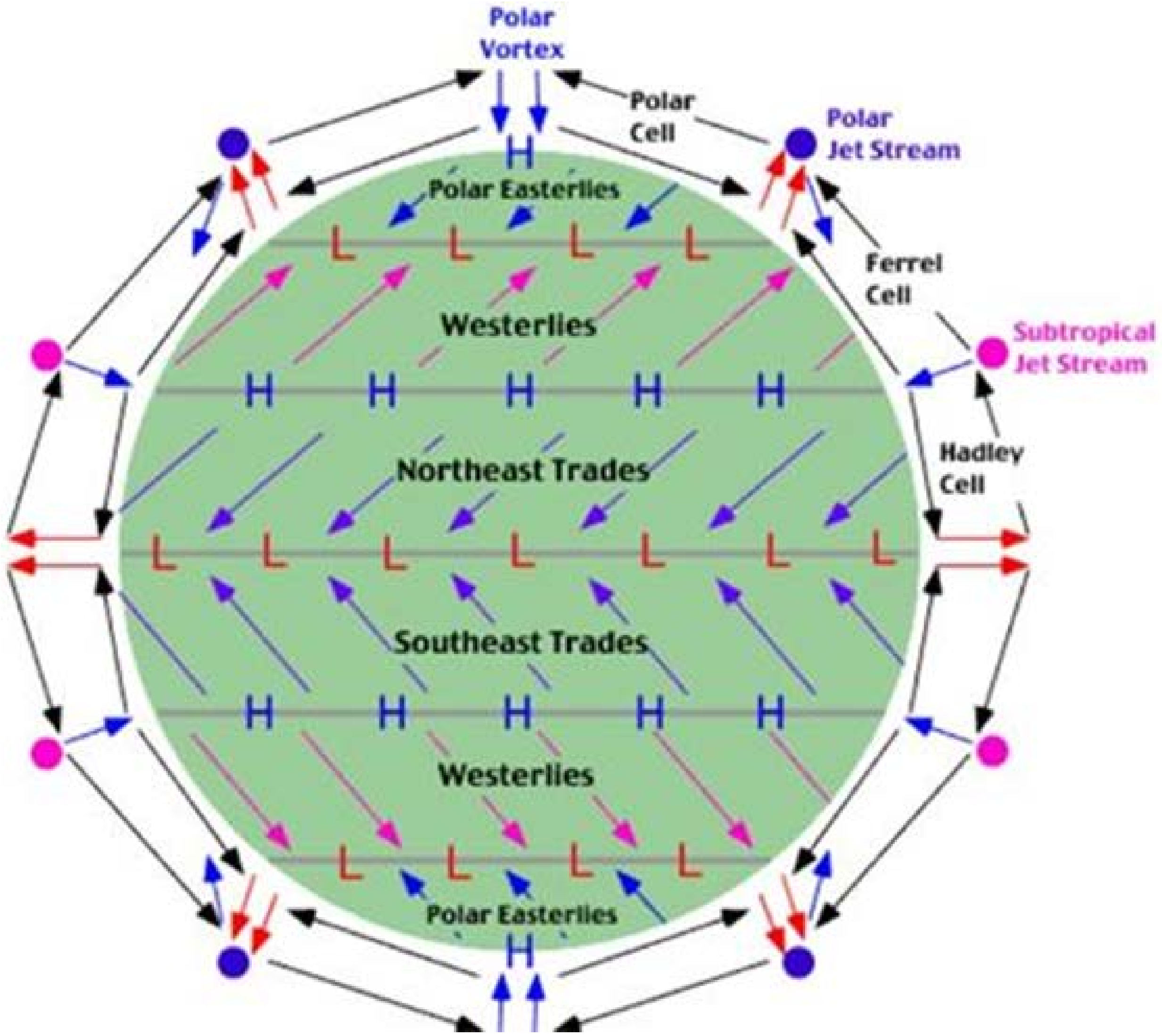
General circulation, Air masses, Fronts, Frontal trapping, Topographical influences

General circulation

A general circulation model (GCM) is a type of climate model. It employs a mathematical model of the general circulation of a planetary atmosphere or ocean. It uses the Navier–Stokes equations on a rotating sphere with thermodynamic terms for various energy sources (radiation, latent heat). These equations are the basis for computer programs used to simulate the Earth's atmosphere or oceans. Atmospheric and oceanic GCMs (AGCM and OGCM) are key components along with sea ice and land-surface components.
GCMs and global climate models are used for weather forecasting, understanding the climate and forecasting climate change.

General circulation

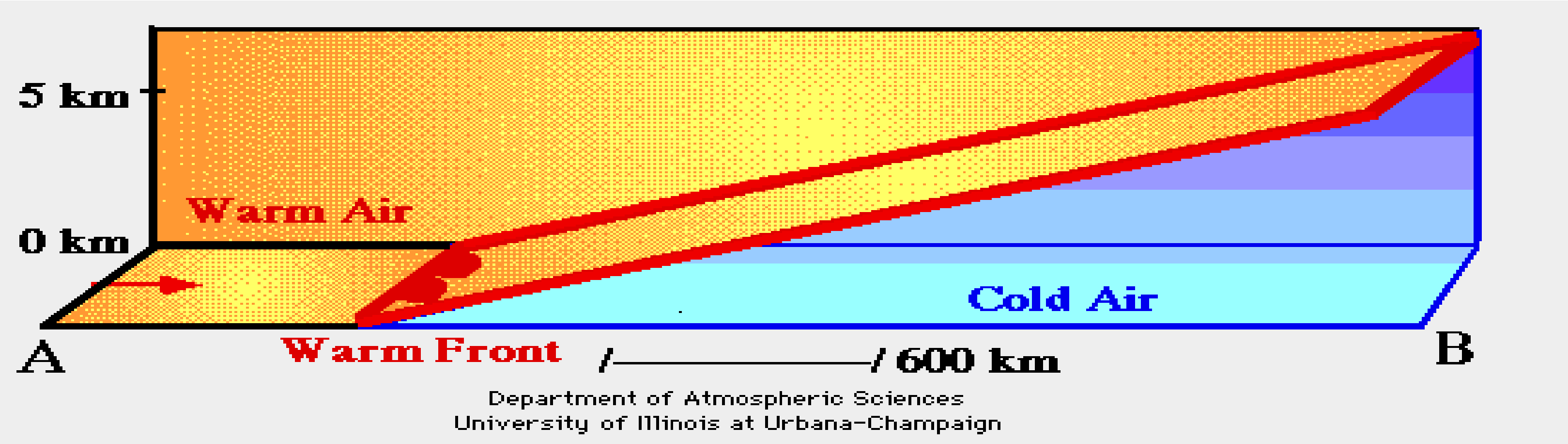


Air Masses and Fronts

Fronts

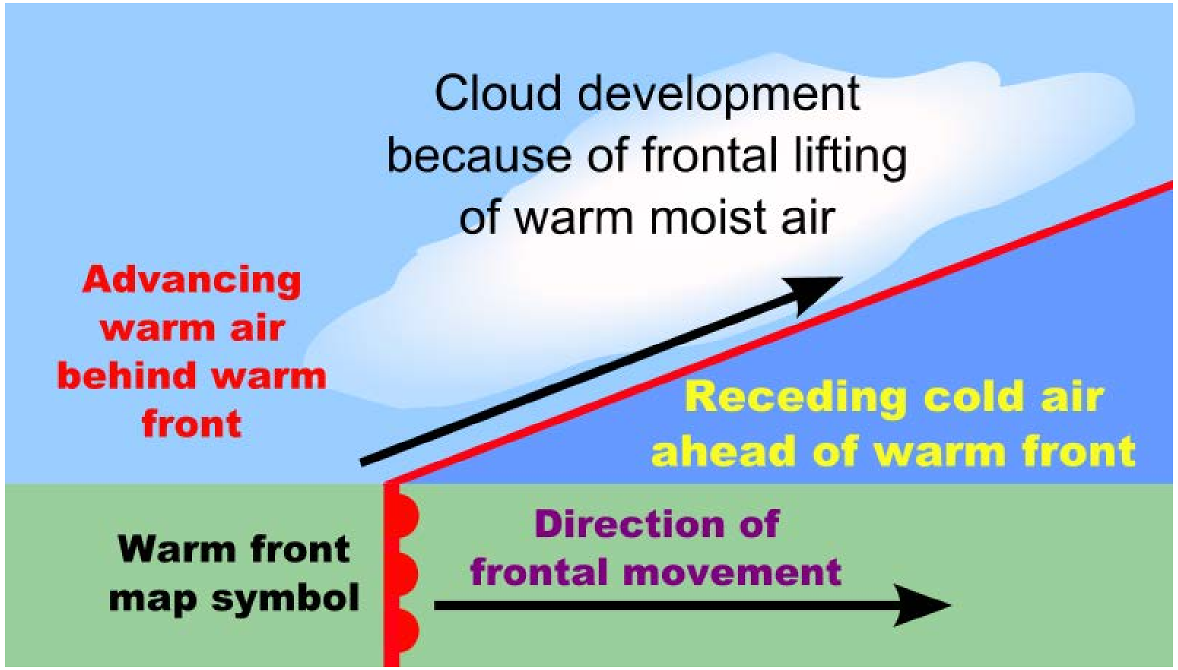
- Definition - boundary, transition zone between two different air masses fronts.
- The two air masses have different densities. Frequently, they are characterized by different temperatures and moisture contents
- Front has horizontal and vertical extent
- Frontal boundary/zone can be 1-100 km wide
- Types of synoptic-scale fronts:
  - warm fronts
  - cold fronts
  - stationary fronts
  - occluded fronts

Warm Front



- A transition zone where a warm air mass replaces a cold air mass
- Drawn as a red line with red semi-circles pointing in the direction of the front's movement

Warm Front

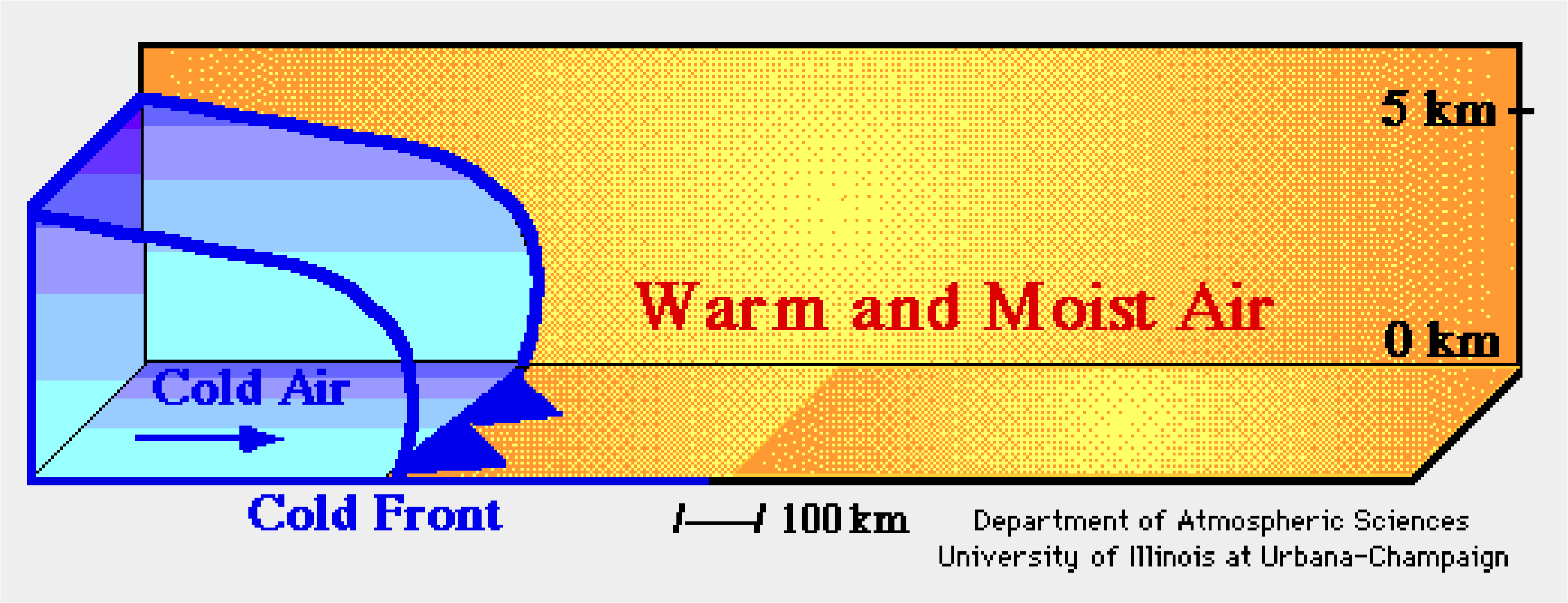


- Again, warm air is less dense than cold air.
- As the warm air moves north, it slides up the gently sloping warm front.
- Because warm fronts have a less steep slope than cold fronts, the precipitation associated with warm fronts is more "stratiform" (less convective), but generally covers a greater area.

Common Characteristics Associated with Warm Fronts

	Before Passing	While Passing	After Passing
Winds	South-southeast	Variable	South-southwest
Temperature	Cool-cold, slowly warming	Steady rise	Warmer, then steady
Pressure	Usually falling	Leveling off	Slight rise, followed by fall
Clouds	Cirrus, Cirrostratus, Nimbostratus	Stratus-type	Clearing with scattered Stratocumulus
Precipitation	Light to moderate rain, snow, sleet or drizzle	Drizzle or none	Usually none, sometimes light rain in showers
Visibility	Poor	Poor, but improving	Fair in haze
Dew Point	Steady rise	Steady	Rise, then steady

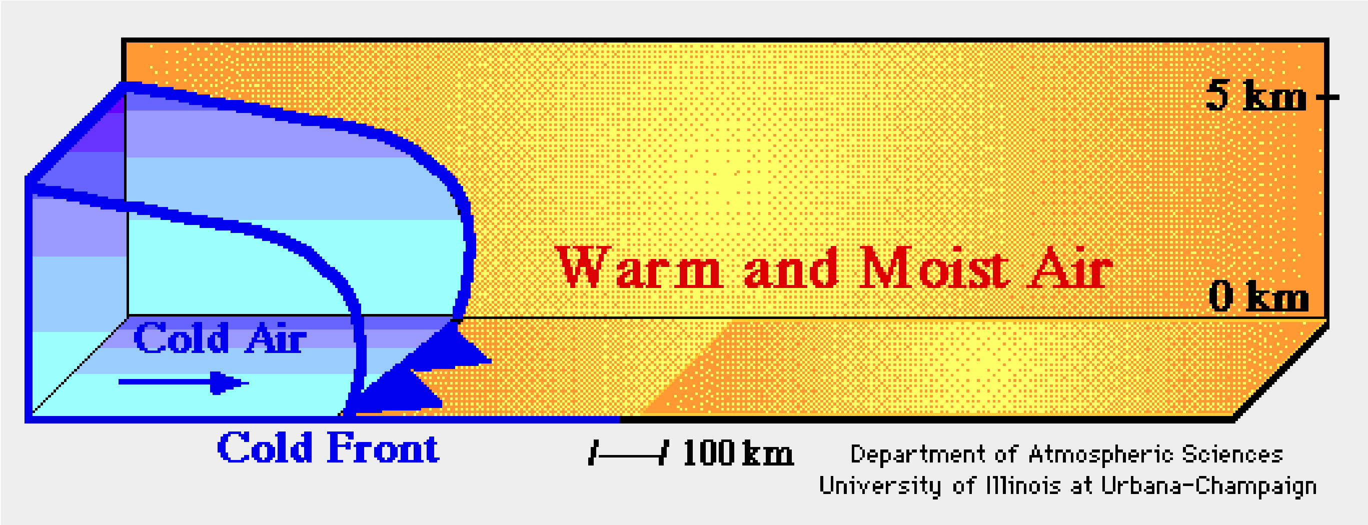
Cold Fronts



- A transition zone where a cold air mass replaces a warm air mass

- Drawn as a blue line with blue triangles pointing in the direction of the front's movement

Cold Fronts

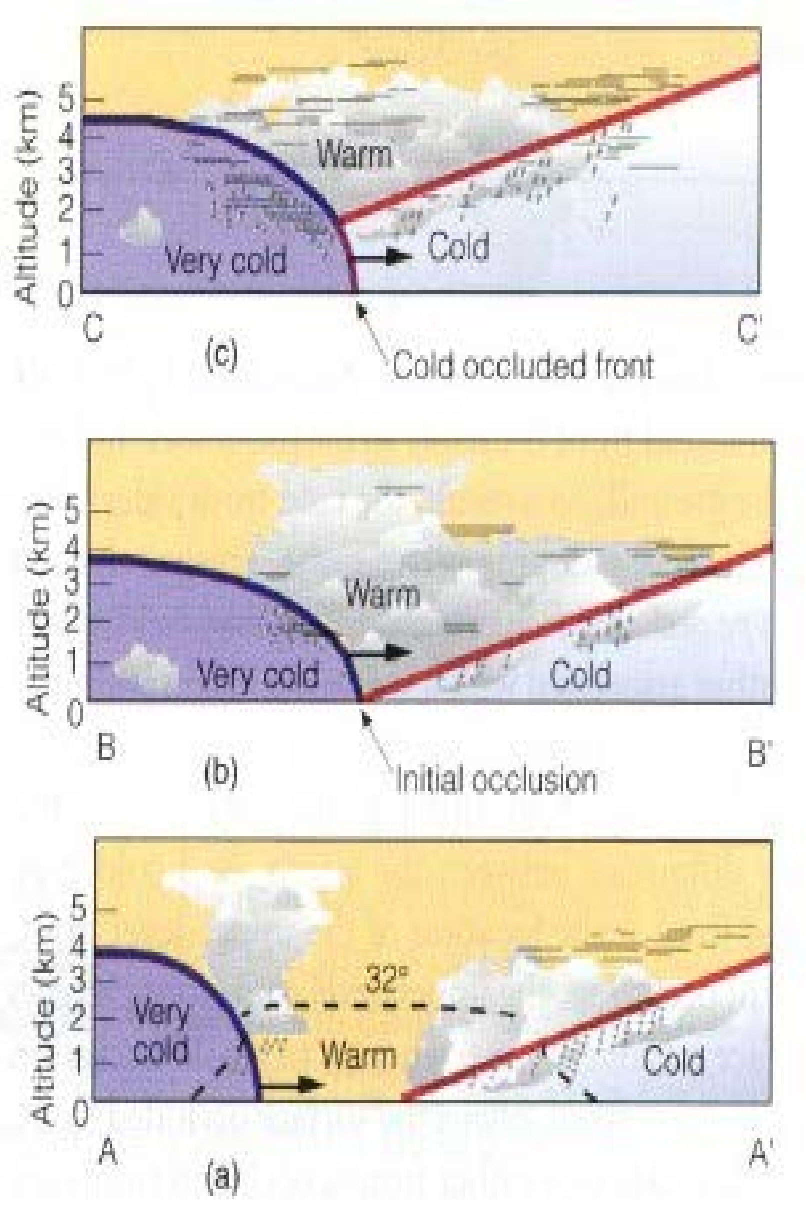


- Cold air is more dense than warm air.
- As the dense, cold air moves into the warm air region, it forces the warm air to rapidly rise just ahead of the cold front.
- This results in deeper clouds and precipitation than we saw with a warm front. The clouds that form can be convective and can be associated with more intense precipitation and thunderstorms
- Often, the precipitation along a cold front is a very narrow line of thunderstorms

Common Characteristics Associated with Cold Fronts

	Before Passing	While Passing	After Passing
Winds	South-southwest	Gusty; shifting	West-northwest
Temperature	Warm	Sudden drop	Steadily dropping
Pressure	Falling steadily	Minimum, then sharp rise	Rising steadily
Clouds	Increasing: Cirrus, Cirrostratus, Cumulonimbus	Cumulonimbus	Cumulus
Precipitation	Short periods of showers	Heavy rains, sometimes with hail, thunder, lightning	Showers, then clearing
Visibility	Fair to poor in haze	Poor, followed by improving	Good, except in showers
Dew Point	High; remains steady	Sharp drop	lowering

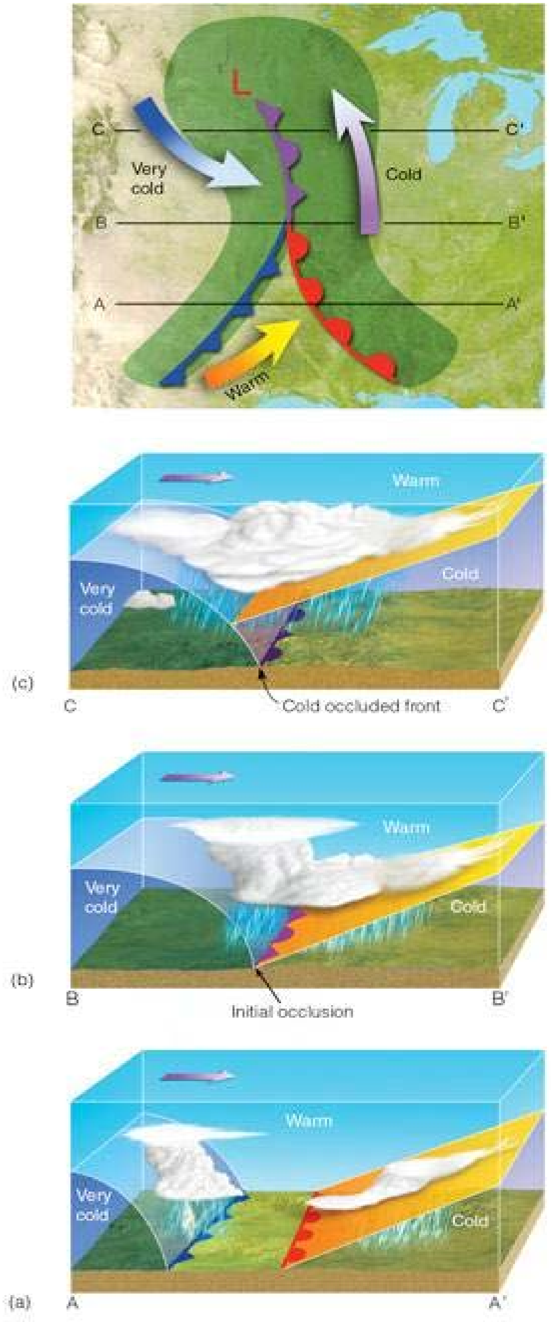
Occluded Fronts



- A region where a faster moving cold front has caught up to a slower moving warm front.
- Generally occurs near the end of the life of a cyclone
- Drawn with a purple line with alternating semicircles and triangles

Cold Occlusion

- The type most associated with mid-latitude cyclones
- Cold front "lifts" the warm front up and over the very cold air
- Associated weather is similar to a warm front as the occluded front approaches
- Once the front has passed, the associated weather is similar to a cold front
- Vertical structure is often difficult to observe

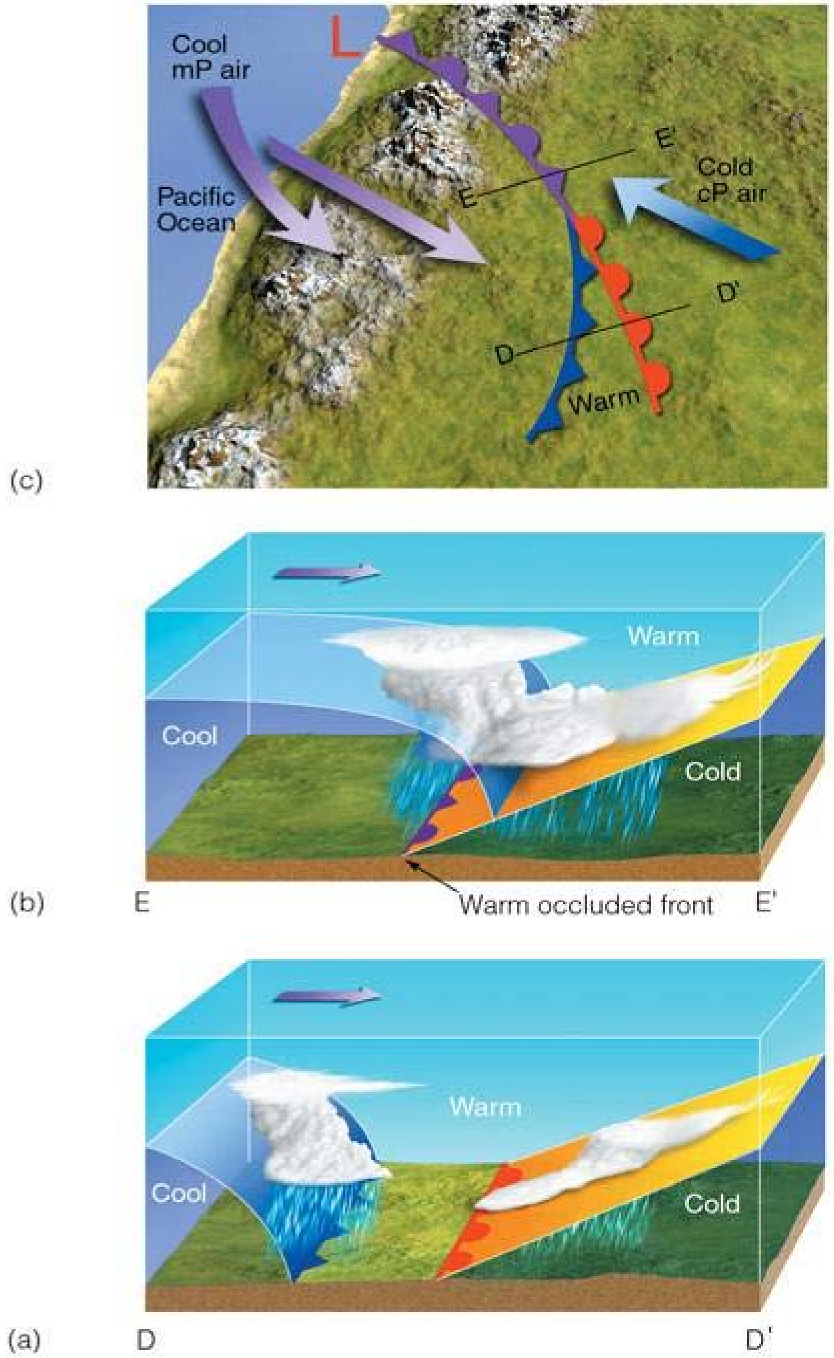


http://apollo.lsc.vsc.edu/classes/met130/notes/chapter11/index.html

Warm Occlusion

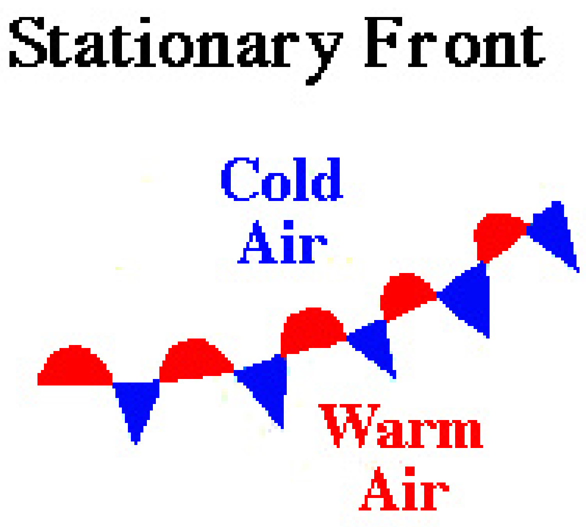
- Cold air behind cold front is not dense enough to lift cold air ahead of warm front
- Cold front rides up and over the warm front
- Upper-level cold front reached station before surface warm occlusion

http://apollo.lsc.vsc.edu/classes/met130/notes/chapter11/index.html



Stationary Front

- Front is stalled
- No movement of the temperature gradient
- But, there is still convergence of winds, and forcing for ascent (and often precipitation) in the vicinity of a stationary front.
- Drawn as alternating segments of red semicircles and blue triangles, pointing in opposite directions

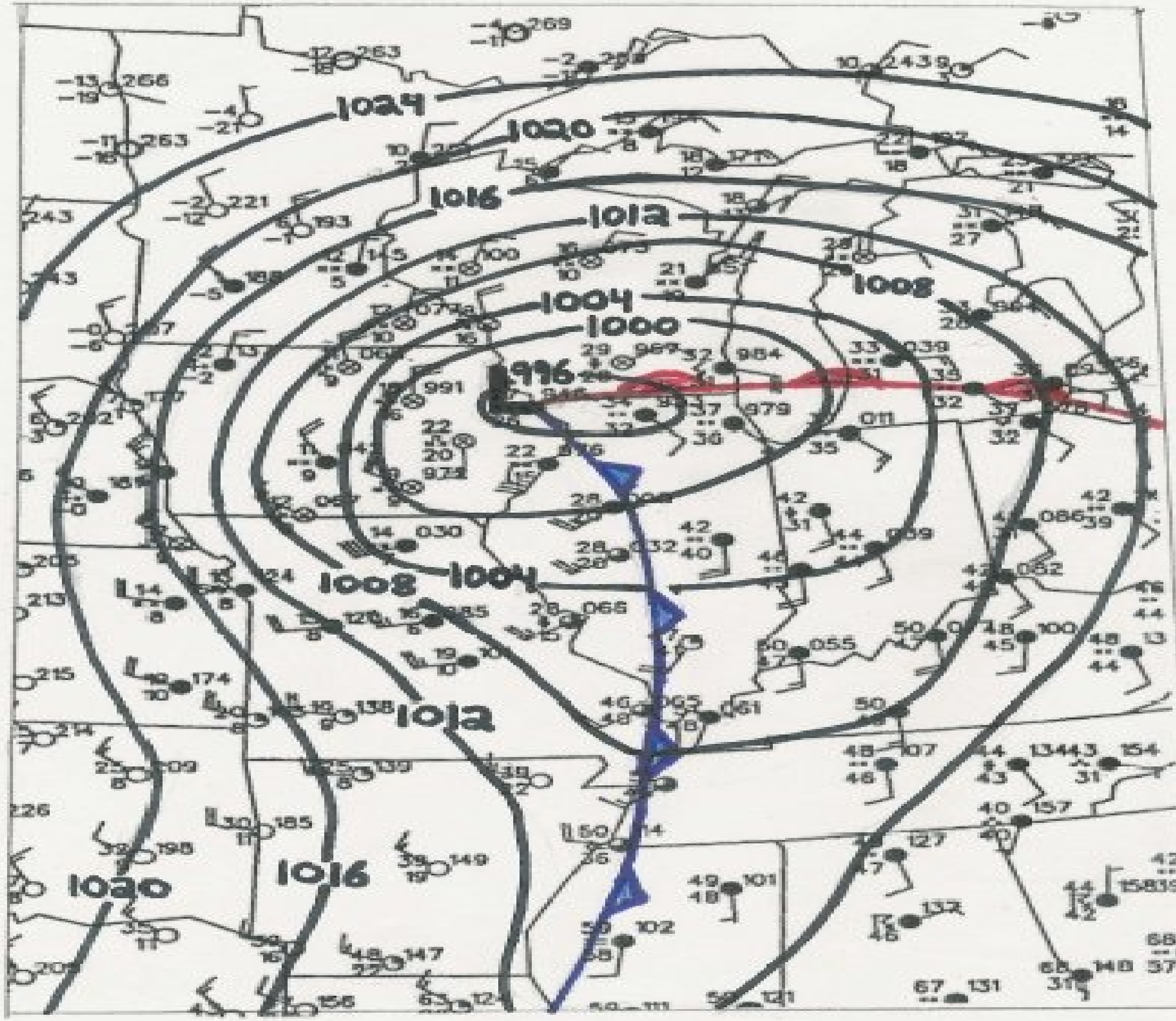


How to Locate a Front

We know that we need to look for low pressure and a boundary of cold and warm air.

To pinpoint the parts of our cyclone, look for specifics in the observation maps

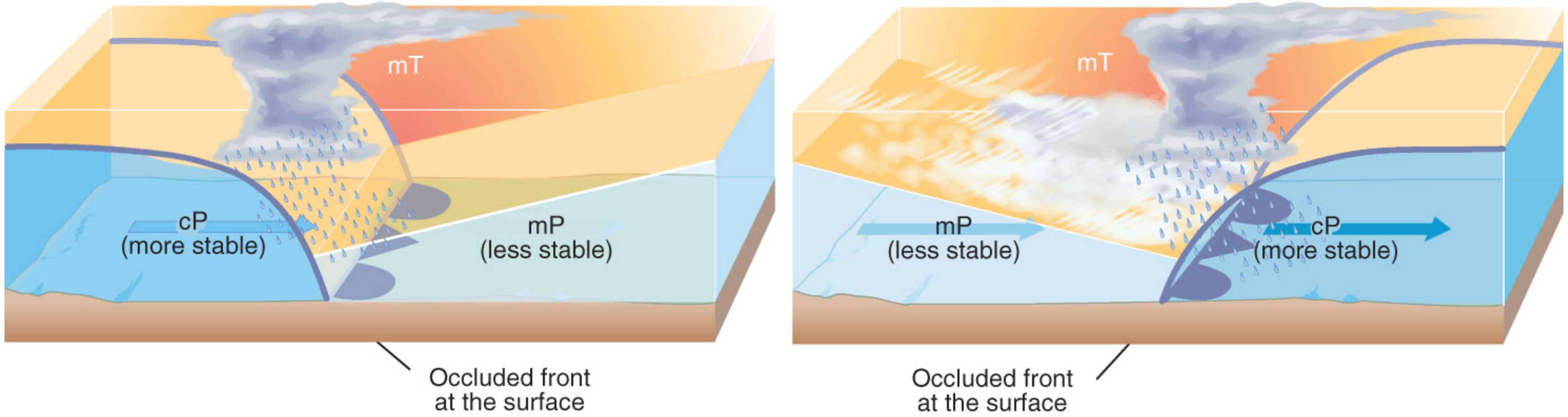
- Find the center of cyclonic rotation
- Find the large temperature gradients
- Identify regions of wind shifts
- Identify the type of temperature advection (change in **temperature** caused by movement of air by the wind)
- Look for kinks in the isobars



27 Jan 1996 0000 UTC

Occluded Fronts

- Involve 3 air masses
  - 2 polar air masses at the surface, usually mP and cP
  - 1 tropical air mass, mT that has been lifted entirely off the surface, and is occluded or hidden from the surface weather map
- Have weather like warm fronts where mT and mP air masses meet, and weather like cold fronts where mT and mP air masses meet



Occluded front Norwegeian model

Air Masses

- An **air mass** is an extremely large body of air whose properties of temperature and moisture content (humidity) are similar in any horizontal direction
- In a typical year, air mass weather kills more people in the world, all other weather phenomena combined
  - Heat waves, most dangerous weather type
  - Cold air outbreaks are also dangerous

Air mass types by temperature

- Polar (P): formed poleward of 60º
  - Cold or cool
- Arctic (A): formed over the arctic
  - Very cold
- Tropical (T): formed within 30º of the equator
  - Hot or warm

Air mass types by moisture amount

- Continental (c): formed over large land masses
  - Dry
- Maritime (m): formed over the oceans
  - Moist

Air Mass	Winter Characteristics	Summer Characteristics
Continental polar (cP)	Very cold and dry	Cool and dry
Maritime polar (mP)	Cool and humid	Mild and humid
Continental tropical (cT)	Cool and dry	Very hot and dry
Maritime tropical (mT)	Warm and humid	Warm and humid
Continental arctic (cA)	Bitter-cold and dry	—

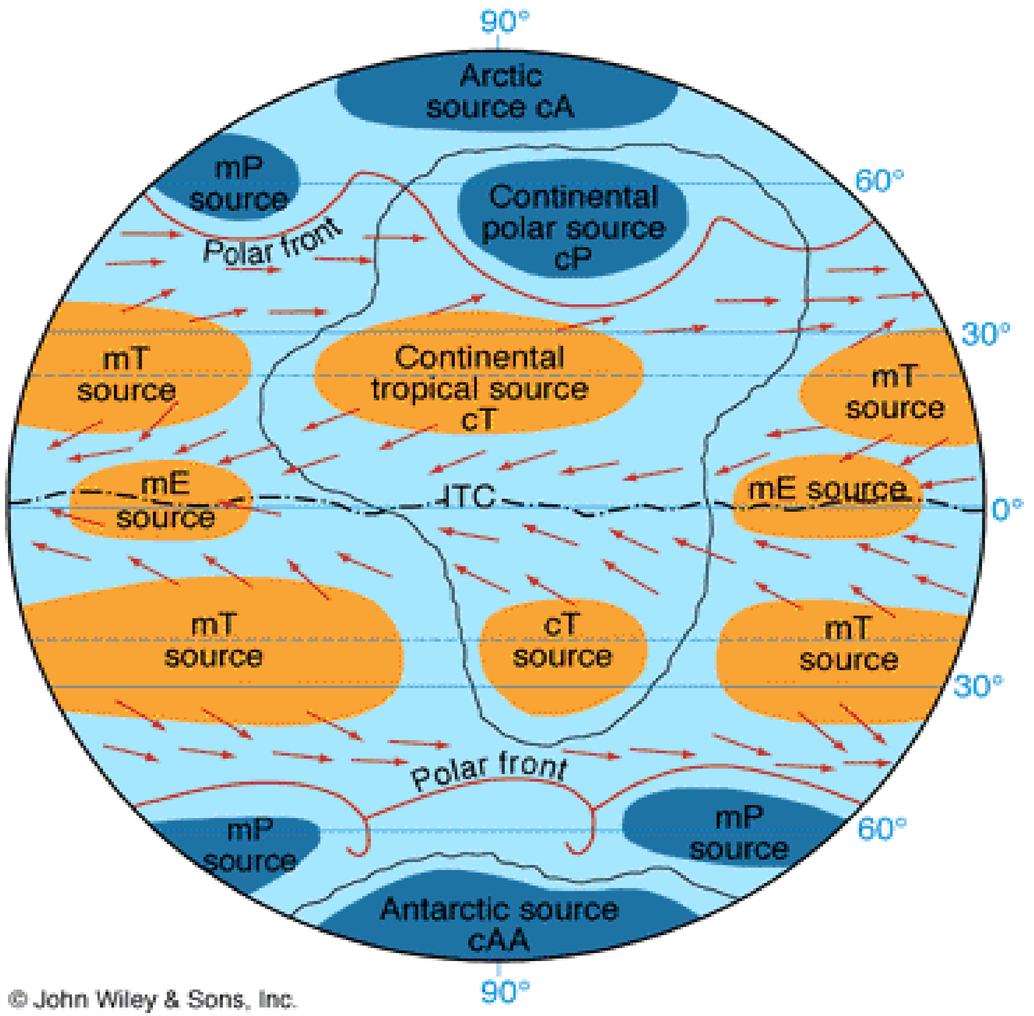
Temperature and Moisture Characteristics of Air Masses

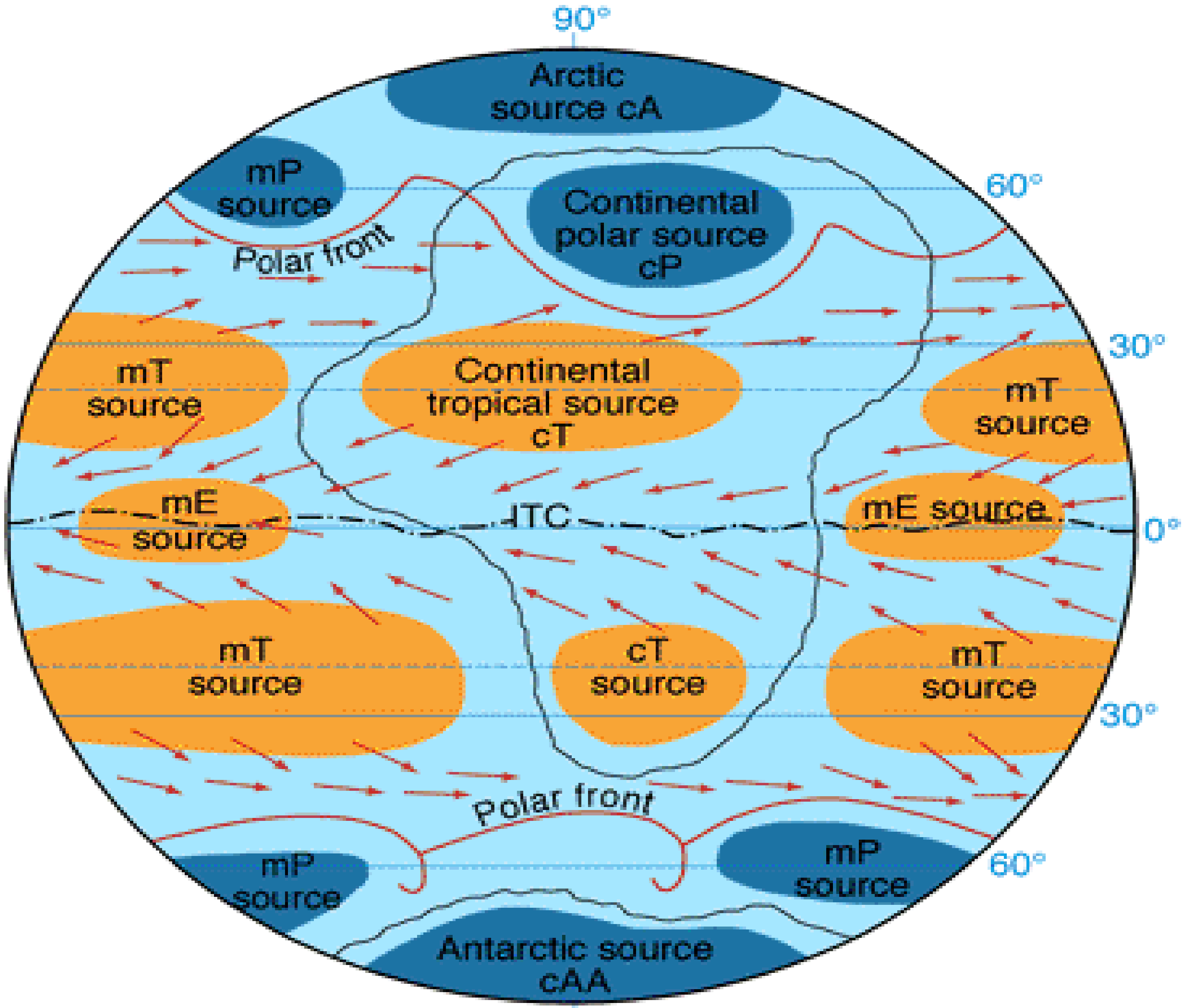
Air Mass Source Regions

- Have similar characteristics
  - Light winds
  - A uniform surface over a large region
  - Not coastline
- Air masses can move away from their source regions

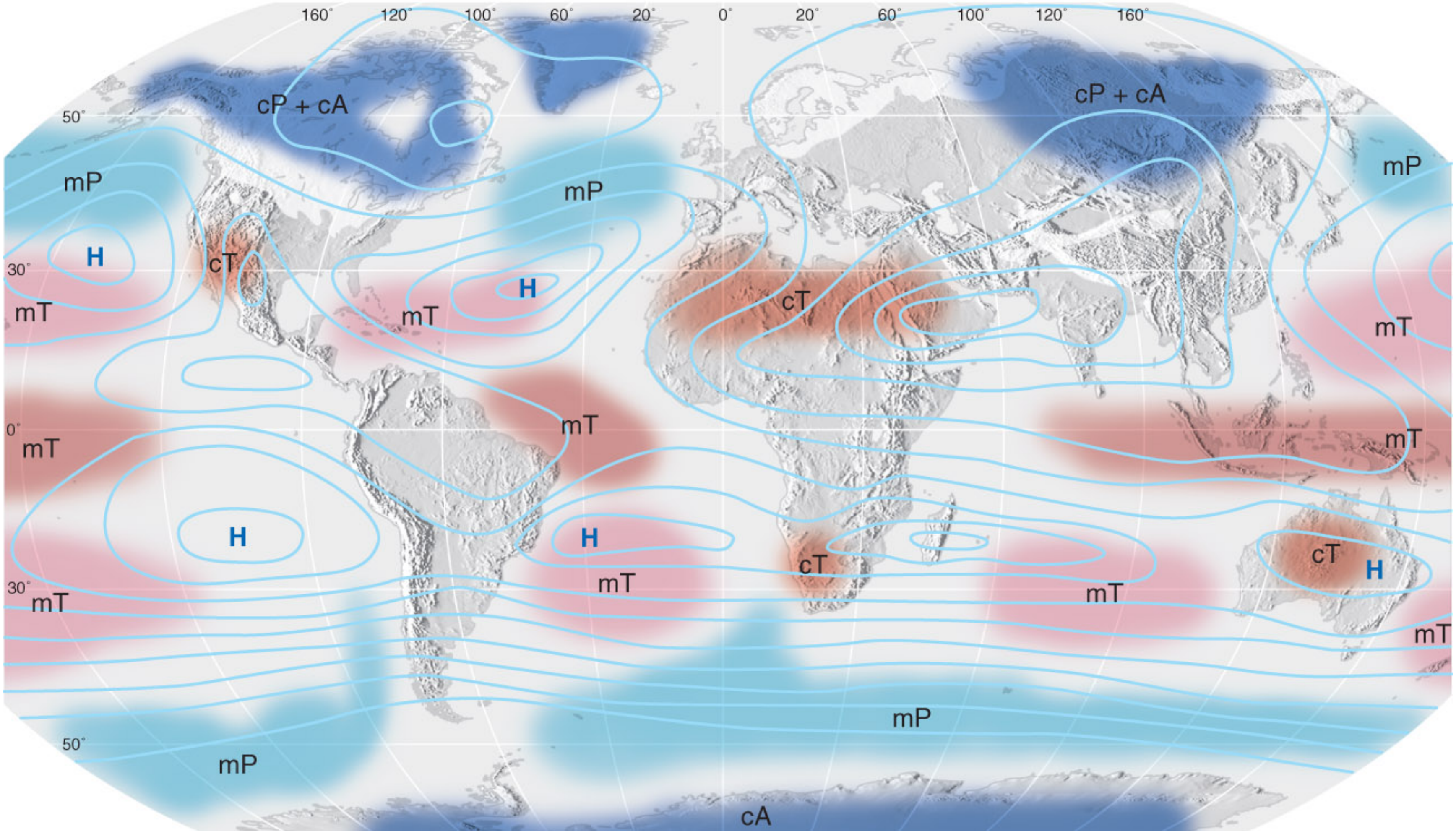
Major air mass source regions of the world

- **Combination:**
  - **Maritime Polar (mP)**
  - **Maritime Tropical (mT)**
  - **Continental Tropical (cT)**
  - **Artic (cA) or Antarctic (cAA)**
  - **Maritime Equatorial (mE)**





90°
Arctic source cA
mP source
Continental polar source cP
60°
Polar front
30°
mT source
Continental tropical source cT
mT source
mE source
ITC
mE source
0°
mT source
cT source
mT source
30°
Polar front
mP source
60°
mP source
Antarctic source cAA
90°



Major air mass source regions of the world.

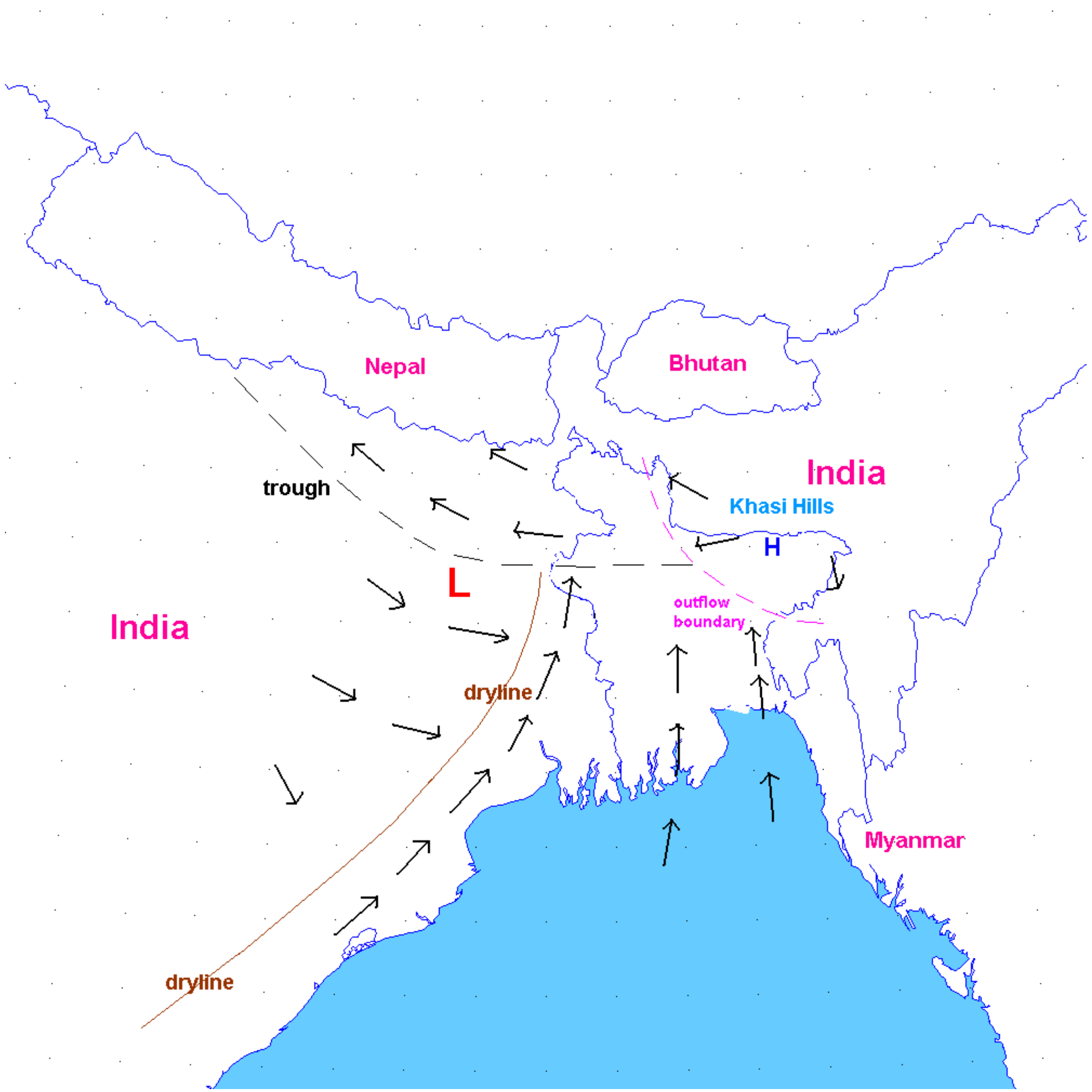
Air Mass Modification

- Properties of air masses change as they move and exchange energy and moisture with the underlying surface—called air mass modification
  - Temperature, moisture, stability
- Mechanisms that modify an air mass
  - Energy (heating) and moisture exchanges with the surface
  - Mechanical lifting

Examples of Air Mass Modification

- When a cold cP air mass moves over a warm body of water
  - Rapid exchange of energy and moisture
  - Rapid evaporation may cause steam fog
- When a cold cP air mass stalls over the warm Gulf of Mexico
  - Rapid modification
  - Large-scale weather pattern draws air north again
  - Called a return flow event
  - Responsible for severe weather along Gulf Coast

Mean position of mesoscale features during Indian / Bangladeshi severe events



Frontal trapping:

- Trapping mechanism by which mid-density water trapped over intertidal mudflats converges with dense water in the main channel forming a sharp front.
- The frontal presence and propagation give rise to spatial and temporal variations in stratification and vertical mixing.
- Front leads to enhanced stratification and suppressed vertical mixing at the end of the large flood tide, in contrast to what is found in many estuarine systems.
- Frontal trapping-generated fronts may occur in a wide variety of estuaries with shoal/channel morphology and/or braided channels and will similarly influence stratification, mixing, and transport.

Topographical influences:

1. Orographic Effect
2. 2. Topographical effect
3. Air Mass Characteristics