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S589: Weather and Atmospheric Stability

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Objectives

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- Identify atmospheric stability types
- Know the difference between dry and moist adiabatic lapse rates
- Understand how atmospheric stability affects fire and smoke
- Introduce thermodynamic diagrams and perform simple temperature plots

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Convective Stability

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- **Convective** vs baroclinic (synoptic)
- **Convective stability/instability:**
  - Atmosphere's resistance to vertical motion
  - Types/degrees/conditions: stable, neutral, unstable
  - Air parcel concept used to assess stability:
    - Adiabatic: no mixing with the environment
    - Allowed to expand or compress
    - Unit mass or volume of air

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Types of Atmospheric Stability

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- **Stable atmosphere**
  - Warm air overlays cool air
  - Potential temperature rises with height
  - Lifted air parcel is cooler than environment
- **Neutral atmosphere**
  - Potential temperature constant
  - Lifted air parcel is same temperature as environment
- **Unstable atmosphere**
  - Cooler air overlays warm air
  - Potential temperature falls with height
  - Lifted parcel is warmer than environment

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Inversions

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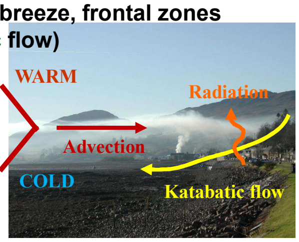
- **Warm air overlays cool air**
- **Katabatic flow: subsidence**
- **Advection: sea/land breeze, frontal zones (warm front anabatic flow)**
- **Radiation: night**



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Stable, Neutral, and Unstable Depiction

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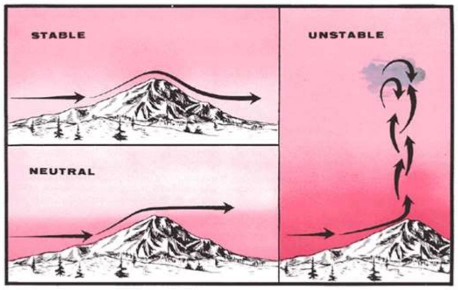
Schroeder and Buck, *Fire Weather*, 1970, pg 57



As air is lifted over mountain, the resulting airflow depends to some extent upon the stability of the air. These simple airflows may be complicated considerably by daytime heating and, in some cases, by wave motion.

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Lapse Rates

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- **Lapse rate: Change of temperature with change of altitude (elevation)**
  - **Adiabatic process: no mixing of environmental air with air parcel**
  - **Dry or wet (moist)**

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Dry Adiabatic Lapse Rate

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- **Dry air rising and falling follows the dry adiabatic lapse rate:**
  - $\Gamma_d = g/Cp$ **(e.g. degrees C or K per metre)**
  - **~3C/1000 feet or 9.8C/km**
  - **Sinking air compresses and warms → potential temperature ϴ**

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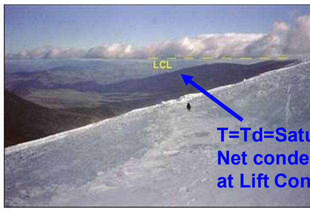
Moist Adiabatic Lapse Rate

- Moist air rising follows the moist (wet) adiabatic lapse rate:
  - 1.5C/1000 feet or 5C/km
  - Varies with temperature, greater value in cold air



Moist air sinking compresses and warms, so follows the dry adiabatic lapse rate when unsaturated

T=Td=Saturation
Net condensation
at Lift Condensation Level (LCL)

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Inversions applied to fire operations

- Inversion present: dense smoke near ground
  - Fumigation
  - Health impacts
  - Reduced visibility: hampers aircraft operation
  - Crew safety affected?

Need photo of dense smoke near ground

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Inversion breaking applied to fire operations

- Inversion breaks: fire intensity increases
  - Improves visibility near surface
  - Safety of crews above fire compromised
  - Plume-driven fire?

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What does this plume look like?

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Ground-based Stability Observations

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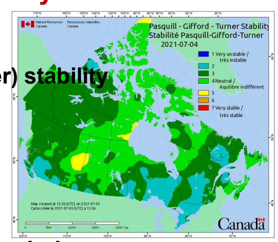

- Estimates
- Pasquill (-Gifford-Turner) stability assessment
  - Solar radiation
    - Sun angle
    - Cloud cover
  - Wind speed
- Lavdas (1986) Dispersion Index
- Ventilation Index
  - More information on venting in II-B-3

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Thermodynamic Diagrams

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Upper Air Data Sources

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- Weather balloons
  - Pibals
- Aircraft … helicopters
- Dropsondes
- Rocket sondes
- Data from fixed stations available in text and thermodynamic diagram form
  - Plot examples in the previous chapter, “Weather Data Sources”

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Emagram

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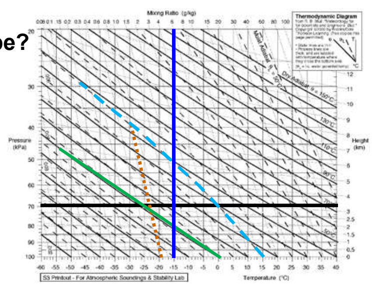
- Predecessor to the T-phi (tephigram)
- Used in Europe?

Isotherms
Isobars/height
Mixing Ratio
Dry Adiabats
Moist Adiabats



https://upload.wikimedia.org/wikipedia/commons/1/13/Emagram.GIF
Accessed May 28, 2021.

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T-Phi Diagram

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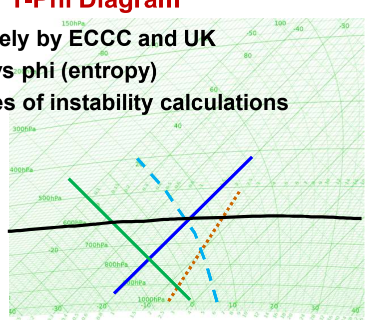
- Used extensively by ECCC and UK
- Temperature vs phi (entropy)
- Allows all types of instability calculations

Isotherms
Isobars/height
Mixing Ratio
Dry Adiabats
Moist Adiabats



https://en.wikipedia.org/wiki/File:Tephigram.png
Accessed May 28, 2021.

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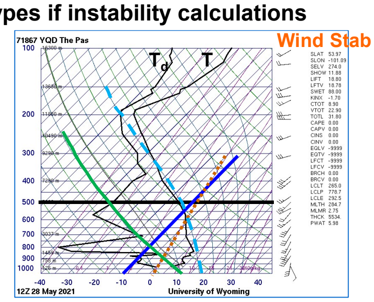
Skew T/log P Diagram

- Common
- Allows all types if instability calculations

Isotherms
Isobars/height
Mixing Ratio
Dry Adiabats
Moist Adiabats



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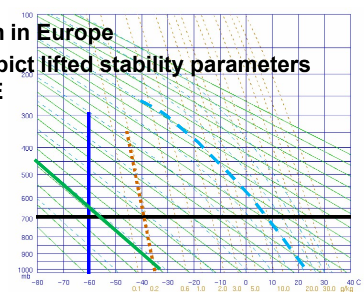
Stüve Diagram

- Simple
- More common in Europe
- Difficult to depict lifted stability parameters such as CAPE

Isotherms
Isobars/height
Mixing Ratio
Dry Adiabats
Moist Adiabats



https://en.wikipedia.org/wiki/File:Stüve_diagram
Accessed May 28, 2021.

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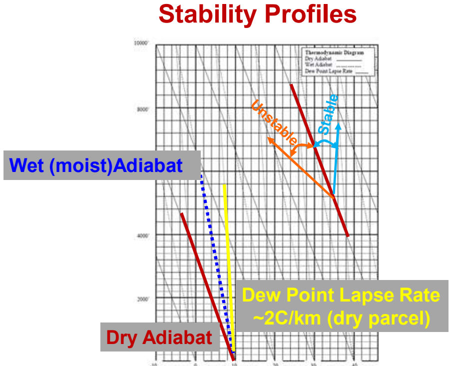
Stability Profiles



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Temperature Plot Example

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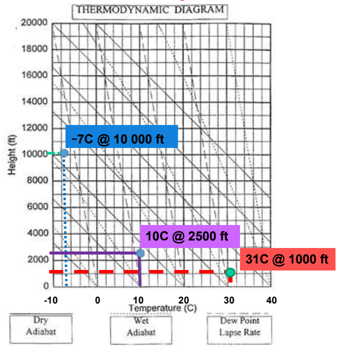
- We will go through some sample plots then do an exercise
- We use the Stüve Diagram



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Sample helicopter sounding

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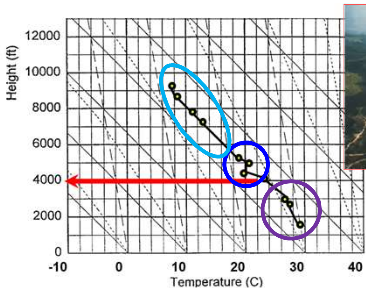
- Salmon Arm, BC August 4, 1998 16:00



Dry Adiabat

Wet Adiabat

Dew point lapse rate

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Exercise 1: Helicopter sounding example

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Stability Assessment

Plot the data supplied by helicopter pilots working in the vicinity at 5 am on the morning of August 5th to determine the stability of the lower atmosphere.

What is of concern this morning?
What surface temperature is required to break the inversion?

Altitude (m)	Altitude (ft)	Temperature (°C)
457	1500	22
548	1800	25.6
731	2400	29.8
762	2500	29.5
1005	3300	27.8
1524	5000	24.8
2042	6700	21.4
2591	8500	16.4

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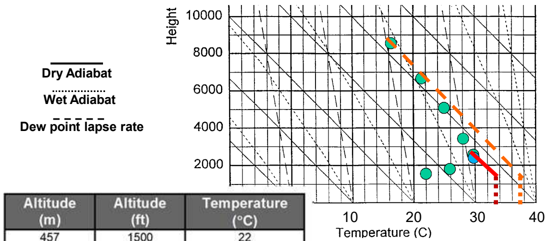
Exercise 1: Plot



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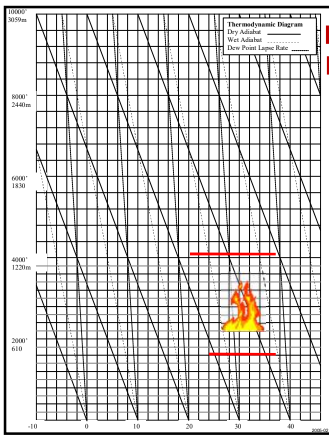

Exercise 2: OK Mtn Park Fire (at home)

Stability Assessment

Use the data you collected over the fire at 8 am on the morning of August 31st to determine the stability of the lower atmosphere.

What is concerning this morning?

Exercise 2: Helicopter sounding

Altitude (m)	Altitude (ft)	Temperature (°C)
381	1250	22
610	2000	22
762	2500	20
914	3000	19
1067	3500	18
1219	4000	16
1372	4500	16
1524	5000	15
1676	5500	14
1829	6000	12
1981	6500	12
2133	7000	10
2286	7500	10
2438	8000	8
2591	8500	7
2743	9000	6
2896	9500	6
3048	10000	6

Okanagan Mountain Park fire, Kelowna, 2003

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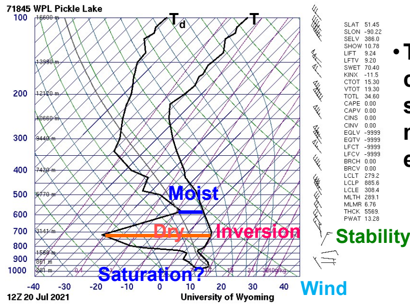
Adding humidity

- Sample plot from University of Wyoming



- The T/T_d/RH conversion spreadsheet may help estimate RH

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Clouds

- Stability indicator: *cumulus* vs *stratiform*
- Cloud base height estimate: H=400(T-Td)
  - >8000 ft = dry
  - ≤4000 ft = wet
- Low cloud: <6500 ft (~2000m)
- Mid-level cloud: 6500-23000 ft (2000-7000m)
- High cloud: >23000 ft (> 7000m)
- Dew point depression can indicate scattered, broken, continuous, or no cloud

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Thermodynamic Diagrams: Other uses

- Stability indexes
  - Brief discussion in III-A-2 (“Upper Air Influences”)
- Cloud assessment
- Adiabatic heating (chinooks, for example)
- Wind profiles
- Others …

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Summary and Skills

- Understand definition and conditions of stability using the air parcel model
- Recognize a few thermodynamic diagrams
- Perform simple temperature plots and interpret stable and unstable layers
- Identify dew point and temperature lines on a thermodynamic diagrams and estimate RH from the accompanying spread

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