What is "Mesoscale"?

- Meaning is: "middle scale" or "in-between" scale
- Synoptic – Mesoscale – Convective scale
- Division of scales is not rigid – there is a continuum so that any phenomena is affected by other scales. For example, convective elements organized into a mesoscale system have both important convective elements and the combination; synoptic scale systems have important mesoscale features (extratropical cyclone is synoptic-scale while fronts are mesoscale)
- Scales can be defined in several ways:

1. **Arbitrary Division of Space/Time**
    1. Synoptic => L of 1000 km or greater (or T > 1 day)
    2. Mesoscale => 10 km < L < 1000 km; 1h < T < 1 day
    3. Convective => L < 10 km

examples….. Turbulence (T = 10 sec, L=1 m)

Thermal (T=5 min , L = 500 m)

Cb (T=30 min, L = 3km)

MCC (T=10 hr, L=250 km)

2. **Phenomenology or empiricism:**

A) Based on recognizable patterns => visual (can be from satellite, radar, plotted charts, etc.)

B) Spectral Analysis to determine dominant energy-containing wavelengths

1. Sharp peaks at 1 year and 1 day correspond to well-defined periodicities of external forcing

2. Broad peaks at periods of days-weeks reflects global long-wave pattern and eddies therein (I.e., extratropical cyclones)

3. Seconds/minutes reflects convection/turbulence

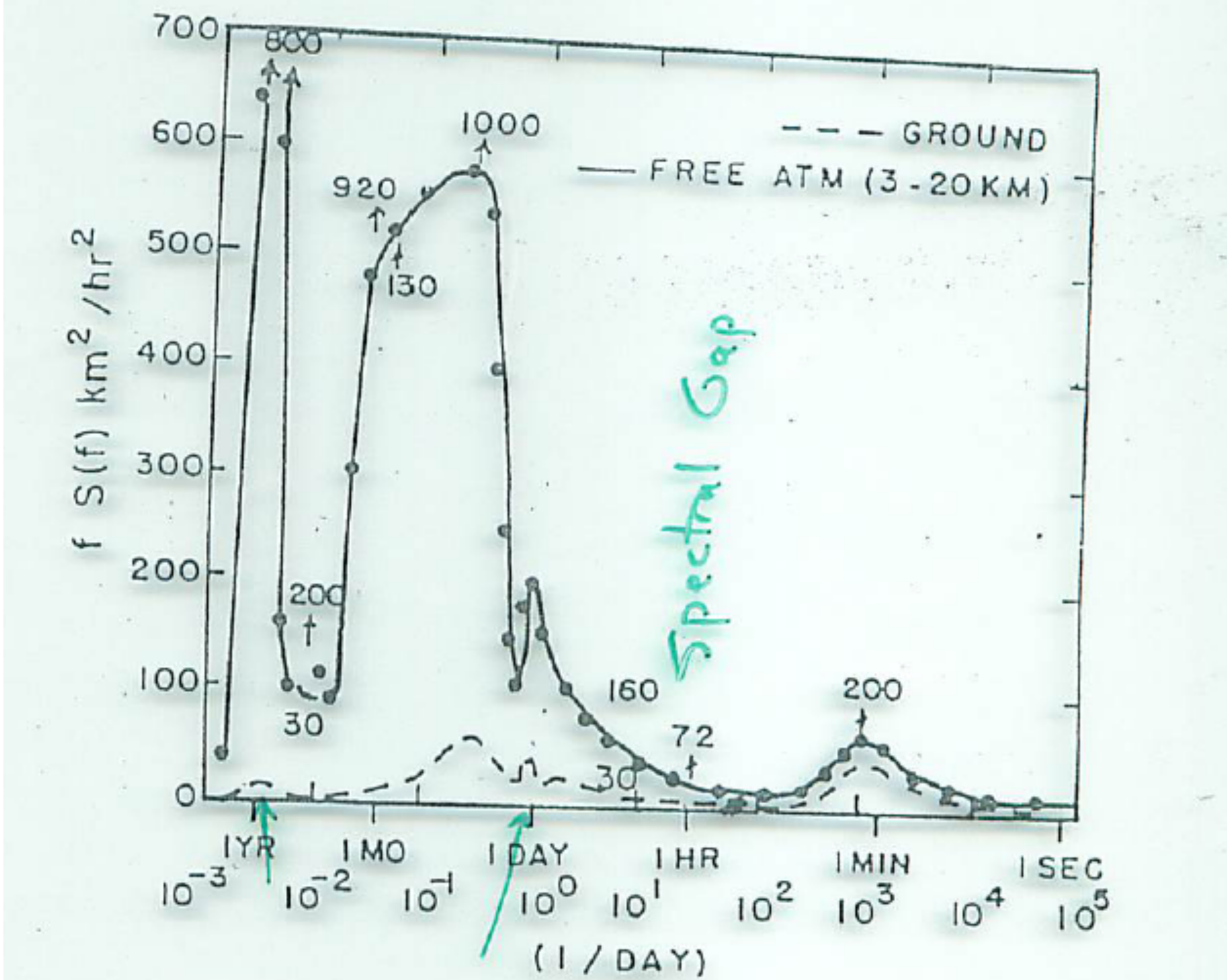

Figure 1.1. Average kinetic energy of west-east wind component in the free atmosphere (solid line) and near the ground (dashed line). Numbers indicate maximum values of kinetic energy. (After Vinnichenko, 1970.)

3. **Scale Analysis:**

Compares magnitudes of important physical processes for different scales

For example, we could begin with the horizontal equation of motion:

$$d\mathbf{V}/dt = \partial\mathbf{V}/\partial t + \mathbf{V}\cdot\nabla\mathbf{V} + w\,\partial\mathbf{V}/\partial z = -1/\rho\nabla p - f\mathbf{k}x\mathbf{V} - \sigma\mathbf{V}$$

Where $\mathbf{V} = u\mathbf{i} + v\mathbf{j}$ and $\nabla = \mathbf{i}\partial/\partial x + \mathbf{j}\,\partial/\partial y$

Next, specify a length scale, *L*, and a velocity scale, *V*, yielding a consistent time scale *T=L/V*

Insert scales into equations

- $d\mathbf{V}/dt \sim V[V/L] = V^2/L$
- $-1/\rho\nabla p \sim -1/\rho(p'/L)$
- $f\mathbf{k}x\mathbf{V} \sim fV$
- $\sigma V \sim \sigma V$, where $\sigma \approx 0$ above boundary layer

Then we have $V^2/L \sim -1/\rho(p'/L) + fV$

For synoptic scale, $L \sim 1000$ km, $V \sim 10$ m/s, $\rho \sim 1$ kg/m^3, $p' \sim 10$ mb$=10^3$ Pa, $f \sim 10^{-4}$ s^{-1}

- Lagrangian tendency is $V^2/L \sim 10^{-4}$ ms^{-2}
- PGF is 10^{-3} ms^{-2}
- Coriolis (fV) is 10^{-3} ms^{-2}

- So for the synoptic scale, motions tend to approach geostrophic balance; departures are small but perhaps not completely negligible. An appropriate definition of synoptic scale is terms of dynamics could be that quasi-geostrophic theory provides a useful conceptual framework. Typical length scales are of order 10^6 m (1000 km)

Vertical equation of motion

- Subtract a hydrostatic basic state to get:
- $dw/dt = -1/\rho \partial p' / \partial z - \rho' / \rho g$ (boussinesq approximation)
- For convective motions,

  $w \sim 1\text{-}10$ ms-1, $L \sim 10^3$ m, $\rho' / \rho \sim 1/100$, $p' \sim 100$ Pa, $g \sim 10$ ms^{-2}

So, $dw/dt \sim W^2/L \sim 10^{-1}$ ms^{-2}

$-1/\rho \partial p' / \partial z \sim 1/\rho\ (10^2 \text{ Pa}/10^3 \text{m}) \sim 10^{-1}$ ms^{-2}

$\rho' / \rho g \sim (10^{-2})(10 \text{ms}^{-2}) \sim 10^{-1}$ ms^{-2}

- Convective scale is small enough that departures from hydrostatic balance begin to have significance

Rossby Number

- We can define various (usually non-dimensional) combinations of terms which are useful in scale analysis: a familiar example is the Rossby Number
- Ro ~ (du/dt) / (fV) ~ $(V^2/L)/(fV) \sim V/(fL)$
- A related parameter is the Rossby Radius = $(gH\Delta\theta/\theta_0)^{**0.5}/f$ (which is gravity wave speed compared to Coriolis parameter)
- Synoptic scale often defined as Ro << 1

Thus…

- Mesoscale is a wide range

$1 < L < 1000$ km

Maso-, meso-, miso-, moso-, muso-

Also meso-α, meso-β, meso-γ

Some other considerations for defining “mesoscale”

- Pielke – small enough to be significantly out of geostrophic balance (e.g. QG theory invalid) but large enough that hydrostatic aproxmation IS valid.

Conclusions

- Several different ways to do scaling
- All scaling is somewhat arbitrary, even if based on physical conditions
- Can't be too pedantic about classifications

  "Big whirls have little whirls which feed on their velocity, and little whirls have lesser whirls and so on to viscosity" (famous quote by Richardson).

We are trying to look at a subset of these "whirls" in the middle → mesoscale meteorology

Two broad classes of mesoscale phenomena

- Internally forced – mesoscale phenomena that derive structure and circulation primarily from processes within the atmosphere. Examples include:

  -- MCCs, forced mainly by consequences of latent heat release

  -- fronts, forced by dynamical processes that act to sharpen atmospheric temperature gradients

Two broad classes of mesoscale phenomena

- Externally forced – mesoscale phenomena resulting from interaction of atmosphere with the earth's surface; i.e., forcing is external to the atmosphere. This forcing is commonly due to either:

  -- differential heating of earth's surface, which in turn creates differential heating of the atmosphere (i.e., thermal forcing)

  -- atmospheric response to irregular terrain (i.e., mechanical forcing).

- These distinctions are not rigid. Often, several differnet types of forcing are important to a given mesoscale phenomenon.

Classification of the Mesoscale

(from COMET module)

Nomenclature	Dimensions		Typical WX Feature
Mesoscale-alpha (a)	200 - 2000 km	6 hrs - 2 days	Jet stream, small hurricanes, weak anticyclones
Mesoscale-beta (b)	20 - 200 km	30 mins - 6 hrs	Local wind fields, mountain winds, land/sea breeze, mesoscale convective complexes (MCCs), large thunderstorms
Mesoscale-gamma (c)	2 - 20 km	3 - 30 mins	Most thunderstorms, large cumulus, extremely large tornadoesFujita (1986)

length\time	months	days	hours	minutes	seconds	scale
>10,000 km	Standing waves	Ultra-long waves				Macro-α
>2,000 km		Baroclinic waves				Macro-β
>200 km		fronts hurricanes				Meso-α
>20 km			LLJ, Squall lines			Meso-β
> 2km			thunder IG	storms W		Meso-γ
> 200 m				tornadoes		Micro-α
> 20 m				dust the	devils rmals	Micro-β
< 20 m					turbulence	Micro-γ