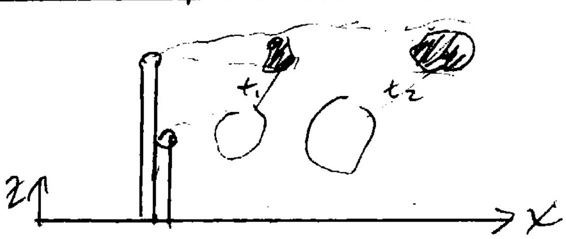
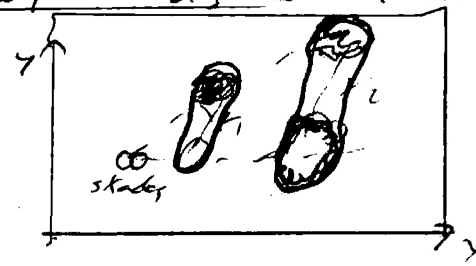
p2-37

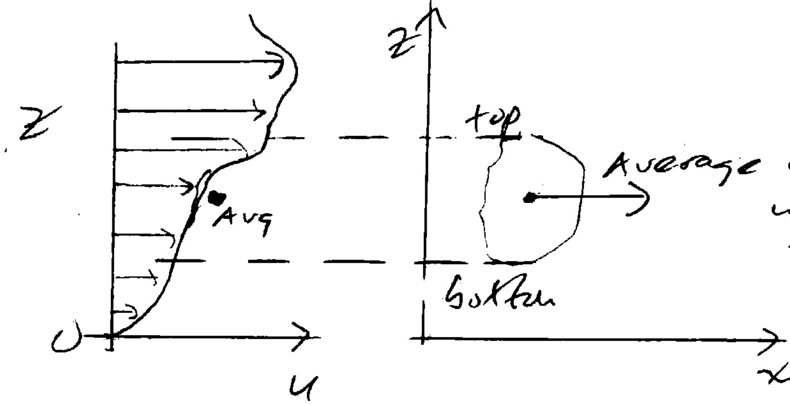
Section 2.2.4 Puff splitting (vertical wind shear)

1. Each puff advected by winds at that puff



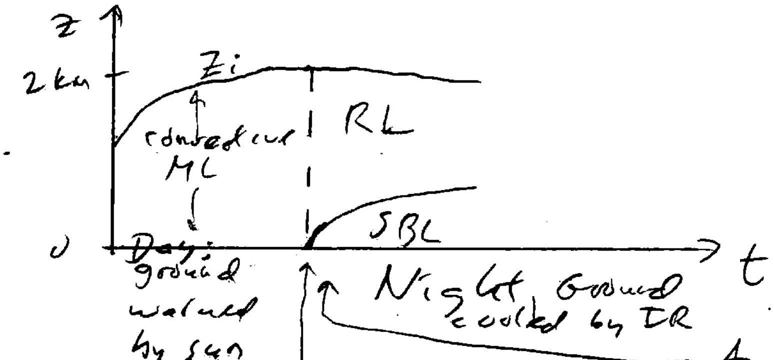


footprint if then mixed down to ground, ∴ mean shear increases dispersion.



Average advection for whole puff, between top & bottom of that puff

2. PBL evolution relevant to puff splitting

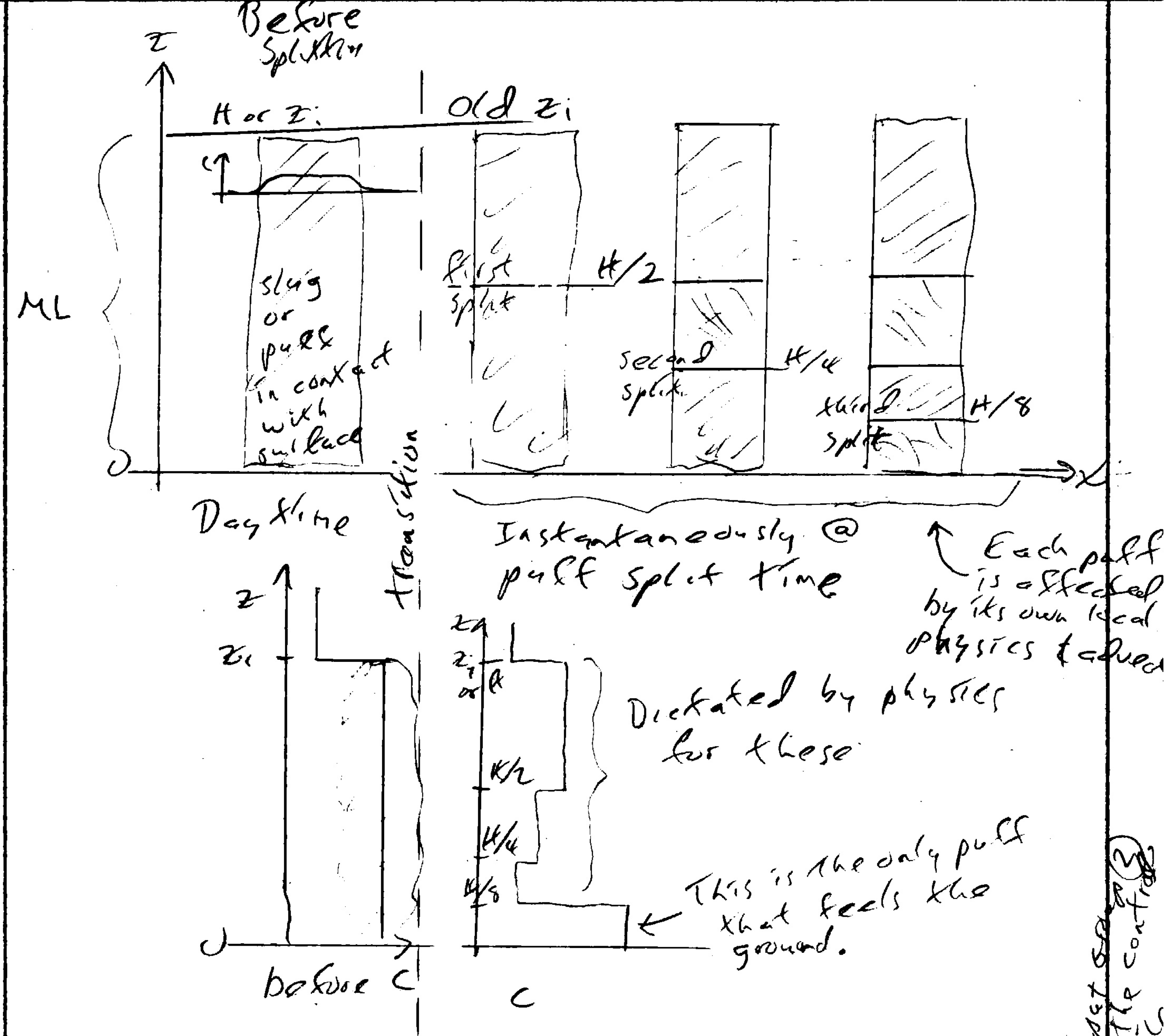


1/2 h before sunset, ground stops being warmer than air, ∴ convection (eg. thermals) cease

☆ This is the transition where puff-splitting is needed

Q for Students:

1) What causes mixing during day? During night
2) How is the nature of mixing different?
3) How "well mixed" is the SBL?



Conditions for Splitting (p 2-39)

0) Splitting must be turned on with MSPLIT flag (2) in input group of the control file

1) Only puffs touching the ground can split.

2) Time of day when splitting is allowed is set by IRESPLIT (re-split) flag

3) The "old" ML height must be sufficiently high, specified by ZISPLIT (z_i)

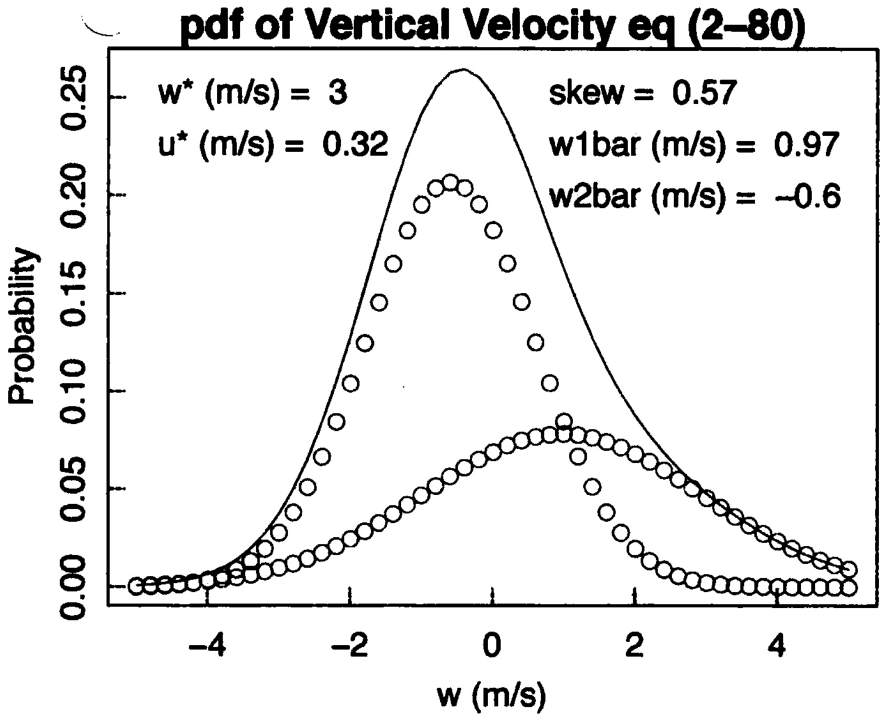
4) The ratio of new to old mixing height must be sufficiently small, specified by ROLDMAX

(Input Group (12))

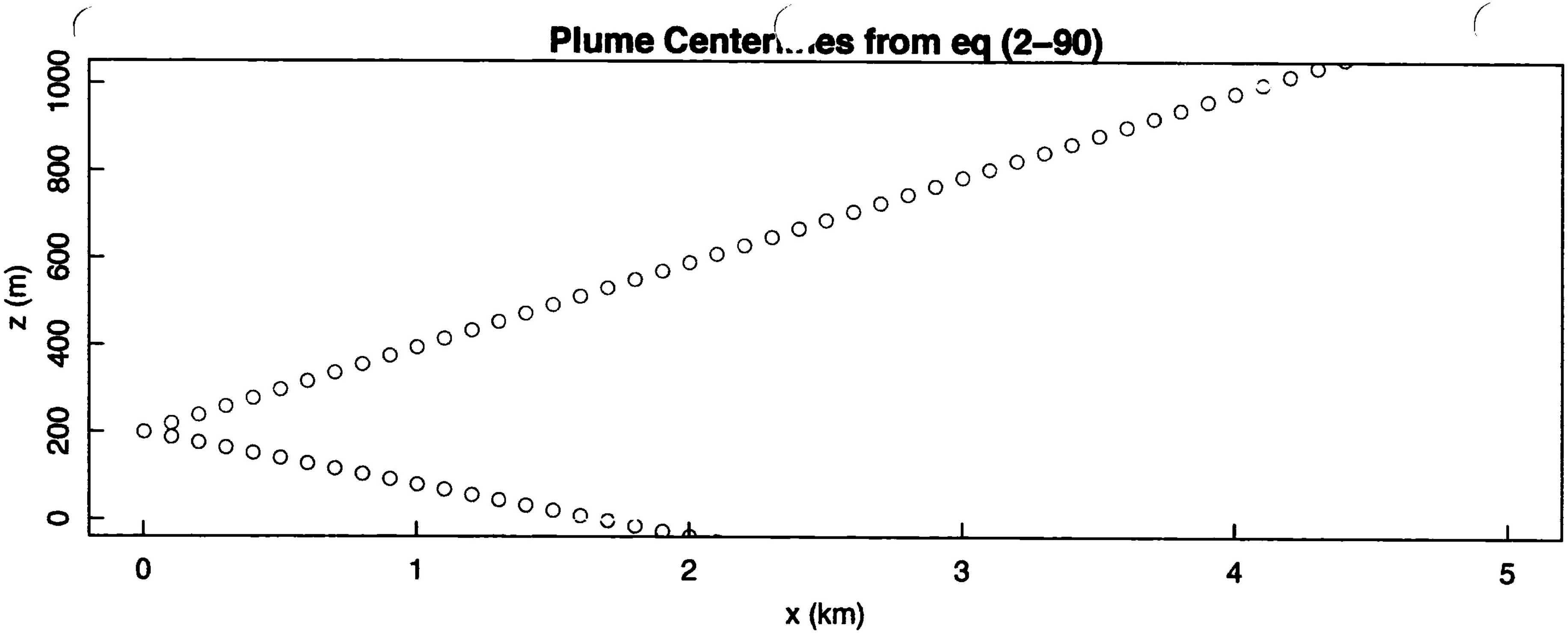
5) Happens only if puff is not gaussian in vertical

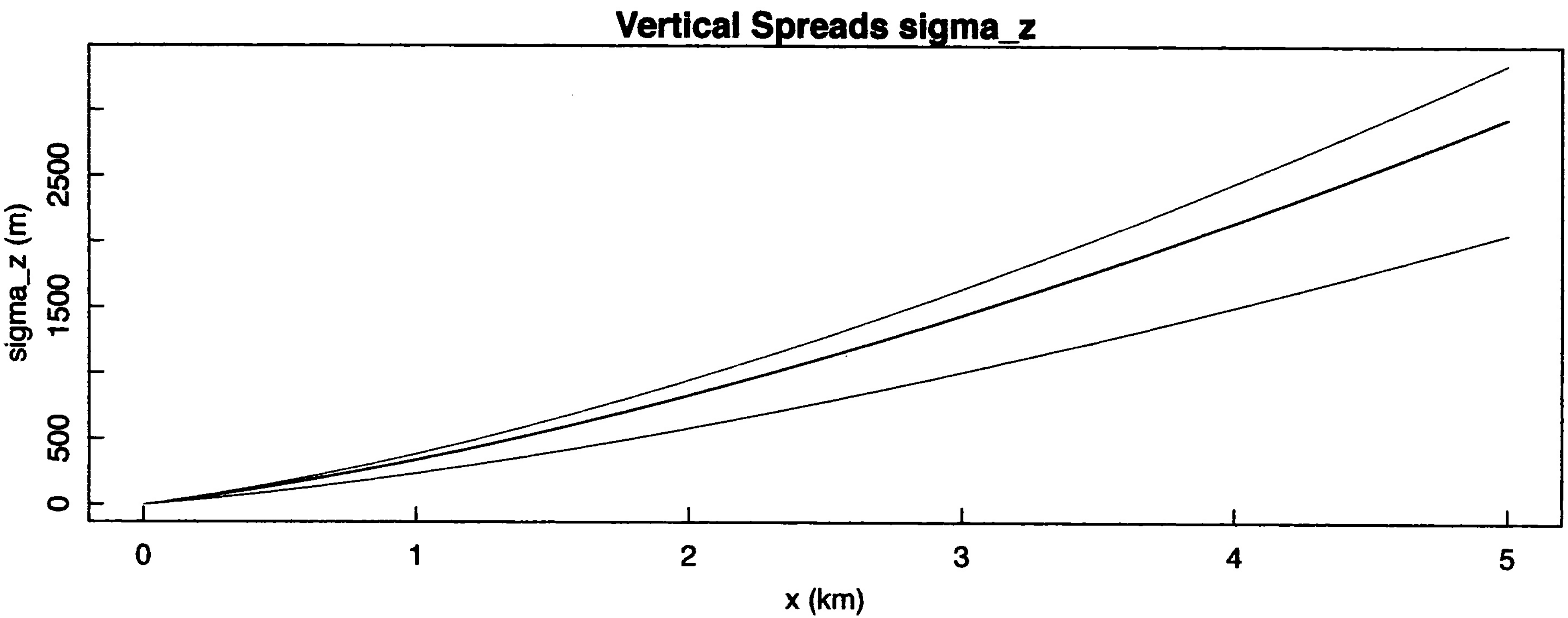
Takes longer to make first

CALPUFF Section 2.2.5 - Deardorff convection probability distribution functions (pdfs)

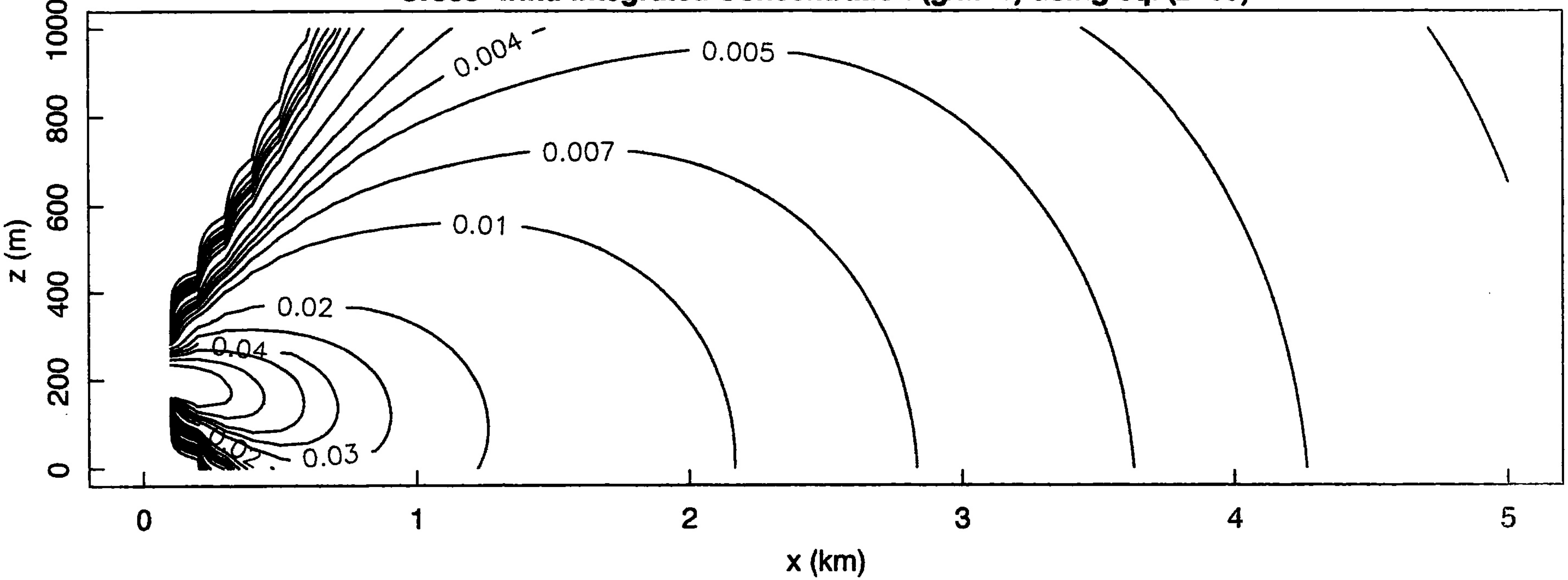


pdf of Vertical Velocity eq (2–80)
w* (m/s) = 3
u* (m/s) = 0.32
skew = 0.57
w1bar (m/s) = 0.97
w2bar (m/s) = –0.6
Probability
0.00
0.05
0.10
0.15
0.20
0.25
–4
–2
0
2
4
w (m/s)

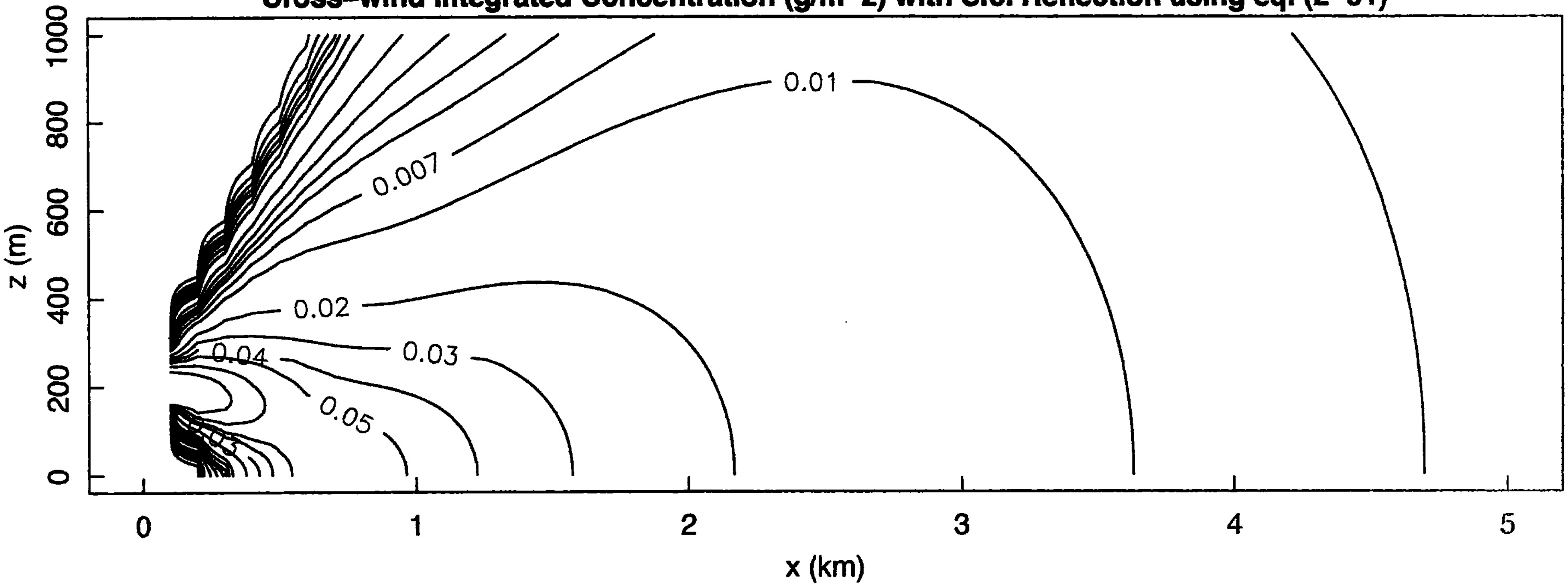

Plume Centerl...es from eq (2–90)
z (m)
0
200
400
600
800
1000
x (km)
0
1
2
3
4
5


Vertical Spreads sigma_z
sigma_z (m)
0
500
1500
2500
x (km)
0
1
2
3
4
5

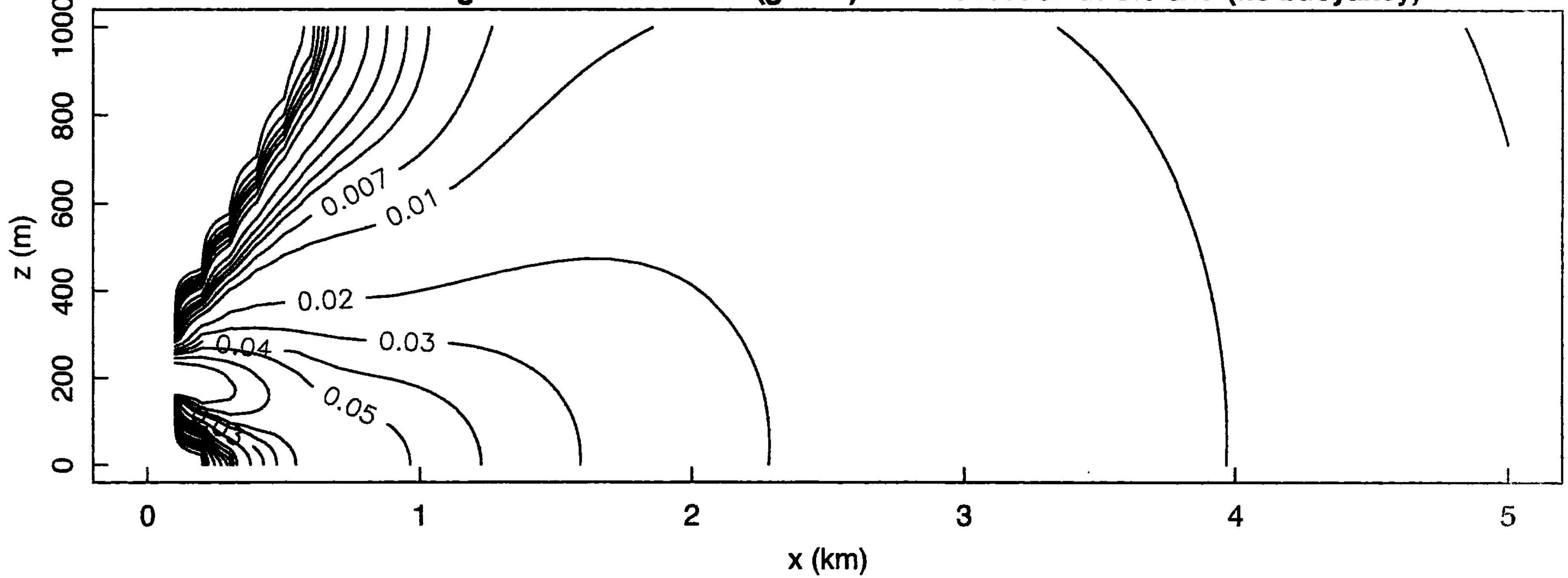
Cross-wind Integrated Concentration (g/m^2) using eq. (2-89)



Cross-wind Integrated Concentration (g/m^2) with Sfc. Reflection using eq. (2-91)



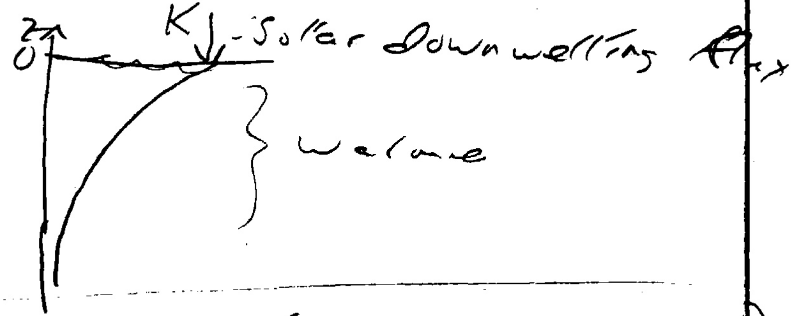
Cross-wind Integrated Concentration (g/m^2) with Reflection at Sfc & Zi (no buoyancy)



CALPUFF - section 2.5 -
Coastal and over water

2.5 Overwater & Coastal

Water has: - high heat capacity
- warmed water turb. mixed w/ cooler
- sunlight absorbed @ range of depths



Sea sfc is:
- uniform (relative)
- flat
- small roughness

Air has: high humidity

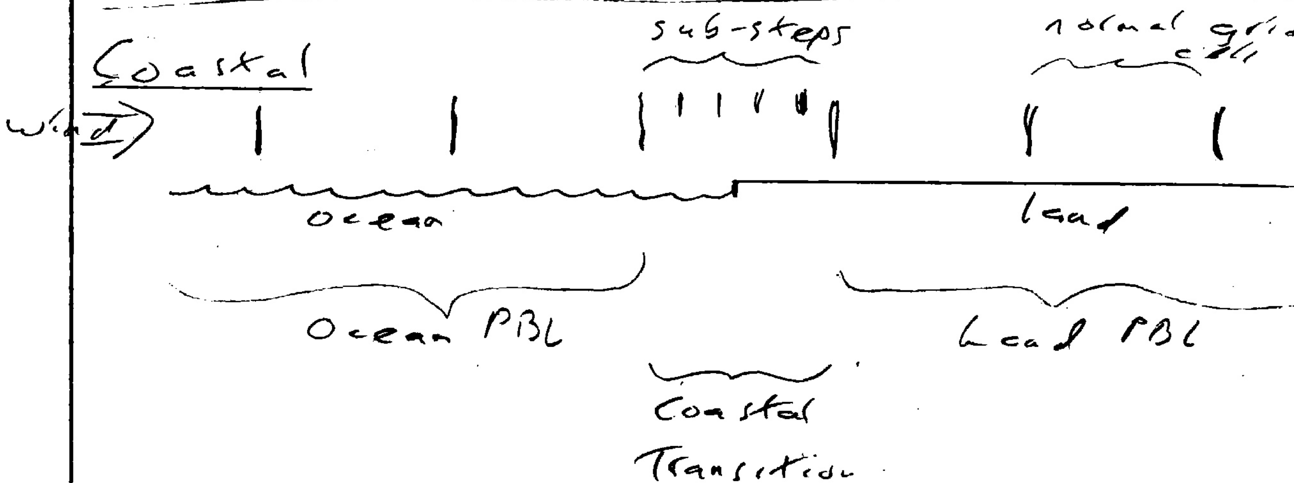
Ocean PBL:
∴ Almost no diurnal cycle (ie, not daily variation)
∴ Cannot use the overland PBL params.

Instead, CALPUFF marine PBL depends on

- $T_{sea} - T_{air}$
- Wind speed
- q_{air} (spec. humid)

} Probably bulk transfer $H_0 = \rho c_p C_D U (T_{sea} - T_{air})$

Coastal



↑
Puff mode works best

Thermal Internal BL (TIBL) - Show fig 2-14 on p 2-66

It is a normal ML where growth vs time translates into growth vs. distance

Mixed Layer Growth – Simple Thermo. Theory

Assumption 1: Bulk approx.

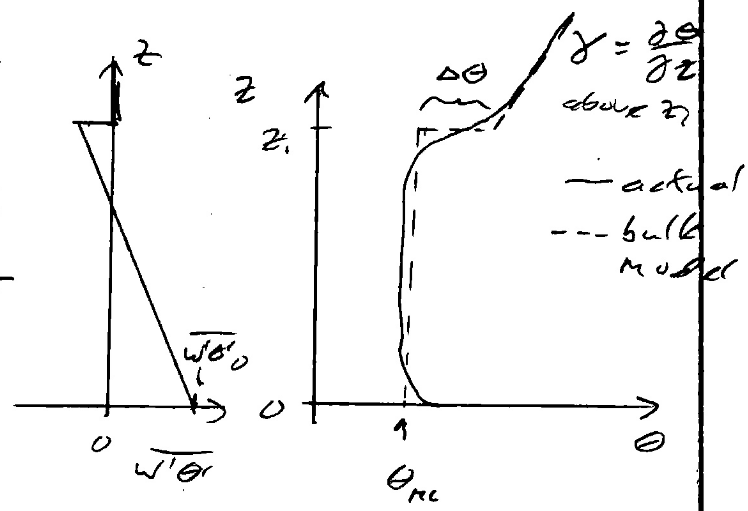
Assumption 2: $\Delta\theta \approx$ const.

Assumption 3: $\overline{w'\theta'}_{z_i} = -\beta\, \overline{w'\theta'_0}$

↑ due to entrainment over land

These are kinematic heat fluxes

$\beta \simeq 0.2$

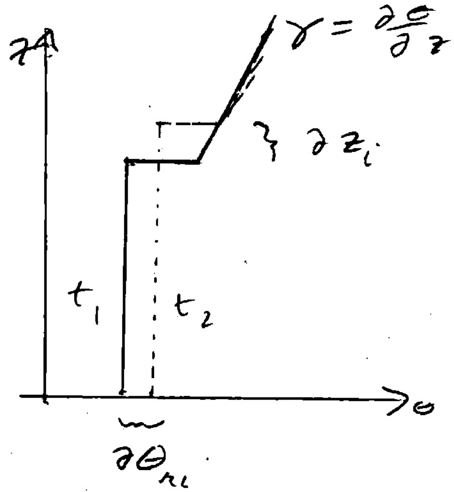


By Geometry

$$\partial z_i = \frac{\partial \theta_{ML}}{\gamma}$$

$$\therefore \frac{\partial z_i}{\partial t} = \frac{1}{\gamma}\frac{\partial \theta_{ML}}{\partial t} \qquad (1)$$

↑ Get this from heat budget



$$\frac{\partial \theta_{ML}}{\partial t} = \frac{\overline{w'\theta'_0} - \overline{w'\theta'_{z_i}}}{z_i}$$

Use assumption 3

$$\frac{\partial \theta_{ML}}{\partial t} = \frac{(1+\beta)\,\overline{w'\theta'_0}}{z_i} \qquad (2)$$

plug into eq (1):

$$\frac{\partial z_i}{\partial t} = \frac{(1+\beta)\,\overline{w'\theta'_0}}{\gamma z_i}$$

convert from kinematic heat flux

$$H_0 = \rho C_p \overline{w'\theta'_0}$$

$$\frac{\partial z_i}{\partial t} = \frac{(1+\beta)\, H_0}{\gamma z_i \rho C_p}$$

Use Taylor's hypothesis

$$\frac{\partial(\ )}{\partial t} = u\frac{\partial(\ )}{\partial x}$$

$$u\frac{\partial z_i}{\partial x} = \frac{(1+\beta)H_0}{\gamma z_i \rho c_p}$$

$$\boxed{\frac{\partial z_i}{\partial x} = \frac{(1+\beta)H_0}{\gamma \rho c_p u z_i}} \qquad (2-151)$$

on p 2-68

Assumption 4: except that they use 2β instead of β.

Namely entrained heat flux = 0.4 × sfc. heat flux

To integrate, separate variables

$$z_i\, dz_i = \frac{(1+2\beta)H_0}{\gamma \rho c_p u}\, dx$$

$\int$

$$\frac{1}{2}\left[z_i^2 - z_{i_0}^2\right] = \frac{(1+2\beta)H_0}{\gamma \rho c_p u} \cdot \underbrace{(x - x_0)}_{S\ =\ \text{substep distance}}$$

$$\boxed{z_i = \sqrt{\frac{2(1+2\beta)H_0}{\gamma \rho c_p u} \cdot S + z_{i_0}^2}} \qquad 2-152$$