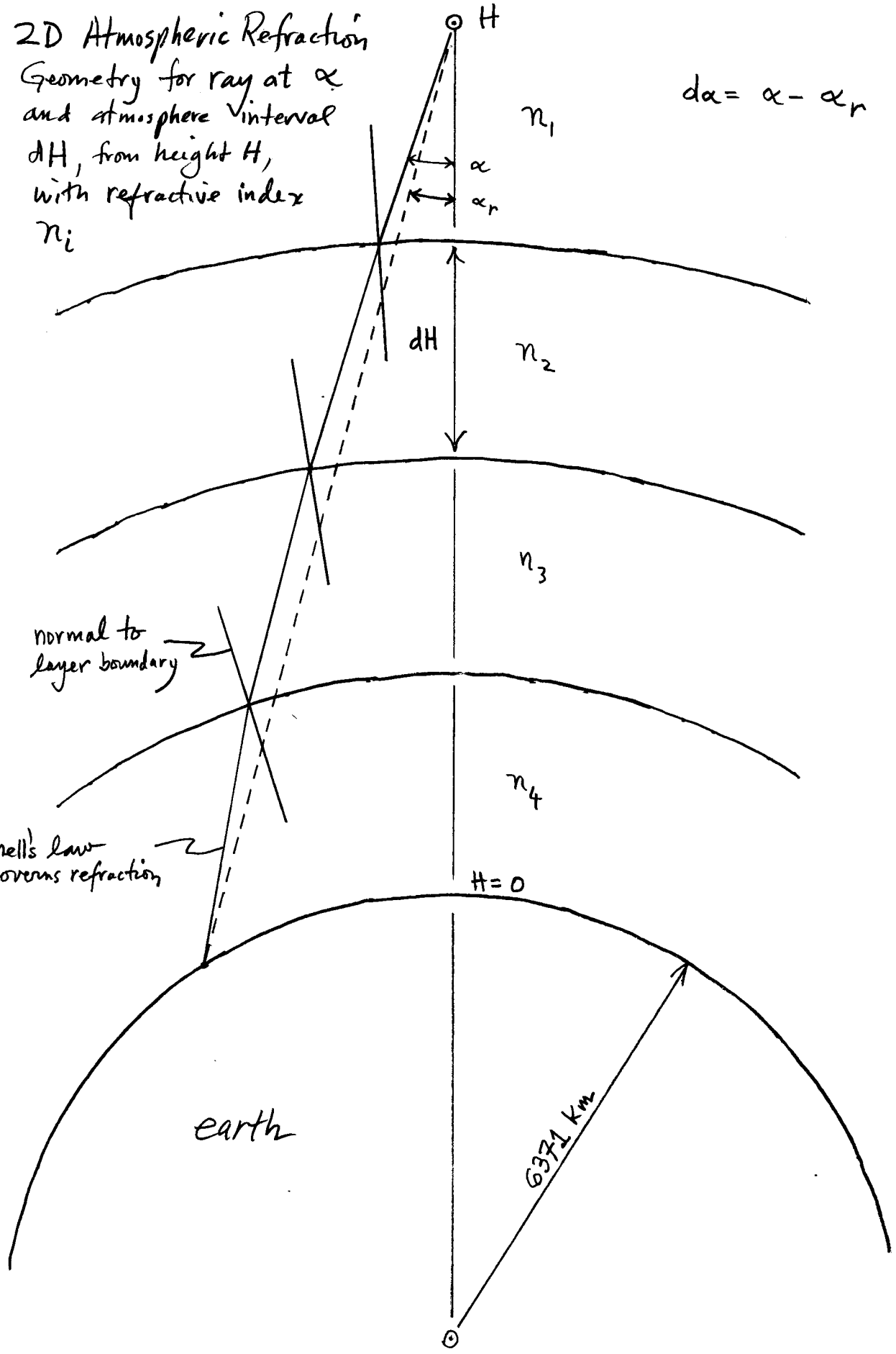
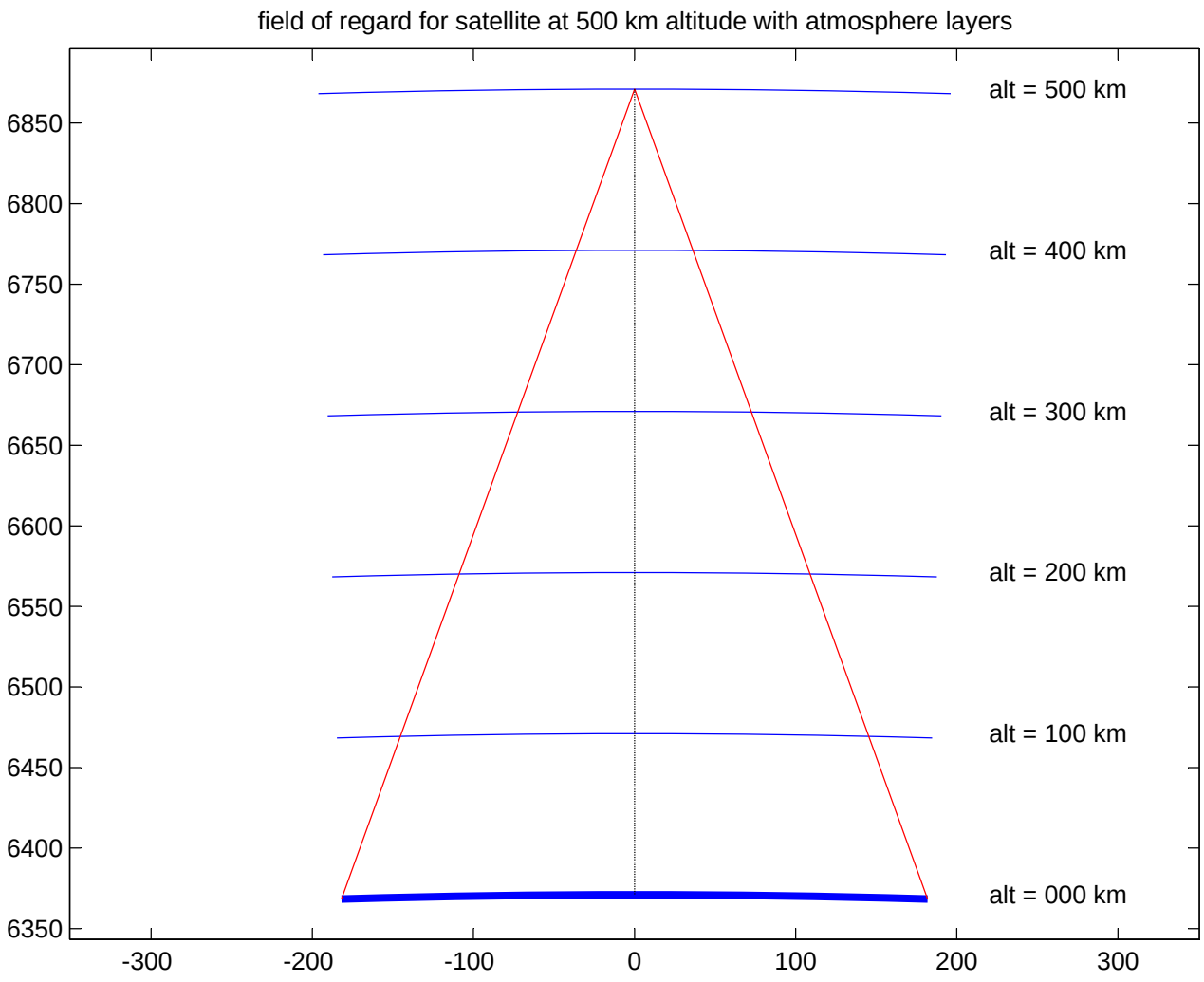

2D Atmospheric Refraction
Geometry for ray at α
and atmosphere interval
dH, from height H,
with refractive index
n_i
H
n_1
$d\alpha = \alpha - \alpha_r$
α
α_r
dH
n_2
n_3
normal to
layer boundary
n_4
Snell's law
governs refraction
H=0
earth
6371 Km


field of regard for satellite at 500 km altitude with atmosphere layers
alt = 500 km
alt = 400 km
alt = 300 km
alt = 200 km
alt = 100 km
alt = 000 km
6850
6800
6750
6700
6650
6600
6550
6500
6450
6400
6350
-300
-200
-100
0
100
200
300

```
% atmdens.m  25-jan-11
% curve fits from nasa glenn
% H meters, T celsius, P kilopascals, rho kg/m^3

function rho=atmdens(H)

rho=0.0;
if(H < 11000)
  T=15.04 - 0.00649*H;
  P=101.29 * ((T+273.1)/288.08)^5.256;
  rho=P/(0.2869 * (T+273.1));
elseif((H >= 11000) & (H < 25000))
  T=-56.46;
  P=22.65 * exp(1.73 - 0.000157*H);
  rho=P/(0.2869 * (T+273.1));
else
  T=-131.21 + 0.00299*H;
  P=2.488 * ((T+273.1)/216.6)^-11.388;
  rho=P/(0.2869 * (T+273.1));
  end
end
```

```
% atmref3.m  13-feb-11
% model atmospheric refraction with layered atmosphere
% and NASA Glenn equations that convert altitude to pressure
% then use simon newcomb's formula to convert pressure
% to refractive index n^2 = 1 + 2*C*rho
% rho = pressure kg/m^3
% C = 0.00022667, constant from schut, PERS v. 35, 1969, p. 81
% do again nadir aligned vertically per sketch
% this one hardwired for H=500 km and 20 degree off-nadir view

C=0.00022667;
degrad=180/pi;
alpha=20/degrad;
x=0;
y=6871;
R=y;
B=-pi/2 - alpha;
H=500;
for i=1:5000
  %i
  v=[cos(B);sin(B)];
  m=v(2)/v(1);
  b=y - m*x;
  % intersect next layer
  R=R-0.1;
  H=H-0.1;
  AA=1+m^2;
  BB=2*m*b;
  CC=b^2 - R^2;
  x=(-BB + sqrt(BB^2 - 4*AA*CC))/(2*AA);
  y=m*x + b;
  % unit normal vector (pointing down)
  n=[-x;-y];
  n=n/norm(n);
  costh1=dot(n,v);
  th1=acos(costh1);
  rho1=atmdens(H*1000 + 50);
  rho2=atmdens(H*1000 - 50);
  n1=sqrt(1+2*C*rho1);
  n2=sqrt(1+2*C*rho2);
  th2=asin((n1/n2)*sin(th1));
  Bnorm=atan2(n(2),n(1));
  Bnew=Bnorm - th2;
  B=Bnew;
  end

alpha
alpha_r=atan(abs(x)/(6871-y))
% effect in meters on the ground
displ_0=500000*tan(alpha)
displ_atm_mod=500000*tan(alpha_r)
```

density

rho is actually density, not pressure

```
dalpha_r=alpha - alpha_r
effect_m=displ_0 - displ_atm_mod

% compare with saastamoinen
K=saasta1(500,0)
dalpha_s=K*tan(alpha)
alpha_s=alpha-dalpha_s;
displ_sas=500000*tan(alpha_s);
effect_s_m=displ_0 - displ_sas
```