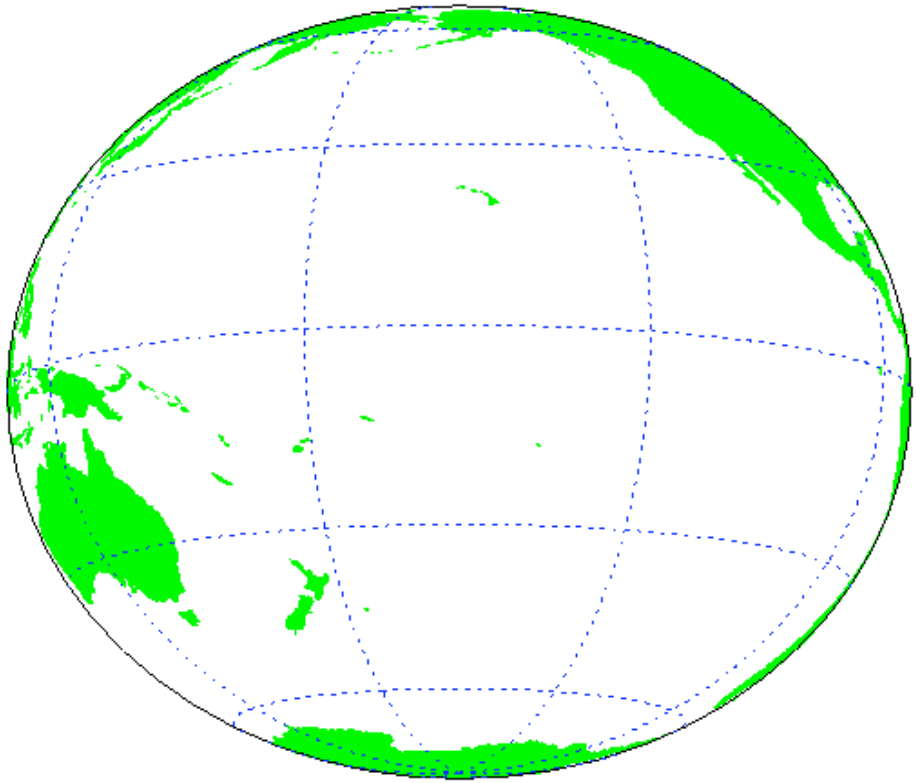
If you're going to do it at all, do it right: Earth radius in raytracing algorithms

Stephen Wood, NIWA



Background

- Most codes work in local coordinates at observing sites and assume a spherical atmosphere
- Non-spherical Earth accounted for by using a value for radius appropriate for the site
- codes I've seen and used, (to setup fscatm) make the radius a function of latitude
- This is not rocket science so far!

Some old code (from 10-20 years ago)

```
SUBROUTINE RADIUS(XLAT,RZ)
  DATA PI/3.14159265/
  RE=6378.69
  RP=6356.91
  PHI=XLAT*PI/180.
  SP2=SIN(PHI)**2
  EC2=1.-(RP*RP)/(RE*RE)
  RZ2=RE*RE*(1.-(2.-EC2)*EC2*SP2)/(1.-EC2*SP2)
  RZ=SQRT(RZ2)
  RETURN
  END
```

Something I came across recently

$$R_c = (R_{NS}^{-1} \cos^2\alpha + R_{EW}^{-1} \sin^2\alpha)^{-1}$$

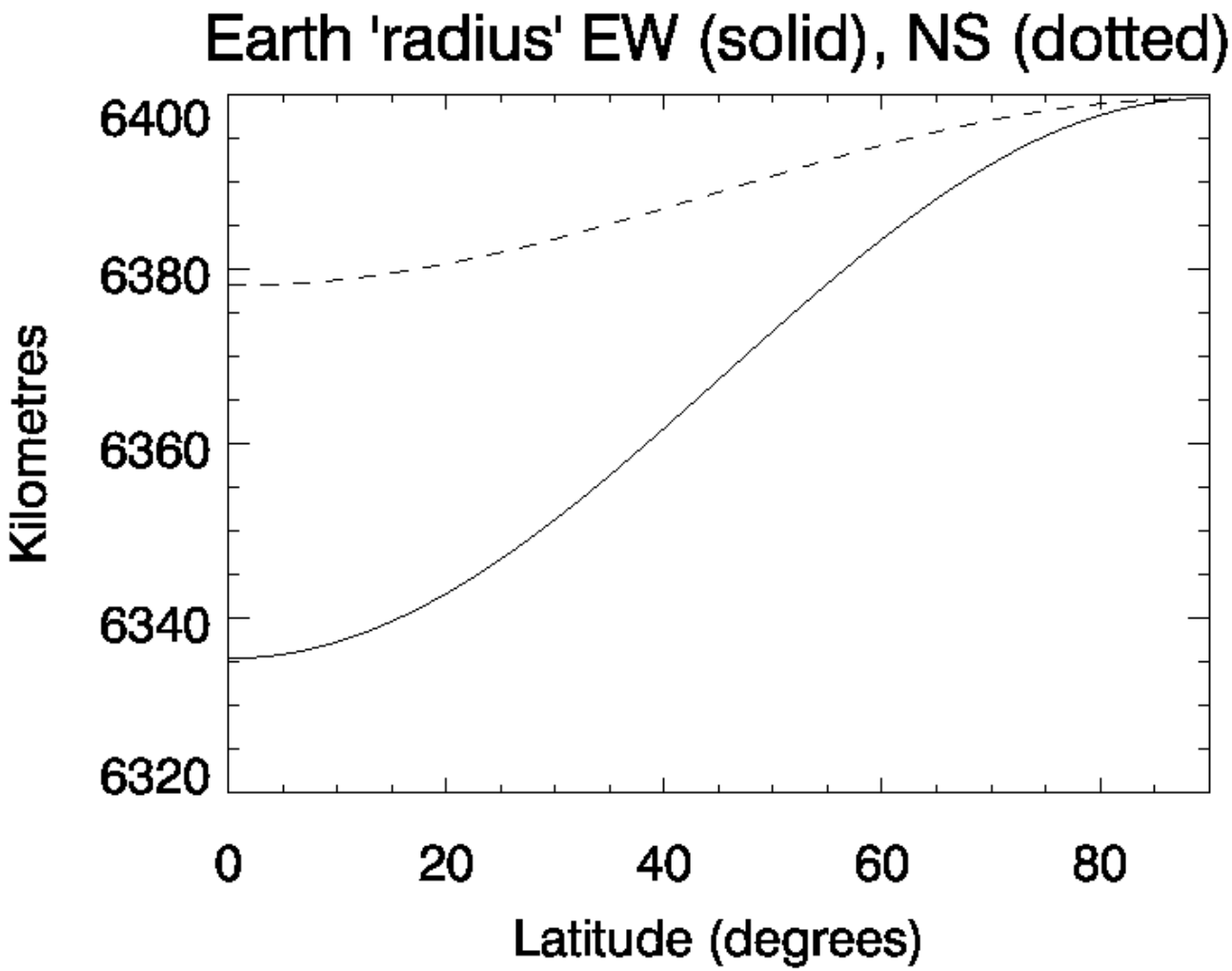
where α is the azimuth of the viewing direction, and

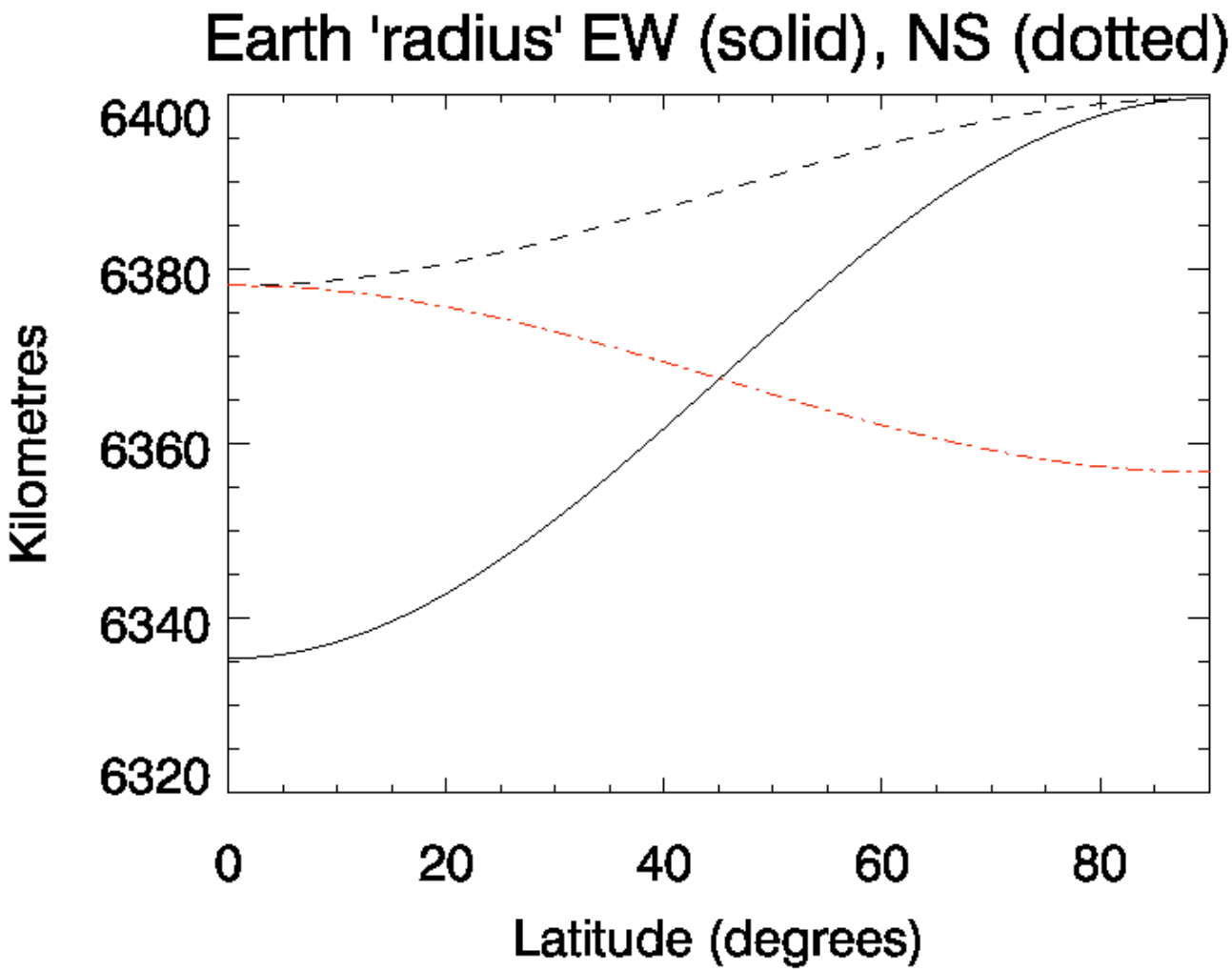
$$R_{NS} = R_q^2 R_p^2 (R_q^2 \cos^2\phi + R_p^2 \sin^2\phi)^{-(\frac{3}{2})}$$

$$R_{EW} = R_q^2 (R_q^2 \cos^2\phi + R_p^2 \sin^2\phi)^{-(\frac{1}{2})}$$

ϕ is the latitude, and

$R_q = 6378.14$ km , $R_p = 6356.75$ km for the WGS-84 reference elipsoid


Earth 'radius' EW (solid), NS (dotted)
6400
6380
6360
6340
6320
Kilometres
0
20
40
60
80
Latitude (degrees)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Latitude (degrees)

The morals of the story

- “Radius” has more than one meaning here. The mistake was to latch onto one without thinking
- Don't assume it's right just because we've been using code for years

For a discussion and an alternative approach see
Hase & Hopfner, *Applied Optics, 38(15)*,3129,1999

TECHNICAL NOTE

Atmospheric ray path modeling for radiative transfer algorithms

Frank Hase and Michael Höpfner

A new method for the determination of ray paths as well as resulting path segments and partial gas columns within a layered atmosphere is presented. Any singularity at the tangent point is avoided. No use is made of the gross spherical symmetry of the Earth's atmosphere. Using this approach we examine the impact of the Earth's oblate shape and horizontal atmospheric inhomogeneities on infrared limb spectra. © 1999 Optical Society of America

OCIS codes: 000.4430, 010.1290, 010.1300, 010.1320, 010.4030, 080.0080, 080.2710, 280.0280.

1. Introduction

Inference of atmospheric trace gas concentration profiles from observed infrared spectra relies on a comparison with synthetic spectra that are calculated from a set of relevant variables that describe the state of the atmosphere. Their values are varied until the

sonably well as long as the ray does not cross the boundary almost tangentially, which is a situation that occurs in limb-sounding observations. In this case, the path segments in the layers near the tangent point become excessively large and the computational error increases. A further subdivision of