Module 3

Modern Navigation Systems

Spherical trigonometry and perturbation theory for solving great and small circle problems on or near the surface of the earth.

Module 3E

Map Projections

525.445 – Modern Navigation Systems

Summary of Module 3

- Students will learn to apply perturbation theory and spherical trigonometry to the problems of surveying and of comparing great circle and small circle routes for navigation on or near the surface of the earth.
- Students will repeat the spherical trigonometry computations performed by Charles Mason when surveying the Mason-Dixon line, and will compute the differences in miles flown between great circle and small circle routes from one city to another using Napier's rules.
- Students will apply perturbation theory to the simplification of the equations of small and great circles. Students will apply perturbation theory to the simplification of the equations of small and great circles.
- **Students will also learn the nuances of Mercator and Lambert Conformal Conic map projections, with particular emphasis on the critical differences between aviation and nautical charts.**

This sub-module

- In this sub-module, you will learn the distinctions between nautical and aviation charts.

The Mercator projection

- On a nautical chart, a Mercator projection is used
  - A straight line is a line of constant bearing
    - This is called a rhumb line, or **loxodrome**
    - All loxodromes eventually intersect the north and south poles

A Loxodrome versus a great circle

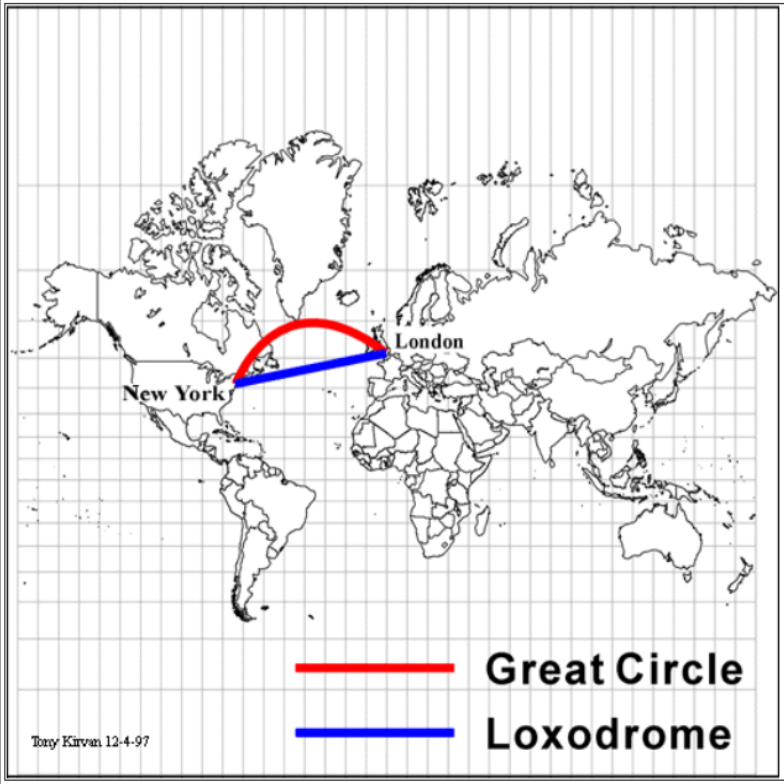
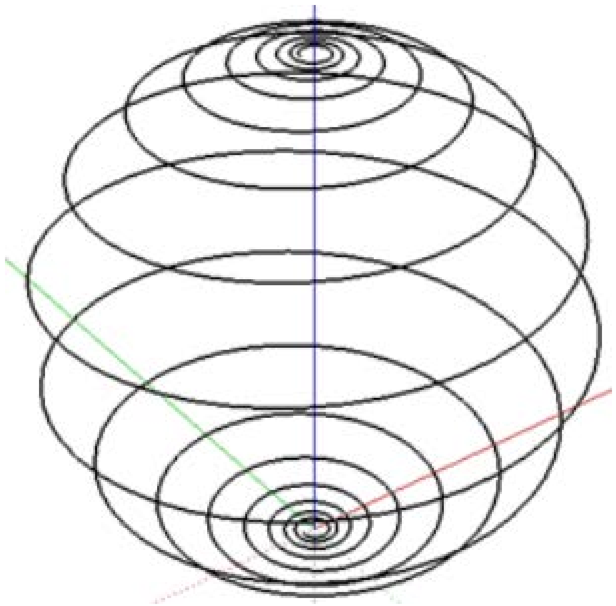


Figure 6. Comparison of Great Circle Route and Loxodrome on the Mercator Projection. The loxodrome is a line of constant heading, and the great circle, although appearing longer than the loxodrome, is actually the shortest route between New York and London.

http://www.ncgia.ucsb.edu/education/curricula/giscc/units/u014/figures/figure06.html

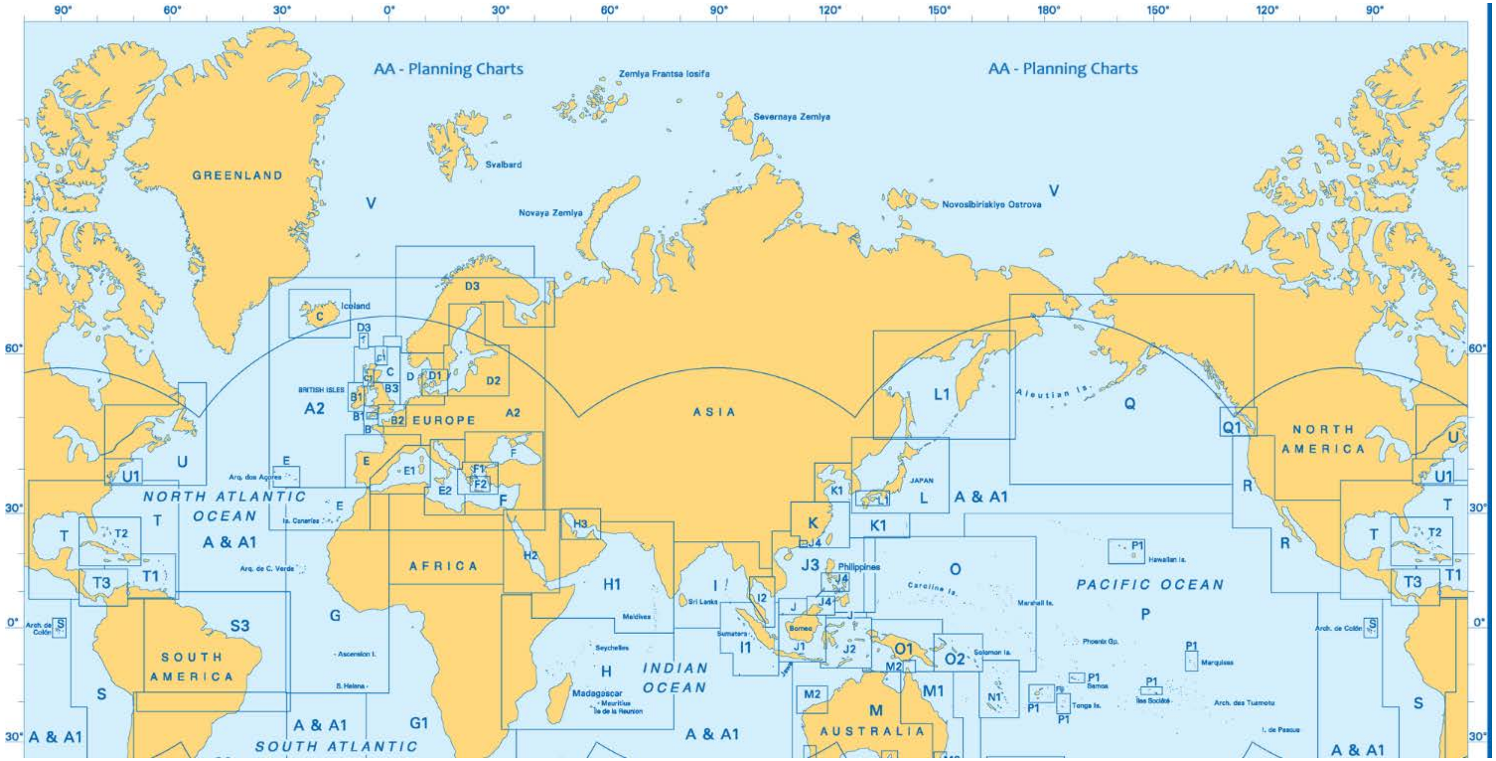
An “apple-peel” view of a loxodrome



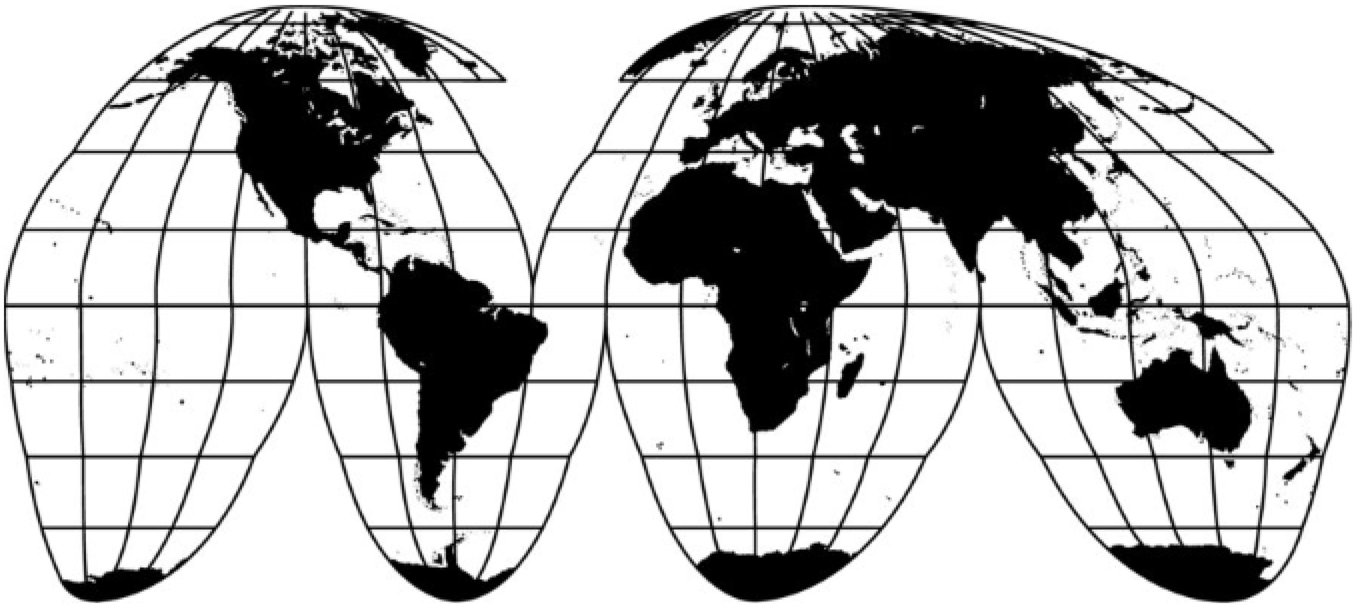
A loxodrome of the sort produced when Peeling an apple (cf. Meg Ryan, Sleepless In Seattle)

https://www.google.com/search?q=loxodrome&biw=1536&bih=718&source=lnms&tbm=isch&sa=X&ei=nAqfVL3uIMKaNtO2hIAL&ved=0CAYQ_AUoAQ#facrc=_&imgdii=_&imgrc=dE3FDYne3oPnHM%253A%3BGPSR2fqOenkI2M%3Bhttp%253A%252F%252Fregularpolygon.org%252Fplugins%252Fimages%252Floxodrome-1-250.png%3Bhttp%253A%252F%252Fregularpolygon.org%252Fplugins%252Floxodrome.php%3B250%3B250

Portion of a British nautical chart showing size distortion due to Mercator projection



Map projection designed to minimize spatial distortion (compare with Mercator projection)

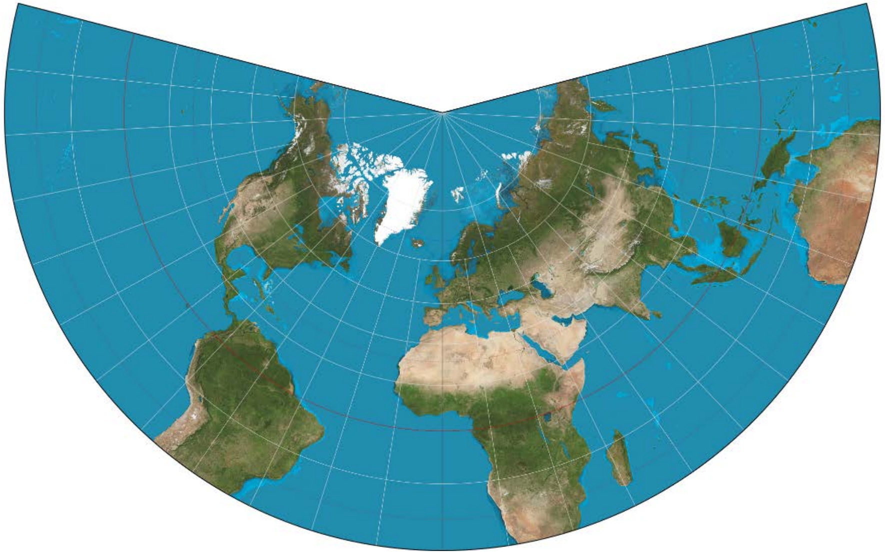


http://inspiredcreativity.deviantart.com/art/World-Map-Projection-97722289

The Lambert projection

- On an aviation chart, a Lambert projection is used
  - A straight line on the chart represents a great circle
    - This is useful because radio signals from navigation beacons on the ground travel the shortest distance, according to Fermat’s principle, and thus “follow” great circles.

The Lambert projection (from Wikipedia)

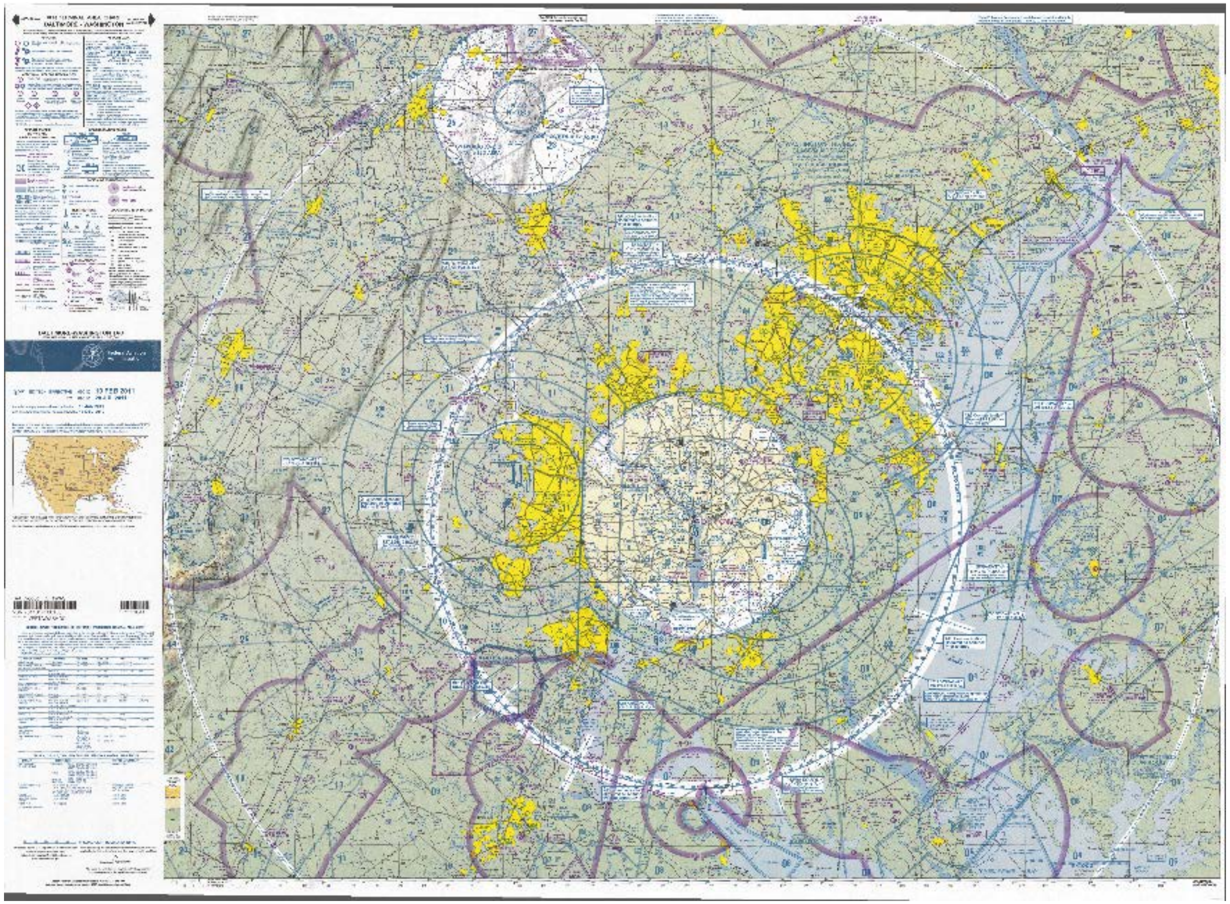


"Lambert conformal conic projection with standard parallels at 20°N and 50°N. Projection extends toward infinity southward and so has been cut off at 30°S."

From Wikipedia

- A **Lambert conformal conic projection** (**LCC**) is a conic map projection used for aeronautical charts, portions of the State Plane Coordinate System, and many national and regional mapping systems. It is one of seven projections introduced by Johann Heinrich Lambert in his 1772 publication *Anmerkungen und Zusätze zur Entwerfung der Land- und Himmelscharten*.
- Conceptually, the projection seats a cone over the sphere of the Earth and projects the surface conformally onto the cone. The cone is unrolled, and the parallel that was touching the sphere is assigned unit scale. That parallel is called the *reference parallel* or *standard parallel*.
- By scaling the resulting map, two parallels can be assigned unit scale, with scale decreasing between the two parallels and increasing outside them. This gives the map two standard parallels. In this way, deviation from unit scale can be minimized within a region of interest that lies largely between the two standard parallels. Unlike other conic projections, no true secant form of the projection exists because using a secant cone does not yield the same scale along both standard parallels.[1]

An aviation chart



A straight line on this chart approximates the great circle path A radio signal from a ground beacon (e.g., a VOR signal) will follow.

In summary…

- Mixing and matching nautical and aviation charts can result in navigation errors.
- No single type of map projection meets all needs.
- Be careful!

End of Mod 3E