

Lecture

Navigation Mathematics: Kinematics (Coordinate Frames)

EE 570: Location and Navigation

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1 ECI

Earth-Centered Inertial (ECI) Coordinate Frame

- An inertial coordinate frame is one that does **not** accelerate (rectilinearly) or change its orientation (*wrt* the “stars”)
 - All inertial sensors measure “inertial” motion
 - * Gyroscopes measure rate of change of inertial orientation
 - * accelerometers measure inertial acceleration
- The ECI frame will be referred to as the *i*-frame

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Coordinate Frame - ECI

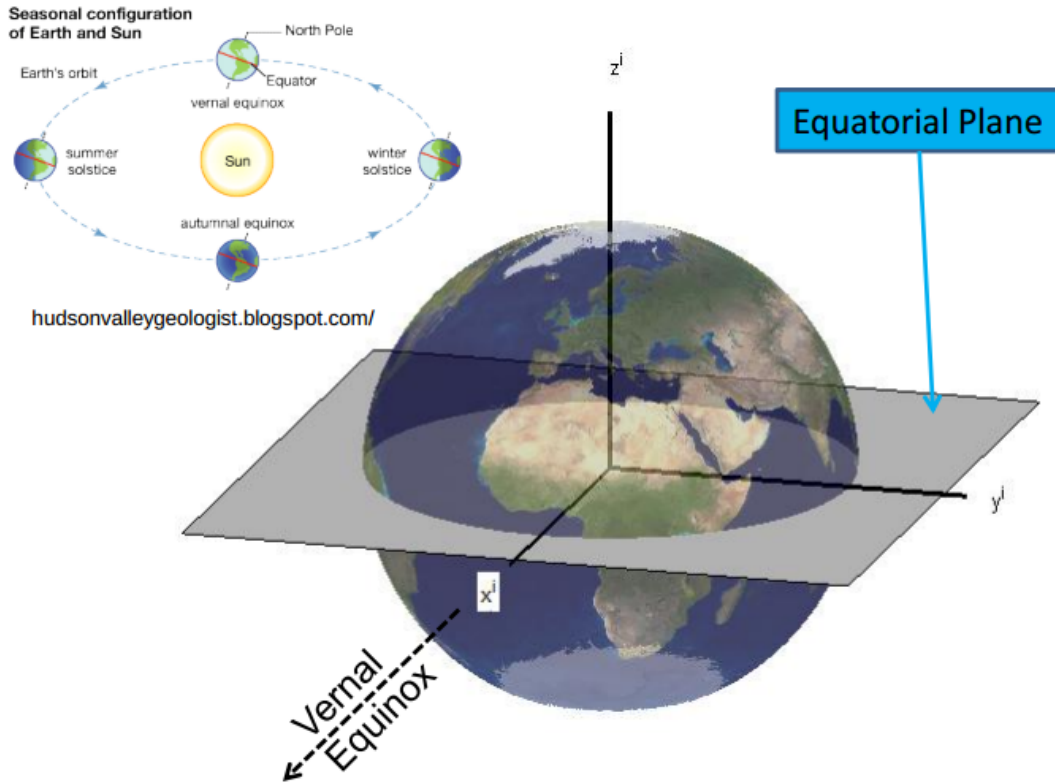
- The origin of the ECI is located at the center of mass of the earth
- the *z*-axis points along the nominal axis of rotation of the earth
 - True north **not** magnetic north!!
- The *x*-axis lies in the equatorial plane and points from the earth to the sun at the vernal equinox
 - Defined by the intersection of the equatorial plane and the earth-sun orbital plane
- The *y*-axis is simply chosen to conform to a right hand coordinate system

*The ECI coordinate frame does **not** rotate with the earth*

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ECI Coordinate Frame

- *z*-axis points along the nominal earth axis of rotation
- *x*-axis points towards vernal (spring) equinox
- *y*-axis completes a right hand coordinate system



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2 ECEF

Earth-Centered Earth-Fixed (ECEF) Coordinate Frame

- The ECEF coordinate frame is **not** an inertial frame
- The ECEF coordinate frame is fixed with respect to the earth
- The ECEF coordinate frame will be referred to as the *e*-frame

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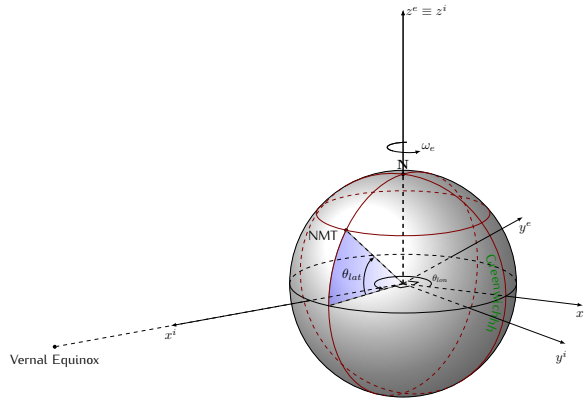
ECEF Coordinate Frame

- The origin of the ECEF frame is located at the center of the mass of the earth (same as ECI)
- The z -axis points along the nominal axis of rotation of the earth (same as ECI)
- The x -axis lies at the intersection of the equatorial plane and the reference meridian plane (i.e., Greenwich meridian)
 - Concept of latitude and longitude
- The y -axis is simply chosen to conform to a right hand coordinate system

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ECEF Coordinate Frame

- z -axis points along the nominal earth axis of rotation
- x -axis points towards zero longitude
- y -axis completes a right hand coordinate system



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Navigation (Nav) Coordinate Frame

- The Nav coordinate frame is typically **not** fixed with respect to the earth
 - the x/y axis lie in a plane which is locally-level or tangential to the earth's surface
- Nav frame is sometimes call the geodetic, geographic, locally level, or tangential frame
- the Nav frame will be referred to as the n -frame

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Nav Coordinate Frame

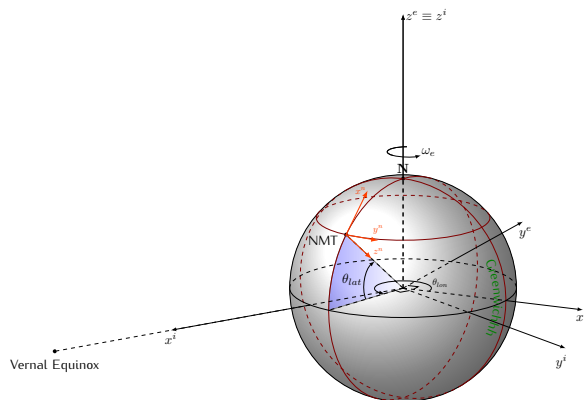
- The origin of the Nav frame is located at the center of mass of the vehicle
- The z -axis points "down" along the normal to the earth's surface
 - Approximately towards the center of the earth
- The x -axis points to the north pole
- The y -axis is simply chosen to conform to a right hand coordinate system
- This configuration is often referred to as the NED frame
 - $x \rightarrow$ north, $y \rightarrow$ East, and $z \rightarrow$ Down

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3 Nav

Nav Coordinate Frame

- x -axis points north
- y -axis points east
- z -axis points down



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4 Body

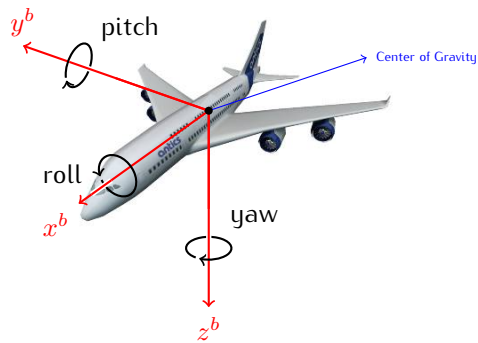
Body Coordinate Frame

- The origin of the body frame is located at the center of mass of the vehicle (same as the Nav frame)
- The x -axis point "forward" wrt the moving vehicle
- The z -axis points loosely "down"
 - Change with the roll/pitch of the vehicle
- The y -axis is simply chosen to conform to a right hand coordinate system

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Body Coordinate Frame

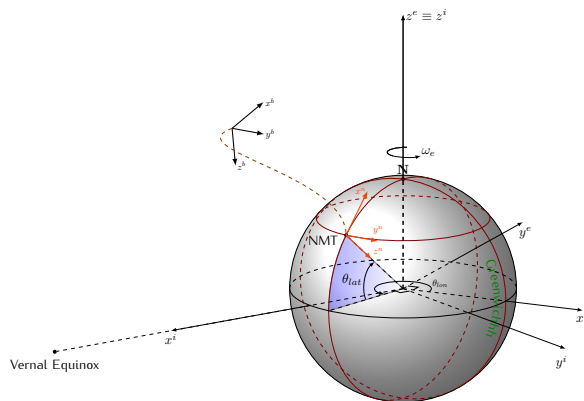
- The body coordinate frame is fixed with respect to the vehicle
- The body frame will be referred to as the b -frame



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Body Coordinate Frame

- x -axis points forward
- z -axis points "down"
- y -axis points "right"



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5 Other

Other Coordinate Frames

- Wander Azimuth Frame (alternative to the Nav frame)
 - Does not always point north to avoid numerical stability problems near the poles

- Other locally level frames
 - Tangential Frame
 - * Typically, refers to another type of the ECEF frame fixed to the Earth's surface (not moving like the n -frame)
 - Computer Frame
 - * Virtual coordinate frame that represents where we think that we are