

Principle of airborne Gravimetry

- $f^i = \ddot{r}^i - g^i \implies g^i = \ddot{r}^i - f^i$
- Specific force: f^i , actual measurement
- Kinematic acceleration: \ddot{r}^i , second abbreviation of the position
- Gravity acceleration: g^i

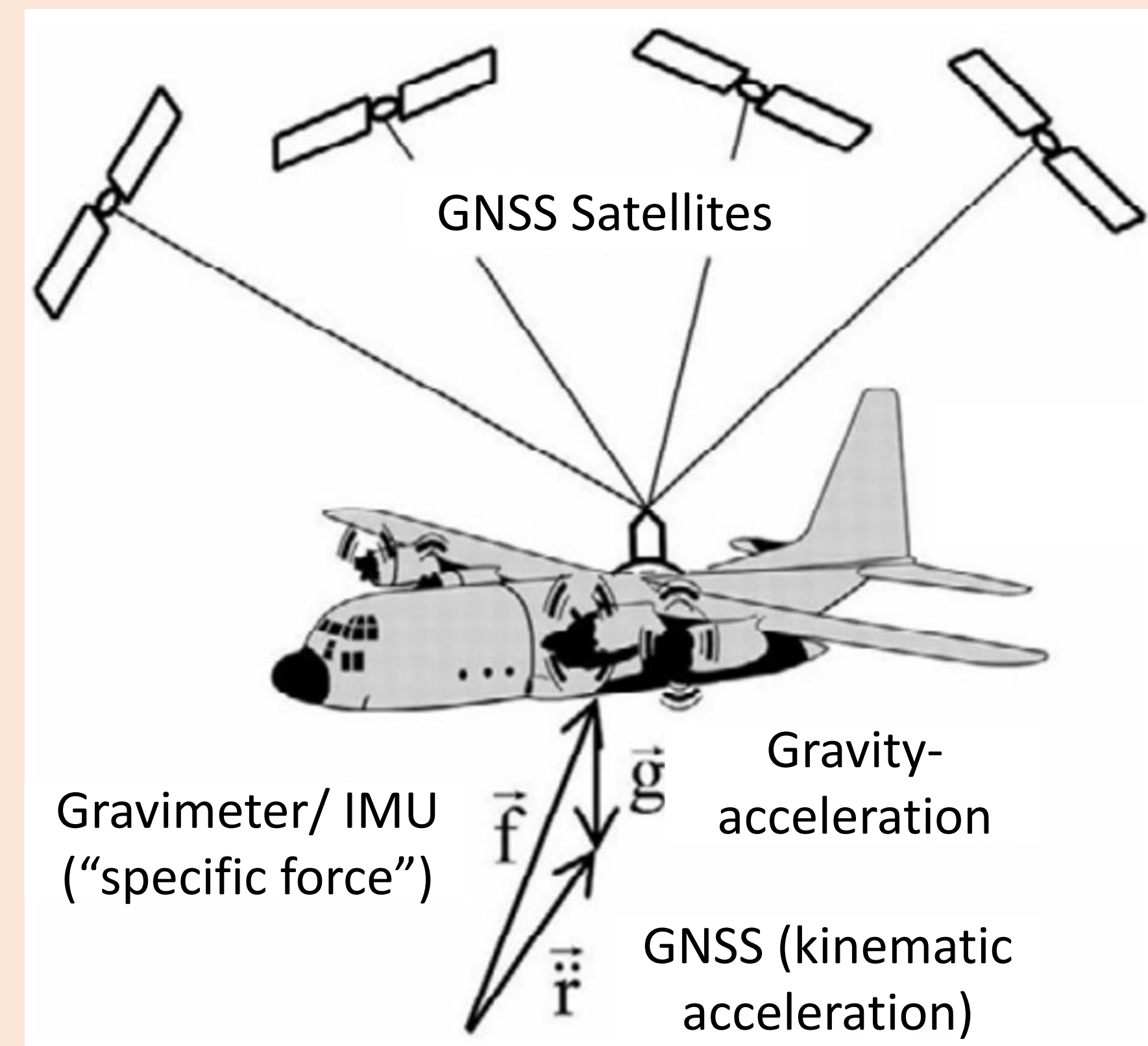


Figure 1: The specific force as the result from kinematic acceleration and gravity acceleration, as well as positioning using GNSS [Torge et al. (2023), modified after Timmen (2010)]

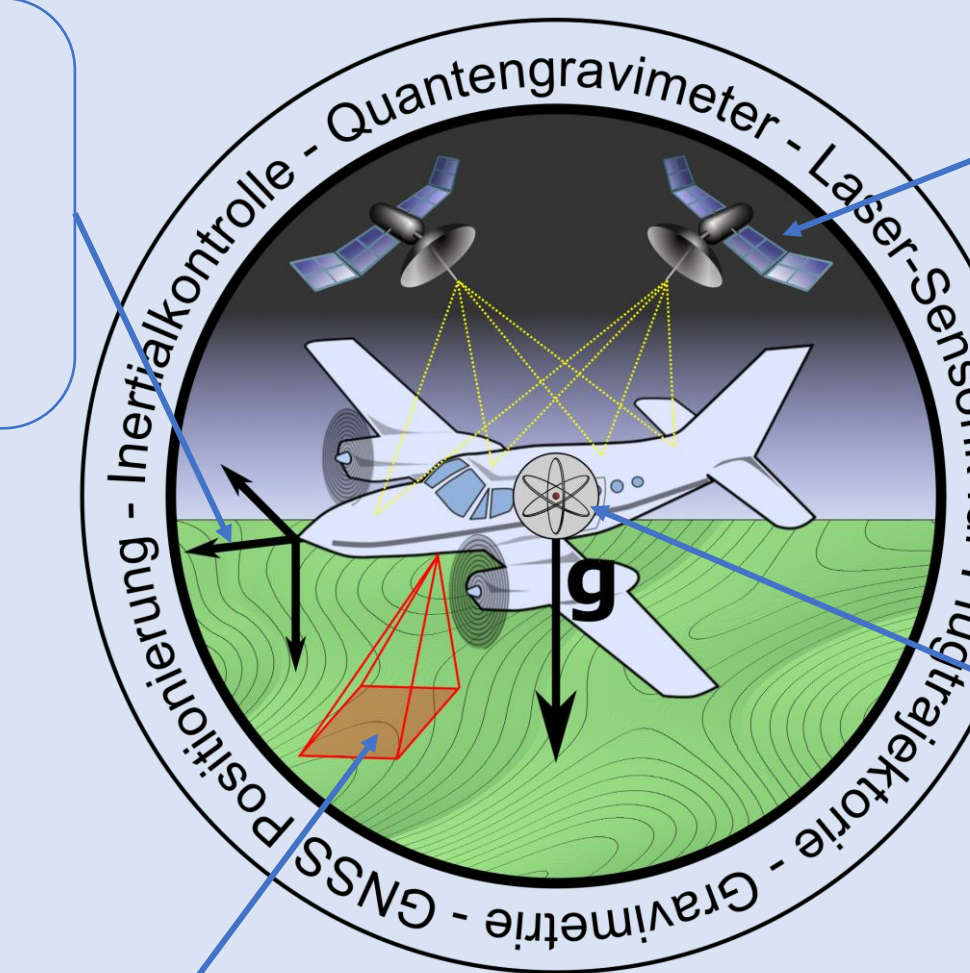
Information about the project

- Goal: Developing an Absolute Quantum Gravimeter for airplanes to advance airborne gravimetry, e.g. for:
 - Quantifying climate changes by measuring changes in mass distribution
 - Searching for resources deposits
- Process:

Dez. 2022	Start of the Project
2025	GNSS sensors and TLS being build (first flight planned: beginning of 2026)
2026	Platform/ LDV (first flight planned: first half of 2026) Gravimeter being build (planned to be finished: summer of 2026)
2027	Gravimeter flight campaign (planned in 2027)

- Accuracy Goal: $1 \mu\text{m/s}^2$ with a 5s averaging time (ca. 400m resolution)

Inertial sensors: Vibration-isolated and inertial-based platform



GNSS: calculating the plane-position and its changes

Gravimetry:

- absolute: quantum gravimetry
- relative: for data comparison

Laser system:

- Laser-Doppler-Velocimeter (LDV): to measure the current vertical velocity
- Terrestrial Laser Scanner (TLS): to measure the relative high difference

Figure 2: Components of the project

- Multisensorsystem:
 - GNSS-Antenna for positioning of the aircraft -> to utilize potential: TLS for the relative altitude change determination and LDV for measuring the current vertical velocity
 - Optimized data fusion of all sensors -> gravitational acceleration separated from aircraft motion acceleration
 - Laser-system for flight trajectory

Our current work

- Developing a simulation for airborne gravimetry measurements
- We have a simulation for satellite gravimetry measurement [HosseiniArani, 2025] -> adapting simulation to airborne application:
 - Input: time series and effective wavenumber (= difference between the optical wave vectors of both laser beams)
 - Processing steps: calculating the simulated truth and adding Noise
 - Result: specific force (= acceleration of the airplane, including gravity-acceleration)

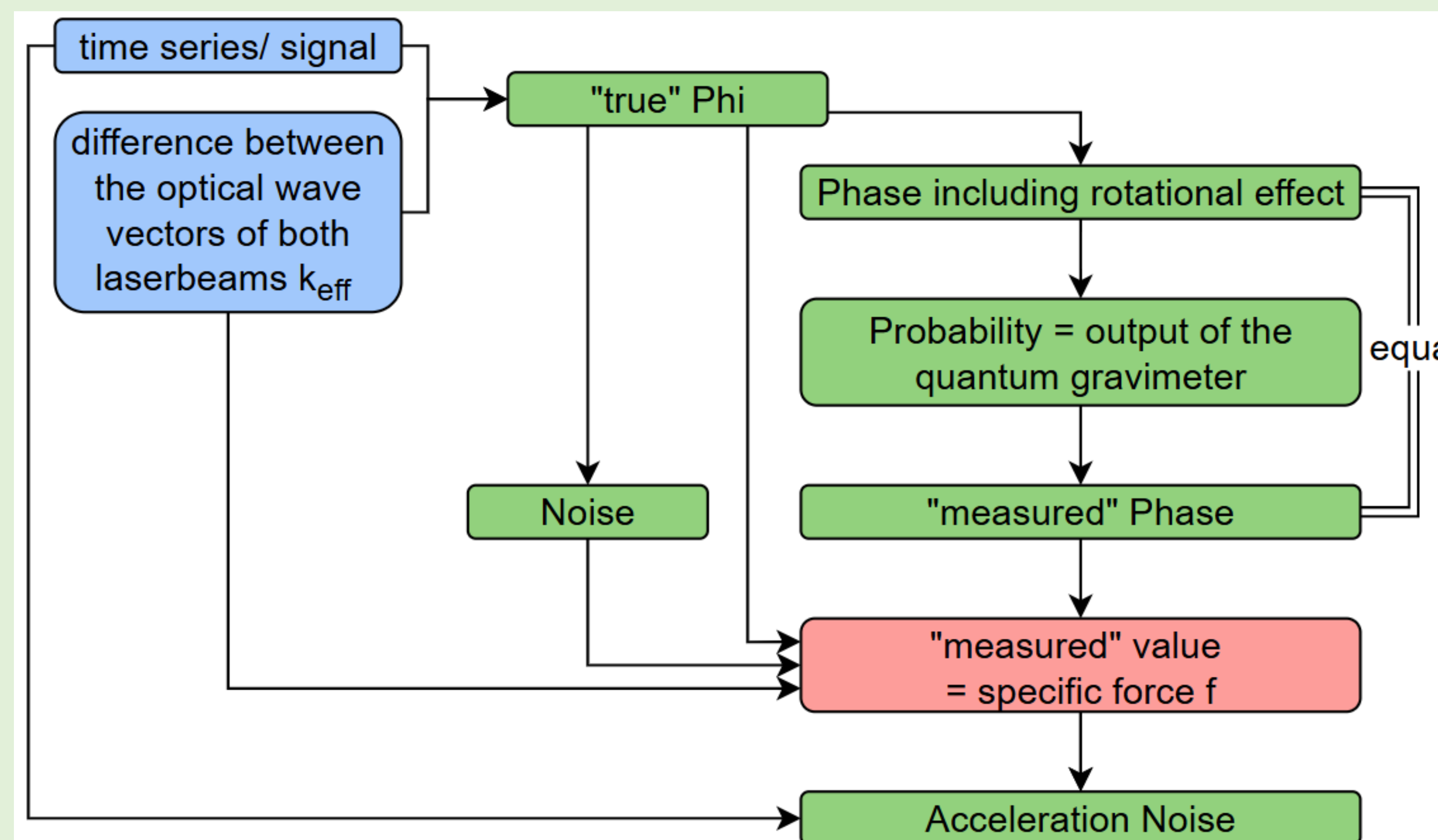


Figure 3: Steps of the simulation (simplified) (blue: Input data, green: steps, red: result)

Calculating the interferometer phase:

$$\Delta\Phi = (k_{\text{eff}} * f) * T^2 + \Phi$$

Φ = arbitrary Raman laser phase, T = interferometer interval

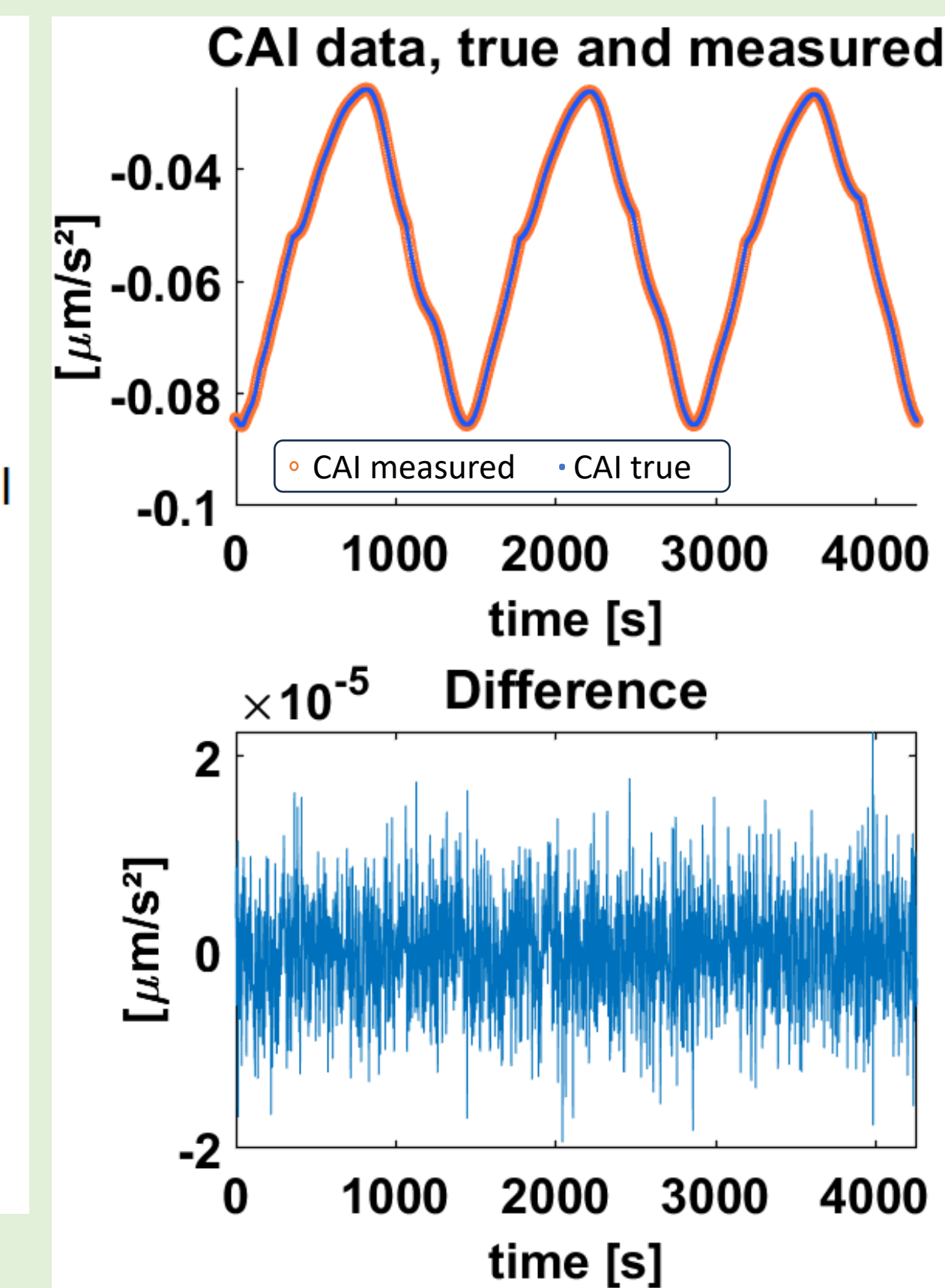


Figure 4: Example using satellite (GRACE) data (-> Orbit period visible. a) Input and Output of the Simulation, b) Difference between Input and Output

- Goal:
 - Knowing the measurements beforehand -> being able to adapt parameters of the instrument (if possible)
 - Having a reference for the actual measurement
 - Calculate accuracies