Branch antennas help to improve satellite acquisition under forest canopies

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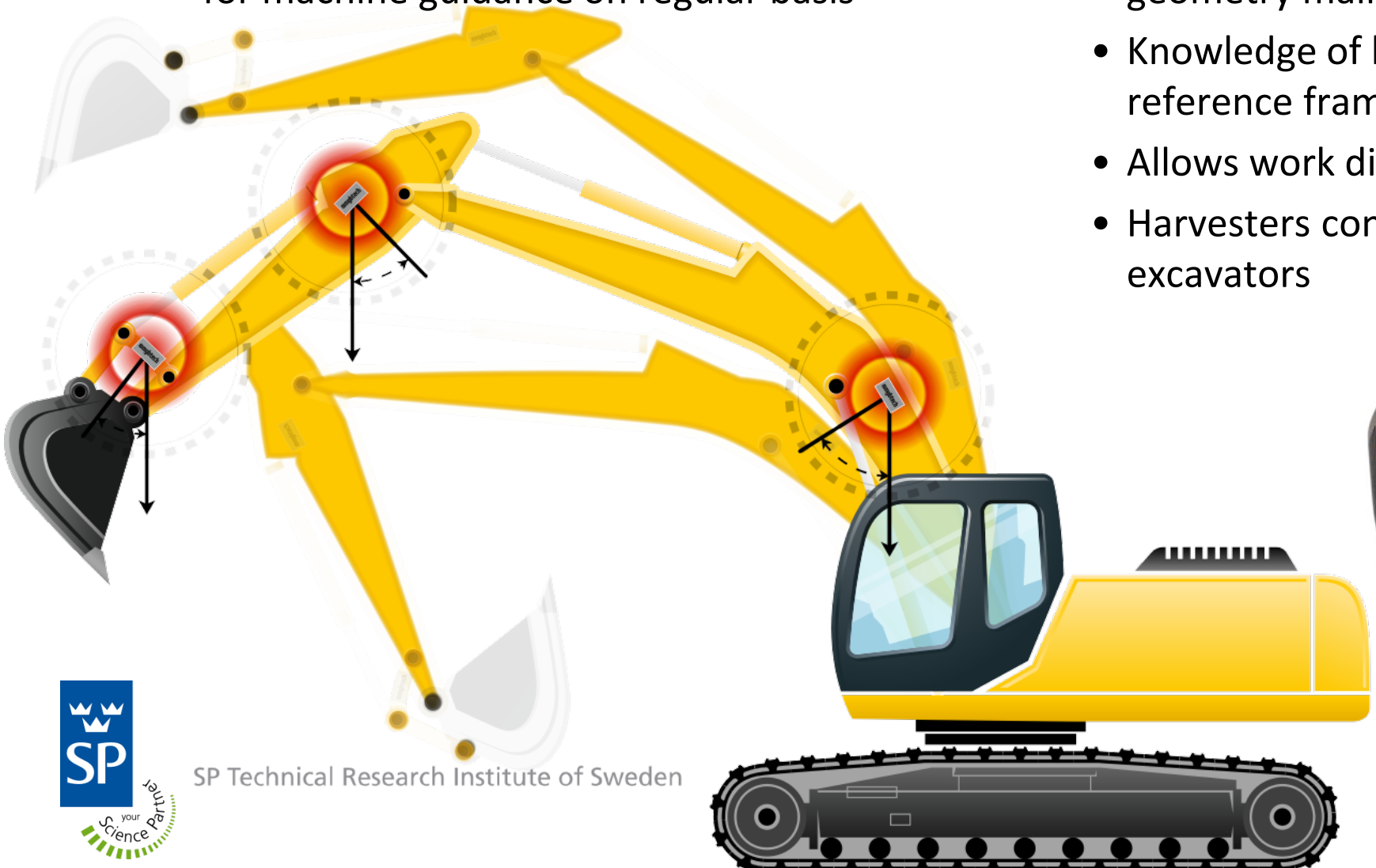
Forestry industry's use of GNSS

- Well established GNSS use for GIS purposes
- GPS only
- Drivers:
  - Harvester cuts trees, scooter collects logs afterwards (days) -> logs are left in the forest
  - Reuse established harvesting road network 30 years later in growing forest -> time and plants
  - Environmental aspects (preservation, soil compaction, driver safety…)

How can GNSS aid forestry machine guidance applications?

- Construction business utilizes RTK equipment for machine guidance on regular basis



- Combination of GNSS signals and machine geometry main constituents for positioning
- Knowledge of bucket position in a global reference frame
- Allows work directly on the design surface
- Harvesters construction is similar to that of excavators

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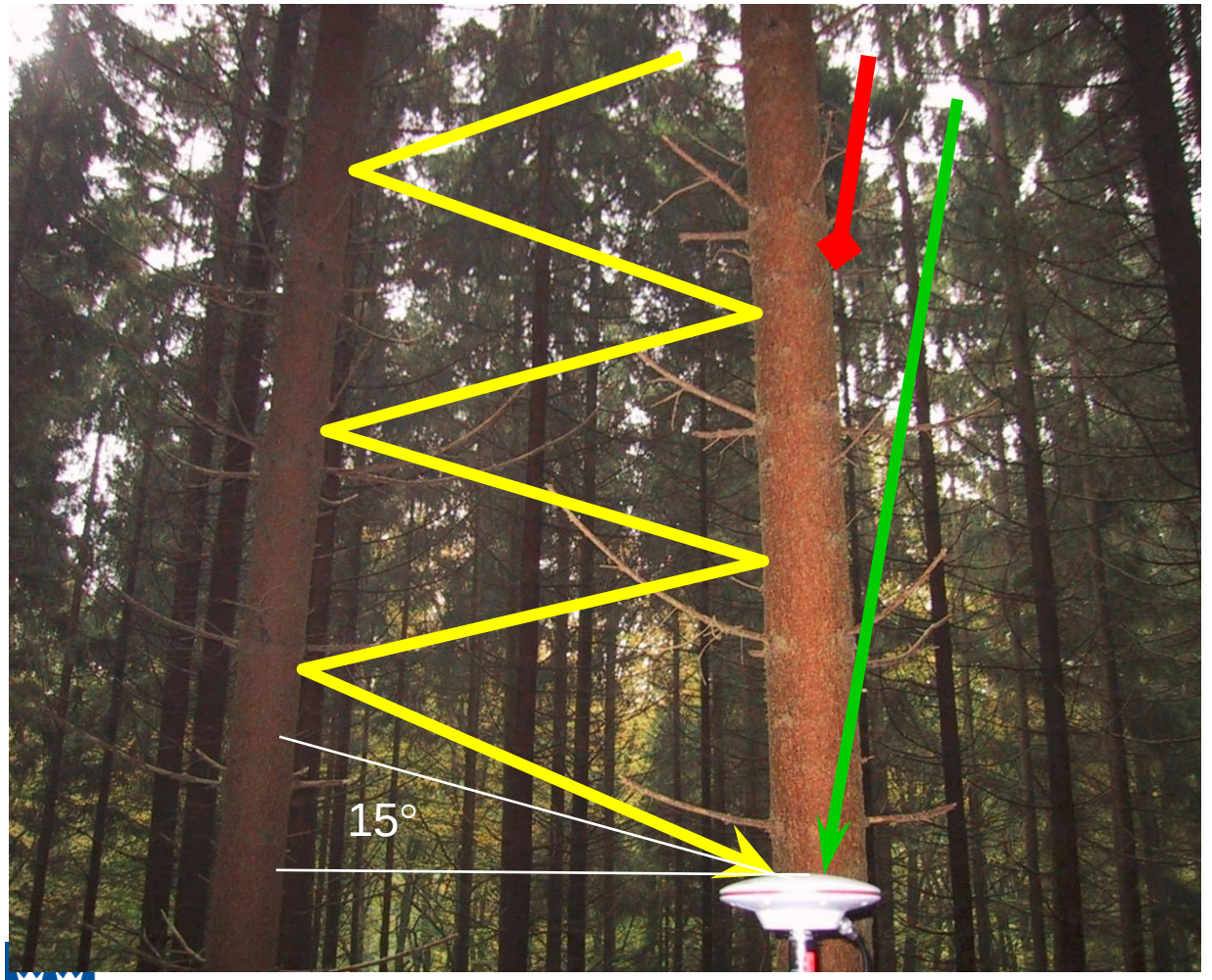
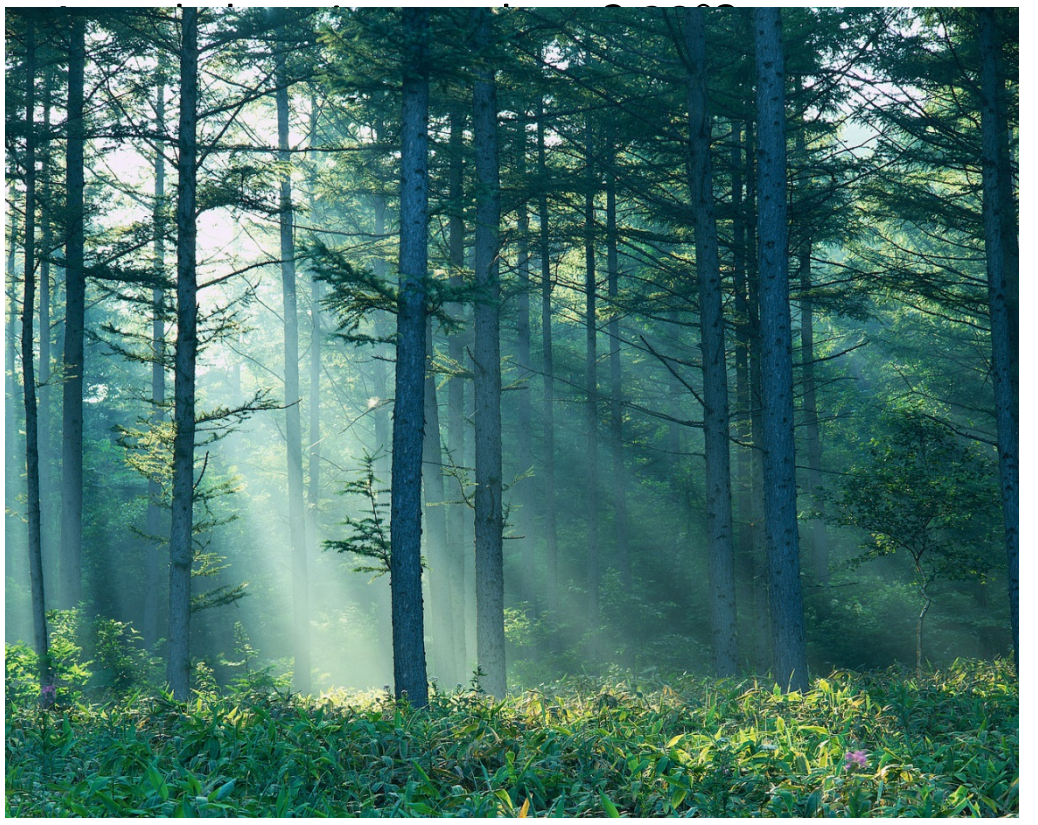
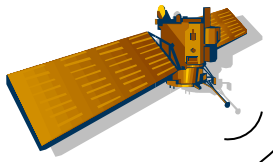
Satellite acquisition problems in forests

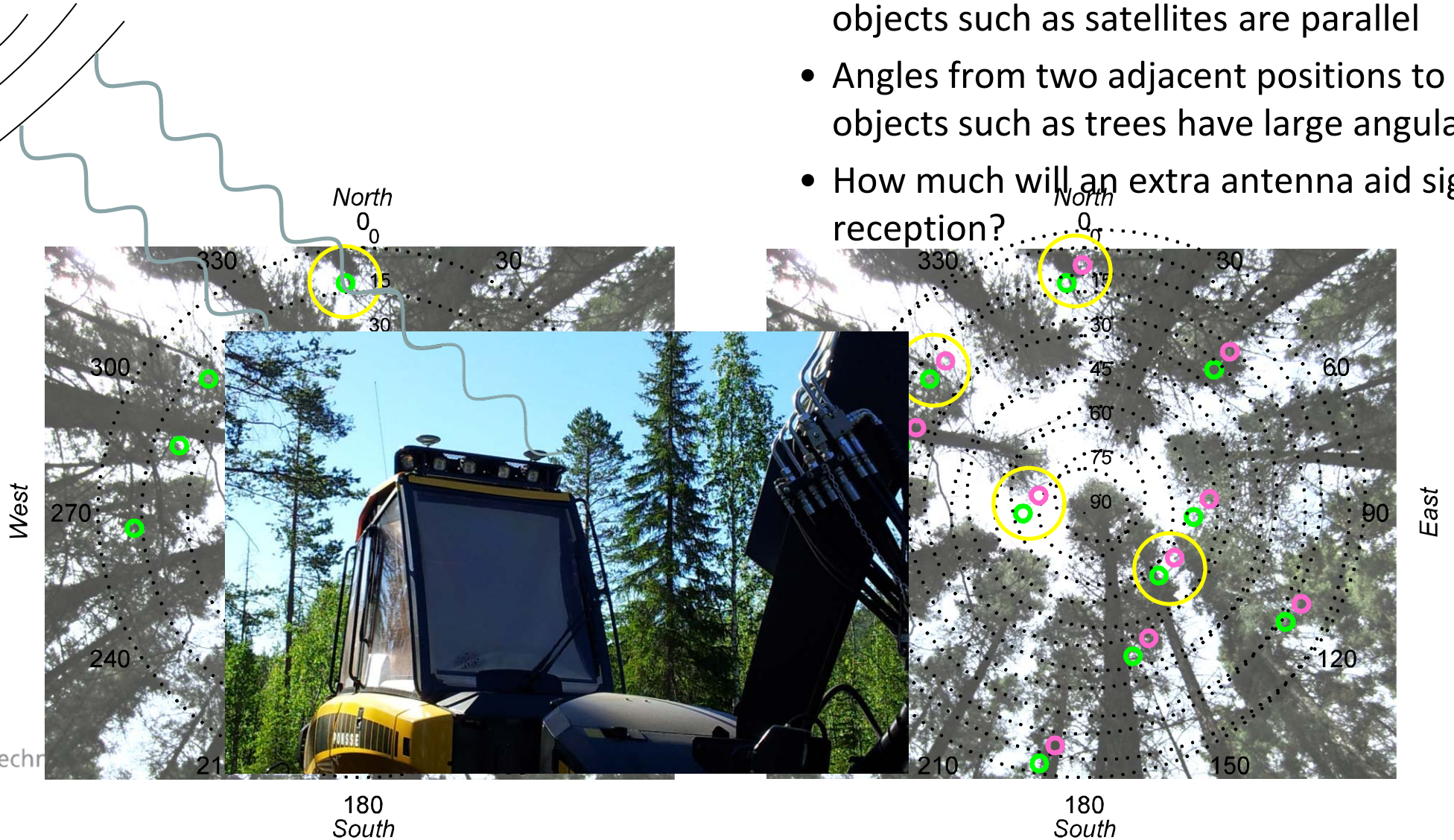


- Four satellites need to be visible
- Leaves and needles are filled with water: limited free sight to satellites
- Tree trunks are full of water: signals blocked
- Tree trunks are full of water: signals reflected



Viable geometric solution to the problem





- Angles from two adjacent positions to distant objects such as satellites are parallel
- Angles from two adjacent positions to close objects such as trees have large angular shifts
- How much will an extra antenna aid signal reception?

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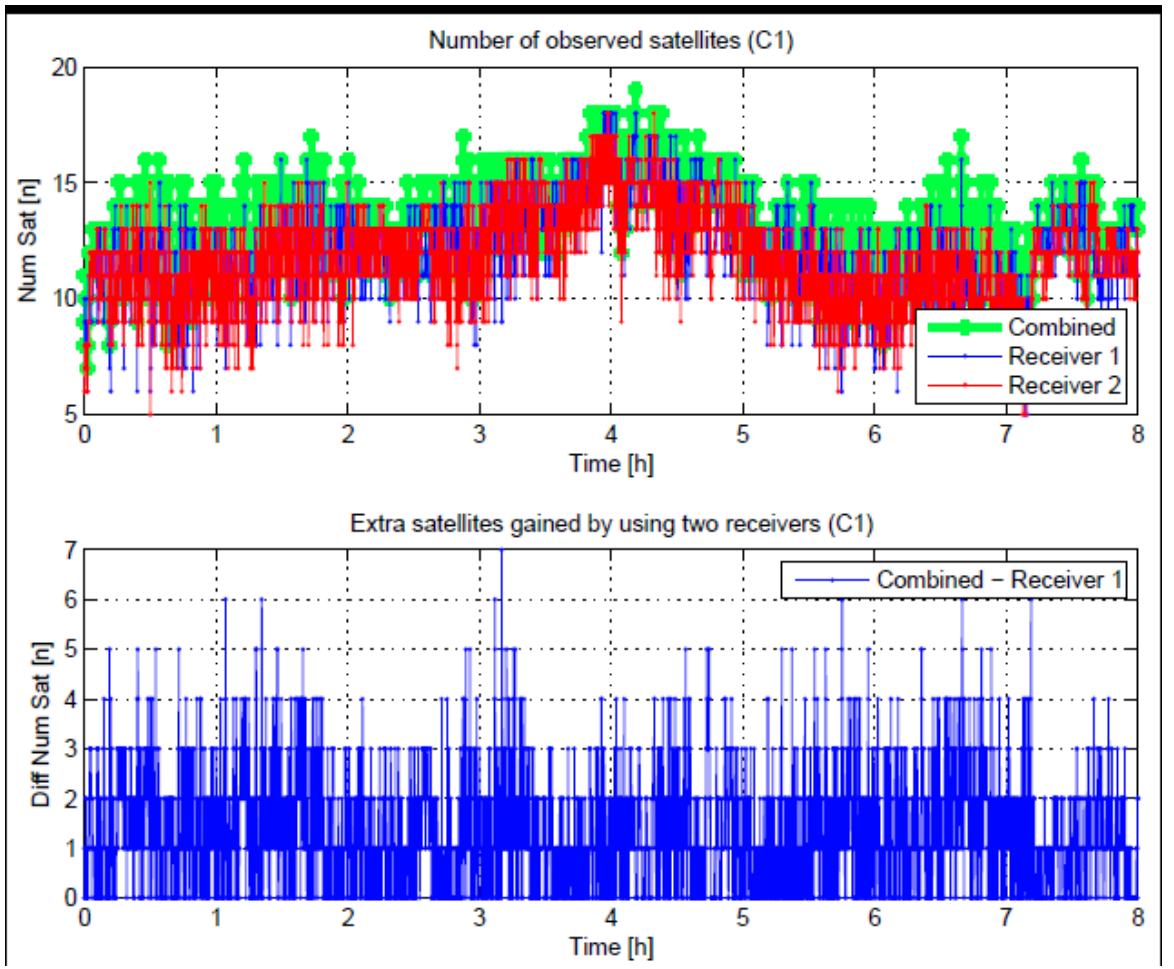
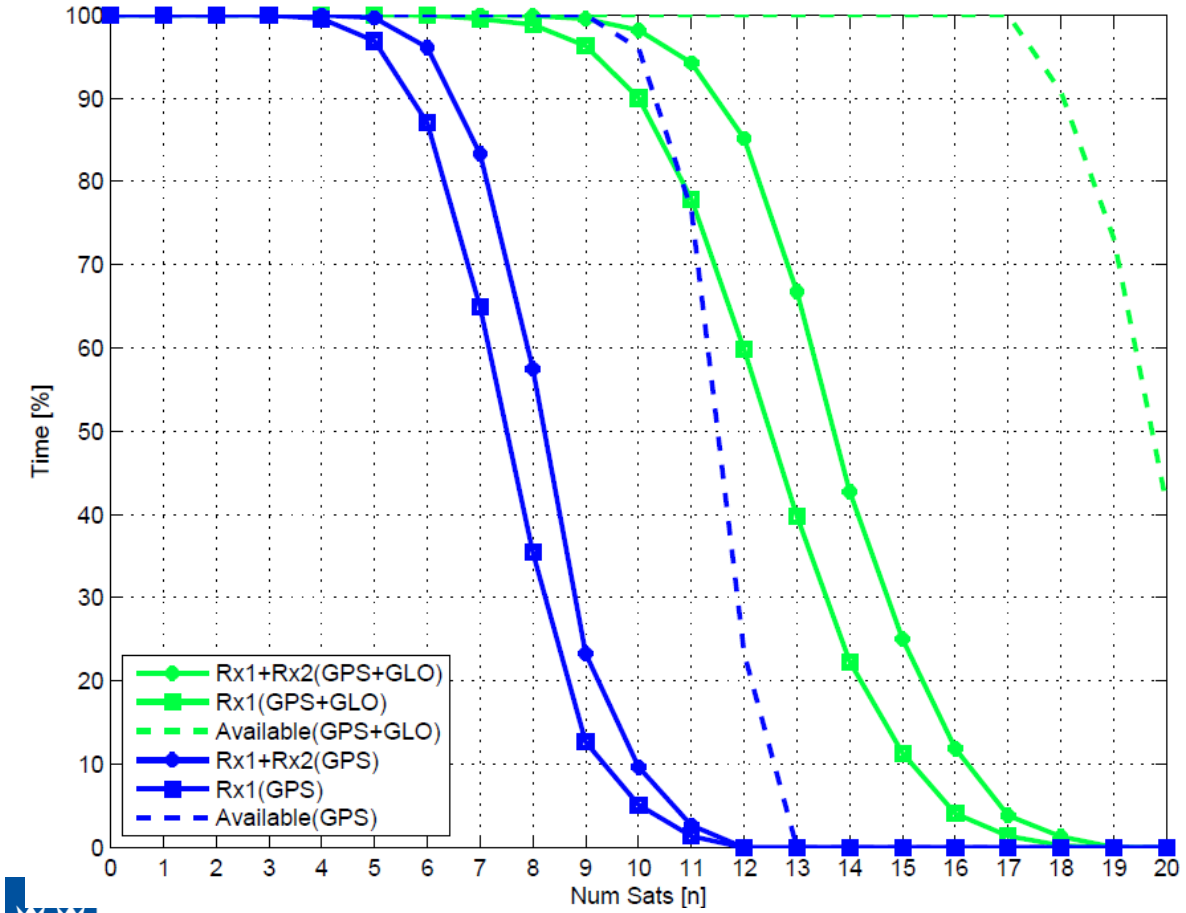
Realistic scenarios wanted for testing



- Code solutions only
- Simulations indicated little latitude but large vegetation dependence (height, trunk spacing, etc)
- Correlation between existing forestial databases and satellite signal acquisition parameters limited…
- Two test sites chosen:
  - Kalix (northern Sweden) final harvesting
  - Rejmyre (southern Sweden) first thinning (30 years)
- Receiving platform is harvester at normal working conditions, 1 working day
- Improvement in terms of number of satellites

More satellite systems improves situation

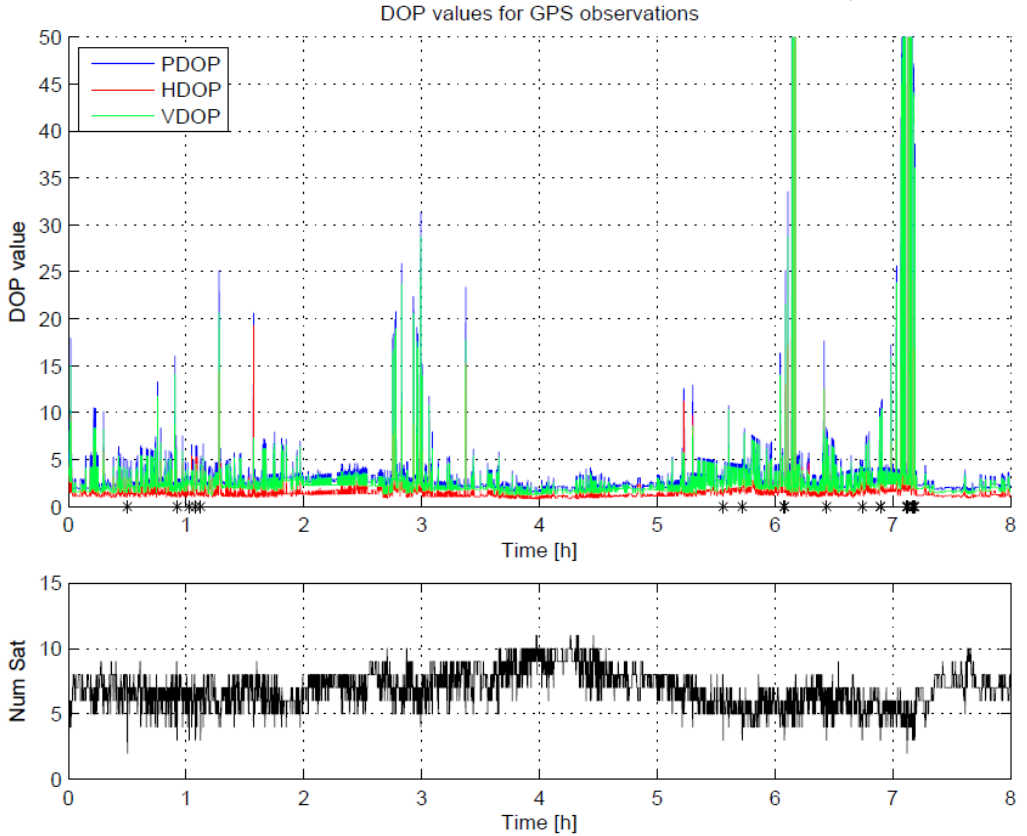


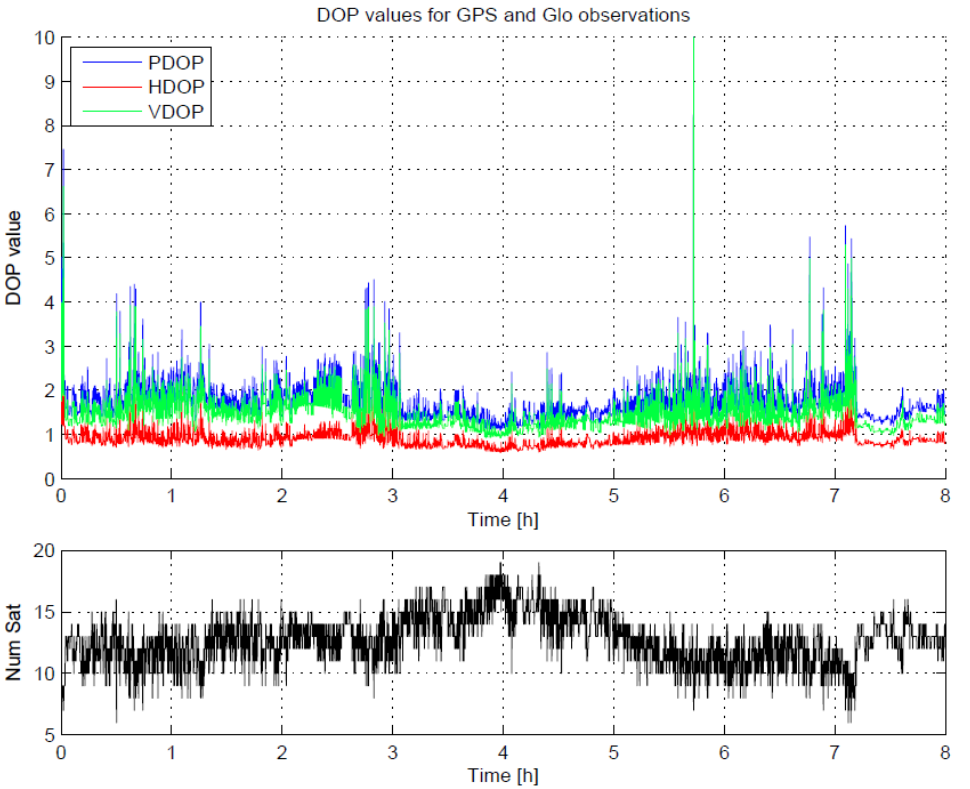
- Test case Rejmyre
- Diversified antennas improves reception an order of 1 satellite /system under the canopy
- Dual systems (GPS+Glonass) improves acquisitioning even more
- Performance is not only number of satellites…

  Positioning accuracy wish <≈ 5 m

Observed DOP values

- Single satellite system DOP in the forest is insufficient for positioning purposes
- GPS+Glonass system DOP promises acceptable values
- DOP refers to broadcast constellation, NOT reflections on trees

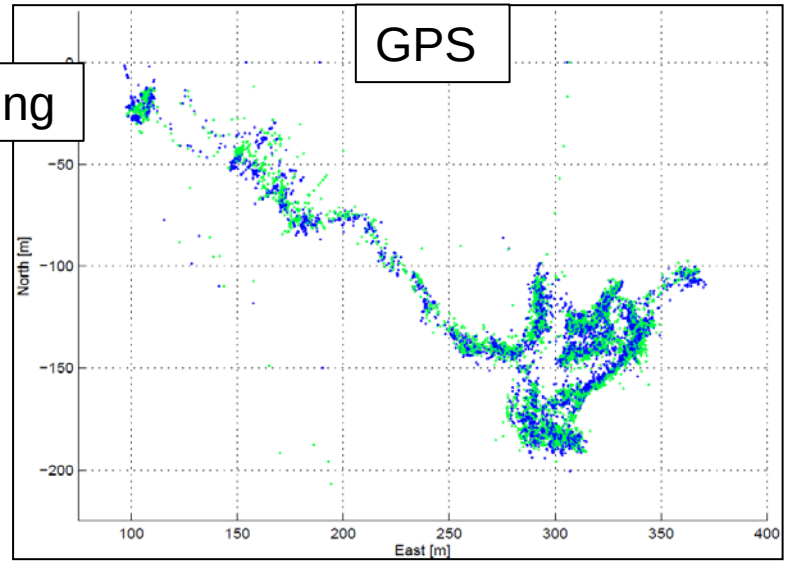


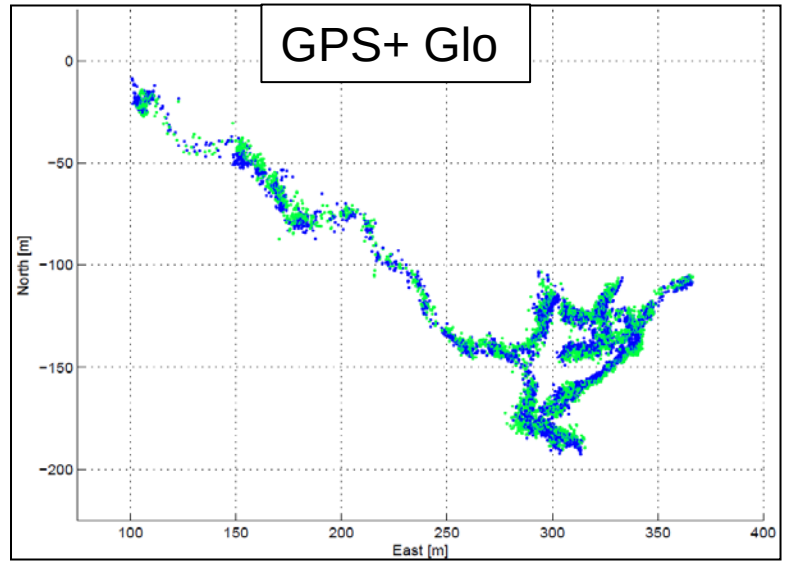


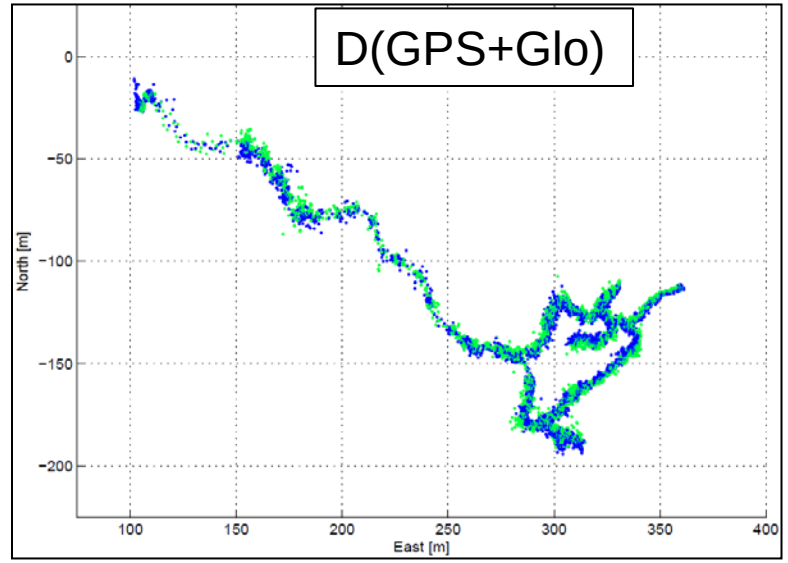
Three scenarios tested

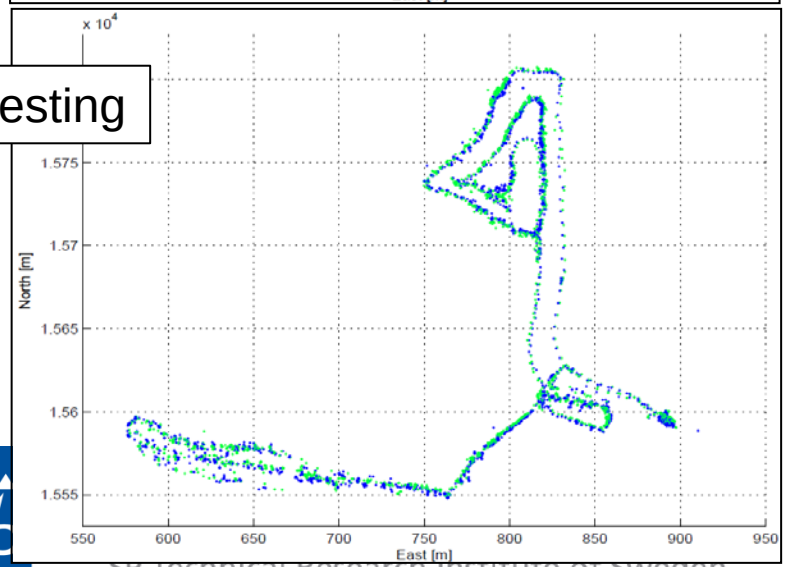
Thinning

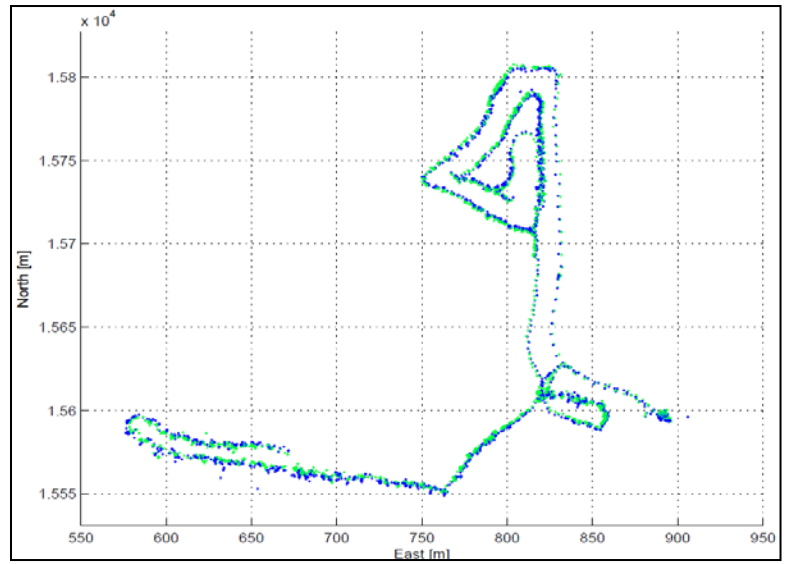
Harvesting

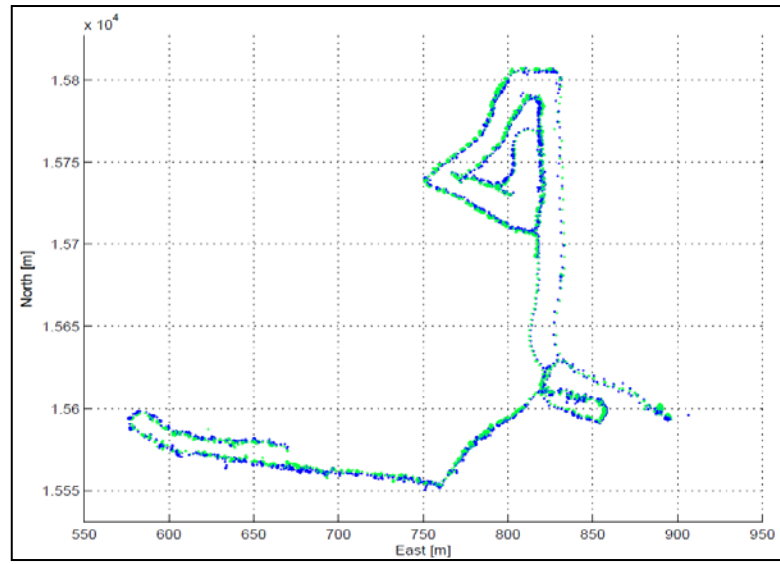






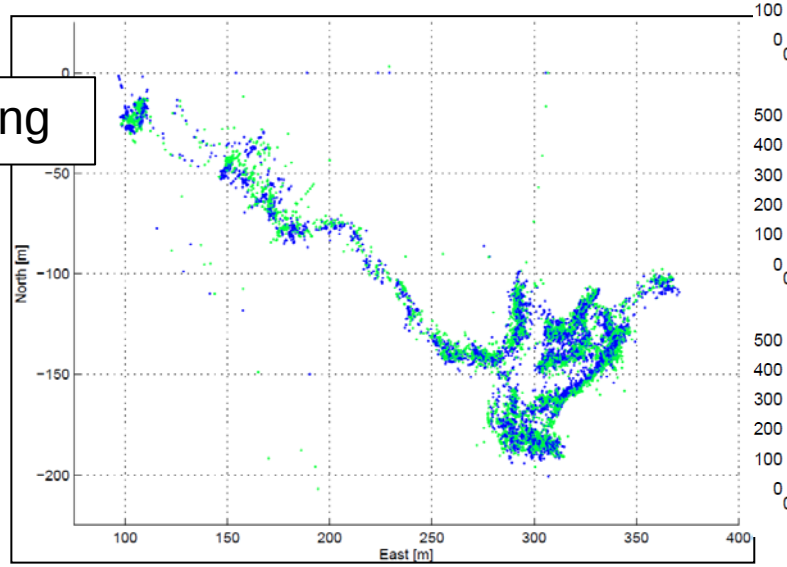


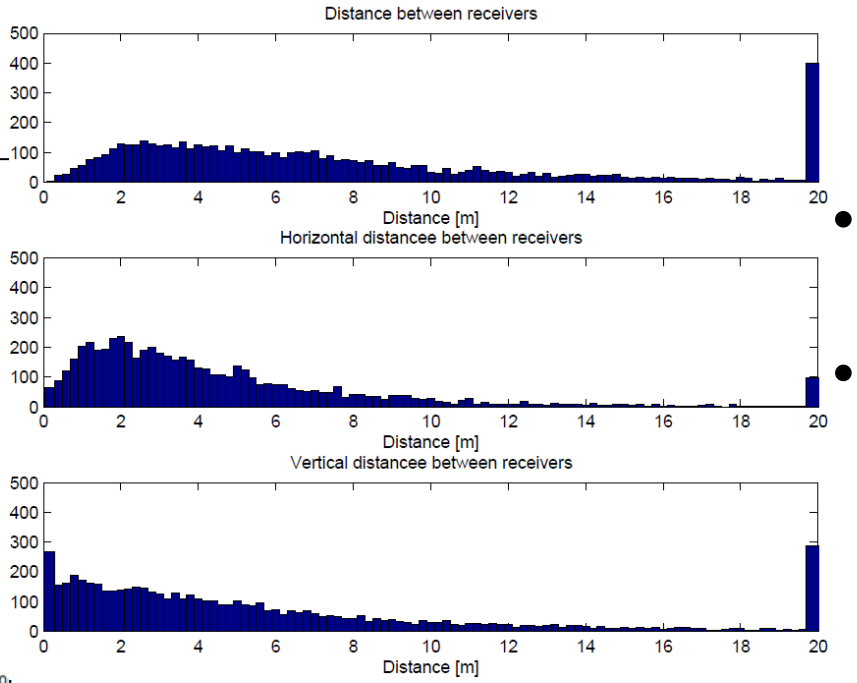




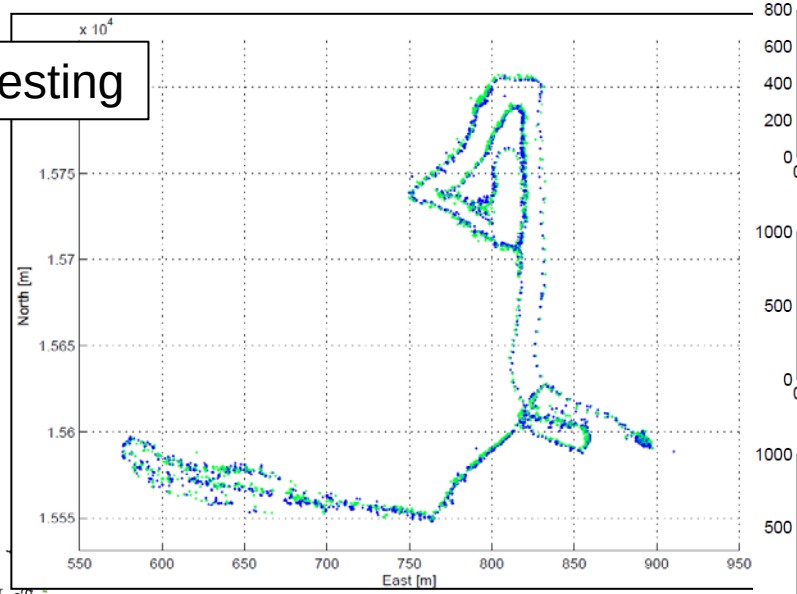
Evaluation: Stand-alone GPS

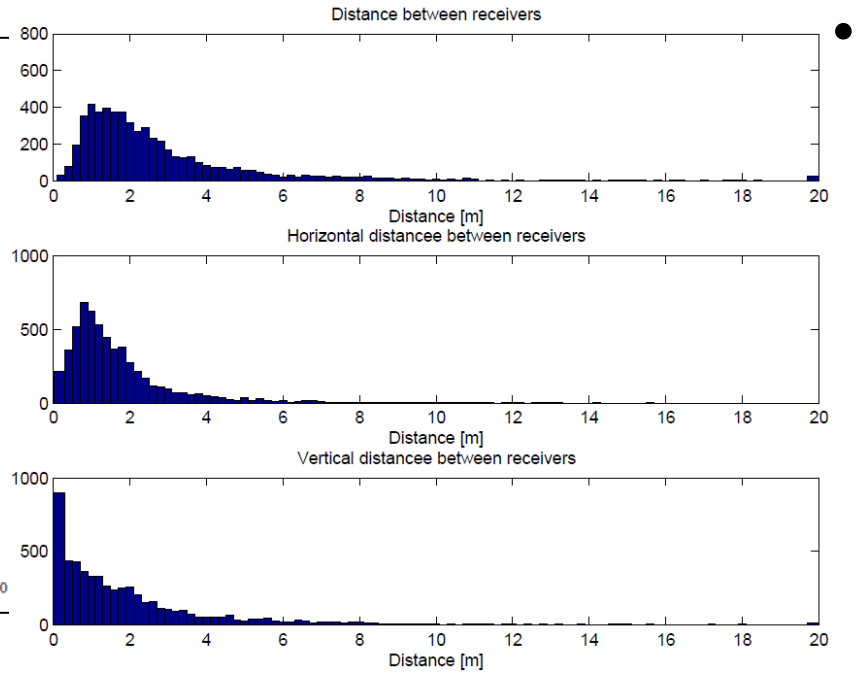
Thinning





Harvesting

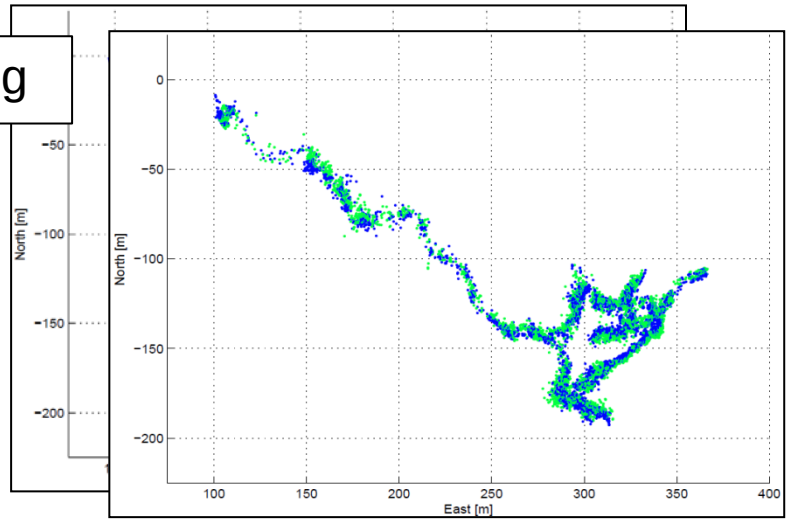




- Currently used situation
- True antenna separation known from set up:
  - 1 m horizontally
  - 0 m vertical
- Target < 5 m not reached

Evaluation: GPS + Glonass

Thinning



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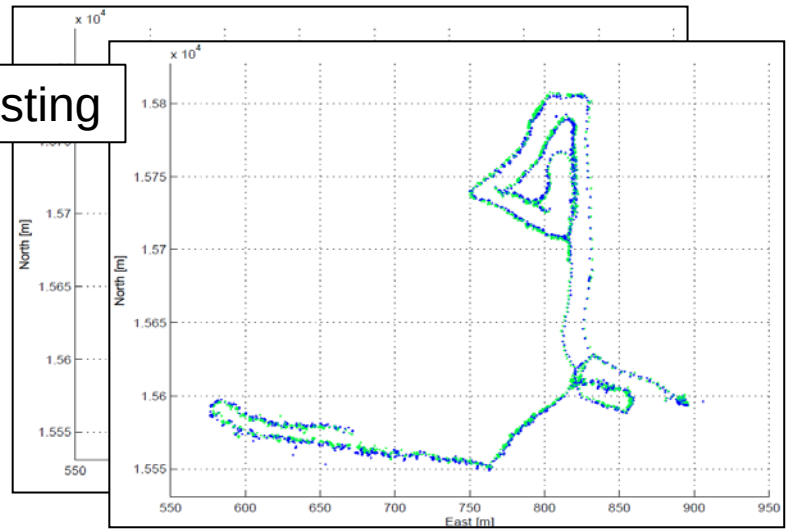
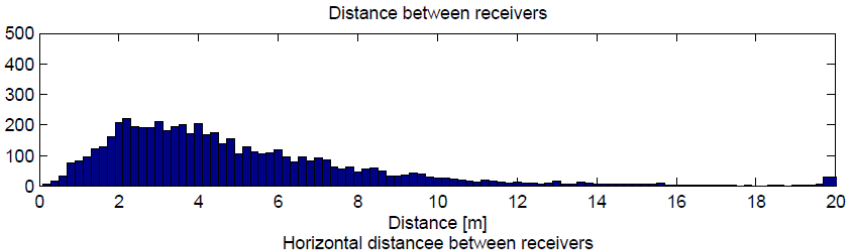
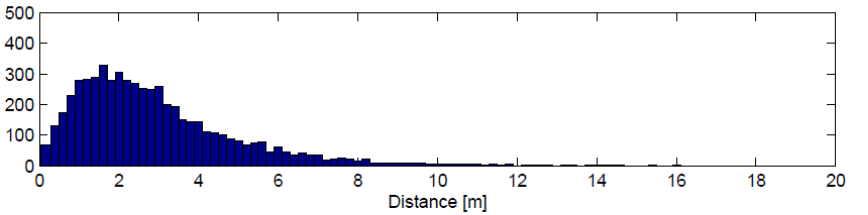
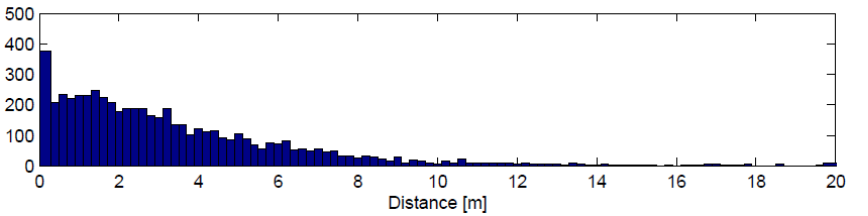
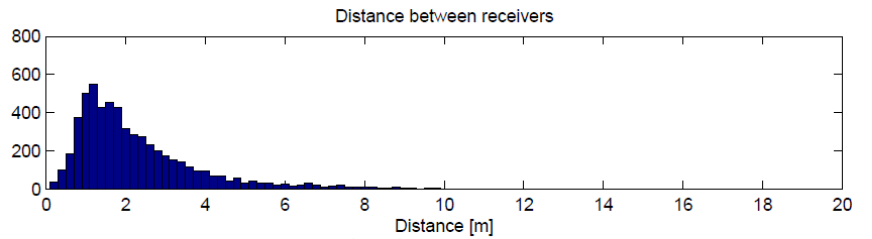
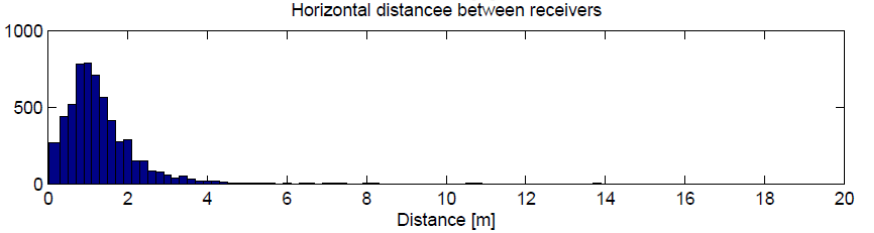


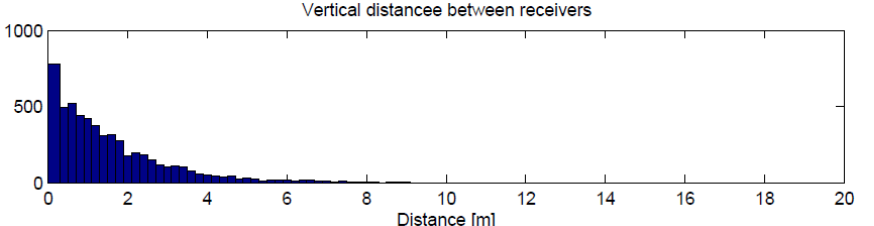






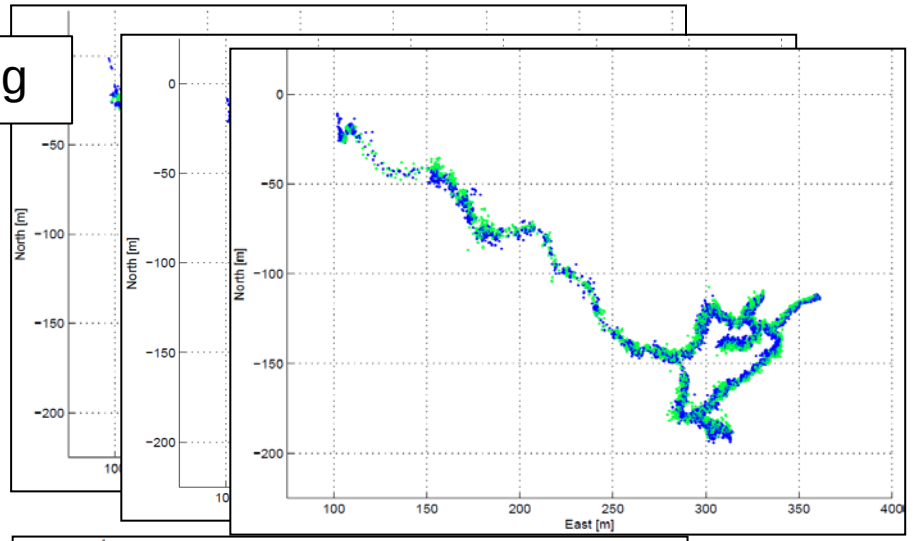


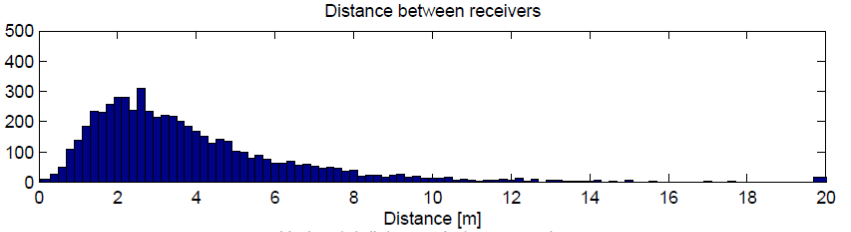


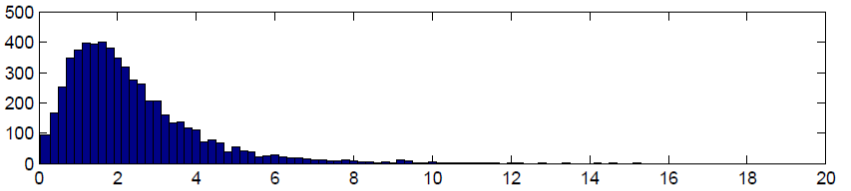


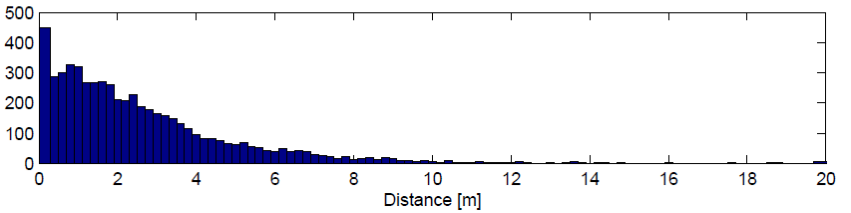
- Situation improved
- Thinning case still out of range
- Harvesting case fulfills specification

Thinning

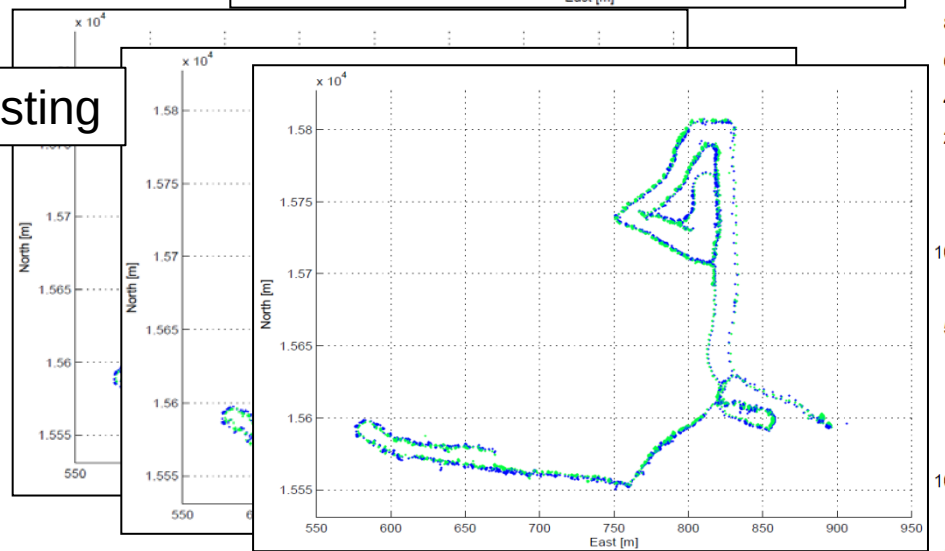


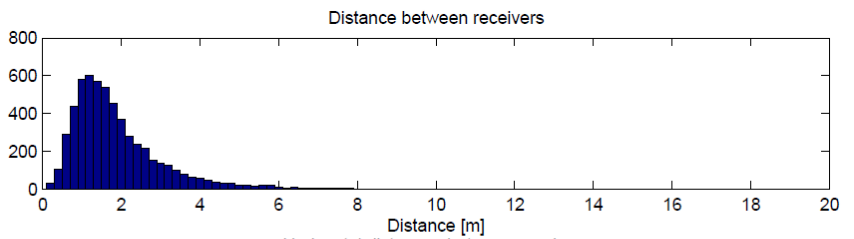


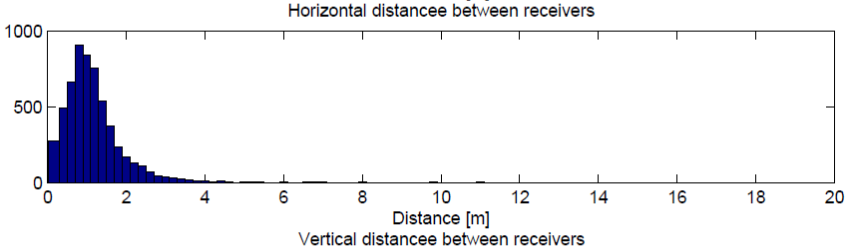


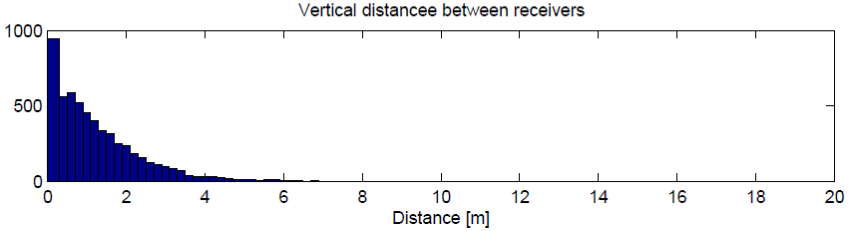


Harvesting









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