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VEHICLE TERRAIN PERFORMANCE LABORATORY

Correcting INS Drift in Terrain Surface Measurements

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Outline

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Laboratory Overview

Vehicle Terrain Measurement System

Addressing the Problem

Correcting INS Drift in Terrain Measurements

Conclusions

Laboratory Overview

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Vehicles

- Passenger cars, commercial off-road, military vehicles, motorcycles (system level)
- Modeling and Simulation

Terrain

- Modeling
- **Measurement**

Performance

- Ride
- Handling
- Reliability
- Durability

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VEHICLE TERRAIN PERFORMANCE LABORATORY

Vehicle Terrain Measurement System

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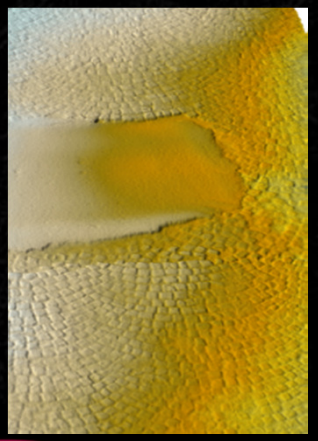
Scanning Laser

- Provides relative height measurement

Inertial Navigation System (INS)

- Differential GPS:
  - Establishes global coordinate system
- Inertial Measurement Unit (IMU):
  - Mitigates body motion



VTMS: Digital Signal Processing

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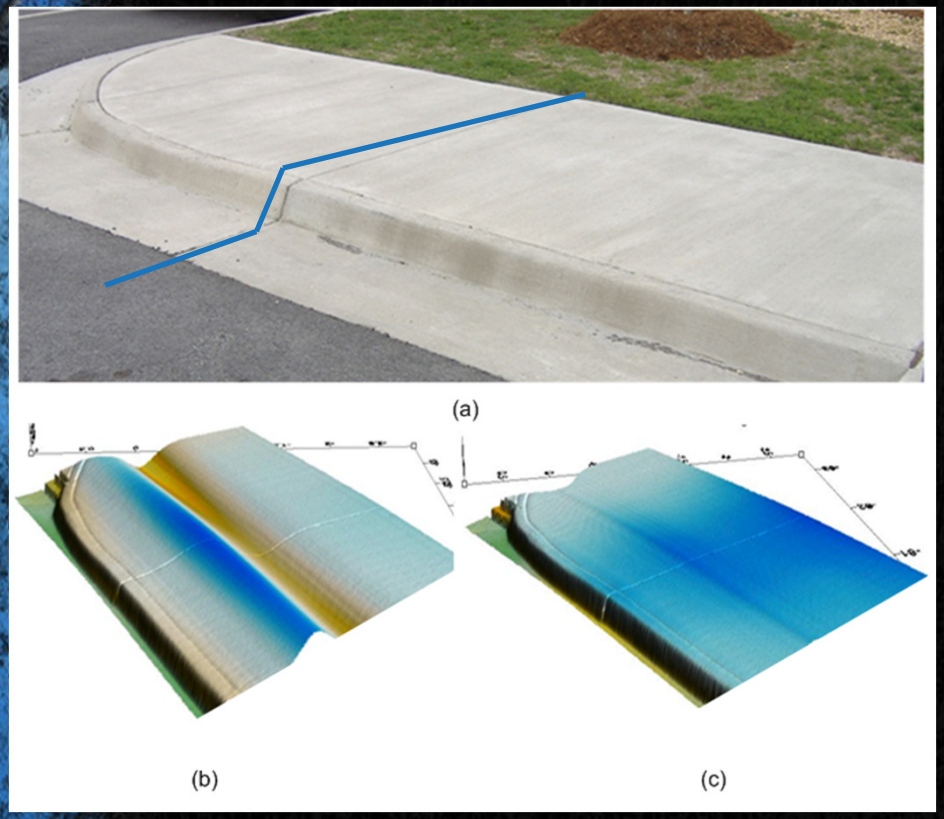
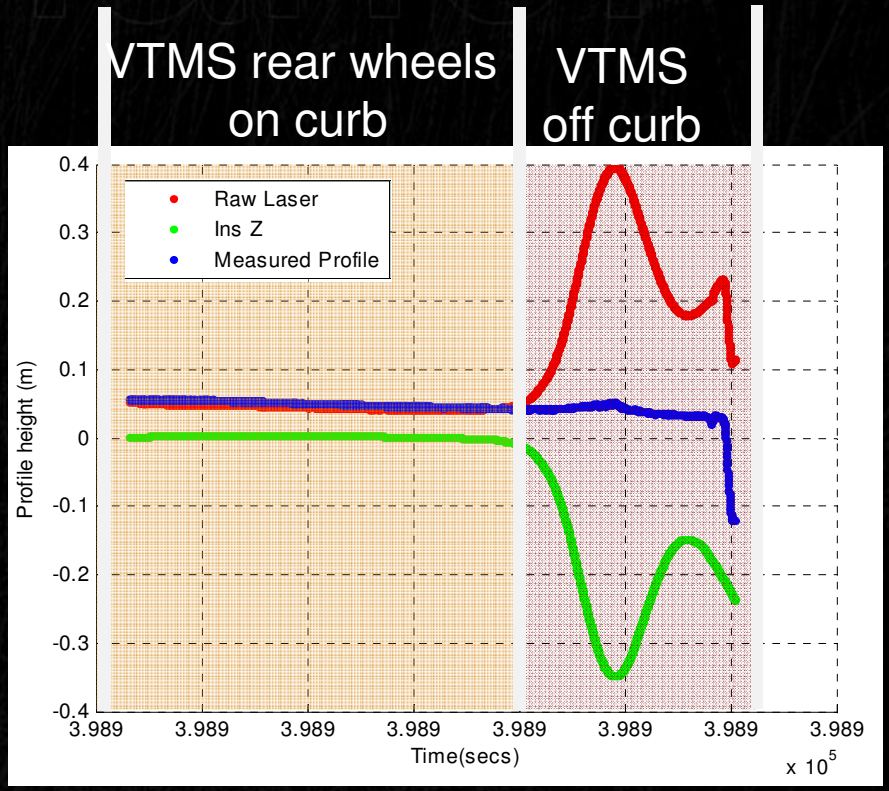
Body Motion Cancellation





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Vehicle Terrain Performance Laboratory

VTMS: Coordinate System

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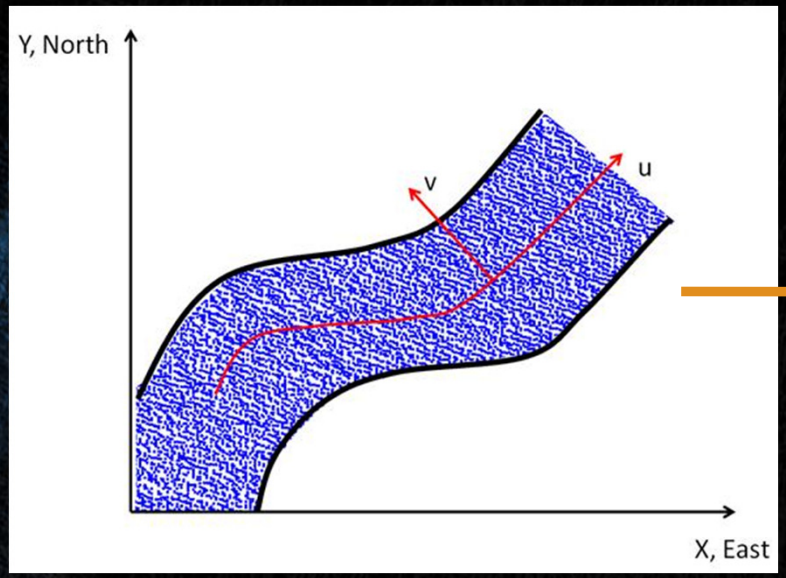
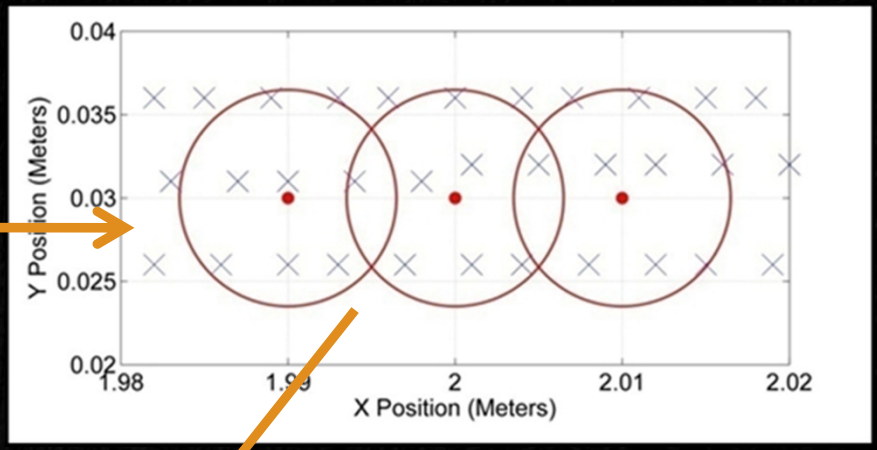
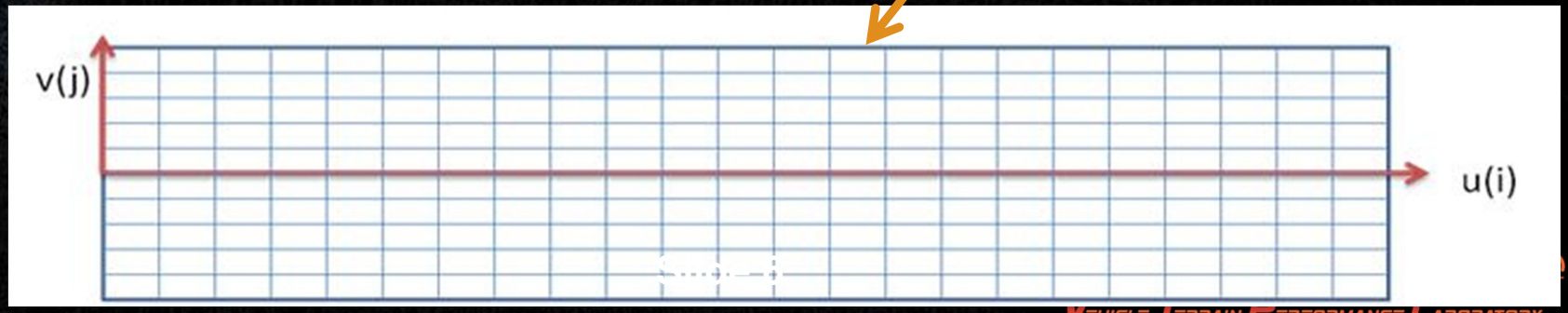
Horizontal Plane

- Map point-cloud data to uniform grid → Defined by Vehicle Path (u)







VTMS: Coordinate System

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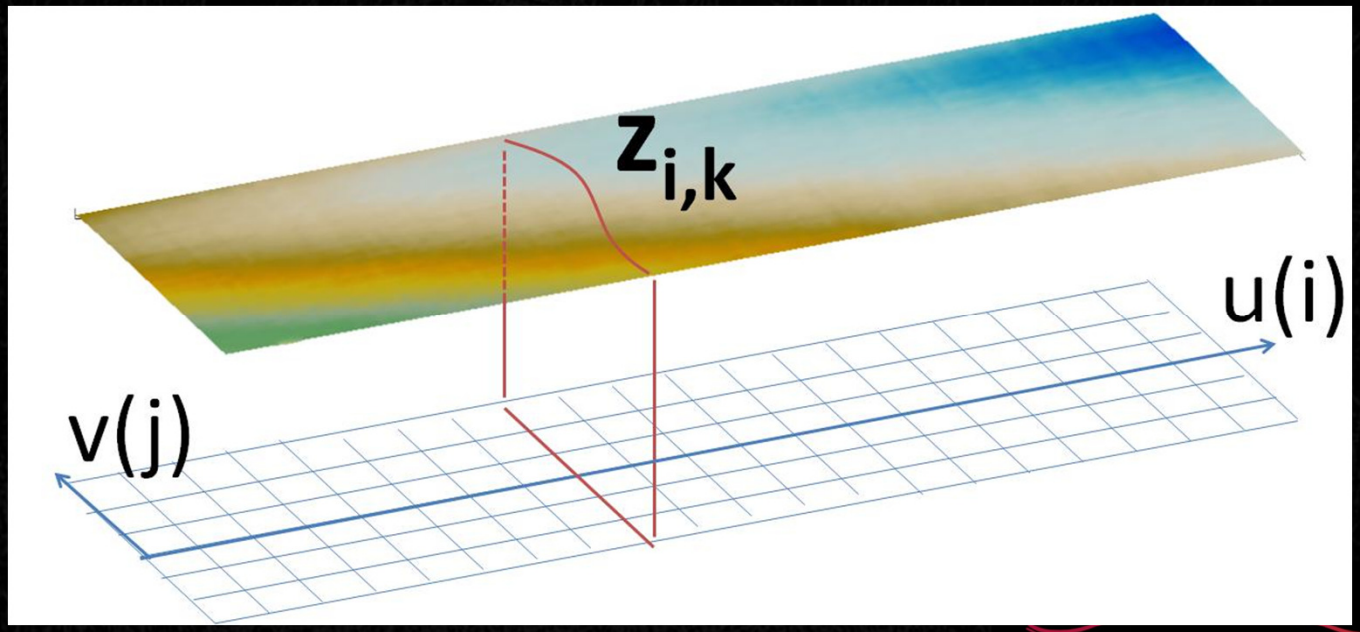
Terrain Height

- i: longitudinal location of transverse profile, where $i \in \{0,1,\ldots,m\}$
- j: transverse location of longitudinal profile, where $j \in \{0,1,\ldots,n\}$
- k: realization (measurement), where $k \in \{1,2,\ldots,r\}$



Addressing the Problem

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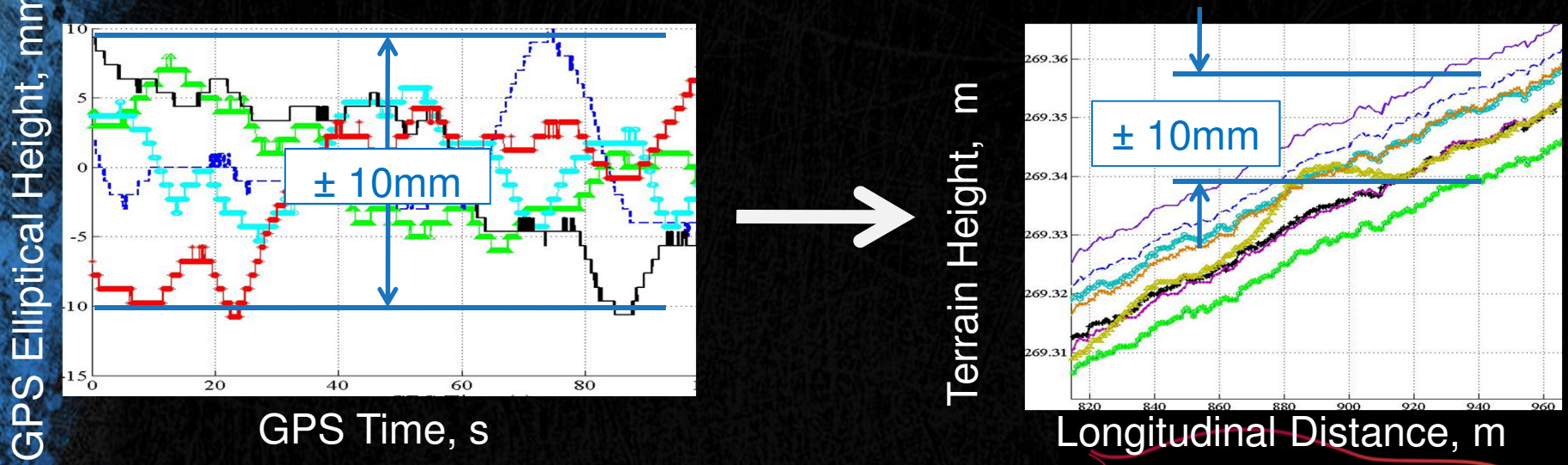
- INS is capable of a establishing a geodetic (latitude & longitude) position with 2cm accuracy with differential GPS
- Experimentation shows artifacts of INS drift
  - Max variation is +/- 10mm in elliptical height
- INS Drift introduces run-to-run variation



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Correcting INS Drift

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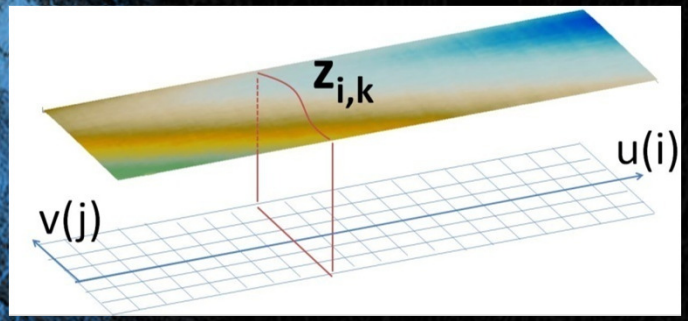
Assumptions

- Elliptical height changes only in time
- Drift is the same within each scan (~1ms)
- Correct from scan to scan
- Non-deformable terrain only
- INS treated as “black box” – combining DGPS + IMU

Correcting INS Drift

Decomposing the Vector Space

Measured Surface : $z_{i,k}$



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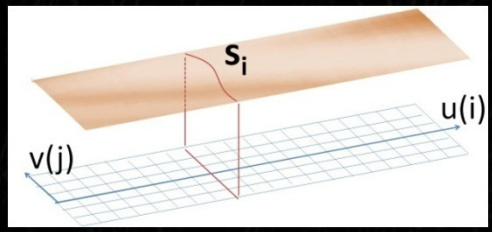
"True" Surface: s_i



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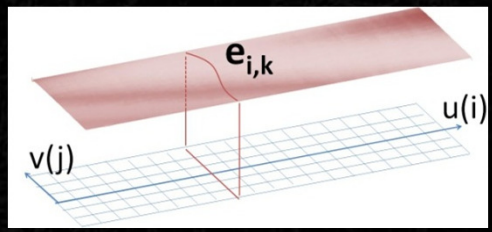
"Total" Error: $e_{i,k}$



Correcting INS Drift

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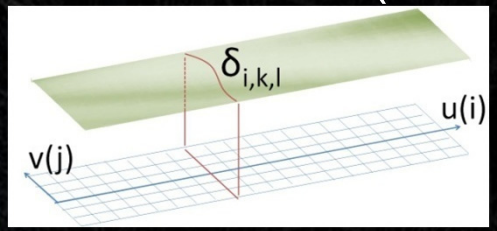
Error Modeling

"Total" Error = Drift + Noise

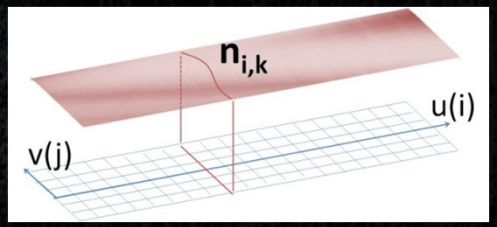
- Global Error (Drift)



INS Drift: $\delta_{i,k,l}$

+

- Local Error (Noise)



Noise: $n_{i,k}$

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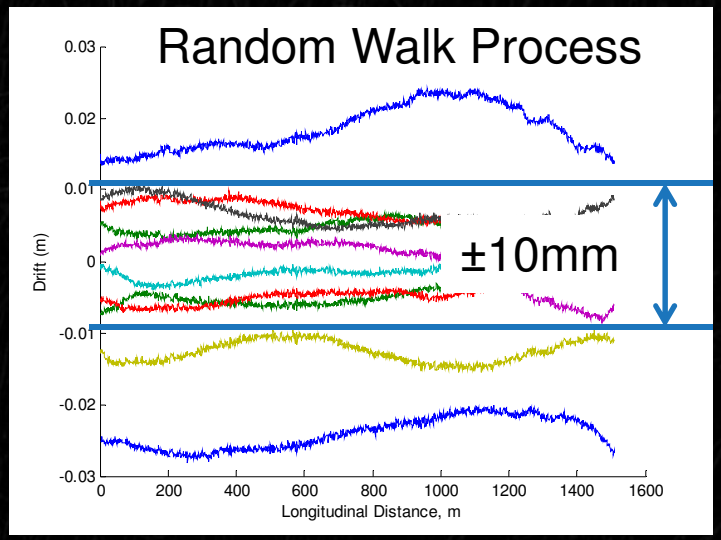
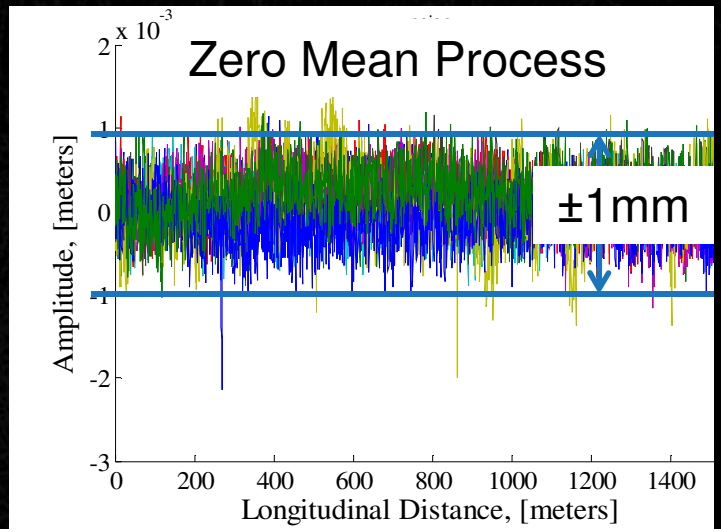
"Total" Error: $e_{i,k}$





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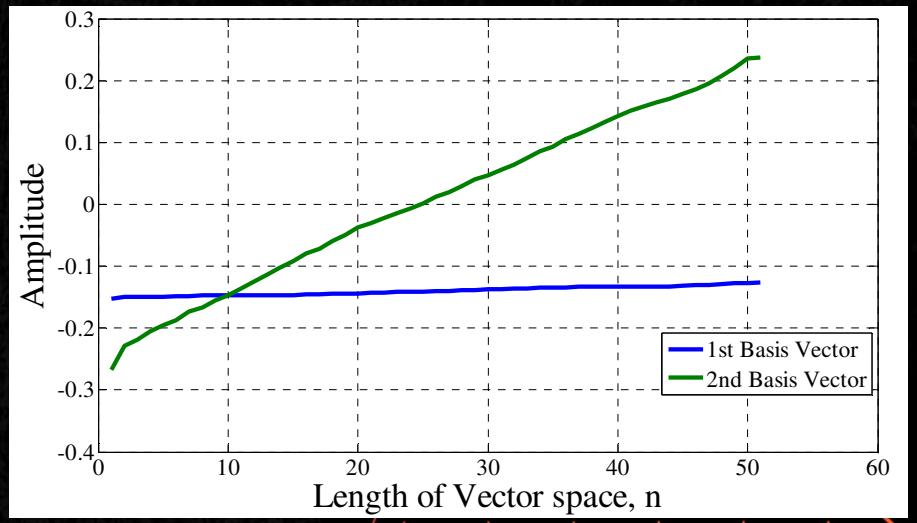
Correcting INS Drift

The "Total" error must be separated into INS drift and noise

- Singular Value Decomposition – determine contributions from different "shapes" to the error
- Noise must be zero-mean and is not correlated to the INS drift



Correcting INS Drift

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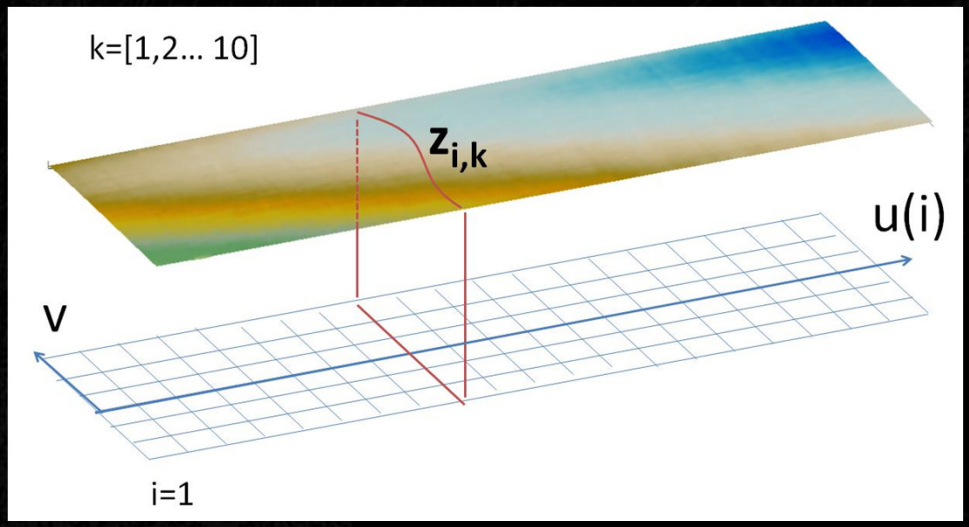
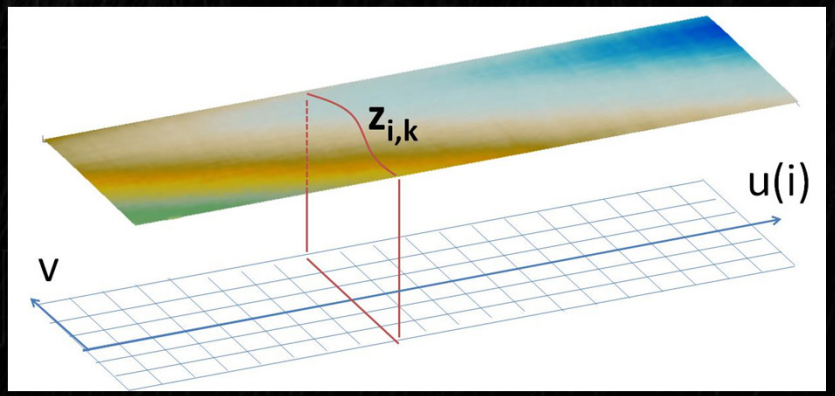
Proof of Concept

- MnRoad Test Facility, Albertville, MN
- 160m section of asphalt, 100mm spacing → i=[1,2… 1518]
- 10 total measurements (alternating directions) → k=[1,2… 10]



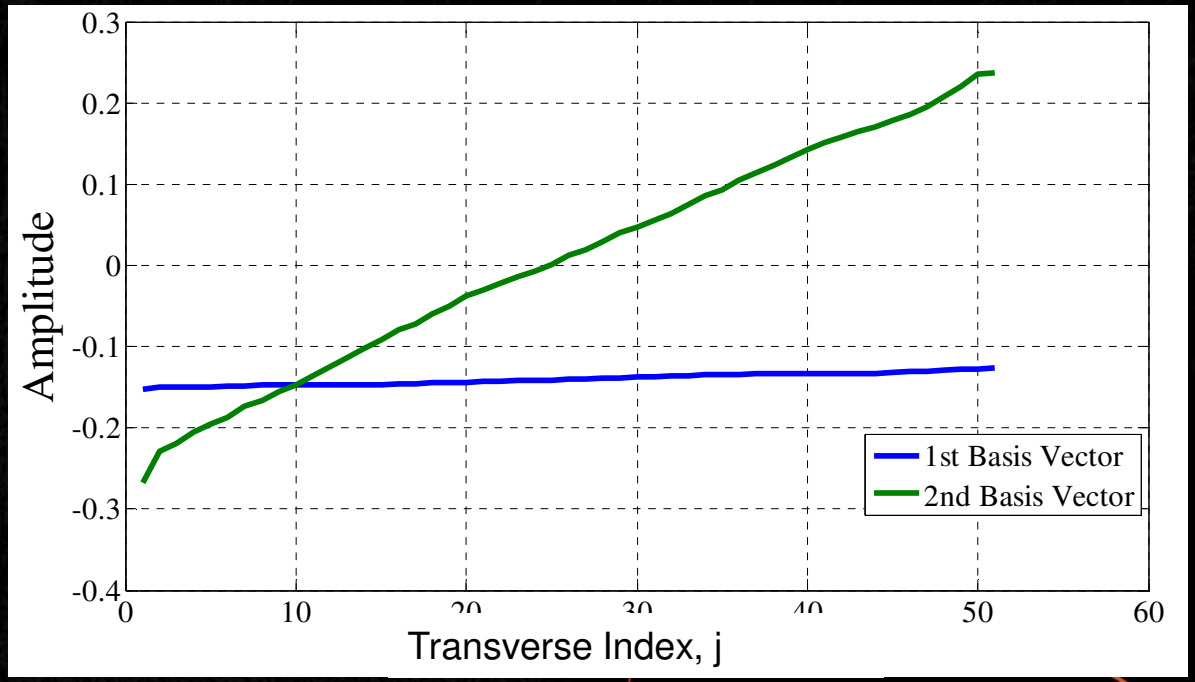
Correcting INS Drift



Proof of Concept

- Two basis vectors imply $E[n_{ik}]=0$
- First Basis Vector= Constant Offset
- Second Basis Vector = Slope Offset

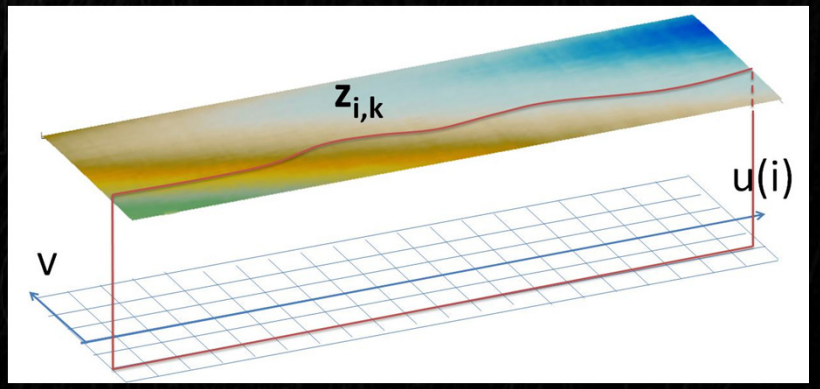
Singular Values	
1	6.63
2	1.76
3	0.1212
4	0.0911

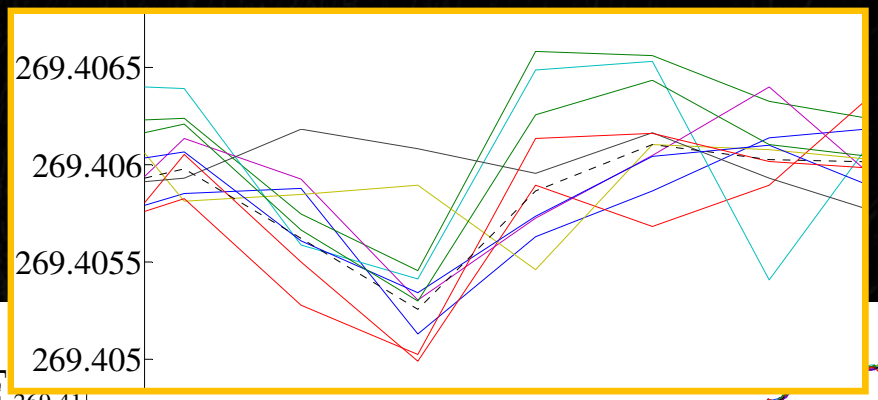


Correcting INS Drift

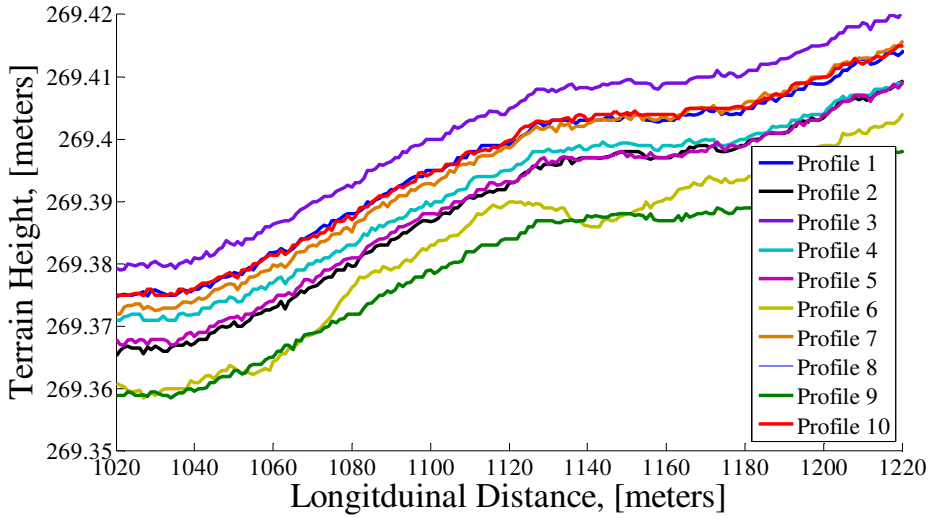
Proof of Concept

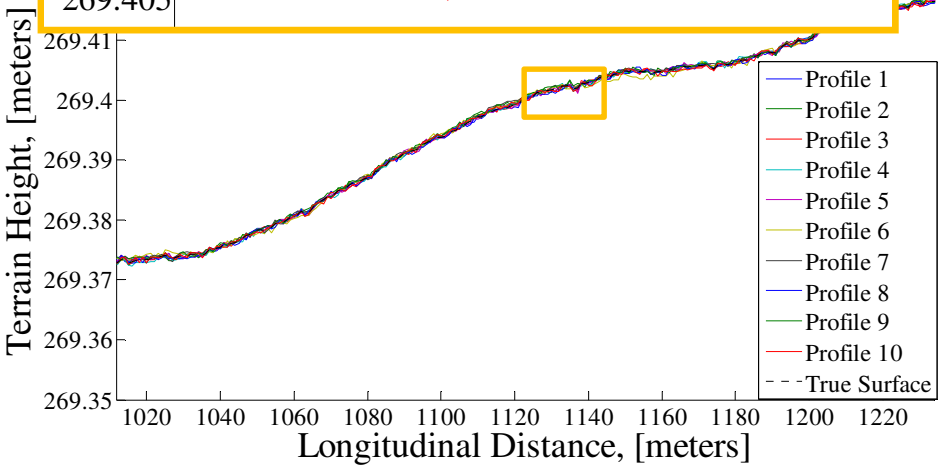
- Longitudinal view of terrain surface





No INS Drift Correction





Conclusions

- INS Drift sufficiently characterized and removed
  - Set of basis vectors identified
    - 1st Basis Vector = Elevation Principal Direction
    - 2nd Basis Vector = Bank Angle Principal Direction
  - Drift is a random walk process
  - Noise is a zero-mean process
  - Variation in measured surfaces reduced to 1mm
  - True Surface established