KRIGING WITH MACHINE LEARNING COVARIANTES IN ENVIRONMENTAL SCIENCES A HYBRID APPROACH

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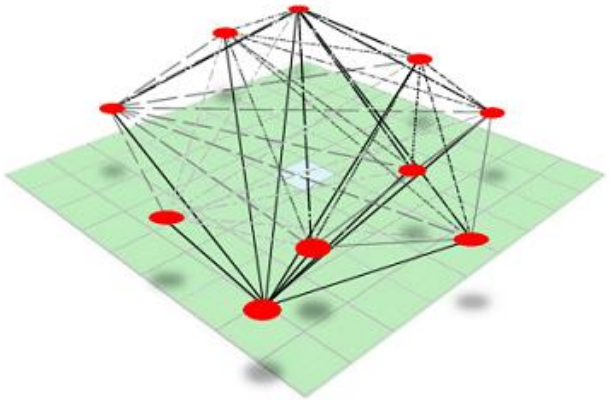
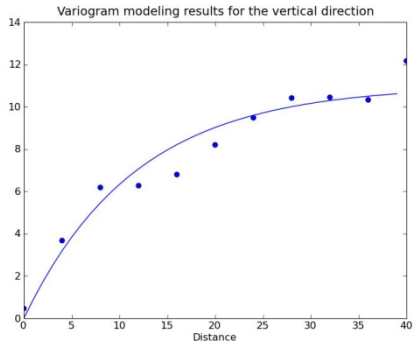
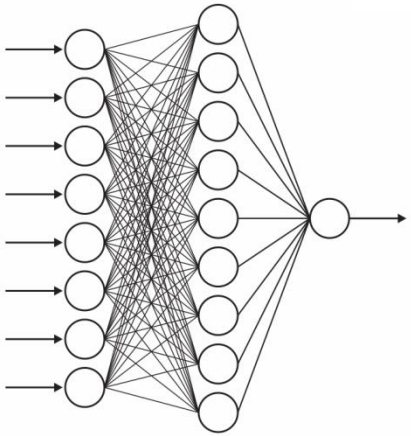
Introduction

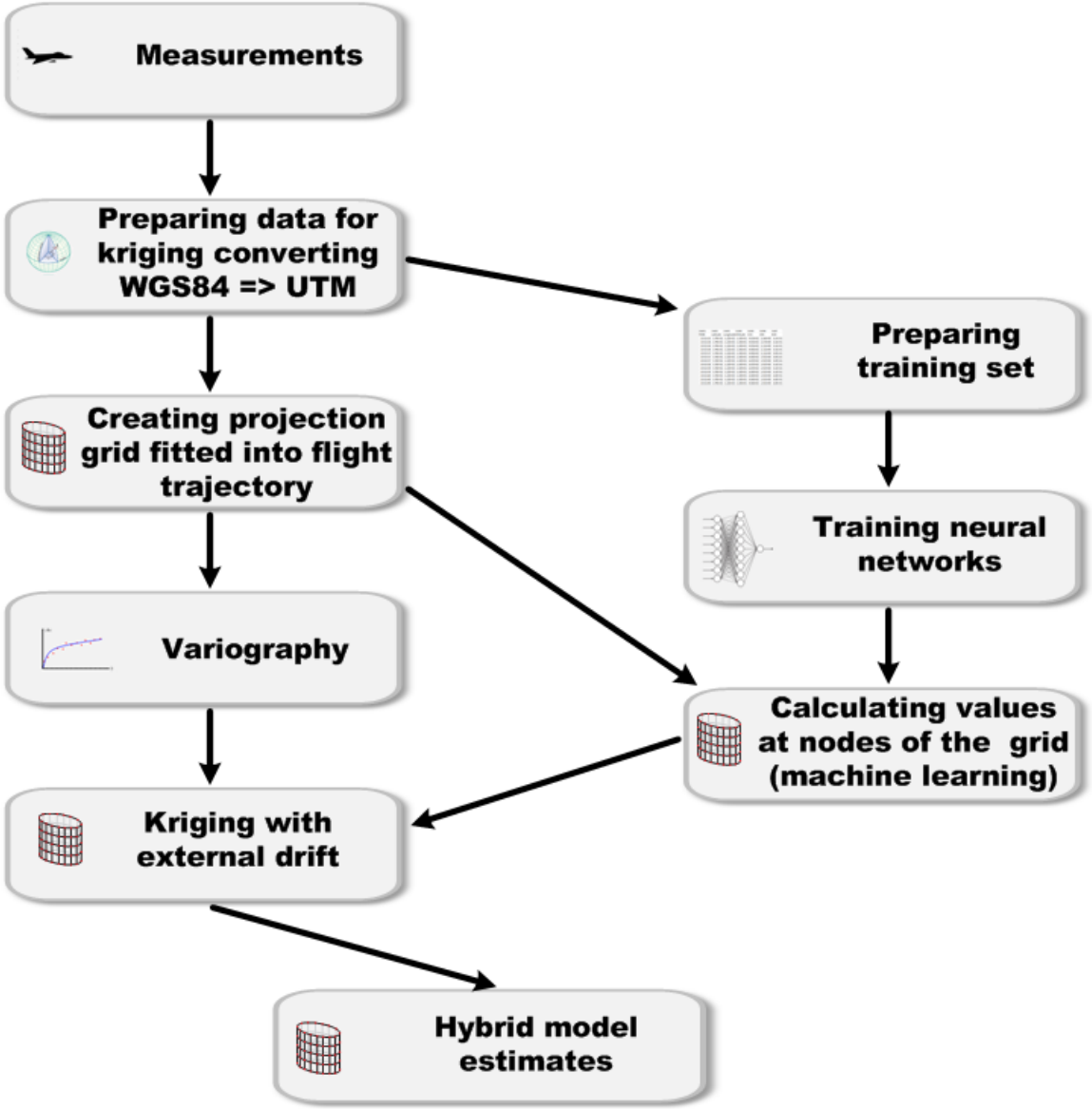


- Kriging
- Auxiliary variables
  - co-kriging,
  - kriging with external drift
- Machine learning methods (Artificial neural networks)
- Combining geostatistical and machine learning methods

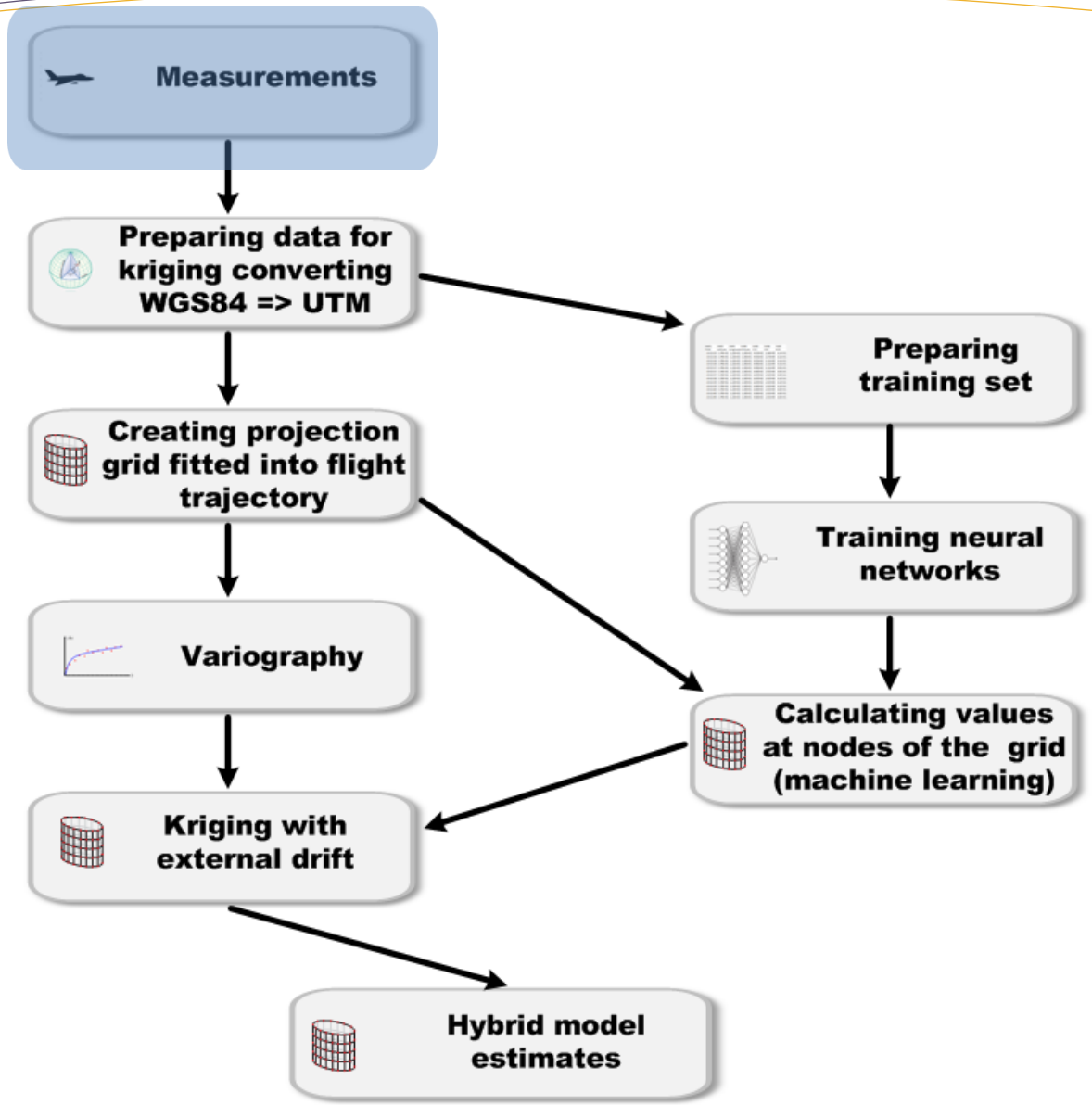




Process overview



Process overview



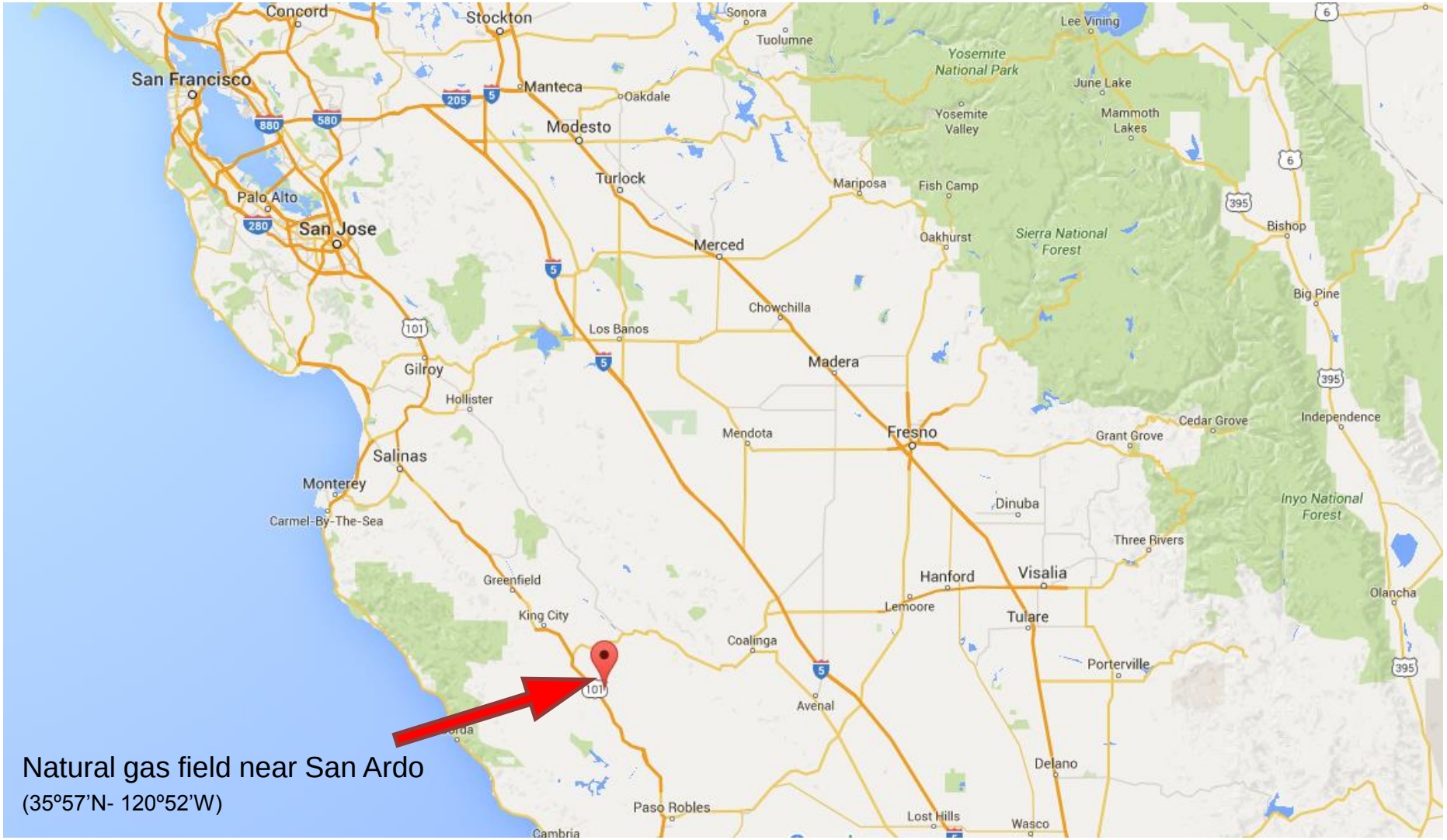
Equipment for measurements

Alpha Jet, based at NASA Ames Research Center

Picarro 2301-m cavity ring-down instrument for CO_2, CH_4 and H_2O

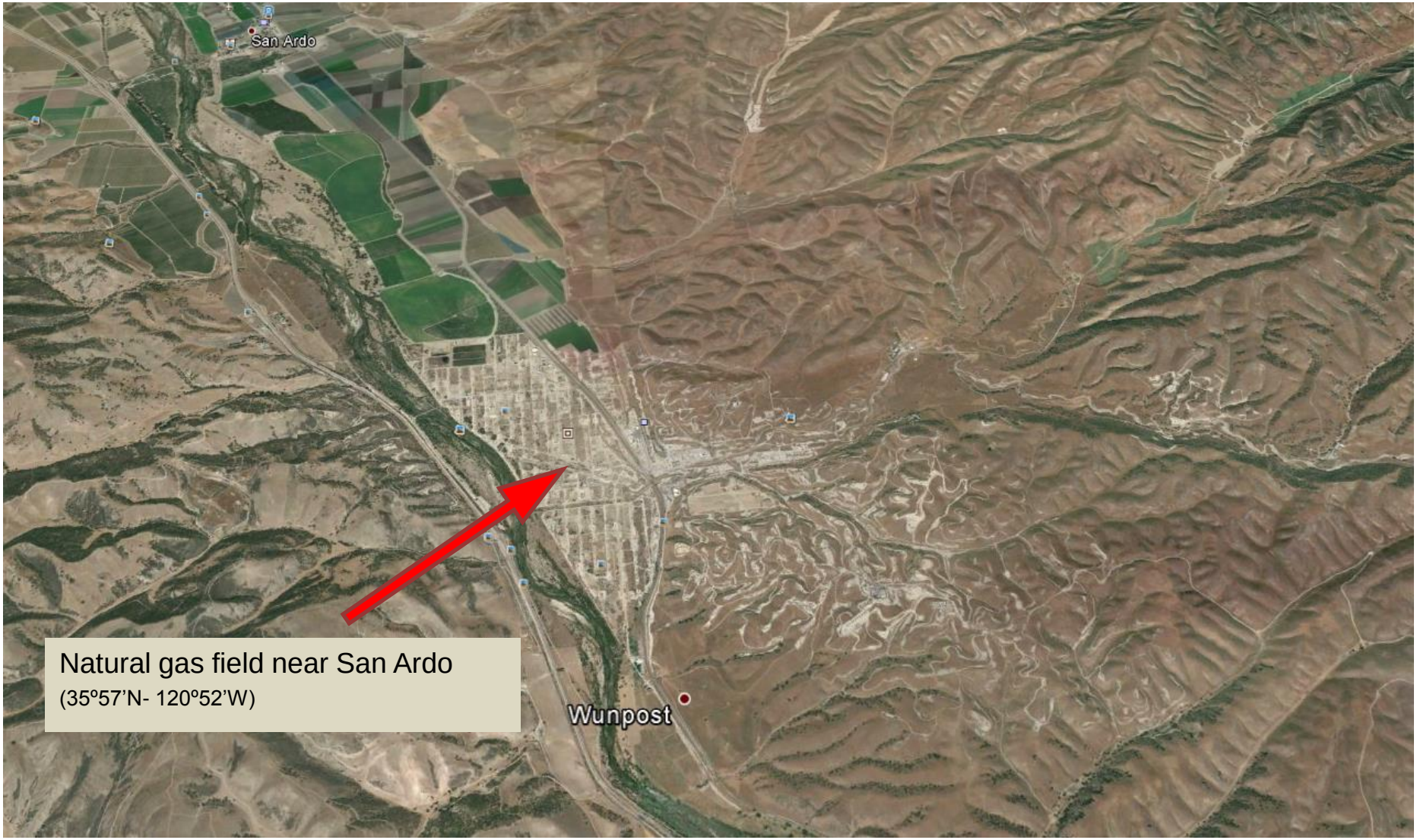
GPS that provide information about position (latitude, longitude, altitude)

Location of measurements - San Ardo

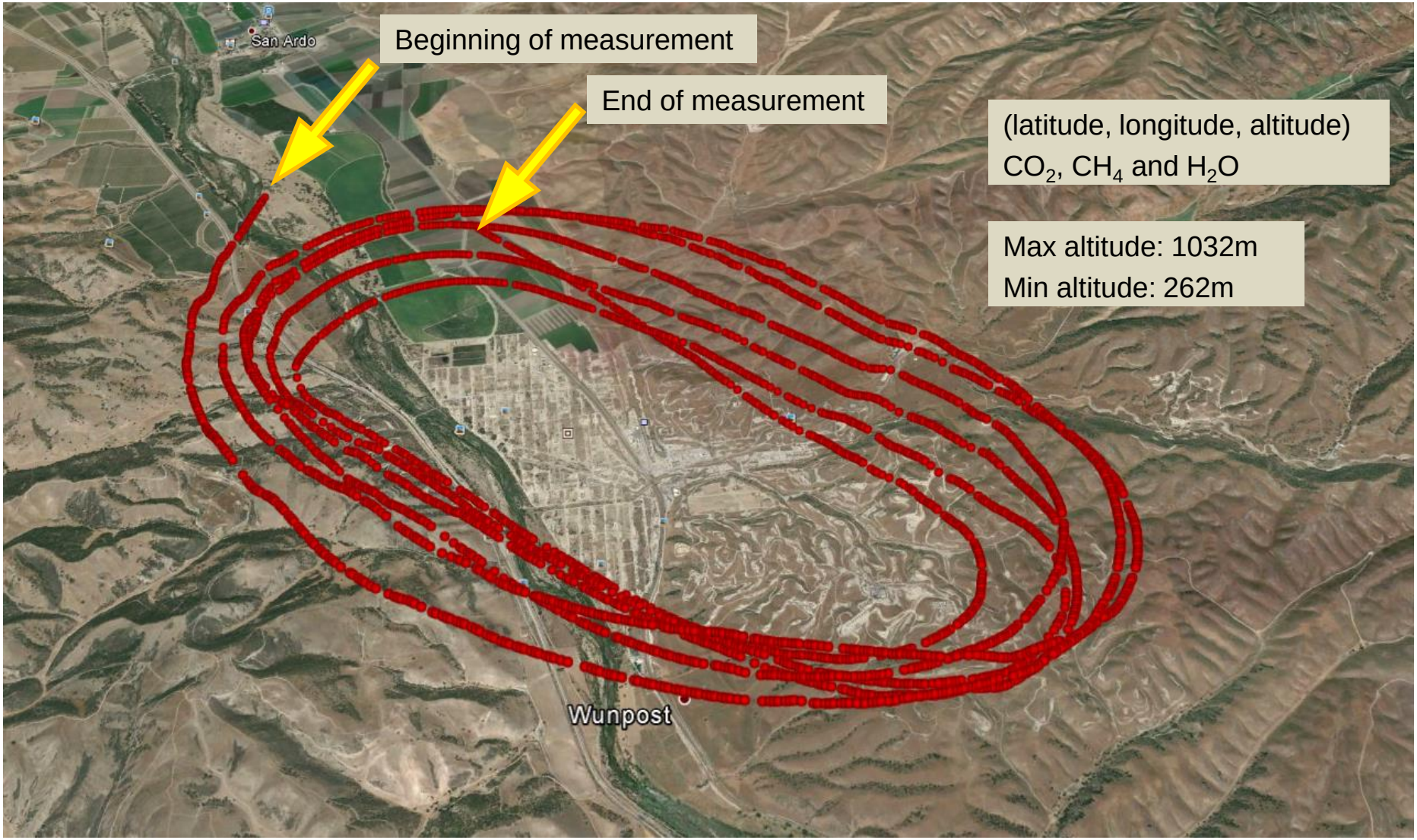


Natural gas field near San Ardo
(35º57'N- 120º52'W)

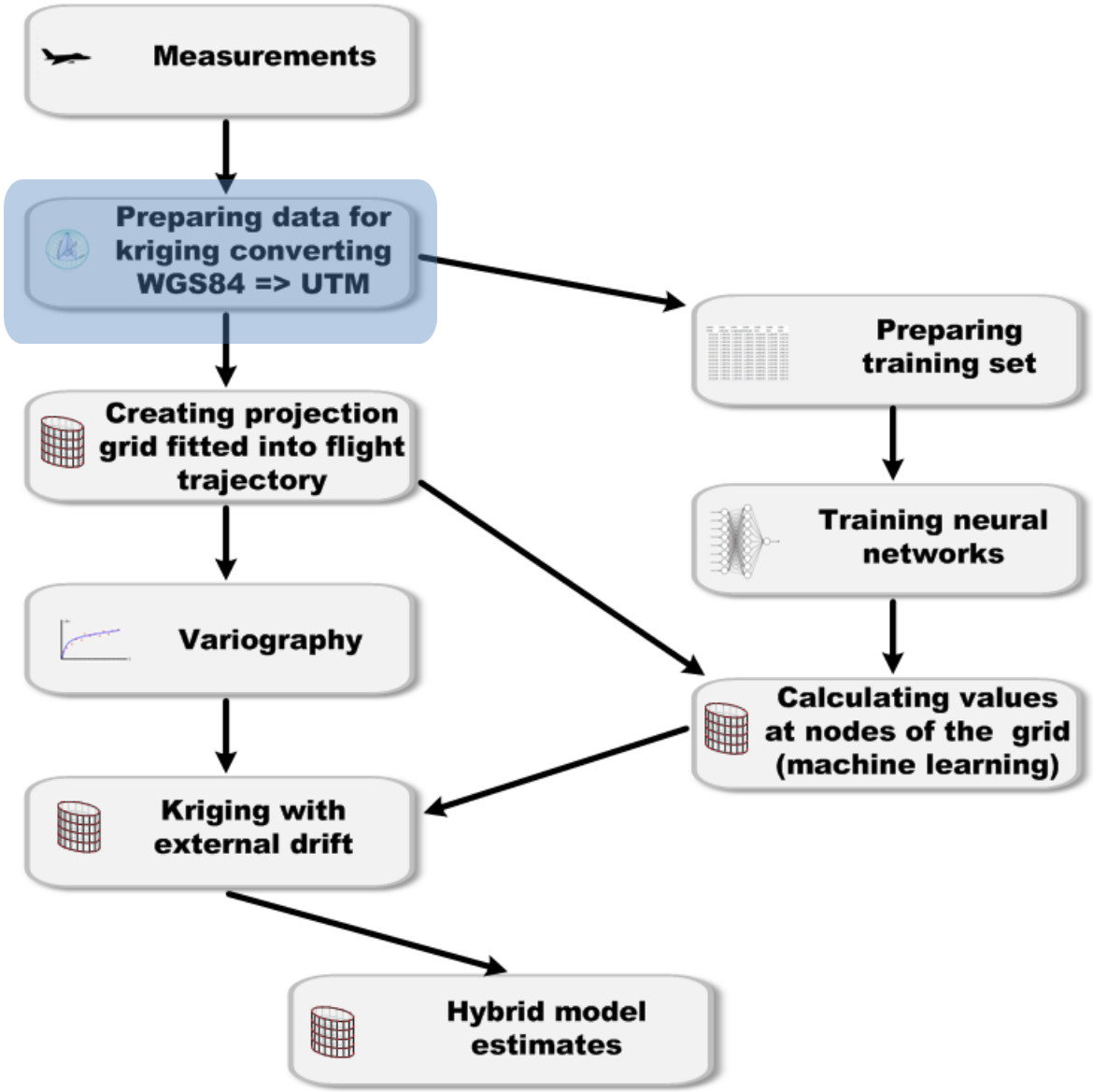
Location of measurements - San Ardo



Location of measurements - Flight path

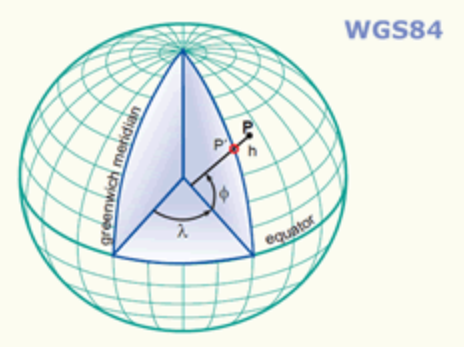


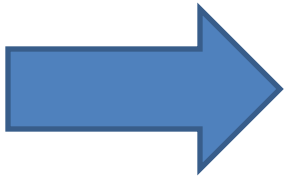
Process overview

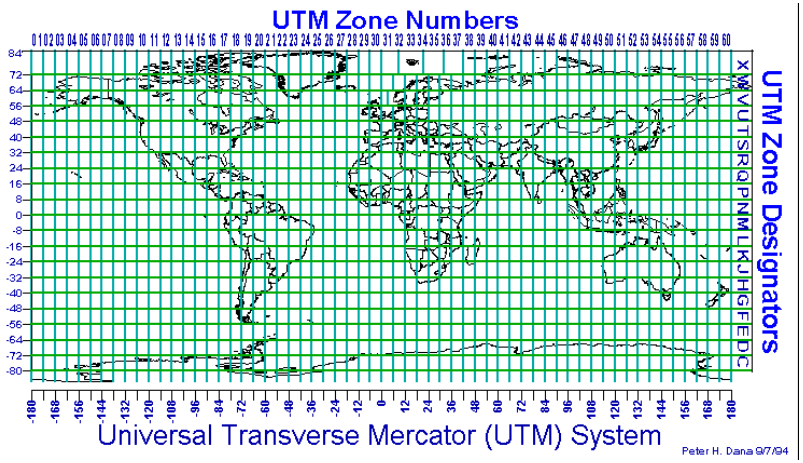


Preparing data for kriging

Before the kriging was performed, the coordinates were converted from WGS84 coordinate system (lat/lon) into a Universal Transverse Mercator (UTM) coordinate system, to allow for computation of distances and angles using Euclidean geometry





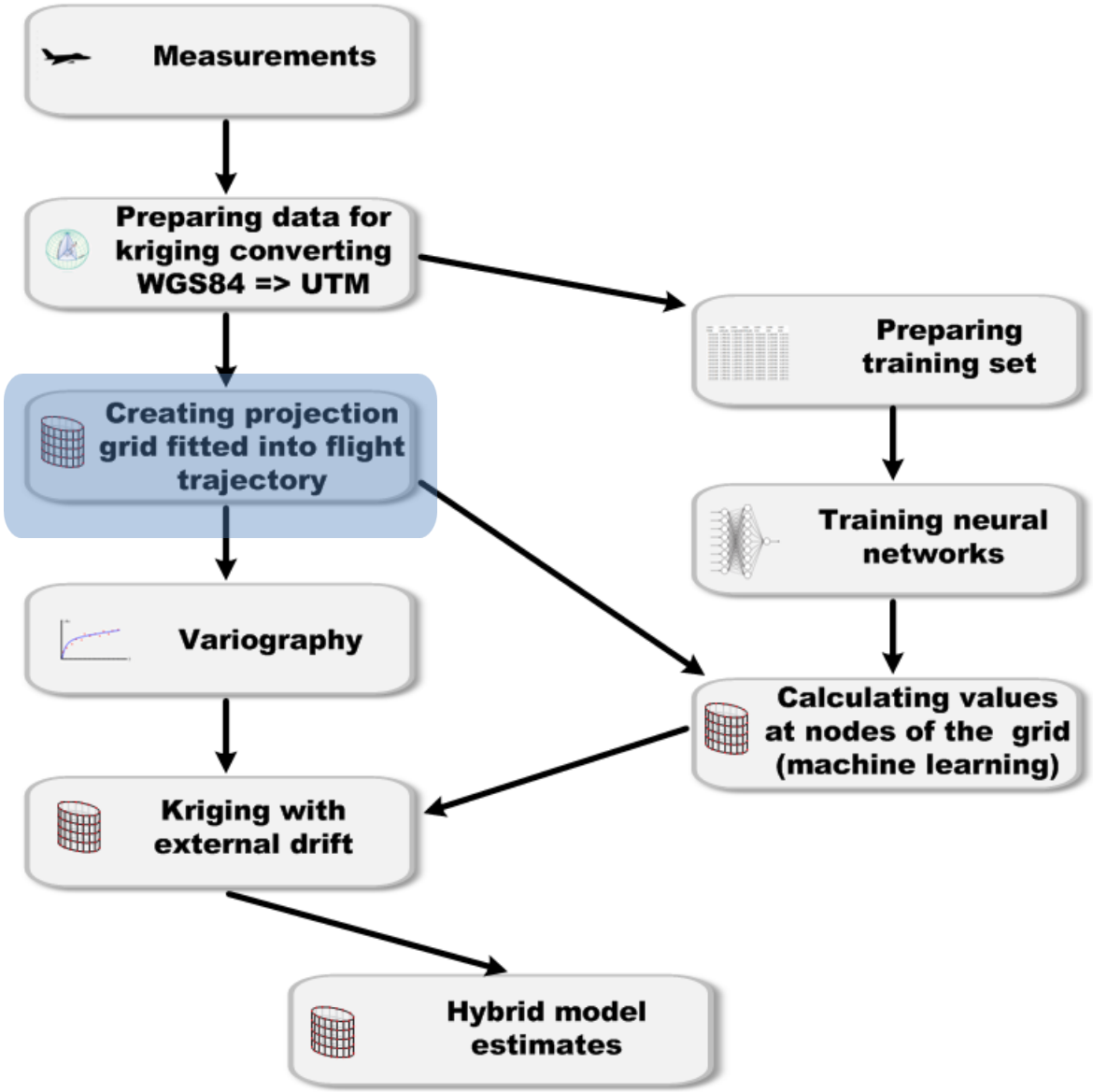


(latitude, longitude, altitude)

(degree, degree, meter)

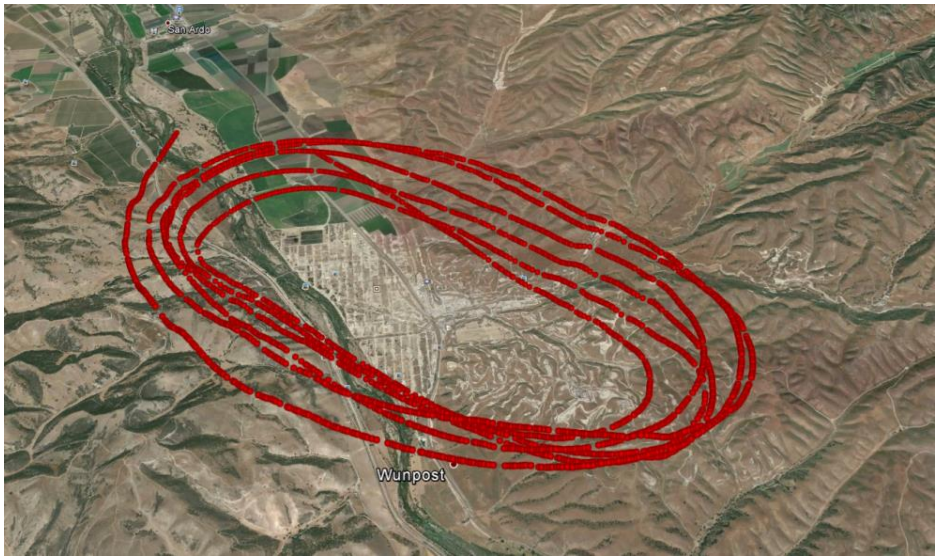
(meter, meter, meter)

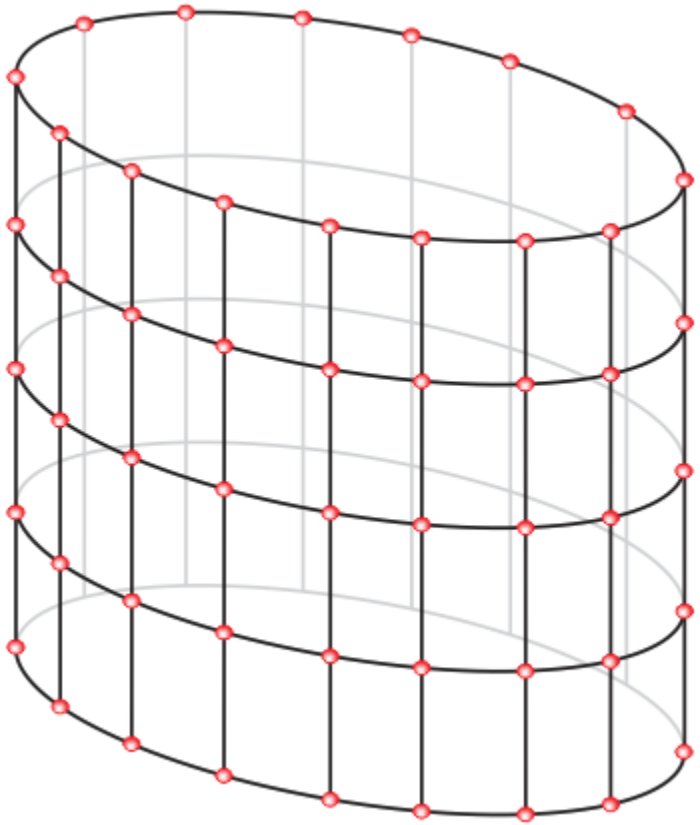
Process overview



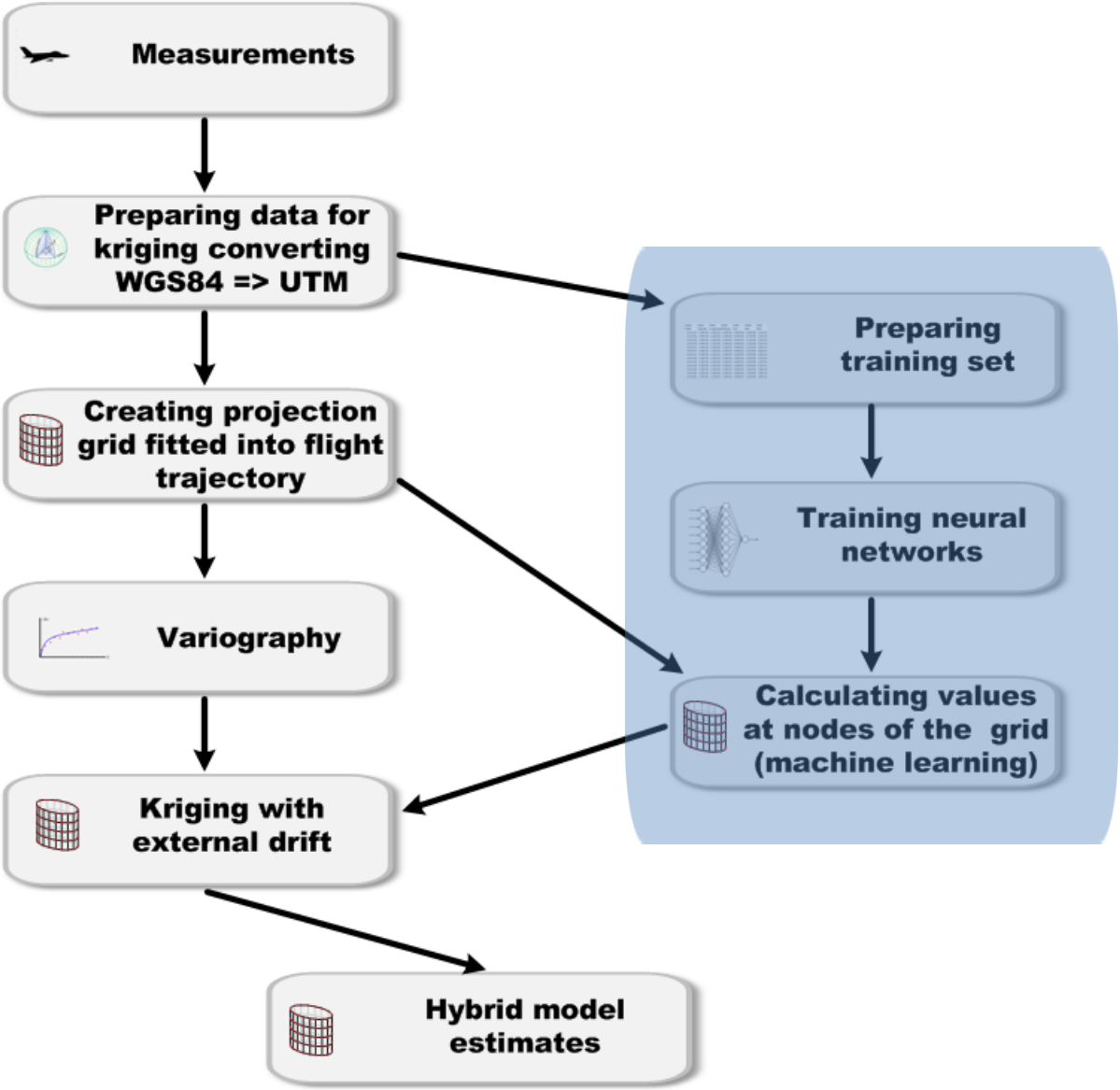
Calculation of grid fitted into flight trajectory

- Grid contains equidistant 200 points per ellipse
- Removing points below ground level



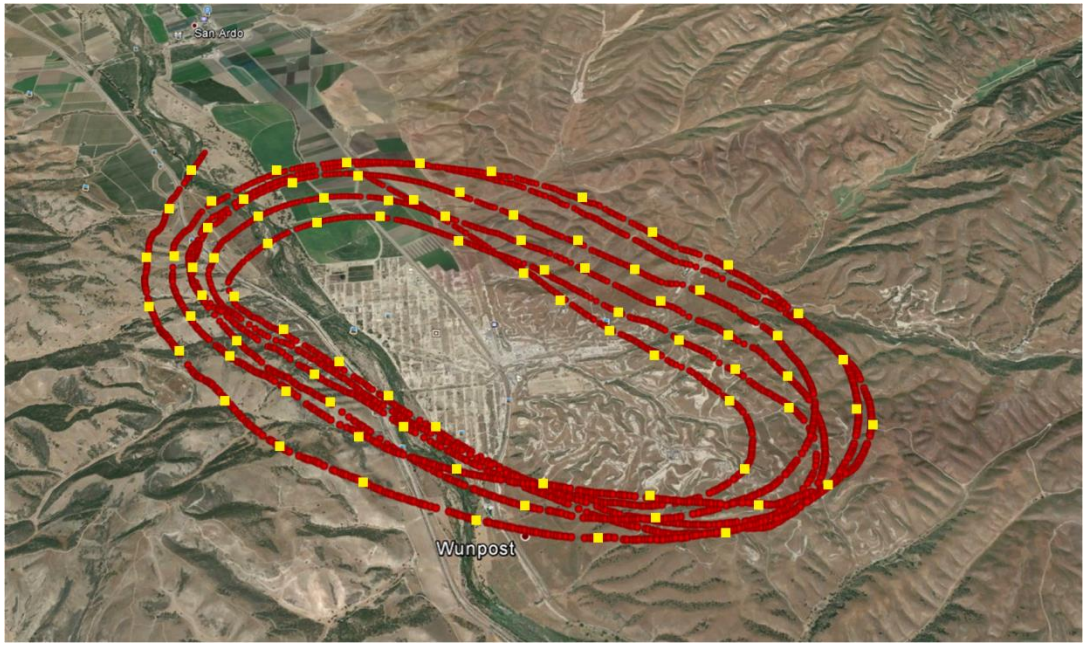


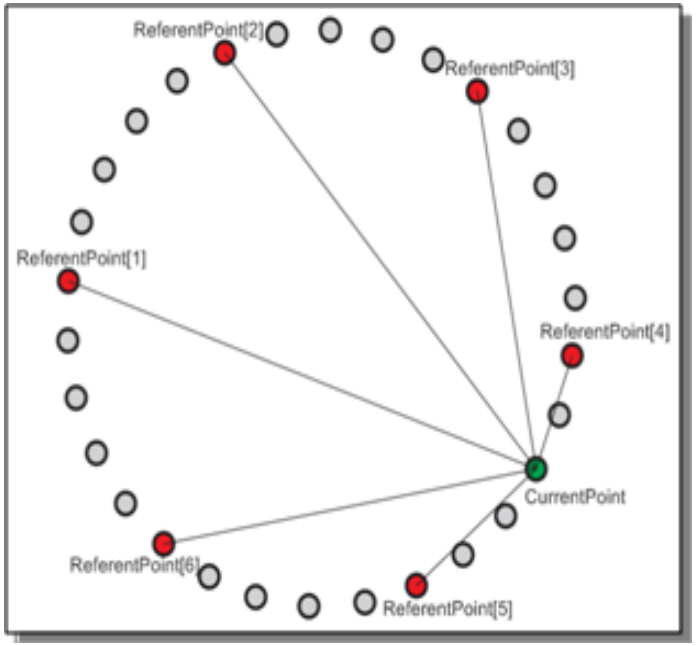
Process overview



Neural networks – preparing training set

- File with the measurement data contains 2749 measured points
- Every 25th point from that file is used as referent point
- in this way is obtained 110 referent points
- Calculating relations between referent points and other measured points is created training set of 290290 pairs





Neural networks - configuration

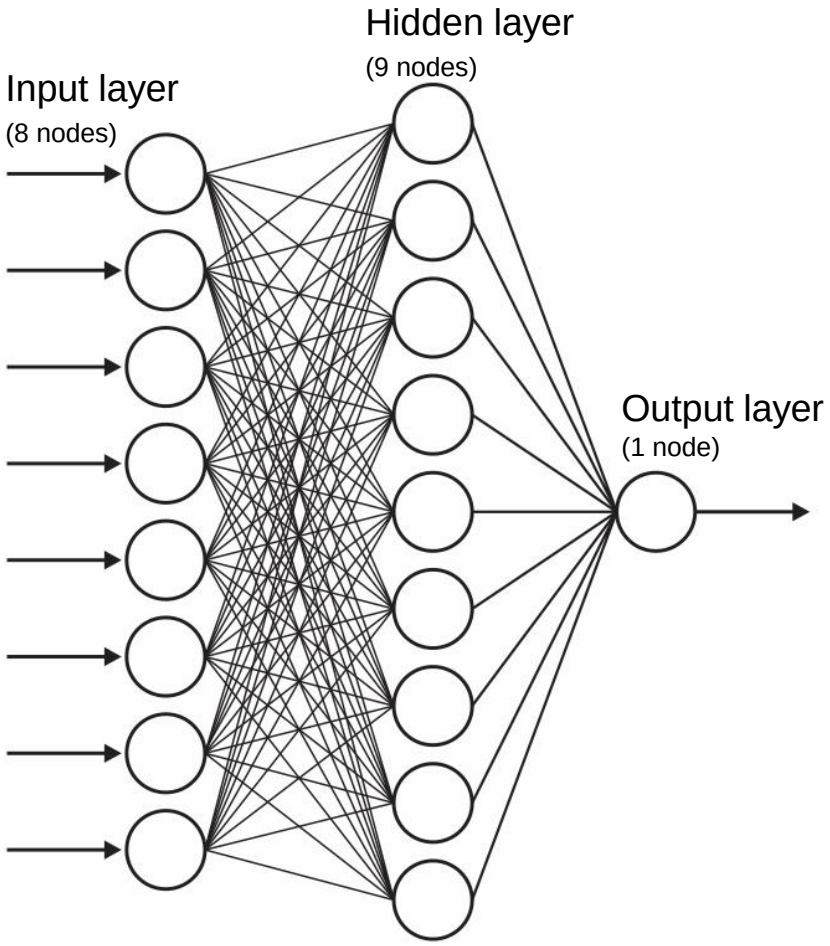
Inputs of neural network:

- Input1 = CurrentPoint[X].Latitude
- Input2 = CurrentPoint[X].Longitude
- Input3 = CurrentPoint[X].Altitude
- Input4 = RefPoint[Y].CO2mixingRatio
- Input5 = Distance(RefPoint[Y], CurrentPoint[X])
- Input6 = (RefPoint[Y].Latitude - CurrentPoint[X].Latitude)
- Input7 = (RefPoint[Y].Longitude - CurrentPoint[X].Longitude)
- Input8 = (RefPoint[Y].Altitude - CurrentPoint[X].Altitude)

Output of neural network:

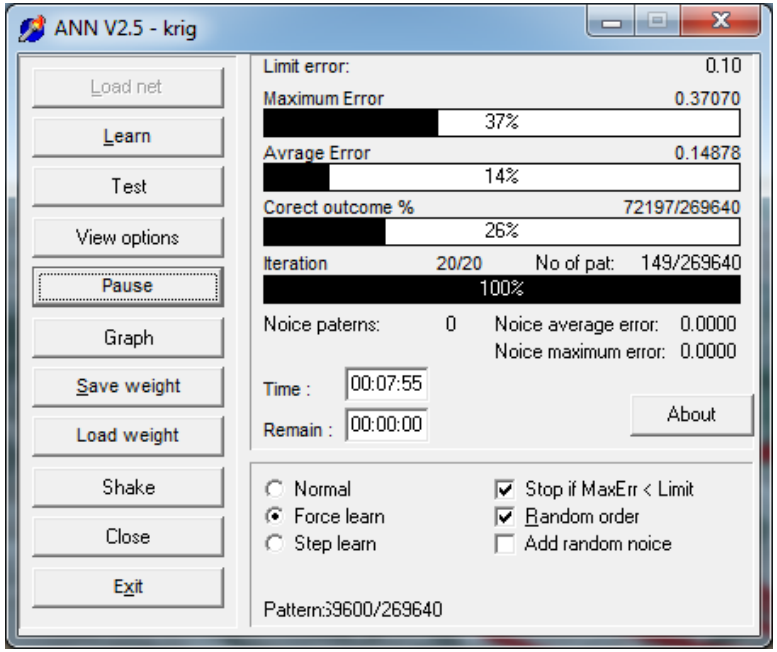
- Output1 = estimated CO_2 mixing-ratio

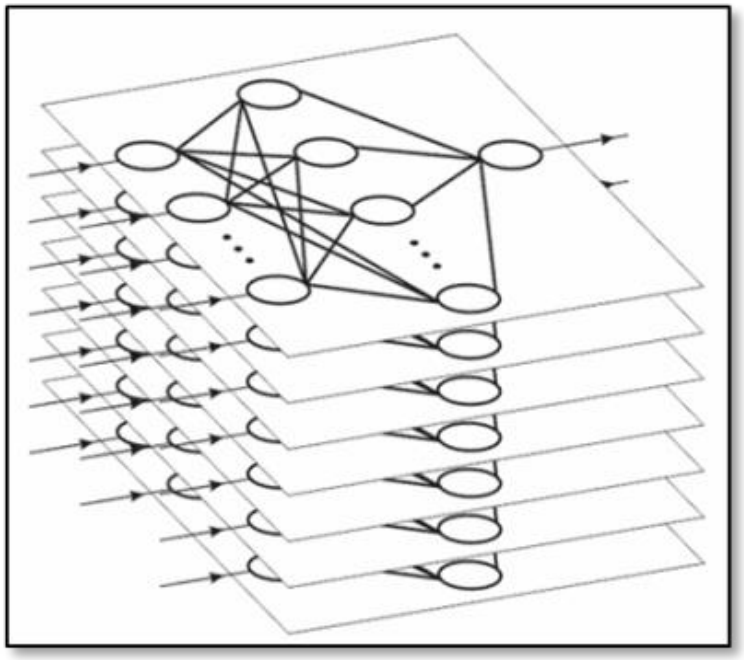
Backpropagation neural network



Neural networks – Training neural networks

- Neural networks are trained using ANN training software
- Ensemble of 25 ANNS was used in interpolations

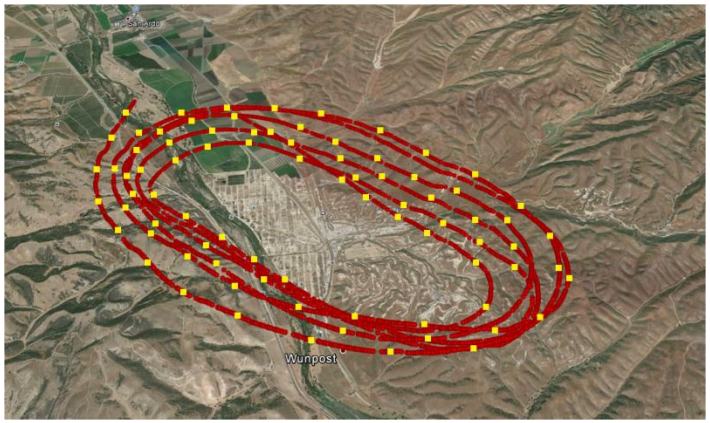




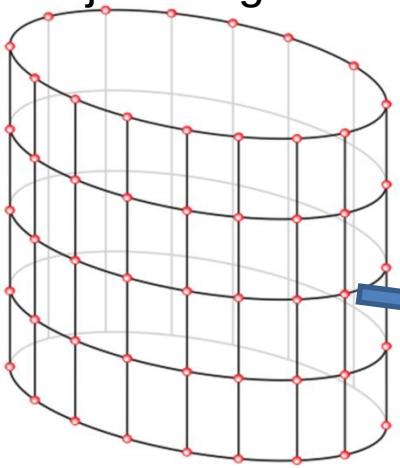
Neural networks – Training neural networks

- Ensemble of 25 ANNS was used in interpolations
- Every point from grid is calculated related to all referent points

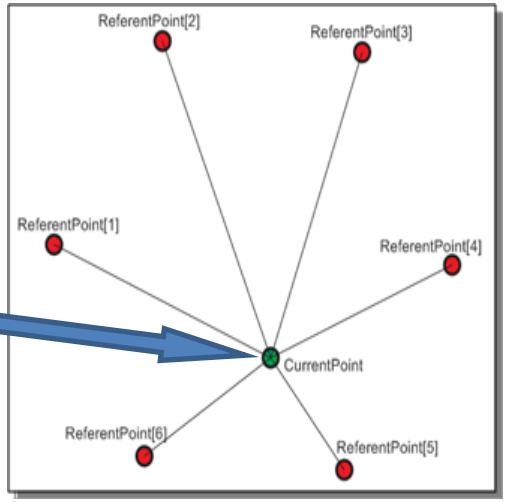
Referent points



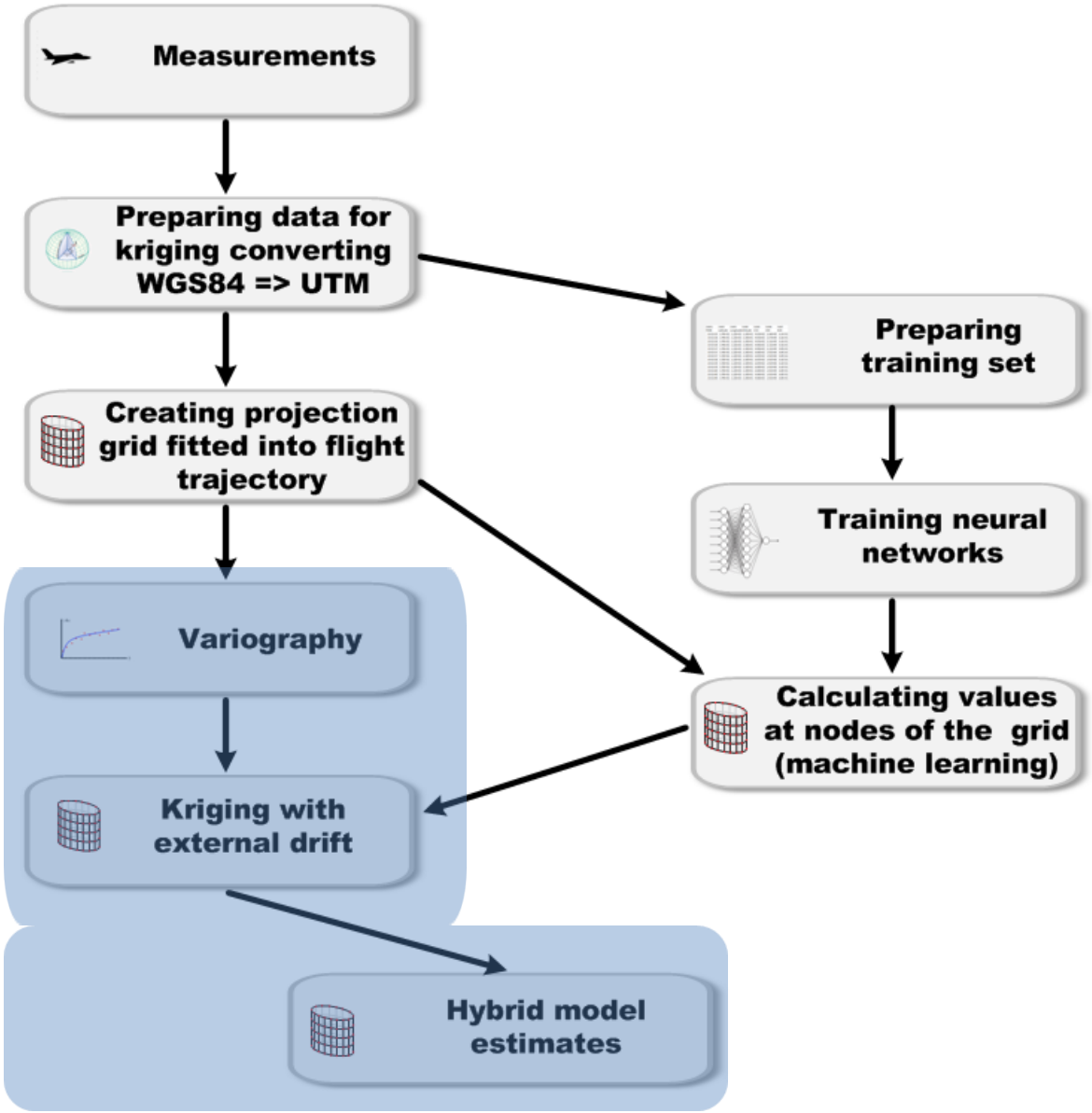
Projection grid



Estimation CO_2 concentration at one of points from grid

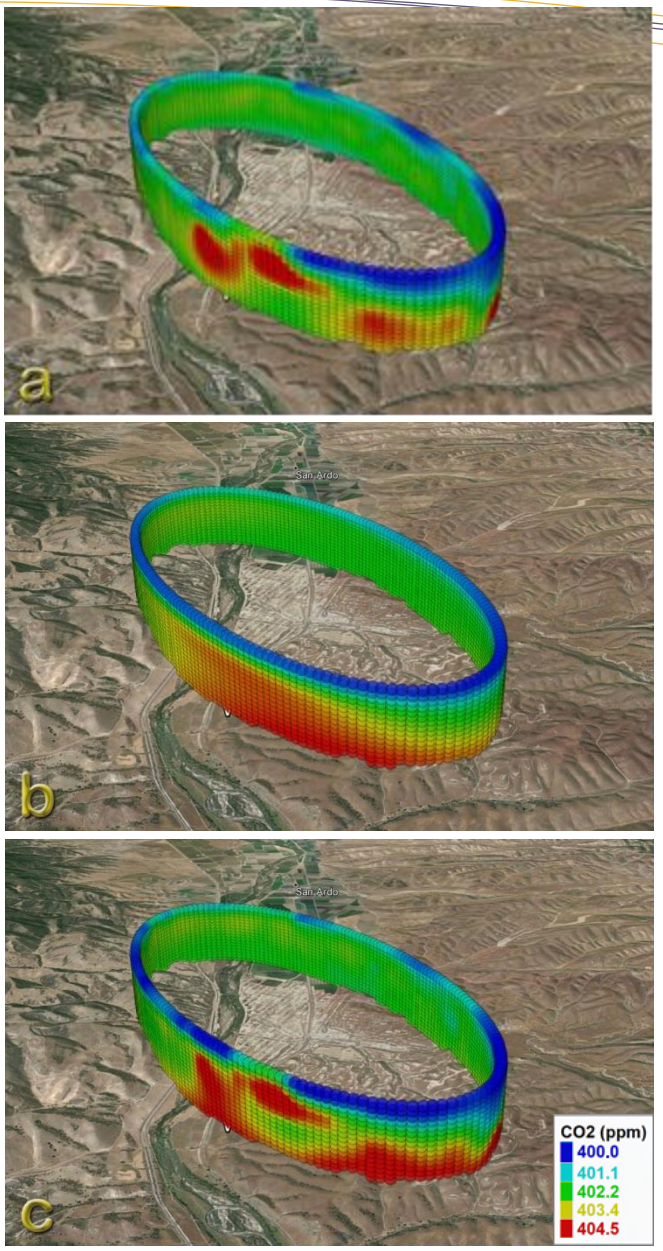


Process overview



Projection grid fitted into flight trajectory

- (a) Universal kriging,
- (b) Neural networks, and
- (c) Kriging with external drift using neural network outputs as covariates



Conclusion & Future work

Conclusion

- neural networks cannot compete with geostatistical tools specifically developed for geospatial analysis,
- incorporation of neural networks outputs as covariates in kriging schemes, can improve the overall accuracy despite the poorer separate neural network results

Future work

- Replacing backpropagation neural networks with deep learning networks
- Replacing measurement with Alphajet with smaller UAVs?

Thank you for attention!

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