1. **Introduction**
   1. **Research Motivation**
      1. Improving geophysical inversion by easy incorporation of a priori data into inversion regularisations
      2. Innovations and improvements upon Nick Williams’ thesis
         * + Maps (pixels versus shape files)  
             non-linearity of GUI
           + image analysis rather than only map polygons  
             cross section input
           + faults
           + ability to edit and QC data (geophysical, petrophysical, and geological) as you go through the inversion process
           + geological models
           + tools to help assign physical properties to geophysical units
           + clustering
           + voxel-parametric inversion
2. **Incorporation** **of prior information** 
   1. **Geology**
      1. **Plan-view map**Background: Geology map with colours -> voxel model constraints  
         New research:
         * + Can take a pixel map and discretize it into a voxel model
           + Assignment of geological unit to each pixel
           + Assignment of geological unit to each model cell
           + Determine topography (just on surface, extend to fixed depth, extend to variable depth below surface, extend to arbitrary surface)
           + Assignment of physical property and bounds to each geological unit to create constraints

Example: El Poma

* + 1. **Cross-section**Background: Geology cross section image with colours -> voxel model  
       New research:
       - * How to insert into 3D model -> 2D mesh to 3D mesh
         * Geo-rectify of 2D mesh onto 3D mesh
         * Geo-rectify of 2D image to view in 3D model

Example: TKC

* + 1. **Faults maps**Background: Lines for faults -> allows discontinuity of physical properties by inputting low spacial weights where a fault would imply a discontinuity  
       New research:
       - * Assuming piece-wise continuous faults, can iteratively create fault-systems and curving faults
         * Need to have “water tight” surface that is only one face thick regardless of mesh
         * can add dip information

Example: El Poma

* 1. **Discretization of point measurements** 
     1. **Borehole physical properties**Background information: bore hole point or interval data -> voxel model constraint  
        New research:
        + - Incorporation of Nick Williams’ tools for loading, and discretizing bore hole data
          - incorporation of bore hole data into GIFtools visualization and quality control tools
          - ability to edit data (e.g., add remanence to susceptibility bore holes)
          - incorporate Nick Williams’ tools for creating constraints from discretized bore hole data

Example: El Poma

* + 1. **Geology IDs**Background information: bore hole point or interval Geology data -> voxel model constraint  
       New research:
       - * Link petrophysical measurements to geological units in bore hole data

Example: TKC

* 1. **Multiple geophysical inversions**
     1. **Clustering**Background information: Create pseudo-geology model by clustering multiple inversion results
        + - Pseudo geology model is one that has geological units and can have physical properties for each unit but which is created from inversion results rather than a prioi information

New research:

* + - * + Tools that cluster several inversion results by multiple clustering algorithms (k-mean, FCM, user defined boundary)

Example: TKC

* + 1. **Creating a geology model**

Background information: Incorporate information from other inversions through clustered pseudo-geological model  
New research:

* + - * + Create constraints from pseudo-geological model (reference, bounds)
        + Create discontinuities between units (face weights based on gradient of geology model)

Example: TKC

**Putting it all together: parametric inversion**Background information: Once a geological interpretation is created through the methods above assigning property values to each unit is useful. Parametric inversion allows the setting of property values based the fit to geophysical data.  
New research:

* + - * + Define voxel-parametric inversion
        + Create synthetic models using voxel-parametric inversion
        + Improve constraints created with geological models by improving assignment of properties

Example: TKC and El Poma

1. **Application to El Poma**
   1. **Information provided**
      * + - Mag data set (ground mag)
          - Surface data susceptibility measurements
          - Surface sample oriented NRM measurement (including Koenigsburger ratio)
          - Bore hole susceptibility measurement
   2. **Create Synthetic model**
      * + - In absence of a geological interpretation the synthetic model is set as two blocks in a half space placed with reference to the magnetic anomaly. The blocks share a face with the faults.
          - Given the block geometry, an MVI voxel parametric inversion is used to assign properties and magnetization directions
          - Using the Koenigsburger ratios provided by the surface samples, determine a synthetic susceptibility of each block
   3. **Remanent magnetization recovery**
      1. Since the magnetization directions of the anomalies point in such different directions I will not forward model simple effective susceptibility models given the blocks in a half space
      2. **Blind**
         * + Invert mag data blind, assuming the inducing field direction
           + Show artifacts from poor assumption
           + Invert with MVIinv (use MVI result to determine new magnetization direction)
      3. **Blind with new direction**
         * + Repeat 3.3.2 with new magnetization direction
           + Show fewer artifacts
      4. **Constrained inversion (Only susceptibility)**
         * + Make reference model and bounds from bore hole data and the plan view map (using only the synthetic susceptibility results from 3.2)
           + Make face weights from faults
           + Apply to inversion
           + Show result, show that cells constrained by the map and bore holes are much lower than the surrounding cells
      5. **Constrained inversion (with true MVI result)**
         * + Make reference model and bounds from bore hole data and the plan view map (using the full magnetization vector recovered)
           + Make face weights from faults
           + Apply to inversion
           + Show result, show better recovery of the synthetic model
   4. **Field Example**
      * + - Use procedure shown in 3.3 (excluding 3.3.4) to recover El Poma anomaly
          - Discuss result (unfortunately we have no idea what the truth is)
2. **Application to TKC**
   1. **Information provided**
      * + - Mag data set (VTEM mag)
          - Gravity Gradiometry
          - Bore hole with geological units (PK,HK,VK)
          - Physical property measurements from bore hole samples, categorised by geological unit (susceptibility, un-oriented NRM, Koenigsburger ratio, saturated density, grain density)
          - Cross section maps interpreted from bore hole data
   2. **Create Synthetic Model**
      1. Point cloud created from borehole data -> voxel model with geological units
      2. given geological model, assign properties with voxel-parametric inversion (MVI for mag, density for grav)
   3. **Recovery Without Remanence recovery**
      1. Forward model mag synthetic model using MAGfor3D using effective susceptibility results from the MVI voxel-parametric inversion
      2. **blind**
         * + Invert mag and grav data blind
           + Show clustered result, show less than ideal fit to synthetic true model
      3. **Constrained inversion**
         * + Make reference model and bounds from subsets of bore hole data and the cross section maps
           + Apply to inversion
           + Show clustered result, show better recovery of synthetic model
      4. **Cooperative inversion**
         * + Use constrained clustered results as a further constraint (reference, bounds, face weights)
           + Show new iterated clustered results
   4. **Recovery With Remanence** 
      1. Forward model mag synthetic model using MVIfwd using magnetization vector, change the direction of the HK unit to be very different from geomagnetic field direction
      2. **Blind**
         * + Invert mag data blind (assuming inducing field direction) with MAGinv3D. show artifacts from poor assumption
           + Show new clustered result (with grav result from 3.3.2)
           + Invert with MVIinv, showing fewer artifacts (use MVI result to determine new magnetization direction)
      3. **Blind with new direction**
         * + Repeat 3.4.2 with new magnetization direction
           + Show fewer artifacts
      4. **Constrained inversion**
         * + Repeat 3.3.3 with new direction
           + Show better fit of clustered result to synthetic model
      5. **Cooperative inversion**
         * + Using constrained clustered model, perform MVI voxel parametric inversion to determine a final magnetization direction
           + Use constrained clustered model results as a further constraint (reference, bounds, face weights) in addition to new anomaly direction
           + Show final result
   5. **Field Example**
      * + - Use procedure shown in 3.4 to recover the anomaly from the TKC field example.
          - Show fit of recovered clustered model to geological units
3. **Appendix A: Application of research to industry**
   1. **Visualization**
      1. Show tools to visualize data and models as shown in the Thesis
   2. **User experience**
      1. Show tools and procedures to create the constraints shown in the thesis
         * + Maps
           + Faults
           + Bore hole data
           + Clustering