Instructions to run the SP solver

The code has two main folders: i) PARENT folder and ii) LGR folder. If the model we are solving has LGRs, the solution need to be carried in two steps using both folders. On the other hand, if there are no LGRs in the model, the PARENT folder is used only.

A) Instructions to run the PARENT folder:

1. Copy the output files from the dynamic modelling to the folder. Make sure that the output files are formatted.
2. In order to run the solver, we need to input and modify some parameters in the **TIME\_LOOP\_COARSE** script and the *SP\_FUNCTION\_COARSE* function as follow
   1. **TIME\_LOOP\_COARSE** script
      1. Vector v: time steps at with the solution need to be performed
      2. DX, DY, DZ: grid size, numbers of cells in x, y, and z.
   2. *SP\_FUNCTION\_COARSE* function
      1. GRID FILES section: this section reads the grid files section to define the x, y and z coordinates and the active/non-active grid cells. Things to consider:
         1. Use the correct file name. The file name is the one output files copied to the PARENT folder.
         2. The format used is compatible with ECLIPSE output files. These lines can be modified if we are using another software that may have different setup for its output files.
         3. the dimensions need to converted to SI units. The code consider converting the dimension units from ft to m. This can be modified if required.
      2. F FILES section: this section reads the output files section to define the dynamic properties (saturation, water potential, salinity and temperature). Things to consider:
         1. Use the correct file name. The file name is the one output files copied to the PARENT folder.
         2. The format used is compatible with ECLIPSE output files. These lines can be modified if we are using another software that may have different setup for its output files.
         3. In case of constant temperature or constant salinity, the temperature and salinity lines could be replaced with simple lines representing a DY by DX by DZ matrices of constant value.
      3. POROSITY AND SATURATION REGIONS AND FINAL DEFINITION OF VARIABLES section: this section reads the porosity and the saturation regions and convert the units of the dynamic properties to SI units. Things to consider:
         1. We used two vectors: porosity vector and SATNUM vector (for saturation regions). These two vectors are exported from the INIT file from ECLIPSE. These lines can be adjusted to read the two parameters using different approaches.
         2. The dynamic properties need to converted to SI units (Pressure, Pa; Salinity, M/L; Temperature, K).
      4. BOUNDARIES section: this section is used to identify the changes in boundary cells in case of the faults. If there is no faults in the system, deactivate this section. Things to consider if the section is active:
         1. If shale layers were added beyond the reservoir domain, we should manually edit the **boundarycon\_Ex**, **boundarycon\_Ey**, **boundarycon\_Wx**, **boundarycon\_Wy** scripts by entering the correct shale layers in all the directions.
      5. SHALE LAYERS section: in this section, shale layers are added around the reservoir model. Adjustment to the dynamic properties and xyz coordinates according to that. Things to consider:
         1. Two cases are included; CASE A and B. CASE A considers adding shale layers above and below the reservoir, while CASE B considers adding the shale in all the directions.
         2. Proper dynamic properties, porosity values should be assigned to the added shale layers. We considered the initial values for dynamic properties.
         3. The coordinates of the shale layers (x, y, and z) are accounted, but can be modified if required.
      6. ELECTRICAL PROPERTIES section: this section calculates the main electrical properties required for the SP solution (coupling terms, coupling coefficients, and conductivities). Things to consider:
         1. Irreducible water saturation and residual oil saturation need to be defined.
         2. The correlations used for the coupling coefficients and rock and water conductivity are the ones that we recommend, but they can be modified if other models are preferred.
         3. We assumed a zero EK coupling terms and an exclusion efficiency of 0.4 for the surrounding shales. Dimensions should be matching with selected shale case (CASE A or B).
      7. SP SOLUTION section: in this section we solve A\*Uek=B\*P, A\*Uec=C\*log(Cf), and A\*Ute=D\*T for Uek, Uec and Ute, respectively. Things to consider:
         1. In case of no faults, it is required to run 4 scripts (**SP\_SIGMA\_3D**, **SP\_Lek\_3D\_JIA\_forcedzero**, **SP\_Lec\_3D\_JIA\_HIGH\_CF**, **SP\_Lte\_3D\_JIA**) to generate A, B, C and D. the lines that are related to the NNC need to be kept deactivated.
         2. If the reservoir model has faults, we need to deactivate the 4 scripts mentioned in section 2.2.7.1 and alternatively activate the following scripts: **SP\_FAULT\_SIGMA\_3D**, **SP\_FAULT\_Lek\_3D\_JIA\_forcedzero**, **SP\_FAULT\_Lec\_3D\_JIA\_HIGH\_CF** and **SP\_FAULT\_Lte\_3D\_JIA.** Also we need to activate the lines under NNC LIST and NNC adjusting sections.
      8. NNC LIST and NNC adjusting sections: these sections are required to identify NNC and adjust the matrices A, B, C and D based on that. we need to consider manually edit the **Extenting\_the\_coordinates\_shale** script by entering the correct shale layers in all the directions (similar to section 2.2.4.1). this section in activated only if we are dealing with faults.
      9. Note: the resulted Uek, Uec, and Ute are in Volts. Required conversion to mV can be done separately.
3. Results processing and plotting functions:
   1. Referencing: The Uek, Uec and Ute results should be reference to the potential a selected location (usually the top of the well). The **referencing** script is used for that purpose. The input for that script are the x and y location (grid wise) and the time steps. The outputs from the script the referenced potentials (Uekw, Uecw, Utew) and the overall SP.
   2. Horizontal Profile. The **HOR\_SECTION** script can be used to generate horizontal profiles of the electrical potentials and the dynamic properties as a function of lateral location. The input for that script are the x and y location (grid wise), time steps and the z-layer at which we need to plot the profile. Consider selecting the right property, the right axis (x or y).
   3. Vertical Profile. The **VER\_SECTION** script can be used to generate horizontal profiles of the electrical potentials and the dynamic properties as a function depth across the well. The input for that script are the x and y location (grid wise), time steps. Consider selecting the right property.

B) Instructions to run the LGR folder:

1. Copy the output files from the dynamic modelling to the folder. Make sure that the output files are formatted.
2. In order to run the solver, we need to input and modify some parameters in the **TIME\_LOOP\_LGR** script and the *SP\_FUNCTION\_LGR* function as follow
   1. **TIME\_LOOP\_LGR** script
      1. Vector v: time steps at with the solution need to be performed
      2. DXC, DYC, DZC: grid size of the LGR, numbers of cells in x, y, and z.
      3. DX, DY, DZ: grid size of the parent model (without the additional shale), numbers of cells in x, y, and z.
      4. DX3D, DY3D, DZ3D: grid size of the parent model (with the additional shale), numbers of cells in x, y, and z.
   2. *SP\_FUNCTION\_LGR* function
      1. GRID FILES section: this section reads the grid files section to define the x, y and z coordinates, the active/non-active grid cells and the host cells. Things to consider:
         1. Use the correct file name. The file name is the one output files copied to the LGR folder.
         2. The format used is compatible with ECLIPSE output files. These lines can be modified if we are using another software that may have different setup for its output files.
         3. the dimensions need to converted to SI units. The code consider converting the dimension units from ft to m. This can be modified if required.
      2. F FILES section: this section reads the output files section to define the dynamic properties (saturation, water potential, salinity and temperature). Things to consider:
         1. Use the correct file name. The file name is the one output files copied to the PARENT folder.
         2. The format used is compatible with ECLIPSE output files. These lines can be modified if we are using another software that may have different setup for its output files.
         3. In case of constant temperature or constant salinity, the temperature and salinity lines could be replaced with simple lines representing a DY by DX by DZ matrices of constant value.
         4. The dynamic properties need to converted to SI units (Pressure, Pa; Salinity, M/L; Temperature, K).
      3. POROSITY AND SATURATION REGIONS section: this section defines the porosity and the saturation regions for the LGR. Things to consider:
         1. Porosity and SATNUM for each grid cell in the LGR is defined based on the porosity and SATNUM value of the host parent cell.
      4. ELECTRICAL PROPERTIES section: this section calculates the main electrical properties required for the SP solution (coupling terms, coupling coefficients, and conductivities). Things to consider:
         1. Irreducible water saturation and residual oil saturation need to be defined.
         2. The correlations used for the coupling coefficients and rock and water conductivity are the ones that we recommend, but they can be modified if other models are preferred.
      5. SP SOLUTION section: in this section we solve A\*Uek=B\*P+STUp-STUek, A\*Uec=C\*log(Cf) +STUsalt-STUec, and A\*Ute=D\*T+STUtemp-STUte for Uek, Uec and Ute, respectively. LGRs do not cross any faults. The scripts used in this section are mainly to define the matrices: A, B, C, D, STUp, STUsalt, STUtemp, STUek, STUec and STUte.
      6. Note: the resulted Uek, Uec, and Ute are in Volts. Required conversion to mV can be done separately.
3. Results processing and plotting functions:
   1. Overall SP. The **SP\_LOCAL** script add the Uekc, Uecc and Utec resulted from the *SP\_FUNCTIO\_LGR* to obtain the overall SP. The input for this script is the time steps.
   2. Horizontal Profile. The **HOR\_SECTION** script can be used to generate horizontal profiles of the electrical potentials and the dynamic properties as a function of lateral location across the LGR. The input for that script are the x and y location (LGR grid wise), time steps and the z-layer (from LGR) at which we need to plot the profile. Consider selecting the right property, the right axis (x or y).
   3. Vertical Profile. The **VER\_SECTION** script can be used to generate horizontal profiles of the electrical potentials and the dynamic properties as a function depth across the well. The input for that script are the x and y location (LGR grid wise), time steps. Consider selecting the right property.
   4. Tables of the Overall SP and its three components as a function of time across well layers. In order to generate this table, **Combined\_profile\_at\_well\_SP** script is used. This inputs for this script are time steps and x and y location (LGR grid wise).