PRINCIPLES FOR CONVENTIONAL CONTRIBUTIONS TO MODELED STATION DISPLACEMENTS

- Guiding principles for IERS Conventions models
- Selection criteria for displacement contributions
- Recommended revisions for Conventions Chapter 4 (ITRF)
- Handling of non-tidal displacements

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Issue & Objective

- **IERS model for station positions**
  - instantaneous positions differ from regularized positions by:

$$X(t) = X_R(t) + \sum \Delta X_i(t)$$

    where $\Delta X_i(t)$ are "regularization corrections" to remove mostly high-frequency (geophysical) variations
  - idea is to simplify time evolution of $X_R(t)$ by removing known effects

- **Question: which effects to include as corrections $\Delta X_i(t)$?**
  - current IERS Conventions not complete or fully self-consistent

- **Objective: provide set of "principles" for selection process**
  - aim for rational set of guidelines
  - but must also consider historical context

Proposed Classification of IERS Models

- **Class 1 – "reduction"**
  - used *a priori* in data reductions to derive geodetic estimates
  - ideally, models not adjusted in reductions
  - must be highly accurate, errors < ~1 mm
  - geophysically based & as independent of space geodesy as possible
  - inter-solution consistency important for combinations
  - e.g., solid Earth tide model

- **Class 2 – "conventional"**
  - to remove an observational singularity or is purely conventional
  - choice is effectively arbitrary
  - e.g., ITRF rotational datum (NNR w.r.t. crust)

- **Class 3 – "useful"**
  - helpful to interpret data, but not required as Class 1 or 2
  - should *not* be embedded in exchanged results
  - e.g., zonal UT1/LOD models

Proposed Scope of IERS Conventions

- **Class 1 – "reduction"**
  - **provide complete & consistent set of highly accurate models**
  - **provide implementing software & test data sets**
- **Class 2 – "conventional"**
  - **provide unique set without ambiguities**
  - **but only where necessary**
  - **choices guided by Union resolutions & historic practice**
- **Class 3 – "useful"**
  - **include those whose use is likely to be sufficiently common**
  - **or to minimize user confusion**

Conventional Model for ITRF Positions

- **Chapter 4, eqn 11**
  - general model to relate instantaneous *a priori* position, X(t), on Earth's surface at epoch t to regularized position $X_R(t)$ is:

$$X(t) = X_R(t) + \sum \Delta X_i(t)$$

    where $\Delta X_i(t)$ are "regularization corrections" to remove mostly high-frequency (geophysical) variations
  - idea is to simplify time evolution of $X_R(t)$

- **Current model for $X_R(t)$ is linear**

$$X_R(t) = X_0 + V * (t - t_0)$$

  - set of values $\{X_0, V\}$ for global set of stations constitutes a specific TRF realization, at reference epoch t_0

- **Which "regularization corrections" to include in $\Delta X_i(t)$?**

Proposed Criteria for Displacement Models

- **Guiding principles**
  - include only Class 1 ("reduction") models, plus any technique-specific effects
  - selection of regularization corrections should be rational process
  - included effects should not be chosen randomly or haphazardly
  - but consistency with historic practice often wise to avoid confusion

- **Specific criteria**
  - include complete daily & sub-daily tidal variations
  - model corrections must be accurate, errors < obs errors
  - models must be as independent of geodetic data as possible
  - prefer models in closed-form expressions for ease of use
  - try to maintain flexibility to evaluate different models easily *a posteriori* when accuracy is questionable

Recommendations for Revised Chapter 4

- **Keep current eqn 11 & linear model for $X_R(t)$**
- **Retain 2003 models for $\Delta X_i(t)$ corrections, including periods > daily for consistency with past:**
  - **solid Earth (body) tide (no change)**
  - **ocean tidal loading (text clarified)**
  - **solid Earth pole tide (no change)**
- **Add new models:**
  - **ocean pole tide loading (recent update), including long periods**
  - **S1/S2 atmospheric pressure tidal loading (under evaluation)**
- **Geocenter motions**
  - **compensating motions of solid Earth due to tidal variations of fluid loads *should be included* in site displacements (explicit clarification)**

Recommendations for Chapter 4 (cont'd)

- **Technique-dependent corrections**
  - **may be included by Technique Services**
  - **can cause position-like displacements**
  - **but models need not be given explicitly in IERS Conventions**
  - **care must be taken for effects on local ties, for instance**

- **Non-tidal displacements *should not be included***
  - **do not satisfy selection criteria**
  - **therefore, should be excluded from operational reductions**
  - **but research tests are encouraged**
  - **some specific objections & issues follow next . . .**

Non-Tidal Displacements Fail Criteria

- **Reliability not adequate in sub-daily band**
  - need fully self-consistent treatment of “dynamic barometer”
  - IB & non-IB approximations not adequate for <fortnightly periods
- **Accuracy of fluid models not well demonstrated**
  - studies of accuracy & comparisons lacking
  - combined product series should be investigated for improved accuracy & ease of use
- **Tidal effects must be cleanly removed**
  - tides treated separately
  - all treatments must be self-consistent
- **Long-term biases in ITRF must be avoided**
  - mass conservation often not enforced in fluid models
  - could lead to secular drifts in ITRF

Non-Tidal Displacements Failures (cont'd)

- **Would force new ITRF datum requirements**
  - **reference positions would depend on reference pressure field**
  - **might require average long-term pressure for every point**

- **Not easy to test alternative models**
  - **better to test non-tidal loadings *a posteriori***
  - **assumes net non-tidal loads not significant over geodetic integration intervals (usually, 1 d to 1 week)**
  - **but, need rigorous methods to compute daily/weekly averages**

Non-Tidal Displacements Recommendations

- **GGFC to provide validated Class 3 load displacement models**
  - validated "operational" IERS models should appear at 1st level of GGFC bureaux
    - other "research" models should appear elsewhere
  - must provide model data fields, documentation, & software
  - provide accuracy assessments
    - consider errors in raw fluid fields
    - also errors in modelling, etc
  - suggest issues be studied better & evaluated in near future

- **IERS Conventions changes**
  - expand Chapter 7 to discuss use of non-tidal models as Class 3 type

Study Non-Tidal Effects in ITRF

- **Rather than apply non-tidal corrections in data reductions, test *a posteriori* effects in ITRF combination**
  - **try non-tidal corrections in stacking of technique frames**
  - **would be more important for techniques with sparse or non-continuous observing (i.e., VLBI, SLR)**

- **Instead of simple Helmert stacking of raw frames, try:**

$$\text{Helmert}\{\ XYZ_k(x,t) - \text{Load}(x,t)\ \} \rightarrow TRF_k(x,v)$$

  - **effect of loads on long-term inter-site positions probably minor if loads average close to zero**
  - **but time-varying network effects for different techniques could be mitigated**
  - **interpretation of EOPs & Helmert parameters would be affected since load effects would be nominally removed**

- **Requires careful testing & evaluation**
  - **must be esp concerned with long-term stability of frame**

Summary of Recommendations

- **Revise IERS Conventions Introduction**
  - define classes of models explicitly & specify scope
  - give criteria for selection of site displacement models
- **Revise IERS Conventions Chapter 4**
  - proposed text given in Position Paper
- **Handling of non-tidal displacements**
  - do not include as conventional site model contributions
  - expand Chapter 7 to discuss effects as Class 3 type
  - refocus GGFC activities to address questions raised here
- **Study non-tidal displacements in ITRF combination**
  - evaluate *a posteriori* corrections in frame stacking
  - determine if network effects can be mitigated
  - take great care with datum & interpretation issues