

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:

$$\mathbf{X}(t) = \mathbf{X}_R(t) + \sum \Delta \mathbf{X}_i(t)$$

where $\Delta \mathbf{X}_i(t)$ are “regularization corrections” to remove mostly high-frequency (geophysical) variations

- idea is to simplify time evolution of $\mathbf{X}_R(t)$ by removing known effects

- **Question: which effects to include as corrections $\Delta \mathbf{X}_i(t)$?**

- 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 $< \sim 1$ 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:**
$$\text{Helmert}\{ \text{XYZ}_k(\mathbf{x},t) - \text{Load}(\mathbf{x},t) \} \rightarrow \text{TRF}_k(\mathbf{x},v)$$
 - 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