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**

Issue & Objective

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

$$X(t) = XR(t) + \sum \Delta Xi(t)$$

where ΔXi(t) are "regularization corrections" to remove mostly high-frequency (geophysical) variations

  - **idea is to simplify time evolution of XR(t) by removing known effects**

- **Question: which effects to include as corrections ΔXi(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 XR(t) is:**

$$X(t) = XR(t) + \sum \Delta Xi(t)$$

where ΔXi(t) are "regularization corrections" to remove mostly high-frequency (geophysical) variations

  - **idea is to simplify time evolution of XR(t)**

- **Current model for XR(t) is linear**

$$XR(t) = X0 + V * (t - t0)$$

  - **set of values {X0, V} for global set of stations constitutes a specific TRF realization, at reference epoch t0**

- **Which "regularization corrections" to include in ΔXi(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 XR(t)**
- **Retain 2003 models for ΔXi(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:**

  Helmert{ XYZk(x,t) – Load(x,t) } TRFk(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**