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The OAT Software and the Experimental Open Loop Processing of CHAMP and SAC-C Data

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The OAT set of software tools was developed at IEEC to process radio occultation data. We are presenting an extension that was prepared in order to process these data in open loop mode. The rationale of the inversion algorithm will be presented, as well as an outlook of its performance. A test workbench was perpared to test these tools in a large scale. Thus over one year of CHAMP and SAC-C data were processed in order to verify the robustness and requirements of the system. The system is still running in the processing of new data being produced by both platforms.

The OAT Open Loop software

Josep M. Aparicio

with the cooperation of members of the IEEC team

A bit of History

- OAT (Occultation Analysis Tools) development began early 1999, in F90
- OO capabilities are key to flexible & rapid development
- Reengineered as C++ in 2002 to better benefit from OO
- The idea, in general:
  - Large library of tools (s/r, classes, functions…)
  - Specific programs are small and focused

Open & closed loop

- Closed loop can be based upon geometrical or wave optics
- Open loop has to interpret the complex phasor (requires wave optics)
- Does the phasor represent the EM field?
- Strictly OL is defined only by opposition:
  - Any algorithm that is not an on-board PLL
- Within OAT: An algorithm that does not try to take advantage from an on-board PLL

The Objective

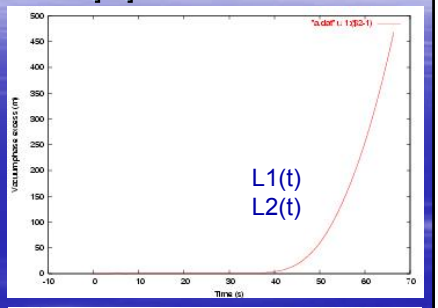
- We do not need Radio Occultation to measure the climate (we already know)
- In any measure we distinguish:
  - Climate
  - Meteorological signal
    - NWP (i.e. already known)
    - Unknown

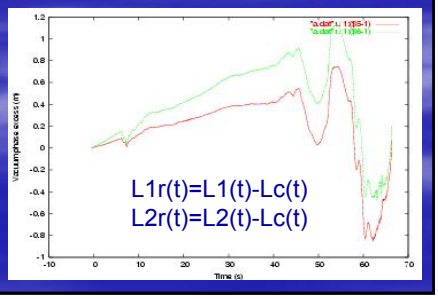
Some ideas for OAT OL

- Based on processing the mismatch observation vs a fwd model
- FWD: Given orbits of GNSS & LEO→L(t), etc
- FWD could be based on
  - Vacuum (trivial, already factored)
  - Climate (can be stand alone)
  - NWP
    - Accurate
    - similar to 3DVar
    - introduces dependence wrt specific NWP
    - risk of nonconvergence
    - too expensive within a 3DVar
    - affordable as preprocessing

Chosen OAT OL approach

- Mismatch Observation vs FWD(Climate)
- Identifies well over 90% of signal (and its Doppler)
  - Excess wrt vacuum: up to ~1km
  - Excess wrt climate: few meters
- New L1(t), L2(t) to analyze
- New phases have much smaller dynamic behavior (i.e. less bandwidth)
- Not limited to PLL phases
  - Aexp(iφ)→ Aexp(iφ-2πLc/λ)





OAT Inversion

- FWD Climate: Lc(t)
- Reduced excess phases L1r(t), L2r(t)
  - Mismatch very small
  - Non-PLL Phasors can also be counterrotated
- Interpreted linearly with a thin screen (TS)
  - TS is a too coarse method upon L1(t), L2(t)
  - Appropriate for the residual
- Backpropagation to TS
- Abel inversion of TS

OAT Inversion II

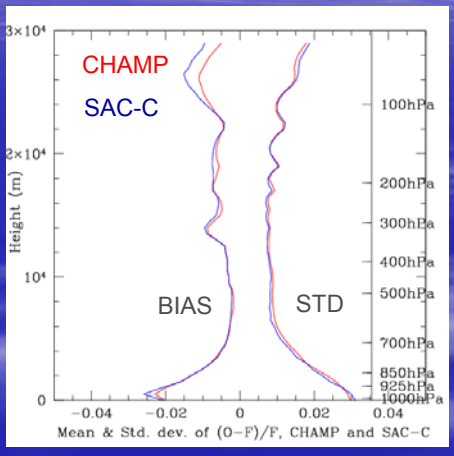
- FWD, given N(h), records
  - Tangent point height (≡ h)
  - L(t), dL/dh(t), $d^2L/dh^2(t)$ → Beam shape, Wave optics
  - Emission, reception bending
  - Reflection, $L_R(t)$ …
- These parameters used to backpropagate
  - Backpropagation not over straight lines, but we have the (non-straight) geometry
- Thin screen captures all residuals (***not all atmosphere!***)

FWD & BWD Model Analysis

- A number of tests have been performed to check the basis of FWD/BWD
- Comparisons with NWP, Radio sondes
- NWP: GEM (Canada)
- Discrepancies can be caused by
  - Physics of observation
  - Interpretation/inversion of observation
  - NWP model
- But useful to focus attention on specific areas

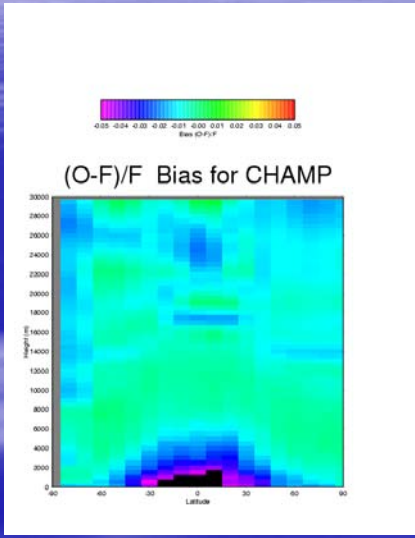
Bias Obs-Short Forecast I

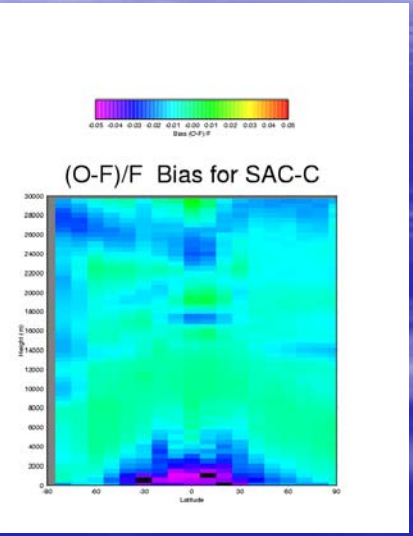
- Comparison of refractivity
- CHAMP and SAC-C data statistically very similar
- Receiver bias?
- Or systematic interpretation error?



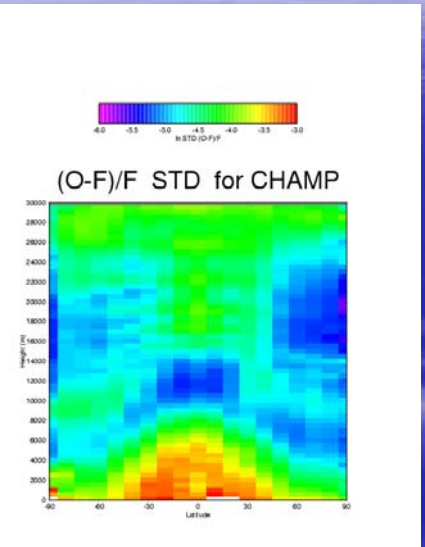
6-month stats (2004/01-06)

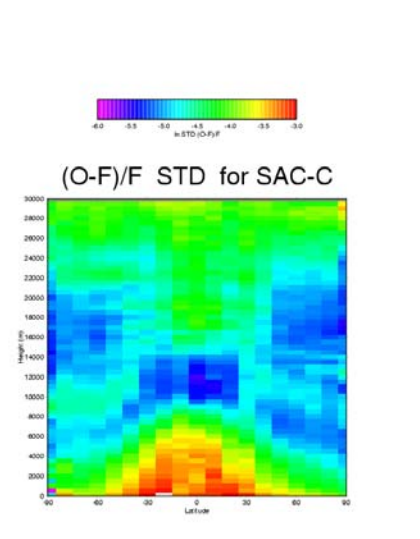
Bias Obs-Short Forecast II



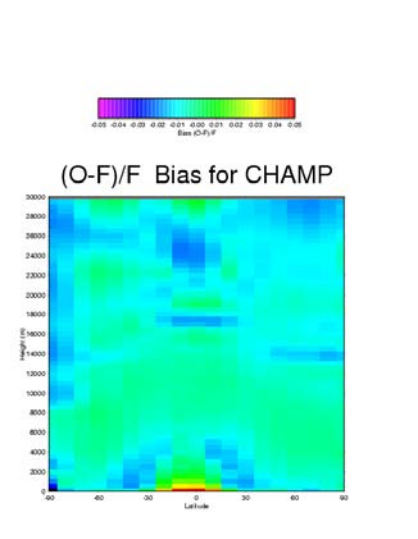


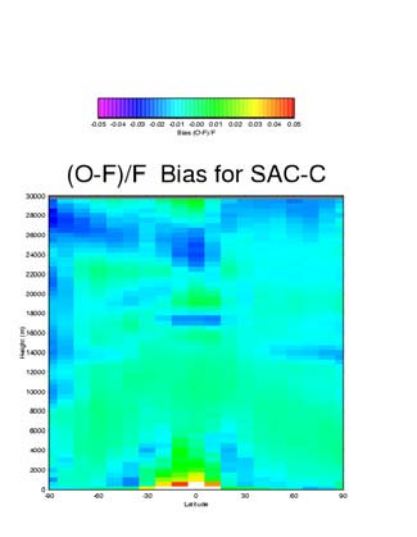
Obs-Forecast III





Obs-Short Forecast IV





Conclusion

- An OL algorithm was developed
- A number of aspects tested
  - NRT ability, stability, …
  - Scale of test: months of data and NRT
  - Accuracy/interpretation of FWD/BWD operators
  - Checked also against RS & NWP
- CPU use currently rather high, but many details believed inefficient & could be improved in a production implementation.