KOKEE12M-KOKEE20M VLBI Tie and Mixed-mode Processing

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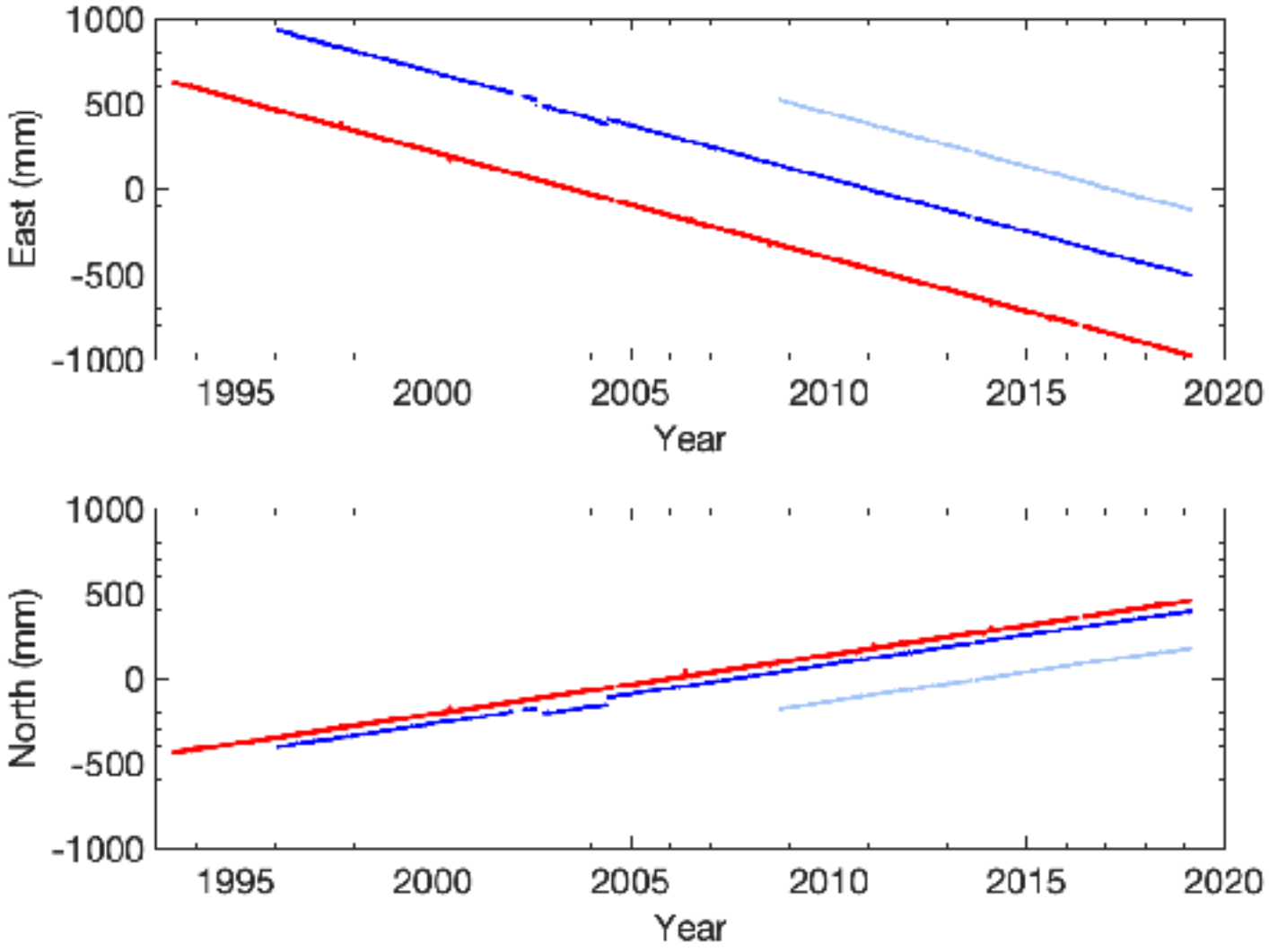
Improving the ITRF

- VGOS network is expected to be more accurate than current legacy SX network
- Incorporation of the VGOS antennas in the existing reference frame is crucial
  - Benefit from long history of legacy observations
  - Improve the TRF accuracy and enable continuity.

KPGO GPS and VLBI histories



Strategies for linking VGOS and legacy

- Include in a legacy session those VGOS antennas that are capable of S-band reception
  - Obtain the positions of the VGOS antennas directly in the legacy frame
  - Improve the legacy networks by including more sites for each session
- Tie VGOS and legacy antennas at the same site with VLBI
  - Provides much more accurate position of the VGOS antenna in fewer sessions

Kokee Ties observations

- Kokee12m-Kokee20m
  - Four sessions in 2016 March (45 min to 22.5 hours)
  - 12m and 20m as scheduled antennas
  - Westford and/or GGAO tagged along
  - Phase cal turned off at 20m
  - Cable delay applied for both antennas
  - Required mixed-mode correlation and processing
    (same as will be used for R1/R4)

Kokee Ties analysis

- Geodetic solution with *nuSolve 0.6.4*
  - X-band only
  - 20m as reference station
  - Estimate the 12m position
  - Estimate the 12m clock as 30 min PWL segments
  - No atmosphere parameters estimated (L = 31m)
  - Both group and phase delay solutions obtained
- Compare to optical survey made by NGS

Group vs phase delay

Observing frequency: $\nu \approx 8$ GHz

RMS bandwidth: $\Delta\nu \approx 0.25$ GHz

Group delay error per scan $\propto 1/\Delta\nu$

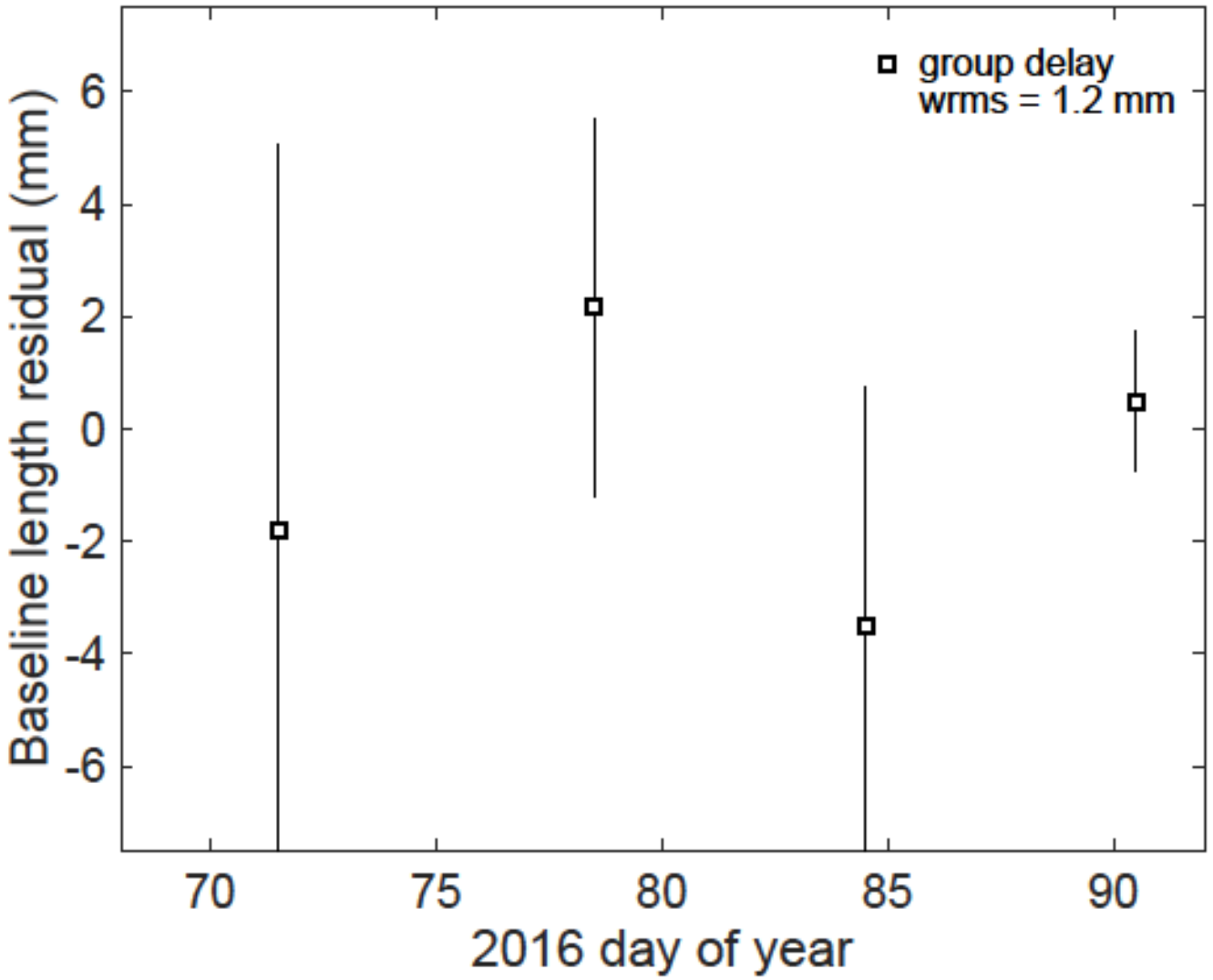
Phase delay error per scan $\propto 1/\nu$

So $\sigma(\text{phase}) \approx \sigma(\text{group})/30$

before additive noise is included, then

$\sigma(\text{phase}) \approx \sigma(\text{group})/3$

Repeatability



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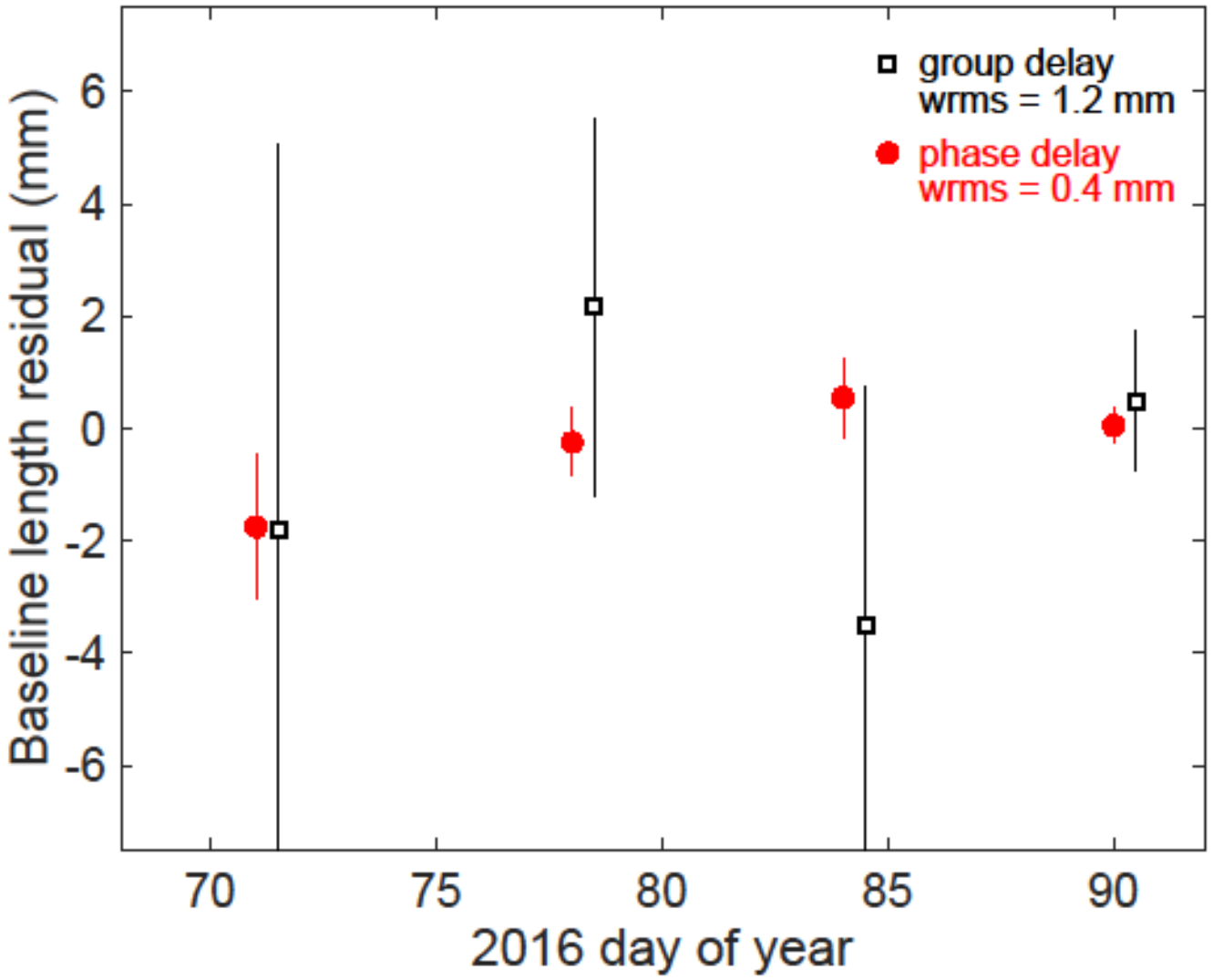

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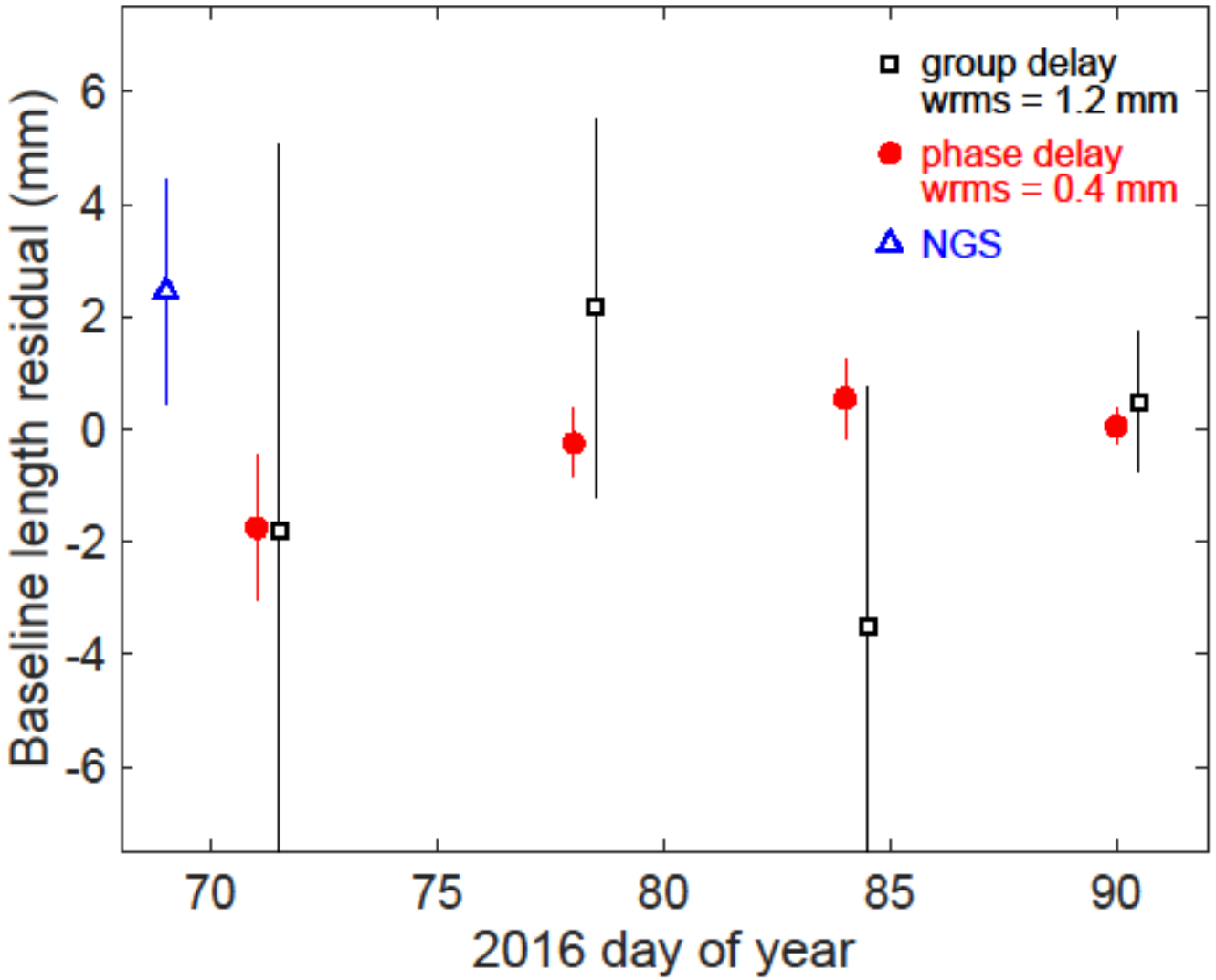
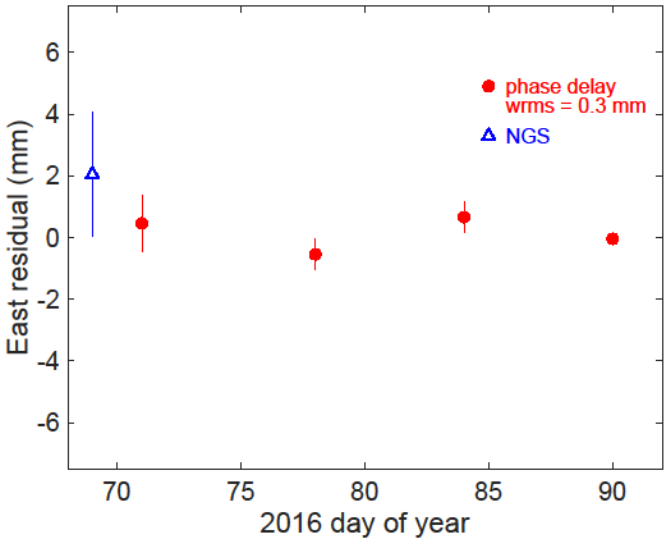
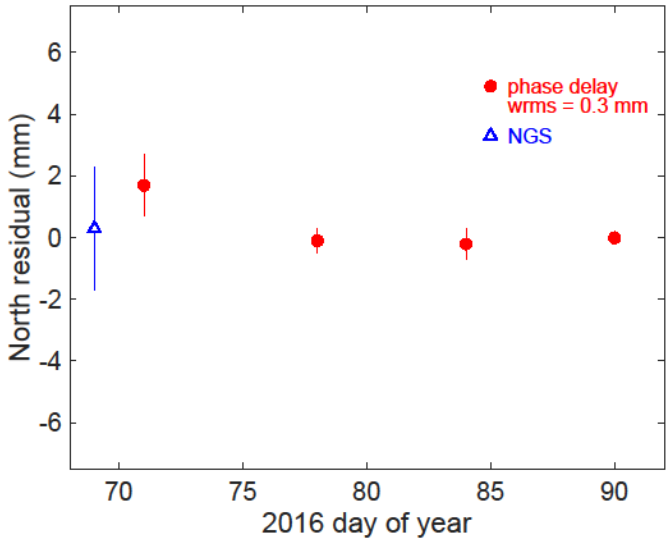
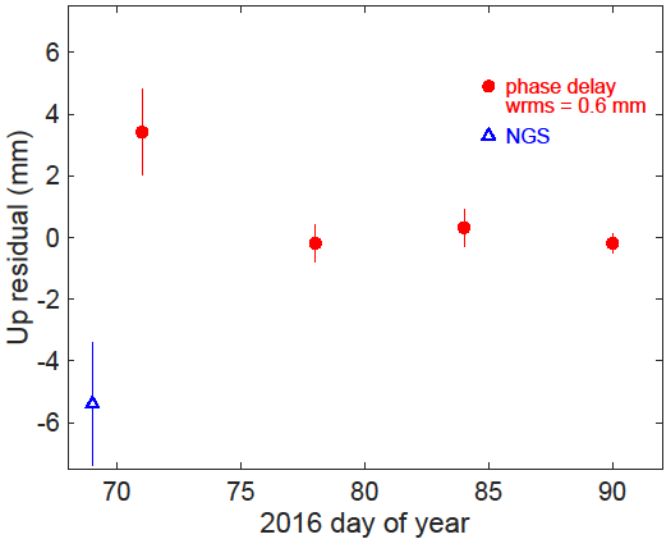
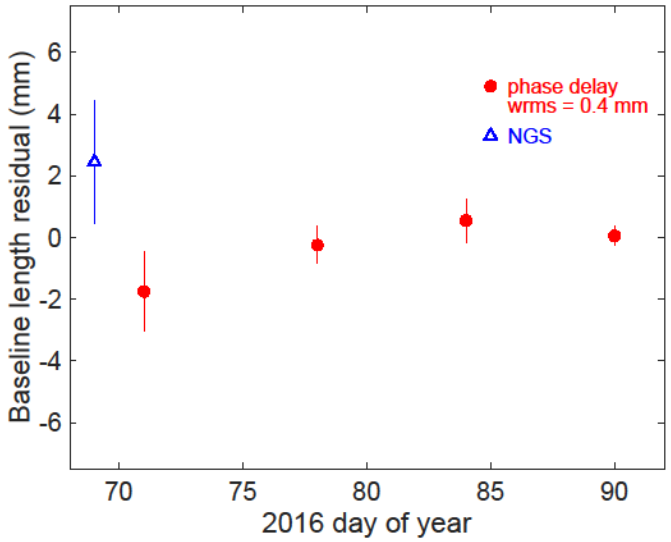


Repeatability









Future Kokee Ties Observations

- Local 12m-20m VLBI sessions
  - Receiver-box change is planned for the 20m that will allow broadband installation
  - Do additional VLBI tie sessions before and after box change
- Global S/X sessions
  - Verify and refine observing and correlation procedures
  - Include VGOS antennas in S/X sessions

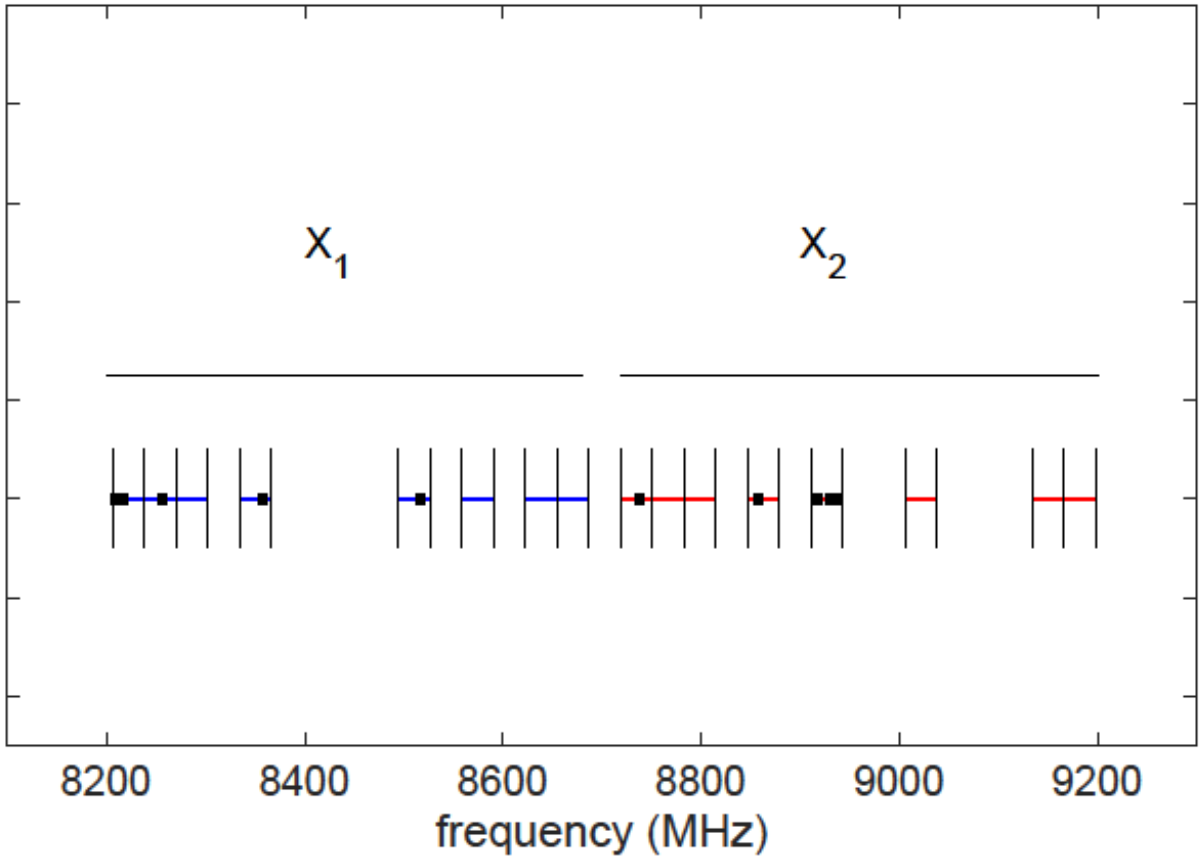
Next actions

- Refine the analysis of the initial Kokee Ties sessions
- Complete the processing of RD1810
  - included GGAO12M, KOKEE12M, and WESTFORD as VGOS antennas
  - plus 6 legacy antennas
- Verify the processing procedures for mixed-mode sessions
- Schedule the next four Kokee Tie sessions

Mixed-mode observing

- Same-session observations with both S/X and broadband (VGOS) systems
- Frequencies
  - Global sessions
    - All antennas observe S/X
    - VGOS antennas may include another band
      - e.g. S/C/X_1/X_2
  - Local tie sessions
    - Utilize X-band only

Frequencies for mixed-mode: X-band



Summary

- Incorporation of the VGOS antennas in the existing reference frame is crucial for improving the TRF accuracy and for enabling continuity
- Have measured the vector between the colocated KPGO VGOS and legacy antennas with a repeatability of <1mm in all components
- Procedures for mixed-mode observing and correlation are being developed and documented

Thank you.

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Kokee12m and Kokee20m

Global session considerations

- The number of scans per hour will be limited by slow speed of the legacy antennas so global sessions will not achieve the temporal density of a VGOS-only session.
- Sensitivity at X-band may not be a problem for VGOS antennas, but may be at S-band due to RFI.
- Some VGOS stations will not be usable for global ties due to having a 3-GHz lower frequency cutoff.

Local ties considerations

- Proximity of the antennas potentially allows excellent full-sky coverage, but one antenna may shadow the other
- Proximity of the antennas means ionosphere difference may be negligible; if so, use X-band only
- Phasecal signals must be made non-interfering*
  - Turn phasecal off for one antenna

    or
  - Offset the reference frequency for one antenna
- Local RFI is common to all antennas at the site*

* Use frequency notching in fourfit?

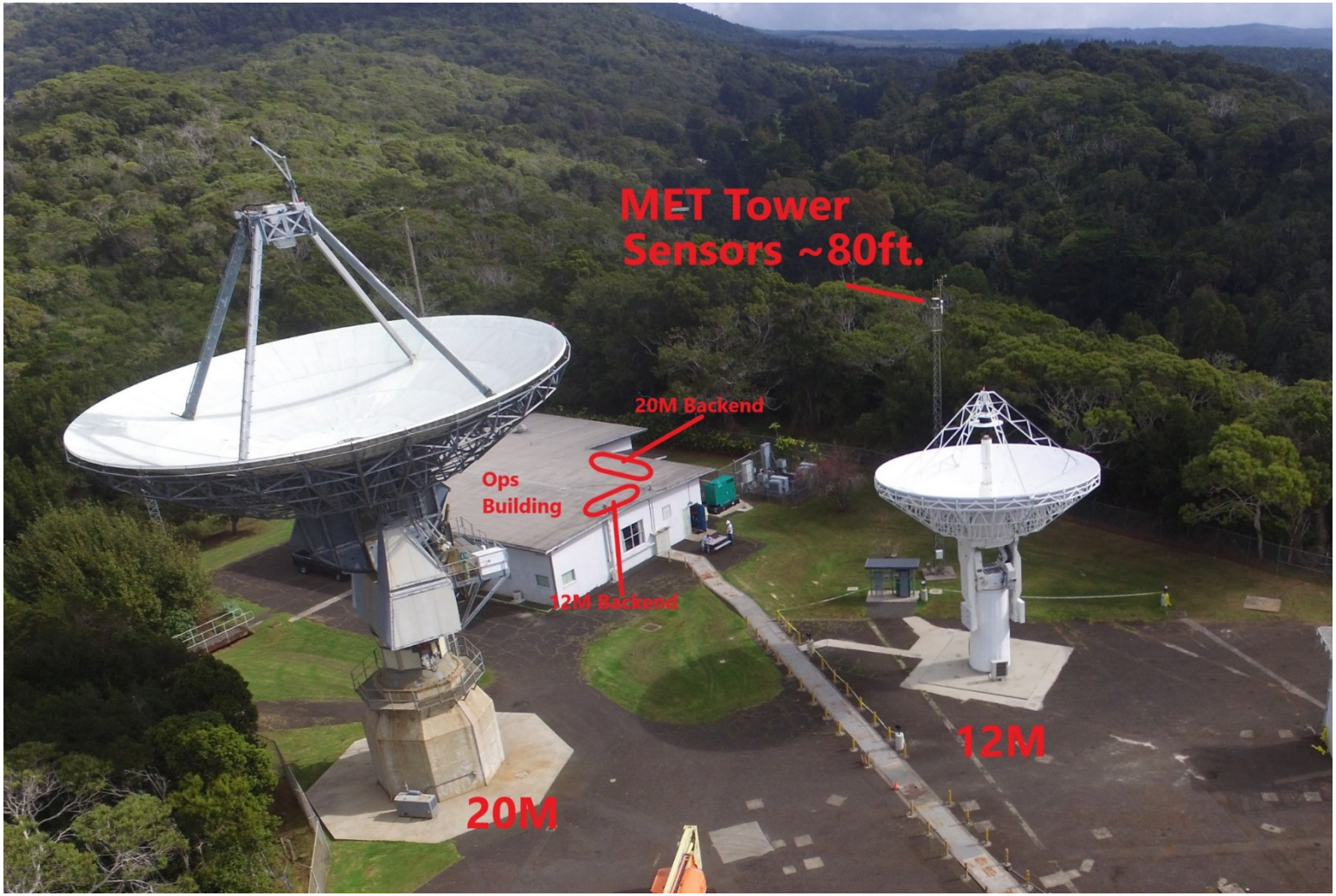
KT-sessions: 30-minute clock; posn of K2
aen_vmlinux GUI phase-delay
KOKEE: cablecal; no phasecal; KOKEE12M: pcmt cablecal applied

	U	sigU	E	sigE	N	sigN	L	sigL	used	total
16071	-8011.3	1.4	20127.2	0.9	-22343.8	1.0	31121.3	1.3	17	19
16078	-8014.9	0.6	20126.2	0.5	-22345.6	0.4	31122.8	0.6	99	104
16084	-8014.4	0.6	20127.4	0.5	-22345.7	0.5	31123.6	0.7	99	104
16090	-8014.9	0.3	20126.7	0.2	-22345.5	0.2	31123.1	0.3	99	104

KT-sessions: 30-minute clock; posn of K2
aen_vmlinux GUI group-delay
KOKEE: cablecal; no phasecal; KOKEE12M: no cablecal applied

	U	sigU	E	sigE	N	sigN	L	sigL	used	total
16071	-3.17	6.74	-4.19	2.86	0.73	2.59	31121.25	6.84	17	19
16078	1.53	2.45	1.03	1.15	-1.77	1.40	31125.21	3.36	99	104
16084	4.72	3.62	-1.96	1.86	2.30	1.61	31119.53	4.27	90	98
16090	0.09	1.00	-0.01	0.48	0.14	0.47	31123.53	1.24	410	427

NGS survey 2015 November (reported by Jim Long)

	U	sigU	E	sigE	N	sigN	L	sigL	used	total
16069	-8020.1	2.0	20128.8	2.0	-22345.2	2.0	31125.5	2.0	1	1

Local ties at KPGO
(Kokee Park Geophysical Observatory)