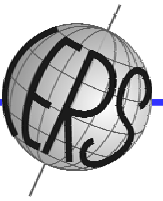


Status and Future of the IERS Combination Pilot Project

Markus Rothacher

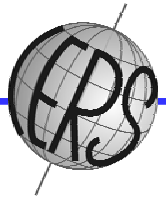
Forschungseinrichtung Satellitengeodäsie
TU München (FESG)

**IERS Workshop 2004:
IERS Combination Pilot Project (CPP)
December 11, 2004
Napa, USA**



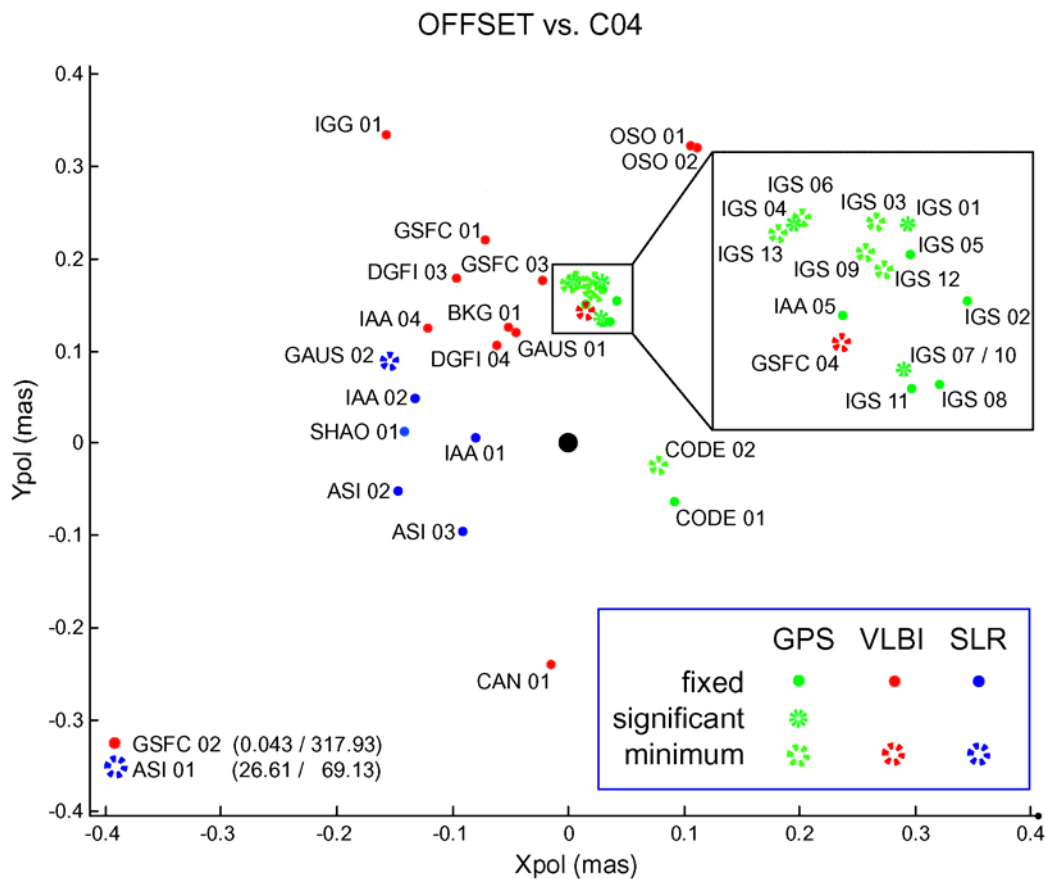
- **Motivation**
- **IERS Combination Pilot Project**
- **Status of the IERS CPP**
- **Future Goals: IERS2005, CONT'05, ...**

Inconsistency between EOPs and ITRF2000

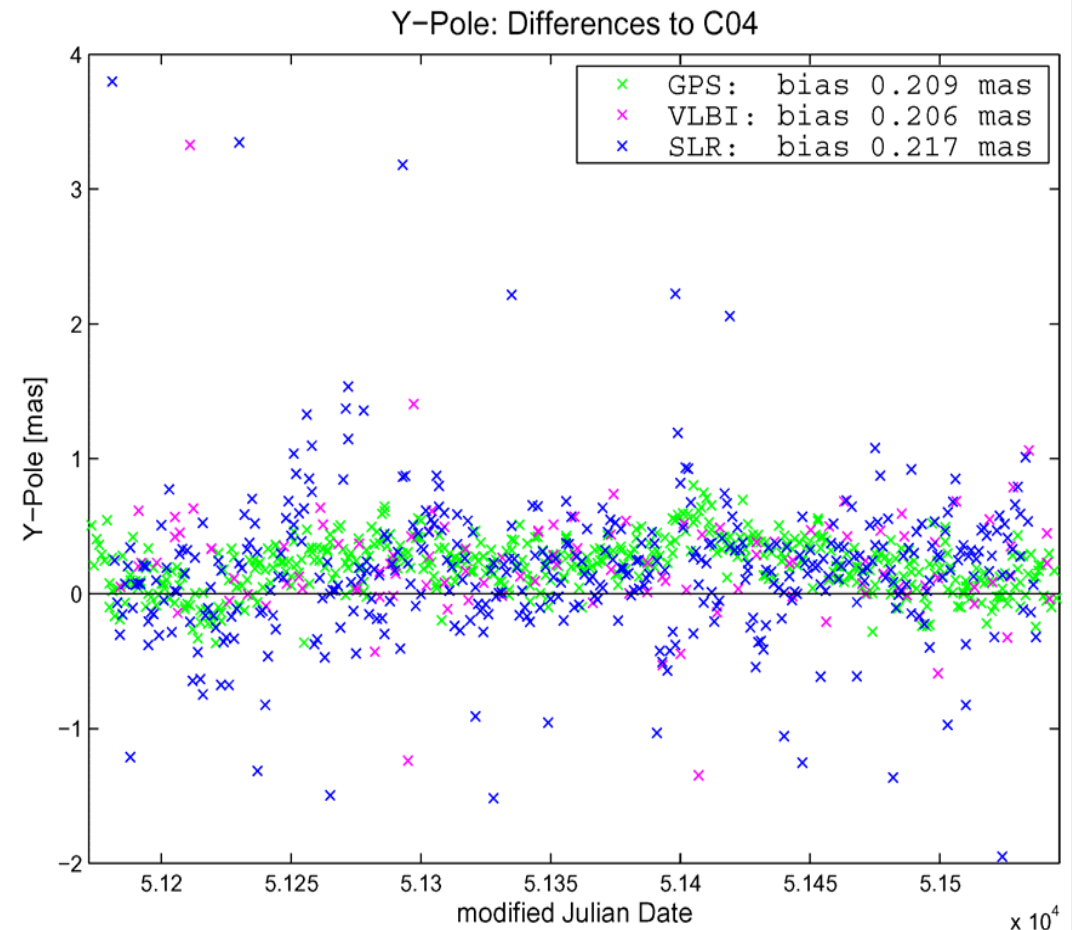


Offset of ca. 0.2 mas in Y-Pole

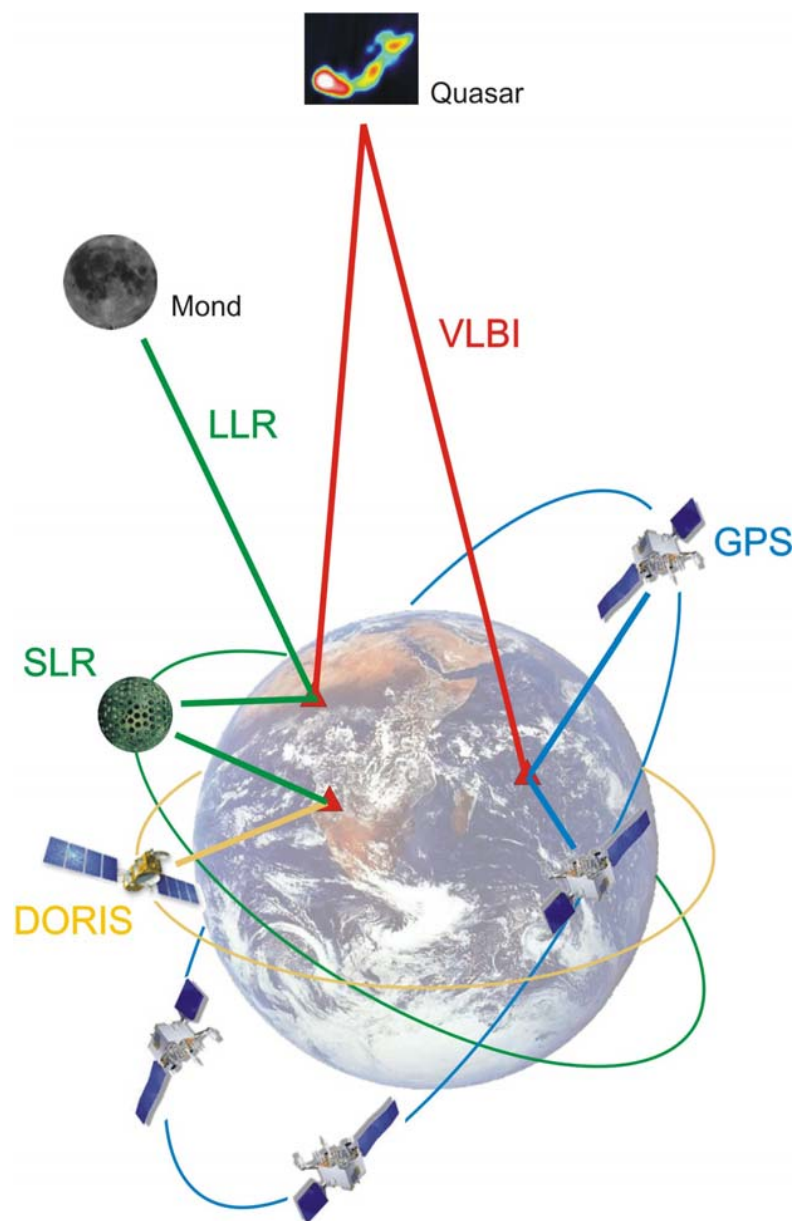
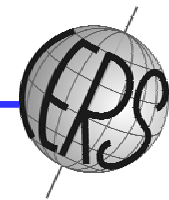
IERS EOP Alignment Campaign
to ITRF2000/ICRF:



IERS SINEX Combination Campaign:

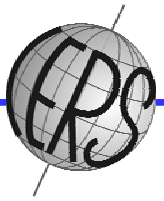


Vision of a Rigorous Combination



- Make use of the **strengths** of the individual observation techniques
- Profit from **co-location** of instruments (sites and satellites)
- Ensure **consistency** of all IERS products
$$\mathbf{X}_{\text{inertial}}(\mathbf{t}) = \mathbf{R}(\mathbf{t}) \cdot \mathbf{X}_{\text{earth-fixed}}(\mathbf{t})$$
- Differ between technique-specific systematic **biases** and genuine geodetic/geophysical **signals**
- **Final goal:** All common parameters of all observing techniques are rigorously combined to consistent IERS products

IERS Combination Pilot Project

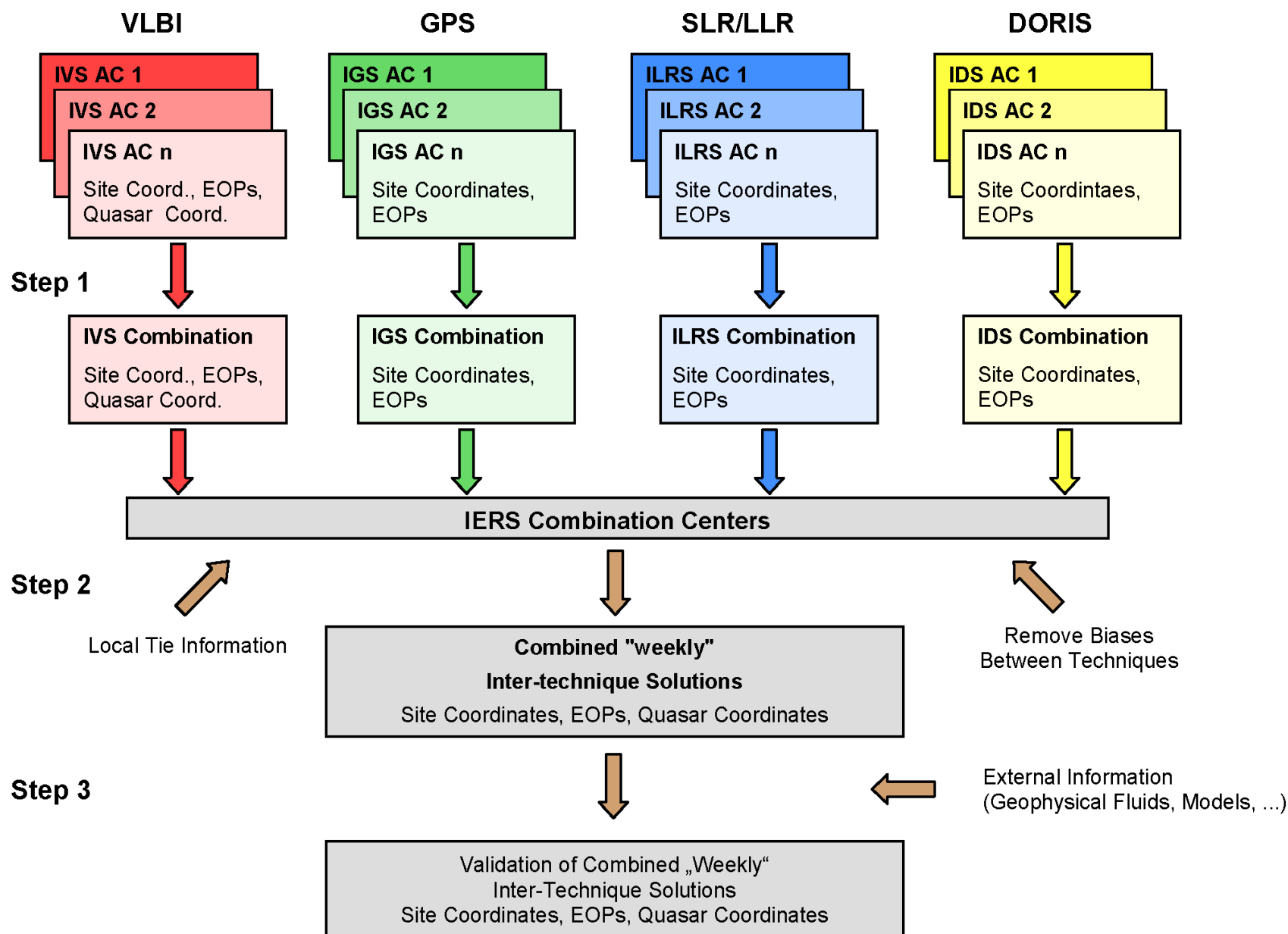


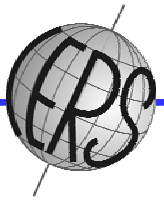
Parameter space for a rigorous combination:

	Parameter Type	VLBI	GPS/ GLON.	DORIS/ PRARE	SLR	LLR	Alti- metry	
ICRF	Quasar Coord. (ICRF)	X						Earth Rotation
	Nutation	X	(X)		(X)	X		
	Polar Motion	X	X	X	X	X		
	UT1	X						
	Length of Day (LOD)		X	X	X	X		
ITRF	Coord.+Veloc.(ITRF)	X	X	X	X	X	(X)	Gravity Field
	Geocenter		X	X	X		X	
	Gravity Field		X	X	X	(X)	X	
	Orbits		X	X	X	X	X	
	LEO Orbits		X	X	X		X	
Atmosphere	Ionosphere	X	X	X			X	
	Troposphere	X	X	X			X	
	Time/Freq.; Clocks	(X)	X		(X)			

IERS Combination Pilot Project: sub-space (red rectangle)

IERS Combination Pilot Project



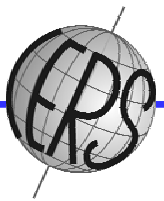


IERS CPP Proposals (1)

PARTICIPANTS: STEP 1 (= Intra-technique combination)

Institute/ Organization	Technique	Resulting parameters	Additional information
IDS	DORIS	Coordinates: weekly ERP (pole): daily	a) IDS Analysis Centers b) minimum constraints
IGS	GPS	Coordinates: weekly ERP (pole + rate, LOD): daily	a) IGS Analysis Centers b) inner constraints
ILRS	SLR	Coordinates: weekly ERP (pole, LOD): daily	a) ILRS Analysis Centers b) no constraints
IVS	VLBI	Coordinates: daily ERP (pole, UT1-UTC, nutation): daily	unconstrained normal equations
AUSLIG	VLBI	Coordinates: daily ERP + rates, nutation: daily	a) Kalman filter technique b) NNR/NNT for TRF c) ICRF fixed
CNES	DORIS	Coordinates: weekly ERP (pole): daily	unconstrained solutions
IGN/JPL	DORIS	Coordinates: weekly EOP: daily	free-network solutions
JCET	SLR	Coordinates: weekly ERP (pole, LOD): daily	loose constraints
NCL	GPS	Coordinates: weekly ERP (pole, LOD): daily	a) minimum constraints b) as IGS GNAAC
NCL	SLR	Coordinates: weekly ERP (pole, LOD): daily	a) minimum constraints b) as for ILRS pilot project

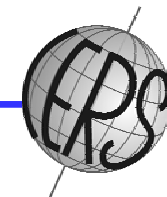
IERS CPP Proposals (2)



PARTICIPANTS: STEP 2 (= Inter-technique combination)

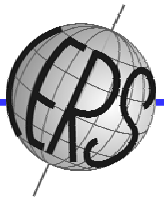
Institute	Techniques	Short description of combination process
ASI	all	a) weighting based on chi square b) additional site eccentricities c) geocenter as additional parameter d) loosely constrained solution
DGFI	all	a) variance component estimation b) additional helmert parameters
IGN	all	a) variance component estimation b) additional helmert parameters
JCET	SLR + LEO GPS	a) variance component estimation b) loose constrained solution
NCL	GPS + SLR	a) variance component estimation
Wuhan University	all	a) variance component estimation b) set up of systematic parameters between techniques

IERS CPP Proposals (3)



PARTICIPANTS: STEP 3 (= Validation)

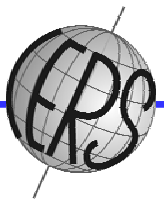
Institute	Parameters	Short description of validation process
IGN	Coordinates EOPs Quasar coordinates	a) reliability + quality of local ties b) comparison with external solutions c) weaknesses, model deficiencies, inconsistencies
JCET	Coordinates ERPs	a) usage in precise orbit determination b) coordinate comparisons and external solutions c) spectral analysis of ERPs
JPL	ERPs	a) comparison with OAM, AAM
NCL	Coordinates ERPs	a) coordinate + ERP residuals after Helmert transformation b) repeatabilities (Helmert parameters, coordinates)
USNO	EOPs	a) comparisons (Bulletin a/B, C04, geophysical fluids, single techniques) b) correlation, coherence, power spectrum
Wuhan University	Coordinates EOPs Quasar coordinates	a) weighted transformation parameter estimation b) parameters after transformation and transformation parameters



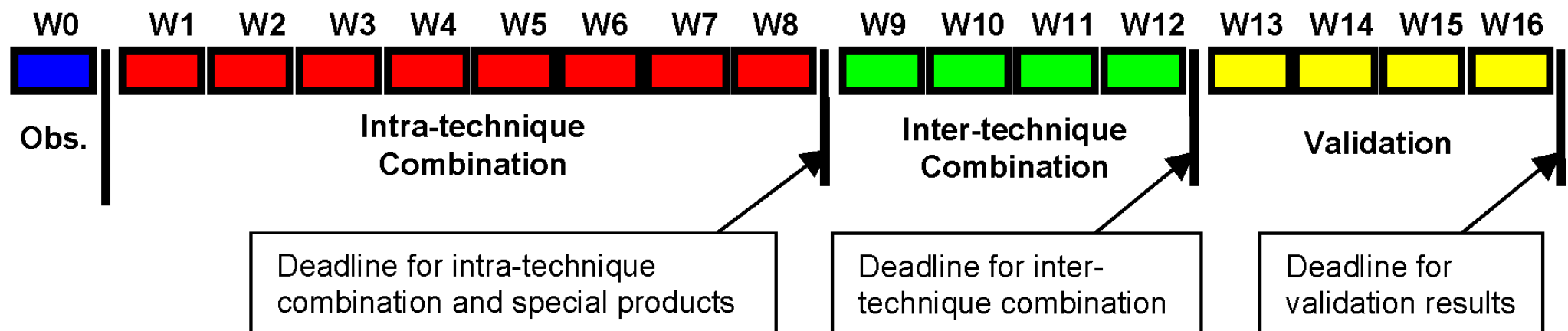
PARTICIPANTS: SPECIAL PRODUCTS

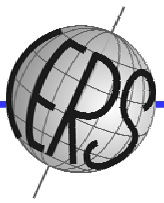
Institutes	Techniques	Short description of special product
AICAS	all	transformed to the celestial system
GRGS	all	combination on observation level including TRF, EOPs (UT1, polar motion, nutation corrections)
JCET	GPS + SLR + DORIS	include orbits in the combination (together with coordinates, EOPs)
USNO	all	sub-daily ERPs
USNO	VLBI + GPS	daily nutation
USNO	all	combined EOPs (polar motion, UT1, nutation), aligned to C04

IERS CPP: Submission Schedule



- **Intra-technique combinations** (weekly SINEX files) due 8 weeks after the observations
- **Inter-technique combinations** (weekly SINEX files) due 12 weeks after the observations
- **Validation of inter-technique combinations** (report) due 16 weeks after the observations
- **Special combined products** due 8 weeks after the observations





IERS CPP: Status

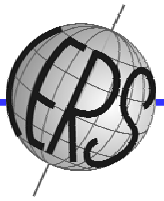
Intra-technique combinations (December 9, 2004):

Technique	Institution	Last Subm.	Delay (days)
IGS	NRCan	326/2004	11
ILRS	ASI	333/2004	4
IVS	GIUB	274/2004	63
IDS *	IGN	298/2004	39
NCL*	Newcastle	326/2004	11

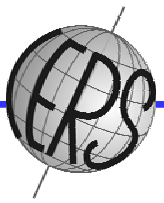
* Individual analysis center

- Intra-technique solutions in time and complete
- Inter-technique solutions not yet available
- No validation yet

IERS CPP: Timetable



- April 29, 2004:** Meeting of IERS WG on Combination (during the EGU Meeting in Nice)
- December 2004:** Progress Meeting of the IERS CPP at the IERS Workshop 2004, Dec. 9-10, 2004
- April 2005:** EGU Meeting in Vienna, Presentations
- October 2005:** IERS Workshop 2005: Evaluation of the CPP and discussions concerning the transitions to new IERS products; merging with the IERS2005 project

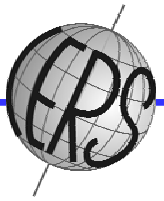


- It took some time for the technique services to start to compute combined intra-technique solutions
- Very important to have technique services fully involved, taking their responsibility for the technique-specific products (SINEX)
- Difficulties within the CPP showing up already now:
 - proper weighting of the technique solutions on a weekly basis
 - proper datum definition for each week
- Long time series from new ITRF2004/IERS2005 are very important to support and complement the CPP
- 9 months (36 weeks) of weekly solutions now available: should really be used now by the inter-technique combination centers

IERS CPP: Future Goals

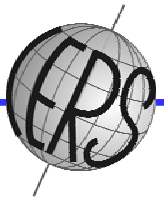


- Start with weekly (or accumulated) **inter-technique solutions**
- Start **validation** of the intra-technique and inter-technique combinations
- ITRF2004/IERS2005: Add **long time series** to the IERS CPP database: Studies of rigorous weekly and multi-year solutions
- **CONT'05**: new continuous VLBI campaign coordinated with the IERS CPP and the other techniques; allows detailed studies of combination strategies etc.
- Encourage combinations on the **observation level**
- Add **new common parameters** to the weekly combinations:
 - Quasar coordinates (ICRF)
 - Nutation offsets and rates (to IAU2000)
 - Troposphere zenith delays and gradients
 - Subdaily ERPs ?
 - Orbits ??
 - Clocks ???



- Very useful experiences with the CONT'02 Campaign
- Possibility to study the details of a rigorous combination (troposphere, local ties, nutation, UT1/LOD, modeling aspects, parameterization, ...)
- Continuous VLBI observations during 2 weeks
- Inclusion of other observation techniques:
 - SLR observations to GPS/GLONASS satellites
 - SLR observations to multi-technique satellites (JASON, CHAMP, ...)
 - DORIS observations (local ties, troposphere, ...)
- Co-location of auxiliary instruments:
 - As many water vapor radiometers as possible
 - Meteorological Information
 - Clock synchronization ?
 - Gravimeters ?

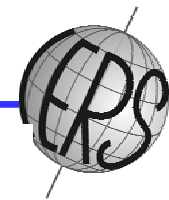
IERS Combination Pilot Project



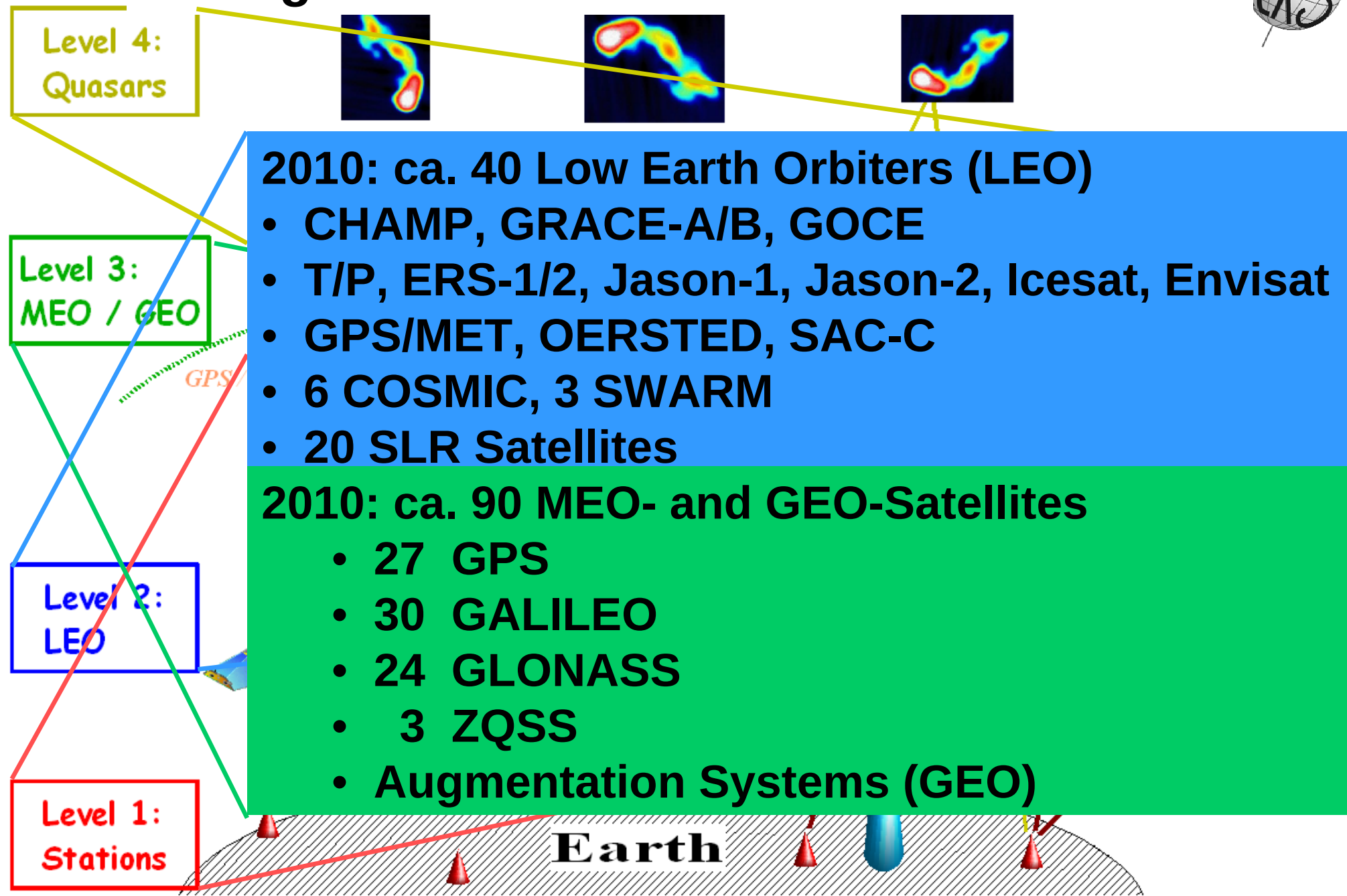
Parameter space for a rigorous combination:

Parameter Type		VLBI	GPS/ GLON.	DORIS/ PRARE	SLR	LLR	Alti- metry
ICRF	Quasar Coord. (ICRF)	X					
	Nutation	X	(X)		(X)	X	
	Polar Motion	X	X	X	X	X	
	UT1	X					
	Length of Day (LOD)		X	X	X	X	
	Coord.+Veloc.(ITRF)	X	X	X	X	X	(X)
ITRF	Geocenter		X	X	X		X
	Gravity Field		X	X	X	(X)	X
	Orbits		X	X	X	X	X
	LEO Orbits		X	X	X		X
Atmosphere	Ionosphere	X	X	X			X
	Troposphere	X	X	X			X
	Time/Freq.; Clocks	(X)	X		(X)		

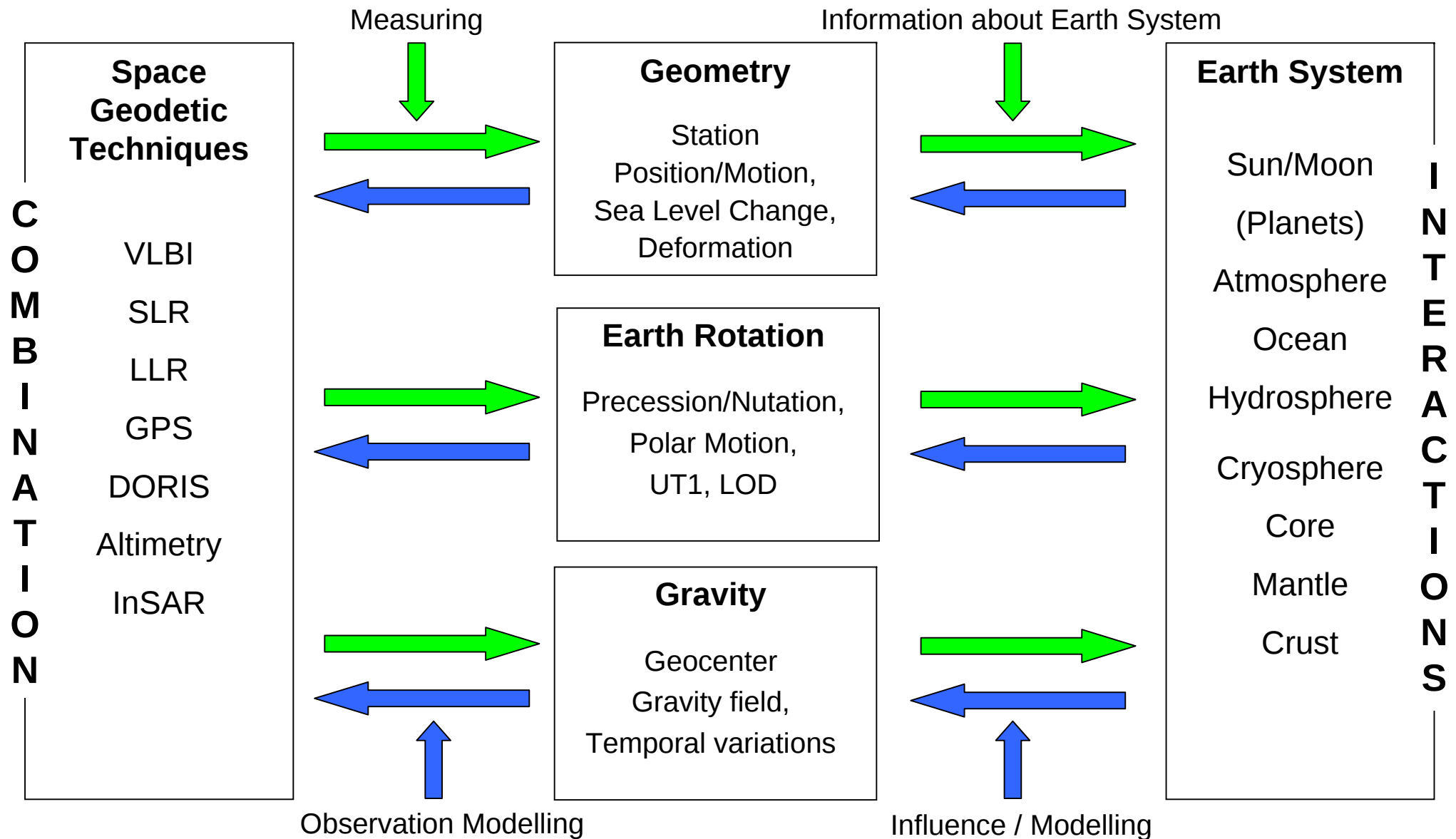
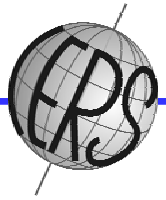
IERS Combination Pilot Project: sub-space (red rectangle)

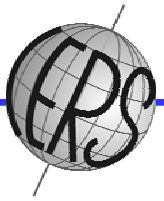


Intergation of 4 Levels into a GGOS



Measuring and Modeling the Earth System





IERS CPP: Timetable

January 26, 2004:	Dissemination of the Call for Participation
February 22, 2004:	Due date for proposals
February 27, 2004:	Information of participants about proposal acceptance
February 29, 2004:	Start of IERS Combination Pilot Project with GPS Week 1260 (first intra-technique combinations due 8 weeks later, i.e. end of April 2004; first inter-technique solutions due 12 weeks later, i.e., end of May).
April 29, 2004:	Meeting of IERS WG on Combination (during the EGU Meeting in Nice)
December 2004:	Progress Meeting of the IERS CPP at the IERS Workshop 2004 (San Francisco)
April 2005:	EGU Meeting in Vienna, Presentations
October 2005:	Evaluation of the CPP and first discussions concerning the transitions to new IERS products