The 2009 horizontal velocity field for South America and the Caribbean

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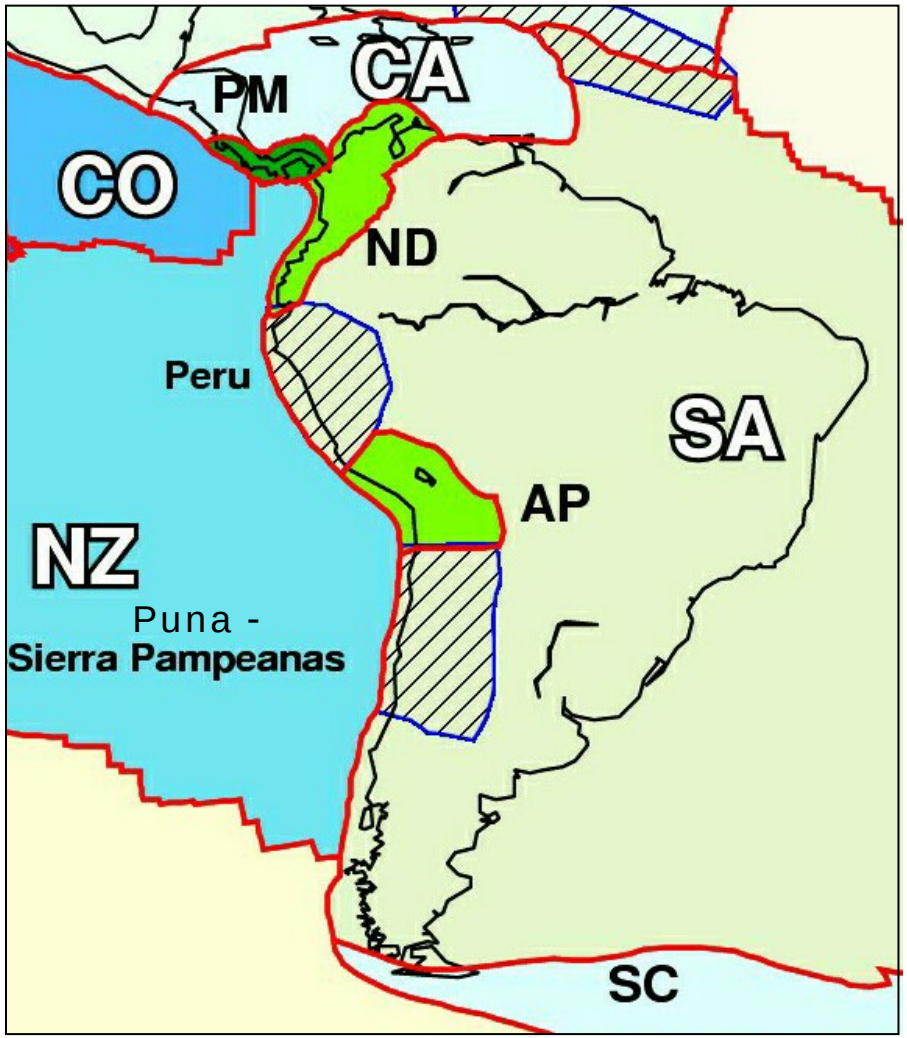
Motivation



Extract of model PB2002 (Bird 2003) for the South American region

The kinematic model for the Earth crust widely used in geodesy is NUVEL-1A (De Mets et al. 1990, 1994). It represents rigid plates only and does **not** include any deformation zones (like Andes).

The geophysical model PB2002 includes deformation zones and (micro-) plates, but not all of them are confirmed by present-day geodetic measurements.

In order to model the motions of the Earth crust for all geodetic purposes we need a realistic present-day crust deformation model.

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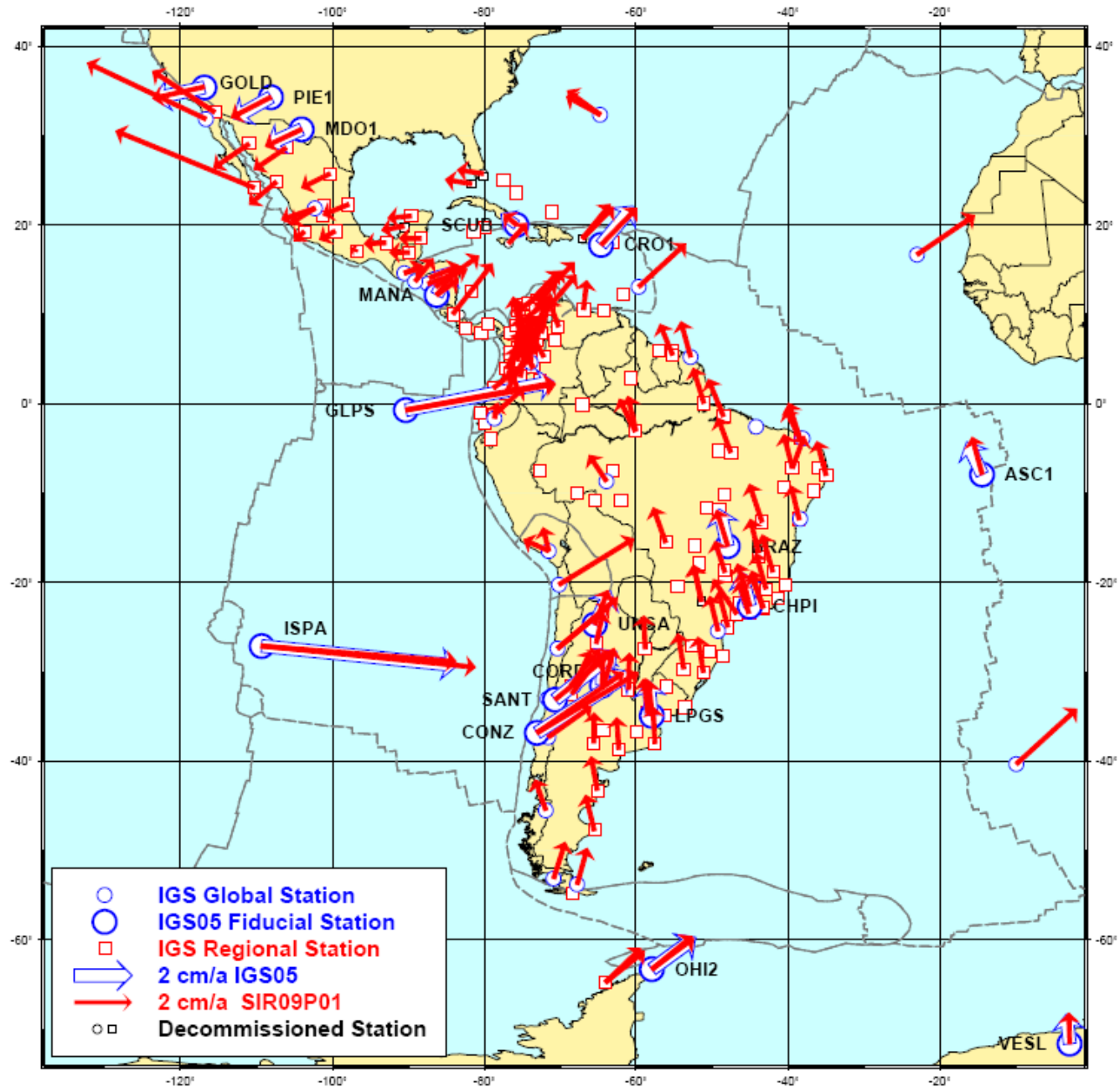


Input Data: Velocities from GPS Projects

1 ITRF Reference:

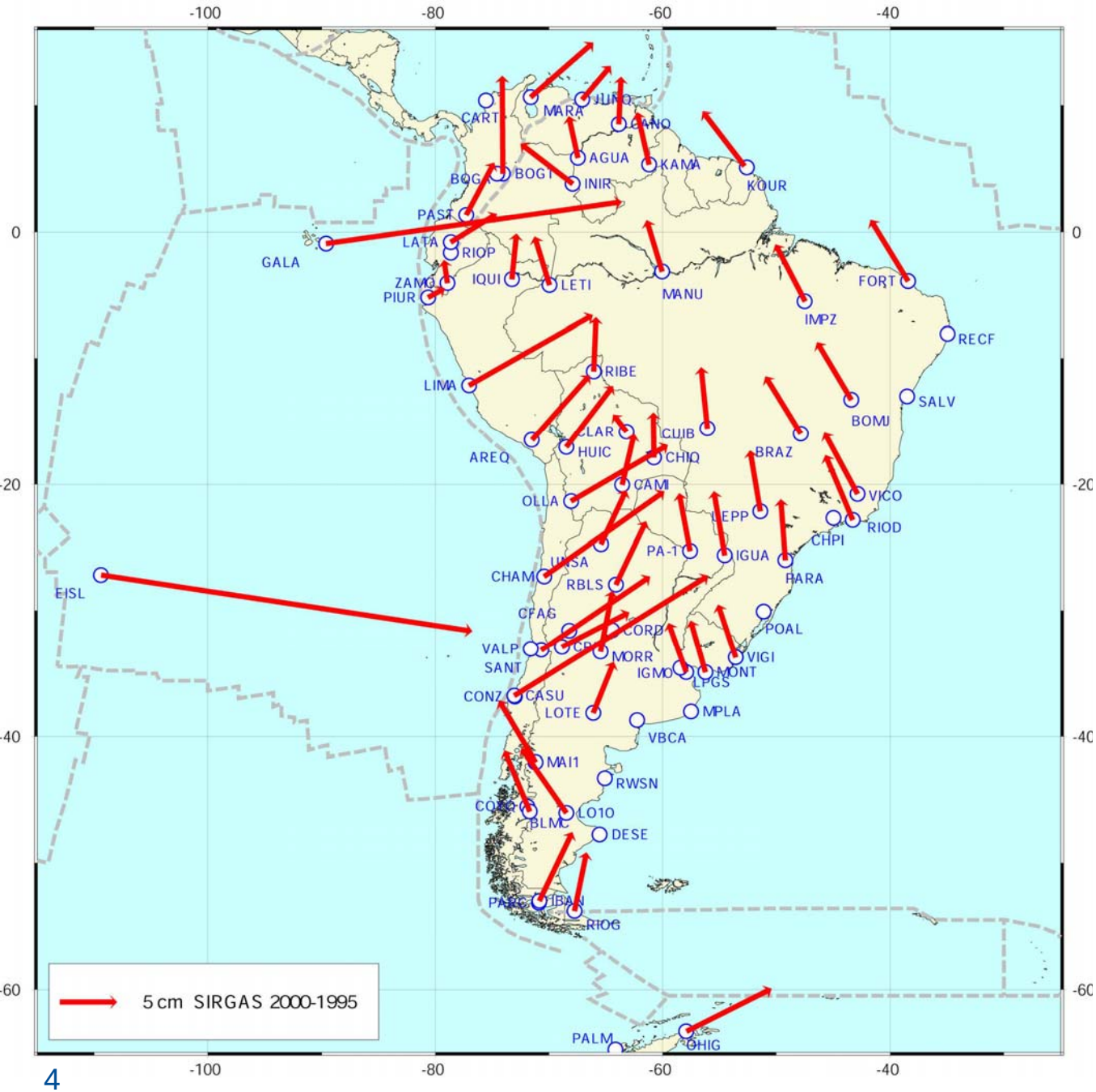
SIRGAS Multi-Year Solution SIR09P01

Observation data: GPS 2000 - 2008

(Seemüller et al., 2009)

128 velocities

Input Data: Velocities from GPS Projects



2 SIRGAS 2000 – SIRGAS 1995

Difference vectors between two campaigns

(Drewes et al., 2005)

53 velocities

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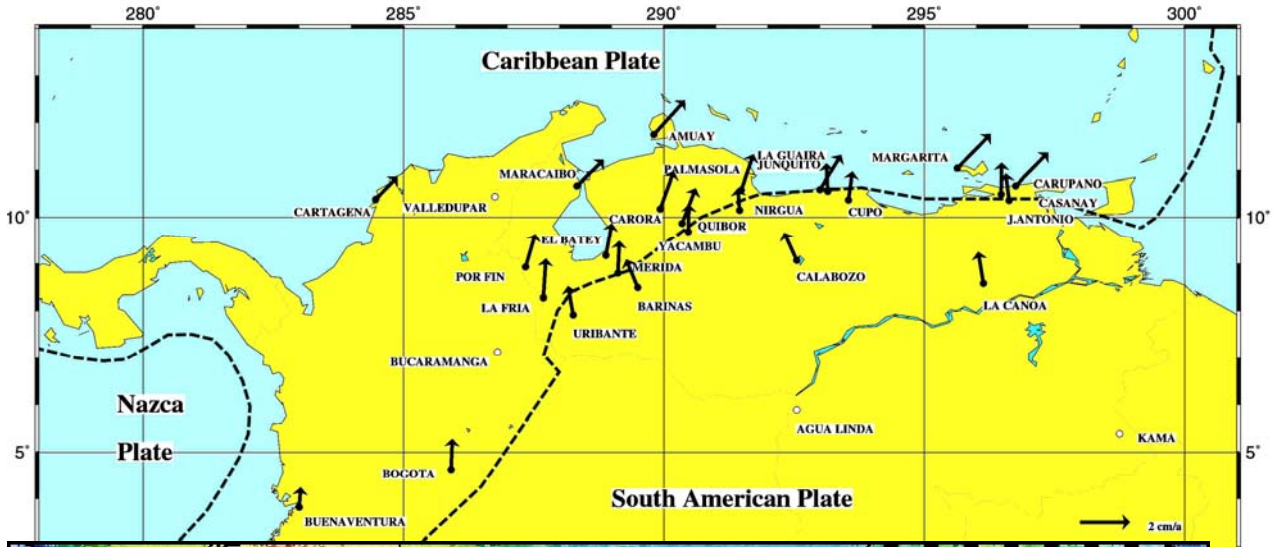

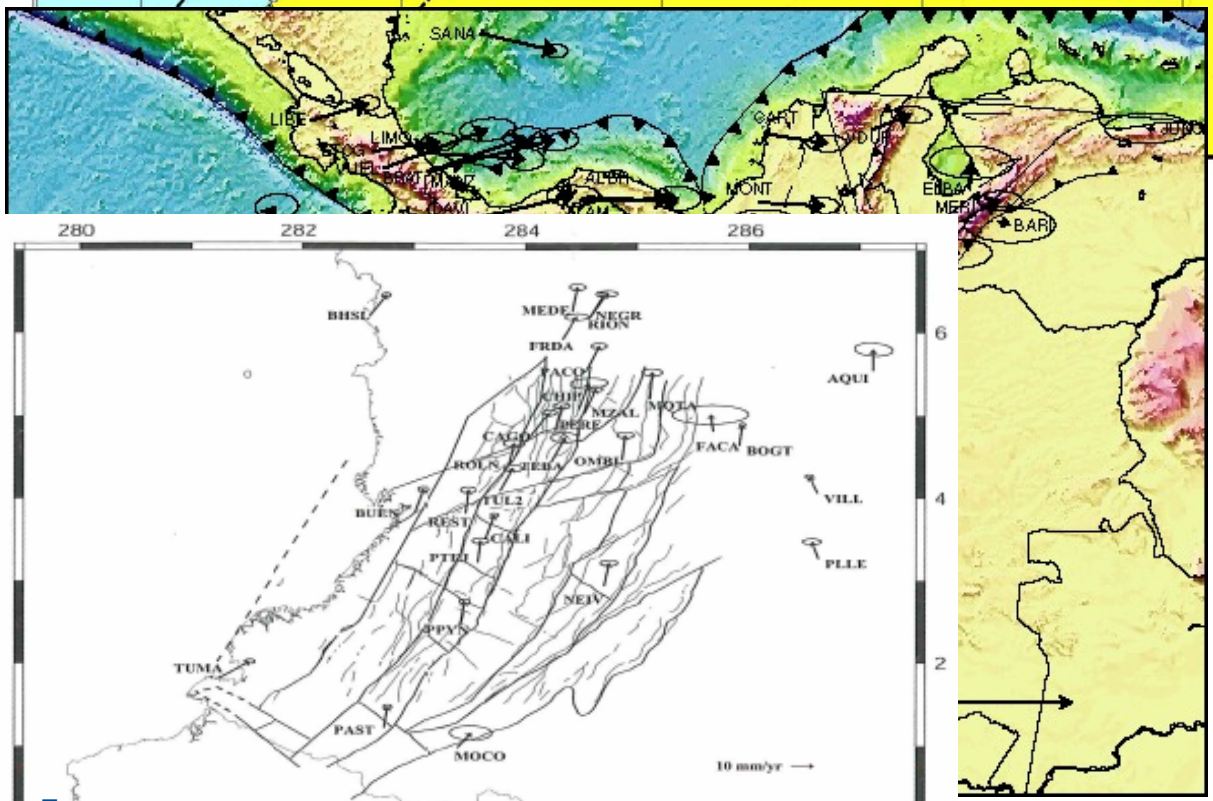

Input Data: Velocities from GPS Projects

3 CASA (East)

Kaniuth et al., 2002
(1988 … 2002)
31 velocities

4 CASA (West)

Trenkamp et al. ‘02
(1991 … 1998)
44 velocities

5 CASA (Cali)

Trenkamp et al. ’04
(1996 … 2003)
29 velocities

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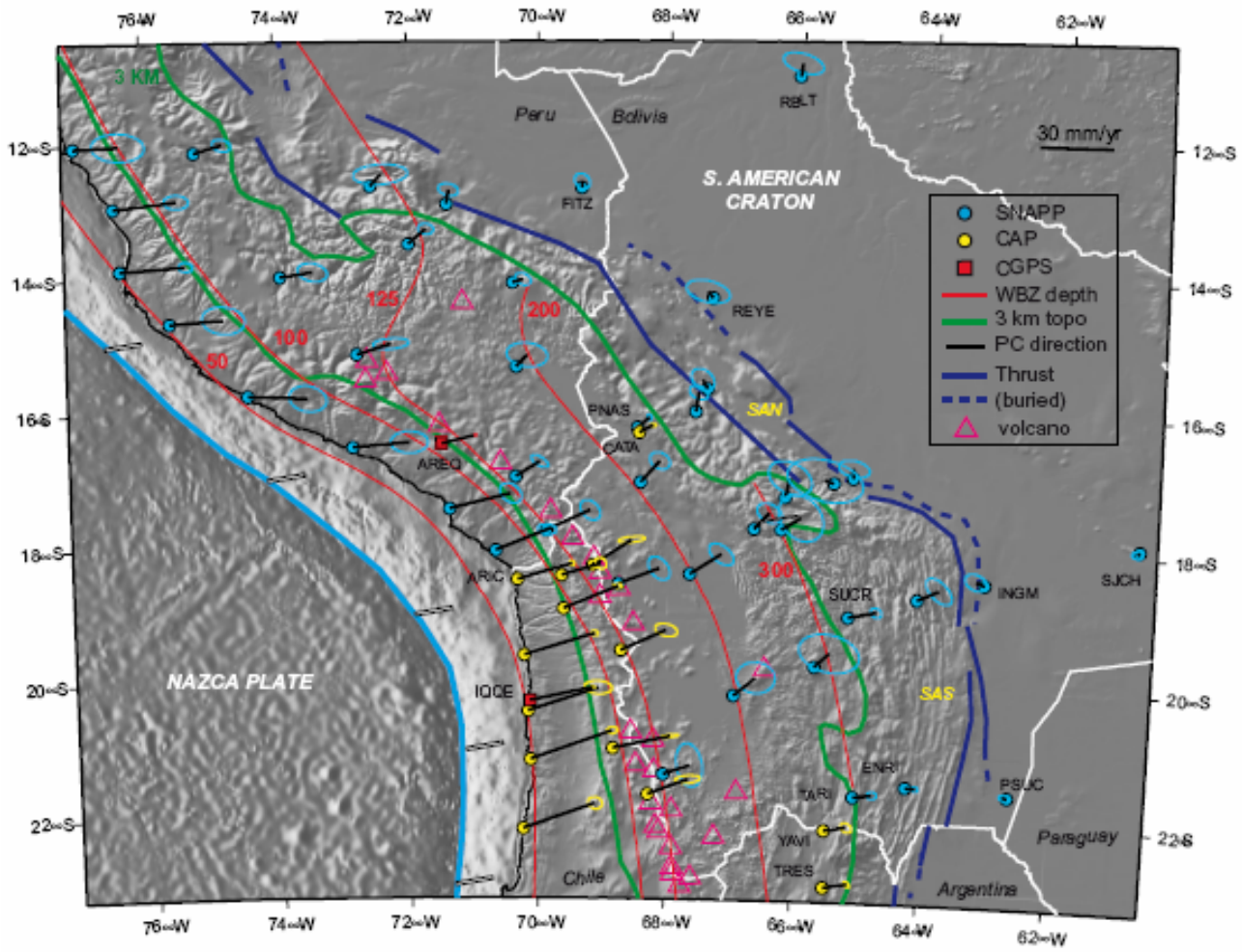

Input Data: Velocities from GPS Projects

6 CAP - SNAPP

Kendrick et al., 2001 (1993 .. 2001)

69 velocities

Integrated processing of SNAPP and CAP data

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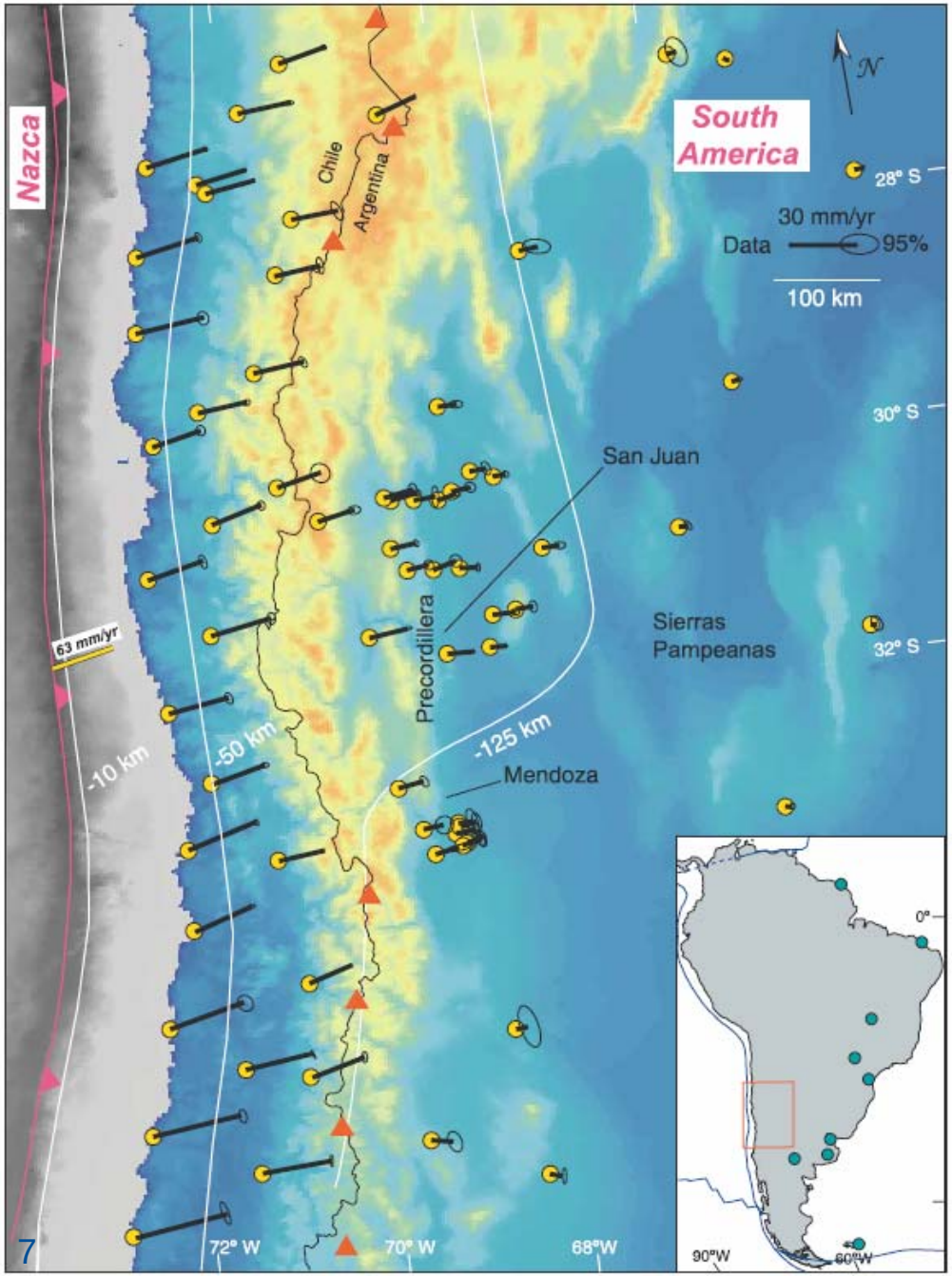

Input Data: Velocities from GPS Projects

7 CAP

Brooks et al., 2003 (1993 .. 2001)

68 velocities

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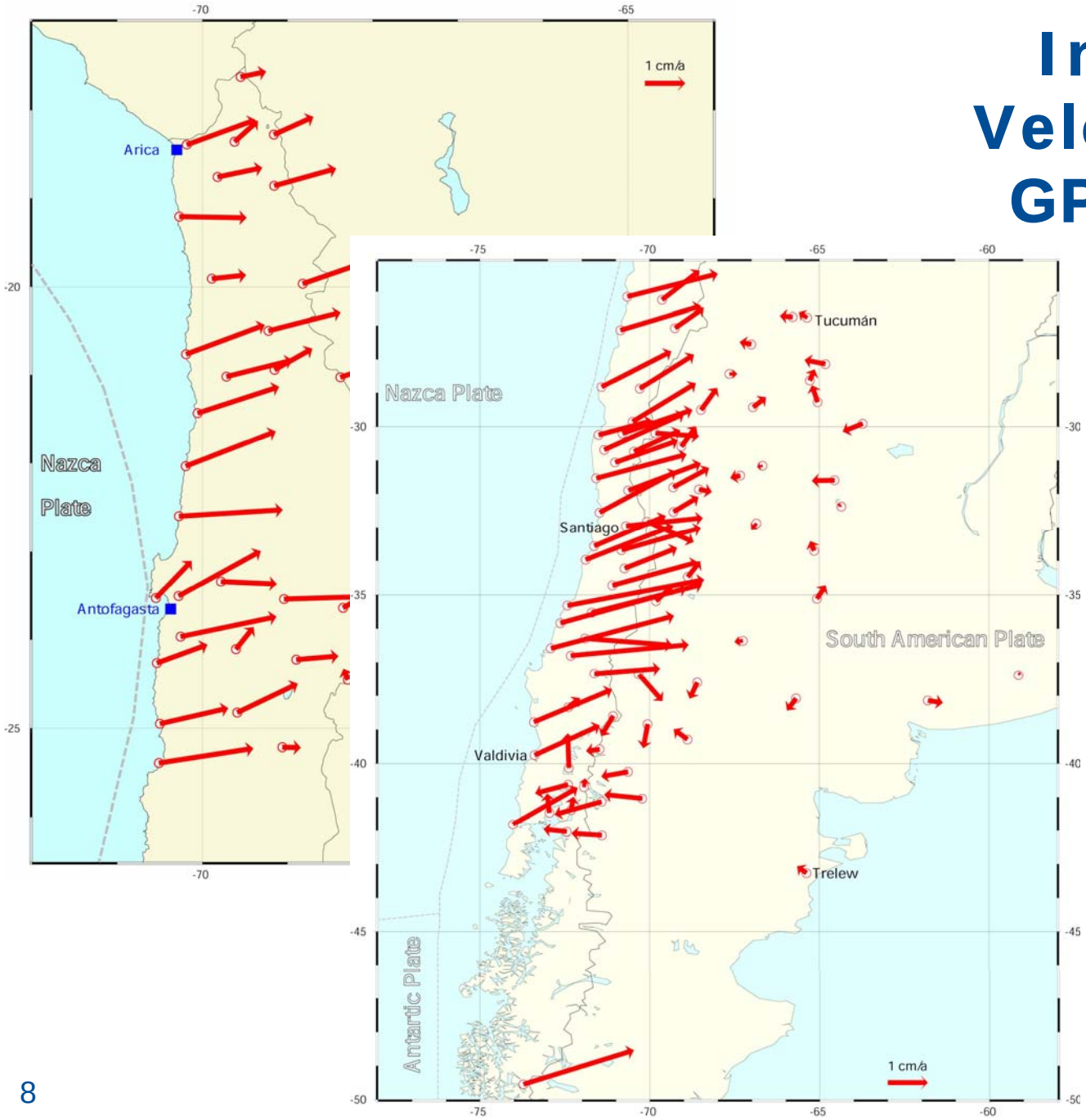
Input Data: Velocities from GPS Projects



8 SAGA NORTH

Khazaradze and Klotz, 2003

(1996 .. 1997)

33 velocities

9 SAGA SOUTH

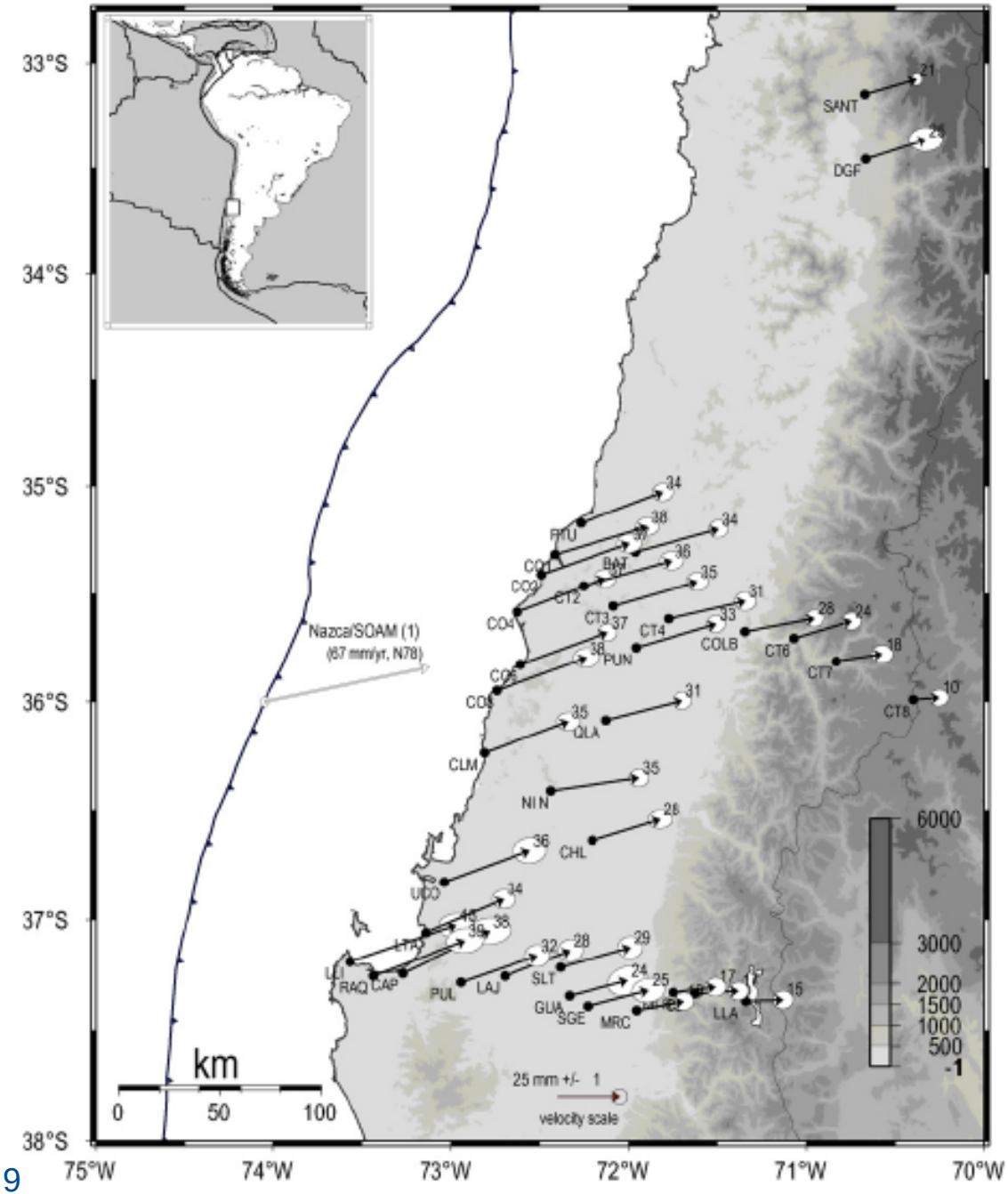
Klotz et al., 2001

(1994 .. 1996)

79 velocities

10 Chile (personal commun. Baez)

10 velocities

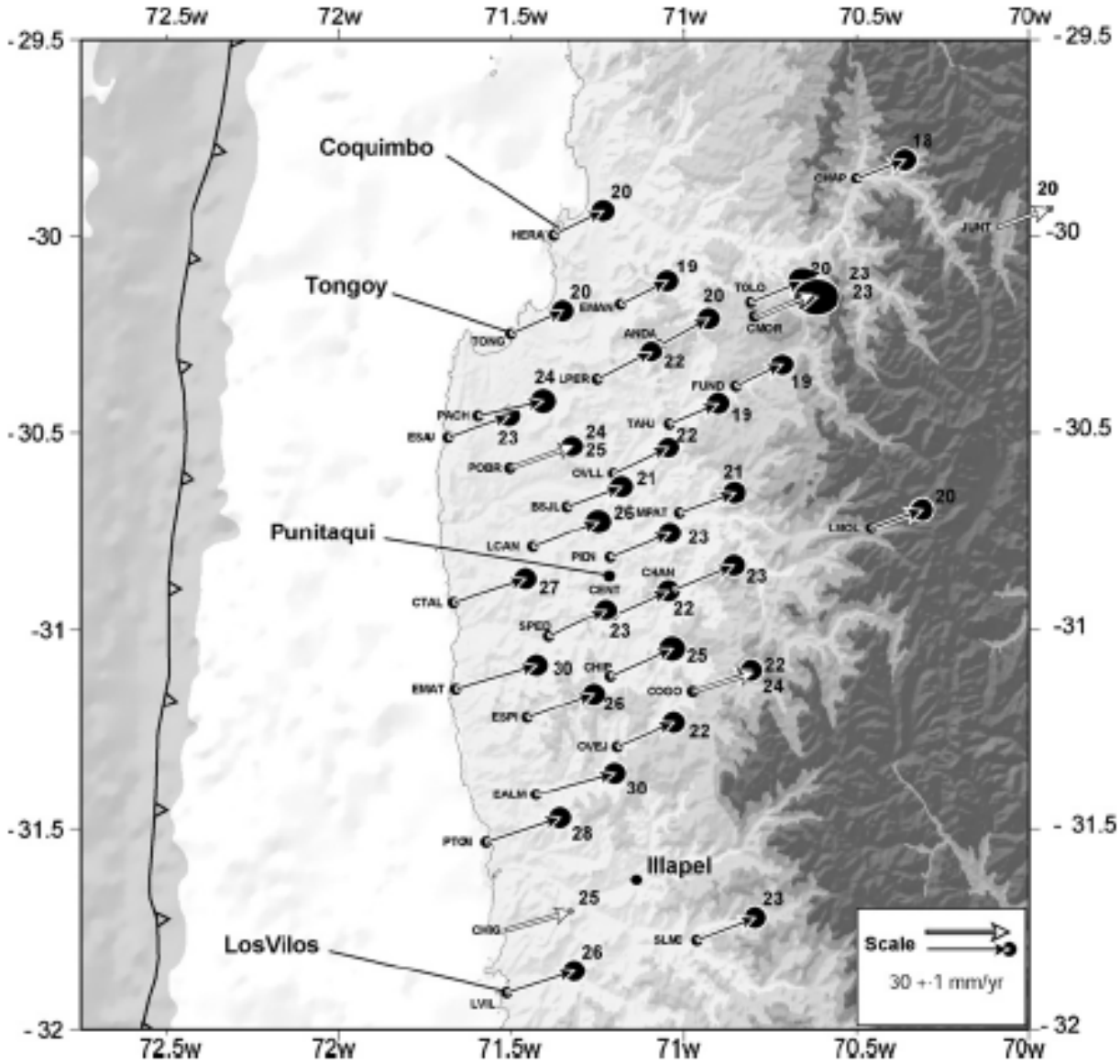


Input Data: Velocities from GPS Projects

11 Constitución – Concepción, Chile

Ruegg et al., 2009 (1996 .. 2002)

44 velocities

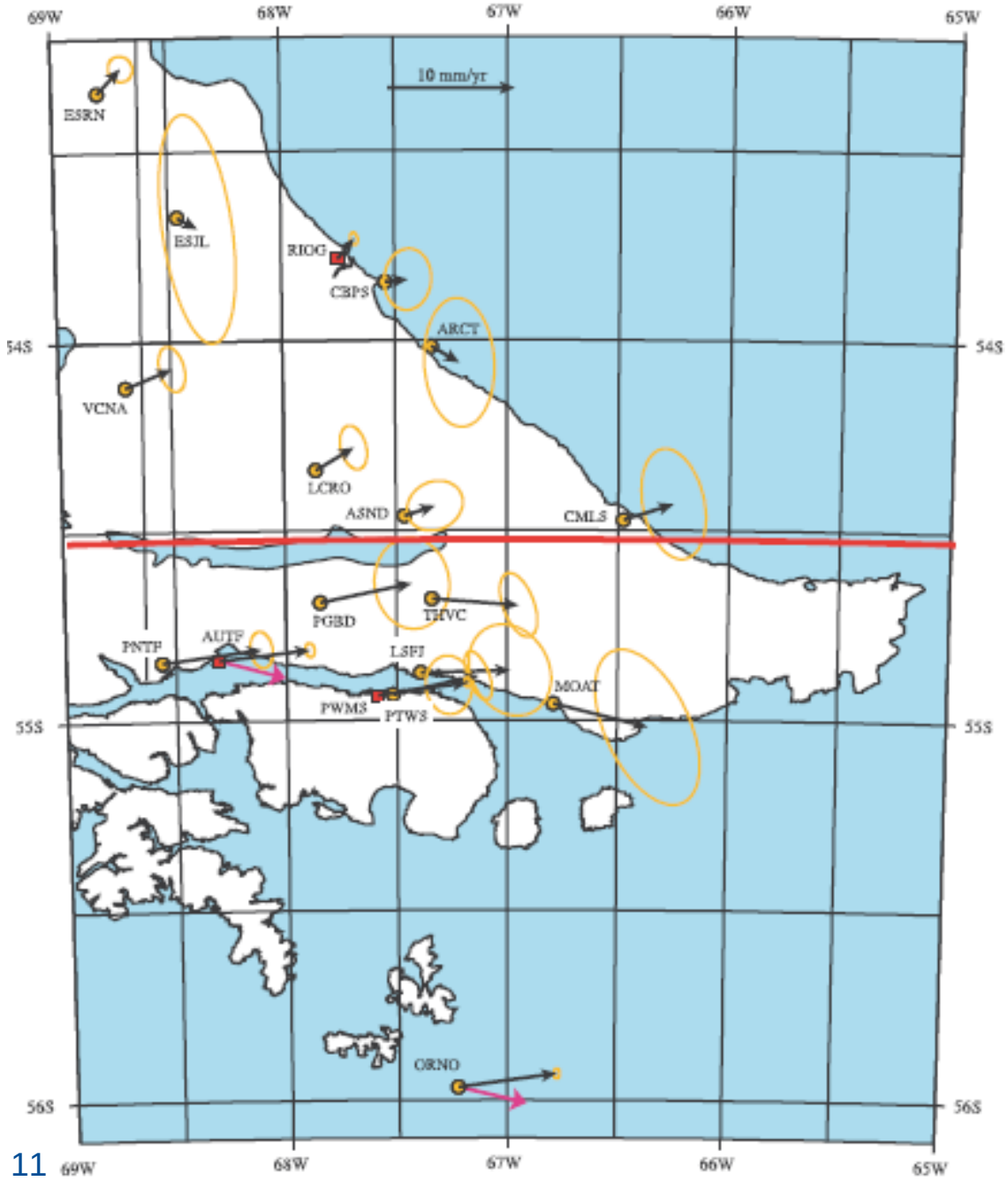


Input Data: Velocities from GPS Projects

12 Coquimbo, Chile

Vigny et al., 2009 (2004 .. 2006)

54 velocities



Input Data: Velocities from GPS Projects

13 Scotia – South America

Smalley et al., 2003
(1993) 1998 .. 2001

20 velocities

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Data Preprocessing

- ➢ Velocities of the regional data sets refer to different kinematic datums (different ITRF realizations or local reference points, respectively).
- ✓ Velocities of all sets were transformed by three rotation parameters to the continental solution SIR09P01 (ITRF2005 datum) via identical points (most projects include IGS stations) and reduced w.r.t. the South American plate by estimated plate rotation parameters.
- ✓ If no identical points with SIR09P01 were available, nearby points and overlapping with other projects were used.

- ➢ Identical stations in different projects were analysed w.r.t. reliability (no. and length of observation periods, total time interval covered)
- ✓ One velocity per site was accepted.
- ✓ Doubtful velocities were eliminated.

- ➢ The final data set was identically used for two model approaches:
- ✓ Geophysical Finite Element Model (FEM)
- ✓ Geodetic Least Squares Collocation Approach (LSC)

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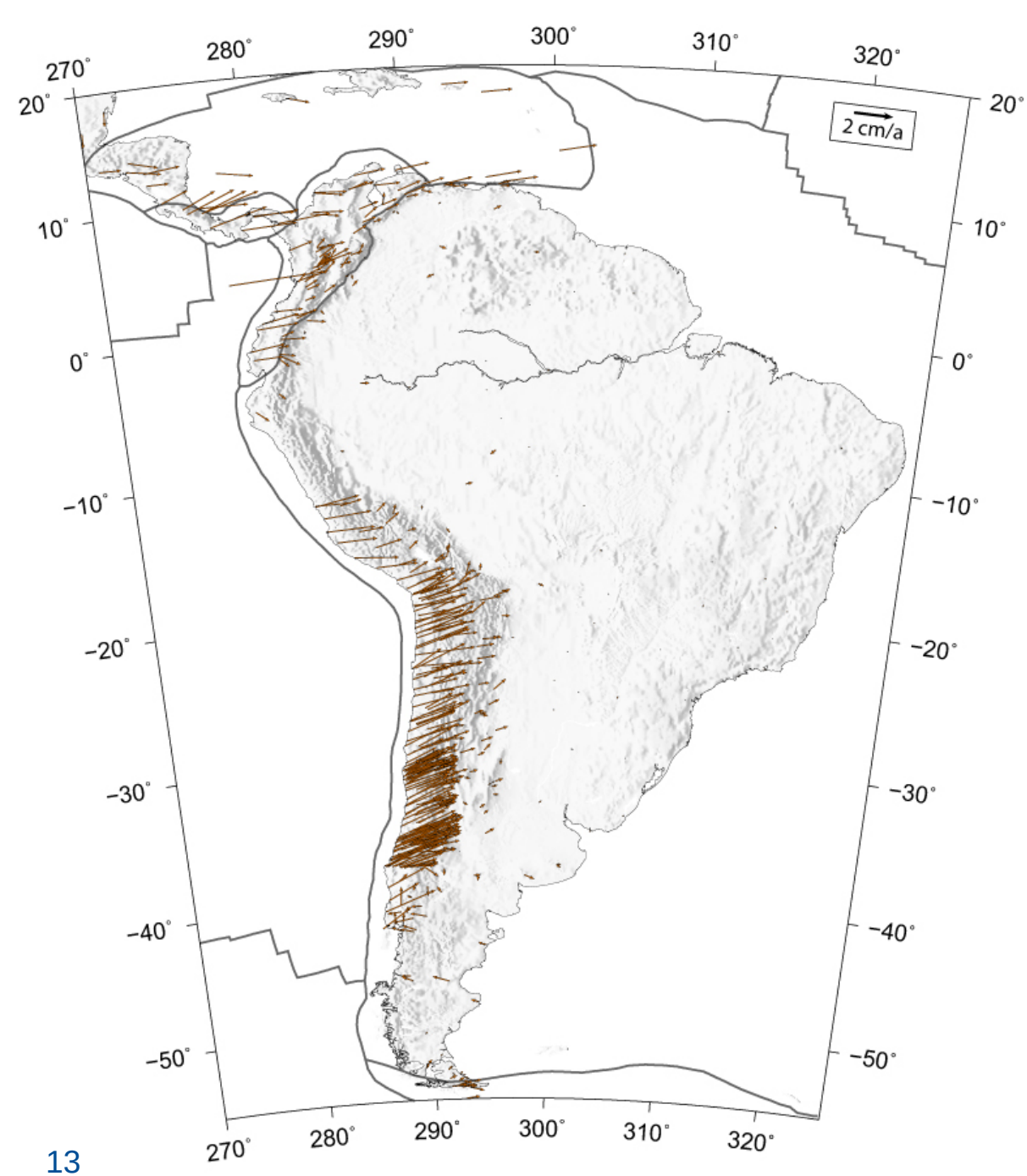

Input Data: Complete Set

SIR09P01:	95
SIRGAS 00-95:	28
CASA (East):	21
CASA (West):	31
CASA (Cali):	17
CAP-SNAPP:	54
CAP:	60
SAGA North:	32
SAGA South:	68
Scotia-SOAM:	19
Constitución:	65
Chile (others):	6
Total:	496

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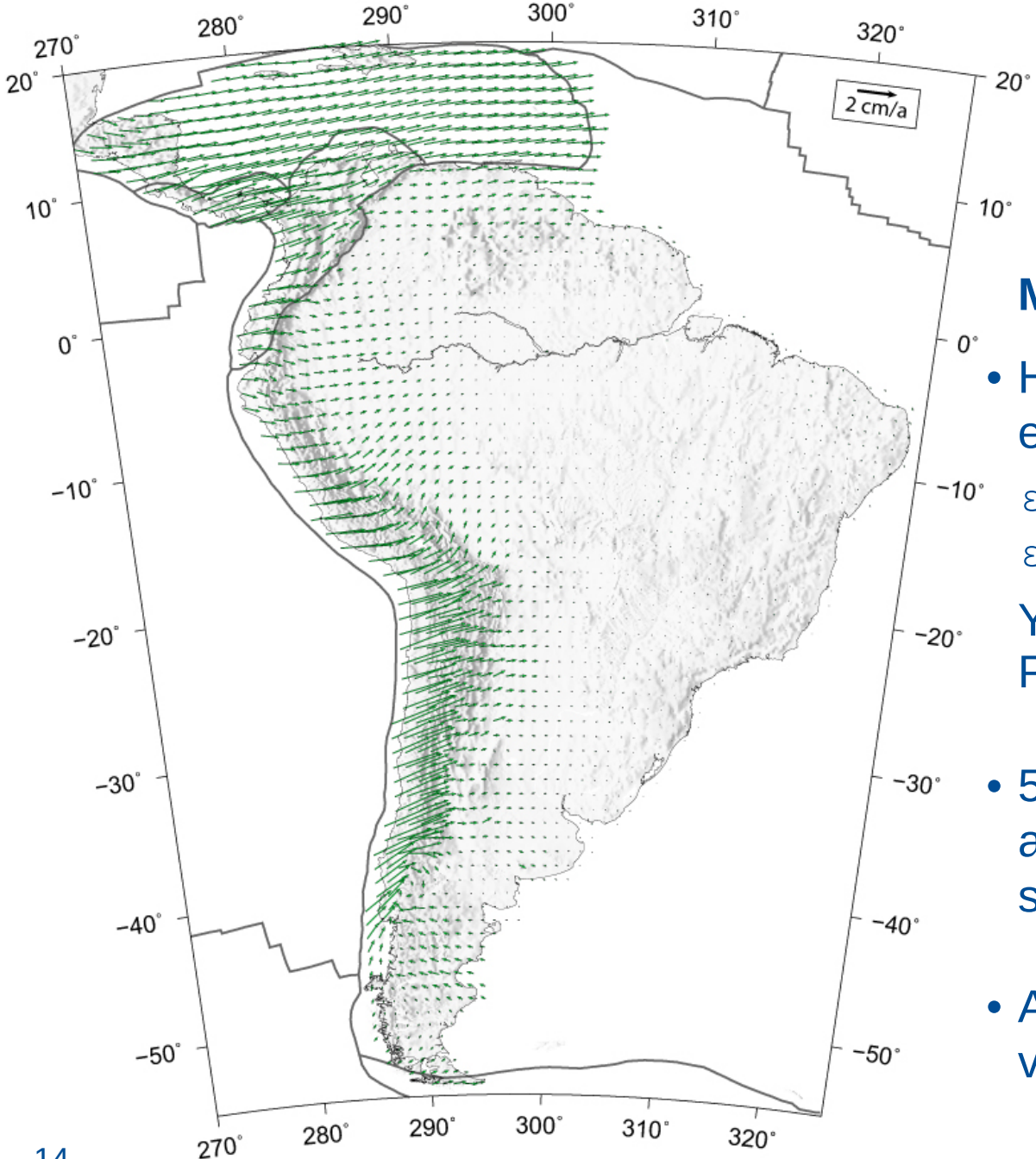

Finite Element Model (FEM)

Main characteristics:

- Homogeneous isotropic elastic (Hooke) material

  $\varepsilon_N = 1/E\ (\sigma_N - \nu\sigma_E)$

  $\varepsilon_E = 1/E\ (\sigma_E - \nu\sigma_N)$

  Young modulus E = 70 GPa

  Poisson number ν= 0.25

- 500.000 linear elements adopted to geographical station distribution

- ABAQUS Program system version 6.9

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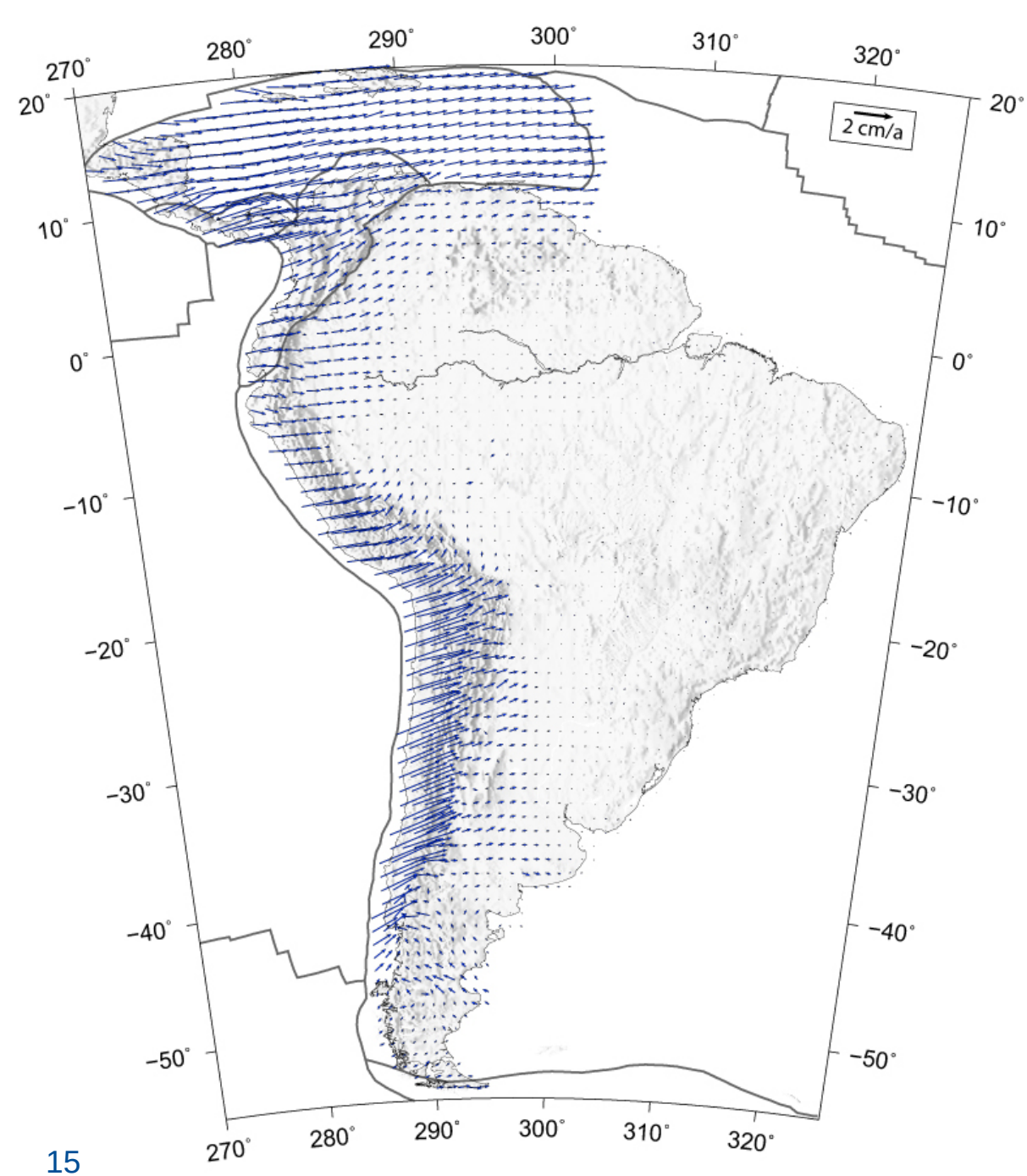

Least Squares Collocation

Vector prediction:

$\underline{\mathbf{v}}_{pred} = \underline{\mathbf{C}}_{new}^{T}\, \underline{\mathbf{C}}_{obs}^{-1}\, \underline{\mathbf{v}}_{obs}$

$\underline{\mathbf{v}}_{pred}$ = predicted velocities in a 1°x 1° grid

$\underline{\mathbf{v}}_{obs}$ = observed velocities in geodetic stations

$\underline{\mathbf{C}}_{new}$= correlation matrix between predicted & observed vectors

$\underline{\mathbf{C}}_{obs}$= correlation matrix between observed vectors

$\underline{\mathbf{C}}$ matrices from empirical isotropic covar-functions.

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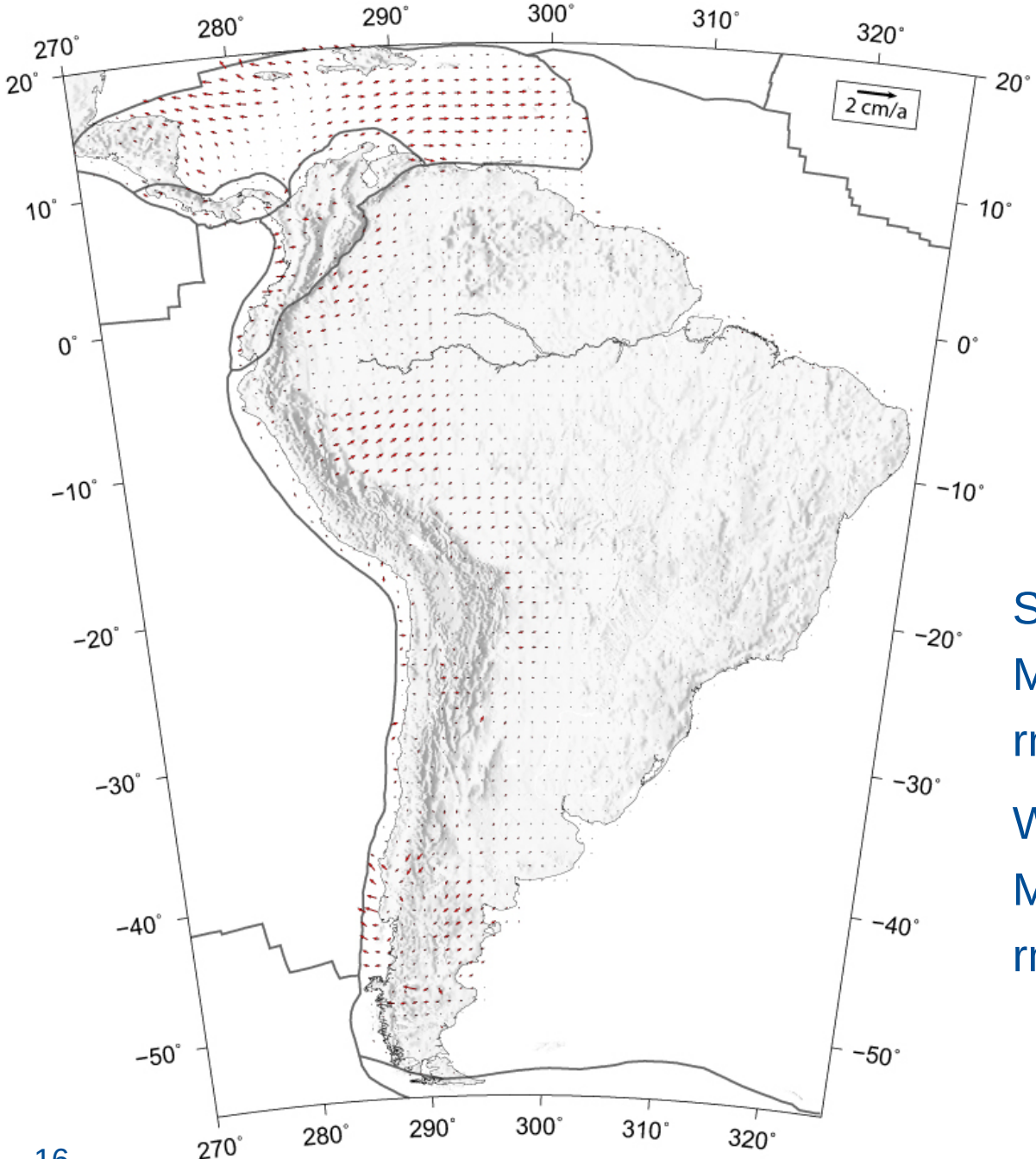

Differences between FEM and LSC

South – North component:

Min./max.: - 5 … 3,5 mm/a

rms: ± 0,8 mm/a

West – East component:

Min./max.: - 6 … 6,3 mm/a

rms: ± 1,4 mm/a

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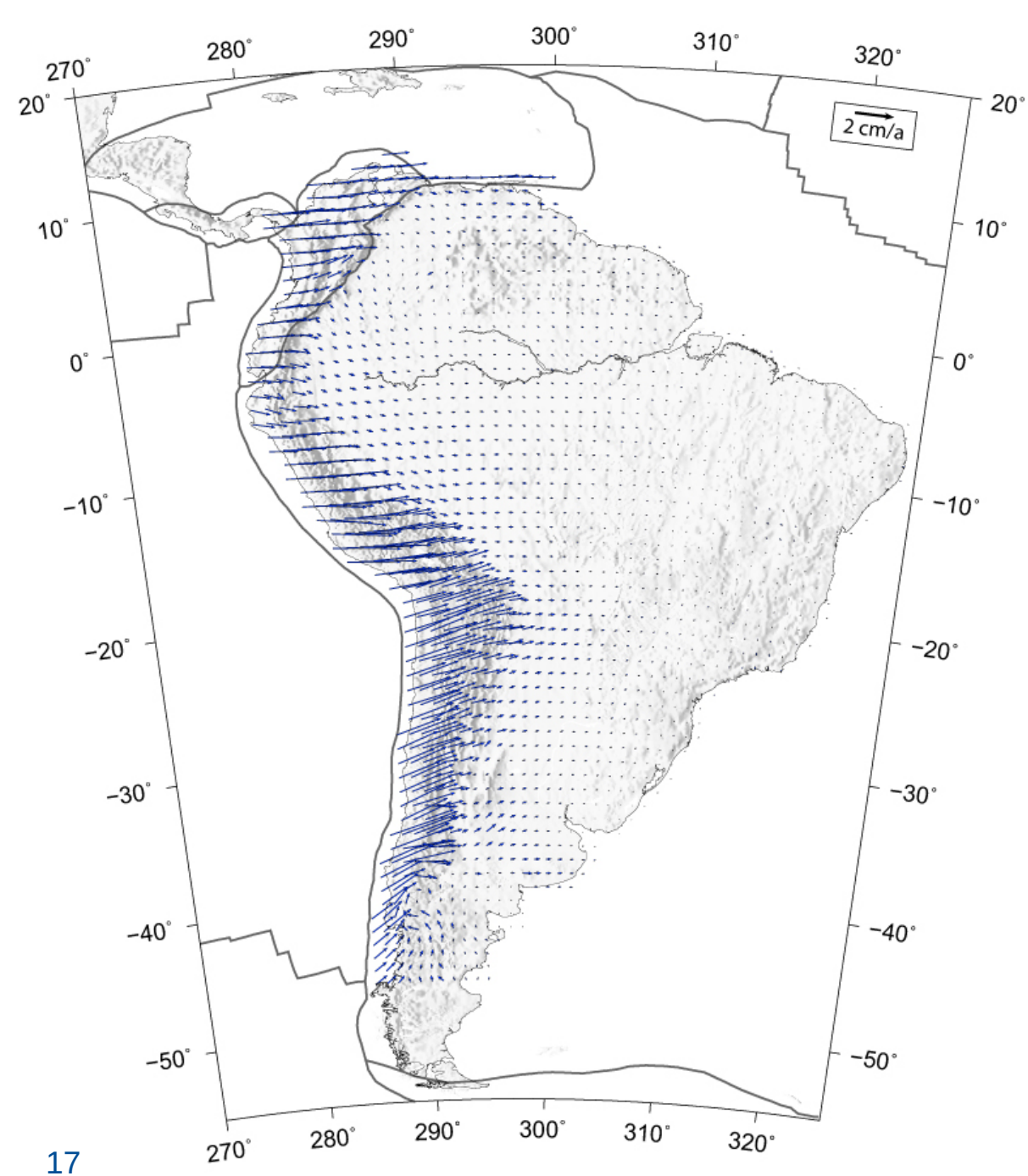

Results from VEMOS 2003

General differences:

- 329 instead of 496 observation sites
- Coverage of South American continent only
- Fault zone modelling by contact zones in FEM
- Separate prediction of “deforming” and “stable” zones in LSC

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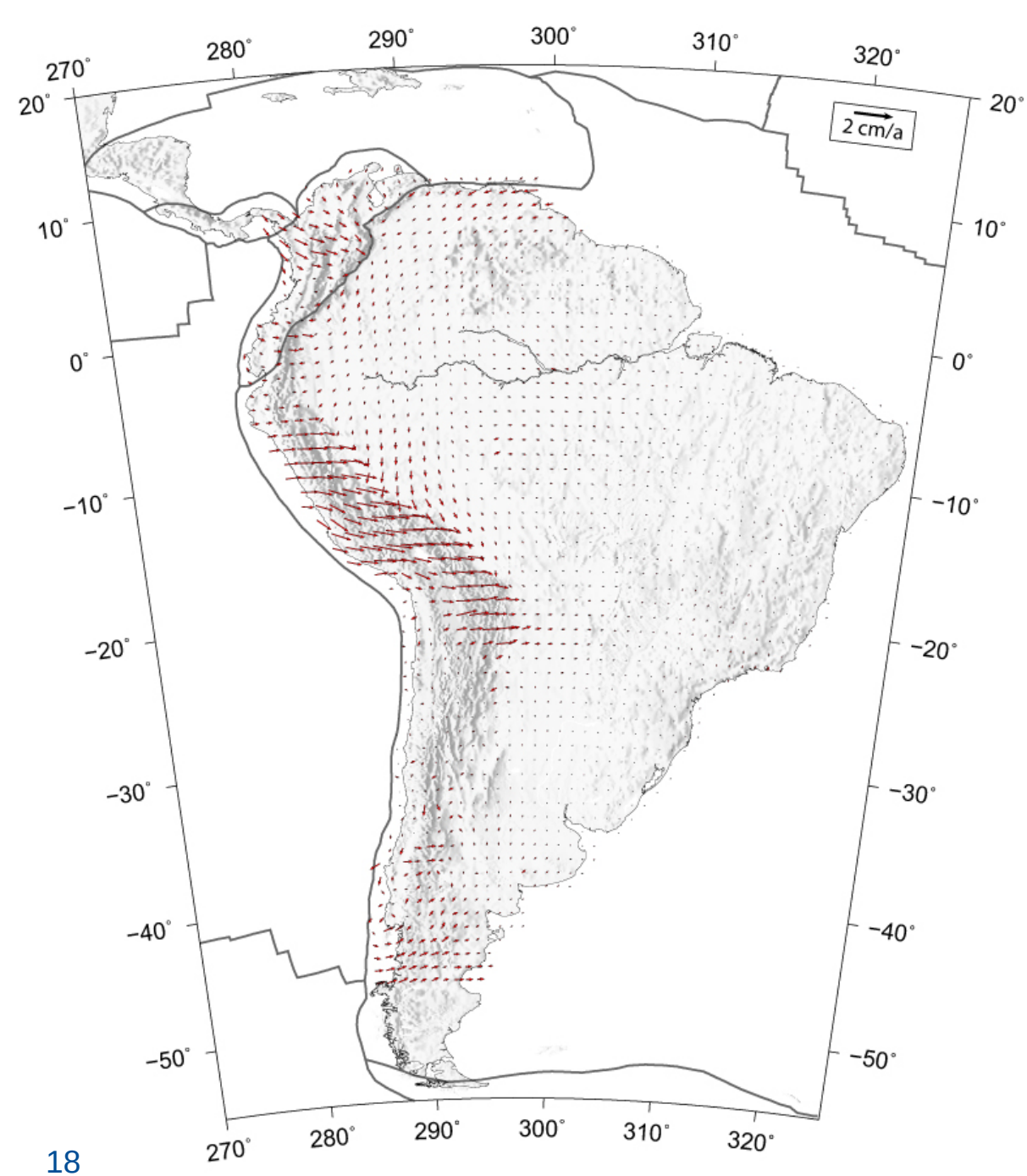

Differences of VEMOS 2003 with respect to VEMOS 2009

Differences to FEM 2009:

max. North: -8 … 3 mm/a

rms North: ± 1,4 mm/a

max. East : -8…18 mm/a

rms East : ± 3,0 mm/a

Differences to LSC 2009:

max. North: -8 … 3 mm/a

rms North: ± 1,2 mm/a

max. East : -9…18 mm/a

rms East : ± 3,4 mm/a

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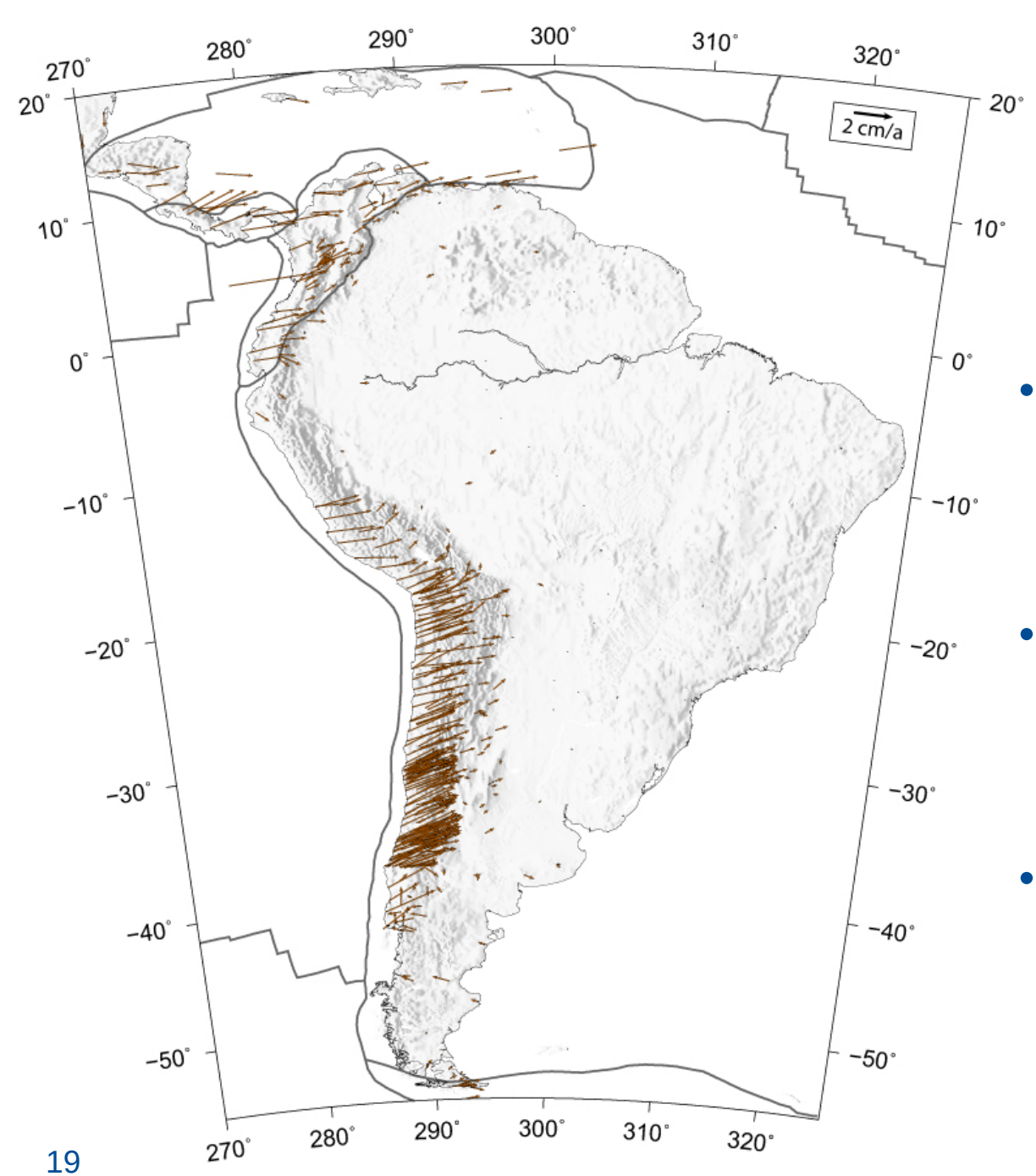

Improvement by VEMOS 2009 new input data

- Major differences from 2003 to 2009 appear, where few or no data are available (Peru, Bolivia).
- Differences in Colombia are due to new data from continuously observing SIRGAS stations.
- Differences in southern Chile are due to recent data from new projects.

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Conclusions

- Nearly 500 station velocities observed in 13 GPS projects provide a good basis for modelling the continuous present-day deformation of the Earth's crust in South America and the Caribbean.
- The overall precision of the point velocities is better than ± 1 mm/a in South-North and about ± 1,5 mm/a in West-East direction for both the finite element method and the least squares collocation approach.
- Major discrepancies appear, where only poor observation data are available. These areas have to be closed by continuously operating GPS stations. Installation is in progress in SIRGAS (www.sirgas.org).

Thank you for your attention!