

Unraveling the Effect of Convergence Obliquity on Overriding-Plate Deformation and Strain Partitioning in Subduction Zones

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Abstract The subduction of an oceanic plate causes deformation of the overriding plate, from the forearc to the back-arc regions. Over the years, to address the physical controls on such deformation, various compilations on active deformation have been made, mixing various types of datasets including fault-slip rates, focal mechanisms and geodetic motions. The growing amount of available data now allows for the construction of consistent compilations in terms of data types. Here, we present a database for the kinematics of subduction zones which includes that of the overriding-plate deformation, consistently based on geodetic data. The database describes the 2-D (trench-normal and trench-parallel) motions of arc blocks for ~90% of active subduction zones, through the magnitude (v_d) and the deformation-obliquity angle (O_{v_d}) between the blocks and the upper plate (undeformed interior of the overriding plate). We classify subduction zones into four dominant strain classes (compressional, strike-slip, extensional, and neutral), and into up to eight classes including intermediate regimes. Focusing on the strike-slip strain class, we show that a non-negligible trench-parallel motion is a widespread feature of active subduction zones. The convergence obliquity exerts, however, a contrasting effect on O_{v_d} , thereby suggesting a limited effect on strain partitioning at oblique subduction zones. On the other hand, O_{v_d} shows a positive correlation with slab dip, where low and high values are both associated with compressional and extensional classes, respectively. Finally, we provide revised estimates of subduction rates, allowing, for instance, refined estimates of the thermal parameter, which will permit future comparative investigations on subduction dynamics and tectonics.

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1 Introduction

Subduction dynamics leads to the deformation of the overriding plate, which encompasses all tectonic regimes from back-arc spreading to mountain building (Uyeda and Kanamori, 1979). Using geological and geophysical global datasets, various statistical studies have characterized the deformation of the overriding plate for present-day subduction zones, focusing on characterization of one-dimensional trench-perpendicular deformation regimes (Doglioni *et al.*, 2007; Heuret and Lallemand, 2005; Jarrard, 1986; Lallemand *et al.*, 2005; Petricca and Carminati, 2016; Schellart, 2008a,b). For instance, arc-to-backarc trench-perpendicular deformation rates were inferred from geodetic velocities and geological deformation rates by Heuret and Lallemand (2005) and Schellart (2008a). In addition, focal mechanisms were used to define semi-quantitative overriding-plate strain classes (Jarrard, 1986; Lallemand *et al.*, 2005). These studies showed some correlations of the trench-normal overriding-plate deformation with overriding-plate

motion (Heuret and Lallemand, 2005; Jarrard, 1986), with the slab dip (Lallemand *et al.*, 2005), and with the combination of overriding-plate motion and distance to a slab edge (Schellart, 2008b, 2024).

While the global statistical studies listed above focused on deciphering the controls on one-dimensional trench-normal deformation of the overriding plate, in nature deformation is, at least, a two-dimensional process, and the direction of maximum deformation most often deviates from the normal to the trench. This can produce, in extensional settings, for instance, a misorientation between the direction of back-arc spreading and the trench normal. This is the case in the southern Marianas, in the North and South Sandwich back-arcs, and most notably in the Andaman Sea. But the most striking observation on the two-dimensionality of overriding-plate deformation is strain partitioning at oblique subduction zones. Oblique subduction zones are those where the convergence vector between the subducting and the overriding plates deviates from the direction of the normal to the trench, and appear as the rule rather than the exception in present-day subduction zones (Jarrard, 1986; Philippon and Corti, 2016). In

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pioneering work, *Fitch* (1972) suggested that oblique convergence was mostly consumed along strike-slip faults quasi-parallel to the trench while the remainder was taken up on thrust structures. *Jarrard* (1986) later demonstrated that the strike-slip or transcurrent motions tend to increase with the obliquity angle (see also *McCaffrey*, 1992; *Yu et al.*, 1993), and that they are more frequent at ocean–continent subduction zones. In many cases, the strike-slip fault (system) that accommodates strain partitioning occurs in the vicinity of the arc and defines a “forearc sliver” that tends to move independently of the interior of the overriding plate. Among the most notable examples of strike-slip faults accommodating partitioning are the Great Sumatran Fault (*Bellier and Sébrier*, 1995), the Philippine Fault (*Barrier et al.*, 1991), the Southern Kuril strike-slip system (*DeMets*, 1992; *Kimura*, 1986), the Chingual-Cosanga-Pallatanga-Puná Fault in the Northern Andes (*Alvarado et al.*, 2016; *Baize et al.*, 2020) or the Yaeyama Fault in the Southern Ryukyus (*Lallemant et al.*, 1999). It is also worth noting that even though strain partitioning originally referred to partition of slip on two localized faults, the term has also been more generally used for any type of deformation partition, whether localized or diffuse, including some component parallel to the subduction trench such as the set of conjugate and transcurrent strike-slip faults in SW Japan (*Gutscher and Lallemant*, 1999) or the Sorong Fault system in New Guinea (*Patria et al.*, 2021).

Despite a long list of physical studies that investigated the conditions which may or may not allow for strain partitioning, no consensus has yet emerged (*Byrne et al.*, 1985; *Chemenda et al.*, 2000; *Cooke et al.*, 2020; *Dominguez et al.*, 1998; *Haq and Davis*, 2010; *Jarrard*, 1986; *Liu et al.*, 1995; *Martínez et al.*, 2002; *McCaffrey*, 1992; *McClay et al.*, 2004; *Suárez et al.*, 2022). One of the potential limitations in addressing strain partitioning and, more generally, the amount of overriding plate deformation in space and its relation to other subduction processes, has been the lack of a globally consistent, geodetically constrained two-dimensional database. This is precisely the purpose of the present study where we have built a database of the direction and intensity of the main sites of overriding plate deformation.

Our work updates the Submap database, which consists of 260 transects covering all present-day subduction zones approximately every 200 km (*Heuret*, 2005; *Lallemant and Heuret*, 2017). The database compiles a wide range of subduction parameters including kinematics (*Cerpa et al.*, 2022a; *Heuret and Lallemant*, 2005), subducting slab geometry (*Lallemant et al.*, 2005), structural parameters (*Heuret et al.*, 2012; *Lallemant et al.*, 2024), and characteristics of the seismogenic zone (*Heuret et al.*, 2011). It has supported studies on diverse topics, from subduction dynamics (*Faccenna et al.*, 2007; *Funiciello et al.*, 2008; *Lallemant et al.*, 2008; *Nakao et al.*, 2022) to the seismogenic behavior of the plate interface (*Brizzi et al.*, 2018; *Marzocchi et al.*, 2016; *Wirth et al.*, 2022; *van Zelst et al.*, 2025). The kinematics component of the Submap database compiles information on the

absolute plate motions and relative motions (convergence and subduction rates), as well as on the deformation rate of the overriding plate, all of which are updated in the present study following preliminary work in *Cerpa et al.* (2022a). Importantly, the previous version of the Submap kinematic database provided only the trench-normal overriding-plate deformation velocity v_{d_n} for only about 50% of the Submap transects (*Heuret and Lallemant*, 2005). Here, we reach a spatial description (full two-dimensional vector v_d) for 88% of them, consistently based on geodetic data.

Below, we describe how we built the kinematic database. Then, we assess global characteristics of overriding-plate deformation, before assessing its relationship to other subduction parameters. Finally, we discuss some implications of revised values of the rates of subducting-plate consumption at trench, i.e., the subduction velocities, which are thought to differ from the far-field convergence rates between the subducting and the overriding plates.

2 Building the kinematic database

2.1 General definitions

For describing the kinematics at each subduction transect of the Submap database, we associate each transect with a subducting plate (SP) and to an undeformed area of the overriding plate, which we refer to as the upper plate (UP) (Figure 1). The SP and the UP move at absolute velocities of V_{sub} and V_{up} , respectively. Here, by “absolute velocities” we mean velocities that describe the motion of the plates relative to a deep, stable reference frame, often taken to be the Earth’s lower mantle. The sum of these two velocities gives the convergence velocity $v_c = V_{\text{sub}} + V_{\text{up}}$, that is, the rate at which the assumed undeformable interiors of the two plates move relative to each other.

In nature, however, the overriding plate generally undergoes deformation in the forearc, in the arc and/or in the back-arc regions. The deformation may either localize on one or more faults, or be diffuse across part or all of the forearc-to-back-arc regions, sometimes leading to the formation of a sliver which moves semi-independently of the UP. Thus, to account for the overriding-plate deformation, we define a deformation velocity v_d which aims to integrate any deformation occurring from the forearc to the back-arc, whether it is distributed or localized at single faults. In doing so, we define a real or an idealized pseudo-kinematic block, which we refer to as the “arc” block (AB). The velocity of the AB relative to the UP is given by v_d . Knowing the latter, we can assess an absolute trench velocity V_{trench} which differs from V_{up} if $v_d \neq 0$. Finally, we can define the subduction velocity $v_s = V_{\text{sub}} + V_{\text{trench}}$ which best represents the rate of SP consumption at trench. It is intended to represent the slip velocity on the subduction interface estimated by geodesy, which can be compared to the seismic slip velocity inferred from the seismic moment of the earthquakes on the subduction interface (*Brune*, 1968).

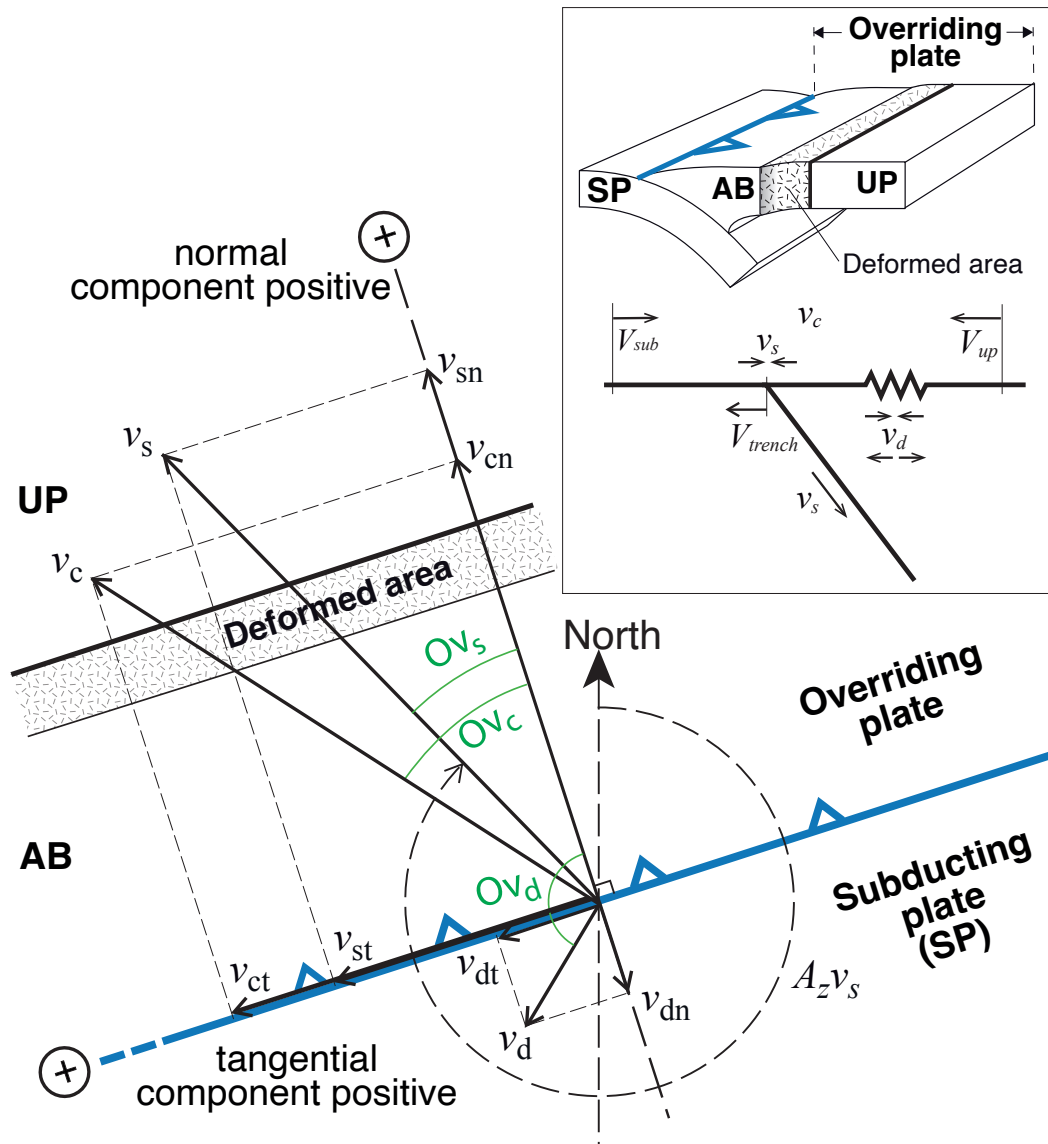


Figure 1 – Conventions used in the geometrical and kinematical description of the subduction transects in the Submap database. UP = upper plate, AB = arc block, SP = subducting plate, v_c : convergence velocity, v_s : subduction velocity, v_d : deformation velocity. The indices n and t denote the normal and tangential components, respectively, of the vectors. O_{v_x} stands for the obliquity and $A_{z v_x}$ for azimuth of the velocities.

We define the SP and UP for each subduction transect from the major plates of the plate set model MORVEL56 (Argus *et al.*, 2011), which also gives us the convergence velocities between those plates. As described in detail below, we assess the deformation velocities in the present-day subduction zones, which also permit us to provide an estimate of the subduction velocity. Moreover, although the present study focuses on relative velocities (v_c , v_s and v_d), we have calculated absolute velocities (V_{sub} , V_{up} , and V_{trench}) for each transect in four selected absolute reference frames: the MORVEL56-NNR model (Argus *et al.*, 2011), the spreading-alignment model (Becker *et al.*, 2015), the T25m model (Wang *et al.*, 2018), and the GMHRF-1Ma model (Dobrovine *et al.*, 2012). Although not exhaustive, such a selection covers part of the variety of absolute plate kinematic models, e.g., in terms of the data used to establish them (see Cerpa *et al.*, 2022a).

For all types of velocities, we calculate their obliquity O ($0 \leq O \leq 180^\circ$) and their directed obliquity $\bar{O}$ ($-180^\circ \leq \bar{O} \leq 180^\circ$) relative to the normal to the trench. We can then calculate the trench-normal and trench-parallel components of all velocities, which are denoted with the subscripts n and t , respectively.

2.2 Arc blocks and estimation of deformation velocities

We seek to characterize the deformation of overriding plates at relatively close distances to the subduction trenches, by estimating v_d for as many subduction transects as possible. This relies on the definition of an AB for several subduction segments, inferred exclusively from GPS data.

To illustrate how we integrated the deformation of the overriding plate predicted by GPS studies into v_d , we take the example of the Southeast Asia region (see

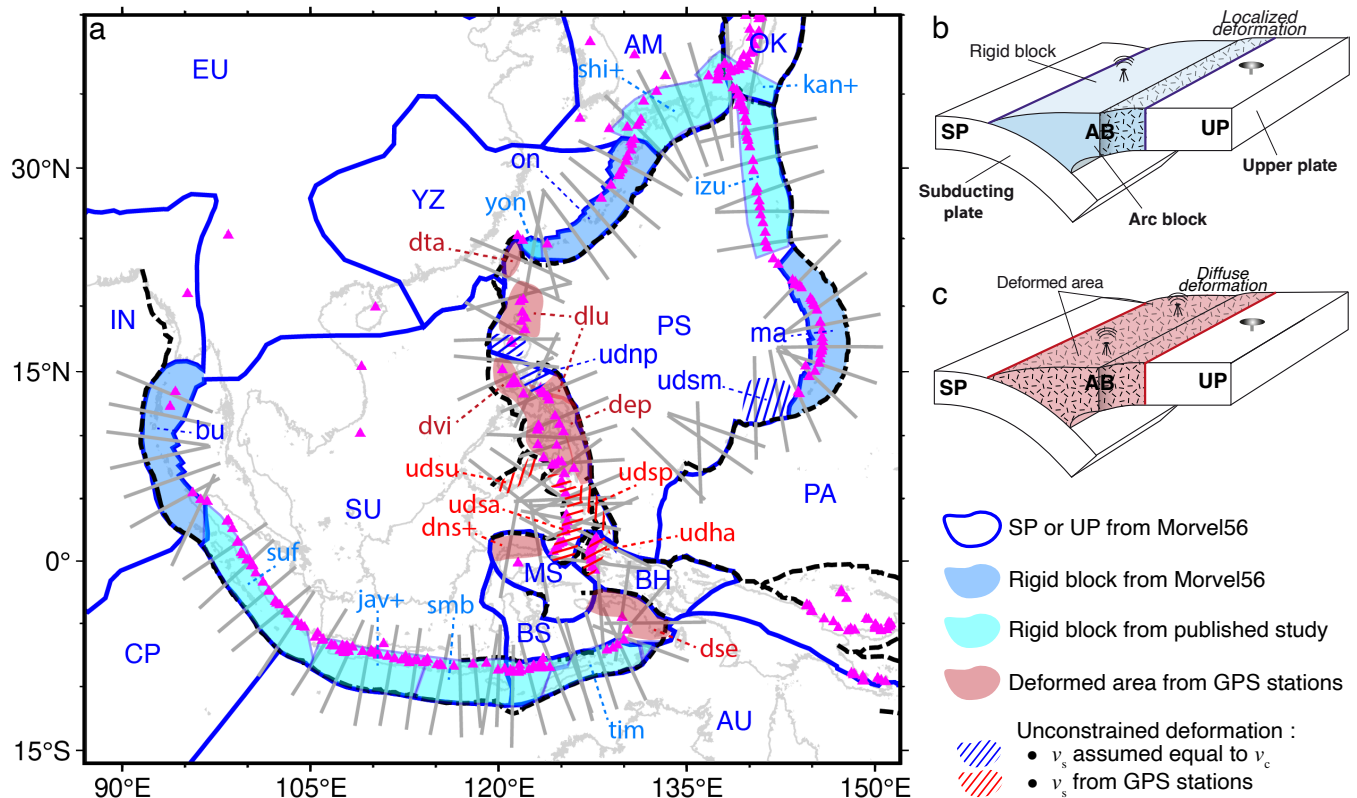


Figure 2 – Major plates and arc blocks in the Southeast-Asia region (a) and schematic illustration of two ways of assessing the AB motion (b,c). Thick blue lines represent the contours of the major plates from MORVEL56 which are used to define our SP and UP. Dark-blue filled regions represent the AB from MORVEL56. Light-blue filled regions represent the AB that we introduce from published studies. Red patches represent the regions where we found single GPS velocities (no block motion defined, i.e., deformed areas) and which we have used to estimate v_d . In a few cases, v_c is undefined but v_s can be estimated from GPS stations (red stripes). The abbreviations of plates and block names are listed in Table 1. Blue-stripe areas indicate regions where geological-evidence of deformation exists but where we have not found geodetic data to characterize the deformation. We thus assume $v_s = v_c$. The gray straight lines represent the subduction transects used in our study (i.e., the Submap transects). Black dashed lines are the subduction trenches.

Figure 2) which illustrates several possible definitions of an AB:

- An AB is defined as one of the plates in the MORVEL56 plate set (dark blue patches in Figure 2a and in Table 1), if the latter plate occupies a region which is small relative to the size of the large plates taken to be the upper plates (Eurasia plate, Sunda plate, Philippine Sea plate, etc.). This is, for instance, the case for the Andaman subduction transects for which we take the Sunda plate from MORVEL56 as the UP, and the Burma plate from MORVEL56 as the AB. This is also the case for the Mariana transects where both the UP and the AB are from the MORVEL56 plate set. Note that the latter large plates correspond to those accounted for in lower-resolution plate set models such as MORVEL (DeMets et al., 2010).
- An AB is taken from a GPS-derived rigid block defined in published studies, with available Euler pole and rotation rate (light blue patches in Figure 2a, b and Table 1). Two sub-cases exist here:
 1. The AB motion was neglected in the MORVEL56 plate set model. This is, for instance, the case for the Sumatra transects

for which the Sunda Plate from MORVEL56 is the UP, and for which we take into account the Sumatra forearc sliver block described by Bradley et al. (2017).

2. An update of the AB motion post-MORVEL56 is available and we thus modify part of a block of the MORVEL56 model. This is for example the case for the Yonaguni block at the southwestern end of the Ryukys transects (Chen et al., 2022), which replaces the southernmost solution given by the Okinawa block of MORVEL56.
- In some other cases (Taiwan, Luzon, Visayas and East-Philippines), the UP deformation appears distributed. GPS velocities have been published for specific stations (Hsu et al., 2026; Rangin et al., 1999; Simons et al., 2007; Socquet et al., 2006) but no rigid blocks have been identified in past studies. In such cases, we extract, from published studies, the motion of the station closest to the trench as a proxy of AB motion, without any threshold criterion on the velocity magnitude. We then post-calculate the deformation rate v_d between the forearc and the UP as the difference between the two GPS velocities,

thereby neglecting the interseismic loading, if any. We refer to these regions as deformed areas (red patches in Figure 2a, c and Table 1).

- In regions such as the Southernmost Marianas or the Northernmost Philippines, we did not find any published geodetic-velocity solution for the overriding plate deformation despite geological evidence of recent deformation (*Hsu et al.*, 2026; *Ribeiro et al.*, 2013). For those cases, we set v_d as undefined (rather than 0), to acknowledge the potential for active deformation (see Section 2.3 below). However, for practical use of the database, we make use of the MORVEL56 solution for v_c and assume that $v_s = v_c$ (blue stripes in Figure 2a and Table 2). Although arbitrary, we think that the latter choice is more useful than assigning an undefined v_s and aligns with the choice made in most, if not all, existing subduction kinematic databases (*Heuret and Lallemand*, 2005; *Schellart*, 2008a).
- Finally, in Halmahera, Sangihe, South Philippines or Sulu, the use of MORVEL56 plate kinematics provides unreasonable values of v_c because the UP or SP is difficult to constrain. Despite the scarcity of GPS data in those regions, we utilized the published motions of a few stations on both sides of the trench to provide first-order estimates of v_s , but not to retrieve v_d . We define these cases as areas with unconstrained deformation (red stripes in Figure 2a and Table 2).

Exceptionally, and for reasons of consistency, we have assigned a v_s extrapolated from adjacent transects to one of our transects across the Manila Trough because at this latitude only the Philippine Sea plate (UP) motion relative to the Sunda plate is known through the GPS stations installed on the Batan islets, despite the fact that the forearc deforms (*Hsu et al.*, 2026).

In addition to the above cases, there are further specificities that are not encountered in the Southeast Asia region but are worth noting for a few transects in other regions:

- For NE Japan subduction transects (Figure 3), the Okhotsk plate from MORVEL56 is taken to be the AB while the Amur plate is taken to be the UP. Further north, for the northern Kurils and for the Kamchatka transects, the Okhotsk plate is rather defined as the UP. For the South-Kuril transects, we use the solution provided by *DeMets* (1992) who combined information on both the slip vectors of subduction earthquakes and GPS data, to define the motion of a forearc sliver (AB). For North-Kuril transects (north of the Bussol Strait) we were not able to define an AB solution and did not find reported evidence of active deformation.
- For the northernmost Andean transects, the AB motion was taken from the up-to-date solution of *Jarrin et al.* (2023) in place of the entire North Andean block of MORVEL56.

Overall, this inventory leads to the use of 11 ABs from the MORVEL56 plate set, 35 additional rigid ABs and 14 additional deformed areas for which v_d is mostly indirectly constrained by single GPS stations (Table 1). Furthermore, we have also identified 13 regions where v_d is not constrained (see below and Table 2): 4 for which v_s can be derived from GPS and 9 for which we assume $v_s = v_c$. The 73 areas are displayed in Figure 3. The names of the blocks, together with the references from which they were taken, are listed in Tables 1 and 2. For the remaining regions, we consider that the deformation is negligible.

A major outcome of our updated inventory is that it enables us to characterize the deformation for 229 transects (88% of the total) of the Submap database (see Section 3.1 below), largely improving the kinematic description of subduction zones over similar past databases. These include 213 transects (82%) with a non-zero deformation velocity and 16 transects (6 %) where we determined a deformation velocity equal to zero, leaving only 31 transects (12 %) with unconstrained overriding-plate deformation.

Lastly, calculating the distance between the subduction trench and the landward boundary of the AB region for each transect, we note that our database describes the deformation of the overriding plates within a mean distance of ~ 340 km, with a minimum of ~ 100 km (in eastern Philippines) and up to a maximum of 900 km (in the Altiplano region).

2.3 Regions with undefined geodetic deformation velocities

For certain regions in which geodetic deformation velocities are, to the best of our knowledge, unavailable but geological evidence of active deformation exists, we define v_d as unconstrained (areas with stripes in Figure 3 and Table 2). However, for the estimation of subduction velocity v_s , we split those regions into those where we considered that the far-field convergence velocity v_c was reasonable and we approximated v_s as $v_c = v_s$ (blue stripes in Figure 3 and Table 2), and regions where we considered that v_c was unconstrained and retrieved v_s from single GPS data (red stripes in Figure 3 and Table 2).

The former case (blue stripes) includes the Kamchatka region, which has undergone Quaternary extension at a geological rate of 17 ± 3 mm/yr (*Kozhurin et al.*, 2006; *Kozhurin and Zelenin*, 2017), Central Chile with evidence of Plio-Quaternary compression through tectonic inversion of former extensional faults (*Becerra et al.*, 2013), southernmost Patagonia where the forearc consists of the western end of the Scotia plate sliding along the Magallanes-Fagnano left-lateral fault system at a rate of 8.1 ± 1.5 mm/yr (*Perucca et al.*, 2016), some poorly constrained subduction zones of Southeast Asia including the Banda Sea (Aru, Seram), the Philippines (S- and N-Philippines), and the Celebes Sea (Cotabato, Sulu), the southernmost Mariana arc and forearc undergoing trench-parallel extension (*Ribeiro et al.*, 2013), the Solomon arc which is shortened by

Table 1 – List of “arc blocks” (ABs), including the short names as they appear in Figures 2 and 3. The symbol “+” stands for cases where we have merged together several blocks into a single one on the figures (i.e., aggregates). The prefix “DEF_” indicates that the deformation is constrained by data on single GPS stations, not from a rigid-block solution. The color code in the last column matches that used in Figures 2 and 3.

AB types (constrained v_d)	Short names incl. aggregates (+)	AB names	Sources	Number of ABs		
MORVEL56 rigid blocks	ok	OKHOTSK	<i>Argus et al.</i> (2011)	11		
	pa	PANAMA	<i>Argus et al.</i> (2011)			
	ap	ALTIPLANO	<i>Argus et al.</i> (2011)			
	sw	SANDWICH	<i>Argus et al.</i> (2011)			
	bu	BURMA	<i>Argus et al.</i> (2011)			
	on	OKINAWA	<i>Argus et al.</i> (2011)			
	ma	MARIANA	<i>Argus et al.</i> (2011)			
	sb	SOUTH BISMARCK	<i>Argus et al.</i> (2011)			
	nb	NORTH BISMARCK	<i>Argus et al.</i> (2011)			
	to	TONGA	<i>Argus et al.</i> (2011)			
	ke	KERMADEC	<i>Argus et al.</i> (2011)			
additional rigid blocks (our compilation of published studies)	aeg+	WESTERN PELOPONNESE	<i>Vernant et al.</i> (2014)	35		
		AEGEAN SEA	<i>Vernant et al.</i> (2014)			
		RHODES	<i>Vernant et al.</i> (2014)			
		ISPARTA	<i>Vernant et al.</i> (2014)			
	lut	LUT	<i>Reilinger et al.</i> (2006)			
	ala+	PENINSULA	<i>Elliott and Freymueller</i> (2020)			
		KODIAK	<i>Elliott and Freymueller</i> (2020)			
		PRINCE WILLIAM SOUND	<i>Elliott and Freymueller</i> (2020)			
		ICY BAY	<i>Elliott and Freymueller</i> (2020)			
	sme	SOUTHERN MEXICO	<i>Andreani et al.</i> (2008)			
	caf	CENTRAL AMERICAN FOREARC	<i>Carvajal-Soto et al.</i> (2020)			
	nan+	BONAIRE	<i>Jarrin et al.</i> (2023)			
		SAN JACINTO	<i>Jarrin et al.</i> (2023)			
		ROMERAL	<i>Jarrin et al.</i> (2023)			
		NORTH ANDEAN WEST	<i>Jarrin et al.</i> (2023)			
		PERUVIAN FOREARC WEST	<i>Jarrin et al.</i> (2023)			
		HISPANIOLA	<i>Calais et al.</i> (2023)			
		his+	PUERTO-RICO		<i>Calais et al.</i> (2023)	
		NORTH HISPANIOLA	<i>Calais et al.</i> (2023)			
	per	PERU	<i>Villegas-Lanza et al.</i> (2016)			
	can	CENTRAL ANDES	<i>Brooks et al.</i> (2003)			
	suf	SUMATRA FOREARC	<i>Bradley et al.</i> (2017)			
	jav+	WEST JAVA	<i>Koulali et al.</i> (2017)			
		EAST JAVA	<i>Koulali et al.</i> (2016)			
	smb	SUMBA	<i>Koulali et al.</i> (2016)			
	tim	TIMOR	<i>Koulali et al.</i> (2016)			
	yon	YONAGUNI	<i>Chen et al.</i> (2022)			
	shi+	SHIKOKU	<i>Nishimura et al.</i> (2018)			
		CHUBU	<i>Nishimura et al.</i> (2018)			
	kan+	IZU	<i>Nishimura</i> (2011)			
		KANTO	<i>Nishimura</i> (2011)			
	izu	IZU BONIN ARC	<i>Nishimura</i> (2011)			
	nhe+	NORTH NEW-HEBRIDES	<i>Bergeot et al.</i> (2009)			
		CENTRAL NEW-HEBRIDES	<i>Bergeot et al.</i> (2009)			
		SOUTH NEW-HEBRIDES	<i>Bergeot et al.</i> (2009)			
additional deformed areas (v_d based on GPS stations, our compilation)	dca	DEF_CALABRIAN ARC	<i>Serpelloni et al.</i> (2007)	14		
	dku	DEF_KURIL FOREARC	<i>DeMets</i> (1992)			
	dko	DEF_KOMANDORSKY FOREARC	<i>Cross and Freymueller</i> (2008)			
	dor+	DEF_VANCOUVER ISLAND	<i>Mazzotti et al.</i> (2003)			
		DEF_OREGON	<i>Mazzotti et al.</i> (2002)			
	dja	DEF_JALISCO	<i>Selvans et al.</i> (2011)			
	dsa	DEF_SOUTH ANDES	<i>Wang et al.</i> (2007)			
	des	DEF_SERAM	<i>Rangin et al.</i> (1999)			
	dns+	DEF_MANADO	<i>Socquet et al.</i> (2006)			
		DEF_NORTH SULA	<i>Socquet et al.</i> (2006)			
	dep	DEF_EAST PHILIPPINES	<i>Rangin et al.</i> (1999)			
	dlu	DEF_LUZON	<i>Hsu et al.</i> (2026)			
	dvi	DEF_VISAYAS	<i>Simons et al.</i> (2007)			
	dta	DEF_TAIWAN	Y.-J. Hsu (pers. comm., 2023)			
	Total				60	

Table 2 – List of complementary areas where we have derived subduction velocities without any constraints on the deformation velocity (which is also highlighted by the use of the prefix “UNDEF_” for these regions). The hatched symbols in the last column match those used in Figures 2 and 3.

AB types (unconstrained v_d)	Short names incl. aggregates (+)	AB names	Sources	Number of ABs
areas with GPS-derived v_s and undefined v_c (our compilation)	udha	UNDEF_HALMAHERA ARC	<i>Rangin et al. (1999)</i>	 4
	udsa	UNDEF_SANGIHE ARC	<i>Rangin et al. (1999)</i>	
	udsp	UNDEF_SOUTH PHILIPPINES	<i>Rangin et al. (1999)</i>	
	udsu	UNDEF_SULU ARC	<i>Simons et al. (2007)</i>	
areas with MORVEL56-derived v_c used as a proxy for v_s (our compilation)	udka	UNDEF_KAMCHATKA		 9
	udcc	UNDEF_CENTRAL CHILE		
	udpa	UNDEF_SOUTH PATAGONIA		
	udsm	UNDEF_SOUTH MARIANA		
	udnp	UNDEF_NORTH PHILIPPINES		
		UNDEF_SOLOMONS		
	udso+	UNDEF_SANTA-CRUZ		
	udma	UNDEF_MATTHEW ISLAND		
	udpu	UNDEF_PUYSEGUR		
Total				13

subduction-collision of the Ontong-Java plateau (*Mann and Taira, 2004*), the southernmost New Hebrides where the arc rotates clockwise as a result of its indentation by the Loyalty Arc (*Patriat et al., 2015*), as well as the Puysegur Ridge hosting the right-lateral transcurrent Puysegur Fault (*Collet et al., 1995*).

The regions where we could only define v_s from GPS stations (red stripes) lie in regions of very complex deformation, often displaying high UP and/or SP deformation such as in the Molucca Sea area (*Rangin et al., 1999*).

3 Upper-plate deformation: general characteristics and comparison to geological constraints

3.1 Defining strain classes from the obliquity of the deformation velocity

To globally analyze the kinematics of overriding-plate deformation from arc to back-arc regions, we define strain classes (e.g., *Lallemand et al., 2005*). Our classification is based on the obliquity O_{v_d} of the overriding plate deformation velocity, which represents the misorientation of v_d relative to the trench-normal and ranges from 0 to 180° (see Figure 1). Alternatively, we use the directed obliquity $\overline{O}_{v_d}$ which spans the range -180° to 180° (positive for right-lateral and negative for left-lateral components of sliver motions). The reasoning behind our choice is based on the fact that, within this framework, ideal cases of pure overriding plate compression, extension, and ideal strike-slip correspond to values of O_{v_d} equal to 0°, 180°, and 90°, respectively (see Figure 1).

However, the direction of overriding plate deformation generally deviates from these three ideal cases. To account for this, we expand the definition by dividing

the angular space into three equal regimes, each corresponding to a dominant strain class (see Figure 4a):

- Dominant compression: $O_{v_d} < 45^\circ$ (or $-45^\circ < \overline{O}_{v_d} < 45^\circ$).
- Dominant extension: $135^\circ \leq O_{v_d} \leq 180^\circ$ (or $135^\circ \leq \overline{O}_{v_d} \leq 180^\circ$ & $-180^\circ \leq \overline{O}_{v_d} \leq -135^\circ$).
- Dominant strike-slip: $45^\circ \leq O_{v_d} < 135^\circ$ (or $45^\circ \leq \overline{O}_{v_d} < 135^\circ$ & $-135^\circ < \overline{O}_{v_d} \leq -45^\circ$).

These three dominant classes can be further subdivided into seven strain (sub)classes composed of three pure-strain classes (C, E, SS) and four other combinations of these endmembers (C-SS, SS-C, E-SS, and SS-E), as illustrated in Figure 4a. We emphasize that, below, we will use the term “dominant compression” to describe collectively the subclasses C and C-SS, “dominant strike-slip” for SS-C, SS, and SS-E, and “dominant extension” for E and E-SS.

It is worth noting that some necessary simplifications underlie our approach to derive strain (sub)classes based on the value of O_{v_d} . In particular, our dominant compressional and extensional regimes are good descriptors of (quasi-)trench normal compression and extension. Quasi-trench parallel compression or extension would instead fall into our SS classes. Likewise, our strike-slip class is well suited to characterize quasi-trench parallel strike-slip deformation, while oblique to trench-normal strike-slip systems would lie in our C or E classes. However, we argue that these concern only a few cases and that the advantage of our classification is that it permits a consistent global analysis.

With the above caveats in mind, Figures 4b–f provide a global view of the overriding-plate deformation calculated for 213 transects of our database (those with non-zero values which represent 82% of the total), as well as their associated strain classes. A more synthetic and schematic global overview is provided in Figure 5 along with a pie chart of absolute number and relative

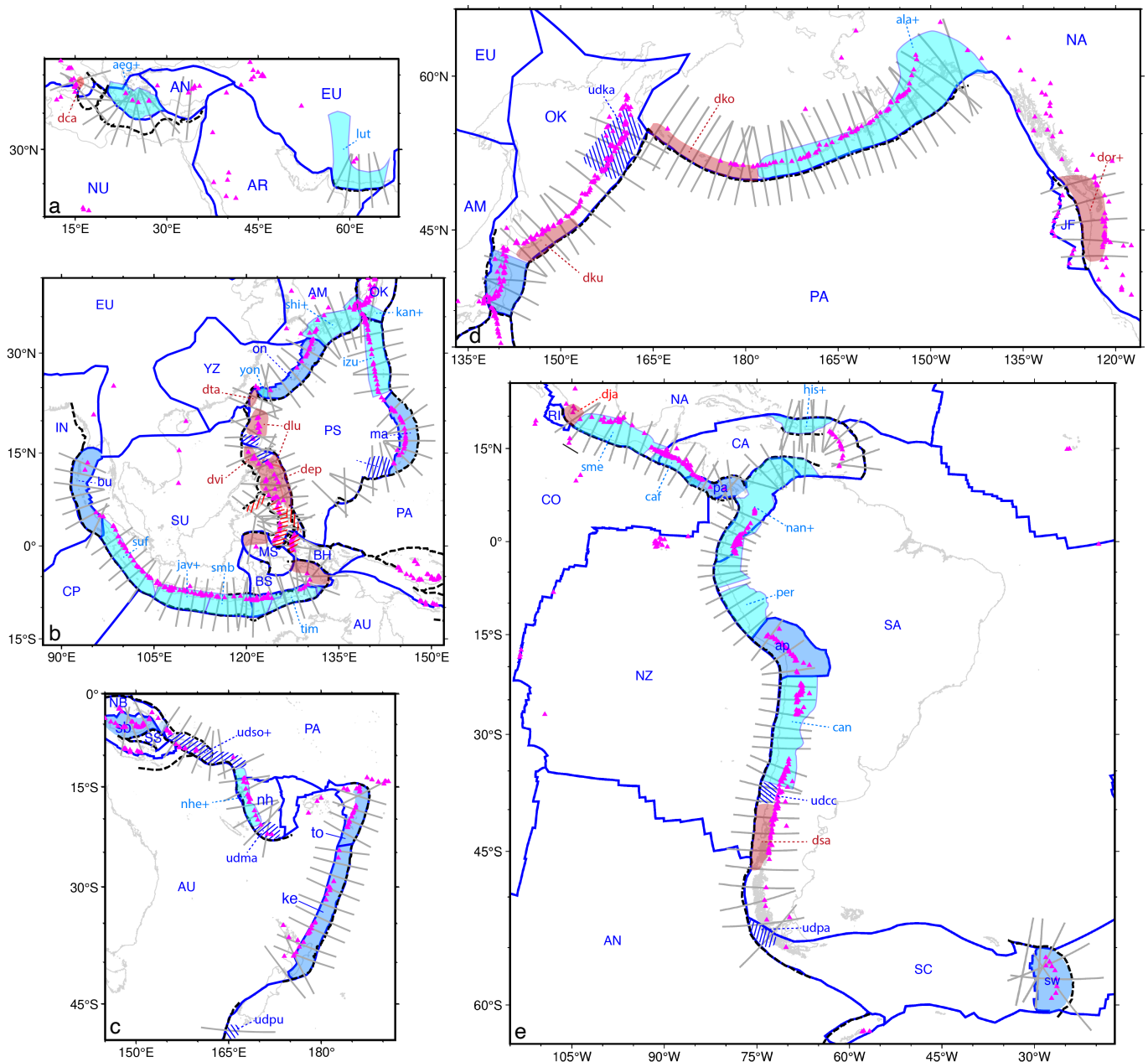


Figure 3 – Maps with all AB and deformed regions accounted for in our kinematic database (a- Mediterranean and Makran, b- Southeast Asia, c- Southwest Pacific, d- North Pacific, e- Central & South America, Caribbean & South Sandwich). See Figure 2 for legend details.

distribution (relative to the total number of transects). In the database, we count 40 (16% of all transects), 39 (15% of all transects), and 134 (52% of all transects) transects belonging to the three classes: dominant compression (C, C-SS), dominant extension (E, E-SS) and dominant strike-slip (SS, SS-C, SS-E), respectively.

Transects in the pure compression (C, $O_{vd} < 10^\circ$) or pure extension (E, $O_{vd} \geq 170^\circ$) regimes are relatively rare (each representing only 3% of all of our transects). The few transects having a pure C regime are in E-Makran (Reilinger et al., 2006), E-Alaska (Elliott and Freymueller, 2020) and C-Andes (Altiplano; Argus et al., 2011). The transects under pure E regime are found in C-Ryukyus (Argus et al., 2011), the C-Sandwich (Argus et al., 2011), in W-Mexico (Andreani et al., 2008; Selvans et al., 2011) and in N-Marianas (Argus et al.,

2011). Compression associated with strike-slip (C-SS, $10^\circ \leq O_{vd} < 45^\circ$) as well as extension associated with strike-slip (E-SS, $135^\circ \leq O_{vd} < 170^\circ$) represent 13 and 12% of the transects, respectively. C-SS regime is observed along the Andes in Ecuador (Jarrin et al., 2023) and in C-Chile (Brooks et al., 2003), in Timor and Flores (Koulali et al., 2016), in W-Makran (Reilinger et al., 2006), or in C-New Hebrides due to the subduction of the D'Entrecasteaux Ridge (Bergeot et al., 2009). E-SS regime is observed in Calabria (Serpelloni et al., 2007) and the Hellenic area (Vernant et al., 2014), in the Tonga-Kermadec (Argus et al., 2011) and in some portions of the Izu-Bonin-Mariana (Argus et al., 2011; Nishimura, 2011), in C-Aleutians (Elliott and Freymueller, 2020) and in New Britain (Argus et al., 2011).

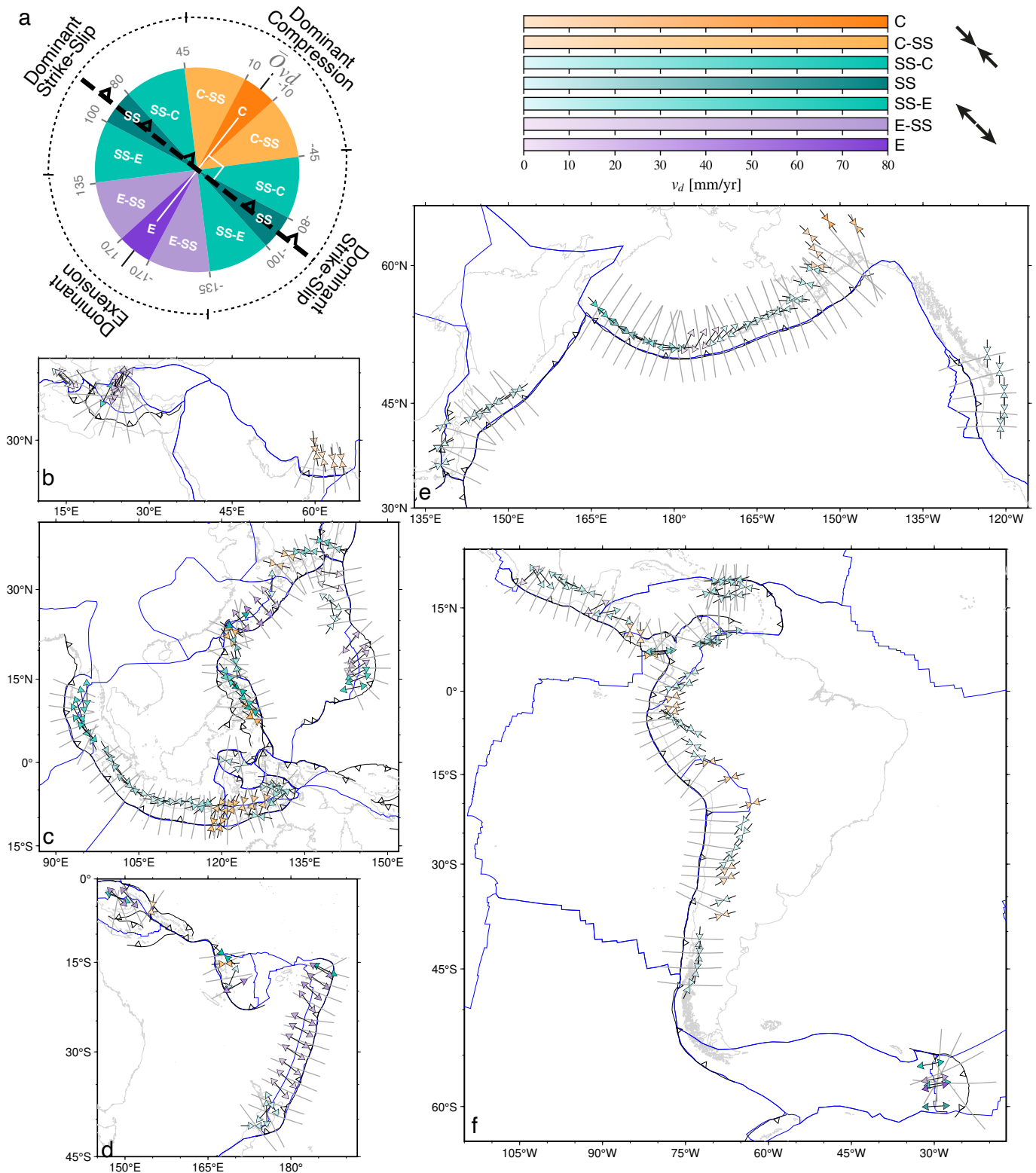


Figure 4 – Maps of the deformation velocity vector v_d represented at the intersection between the subduction transects and the inner boundaries of the arc blocks and colored by the magnitude and the associated strain regime. The top-left diagram (a) illustrates the classes of strain (dominant) regimes defined as a function of the directed obliquity $\bar{O}_{v_d}$ between the trench-normal and v_d .

A pure strike-slip regime (SS, $O_{v_d} = 90 \pm 10^\circ$) is observed in 14% of the subduction zone transects including in the Sumatra (Bradley et al., 2017), the S-Kurils (DeMets, 1992) trenches, in Cascadia (Mazzotti et al., 2002, 2003), in southernmost Chile (Wang et al., 2007), and along some transects of the W- and the E-Aleutians trenches (Cross and Freymueller, 2008;

Elliott and Freymueller, 2020). In a higher number of cases though, the lateral component of the deformation is combined with either compression (23% of transects, SS-C, $45^\circ \leq O_{v_d} < 80^\circ$) or extension (15% of transects, SS-E, $100^\circ \leq O_{v_d} < 135^\circ$). Typical cases of the SS-C regime are in the Andes (Brooks et al., 2003; Jarrin et al., 2023; Villegas-Lanza et al., 2016), in the W-Aleutians

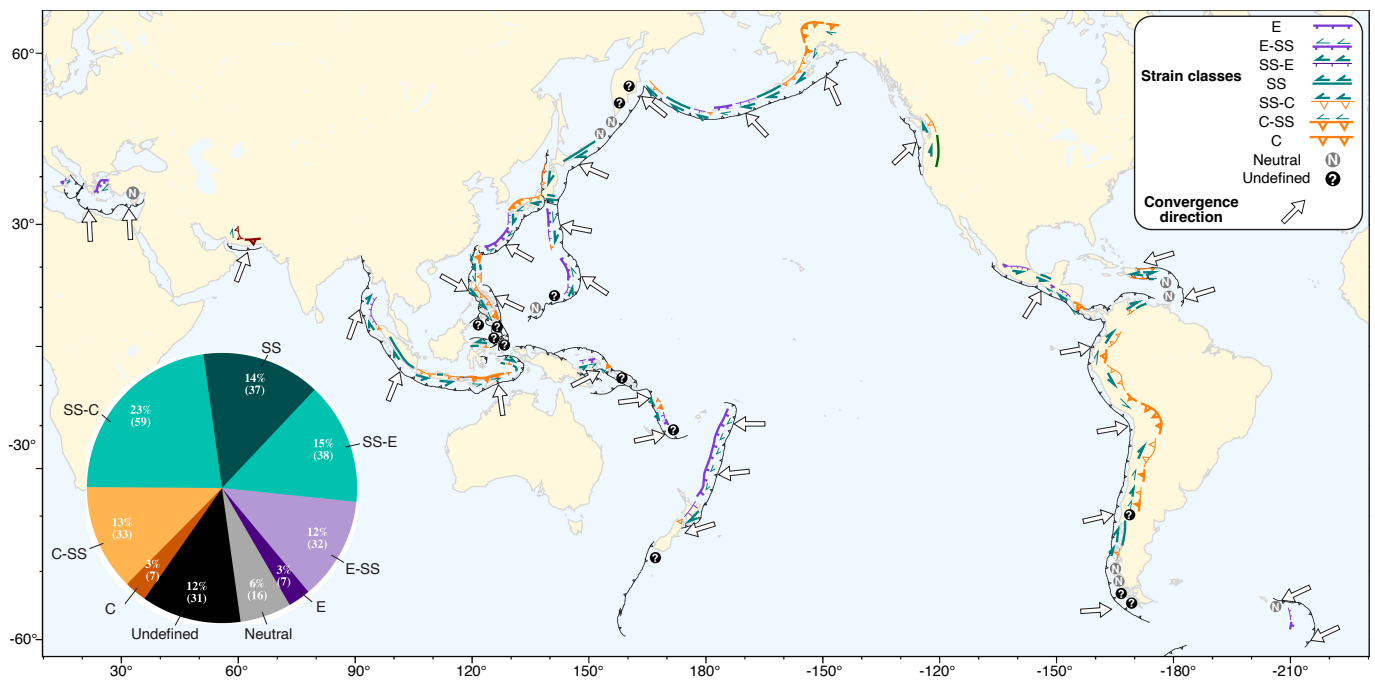


Figure 5 – Schematic global view of the strain classes determined in our study with their distribution (pie chart). The symbolic representation of overriding-plate deformation is positioned at the boundary between AB and UP. Note that our representation is intentionally schematic and is not intended to always represent actual geological structures. The azimuth of some faults may therefore not correspond to that observed in the field.

and in W-Alaska (Cross and Freymueller, 2008; Elliott and Freymueller, 2020), in Japan (Argus et al., 2011; Nishimura et al., 2018), in C-Philippines (Rangin et al., 1999), in W-Java (Koulali et al., 2017), and on the Muertos Trough (Calais et al., 2023). Examples of SS-E strain regime are observed in C-America (Andreani et al., 2008; Carvajal-Soto et al., 2020), in Andaman (Argus et al., 2011), in the Aleutians (Cross and Freymueller, 2008; Elliott and Freymueller, 2020), in the Izu-Bonin-Mariana (Argus et al., 2011; Nishimura, 2011), in Tanimbar (Zhao et al., 2023) and Hikurangi (Argus et al., 2011).

We have further classified 6% of our transects as neutral ($v_d = 0$). Typically, the Lesser Antilles falls into this category as it does not show significant upper plate deformation (Symithe et al., 2015).

Finally, we have 31 transects (12% of the total) which we classify as “undefined” since geological observations suggest active tectonics but no geodetic-based quantification of it has been proposed (see Section 2.3).

In what follows, although we classified our transects into 8 subclasses of strain regimes (and one “undefined” subclass) we will carry out our analysis by describing them only in terms of the three classes of dominant regime (cf. Figure 4a).

3.2 Global trends of UP-deformation velocities

The mean of all magnitudes of v_d is ~ 23 mm/yr but the distribution of the magnitudes shows significant differences depending on the dominant strain class (Figure 6a). The mean v_d for both the dominant compression and strike-slip regimes is around 20

mm/yr, while dominant-extension settings yield a mean v_d of about 40 mm/yr. As expected, the highest magnitudes (> 80 mm/yr) of overriding-plate deformation rates are found exclusively for regimes of dominant extension. These highest v_d are predicted for fast-spreading centers in the back-arcs of Tonga and New Britain subduction zones. More moderate extensional deformation rates (40-80 mm/yr) are observed for the Kermadec, the Ryukyus and the Marianas back-arcs. On the contrary, overriding plates under dominant compression experience mostly deformation rates of less than 50 mm/yr, with 75% of compressive transects deforming at less than approximately 30 mm/yr. Some anomalously high deformation rates are found for the South-Philippines transects, reflecting both strike-slip at the Philippine fault and the presence of retro-subduction zones (Cotabato, Sulu/Negros SZs), and at the site of the collision between the D’Entrecasteaux Ridge and the New Hebrides subduction trench. The transects with overriding plates under a dominant strike-slip regime also show mostly deformation rates of less than ~ 50 mm/yr. The highest value (81 mm/yr) is predicted for one C-Philippines transect for the reason explained above. Other moderately high values of deformation in strike-slip systems (50-60 mm/yr) come from oblique-spreading settings (Andaman, S-Sandwich, S-Marianas).

To further analyze the deformation rates, we can decompose the rate v_d into a trench-normal component v_{dn} and a trench-parallel/tangential component v_{dt} (Figure 1). Our definition of the trench-normal component v_{dn} is such that overriding plates under dominant compression yield positive values of v_{dn} , while those under dominant extension yield negative

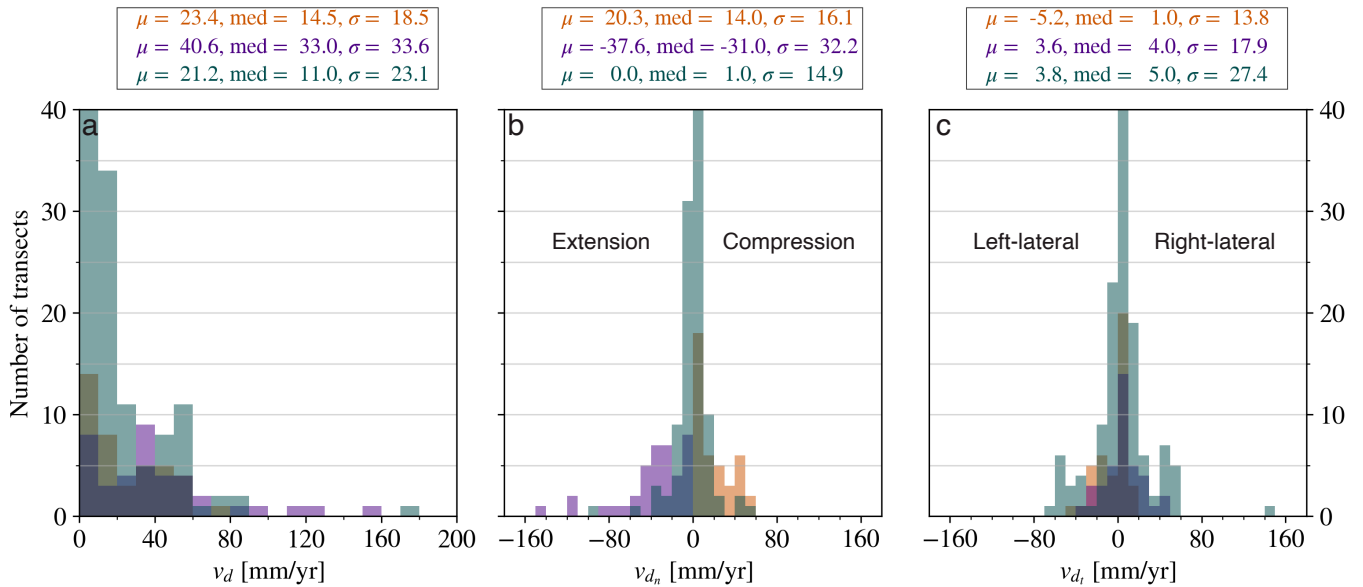


Figure 6 – Distribution of overriding plate deformation rates determined for all transects of the Submap database. a) magnitude of deformation velocity v_d , b) normal component v_{d_n} of deformation velocity, c) tangential component v_{d_t} of the deformation velocity. For each, we provide the mean (μ), the median (med) and the standard deviation (σ).

values. The transects with overriding plates under dominant strike-slip motion can be associated with either positive or negative values of v_{d_n} , depicting either overall transpressional or transtensional regimes, respectively. In addition, the trench-parallel component v_{d_t} is also signed with positive values indicating right-lateral strike slip, and negative values left-lateral strike slip (Figure 6c).

Figure 6b shows that the values of the trench-normal components of deformation v_{d_n} have absolute values of less than 60 mm/yr (mean of 20 mm/yr and of -38 mm/yr for compression and extension, respectively) with a few transects under dominant extension experiencing higher rates of extension. The absolute values $|v_{d_n}|$ are generally higher for extensional regions than for compressional regions, as noted above for the magnitude of the deformation vector. The transects falling under our dominant strike-slip class display values of v_{d_n} with a mean of 0 mm/yr and values of $|v_{d_n}|$ with a relatively low mean of ~ 6 mm/yr. Transtension and transpression are almost equally represented among the subduction transects. Figure 6c shows that the distribution of the trench-parallel component v_{d_t} for all regimes has relatively low mean values (between -5 and 5 mm/yr). For systems under dominant strike-slip the mean of the absolute value $|v_{d_t}|$ is ~ 20 mm/yr and can reach values as high as 60 mm/yr. Within our classification framework there are more right-lateral strike slip systems ($\sim 2/3$) than left-lateral ($\sim 1/3$).

3.3 Relationship between the deformation velocity v_d and the convergence velocity v_c

3.3.1 Degree of strain partitioning

The trench-parallel component of deformation in subduction zones is thought to be promoted by the

obliquity of the convergence between SP and UP (e.g., *Jarrard, 1986; McCaffrey, 1992*). Before re-assessing this relationship based on our estimations of deformation in overriding plates, we first provide an overview of how the convergence and the deformation velocities compare in terms of their normal and tangential components, by calculating the ratios $\frac{|v_{d_n}|}{|v_{c_n}|}$ and $\frac{|v_{d_t}|}{|v_{c_t}|}$, respectively. Hereafter, we refer to the ratios $p_n = \frac{|v_{d_n}|}{|v_{c_n}|}$ and $p_t = \frac{|v_{d_t}|}{|v_{c_t}|}$, as the normal and the lateral partition coefficients, respectively. Note that the latter (which could also be written in the form $p_t = 1 - \frac{|v_{s_t}|}{|v_{c_t}|}$) is identical to the definition used by *Chemenda et al. (2000)* but differs from alternative definitions used in other studies (e.g., $1 - \frac{\theta_s}{\theta_c}$ used in *Liu et al. (1995)* and *Martínez et al. (2002)*).

The first striking observation for the normal partition coefficient (Figure 7a) is that only extensional deformation velocities can exceed the trench-normal component of convergence. This is most notably the case for the Sandwich ($p_n \approx 7-8$), the New Britain ($p_n \approx 8-13$) and the W-Aegean (p_n up to 10) transects, where the trench-normal convergence component mostly remains under 10 mm/yr while the trench-normal component of extension rate is higher than 30 mm/yr, reaching 110 mm/yr in New Britain. The normal partition coefficient p_n for compressive transects mostly display values of less than 0.6 (75% of transects). The highest values (0.6 to 1) of p_n in compressive settings correspond to regions where a retro-subduction zone develops (Panama, Tanimbar, Timor, Flores, Philippines) or where subduction of a prominent buoyant feature tends to create a collisional context (Alaska, New Hebrides).

Figure 7b shows the lateral partition coefficient for transects falling within our dominant strike-slip class. More than 75% of those transects have a lateral

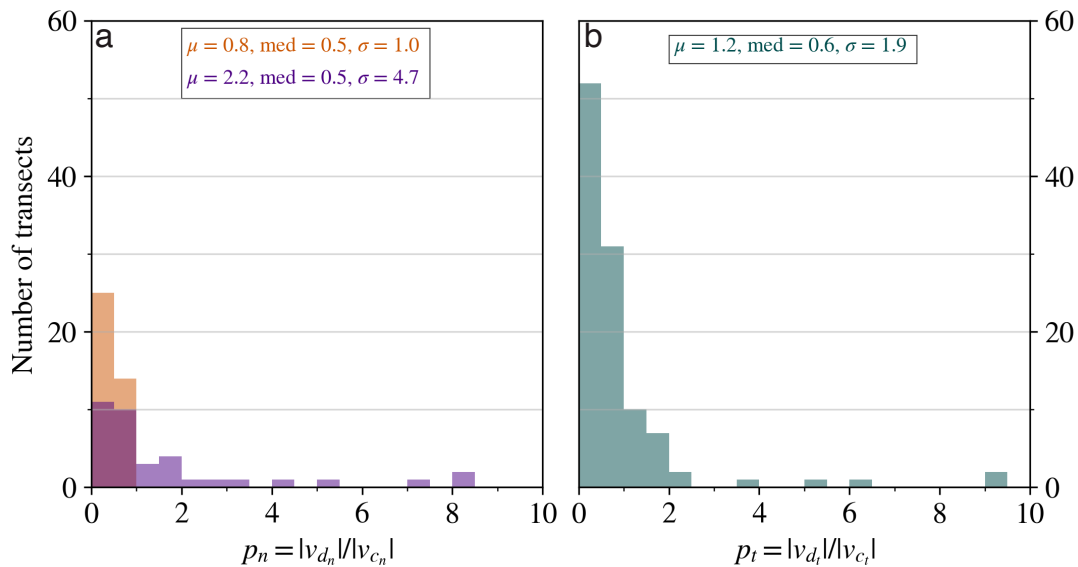


Figure 7 – Ratios of the components of overriding plate deformation velocities to the components of the convergence velocities. Other legend details are as in Figure 6.

partition coefficient p_t of less than 0.9. Those which have a trench-parallel overriding plate deformation velocity largely exceeding the trench-parallel convergence velocity ($p_t \gtrsim 5$) include those portions of subduction zones experiencing spreading in a direction that departs from the normal to the trench due to trench curvature. These cases generally fall into the SS-E regime and include the southernmost Marianas ($p_t \approx 8$), the Sandwich ($p_t \approx 7-8$), the C-New Hebrides ($p_t \approx 8$) and westernmost Aegean ($p_t \approx 5$). Large values of p_t are also found in regions with oblique retro-arc subduction zones falling in our SS-C regime such as Manila ($p_t \approx 9$) and easternmost Java ($p_t \approx 6$). Other transects having a high lateral partition coefficient ($p_t \approx 1-5$) include the northernmost Tonga ($p_t \approx 4$), C- and W-Java ($p_t \approx 1-1.5$), N-Sumatra and Andaman ($p_t \approx 1.5-2$), as well as the Mexican subduction trench ($p_t \approx 1-5$) and fall into various strain classes (E-SS, SS-E, SS-C and C-SS).

3.3.2 Relationship between the directed obliquities $\overline{O}_{v_c}$ and $\overline{O}_{v_d}$

A first-order correlation analysis reveals that, among all kinematic variables (from relative and absolute velocities) and slab dip, the (directed) obliquity of deformation best correlates with the (directed) obliquity of convergence (see Supporting Information Figures S1 and S2). Figure 8 shows the trends between deformation $\overline{O}_{v_d}$ and convergence $\overline{O}_{v_c}$ directed obliquities for all transects with non-null v_d . Seven transects, all under the strike-slip dominant regime, exhibit values $|\overline{O}_{v_c}| > 90^\circ$ which, in the absence of deformation within the arc block, would theoretically represent eduction rather than subduction. We note, however, that these seven transects are all located in five regions (Venezuela, N-Andaman, W-Aegean, E-Tanimbar, Panama) corresponding to subduction zone terminations where the trench azimuth becomes

subparallel to v_c and where lateral displacement of AB re-establishes convergence between AB and SP.

We note that 84% of the transects undergoing overriding-plate deformation display deformation directed obliquities $\overline{O}_{v_d}$ that are compatible (i.e., have the same sign) with the directed obliquity of the convergence $\overline{O}_{v_c}$, regardless of the tectonic regime. We find that, for these transects, the two variables display an apparent linear correlation coefficient of approximately 0.76 despite important scatter (see Figure S2). The other 16% of the transects with different signs of $\overline{O}_{v_d}$ and $\overline{O}_{v_c}$ correspond to collisional areas (Wetar, Timor, New-Hebrides, Makran, Solomons, Alaska) or regions characterized by active back-arc extension (Calabria, Aegean, N-Tonga, S-Sandwich, Ryukyu, Mariana). The latter cases are also often found at trench edges with sharp azimuthal trend changes. Extrusion processes and back-arc rifting caused by the indentation of buoyant features can provide an explanation for these “outliers” (Wallace *et al.*, 2005, 2009).

3.3.3 Focus on the strike-slip dominant-strain regime

Next, we focus on the transects which fall in our dominant strike-slip regime ($45^\circ \leq O_{v_d} < 135^\circ$, cf. Figure 4a) to specifically assess the potential relationship between the kinematics of overriding plate deformation and that of the convergence, as proposed by numerous previous studies (e.g., Jarrard, 1986; McCaffrey, 1992). These theoretical and modeling works suggested that the obliquity of convergence should transmit a shear force on the plate interface with some lateral component, potentially resulting in lateral deformation in the overriding plate. Our dataset reveals that for transects under dominant strike-slip regime, the linear correlation coefficient between the $\overline{O}_{v_d}$ and $\overline{O}_{v_c}$, is 0.80, thus slightly higher than the correlation for all regimes (Fig. S2).

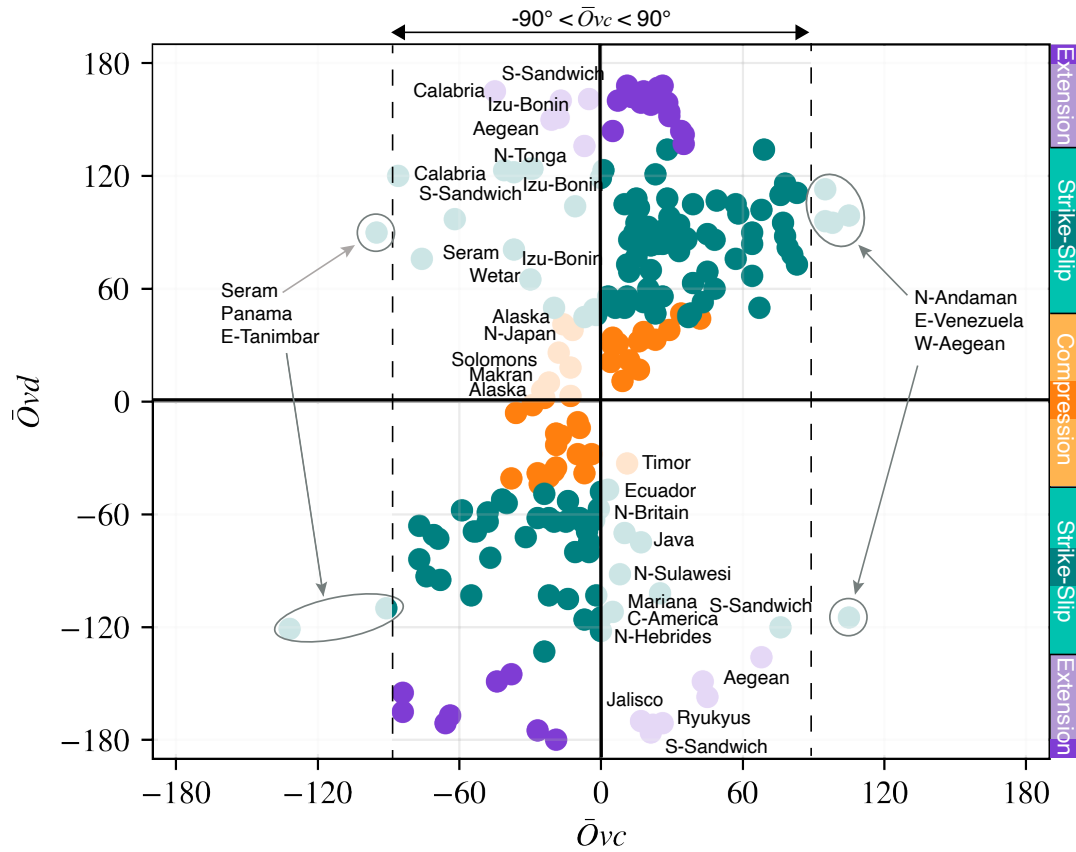


Figure 8 – Obliquity of the convergence between major subducting (SP) and upper (UP) plates against the obliquity of deformation for 213 transects with non-null vd. The transects are colored following their Ovd-based tectonic regimes (blue for extension, green for strike-slip and red for compression). The shaded quadrants highlight cases of opposite signs of obliquities, i.e., the transects for which the convergence obliquity fails to explain the deformation obliquity. The regions for which $|\bar{O}_{vc}| > 90^\circ$ (dotted black line) are also shaded.

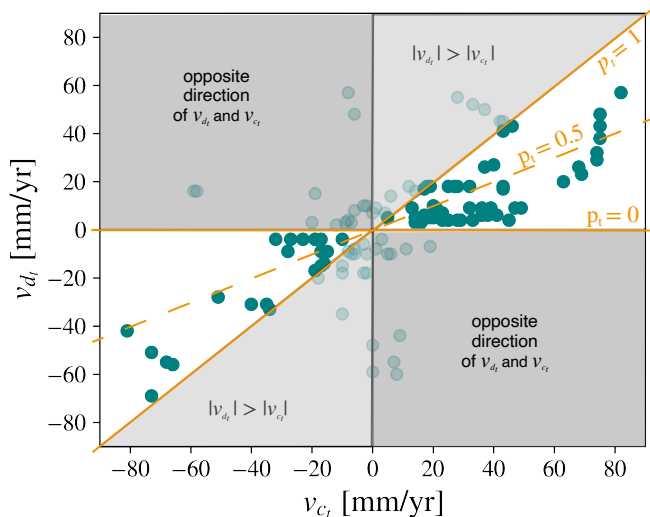


Figure 9 – Tangential component of the deformation velocity as a function of the tangential component of the convergence velocity for all transects in the dominant strike-slip regime. The non-transparent green dots are those for which the magnitude of deformation velocity is higher than 1 mm/yr, which have a lateral partition coefficient equal or less than 1, and which have consistent directions of the tangential components of both velocities. Semi-transparent green dots denote all the remaining transects under the dominant strike-slip strain regime.

Our transects under dominant strike-slip regime in Figure 8 show that the majority of transects have deformation obliquities that are higher than the convergence obliquity, which is consistent with the fact that in most cases the subduction obliquity is lower than that of the convergence. We note, however, a few exceptions for transects in which the convergence is almost tangential to the trench in the presence of a very curved trench such as in the westernmost Aleutians and easternmost Venezuela. In contrast to earlier proposals (Fitch, 1972; McCaffrey, 1992) and in accordance with recent studies (e.g., Morell et al., 2025), our global dataset does not display any convergence obliquity threshold above which strain partitioning would be activated. In particular, relatively low convergence obliquities ($< 30^\circ$) are associated with a variety of deformation obliquities within the range $45\text{--}135^\circ$.

Figure 9 displays the tangential deformation velocity against the tangential convergence velocity. We filter the transects to select those which display values of v_{ct} and v_{dt} of the same sign (or same sign of $\bar{O}_{vd}$ and $\bar{O}_{vc}$, see above) which we interpret as regions where deformation is compatible with the direction of convergence. In addition, we select only the regions with values of p_t equal to or less than 1 (non-transparent green dots) since, in our interpretation, deformation in those regions is most likely due to strain partitioning, that is a conversion of part of the convergence velocity into a deformation

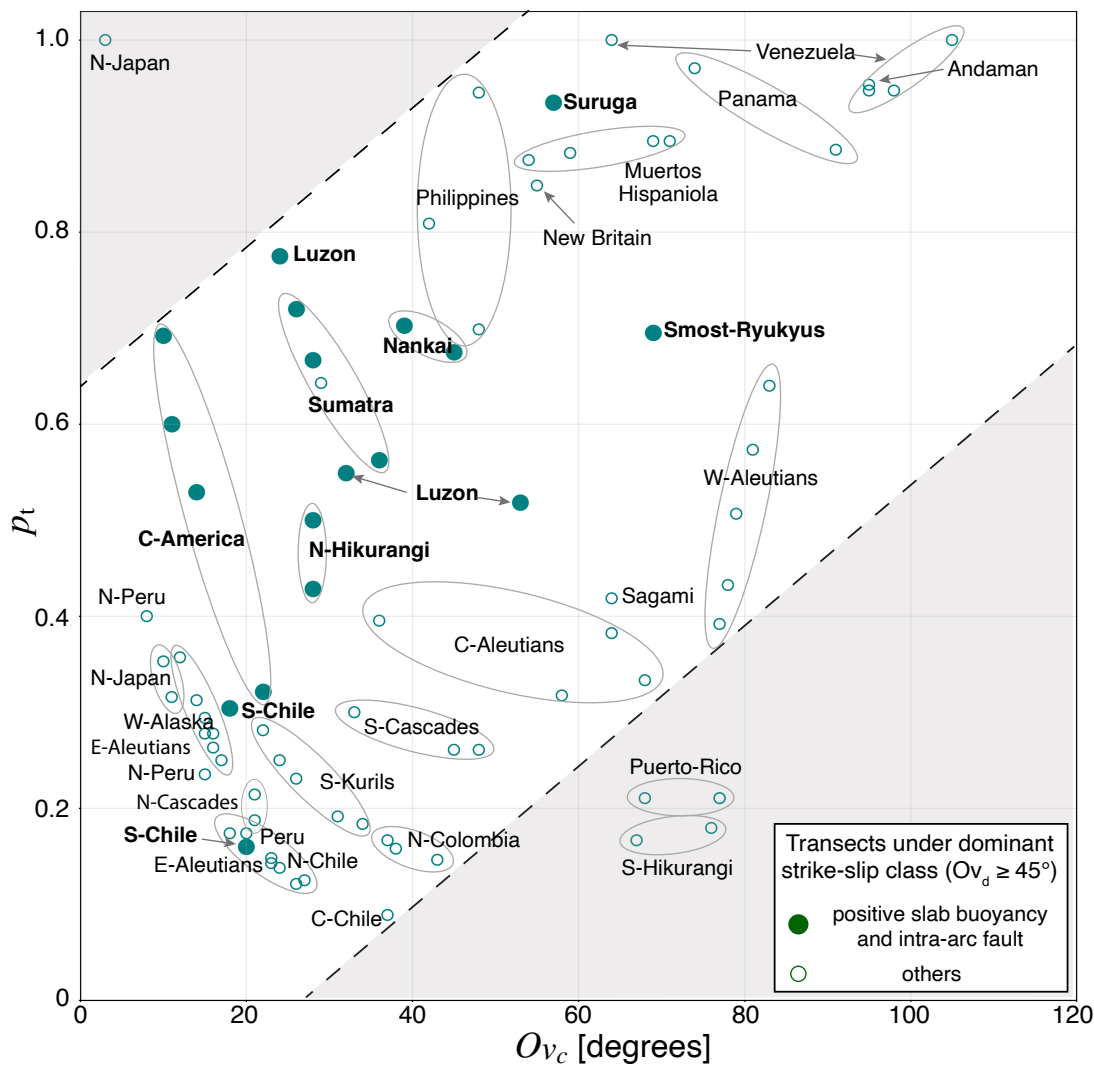


Figure 10 – Lateral partition coefficient p_t as a function of convergence obliquity O_{v_c} for subduction transects under a dominant strike-slip strain class.

velocity. Through this selection, it appears that $|v_{dt}|$ tends to increase with $|v_{ct}|$, which we think is a piece of evidence of a relationship between the convergence obliquity and tangential deformation.

Next, following the proposal by earlier studies, we tested the relationship between convergence obliquity O_{v_c} and the degree of lateral partitioning on the overriding plate p_t , for transects under dominant strike-slip and with $p_t \leq 1$ (84 transects, see Figure 10). A first-order observation is that, on average, the lateral partitioning p_t tends to increase with the convergence obliquity O_{v_c} (Figure 10). However, the scatter is substantial, and the Pearson linear correlation coefficient is moderate ($r = 0.45$, see Figure S3). This trend does not apply at the scale of individual subduction systems. Notably, we can observe that only 34 transects (39%) exhibit relatively high lateral partitioning (i.e., $p_t \geq 0.5$) and only two third of these (21 transects) have convergence obliquities exceeding 45° . Among them, the highest partition coefficients are found in regions of back-arc spreading (oblique to the direction of the trench and/or our transect) such as Andaman and New Britain, in regions of short-distance opposite-polarity subduction zones such as Panama and Puerto-Rico – Muertos, and

in Venezuela where a strong motion along the dextral strike-slip El Pilar Fault may result from the presence of a STEP fault rather than deformation induced by the convergence between the Caribbean and South America plates (*van Benthem et al., 2013*).

For the 12 transects exhibiting high lateral partitioning ($p_t \geq 0.5$) but relatively low convergence obliquities ($O_{v_c} < 45^\circ$), we propose that deformation partition is “efficient”, and we hypothesize that these regions (Central America, N-Hikurangi, Sumatra, Luzon, Philippines, Nankai) might share geodynamic features that promote this efficiency.

To identify geodynamic features that may promote efficient partitioning, we examine the presence of one or more of the following characteristics for each of the 90 subduction transects in Figure 10 (see Supporting Information Section S2 and Table S1):

- prominent bathymetric features entering the subduction trench (e.g., seamounts);
- a neutral-to-positive slab buoyancy based either on the presence of a bathymetric buoyant feature (plateau, ridge, etc.) or on a relatively young slab

considering the threshold estimation suggested to be around 30 Ma by *Afonso et al.* (2007) and *Korenaga and Korenaga* (2016);

- a main localized fault system accommodating partitioning; and
- a main localized fault being an intra-arc fault.

While not exhaustive, these features have been proposed to enhance partitioning. For example, analog sandbox models demonstrated that oblique subducting ridges or seamounts favored strain partitioning at the rear of accretionary wedges (*Dominguez et al.*, 1998; *Lewis et al.*, 2004; *Martinez et al.*, 2002). *Chemenda et al.* (2000) proposed that a weak zone in the overriding plate, such as an intra-arc fault, facilitated strain partitioning. The analysis of our dataset reveals that no single feature alone consistently isolates transects with efficient partitioning. However, transects combining both a buoyant slab and an intra-arc fault zone (filled circles in Figure 10) best explain the predicted high-efficiency partitioning. The north-Hikurangi, the Nankai, the Sumatra, and the Luzon are affected by the subduction of the Hikurangi plateau, the Izu-Bonin ridge, the Wharton fossil ridge and the Palawan ridge, respectively. In addition, the Central America, the Southern Chile, the Nankai, and the Suruga transects are characterized by seafloor age at trench of less than 30 Ma. All of them display an intra-arc fault system that accommodates the predicted deformation partitioning.

4 Discussion

4.1 Potential limitations

One of the key outcomes of our work is the estimation of the 2-D deformation vector v_d for most present-day subduction zones, derived exclusively from geodetic data and primarily from rigid block models. This approach improves upon previous databases, which often mixed geodetic and geological data to constrain 1-D deformation rates. However, our method has some limitations, which we outline below.

While our use of geodetic-only data ensures consistency, our analysis relies on heterogeneous geodetic sources, including blocks from the MORVEL56 global model, blocks from regional studies and single-station GPS data. This heterogeneity is evident in the Andean subduction zone, where we combine multiple GPS data to estimate v_d : ABs from the MORVEL56 plate set (Altiplano), blocks from published studies (North Andes West, Peruvian Forearc West, Central Andes) and single-station GPS data (Southern Andes). Although we do not quantify the uncertainties introduced by mixing these data types, we argue that they are likely smaller than those arising from neglecting overriding-plate deformation. For example, ignoring deformation introduces significant errors in regions such as Central America (deformation velocities of 10-15 mm/yr) and the North Andes (deformation velocities of ~ 10 mm/yr) where we used published rigid blocks, as well as Taiwan (deformation velocities of the order of 50 mm/yr)

and Southern Chile (deformation velocities up to 7 mm/yr) deformed areas where we used data from single GPS stations. Thus, we consider our approach a clear improvement over previous compilations. Future work could further refine these estimates by directly processing public GNSS datasets across all subduction zones (*Morell et al.*, 2025).

We also identified cases where existing rigid-block solutions provided unrealistic deformation velocity estimates, particularly near the extremities of geodetic blocks. In such cases, we excluded these solutions. For example, the Eulerian solution for the motion of the Scotia plate's western termination (relative to the South America plate) did not match field observations (*Perucca et al.*, 2016), leading us to omit it from our analysis.

Additionally, our classification of strain (sub)classes based on O_{v_d} involves simplifying assumptions to categorize deformation into discrete regimes. For example, our compressional (C, C-SS) and extensional (E, E-SS) classes effectively capture (quasi-)trench normal compressional and extensional tectonics but also comprise (quasi-)trench-normal strike-slip systems such as the Puná-Pallatanga fault system in Ecuador (*Alvarado et al.*, 2016; *Jarrin et al.*, 2023). Likewise, our strike-slip classes (SS-E, SS, SS-C) may correspond, in nature, to trench-parallel extensional or compressional structures such as in the Andaman Sea where spreading is quasi-parallel to the subduction trench (*Curry*, 2005). In other words, while our framework provides a robust directional description of overriding-plate deformation, the real geological structures may not always align perfectly with our (sub)class names.

Finally, we note that deformation in submerged forearcs is often poorly resolved by geodetic solutions due to the lack of ocean-bottom geodetic stations. This may lead to underestimating overriding-plate deformation in some cases. For example, in the southern Ryukyus, the accretionary wedge migrates laterally along the Yaeyama transcurrent fault at an estimated rate of ~ 40 mm/yr (*Dominguez et al.*, 1998; *Lallemand et al.*, 1999).

4.2 Comparison to previous studies

Based on previous compilations of overriding plate deformation at present-day subduction zones, several correlations have been highlighted. Here, we first summarize the novelties of our work. We then re-assess and discuss some of those correlations based on our determination of the present-day deformation of upper plates.

4.2.1 Update of the kinematic component of the Submap database

Our work significantly enhances the kinematic component of the Submap database (*Heuret*, 2005; *Lallemand and Heuret*, 2017). Specifically, we reassess the overriding-plate deformation velocity, which is key for assessing relative subduction kinematics and trench absolute motion.

The former versions of the database (*Heuret and Lallemand, 2005*) provided estimates of overriding-plate deformation for only 50% of the 260 transects, with small improvements provided by *Cerpa et al. (2022a)*, and only the trench-normal component was described. In this update, we now provide the estimation for approximately 88% of the Submap transects. We also now include estimations for both the trench-normal and trench-parallel components of overriding-plate deformation, enabling, for instance, assessment of strain partitioning. This improvement enables us to classify transects into three dominant strain classes: compression (16% of the transects, see Section 3.1), extension (15%), strike-slip (52%) alongside neutral (6%) and undefined categories (12%). Previously, strike-slip, neutral, and undefined deformations were grouped under a single “neutral” trench-normal strain class. Notably, transects under a dominant strike-slip regime account for approximately 60% of all transects with defined deformation velocities, making it the most common strain class in present-day subduction zones. This proportion is comparable to, though slightly higher than, the 50% of trenches exhibiting forearc sliver motion recently estimated by *Morell et al. (2025)* through an analysis of 13 subduction zones. Crucially, these refinements in overriding-plate deformation estimates improve the accuracy of subduction velocity calculations (see Section 4.3).

Additionally, following updates to absolute plate motion models (*Cerpa et al., 2022a*), the current version of the Submap database incorporates four absolute plate motion models: MORVEL56-NNR (*Argus et al., 2011*), the spreading-alignment model (*Becker et al., 2015*), T25m (*Wang et al., 2018*), and GMHRF-1Ma (*Dobrovine et al., 2012*). Together with the updated deformation velocities, these models provide a more accurate description of trench motions in absolute reference frames.

4.2.2 Overriding plate strain and slab dip

Lallemand et al. (2005) classified 159 subduction transects into three discrete strain classes (neutral, compressive, extensive) based on a qualitative assessment of focal mechanisms in the back-arc of the overriding plate. Moreover, based on Wadati-Benioff zones, they defined a shallow slab dip α_s representative of a mean subduction angle between the surface and 125 km depth, and a deep slab dip α_d more representative of the subduction angle beyond 125 km depth. The authors suggested a direct relationship between the slab dip and the overriding plate strain. Compressive transects were found for deep slab dips lower than 30° while extensive transects were mostly observed for deep-slab dip values higher than 50° . Their interpretation was that the slab dip modulates the interplate coupling force, favoring a suction or a push force for a steep or a shallow slab dip, respectively.

To revise the correlations, we have re-computed the shallow and the deep slab dips, using the Slab2.0 model (*Hayes et al., 2018*), when available. To keep consistency

with past works, we have adopted similar definitions. For each subduction transect, the shallow slab dip α_s is computed by averaging the estimated dip between 10 and 125 km depth. The deep slab dip α_d is the average dip between 125 and 400 km depth.

We assume that our quantification of the obliquity of the deformation velocity provides a continuous description of the overriding-plate strain (see Section 3.1) and allows for the application of a linear regression analysis with slab dip. Taking all of our 213 subduction transects with a defined value of v_d , we find weak correlations between the obliquity of deformation and both the shallow (linear correlation coefficient $r = 0.23$, Figure 11a) and the deep ($r = 0.28$, Figure 11b) slab dip. However, we might expect the relationship between the slab dip and the overriding-plate deformation to emerge in settings where slab dynamics and the generated interplate coupling can dominate large-scale deformation in the upper plate. Therefore, we exclude areas such as Southeast Asia (Taiwan, Philippines, Banda Sea region, Molucca Sea region) and Melanesia (New Britain, Solomons, New Hebrides) where multiple subduction systems and collision zones are proximal. For similar reasons, we exclude regions where v_d represents the motion of a retro-subduction system such as Panama, Puerto-Rico and Muertos. Lastly, we filter out the regions where the width of the subduction zone is less than 1000 km (e.g., Calabria, Makran). Having excluded those regions, we find a good correlation ($r = 0.58$, Figure 11c) between the shallow slab dip and the obliquity of deformation for the 160 transects. A few large subduction trenches, such as the Alaska-Aleutians from east to west, the Andaman-Sumatra-Java from south to north, and the Izu-Bonin-Marianas, illustrate the tendency of deformation obliquity to increase with the shallow slab dip. On one hand, the transects of subduction zones that fall in the compressive class (Andean, Alaska) generally exhibit values of α_s between 10° and 20° . A few outliers in Central America (Costa Rica) and Southern Japan (Kyushu) are compressive but display higher values of shallow slab dip. Those outliers may be explained by the subduction of shallow bathymetric features: the Cocos ridge and the Kyushu-Palau ridge as well as the Amami-Daito-Okidaito massif, respectively, which may enforce compression locally but do not lead to significant flattening of the subducting plate (*Gardner et al., 2013; Lallemand, 2016*). On the other hand, the transects of subduction zones that fall in the extensional class most often exhibit values of α_s higher than 25° . Note that a few transects belonging to the northernmost and southernmost Sandwich subduction trench lie in our strike-slip class but this is biased by the orientation of the subduction transects relative to the direction of back-arc spreading.

Contrary to the findings of *Lallemand et al. (2005)*, our database suggests a lower correlation between the deep slab dip and the overriding-plate strain class, even when excluding complex areas ($r = 0.36$, Figure 11d). Although some tendency to increase Obv_d with α_d is perceivable, the spread is much larger than with α_s .

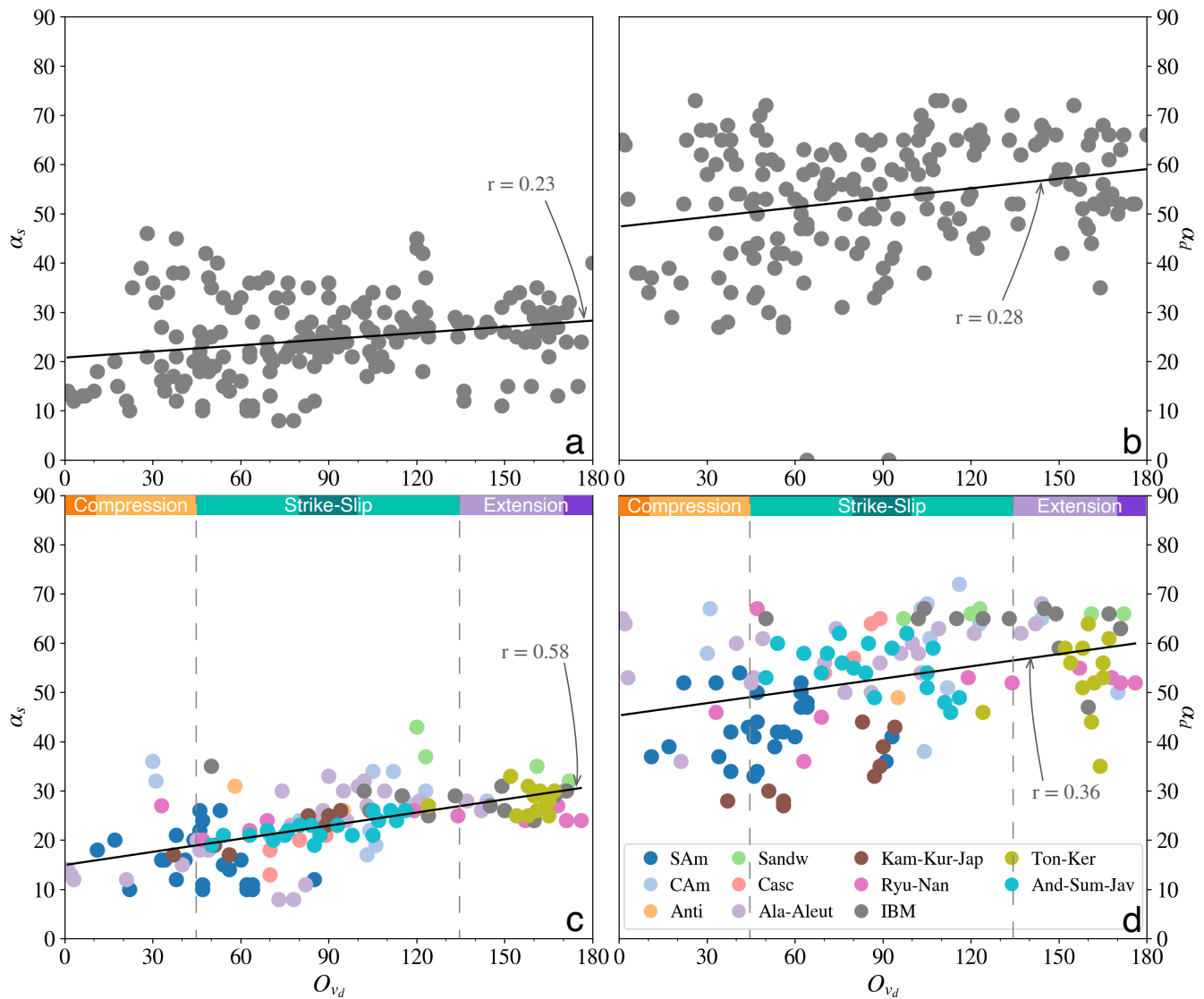


Figure 11 – Obliquity of the deformation velocity with shallow (0 to 125 km depth; left) and deep (125 to 400 km; right) slab dip for all (top) and selected major (bottom) subduction zones (see main text for selection criteria). Sam: South America, CAm: Central America, Anti: Lesser Antilles, Sandw: Sandwich, Casc: Cascadia, Ala-Aleut: Alaska-Aleutians, Kam-Kur-Jap: Kamchatka-Kurils-Japan, Ryu-Nan: Ryukyus-Nankai, IBM: Izu-Bonin-Marianas, Ton-Ker: Tonga-Kermadec, And-Sum-Jav: Andaman-Sumatra-Java.

The relationship between the shallow slab dip and the deformation obliquity, and thus the strain regime, can be interpreted as the expression of the geometrical effect of subduction interface contact on the transmission of forces to the overriding plate and thus on its deformation. A wider plate-to-plate contact, induced by a relatively low value of α_s , promotes compression while the opposite promotes extension. The mean friction coefficient along the subduction interface may modulate this geometrical effect.

4.2.3 Overriding-plate strain and distance to the slab edge

Schellart (2008b) and Schellart (2024) inferred a direct relationship between the overriding plate deformation rate and the distance to the proximal subducting plate edge from a compilation of geodetic and geologic 1-D (i.e., trench-normal) deformation rates at present-day subduction zones. Extension rates were found to be

higher close to a slab edge and decrease away from the edge, while compression rates were found to follow the opposite trend. Such observations were explained by analog and numerical models showing that a mantle toroidal flow around slab edges can facilitate the slab rollback near the edges while preventing rollback far from the edges, especially in wide subduction zones (Schellart and Moresi, 2013; Stegman et al., 2006; Sternai et al., 2014).

Taking our 213 subduction transects with a defined non-zero value of v_d , we observe that the highest deformation rates (> 40 mm/yr) generally lie within the first 2000 km from a slab edge (denoted as X_{edge}), without dependence, to first order, on the strain class (Figure 12a, b). Some scatter is, however, observed, and we note that it is less apparent for dominant extensional regimes. As discussed below, a closer look, region by region, gives a different perspective for this first-order

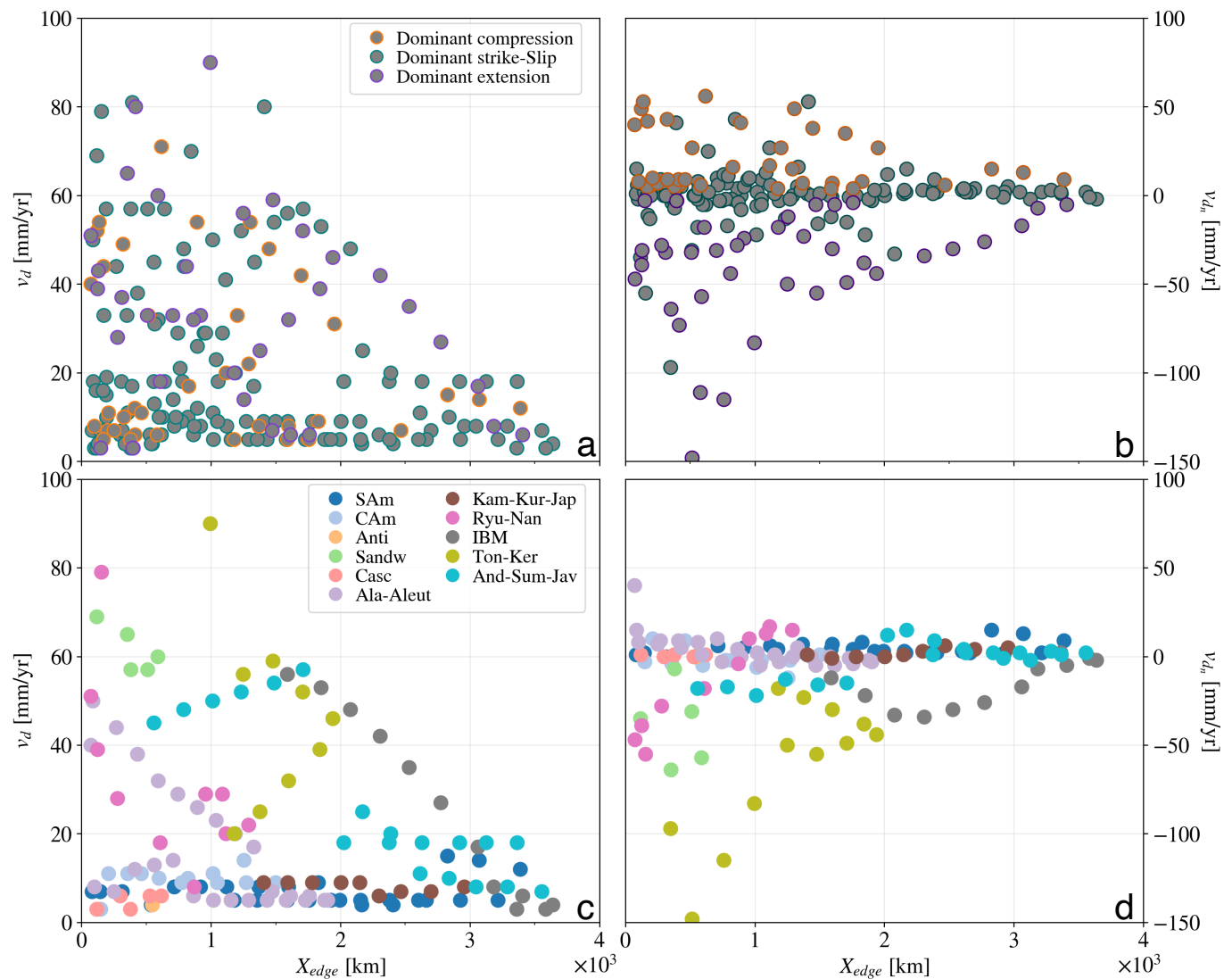


Figure 12 – Overriding-plate deformation velocity with distance to the edge of the trench. Left column (a,c) is for total velocity and right column (b,d) for only the trench-normal component. Top row (a, b) display the values for all 213 subduction transects with defined non-zero values of v_d and the bottom row (c,d) that of 141 transects corresponding to selected “major” subduction zones that are wider than 1000 km.

observation. At distances of more than 2000 km from a slab edge, estimated values of v_d remain below 40 mm/yr.

Restricting the analysis to major, relatively large (widths of more than 1000 km), subduction zones, the general trend still holds when taking the transects as a whole (Figure 12c). However, a more detailed analysis of the trench-normal deformation velocity (v_{dn}) region by region, gives different insights (Figure 12d). We observe that the decrease in trench-normal extension with increasing distance to the slab edge is clearly observable for the Tonga-Kermadec subduction zone, where the highest extension rates are found in the Lau Basin and decrease southward towards the Havre Trough. This is also the case for the Ryukyus where the spreading rates decrease from west to east. On the contrary, in the Marianas-Izu-Bonin system the trench-normal extension is the highest in Central Marianas and decreases both north- and south-wards. For the Andaman and the Sandwich trenches, there is no obvious trend. Among the settings of dominant compression, the Andes show an increase in trench-normal compression rate with

increasing distance to the slab edge, with the highest values observed in the C-Andes (Altiplano region). Likewise, trench-normal compression rates are higher in C-Japan and decrease towards the Kurils. On the contrary, high compression rates are observed in Alaska, close to the slab edge, and decrease westwards towards W- and C-Aleutians, where the regimes switch to dominant strike-slip. Overall, as also discussed by previous studies, our estimation of overriding-plate deformation in systems under dominant compression and extension suggests that the model in which mantle toroidal flow exerts a prime effect on surface deformation may be invoked for only certain subduction zones (Tonga-Kermadec, Ryukyus, the C-Andes) but appears inefficient for explaining the observations in others (e.g., Marianas, Alaska-Aleutians).

One of the novelties of our work is that our kinematic database allows us to classify subduction zones under a dominant strike-slip regime, which differs from those in the neutral regime. For the transects under the strike-slip class, only those

which correspond to regions of oceanic spreading in directions diverging from the trench normal, exhibit high values of deformation within the first 1000 km of the slab edge (e.g., northernmost Tonga, New Hebrides, southernmost Marianas, the northernmost and southernmost Sandwich). Other regions in the strike-slip regime, such as Andaman-Sumatra-Java, Central America, or Southern Chile, do not show any trend with the distance to the slab edge. These observations suggest that mantle flow (alone) is difficult to invoke to explain the lateral deformation in subduction zones experiencing strike-slip dominant regime.

4.2.4 Previous studies on strain partitioning

Early studies suggested that strain partitioning at oblique subduction zones, involving the motion of a forearc sliver, was mainly controlled by the convergence obliquity (e.g., *Fitch, 1972*) and proposed the existence of a threshold convergence angle above which such partitioning could occur (*Jarrard, 1986; McCaffrey, 1992*). Following later studies (*Cooke et al., 2020; Hoffmann-Rothe et al., 2006; Morell et al., 2025; Turner et al., 2007*), we show that the idea of an obliquity threshold is questionable and that trench-parallel overriding-plate deformation can occur at any value of convergence obliquity (Figure 8). We, however, highlight that there is a certain tendency to increase trench-parallel deformation rate with the increase of the trench-parallel convergence velocity (Figure 9) for areas under dominant strike-slip regime. We also show that the relationship between the degree of lateral partitioning p_t and the convergence obliquity O_{vc} is not straightforward. At first-order, high values of p_t are mostly found for high values of O_{vc} , but the scatter is substantial (white band in Figure 10). Relatively high values of O_{vc} can be associated with very low values (≤ 0.2) of p_t such as in Puerto-Rico and South-Hikurangi. In contrast, the opposite (relatively low O_{vc} and high p_t) can also be observed, as in Central America.

Analyzing a variety of active subduction zones, *Jarrard (1986)* suggested that most regions where Pleistocene strike-slip systems were documented, corresponded to subduction zones with a continental overriding-plate. He thus proposed that strain partitioning may be more pronounced in settings with continental crust on the overriding plates than in intra-oceanic subduction zones. Analyzing all of our regions falling in the dominant strike-slip regime we do not observe this correlation whether we look at the type of arc crust or that of the back-arc crust (Figure S4).

Our most important finding is that our dataset suggests that the regions experiencing efficient strain partitioning (relatively high p_t at relatively low O_{vc}) are characterized by an anomalously low to positive slab buoyancy which may involve a bathymetric feature (ridge, plateau) and by the localization of lateral deformation in the overriding-plate on an intra-arc fault or fault system. Our interpretation is as follows: a neutral-to-positive slab density anomaly, with the

possible presence of a bathymetric feature, may increase the long-term coupling (surface contact) between the slab and the overriding-plate. This may be analogous to the suggestion by, e.g., *Chemenda et al. (2000)* that the average long-term “friction” along the plate interface may be key to define partitioning. On the other hand, we speculate that localizing strain partitioning on a single fault (system) along the volcanic arc might illuminate an average rheological response of the overriding plate that might facilitate partitioning. While our dataset leads us to propose such a conceptual model, it is beyond the scope of the paper to further assess this hypothesis.

Recently, *Morell et al. (2025)* have specifically analyzed the arc and forearc active deformation through computation of the vorticity of GNSS velocities, for major subduction zones, amounting to about half of the total length of present-day subduction zones. A main result of their work is that low to moderate obliquity can lead to strain partitioning (see above). Furthermore, their sampled subduction zones show that the vorticity tends to increase with convergence obliquity. Our sampling of $\sim 45\,000$ km of subduction zones for which we have a constrained value of overriding-plate deformation, shows a weak relationship between the convergence and the deformation obliquities, and confirms that low obliquities can lead to a wide range of deformation obliquity. In addition, the finding on the relationship between GNSS vorticity and convergence obliquity by *Morell et al. (2025)* may be compared to our observation that the trench-parallel component of deformation velocity tends to increase with that of the convergence velocity for our 90 transects under a dominant strike-slip regime with values of lateral partition coefficient below or equal to 1 ($\sim 19\,000$ km in terms of length, non-transparent dots in Figure 9). Overall, our study confirms the main conclusions of *Morell et al. (2025)*, showing that they also apply to other subduction zones not considered in their study.

4.3 Consequences of the revised subduction velocities

Accounting for an overriding plate deformation velocity v_d , we are able to correct the convergence velocities v_c inferred from global plate models, and to obtain a better estimate of the rate of SP consumption at trench, that is the subduction velocity $v_s = v_c + v_d$. The values of v_s impact the estimates of mass transfers in present-day subduction zones, including that of volatiles (*von Huene and Scholl, 1991; Lallemand et al., 2024*), of the thermal structure of the subducting plate via the thermal parameter (*Kirby et al., 1996*), and of the seismic potential of the subduction megathrust (*Scholz and Campos, 1995; Wirth et al., 2022*). Moreover, thermo-mechanical models of subduction zones often use estimates of subduction velocities as input parameters, with consequences for the estimates of the thermal structure of present-day subduction zones (e.g., *Syracuse et al., 2010*), that of the release-depth of volatiles (*Cerpa et al., 2022b; van Keken et al., 2011*), or that of the interface strength (*Fraters et al., 2025*). Other indirect impacts through numerical modeling would be

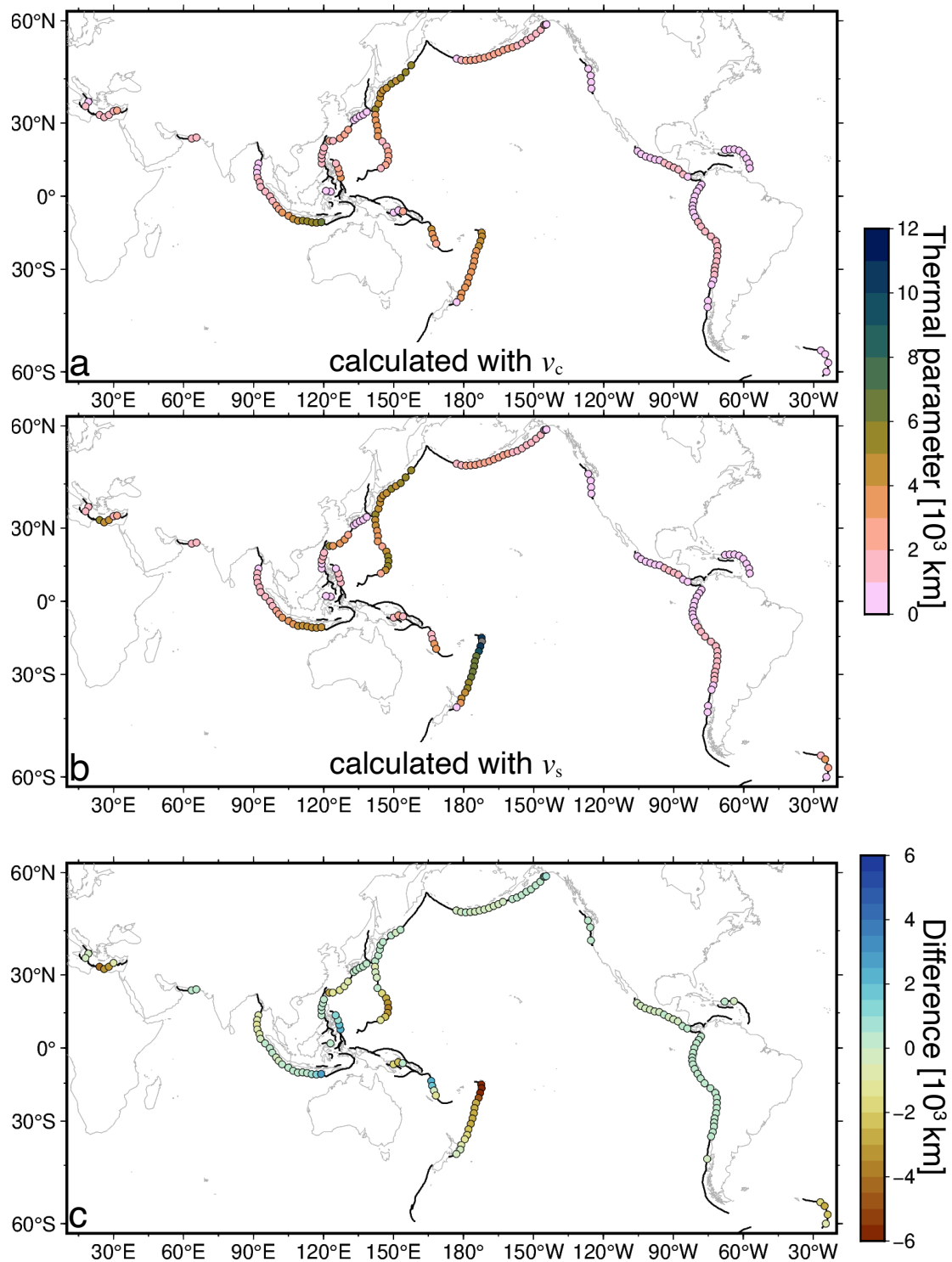


Figure 13 – Global map of the thermal parameter calculated using v_c (a) and our revised v_s (b), as well as their difference (c).

the assessment of the dynamics of plate-mantle coupling (Arcay, 2012; Turino and Holt, 2024), of the deformation of the overriding plate (Cerpa et al., 2018), and of the slab-dynamics in the mantle transition zone (Cerpa et al., 2022a). For obvious reasons, it is beyond the scope of this contribution to reassess or discuss all of these estimates. Here, we therefore choose to illustrate the changes induced by accounting for overriding-plate deformation on the thermal parameter and on the slip length.

4.3.1 Thermal parameter

The thermal parameter φ is generally used as a first-order estimation of the slab-thermal structure. It has been shown to correlate with the seismogenic potential within the slab, especially of intermediate-depth earthquakes (Kirby et al., 1996; Stein and Stein, 1996; Wiens and Gilbert, 1996). Its value, expressed in km, is the product of the slab's rate of descent, $v \sin \alpha$ in km/Myr, α being the slab's dip, and its age in millions of years. We thus calculate the

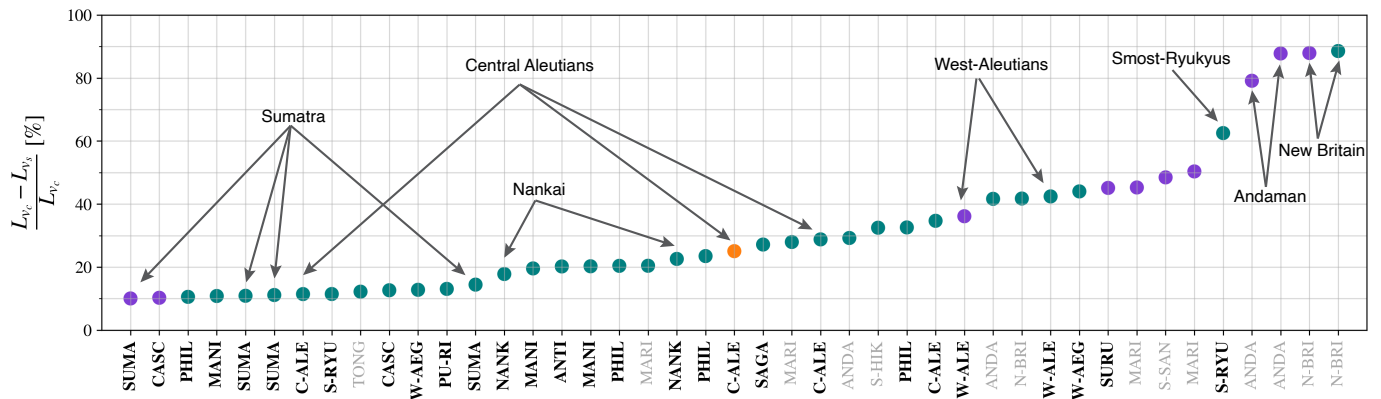


Figure 14 – Slip length reduction expected along the subduction (seismogenic) interface using our estimated values of v_s . Transect-names in black and bold correspond to the transects for which we have added constraints on overriding-plate deformation beyond the MORVEL56 model.

thermal parameter for transects that have a defined convergence/subduction kinematics, slab age and slab dip (Figures 13a, b). Note that for the slab dip, we use the average of α_s and α_d , and we take the trench-normal components of velocities. We also compute the difference between the thermal parameter calculated using v_{c_n} and that using v_{s_n} (Figure 13c). Different values of the thermal parameter are obtained for 155 of our transects (where $v_{d_n} \neq 0$).

The most striking differences between the calculations of the thermal parameter are for the transects undergoing moderate to fast back-arc spreading, such as in Tonga, the Marianas and the Aegean where the thermal parameter increases by a factor of two to three if we use v_{s_n} instead of v_{c_n} . For the Sandwich transects, the difference is up to an order of magnitude. In addition, transects that undergo a high compressional deformation rate, such as those in N-New-Hebrides or those where the overriding plate deformation represents a retro-subduction zone (Timor, Philippines), also lead to high deformation rates and thus to relatively large decreases in the estimations of the thermal parameter if one uses v_{s_n} . Overall, when comparing the two possibilities for estimating the thermal parameter, we find that in approximately 75% of the 155 transects where the two estimates differ, the absolute change in thermal parameter is of 10^3 km or less. In $\sim 10\%$ of cases the absolute difference is between 10^3 and 2×10^3 km, among which $\sim 50\%$ and $\sim 45\%$ are under dominant extension and strike-slip, respectively. In $\sim 10\%$ of cases, it is between 2×10^3 and 3×10^3 km, among which $\sim 70\%$ and $\sim 20\%$ are under dominant extension and strike-slip, respectively. In the remaining $\sim 5\%$ of cases the absolute difference is between 3×10^3 km and up to 9×10^3 km, with 80% and 20% of transects being under dominant extension and strike-slip, respectively. The latter cases are mostly transects undergoing fast back-arc spreading.

Estimations of the thermal parameter at present-day subduction zones have been widely used in various studies. For example, they have been applied to predict the deep-water cycle in both modern subduction zones (Abers et al., 2017; van Keken et al., 2011) and in the geological past (Karlsen et al., 2019), for the prediction

of intra-slab seismicity (Kirby et al., 1996; Wei et al., 2017), as well as to decipher the controls on volcanic arc positioning (England et al., 2004). Our estimates of the thermal parameter, with and without corrections for subduction rates using the overriding-plate deformation velocity are likely to influence these applications and interpretations.

4.3.2 Slip length

For a given seismogenic zone width, the slip length on the megathrust is ideally determined by the angle at which the subducting plate actually enters the trench, that is O_{v_s} . When $O_{v_c} \simeq O_{v_s}$ estimating the slip length using global plate circuit models is a reasonable approach. However, in the case of significant strain partitioning and, for instance, activation of slip on a strike-slip fault, a reduction in the slip length on the seismogenic interface is expected.

Using our up-to-date kinematic database, we can compare the estimations of slip length using the convergence L_{v_c} and that using the subduction velocity L_{v_s} . Figure 14 shows areas where the reduction in slip length due to arc-block deformation exceeds 10%, and reaches, in extreme cases (New Britain, Andaman), as much as 80-90%. These sectors represent 16.5% of subduction zone transects, two-thirds of which were not covered by MORVEL56 (transects with names in black and bold font in Figure 14). As an example, the southernmost section of the Ryukyu subduction zone deforms in a way that the slip length across the seismogenic zone is decreased by more than 60%. This reduction reaches 20% in the Nankai trough, 35% in W-Aleutians, 10 to 30% in Central-Aleutians or 10 to 15% in Sumatra.

5 Conclusions and perspectives

We have built a new database of overriding-plate deformation in present-day subduction zones, consistently based on geodetic data. Our kinematic description of overriding-plate deformation, through the motion of an “arc block” relative to an undeformed upper plate, allows us to characterize both the trench-normal

and the trench-parallel components of deformation, which is a key improvement relative to past versions of the Submap database. To the best of our knowledge, this study presents the first classification of subduction zones into three dominant strain classes (compression, extension, and strike-slip) and seven subclasses (C, C-SS, SS-C, SS, SS-E, E-SS, E), alongside neutral and undefined-deformation categories.

Our analysis confirms that the obliquity of convergence generally leads to a lateral (quasi-trench parallel) deformation in the overriding plate, which we interpret as evidence of a lateral shear component on the subduction interface. However, our dataset allows us to demonstrate that the relationship between the convergence obliquity and the degree of (lateral) strain partitioning is not straightforward. We suggest that key subduction characteristics, such as the subduction of large bathymetric features may largely contribute to shear on the interface and that the localization of partitioning into an intra-arc fault (system) may assist strong lateral deformation in the overriding plate, leading to an efficient strain partitioning (i.e., relatively high partition coefficient at relatively low convergence obliquities). Furthermore, although there are a few counter-examples, we also confirm the trend that the dip of a slab, especially for depths less than 125 km, correlates with the deformation regime of the overriding plate (low values of slab dip leading to compression, high values to extension, and intermediate to strike-slip).

Finally, our estimations of overriding plate deformation permit an enhancement of the estimation of subducting-plate consumption rates at the trenches, relative to studies using estimates based instead on far-field (convergence) relative velocities. This has implications for the predictions of mass transfers from the surface to the mantle, the thermal structure of the slab, the shear on the subduction interface, or seismic coupling, insofar as the slip along the subduction interface predicted by kinematics is compared with seismic slip.

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Author contributions

Conceptualization – N. Cerpa, S. Lallemand
 Methodology – N. Cerpa, S. Lallemand
 Data Curation – N. Cerpa, S. Lallemand
 Formal Analysis – N. Cerpa
 Writing – Original Draft – N. Cerpa
 Writing – Review & Editing – N. Cerpa, S. Lallemand, A. Heuret
 Visualization – N. Cerpa, S. Lallemand
 Funding Acquisition – N/A

Data availability

The dataset of overriding-plate deformation velocity estimates produced in this study is available at <https://doi.org/10.5281/zenodo.23425202>. Our database is also accessible through our web tool Submap (<https://www.submap.fr>).

Competing interests

The authors declare no competing interests.

Peer review

This publication was peer-reviewed by Antoniette Grima and Mohamed Gouiza. The full peer-review report can be found here: [Review Report](#).

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References

- Abers, G. A., P. E. van Keken, and B. R. Hacker (2017), The cold and relatively dry nature of mantle forearcs in subduction zones, *Nature Geoscience*, 10(5), 333–337, <https://doi.org/10.1038/ngeo2922>.
- Afonso, J. C., G. Ranalli, and M. Fernández (2007), Density structure and buoyancy of the oceanic lithosphere revisited, *Geophysical Research Letters*, 34(10), 2007GL029515, <https://doi.org/10.1029/2007gl029515>.
- Alvarado, A., L. Audin, J. M. Nocquet, E. Jaillard, P. Mothes, P. Jarrín, M. Segovia, F. Rolandone, and D. Cisneros (2016), Partitioning of oblique convergence in the Northern Andes subduction zone: Migration history and the present-day boundary of the North Andean Sliver in Ecuador, *Tectonics*, 35(5), 1048–1065, <https://doi.org/10.1002/2016tc004117>.
- Andreani, L., X. Le Pichon, C. Rangin, and J. Martínez-Reyes (2008), The southern Mexico block: main boundaries and new estimation for its Quaternary motion, *Bulletin de la Société Géologique de France*, 179(2), 209–223, <https://doi.org/10.2113/gssgfbull.179.2.209>.
- Arcay, D. (2012), Dynamics of interplate domain in subduction zones: influence of rheological parameters and subducting plate age, *Solid Earth*, 3(2), 467–488, <https://doi.org/10.5194/se-3-467-2012>.
- Argus, D. F., R. G. Gordon, and C. DeMets (2011), Geologically current motion of 56 plates relative to the no-net-rotation reference frame: NNR-MORVEL56, *Geochemistry, Geophysics, Geosystems*, 12(11), <https://doi.org/10.1029/2011gc003751>.

- Baize, S., L. Audin, A. Alvarado, H. Jomard, M. Bablon, J. Champenois, P. Espin, P. Samaniego, X. Quidelleur, and J.-L. Le Pennec (2020), Active tectonics and earthquake geology along the pallatanga fault, central Andes of Ecuador, *Frontiers in Earth Science*, 8, <https://doi.org/10.3389/feart.2020.00193>.
- Barrier, E., P. Huchon, and M. Aurelio (1991), Philippine fault: A key for Philippine kinematics, *Geology*, 19(1), 32, [https://doi.org/10.1130/0091-7613\(1991\)019<0032:p fakfp>2.3.co;2](https://doi.org/10.1130/0091-7613(1991)019<0032:p fakfp>2.3.co;2).
- Becerra, J., E. Contreras-Reyes, and C. Arriagada (2013), Seismic structure and tectonics of the southern Arauco Basin, south-central Chile (38°S), *Tectonophysics*, 592, 53–66, <https://doi.org/10.1016/j.tecto.2013.02.012>.
- Becker, T. W., A. J. Schaeffer, S. Lebedev, and C. P. Conrad (2015), Toward a generalized plate motion reference frame, *Geophysical Research Letters*, 42(9), 3188–3196, <https://doi.org/10.1002/2015gl063695>.
- Bellier, O., and M. Sébrier (1995), Is the slip rate variation on the Great Sumatran Fault accommodated by fore-arc stretching?, *Geophysical Research Letters*, 22(15), 1969–1972, <https://doi.org/10.1029/95gl01793>.
- Bergeot, N., M. N. Bouin, M. Diamant, B. Pelletier, M. Régnier, S. Calmant, and V. Ballu (2009), Horizontal and vertical interseismic velocity fields in the Vanuatu subduction zone from GPS measurements: Evidence for a central Vanuatu locked zone, *Journal of Geophysical Research*, 114(B6), 2007JB005249, <https://doi.org/10.1029/2007jb005249>.
- Bradley, K. E., L. Feng, E. M. Hill, D. H. Natawidjaja, and K. Sieh (2017), Implications of the diffuse deformation of the Indian Ocean lithosphere for slip partitioning of oblique plate convergence in Sumatra, *Journal of Geophysical Research: Solid Earth*, 122(1), 572–591, <https://doi.org/10.1002/2016jb013549>.
- Brizzi, S., L. Sandri, F. Funiciello, F. Corbi, C. Piromallo, and A. Heuret (2018), Multivariate statistical analysis to investigate the subduction zone parameters favoring the occurrence of giant megathrust earthquakes, *Tectonophysics*, 728–729, 92–103, <https://doi.org/10.1016/j.tecto.2018.01.027>.
- Brooks, B. A., M. Bevis, R. Smalley, Jr, E. Kendrick, R. Manceda, E. Lauría, R. Maturana, and M. Araujo (2003), Crustal motion in the Southern Andes (26°–36°S): Do the Andes behave like a microplate?, *Geochemistry, Geophysics, Geosystems*, 4(10), 2003GC000505, <https://doi.org/10.1029/2003gc000505>.
- Brune, J. N. (1968), Seismic moment, seismicity, and rate of slip along major fault zones, *Journal of Geophysical Research*, 73(2), 777–784, <https://doi.org/10.1029/jb073i002p00777>.
- Byrne, D. B., G. Suarez, and W. R. McCann (1985), Muertos Trough subduction—microplate tectonics in the northern Caribbean?, *Nature*, 317(6036), 420–421, <https://doi.org/10.1038/317420a0>.
- Calais, E., S. J. Symithe, and B. M. de Lépinay (2023), Strain partitioning within the Caribbean–north America transform plate boundary in southern Haiti, tectonic and hazard implications, *Bulletin of the Seismological Society of America*, 113(1), 131–142, <https://doi.org/10.1785/0120220121>.
- Carvajal-Soto, L. A., T. Ito, M. Protti, and H. Kimura (2020), Earthquake potential in Costa Rica using three scenarios for the central Costa Rica deformed belt as western boundary of the Panama microplate, *Journal of South American Earth Sciences*, 97(102375), 102,375, <https://doi.org/10.1016/j.jsames.2019.102375>.
- Cerpa, N. G., B. Guillaume, and J. Martinod (2018), The interplay between overriding plate kinematics, slab dip and tectonics, *Geophysical Journal International*, 215(3), 1789–1802, <https://doi.org/10.1093/gji/ggy365>.
- Cerpa, N. G., K. Sigloch, F. Garel, A. Heuret, D. R. Davies, and M. G. Mihalynuk (2022a), The effect of a weak asthenospheric layer on surface kinematics, subduction dynamics and slab morphology in the lower mantle, *Journal of Geophysical Research: Solid Earth*, 127(8), e2022JB024494, <https://doi.org/10.1029/2022jb024494>.
- Cerpa, N. G., D. Arcay, and J. A. Padrón-Navarta (2022b), Sea-level stability over geological time owing to limited deep subduction of hydrated mantle, *Nature Geoscience*, 15(5), 423–428, <https://doi.org/10.1038/s41561-022-00924-3>.
- Chemenda, A., S. Lallemand, and A. Bokun (2000), Strain partitioning and interplate friction in oblique subduction zones: Constraints provided by experimental modeling, *Journal of Geophysical Research*, 105(B3), 5567–5581, <https://doi.org/10.1029/1999jb900332>.
- Chen, H.-Y., Y.-J. Hsu, R. Ikuta, H. Tung, C.-H. Tang, C.-S. Ku, H.-H. Su, P.-R. Jian, M. Ando, and T. Tsujii (2022), Strain partitioning in the southern Ryukyu margin revealed by seafloor geodetic and seismological observations, *Geophysical Research Letters*, 49(6), e2022GL098218, <https://doi.org/10.1029/2022gl098218>.
- Collot, J.-Y., G. Lamarche, R. A. Wood, J. Delteil, M. Sossou, J.-F. Lebrun, and M. F. Coffin (1995), Morphostructure of an incipient subduction zone along a transform plate boundary: Puysegur Ridge and Trench, *Geology*, 23(6), 519, [https://doi.org/10.1130/0091-7613\(1995\)023<0519:moaisz>2.3.co;2](https://doi.org/10.1130/0091-7613(1995)023<0519:moaisz>2.3.co;2).
- Cooke, M. L., K. Toeneboehn, and J. L. Hatch (2020), Onset of slip partitioning under oblique convergence within scaled physical experiments, *Geosphere*, 16(3), 875–889, <https://doi.org/10.1130/ges02179.1>.
- Cross, R. S., and J. T. Freymueller (2008), Evidence for and implications of a Bering plate based on geodetic measurements from the Aleutians and western Alaska, *Journal of Geophysical Research*, 113(B7), 2007JB005136, <https://doi.org/10.1029/2007jb005136>.
- Curry, J. R. (2005), Tectonics and history of the Andaman Sea region, *Journal of Asian Earth Sciences*, 25(1), 187–232, <https://doi.org/10.1016/j.jsaes.2004.09.001>.
- DeMets, C. (1992), Oblique convergence and deformation along the Kuril and Japan Trenches, *Journal of Geophysical Research*, 97(B12), 17,615–17,625, <https://doi.org/10.1029/92jb01306>.

- DeMets, C., R. G. Gordon, and D. F. Argus (2010), Geologically current plate motions, *Geophysical Journal International*, 181(1), 1–80, <https://doi.org/10.1111/j.1365-246x.2009.04491.x>.
- Doglioni, C., E. Carminati, M. Cuffaro, and D. Scrocca (2007), Subduction kinematics and dynamic constraints, *Earth-Science Reviews*, 83(3-4), 125–175, <https://doi.org/10.1016/j.earscirev.2007.04.001>.
- Dominguez, S., S. Lallemand, J. Malavieille, and P. Schnürle (1998), Oblique subduction of the Gagua Ridge beneath the Ryukyu accretionary wedge system: Insights from marine observations and sandbox experiments, *Marine Geophysical Research*, 20(5), 383–402, <https://doi.org/10.1023/a:1004614506345>.
- Dobrovine, P. V., B. Steinberger, and T. H. Torsvik (2012), Absolute plate motions in a reference frame defined by moving hot spots in the Pacific, Atlantic, and Indian oceans, *Journal of Geophysical Research*, 117(B9), 2011JB009072, <https://doi.org/10.1029/2011jb009072>.
- Elliott, J., and J. T. Freymueller (2020), A block model of present-day kinematics of Alaska and western Canada, *Journal of Geophysical Research: Solid Earth*, 125(7), e2019JB018378, <https://doi.org/10.1029/2019jb018378>.
- England, P., R. Engdahl, and W. Thatcher (2004), Systematic variation in the depths of slabs beneath arc volcanoes, *Geophysical Journal International*, 156(2), 377–408, <https://doi.org/10.1111/j.1365-246x.2003.02132.x>.
- Faccenna, C., A. Heuret, F. Funiciello, S. Lallemand, and T. W. Becker (2007), Predicting trench and plate motion from the dynamics of a strong slab, *Earth and Planetary Science Letters*, 257(1-2), 29–36, <https://doi.org/10.1016/j.epsl.2007.02.016>.
- Fitch, T. J. (1972), Plate convergence, transcurrent faults, and internal deformation adjacent to Southeast Asia and the western Pacific, *Journal of Geophysical Research*, 77(23), 4432–4460, <https://doi.org/10.1029/jb077i023p04432>.
- Fraters, M., M. Billen, J. Naliboff, L. Staisch, J. Watt, and H. Li (2025), Using subducting plate motion to constrain Cascadia slab geometry and interface strength, *Geochemistry, Geophysics, Geosystems*, 26(5), e2024GC011895, <https://doi.org/10.1029/2024gc011895>.
- Funiciello, F., C. Faccenna, A. Heuret, S. Lallemand, E. Di Giuseppe, and T. W. Becker (2008), Trench migration, net rotation and slab–mantle coupling, *Earth and Planetary Science Letters*, 271(1-4), 233–240, <https://doi.org/10.1016/j.epsl.2008.04.006>.
- Gardner, T. W., D. M. Fisher, K. D. Morell, and M. L. Cupper (2013), Upper-plate deformation in response to flat slab subduction inboard of the aseismic Cocos Ridge, Osa Peninsula, Costa Rica, *Lithosphere*, 5(3), 247–264, <https://doi.org/10.1130/L251.1>.
- Gutscher, M.-A., and S. Lallemand (1999), Birth of a major strike-slip fault in SW Japan, *Terra Nova*, 11(5), 203–209, <https://doi.org/10.1046/j.1365-3121.1999.00247.x>.
- Haq, S. S. B., and D. M. Davis (2010), Mechanics of fore-arc slivers: Insights from simple analog models, *Tectonics*, 29(5), <https://doi.org/10.1029/2009tc002583>.
- Hayes, G. P., G. L. Moore, D. E. Portner, M. Hearne, H. Flamme, M. Furtney, and G. M. Smoczyk (2018), Slab2, a comprehensive subduction zone geometry model, *Science*, 362(6410), 58–61, <https://doi.org/10.1126/science.aat4723>.
- Heuret, A. (2005), Dynamique des zones de subduction: étude statistique globale et approche analogique, Ph.D. thesis, Université Montpellier II-Sciences et Techniques du Languedoc.
- Heuret, A., and S. Lallemand (2005), Plate motions, slab dynamics and back-arc deformation, *Physics of the Earth and Planetary Interiors*, 149(1-2), 31–51, <https://doi.org/10.1016/j.pepi.2004.08.022>.
- Heuret, A., S. Lallemand, F. Funiciello, C. Piromallo, and C. Faccenna (2011), Physical characteristics of subduction interface type seismogenic zones revisited, *Geochemistry, Geophysics, Geosystems*, 12(1), <https://doi.org/10.1029/2010gc003230>.
- Heuret, A., C. P. Conrad, F. Funiciello, S. Lallemand, and L. Sandri (2012), Relation between subduction megathrust earthquakes, trench sediment thickness and upper plate strain, *Geophysical Research Letters*, 39(5), <https://doi.org/10.1029/2011gl050712>.
- Hoffmann-Rothe, A., N. Kukowski, G. Dresen, H. Echtler, O. Oncken, J. Klotz, E. Scheuber, and A. Kellner (2006), Oblique convergence along the Chilean margin: Partitioning, margin-parallel faulting and force interaction at the plate interface, in *The Andes*, edited by O. Oncken, G. Chong, G. Franz, P. Giese, H.-J. Götze, and V. A. Ramos, pp. 125–146, Springer Berlin Heidelberg, https://doi.org/10.1007/978-3-540-48684-8_6.
- Hsu, S.-K., W.-N. Wu, B.-S. Huang, Y.-J. Hsu, T. Bacolcol, A. Luis, Jr, A. Pelicano, S.-B. Yu, R.-J. Rau, K. Jabagat, Y.-H. Lee, P.-F. Chen, K.-E. Ching, L. T. Armada, and C.-L. Lo (2026), Recent advances on the tectonics of the Philippine arc-trench system, in *Tectonic Evolution and Natural Hazards in Southeast Asia: From Scientific Observations to Disaster Reduction*, edited by S.-L. Chung, W.-Y. Chang, and S.-Y. Huang, Atmosphere, Earth, Ocean & Space, pp. 1–33, Springer Nature Singapore, Singapore, https://doi.org/10.1007/978-981-95-8549-6_1.
- Jarrard, R. D. (1986), Relations among subduction parameters, *Reviews of Geophysics*, 24(2), 217–284, <https://doi.org/10.1029/rg024i002p00217>.
- Jarrin, P., J.-M. Nocquet, F. Rolandone, L. Audin, H. Mora-Páez, A. Alvarado, P. Mothes, F. Audemard, J. C. Villegas-Lanza, and D. Cisneros (2023), Continental block motion in the Northern Andes from GPS measurements, *Geophysical Journal International*, 235(2), 1434–1464, <https://doi.org/10.1093/gji/ggad294>.
- Karlsen, K. S., C. P. Conrad, and V. Magni (2019), Deep Water cycling and sea level change since the breakup of pangea, *Geochemistry, Geophysics, Geosystems*, 20(6), 2919–2935, <https://doi.org/10.1029/2019gc008232>.
- Kimura, G. (1986), Oblique subduction and collision: Forearc tectonics of the Kuril arc, *Geology*, 14(5), 404, [https://doi.org/10.1130/0091-7613\(1986\)14<404:osacft>2.0.co;2](https://doi.org/10.1130/0091-7613(1986)14<404:osacft>2.0.co;2).

- Kirby, S. H., S. Stein, E. A. Okal, and D. C. Rubie (1996), Metastable mantle phase transformations and deep earthquakes in subducting oceanic lithosphere, *Reviews of Geophysics*, 34(2), 261–306, <https://doi.org/10.1029/96rg01050>.
- Korenaga, T., and J. Korenaga (2016), Evolution of young oceanic lithosphere and the meaning of seafloor subsidence rate, *Journal of Geophysical Research: Solid Earth*, 121(9), 6315–6332, <https://doi.org/10.1002/2016jb013395>.
- Koulali, A., S. Susilo, S. McClusky, I. Meilano, P. Cummins, P. Tregoning, G. Lister, J. Efendi, and M. A. Syafi'i (2016), Crustal strain partitioning and the associated earthquake hazard in the eastern Sunda-Banda Arc, *Geophysical Research Letters*, 43(5), 1943–1949, <https://doi.org/10.1002/2016gl067941>.
- Koulali, A., S. McClusky, S. Susilo, Y. Leonard, P. Cummins, P. Tregoning, I. Meilano, J. Efendi, and A. B. Wijanarto (2017), The kinematics of crustal deformation in Java from GPS observations: Implications for fault slip partitioning, *Earth and Planetary Science Letters*, 458, 69–79, <https://doi.org/10.1016/j.epsl.2016.10.039>.
- Kozhurin, A., and E. Zelenin (2017), An extending island arc: The case of Kamchatka, *Tectonophysics*, 706–707, 91–102, <https://doi.org/10.1016/j.tecto.2017.04.001>.
- Kozhurin, A., V. Acocella, P. R. Kyle, F. M. Lagmay, I. V. Melekestsev, V. Ponomareva, D. Rust, A. Tibaldi, A. Tunesi, C. Corazzato, A. Rovidia, A. Sakharov, A. Tengonciang, and H. Uy (2006), Trenching studies of active faults in Kamchatka, eastern Russia: Palaeoseismic, tectonic and hazard implications, *Tectonophysics*, 417(3–4), 285–304, <https://doi.org/10.1016/j.tecto.2006.01.004>.
- Lallemand, S. (2016), Philippine Sea Plate inception, evolution, and consumption with special emphasis on the early stages of Izu-Bonin-Mariana subduction, *Progress in Earth and Planetary Science*, 3(1), 15, <https://doi.org/10.1186/s40645-016-0085-6>.
- Lallemand, S., and A. Heuret (2017), Subduction Zones Parameters, in *Reference Module in Earth Systems and Environmental Sciences*, Elsevier, <https://doi.org/10.1016/b978-0-12-409548-9.09495-1>.
- Lallemand, S., C.-S. Liu, S. Dominguez, P. Schnürle, and J. Malavieille (1999), Trench-parallel stretching and folding of forearc basins and lateral migration of the accretionary wedge in the southern Ryukyus: A case of strain partition caused by oblique convergence, *Tectonics*, 18(2), 231–247, <https://doi.org/10.1029/1998tc900011>.
- Lallemand, S., A. Heuret, and D. Boutelier (2005), On the relationships between slab dip, back-arc stress, upper plate absolute motion, and crustal nature in subduction zones, *Geochemistry, Geophysics, Geosystems*, 6(9), 2005GC000917, <https://doi.org/10.1029/2005gc000917>.
- Lallemand, S., A. Heuret, C. Faccenna, and F. Funiello (2008), Subduction dynamics as revealed by trench migration, *Tectonics*, 27(3), 2007TC002212, <https://doi.org/10.1029/2007tc002212>.
- Lallemand, S., M. Peyret, D. Arcay, and A. Heuret (2024), Accretion versus erosion and sediment transfer balance near the subduction interface, *Comptes Rendus. Géoscience*, 356(S2), 27–51, <https://doi.org/10.5802/crgeos.252>.
- Lewis, K. B., S. E. Lallemand, and L. Carter (2004), Collapse in a Quaternary shelf basin off East Cape, New Zealand: Evidence for passage of a subducted seamount inboard of the Ruatoria giant avalanche, *New Zealand Journal of Geology and Geophysics*, 47(3), 415–429, <https://doi.org/10.1080/00288306.2004.9515067>.
- Liu, X., K. C. McNally, and Z.-K. Shen (1995), Evidence for a role of the downgoing slab in earthquake slip partitioning at oblique subduction zones, *Journal of Geophysical Research*, 100(B8), 15,351–15,372, <https://doi.org/10.1029/95jb00870>.
- Mann, P., and A. Taira (2004), Global tectonic significance of the Solomon Islands and Ontong Java Plateau convergent zone, *Tectonophysics*, 389(3–4), 137–190, <https://doi.org/10.1016/j.tecto.2003.10.024>.
- Martinez, A., J. Malavieille, S. Lallemand, and J.-Y. Collot (2002), Strain partitioning in an accretionary wedge, in oblique convergence : analogue modelling, *Bulletin de la Société Géologique de France*, 173(1), 17–24, <https://doi.org/10.2113/173.1.17>.
- Marzocchi, W., L. Sandri, A. Heuret, and F. Funiello (2016), Where giant earthquakes may come, *Journal of Geophysical Research: Solid Earth*, 121(10), 7322–7336, <https://doi.org/10.1002/2016jb013054>.
- Mazzotti, S., H. Dragert, R. D. Hyndman, M. M. Miller, and J. A. Henton (2002), GPS deformation in a region of high crustal seismicity: N. Cascadia forearc, *Earth and Planetary Science Letters*, 198(1–2), 41–48, [https://doi.org/10.1016/s0012-821x\(02\)00520-4](https://doi.org/10.1016/s0012-821x(02)00520-4).
- Mazzotti, S., H. Dragert, J. Henton, M. Schmidt, R. Hyndman, T. James, Y. Lu, and M. Craymer (2003), Current tectonics of northern Cascadia from a decade of GPS measurements, *Journal of Geophysical Research*, 108(B12), 2003JB002653, <https://doi.org/10.1029/2003jb002653>.
- McCaffrey, R. (1992), Oblique plate convergence, slip vectors, and forearc deformation, *Journal of Geophysical Research*, 97(B6), 8905–8915, <https://doi.org/10.1029/92jb00483>.
- McClay, K. R., P. S. Whitehouse, T. Dooley, and M. Richards (2004), 3D evolution of fold and thrust belts formed by oblique convergence, *Marine and Petroleum Geology*, 21(7), 857–877, <https://doi.org/10.1016/j.marpetgeo.2004.03.009>.
- Morell, K. D., K. Gilroy, T. Finley, and N. Harriehausen (2025), Subduction zone obliquity dictates global trench-parallel inner forearc deformation, *AGU Advances*, 6(1), e2024AV001468, <https://doi.org/10.1029/2024av001468>.
- Nakao, A., T. Kuwatani, K. Ueki, K. Yoshida, T. Yutani, H. Hino, and S. Akaho (2022), Subduction-zone parameters that control slab behavior at the 660-km discontinuity revealed by logistic regression analysis and model selection, *Frontiers in Earth Science*, 10, <https://doi.org/10.3389/feart.2022.1008058>.

- Nishimura, T. (2011), Back-arc spreading of the northern Izu-Ogasawara (Bonin) Islands arc clarified by GPS data, *Tectonophysics*, 512(1-4), 60–67, <https://doi.org/10.1016/j.tecto.2011.09.022>.
- Nishimura, T., Y. Yokota, K. Tadokoro, and T. Ochi (2018), Strain partitioning and interplate coupling along the northern margin of the Philippine Sea plate, estimated from Global Navigation Satellite System and Global Positioning System-Acoustic data, *Geosphere*, 14(2), 535–551, <https://doi.org/10.1130/ges01529.1>.
- Patria, A., H. Tsutsumi, and D. H. Natawidjaja (2021), Active fault mapping in the onshore northern Banda Arc, Indonesia: Implications for active tectonics and seismic potential, *Journal of Asian Earth Sciences*, 218(104881), 104,881, <https://doi.org/10.1016/j.jseaes.2021.104881>.
- Patriat, M., J. Collot, L. Danyushevsky, M. Fabre, S. Meffre, T. Falloon, P. Rouillard, B. Pelletier, M. Roach, and M. Fournier (2015), Propagation of back-arc extension into the arc lithosphere in the southern New Hebrides volcanic arc, *Geochemistry, Geophysics, Geosystems*, 16(9), 3142–3159, <https://doi.org/10.1002/2015gc005717>.
- Perucca, L., P. Alvarado, and M. Saez (2016), Neotectonics and seismicity in southern Patagonia, *Geological Journal*, 51(4), 545–559, <https://doi.org/10.1002/gj.2649>.
- Petricca, P., and E. Carminati (2016), Present-day stress field in subduction zones: Insights from 3D viscoelastic models and data, *Tectonophysics*, 667, 48–62, <https://doi.org/10.1016/j.tecto.2015.11.010>.
- Philippon, M., and G. Corti (2016), Obliquity along plate boundaries, *Tectonophysics*, 693, 171–182, <https://doi.org/10.1016/j.tecto.2016.05.033>.
- Rangin, C., X. Le Pichon, S. Mazzotti, M. Pubellier, N. Chamot-Rooke, M. Aurelio, A. Walpersdorf, and R. Quebral (1999), Plate convergence measured by GPS across the Sundaland/Philippine Sea Plate deformed boundary: the Philippines and eastern Indonesia, *Geophysical Journal International*, 139(2), 296–316, <https://doi.org/10.1046/j.1365-246x.1999.00969.x>.
- Reilinger, R., S. McClusky, P. Vernant, S. Lawrence, S. Ergintav, R. Cakmak, H. Ozener, F. Kadirov, I. Guliev, R. Stepanyan, M. Nadariya, G. Hahubia, S. Mahmoud, K. Sakr, A. ArRajehi, D. Paradissis, A. Al-Aydrus, M. Prilepin, T. Guseva, E. Evren, A. Dmitrova, S. V. Filikov, F. Gomez, R. Al-Ghazzi, and G. Karam (2006), GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions, *Journal of Geophysical Research*, 111(B5), 2005JB004,051, <https://doi.org/10.1029/2005jb004051>.
- Ribeiro, J. M., R. J. Stern, F. Martinez, O. Ishizuka, S. G. Merle, K. Kelley, E. Y. Anthony, M. Ren, Y. Ohara, M. Reagan, G. Girard, and S. Bloomer (2013), Geodynamic evolution of a forearc rift in the southernmost Mariana Arc: Geodynamic evolution of SEMFR, *Island Arc*, 22(4), 453–476, <https://doi.org/10.1111/iar.12039>.
- Schellart, W. P. (2008a), Subduction zone trench migration: Slab driven or overriding-plate-driven?, *Physics of the Earth and Planetary Interiors*, 170(1-2), 73–88, <https://doi.org/10.1016/j.pepi.2008.07.040>.
- Schellart, W. P. (2008b), Overriding plate shortening and extension above subduction zones: A parametric study to explain formation of the Andes Mountains, *Geological Society of America Bulletin*, 120(11-12), 1441–1454, <https://doi.org/10.1130/b26360.1>.
- Schellart, W. P. (2024), Subduction dynamics and overriding plate deformation, *Earth-Science Reviews*, 253(104755), 104,755, <https://doi.org/10.1016/j.earscirev.2024.104755>.
- Schellart, W. P., and L. Moresi (2013), A new driving mechanism for backarc extension and backarc shortening through slab sinking induced toroidal and poloidal mantle flow: Results from dynamic subduction models with an overriding plate, *Journal of Geophysical Research: Solid Earth*, 118(6), 3221–3248, <https://doi.org/10.1002/jgrb.50173>.
- Scholz, C. H., and J. Campos (1995), On the mechanism of seismic decoupling and back arc spreading at subduction zones, *Journal of Geophysical Research*, 100(B11), 22,103–22,115, <https://doi.org/10.1029/95jb01869>.
- Selvans, M. M., J. M. Stock, C. DeMets, O. Sanchez, and B. Marquez-Azua (2011), Constraints on Jalisco block motion and tectonics of the Guadalajara triple junction from 1998–2001 campaign GPS data, *Pure and Applied Geophysics*, 168(8-9), 1435–1447, <https://doi.org/10.1007/s00024-010-0201-2>.
- Serpelloni, E., G. Vannucci, S. Pondrelli, A. Argani, G. Casula, M. Anzidei, P. Baldi, and P. Gasperini (2007), Kinematics of the Western Africa-Eurasia plate boundary from focal mechanisms and GPS data, *Geophysical Journal International*, 169(3), 1180–1200, <https://doi.org/10.1111/j.1365-246x.2007.03367.x>.
- Simons, W. J. F., A. Socquet, C. Vigny, B. A. C. Ambrosius, S. Haji Abu, C. Promthong, C. Subarya, D. A. Sarsito, S. Matheussen, P. Morgan, and W. Spakman (2007), A decade of GPS in Southeast Asia: Resolving Sundaland motion and boundaries, *Journal of Geophysical Research*, 112(B6), <https://doi.org/10.1029/2005jb003868>.
- Socquet, A., W. Simons, C. Vigny, R. McCaffrey, C. Subarya, D. Sarsito, B. Ambrosius, and W. Spakman (2006), Microblock rotations and fault coupling in SE Asia triple junction (Sulawesi, Indonesia) from GPS and earthquake slip vector data, *Journal of Geophysical Research*, 111(B8), <https://doi.org/10.1029/2005jb003963>.
- Stegman, D. R., J. Freeman, W. P. Schellart, L. Moresi, and D. May (2006), Influence of trench width on subduction hinge retreat rates in 3-D models of slab rollback, *Geochemistry, Geophysics, Geosystems*, 7(3), 2005GC001,056, <https://doi.org/10.1029/2005gc001056>.
- Stein, S., and C. A. Stein (1996), Thermo-mechanical evolution of oceanic lithosphere: Implications for the subduction process and deep earthquakes, in *Subduction Top to Bottom*, vol. 96, pp. 1–17, American Geophysical Union, Washington, D. C., <https://doi.org/10.1029/gm096p0001>.
- Sternai, P., L. Jolivet, A. Menant, and T. Gerya (2014), Driving the upper plate surface deformation by slab rollback and mantle flow, *Earth and Planetary Science Letters*, 405, 110–118, <https://doi.org/10.1016/j.epsl.2014.08.023>.

- Suárez, R. J., B. Guillaume, J. Martinod, M. C. Ghiglione, C. Sue, and J.-J. Kermarrec (2022), Role of convergence obliquity and inheritance on sliver tectonics: Insights from 3-D subduction experiments, *Tectonophysics*, 842(229583), 229,583, <https://doi.org/10.1016/j.tecto.2022.229583>.
- Symithe, S., E. Calais, J. B. de Chaballier, R. Robertson, and M. Higgins (2015), Current block motions and strain accumulation on active faults in the Caribbean, *Journal of Geophysical Research: Solid Earth*, 120(5), 3748–3774, <https://doi.org/10.1002/2014jb011779>.
- Syracuse, E. M., P. E. van Keken, and G. A. Abers (2010), The global range of subduction zone thermal models, *Physics of the Earth and Planetary Interiors*, 183(1-2), 73–90, <https://doi.org/10.1016/j.pepi.2010.02.004>.
- Turino, V., and A. F. Holt (2024), Spatio-temporal variability in slab temperature within dynamic 3-D subduction models, *Geophysical Journal International*, 236(3), 1484–1498, <https://doi.org/10.1093/gji/ggad489>.
- Turner, H. L., III, P. LaFemina, A. Saballos, G. S. Mattioli, P. E. Jansma, and T. Dixon (2007), Kinematics of the Nicaraguan forearc from GPS geodesy, *Geophysical Research Letters*, 34(2), <https://doi.org/10.1029/2006gl027586>.
- Uyeda, S., and H. Kanamori (1979), Back-arc opening and the mode of subduction, *Journal of Geophysical Research*, 84(B3), 1049, <https://doi.org/10.1029/jb084ib03p01049>.
- van Benthem, S., R. Govers, W. Spakman, and R. Wortel (2013), Tectonic evolution and mantle structure of the Caribbean, *Journal of Geophysical Research: Solid Earth*, 118(6), 3019–3036, <https://doi.org/10.1002/jgrb.50235>.
- van Keken, P. E., B. R. Hacker, E. M. Syracuse, and G. A. Abers (2011), Subduction factory: 4. Depth-dependent flux of H₂O from subducting slabs worldwide, *Journal of Geophysical Research*, 116(B1), B01,401, <https://doi.org/10.1029/2010jb007922>.
- van Zelst, I., S. Brizzi, E. van Rijsingen, F. Funicello, and Y. van Dinther (2025), Investigating global correlations between earthquake-generated tsunamis and subduction zone characteristics, *Tektonika*, 3(1), 46–63, <https://doi.org/10.55575/tektonika2025.3.1.88>.
- Vernant, P., R. Reilinger, and S. McClusky (2014), Geodetic evidence for low coupling on the Hellenic subduction plate interface, *Earth and Planetary Science Letters*, 385, 122–129, <https://doi.org/10.1016/j.epsl.2013.10.018>.
- Villegas-Lanza, J. C., J.-M. Nocquet, F. Rolandone, M. Vallée, H. Tavera, F. Bondoux, T. Tran, X. Martin, and M. Chlieh (2016), A mixed seismic–aseismic stress release episode in the Andean subduction zone, *Nature Geoscience*, 9(2), 150–154, <https://doi.org/10.1038/ng eo2620>.
- von Huene, R., and D. W. Scholl (1991), Observations at convergent margins concerning sediment subduction, subduction erosion, and the growth of continental crust, *Reviews of Geophysics*, 29(3), 279–316, <https://doi.org/10.1029/91rg00969>.
- Wallace, L. M., R. McCaffrey, J. Beavan, and S. Ellis (2005), Rapid microplate rotations and backarc rifting at the transition between collision and subduction, *Geology*, 33(11), 857, <https://doi.org/10.1130/g21834.1>.
- Wallace, L. M., S. Ellis, and P. Mann (2009), Collisional model for rapid fore-arc block rotations, arc curvature, and episodic back-arc rifting in subduction settings, *Geochemistry, Geophysics, Geosystems*, 10(5), 2008GC002,220, <https://doi.org/10.1029/2008gc002220>.
- Wang, K., Y. Hu, M. Bevis, E. Kendrick, R. Smalley, Jr, R. B. Vargas, and E. Lauría (2007), Crustal motion in the zone of the 1960 Chile earthquake: Detangling earthquake-cycle deformation and forearc-sliver translation, *Geochemistry, Geophysics, Geosystems*, 8(10), <https://doi.org/10.1029/2007gc001721>.
- Wang, S., H. Yu, Q. Zhang, and Y. Zhao (2018), Absolute plate motions relative to deep mantle plumes, *Earth and Planetary Science Letters*, 490, 88–99, <https://doi.org/10.1016/j.epsl.2018.03.021>.
- Wei, S. S., D. A. Wiens, P. E. van Keken, and C. Cai (2017), Slab temperature controls on the Tonga double seismic zone and slab mantle dehydration, *Science Advances*, 3(1), e1601,755, <https://doi.org/10.1126/sciadv.1601755>.
- Wiens, D. A., and H. J. Gilbert (1996), Effect of slab temperature on deep-earthquake aftershock productivity and magnitude–frequency relations, *Nature*, 384(6605), 153–156, <https://doi.org/10.1038/384153a0>.
- Wirth, E. A., V. J. Sahakian, L. M. Wallace, and D. Melnick (2022), The occurrence and hazards of great subduction zone earthquakes, *Nature Reviews Earth & Environment*, 3(2), 125–140, <https://doi.org/10.1038/s43017-021-00245-w>.
- Yu, G., S. G. Wesnousky, and G. Ekström (1993), Slip partitioning along major convergent plate boundaries, in *Shallow Subduction Zones: Seismicity, Mechanics and Seismic Potential Part 1*, pp. 183–210, Birkhäuser Basel, Basel, https://doi.org/10.1007/978-3-0348-5846-5_2.
- Zhao, S., S. McClusky, P. R. Cummins, M. S. Miller, and H. Nugroho (2023), New insights into crustal deformation of the Indonesia–Australia–new guinea collision zone from a broad-scale kinematic model, *Journal of Geophysical Research: Solid Earth*, 128(2), e2022JB024,810, <https://doi.org/10.1029/2022jb024810>.