International Association of Oil & Gas Producers

REPORT 373-27 | JUNE 2023

Coordinate Reference Systems and transformations for offshore Angola

Acknowledgements

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About

The Angolan government has mandated the adoption of a new geodetic datum for all topographic cartography in the country. This document provides a brief overview of Coordinate Reference Systems (CRS) historically used in Angola, the CRS currently used by oil and gas operating companies, details of CRS transformation systems, and a list of recommendations for oil and gas industry geospatial professionals working in Angola.

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Coordinate Reference Systems and transformations for offshore Angola

Revision history

VERSION	DATE	AMENDMENTS
1.0	June 2023	First issue

Contents

Introduction

When offshore oil and gas exploration operations commenced in Angola during the late 1970s, there was a notable absence of officially published positional data available for use by the associated operating companies. Operators devised methods to transform geospatial data acquired using the Global Positioning System (GPS) that was referenced to the World Geodetic System 1984 (WGS 84) to local geodetic datums specified by the Angolan government using the best available information.

Since then, the Angolan government has been systematically working towards modernization of the national geodetic framework by introducing a programme of field campaigns. This has culminated in the implementation of the government's Presidential Decree No. 9/18, supported by Instruction No. 1/21 that mandates the adoption of a new geodetic datum.

This guidance note has been produced to support the objectives of the presidential decree and associated instructions, and has been developed in close consultation with the ANPG (Angolan National Oil, Gas and Biofuels Agency) data management team. The target audience is geospatial professionals working in the oil and gas industry in Angola, including operating companies, government authorities, contractors, and service providers.

This document includes the following:

- Brief history of the development of CRSs
- Current CRSs used by gas and oil operators
- Details of coordinate transformations, with examples
    - Source of licence boundary definitions and awards
    - List of recommendations

All the information contained in the tables and figures is the best available information as of 1st January 2023

1. Background

In general, oil and gas operators in Angola have referenced geospatial data to the Camacupa datum. There was, however, an exception for operations onshore and offshore Cabinda, where one oil and gas company used the Malongo datum.

In 2010, the Angolan government conducted the first of two field campaigns to update the national geodetic framework. Under the direction of the IGCA (Instituto Geográfico e Cadastral de Angola, the Geographic and Cadastral Institute of Angola), a network of 18 Continuously Operating Reference Stations (CORS) was established. This network defines the Reference System de Angola 2013 (RSAO13).

The second campaign in 2015 expanded on the previous geodetic observations from the GNSS field work to establish a revised understanding of the regional Camacupa datum. This was significantly different from that being used by the operating companies, and to address this IOGP renamed the historical Camacupa datum as 'Camacupa 1948', and refer to this new understanding as 'Camacupa 2015'.

The results of the new realisation of the Camacupa datum were published in January 2016 by CIDDEMA (the Interministerial Commission for the Delimitation and Demarcation of Maritime Zones in Angola) provided, for the first time, a single unified network of geodetic control points that covers the entire country.

In 2018 the Angolan government issued Presidential Decree No. 9/18, which mandated the adoption of RSAO13 as the geodetic datum for all topographic cartography in Angola, with a ten-year transition period for its full implementation. The Decree also defined the use of the Lambert conformal conical projection for all national cartography. The IGCA has subsequently advised that the Lambert projection is subject to revision and that clarification and further guidance on projections will follow, and so this is not discussed further in this guidance note.

In 2021, the ANPG – the arbitrating authority for interpretation and application of the Decree – informed oil and gas companies with active operations in Angola that additional guidance on the standardization and use of geodetic CRSs had been made available in the publication *Diário da República*. This guidance mandated the application of RSAO13 as the geodetic reference system for all 'new blocks'.

However, the primary issue was still the possible confusion and significant horizontal offset between coordinate values referenced to different CRSs. For example, the difference in position that arises by referencing common coordinate values to the historic regional Camacupa 1948 and RSAO13 is approximately 400 metres. This is problematic because of the volume of data gathered from exploration and development operations over the last forty years that is referenced to either the Camacupa 1948 or Malongo datums. Retrospectively transforming geospatial data referenced to these historic CRSs would create significant operational risks and technical challenges, and would result in significant additional costs for producing assets.

Following extensive consultation and discussions between ANPG, the IGCA, and IOGP, it has been agreed that the retrospective implementation of RSA013 will apply only to areas that have not previously been licensed, and that operators can continue to use the existing, historical CRSs elsewhere. In addition, geospatial data submitted to ANPG for operations in areas where the use of historic regional datums persist shall include details of the applicable transformation to RSA013 so that ANPG may transform this data to RSA013, as required. ANPG has confirmed that the boundaries of the original exploration licence blocks framework, referenced to the Camacupa 1948 CRS graticule, will remain unchanged.

ANPG has also agreed that the term 'blocks' in Presidential Decree No. 9/18 refers to the initial exploration blocks referenced in Appendix A, as opposed to blocks derived from relinquishments or from development areas. The term 'new blocks' relates to exploration or development licences awarded after 2021, for areas that do not intersect blocks that have previously been licensed for exploration.

2. Coordinate reference systems currently used by oil and gas operators

The Transverse Mercator projection is used by all offshore operators. However, as the offshore area is bisected by the boundary between Universal Transverse Mercator (UTM) zones 32 and 33, different UTM zones and some custom Transverse Mercator projections have been used.

Currently, the geographic CRSs used by oil and gas operators in Angola, compiled from consultation with IOGP Members, are shown in Table 1.The relationships between these CRSs are discussed in section 3.

Table 2 and Figure 1 show the associated projected CRSs, together with the areas of use, based on the boundaries of the exploration block licences defined in Appendix A. This information is limited to active onshore and offshore licences and excludes licences that are currently in the process of relinquishment. These are the projected CRSs to which coordinates are referenced in support of operations and the submission of data to ANPG.

Table 1: Geographic CRSs used by oil and gas operators in Angola

EPSG name	EPSG code	Comments
Camacupa 1948	4220	Used by the majority of operators.
Malongo 1987	4259	Used only in Cabinda.
RSAO13	8699	Specified by ANPG for operational use in the oil and gas industry in 2021.
WGS 84	4326	CRS for the GPS satellite positioning system.

Table 2: Projected CRSs in current use by current oil and gas operators in Angola

EPSG name	EPSG code	Blocks
Camacupa 1948/UTM zone 33S	22033	1, 2, 3, 4, 5, 16, 17, 18, 23, 28 All onshore blocks
Camacupa 1948/TM 11.30 SE	22091	15
Camacupa 1948/TM 12 SE	22092	31, 32
Malongo 1987/UTM zone 33S	7992	0, 14
RSAO13/UTM zone 32S	9156	48
RSAO13/UTM zone 33S	9157	20, 21, 29
WGS 84/UTM zone 32S	32732	30, 44, 45

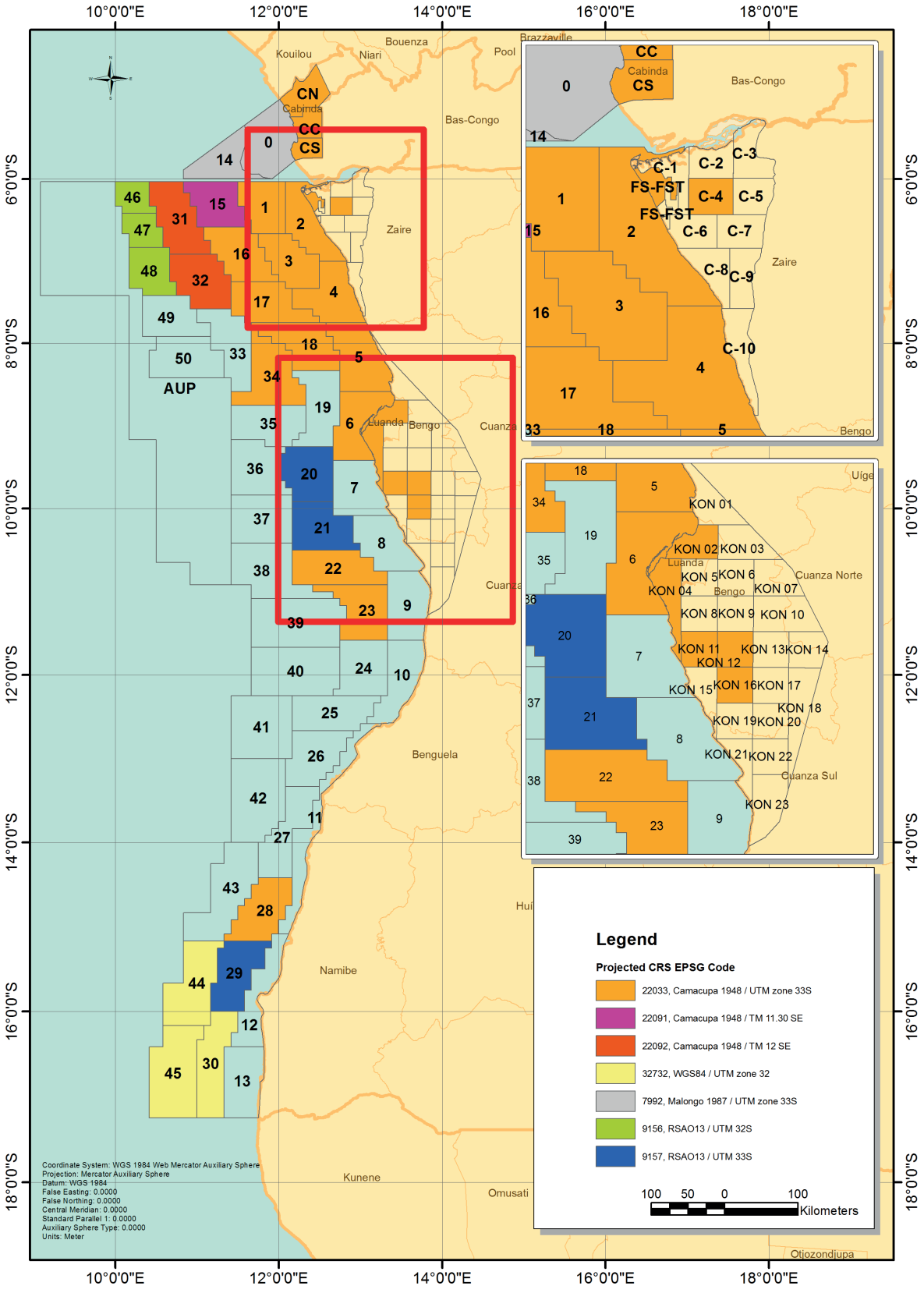

Figure 1: Projected CRSs used by current operators

3. Coordinate transformations

Prior to 2015 there was no official established relationship between regional datums and WGS 84, the CRS to which GPS positions are referenced. This resulted in the development of multiple solutions by different operators for the transformation between the local CRSs and WGS 84. The majority of these transformations are documented in the EPSG Registry maintained by IOGP.

Following analysis of the control coordinates derived from the 2015 field campaign and those used historically to support offshore oil and gas operations, it was recognized that this work resulted in significant revisions of the Camacupa coordinates. As previously mentioned, this resulted in the renaming of the new and existing Camapuca datums, and the relevant transformations were updated accordingly in the EPSG Registry.

3.1 Coordinate transformations to and from WGS 84

Details of the coordinate transformations between the national CRSs and the GPS CRS WGS 84 that are in current use in different exploration blocks are shown in Table 3 and Figure 2.

Table 3: Coordinate transformations between regional CRSs and WGS 84 used by oil and gas operators in Angola

EPSG name	EPSG code	Blocks
Camacupa 1948 to WGS 84 (6)	1323	1, 2, 3, 4, 5, 23, 28 All operated onshore blocks
Camacupa 1948 to WGS 84 (7)	1324	15
Camacupa 1948 to WGS 84 (9)	1326	16
Camacupa 1948 to WGS 84 (10)	1327	17, 18, 31, 32
Malongo 1987 to WGS 84 (2)	1557	0, 14
RSAO13 to WGS 84 (1)	8819	20, 21, 29, 48

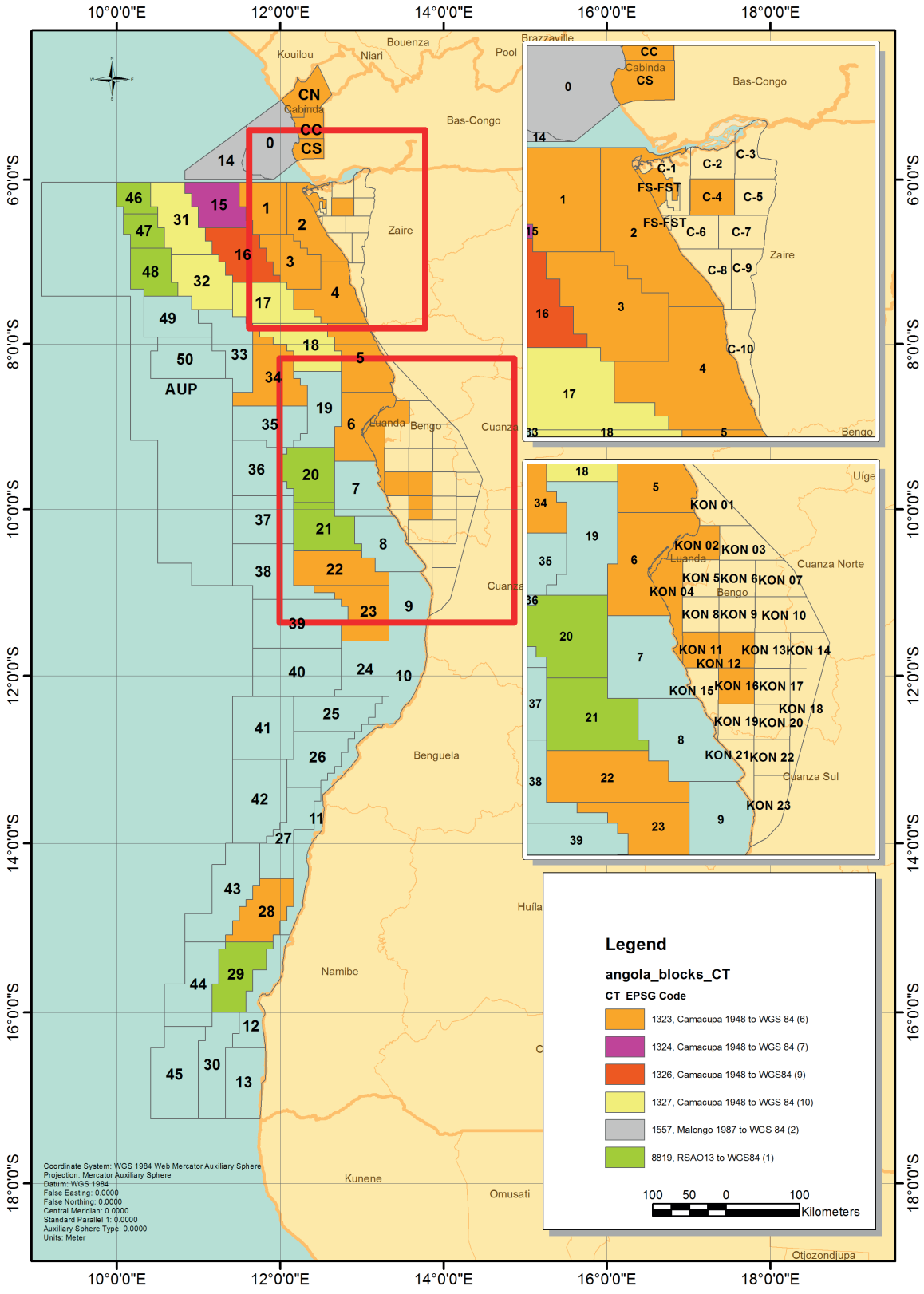

Figure 2: Coordinate transformations to WGS 84 used by current operators

3.1.1 Transformations between Camacupa 1948, Malongo 1987, and WGS 84

When offshore oil and gas exploration operations first commenced, individual companies derived their own transformations between Camacupa 1948 and WGS 84, and Malongo 1987 and WGS 84, by using the best available geodetic information and methods. For technical reasons that are not covered within the scope of this guidance note, this resulted in multiple sets of transformation parameters for the 'same' transformation in offshore areas spanning the entire coast of Angola.

For Camacupa 1948, ten of these transformations are recorded in the IOGP EPSG dataset, as transformation codes 1318 to 1327 inclusive, but only four of these are currently used in operations (see Table 3).

Figure 3 illustrates the horizontal position shifts, that would result from the use of different realizations of the Camacupa 1948 to WGS 84 coordinate transformation, relative to the most commonly used variant (recorded as code 1323 in the EPSG registry). The circles show the published accuracy for each coordinate transformation.

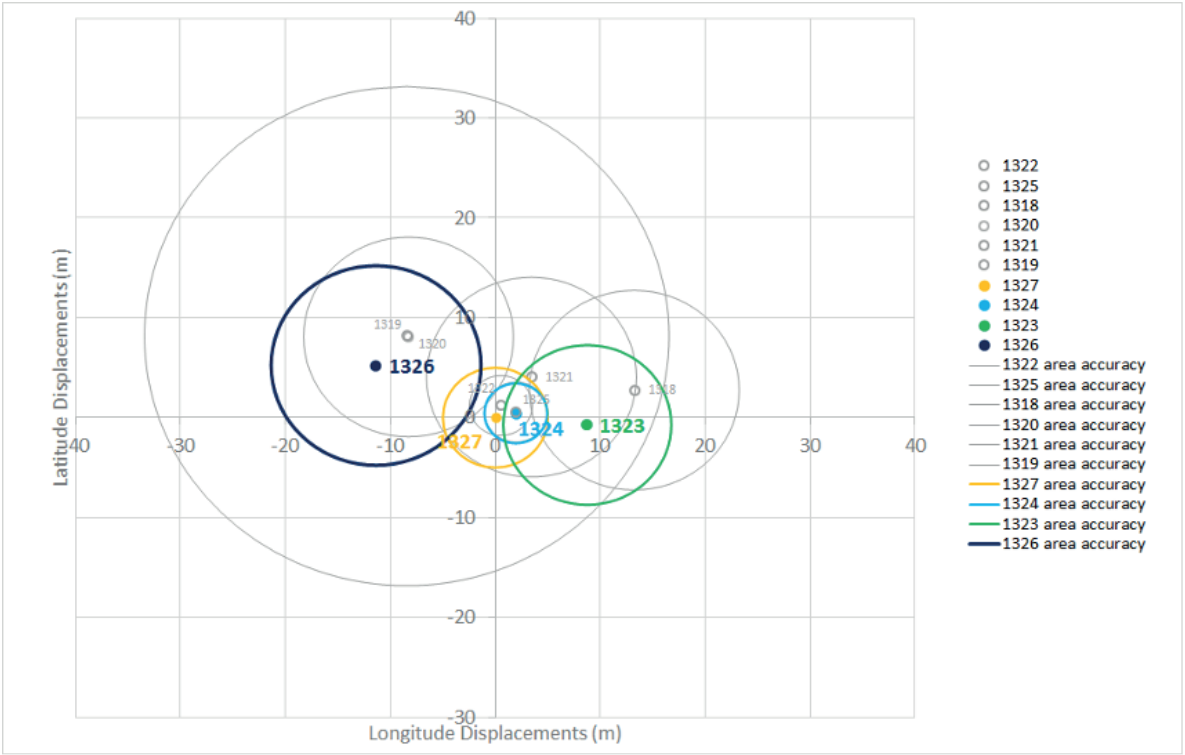

Figure 3: Effective differences between the Camacupa 1948 to WGS 84 coordinate transformation

Note that the positional uncertainty associated with these transformations is estimated at between 3 and 10 m. This level of absolute accuracy is acceptable for oil and gas operations as it does not impact relative positioning within each block. For exploration and production activities, consistency in coordinates is as important as absolute accuracy.

3.2 Coordinate transformations to and from RSAO13

3.2.1 Transformations between RSAO13 and WGS 84

RSAO13 is fixed to the African tectonic plate and was aligned with respect to ITRF2008 at epoch 2010.90. Since then, and because of the movement of the tectonic plate, RSAO13 has been very slowly diverging from ITRF2008.

WGS 84 (G1762), the sixth update to the realization of the WGS84 Reference Frame, was aligned with the ITRF2008 to within a few centimetres. As both RSAO13 and WGS 84 were aligned to ITRF2008, the relationship between WGS 84 and RSAO13 was within a few centimetres at the RSAO13 reference epoch of 2010.90 – increasing through the movement of the African tectonic plate by approximately 2.5 cm per year.

The relationship between RSAO13 and the WGS 84 datum ensemble has been defined by IOGP as a 'null transformation'. While this level of accuracy would not be appropriate for geodetic work, it is acceptable in the context of offshore oil and gas operations. This transformation is an approximation, with an uncertainty of 1 metre, as it assumes equality between the plate-fixed static regional RSAO13 CRS and the earth-fixed dynamic WGS 84 CRS. It needs to be recognized that due to it being dynamic, locations defined by WGS 84 coordinates change with time, and to be unambiguous the coordinate epoch expressed as a decimal year value, e.g., 2010.90, is required (refer to IOGP Guidance Note 373-25).

3.2.2 Transformations between Camacupa 1948, Malongo 1987, and RSAO13

The transformations between Camacupa 1948 and WGS 84, and Malongo 1987 and WGS 84 (as described in section 3.1) have been concatenated with the transformation from WGS 84 to RSAO13 (as described in section 3.2.1), to derive direct transformations between Camacupa 1948 or Malongo 1987 and RSAO13. These are shown in Table 4. An example transformation is included in Appendix B.

Table 4: Coordinate derivation of transformations between regional CRSs and RSAO13

EPSG name	EPSG code	Derivation (EPSG codes)	Blocks
Camacupa 1948 to RSAO13 (1)	8883	EPSG 1324 and EPSG 8819	15
Camacupa 1948 to RSAO13 (2)	8884	EPSG 1327 and EPSG 8819	17, 18, 31, 32
Camacupa 1948 to RSAO13 (3)	9904	EPSG 1323 and EPSG 8819	1, 2, 3, 4, 5, 23, 28 All onshore blocks
Camacupa 1948 to RSAO13 (4)	9905	EPSG 1326 and EPSG 8819	16
Malongo 1987 to RSAO13 (1)	9906	EPSG 1557 and EPSG 8819	0, 14

From EPSG dataset version v10.066, the EPSG Registry records five direct transformations to cover those between the local datum (Camacupa 1948 and Malongo 1987) and RSAO13, as shown in Table 5.

Table 5: Direct coordinate transformations between regional CRSs and RSAO13

EPSG name	EPSG code	Accuracy (m)	Blocks
Camacupa 1948 to RSAO13 (1)	8883	3	15
Camacupa 1948 to RSAO13 (2)	8884	5	17, 18, 31, 32
Camacupa 1948 to RSAO13 (3)	9904	8	1, 2, 3, 4, 5, 23, 28 All onshore blocks
Camacupa 1948 to RSAO13 (4)	9905	10	16
Malongo 1987 to RSAO13 (1)	9906	5	0, 14

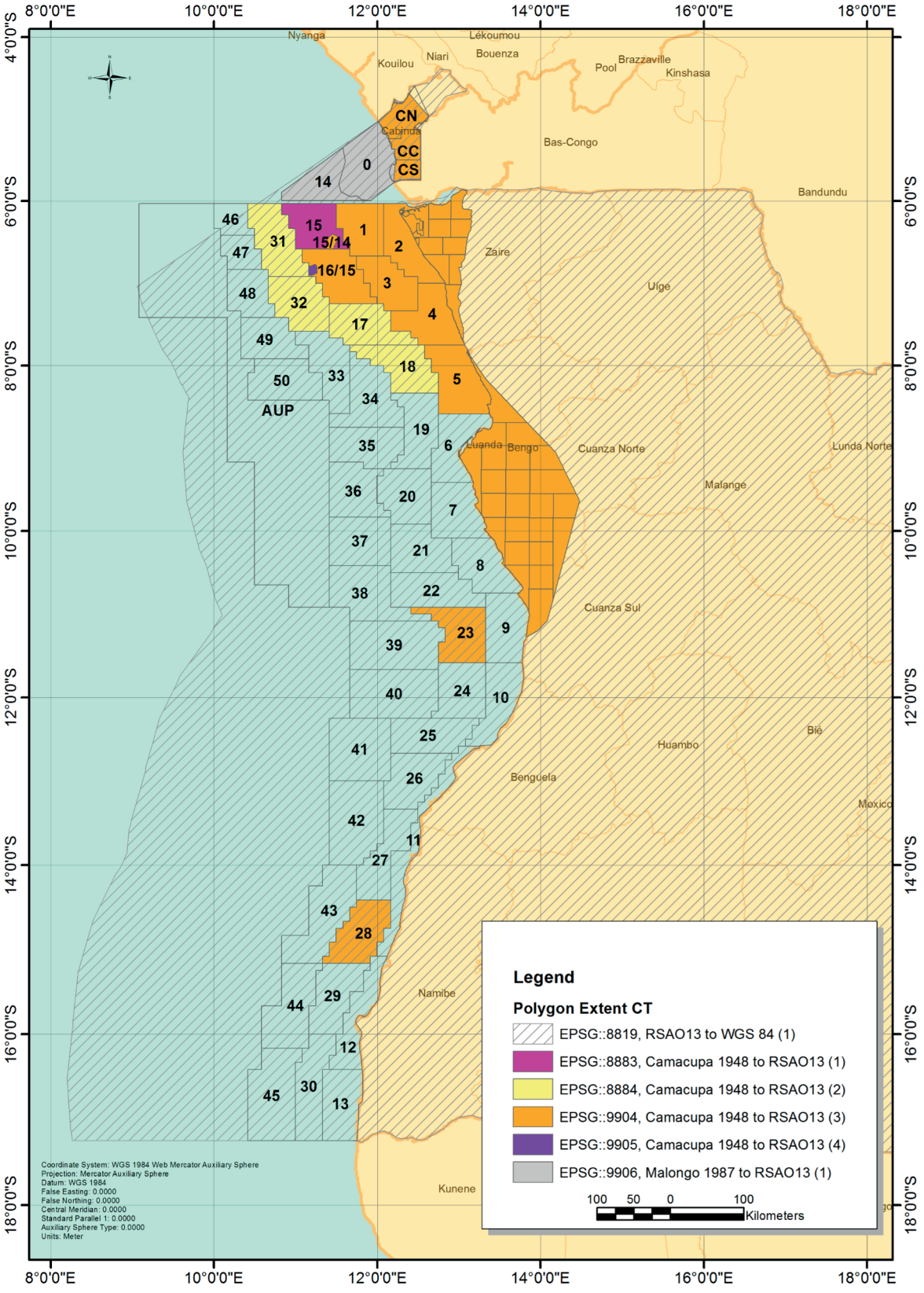

Figure 4: Transformation to RSAO13 by block

4. Definition and date of award of offshore exploration licences

Tables A-1 to A-3 in Appendix A provide details of the source of the exploration licence boundary definitions for those licences awarded before 2016, between 2016 and 2021, and those yet to be awarded (see also Figure A-1).

To date, the vertices of offshore licence boundaries published in the *Diário da República* have been expressed as geographical coordinates, sometimes referenced to Camacupa 1948, and sometimes to WGS 84. In the official definitions, the relationship between Camacupa 1948 and WGS 84 is defined by the coordinate transformation Camacupa 1948 to WGS 84 (6) (EPSG code 1323).

5. Recommendations

1) All licence agreements for future blocks should contain the boundary, CRS, and coordinate transformation definitions as recommended in IOGP Guidance Note 373-03: *Contract area description* (available from the IOGP bookstore).
2) The following protocols should be applied to define the geographic CRS in which the vertices of new licence boundaries are defined:
   - For areas that have not been previously licensed, the licence boundary definition and data acquired in the licence area should be referenced to RSAO13.
   - For new licences in areas that been previously licensed, the licence boundary definition and data acquired in the licence area should be referenced to the CRS used previously. This will most often be Camacupa 1948.
3) 'Blocks' are the exploration blocks defined in the ANPG concession map (see Figure A-1 in Appendix A), as opposed to derivative blocks from relinquishments, or development areas.
4) 'New' blocks are exploration or development licences awarded after 2021, for areas that do not intersect blocks that have previously been licensed for exploration or development.
5) All geospatial data submitted to ANPG should be in the operating CRS for the licence and should include the CRS to which coordinates are referenced and, if applicable, any coordinate transformations used, including their EPSG code.
6) Where licences with definitions referenced to Camacupa 1948 and to RSAO13 are adjacent, care is needed to ensure that the definitions have no overlap or leave unlicensed areas.
7) Coordinate transformations between WGS 84 and Camacupa 1948 or Malongo 1987 should be selected from the transformations described in section 3.1.1 of this guidance note.
8) Coordinate transformations between RSAO13 and Camacupa 1948 or Malongo 1987 should be selected from the transformations described in section 3.2.2 of this guidance note.
9) Coordinates referenced to RSAO13 can be assumed to have a 'null transformation' with WGS 84, i.e., EPSG code: 8819 – RSAO13 to WGS 84 (1).
10) It is preferable for coordinates to be referenced to RSAO13 rather than WGS 84 as they will not change with time.

Appendix A - Definition and date of award of offshore exploration licences

Table A-1: Source of official boundary definition for offshore exploration licences awarded before 2016 (from *Diário da República*, with publication edition number and date)

Block	Edition (Série No.)	Publication date (d/m/y)	Year of licence award
0	37	07/05/2004	2004
1	23	10/06/1994	1979
2	38	16/09/1992	1992
3	116	28/09/2005	1980
4	115	26/09/2005	1984
5	9	25/02/1999	1986
6	132	01/11/2006	1980
7	44	25/10/1991	1991
8	132	01/11/2006	1989
9	26	12/06/1998	1981
10	56	16/12/1994	1994
12	19	06/02/2015	1994
13	19	06/02/2015	1994
14	51	18/11/1994	1994
15	27	08/07/1994	1994
16	62	06/08/2002	1992
17	38	16/09/1992	1992
18	33	09/08/1996	1996
19	241	15/12/2011	1998
20	34	16/08/1996	1996
21	107	11/06/2009	1998
22	53	16/12/1998	1998
23	132	01/11/2006	2006
24	241	15/12/2011	1998
25	241	15/12/2011	1999
26	132	01/11/2006	2006
31	10	10/03/1998	1999
32	10	10/03/1998	1999
33	10	10/03/1998	1999
34	10	10/03/1998	2001

Block	Edition (Série No.)	Publication date (d/m/y)	Year of licence award
35	241	15/12/2011	2011
36	241	15/12/2011	2011
38	241	15/12/2011	2011
39	241	15/12/2011	2011

Table A-2: Source of official boundary definition for offshore exploration licences awarded between 2016 and 2021 (from *Diário da República*, with publication edition number and date)

Block	Edition (Série No.)	Publication date (d/m/y)	Year of licence award
27	19	06/02/2015	2021
28	19	06/02/2015	2021
29	19	06/02/2015	2021
30	19	06/02/2015	2019
44	19	06/02/2015	2019
45	19	06/02/2015	2019
46	3	07/01/2008	2019
47	3	07/01/2008	2019
48	3	07/01/2008	2016

Table A-3: Offshore exploration licences that have yet to be awarded (from *Diário da República*, with publication edition number and date, except for ultra-deep waters)

Block	Edition (Série No.)	Publication date (d/m/y)
Ultra-deep Waters	Not available	
11	19	06/02/2015
37	241	15/12/2011
40	241	15/12/2011
41	19	06/02/2015
42	19	06/02/2015
43	19	06/02/2015
49	3	07/01/2008
50	3	07/01/2008

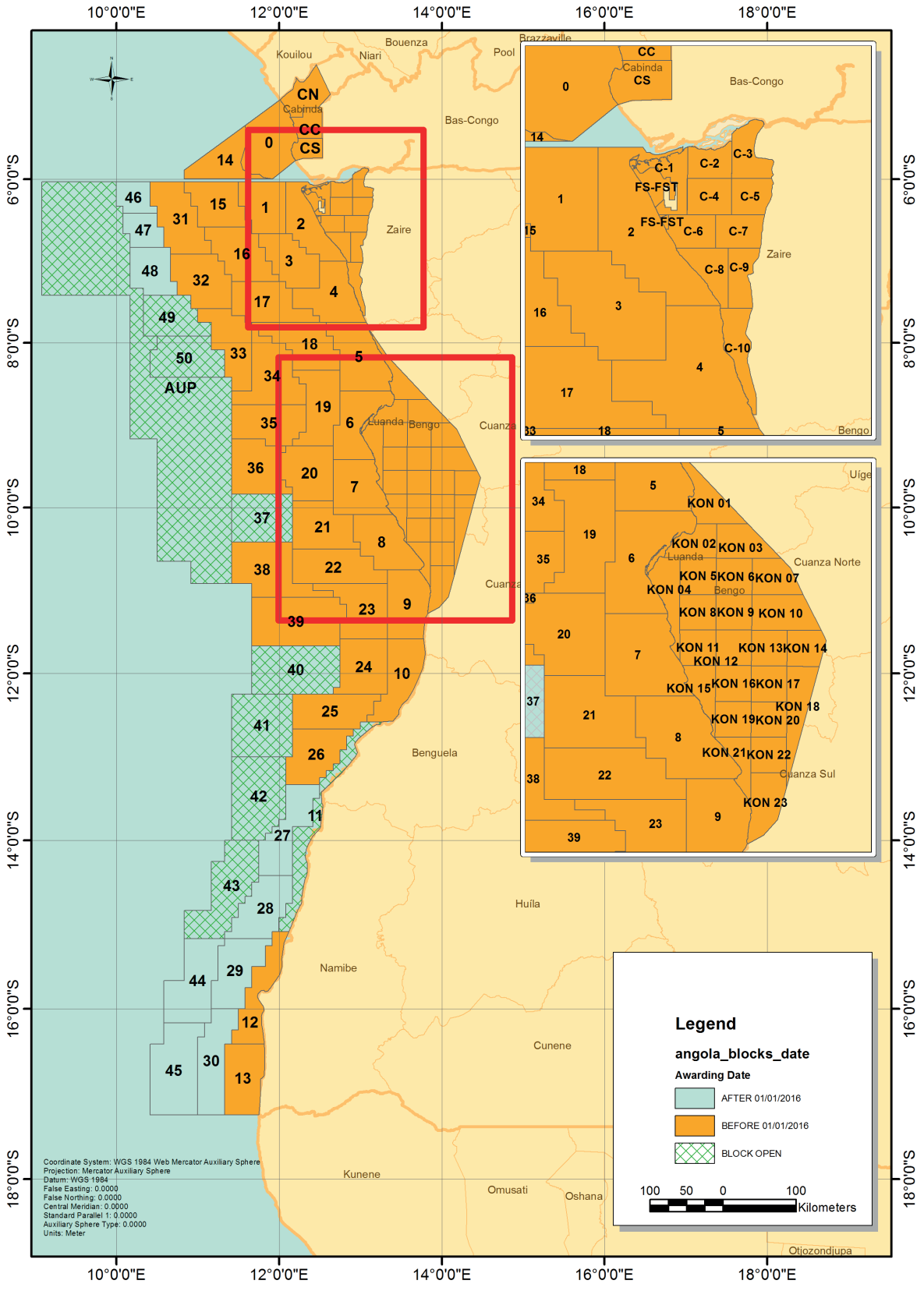

Figure A-1: Offshore blocks by awarding date

Appendix B - Example coordinate transformation between Camacupa 1948 and RSAO13

- Camacupa 1948 to RSAO13 (1) – EPSG code 8883

  Transformation method: Geocentric translations (geog2D domain)

  Transformation direction: Forward

  Transformation parameters:

Parameter	Value	Unit	Reversible
X-axis translation	–48	metre	Yes
Y-axis translation	–345	metre	Yes
Z-axis translation	–231	metre	Yes

CRS	Latitude	Longitude
Camacupa 1948 – EPSG code 4220	06° 15' 00.0000" South	11° 30' 00.0000" East
RSAO13 – EPSG code 8699	06° 15' 05.4305" South	11° 29' 49.3133" East

  The accuracy of the transformation is 3 m.

- Camacupa 1948 to RSAO13 (2) – EPSG code 8884

  Transformation method: Geocentric translations (geog2D domain)

  Transformation direction: Forward

  Transformation parameters:

Parameter	Value	Unit	Reversible
X-axis translation	–50.9	metre	Yes
Y-axis translation	–347.6	metre	Yes
Z-axis translation	–231.0	metre	Yes

CRS	Latitude	Longitude
Camacupa 1948 – EPSG code 4220	07° 30' 00.0000" South	11° 30' 00.0000" East
RSAO13 – EPSG code 8689	07° 30' 05.0258" South	011° 29' 49.2211" East

  The accuracy of the transformation is 5 m.

- Camacupa 1948 to RSAO13 (3) – EPSG code 9904

  Transformation Method: Geocentric translations (geog2D domain)

  Transformation direction: Forward

  Transformation parameters:

Parameter	Value	Unit	Reversible
X-axis translation	–43	metre	Yes
Y-axis translation	–337	metre	Yes
Z-axis translation	–233	metre	Yes

  Example Transformation

CRS	Latitude	Longitude
Camacupa 1948 – EPSG code 4220	09° 45' 00.0000" South	13° 01' 00.0000" East
RSAO13 – EPSG code 8689	09° 45' 04.3373" South	13° 00' 49.5449" East

  The accuracy of the transformation is 8 m.

- Camacupa 1948 to RSAO13 (4) – EPSG code 9905

  Transformation method: Positive vector (geog2D domain)

  Transformation direction: Forward

  Transformation parameters:

Parameter	Value	Unit	Reversible
X-axis translation	–41.057	metre	Yes
Y-axis translation	–374.564	metre	Yes
Z-axis translation	–226.287	metre	Yes
X-axis rotation	0.000	arc-second	Yes
Y-axis rotation	0.000	arc-second	Yes
Z-axis rotation	0.554	arc-second	Yes
Scale difference	0.219	parts per million	Yes

  Example Transformation

CRS	Latitude	Longitude
Camacupa 1948 – EPSG code 4220	07° 00' 00.0000" South	11° 30' 00.0000" East
RSAO13 – EPSG code 8689	07° 00' 05.0230" South	11° 29' 48.8622" East

  The accuracy of the transformation is 10 m.

Appendix C - Example coordinate transformation between Malongo 1987 and RSAO13

- Malongo 1987 to RSAO13 (1) – EPSG code 9906

  Transformation method: Geocentric translations (geog2D domain)

  Transformation direction: Forward

Transformation parameters:

Parameter	Value	Unit	Reversible
X-axis translation	-254.1	metre	Yes
Y-axis translation	-5.36	metre	Yes
Z-axis translation	-100.29	metre	Yes

Example Transformation

CRS	Latitude	Longitude
Malongo 1987 – EPSG code 4259	05° 45' 00.0000" South	11° 30' 00.0000" East
RSAO13 – EPSG code 8689	05° 45' 03.4730" South	11° 30' 01.4758" East

The accuracy of the transformation is 5 m.

References

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Diário da República II Série No. 40 - AGÊNCIA NACIONAL DE PETRÓLEO, GÁS E BIOCOMBUSTÍVEIS Instruitivo n. 1/21 de 17 de Março de 2021 (with English translation in italics).

Article 6 (Reference Coordinates):

2. Para os novos Blocos é adoptada a referência RSA013 e mantêm-se a nomenclatura «Camacupa 1948» para os Blocos adjudicados antes de 2015, por forma a preservar a integridade dos activos existentes.

2. For new Blocks, the reference RSA013 is adopted and Camacupa 1948 will be maintained for the Blocks adjudicated before 2015, in order to maintain the integrity of the existing assets.

Article 8 (Doubts and Omissions):

The doubts and omissions resulting from the interpretation and application of this instruction are to be resolved by ANPG.

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