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- (72) Inventors: **SARMA, Pallav**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **CHEN, Wen Hsiung**; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).
- (74) Agents: **VAN DER PLOEG, Craig, R.** et al.; Chevron Corporation, Law Department, Post Office Box 6006, San Ramon, California 94583-0806 (US).
- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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**Declarations under Rule 4.17:**

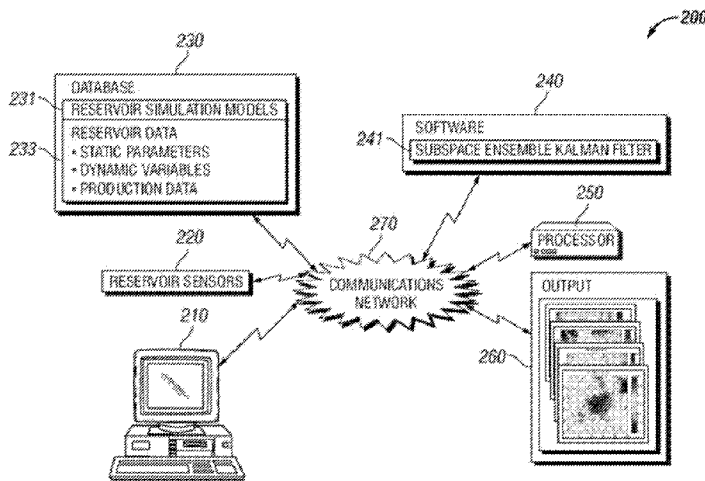
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

**Published:**

- *with international search report (Art. 21(3))*

*[Continued on next page]*

(54) Title: SYSTEM AND METHOD FOR USE IN SIMULATING A SUBTERRANEAN RESERVOIR



**FIG. 35**

(57) Abstract: A computer-implemented method, system, and computer program product are disclosed for updating simulation models of a subterranean reservoir. An ensemble of reservoir models representing a subterranean reservoir having non-Gaussian characteristics is provided and the ensemble of reservoir models is updated using a subspace ensemble Kalman filter. Kernel principle component analysis parameterization or K-L expansion parameterization can be used to update the ensemble of reservoir models.





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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

**(15) Information about Correction:**

**Previous Correction:**  
see Notice of 12 June 2014

**(88) Date of publication of the international search report:**

21 August 2014

**PATENT COOPERATION TREATY**

**PCT**

**INTERNATIONAL SEARCH REPORT**

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference T-8865	<b>FOR FURTHER ACTION</b>		see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2013/045386	International filing date ( <i>day/month/year</i> ) 12 June 2013 (12-06-2013)	(Earliest) Priority Date ( <i>day/month/year</i> ) 15 June 2012 (15-06-2012)	
Applicant  CHEVRON U.S.A. INC.			

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 5 sheets.

It is also accompanied by a copy of each prior art document cited in this report.

**1. Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

- the international application in the language in which it was filed  
 a translation of the international application into \_\_\_\_\_, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b))

b.  This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6**bis**(a)).

c.  With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2.  **Certain claims were found unsearchable** (See Box No. II)

3.  **Unity of invention is lacking** (see Box No III)

4. With regard to the **title**,

- the text is approved as submitted by the applicant  
 the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

- the text is approved as submitted by the applicant  
 the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,

- a. the figure of the **drawings** to be published with the abstract is Figure No. 35  
 as suggested by the applicant  
 as selected by this Authority, because the applicant failed to suggest a figure  
 as selected by this Authority, because this figure better characterizes the invention
- b.  none of the figures is to be published with the abstract

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2013/045386

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. G01V99/00 E21B49/00 G06F17/50  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
G01V E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Abul Fahimuddin: "4D Seismic History Matching Using the Ensemble Kalman Filter (EnKF): Possibilities and Challenges", 31 March 2010 (2010-03-31), XP55121087, Bergen Retrieved from the Internet: URL:https://bora.uib.no/bitstream/handle/1956/4001/Dr.thesis_AbulFahimuddin.pdf?sequence=1 [retrieved on 2014-06-02]	1-4,8-12
Y	page 7, line 19 - line 22 page 24, line 11 - line 12 page 49, line 1 - page 65, line 13 page 76, line 19 - page 77, line 28 page 85, line 1 - page 87, line 10 ----- -/--	5-7, 13-15

Further documents are listed in the continuation of Box C.

See patent family annex.

\* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

4 June 2014

Date of mailing of the international search report

25/06/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
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Authorized officer

Breccia, Luca

## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/045386

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PALLAV SARMA ET AL: "Kernel Principal Component Analysis for Efficient, Differentiable Parameterization of Multipoint Geostatistics", MATHEMATICAL GEOSCIENCES, SPRINGER-VERLAG, BERLIN/HEIDELBERG, vol. 40, no. 1, 15 December 2007 (2007-12-15), pages 3-32, XP019578208, ISSN: 1874-8953 abstract	5-7, 13-15
A	----- Edward Ott ET AL: "A local ensemble Kalman filter for atmospheric data assimilation", Tellus, vol. 56a 13 April 2004 (2004-04-13), pages 415-428, XP55121636, Retrieved from the Internet: URL: <a href="http://www.tellusa.net/index.php/tellusa/article/download/14462/16240">http://www.tellusa.net/index.php/tellusa/article/download/14462/16240</a> [retrieved on 2014-06-04] page 416, line 45 - line 51 page 417, line 3 - line 8	1,8,9
A	----- Pallav Sarma: "EFFICIENT CLOSED-LOOP OPTIMAL CONTROL OF PETROLEUM RESERVOIRS UNDER UNCERTAINTY", PhD Dissertation Stanford University, 30 September 2006 (2006-09-30), XP55121678, Retrieved from the Internet: URL: <a href="https://pangea.stanford.edu/ERE/pdf/pe-reports/PhD/Sarma06.pdf">https://pangea.stanford.edu/ERE/pdf/pe-reports/PhD/Sarma06.pdf</a> [retrieved on 2014-06-04] page 166 - page 177	1,8,9
A	----- US 2010/198570 A1 (SARMA PALLAV [US] ET AL) 5 August 2010 (2010-08-05) paragraph [0007] - paragraph [0009] paragraph [0039] - paragraph [0045] paragraph [0058] - paragraph [0059]	1,8,9
A	----- Balaji Vasan Srinivasan: "Gaussian Process Regression for Model Estimation", Master Thesis - University of Maryland, 31 December 2008 (2008-12-31), XP55121705, Retrieved from the Internet: URL: <a href="http://drum.lib.umd.edu/bitstream/1903/8962/1/Srinivasan_umd_0117N_10004.pdf">http://drum.lib.umd.edu/bitstream/1903/8962/1/Srinivasan_umd_0117N_10004.pdf</a> [retrieved on 2014-06-04] paragraph [03.2]	1,8,9
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**INTERNATIONAL SEARCH REPORT**

International application No PCT/US2013/045386
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>SIGURD I. AANONSEN ET AL: "The Ensemble Kalman Filter in Reservoir Engineering--a Review", SPE JOURNAL, vol. 14, no. 03, 30 September 2009 (2009-09-30), pages 393-412, XP55121717, ISSN: 1086-055X, DOI: 10.2118/117274-PA page 398, column 1, line 9 - line 13 -----</p>	1,8,9
A	<p>Abul Fahimuddin ET AL: "4D Seismic History Matching of a Real Field Case with EnKF: Use of Local Analysis for Model Updating", SPE Annual Technical Conference and Exhibition in Florence, 22 September 2010 (2010-09-22), XP55121734, Retrieved from the Internet: URL:<a href="https://www.onepetro.org/download/conference-paper/SPE-134894-MS?id=conference-paper/SPE-134894-MS">https://www.onepetro.org/download/conference-paper/SPE-134894-MS?id=conference-paper/SPE-134894-MS</a> [retrieved on 2014-06-04] page 11, line 16 - line 24 -----</p>	1,2,8,9

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/045386

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010198570	A1	05-08-2010	
		AU 2010208105 A1	18-08-2011
		CA 2750926 A1	05-08-2010
		EP 2391831 A2	07-12-2011
		US 2010198570 A1	05-08-2010
		WO 2010088516 A2	05-08-2010
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