



US009514493B2

(12) **United States Patent**
Marino

(10) **Patent No.:** **US 9,514,493 B2**
(45) **Date of Patent:** ***Dec. 6, 2016**

(54) **SYSTEM OF SYSTEMS FOR MONITORING GREENHOUSE GAS FLUXES**

(71) **Applicant:** **Planetary Emissions Management, Inc.**, Cambridge, MA (US)

(72) **Inventor:** **Bruno D. V. Marino**, Brunswick, ME (US)

(73) **Assignee:** **PLANETARY EMISSIONS MANAGEMENT, INC.**, Cambridge, MA (US)

(*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 562 days.

This patent is subject to a terminal disclaimer.

(21) **Appl. No.:** **14/040,206**

(22) **Filed:** **Sep. 27, 2013**

(65) **Prior Publication Data**

US 2014/0172323 A1 Jun. 19, 2014

Related U.S. Application Data

(63) Continuation of application No. 12/698,460, filed on Feb. 2, 2010, now Pat. No. 8,595,020.

(60) Provisional application No. 61/149,122, filed on Feb. 2, 2009.

(51) **Int. Cl.**

G06Q 10/00 (2012.01)
C01B 31/14 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC **G06Q 50/00** (2013.01); **G01N 21/00** (2013.01); **G01N 21/3504** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC G01B 21/00; G01B 33/0004; G01B 21/3504; G01B 21/39; G06Q 50/00; G06Q 40/04; G06Q 10/30; G06Q 30/018

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,317,156 A 5/1994 Cooper et al.
5,394,236 A 2/1995 Murnick

(Continued)

FOREIGN PATENT DOCUMENTS

JP 3238109 A 10/1991
JP 04-027854 B2 1/1992

(Continued)

OTHER PUBLICATIONS

Japanese Office Action issued by the Japan Patent Office for Application No. 2014-149944 dated Jun. 16, 2015 (5 pages).

(Continued)

Primary Examiner — Matthew G Marini

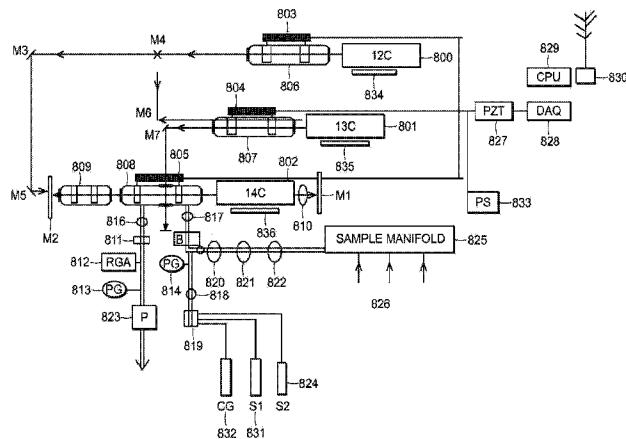
Assistant Examiner — Leo T Hinze

(74) *Attorney, Agent, or Firm* — Wilmer Cutler Pickering Hale and Dorr LLP

(57) **ABSTRACT**

A system of systems to monitor data for carbon flux, for example, at scales capable of managing regional net carbon flux and pricing carbon financial instruments is disclosed. The system of systems can monitor carbon flux in forests, soils, agricultural areas, body of waters, flue gases, and the like. The system includes a means to identify and quantify sources of carbon based on simultaneous measurement of isotopologues of carbon dioxide, for example, industrial, agricultural or natural sources, offering integration of same in time and space. Carbon standards are employed at multiple scales to ensure harmonization of data and carbon financial instruments.

25 Claims, 33 Drawing Sheets



(51) **Int. Cl.**
G06Q 50/00 (2012.01)
G01N 21/3504 (2014.01)
G06Q 30/00 (2012.01)
G01N 21/00 (2006.01)
G01N 33/00 (2006.01)
G06Q 40/04 (2012.01)
G01N 21/39 (2006.01)

(52) **U.S. Cl.**
CPC **G01N 33/0004** (2013.01); **G06Q 10/30** (2013.01); **G06Q 30/018** (2013.01); **G06Q 40/04** (2013.01); **G01N 21/39** (2013.01); **Y02P 60/30** (2015.11); **Y02W 90/20** (2015.05)

(56) References Cited

U.S. PATENT DOCUMENTS

5,747,809 A	5/1998	Eckstrom
5,783,445 A	7/1998	Murnick
5,818,580 A	10/1998	Murnick
5,864,398 A	1/1999	Murnick
6,164,129 A	12/2000	Shin et al.
7,154,595 B2	12/2006	Paldus et al.
7,426,489 B2	9/2008	van Soestbergen et al.
7,616,305 B2	11/2009	Murnick
8,595,020 B2	11/2013	Marino
2007/0224085 A1	9/2007	Tooley
2007/0250329 A1	10/2007	Richards et al.
2008/0015975 A1	1/2008	Ivchenko et al.
2008/0015976 A1	1/2008	Sandor et al.
2008/0059206 A1	3/2008	Jenkins
2008/0221750 A1	9/2008	Baraty
2008/0228628 A1	9/2008	Gotthelf et al.
2008/0228630 A1	9/2008	Gotthelf et al.
2008/0228632 A1	9/2008	Gotthelf et al.
2008/0228665 A1	9/2008	Gotthelf et al.
2009/0273781 A1	11/2009	Clegg et al.
2010/0198736 A1*	8/2010	Marino G01N 21/3504 705/308

FOREIGN PATENT DOCUMENTS

JP	11-094737 A	4/1999
JP	2000-505558 A	5/2000
JP	2002-286638 A	10/2002
JP	H07-020054 A	1/2007
WO	WO-99/42814 A1	8/1999

OTHER PUBLICATIONS

- Murnick, D. E. and Okil, J. O., "Use of the optogalvanic effect (OGE) for isotope ratio spectrometry of $^{13}\text{CO}_2$ and $^{14}\text{CO}_2$," Isotopes in Environmental and Health Studies, vol. 41, No. 4 pp. 363-371 (Dec. 2005).
- Adler, Ben. Apr. 26, 2010. Senate Energy Bill Could Halt California's Emission Reduction Efforts. <http://capradio.org/articles/2010/04/26/senate-energy-bill-could-halt-california's-emission-reduction-efforts>. 3 pages.
- Air Resources Board, State of California. ARB 2009 <http://www.arb.ca.gov/cc/factsheets/ab32factsheet.pdf>, 2 pages (2009).
- Allison C.E., Francey R.J., White J.W.C., Vaughn B.H., Wahlen M., Bollenbacher A., Nakazawa T. What have we learnt about stable isotope measurements from the IAEA Classic? In: Report of the eleventh WMO/IAEA meeting of experts on carbon dioxide concentration and related tracer measurement techniques, Tokyo, Japan, Sep. 25-28, 2001, MO/GAW Report No. 148, Geneva, pp. 17-30 (2003).
- Allison, C.E., Francey R.J., and Steele, L.P. The International Atomic Energy Agency circulation of laboratory air standards for stable isotope comparisons: aims, preparation and preliminary results. In: Isotope aided studies of atmospheric carbon dioxide and other greenhouse gases Phase II (IAEA-TEDOC-1269). IAEA, Vienna, Austria, pp. 5-23 (2002).
- Amico di Meane, E., Plassa, M., Rolle, F., Segà, M. Metrological traceability in gas analysis at I.N.R.I.M: gravimetric primary gas mixtures. *Accred Qual Assur* 14:607-611 (2009).
- Amundson, R., Sanderman, J., and Yoo, K. Environmental and geological controls on the soil carbon cycle in a changing world (in Geological Society of America, 2008 annual meeting, Anonymous, *Abstracts with Programs—Geological Society of America* (October, vol. 40(6):24 (2008).
- ASTM D6866-08. Active Standard: D6866-08. Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis. ASTM, 2 pages (2008).
- Barford, C., Steven C. Wofsy, Michael L. Goulden, J. William Munger, Elizabeth Hammond Pyle, Shawn P. Urbanski, Lucy Hutyra, Scott R. Saleska, David Fitzjarrald, and Kathleen Moore. *Science* 294: 1688-1691 DOI: 10.1126/science.1062962, 4 pages (2001).
- Becker, J.F., Sauke, T.B., Loewenstein, M. *Appl. Opt.* 31: 1921, 7 pages (1992).
- Bonan, G. B. A land surface model (LSM version 1.0) for ecological, hydrological, and atmospheric studies: Technical description and user's guide, 150 pp., Natl. Cent. for Atmos. Res., Boulder, Colo., 156 pages (1996).
- Bradley, L.C., Soohoo, K.L., Freed, C. Absolute frequencies of lasing transitions in nine CO₂ isotopic species. *IEEE Journal of Quantum Electronics* vol. QE-22, No. 2, 34 pages (1986).
- Broecker, W. Radiocarbon. In: *Treatise on Geochemistry*, Elsevier, 18 pages, 2007.
- Brown, M.A., Levine' M.D., Short, W., Koomey, J.G., Energy Policy 29(14): 1179-1196 (2001).
- Canadell, J., Quere C., Raupach M., Field C., Buitenhuis E., Ciais P., Conway T., Gillett N., Houghton R., Marland G. Contributions to accelerating atmospheric CO₂ growth from economic activity, carbon intensity and efficiency of natural sinks. *PNAS* early edition, 10.1073, 5 pages (2007).
- Capoor, K., and Ambrosi. 2007. State and Trends of the Carbon Market 2007. World Institute, Washington, DC, 2007, 52 pages.
- Chicago Climate Exchange 2010. <http://www.chicagoclimatex.com/content.isf?id=781>. 2 pages.
- Ciais P., and four others. A Large northern hemisphere terrestrial CO₂ sink indicated by the $^{13}\text{C}/^{12}\text{C}$ ratio of atmospheric CO₂. *Science* 269(5227): 1098-1102 (1995).
- Convery' F.J. and Redmond, L. Market and Price Developments in the European Union Emissions Trading Scheme. *Rev Environ Econ Policy* 1: 88-111 (2007).
- Coplen T.B. et al., and five others. New Guidelines for delta ^{13}C measurements. *Anal. Chem.* 78: 2439-2441 (2006).
- Coplen, T.B. New manuscript guidelines for the reporting of stable hydrogen, carbon, and oxygen isotope-ratio data. *Geothermics* 24(5-6):707-712 (1995).
- Davis, W. Carbon-14 production in nuclear reactors. ORNL/NUREG/TM-12, 42 pages (1977).
- Dias, C.M. and 4 others. ^{14}C content in vegetation in the vicinities of Brazilian nuclear power reactors. *J. Env. Radio.* 99(7): 1095-1101 (2008).
- Diaz, David. Mar. 3, 2010. "California Moves Carbon Offset Goalposts." <http://www.fluxnet.ornl.gov/fluxnet/index.cfm>. Page 3.
- Ellerman, D.A. and Joskow, P.L. The European Union's Emissions Trading System in Perspective. MIT, 64 pages, May 2008.
- European Search Report for European Patent Application No. 10736564.5 mailed Nov. 25, 2013. 9 pages.
- European Union Emissions Trading Scheme. www.euets.com. 45 pages 2009.
- Flesch, T.K., Wilson, J.D., Harper, L.A., Crenna, B.P., Sharpe, R.R. Deducing ground-to-air emissions from observed trace gas concentrations: a field trial. *J. Appl. Meteorol.* 43, 487-502 (2004).
- Fluxnet. <http://www.fluxnet.ornl.gov/fluxnet/index.cfm>, 1 page, retrieved Jun. 14, 2012.
- Freed C. CO₂ Isotope Lasers and their applications in tunable laser spectroscopy. Chapter 4, pp. 63-165 in "Tunable Lasers Handbook", 103 pages (Academic Press, 1995, F.J. Duarte, Editor).