The Worldwide Use of the SWAT Model:
Networking Impacts, Simulation Trends, and Future Developments

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Literature,Technological, and Networking Factors Driving SWAT Use

- SWAT website
- Extensive & rapidly expanding literature
- Open software and comprehensive documentation
- GIS interfaces; other interfaces/software
  - SWAT-CUP is a key software development
- Workshops and conferences
  -wide range of modeling methods/results
  -extensive networking opportunities

SWAT Literature

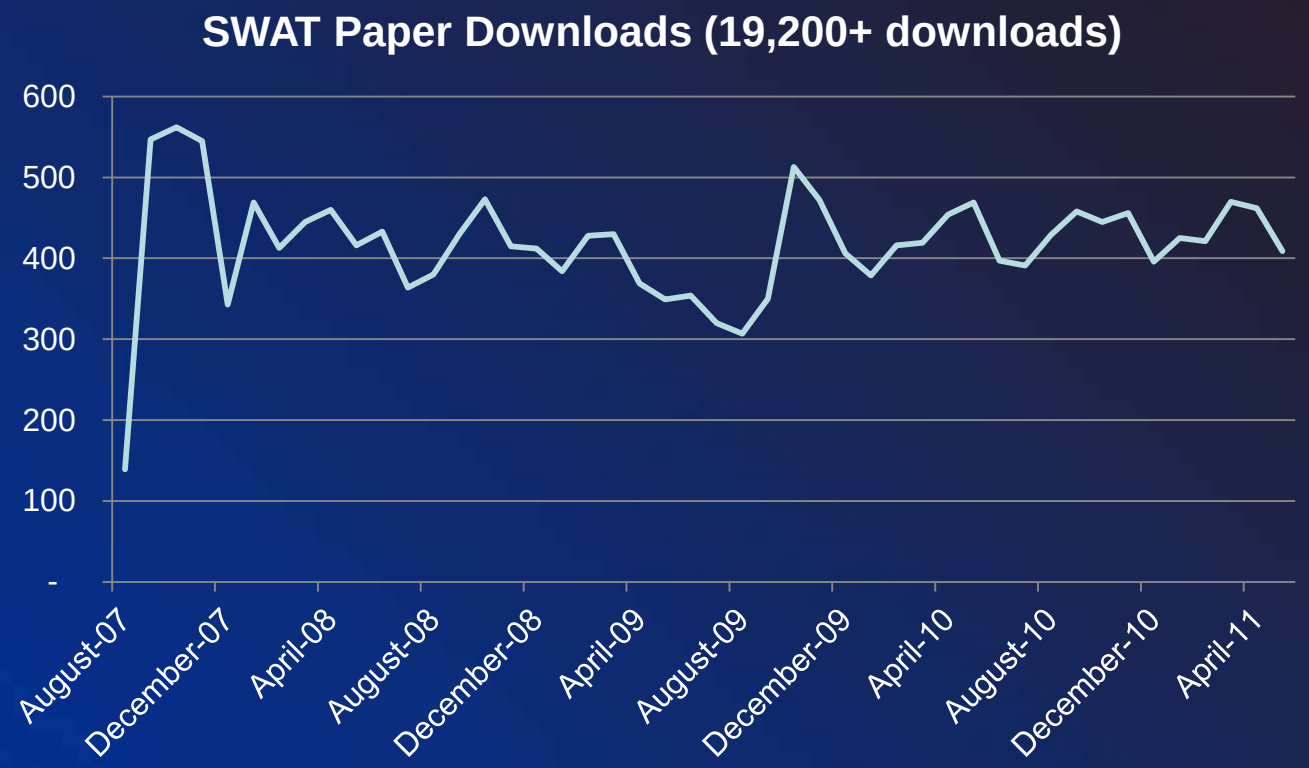
- Arnold, Srinivasan, Muttiah, and Williams. 1998. Large area hydrologic modeling and assessment part I: model development. *JAWRA* 34(1): 73-89.
  - Cited 650 times in ISI Web of Knowledge (#1 all-time in JAWRA; Jeff also co-author on #3, 5, & 10 JAWRA papers)

- Arnold & Fohrer. 2005. SWAT2000: current capabilities and research opportunities in applied watershed modeling. *Hydrol. Process*. 19(3): 563-572.
  - Cited 175 times in ISI (#8 all-time in Hydrological Processes)

- Arnold, J.G., Allen, P.M. and G. Bernhardt. 1993. A comprehensive surface-groundwater flow model. *J. Hydrol*. 142(1-4): 47-69.
  - Cited 221 times in ISI (#21 all-time in Journal of Hydrology)

SWAT Review Paper

- Gassman et al. 2007. Trans. ASABE 50(4): 1211-1250
  - reviewed ~250 SWAT-related articles
  - cited 159 times in ISI (#1 in Trans. ASABE; since 2006; Jeff also co-author on #2, 3, 5, & 9 papers)
  - accessible at CARD and SWAT websites



SWAT Literature

- SWAT literature database:
  - https://www.card.iastate.edu/swat_articles/
  - also accessible via link at SWAT website
  - Citation info/abstracts for peer-reviewed journal articles

- Range of articles included in database
- - Currently 800+ peer-reviewed articles
  - ~750 describe SWAT or SWAT-spinoff applications
  - Other relevant papers included
  - Nearly 190 different journals currently represented

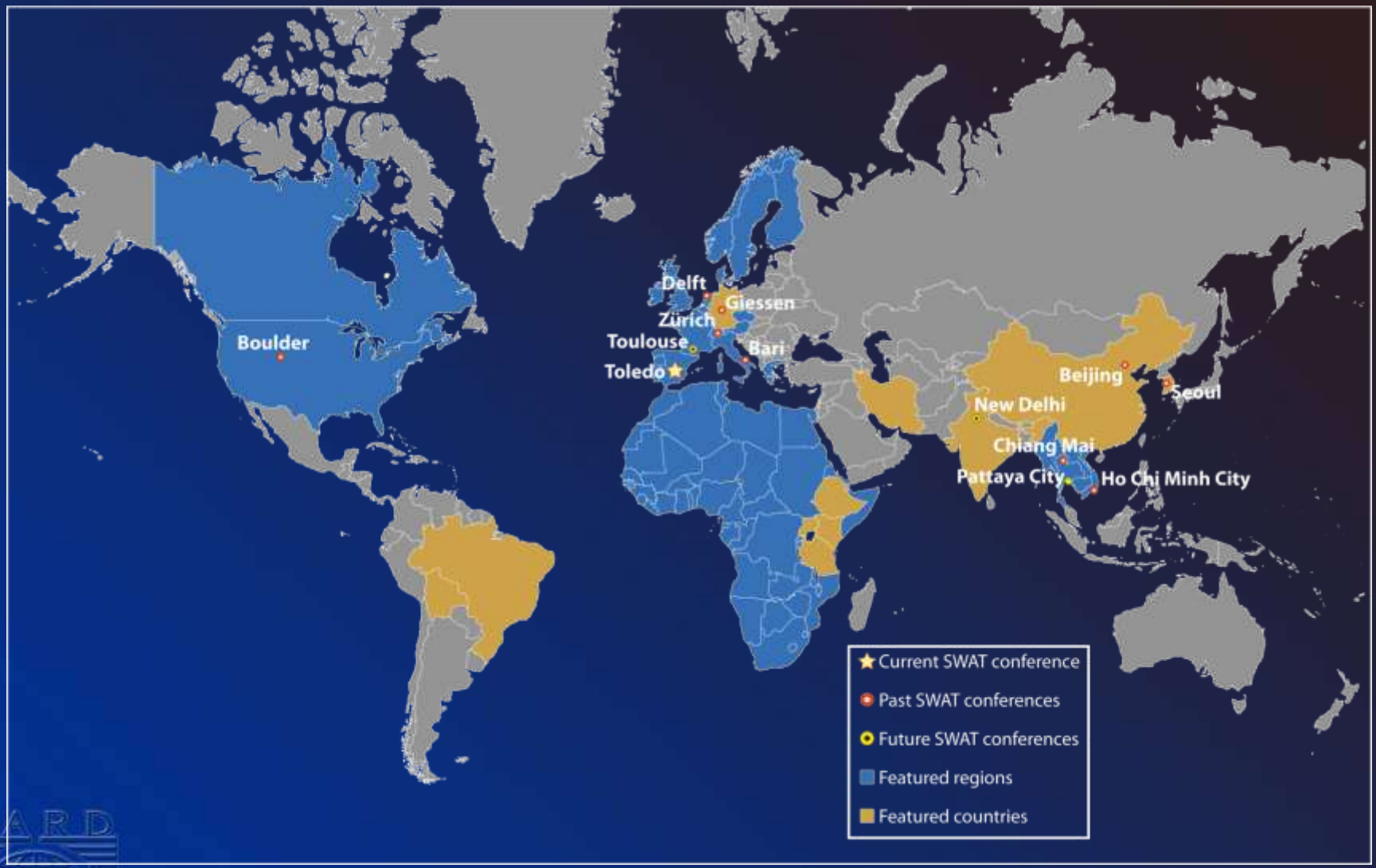
SWAT GIS Interfaces

Interface	Platform	Comments
SWAT/GRASS	GRASS	Original interface
AVSWAT	ArcVIEW 3.x	AVSWAT-X includes SSURGO Soils and other enhancements
BASINS	ArcVIEW 3.x	USEPA software package with multiple models
ArcSWAT	ArcGIS 9.x	Many enhancements versus AVSWAT
ArcAPEX	ArcGIS 9.x	Supports applications of APEX imbedded within SWAT simulations
SWAPP	ArcVIEW 3.x	Another APEX-SWAT interface
AGWA	ArcVIEW 3.x / ArcGIS 9.x	Different versions exist for different platforms
MWSWAT	MapWindow	Public domain software; may be of particular interest to SWAT users in developing countries
CRP-DSS	ArcIMS / ArcGIS	For Conservation Reserve Program analyses

Modified SWAT Models

Model	Description
SWAT-G	Improved flow estimates for German low mountain conditions
ESWAT	Extended SWAT; enhanced hydrology & streamflow components
SWIM	Developed from SWAT and MATSALU models
SWAT-DEG	Simulates channel degradation processes more accurately
$SWAT_{BF}$	Forested watershed processes for Canadian Boreal Plain
SWAT-K	Multiple modified modules for Korean conditions including interfaces with MODFLOW and SWIM models
SWAT-VSA	Re-conceptualized approach for variable source area hydrology
SWAT-WH	Effects of water harvesting systems in southeast Tunisia
SWAT-N	Modified nitrogen cycling routine based on DNDC model
SWAT-WB	Modified model with alternative water balance approach
SWAT-landscape	Experimental version designed to represent landscape processes more accurately

SWAT Conference Sites & Key Countries/Regions



North America

- Extensive reporting in peer-reviewed and other literature
- Widely used by U.S. state and federal agencies
  - Hydrologic Unit Model for the U.S. (HUMUS)
    - other national applications
  - State agencies: Total Maximum Daily Load (TMDL) & other water quality analyses for specific watersheds
- Canadian FORWARD project (for Boreal Forest)
- Extensive networking via workshops and users groups
  - SWAT Midwest America Users Group (SMAUG)
  - Developer's workshops: Purdue & Col. State Univ.
- 2008 Conference in Boulder, Colorado
  - *Trans. ASABE* special issue: Vol. 53(5), 2010

18 U.S. Major Water Resource Regions that are Simulated in HUMUS-based Applications

Europe

- Extensive peer-reviewed & other publications

  - SWAT conference special journal issues: *Hydrol. Process.* 19(3), 2005; *Hydrol. Sci. J.* 53(5), 2008
- Modified SWAT models

  - SWAT-G, SWIM, ESWAT
- Especially intensive use in some countries (e.g., Germany)

  - Germany SWAT review chapter (Martin Volk et al.) in forthcoming CABI international book
- EU level projects

  - EUROHARP: *J. Environ. Monitoring;* Vol. 11(3), 2009

  - Eawag (Karim Abbaspour & others): leading SWAT modeling of Black Sea watershed & entire continent

Africa

- Use of SWAT increasing
  - Over 30 studies published in English peer-reviewed literature; most within past three years
  - majority in eastern Africa (Ethiopia, Uganda, Kenya, & Tanzania)
  - some in northern Africa and South Africa
  - recurring theme: problems with data limitations

- Eawag application for entire African continent
  - analysis of “blue” vs. “green” water resources
  - Schuol et al. 2008. Assessing the impact of climate change on water resources in Iran. *Water Resources Research.* 45: 1-16.

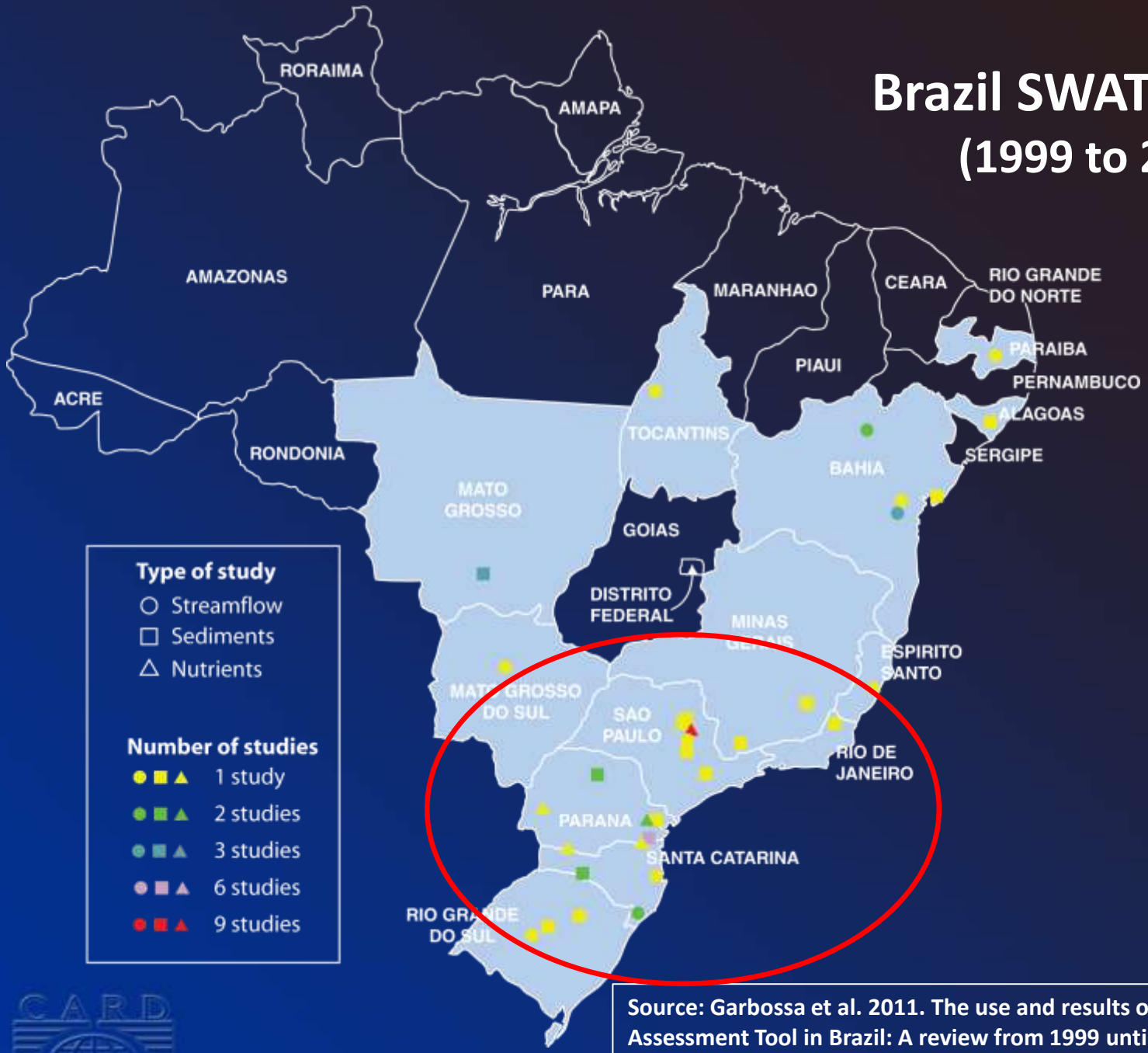
Latin America

- 60 known studies in Brazil reviewed by Garbossa et al. (2011)
  - Over 90% in Portuguese literature
  - Data limitations key problem for many studies
  - Model testing results were still generally successful

- World Bank analysis performed for Bolivia with SWAT
  - Blue/green water and climate change analyses

- Several applications for watersheds partially in Andean mountain range, particularly in Chile
  - Some published in English peer-reviewed literature

Brazil SWAT Studies (1999 to 2010)



Source: Garbossa et al. 2011. The use and results of the Soil and Water Assessment Tool in Brazil: A review from 1999 until 2010. Proceedings of the 2011 SWAT International Conference, June 15-17, Toledo, Spain (forthcoming).

Asia

- Intensive use in China, India, Iran, South Korea
  - Increasing numbers of applications being reported in peer-reviewed literature, especially in China
  - Modified versions also being used; e.g., SWAT-K (SWAT-Korea)
  - Networking via conferences and workshops
    - -2008: Beijing conference
    - -2009/2011/2013: Southeast Asia conferences
    - -2012: New Delhi, India
  - Other strategic networking:
    - Eawag (Switzerland) with Iranian institutions

China SWAT Applications

- Over 60 Chinese SWAT studies published in English peer-reviewed literature; majority in last five years
- Several of the studies feature adaptations of SWAT to better simulate the specific watershed conditions
- Initial review performed by Feng Huang, Dept. of Soil and Water Sciences, China Agricultural Univ. Beijing, China (working on China SWAT review paper)

Distribution of Chinese SWAT studies in English peer-reviewed literature

SWAT studies performed for "blue watersheds"

Blue/green water study performed for "green basins"

Data compiled by Dr. Feng Huang, Department of Soil and Water Sciences, China Agricultural Univ. Beijing, China

Overview of Applications/Statistics for Chinese Studies

A preliminary summary on SWAT use in China grouped by basins

Basins	No. of applications	Field and No. of Appl.	Cali. *NSE*	Cali. R^2	Valid. *NSE*	Valid. R^2
Yellow	23	Climate and land use change (6); hydrology assess(3); Auto-calibration(2); pollutant loading (2); input uncertainty (2);irrigation (2).crop growth (1);	0.58-0.94	0.54-0.88	0.46-0.87	0.76-0.84
Yangzte	18	Pollutant loading (7);input uncertainty (5);climate and land use change (2); hydrology assess (2);model compare (1); impoundment (1)	0.45-0.96	0.50-0.96	0.40-0.95	0.60-0.96
Hai	9	Hydrology assess (2);climate change (1);pollutant loading (1); irrigation (1); input uncert. (1);impoundment (1); interface (1);delineation (1)	0.62-0.95	0.76-0.97	0.67-0.91	0.61-0.93
Southwest	4	Climate and land use change (3); hydrology assess (1)	0.75	0.5	0.91	0.3
Northwest	3	Climate and land change (1);hydrology assess (1);input uncertainty (1)	0.85	0.73-0.89	0.82	0.68-0.85
Songliao	3	Hydrology assess (1); input uncertainty (1); delineation(1)	0.16-0.27	0.57-0.58	0.18-0.25	0.44-0.72
Huai	2	Impoundments (2)	-5.04-1.00	0.00-1.00	0.36-0.97	0.48-1.00
Southeast	1	Interface (1)				
Pearl	1	Pollutant loading(1)	0.87	0.87	0.86	0.87

Information compiled by Dr. F. Huang, Department of Soil and Water Sciences, China Agricultural Univ. Beijing, China

Southeast Asia

- Emerging use in Southeast Asia
  - Mekong River Commission: pioneered use of SWAT in region for Lower Mekong River system (started ~2003)
  - Rossi et al. 2009. Hydrologic evaluation of the lower Mekong River basin with the Soil and Water Assessment Tool model. *Int. Agric. Engr. J*. (*IAE*J) 18(1-2): 1-13.
    - SWAT streamflow results reported for ~60 gauges

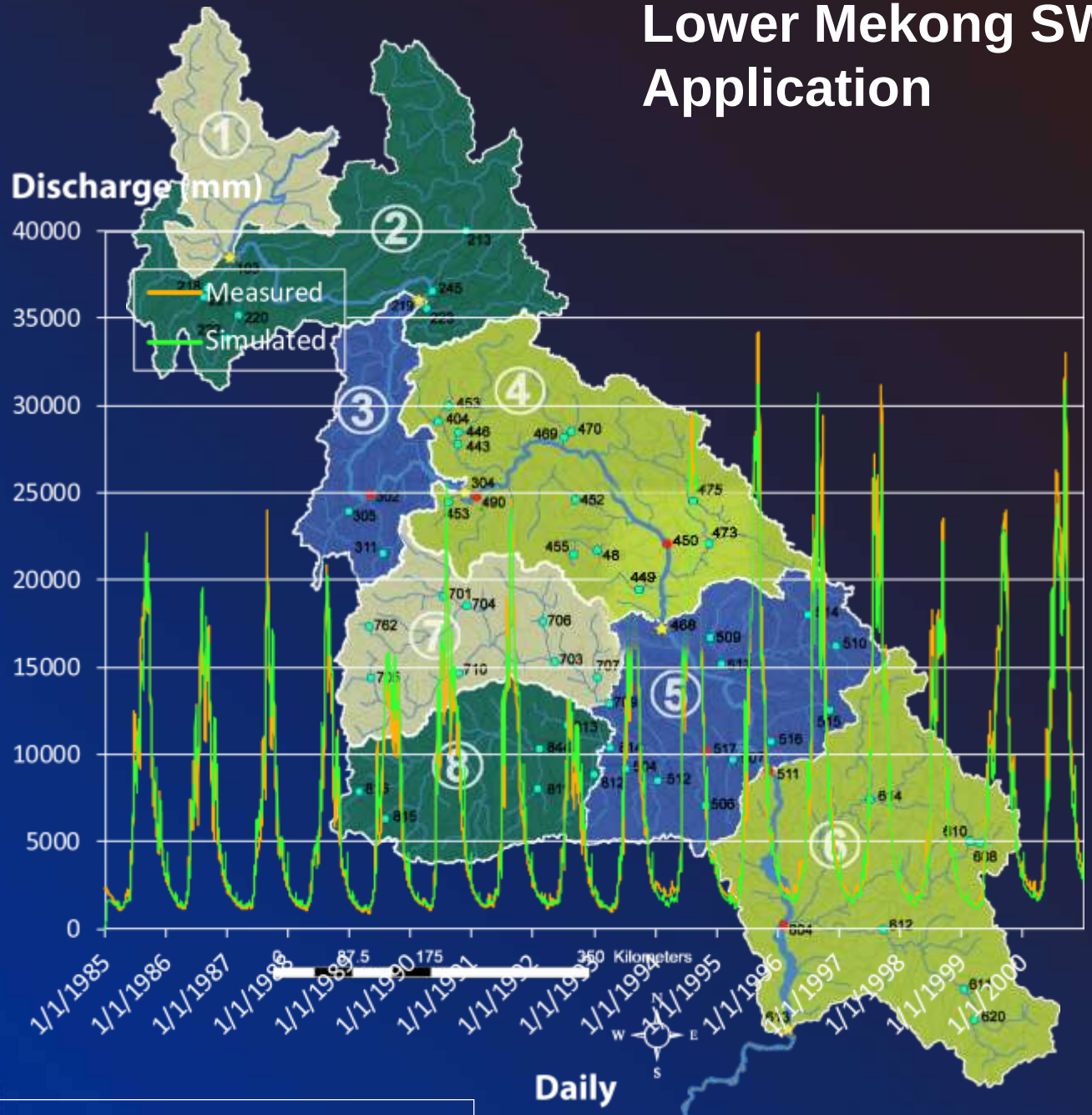
- Southeast Asia SWAT conferences

  -2009: Chiang Mai, Thailand; 2011: Ho Chi Minh City, Vietnam; 2013: Pattaya City, Thailand

Lower Mekong River Basin

Rossi et al. 2009. *IAEJ*. 18(1-2): 1-13

Lower Mekong SWAT Application



Rossi et al. 2009. *IAEJ*. 18(1-2): 1-13

Future Developments

1) Worldwide use of SWAT will continue to expand, especially in Asia

   - China & Africa review papers are being drafted

2) Range of problems that SWAT will be applied to will also expand; e.g.:

   - more urban applications

   - expanded BMP scenarios

Future Developments

3) Modified SWAT versions will continue to emerge for many applications

4) Many other applications will demand new software tools and model interfaces

5) Data limitations will continue to be a problem in many regions; improved ways of dealing with data gaps will likely be developed