State of the Science: Modeling N2O using the DNDC Model

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Quick Outline

- Why do we need process (or mechanistic) modeling tools for N2O?
- DNDC Model background: applications and research in California
- Pros and Cons of DNDC
- Way forward?

What are Process-based Models?

- Process-based, or mechanistic, modeling refers to biochemical and geochemical reactions or processes
- **Biogeochemical processes**… like decomposition, hydrolysis, nitrification, denitrification, etc…
- True process-based models **do not rely on constant emission factors**.
- They simulate and track the impact on emissions of varying conditions within soil and crop environment

Advantage of Process-based Models

- Capture impact of soils on C and N cycling and GHG emissions
- Capture variability of weather/climate on C and N cycling
- Capture impact of management practices on crop yields and GHG emissions
- Can be used to assess a wide range of ecosystems services (climate, food/fiber, air quality, water quality)
- Not limited to sites/regions where they were develop (empirical models are limited)

Role of process models?

Science: Interpret, integrate and extrapolate field observations – feedback between field research and modeling science

Link with spatial GIS databases for regional emissions estimates and inventories

Decision Support:

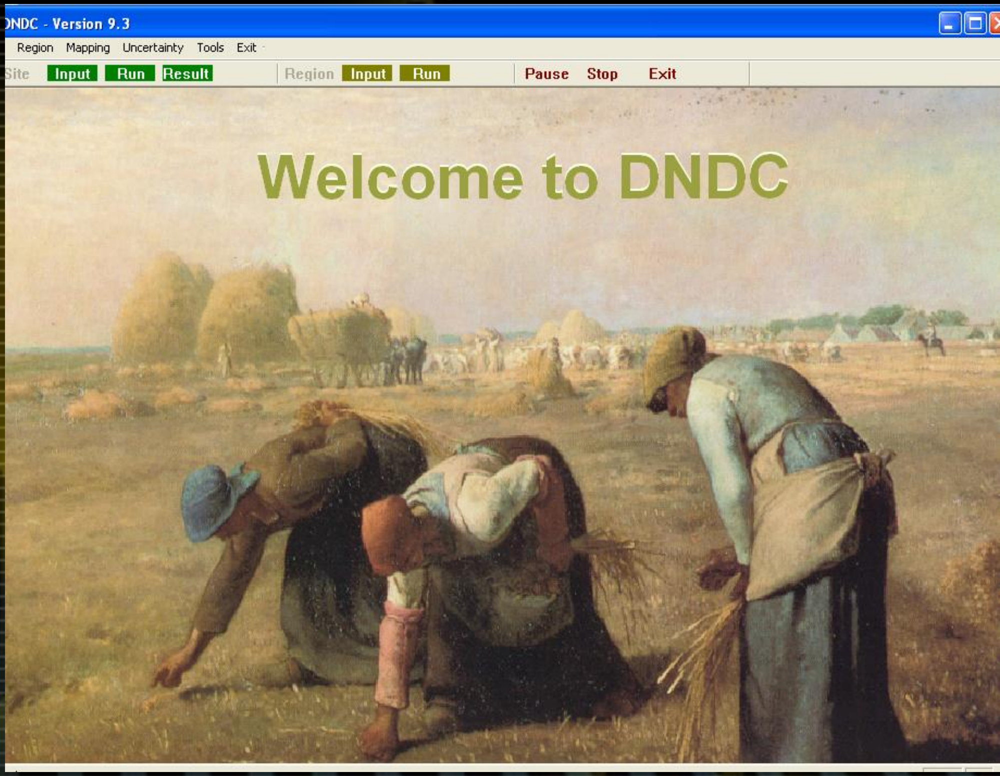
- Assess mitigation opportunities
- Quantification tools for offset protocols

DNDC Model

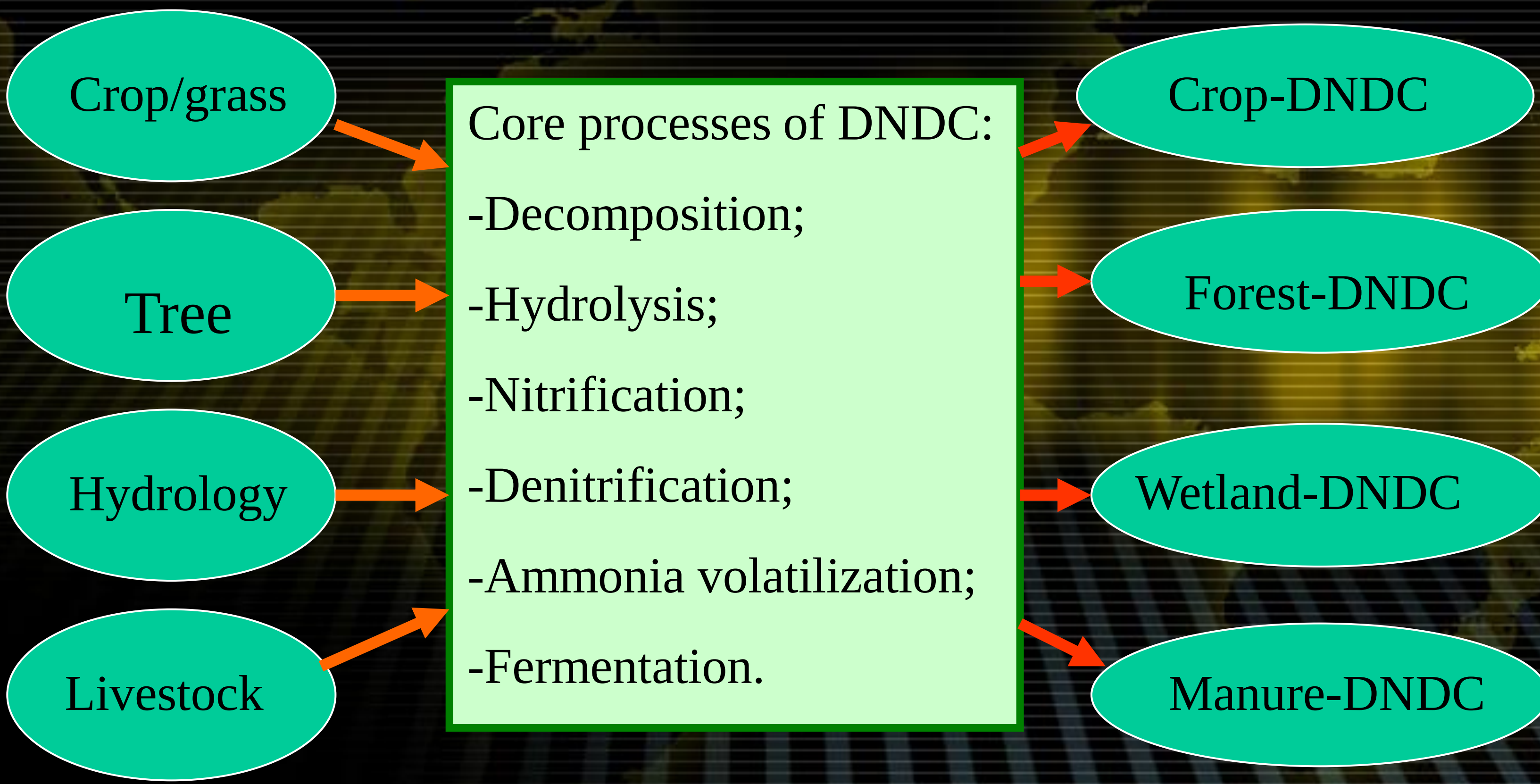
DNDC stands for **De**nitrification and **De**composition, two processes dominating losses of N and C from soil into the atmosphere, respectively.

DNDC Biogeochemical Model Suite:

- DNDC
  - First model, development started in 1990
  - Initial focus on N2O
  - Focus on crop lands (>30 types of crops)
  - Models CO2, CH4, N2O, and crop growth/yields



The DNDC Family



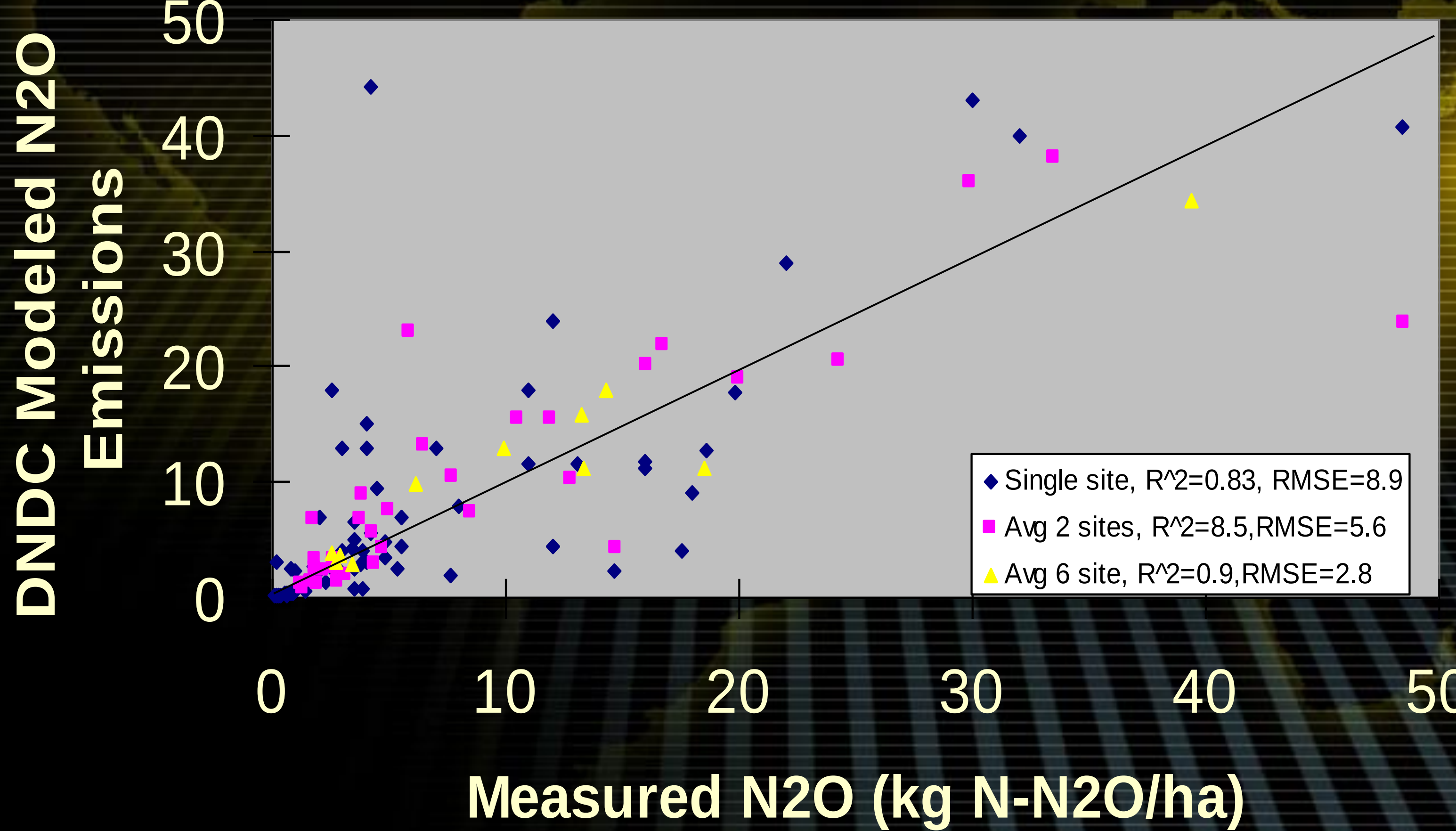
DNDC Model Validation…

- Rigorous model validation is key for acceptance (scientific and market)
- DNDC has been validated extensively for agroecosystems worldwide
- Additional validation efforts underway:
  - ✓ Specialty crops
  - ✓ Animal agriculture systems
- Scientific process: feedback between laboratory, field and modeling science

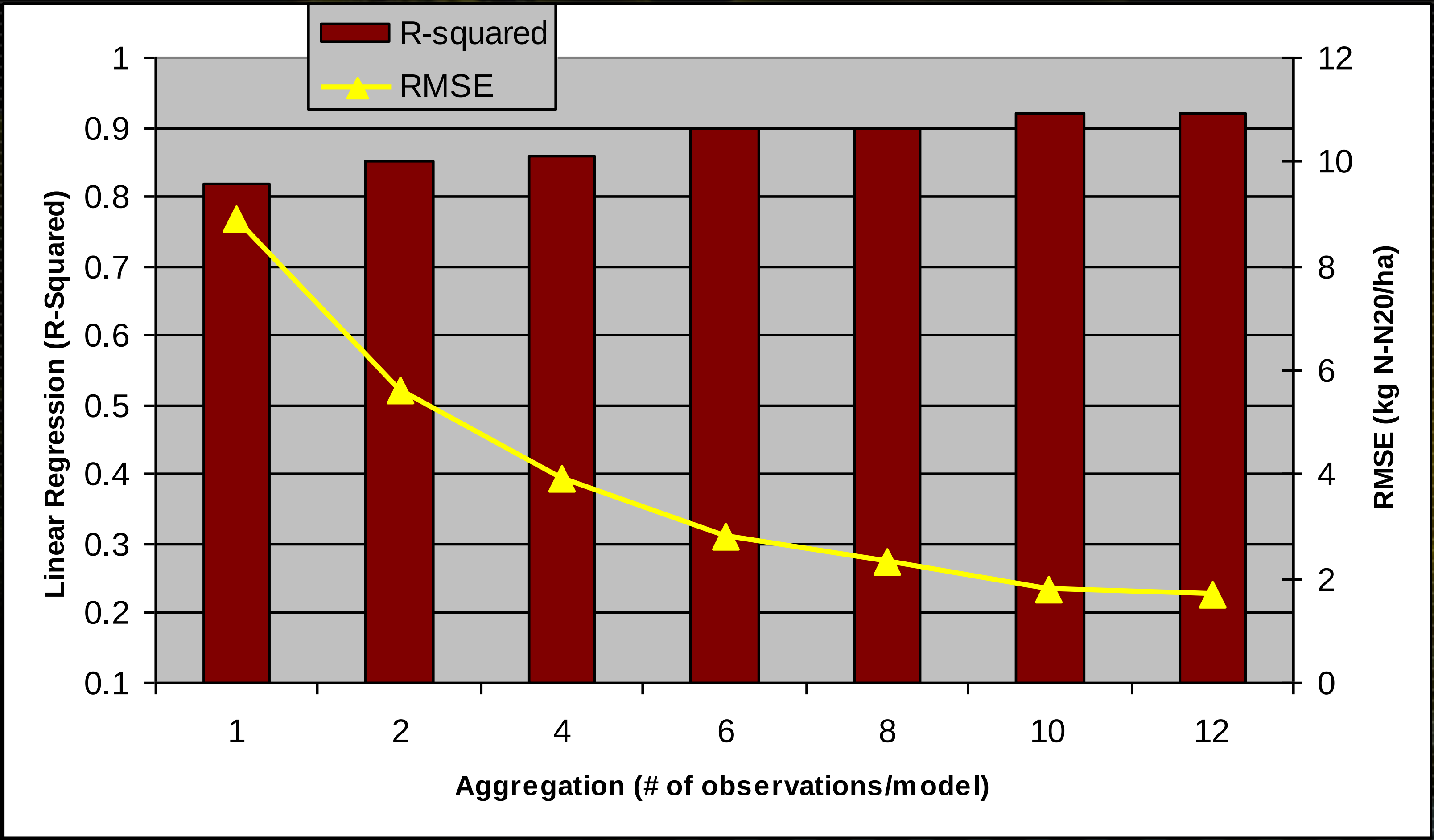
Motivation for Validation and Assessing Uncertainty has Changed

- ➢ New role for models ---- moving from basic research to regional assessments/inventories and decision support and policy tools
- ➢ New questions
  - ✓ Structural uncertainty versus sensitivity to inputs? Uncertainty propagation in scaling up.
  - ✓ Calibration trade-offs: ease of use versus precision/accuracy
  - ✓ Uncertainty in model estimates for changes in management: relative changes?
  - ✓ Impact of aggregation on model performance – implications for offset protocols

Impact of Scale: Does the model perform better when we aggregate?



Performance improves with aggregation



…implications for use in protocols and for emission inventories.

Examples of On-going DNDC Applications in California

Basic Science/Research

- Field N_2O measurement and research projects (led by Drs. Six and Horwath at UC Davis and Dr. Goorahoo at CSUF)
- Modeling GHG, VOCs and NH_3 emissions from dairy and swine production systems (in collaboration with Dr. Mitloehner)

Example of range of DNDC Applications in California cont.

Regional Assessments & Decision Support

- NRCS Rice project with EDF and CRC
  - ✓ Model validation, new statewide estimate of GHG emissions from rice, rice offset protocol in development
- ARB Research Division Project
  - ✓ Build spatial databases and crop libraries for statewide quantification of N2O emissions (April 2011 start)
- CDFA SCBG Projects to develop and test N2O decision support tools for winegrape and almond industries.

Pros and Cons of DNDC

- Represents the state of the science regarding N2O emissions: utilizes a more mechanistic approach (microbes dynamics, soil Eh).
- Strong linkage with field/lab research – Model evolves with science (lg user base)
- Designed to examine wide range of management impacts
- Easy to calibrate new crops/cultivars
- Extensively validated
- Free to download

Pros and Cons of DNDC

- Mechanistic approach ---- requires specific input information
  - Daily management, weather, etc
- Been extensively used for research and historically been hard to use outside of academia/gov't research labs
  - On-going efforts to make it easier to use without sacrificing science
  - Developing crop calibration databases
  - Web-GIS implementation

Way forward…

- N2O emissions from agricultural is a complex, driven by environmental condition, management and microbial processes
- Process models are critical tools for developing N2O inventories, assessing options for N2O reductions and integration in offset protocols
- Rigorous validation is key…must rely on sound field measurements.
- Remote sensing has an important role for mapping and monitoring.
- Tools for tracking uncertainty: model structural and due to uncertainties in input conditions.

Bottom line…

If we want agriculture engaged and involved in markets for N2O reductions...need to provide scientifically sound tools for quantification of field level N2O emissions that:

- Provide more options that just “reduce fertilizer use” (aka constant emission factor approach)
- Capture local conditions
- Capture broad range of management alternatives (e.g. timing and placement of fertilizer, type and timing of irrigation system)
- Not too difficult to use

…Role for Process Models

Thank you!

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