CRRC Spill Modeling Summit

- State-of-the-Art for Spill Modeling
- Future of Spill Modeling
- Research Questions for Spill Modeling

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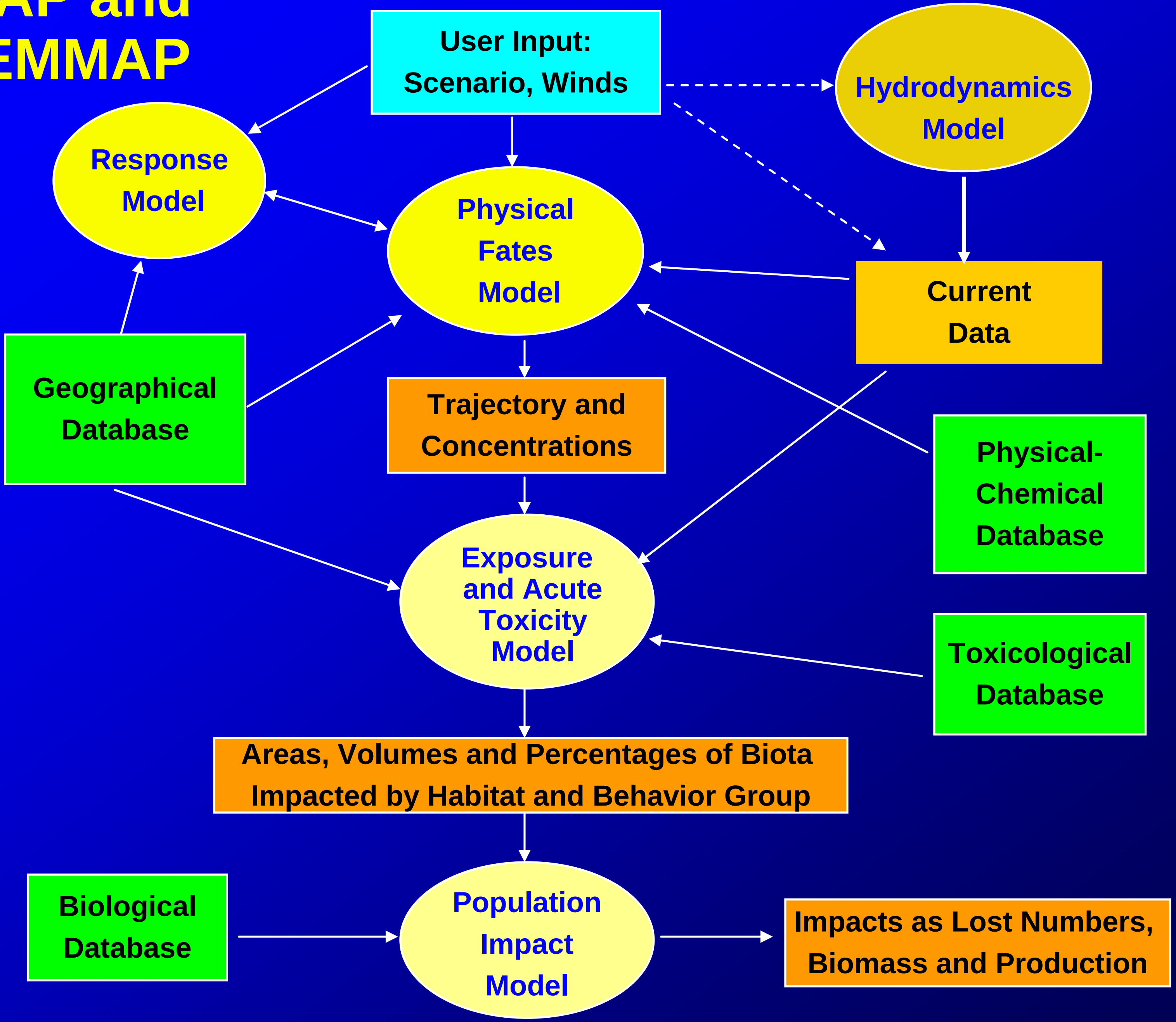
State-of-the-Art

SIMAP and CHEMMAP



References

- **SIMAP (Oil)**
  - **French McCay, D.P., 2002. Development and Application of an Oil Toxicity and Exposure Model, OilToxEx. Environmental Toxicology and Chemistry 21(10): 2080-2094.**
  - **French McCay, D.P., 2003. Development and Application of Damage Assessment Modeling: Example Assessment for the North Cape Oil Spill. Marine Pollution Bulletin, Volume 47, Issues 9-12, September-December 2003, pp. 341-359.**
  - **French McCay, D.P., 2004. Oil spill impact modeling: development and validation. Environmental Toxicology and Chemistry 23(10): 2441-2456.**
- **CHEMMAP (Chemicals)**
  - **French McCay, D.P., 2001. Chemical Spill Model (CHEMMAP) for Forecasts/Hindcasts and Environmental Risk Assessment. In: Proceedings of the 24th Arctic and Marine Oilspill (AMOP) Technical Seminar, Edmonton, Alberta, Canada, June 12-14, 2001, Environment Canada, pp.825-846.**
  - **French McCay, D.P. and Isaji, T., 2004. Evaluation of the consequences of chemical spills using modeling: chemicals used in deepwater oil and gas operations. Environmental Modelling & Software 19(7-8):629-644.**
  - **French McCay, D., N. Whittier, M. Ward, and C. Santos, 2006. Spill hazard evaluation for chemicals shipped in bulk using modeling. Environmental Modelling & Software 21(2): 158-171.**

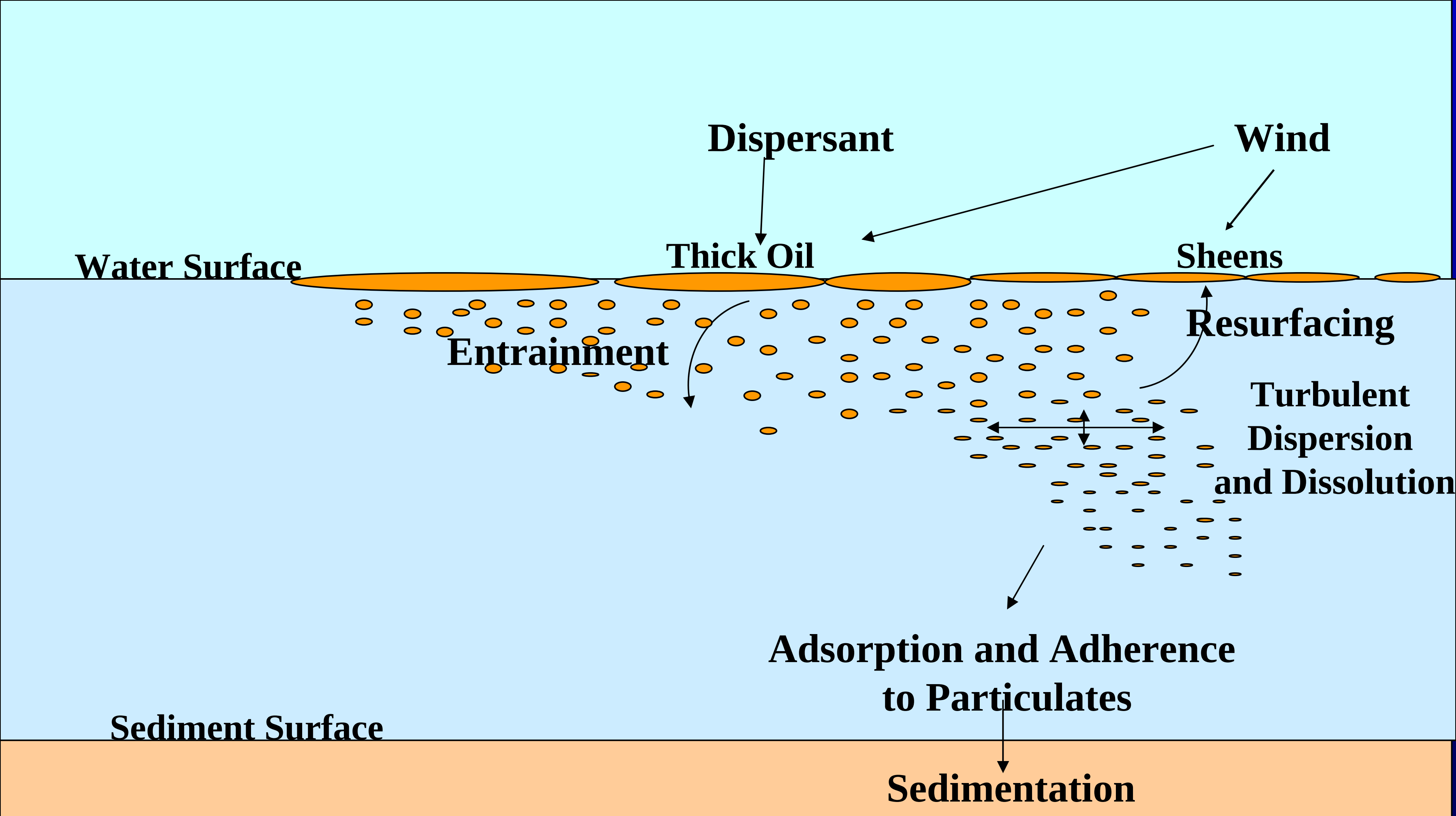
Oil and Chemical Spill Modeling State-of-the-Art for Physical Fates

- Lagrangian approach, allowing
  - Complex releases in space and time
  - Weathering, phase changes and chemical reactions
  - Hydrodynamics can be independent
- Three-dimensional necessary
  - Subsurface concentrations
  - Spreading and transport processes
  - 2D floating trajectory OK if no significant entrainment (light winds, floating oils and chemicals)
  - Primary uncertainty – wind and current inputs
- Mixtures
  - Oil a mixture, handled as pseudo-components
  - Chemicals

    State: pure, in solution, adsorbed to particles

    Mixtures, model each

    Chemistry: acid-base



Buoyant Oils and Chemicals

Oil and Chemical Spill Modeling State-of-the-Art for Biological Effects

- Lagrangian approach, allowing
  - Simulation of behavior
    - Movements
    - Habitats used
  - Tracking of individuals
    - Accumulation of dose
    - Previous effects
- Model functional groups, rather than every species
    - Potentially thousands of species, life stages
    - Unknown and variable densities: inferences from volumes/areas/percentage of populations affected
    - Use species densities if needed (NRDA)

Biological Exposure Model in SIMAP and CHEMMAP

- Organisms classified by behavior
  - Wildlife
    - % of time on water surface
    - Habitats used
    - Feathers & fur
  - Fish and Invertebrates
    - Swimming
    - Drift with currents
    - Stationary

- Movements of organisms are tracked to calculate exposure of individuals

- Impact a function of dose
  - Wildlife
    - Area swept by oil
    - Oil thickness
  - Fish and Invertebrates
    - Concentration
    - Exposure time
    - Temperature

Potential Effects of Oil

- Smothering / Coating [Floating oil and chemicals]
  - Mechanical (smothering, prevention of uptake and depuration, interference with motility, etc.)
  - Thermal regulation (birds, mammals)
  - Absorption of toxic compounds (via skin or gut)
- Mechanical interference [Dispersed droplets]
  - Contact exposure
  - Clogging of feeding appendages and gills
  - Impeding movements
- Behavioral interference [Floating or dispersed droplets]
  - Avoidance (leave area or shut down)
  - Attraction (more exposure)
- Toxicity – requires uptake into tissues

Effects Levels for Whole Oil

- Smothering
  - Need effects threshold or dose-response curve based on mass per surface area
  - Dose-response data available for birds
- Mechanical interference
  - Need concentration threshold or dose-response curve
  - Little or no *quantitative* data
  - How relate to injury?
- Behavioral interference
  - Little or no *quantitative* data
  - Need to model behavior and change in exposure because of the avoidance/attraction

Potential Toxic Effects

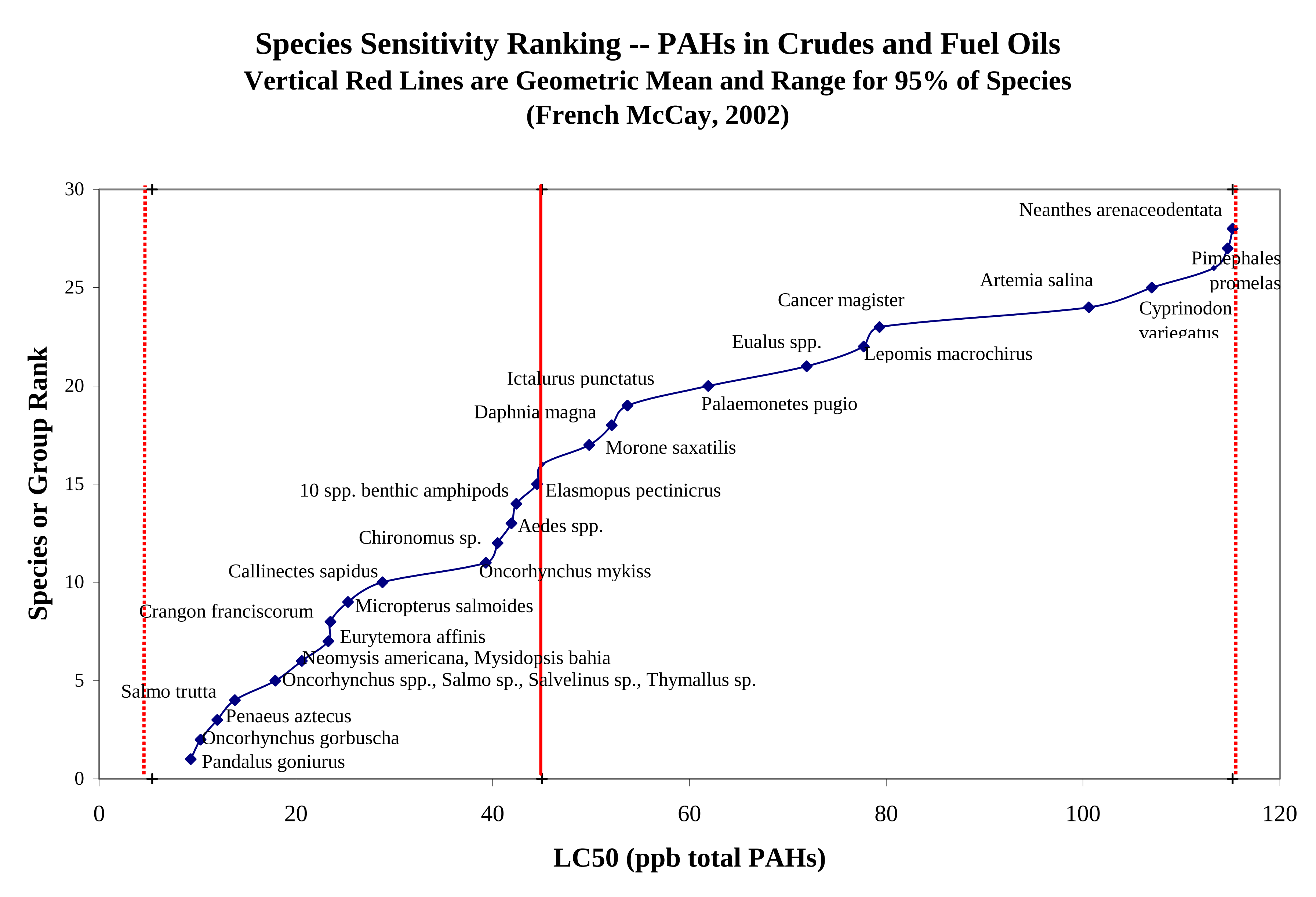
- Pathways involving uptake of hydrocarbons into tissues (membrane processes) → toxicity
  - Via gill and body surfaces (absorption)
  - In gut (assimilation)
  - From dissolved phase, originating from droplets adhering to external or internal surfaces
- Effects
  - Acute toxicity (first 2 weeks) –Toxic Units approach well established

    Additive effects all components

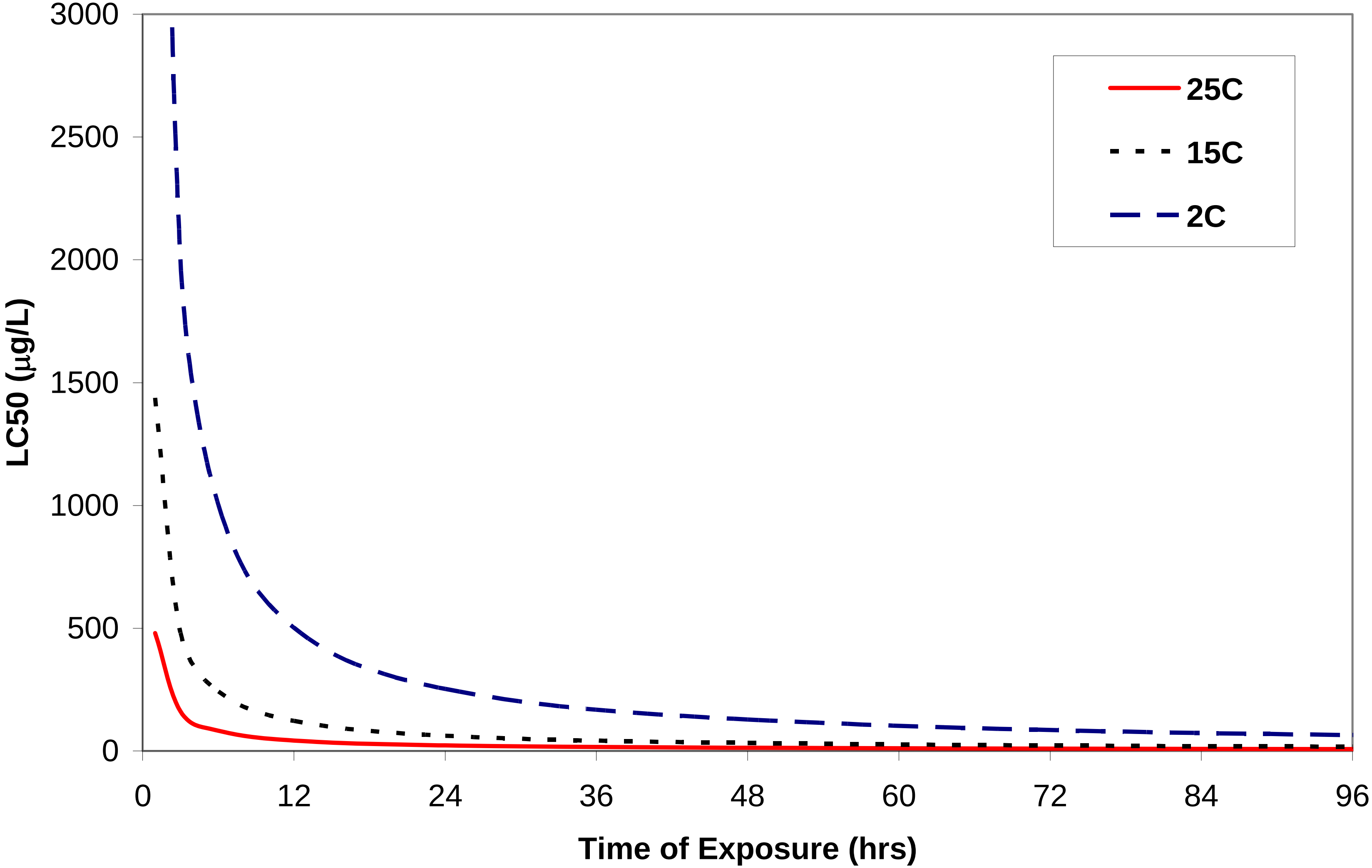
    Function of solubility

    1 to 3-ring aromatics most important (validated)
  - Chronic (>2 weeks exposure) – on-going research

Acute Toxicity – Varies Greatly by Species



Acute Toxicity = *f* (Duration of Exposure and Temperature)



Future of Spill Modeling
Research Questions for Spill Modeling

Better Input Data

- Winds
  - Real time measurements on line
  - Meso- and small-scale modeling
- Currents
  - Hydrodynamic modeling in real time, on-line products
  - Measurements in real time
    - High frequency radar
    - Satellite remote sensing
- Turbulent dispersion
  - Handled as random motion
  - Still high uncertainty

More Accurate and Detailed Transport and Fate Algorithms

- Mixed layer processes –
  - Langmuir circulation
  - Wind-induced currents
  - Stokes Drift from wave motions
  - Need a simplified algorithm, rather than solve time-varying computational fluid dynamics equations within oil fates and effects models
- Droplet processes
  - Droplet size distribution
  - Oil-particle interactions
- Shoreline processes
  - Related to viscosity, shore type, and exposre
  - Not so data intensive that can't be applied

Research for Biological Effects

- Acute toxicity
  - Short term exposures
  - Variable exposure
  - Species sensitivities
- Chronic toxicity
  - Mechanisms
  - Effects levels
  - Species and life stage variability
- Biological distributions and behavior most uncertain model inputs
  - Density and patchiness
  - Basic population biology

What is the Question?

- The approach and required accuracy depends on
  - The question being asked
  - The precision of the inputs
  - The urgency for the results
  - The level-of-effort the problem merits (or is allotted)

- Example: Type A model vs Type B site- and event-specific analysis

Format the Question

- What are the Issues?
  - e.g., should dispersants be applied to floating oil?
- What is to be the basis of the decision?
  - e.g.:

    Effectiveness considering weathering and conditions

    Trade-offs of dispersant use: water column vs wildlife and shorelines
- How soon do we need the answer?
- What is the required accuracy? Can it be a relative answer?
  - e.g., evaluate relative areas affected, rather than numbers or biomass impacted

Forecast / Hindcast / Probabilistic

- Forecast needed for:
  - Where is the oil going?
  - How soon will it get there?
  - What might be impacted?
  - Most uncertainty
- Hindcast used for:
  - Impact assessment (biological, economic)
  - NRDA
  - Uncertainty handled with
    - Sensitivity analysis
    - Additional research and analysis
- Probabilistic
  - Appropriate approach for planning and risk assessment
  - Less focus on specific scenarios and details of certain environmental events
  - Statistics: mean/median, range, worst case
  - Can/should be used more

Needs for Real-Time Forecast Modeling

- Transport
  - Winds
  - Currents
  - Entrainment
  - Dispersion
- Fates
  - Particle interactions
  - Dissolution
- Acute toxicity
- Biological Distributions

Focus of Hindcast Modeling

- Fates
  - Shoreline processes
  - Degradation
- Biological
  - Exposure vis-à-vis behavior
  - Short term (acute) and chronic effects
  - Population response and recovery
  - Ecosystem level effects
- Economic
  - Response costs
  - Socioeconomic impacts

Use Probabilistic Modeling

- Ecological risk analyses
  - Likelihood and potential range of impacts
- Cost-benefit analyses
- Spill response requirements/capacities
- Dispersant Decision Making
  - Worst case analysis
  - Potential areas and volumes affected

Less focus on using real-time and single-scenario (deterministic) modeling for such purposes

How Much Detail is Required?

"It is not enough to be busy. So are the ants. The question is: What are we busy about?" Henry David Thoreau

- If we make a model more complex, is it in fact more accurate?
  - Depends on the certainty of the model inputs
  - More refined but less certain answer