

Developments Towards a Satellite-Informed High-Resolution $PM_{2.5}$ Modeling System

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Goals ...

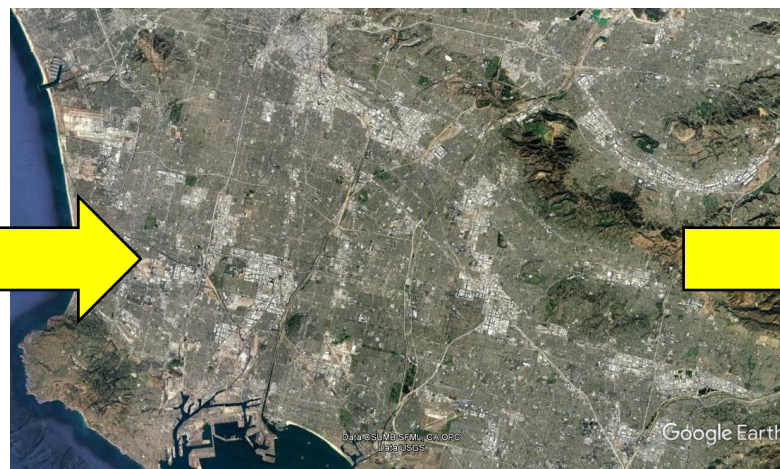
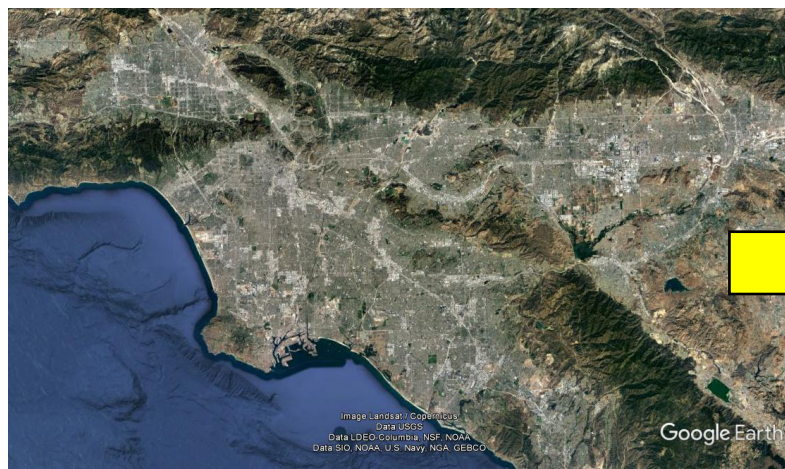
- PM2.5 @ sub-km resolution around a point of interest (POI)
- All scales (large -> neighborhood)
- Full physics (primary, secondary)
- Flexible & computationally efficient
- Wide applicability
 - AQ management, Health Effects & Forecasting
- Satellite key component
 - Linkage to large scale
 - Provide constraints due to emission uncertainty

Basis: Downscaling satellite AQ fields to sub-km ...

Large Scale / Regional
(satellite-informed)
(e.g. MODIS AOD -> PM_{2.5})
(~ 10 km)

Local
(~ 1 km)
(HYSPLIT + LBM)

Near-Source
(~ 100 m)
AERMOD



Primary + Secondary Background PM_{2.5}



Near-Source PM_{2.5}



Total PM_{2.5}

HYSPLIT Stilt Emulation Mode

- Lagrangian Particle Model
- Backwards in integration
- Map out influence functions (I)
- Spatial maps: Influence of upwind regions on concentrations @ point of interest

Concentration @ point of interest 

$$C(\mathbf{x}_r, t_r) = \int_{t_0}^{t_r} dt \int_V d^3x I(\mathbf{x}_r, t_r | \mathbf{x}, t) S(\mathbf{x}, t)$$

Term 1: Couple to Surface Emissions

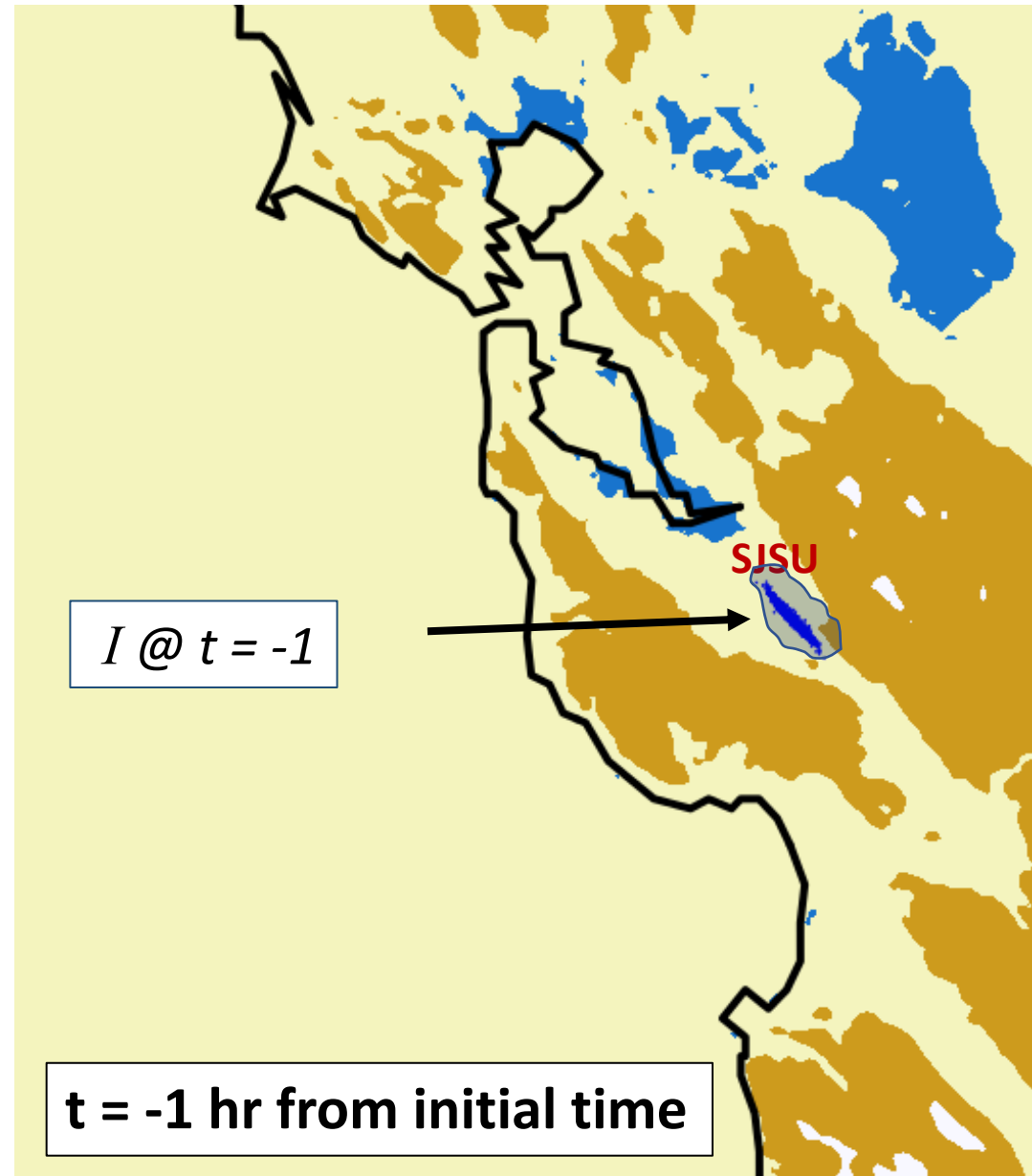
$$+ \int_V d^3x I(\mathbf{x}_r, t_r | \mathbf{x}, t_0) C(\mathbf{x}, t_0).$$

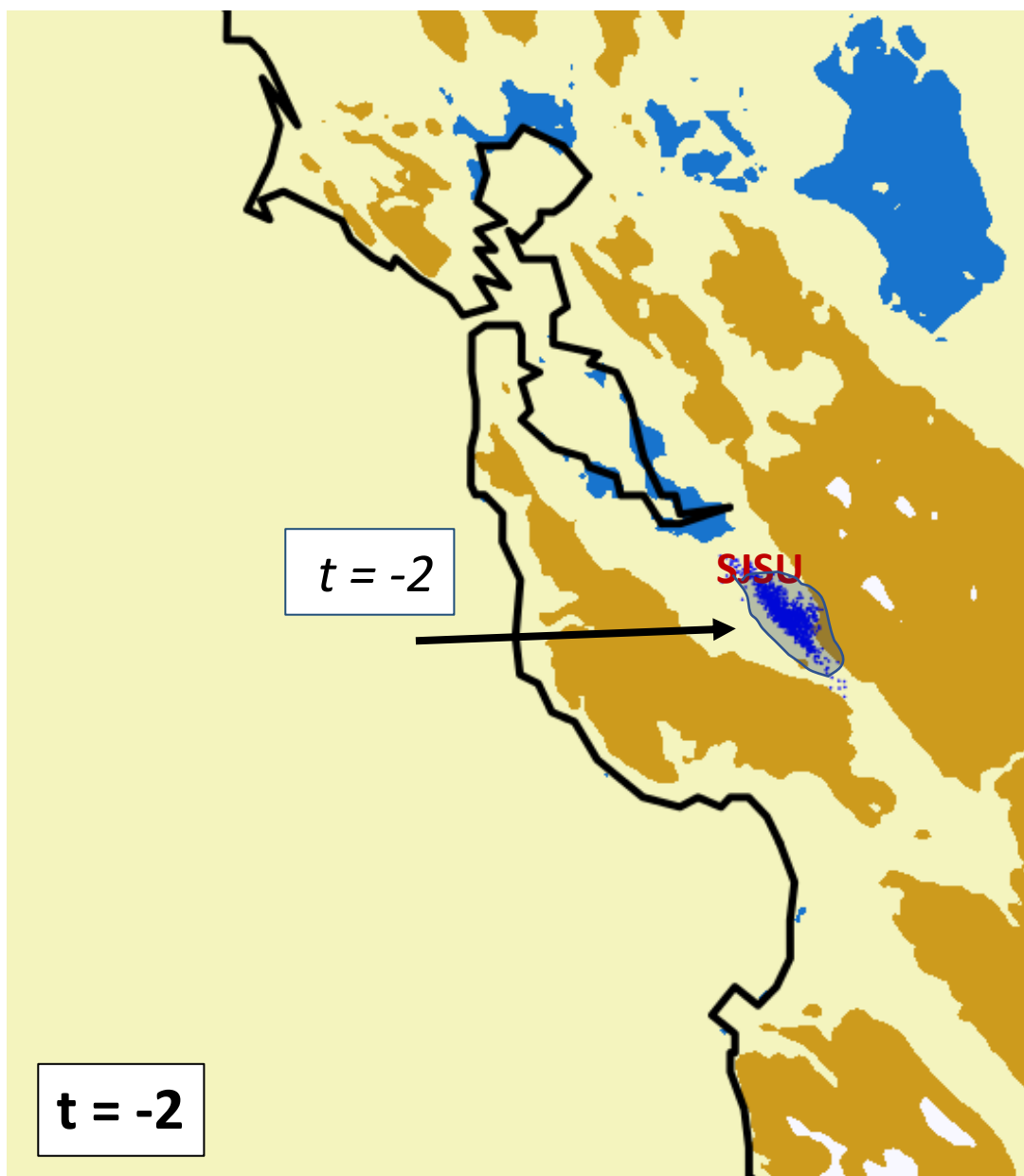
Term 2: Couple to initial conditions

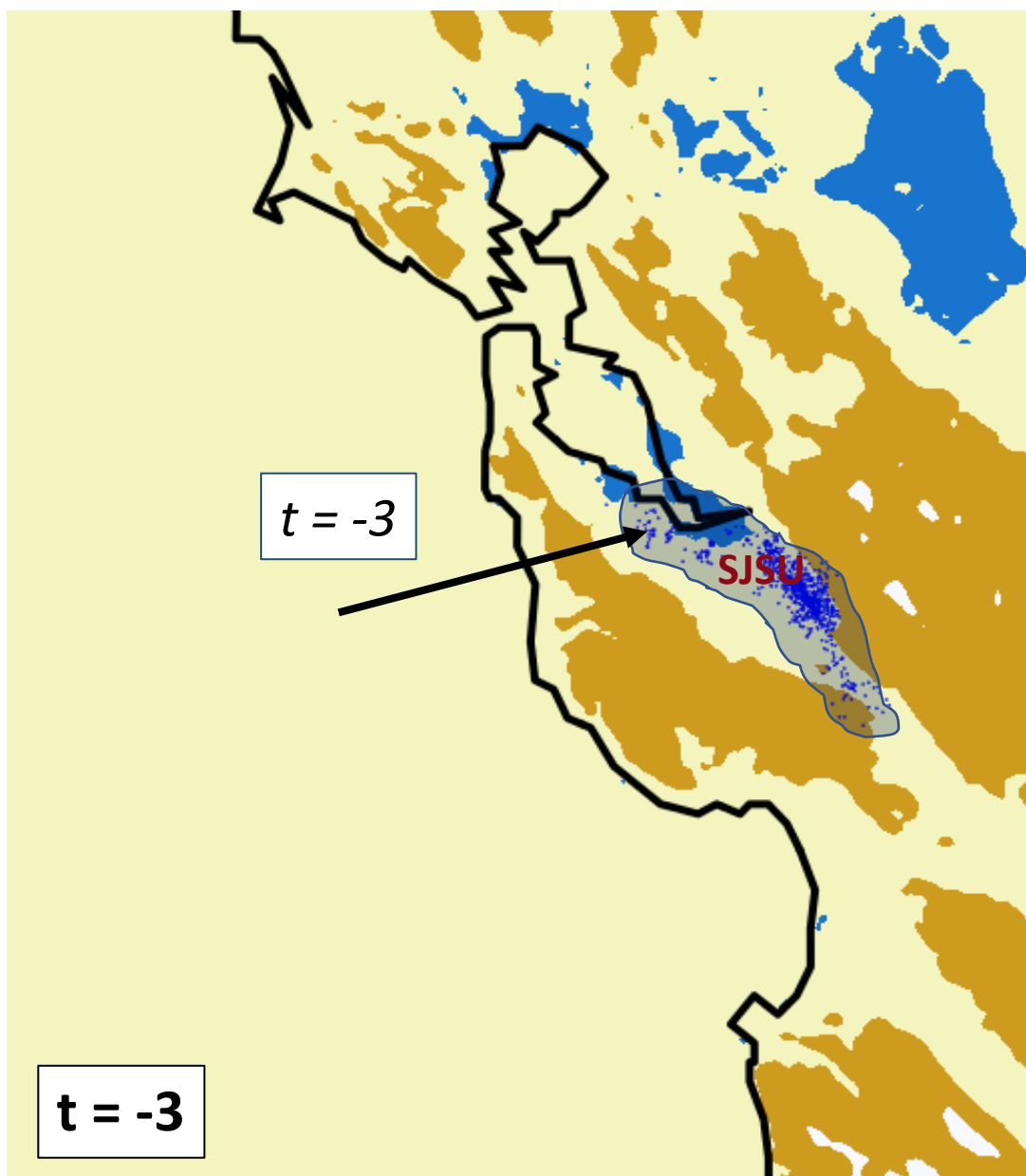
Ref: Lin et al. 2003 (JGR)

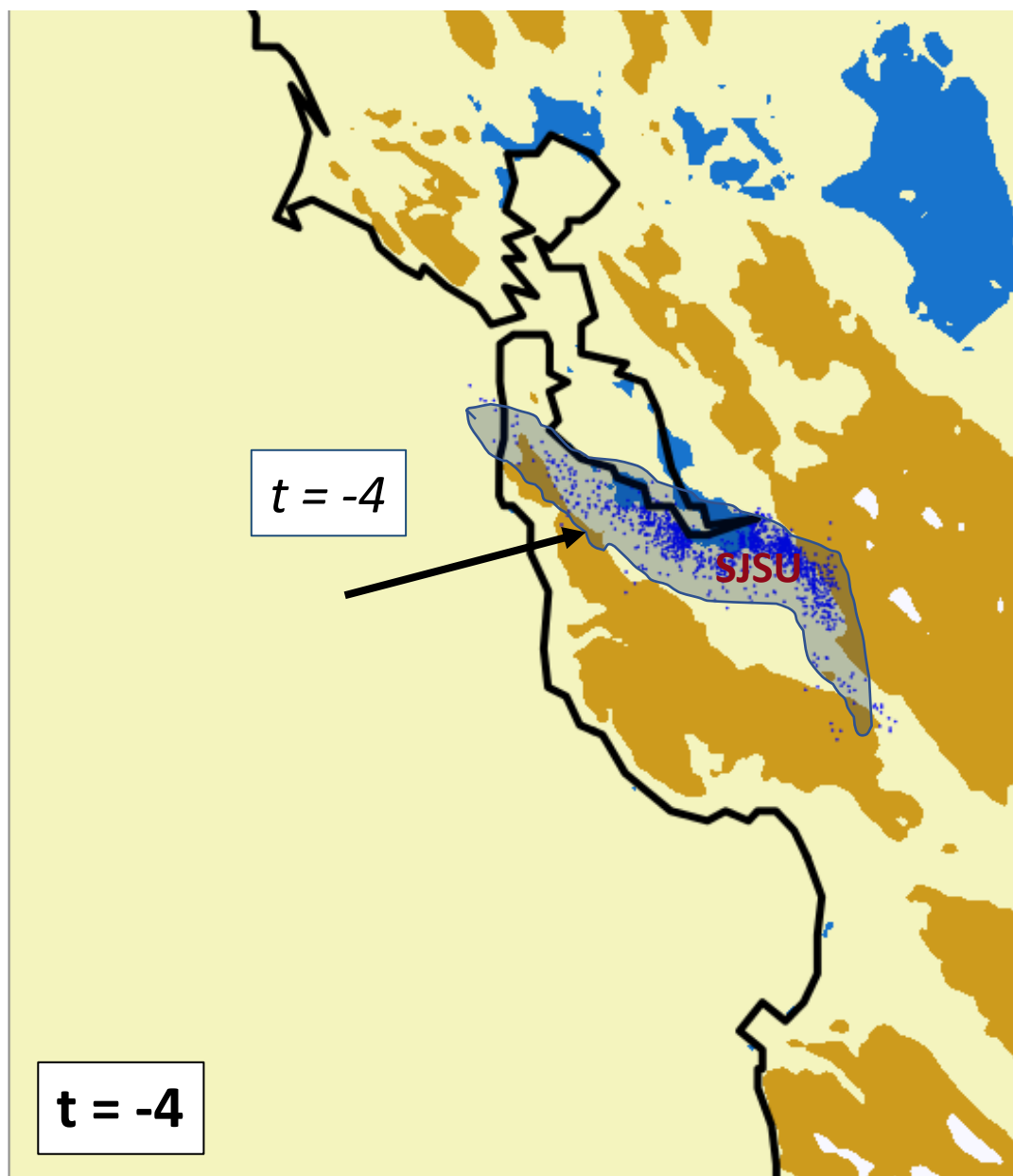
Illustrative example ...

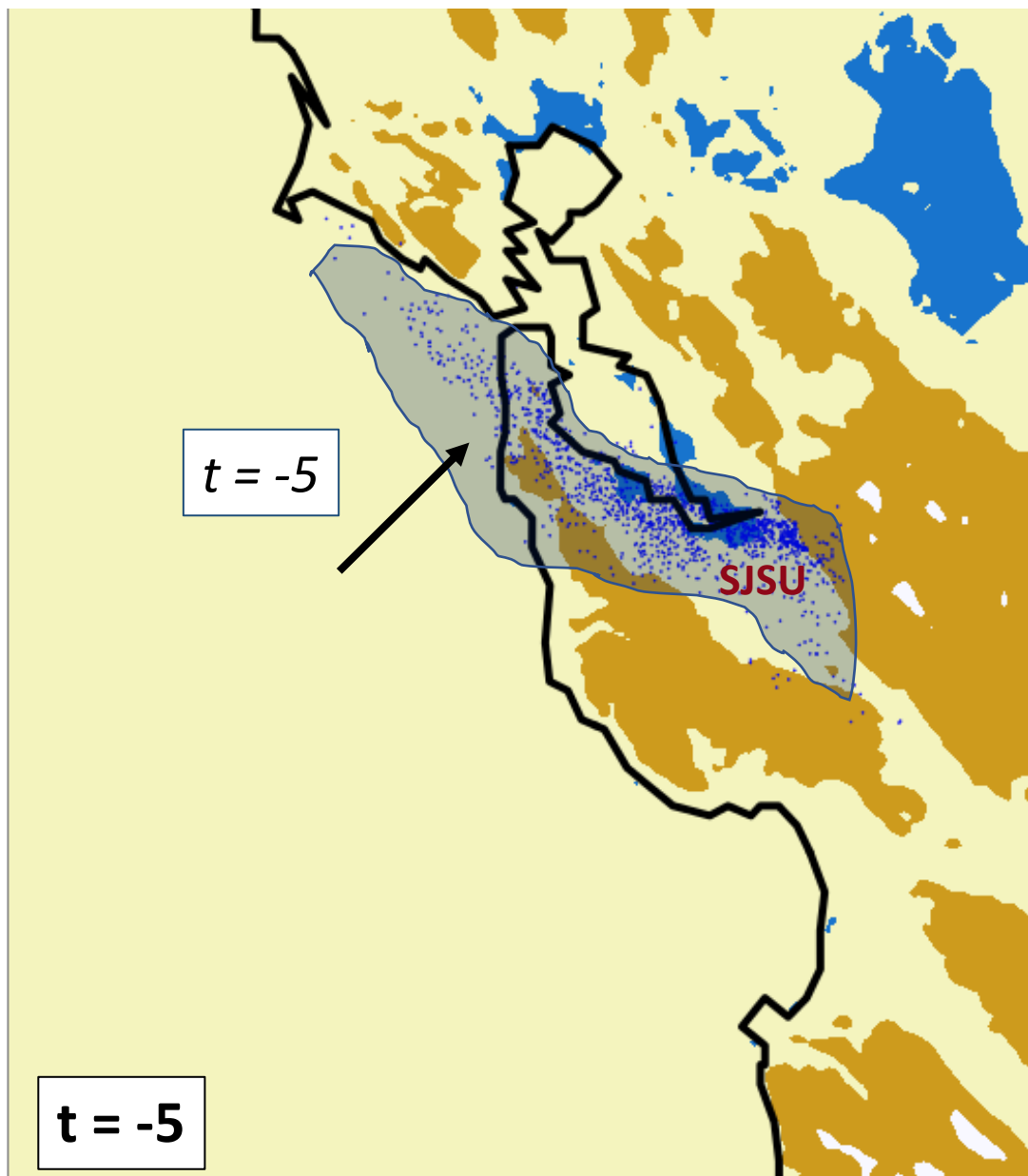
- HYSPLIT
- Backwards-in-time nine hours
- Point of Interest: SJSU
- Driven by WRF wind field

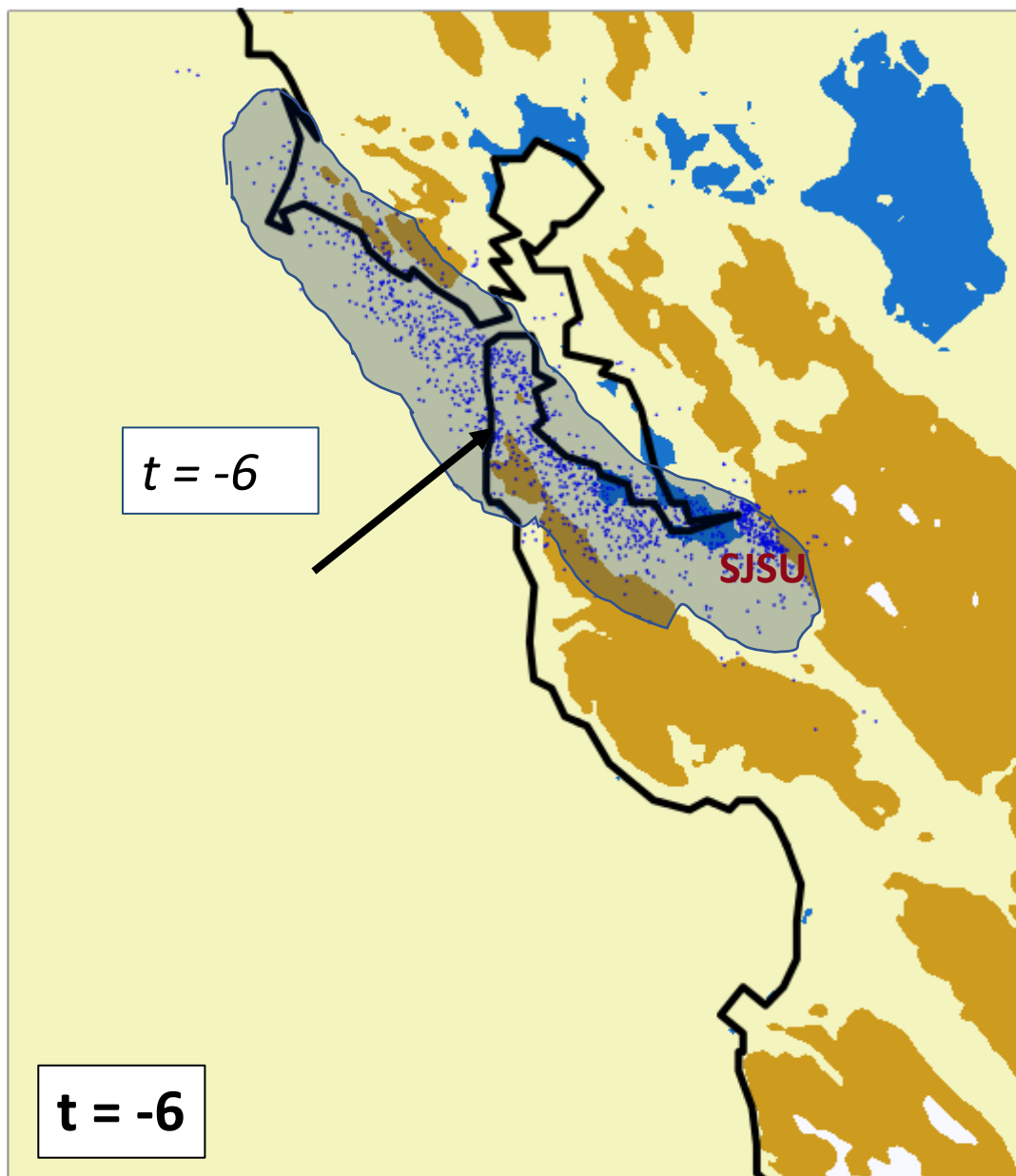


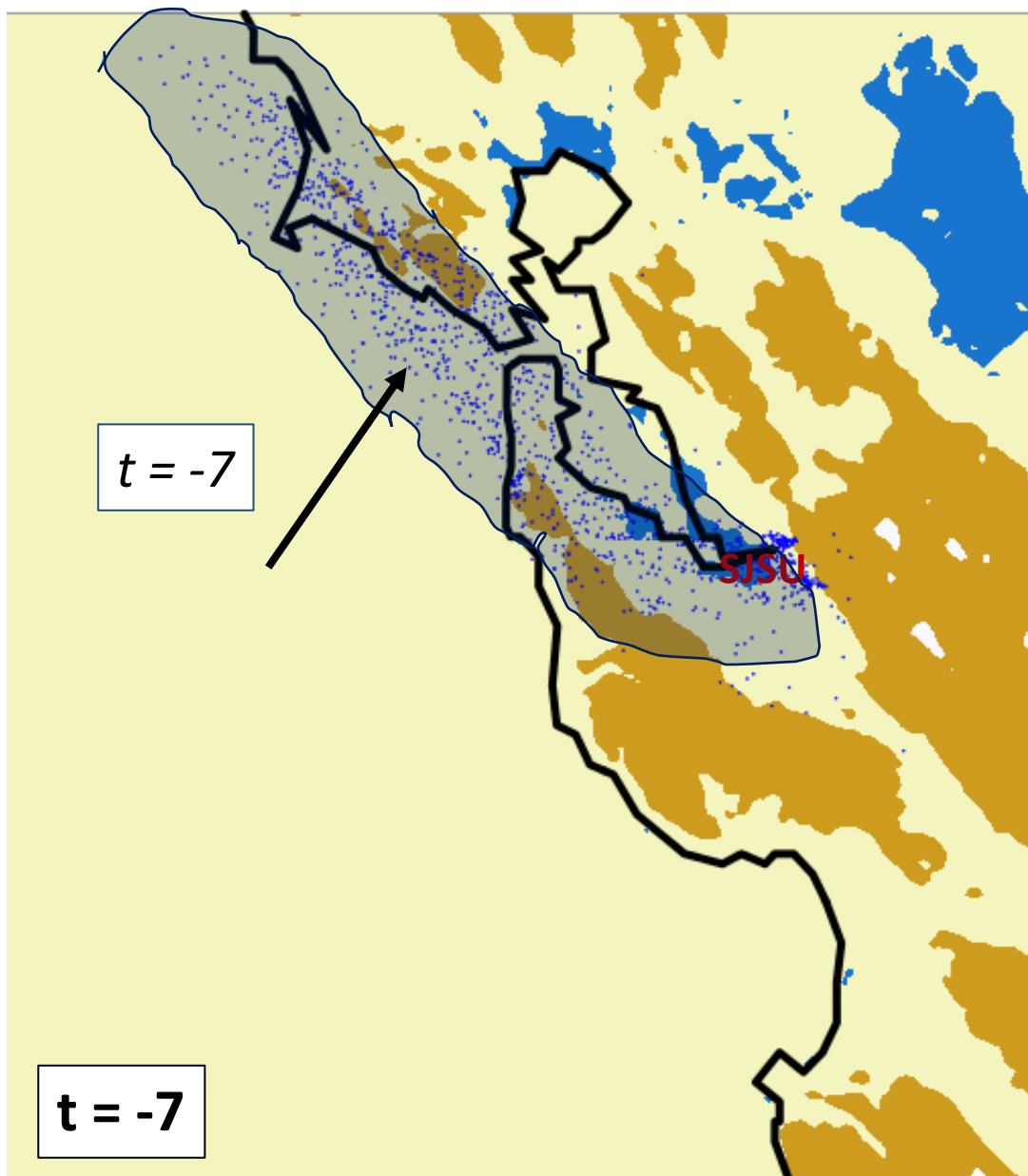


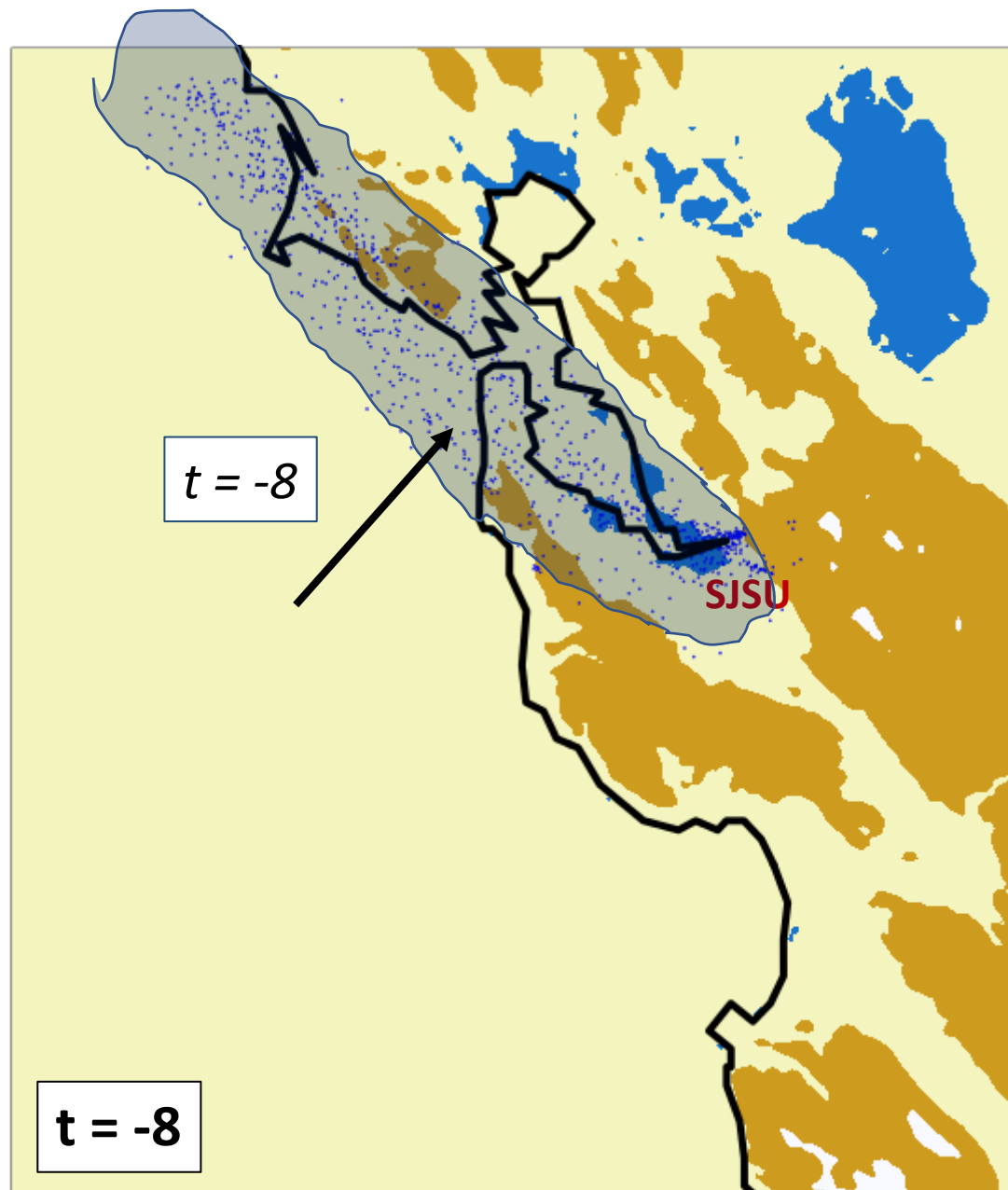


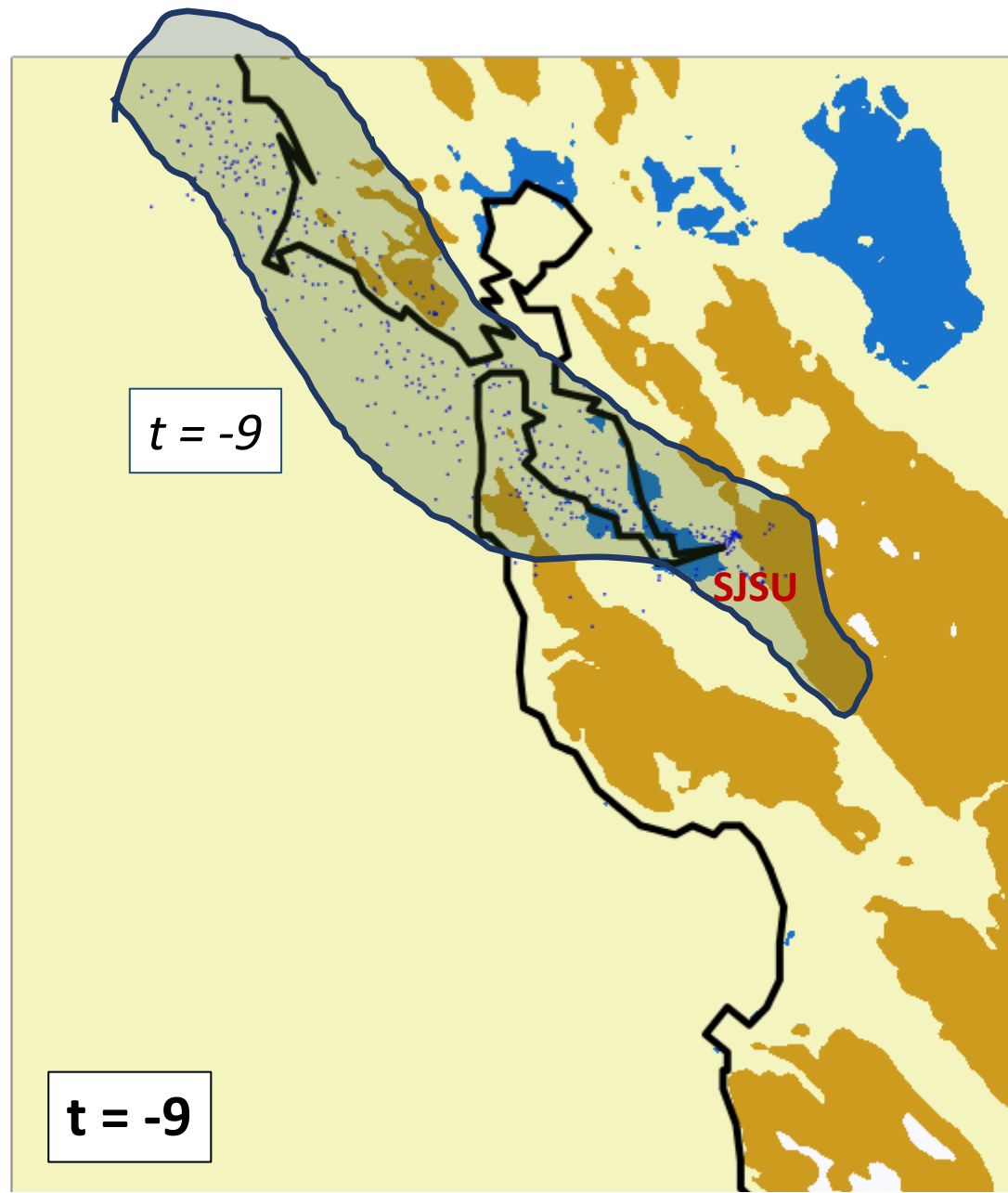












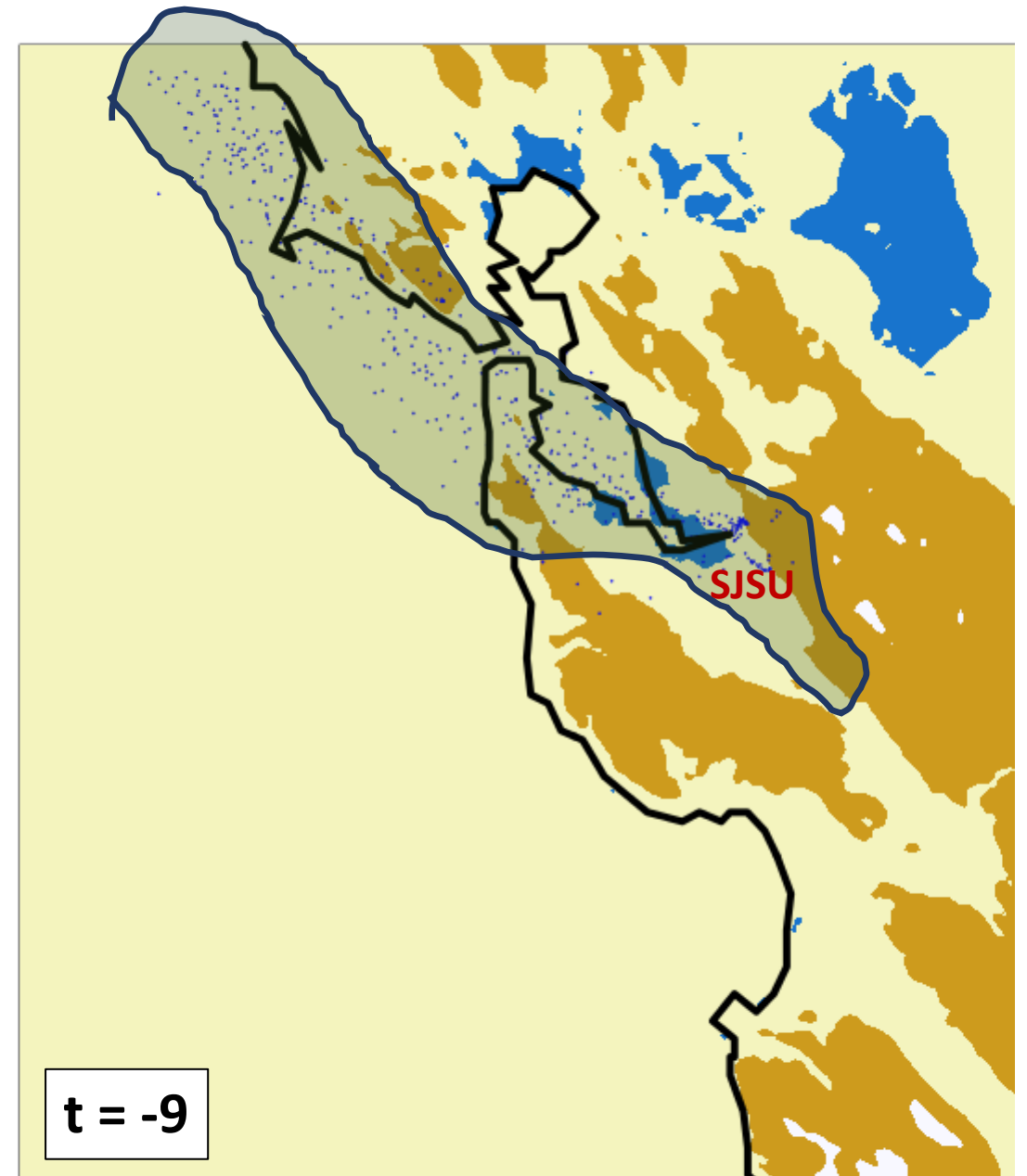
Apply to ...

- *PM₂₅ (primary local)*
- *NO_x (precursors, secondary local)*
- *VOC (precursors, secondary local)*

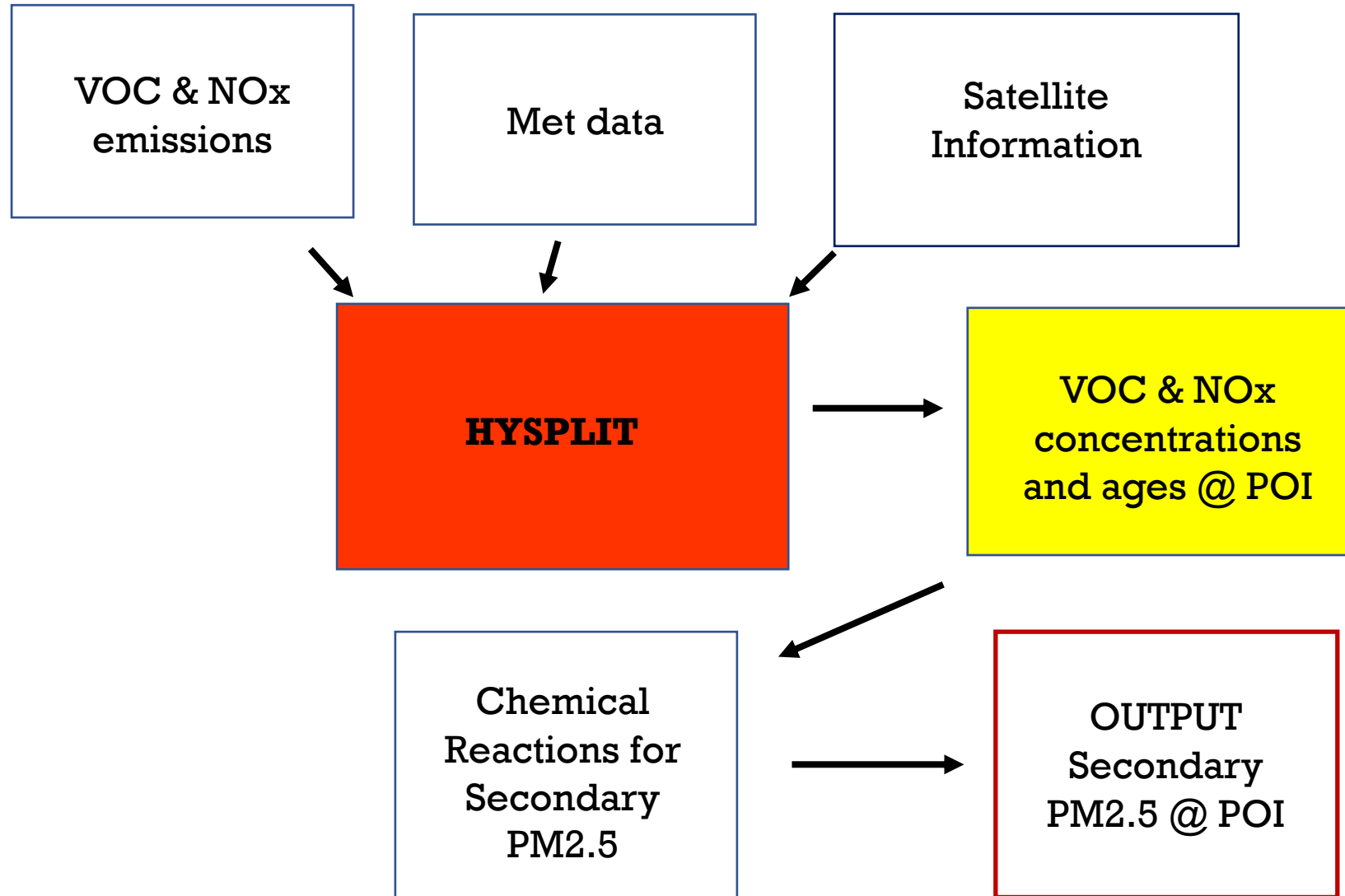
Role of Satellite Fields

Probe large-scale satellite field within influence region to provide ...

- *Initial conditions ($t = -9$)*
- *Constraints on model calculations ($t = 0$ to -9)*

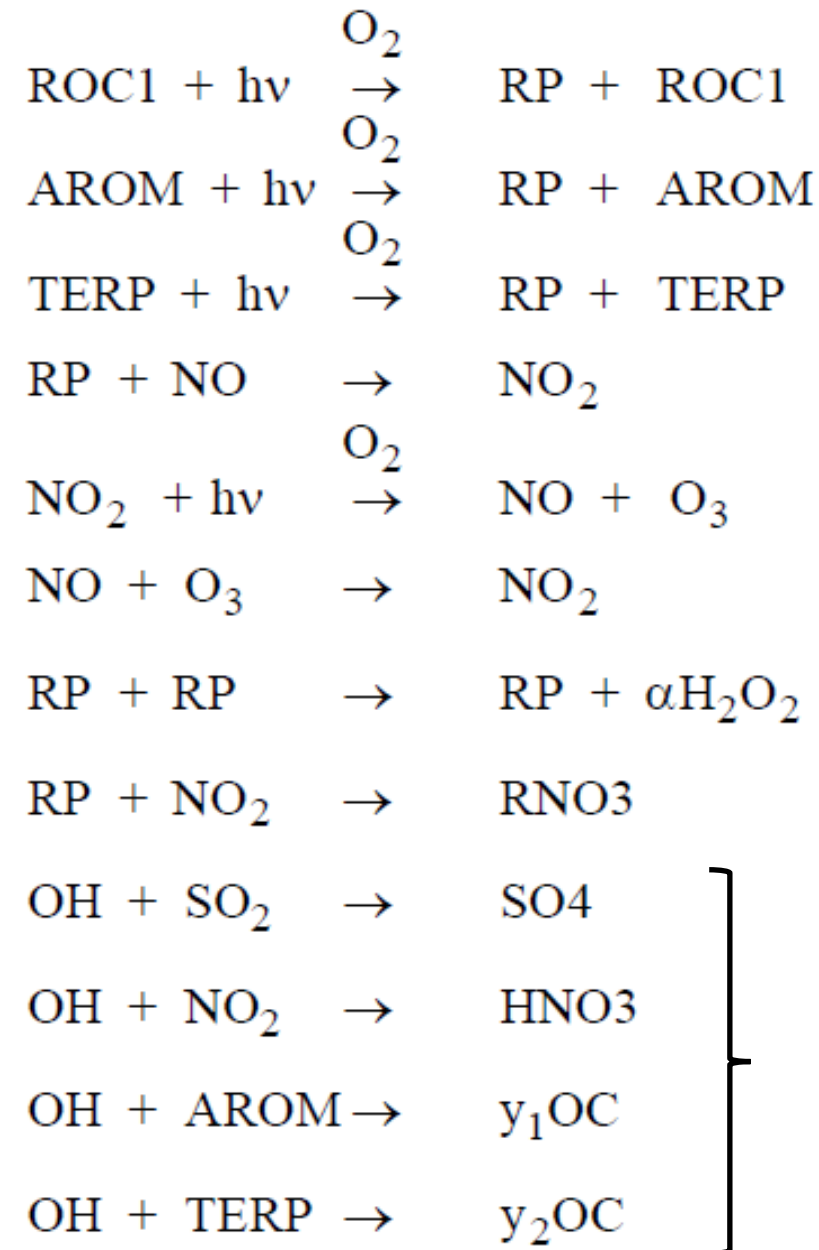


Local Secondary: Lagrangian Background Model (LBM)



LBM achieves computational efficiency by uncoupling transport and chemistry using the concept of species age (Venkatram et al. 1998; Pournazeri et al., 2014).

We can reduce computing time using time using parameterized chemistry to compute PM2.5 concentrations (Venkatram et al, 2011).



RP: “Radical pool”

Secondary PM2.5

- Sulfate
- Nitrate
- Secondary Organic

$$[\text{OH}] = 2.2 \times 10^{-6} [\text{O}_3] - 4.81 \times 10^{-9}$$

Ongoing Work ...

- **Fuse Components**

- MODIS AOD -> PM2.5: large-scale, regional
- HYSPLIT: primary local
- LBM: secondary local
- AERMOD: near-source

- **Details of Satellite Linkage**

- Suggestions from HAQAST & others

- **Applications & first use cases**

- **Evaluation**

- EPA AQS
- Low cost sensors

References & further details ...

Pournazeri, S., Tan, S., Schulte, N., Jing, Q., & Venkatram, A. (2014). A computationally efficient model for estimating background concentrations of NO_x, NO₂, and O₃. *Environmental Modelling & Software*, 52, 19-37.

Venkatram, A., & Horst, T. W. (2006). Approximating dispersion from a finite line source. *Atmospheric Environment*, 40(13), 2401-2408.

Venkatram et al. (1998). The Concept of Species Age in Photochemical Modeling, *Atmospheric Environment*, 32, 3403-3413.

Venkatram et al. (1997). The Development of a Model to Examine Source-Receptor Relationships for Visibility on the Colorado Plateau, *J. Air Waste Manage. Assoc.*, 47, 286 – 301.

See <https://sites.google.com/a/sjsu.edu/met-haqast/home> for more details.