The ORCA West Coast Regional Project – Diagnosis and Attribution

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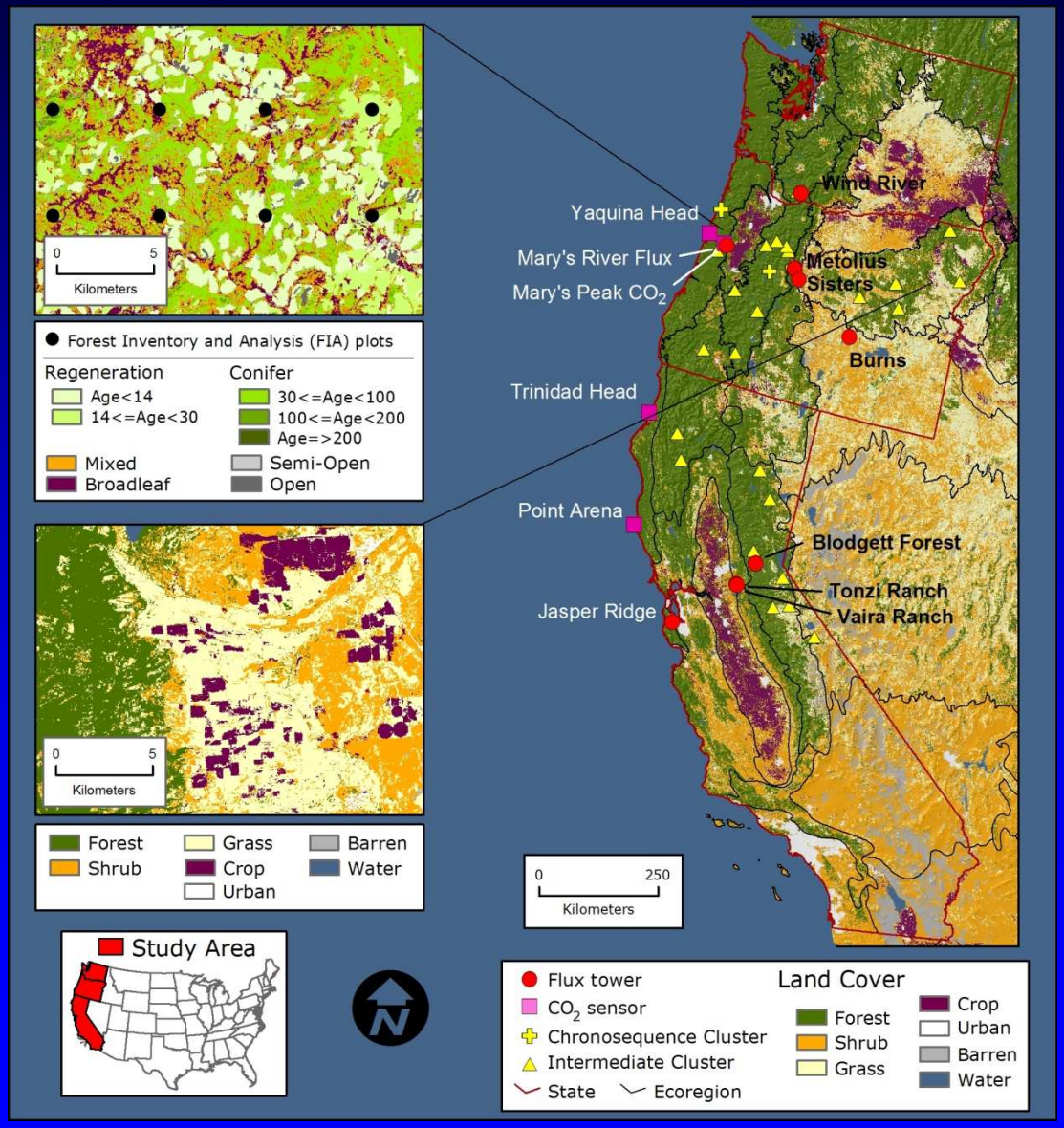
And other contributions: K Gourney (Vulcan), A Michalak, CarbonTracker

ORCA Objectives

Region: WA, OR, CA

Objectives:

- Multiple constraints to reduce uncertainty
- Bottom-up, top-down approaches
- Inventories, flux sites, intermediate plots, Landsat, MODIS data
- Effects of disturbance and climate on carbon balance



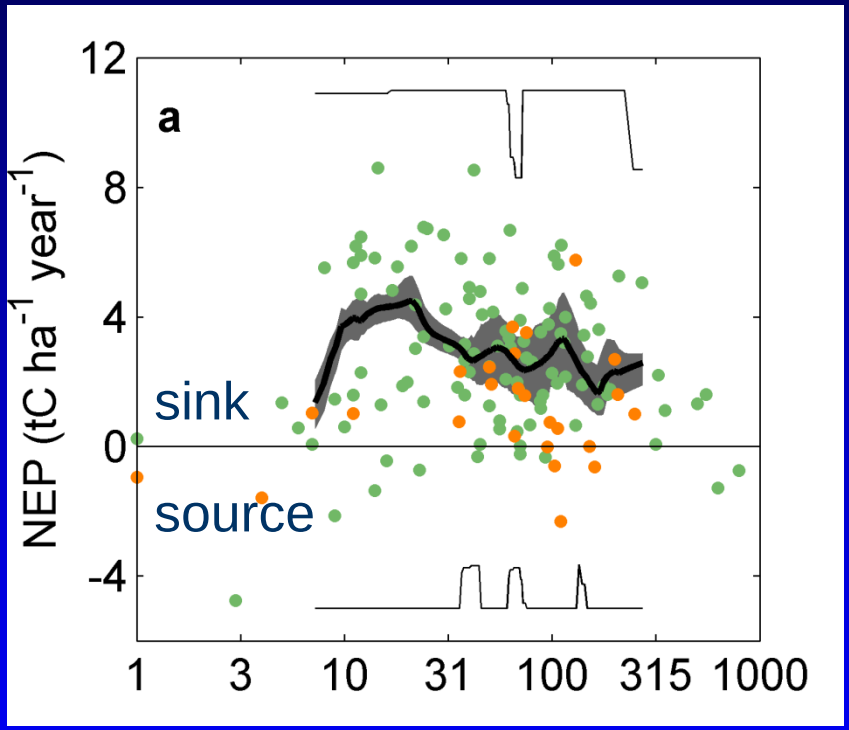
Field Studies to Fill Knowledge Gaps

- Changes in C stocks and fluxes with age – differences among ecoregions
- Wildfire C emissions
- Effects of partial disturbance (thinning) on decomposition, soil respiration, C allocation

Publications:
http://terraweb.forestry.oregonstate.edu

Old Forests as Carbon Sinks – N hemisphere Data from Flux Networks

- Majority of old forests were net sinks for CO_2
- ~15% of global forest area responsible for ~10% of land C uptake
- Future C accounting should include old forests



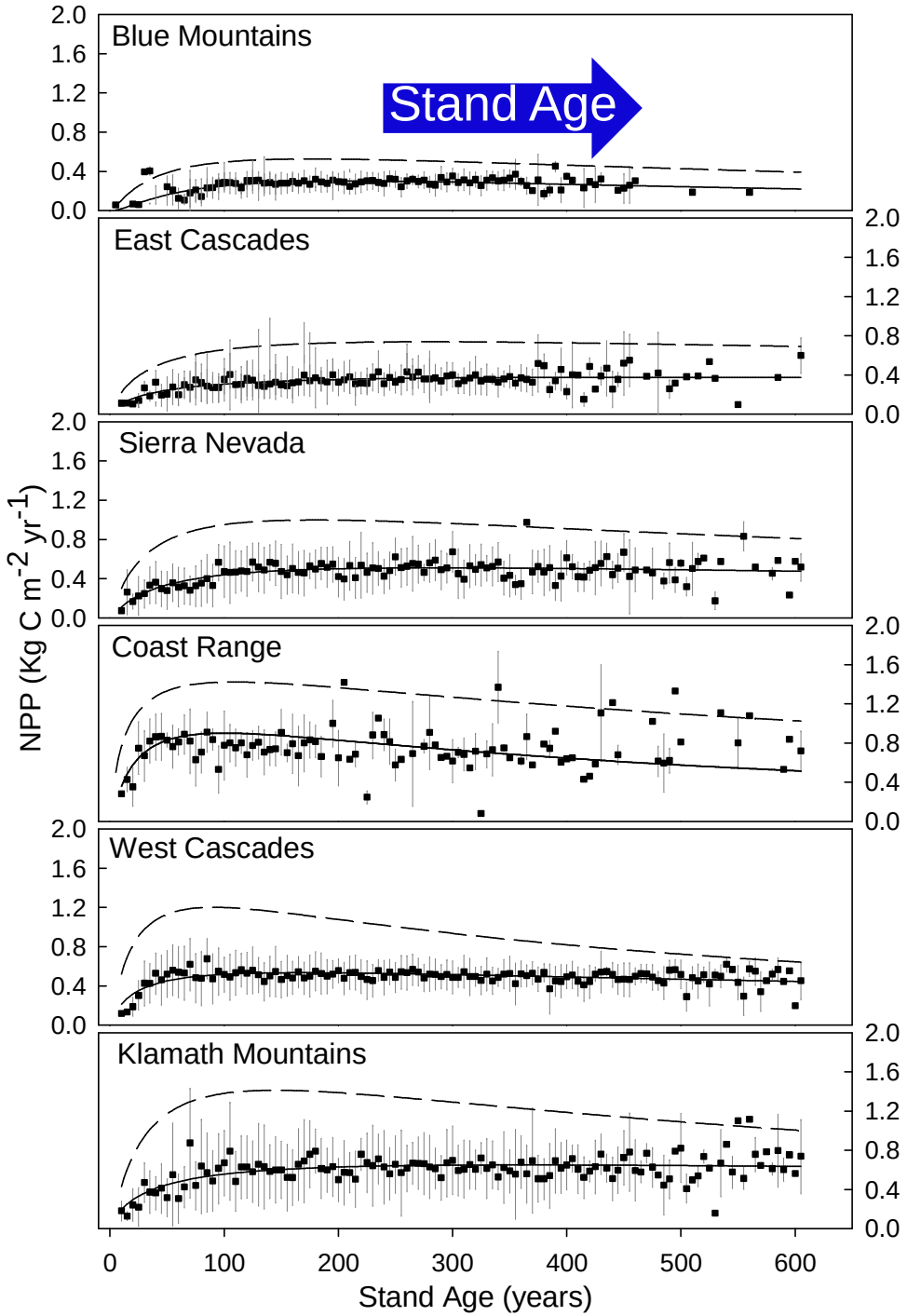
Age (years)

(Luyssaert et al. Nature 2008)

Regional Inventory: Changes in NPP with Forest Age (OR, N CA)

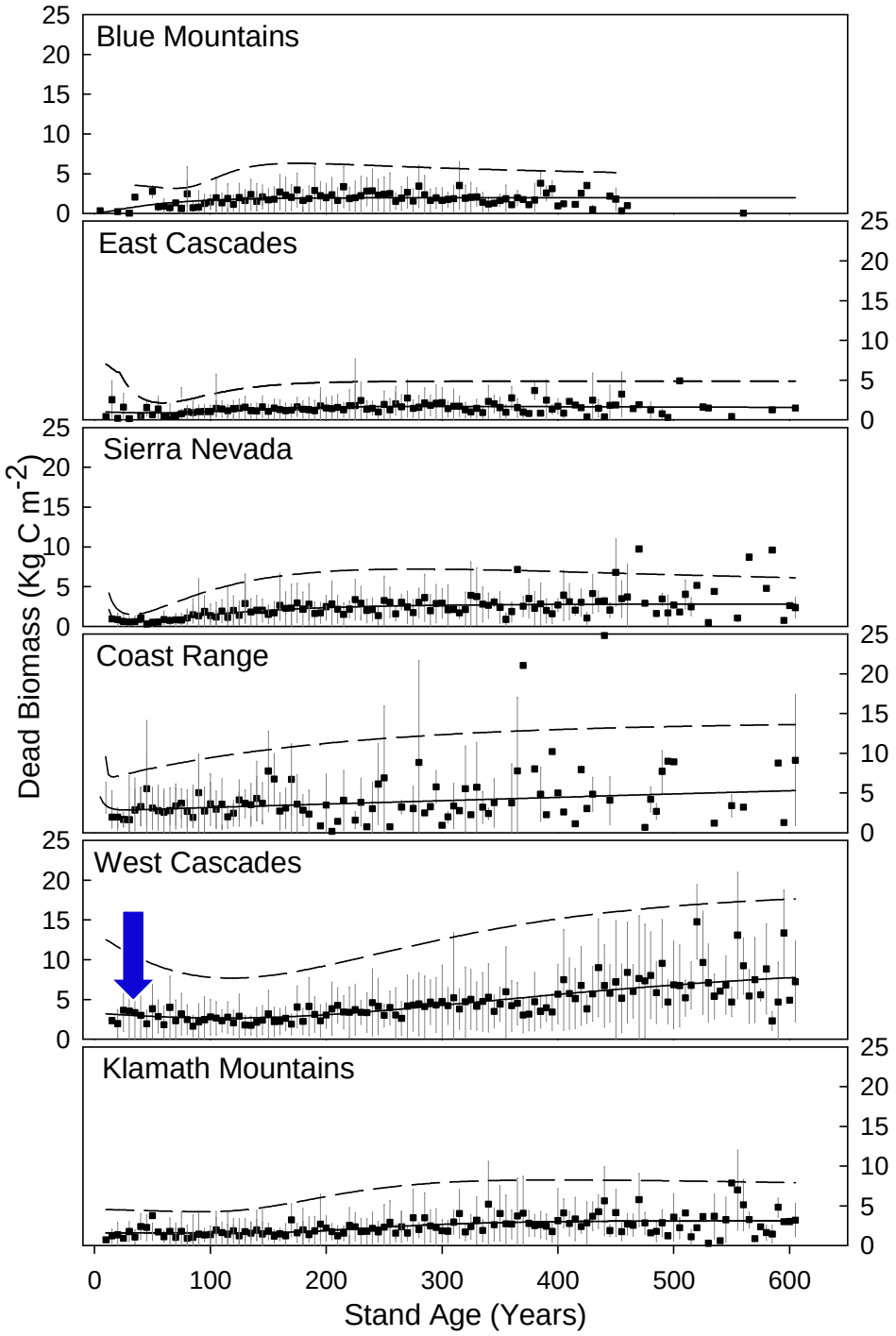
- ~!5,000 plots, 15 ecoregions
- Decline of NPP with age is not apparent in some ecoregions

(Hudiburg et al. Ecol App 2009)



Regional Inventory: Changes in Dead Biomass with Forest Age (OR, N CA)

- Theoretical u-shaped curve of dead biomass (and Rh) is not apparent in most ecoregions



(Hudiburg et al. Ecol App 2009)

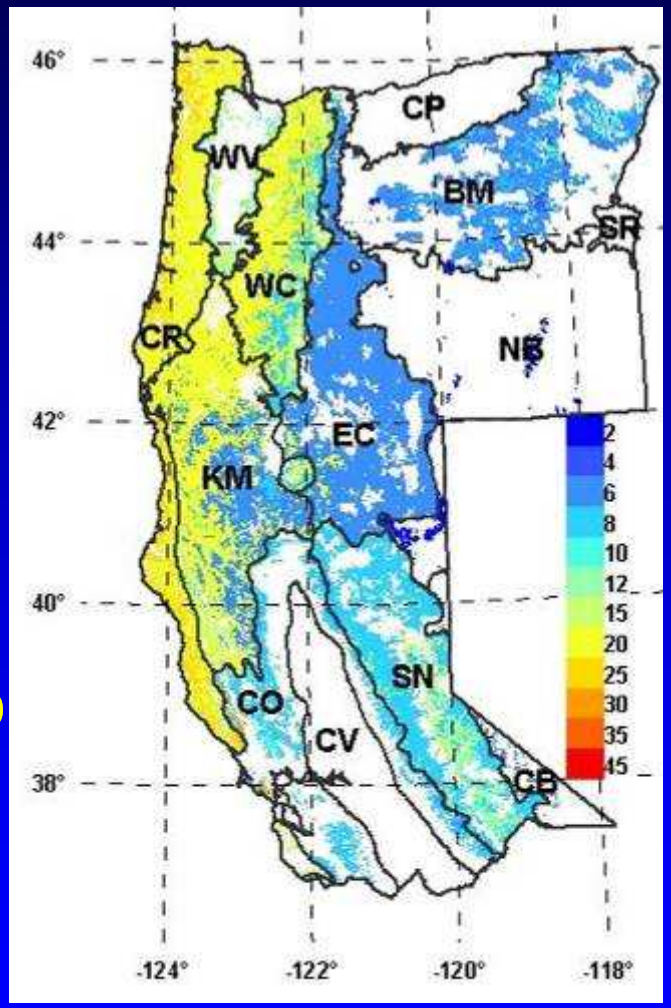
Current and Potential Biomas Carbon

Inventory analysis:

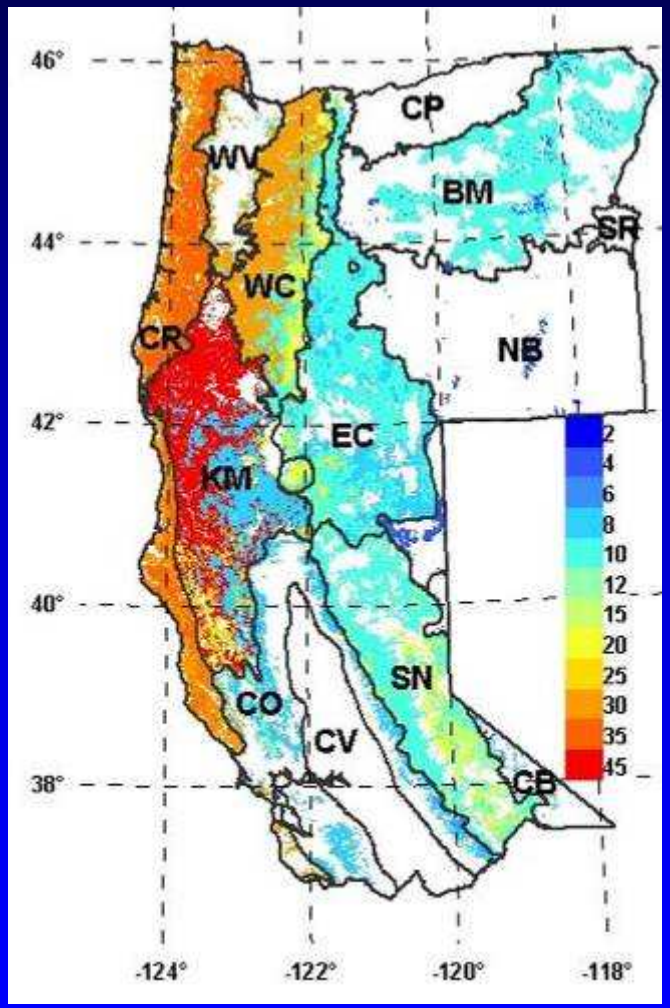
OR & N CA forests store 54% potential biomass C (red = high)

Biomass used to optimize BGC

Current Live Biomass



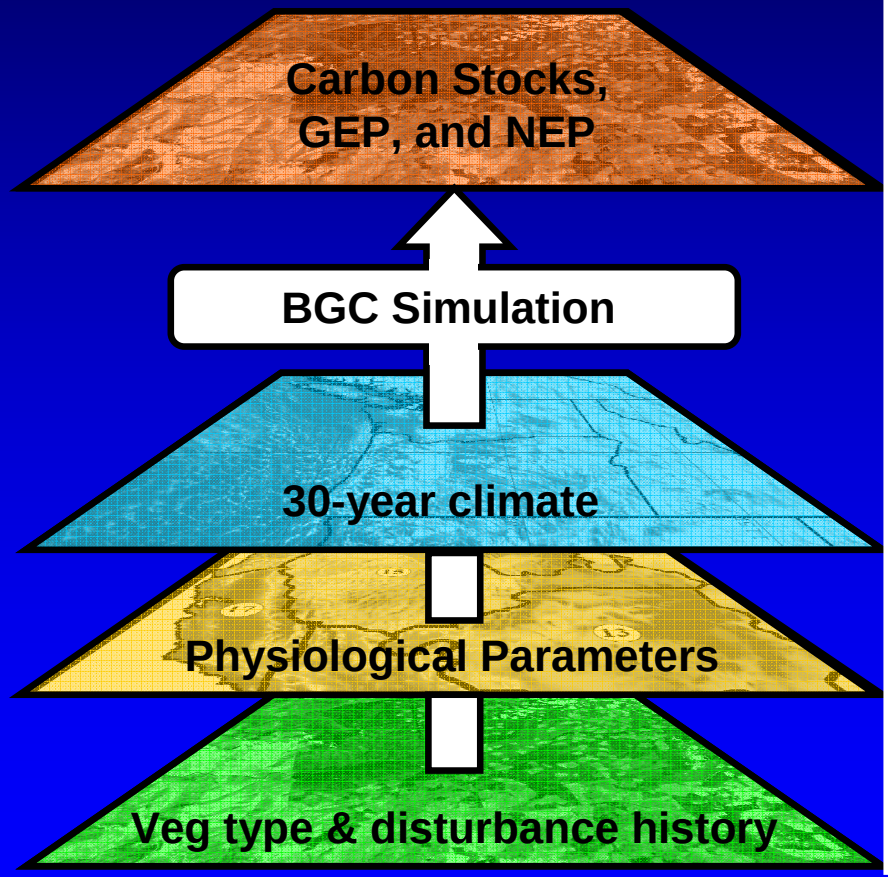
Potential **(kg C m^{-2})**

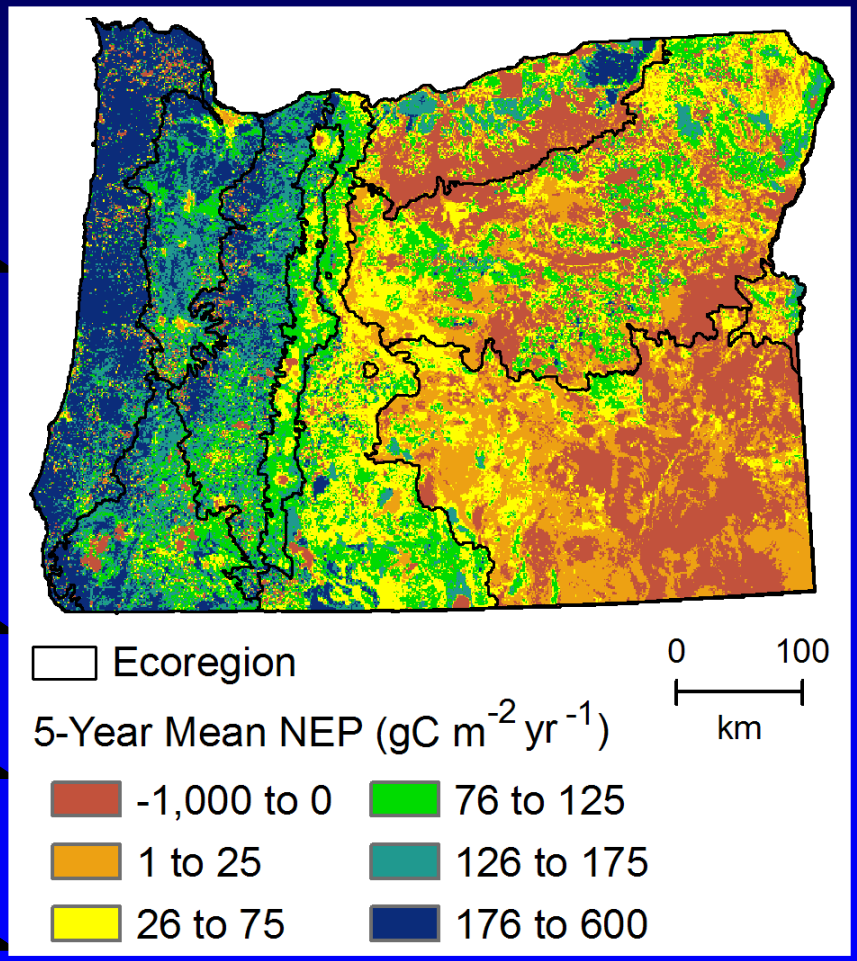


(Hudiburg et al. 2009) 3.2 ± 0.34 Pg C vs 5.9 ± 1.34 Pg C

Bottom-up Approach

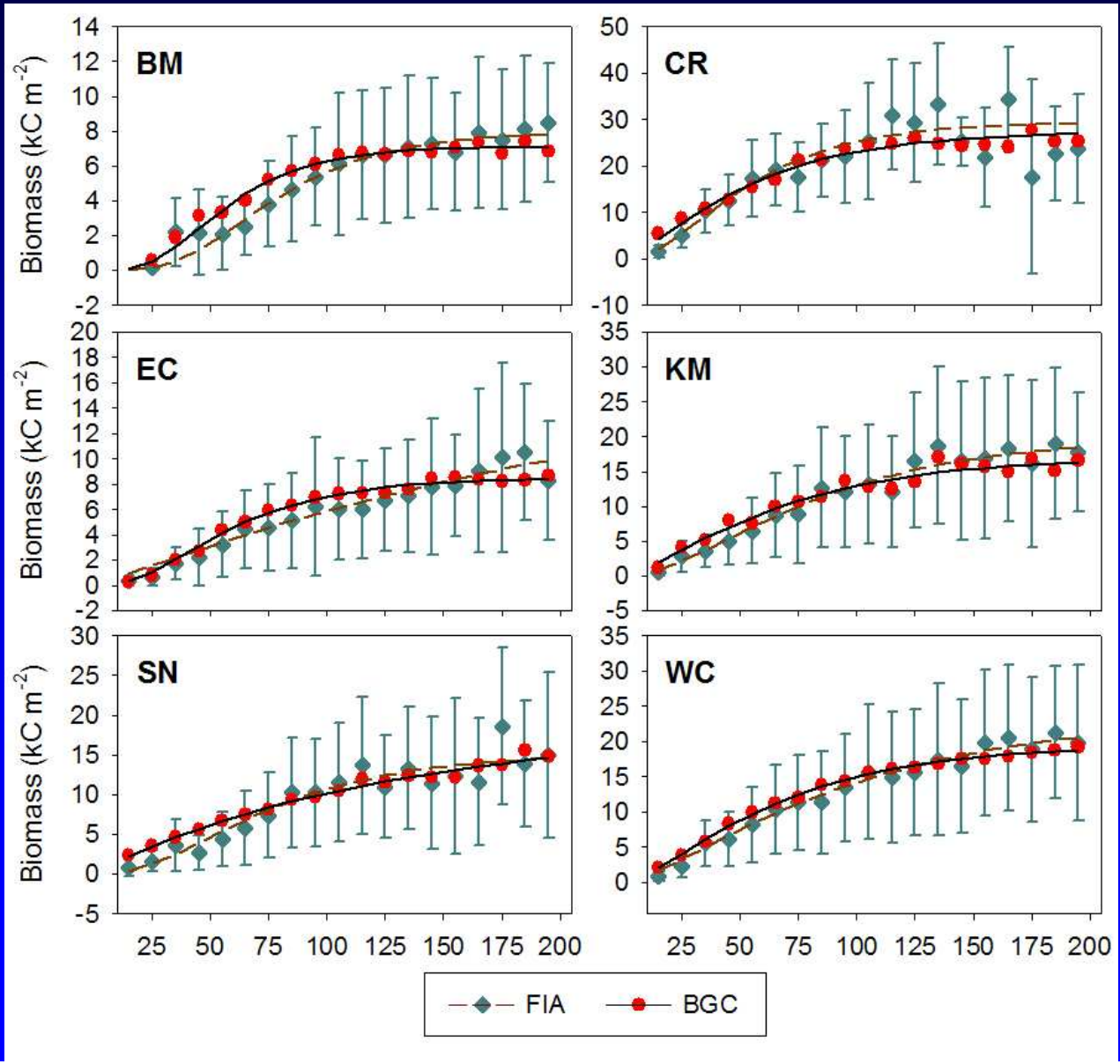
Biome-BGC: NEP for Oregon





Age Trends in Biomass by Ecoregion

BGC Parameters Optimized w/FIA

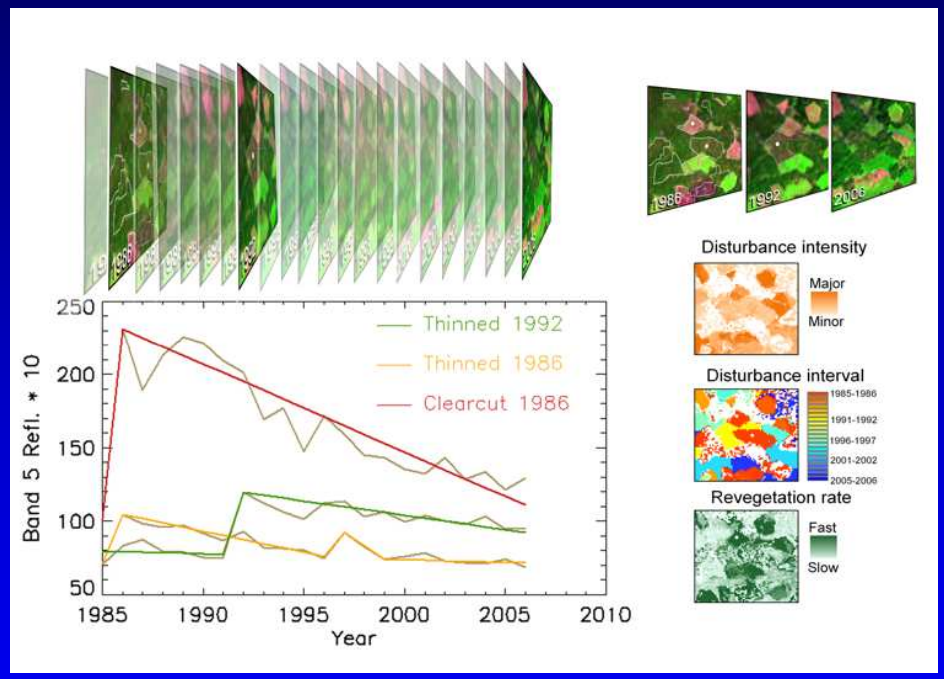


LandTrendr: Landsat-based Detection of Trends in Disturbance and Recovery

Steps in the LandTrendr process

Prepare stack of yearly imagery

Extract spectral trajectories for pixels



Statistically identify and fit segments with consistent trends

Extract summary information from segments

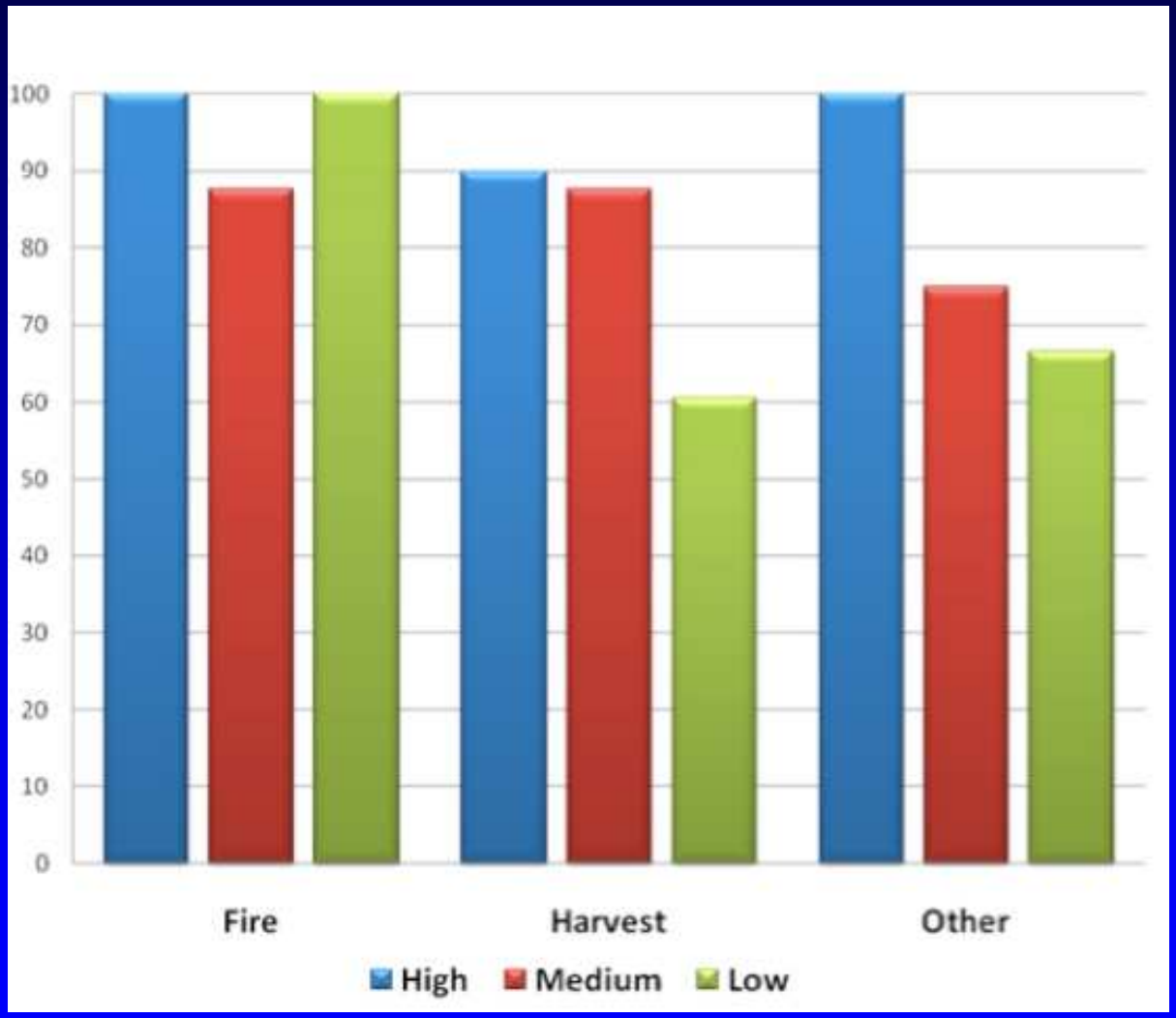
Evaluate veracity of selected events

Kennedy et al. developed, tested, and made LandTrendr operational in ORCA and NWFP

Evaluation of LandTrendr Disturbance

Percent agreement:
disturbance agent
and
relative intensity

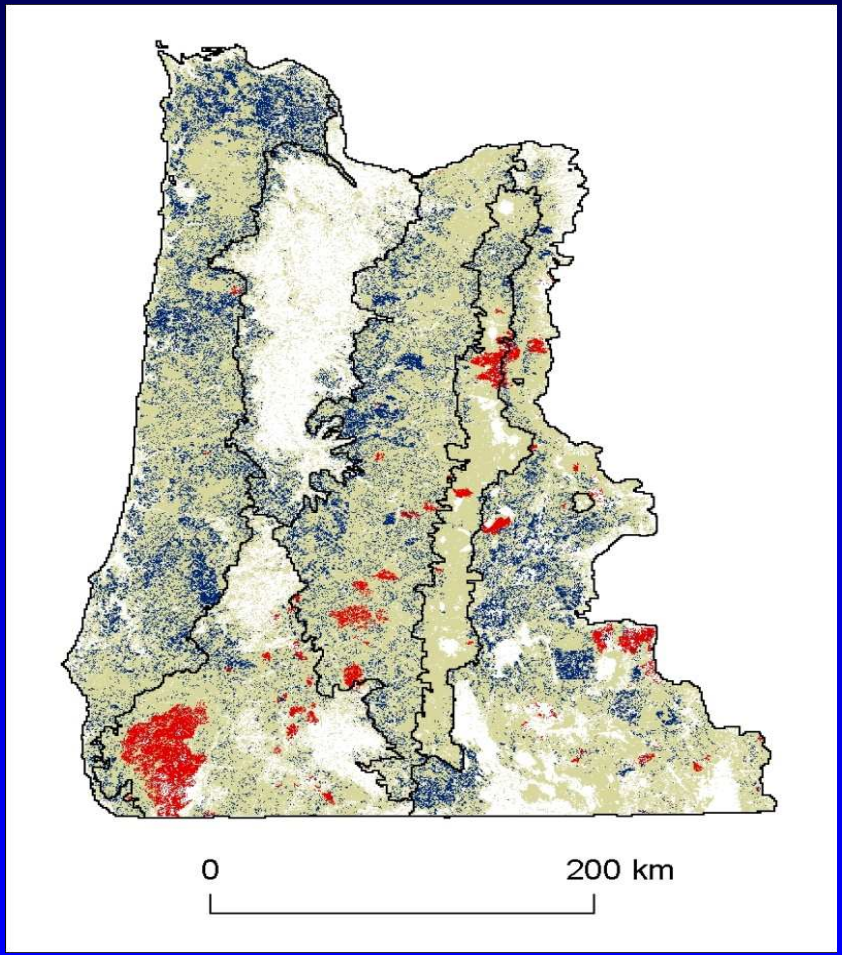
Type 1 validation: human assessment of time series vs automated mapping (TimeSync validation tool)



(Warren Cohen)

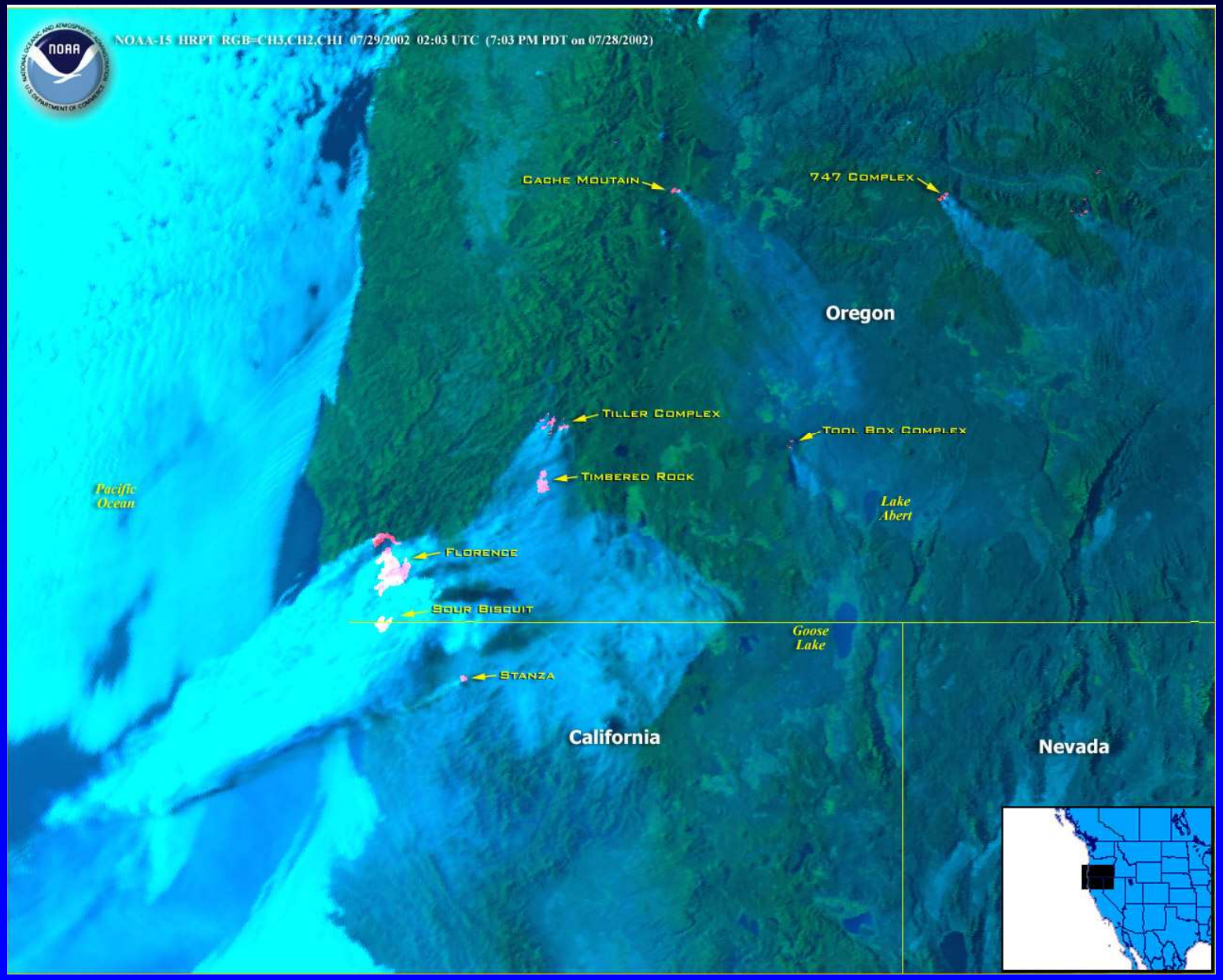
Substantial Forest Disturbance Since 1972

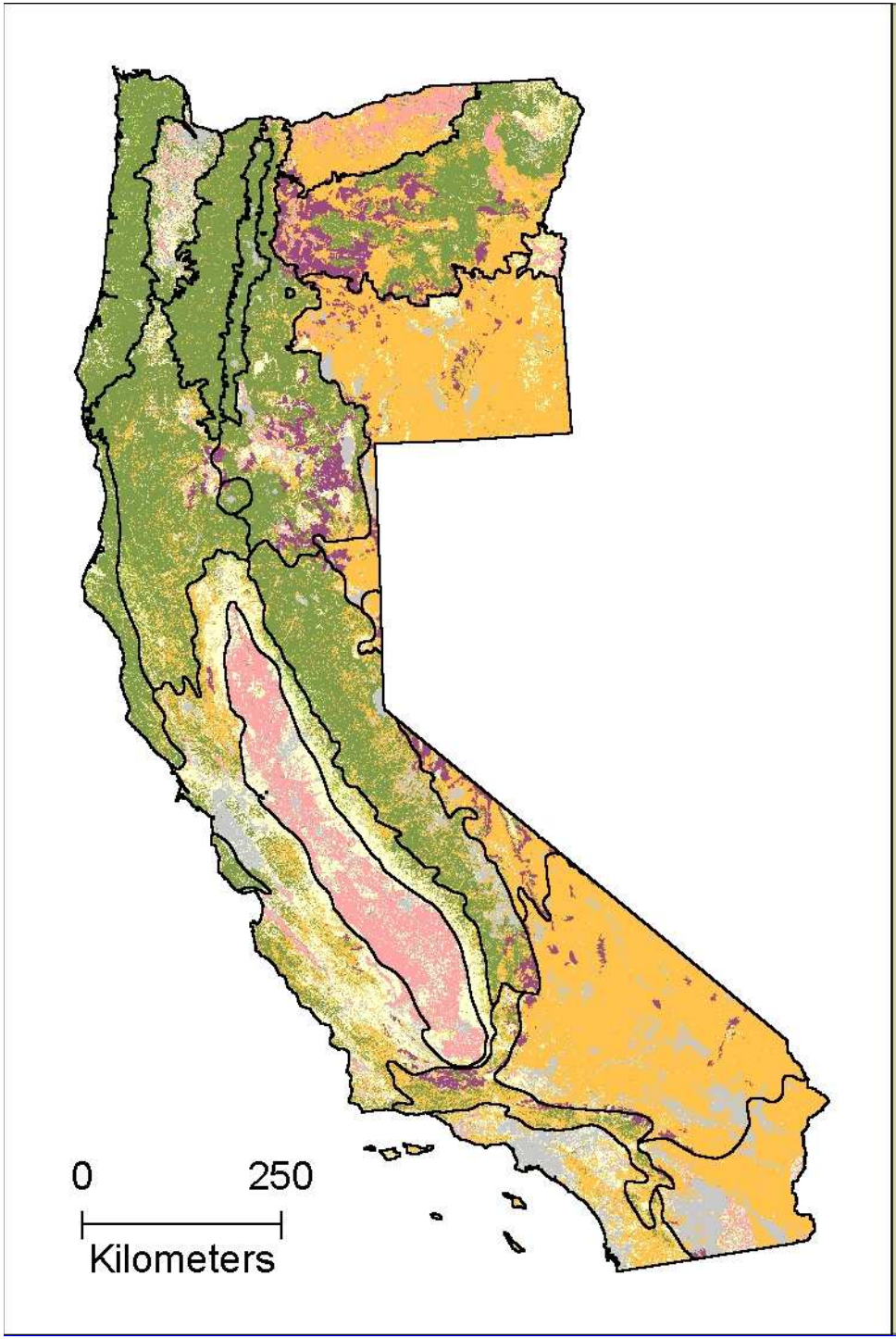
- 23% of forest in W OR experienced stand replacing disturbance since 1972 (Landsat era)



Red = fire, blue = cut since 1972

2002 Fires in OR and N CA



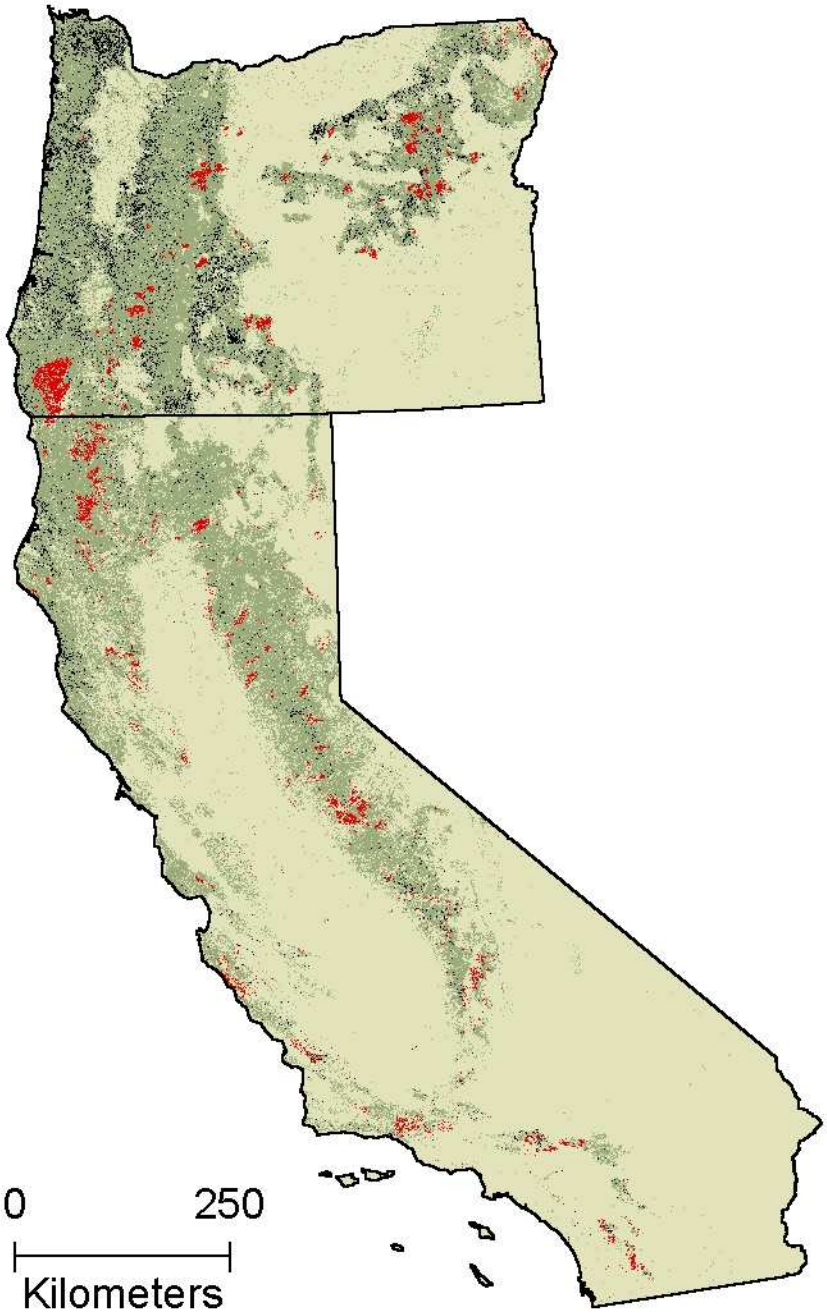


ORCA Landcover

- Conifer Forest
- Deciduous Forest
- Woodland
- Shrubland
- Grassland
- Cropland
- Not Vegetated

— Ecoregion

Source:
NLCD 2001
Juniper Woodland from GAP Veg
EPA Level III Ecoregions



ORCA Disturbance

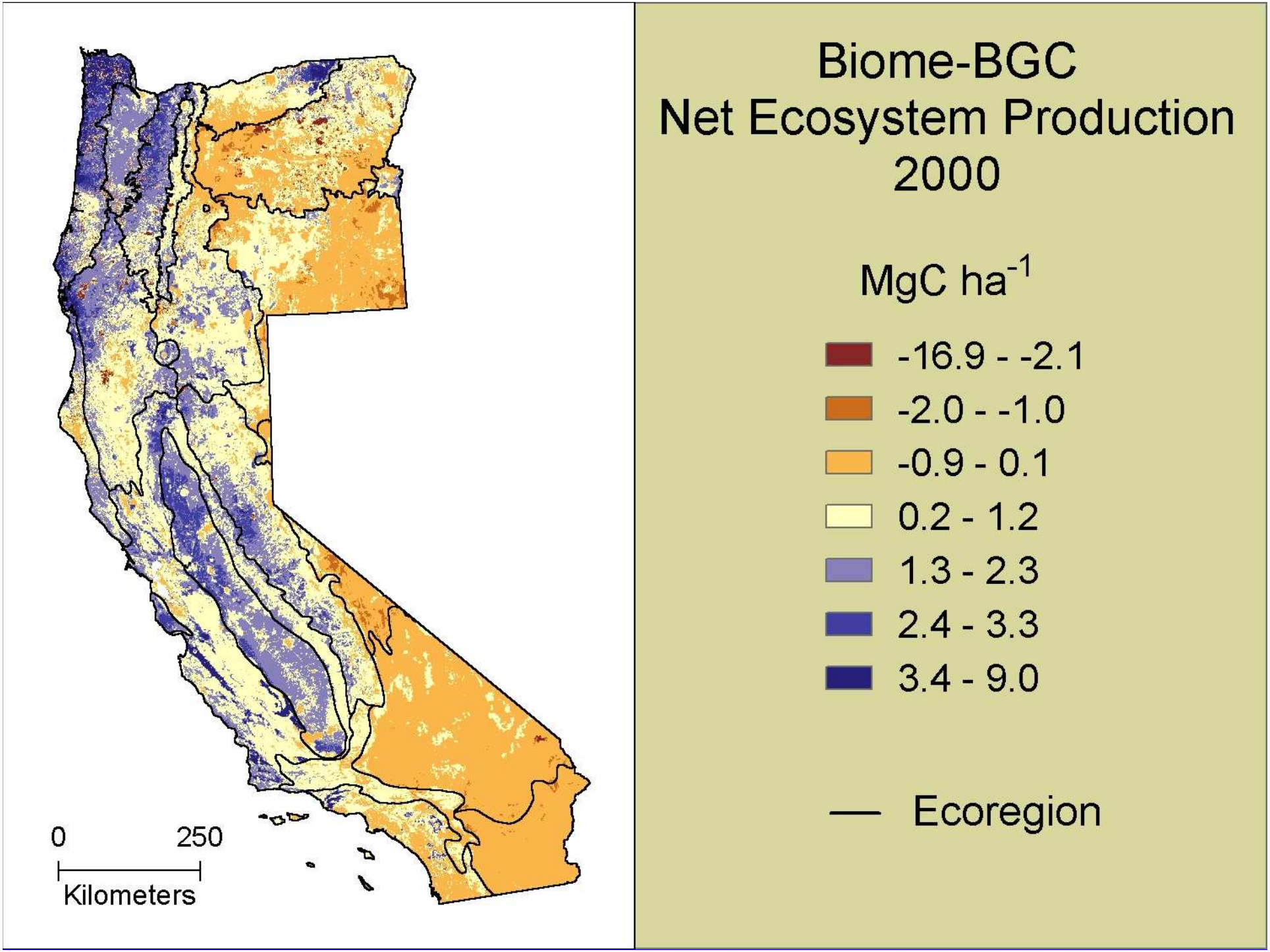
Disturbance 1984-2004

- Fires
- Timber Harvest

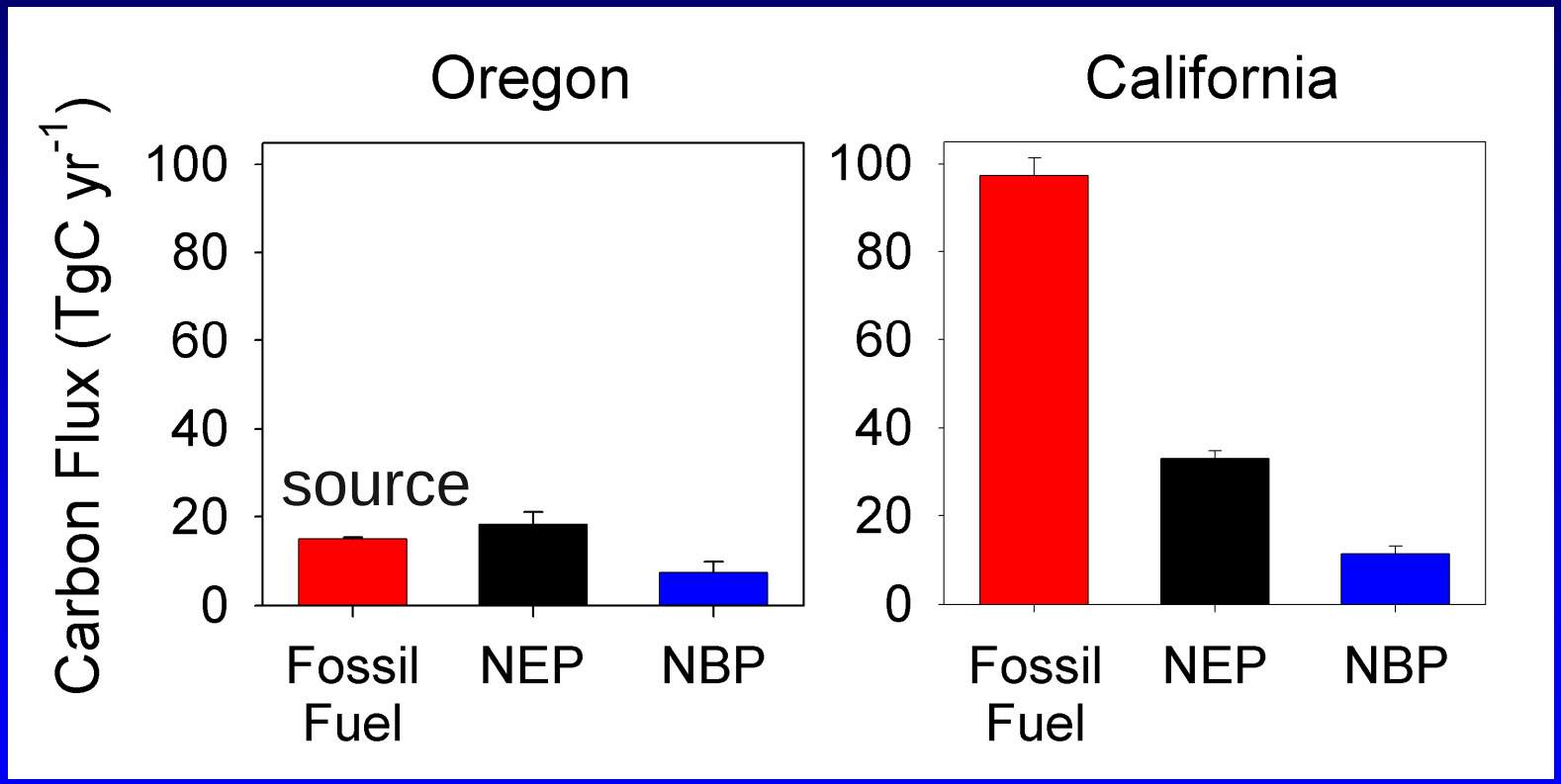
Other

- Forest
- Non-Forest

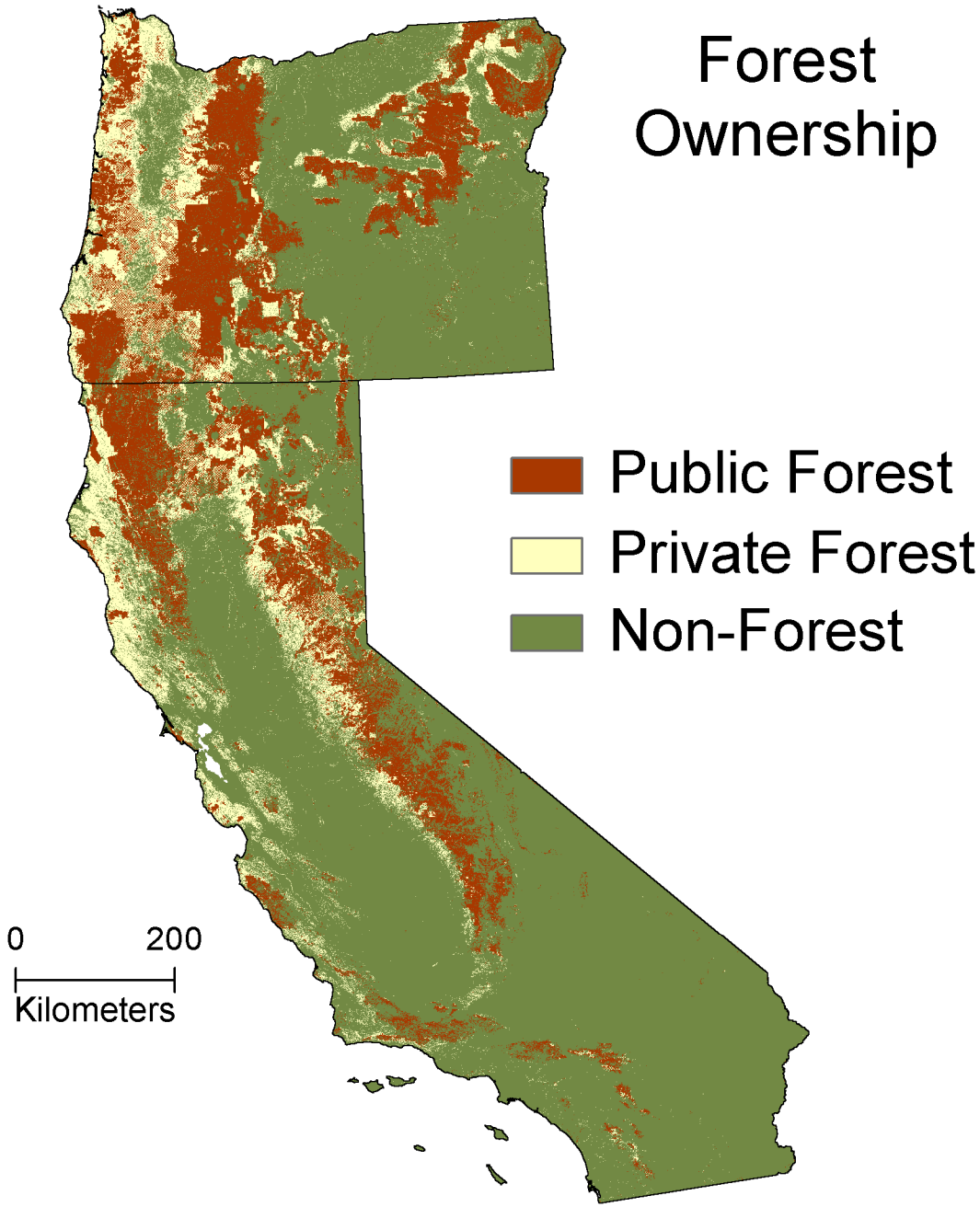
Timber Havest Source:
OR/NCA: Stand Replacing
SCA: Landtrendr
Fire Source:
OR/NCA/SCA: MTBS


Biome-BGC
Net Ecosystem Production
2000
MgC ha-1
-16.9 - -2.1
-2.0 - -1.0
-0.9 - 0.1
0.2 - 1.2
1.3 - 2.3
2.4 - 3.3
3.4 - 9.0
Ecoregion
0
250
Kilometers

Oregon & California Carbon Budget (1996-2000 means)

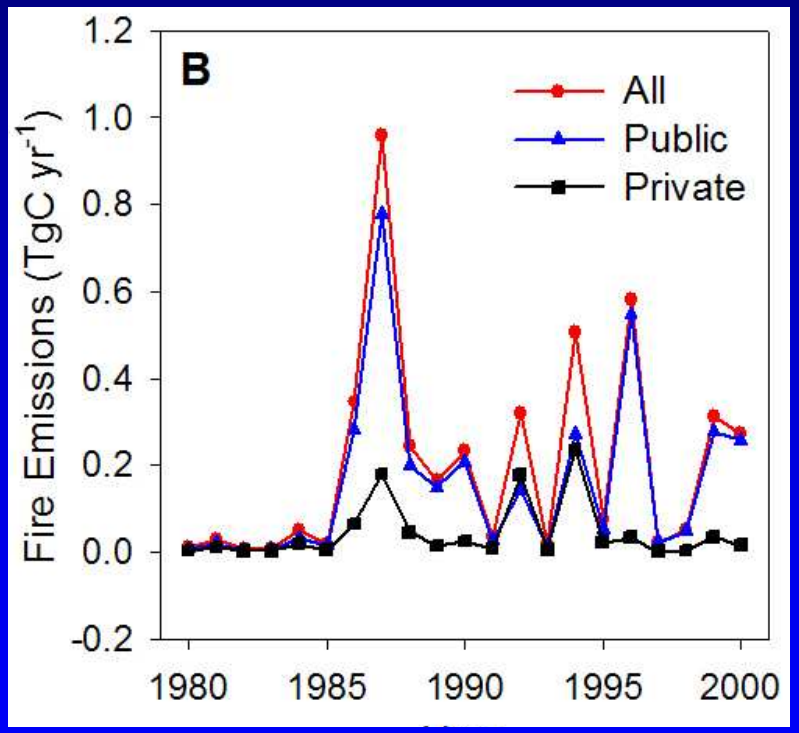


Ratio of NBP to FF is ~50% in OR, and ~10% in CA


Forest Ownership
Public Forest
Private Forest
Non-Forest
0
200
Kilometers

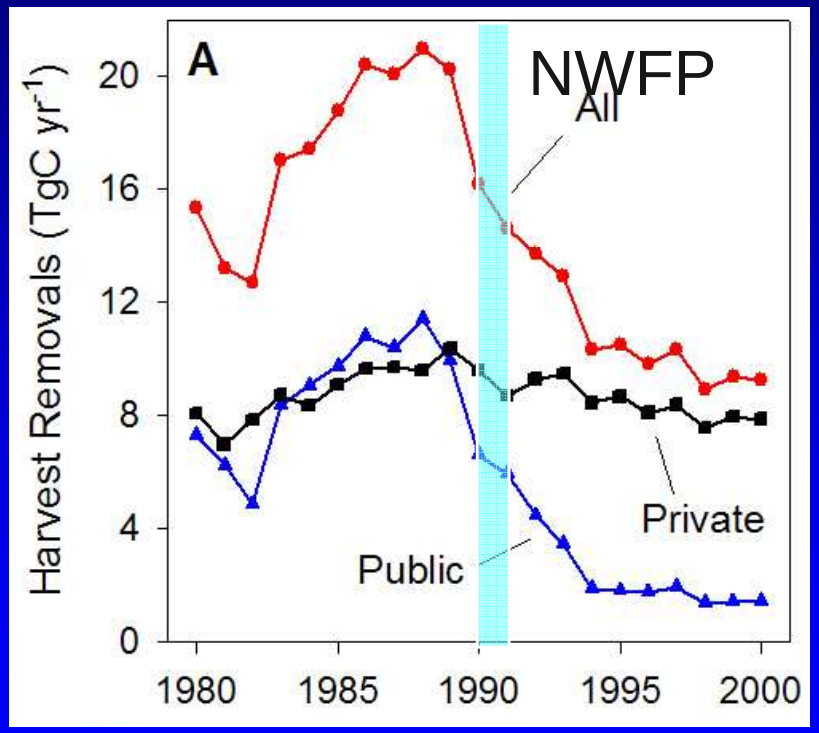
Harvest Removals and Fire Emissions OR, N CA (1980-2000)

- Fire emissions

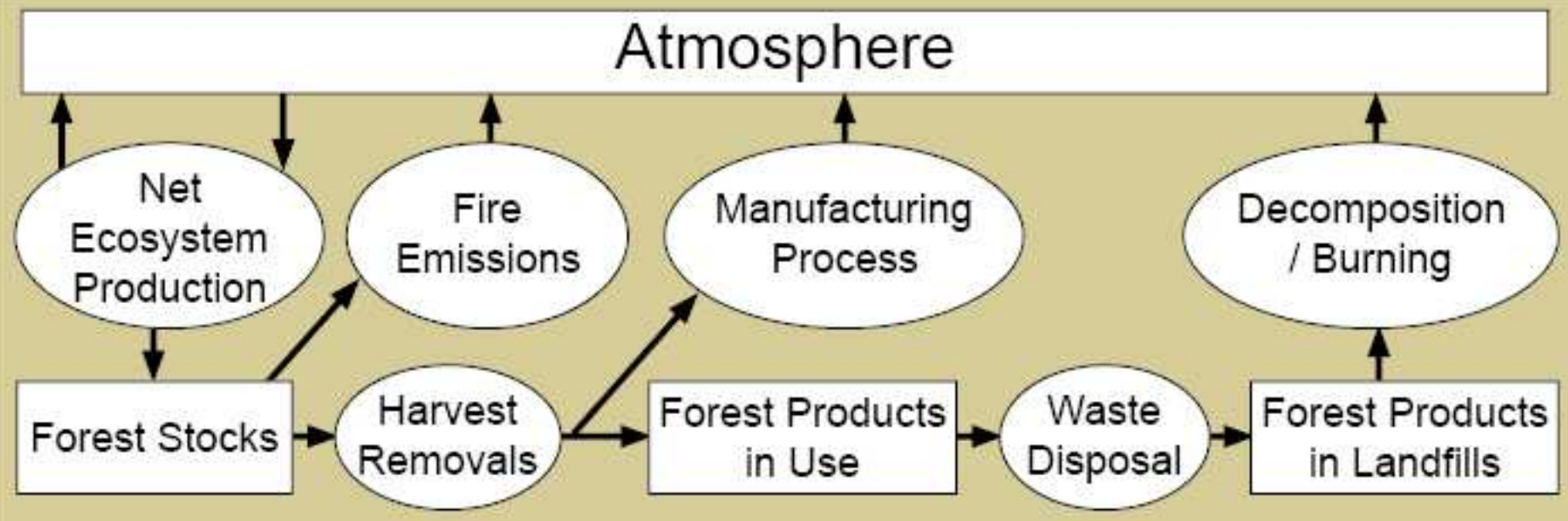


- Fire emissions small vs harvest removals

- Harvest removals



- Large decrease harvest removals on public land



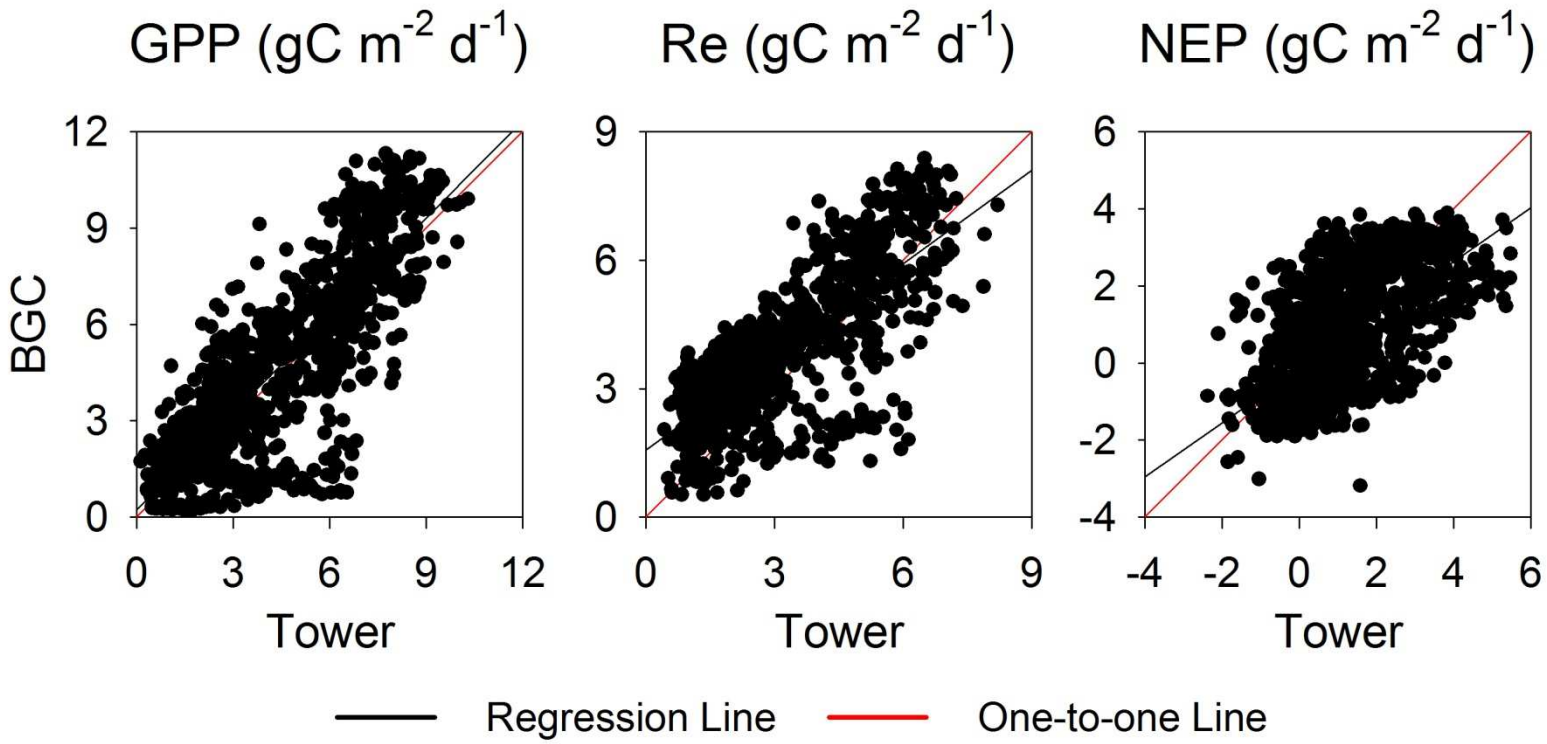
NEP = Net Ecosystem Production
= Balance of growth and decomposition
= Gross Primary Production - Autotrophic Respiration - Heterotrophic Resp.

NBP = Net Biome Production
= Change in stocks on the forest land base
= NEP - Harvest Removals - Fire Emissions

Products Sink = Change of stocks in forest products and landfills
= Input to Products In Use - Decomposition/burning of Forest Products

Forest Sector Carbon Balance = Net change in carbon storage (land + products)
= NBP + Products Sink

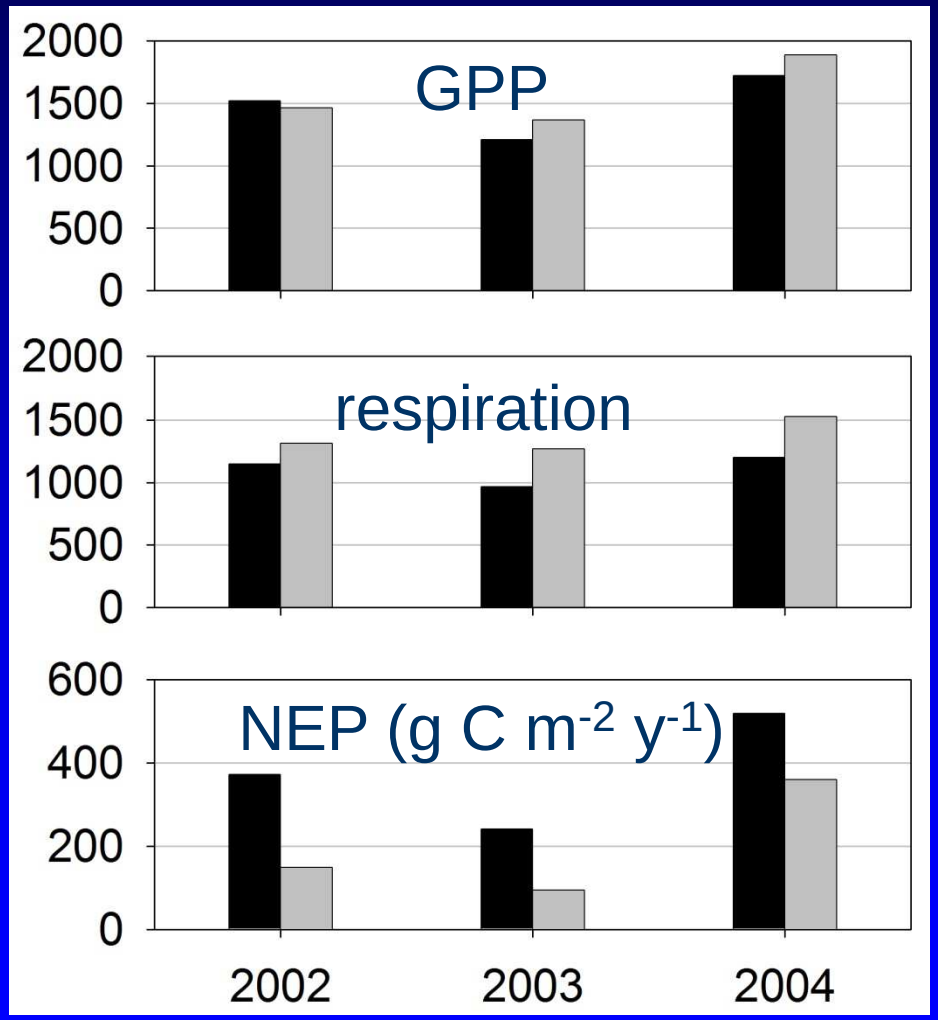
Evaluation of Biome-BGC at Semi-arid Pine Flux Site



GPP Fit	Re Fit	NEP Fit
$y = 1.0101x + 0.2056$	$y = 0.7256x + 1.5604$	$y = 0.6984x - 0.1713$
$R^2 = 0.72$	$R^2 = 0.59$	$R^2 = 0.41$
RMSE = 1.63	RMSE = 1.36	RMSE = 1.41

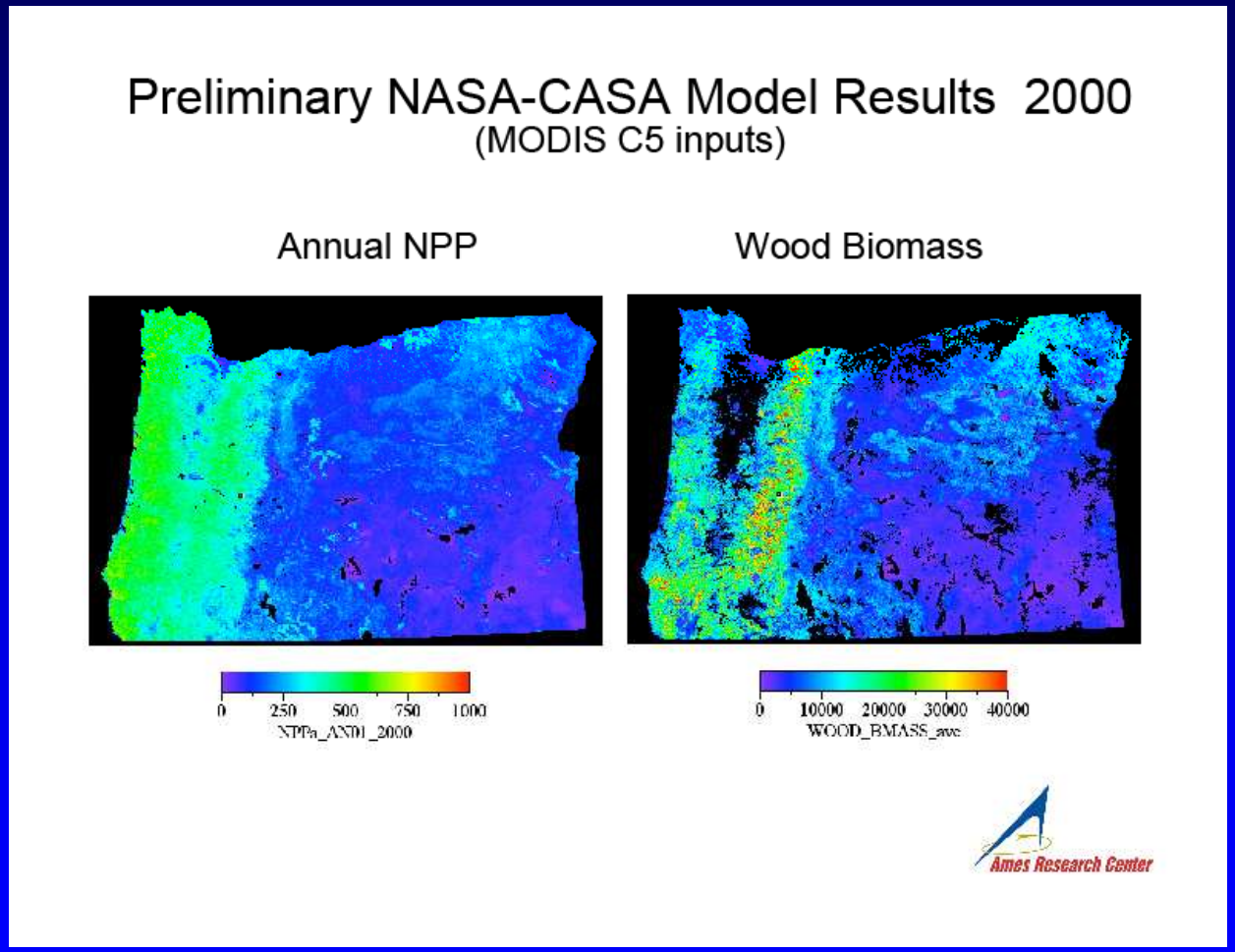
Tower Flux Data Used to Evaluate Carbon Process model (Biome-BGC)

- Important to determine if models capture carry-over effects over multiple years
- Model tends to underestimate NEP in semi-arid and old forests

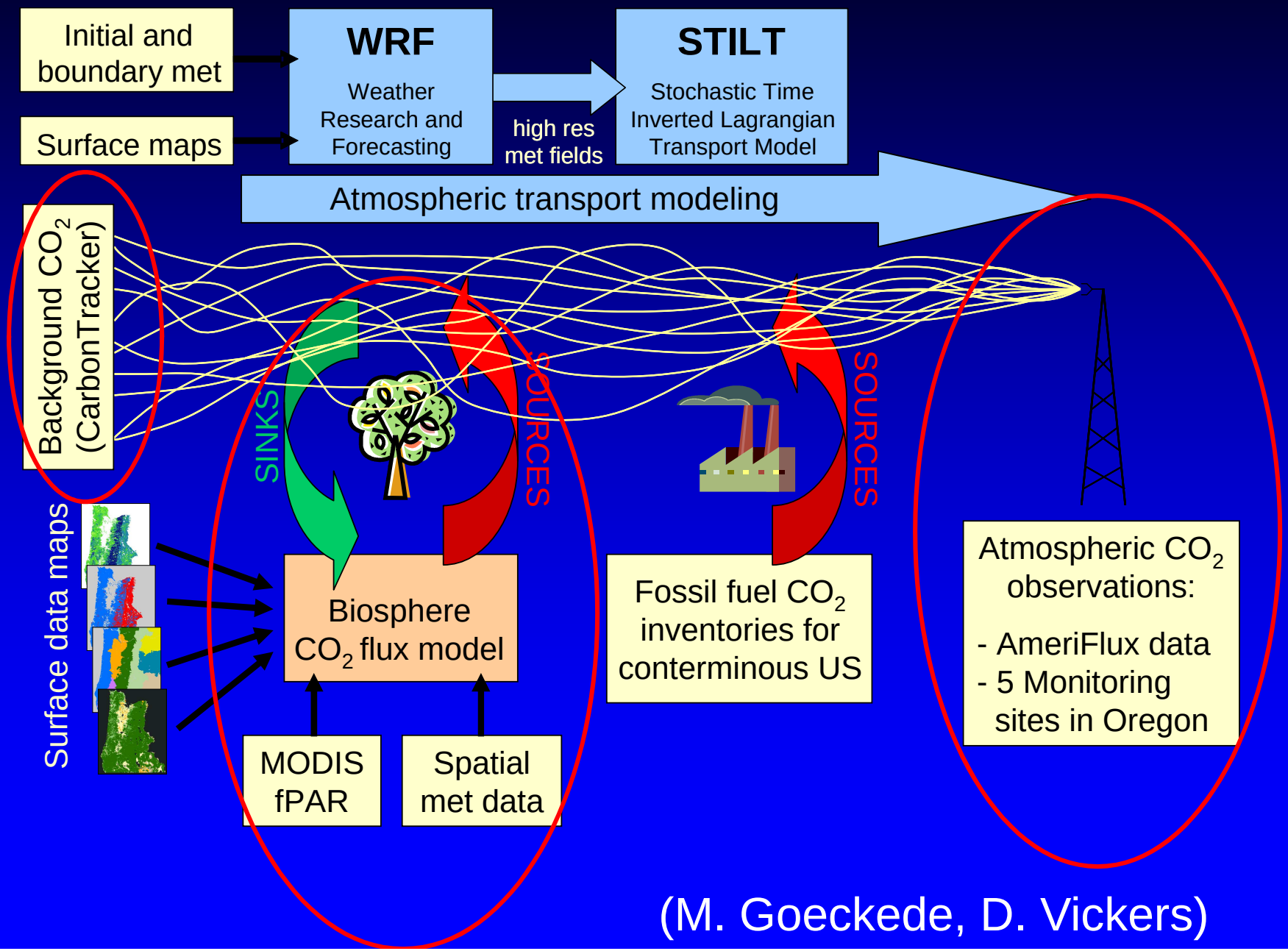


Black = tower obs
Gray = model

Beginning Comparison BGC and CASA



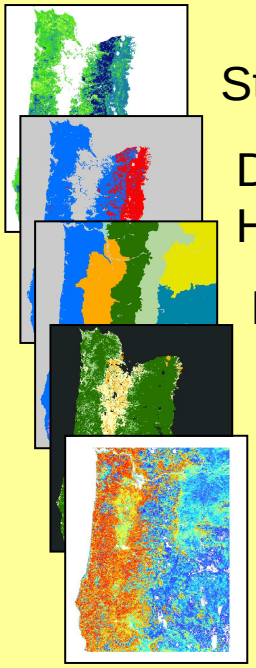
ORCA Top-down Modeling



(M. Goeckede, D. Vickers)

ORCA Diagnostic Biosphere CO_2 Flux Model

RS surface data



Stand Age

Disturbance History

Ecoregion

Land cover type

MODIS fPAR

<1km spatial resolution

Reference Flux Data

A-priori optimization: Shuffled complex evolution

$$GPP = a_1 \cdot f(T, VPD, APAR, cloud, age, SWC)$$
$$R_A = a_2 \cdot f(T, GPP, fPAR)$$
$$R_H = a_3 \cdot f(age, T_{soil}, SWC, fPAR)$$

Bayesian inversion

Solve for optimized flux baserates

Spatial meteo data (WRF)

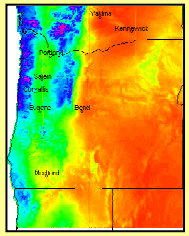
Temperature

VPD

Radiation

Pressure

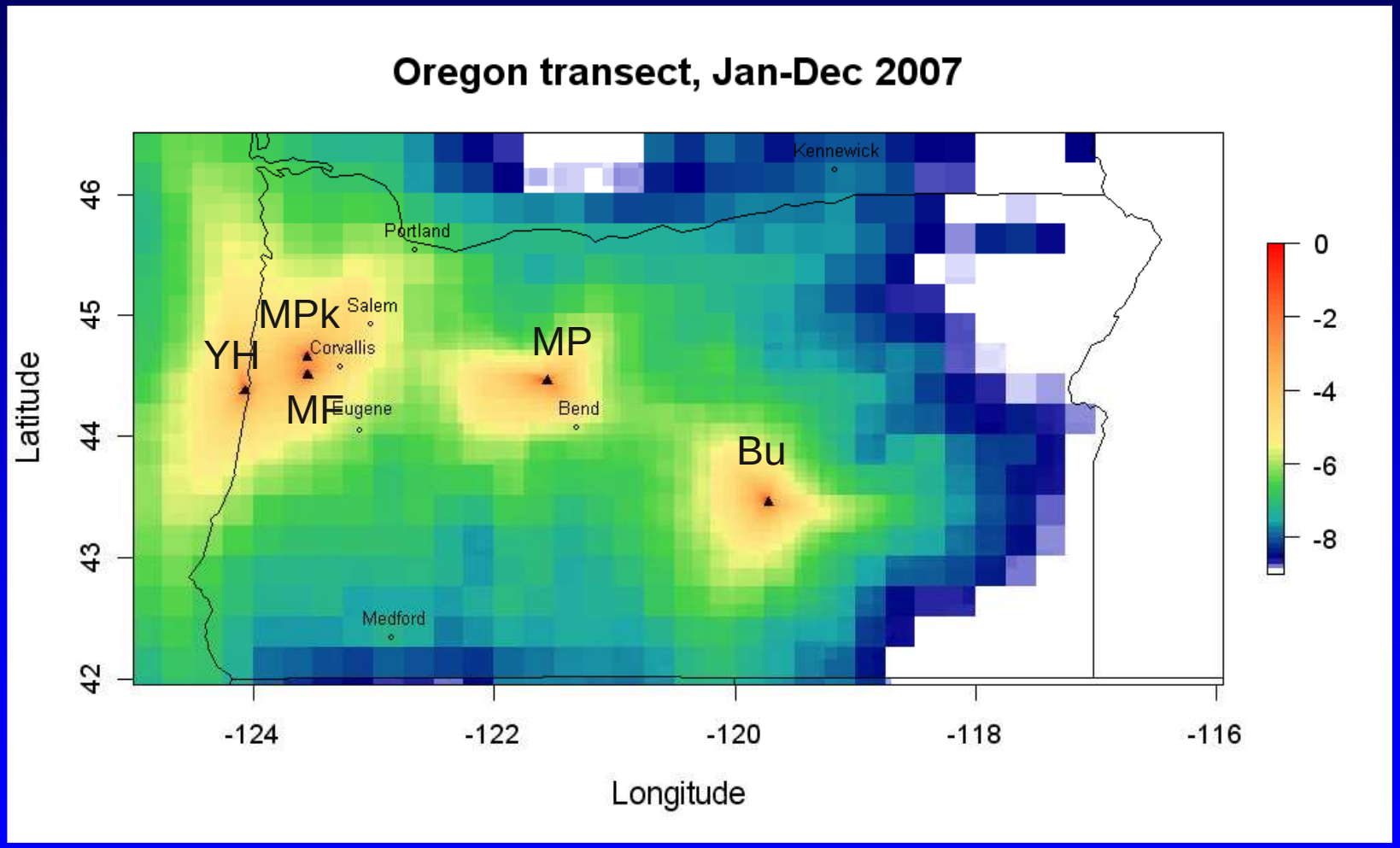
Precipitation



sub-daily timestep

Top-Down: Oregon Transect CO_2 Observations

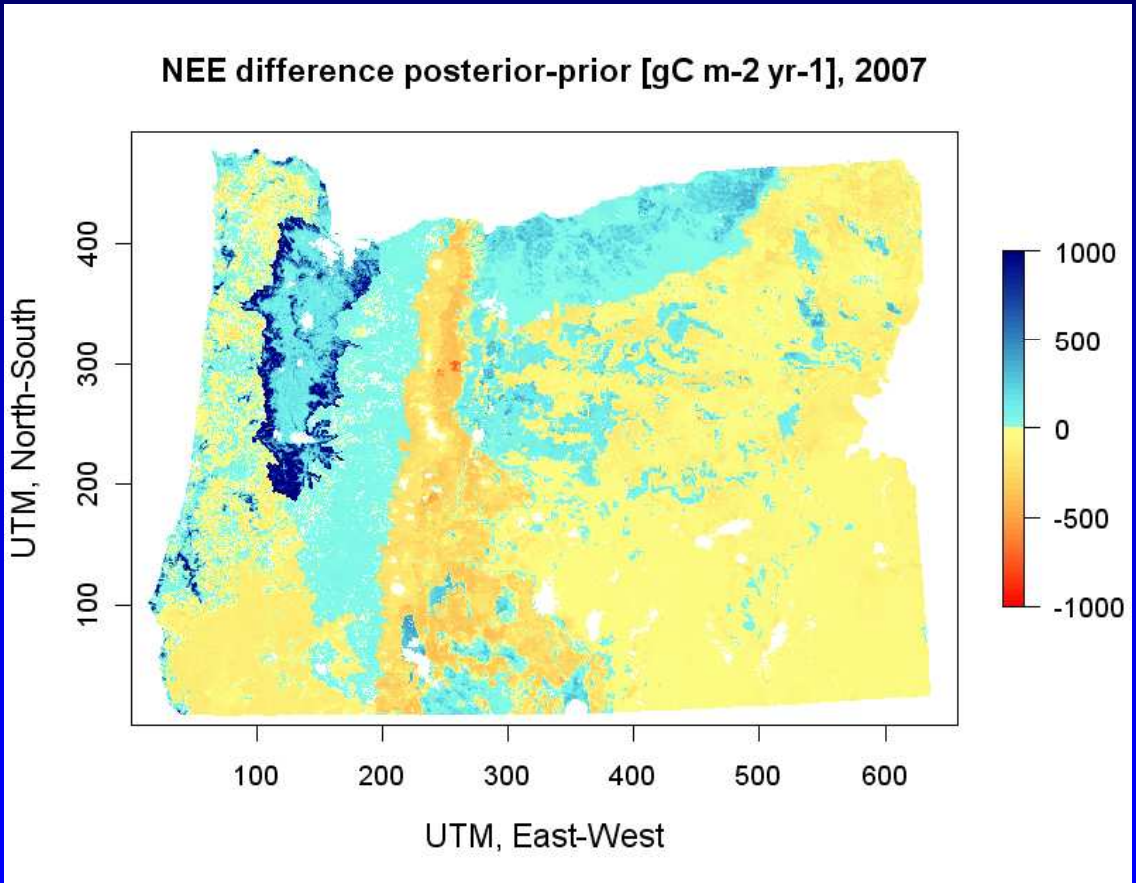
Accumulated Source Weight Function for 2007



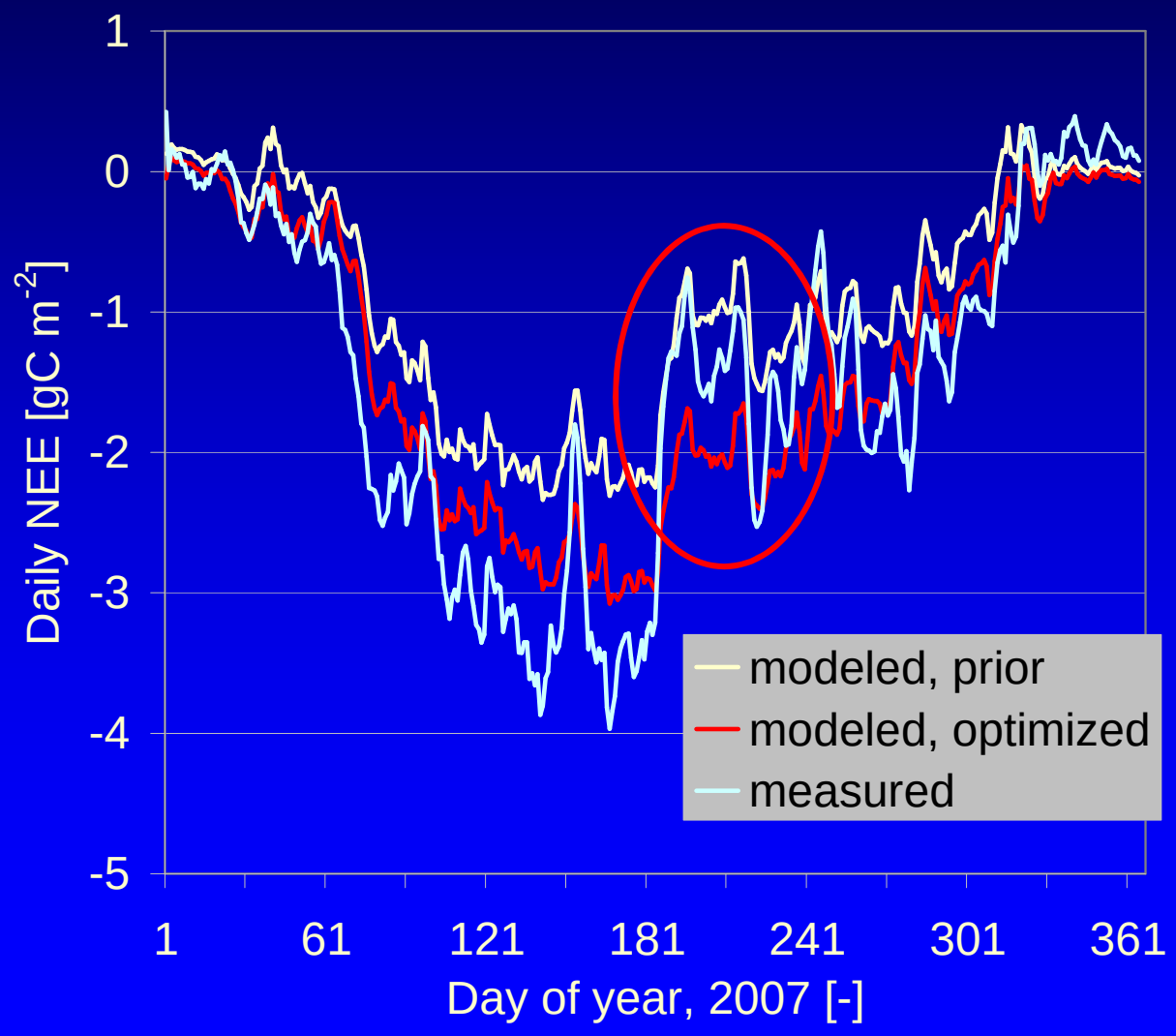
NEE Differences (Posterior – Prior, 2007) Optimization

Shifts in flux estimates:

- More uptake in grass/shrub E OR
- Less uptake in ENF W OR (blue)
- Less uptake agric crops

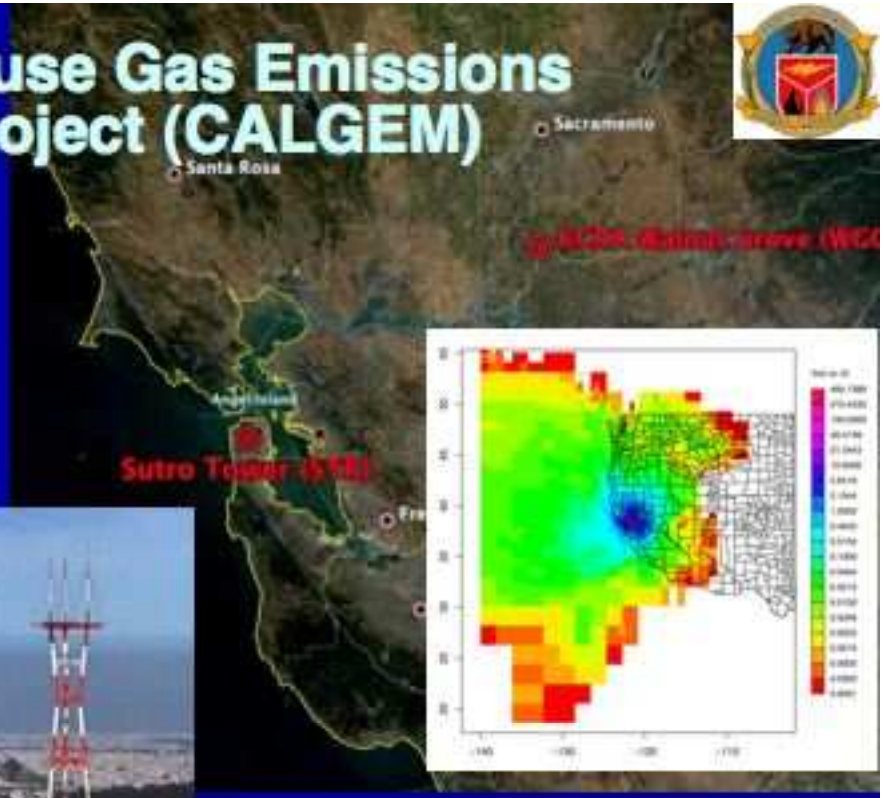


Comparison of NEE - Model vs Metolius AmeriFlux Site (2007)

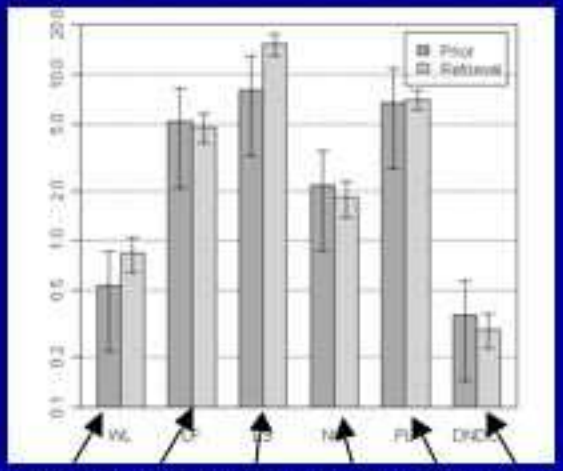


California Greenhouse Gas Emissions Measurement Project (CALGEM)

- LBNL- NOAA collaboration evaluating Central California's GHG emissions
- 2007- present tall-tower measurements of CO_2, CH_4, N_2O, CO + HGWP gases above San Francisco (STR) and Central Valley (WGC)
- Operational nested WRF-STILT footprints for Western US evaluated against radar wind profilers
- Regional inverse estimates of CH_4 emissions indicate livestock emissions significantly higher than current inventory in summer and winter (see poster Thurs.)
- Currently conducting inverse analysis of flask N_2O measurements
- Planning analysis of CO_2 from fossil fuel and agriculture in Bay Area and Sacramento Valley regions



CA CH_4 Emissions (Mt CO_2eqiv. yr^{-1})



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Summary Results

- Disturbance effects on C
  - Significant portion of forested part of region disturbed since 1980s
  - Forest harvest removals decreased on public lands after 1990 due to NWFP implementation, and NBP increased compared with private lands
  - Wildfire emissions small compared with harvest removals
- Fossil fuel emissions dominate land-based sink, even in OR (NBP:FF ratio ~50% in OR, 10% in CA)

Critical Needs for Regional Budgets

- Important to incorporate/improve disturbance in models
- Long-term observations are essential to reducing uncertainty in modeled C budgets!
  - Flux towers
  - CO_2 concentration sites
  - Inventories
  - Spatial meteorology
  - Remote sensing of disturbance, land cover changes