Remote Sensing Assessment of Kelp Forest and Seagrass Meadow Productivity

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Acknowledgements

- Dan Reed, UCSB Santa Barbara Coastal LTER
  - Kelp productivity data
- Mike Donnellan, MLML
  - Kelp canopy time series

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CICORE (*SEA-core*) *acronym*

1. Center For Integrative Coastal Observation, Research and Education.

Remote Sensing Applications in Coastal and Optically Shallow Environments

- Coastal bathymetry
- Shoreline dynamics
  - erosion & deposition
- Natural resources
  - Coral reefs
  - Kelp forests and rocky habitats
  - Seagrass meadows
- Coastal water quality
  - chemical pollution
  - eutrophication
  - sediment loading
- Feature Detection
  - rock outcrops
  - debris fields
- Surveillance
  - object identification & tracking

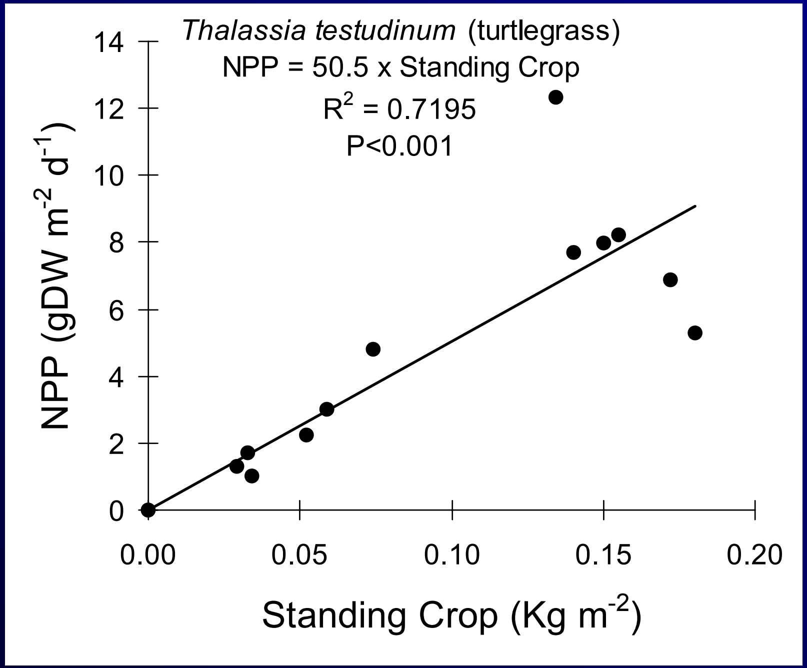
Remote sensing is useful for distribution maps

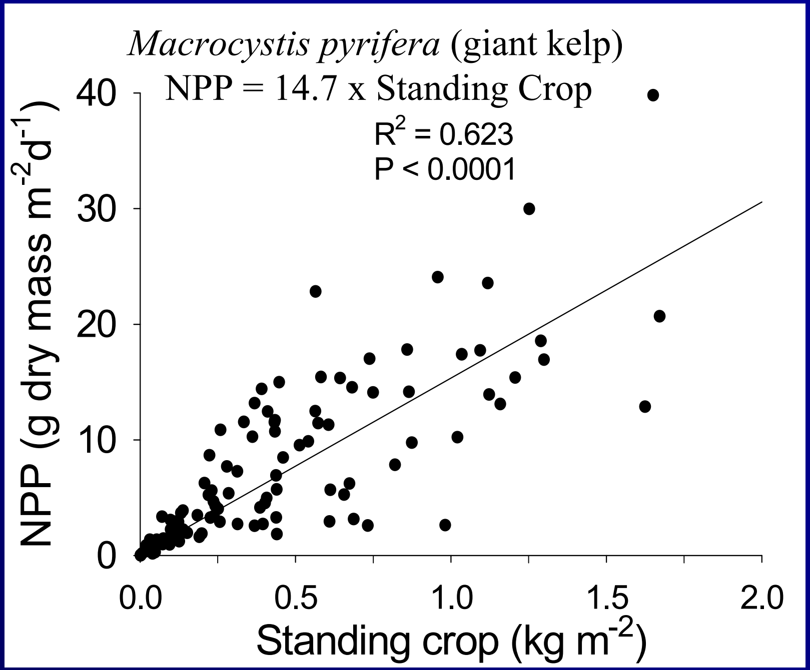
Can it be used to assess benthic ecosystem processes?

Primary production rates & biogeochemical fluxes provide key links to understanding:

- –physical (bottom up) forcing
  - •temperature, nutrients, water motion
- – biological (top-down) control
  - • direct impacts of grazers
  - • indirect effects of predators

Biomass explains most variation in primary productivity

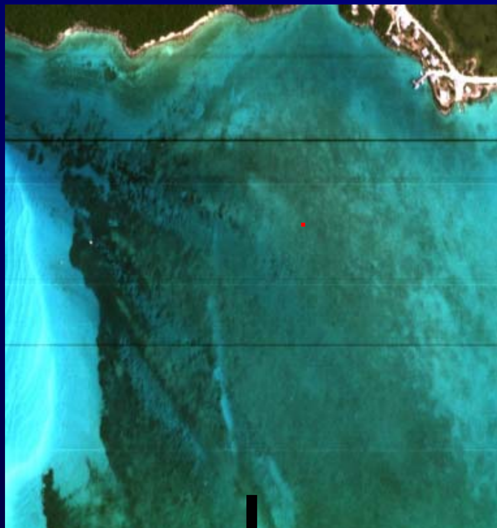


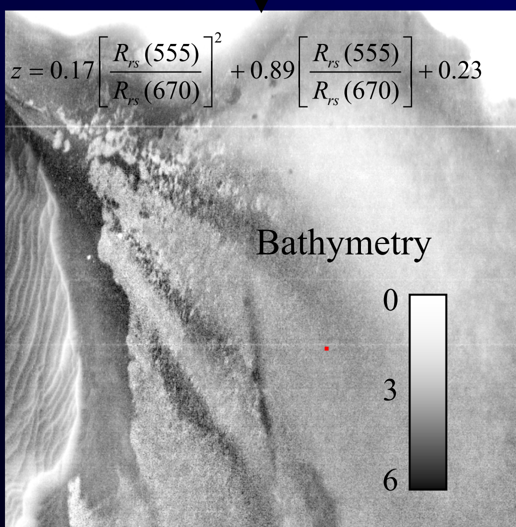


Can BIOMASS be determined remotely?

Continuous spectral information permits retrieval of bathymetry and turtlegrass density from the same data set

Dierssen, H., R. Zimmerman, R. Leathers, T. Downes and C. Davis. 2003. Limnol. Oceangr., **48:444-555**

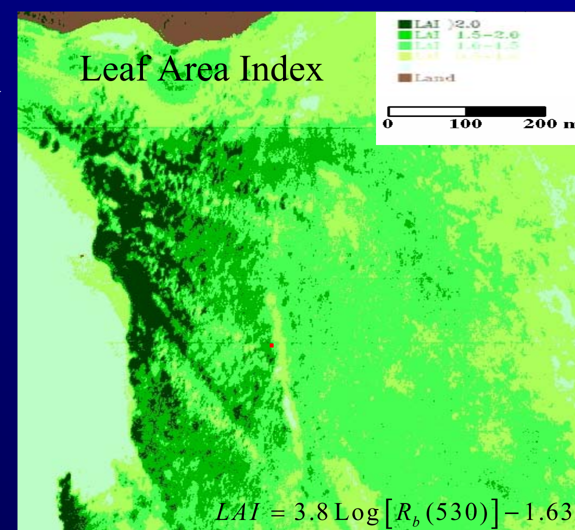




Bottom Reflectance

$$R_b \propto R_{rs}\left[\frac{E_u(z)}{L_u(z)}\right]\frac{\exp(-K_{Lu})}{\exp(-K_d)}$$

Water Column Optical Properties

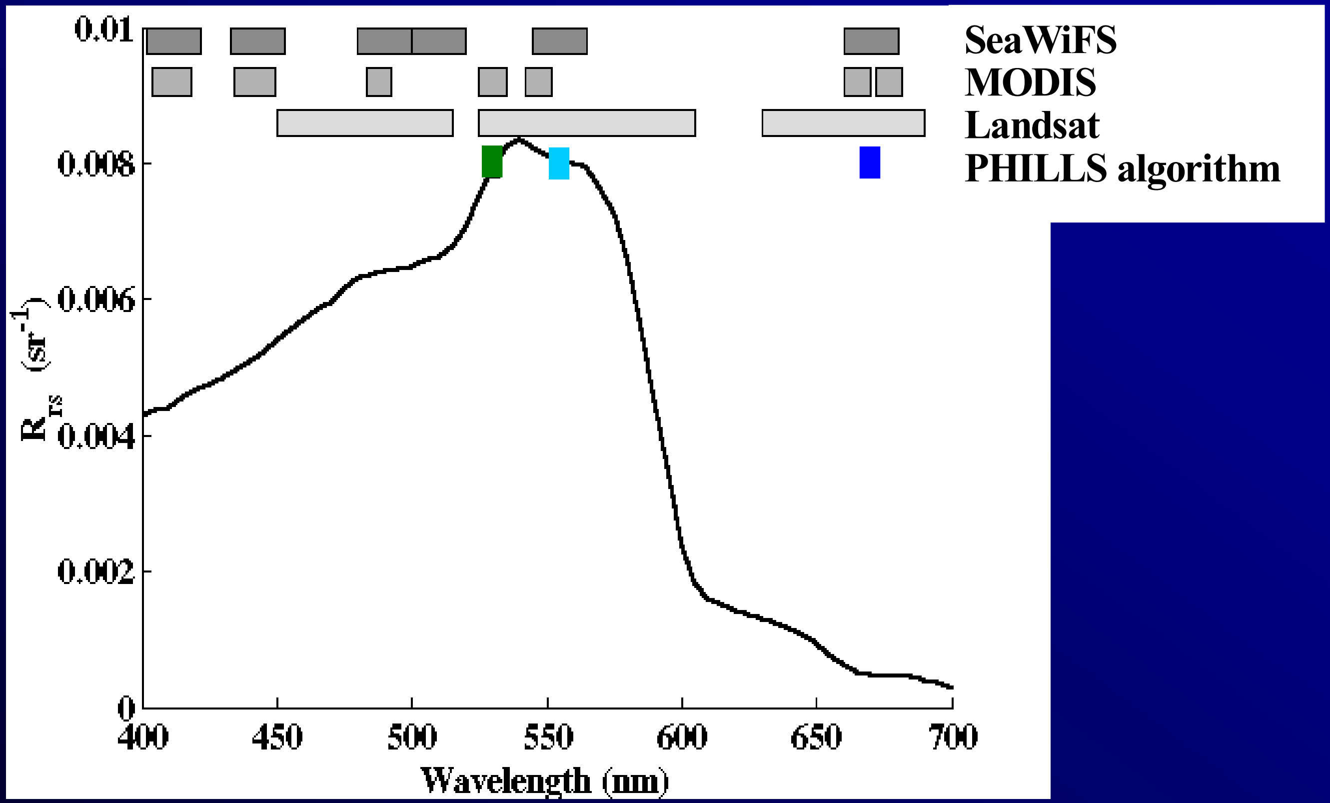


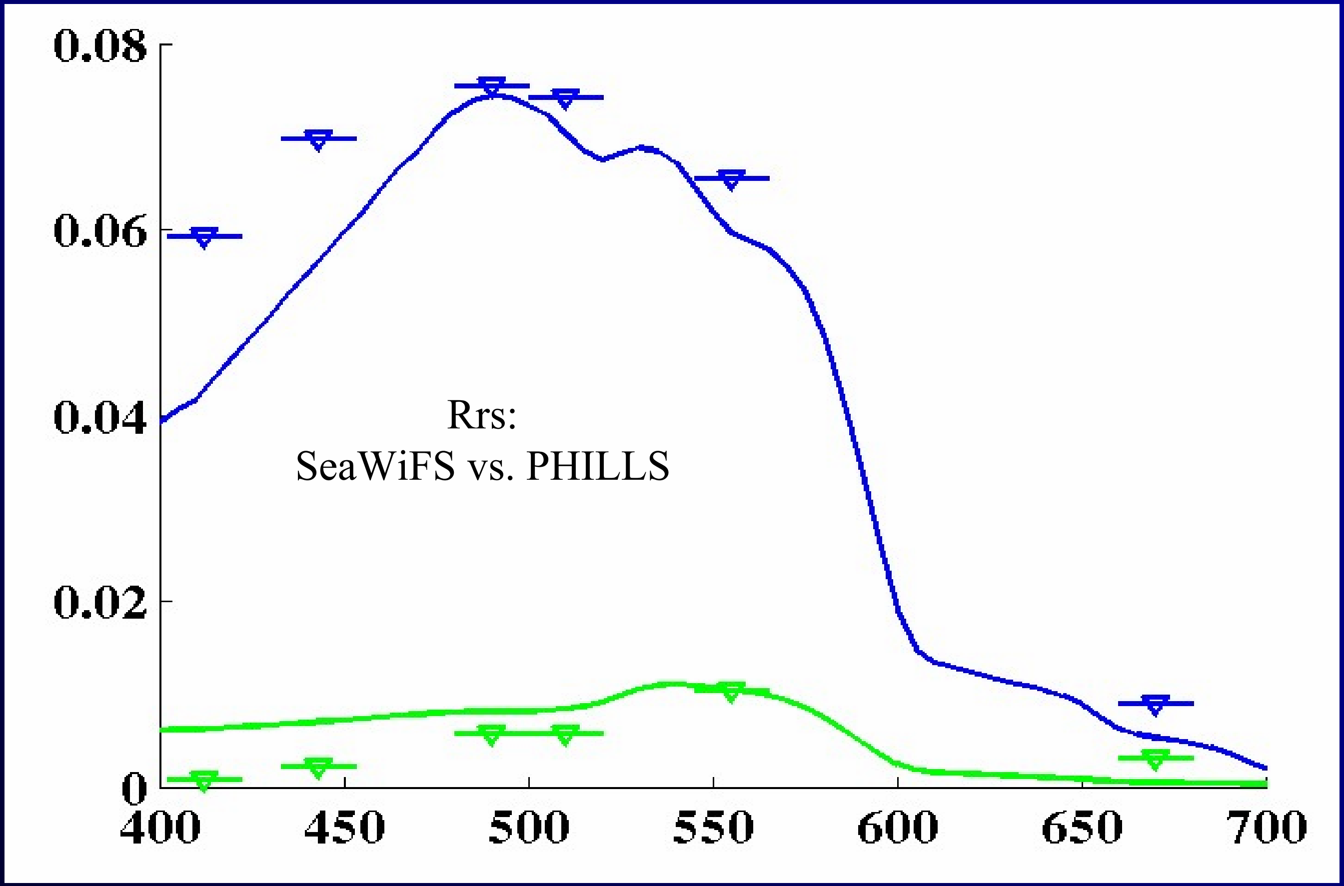
Scaling up to Regional & Global Distributions

- Ratio-based algorithms are transferable to multi-spectral platforms (SeaWiFS, MODIS) for global coverage

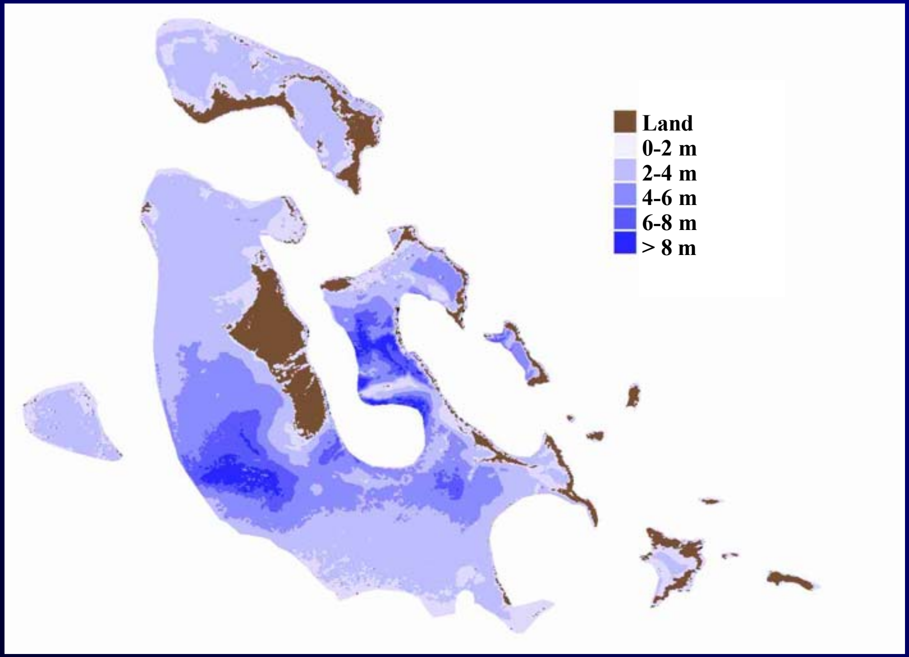
Scaling Up the Hyperspectral Algorithm:

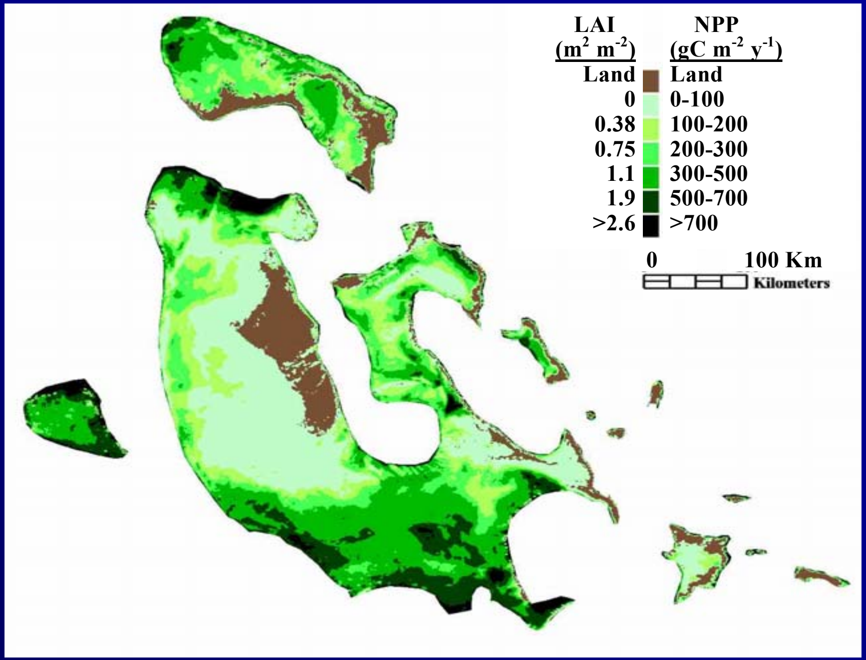
Wavelengths for retrieval of bathymetry and LAI are compatible with SeaWiFS and MODIS, not Landsat




0.08
0.06
0.04
0.02
0
400
450
500
550
600
650
700
Rrs:
SeaWiFS vs. PHILLS

Bahamas Banks

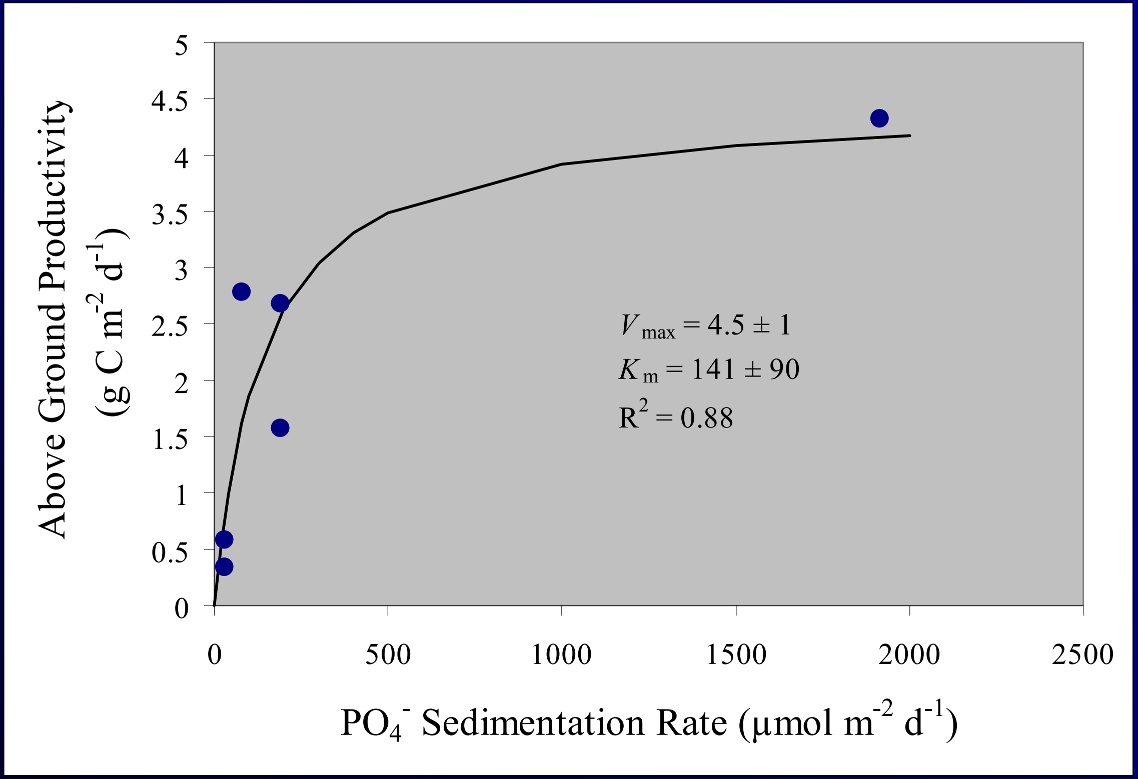




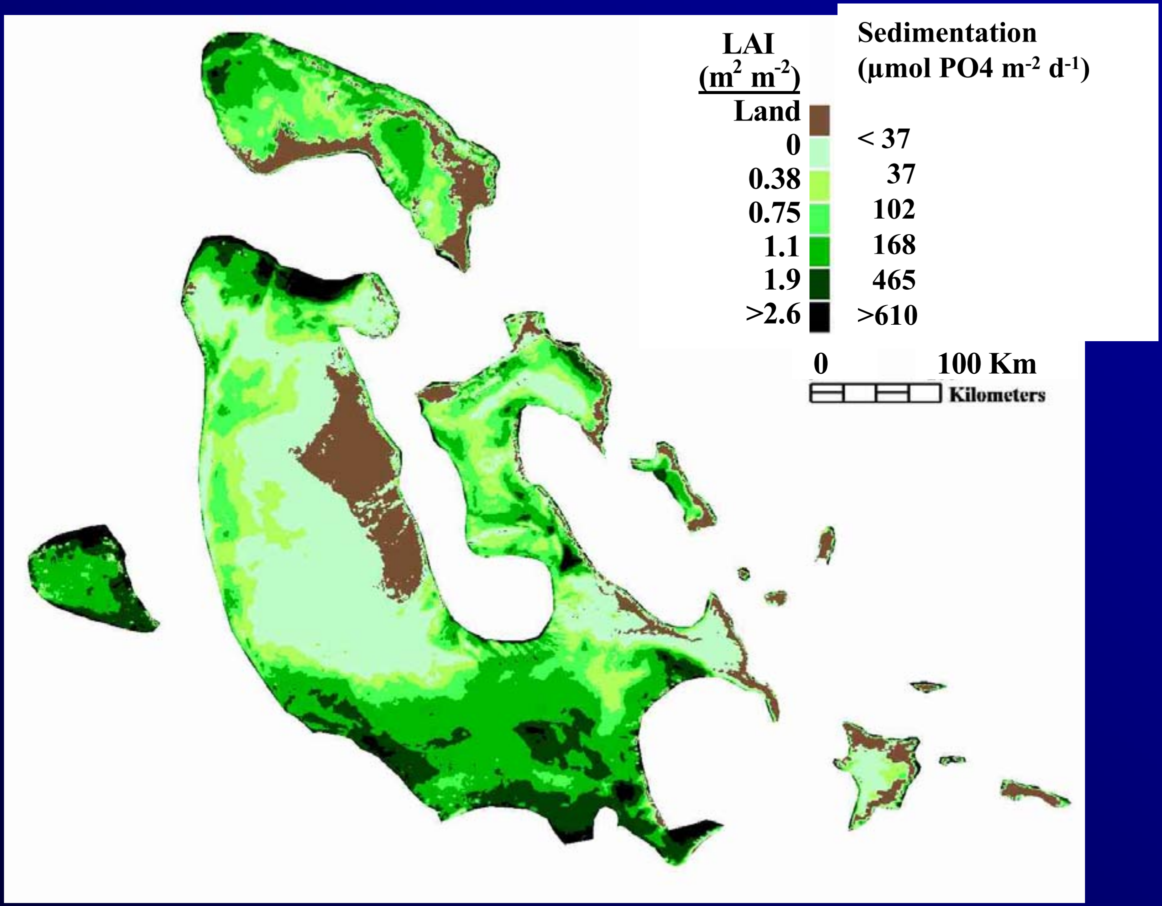
- 130,000 km^2 total area
- Average depth = 3 m

- 78,000 km^2 seagrass
- Mean LAI = 1.4   Max LAX > 4
- Mean Annual NPP = 2.8×10^{13} gC y^{-1}
- 0.06% of total ocean NPP

PO_4^- sedimentation rate predicts above ground productivity of turtlegrass on the Great Bahamas Bank

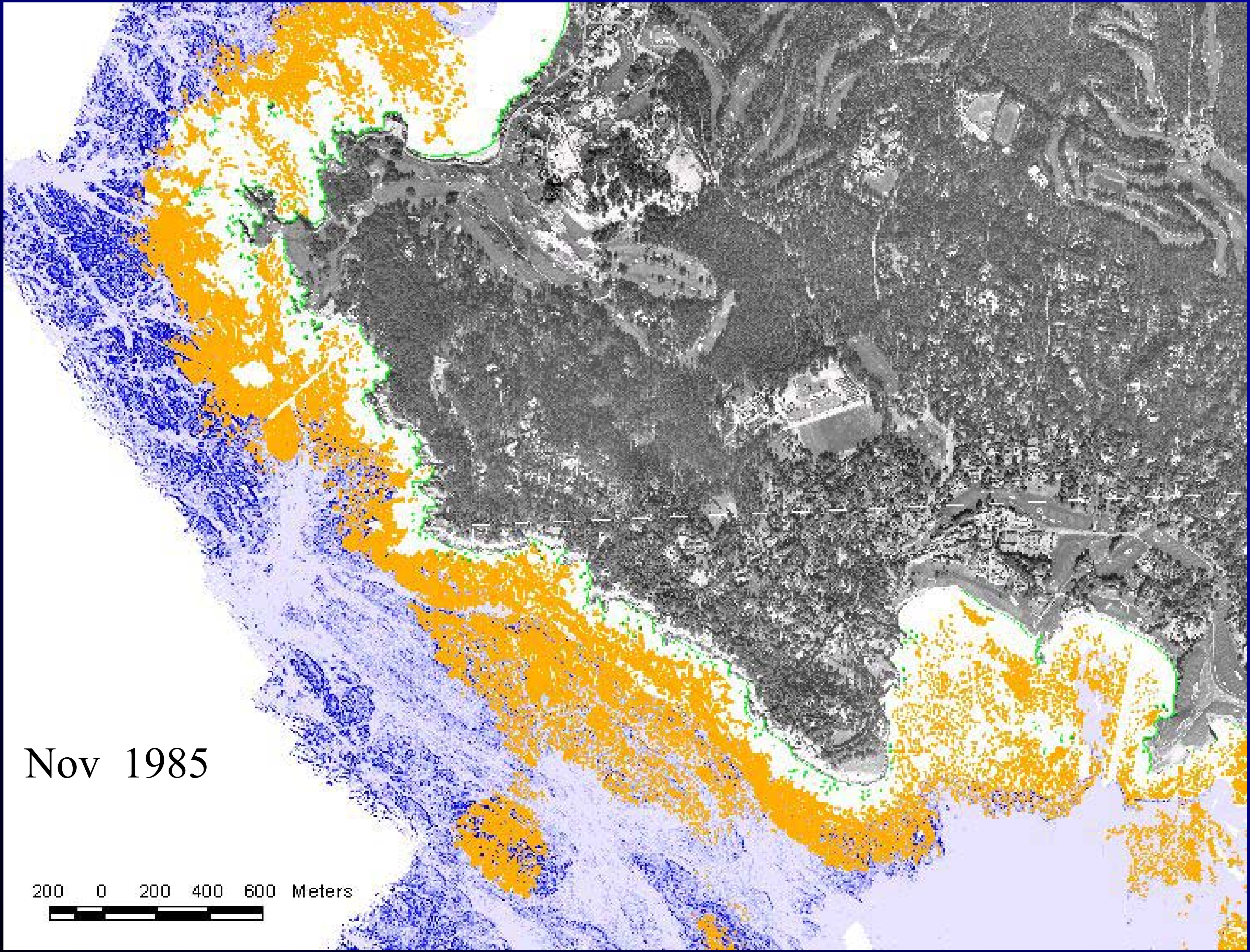


Maps of biomass distribution & productivity can be inverted to predict biogeochemical dynamics



Can we use imaging spectroscopy to remotely assess giant kelp forest productivity?

- **The challenge**
  - **Biomass distributed through 10 – 20 m of water**
  - **Large variations in standing biomass (intra- and interannual variations)**
  - **Water column clarity often low**
- **The opportunity**
  - **Floating canopy provides a strong reflecting target**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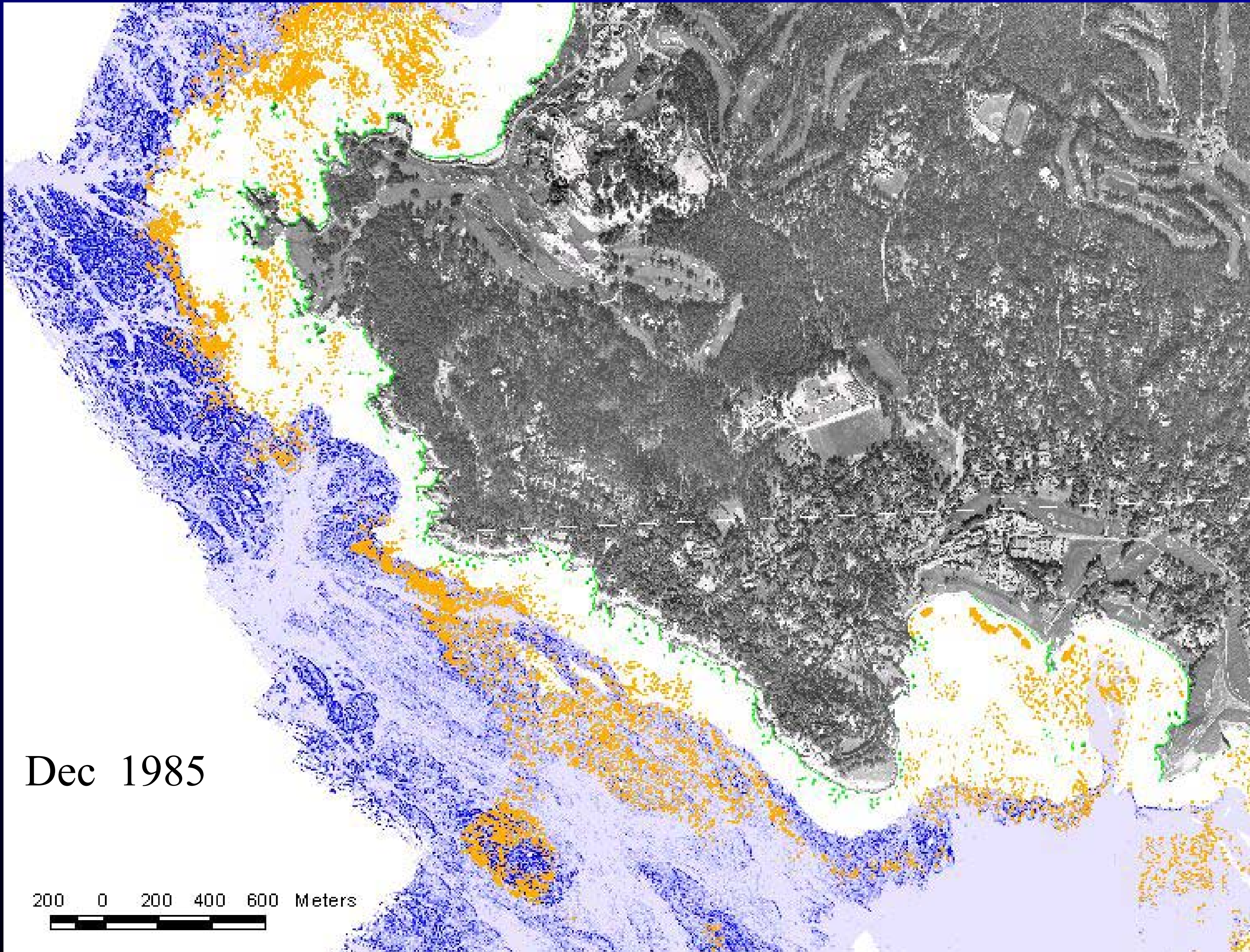

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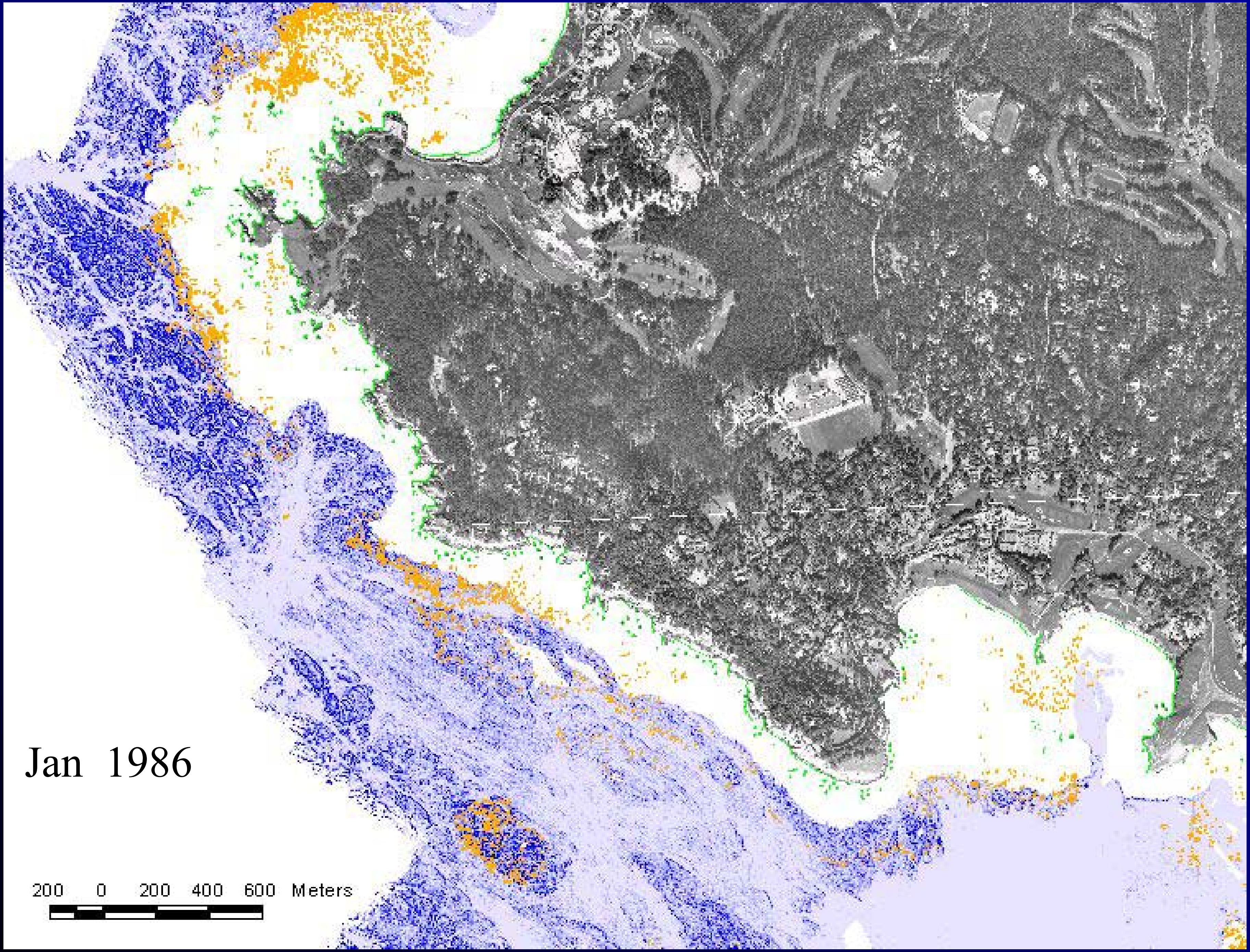

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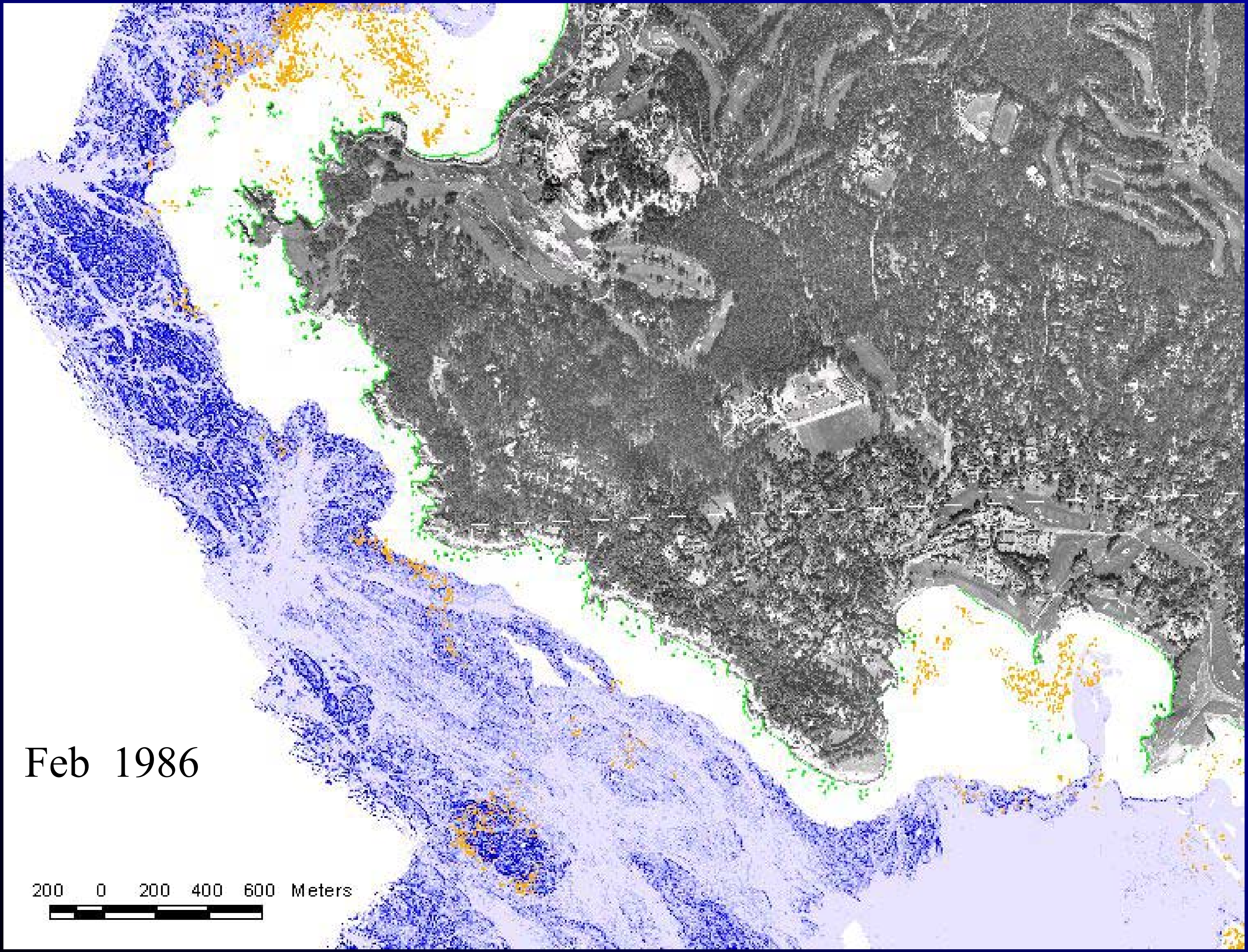
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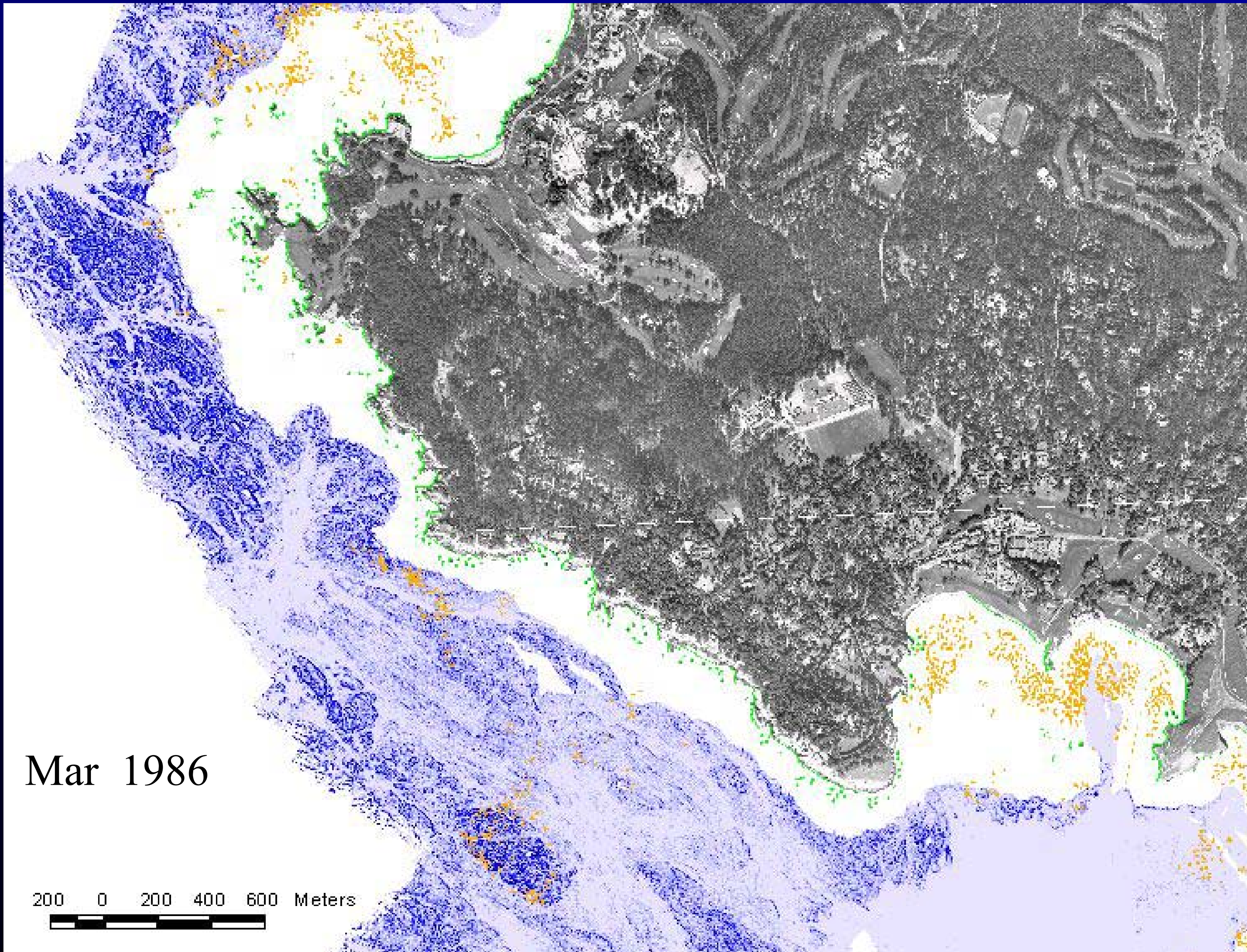
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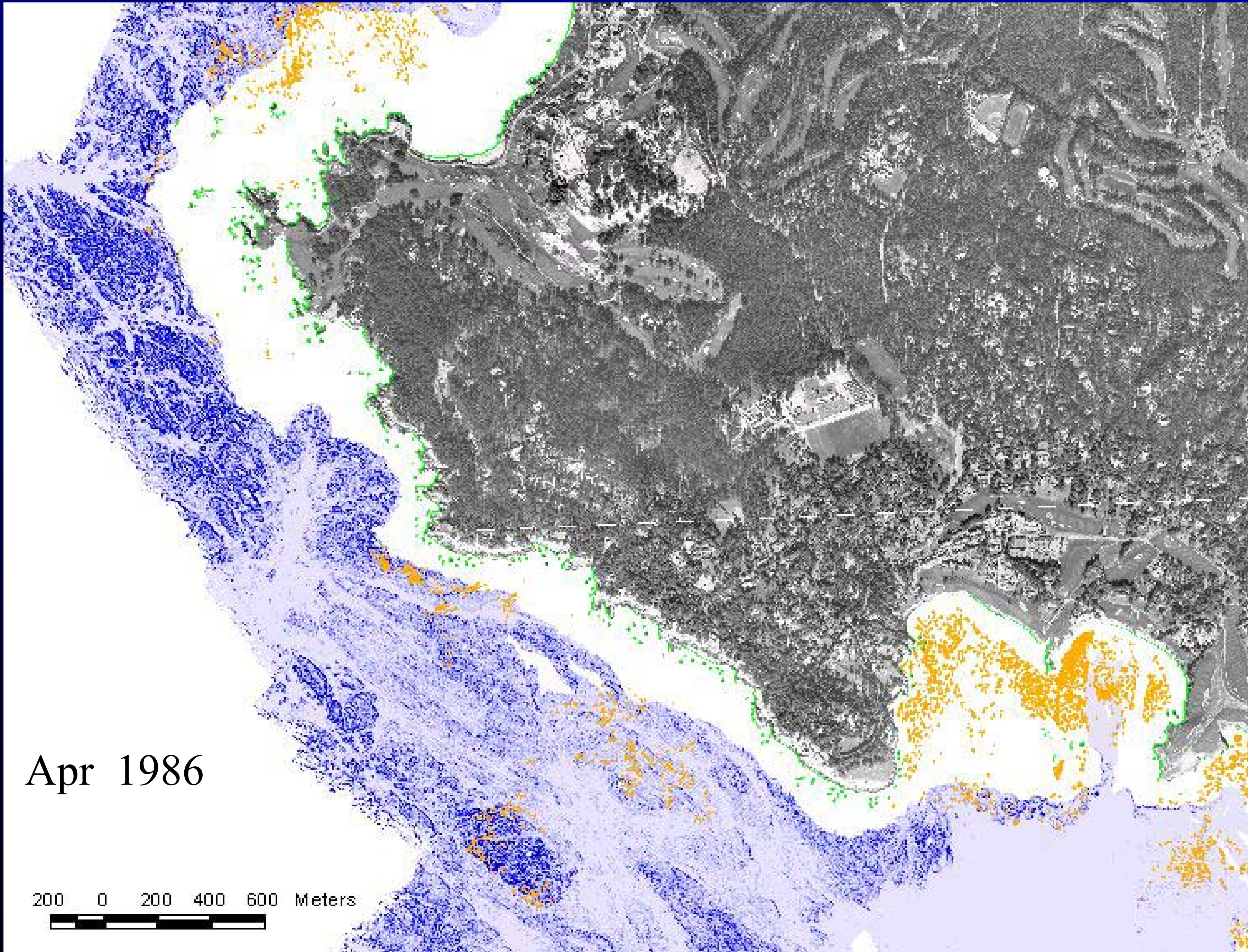
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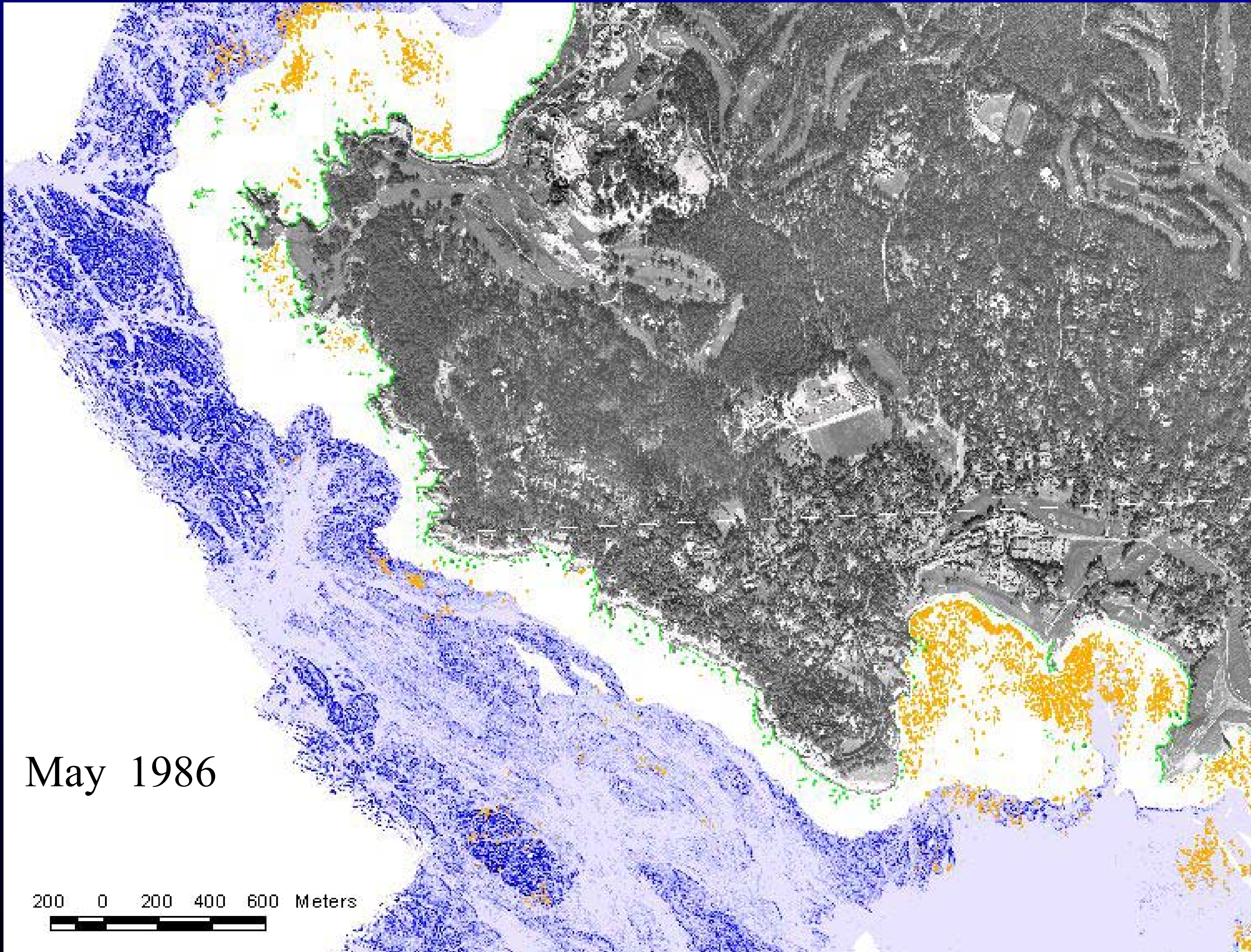
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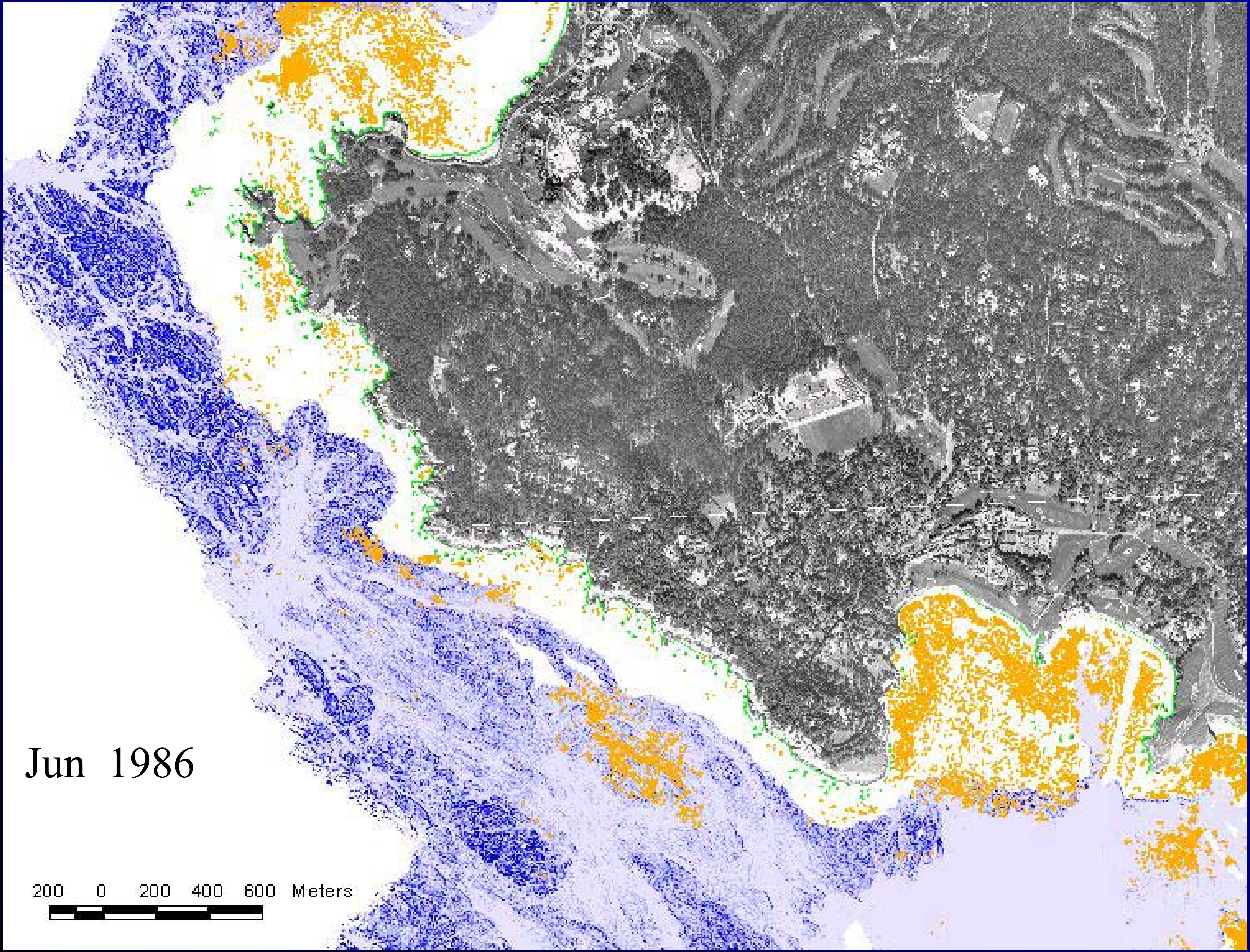

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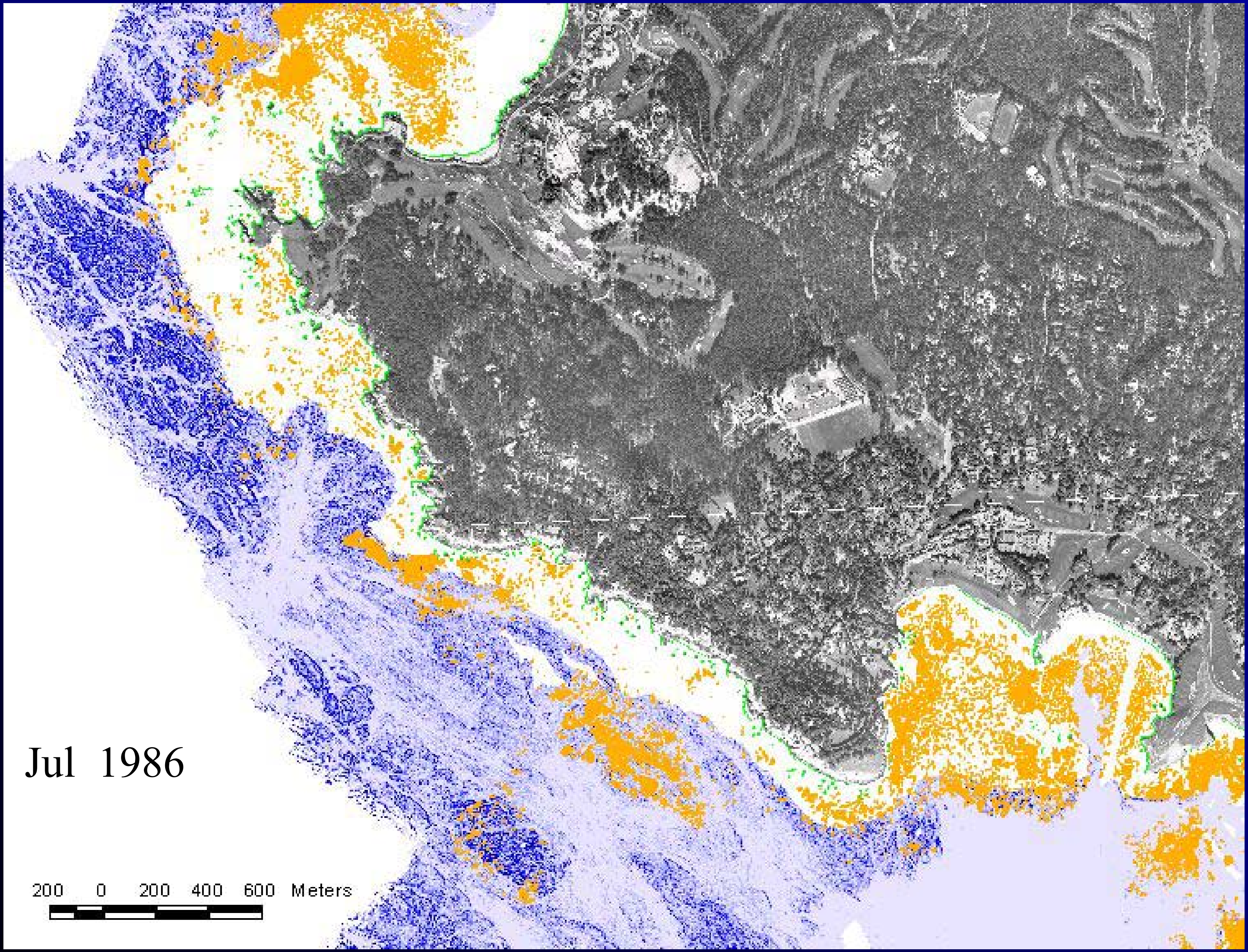
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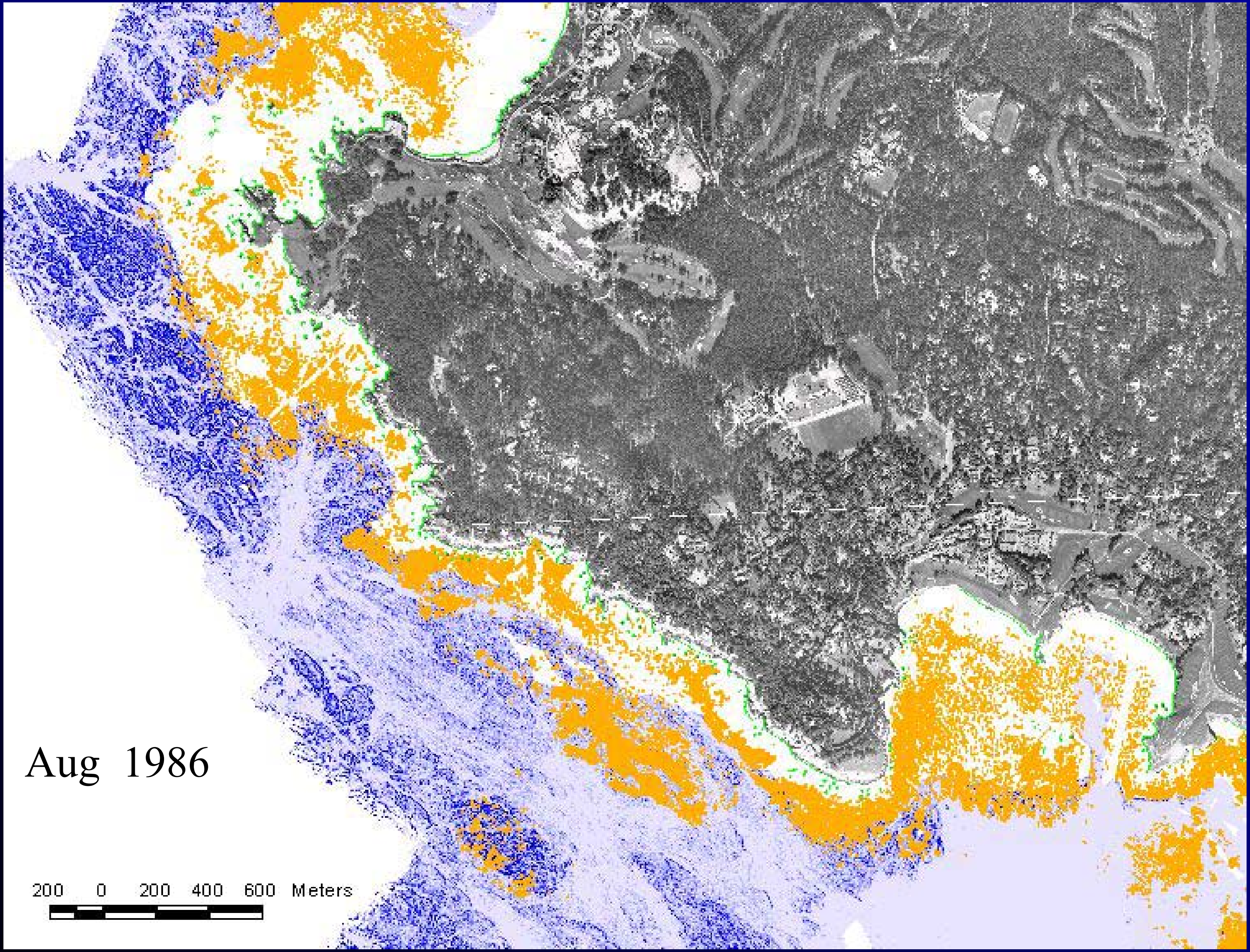
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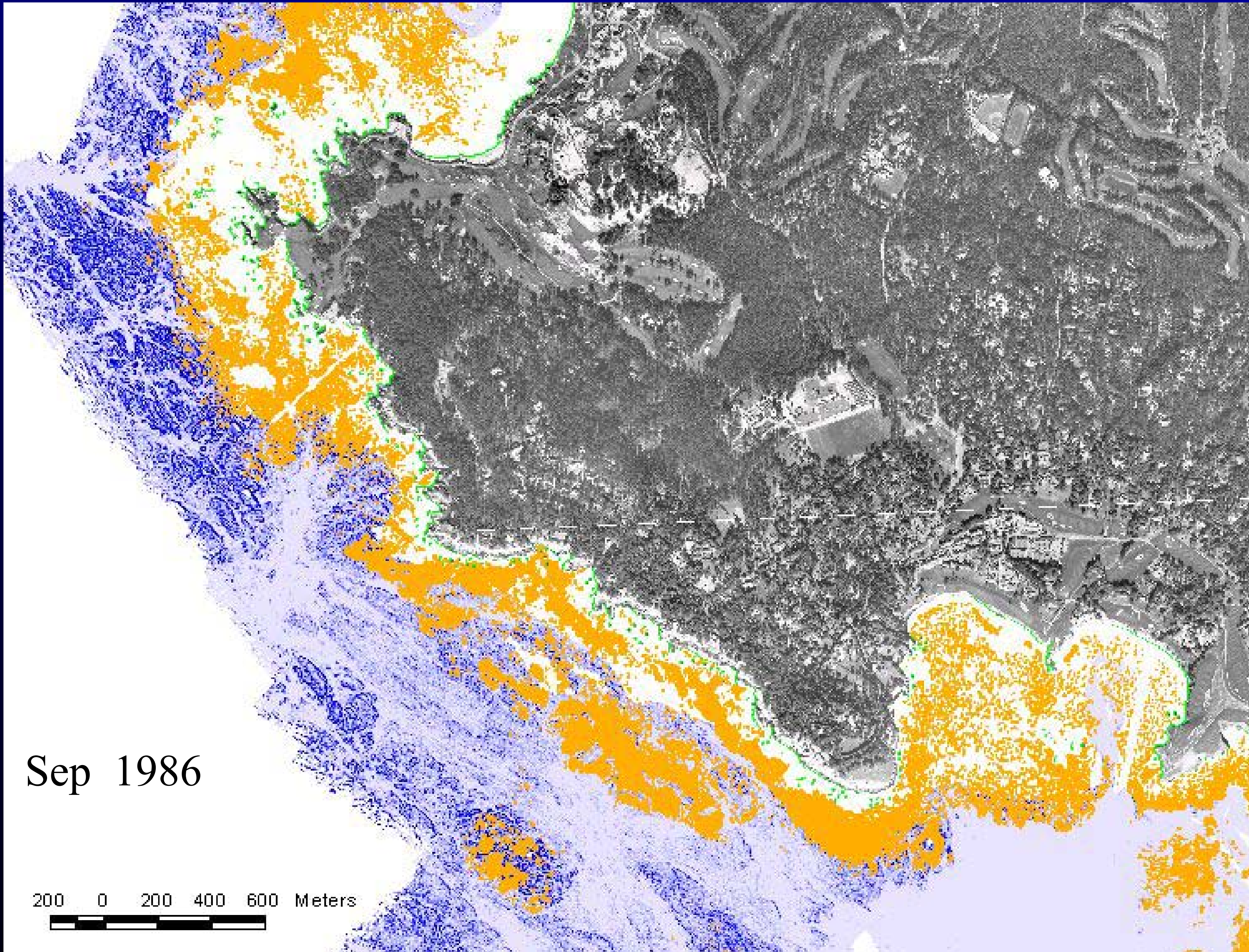
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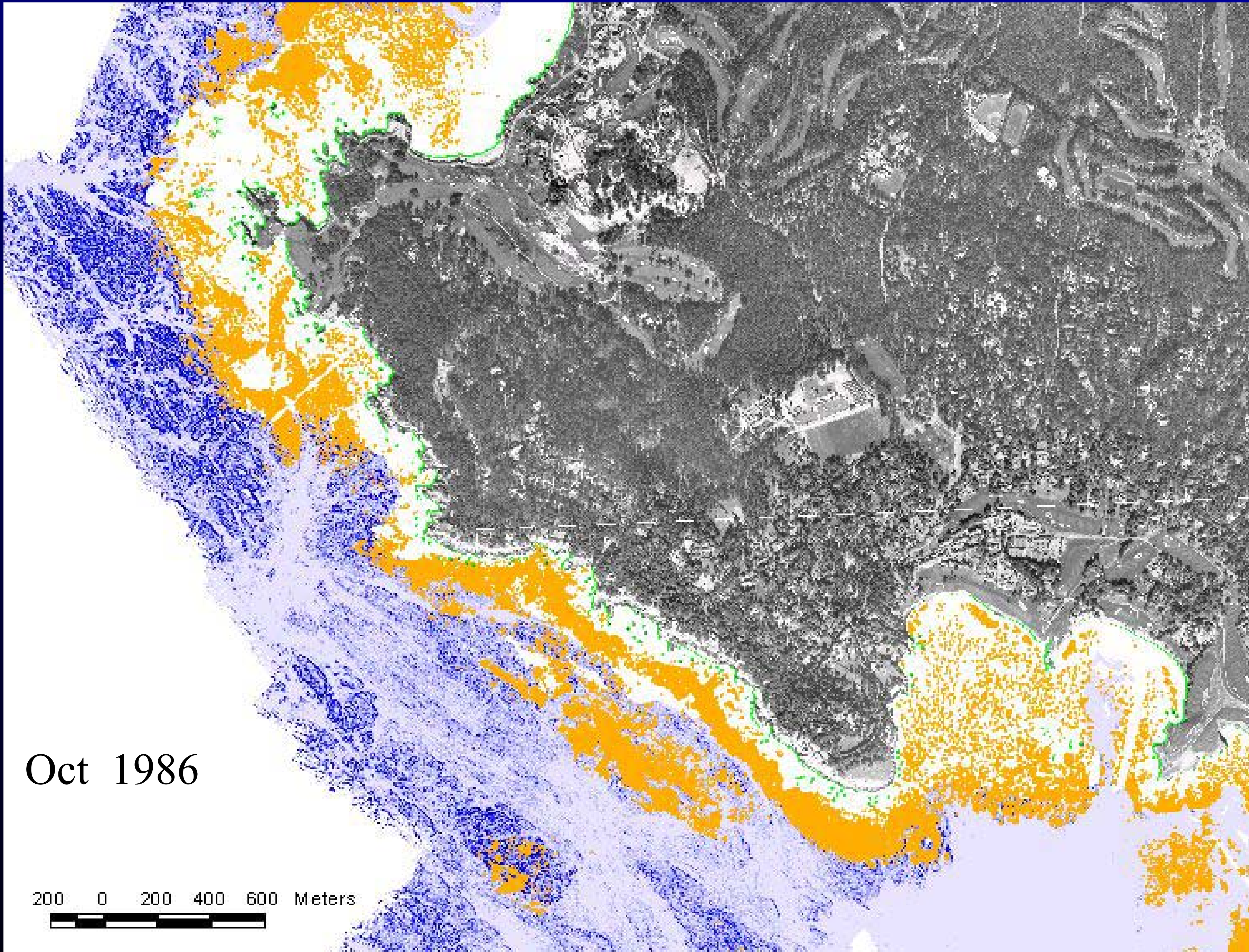
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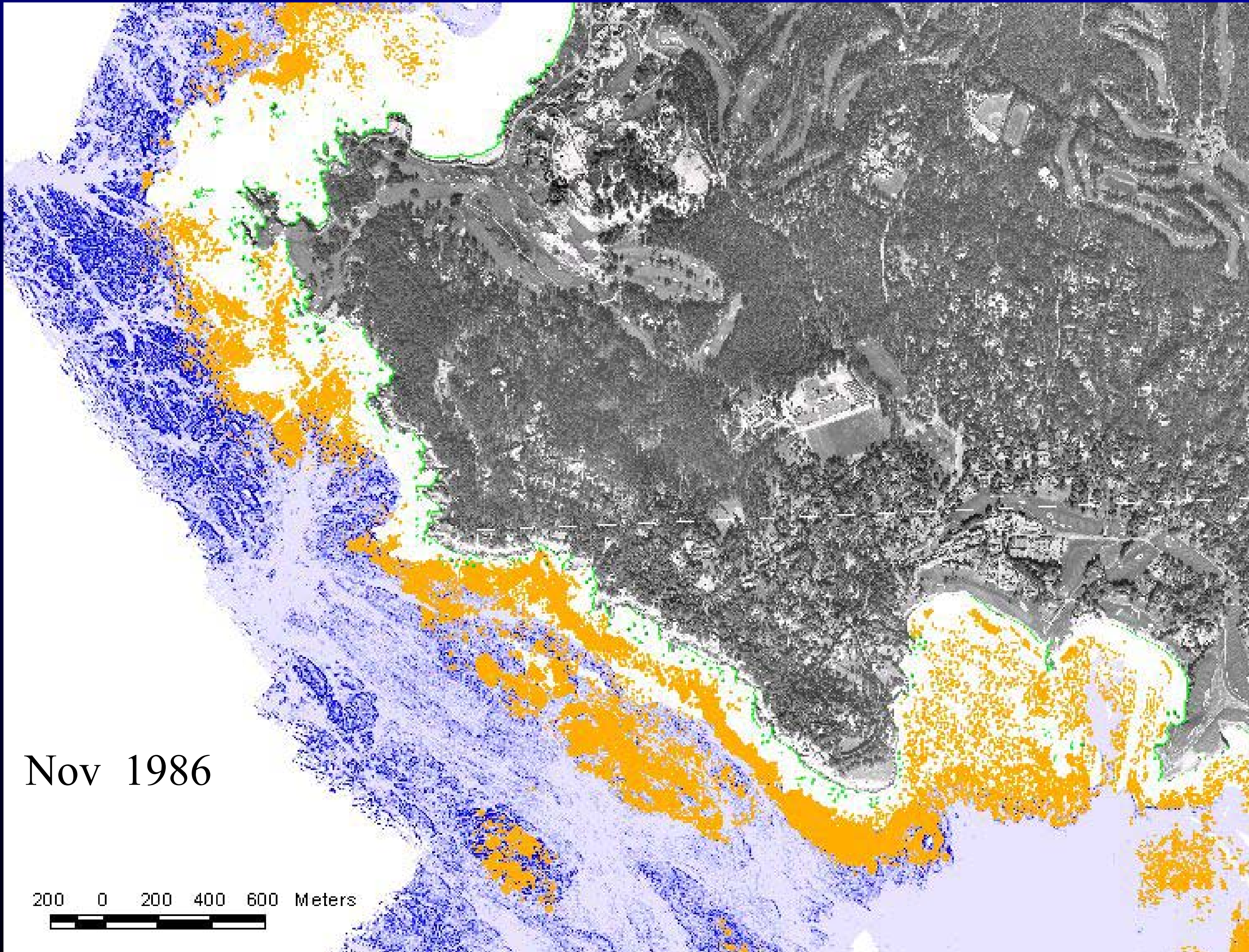
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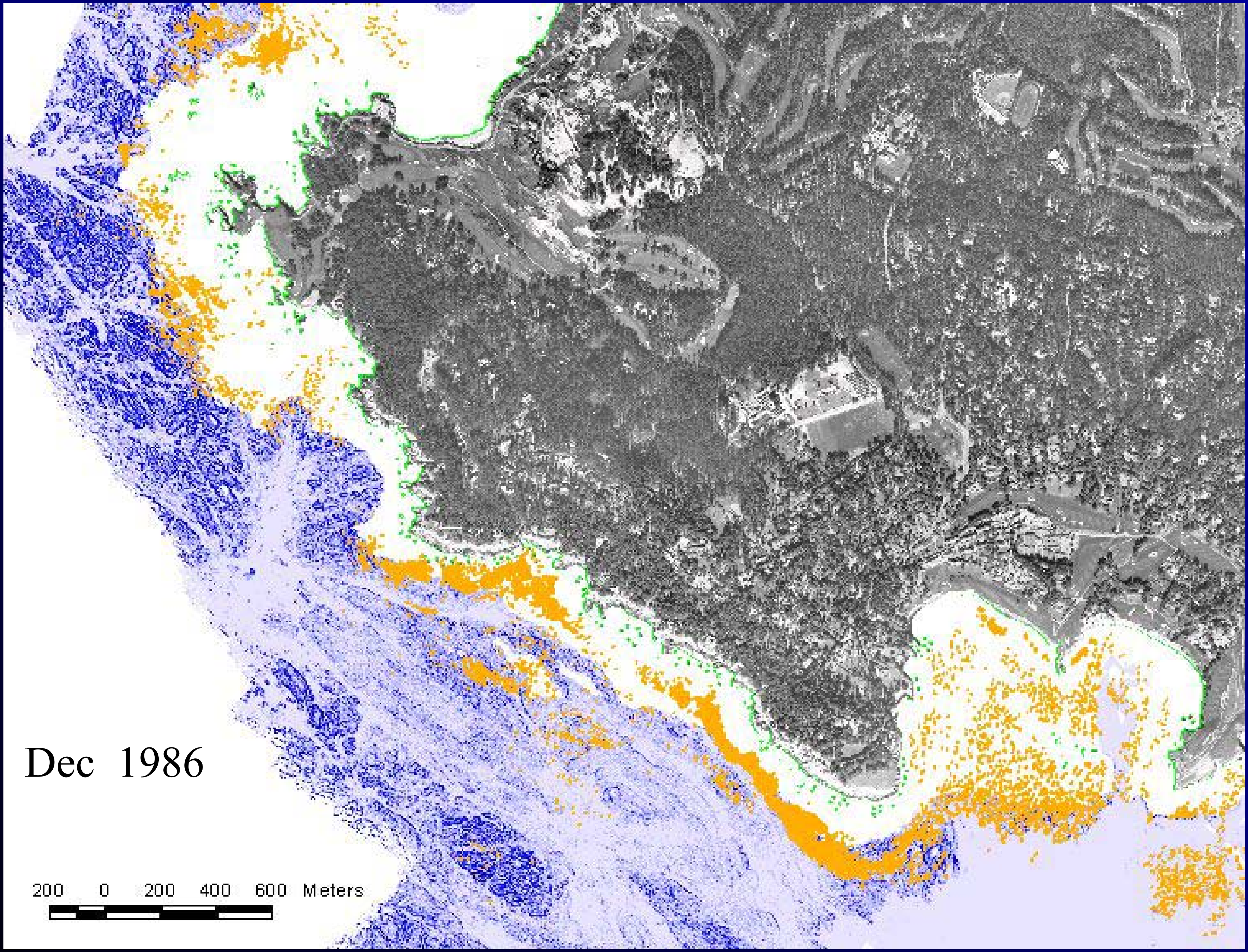
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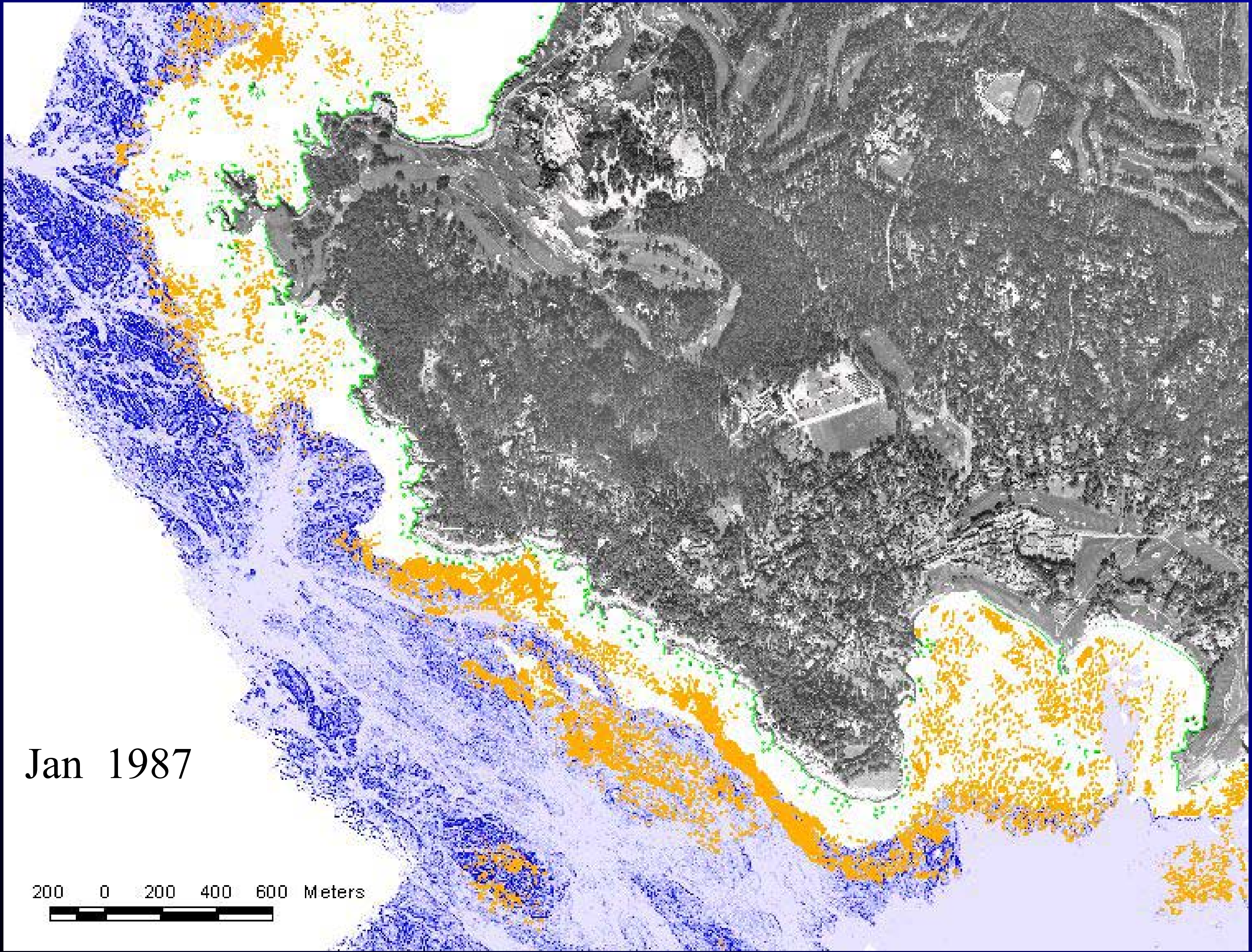
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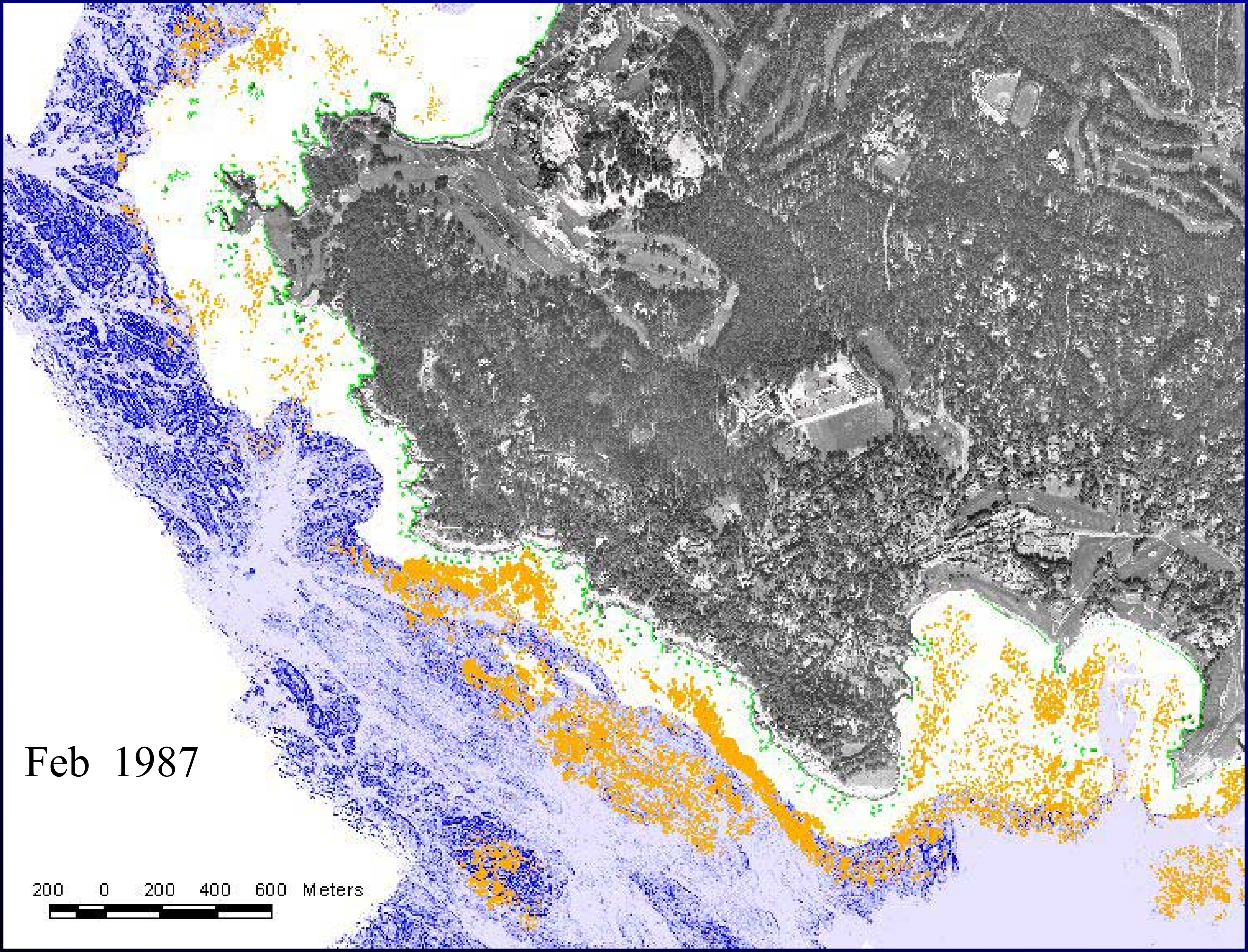
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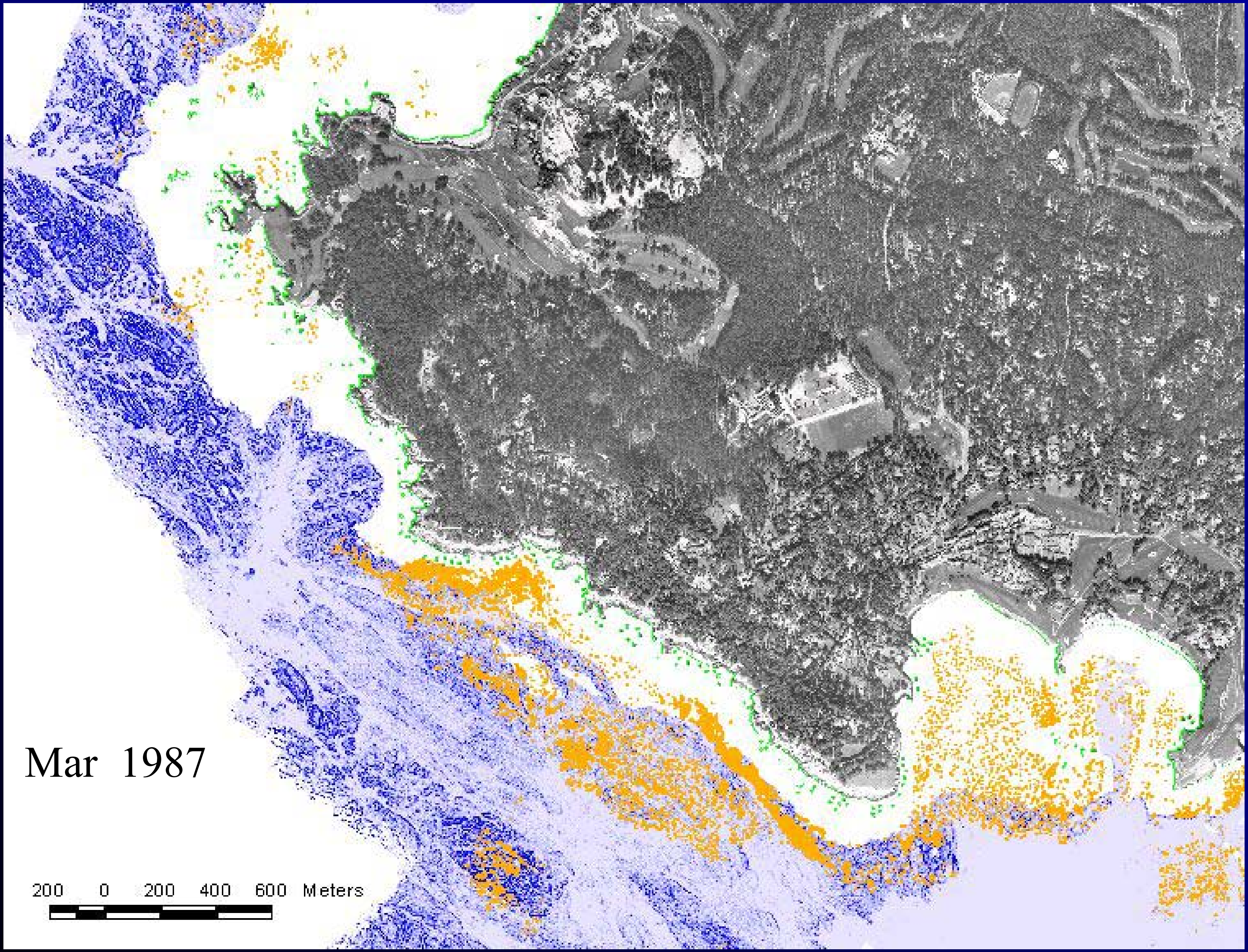
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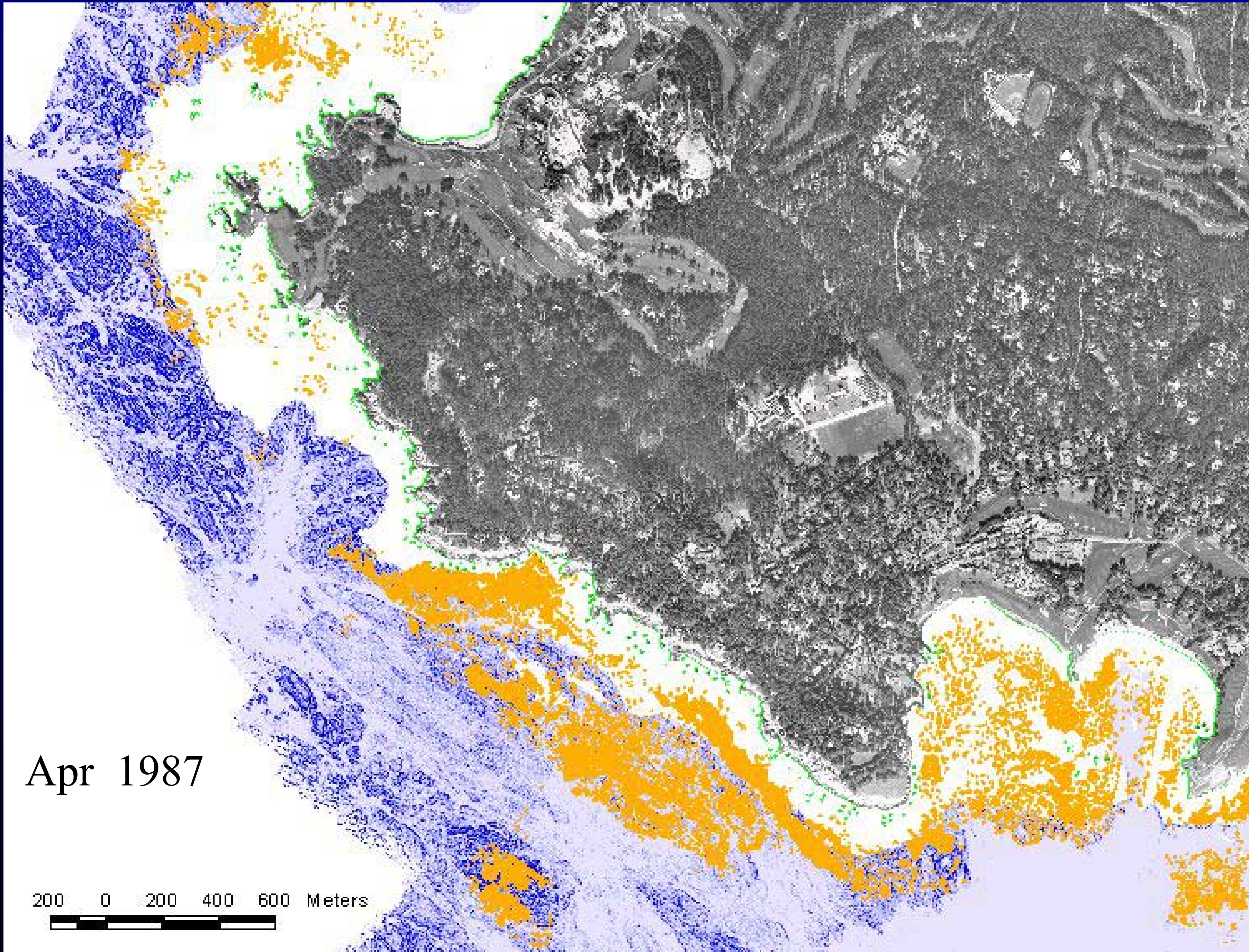
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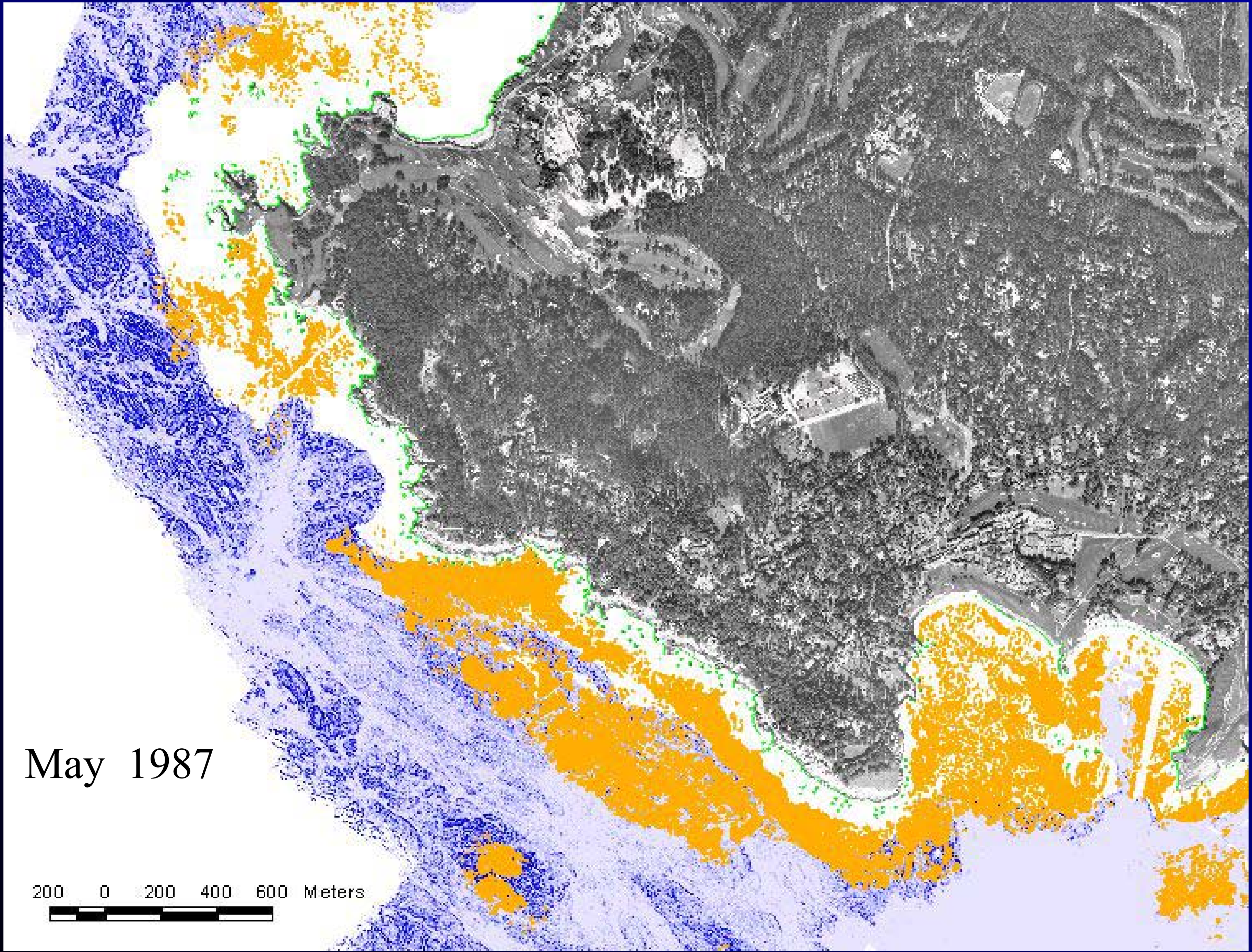
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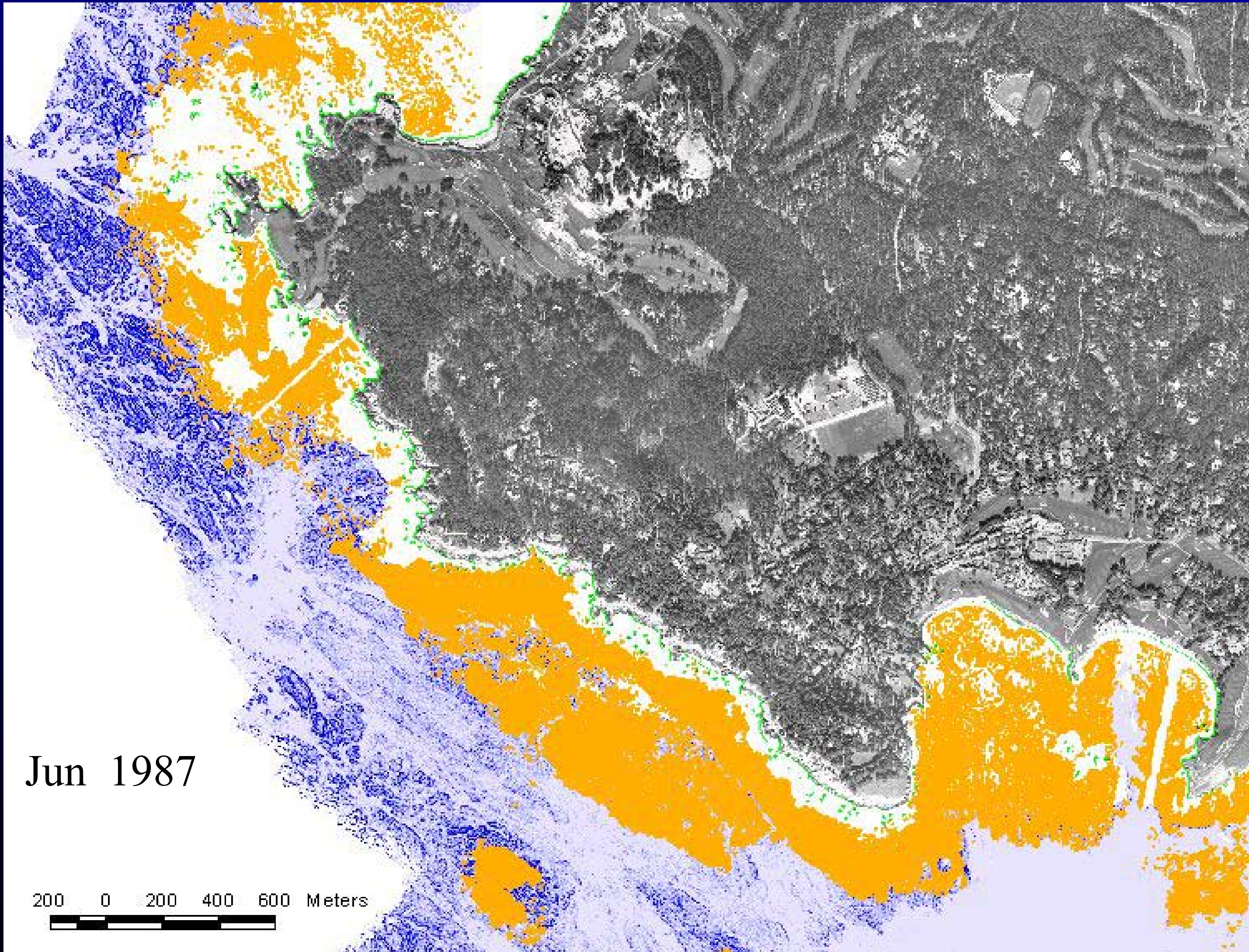
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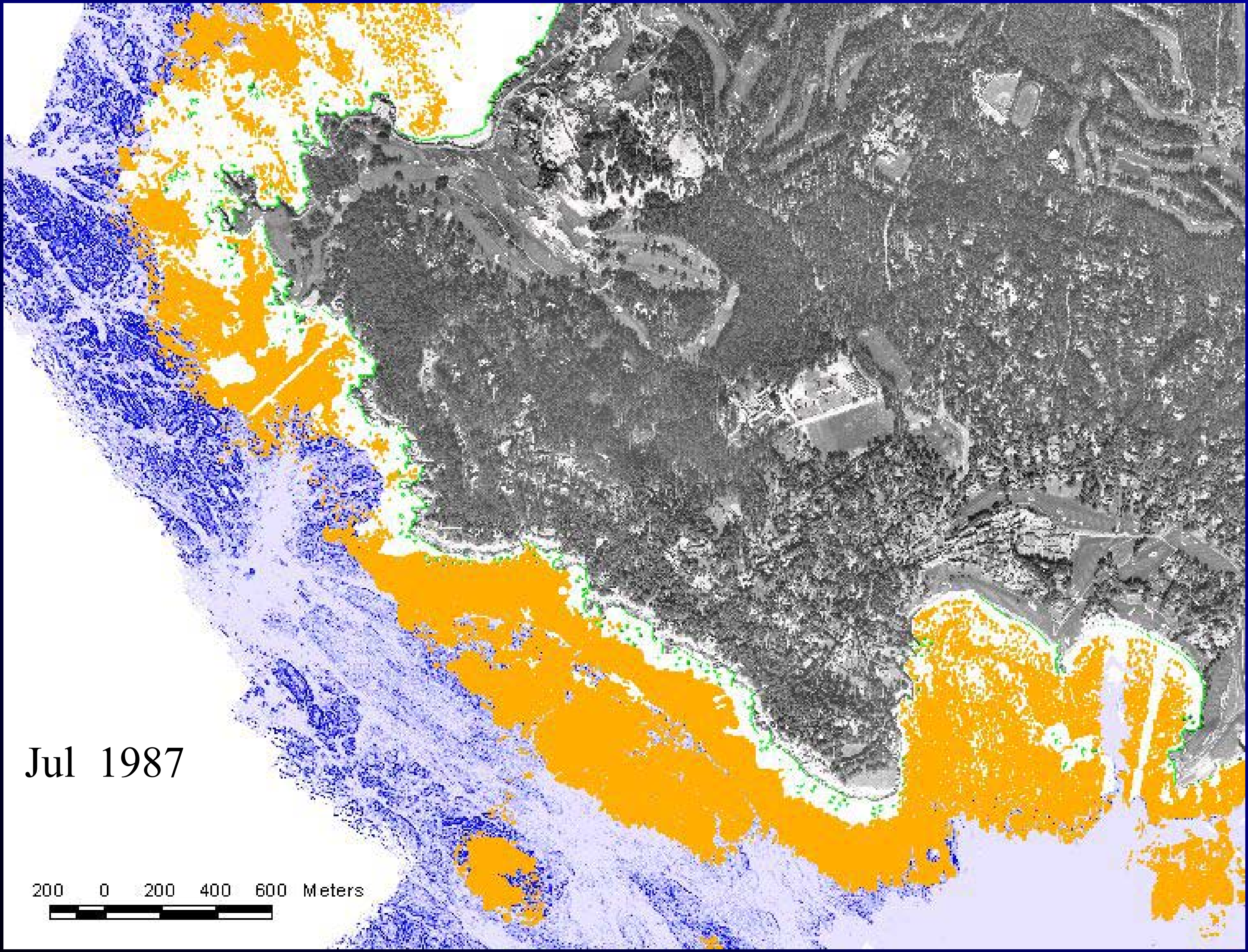

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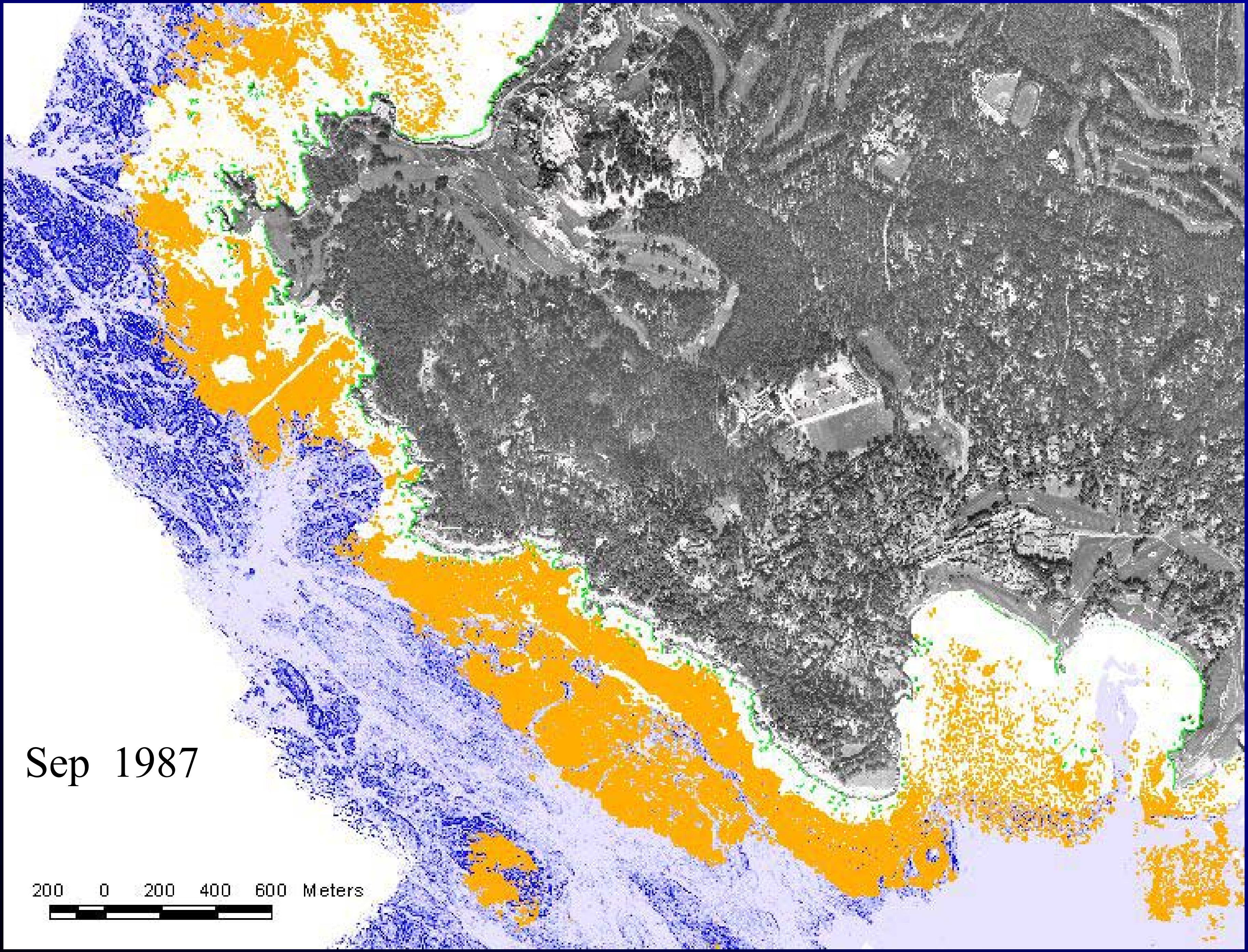
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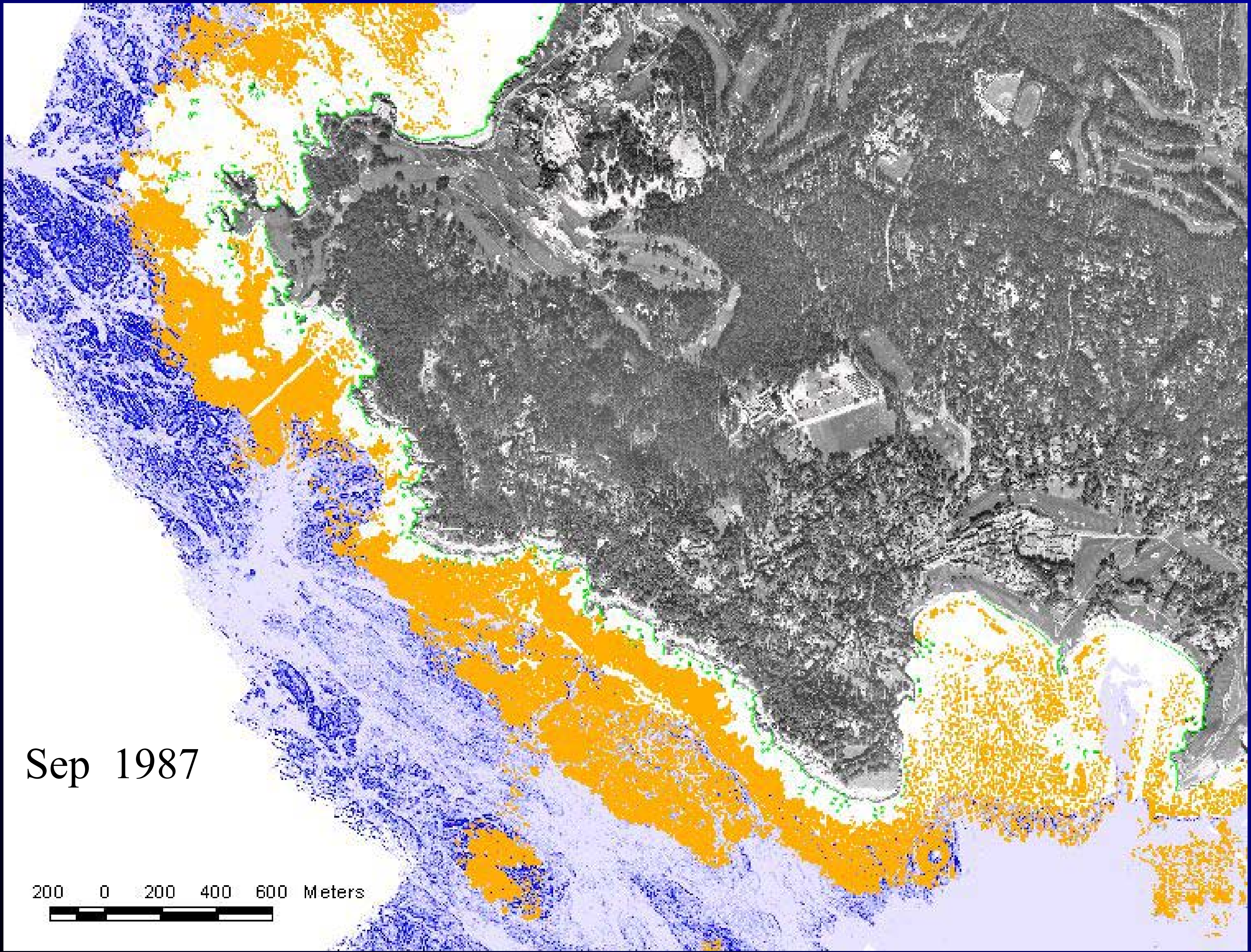
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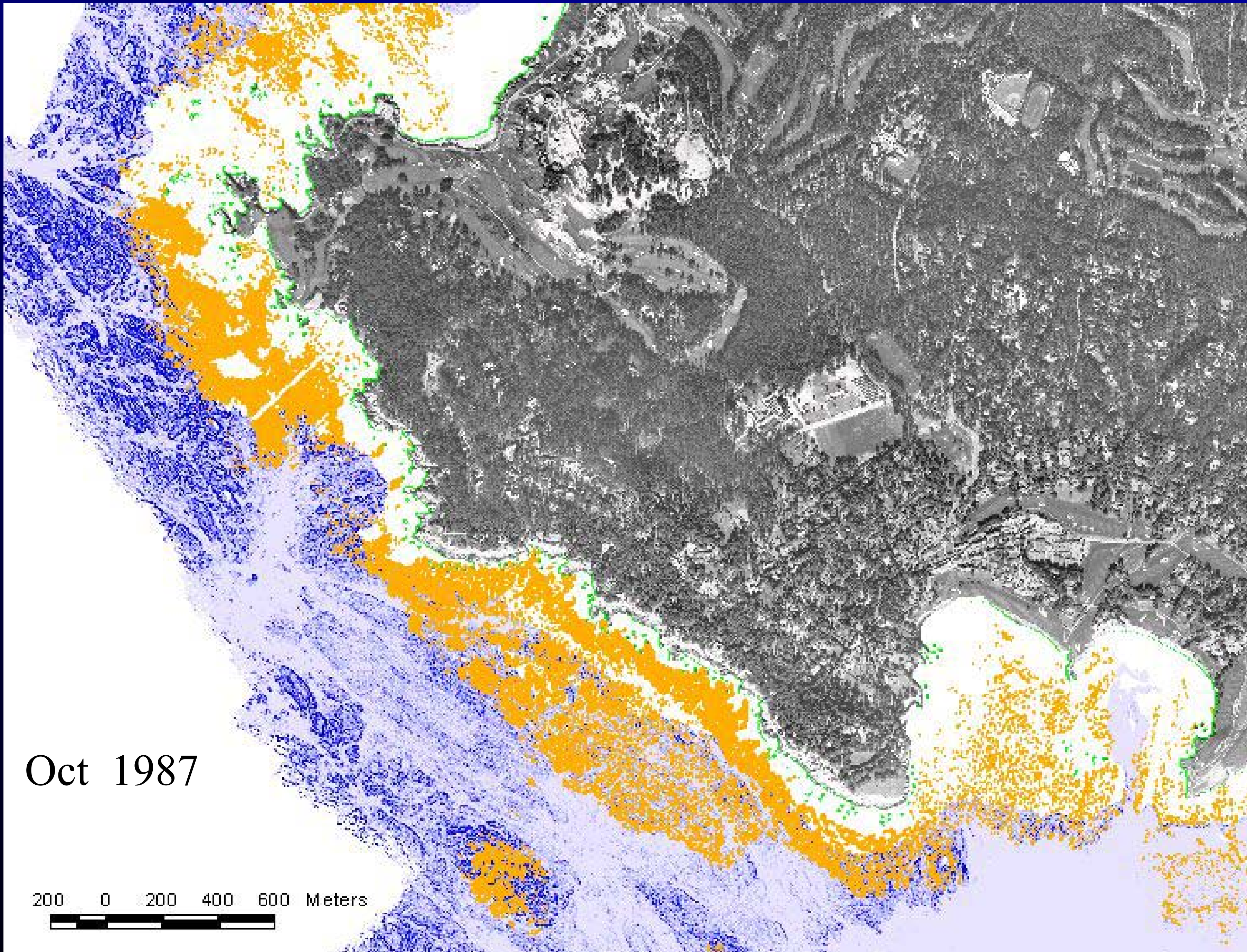
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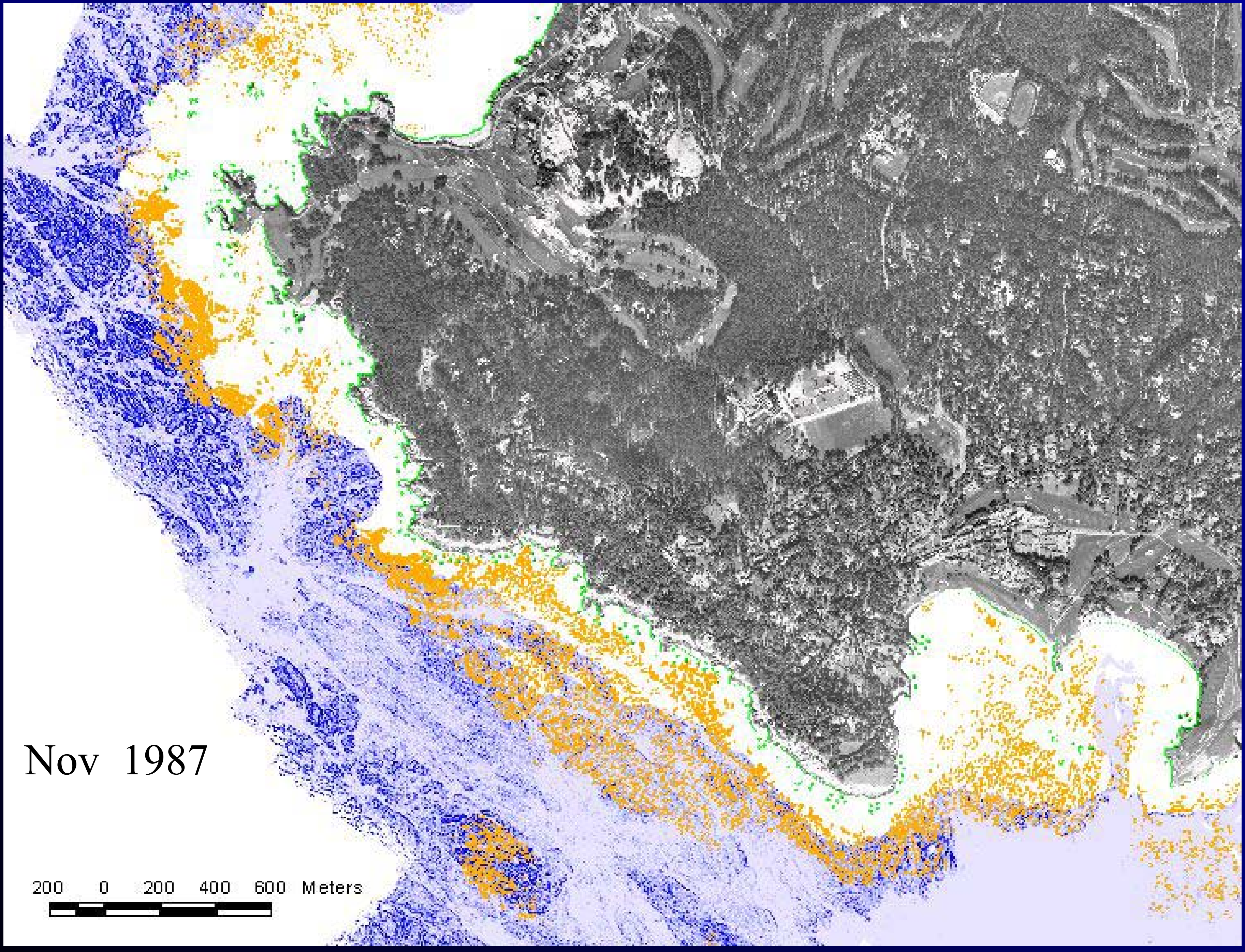
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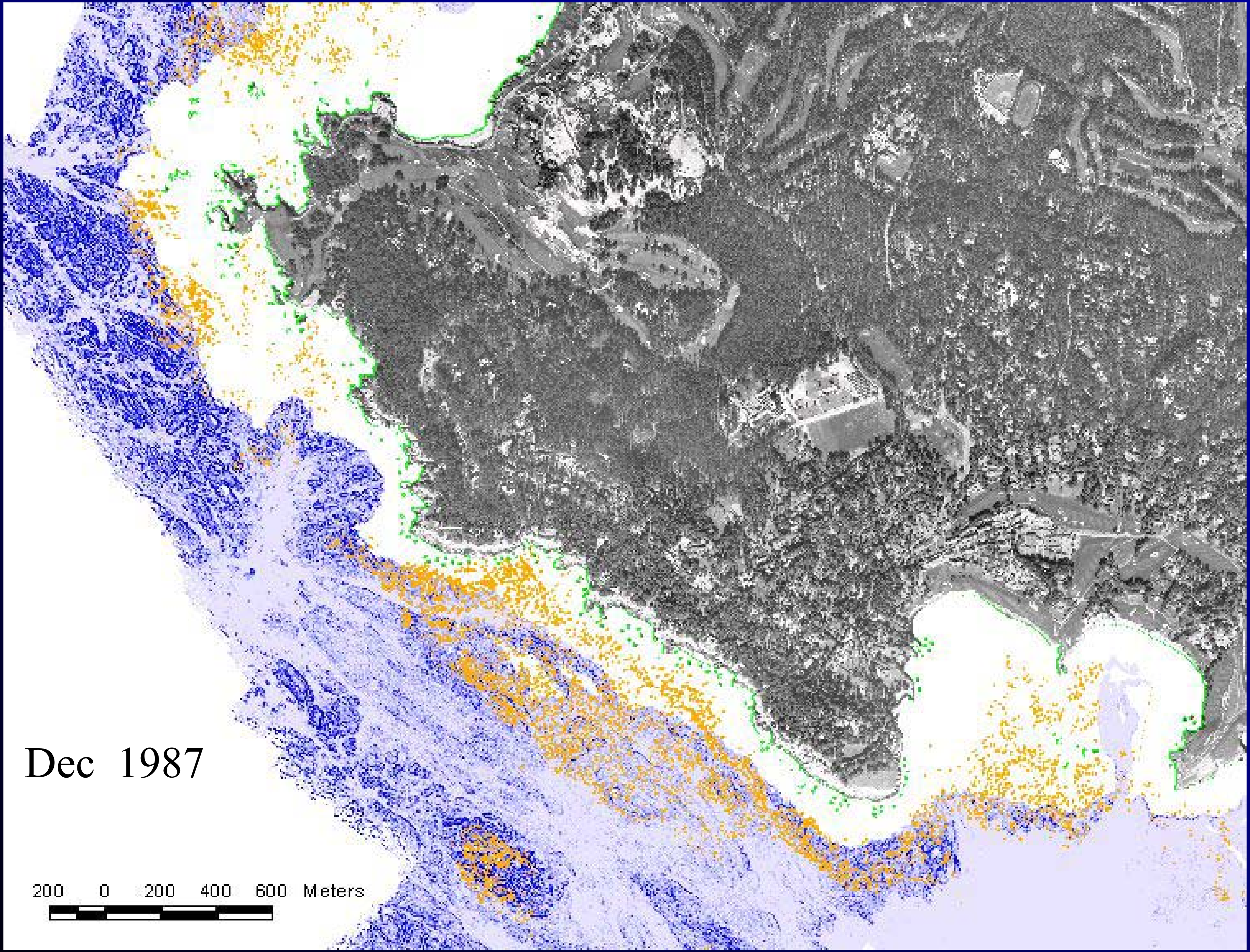
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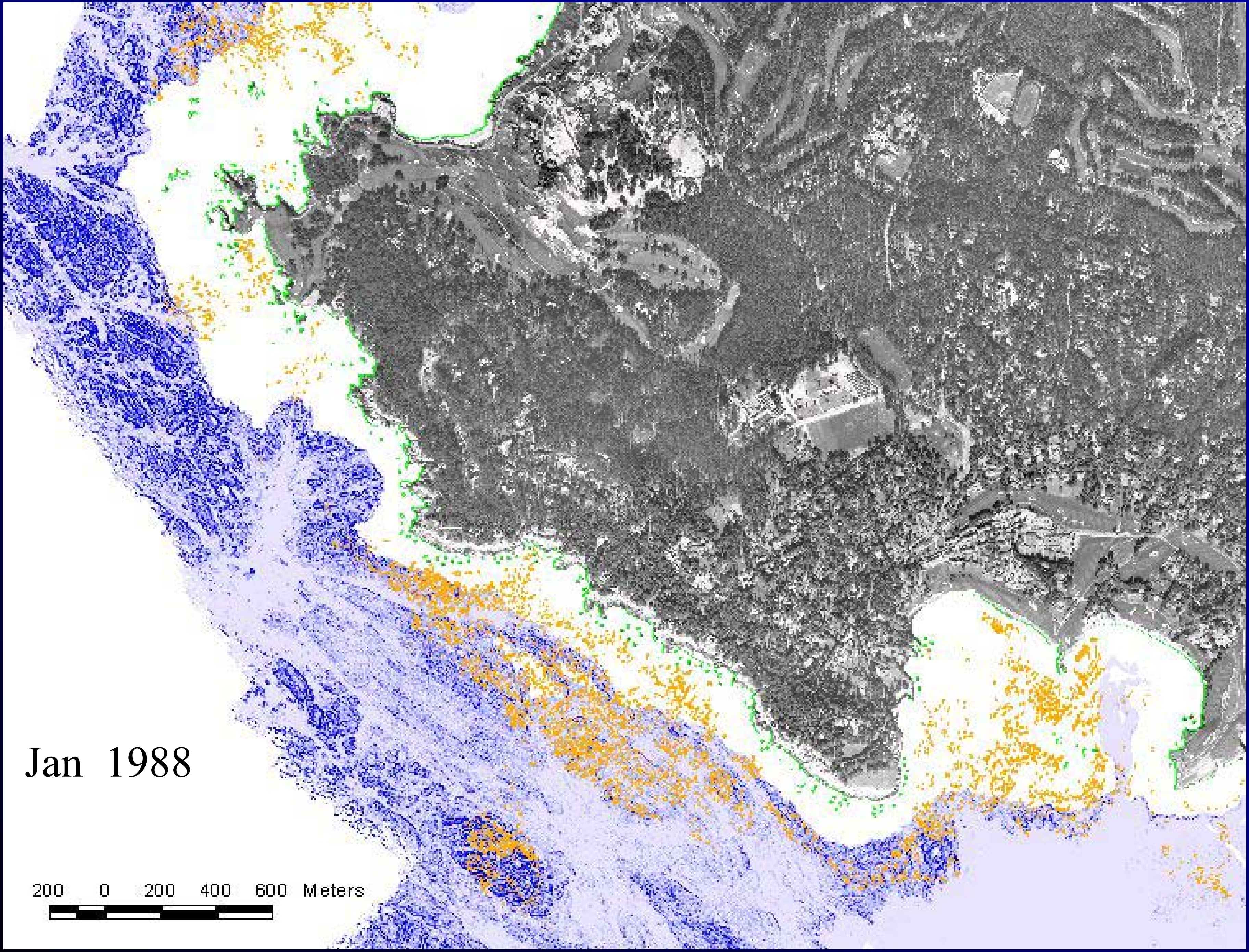
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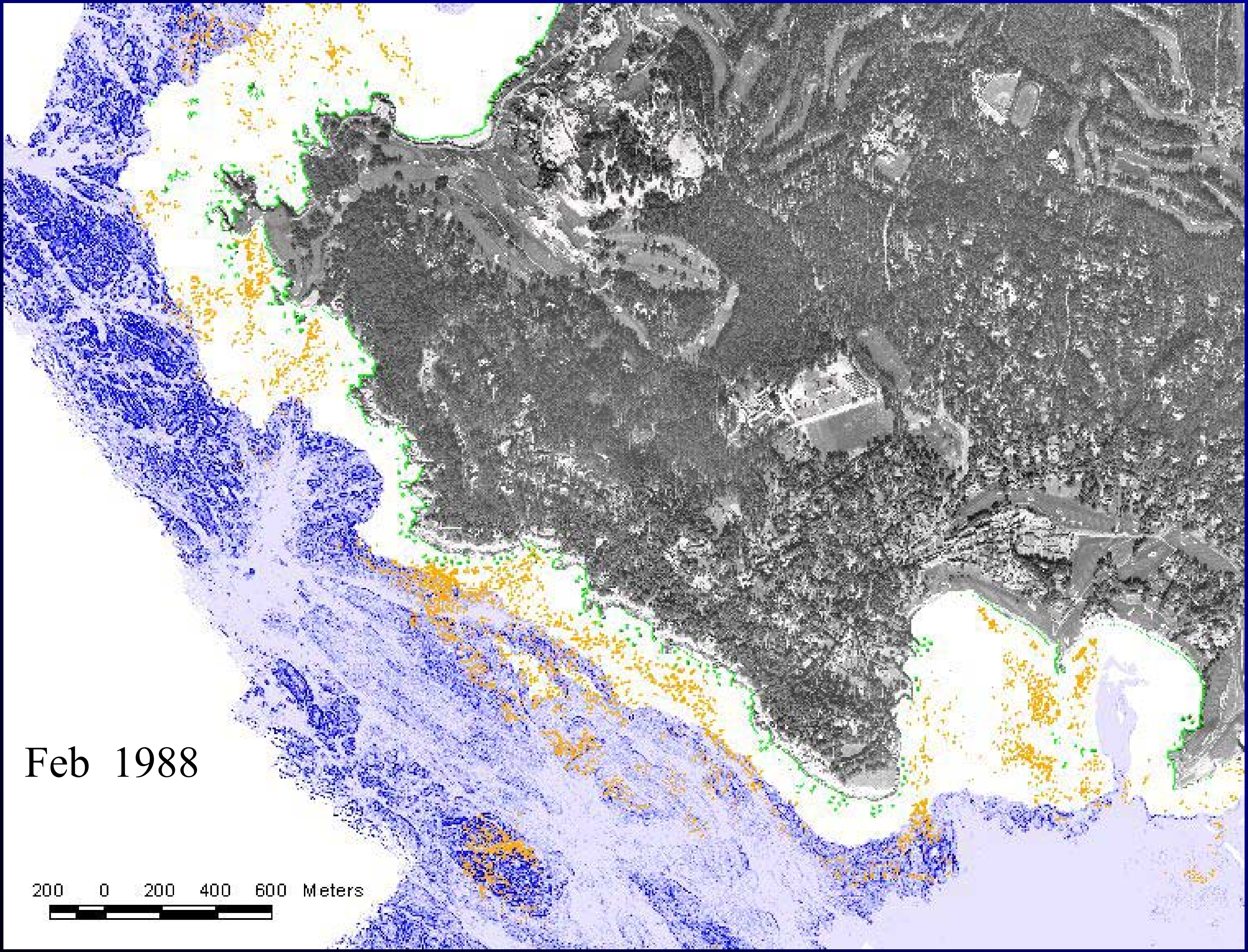
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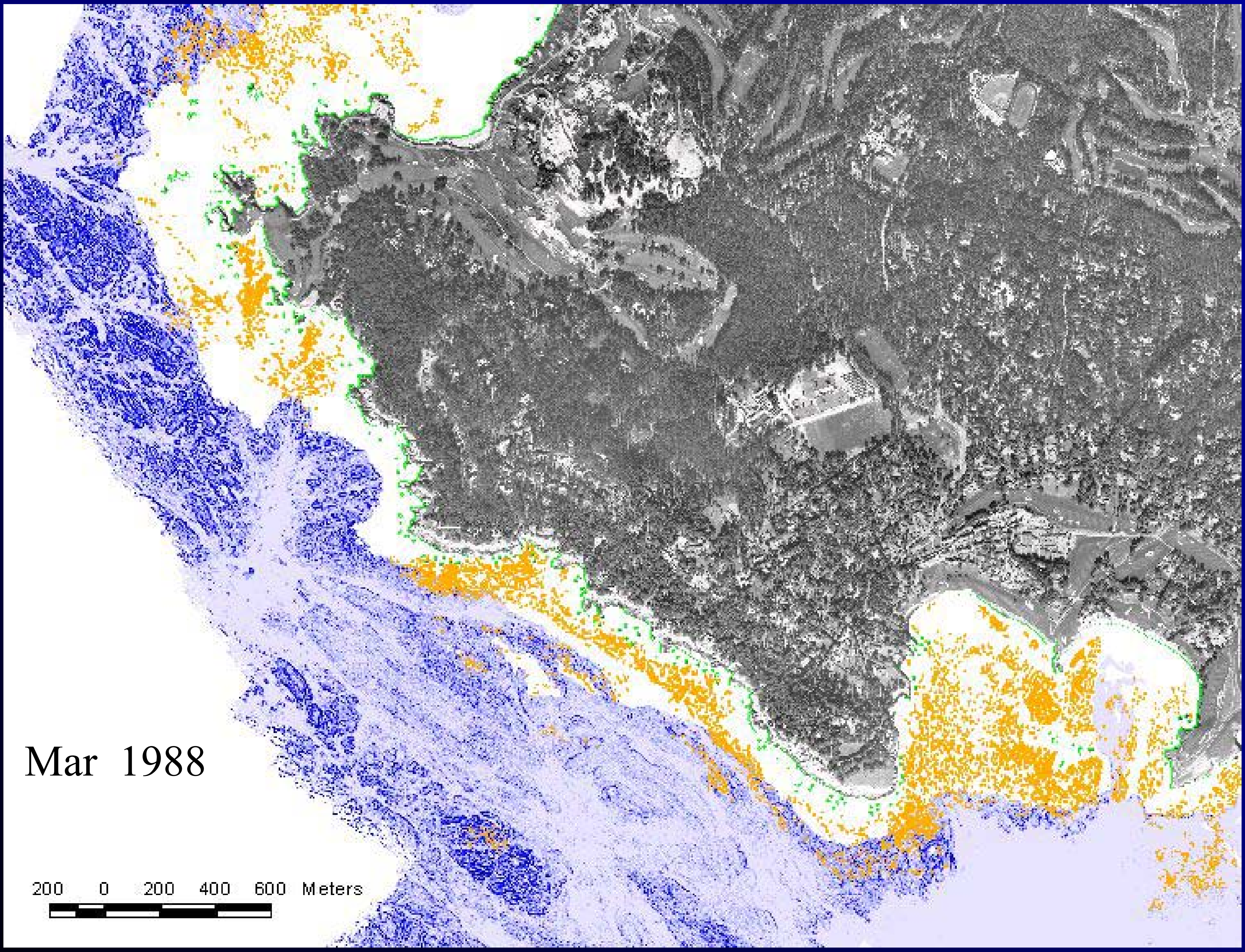
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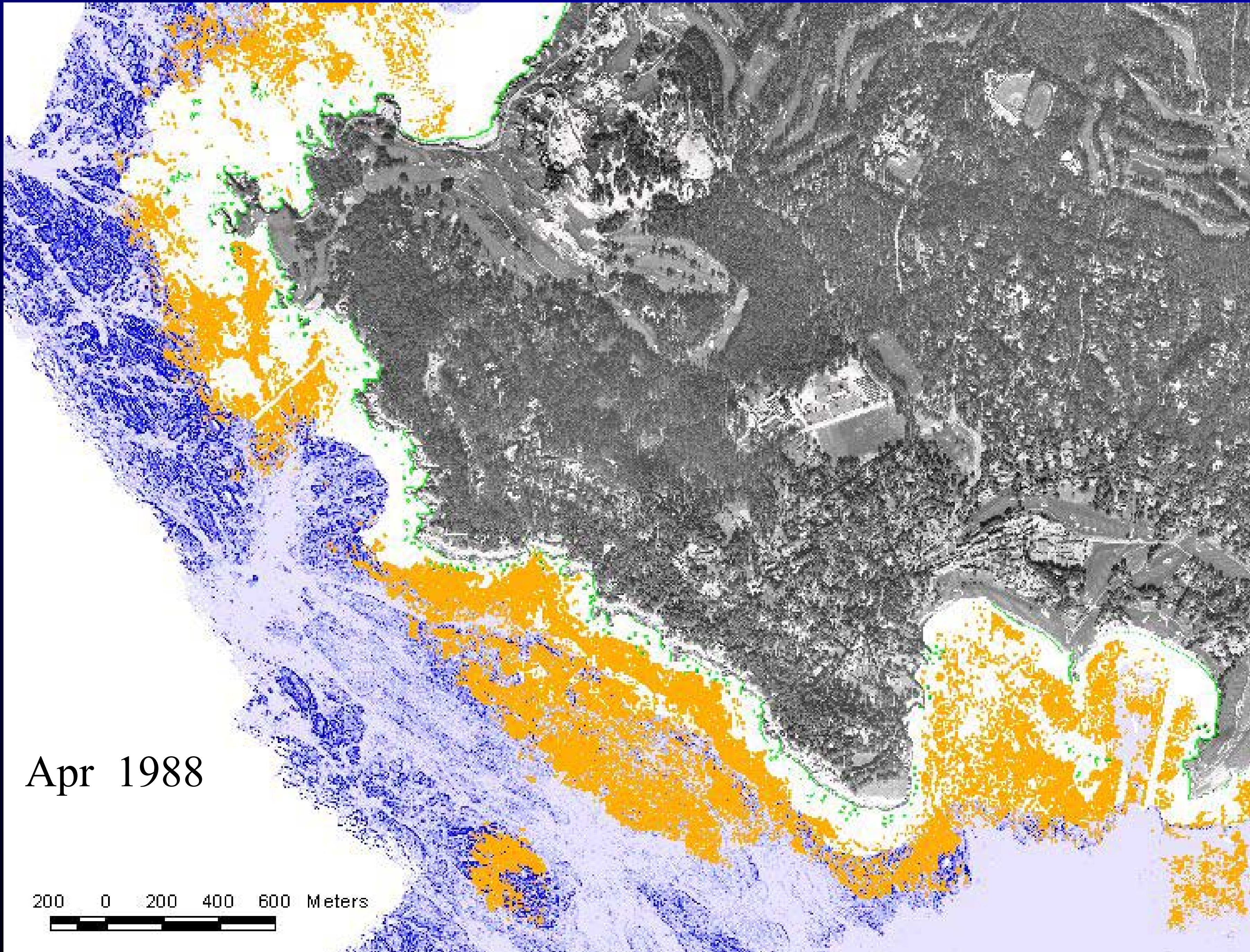
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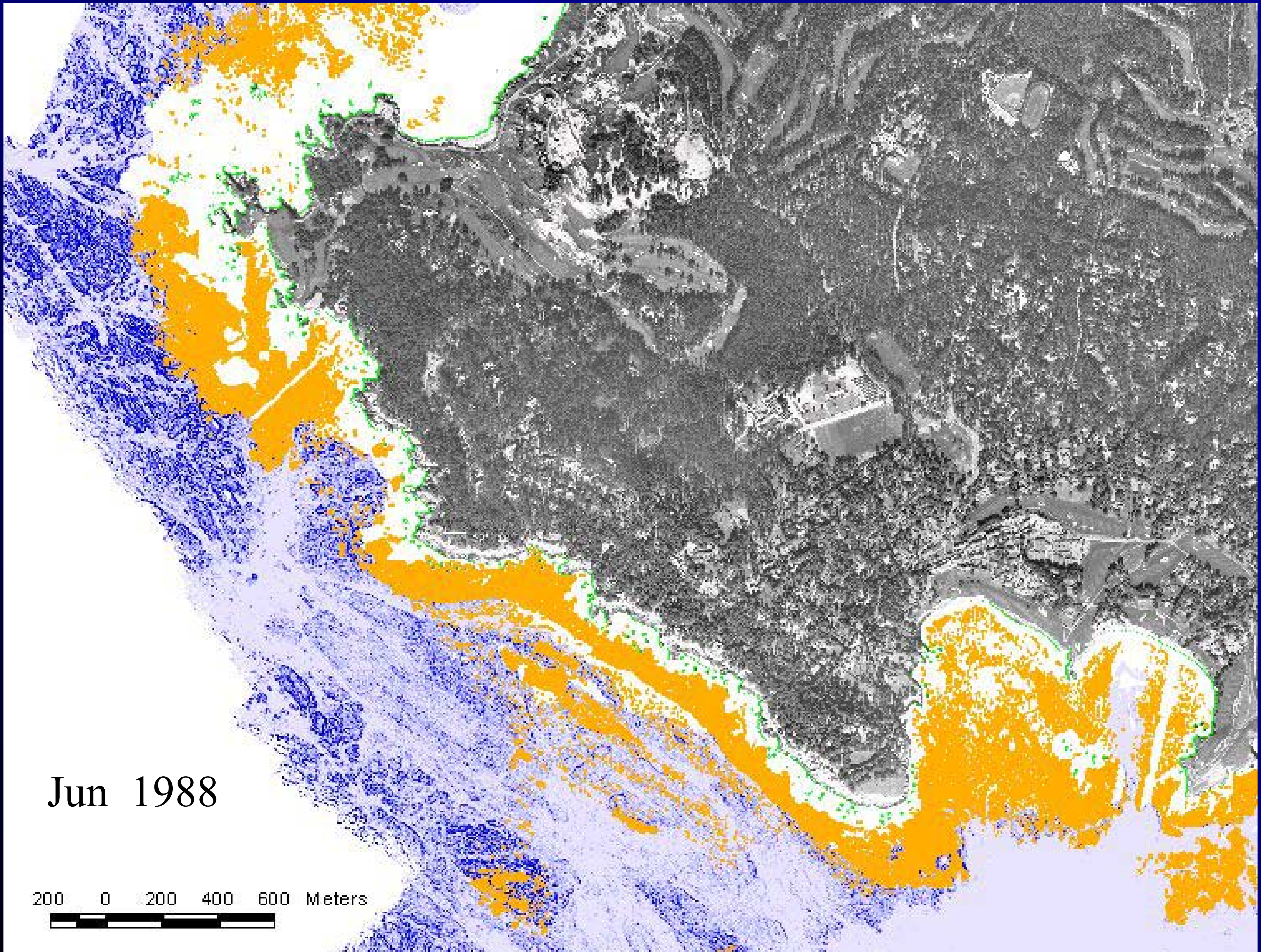
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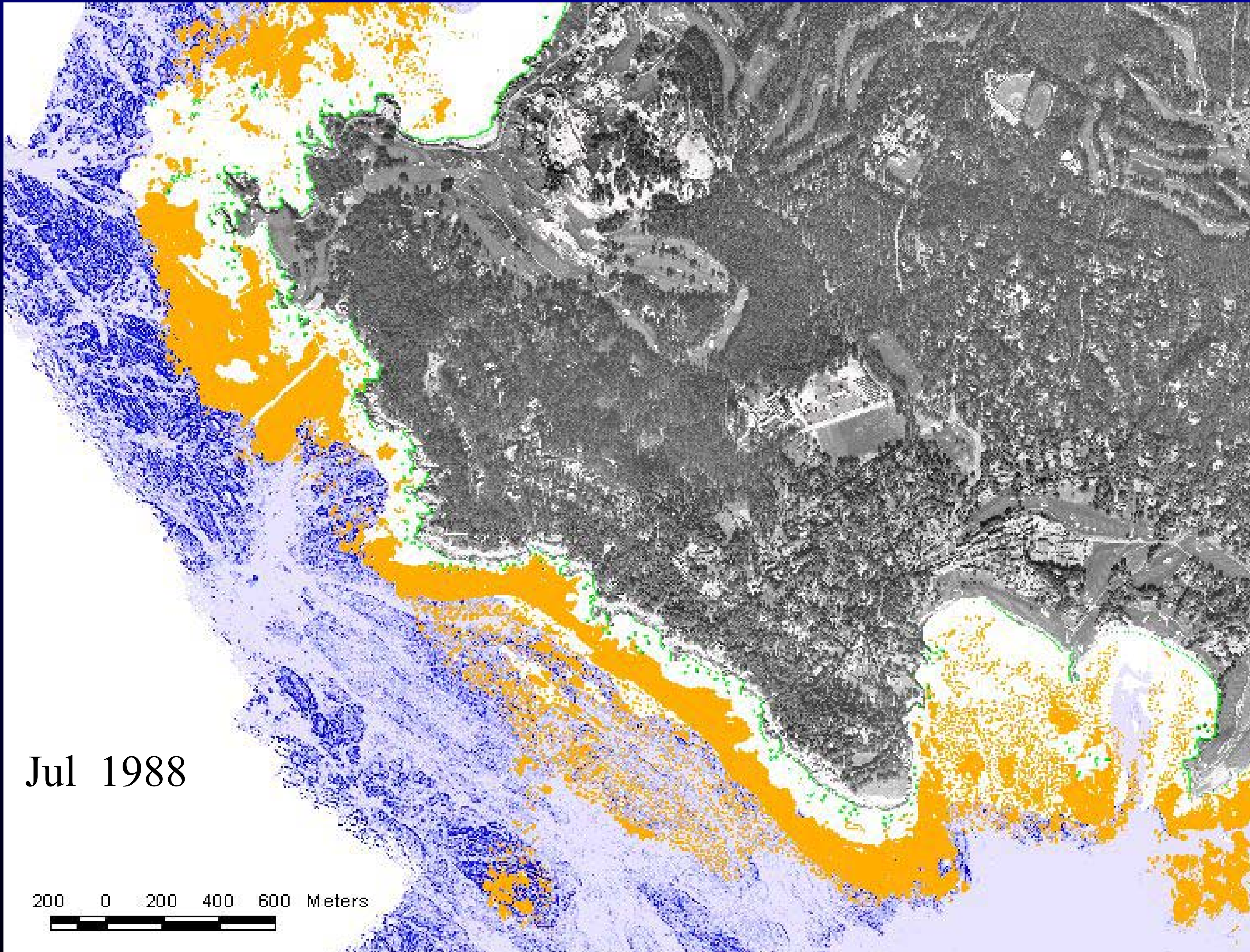
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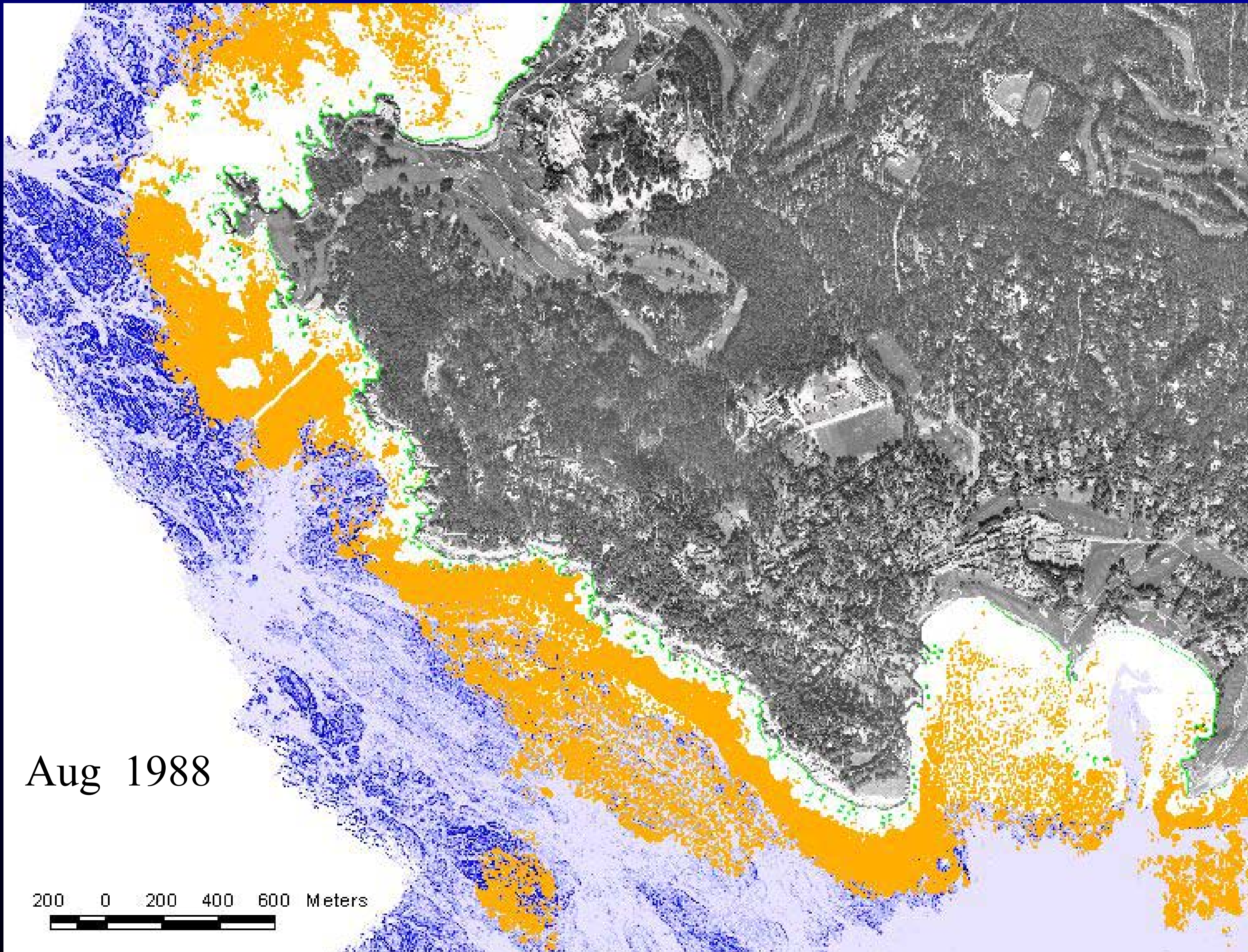
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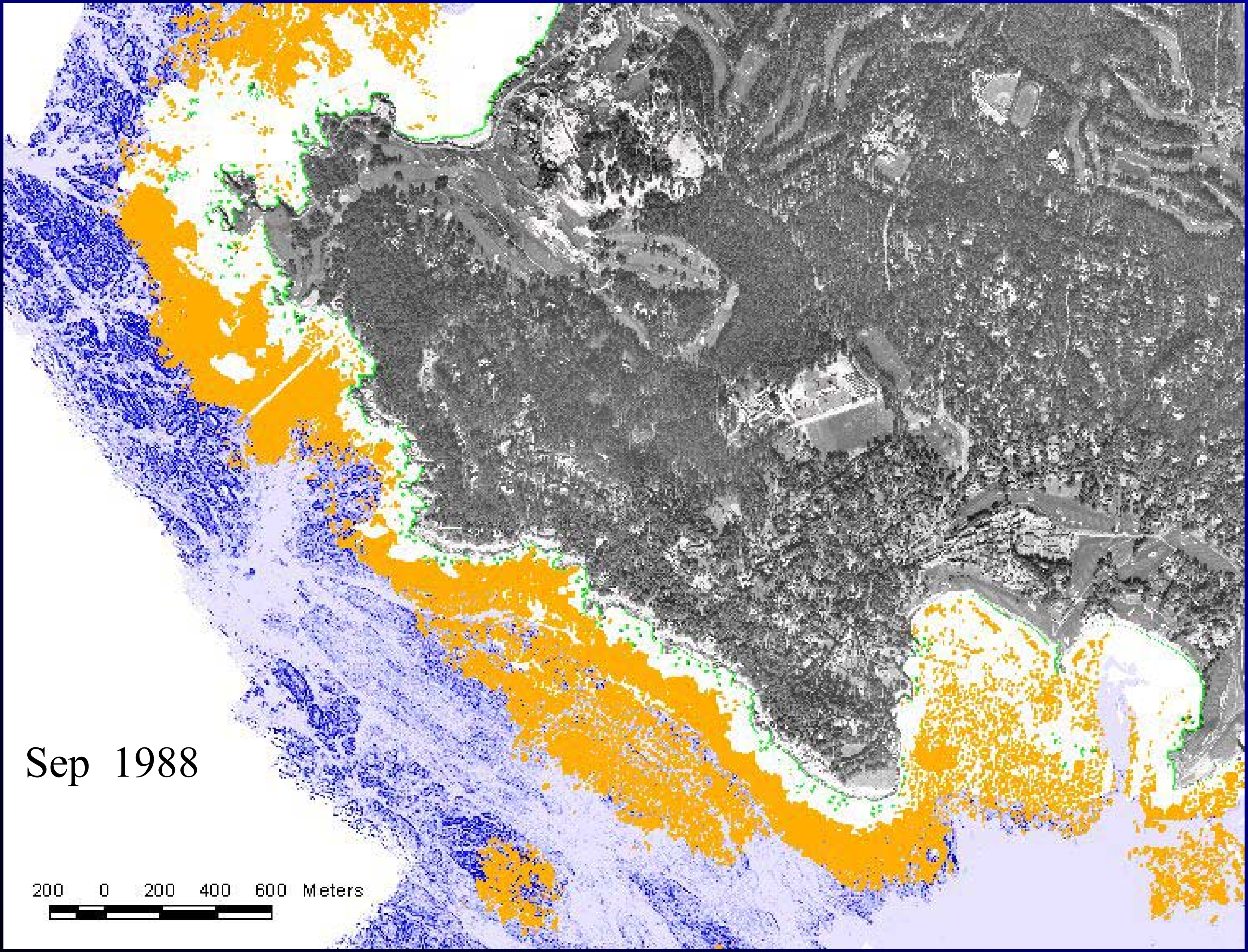
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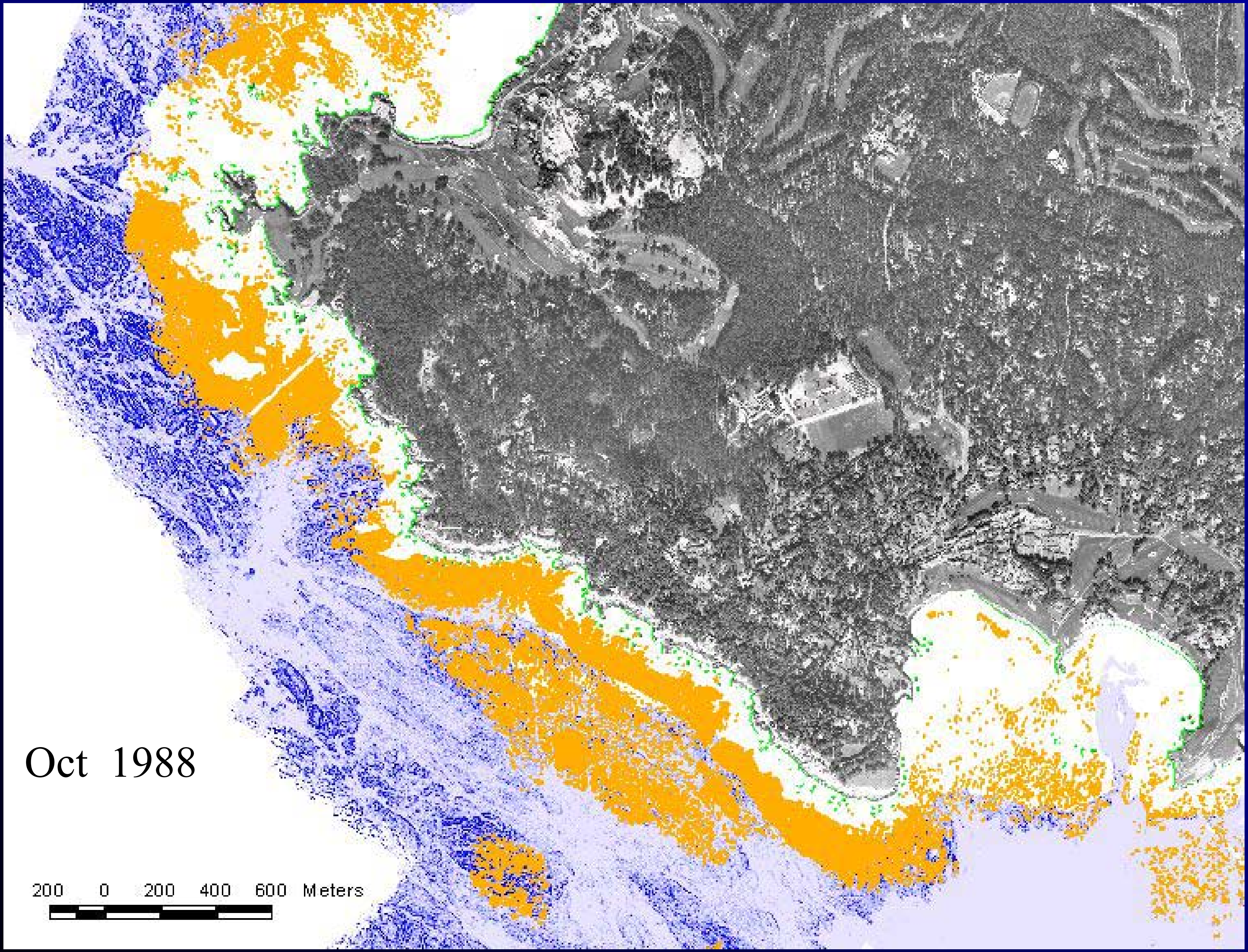
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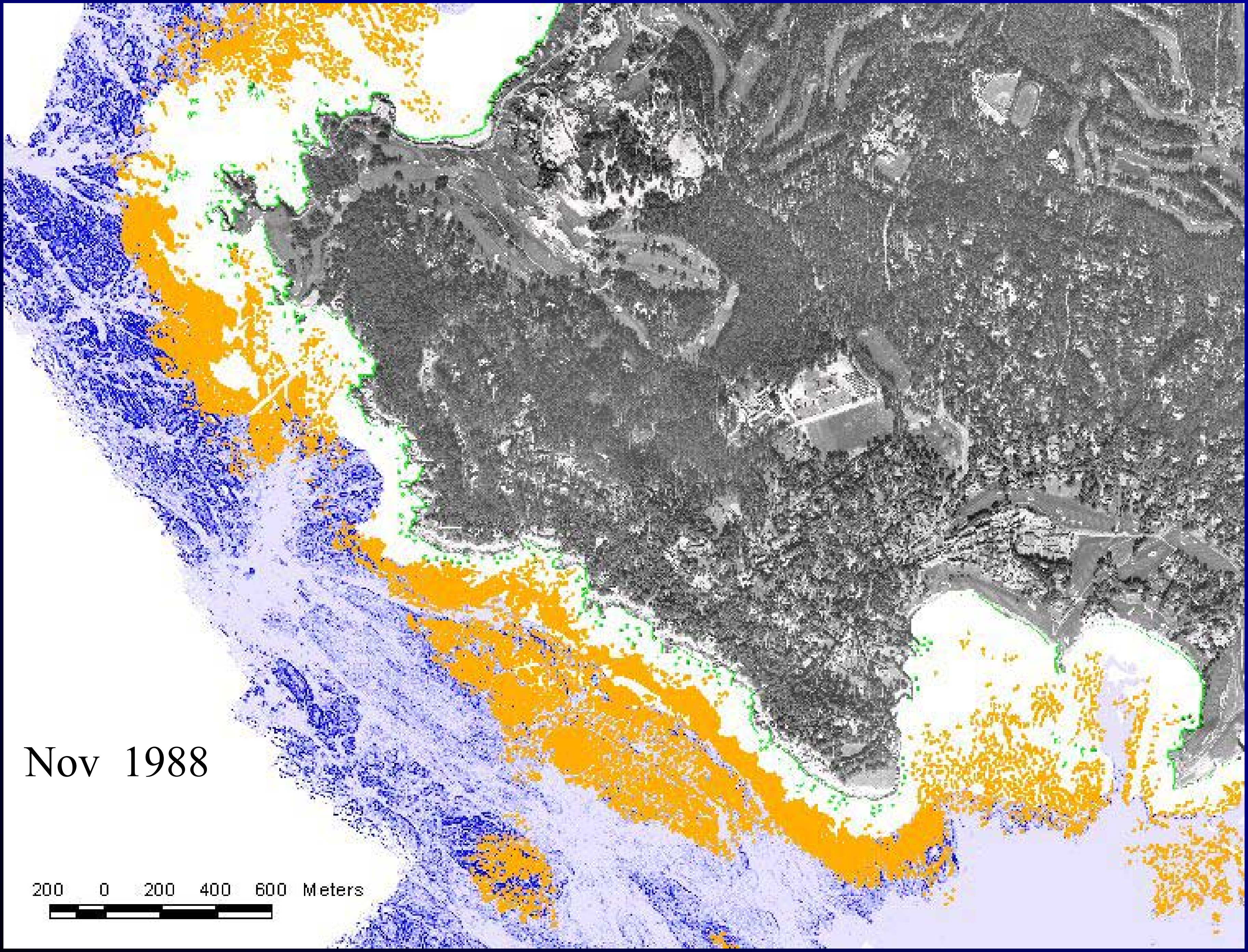
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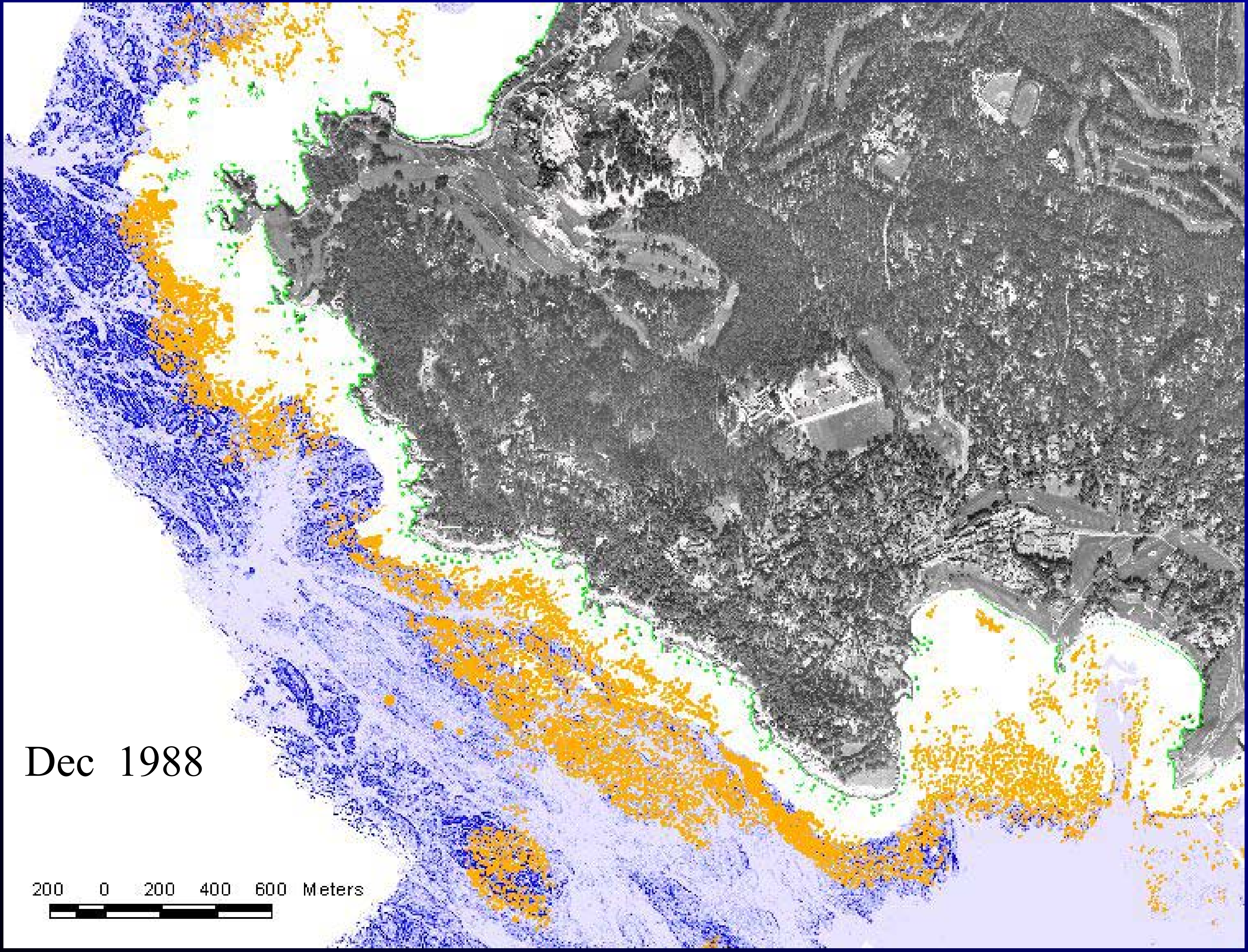
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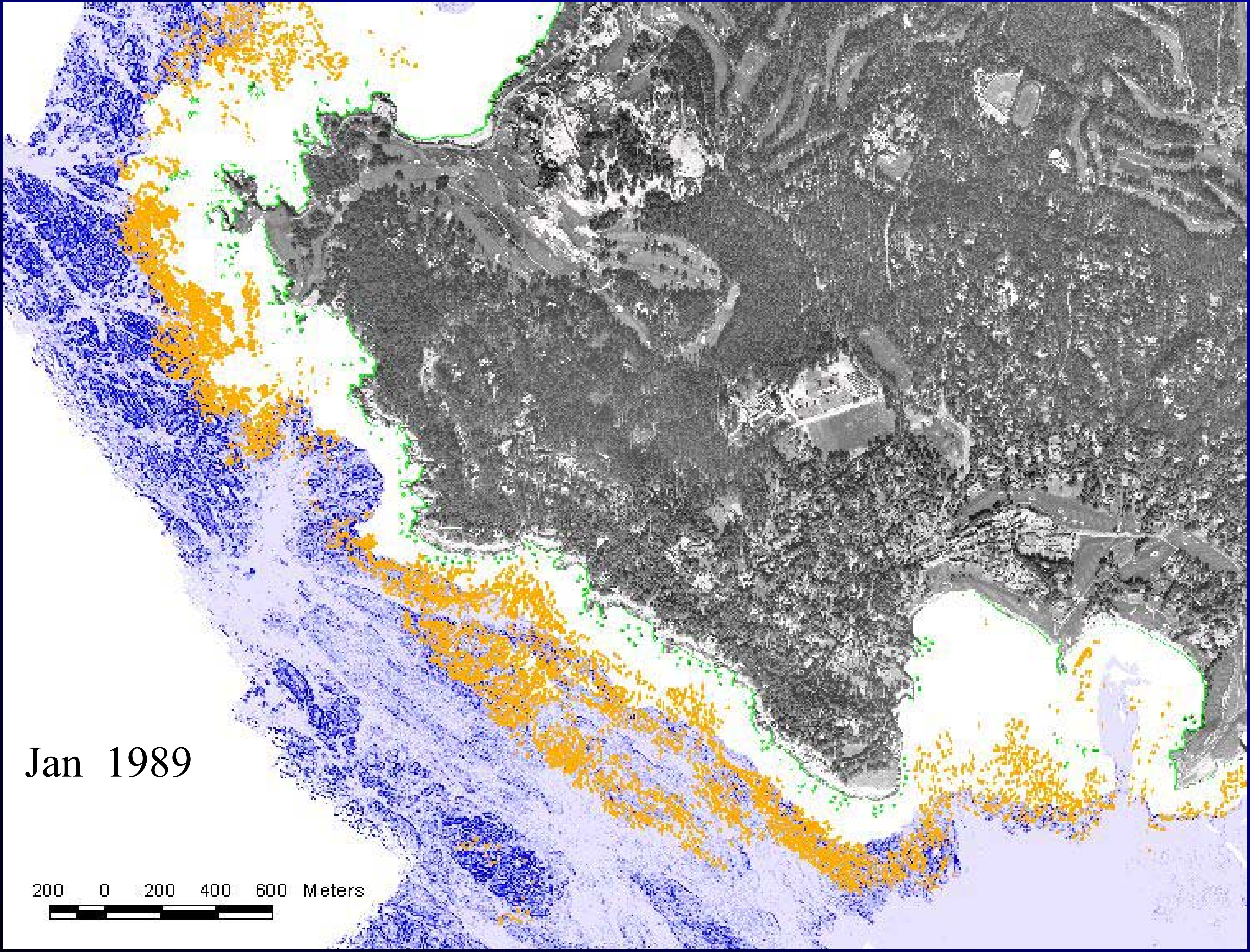
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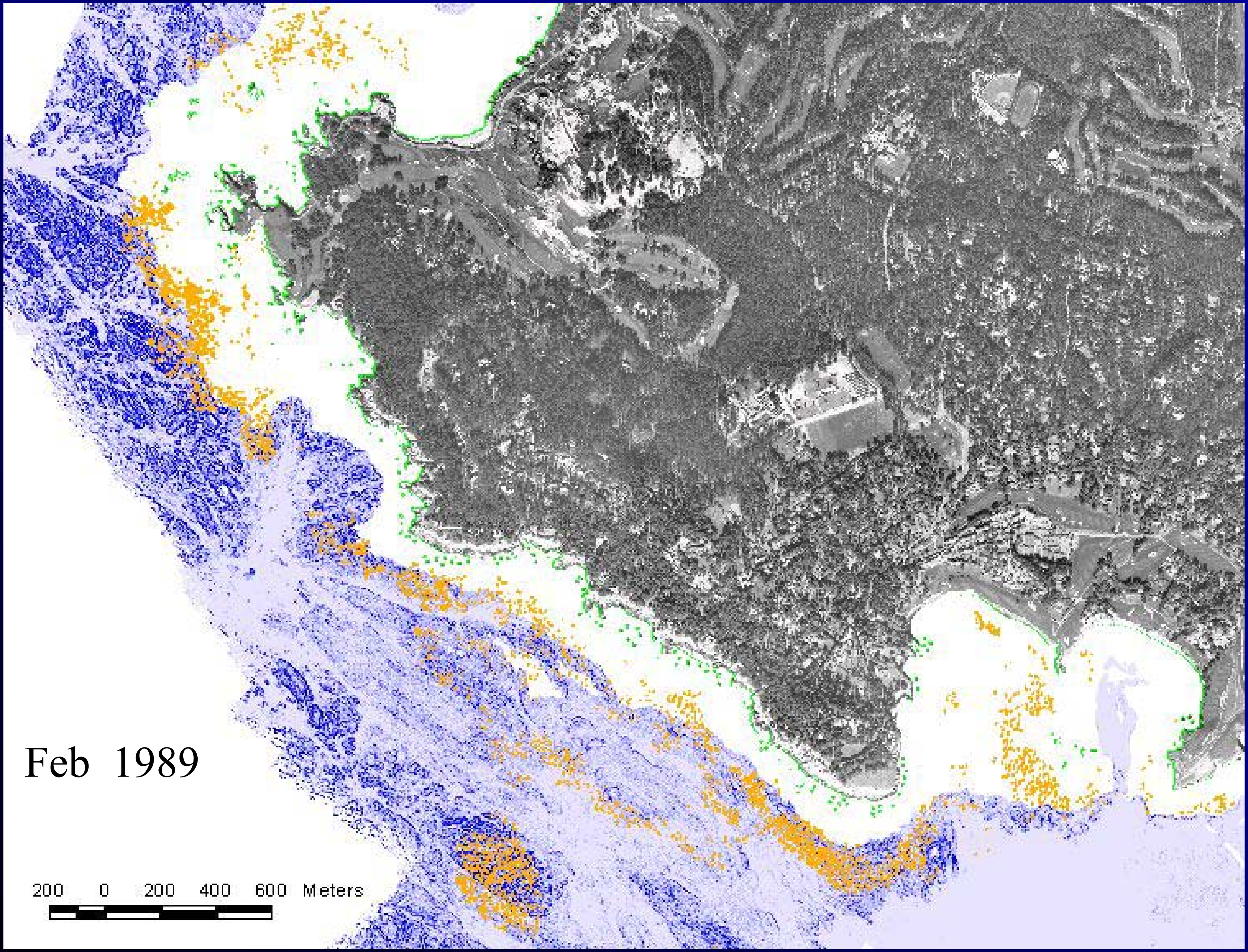

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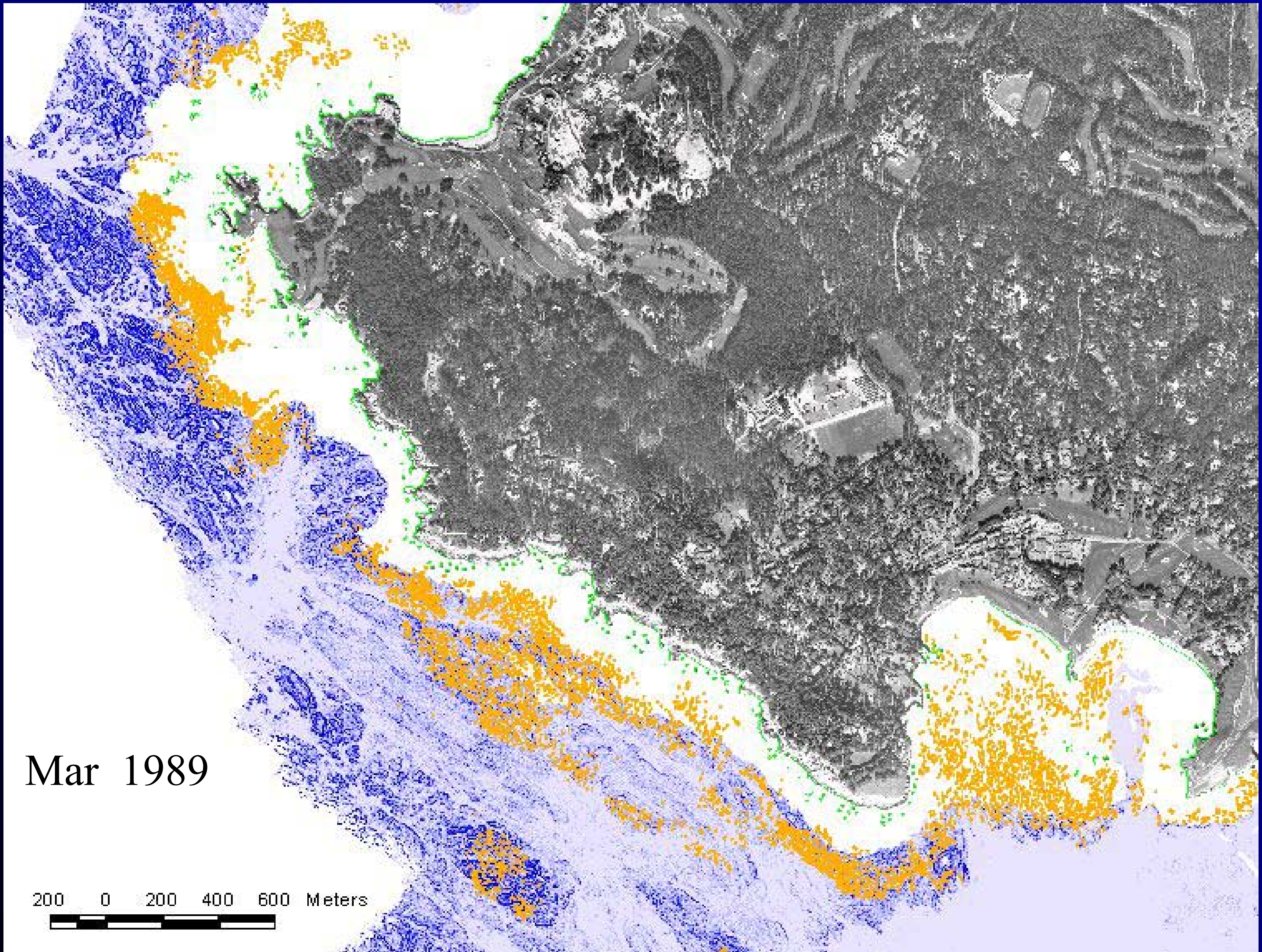
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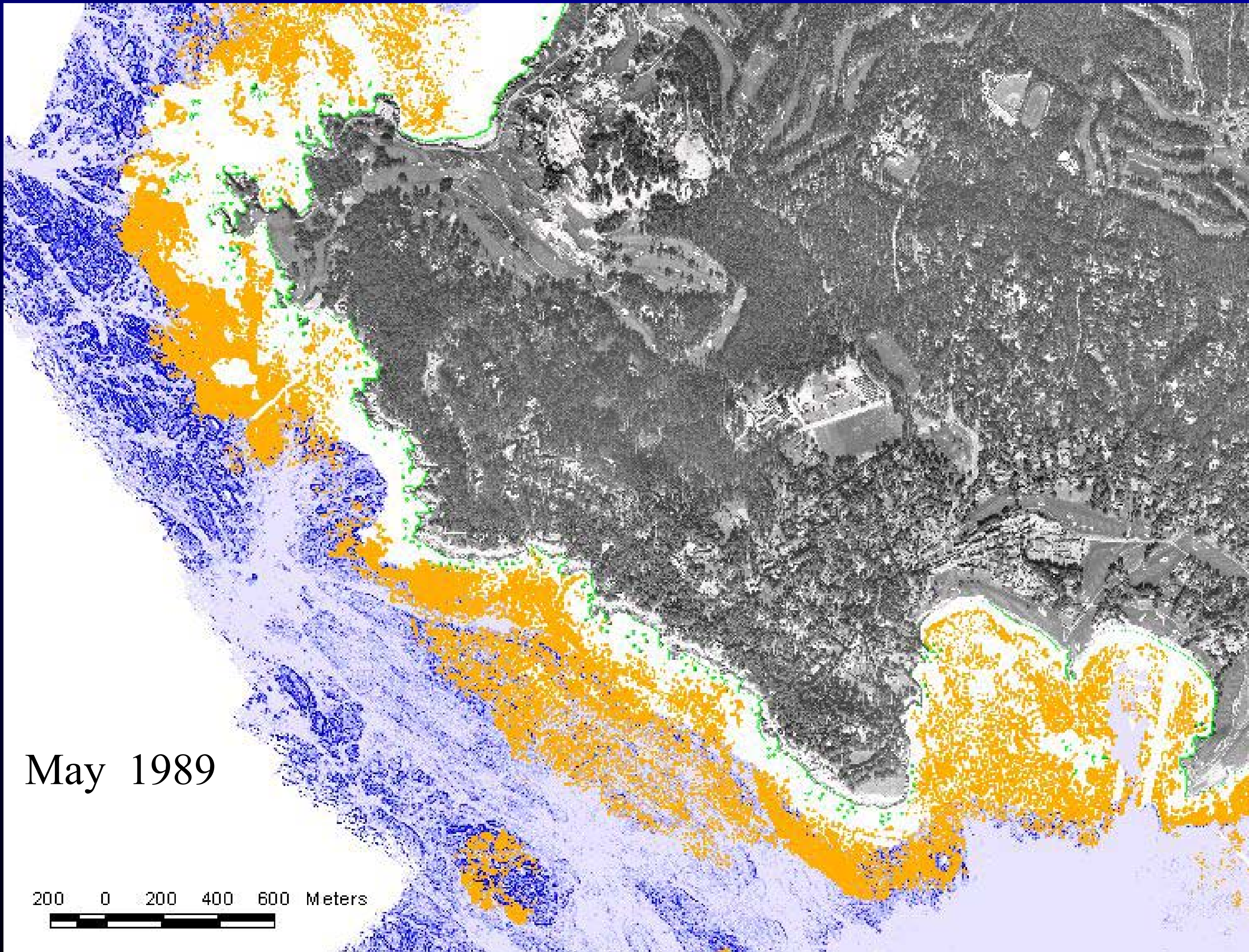
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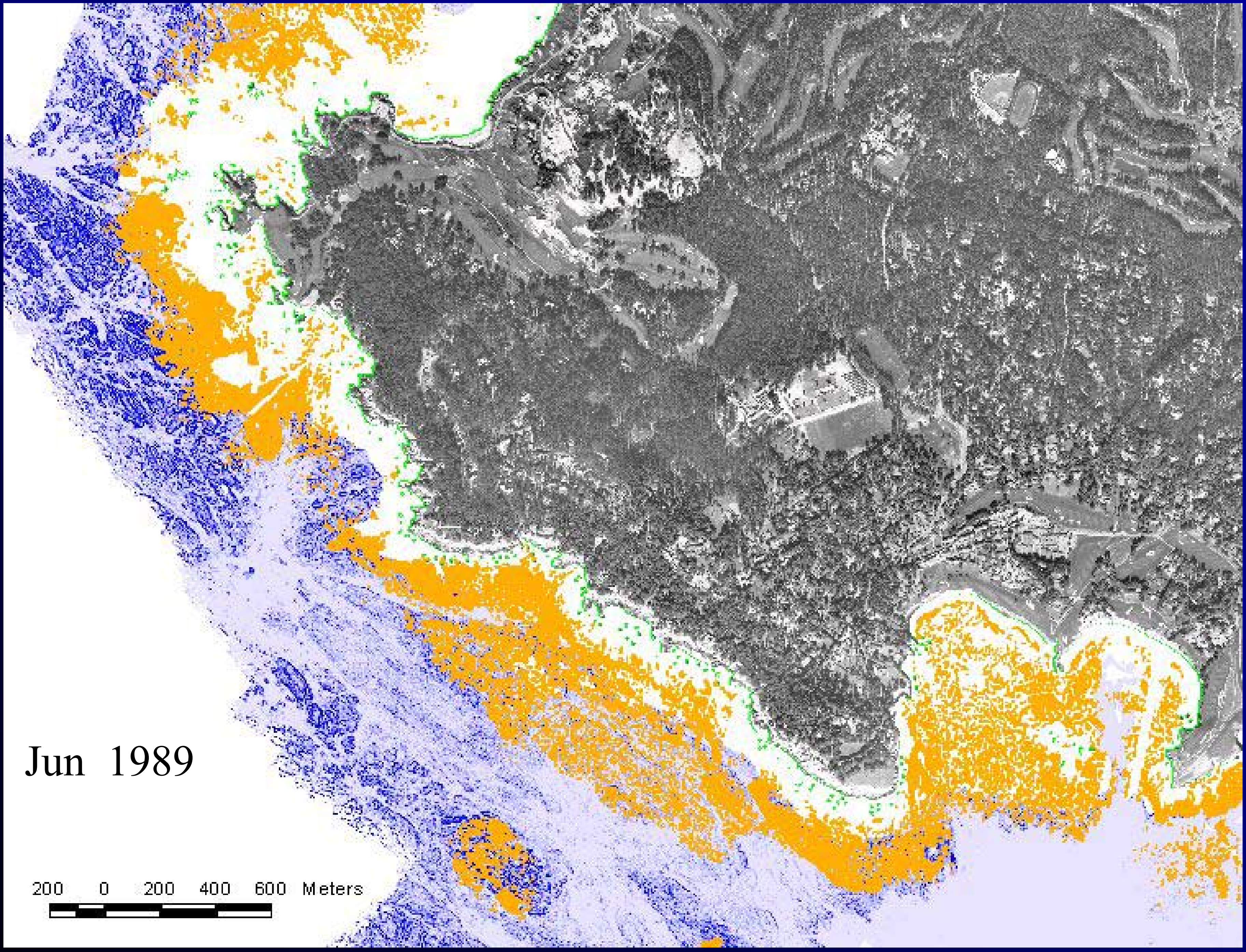
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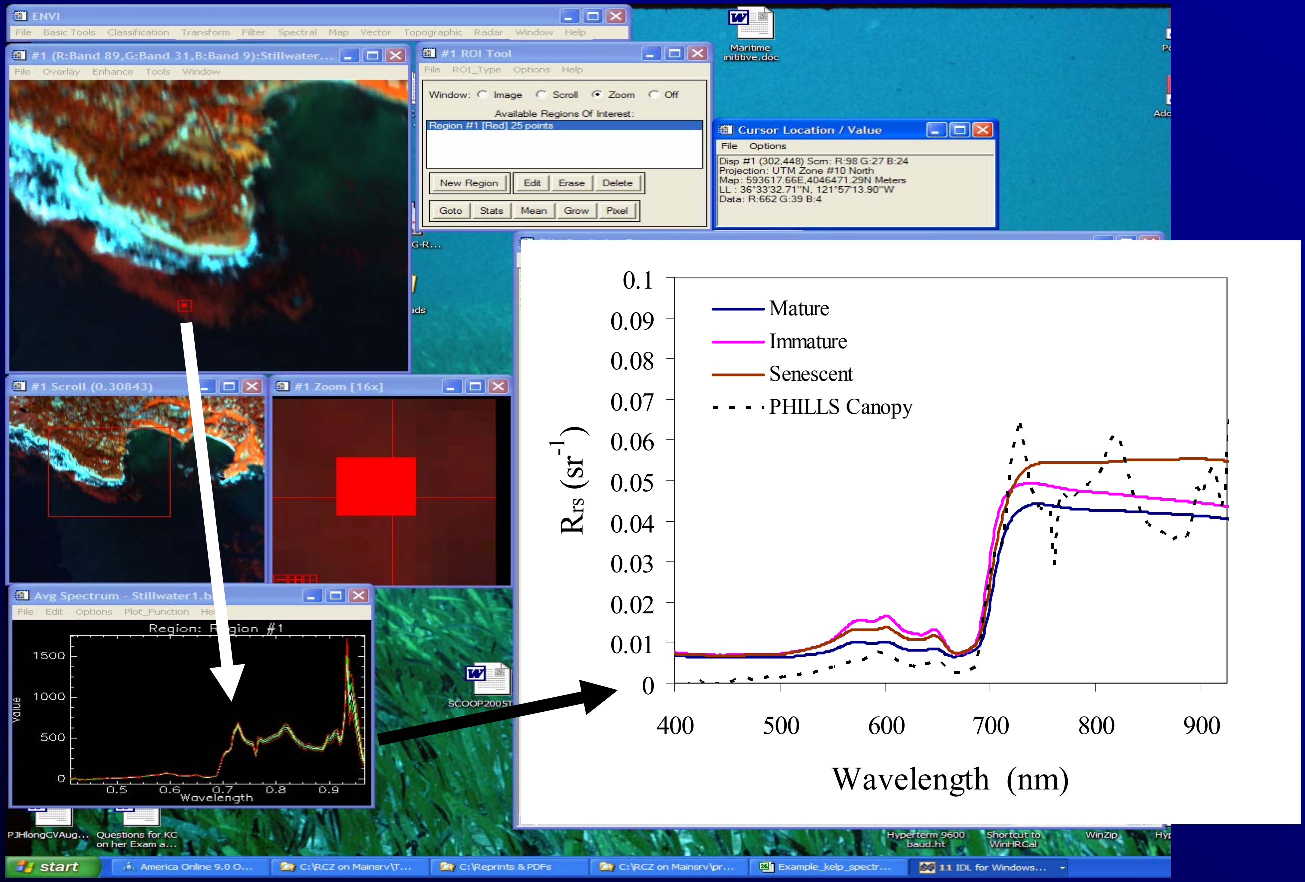
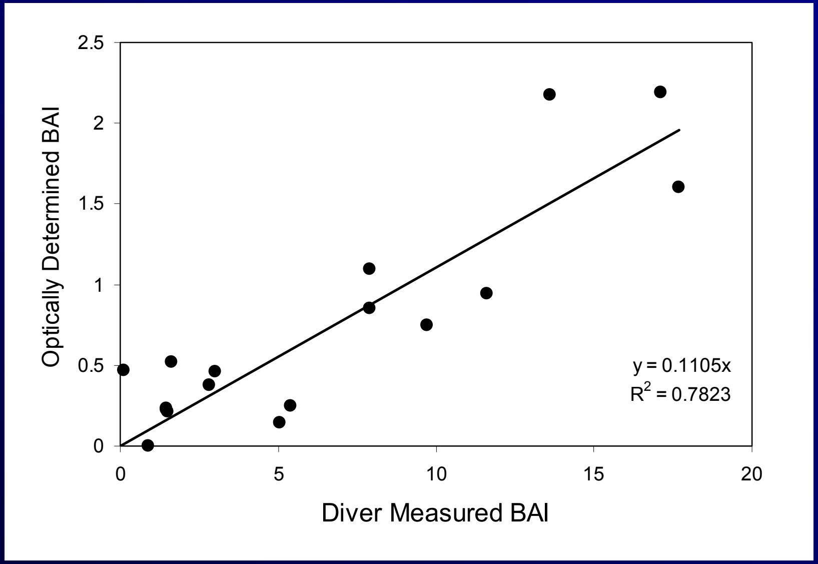
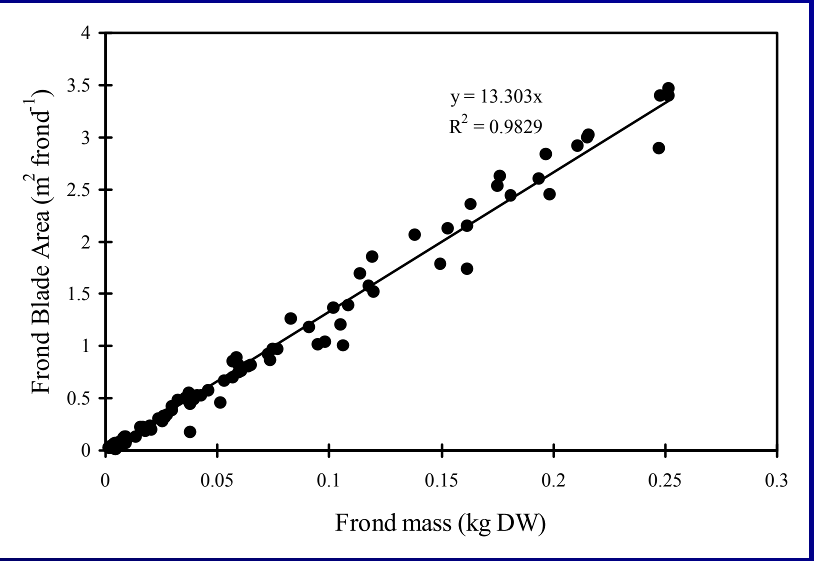
• PHILLS spectra are similar to lab measures:



NDVI can provide optical estimates of kelp abundance

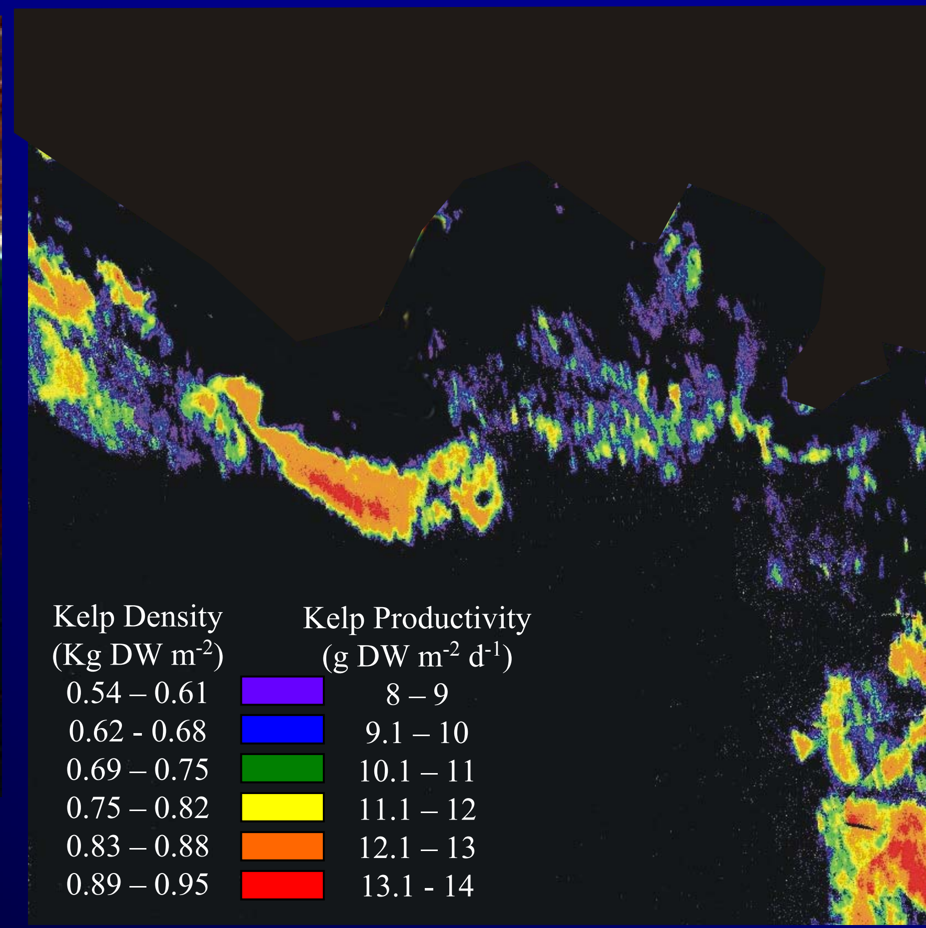
- **Converting NDVI into absolute kelp abundance and productivity:**



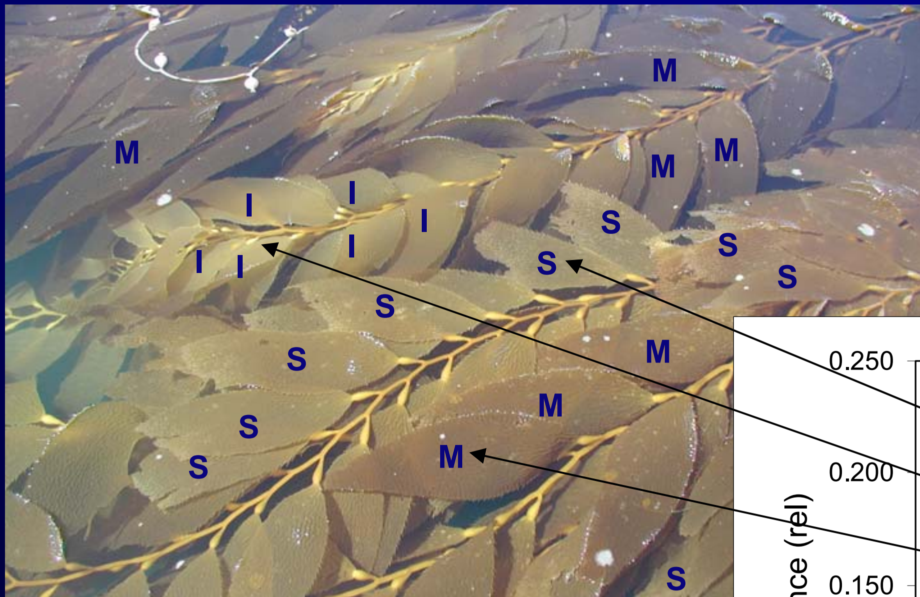


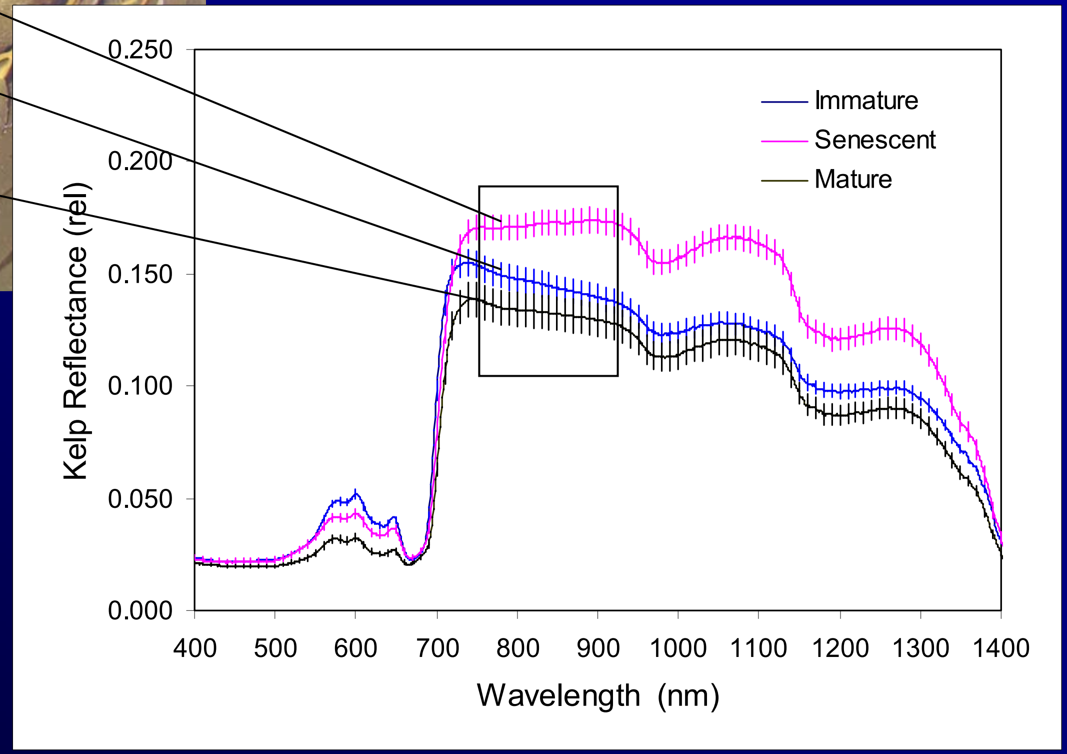
- **Optical BAI = NDVI/0.71**
- **True BAI = Optical BAI * 9.04**
- **Biomass = True BAI/13.3**
- **Productivity = Biomass * 14.7**

NDVI Derived Density and Productivity of Giant Kelp

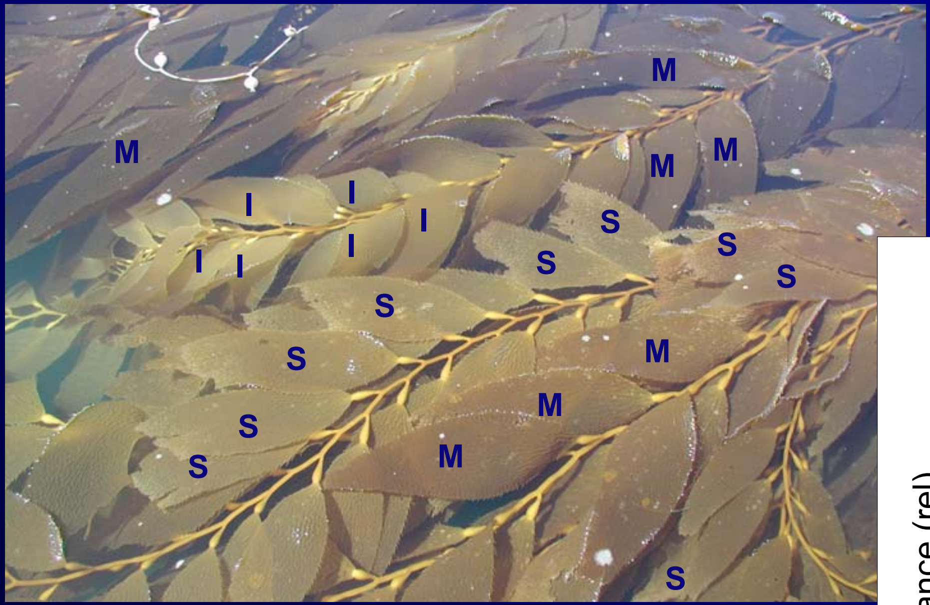


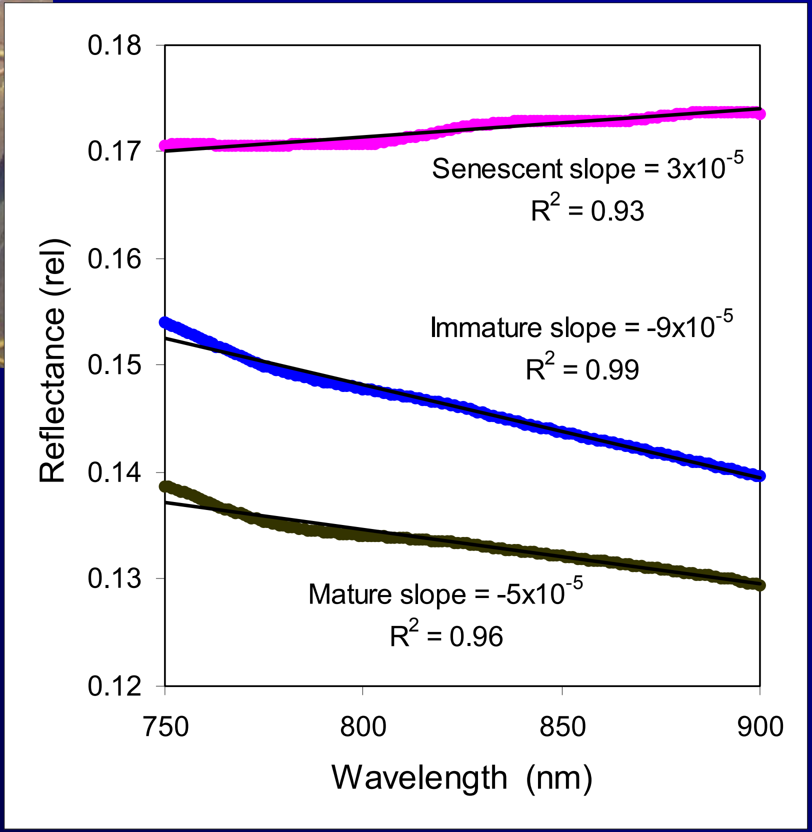
Kelp reflectance spectra show age-dependent differences



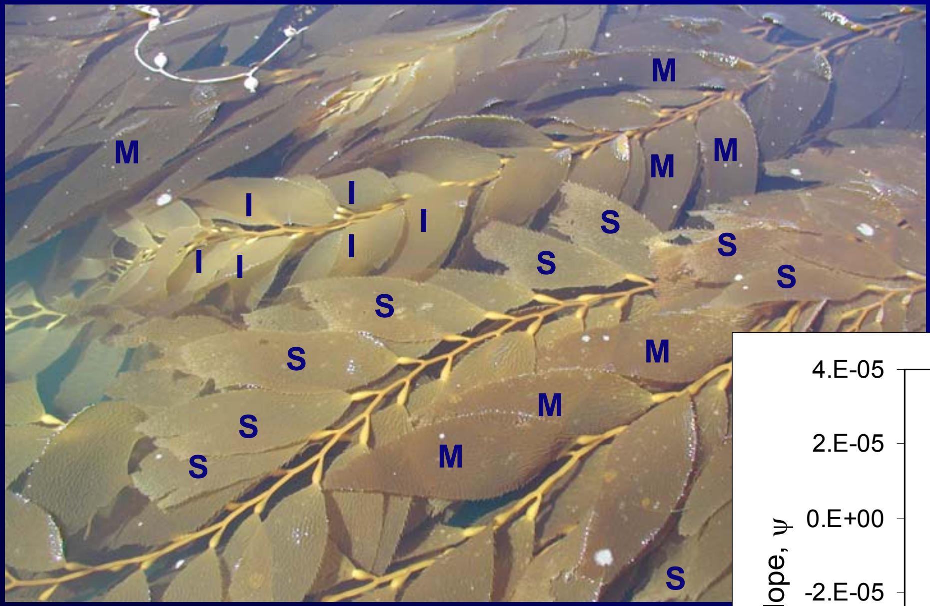


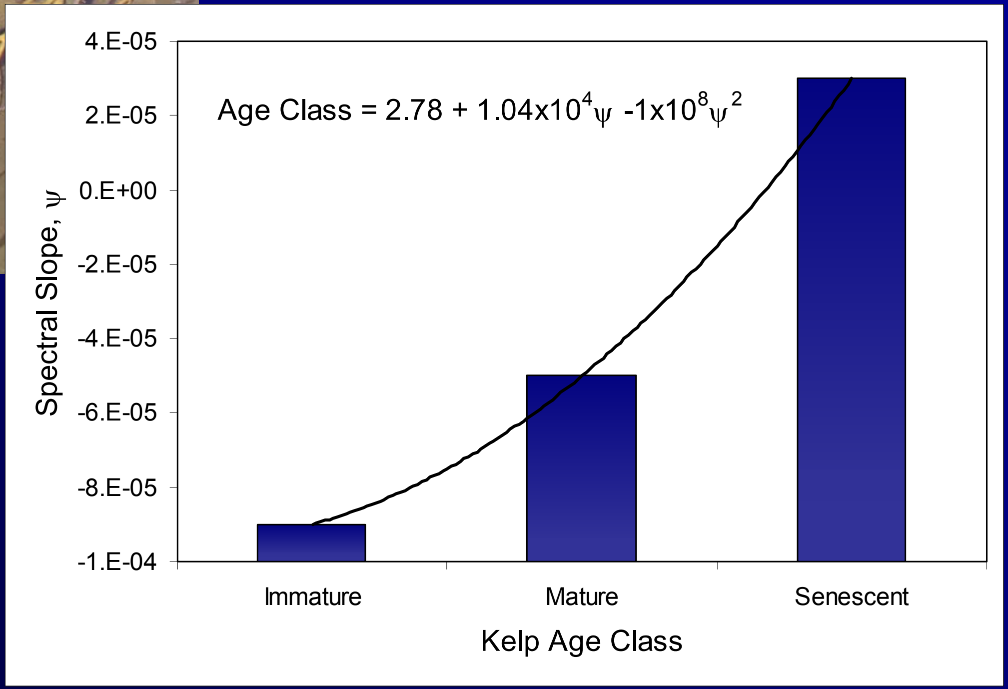
Age Class-dependent spectral slopes…..

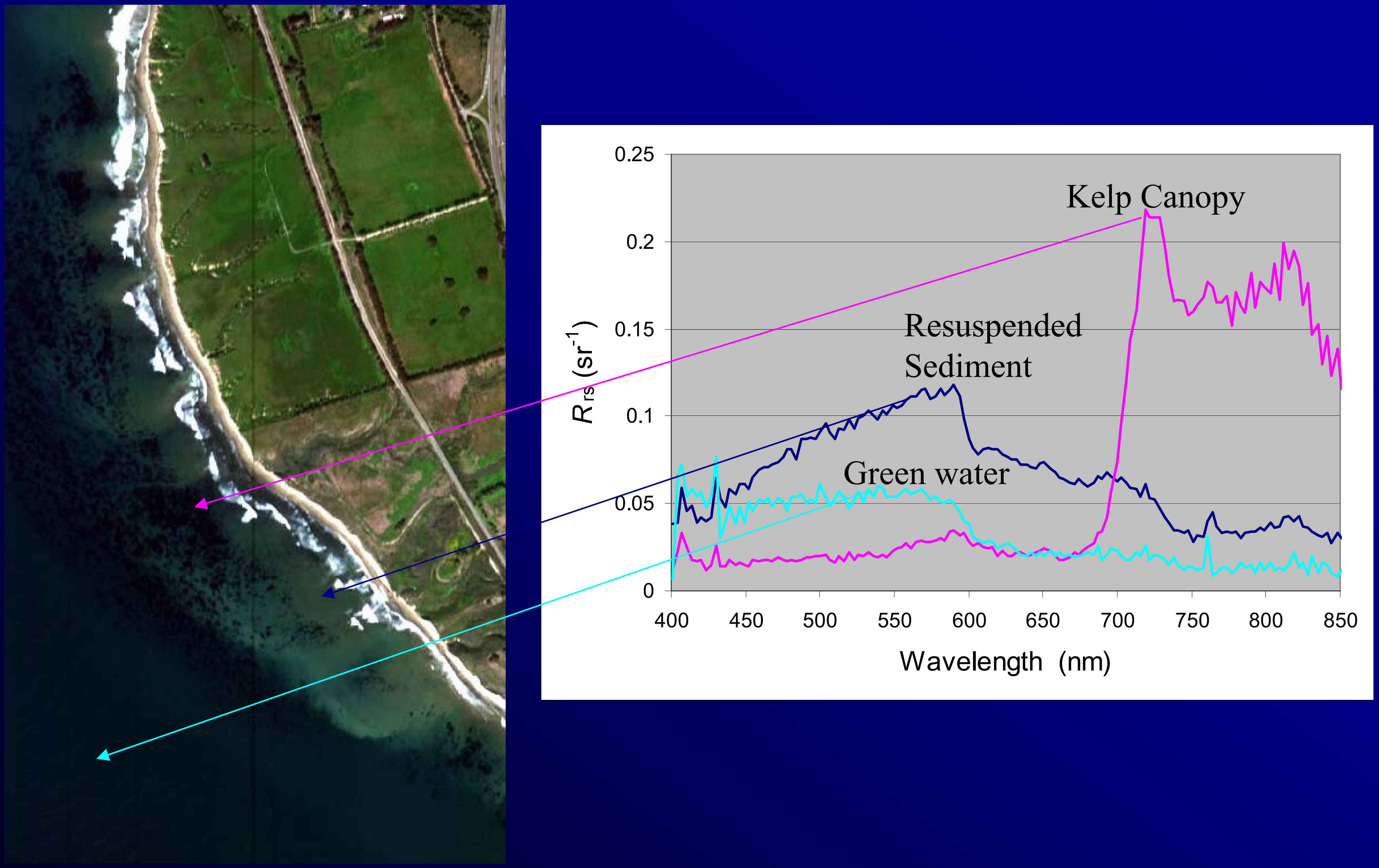




…may permit estimation of mean age class (i.e. condition) of the kelp canopy






Kelp Canopy
Resuspended
Sediment
Green water
0.25
0.2
0.15
0.1
0.05
0
R_{rs} (sr^{-1})
400
450
500
550
600
650
700
750
800
850
Wavelength (nm)

Conclusions

- **Biomass is a strong predictor of submerged macrophyte productivity**
- **Biomass of coastal macrophytes quantified from R_{rs} can be used to estimate system productivity**
  - **Submerged seagrass meadows**
  - **Giant kelp forests**
- **Analysis of spectral slopes from hyperspectral imagery may provide additional information on age and condition of populations that produce floating canopies**