IMPACT OF THE AMUR RIVER DISCHARGE ON THE SHELF REGIONS OF THE OKHOTSK AND JAPAN SEA

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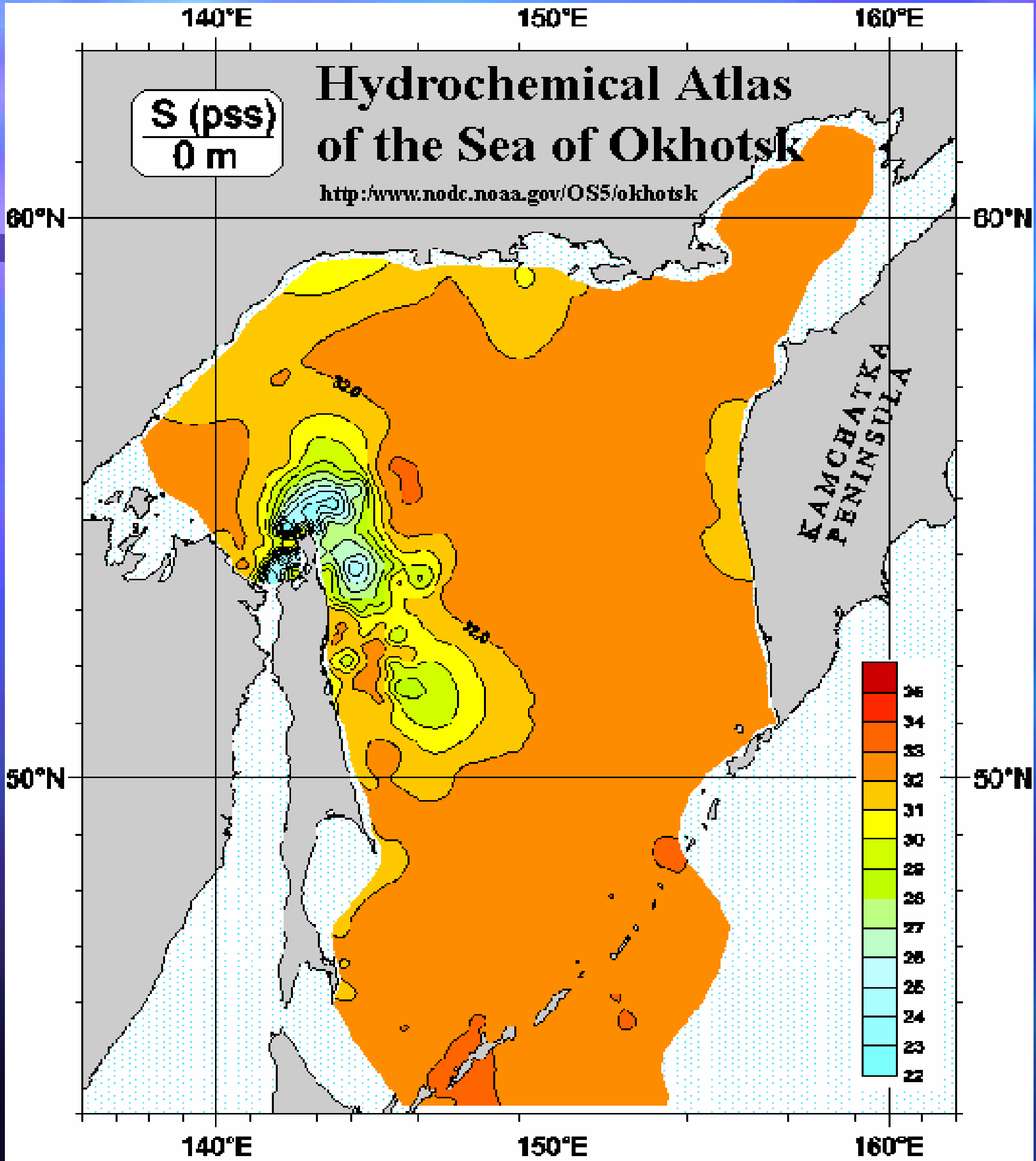
BACKGROUND INFORMATION

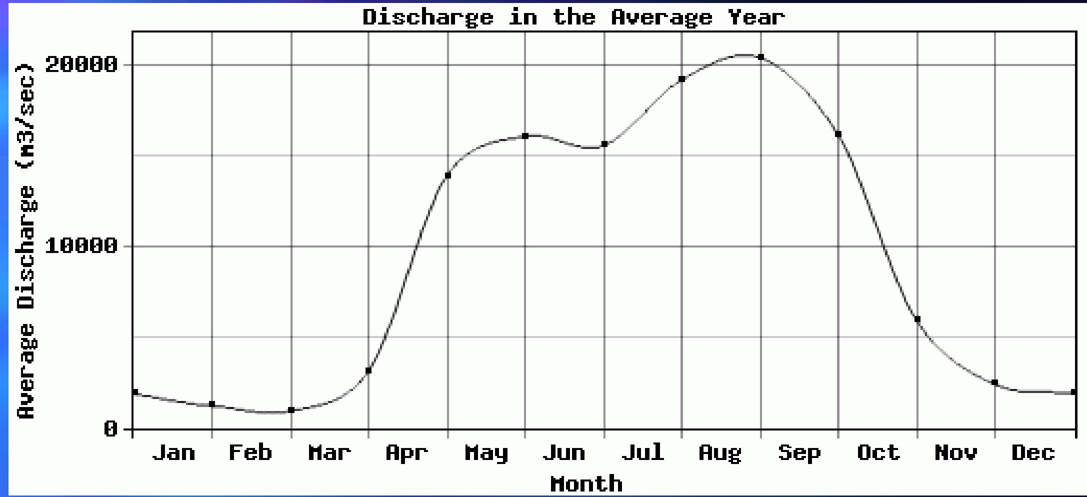
The basin area of the Amur River is 1855000 km^2.

The total length of the Amur River is 4,350 km.

The total annual discharge of the Amur River is 394 km^3

The Amur River brings into the sea about 24.0 million tons of particulate matter, 20.2 million tons of dissolved substances, and 5.3 million tons of organic matter.





The maximum Amur River discharge occurs during summer (from May to October). In summer the background sea level difference between the Japan Sea and the Sea of Okhotsk becomes positive and the mean flow is directed northward. The northward flow is stronger under prevailing southerly winds.

The objective of the talk is to characterize the effects of the Amur River discharge on structure and circulation of the shelf regions of the Okhotsk and Japan Seas using satellite data and hydrographic measurements .

HYDROGRAPHYC AND CHEMICAL DATA

were obtained during 3 cruises:

July 2003 - R/V Akademik Oparin (FEB RAS),

July 2005 – R/V Professor Gagarinskiy (FEB RAS)

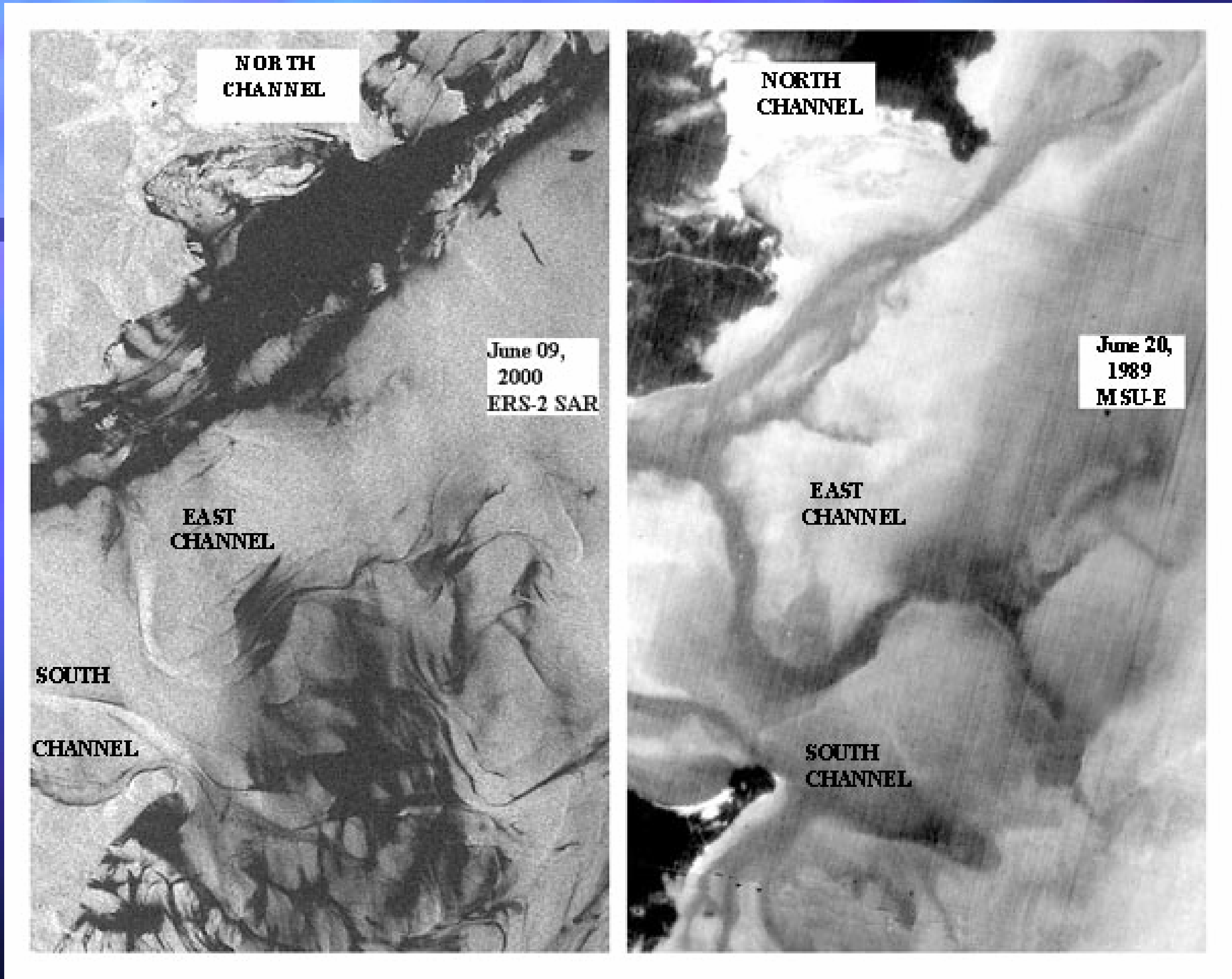
June 2007 – R/V Professor Gagarinskiy (FEB RAS)

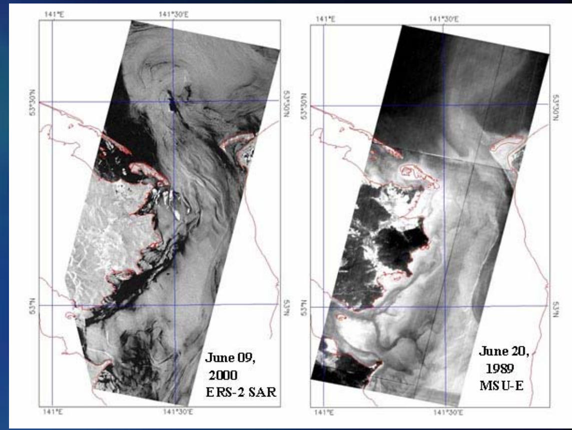
SATELLITE DATA

Satellite information includes sea surface temperature, ocean color and sea surface roughness.

1. **NOAA-AVHRR SST images,**
2. **MODIS/Terra and MODIS/Aqua quasi-true color data.**
3. **ERS SAR images.**

STRUCTURE OF THE AMUR RIVER ESTUARY

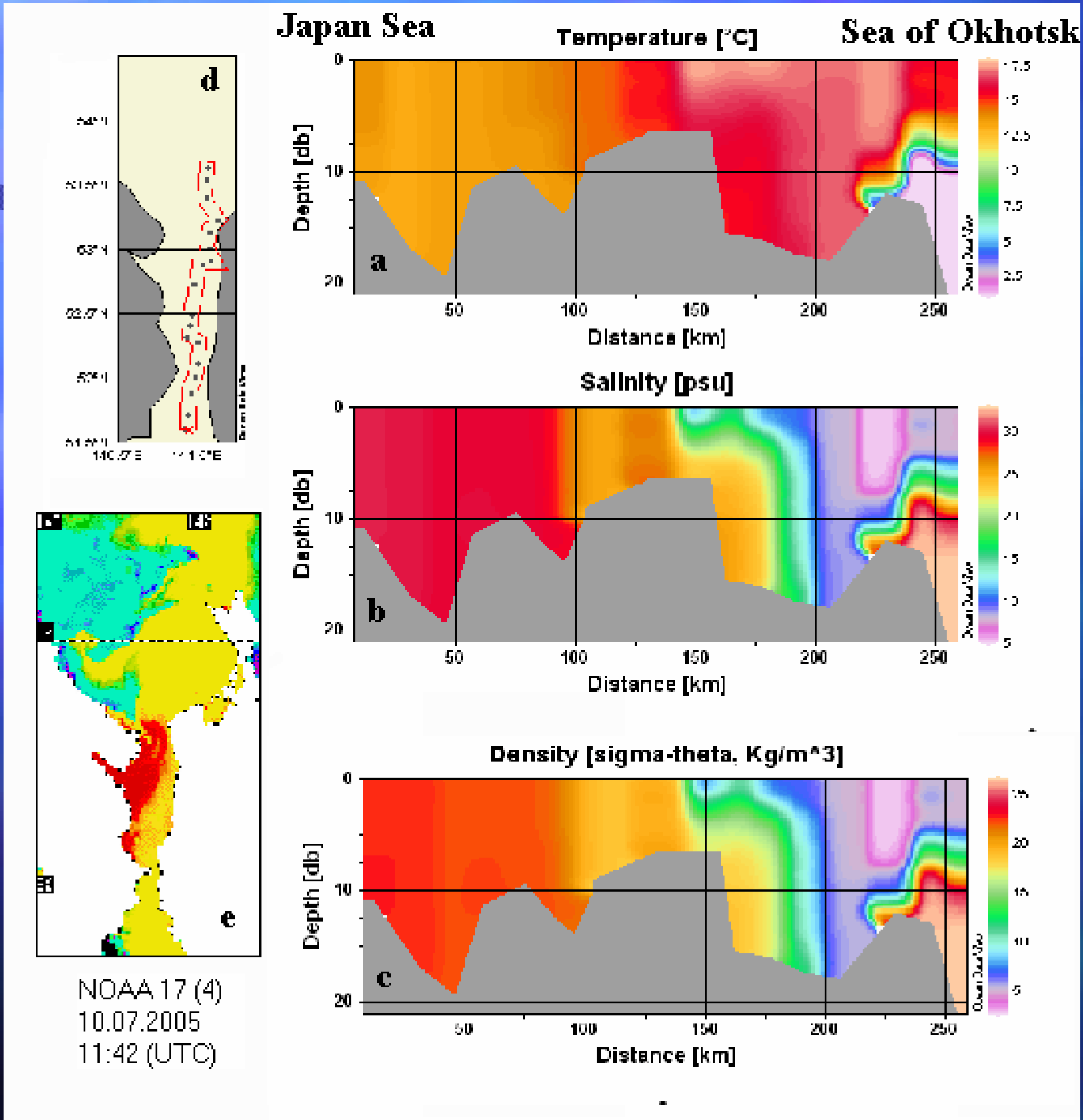




This slide shows high-resolution ERS SAR and visible images of the Amur River estuary.

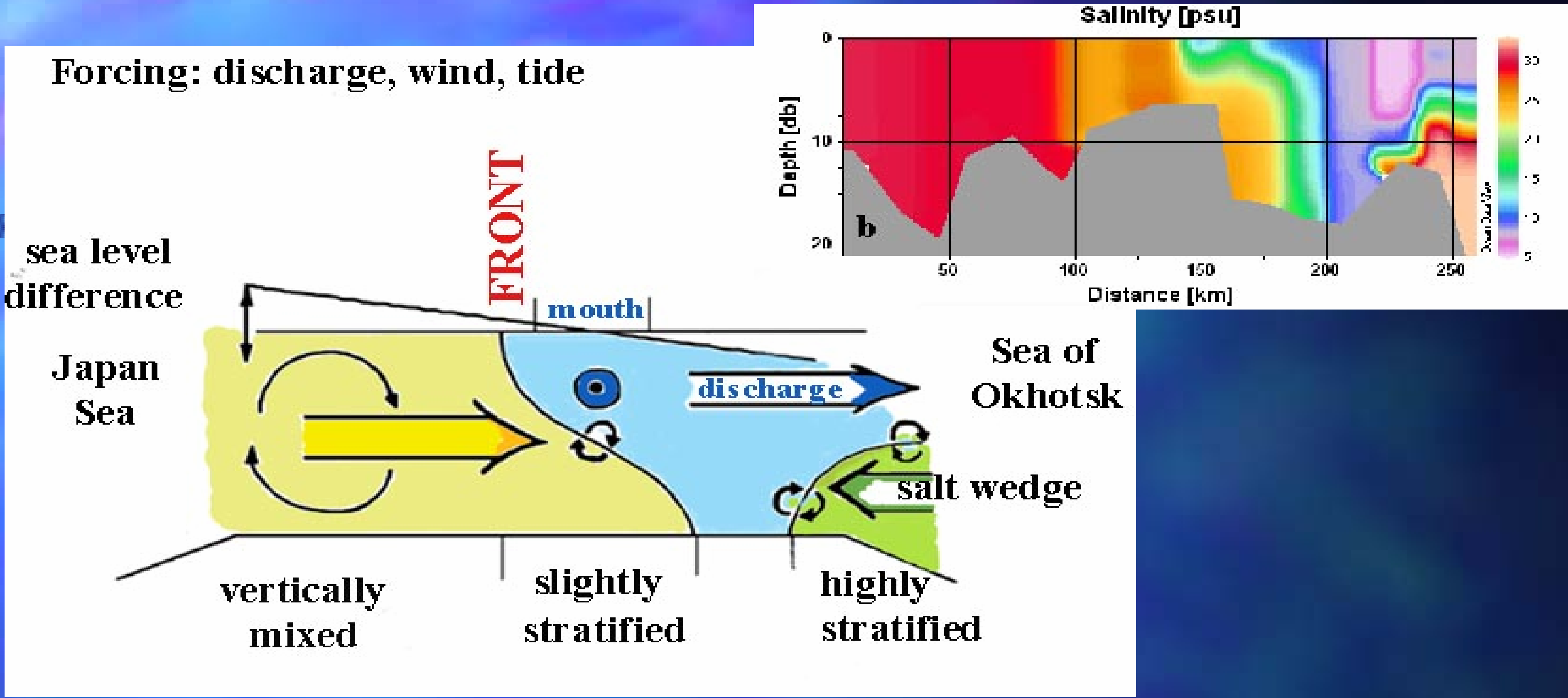
The Amur River discharge branches into three major distributaries: North Channel, South Channel and East Channel. At the mouth of channels, the river water experiences buoyant expansion and mixing due to wave, wind and tidal currents.

STRUCTURE OF THE AMUR RIVER ESTUARY



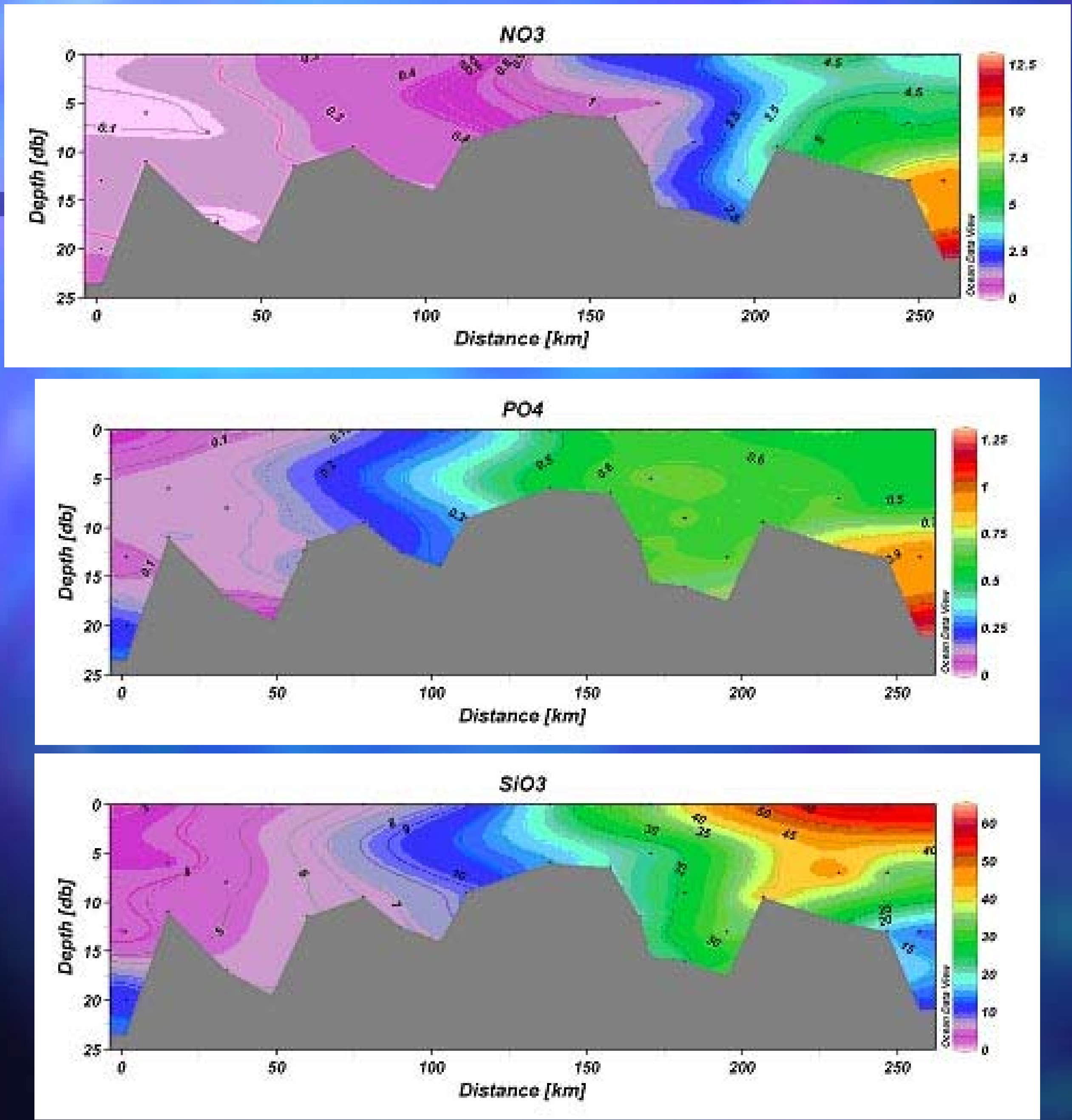
Vertical distribution of temperature (a), salinity (b), density (c) along the section (d) through the Amurskiy Liman in July 2005. The vertically mixed waters are separated from stratified waters by a sharp front. The position of the front is clearly seen in the IR image (e).

STRUCTURE OF THE AMUR RIVER ESTUARY



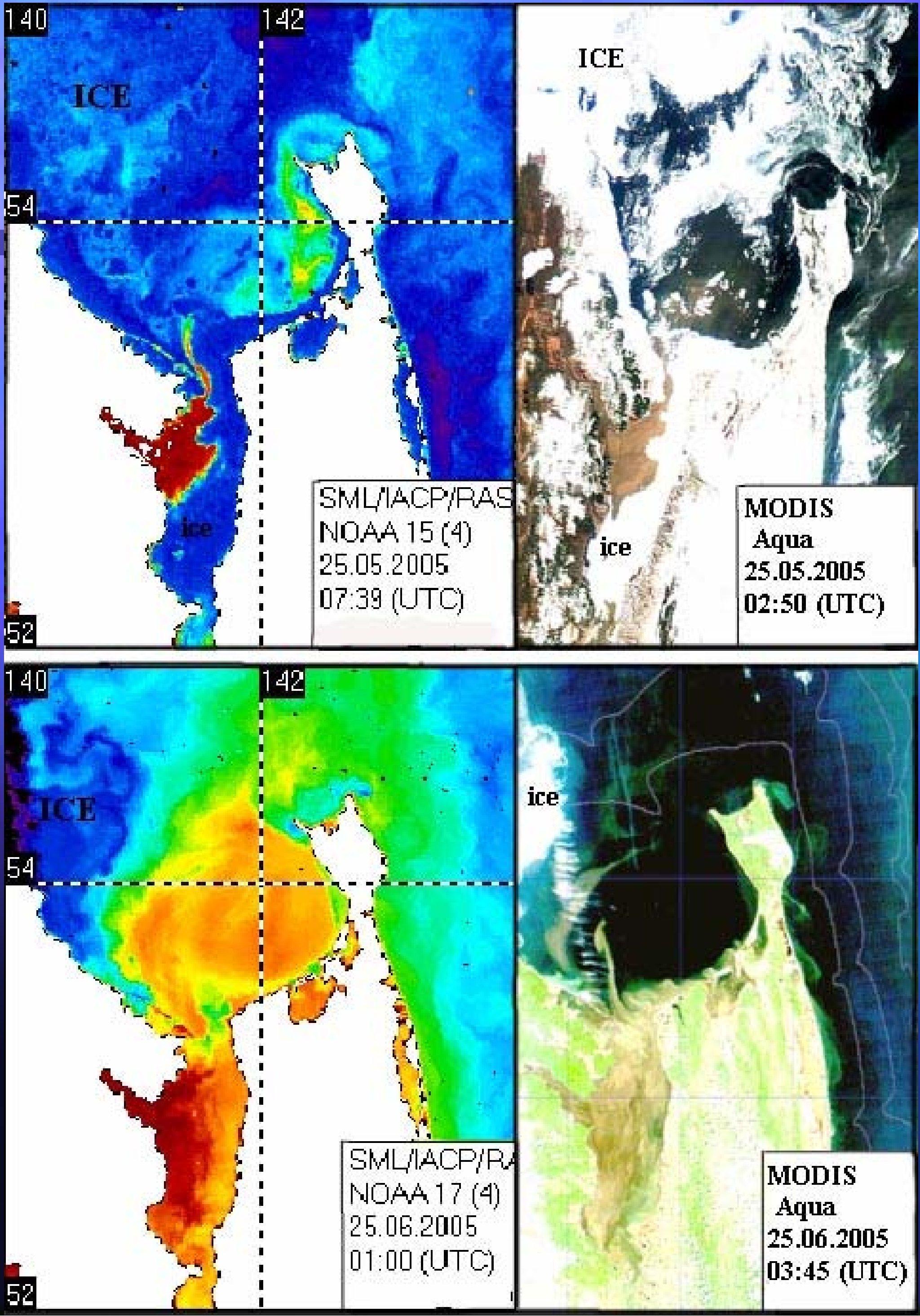
Within the vertically mixed part of the estruary the salinity increases towards the Japan Sea but does not vary with depth. In a slightly stratified part of the Amur River estuary, saltwater and freshwater mix at all depths; however, the lower layers of water typically remain saltier than the upper layers. Vertically mixed freshwater regime is directly connected with the mouth of the river. In this area the mean freshwater flow is strong. In the northern part of the Liman the estuary turns into highly stratified estuary. Near the northern mouth of estuary a wedge of the Sea of Okhotsk salt and cold water seems to intrude into the Liman.

DISTRIBUTION OF NUTRIENTS IN THE AMUR RIVER ESTUARY



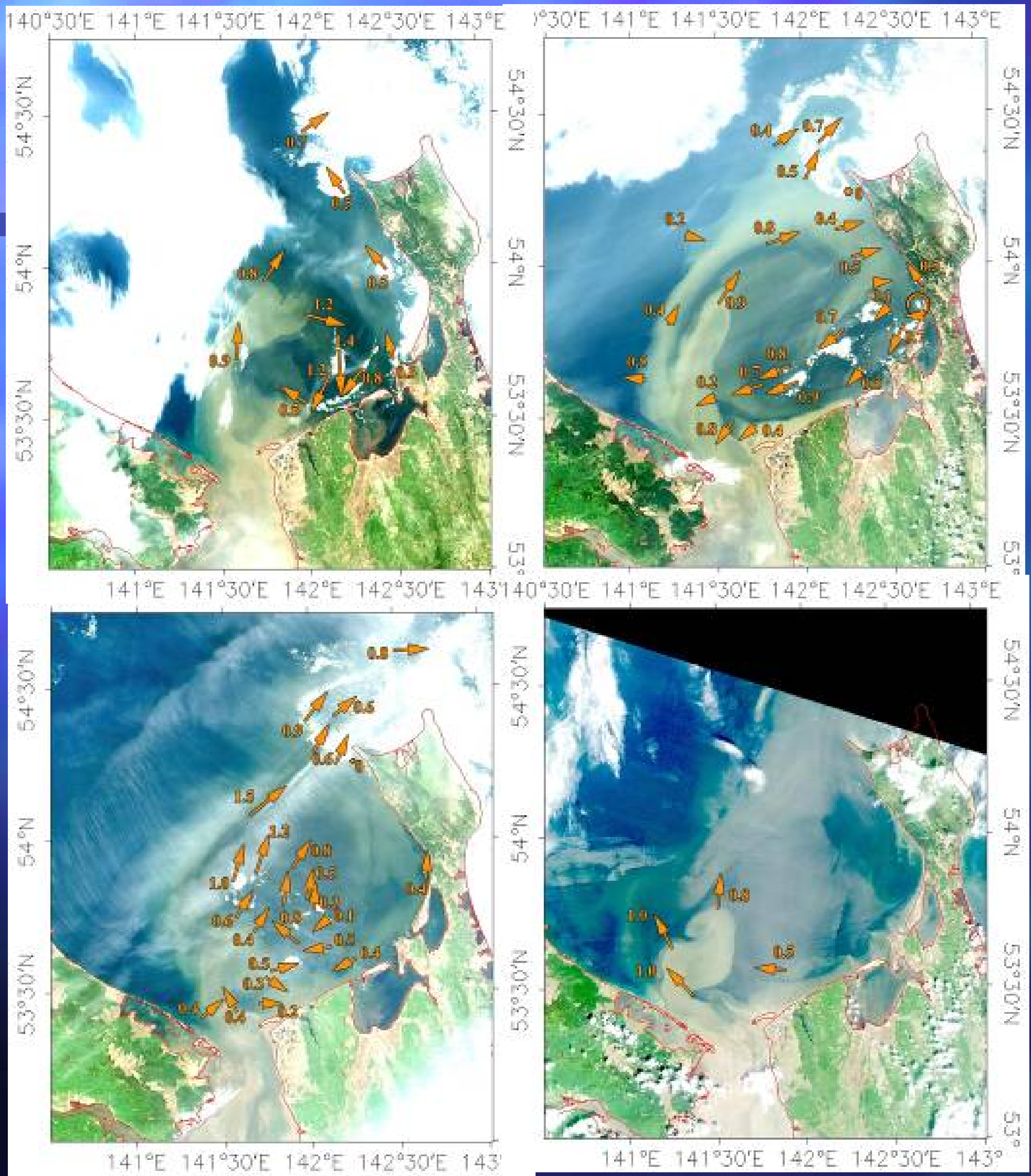
The distribution of nutrients is strongly linked to the water mass structure. Low nutrients concentrations are observed within the vertically mixed waters originated from the Japan Sea. It is seen that the vertical distribution of silicate differs from that of phosphate and nitrate. High values of silicate are related with the Amur River discharge. Highest nitrate and phosphate concentrations are found in the salt wedge of the Sea of Okhotsk water.

FORMATION OF THE AMUR RIVER PLUME IN THE SAKHALIN BAY



Satellite – acquired data can provide information on the distribution of the Amur River water and sediments on the continental shelf of the Sea of Okhotsk. This figure shows the IR AVHHR images (left panel) and MODIS true color (bands 1-4-3) images (right panel). During spring-summer flood the jet –like outflow from the Liman forms the Amur River plume and associated frontal structure in the Sakhalin Bay.

FORMATION OF THE AMUR RIVER PLUME IN THE SAKHALIN BAY



- On the satellite images (June 2007, « Aqua » and «Terra» satellites) the maps of current speed vectors, calculated by the sea markers method are imposed.
- In the jet current which is passing on periphery of the plume, speed changed in a range from 0.4 to 1.5 m/s.

A dynamical system for classifying buoyant discharges (Garvine, 1995):

Kelvin number: $K=L/L_D$

L – length scale

Radius of deformation $L_D = c/f = (g'h)^{0.5} / f$

c - phase speed of long internal waves on an interface between layers, f - Coriolis parameter, h - thickness of plume

The reduced acceleration of gravity: $g' = g(\rho_2 - \rho_1)/\rho_2$

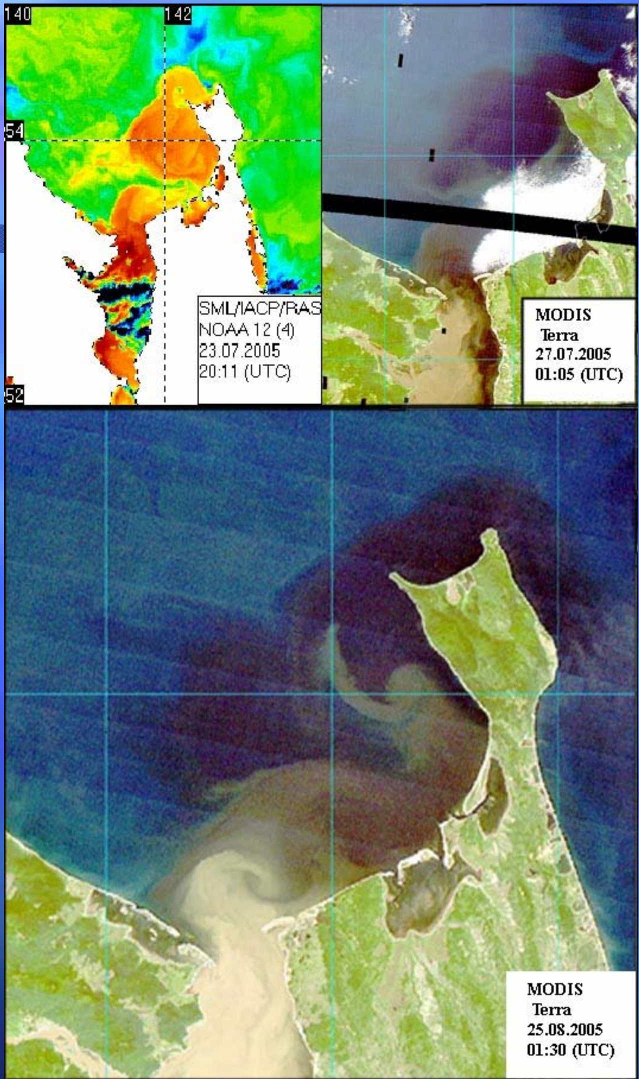
g - acceleration of gravity, ρ_1 and ρ_2 - density of the top and bottom layer

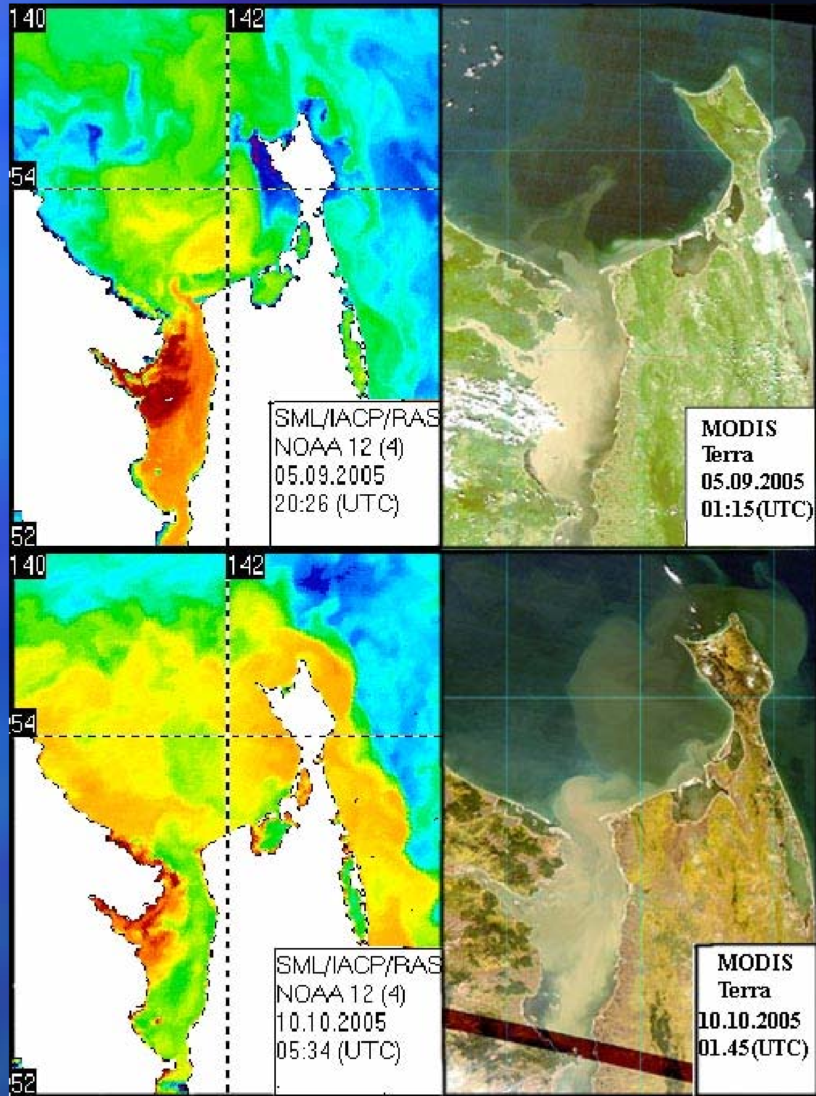
Froude number: $F=u/c$

u - characteristic speed

The calculated values of the Kelvin number ($K = 2 > 1$) and Froude number ($F = 0.7 < 1$) show that for dynamics of the Amur River discharge during spring-summer flood the effect of the Earth’s rotation is more important, in comparison with the contribution of inertial effects. The regime of movement will be subcritical and the river discharge should extend as superficial current above the layer of more dense surrounding waters .

EVOLUTION OF THE AMUR RIVER PLUME

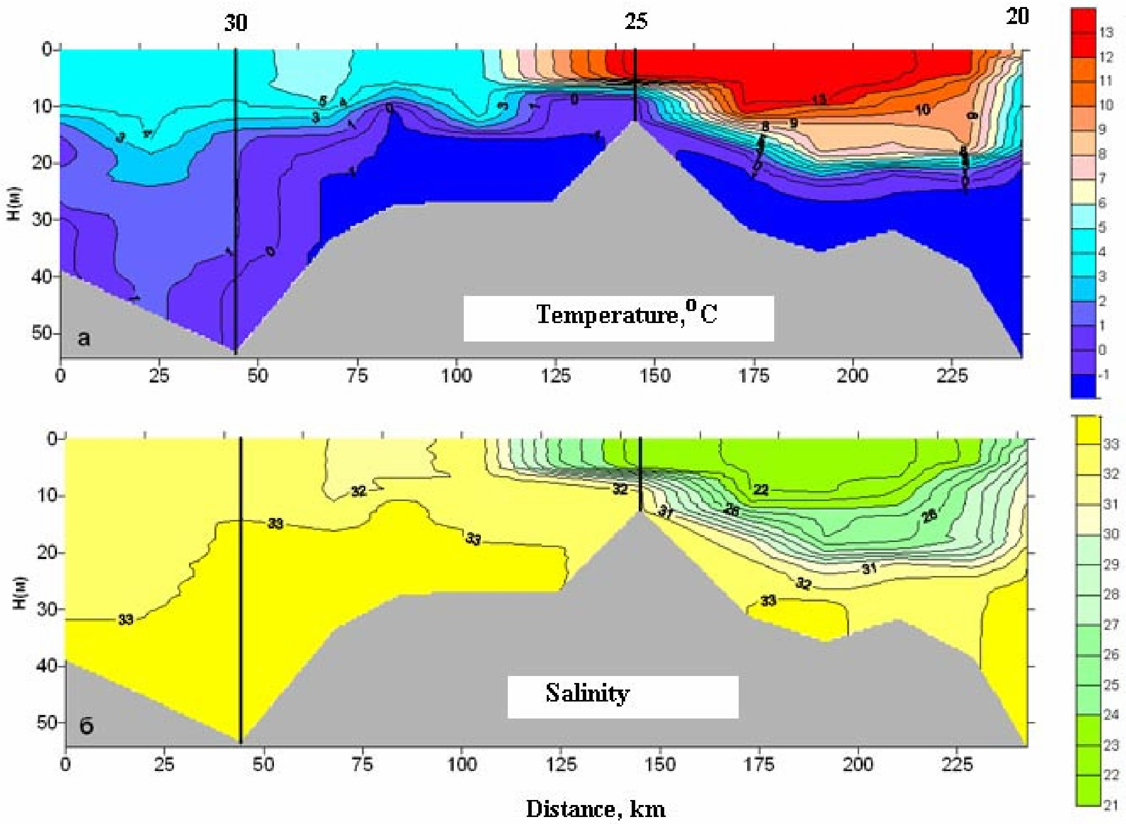


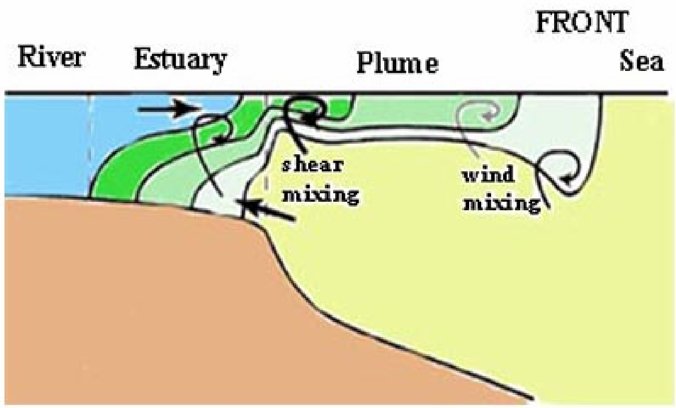


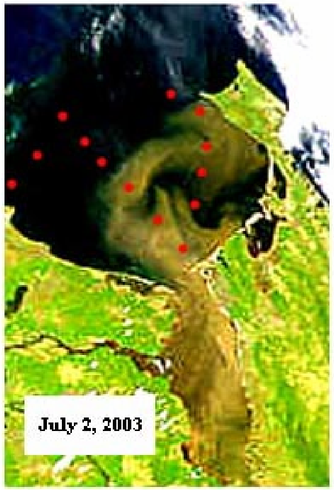
During summer flood new portion of warm, turbid, low salinity water from the Amurskiy Liman was pushed through an opening in the north side of the estuary and moved along Sakhalin Island coast. The "old" freshwater lens was displaced in the northern direction.

During autumn thermal contrasts within the Sakhalin Bay decrease due to cooling. However, the location of the Amur River plume can be detected using the satellite color data. These images show the little temporal change in river plume location.

THERMOHALINE STRUCTURE OF THE AMUR RIVER PLUME

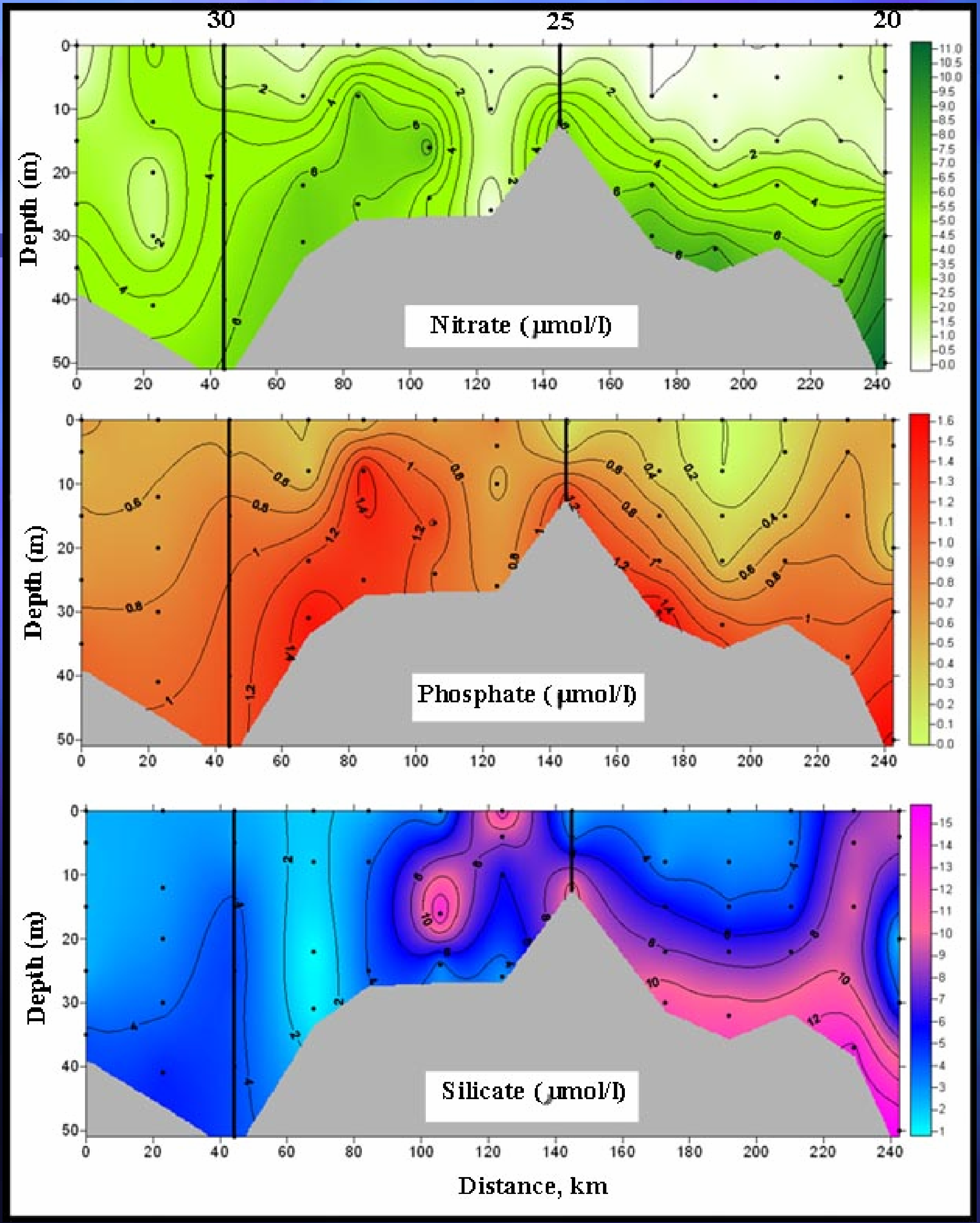






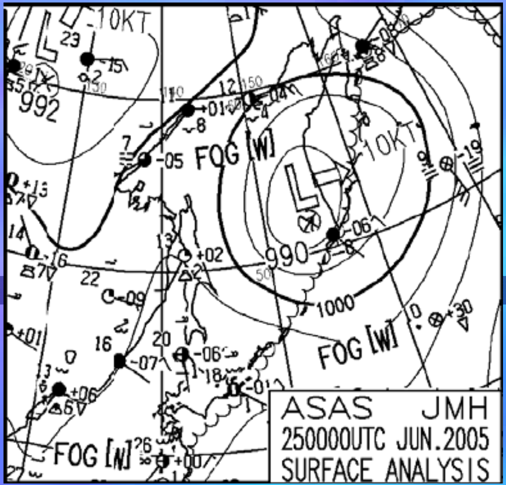
Observations show that the Amur River Plume is typically 10 to 15 m thick and 50 to over 75 km wide. Between the river plume and the sea strong horizontal and vertical T and S gradients were observed. Salinity increase of 10 was observed across the plume front.

DISTRIBUTION OF NUTRIENTS

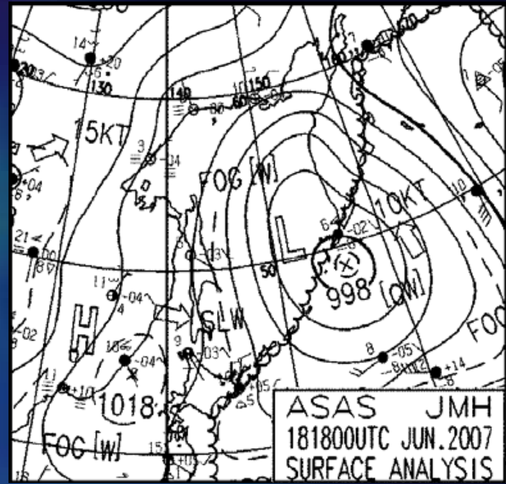


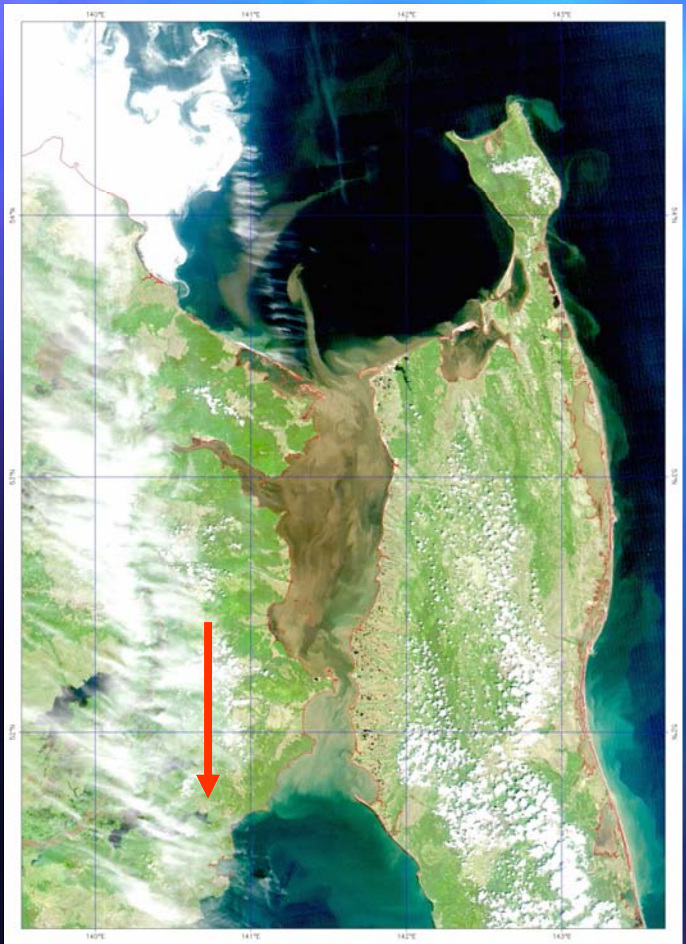
Concentrations of nutrients showed similar distribution patterns. Concentrations of nutrients were depleted within the plume after the spring plankton bloom. Maximum concentrations occurred in the bottom water. Silicate concentrations were relatively higher near plume front. All of these nutrient distributions showed the effect of the jet current at the plume boundary.

THE EFFECT OF WIND ON THE DISTRIBUTION OF THE AMUR RIVER DISCHARGE

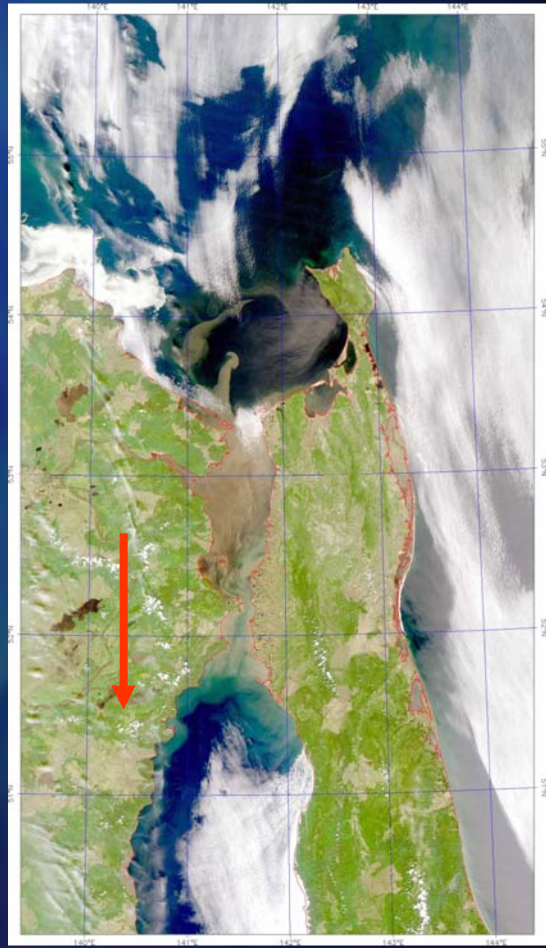


During summer the intense low pressure center that tracked west of the Sakhalin Island caused the very strong northerly winds to develop over the Sakhalin Bay and Amur River estuary.

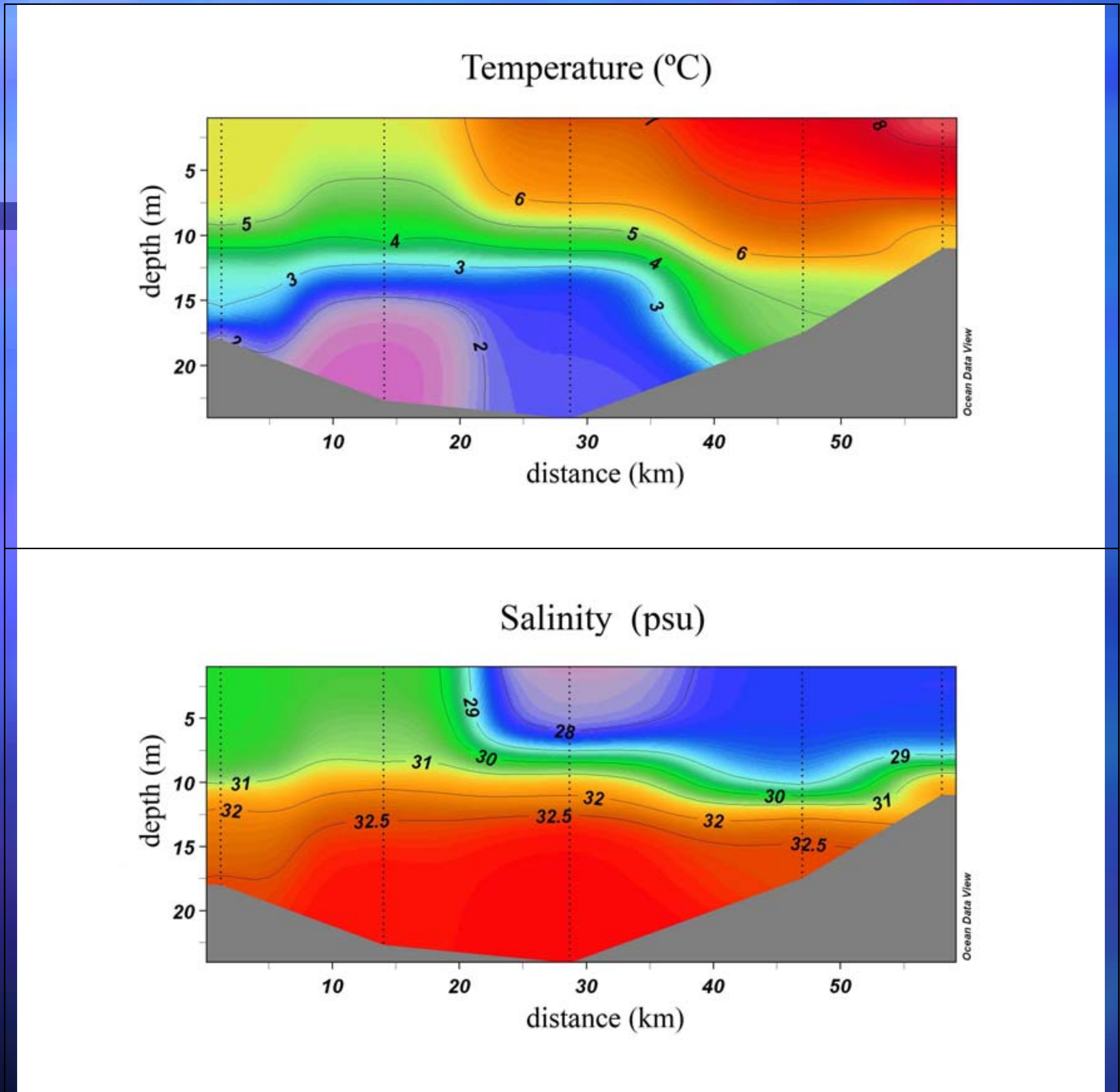


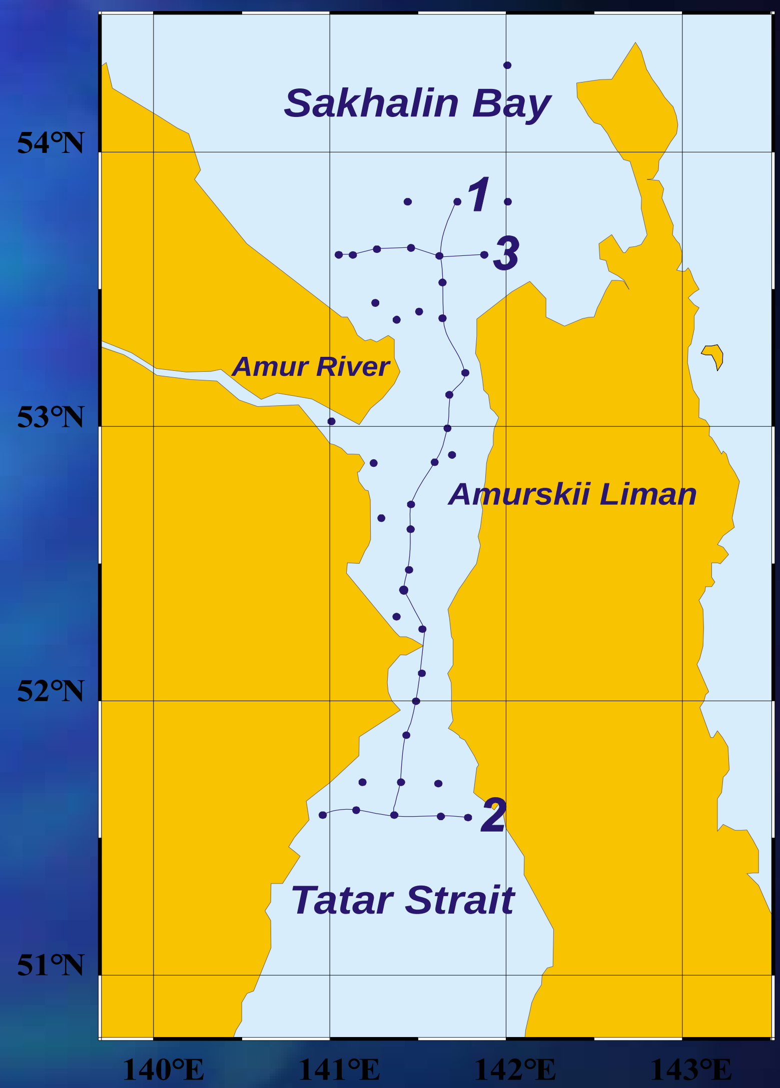


A storm surge of 1.6 to 2.1 m above normal tide levels was observed for the Amurskiy Liman and Sakhalin Bay coast. As example the storm surges of June 25th 2005 and June 18th 2007 are chosen. Water color observation show effects of storm surges. The strong northerly/northwesterly winds tend to push water from the Amurskiy Liman towards the Japan Sea through the Nevelskoy Strait.



THERMOHALINE STRUCTURE OF THE NORTHERN TARTAR STRAIT





Vertical distributions of temperature and salinity along the section 2 through the northern Tartar Strait in June 2007.

SUMMARY

- *The Amur River influences a large portion of the continental shelf in the northwestern Okhotsk Sea and the northern Japan Sea.*
- *During most of the ice-free season (June-October), the northward current flows from the estuary (Amurskiy Liman) into the Sakhalin Bay of the Okhotsk Sea. The buoyant water forms an anticyclonic bulge at the estuary mouth.*
- *Occasionally strong northerly winds tend to push fresh water towards the Japan Sea.*